Revisiting the 3α reaction rates in helium burning stars

T. Depastas, S.T. Sun, H.B. He, H. Zheng and A. Bonasera

Helium burning is one of the most fundamental steps of stellar nucleosynthesis, as it describes the formation of the life-determining element of carbon, while it plays a key role in the evolution of Red Giant, accreting White Dwarfs and Neutron Stars. In this work [5], we develop a generalized statistical theory for the 3α reaction, which is based on the use of the Imaginary Time Method [3], along with the semi-classical Hybrid α-Clustering (HαC) [2] and Neck Model (NM) [6] frameworks. The results are compared to the methodology and data of the NACRE collaboration [7], following in several orders of magnitude discrepancies, especially at low temperatures. This may be crucial for the early dynamics of helium burning stars.

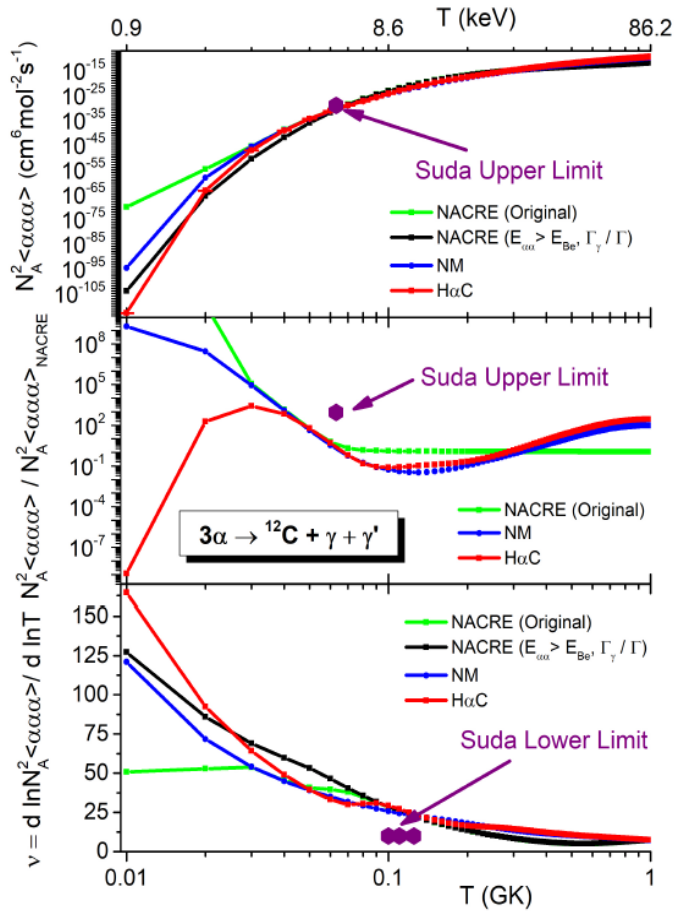

FIG. 1. (Color online) The reaction rate per α triplet (top), the same quantity normalized by the corrected NACRE data (middle) and the temperature dependence (bottom). The original (Angulo et al. (1999)) and corrected NACRE data, as well as the HαC and NM results are shown, according to the key. We also emphasize the astronomical constraints by Suda et. al (Suda et al. (2011)) with purple points.

[1] T. Depastas, S.T. Sun, H. Zheng and A. Bonasera, Phys Rev C **108**, 035806 (2023).
[2] H. Zheng and A. Bonasera, Symmetry **13**, 1777 (2021).
[3] A. Bonasera and V. Kondratyev, Phys. Lett. B **339**, 207 (1994).
[4] A. Tumino *et al.*, Nature (London) **557**, 687 (2018).
[5] T. Depastas, S.T. Sun, H.B. He, H. Zheng, A. Bonasera, Phys Lett B (2024) submitted.
[6] A. Bonasera, G. Bertsch, E. El-Sayed, E., Phys. Lett. B **141** (1984).
[7] C, Angulo *et al.*, Nuclear Physics A **656**, 3–183 (1999).