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The quest for the Hoyle-analog states in light hypernuclei

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To resolve a long-standing problem of nuclear astrophysics regarding of synthesis of ^{12}C and heavier nuclei, in 1953, F. Hoyle suggested that the nuclei ^{12}C were created in a collision of three alpha particles. This collision leads to the creation of a very narrow (long-lived) 0^+ resonance state, which emits a photon and then transforms into a bound state of ^{12}C. Moreover, F. Hoyle predicted the energy and width of the 0^+ resonance state with high precision. Later, this assumption was experimentally confirmed and now this resonance state is called the Hoyle state. Many theoretical models have been used to describe such an exotic state and to reveal its nature. A microscopic three-cluster method, proposed in [1], has been successfully applied in [2] to study the peculiarities of the Hoyle state and find the Hoyle-analog states [3] in a set of light nuclei.

In the present work, we study the resonance structure of light hypernuclei ${}^{6}_{\Lambda}$H, ${}^{6}_{\Lambda}$He, ${}^{6}_{\Lambda}$Li, ${}^{7}_{\Lambda}$He, ${}^{7}_{\Lambda}$Li, ${}^{7}_{\Lambda}$Be, and try to find the Hoyle-analog states, i.e., the long-lived resonance states which can be formed in a three-cluster collision. The quest is performed with a three-cluster microscopic model, which was suggested in Ref. [1] and modified to study hypernuclei. The selected hypernuclei are considered as three-cluster systems, where one cluster is the lambda hyperon. For each hypernuclei we selected a three-cluster configuration, which has the minimal threshold energy among other three-cluster configurations. This dominant three-cluster configuration allows us to study bound states of a compound hypernuclear system and its resonance states in two- and three-cluster continua.

In hypernuclei ${}^{6}_{\Lambda}$H, ${}^{6}_{\Lambda}$He, ${}^{6}_{\Lambda}$Li, ${}^{7}_{\Lambda}$He, ${}^{7}_{\Lambda}$Li, we found several very narrow resonance states, their total width is very small, less than 10 keV, and they lie close to the corresponding three-cluster threshold. The narrowest resonance states have wave-function structures typical of those of the Hoyle-analog states in ordinary nuclei [3]. Thus, the Hoyle analog states can be excited in hypernuclei ${}^{6}_{\Lambda}$H, ${}^{6}_{\Lambda}$He, ${}^{6}_{\Lambda}$Li, ${}^{7}_{\Lambda}$He, ${}^{7}_{\Lambda}$Li in triple collisions of three clusters, one of which is the lambda hyperon.
We assume that the narrowest resonance states revealed by our model can be experimentally detected.

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