Chiral doublet bands in odd-odd nuclei*

WANG Shou-Yu(王守宇)[1] ZHANG Shuang-Quan(张双全)[2,3]
QI Bin(亓斌)[2] MENG Jie(孟杰)[2,1,3,4,5]

1 (Department of Space Science and Applied Physics, Shandong University at Weihai, Weihai 264209, China)
2 (School of Physics, Peking University, Beijing 100871, China)
3 (Institute of Theoretical Physics, Chinese Academy of Science, Beijing 100080, China)
4 (Center of Theoretical Nuclear Physics, National Laboratory of Heavy Ion Accelerator of Lanzhou, Lanzhou 730000, China)
5 (Department of Physics, University of Stellenbosch, Stellenbosch, South Africa)

Abstract The criteria for chiral doublet bands based on one particle and one hole coupled to a triaxial rotor have been summarized. Candidate chiral doublet bands in $A\sim100$ and 130 odd-odd nuclei were checked against these chiral criteria. Two representative cases, nearly degenerate $\Delta I=1$ doublet bands in ^{126}Cs and ^{106}Rh were investigated in the two quasiparticles coupled with a triaxial rotor model. After including the pairing correlation, good agreement has been obtained between the calculated results and the data available, which supports the interpretation of observed doublet bands as chiral bands.

Key words chiral doublet bands, pairing correlation, particle rotor model

PACS 21.10.Re, 21.60.Cs, 21.60.Ev

1 Introduction

Chiral doublet bands[1] have been suggested to appear in odd-odd nuclei with substantial triaxial deformation. Extensive experimental studies have been made to search for such bands. So far, candidate chiral doublet bands have been proposed in quite a number of odd-odd nuclei in the $A\sim130$ and $A\sim100$ mass regions[2—4]. The smallest level degeneracy of doublet bands is observed in ^{134}Pr and ^{104}Rh, where the states at spins 15^+ and 17^- are separated by energies 36 keV and 2 keV, respectively. Thus, ^{134}Pr and ^{104}Rh have been often considered as the best examples of chiral rotation in the $A\sim130$ and $A\sim100$ mass regions. However, the recent lifetime experiment for ^{134}Pr gives different E2 transition rates for the partner bands[5, 6], which is contradictory to the chiral interpretation of the doublet bands. Similarly, it is interesting to test whether the other examples of partner bands observed in odd-odd nuclei satisfy the ideal chiral criteria. In this paper, The criteria for chiral doublet bands based on one particle and one hole coupled to a triaxial rotor have been summarized. Candidate chiral doublet bands in $A\sim100$ and 130 odd-odd nuclei were checked against these chiral criteria. Two representative cases, candidate chiral doublet bands in ^{126}Cs and ^{106}Rh were investigated in the two quasiparticles coupled with a triaxial rotor model.

2 Results and discussion

In Ref. [7], a set of criteria for chiral doublet bands based on one particle and one hole coupled to a triaxial rotor have been summarized. The most important of these criteria is the nearly degenerate levels of the same spin and parity in two $\Delta I=1$ bands built on the same single-particle configuration. It is the most essential consequence of the spon-

Received 8 July 2008
* Supported by National Natural Science Foundation of China (10605001, 10435010, 10221003, 10505002)

taneous formation of chirality. Correspondingly, a smooth dependence of the energy staggering parameter $S(I)=[E(I)-E(I-1)]/2I$ with spin and similar spin alignments between the doublet bands are expected. The next experimental signature will be the electromagnetic properties. Again based on one particle and one hole siting in high-j orbits coupled to a triaxial rotor, the ratios $B(\mathrm{M1})/B(\mathrm{E2})$ staggering as a function of spin, similar $B(\mathrm{M1})$ and $B(\mathrm{E2})$ transition strengthes between the chiral partner states, and the suppressed interband $B(\mathrm{E2}, I\rightarrow I-2)$ transitions are expected.

The candidate chiral doublet bands in the $A\sim130$ and $A\sim100$ odd-odd nuclei have been systematically checked against these chiral criteria. It has been found that the doublet bands in ^{126,128,130}Cs and ^{106}Rh possess better chiral geometry than ^{134}Pr and ^{104}Rh. Motivated by these considerations, two quasiparticles coupled with a triaxial rotor model is employed for the analysis of the candidate chiral doublet bands in ^{126}Cs and ^{106}Rh.

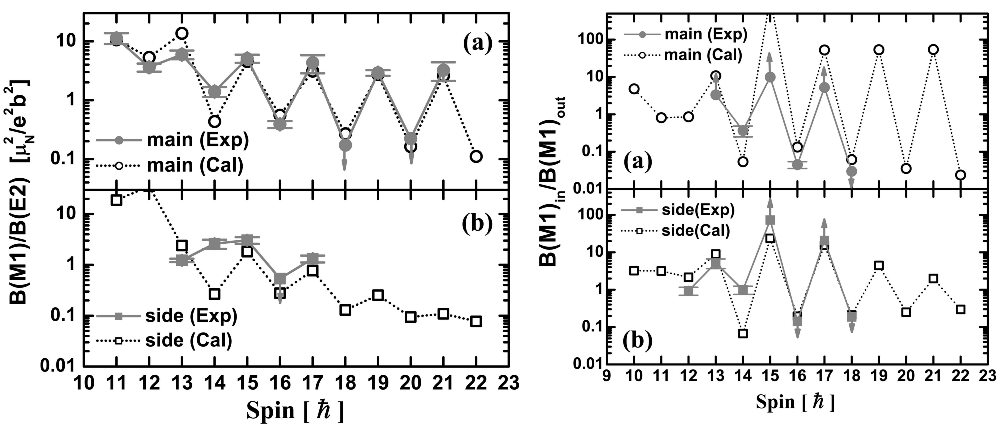

Fig. 1. The Comparisons between the calculated $B(\mathrm{M1})/B(\mathrm{E2})$, $B(\mathrm{M1})_{\mathrm{in}}/B(\mathrm{M1})_{\mathrm{out}}$ and data for the doublet bands in ^{126}Cs.

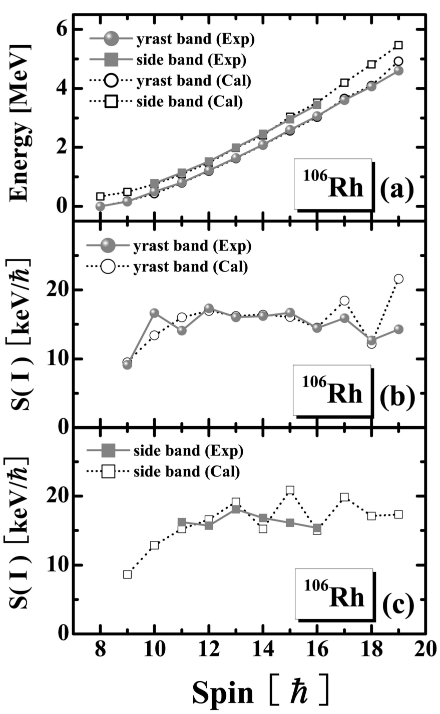

Fig. 2. (a) Excitation energy and (b, c) staggering $S(I)=[E(I)-E(I-1)]/2I$ as a function of spin for the yrast and side band in ^{106}Rh.

In Ref. [1], the PRM with one particle and one hole coupled with a triaxial rotor has been developed and used in the analysis of chiral bands. Including the pairing by the usual BCS quasiparticle approximation, the PRM can be generalized to the two quasiparticles coupled with a triaxial rotor cases[8, 9]. The single-particle energies ϵ_ν obtained by diagonalizing the single proton (neutron) Hamiltonian in PRM[1] are replaced with the corresponding quasiparticle energies E_ν,

$$E_{\nu\mathrm{i}}=\sqrt{(\epsilon_{\nu\mathrm{i}}-\lambda_\mathrm{i})^2+\Delta_\mathrm{i}^2}, \qquad \mathrm{i}=\mathrm{n},\mathrm{p}, \tag{1}$$

where $\varepsilon_{\nu i}$ is the single particle energies, Δ_i the pairing gaps and λ_i the Fermi energy, and the pairing factors $(u_\mu v_\nu+u_\mu v_\nu)$ have to be included in the calculations of the single-particle matrix elements. The BCS occupation probabilities v^2 are given by

$$v_\nu^2=\frac{1}{2}\left[1-\frac{\epsilon_\nu-\lambda}{E_\nu}\right]. \tag{2}$$

The calculated electromagnetic transition ratios together with their corresponding experimental results[10] for the doublet bands in ^{126}Cs are presented in the Fig. 1. It can be seen that the agreement for the $B(\mathrm{M1})/B(\mathrm{E2})$ ratios at the whole spin region is excellent. The magnitude, staggering and the decreasing trend of the ratios with spin are reproduced quite well. Furthermore the experimental staggering phase is exactly reproduced in the calculation. Similarly, the calculated $B(\mathrm{M1})_{\mathrm{in}}/B(\mathrm{M1})_{\mathrm{out}}$ ratios also reproduce the experimental magnitude, staggering and the trend pattern quite well.

For ^{106}Rh, the configuration-fixed constrained triaxial relativistic mean field (RMF) approach is applied to determine the quadrupole deformations β and γ for the $\pi g_{9/2}\otimes\nu h_{11/2}$ configuration[11]. Self-consistent deformation parameters $\beta=0.251$ and γ=23.1° are obtained from the RMF approach. In the second step, using these self-consistent deformation parameters as inputs for the PRM, energy spectra are calculated based on our model of a triaxial rotor coupled with two quasi-particles.

The calculated energy spectra $E(I)$ and the energy staggering parameter $S(I)$ for doublet bands in ^{106}Rh are presented in Fig. 2, together with the corresponding experimental results[4]. Using the present self-consistent deformation parameters for the configuration $\pi g_{9/2}\otimes\nu h_{11/2}$ as input for the PRM, the experimental energy displacement around 300 keV constant energy separation is well reproduced. From panels (b) and (c), the calculated values of $S(I)$ also reproduce quite well the experimental amplitudes for the yrast and side bands in ^{106}Rh and yield an almost constant value of ~15 keV/$\hbar$. In the other hand, the calculated electromagnetic transition ratios for the doublet bands in ^{106}Rh are also reproduced[12].

3 Summary

The criteria for chiral doublet bands have been summarized. Candidate chiral doublet bands in $A\sim$ 100 and 130 odd-odd nuclei were checked against these chiral criteria. Two representative cases, doublet bands in ^{126}Cs and ^{106}Rh were investigated in the two quasiparticles coupled with a triaxial rotor model. The good agreement has been obtained between the calculated results and the data available, which supports the interpretation of observed doublet bands as chiral bands.

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