学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Comprehensive study of ^{12}C by precise three-α cluster model wave functions
（精密３αクラスター模型波動関数による炭素 12 原子核の包括的研究）

The cluster structure is an essential ingredient to describe nuclear structure, in which nuclear systems are composed of some subunits of several nucleons. ^{4}He cluster, called α cluster is one of the most basic clusters which has extraordinarily large binding energy and the excited states are located in comparably high energy region. In particular, ^{12}C has been investigated as a three-α system for a long time because of its first $J^{\pi} = 0^{+}$ excited state, the Hoyle state, in which three α clusters are well developed. The Hoyle state plays a crucial role in the triple-α reaction process where an α particle sequentially captures two more α particles and finally ^{12}C is synthesized. There are mainly two remarkable points. One is that recently, the rotational excited states series of the Hoyle state, the Hoyle band, was proposed and the structure of the first $J^{\pi} = 2^{+}$ excited state has been paid attention. However, the structure of the 2_2^+ state, especially for its geometric three-α structure is still unclear. The other point is that the triple-α process usually occurs in astrophysical environments e.g., X-ray bursting of an accreting neutron star, where three α particles have background of neutron matter. Thus, it is necessary to consider the effect to the Hoyle state from the neutron matter. To settle these points, I comprehensively investigate three-α cluster structure of ^{12}C, using precise three-α cluster wave function obtained by the stochastic variational method and the correlated Gaussian basis. In the three-α cluster model, α clusters are treated as structureless charged particles (macroscopic cluster model) and the orthogonality condition to the Pauli forbidden states between α particles is imposed which is called the orthogonality condition model (OCM). For the former, I introduced the confining potential to obtain the wave function in the square integrable form, allowing an analysis of the density distributions of three-α particles. It is concluded that the 2_2^+ state is not a simple rigid rotational excited state of the Hoyle state because the ^{8}Be+α component of 2_2^+ state is 2/3 of that of the Hoyle state. For the latter, to evaluate the effect from dilute cold neutron matter, a polaron picture of α particle is introduced, where the impurity α particles polarize the majority neutron matter via interaction between α and neutrons. It is concluded that the Hoyle state in the neutron matter stabilizes and shrinks, which may impact the reaction rate for the nucleosynthesis. It is interesting to extend discussion of α cluster structure to heavier nuclear systems such as ^{16}O, ^{20}Ne, and ^{24}Mg. However, the macroscopic OCM is difficult for these nuclei because the numerical calculations become instable. Finally, I propose a novel approach to overcome the numerical instability toward applications to the heavier nuclear systems.