Theoretical Investigation of Triaxial Strong Deformation and Tidal Waves in Nuclei

Abstract

by

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The appearance of triaxial nuclear shapes and the question how to prove their existence is a long-standing problem in nuclear physics. The recent discovery of wobbling rotational bands is considered as first clear cut evidence for this type of nuclear shape. So far wobbling bands have only be found in the Lu isotopes. In this thesis, the results of experimental search for wobbling bands in ^{163}Tm are theoretically analyzed. Calculations of the energy and electromagnetic transition probabilities are carried out in the framework of the microscopic Tilted Axis Cranking (TAC) model. The calculations account well for the data. It is found that the bands have a triaxial strong deformation (TSD). However, the two observed rotational sequences do not correspond to a zero and one wobbling phonon but to the two signature branches of the odd proton orbital, which is a very low lying particle-hole excitation. It is demonstrated that in general wobbling phonons compete with particle-hole excitations. With present-day types of experiments, the two modes can only be disentangled if the wobbling states are the lowest excitations, as in the Lu isotopes, whereas in many other cases, including ^{163}Tm, the particle-hole excitations make up the spectrum of observed rotational TSD bands.

There exists a large group of transitional nuclei that show a behavior in-between harmonic vibration and rotation, a description of which has been a long-standing challenge to nuclear theory. The new concept of nuclear tidal waves allows one to calculate the sequence of states with maximal angular momentum (yrast states). These states correspond to a surface wave running around the nucleus as tidal waves run over the earth's oceans. Such a wave corresponds to a static deformation in the rotating frame of reference, which allows one to calculate its properties by means of the microscopic cranking model. For the first time such calculations are carried out in this thesis for nuclei with Z = 44, 46, 48 and N = 56-66. The calculations reproduce very well energies and E2-transitions probabilities of these nuclei. The low-spin parts show the expected gradual transition from vibration-like behavior of the nuclides near the closed shell (Z=48,N=56) to rotation-like behavior of the nuclide farthest in the open shell (Z = 44, N = 66). In addition, the strong irregularity (back-bending) caused by the alignment of the angular momentum of two $h_{11/2}$ neutrons with the rotational axis is well accounted for. At spins larger than 10 $\hbar$, where the back-bending occurs, all nuclei behave more rotation-like, which is borne out by the calculations in accordance with experiment. Such a detailed theoretical description of the yrast states of transitional nuclei has been achieved for the first time in this thesis.