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Implications from Inhomogeneous Chemical Evolution: Yields of O–Zn

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Observations of metal-poor stars show intrinsic large dispersions in their chemical abundances. This may indicate that these stars are enriched by only one or a few supernovae, since the inter-stellar gas was not mixed enough at the early epoch. We construct an inhomogeneous chemical evolution model, and compare predicted stellar abundance distributions for O–Zn with observations. Using statistical method, we show clear differences between two sets of yields; by Nomoto et al. (1997) and by Woosley & Weaver (1995).

1. Inhomogeneous chemical evolution

Metal-poor stars can provide clues for the early evolution of our Galaxy. Observations show intrinsic large dispersions in their chemical abundances. Possible explanation is that the interstellar-medium (ISM) was not mixed well, and metal-poor stars contain products of only one or a few supernovae (SNe). In this study, we understand nucleosynthesis of individual SNe from the point of view of early enrichment history of our Galaxy. We have constructed a new Galactic chemical evolution model, assuming SNe induce star formation. Since a new star is formed from a mixture of a supernova remnant (SNR) and the ISM gathered by expansion of the SNR, its chemical composition can be calculated from the mass average of that of the SNR and the ISM. We take two sets of yields given by known SN models; Nomoto et al. 1997 [1] (N97) and Woosley & Weaver 1995 [2] (WW95). The yields of WW95 take into account dependency of yields on stellar metallicity, whereas N97 assumes constant yields irrespective of metallicity. Thus, differences in predictions by two SN models must reveal effect of metallicity dependency of yields on chemical evolution and scatters in [X/Fe] of metal-poor stars.

2. [X/Fe] vs. [Fe/H] predicted by two models

We calculate stellar distributions on diagrams of relative abundance ratios of [O–Zn/Fe] vs. [Fe/H]. Figure 1 shows examples of [Mg/Fe] vs. [Fe/H] relations predicted by N97 and WW95. Obviously, we can see the distribution of stellar fractions (shades) shrinks with increasing of metallicity. We also put several stars formed via SNe of the first generation

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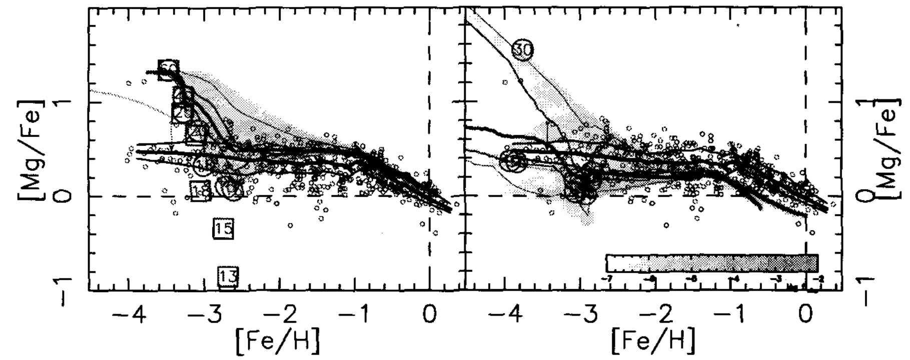

Figure 1. [Mg/Fe] vs. [Fe/H] relations predicted from N97 (left panel) and WW95 (right panel). Predicted distributions of stellar fraction (shade) are compared to observational data (small circles). Large symbols indicate stars formed from the SNe of the fist generation stars (N97) and from SNe of $10^{-4}Z_{\odot}$ stars (WW95). The numbers in the circles indicate progenitor masses in a unit of the solar mass. The average lines and 50% confience regions of observations are given by black thick and thin lines, respectively. Those of model predictions are also given by red thick, thin, and thinner (90%) lines.

stars (large symbols). It is shown that the widths of stellar distributions are determined by variations in yields of different progenitor mass. Stellar distribution shows extremely large dispersion, if SN products of the first generation stars are mixed with *zero-metal gas* (large squares in N97). But if ISM is already enriched efficiently by higher mass stars when lower mass progenitors explode (large circles in N97), a predicted scatter is smaller. Thus, since the efficiency of gas mixing has some uncertainties, actual stars can distribute between these two extreme cases. A similar result is obtained also by WW95 (right panel). We also put the average values (thick gray lines) and 50% and 90% confidence regions (thin and thinner gray lines) of stellar distributions to compare model predictions quantitatively with observational values of average (thick black lines) and 50% confidence (think black lines) [4].

3. Statistical analysis of dispersions and SN yields

Concerning the average trends of [X/Fe], several elements such as Na, Al, Sc, Cu, Zn, etc. are already known to show clear differences between two yield sets, while some elements such as α-elements are believed to be rather stable and show similar trends irrespective of models. However, as shown in Fig. 1, the width of scatters in metal-poor stars shows clear difference of two models even in α-elements. Thus, we take 50% confidence intervals and compare them with observational values. Figure 2 shows the ratios of predictions over observations of width of 50% confidence intervals. Although both of two models seem to predict underestimated dispersions in [Fe/H] > -2, it can be understood if we take into account observational errors which are comparable to dispersions in higher metallicity stars. On the other hand, dispersions by N97 seem small especially in [Fe/H] < -3, since few stars are predicted in this area. The distributions

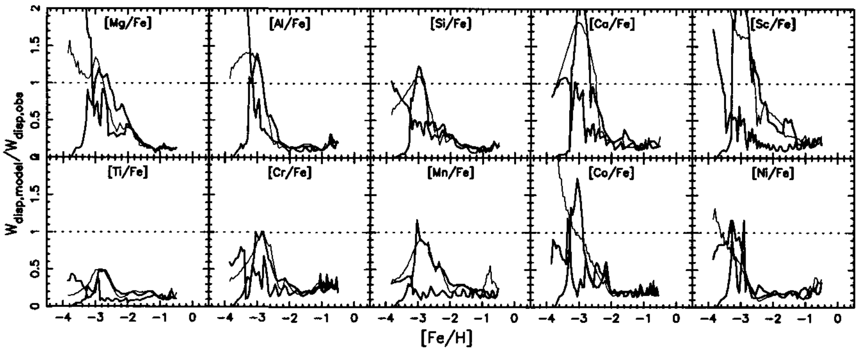

Figure 2. Relation between [Fe/H] and the ratio of predicted width of 50% confience intervals over observed value. Black and gray lines indicate the case of N97 and WW95, respectively. Black thin lines indicate the case when dispersion of gas mixing length is taken into account.

of lower metallicity stars are affected also by the efficiency of gas mixing. In our model, a parameter for gas mixing is given by the expansion radius of SNR, which is calculated from an analytical function of density of the ISM [3]. If SNR radius has 1.5σ uncertainty in logarithmic scale, some stars are formed from the gas more diluted by the ISM. As a result, stellar dispersions are elongated towards lower metallicity and show better agreements with observations. However, the maximum width of 50% confidence interval is affected little. Therefore, if predicted dispersion exceeds observational value significantly, the inconsistency comes from the SN model rather than gas dynamics. Figure 2 shows overestimates of dispersions in Mg and Al of WW95 and in Ca and Co in N97. Both models predict too large dispersions in Sc. These elements suggest problems in supernova models.

4. Conclusion

We constructed a chemical evolution model, assuming SN induced star formation. Predicted dispersions in [O–Zn/Fe] are compared with observational data. The differences between two sets of yields; N97 and WW95, clearly appear in dispersions. The widths of 50% and 90% confidence regions are determined by stellar mass dependency of SN yields, but are not affected significantly by the mixing length of SNR. Thus, the overestimate in dispersions suggests problems for SN models; Mg and Al for WW95, Ca and Co for N97 and Sc for both models.

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