ABUNDANCE GRADIENTS IN THE OUTER GALACTIC DISK

W.J. MACIEL and C. QUIREZA
IAG/USP, São Paulo, Brazil

Abstract. Radial abundance gradients of the element ratios O/H, Ne/H, S/H, and Ar/H are determined for a sample of disk planetary nebulae, emphasizing the behaviour of the gradients at large galactocentric distances.

1. Introduction

The existence of radial abundance gradients is firmly established, both in the Galaxy and in other spirals. The gradients can be derived for several abundance ratios from photoionized nebulae (HII regions and planetary nebulae) and young stars (cf. Maciel, 1997). These gradients have some important consequences on chemical evolution models, particularly considering their *magnitudes*, *spatial* and *temporal* variations in the galactic disk.

Planetary nebulae (PN) play a distinct role in the solution of these problems. In the present work, gradients of the element ratios O/H, Ne/H, S/H, and Ar/H are determined for a sample of disk PN, emphasizing the behaviour of the gradients at large galactocentric distances.

2. The Data

The present investigation is based on a sample of disk PN generally classified as Type II objects. The basic sample is that of Maciel and Köppen (1994) and Maciel and Chiappini (1994), supplemented by some new objects with abundances derived by the IAG/USP group or from the recent literature. As a consequence, our new sample forms the largest database of galactic PN with reliable abundances and distances ever to be considered in order to estimate radial abundance gradients.

3. Results and Discussion

We have obtained plots of the O/H, Ne/H, S/H and Ar/H ratios as a function of the galactocentric distance R, and derived linear and second order fits to the data. The main conclusions by Maciel and Köppen (1994) are maintained, in the sense that

Astrophysics and Space Science is the original source of publication of this article. It is recommended that this article is cited as: *Astrophysics and Space Science* **265:** 269–270, 1999.

for $R \leq R_0 = 7.6$ kpc a radial gradient is obtained averaging $d\log(\mathrm{X/H})/dR \simeq -0.06$ dex kpc^{-1}, in excellent agreement with the well known O/H gradient of about -0.07 dex kpc^{-1} derived from HII regions. Moreover, the new results suggest some flattening for $R > R_0$, particularly for $R \geq 10$ kpc, in agreement with the recent results for HII regions by Vílchez and Esteban (1996).

Open cluster stars generally produce consistent results with HII regions, as also cepheids and supergiants. Data for Be stars are somewhat contradictory, but a recent work by Smartt and Rolleston (1997) suggests a similar gradient as seen in the HII region and PN data near R_0. For larger R, there may be no flattening for B stars, which could be explained by the temporal variations of the gradients suggested by Maciel and Köppen (1994).

Our results can be used to constrain some of the recent chemical evolution models of the Galaxy. Classical models (Chiappini *et al.*, 1997) predict flatter gradients than observed, but are consistent with the observed flattening at the outer Galaxy. The multiphase models (cf. Mollá *et al.*, 1997) predict some temporal flattening of the gradients, in contrast with the suggestion by Maciel and Köppen (1994). The predicted magnitudes of the gradients are similar, and even steeper than observed, but the models predict a steepening for large R, in contrast with the results of the present work. Probably the most promising theoretical models are the so-called chemodynamical models (cf. Samland *et al.*, 1997). Their predictions are in good agreement with the gradients from photoionized nebulae, both regarding the magnitude of the gradients and their space variations. Since the application of these models to galaxies like our own is still in its infancy, it is expected that more detailed models will be able to account also for the time behaviour of the abundance variations in the near future.

Acknowledgements

This work was partially supported by CNPq and FAPESP.

References

Chiappini, C., Matteucci, F. and Gratton, R.: 1997, *Astrophys. J.* **477**, 765.
Maciel, W.J.: 1997, in: H.J. Habing and H.J.G.L.M. Lamers (eds.), *IAU Symp. 180*, Kluwer, Dordrecht, p. 397.
Maciel, W.J. and Chiappini, C.: 1994, *Astrophys. Space Sci.* **219**, 231.
Maciel, W.J. and Köppen, J.: 1994, *Astron. Astrophys.* **282**, 436.
Mollá, M., Ferrini, F. and Díaz, A.I.: 1997, *Astrophys. J.* **475**, 519.
Samland, M., Hensler, G. and Theis, C.: 1997, *Astrophys. J.* **476**, 544.
Smartt, S.J. and Rolleston, W.R.J.: 1997, *Astrophys. J.* **481**, L47.
Vílchez, J.M. and Esteban, C.: 1996, *Mon. Not. R. Astron. Soc.* **280**, 720.