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He abundance in Planetary Nebulae

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Abstract. Type I planetary nebulae (PNe), defined as those with high He (and N) abundances, generally present bipolar geometries and high stellar temperatures. The main goal of this paper is to check if the empirically derived He overabundance for Type I PNs is real, or if it is a consequence of geometrical effects due to the bipolarity and/or to the ionization stratification due to the high stellar temperature of these objects.

1. Introduction

The determination of the chemical abundance in PNe provides information on the products of stellar evolution, as well as on the enrichment of the interstellar medium, establishing constraints for stellar evolutionary models as well as for the study of the chemical evolution of galaxies. Chemical abundances in PNe are usually obtained using empirical methods (as for example in Peimbert & Torres-Peimbert 1987). Photoionization models also provide the gas chemical composition when applied to specific nebulae (for example, Harrington et al. 1982; Gruenwald, Viegas & Broguière 1997). Empirical methods, using a few bright emission-lines, are commonly used since they can easily be applied to a great number of objects. Following their abundance, PN are classified in types (Peimbert 1978; Peimbert & Torres-Peimbert 1983). In particular, Type I PNe are those with high He and N abundances, e.g. $He/H \geq 0.125$ and $\log(N/O) > -0.30$. In a study of morphological and physical properties of PNe, Corradi & Schwarz (1995) stated that bipolar nebulae have the hottest stars among PNe, and, except for two objects, all bipolar PNe for which chemical data are available are Type I. Therefore, objects with high He and N abundances have bipolar morphologies and high stellar temperatures. However, new evolutionary models fail to explain the high abundance of He and N in Type I PNe (van den Hoek & Groenewegen 1997). In this paper we analyze the effect of the geometry and of the stellar temperature on the empirical abundance determinations, in order to verify if the high abundances of He obtained for Type I PNe are real. For this, we apply our self-consistent 3D photoionization code (Gruenwald et al. 1997) to simulate planetary nebulae.

2. Method and results

For a wide range of nebular and stellar characteristics, we obtain the physical conditions in each point of the nebula, and calculate the resulting line intensity

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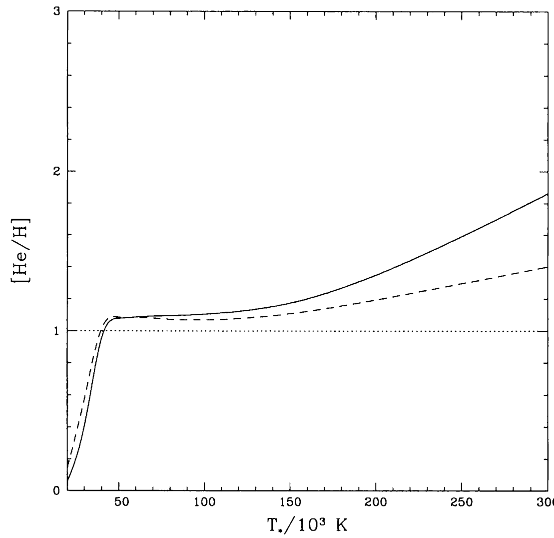

Figure 1. Fig. 1 - Ratio between the empirical and the adopted values for He/H versus the stellar temperature. The curves correspond to a nebula with uniform density (n_H = 100 cm^{-3}, L_* = 3000$L_\odot$). The solid line represents the results obtained from line intensities corresponding to the whole nebula, while the dashed line corresponds to the results from a narrow slit crossing the nebula through its center.

ratios at different lines of sight to the nebula. From the calculated line intensity ratios we derive the abundances applying the empirical methods used in the literature. These abundances are then compared to those assumed in the models. The effect of the central stellar temperature can be seen in Figure 1. For low stellar temperatures ($T_* < 5\ 10^4$ K), the empirical He/H abundance ratio is lower than the real value, while for higher T_* ($> 10^5$ K) the opposite is true. This is due to the fact that the ionic distribution inside the nebula depends on T_*; for example, for low stellar temperatures the He^{++} zone is much smaller than the H^+ zone; for increasingly temperatures the He^{++} zone is relatively larger. A further consequence is that the obtained abundance depends also on the size and position of the slit used for the observation. In order to check for a geometrical effect, models for bipolar nebulae were also obtained, assuming a spherically symmetrical cloud with an equatorial torus of denser gas close to the ionizing star. Our results show that the abundance obtained from empirical methods can mimic an overabundance and/or the presence of abundance gradients of He in planetary nebulae with high stellar temperature. Geometrical effects strengthen this problem.

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