

PLANETARY NEBULAE WITH [WR] NUCLEI

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RESUMEN

Se presentan los primeros resultados de un extenso programa donde se pretende analizar y correlacionar las características nebulares y estelares de nebulosas planetarias con estrella central de tipo [WR]. El análisis se basa en datos espectrofotométricos de alta resolución espectral y espacial.

ABSTRACT

The first results on an extensive program for analyzing the nebular and stellar characteristics of planetary nebulae ionized by a [WR] central star are presented. Spatially resolved spectrophotometric data are used for the analysis.

Key Words: **ISM: ABUNDANCES — PLANETARY NEBULAE: GENERAL — STARS: WOLF-RAYET**

1. INTRODUCTION

We have started an extensive program of systematic observations of planetary nebulae excited by [WR] nuclei with the aim of understanding the evolutionary status of the central stars. Detailed analysis of the nebular and stellar properties might reveal the presence of abundance variations across the nebulae, and allows to detect possible interactions between the massive stellar wind and the nebula.

Such an analysis requires spatially resolved spectra, together with a reliable procedure to derive chemical abundances. This is best achieved by constructing individual photoionization models that reproduce the main observed properties. Ionizing fluxes predicted by *ad hoc* models of expanding atmospheres are being used. Such models have been computed for a number of [WR] central stars (Koesterke & Hamann 1997; Peña et al. 1997).

Long-slit and echelle spectrophotometric data for a wide sample of planetary nebulae with [WR] nuclei have been obtained at CTIO and the Observatorio Astronómico Nacional, San Pedro Mártir, B.C., México. Different knots have been observed in each nebula for which we derive physical conditions and chemical compositions searching for abundance gradients along the nebulae.

2. FIRST RESULTS

The spectroscopic analysis made for different knots of the planetary nebulae PB 6, NGC 2452, NGC 2867, NGC 6905 and He 2-55 was reported in Peña et al. (1998). All these nebulae are ionized by a [WC 2–3] star and present a very high ionization degree. For each object, an expanding model atmosphere, taking into account the extreme non-LTE situation and the velocity field, was built to fit the observed stellar features (Koesterke & Hamann 1997). The spectral distributions predicted by these models were then used to compute photoionization models which were required to reproduce the observed intensity ratios of important lines of different ionization stages, and to be roughly consistent with the observed $H\beta$ flux, angular diameter and morphology of the nebulae.

The photoionization models were rather succesful in reproducing the ionization structure and the electron temperature of the nebulae, using model atmospheres that were close ($\pm 20,000$ K) to the best fit for reproducing

TABLE 1
PHOTOIONIZATION MODELS AND TOTAL ABUNDANCES

	PB 6	NGC 2452	NGC 2867	NGC 6905	He 2-55
$T_*, R_t^{(1)}$	158, 3.98	158, 3.98	128, 5.20	128, 5.20	128, 5.20
He/H	0.176±0.008	0.127±0.006	0.112±0.006	0.108±0.007	0.130±0.010
O/H (10^{-4})	3.2±0.5	4.2±0.6	4.3±0.6	3.7±0.7	3.4±0.5
N/O	1.3±0.2	0.6±0.1	0.27±0.05	0.37±0.07	0.35±0.06
C/O ⁽²⁾	2.6±1.1	1.1±0.5	3.1±1.3	0.9±0.4	1.3±0.5
C/O ⁽³⁾	7.3±1.8	3.9±1.6	4.2±1.1	...	5.5±1.4
Ne/O	0.25±0.04	0.21±0.03	0.19±0.03	0.23±0.04	0.23±0.03
S/O	0.04±0.02	0.04±0.02	0.03±0.02	0.08±0.04	0.04±0.02
Ar/O	0.012±0.006	0.013±0.007	0.004±0.002	0.03±0.01	0.013±0.007

⁽¹⁾ Stellar temperature (kK) and transformed radius (R_\odot) of model atmospheres used.

⁽²⁾ From the C III 1909 / O III 5007 ratio.

⁽³⁾ From the C II 4267 / O III 5007 ratio.

the stellar features. For some objects, only two-density models with an inner zone of lower density can fit the observational constraints. These density structures are consistent with the nebular morphologies.

Some interesting problems raised by the models are: (a) for PB 6 and NGC 6905, we found that the model atmospheres used could be lacking *UV* photons with respect to their emission in the *V* band, (b) for PB 6 and NGC 2867, the C/O ratios derived from the C III 1909 / O III 5007 line ratios observed induce computed electron temperatures significantly lower than observed. That is to say, the photoionization models predict a lower C/O ratio. The problem becomes worse if the C II 4267 / O III 5007 ratios are used (see Table 1).

Chemical abundances in the different knots of the nebulae were computed from the ionic abundances derived from the observations and the ionization correction factors obtained from the models. The results, for the central zone of each nebula, are presented in Table 1. We found that, while the five nebulae are excited by [WC 2–3] stars with very similar stellar temperatures, mass loss rates and chemical compositions, the chemical patterns of the nebulae are different: PB 6 and NGC 2452 (the most highly excited objects in the sample) are He-, N-, and C-rich, indicating massive progenitors ($M_{\text{initial}} \geq 2.8M_\odot$). In particular, the high He and N abundances in PB 6 indicate a scenario of freshly made C, being brought to the surface by the third dredge-up event and partially converted into N through envelope-burning. On the other side, NGC 2867, NGC 6905 and He 2-55 only show C enrichment and they seem to be typical Type II PNe. Therefore their progenitors were not massive, but all underwent the third dredge-up.

Thus, clearly, post-AGB stars of quite different initial masses can pass through a [WC] stage with similar atmospheric parameters. No evidence for abundance variations (or mixing of stellar wind and nebular material) inside any of the nebulae was found. We are presently studying the properties of a number of PNe with intermediate and late [WC] central stars. Imaging and high resolution spectroscopy of about 30 objects have been obtained to study the morphology, the kinematics and the abundances in the nebulae. Possible correlations between the nebular parameters and the properties of the central stars are being analyzed.

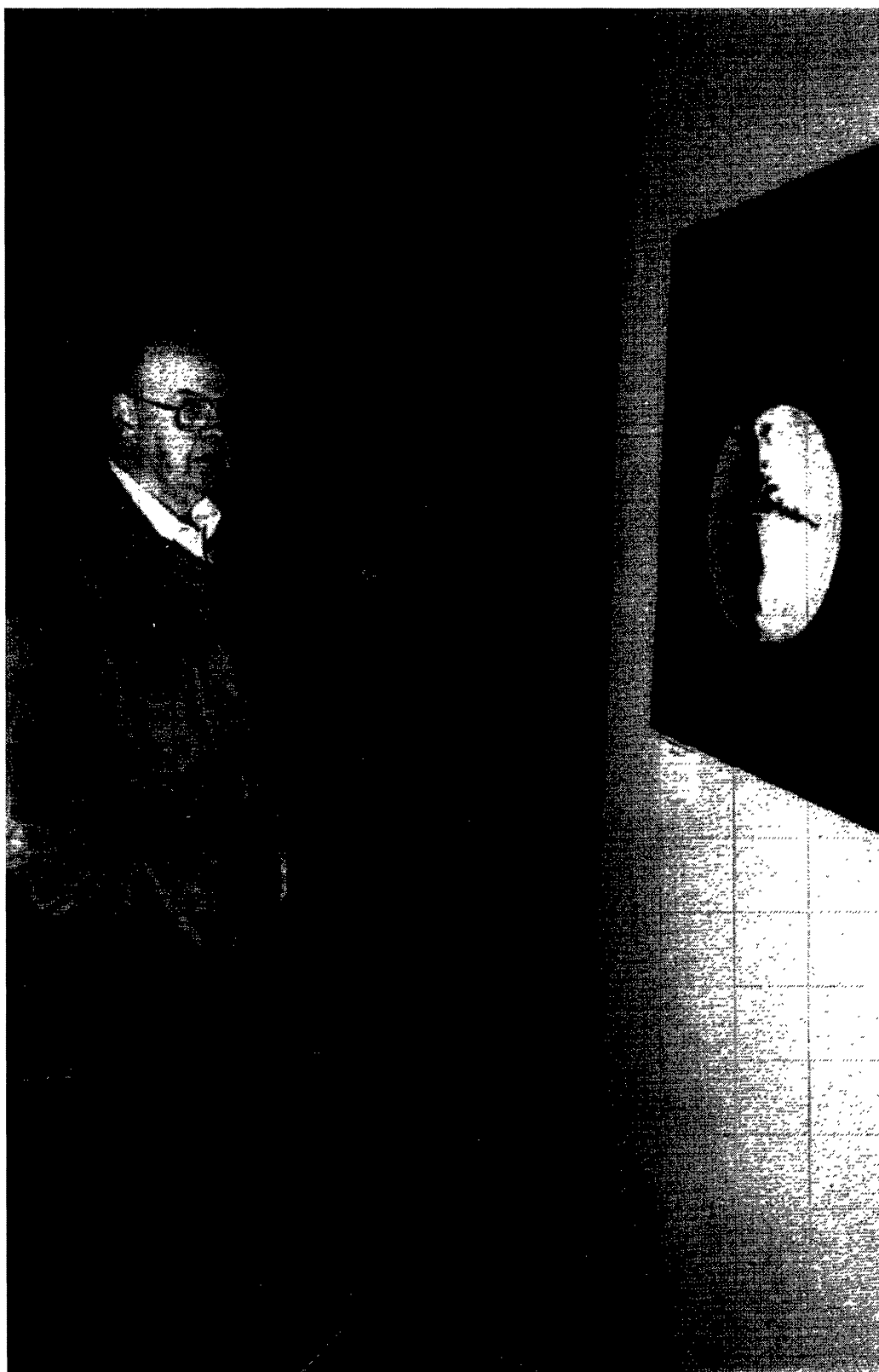
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Focal Point 3b:

Star Formation



Guido Münch at the exhibition “Oteando el Universo”