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BROAD Hα WINGS IN YOUNG PLANETARY NEBULAE

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RESUMEN

De una muestra de 30 nebulosas planetarias jóvenes, proto-NPs y otros objetos con líneas de emisión hemos encontrado 11 NPs jóvenes y dos estrellas simbióticas que muestran la línea de emisión Hα extremadamente ancha (desde 800 km s^{-1} hasta 5100 km s^{-1}). En 7 objetos estas líneas anchas se reportan por primera vez.

ABSTRACT

In a sample of 30 young planetary nebulae, proto-PNe and other emission line objects we have found 11 young PNe and 2 symbiotic stars that show very broad wings of the emission Hα line (from 800 km s^{-1} and up to 5100 km s^{-1}). For 7 objects it is the first time that these wide lines are reported.

Key Words: **CIRCUMSTELLAR MATTER — LINE: PROFILES — BINARIES: SYMBIOTIC — PLANETARY NEBULAE: GENERAL — STARS: AGB AND POST-AGB**

1. INTRODUCTION

Very wide Hα emission lines have been reported previously in other objects in the early stages of planetary nebulae phase; these include seven post-AGB, five young PNe and one symbiotic star (Van de Steene et al. 2000; Lee & Hyung 2000; Miranda et al. 1997; Balick 1989; López & Meaburn 1983; Wallerstein 1978). However, at present no satisfactory explanation has been given to the widening mechanism that gives rise to such extended wings.

The observations were carried out at the Observatorio Astronómico Nacional in San Pedro Mártir, Baja California with the 2.1-m telescope and the REOSC echelle spectrograph ($R \sim 18,000$ at 5000 Å) and a 1024×1024 Tektronix detector that yielded a spectral resolution of 10.6 km s^{-1}. For extended objects the slit was centered on the nucleus.

The full extent of the broadening can only be appreciated only in those objects with strong emission lines and faint stellar continuum. Furthermore, we have only included those cases significantly broadened above the instrumental effects.

2. POSSIBLE FORMATION MECHANISMS

2.1. *Circumstellar Disks*

Rotating disks cannot explain the wing extent; for stars of $\leq 1 M_{\odot}$ (like PNe central stars) the sizes of the disks would be smaller than the stellar radius.

2.2. *Electron Scattering*

This mechanism has been proposed, and has been intensely studied, as the line widening mechanism in QSOs (e.g., Mathis 1970; Shields & McKee 1981; Lee 1999) and in WRs (e.g., Hillier 1991).

Given that the cross section of electron scattering is independent of wavelength it is to be expected that other emission lines formed in the same region as the hydrogen lines are also widened. The objects do not show a wide component in [O III], this fact requires three different regions to be present:

1. An ionized dense region where the bulk of Hα is produced;
2. A high-temperature region where scattering takes place;
3. A lower-density region where the forbidden lines are produced.

Ionized regions of different density, $n_{\rm e} \sim 10^5$ and $n_{\rm e} \sim 10^7$ cm^{-3} at $T_{\rm e} \sim 10^4$ K, have been reported for M 2-9 for the regions where the recombination and collisionally excited lines are produced (Torres-Peimbert & Arrieta 1998). However, no additional evidence is found for a high-temperature intervening scattering region.

2.3. *Stellar Winds*

The possibility that the wings are formed in the region dominated by stellar winds has been proposed. To test this hypothesis we have examined the existing *IUE* spectra for each object looking for evidence of P Cyg profiles in the lines of C IV, C III, He II, Al III, Mg II, and Si IV. One object (IRAS 20463+3416) shows evidence of P Cyg profiles both in our optical spectra and in the UV, with a terminal velocity in the resonant lines of ~ 2000 km s^{-1}. Another object (M 1-92) shows a blueward absorption at ~ 700 km s^{-1}. Both features are evidence of mass loss in these objects.

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2.4. *Rayleigh-Raman Scattering*

This process has been suggested as the mechanism to widen Hα in IC 4997 by Lee & Hyung (2000). They propose that hydrogen Lyβ photons with a velocity width of a few hundred km s^{-1} are converted to optical photons and fill the Hα broad wing region.

For this they require an inner compact core of high density, $n_{\rm e} \sim 10^9$–10^{10} cm^{-3}, and a scattering region with H I column density, $N_{\rm H} \sim 10^{20}$ cm^{-2}, with a substantial covering factor. These conditions could correspond to those prevailing in symbiotic stars and bipolar planetary nebulae.

In M 2-9 we find evidence of a very high density compact core $n_{\rm e} \sim 10^6$–10^8 cm^{-3} (Arrieta, Torres-Peimbert & Bautista 2000) and there is evidence of a torus of molecular material. This mechanism could indeed be responsible for Hα broadening.

3. CONCLUSIONS

It is possible that Raman scattering is the mechanism responsible for the line broadening. Indeed, most of the objects with broad lines seem to have common characteristics: bipolar morphology, composite emission line profiles, compact objects in the process of forming a planetary nebulae. Very probably they are sites of wind interaction. This process should be analyzed further.

IRAS 20463+3416 and M 1-92 show evidence of mass loss.

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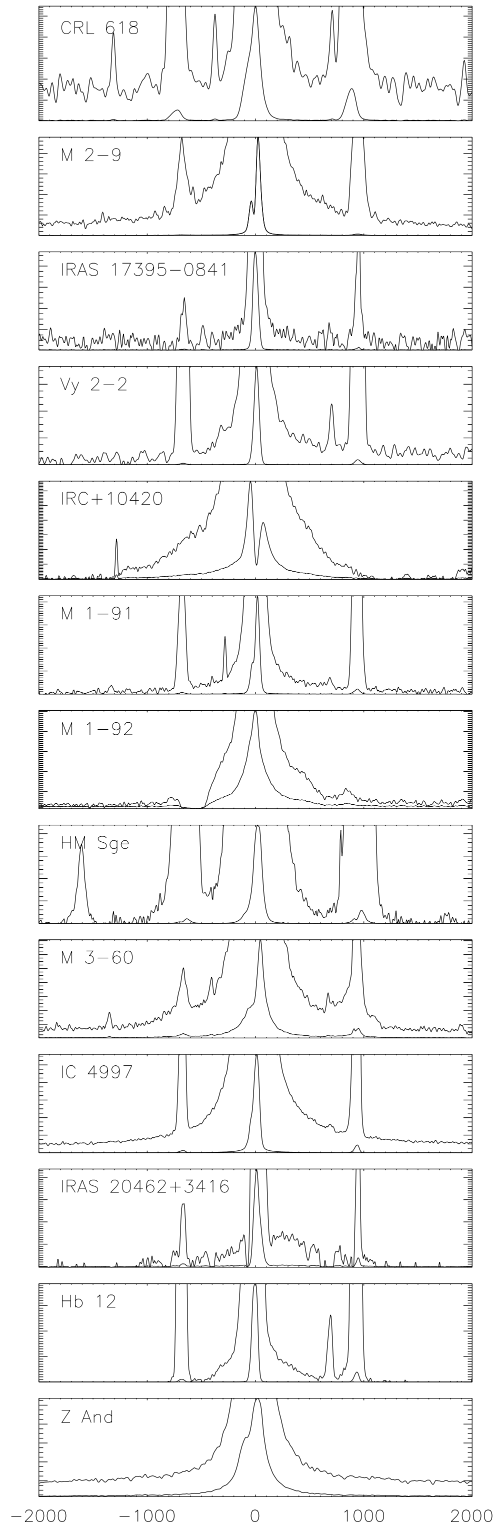

Fig. 1. Spectra centered at Hα. The abscissa is radial velocity in km s^{-1}. In each frame, a vertical enlargement has been included to display better the Hα wings.