RevMexAA (Serie de Conferencias), **26**, 68–69 (2006)

CARBON AND OXYGEN GALACTIC GRADIENTS

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RESUMEN

Se ha calculado un modelo de evolución química de la Galaxia para reproducir el gradiente de O/H obtenido de regiones H II Galácticas. Este modelo resuelve el problema del enriquecimiento de C ya que ajusta los gradientes de C/H y de C/O y la historia de la evolución de C y O en la vecindad solar. El modelo se basa en rendimientos químicos de C dependientes de la metalicidad (Z) debido a los vientos estelares. Los rendimientos de C de estrellas masivas (MS) aumentan con la metalicidad, mientras que los de estrellas de masa intermedia y baja (LIMS) disminuyen con Z. Un resultado importante es que la fracción de C en el medio interestelar (ISM) debida a las MS y LIMS es dependiente de la Z del medio interestelar y por lo tanto esa fracción depende fuertemente del tiempo y de la distancia Galactrocéntrica. En la actualidad y en la vecindad solar la mitad del C en el medio interestelar ha sido producida por las MS y la otra mitad por las LIMS.

ABSTRACT

A chemical evolution model of the Galaxy has been computed to reproduce the O/H gradients from Galactic H II regions. This model solves the C enrichment problem because it fits the C/H and C/O gradients and the C and O histories of the solar vicinity. The model is based on C yields dependent on metallicity (Z) owing to stellar winds. The C yields of massive stars (MS) increase with Z and those of low and intermediate mass stars (LIMS) decrease with Z. An important result is that the fraction of carbon in the interstellar medium (ISM) due to MS and LIMS is strongly dependent on Z of the ISM, therefore, that fraction depends on time and on the Galactocentric distance. At present and in the solar vicinity about half of the C in the interstellar medium has been produced by MS and half by LIMS.

Key Words: **GALAXY: EVOLUTION — ISM: ABUNDANCES — STARS: MASS LOSS**

Most of the Galactic chemical evolution models predict a similar history for C/O vs. O/H at the solar vicinity, but predict different C/O Galactocentric gradients. All authors agree that both MS and LIMS play a significant role in the C production of the solar vicinity, nevertheless some authors find that most of the C is due to MS while other authors find that most of the C is due to LIMS (see Bensby & Feltzing 2006 and references therein). The different predictions on: the C/H value in the solar vicinity, the Galactic C/O gradient, and the relative importance of MS and LIMS in the C production are mainly due to C yields obtained from the stellar chemical evolution models. We called "the C enrichment problem" the difficulty of estimating the proper C yields for MS and LIMS. The C/H and O/H gradients derived from H II regions by Esteban et al. (2004), provide us with the additional constraints necessary to study this problem.

We present a model built to reproduce the observed gas fraction distribution of the Galaxy and the observed O/H H II region values from 6 to 11 kpc at 13 Gyr, the age of the model. The model does not reach the central regions of the Galaxy because the evolution of the central regions might not correspond to an extrapolation of the disk values to the center for the following reasons: a) the bulge has a different chemical evolution history; b) the effect of the bar has to be considered; c) the extrapolation of the models to higher metallicities might not be correct due to saturation effects.

The chemical history produced by the model fits relevant observational constraints of the solar vicinity (r = 8 kpc) and the C/Fe, O/Fe vs Fe/H and C/O vs O/H relations derived from stars, the Sun, and in H II regions (see Carigi et al. 2005, for details).

The model predicts enrichments in the C/H ,O/H ratios of 0.29, 0.13 dex, since the Sun was formed. By adding this value to the Asplund et al. (2005) 12 + log C/H, O/H = 8.39, 8.66 solar values, we predict for the ISM in the solar vicinity a value of 12 + log C/H, O/H = 8.68, 8.79 in excellent agreement with the values derived from the recombination line observations, after correcting by the dust presence,

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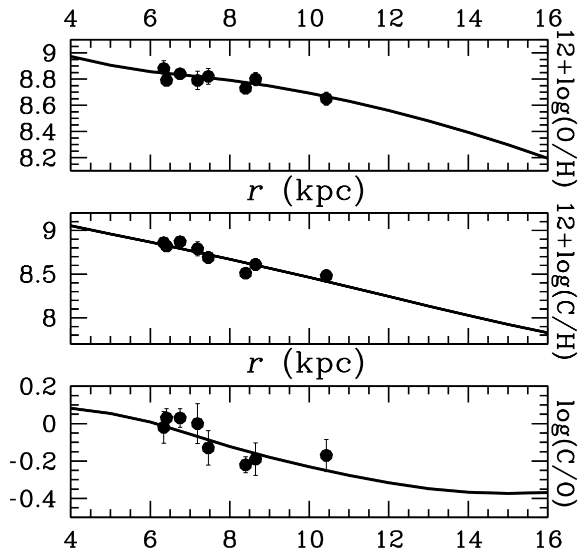

Fig. 1. The present-day ISM gradients. *Solid lines:* Predictions from the model that considers yields dependent on metallicity and stellar winds. *Filled circles:* H II regions, gas plus dust values; the gaseous values from Esteban et al. (2004) have been corrected by the dust fraction (Esteban et al. 1998).

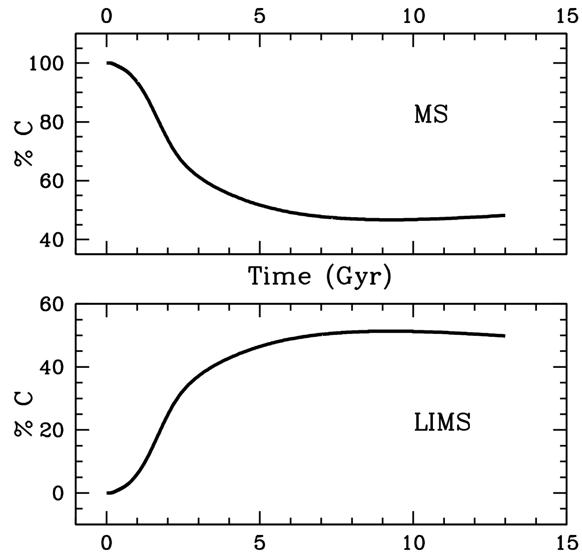

Fig. 2. Cumulative percentage of C as a function of time, due to massive stars and to low and intermediate-mass stars, at the solar vicinity.

that amount to 12 + log C/H, O/H = 8.67, 8.77 $\pm$ 0.07, 0.05.

The model produces an excellent fit to the C/H gradient and a good fit to the C/O gradient (see Figure 1). Note that for $r < 6$ kpc the predicted C/O values start to saturate. Additional observational data as well as a model that includes the behavior of the bulge are needed to study that region. For $r > 11$ kpc, the predicted C/O ratio flattens and again additional observations are needed.

In Figure 2 we present the cumulative C enrichment of the ISM of the solar vicinity as a function of time. We find that about half of the C in the ISM of the solar vicinity, at the present time, has been produced by MS and half by LIMS. Also, at the present time, for a Galactocentric distance of 6 kpc about 53% of the C has been produced by MS and 45% by LIMS, while for 11 kpc the opposite is true, about 42% of the C has been produced by MS and 56 % by LIMS. Therefore, the fraction of C present in the ISM produced by MS increases with decreasing r (for higher Z values) while for LIMS they decrease with Z.

We present a solution to the C enrichment history of the Galaxy based on the yields and observations available. The solution is based on the adoption of C yields that increase with metallicity owing to stellar winds in MS (Maeder 1992, Meynet & Maeder 2002) and decrease with metallicity owing to stellar winds in LIMS (Marigo, Bressan, & Chiosi 1996, 1998).

It is clear that a more powerful treatment of convection, a better value of the $^{12}C(\alpha,\gamma)^{16}O$ rate, and a more realistic mass loss rate scheme will produce a better solution to the C enrichment problem. Moreover to produce a more stringent test for the C yields it is necessary to obtain observations of the C/O ratio for $r < 6$ kpc and $r > 11$ kpc and to include a model of the bulge formation and its effect on the C/O values for the inner regions of the Galaxy.

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