

## CNO ISOTOPES AND THE CHEMICAL EVOLUTION OF SPIRAL GALAXIES

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We have computed chemical evolution models for eight nearby spirals (M31, M33, M51, M83, M101, NGC2403, NGC6946, and IC342) plus our own Galaxy in order to investigate the primary and secondary nature of <sup>13</sup>C and <sup>14</sup>N. Although the number and quality of the observational data are continuously increasing (see B.E.J. Pagel, this meeting) their present interpretation is still far from being clear, ranging from purely primary to purely secondary nitrogen (Tomkin and Lambert 1984; Serrano and Peimbert 1983). As far as nitrogen and oxygen are concerned, abundance data are available for both the Galaxy (stars, planetary nebulae, HII regions, supernova remnants, etc.) and nearby spirals (HII regions and supernova remnants). In the case of carbon, only data in our own Galaxy exist (molecular clouds and stars) but they are of great importance in order to further constrain the models.

The main characteristics of our numerical models are as follows:

a) No instantaneous recycling approximations have been used in order to take into account the different lifetimes of stars of different initial masses.

b) The star formation rate,  $\psi$ , is assumed to follow an exponential law,  $\psi \propto \exp(-t/\tau)$  with  $\tau \leq \infty$ .

c) Infall is allowed to occur at a rate,  $F$ , that becomes constant after the disk formation.

d) The initial mass function is assumed to be constant and uniform and equal to that derived by Tinsley (1980) for the solar neighbourhood.

Under these assumptions, the two free parameters of the models are the star formation and infall rates (see Diaz and Tosi 1985 for details).

The stellar yields used in combination with the chemical evolution models have been taken from Arnett (1978) and Maeder (1981, 1983) for massive stars

( $M \geq 10 M_{\odot}$ ) and from Renzini and Voli (1981) for low and intermediate mass stars. Detailed computations are presented by these authors for  $^{12}\text{C}$ ,  $^{13}\text{C}$ ,  $^{14}\text{N}$  and  $^{16}\text{O}$ . From their nucleosynthetic results, the main sites for the production of these isotopes are:  $^{12}\text{C}$  is produced in both high and intermediate mass stars, its production being larger in these latter ones;  $^{13}\text{C}$  and  $^{14}\text{N}$  are produced in stars with masses between 3 and  $8 M_{\odot}$  at most, depending on the adopted mixing length ( $\alpha_{\text{RV}}$ ); finally,  $^{16}\text{O}$  is produced in high mass stars.

In Fig.1 we show the results of the models described above for the N/O vs O/H distribution in the Galaxy. The dots represent the abundances derived by Shaver et al. (1983) from HII region observations. Only the models which best fit the observed radial oxygen distribution are shown. These models correspond to values of  $\tau$  15 Gyr and  $F=3.5$  (thick lines) and 4 (dashed lines) in units of  $10^{-3} M_{\odot} \text{kpc}^{-2} \text{yr}^{-1}$ . Every set of lines in the figure results from different choices of  $\alpha_{\text{RV}}$  and of the upper mass limit  $M_{\text{up}}$  for intermediate mass stars. Stars with initial masses larger than  $M_{\text{up}}$  ignite carbon in a non degenerate core and therefore do not experience the asymptotic giant branch phase and do not produce primary  $^{13}\text{C}$  and  $^{14}\text{N}$  (Renzini and Voli 1981). The top and bottom sets of lines correspond to models computed with the standard value of  $M_{\text{up}}=8 M_{\odot}$ , while for the other two we have adopted values of  $M_{\text{up}}$  of 5 and  $6 M_{\odot}$  as suggested by Bertelli et al. (1985), Castellani et al. (1985) and Renzini et al. (1985). The best agreement between models and observations is attained either for a value of  $\alpha_{\text{RV}}$  close to 1.0 and the standard  $M_{\text{up}}$  or for a value of  $\alpha_{\text{RV}}$  close to 1.5 and  $5 \leq M_{\text{up}}/M_{\odot} \leq 6$ .

Results similar to those shown in Fig.1 have been found for the other analyzed spirals, i.e. the chemical evolution models which best fit the observed radial O/H distribution also fit the N/O vs O/H observed distribution with the same combination of  $\alpha_{\text{RV}}$  and  $M_{\text{up}}$  (Diaz and Tosi 1985).

Table 1: Observed and predicted  $^{12}\text{C}/^{13}\text{C}$  ratios by mass.

observed*	82	65
$\alpha_{\text{RV}} = 1.0 \quad M_{\text{up}} = 8 M_{\odot}$	189	170
$\alpha_{\text{RV}} = 1.5 \quad M_{\text{up}} = 8 M_{\odot}$	46	44
$\alpha_{\text{RV}} = 1.5 \quad M_{\text{up}} = 6 M_{\odot}$	51	48
$\alpha_{\text{RV}} = 1.5 \quad M_{\text{up}} = 5 M_{\odot}$	107	99

\* Data from Henkel et al.(1982) and Henkel et al.(1985)

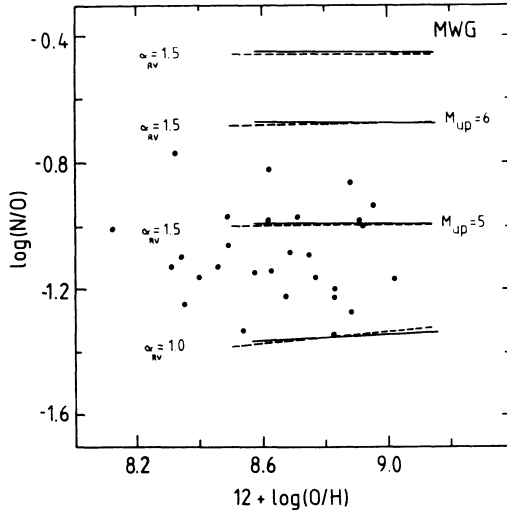


Fig.1. The Galaxy: Logarithmic N/O vs O/H distribution as derived from HII region observations (dots) and from theoretical models (thick and dashed lines). See text for details.

The results concerning the  $^{12}\text{C}/^{13}\text{C}$  ratio by mass in the solar neighbourhood are summarized in Table 1 together with the values observed in molecular clouds and in the solar system (Henkel et al. 1982, Henkel et al. 1985). We have assumed the solar system value as representative of the local interstellar medium composition at the time of the sun formation 4.5 Gyr ago.

It is apparent from this table that models with  $\alpha_{\text{RV}}=1.0$  are unable to reproduce the observed values, while models with  $\alpha_{\text{RV}}=1.5$  and  $M_{\text{up}}$  between 5 and  $6 M_{\odot}$  can actually reproduce both the cosmic value and the present one.

As a further check of this choice, we have plotted in Fig.2 the N/C vs C/H distribution as derived from the corresponding models and from Laird's (1985) observations of 116 field stars. The adopted solar values are indicated by the usual sun symbol. This plot represents the time behaviour of the shown distributions, contrary to Fig.1 where HII regions are representative of the abundances at the present epoch and therefore give only their spatial behaviour. Once again it is apparent that models with  $\alpha_{\text{RV}}=1.5$  and  $M_{\text{up}} \approx 6 M_{\odot}$  fit very well the data.

The main conclusions of our work can be summarized as follows:

1) A primary fraction of  $^{14}\text{N}$  of  $\sim 40\%$  is required to explain the observed N/O vs O/H distribution.

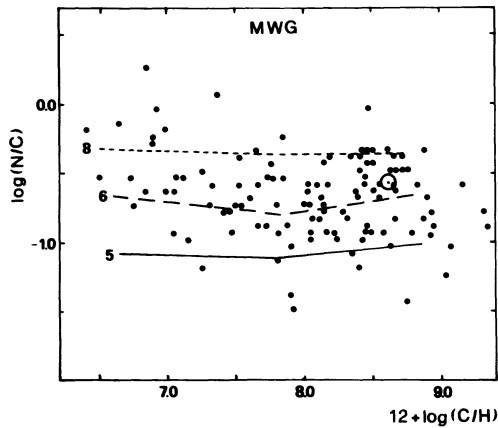


Fig.2. The Galaxy: Logarithmic N/C vs C/H distribution as derived from stellar observations in the solar neighbourhood (dots) and from a model with  $\tau = 15$  Gyr,  $F = 4 \cdot 10^{-3} M_{\odot} \text{kpc}^{-2} \text{yr}^{-1}$ ,  $\alpha_{RV} = 1.5$  and  $M_{up} = 5, 6$  and  $8 M_{\odot}$ , as labelled beside the corresponding lines.

2) The recent suggestion that the upper mass limit for intermediate mass stars is as low as  $5-6 M_{\odot}$  is confirmed.

3) The combination of this value of  $M_{up}$  and  $\alpha_{RV}=1.5$  reproduces not only the N/O vs O/H observed distribution but also the  $^{12}\text{C}/^{13}\text{C}$  ratios and the N/C vs C/H distribution observed in the solar neighbourhood.

It should be emphasized that these results on the values of  $M_{up}$  and  $\alpha_{RV}$  are independent of the chemical evolution models since they have also been obtained for the case of dwarf irregular galaxies whose evolution is completely different from that of the spirals we have presented here (Matteucci and Tosi 1985 and also this meeting).

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DISCUSSION

- P.G. WANNIER: I am quite curious, given the title of your talk, why you have restricted your attention to only the  $^{12}\text{C}/^{13}\text{C}$  isotope ratio. After all, all the CNO isotopes are coupled nucleosynthetically and quite accurate data exist for the isotopes  $^{15}\text{N}$ ,  $^{17}\text{O}$  and  $^{18}\text{O}$ .
- M. TOSI: In order to avoid any "ad hoc" assumption, we have restricted our analysis to the isotopes for which detailed nucleosynthesis computations were available in all mass ranges. Unfortunately, the production of  $^{15}\text{N}$ ,  $^{17}\text{O}$  and  $^{18}\text{O}$  in low and intermediate mass stars has not been computed in detail yet, and we wait for such models to be available to extend our analysis.