PROCEEDINGS OF
THE XVII RCNP INTERNATIONAL
SYMPOSIUM ON

INNOVATIVE COMPUTATIONAL METHODS IN NUCLEAR MANY-BODY PROBLEMS

Towards a new generation of physics in finite quantum systems

(INNOCOM97), Osaka, Japan 10-15 November 1997

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RELATIVISTIC MEAN FIELD DESCRIPTION OF NUCLEAR COLLECTIVE ROTATION –THE SUPERDEFORMED ROTATIONAL BANDS IN THE A∼60 MASS REGION–

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Relativistic Mean Field Theory is applied to the description of rotating nuclei. Since the previous formulation of Munich group was based on a special relativistic transformation property of the spinor fields, we reformulate in a fully covariant manner using tetrad formalism. The numerical calculations are performed for 3 zinc isotopes, including the newly discovered superdeformed band in ^{62}Zn which is the first experimental observation in this mass region.

In recent years, Relativistic Mean Field Theory(RMFT) has been successful in describing various properties of nuclear matter and ground states of finite nuclei. Some groups also tried to apply this model to the excited states in finite nuclei. In 1989, Munich group made a first attempt to describe rotating nuclei by combining RMFT and the cranking assumption.[1] They applied this model mainly to the description of the superdeformed(SD) rotational bands in the A∼150, 80, and 190 mass regions.[2] In their formulation, however, the transformation property of the spinor fields was based on the Lorentz transformation in spite of the fact that the rotating frame was not an inertial one. In general relativity, it is known that the spinor fields transform as scalars under such coordinate transformation, and hence, we think the formulation of Munich group should be checked. Therefore, we reformulated in a fully covariant manner using the technique of general relativity known as tetrad formalism.[3] The resulting equations of motion were, in fact, the same as those of Munich group. Why they obtained the correct result was also clarified in our formulation. For detail, see ref.4. By solving these equations self-consistently, we can calculate various properties of rotating nuclei. As an application of the present model, we calculate the SD bands in the A∼60 mass region. This mass region is chosen because, very recently, McMaster group reported the discovery of the SD band in ^{62}Zn, which was the first experimental observation of the SD bands in this mass region.[5]

Our calculations are performed for 3 zinc isotopes, ^{60}Zn, ^{62}Zn, and ^{64}Zn using the parameter set NL-SH. Theoretically, Ragnarsson calculated the SD states in ^{60}Zn and predicted that the SD minimum became yrast at $I = 22$.[6] Experimentally, on the other hand, the SD band in ^{62}Zn was very recently discovered. This band seems to become yrast at $I \geq 24$, and the extracted β_2 value is 0.45. In Fig. 1(a) the calculated moments of inertia of several SD bands in ^{62}Zn are shown as functions of the rotational frequency. The experimental values are denoted by crosses. Also shown are the excitation energies as functions of the total spin in Fig. 1(b). The lowest SD band is the one named 'band A'. Therefore, if we assume that this band A corresponds to the experimentally observed one, the calculated moments of inertia are somewhat too small compared to the experimental values, although we can not give any decisive conclusion at the present stage, because there are only limited number of experimental data.

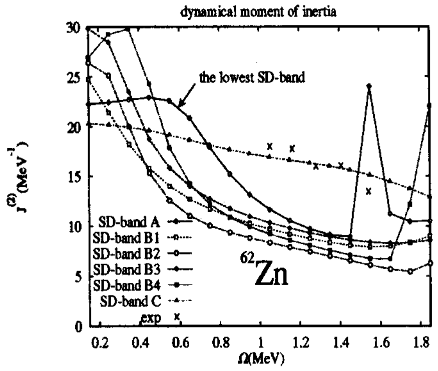

Figure 1(a): Calculated and experimental dynamical moments of inertia of several SD bands in ^{62}Zn. The configurations of each band are A:$\nu[3]^{-2}[4]^2\pi[3]^{-2}[4]^2$, B1∼B4:$\nu[3]^{-1}[4]^1\pi[3]^{-2}[4]^2$, C:$\nu[3]^{-4}[4]^4\pi[3]^{-2}[4]^2$.

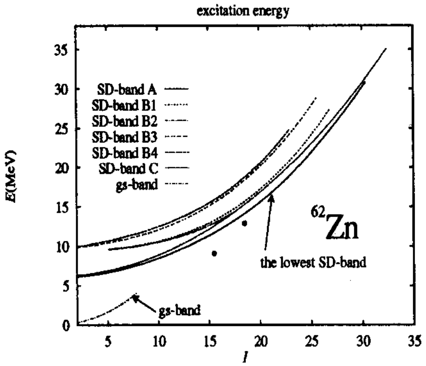

Figure 1(b): Excitation energies of several SD bands together with the ground state band in ^{62}Zn. The discrete points represent the oblate terminating states. The meaning of each SD band is the same as (a).

For other isotopes, there are no experimental observations and we show only the calculated excitation energies of the lowest one or two SD state(s). Figure 2 shows the excitation energies as functions of the total spin. For comparison we also show the ground state bands and the several oblate terminating states. The lowest SD states seem to become yrast at $I \simeq 16 \sim 24$ in all these isotopes. For ^{60}Zn, this is consistent with the prediction of Ragnarsson.

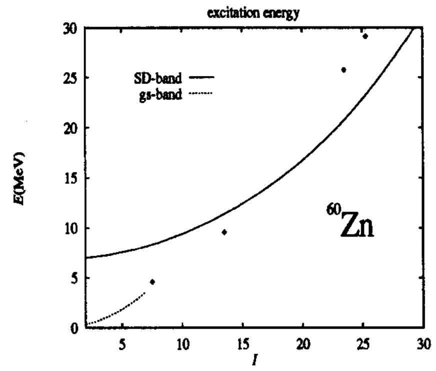

Figure 2(a): Excitation energies of the lowest SD band and the ground state band in ^{60}Zn. The discrete points represent the oblate terminating states. The configuration of the SD band is $\nu[3]^{-2}[4]^{2}\pi[3]^{-2}[4]^{2}$.

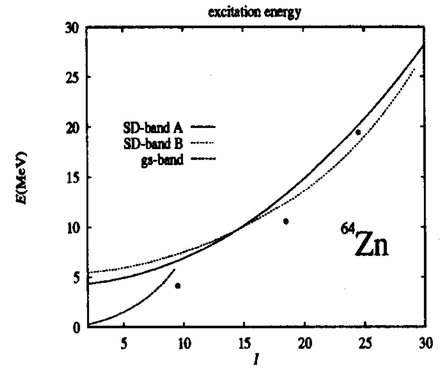

Figure 2(b): The same as (a) but the lowest two SD bands in ^{64}Zn are shown. The configurations of the SD bands are
A:$\nu[3]^{-4}[4]^{4}\pi[3]^{-2}[4]^{2}$,
B:$\nu[3]^{-2}[4]^{2}\pi[3]^{-2}[4]^{2}$.

To summarize, we applied Relativistic Mean Field Theory to the description of the SD rotational bands in the A$\sim$60 mass region, including the newly discovered SD band in ^{62}Zn. The calculated dynamical moments of inertia were somewhat too small compared with the experimental values. In future, more systematic investigation both in theoretical and experimental way will be necessary to arrive at a definite conclusion on the SD bands in this mass region.

References

1. W.Koepf and P.Ring, *Nucl. Phys.* A **493**, 61 (1989); *Nucl. Phys.* A **511**, 279 (1990).
2. J.König and P.Ring, *Phys. Rev. Lett.* **71**, 3079 (1993); A.V.Afanasjev, J.König and P.Ring, *Phys. Lett.* B **367**, 11 (1996); *Nucl. Phys.* A **608**, 107 (1996); J.König, *Ph.D.thesis,* 1996 (unpublished).
3. S.Weinberg, *Gravitation and Cosmology: Principles and Applications of The General Theory of Relativity* (John Willy and Sons, New York, 1972), p. 365; N.D.Birrell and P.C.W.Davies, *Quantum Fields in Curved Space* (Cambridge Univ. Press, London, 1982), p. 81.
4. H.Madokoro and M.Matsuzaki, *Phys. Rev.* C **56**, R2934 (1997).
5. C.E.Svensson *et al*, *Phys. Rev. Lett.* **79**, 1233 (1997).
6. I.Ragnarsson, *Proceedings of the Workshop on the Science of Intense Radioactive Ion Beams*, Los Alamos, April 10-12(1990), p. 199.