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IRON ABUNDANCE IN GALACTIC H II REGIONS

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RESUMEN

Algunos resultados recientes sugieren la existencia de una discrepancia entre la abundancia de Fe en M42 derivada a partir de los distintos iones del Fe, pero se argumenta que las incertidumbres son todavía demasiado altas como para decidir si la discrepancia es real. Se comentan los resultados de un reciente análisis de la abundancia de Fe en 7 regiones H II galácticas y se discuten las implicaciones que podrían tener para el polvo en regiones H II.

ABSTRACT

Some recent results point to a possible discrepancy between the Fe abundance in M42 as derived from the emission of the different Fe ions, but it is argued that the uncertainties are currently too high to decide whether the discrepancy is real. The results of a recent analysis of the Fe abundance in 7 Galactic H II regions are discussed as well as the implications they could have for dust in H II regions.

Key Words: **DUST, EXTINCTION — H II REGIONS — ISM: ABUNDANCES**

1. INTRODUCTION

1.1. *Fe Abundance and Dust*

Most of the Fe atoms in the interstellar medium are located in dust grains. For dense clouds, the abundance of Fe in the gas can be lower than 1/100 of the solar abundance (Jenkins 1987), whereas for Galactic H II regions the value seems to be higher by a factor of ten (Osterbrock, Tran, & Veilleux 1992; Peimbert, Torres-Peimbert, & Dufour 1993). Shock waves are known to be the main dust destruction agent in the interstellar medium, but the processes that could destroy dust in H II regions are expected to be very inefficient, and refractory dust grains—such as those containing Fe—are expected to survive within the ionized gas (Osterbrock 1989). Therefore, this difference in the depletion factors for H II regions and the dense interstellar medium is not readily explained.

1.2. *The Fe Ions*

In Galactic H II regions we can expect Fe to be in three ionization states: Fe^{+}, Fe^{++}, and Fe^{3+}. The Fe^{+} and Fe^{++} abundances can be determined from several optical [Fe II] and [Fe III] lines (although one should be careful with [Fe II] emission, since some optical lines are affected by fluorescence, Rodríguez 1999; Verner et al. 2000). The total Fe abundance in the gas can then be obtained by correcting for the contribution of Fe^{3+}. Following this procedure, Osterbrock et al. (1992) derived Fe/H = 1/12 $[\mathrm{Fe/H}]_{\odot}$ in M42, with more recent results, relying on updated atomic data, giving Fe/H = (1/40–1/18) $[\mathrm{FeH}]_{\odot}$ for several areas within the nebula (Rodríguez 2000). However, it has been suggested that by deriving the Fe abundance in M42 just from [Fe II] or [Fe IV] emission, and the corresponding ionization correction factors, much different abundances can be obtained: solar and 1/70–1/200 the solar value, respectively (Bautista & Pradhan 1995; Rubin et al. 1997). The value derived from [Fe II] cannot be considered as reliable, the main reason being that Fe^{+} has a low concentration in H II regions ($\sim$ 10% in M42), and the ionization correction factors predicted by models for ions with low concentration are highly unreliable: the errors can be as high as a factor of 10. As an example, a recent model for M42, which reproduces fairly well the measured [Fe II] intensities, leads to an Fe abundance similar to that implied by [Fe III] (Verner et al. 2000).

On the other hand, the low Fe abundance calculated from [Fe IV] relies on the only [Fe IV] line that has ever been measured in an H II region ([Fe IV] λ2837, in M42) and on two ionization models for this nebula. The discrepancy with the Fe abundance used in the models to reproduce the [Fe III] lines is at least a factor of 6.5. With the latest values for the atomic data, and considering that different positions in M42 can have different Fe abundances (Rodríguez 2000), the discrepancy can be reduced to (at least) a factor of 2. Further uncertainties related to the determination of the Fe abundance from this weak, UV line could further reduce the discrepancy, but more work will need to be done to find out if [Fe III] and [Fe IV] emission are truly compatible.

2. RECENT RESULTS

The most reliable way of determining Fe abundances in H II regions relies then mainly on [Fe III] emission and ionization correction factors. Such a determination has been done from the analysis of the Fe emission in the optical spectra of 7 bright Galactic H II regions: M42, M43, M8, M16, M17, M20 and NGC 7635 (Rodríguez 1996; 2000), leading to some suggestive results. The values found for the Fe^{++} and Fe^{+} abundances, along with ionization correction factors for the contribution of Fe^{3+}, obtained from available grids of photoionized models, imply that 2 to 30% of the solar Fe/O is present in the ionized gas. The Fe abundances derived for most areas are found to be correlated with the ionization degree given by O^{++}/O^{+}. The relative abundances of most areas are mainly determined by the values calculated for the Fe^{+} and Fe^{++} abundances, so that the correlation for these areas is not introduced by the ionization correction factor and hence must be real at least for the low ionization regions. Since the ratio O^{++}/O^{+} is proportional to the number of photons with energies above 35 eV, the correlation provides an explanation to most of the differences between the regions and for the difference with the ISM value, by relating these energetic photons to the release of Fe atoms from dust. In order to account for the expected low efficiency of dust-destroying processes in H II regions, it might be necessary to consider very small grains, which are more easy to destroy, maybe through sublimation during temperature fluctuations.

The Fe abundances are also found to be loosely anticorrelated with the color excess measured with the H I Balmer lines. To explain this relation, we can assume that most of the extinction in the studied H II regions is due to local and not interstellar dust, a fact that could be easily due to a selection effect, since the studied areas are the brightest of bright H II regions. However, the highest measured color excess of about 1 magnitude cannot be produced just by internal dust (Gómez Garrido & Münch 1984). Therefore, we have a relation between the number of Fe atoms in the gas, which presumably come from the destruction of dust originally mixed with the ionized gas, and the amount of extinction, mainly produced by external dust. This could be explained through the effects of radiation pressure or stellar winds on dust grains, but, again, the grains considered must be small enough (with sizes $a \lesssim 0.01\ \mu$m, see e.g., Cardelli & Clayton 1988), since big grains ($a \sim 0.1\ \mu$m) are strongly coupled with the gas (Osterbrock 1989).

A possible explanation for both correlations could then be the presence of a population of small grains in H II regions, probably originating from the fragmentation of larger grains. These small grains, containing up to 20% of the Fe abundance, would release Fe atoms into the gas after the absorption of energetic photons; the small grains surviving this destruction process would be swept out of the ionized region by the action of radiation pressure or stellar winds. An indication of a further and more efficient destruction agent is given by the high Fe abundance derived for a position sampling the optical jet H 399 in M20, where dust destruction due to shock waves has presumably taken place.

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