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Stellar Winds from Central Stars of Planetary Nebulae: Metallicity Effects

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Abstract. Radiative wind theory applied to hot stars and central stars of planetary nebulae (CSPN) predicts a dependence of observed wind properties, such as the modified wind momentum, and basic stellar parameters, such as the stellar luminosity. Also, some dependence of this quantity is expected on the stellar metallicity, in view of the fact that the driving mechanism of the wind involves absorption lines of heavy elements. On the other hand, the mass-luminosity relation as applied to these stars shows some discrepancies when derived from either recent improved model atmospheres or evolutionary tracks for post-AGB stars. In this work, we analyze the metallicity effects on the modified wind momentum for CSPN by considering the expected dispersion in this quantity caused by the metallicity range of the CSPN. Also, the mass-luminosity relation of these stars is investigated on the basis of a recently proposed relation between the core mass of planetary nebulae and the observed nebular abundances. The IAG/USP database on chemical abundances is used as well as observed wind characteristics of the central stars.

1. Introduction

Stellar winds are observed in central stars of planetary nebulae (CSPN), both for H-rich stars and for stars with Wolf-Rayet characteristics. The origin of the winds of these stars is attributed to radiation pressure on heavy metal lines, a similar mechanism known to be active in hot, massive stars. The correlation between the modified wind momentum p_w and the stellar luminosity $\log(L/L_\odot)$, which is well defined for massive stars, is also approximately valid for CSPN. However, several problems remain, such as the relatively large spread in the modified wind momentum at a given luminosity for CSPN, and the discrepancy between the derived masses for many of these objects and the masses expected from stellar evolution models for AGB stars (Pauldrach, Hoffmann, & Méndez 2004, Kudritzki et al. 1997). In this work, we analyze both problems taking into account the observed chemical composition of the nebulae associated with the central stars, and investigate the effect of metallicity on the correlations involving the stellar mass and the modified wind momentum.

2. Winds from CSPN: Metallicity Effects

The mass of the central star is a key parameter, which is usually derived from model atmospheres using standard techniques. An alternative approach, as suggested by , assumes a relationship between the central star mass and the nebular N/O abundance ratio. Such a relation is expected from theoretical evolution models of AGB stars, and has been successfully applied to planetary nebulae in order to study the time variation of the radial abundance gradients by Maciel, Costa, & Uchida (2003). Since the chemical composition of most CSPN with observed winds is relatively well known, we have an independent determination of the stellar mass.

The metallicity effect on the modified wind momentum can be estimated by assuming that the average relationship between the modified wind momentum and the stellar luminosity as derived for example by Pauldrach et al. (2004) corresponds the the average oxygen abundance of the planetary nebulae, which is about $\log(\mathrm{O/H}) + 12 \simeq 8.5$. Therefore, the expected relationship between these quantities can be readily estimated for a given chemical composition, in particular for the largest and lowest oxygen abundances observed in galactic planetary nebulae, which are $\log(\mathrm{O/H}) + 12 \simeq 9.2$ and $\log(\mathrm{O/H}) + 12 \simeq 7.5$, respectively. For a discussion on the abundances of galactic planetary nebulae the reader is referred to Maciel (2000b), Costa, Uchida, & Maciel (2004) and references therein. For simplicity, we have assumed that the modified wind momentum is proportional to the stellar metallicity Z, which is itself proportional to the oxygen abundance.

3. Results and Discussion

We have applied this method to all CSPN studied by Pauldrach et al. (2004) and Kudritzki et al. (1997), and have also extended the calculations to the objects analyzed by Perinotto (1993). As a result, (i) we confirmed the mass-luminosity relation as predicted by theoretical models of AGB stars, in the sense that almost all CSPN masses are under 0.8 $M_\odot$, in agreement with the white dwarf mass distribution of Madej, Nalezyty, & Althaus (2004) and in disagreement with some large masses obtained by Pauldrach et al. (2004). Also, (ii) the observed dispersion in the $\log p_w \times \log(L/L_\odot)$ plane is even larger than obtained by Pauldrach et al. (2004) and Kudritzki et al. (1997), and can be explained by the expected dispersion of the CSPN (and nebular) metallicities, that is, the scatter of the CSPN data on this plane is probably real, and can be attributed to the observed metallicity spread of the nebulae.

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