Oxygen and Fe Evolution: The Effect of Refractory Element Deposition Delays

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Abstract

The delay of Fe deposition relative to O, due to the incorporation of supernova ejecta refractories in high velocity grains, can account for the possible rise of [O/Fe]. The predicted behavior of refractory Mg, Si, Ca and Ti, and volatile S, appears to be consistent with this model

1 Introduction

understanding of the trend of [O/Fe] as a function of [Fe/H] in old metal-deficient stars, even though still very controversial, is an important problem in Galactic chemical evolution. In two recent publications (1; 2) on Fe, O and LiBeB evolutions we showed that the possible rise of [O/Fe] with decreasing [Fe/H] could be due the delayed deposition of refractory nucleosynthetic products (e.g. Fe) due to their incorporation into high velocity grains. Based on arguments of energetics we also showed that cosmic ray acceleration from the metal poor interstellar medium in the early Galaxy is untenable, the rise in the O abundance notwithstanding.

2 Discussion

We constructed (1) a Monte-Carlo based Galactic chemical evolution model based on the births and deaths of stars in the mass range 0.1-100 $M_{\odot}$ with an IMF which remained constant throughout the whole evolution. We allowed each core collapse supernova to eject Fe and O according to the calculations of Woosley and Weaver (3) or the values given by Tsujimoto and Shigeyama (4).

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For Fe, we added the contributions of thermonuclear supernovae, as described in detail in (1).

In order to account for the possible rise of [O/Fe] with decreasing [Fe/H], we allowed the deposition into star forming regions of the ejected Fe to be delayed relative to that of O. The possibility of incorporating such delays into the calculation is particularly easy in a Monte-Carlo approach. The delayed deposition of Fe is possible if the bulk of the refractory ejecta are incorporated into fast grains. This is supported by the observation of a gamma ray line at 1.809 MeV resulting from radioactive ^{26}Al whose observed width turned out to be much larger than expected (5). The best explanation for this broadening is the incorporation of the bulk of the synthesized Al into fast supernova grains which must still be moving at velocities of about 450 km/s some million years (the mean life of ^{26}Al) after the synthesis in supernovae.

Our model is consistent with the abundance ratios of the refractory α-nuclei Mg, Si, Ca and Ti relative to Fe which are also in the grains and thus do not increase with decreasing [Fe/H] below [Fe/H] $= -1$ [see Ryan et al. (6)]. And the model predicts that volatile S should behave like O, a trend which appears to be confirmed by Takeda et al. (7).

A different explanation for the possible the rise of [O/Fe] with decreasing [Fe/H] was presented by Qian and Wasserburg (8) in a model in which nucleosynthesis in the low metallicity era was dominated by core collapse supernovae from very massive progenitors which synthesized O and Fe in a ratio so as to fit the observed [O/Fe] vs. [Fe/H] trend. More detailed observations of the trends of the refractory and volatile elements mentioned above could differentiate between the models.

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