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The role of nova nucleosynthesis in Galactic chemical evolution

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Abstract. In this paper we study the impact of nova nucleosynthesis on models for the chemical evolution of the Galaxy. It is found that novae are likely to be the sources of non-negligible fractions of the ^{7}Li and ^{13}C observed in disc stars. Moreover, they might be responsible for the production of important amounts of ^{17}O at late times and probably account for a major fraction of the Galactic ^{15}N.

Key words. Galaxy: abundances – Galaxy: evolution – novae, cataclysmic variables – nuclear reactions, nucleosynthesis, abundances

1. Introduction

Classical novae are binary systems consisting of a CO or ONeMg white dwarf accreting hydrogen-rich matter from a main-sequence companion, which sporadically inject nuclearly processed material into the interstellar medium (ISM). The thermonuclear runaway (TNR), responsible for the explosion causing the ejection of almost the whole previously accreted envelope, also leads to the synthesis of some rare nuclei: ^{7}Li, ^{13}C, ^{15}N, ^{17}O, ^{22}Na and ^{26}Al (e.g., Starrfield et al. 1972, 1974, 1978; Politano et al. 1995; Hernanz et al. 1996; José & Hernanz 1998). Here we address the issue of the evolution of ^{7}Li and CNO isotopes in the Milky Way, putting emphasis on the contribution from nova systems.

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2. Lithium evolution in the solar neighborhood

The upper envelope of the observed $\log \varepsilon(^{7}\mathrm{Li})$ versus [Fe/H] diagram, as traced by warm ($T_{\rm eff} \geq 5700$ K) field dwarfs in the solar neighborhood (see Fig. 1), is generally believed to reflect the ^{7}Li enrichment history of the ISM due to different production processes which rise its content from the primordial abundance to the higher values observed in meteorites and local ISM (e.g., D'Antona & Matteucci 1991; Matteucci et al. 1995; Romano et al. 1999, 2001). While halo dwarfs lying on the *Spite plateau* share almost the same lithium abundance, a broad spread in the data is seen at high metallicities. This is

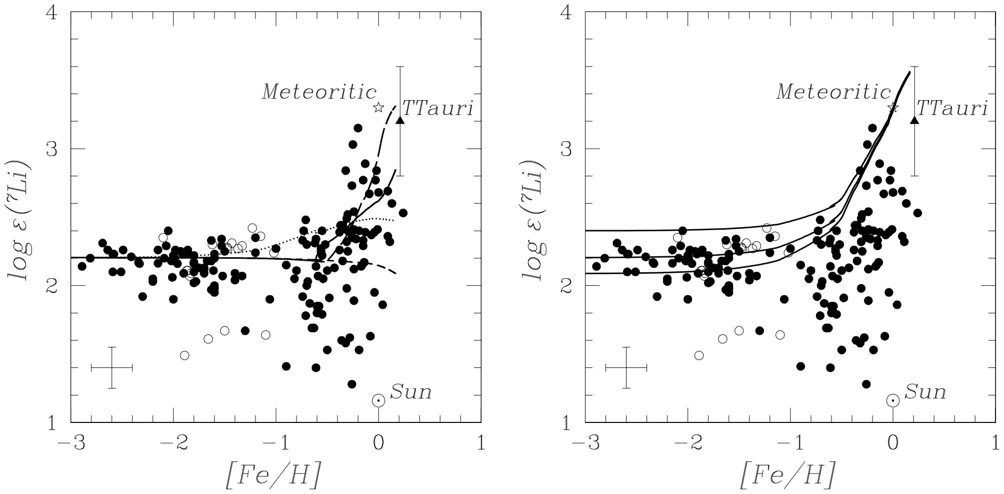

Fig. 1. Evolution of ^{7}Li in the solar vicinity. Data are from the compilation of Romano et al. (1999) (dots) and from Ryan et al. (2001) (empty circles). The meteoritic, T Tauri and Sun values are shown as well. Explanation of the different models is given in the text.

commonly explained as due to lithium dilution/destruction mechanisms, which activate at high metallicities. In Fig. 1, left panel, we show the results of four chemical evolution models; in each of them ^{7}Li is produced by a single category of stellar ^{7}Li producers: asymptotic giant branch (AGB) stars (short-dashed line), Type II supernovae (SNeII) (dotted line), novae (solid line), and low-mass red giants (long-dashed line). Novae and low-mass stars on the red giant branch (RGB) are the best candidates in order to reproduce the observed rise off the plateau (see Romano et al. 1999, 2001 for details). In Fig. 1, right panel, we show the results of models where all the different Li sources of Fig. 1, left panel, are taken into account. Lithium production from Galactic cosmic rays (GCRs) is included as well. These models differ only in the adopted primordial Li abundance. It can be immediately seen that lithium evolution during most of the Galactic lifetime is practically independent of the adopted primordial ^{7}Li abundance. Therefore, *we conclude that novae should contribute a non-negligible Li amount* independently of the assumed primordial Li abundance. This result is particularly relevant in view of recent *WMAP* data, suggesting a high primordial lithium abundance of $\log \varepsilon(^7\mathrm{Li})_\mathrm{p} \sim 2.6$ (see Romano et al. 2003 for a discussion on this point).

3. CNO isotope evolution in the Milky Way

Among the CNO group nuclei, ^{16}O is the best understood. It is a primary element, i.e., it is always synthesized starting from H and He in the parent star. The bulk of ^{16}O comes from massive stars ($m > 10\ M_\odot$). The production of ^{12}C is more uncertain: it is synthesized as a primary element, but the exact amount restored into the ISM by stars of different masses is still uncertain. We favor the hypothesis that ^{12}C is mostly produced by low- and intermediate-mass stars (LIMS) (Chiappini et al. 2003). ^{14}N should be a typical secondary element, but with a primary component as well, coming mostly from LIMS (Chiappini et al. 2003; Chiappini & Matteucci, these proceedings).

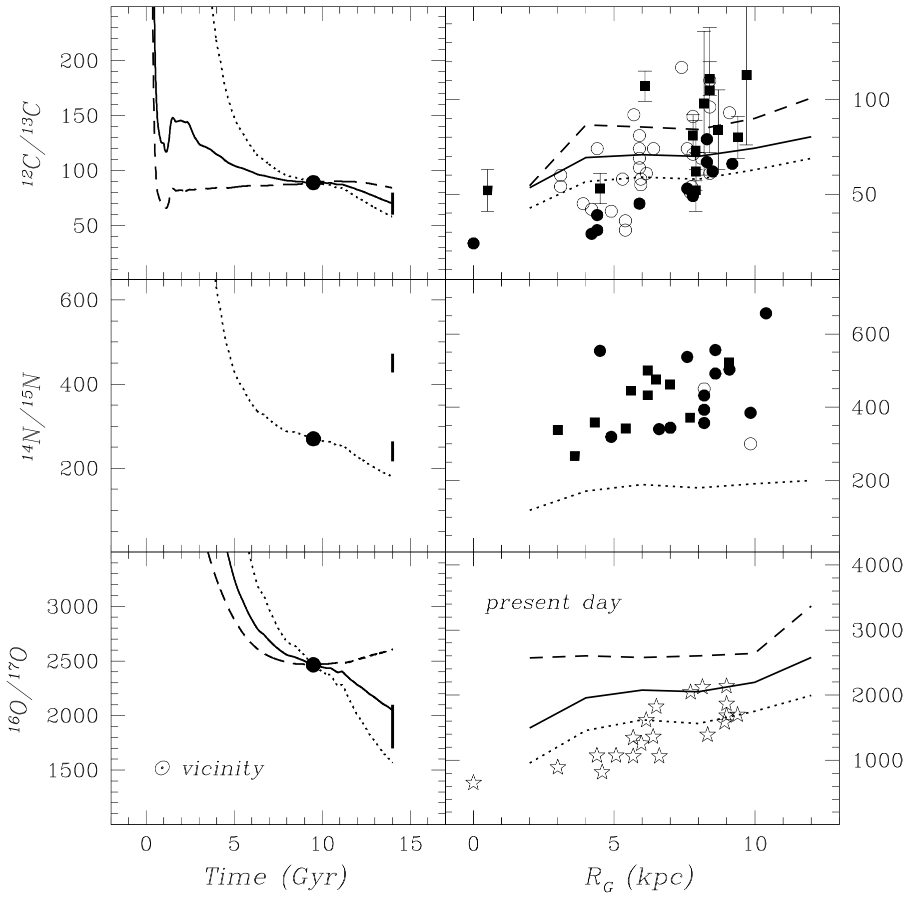

Fig. 2. Theoretical evolution of $^{12}C/^{13}C$ (upper panels), $^{14}N/^{15}N$ (middle panels) and $^{16}O/^{17}O$ (lower panels) in the solar vicinity (left panels) and across the Galactic disc at the present time (right panels), versus observations. See text for details.

The TNR leading to nova outbursts has been identified as a promising channel for the synthesis of ^{13}C, ^{15}N and ^{17}O (see references quoted in the Introduction). ^{13}C and possibly ^{17}O are also formed in the external regions of stars in the RGB, planetary nebula and SN phase, while part of ^{15}N production could be due to rotationally induced mixing of protons into the helium-burning shells of massive stars (Chin et al. 1999, and references therein). In the following, we try to ascertain whether the contribution from novae is needed in order to reproduce the observations concerning both the temporal and the spatial variation of the CNO isotopic ratios in the Galaxy.

The data on the CNO isotopic ratios in the Galaxy suggest that ^{13}C, ^{15}N and ^{17}O behave as secondary elements. In fact, their abundances do increase with increasing time and decreasing Galactocentric distance, i.e., with metallicity (see Romano & Matteucci 2003 for a summary of the available data).

Here we show results from:

- a model considering CNO production only from single low-, intermediate- and high-mass stars (Model 1);
- a model assuming novae as the sole producers of ^{13}C, ^{15}N and ^{17}O (Model 2);
- a model where ^{13}C, ^{15}N and ^{17}O are produced both by novae and single stars (Model 3).

The nucleosynthesis prescriptions are from van den Hoek & Groenewegen (1997) and Ventura et al. (2002) for LIMS; Nomoto et al. (1997) for massive stars; José & Hernanz (1998) for novae. ^{13}C, ^{15}N and ^{17}O from novae are assumed to be of primary origin in both Models 2 and 3. However, from the point of view of Galactic chemical evolution, they behave as secondary elements, owing to the long time-scales on which they are restored into the ISM by their long-lived stellar progenitors (details can be found in Romano & Matteucci 2003).

In Fig. 2, left panels, we display the temporal evolution of the carbon (upper panel), nitrogen (middle panel) and oxygen (lower panel) isotopic ratios in the solar neighborhood as predicted by Models 1 (dashed line), 2 (dotted line) and 3 (solid line). The meteoritic and local values are shown as well (see Romano & Matteucci 2003 for references). In Fig. 2, right panels, model predictions regarding the spatial variation along the disc at the present time are compared to the data (models are labeled according to Fig. 2, left panels).

A model in which ^{13}C and ^{17}O are produced by intermediate- and high-mass stars as well as novae fits better the observations regarding both the temporal and the spatial variation of the CNO isotopic ratios in the Milky Way; however, in the case of ^{17}O we find that it is necessary to lower by hand the yields of both intermediate-mass stars and novae in order to reproduce the solar ^{17}O abundance (Romano & Matteucci 2003). The behaviour of the nitrogen isotopic ratio along the Galactic disc seems to suggest that ^{15}N has to be produced on long time-scales, and *novae are the best candidates for producing ^{15}N on long time-scales in the framework of the presently available nucleosynthesis calculations.* However, it is apparent that the issue of ^{15}N nucleosynthesis in stars deserves further investigation.

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