The Structure of the Hoyle State and its 2^+ Partner State in ^{12}C

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Abstract

We measured the $^{12}C(\gamma, 3\alpha)$ reaction with an Optical Time Projection Chamber (O-TPC) detector and gamma-ray beams from the HIγS facility of the TUNL at Duke. Clear Evidence for the second 2^+ state in ^{12}C was observed at 10.4 MeV. The measured $B(E2: \ 2_2^+ \ \rightarrow \ g.s.)$ and the measured alpha-particle width which exhausts the Wigner limit, provide clear evidence for a structure similar to the structure of the 0_2^+ Hoyle state at 7.654 MeV in ^{12}C. Thus the long sought for "Hoyle Partner" 2^+ state is unambiguously identified in ^{12}C. However, the measured energy, width and gamma width of the 2_2^+ state exclude significant contribution from this state to the formation of ^{12}C in stellar helium burning (even) at high temperatures (T > 3GK) beyond the contribution predicted from the Hoyle state. The structure of the 2_2^+ and the 0_2^+ Hoyle Partner states in ^{12}C remains an open question and existing data cannot distinguish between a spherical (e.g. low N limit of a BEC condensate) vibrational structure and a deformed rotational structure.