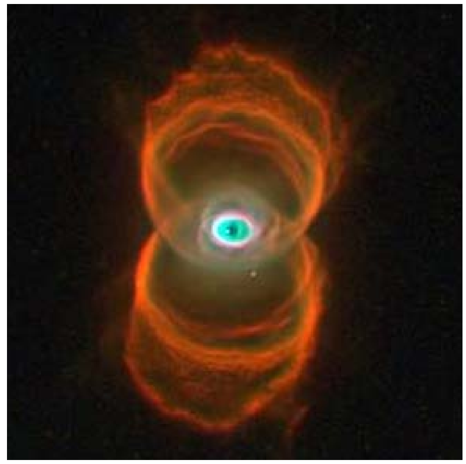
AGB Stars Nuclear Rates and Carbon



The Hourglass Nebula, the remnant of a star that has gone through advanced stages of evolution. During the Asymptotic Giant Branch phase we describe here such a star blows much of its carbon enriched envelop into the interstellar medium, leaving behind a white dwarf and the nebula we see here.

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Early in their lives, stars with masses a few times that of the sun burn the hydrogen in their cores to make helium, become red giant stars, and then burn that helium to make carbon and oxygen. What happens subsequently, in the Asymptotic Giant Branch (AGB) phase, is much less certain. We know that AGB stars continue to burn hydrogen and helium, now in shells that surround the carbon-oxygen core. And we know that flashes occur in the helium shell and that the carbon they produce is eventually dredged up into the envelop of the star and then to the stellar surface. These flashes also lead eventually to the ejection of much of the star's envelop to form a planetary nebula. leaving behind a white dwarf.

We also know that this picture cannot be entirely correct. The standard model of the process leads to stars with a dominantly oxygen envelop. Yet light AGB stars observed in nature appear to have carbon rich envelopes. The standard models involve certain approximations whose detailed effect is not certain and which might explain the discrepancy. There have, however, been no evaluations of the sensitivity of the AGB process to uncertainties in the important nuclear reaction rates that govern the process. We have undertaken such sensitivity studies using detailed calculations based first on the standard nuclear reaction rates and then on rates changed within their uncertainties. We find that production of carbon is insensitive to the $^{12}C$ + alpha → $^{16}O + \gamma$ reaction, but that changes in the $^{14}N + p \rightarrow {}^{15}O + \gamma$ or the $3\alpha \rightarrow {}^{12}C$ (triple alpha) reaction can increase the carbon abundance by a factor of two, leading to a carbon rich surface.

This does not imply that changing the reaction rates is *the* solution to the problem. But it may be, and it tells us that better measurements of the reaction rates are imperative. New measurements of these reactions are in various stages and will in the next few years tell us whether we have truly found the solution to the problem.

It is important for several reasons that we do find a solution. ABG stars are the source of a substantial carbon and affect our understanding of galactic chemical evolution. They also serve as diagnostics for extragalactic populations, so it is important to know the conditions for the oxygen rich to carbon rich transition—carbon rich giants are the brightest infrared population in extragalactic systems. And finally, the envelopment enrichment of AGB stars with the s-process elements is intimately related to the dredge up properties of these models.

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**Papers:**

F. Herwig and Sam M. Austin, Astroophysical Journal Letters 613:L73-L76 (2004)
F. Herwig, Sam M. Austin, and John C. Lattanzio, astro-ph/0511386

**Support:**

U.S. DOE contract W-7405-ENG-36 to LANL
US NSF grants PHY01-10253 and Phy02-16783 (JINA)
Australian Research Council