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1.DIO razna područja - primjeri

citirani rezultati Vladimira Paara

PART1 different fields – selection

quoted results of Vladimir Paar

B. Mottelson (*NORDITA, Copenhagen, Denmark*), Elementary modes of excitation in the nucleus - Lecture delivered by Nobel laureate on the occasion of the presentation of the 1975 Nobel Prize in Physics, Rev. Mod. Phys. 48, 375 (1975):
"Acting in higher order, the particle-vibration coupling gives rise to a wealth of different effects, including interactions between the different elementary modes, anharmonicities between a single particle and a phonon in ^{209}Bi. The discovery of the weak coupling multiplet in ^{209}Bi (Alster, 1966; Hafele, Woods, 1966) was a major incentive to the exploration of the scope of the particle-vibration coupling (Mottelson, 1968; Hamamoto, 1969; Bes, Broglia, 1971; Broglia, **Paar,** Bes, **1971;** Bohr, Mottelson, 1975). The lowest single-proton state $h_{9/2}$ can be superposed on the octupole excitation observed in ^{208}Pb and gives rise to a septuplet with I = 3/2 - 15/2. The splitting of the septuplet receives contributions from the octupole coupling, which can be estimated from the second order diagrams (which are seen to correspond to those of the Compton effect in electrodynamics). It is an important feature of this calculation that the interactions contain the effect of the antisymmetry between the single particle considered and the particles out of which the vibration is built. In a similar manner, the third diagram contains the effect of the Bose symmetry of the two identical octupole quanta."

V. Romero, H. Nakaoka, I. Inoue, K. Hosomichi *(Department of Genetics School of Life Sciences, SOKENDAI Graduate University of Advanced Studies, Japan; National Institute of Genetics, Mishima, Japan; Department of Bioinformatics and Genetics, Gradual School of Medical Sciences, Kanezawa University, Japan)*, High order formation and evolution of hornerin in primates, Genome Biology and Evolution 10, 3167-3175 (2018):
"**Paar et** al. (**Paar,** Glunčić, Rosandić , Basar, Vlahović, 2011) and Takaishi et al. (2005) have different theories as to the formation of the repeated region of HRNR; both groups share the longest repeat length of 1,404 bp (longest unit), but they differed in the process. We identified

the formation described by **Paar et al.** (2011): {[(39bp(primary)×9"×2(secondary) ×2(tertiary)]×5(quartic)},

$\left\{\left[\left(39\ \mathrm{bp}\right)_{\mathrm{primary}}\times 9\right]_{\mathrm{secondary}}\times 2\right\}_{\mathrm{tertiary}}\times 2\Big]_{\mathrm{quartic}}\times 5$ (quartic) to be conserved in all primate species except the crab-eating macaque. Introduction: **Paar et al.** (2011) described HRNR formation using the Global Repeat map algorithm as follows: a primary repeat unit sequence (39 bp) was amplified by nine to form a secondary repeat unit (351 bp), duplication of the secondary repeat unit forms a tertiary repeat unit of 0.70 kb, and finally two tertiary repeat units form a 1.4 kb quartic repeat unit. Notably, **Paar et al.** (2011) detected the higher order repeat structure only in human HRNR but not in chimpanzee, which could be a driving force for the evolutionary process. **Paar et al.** (2011) description starts with 39 bp to form the primary repeat unit, which amplified 9 times to form the secondary unit (type n01 and n02), the secondary unit duplicated to form the tertiary unit (type v01 and v02) and finally the tertiary unit duplicated again to form the quartic unit (w01). Fig.2. Longest, second–longest, quartic, tertiary, and secondary units of hornerin in primates by Takaishi et al. and **Paar et al.** formation. By **Paar et al.** formation, the number of quartic units was six for human, chimpanzee, orangutan, and crab-eating macaque and four for gorilla and ranged from 936 to 1,410 bp. The length of the longest repeat formed was 1,404 bp and shared both formations proposed by **Paar et al.** and Takaishi. Primary units (39 bp) described by **Paar et al.** (2011). The proposed formation by Takaishi et al. (2005) was [(117 bp×4) ×3(subunits)] × 6(units)} (fig. 1A), whereas the formation by **Paar et al.** (2011) was {[("39bp(primary)×9"×2(secondary)) ×2(tertiary)]×5(quartic)}. We examined both possibilities and clarified which structure was detectable in primates. The phylogeny of the primary units divided primary units into nine clusters (order, 1-9) in each species tree by **Paar et al.** (2011). This pattern was observed for human, chimpanzee, gorilla, and orangutan... We next focused on tertiary units proposed by **Paar et al.** (2011). We used the secondary units to reconstruct the tertiary units (fig. 2). **Paar et al**. divided tertiary units into "v01" and "v02" types. Fig. 5. Maximum-likelihood tree analyses for human initial-117 bp units and schematic representation. The cluster pattern follows, "Group-1st," "Group-2nd," "Group-3rd," which fits the length of the secondary unit described by **Paar et al**. Hornerin has a unique and complex duplicate formation that is different from other SFPTs. The hornerin repeat formations proposed by Takaishi et al. (2005) {[(117 bp×4) ×3(subunits)]×6(units)} (fig. 1A), and by **Paar et al.** (2011) {[("39bp(primary)×9"×2(secondary))×2(tertiary)]×5(quartic)}. were examined and compared among several primates (fig. 1). In the repeat organization by **Paar et al.** (2011), 39bp of the primary unit was detected in chimpanzee, gorilla, orangutan, and crab-eating macaque (fig. 2). We confirmed that in all primates except crab-eating macaque the formation model started with the primary units which duplicated to make the secondary units, and the secondary units duplicated twice again to form the tertiary structure as described by **Paar et al.** (2011) (fig. 1B). The biological importance of tandem repeats was mentioned by **Paar et al.** (2011) as a rapidly evolving type of DNA that could contribute to phenotypic differences, even between closely related species such as humans and chimpanzees. The Global Repeat Map of **Paar et al.** (2011). Neuroblastoma break-point family (NBPF) copy number variability is a dramatic example of high order repeat in human and chimpanzees (**Paar et al.** 2011). The NBPF repeat is related to the evolutionary level of higher primates and the high order repeat pattern shows a discontinuous jump in the evolutionary step from 48 monomers in chimpanzee to 165 monomers in human, possibly related to a regulatory function of high order repeats (**Paar et al.** 2011)."

A.Klein, Ching-Teh Li (*University of Pennsylvania, Philadelphia, USA*), M. Vallieres (Drexel University, Philadelphia), Phys. Rev. C25, 2733 (1982):
"Each of SU(6) postulations puts restrictions on the form of the Hamiltonian which renders the two models exactly equivalent as has been remarked by **V. Paar** in Interacting bosons in nuclear physics (Plenum Press, New York, p.163, 1979)."

E.G. Altmann, L.S.E. Portela, T. Tel *(Max Planck Institute for the Physics of Complex Systems, Dresden), (Max Planck Institute for the Physics of Complex Systems, Dresden and Fraunhofer Institute for Industrial Mathematics, Kaiserslautern), (Eötvös University, Budapest)*, Leaking chaotic systems, Revs. Mod. Phys. 85, 869-918 (2013): "Leaking systems have been explored in the context of synchronization of chaotic oscillators, and of the control of chaos (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001). One of the most striking and best studied effects arising due to this difference is the dependence of the escape rate on the position of a fixed-size leak (**Paar** and Pavin, 1997; Schneider, Tel, and Neufeld, 2002; Altmann, da Silva and Caldas; Bunimovich and Dettmann, 2007; Afraimovich and Bunimovich, 2010; Bunimovich and Yurchenko, 2011; Denvers and Wright, 2011). This result is shown in Fig. 13.
Apparently the first to report the dependence of the maps escape rate gamma on leak position were **Paar** and Pavin (1997). An intuitive explanation of these results is found by looking at the images and preimages of leak I (**Paar** and Pavin, 1997; Buljan and **Paar**, 2001).
Quantum Systems often have more than one leak due to input, output, transmission, reflection, or antennas, and multiple leaks in chaotic systems have also been considered (Buljan and **Paar**, 2001; Bunimovich and Dettmann, 2005; Portela et al., 2007; Dettmann and, 2011).
Indeed, the difference reported in Eq. (85) has been understood in terms of the overlap of the preimages of the two leaks (Buljan and **Paar**, 2001; Pikovsky and Popovich, 2003)."

E.G. Altmann, T. Tel *(Max Planck Institute for the Physics of Complex Systems, Dresden; Northwestern Institute on Complex Systems, Northwestern University; Institute of Theoretical Physics, Eötvös University, Budapest)*, Poincare recurrences and transient chaos in systems with leaks. Phys. Rev. E79, 016204 (2009):
"This problem was discussed in detail in the context of fractal exit boundaries (Bleher et al., 1988), of geometrical acoustics (Bauer, Bertsch, 1990), of quantum chaos (Doron and Smilansky, 1992), of controlling chaos (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001), of resetting in hydrodynamical flows (Pierrehumbert, 1994; Schneider et al., 2002), of leaked Hamiltonian systems (Sanjuan et al., 2003), of astronomy (Nagler et al., 2004)

and of cosmology (Motter etr al., 2001). The possibility of comparing a system with leaks to its corresponding closed system shows numerous advantages in comparison to naturally opened systems. For instance, the rate $\gamma_{r,e}$ in Eq. (1) can be estimated from the probability of escaping or returning. For small leaks, this probability is obtained by computing the closed-system natural measure μ of a typical leak region *I*, and it folows that (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001; Zaslavsky, 2002; Altmann et al., 2004) $\gamma_r = \gamma_e = \mu(I) = 1/\langle t \rangle \quad for\ 1 \gg \mu(I) \geq 0$, where $\langle t \rangle$ denotes the mean recurrence or escape time, $\langle T \rangle$ or $\langle n \rangle$. An estimate γ_e^* of the escape rate γ_e in systems with leaks is usually given in terms of the Frobenius-Perron relation (**Paar** and Pavin, 1997; Dorfman, 1999), which expresses that the number of particles not escaping within one time step is proportional to the natural measure outside of the leak , exp(- γ_e^*) = 1- $\mu(I)$, i.e., γ_e^* = - $\ln[1-\mu(I)]$ $[\approx \mu(I) \quad for\ \mu(I) \to 0]$, where $\mu(I)$ is the natural measure of leak *I*. This relation is equivalent to the binomial estimate for recurrence times, and we call it hereafter the naive estimate of γ_e. Deviations of γ_e from γ_e^* were reported in Refs. (**Paar** and Pavin, 1997; Schneider et al., 2002; Schneider et al., 2007) and associated with the existence of short-time periodic orbits of the closed system inside *I*. The following simple relation is obtained from (11): γ_e = - ln $[1-\mu_c(I)]$ (14). This exact expression, which was previously obtained in Ref. (**Paar** and Pavin, 1997), corresponds to the naive estimate replacing $\mu(I)$ by $\mu_c(I)$. Since γ_e is given by Eq. (14) and the distribution is normalizable, $p_e(n)$ follows a binomial distribution $p_e(n) = \mu_c(1-\mu_c)^{n-1} = \frac{\mu_c}{1-\mu_c} e^{ln(1-\mu_c)n}$, with μ_c=μ_c (*I*). It is now possible to compare the results of Ref. (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001) for escape with those of Ref. (Altmann et al., 2004) for recurrence. In both cases the fully chaotic logistic map was carefully investigated and deviations of γ from the naive estimate γ^* were reported. The deviations were associated with the presence of periodic orbits inside *I* and interpreted in terms of the overlap of the preimages of *I* (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001) and of the short time oscillations (in Ref. Altmann et al., 2004). In our unified perspective, the results from Refs. (**Paar** and Pavin, 1997; Altmann et al., 2004) correspond to choosing initial densities ρ_r and ρ_μ or ρ_s, respectively (see Table I). Since the escape rate is independent of this choice, we see that both references are giving intuitive interpretations for the deviation of the actual γ from the naive estimateγ^*. The remarkable exceptions are related to the existence of short-time periodic orbits inside the leak, as previously described in Refs. (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001; Altmann et al., 2004; Bunimovich and Yurchenko, 2011). From this expression, it is clear that short-time periodic orbits have a strong influence on γ since not only primitive orbits, but also all their multiplets, appear in the sum. This dependence is apparent in Fig. 5(b) and was previously reported in Refs. (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001; Altmann et al., 2004; Bunimovich and Yurchenko, 2011).

Applying the ergodic theory of transient chaos to chaotic systems with leaks, an expression for the escape rate γ_c is obtained (**Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001) in terms of the *c* measure (associated with the invariant chaotic saddle) of the leak *I*.

We have shown that the classical problem of Poincare recurrences in closed systems can be described as a problem of escape from a system with a leak, once the recurrence region is identified with the leak *I* and the initial density is chosen properly. This allows us to treat both problems in a unified framework and compare previous similar results that were reported independently in both fields (compare Ref. **Paar** and Pavin, 1997; **Paar** and Buljan, 2000; Buljan and **Paar**, 2001; Schneider et al., 2002; Altmann et al., 2004), and to adapt a previous method to efficiently obtain γ. All our results apply to such cases as well, with the remark that the escape rate is not the mere sum of the escape rates characterizing the components, due to the overlap among preimages, as pointed out by Buljan and **Paar** (Buljan and **Paar**, 2001) and Bunimovich and Dettmann (Bunimovich and Dettmann, 2005).

E.G. Altmann, A. Endler ***(Max Planck Institute for the Physics of Complex Systems, Dresden Germany; Instituto de Fisica, Univesidade Federal do Rio Grande do Sul, Porto Alegre, Brazil)*****, Noise enhanced trapping in chaotic scattering, Phys.Rev.Lett. 105, 244102 (2010):** "Chaotic scattering is a basic process of Hamiltonian dynamics, with fundamental applications in classical and quantum systems, and recent applications ranging from plankton populations (Tel, 2000) to blood flows (Schelin, 2009) and even the origin of life (Scheuring, 2003). Noise also plays a constructive role in chaotic scattering, enhancing the trapping of trajectories. There are two different mechanisms responsible for this surprising effect. The first mechanism acts in fully chaotic system and reduces the escape rate of particles. The second mechanism enhances trapping by throwing trajectories inside KAM islands. To illustrate how noise enhances trapping in fully chaotic systems, consider the baker map (Ott, 2002):

$$M: \quad (x_{i+1},\ y_{i+1}) = (x_i/2,\ 2y_i) \qquad\qquad y \leq 1/2$$
$$M: \quad (x_{i+1},\ y_{i+1}) = ((x_i+1)/2,\ 2y_i - 1) \qquad y \succ 1/2$$

defined in $[0,1] \times [0,1]$. Escape is introduced through an arbitrary leak *I* (**Paar,** Pavin, **1997; Paar,** Buljan, **2000;** Schneider et al., 2002; Altmann et al, 2008,2009; Aframovich, Bunimovich 2010):

$$\widetilde{M}(x_i, y_i) = M(x_i, y_i) \quad \text{if } (x_i, y_i) \not\subset I$$
$$\widetilde{M}(x_i, y_i) = \text{escape} \quad \text{if } (x_i, y_i) \subset I$$

For concreteness, consider I to be a vertical stripe ($I = [x_c - \Delta_x,\ x_c + \Delta_x] \times [0,1]$) at the center of the map ($x_c = 0.5,\ \Delta_x = 0.05$). The survival probability $P(t)$ of typical initial conditions decays asymptotically as $P(t) \sim e^{-t/\tau}$ (Ott, 2002; Gaspard, 1998; Sommerer et al., 1996). The trapping strength is quantified through the characteristic lifetime τ, which is the reciprocal of the escape rate and is different from the mean escape time (Altmann, Tel, 2008,2009). Let us first consider the simplest case of periodic boundary conditions for trajectories driven by noise outside $[0,1] \times [0,1]$. This would be the natural choice for maps defined on the torus. In this case, for $\xi \to \infty$ trajectories are uniformly distributed in $[0,1] \times [0,1]$ and $\tau \to \tau^*$ with (**Paar,** Pavin, **1997; Paar,** Buljan, **2000;** Schneider et al., 2002; Altmann et al, 2008,2009) $\tau^* = \{-\ln[1 - \mu(I)]\}^{-1}[\approx 1/\mu(I)$ for small $\mu(I)]$, where $\mu(I)$ is the Liouville measure (phase space area) of the leak *I*. In the baker's map example above, $\mu(I) =$

$2\Delta_x = 0.1$ and $\tau^* = 9.49$, which is greater than the noiseless case $\tau_{\xi=0} = 6.06$ calculated above. The trapping is enhanced by noise. The second crucial point in the derivation above is $\tau^* > \tau_{\xi=0}$. References (**Paar,** Pavin, **1997; Paar,** Buljan, **2000;** Schneider et al., 2002; Altmann, Tel, 2008,2009; Aframovich, Bunimovich 2010) show that this holds for most leaks. The difference between τ^* and $\tau_{\xi=0}$ is a consequence of the difference between the Liouville invariant density ρ_μ and the open system's quasi-invariant density $\rho_{\xi=0}$ inside I (**Paar,** Pavin, **1997; Paar,** Buljan, **2000;** Altmann et al, 2008,2009). The dominant effect of noise is to move trajectories outside *I*, avoiding their escape and increasing τ. This τ-increasing effect is shown in Fig. 2 (**Paar,** Pavin, **1997; Paar,** Buljan, **2000).** We have verified that this trapping is enhanced also for random maps, where dimensions remain fractal (Tel, 2000; Romeiras et al., 1990)."

A. Arima (*University of Tokyo, Japan*), Interacting bosons in nuclear physics, Ettore Majorana International Science Series, Plenum Press, New York (ed. F. Iachello, *Yale University*), Concluding remarks (1978):

"**Paar** proved that a similar identity to Ward identity works well in nuclear physics. He showed that an effective M1 operator $(\sigma Y^{(2)})^{(1)}$ does not contribute very much in vibrational nuclei. His work indicates that there is a mechanism to suppress higher order contributions.
Broglia and Bortignon developed their Nuclear Field Theory and showed cancellation among higher order terms. **Paar** showed that the Alaga model works well in odd-A nuclei. In this model three nucleons are assumed to form a cluster which in turn couples with even-even core. Although some calculations have been done by using IBM1, we need some more calculations. Coupling with two extra nucleons in an intruder orbit (such as $h_{11/2}$ and $i_{13/2)}$ appears to play an important role (for example Toki, Faessler; **Paar**)."

C.A. Stone, W.B. Walters *(Department of Chemistry, University of Maryland, USA)*, The parabolic rule, the Pandya transformation, and the structure of 100In, Hyperfine Int. 22, 363-376 (1985):

"The $7/2^+$ level in 93Tc has long **(Paar, 1973)** been identified as a $(g9/2)^3$ cluster. Similar levels are likely to be present in 95Rh and 97Ag. Another approach to the structure of odd-odd nuclides where the multiplet splitting is parabolic versus $I(I+1)$ has been suggested by **Paar (Paar, 1979)** and utilized extensively by Fenyes and co-workers (Fenyes,1984) to describe the particle-particle to particle-hole transition in both the Nb and Tc nuclides. The Pandya transformation does not easily describe changes in splitting as particle or hole numbers change. An important new feature of the **Paar formula** is the explicit dependence of the magnitude of the splitting on $(u_p^2 - v_p^2)(u_n^2 - v_n^2)$. This dependence allows for a systematic quenching and inversion of a multiplet such as been clearly observed in the odd-odd N = 83 isotones (Walters et al., 1983)."

Л.К. Пекер, В.М. Сигалов, О структуре "сферических" состояний нечетно-нейтронных ядер с A = 145-153, Известия Академии Наук СССР 10, 2119-2122 (1974):
"Hotya detaljnye rascheti cpektra urovnej dlya konfiguracii $\{(2f7/2)^{\pm 3}$ + fononi$\}$ v ramkah modeli Alagi eshe ne provedeny, ryad zaklyuchennij o strukture nizhnih urovnej s $I^{\pi} = j^{\pi} = 7/2^{-}$ i $I^{\pi} = (j-1)^{\pi} = 5/2^{-}$mozhet byt sdelan na osnovanii imeyushihsya rezultatov raschetov dlya konfiguracii $\{(1f7/2)^{\pm 3}$ + fonony$\}$ (**Paar, 1973)**. Na ris. 1 iz (**Paar, 1973)** priveden spektr urovnej s $I^{\pi} \leq 11/2^{-}$ v zavisimosti ot velichiny vzaimodejstviya konfiguracii $(j)^3$ s fononnym polem. Iz risunka vidno, chto urovni s $I = j$ i $j-1$ s usileniem vtorogo vzaimodejstviya bystro sblizhayutsya i peresekayutsya, tak chto uroven s $I = j-1$ mozhet okazavatsya osnovnym sostoyaniem yadra, chto i nablyudaetsya v posledovatelnosti yader $_{60}$Nd, $_{62}$Sm, $_{64}$Gd. Osnovnoe sostoyanie 145Nd, 147,149Sm, 149,151Gd, 153Dy imeet $I^{\pi} = j^{\pi} = 7/2^{-}$, a 147,149Nd, 151Sm $I^{\pi} = (j-1)^{\pi} = 5/2^{-}$. Provedennye v (**Paar, 1973)** raschety dlya urovniya 1f7/2 pokazyvayut, chto volnovye funkcii obsuzhdaemyh sostoyanij yavlyayutsja superpoziciyami chactichnyh i fononnyh volnovyh funkcij.
Ris. 2. Razryadka kvazirotacionnyh polos 151Gd: a – teoreticheskij spektr, tolshina strelok proporcionalna $B(E2)_{teor}$ v teh sluchayah, kogda posledny v (**Paar, 1973)**. V rabote (**Paar, 1973)** v ramkah modeli Alagi byla rasschitana takzhe energiya urovnej konfiguracii $\{(1f7/2)^{-3}$ + fonony$\}$s bolshimi spinami $I^{\pi} \leq 21/2^{-}$ i velichinny $B(E2)$ dlya perehodov mezhdu nimi. Otmechaetsya, chto poluchivshiesya v raschetah urovni razbivayutsya naneskolko klvazirotacionnyh polos so spinami $I,\ I+2,\ I+4\ldots$, prichem, E2 perehody mezhdu urovniyami odnoj polosy obychno uskoreny bolee znachitelno, chem E2 –perehody me zhdu urovnyami raznyh polos."

A.Yu. Perevaryukha ***(Sankt-Peterburgskogo instituta informatiki i avtomatizacii RAN, Sankt-Peterburg, Rossiya)*****, Kompyuternoe modelirovanie populyacii osetrovih kaspiya s dvumya vidami vozniknoveniya aperiodicheskih kolebanij, Matematicheskoe i kompyuternoe modelirovanie / Mathematical and computer modelling 1, 26-32 (2015):**
"Nami issledovalsya sluchaj obrazovaniya kantorovskoj strukturi granicy, kotoraya predstavlyaet soboj vsyudu razrivnoe mnozhestvo tochek, privodit k poyavleniyu dlitelnogo haoticheskogo rezhima, realizuyushegosya do momenta $\varphi^{z}(R_0) > R_3^{*}$ (ili $\varphi^{z}(R_0) < R_1^{*}$), ego dostizhenie oznachaet stremitelnoe razvitie redkogo yavleniya dlya ryb, neozhidannoj "vspyshki" chislennosti (ris. 2) populacii. Chislo iteracij z prebyvaniya traektorii v perehodnom aperiodicheskom rezhime chuvstvitelno zavisit ot nachalnyh uslovij (**Paar,** Pavin, **1996)** i sootvetstvenno ot tochnosti vychislenij."

**Y.K. Ruzha, T.V. Guseva, Y.Y. Tamberg, M.K. Balodis (*University of Latvia, Riga, Latvia)*
zvestiya akademii nauk SSSR seriya fizicheskaya 52, 119-125 (1988):**
"Dlya odnovremenogo opisaniya supermultipleta , kotori sostoyalbi iz 1) chetno-chetnogo yadra $^{A}_{Z}X_N$, 2) nechetno-neitronnogo yadra $^{A+1}{}_{Z}X_{N+1}$, 3) nechetno-protonnogo yadra $^{A+1}_{Z+1}X_N$, 4) nechetno-nechetnogo yadra $^{A+2}_{Z+1}X_{N+1}$ neobhodimo supersimmetriyu obobshit. Ni budem polzovatsya bolee prostoi gruppoi (Van Isacker et al., 1985), t.e., ne budem delat razlichiya po neitronam i bozonnom sektore. Gruppoi symmetrii v takom sluchae budet (Hübsch, **Paar,**

Vretenar, **1985)** $U^B(6) \otimes U^{F_\nu}(\Omega_\nu) \otimes U^{F_\pi}(\Omega_\pi)$, a sootvetstvuyushei supergruppoi $U(6/(\Omega_\nu + \Omega_\pi)$. Supermultiplet harakterizuetsya polnostlyu supersymmetrichnim predstavleniem $\mathfrak{A}) = N_B + M_\nu + M_\pi$, gde N_B chislo bozonov chetno-chetnogo yadra, a M_ν, M_π - chislo nesparennih neitronov ili protonov – prinnimayut zhacheniya 0 ili 1."

D.M. Naplekov, V.V. Yanovsky *(Institute for Single Crystals, National Academy of Sciences, Kharkov, Ukraine; V.N. Karazin Kharkiv National University, Ukraine)*, Thin structure of the transient time distribution of open billiards, Phys.Rev. E97, 012213 (2018):
"Mathematical billiard is a standard model system in the chaos theory. Billiards are currently intensively studied, due to a large number of applications. A billiard type of dynamics is also associated with some theoretical issues – the justification of statistical physics, interconnection between the classical and quantum descriptions of a system, etc. (Buljan, **Paar, 2001;** Aguirre, Sanjuan, 2003; Bleher et al., 1988; Chirikov, Shepelyansky, 1984; Zaslavsky, 2002; Jacquod, Petitjean, 2009). Detailed description of the relationship between open billiards and these fields can be found in the review in (Altmann et al., 2013)."

O.W.B. Schult (*Institut für Kernphysik, KFA Jülich, Germany*), Inst.Phys.Conf.Ser. 62, 705 (1982):
"I am grateful to **Vladimir Paar** for outlining the equivalence of the Interacting Boson Approximation and the Truncated Quadrupole Phonon Model for even-even nuclei, and of the Interacting Boson Fermion Model and the Particle Truncated Quadrupole Phonon Model for odd-A nuclei. **Paar** has drawn our attention to the problem of the truncation of the boson number, and he has shown that this point is essential for the understanding of the B(E2) values of 238U."

A.N. Andreyev, D. Ackermann, F.P. Hessberger, S. Hofmann, M. Huyse, I. Kojouharov, B. Kindler, B. Lommel, G. Munzenberg, R.D. Page, K. Van de Vel, P. Van Duppen, K. Heyde (*University of Liverpool, United Kingdom; GSI Darmstadt, Germany; University of Leuven, Belgium; University of Gent, Belgium; Johannes Gutenberg-University, Mainz, Germany*), α-decay spectroscopy of light odd-odd Bi isotopes – II: ^{186}Bi and the new nuclide ^{184}Bi, Eur. Phys. J. A18, 55-64 (2003):
"According to **Paar´s rule (Paar, 1979),** which results in a splitting within of the multiplet members as a quadratic function in spin J(J+1), the 3^+ state is predicted to stay lowest in the $(\pi 1h_{9/2} \nu 3p_{3/2})_{3+\to 6+}$ multiplet, which was experimentally proved down to ^{190}Bi and in ^{188}Bi. As shown above, possibly, this configuration could be also responsible for the longer-lived isomer of ^{186}Bi."

R.F. Casten (*Brookhaven National Laboratory, Upton, New York, USA*): Nuclear structure from a simple perspective, Oxford studies in nuclear physics, Oxford University Press,

Oxford (1990):
“This is the parabolic rule discussed frequently by **Paar**. The parabolic rule is often an excellent approximation. Fig. 4.15 shows a few examples taken from **Paar** and introduces one final but important point. The ($g_{7/2}d_{3/2}$) multiplet of J=2^+-5^+ states in 122Sb is well reproduced by a simple parabola in J(J+1), as is the ($g_{7/2}h_{11/2}$) multiplet. The nuclei 48Sc and 116In also show multiplets with beautiful empirical parabolic behavior, except that they are inverted! The reason is well understood. In 48Sc the ($f_{7/2p}f_{7/2n}$) multiplet really a particle-hole p-n configuration ($f_{7/2p}f_{7/2n}{}^7$) = ($f_{7/2p}f_{7/2n}{}^{-1}$), as is the ($g_{9/2p}{}^{-1}h_{11/2n}$) configuration in 116In. In this case, the residual interaction has the opposite sign of a particle-particle or hole-hole multiplet. In other words, it is repulsive and the J states with high p-n overlap (J_{max}, J_{min}) are raised in energy, while J_n is lowered the most.
Fig. 4.15: Illustrations of the parabolic rule for a quadrupole residual interaction for several p-n multiplets (**Paar, 1979**)."
The parabolic rule diagrams from the publication by **Paar (1979)** are, by permission of publisher of Paar’s publication, reproduced in the Casten’s book.

R.E. Anderson, J.J. Kraushaar, I.C. Oelrich, R.M. DelVecchio, R.A. Naumann, E.R. Flynn, C.E. Moss *(Department of Physics and Astrophysics, University of Colorado, Colorado, USA; Joseph Henry Laboratories, Princeton University, Princeton, New Jersey, USA; Los Alamos Scientific Laboratory, Los Alamos, New Mexico, USA)*, Excitation of particle-vibration multiplets in the A=110 region by two-neutron stripping reactions, Phys.Rev. C15, 123-145, (1977):
"The mixing of 0_1^+ and 0_2^+ core states appears small, and this observation is consistent with the wave functions given in Refs. (Kuhfeld, Hintz, 1975) and (**Paar, 1973**). The 2_1^+ and 2_2^+ states, however, are only about 500 keV apart and significant mixing is predicted in Ref. (**Paar, 1973**). A more complex form of this type of mixing occurs when higher-order diagrams which couple several core phonons and single-particle orbitals are included, e.g., one may find a $\left|2_1^+ \otimes 2p_{1/2}; \frac{3}{2}^-\right\rangle$ component in the nominally $\left|2_2^+ \otimes 2p_{3/2}; \frac{3}{2}^-\right\rangle$ state. Such mixing is predicted in Ref. (**Paar, 1973**) although it is difficult to make detailed comparisons of those calculations to the present results because the two nucleon overlaps are not presented. **Paar (Paar, 1973)** has made calculations involving the coupling of three particles or holes to quadrupole vibrations. For odd-A silver isotopes he took a three proton-hole cluster moving in the g9/2, p1/2 and p3/2 shell model orbitals coupled to a quadrupole vibrational field with vibrator states of up to three phonons. Only a few results of his calculations can be directly compared to the results of the (t, p) studies. **Paar** predicts the energies of the levels of 107Ag and 109Ag and in fact has the correct ordering for the first six excited states. In general, he predicts these levels to lie somewhat higher in energy than is given by experiment. For example, the lowest $9/2^-$ and $7/2^-$ levels in 109Ag are predicted to be at about 1330 and 1030 keV while in reality they are 1091 and 912 keV. The lowest $1/2^-$ excited state in 109 Ag is predicted to be around 2000 keV while it is at 1260 keV, which in turn is considerably above the position of the 0^+ core state at 1054 keV. Above this point the comparison of theory and experiment becomes rather inconclusive. It is apparent from **Paar’s** calculations, however, that while a major part of the wave functions for the

low-lying states of 109Ag have the simple weak coupling components, other components play an important role. For example, if the two g9/2 hole states are recoupled to spins of 2 and 4, then various 0, 1, and 2 phonon states can be coupled using either p1/2 or p3/2 proton state to form from six to eight important components of the wave function."

L.R. Medsker, H.T. Fortune, S.C. Headley, J.N. Bishop (*Physics Department, University of Pennsylvania, Philadelphia, USA*), Proton states in 87Rb, Phys.Rev. C12, 1516-1523 (1975):
"As nucleons are subtracted from the (Z,N) = (38,50) core, the nuclei may possibly be described also by deformed-nucleus calculations (Gloeckner, Serduke, 1974), weak-coupling models (Paradellis, Hontzeas, 1971), or the coupling of a few particles or holes (**Paar, 1973**)."

D.D. Nguyen *(Institute of Theoretical Physics, Academy of Sciences of Vietnam, Hanoi, Vietnam)*, Equations for Green Functions with the use of the exact Hamiltonian in the quasiparticle-phonon model, Z.Physik A327, 41-49 (1987):
"We notice also that, as has been shown in (Kyrchev, Voronov, 1985) the exact QPM (Quasiparticle Phonon Model) Hamiltonian (Nguyen, Voronov, 1984) has the SU(6) limit and can be represented under some conditions as a rotational invariant which is constructed of the generators of the SU(6) algebra.. In this way in (Kyrchev, Voronov, 1985) a direct connection between the QPM, the Truncated Quadrupole Phonon Model (TQPM) (Janssen et al., 1974; Kyrchev, 1980; **Paar** et al, **1982;** Klein et al., 1983) and the Interacting Boson Model (IBM) (Arima, Iachello, 1975, 1976, 1978; Otsuka et al., 1978; Iachello, 1979) has been pointed out."

F. Iachello, P. Van Isacker (*Yale University, New Haven, Connecticut, USA; Daresbury Laboratory, Daresbury, United Kingdom*), The interacting boson-fermion model, Cambridge monographs on mathematical physics, Cambridge University Press, Cambridge (1991):
"The algebra of creation and annihilation operators can be realized in several ways. One of these is the Holstein-Primakoff realization which leads to a slightly different version of the interacting boson-fermion model called the truncated quadrupole phonon-fermion model (**Paar 1980; Paar,** Brant, **1981**) ... In addition to properties originating from the collective nature of the spectra, there is in odd-odd nuclei a new aspect originating from the residual interaction between the unpaired proton and neutron. This aspect is in particular evident in the so-called parabolic rule of proton-neutron multiplets (**Paar, 1979**). In Fig. 10.13 we show the results of such a calculation (Lopac, Brant, **Paar,** Schult, Seyfarth, Balantekin, **1986**) in comparison with experimental spectra of the odd-odd nucleus 198Au. The dependence of the energies on J arises from the residual proton-neutron interaction...To a good approximation one obtains $E(J) = a + b(J(J+1) - J_0(J_0+1))^2$ where a, b and J_0 are appropriate numbers that depend on the values j_π and j_υ. The occurrence of this rule within the framework of the interacting boson-fermion model has been investigated recently (Balantekin**, Paar, 1986**) in the case of bosons with U (5) and O (6) symmetry... A similar rule can be derived for nuclei with SU (3) symmetry (**Paar,** Sunko, Vretenar, **1987**), although the situation in this case is more involved in view of the strong

interaction between bosons and fermions."
This book contains in the list of references 12 scientific publications of **Vladimir Paar**.

F. Iachello (*Center for Theoretical Physics, Yale University, USA*), Symmetry in nuclei and beyond, Nucl. Phys. A751, 329c-342c (2005):
"The latest developments are based on a more accurate description of nuclei called Interacting Boson-Fermion Model-2 in which the basic constituents are proton bosons and neutron bosons (IBM-2) and unpaired protons and neutrons (Alonso et al., 1984; Bijker,2004). The algebraic structure of this model is $U_{\pi}(6/\Omega_{\pi}) \oplus U_{\nu}(6/\Omega_{\nu})$, where the index π, ν distinguishes protons from neutrons (van Isacker et al., 1985; Hübsch, **Paar,** Vretenar, **1985)**. If supersymmetry occurs for these very complex systems one expects to have supersymmetric partners composed of a quartet of nuclei, even-even, even-odd, odd-eve and odd-odd."

G. Lhersonneau, A. Wöhr, B. Pfeiffer, K.L. Kratz *(ISOLDE Collaboration, CERN, Geneva, Switzerland; Institut für Kernchemie, Universität Mainz, Mainz, Germany; Department of Physics, University of Jyväskylä, Jyväskylä, Finland; Clarendon Laboratory, University of Oxford, Oxford, United Kingdom)*, First decay of the very neutron-rich isotope 93Br, Phys.Rev. C63, 034316 (2001):
"A deformed minimum in the potential energy surface at about 1.5MeV has been reported for the N = 58 isotones 96Sr and 98Zr based on rotational band structure (Hamilton et al.,1995). These deformed structures rapidly come down in energy with increasing neutron number, until the N = 60 isotones 98Sr and 100Zr exhibit well developed rotational ground state bands. Asimilar shape transition is also observed in Z = 39 yttrium isotopes (Lhersonneau, Brant, **Paar,** Vretenar, **1998;** Lhersonneau et al., 1986; Meyer, Monnand, Pinston, Schussler, Pfeiffer, **Paar, 1987)**. So far, the heaviest Z = 37 rubidium isotope studied by γ-spectroscopy is 94Rb with N = 57, the nearest neighbor isotone of 93Kr. Its low-lying levels were interpreted in the interacting boson-fermion-fermion frame as being spherical (Lhersonneau, Brant, Ohm, **Paar,** Sistemich, Weiler, **1989)**.
It is quite obvious that a dramatic discontinuity in the N = 57 systematics occurs at 97Zr, i.e., at Z = 40 when protons start to occupy the g9/2 subshell (Lhersonneau et al., 1997). The level structures of $Z \geq 42$ nuclei do not show signatures of the N = 56 gap associated with the spherical $\nu d5/2$ subshell closure. In this region, the d5/2 and g7/2 neutron orbitals are remarkably close to each other. Furthermore, the $\nu s1/2$ level comes down rapidly in energy when protons are removed and becomes the ground state in $^{99}_{42}\mathrm{Mo}$. When reaching $^{97}_{40}\mathrm{Zr}$ and continuing towards even lower Z values, the first excited state is a $3/2^{+}$ level, while the d5/2 orbital has not been identified but is not any longer a quasiparticle below g7/2 (Kratz et al., 1983; Lhersonneau et al., 1997). Calculations performed for the N = 59 isotones 97Sr and 99Zr, where a similar level structure exists, indicate a rather complex character of this $3/2^{+}$ level, thus excluding the d3/2 single neutron parentage (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990;** Brant, **Paar,** Wolf, **1998)**. Its structure rather consists mainly of g7/2 and d3/2 neutron components coupled to core states. According to the IBFM calculations for 97Sr

(Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)**, the 523 keV level is the $3/2^+_2$ state. Its characteristic feature is a large branching ratio for the $3/2^+_2 \rightarrow 3/2^+_1$ transition. In 97Sr the $5/2^+_1$ level at 600 keV has an $E2$ transition to the ground state which is several times stronger than the $M1$ to the $3/2^+_1$ level. One may speculate that – as observed in the *N* = 57-59 Sr and Zr isotopes (Kratz et al., 1983; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990;** Brant, **Paar,** Wolf, **1998**) - also their respective Kr isotones will exhibit coexistence of spherical states at low energy and levels of deformed collective nature at higher energy."

W.B. Walters, (*University of Maryland, USA*), Nuclear structure, reactions and symmetries, World Scientific, Singapore, p. 747 (1986):
"On observing this structure, **Vladimir Paar** recognized the need to develop a description for the residual interaction in odd-odd nuclei. In a 1979 paper (**Paar**, **1979)** proposed decomposition of the interaction into dipole and quadrupole parts and has recently suggested acting an octupole part. It is quite likely that Paar approach with an octupole term would describe these nuclides equally well.
The parabolic splitting rules of **Paar** and the related predictions on electromagnetic properties and spectroscopic factors can be used to assign suitable experimental states to the multiplets. The parabolic rule predicts the energy splitting to be parabolic concave down. This splitting is observed in 106,108,110Ag. For the $d_{5/2}$ neutron, **V. Paar** (**Paar, 1979)** predicts positive slope for the additional energy splitting. According to **Paar** for j_p or j_n = 1/2 the energy splitting of the resulting doublet comes in leading order from the exchange of the spin vibrational phonon."

S.V. Jackson, W.B. Walters, R.A. Meyer (*Lawrence Livermore Laboratory, Californa, USA; Chemistry Department, University of Maryland, College Park, Marland, USA*), Levels in the three-hole nucleus 105Ag and the decay of 55.5-min 105Cd, Phys.Rev. C13, 803-830 (1976):
"In this investigation of the decay of $5/2^+$ 55.5-min 105Cd, we have examined the character of a large number of excited states in 105Ag. The general features of the low-energy ($\leq$ 2 MeV) level structure of 105Ag may be understood by examining the level of energy systematics of the nearby odd-mass nuclei and by comparing the 105Ag level structure with the results of a recent calculation of 107,109Ag levels by **Paar (Paar, 1973)**, who used a three-proton hole plus quadrupole-vibrator model. The levels of 105Ag provide an extension of both the isotonic, N = 58, and the isotopic, Z = 47, odd-A systematics. Detailed calculations of levels other than $7/2^+$ anomalous coupling state have been reported **(Paar, 1973)** only for an "average" 107,109Ag nucleus. In Fig.4, we present the systematics of the odd-parity levels observed in the odd-mass silver nuclei 105,107, 109,111Ag along with the odd-parity levels. The theoretical calculation **(Paar, 1973)** appears to reproduce the level ordering and spacing very well up to at least 1 MeV.
Fig. 4: The systematics of the odd-parity levels observed in the odd-mass silver nuclei 105,107, 109,111Ag. Also shown are the calculated odd-parity levels **("Paar** calculation**") (Paar, 1973)** for an "average" 107,109Ag nucleus.

It may be noted, however, that an intermediate-coupling model calculation might well result in an equally good fit to the experimental data. In that model, a 2p1/2 plus one phonon doublet with $J^\pi = 3/2^-$ and $5/2^-$ is expected near the first core phonon energy, and five 2p1/2 plus two-phonon states ranging from $J^\pi = 1/2^-$ to $9/2^-$ are expected in the vicinity of the two-phonon energy. In fact, the three-hole plus quadrupole model determines configurations for these states that are largely $\left[(1g9/2)_0^{-2}2p1/2^{-1}\right]$ plus one phonon (or two phonons) in character. The structure of the even parity levels is quite different from that of the odd-parity level. The even-mass Ag nuclei are observed to have a very low-lying $7/2^+$ level and a lack of any levels near the Pd core energy. This is illustrated in Fig. 5, where we present the low-energy systematics of the even-parity levels in the odd-mass silver nuclei 105,107, 109,111Ag along with the levels calculated for an "average" 107,109Ag nucleus.
Fig. 5: The low-energy systematics of the even-parity levels observed in the odd-mass silver nuclei 105,107, 109,111Ag. Also shown are the calculated even-parity levels **("Paar** calculation**") (Paar, 1973)** for an "average" 107,109Ag nucleus. As in Fig. 4, the Pd and Sn core-quadrupole vibration excitations are also shown. The three-hole plus phonon model appears to explain the two major features of the level structures, namely, the low-lying $7/2^+$ anomalous coupling state, and the large gap between the $9/2_1^+$ level and the next even-parity level, generally a $5/2^+$ state.
Recent theoretical calculations of the odd-mas silver nuclei by **Paar (Paar, 1973)** using a three-hole plus quadrupole-vibration model and of odd-mass silver, rhodium and technetium nuclei by Kuriyama, Marumori and Matsuyanagy (Kuriyama et al., 1972,1973) using a dressed three-quasiparticle model have also predicted the $7/2^+$ state to be mainly $(1g9/2)^{-3}{}_{7/2}$. In both calculations, the explicit treatment of the Pauli principle in the valence shell results in the $\left[(J^{-2})_2 J^{-1}\right]$ multiplet being split, with the *J*-1 coupling being brought down and the other four couplings $(J-2, J, J+1, \text{and } J+2)$ being raised. In conclusion, it is clear that a three-hole model of some type is necessary to explain the $7/2^+$ anomalous coupling state observed in odd-mass silver nuclei. The three-hole plus quadrupole vibrator model of **Paar** successfully explains many of the characteristics of the low-energy level structures in the odd-mass silver nuclei. However, further theoretical calculations are needed to make more detailed comparison between theory and experiment.
Note Added: Recent studies (Svensson et al., 1975) of the 105Pd(p,n) 105Ag reaction are consistent with ours and permit the additional assignment of γ rays that we observe. The 668.6- and 917.2-keV levels are good candidates for the $11/2^+$ and $13/2^+$ members, respectively, of the $g9/2 \otimes 2_1^+$ multiplet. We observe a γ ray at 1371.41 ± 0.11 keV that could populate the 668.6-keV level from the $7/2^+$ level at 1986.3 keV, which is consistent with a possible $11/2^+$ assignment for the 668.6-keV level. The positions of these two levels agree quite well within the $11/2^+$ and $13/2^+$ states predicted by **Paar** (see Fig. 5 / **"Paar** calculation**"**)."

C.K. Volos, V.T. Pham, S. Vaidyanathan, I.M. Kyprianidis. I.N. Stouboulos (Physics Department, Aristotle University of Thessaloniki, Greece; School of Electronics and

Telecommunications, Hanoi University of Science and Technology, Hanoi, Vietnam; Research and Development Centre, Vel Tech University, Chennai, Tamil Nadu, India), Synchronization phenomena in coupled hyperchaotic oscillators with hidden attractors using a nonlinear open loop controller, Advances and Applications in Chaotic Systems, S. Vaidyanathan, C. Volos (eds.), Studies in Computational Intelligence 636, 1-36 (2016):
"The simplest four-dimensional hyperchaotic Lorenz-type system has many interesting properties, such as: There is a series of Arnold tongues (**Paar,** Pavin, **1998)** within the quasiperiodic region where two fundamental oscillations mode-lock and form limit cycles of various periodicities."

J.R. Vanhoy, J.M. Anthony, B.M. Haas, B.H. Benedict, B.T. Meehan, S.F. Hicks, C.M. Davoren, C.L. Lundstedt (Department of Physics, United States Naval Academy, Annapolis, Maryland, USA; Department of Physics, University of Dallas, Irving, Texas, USA), Structural characteristics of 142Ce through inelastic neutron scattering, Phys.Rev. C52, 2387-2400 (1993):
"The *N* =84 isotones have been the subject of many theoretical (Hamilton et al., 1984; Meyer, Scholten, Brant, **Paar, 1990;** Nojarov, Faessler, 1987; Lipas et al., 1990; Copnell et al., 1992; Thai Khac Dinh et al., 1992) and experimental investigations (Kim et al., 1991; Vermeer et al., 1988) into the collective and particle nature of low lying excitations in nuclei near the closed *N* = 82 neutron shell. These nuclei became of considerable interest when Hamilton et al. (Hamilton et al., 1984) suggested that the 2_3^+ level in 140Ba, 142Ce, and 144Nd exhibited isovector or mixed-symmetry properties consistent with predictions (Iachello, 1984) of the interacting boson model-2 within the U (5) vibrational limit. Fragmentation of isovector strength has been observed extensively in 1^+ mixed symmetry states in deformed nuclei (Lipas et al., 1990) and suggested for 2^+ states in the *N* = 84 isotones (Meyer, Scholten, Brant, **Paar, 1990;** Copnell et al., 1992; Thai Khac Dinh et al., 1992; Cottle et al., 1991). Experimental information has not been extensive enough in the past to examine thoroughly the possible fragmentation of mixed symmetry strength in vibrational nuclei or to look for higher lying 1^+ and 3^+ mixed symmetry states. Our extended 142Ce data allows us to examine the mixed symmetry of such states."

S.F. Hicks, C.M. Davoren, W.M. Faulkner, J.R. Vanhoy (Department of Physics, University of Dallas, Texas, USA; Department of Physics, United States Naval Academy , Annapolis, Maryland, USA), Structural characteristics of 144Nd through γ-ray spectroscopy following inelastic neutron scattering, Phys.Rev. C57, 2264-2280 (1998):
"Mixed symmetry excitations in these isotones have been investigated theoretically Meyer, Scholten, Brant, **Paar, 1990;** Hamilton et al.,1984; Nojarov, Faessler, 1987; Lipas et al., 1990; Copnell et al., 1992; Thai Khac Dinh et al., 1992) and experimentally Cottle et al., 1991; Perrino et al., 1993; Eckert et al., 1997; Vermeer et al., 1988; Vanhoy et al., 1995). New information enables us to investigate mixed-symmetry strength in low-lying 144Nd excited levels and the fragmentation of this strength, particularly in 2^+ states, by comparing our experimental results with calculations from the interacting boson model (IBM-2), the quasiparticle phonon model

(QPM) (Perrino et al., 1993; Thai Khac Dinh et al., 1992), the cluster vibration model (CVM) (Meyer, Scholten, Brant, **Paar, 1990)**, and the particle-core coupling model (PCM) (Copnell et al., 1992). 2655.6-keV 1^+ state was recently assigned $J^\pi = (1,2)^+$ by Eckert et al. (Eckert et al., 1997). The excitation function of the 2655.6-keV transition from our measurement is shown in Fig. 2 and the angular distribution of the same γ-ray is shown in Fig. 3. Both data support the J = 1 spin assignment. Meyer et al. (Meyer, Scholten, Brant, **Paar, 1990)** report a strong 582-keV transition associated with this level.

Fragmentation of the $M1$ mixed-symmetry mode has been observed in numerous deformed nuclei (Lipas et al., 1990). In spherical nuclei, specifically in the N = 84 isotones, fragmentation has been predicted by various models (Meyer, Scholten, Brant, **Paar, 1990;** Copnell et al., 1992; Thai Khac Dinh et al., 1992; Robinson et al., 1991) and was recently observed in 142Ce by Vanhoy et al. (Vanhoy et al., 1995). Our extended data set allows us to investigate further thequestion of low-lying nixed symmetry states in 144Nd and the fragmentation of mixed symmetry strength. We include below a discussion of our IBM-2 calculations completed and discuss the model calculations from Refs. (Meyer, Scholten, Brant, **Paar, 1990;** Copnell et al., 1992; Thai Khac Dinh et al., 1992).

Extensive calculations we have included in this work are from Copnell et al. (Copnell et al., 1992) using the IBM-2 and the PCM. Calculations from three other models, the PCM, QPM, and CVM, are presented in Table IV. These models all contain both particle and collective features, but they treat these configurations in different ways. No new calculations have been completed using these models, rather the reader is referred to the literature for details of the models and for the specific calculations for 144Nd. In particular, the calculations we have included in this work are from Copnell et al. (Copnell et al., 1992). Meyer et al. for the CVM (Meyer, Scholten, Brant, **Paar, 1990**) and Perrino et al. for the QPM (Perrino et al., 1993). Experimental transition rates for the five lowest 2^+ states in both 144Nd and 142Ce are given in Table IV along with theoretical calculations for 144Nd from the PCM (Copnell et al., 1992), the CVM (Meyer, Scholten, Brant, **Paar, 1990**), the QPM (Thai Khac Dinh et al., 1992), and the IBM-2. The distributions of $B(M1; 2_x^+ \rightarrow 2_1^+)$ and $B(E2; 2_x^+ \rightarrow 0_1^+)$ for x = 2-6 are shown in Fig. 7 for 144Nd and 142Ce. The CVM does very well with most decays, especially the ground-state decays of the 2^+ levels (Meyer, Scholten, Brant, **Paar, 1990).** This model, like the QPM, predicts that the mixed symmetry strength is spread between 2_2^+ and 2_3^+ levels. The CVM, however, predicts a much bigger difference in $M1$ decay rates for these two levels into the 2_1^+ than does the QPM or than is observed experimentally. The QPM calculations of Dinh et al. (Thai Khac Dinh et al., 1992) give results similar to the IBM-2 for both $E2$ decays but overpredict the $M1$ decays. The CVM (Meyer, Scholten, Brant, **Paar, 1990)** does very well with the ground-state decay of the 2_2^+ level but shows mixed results for other decays."

E.R. Marshalek ***(University of Notre Dame, Notre Dame, Indiana, USA)*****, A new boson expansion for odd-particle systems, Phys.Lett. 44B, 5-8 (1973):**

"The boson-expansion formalism presented here may be considered as a possible alternative to the graphical particle-vibration coupling theory of the Copenhagen school **(Paar, 1971)** or even the Green's function formalism of Fermi-liquid theory (Speth, 1969), all three of which are perturbation theoretic and, judging by the lower orders, apparently capable of yielding equivalent results when the same interactions are used."

A. Wolf, R.L. Gill, Z. Berant, D.S. Brenner ***(Nuclear Research Center Negev, Beer-Sheva, Israel; Brookhaven National Laboratory, Upton, New York, USA; Clark University, Worcester, Massachusetts, USA)***, ***g*** **factor of the 3/2$^+$ 121.8keV level in 99Zr, Phys.Rev. C51, 2381-2384 (1995):**

"The A = 100 region of the periodic table is of special interest for nuclear structure studies. The *N* = 59 isotones, located at the transition point, are expected to exhibit shape coexistence. Indeed, experimental evidence has been found (Lhersonneau, Pfeifer, Kratz, Ohm, Sistemich, **Paar, 1990)**; Lhersonneau et al., 1988; Liang et al., 1991) for the existence of spherical and deformed structure in the neutron-rich $^{97}_{38}\mathrm{Sr}_{59}$, $^{98}_{39}\mathrm{Y}_{59}$, and $^{99}_{40}\mathrm{Zr}_{59}$ isotones. Until now, a number of E2 and M1 transition rates have been measured for the above isotones and have provided important information on the structure of the states involved in the transitions. However, no information exists to date about magnetic moments of excited states for these nuclei. Since *g*-factors are known to be good probes of both spherical and deformed states, an experiment was undertaken to measure the magnetic moment of the first excited, *E* = 121.8 keV, 3/2$^+$, level of 99Zr. In this work we present the result of this measurement and compare it with calculations. **V. Paar** and S. Brant have recently performed a theoretical calculation of *g* (3/2$^+$) for 99Zr, within the Interacting Boson-Fermion model, and obtained +0.34, in good agreement with the experimental result presented in this work."

T. Harada, Y. Hirabayashi ***(Research Center for Physics and Mathematics, Osaka Electro-Communication University, Osaka, Japan; Information Initiative Center, Hokkaido University, Sapporo, Japan)***, **Coulomb assisted Σ^-- nucleus bound states in the (K^-, π^+) reaction, Nucl.Phys. A829, 100-125 (2009):**

"Let us consider the Coulomb-assisted Σ^-- nucleus bound states by the (K^-, π^+) reaction on the 58Ni target. The nucleus 58Ni is very suitable because it is nearly a subclosed-shell nucleus of the proton f7/2orbit, and its proton hole strength is well concentrated on the J^π = 7/2$^-$, *T* = 3/2 ground-state of 57Co (Marinov, Oelert, Gopal, Brinkmöller, Hlawatsch, Mayer-Böricke, Meissburger, Paul, Rogge, Römer, Tain, Turek, Zemlo, Mooy, Glaudemans, Brant, **Paar,** Vouk, Lopac, **1985)**. Thus the Σ^-- 58Fe hypernucleus, which consists of the Σ^- and the 57Co nucleus, can be produced with total isospin $T = 5/2, T_z = -5/2$. As seen in Fig.3, the energies and widths of the Σ^-- 58Co bound states with the DD potential are very different from those with the $t_{\mathrm{eff}}\rho$ potential, as well as those with only the finite Coulomb one. To establish properties of the Σ^-- nucleus potentials for Σ^-- 57Co, we demonstrate the production spectra of the Σ^-- nucleus bound states by utilizing the near-recoilless (K^-, π^+) reaction.

E.R. Flynn, P. Rex Christensen, O. Nathan, D.G. Fleming *(Niels Bohr Institute, University of Copenhagen, Denmark; Los Alamos Scientific Laboratory, Mew Mexico, USA)*, Resonant proton scattering from 204Hg (II), Nucl.Phys. A193, 247-256 (1972):
"The elastic and inelastic 2^+ proton scattering excitation functions were measured from a 204Hg target. The observed distribution of g- and d-strength is compared with a recent calculation for 205Hg by **Paar**. The present results give further evidence on the fragmentation of the single-particle strength in 205Hg. As pointed out previously (Casten et al., 1972), this fragmentation is consistent with general expectations based on the particle-core coupling model and the strength and energy of the 2^+ excitations in the even cores near 208Pb. **Paar (Paar, 1972)** has performed a theoretical analysis of 205Hg within the single-particle vibration picture in which he calculates spectroscopic factors for the "particle-like" states in this nucleus. His results have many gross features in common with the experimental findings, but the details of the calculated strength distribution differ somewhat from the experimental picture. As pointed out by **Paar (Paar, 1972)** such shortcomings of the calculations should be expected because the underlying model neglects the effects of two-hole proton and neutron correlations. Generally speaking, the 2^+ resonant structure of 204Hg is less distinct than that of 206Pb, reflecting the existence of a larger number of states with appreciable one-phonon components in 205 Hg than in 207Pb. This is in good agreement with the elastic data for the two targets and with predictions of **Paar (Paar, 1972)**."

V.A. Knatko (Institute of Physics, BSSR Academy of Sciences, Minsk, USSR), On simulation of nonstatistical effects in neutron resonance gamma-decay, American Institute of Physics Conf.Proc. 125, 439-442 (1985):
"The properties of the γ-widths of *s*-neutron resonances of 84,66,68Zn are analyzed in terms of a quasiparticle-cluster–vibration model (QCVM). The main contribution to the nonstatistical effects observed in resonance neutron capture is made by primary high-energy γ-transitions. In (Knatko, Rudak ,1972) it was proposed to analyze such transitions in terms of a model used to describe low-lying levels in a product nucleus. Knowing the wave functions of the final states and generating the resonance wave function components, one may attempt to simulate widths for high-energy γ-transitions and estimate their role in nonstatistical effects. This approach is used to analyze the properties of γ-widths of *s*-neutron resonances of zinc isotopes with $A = 64$, 66 and 68. The Γ_m^f width values were calculated in terms of a quasiparticle-cluster –vibration model (QCVM) (Allaart, Hofstra, **Paar, 1981)** which satisfactorily describes low-lying levels in odd-mass Zn isotopes. Depending on the structure of the populated *p*-levels, the three-quasiparticle (3QP), 3QP-plus-phonon, and 1QP-plus-phonon configurations were taken into account in the resonance wave functions."

A. Wolf, R.L. Gill, D.S. Brenner, Z. Berant, R.B. Schuhmann, N.V. Zamfir (Brookhaven National Laboratory, Upton, New York, USA; Clark University, Worcester, Massachusetts, USA; Nuclear Research Center Negev, Beer-Sheva, Israel; Institute of Atomic Physics, Bucharest, Romania), *g* factor of the $3/2^+$ 93.6 keV level in 91Sr, Phys.Rev. C48, 562-565 (1993):

"In a different approach, **Paar (Paar, 1974)** showed that the low-lying levels of 95Mo can be reasonably well described by a cluster-vibrational field coupling model. However, within this model the value -0.17 obtained for $g(3/2^+)$ of 95Mo is again far from the experimental value.-0.23."

G. Lhersonneau, B. Pfeiffer, K.L. Kratz *(Ganil, Caen, France; Mainz University, Germany)*, Decay spectroscopy of neutron-rich nuclei with $A \simeq 100$, Hyperfine Interact. 223, 137-146 (2014):

"A detailed investigation of the levels in 97Sr revealed a strongly enhanced E2 component in a transition from a level at 687 keV (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)**. This was the first hint for a deformed structure in a N = 59 isotone of Sr, Y and Zr. Whereas reasonable evidence for excited deformed 0^+ states in even-even 96Sr and 98Zr was growing, hardly anything pointed to a deformed level in their intermediate isotone 97Y. Such a level being presumably a $5/2^+$ state by analogy with the ground state of 99Y, and being around 1.5 MeV, would be very difficult to identify as such. Neither β decay of 97Sr nor isomeric decay of 97Y led to such a level. The only candidate is a level at 1428 keV, basing the arguments for the assignment to the otherwise very close level correspondence in the isotones 97Y and 99Nb (Lhersonneau, Suhonen, Dendooven, Honkanen, Huhta, Jones, Julin, Juutinen, Oinonen, Penttila, Persson, Perajarvi, Savelius, Wang, Aysto, Brant, **Paar,** Vretenar, **1998)**.
The main goal of the A = 97 experiment was the study of decay of the high-spin isomer in 97Y discovered at JOSEF. New levels in 97Y were indeed found. The high-spin levels in 97Y were later analysed in terms of the interacting Boson+ Fermion + broken pair model developed in Zagreb (Lhersonneau, Brant, **Paar,** Vretenar, **1998)**. They result from the odd g9/2 proton being coupled with a broken neutron pair. The postulated $27/2^-$ spin and parity of the isomer appeared likely in view of that analysis, the neutron pair being in the aligned $(d5/2 \otimes h11/2)8^-$ configuration. The level scheme of 99Nb has been considerably extended with respect to the older works at OSTIS (Lhersonneau, Suhonen, Dendooven, Honkanen, Huhta, Jones, Julin, Juutinen, Oinonen, Penttila, Persson, Perajarvi, Savelius, Wang, Aysto, Brant, **Paar,** Vretenar, **1998)**. A IBFBPM calculation including a proton and a broken neutron pair outside the N = 56 closure was carried out. The good agreement with experiment showed that the N = 56 shell gap is not destroyed by the proton outside Z = 40."

P.F. Mantica, B.E. Zimmerman, W.B. Walters, H.K Carter, D. Rupnik, E.F. Zgnjar, W.L. Croft, Y.S. Xu *(Department of Chemistry and Biochemistry, University of Maryland, College Park, USA; Oak Ridge Associated Universities, Oak Ridge, Tennessee, USA; Department of Physics and Astronomy, Louisiana State University, Baton Rouge, USA; Department of Physics, Mississippi State University, Mississippi, USA; Department of Physics, Oregon State University, Corvallis, Oregon; USA)*, Weak coupling in the odd-mass Xe nuclides: Decay of 6.2-h 127Cs to levels of odd-neutron 127Xe, Phys.Rev. C42, 902-921 (1990):

"The cluster-vibration model calculations for 131 Xe by **Paar** and Koene **(Paar** and Koene,

1976) are quite reasonable. Since those calculations were reported, $3/2^+$ and $1/2^+$ levels near 1MeV have been identified near he predicted positions **(Paar** and Koene, **1976)**. In 133Xe, there are only three holes in the N = 82 closed shell and a significant portion of the vacancy lies in the d3/2 and s1/2 orbitals, leaving the h11/2 orbital with vacancy less than three **(Paar,** Eberth, Eberth, **1976)**. The depression of the $9/2^-$ and $7/2^-$ levels in many odd-neutron nuclides (Hagamann et al., 1979) in this mass region is well known and usually attributed to an $(h11/2)^3$ configuration (Vanden Berghe and **Paar, 1980)**. The negative-parity levels are marked by the depression of the *j*-1 $9/2^-$ level as neutrons are removed while the $15/2^-$ and $13/2^-$ *j*+2 and *j*+1 levels are slightly elevated relative to the position of the 2^+ level in the adjacent even-even nuclide. The $15/2^-$ and $13/2^-$ levels remain quite close to each other across these nuclides. These features of the structure have been particularly difficult to fit. Hagemann et al. (1979) attempted to fit the similar structures in the odd-N Te nuclides with both a rigid triaxial and a soft rotor core. While both models were able to fit the higher-spin levels, it was not possible to lower both the $9/2^-$ and $7/2^-$ levels at the same time. It was shown that in cluster-vibration model calculations for unique parity orbitals, the levels with spin *j* -1 and j -2 both are depressed as a function of coupling strength for particles, while for holes, only the *j* -1 level is depressed (Meyer, Monnand, Pinston, Schussler, Pfeiffer, **Paar, 1987)**."

D.R. Bes, R.A. Broglia, G.G. Dussel, R. Liotta ***(Comision Nacional de Energia Atomica, Buenos Aires, Argentina; Niels Bohr Institute, University of Copenhagen, Denmark)*****, Simultaneous treatment of surface and pairing nuclear fields, Phys.Lett. B56, 109-111 (1975):**

"The problems of non-orthogonality and overcompleteness are automatically taken into account. Actually, this interplay was already utilized in refs. (Bes, Broglia, 1971; Barnes et al., 1975; Broglia, **Paar,** Bes, **1971)** to explain the properties of the 2p-1h states of 207, 209Pb and 209Bi and of 2p-2h states of 208Pb and is here justified."

R.A. Broglia, P.F. Bortignon ***(Niels Bohr Institute, University of Copenhagen, Denmark; Theoretical Division, University of California, Los Alamos Scientific Laboratory, USA; Universite degli Studi di Padova, Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy)*****,** $\alpha-$**vibrations, Phys.Lett. B65, 221-224 (1976):**

"Among the $J^{\pi}=0^{+}$ states which are strongly excited in the $(N-2,Z-2)\rightarrow(N,Z)$ reaction, one should observe all the states strongly excited in the $(N-2,Z)\rightarrow(N,Z)$ and $(N,Z-2)\rightarrow(N,Z)$ reactions. Limited evidence of such systematic has been found (Betts, 1976) in the f7/2 nuclei. In 208Pb the proton and neutron pairing vibrations (two-phonon states) are expected at similar energies (Broglia, **Paar,** Bes, **1971;** Blomqvist, 1970). Utilizing the results of these references and the nuclear field theory (Bes et al., 1974; Bes, Broglia, 1971) techniques, we work out the energy of the two-phonon α -vibration in 208Pb."

W. Urban, W.R. Philips, I. Ahmad, J. Rekawek, A. Korgul, T. Rzaca-Urban, J.L. Durell, M.J. Leddy, A.G. Smith, B.J. Varley, N. Schulz, L.R. Morss ***(Institut of Experimental Physics, Warsaw University, Poland; Schuster Laboratory, Department of Physics and Astronomy, University of Manchester, United Kingdom; Argonne National Laboratory, Lemont, Illinois, USA; Institut de Recherches Subatmiques and Universite Louis Pasteur, Strasbourg France),*** **Near-yrast structure of neutron-rich, *N* = 85 isotones, Phys.Rev. C66, 044302 (2002):**

"At low excitation energy all three neutrons occupy the *f*7/2 orbital, producing a $\nu(f7/2^3)_j$ multiplet with the $3/2^-$, $5/2^-$, and $7/2^-$ multiplet members lowest in energy (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**). This characteristic configuration appears systematically in the *N* = 85 isotones, as illustrated in Fig.3. The $(\nu f^3)_j$ cluster was introduced in Ref. (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**) to describe the multiplet of the three lowes states in the *N* = 85 isotones by analogy to the so-called "$\nu f7/2$ nuclei" with *Z* = 23 or *N* = 23, where a similar $(\nu f^3)_j$ cluster is present. It should be mentioned here that in the *N* = 85 isotones the $\nu p3/2$ is much closer to the $\nu f7/2$ than it is at $N = Z = 23$. Therefore the $3/2^-$ level has at *N* = 85 a significant admixture of the $\nu f7/2^2 p3/2$ configuration, as discussed in detail in Ref. (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**).
The $I^\pi = 11/2^-$ and $15/2^-$ yrast levels in the *N* = 85 isotones were interpreted as higher-spin members of the $(\nu f^3)_j$ multiplet (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**). The $\nu(f7/2^3)_j$ multiplet origin of these excitations is manifested by a significant decrease of the in-band transition intensities above the spin $15/2^-$. In the cluster-vibration model of Ref. (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**) the $I^\pi = 11/2^-$ and $15/2^-$ yrast levels were reproduced by coupling the $f7/2^3$ cluster to the quadrupole vibration. The resulting configuration was called a collective quasi- $f7/2$ multiplet. Let us note that the quasi- $f7/2$ multiplet, with one quadrupole phonon (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**) cannot generate spin 21/2. The 1085 keV level in 139Xe is a good candidate for the $9/2_2^-$ state, as discussed in Refs. (Yamamoto et al., 1982; **Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**) and it follows the systematics of Fig. 3. The 1108 keV level in 147Sm, however, proposed as the $9/2_2^-$ excitation (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980)**, deviates from the systematics as illustrated in Fig. 10(a), which shows the $9/2_2^-$ excitation relative to the $5/2^-$ level with the 1108 keV level included. It seems that the correct calculations of octupole excitation energies at *N* = 85 will require going beyond the shell-model scheme. In particular the effect of polarization of cores towards octupole instability has to be taken into account, similarly, as proposed for coupling of quadrupole phonon to valence neutrons at *N* = 85 (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**). To describe properly such excitations the energy of the quadrupole phonon was taken at 1 MeV in Ref. (**Paar,** Van den Berghe, Garrett, Leigh, Dracoulis**, 1980**), which is significantly lower than energies of 2^+ excitations in the corresponding *N* = 82 cores. This arbitrary selection takes care of the effect of "softening" of the *N* =82 cores towards quadrupole distortions, when neutrons are added."

N.D. Dang ***(Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Moscow, USSR)*****, Thermo field boson realizations for operators of the finite temperature random phase approximation, Phys.Lett. B229, 181-187 (1989):**
"Considering only the momentum $J = 2$ in the collective approximation with the first ($i = 1$) solution of the RPA we have from eq. (15) for the zero-temperature case:

$$Q^{\dagger}_{2M1} = \frac{1}{2}\sum_{j_a j_b}\left[\psi^{21}_{ab}A^{\dagger}_{2M}(ab) - \varphi^{21}_{ab}A_{2\tilde{M}}(ab)\right],\; Q_{2\tilde{M}1} = \frac{1}{2}\sum_{j_a j_b}\left[\psi^{21}_{ab}A_{2\tilde{M}}(ab) - \varphi^{21}_{ab}A^{\dagger}_{2M}(ab)\right]$$

In ref. (Kyrchev, **Paar, 1988)** it has been shown that the operators (20) together with their commutators close to SU (6) algebra under some conditions on the amplitudes $\psi^{21}_{ab}, \varphi^{21}_{ab}$. In this way, a microscopic interpretation on the Hamiltonian level for the IBM and the quadrupole phonon model (QPM) (Janssen, Jolos, Dönau, 1974) has been proposed within the framework of the quasiparticle phonon nuclear model (QPNM) (Voronov, Kyrchev, 1986). In the present case at finite temperature employing (16), (17) and the results obtained at $T = 0$ (Kyrchev, **Paar, 1988)** we can show that the quadrupole Finite Temperature RPA (FT-RPA) operators (15) together with their commutation relations will form an SU (6) algebra if the following conditions hold (21)-(25). Under the conditions (21) and (22), the Dyson (DR), Hostein-Primakoff (HPR) and Schwinger (SR) boson realizations for the quadrupole thermal operator (15) ($J = 2$) can now be readily obtained by the usual procedure (Kyrchev, **Paar, 1988)**. They have similar forms as in the zero-temperature case (Kyrchev, **Paar, 1988)**. "

K. Takada, K. Yamada, H. Tsukuma ***(Department of Physics, Kyushu University, Fukuoka, Japan; Institute for Nuclear Study, University of Tokyo, Japan)*****, Microscopic study on the shape phase transition in the Sm isotopes (I). Effect of ground-state correlation), Nucl.Phys. A496, 224-238 (1989):**
"Following ref. (Takada, 1988), we call this the Dyson boson mapping condition, which is essentially equivalent to the RPA-SU (6)-enforcing condition proposed by Kyrchev and **Paar** (Kyrchev, **Paar, 1988)**."

T. Fenyes, Z. Dombradi ***(Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary)*****, Structure of 120Sb nucleus, Phys.Lett. B275, 7-11 (1992):**
"In this work we have calculated the level spectrum, magnetic dipole and electric quadrupole moments, as well as the decay properties of the low-lying states of 120Sb on the basis of the interacting boson-fermion-fermion model (IBFFM). This model proved to be successful in the case of 116Sb, as our calculations (Gacsi et al., 1991; Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991)** showed. The Hamiltonian and computer codes used in the calculations are described in refs. (**Paar, 1984;** Iachello, Scholten, 1979; **Paar,** Brant, Canto, Leander, Vouk, **1982;** Jansen, Jolos, Dönau, 1974; Arima. Iachello, 1975) and ref. (Brant, **Paar,** Vretenar, **1985**), respectively. The occupation probabilities for neutrons were taken from the systematics of the experimental data: $V^2(\nu d5/2) = 0.93$, $V^2(\nu g7/2) = 0.87$, $V^2(\nu s1/2) = 0.62$, $V^2(\nu d3/2) = 0.35$, $V^2(\nu h11/2) = 0.32$ (see references in ref. (Kibedi, Dombradi, Fenyes, Krasnahorkay, Timar,

Gacsi, Passoja, **Paar,** Vretenar, **1988)**. Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991)**. We remark that both in the case of 120Sb and 116Sb (Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991)** the detailed IBFFM calculations approved the approximate classification of the low-lying proton-neutron multiplet states, performed on the basis of the simple parabolic rule."

N. Amiri, M. Ghapanvari, M.A. Jafarizadeh, S. Vosoughi ***(Department of Nuclear Physics, University of Tabriz, Iran; Plasma and Nuclear Fusion Research, Nuclear Science and Technology Research Institute, Tehran, Iran; Department of Theoretical Physics and Astrophysics, University of Tabriz, Iran; Research Institute for Fundamental Sciences, Tabriz, Iran; Irradiation Applications, Nuclear Science and Technology Research Institute, Tehran, Iran)*****, Nuclear Structure and phase transition of odd-odd Cu isotopes: A neutron-proton interacting boson-fermion-fermion model calculation, Nucl.Phys. A1002, 121961 (2020):**
"The IBFM consists of an even-even core which is characterized by IBM and a single fermion that is coupled to the core by an appropriate boson-fermion interaction (Iachello et al., 1979,1980,1981,1991; **Paar,** Sunko, Vretenar, **1987;** Barea et al., 2005; Yoshida, Iachello, 2013; Thomas et al., 2014; Nomura et al., 2019,2020). As to the odd-odd nuclei, the one-to-one correspondence between experimental and calculated levels is difficult to propose because of complexity of their experimental spectra. The concepts and techniques of the boson-fermion symmetries can be extended to include odd-odd nuclei (Brant, **Paar,** Vretenar, **1984,1987;** Vervier, 1987; Brant, **Paar, 1988;** Van Isacker, Jolie, 1989). An analytical calculation was performed for the nucleus 62Cu by Hübsch and **Paar** (Hübsch, **Paar, 1987)**. They constructed an algorithm for the subsequent reduction appropriate for the boson-fermion group chain associated with an odd proton and neutron in *j* = 3/2 configurations and the corresponding energy formula was given and exemplified for 62Cu in the case of associated supersymmetry (Hübsch, **Paar, 1987)**. For odd-odd nuclei. three dynamical boson-fermion symmetries associated with $j_\pi = 3/2,\ j_\nu = 3/2$ and U^B (5) symmetry of the boson core were introduced (Hübsch, **Paar, 1984)**. The corresponding energy formulas and quantum numbers for low-lying states were explicitly given (Hübsch, **Paar, 1984;** Hübsch, **Paar,** Vretenar, **1985)**. The structure of 62,64,66Cu nuclei in the framework of the IBFFM was studied by Singh and Gangopadhyay. The proposed model could explain the low energy structure with reasonable success (Singh, Gangopadhyay, 1997). There are some examples of dynamic Bose-Fermi symmetries in the spectra of the odd-odd Cu isotopes (Singh, Gangopadhyay, 1997; Singh et al., 1999). Also, odd-odd nuclei from the viewpoint of the boson-fermion supersymmetry have been considered (Hübsch, **Paar, 1984,1987;** Hübsch, **Paar,** Vretenar, **1985;** Kitipova, 1986; Warner et a., 1986; Rotbard et al., 1993)."

D. Bazzacco, A.M.I. Haque, K.O. Zell, W. Neumann, J. Eberth, P. von Brentano, C. Protop ***(Institut für Kernphysik der Universität zu Köln, Germany; Institut for Physics and Nuclear Engineering, Bucharest, Romania)*****, Excited states in 145Gd from the (3He,2n) reaction, Z.Phys. A310, 65-73 (1983):**
"The $9/2^-$ 1,810 keV and $11/2^-$ 2,258 keV states have some characteristics which suggest that

they belong to the multiplet from the coupling of the f7/2 neutron with the 2^+ cores state in 144Gd: the quadrupole mixing ratio of the $11/2 \rightarrow 9/2$ and $9/2 \rightarrow 7/2$ transitions is positive and larger for the lower one in agreement with **Paar's** prediction (**Paar, 1978)** for the mixing of the yrast transitions in the coupled bands of odd vibrational nuclei: sign δ = sign $\frac{Q_j}{g_j - g_R}$, and $|\delta(I \rightarrow I-1)| < |\delta(I-1 \rightarrow I-2)|$, where I - 2 = j. Indeed, the quadrupole moment of a particle in a quasispherical nucleus is negative and the g-factor of a neutron in the f7/2 state is also negative so that **Paar's** relation implies that the mixing ratio has a positive sign as it is observed."

A. Algora, J. Jolie, Z. Dombradi, D. Sohler, Z. Podolyak, T. Fenyes (Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary; IFIC – University of Valencia, Spain; Institut für Kertnphysik, University of Köln, Germany; Department of Physics, University of Surrey, Guildford, United Kingdom), Supersymmetry model in 73As revisited: Electromagnetic transition rates and U (6/12), Phys.Rev. C67, 044303 (2003):
"The recognition that the U(6/12) scheme works much better for the 74Se, 73As members of the supermultiplet than for 74Se, 75Se encouraged us to study further 73As both experimentally and theoretically (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)**. The U (6/12) dynamical supersymmetry (in its vibrational limit) has been used earlier to describe the states of 76Se, 75As (Vervier et al., 1985). Necessarry but certainly not sufficient conditions for the applicability of this approximation are the following (Bijker, 1984): (i) the even-even nucleus can be described by the U (5) dynamical symmetry of the IBM, (ii) the available single-particle orbits that can be occupied by the odd nucleon in the odd-even nucleus have angular momenta j = 1/2, 3/2, 5/2. Conditions (i) ad (ii) are partially fulfilled by 74Se, 73As. Earlier studies on 74Se by means of the IBM have shown that this nucleus can be considered to be between the U (5) and SU (3) symmetry limits (Tokunaga, Seyfarth, Schult, Brant, **Paar,** Vretenar, Börner, Barreau, Faust, Hofmeyr, Schreckenbach, Meyer, **1984)** with a strong U(5) character. Here we have followed a procedure similar to that of Ref. (Algora et al., 1995), based mainly on the decay pattern of the levels, the result of earlier IBFM calculations (Algora et al., 1995; Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)**, and single-particle transfer reaction results (Rotbard et al., 1976; Schrader et al., 1979). We remark that our identification of the levels $3/2_1$, $5/2_1$, $1/2_1$, $1/2_2$ qualitatively agrees with the Ten Brink's results (Ten Brink, 1978) using the cluster-vibrational coupling model. In Fig. 2 we show a comparison of the present calculations with the earlier IBFM results (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997).** The choice of the $T(M1)$ operator was similar to that used in Ref. (Jolie, 1992). The parameters of the $T(M1)$ operator were taken in accordance with Ref. (Algora, Sohler, Fenyes, Gacsi, Brant, **Paar, 1995)**. The used v_j were $v(\pi p1/2) = 0.344$, $v(\pi p3/2) = 0.761$, and $v(f5/2) = 0.584$, as in Ref. (Algora, Sohler, Fenyes, Gacsi, Brant, **Paar, 1995)**. Using the $B(M1)$ and B(E2) values we have also derived theoretical branching ratios for the states using the experimental energies. The results are presented in Table III., where the earlier IBFM model branchings (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)** are given for comparison. The overall agreement of calculated and experimental results is

remarkable: for six states the leading branches are well reproduced. Only the branches of states $1/2_3, 5/2_4$ are poorly reproduced, indicating that the weight of the different components of the wave functions is not appropriated or that they should include additional components to obtain a better agreement. This problem was already pointed out in Ref. (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)**. At this point it is worth mentioning that using a slightly different parametrization than that used in Ref. (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)**, Bucurescu et al. (Bucurescu et al., 1999) obtained an IBFM description of 73As, which for some levels gives a slightly better agreement with the experimental branching ratios than the results of Ref. (Sohler, Podolyak, Gulyas, Fenyes, Algora, Dombradi, Brant, **Paar, 1997)**.

K. Allaart, E. Boeker, G. Bonsignori, M. Savoia, Y.K. Gambhir ***(Natuurkundig Laboratorium, Vruje Universiteit, Amsterdam, Netherlands; INFN, Sezione of Bologna and Department of Physics "A. Righi", Bologna, Italy; Indian Institute of Technology, Bombay, India)*****, The broken pair model for nuclei and its recent applications, Phys.Rep. 169, 209-292 (1988):**

"The broken pair model has been applied however, in a hybrid form, to odd nuclei with both open proton and neutron shells. In this model, called Quasiparticle Cluster Vibration Model (QCVM) (Allaart, Hofstra, **Paar, 1981)**, the odd number of identical nucleons are described by $v_g \leq 3$ states. These are coupled to states for the other kind of nucleons which, in order to keep the dimensions of the problem within workable limits, are represented in a phenomenological phonon or boson model. The model is an improvement over the quasiparticle-vibration model (Kisslinger, Sorensen, 1963) in that it treats the Pauli principle for the odd set of nucleons explicitly. Rather successful applications have been reported for the odd Zn isotopes (Van Egmond, Hofstra, Boeker, Allaart, **Paar, 1981)**. In these calculations the neutron single-particle energies were taken from 57Ni and the phonon energy $\hbar\omega_2 = 1.2$ MeV from the 2_1^+ states of the even nuclei. A pairing force between the neutrons was adopted. The model Hamiltonian then contains only two parameters, viz. the strengths of this pairing force and of the particle-phonon coupling. These were fitted to describe the whole sequence of Zn isotopes. Because the model contains the essential degrees of freedom, the quality of the description turned out to be as good as that of much more elaborate shell model calculations. As a typical example of the results that one obtained the calculated spectrum (Van Egmond, Hofstra, Boeker, Allaart, **Paar, 1981)** of 63Zn is shown in fig. 19. Fig. 19. Spectrum and composition of the wave functions for 63Zn were calculated as a one-broken-pair ($v_g \leq 3$) neutron system coupled to a vibrational core (Van Egmond, Hofstra, Boeker, Allaart, **Paar, 1981)**. The last two columns give the percentages of v_g = 1 components coupled with one or more phonons (v_g = 1 + ph) and v_g = 3 components coupled with one or more phonons (v_g = 3 + ph). The composition of the wave functions is displayed in the same figure. It is seen that the contribution of v_g = 3 plus one phonon components is very important. This illustrates that probably v_g = 5 components would contribute significantly as well; the description within the $v_g \leq 3$ truncated model is at best an "effective" one. For nuclei with both open proton and neutron shells one may need to break many or even all the S-pairs.

The Interacting Boson Model (IBM) (Arima, Iachello, 1976, 1978,1979) provides a successful phenomenological description of collective low-lying states in many vibrational, rotational and transitional nuclei (Iachello, 1979; Casten, 1985). Some results that have been obtained for the $50 < N < 82$ shell arec displayed in figs. 23 and 24. To introduce the figures we mention that in (Allaart, Bonsignori, Savoia, **Paar, 1986)** several alternatives for the state (6.21) were also considered, which might reflect the properties of the boson model state (6.22) better. It was found that sometimes a state constructed with two particle-hole operators instead of two D-pair operators should be preferred or in other case the state (6.21) with a projection on v_{g} = 4. None of these alternatives were completely satisfactory, however. The recipe (6.26) provides no reason to expect that such a relation will indeed be satisfied by the broken-pair model matrix elements. Nevertheless, it was found that the matrix elements of (6.26) are surprisingly close to the IBM relation (6.27), as shown in fig. 25. This result may be considered as support for the use of the broken-pair model recipe (6.26) as a tool to construct a microscopic basis for the IBM (Allaart, Bonsignori, Savoia, **Paar, 1986)**."

J. Ludziejewski, A.W.B. Kalshoven, W.H.A. Hesselink, H. Verheul, M.J.A. de Voigt ***(Institute of Nuclear Research, Swierk, Poland; Natuurkundig Laboratorium, Vrije Universiteit, Amsterdam, Netherland)*****, Level structure of odd 101-107Ag and doubly odd 104Ag nuclei in the light of different nuclear models, Nukleonika A25, 315-329 (1980):**

"A more complete description of odd silver nuclei is given by **Paar (Paar, 1973)** who showed that the coupling of the cluster of three proton holes to a vibrational Sn core gives a good description of the low-spin states either with negative and positive parity. In contradiction to the weak coupling model, the existence of the low-lying $7/2^{+}$ state is explained by this model. Also, electromagnetic properties of the low spin states are reasonably well reproduced by the cluster vibrational model. It was shown by **Paar (Paar, 1973)** that the coupling of three proton holes in the p1/2, p3/2 and g9/2 orbitals to a vibrational Sn core gives a good description of all low spin states in odd silver nuclei. Furthermore, in contradiction to the weak coupling model, the anomalous 7/2 state is nicely explained by this model (Fig. 3). Fig. 3. Comparison of the observed energy levels in 105Ag (observed $\alpha, 2n\gamma$) with the prediction of the three-proton cluster vibration model (**Paar** calculation).

In order to check the applicability of this model to describe high-spin states observed in silver nuclei we extended the calculation by **Paar** to the states with spin as high as 23/2, using this program. For the positive parity states only the cluster of three proton-hole on the g9/2 subshell was taken into account while for negative parity states the p1/2, p3/2 and g9/2 subshells were considered. In the calculation we used the same parameters as **Paar**: phonon energy $\hbar\omega$ = 1 MeV, the normalized particle vibration coupling strength a = 0.8 MeV, the effective pairing strength G = 0.2 MeV, the single particle energies $E_{g9/2} = 0.0\,\mathrm{MeV}$, $E_{p1/2} = 0.3\,\mathrm{MeV}$, and $E_{p3/2} = 1.5\,\mathrm{MeV}$. The results of this calculations for the 105Ag are compared to the experimental in Fig. 3. It follows from this figure that the negative parity levels up to spin value $11/2^{-}$ are well reproduced. Also, the positive parity states with spin value up to $13/2^+$ are reproduced in approximately the right position."

A.Amusa ***(University of Ife, Ile-Ife, Nigeria; Physics Division, Argonne National Laboratory, Lemont, Illinois, USA)*****, Shell model studies in 89Nb, Z.Phys. A322, 567-572 (1985):**
"In general, nuclei near the strong $N = 50$ shell closure and the $Z = 38$ subshell closure have been fairly well described in terms of the nuclear shell model scheme (Serduke et al., 1976; Gloeckner et al., 1976; Amusa et al., 1972). However, the properties of some nuclei in this region can only be explained with the weak coupling model (Krishan, Sen, 1976; Shibata et al., 1975) or with the Alaga model (**Paar, 1974)** of coupling some particle clusters to a vibrating core. It seems that a refinement or modification of weak coupling model might be capable of a correct theoretical explanation of the level scheme of 87Y. Alternatively, the application of a semimicroscopic model of coupling neutron clusters to quadrupole vibrations that **Paar** et al. (**Paar**, Eberth, Eberth, **1976)** applied successfully to 67,71Ge might also be considered for 87Y."

W. Hampel et al. GALLEX Collaboration ***(Max Planck Institut für Kernphysik, Heidelberg, Germany; Institut für Technische Chemie, Forschungszentrum Karlsruhe, Germany; Laboratori Nazionali di Gran Sasso, L'Aquila, Italy; Dipartimento di Fisica, Universita di Milano, Italy; Physik Department, Technische Universität München, Garching, Germany; Observatoire de la Cote d'Azur, Nice Cedex, France; Weizmann Institute of Science, Rehovot Israel; Dipartimento di Fisica, Universita di Roma, Italy; INFN, Sezione di Roma, Italy; Service de Physique des Particules, CEA/Saclay, France; Brookhaven National Laboratory, Upton, New York, USA)*****,Verification tests of the GALLEX solar neutrino detector, with 71Ge produced in-situ from the beta-decay of 71As, Phys.Lett. B436, 158-173 (1998):**
"The decay scheme for 71As is shown in Fig, 1. The absolute activity of the As-samples was determined via Ge (HP) spectrometry at the Gran Sasso underground laboratories, using the 175 keV γ transition to the 71Ge ground state. The branching ratio adopted by us initially is $82 \pm 3\%$ (Meyer, Nagle, Brant, Frlež, **Paar,** Hopke, **1990)**. Our measurements of the three external samples, A1e, A2e and B3e, provide a well-controlled experiment for the independent determination of the branching ratio of the 175 keV gamma ray. The nominal results for the recovery, R, of the e-samples, are, in percent, 98.6 ± 1.6, $99.2 \pm 1.7$and 98.0 ± 1.8;note that these values depend on the published value of the γ_{175} branching ratio, 0.82 (Meyer, Nagle, Brant, Frlež, **Paar,** Hopke, **1990)**."

J. Äystö, P. Taskinen, M. Yoshii, J. Honkanen, P. Jauho, H. Penttilä, C.N. Davids ***(Department of Physics, University of Jyväskylä, Finland)*****, Identification and decay of new neutron-rich isotopes 115Rh and 116Rh, Phys.Lett. B201, 211-214 (1988):**
"Allowed β decay in this mass region is mainly expected to be mediated via transitions between the spin-orbit partners $\nu 1g7/2 - \pi 1g9/2$. In a simple picture the ground state wave function of the odd heavy Rh isotopes has a large component from the coupling of the $\pi 1g9/2$ hole to the

even-even Pd core, leading to spins of $7/2^+$ and $9/2^+$ for the lowest levels (Heyde, **Paar, 1986)**. This results in allowed β decays to positive-parity levels arising from 2d5/2, 1g7/2, 3s1/2, and 2d3/2 neutron orbitals and to some complex structure states of more collective nature. The strong influence of the $(\pi 1g9/2, \nu 1g7/2; 1^+)$ proton-neutron pairing interaction, as observed earlier for the lighter Rh's, is also clearly present in the decays of 115Rh and 116Rh. This strong interaction is believed to be partly responsible for the minimum in the excitation energy of the 2_1^+ states of even Pd isotopes at $N = 68$, indicating a maximum quadrupole deformation. This region should then provide an interesting extension to study the recently proposed reduction of pairing in the isomeric or ground states of odd Tc, Rh and Ag isotopes (Federman, Pittel, 1979; Peker et al., 1986; Heyde, **Paar, 1986)**."

P.F. Bortignon, R.A. Broglia, D.R. Bes, R. Liotta ***(Niels Bohr Institute, University of Copenhagen, Denmark; State University of New York at Stony Brook, New York, USA; Comision de Energia Atomica, Buenos Aires, Argentina)*, Nuclear Field Theory, Physics Reports, 30, 365-370 (1977):**
"As pointed out in refs. **[**Barnes et al., 1972; Broglia, Liotta, **Paar,** Bes, Effect of the multipole pairing phonons in the $(h9/2 \otimes 3^-)$ multiplet of 209Bi, preprint, Niels Bohr Institute **1972** (unpublished); Bortignon, Broglia, Bes, Liotta, **Paar, 1976]**, the pairing modes are basic to simultaneously describe the 210Po(t, α) and 209Bi (d,d') data. The main influence of the pairing degree of freedom on the members of the $\left[h_{9/2} \otimes 3^- (208\text{Pb})\right]$ multiplet is to be found in the corresponding $3/2^+$ level. The need for treating the particle-hole and pairing modes on equal footing in describing the spectrum of odd and even nuclei around closed shell was recognized at an early stage **[**cf. 21, 37, 38 Bes, Broglia, 1971); Broglia, **Paar,** Bes, **1971**a; Broglia, Paar**,** Bes, **1971**b; Bortignon, Broglia, Bes, Liotta, **Paar, 1976;** see also 35 Hamamoto, 1969; 1974**]**. In fact, it was realized (21 Bes, Broglia, 1971) in analyzing the spectrum of 209Pb that a description in terms of the states $\left| j \otimes (208Pb); j' \right\rangle$ was too limited to account for the variety and richness of the experimental data, and that both surface and pairing vibrations had to be included. The difference between the unperturbed energies of the two states $|1\rangle = \left|d_{3/2}^{-1} \otimes \text{gs (210Po)}; 3/2^+\right\rangle$ (2.733 MeV) and $|2\rangle = \left|h9/2 \otimes (208\text{Pb}); 3/2^+\right\rangle$ (2.615 MeV) is 118 keV. These mix strongly through the couplings depicted by graphs (b) and (c) of Fig. 4.1. This is important for the case of $3/2^+$ states ($\delta E(3/2_1^+) = -136$ keV). The picture achieved in terms of these fields displays to a high degree of accuracy the observed properties."

I.A. Kondurov, Y.U. Loginov, E.A. Malyutenkov, P.A. Sushkov ***(Peterburgskij institut yadernoj fiziki im. B.P. Konstantinova, Rossijskoj akademii nauk, Rossiya)*, Issledovanie mgnovennyh i zaderzhannyh γγ-sovpadenij v reakkcii 193Ir(nγ)194Ir, Izvestiya Akad.Nauk Ser.Fiz. 57, 119-121 (1993):**
"Issledovanie svojstv vozbuzhdennyh sostoyanij nechetno-nechetnih yader ${}^{192}_{77}\text{Ir}_{115}$ i ${}^{194}_{77}\text{Ir}_{117}$, nahodyashihsya v oblasti formirovaniya obolochki Z = 82, interesno s tochki zreniya yadernyh

modelej, opisyvayushih yadernuyu deformaciyu v etoj oblasti yader. V nastoyashee vremya eksperimentalnoe izuchenie etih yader vedetsya v ramkah mezhdunarodnoj kolaboracii, v kotoroj uchastvuyut neskolko issledovatelskih centrov. Pervim rezultatom yavilas rabota po podrobnomu izucheniyu izucheniya i shemi urovnej yadra 192Ir v (n γ)-reakcii (Kern, Raemy, Beer, Dousse, Schwitz, Balodis, Prokofjev, Kramer, Simonova, Hoff, Gardner, Gardner, Casten, Gill, Eder, von Egidy, Hagn, Hungeford, Scheerer, Schmidt, Zech, Chalupka, Murzin, Libman, Konenko, Coceva, Giacobbe, Kondurov, Loginov, Sushkov, S. Brant, **Paar, 1991)**."

E. Grodner, A.A. Pasternak, J. Srebrny, M. Kowalczyk, J. Mierzejewski, P. Decowski, C. Droste, J. Perkowski, T. Abraham, J. Andrzejewski, K. Hadynska-Klek, L. Janiak, A. Kasparek, T. Marchlewski, P. Napiorkowski, J. Samorajczyk ***(Faculty of Physics, University of Warsaw, Poland; A.F. Ioffe Physical Technical Institute, St. Petersburg, Russia; Heavy Ion Laboratory, Warsaw University, Poland; A. Sotan Institute for Nuclear Studies, Swierk, Poland; Smith College, Northampton, Massachusetts, USA; Faculty of Physics and Applied Informatics, University of Lodz, Poland)*****, DSA lifetime measurements of 124Cs and the time-reversal symmetry, J.Phys. Conf.Ser. 381, 012067 (2012):**
"A quantum description of microscopic processes has been postulated by Schrödinger as wave mechanics following a non-relativistic wave equation (Schrödinger, 1926), the understanding of relativistic formula came with the paper of Dirac (Dirac, 1928). A hypothesis of the chiral symmetry breaking opened a new opportunity for the study of spontaneous time-reversal symmetry breaking in an atomic nucleus (see for example Gimlett et al., 1982; Christensen, 1987). Here, recent DSA measurements of chirality in the 124Cs nucleus are presented, where level spin and parity assignment follow Ref. (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001)**. The presence of two rotational bands, with almost degenerate spin and parity levels indicates spontaneous breakdown of the chiral symmetry in 124Cs."

H.W. Li, J.B. Lu, G.S. Li, Y. Zheng, S.H. Yao, X.G. Wu, C.Y. He, Q-L- Xia, J.J. Liu, C.B. Li, S.P. Hu, J.L. Wang, Y.H. Wu, P.W. Luo, K.Y. Ma, C. Xu, J.J. Sun ***(College of Physics, Jilin University, Changchun, China; China Institute of Atomic Energy, Beijing, China; College of Physics and Technology, University Shenzhen, China; School of Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, China)*****, New high spin level scheme of 87Sr, Chin.Phys. C38, 074004 (2014):**
"The following structure of 87Sr has been studied by Ekström et al., using the reaction 84Kr(α, nγ)87Sr (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**. In comparison with earlier work on the nucleus 87Sr (Arnell et al., 1975; Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**, a new partial level scheme including 21new γ-ray transitions and 10 new levels deduced in the present work. In Ref. (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**, angular distribution and linear polarization measurements have been used to obtain definite spin

and parity assignments for the 2595.3 and 2830.5 keV levels with I^{π} = 13/2$^-$ and 15/2$^-$, respectively. We assign I^{π} = 17/2$^{(-)}$, 19/2$^{(-)}$ up to 23/2$^{(-)}$ for the 3248.7, 3390.2 to 4440.0 keV levels, respectively, which is in agreement with Refs. (Arnell et al., 1975; Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**."

E.V. Vasileva, A.V. Vojnov, A.M. Suhovoj, V.A. Hitrov, Yu.V. Holnov (Obedinennyj institut yadernyh issledovaniya, Dubna, Rossiya), Dvuhkvantovye kaskady raspada kompaund-sostoyaniyayadra 192Ir , vozbuzhdaemogo pri zahvate teplovyh nejtronov, Izvestiya Akad.Nauk Ser.Fiz. 59, 99-110 (1995):

"Pri raschete v sootvetstvii c (Mughabghab, 1984) prinyato, shto prakticheski vse sluchai zahvata teplovyh nejtronov privodyat k vozbuzhdeniyu kompaund-sostoyaniya s $J^{\pi} = 2^{+}$, a spiny i chetnosti konechnyh urovnej kaskadov vzety iz (Kern, Raemy, Beer, Dousse, Schwitz, Balodis, Prokofjev, Kramer, Simonova, Hoff, Gardner, Gardner, Casten, Gill, Eder, von Egidy, Hagn, Hungeford, Scheerer, Schmidt, Zech, Chalupka, Murzin, Libman, Konenko, Coceva, Giacobbe, Kondurov, Loginov, Sushkov, Brant, **Paar, 1991)**."

D.R. Bes *(Physics Department, CAC, CNEA, Argentina)*, The field treatment of the nuclear spectrum. Historical foundation and two contributions to its ensuing development, Physica Scripta 91, 063010 (2016):

"An application of the NFT results has been carried out for the 3/2$^+$ states in 209Bi, $d^{-1}_{3/2} \times gs(210\text{Po});\ 3/2^{+}$ and $h_{9/2} \otimes 3^{-}(208\text{Pb});\ 3/2^{+}$ at 2.733 and 2.615 MeV, respectively (Bortignon, Broglia, Bes, Liotta, **Paar, 1976)**. The NFT calculation predicts a mixture of the two configurations which takes into account the underlying lack of orthogonality between both states. The calculation reproduces the energies, inelastic scattering, and transfer data well (table 2).
Table 2. The experimental and NFT theoretical values of the properties of the two lowest 3/2$^+$ states in 209Bi (Bortignon, Broglia, Bes, Liotta, **Paar, 1976)**.

Physical magnitude	Exp	NFT
E(MeV)	2.49	2.48
E(MeV)	2.95	3.07
$B(E3;\ 2.49\ \text{MeV}) / B(E3;\ 2.95\ \text{MeV})$	3.8 ± 0.8	2.5
$\sigma(t,\alpha;\ 2.49\ \text{MeV})/\sigma(t,\alpha;\ 2.95\ \text{MeV})$	$0,8 \pm 0.3$	0.8

Such agreement could not have been the result of a conventional 2×2 diagonalization between the two states."

J.P. Elliott (School of Mathematical and Physical Sciences, University of Sussex, Brighton, United Kingdom), The interacting boson model of nuclear structure, Rep.Prog.Phys. 48, 171-221 (1985):

"We have been careful to distinguish between supersymmetries which include bosons and fermions in the same multiplet and the Bose-Fermi symmetries which simply have a simultaneous transformation of boson and fermion. Unfortunately there is no uniformity in the literature since (i) in particle physics the expression Fermi-Bose ia sometimes used for supersymmetry and (ii) the expression *supersymmetry* is used in nuclear physics by **Paar** et al., (**Paar,** Brant, Kraljević, **1982)** to describe simultaneous SU (3) transformations for boson and fermions."

G. Lhersonneau, H. Gabelmann, M. Liang, B. Pfeiffer, K.L. Kratz, H. Ohm (*ISOLDE Collaboration, CERN, Geneve, Switzerland; Institut für Kernchemie, Universität Mainz, Germany; Institut für Kernphysik, Forschungszentrum Jülich, Germany)*, Level scheme of 101Zr and structure of the *N* = 61 Sr, Zr, and Mo isotones, Phys.Rev. C51, 1211-1225 (1995):

"The $[404]9/2$ orbital was postulated by Meyer et al. (Meyer, Kaffrell, Lawin, Lhersonneau, Monnand, **Paar,** Pfeiffer, Pinston, Ragnarsson, Schussler, Schmitt, Seo, Sistemich, Trautmann, **1983)** to correspond to an isomer observed in former prompt fission experiments (Clark et al.,1974). These data suggest the existence of an isomer at 323.5 keV, decaying to the $7/2^+$ level at 231.9 keV (of the $K = 3/2$ ground state band) through the 91.6 keV transition. We conclude that the $9/2^+$ isomer discussed by (Meyer, Kaffrell, Lawin, Lhersonneau, Monnand, **Paar,** Pfeiffer, Pinston, Ragnarsson, Schussler, Schmitt, Seo, Sistemich, Trautmann, **1983)** is not populated in β decay of 101Y. For 101Zr the best agreement with the experiment was achieved at the deformation of $\beta = 0.36$. The odd-parity band head $\nu[532]5/2$ is predicted at 142 keV, fairly close to the experimental energy of 217 keV. The $[404]9/2$ orbital, discussed in (Meyer, Kaffrell, Lawin, Lhersonneau, Monnand, **Paar,** Pfeiffer, Pinston, Ragnarsson, Schussler, Schmitt, Seo, Sistemich, Trautmann, **1983)**, is calculated below the $7/2^+$ member of the ground state band."

R.F. Casten, D.D. Warner (*Brookhaven National Laboratory, USA; Daresbury Laboratory, United Kingdom*), Rev. Mod. Phys. 60, 389 (1988):

"Although this review will concentrate on the structure, properties and tests of the IBA model and its offshoots, its equivalence to the quadrupole phonon approach which has been emphasized by **Paar** (**V. Paar**, in Interacting Bosons in Nuclear Physics, New York, p. 163, 1979) should not be forgotten."

S. Landowne, C.H. Dasso, R.A. Broglia, A. Winther *(NORDITA, Copenhagen, Denmark; Niels Bohr Institute, University of Copenhagen, Denmark)*, Estimate of double octupole phonon excitation in the Xe+Pb reaction using the coupled channel WKB approximation, Phys.Lett. B70, 292-296 (1977):

"The $I^{\pi} = 3^-$ state of 208Pb at 2.615 MeV is one of the best-known examples of an octupole vibration. Its coupling to both protons and neutrons and to pairing vibrational modes has been accurately determined (Broglia et al., 1970; Ungrin et al., 1971; Ellegaard et al., 1970; Flynn, Igo, Broglia, Landowne, **Paar**, Nilsson, **1972).** Great importance is attached to identifying higher members of the octupole band in 208Pb, in particular the members $I^{\pi} = 0^{+}, 2^{+}, 4^{+}, 6^{+}$ of the two phonon multiplet (3^{-} (208Pb) $\otimes$ 3^{-} (208Pb)). The knowledge of the coupling of the multiplet to the two-phonon monopole neutron pairing vibration is expected to provide an important test of the description of the nuclear spectrum in terms of elementary modes of excitation (Broglia, **Paar,** Bes, **1971)**."

B. Jonson, M. Alpsten, Å. Appelqvist, B. Bengtsson, K.A. Johansson *(CERN, Geneva, Switzerland; Chalmers University of Technology, Göteborg, Sweden)*, The decay of 209Rn to levels of 209At, Physica Scripta 8, 142-148 (1973):

"The 408 keV level would then essentially be due to $(h_{9/2}^{3})7/2^{-}$ or $\left[(h_{9/2}^{3}) + (2)_{v}\right]$ configurations. It is known that $j = J - 1$ states tend to appear at very low energies. The same effect is seen in $7/2^{+}$ states in Ag isotopes **(Paar, 1972)** where, according to interpretations, important components of $\pi(g_{9/2}^{-3})$-phonon character are present in the wave function."

A.I. Georgieva, H.G. Ganev, J.P. Drayer, V.P. Garistov *(Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria; Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana, USA)*, Description of mixed-mode dynamics within the symplectic extension of the interacting vector boson model, Physics of Particles and Nuclei 40, 461-501 (2009):

"A number of algebraic models describing the collective properties of nuclei have been built based on certain groups of dynamical symmetries. The first one that is based on the symmetry group SU (3) for the classification of many nucleon states is the microscopic Elliot's model of nuclear rotations (Elliott, 1958). For example, a two-vector–boson model has been constructed (Raychev, 1970; Raychev, Roussev, 1978) for the description of the collective properties of heavy deformed nuclei in the framework of the broken SU (3) symmetry. Another example is the phenomenological model of interacting bosons (IBM) by Arima and Iachello (Arima, Iachello, 1975, 1976), which introduces s and d bosons considered as fermion pairs coupled to a total angular momentum $L = 0$ and $L = 2$, respectively. This brings in again the group U (6) as a group of dynamical symmetry of collective motions in nuclei. It had been shown even earlier (Vanagas et al., 1975), that in the framework of a microscopic description of the collective modes, it is quite natural to introduce six collective variables related to the monopole and quadrupole degrees of freedom, as the same type of algebraic structure is generated by the five generalized coordinates of the quadrupole degree of freedom, their conjugated momenta and the commutators between them (Janssen et al., 1974). Even earlier the equivalence of the IBM and the microscopic TQM (Rosensteel, Rowe, 1977) has been established in respect to the matrix elements of their physical observables and their corresponding operators (Kyrchev, **Paar, 1986)**. Something more, the strict mathematical proof of the basis states of the two models also exists

(Jolos, Kyrchev, **Paar, 1987)**, which is the reason for considering the two models as different realizations of the same phenomenological SU (6)-boson model."

J.S. Dionisio, C. Vieu, E. Gueorgieva, M. Kaci, E.B. Kharraja, M.G. Porquet, C. Schück, J.M. Lagrange, M. Pautrat, W.R. Philips, J.L. Durell, P.G. Dagnall, S.J. Dorning, M.A. Jones, A.G. Smith, B.J. Varley, J.C.S. Bacelar, W. Urban, T. Rzaca-Urban, A. Minkova, T. Venkova, H. Folger, J. Vanhorenbeeck, A. Passoja ***(CSNSM, Orsay Campus, France; IPN, Orsay Cedex, France; Department of Physics and Astronomy, University of Manchester, United Kingdom; KVI, University of Groningen, Netherlands; Institute of Experimental Physics, Warsaw University, Poland; Faculty of Physics, University of Sofia, Bulgaria; GSI, Darmstadt, Germany; ULB, Brussels, Belgium; University Joensuu, Finland)*****, Recent development of multi e-γ spectrometers, Nuclear Instruments and Methods in Physics Research A 437, 282-334 (1999):**
"Spectroscopic results concerning 145,147,149Pm give useful information on n-p interaction in these nuclei and simulate the development of new nuclear models. A typical illustration of that kind is given by the comparison (see Fig. 4) between the experimental levels of 145Pm, 147Pm and 149Pm and the corresponding theoretical predictions with the three holes cluster – vibration model (3HCVM). In these calculations, taken from Ref. (Kortelahti,Piiparinen, Pakkanen, Komppa, Komu, Brant, Udovicic, **Paar, 1980)**, all the parameters are the same except for the particle-vibration coupling parameter *a*. Indeed, *a* = 0.36 for 145Pm, *a* = 0.60 for 147Pm and *a* = 0.75 for 149Pm. In this model the vibrating core has a mean spherical shape which is a rough approximation for transitional nuclei like these. The single-particle asymmetric rotor generalized model (1PARGM) used earlier for the theoretical interpretation of analogous odd A isotopes (i.e., 193,195Au and 107Ag) has not yet been used for the odd *A* Pm isotopes, see Refs. (Vieu et al., 1976,1978,1980) for a detailed comparison between the 3HCVM and the 1PASRGM models for Au and Ag isotopes. Fig. 4. Experimental test of the cluster-vibration model predictions according to Ref. (Kortelahti, Piiparinen, Pakkanen, Komppa, Komu, Brant, Udovicic, **Paar, 1980)** for the positive parity states of 143-149Pm investigated with the e-γ device (see Refs. Urban et al., 1995,1996; Jones et al., 1996)."

A.Korgul, K.P. Rykaczewski, R. Grzywacz, H. Sliwinska, J.C. Batchelder, C. Binghham, I.N. Borzov, N. Brewer, L. Cartegni, A. Fijalkowska, C.J. Gross, J.H. Hamilton, C. Jost, M. Karny, W. Krolas, S. Liu, C. Mazzocchi, M. Madurga, A.J. Mendez, K. Miernik, D. Miller, S. Padgett, S. Paulauskas, D. Shapira, D. Stracener, K. Sieja, J.A. Winger, M. Wolinska-Cichocka, E.F. Zganjar (Oak Ridge National Laboratory, Tennessee, USA; Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee, USA; Universite de Strasbourg, IPHC, France; UNIRIB, ORAU, Oak Ridge Associated Universities, Tennessee, USA; Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia; Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee, USA; Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland; Department of Physics and Astronomy, Mississippi State University,

Mississippi, USA; Heavy Ion Laboratory, University of Warsaw, Poland; Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana, USA), Experimental study of the *β-γ* and *β-nγ* decay of the neutron-rich nucleus 85Ga, Phys.Rev. C88, 044330 (2013):
"The sequence of the excited states can be different for the $N = 53$ isotones. By filling the ν2d5/2 orbital, the $5/2^+$ and $3/2^+$ states can be produced. It was observed in $N = 53$, 95Mo **(Paar, 1974)** that the seniority $v = 1;\ I = j-1, 3/2^+$ state lies very close to the seniority $v = 1;\ I = j, 5/2^+$ state."

T- Fenyes, Z. Dombradi *(Institute of Nuclear Research of the Hungarian Academy of Scviences, Debrecen, Hungary)*, Structure of 120Sb nucleus, Phys.Lett. B275, 7-11 (1992):
"In this work we have calculated the level spectrum, magnetic dipole and electric quadrupole moments, as well as the decay properties of the low-lying states of 120Sb on the basis of the interacting boson-fermion-fermion model (IBFFM). This model proved to be successful in the case of 116Sb, as our earlier calculations (Gacsi, Fenyes, Dombradi, 1991; Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991)** showed. The Hamiltonian and computer codes used in the calculations are described in refs. (**Paar, 1984;** Iachello, Scholten, 1979; **Paar**, Brant, Canto, Leander, Vouk, **1982;** Janssen et al., 1974; Arima, Iachello, 1975) and ref. (Brant, **Paar,** Vretenar, **1985)**, respectively. The d-boson energy of the core was taken as the energy of the 2_1^+ state of the neighboring 118Sn nucleus: $E(2_1^+)$ = 1.23 MeV. The occupation probabilities V^2 for neutrons were taken from the systematics of the experimental data: 0.93, 0.87, 0.62, 0.35 and 0.32 for d5/2, g7/2, s1/2, d3/2 and h11/42, respectively (see references Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, **1988)**. We remark that both in the case of 120Sb and 116Sb (Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991)** the detailed IBFFM calculations approved the approximate classification of the low-lying proton-neutron multiplet states, performed on the basis of the simple parabolic rule."

X.F. Li, Y.J. Ma, Y.Z. Liu, J.B. Lu, G.Y. Zhao, L.C. Yin, R. Meng, Z.L. Zhang, L.J. Wen, X.H. Zhou, Y.X. Guo, X.G. Lei, Z.Liu, Y. Zheng, J.J. He *(Department of Physics, Jilin University, Changchun, China; Institute of Modern Physics, Chinese Academy of Science, Lanzhou, China)*, Configuration assignments of yrare high-spin structures in 126Cs, Eur.Phys.J. A17, 523-528 (2003):
"In Cs nuclei 122,124,128,130Cs (Moon et al., 2000; Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001;** Paul et al., 1989; Ma et al., 2001) surrounding 126Cs, while the two-quasiparticle yrast bands are commonly built on the positive–parity $\pi h11/2 \nu h11/2$ configuration, the hitherto-known various two-quasiparticle yrare bands are mostly built on a negative parity configuration which consists of either an h11/2 proton coupled with a positive-parity neutron or an h11/2 neutron coupled with a positive-parity proton. In odd-proton nuclei of this region in 127Cs (Ward et al., 1992), the h11/2 quasiproton is observed to carry a much larger aligned angular

momentum than the other single quasiprotons available near the Fermi surface. The case is also true for the h11/2 quasineutron (Liang et al., 1990). Therefore, in an odd-odd nucleus of this region, bands having an h11/2 quasiproton or h11/2 quasineutron or both are expected to approach the yrast line more rapidly, thereby allowing such bands to be observed more easily in a heavy-ion-induced fusion-evaporation reaction. In the used reaction, band 2 was observed to be the most strongly populated band in 126Cs, and bands 3-6 were populated with similar intensities. This indicates that, just like in the surrounding odd-odd Cs isotopes (Moon et al., 2000; Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001;** Paul et al., 1989; Ma et al., 2001), the $\pi h11/2\nu h11/2$ band is the yrast band in 126Cs."

K.H. Maier, T. Nail, R.K. Sheline, W. Stöffl, J.A. Becker, J.B. Carlson, R.G. Lanier, L.G. Mann, G.L. Struble, J.A. Cizewski, B.H. Erkkila ***(Hahn-Meitner Institute, Berlin, Germany; Department of Physics, Florida State University, Tallahassee, Florida, USA; Lawrence Livermore National Laboratory, Livermore, California, USA; Los Alamos National Laboratory, Los Alamos, Mew Mexico, USA)*****, Structure of 209Bi deduced from the 208Pb(t,2$n\gamma$) reaction, Phys.Rev. C27, 1431-1453 (1983):**

"The nucleus 209Bi consists of the doubly magic 208Pb core and one valence proton. Due to this particularly simple structure, it has played an essential role in the understanding of nuclear structure and reaction mechanisms. The well-known septuplet of states arising from the coupling of the h9/2 proton to the highly collective octupole vibration of the 208Pb core at $E_x = 2.62$ MeV is probably the best example of particle-vibration coupling. The levels and transitions that involve the septuplet are shown in Fig. 7. This group of levels has been studied experimentally by inelastic scattering (Wagner et al., 1975; Cleary et al., 1974; Ungrin et al., 1971) and by Coulomb excitation (Hertel et al., 1969; Broglia et al., 1970). Many theoretical models have been used to describe it (Bohr, Mottelson, 1975; Hamamoto, 1969, 1970; Zavischa, 1974; Arita, Horie, 1971; Bortignon et al., 1977; Bortignon, Broglia,Bes, Liotta, **Paar, 1976**; Khodel et al., 1980; Iwasaki et al., 1980). The significance of this finding is that the septuplet is the standard textbook example for particle-vibration coupling, and that it is very often used to test new theoretical approaches."

Y. Alhassid, A. Novoselsly, N. Whelan ***(Center for Theoretical Physics, Sloane Physics Laboratory, Yale University, New Haven, Connecticut, USA; A.W. Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut, USA)*****, Chaos in the low-lying collective states of even-even nuclei, Phys.Rev.Lett. 65, 2971-2974 (1990):**

"We have studied the chaos of the spectra and the $E2$ intensities as a function of χ, for several fixed values of the spin-parity. A study of spectral fluctuations alone using the IBM in the SU (3) and O (6) limits was presented in Ref. (**Paar,** Vorkapić, **1988)** but did not include the transition region."

F. Barranco, R.A. Broglia, G. Gori, E. Vigezzi, P.F. Bortignon, J. Terasaki (Escuela de Ingenieros Industriales, Universidad de Sevilla, Sevilla, Spain; Dipartamento de Fisica, Universita di Milano, Milano, Italy; INFN, Sezione di Milano, Milano, Italy; Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark), Surface vibrations and the pairing interaction in nuclei, Phys.Rev.Lett. 83, 2147-2150 (1999):
"We show that Cooper pair formation in nuclei can particularly benefit from the exchange of low-lying collective surface vibrations, cf. Refs. (Bohr, Mottelson, 1975; Broglia, **Paar,** Bes, **1971;** Bes et al, 1975)**,** a mechanism which gives rise to pairing gaps which account in most cases for 50 % - 70 % of the experimental values. The results provide insight into the role the induced interaction plays in neutron and proton pairing correlations in nuclei."

E.R. Flynn, R.A. Hardkopf, J.D. Sherman, J.W. Sunier *(Los Alamos Scientific Laboratory, University of California, Los Alamos. New Mexico, USA)*, Analyzing power in two-neutron stripping reactions, Phys.Lett. B5, 433-436 (1976):
"The present experiments were carried out on a medium mass nucleus, 90Zr, and a heavy nucleus 208Pb. Both targets have been used previously in (t, p) reaction studies (Flynn et al., 1974; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972),** and DWBA calculations were shown to successfully describe the observed differential cross sections. These calculations required complex theoretical wave functions as, in general, their coherent nature of the two-nucleon transfer process is sensitive to mixed configurations."

P. Cejnar, P. Stransky (Institute of Particle and Nuclear Physics, Charles University, Prague, Czech Republic), Regular and chaotic vibrations of deformed nuclei with increasing γ rigidity, Phys.Rev.Lett. 93, 102502 (2004):
"We use the geometrical model to study regular and chaotic classical motions (Gutzwiller, 1990) of a quadrupole vibrator with increasing stability of an axially symmetric deformation. This has been investigated in the IBM classical limit by Alhassid and co-workers (Alhassid et al., 1990; Alhassid, Whelan, 1991; Whelan, Alhassid, 1993; Alhassid, 1994) and by **Paar** et al. (**Paar,** Vorkapić, Dieperink, **1992)**, demonstrating the existence of regular domains in the IBM parameter space and the correspondence between classical and quantal measures of chaos."

C.Y. He, X.Q. Li, L.H. Zhu, X.G. Wui, Y. Liu, B. Pan, L.H. Li, Z.M. Wang, G.S. Li, Z.Y. Li, S.Y. Wang, Q. Xu, J.G. Wang, H.B. Ding, J. Zhai *(China Institute of Atomic Energy, Beijing, China; School of Physics and Nuclear Energy Engineering, Beihang University, Beijing, China; College of Physics and Technology, Shenzhen University, Shenzhen, China; School of Physics and SK laboratory of Nuclear Physics and Technology, Peking University, Beijing, China; School of Space Science and Physics at Weihai, Shandong University, Weihai, China; Department of Physics, Tsinghua University, Beijing, China; Department of Physics, Jilin University, Changchun, China)*, High-spin yrast and yrare structures in 112In, Eur.Phys.J. A46, 1-4 (2010):

"The excited states of 112In have been studied previously both by M. Eibert et al. (Eibert et al., 1976) and T. Kibedi et al. (Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, **1988)**. In their work, the low-spin transitions were identified and spins were pushed up, respectively, to $10^- \hbar$ and $8^+ \hbar$ for the negative and positive portion, thereof the low-lying transitions with the energies 188, 263, 187, 588 and 319keV are confirmed in the present study. From the DCO ratios, the previous works (Eibert et al., 1976; Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, **1988)** and systematic comparison with its neighboring odd-odd nuclei, we tentatively assigned the spins and parities of the levels in 112In. The yrast states in band 1 of odd-odd 112In are built on the 8^- state located at 614 keV above the 1^+ ground state (Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, **1988)**. Its configuration has been assigned to $\pi g9/2 \otimes \nu h11/2$ in the previous work. The proton Fermi level is located among the high-*K* orbital of the $\pi g9/2$ subshell, while the neutron Fermi level lies at the bottom of the $\nu h11/2$ subshell."

P. Van Isacker ***(Grand Accelerateur National d'Ions Lourds GANIL, Caen Cedex, France)*****, Exact level densities for the harmonic oscillator, Phys.Rev.Lett. 89, 262502 (2002):**
"After Bethe's work (Bethe, 1936,1937), it was soon realized that his approach approximates exact state-counting formulas (Bardeen, Feenberg, 1938). With the advent of the nuclear shell model, effects of shell structure on nuclear level densities were investigated in this way (Bloch, 1954), and combinatorial counting techniques were used to evaluate the level density of Fermi systems consisting of equally spaced single-particle levels (Rosenzweig, 1957). This approach continues to inspire research in this field (see, e.g., **Paar,** Pezer, **1997;** Zuker, 2001)."

H. Dias F. Krmpotić, L. Losano, R.C. Mastroleo ***(Instituto de Fisica da Universidade de Sao Paulo, Brasil; Departamento de Fisica, Facultad de Ciencias Exactas, Universidad Nacional de la Plata, Argentina; Divisiao de Fisica Teorica, Instituto de Estudos Avancados, Centro Tecnico Aeroespacial, Sao Jose dos Campos, Brazil)*****, Semi Microscopic Description of 84Kr, Z.Phys. A324, 53-58 (1986):**
"A detailed description of the model is given in Refs. (Alaga, 1969; **Paar, 1975)**. It is worth noting that recently **Paar** (**Paar, 1978)** has discussed, within the particle-vibration coupling model, the $E2/M1$ mixing ratios in odd-mass spherical and transitional nuclei. He obtained, for example, for transitions of the type $\Delta N = 0$ between unique-parity states
$D(j + 2N \rightarrow j + 2N - 1) = \frac{\sqrt{5}}{2j}\left(\frac{2j+4N+2}{2J+4N-2}\right)\frac{Q^{sp}(j)}{g_j^{sp} - g_R} e'_{eff}$, with $e'_{eff} = e_p^{eff} + \frac{5}{\sqrt{\pi}} \frac{a}{\hbar\omega} e_\nu^{eff}$. Therefore, now we can relate the ratios of the odd-mass nuclei with those of the neighboring even-mass nuclei."

A.Gizon, J. Genevey, C.F. Liang, P. Paris, D. Barneoud, J. Inchaouh, I. Penev, A. Plochocki ***(Institut des Sciences Nucleaires, Universite Joseph Fourier, Grenoble Cedex, France; CSNSM, Campus Orsay, France; Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria; Institute of Experimental Physics, Warsaw, Poland)*****, The 130Nd$\rightarrow$130Pr$\rightarrow$130Ce decay revisited, Eur.Phys.J. A12, 309-316 (2001):**
"The low-spin partial level scheme of 130Pr fed from 130Nd (0^+) is proposed as based on a I^π = 2^+ assignment for the lowest lying state in 130Pr. It has many similarities with the 132Pr level scheme established in the β-decay of 132Nd (0^+) and based on a $I^\pi = 2^+$ ground state (Bucurescu, Barneoud, Cata-Danil, von Egidy, Genevey, Gizon, Gizon, Liang, Paris, Weiss, Brant, **Paar,** Pezer, **1995)**."

K.Y. Ma, J.B. Lu, X. Xu, Y.M. Liu, Z. Zhang, X.Y. Li, D. Yang, Y.Z. Liu, X.G. Wu, C.Y. He, Y. Zheng, C.B. Li ***(College of Physics, Jilin University, Changchun, China; College of Electronic Science & Engineering, Changchun, China; China Institute of Atomic Energy, Beijing, China)*****, Structure of a positive –parity band in 130Pr, Eur.Phys.J. A53, 10 (2017):**
"In the $A \sim 130$ mass region, the newly degenerate $\Delta I = 1$ doublet bands built on the $\pi h11/2 \otimes \nu h11/2$ configuration have attracted significant attention and intensive discussion in odd-odd N = 77 (132CS, 134La) (Rainovski et al., 2003); Bark et al., 2001), N = 75 (130Cs, 132La, 134 Pr, 136Pm, 138Eu) (Starosta et al., 2001); Petrache et al., 1996; Timar et al., 2011; Hecht et al., 2001), N = 73 (128Cs, 130La, 132 Pr) (Koike et al., 2001,2003), N = 71 (126Cs, 128La) (Wang et al., 2006; Ma et al., 2012), N = 69 (124Cs, 126La, 128 Pr) (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001;** Ma et al., 2013; Hartley et al., 2002) and N = 67 (122Cs, 124La) (Yong-Nam et al., 2005; Chautler et al., 2002) isotones. These $\Delta I = 1$ doublet bands with the same positive parity are mostly interpreted as a manifestation of "chirality" in the sense of the angular momentum coupling (Frauendorf, Meng, 1997). As mentioned above, the configuration of the yrast band (band 1) had previously been assigned as $\pi h11/2 \otimes \nu h11/2$ (Ma et al., 1988; Petrache, Brant, Bazzacco, Falconi, Fornea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1998)**. The positive parity yrast band 1 is the most intensely populated in the present experiment, and its configuration has been assigned to $\pi h11/2 \otimes \nu h11/2$ in the previous work (Ma et al., 1988; Brant, Bazzacco, Falconi, Fornea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1998**). In the present work, two new 199.5 and 53.5 keV transitions have been observed at the bottom of this band, and the spin of the lowest observed state is extended to (6^+)."

Y.D. Devi, V.K.B. Kota ***(Physical Research Laboratory, Ahmedabad, India; Center for Theoretical Physics, Sloane Physics Laboratory, Yale University, New Haven, Connecticut, USA)*****, Correspondence between the SU (3)$\otimes$U (2) limit of IBF^{2}M and two quasi-particle Nilsson configurations, Phys.Lett. B334, 253-258 (1994):**
"The cases of applying IBF^{n}M with n = 2, 4 for even-even and n = 1, 3 for odd-A nuclei are relevant for high spin physics (Gelberg, Zemel, 1980; Morrison et al., 1981; Yoshida et al., 1982;

Zemel, Dobes, 1983; Kuyucak et al., 1984; Alonso et al., 1986; Iachello, Vretenar, 1991; Chowdhury et al., 1991; Hsieh et al., 1992; Vretenar et al., 1993; Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Vretenar, **Paar,** Savoia, Bonsignori, **1991)** and also for describing some aspects of superdeformed bands (Iachello, 1991; Cizewski, 1993; Gelberg et al., 1990). In order to studying correspondence between the IBF^2M and the Nilsson model for deformed nuclei, the purpose of this letter is to establish this correspondence for the case when the twoo q.p. are occupying all the natural parity orbits in a given shell. To this end we employ the $SU(3) \otimes U(2)$ limit of IBF^2M. The simpler problem of IBF^2M with the two q.p. in a single intruder parity orbit is being studied by Vrtetenar and collaborators **(**Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Vretenar, **Paar,** Savoia, Bonsignori, **1991).**
One has probabilities for spherical j-orbits similar to the case with one q.p. band in IBFM (Biker, Kota, 1988) but however we find that V_{exch} used in ref. (Biker, Kota, 1988) , which is one-body in fermion space, is in general not diagonal unlike in IBFM (the $Q_B^2 \cdot Q_F^2$ force used in Ref. (Biker, Kota, 1988) is diagonal as in IBFM) but it is found to be diagonal in the two q.p. Nilsson basis. Therefore, one has to look for alternative forms for the exchange force (Scholten, Warner, 1984; Kota, 1986; **Paar,** Vretenar, Coster, Heyde, Scholten, **1992)**. The forms considered in Ref. (Scholten, Warner, 1984; Kota, 1986) will take us away from the group chain (1) and the modifications of V_{exch} as done in Ref. (**Paar,** Vretenar, Coster, Heyde, Scholten, **1992)** fail in general to make it diagonal in the $SU(3) \otimes U(2)$ basis. By adding a suitable two-body exchange term it is possible to construct an extended V_{exch} force which is diagonal in the $SU(3) \otimes U(2)$ basis."

D. Chowdhury, C.J. Lister, D. Vretenar, C. Winter, V.P. Janzen, H.R. Andrews, D.J. Blumenthal, B. Crowell, T. Drake, P.J. Ennis, A. Galindo-Uribarri, D. Horn, J.K. Johansson, A. Omar, S. Pilotte, D. Prevost, D. Radford, J.C. Waddington, D. Ward ***(A.W. Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut, USA; Atomic Energy of Canada Limited Research, Chalk River Laboratories, Ontario, Canada; Tandem Accelerator Laboratory, McMaster University, Hamilton, Ontario, Canada; University of Toronto, Toronto, Canada; Laboratoire de Physique Nucleaire, Universite de Montreal, Montreal, Quebec, Canada)*****, Large $B(M1)$ staggering at high spins in 86Zr: Broken boson pairs in the four-quasiparticle regime, Phys.Rev.Lett. 67, 2950-2953 (1991):**
"The distinctive pattern of the $B(M1)$ values in this transitional nucleus suggests an underlying symmetry in the structure of these states. To probe this underlying symmetry, we have used a recent extension of the IBM, which addresses the physics of high spins in transitional nuclei in terms of broken pairs (Iachello, Vretenar, 1991; Vretenar, **Paar,** Bonsignori, Savoia, **1990)**. The $M1$ and $E2$ transition operators are defined in Ref. (Vretenar, **Paar,** Savoia, Bonsignori, **1991)**. The calculated transition rates are compared to the experimental values in Fig. 2. The calculations reproduce the large staggering which is observed experimentally."

D.G. Fleming, F.D. Becchetti, E.R. Flynn ***(Department of Chemistry, University of British Columbia, Vancouver, British Columbia, Canada; Department of Physics, Michigan State University, East Lansing, Michigan, USA; Los Alamos Scientific Laboratory, Los Alamos, New Mexico, USA)*****, Inelastic proton scattering and particle-vibration coupling in 115Sn, 117Sn, and 119Sn, Phys.Rev. C20, 1993-2002 (1979):**

"In the pv coupling picture, one expects a low-lying $7/2^-$ level to arise from the coupling h11/2 $\times 2^+$, which should lie at an (unperturbed) excitation energy of ≈ 1.5 ¨MeV for $A = 115 - 119$. Calculations have been reported by Sorensen (Sorensen, 1961) and by De Barros et al. (De Barros, Bechara, Borello-Lewin, **Paar, 1974)**. The latter calculation, in particular, finds good agreement in the calculated spectroscopic factors for the first $7/2^-$ transition seen in (d.p) studies, which provide a measure of the degree of mixing with the f7/2 single-particle component (De Barros, Bechara, Borello-Lewin, **Paar, 1974)**. These levels are found to lie in 117Sn and 119Sn at 1.30 and 1.06 MeV, respectively."

G. Vanden Berghe, M . Waroquier, K. Heyde ***(Rijksuniversiteit Gent, Instituut voor Nukleaire Wetenschappen, Belgium; Rijksuniversiteit Utrecht, Netherlands Fysisch Laboratorium, Netherland)*****, On the perturbation approach to the particle-vibration coupling model, Ann.Phys. 78, 467-495 (1973):**

"The particle-vibration coupling model is treated in a perturbation approach. In this model, single-particle features and collective degrees of freedom are described in a unified picture. As has been suggested by Mottelson (Mottelson, 1968), the particle-vibration coupling model can be treated in a perturbation approach. This idea has been developed by Alaga et al. (Alaga, Krmpotic, Lopac, **Paar,** Sips, **1970;** Alaga, 1969), where the Rayleigh-Schrödinger perturbation expansion has been used. Using a diagrammatic method based on Goldstone and Jutsis-Bandzaitis-Vizbaraite (JVB) formalisms (**Paar, 1971)**, we can extend the method to higher orders in the perturbation expansion. For the determination of amplitudes of the components of the wavefunctions, quite good values for the parameters ε_j (or $\Delta_j = \varepsilon_j - \varepsilon_{\text{g.s.}}$) and coupling strength *a* are necessary. Values for Δ_j have been determined in (Vanden Berghe, Heyde, 1971) by fitting the eigenvalues to the experimental excitation energies. These quantities, however, are bare single-particle energies (**Paar, 1971a)** with respect to both quadrupole and octupole vibrations. Expressions for the reduced *E*2 matrix element for transitions in a perturbation approach are already given in Refs. (**Paar, 1971a)** and (Alaga, Krmpotic, Lopac, **Paar,** Sips, **1970)**. In Fig. 1 we give the diagrams, representing collective and single-particle contributions to the reduced *E*2 matrix elements. For the notation we refer to **Paar (Paar, 1971a)**.

The $5/2^+ \rightarrow 7/2^+$ transition in 123Sb has a $B(E2)$ value of $0.0058 \pm 0.0010\, e^2b^2$ (Barnes et al., 1966), which is in good agreement with the values obtained in the calculations. The zeroth order and the first-order collective part are in phase. The formula for the reduced E2 matrix element can be derived in a perturbation approach, taking into account the same restrictions as before (**Paar, 1971b)**. It is interesting to extend the expansion up to higher order, in order to study the convergence properties, which easily can be done due to diagrammatic method based on Jutsis-Bandazaitis-Vizbaraite formalisms. This method has been studied by **Paar (Paar, 1971a)**. For the $5/2^+$ and $7/2^+$ single–particle states rapid convergence of the perturbation series is obtained. However, there is no alternation of sign between the contributions in second, fourth, and sixth order, as was the case for 201Tl (**Paar, 1971b)**."

A.V. Afanasjev, D.B. Fossan, G.J. Lane, I. Ragnarsson ***(Department of Mathematical Physics, Lund Institute of Technology, Lund Sweden; Department of Physics, State University of New York at Stony Brook, New York, USA; Physik Department, Technische Universität München, Garching, Germany; Nuclear Research Center, Latvian Academy of Sciences, Salaspils, Latvia; Lawrence Berkeley National Laboratory, Berkeley, California, USA)*****, Termination of rotational bands: disappearance of quantum many-body collectivity, Physics Reports 322, 1-124 (1999):**
"Although several nuclei in the $A \sim 160 - 170$ mass region have been discussed in Refs. (Wu, 1990; Guidry et al., 1987), no terminating structures have been observed in any of them as yet. Additionally, the FDSM results for these nuclei have been obtained within certain limits. It was concluded (Wu, 1990; Guidry et al., 1987), that the inclusion of additional symmetry breaking terms causing configuration mixing is necessary to make these calculations more realistic. An alternative model, which has many common features with the FDSM, is the approach developed in Refs. (Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Chisti et al., 1993)."

X.H. Zhou, E. Ideguchi, Y. Gono, T. Kishida, S. Mitarai, T. Morikawa, H. Tsuchida, M. Shibata, H. Watanabe, M. Miyake, A. Odahara, M. Oshima, Y. Hatsukawa, S. Hamada, H. Iimura, M. Shibata, T. Ishii, M. Ishihara ***(Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China; Institute of Chemical Research (RIKEN), Wako, Saitama, Japan; Department of Physics, Kyushu University, Hakozaki, Fukuoka, Japan; Nishinippon Institute of Technology, Kanda, Fukuoka, Japan; Japan Atomic Energy Research Institute (JAERI), Tokai, Ibaraki, Japan)*****, Study of high-lying states in 147Eu, Z.Phys. A358, 285-286 (1997):**
"It could be expected that the yrast states in 147Eu arise from the stretched coupling of $d5/2^{-1}$ and $g7/2^{-1}$ proton holes to a 148Gd core (Lunardi et al., 1984; Piiparinen et al., 1987) and h11/2 protons to a 146Sm core (Kownacki, Sujkowski, Hammaren, Liukkonen, Piiparinen, Lindblad, Ryde, **Paar, 1980)**. In the previous experiments (Fleissner et al., 1977; Bianco et al., 1981) it was identified that the $\pi d5/2^{-1}$, $\pi g7/2^{-1}$ and $\pi h11/2$ states in 147Eu located at 0, 229 and 625 keV, respectively. The predictions of the zeroth-order weak coupling calculation are compared with the experimental results in Fig. 1. It indicates that the low-lying yrast states in 147Eu can be formed by the coupling of a h11/2 proton to the two f7/2 neutron yrast states in the 146Sm core (Kownacki, Sujkowski, Hammaren, Liukkonen, Piiparinen, Lindblad, Ryde, **Paar, 1980)**."

R. Duffait, L. Van Maldeghem, A. Charvet, J. Sau, K. Heyde, A. Emsallem, M. Meyer, R. Beraud, J. Treherne, J. Genevey ***(Institut de Physique Nucleaire, Universite Claude Bernard***

Lyon-I, Villeurbanne, France; Institut de Sciences Nucleaires, Grenoble, France), **High spin states and multiquasiparticle excitations in odd-odd 114,116Sb nuclei, Z.Physik A307, 259-268 (1982):**
"Concerning the negative parity band in 116Sb, one may assume that it proceeds from the coupling of a g9/2 proton hole and 1h11/2 neutron quasiparticle to a suitable core, which is then a 116Te core. We have thus performed a calculation of the negative parity band in the framework of the unified model in the weak coupling limit. Let the Hamiltonian be written $H = H_c + H_{pc} + H_{nc} + H_{pn}$, where H_c is the usual vibrational quadrupole Hamiltonian of the core. H_{pc}, H_{nc} and H_{pn} are respectively the proton-core, neutron-core, and proton-neutron interactions. The resulting spectra is given in the left part of Fig. 7. As predicted by the **Paar** parabolic rule **(Paar, 1979)** the spin of the lowest state is $I_v = \sqrt{j_n(j_n+1) + j_p(j_p+1) - \frac{1}{4}} - \frac{1}{2} \approx 7$which is also found experimentally. "

M. Niwano, T. Ishimatsu, R. Asano, T. Suehiro ***(Department of Physics, Tohoku University, Sendai, Japan; Tohoku Institute of Technology, Sendai, Japan)***, **The 59Co (d, 3He)58Fe reaction and 58Fe levels in the particle-vibration coupling model, Nucl.Phys. A377, 148-162 (1982):**
"A PVCM (particle-vibration coupling model) calculation of 56Fe has been performed by **Paar** **(Paar, 1972)**, and general agreement with experiment has been obtained. In this study it has been pointed out also that the coupling of shell-model degrees of freedom to quadrupole vibration can give quasirotational band structure around the yrast line. Later, the existence of band structure in 56Fe was reported (Bendjaballah et al., 1976,1977). Lopac and **Paar** (Lopac, **Paar, 1978)** have recently made PVCM calculations of energy spectra and electromagnetic properties of even Zn isotopes and succeeded in obtaining general agreement with experiment and in particular reproducing observed band structure."

I.M. Naqib, D.J. Thomas, B. Wakefield ***(Oliver Lodge Laboratory, University of Liverpool, United Kingdom)***, **Negative parity states of 109Ag in the intermediate-coupling unified nuclear model, J.Phys. A6, 1580-1593 (1973):**
"Further improvement in the theoretical description of the nucleus may be achieved through one of the following approaches: (i) Description of 109Ag in terms of three proton holes coupled to a 112Sn core. This method has been applied by **Paar (Paar, 1972)** to the positive parity states in 109Ag. Experiments on proton transfer reactions leading to states in 109Ag would obviously provide further useful tests of the present calculation. It would also be of interest to compare the present results with those obtained based on coupling three proton holes to a $Z = 50$ closed shell **(Paar, 1972)**."

O.M. Mustaffa, L.P. Ekström, G.D. Jones, F. Kearns, T.P. Morrison, H.G. Price, D.N. Simister, P.J. Twin, R. Wadsworth, N.J. Ward ***(Oliver Lodge Laboratory, University of Liverpool, United Kingdom)*****, Gamma-ray spectroscopy in 63Zn and 63Cu, J.Phys. G5, 1283-1306 (1979):**
"At the moment the only theoretical predictions for the Zn isotopes using the quasiparticle-cluster coupling model is for 67Zn (Vanden Berghe, 1976; **Paar,** Coffou, Eberth, Eberth , **1976)**. The good agreement obtained for this nucleus indicates that it would be fruitful to extend the model to the other zinc isotopes."

G. Rotbard, G. Berrier, M. Vergnes, S. Fortier, J. Kalifa, J.M. Maison, L. Rosier, J. Vernotte, P. Van Isacker, J. Jolie ***(Institut de Physique Nucleaire, Orsay Cedex, France; Physics Department, University of Surrey, Guildford, United Kingdom; Institut de Physique, Universite de Fribourg, Fribourg, Switzerland)*****, Transfer results for odd-odd 196Au and the extended supersymmetry, Phys.Rev. C47, 1921-1928 (1993):**
"A more recent development is the extension of supersymmetry (Van Isacker et al., 1985; Balantekin, **Paar, 1986)** to odd-odd nuclei. In this approach the properties of a quartet of nuclei (with an even-even, an even-odd, an odd-even, and an odd-odd member) are studied and hence it represents a further step towards more unified models."

N. Bendjaballah, J. Delaunay, T. Nomura, H.J. Kim ***(Departement de Physique Nucleaire, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France; Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA)*****, Possible shape transition in the yrast band of 56Fe, Phys.Rev.Lett. 36, 1536-1539 (1976):**
"The wave function of the 6_2^+ state is much more complex. There is no dominant configuration in its wave function which mainly consists of various seniority-four states. Complex configurations of this kind also appear in the ground, 2_1^+, and 4_1^+ states. The similar features as mentioned above in the wave functions of the 6_1^+ and 6_2^+ states have also been pointed by **Paar (Paar, 1972)**."

S.P. Ahlen ***(Physics Department, Boston University, Massachusetts, USA)*****, Time-projection–chambers with optical readout for dark matter, double beta decay, and neutron measurements, Int.J.Mod.Phys. A25, 4525-4575 (2010):**
"Experience with the development of high-flux quasimonoenergetic beams at nuclear reactors, and with the need to develop convenient, inexpensive neutron sources for boron neutron capture therapy (BNCT), have contributed to the design of filters and beam shapers that can be used to reduce neutron energy without seriously degrading the neutron flux. The High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory used several filters (Chrien, Koene, Stelts, Meyer, Brant, **Paar,** Lopac, **1993)**."

L. Trache, J. Wrzesinski, C. Wesselborg, D. Bazzacco, R. Reinhardt, C.F. Moore, P. von Brentano, G.P.A. Berg, W. Hürlimann, I. Katayama, J. Meissburger, J.G.M. Römer, J.L. Tain ***(Institut für Kernphysik, Universität zu Köln, Köln, Germany; Institut für Kernphysik, KFA Jülich, Jülich, Germany)*****, Identification of a complete particle-octupole multiplet in 143Nd, Phys.Lett. 131B, 285-288 (1983):**

"The near degeneracy of the sp i13/2 and $(3^- \times f7/2)13/2^+$ unperturbed states in 143Nd shows that actually the spectroscopic factor for the lower state must be large, even though (d, p) spectroscopic factors can be doubtful for l = 6. Then the apparent contradiction can be explained by the in- and out-of-phase addition of the collective and the sp parts in the inelastic scattering transition amplitude. Similar in-phase addition of the two components can account for the large $B(E3)$ values observed for the transition of the lower $13/2^+$ state to the gs in other N = 83 nuclei 141Ce, 145Sm, 147Gd) despite large sp admixtures. A similar interference phenomenon was previously observed in 63Cu and is explained in ref. (Klaasse, **Paar, 1978)**."

F.H. Al-Khudair, G.L. Long, Y. Sun ***(Department of Physics, Tsinghua University, Beijing, China; Lanzhou Heavy Ion National Laboratory, Lanzhou, China; Department of Physics, Basrah University, Basrah, Iraq; Shanghai Jiao Tong University, Shanghai, China; Joint Institute for Nuclear Astrophysics, University of Notre Dame, Notre Dame, Indiana, USA)*****, Negative parity states and beta decays in odd Ho and Dy nuclei with *A* = 151, 153, Phys.Rev. C77, 034303 (2008):**

"Calculations of positive– and negative-parity states and the electromagnetic transitions of odd mass nuclei have been performed within the framework of the IBFM, for instance, in Refs. (Cunningham, 1982; Arias et al., 1985; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990;** Yoshida et al., 1997; Brant, **Paar,** Wolf, **1998;** Yazar, Uluer, 2007)."

A.K. Singh, G. Gangopadhyay, D. Banerjee, R. Bhattacharya, R.K. Bhowmik, S. Muralithar, R.P. Singh, A. Mukherjee, U. Datta Pramanik, A. Goswami, S. Chattopadhyay, S. Bhattacharya, B. Dasmahapatra, S.Sen ***(Department of Physics, University of Calcutta, Calcutta, India; Nuclear Science Centre, New Delhi, India; Saha Institute of Nuclear Physics, Calcutta, India)*****, Level structure of odd-odd 62Cu isotope, Phys.Rev. C59, 2440-2445 (1999):**

"The interacting boson-fermion-fermion model (IBFFM) has already been used to describe odd-odd Cu isotopes (Singh, Gangopadhyay, 1997). For the sake of completeness, we briefly discuss the method of calculation followed in that work. The structure of odd-odd nuclei may be described as an unpaired proton and an unpaired neutron coupled to a boson core. The Hamiltonian for the odd-odd nuclei may be written as a sum of a boson part, two parts describing odd proton-core and odd neutron-core interactions , two parts describing the one body fermion terms and a part describing the residual interaction between the odd particles (Timar, Quang, Fenyes, Dombradi, Krasznahorkay, Kumpulainen, Julin, Brant, **Paar,** Šimičić, **1994)**: $H = H_B +$

$H_{B\pi} + H_{B\nu} + H_{\pi} + H_{\nu} + H_{\pi\nu}$, where $\pi(\nu)$ refers to proton (neutron) and B refers to the boson core."

T. Hübsch *(Howard University, Washington DC, USA)*, Advanced Concepts in Particle and Field Theory, Cambridge University Press, Cambridge (1987):
"On the phenomenological side, supersymmetry is used also in the analysis of nuclear structure; see Ref. (Metz et al., 1999) for experimental confirmation, a recent article (Ganev, Brant, 2010), the review (**Paar,** Brant, Vretenar, Sunko, Balantekin, Hübsch, **1987)** and references therein. Indeed, atomic nuclei of adjacent isotopes and elements, which differ in only one neutron or proton, may be treated as superpartners: Suppose a particular atomic nucleus ${}^{A}_{Z}X$ has an even atomic number (the number of protons and neutrons together) and so is a boson. Then the nuclei that have one neutron more or less, ${}^{A\pm1}_{Z}X'$, or one proton more or less, ${}^{A\pm1}_{Z\pm1}X''$, are fermions. The formal boson-fermion (supersymmetric) transformations may all be used to predict the structure and the energy levels of the ${}^{A\pm1}_{Z}X'$ and ${}^{A\pm1}_{Z\pm1}X''$ nuclei, starting with the known properties of the ${}^{A}_{Z}X$ nucleus. This approximate supersymmetry may even be used for estimating information about nuclei that in comparison to a well-known ${}^{A}_{Z}X$ nucleus have both an additional proton and an additional neutron, ${}^{A\pm2}_{Z\pm1}X'''$ (Hübsch, **Paar, 1984a**), which fit in the c0rners of the diagram (10.30), as well as the so-called hypernuclei, which are short-lived nuclei that captured a Λ^0 baryon (Hübsch, **Paar, 1984b**) and which extend the diagram (10.30) in a third dimension. This application of supersymmetry is similar to Gell-Mann's application of SU (3) algebra in classifying hadrons."

A.A.C. Klaasse, P.F.A. Goudsmit *(Instituut voor Kernphysisch Onderzoek, Amsterdam, Netherlands)*, The decay of 63Zn, Z.Phys. 266, 75-82 (1974):
"Numerous attempts have been undertaken to explain quantitatively the character of the low-energy states of 63Cu from a combination of collective and single particle motion (Markham, Fulbright, 1973; Lawson, Uretsky, 1957; Bouten, Leuven, 1966; Simons, Sundius, 1969; **Paar, 1970;** Paradellis, Hontzeas, 1971; Gomez, 1971; Castel et al., 1972; Thankappan, True, 1965; Larner, 1970; Beres, 1966; Wong, 1970; de Jager, Boeker, 1972). **Paar (1970)** and Gomez (1971) suggest that possibly the low $B(E2)$ value can be explained by the opposite phase of the single particle and collective contributions."

R.M. Lieder, J.P. Didelez, H. Beuscher, D.R. Haenni, M. Müller-Veggian, A Neskakis, C. Mayer-Böricke *(Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany)*, Observation of a new isomer in 212Po, Phys.Rev.Lett. 41, 742-745 (1978):
"The 727.7-keV line is known to be the $2^+ \to 0^+$ transition in 212Po (Pancholi, Martin, 1972). This transition as well as the 222.9- and 405.2-keV lines have the same intensities within

statistical uncertainty in the $\alpha - \gamma$ coincidence experiment of 212Po. The ordering of the latter two transitions could not be determined experimentally, therefore. An ordering may be obtained, however, by considering the systematic features of the low-lying yrast levels of the isotopes 202,204,206,208,210Po (Yamazaki, 1970; Bergström et al., 1971; Beuscher et al., 1976; Schneider et al., 1975) and the isotone 210Pb (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**. They all show 2^+, 4^+, 6^+, 8^+ level sequences with decreasing energy spacings (Yamazaki, 1970; Bergström et al., 1971; Beuscher et al., 1976; Schneider et al., 1975; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**. The 8^+ states in 202,204,206,208,210Po are known to be isomeric (Yamazaki, 1970; Bergström et al., 1971; Beuscher et al., 1976; Schneider et al., 1975). These level sequences have been interpreted to result from the $(\pi h9/2)^2$ configurations in the even-mass Po isotopes (Yamazaki, 1970; Bergström et al., 1971; Beuscher et al., 1976) and from $(\nu g9/2)^2$ configuration for 219Pb (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Redlich, 1965). Similar level sequences based on either of these two configurations may be expected for 212Po. The 222.9-keV transition has been placed, therefore, above the 405.9-keV transition. The excitation energy of the 14.2–ns isomer can be calculated from the energy of the 10.18-MeV α transition. The isomer lies 67 ± 30 keV above the state de-excited by the 222.9-keV line."

T.S. Bhatia, T.R. Canada, P.D. Barnes, R. Eisenstein, C. Ellegaard, E. Romberg *(Nuclear Physics Laboratory, University of Pittsburgh, Pennsylvania, USA; Department of Physics, Carnegie-Mellon University, Pittsburgh, Pennsylvania, USA)*, Mixing of two-particle, two-hole states in 208Po, Phys.Rev.Lett. 30, 496-500 (1973):

"It is interesting to estimate the matrix element V_{12} connecting two-neutron-hole and two-proton-particle 2^+ excitation modes. We follow the procedure used (Igo et al., 1970; Broglia, **Paar,** Bes, **1971;** Siegal, 1972) for the interaction of two-neutron-hole and two-neutron-particle 2^+ modes observed in 208Pb. In that case the two 208Pb states are $\left[206\text{Pb}(2^+) \otimes 210\text{Pb}(0^+)\right]$ and $\left[206\text{Pb}(0^+) \otimes 210\text{Pb}(2^+)\right]$. Here the interaction matrix element, V_{12} (208Pb), extracted from the observed shifts (Igo et al., 1970) is ~¨125 keV. This matrix element has been estimated (Broglia, **Paar,** Bes, **1971;** Siegal, 1972) by using standard microscopic particle-vibration coupling Hamiltonian. The resulting matrix element is $V_{12}(\text{208Pb}) \simeq 0.012 \left\langle k_2 \right\rangle$ that becomes □ 600 keV. In order to explain this large overestimate, Broglia, **Paar** and Bes (Broglia, **Paar,** Bes, **1971)** have introduced a coupling to an isovector quadrupole mode which reduces the above result. The predicted matrix element for 208Po becomes $V_{12}(208\text{Po}) = \left(\frac{1.4}{3.5}\right)^{1/2} V_{12}(208\text{Pb}) \simeq 380 \text{ keV}$. This may be compared with the value of 250 keV derived above from the experimental data. Thus, in the present 208Po case the experimentally determined value is somewhat smaller than the simple estimate, but the discrepancy is not nearly as large as in 208Po. It will be important to determine whether the introduction of the isovector quadrupole mode can explain simultaneously the large deviation from the simple model in 208Pb and the near agreement in 208Po."

G.J. Lane, K.H. Maier, A.P. Byrne, G.D. Dracoulis, R. Broda, B. Fornal, M.P. Carpenter, R.M. Clark, M. Cromaz, R.V.F. Janssens, A.O. Macchiavelli, I. Wiedenhöver, K. Vetter ***(Department of Nuclear Physics, Australian National University, Canberra, Australia; Lawrence Berkeley National Laboratory, Berkeley, California, USA; Niewodniczanski Institute of Nuclear Physics, Cracow, Poland; Physics Division, Argonne National Laboratory, Lemont, Illinois, USA)*****, High-spin isomers and three-neutron valence configurations in 211Pb, Phys.Lett. B606, 34-42 (2005):**

"While low-spin states have been studied in 210Pb with the 208Pb(t, p) and 208Pb(t, pγ) reactions (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Decman et al., 1983) and a few high-spin states have been found with γ-ray spectroscopy following deep inelastic reactions (Rejmund et al., 1997), most of the expected simple two-neutron states are not known and, therefore, the neutron-neutron interaction is not well defined. The primary valence configurations in 211Pb will involve only the g9/2, i13/2 and j15/2 neutron orbitals, with the lowest yrast levels expected to arise from the $\nu g_{9/2}^{3}$ and the $\nu g_{9/2}^{2} i11/2$ configurations, for which all the relevant diagonal matrix elements have been measured in 210Pb (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Decman et al., 1983; Rejmund et al., 1997). Therefore, these states can be calculated without free parameters and the results compared to experiment. Further predictions for even more neutron-rich nuclei can be made more reliably."

K. Selvakumar, A.K. Singh, C. Ghosh, P. Singh, A. Goswami, R. Raut, A. Mukherjee, U. Datta, P. Datta, S. Roy, G. Gangopadhyay, S. Bhowal, S. Muralithar, R. Kumar, R.P. Singh, M. Kumar Raju ***(Department of Physics, Indian Institute of Technology Kharagpur, Kharagpur, India; Saha Institute of Nuclear Physics, Kolkata, India; Department of PhysicsAnanda Mohan College, Kolkata, India; S.N. Base National Centre for Basic Science, Kolkata, India; Department of Physics, University College of Science, University of Calcutta, Kolkata, India; Department of Physics, Surendranath Evening College, Kolkata, India; Inter-university Accelerator Center, Aruna Asaf Ali Marg, New Delhi, India, Department of Nuclear Physics, Andhra University, Visakhapatnam, India)*****, Evidence for octupole correlation and chiral symmetry breaking in 124Cs, Phys.Rev. C92, 064307 (2015):**

"The partial level scheme of 124Cs is shown in Fig. 1.Spin and parity of the levels are taken from the earlier studies (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001;** Komatsubara et al., 1990; Lu et al., 2000). The positive- and negative-parity bands, as shown in Fig. 1, were established in an earlier work (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001).** Later, several transitions with E1 character, linking the yrast negative-parity (band 3) and positive-parity (band 1) sequences, were observed (Dong et al., 2009; Lu et al., 2000). In the present work, we confirm the linking transitions. The configurations of bands 3 and 4 were investigated using the cranked shell model and the interacting boson fermion fermion model (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001)**. It was proposed that the band 3 has a two-quasiparticle configuration, $\pi h11/2 \otimes \nu(d5/2, g7/2)$ below the alignment at (h/2π) ω ~ 0.4 MeV and $\pi h11/2 \otimes \nu\left[(d5/2, g7/2)h_{11/2}^{2}\right]$ after the band crossing. In band 1, band crossings were observed at rotational frequencies 0.55 and 0.63 MeV in the α = 1 and α = 0, respectively (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001**). In triaxial nucleus the sudden change in γ values above spin 22 may be related to shape changes due to alignment of neutrons observed in the band (Gizon, Timar, Gizon, Weiss, Barneoud, Foin, Genevey, Hannachi, Liang, Lopez-Martens, Paris, Nyako, Zolnai, Merdinger, Brant, **Paar, 2001;** Komatsubara et al., 1990)."

A. Ekström, J.K. Cederkäll, C. Fahlander, M. Hjorth-Jensen, T. Engeland, A. Blazhev, P.A. Butler, T. Davinson, J. Eberth, F. Finke, A. Görgen, M. Gorska, A.M. Hurst, O. Ivanov, J. Iwanicki, U. Köster, B.A. Marsh, J. Mierzejewski, P. Reiter, S. Siem, G. Sletten, I. Stefanescu, G.M. Tweten, J. van de Walle, D. Voulot, N. Warr, D. Weisshaar, F. Wenander, M. Zielinska ***(Physics Department, University of Lund, Sweden; PH Department, CERN, Geneva, Switzerland; Physics Department and Center of Mathematics for Applications, University of Oslo, Norway; Institute of Nuclear Physics, University of Cologne, Germany; Oliver Lodge Laboratory, University of Liverpool, United Kingdom; Department of Physics and Astronomy, University of Edinburgh, United Kingdom; CEA Saclay, Gif-sur-Yvette, France; Gesellschaft für Schwerionenforschung, Darmstadt, Germany; Instituut voor Kern- en Stralingsfysica, K.U. Leuven, Belgium; Heavy Ion Laboratory, University of Warsaw, Poland; Institute Laue Langevin, Grenoble, France; Department of Physics, University of Manchester, United Kingdom; AB Department, CERN, Geneva, Switzerland; Institute of Experimental Physics, University of Warsaw, Poland; Department of Physics, University of Oslo, Norway; Physics Department, University of Copenhagen, Denmark)*****,** **Coulomb excitation of the odd-odd isotopes 106,108In, Eur.Phys.J. A44, 355-361 (2010):**
"In two previous efforts (Krasznahorkay et al., 1989; Chiara et al., 2001) the excited states in 108In have been interpreted in term of the $\pi g9/2^{-1} \otimes \nu g7/2$ and $\pi g9/2^{-1} \otimes \nu d5/2$ muiltiplets. However, the previous measurements were not directly sensitive to the transition matrix elements but had to rely on branching and mixing ratios. These were based on decay data, angular distributions from a (p, nγ) reaction, and from a high-spin study of 108In. The results were compared with an interacting-boson-fermion-fermion (IBFFM) calculation (Brant, **Paar, 1988)**."

R.A. Meyer, J.W.T. Meadows, E.S. Macias ***(Lawrence Livermore National Laboratory, Livermore, California, USA)*****, Opposing properties of particle-hole and intruder-hole bands in *N* = 87 nuclei and 149Sm levels populated by 149Pm(β^-) and 149Eu(EC), J.Phys. G8, 1413-1429 (1982):**
"As expected from CV model predictions **(Paar, 1972,1980; Paar,** Meyer, **1982)** , the $J-1$ state of $f_{7/2}^{N}$ multiplet increases in energy from below the parent $f_{7/2}^{N}$ state in 147Nd to well above it

in Gd and Dy (**Paar,** Meyer, **1982)** (see figure 9 and references cited in the section). In the Coulomb excitation studies, the $5/2^-$ 277 keV level is only weakly excited. We suggest that these $7/2^-$ levels represent the h9/2 *J* - 2 level. For 147Nd the $1/2^-$ level lifetime has been measured, as have the branching to the $f^N_{7/2}$ CV $5/2^-$ and h9/2 *J* – 2 levels (Dorikens, Dorikens-Vanpraet, 1975; Pingel et al., 1976; Roussille et al., 1975,1976). The $B(E2)\downarrow$ value for the $1/2^-$ to $5/2^-$ h9/2 transition is 89 Wu, while that for the $1/2^-$ to $5/2^-$ CV transition is 0.03 Wu (that is, hindered by a factor of 30). The former agrees well with the value of about 80 Wu in 145Ce. The collectivity of the former and the inverted *J* – 2 and *J* relative energy suggest a weakly deformed configuration for this band **(Paar** and Meyer, **1982)**. Using the systematic properties of the *N* = 87 nuclei we have established; we suggest that the ground states of 143Ba or 143Ce have a measurable deformation. This suggestion arises from the observation of collective *E*2 ground-state transitions, that the h9/2 *J* and *J* -2 states are steadily decreasing in energy as proton pairs are deleted from 151Gd. Support for this comes from experiments on 143Ba similar to those by (Ekström et al., 1980,1981). In the latter a small deformation is measured and is consistent with our suggestion of a $J-2$ bandhead **(Paar,** Meyer, **1982)**."

R.A. Meyer, J.E. Fontanilla, N.L. Smith, C.F. Smith, R.C. Ragaini ***(Lawrence Livermore National Laboratory, California, USA)*****, Level properties of $^{85}_{37}Rb_{48}$ from the decay of the 85Kr and 85Sr isomers and the cluster-vibration model, Phys.Rev. C21, 2590-2599 (1980):**
"The 37 neutron nuclei have been treated by the cluster-vibration model (CVM) **(Paar** et al., **1976a,b)**. Negative-parity states in 69Ge and 67Zn were described by coupling three holes in the subshell with single-particle configurations p1/2, p3/2, and f5/2 to the quadrupole vibration, i.e., it was assumed that for these nuclei N = 40 plays the role of a closed subshell. Here we extend this approach to 85Rb, which is a Z = 37 nucleus. The overall agreement between the experimental and calculated energy spectra and electromagnetic properties is reasonably good. In the present calculation we also include the tensor term in the M1 operator. Generally, it drastically affects the M1 transitions, which are *l*-forbidden in zeroth order. In our case, such a transition is the $3/2_1^- \rightarrow 5/2_1^-$ M1 transition, which is in zeroth order of the type $|((f7/2^{-2})0, p3/2^{-1})3/2,00;3/2\rangle \rightarrow |(f7/2^{-3})5/2,00;5/2\rangle$. In this case, the destructive interference between the higher-order contributions to the M1 transition moment for a standard M1 operator is large, and such a transition is therefore strongly hindered in the presence of mixed wave functions **(Paar,** Brant, **1978)**. Inclusion of the tensor term in theM1 operator, with the usual value of the gyromagnetic ratio, g_p = 1.33 (Hamamoto, 1976; **Paar,** Brant, **1978)**, results in the calculated value B(M1)($3/2_1^- \rightarrow 5/2_1^-$) = 0.023 μ_N^2. This leads to a correct order of magnitude for the half-life $\tau(3/2_1^-)$. On the other hand, the other M1 transitions, which are not *l*-forbidden in zeroth order, are much less affected by the tensor M1 term."

Z. Gacsi, S. Raman ***(Institute of Nuclear Research, Hungarian Academy of Sciences,Debrecen, Hungary; Oak Ridge National Laboratory, Tennessee, USA)*****, Decays of 116Sb isomers to levels in 116Sn, Phys. Rev. C49, 2792-2795, (1994):**

"In studying levels in 116Sb reported earlier (Gacsi, Dombradi, Fevyes, Brant, **Paar, 1991)**, $\sim 56 \times 10^6$ $\gamma\gamma$ $-$coincidence events were recorded in $\sim$100 h from and in-beam study of the 113In($\alpha, n\gamma$) reaction. This experiment also yielded coincidence information pertaining to γ-rays emitted in the subsequent decays of 116Sb activities."

A.K. Singh ***(Department of Physics, University College of Science, University of Calcutta, India)*****, Structure of low and high spin states in 112Sb in interacting boson fermion fermion model, Eur.Phys.J. A3, 9-15 (1998):**
"Interacting Boson Fermion Fermion Model (IBFFM) was used to understand the low-lying structures of heavier odd-odd Sb nuclei (Gacsi, Dombradi, Fenyes, Brant, **Paar, 1991;** Gulyas et al., 1992; Fenyes, Dombradi, 1992; Fenyes et al., 1992; Dombradi, Fenyes, Gacsi, Gulyas, Brant, **Paar, 1994)** and nice systematics in energy splitting of proton-neutron multiplets have been obtained. The ground state spin 3^+ of 112Sb is correctly reproduced and has a major contribution from the $\pi d5/2 \otimes \nu g7/2$ configuration in its wavefunction. The calculated energy values of the multiplets of $\pi d5/2\nu g7/2$, $\pi d5/2\nu d5/2$, $\pi d5/2\nu s1/2$ and $\pi d5/2\nu d3/2$ proton-neutron combination are plotted against $J(J+1)$ in Fig. 3. It is clear from Fig.3 that the parabolic feature (**Paar, 1979)** of the multiplets of different proton neutron combinations is approximately reproduced by this calculation."

I.Stefanescu, W.B. Walters, P.F. Mantica, B.A. Brown, A.D. Davies, A. Estrade, P.T. Hosmer, N. Hoteling, S.N. Liddick, W.D.M. Rae, T.J. Mertzimekis, F. Montes, A.C. Morton, W.F. Mueller, M. Oulette, E. Pellegrini, P. Santi, D. Seweryniak, H. Schatz, J. Shergur, A. Stolz, J.R. Stone, B.E. Tomlin ***(Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland, USA; Argonne National Laboratory, Argonne, USA; NSCL, Michigan State University, East Lansing, Michigan, USA; Department of Chemistry, Michigan State University, East Lansing, Michigan, USA; Department of Physik and Astronomy, Michigan State University, East Lansing, Michigan, USA; Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, Michigan, USA;Garsington, Oxfordshire, United Kingdom; Department of Physics, Oxford University, United Kingdom)*****, Spectroscopy of exotic 121,123,125Ag produced in fragmentation reactions, Eur.Phys.J. A42, 407-413 (2009):**
"The trend of the odd-mass Pd nuclei indicate that a $3/2^+$ ground state might also be expected for heavier odd-mass 119,121Pd nuclei. The levels in 113,115Ag populated in the decay of 113,115Pd have been presented and discussed in some details in refs. (Kaffrell et al., 1988; Rogowski, Alstad, Brant, Daniels, De Frenne, Heyde, Jacobs, Kaffrell, **Paar,** Skanemark Trautmann, **1990;** Fogelberg et al., 1988)."

T. Rauscher, F.K. Thielemann, K.L. Kratz ***(Institut für Physik, Universität Basel, Basel, Switzerland; Institut für Kernchemie, Universität Mainz, Mainz, Germany)*****, Nuclear level density and the determination of thermonuclear rates for astrophysics, Phys.Rev. C56,**

1613-1625 (1997):
"The nuclear level density has given rise to the largest uncertainties in the description of nuclear reactions (Cowan et al., 1991;Holmes et al., 1976; Thielemann et al., 1987; 1988). For large-scale astrophysical applications it is also necessary to not only find reliable methods for level density predictions, but also computationally feasible ones. Such a model is the noninteracting Fermi-gas model (Bethe, 1936). Most statistical model calculations use the back-shifted Fermi-gas description (Gilbert, Cameron, 1965). More sophisticated Monte Carlo shell model calculations (Dean et al., 1995), as well as combinatorial approaches (see, e.g., **Paar,** Pezer, **1997)**, have shown excellent agreement with this phenomenological approach and justified the application of the Fermi-gas description at and above the neutron separation energy."

H. Reinhardt *(Zentralinstitut für Kernforschung, Dresden, Germany)*, Investigation of anharmonic effects in nuclear field theory: The influence of noncollective roots, Nucl.Phys. A262, 231-243 (1976):
"Many attempts have been made to explain experimental results of spherical nuclei by including anharmonicities. A way out of these difficulties is achieved in nuclear field theory (NFT) (Mottelson, 1968; Bohr, Mottelson, 1975; Bes, Broglia, 1971; Broglia, **Paar,** Bes, **1971;** Bes et al., 1974,1975; Broglia, Liotta, **Paar, 1972),** originally introduced by Copenhagen group for the graphical perturbation treatment of the particle-vibration coupling (PVC), which may be considered the origin of the anharmonicities, as first pointed out by Mottelson (Mottelson, 1968; Bohr, Mottelson, 1975). The NFT provides us with a method which automatically involves the coupling between the collective and the quasiparticle motion and at the same fully takes into account the Pauli principle up to the order to which the perturbation treatment is carried out. The basic vertices of the NFT Hamiltonian are displayed in Fig. 1: (a) particle scattering, (b) and (c) pair creation and annihilation, and (d) two-body interaction processes. For details of the diagrammatic perturbation treatment, see e.g. ref. **(Paar, 1971a,b).** In the NFT description (PVC model) the contribution from the third order anharmonicity to the triplet spacing (which is directly related to the phonon-phonon interaction) is given by the two triangle diagrams. Some of these diagrams which contribute in the adiabatic limit ($\omega_0 = 0$) have already been considered by **Paar (Paar,1971c)**. According to eq. (4.1) the electric quadrupole field can interact directly with the quasiparticles (single particle process) or via the creation or annihilation of a phonon (collective processes). Applying the factorization theorem to the class of diagrams offering only in the time ordering of the phonon-electromagnetic field interaction **(Paar, 1973)** it can be shown that the collective processes give rise to a renormalization of the corresponding single particle process which results in an effective single particle charge $\tilde{e}^{(t_z)}(\Omega) = e^{(t_z)} - \sum_n e_{ph}^n \Lambda^n D_n(\Omega)$, where Ω is the amount of energy by which the electric transition operator M(E2) is "off-the-energy shell". We can define an effective transition operator $\widetilde{M}(E2\mu, \Omega) = \sum_{t_z} \tilde{e}^{(t_z)}(\Omega) Q_\mu^{(t_z)}$ whose diagrammatic representation are given by the phonon diagrams shown in figs. 4b and 4c, respectively. Corresponding the quadrupole moment, the thirty triangle diagrams involved in fig. 4b were explicitly given in ref. (Broglia, Liotta, **Paar, 1972).** It can be shown that for a nonadiabatic collective motion the anharmonicities induced by PVC involve

higher order contributions as compared to the corresponding static anharmonic coefficients w30, etc., which becomes important with increasing phonon energy ω_0. On the other hand, in the adiabatic limit the nuclear field introduces just the contributions from the usual anharmonicities, the strengths of which are then explicitly expressed in terms of shell model configurations **(Paar, 1971c)**."

N. Yoshida, H. Sagawa, T. Otsuka *(Institute of Physical and Chemical Research (RIKEN), Hirosawa, Japan; Faculty of Science, University of Tokyo, Japan; Center for Mathematical Sciences, University of Aizu, Fukushima, Japan)*, Signature inversion in odd-odd nuclei in the interacting boson-fermion model, Nucl. Phys. A567, 17-32 (1994):
"Brant at al. (Brant, **Paar,** Vretenar, **1984)** introduced the interacting boson-fermion-fermion model (IBFFM) and studied the dynamical symmetries in odd-odd nuclei. Several nuclear species have been studied in this model (Lopac, Brant, **Paar,** Schult, Seyfarth, Balantekin**, 1986;** Brant, **Paar,** Vretenar, Alaga, Seyfarth, Schult, Bogdanovic, **1987;** Brant, **Paar, 1988;** Brant, Lhersonneau, Stolzenwald, Sistemich, **Paar).** Odd-odd nuclei have been noted also from the viewpoint of the boson-fermion supersymmetry (Hübsch, Paar, **1984;** Hübsch, Paar, Vretenar, **1985;** Balantekin, **Paar, 1986a; 1986b)**."

P. von Brentano, A. Dewald, W. Lieberz, R. Reinhardt, K.O. Zell and V. Zipper (*Department of Physics, Universität Köln, Köln, Germany*), in Nuclear structure in the Zirconium region, Springer, Berlin, p.157 (1988):
"A further incentive to study all nuclear levels in a given spin and energy window is that we can learn from the distribution of nuclear levels very much about nuclear chaos, a field which has become quite exciting in recent years as is discussed by **Vladimir Paar**."

G. Lhersonneau, B. Pfeiffer, J.R. Persson, J. Suhonen, J. Toivanen, P. Campbell, P. Dendooven, A. Honkanen, M. Huhta, P.M. Jones, R. Julin, S. Juutinen, M. Oinonen, H. Penttilä, K. Peräjärvi, A. Savelius, W. Jicheng, J.C. Wang, J. Äystö *(Department of Physics, University of Jyväskylä, Jyväskylä, Finland; Institut für Kernchemie, Universität Mainz, Mainz, Germany; School of Physics and Space Research, University of Birmingham, Birmingham, United Kingdom; Department of Physics, University of Manchester, Manchester, United Kingdom; Institute of Modern physics, Lanzhou, China)*, Detailed investigation of the β-decay of the $9/2^+$ ground state of 99Nb to levels in 99Mo, Z.Phys. A358, 317-327 (1997):
"Up to filling the g9/2 proton shell, all the known *N* = 57 and 59 isotones 93Kr (Wöhr et al., 1993), 95Sr (Kratz et al., 1983), 97Zr (Lhersonneau et al., 1996), 97Sr (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** and 99Zr (Lhersonneau et al., 1994) have the same level sequence with a $1/2^+$ ground state, a low lying $3/2^+$ state and a $7/2^+$ state. The $1/2^+$ and $7/2^+$ levels correspond to the s1/2 and g7/2 subshells, respectively. However, as soon as protons are

put in the g9/2 orbital, this smooth systematics changes dramatically. Most spectacular is in energy of the d5/2 subshell. The $3/2^+$ level also changes its character. The first excited $3/2^+$ level in 97Sr is calculated with the Interacting Boson Fermion model (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** to have a complex structure in which the $2_1^+ \otimes g7/2$ configuration has a large amplitude. In 99Mo, the wave functions for both low-lying $3/2^+$ states do not contain a large amplitude of the $2_1^+ \otimes g7/2$ configuration."

J. Jolie, U. Mayerhofer, T. von Egidy, H. Hiller, J. Klora, H. Lindner, H. Trieb *(Institut Laue-Langevin, Grenoble, France; Physik Department, Technische Universität München, Garching, Germany)*, Predictive power of supersymmetry in nuclear structure tested by pickup transfer reactions to 196Au, Phys.Rev. C43, R16-R20 (1991):

"Taking all this into account, we conclude that, as far as this experiment is concerned, supersymmetry has predictive power. It would be extremely interesting to have more experimental information on 196Au and to investigate what the predictions are of other theoretical models, for instance, the ones used in Refs. (Mayerhofer, von Egidy, Dürner, Hlawatsch, Klora, Lindner, Brant, Seyfarth, **Paar,** Lopac, Kopecky, Warner, Chrien, Pospisil, **1989)** and (Balantekin, **Paar, 1986)**."

J. Suhonen, G. Lhersonneau *(Department of Physics, University of Jyväskylä, Jyväskylä, Finland)*, β-decay of the 5^+ isomer of the odd-odd nucleus 100Nb, Phys.Rev. C64, 014315 (2001):

"The quasiparticle random phase approximation (QRPA) and the microscopic quasiparticle–phonon model (MQPM) (Suhonen, 1993; Toivanen, Suhonen, 1998) have proven to provide a useful approach to describe β-decay properties of spherical nuclei with a large configuration space. In particular, the MQPM was used recently to account for the decay properties of 99Nb $9/2^+$ isomer (Lhersonneau et al, 1997) and of 99Zr decay (Lhersonneau, Suhonen, Dendooven, Honkanen, Huhta, Jones, Julin, Juutinen, Oinonen, Penttilä, Persson Peräjärvi, Savelius, Wang, Äystö, Brant, **Paar,** Vretenar, **1998)**. It is natural to extend these calculations to the decay of 100Nb to 100Mo especially since the 3 s isomer of 100Nb has been proposed to be built on the proton g9/2 and neutron s1/2 orbitals, those involved in the ground states of 99Nb and 99Zr (Lhersonneau, Brant, **Paar, 2000)**.

The N = 59 isotones 97Sr, 98Y, and 99Zr have spherical ground states. Their lowest states could be reproduced by IBA-type calculations extended to even-odd and odd-even nuclei (interacting boson-fermion model (IBFM)) and to the odd-mass nuclei (interacting boson-fermion-fermion model (IBFFM)) (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990;** Brant, Paar, Lhersonneau, Schult, Seyfarth, Sistemich, 1989; Brant, **Paar,** Wolf, **1998)**. The lowest deformed levels were identified near 500 keV in 97Sr (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** and 98Y (Lhersonneau et al., 1986; Hamilton et al., 1995; Urban et al., 2001). Among the 100Mo levels observed in $100Nb^m$ decay two levels are defined with only a transition to the 6^+ yrast level or alternatively they could be in cascade. Levels at 3623(5) and

3652(5) keV were reported in (p,p') and (α,α') reactions, the latter being assigned as l = 5. However, the absence of γ-rays linking these levels to states with 6^+ could be the consequence of their spins larger than 6. Levels with l = 7 or 8 are not expected to be that much strongly populated in the decay of the 5^+ isomer. This could be an indication of the decay of one of the higher 8^+ or 10^- possible isomers in 100Nb postulated in Ref. (Lhersonneau, Brant, **Paar, 2000)**."

G. Lhersonneau, S. Brant, ***(INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy; Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia)***, **Levels in 99Zr observed in the decay of 99Y, Phys.Rev. C72, 034308 (2005):**

"The lowest lying levels of the intermediate N = 59 isotones were proposed to be spherical, first based on level structure arguments. They have been studied in the framework of the interacting boson fermion and interacting boson fermion-fermion models (IBFM) (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990;** Brant, **Paar,** Lhersonneau, **1989;** Brant, **Paar,** Wolf, **1998;** Lhersonneau, Brant, **Paar, 2000)**. The low-lying levels of 99Zr are spherical with $\nu s1/2$ associated with the ground state and $\nu g7/2$ with the second excited state at 252 keV. Particular attention has been devoted to the $3/2^+$ first excited state at 122 keV of more complex character (Brant, **Paar,** Wolf, **1998).** The interacting-boson-fermion model has been previously applied to the description of spherical states in 97Sr (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990**) and 99Zr (Brant, **Paar,** Wolf, **1998**). Very limited information on the level spectra and electromagnetic properties of 97Sr and 99Zr was used to determine the fermion-boson interaction strengths, effective charges, and gyromagnetic factors. For the lowest three positive parity states, $1/2^+_1$, $3/2^+_1$, and $7/2^+_1$, the theoretical description is very good. At an excitation energy of approximately 600 keV the IBFM calculations in both nuclei predicted a pair of $3/2^+_2$ and $5/2^+_1$ spherical states, predominantly based on the $2^+ \otimes s1/2$ configuration. In the present work we attempt to assign these states to the levels at 522 and 601 keV (in 97Sr) and 725 and 762 keV (in 99Zr), using the corresponding wave functions from calculations in Refs. (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990**) and (Brant, **Paar,** Wolf, **1998**). For both nuclei we use the same effective charges and g factors, namely those from the former calculation of the low-lying levels of 99Zr (Brant, **Paar,** Wolf, **1998**). The IBFM predictions for the ordering of $5/2^+$ and $3/2^+$ $2^+\otimes s1/2$ levels in both nuclei (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990** and Brant, **Paar,** Wolf, **1998**) show an inversion, the $5/2^+$ level being above the $3/2^+_2$ level in 97Sr and conversely in 99Zr.This scheme is in accordance with the analysis of transitions."

S.M. Abecacis, J.M. Carcione ***(Departamento de Fisica, Facultad de Ciencias Exactas y Naturales, Buenos Aires, Argentina)***, **Classical semimicroscopic model applied to doubly even titanium isotopes, Phys.Rev. C19, 1535-1543 (1979):**

"The success obtained with the classical semimicroscopic model (Alaga, 1969) when applied to some nuclei of the 1f-2p shell (**Paar, 1972)** has encouraged us to explore the possibilities of its

applications to even-mass titanium isotopes which are expected to be adequately described by this model. In the classical semimicroscopic model these nuclei can be analyzed in terms of the coupling of a two-proton cluster to the corresponding vibrational cores.
Our calculations for even Ti nuclei predict rather large negative quadrupole moments for some low-lying states as well as enhanced *E*2 transition between them. On the other hand, inspection of Table II shows that the 0_1, 2_1, 4_1, 0_2, and 2_2 levels are mainly built on the $(f7/2)^2 0$ pair coupled to zero-, one-, and two-phonon states. A point which deserves special attention is that the 6_1 state is based mainly on the $(f7/2)^2 6$ pair, a situation already found in the case of 58Fe by **Paar (Paar, 1972)** with the same model as used here. Since it seems of importance to compare the present results with those of 56Fe, we repeated the calculations performed by **Paar** using our computational program in order to have available some additional information. From the comparison between the strongest *E*2 transitions corresponding to 56Fe and the titanium isotopes emerges the existence of a second quasirotational band. In the present case the new band lies above the ground state band which is the inverse situation to that found in 56Fe. This set of features - when considered together – favors the assumption of a quasirotational structure in coexistence with a quasivibrational one, a fact which is generally established by the classical semimicroscopic model."

F.L. Goodin, P.J. Ellis ***(School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota, USA; Physics Department, University of Manchester, Manchester, United KIngdom)*****, Study of effective operators in the 16O region, Nucl.Phys. A334, 229-247 (1980):**
"We focus our attention on a number conserving set of diagrams for the effective charge. These diagrams are said to comprise a number conserving set since if the electromagnetic operator *E* were replaced by the number operator, the sum of diagrams would be identically zero. It is worth noting that **Paar (Paar, 1976)** has shown that the number conserving set cancels identically in the particle-vibration model if one goes to the asymptotic limit of large angular momentum."

J.M.G. Gomez ***(Departamento de Fisica Teorica, Universdad de Valencia, Valencia, Spain; GIFT, Instituto de Estudios Nucleares, Spain)*****, Quadrupole vibrations in the nickel region: structure of odd-mass Cu isotopes, Nucl.Phys. A173, 537-550 (1971):**
"Very recently **Paar (Paar, 1970)** has published a semi-microscopic study of 63Cu and some of his results for this nucleus overlap with our results. However, in the present paper a different parametrization is used and some other properties such as mixing ratios and branching ratios of γ-rays are given. In a recent study of 63Cu, **Paar** has shown that the observed strength for the $1/2^-$ state can be reproduced in the framework of the unified model. The third calculated $5/2^-$ state has a considerable single-particle strength and it is worthwhile to note that a strong $l = 3$ transition to the 1.863 MeV level has been observed in proton pick-up reactions. The $I^\pi = 5/2^-$ assignment is therefore the most probable."

M.A.J. Mariscotti, D.R. Bes, S.L. Reich, H.M. Sofia, P. Hungerford, S.A. Kerr, K. Schreckenbach, D.D. Warner, W.F. Davidson, W. Gelletly ***(Departamento de Fisica, Comision Nacional de Energia Atomica, Buenos Aires, Argentina; Institut Laue-Langevin, Grenoble Cedex, France; Division of Physics, National Research Council of Canada, Ottawa, Canada; Schuster Laboratory, University of Manchester, Manchester, United Kingdom)***, **Search for two-octupole-phonon states in 208Pb, Nucl.Phys. A407, 98-126 (1983):**

"Two 0^+ and four 2^+ states have been identified within 600 keV of the expected zeroth-order energy of the $\left(3^- \otimes 3^-\right)_I$ multiplet (Lewis, 1971). Since both types of excitations consist of 2p-2h states a more detailed analysis of these levels must include an evaluation of the interaction between the two-phonon pairing and octupole vibration modes. This problem was investigated by Broglia, **Paar** and Bes (Broglia, **Paar,** Bes, **1971a,b)** who discussed a method of calculating the matrix elements between the unperturbed states:

$$|\Phi_1\rangle = \left|g.s.(^{206}\mathrm{Pb}) \otimes g.s.(^{210}\mathrm{Pb});0+ \quad (4.88\ \mathrm{MeV})\right\rangle,$$

$$|\Phi_2\rangle = \left|3^-(^{208}\mathrm{Pb}) \otimes 3^-(^{208}\mathrm{Pb});0+ \quad (5.23\ \mathrm{MeV})\right\rangle,$$

$$|\Phi_3\rangle = \left|g.s.(^{210}\mathrm{Po}) \otimes g.s.(^{206}\mathrm{Hg});0+ \quad (5.30\ \mathrm{MeV})\right\rangle.$$

Their results indicate that the first 0^+ state at 4.88 MeV should have approximately 80 % of $\left|\Phi_1\right\rangle$, 10 % of $\left|\Phi_2\right\rangle$, and 10 % of $\left|\Phi_3\right\rangle$, and that there should be two almost degenerate states at 5.3 MeV weakly populated in the two-neutron transfer reactions. As a result, the interpretation of the 0^+ level at 4.88 MeV seems well established as the two-phonon state of any kind identified in a doubly magic nucleus, while the character of the 5.26 MeV 0^+ state remains unclear.
The (t, p) and (p, t) studies have also given evidence of pairing vibrational states with angular momentum $I = 2$. Two are expected with the configurations $\left|2^+(^{210}\mathrm{Pb}) \otimes 0^+(^{206}\mathrm{Pb});2^+\right\rangle$, $\left|2^+(^{206}\mathrm{Pb}) \otimes 0^+(^{210}\mathrm{Pb});2^+\right\rangle$, which should come about 800 keV (the energy of the first 2^+ states in $^{206,210}\mathrm{Pb}$) above the 0^+ two-neutron pairing vibration state. The levels with $L = 2$ observed at 5.55 and 5.80 MeV (ref. Igo et al., 1970) have been associated (Broglia, **Paar,** Bes, **1971a,b;** Igo et al., 1971) with these configurations because they are strongly excited in the two-neutron transfer reactions. To summarize, our present knowledge of the positive-parity states around 2 $\frac{h}{2\pi}\omega$ in ^{208}Pb includes two 0^+ states, one of which is established as the two-neutron pairing vibration, while the other may correspond to either the two-proton pairing vibration or the two-phonon octupole vibration. The work of (Broglia, **Paar,** Bes, **1971a,b**) indicates that the $(3^- \otimes 3^-)_{0^+}$ state should lie close to $2\frac{h}{2\pi}\omega$ since its interaction with the two-phonon pairing vibration modes does not induce a large shift. The 0^+ member of the quadruplet is of particular interest because it would provide a test of the coupling with the two-phonon monopole neutron pairing vibration which is important for our understanding of the nuclear spectrum in terms of the elementary modes of excitation (Broglia, **Paar,** Bes, **1971a, b**)."

K.J. Weeks, J.P. Draayer ***(Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana, USA)*****, Shell model predictions for unique parity yrast configurations of odd-mass deformed nuclei, Nucl.Phys. A393, 69-94 (1983):**
"For transitional weakly deformed nuclei, the particle-vibration –coupling model has been developed (Alaga, **Paar, 1976; Paar,** Brant, **1981**). The abnormal parity levels of odd mass nuclei have been the subject of numerous theoretical studies. The role of deformation in determining the appearance of a stretched or ordered spectrum was also investigated in detail by Alaga and Paar (Alaga, **Paar, 1976)** using the weak coupling of the abnormal parity particle to the vibrational excitations of the parent nucleus."

V. Berg, J. Oms, K. Fransson, Z. Hu (Institut de Physique Nucleaire, Orsay, France; Department of Physics, University of Stockholm, Stockholm, Sweden; Institute of Atomic Energy, Beijing, China; ISOCELLE Collaboration), Half-life and electromagnetic deexcitation rate measurements for $1/2^+$ and $3/2^+$ states in odd-proton nuclei around Z = 82, Nucl.Phys. A453, 93-103 (1986):
"Several attempts have been made to interpret the *l*-forbidden M1 transitions in vibrational nuclei. Sorensen (Sorensen, 1963) using a shell model with a residual pairing-plus quadrupole force found that this coupling could explain most of the transition rate in a number of cases, but particularly for the odd-*N* nuclei fast transitions occur which are still unexplained. The evolution of all these transitions seems to follow a common rule and in the Pb region one would expect the minimum value in 207Tl with Z = 81 and N = 126. Instead, one finds for this nucleus the highest B(M1) value of all. The calculations of Sorensen were further developed by Freed and Kisslinger (Freed, Kisslinger, 1968) who also took into account admixtures of higher-seniority states in the wave functions. The agreement with experiment was improved but was not entirely satisfactory and the authors proposed that the influence of 1^+ core polarization simulated by a tensor force should be considered. This effect in which nucleons from the core are excited to empty spin-partner orbits is important in the Pb region where protons in the h11/2 subshell and neutrons in the i13/2 subshell can be excited to empty h9/2 and i11/2 states outside the core. The effect long studied (Blin-Stoyle, 1953), should in principle be strong enough to account for the strength of all the *l*-forbidden transitions. On the basis of this theory, **Paar** and Brant (**Paar,** Brant, **1978a,b)** propose that in nuclei with soft vibrations the dominating contribution to the forbidden M1 transitions comes from core polarization and show that, in contrast to what has been quoted earlier, the inclusion of particle-vibration coupling has very small influence on the transition rate as its partial contributions add incoherently and thus tend to cancel. The calculations show that the remaining contribution to the transition rates coming from the particle-vibrator coupling tends to counteract the one due to the core polarization. When going towards lighter isotopes the core-polarization effect slowly weakens, while the particle vibration coupling contribution grows. As a result, the M1 transition rates should progressively diminish with decreasing neutron

number. Fig. 6 in part corroborates this theory, the trend in Ir and in heavier Au nuclei being that predicted."

C.J. Chiara, D.B. Fossan, V.P. Janzen, T. Koike, D.R. LaFosse, G.J. Lane, S.M. Mullins, E.S. Paul, D.C. Radford, H. Schnare, J.M. Sears, J.F. Smith, K. Starosta, P. Vaska, R. Wadsworth, D. Ward, S. Frauendorf ***(Department of Physics and Astronomy, State University of New York at Stony Brook, Stony Brook, New York, USA; AECL Research, Chalk River Laboratories, Chalk River, Ontario, Canada; Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada; Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom; Department of Physics, University of York, Heslington, York, United Kingdom; Department of Physics, University of Notre Dame, Notre Dame, Indiana, USA; Institut of Kern- and Hadronenphysik, Forschungszentrun Rossendorf, Dresden, Germany)*****, Spectroscopy in the *Z* = 49 ^{108,110}In isotopes: Lifetime measurements in shears bands, Phys.Rev. C64, 054314 (2001):**

"The low-spin parts of the 108In and 110In level schemes have been studied by Krasznahorkay et al. (Krasznahorkay et al., 1989; Krasznahorkay, Dombradi, Timar, Gacsi, Kibedi, Passoja, Julin, Kumpulainen, Brant, **Paar, 1989)**. In those analyses, the experimentally established low-spin states were compared with interacting boson-fermion-fermion (IBFFM) calculations in an effort to identify underlying configurations. Calculations for both nuclei predicted that the excitation energies of the 2^+-7^+ states of the $\pi[(g9/2)^{-1}] \otimes \nu[d5/2)]$ multiplet form an approximate concave-down parabola at low excitation energy. This is illustrated for 108In in Fig. 21 (a). The 1^+ - 8^+ states of the $\pi[(g9/2)^{-1}] \otimes \nu[g7/2)]$ multiplet are expected at higher excitation energies. The later multiplet was shown to exhibit deviations from a parabolic rule in the indium isotopes as the mass decreases from 112In down to 106In (see Ref. Krasznahorkay, Dombradi, Timar, Gacsi, Kibedi, Passoja, Julin, Kumpulainen, Brant, **Paar, 1989** and references therein**).** The concave down parabola at higher neutron numbers, where the g7/2 neutron has holelike character, is predicted to become a W shape, as shown in the left half of Fig. 21(b), and then become a concave-up parabola at lower neutron numbers as the neutron Fermi level occupies g7/2 orbitals which have a greater particle-like character. This behavior is sensitive to to the boson-quasineutron interaction strength and Fermi level and is general characteristic of IBFFM calculations Krasznahorkay, Dombradi, Timar, Gacsi, Kibedi, Passoja, Julin, Kumpulainen, Brant, **Paar, 1989;** Brant and **Paar, 1988)**. The excited 7^+ and 8^+ states in 110In (at 413 and 714 keV, respectively) confirmed the distorted parabolic shape in that nucleus (Krasznahorkay, Dombradi, Timar, Gacsi, Kibedi, Passoja, Julin, Kumpulainen, Brant, **Paar, 1989;** Brant and **Paar, 1988)**."

Y. Iwasaki, M. Sekiguchi, F. Soga, N. Takahashi ***(Department of Physics, Shizuoka University, Shizuoka, Japan; Institute for Nuclear Study, University of Tokyo, Tanashi-shi, Tokyo, Japan; Research Center for Nuclear Science and Technology, University of Tokyo, Tokyo, Japan; Department of Physics, University of Tokyo, Tokyo, Japan)*****, Study of the particle-vibration coupling in odd copper isotopes with two-neutron transfer reactions,**

Phys.Rev.Lett. 29, 1528-1530 (1972):
"Low-lying excited states in odd copper isotopes have been interpreted theoretically with the particle-vibration coupling picture (Bouten, Van Leuven, 1966; Thankappan, True 1964; Beres, 1965; **Paar, 1970)**. Regarding the relative strengths of the low-lying excited states in 65Cu, a marked parallelism is observed between the two-neutron transfer reaction and the inelastic scattering, and an antiparallelism between the two-neutron transfer and the single-proton transfer reactions. This experimental fact suggests possible usefulness of two-neutron transfer reactions in studying the phonon components of particle-vibration coupled states in proton-odd nuclei. In an odd copper isotope, the odd particle is a proton occupying the 2p3/2 orbit outside the Z = 28 closed shell in the ground state, and the 2^+ phonon of the core consists mainly of neutron quasiparticle excitations outside the N =28 closed shell (**Paar, 1970).** The two-neutron experimental results are, on the whole, consistent with the simple particle-vibration picture: the phonon of the core is excited in two-neutron transfer reactions on the odd isotopes of copper."

M. Oinonen, U. Köster, J. Äystö, V. Fedoseyev, V. Mishin, J. Huikari, A. Jokinen, A. Nieminen, K. Peräjärvi, G. Walter ***(EP Division, CERN, Geneva, Switzerland; Institute of Spectroscopy, Russian Academy of Sciences, Troitsk, Russia; Department of Physics, University of Jyväskylä, Finland; Institut de Recherches Subatomiques, Strasbourg Cedex, France)*****, Ground state spin of 59Mn, Eur.Phys.J. A10, 123-127 (2001):**
"Nature of the low-lying levels in the odd-A Mn isotopes between 53-57Mn has been studied by Puttaswamy et al. (Puttaswamy, Oelert, Djaloeis, Mayer-Böricke, Turek, Glaudemans, Metsche, Heyde, Waroquier, van Isacker, Wenes, Lopac, **Paar, 1983**). Indeed, the $7/2^-$ state was found to have a strong single-particle nature unlike the other states including the $5/2^-$ level which possesses a very strong collective character. Nucleon-nucleon interaction forces the state with $J^\pi = 5/2^-$ to be the ground state for all the odd-even Mn isotopes between A =49 and 57 except for 53Mn. The closest neutron shell with N = 28 in the case of 53Mn leaves a possibility for the odd proton to define the ground state as $J^\pi = 7/2^-$."

D. Vretenar, G. Bonsignori, M. Savoia (Physics Department, Technical University Munich, Garching, Germany; Istituto Nazionale di Fisica Nucleare, Sezione di Bologna and Department of Physics, University of Bologna, Bologna, Italy), One and two broken pairs in the interacting boson model: High-spin states in 190,192,194Hg, Phys.Rev. 47, 2019-2023 (1993):
"Various extensions of the IBM have been reported that include two-fermion states (one broken pair) in addition to bosons (Gelberg, Zemel, 1980; Morrison et al., 1981; Kuyucak et al., 1984; Faessler et al., 1985; Yoshida et al., 1982,1985; Alonso et al., 1986; Chuu et al., 1988,1989; Hsieh et al., 1992). In Refs. (Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Iachello, Vretenar, 1991; Vretenar, **Paar,** Bonsignori, Savoia, **1991**) we have further extended the IBM to include two- and four-fermion noncollective states. In the present article, we apply the interacting boson model with one and two broken pairs to description of yrast states in the transitional nuclei 190,192,194Hg. High-spin states are described in terms of brokren pairs. The model space for an

even-even nucleus with $2N$ valence nucleons is: $|N \text{ bosons}\rangle \oplus |(N-1) \text{ bosons} \otimes 1 \text{ broken pair}\rangle \oplus (N-2) \text{ bosons} \otimes 2 \text{ broken pairs}$. The model Hamiltonian is (Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Iachello, Vretenar, 1991; Vretenar, **Paar,** Bonsignori, Savoia, **1991**): $H = H_B + H_F + V_{BF} + V_{\text{mix}}$, where H_B is the IBM-1 boson Hamiltonian (Iachello, Arima, 1987), the fermion Hamiltonian H_F contains the single-fermion energies and fermion-fermion interactions, the boson-fermion coupling H_{BF} contains three terms representing the dynamical, exchange and monopole interactions of the interacting boson-fermion model (IBFM) (Iachello, Scholten, 1979), respectively. V_{mix} is the pair-breaking interaction that mixes states with different number of fermions, conserving only the total nucleon number."

C.M. Petrache, G. Lo Bianco, P.G. Bizzeti-Sona, D. Bazzacco, S. Lunardi, M. Nespolo, G. de Angelis, P. Spolaore, N. Blasi, V. Krstić, D. Vretenar ***(Dipartimento di Fisica, Universita di Camerino and INFN, Sezione di Perugia, Italy; Dipartimento di Fisica and INFN, Sezione di Firenze, Italy; Dipartimento di Fisica and INFN, Sezione di Padova, Italy; INFN Laboratori Nazionali di Legnaro, Italy; INFN, Sezione di Milano, Italy; Department of Physics, Faculty of Science, University of Zagreb, Croatia)*****, Spectroscopy of the deformed 125Ce nucleus, Eur.Phys. J. A14, 430-449 (2002):**
"We notice the very weak transitions in the regions of band crossings. This is characteristic for the interacting boson plus broken-pairs models and reflects the weak mixing between states with different number of broken pairs (Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Vretenar, **Paar,** Savoia, Bonsignori**, 1991)**."

M.P. Pato, C.A. Nunes, C.L. Lima, M.S. Hussein, Y Alhassid ***(Instituto fe Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil; Center for Theoretical Physics, Sloan Physics Laboratory, Yale University, New Haven, Connecticut, USA)*****, Deformed Gaussian orthogonal ensemble analysis of the interacting boson model, Phys.Rev. C49, 2919-2923 (1994):**
"It is widely assumed that the random matrix theories (Bohigas et al., 1984) provide a basis to study quantum chaotic systems. In particular, it is expected that fluctuation properties of fully chaotic systems with time reversal symmetry follow the Gaussian orthogonal ensemble whereas nonchaotic ones follow the Poissonian ensemble. Some physical systems, however, may exhibit statistics between these two limits, as recent investigations have shown in the case of the efcitation soectra and intensities of deformed (Alhassid, Novoselsky, 1992; Matsuo et al., 1992; **Paar,** Vorkapić, **1990)**."

N. Yoshinaga, N. Yoshida, T. Shigehara, T. Cheon ***(Department of Physics, Saitama University, Saitama, Japan; Institute of Physical ana Chemical Research RIKEN, Saitama, Japan; Computer Centre, University of Tokyo, Tokyo, Japan; Department of Physics, Hosei University, Tokyo, Japan)*****, Nuclear mass dependence of chaotic dynamics in the Ginocchio**

model, Phys.Rev. C48, R509-R512 (1993):
"Several recent studies have revealed an intriguing interplay of chaotic and regular motion in the low-lying collective states of the medium-heavy nuclei **(Paar,** Vorkapić, **1988,1990;** Alhassid et al., 1991,1992; Mizusaki et al., 1991)."

D. Seweryniak, J. Kownacki, L.O. Norlin, C. Fahlander, A. Atac, J. Blomqvist, B. Cederwall, H. Grawe, A. Johnson, A. Kerek, J. Nyberg, R.Schubart, E. Adamides, E. Ideguchi, R. Julin, S. Juutinen, W. Karczmarczyk, S. Mitarai, M. Piiparinen, G. Sletten, S. Törmänen, A. Virtanen ***(Svedberg Laboratory and Department of Radiation Sciences, Uppsala University, Uppsala, Sweden; Institute of Experimental Physics, University of Warsaw, Warsaw, Poland; Royal Institute of Technology, Department of Physics, Stockholm, Sweden; Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark; Hahn-Meitner Institute, Berlin, Germany; National Centre for Scientific Research, Attiki, Greece; Department of Physics, Faculty of Science, Kyushu University, Fukuoka, Japan; Department of Physics, University of Jyväskylä, Jyväskylä, Finland)***, **In-beam study of 102In, 104In and 106In, Nucl.Phys. A589, 175-200 (1995):**
"The structure of the low-lying positive-parity states in odd-odd 104,106,108,110,112In nuclei has been studied theoretically by means of the interacting boson-fermion-fermion model (IBFFM) in Refs. (Dombradi, Brant, **Paar, 1991;** Gulyas et al., 1990; Krasznahorkay et al., 1989; Krasznahorkay, Dombradi, Timar, Gacsi, Kibedi, Passoja, Julin, Kumpulainen, Brant, **Paar, !989;** Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, 1988).This model accounted well for the level energies, for the measured branching ratios and for the magnetic dipole and electric quadrupole moments of the ground state and the isomeric states. The results of recent IBFFM calculations (Dombradi, Algora, Brant, **Paar, 1994)**, are shown in Figs. 12, 13 and 14 for 102,104,106In for some of the states. The IBFFM correctly predicts the ground-state spins of 104In and 106In and suggests spin $6h/2\pi$ and positive parity for the ground state of 102In in agreement with the shell-model calculations. It reproduces fairly well the energies of the observed 7^+ and 8^+ states but the calculated 9^+ states have too high energy as compared to the experiment. Also, the agreement for the negative-parity states in 104In is satisfactory. Only the calculated 13^- and 14^- states have slightly too high energy. This is due to the harmonic-vibrator approximation which gives too high energy for the 4^+ states in the tin isotopes."

W. Andrejtscheff, L.K. Kostov, J. Eberth, J. Busch, M. Senba, Z.Z. Ding ***(Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria; Institut für Kernphysik der Universität zu Köln, Germany; Department of Physics and Astronomy, Rutgers University, New Brunswick, New Jersey, USA)***, **Transition probabilities and hole-core coupled configurations in 107In, Z.Phys. A328, 23-29 (1987):**
"In the nucleus 111In, a $21/2^+$ isomer was found (Hesselink, Bron, Van der Kam, **Paar,** Van Poelgeest, Zephat, **1978)** with an E2 transition of a strength of 1.1 Wu to a $17/2^+$ level. These

$21/2^+$ and $17/2^+$ levels were interpreted as arising from a π g9/2 hole coupled to maximum angular momentum to the 6_1^+ and 4_1^+ states of the 112Sn-core, respectively. In this case of coupling, the transition rate B (E2, $21/2^+ \rightarrow 17/2^+$) should be equal (Hesselink, Bron, Van der Kam, **Paar,** Van Poelgeest, Zephat, **1978)** to the core value B (E2, $6^+ \rightarrow 4^+$). For the latter, the experimental result amounts to 0.5 Wu (Endt, 1981). The observed agreement within a factor of 2 appears sufficient for a qualitative confirmation of the hole-core coupling interpretation.
The available data imply suggestions concerning the structure of some states in 107In. The $13/2^+$(1414.9 keV) and $11/2^+$ (1001.5 keV) levels lie in a similar way with respect to the 2^+ level in the core nucleus 110Sn (1206.4 keV) as in other odd-A neighbors: 1428.3 keV ($13/2^+$) and 1026.4 keV ($11/2^+$) in 109In relative to 1211.7 keV (2^+) in 110Sn as well as 1401.2 keV ($13/2^+$) and 1152.8 keV ($11/2^+$) relative to 1257.2 keV (2^+) in 112Sn. From this systematics and the discussion in (Hesselink, Bron, Van der Kam, **Paar,** Van Poelgeest, Zephat, **1978)** it may be concluded that the $13/2^+$ state in 107In arises from a coupling of a πg9/2 hole to the 2^+ core state. Consequently, the $17/2^+$ state would be of the type $\pi g_{9/2}^{-1} \times 4^+$. In the hole-core coupling picture the $17/2^+ \rightarrow 13/2^+$ E2 transition strength is closely related to the transition between the underlying core states. As outlined below, we additionally expect appreciable admixtures of the configuration $\pi g_{9/2}^{-1} \times 6^+$ in the $13/2^+$ state. In case of such couplings, the transition strength in the odd-A nucleus (107In) would be related to that in the core nucleus (108Sn) in the following way (Bohr, Mottelson, 1969): $B(E2{,}17/2^+ \rightarrow 13/2^+,\ 107\text{In}) = 0.68B(E2, 6^+ \rightarrow 4^+,\ 108\text{Sn})$. In the case of complete alignment in 111In $\left(\pi g_{9/2}^{-1} \times 6^+\ (J^\pi = 21/2^+\right)$ and $\pi g_{9/2}^{-1} \times 4^+$ (J^π=$17/2^+$)) the corresponding $B(E2)$ should be equal: $B(E2,\ 21/2^+ \rightarrow 17/2^+,\ 111\text{In}) =$ $B(E2, 6^+ \rightarrow 4^+, 110\text{Sn})$. The corresponding experimental values reveal an agreement within a factor of two (however, in the opposite direction, cf. Table 1 and the relevant discussion in (Hesselink, Bron, Van der Kam, **Paar,** Van Poelgeest, Zephat, **1978).** In 108,110Sn, the experimental transition strengths $B(E2, 4^+ \rightarrow 2^+ \rightarrow 0^+)$ are unfortunately not known but in the heavier even Sn isotopes these quantities are usually by one order of magnitude higher than the $B(E2, 6^+ \rightarrow 4^+)$ values. From the above considerations, we conclude that the structure of the $17/2^+$ state in 107In is probably determined by a mixture of the $\pi g_{9/2}^{-1} \times 6^+$ and $\pi g_{9/2}^{-1} \times 4^+$ configurations. In the $13/2^+$ state, the $\pi g_{9/2}^{-1} \times 4^+$ and $\pi g_{9/2}^{-1} \times 2^+$ configurations appear to be mixed. Future calculations could reveal if the experimental level energies and transition strengths can be understood within a hole-core coupling model including configuration mixing. We note that the $17/2^+ \rightarrow 13/2^+$ B(E2) value (0.5 Wu) is even smaller than the one expected for pure couplings to the 6^+ and 4^+ core levels, respectively. Therefore, in the formation of the $17/2^+ \rightarrow$ $13/2^+$ E2 transition matrix element within such a model, cancellations between different terms should occur in order to reproduce this small $B(E2)$ value."

T. Ishii, A. Makishima, M. Nakajima, M. Ogawa, M. Ishii, Y. Saito, S. Garnsomsart
(Department of Physics, Japan Atomic Energty Research Institute, Tokai-mura, Ibaraki-ken, Japan; National Defense Medical College, Tokorozawa, Saitama-ken, Japan; Department of

***Energy Sciences, Tokyo Institute of Technology, Midori-ku, Yokohama, Japan; Burapha University, Chonburi, Thailand)*, In-beam study of 105In and 103In, Z.Phys. A343, 261-266 (1992):**

"As shown in Fig. 2a and b, the positive parity branch of the level scheme of 105In bears a resemblance to the level scheme of 106Sn. A hore-core coupling model gives a description of an aspect of odd In isotopes (Kikuchi et al., 1986; Andrejtscheff et al., 1987; Poelgeest et al., 1979; Hesselink, Bron, Van der Kam, **Paar,** Van Poelgeest, Zephat, **1978)**. For example, the $11/2^+$ and $13/2^+$ states may be taken as the members of the multiplet comprising the proton hole $\pi g_{9/2}^{-1}$ and the 2^+ state of the core 106Sn. On the other hand, the ground state has the configuration $\pi g_{9/2}^{-1} \otimes \{0^+ \text{ of } 106\text{Sn}\}$. As a result, the $11/2^+$ state de-excites to the ground state by $E2$ transition of the core from the 2^+ to the 0^+ state.

The mixing ratio δ can be determined from the linear polarization and the coefficient A_2 by the procedure given in Fig. 6 (Mateosian et al., 1974; Green et al., 1972): $\delta = 0.5 \pm 0.1$. It should be noted that this value is close to those for similar transitions in 107,109,111In (Andersson et al. 1981; Poelgeest et al., 1979; Hesselink, Bron, Van der Kam, **Paar,** VanPoelgeest, Zephat, **1978)**. Thus $F(E2)/F(M1)$ is about 200. The present result suggests that the ground state of 105In has a rather pure configuration: $\pi g_{9/2}^{-1} \otimes \{0^+\}$ with an admixture of about 10 % of $\pi g_{9/2}^{-1} \otimes \{2^+\}$."

N. Goutev, M.S. Yavahchova, D. Tonev, G. de Angelis, P. Petkov, R.K. Bhowmik, R.P. Singh, S. Muralithar, N. Madshavan, R. Kumar, M. Kumar Raju, J. Kaur, G. Mahanto, A. Singh, N. Kaur, R. Garg, A. Sukla, T.K. Marinov, S. Brant *(Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria; INFN, Laboratori Nazionali di Legnaro, Italy; Inter-University Accelerator Center, New Delhi, India; Nuclear Physics Department, Andhra University, Visakhapatnam, India; Department of Physics, Punjab University, Chandigarh, India; Department of Physics and Astrophysics, Delhi University, New Delhi, India; Department of Physics, Banaras Hindu University, Varanasi, India; Faculty of Natural Sciences, Shumen University, Bulgaria; Department of Physics, Zagreb University, Croatia)*, Level scheme investigation of 102Rh, J.Phys.Conf.Ser. 366, 012021 (2012):

"The difference spectrum in Fig. 2 reflects the linear polarization of the transitions observed. The negative lines correspond to transitions of predominantly magnetic character while the positive lines correspond to transitions of predominantly electric character. For example, the negative lines that appear around 305.8 and 363.0 keV are due to $M1/E2$ transitions in 102Rh (Gizon, Gizon, Timar, Cata-Danil, Nyako, Zolnai, Boston, Joss, Paul, Semple, O′Brien, Parry, Bucurescu, Brant, **Paar, 1999)**. According to DCO ratios measurements (Gizon, Gizon, Timar, Cata-Danil, Nyako, Zolnai, Boston, Joss, Paul, Semple, O′Brien, Parry, Bucurescu, Brant, **Paar, 1999),** the lines at 283.3, 334.4, 352.1 and 385.4 keV are due to transitions of dipolar character in 102Rh. The positive sign of these lines proves that the corresponding transitions are of predominantly electric ($E1/M2$) character. Based on the known transitions of the level-scheme published in (Gizon, Gizon, Timar, Cata-Danil, Nyako, Zolnai, Boston, Joss, Paul, Semple, O′Brien, Parry, Bucurescu, Brant, **Paar, 1999)** we have succeeded to extend the level scheme with a new $\Delta I = 1$ band with a negative parity. The comparison of the excitation energies of the analogous states of the two sister bands in 102Rh together with their electromagnetic properties will give an answer whether the chiral phenomenon is present in this nucleus."

D. Howe, S. Shastry, P. Sen, H. Bakhru ***(State University of Ney York, Albany, New York, USA)*****, Directional correlation measurements in 69Ga, Z.Phys. A276, 341-345 (1076):**
In view of several theoretical calculations employing different models (Kisslinger, Kumar, 1967; Paradellis, Hontzeas, 1971; Almar et al., 1972; **Paar, 1972)** and lack of the unique experimental information on spins, a direct measurement of the spins of various states in 69Ga using gamma-gamma directional correlation experiments has been presented here."

P. Schuck ***(Physik Department, Technische Universität München, Garching, Germany)*****, Mode coupling theory for the description of two particle-two hole states of 208Pb, Z.Phys. A279, 31-40 (1976):**
"As we see by inspection of Tables 2 to 9, most of the calculated low-lying 2p-2h states fall into two categories: they are either almost pure pairing vibrations, or they belong to the $3^- \times 3^-$ quadruplet. It should be noticed that for instance the 4^+ state at 5.326 MeV and the 6^+ state at 5.418 MeV are almost pure two octupole phonon states which to our knowledge are not found experimentally as yet; but also the first 2^+ at 5.306 MeV and the second 0^+ at 5.424 MeV have large $3^- \times 3^-$ components so that these four states are representing the $3^- \times 3^-$ quadruplet which thus shows only very little anharmonicity. The second and third 2^+ states are almost pure quadrupole pairing vibrations, but neither of the first three 2^+ states has quite the structure reported by Broglia, **Paar,** Bes, **1971**. "

W. Urban, J.L. Durell, A.G. Smith, W.R. Philips, M.A. Jones, B.J. Varley, T. Rzaca-Urban, I. Ahmad, L.R. Morss, M. Bentaleb, N. Schulz ***(Institut of Experimental Physics, Warsaw University, Warszawa, Poland; Department of Physics and Astronomy, University of Manchester, Manchester, United Kingdom; Argonne National Laboratory, Argonne, USA; Centre de Recherches Nucleaires, Universite Louis Pasteur, Strasbourg, France)*****, Medium-spin structure of 96,97Sr and 98,99Zr nuclei and the onset of deformation in the $A \sim 100$ region, Nucl.Phys. A689, 605-630 (2001):**
"To account for the sudden shape transition between the neutron number $N = 58$ and $N = 60$, the shape coexistence idea (Sheline et al., 1972) has been recalled (Lhersonneau et al., 1994; Wohn et al., 1990; Büscher et al., 1990; Mach et al., 1991). The proposed deformed minima in spherical nuclei with $N < 60$ were searched for and a strong deformation of $0.35 < \beta_2 < 0.40$ has been reported in the excited states of $N = 58$ and $N = 59$ strontium and zirconium isotopes

(Lhersonneau et al., 1994; Büscher et al., 1990; Mach et al., 1991; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)**, supporting "two minima" explanation of the deformation onset in the $\boldsymbol{A \sim 100}$ region. The difficulty in getting reliable evidence for shape coexistence in the *N* = 59 nuclei originated from the experimental limitations. The 97Sr and 99Zr nuclei studied in (Lhersonneau et al., 1994; Büscher et al., 1990; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** were produced in β^- decay of spontaneous fission products. Deformed excited bands in the nuclei discussed above were searched for in a recent measurement of prompt γ rays following spontaneous fission of 252Cf (Hamilton et al., 1995). This new study did not confirm the strongly deformed bands based on the 0_3^+ levels in the 96Sr and 98Zr nuclei, suggested in Refs. (Lhersonneau et al., 1994; Büscher et al., 1990; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)**. Instead, quasivibrational cascades were reported, based on the 0_2^+ in 98Zr and starting from the 4_1^+ in 96Sr. The study (Hamilton et al., 1995) extended the strongly coupled band on top of the 585 keV level in the *N* = 59 nucleus 97Sr, proposed in (Lhersonneau et al., 1994; Büscher et al., 1990; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)**. These new data suggested that there is a sudden appearance of strongly deformed structures at *N* = 59 and again raised the question about their origin. Two M1/E2 transitions of 102 keV and 135 keV, and an E2 transition of 237 keV have been identified as belonging to this band. For this band a deformation of $\beta_2 \geq 0.23$ (Lhersonneau et al., 1988; Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** or $\beta_2 = 0.36(4)$ (Büscher et al., 1990) has been reported. The band on top of the 584.9 keV level in 97Sr proposed in Ref. (Lhersonneau, Pfeiffer, Kratz, Ohm, Sistemich, Brant, **Paar, 1990)** has been extended to higher spins. Surprisingly, apart from the 102.0 keV and 135.4 keV transitions there is no other $\Delta I = 1$, M1+ E2 transition in the band."

M.G. Vassanji, C.T. Li, A. Klein, A.K. Chattopadhyay (Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania, USA), An equations-of-motion method for anharmonic vibrations: application to a degenerate shell model, Nucl.Phys. A283, 423-433 (1977):
"A large proportion of calculations dealing with anharmonicities (Beliaev, Zelevinsky, 1962; Marumori et al., 1964; Marshalek, 1972,1974,1976; Almoney, Borse 1971; Sørensen, 1970) have used some kind of a boson-expansion technique, in which a many-fermion Hilbert space is mapped into a boson space, and the Hamiltonian re-expressed in terms of boson (phonon) operators. Uncertainties in this method arise from the truncation of anharmonic terms in the resulting boson Hamiltonian, and the restriction to a collective branch only. In the particle-vibration model (Bohr, Mottelson, 1976), the anharmonicities can be calculated perturbatively as higher-order effects in the coupling between the particle and the collective degrees of freedom. Leading order contributions to the static quadrupole moments Q_2 of some doubly even nuclei have been calculated in this model (Broglia, Liotta, **Paar, 1972;** Reinhardt, 1976)."

W.K. Koo, L.J. Tassie *(Department of Theoretical Physics, Research School of Physical Sciences, Australian National University, Canberra, Australia)*, Electronuclear energy weighted sum rules and the quadrupole moments of excited states of nuclei, Nucl.Phys. A315, 21-44 (1979):
"The effect of neutrons on $Q(2_1^+)$ is reflected in our calculation which shows a monotonic increase of $|Q(2_1^+)|$ as the neutron number is increased from 52, which is near a major closed shell, to 58. Other model calculations (Bindal et al., 1974; **Paar, 1974)**, employing an essentially particle-core coupling model have not only predicted a significant change of $Q(2_1^+)$ as one goes from 94Mo to 100Mo but have also given results in good agreement with our calculation. Also the value of Q(2_2^+) (94Mo) calculated by **Paar (Paar, 1974)** is 29e$\cdot$fm^2 which agrees very well with our calculated value 27$\pm$6 $e\cdot$fm^2. For 204,206Pb nuclei the comparison of our calculation and experimental measurements (Joye et al., 1977; Olin et al., 1974) and other theoretical calculations (Broglia, Liotta, **Paar, 1972;** Hadermann, 1968; Sørensen, 1970) is summarized in table 8."

D.R. Bes, G.G. Dussel, R.P.J. Perazzo, H.M. Sofia (Comision Nacional de Energia Atomica, Departamento de Fisica, Buenos Aires, Argentina), The renormalization of single-particle states in nuclear field theory, Nucl.Phys. A293, 350-364 (1977):
"Ward or Ward-Pitaerskii identity (Nozieres, 1964) states that the electron self-energy and vertex corrections mutually cancel in the limit of low momentum transfer. The application of this identity to the nuclear spectrum has been recently discussed by **Paar (Paar, 1976)**."

F. Iachello *(Center for Theoretical Physics, Sloane Physics Laboratory, Yale University, New Haven, Connecticut, USA)*, Superconductivity in finite Fermi systems, Nucl.Phys. A570, 145c-160c (1994):
"The interacting boson model with broken pairs has been extensively investigated by many authors (Gelberg, Zemel, 1980; Morison et al., 1981; Yoshida et al., 1982; Zemel, Dobes, 1983; Kuyucak et al., 1984; Alonso et al., 1986; Chuu et al., 1988,1989). Its Hamiltonian is $H = H_B + H_F + V_{BF} + W$, where H_B describes the bosons (S-D pairs), H_F the fermions, V_{BF} the boson-fermion interaction and W the pair breaking interaction. A computer program has been written recently by Vretenar, **Paar,** Bonsignori and Savoia (Vretenar, **Paar,** Bonsignori, Savoia, **1990)**. This program diagonalizes the Hamiltonian H up to two broken pairs and is particularly important for physics of nuclei at high-angular-momentum as shown recently by Lister, Chowdhury and Vretenar (Lister, Chowdhury, Vretenar, 1993)."

Y.X. Luo, J.O. Rasmussen, J.H. Hamilton, A.V. Ramayya, C. Goodin, S.J. Zhu, J.K. Hwang, Ke Li, D. Fong, I. Stefanescu, I.Y. Lee, G.M. Ter-Akopian, A.V. Daniel, M.A.

Stoyer, R. Donangelo, W.C. Ma, J.D. Cole ***(Physics Department, Vanderbilt University, Nashville, Tennessee, USA; Lawrence Berkeley National Laboratory, Berkeley, California, USA; Physics Department, Tsinghua University, Beijing, China; Department of Chemistry and Biochemistry, University of Maryland, Maryland, USA; Flerov Laboratory for Nuclear Reactions, JINR, Dubna Russia; Joint Institute for Heavy Ion Research, Oak Ridge, Tennessee, USA; Lawrence Livermore National Laboratory, Livermore, California, USA; Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; Mississippi State University, Mississippi State, USA; Idaho National Laboratory, Idaho Falls, Idaho, USA)*****, The first observation of a deformed $K^{\pi}=1^{+}$ ground-state band in 100Nb and the high–spin level scheme of its 4*n* fission partner 148La, Nucl.Phys. A825, 1-15 (2019):**

"The nuclear structure of neutron-rich nuclei with $Z \sim 40$ and $A \sim 100$ has long been of great interest for the sudden shape transitions, shape coexistence, shape mixing and reinforcing shell structure at $Z =$ 40 and $N = 56$ (Skalski et al., 1997; Hamilton et al., 1995; Lhersonneau et al., 1997; Hotchkis et al., 1991; Lhersonneau, Suhonen, Dendooven, Honkanen, Huhta, Jones, Julin, Juutinan, Oinonen, Pentilla, Persson, Perajarvi, Savelius, Wang, Aysto, Brant, **Paar,** Vretenar, **1998)**. Spherical character was observed for the ground and low-lying states with $N \leq 59$ in the Sr (Z = 38), Y (Z = 40) and Zr (Z = 40) neutron-rich isotopes in this region , e.g. (Mach, Gill, 1987; Skalski et al., 1997; Hamilton et al., 1995; Hotchkis et al., 1991; Lhersonneau et al., 1997; Lhersonneau, Suhonen, Dendooven, Honkanen, Huhta, Jones, Julin, Juutinan, Oinonen, Pentilla, Persson, Perajarvi, Savelius, Wang, Aysto, Brant, **Paar,** Vretenar, **1998**). The onset of deformation was due to the rapid lowering of potential energy with increasing neutron number, e.g. (Lhersonneau et al., 1994), which in turn is caused by intruder orbitals from adjacent major shells.The ground and low-lying states in the region were reproduced by the interacting boson model and the extensions of the interacting boson fermion model (IBFM) and interacting boson fermion fermion model (IBFFM) (Lhersonneau et al., 1990; Brant, **Paar,** Lhersonneau, Schult, Seyfarth, Systemich, **1989;** Brant, **Paar,** Wolf, **1998)**."

P.D. Cottle, M.Gai, J.F. Ennis, J.F. Shriner, D.A. Bromley, C.W. Beausang, L. Hildingsson, W.F. Piel, D.B. Fossan, J.W. Olness, E.K. Warburton ***(A.W. Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut, USA; Department of Physics, State University of New York, Stony Brook, New York, USA; Department of Physics, Brookhaven National Laboratory; Upton, New York, USA)*****, Level spectrum of 219Ra and weak coupling in the light actinide region, Phys.Rev. C36, 2286-2296 (1987):**

"In a general weak coupling model, the coupling of a state of the even-even core to the unpaired nucleon generates a multiplet of states having angular momenta $|j_{s..p.} - J_c| \leq J \leq j_{s.p.} + J_c$, where $j_{s.p.}$ and J_c are the angular momenta of the single particle and core states, respectively. Of these states, only the one or two states of highest angular momentum would be strongly populated in the heavy ion fusion-evaporation reactions which have been used to study these isotopes. If the multiplet member with angular momentum $Js.p._{c_{max}}$ has a lower excitation energy than the member having $J = J_{max}$, only the state having $J = J_{max}$ will usually be observed. Both $J = J_{max}$ and $J = J_{max}$ states may be seen if the reverse is true. We find one exception to the weak coupling pattern among the spectra displayed in Fig. 9. The band head of the negative parity band in 219Ra is tentatively assigned to have $J^{\pi} = (11/2^{-})$; the unique parity orbital in the N >126 neutron shell, however, is the $j15/2$ one. Clearly, this state has an origin different from the classical weak coupling of a $j^{\pi} = 15/2^{-}$ particle to the 0^{+} ground state of the even-even core. Such configuration of levels, called anomalous coupling by several authors (Ring, Schuck, 1980), signals that additional strength in the core-particle interaction will invalidate the weak coupling picture. The two recently studied nuclei in which anomalous coupling is observed (Tokunaga, Seyfarth, Schult, Brant, **Paar,** Vretenar, Börner, Barreau, Faust, Hofmeyr, Schreckenbach, Meyer, **1984;** DeGelder et al., 1983) are 75Se and 103Tc. Many treatments of particle-core coupling take pairing into account. One such treatment is that of Hagemann and Dönau (1975) which includes the pairing factor $\left(u_j^2 - v_j^2\right)$ in the coupling strength. Theoretical investigations of anomalous coupling behavior usually invoke Pauli effects as well (see, e.g., refs. (Tokunaga, Seyfarth, Schult, Brant, **Paar,** Vretenar, Börner, Barreau, Faust, Hofmeyr, Schreckenbach, Meyer, **1984;** DeGelder et al., 1983)."

J. Kownacki, M. Lipoglavšek, L.O. Norlin, J. Nyberg, D. Seweryniak, J. Cederkäll, M. Palacz, J. Persson, A. Atac, B. Cederwall, C. Fahlander, H. Grawe, A. Johnson, A. Kerek, W. Klamra, M. Karny, F. Liden, A. Likar, R. Schubart, R. Wyss, E. Adamides, G. de Angelis, P. Bednarczyk, Z. Dombradi, D. Foltescu, M. Gorska, E. Ideguchi, D. Jerrestam, R. Julin, S. Juutinen, S. Mitarai, E. Mäkelä, G. Perez, M. Piiparinen, M. de Poli, H.A. Roth, T. Shizuma, Ö. Skeppstedt, G. Sletten, S. Törmänen, T. Vass, A. Virtanen ***(Heavy Ion Laboratory, University of Warsaw, Warsawn Poland; Svedberg Laboratory, Uppsala University, Uppsala, Sweden; J. Stefan Institute, Ljubljana, Slovenia; Physics Department Frescati, Royal Institute of Technology, Stockholm, Sweden; Department of Radiation Sciences, Uppsala University, Sweden; Institute for Nuclear Studies, Swierk, Poland; Institute of Experimental Physics, University of Warsaw, Poland; Gesellschaft für Schwerionenforschung, Darmstadt, Germany; National Centre for Scientific Research, Ag. Paraskevi, Attiki, Greece; INFN. Laboratori Nazionali di Legnaro, Padova, Italy; Institute of Nuclear Physics, Bronowice, Krakow, Poland; Institute of Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary; Chalmers University of Technology, Gothenburg, Sweden; Department of Physics, Faculty of Science, Kyushu University, Fukuoka, Japan; Department of Neutron Research, Uppsala University, Nyköping, Sweden; Department of Physics, University of Jyväskylä, Finland; Niels Bohr Institute, University of Copenhagen, Denmark)*****, High-spin studies of the neutron deficient nuclei 103In, 105In, 107In, and 109In, Nucl.Phys. A627, 239-258 (1997):**

"Nuclei close to 100Sn are of great interest for extending our knowledge on the nuclear shell model close to the proton drip line. The possibility of gathering information on the entire range of nuclei between the doubly magic 100Sn and 132Sn is of great significance. Such studies provide a deeper insight into the role of residual interaction. The odd-A indium isotopes from 103In to 117In have been studied by mean of the interacting–boson-fermiom-fermion model (Dombradi, Sohler, Brant, **Paar, 1995)**. It explains fairly well the excitation energies of the yrast

$11/2^+$ and $13/2^+$ states, suggesting a qualitative interpretation of the lowest excited states as a coupling between the g9/2 proton hole and vibrational core excitations. The correspondence between the observed positive parity states and the core Sn isotopes is shown in Fig. 9. The negative parity states are not shown, since the IBF model is only able to reproduce the negative parity states on the configurations involving the p1/2 proton hole. As pointed above, the observed negative parity states are based on the configurations involving an h11/2 neutron. This is supported by the fact that the high spin negative parity states do not decay to the low spin negative parity states predicted by the IBF model (Dombradi, Sohler, Brant, **Paar, 1995)**."

G. Wenes, K. Heyde, M. Waroquier, P. Van Isacker *(Institute for Nuclear Physics, Gent, Belgium)*, Projected quasiparticle calculations in the heavy N = 82 isotones, Phys.Rev. C26, 1692-1700 (1982):
"Effective charges (electric and magnetic) have been determined by a fit to all known electromagnetic rates. Moreover, we found it necessary to include in the M1 operator a tensor term $g_p\left(Y_2 \times s\right)^{(1)}$ (Bohr, Mottelson, 1969; **Paar,** Brant, **1978),** with $g_p = 0.35$ nm."

B. Caurier, J.M.G. Gomez, V.R. Manfredi, L. Salasnich *(Universite Louis Pasteur, Strasbourg-Cedex, France; Facultad de Ciencias Fisicas, Universidad Complutense de Madrid, Spain; Dipartimento di Fisica G. Galilei dell'Universita di Padova, Italy; Interdisciplinary Laboratory, International School for Advanced Studies, Trieste, Italy)*, Quantum chaos in *A* = 46-50 atomic nuclei, Phys.Lett. B365, 7-11 (1996):
"The statistical analyses of shell-model energy spectra and wave functions have been mainly concentrated on the *sd* shell region, and a very chaotic behaviour has been found for these nuclei (Brody et al., 1981; Dias et al., 1989; **Paar,** Vorkapić, Heyde, van Hees, Wolters, **1991;** Osmand, Broglia, 1992; Zelevinsky et al., 1995)."

A. Klein, E.R. Marshalek (*University of Pennsylvania, USA; University of Notre Dame, USA*), Rev. Mod. Phys. 63, 375-558 (1991):
"We start with a recent algebraic contribution by (Kyrchev, **Paar**, **1986**; Kyrchev, **Paar**, **1987**; Kyrchev, **Paar**, **1988**). The subalgebra generated by the commutators involving the collective operators is forced to close. The nontrivial step comes next in forcing the Q and Q^+ and their mutual commutators to satisfy appropriate Jacobi identities. This leads to constraints on the RPA solutions. In any event, the method of Kyrchev and **Paar** is weakly microscopic.
In the following we shall rely heavily on review papers of the group that has done the most extensive work in the area: Allaart, Bonsignori, Savoia and **Paar** (Allaart, Bonsignori, Savoia, **Paar**, 1986; Allaart, Savoia, Bonsignori, **Paar**, 1986). We show in Fig. 18 taken from Allaart, Bonsignori, Savoia and **Paar (1986)** the transition charge density for a neutron boson and a proton boson. The same equation had been derived within the framework of nuclear field theory (Broglia, Liotta, **Paar**, **1972)**. In the work of Broglia, Liotta and **Paar** it was assumed that this

sum is saturated by the contribution for the first excited state, which can be obtained empirically. The result was that the calculations of Broglia, Liotta and **Paar** agreed much better with experiment."

G. Lhersonneau, B. Pfeiffer, J. Alstad, P. Dendooven, K. Eberhardt, S. Hankonen, I. Klöckl, K.L. Kratz, A. Nähler, R. Malmbeck, J.P. Omtvedt, H. Penttilä, S. Schroedder, G. Skarnemark, N. Traitmann, J. Aysto (*Department of Physics, University of Jyväskylä, Finland; Institut für Kernchemie; Universität Mainz, Germany; Department of Chemistry, University of Oslo, Oslo, Norway; Department of Nuclear Chemistry, Chalmers University of Technology, Göteborg, Sweden*), Shape coexistence near the double-midshell nucleus ^{111}Rh, Eur. Phys. J. A1, 285 (1998):

"According to the description by **Paar (Paar, 1973)**, the Rh ground states have a structure with a large $(\pi g_{9/2})^3$ component. Therefore, their β-feeding requires some amplitude of a three-quasiparticle $(\pi g_{9/2})^2_{2^+}\ \nu g_{7/2}$ configuration in the ground state of their Ru parents."

O. Hashimoto, Y. Shida, G.C. Madueme, N. Yoshikawa, M. Sakai, S. Ohya *(Institute of Nuclear Study, University of Tokyo, Tanashi-shi Tokyo, Japan; Department of Physics, Faculty of Science, Niigata University, Niigata, Japan)*, Study of high-spin states in odd Sn isotopes, Nucl.Phys. A318, 145-161 (1979):

"High-spin states in odd nuclei have been extensively studied in the $Z = 50$ region, for Pd (Kimra et al., 1976; Kim et al., 1975; Rickey et al., 1973), Cd (Hagemann et al., 1974; Meyer et al., 1975; Ohya et al., 1977; Stromswold et al., 1978) and Te (Kerek et al., 1972; Hagemann et al., 1977). Band structures above single particle states have been widely observed in these nuclei. The structures were characterized by the decoupling of a last odd neutron as in the other regions (La etc.) (Stephens, 1975). They were compared with theoretical approaches on the basis of a spherical core (Sen, 1975; Dönau, Hagemann, 1976; Alaga, **Paar, 1975;** Hagemann, Dönau, 1975), where a particle was assumed to weakly couple to the vibrator of the core. Such approaches have reproduced rather well the level structures, while Pd isotopes were also interpreted in the framework of the rotational model (Rickey, Simms, 1973). In Fig. 11, these ratios are plotted as a function of neutron number for Sn isotopes together with Pd, Cd, and Te. There are several ways to understand the band structure of odd isotopes in near-spherical regions. In the particle-core coupling model, it is well known that the band structures are determined by the sign of qQ, where q and Q are the quadrupole moments of a quasiparticle and a core (Dönau, Hagemann, 1976; Alaga, **Paar, 1975)**. When the sign of qQ is positive, we should observe a $\Delta I = 2$ decoupled band structure. Since in this region the sign of qQ is almost all positive, it is quite natural that we see such band structures."

J. Vervier (*Institut de Physique Nucleaire, Universite Catholique de Louvain, Belgium*), Boson-Fermion Symmetries and Supersymmetries in Nuclear Physics, Riv. Nuovo Cim. 10,

1-102 (1987):
“The concepts and techniques of the boson-fermion symmetries and supersymmetries can be extended to include odd-odd nuclei, ass first suggested by Bars (Bars, 1984), and recently shown by **Paar** et al. (Hübsch, **Paar,** Vretenar, **1985;** Balantekin, Hübsch, **Paar, 1986;** Balantekin, **Paar, 1986)** and by (Van Isacker et al., 1985)**.** Conditions for the applicability of the $O_6 \times 1/2{,}3/2{,}5/2$ symmetry, related to the occupancies of j = 1/2 3/2, 5/2 s.p. orbits, have been deduced, which are best fulfilled for the nucleus 195Pt (Bijker, 1985). A similar work has been performed recently (Scholten, Brant, **Paar, 1986**), in order to study the foundations of the $O_6 \times 3/2 \supset Spin_6$symmetry. The main conclusion is that a correspondence can indeed be found between the $Spin_6$ Hamiltonian and the general IBFM Hamiltonian."

D. Vretenar, G. Bonsignori, M. Savoia ***(Physics Department, University of Zagreb, Zagreb, Croatia; Istituto Nazionale di Fisica Nucleare, Sezione di Bologna, Bologna, Italy; Physics Department, University of Bologna, Bologna, Italy)*****, One and three fermion states in the interacting boson fermion model: high-spin states in 191,193Hg, Z.Phys. A351, 189-294 (1995):**
"To extend the IBM to the physics of high-spin states one has to include, in addition to bosons, selective noncollective fermion pairs that occupy part of the original shell model space. Several extensions have been investigated for even-even nucleus that include two-fermion states (one broken pair) in addition to bosons (Morrison et al., 1981; Kuyucak et al., 1984; Faessler et al., 1985; Yoshida et al., 1982; Yoshida, Arima, 1985; Alonso et al., 1986; Chuu et al., 1988,1989; Hsieh et al., 1992). In (Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Iachello, Vretenar, 1991; Vretenar, **Paar,** Bonsignori, Savoia, **1991;** Chowdhury et al., 1991; Vretenar et al., 1993) we have further extended the IBM to include two- and four-fermion noncollective states (one and two broken pairs) and applied the model in the description of high-spin states in the zirconium and mercury regions. Here we extend the interacting boson fermion model for odd nuclei to include one broken pair. The model Hamiltonian is identical to that of the corresponding even-even nucleus $H = H_B + H_F + V_{BF} + V_{mix}$. The fermion Hamiltonian H_F contains the single-fermion energies and fermion-fermion interactions where the matrix element V^J_{abcd} of a two-fermion interaction in the coupled basis is defined in (Vretenar, **Paar,** Bonsignori, Savoia, **1990**)."

V.K.B. Kota, U. Datta Pramanik ***(Physical Research Laboratory, Ahmedabad, India; Saha Institute of Nuclear Physics, Calcutta, India)*****, Strong coupled and doubly decoupled bands in the $SU^{BF}(3) \otimes U^F(2j+1)$ limit of interacting boson-fermion-fermion model, Z.Phys. A358, 25-31 (1997):**
"With a simple IBFFM Hamiltonian several numerical studies of odd-odd nuclei are undertaken recently (Casten et al., 1994; Garrett, Burke, Qu, **Paar,** Brant, **1994;** Bucurescu, Barneoud, Cata-Danil, von Egidy, Genevey, Gizon, Gizon, Liang, Paris, Weiss, Brant, **Paar,** Pezer, **1995)**. There are limited but significant applications of symmetry limits of IBFFM associated with the U (5) (Van Isacker et al., 1989; Hoyler et al., 1990; Algora et al., 1995) and O (6) (Van Isacker et al.,

1985; Jolie, Garrett, 1996) limits. Some formal aspects of the band structures associated with SU (3) even-even core coupled to configuration where both odd particles are in single j-orbits are being studied by **Paar** et al. (Brant, **Paar,** Sunko, Vretenar, **1988;** Vretenar, Brant, **Paar,** Sunko, **1990; Paar,** Sunko, Vretenar, **1987)**."

C. Baktash, J.X. Saladin, J.J. O'Brien, J.G. Alessi (Physics Department, Brookhaven National Laboratory, Upton, New York, USA; Physics Department, University of Pittsburgh, Pennsylvania, USA), Electromagnetic properties of the low-lying states in heavy $A \simeq 190$ **transitional nuclei, Phys.Rev. C22, 2383-2395 (1980):**

"The negative parity bands in these nuclei were initially explained in terms of a particle-rigid asymmetric rotor model (Meyer-ter-Vehn,1975). Inasmuch as the deduced core asymmetry agreed with the asymmetry of the neighboring even-even nuclei, the success of this model was interpreted as evidence in support of rigid triaxiality in this region. However, as **Paar** et al. **(Paar,** Vieu, Dionisio, **1977)** have shown, soft cores or even models within spherical representation have equal success in fitting not only the negative parity but also the positive parity bands in these nuclei."

D. Kusnezov, D. Mitchell ***(Ceneter for Theoretical Physics, Sloan Physics Laboratory, Yale University, New Haven, Connecticut, USA)*****, Universal predictions for statistical nuclear correlations, Phys.Rev. C54, 147-158 (1996):**

"The statistics of nuclear excitations has been explored from the shell model to collective models, with studies ranging from the relation of observed quantum fluctuations to those in random matrix models, to the connection with chaos using classical limits of the Hamiltonian (Bohigas, Weidenmüller, 1988; Horoi et al., 1995; Meredith et al., 1988; **Paar,** Vorkapić, **1988;** Drozdz etal., 1995; Shriner et al., 1991; Espino, Garrett, 1989).
IBM (Interacting boson model) provides a solvable theory with known spectral properties, which can be composed to those of the Gaussian orthogonal ensemble (GOE) throughout its parametric range. Certainly, a more realistic description of the spectrum would embody the same features. For example, when broken pair states are added to the IBM model space, the spectrum becomes more GOE, as the interactions in the Hamiltonian become more complicated (Iachello, Vretenar, 1991; **Paar** et al.**, 1990;** Wu et al., 1990; Alhassid, Vretenar, 1992)."

Y. Alhassid, D. Vretenar ***(Center for Theoretical Physics, Sloane, Physics Laboratory, Yale University, New Haven, Connecticut, USA; Physik Department, Technische Universität München, Garching, Germany)*****, Chaos in nuclei with broken pairs, Phys.Rev. C46, 1334-1338 (1992):**

"The interest in phenomenon known as quantum chaos led to the investigation of the fluctuation properties of experimental low-lying levels in nuclei (Abul-Magd, Weidenmüller, 1985; Von Egidy et al., 1988; Raman et al., 1991; Garrett et al., 1992). We have initiated (Alhassid et al., 1990,1991,1992) such an investigation for the low-lying states of nuclei by using the interacting boson model (IBM). Level fluctuations in the IBM were also studied near the U (3) and O (6) limits in Ref. **(Paar,** Vorkapić, **1988,1990)** and in the Casten triangle in Ref. (Mizusaki et al., 1991)**.** The IBM can be extended to high-spin physics by including noncollective fermion states through the breaking of the correlated S and D pairs. The model has been extended to one broken pair (Gelberg, Zemel, 1980; Morrison et al., 1981; Yoshida et al., 1982) (two-quasiparticle states) and two broken pairs (Vretenar, **Paar,** Bonsignori, Savoia, **1990, 1991;** Iachello, Vretenar, 1991; Chowdhury et al., 1991) (four-quasiparticle states)."

A.A. Alexandrov, M.P. Kudoyarov, I.K. Lemberg, A.A. Pasternak ***(A.F. Ioffe Physical Technical Institute, USSR Academy of Sciences, Leningrad, Russia)*****, Lifetimes and spin-parity assignments of excited states in 69Ge populated in the 64Zn (**$\alpha, n\gamma$**) reaction, Nucl.Phys. A321, 189-206 (1979):**

"The main purpose of the present study was the determination of lifetimes in 69Ge by use of DSA technique. The results are compared with calculations carried out in the framework of the Alaga model (**Paar,** Eberth, Eberth, **1976**). In ref. (**Paar,** Eberth, Eberth, **1976**) the electromagnetic transition probabilities obtained from the lifetime measurements have been discussed in the framework of the Alaga model. Negative parity states have been treated as arising from the coupling of three neutron holes in the (2p3/2, 1f5/2, 2p1/2) subshell to the collective core vibrations. Positive parity states have been interpreted in the same paper (**Paar,** Eberth, Eberth, **1976**) as arising from the coupling of the $(g9/2)^3$ cluster to the phonon spectrum. Two possible interpretations have been proposed for the nature of these levels based on a consideration of a "4h-1p" type neutron cluster or a "6h-3p"b type cluster. However, coupling one particle and three particles to core vibrations, respectively, have been accepted as a first approximation. Calculations involving three valence particles account better for the observed number of states.

The decoupled band in 69Ge based on the $9/2^+$ level, as supposed by us, is of interest in connection with the article by Alaga and **Paar** (Alaga, **Paar, 1976)**. They discuss the particle-anharmonic vibrator coupling model applied to states with unique parity (in the case of 69Ge such a state is g9/2). They state that the occurrence of normal bands ($J, J+1, J+2, ...$) or decoupled ones $(J, J+2, J+4, ...)$ is determined by the sign of the product of the particle quadrupole moment $Q(j)$ and the core quadrupole moment $Q(2^+)$. The decoupled band occurs if this sign is positive (Alaga, **Paar, 1976)**. Just such a situation is observed in 69Ge, where both $Q(j)$ and $Q(2^+)$ are negative. Our data may be considered as additional support to the conclusion (Alaga, **Paar, 1976)** that the occurrence of decoupled bands based on a state with unique parity can be understood without the hypothesis of rotational alignment. On the whole, comparison of the experimental results, both for states with positive and negative parity, with predicted B(E2) and B(M1) values shows that calculations performed in terms of the Alaga model reproduce the experimental data obtained fairly well, at least in cases where levels observed can be identified unambiguously."

E.R. Flynn, G.J. Igo, R.A. Broglia ***(Los Alamos Scientific Laboratory, University of California, Los Alamos, USA; University of California, Los Angeles, USA; Institute for Theoretical Physics, State University of New York, Stony Brook, New York, USA; Niels Bohr Institute , University of Copenhagen, Denmark)*****, Three-phonon monopole and quadrupole pairing vibrational states in 206Pb, Phys.Lett. B41, 397-402 (1972):**

"Levels with $J^{\pi} = 0^{+}$ and 2^{+} have been observed near an excitation energy of 6 MeV in 206Pb by means of the reaction 204Pb (t, p)206Pb. The striking feature of these levels is that their *Q*-values, intensities and angular distributions are very similar to the corresponding quantities associated with the ground state and the lowest 2^{+} level of 210Pb as excited in the 208Pb(t, p)210Pb reaction (Bjerregaard et al., 1968; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)** and with previously observed high-lying levels in the 206Pb(t, p)208Pb reaction (Bjerregaard et al., 1966; Igo et al., 1971). Presented here are the excitation energies, (t, p) *Q*-values and ratios of cross sections $R = \sigma({}^{A-2}\mathrm{Pb(t,\ p)}{}^{A}\mathrm{Pb}(J^{\pi})) / \sigma({}^{208}\mathrm{Pb(t,\ p)}{}^{210}\mathrm{Pb}(J^{\pi}))$ .Also given are the theoretical values for these quantities based on the harmonic pairing vibrational model. For 208Pb the results of ref. (Broglia, **Paar,** Bes, **1971)** are also quoted."

V.K.B. Kota, U. Datta Pramanik ***(Physical Research Laboratory, Ahmedabad, India; Saha Institute of Nuclear Physics, Calcutta, India)*****, SU (3) coupling schemes for odd-odd nuclei in the interacting boson-fermion-fermion model with both proton and neutron in natural parity orbits, Eur.Phys.J. A3, 243-253 (1998):**

"The interacting boson-fermion-fermion model (IBFFM) provides a framework for understanding the structure of quadrupole collective states in heavy odd-odd nuclei. In recent years, with simple IBFFM Hamiltonians several numerical studies of odd-odd nuclei are reported (Casten et al., 1994; Garrett, Burke, Qu, **Paar,** Brant, **1994;** Bucurescu, Barneond, Cata-Danil, von Egidy, Genevey, Gizon, Gizon, Liang, Paris, Weiss, Brant, **Paar,** Pezer, **1995);** Seweryniak et al., 1995; Petrache et al, 1996), and references there in) and there is also progress in developing dynamical symmetry limits of this model associated with the U(5) (Van Isacker, Jolie, 1989; Hoyler et al., 1990; Algora et al., 1995), O(6) (Van Isacker et al., 1985; Jollie, Garrett, 1996) and SU(3) limits of IBM (**Paar et al., 1987;** Brant, **Paar,** Sunko, Vretenar, 1988; Vretenar, Brant, **Paar,** Sunko, 1990; Kota et al.(1997); the SU(3) limit is appropriate for heavy deformed nuclei. Some formal aspects of the band structures associated with SU (3) even-even core coupled to configuration (i) where both odd particles are in single *j*-orbits are being studied by Paar et al. (**Paar et al., 1987;** Brant, **Paar,** Sunko, Vretenar, 1988; Vretenar, Brant, **Paar,** Sunko, 1990); Kota et al. 1997)."

J. Gröger, J. Jolie, R. Krücken, C.W. Beausang, M. Caprio, R.F. Casten, J. Cederkall, J.R. Cooper, F. Corminboeuf, L. Genilloud, G. Graw, C. Günther, M. de Huu, A.I. Levon, A. Metz, J.R. Novak, N. Warr, T. Wendel ***(Institut für Strahlen- und Kernphysik, Universität Bonn, Germany; Institut de Physique, Universite de Fribourg, Perolles, Fribourg,***

Switzerland; A.W. Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut, USA; Ludwig Maximilian Universität, Garching, Germany; Institut for Nuclear Research, Kiev, Ukraine)**, Nuclear structure of 196Au: More evidence for its supersymmetric description, Phys.Rev. C62, 064304 (2000):**

"In 1980 Iachello developed a supersymmetric theory in which bosonic and fermionic levels are combined in common multiplets (Iachello, 1980). This theory leads to relations between odd-*A* nuclei and their even-even core nuclei which were found to be realized in several pairs of nuclei, providing firm evidence for this aspect of nuclear supersymmetry. As a logical final step it was proposed that this theory could be extended to odd-odd nuclei (Van Isacker et al., 1985; Balantekin, **Paar, 1986).** A theoretical formalism of "quartet supersymmetry" was developed in which the properties of a quartet of nuclei with equal number of bosons plus fermions could be linked to supersymmetry. In addition to the negative-parity states built on the 2^- ground state of 196Au we observe two almost unconnected level schemes: (i) a structure of levels based on the 8.1 s 5^+ isomer of 196Au. (ii) A second structure based on the positive-parity high-spin states (6^+ to 8^+) from the radioactive decay of the 9.6 h 12^- isomer of 196Au (Chunmei et al., 1998). The most striking feature of the two positive-parity level schemes is the almost complete absence of transitions to the negative parity states and between these structures. The E1 transitions from the positive-parity to the negative-parity levels are strongly hindered as indicated by the decay of the 388.2 keV 3^+ level summarized in Table. The $B(E2, 3^+ \rightarrow 5^+) \geq 7$ W.u is comparable with $B(E2, 7^+ \rightarrow 5^+) = 34(4)$ W.u. (Chunmei et al., 1998), and thus the E1 transitions have hindrance factors of $\sim 10^6$. Similar hindrance factors have been found for the corresponding transitions in the neighboring nucleus 198Au (Petkov, Andrejtscheff, Robinson, Mayerhofer, von Egidy, Brant, **Paar,** Lopac, **1993)**. A qualitative explanation for the development of different approximately unconnected level structures is suggested by the calculations reported for 198Au (Petkov, Andrejtscheff, Robinson, Mayerhofer, von Egidi, Brant, **Paar,** Lopac, **1993;** Mayerhofer, von Egidy, Durner, Hlawatsch, Klora, Lindner, Brant, Seyfarth, **Paar,** Lopac, Kopecky, Warner, Chrien, Pospisil, **1989)**. Mayerhofer et al. (Mayerhofer, von Egidy, Durner, Hlaeatsch, Klora, Lindner, Brant, Seyfarth, **Paar,** Lopac, Kopecky, Warner, Chrien, Pospisil, **1989)** performed IBFM calculations with fermions occupying the proton d3/2, s1/2, h11/2 and neutron p1/2, f5/2, p3/2, i13/2 orbitals. The low-lying levels have wave functions consisting predominantly of the quasiparticle configurations $\pi d3/2\nu(p1/2, f5/2, p3/2)$ for negative parity, and $\pi h11/2\nu f5/2$ or π d3/2νi13/2 for positive parity, coupled to a few quadrupole phonons. In this approximation all E1 transitions are forbidden. Furthermore, one can perhaps expect that the transitions between the positive-parity levels with different 2*qp* configurations are highly hindered compared to those between levels with the same 2*qp* configuration, leading to a natural division of the low-lying positive-parity levels into two only weakly connected structures."

M. Kortelahti, M. Piiparinen, A. Pakkanen, T. Komppa, R. Komu (Department of Physics, University of Jyväskylä, Finland), Medium-spin states in the *N* = 82 nuclei 141Pr and 143Pm, Physica Scripta 24, 10-16 (1981):

"Prade et al. (Prade, Käubler, Hagemann, Jäger, Kirchbach, Schneider, Stary, Roller, **Paar,**

1980) have done shell-model calculations for positive-parity levels in 143Pm and cluster-vibration model calculations for both negative- and positive-parity states. They could quite well reproduce properties of many excited states of 143Pm. Prade et al. (Prade, Käubler, Hagemann, Jäger, Kirchbach, Schneider, Stary, Roller, **Paar, 1980)** have reported their extensive work of high-spin states in 143Pm populated in 141Pr(α, 2*n*) and 143Nd(*d*, 2*n*) reactions. Comparing to the 146Gd core 143Pm is a three-proton –hole nucleus. The $(d5/2g7/2)^{-3}$ seniority three excitations can make levels up to spin 17/2. Also, the second $T_{1/2} = 10.3\,\text{ns}\ 15/2^{+}$ isomer in 143Pm at 1898 keV most probably has a three-proton-hole character. The proton nature was also suggested by the *g*-factor measurement (Prade, Käubler, Hagemann, Jäger, Kirchbach, Schneider, Stary, Roller, **Paar, 1980).** The most natural configuration would be the maximum aligned $(d_{5/2}^{-2})4, g_{7/2}^{-1}$ state, probably mixed with other $(d5/2g7/2)^{-3}$ proton configurations."

P.E. Garrett, D.G. Burke ***(Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada; Department of Physics, University of Fribourg, Fribourg, Switzerland)*****, Study of 190Ir via single-proton and single-neutron transfer reactions, Nucl.Phys. A581, 267-293 (1995):**

"The investigations of 192,194Ir have already been published (Garrett, Burke, 1994; Garrett, Burke, Qu, **Paar,** Brant, **1994)**. These studies have demonstrated the complexity of the structure in these nuclei and have raised some interesting questions. Detailed comparisons of the results for 192Ir with both Nilsson model approach and the interacting boson-fermion-fermion model (IBFFM) revealed that the models could account for the structure of only some of these low-lying states. In 194Ir it was found (Garrett, Burke, Qu, **Paar,** Brant, **1994)** that the IBFFM description was better than for 192Ir, although there were some discrepancies. In making assignments with the Nilsson model, the similarities of population strengths to states in different nuclei were taken advantage of. For instance, many of the spins and parities of states in 192Ir are known (Garrett, Burke, 1994; Kern, Raemy, Beer, Dousse, Schwitz, ... Sushkov, Brant, **Paar, 1991** (32 authors)), and thus if states in 190Ir were found with similar patterns of energies and (d,t) strengths, it was considered likely that the levels had the same configurations as those in 192Ir. For example, the three lowest states in 192Ir were populated with *l* =1 and 3, *l* = 3 and *l* = 5 transitions in the (d,t) reaction, and have I^{π} values of 1^-, 4^- and 3^-, respectively. In 190Ir, the three lowest levels populated in the (d,t) reaction have *l* = 3, *l* = 1 and *l* = 5 transitions of similar strengths to those in 192Ir, and we considered likely to correspond to the same configurations. Of the three lowest levels in 190Ir, only the 1^- state was populated in the (3He, d) and (α, t) reactions. The cross section in the single-proton transfer to the 1^- state was small compared with the largest peaks in the spectrum, and it will be argued that a logical assignment is the $3/2^{+}[402]_{\pi} - 1/2^{-}[510]_{\nu}$ band head. This is consistent with the assignment (Garrett, Burke, 1994; Kern, Raemy, Beer, Dousse, Schwitz, ... Sushkov, Brant, **Paar, 1991** (32 authors)) of the same configuration for the corresponding 1^- state at 56.7 keV on 192Ir. The $11/2^-[505]$ proton orbital has been observed (Price et al., 1971; Andre et al., 1975) at low excitation energies in 189Ir and 191Ir and expected to be involved in low-lying configurations in 190Ir as well. In 192Ir, based on the analysis (Kern, Raemy, Beer, Dousse, Schwitz, ... Sushkov, Brant, **Paar,**

1991 (32 authors)) of magnetic moment , it was suggested that the ground state was a mixture of the $11/2^{-}[505]_{\pi} - 3/2^{-}[512]_{\nu}$ and $-3/2^{+}[402]_{\pi} + 11/2^{+}[615]_{\nu}$ configurations."

J. Jolie, P.E. Garrett ***(Department of Physik, University of Fribourg, Switzerland; Department of Physics and Astronomy, University of Kentucky, Lexington, Kentucky, USA)*****, Investigation of the low-lying negative-parity states in 194Ir using extended supersymmetry, Nucl.Phys. A596, 234-250 (1996):**

"The second extended supersymmetry is $U_{\nu}(6/12) \otimes U_{\pi}(6/12)$, which extends the proton fermion space from that given above to include the j_{π} = 1/2 and 5/2 orbitals. This symmetry has a very rich group structure and two dynamical symmetry limits have been constructed. The first was the O (6) limit (Balantekin, **Paar, 1986),** which was also used in the Au region. The second limit is the U (5) limit (Van Isacker, Jolie, 1989) and is appropriate for the *A* = 80 region (Van Isacker, Jolie, 1989; Hoyler et al., 1990; Algora et al., 1996). In Fig.1 the fitted levels of 192Os, 193Os and 193Ir are shown. In Fig. 3 the calculated spectrum and the known level scheme are compared: comparison between theoretical and experimental (Singh, 1989; Balodis et al., 1988; Kondurov et al., 1994) low-lying levels of negative parity in 194Ir. Besides the results of this work, predictions from the IBFFM model (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)** are also presented. The agreement between experiment and theory is very promising: not only is the ground state correct but also the number of states with a certain spin corresponds nicely to the experimental situation. The density of theoretical levels above 300 keV is greater than observed, but this can be related to the fact that these levels are not yet observed experimentally. The figure also shows the result (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)** of the semi-microscopic interacting boson-fermion-fermion model (IBFFM) for 194Ir.
Recently, 194Ir was studied using the 193Ir(d,p)194Ir reaction with 16 MeV deuteron beams (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)**, and complete angular distributions of the cross sections were obtained. In most cases the angular distributions could be described by the transfer of a single *l*-value. The data were most sensitive to *l* = 1 transfer. However, a few strong *l* = 3 transitions were observed, along with several states which required a mixture of *l* = 1 and *l* = 3 transitions to describe their angular distribution (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)**. In Table 1, the strengths predicted by the model and the experimental data (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)** are presented. As mentioned before, calculations with the IBFFM were performed for 194Ir in Ref. (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)**. Briefly, the calculations were made using a fermion space of p1/2, p3/2, f5/2, h9/2, and i13/2 for neutrons and s1/2, d3/2, d5/2, and h11/2 for the protons. The boson core was described in the O (6) limit, and the number of bosons was truncated to 4 so that the calculations would not be prohibitively long. Such a truncation, which has significant consequences (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994;** Garret, Burke, 1994) was not needed for the supersymmetric calculation. Most of the model parameters were determined by fits to the adjacent even and odd-A nuclei, taken from the IBFFM calculations (Kern, Raemy, Beer, ... Sushkov, Brant, **Paar, 1991** (33 authors)) for 192Ir, or adjusted to describe the lowest lying positive- and negative-parity states in 194Ir. The transfer operator used was ((Garrett, Burke, Tao Qu, **Paar,** Brant, **1994)**:

$T^{(j)} = v_j a_j^+ + \gamma_0 \sqrt{\frac{5}{4\pi}} \sqrt{\frac{1}{2j+1}} \sum_{j'} F_{jj'} (-1)^{j+j'} (s^+ (d a_{j'}^+)_j + (d^+ a_{j'}^+)_j s)$. Here, s^+ and d^+ denote s- and d-boson creation operators, and γ_0 is an additional parameter which had a value of γ_0 = -0.2. The calculated (d,p) strengths were renormalized, as outlined on Refs. (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994;** Garret, Burke, 1994). Detailed comparisons of the results of the calculations with the 193Ir(d,p)194Ir reaction were made in Ref. (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994;** Garret6, Burke, 1994), and it was found that the model could approximately reproduce the low-lying structure. In Fig. 3, the energy spectrum calculated in Ref. (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994;** Garret, Burke, 1994) with the IBFFM is also shown. As can be seen, there is a great similarity between the IBFFM spectrum and the one from the SUSY predictions. The SUSY spectrum, however, bears a closer resemblance to the experimental spectrum than does the one obtained from the IBFFM. In Fig. 4 the sums of the $l = 1$ and $l = 3$ strengths predicted (Garrett, Burke, Tao Qu, **Paar,** Brant, **1994;** Garret, Burke, 1994) in the IBFFM are also shown. The $l = 1$ strength in the IBFFM matches the experimental sum reasonably well up to ≃ 350 keV, under-predicting the data above this energy."

S.S. Bhattacharjee, R.P. Singh, S. Muralithar; I. Bala, R. Garg, S. Rajbanshi, D. Singh, A. Dhal, M. Kumar Raju, S. Saha, J. Sethi, R. Palit ***(Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi, India; Department of Physics, Dum Dum Motijheel College, Kalkata, India; Centre for Applied Physics, Central University of Jharkhand, Brambe, Ranchi, India; Variable Energy Cyclotron Centrem Kalkata, India; Nuclear Physics Department, Andhra University, Visakhapatnam, India; Tata Institute of Fundamental Research, Mumbai, India)*****, Shape evolution with increasing angular momentum in the 66Ga nucleus, Phys.Rev. C95, 054330 (2017):**

"In the case of $N \sim Z$ and $A \sim 70$ region, valence nucleons lie in *fpg* orbitals (Nichols et al., 2015; Danko, ..., **Paar,** ..., Tomanen, **1999;** Singh et al., 2000). The high-*j* intruder 0g9/2 orbital plays an important role in nuclear structure studies in this region. The increase of occupancy in the deformation driving 0g9/2 orbital increases the collectivity for nuclei in this mass region. In the A 60 region as one goes away from N and $Z \sim 40$ shell closure a variety of structural phenomena have been observed and nuclear shape evolves from prolate to oblate with decreasing nucleon numbers (Weiszflog et al., 2001)."

T. Paradellis, A. Xenoulis, C.A. Kalfas (***Tandem Accelerator Laboratory, Nuclear Research Center Demokritos, Athens, Greece*****), Gamma-gamma directional correlations in 69Ga, Z.Physik A275, 269-275 (1975):**

"In Fig 3, the experimental level scheme, which includes only the negative parity states of 69Ga, is compared with the theoretical calculations of **Paar (Paar, 1973)** and Paradellis-Hontzeas (Paradellis, Hontzeas, 1971). The theoretical prediction and experimental data on the transition probabilities are compared in Table2. In the calculations of **Paar (Paar, 1973)** the excited states of 69Ga arise from the coupling of a three-proton cluster moving in the p3/2, f5/2 and p1/2 shell model states. Both models give an adequate overall description of the excited states of 69Ga, especially. They both suggest that at approximately 0.9-1.0 MeV there exist a group of three states with spin values $1/2^-$, $3/2^-$, $5/2^-$. The $3/2^-$ state is identified with the 871 keV experimental level, while $1/2^-$ state is identified with the 1027 keV state observed in the $(n, n'\gamma)$ (Velkely et al., 1969) and $(^3\text{He}, d)$, (d,n)-reactions (Ivascu et al., 1974; Zeidman et al., 1974; Riocatto et al., 1974). The level at 1107 keV, which was assigned here a $5/2^-$ spin can be now identified with the $5/2^-$ member of this group. It is interesting to mention that both theoretical models expect this level to deexcite with strong E2 transition rates and to have extremely small spectroscopic factor (Paradellis, Hontzeas, 1971; **Paar, 1973)** and that is exactly what is experimentally observed (see Refs. Couch et al., 1970; Zeidman et al., 1974; Riccatto et al., 1974). The good agreement between experiment and theory extends also to the electromagnetic properties, at least for levels below 1.5 MeV. As far as the two models are concerned, the comparison of both with experiment indicates that they both predict correctly the excitation energy and spin of the levels in 69Ga. However, a close comparison with the experimental transition rates indicates that the three-particle cluster is more successful than the one particle coupling model in describing these properties, and especially the M1 transitions. This may be due to the fact that the three-particle cluster model, being more elaborate than the single particle model, provides more accurate description of the relevant nuclear wave function."

S. Raman, T.A. Walkiewicz, L.G. Multhauf, K.G. Tirsell, G. Bonsignori, K. Allaart ***(Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA; Edinboro University, Edinboro, Pennsylvania, USA; Lawrence Livermore National Laboratory, Livermore, California, USA; Dipartimento di Fisica dell'Universita Bologna, Istituto Nazionale di Fisica Nucleare, Sezione di Bologna, Italy; Natuurkundig Laboratorium, Vrije Univesiteit Amsterdam, Netherlands)*****, Decays of 118In, 120In, and 122 In isomers to levels in 118Sn, 120Sn, and 122Sn, Phys.Rev. C37, 1203-1228 (1988):**

"In a model space containing up to two-broken-pair excitations we obtain at least one 0^+, 2^+ and 4^+ state of mainly two-broken pair nature around twice the excitation energy of the 2^+_1 states. These are the calculated 2^+_4 and 4^+_4 states in 118Sn and 2^+_2 and 4^+_2 states in 120Sn and 122Sn Indeed, we calculate also the largest $B(E2, J \to 2^+_1)/B(E2, 2^+_1 \to 0^+_1)$ ratio for these states. For 0^+ states, this B(E2) ratio is large both for the 0^+_2 and the lowest lying two-broken-pair 0^+ state, which is the calculated 0^+_3 state in 118Sn and the calculated 0^+_4 state in 120Sn. The appearance of a noticeable two-phonon strength in the 0^+_2 states, which are mainly of one-broken-pair nature, should not be a surprise. There are no reasons why a two-phonon state should be a mainly two-broken-pair state. Especially for 0^+ configurations, a state obtained by breaking a second pair may sometimes have a dominant one-broken-pair nature due to angular momentum recoupling, as has been shown in Ref. (Allaart, Bonsignori, Savoia, **Paar, 1986)**."

M. Balodis, T. Krasta ***(Institute of Solid State Physics, University of Latvia, Riga, Latvia)*****, Levels of two-particle and gamma bands in 192Ir, Nucl.Phys. A933, 189-211 (2015):** "In the paper of Kern et al. (Kern, Raemy, Beer, Dousse, Schwitz, Balodis, Prokofjev, Kramer, Simonova, Hoff, Gardner, Gardner, Casten, Gill, Eder, von Egidy, Hagn, Hungeford, Scheerer, Schmidt, Zech, Chalupka, Murzin, Libman, Konenko, Coceva, Giacobbe, Kondurov, Loginov, Sushkov, Brant, **Paar, 1991)**, two long-standing problems for understanding the 192Ir nuclear structure were solved. The model independent level scheme of 192Ir was developed resulting from the work of international team of 31 co-authors, and the ground state parity of 192Ir was deduced to be positive. The level scheme, based on strong criteria, included 35 levels up to 531 keV energy. The established level scheme of 192Ir was partially analyzed using the rotor-plus-particle coupling (RPC) model and Gallagher-Moszkowski (GM) rule. Ground state parity was deduced from the orientation study of 192Ir nuclei in Fe (Kern, ... **Paar, 1991)**. Magnetic moment of the 192Ir ground state was measured and the measured value was compared with theoretical predictions for three possible spin configurations. A strongly mixed proton-neutron configuration was assumed. Meanwhile, two large studies of the neighboring 194Ir nucleus have been published (Balodis, Prokofjevs, Kramere, Simonova, Berzins, Krasta, Kern, Raemy, Dousse, Schwitz, Cizewski, Colvin, Boerner, Geltenbort, Hoyler, Kerr, Schreckenbach, Georgii, von Egidy, Klora, Lindner, Mayerhofer, Walter, Murzin, Libman, Kondurov, Loginov, Sushkov, Brant, **Paar,** Lopac, **1998;** Balodis et al., 2008). These studies have shown that there are two questions about 192Ir which should be answered: (1) is 192Ir structure more "deformed" than that of 194Ir; (2) are there 11^{-} long-lived isomers in both 192Ir and 194Ir nuclei, as predicted by available proton-neutron configurations?

In Table 2 of Ref. (Kern, ... **Paar, 1991)**, placement of the 128.7 keV transition is given in parentheses as connecting the 128.7 keV 0^{-} level and 4^{+} ground state. Intensity of the 128.7 keV transition is equal to 1.3 relative units. Such very weak transition, in principle, can be explained by higher order mixing. Let us analyze the ARC data of 192Ir given in (Kern, ... **Paar, 1991)**. There are two measurement sets: one from BNL, and another from the Institute of Nuclear Research, Kiev. Data from spectra obtained in capture of 2 keV averaged neutrons are similar within error limits. We estimate the I_{γ} (ARC) values for $(1, 2)^{-}$ levels to be about 50-60 units, and for 3^{-} levels – about 25 units (see Table 6 in Ref. Kern, ... **Paar, 1991).** From the already established levels and summary ARC intensities below 100-200 units, we suggest existence of two-level doublets: the 366.7 keV 2^{-}, 368.3 keV 3^{-}, and the 389.7 keV 3^{-}, 392.3 keV 2. In (Balodis, Prokofjevs, Kramere, Simonova, Berzins, Krasta, Kern, Raemy, Dousse, Schwitz, Cizewski, Colvin, Boerner, Geltenbort, Hoyler, Kerr, Schreckenbach, Georgii, von Egidy, Klora, Lindner, Mayerhofer, Walter, Murzin, Libman, Kondurov, Loginov, Sushkov, Brant, **Paar,** Lopac, **1998)**, both doublets were assigned spins and parities 2^{-} plus 2^{-}. Levels at 415.0 and 451.2 keV have no definite spin assignments in Ref. (Kern, ... **Paar, 1991)**, while their ARC intensities are larger than in the case of spin-parity 3^{-}. In Table 1, there are three new levels: 416.5 keV 3^{-}, 449.7 keV 3^{-}, and 452.2 keV 3^{-}, established via energy combinations. As a result, we have a doublet of 3^{-} levels at ∼ 415 keV, and a triplet of 3^{-} levels at ∼ 450 keV."

P.E. Garrett, D.G. Burke ***(Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada; Department of Physics, University of Fribourg, Switzerland)*****, Nuclear structure of 192Ir studied with direct transfer reactions, Nucl.Phys. A568, 445-498 (1994):**

"The A = 190 shape transitional region has recently received much attention. Secondly, more work needs to be done on the theoretical description of shape transitional odd-odd nuclei. Recently, an extension of the IBM, the interacting boson-fermion-fermion model (IBFFM) (Brant, **Paar,** Vretenar, **1984;** Hübsch, **Paar, 1984)** and the symmetry limit of the extended supersymmetry (ESUSY) model (Van Isacker et al., 1985; Van Isacker, 1987) applicable in the transitional region have been investigated. Results of calculations performed by **Paar** and Brant **(Paar,**Brant, **1990)** within the context of the interacting boson-fermion-fermion model (IBFFM) have been obtained. The IBFFM Hamiltonian is written (Brant, **Paar,** Vretenar, **1984; Paar,** Sunko, Vretenar, **1987)** as $H_{IBFFM} = H_{IBFM}(\pi) + H_{IBFM}(\nu) - H_{IBM} + H_{RES}(\pi\nu)$, where $H_{IBFM}(\pi)$ and $H_{IBFM}(\pi)$ denote the IBFM Hamiltonian (Iachello, Scholten, 1978; **Paar et al., 1982)** for the neighboring odd-proton and odd-neutron nuclei, respectively, and H_{IBM} denotes the IBM Hamiltonian (Arima, Iachello, 1975, 1978). The calculations were performed (Kern, ... Brant, **Paar, 1991)** with the computer code IBFFM, which has been described in the literature (Brant, **Paar,** Sunko, Vretenar, **1988;** Mayerhofer, von Egidy, **...Brant, Paar,** Lopac, **1989;** Meyer, Marsh, ...Brant, **Paar; 1990).**

The spectroscopic strengths obtained from the IBFFM calculations of **Paar** and Brant **(1990),** on the other hand, are normalized such that for each angular momentum value I_f of the final nucleus, the sum of strengths is $(2j+1)v_j^2$ for pickup reactions. Once the renormalization is achieved, the experimental values of the strength can be directly compared to the calculated values. The stripping strengths obtained from **Paar** and Brant **(1990)** must also be renormalized with the same parameters. Table 7 presents the results of the IBFFM spectroscopic strengths for 192Ir calculated by **Paar** and Brant **(1990).** In the IBFFM comparison with the experimental data, a total of 14 renormalization parameters was applied to the spectroscopic strengths obtained by **Paar** and Brant **(1990)**. These parameters were determined from a examination of the strength distribution for each j-transfer to final states with angular momentum I_f."

C. Baktash, J.X. Saladin, J.J. O'Brien, J.G. Alessi (Department of Physics, University of Pittsburgh, Pittsburgh, Pennsylvania), Electromagnetic properties of 194Pt and the question of its triaxiality, Phys.Rev. C 18, 131-17 (1978):

"Evidence regarding rigidity or softness of the transitional cores: The experimental evidence regarding this question is both varied and controversial. Recent observations (Meyer-ter-Vehn et al., 1974; Khoo et al., 1976; Piiparinen et al., 1976; Saha et al., 1977) of unique-parity rotational bands built on high-*j* states in odd-mass transitional nuclei, have been interpreted in terms of a quasiparticle coupled to an asymmetric rotor core (Meyer-ter-Vehn, 1975). It is worth mentioning that while these quasiparticle-plus-asymmetric core models seem to be a reasonable and simple approximation to the nuclear structure of odd-*A* nuclei, they are by no means conclusive. That is, a good fit to the energy spectrum based on a particle-plus-asymmetric core does not necessarily imply rigid asymmetry for the core. It appears that the core triaxiality might be interpreted as being dynamical in origin. Furthermore, Baker and Goss (1976) studied the effect of β_4 deformations on the nuclear shapes and concluded that one obtains band structures in odd-*A* nuclei very similar to those predicted by the asymmetric rotor – core models, if one instead considers an axially symmetric core, but includes the β_4 deformation effects. Finally, **Paar** et al. **(Paar,** Vieu, Dionisio, **1977)** have used a cluster-vibration coupling model in spherical representation to perform calculations for 193,195Au, and have successfully reproduced both unique parity and normal parity states in these isotopes. These investigations have, therefore, demonstrated that fits to the energy spectra of the negative parity bands in odd-*A* nuclei are not unique."

F.G. Kondev, M.A. Riley, D.J. Hartley, T.B. Brown, R.W. Laird, M. Lively, J. Pfohl, R.K. Sheline, R.M. Clark, P. Fallon, D.G. Sarantites, M. Devlin, D.R. LaFosse, F. Lerma, R. Wadsworth, I.M. Hilbert, N.J. O'Brien, E.S. Paul, D.T. Joss, P.J. Nolan, S.L. Shepherd, D.E. Archer, J. Simpson ***(Department of Physics, Florida State University, Talahassee, Florida, USA; Lawrence Berkeley National Laboratory, Berkeley, California, USA; Department of Chemistry, Washington University, St. Louis, Missouri, USA; Department of Physics, University of York, Heslington, York, United Kingdom; Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom; Lawrence Livermore National Laboratory, Livermore, California, USA; CLRC, Daresbury Laboratory, Daresbury, Waddington, United Kingdom)*****, Relative quadrupole deformations for decoupled structures in odd-odd 130Pr and 132Pr nuclei, Phys.Rev. C59, 3076-3085 (1999):**

"The band decays via several branches to the yrast $\pi h11/2 \otimes \nu h11/2$ structure (Shi et al., 1988; Petrache, Brant, Bazzacco, Falconi, Farnea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1988)**, which enabled firm spin and parity (relative to the values for the $\pi h11/2 \otimes \nu h11/2$ band) to be assigned. Table II: Spin and parity of the initial level relative to those proposed for the $\pi h11/2 \otimes \nu h11/2$ band in Ref. (Petrache, Brant, Bazzacco, Falconi, Farnea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1988).** For example, the DCO ratio of 0.6(1), deduced for the 576.6 keV interband transition that feeds the (10^+) level of the $\pi h11/2 \otimes \nu h11/2$ band (Petrache, Brant, Bazzacco, Falconi, Farnea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1988)**, using the 540.6 keV stretched quadrupole transition as a gate, implies that the former γ ray has a dipole character. The observation of the 706.5 keV γ ray to the (9^+) state of the $\pi h11/2 \otimes \nu h11/2$ band in parallel with the 576.6 keV transition and the measured DCO ratio of 1.0(1) indicate that the former transition is a stretched quadrupole, thus establishing odd spins and positive parity for the band.

Two decoupled bands were identified in 130Pr. One band is observed to decay to levels of the $\pi h11/2 \otimes \nu h11/2$ band (Petrache, Brant, Bazzacco, Falconi, Farnea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1988;** Ma et al., 1988) in a similar way to that related for the decoupled structure in 132Pr and is also assigned odd spins and positive parity. The decay path of the second band in 130Pr was difficult to establish; however, it was clear that it proceeded through levels at the bottom of the $\pi h11/2 \otimes \nu h11/2$ band (Petrache, Brant, Bazzacco, Falconi, Farnea, Lunardi, **Paar,** Podolyak, Venturelli, Vretenar, **1988;** Ma et al., 1988)."

E. Hammaren, O. Häusser, H.R. Andrews, P. Taras, A. Larabee *(Department of Physics, University of Jyväskilä, Finland; Chalk River Nuclear Laboratories, Ontario, Canada; Departement de Physique, Universite de Montreal, Canada*, 136Xe (13C, 4nγ) reaction study of 145Nd, Nucl.Phys. A456, 317-336 (1986):

"The N = 85 odd isotones from 147Sm to 153Er studied recently (Kownacki, Sujkowski, Hammaren, Liukkonen, Piiparinen, Lindblad, Ryde, **Paar, 1980;** Piiparinen et al., 1981; Fleissner et al., 1979; Horn et al., 1981) display at least qualitatively the characteristic features of the main particle multiplets expected to appear. The lowest shell model multiplets $\nu f_{7/2}^{3},\ \nu h_{9/2} f_{7/2}^{2},\ \nu f_{7/2}^{3} \times 3^{-}$ have been identified from SM to Er with a surprisingly stable behavior of relative energies inside a given multiplet. The only N = 85 isotone in the proton holes side with respect to the 146Gd core, where the above mentioned multiplets have been observed (Kownacki, Sujkowski, Hammaren, Liukkonen, Piiparinen, Lindblad, Ryde, **Paar, 1980;** Piiparinen et al., 1980) is 147Sm. Obviously one should keep in mind that collective phenomena can be expected to mix extensively with the single particle degrees of freedom as indcated e.g. by the particle-cluster vibrational model calculations (Kownacki, ..., **Paar, 1980)** for 147Sm."

H. Prade, W. Enghardt, W.D. Fromm, H.U. Jäger, L. Käubler, H.J. Keller, L.K. Kostov, F. Stary, F. Winkler *(Zentralinstitut für Kernforschung, Rossendorff, Dresden, Germany)*, New positive-parity states and the shell-model description of 111Sn, Nucl.Phys. A425, 317-344 (1984):

"Our former investigations of the *N* = 82 isotones 141Pr and 143Pm demonstrated (Prade, Käubler, ... **Paar, 1980;** Prade et al., 1981) that an extended shell-model description is capable of reflecting the essential structural aspects of their even-parity states, including high-spin states , and that a weak-coupling description might be suitable for odd-parity states only. The theoretical models used so far in the tin nuclei are the number-projected BCS quasiparticle or broken-pair approximation (van Gunsteren et al., 1974,1976, 1978) and the weak-coupling picture (Hashimoto et al., 1979; Blankert et al., 1981). In analogy to the neighboring nucleus 109Sn (Hashimoto et al., 1979) and to the quasimirror nucleus 143Pm (Prade, Käubler, ... **Paar, 1980;** Prade et al., 1981) a sequence of positive-parity states was newly found, which besides the negative-parity band carries a large part of the γ-ray intensity down to the $7/2^{+}$ ground state of 111Sn. The 111Sn level scheme obtained bears much similarity to the 143Pm level scheme (Prade, Käubler, ... **Paar, 1980;** Prade et al., 1981). In particular, the $7/2^{+}$, $11/2^{+}$, $15/2^{+}$ and $17/2^{+}$ states of both nuclei are connected by a strong γ-cascade and their $13/2^{+}$ states were found to be isomeric. An obvious difference us the much weaker branching between negative- and positive-parity states for 111Sn, favoring de-excitation through the negative-parity band."

E.R. Flynn, R.A. Broglia, R. Liotta, B.S. Nilsson ***(Los Alamos Scientific Laboratory, University of California, Los Alamos, USA; Niels Bohr Institute, University of Copenhagen, Denmark; NORDITA, Copenhagen, Denmark)*****, Elementary modes of excitation in the 204Pb (t, p) 206Pb reaction, Nucl.Phys. A221, 509-527 (1974):**

"The states expected to be strongly excited in the (t, p) reactions are those in which the two particles are correlated as in the states of 210Pb which are enhanced in the 208Pb (t, p) reaction. Again, the *Q*-values for the (t, p) reactions to these levels will be closely related to the 208(t, p) 210Pb *Q*-values (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972**). In fig. 2 all the measured angular distributions are collected. The solid lines in the figure are the result of distorted wave (DW) calculations and the dashed lines are empirically determined shapes for various *L*-values from refs. (Flynn et al., 1971; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972**). Because the monopole pairing force is a schematic representation of the short-range nucleon-nucleon force, it is expected that similar effects are to be found for pairs of particles coupled to angular momentum different from zero. Actually, this expectation has been borne out from experiment (Flynn et al., 1971; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Broglia et al., 1973) in particular around closed shell nuclei, where enhanced two-particle stripping cross sections have been found for states in the N_0 +2 systems. Thus, these states with $J^{\pi} \neq 0^{+}$, can be thought of as multipole pairing vibrations of the core N_0. As in the case of the monopole pairing vibrations, the multipole pairing modes can be produced by a separable pairing interaction which scatters pairs of particles coupled to λ. Table 5 contains the results obtained from the multipole pairing calculation using the DW calculations to compare to the data. For those cases in which the theoretical cross section was large enough to be set in relation to an observed level, the corresponding theoretical and experimental angular distribution are compared in fig. 2. The quality of the fit is generally good and comparable to that reported for other (t, p) results in the lead region. (Flynn et al., 1971; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Igo et al., 1971). The 2^+ state at 802 keV is the second most populated state in the low energy part of the spectrum. Again, the magnitude of this state is well reproduced by the calculation. The shape of the observed angular distribution also agrees well with the DW shape. The same type of agreement between the multipole pairing theory and the data for both the ground state and lowest quadrupole state was also observed in the 208Pb (t, p)210Pb reaction (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972).** A total of three 2^+ states seen in the energy region expected for the lowest 2p-4h type states, and together represent 0.91 of the (t, p) strength of the 2^+ state of 210Pb. This near equality of the strength is rather misleading, however, as the 206Pb (t, p)208Pb reaction to the pairing quadrupole statesa indicated twice as much strength as expected (Igo et al., 1971). It was shown (Broglia, **Paar,** Bes, **1971**) that qualitatively this result could be understood in terms of the admixture of higher excited 2^+ states of 210Pb which carry large (t, p) cross section. This admixture seems to change quite strongly with mass number and is still an open question; however, the basic features of the pairing quadrupole many-phonon state are retained. Only a fraction of the 4^+ strength is seen with the 5688 keV state being a likely candidate for containing 2 particles in a configuration similar to that of the 1092 keV state of 210Pb. A higher 4^+ state is seen at 7758 keV with similar strength and this state could well be related to the large 4^+ state (the 210Pb (4_3^+)) seen (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)** in 210Pb at 2700 keV. Indeed, the energy difference between the two states observed here is 2070 keV as compared to the 210Pb case where the energy difference is equal to 1600 keV. The near equality in cross sections for the two 4^+ states observed here, in contrast to the 210Pb case where the upper state is almost three times as intense as the lower one, indicates that the arguments about the percentage of these 206Pb states are at most qualitative. The only states of those collected in Table 6 for which there should be a correspondence with the 208Pb (t, p)210Pb reaction are the collective states, i.e. lowest 3^- and 5^- states. In such case the transition can proceed through ground state correlations (Broglia, Landowne, **Paar,** Nilsson, Bes, Flynn, **1971).** Levels of 8^+ character were observed at 6416 keV, 6626 keV, and 6688 keV with higher 8^+ states at 7830 keV and 7874keV. The lower three states have an energy centroid of 6570 keV and a strength of 0.79 of the 210Pb (8^+_1) state as excited by the (t, p) reaction. The strong excitation of the two 8^+ states with an energy centroid bear 7850 keV may be due to the large 8^+strength both observed and predicted in excitation in 210Pb (ref. Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972).** The main features of the 204Pb (t, p)206Pb reaction can be described in terms of multipole pairing and surface vibrations."

P. Prokofjevs, L.I. Simonova, M. Balodis, J. Berzins, V. Bondarenko, H.F. Wirth, T. von Egidy, C. Doll, J. Ott, W. Schauer, R.W. Hoff, R.F. Casten, R.L. Gill, J. Honzatko, I. Tomandl, S. Boneva, V.A. Khitrov, A.M. Sukhovoj, D.G. Burke, J. Kvasil, A. Mackova ***(Nuclear Research Center, Salaspils, Latvia; Technical University Munich, Garching, Germany; Lawrence Livermore National Laboratory, Livermore, California, USA; Yale University, New Haven, Connecticut, USA; Brookhaven National Laboratory, Upton, New York, USA; Nuclear Physics Institute, Rez, Czech Republic; Joint Institute of Nuclear Research, Dubna, Moscow, Russia; Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada; Department of Nuclear Physics, Charles University, Praha, Czech Republic)*****, Nuclear structure of 166Ho studied in neutron-capture, (d,p), and (d,3He) reactions, Phys.Rev. C61, 044305 (2000):**
"The first paper studying the coupling of quasiparticle and vibrational degrees of freedom in odd-odd nuclei was that of Soloviev (Soloviev, 1966). The coupling of quasiparticle and vibrational degrees of freedom leads to the appearance of collective vibrational (phonon) components in the low-lying states. The importance of vibrational admixtures in low-lying states for the description of energy spectra transition probabilities was demonstrated in numerous calculations in the framework of the quasiparticle-plus-phonon model (Sood et al., 1991; Soloviev et al., 1983). Phenomenological models (Afanasjev et al., 1988; Balantekin et al. 1981; Chow et al., 1981; **Paar, 1979;** Brant, **Paar,** Vretenar, Alaga, Seyfarth, Schult, Bogdanovic, **1987)**."

D.M. Gordon, M. Gai, A.K. Gaigals, R.E. Shroy, D.B. Fossan ***(Department of Physics, State University of New York, Stony Brook, New York, USA)*****, Collective properties of *A* = 117-127 odd-*A* I nuclei, Phys.Lett. B67, 161-164 (1977):**
"Two different theoretical approaches have been used to interpret the collective nuclear

excitations which have been observed via heavy-ion experiments in odd-*A* transition nuclei. In the first approach, an odd particle (quasiparticle) of angular momentum *j* is coupled to a symmetrical triaxial rotor leading to rotational bands with spin *J* sequences *j, j+2, j+4, ...* (ΔJ =2 decoupled bands) or to bands with sequences $j, j+1, j+2, \ldots$ (ΔJ = 1 strongly coupled bands) (Stephens, 1975; Toki, Faessler, 1975). In the second approach, similar band properties are obtained by coupling an odd particle to an anharmonic vibrator (Hagemann, Dönau, !975; Alaga, **Paar, 1976;** Arima, Iachello, 1976). The odd-A band properties depend, in either theoretical model, on the parameters describing the core and the particle-core coupling. Both models can account for the observed ΔJ =2 and ΔJ = 1 energy spacings.
The particle –vibrator interaction also provides a mechanism for obtaining the variation with *A* of the spacings of the ΔJ =2 bands based on the h11/2 states. Arima et al. (1977) have obtained fits to systematic variations from a second order perturbation expansion of the particle-vibrator interaction that involved linear and quadratic terms of the neutron number in an effective shell. A consistent but altered interaction that would yield the lack of any variation observed for the d5/2 and g7/2 bands is then required, although Pauli principle effects are more important for these bands. Alaga and **Paar** (Alaga, **Paar, 1976)** have suggested that better results for the odd-I nuclei can be obtained with three quasiparticles coupled to a vibrator core."

T. Paradellis, I. Galanakis, G. Vourvopoulos ***(Tandem Accelerator Laboratory, Nuclear Research Center Demokritos, Athens, Greece)*****, Excited states in 69Ge observed in the 69Ga(p,nγ) reaction, Nucl.Phys. A307, 472-492 (1978):**
"Recently, Paar et al. (**Paar,** Eberth, Eberth, **1976)** have studied the nuclear structure of 69,71Ge in the framework of the Alaga and Bohr-Mottelson models. The results obtained in the present work are compared with the results of this study. As a result of present investigation, several spin and parity assignments for 69Ge levels were made possible. The measured mean lives and mixing ratios of the present work, along with the work of Eberth et al. (Eberth et al., 1975,1976) with emphasis on higher spin states result in a fully complete experimental picture of the nuclear structure of 69Ge up to an excitation of 1.6 MeV. In Fig.7 the experimentally observed states of 69Ge and 71Ge are compared with the predictions of the particle-core coupling model calculations of **Paar** et al. **(Paar,** Eberth, Eberth, **1976)**. In the framework of this model the negative parity states of odd Ge nuclei are described either in terms of an odd neutron hole moving in the p1/2, f 5/2 or p3/2 orbits (71Ge) or a three-neutron-hole cluster moving in the same orbits (69Ge), coupled to the 72Ge vibrational states. In the framework of the same model, positive parity states are assumed to arise from the coupling to the 72Ge vibrational states of either the one or three neutrons moving in the g9/2 or d5/2 orbits. As seen from fig. 7, the structure of negative parity states of both 69Ge and 71Ge is well reproduced by the model calculations. Although the calculated spectra appear more compressed than the experimental spectra, the interchange of ground and first excited states from 69Ge to 71Ge is explained, while the position and the sequence of the higher states generally agree with a three-particle-cluster – core coupling description of 69Ge. In the case of the positive-parity states in 69Ge, as a result of the present work both the $(7/2)^+_1$ and $(9/2)^+_2$ excited states predicted by the neutron-vibration

coupling are preserved experimentally. In table 5 the measured B(E2) and B(M1) strengths of some selected transitions between states of 69Ge are shown for negative- and positive-parity levels and compared with the theoretical predictions from ref. (**Paar,** Eberth, Eberth, **1976)**. Although there is a general qualitative agreement, there are cases where some disagreement is observed. Such differences may simply mean that the possible core for the cluster-vibration description of the Ge nuclei is more complex than assumed in the calculations."

A.W.B. Kalshoven, F.W.N. De Boer, W.H.A. Hesselink, S. Idzenga, J. Ludziejewski, F. Ottenhof, J.J. Van Ruyven, H. Verheul, A. Knipper, G. Marguier, C. Richard-Serre, B. Bergersen, E Hagebø, O. Scheidemann (*Natuurkundig Laboratorium, Vrije Universiteit, Amsterdam, Netherlands; Centre de Recherches Nucleaires, Strasbourg, France; Institut de Physique Nucleaire, Universite Claude Bernard, Villeurbanne, France; ISOLDE, CERN, Geneva, Switzerland*), Level structure of 99,101,103Ag observed in the decay of light Cd isotopes, Nucl.Phys. A337, 120-142 (1980):

"The negative parity states of odd Ag nuclei exhibit a multiplet structure which is characteristic of the coupling of a p1/2 proton hole to vibrational motions of the core (De Shalit, 1961; Kisslinger, Sorensen, 1963; Del Vecchio et al., 1975; Anderson et al., 1977). The results from direct reaction studies for 105,107,109,111Ag support this idea (Anderson et al., 1975, 1977; Ridley, 1975; Kuhfeld et al, 1975; Auble et al., 1973; Van der Werf et al., 1976). However, the anomalous low-lying $7/2_1^+$ state observed in all odd-mass silver isotopes from A = 101 to A = 113 is not described by this type of coupling. **Paar** showed **(Paar, 1973)** that the coupling of a cluster of three proton holes in the p1/2, p3/2 and g9/2 subshells to vibrational motions of the Sn core can explain this $7/2_1^+$ state. The specific hole-core coupling feature of the negative parity states are also included in a natural way in this model. Typical for all the odd Ag isotopes is the low-lying $7/2^+$, $9/2^+$ doublet. It is known that this $7/2^+$ state cannot be explained in the one-particle-core coupling model. **Paar** has shown **(Paar, 1973)** that a cluster of three proton holes moving in the g9/2, p1/2 and p3/2 subshells coupled to phonon-excitations of the even Sn core well reproduces this $7/2_1^+$ state (J-1 anomaly) and the other low-lying states. The wave functions from this calculations are rather complex, for the lowest $7/2_1^+$ state the main components are $\pi(g9/2)^{-3}_{7/2^+}$, with and without phonon coupling and a $\pi(g9/2)^{-3}_{9/2^+}$ configuration coupled to e one-phonon state. Fig. 9: Systematics of the positive parity states in the light Ag isotopes. The parameters used in the calculation of **Paar (Paar,1973)** were a = 0.8, G = 0.2 MeV and $\hbar\omega/2\pi$ = 1.0 MeV. Fig. 10: Systematics of the negative parity states in the light odd Ag isotopes. The parameters used in the calculation of **Paar (Paar,1973)** are the same as those used for the positive parity states.

The negative parity states are also explained by this model. The electromagnetic properties of the low-lying positive and negative parity states are satisfactorily reproduced by cluster-phonon coupling as well (**Paar, 1973;** Kalshoven et al., 1979). The original calculations **(Paar, 1973)** were performed for an "average" 107,109Ag nucleus, however the properties of the lighter Ag nuclei can better be described by a smooth change of the model parameters. It should be mentioned that for the negative parity states the predictions of the Alaga model preserve the multiplet structure characteristic for the one-particle-core coupling, which can be seen from the main components of the wave functions given in the original paper **(Paar, 1973).** This is in agreement with the results obtained from (t, p) and (p, t) reactions (Del Vecchio et al., 1975; Anderson et al., 1977; Kuhfeld at al., 1975). For all Ag isotopes a characteristic retardation of the E3 transition between the lowest $1/2^-$ and $7/2^+$ state is observed. In the simplest description of these states the E3 transition between the $\pi(p1/2)^{-1}$ and the $\pi(g9/2)^{-3}_{7/2}$ states is forbidden. However the wave function given by **Paar (Paar, 1973)** for the $1/2^-$ state, contains about 10 % of the $[\pi(g9/2)_0^{-2} \otimes \pi(p3/2)^{-1} \otimes 2^+]_{1/2^-}$ component, while the wave function of the $7/2^+_1$ state contains about 18% of the $[\pi(g9/2)_0^{-2} \otimes \pi(g9/2)^{-1} \otimes 2^+]_{7/2^+}$ component **(Paar, 1973)**. Using these wave functions the retardation factor for the E3 $1/2^- \rightarrow 7/2^+$ transition is estimated to be about 50, in agreement with the observed retardation (Lhersonneau et al., 1978; Huyse et al., 1978). The increasing retardation observed in 99Ag and 101Ag indicates that the above-mentioned components of the wave functions are less important for these isotopes."

E.R. Flynn, J.G. Beery, A.G. Blair *(Los Alamos Scientific Laboratory, University of California, Los Alamos, USA)*, The (t,p) reaction to the low-lying levels of the zirconium isotopes, Nucl.Phys. A218, 285-306 (1974):

"The zirconium isotopes span an extremely interesting region of the known nuclides. The (t,p) reaction is an extremely useful probe for examining the details of the nuclear structure from shell model and pairing multiple viewpoints, as has been demonstrated in 210Pb (ref. Flynn, Igo, Broglia, Landowne, **Paar, 1972)** or for observing transitional features (Casten et al., 1972). The usefulness of the (t,p) reaction for these purposes is increased when the study is carried out over a series of isotopes and the trend of particular states may be observed.

There is a substantial gap, 1.5 MeV, expected between 2d5/2 orbital and the next one, the 2s1/2 (Cohen, 1963). Thus, one may expect that the dominant configuration of the lowest-lying 0^+, 2^+ and 4^+ states of 91Zr and 94Zr will be the $(2d5/2)^n_J$. However, if only these configurations are considered, the DW results are too small by factors ranging from 1.8 to 2.5 for the various states examined. Therefore, the small admixtures of other components such as the 2d3/2 and 3s1/2 are important in calculating the correct two-nucleon overlap integrals. Such a situation has been previously reported in 210 Pb (ref. Flynn, Igo, Broglia, Landowne, **Paar, 1972)** where although the theoretical wave functions for the 0^+, 2^+ and 4^+ indicated amplitudes greater than 0.9 for a single configuration, the cross section was enhanced more than a factor of three over DW calculations using only this configuration. The weak excitation of the 1.842 MeV 2^+ level in 92Zr could be the result of several factors related to the limited configuration space of the shell model used by Ball and Bhatt. In the case of 210Pb, it was found that pairing quadrupole forces were sufficiently strong that higher-lying 2^+ states were considerably weakened in the (t, p) reaction (Flynn, Igo, Broglia, Landowne, **Paar, 1972)**. A similar effect could be occurring here. In general, these states which are not principally due to the $(2d5/2)^n_J$ configuration show significant deviations from the shell model calculations considered here. This is a feature quite reminiscent of the 210Pb results **(**Flynn, Igo, Broglia, Landowne, **Paar, 1972)** where multiple pairing forces produced results superior to straightforward shell model calculations."

P. von Neumann-Cosel, P. Schenk, U. Fister, T.K. Trelle, R. Jahn ***(Institut für Kernphysik, Technische Hochschule Darmstadt, Germany; Institut für Strahlen- und Kernphysik, Unversität Bonn, Germany)*****, Stretched two-nucleon configurations in 210Pb, Phys.Rev. C47, 1027-1032 (1993):**

"So far, studies of the two-neutron transfer reaction (t,p), of inelastic scattering , and of the (7Li, α n) reaction on 210Pb have been reported (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Decman et al., 1983; Ellegaard et al., 1971; Sjoreen et al., 1980). The g.s. angular distribution has been used to fix the real potential depth correction for the exit channel with respect to the values of Ref. (Hinterberger et al., 1968). The 1.21-MeV state is known from earlier work as the 8^+ member of the $(2g9/2)^2$ ground state multiplet. An L = 8 calculation describes the data reasonably and the resulting normalization constant compares well with other deduced values. The 1.80-MeV transition was tentatively assigned $J^{\pi} = 10^{+}$by Flynn et al. (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**. The present values fully confirm the assignment of a pure $(2g9/2{,}1i11/2)_{10^+}$ configuration. The most likely candidates for the 2.52-MeV state are $(2g9/2{,}1j15/2)_{11^-}$ and $(2g9/2{,}3d5/2)_{6^+}$. "

D.J. Decman, J.A. Becker, J.B. Carlson, R.G. Lanier, L.G. Mann, G.L. Struble, K.H. Maier, W. Stöffl, R.K. Sheline ***(Lawrence Livermore National Laboratory, Livermore, California, USA; Hahn-Meitner Institute, Berlin, Germany; Florida State University, Tallahassee, Florida, USA)*****, Electromagnetic properties of isomers in 210Pb, Phys.Rev. C28, 1060-1064 (1983):**

"The members of the $\nu(g9/2)^2$ configuration in 210Pb have been identified by charged particle studies using the 208Pb(t,p) (Ref. Flynn, Igo, Broglia, Lamdowne, **Paar,** Nilsson, **1972)** and 210Pb(t,t') (Ref. Ellegaard et al., 1971) reactions. These levels are shown in Fig. 1. The members of $\nu(g9/2)^2$ configuration in 210Pb. The gamma-ray energies are from the present work. The energy of the 8^+ level is taken from the (t,p) and (t,t') reaction studies of Refs. (Flynn, Igo, Broglia, Lamdowne, **Paar,** Nilsson, **1972)** and Ellegaard et al., 1971)."

L.J. Jardine, S.G. Prussin, J.M. Hollander ***(Lawrence Berkeley Laboratory, University of California, Berkeley, California, USA; Department of Nuclear Engineering, University of California, Berkeley, California, USA)*****, Decay of 209At to levels in 209Po, Nucl.Phys. A233, 25-47 (1974):**

"Theoretical calculations (Ma, True, 1973; Redlich, 1965) of the level structure of $^{210}_{84}$Po and $^{210}_{82}$Pb assuming two particles outside a $^{208}_{84}$Pbcore have been found to give remarkable agreement with the experimental (Jardine et al., 1972; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)** level structures. Due to the proximity of $^{209}_{84}$**Po** to these nuclei, onemight hope tp describe the low-lying level structure of ^{209}Po in terms of three-particle states arising from couplings of the odd neutron with the two protons outside a lead core. The existence of such three-particle states was first ascribed to ^{209}Po by Yamazaki and Matthias (Yamazaki, Matthias, 1968) who investigated the ^{208}Pb(α,3$n\gamma$) reaction."

G. Berrier-Ronsin, G. Rotbard, M. Vergnes, S. Fortier, J.M. Maison, L.H. Rosier, J. Vernotte, P. Van Isacker, J. Jolie ***(Institut de Physique Nucleaire, CNRS, Orsay Cedex, France; Grand Accelerateur National d'Ions Lourds, Caen Cedex, France; Institut de Physique, Universite de Fribourg, Perolles, Fribourg, Switzerland),*** **Transfer results for odd-odd 198Au as a test of extended supersymmetry, Phys.Rev. C55, 1200-1210 (1997):**
"The formulation of the supersymmetry model of nuclear structure by Iachello (1980) was motivated by the goal of unifying in a common framework, both even-even and odd-A nuclei. The same search for unification was responsible for the subsequent development (Van Isacker et al., 1985; Balantekin, **Paar, 1986)** of an extended supersymmetric model to also include odd-odd nuclei. Angular momentum *l* values have been assigned to most of the observed peaks and the corresponding spectroscopic strengths have been extracted. Extraction of the corresponding spectroscopic strengths for *l* = 1 and 3 was done with the assumption of 3p3/2 and 2f5/2 transfers. It has been checked that the DWUCK4 cross sections for the $j = l + 1/2$ and the $j = l - 1/2$ transfers are in a constant ratio, within less than 2% in the angular range in which the spectroscopic strengths are extracted. The ratio depends slightly on the excitation energy between E_x = 0 and 2.7 Mev, the ratio $G(j = l + 1/2)/G(j = l - 1/2)$ varies from 0.91 to 0.94 for *l* = 1 and from 0.76 to 0.80 for *l* =3. The results up to 2.7 MeV are shown in Tables II-IV, together with already known data (Warner et al., 1986; Chunmei, 1995; Mayerhofer, von Egidy, Durner, Hlawatsch, Klora, Lindner, Brant, **Paar,** Lopac, Kopecki, Warner, Pospisil (12 authors), **1989).** To determine the distribution of strength among the members of a multiplet peak, we used the published results of a previous study (Mayerhofer, ..., **Paar,** ... Pospisil (12 authors), **1989)** of the (d,p) reaction at 20 MeV in 197Au, at only one angle (35°). The relative values of cross sections at 22 MeV are in good agreement for the whole energy domain considered with the one of Ref. (Mayerhofer et al., 1988), although they disagree above ≈ 300 keV with theory of Ref. (Mayerhofer, ..., **Paar,** ... Pospisil (12 authors), **1989).** It should be stressed, however, that the unexplained disagreement above 300 keV between Ref. (Mayerhofer, von Egidy, Hlawatch, Klora, Lindner, 1988) and (Mayerhofer, ..., **Paar,** ... Pospisil (12 authors), **1989)** does not concern the ratio of cross sections for members of multiplets unresolved in our work. This ratio can therefore be used safely to evaluate the distribution of spectroscopic strengths between the members of these multiplets. The authors of Refs. (Mayerhofer et al., 1988; Mayerhofer, von Egidy, Durner, Hlawatsch, Klora, Lindner, Brant, **Paar,** Lopac, Kopecki, Warner, Pospisil (12 authors), **1989)** performed an IBFFM calculation for 198Au, assuming an O(6) even-even core, and they have computed (among other properties) the (d,p) spectroscopic factors $S_{l,j}$. The details and parameters of this calculation can be found in Ref. (Mayerhofer, von Egidy, Durner,

Hlawatsch, Klora, Lindner, Brant, **Paar,** Lopac, Kopecki, Warner, Pospisil, (12 authors) **1989)**. The spectroscopic strengths $G_{l,j} = \left[(2J_f + 1)/(2J_i + 1)\right]S_{l,j}$, calculated from Table 10 of Ref. (Mayerhofer, ..., **Paar,** ... Pospisil (12 authors), **1989)** are also compared in Fig. 4 to data. Approximative values of the calculated energies have been extracted from Ref. (Mayerhofer, ..., **Paar,** ... Pospisil (12 authors), **1989)**."

C. Rossi Alvarez, D. Vretenar, Z. Podolyak, D. Bazzacco, G. Bonsignori, F. Brandolini, S. Brant, G. de Angelis, M. Dr Poli, M. Ionescu-Bujor, Y. Li, S. Lunardi; N.H. Medina, C.M. Petrache ***(Dipartimento di Fisica dell'Universita and INFN, Sezione di Padova, Padova, Italy; Physics Department, Faculty of Science, University of Zagreb, Zagreb, Croatia; Dipartimento di Fisica dell'Universita and INFN, Sezione di Bologna, Bologna, Italy; INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy; Institute of Physics and Nuclear Engineering, Bucharest, Romania)*****, Excited states in 139Sm described with the interacting boson model plus broken pairs, Phys.Rev. C54, 57-71 (1996):** "In Refs. (Iachello, Vretenar, 1991; Vretenar et al., 1995; Vretenar, **Paar,** Bonsignori, Savoia, **1990;** Vretenar, **Paar,** Bonsignori, Savoia, **1991;** Chowdhury et al., 1991; Vretenar et al., 1993; Lister et al., 1993; Chisthi et al., 1993; De Angelis et al., 1994) an extension of the IBM has been investigated that includes two- and four-fermion noncollective states (one and two broken pairs). The neutron orbitals included in the calculation are d3/2, s1/2, g7/2 for positive-parity states, and h11/2 for negative parity states. In N =79, 81 nuclei, the $1/2^+_1$ state (predominantly s1/2 quasiparticle state) is very low in energy. For these nuclei the reported IBFM calculations (Bondarenko, Kuvaga, Prokofjev, Khitrov, Kholnov, Nong Khiem, Popov, Sukhovoj, Brant, **Paar,** Lopac, **1993**; Chrien, Koene, Stelts, Meyer, Brant, **Paar,** Lopac, **1993**; Bondarenko, Kuvaga, Prokofjev, Sukhovoj, Khitrov, Popov, Brant, **Paar, 1995;** Chrien, 1996) employed quasiparticle energies and occupation probabilities obtained from a simple BCS calculation using the Kisslinger-Sorensen parametrization (Kisslinger, Sorensen, 1963). On theother hand, in the N =73 nuclei 131Ce and 132Pr (Bucurescu, Barneoud, Cata-Danil, Von Egidy, Genevey, Gizon, Gizon, Liang, Paris, Weiss Brant, **Paar,** Pezer, **1995)**, a Reehal-Sorensen parametrization (Reehal, Sorensen, 1970). This parametrization produces low-lying s1/2 and g7/2 quasiparticle states, in agreement with the experimental data."

F. Iachello, D. Vretenar ***(Center for Theoretical physics, Yale University, New Haven, Connecticut, USA)*****, Physics of high-spin states in nuclei, Phys.Rev. C43, R945-948 (1991):** "The inclusion of 2qp states allows one to go above the so-called first backbending up to $J \approx 20h/2\pi$. Recently, the interacting boson model has been further extended to include two broken pairs (4qp states) (Vretenar, **Paar,** Bonsignori, Savoia, **1990)**. In conclusion, we have presented here the results of the first calculation of high-spin states in nuclei within the framework of the interacting boson model with two broken pairs (Vretenar, **Paar,** Bonsignori, Savoia, **1990).** The broken pair space we have used includes two fermion states with angular momenta up to twelve and four fermion states with angular momenta up to 20."

M.L. Liu, Y.H. Zhang, X.H. Zhou, Y.X. Guo, X.G. Lei, Z. Liu, J.J. He, S.X.Wen, X.G. Wu, G.J. Yuan ***(Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China; Graduate School of the Chinese Academy of Sciences, Beijing, China; China Institute of Atomic Energy, Beijing, China)*****, High-spin level scheme and decay of the 67- μs isomer in 142Pm, Phys.Rev. C70, 014304 (2004):**

"Decomposing the $\left(\pi g_{7/2}^{-1} d_{5/2}^{-2} \otimes \nu h_{11/2}^{-1}\right)_{13^-}$ structure into $\left[(\pi g_{7/2}^{-1} d_{5/2}^{-2})_{15/2^+} \otimes \nu h_{11/2}^{-1}\right]_{13^-}$, the excitation energy can be calculated using the expression: $E^{142Pm}_{\left[\left(\pi g_{7/2}^{-1} d_{5/2}^{-2}\right)_{15/2^+} \otimes \nu h_{11/2}^{-1}\right]_{13^-}} =$

$$E^{143Pm}_{\left[\left(\pi g_{7/2}^{-1} d_{5/2}^{-2}\right)_{15/2^+}\right]} + E^{145Gd}_{\nu h_{11/2}^{-1}} + S + \Delta^{144Eu}_{(\pi g_{7/2}^{144Eu} \otimes \nu h_{11/2}^{-1})9_-} +$$

$$2 \sum_{I=7,8} \left[\sqrt{9(2I+1)}\ W(\frac{5}{2}\frac{5}{2}\frac{19}{2}\frac{11}{2};4I)\right]^2 \times \Delta^{144Eu}_{\left(\pi d_{5/2}^{-1} \otimes \nu h_{11/2}^{-1}\right)_I} = 2723 \text{ keV}$$

where E represents excitation energy of the corresponding nucleus (Piiparinen et al.,1996; Prade, Käubler, Hagemann, Jäger, Kirchbach, Schneider, Stary, Roller, **Paar, 1980;** Kownacki et al., 1974; Pakkanen et al., 1982). The binding energy term is $S = B_{147Pm} + B_{146Gd} - B_{143Pm} - B_{145Gd}$ = 1265.9 keV (Audi, Wapstra, 1995). Δ is the proton-neutron residual interaction."

D.E.J. Riedeman, K. Allaart, H.P. Blok, M.N. Harakeh, K. Heyde, C.W. de Jager, H. de Vries ***(National Institute for Nuclear Physics and High-Energy Physics, Amsterdam, Netherlands; Department of Physics and Astronomy, Vrije Universiteit, Amsterdam, Netherlands; Laboratorium voor Kernfysica, Gent, Belgium)*****, Electron scattering off 65Cu and 71Ga, Nucl.Phys. A573, 173-215 (1994):**

"Electron scattering on the f p-shell nuclei 65Cu and 71Ga has been investigated. This allowed the extraction of the transition densities and probabilities, which are compared to Particle–core coupling calculations: particle-vibration coupling model (PVCM) and Quasiparticle–cluster vibration model (QCVM). These models appear to be more applicable to 65Cu than to 71Ga. Transition current densities are often less well predicted than charge densities and are quite sensitive to the model used. The E2 transition strengths as measured in Coulomb-excitation experiments and the spectroscopic factors for the member levels as reflected in the nucleon-stripping reactions cannot be explained by a weak-coupling picture. The PVCM Hamiltonian is with the oscillator Hamiltonian of the core, single-particle shell-model Hamiltonian and the interaction Hamiltonian (Bohr, Mottelson, 1975). For nuclei more remote from a closed shell the odd particle may in the first approximation be considered as a BCS quasiparticle. In this sense the PVCM was extended by Kisslinger and Sorensen (Kisslinger, Sorensen, 1965). The label "PVCM" for the nucleus 71Ga in the tables refers to this model, while moreover an anharmonic vibrator part (Heyde et al., 1983) turned out to be required for this nucleus. One of the well-known shortcomings of the PVCM is that it neglects Pauli effects, viz. antisymmetrization of the wave functions of the particle and of the vibrating core particles. This is a serious problem when the vibrator is used to include also an even number of valence particles of the same kind as the odd nucleon. **Paar et al. (Paar**, Alaga, Šips, **1975)** introduced the cluster-vibration model (CVM) for nuclei having just three particles or holes in the valence shell. These three particles (the "cluster") were then again coupled to a vibrational core. In the same spirit the quasiparticle-cluster vibration model (QCVM) was introduced later (Allaart, Hofstra, **Paar, 1981)** for the cases where the number of valence particles or holes of the odd kind of nucleons is larger than three. In that case one relies on the pairing correlations of nucleons, assuming that all but three of the odd particles occur as Cooper pairs. The QCVM Hamiltonian contains the full shell-model Hamiltonian for the odd kind of particles $H_{QCVM} = H_{vib} + H_{SM}^{odd} + \sum_{i=1}^{2p+1} H_{PVC}(i),$ but the shell-model space is restricted to (1) states with no broken pairs ($p = 0$), i.e., states in which all except one particle appear in coherent pairs which are coupled to angular momentum zero; (2) states with one broken pair ($p = 1$), i.e. states in which all except three particles appear in coherent pairs which are coupled to angular momentum zero."

R. Duffait, L. Van Maldeghem, A. Charvet, J. Sau, K. Heyde, A. Emsallem, M. Meyer, R. Beraud, J. Treherne, J. Genevey ***(Institut de Physique Nucleaire, Universite Claude Bernard Lyon-I, Villeurbanne, France; Institut de Sciences Nucleaires, Grenoble, France)*****, High spin states and multiquasiparticle excitations in odd-odd 114,116Sb nuclei, Z.Physik A307, 259-268 (1982):**

"Concerning the negative parity band in 116Sb, one may assume that it proceeds from the coupling of a g9/2 proton hole and 1h11/2 neutron quasiparticle to a suitable core, which is then a 116Te core. We have thus performed a calculation of the negative parity band in the framework of the unified model in the weak coupling limit. Let the Hamiltonian be written $H = H_c + H_{pc} + H_{nc} + H_{pn}$, where H_c is the usual vibrational quadrupole Hamiltonian of the core. H_{pc}, H_{nc} and H_{pn} are respectively the proton core, neutron core and proton-neutron interactions. The resulting spectra is given in the left part of Fig. 7. As predicted by the **Paar** parabolic rule **(Paar, 1979)** the spin of the lowest state is $I_\nu = \sqrt{j_n(j_n+1) + j_p(j_p+1) - \frac{1}{4}} - \frac{1}{2} \approx 7$ which is also found experimentally. "

B.L. Burks, R.E. Anderson, T.B. Clegg, E.J. Ludwig, B.C. Karp, Y. Aoki ***(University of North Carolina, Chapel Hill, USA; Triangle Universities Nuclear Laboratory, Durham, USA)*****, A DWBA analysis of the 86Sr ($\vec{d}$,p)87Sr reaction and implications for an 87Rb solar neutrino detector, Nucl.Phys. A457, 337-350 (1986):**

"One of the earliest nuclei to be recognized as a possible low-threshold detector for solar neutrino was 87Rb. Two states were identified in 87Sr below 4.0 MeV in excitation energy that would be populated by allowed solar neutrino captures in 87Rb solar neutrino detector.

Information concerning the level structure of 87Sr has resulted from studies of the 86Sr(d,p) 87Sr reaction (Bercaw, Warner, 1971; Bucurescu et al., 1971; Morton et al., 1971) and several other reactions. Other transfer reaction experiments include the 89Y(d, α)87Sr reaction (Brien et al., 1972; Peterson et al., 1973) and the 88Sr(p,d)87Sr reaction (Blok et al., 1977). Kaptein et al. (1978) measured angular distributions of protons from the 87Sr (p, p')87Sr reaction. Investigations of high-spin states have utilized the 84Kr $(\alpha, n\gamma)$ 87Sr reaction (Ekstrom, Jones, Kearns, Morrison, Nilsson, **Paar**, Twin, Wadsworth, Wallander, Ward, **1981**; Arnell et al., 1975). The 84Kr $(\alpha, n\gamma)$ 87Sr study of (Ekstrom, Jones, Kearns, Morrison, Nilsson, **Paar**, Twin, Wadsworth, Wallander, Ward, **1981)** did suggest a tentative spin-parity of $9/2^+$ for 2.82 MeV state, which is confirmed in the recent investigation."

C. Chung, W.B. Walters, R. Gill, M. Schmid, R.E. Chrien, D.S. Brenner ***(Department of Chemistry, University of Maryland, USA; Department of Physics, Brookhaven National Laboratory, Upton, New York, USA; Department of Chemistry, Clark University, Worcester, Massachusetts, USA)*****, Decay of neutron-rich 144Ba to levels of 144La, Phys.Rev. C26, 1198-1214 (1982):**

"The sequence of states near the ground state that can be attributed to the $(\nu f7/2\pi g7/2)0^-\ldots 7^-$ and $(\nu f7/2\pi d5/2)1^-\ldots 6^-$ multiplets can be interpreted with the parabolic rule described by **Paar (Paar, 1979)**. The lowest state is expected to have a spin given by $j_p + j_n - \beta$, where $\beta \approx \left(1/j_p + 1/j_n\right)^{-1} \pm 1$. The +1 occurs when S_n and S_p are both aligned or ant aligned with l_n and l_p and the -1 occurs when only S_n or S_p is aligned with l_n or l_p. When applied to the $\nu f7/2\pi g7/2$ multiplet, a minimum spin of 6 is predicted, whereas the observed spin of 3 is predicted when this rule is applied to the $\nu f7/2\pi d5/2$ multiplet. The nearby 4^-, 2^-, and 1^- levels, although surely mixed, do lie in sequences that are suggested by the parabolic rule."

F. Iachello, S. Bastiani ***(Kernfysisch Versneller Instituut, University of Groningen, Netherlands; Istituto di Fisica, Politecnico di Torino, Italy)*****, Effects of proton pair vibrations in the low-lying spectrum of closed-shell nuclei: structure of 48Ca, Nucl. Phys, A228, 356-364 (1974):**

"In recent years detailed experimental studies have shown the occurrence of low-lying collective states in closed-shell nuclei. In nuclei with $Z = N$ (16O and 40Ca), these states have been interpreted as multi-particle-hole states (Bassichis, Ripka, 1965; Kelson, 1965; Brown, Green, 1966). In terms of elementary excitations (phonons) of angular momentum (λ), parity (π) and transfer quantum number (α) they have been described (Feshbach, Iachello, 1973) as $\left(\lambda^{\pi}\ \alpha = 0\right)^n$ where n = 4 in 16O and n = 4 or 8 in 40 Ca . On the other hand, in closed shell nuclei with $Z \neq N$ (208Pb) the low-lying collective states appear to be of a different nature and have been interpreted as pair vibrations (Broglia, **Paar,** Bes, **1971a,1971b)**. In terms of elementary excitations, pair vibrations are describable as $(\lambda^{\pi}\ \alpha = +2) \otimes (\lambda^{\pi}\ \alpha = -2)$."

E. Wallander, A. Nilsson, L.P. Ekström, G.D. Jones, F. Kearns, T.P. Morrison, H.G. Price, P.J. Twin, R. Wadsworth, N.J. Ward ***(Department f Physics, Chalmers University of Technology, Gothenburg, Sweden; Research Institute of Physics, Stockholm, Sweden; Oliver Lodge Laboratory, University of Liverpool, United Kingdom)*****, States in 89Sr excited by the 86Kr (α, n)89Sr reaction, Nucl.Phys. A361, 387-398 (1981):**

"The configurational properties of the levels below 2.1 MeV in 89Sr are well known from previous work (Blok et al., 1977). Thus, the first excited $5/2^+$, $7/2^+$ and $9/2^+$ levels have been established as almost pure core-coupled states ($2^+ \otimes \nu d5/2$), whereas the first $1/2^+$ and $3/2^+$ levels have strong single-particle components. It is thus of great interest to compare the position of these core-coupled states and the B(E2) values for their decay with the predictions of some reasonable model, e.g., the particle-anharmonic vibrator model. The formalism of such a model has recently been presented in a paper on 87Sr (ref. Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**. A more thorough account is given by **V. Paar (1981).** The only free parameter of the model is the spectroscopic quadrupole moment $Q_v(2)$ of the 2^+ state of the core nucleus, which has so far not been measured for 88Sr. As can be seen in fig. 4, the level energies fit reasonably well for $0.15 \le Q_v(2) \le 0.20$, the minimum rms deviation being obtained at $Q_v(2) = +0.16$ e$\cdot$b. The relative magnitudes of the B(E2) values also fit well for the same $Q_v(2)$ range; however, their absolute values are almost a factor of two smaller than calculated (see table 4). It is very gratifying to find that the theory yields almost the same prediction for $Q_v(2)$ from the 87Sr data (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981),** viz. +0.24 e$\cdot$b. As for the absolute B(E2) discrepancies they were almost the same in the two nuclei. The $5/2^+ \rightarrow$g.s. transition in 87Sr (ref. Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)** is just as much faster as the theory demands than the other transitions from the same multiplet."

R.A. Broglia, G. Colo, F. Barranco, G. Gori, E. Vigezzi, J. Terasaki, P.F. Bortignon, N. Breda ***(Dipartimento di Fisica, Universita di Milano, Italy; INFN, Sezione di Milano, Italy; Niels Bohr Institute, Copenhagen, Denmark; Escuela de Ingenieros Industriales, Universidad de Sevilla, Spain; INFM, Sezione di Milano, Italy)*****, Pairing in finite systems: nuclei and fullerenes, Phys.Scipta T88, 173-181 (2000):**

"While much work has been invested in the study of the renormalization effects of the exchange between nucleons of high-lying modes (giant resonances), little has been done in exploring the consequences of the exchange of low-lying surface vibrations. This in spite of the fact that in the few cases studied it was found to lead to matrix elements of the same order of magnitude as those typically associated with the standard nucleon-nucleon interaction (Bohr, Mottelson, 1975; Broglia, **Paar**, Bes, **1971)**."

A.N. Andreyev, D. Ackermann, S. Antalic, H.J. Boardman, P. Cagarda, J. Gerl, F.P. Hessberger, S. Hofmann, M. Huyse, D. Karlgren, A. Keenan, H. Kettunen, A. Kleinbohl, B. Kindler, I. Kojouharov, A. Lavrentiev, C.D. O´Leary, M. Leino, B. Lommel, M. Matos, C.J. Moore, G. Munzenberg, R.D. Page, S. Reshitko, S. Saro, H. Schaffner, C. Schlegel, M.J. Taylor, K. Van de Vel, P. Van Duppen, L. Wissman, K. Heyde (*University of Liverpool, United Kingdom; GSI Damstadt, Germany; University of Leuven, Belgium; University of Jyväskylä, Finland; JINR Dubna, Moscow, Russia; Comenius University Bratislava, Slovakia; Royal Institute of Technology Stockholm, Sweden; University of Gent, Belgium; Johannes Gutenberg-University Mainz, Germany*), α-decay spectroscopy of light odd-odd Bi isotopes – I: ^{188,190}Bi nuclei, Eur. Phys. J. A18, 39-54 (2003):

"**Paar´s** rule **(Paar, 1979)** which results in an energy splitting within a given proton-neutron multiplet that depends quadratically on spin J(J+1) can be applied in many cases to deduce relative positions of the multiplet states. The **Paar´s rule** can be considered as a particular case of a more general approach.

One could tentatively assign the states at 441, 356, 281 and 255 keV as the members of the $(\pi 2d_{3/2}^{-1}\nu 1i_{13/2})_{5+\rightarrow 8+}$ multiplet cannot be below the long-isomeric (10^-) state at 374 keV and therefore the 441 keV state could be tentatively assigned the spin and parity of $I^\pi = (8^+)$. In such a case, the states at 356, 281 and 255 keV should have the spin and parity of $5^+ \rightarrow 7^+$. This scenario is in general agreement with the predictions of the **Paar´s rule** (**Paar, 1979**). Taking into account all above arguments, the state at 356 keV should have I^π (5^+), while the states at 281 and 255 keV should be assigned the values of (6^+) and (7^+), see (**Paar, 1979**)."

C.A. Stone, S.H. Faller, W.B. Walters (*US National Institute of Standards and Technology; University of Maryland, USA*), Structure of odd-odd Sb-132, Phys. Rev. C39, 1963-1971 (1989):

"**Paar** showed that level splitting within odd-odd multiplets has a J(J+1) dependence and that the centroid of particle-hole multiplets in ^{132}Sb moves down in energy while the centroid of particle-particle and hole-hole multiplets moves up in energy. The staggering can be accounted for in the **Paar´s** model (**V. Paar**, Nucl. Phys. A331, 16 (1979)."

F. Iachello (*A.W. Wright Nuclear Structure Laboratory, Yale University, USA*), Supersymmetry in nuclei, ACS Symp. Ser. 324, 2-13 (1986):

"Conclusions: The concept of supersymmetry in nuclei has been extended in the last year to include the proton-neutron degree of freedom (Hübsch, **Paar, Vretenar, 1985;** Van Isacker et al., 1985). With this extension, it becomes possible now to predict properties of odd-odd nuclei. This, in addition to providing the first experimental example of supersymmetry in physics (Casten, Feng, 1984; Iachello, 1985), this concept appears now to be able to make predictions for yet unknown quantities. The experimental determination of the predicted spectra will indicate to what extent supersymmetry is useful in nuclear physics."

S. Landowne, R.A. Broglia, R. Liotta *(Niels Bohr Institute, University of Copenhagen, Denmark)*, On the importance of indirect processes in one particle transfer reactions induced by heavy ions, Phys.Lett. 43B, 160-164 (1973):
"We now note that the mechanism responsible for indirect processes in the transfer reaction also produces correlations in the 96Zr ground state and single-particle admixtures in the 97Nb multiplet (Flynn, Igo, Broglia, Landowne, **Paar**, Nilsson, **1972**). The admixtures give rise to the dressed states$|1g9/2 \otimes 3^-(96Zr); j\rangle_{dressed} = |1g9/2 \otimes 3^-(96Zr); j\rangle + a_{nlj}|nlj\rangle$. The values of the a_{nlj} calculated with the macroscopic particle-vibration coupling model (Mottelson,1968; Broglia et al., 1969; Hamamoto, 1969) are given in Table 1. The large result for $a_{1h11/2}$ is due to the 1h11/2 and 1h9/2 states being only $lh\omega/2\pi$ apart and the matrix element between them implies no spln-flip."

R.E. Anderson, P.A. Batay-Csorba, R.A. Emigh, E.R. Flynn, D.A. Lind, P.A. Smith, C.D. Zafiratos, R.M. DeVries *(Department of Physics, University of Colorado, Boulder, USA; Nuclear Structure Research Laboratory, University of Rochester, New York, USA)*, (3He, *n*) reaction near and above *Z* = 82, Phys.Rev. C19, 2138-2145 (1979):
"We might expect the normalization *N* value to lie between 20 and 40 depending upon optical model choices. In fact, the present reaction provides an ideal case for an empirical determination of *N*, for any given set of optical potentials, as there exist numerous wave function sets relative to the doubly closed 208Pb cores. These sets have been shown to reproduce the (t, p) cross sections quite well as, for example, in the case of 210 Pb (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**. Tables III and IV summarize the results for various wave functions relative to the 208Pb core for the (3He, n) reaction using both a value of N = 22 and the value N = 30 which is the average value of N giving ε = 1.0 for the various theoretical wave functions."

C. Chung, W.B. Walters, D.S. Brenner, A. Aprahamian, R.L. Gill, M. Shmid, R.E. Chrien, L.J. Yuan, A. Wolf, Z. Berant (*University of Maryland; USA; Clark University, Worcester, USA; Iowa State University, USA*), Decay of Ba-142 to levels of odd-odd La-142, Phys.Rev. C28, 2099-2114, 1983:
"We showed the quantitative parabolic relationship in odd-odd N=83 nuclides using a method outlined by **Paar.** In this section we will extend the results of that analysis to higher lying multiplets in 140La and 142Pr. Here α_1^0 is the spin vibration interaction as defined by **Paar**."

R.A. Broglia, P.F. Bortignon, F. Barranco, E. Vigazzi, A. Idini, G. Potel (*Dipartimento di Fisica, Universita di Milano, Italy; Niels Bohr Institute, University of Copenhagen, Denmark; INFN, Sezione di Milano, Italy; Departamento de Fisica Aplicada III, Universidad de Sevilla, Spain; Department of Physics, University of Jyvyskyla, Finland; National Superconducting Cyclotron Laboratory, Michigan State University, USA; Lawrence Livermore National Laboratory, California, USA*), Unified description of structure and reactions: implementing the Nuclear Field Theory program, Phys. Scr. 91, 063012 (2016):
"This theory, tailored after Feynman's version of QED (Feynman, 1962) and based on the concept of elementary modes of excitation and of their interweaving through the particle-vibration coupling mechanism (Bohr, Mottelson, 1975), (Mottelson, 1968; Hamamoto, 1969,1970; Bes, Broglia, 1971; Broglia, **Paar,** Bes, **1971**), was, at the time, essentially developed conceptually, mainly as the result of Copenhagen-Buenos Aires collaboration (Broglia, **Paar,** Bes, **1971;** Bes et al., 1974,1975,1976; Bes, Broglia, 1975,1977), Broglia et al., 1976; Bortignon, 1977; Bortignon, Broglia, Bes, Liotta, **Paar, 1976**; Bortignon et al., 1977, 1978). In what follows we take up one example from structure and one from reactions, namely: 1) The quantitative role multipole pairing vibrations (Bes, Broglia, 1971a; Bes, Broglia, 1971b; Broglia, **Paar,** Bes, **1971a;** Broglia, **Paar,** Bes, **1971b;** Flynn et al., 1971,1972; Bes et al., 1972; Broglia et al., 1974; Bes, Broglia, 1978; Bortignon, Broglia, 1978; Broglia, 1981; Bohr, Mottelson, 1982; Barranco et al., 1987; Bes et al., 1988; Baroni et al., 2005) play in clothing elementary modes of excitation, and the systematic and detailed description of the properties of non-conventional modes of vortex-like nature (1^- Cooper pairs)."

W. Baldridge, N. Freed, J. Gibbons (Department of Physics, Pennsylvania State University, USA), Semi-realistic shell model studies in the lead region. II. 211Bi, Phys.Lett. B46, 341-345 (1973):
"The even-parity 13/2, 3/2 and 15/2 levels are also strongly affected by the vibration coupling. The mixing for the $13/2^+$ state occurs between the configurations i13/2 and f7/2 $\otimes 3^-$ while that for the $3/2^+$ and $15/2^+$ states, between the g9/2 and j15/2 neutron configuration and the vibration. The latter mechanism is responsible for the fractionation of the octupole strength in 210Pb (Hamamoto, 1969; (Flynn, Igo, Broglia, Landowne, **Paar**, Nilsson, **1972**)."

N. Blasi, G. Lo Bianco (*Universita di Milano, Italy*), High-spin states of odd-odd nuclei in the interacting boson-fermion-fermion, Phys. Lett. B185, 254-258 (1987):
"The supersymmetry formalism was extended to odd-odd case by Hübsch and **Paar**."

A.B. Balantekin, Y. Pelivan *(Department of Physics, University of Wisconsin, Madison, Wisconsin, USA)*, Supersymmetry and nuclear pairing, J.Phys. G34, 1783-1787 (2007):
"Dynamical supersymmetries relate the spectra of even-even nuclei, considered as states of a

system of correlated fermion pairs approximated as bosons, and odd-even nuclei, considered as states of a system of such bosons plus unpaired fermions (Balantekin et al., 1981, 1983; Iachello, 1980; Amado et al., 1991; Balantekin and **Paar, 1986;** Schmitt et al., 1988; Navratil et al., 1996; Metz et al., 2000, 2003, Cejnar et al., 2003, Barea et al., 2005; Jolie et al., 2004; Leviatan, 2004, 2005)."

P. Paradis, G. Lamoureux, R. Lecomte, S. Monaro (*Departement de Physique, Universite de Montreal, Canada*), Measurement of static quadrupole moments of the first 2^+ states in 94Mo, 96Mo, 98Mo, and 100Mo. Phys.Rev. C14, 835-841 (1976):

"Very few theoretical calculations on the sign and magnitude of Q_2^+ of the molybdenum nuclei exist in the literature. Only very recently **Paar** (**Paar, 1974**) has calculated the level structure and nuclear properties of 94Mo and 95Mo using the particle-vibrational coupling model. The Q_2^+ value calculated by this author for 94Mo is -0.26 eb. Even though this value is larger than that found experimentally, the sign and magnitude are consistent with those determined with the positive sign of the interference term. It appears, however, that the magnitude of Q_2^+ depends strongly on the competition among the contributions of the available shell model levels of the two valence neutrons. In turn, these contributions are crucially dependent on the positions of some single particle states. For instance, in 94Mo the Q_2^+ value sensitive to the position of the s1/2 state with respect to the d5/2 state. By slightly raising the position of the s1/2 state (the neutron single-particle levels are taken by **Paar** as determined by a 92Mo(d,p)93Mo reaction (Moorhead and Moyer, 1969)) the Q_2^+ decreases in absolute value, and for large displacement of the s1/2 level the Q_2^+ could even become positive and small (Q_2^+ = 0.1 eb). Thus, it seems that for 94Mo (and probably also for the other even molybdenum isotoppes) there exists a situation similar to that found in the cadmium and tellurium nuclei (**Alaga, Paar, Lopac, 1973; Paar, 1973**).

K. Yanase, E. Teruya, K. Higashiyama, N. Yoshinaga (*Department of Physics, Saitama University, Japan; Department of Physics, Chiba Institute of Technology, Japan*), Shell-model study of Pb, Bi, Po, At, Rn, and Fr isotopes with masses from 210 to 217. Phys.Rev. C98, 014308 (2018):

"In 210Pb and 212Pb the almost degenerate 3_1^-, 4_1^-, ..., 12_1^- states are predicted at 2.682 MeV and around 2.69 MeV, respectively. However, the experimental 3_1^- states are located at 1.870 MeV and 1.820 MeV, respectively. These octupole one-phonon states are constructed by the particle-hole excitations (Hamamoto, 1970; Flynn, Igo, Broglia, Landowne**, Paar,** Nilsson, **1972**), which are beyond the present shell-model framework "

G. Vanden Berghe (*Seminarie voor Wiskundige Natuurkude, Rijksuniversiteit Gent, Balgium*), A semi-microscopic calculation for the (2p-1f) nuclei 59Ni, 56Fe and 57Fe, Z. Phys. A279, 223-232 (1976):

"**Paar (Paar, 1972a)** has treated 56Fe in a semi-microscopic model, where two-proton hole clusters are coupled to a quadrupole vibrational field in 58Ni. Although this approach does not explain all the levels observed below 3.6 MeV in 56Fe, it gives a rather fair description for the experimentally known reduced E2 transition probabilities. The isotope 57Fe has been treated in different theoretical approaches. Hamamoto and Arima (1962) and McGrory (1966) used shell model calculations, whereas Lawson and MacFarlane (1961), Sood and Hutcheon (1967) and Comfort et al. (1971) treated this nucleus with the rotational model in the strong coupling limit. On the contrary, **Paar (Paar, 1972b)** applied the three-particle-neutron-cluster core coupling model (Alaga model) to 57Fe and was able to reproduce very well the electromagnetic properties, in particular the ground state magnetic moment. However very recently, new experimental information became available for that nucleus. High-spin states are reported in a 34Cr(α,n)57Fe reaction (Sawa.1972). Spectroscopic factors for states up to 5.3 MeV were extracted from a 56Fe(d,p) reaction (Thomson, 1974). While the agreement between **Paar's** results and the new experimental data seems very convincing and almost every experimental state has a calculated counterpart, the correlations remain speculative as long as spectroscopic factors are not calculated.

The particle-cluster core coupling model, applied here for description of considered nuclei, has already been successfully used in the same mass region by (**Paar, 1972b**; Vanden Berghe, 1975,1976). The appreciable amount of quenching for the g_S value seems to be typical for that mass region. **Paar (Paar, 1972b)** also used in his calculation for 57Fe a g_S value of that order of magnitude. Our semi-microscopic approach and the one of **Paar (Paar, 1972a)** report rather large B (E2, $6_1^+ \rightarrow 4_1^+$) values, which are of the order of magnitude of the B(E2, $2_1^+ \rightarrow 0_1^+$) value. We want to remark that the cluster field coupling model in even-even nuclei gives rise to generalized vibrational and intensity rules (GVISR) (Alaga, **Paar,** Lopac, **1973; Paar, 1975a, 1975b**). The quasi-vibrational situation for low-lying states with large B(E2) values for stop-over ($2_1^+ \rightarrow 0_1^+$, $4_1^+ \rightarrow 2_1^+$, $6_1^+ \rightarrow 4_1^+$, $2_2^+ \rightarrow 2_1^+$) and small B(E2) values for cross-over $2_2^+ \rightarrow 0_1^+$ transitions are qualitatively explained in the framework of these GVISR. The only experimentally known quadrupole moment is that of the first excited 2^+ state: $Q^{\exp} \approx$ -0.24 $\pm$ 0.058 eb (Legg, 1964). In the same parametrization as before we obtain a value of Q^{theory} = -0.25 eb. Since the results, obtained for the level scheme and the wave functions in the present investigation, are completely similar to the ones reported by **Paar (Paar, 1972b),** we shall restrict ourselves mainly to the comparison between the theoretical and experimental spectroscopic factors for 56Fe(d,p) reaction. The present results clearly indicate that the three-particle cluster core coupling model explains the structure of the negative-parity states in 57Fe up to 2.7 MeV quite satisfactorily.

Paar (Paar, 1972b) has discussed the electromagnetic properties of 57Fe. He predicted some band structure around the yrast line. The following two sequences with strong $\Delta I = 2$ transitions in each band appear in his calculation: $... 21/2_1^- \rightarrow 17/2_1^- \rightarrow 13/2_1^- \rightarrow 9/2_1^- \rightarrow 5/2_1^-$, $...19/2_1^- \rightarrow 15/2_1^- \rightarrow 11/2_1^- \rightarrow 7/2_1^-$. The E2 transitions between the sequences are retarded. Sawa (1972) has excited in his 54Cr(α,n) experiment high spin states up to 15/2⁻. He reports strong E2 transitions connecting the states $13/2_1^-$ and $9/2_1^-$, and $9/2_1^-$ and $5/2_1^-$, $11/2_1^-$ and $7/2_1^-$, confirming the model predictions. However, no transition has been observed between the

$15/2_1^-$ and $11/2_1^-$ states, indicating that the observed $15/2_1^-$ state has a structure which differs from the one calculated by **Paar (Paar, 1972b)**."

V.K.B. Kota, D. Majumdar ***(Physical Research Laboratory, Ahmedabad, India)*****, Application of spectral averaging theory in large shell model spaces: Analysis of level density data of *fp*-shell nuclei, Nucl.Phys. A604, 129-162 (1996):**
"Starting from the Bethe's Fermi gas form, there is a large growth in the development of NIP theories for calculating level densities. These include: (i) modifications of the Bethe form mainly via various parametrizations of level density parameter *a* (Ignatyuk,1983; Katarya, Rananurthy, 1980); (ii) inclusion of pairing via a temperature-dependent gap equation (Behkami, Huizenga, 1973; Huizenga, Moretto, 1972); (iii) collective effects via a convolution which gives an enhancement of the level densities by a collective enhancement factor given by the partition function of the collective Hamiltonians (D'Arrigo et al, 1991; Kota, 1993). On the other hand, there are attempts to develop an interacting particle level density theory. These studies include: (i) via Casimir operators of groups as done in the case of Wigner SU(4) (46 Bloch, 1954); Elliott SU(3) (Kanestrom, 1966; Hansen, Jensen, 1983) and single j-shell pairing (**Paar,** Sunko, Brant, Mustafa, Lanier, **1993)**; (ii) employing the CLT results of SAT, a preliminary attempt in this direction (Ayik, Ginnochio, 1974) and a more elaborate study (Grimes et al., 1983; Strohmaier, Grimes, 1988)."

B.K. Agrawal, A. Ansari ***(Saha Institute of Nuclear Physics, Cakcutta, India; Institute of Physics, Bhubaneswar, India)*****, Excitation energy and angular momentum dependence of nuclear level densities and spin cut-off factor in SPA and SPA+RPA approaches, Nucl.Phys. A640, 362-374 (1998):**
"For a correct theoretical investigation of nuclear level densities one should rely on the path integral representation of the partition function for a given interaction Hamiltonian. During the initial developments of the theory the effects of thermal fluctuation were incorporated in the static path approximation (SPA) to the path integral representation of the grand canonical partition function (Lauritzen, Bertsch, 1989; Arve et al., 1988; Agrawal, Ansari, 1992,1994; Alhassid, Bush, 1992; Rosignoli et al., 1996) where some model calculations were carried out. Now, we compare the values of fixed–J level density obtained uing (i) SPA approach, (ii) SPA+RPA approach and (iii) Bethe's formula. In Fig. 6 we have displyed the results for $\rho(E^*, J)$ in SPA at E^*= 10 and 30 MeV. Similar plots shown in Fig. 7 represent the ressults obtained within SPA+RPA. As pointed out in earlier works (Agrawal, Kataria, 1997; **Paar,** Sunko, Brant, Mustafa, Lanier, **1993;** Majumdar et al., 1996), we find here that Bethe's formula overestimates $\rho(E^*, J)$ for high *J* at fixed E^*. This is because Bethe's formula is based on spin cut-off (or Gaussian) approximation which ignores the effects of Pauli's exclusion priciple. On the other hand, the saddle point expression for $\rho(E^*, J)$ properly incorporates the effects of Fermi statistics and gives rise to a steeper fall of $\rho(E^*, J)$ near the yrast line."

U. Mayerhofer, T. von Egidy, G. Hlawatsch, J. Klora, H. Linder *(Physik Department, Technische Universität München, Garching Germany)*, Nuclear structure investigation with high resolution transfer reactions and n-capture results, J. Phys. G14, S137-S142 (1988):
"Recent theoretical publications describe odd-odd nuclei, for example 198Au, with the Interacting boson fermion fermion model, the so called IBFFM, and a model which describes the coupling of a particle with the core, the truncated quadrupole model PTQM (Balantekin, Brant, Lopac, **Paar,** Schult, Seyfarth, **1986;** Balantekin, **Paar, 1986;** Casten et al., 1986).
Fig.2. Comparison of the new experimental level scheme with the predicted scheme by (Balantekin, Brant, Lopac, **Paar,** Schult, Seyfarth, **1986)**.
Figure 2 compares the theoretical scheme of (Balantekin, Brant, Lopac, **Paar,** Schult, Seyfarth, **1986)** with the experimental scheme from the (d,p) and (n,γ) reactions. There is good agreement at low excitation energies. New calculations by **Paar et al.** are presently being performed in order to reproduce at the same time level energies, γ-branching ratios and (d,p) cross sections."

G.F. Bertsch, P.F. Bortignon, R.A. Broglia (*Michigan State University, USA; Istituto di Fisica Galileo Galilei Padova, Italy; Niels Bohr Institute, Copenhagen, Denmark*), Damping of nuclear excitations, Rev. Mod. Phys. 55, 287-314 (1983):
"The mean field RPA theory of nuclear motion has been remarkably successful for describing vibrational properties (see, for example, Broglia, **Paar,** Bes, **1971;** Ring, Speth, 1974; Bertsch, Tsai, 1975; Liu, Brown, 1976; Blaizot, Gogni, 1977). We wish to summarize the results of RPA here for two reasons. First, vibrational motion can be damped already in the mean-field theory, and we need to see how important this actually is for the vibration under consideration. Second, the coupling of nucleons to the internal degrees of freedom of the nucleus, a central problem of damping theory is closely related to the coupling of external fields to the nucleus, which the RPA treats. The recent progress is due to two improvements in the model. First, the use of large configuration spaces makes it possible to calculate absolute transition strengths, if the interaction is known or is adjusted to fit vibrational frequencies (Broglia, **Paar,** Bes, **1971;** Ring and Speth, 1974). The second advance in RPA is the use of self-consistent interactions derived from Hartree-Fock models."

G. Vanden Berghe (*Seminarie voor Wiskundige Natuurkunde, Rijksuniversiteit Gent, Belgium*), Semimicroscopic description for the negative parity states of 67Zn. Nucl.Phys. A265, 479-492 (1976):
"We describe the negative parity states by coupling three neutron hole clusters moving in 2p-1f shell to a quadrupole vibrational field (Alaga model) (Alaga, 1959**; Paar**, **1973,1974**; Vanden Berghe, 1974). Electromagnetic properties (B(E2) and B(M1) values, branching ad mixing ratios, static moments and lifetimes) are discussed in sect. 4. Some of them are explained in the framework of the generalized vibrational intensity and selection rules (GVISR) (Alaga, **Paar,** Lopac, **1973; Paar, 1975**). The Q-Q component of the residual force is included effectively in

the renormalization of the particle-field strength (**Paar, 1973, 1974**). The quantities N and R represent the mumber of phonons and the corresponding angular momentum of the N-phonon state, respectively. More details about the model can be found in refs. (Alaga, 1959; **Paar, 1973, 1974**; den Berghe 1974). The truncation of phonon states mostly gives rise to some stretching of the theoretical spectrum (**Paar, 1973, 1974).** The electric quadrupole moment of the ground state can be understood in terms of the generalized vibrational intensity and selection rules (GVISR) (**Paar, 1973, 1974;** Alaga, **Paar,** Lopac, **1973; Paar 1975**). The electric quadrupole moment of the ground state can be understood in terms of the generalized vibrational intensity and selection rules (GVISR) (**Paar 1973, 1974;** Alaga, **Paar,** Lopac, **1973; Paar, 1975**). Due to rule G1' (Alaga, **Paar,** Lopac, **1973; Paar, 1975)**, the static quadrupole moment of such a cluster state is enhanced over the single-particle estimate. The appearance of such sequences are characteristic for the present model and are created by the mechanism for the particle field coupling (Alaga, **Paar,** Lopac, **1973; Paar, 1975)**. We can present a qualitative discussion of the E2 transitions based on the generalized vibrational intensity and selection rules (GVISR) (Alaga, **Paar,** Lopac, **1973; Paar, 1975)**. The largest components in the $3/2^-_1$ and $3/2^-_2$ wave functions, revel the character of zhese states in the zeroth-order approximation. It should be pointed out that the basis of GVISR is not the usual but the rearranged perturbation series (Alaga, **Paar,** Lopac, **1973; Paar, 1975**). Therefore, GVISR stay effective, in spite of rather strong configuration mixing. Their predictions are conserved in the exact calculation and reflected in experiments. Calculations for 57Fe have already been performed in the same model by **Paar** (**Paar, 1972**)."

S. Leoni, A. Bracco, G. Colo, B. Fornal (*Department of Physics, University of Milano, Italy; Institute of Nuclear Physics PAN, Krakow, Poland*), Particle-phonon coupling: Understanding the variety of excitations in the low-lying spectra of odd nuclei. Eur.Phys.J A55, 247 (2019):
"In this context, we deem relevant to mention also other early works that have elucidated the special role played, in the region around 208Pb, by the coupling with the very collective 3^- (octupole) vibration (Hamamoto, 1974), as well as with the pairing vibrational modes (Bortignon, Broglia, Bes, Liotta**, Paar, 1976**). For instance, the multiplet made up in 209Bi by the odd h9/2 proton coupled with the 3^- phonon has been a remarkable testing ground. At the same time, (α, α'), (e, e'), and (p, p') inelastic scattering data (Harvey et al., 1965; McCarthy et al., 1966; Iwasaki et al., 1979; Klaasse**, Paar, 1978**) give, at least in the case of 63Cu and 65Cu, a significantly large E3 strength for these states (≈20 W.u.), that one would attribute to the coupling with the 3^- phonons of 62Ni (B(E3)=13(2) W.u..) and 64Ni (B(E3) =10(2) W.u.) (Speak, 1989), respectively.

K. Vetter, A.O. Macchiavelli, D. Cline, H. Amro, S.J. Asztalos, B.C. Busse, R.M. Clark, M.A. Deleplanque, R.M. Diamond, P. Fallon, R. Gray, R.V.F. Janssens, R. Krucken, I.Y. Lee, R.W. MacLeod, E.F. Moore, G.J. Schmid, M.W. Simon, F.S. Stephens, C.Y. Wu (*Lawrence Berkeley National Laboratory, California, USA; University of Rochester, New*

York, USA; Argonne National Laboratory, Lemont, Illinois, USA; North Carolina State University, Raleigh, North Carolina, USA; Triangle Universities Nuclear Laboratory, Durham, North Carolina, USA), **Fragmentation of the two-phonon octupole vibrational states in ^{208}Pb, Phys. Rev. C58, R2631-R2635 (1998):**
"A deviation from a pure harmonic vibration and a splitting of the $J^{\pi} = 0^{+}, 2^{+}, 4^{+}$ and 6^{+} members of the two-phonon multiplet has been predicted due (iii) to the interaction with pairing vibrations (Blomquist, 1970; Broglia, **Paar,** Bes, **1971a, 1971b**; Schuck, 1976; Curuchet etal., 1988)."

F. Iachello, A. Arima (*Yale University, USA; University of Tokyo, Japan*): The interacting boson model, Cambridge monographs on mathematical physics, Cambridge University Press, Cambridge (1987):
"From the mathematical point of view, the two realizations are equivalent and produce identical results. The realization (1.24) is called the Schwinger realization (Schwinger, 1965) since it is based on a realization of the algebra of bilinear products of boson operators introduced originally by Schwinger. A third realization, called the Dyson realization (Dyson, 1956) is also sometimes used. The interrelation among the three realizations have been discussed recently in detail by Kyrchev and **Paar (1986)**.
As in the case of the Hamiltonian and transition operators, other realizations of the transfer operators are possible. Kyrchev and **Paar** (Kyrchev, **Paar, 1983**) have developed an algorithm by means of which two-nucleon transfer reaction strengths can be evaluated within the framework of the Holstein-Primakoff realization."

H. Feshbach (*Massachussetts Institute of Technology, USA*), Nuclear structure, reactions and symmetries, World Scientific, Singapore (1986):
"A direct attack on the properties of 198Au couples valence proton and neutron quasiparticles to the IBM O (6) core, using spin-spin residual interaction as well as boson-fermion interaction (Balantekin and **Paar**). The calculated spectrum is in good agreement with the experimental data."

J.E. Lynn (*AERE, Harwel, United Kingdom*), Capture gamma-ray spectroscopy and related topics, American Institute of Physics, New York, p. 951 (1985):
"**Paar** presented a detailed set of calculations, culminating in a complete spectrum prediction for a hypernucleus."

T.V. Ragland, R.J. Mitchell, R.P. Scharenberg (*Physics Department, Purdue University, West Lafayette, USA*), On the static quadrupole moments of the 2_1^+ states in 126Te and

128Te, Nucl. Phys. A250, 333-340 (1975):
"The problem of correctly predicting from some theory the quadrupole moments Q_{2^+} of the first 2^+ states in the doubly even tellurium isotopes is easily seen by examining the literature (Tanura, Udagawa,1966; Balbutsev, Dzholos, 1968; Lopac, 1970; Almoney, Borse, 1971; Marshalek, 1972; Alaga, **Paar,** Lopac, **1973;** Tamura, Kishimoto, 1973; Sorensen, 1973; Degrieck, Vanden Berghe, 1974). It should be pointed out that the sign and magnitude of the Q_{2^+} is very sensitive to the positions of the single-particle states in which the two extra protons are allowed to move. Particularly important is the position of the 2d3/2 state.This effect is seen in two other semimicroscopic calculations (Lopac, 1970; Alaga, **Paar,** Lopac**, 1973**) and is also seen in the microscopic calculations. The experimentally determined quadrupole moments now available should help in understanding the structure of the tellurium isotopes."

A. Kuriyama, T. Marumori, K. Matsuyanagi, R. Okamoto, T. Suzuki (*Department of Physics, Kyushu University, Japan; Institute for Nuclear Study, University of Tokyo, Japan; Department of Physics, Kyoto University, Japan*), Microscopic structure of breaking and persistency of "Phonon-plus-odd-quasi-particle picture", Suppl. Prog. Theor. Phys. 58, 138-159 (1975):
"These conclusions do not exclude a possibility of a decomposition among many-quasi-particles if, e.g., some of them lie far from the chemical potential: In some cases of physical situations in shell structure, there may be frequent occurrence of a possibility that the dressed n-quasi-particle mode with n > 3 can be approximately decomposed into the correlated cluster in the valence shell and the phonons of the "core". Recall here that such a possibility was already pointed in Chaps. 3 and 4 in relating the picture of the dressed 3QP mode to that of the Alaga model (Alaga, 1959,1967; **Paar, 1973**)."

A.Kuriyama, T. Marumori, K. Matsuyanagi, R. Okamoto (*Department of Physics, Kyushu University, Japan; Institute for Nuclear Study, University of Tokyo, Japan; Department of Physics, Kyoto University, Japan*), Persistency of AC state-like structure in collective excitations, Suppl. Prog. Theor. Phys. 58, 103-137 (1975):
"Recently, the collective structure of the $3/2_1^+$ state in 95 Mo has been investigated in terms of the semimicroscopic model in which the three-neutron valence-shell cluster is interacting with the quadrupole vibration of the "core" (Choudhury, Clemens, 1969; **Paar, 1974**). Similar investigations have also been done for odd-proton I isotopes with Z=53 (**Paar, 1973;** Almar et al., 1973; Vaden Berghe, 1974; Choudhury, Friedman, 1971). The results of these investigations indicate the remarkable improvements over the conventional particle-vibration-coupling model. Namely, the appearance of the low-lying $3/2_1^+$ state (in 95Mo) and $5/2_2^+$ states (in I isotopes) is well reproduced in these calculations, together with their enhanced E2-transition properties. This fact implies the importance of explicitly taking into account the three-particle correlations in the valence-shell orbits."

A.Kuriyama, T. Marumori, K. Matsuyanagi (*Department of Physics, Kyushu University, Japan; Institute for Nuclear Study, University of Tokyo, Japan; Department of Physics, Kyoto University, Japan*), Analysis of low-lying states in spherical odd-mass nuclei, Suppl. Prog. Theor. Phys. 58, 53-102 (1975):

"By investigating the stability of the spherical BCS vacuum against the collective 3QP vacuum against the collective 3QP correlation, we point out an interesting relation between our new viewpoint and the Bohr-Mottelson's old suggestion (Bohr, Mottelson, 1953) concerning the possible connection between the appearance of the spin (j-1) state as the ground state and the onset of quadrupole deformation. In the course of these, the relation between our microscopic model and the recent works based on the semi-microscopic models (**Paar, 1973;** Alaga, 1967) (which start from the particle-vibration coupling Hamiltonian (Bohr, Mottelson, 1975)) are also discussed by putting special emphasis on their underlying picture for the AC states."

D. Ardouin, R. Tamisier, M. Verges, G. Rotbard, J. Kalifa, G. Berrier, B. Grammaticos (*Institut de Physique de Nantes; Institut de Physique Nucleaire, Orsay, France; Centre d'Etudes Nucleaires de Saclay, France*), Systematics of the proton stripping reaction on 69,71Ga, 75As, 79,81 Br isotopes and nuclear structure of the Ge-Se isotopes, Phys.Rev. C12, 1745-1781 (1975):

"This suggests the existence in these nuclei of sizable distinct components such as $(p1/2)^2(p3/2)$ or the coupling of single-particle components with collective excitations as in the recent results of **Paar (Paar, 1973)** for 69Ga. However, these calculations, as well as the result for the 72Ge ground state, mean that the f5/2 or p1/2 subshells are filling before the p3/2 subshell is filled. This is qualitatively consistent with the existence of $J^{\pi}=3/2^-$ ground state observed for all of the nuclei between Z=29 and 37 except 71As and 83,85Rb."

A.Kuriyama, T. Marumori, K. Matsuyanagi, R. Okamoto (*Department of Physics, Kyushu University, Japan; Institute for Nuclear Study, University of Tokyo, Japan; Department of Physics, Kyoto University, Japan*), Microscopic structure of a new type of collective excitation in odd-mass Mo, Ru, I, Cs and La isotopes, Suppl. Prog. Theor. Phys. 53, 489-503 (1975):

"Here it should also be emphasized that, even if the special role of the 3QP correlation in the specific orbit is relatively relaxed, this does not necessarily mean that we return to the physical situation which can be treated within the framework of QPC theory. Rather, it may indicate the necessity of investigating the roles of the 3QP correlations newly arises in the different orbits. This will be discussed in a forthcoming paper, in connection with the investigation on microscopic structure of breaking and persistency of the "phonon-plus-quasi-particle picture" based on the semi-phenomenological approaches (Kisslinger, Sorensen, 1963; Yoshida, 1962; **Paar, 1973**; Choudhury, Clemens, 1969; Hamamoto, 1969).

G. Lhesonneau, J. De Raedt, H. Van de Voorde, H. Ooms, R. Haroutunian, E. Schoeters, R E. Silverans, L. Vanneste (*Katolieke Universiteit Leiden, Departement Natuurkunde, Netherlands*), Angular correlation and nuclear orientation study of 131I populated in the decay of $131Te^{m}$, Phys.Rev. C12, 609-615 (1975):
"Very recently several theoretical calculations have been carried out on odd iodine isotopes. In these calculations the coupling of a three-proton cluster to the quadrupole vibrational field is considered (Vanden Berghe, 1974; **Paar, 1973;** Almar et al., 1973). In general, this model gives a better account of the complexity of the experimental spectra than the simpler quasiparticle plus phonon calculations (Kisslinger, Sorensen, 1963). The lowest negative parity state is the $11/2^-$ state at 1646 keV. This agrees with the predictions of **Paar (Paar, 1973).** According to Ref. **(Paar, 1973)** this state is to be interpreted as a h11/2 single particle state. Indeed, the M2(E3) transition (1646 keV) and the E3 transition (1496 keV) the ground state ($g7/2^+$) and the first excited state (d5/2) are intense compared to the E1 transitions to the $9/2^+$ states at 852, 910, and 1060 keV."

E.A. Henry, R.A. Meyer (*Lawrence Livermore National Laboratory, Livermore, California, USA*), Systematic study of the structure of odd-mass lanthanum nuclei. II. Levels in 135La from 135Ce decay, Phys.Rev. C12, 1321-1335 (1975):
"Recent calculations by **(Paar, 1973)** and Almar et al. (1973), which use a particle-phonon coupling scheme with a quadrupole force and include three-particle configurations of the type $(1g7/2)^3_{5/2}$, have been more successful in predicting the energy of the low-lying $5/2^+_2$ in iodine nuclei."

D.G. Sarantites (*Department of Chemistry, Washington University, St. Louis, Missouri, USA*), Properties of high-spin states in 95Tc from 93Nb(α,2n)95Tc*(γ) reaction spectrometry: A test of the cluster-core coupling model; Phys.Rev. C12, 1176-1204 (1975):
"Recently, **Paar (Paar, 1973)** considered the coupling of a three-quasiparticle or -hole valence-shell cluster to quadrupole vibrations of the core and concluded the coexistence of quasivibrational and quasirotational features in the 107Ag spectrum. These calculations for 95Tc are identical with those of **Paar (Paar, 1973)** based on the Alaga model (Alaga, 1959) except for the choice of the model parameters., in this model, excitations of the core up to four phonons are included and the coupling constant is treated as an adjustable parameter to reproduce the $9/2^+_1 \rightarrow 7/2^+_1$ energy separation in $^{103}_{45}Rh_{58}$, which in turn is treated as arising from the particle configuration $[(\pi p1/2\ \pi p3/2\ \pi f5/2)^{-2}\ (\pi g9/2)^7]$ coupled to the core."

R.M. Del Vecchio, I.C. Oerlich, R. A. Naumann (*Joseph Henry Laboratories, Princeton University, USA*), Study of 105Ag and 107Ag with the (p,t) reaction, Phys.Rev. C12, 845-855 (1975):
"A theoretical treatment of the silver isotopes employing a basis of three proton holes in the

Z=50 shell coupled to phonon states of a vibrational core has been given (**Paar, 1973)**.The Hamiltonian included particle-particle and particle-phonon interactions. The eigenstates which emerge are rather complicated but give a good account of electromagnetic properties of 107Ag and 109Ag. Figure 7 shows a comparison of the theoretical spectrum of the negative parity states with our 107Ag spectrum. The agreement is quite reasonable and shows that some aspects of weak coupling are preserved despite the complexity of the model. The interesting appearance of low lying $11/2^-$ and $13/2^-$ theoretical states seems to be a feature of the experimental spectrum as well."

V. Berg, C. Bourgeois, R. Foucher (*Institut de Physique Nucleaire Orsay, France*), Some features of odd Au nuclei revealed by half-life measurements, Journal de Physique 36, 613-616 (1975):

"For the identification of the $9/2^-$ state in 193Au, the extensive studies by Vieu and Dionisio (1974) give aid. Their table of analogue states in 193Au and 195Au, i.e., states with the same spin and parity, nearly same excitation energy and identical depopulation mode, shows that the 789.9 keV $9/2^-$ level in 193Au has no equivalence in the 195Au isotope. The level lies about 200 keV higher than the $9/2^-$ state in 191Au. It decays to the $11/2^-$ isomer and is fed as the $9/2^-$ states in 189Au and 191Au by a pure E2 and a mixed M1+E2 transition (Fig. 1). However, calculations of transition rates performed within a frame of the Alaga-Paar 3-hole cluster model (**Paar, 1973**) (using parameters fitting for the positive parity states and without octupole coupling), do not give the large retardation factors expected for the deexciting transitions (Vieu, Dionisio, 1974)."

U. Hagemann, H.J. Keller, H.F. Brinkmann (*Zetralinstitut für Kernforschung, Rossendorf bei Dresden, Germany*), Collective excitations in the 123,125I nuclei, Nucl.Phys. A289, 292-316 (1977):

"Calculations with a single particle (Rustgi et al., 1968) and a three-quasiparticle–vibration coupling model (**Paar, 1973;** Vanden Berghe, 1974; Kuriyama et al., 1975) have already been carried out for the 127-131I nuclei. It was shown that the coexistence of quasirotational and quasivibrational structures should also occur in the odd-mass I-isotopes (**Paar, 1973).** Theoretical studies were made within the framework of the pairing plus quadrupole force model (Kisslinger, Sorensen, 1963) and of the particle-core coupling model (Rustgi et al., 1968). However, these models are incapable of explaining the complex schemes. It has been shown that one has to consider explicitly the particle clustering in these nuclei (**Paar, 1973;** Vanden Berghe, 1974; Kuriyama et al., 1975) (the iodine isotopes have three protons outside the closed proton shell at Z = 50. **Paar (Paar, 1973)** and Van den Berghe (Vanden Berghe, 1974) obtained good agreement with the experimental data for the low-lying states by using a model of a three-particle valence proton shell cluster coupled to the quadrupole vibration field."

R.E. Anderson, J.J. Kraushaar, R.A. Emigh, P.A. Batay-Csorba, H.P. Blok (*Department of Physics and Astrophysics, University of Colorado, Boulder, USA*), The level structure of

111Ag via the 110Pd (3He, d)111Ag reaction, Nucl.Phys. A287, 265-279 (1977):
"Information on the extent to which such mixings are expected and a more general understanding of the levels of the odd silver isotopes has been provided by the calculations of **Paar (Paar, 1973)**. Using the Alaga model, calculations have been carried out using a three proton-hole cluster moving in the 1g9/2, 2p1/2 and 2p3/2 shell model orbitals which are coupled to the quadrupole vibrations of the core. For the low-lying negative-parity states the results of these calculations are generally equivalent to the predictions of the simple weak coupling model, but in addition, the single-particle strengths observed in this experiment are reasonably well accounted for. For these low-lying states the $(g9/2)_0^{-2}$ cluster appears to be mainly an inert spectator and the Ag states can be for the greater part represented by a proton hole coupled to the Cd core states. For the positive-parity states **Paar's** calculations explain the occurrence of the low-lying $7/2^+$ and $9/2^+$ states and predict a series of higher-spin states ($11/2^+$ to $17/2^+$) up to about 2 MeV which are difficult to associate with the data because of incomplete information on these states. The present experiment, along with the earlier decay studies, indicates that there are many more low-spin ($1/2^+$ to $7/2^+$) states than can be accounted for by the calculation."

R.J. Peterson, R.A. Emigh, R.E. Anderson (*Department of Physics and Astrophysics, University of Colorado, Boulder; USA*), Level structure of 99Tc by inelastic scattering and proton stripping, Nucl.Phys. A290, 155-172 (1977):
"Finally, more sophisticated calculations could also be performed for 99Tc. The most obvious would utilize the method of **Paar (Paar, 1973)**, who calculates both positive and negative parity spectra of nuclei with three protons removed from closed cores. Although the presence of stripping into p1/2 and p3/2 orbitals indicates that the description of 99Tc must be more complicated than three protons plus a 96Zr core, it is not obvious that such a description would be inadequate. The low-lying spectrum of 99Tc does not exhibit the strong, low-lying strength for orbitals with Z > 50 which are present in the Ag isotopes (Auble et al., 1973), especially 111Ag (Anderson et al., 1977).These intruder states which are not treated in the basis assumed by **Paar (Paar, 1973)** provide the principle deviations from the predicted spectra for the Ag isotopes."

J. Liptak, K. Krištiakova, J. Krištiak (*Joint Institute for Nuclear Research, Dubna, Russia; Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic; Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*), Properties of 81Rb levels populated in the decay of 81Rb isomers, Nucl.Phys. A286, 263-281 (1977):
"The structure of the levels of odd-A nuclei in the vicinity of N or Z = 50 has been examined theoretically using different approaches ranging from the shell model with a residual interaction to the Coriolis-coupling model of the odd particle in the deformed nucleus, see refs. (Talmi, Unna, 1960; **Paar, 1973;** Kuriyama et al., 1975; Heller, Friedman, 1974). In $N \approx 81$ the unique-parity level of large spin *j* in the major shell (1g9/2) is being filled by neutrons. In these nuclei there is competition between spin *j* and spin (*j*-1) for the ground state. The simple shell model cannot account for the low-lying (*j*-1) state and therefore such an extra low-lying state with spin

$J = j-1$ and with unique parity has been called the anomalous coupling state. The structure of such states is not clear but two theories, **Paar (Paar, 1973)** and Kuriyama (Kuriyama et al., 1975) have attempted to explain it thoroughly. Furthermore, Bohr and Mottelson (Bohr, Mottelson, 1953) have pointed out a possible connection between the appearance of the (*j*-1) state as the ground state and the quadrupole deformation of the nucleus.

Our experimental results suggest a possibility of the existence of more than one state with $J^{\pi} = 3/2^{-}$, which have similar structure in the region of 0.5-1.0 MeV excitation energy.

The results of **Paar's** calculations **(Paar, 1973)** show one more $3/2^-$ state at ~ 0.8 MeV excitation energy. Moreover, if we take his calculated values of the reduced probabilities $B(M1, 5/2_2^- \rightarrow 3/2_1^-)$ and $B(E2, 5/2_2^- \rightarrow 1/2_1^-)$ for the $5/2_2^-$ state at 994.2 keV excitation energy, we are able to reproduce our experimental γ – ray branching ratio for the 357.7 and 803.5 keV γ -transitions. More detailed analysis of the decay modes of the excited levels with negative parity is difficult because we cannot identify our experimental levels with the levels of Paar's calculations unambiguously. But there is an indication that the excited states with π =-1 can be described as a neutron cluster coupled to the vibrating nucleus. The neutron cluster should be composed of the holes in the g9/2, p1/2 and p3/2 shells. At present, no definite conclusion can be made regarding the validity of Alaga's **(Paar, 1973)** or Kuriyama's (Kuriyama et al., 1975) model. However, if our extrapolation from Z = 47 to N = 45-47 is correct, then Alaga's model is more appropriate."

J. Liptak, J. Krištiak (*Joint Institute for Nuclear Research, Dubna, Russia; Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic; Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*), The excited states of 79Kr, Nucl.Phys. A311, 421-444 (1978):

"There are several theoretical papers aimed at explaining the structure of nuclei with N or Z $\approx$ 45 and, in particular, the $7/2^+$ state – the anomalous coupling state, by using the concept of spherical or deformed nucleus. The very successful quasiparticle-phonon coupling model of Kisslinger and Sorensen (Kisslinger, Sorensen, 1963) does not yield the anomalous coupling states. More rcently, **Paar (Paar, 1973)** has applied Alaga's model to odd nuclei with Z = 47. He obtained good agreement with experimental data, especially with regard to the anomalous coupling state. In the Alaga model (Alaga, 1959; **Paar, 1973)** the nucleus is described as a cluster of some particles outside of a vibrating core. Within the cluster the Pauli principle is conserved and as a residual interaction the pairing force is taken. Unfortunately, no calculations of this type exist for N $\approx$ 45. However, results of Ref. (Krištiak et al., 1978) have shown that the properties of positive-parity states on 83Kr can be described by using **Paar's** wave functions **(Paar, 1973),** taking into account an effective charge and the gyromagnetic ratio of neutron. Therefore, we tried to compare our level scheme of 79Kr (the neutron shell structure $n(1g9/2)^3$) with the calculations of the level scheme of 47Ag$\left[p(1g9/2)^{-3} \right]$). The comparison has shown that **Paar's** calculation **(Paar, 1973)** of negative-parity states reproduces the number and the order of states as well as their spins but does not reproduce their energies. Nevertheless, the overall agreement is remarkable. The comparison of **Paar's** calculation of even parity states with our proposed level scheme shows that the model is able to reproduce the $7/2^+$ and $9/2^+$ sates, as well as some others, but fails to reproduce the $1/2^+$ state (533.4 keV and the $5/2^+_3$ state (752.0 keV)."

L.G. Mann, W.B. Walters, R.A. Meyer (*Lawrence Livermore Laboratory, University of California, USA*), Levels of 129I populated in the decay of $129Te^m$ and $129Te^g$, Phys.Rev. C14, 1141-1151 (1976):

"For the structure of iodine nuclei, the simple particle-vibration model used by Kisslinger and Sorensen (Kisslinger, Sorensen, 1963; Heyde, Brussaard, 1967) failed on several points. The situation was improved when calculations based on the suggestions of Alaga, **Paar,** and coworkers (Alaga, Ialongo, 1965; **Paar, 1972a, 1972b; Paar, 1973)** were undertaken. These calculations introduce the effects of three-particle clustering in nuclei such as iodine. Table III lists a number of B(E2) values for 129I obtained by the Coulomb excitation work of Renwick et al. (1973), the conversion electron measurements by Bemis and Fransson (1965), the γ-ray multipolarity determinations of Silverans et al. (1973), and of DeRaedt et al. (1974), and the present work. The data are compared with calculations based on a single-particle or quasiparticle phonon model and on a three-particle cluster phonon model. The latter model gives excellent agreement for the $5/2_1$ to $7/2_1$ transition, and there is some overall improvement for the other transitions. Figure 7 shows a comparison between the 129I experimental level structure, and two calculated level structures based on the three-particle cluster-phonon model. There is good agreement between position and number of levels predicted for 129I and those found experimentally."

K. Krien, I.C. Oelrich, R.M. Del Vecchio, R.A. Naumann (*Joseph Henry Laboratories and Frick Chemical Laboratories, Princeton University, USA*), 108,106Pd(p, t) reactions and the core-coupling model, Phys.Rev. C15, 1288-1297 (1977):

"In view of the strong (p, t) population of the two phonon 0^+ levels in 104,106Pd the previous tentative$1/2^-$ to the weakly excited levels at 1096 and 1061 keV in 105,107Ag, respectively, must now be regarded as erroneous (DelVecchio et al., 1975). Recent (3He, d) reaction studies (Anderson, Kraushaar, 1975) indicate these states in Ag are not $1/2^-$ but rather positive parity states. Hence, one must look at higher excitations for the $1/2^-$ core-coupled states associated with 0^+ two phonon level. Unfortunately, possible candidates for the $1/2^-$ states are considerably higher in excitation than anticipated from the simplest core-coupling model. A recent theoretical calculation (**Paar, 1973)** which includes particle-vibration mixing places the first excited $1/2^-$ state in the odd-Ag isotopes above 2 MeV. Indeed, experimentally they are observed at about 2 MeV. The spacing between these $1/2^-$ states is comparable to the energy differences between the members of the doublet states. Therefore, phonon mixing is probably present in these $1/2^-$ states and a one-to-one correspondence between the even-Pd and the odd-Ag isotopes is not justified.

For this reason, we compare the summed (p, t) strength for all L = 0 states except the ground state and find good agreement."

S.V. Jackson, J.W. Starner, W.R. Daniels, M.E. Bunker, R.A. Meyer ***(Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico, USA; Lawrence Livermore Laboratory, University of California, Livermore, California, USA)*****, N = 85 nuclei. II. Decay of 4.15-h 149Tb^g to levels of 149Gd, Phys.Rev. C18, 1840-1856 (1978):**

"Odd-mass nuclei three nucleons away from closed shells have recently been the subject of many experimental and theoretical studies in an effort to determine the applicability of the dressed *n*-quasiparticle model (Kuriyama et al., 1975a,1975b,1975c,1975d; Fuyki et al, 1975) and the three-particle – clustering model (Alaga, Ialongo,1965; **Paar, 1972a,1972b,1972c; Paar, 1974;** Alaga, 1959,1969; Lopac, 1970; Alaga, **Paar,** Lopac, **1973; Paar, 1973;** Almar et al., 1973; Vanden Berghe, 1974a, 1974b ; Szanto de Toledo et al., 1977) to the nuclear structure of these nuclei. To date, the most of this work has dealt with nuclei near the *Z* = 28 and *Z* = 50 closed shells (see especially Refs. Kuriyama et al, 1975 and 18-21 Paar, 1973; Almar et al., 1973, Vanden Berghe, 1974; Szanto de Toledo et al., 1977) for theory and Refs. (Jackson, 1975; Meyer 1974,1975; Lhersonneau et al., 1975; DeRaedt et al., 1976) for examples of experimental work. Recent attempts (Peker, Sigalov, 1974,1975; **Paar, 1976)** to treat odd-mass nuclei near the *N* = 82 closed shell (especially *N* = 85 nuclei) with the above models have been hampered by a lack of data on the level structure of these nuclei.

This type of structure change, involving the appearance at low energy levels having spin values of *J* -1 and *J* – 2, where *J* is the shell-model-predicted ground-state spin ($J \geq 7/2$), is observed in several nuclide regions where three identical particles or identical holes become available near a shell closure (Jackson, 1975; Meyer, 1974,1975). The observed properties of these levels have led to two nuclear models: the dressed *n* – quasiparticle model of Marumori, Kuriyama, and coworkers (1975a,1975b,1975c,1975d; Fuyki et al, 1975) and the three-particle-clustering (Alaga) model of Alaga, Paar, and Sips (Alaga, Ialongo,1965; **Paar, 1972a,1972b,1972c; Paar, 1974;** Alaga, 1959,1969; Lopac, 1970; Alaga, **Paar,** Lopac, **1973; Paar, 1973**). In both models the explicit treatment of the Pauli principle for the three particles (or holes) in the valence shell results in the $(J)^{\pm 3}$ multiplet being split, with the *J*-1 state dropping down near the ground state (of spin *J*). In fact, for a sufficiently high coupling constant, the $J-1$ state can become the ground state (e.g., Ref. **Paar, 1973)**. The $J-2$ state can also be brought down, either through the explicit treatment of five particles (Kuriyama et al., 1975) (for example in $^{101}_{43}$Tc where the $9/2^+$, $7/2^+$, and $5/2^+$ states from the 1g9/2 clustering lie at 0, 9, and 15 keV, respectively) or as a consequence of including the identical-parity $J-2$ shell-model orbital in the model space (Kuriyama et al., 1975). Two calculations (**Paar, 1976;** Garrett et al., 1976) using a limited form of the Alaga model have been performed. In both cases the neutrons were restricted to the 2f7/2 shell model orbital. The *N* = 85 nuclei were treated as having a $(2f7/2)^3$ cluster coupled to quadrupole phonons, whereas the *N* = 87 nuclei were treated as having a $(2f7/2)^{-3}$ cluster coupled to quadrupole phonons. Peker and Sigalov (1974,1975) showed that the Alaga model provides a good qualitative description of some of the observed states of several *N* = 85 and *N* =

87 nuclei even though the model parameters reported for 1f7/2 nuclei were employed in the calculation. They were able to account qualitatively for the occurrence of the low-lying 5/2$^-$ state, the relative magnetic moments of the 7/2$^-$ and 5/2$^-$ states, the variation in the $7/2^- - 5/2^-$ energy difference for Nd, Sm, and Gd nuclei, and the decay patterns of the yrast states with $J \leq 27/2$ in 151Gd. Garrett et al. (Garrett et al., 1976) performed a similar calculation for levels in 147Sm and 149Sm and were able to account qualitatively for much of the low-energy level structure, the enhanced ground-state E2 transition probabilities and the yrast decay patterns for $J \leq 17/2$. In Fig. 5 we present the odd-parity levels observed in the *N* = 85 nuclei 149Gd, 147Sm, and 145Nd , along with the preliminary results of detailed Alaga model calculation of 145Nd levels by Paar **(Paar, 1976)**.This calculation includes the 2f7/2, 1h9/2, and 3p3/2 shell model orbitals in its model space, but is relatively simplistic in its choice of single-particle energies and the value for the coupling constant between the three-particle cluster and the quadrupole phonons. It is clear nevertheless, that the Alaga model can explain many features of the level structures displayed in Fig. 5. An even better fit to the 147Sm and 149Gd levels could of course be obtained if the model parameters were varied as a function of *Z*."

M.N. Vergnes, G. Rotbard, E.R. Flynn, D.L. Hanson, S.D. Orbesen, F. Guilbaut, D. Ardouin, C. Lebrun (*Institut de Physique, Nucleaire, Orsay, France; Los Alamos Scientific Laboratory, University of California, USA; Institut de Physique, Nantes, France*), 71Ga and 73Ga levels as observed in the (t, p) reaction, Phys.Rev. C19, 1276-1287 (1979):
"Odd Ga isotopes have only 3 protons outside the Z = 28 closed shell and an even number of neutrons. They are therefore amenable to relatively simple theoretical interpretation. As an example, calculations **(Paar, 1973)** describing the negative parity levels by coupling a three-proton cluster to the quadrupole vibrations of a doubly even core reproduce rather well the low energy part of the spectra for the 65Ga, 67Ga, and 69Ga isotopes. The striking splitting of the L = 0 strength in three approximately equal components, observed in 73Ga strongly supports a transition in nuclear deformation between N = 40 and 42."

T. Paradellis, C.A. Kalfas (*Tandem Accelerator Laboratory, Nuclear Research Center "Demokritos", Athens, Greece*), Excited states in 107Ag from the decay of 107Cd, Z.Physik 271, 79-87 (1974):
"Information concerning the structure of 107Ag is of particular importance from a theoretical point of view. Recently **Paar (Paar, 1973)** presented the results of his calculations of a three-hole cluster coupling to a vibrator for the case of Ag isotopes among others. A comparison of theory and experiment is presented in the closing paragraph of this work. The experimental level structure of the positive and negative parity states of 107Ag is separately compared in Fig. 3 with the predictions of the calculations of **V. Paar (Paar, 1973)**. In these calculations the excited states of Ag are regarded as arising from the coupling od a three-proton hole cluster moving in the g9/2, p3/2 and p3/2 shell model states with the quadrupole vibrations of a vibrator which include up to three phonons. It should be noted that in these calculations no attempt has been made for a best fit. The model explains the lowering of the 7/2$^+$ state over the 9/2$^+$ as a

characteristic geometrical effect of coupling three holes in the g9/2 configuration to quadrupole phonons **(Paar, 1973)**. Fig. 3. Comparison of experimental and theoretical **(Paar, 1973)** level structure of 107Ag. Table 4. Experimental and theoretical (**Paar, 1973)** electromagnetic properties of transitions proceeding between negative parity states in 107Ag.
From Fig. 3 it is evident that the model successfully reproduces the position of the $5/2^+$ states observed experimentally at 922.1 and 1 223 keV. This is true also for the tentative $7/2^+$ level introduced at 1 389 keV. The other positive parity states predicted by theory below 1.5 MeV bear high spin and probably are not populated at all in the β-decay of 107Cd. Exception is the $3/2^+$ state predicted by theory at 0.9 MeV. No experimental level could be identified with this state. Unfortunately, not enough information is available for the electromagnetic properties of the transitions proceeding between the positive parity states to allow a meaningful comparison with theory. Exception is the 32.3 keV transition between the $9/2^+$ and $7/2^+$. Theory predicts for this transition B(M1) = 0.033 $(nm)^2$ and B(E2) = 0.22 $(eb)^2$ while the experiments indicate B(M1) = 0.029 $(nm)^2$ and $0.08 \leq B(E2) \leq 1.0$ $(eb)^2$ (in agreement between theory and experiment). As for the negative parity states the model reproduces very well the level sequence up to 1.0 MeV **(Paar, 1973)**. In Table 4 the experimental branching ratio, mixing ratio, B(M1) and B(E2) values are compared with the predictions of the theory. An inspection of this table indicates that the agreement with theory extends to all other electromagnetic properties as far as the levels below 1 MeV are concerned."

D.D. Warner, R.F. Casten, M.L. Shelts, H.G. Börner, G. Barreau *(Brookhaven National Laboratory, Upton, New York, USA; Institute Laue-Langevin, Grenoble, France)*, Nuclear structure of 195Pt, Phys.Rev. C26, 1921-1935 (1982):
"Limitations on the use of the simple Nilsson potential in this region become particularly evident when the negative parity structure is considered, as will be seen below. Nevertheless, the use of a more realistic core description will not necessarily lead to problems in the description of the observed positive parity structure, since it has been shown (Alaga, **Paar, 1976)** that a structure resembling a decoupled band can result from a core particle coupling calculation involving a core which is not rotational."

K. Heyde, M. Waroquier, P. van Isacker, H. Vincx *(Laboratorium voor Kernfysica, Gent, Belgium; Institut de Physique Nucleaire, Universite Lyon I, France)*, Description of positive parity bands in odd mass In isotopes, Nucl.Phys. A292, 237-252 (1977):
"Many of the properties of odd mass In isotopes, described by means of a band-mixing calculation with all Nilsson orbitals originating from the N = 4 h.o shell can also be described by means of coupling the spherical proton single-particle orbitals above the Z = 50 core, i.e. 2d5/2, 1g7/2, 2d3/2, 1h11/2, 3s1/2, to anharmonic vibrations of the underlying Cd core nuclei (Alaga, 1969; **Paar, 1975;** Alaga, **Paar, 1976)**. This is a macroscopic version of what could be performed in a semi-microscopic way by means of coupling all 1p-2h (seniority v = 1 and v = 3) configurations to the harmonic core vibrations of the Sn core nuclei. Recently, Alaga (Alaga, **Paar, 1976)** has indicated the importance of performing particle (hole) anharmonic-core

coupling calculations in order to reproduce decoupled" and "strong coupling" band systems in transitional odd-mass nuclei. These calculations refer to a single-*j* shell (particle or hole configuration) and therefore lead to rather simple analytic expressions. This becomes clear from the rule given by Alaga (Alaga, **Paar, 1976)** that for $Q(j)Q(2_1^+)$ > 0, as is the case for odd-mass In isotopes *j* is a particle orbit above Z = 50 (thus $Q(j) < 0$) and $Q(2_1^+)$ < 0 in all doubly even Cd nuclei, a decoupled band structure should develop. The interaction considered in this calculation reads $H = H_{p.c.} + \left[h\omega_2 / 2\pi A^{21} ((b_2^+ b_2^+)_2 b_2)_0 + \text{h.c.} \right]$, where $H_{p.c.}$ is the core-coupling interaction for harmonic vibrations (Bohr, Mottelson, 1969, 1975; Alaga, 1969; **Paar, 1975;** Alaga, **Paar, 1976;** Heyde, Brussard, 1967) and A^{21} describes the anharmonicity, being related to the quadrupole moment of the underlying core by means of the approximate relation $Q(2_1^+) = -3.03 A^{21} B(E2; 2_1^+ \to 0_1^+)^{1/2}_{\text{harmonic}}$. The core-coupling strength was fixed at ξ_2 =6.0 as resulting from the B(E2) values in the adjacent doubly even nuclei in the harmonic approximation (Bohr, Mottelson, 1969, 1975; Alaga, **1969; Paar, 1975;** Alaga, **Paar, 1976).** The electromagnetic operators within the particle-core coupling model will not be given here explicitly (Bohr, Mottelson, 1969, 1975; Alaga, **1969; Paar, 1975;** Alaga, **Paar, 1976;** Heyde, Brussard, 1967)."

J. Gizon, A. Gizon, R.M. Diamond, F.S, Stephens ***(Institut des Sciences Nucleaires, Grenoble Cedex, France; Lawrence Berkeley Laboratory, University of California, USA)*****, The h11/2 and g7/2 band structures in 131Ce and 129Ce, Nucl.Phys. A290, 272-284 (1977):** "Meyer-ter-Vehn (Meyer-ter-Vehn, 1975) has shown that consideration of a γ-deformation in addition to the β-deformation can better account for the level energies and transition probabilities of odd-A nuclei in the $A \approx 190$ and $A \approx$ 135 regions. Probably other theories can equally well treat the problem of transitional nuclei in particular, anharmonic vibrator models (Alaga, **Paar, 1976;** Dönau, Hagemann, 1976)."

M.L. Stolzenwald, G. Lhersonneau, S. Brant, K. Sistemich ***(Institut für Kernphysik, KFA Jülich, Germany)*****, The $\left[g_{9/2}^2 \right] 8^+$ state in 96Zr, Z.Physik A327, 359-360 (1987):**
"An 8^+ state has been identified at 4390 keV in the doubly semi-magic nucleus 96Zr Calculations with the formalism of the parabolic rule **(Paar, 1979)** for the splitting of the members of the $[g9/2 \otimes g7/2]$ multiplet support this interpretation of the isomer since they show that the 8^+ level is strongly lowered with respect to the unperturbed energy. The $\pi - \nu$ interaction brings this state down to 1.2 MeV in agreement with the approximate excitation energy of the isomer."

W.F. Mueller, B. Bruyneel, S. Franchoo, M. Huyse, J. Kurpeta, K. Kruglov, Y. Kudryavtsev, N.V.S. Prasad, R. Raabe, I. Reusen, P. Van Duppen, J. Van Roosbroeck, L. Vermeeren, L. Weissman, Z. Janas, M. Karny, T. Kszcot, A. Plochocki, K.L. Kratz, B. Pfeiffer, H. Grawe, U. Köster, P. Thirolf, W.B. Walters ***(Instituut voor Kern- en***

*Stralingsfysika, University of Leuven, Leuven, Belgium; Institute of Experimental Physics, Warsaw, Poland; Institut für Kermchemie, Universität Mainz, Mainz, Germany; Gecsellschaft für Schwerionenforschung, Darmstadt, Germany; Physik Department, Technische Universität München, Garching, Germany; Sektion Physik, Universität München, Garching, Germany; Department of Chemistry, University of Maryland, College Park, Maryland, USA)***, Beta decay of 66CO, 68Co, and 70Co, Phys.Rev. C61, 054308 (2000):**

"Probable configuration and spin assignments for the two isomeric states in 68Co can be made by comparison with odd-A Co and Ni isotopes. With Z = 27 the proton configuration observed in Co nuclei is $\pi f_{7/2}^{-1}$ with a consequent spin and parity for the ground states of odd-A Co nuclei of $7/2^-$ (Weissman et al., 1999; Mueller et al., 1999). Neutron single particle configurations can be deduced from levels in 69Ni. It is observed to have two β decaying isomers with spins and parities $9/2^+$ and $1/2^-$ (Mueller et al., 1999). The configurations of these two states have been interpreted as $\nu g_{9/2}^{+1}$ and $\nu p_{1/2}^{-1} \nu g_{9/2}^{+2}$, respectively. Thus, the two isomers observed in 68Co are formed by the coupling of an f7/2 proton hole to the $\pi g_{9/2}^{+1}$ and $\nu p_{1/2}^{-1} \nu g_{9/2}^{+2}$ configurations. Based on studies for coupling the angular momentum of particle and hole states (Moinester et al., 1969; **Paar, 1979)** the lowest state of the $\pi f_{7/2}^{-1} \nu g_{9/2}^{+1}$ multiplet is the $I_1 + I_2 - 1$ level, namely 7^-. Additional justification for this assignment comes from comparison to the $\pi g_{9/2}^{-1} \nu g_{9/2}^{+1}$ states in 90Nb (Firestone, 1996) where the $I_1 + I_2 - 1$ level is indeed the lowest state of this multiplet. Using similar arguments, but for hole-hole coupling rather than particle-hole, the likely spin and parity of the $\pi f_{7/2}^{-1} \nu p_{1/2}^{-1} \nu g_{9/2}^{+2}$ configuration is 3^+."

J. Dobes, S.P. Ivanova, R.V. Jolos, R. Pedrosa *(Institute of Nuclear Physics, Rez, Czech Republic; Joint Institute for Nuclear Research, Moscow, Russia)*, Boson mapping and the microscopic collective nuclear Hamiltonian, J.Phys. G17, 125-134 (1991):

"In recent years, methods that map many-fermion problems onto many-boson ones have been studied intensively. In nuclear physics, an aim of such studies is to obtain a microscopic support for the phenomenological models of nuclear collective states. The bosonization of the fermion problem is accompanied by an identification of the subspace of relevant collective degrees of freedom and truncation of this full space to that subspace. There are three classes of microscopic investigations of nuclear collective structure in terms of boson models. In the first, the collective Hamiltonian is constructed within a simple underlying symmetry group (Chen et al., 1986; Wu et al., 1986, 1987; Kyrchev and **Paar, 1988;** Karadjov et al., 1988; Georgieva et al., 1989). Thus, the collective variables are fixed independently of the real physical system. As a result, a considerable coupling of the collective and non-collective degrees of freedom may occur."

A.W.B. Kalshoven, W.H.A. Hesselink, T.J. Ketel, J. Ludziejewski, L.K. Peker, J.J. Van Ruyen, H. Verheul (*Natuurkundig laboratorium, Vrije Universiteit, Amsterdam, Netherlands*), High spin states in 105Ag, Nucl.Phys. 315, 334-352 (1979):

"Typical for all the odd Ag isotopes is the low-lying $7/2^+$, $9/2^+$ doublet. An adequate description of the $7/2^+$ levels (I = j-1 anomaly) cannot be given in the one-particle-core coupling model. **Paar** has shown that the Alaga model can account well for this phenomenon (Paar, 1973). In the description of these nuclei with the Alaga model a cluster of three proton holes, moving in the g9/2, p1/2 and p3/2 shell orbits, is coupled to phonon excitations of the even Sn core. In this calculation the known properties of the low spin states are rather well reproduced. A comparison of the predictions of this model with experimental data on high spin states is interesting. In a similar case, the odd Au isotopes having three proton holes in the Z = 82 closed shell, both the axial symmetric and triaxial rotator models reproduce the experimental data for the unique parity band equally well as the cluster-vibrational model (**Paar,** Vieu, Dionisio, **1977**).
Starting with a description of 105Ag from a spherical basis we extended the cluster-vibrational calculations made by **Paar (Paar, 1973)**, to spins as high as 21/2. Only a $\left(g9/2\right)^{-3}$ configuration has been considered for the cluster of three proton holes. The phonon energy hω/2π = 1.o MeV, the coupling strength a = 0.8 MeV and the effective pairing strength G = 0.2 MeV were taken from ref. (**Paar, 1973)**. In fig. 8 the experimental level scheme is compared with the theoretical predictions. It was already shown by **Paar** that the cluster-phonon coupling model can account well for the anomalous $7/2^+$ level. Fig. 8 shows reasonable agreement between experimental and theoretical results.
The effective charges and gyromagnetic ratios taken in the cluster-phonon coupling calculations were in accordance with values previously used by **Paar (Paar, 1973)**. For g_R the lower limit (g_R = 0) and the upper limit (g_R = Z/A) were both used in the calculation. Transition probabilities, especially those for transitions between levels close to the yrast line, are satisfactory reproduced in both models. It is worthwhile noticing that the agreement of the cluster-phonon model is better for g_R = 0. This is due to a destructive interference between single particle and collective contributions in the M1 transition probabilities. The same fact has been noticed before for the odd In isotopes (Hesselink, Bron, Kam, **Paar**, van Peilgeest, Zephat, 1978). The high spin negative parity states excited in this reaction exhibit aregular band structure which is very similar to the bands observed in 109,11In (Hesselink, Bron, Kam, **Paar**, van Poelgeest, Zephat, 1978). It is worthwhile considering the results for a comparable situation with three proton holes in the Z = 82 closed shell, e.g., the odd 193,195Au isotopes. In these isotopes “decoupled" bands based on a h11/2 proton hole were observed. **Paar (Paar,** Vieu, Dionisio, 1977) showed that this band structure could also be reproduced with the cluster-vibration model."

G. Wenes, P. Van Isacker, M. Waroquier, K. Heyde, J. Van Maldeghem (*Institute of Nuclear Physics, Gent, Belgium; Institut de Physique Nucleaire, Universite Lyon, France*), Collective bands in doubly-even Sn nuclei: Energy spectra and electromagnetic decay properties, Phys.Rev. C23, 2291-2304 (1981):
"A general Hamiltonian, describing an interacting system of boson and fermion degrees of freedom can be written as ... The third term describes the interacting boson-fermion Hamiltonian with ξ_λ as the coupling strength, for its definition see Refs. (Heyde, Brussard, 1967; **Paar, 1973**). In a first step we solve the secular equation $H^{'} = |k; IM\rangle = \omega(I,k)|k; IM\rangle$ with

$|k; IM\rangle = \sum a^k((h_1h_2)J_h, NR; I)|(h_1h_2)J_h \otimes NR; IM\rangle$, where $\omega(I,k)$ gives the energy spectrum (describing the Cd nuclei) and a^k gives the expansion coefficients. Such calculations have been carried out before in describing doubly-even Cd nuclei (Alaga, 1969; Alaga et al., 1967; Alaga, **Paar,** Lopac, **1973; Paar,** Meyer, **1979**). In these references, full details on the formalism can be found. One can now approximate the collective E2 matrix elements $\langle I'k'|M(E2)_{coll}|Ik\rangle$ as being defined with respect to Cd core matrix elements. The later assumption is very plausible since the proton 2h system (for Sn and Cd, where the pairing energy $\Delta_{1g9/2} > \hbar\omega_2(\text{Sn})$) interferes in such a way with the collective E2 transition rate in the Sn nucleus to induce coherence **(Paar, 1972)**."

R.A. Meyer, J.E. Fontanilla, N.L. Smith, C.F. Smith, R.C. Ragaini ***(Lawrence Livermore National Laboratory, California, USA)*****, Level properties of $^{85}_{37}Rb_{48}$ from the decay of the 85Kr and 85Sr isomers and the cluster-vibration model, Phys.Rev. C21, 2590-2599 (1980):**
"The 37 neutron nuclei have been treated by the cluster-vibration model (CVM) **(Paar** et al., **1976a,b)**. Negative-parity states in 69Ge and 67Zn were described by coupling three holes in the subshell with single-particle configurations p1/2, p3/2, and f5/2 to the quadrupole vibration, i.e., it was assumed that for these nuclei N = 40 plays the role of a closed subshell. Here we extend this approach to 85Rb, which is a Z = 37 nucleus. The overall agreement between the experimental and calculated energy spectra and electromagnetic properties is reasonably good. In the present calculation we also include the tensor term in the M1 operator. Generally, it drastically affects the M1 transitions, which are *l*-forbidden in zeroth order. In our case, such a transition is the $3/2^-_1 \rightarrow 5/2^-_1$ M1 transition, which is in zeroth order of the type $|((f7/2^{-2})0, p3/2^{-1})3/2,00; 3/2\rangle \rightarrow |(f7/2^{-3})5/2,00; 5/2\rangle$. In this case, the destructive interference between the higher-order contributions to the M1 transition moment for a standard M1 operator is large, and such a transition is therefore strongly hindered in the presence of mixed wave functions **(Paar,** Brant, **1978)**. Inclusion of the tensor term in theM1 operator, with the usual value of the gyromagnetic ratio, g_p = 1.33 (Hamamoto, 1976; **Paar,** Brant, **1978)**, results in the calculated value B(M1) ($3/2^-_1 \rightarrow 5/2^-_1$) = 0.023 μ^2_N. This leads to a correct order of magnitude for the half-life $\tau(3/2^-_1)$. On the other hand, the other M1 transitions, which are not *l*-forbidden in zeroth order, are much less affected by the tensor M1 term."

Z. Gacsi, S. Raman ***(Institute of Nuclear Research, Hungarian Academy of Sciences,Debrecen, Hungary; Oak Ridge National Laboratory, Tennessee, USA)*****, Decays of 116Sb isomers to levels in 116Sn, Phys. Rev. C49, 2792-2795, (1994):**
"In studying levels in 116Sb reported earlier (Gacsi, Dombradi, Fevyes, Brant, **Paar, 1991),** $\sim 56 \times 10^6$ $\gamma\gamma$ −coincidence events were recorded in ~100 h from and in-beam study of the 113In($\alpha, n\gamma$) reaction. This experiment also yielded coincidence information pertaining to γ-rays emitted in the subsequent decays of 116Sb activities. The semimicroscopic model of Alaga gives a satisfactory description of 107-109Ag isotopes by coupling three proton holes, in the p1/2, p3/2, g9/2 subshells, to quadrupole vibrations of the core **(Paar, 1973)**. This intermediate

coupling model predicts the preponderate influence of the p1/2 configuration and noticeable contributions from the neighboring p3/2 and the $g9/2^{-2}$ pair of proton holes."

P.D. Barnes, E. Romberg, C. Ellegaard, R.F. Casten, O. Hansen, T.J. Mulligan, R.A. Broglia, R. Liotta ***(Department of Physics, Carnegy Mellon University, Pittsburgh, USA; Niels Bohr Institute, University of Copenhagen, Denmark; Los Alamos Scientific Laboratory, University of California, Los Alamos, USA; Institute for Theoretical Physics, State University of New York, Stony Brook)*****, Proton-hole states in 209Bi from the 210Po(t, α) reaction, Nucl.Phys. A195, 146-158 (1972):**

"Blomquist (1970) derived an effective proton $h9/2j^{-1}$ states) observed (McClatchie et al., 1970) in the reaction 209Bi (d, ^{3}He)^{208}Pb of 0.324 MeV attractive and almost independent of the hole configuration. The excellent agreement between the effective monopole interactions derived from 209Bi and from 208Pb strongly supports Blomquist's analysis and his contention that the proton pairing –vibration in 208Pb probably is shifted towards lower excitation energies by an amount of $\approx 4 \cdot 0.33$ MeV = 1.3 MeV (see ref. Broglia, **Paar,** Bes, **1971).**"

C. Ellegaard, P.D. Barnes, E.R. Flynn (Carnegie-Mellon University, Pittsburgh, Pennsylvania, USA; Los Alamos Scientific Laboratory, Los Alamos, New Mexico, USA), Levels of 209Tl amd 211Pb populated in the 210Pb(t,α)209Tl and 210Pb(t,d)211Pb reactions, Nucl.Phys. A259, 435-444 (1976):

"For the case of 211Pb one might expect to see a multiplet of states around 0.8 MeV corresponding to the coupling of the neutron in the g9/2 orbit to the 2^+ state. In fact, a calculation from the simple particle-vibration model (Mottelson, 1968) would predict about 10 % admixtures of both g9/2 and d5/2 single-particle strength. The striking thing in this case is that there is no indication of the expected admixtures. The experimental data, examples of which are given in fig. 7, set an upper limit of $\leq$ 1 % for both g9/2 and d5/2 admixtures. For 211Pb the above simple particle-vibration model is obviously not adequate. The properties of the low-lying 2^+ state of 210Pb have been discussed by Flynn et al. (Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**, who find that the state is accurately described, in terms of the paring model, as a collective pairing phonon. Thus, the coupling here is the coupling of a neutron to a neutron pairing vibration. For the low-lying states this means a neutron in a g9/2 orbit coupled to a vibration which is predominantly $(g9/2)^2$. This will give rise to exchange (blocking) effects, which could reduce the coupling significantly."

K. Heyde, P. Van Isacker, M. Waroquier, G. Wenes, M. Sambataro (*Institute of Nuclear Physics, Gent, Belgium; Kernfysisch Versneller Instituut, Groningen, Netherlands*), Description of the low-lying levels in 112,114Cd, Phys.Rev. C25, 3160-3177 (1982):

"A general Hamiltonian, describing the interacting system of vibrational excitations coupled to a few fermion degrees of freedom, can be written as ... Here, $\hbar\omega_2$ denotes the quadrupole phonon energy and ε_α the single-particle (-hole) energy. The third term describes the particle (hole) –

core coupling interaction with ξ_2 as the coupling strength (see Ref. Heyde, Brussard, 1967 and **Paar, 1973** for its definition); the fourth term describes the residual fermion interaction. Also, the Coulomb contribution for proton p-h residual interaction is included. One has to remark that the quadrupole operator, describing the particle-core coupling, has the standard expression obtained from the residual interaction between collective surface quadrupole vibrations and single-particle degrees of freedom (Heyde, Brussard, 1967 and **Paar, 1973**)."

J. Ludziejewski, A.W.B. Kalshoven, W.H.A. Hesselink, J. Bron, A. Van Poelgeest, H. Verheul, M.J.A. De Voigt (*Natuurkundig Laboratorium, Vrije Universteit, Amsterdam, Netherlands; Kernfysisch Versneller Instituut Groningen, Netherlands; Institute of Nuclear Research Swierk, Poland*), High-spin states in 103Ag and particle-core coupling at intermediate deformation, Nucl. Phys. A344, 266-282 (1980):

"The negative-parity states observed in odd silver nuclei are assumed to be the members of the multiplet arising from the coupling of odd particles to core excitations (Del Vecchio et al., 1975). However, the positive-parity states, particularly the so-called anomalous low-lying $7/2^+$state, cannot be explained by this simple model. A more complete description of the odd silver nuclei is given by **Paar (Paar, 1973)**, who showed that the coupling of the cluster of three proton holes to a vibrational Sn core gives a reasonably good description of the low-lying states either with negative or positive parity. In contradiction to the weak coupling model, the anomalous $7/2^+$ state is nicely explained by this model. Also, electromagnetic properties of the low-spin states are reasonably well reproduced by the three-proton-cluster vibrational model."

I. Burde, V. Richter, J. Tsaliah, I. Labaton (*Racah Institute of Physics, The Hebrew University, Jerusalem, Israel*), The excited states in the odd-odd 124I nucleus produced by the (p, n) reaction, Nucl. Phys. A385, 29-42 (1982):

"The occurrence of three groups of interconnected negative-parity low-lying states and the appearance of either two 2^- states or three 3^- states cannot be accounted for by only the two $\pi d5/2 \upsilon h11/2$ and $\pi g7/2 \upsilon h11/2$ multiplets. Apparently, the transition from 122Sb to 124I by interchanging one proton outside the closed shell by a cluster of three protons produces additional multiplets of low-lying negative-parity states. The implication of such a transition on the level structures have been discussed (Almar et al., 1973; **Paar, 1973**) for the odd iodine isotopes."

J.R. Lien, J. Gard, C. Lunde Nilsen, G. Løvhøiden, P.B. Vold (*Department of Physics, University of Bergen, Norway; Nuclear Structure Laboratory*, *University of Rochester, USA*) Level structure of 123,125I from the 122,124Te (3He, d) reactions, Nucl.Phys. A281, 443-460 (1977):

"Strong transitions are observed for the lowest $7/2^+$ and $5/2^+$ states corresponding to these states being of predominantly single particle nature. This is consistent with the theoretical calculations of Kisslinger-Sorensen model (Kisslinger, Sorensen, 1963) and the predictions of the particle cluster-vibration coupling model (**Paar, 1973;** Vanden Berghe, 1973). Above 1MeV excitation energy the higher-level density in the light I-isotopes makes a direct comparison between levels among different isotopes more difficult. A few levels where similar structure is observed are connected by dashed lines in fig. 5. It would be interesting to see whether this new information on the level structure in 123I and 125I can be explained in terms of the particle cluster-vibration model which has proved to be reasonably successful in explaining the structure of the heavier I-isotopes (**Paar, 1973;** Vanden Berghe, 1973)."

G.F. Neal, Z.P. Sawa, F.P. Venezia, P.R. Chagnon (*Department of Physics, University of Notre Dame, Indiana, USA*), Gamma-ray spectroscopy of 66Zn and 67Zn and the role of the g9/2 orbital, Nucl.Phys. A280, 161-179 (1977):
"Several authors (Veje, 1966; Goswami et al., 1973; Throop et al., 1975; Salzman et al., 1972; Kuriyama et al., 1971; **Paar, 1973;** Alaga, **Paar, 1976**) have discussed particle-phonon or quasiparticle–phonon coupling as it may apply to intermediate-mass nuclei. Alaga and **Paar (**Alaga, **Paar, 1976)** have recently discussed the particle-anharmonic-vibration coupling model as applied to unique-parity states in transitional nuclei, which may be directly applicable here. What they have found is that the appearance of either decoupled or strongly coupled sequences may result, depending on the values of $Q(j)$ and $Q_{vib}(2_1)$, the quadrupole moments of the particle and quadrupole phonon respectively, and the strength of the coupling. In particular the following features are predicted for moderately large, negative values of $Q_{vib}(2_1)$: (a) the I = j (here, 9/2) level is lowered, (b) the next group of levels holds the j+R, j+R-1 (but also j-R) states almost degenerate with one another while other states are relatively raised, and (c) the spacing of these levels above the I = j level is roughly independent of the coupling strength and approximately equal to the collective excitation energy alone. The relevant levels of 67Zn, fig. 8b, bear out this description, with $13/2^+$ and $11/2^+$ levels lining up with core 2^+ levels, $17/2^+$ possibly accompanied by $15/2^+$ levels corresponding to 4^+, and an apparent $11/2^+$ state corresponding to the $66Zn^+$ one. In this context it is interesting to note that the energies of the favored band in 67Zn, i.e., of the states with I = j, j+2, j+4, and j+6, are in better agreement with the rotational energy rule than the energies of the corresponding states in 66Zn."

L.G. Svensson, D.G. Sarantites, A. Bäcklin (*Uppsala University, Institute of Physics, Sweden*), Coulomb excitation of 99Tc, Nucl.Phys. A267, 190-204 (1976):
"Various theoretical models have been considered for odd mass Tc nuclei. The E2 transition from the $7/2^+$ state to the ground state has been observed to be considerably enhanced (Bond et al., 1972; Bergman et al., 1974; Svensson et al., 1974). Therefore, approaches involving collective effects, such as the phonon coupling model of Goswami et al. (1967,1968) involving coupling between forward- and backward-going amplitudes, the description in terms of "dressed three-quasiparticle states" by Kuriyama et al. (1972,1975) or calculations involving the coupling of three-particle "clusters" to phonons (**Paar, 1973**, Bargholtz, 1975) seem to be more adequate than e.g. a description of the $7/2^+$ state as a pure three-quasiparticle state (Kisslinger, 1966)."

P.R.G. Lornie, A. Kogan, G.D. Jones, M.R. Nixon, H.G. Price, R. Wadsworth, P.J. Twin ***(Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom)*****, Gamma-ray studies of the odd-parity states in Zn isotopes. II: Levels below 2.0 MeV in excitation energy in 67Zn, J.Phys. G4, 923-941 (1978):**

"In 67Zn the Alaga model (Alaga, 1959) has been utilized by Vanden Berghe (1976) and by **Paar,** Coffou, Eberth, Eberth (1976). In this model a cluster of three neutron holes was coupled to the quadrupole vibrations of 70Zn. Energy levels and electromagnetic decay properties of the low-lying states were calculated. Their level schemes are reproduced in figure 7. This model has one immediate success: low-lying $3/2^-$ states are reproduced. Transition strengths were again calculated only for the lowest few states, where reasonable agreement was found for the E2 enhancements. The ground-state decay of the 0.815 MeV level is better reproduced by this model than by Dikshit and Singh (1976). The E2 strength of the ground-state transition from the 1.517 MeV state was predicted to be 12 Wu, slightly smaller than observed."

G Rotbard, M. Vergnes, G. Berrier-Ronsin, J. Vernotte, R. Tamisier (***Institut de Physique Nucleaire, Orsay Cedex, France; Institut de Physique, Nantes, France*****), (p,t) strengths in the Ga isotopes, Nucl.Phys. A430, 409-425 (1984):**

"The spectra of the light Ga isotopes have been described in terms of a coupling scheme where a three-proton cluster, outside the Z = 28 closed shells, is coupled to the collective quadrupole excitations of the Ni core (**Paar, 1973;** Almar et al., 1972). This description predicts three states of proton cluster structure, a $3/2^-$ ground state and two low-lying $1/2^-$ and $5/2^-$ states, followed by a quadruplet of states with $J^\pi = 1/2^-$ to $7/2^-$, arising mainly from the proton ground-state configuration coupled to the 2^+ vibrational state of the core. If one assumes that the target ground state simply consists of an even-even core in its 0^+ ground state, coupled to a $3/2^-$ odd proton cluster (the calculations (**Paar, 1973;** Almar et al., 1972) indeed show that this is at least the dominant component), the (p,t) reaction populates only levels with at least one component in their wave function containing the target ground-state proton configuration. The momentum transfer L of the neutrons indicates, for each final level, the nature (0^+, 2^+, ...) of the core state involved. This allows, at least for the strongly populated levels, the determination of the nature of the collective and cluster parts of the component involved and gives an idea of the importance of this component in the wave function of the level. In the framework of the cluster-phonon-coupling model (**Paar, 1973;** Almar et al., 1972) the states of the quadruplet $1/2^-_2$, $3/2^-_2$, $5/2^-_2$, $7/2^-_1$ are of a rather mixed character, each state having two dominant components of similar magnitude: the zero-phonon component coupled to a seniority-three cluster and the one-phonon component coupled to the ground-state , seniority-one, cluster. The difference observed for the $7/2^-_2$ level, when comparing the distribution of the L = 2 (p,t) strength with the distribution of the $B(E2)\uparrow$ strength may be an effect of the mixed character of the wave function of this state, similar to the one predicted for the $1/2^-_2$, $3/2^-_2$, $5/2^-_2$, $7/2^-_1$ states of the multiplet, in the cluster-vibration model."

L.D. Wood, H.H. Bolotin, I. Morrison, R.A. Bark, H. Yamada, A.E. Stuchbery (*School of Physics, University of Melbourne, Australia; Department of Nuclear Physics, Australian National University, Canberra, Australia*), Gyromagnetic ratios of excited states in 107,109Ag, Nucl.Phys. A427, 639-649 (1984):

"The low-lying levels of the 107,109Ag nuclides have been the subject of considerable interest over the pat score of years (De Shalit, 1961; Robinson et al., 1969; Hasselgren et al., 1976; Vervier, Janssens , 1982; **Paar, 1973;** Kuhfeld, Hintz, 1975; Roney et al., Miller et al., 1973).It has been found that somewhat improved descriptions of 107Ag obtain in weak-coupling model-based analyses by consideration of the participation of the 1p3/2, 0f5/2, and 0g9/2 single particle orbitals as well (**Paar, 1973;** Kuhfeld, 1975)."

N. Kaffrell, P. Hill, J. Rogowski, H. Tetzlaff, N. Trautmann, E. Jacobs, P. de Gelder, D. De Frenne, K. Heyde, G. Skarnemark, J. Alstad, N. Blasi, M.N. Harakeh, W.A. Sterrenburg, K. Wolfsberg (*Institut für Kernchemie, Universität Mainz, Germany; Laboratorium voor Kernfysica, Gent, Belgium; Department of Nuclear Chemistry, Chalmers University of Technology, Göteborg, Sweden; Department of Chemistry, University of Oslo, Oslo, Norway; Universitas Gadjah Mada, Yogyakarta, Indonesia; Kernfysisch Versneller Instituut, Rijksuniversiteit, Groningen, Netherlands; Los Alamos National Laboratory, Los Almos, New Mexico, USA*), Levels in 107Rh, Nucl.Phys. A460, 437-454 (1986):

"The ground state of 107Rh: From simple shell-model considerations the 45th proton would be expected to occupy the 1g9/2 or 2p1/2 orbital. The later configuration is indeed found to be the ground stat in 99,101,103Rh, while the $9/2^+$ configuration represents the first excited state. With increasing neutron number, the energy difference between these two states is getting smaller, and in 105Rh a change occurs, shifting the $1/2^-$ state up to 130 keV excitation energy. Interestingly enough, the $9/2^+$ configuration does not become the ground state but is observed at 149 keV, still higher in energy than the $1/2^-$ state. The ground state is given a $7/2^+$ assignment by Flynn et al. (Flynn et al., 1983) which may be explained as a $\left|(1g9/2)^5_{v=3},\ 7/2^+\right\rangle$ configuration in lowest order. **Paar (Paar, 1973)** has shown, for the nearby odd-mass silver nuclei, that in addition important admixtures of the seniority v = 1 $9/2^+$ shell model wave function coupled to a 2^+ core-excited configuration (e.g. the $\left|(1g9/2)^5_{v=1},\ 9/2^+ \otimes 2^+; 7/2^+\right\rangle$ configuration), contributes in establishing both the excitation energy of the $7/2^+$ level and its electromagnetic (static and decay) properties. A similar situation is observed for 197Rh, where the ground state is populated by an *l* = 4 transfer in the (d,3He) reaction. Taking into account the analyzing power result of the ($\vec{t}, \alpha$) reaction work (Flynn et al., 1983), $7/2^+$ can be assigned unambiguously to the ground state of 107Rh. Possible three quasi-particle admixtures of the type $(\nu 2d5/2, \nu 1g7/2, \pi 1g7/2)_{7/2^+}$ in the final state will contribute to $1g7/2(\nu) \rightarrow 1g9/2(\pi)$ Gamow-Teller β-decay since the initial $5/2^+$ state also contains the 2d5/2 single-particle component. The latter decay possibility is in agreement with the calculations of **Paar (Paar, 1973)**, indicating that the core-excited 2^+ configuration is present in the final $7/2^+$ state (via the configuration $\left|(1g9/2)^5_{v=1},\ 9/2^+ \otimes\right.$

$2^+; 7/2^+\rangle)$, since in a microscopic decomposition of this 2^+ core state, the $\left|\nu_1(g7/2)\nu_2(d5/2)2^+\right\rangle$ component will clearly be present. Only the seniority v = 3 configuration suggested above is in line with the single-particle transfer studies. Moreover, the fact that no low-lying $3/2^+$ state can be calculated in the IBFM -1 model (in which three-quasiparticles are not explicitly treated) is consistent with the present suggestion. Detailed three-particle (hole) core coupling calculations by **Paar (Paar, 1973)** indicate that the lowest $3/2^+$ level has a more complex structure, i.e., collective admixtures are also present."

W. Andrejtscheff, L.K. Kostov, L.G. Kostova, P. Petkov, M. Senba, N. Tsoupas, Z.Z. Ding, C. Tuniz (*Bulgarian Academy of Sciencesn Institute of Nucler Research and Nuclear Energy, Sofia, Bulgaria; DEpartment of Physics and Astronomy, Rutgers University, New Brunswick, USA*), Some M1 transition strengths in odd-A nuclei away from closed shells, Nucl.Phys. A445, 515-533 (1985): "Low-spin states in arsenic (Z = 33) isotopes with A = 71 and 73 have recently been investigated (ten Brink et al., 1980) in the radioactive decay as well as in the (p, n) reaction. The results have been interpreted within the cluster-vibrational model (Alaga, 1959; **Paar, 1973**) and for positive-parity states also compared to some predictions of the asymmetric-rotor model (Toki, Faessler, 1976). Some general features of the *l*-forbidden M1 transitions have been studied within the cluster-vibrational model **(Paar,** Brant, **1978;** Meyer, ... , **Paar, 1980)**. In these studies, M1 transitions prohibited in zeroth order are shown to be only weakly influenced by the particle-vibration coupling, i.e., *l*-forbiddeness remains approximately valid. The role of the tensor term $\left[Y_2 s\right]^1$ in the Hamiltonian for the quantitative understanding of the transition rates has been stressed. This term is associated with the effects of the 1^+ core polarization and of the mesonic exchange current. These studies are of special interest as they might be interpreted in the sense that a complete consideration of all possible configuration admixtures away from doubly closed shells would have a weak influence due to destructive interference **(Paar, 1985)**. The most important effects seem to be governed by the tensor term providing non-negligible matrix elements between the main components in the wave functions. The above-mentioned model considerations **(Paar, Brant, 1978)** would suggest similar experimental *l*-forbidden B(M1) values around and away from closed shells. The quantities presented and discussed in this paper for nuclei away from closed shells facilitate some comparison with the known values around doubly-closed shells, e.g., in the vicinity of 208Pb."

Y. Shikata, M. Sakakura, T. Sebe (*Department of Physics, Aoyama Gakuin University, Tokyo, Japan; Department of Applied Physics, Hosei University, Tokyo, Japan*), A shell-model study on M1 and E2 properties of Zn, Ga, and Ge, Z.Phys. A300, 217-226 (1981): "The CVM results on 69Ga are taken from a work of **Paar (Paar, 1973)**. It is seen from the table that the present calculation explains most of the experimental data very well. Further, the shell model explains the E2 transitions in 69Ga better than the CVM. The transition strengths in 69Ge are deduced from lifetimes in (Auble, 1976) with the aid of mixing ratios and branching ratios reported by Paradellis et al. (1978). The CVM results are those calculated by **Paar** et al. **(Paar,**

Eberth, Eberth, **1976**). An agreement between theory and experiment is good for the E2 transitions in Table 5. Results of a CVM calculation on 64Zn are taken from a work by Lopac and **Paar** (Lopac, **Paar, 1978).** The effective M1 operator determined in Sect. 2 is used in the calculation of M1 transitions which are discussed in the following. The shell-model calculation on the even-even nuclei shows that the transition between the two lowest eigenstates is enhanced over other transitions. For example, the transitions $2_1 \rightarrow 0_1, 4_1 \rightarrow 2_1$, and $2_2 \rightarrow 2_1$ are enhanced in the calculation; whereas the transitions $2_2 \rightarrow 0_1, 4_1 \rightarrow 2_2$, and $0_2 \rightarrow 2_1$ are hindered. Therefore, the present model can well explain some features of the vibrational nuclei, but it does not reproduce the enhancement observed in the $0_2 \rightarrow 2_1$ transition. In the other hand, the CVM calculation by Lopac and **Paar (**Lopac, **Paar, 1978)** reproduces the enhancement in the E2 transitions in which the phonon number changes by one. In CVM, the $0_2 \rightarrow 2_1$ transition in 64Zn takes place essentially through a change of the vibrational motion. A proton cluster does not change its state during the transition. The enhancement in the calculated B/E2) comes from an enhanced transition matrix element between the two-phonon state with $J = 0$ and the one-phonon state. The corresponding neutron matrix element in the shell-model calculation is about one-third of this. As we have seen in Sect. 3, the experimental E2 transitions in the odd-A nuclei are rather better explained by the present shell model than the CVM. A role played by the vibrational motion, if it really exists, seems to be approximated by the use of the effective charges. The CVM can, however, reproduce the enhanced $0_2 \rightarrow 2_1$ transition in the even-even nuclei, whereas the present shell model cannot. **Paar** et al. (Lopac, **Paar, 1978)** explain this enhancement in 64Zn by a large E2 matrix element assumed between the neutron states. In order to reproduce this large matrix element by the present model (shell-model), an extraordinary large polarization charge is required for a neutron. The description of the 0_2 state is a future problem of shell-model calculations."

S. Roodbergen, H. Visser, W. Molendijk, H.S. Bedet, H. Verheul (*Natuurkundig Laboratorium,Vrije Universiteit, Amsterdam, Netherlands*), Transition probabilities in the Ni-Zn region, Z.Physik, A275, 45-50 (1975):

"For odd-mass gallium isotopes 65Ga, 67Ga and 69Ga Harms-Ringdahl et al. (Harms-Ringdahl et al., 1974) observed a strong resemblance for some properties e.g. the mainly single-particle character of the ground state, the first and second excited state. **Paar (Paar, 1973)** and Almar et al. (Almar et al., 1972) described these nuclei in a first approximation as consisting of a vibrating even-even Ni core and three valence protons in the 2p3/2, 1f5/2 and 2p1/2 orbits. For 69Ga not only the level scheme but also the transition probabilities were calculated. We calculated the theoretical values for the half-life of the $1/2^- \rightarrow 3/2^-$ transition of 62.0 keV in 65Ga, adopting the same B(N1) and B(E2) values as given for the corresponding transition in 69Ga by **Paar** and Almar et al. A comparison of these calculated value with calculated values is given in Table 4."

B. Hinfurtner, E. Hagn, E. Zech (*Physik-Department, Technische Universität München, Garching, Germany*), Nuclear magnetic resonance on oriented 103Ru in Fe, Nucl.Phys. A509, 541-549 (1990):

The existence of low-lying $3/2^+$ neutron states around A□ 100 can be explained with several theoretical models (De Shalit, 1961; Kisslinger, Sorensen, 1963;Sherwood, Goswami, 1966; Kuriyama et al., 1974) with some analogy to the proton $7/2^+$ non-single-particle states in this mass region **(Paar, 1972, 1973).** For 103Ru the situation is more complicated as the first excited state lies only 2.7 keV above the ground state. From 102 Ru(n, γ) studies, $I^\pi = 3/2^+$ was proposed for the 103Ru ground state (Delang et al.,1973). This assignment was supported by in-beam γ-ray studies (Klamra, Rekstad, 1975). The systematic trend of magnetic moments of $5/2^+$ (υd5/2) and $3/2^+$ states is illustrated in fig. 3. It is obvious that the magnetic moments of the $3/2^+$ states are smaller in magnitude by a factor of □ 2, indicating the existence of collective contributions reducing the neutron-single-particle magnetism. The structure of the $7/2^+$ non-single-particle proton states has been well described by **(Paar, 1972, 1973).** According to his calculations, the main components of the wave functions of these $7/2^+$ states (in 107,109Ag) a $|(\pi g9/2)^n_{s=3}; 7/2^+\rangle$, $|(\pi g9/2)^n_{s=1}; 9/2^+ \otimes 2^+; 7/2^+\rangle$, $|(\pi g9/2)^n_{s=3}; 7/2^+ \otimes 2^+; 7/2^+\rangle$, the amplitudes being of the order of 0.5. In analogy, the main components for the $3/2^+$ neutron states could be $|(\nu d5/2)^n_{s=3}; 3/2^+\rangle$, $|(\nu d5/2)^n_{s=1}; 5/2^+ \otimes 2^+; 3/2^+\rangle$, $|(\nu d5/2)^n_{s=3}; 3/2^+ \otimes 2^+; 3/2^+\rangle$.The g-factors of these components are easily calculated with the Lande formula. The g-factor of the second component describes the experimental values moderately well, the agreement being not perfect, however. Assuming the wave function being a sum of above three components, it is obvious that the contribution to the g-factor from the first and the third component may cancel if the amplitudes are of equal size, as predicted by **Paar (Paar, 1972, 1973).**

R.W. Hoff, R.F. Casten, M. Bergoffen, D.D. Warner (Lawrence Livermore National Laboratory, California, USA; Brookhaven National Laboratory, Upton, New York, USA), Test of a phenomenological model of odd-odd deformed nuclei: an ARC study of 176La, Nucl.Phys. A437, 285-300 (1985):

"The level structure of odd-odd nuclei has always presented a particularly difficult challenge. Their theoretical description necessitates the coupling of both neutron and proton single-particle degrees of freedom to the core motion as well as the inclusion of effects arising from the additional np interaction. Some simple models (Schiffer, 1971; **Paar, 1979)** applicable to near closed-shell nuclei with little configuration mixing are available and have recently been rather successful."

J**. Treherne, J. Genevey, R. Beraud, A. Charvet, R. Duffait, M. Meyer, F.A. Beck, T. Byrski** ***(Institut des Sciences Nucleaires, Grenoble Cedex; Institut de Physique Nucleaire, Universite Lyon-1, Villeurbanne Cedex, France; Centre de Recherches Nucleaires et Universite Louis Pasteur, Strasbourg Cedex, France)*****, Collective excitation of 103Ag following the (12C, p 2n γ) reaction, Nucl.Phys. A342, 357-372, (1980):**

"The low-spin structure of silver isotopes (Z = 47) from A = 101 to A = 113 (refs. Lhersonneau et al., 1978; Kalshoven et al., to be published). has been extensively studied in the last few years because of their particular situation in the nuclear chart three proton holes away from the Z = 50 magic shell. The structure of the heavier isotopes has been successfully interpreted in the framework of the unified model coupling a vibrational Sn core to a cluster of three proton holes **(Paar, 1973)**. In this way the *j*-1 anomaly, characterized by the existence of $7/2^+$ state $(\pi g9/2)^{-3}_{7/2^+}$ lower in energy than the $9/2^+$ state $(\pi g9/2)^{-3}_{9/2^+}$ was well reproduced. However, these interpretations (**Paar, 1973;** Kalshoven et al., 1979; Kuriyama et al., 1974) of ordering of high-spin states of positive parity, calculated for 105,107,109 Ag, is not in good agreement with the experimental one. This discrepancy is probably due to the limited number of phonons involved in the calculations. This evidence for band structure in 103,105Ag led us to interpret the high-spin states structure with the rotor-plus-particle model."

R.F. Casten, J. Yan, R. Wirowski, A. Gelberg, P. von Brentano, D.S. Brenner (Brookhaven National Laboratory, Upton, New York, USA; Institut für Kernphysik, Universität zu Köln, Germany; Clark University, Worcester; USA), Simplified shell model calculations for valence mirror nuclei, Nucl.Phys. A514, 252-272 (1990):
"The lower 9^- states in the N = 82 region may find its origin in differences in particle core structure. For protons in the Sn region and neutrons in the N = 82 region the negative-parity particle-core excitations span different shell gaps (50 and 82, respectively). The principal contributions in Sn, therefore, come from $\left(1g^{-1}_{9/2},\ 1h_{11/2}\right)_\pi$ while for N = 82, they are largely from $\left(1h^{-1}_{11/2},\ 1i_{13/2}\right)_\nu$. In each case, the dominant residual interaction which splits these multiplets is known to be quadrupole particle-core interaction. As shown by **Paar (Paar. 1979)**, the multiplet states will then be arrayed in a parabola in $J(J+1)$ whose minimum energy is at

$$J_{\min}\text{ (particle-core parabola)} = \left[j_1(j_1+1)+j_2(j_2+1)-\tfrac{1}{4}\right]^2-\tfrac{1}{2}$$

$$=\begin{Bmatrix} 7^- & \text{for } (1g^{-1}_{9/2}\ 1h_{11/2})_\pi & (\text{Sn}) \\ 9^- & \text{for } (1h^{-1}_{11/2}\ 1i_{13/2})_\nu & (N=82) \end{Bmatrix}$$

Therefore, in Sn, the 9^- particle-core state is rather high lying on the parabola and should be far above the 9^-_1 state of the $\left(1g_{7/2}\, 1h_{11/2}\right)$ configuration, affecting it only slightly. In the N = 82 region, the 9^- particle-core state lies lowest in the parabola and should therefore play a larger role in the structure of the 9^-_1 state: its increased complexity will result in a lower energy."

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J. Kern, A. Bruder, S. Drissi, V.A. Ionescu, D. Kusnezov *(Physics Department, University Fribourg, Switzerland; National Superconducting Cyclotron Laboratory and Physics Department, Michigan State University, USA)*, Study of 110Cd by the 108Pd(α,2nγ) reaction, Nucl.Phys. A512, 1-45 (1990):

"Quite generally, one expects in the energy region 2 < E_x < 4 MeV a number of non-collective proton low-spin broken-pair excitations that result from the two-proton hole motion. Considering two-hole core coupling calculations (Alaga, 1969; **Paar, 1979;** Heyde, 1967; Brussard, Glaudemans, 1977) and using the proton relative energy spacing $\varepsilon_{2p1/2} = 0.8$ MeV; $\varepsilon_{2p3/2} = 1.4$ MeV; $\varepsilon_{1f5/2} = 2.1$ MeV; an energy of the 112Sn core to which the proton two-hole motion is $(E_x(2_1^+) = \hbar\omega_2 = 1.257$ MeV) and with the quadrupole hole-core coupling strength determined as $\xi_2 = 2.4$ (in order to obtain a good fit for the $0_1^+ - 2_1^+$ energy spacing in 110Cd) there results a large number of broken-pair proton excitations, with relative low spin, starting at about $E_x \sim 2$ MeV. "

S.Y. Van Der Werf, B. Fryszczyn, L.W. Put, R.H. Siemssen (Kernfysisch Versneller Instituut, University of Groningen, Netherlands), Investigation of proton hole states in 109,111Ag excited in the 110,112Cd (d, 3He) reaction, Nucl.Phys. A273, 15-28 (1976): "The low-lying negative parity states in odd-A Ag isotopes are known to follow a multiplet pattern suggesting the picture (de Shalit, 1961) of a 2p1/2 proton (hole) coupled to the low-lying excited states of the neighboring Pd (Cd) isotopes. Especially the results of refs. (Ford et al., 1967; Robinson et al., 1970; Del Vecchio et al., 1975) seem to support this picture. Recently an alternative description has been given by **Paar (Paar, 1973),** using the Alaga model. We did not take the parameters used by **Paar** but extracted them as much as possible from data on neighboring nuclei. The particle-phonon coupling parameter *a* and the single hole energies are chosen such as to best reproduce the level scheme of 115In and the spectroscopic factors found from the 116Sn (d, 3He)115In reaction (Hesselink et al., 1974). Our attempt to obtain the parameters of the model completely from experimental information on neighboring nuclei has led to a parametrization different from **Paar**. There is nevertheless a close overall resemblance between our level scheme and **Paar's**, apart from one detail. The $9/2_2^+$ state which in our calculation is found at 0.88 MeV is missing in **Paar's** calculation. We verified that it is also reproduced using **Paar's** parametrizaton, so that this state probably was taken out in his truncation procedure for the configuration space."

K. Heyde, M. Waroquier, H. Vincx (Institute for Nuclear Research, INW, Gent, Belgium), Coupling between collective and generalized neutron particle-hole excitations: application to 142Nd, Nucl.Phys. A241, 219-228 (1975): "Two complex models have enjoyed good success in explaining the level structure of the odd A silver isotopes: 1) the Alaga model **(Paar, 1973)**, which assumes that the levels arise from a three-proton cluster moving in shell model orbits which are coupled to core quadruple vibrations and 2) the slightly deformed symmetric rotor model."

R.A. Broglia, E. Maglione, A. Vitturi ***(Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark; Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA)*****,**

Particle-pairing vibration coupling description of strongly anharmonic odd-A spectra, Nucl.Phys. A376, 45-60 (1982):
"In an attempt to assess the differences between the two models in a quantitative way, the pair aligned model was translated (Bes, Broglia, 1979) into the language of the nuclear field theory (NFT) (cf. ref. Bortignon et al., 1977 and references therein). A microscopic version of the pair aligned model is thus obtained based on the particle-vibration coupling scheme. Interpreting the S- and D-pairs as pairing vibrations, and utilizing for the strength of the quadrupole force the self-consistent value (Bohr, Mottelson, 1975), renormalized by the exchange of collective surface modes (cf. e.g., ref. Broglia, **Paar,** Bes, **1971)**, the model has no free parameter. The microscopic version of the interacting boson model seems to display the main features of the particle-vibration weak coupling scheme of spherical nuclei and of the Nilsson model for deformed nuclei. For a number of particles such that the effect of the Pauli principle is comparable to deformation effects the model leads to the wrong sequence of rotational bands. In any case, there seems to exist in this microscopic picture an inconsistency between the parameters needed to describe the even and odd systems."

L.P. Ekström, G.D. Jones, F. Kearns, T.P. Morrison, A. Nilsson, P.J. Twin, R. Wadsworth, E. Wallander, N.J. Ward ***(Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom; Research Institute of Physics, Stockholm, Sweden; Department of Physics, Chalmers Institute of Technology, Gothenburg, Sweden)*****, Lifetime and linear polarization measurements with the 80Kr(α, nγ)83Sr and 82Kr(α, nγ)85Sr reactions, J.Phys. G6, 1415-1426 (1980):**
"Since the work of Arnell et al. (1977) was published, low-spin 85Sr levels have been studied by Basu, Patro, Brant, **Paar (1979)** with the 85Rb(p, nγ)85Sr reaction. 83Sr and 85Sr states have been discussed theoretically in terms of the shell model, the cluster-vibration model and in terms of quasiparticle-vibration coupling, but no extensive calculations of strengths between positive-parity states in strontium isotopes have been published."

A.Szanto de Toledo, M.N. Rao, O. Sala, F. Krmpotić (***Instituto de Fisica, Universidade de Sao Paulo, Brazil; Departamento dr Fisica, Universidad Nacional de la Plata, Argentina*****), Semimicroscopic description of the odd iodine nuclei in the mass region 123** $\leq A \leq$ **133, Phys.Rev. C16, 438-452 (1977):**
"The coexistence of shell-model and collective features seems to be dominant in creating the properties of odd-mass I nuclei, and, a few years ago, the Alaga model was applied to 127I by **Paar (Paar, 1973)**, to 129I by Vanden Berghe (1974), and to 129I and 131I by Almar et al. (1973). The above mentioned theoretical studies (Almar et al., 1974; **Paar, 1973**; Vanden Berghe, 1974), in addition to being limited to isolated nuclei, differ in several important aspects, namely: (1) while **Paar (1973)** and Almar et al. (1974) approximated the residual interaction by a pairing force, Vanden Berghe (1974) used the surface δ interaction; (2) the protons were distributed among four single-particle levels: 2d5/2, 1g7/2, 3s1/2, and 2d3/2 in Refs. **(Paar, 1973)** and (Alaga;1959; Alaga, Ialongo,1967), while in Ref. (Almar et al., 1973) the

single-particle state 1h11/2 was also considered; and (3) the cutoff energies for the configuration space were not uniform. Since a detailed description of the model can be found in the literature (Civitarese et al., 1974; Almar et al., 1973; **Paar, 1973;** Vanden Berghe, 1974; Alaga, 1959; Alaga, Ialongo, 1967; Alaga, Krmpotić, **Paar,** Šips, 1970,1973; Almar et al., 1972; **Paar, 1975**), only the main formulas are presented here. For the radial part of the particle-phonon interaction we have taken the fixed value $\langle K \rangle$=50MeV, which corresponds to the estimate from Ref. (Bohr, Mottelson, 1975). In this way the measure of the vibrational field with the valence particles is mainly given by the effective deformation parameter β, which is related to the coupling strength a, used in previous calculations (Almar et al., 1973; **Paar, 1973**) by $a = \frac{\langle K \rangle \beta}{\sqrt{20\pi}}$. The values of β which we need in order to reproduce the low-lying energy spectra of 123I, 125I, and 127I are appreciably larger than the ones used in the calculation of odd-mass Sb nuclei. This is mainly due to the truncation of the configuration space we are obliged to perform here.
When only the first order effects are included, the quadrupole moment for a predominantly particle state is enhanced due to the collective effects (Alaga, Krmpotić, **Paar,** Šips, **1970, 1973; Paar, 1975**) i.e.,$Q(J) = Q^p(J) e^{eff}$, where $eQ^p(J)$ is the bare quadrupole moment of the cluster and $e^{eff} = e_p^{eff} + \frac{\langle K \rangle \beta^2 Ze}{h\omega}$."

D. Bonatsos (*University of Tübingen, Germany*): Interacting boson models of nuclear structure, Oxford studies in nuclear physics, Oxford University Press, Oxford (1988):
"It must be emphasized that the IBM model is equivalent to the Truncated Quadrupole Model (TQM) of **Paar** et al. (**V. Paar**, Interacting bosons in nuclear physics , Plenum Press, New York, 1980, p.163; G. Kyrchev and **V. Paar**, Ann. Phys. (New York) 170, 257, 1986). It must be emphasized that the IBFFM model is equivalent to the Odd Truncated Quadrupole Model (OTQM) of **Paar et al. (Paar,1984; Paar,** Brant, et al.**, 1982**; Lopac, Brant, **Paar,** Schult, Seyfarth, Balantekin**, 1986**)."
The references in Bonatsos's book contain 16 publications by **Vladimir Paar.**"

P. von Brentano (*Universität Köln, Germany*), Problems of vibrational nuclei, North-Holland, Amsterdam, p.160 (1975):
"An interesting puzzle for the shell model is the existence of j=25/2$^+$ and j=29/2$^+$ states in 93Tc and in 95Tc. The shell model cannot describe such states. These states can be explained in a natural way in the Alaga-**Paar** model. The deformed basis is used by the rotation-aligned coupling model, the spherical basis is used in the Alaga-**Paar** model."

V.G. Solovjev (*JINR, Dubna, Moskva, Russia*), Teorija atmnogo jadra, Atomizdat, Moskva (1981):
"Obmenie efekti vo vzaimodeistivii nechetnogo nuklona s ostalnimi nuklonami i angarmonicheskie efekti v kolebaniyah chetno-chetnogo ostova uchitivalis v rabot G. Alaga, **V. Paar** pri vichislenii harakteristik niskolezhashih sostojanii sfericheskih i perehodnih yader."

H. Reinhardt ***(Joint Institut for Nuclear Research, Laboratory of Theoretical Physics Dubna, Moscow, Russia)*****, Nuclear field theory, Nucl.Phys. A298, 77-92 (1978):**
"In recent years, nuclear field theory (NFT) has become an attractive theory for treating the different anharmonic and coupling effects of nuclear structure in a unified manner (Broglia, **Paar,** Bes, **1971a, b;** Broglia, Liotta, **Paar, 1972;** Reinhardt, 1975). The NFT has proved most successfully in the lead region where its systematic application by the Copenhagen group has led to an overall understanding of the low-energy spectroscopic data (Broglia, **Paar,** Bes, **1971a, b;** Broglia, Liotta, **Paar, 1972;** Bortignon, Broglia, Bes, Liotta, **Paar, 1976).** The most striking advantage of the NFT is that it allows a simultaneous treatment of the single-particle and collective degrees of freedom so that care is taken of the overcompleteness of the basis and the Pauli principle. The interplay between the different excitation modes (single-particle excitations, shape oscillations and pairing vibrations) can be studied in a sophisticated way."

H. Reinhardt ***(Niels Bohr Institute, University of Copenhagen, Denmark)*****, Application of the nuclear field theory to superfluid nuclei: The quasiparticle-phonon multiplet, Nucl.Phys. A337, 176-188 (1980):**
"In recent years the nuclear field theory (NFT) (refs. Bes et al., 1974; Reinhardt, 1975; Bes et al, 1976; Reinhardt, 1978a,b; Bortignon et al.m 1977) has been successfully applied to doubly and singly closed shell nuclei (Bortignon et al., 1977; Broglia, Liotta, **Paar, 1972; Paar, 1971**)."

F. Iachello, I. Talmi (***Yale University, USA; Weizman Institute of Science, Rehovot, Israel*****), Revs. Mod. Phys. 59, 339 (1987):**
"This number N determines the maximum number of d bosons that may appear in a state of a given representation, hence the name truncated quadrupole model (TQM) given to this model (**V. Paar**, Interacting bosons in nuclear physics, Plenum Press, New York, 1979, p. 163)."

E.R. Flynn, D.G. Burke, J.D. Sherman, J.W. Sunier ***(Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico, USA)*****, A study of particle pairing vibration multiplets in 211Bi, Nucl.Phys. A263, 365-378 (1976):**
"In particular, 210 Pb represents the fundamental mode for the neutron pairing vibrations above the vacuum state of 208Pb (ref. Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972)**. When considering the coupling of various fundamental excitations in this region a weak coupling model is expected to produce good agreement with the observed experimental results. Indeed in the cases of the 209Bi (p, t)207Bi (ref. Erb, Bhatia, 1973) and 207Pb (t, p)209Pb (ref. Flynn et al., 1971) reactions, such a model, when all of the necessary coupling diagrams are included, does reproduce the experiments quite well (Bes, Broglia, 1971). As a further study of the interactions of these nuclear excitations, the present work reports on the 209Bi(t, p)211Bi

reaction. The levels of 210Pb excited in this reaction are considered to be pairing multipole vibrations and the 211Bi results are analyzed in terms of a proton coupled to these multipoles."

I.Ragnarsson, R.A. Broglia ***(NORDITA, Copenhagen, Denmark; Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark)*****, Pairing isomers, Nucl.Phys. A263, 315-348 (1976):**

"The specific experimental tool to probe pairing correlations are (t,p) and (p,t) reactions (see e.g. ref. Broglia et al., 1973; Bes, Broglia, 1966), where two neutrons are transferred in time reversal states. The very large two-particle cross sections to states with angular momentum $L = 0, 2, 4$ and 6 which are reached from closed shell nuclei are strong evidence for the existence of monopole and multipole pairing vibrations (Bes, Broglia 1971; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Broglia et al., 1974)."

A.I. Morales, G. Benzoni, H. Watsanabe, G. de Angelis, S. Nishimura, L. Coraggio, A. Gargano, N. Itaco, T. Otsuka, Y.Tsunoda, P. Van Isacker, F. Browne, R. Daido, P. Doornenbal, Y. Fang, G. Lorusso, Z. Patel, S. Rice, L. Sinclair, P.A. Soderstrom, T. Sumikama, J.J. Valiente-Dobon, J. Wu, Z.Y. Xu et al. (***Universita degli Studi di Milano, Italy; Istituto Nazionale di Fisica Nucleare Milano, Italy; Universitat de Valencia, Spain; Beihang University, China; RIKEN Nishina Center, Japan; Istituto Nazionale di Fisica Nucleare Legnaro, Italy; Istituto Nazionale di Fisica Nucleare Napoli, Italy; University of Tokyo, Japan; National Superconducting Cyclotron Laboratory; Michigan State University, USA; Katolieke Universiteit Leuven, Belgium; University of Brighton, United Kingdom; Osaka University, Japan; University of Surrey Guildford, United Kingdom; Tohoku University, Japan; University of Oslo, Norway; GSI Darmstadt, Germany; INFN Sezione di Firenze, Italy; Universita degli Study di Padova, Italy; Advanced Science Research Center JAFA Tokai, Japan; National Physical Laboratory Teddington, United Kingdom; Instituto de Estructura de la Materia Madrid, Spain; Universidad Autonoma de Madrid, Spain; Istanbul University, Turkey*****), Is seniority a partial dynamic symmetry in the first $\nu g_{9/2}$ shell? Phys. Lett. B781, 706-712 (2018):**

"It is to note that in 74Co the νg9/2 orbital is well over half-filled (with three neutron holes) and the parabolic splitting of the $\pi f_{7/2}^{-1} \times \nu g_{9/2}$ multiplet may have inverted its orientation with respect to the proton hole-neutron particle system (**Paar, 1979**). The two isomeric states reported here may correspond to the lowest-lying members of the multiplet, the 8^- and 1^- states."

V. Brabec, A. Kovalik, O. Dragoun, M.Ya. Kuznetsova, A. Maštalka, J. Adam (Nuclear Physics Institute, Czechoslowak Academy of Siences, Prague, Czech Republic; Joint Institute of Nuclear Research, Dubna, Russia), A full proton-neutron multiplet confirmed in odd-odd 204Bi, J. Phys. G16, 1221-1226 (1990):

"In a spherical odd-odd 204Bi, Schmorak expects from the shell model and his systematics (Schmorak, 1987) the $(\pi 1h9/2)(\nu 2f5/2)$ configuration with $I^{\pi} = 2^{+}$ to 7^{+}. The missing 5^{+} level was found in the present work. According to **Paar (Paar, 1979)** the energy splitting of the multiplet should follow the parabolic rule $y = a(x - x_\nu)^2$ where $x = I(I+1)$, *y* and *I* are the excitation energy and spin of the level in question. and $x_\nu = I_\nu(I_\nu + 1)$ denotes a vertex of the parabola. The parameter *a* is related in a simple way to the quadrupole coupling strength α_2. The parabolic rule (**Paar, 1979**) proved to be a useful tool in the classification of states in odd-odd nuclei (see e.g., Kibedi, Dombradi, Fenyes, Krasznahorkay, Timar, Gacsi, Passoja, **Paar,** Vretenar, **1988**). The least-squares fit of parabola to the experimental data on 204B is demonstrated in figure 3. The I_ν values derived from the fit are in reasonable agreement with the experimental spin *I* = 6 of the 204Bi ground state as well as with the value of 5.3 calculated assuming the quadrupole phonon exchange between proton and neutron through the nuclear core (**Paar, 1979**). The small value of the quadrupole coupling strength α_2 is undoubtedly connected with the half-filling of the 2f5/2 single-particle configuration. This statement is strongly supported by the following sequence of the experimental values of the ground-state spins and their shell model assignments for 203Pb. Also confirmed is the expectation about M1 transitions between neighboring $I \to I \pm 1$ members of the investigated multiplet."

S. Lalkovski, A.M. Bruce, A. Jungclaus, M. Gorska, M. Pfutzner, L. Caceres, F. Naqvi, S. Pietri, Z. Podolyak, G.S. Simpson et al., (*University of Sofia, Bulgaria; University of Brighton, United Kingdom; CSIC, Madrid, Spain; GSI Darmstadt, Germany; Univ. Autonoma Madrid, Spain; Univ. Cologne, Germany; Univ. Surrey, United Kingdom; Univ. Grenoble, France; KTH Stockholm, Sweden; Polish Acad, Sci, Poland; Univ. Santiago de Campostela, Spain; Ist. Nazl. Fis. Nucl., Italy;Univ.Vigo; Spain; Univ. Milan, Itay; Bulgarian Acad. Sci, Bulgaria; Lund Univ., Sweden; Tech. Univ. Munich, Germany; Wasaw Univ. Technol., Poland; Univ. New Delhi, India; Hungarian Acad Sci., Hungary; Warsaw Univ., Poland*), Core-coupled states and split proton-neutron quasi-particle multiplets in 122-126Ag, Phys. Rev. C87 (2013):

"In odd-odd nuclei at the top of the shells, long-lived isomers emerge from the structure of the split proton-neutron multiplets (**Paar, 1979**). The low-lying excited states in the odd-odd neutron-rich silver nuclei can be described by using cluster-vibration model, where the proton-neutron residual interaction is a result of quadrupole and spin vibration phonon exchange between the odd particles and the nuclear core (**Paar, 1979**) As a result, split multiplets with level energies $E(j_p,j_n)$ J as a function of the nuclear spin J arise. The level energies obey the parabolic rule.

A different theoretical approach was given many years ago by a model where a cluster of three valence protons was coupled to quadrupole vibrations (**Paar, 1973**). In these calculations the particles are allowed to move in the $\pi g_{9/2}$, $\pi p_{1/2}$ and $\pi p_{3/2}$ sub-shells and are coupled to Sn vibrational core...The energy levels were calculated in (**Paar, 1973**) for the negative-parity states up to $19/2_1^-$ and for positive-parity to $13/2_1^+$... The model gives a good qualitative description of the level sequence, and the multiplet structure. High-j intruder states appear at the upper part of the shells, where low-j normal parity states are present, and are often responsible for the islands of isomerism emerging in the vicinity of the magic numbers. In the odd-odd nuclei at the top of the shells, long-lived isomers emerge from the structure of the split proton-neutron multiplets

(**Paar, 1979**). A good overall description of the medium-mass silver nuclei, where the j-1 anomaly takes place, can be obtained with a coupling parameter strength a $\geq$ 0.7. The energy levels were calculated in Ref. (**Paar, 1973**) for negative parity states up to $19/2^-_1$ and for the positive-parity states up to $13/2^+_1$. The $7/2^+_1$ level has a seniority v = 3 zero-phonon and one-phonon component, as well as a v = 1 one-phonon contribution, each with an amplitude of approximately 20%. The $9/2^+_1$ level has a dominant contribution of the v = 1 zero-phonon component with an amplitude of 30% and a v = 3 one-phonon component with contribution of 17%. The models have clear predictions which can be tested in future experiments."

J.P. Elliott (*University of Sussex, Brighton, United Kingdom*), The interacting boson model of nuclear structure, Rep. Prog. Phys. 48, 171 (1985):
"The expression "supersymmetry" is used in nuclear physics by **Paar** et al. (**Paar**, Brant, Kraljević, **1982**) to describe simultaneous SU (3) transformations for bosons and fermions."

A.Bohr and B.R. Mottelson (Niels Bohr Institute and NORDITA, Copenhagen, Denmark), Nuclear structure, Vol. 2, Benjamin, New York (1974):
"The discovery of the weak-coupling multiplet stimulated theoretical developments concerning the coupling between particle and octupole motion as well as couplings involving other elementary modes of excitations of the 208Pb core (Broglia, **...** **Paar,** 1971 (6 authors))... The energies of the pair vibrational excited states and the transfer cross sections are from 208Pb (t, p) (Flynn, Landowne, Broglia, Igo, **Paar,** Nilsson, **1972**) ..."

P.F. Bortignon (University of Padova), R.A. Broglia (Niels Bohr Institute, Copenhagen, Denmark), D.R. Bes, R. Liotta (*CNEA, Buenos Aires, Argentina*), Phys. Rep. 30C, 305-360 (1977):
"The need for treating the particle-hole and pairing modes on equal footing in describing the spectrum of odd and even nuclei around closed shell were recognized at an early stage, cf. Broglia, **Paar**, Bes, 1971); Bortignon, Broglia, Bes, Liotta, **Paar, 1976)**."

H. Yamamoto, F.K. Wohn, K. Sistemich, A. Wolf, W.B. Walters, C. Chung, R.L. Gill, M. Shmid, R.E. Chrien (*Iowa State University, USA; University of Maryland, USA; Brookhaven National Laboratory, USA*), Decay of mass-separated Cs-141 to Ba-141 and systematics of *N* = 85 isotones, Phys. Rev. C26, 1215-1236 (1982):
"The odd-A N=85 isotones have been described as quasi-$f_{7/2}$ nuclei (**Paar, 1980)**. Cluster-vibration model or CVM calculations have been made by **Paar** et al. (**Paar,** Vanden Berghe, Barrett, Leigh, Dracoulis, **1980**). Comparison and interpretation of the level structure using the CVM treatment by **Paar** are presented for 147Sm in the detailed analysis of **Paar** et al. (**Paar,** Vanden Berghe, Barrett, Leigh, Dracoulis, **1980**) and Kownacki et al. (Kownacki, Sujkowski, Hammaren, Liukkonen, Piiparinen, , Lindblad, Ryde, **Paar, 1980)**. Both theory and experiment

point towards considerable mixing and the consequent enhancement of E2 transitions. The levels, according to the analysis of **Paar** et al., are predominantly formed from the three-neutron clusters. Owing to this additional lowering, the N=85 isotones are referred to as quasi-$f_{7/2}$ nuclei by **Paar et al. (1980).** In addition to the low-lying triplet, quasi-$f_{7/2}$ nuclei are characterized, according to **Paar** et al., by states of collective character. In the CVM calculations of **Paar** et al., the phases of the wave functions they deduced (**V. Paar** et al., 1980) were such that these E2 transitions all had constructive interference from the various terms. With this designation of $9/2^-$ states in terms of their collectivity are defined by **Paar.** This *simple but therefore transparent version of the CVM*, to quote **Paar** et al., was successful in reproducing the energies and B(E2) values".

J.K. Hwang, J.H. Hamilton, A.V. Ramayya (*Department of Physics, Vanderbilt University, Nashville, Tennessee, USA)*, Search for two-POV states, excited quintuplets, and septuplets in 88-92Sr and 94,96Zr, J. Phys. G40, 015106 (2013):

"A neutron 1g9/2 hole and neutron 2d5/2 particle can be weakly coupled to the 88Sr core for 87Sr and 89Sr, respectively. The level energies of $15/2^-$ and $13/2^+$ in 87Sr (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)** are similar to those with 3^- and 2^+ in 88Sr (Stefanova et al., 2000), respectively. This has been explained as the weak coupling of a neutron hole ($\nu 1g9/2^{-1}$) to 88Sr. The $9/2^+$ level energy in 89Sr is similar to the 2^+ level energy in 88Sr. This has been explained as the weak coupling of a neutron particle (ν1g5/2) to 88Sr (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)**. The quintuplets of $9/2^+ \otimes 2^+$ in 87Sr (Ekström, Jones, Kearns, Morrison, Nilsson, **Paar,** Twin, Wadsworth, Wallander, Ward, **1981)** and $5/2^+ \otimes 2^+$ in 89Sr (Wallander et al., 1981) were previously well established."

T.K. Dinh, M. Grinberg, C. Stoyanov *(Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria)*, Interplay of collective and non-collective models in low-lying quadrupole states of 140Ba, 142Ce, 144Nd and 146Sm, J. Phys. G18, 329-337 (1992):

"Recently, 144Nd was studied in detail in the framework of the cluster vibrator model (CVM) (Meyer, Scholten, Brant, **Paar, 1990)** and the two-particle-core coupling model (PCM) (Copnell et al., 1989). In (Meyer, Scholten, Brant, **Paar, 1990**; Copnell et al., 1989) a mapping into IBM-2 was performed and it was found that the strength of the mixed-symmetry state is distributed over several excited states."

A.D. Irving, P.D. Forsyth, I. Hall, D.G.E. Martin *(Oliver Lodge Laboratory, University of Liverpool, United Kingdom)*, Low-lying levels in 125Xe and 127Xe, J. Phys. G9, 1245-1269 (1983):

"We (Irving et al., 1979) had concluded that, although some features of 129Xe and 131Xe supported a simple particle-vibrator coupling model, others suggested that a more refined model was required, possibly of the cluster-vibrator coupling type (**Paar,** Koene, **1976)**. Allaart, Hofstra, and **Paar (1981)** have recently shown how a quasiparticle-cluster. vibration model (QCVM) may be developed for odd-A nuclei with more than three extra-core particles or holes (the previous limit of the cluster-vibrator model), thus enabling systematic studies of isotone and isotope sequences. As an illustration they consider nuclei with a varying number of s1/2, d3/2 or d5/2 holes in the 50-82 shell. There are, however, some drawbacks of this calculation. The need to adjust the collective parameters across a range of isotopes indicates a difficulty with the QCVM as remarked by Allaart, Hofstra and **Paar (1981)**: the systematic variation of nuclear properties is not adequately reproduced explicitly by change in particle or hole number alone. Also, a disadvantage of the particular calculation by Allaart, Hofstra and **Paar (1981)** is that the g7/2 orbital was not included. The odd-A Te isotopes show some similarities in level structure to the Xe isotopes and in the case of 125Te (the isotone of 127Xe) the two lowest 7/2 states are only 6keV apart and Walters and Meyer (1976) suggested that the second $7/2^+$ level is a g7/2-hole state. Finally, Allaart, Hofstra and **Paar (1981)** point out that as the number of holes increases, the structure of even the low-lying states gets rapidly more complicated."

J.K. England, J.S. Grant, J.A.R. Griffith, D.E. Evans, D.A. Eastham, G.W.A. Newton, P.M. Walker ***(Department of Physics, Manchester University, Manchester, United Kingdom; Department of Physics, Birmingham University, Birmingham, United Kingdom; Daresbury Laboratory, Warrington, United Kingdom; Department of Chemistry, University of Manchester, Manchester, United Kingdom; Department of Physics, University of Surrey, Guildford, United Kingdom)*****, Isotope shifts and hyperfine splitting in 144-154Sm I, J. Phys. G16, 105-123 (1990):**

"The cluster-vibration model has been applied to 147Sm by **Paar,** Vanden Berghe, Garrett, Leigh, Dracoulis **(1980)**. In this model the three neutrons outside the $N = 82$ shell are allowed to occupy any of the 3p, 2f or 1h9/2 orbits, and the cluster is coupled to two or more phonons. For the lowest three states the phonon components in the wavefunctions are not very large (around 10%), though they generate the large B(E2) values for transitions between the states. There is no doubt a large overlap of the cluster-vibrational wavefunctions and the particle-rotor wavefunctions for these states, and it is not fortuitous that, while both models are able to give a reasonably good account of the ground-state properties."

D.R. Bes, R.A. Broglia, G.G. Dussel, R.J. Liotta, R.P.J. Perazzo ***(Comision Nacional de Energia Atomica, Buenos Aires, Argentina; Niels Bohr Imstitute, University of Copenhagen, Denmark)*****, On the many-body foundation of the nuclear field theory, Nucl.Phys. A260, 77-94 (1976):**

"We discuss the problem of fermions moving in a set of single particle levels and interacting through a residual two-body force. This problem may be solved, either by performing a shell-model diagonalization (see, for instance, ref. French et al., 1969), or, in perturbation theory, using a Feynman diagrammatic expansion (see, for instance, ref, Baranger,1968; Barrett, Kirson, 1972). Conceptual and practical simplifications are achieved by describing this physical situation in terms of fermion and collective variables. These two degrees of freedom are coupled through the particle-vibration interaction, which has been usually assumed to be linear in the phonon coordinate and quadratic in the fermion creation and annihilation operators. This framework has been extensively used in nuclear physics, ever since suggested in ref. (Bohr, 1952; Bohr, Mottelson, 1953). However, for a long time, only the vertices of figs 6c and d were taken into account. An important development, within this framework, consisted in relating the value of the collective parameters to the microscopic structure (Brown, Bolsterli, 1959; Brown et al., 1961), and, also to consider two particles (Raz, 1959) or one superconducting particle (Kisslinger, Sorensen, 1963) interacting with the phonons. Fig. 6: The particle-vibration coupling vertices for the particle-hole bosons: (a, particle-hole pair creation by a phonon; b, phonon-particle-hole annihilation; c, phonon absorption by a hole; d, phonon absorption by a particle). In 1967, Mottelson (Mottelson, 1968; Bohr, Mottelson, 1976) introduced the vertices of figs. 6a and b, thus including all possible orientations of the lines entering a given vertex. In this way, the Pauli principle between the odd particles and the phonons was taken into account, at least to first order in the interaction strength. Detailed application of this formalism was performed in the Pb region (Hamamoto, 1973; Bes, Broglia, 1971; Broglia, **Paar,** Bes**, 1971)**. The particle-pairing phonon vertices were introduced in refs. Bes, Broglia, 1971; Broglia, **Paar,** Bes**, 1971).**

K. Heyde, M. Waroquier, H. Vincx *(Natuurkundig Laboratorium, INW, Gent, Belgium)*, Generalized neutron particle-hole states in an extended unified model, Nucl.Phys. A234, 216-252 (1974):

"In order to evaluate better the agreement between theory and experiment, we are going to discuss the underlying parameters of the model i.e., particle-core and hole-core coupling strength as well as the unperturbed energies $\omega_{J\beta}$ and $\tilde{\varepsilon}_{jh}$ used. The bare particle (hole) – vibrational coupling strength can be given as (Vanden Berghe et al., 1971; Mottelson, 1967; **Paar, 1973):** $\xi_2 = \left\langle r\frac{\partial V}{\partial r}\right\rangle \frac{4}{h/2\pi\cdot\omega}\frac{(5\pi)^{1/2}}{3Z_eR_0^2}B(E2;2^+\rightarrow 0^+)^{1/2}$. Another equivalent expression for the coupling strength is $\xi_2 = \left\langle r\frac{\partial V}{\partial r}\right\rangle \beta_2\frac{\pi^{-1/2}}{h/2\pi\cdot\omega}$, with β_2, the rms deformation parameter in the vibrational motion ($\beta_2 = (5h/2\pi\cdot\omega/2C)^{1/2}$, as can be determined directly in (p, p') or (α,α') inelastic scattering experiments. The last equation leads to a coupling strength for the particle-vibration coupling $\langle r\partial v/\partial r\rangle\beta_\lambda/(2\lambda+1)$, which is consistent with the coupling strength, defined as $\Lambda_\lambda(t_z)$ in ref. (Broglia, **Paar,** Bes, **1971a,b;** Broglia, Liotta, **Paar, 1972)**, and references therein. Effects of residual interactions (Broglia, **Paar,** Bes, **1971a,b;** Broglia, Liotta, **Paar, 1972),** neglected in this approach, can be included in a renormalization of the bare coupling strength thus obtained. As no larger renormalization effects are expected (Broglia, **Paar,** Bes, **1971a,b;** Broglia, Liotta, **Paar, 1972)**, we have fitted $\boldsymbol{\xi_2}$ in order to obtain as good agreement as possible in the N = 83 and N = 81 nuclei."

R.P.J. Perazzo, S.L. Reich, H.M. Sofia (Comision Nacional de Energia Atomica, Departamento de Fisica, Buenos Aires, Argentina), Renormalization of particle and hole

states in 208Pb, Nucl. Phys. A339, 23-42 (1980):
"In order to use (9) as a renormalization condition all the roots E_s of (7) have to be obtained, and this is quite impractical, since the number of poles E_s of the dressed propagator grows very rapidly with the number of collective modes $(n\lambda\rho)$ and single-particle states (j) that are included in the calculation (see appendix). An additional condition on the columns of the matrix $(y_s j)$ can be obtained through the Ward identity (**Paar, 1976;** Bes et al., 1977) that is equivalent to imposing the condition that the dressed propagator G is an eigenstate of the particle number operator. With this procedure one obtains (Bes al, 1977):$\delta_{ss'} = \sum_j y_s^*(j) y_{s'}(j) + \sum_{qn\lambda}(1-nq)\left[\frac{R_s^*(q,n\lambda 0)R_{s'}(q,n\lambda 0)}{\Delta_s^{-0}(q,n\lambda 0)\Delta_{s'}^{-0}(q,n\lambda 0)}\right] + \ldots$"

A. Ekström, J. Cederkäll, D.J. DiJulio, C. Fahlander, M. Hjorth-Jensen, A. Blazhev, B. Bruyneel, P.A. Butler, T. Davinson, J. Eberth, C. Fransen, K. Geibel, H. Hess, O. Ivanov, J. Iwanicki, O. Kester, J. Kownacki, U. Köster, B.A. Marsh, P. Reiter, M. Scheck, B. Siebeck, S. Siem, I. Stefanescu, H.K. Toft, G.M. Tveten, J. Van de Walle, D. Voulot, N. Warr, D. Weisshaar, F. Wenander, K. Wrzosek, M. Zielinnska ***(Physics Department, University of Lund, Lund, Sweden; PH Department, CERN, Geneva, Switzerland; Physics Department and Center of Mathematics for Applications, University of Oslo, Norway; Institute of Nuclear Physics, University of Cologne, Germany; Oliver Lodge Laboratory, University of Liverpool, United Kingdom; Department of Physics and Astronomy, University of Edinburgh, United Kingdom; Instituut voor Kern- en Stralingsfysica, K.U. Leuven, Belgium; Heavy Ion Laboratory, University of Warsaw, Poland; Gesellschaft für Schwerionenforschung, Darmstadt, Germany; Institut Laue Langeven, Grenoble, France; Department of Physics, University of Manchester, United Kingdom; AB Department, CERN, Geneva, Switzerland; Department of Physics , University of Oslo, Norway; CEA Saclay, Service de Physique, Gif-sur-Yvette, France)***, **Electric quadrupole moments of the 2_1^+ states in 100,102,104Cd, Phys.Rev. C80, 054392 (2009):**
"In a spherical harmonic vibrator model the static quadrupole moment is also predicted to be identical to zero (Bohr, Mottelson, 1969). In a article by Alaga et al. (Alaga, **Paar,** Lopac, **1973)**, the particle-vibrator model was shown to give a $\boldsymbol{Q(2_1^+) = -0.33}$ b for the Cd isotopes in the midshell region, which is in agreement with the later adopted experimental value, see Fig. 11 and Refs. (Esat et al., 1976a,b). Within that model the quadrupole moment in vibration-like nuclei is a consequence of the interaction between the proton degree of freedom and the vibrator here given by the neutrons. Moreover, energy-weighted sum-rule calculations (Koo et al., 1979) and investigations (Morrison et al., 1980) using the interacting boson approximation are in agreement with the experimental $Q(2_1^+)$ values in 106-116Cd."

H. Orihara, M. Takahashi, Y. Ishizaki, T. Suehiro, Y. Hiratate, K. Miura, H. Yamaguchi ***(Department of Physics, Faculty of Science, Tahoku University, Sendai, Japan; Institute for Nuclear Study, University of Tokyo, Tokyo, Japan; Tohoku Institute of Technology, Sendai, Japan; Faculty of General Education, Tokushima University, Tokushima, Japan)***, **Structure**

of 74Se with the (p,t) reaction at 52 MeV, Nucl.Phys. A267, 276-284 (1976):
"From systematic studies of the (t,p) and (p,t) reactions, these factors were determined to be Δ = 1.7 fm and $D_0^2 = 22$ MeV^{2} · fm^3 (refs. Flynn, Hansen, 1970; Flynn, Igo, Broglia, Landowne, **Paar,** Nilsson, **1972;** Ball et al., 1971).The parameter ε is an enhancement factor and gives information about the degree of "enhancement" beyond the framework of the shell model. The enhancement factors have been deduced assuming a pure shell-model configuration for the picked-up pair of neutrons. From the analysis of the (p, d) reaction on germanium isotopes (Fournier et al., 1973; Kato, 1973), it was found that the 2p1/2 and 1f 5/2 shells were almost filled in the region $N > 38$."

G. Winter, F. Dönau, L. Funke, P. Kemnitz, E. Will ***(Central Institute of Nuclear Physics, Rossendorf/Dresden, Germany)*****, Proton-neutron excitations in the high-spin states of 95Tc, Nucl.Phys. A291, 401-412 (1977):**
"In some odd-mass nuclei in the mass region around $A = 100$ high-spin excitations have been interpreted as members of collective bands (Grau et al., 1974; Kim et al., 1975). These bands are usually described by coupling the motion of one (or three) unpaired particle(s) to the collective excitations of the core (Dönau, Hagemann, 1976; **Paar, 1974)**. On the other hand, the properties of a few neighboring nuclei situated in the vicinity of the magic neutron number $N = 50$ can be understood on the basis of the shell-model wave functions in a limited configuration space (Auerbach, Talmi, 1965; Gloeckner, 1975)."

B. Fogelberg, K. Heyde, J. Sau ***(Studsvik Science Research Laboratory, Nyköping, Sweden; Institute for Nuclear Physics, Gent, Belgium)*****, Energy levels and transition probabilities in 130Sn, Nucl.Phys. A352, 157-180 (1981):**
For the particular cases of 128,130Sn the M1 operator has been modified in order to allow for eventual corrections, originating from the tensor part of the Ma operator i.e. an additional contribution (Meyer et al, 1981; **Paar,** Brant, **1978a,b;** Bohr, Mottelson, 1969),
$M(M1,\text{tensor}) = g\left[r^2\vec{Y}_2 \otimes \vec{s}\right]^{(1)}$ was introduced."

M. Kikuchi, T. Ishimatsu, S. Hayashibe, N. Fawamura, Y. Kimura, K. Iura, H. Miyatake, M. Fujioka ***(Department of Physics, Faculty of Science, Tohoku University, Sendai, Japan; Cyclotron and Radioisotope Center, Tohoku University, Sendai, Japan)*****, In-beam spectroscopic study of 107In, Nucl.Phys. A455, 301-314 (1986):**
"Detailed in-beam spectroscopic studies of the lighter odd-mass In isotopes 109In (van Poelgeest et al., 1979) and 111In (Hesselink, Bron, van der Kam, **Paar,** Poelgeest, Zephat, **1978)** have been performed with the 107Ag(α,2nγ)109In and 109g(α,2nγ)111 reactions. The results of these studies are compared with predictions of the hole-phonon coupling model; most of the high-spin positive-parity states observed are reproduced adequately by the calculations. The strength parameter ξ in this calculation for 107In is 3.0, which has been used for hole-phonon coupling

moel analyses of 109In (ref. van Poelgeest et al., 1979) and 111In (Hesselink, Bron, van der Kam, **Paar,** Poelgeest, Zephat, **1978)** to give an adequate description of the experimental data."

M. Balodis, T. Krasta ***(Institute of Solid State Physics, University of Latvia, Riga, Latvia)*****, Levels of two-particle and gamma bands in 192Ir, Nucl.Phys. A933, 189-212 (2015):**
"For a long time 192Ir was known as extremely complicated transitional nucleus. However, in the beginning of 1990-ties two fundamental studies of 192Ir levels were published. In the paper of Kern et al. (Kern, Raemy, Beer, Dousse, Schwitz, Balodis, Prokofjev, Kramer, Simonova, Hoff, Gardner, Gardner, Casten, Gill, Eder, von Egidy, Hagn, Hungerford, Scheerer, Schmidt, Zech, Chalupka, Murzin, Libman, Kononenko, Coceva, Giacobbe, Kondurov, Loginov, Sushkov, Brant, **Paar, 1991)**, the model-independent level scheme of 192Ir was developed resulting from the work of international team of 32 co-authors. The level scheme included 35 levels up to 531 keV. Several years later, Garrett and Burke (Garrett, Burke, 1994) published a study of 192 Ir levels using charged particle transfer reactions. This work resulted in partially alternative interpretation of the 192Ir level structure differing in several important points from that proposed by Kern et al. (1991). Meanwhile, two large studies of the neighboring 194Ir nucleus have been published (Balodis, Prokofjevs, Kramere, Simonova, Berzins, Krasta, Kern, Raemy, Dousse, Schwitz, Cizewski, Colvin, Borner, Geltenbort, Hoyler, Kerr, Schreckenbach, Georgii, von Egidy, Klora, Lindner, Mayerhofer, Walter, Murzin, Libman, Kondurov, Loginov, Sushkov, **Paar,** Lopac, **1998;** Balodis, Wirth, Graw, Hertenberger, Berzins, Kramere, Jolie, Christen, Möller, Tonev, Barea, Bijker, Frank, von Egidy, **2008)**. On the basis of available experimental data, we have presented in present paper the internally consistent level scheme of 192Ir."

F. Hoyler, J. Jolie, G.G. Calvin, H.G. Börner, K. Schreckenbach, P. Van Isacker, F. Fettweis, H. Göktürk, J.H. Dehaes, R.F. Casten, D.D. Werner, A.M. Bruce (***Universität Tübingen, Germany; Institut Laue-Langevin, Grenoble, France; Daresbury Laboratory, United Kingdom; S.C.K./C.E.N., Mol, Belgium; University of Ankara, Turkey; University of Brussels, Belgium; Brookhaven National Laboratory, Upton, New York, USA; University of Manchester, United Kingdom*****), Spectroscopy of the odd-odd nucleus As-76 and its supersymmetric description, Nucl. Phys. A512, 189-216 (1990):**
"According to **Paar´s** parabolic rule (**Paar, 1979)**, the 4^+ or 5^+ member of the $1g_{9/2}\times1g_{9/2}$ neutron-proton multiplet is expected to be lowest in energy and, since none of these states is yet observed at low energy, we can confidently assume that the low-lying positive-parity states in 76As contain only minor $1g_{9/2}$ components."

O.W.B. Schult ***(Institut für Kernphysik, KFA Jülich, Germany)*****, Nuclear structure studies with slow neutrons, Naturwissenschaften 75, 591-603 (1988):**
"Die theoretische Beschreibung der u-u Kerne, die keine Rotations-struktur zeigen, war bislang

besonders schwierig. Kürzlich wurden die Niveaus des u-u Kerns 198Au erstmals im Rahmen des IBFFM-OTQM Modells untersucht (Lopac, Brant, **Paar, et al., 1986**). Die Űbereinstimmung der gemessenen und berechneten Niveau-Energien ist erstaunlich gut. Es gelang, nicht nur die gemessenen Niveausequenzen, sondern auch das Grundzustand-Quadrupolmoment, g-Faktoren und Mischungsverhältnisse vieler Űbergänge zu reproduzieren (Brant, **Paar,** Vretenar et al., **1987**). Grundlegenden Fragen wurden gestellt: Gibt es Niveaugruppen mit gleichen I^{π}, die stochastisch verschieden sind von anderen? Das wird bestätigt durch eine Arbeit (**Paar,** Vorkapić, **1988)** über die Stochastizität im O (6)- und SU (3) Grenzfall, wobei chaotisches Verhalten für $0^{\pm}$ and $3^{\pm}$ Niveaus festgestellt wurde. Wie reichhaltig und complex zugleiche diese Thematik ist, zeigt der Befund (**Paar**, Vorkapić, Heyde, **1988**), dass die Berücksichtigung von Intruderzuständen den Grad der Chaotizität erhöht."

J. Genevey, F. Ibrahim, J.A. Pinston, H. Faust, T. Friedrichs, M. Gross, S. Oberstedt *(Institut des Sciences Nucleaires Grenoble, France; Institut Laue-Langevin, Grenoble, France)*, Identification of μs isomers in the fission products of $^{241}Pu(n_{th},f)$, Phys. Rev. C59, 82-89 (1999):

"Moreover the parabolic rule of **Paar (Paar, 1979)** shows that the 5^+ is the lowest state if the spin-vibration coupling strength parameter α takes the value of $\alpha = 40/A$, A being the atomic number. The half-life of 1.35 μs is too fast to be compatible with an E3-character for the 769.9 keV transition, and the 6^+ hypothesis for the isomer is not possible either. Consequently $I^{\pi} = 5^+$ is the only possible assignment. The parabolic rule of **Paar** indicates that the 6^+ or the 7^+ state is the possible g.s. of the p-h $\nu(h_{11/2})\,\pi(f_{5/2})^{-1}$ configuration. ^{96}Rb, this state will decay by emitting two M2 transitions in parallel to two negative parity states. The hindrance factors of the $\nu(h_{11/2}) \rightarrow \nu(g_{7/2})$ M2 particle transitions, computed like in the previous cases, are respectively 16 and 29 W.u. for the 368.9 and 461.2 keV transitions in ^{96}Rh. These values are close to the value $F_W = 13$ W.u. deduced for ^{97}Sr."

V.V. Voronov, G. Kyrchev *(Joint Institute for Nuclear Research, Dubna, Russia)*, SU (6) limit of the quasiparticle-phonon model, (Translated from Teoreticheskaya Matematicheskaya Fizika, Russia, 1985), Theor.Math.Phys. 69, 1121-1126 (1986):

"In recent years, the properties of low-lying collective states of nuclei have been widely analyzed by means of the quadrupole phonon model (Jolos, Dönau, Janssen, 1974; Janssen, Jolos, Dönau, 1974) and the interacting boson model (Arima, Iachello, 1975), which are based on SU(6) symmetry. A microscopic derivation of the Hamiltonian of the quadrupole phonon model was given for the first time in (Jolos, Dönau, Janssen, 1974) and has been used to describe the properties of many transitional nuclei (Jolos et al., 1977). However, the parameters of the Hamiltonian in these calculations were chosen phenomenologically. As was shown in (Kyrchev, 1980; **Paar,** Brant, Canto, Leander, Vouk, **1982;** Mikhailov, Panin, 1983; Klein et al., 1983), the two models are equivalent at the phenomenological level. After a complete and rather laborious analysis of all possible Jacobi identitites, one can show that the requirement of fulfillment of these identities leads to certain relations for phonon amplitudes (Kyrchev, Paar, 1986): $W(j_1 j_2; \lambda\mu) = 0, \quad D = 0, \ k = 0,1,2,3.4, \quad C_1 = C_3 = 0, \quad C_2 = C_4 = C_6 = C,$

$[Q_\nu^+, Q_\mu^+] = [Q_\nu, Q_\mu] = 0$. By virtue of commutators, only 35 out of the set of operators have zero trace$(Q_{\mu,} Q_\mu^+, [Q_\nu, Q_\mu{}^+])$, i.e., we obtain the SU (6) algebra."

N.D. Dang (Joint Institute for Nuclear Research, Dubna), Russia), Dynamical symplectic symmetry in the quasiparticle–phonon nuclear model, (Translated from Teoreticheskaya Matematicheskaya Fizika, Russia, 1988), Theor.Math.Phys. 80, 922-928 (1989):
"It is shown that under certain restrictions the quasiparticle-phonon nuclear model (QPM) has a limited dynamical WSp (2d, R) symmetry. The QPM is based on a definite form of a model Hamiltonian and on the concept of multicomponent operator wave functions. These last are constructed from quasiparticle and phonon operators. The structure of the phonon operators is found from solutions of the equations of the RPA (Soloviev 1976,1987). In (Kirchev, **Paar, 1988;** Voronov, Kyrchev, 1986), with the aim of a microscopic calculation of the parameters of the interacting boson model (IBM), conditions that must be satisfied by the phonon operators of the QPM, if the SU (6) algebra is to be closed, were obtained. In (Dang, 1988) generalized conditions on the phonon operators, under which the Hamiltonian possesses limiting SU(m) symmetry and limiting SU(m/n) supersymmetry, were obtained. The expressions (10) correspond to the C_k and D_k in (Kyrchev, **Paar, 1988;** Voronov, Kyrchev, 1986). However, the conditions (8) and (9) differ from the conditions on C_k and D_k in (Kirchev, **Paar, 1988;** Voronov, Kyrchev, 1986)."

A.Charvet, R. Duffait, R. Beraud, K. Deneffe, A. Emsalem, M. Meyer, J. Treherne, A. Gizon (*Institut de Physique Nucleaire, Universite Lyon-1, France; Institut des Sciences Nucleaires Grenoble, France*), High spin states in 103Rh, Z. Phys. A315, 163-167 (1984):
"As in 103Ag, we observe a ($\Delta I = 1$) $9/2^+$ band located a few keV above $7/2^+$ level. In odd silver, **Paar (Paar, 1973)** has shown that the coupling of a three-proton hole cluster to a vibrational core gives a relatively good description of the lower spin states ($J < 15/2^+$). Particularly, the $7/2^+$ state, at lower energy than the $(\pi g_{9/2})^{-1}$ $9/2^+$, cannot be explained by a single proton-hole."

D. Tadić (Faculty of Science, University of Zagreb, Croatia), Parity nonconservation in nuclei, Rep.Prog.Phys. 43, 67-123 (1980):
"Weak interactions can act in two ways. (i) The parity –violating hadronic interaction leads to parity mixing in nuclear wavefunctions and thus to apparent parity violation associated with γ-emission. (ii) An effective PV NNγ vertex is induced by weak interactions, analogously to weak radiative decays of baryons ($\Sigma^+ \to p + \gamma$, etc). The magnitude of contribution (ii) was also estimated to be negligible **Paar** et al. (**Paar,** Picek, Tadić, **1978)**. This estimate was based on

quite a schematic quark model, fixed in such a way as to reproduce a surprisingly large value for parity violation measured in the $\Sigma^{+} \rightarrow p+\gamma$ transition."

B. Himpe, G. Neyens, D.L. Balabanski, G. Belier, J.M. Daugas, F. de Oliveira Santos, M. de Rydt, K.T. Flanagan, I. Matea, P. Morel, Y.E. Penionzhkevich, L. Perrot, N.A. Smirnova, C. Stodel, J.C. Thomas, N. Vermeulen, D.T. Yordanov, Y. Utsuno, T. Otsuka (*K.U. Leuven, Belgium; Bulgarian Academy of Sciences, Bulgaria; CEA/DIF/DPTA /PN Bruyeres le Chatel, Belgium; GANIL, Caen Cedex, France; CENBG, Gradignan, France; JINR Dubna, Russia; Universiteit Gent, Belgium; Japan Atomic Energy Agency Tokai, Japan; University of Tokyo, Japan; RIKEN Hirosawa, Japan*), g factor of the exotic N = 21 isotope ^{34}Al: probing the N = 20 band N = 28 shell gaps at the border of the "island of inversion", Phys. Lett B658, 203-208 (2008):

"The 1p1h intruder configuration $\pi d_{5/2}^{-1}\nu(d_{3/2}^{-1}f_{7/2}^{2})$ leads to $(1...4)^{+}$ spin/parities. According to **Paar´s** parabolic rule (**Paar, 1979)**, ground state candidates are then 3^-, 4^-, 5^- or 1^+, 4^+. As no feeding to the 0^+ ground state of ^{34}Si is observed in the ^{34}Al β-decay, a 1^+ ground state is excluded... The $I^{\pi} = 4^-$ assignment remains the only one that is compatible with both the decay and the g factor data."

A.D. Efimov, V.M. Mihailov (*JINR, Dubna, Moskva, Russia*), Kollektivnaja jadernaja dinamika, Akad Nauk SSSR, p.120 (1990):

"V rabote Lopaca i **Paara** (Lopac, **Paar**, **1984)** pokazano chto ispolzovanie obrezajushej funkcii vida $(\Omega\text{-}n_d)^{1/2}$ ne javljaetsja edinstvenno vozmozhnim i, naprimer, vozniknovenie rotacionnih polos mozhet bit polucheno pri drugih formah etoj funkcii. Odnako otkaz ot kvadratnogo kornja snimet SU (6) simetriju kollektivnogo hamiltonijana. V rabote **V. Paar,** G. Kyrchev (**Paar,** Kyrchev, **1984)** podobnoe slagaemoe bilo vkljucheno v operator kvadrupoljnoi komponenti perehodnoj plotnosti, chtobi objasnit rezultati po neuprugomu rassejaniju elektronov na 154Gd. V takom sluchae pojavljaetsja dopolniteljnaja funkcija $\gamma(r)$ $(2_i \,|\, (d^+d^+)^2\, ss + s^+s^+(dd)^2 \,|\, 0_1)$ i tri perehodnjie plotnosti okazivajutsja linejno nezavisimi... Odna iz vozmozhnostej postroenija hamiltonijana MVB1na osnove fononov MSF bila rassmotrena Kirchevim, **Paarom** i Voronovim (Kyrchev, **Paar**, Voronov, 1988). V etih rabotah avtorami bili sformulirovani uslovija pri vipolnenii kotorih operatori D_μ^+, D_μ i $\lfloor D_{\mu 1}, D_{\mu 2} \rfloor$ mogut sostavit zamknutuju algebru tipa SU(6)."

P. von Brentano (*Institut für Kernphysik, Universität Köln, Köln, Germany*), Recent progress in nuclear structure physics, Inst. Phys. Conf. Ser. 62, 1-14, 1982:

"In a sense we are at the beginning of the field of precision nuclear spectroscopy once more. One reason is the advent of exciting models of collective states. Here we want to mention the Bohr-Mottelson model, the Greiner-Gneuss-Hess model, the **Alaga-Paar** model."

U.I. Zholiev, V.G. Kiptilyi, M.F. Kudoyarov, I.K. Lemberg, A.I. Muminov, A.A. Pasternak, L.A. Rassadin, (*Physico-technical Institute A.F. Joffe, Leningrad, Russia*), Lifetimes and structure of the ^{83}Rb, Izvestiya Akademii Nauk SSSR Seriya Fizicheskaya 49, 2096 (1985): "Experiments and calculations were compared. A generalized model of core-quasiparticle coupling reproduces well basic peculiarities of spectra and probabilities of electromagnetic transitions. The Alaga-**Paar** model describes quite satisfactorily results of time measurements of ^{83}Rb low-energy states. Good agreement of experimental and calculated B(M1) values for ^{83}Rb is a forcible argument in favor of adequacy of quasi-classical approach and M1 transition interpretation inside aligned bands constructed on three-quasi-particle states."

I.Stefanescu, G. Georgiev, F. Ames, J. Aysto,D.L. Balabanski, G. Bollen, P.A. Butler, J. Cederkall, N. Champault, T. Davinson, A. De Maesschalck, P. Delahaye, J. Eberth, D. Fedorov, V.N. Fedoseev, L.M. Fraile, S. Franchoo, K. Gladnishki, D. Habs, K. Heyde, M. Huyse, O. Ivanov, J. Iwanicki, J. Jolie, B. Jonson, T. Kroll, R. Krucken, O. Kester, A. Lagoyannis, L. Liljeby, G. Lo Bianco, B.A. Marsh, O. Niedermaier, T. Nilsson, M. Oinonen, G. Pascovici, P. Reiter, A. Saltarelli, H. Scheit, D. Schwalm, T. Sieber, N. Smirnova, J. Van De Walle, P. Van Duppen, S. Zemlyanoi, N. Warr, D. Weisshaar, F. Wenander (*Universite Paris-Sud Orsay, France; Ludwig Maximilians Universität, München, Germany; University of Jyväskylä, Finland; Universita di Camerino, Italy; Bulgarian Academy of Science, Bulgaria; University of Liverpool, United Kingdom; University of Edinburgh, United Kingdom; Universiteit Gent, Belgium; Universität Köln, Germany; Petersburg Nuclear Physics Institute, Gatchina, Russia; Warsaw University, Poland; Chalmers Tekniska Hogskola, Göteborg, Sweden; Technische Universität München, Germany; National Research Center Demokritos, Athens, Greece; Manne Siegbahn Laboratory, Stockholm, Sweden; Max Planck Institute für Kernphysik, Heidelberg, Germany; JINR Dubna, Moscow, Russia; University of Helsinki, Finland*), Coulomb excitation of 68,70Cu: First use of post accelerated isomeric beams, Phys. Rev. Lett. 98, 122701 (2007): "The prompt γ ray of 178 keV deexcites the state at 956 keV, populated in our work by Coulomb excitation. It feeds the 3^- state at 778 keV, which further deexcites via the 693 and 84 keV transitions defining the $3^- \rightarrow 2^+ \rightarrow 1^+$ sequence. A spin $I^\pi = 4^-$ was suggested in Refs. (14,15) for the state at 956 keV, based on the parabolic rule for proton-neutron multiplets proposed by Paar (**Paar,** 1979)."

M. Lebois, D. Verney, F. Ibrahim, S. Essabaa, F. Azaiez, M. Cheikh Mhamed, E. Cottereau, P.V. Cuong, M. Ferraton, K. Flanagan, S. Franchoo, D. Guillemaud-Mueller, F. Hammache, C. Lau, F. Le Blanc, J.F. Le Du, J. Libert, B. Mouginot, C. Petrache, B. Roussiere, L. Sagui, N. de Sereville, I. Stefan, B. Tastet (*Universite Paris-Sud Orsay, France*), Experimental study of ^{84}Ga β decay: Evidence for a rapid onset of collectivity in the vicinity of ^{78}Ni, Phys. Rev. C80, 044308 (2009):

"For protons, $1f_{5/2}$ and $2p_{3/2}$ are close to each other and in this order in energy while for neutrons, $2d_{5/2}$ is the lowest closely followed by $3s_{1/2}$. Then the natural proton-neutron configuration for ground state is $(\pi 1f_{5/2})^3(\nu 2d_{5/2})^3$. Use of Paar **model** describing the proton and neutron coupling to the core vibration (**Paar, 1979)** shows that $I^\pi = 0^-$ is the favored member of the proton-neutron multiplet which fits well with our experimental findings. The first excited configuration is either $(\pi 1f_{5/2})^3(\nu 2d_{5/2})^2(\nu 3s_{1/2})^1$ or $(\pi 1f_{5/2})^2(\pi 2p_{3/2})^1(\nu 2d_{5/2})^3$. The first configuration gives rise to a doublet 2^- - 3^- and the second produces a state $I^\pi = 4^-$ which is energetically favored in **Paar´s model**."

D. Voitenkov, S. Kamerdzhiev, S. Krewald, E.E. Saperstein, S.V.Tolokonnikov ***(Institute for Physics and Power Engineering, Obninsk, Russia; Institut für Kernphysik, Jülich, Germany; Kurchatov Institute, Moscow, Russia; Moscow Institute for Physics and Technology, Moscow, Russia)*****, Self-consistent calculations of quadrupole moments of the first 2^+ states in Sn and Pb isotopes, Phys.Rev. C85, 054319 (2012):**
"Widely used theoretical approaches including phonons are the quasiparticle-phonon model (QPM) (Soloviev, 1992), the quasiparticle random-phase approximation + phonon coupling (QRPA+PC) (Colo et al., 1994) and the extended theory of finite Fermi systems (ETFFS) (Kamerdzhiev et al., 2004). The quadrupole moments of excited states in spherical nuclei with pairing have been calculated earlier within many body approaches in Refs. (Birbrair, 1970; Broglia. Liotta, **Paar, 1972)** and within QPM in Refs. (Vdovin, Stoyanov, 1974). In Ref. (Broglia. Liotta, **Paar, 1972**), the authors use the field theory with a set of phenomenological parameters taken from experiment for each nucleus. In this article, a reasonable agreement was obtained with the experimental data for Sn and Ni isotopes available at that time. For magic nuclei this problem was considered also within self-consistent TFFS in Ref. (Platonov, 1982). The main difference of our approach from those of Refs. (Birbrair, 1970; Broglia. Liotta, **Paar, 1972;** Vdovin, Stoyanov, 1974) is its self-consistency on the (q)RPA level and absence of any phenomenological or fitted parameters."

L. Cleemann, J. Eberth, W. Neumann, N. Wiehl, V. Zobel ***(Institut für Kernphysik der Universität zu Köln, Köln, Germany)*****, In-beam γ-ray spectroscopy of 66Ge, Nucl. Phys. A334, 157-176 (1980):**
"Recently, Lopac and **Paar** (Lopac, **Paar, 1978)** presented calculations in the framework of the cluster-vibration coupling model (CVM) on the even Z isotopes. In contrast to extensive shell model calculations (van Hienen et al., 1976), in this description the g9/2 orbital could be included. The results confirm the coexistence of the quasivibrational and quasirotational characteristics of the even Zn isotopes. Besides two positive parity bands the CVM reveals one negative parity band and suggests the origin and possibilities for their distortion. A comparison between corresponding Ge and Zn isotopes shows that the structure of nuclei does not change drastically when adding two protons to the $Z = 30$ Zn nuclei. The Ge isotopes are also rather spherical which is consistent with the results of calculations by Kumar (Ardouin et al., 1978) for the low-lying excitation spectra in the framework of the dynamic deformation theory. The choice

of effective charges in these calculations has to account for polarization which cannot be predicted exactly. Therefore, two different choices of parameters were presented. As vibrator charge, we adopted the bare value of the 64 Zn core. The B(E2) value we took from Ref. **(Paar, 1972)**."

R. Ferrer, N. Bree, T.E. Cocolios, I.G. Darby, H. De Witte, W. Dexters, J. Diriken, J. Elseviers, S. M. Huyse, S. Franchoo,M. Huyse, K. Kesteloot,Y. Kudriatsev, D. Pauwels, D. Radulov, T. Roger, H. Savajols, P. Van Duppen, M. Venhart (*Katholieke Univ. Leuven, Belgium; Inst. Kern Stralingsfys. Louvain, Belgium; Inst. Phys. Nucl., Orsay, France; GANIL CAEN, France; CEN SCK MOL, France),* In-gas-cell laser ionization spectroscopy in the vicinity of 100Sn: Magnetic moments and mean-square charge radii of N=50-54Ag, Phys. Lett. B728, 191-197 (2014):
"The experimental g-factors found in the literature are remarkably constant although the ground-state configuration changes in 101Ag from $(\pi g_{9/2})_{7/2+}^{-3}$ to $(\pi g_{9/2})_{9/2+}^{-3}$. This is in good agreement with the predictions of **V. Paar (Paar, 1973)**."

J. Kurpeta, A. Andreyev, J. Aysto, A.H. Evensen, M. Huhta, M. Huyse, A. Jokinen, M. Kamy, E. Kugler, J. Lettry et al., (*University of Warsaw, Poland; University of Leuven, Belgium; ISOLDE, CERN, Switzerland; Universityof Jyväskylä, Finland*), The decay of the neutron-rich nucleus 216Bi, Eur.Phys.J. A7, 49-54 (2000): "By applying the parabolic rule described by **Paar** (**V. Paar**, Nucl. Phys. A331, 16, 1979), it is possible to calculate the energies between the members of the multiplet. Using as coupling constants 40MeV/A and 4MeV for the dipole and quadrupole interaction, respectively, the parabola changes from upward bands (210Bi, 212Bi) over almost at 214Bi to downwards band (216Bi) as the number of particles in the $2g_{9/2}$ shell increases from 1 to 7. The validity of this simple prescription can be estimated for 210Bi where the multiplet splitting according to **Paar** is compared with experiment. Fig. 4.: The full dots present the relative energy splitting predicted with a parabolic rule of **Paar** (**V. Paar**, Nucl. Phys. A331, 16, 1979)."

D.R. Bes, R.A. Broglia, B. Nilsson (*CNEA, Buenos Aires, Argentina; Niels Bohr Institute, Copenhagen, Denmark*), Importance of quadrupole pairing field in J^{π} vibrations if shape deformed nuclei, Phys. Lett. B40, 338 (1972):
"Evidence for the existence of quadrupole pairing correlations has been found in the Pb-region (E.R. Flynn, G. Igo, R.A. Broglia, S. Landowne, **V. Paar,** S.G. Nilsson, Nucl. Phys.A195, 97,1972)."

Zs. Podolyak, T. Fenyes, J. Timar (*Institute of Nuclear Research, Hungarian Academy of Sciences, Hungary*), Structure of the 70As nucleus, Nucl. Phys. A584, 60-83 (1995):

"This work is a part of a wider program, in which we have investigated the structure of odd-odd 68Ga (Timar et al, 1993; Timar, **...** Brant, **Paar,** Šimičić, **1993** (7 authors)), 66Ga (Timar, ... Brant, **Paar,** Šimičić, **1994** (10 authors)); 74As (Algora, ... Brant, **Paar,** **(**6 authors) and 72As (Sohler, ... Brant, **Paar,** (6 authors), to be published). The program includes also a theoretical description of the level spectra and electromagnetic properties on the basis of the interacting boson-fermion-fermion model (IBFFM) and the study of dynamical and supersymmetries in the Ga-As region. In order to have more information about the configurations of the other low-lying 70As levels, we have performed parabolic rule (**Paar, 1979)** calculations. These calculations proved very useful for the description of the energy splitting of different p-n multiplets in the odd-odd In (Fenyes et al., 1990) and Sb (Fenyes et al., 1992) nuclei.
In order to get deeper insight into the structure of the low-lying 70As states, we have calculated the level energies, wave functions, and electromagnetic moments on the basis of the interacting boson-fermion-fermion model. The Hamiltonian of the model is (**Paar, 1984**): $H_{IBFFM} = H_{IBFM}(\pi) + H_{IBFM}(\upsilon) - H_{IBM} + H_{RES}$. The computer codes, used in calculations, were written by Brant, **Paar** and Vretenar (Brant, **Paar,** Vretenar, **1985).** We have used the following parameters in the calculation of the level spectrum of 68Ge .... These were not far from the parameters used by Meyer et al. (Meyer, ... Brant, **Paar, 1990**) for the description of the 70Ge level spectrum. The level spectrum of 69As is very scarcely known. Thus, we have fitted the boson-proton-fermion interaction parameters in zeroth-order approximation to the properties of 71As. These calculations are described in detail in Ref. (Sohler, ... Brant, **Paar,** to be published). Quasiproton occupation probabilities are as in the case of 72As (Sohler, ... Brant, **Paar,** to be published). The results of the IBFFM calculation are in accordance with the prediction of the parabolic rule."

T. Paradellis, G. Vourvopoulos (*Tandem Accelerator Laboratory, Athens, Greece*), Phys. Rev. C18, 660, 1978:
"**Paar** described the structure of the low-lying states of 69Ga (**Paar**, 1973). As a result of such a description a $3/2^-$ ground state is predicted together with two low-lying $1/2^-$ and $5/2^-$ states."

L. Cleemann, J. Eberth, W. Neumann, V. Zobel *(Institut für Kernphysik der Universität zu Köln, Germany*), On the structure of negative parity states in 66Zn and 70Ge, Nucl. Phys. A386, 367-380 (1982):
"Lopac and **Paar** calculated the even Zn isotopes in the framework of a two-proton-cluster-vibration coupling model and showed up the possibility to explain the negative-parity states as a two-proton-cluster coupled to vibrations of the corresponding $Z = 28$ Ni cores (Lopac, **Paar, 1978**). The calculations on the even Zn isotopes from Lopac and **Paar** published in ref. (Lopac, **Paar, 1978**) were extended to 66Zn in more detail with emphasis on $B(\lambda L)$ values of the negative-parity states and to 70Ge which, as we pointed out in our calculations on 66Ge (Cleemann et al., 1980), is believed to be reasonable as a good approximation. Te model distinguishes phenomenologically between collective and single-particle degrees of freedom. The collective excitation modes are described as vibrations of a closed A -2 core and the single-particle degrees of freedom by the motion of two particles in a spherical shell-model potential

coupled to the vibrations of the core. By coupling two protons to a 64Ni core in the case of 66Zn core in the calculations of 70Ge one implies that the collective excitations are mainly built up of quasineutrons. This assumption is confirmed by the CVM calculations on 64Zn in ref. (Lopac, **Paar, 1978)** and by the truncated shell-model calculations from ref. (Van Hienen et al., 1976). The parameters of the model for the calculation of excitation energies are the single-particle energies, the phonon energy, the particle-vibration coupling strength, and the pairing strength. The $E2$ and $M1$ operations are described in ref. (Lopac, **Paar, 1978)**. The single-particle energies were deduced from Bohr-Mottelson calculations of 63Cu (ref. **Paar, 1970)**. The B(M1) values were also calculated with two different sets of parameters, which differ in the value of $g_s = 0.7 g_s^{\mathrm{free}}$ (refs. Alaga, Ialongo, 1967; **Paar, 1972)** and $g_s = g_s^{free}$."

N. Takagi (Department of Applied Physics, Faculty of Science, Fukuoka University, Nishi-ku, Fukuoka, Japan), Levels in 87Y from a study of the (p,nγ) reaction, Nucl.Phys. A346, 93-116 (1980):

"**Paar** et al. (**Paar,** Eberth, Eberth, **1976)** discussed the level structures of 69,71Ge (N = 37,39) within framework of a semimicroscopic model by coupling neutron clusters to quadrupole vibrations. The ordering of the positive parity states below 1.65 MeV excitation energy of 87Y (Z = 39) resembles the results of one particle coupled to the quadrupole vibration except for the absence of $7/2^+$, if the spin and parity of the 1405.2 keV level is $13/2^+$. As the spins and parities of the levels above 2.0 MeV excitation energy in 87Y are not uniquely assigned, it is difficult to discuss the level structure, in terms of this model."

P. von Brentano (*Universität Köln, Germany*), Inst. Phys. Conf. Ser. 62, 1-14, 1982:

"In a sense we are at the beginning of the field of precision nuclear spectroscopy once more. One reason is the advent of exciting models of collective states. Here we want to mention the Bohr-Mottelson model, the Greiner-Gneuss-Hess model, the **Alaga-Paar** model."

E.F. Zganjar, Future directions in studies of nuclei far from stability, North-Holland, Amsterdam, p.50 (1980):

"**Paar et al.** (**V. Paar, Ch. Vieu, J.S. Dionisio**, Nucl. Phys. A284, 199, 1977) use a spherical representation in which a cluster of three proton holes is coupled to quadrupole vibrations and described the $h_{11/2}$ and the positive parity band structure. This results simultaneously in both a weak coupling pattern for the positive-parity states and a decoupled pattern for the negative-parity $h_{11/2}$ states."

N.G. Puttaswamy, W. Oelert, A. Djaloeis, C. Mayer-Boricke, P. Turek (*Institut für Kernphysisk, KFA Julich, Germany; Department of Physics, Bangalore University, India*), Energy levels of the odd manganese nuclei from the (d, 3He) reaction. IEEE Trans.Nucl.

Sci. NS-30, 1140-1142 (1983): "The negative-parity levels can be calculated with the usual shell-model codes; however, a shell-model prediction of the positive-parity levels is at present very difficult due to the very large model space required. Information on the positive parity levels can, however, be obtained rather easily from calculations involving the coupling of either quasiparticles (Bohr and Mottelson,1975; **Paar, 1975**; Heyde and Brussard, 1967) or few-particle cluster (**Paar, 1973;1980**) to the vibrational core. The experimentally deduced excitation energies and spectroscopic strengths for the $½^+$ and $3/2^+$ levels in manganese isotopes are rather well predicted by the QPOO (Bohr and Mottelson, 1975; **Paar, 1975**) and CVM (**Paar, 1973**) calculations; in particular, the agreement for the lowest $1/2^+$ and $3/2^+$ levels, is very good."

E. Hagn (*Technische Universität München, Garching, Germany*), Phys. Lett. B 184, 309-310 (1987):
"Heyde and **Paar** commented on the nature of $7/2^+$ states (Heyde, **Paar**, 1986). These authors pointed out that calculations within the cluster-vibrator model provide an explanation for the $7/2^+$ level. Within these calculations also the beta-decay properties can be well explained. According to the calculations by **Paar** (**Paar, 1972; Paar, 1973)**. **Paar** has calculated g $(7/2^+)$ = 1.27 and g$(9/2^+)$ = 1.23, which is in excellent agreement with experimental data."

T. Paradellis (*Tandem Accelerator Laboratory, Athens, Greece*), Excited-states in Ga-67 observed in Zn (p, n gamma)-Zn-67 reaction, Nucl. Phys. A279, 293 (1977):
"The experimental decay scheme of 67Ga is compared with the theoretical predictions of **Paar** (**Paar**, **1973)**. In these calculations these states arise from the coupling of the $(p_{3/2})^3$ proton configuration with one phonon. This is indeed what experimentally is observed. Moreover, the model accounts correctly for the observed ordering of these four levels. It should be noted that **Paar** predicted that the 1107 and 910 keV states in ^{69}Ga and ^{67}Ga, respectively, are the $5/2^-$ members of this multiplet, despite the experimental evidence at that time which favored $3/2^-$ assignment for these levels. The 910 keV level has been shown here to be indeed $5/2^-$. The 1107 keV level in ^{69}Ga has also been shown recently to be $5/2^-$ state. Such a behavior agrees with the predictions of **Paar.** The experimental reduced transition probabilities are compared with theoretical predictions by **Paar**. The agreement with experiment gives even greater confidence to the ability of this model to describe reliably many nuclear properties."

G. Maino, A. Ventura, A.M. Bizetti-Sona, P. Blasi (*Comitato Nazionale per l'Energia Nucleare e le Energie Alternative, Bologna, Italy; Department of Physics, University of Florence, Italy; Istituto Nazionale di Fisica Nucleare, Firenze, Italy*), Interacting boson-fermion model description of Ru and Rh isotopes, Z. Phys. A340, 241-248 (1991):
"Recent advances have also been made in a theoretical approach to the spectroscopy of odd-odd nuclei (Brant, **Paar,** Vretenar, **1984;** Hübsch, **Paar,** Vretenar, **1985;** Lopac, Brant, **Paar,** Schult, Seyfarth, Balantekin, **1986),** where the Interacting Boson- fermion-fermion model (IBFFM)

allows a simple, yet detailed treatment of very complicated spectra with a limited number of adjustable parameters."

T. Bzedikz, I. Popesku (*Institut yadernoj fiziki, Bukarest, Romania*), Svoistva energetichetichestih urovnei yadra 68As, Izvestiya Akademii Nauk 58, 170-175 (1994):
"Energeticheskie sdvigi urovnei v 68As bili raschitani s pomoshju virazheniya (2) i (11) iz (**Paar, 1979**)."

J.A. Thomson *(University of Wisconsin, Madison, Wisconsin, USA)*, Structure of 57Fe studied with 56Fe(d,p)57Fe reactions, Nucl.Phys. A227, 485-505 (1974):
"A number of models have been proposed to account for the structure of 57Fe. These include: (i) shell model calculations with expanded bases and a residual interaction between the valence nucleons (Hamamoto, Arima, 1962; McGrory, 1966); (ii) collective calculations coupling a single neutron with a deformed core via the Coriolis interaction (Sood, Hutcheon, 1967; Comfort et al., 1971); (iii) a model in which three neutrons in the valence shell are coupled to the quadrupole vibration **(Paar, 1972).** In a different approach **Paar (Paar, 1972)** has coupled a three-neutron valence-shell cluster to a quadrupole vibration (the Alaga model). The three neutrons outside the assumed vibrational 54Fe core were constrained to the 2p1/2, 2p3/2 and 1f5/2 shells. Most parameters in the calculations were deduced from the properties of nearby nuclei. The electromagnet properties are reproduced well; in particular the ground state magnetic moment is calculated to be 0.09 n.m. The calculated energy spectrum is compared with the experimental spectrum on the left-hand side of fig. 10. While the agreement with experiment is good and almost every experimental state has a calculated counterpart, the correlations are speculative because spectroscopic factors were not calculated. The argument is made **(Paar, 1972)** that vibrational and rotational structure coexist in 57Fe. Rotational-like bands are built on the lowest $5/2^-$ and $7/2^-$ states while the rotational structure dissolves in the lowest lying part of the spectrum. That the models of refs. (Comfort et al., 1971 and **Paar, 1972**) starting from different assumptions describe situation intermediate to these two extremes is due to: (a) the Coriolis coupling introducing vibrational structure into the rotational model calculations of ref. (Comfort et al., 1971), and b) the cluster field interaction introducing rotational structure into the vibrational model calculations of ref. (**Paar, 1972**)."

H. Seyfarth (*KFA Jülich, Germany*), Systematics in the properties of the odd-A and odd-odd Ag isotopes, J. Phys. G14, Suppl. S87 (1988):
"The parabolic multiplet splitting rules of **Paar** (**Paar, 1979**) and the related predictions on electromagnetic properties and spectroscopic factors applied to odd-odd nucleus can be used as a first approach to assign suitable experimental states to the multiplets which are derived from the ground and low-lying states of the adjacent odd-neutron and odd-proton nuclei."

W.B. Walters (*University of Maryland, College Park, Maryland, USA*), In-beam nuclear spectroscopy, Akademiai Kiado, Budapest, p. 251 (1984):
"Most significant is the excellent fit for all of the levels in 146Eu. The displacement of the two multiplets is closely approximated by the **Paar´s** formula".

D. Cline (Nuclear Structure Laboratory, University of Rochester, New York, USA), Collective modes studied by Coulomb excitation, Acta Phys. Polon. B30, 1291-1308 (1999):
"Calculatioins predict that the 0^+, 2^+, 4^+, 6^+ octupole double-phonon multiplet will split by 200 keV due to coupling of octupole vibrations to quadrupole phonons (Spear et al., 1983), to particle-hole excitations (Hamamoto, 1974; Curutchet et al., 1988; Takada, Shimizu, 1991) and due to the interaction with pairing vibrations (Blomqvist, 1970; Broglia, **Paar,** Bes, **1971)**."

M. Ramdhane, G.S. Simpson, F. Drouet, T. Malkiewicz, A. Vancraeyenest, G. Gey, P. Alexa, G. Thiamova, G. Kessedjian, C. Sage, T. Grahn, P.T. Greenlees, K. Hauschild, A. Herzan, U. Jakobsson, P. Jones, R. Julin, S. Juutinen, S. Ketelhut, A. Lopez-Martens, P. Nieminen, P. Peura, P. Rahkila, S. Rinta-Antila, P. Ruotsalainen, M. Sandzelius, mJ. Saren, C. Scholey, J. Sorri, J. Uusitalo *(Laboratoire de Physique Subatomique et de Cosmologie; Universite Joseph Fourier Grenoble, Grenoble Cedex, France; Institute of Physics and Institute of Clean Technologies, Technical University Ostrava, Czech Republic; Department of Physics, University of Jyväskylä, Finland)*, Study of intermediate-spin states of 98Y, Acta Phys. Polon. B47, 911-916 (2016):
"The neutron-rich odd-odd 98Y (N = 39, Z = 59) nucleus is of particular interest owing to its position on the border of a ground-state shape change. The spherical N = 56 subshell closure is still effective in 97Y (N = 58) (Lhersonneau, Brant, **Paar,** Vretenar, **1998)** while, with only two more neutrons, 99Y (N = 60) has a strongly deformed ground state (Meyer et al., 1985; Mach et al. 1990; Wohn et al., 1990). The spherical nature of the low-lying levels was proposed in a study of the β decay of 98Sr to 98Y (Mach et al., 1987) and was confirmed by calculations using the interacting-boson-fermion-fermion model (IBFFM) framework (Brant, **Paar,** Lhersonneau, Schult, Seyfarth, Sistemich, **1989).** It was shown that levels of 98Y below 500 keV could be described by coupling the $\pi p1/2$ orbit to the lowest-lying spherical neutron levels of the neighboring isotones (N =59) 97Sr and 97Zr."

A.A. Avaa, P. Jones, I.T. Usman, M.V, Chisapi, T. Kibedi, B.R. Zikhali, L. Msebi *(School of Physics, University of Wiwatersrand, Johannesburg, South Africa; Themba Laboratory for Accelerator Based Sciences, Somerset West, South Africa; Department of Physics, Stellenbosch University, Matieland, South Africa; Department of Nuclear Physics, Australian National University, Canberra, Australia; Department of Physics, University of the Western Cape, South Africa)*, Electron spectrometer for electric monopole (E0) transition studies in

nuclei, Nuclear Instruments and Methods in Physics Research A964, 163809 (2020):
"The measured ICC values from this work for the 213, 310, 563 and 981 keV transitions decaying via pairs of *E*2 and *E*1 are in fair agreement with theoretical values, thus providing evidence to strengthen the previously assigned multipolarities and spin-parity values from Refs. (Mariscotti et al, 1976; Sohler, Podolyak, Dombradi, Gulyas, Algora, Brant, Krstić, **Paar, 1999;** Abriola et al., 2010). Another enhancement was also observed at $(6_1^- \rightarrow 5_1^-)$ transition from 72As which was assigned a mixed multipolarity ($M1+E2$) by Ref. (Sohler, Podolyak, Dombradi, Gulyas, Algora, Brant, Krstić, **Paar, 1999;** Sohler, Algora, Fenyes, Gulyas, Brant, **Paar, 1996)**."

U.S. Ghosh, S. Rai, B. Mukherjee, A. Biswas, A.K. Mondal, K. Mondal, A. Chakraborty, S. Chakraborty, G. Mukherjee, A. Sharma, I. Bala, S. Muralithar, R.P. Singh *(Department of Physics, Siksha-Bhavana, Santiniketan, West Bengal, India; Department of Physics, Institute of Science, Banaras Hindu University, Varanasi, India; Variable Energy Cyclotron Centre, Bidhannagar, Kolkata, India; Department of Physics, Himachal Pradesh University, Shimla, India; Inter University Accelerator Centre, New Delhi, India)*, Spectroscopic investigation of complex nuclear excitations in 66Ga, Phys.Rev. C102, 024328 (2020):
"In order to understand how this coupling of phonons with single particles qualifies to yield the measured energy values, we have compared some already existing data with the coupling configurations. Intermediate spin values of 63,65,67Ga , viz., $13/2^+$, $17/2^+$ and $21/2^+$ (Weiszflog et al., 2001; Danko, Sohler, Dombradi, Brant, Krstić, Cederkäll, Lipoglavšek, Palacz, Persson, Atac, Fahlander, Grawe, Johnson, Kerek, Klamra, Kownacki, Likar, Norlin, Nyberg, **Paar,** Schubart, Seweryniak, Vretenar, de Angelis, Bednarczyk, Foltescu, Jerrestam, Juutinen, Mäkela, Nyako, de Poli, Roth, Shizuma, Skeppstedt, Sletten, Törmänen, **1999)**, are compared with $2_1^+ \otimes 9/2^+$, $4_1^+ \otimes 9/2^+$ and $6_1^+ \otimes 9/2^+$ coupled states, respectively, in Fig. 1. Observed states $13/2^+$, $17/2^+$ and $21/2^+$ of 63Ga are very close in energy respectively to those states originating from couplings of $2_1^+, 4_1^+$, and 6_1^+ core states of 62Zn (Svensson et al., 1998) with $9/2^+$ state of 63Ga. (b) Same as panel for 63Ga, but for 65Ga , which has core states originating from 64Zn (Karlgren et al., 2004) and $9/2^+$, $13/2^+$, $17/2^+$ and $21/2^+$ states from 65Ga (Weiszflog et al., 2001; Danko, Sohler, Dombradi, Brant, Krstić, Cederkäll, Lipoglavšek, Palacz, Persson, Atac, Fahlander, Grawe, Johnson, Kerek, Klamra, Kownacki, Likar, Norlin, Nyberg, **Paar,** Schubart, Seweryniak, Vretenar, de Angelis, Bednarczyk, Foltescu, Jerrestam, Juutinen, Mäkela, Nyako, de Poli, Roth, Shizuma, Skeppstedt, Sletten, Törmänen, **1999)**. (c) Same as panel (a) but for 67Ga (Danko, Sohler, Dombradi, Brant, Krstić, Cederkäll, Lipoglavšek, Palacz, Persson, Atac, Fahlander, Grawe, Johnson, Kerek, Klamra, Kownacki, Likar, Norlin, Nyberg, **Paar,** Schubart, Seweryniak, Vretenar, de Angelis, Bednarczyk, Foltescu, Jerrestam, Juutinen, Mäkela, Nyako, de Poli, Roth, Shizuma, Skeppstedt, Sletten, Törmänen, **1999)**. Earlier studies on 66Ga were done to explore only low and medium spin states (Bolotin, McClure, 1969; Morand et al., 1978; Filevich et al., 1978; Timar, Quang, Fenyes, Dombradi, Krasznahorkay, Kumpulainen, Julin, Brant, **Paar, 1994)**."

R. Banik, S. Bhattacharyya, M. Rejmund, A. Lemasson, S. Biswas, A. Navin, Y.H. Kim, C. Michelagnoli, I. Stefan, P. Bednarczyk, Soumik Bhattacharyya, E. Clement, H.L. Crawford, G. de France, P. Fallon, G. Fremont, J. Goupil, B. Jacquot, H.J. Li, J. Ljungvall, A. Maj, L. Menager, V. Morel, G. Mukherjee, R. Palit, R.M. Perez-Vidal, J. Ropert C: Schmitt ***(Variable Energy Cyclotron Centre, Kolkata, India; Homi Bhabha National Institute, Mumbai, India; GANIL, Caen Cedex, France; Institut de Physique Nucleaire, Universite Paris Sud, Universite Paris Saclay, Orsay Cedex, France; Institut of Nuclear Physics, Krakow, Poland; Lawrence Berkeley National Laboratory, Berkeley, California, USA; Tata Institute of Fundamental Research, Mumbai, India; Instituton de Fisica Corpuscular, Valencia, Spain)*****, High-spin states above the isomers in neutron-rich iodine nuclei near *N* =82, Phys.Rev. C102, 044329 (2020):**

"Spectroscopic information of the low spin states of 133I was first extracted from β -decay measurements (Hicks, Landrum, Henry, Meyer, Brant, **Paar, 1983;** Walters et al., 1984)."

L.W. Iskra, S- Leoni, B. Fornal, C. Michelagnoli, F. Kandzia, N. Marginean, M. Barani, S. Bottoni, N. Cieplicka-Orynczak, G. Colombi, C. Costache, F.C.L. Crespi, J. Dudouet, M. Jentschel, Y.H. Kim, U. Kõster, R. Lica, R. Marginen, C. Mihai, C.R. Nita, S. Pascu, C. Porzio, D. Reygadas, E. Ruiz-Martinez, A. Turturica ***(INFN sezione di Milano, Italy; Dipartimento di Fisica, Universita degli Studi di Milano, Italy; Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland; Institut Laue-Langevin, Grenoble, France; Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania; Universite Lyon 1, France)*****, γ spectroscopy of the 96Y isotope: Searching for the onset of shape coexistence before *N* = 60, Phys.Rev. C102, 054324 (2020):**

"Laser spectroscopy studies (Cheal et al., 2007 have clearly shown that in 96Y the 0^- ground stte, as well as the 8^+ 9.6-s isomer, have spherical shape. This is in agreement with the conclusions of Ref. (Brant, Lhersonneau, Stolzenwald, Sistemich, **Paar, 1988)**, where the first excited states were interpreted as shell-model states, arising from the couplings of an unpaired p1/2 or p3/2 proton with an s1/2 or g7/2 neutron. Also, in that work the 8^+ isomer was proposed to originate from the maximum spin coupling between the unpaired proton and neutron promoted ro the $\pi g9/2$ and νg7/2 orbitals."

A.I. Levon, D. Bucurescu, C. Costache, T. Faestermann, R. Hertenberger, A. Ionescu, R. Lica, A.G. Magner, C. Mihai, R. Mihaiu, S. Pascu, K.P. Shevchenko, A.A. Shevchuk, A. Turturica, H.F. Wirth ***(Institute for Nuclear Research, Academy of Science, Kiev, Ukraine; Fakultät für Physik, Ludwig-Maximilians-Universität München, Garching, Germany; H. Hulubei Institute of Physics and Nuclear Engineering, Bucharest, Romania; Faculty of Physics, University of Bucharest, Romania)*****, High-resolution study of excited states in 158Gd with the (p,t) reaction, Phys.Rev. C102, 014308 (2020):**

"The present analysis is triggered by the publication of **Paar** and Vorkapić (**Paar,** Vorkapić, **1990)**, which is devoted to the investigation of effects of the exact *K* quantum number on the fluctuation properties of the energy spectra for 0^+ and 2^+ states in the SU(3) limit of the IBM. The Δ_3 statistics (Dyson, Mehta, 1963) was used to obtain information about the long-range correlations of level spacings. In Ref. (**Paar,** Vorkapić, **1990)**, the Δ_3 statistics for pure sequence of the 0^+ levels are close to the Wigner (chaotic) behavior while for the mixed sequence of all 2^+ levels it is close to Poisson (regular) behavior (see also Ref. Gomez et al. 2011). The Δ_3 statistics with the fixed K sequences (I = 2, K = 0) and (I = 2, K = 2) returns back to the Wigner distribution."

V.P. Karassiov ***(Lebedev Physical Institute, Moscow, Russia)*****, G-invariant polynomial extensions of Lie aklgebras in quantum many-body physics, J.Phys. G27, 153-165 (1994):**
"In certain special models nonlinear Hamiltonians can be transformed to linear forms in generators of some Lie algebras via the Holstein-Primakoff type mappings (Holstein, Primakoff, 1940; Brandt, Greenberg, 1969) or their extensions (Katriel et al., 1987; Kyrchev, **Paar, 1988;** Nadjakov, 1990; Klein, Marshalek, 1991). But, in general, it is not the case, and therefore a direct application of Lie algebraic techniques to solving physical tasks is less efficient than for linear realizations of Hamiltonians in generators of Lie algebras. But recently a new class of Lie algebraic structures g_d is revealed in some multi-particle processes of quantum physics having internal symmetry groups. They are extensions of some Lie algebras h, by G invariant h-tensors v which are polynomials in boson operators."

R. Bhattacharya (University of Botswana, Gaborone, Botswana), Scenario of charge distributions of f-p shell nuclei, Z.Phys. A351, 137-141 (1995):
"Using the experimental occupation probabilities for the single particle states near the Fermi surface, the charge distribution of 54Fe, 58-64Ni and 64,66Zn have been calculated on the basis of an optimized one body potential. In Table I we present the set of parameters for the potential after optimization. The reaction studies (Marinov, Oelert, Gopal, Berg, Bojowald, Hürlimann, Katayama, Martin, Mayer-Böricke, Meissburger, Römer, Rogge, Tain, Turek, Zemlo, Mooy, Glaudemans, Brant, **Paar,**Vouk, Lopac, **1984;** Armstrong, Blair, 1965; Britton, Watson, 1976; Tagishi et al., 1980) in this region show that our geometrical parameters are quite reasonable."

H.C. Lee ***(Atomic Energy of Canada Limited, Chalk River Nuclear Laboratoriers, Chalk River, Ontario, Canada)*****,** $\gamma_{pol} + N \rightarrow \pi^{\pm} + N$ **and the hadron weak current, Phys.Lett. 86B, 125-128 (1979):**
"One class of reactions which could tell us something about these contents involves the study of parity-nonconserving effects induced by weak interaction in the nucleus. There has been a vigorous program of such studies experimentally (Snover et al., 1978; Barnes et al., 1978; Adelburger et al., 1975; Lobashov et al., 1972) and theoretically (Desplanques, Missimer, 1978; Lee, 1978; **Paar,** Picek, Tadić, **1978;** Millener et al., 1978) in the past several years."

C. Zhang, W. Ding, L.Li ***(School of Information Science and Engineering, Lanzhou University, China)*****, Image encryption algorithm based on tent delay –sine cascade with logistic map, Symmetry 12, 355 (2020):**

"As an important data format, images occupy a large proportion of network data. Their secure transmission plays a vital role. In recent years, many chaotic image encryption algorithms have been proposed (Zhu et al., 2018,2019; Hu et al., 2019; Xie et al., 2009; Wu et al, 2017,2018; Cai et al., 2018) due to the excellent properties of chaotic maps, such as initial value sensitivity and intrinsic randomness. For a chaotic system, the trajectory on the phase plane can show the randomness of outputs (**Paar,** Buljan, **2000)**. The larger the space occupied by the trajectory, the better the random outputs of the chaotic systems. Figure 3 shows the trajectories of tent delay-sine cascade with logistic map (TDSCL) (Shan et al., 2005), delay and linearly coupled logistic chaotic map (DLCL) (Li et al., 2018), and two-dimensional logistic-modulated sine-coupling logistic chaotic map (LSMCL) (Zhu et al., 2019). The trajectory of TDSCL can fill the entire phase space compared to DLCL and LSMCL. This indicates that the sequence generated by the TDSCL chaotic map has better randomness and ergodicity."

H. Attarchi, L.A. Bunimovich ***(School of Mathematics, Georgia Institute of Technology, Atlanta, USA)*****, Why escape is faster than expected? J.Phys. A53, 435002 (2020):**

"A standard approach going back to Sinai is to consider a sequence of Markov partitions with smaller and smaller elements (Sinai, 1972). Then the map becomes closer and closer to a linear on the elements of Markov positions, and thus the entire dynamical system is approximated by a sequence of Markov chains. To perform such proofs, it seems that the higher (second) order approximation for escape rate in terms of the size of a "hole" obtained in (Georgiou et al., 2012) could be quite useful. It is also worthwhile to mention in this respect that it was observed numerically (**Paar,** Pavin, **1997)** that in (nonlinear) logistic maps the process of escape also slows down near periodic orbits."

H. Sabri, B.R. Maleki, H. Fathi, M.A. Jafarizadeh (University of Tabriz, Iran), Nearest neighbor spacing distribution of U (5) $\leftrightarrow$SO (6) transitional region, Eur. Phys. J. 129, 52 (2014):

"From these figures, we see an apparent regularity of both dynamical symmetry limits in comparison with the transitional region. ML-based estimated values for the chaoticity degree propose an approach to a more regular dynamics by nuclei which are the best candidate for the U (5) dynamical symmetry limit. Also, nuclei which provide evidence for the SO (6) dynamical symmetry limit exhibit less regularity. Since the identity of nucleons makes it impossible to define the rotation for spherical nuclei, these results, similar to the predictions by **Paar** et al. in (**Paar** and Vorkapić, 1988, 1990; **Paar**, Vorkapić and Dieperink, 2002), confirm that the rotation of nuclei contribute to the suppression of their chaotic dynamics which is known as Abul Magd-Weidenmuller effect. On the other hand, some nuclei such ^{110}Cd, ^{104}Ru, and ^{114}Cd which are regarded as the best candidates for the U (5) critical symmetry, exhibit more regular dynamics in comparison with other ones in the transitional region. These results may be interpreted as evidence that the partial dynamical symmetry, which is applied to the critical point, causes some regular dynamics. Results confirm the theoretical prediction about a more regular dynamics for both dynamical symmetry limits in comparison with the transitional regions."

W.M. Zhang, D.H. Feng ***(Institute of Physics, Academia Sinica, Taipei, Taiwan; Department of Physics, Ohio State University, Columbus, Ohio, USA; Department of Physics and Atmospheric Sciences, Drexel University, Philadelphia, Pennsylvania, USA; Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA)*****, Quantum nonintegrability in finite systems, Physics Reports 252, 1-100 (1995):**
"Realistic microscopic systems are of current interest in the exploration of chaotic motions. They include atomic systems coupled with photon excitations in condensed matter and quantum optics (Belobrov et al., 1976; Graham, Hohnerbach, 1984; Fox, Eidson, 1986,1987; Zhang et al., 1990), and many-body boson and fermion systems in nuclear physics (Wu et al., 1990; Zhang, Feng, 1991; Alhassid, Whelan, 1991; Alhassid, Vretenar, 1992; **Paar,** Vorkapić, Dieperink, **1992)**."

S. Mizutori, V.G. Zelevinsky ***(Institute of Nuclear Study, Tanasi, Tokyo, Japan; Niels Bohr Institute, Copenhagen, Denmark)*****, Level and width statistics for a decaying chaotic system Z.Phys. A346, 1-9 (1993):**
"The nearest level spacing distribution and the Δ_3- statistics characterize an interplay of regular and chaotic trends in the dynamics. These functions turn out to be sensitive to the symmetry of mean field (Raman et al., 1991; Garrett et al., 1991; Lopac, Brant, **Paar, 1990;** Mizusaki et al., 1991), purity of approximate integrals of motion like isospin (Bohigas, Weidenmüller, 1988; **Paar,** Vorkapić, Heyde, Hees, Wolters, **1991)** or K – quantum number (**Paar,** Vorkapić, **1988)**, as well as magnitude of residual interaction (Åberg, 1992)."

S. Drozdz, J. Speth ***(Institut für Kernphysik, Forschungszentrum Jülich, Jülich, Germany)*****, Near-ground-state spectral fluctuations in multidimensional separable systems, Phys.Rev.Lett. 67, 529-532 (1991):**
"The repulsion observed in the empirical or theoretical spectrum is treated as an indication that

the underlying Hamiltonian involves nonintegrable terms. Such an analysis is, however, usually based on a very limited number of states, typically 100-400 (Alhassid et al., 1990; Zimmermann et al., 1988; **Paar,** Vorkapić, **1988;** Camarda, Georgopulos, 1983). This has to be taken with a particular care because the above statistics are to be understood as the asymptotic properties. Especially critical are systems close to harmonic oscillator. Anharmonic effects tend to improve the convergence rate."

A. Abd El-Hady, A.Y. Abul-Magd, M.H. Simbel ***(Faculty of Science, Zagazig University, Zagazig, Egypt)*****, Influence of symmetry breaking on the fluctuation Properties of spectra, J.Phys. A35, 2361-2372 (2002):**

"We consider the effect of gradual symmetry breaking on the fluctuation properties of nuclear energy levels. Energy level data offered a testing ground for studying the influence symmetry breaking on the fluctuation properties of energy spectra (see, e.g., **Paar,** Vorkapić, Heyde, van Hees, Wolters, **1979**; Guhr, Weidenmüller, 1990; Hussein, Pato, 1993; Abul-Magd, Simbel, 1997). In the following, we shall restrict our consideration to the case when the symmetry In the following, we shall restrict our consideration to the case when the symmetry investigation is represented by an operator that has two possible eigenvalues, such as parity, or i9sospins 0 and 1 as considered in (**Paar,** Vorkapić, Heyde, van Hees, Wolters, **1979**; Guhr, Weidenmüller, 1990; Hussein, Pato, 1993; Abul-Magd, Simbel, 1997)."

R. Wackerbauer, S. Kobayashi ***(Department of Physics, University of Alaska, Fairbanks, Alaska, USA)*****, Noise can delay and advance the collapse of spatiotemporal chaos, Phys.Rev. E75, 066209 (2007):**

"Very few studies have addressed the collapse of spatiotemporal chaos in the presence of noise so far. From the robustness of the transient times in a noisy diffusely coupled logistic map lattice, Lai concludes for the model that the presence of noise is not advantageous in attempts to reduce the transient lifetime (Lai, 1995). Even in low-dimensional systems, where the collapse mechanism for transient chaos is mathematically understood (Grebogi et al., 1983), the effects of noise are less clear, and the findings range from a reduction of the lifetime (Gassmann, 1997; **Paar,** Pavin, **1997),** to robustness against noise (Blackburn et al., 1995), to prolonged lifetimes in a post-crisis parameter regime (Franaszek, 1991)."

D. Majumdar, B.K. Agrawal, S.K. Kataria ***(Institute of Physics, Bhubaneswar, India; Bhabha Atomic Research Centre, Bombay, India)*****, On angular momentum and parity dependence of nuclear level densities in a simple random sampling approach, Nucl.Phys. A597, 212-230 (1996):**

"Nuclear level densities are important quantities since they enter the calculations of several nuclear processes like nuclear reaction cross section (Feshbach, 1992), resonances, etc. Moreover, nuclear level density has its profound applications in the fast-emerging field of nuclear astrophysics. In this work we present a Monte Carlo method, based on simple random sampling (SRS), to calculate the smoothed part of nuclear state densities. One may argue that the deviation of $I_{l-SRS}(E,J)$ at high J values could be due to the truncation of the model space. In order to verify this, we extend the model space up to the 0h11/2 orbit and repeat the calculations for a few selected energy bins. The results are plotted in Fig. 5. It is clear from Fig.5 that the behavior of $I_{l-SRS}(E,J)$ remains essentially the same. A similar disagreement at high J values for $I_l(E,J)$ has also been observed by **Paar et al.** (**Paar,** Sunko, Brant, Mustafa, Lanier, **1993)** when $I(E,M)$ was assumed to be a Gaussian (i.e., Bethe type). We analyze further the behavior of $I(E,M)$ for different forms considered. In Fig. 6 we plot the normalized M-distributions are a fixed E defined as $\rho_E(M) = \frac{I(E,M)}{\int I(E,M)dM}$. It is evident from Fig. 6 that the values $\rho_E(M)$ obtained from the bivariate Edgeworth approximation for $I(E,M)$, i.e. case (a), is not at all satisfactory since they differ significantly from the combinatorial values of $\rho_E(M)$. Whereas for cases (b) and (c) $\rho_E(M)$ is close to the combinatorial values around $M \simeq 4-9$. It can be clearly noticed from Fig.6 that the combinatorial values of $\rho_E(M)$ decrease rapidly in comparison to the cases (a)-(c). This rapid decrease of $\rho_E(M)$ in the former case can be understood in terms of Pauli Blocking which hinders the generation of configurations with high M values as is also pointed out in Ref. (**Paar,** Sunko, Brant, Mustafa, Lanier, **1993)**. On the other hand, the Gaussian approximations are based on the application of central limit theorem which does not take into account the effect of Pauli blocking. We may thus say that the situation at high J can be further improved provided one uses random spin coupling (Cerf, 1994) to assign a J value to each randomly chosen sample and considers $I_f(E,J) = I(E)I(J|E)$ with the form for $I(J|E)$ assumed to be that suggested by **Paar et al.** (**Paar,** Sunko, Brant, Mustafa, Lanier, **1993)**."

E.G. Altmann, T. Tel ***(Max Planck Institute for the Physics of complex systems, Dresden, Germany; Institute for Theoretical Physics, Eötvös University, Budapest, Hungary)*****, Poincare recurrences from the perspective of transient chaos, Phys.Rev.Lett. 100, 174101 (2008):**
"Closed systems can be converted into open ones by defining a finite region of the phase space as a leak. Leaking dynamical systems mimics the effect of experimental observations (Doron, Smilansky, 1992; Bunimovich, Dettmann, 2007; Lee et al., 2004; Schwefel et al., 2004; Ryu et al., 2006) and has also been applied as a tool to investigate the dynamics of closed systems (Pierrehumbert, 1994; **Paar,** Pavin, **1997;** Schneider et al., 2002). Recently, it has been urprisingly observed that different leaks I with equal $\mu(I)$ lead to different escape rates γ_e's (**Paar,** Pavin, **1997;** Schneider et al., 2002**)**. Location dependence of relaxation rate γ_r has also been reported (Zaslavsky, Tippett, 1991; Altmann et al., 2004; Baptista et al., 2005)."

L.A. Bunimovich, A. Yurchenko ***(Goorgia Institute of Technology, Atlanta, Georgia, USA)*****, Israel J. Math. 182, 229-252 (2011):**
"Apparently there are interesting unexplored questions on the dynamics of open dynamical systems. In this paper we dealt with one such problem, the dependence of the escape rate on the position of a hole." (Among 36 references, the following four are included: Buljan, **Paar, 2000,2001; Paar,** Pavin, **1997a,1997b.)** "

P. Stransky, M. Kurian, P. Cejnar ***(Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic; Nuclear Physics Institute, Academy of Sciences of Czech Republic, Rez, Czech Republic)*****, Classical chaos in the geometric collective model, Phys.Rev. C74, 014306 (2006):**
"Affiliation to the regular, chaotic, or mixed class of dynamics represents an essential feature of any physical system (Gutzwiller, 1990). Since residual interactions are responsible for highly correlated collective modes of notions, one may try to search for signature and chaos in the known elementary collective models, such as the interacting boson model IBM (Iachello, Arima, 1987) or the geometric collective model GCM (Eisenberg, Greiner, 1987). This approach was pioneered by Alhassid et al. and **Paar** et al. (Alhassid et al., 1990; Alhassid, Whelan, 1991; Alhassid Nooselsky, 1992; Alhassid, Vretenar, 1992), **Paar,** Vorkapić, **1988; Paar**, Vorkapić, **1990; Paar,** Vorkapić, Dieperink, **1992)** using the IBM and was later followed by Cejnar and Stransky (Cejnar, Stransky, 2004) using GCM. It turned out that nuclear collective motions belong to the most interesting cases of dynamics on the border between Sphairos and Chaos. According to Empedocle, the real world (Cosmos) is a mixture of Sphairos, the exquisite world of perfect order, and Chaos, the world of complete disorder."

A.Y. Abul-Magd, M.H. Simbel ***(Department of Mathematics and Computer Science, Faculty of Science, UAE University, Al-Ain, United Arab Emirates; Department of Physics, Faculty of Science, Zagazig University, Zagazig, Egypt)*****, Nearest-neighbor-spacing distribution of low-lying nuclear energy levels, J.Phys. G22, 1043-1051 (1996):**
"Arvieu et al. (Arvieu et al., 1987) studied the classical trajectories of a neutron in a deformed potential and found, among other things, that rotation of the potential around its symmetry axis tends to stabilize the single particle motion. **Paar** and Vorkapić (**Paar,** Vorkapić, **1988)** arrived to a similar conclusion using the algebraic interacting boson model in the SU (3) dynamical symmetry limit. These authors also discussed (**Paar,** Vorkapić, **1990)** the possibility that ignoring the *K* quantum number (the projection of angular momentum along the symmetry axis) might be the reason for the apparent regular behavior of axially symmetric deformed nuclei, showing that a small break in this quantum number rapidly changed the fluctuation properties of a mixed sequence of different *K* towards those of a pure sequence. If the observation of relatively large values of *q* for deformed nuclei were the result of considering mixed sequences of different values of *K*, it would indeed be difficult to understand the difference between the NNS distributions of the 0^+ and 3^+ states and those of the 2^+ and 4^+ states in figure 2."

A.T. Kruppa, K.F. Pal, N. Rowley ***(Institute of Nuclear Research, Debrecen, Hungary; Department od Physics and Astronomy, University of Manchester, United Kingdom, Department of Physics, University of Surrey, Guildford, United Kingdom)*****, Chaotic behavior in the cranking and particle-rotor models, Phys.Rev. C52, 1818-1826 (1995):**
"A theoretical investigation **(Paar,** Vorkapić, **1988)** in the low-spin region ($I \le 8$) using the

algebraic interacting-boson model in the SU(3) dynamical symmetry limit also confirmed that rotational states behave more regularly. The spectral statistics of other limits of the interacting boson model and intermediate situation (vibrational and rotational coupling) **(Paar,** Vorkapić, **1990;** Alhassid et al., 1990; Alhassid, Whelan, 1991; Whelan, Alhassid, 1993) have been thoroughly investigated."

M. Macek, P. Stransky, P. Cejnar, S. Heinze, J. Jolie, J. Dobeš ***(Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic; Institute of Nuclear Physics, Universität zu Köln, Köln, Germany; Nuclear Physics Institute, Academy of Sciences of the Czech Republic, Rez, Czech Republic)*****, Classical and quantum properties of the semiregular arc inside the Casten triangle, Phys.Rev. C75 064318 (2007):**
"Apart from being successful in the description of low-lying collective states of even-even nuclei, the interacting boson model has also served as a useful "toy model" to study various general phenomena, such as quantum phase transitions (Dieperink et al., 1980; Feng et al., 1981; Lopez-Moreno et al., 1996; Casten et al., 1999; Cejnar, Jolie, 2000) or order-chaos coexistence (Alhassid et al., 1990,1991, 1992, 1993; Alhassid, Vretenar, 1992; **Paar,** Vorkapić, **1988, 1990; Paar et al., 1992;** Mizusaki et al.,1991; Caneta, Maino, 2000). The interplay between regular and chaotic behaviors, observable on both the quantum and classical levels of the model, is surely one of the most intriguing properties. It seems to be a common feature of nuclear collective motions in general. We hope that results presented in this paper will help to eventually disclose microscopic origins of regularity in nuclear collective dynamics. This is an important fundamental task in itself, but in view of the recent revival of interest in statistical analyses of nuclear 0^+ spectra (Bucurescu et al., 2006) it may also turn relevant from the experimentalist's viewpoint."

H. Sabri, A.O. Ezzati ***(University of Tabriz, Iran)*** **A transition in the spectral statistics of quantum optical model by different electromagnetic fields. Eur. Phys. J. B90, 35 (2017):**
"For different sets of Hamiltonian parameters, when the number of two-level atoms increases and tends to N_A =200, the regularity, e.g., Poisson limit or $q\rightarrow1$, is the dominant behavior in the spectral statistics. The apparent regularity for different systems in this condition, may show that the identity of atoms makes it impossible to define the rotation of these systems. These results are similar to the predictions of **Paar** and Vorkapić in (**Paar,** Vorkapić, **1988, 1990)**, confirming that the rotation of systems contributes to the suppression of their chaotic dynamics."

B. Lauritzen, Y. Alhassid, N. Whelan ***(Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA; Center for Theoretical Physics, Yale University, New Haven, Connecticut, USA)*****, Nongeneric nuclear spectral fluctuations, Phys.Rev.Lett. 72, 2809 (1994):**
"In a recent Letter (**Paar,** Vorkapić, Dieperink, **1992)**, spectral fluctuations are calculated in the

rotational limit of the interacting boson model (IBM). The Hamiltonian possesses an SU (3) dynamical symmetry and its eigenstates by a complete set of conserved quantum numbers (Alhassid et al., 1990). In Ref. (**Paar,** Vorkapić, Dieperink, **1992)**, states with a fixed number of bosons and angular momentum $J = 0$ are shown to have spectral fluctuations more resembling Gaussian orthogonal ensemble type spectra (level repulsion) than a sequence of random energies having Poisson statistics (level clustering). The results are taken as evidence of "chaotic features" in the otherwise integrable Hamiltonian and "contrary to (semiclassical) expectations". The purpose of this Comment is to explain that the spectral fluctuations of the IBM Hamiltonian in the rotational limit are nongeneric and do not contradict the semiclassical arguments (Berry, Tabor, 1977) which lead to Poisson-like statistics for integrable systems. It is plausible that a more realistic Hamiltonian than the IBM in the SU (3) limit will not show the peculiarities of a "flat" Hamiltonian."

T. Mizusaki, N. Yoshinaga, T. Shigehara, T. Cheon ***(Department of Physics, University of Tokyo, Japan; Department of Physics, Saitama University, Japan; Computer Centre, University of Tokyo; Department of Physics, Hosei University, Tokyo, Japan)*****, Chaos and symmetry in the interacting boson model, Phys.Lett. B269, 6-12 (1991):**

"The study of chaos in the IBM was pioneered by **Paar** and Vorkapić with their selected examples of level statistics **(Paar,** Vorkapić, **1988, 1990)**. They pointed out that 2^+, 4^+, and 0^+, 3^+ states of rotational bands belong to the different classes both in the rotational and in the gamma unstable limits of the IBM. More recently, Alhassid, Novoselsky and Whelan analyzed both level statistics and the Kolmogorov-Sinai entropy in a classical limit of the system using the boson coherent states (Alhassid et al., 1990). We are in a similar spirit to these authors but differing that we study the signature of chaos in the whole range of parameters covering the Casten triangle, thus drawing the "quantum chaos map" for the nuclear collective motion."

V. Zelevinsky, B.A. Brown, N. Frazier, M. Horoi ***(National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan, USA; Deartment of Physics and Astronomy, Michigan State University, East Lansing, Michigan, USA; Budker Institute of Nuclear Physics, Novosibirsk, Russia; Physics Department, Central Michigan University, Mount Pleasant, Michigan, USA; Institute of Atomic Physics, Bucharest, Romania)*****, The nuclear shell model as a testing ground for many-body quantum chaos, Physics Reports 276, 85-176 (1996):**

"Truncating the nuclear Hilbert space to a small number of collective modes, as in the interacting boson model, one can consider corresponding quasiparticles (phonons) and their interaction in analogy to classical coupled oscillators. Here again chaotic or regular properties can be related to those of the semiclassical limit (Alhassid, Novoselsky, 1992). The natural generalization leads to chaotic dynamics of the interacting boson-fermion model (Lopac, Brant, **Paar, 1990)** which can be viewed as one-body chaos for a billiard with vibrating boundaries."

A.J. Majarshin, H. Sabri, S.K.M. Mobarakeh, F. Pan, Y.A. Luo, Y. Zhang, J. Draayer ***(School of Physics, Nankai University, Tianjin, China; Department of Physics, Liaoning Normal University, Dalian, China; Department of Physics, University of Tabriz, Iran; Department of Physics and Astronomy, Louisiana State University, Baton Rouge, USA)*****, Chaos and regularity of radionuclides with maximum likelihood estimation method, Physica Scripta 95, 105305 (2020):**
"As **Paar** et al. stated in (**Paar,** Vorkapić, **1988)**, the identity of nucleons makes it impossible to define the rotation for spherical nuclei, and consequently, the rotation of nuclei contributes to the suppression of their chaotic dynamics. This means the spherical nuclei explore more chaotic dynamics in comparison with deformed ones. Also, we can expect more chaotic behavior for spherical radionuclides with the predictions of GOE limit, e.g., the spherical radionuclides, namely magic or semi-magic isotopes, are expected to have shell model spectra and therefore, explore predominantly fewer regular dynamics in comparison with deformed ones."

T. Guhr, A. Müller-Groeling, H.A. Weidenmüller ***(Max Planck Institut für Kernphysik, Heidelberg, Germany)*****, Random-matrix theories in quantum physics: common concepts, Physics Reports 299, 189-425 (1998):**
"Certain features of the interacting boson model (IBM), which can be related to chaotic motion, have been studied intensely (Alhassid et al., 1990; Alhassid Whelan, 1991). Lopac et al. (Lopac, Brant, **Paar, 1990)** investigated numerically the interacting boson model. Here the mass number *A* is odd, and the odd nucleon is coupled to the bosons of the IBM. Analyzing the spectral rigidity, they found properties between Poisson and GOE."

V.G. Zelevinsky ***(Niels Bohr Institute, Copenhagen, Denmark; Budker Institute of Nuclear Physcs, Novosibirsk, Russia)*****, Chaotic vs. regular dynamics in nuclei, Nucl.Phys. A553, 125c-136c (1993):**
"The current stage of research in quantum chaos is characterized by switching efforts from schematic models to actual physical systems. Among such systems, complex nuclei are especially interesting. In fact, the concept of quantal statistical motion has been introduced by Niels Bohr (1936). Nuclear data (Haq et al., 2982) supported the conjecture of correspondence between the random matrix ensembles (RME) and classical chaos. Many authors have studied the onset of chaos in boson models (Alhassid, Novoselsky, 1992). In (Lopac, Brant, **Paar, 1990)** the "interacting bosons + fermion" model was used for odd-neutron nuclei. An even-even core acts for an odd particle as a billiard with a certain symmetry and fluctuating boundaries which determine the trend of chaoticity in $\Delta(L)$. The whole pattern is in line with what I call *one body chaos*."

P. Cejnar, J. Jolie ***(Charles University, Prague, Czech Republic; Department of Physics, University, Perolles, Fribourg, Switzerland)*****, Wave-function entropy and dynamical symmetry breaking in the interacting boson model, Phys.Rev. E58, 387-399 (1998):**

"A U(6)-generated boson Hamiltonian, for instance, with a given dynamical symmetry does not have to follow the special form assumed in the IBM-1, but could be an arbitrary function of general-order Casimir operators of the given group chain. The nongeneric spectral properties of various integrable systems, such as non-Poissonian level spacing distribution recently noticed **(Paar,** Vorkapić, Dieperink, **1992)** and explained (Lauritzen et al.,1994) in the IBM-1 for a particular SU (3) Hamiltonian seem to illustrate these matters. Whelan and Alhassid (1993) observed an overall decrease of chaotic measures with angular momentum. In Fig. 9, we present a detailed *L* dependence of the average wave function entropy ratios for all momenta between *L* = 0 and 20 for two particular points of the Casten triangle. One sees (in the upper two diagrams in Fig. 9) that the trend to decrease is common to all the five entropies. However, also apparent from Fig. 9 is the staggering of all entropy ratios, particularly strong for small angular momenta, which gives rise to large oscillations in the *L* dependence of the entropy-ratio product *R*. This behavior of the wave function entropy, noticed already in ref. (Jolie, 1994) for a different IBM-1 parametrization, refers to an early observation made by **Paar** and Vorkapić **(Paar,** Vorkapić, **1988)."**.

J. Shu, Y. Ran, T. JI, Y.X. Liu ***(The Key Laboratory of Heavy Ion Physics of the Chinese Ministry of Education, Peking University, Beijing, China; Institute of Theoretical Physics, Academia Sinica, Beijing, China; Center of Theoretical Nuclear Physics, National Laboratory of Heavy Ion Accelerator, Lanzhou, China)*****, Energy level statistics of the U(5) and O(6) symmetries in the interacting boson model, Phys.Rev. C67, 044304 (2003):**

"In recent years, many numerical studies concerning different types of symmetries and their relations to the onset of chaos have been carried out (Zhang et al., 1988,1989; Meredith et al., 1988; **Paar,** Vorkapić, **1990; Paar,** Vorkapić, Dieperink, **1992;** Whelan et al., 1993; Leitner et al., 1994; Leviatan et al., 1996). In the framework of IBM, except for the case of SU (3) symmetry, the energy level statistics has not yet been analyzed for dynamical symmetries. Such a neglect is quite natural since, according to the symmetry paradigm, the energy level statistics should be of Poisson type. Nevertheless, the investigation on the SU (3) symmetry showed that the statistics depended strongly on the boson number of the system *N*, and it was quite close to GOE statistics in the realistic cases where *N* was not very large (**Paar,** Vorkapić, Dieperink, **1992)**. In this aspect, the energy level statistics of the states in a dynamical symmetry may be more complicated than the symmetry paradigm predicts. We will then analyze the energy level statistics of the U (5) and O (6) symmetries in this work.

When we analyze the statistics in the dynamical symmetries, we have to handle the problem since the additional quantum number *K* can be quite large if the boson number *N* is large. In the previous investigation of the energy levels in SU(3) symmetry (**Paar,** Vorkapić, **1990; Paar,** Vorkapić, Dieperink, **1992)**, **Paar** and co-workers discussed the case of $J^{\pi} = 0^{+}$, where the additional quantum number *K* takes only one value *K* = 0, and also the case of $J^{\pi} \geq 2^{+}$, where *K* could have more than one value. Such an additional quantum number *K* may be viewed as a result of hidden symmetry (Kusnezov, 1997), since the states with the same angular momentum but different *K* are degenerate. In the analysis we select only one level from each set of degenerate states to establish the level set for statistics, which is just the same as that taken for the U (5) and O (6) symmetries and is equivalent to that with $K = 0$ in **Paar's** work. The obtained results of $J^{\pi} = 6^{+}$ in the systems with boson number $N = 25$, 70 and 200 are illustrated in Fig. 7. The calculated results show that the trend of statistics from GOE type to Poisson type as N increases is clear, which coincides with the results of **Paar** and coworkers (**Paar,** Vorkapić, **1990; Paar,** Vorkapić, Dieperink, **1992**). The results for the case with $N = 25$ are shown in Fig. 6. Comparing Fig. 6 with Figs. 1-4 in the case of the same parameters, one can easily infer that the manually introduced symmetry breaking makes the statistics from over-Poisson type to GOE type. The results are quite consistent with the work of **Paar** and coworkers (**Paar,** Vorkapić, **1990)**, where they introduce an additional term that breaks the K quantum number but conserves SU (3) dynamical symmetry. Their results show that increasing the strength of the K breaking term makes the statistics change continuously from over-Poisson type to GOE type."

K Sathiyadevi, S. Karthiga, V.K. Chandrasekar, D.V. Senthilkumar, M. Lakshmanan ***(Indian Institute of Science Education and Research;Centre for Nonlinear Dynamics, Bharathidasan University)*****, Frustration induced transient chaos, fractal and riddled basins in coupled limit cycle oscillators. Commun. Nonlinear Sci. Numerical Simulation 72, 586-599 (2019):**
"In the region $\varepsilon_1 > \varepsilon_1^*$, transient chaotic evolution prevails where the system behaves chaotically up to a time τ and then it reemerges from the chaotic attractor to a stable periodic or point attractor. The mean exit time scale τ can be obtained by averaging for different unified conditions. In variety of dynamical systems, it has been illustrated that this mean exit time scale follows a power law relationship for the value of ε_1 near to the critical value of ε_1^* as $\tau = \nu\,(|\varepsilon_1 - \varepsilon_1^*|)^{-\gamma}$. In the above, γ is often known as critical exponent and it depends on the stability properties of the basic periodic orbit (**Paar,** Pavin, **2003)**. When ε_1 deviates from $\varepsilon_1^* = 1.128$, the mean exit time shows sudden increase in its value and attains a maximum near the boundary between regions I and II. However, in the region I, the mean exit time again decreases. Such an absence of monotonic decrease in the mean exit timescale has also been reported in (**Paar,** Pavin, **2003)**."

G. Georgiou, C.P. Dettmann, E.G. Altmann ***(Max Planck Institute for the Physics of Complex Systems, Dresden, Germany; University of Bristol, United Kingdom)*****, Faster than expected escape for a class of fully chaotic maps, Chaos 22, 043115 (2012):**
"In recent years physical problems and mathematical results have motivated a renewed interest in the problem of placing holes through which trajectories can leak out from otherwise closed chaotic dynamical systems. The non-trivial aspect of this problem is that the properties of the open system depend sensitively on the position of the hole (Refs. **V. Paar** and N. Pavin, Bursts in average lifetime of transients for chaotic logistic map with a hole, Phys. Rev. E55, 4112 (**1997**); E.G. Altmann and T. Tel, Poincare recurrences and transient chaos in systems with leaks, Phys. Rev. E79, 016204 (2009); G. Keller and C. Liverani, Rare events, escape rates, and quasistationarity: some exact formulae, J. Stat. Phys. 135, 3 (2009); A.S. Afraimovich and L.A. Bunimovich, Which hole is leaking the most: a topological approach to study open systems,

Nonlinearity, 23, 643 (2010); L.A. Bunimovich and A. Yurchenko, Where to place a hole to achieve a maximal escape rate, Israel Journal of Mathematics 182, 229(2011); C.P. Dettmann and O. Georgiou, Transmission and reflection in the stadium billiard: Time-dependent asymmetric transport, Phys. Rev. E83, 036212 (2011); O. Knight. O. Georgiou, C.P. Dettmann and R. Klages, Dependence of chaotic diffusion on the size and position of holes, Chaos 22, 023132 (2012); M.F. Demers and P. Wright, Behavior of the escape rate function in hyperbolic dynamical systems, Nonlinearity, 25, 2133 (2012); A Ferguson and M. Pollicott, Escape rates for Gibbs measures, Ergodic Theory Dyn. Syst. 32, 961 (2012). The calculated escape rate correctly predicts the order of magnitude of the escape rate. The most striking deviation from this general feature are the deep minima, which are located at the positions of the lowest order periodic orbits (**Paar** and Pavin, 1997). It originally is a surprise when the escape rate of uniformly hyperbolic systems was shown to be strongly dependent on the hole position H_i, allowing for the possibility of escape through some holes to be as fast as through holes which are twice as big (**Paar** and Pavin, 1997)."

E. Fimmel, M. Gumbel, A. Karpuzoglu, S. Petoukhov ***(Competence Center for Mathematical and Algorithmic Methods in Biology, Biotechnology and Medicine, Mannheim University of Applied Sciences, Germany; Laboratory of Biomechanical Systems, Russian Academy of Sciences; Moscow, Russia)*****, On comparing composition principles of long DNA sequences with those of random ones, BioSystems 180, 101-108 (2019):**
"A useful review of publications from different authors on Chargaff's second parity rule (CSPR) and its possible origin is given by Rosandić et al., (Rosandić, Vlahović, Glunčić, **Paar, 2016)**. In particular, the work (Rapoport and Trifonov, 2012) emphasizes that his rule may be maintained in nature by alternating sequence segments with different signs of deviation from parity. Alternatively, it was suggested that CSPR would probably exist from the very beginning of genome evolution. Different chromosomes of a biological species can greatly differ in their length, characteristics, and quantities of genes within them, the cytogenetic bands (which show the biochemical specificity of the different parts of chromosomes), etc. However, Chargaff's second rule and its generalizations are performed almost identically for different chromosomes (see for example Okamura et al., 2007). It was noted that the CSPR can reveal general properties common to all species and have remarkable implications of some unknown mechanism that seems to be present (Albrecht-Buehler, 2006; Rapoport and Trifonov, 2012). The work by Rosandić net al., (Rosandić, Vlahović, Glunčić, **Paar, 2016)** proposes that DNA growth might be viewed as being programmed from start by non-local natural symmetry laws of DNA creation; it considers *interplay of DNA language and symmetry forcing – as a possible simple but magnificent aspect for the code of life*."

M. Chaley, V. Kutyrkin (***Russian Academy of Sciences, Institute Math. Problems Biol., Russia; Moscow State Technical University, Dept. Computat. Math. & Math. Phys, Russia*****), Data Mining Techniques for the Life Sciences, Methods in Molecular Biology 1415, 315-340**

(2016):

"Until recently the reliable methods for recognizing latent periodicity in genome were based on the notion of approximate tandem repeat (Benson, 1999; Sokol et al., 2007). However, employment of these methods has been shown that approximate tandem repeats constitute a small part in the genome sequences of various organisms. So, the indirect methods for estimating latent periodicity period have spread, exploited without determination of periodicity type and its corresponding pattern. Fourier analysis (Singh et al., 2002; Sharma et al., 2004; **Paar,** Pavin, Basar, Rosandić, Glunčić, **Paar, 2008;** Wang et al., 2010; Nunes et al., 2011) and the other techniques (Stoffer et al., 2000; Korotkov et al., 2003; Kumar et al., 2006; Nair et al., 2006; Chaley, Kutyrkin, 2008; Salih et al., 2008; Epps, 2009; Glunčić, **Paar, 2013**) displaying dominant peaks in the graphs of a single statistical parameter which values depend on the tested periods of DNA sequence can be referred to such methods. Without a model of periodicity, the latent period estimate obtained by such methods cannot be unambiguously interpreted."

J. Brajković, Ž. Pezer, B. Bruvo-Mađarić, A. Sermek, I. Felicielo, Đ. Ugarković ***(Department of Molecular Biology, Ruđer Bošković Institute, Zagreb, Croatia; Dipartimento di Medicina Clinica e Chirurgia, Universita degli Studi di Napoli Federico II, Napoli, Italy)*****, Dispersion profiles and gene associations of repetitive DNAs in the euchromatin of the beetle Tribolium castaneum, G3-Genes Genomes Genetics 8, 875-886 (2018):**

"Diversity in genomic organization and the distribution of repetitive families in T. castoreum genome might be related to their potential multiple roles in genome organization and evolution, as well as in gene modulation. It is interesting that higher-order repeats are detected in tandemly repeated families residing either in the heterochromatin or euchromatin of T. castaneum (Vlahović, Glunčić, Rosandić, Ugarković, **Paar, 2017)**. "

V. Andries, K. Vandepoele, F. van Roy ***(Department for Molecular Biomedical Research VIB, Department of Biomedical Molecular Biology, Ghent University, Belgium),*** **The *NBPF* Gene Family, Neuroblastoma – Present and Future, Ed. H. Shimada, InTech, Rijeka, Croatia, 185-214, DOI: 10.5772/28470 (2012):**

"The dramatically elevated copy number in humans indicates the importance of the NBPF/DUF1220 repeat in human evolution. Moreover, comparison of the human chromosome 1 with that of chimpanzee revealed a remarkable human 3mer higher order repeat (HOR) organization based on an ~1.6-kbp primary repeat unit fully embedded within the NBPF genes (Figure 4A). This HOR pattern is not found in chimpanzee and shows some peculiarities, namely that the repeat unit is much longer than most primary repeat units identified so far and that the HOR is fully embedded within a gene. Additionally, the total absence of tandem repeats of NBPF HOR copies in chimpanzees while 47 tandem repeat HOR copies are present in human genomes reflects a human accelerated HOR pattern that distinguishes humans from nonhuman primates (Figure 4B) **(Paar et al., 2011)**.

Fig. 4. Schematic illustration of the NBPF HOR copy. A/ The NBPF HOR copy consists of three

1.6-kbp primary repeat units organized into ~4,770–bp secondary repeat units. The divergence between the three consensus monomers (m01, mo2 and m03) is between 15 and 20 %, whereas the average divergence between the 3-mer HOR copies is mostly below 0.5%, which is characteristic of a well-developed HOR pattern. Figure not drawn to scale. B/The total number of NBPF monomers and the number of NBPF HOR copies (both tandemly organized and dispersed) gradually increases with evolutionary development, but the tandem repetition of the NBPF HOR copies is exclusive to humans:

Species	NBPF monomers	Number of NBPF HOR copies	Number of . tandem NBPF HOR copies
Human	165	57	47
Chimpanzee	48	14	0
Orangutan	17	7	0
Rhesus macaque	7	2	0
Mouse	0	0	0

Modified after **Paar** et al.**, 2011** (***V. Paar***, *M. Glunčić, M. Rosandić, I. Basar, I. Vlahović, Intragene higher order repeats in neuroblastoma breakpoint family genes distinguish humans from chimpanzees, Mol. Biol. Evol. 28 (**2011**) 1877-1892)*), reproduced by permission of publisher of journal Molecular Biology and Evolution .”

J. van Klinken ***(University of Groningen, Groningen, Netherlands)*****, Tests of fundamental symmetries with β decay, J.Phys. G22, 1239-1285 (1996):** "Louis Pasteur concluded that organic life exhibits a maximal symmetry breaking by employing exclusively left-handed amino acids. The debate, in which parity violating β decay was involved, leaves the origin of this biochirality unsolved to this day. The work of Yang and Lee led to the finding that parity is also violated in the regime of β decay and weak interactions. The initiating p+p fusion (p+p $\rightarrow$d+e^{+}+ν_e) causes the well understood and dominant low-energy part of the solar neutrino spectrum. The solar-neutrino problem arose with the pioneering experiments by Davis et al. (1994) with the reaction $\nu_e + 37\text{Cl} \rightarrow 37\text{Ar}+\beta^-$. They showed solar neutrinos but at a lower rate than expected. Four major underground solar-neutrino detectors are signaling a solar neutrino deficit with respect to solar-model expectations. It is difficult to escape the conclusion that there is a real ν_e deficiency, implying a signal of neutrino oscillations with a non-zero ν mass. Some old minerals may contain long-lived ν-made isotopes: 205Pb (4.2 My) from $\nu + 205\text{Tl}$ with an interesting low threshold of 44 keV (Stipčević, Brant, **Paar,** Ljubičić, **1995).** Future accelerator mass spectroscopy may detect this 205Pb as a measure of p+p solar neutrino fluxes over the last million years."

Lower SS, McGurk MP, Clark AG, Barbash DA ***(Department of Molecular Biology and Genetics, Cornell University, New York)*** **Satellite DNA evolution: old ideas, new approaches,**

Current Opinion in Genetics & Development 49, 70-78 (2018):
"The processes generating and maintaining different satellite DNA are important to understand as satellites DNA have been linked to chromosome mis-segregation, disease phenotypes , and reproductive isolation between species. Advances in computational tools and quantification of satellite sequence technologies now enable identification and quantification of satellites genome wide. Here, we describe some of these tools and how their applications are furthering our knowledge of satellite evolution and function.
Software for assessing satellite DNA: We focus on recently developed assembly free methods for analysis of large tandem arrays. They will continue to prove useful as improved read lengths enable assembly of satellite arrays.
Name: Global Repeat Map (GRM)
Vlahovic I, Glunčić M, Rosandić M, Ugarković Đ, **Paar V**: Regular higher order repeat structures in Beetle *Tribolium castaneum* genome. Genome Biol Evol **2017**, 9:2668-2680;
Glunčić M, **Paar V**: direct mapping of symbolic DNA sequence into frequency domain in global repeat map algorithm. Nucleic Acids Res **2013**, 41: e17.
Purpose: HOR discovery.
Assessment: Clustering of reads by sequence similarity. Long reads. Identifies structural and sequence polymorphism. Assesses divergence of each monomer from the consensus."

R. Antao, A. Mota, J.A. Tenreiro Mota (*Department of Electronics, Telecommunications and Informatics, University of Aveiro, Portugal; Institute of Engineering, Polytecnic of Porto, Portugal*), Kolmogorov complexity as a data similarity metric: application in mitochondrial DNA. Nonlinear Dyn. 93, 1059-1071 (2018).
"In the particular case of DNA analysis, the L_2 norm supports many different algorithms (Yin et al., 2014; Glunčić, **Paar, 2013**; Kubicova, Provaznik, 2014) that, with the application of the Parseval theorem, enable a straightforward comparison of sequences by manipulating their data in the frequency domain"

Meucci S (*Centre for Digital Philosophy, University of Western Ontario, Canada*) The neoclassical interpretation of modern physics and its implications for an information theory-based interpretation of spirituality. Cosmos and History: The Journal of Natural and Social Philosophy 11, 8-27 (2015):
"It has been shown that there is a link between the truncated fractals found in biology and coupled oscillation (**Paar,** Pavin, Rosandić; **2001**)."

S. Čalošević, K. Dinjar, S. Čalošević, S. Kurbel, R. Steiner (*Osijek University Hospital Center; Osijek Medical Faculty, Croatia*), Hidden information in three-axial ECG data of normal subjects: Fractal dimensions of corresponding points from successive QRS loops as potential sport age dependent marker. Gen. Physiol. Biophys. 35, 406-415 (2016):

"Electrical activita in the heart is so complex that it cannot be described as a simple rhythm with an increasing amount of evidence that the hart is not a periodic oscillator in normal physiological conditions (Goldberger et al. 1985, 2002; Sperelakis, 2000; **Paar,** Pavin, Rosandić,, **2001;** Sharma, 2009; losa 2014).

A.Takeiri, S. Motoyama, K. Matsuzaki, A. Harada, J. Taketo, C. Katoh, K. Tanaka, M. Mishima *(Research Division, Chugai Pharmaceutical Co., Shizuoka)*, New DNA probes to detect aneugenicity in rat bone marrow micronucleated cells by a pan-centromeric FISH analysis, Mutation Research 755, 73-80 (2013):
"Our finding suggests that, similar to other mammals including human and mice (Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš, **2006;** Pietras et al. 1983; de la Herran et al., 2008), in rats and interaction between CENP-B box sequences on centromeric DNA and CENP-B proteins on the kinetochore might be a key factor for disjunctions of daughter chromosomes during mitosis and meiosis. A sequence alignment of satellite I, satellite II and satellite III elucidated a sequence on satellite I which seemed to correspond to the CENP-B box sequence on satellite II or satellite III. Therefore, the sequence may act as an alternative CENP-B box on 15 chromosomes of rat. CENP-B box motif of nCCCGnnTnnnnTnnnnCGAAn (capitals show the characteristic sequence of CENP-B box) (Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš, **2006;** Pietras et al. 1983; de la Herran et al., 2008). Satellite III also has a nearly complete CENP-B box motif."

Reviewer of journal GENE in review of the manuscript Marija Rosandić, Vladimir Paar, Codon sextets with leading role of serine create "ideal" symmetry classification scheme of the genetic code, Gene 543, 45-52 (2014):
"This is indeed an intriguing new idea."

V.R. Chechetkin *(Theoretical Department of Division for Perspective Investigations, Troitsk Institute of Innovation and Thermonuclear Investigations, Troitsk, Moscow Region, Russia)*, Spectral sum rules and search for periodicities in DNA sequences, Phys.Lett. A 375, 1729-1732 (2011):
"Tandem repeats and scattered DNA repeats play important roles in the structural organization of chromosomes and regulatory mechanisms in a variety of organisms (Lewin, 2000). Commonly, however, the periodic patterns in DNA sequences are strongly randomized by the point mutations and insertions/deletions during molecular evolution. In this case discrete Fourier transform provides the efficient tool to study the intricate relationships between structure and function from their underlying quasiperiodic patterns in DNA or protein sequences (McLachlan, Stewart, 1976; Chechetkin, Turygin, 1994.1995; Makeev, Tumanyan, 1996; Lee, Luo, 1997; Tivary et al., 1997; Kutuzova et al., 1997; Trifonov, 1998; Dodin et al., 2000); Yin et al., 2007; **Paar,** Pavin, Basar, Glunčić, Paar, **2008;** Illingworth et al., 2008; Lobzin, Chechetkin, 2000; Anastassiou, 2001). Generally, the latent periodicities in DNA sequences should be searched through the sums of equidistant peaks in Fourier spectrum (Chechetkin, Turygin, 1995; **Paar,**

Pavin, Basar, Glunčić, Paar, **2008;** Lobzin, Chechetkin, 2000). The relevant characteristics for the sum of *k* structure factors in random sequences can be assessed with distributions $P(S_k > S)$."

Shepelev VA, Uralsky LI, Alexandrov AA, Yurov YB, Rogaev EI, Alexandrov IA ***(Institute of Molecular Genetics, Russian Academy of Sciences; Department of Genomics and Human Genetics, Vavilov Institute of General Genetics, Russian Academy of Sciences; Center for Brain Neurobiology and Neurogenetics, Institute of Cytology and Genetics, Siberian Branch of Russian Academy of Sciences; Faculty of Bioengineering and Bioinformatics, Lomonosov Moscow State University)*****, Annotation of suprachromosomal families reveals uncommon types of alpha satellite organization in pericentromeric regions of hg38 human genome assembly. Genome Data 5, 139-146 (2015):**
"Usually SF5 domains are formed by irregular alternation of R1 and R2 monomers and contain no HORs. However, several exceptions were reported, such as low copy–number HOR domains on chromosomes 4, 7, 5, 19 and acrocentrics (Rudd, Willard, 2004; Rosandić, **Paar**, Basar, Glunčić, Pavin, Pilaš **2006)**."

M. Degen, F. Brellier, S. Schenk, R. Driscoll, K. Zaman, R. Stupp, L. Tornillo, L. Terracciano, R. Chiquet-Ehrismann, C. Rüegg, W. Seelentag ***(Friedrich Mischer Institute for Biomedical Research, Novartis Research Foundation, Basel, Switzerland; Division of Experimental Oncology, Centre Pluridisciplinaire, University of Lausanne, Switzerland; Swiss Institute for Experimental Cancer Research, NCCR Molecular Oncology, Epalinges, Switzerland; Centre Pluridisciplinaire d'Oncologie, Universty of Lausanne and Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland; Institute of Pathology, University of Basel, Switzerland; Institute de Pathologie, Universty of Lausanne and Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland)*****, Tenascin-W, a new marker of cancer stroma, is elevated in sera of colon and breast cancer patients, Int. J. Cancer122, 2454-2461 (2008):**
"Because of the low accuracy and sensitivity of the classical fecal occult bloodtest, several biochemical markers have been developed over the years for colorectal cancer screening, including carcinoembryonic antigen (CEA) serum levels (Rosandić, Škegro, **Paar,** Šćukanec-Špoljar, Juričić, Vucelić, Pulanić, Rustemović, Ostojić, Ljubojević, **1999)**, galactose-N acetylgalactosamine fecal levels (Shamsuddin, 1996) and K-Ras mutations in human stool (Doolittle et al., 2001; Rennert et al., 2007), but none is enough sensitive and specific for early cancer detection."

W. Ziccardi, C. Zhao, V. Shepelev, L. Uralsky, I. Alexandrov ***(Loyola University Chicago, USA; Russian Academy of Sciences, Moscow, Russia)*****, Clusters of alpha satellites on human chromosome 21 are dispersed far onto the short arm and lack ancient layers, Chromosome Res. 24, 421-436 (2016):**
"While the α21-II region had been assumed to consist only of monomeric alpha satellites, the

current work directly identifies a low copy number SF4+HOR array in the Mp3 cluster and provides indirect evidence that few other SF3 +HOR exist elsewhere on HC21. Such small scale secondary amplifications within SF5 and SF4+ dead layers were also reported in other chromosomes (Alexandrov et al., 2001; Rosandić, **Paar,** Basar, Glunčić, Pavin and Pilaš, 2006; Hayden et al., 2013; Shepelev et al., **2015)**."

J.J. Shu ***(Nanyang Technological University Singapore)*****, A new integrated symmetrical table for genetic code, BioSystems 151, 21-26 (2017):**
"A better understanding of symmetry and an appreciation for its essential role in the genetic code formation can improve our understanding of nature´s coding processes. Thus, it is worth formulating a new integrated symmetrical table for genetic codes. The appearance of degeneracy in the conventional table implies the existence of certain symmetry for codon multiplicity assignment (Findley et al., 1982; Shcherbak, 1988; Bashford et al., 1998; Hornos et al. 2004; Nikolajewa et al., 2006; Gavish et al. 2007; Rosandić and **Paar, 2014)**.
The five genetic codes, euploid nuclear code (N1), alternative yeast nuclear code (N4), echinoderm & flatworm mitochondrial code (M4), and nematode mitochondria code, do not follow the intuition based on standard nuclear code (Nirrenberg and Matthaei, 1961), which asymmetry is restricted to the "punctuation" codons, START (Met/M) and STOP codons (Rumer, 1966; Kozyrev and Khrennikov, 2010; Rosandić, **Paar,** Glunčić, **2013;** Seligmann, 2015)."

C. Yin ***(Department of Mathematics, Statistics and Computer Science, University of Illinois at Chicago)*****, Representation of DNA sequences in genetic codon context with applications in exon and intron prediction, J. Bioinformatics Comput.Biol. 13, 1550004 (2015):**
"Digital signal processing (DSP) is the transformation of *N* observation data (time domain) to *N* new values (frequency domain). DFT spectral analysis of DNA sequences detects any latent, hidden and higher order periodical signals in the original sequences (**Paar,** Pavin, Basar, Rosandić, Glunčić, Paar, **2008**). "

V.R. Chechetkin, V.V. Lobzin ***(Engelhardt Institute of Molecular Biology, Russian Academy of Sciences, Moscow, Russia; School of Physics, University of Sydney, Australia)*****, Large-scale chromosome folding versus genomic DNA sequences: A discrete double Fourier transform technique. J.Theor.Biol. 426, 162-179 (2017):**
"Approximate quasi-periodic regularities in genomic DNA sequences can be efficiently displayed via discrete Fourier transform (DFT) (McLachlan and Stuart, 1976; Chechetkin and Turygin,1994; Makeev and Tumanyan, 1996; Tiwari et al, 1997; Dodin et al., 2000; Lobzin and Chechetkin, 2000; Anastassiou, 2001; Yin and Yau, 2007; **Paar** Pavin, Basar, Rosandić, Glunčić, Paar, **2008;** Wang and Stein, 2010; Marhon and Kremer, 2011; Kravatskaya et al., 2011). As has been proved earlier (Chechetkin and Turygin,1994; Lobzin and Chechetkin, 2000;

Paar, Pavin, Basar, Rosandić, Glunčić, Paar, **2008)**, the periodic patterns p = M/n generate a set of equidistant harmonics with wave numbers n, 2n, ..., $k_{max}n < N$."

K. Kugou, H. Hirai, H. Masumoto, A. Koga *(Kazusa DNA Research Institute, Kyoto University)*, Formation of functional CENP-B boxes at diverse locations in repeat units of centromeric DNA in New World monkeys, Sci. Rep. 6, 27833 (2016): "The frequency of CENP-B box sequeces in alpha satellite repeat units of Mar, Squ, ant Tam was not strongly correlated with the number of CENP-B immunofluorescence signals (relative to that of CENP-A signals). In addition, a CENP-B box sequence was not found in Spi. However, a fact to be taken into consideration is that CENP-B boxes are, in humans, not uniformly distributed but concentrated in specific regions of alpha satellite DNA (Masumoto et al., 1989; Ikeno et al., 1994; Rosandić, **Paar**, Basar, Glunčić, Pavin and Pilaš, **2006)**."

Navarro-Costa P. *(University of Lisbon, Portugal)*: Sex, rebellion and decadence: The scandalous evolutionary history of the human Y chromosome, Biochim. Biophys. Acta – Molecular Basis of Disease, 1822, 1851-1863 (2012):
"When comparing the human and chimpanzee Y chromosomes, the recorded differences are preferentially located in large repeat structures (**Paar,** Glunčić, Basar, Rosandić, Paar, M. Cvitković, **2011**)."

L. Cacheux, l. Ponger, M. Gerbault-Seureau, F.A. Richard, C. Escude *(Sorbonne Universites Paris, Universite Versailles, France)*, Diversity and distribution of alpha satellite DNA in the genome of an Old World, BMC Genomics 17, 916 (2016):
"New approach provides an unprecedented and comprehensive view of the diversity and organization of alpha satellites in a species outside the hominoid group. We consider these data with respect to previously known alpha satellite families and to potential mechanisms for satellite DNA evolution. The disposition of sequences from the C1 and C2 groups on this tree provided a further support to our classification into two groups. Moreover, this tree showed a higher degree of divergence between C2 sequences compared to C1 sequences. Actually, the comparison of a subset of 500 randomly selected sequences within each group showed that the average sequence identity inside C1 was 95%, whereas the average sequence identity inside C2 was only 85%. The consensus sequences of C1 and C2 were 172 bp in length and differed from each other by a total of 9 positions. Finally, monomers were searched for the presence of CENP-B and pJalpha boxes (Rosandić, **Paar**, Basar, Glunčić, Pavin and Pilaš, **2006)**. A pJ alpha box was present in the consensus of C1 and C2 and was found in 95% of C1sequences and 85% of C2 sequences, whereas a CENP-B box was only found in 0.05% and 0.04% of these sequences, respectively. CENP-B and pJalpha boxes were searched with the patterns TTCGTTGGAARCGGGA and TTCCTTTTYCACCRTAG, respectively (Rosandić, **Paar**, Basar, Glunčić, Pavin, Pilaš, **2006)**."

C. Alkan, M. Ventura, N. Archidiacono, M. Rocchi, S.C. Sahinalp, E.E. Eichler *(University of Washington, University of Bari, Italy, Howard Hughes Medical Institute, Seattle, Washington, USA; Bilkent University, Ankara, Turkey)*, Organization and evolution of primate centromeric DNA from whole-genome shotgun sequence data, PLOS Comput. Biol. 3, e181 (2007):
"In the human genome, it is usually possible to partition alpha-satellite sequence into blocks of some k monomers (HOR). Such patterns can be easily deduced from high-quality sequence using the key string and colorHOR algorithms (**Paar**, Pavin, Rosandić, Glunčić and Basar, 2005; Rosandić, **Paar** and Basar, **2003)**."

A.S. Komissarov, E.V. Gavrilova, S.J. Demin, A.M. Ishov, O.I. Podgornaya *(Institute of Cytology RAS, St. Petersburg, Russia)*, Tandemly repeated DNA families in the mouse genome, BMC Genomics 12, 531 (2011):
"A large fraction of alpha satellite is arranged into HOR arrays where corresponding monomers are organized as multimeric repeat units ranging in size from 3 to 5 Mb (**Paar,** Pavin, Rosandić, Glunčić, Basar, Pezer and Zinic, **2005)**."

M. Dumont, D. Fachinetti *(Institut Curie, PSL Research University Paris, CNRS, France)*, DNA sequences in centromeric formation and function, Centromeres and kinetochores, ed. B.E. Black, Progress in molecular and subcellular biology 56, 305-336, Springer (2017):
"The CENP-B box consists of a 17 bp motif that is found at regular intervals in the alphoid DNA (Ikeno et al., 1994) of all human chromosomes, except for the Y chromosome, and the varying frequencies between the chromosomes (Masumoto et al. 1989; (Rosandić, **Paar**, Basar, Glunčić, Pavin and Pilaš, **2006)**. The fact that HORs might play a role in centromere folding was hypothesized by Rosandić et al. (Rosandić, Glunčić, **Paar**, Basar, **2008)**.Using computational method, they generated different centromere structural models for the distribution of the HORs in the three known 30-nm DNA fiber models (a crossed-linker model, a solenoid model, and a helical-ribbon model), in which the characteristic geometrical pattern of the DNA folding allows recognition of specific microtubules."

C. Yin, J. Wang *(University of Illinois at Chicago, Illinois, USA; Nanjing University, China)*, Periodic power spectrum with applications in detection of latent periodicities in DNA sequences, J. Math. Biol. 73, 1053-1079 (2016):
"The DNA sequences are primarily studied by digital signal processing approaches such as Fourier transform (Silverman and Linsker, 1986) and wavelet transform (Wang and Stein, 2010). The DNA sequences are converted to a numeric sequence and then Fourier transform is applied for power spectrum analysis. The other periodicity detection methods include statistics method (Epps et al., 2011), maximum likelihood estimation (Arora and Sethares, 2007), information

decomposition (Korotkov et al., 2003), direct frequency mapping (Glunčić and **Paar, 2012**), and chaos game representation (Messaoudi et al., 2014)."

G.I. Kravatskaya, Y.V. Kravatsky, V.R. Chechetkin, V.G. Tumanyan *(Russian Academy of Sciences, Moscow, Russia)*, Coexistence of different base periodicities in prokaryotic genomes as related to DNA curvature, supercoiling, and transcription, Genomics 98, 223 (2011):
"The structure factors will always be normalized with respect to the mean spectral values which are determined by the exact sum rules. The spectrum of structure factors is symmetrical relative to $q_n = \pi$. Therefore, the spectrum can be restricted to the left half of the characteristic period and harmonic numbers are related as p = L/n, though generally the periodicities should be identified through sets of equidistant peaks (Chechetkin and Turygin, 1995; **Paar,** Pavin, Basar, Rosandić, Glunčić, **2008;** Lobzin and Chechetkin, 2000)."

V.R. Chechetkin, V.V. Lobzin *(Engelhardt Institute of Molecular Biology, Russian Academy of Sciences, Moscow, Russia; Troitsk Institute of Innovation and Thermonuclear Investigation, Moscow, Russia; University of Sidney, Australia)*, Genome packaging within icosahedral capsids and large-scale segmentation in viral genomic sequences, J.Biomol.Struct.Dyn. 37, 2322-2338 (2019):
"The period p is measured in terms of the number of nucleotides or base pairs. The periodic patterns generate a series of equidistant peaks in the space of spectral numbers (Chechetkin, Turygin, 1995; Lobzin, Chechetkin, 2000; Sharma et al. 2004; **Paar,** Pavin, Basar, Rosandić, Glunčić, Paar, **2008**)."

A.V. Kononenko, R. Bansal, N.C.O. Lee, B.R. Grimes, H. Masumoto, W.C. Earnshaw, V. Larionov, N. Kouprina *(National Cancer Institute, Developmental Therapeutics Branch, Bethesta, Maryland, USA; Department of Medical and Molecular Genetics, Indiana University, Indianapolis, Indiana, USA; Laboratory of Cell Engineering, Kazusa DNA, Chiba, Japan; Wellcome Trust Centre for Cell Biology, University of Edinburgh, Scotland, United Kingdom)*, A portable BRCA1-HAC (human artificial chromosome) module for analysis of BRCA1 tumor suppressor function, Nucleic Acids Res. 42, e164 2014):
"We demonstrated that tumor suppression gene BRCA1 deficiency results in a specific activation of transcription of higher order alpha satellite repeats (HORs) assembled into heterochromatin domains flanking the kinetochore. It was shown that loss of BRCA1 results in transcriptional de-repression of tandemly repeated satellite DNA. Earlier analyses revealed that the kinetochore forming CENP-A domain is predominantly localized to D5Z2 while being largely excluded from the pericentromeric D5Z1 domain in a range of human cell lines (Slee et al 2012). It is also shown that D5Z2 possesses intact CENP-B box sequences (Rosandić, **Paar**, Basar, Glunčić, Pavin, Pilaš, **2006)**, a 17 bp motif necessary for binding of the CENR-B protein."

W. Li, J. Freudenberg, P. Miramontes ***(Feinstein Institute for Medical Research, Manhasset, New York, USA)*****, Diminishing return for increased Mappability with longer sequencing reads: implications of the k-mer distributins in the human genome, BMC Bioinformatics 15, 2 (2014):**
"The two stretches on chromosome 1 contain copies of the neuroblastoma breakpoint family genes (NBPF) (Vandepoele et al., 2011; **Paar,** Glunčić, Rosandić, Basar, Vlahović, **2011;** Dumas et al., 2012)."

R. Chaves, D. Ferreira, A. Mendes-da-Silva, S. Meles, F. Adega ***(Department of Genetics and Biotechnology, University of Tras-os-Montes and Alto Douro, Vila Real, Portugal; Biosystems & Integrative Sciences Institute,Faculty of Sciences, University of Lisboa, Portugal)*****, FA-SAT is an old satellite DNA frozen in several bilateria genomes. Genome Biol. Evol. 9, 3073-3087 (2017):**
"It is also important to highlight that in the conserved motifs of SA-SAT, we found flanking coding genes, these conserved motifs could be linked to gene regulation and/or chromatin structure (**Paar,** Glunčić, Rosandić, Basar, Vlahović, **2011**; Kuhn et al., 2012; Maumus and Quesneville, 2014; Feliciello et al., 2015)."

S.Louzada, M. Lopes, D. Ferreira, F. Adega, A. Escudeiro, M. Gama-Carvalho, R. Chaves ***(Department of Genetics and Biotechnology, University of Traps-os-Montes and Alto Douro, Vila Real, Portugal; Biosystems and Integrative Sciences Institute, Faculty of Sciences, University of Lisboa, Portugal)*****, Decoding the role of satellite DNA in genome architecture and plasticity – An evolutionary and clinical affair, Genes 11, 72 (2020):**
"SatDNA is typically organized as long arrays of head –to-tail linked repeats and usually present in the genomes in several million copies (Charlesworth et al, 1994). The length of the repeating unit (monomer) can range from a few base pairs up to more than 1 kb, forming arrays that may reach 100 Mb in length (reviewed by Plohl et al., 2008), and can form higher-order repeat (HOR) units (e.g., Willard, 1985; Alexandrov et al., 1993; McNulty and Sullivan, 2018). Complex HORs have been found in non-human mammals such as insects, mouse, swine, bovids, horse, dog ad elephant (reviewed in Vlahović, Glunčić, Rosandić, Ugarković, **Paar, 2017**)."

M. Radavicius, T. Rekasius, J. Zidanaviciute ***(Institute of Data science and Digital technologies, Vilnius University, Lithuania; Vilnius Gediminas Technical University, Lithuania)*****, Local symmetry of non-coding genetic sequences, Informatica 30, 553-571 (2019):**
"Rosandić, Vlahović, Glunčić, **Paar (**2016) considered 20 symbolic quadruplets of trinucleotides obtained via interstrand mirror symmetry mappings (direct, reverse complement, complement

and reverse) and demonstrated quadruplet's symmetries in chromosomes of wide range of organisms, from Escherichia coli to human genomes."

M. AlQuraishi, H.H. McAdams ***(Department of Developmental Biology, Stanford University School of Medicine, California, USA)*****, Three enhancements to the inference of statistical protein-DNA potentials, Proteins, 81, 426-442 (2013):**
"The energetics of protein-DNA interaction are often modeled using so-called statistical potentials, that is, energy models derived from the atomic structures of protein-DNA complexes. We describe three enhancements to statistical potential inference that significantly improve the accuracy of predicted protein-DNA interactions. In the development of our dataset, we searched primary sources and online repositories such as TRANSFAC (Matys et.al., 2006) for experimentally verified DNA binding sites each of the proteins in our data set. More than 45 repositories and primary sources were used (... Moskowitz et al.,1991; Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš; **2006;** Tronche et al., 1992…) providing experimental evidence in the form of footprints, SELEX experiments, and dsDNA microarray assays. The experimentally verified DNA binding sites for each protein were then aligned and combined into a single PWM, by setting the probability of a given nucleotide in the PWM to its frequency as observed in the set of DNA binding sites. The resulting PWMs serve as the gold standard in our tests."

C.R. Catacchio, R. Ragone, G. Chiatante, M. Ventura ***(University of Bari Aldo Moro, Department of Biology, Italy)*****, Organization and evolution of Gorilla centromeric DNA from old strategies to new approaches, Scientific Reports 5, 14189 (2015):**
"(i) Sequence analyses revealed that all existing primate types of alphoid monomers are most likely to be derived from only two ancient types of units and are therefore designed as "A" or "B" monomers (Romanova et al., 1996). (ii) α-satellite sequences can either form tandem heterogeneous monomeric arrays (10-40 % divergence between individual monomers) or organize multimeric structures assembled in a period known as higher-order repeats (HORs) (Warburton et al., 1996; Alexandrov et al., 2001; Rudd, Willard, 2004; Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš, **2006; Paar,** Basar, Rosandić, Glunčić, **2007;** Rosandić, Glunčić, **Paar,** Basar, **2008)**. HOR units may be composed of two to over 30 monomers and are tandemly repeated several hundreds to thousands of times per single centromere (Willard, Waye, 1987; Wevrick, Willard, 1989; Oakey, Tyler-Smith, 1990). (iii) Where investigated, multimeric arrays have been found to contribute to the bulk of the centromeric chromatin, bordered by a monomeric α-satellite that acts as a junction to the pericentromeric regions (Alexandrov et al., 2001; Rudds, Willard, 2004; Warburton, Willard, 1990). In HORs, monomers within a period differ greatly in sequence, while monomers standing at corresponding positions of different periods are virtually identical (≤ 2% sequence divergence) (Rudd, Willard, 2004). The presence of alphoid HORs has been reported throughout the superfamily Hominoidea and is the evolutionary result of sequence homogenization created by molecular drive mechanisms, such as amplification, unequal crossing over and gene conversion (Terada et al., 2013; Schindelhauer et al., 2002). In particular, homogenization shows three patterns: local homogenization in tandem,

intrachromosomal homogenization patterns that are regional but not in tandem, and intrachromosomal or interarray patterns (Hayden et al., 2013)." ¨

P. Sujiwattanarat, W. Thappana, K. Srikulnath, Y. Hiraj, H. Hiraj, A. Koga *(Primate Research Institute, Kyoto University, Japan; Faculty of Science, Kasetsart University, Bangkok University, Thailand)*, Higher-order repeat structure in alpha satellite DNA occurs in New World monkeys and is not confined, Scientific Reports 5, 10315 (2015):
"The alpha satellite of humans, which has been extensively studied for its structural features, is known to contain sequences organized into higher-order repeat (HOR) structures, which are tandem arrays of larger repeat units that consist of multiple basic repeats (Willard, Waye, 1987; Warburton, Willard, 1990). The larger repeat units that have so far been identified include those comprising 2, 4, 5, 6, 8, 11 and 13 basic repeat units (Warburton, Willard, 1990; Haaf, Willard, 1998; Looijenga et al., 1992; Alexandov et al, 1993; Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš, **2006;** Waye, Willard, 1989; Greig et al., 1993). The HOR structure also occurs in other hominoid species (Rudd et al., 2006; Alkan et al., 2007), including gibbons (Terada et al., 2013; Koga et al., 2014)."

E. Balzano, S. Giunta (Dipartimento di Biologia e Biotecnologie *Charles Darwin,* Sapienza Universita di Roma, Italy; *Laboratory of Chromosome and Cell Biology, Rockefeller University, New York, USA)*, Centromeres under pressure: Evolutionary innovation in conflict with conserved function, Genes 11, 912 (2020):
"Inside human HORs, the number of monomers ranges from two, for example, in chromosome 1 (Carine et al., 1989) to 34 monomers in chromosome Y (Tyler-Smith, Brown, 1987; Willard et al., 1987). The sequence of monomers has up to 35% variability among chromosomes and within the same chromosome (Fukagawa, Earnshaw, 2014), indicating that the formation of HOR followed a different mutagenic process than HOR amplification through homogenization. Despite the human HOR on the Y chromosome possessing alphoid DNA sequences, it differs from other HORs on autosomes and X chromosomes because it lacks CENP-B boxes (Fukagawa, Earnshaw, 2014), indicating that CENP-B is not essential for a functional centromere (Fachinetti et al., 2015; Durfy, Willard, 1989). Notably, some younger HORs with more homogenized monomers (Hartley et al., 2019) that have yet to accumulate additional mutations and SNPs are shared among non-homologous autosomes (Glunčić, Vlahović, **Paar, 2019)**, as for the chromosome groups 1, 5, 19-13,21-14 and 22 (Guin et al., 2020). Some of these sequences are regarded as “pan-centromeric" and are often used for the rapid detection of multiple centromeres in different chromosomes."

M.A. Garrido-Ramos (Universidad de Granada), Satellite DNA: An evolving topic, Genes 8(9), 230 (2017):
"Vlahović et al. (Vlahović, Glunčić, Rosandić, Ugarković and **Paar,** 2017) have proposed that HORs could act as regulatory elements and that variation in HOR composition among

individuals or populations can generate gene expression diversity and contribute to the evolution of gene regulatory network. Regular HORs similar to those found in humans, but usually dimeric, have been found in several species of beetles (Vlahović, Glunčić, Rosandić, Ugarković and **Paar,** 2017). However, the formation of complex HORs, shaped from interspersed and/or inversely oriented monomers and frequently with extraneous sequence elements, is usual. Complex HORs have been found in non-human mammals, such a mouse, swine, bovine, horse, dog, and elephant and in insects (reviewed in Vlahović, Glunčić, Rosandić, Ugarković and **Paar,** 2017."

T. Gržan, E. Despot-Slade, N. Meštrović, M. Plohl, B. Mravinac ***(Ruđer Bošković Institute, Zagreb, Croatia),*** **CenH3 distribution reveals extended centromeres in the model beetle *Tribolium castaneum*, PLOS Genet. 16, e1009115 (2020):**
"Computational analysis of higher order repeat (HOR) structures in *T. castaneum* disclosed TCAST–incorporating HORs found solely in unplaced scaffolds and singletons; particularly interesting is the fact that the TCAST monomers in those HORs are very heterogeneous, come from different subfamilies and are combined with extraneous elements (Vlahović, Glunčić, Rosandić, Ugarković, **Paar, 2017)**. Our ChiP results corroborate previous cytogenic TCAST localization (Pavlek et al., 2015) and bioinformatic HOR analysis (Vlahović, Glunčić, Rosandić, Ugarković, Paar, **2017)**, and suggest that functional *T. castaneum* centromeres are not built upon an exclusive fraction of TCAST satellite. Instead, it is more likely that they comprise different variants/subfamilies of the major satellite DNA intermingled with other DNA sequences."

J.A. Tenreiro Machado, J.M. Rocha-Neves, J.P. Andrade ***(Institute of Engineering, Polytechnic of Porto, Portugal; Department of Biomedicine, Faculty of Medicine, University of Porto, Portugal; Department of Physiology and Surgery, Faculty of Medicine, University of Porto, Portugal; Center for Health Technology and Services Research, Porto, Portugal)*****, Computational analysis of the SARS-CoV-2 and other viruses based on Kolmogorov's complexity, Nonlinear Dyn. 101, 1731-1750 (2010):**
"We find in the literature a variety of different functions that can tackle datasets and shed light to distinct characteristics (Deza, 2009). For a set of numerical vectors $(x_1,\ldots,\ x_N)^T \leq \mathbb{R}^n$, the Minkowski norm L_n: $\left(\sum_{k=1}^{N}|x_k|^n\right)^{\frac{1}{n}}$, and in particular the Manhattan and Euclidean cases, L_1 and L_2 for $n = 1$ and $n = 2$, are often used (Cha, 2008). In the case of DNA analysis, these norms support different algorithms (Yin et al., 2014; Kubicova, Provaznik, 2014; Glunčić, **Paar, 2013)** that allow the comparison of data sequences."

S.V. Petoukhov (Mechanical Engineering Research Institute of Russian Academy of Sciences, Moscow, Russia), Hyperbolic rules of the cooperative organization of eukaryotic and prokaryotic genomes, BioSystems 198, 104273 (2020):
"For long nucleotide sequences of single stranded DNA, the second Chargaffs rule is well known which states that in such sequences the amount of guanine G is approximately equal to the

amount of cytosine C and the amount of adenine A is approximately equal to the amount of thymine T. Many authors have devoted their work to the analysis and discussion of this rule (Fimmel et al., 2019; Prabhu, 1993; Rapoport, Trifonov, 2012; Rosandić, Vlahović, Glunčić, **Paar, 2016;** Shporer et al., 2016; Yamagishi, 2017). According to (Albrecht-Buehler, 2006), this rule applies to the eukaryotic chromosomes, the bacterial chromosomes, the double-stranded DNA viral genomes, and the archaeal chromosomes provided they are long enough."

J. Shao, X. Yan, S. Shao ***(Science College, Nanjing University of Technology, China; Language Technology Institute, Carnegie Mellon University; Pittsburgh,Pennsylvania, USA; Department of Electrical and Computer Engineering, Faculty of Engineering, McMaster University, Hamilton, Canada)*****, SNR of DNA sequences mapped by general affine transformations of the indicator sequences, J.Math.Biol. 67, 433-451 (2013):**
"The identification of gene coding regions of DNA sequences through digital signal processing techniques based on the so-called 3-base periodicity has been an emerging problem in bioinformatics. The signal to noise ratio (SNR) of a DNA sequence is computed after mapping the DNA symbolic sequence into numerical sequences. The periodic feature of DNA sequences is also instrumental for identification of protein coding regions (Gao et al., 2005), repetitive sequences (Sharma et al., 2004), alphoid higher order repeats (**Paar,** Pavin, Basar, Rosandić, Glunčić, Paar, **2008)** and detection of human nucleosomes (Bettecken, 2011), etc."

G.I. Kravatskaya, V.R. Chechetkin, Y.V. Kravatsky, V.G. Tumanyan (Engelhardt Instotute of Molecular Biology of Russian Academy of Sciences, Moscow, Russia), Structural attributes of nucleotide sequences in promoter regions of supercoiling-sensitive genes: How to relate microarray expression data with genomic sequences, Genomics 101, 1-11 (2013):
"The periodic patterns in promoter sequences were studied by Fourier transform The characteristic period and the harmonic number are related as $p = L/n$. Generally, the significant periodicities should be identified not only by the singular high peaks in Fourier spectra but also by the singular high peaks in Fourier spectra but also by the sets of equidistant harmonics with the numbers $n, 2n, ..., m \le L/2$ (43-47 Chechetkin, Turygin, 1995; Lobzin, Chechetkin, 2000; Tiwari et al., 1997; **Paar,** Pavin, Basar, Rosandić, Glunčić, Paar, 2008; Chechetkin , 2011) **.**"

S.M. McNulty, B.A. Sullivan ***(Department of Molecular Genetics and Microbiology, Duke University Medical Center, Durham, North Carolina, USA; Division of Human Genetics, Duke University Medical Center, Durham, North Carolina, USA)*****, Alpha satellite DNA biology: Finding function in the recesses of the genome, Chromosome Res. 26, 115-138 (2018):**
"Alpha satellite monomers within each suprachromosomal family have specific sequence and higher order characteristics, but all monomers can be broadly classified into two groups based on their identity to the alpha satellite consensus: A-type and B-type monomers (Rosandić, **Paar,**

Basar, Glunčić, Pavin and Pilaš, **2006)**. A-type monomers include J1, D2, W4, W5, M1, and R2 monomers, while B-type consist of J2, D1, W1-W3, and R1 monomers. A and B monomers differ in sequence positions 35-51, a region that correlates with proton binding. B-type monomers contain CENP-B boxes, while A-type monomers contain a binding site for pJα (Rosandić, **Paar,** Basar, Glunčić, Pavin and Pilaš, **2006)**, a protein that has not been well characterized and whose function is unclear. Interestingly, DYZ3 of HSAY completely lacks monomers that contain CENP-B boxes but does contain monomers that have the pJα motif."

K.G. Srinivasa, G.M. Siddesh, S.R. Manisekhar, ***(Indian Institute of Science, Bangalore, India; Visvesvaraya Technological University, Ramaiah Institute of Technology, Belagavi, India)*****, Statistical modelling and machine learning principles for bioinformatics techniques, tools and applications, Book Series: Algorithms for Intelligent Systems, Springer, ISBN-13: 978-981-15-2444-8 (2020):**
"Quoted reference (23): Marija Rosandić, Vladmir **Paar,** Codon sextets with leading role of serine create "ideal" symmetry classification scheme of the genetic code, Gene 543, 45-52 **(2014).**"

M.E. Aldrup-MacDonald, B.A. Sullivan ***(Duke University Medical Center, Duke University)*****, The past, present, and future of human centromere genomics, Genes 5, 33-50 (2014):**
"The bottleneck in generating alpha satellite assemblies has undoubtedly been the sophistication of assembly tools that are required to order distinguishable monomeric sequences within highly homogenous arrays. Several groups have developed in silico tools for analyzing higher order alpha satellite sequence available in genome assemblies (**Paar,** Pavin, Rosandić, Glunčić, Basar, Pezer, Žinić, 2005; Rosandić, **Paar,** Glunčić, Basar, Pavin, 2003)."

Contreras-Galindo R, Fischer S, Saha AK, Lundy JD, Cervantes PW, Mourad M, Wang C, Qian B, Dai M, Meng F, Chinnaiyan A, Omenn GS, Kaplan MH, Markowitz DM ***(Department of internal medicine, University of Michigan, Ann Arbor, Michigan, USA; Laboratory of molecular virology, Facultad de ciencias Montevideo, Uruguay; Program in cancer biology, University of Michigan, Ann Arbor, Michigan, USA; Molecular and behavioral neuroscience institute, University of Michigan, Ann Arbor, Michigan, USA; Department of psychiatry, University of Michigan, Ann Arbor, Michigan, USA; Michigan center for translational pathology and comprehensive cancer center, University of Michigan, Ann Arbor, Michigan, USA; Howard Hughes Medical Institute, Chevy Chase, Maryland, USA; Department of human genetics; Department of computational medicine and bioinformatics, University of Michigan, Ann Arbor, Michigan, USA; Program in immunology, University of Michigan; Program in Cellular and Molecular Biology, University of Michigan, Ann Arbor, Michigan, USA)*** **Rapid molecular assays to study human centromere genomics. Genome Res 27, 2040-2049 (2017):**

"CENP-A nucleosomes at functional centromere sequences interact with CENPB, a protein that binds specifically to CENPB boxes, 17-nt sequences present in the majority of alpha-repeats, to stabilize CENPA nucleosomes (Ohzeki et al. 2002; Rosandić, **Paar,** Basar, Glunčić, Pavin, Pilaš, **2006;** Fachinetti et al. 2015; Fujita et al. 2015)."