FLUORINE PRODUCTION IN ASYMPTOTIC GIANT BRANCH STARS

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Abstract. The present status of our understanding of fluorine production in asymptotic giant branch stars is reviewed, and future perspectives are presented.

1. Introduction

The question of the origin of the galactic ^{19}F remained unanswered until the suggestion by Goriely et al. (1989) that it can be produced in He-burning environments by the $^{14}\mathrm{N}\,(\alpha\,,\gamma)\,^{18}\mathrm{F}\,(\beta)^{18}\mathrm{O(p},\alpha)\,^{15}\mathrm{N}\,(\alpha\,,\gamma)\,^{19}\mathrm{F}$ reaction chain. The required protons are produced by $^{14}\mathrm{N}\,(\mathrm{n}\,,\mathrm{p})\,^{14}\mathrm{C}$, while the neutrons are supplied by $^{13}\mathrm{C}\,(\alpha\,,\mathrm{n})\,^{16}\mathrm{O}$. Fluorine produced in such a way has been predicted to contaminate the surfaces of asymptotic giant branch (AGB) stars (Mowlavi et al. 1996, and references therein) or of Wolf-Rayet stars (Meynet & Arnould 1996), and consequently to contribute to the ^{19}F galactic enrichment. These expectations have received an observational confirmation in the case of AGB stars (Jorissen et al. 1992). It has also been speculated that ^{19}F could be a product of the ν-process possibly accompanying Type II supernovae (Woosley et al. 1990 and references therein). However, the corresponding ^{19}F yields remain very uncertain, as they depend sensitively on the neutrino temperature, which is a free parameter in the calculations. No observational test of this type of production is available to date.

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This paper summarizes the status of ^{19}F observations at the surface of AGB stars, and our present understanding of its production in these objects (§2). Perspectives for future studies are presented in §3.

2. Present Status

A definite proof that AGB stars can be net producers of ^{19}F has been provided by the discovery that it is overabundant at the surface of S and C stars (Jorissen et al. 1992). So far, this is the only stellar site for which ^{19}F production is directly confirmed by observation. In addition, these observations show that the surface ^{19}F overabundance and the ^{12}C/^{16}O ratio are correlated, confirming that fluorine is indeed produced in a He-burning environment.

Former AGB models including all reactions relevant to fluorine production (Mowlavi et al. 1996, and references therein) predicted that ^{19}F is produced in abundances too low to match the observed values. In these models, the neutrons are supplied by ^{13}C left over by the H-burning shell. More neutrons than those produced by this 'secondary' supply of ^{13}C (since it scales as the primordial CNO content of the star) are needed to account for the observed fluorine abundances, thus calling for a primary ^{13}C source.

Interestingly, the need for a primary ^{13}C source in the He-burning layers of AGB stars also comes from the observations of *s*-process elements in S stars (Smith & Lambert 1990). Moreover, the *s*-process and ^{19}F overabundances appear to be correlated in those stars (Jorissen et al. 1992). Parametric calculations of ^{19}F and *s*-process nucleosynthesis mimicking the situation encountered in the He-burning shell of AGB stars (Mowlavi et al. 1998) indeed confirm that a primary $^{13}\mathrm{C}\,(\alpha\,,\mathrm{n})\,^{16}\mathrm{O}$ neutron source is able to account for the observed abundances of both ^{19}F and *s*-process elements in these stars.

3. Perspectives

The efficient production of fluorine along with *s*-nuclides in AGB stars is now well understood, at least qualitatively (the only puzzling fact is the large F overabundance reported for the super Li-rich star WZ Cas, since the Cameron-Fowler process invoked for the production of Li is expected to destroy F). However, reliable *quantitative* predictions of the surface ^{19}F abundance in AGB stars are still hampered by two important shortcomings affecting current AGB models: (*a*) the *primary* ^{13}C supply and the subsequent neutron production at the level required by both the ^{19}F and *s*-process nucleosynthesis in the He-burning shell are not yet obtained in a self-consistent way by the current stellar models; (*b*) neither is the so-called third dredge-up (bringing material from the He-burning shell to

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the surface) predicted self-consistently by the current AGB models (but see Mowlavi 1998). These two problems *must* be solved before any *reliable s*-process and ^{19}F yields can be obtained and compared with the observations.

Once reliable F yields become available for AGB stars with a large variety of masses and metallicities, their contribution to the solar system F may be estimated through the use of a galactic chemical evolution model. Preliminary estimates (Mowlavi & Meynet 1998) suggest that this contribution may be significant. On the other hand, Meynet & Arnould (1996) conclude that Wolf-Rayet stars alone might well account for the entire solar system F.

A complementary question of importance concerns the relative contribution of these two classes of stars to the F content of the Galaxy at different epochs. As AGB and Wolf-Rayet stars are expected to lead to different trends of [F/Fe] versus [O/Fe], observations of F abundances in low-metallicity stars are of utmost importance. They have in fact already been undertaken by V. Smith and colleagues. Such an analysis might also shed light on the question of the necessity (advocated by Timmes et al. 1995) of calling for the ν-process in order to account for the F in the Galaxy at some point in its history.

As an extension of the study of the metallicity dependence of the F content of the Galaxy, one might also envision detecting ^{19}F in high-redshift objects. The interest of such observations relates to the recent claim by Timmes et al. (1997) that "any positive detection of ^{19}F at sufficiently high redshifts ($z > 1.5$) would suggest strongly a positive detection of the neutrino process." The possibility of a significant thermonuclear production of ^{19}F by short-lived (non-exploding) Wolf-Rayet stars would evidently blur this picture.

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Discussion

Plez: I would like to warn observers to be very careful in the derivation of abundances in stars with C/O ratios very close to 1. Due to the relative absence of strong blanketing, their atmospheric thermal structure is quite different from more O- or C-rich stars. Good models with the appropriate chemical composition, especially the C/O ratio, must be used in the analysis.

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