Contribution ID: **145** Type: **Oral presentation**

A saga on the γ-decay branching ratio of the Hoyle State

Monday 16 June 2025 15:45 (15 minutes)

The triple-alpha process is one of the most fundamental processes in stellar nucleosynthesis, particularly the production of ^{12}C. This process entails the fusion of three helium nuclei to form an intermediate state in ^{12}C. This intermediate state can decay back into its three constituent alpha particles or radiatively decay to form stable ^{12}C. At temperatures between 0.1 - 2 GK, the triple-alpha reaction is almost exclusively mediated by the Hoyle state in ^{12}C. Understanding the properties of the Hoyle state is therefore important for the modeling of the subsequent stellar evolution.

The creation of stable carbon through this process happens mainly through two available decay branches, leaving the ^{12}C in its ground state. The radiative decay of the Hoyle state to form stable ^{12}C proceeds mainly through gamma decay and pair production. The radiative width of the gamma-branch has been measured several times between the period 1961 to 1976 [1-7]. Most of the measurements performed up until 1976 have yielded results which are in agreement with one another. However, a recent measurement published in 2020 by Kibédi *et al.* [8] resulted in a significantly larger radiative branching ratio (Γ_{rad}/Γ) compared to all previous measurements. Recently several measurements have been published as a direct result of this discrepancy [9-12].

Given the astrophysical significance of the Hoyle state, resolving this conflict is crucial. Therefore, new measurements have been performed to reinvestigate the gamma-decay branching ratio of the Hoyle state, with a complete reanalysis of the data published by Kibédi *et al.* [8]. The experiments have been performed at the Oslo Cyclotron Laboratory through the ^{12}C(p, p'$\gamma\gamma$)-reaction. In these experiments, the SiRi particle telescope [13] was employed to detect proton ejectiles and the OSCAR [14] LaBr3 array was used to detect the coincident gamma-ray decays. Results from the new measurement and the reanalysis of the data published by Kibédi *et al.* [8] will be presented.

References

[1] David E. Alburger, Gamma-ray decay of the 7.66-mev level of C-12, Phys. Rev., **124**, (Oct 1961) 193-198.
[2] I. Hall and N.W. Tanner. The radiative decay of the 7.66 MeV level of C-12, Nuclear Physics, **53**, (1964) 673-684.
[3] D. Chamberlin *et al.*, Electromagnetic decay of the 7.65-MeV state of C-12, Phys. Rev. C, **9**, (1974) 69-75.
[4] C. N Davids, R.C Pardo, and A.W Obst, Radiative Deexcitation of the 7.655-MeV State of C-12, Phys. Rev. C, **11**, (1975).
[5] H. B. Mak, H. C. Evans *et al.*, Radiative decay of the second excited state of C-12, Phys. Rev. C, **12**, (Oct 1975) 158-1166.
[6] R.G. Markham *et al.*, A measurement of (Γ_{rad}/Γ) for the 7.654 MeV state of C-12 and the rate of the stellar 3α reaction, Nuclear Physics A, **270(2)**, (1976) 489-500.
[7] A. W. Obst and W. J. Braithwaite, Measurement of the radiative branching ratio for the 7.65-MeV state in C-12 using the cascade gamma decays, Phys. Rev. C, **13(5)**, (1976) 2033-2043.
[8] T. Kibédi, B. Alshahrani *et al.*, Radiative Width of the Hoyle State from γ-ray spectroscopy, Phys. Rev. Lett, **125**, (Oct 2020) 182701-182707.
[9] M. Tsumura *et al.*, First experimental determination of the radiative-decay probability of the 3_1^- state in C-12 for estimating the triple alpha reaction rate in high temperature environments, Phys. Rev. B, **817**, (2021) 136283.
[10] Z. Luo *et al.*, Radiative branching ratio of the Hoyle state, Phys. Rev. C, **109**, (2024) 025801.
[11] D. Dell'Aquila *et al.*, Clarifying the radiative decay of the Hoyle state with charged-particle spectroscopy, Scientific Reports, **14**, (2024) 18958.
[12] T. Rana *et al.*, New measurement of the Hoyle state radiative transition width, Phys. Lett. B., **859**, (2024) 139083.
[13] M. Guttormsen *et al.*, The SiRi particle-telescope system, Nucl.Instrum.Meth., **648(1)**, (2011) 168-173.
[14] F. Zeiser *et al.*, The γ-ray response of the Oslo scintillator array OSCAR, Nucl.Instrum.Meth., **985**, (2021) 164678.

Author: PAULSEN, Wanja (university of Oslo)

Co-authors: GÖRGEN, Andreas (University of Oslo); LARSEN, Ann-Cecilie (University of Oslo (NO)); GJESTVANG, Dorthea (University of Oslo); SAHIN, Eda; BELLO GARROTE, Frank Leonel (U); TVETEN, Gry Merete (University of Oslo); BERG, Hannah; LI, Kevin Ching Wei (University of Oslo); MARKOVA, Maria (University of Oslo); SIEM, Sunniva (University of Oslo); ERIKSEN, Tomas Kvalheim (University of Oslo); Ms VALSDOTTIR, Vala (University of Oslo); INGEBERG, Vetle Wegner (University of Oslo (NO)); MODAMIO, Victor (University of Oslo)

Session Classification: Parallell A1