A&A 392, 501–503 (2002)
DOI: 10.1051/0004-6361:20021059

Astronomy & Astrophysics

Research Note

The ISO⋆ Galactic metallicity gradient revisited

U. Giveon[1], C. Morisset[2], and A. Sternberg[1]

[1] School of Physics and Astronomy and the Wise Observatory, The Beverly and Raymond Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv 69978, Israel
[2] Institut d'Astrophysique de Marseille, CNRS & Univ. de Provence, BP 8, 13376 Marseille Cedex 12, France

Received 7 May 2002 / Accepted 16 July 2002

Abstract. Two independent groups (Giveon et al. 2002; Martín-Hernández et al. 2002) have recently investigated the Galactic metallicty gradient as probed by ISO observations of mid-infrared emission-lines from HII regions. We show that the different gradients inferred by the two groups are due to differing source selection and differing extinction corrections. We show that both data sets in fact provide consistent results if identical assumptions are made in the analysis. We present a consistent set of gradients in which we account for extinction and variation in electron temperature across the Galactic disk.

Key words. Galaxy: abundances – ISM: HII regions

1. Introduction

In two recent studies Giveon et al. (2002) and Martín-Hernández et al. (2002) analyzed mid-infrared fine-structure emission lines, as observed by the *Infrared Space Observatory* (ISO), to study the excitation and metallicity of HII regions across the Galactic disk. Discrepancies appear to be present between the gradients published in these two papers. In this note we re-analyze the reduced data compiled by Giveon et al. and Martin-Hernandez et al. and we demonstrate that similar results are obtained if the same source samples are chosen, and no assumptions are made for the extinction correction. We then apply extinction and electron temperature corrections to both data sets and infer consistent Galactic abundance gradients from the two independent ISO studies.

2. The Galactic metallicity gradient

Giveon et al. (2002) presented a sample of 112 Galactic H II regions, observed by ISO-SWS, spanning galactocentric radii <18 kpc. Most of their sources show prominent [Ar II]6.99 μm, [Ar III]8.99 μm, [Ne II]12.8 μm, [Ne III]15.6 μm, [S III]18.7 μm and [S III]33.5 μm fine-structure lines and also the hydrogen recombination lines Brα and Brβat 4.05 and 2.60 μm. Only 48 sources have both argon or neon lines and a physical Brackett ratio. For case-B recombination, the Brα/Brβ ratio ranges from 1.7 to 1.9 for temperatures 5×10^3–2×10^4 K. Since extinction should only increase the ratio, five sources with Brackett ratios <1.68 were excluded from the analysis. The Brackett line ratios, an assumed gas temperature of 10^4 K, and the Draine (1989) mid-infrared extinction curve (see below) were used to de-redden the fine-structure lines intensities.

A similar analysis was performed by Martín-Hernández et al. (2002), who used the ISO-SWS & LWS spectral catalog of 34 compact H II regions (Peeters et al. 2002). The line intensities in their paper were not corrected for dust extinction due to the small number of sources for which the Brackett recombination lines were observed. However, corrections due to possible electron temperature variations across the disk were applied. In contrast, Giveon et al. did not apply such corrections to their data. Martín-Hernández et al. also published gradients of S/H and N/O. Here we discuss only the common results as analyzed by Martín-Hernández et al. Giveon et al., and show results for Ar/H, Ne/H, and S/H.

The results published in Giveon et al. and Martín-Hernández et al. are listed in the first row of each panel in Table 1. In this table we also list the argon, neon, and sulfur abundance gradients determined using a linear fit to the logarithmic abundances values, under various assumptions, that we discuss below. The gradients coefficients are given in the form $A \pm \Delta A$ and $B \pm \Delta B$, where

$$\left[\frac{X}{\mathrm{H}}\right] = A(\pm\Delta A) + B(\pm\Delta B)R_{\mathrm{gal}}(\mathrm{kpc}), \qquad (1)$$

where X is argon, neon or sulfur.

Send offprint requests to: A. Sternberg,
e-mail: amiel@wise.tau.ac.il

⋆ Based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, The Netherlands, and the UK) with the participation of ISAS and NASA.

Table 1. Galactic abundance gradients.

	NEON			
	Martín-Hernández Catalog		Giveon Catalog	
ASSUMPTIONS	$A \pm \Delta A$	$B \pm \Delta B$	$A \pm \Delta A$	$B \pm \Delta B$
1. Published (2002[1])	−3.49 ± 0.06	−0.039 ± 0.007	−3.71 ± 0.06	−0.021 ± 0.007
2. Sub-catalog, not corrected	−3.58 ± 0.09	−0.024 ± 0.011	−3.67 ± 0.08	−0.03 ± 0.01
3. Full catalog, not corrected	−3.49 ± 0.06	−0.036 ± 0.007	−3.61 ± 0.06	−0.019 ± 0.008
4. Full catalog, att. corrected	−3.58 ± 0.09	−0.028 ± 0.011	−3.66 ± 0.07	−0.017 ± 0.009
5. Full catalog, att. & temp. corrected	−3.48 ± 0.09	−0.044 ± 0.011	−3.55 ± 0.06	−0.035 ± 0.009
	ARGON			
	Martín-Hernández Catalog		Giveon Catalog	
ASSUMPTIONS	$A \pm \Delta A$	$B \pm \Delta B$	$A \pm \Delta A$	$B \pm \Delta B$
1. Published (2002[1])	−5.10 ± 0.09	−0.045 ± 0.011	−5.31 ± 0.06	−0.018 ± 0.008
2. Sub-catalog, not corrected	−5.17 ± 0.12	−0.036 ± 0.014	−5.23 ± 0.09	−0.05 ± 0.01
3. Full catalog, not corrected	−5.11 ± 0.07	−0.041 ± 0.009	−5.14 ± 0.06	−0.043 ± 0.009
4. Full catalog, att. corrected	−5.20 ± 0.09	−0.030 ± 0.012	−5.25 ± 0.06	−0.026 ± 0.008
5. Full catalog, att. & temp. corrected	−5.09 ± 0.09	−0.048 ± 0.012	−5.13 ± 0.06	−0.046 ± 0.009
	SULFUR			
	Martín-Hernández Catalog		Giveon Catalog	
ASSUMPTIONS	$A \pm \Delta A$	$B \pm \Delta B$	$A \pm \Delta A$	$B \pm \Delta B$
3. Full catalog, not corrected	−4.85 ± 0.15	−0.024 ± 0.017	−5.00 ± 0.15	−0.002 ± 0.02
4. Full catalog, att. corrected	−4.95 ± 0.15	−0.015 ± 0.020	−5.01 ± 0.15	−0.001 ± 0.02
5. Full catalog, att. & temp. corrected	−4.85 ± 0.15	−0.030 ± 0.020	−4.91 ± 0.15	−0.016 ± 0.02

Note 1. These rows show the results as originally published by Martín-Hernández et al. (2002) and Giveon et al. (2002).

If only the common sources for the two samples, and no extinction corrections are applied, the two data-sets give comparable metallicity gradients. There are 22 sources in Giveon et al. which are common with Martín-Hernández et al. We exclude the most distant source (WB89 380; IRAS 01045+6506) in the samples, since the assumed distance to this source differs between the two studies. For the 21 common sources we obtain the coefficients listed in the second row of Table 1. The results derived from the common sources are in reasonable agreement. The small discrepancies may be due to differing (<5%) inferred line fluxes in the independent data reduction and small differences (<10%) in the assumed galactocentric positions of the sources.

3. Combined extinction and temperature corrections

We now consider the gradients resulting from the full samples of Giveon et al. (2002) and Martín-Hernández et al. (2002), with corrections due to extinction and electron temperature dependence of the line emissivities.

We first take the entire samples and compute the abundance gradients with no corrections applied. An electron temperature of 10^4 K is assumed. The resulting gradients are given in the third row of Table 1. The upper limits were included in these fits. We show the total gradients for the uncorrected data in Fig. 1.

Next, we apply extinction corrections to the full catalogs. Both Giveon et al. (2002) and Martín-Hernández et al. (2002) employed the mid-infrared Draine (1989) extinction curve in their analysis. For short wavelengths ($\lambda \leq 7$ μm) both groups assumed $A_\lambda/E(J-K) = 2.4\lambda_{\mu\mathrm{m}}^{-1.75}$. However, for long wavelengths ($\lambda > 7$ μm) Giveon et al. adopted the Draine mid-IR extinction curve assuming a "strong" 9.7 μm silicate absorption normalization, $A_{9.7}/E(J-K) = 0.7$, whereas Martín-Hernández et al. assumed a "weak" normalization $A_{9.7}/E(J-K) = 0.3$. Here we adopt an intermediate value, $A_{9.7}/E(J-K) = 0.5$, for *both* catalogs. The associated values of A_λ/A_K for the various emission lines are listed in Table 2. The resulting gradients for the attenuation-corrected full catalogs are given in the fourth row of Table 1.

We note that the attenuation-corrected argon and sulfur gradients are much flatter than the uncorrected ones, while the neon gradients are only slightly affected. This is mainly due to the large extinction of [Ar III]8.99 μm and [S III]18.7 μm. These lines coincide with the silicate absorption features at 9.7 and 18 μm (Draine 1989).

Next, we apply an electron temperature correction to the data. The temperature correction accounts for possible variation in the H II region temperatures across the disk. Following Martín-Hernández et al. we assume that the electron temperature varies as

$$T_\mathrm{e} = 5000 + 5000 \times \frac{R_\mathrm{gal}(\mathrm{kpc})}{15}. \qquad (2)$$

Applying this correction to the full catalogs results in the gradient given in the fifth row of Table 1. We note that *both* the fine-structure lines and recombination lines are temperature dependent. From a fit to the computations provided by Storey & Hummer (1995), we find that the Brα recombination coefficient is proportional to $T_\mathrm{e}^{-1.2}$. The fine-structure line emissivities are proportional to $T_\mathrm{e}^{-0.5}$ (and to a temperature dependent exponential term). Thus, the abundances vary as $T_\mathrm{e}^{-0.7}$. Given our assumed galactic temperature profile (with temperaure increasing with radius) applying the temperature correction steepens

Table 2. A_λ/A_K line-extinction ratios.

Line	Br_β	Br_α	[ArII]	[ArIII]	[SIV]	[NeII]	[NeIII]	[SIII]
Wavelength(μm)	2.60	4.05	7.0	9.0	10.5	12.8	15.5	18.7
A_λ/A_K	0.72	0.33	0.13	0.64	0.70	0.28	0.22	0.32

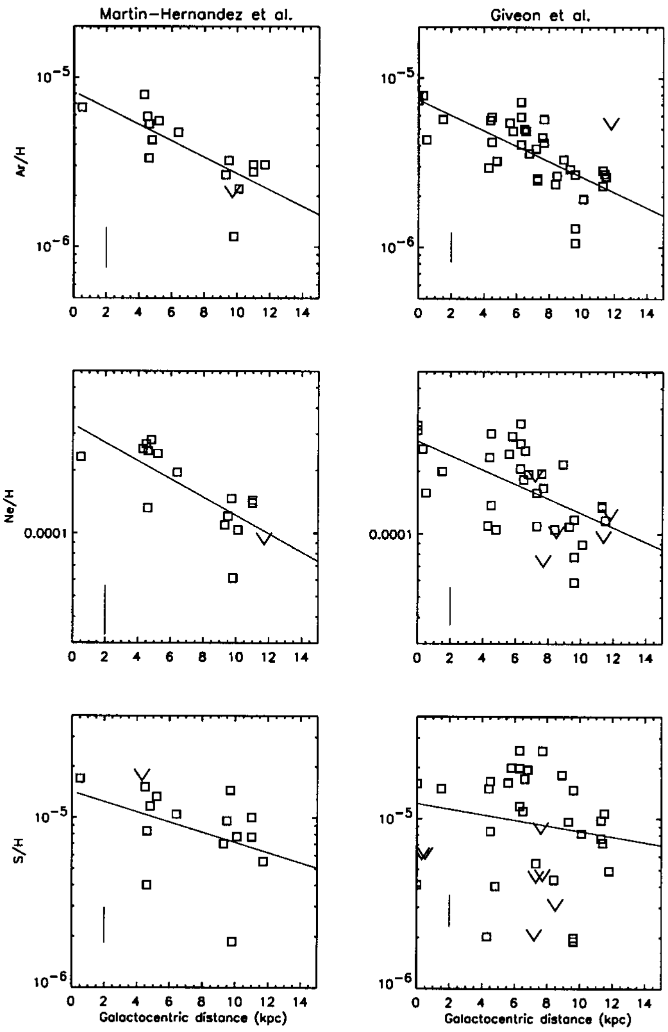

Fig. 1. Argon, neon, and sulfur abundances vs. galactocentric radius for the full catalogs of Martín-Hernández et al. and Giveon et al. (raw data). Solid lines are fits to the data, whose values are given in the third row of Table 1. In these plots no extinction or electron temperature corrections have been applied. The vertical lines are representative error bars.

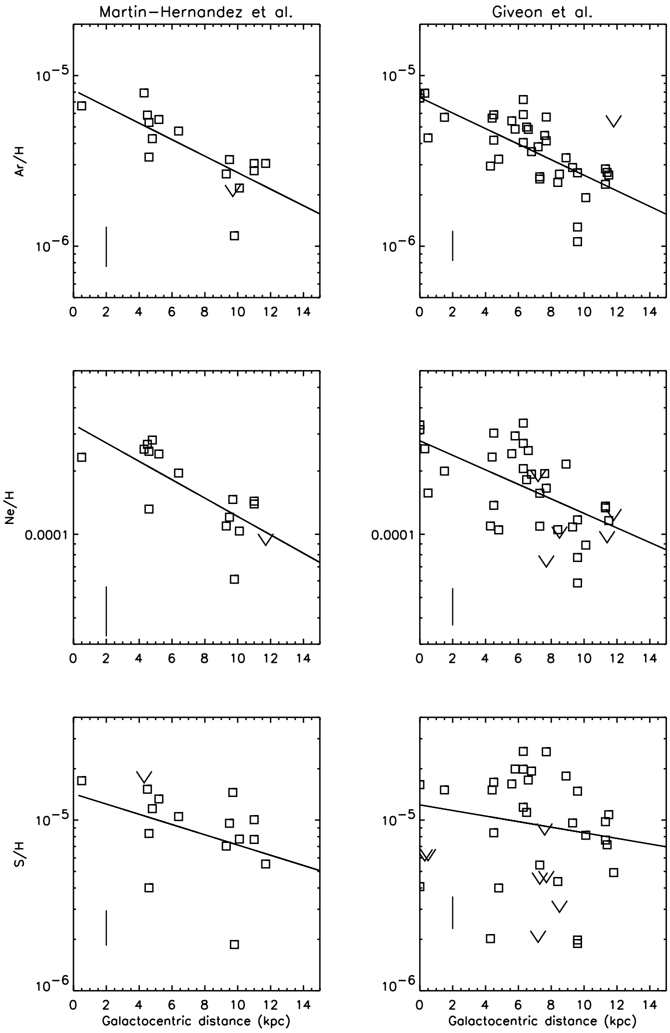

Fig. 2. Argon, neon, and sulfur abundances vs. galactocentric radius for the full catalogs of Martín-Hernández et al. and Giveon et al. attenuation and temperature corrected. Solid lines are fits to the data, whose values are given in the fifth row of Table 1.

the resulting abundance gradients. The attenuation and temperature corrected data and gradients of the full catalogs are shown in Fig. 2. The agreement between the two data sets is excellent.

We conclude that the Galactic metallicity gradients, as expressed by the argon, neon, and sulfur abundances gradients, of Giveon et al. (2002) and Martín-Hernández et al. (2002) are consistent within the error bars. This conclusion applies both to the raw data and the fully corrected data.

Acknowledgements. The ISO spectrometer data center at MPE is supported by DLR under grants 50 QI 8610 8 and 50 QI 9402 3. Our research is supported by the German-Israeli Foundation (grant I-0551-186.07/97). We thank the referee for useful comments.

References

Draine, B. T. 1989, ESA, Infrared Spectroscopy in Astronomy, 93 (SEE N90-19084 11-89)
Giveon, U., Sternberg, A., Lutz, D., Feuchtgruber, H., & Pauldrach, A. W. A. 2002, ApJ, 566, 880
Martín-Hernández, N. L., Peeters, E., Morisset, C., et al. 2002, A&A, 381, 606
Peeters, E., Martín-Hernández, N. L., Damour, F., et al. 2002, A&A, 381, 571
Storey, P. J., & Hummer, D. G. 1995, MNRAS, 272, 41