Nuclei in the Cosmos XV

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Weak interference between the 1^- states in the vicinity of alpha-particle threshold of 16O

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The subthreshold 1^-_1 state at an excitation energy E_x = 7.12 MeV in 16O has been believed to enhance the astrophysical S-factor for 12C(alpha,gamma_0)16O. The enhancement seems to originate from strong interference between 1^-_1 and 1^-_2 (E_x ~ 9.6 MeV) in the vicinity of the alpha-particle threshold. However, the weak interference between two states and a resulting small E1 S-factor are exemplified with R-matrix theory in this presentation.
In my previous reports [1], I have predicted the small E1 S-factor at E_c.m.= 300 keV from the potential model, because non-absorptive scattering results in weak coupling between shell and cluster structure in 16O. In the present example, I utilize the previous results to estimate the reduced alpha-particle width of 1^-_1 and 1^-_2. In addition, the formal parameters in R-matrix are obtained from an exact expression, including a higher-order correction, because it has been reported that the resonance parameters for 1^-_2 are not appropriately treated in the linear approximation. This correction ensures that the R-matrix calculation corresponds to the experimental data.
In the calculation [2], a large energy shift for the pole of 1^-_2 is expected from the alpha+12C cluster structure in 16O. The resultant energy of the 1^-_2 pole is found to be located in the vicinity of 1^-_1. This proximity of the poles suppresses their interference, and it consequently makes the small E1 S-factor below the barrier (Figure 1). The corresponding results of the \beta-delayed alpha-particle spectrum of 16N and the calculated p-wave phase shift of alpha+12C elastic scattering are consistent with the previous experimental results. The experimental alpha-particle width of 1^-_2 is also reproduced by the present example.
It would therefore be possible in the R-matrix method that the E1 S-factor is reduced from the enhanced value currently expected. At the same time, the reaction rates of 12C(alpha,gamma)16O are expected to be obtained from the direct-capture component, rather than compound nucleus mechanisms.

[1] M. Katsuma, Proc. Nuclei in the Cosmos XIV, JPS Conf. Proc. 14 (2017) 021009; M. Katsuma, Phys. Rev. C78, 034606 (2008); ibid. 81 (2010) 067603; Astrophys. J. 745 (2012) 192; PoS(NIC XIII) (2015) 106.
[2] M. Katsuma, arXiv:1701.02848 [nucl-th].

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