Abstract of Doctoral Dissertation

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α Cluster Structure and Resonance States of ^{13}C
（炭素 13 のアルファクラスター構造と共鳴状態）

Carbon isotopes have attracted great interest and have been important subjects in nuclear physics as they exhibit a rich variety of cluster phenomena. The Hoyle state, the 0_2^+ state of ^{12}C, has very interesting clustering aspects; Bose-Einstein condensate (BEC) of the three α particles. In the recent two decades, the structure of the Hoyle state and its analogous states in neighboring nuclei have been a major topic. ^{13}C is one of the particularly important nuclei as the system can be described as three α particles (bosons) with a valence nucleon (fermion). The BEC of the three α particles with a neutron as an impurity, which is referred to as the Hoyle-analog state, and the predominant α cluster states in ^{13}C are the main interests. For example, ^{13}C as the $3\alpha + n$ system exhibits the evidence of the triangular symmetry of the 3α particles with the spinor effect accompanied by the valence neutron, in which the triangular symmetry successfully predicted rotational bands and excited states in ^{12}C.

In my thesis, the band structures and resonance states of ^{13}C are studied. The real-time evolution method (REM), which uses the equation-of-motion of clusters, has been applied. First, the symmetry of ^{13}C is investigated in comparison with the study by Bijker *et al*. [Phys. Rev. Lett. 122, 162501 (2019)], which explained the rotation-vibration spectrum of ^{13}C by assuming a triangular nuclear shape of 3α particles with a neutron. REM is a full microscopic nuclear model that does not assume any nuclear shape. As a result, REM described the low-lying states more accurately than the previous studies. The wave functions are analyzed to understand the shape of each state and showed that the ground band has a triangular symmetry, while the other excited bands do not.

In subsequent, the Hoyle-analog state in ^{13}C, the three α plus one neutron condensate, is investigated. It is still under debate which state is the Hoyle-analog state in ^{13}C. Several experimental studies showed that the $1/2^-$ states exhibit strong cluster aspects that can be the Hoyle-analog state, while other theoretical studies concluded that there is no Hoyle-analog state in the $1/2^-$ states. In order to figure out the Hoyle-analog state and deal with the resonance states located around the $3\alpha + n$ threshold, the analytic continuation in the coupling constant (ACCC) is introduced. ACCC with REM properly estimated the resonance states of the $1/2^-$ states together with their characteristics such as the radii and monopole transition probabilities. This study suggests that the $1/2_4^-$ state can be the possible candidate for the Hoyle-analog state in ^{13}C revealing large spatial excitation and transition strength as the signature of the Hoyle state.