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Radial abundance gradients as a constraint of the [O/Fe]×[Fe/H] relation in the galactic disk

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Abstract

Radial O/H abundance gradients from HII regions, hot stars and planetary nebulae are combined with [Fe/H] gradients from open cluster stars in order to derive an independent [O/Fe]×[Fe/H] relation for the galactic disk. A comparison of the obtained relation with recent observational data and theoretical models suggests that the [O/Fe] abundances do not reach values higher than 0.4 dex, at least within the metallicity range of the considered samples, [Fe/H] > −1.5.

1. Introduction

Recently, some discrepancy has been observed between different sets of observational data regarding the [O/Fe]×[Fe/H] ratio. Results based on the [OI] line doublet at 6300/6364 Å in metal-poor giants lead to [O/Fe] ~0.5 for [Fe/H]~−2, with a plateau in [O/Fe] for lower metallicities. On the other hand, abundances from the OI infrared lines and studies based on ultraviolet OH bands in metal-poor stars reach a much higher ratio, [O/Fe]~1 at low metallicities, with a similar slope of about −0.3 for the galactic thin disk, thick disk and halo. A contribution to the understanding of this problem can be obtained by the analysis of radial abundance gradients in the galactic disk. Such gradients are observed both for O/H from HII regions, planetary nebulae and hot stars and also for [Fe/H], principally from open cluster stars. In this work, both sets of data are taken into account in order to derive an independent [O/Fe]×[Fe/H] relation.

2. Radial abundance gradients

The best determinations of the O/H radial gradient are based on photoionized nebulae (HII regions and planetary nebulae) and hot stars (Maciel, 2001). On the other hand, recent stellar data based on O and B stars settled out previous contradictions and pointed to a clear gradient of the same order as the one derived from the photoionized nebulae. The O/H gradient can be written as $\log(\mathrm{O/H}) + 12 = a + bR$, where R is the galactocentric distance in kpc. The constants a and b have slightly different values depending on the nature of the objects considered. HII regions and hot stars have very similar gradients, while most planetary nebulae show a slightly flatter gradient. An average gradient of the former, referring thus to the younger population, is characterized by the values $a = 9.34$ and $b = -0.070$ dex/kpc for $R_0 = 7.6$ kpc.

Determinations of the [Fe/H] gradient from open cluster stars indicate a steeper [Fe/H] gradient as compared with the O/H gradient. The [Fe/H] gradient can be approximately written as $[\mathrm{Fe/H}] = c + \mathrm{d}R$, where $c = 0.50$ and $d = -0.085$ dex/kpc.

The time variation of the radial abundance gra-

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dients is not well known, but we may consider the HII regions and open cluster stars as referring to essentially similar epochs, so that the given constants *a*, *b*, *c* and *d* can be safely assumed as reflecting the present interstellar abundances of oxygen and iron in the galactic disk. Assuming that the gradients hold throughout the galactic disk, it can easily be shown that $[O/Fe] = \alpha + \beta[Fe/H]$, where we have defined $\alpha = a - bc/d - [\log(O/H)_{\odot} + 12]$ and $\beta = b/d - 1$. Similar relationships can also be obtained for $[O/H]\times[Fe/H]$ and for $[Fe/H]\times\log(O/H)+12$. The latter is particularly useful for HII regions and planetary nebulae, for which the [Fe/H] abundance usually cannot be obtained directly.

3. Results and discussion

Adopting the given values of the constants *a*, *b*, *c* and *d*, we obtain $\alpha = 0.098$ and $\beta = -0.176$, where we have used the solar abundance $\log(O/H)_{\odot} + 12 = 8.83$. Using these values, we can derive the usual $[O/Fe]\times[Fe/H]$ relationship and the equivalent relation $[Fe/H]\times\log(O/H)+12$. We have compared our results with theoretical models by Matteucci et al. (1999) and Ramaty et al. (2000). The former are representative of models predicting an [O/Fe] plateau for metallicities under solar, without a significant increase in the [O/Fe] ratio above 0.5 dex for $[Fe/H] < -1.5$, while the latter have been selected to display higher [O/Fe] ratios at lower metallicities. We have also included some representative observational data from the literature (Barbuy and Erdelyi-Mendes, 1989; Boesgaard et al., 1999; Israelian et al., 1998; Spiesman and Wallerstein, 1991; Spite and Spite, 1991; Mishenina et al., 2000; Cavallo et al., 1997).

Our results show that for metallicities close to the solar value, all observational data and models have a reasonable agreement, while for lower metallicities the spread is considerably larger. The gradient data support the lower [O/Fe] abundances, at least for $[Fe/H] > -1.5$, which are appropriate for the oldest populations of the disk. Extrapolating to $[Fe/H] \sim -1.5$, we obtain an upper limit $[O/Fe] \sim 0.4$, which is still closer to the 'low [O/Fe] regime', than to the 'high [O/Fe] regime'. Therefore, our data is consistent with a maximum $[O/Fe] \sim 0.4$ for the galactic disk, at least for the metallicities $[Fe/H] > -1.5$ appropriate to the region where abundance gradients are observed. These results are also supported by the recent work of Carretta et al. (2000) and Fulbright and Kraft (1999), according to which it is premature to conclude that the oxygen abundances of metal-poor stars should be increased.

The average slope of our $[O/Fe]\times[Fe/H]$ relation is -0.18. The simplicity of the linear model does not allow to predict any changes of slope or the presence of a plateau, but we have computed the variations of the slope for different values of the gradients. Since the O/H gradient of -0.07 dex/kpc is firmly established, steeper slopes would require an [Fe/H] gradient higher than -0.085 dex/kpc, for which there is no observational evidence.

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