Multi-Antikaonic Nuclei and Kaon Condensation in Dense Matter

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Strangeness degree of freedom provides an important aspect for dense matter which may be realized in neutron stars and/or heavy ion collisions. Kaon condensation, a Bose-Einstein condensed state of antikaons (K⁻) in dense hadronic matter, has been studied both theoretically and observationally. Recently deeply bound antikaonic nuclear states in terrestrial experiments have also been investigated extensively. Stimulated by these studies, we investigate multi-antikaonic nuclei (MKN), where several K⁻ mesons are bound in the nucleus. We base our study on the relativistic mean-field theory (RMF), coupled with Kbar-nucleon (N) and Kbar-Kbar interactions which respect chiral symmetry (the chiral model).

Here we also introduce the Λ(1405) (Λ*), which plays an important role on in-medium kaon properties in dense matter, as a pole contribution to the energy together with the range effects as the second-order perturbation with respect to the relevant axial-vector current following the framework of current algebra and PCAC (the second-order effect, abbreviated as SOE).

We clarify the structure of the MKN through obtaining the density profiles of the proton, neutron, and K⁻ mesons, binding energy of the MKN, and other quantities. We also discuss the relation between the MKN in experiments and kaon condensation in dense stellar matter.

The density profiles of the proton, neutron, and strangeness carried by the K⁻ are shown for the MKN with mass number A=15, atomic number Z=8, and the number of the embedded K⁻ mesons |S|=8, in the case of the K⁻ optical potential depth U_K⁻ = -80 MeV. The isospin I=0 Kbar-N attraction is enhanced as a result of avoiding the Λ* pole, so that the protons are more attracted to the K⁻ mesons lying around the center of the MKN. As a result, both protons and K⁻ mesons are denser around the center of the MKN as compared with the previous result without the SOE. The central baryon density attains to be (3-4)ρ₀ with ρ₀ being the saturation density of nuclear matter. The MKN is a strangeness-conserving system and should be formed by embedding K⁻ mesons in the nucleus through strong processes. On the other hand, kaon condensation in neutron stars may exist as a strangeness-nonconserving system, where kaon condensates are spontaneously produced from normal matter through weak processes, N+n→N+p+K⁻, N+e⁻→N+K⁻+νₑ (N=p,n). We discuss the similarity and difference between the MKN in experiments and kaon condensation in dense stellar matter.