The Structure of Excited 0^+ States in Nuclei and the Effect of the γ Degree of Freedom*

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The comprehensive review of Garrett [1] demonstrates that most first excited 0^+ states in nuclei do not have the characteristics of β-vibrations. We have conclusively shown [2] that in N=88 and 90 nuclei these 0_2^+ states are a second vacuum formed by the combination of the quadrupole pairing force and the low density of oblate orbitals near the Fermi surface. This is confirmed by the blocking of this collective 0_2^+ mode in the even-even nuclei from coupling to the [505]11/2$^-$ single-particle quasi-neutron orbital in the neighbouring odd neutron nuclei. The fact that these 0_2^+ states are 2p-2h neutron states demonstrates the futility of attempts to describe them [3,4] using non-microscopic models that use the Bohr Hamiltonian and alleged β-softness in transitional nuclei and/or various variants of the IBA. Even the most sophisticated models [5,6], that do not include 2p-2h configurations, do not have the crutial physics and cannot expect to get good agreement with the experimental data on 0_2^+ bands. The structure of 0_2^+ and 0_n^+ states, in various regions of the nuclear chart, will also be discussed.

Recently K=2^+ "γ-vibrational" bands have been observed up to 17^+ in $^{154}Gd_{90}$ [2] and to 28^+ in $^{156}Dy_{90}$ [7]. These bands "track" the ground state band up to their highest spins. Positive parity bands have also been observed that decay to second vacuum states based on the 0_2^+ levels in both these nuclei. These bands "track" the band based on 0_2^+ and have the characteristics of the second vacuum K=2^+ "γ-vibrational" band.

Starting with the Bohr Hamiltonian, the rotation-vibration model gives [8], in an obvious notation;

$$E_x(n_\beta n_\gamma IK) = \hbar\omega_\beta(n_\beta + ½) + \hbar\omega_\gamma(2n_\gamma + ½|K| + 1) + [I(I + 1) – K^2]\, \hbar^2/2I$$

so that the traditional K=2^+ γ-band is not a band containing a quantum in the γ direction but has $n_\gamma = 0$ and a bandhead energy given by $E_x = \hbar\omega_\gamma + \hbar^2/I$. In the rotation-vibration model there is a strong coupling between rotations and γ-vibrations, physically expressing the fact that rotations with non-vanishing K become possible only in the presence of dynamical triaxiality [8]. Any model having the γ degree of freedom will have zero-point fluctuations and a similar origin for K=2^+ bands. The systematics of known γ-bands and candidates for K=4^+, $n_\gamma = 0$ bands will be discussed.

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[1] P. E. Garrett, J. Phys. **G** (London) **27**, R1 (2001)
[2] J. F. Sharpey-Schafer *et al.,* Nucl. Phys. **A834**, 45c (2010)
[3] F. Iachello, Phys. Rev. Lett. **85**, 3580 (2000) and **87**, 052502 (2001)
[4] R. F. Casten and N. V. Zamfir, Phys. Rev. Lett. **87,** 052503 (2001)
[5] S. Y. Chu et al, Phys. Rev. **C52**, 1407 (1995)
[6] J.-P. Delaroche *et al.,* Phys. Rev. **C81,** 014303 (2010).
[7] S. N. T. Majola *et al.,* this conference, poster.
[8] W. Greiner and J. A. Maruhn, *Nuclear Models (Springer 1996)* p158/9