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The Evolution of Radial Abundance Gradients: The two infall episode model

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1. Introduction

Recently Gratton et al. (1995) showed that the distribution of O and Fe abundances for a large and homogeneous sample of stars in the solar neighborhood indicates a short timescale for the evolution of the halo and thick disk phases and a sudden decrease in the star formation at the time of formation of the thin disk. Based on these facts, they proposed that a model with two distinct infall episodes and a threshold in the star formation could account for these observations.

The model presented here assumes that the e-folding time of the halo infall rate is 0.3 Gyr, which roughly coincides with the appearance of the first type Ia SNe, whereas that of the disk is assumed to be 3 Gyr at the solar neighborhood. The disk is assumed to form by accretion of mainly primordial material, at the end of the halo phase. The threshold in the star formation rate - assumed proportional to the surface gas density - is $7M_{\odot}pc^{-2}$ (see Gratton et al. 1995 and references therein). These assumptions naturally produce a hiatus in the star formation as required by observations.

In this work we computed the evolution of [O/Fe] versus [Fe/H] in the solar neighborhood and the radial abundance gradients and compared them with the results of a model with a single infall episode. This model has been discussed by Tosi (this conference). To compute the radial gradients we assumed, in both models, that the disk infall timescale is a linear function of the galactocentric distance as in Matteucci and François (1989, MF89).

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2. Results and Discussion

Figure 1a shows the oxygen/iron ratio with respect to iron relative to the sun. Although both models predict an overabundance of oxygen for the halo stars, the predicted [O/Fe] is lower than the observed values. This is a consequence of the high iron yield for type II SNe taken from Timmes et al (1995).

The looping predicted by the two infall episode model, also suggested by observations (see Gratton et al. 1995 and references therein), can be understood as to be caused by the strong dilution of the interstellar medium abundances at the moment of maximum infall onto the disk coupled to a sudden decrease of the SFR at the end of the halo-thick disk phase. The dilution lowers the absolute abundances but does not affect their ratios, whereas the gap in the SFR lowers the oxygen abundance (whose progenitors are mainly the type II SNe), but not that of iron which continues to grow due to the contribution of the type Ia SNe.

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Figure 1. a) Delayed infall model (*solid line*) and single infall episode model (*dotted line*) predictions. The data were taken from Gratton et al. (1995); b) Temporal evolution of the abundance gradient of oxygen

However, the star formation gap lasts a very short time because of the gas which is setting onto the disk at a high rate, and so the decrease of the [O/Fe] ratio is much smaller than the decrease of the iron abundance, as can be observed in figure 1a.

In figure 1b we show the temporal evolution of the oxygen gradient. We see that initial and final values of the abundance gradient for the two models are similar whereas for the intermediate times the two models predict different gradients. This is due to the fact that, although both models predict gradients which steepen in time, in the two infall episode model the evolution of the disk is delayed by 2 Gyrs. So, the gradient has not yet reached a saturation as in the single infall model, but it grows at a slower rate in the last Gyrs of the Galaxy evolution. It is important to observe that the saturation effect of the radial abundance gradients occurs only in the last phases of the history of the Galaxy at variance with the results presented by Ferrini el al. (1994).

It is worth mentioning that the two infall model predicts a rather flat radial distribution for the SFR and for the gas mass density along the disk of the Galaxy. This behavior is clearly a consequence of the star formation threshold. Note, however, that a flat gas distribution is observed for HI whereas that of H_2 decreases with the galactocentric distance. As a consequence, we should consider models with these two gas phases separately (the subject of a future paper).

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References

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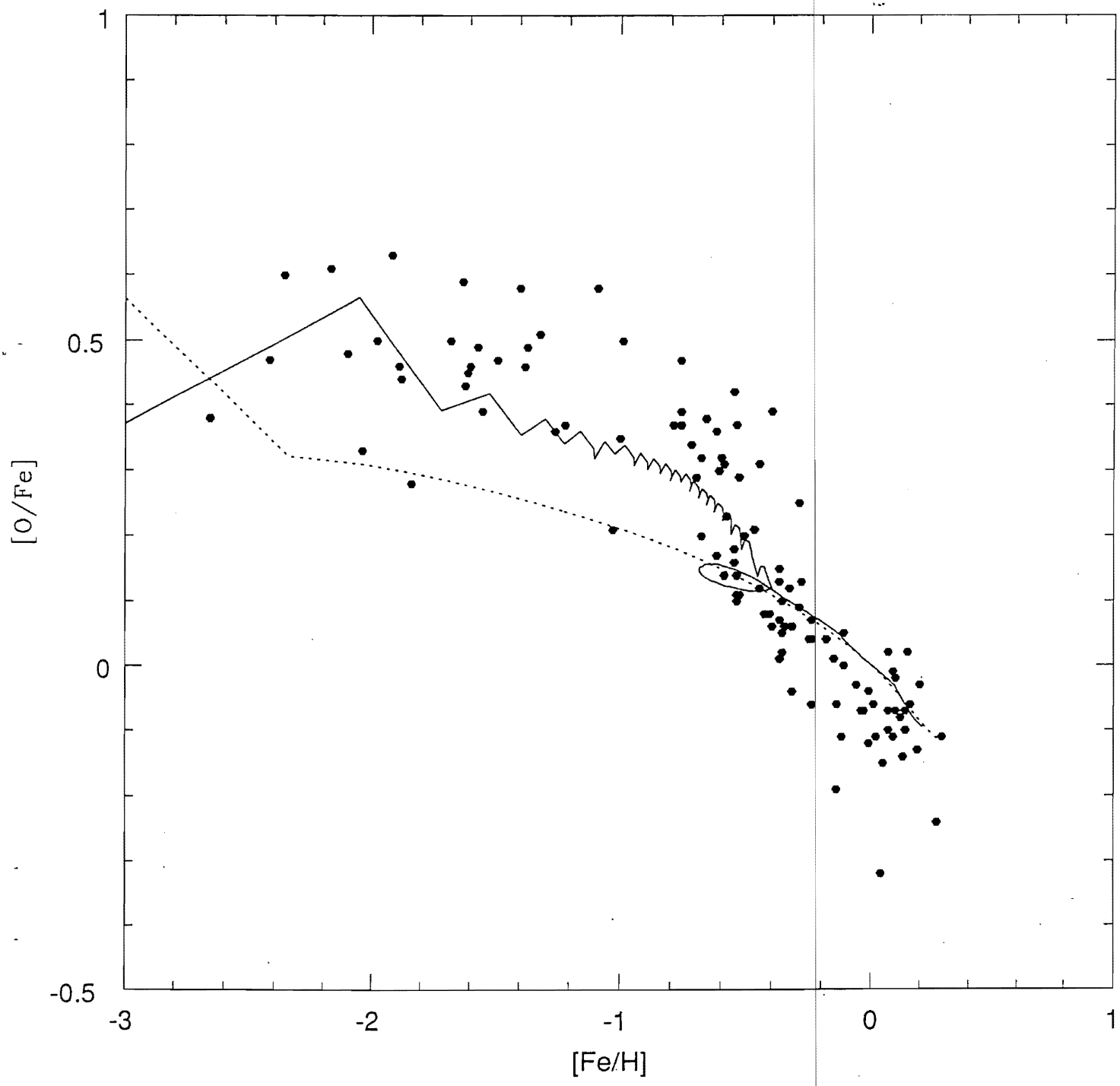
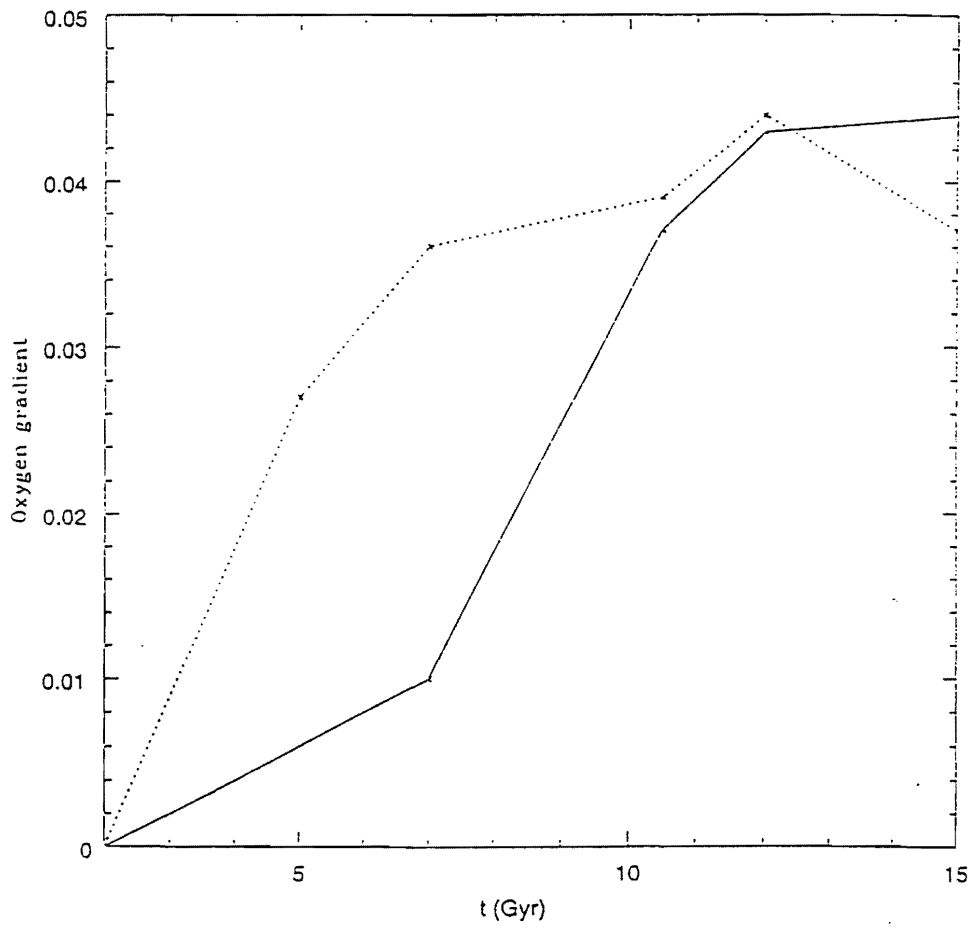

1
0.5
0
-0.5
[O/Fe]
-3
-2
-1
0
1
[Fe/H]


0.05
0.04
0.03
0.02
0.01
0
Oxygen gradient
5
10
15
t (Gyr)