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SOLAR ORIGINS: PLACE AND CHEMICAL COMPOSITION

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RESUMEN

Discutimos un modelo de evolución química con rendimientos dependientes de Z que reproduce los gradientes de O/H, C/H y C/O del disco Galáctico y la historia química de la vecindad solar. El modelo ajusta las abundancias de H, He, C y O derivadas a partir de líneas de recombinación en la región H II M17 (incluyendo la fracción de átomos de C y O embebida en polvo); las abundancias protosolares de H, He, C, O y Fe; y las relaciones C/O-O/H, C/Fe-Fe/H y O/Fe-Fe/H derivadas de estrellas de la vecindad solar. El ajuste del modelo con las abundancias protosolares al tiempo de formación del Sol implica que el Sol se originó en un medio químicamente bien mezclado a una distancia galactocéntrica de 7.6 ± 0.8 kpc.

ABSTRACT

We discuss a chemical evolution model with Z-dependent yields that reproduces the O/H, C/H, and C/O gradients of the Galactic disk and the chemical history of the solar vicinity. The model fits the H, He, C, and O abundances derived from recombination lines of the H II region M17 (including the fraction of C and O atoms embedded in dust); the protosolar H, He, C, O, and Fe abundances; and the C/O-O/H, C/Fe-Fe/H, and O/Fe-Fe/H relations derived from stars of the solar vicinity. The agreement of the model with the protosolar abundances at the Sun-formation time implies that the Sun originated from a well mixed ISM at a galactocentric distance of 7.6 ± 0.8 kpc.

Key Words: galaxies: chemical evolution — H II regions (M17, Orion nebula) — ISM: abundances — Sun: abundances

1. INTRODUCTION

The comparison of detailed Galactic chemical evolution models, GCE models, with accurate abundance determinations of stars and gaseous nebulae provides a powerful tool to test the GCE models and the accuracy of observational abundance determinations of stars of different ages and of H II regions located at different galactocentric distances.

To find a robust model for the Galaxy we decided to use as main observational constraint the slope and absolute value of the O/H gradient. This model has been tested with other observational constraints of high quality. A full discussion of this problem on the GCE has been presented elsewhere (Carigi & Peimbert 2011).

2. DISCUSSION

GCE models can be constrained by chemical gradients obtained by different methods used in the literature. Those Galactic disk gradients in general show similar slopes but a considerable spread in the absolute O/H ratios. A comparison of many of the different methods used has been made by Kewley & Ellison (2008). They find that the O/H differences derived by different methods for a given H II region can be as large as 0.7 dex. Most of the differences among the various calibrations are due to the temperature distribution inside the nebulae. The recombination lines (RL) method, that is almost independent of the electron temperature, produces gaseous O and C abundances higher by about 0.15 to 0.35 dex than the forbidden lines (FL) method, that is strongly dependent on the electron temperature. It is possible to increase the FL abundances under the assumption of temperature inhomogeneities to reach agreement with the RL values (Peimbert & Peimbert 2011).

In this work we use H, He, C, and O abundances of H II regions at different galactocentric distances based only on the RL method. Since the recombinatio line ratios among these four elements are practically independent of the electron temperature their relative abundances are very reliable.

Moreover, these abundances were corrected under the assumption that 35% of the O atoms and 25% of the C atoms are trapped in dust grains (Peimbert & Peimbert 2010), increasing the O/H and C/H values by 0.12 and 0.10 dex, respectively. In order to constrain the chemical history of the interstellar medium, we considered stellar abundances of different ages.

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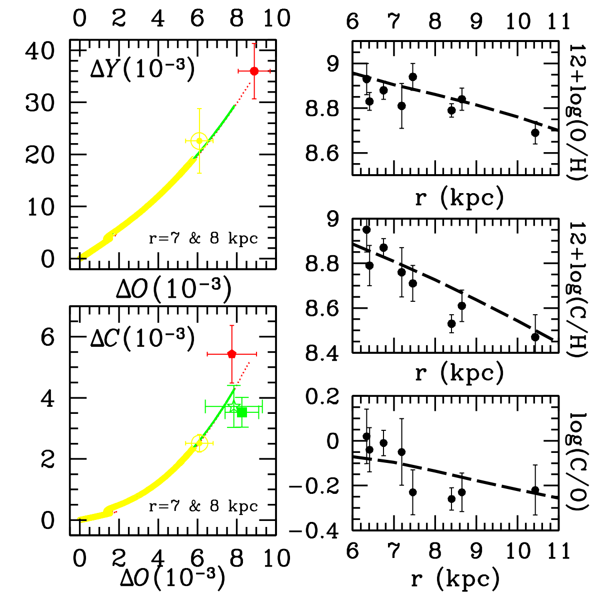

Fig. 1. Chemical evolution model for the solar vicinity and the Galactic disk. The left panels show the 0–13 Gyr evolution of ΔY vs ΔO and of ΔC vs ΔO for $r = 7$ kpc (dotted red lines) and $r = 8$ kpc (thin solid green line), the thick yellow lines show the evolution from 0 to 8.5 Gyr for $r = 8$ kpc. The right panels show the present-day ISM abundance ratios as a function of galactocentric distance. Data. Filled red pentagon: Average values of the M17 and M20 H II regions from Carigi & Peimbert (2008) at $r = 6.75$ and 7.19 kpc, respectively. Yellow $\odot$: Protosolar values by Asplund et al. (2009). Empty green star: Average values of young F-G dwarf stars of the solar vicinity from Bensby & Feltzing (2006). Filled green square: Average values of NGC 3576 and Orion H II regions at $r = 7.46$ and 8.40 kpc. Filled black circles: H II regions (García-Rojas & Esteban 2007), gas (García-Rojas & Esteban 2007) plus dust correction (Peimbert & Peimbert 2010).

In Figure 1 we present our model together with the best observational constraints available (those listed above). The model was built to reproduce the O/H gradient (upper right panel) assuming an inside-out scenario and intermediate wind yields (moderate mass loss rate for massive stars of $Z_\odot$). Specifically our model is able to reproduce the following observational constraints presented in the other four panels: (a) the current O/H, C/H, and C/O abundance gradients (slopes and absolute values) derived from Galactic H II regions; (b) the O/H, C/H, and Fe/H values and Fe/H-time relation derived from halo and disk stars of different ages in the solar vicinity; (c) the He/H, C/H, O/H, and Fe/H protosolar abundances that correspond to those present in the interstellar medium 4.5 Gyr ago; and (d) the He/H, C/H, and O/H values of the Galactic H II regions M17 and M20.

From the protosolar $12 + \log(\mathrm{O/H}) = 8.73 \pm 0.05$ value by Asplund et al. (2009) and the O/H values predicted by our GCE model for $r = 8$ and $r = 7$ kpc of 8.70 and 8.77 for the ISM when the Sun was formed ($t = 8.5$ Gyr), we obtain that the Sun originated at $r = 7.6 \pm 0.8$ kpc.

We also decided to compare our best models with the C/O vs O/H results derived by Esteban et al. (2002, 2009) from bright H II regions in nearby spiral galaxies based on recombination lines and including the dust correction.

3. CONCLUSIONS

The agreement of the He/O, C/O, and Fe/O ratios between the model and the protosolar abundances implies that the Sun formed from a well mixed ISM, since about half of the freshly He (and C) is produced by massive stars and half by low-and-intermediate-mass stars (Carigi et al. 2005; Carigi & Peimbert 2008), and an important fraction of the Fe comes from SNIa.

The agreement of our model with the protosolar abundances and the Sun-formation time supports the idea that the Sun originated at 7.6±0.8 kpc, close to its current galactocentric distance ($r = 8$ kpc).

We obtain that our chemical evolution model of the Galactic disk for the present time produces a reasonable fit to the O/H-C/O relation derived from H II regions of nearby spiral galaxies. This agreement might imply that spiral galaxies have a similar IMF, no selective outflows, and probably a formation scenario similar to that of our galaxy (for a more general discussion of this issue see Carigi & Peimbert 2011).

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