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Search for cluster states in ^{13}C

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^{13}C is a good example of a "normal"nucleus that is well described in the framework of the shell model. Its level scheme is reliably determined up to excitation energies ˜ 10 MeV. However, not so long ago, in the framework of the development of the theory of the α-condensation in light nuclei (αBEC), the existence of exotic cluster states in light nuclei with a significantly increased, by 40-70%, size was announced. One of the most likely candidates was the Hoyle state (0_2^+, E= *7.65 MeV) in* ^{12}*C. It was expected that analogues of the Hoyle state would appear in some neighboring nuclei, for example, the 1/2*$^-$ (*E* = 8.86 MeV) state of ^{13}C. This was successfully shown by the the Modified Diffraction Model (MDM) method, but obtained radius was much smaller than that predicted by the αBEC theory.

However, some open questions remain regarding the structure of low-lying ^{13}C states. This leads to increased attention to ^{13}C so far.

In 2014, our group announced the discovery of a state of ^{13}C with an abnormally small radius. In the framework of the MDM method, when analyzing data on α-scattering on ^{13}C at energies of 65 and 90 MeV, it was shown that this state has a radius reduced by 10%. At the same time, in the works of theoreticians dilute structure and increased radius were predicted for this state, and in part of the works, assumptions were made about the rotational structure of this state and the possibility of the formation of a rotational band on it.

Another important question is the search for possible analogues of the Hoyle state in ^{13}C in highly excited states. At present confirmed analog of the Hoyle state is 1/2$^-$ (8.86 MeV) state in ^{13}C. Other possible candidate is the state 1/2$^-$ 11.08 MeV. Increased radius close to the radius of the state of 8.86 MeV ^{13}C was obtained within MDM method analysis. However, this result was obtained only at one energy, on the applicability boundary of the MDM method.

Moreover, the presence of a rotational band based on the Hoyle state in ^{12}C was confirmed. A reasonable question arises about the existence of rotational bands on analogues of the Hoyle state in ^{13}C. In [1] a hypothesis was put forward about a new type of symmetry in the ^{13}C structure - D'$_{3h}$ symmetry. Earlier in the work of the same team of authors, a similar type of D$_{3h}$ symmetry was predicted for the ^{12}C nucleus. On the basis of D'$_{3h}$ symmetry, the rotational nature of a whole group of low-lying ^{13}C states was predicted. If this hypothesis is confirmed, our understanding about the ^{13}C structure will radically change. In the work, 6 rotational bands were proposed, that is, almost all low-lying ^{13}C states were distributed among the rotational bands.

Thus, a critical analysis of the available data is required to answer the question about the nature of low-lying excited ^{13}C states.

1. R. Bijker, Phys. Rev. Lett. 122, 162501 (2019)

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