

Symmetry and Structure of Quantal Many-body System

Nuclei and Microclusters

H. Sagawa

Center for Mathematical Sciences
the University of Aizu
Aizu-Wakamatsu, Fukushima 965-80, Japan

Abstract

The symmetry and structure of quantal many-body system are discussed in relations with shell structures of nuclei and microclusters. We will study the competition between the solid symmetry and the mean field in the case of microclusters with the atoms of 2 to several thousands. Especially the effect of the icosahedral symmetric lattice is introduced to study the supershell structure.

There exists in nuclear many-body system geometrical symmetry like spherical, axial symmetric prolate and oblate shapes. The structure of nucleus is much related with the symmetry of shapes [1]. The well-known example is the shell structure of single-particle orbits in the mean field of nucleons. Moreover, new symmetry will predict some peculiar features of the many-body system like super-deformation or super-heavy nuclei.

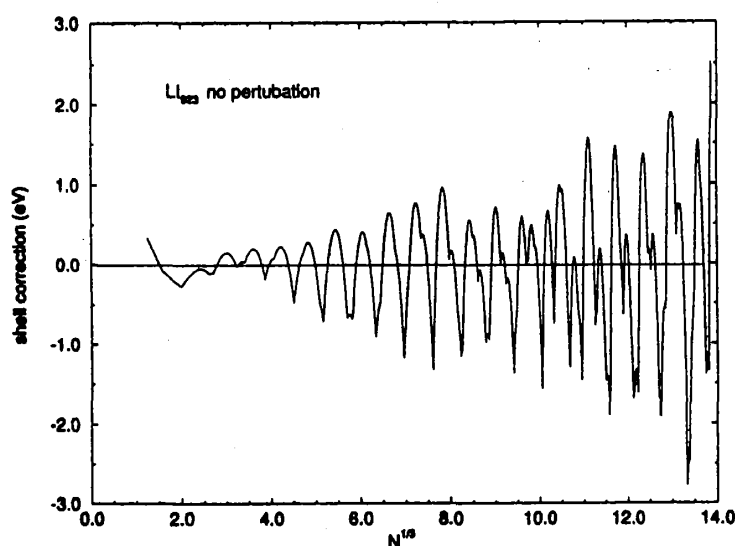


Fig. 1 Shell and supershell structure of Li atomic clusters. The shell correction energies are calculated from the total energies subtracting the smooth part of energy. Each dip corresponds to the shell minimum. We can see the oscillating feature of the shell corrections having a minimum at around $N^{1/3}=8$.

Recently, study of microclusters is very popular because of development of experimental devices and also new attractive properties of these objects. At the same time, microclusters open a new challenging field of many-body quantal system, i.e., from 2-body to several thousands particles. The number might go up continuously to infinity in some future.

There are two competing structures in microclusters; electronic mean-field and atomic-ion geometrical structures[2]. It is known in the clusters, especially metal clusters, the electrons move in a mean field potential which has close similarity to that of nucleons in atomic nuclei, except the spin-orbit interaction. Characteristic shell closures of the spherical symmetric potential have been observed in many metal clusters, which are caused by the degeneracy of each electron orbit in the mean field. Moreover, the supershell structure is also reported in some alkali metal clusters with 1000-2000 ions. It is, however, obvious that geometrical structures will govern large clusters. Typical important geometrical structures are body-center cubic lattice and icosahedral symmetric lattice. It is a quite interesting and open question when the phase transition from the mean-field picture to the geometrical symmetry occurs when one increases the cluster size. I will report this study adopting a microscopic model of the electronic mean field with the effect of ion potentials of atoms at the lattice points.

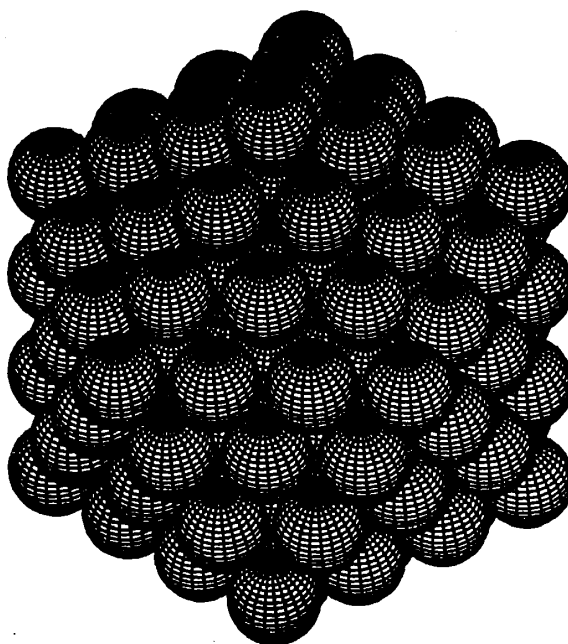


Fig. 2 Icosahedral symmetry of atomic ions with 5 layers.

References

- [1] A. Bohr and B. R. Mottelson, Nuclear Structure Vol.I, II (1969, 1975, Benjamin, New York).
- [2] T. P. Martin et al., J. Phys. Chem. 95 (1991) 6429.