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Chemical evolution of intermediate mass nuclei in the solar neighbourhood and the halo of the galaxy

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Abstract. Recent observations of Fe group elements in very low metallicity stars show an evolutionary trend very different from that of Fe, implying divergent paths of chemical evolution for these elements. In the present work we have investigated the chemical evolution of intermediate mass nuclei in the solar neighbourhood and the halo of the Galaxy with a two zone model of Galactic chemical evolution using a comprehensive set of theoretically computed yields covering the entire range from H to Ge. It is shown that with a two zone model the main observational constraints of the solar neighbourhood can be satisfied.

1. Introduction

The Chemical evolution of the Galaxy leading to the observed elemental abundances still remains one of the least understood aspects in contemporary astrophysics. At present, Galactic chemical evolution models provide the main principal theoretical tool for investigating this complex problem. The enrichment and spatial distribution of the chemical elements depend on a variety of galactic and stellar processes such as star formation rate, infall and mixing processes in ISM the effects of which can not be quantified directly from observations. As such, a model describing all these processes stands out as an important tool for understanding the chemical evolution of the Galaxy. Although various abundance ratios observed in low matallicity stars can be interpreted in the framework of current nucleosynthesis theories, a few Fe group elements such as Mn, Cr, and Co show an evolutionary trend very different from that of Fe, suggesting a different nucleosynthetic scenario for these elements.

The input parameters that play a crucial role in determining the degree of success of a model because most of these input parameters also represent implicit physical scenario. One such important input parameter of a chemical evolution model is the initial stellar yields where the term yield represents the mass of a particular element ejected as computed from a model of star leading to a supernova. This yield not only depends on the mass of metals ejected by stars but also on the relative frequency of different mass stars born in a stellar generation which is often referred to as the initial mass function (IMF). Another important parameter in a chemical

evolution model is the star formation rate (SFR). postulated to be proportional to some power of the gas density and the total mass density. The present work uses the input yields from Woosley and Weaver (1995).

2. The model of galactic chemical evolution

The primary basis of our galactic chemical evolution model is the scenario that, except for the lightest elements, the chemical composition of the Galaxy is the result of nucleosynthesis occurring in many generations of stars. A primary assumption of the model is that each radial zone in the disk begins with zero gas and subsequently accretes primordial and near primordial material over a 4Gyr e-folding time scale. The isotopic evolution at each radial co-ordinate is calculated using 'zone' model of chemical evolution (Talbat & Arnett 1971). Stellar yields from massive stars are taken from Woosely and Weaver (1995) and contributions from Sn Ia are taken from Nomoto et al. (1997). We have adopted the star formation rate according to Schmidt law

$$\Psi(t) = \nu\sigma^{k}_{gas}(t) \tag{1}$$

with $\nu = 0.2$ Gyr^{-1} and $k = 1$. The stellar initial mass function (IMF) is parameterized according to Kroupa et al. (1993).

3. Results

Observational data mostly provide elemental abundances, although in a few cases isotopic ratios are also available. Thus to make a logical comparison with observation it is necessary to compute the total isotopic yields for each element. We have therefore compared the computed abundances (the total isotopic yields for each element) as a function of metallicity [Fe/H] with the observed data from Ryan et al. (1996).

In figure 1. we have compared the computed abundances of alpha elements, O, Mg, i Si, Ca and Ti from Ryan et al. (1996). In the first panel of figure 1a, solid dots represent the observed values of oxygen abundances. In the 3rd panel of the same figure the solid dots represent observed abundances of A1 derived using non-LTE (non local thermodynamic equillibrium) considerations and are taken from (Baumuller & Gehren 1997). It is noticed that the large discrepancy between LTE aluminium abundances resulting from the compilation of Ryan et al (1996) and computed model is largely removed when LTE abundances are replaced by non-LTE data.

Our two zone model calculations generally show a reasonable agreement with observations. [Ti/Fe] ratio is however not well reproduced indicating that the input yields and thus the SN nucleosynthesis scenarios implicity contained in them fail to account for the observed [Ti/Fe] ratio in the Galaxy. Figure 2 shows a comparison of the computed abundances of iron peak elements Sc, Cr, Mn, Co and Ni with the observed abundances of Ryan et al (1996). The model simulates chemical compositions at solar birth and the age-metallicity relation close to observation.

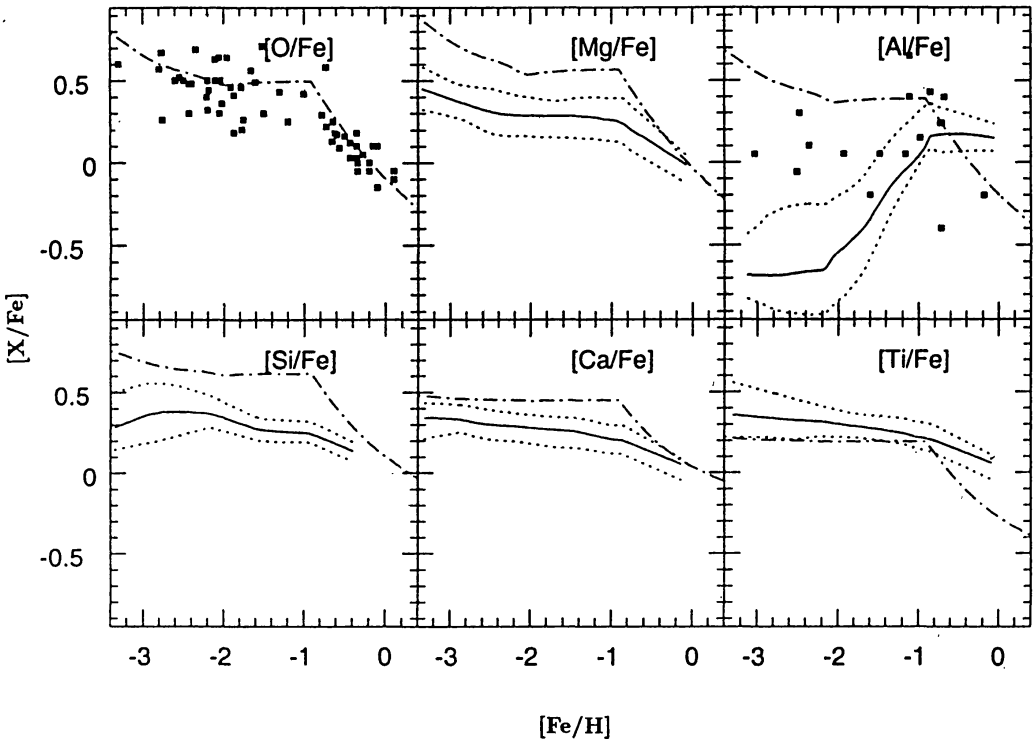

Figure 1. A comparison of the model simulated curve (marked with dash-dot-dash lines) with the abundance ratios [X/Fe] for α elements in stars of the halo and the local disk, compiled by Ryan et al. (1997). The solid and dotted lines represent mean values and 1σ scatter, respectively. The abundance ratios [X/Fe] are plotted along the Y-axis as a function of metallicity [Fe/H] along the X-axis.

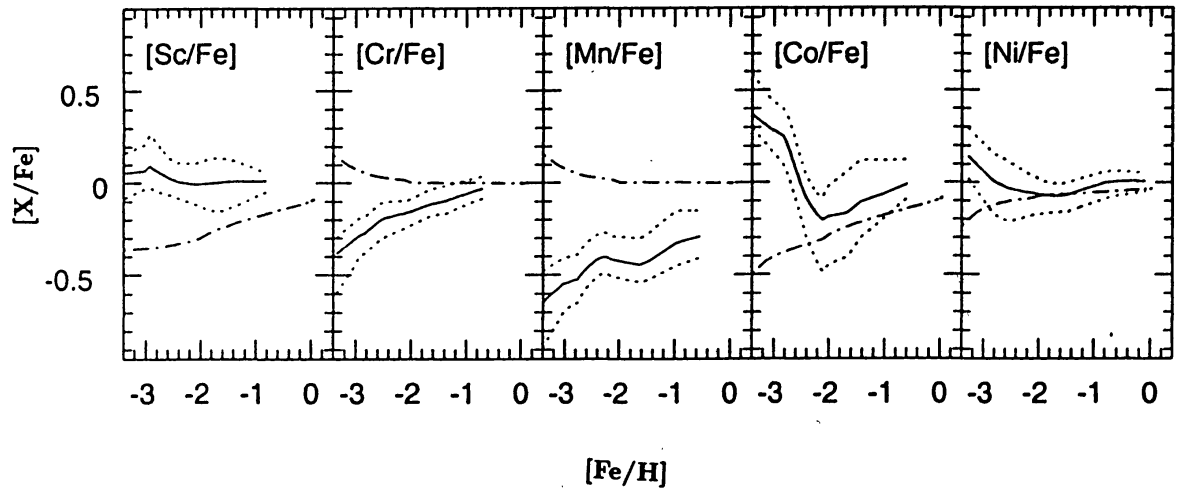

Figure 2. A comparison of the model simulated curve (marked with dash dot-dash lines) with the abundance ratios [X/Fe] for Fe-peak elements in stars of the halo and the local disk, compiled by Ryan et al. (1997). The solid and dotted lines represent mean values and 1σ scatter, respectively. The abundance ratios [X/Fe] are plotted along the Y-axis as a function of metallicity [Fe/H] along the X-axis.

4. Discussion and conclusions

The initial input yields in a chemical evolution model implicity contain a physical scenario of nucleosynthesis and evolution. Thus improved input yields is expected to result in a better simulation of observed abundances. We have examined and verified this hypothesis with a two zone model and found that with such a model the main observational constraints of the solar neighbourhood and the halo of the galaxy can be satisfied. The abundances of the iron group elements with a few exceptions of Cr and Mn are also found to be in good agreement with stellar abundance data. Within marginal uncertainties our model could reproduce the chemical compositions at solar birth. The derived age-metallicity relation too is in satisfactory agreement with observation.

While in the present work we have mainly examined our simulations against available observations, the scope of such a model is, however, much wider. In particular, it is possible to examine the evolution of a much wider variety of elements than discussed before. As an example, we present in figure 3 simulated curves for abundances for elements Na, S,K,V, & Cu. As can be seen from these curves they exhibit distinct evolutionary features. Availability of observed data on these elements in the future would enable an exciting and objective evaluation of the model.

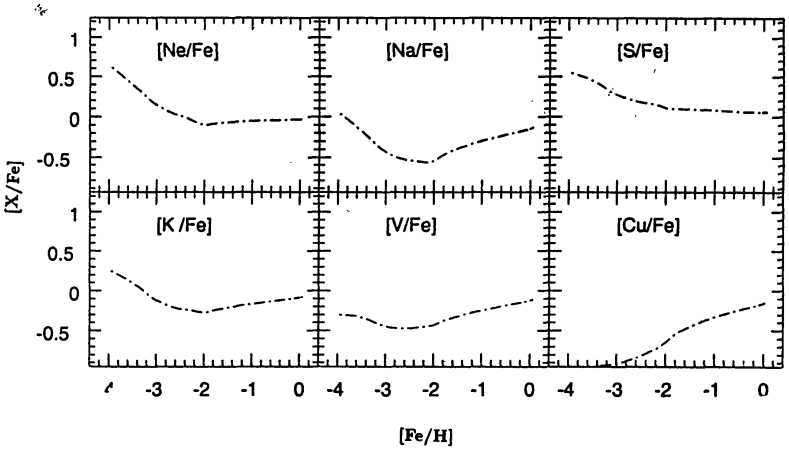

Figure 3. Simulated curves of abundance ratios for elements Ne, Na, S, K, V & Cu. The abundance ratios [X/Fe] are plotted along the Y-axis as a function of metallicity [Fe/H] along the X-axis.

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