THEORETICAL PREDICTIONS FOR THE RADIAL DISTRIBUTION OF OXYGEN IN SPIRAL GALAXIES

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To the aim of reproducing the oxygen abundances and gradients observed in the disk of our Galaxy and four nearby spirals (M31, M33, M83, and M101), we have computed numerical models of galactic evolution assuming only two free parameters: the infall of gas from outside the disk and the law of star formation (e.g. proportional to some power of the gas density, decreasing with time, constant, etc.).

Input data required for our models are: a) the present total mass distribution observed in the disk; b) the present gas distribution observed in the disk; c) the stellar yields, i.e. the amount of heavy elements ejected by stars of any mass during and at the end of their lives; d) the initial mass function, IMF. The present oxygen abundances resulting from the models have been compared with those observed in the HII regions of each galaxy. Details concerning both the models and the references for the observed data are given by Diaz and Tosi (1983).

In Figure 1, the oxygen abundances observed in the disk of the Galaxy are compared with the results of different models. The dashed line in panel **a** shows that the combination of a star formation rate slowly decreasing with time ($\psi = \psi_0 \exp(-t/\tau)$, $\tau = 15$ Gyr) with a constant infall $F = 3\ 10^{-3}\ M_\odot\ \mathrm{kpc}^{-2}\ \mathrm{yr}^{-1}$ (the value derived by Oort (1970) from measurements of high velocity clouds) gives results in very good agreement with both the observed gradient and the absolute abundances. The same model also reproduces (Tosi 1982) the age-metallicity relation derived by Twarog (1980) in the solar neighbourhood and the metallicity gradients obtained by Mayor (1976) for old stars and by Panagia and Tosi (1981) for young stars and clusters. The dotted line represents a 'simple' model with constant star formation and no infall. Both models have been computed by assuming stellar yields derived from stellar evolution theory taking mass loss into account (Chiosi and Caimmi 1979, Renzini and Voli 1981). The other three panels of Fig.1 show the effect of varying the main model assumptions: in panel **b**, the same models of

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panel **a** are presented, but with stellar yields computed without mass loss (Arnett 1978). Panel **c** shows the effect on the F=3, τ =15 model of reducing the upper mass limit of the IMF. Since the oxygen is mainly produced by stars in the range 10-30 $M_\odot$, this effect becomes significant when the limit is lower than 30 $M_\odot$. The curves of panel **c** refer to a uniform IMF. By adopting an IMF varying with galactocentric distance the effect would be a steepening (flattening) of the gradient slope if we assume more (less) massive stars toward the center. Panel **d** presents the abundance distributions resulting from models with star formation proportional to the n^{th} power of the gas density and the same infall as in panel **a**.

It is apparent that the only choice of parameters leading to a good agreement between model results and observations is that of panel **a**. Furthermore, any other reasonable variation of the parameters would not recover the discrepancies between models and observations in panels **b**,**c**,**d**. For this reason, we present for the other galaxies only the same class of models as in Fig.1a, i.e. with exponentially decreasing star formation and constant infall.

For each galaxy of Figure 2, the upper dotted line represents a 'simple' model with constant mass yields, while in all the other cases mass loss has been taken into account. In particular, the lower dotted line is again a 'simple' model and the other curves represent the models

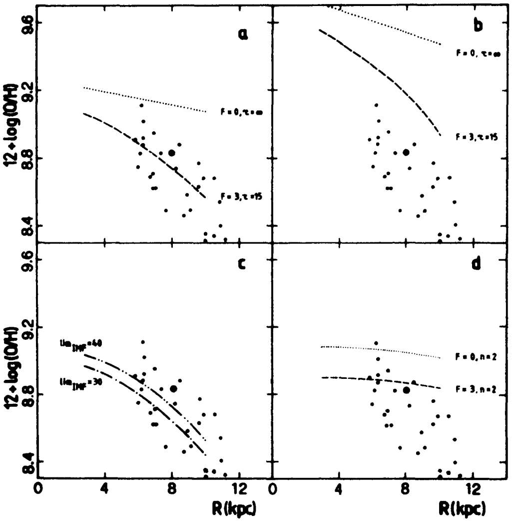

Fig.1. The Galaxy: Radial distribution of the oxygen abundances as derived from the indicated models. The infall rate F is in units of 10^{-3} $M_\odot\,kpc^{-2}\,yr^{-1}$ and the star formation e-folding time τ in Gyr. The dots represent the observed HII region abundances while the solar abundance is indicated by the usual sun symbol. See text for details on each panel.

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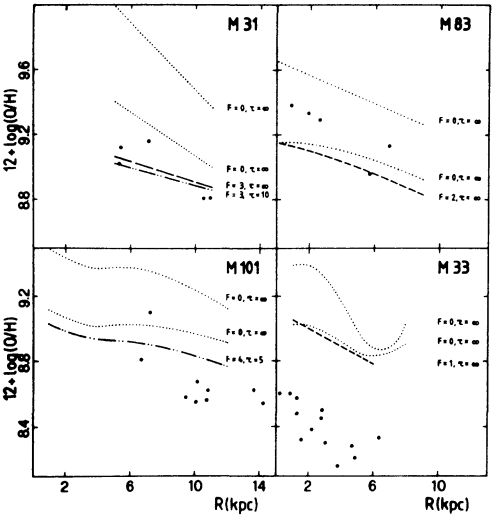

Fig.2. Radial distribution of the oxygen abundances in M31, M33, M83 and M101 as derived from the indicated models. Symbols are as in Fig.1.

in better agreement with the oxygen distribution observed in each galaxy (see Diaz and Tosi 1983 for details). The strong discrepancy apparent in M33 might be due to: a) the very high uncertainty on the gas and mass observational data, b) the fact that M33 is a sort of big dwarf galaxy which might evolve in a way completely different from that of normal spirals, c) an IMF with much less massive stars than here adopted, although there is no observational evidence for this latter case.

From Figures 1 and 2, we can derive the following main results:

i) the star formation rate is slowly decreasing with time in most of these spirals and is not simply proportional to some power of the gas density;

ii) the IMF is independent of time and galactocentric distance in all our spirals, having in both the Galaxy and M31 the same slopes as derived for the solar neighbourhood by Tinsley (1980), slightly more massive stars in M83 and slightly less in M101;

iii) the observed abundances and gradients are reproduced only by models taking mass loss into account.

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DISCUSSION

Humphreys: Your results on M33 are very surprising. Elly Berhuijsin has determined an IMF based on the Humphreys and Sandage (1980) catalogue which is consistent with the galactic IMF. Also in M101 the observations of its brightest stars show that there are many very massive stars in that galaxy.

Tosi: In fact, I think that the present discrepancy between our model results and the observed abundances in M33 is due much more likely either to the high uncertainty on the mass data or to a completely different galactic evolution than to a very steep IMF.

Audouze: By what factors the SFR decreases in your models?

Tosi: Our best model for the Galaxy (exponentially decreasing SFR with e-folding time τ = 15 Gyr) gives a ratio $\psi_o/\psi_{now} = 2.4$ for the initial over present SFR in the solar neighbourhood. This value is well within the range derived by many authors (e.g. Mayor and Martinet, Miller and Scalo, Twarog) from different observational constraints: $0 \leqslant \psi_o/\psi_{now} < 7$.

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