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PHYSICAL PROPERTIES OF PLANETARY NEBULAE AROUND [WC] CENTRAL STARS

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We have analyzed high resolution spectra for a sample of 34 galactic planetary nebulae with [WC]-type central stars. The sample includes objects in a wide range of stellar characteristics: early and late [WC] stars, weak-emission line stars (WELS) and some normal (non-WR) PNe. Physical conditions in the nebulae have been obtained from various diagnostic line ratios, and chemical abundances have been derived. Expansion velocities were estimated in a consistent manner from the line profiles of different ions for the sample. A statistical study was developed for the data in order to find fundamental relationships casting some light on the evolutionary status of WRPNe.

Observations were performed with the *echelle* spectrograph attached to the 2.1-m telescope at the Observatorio Astronómico Nacional, México. The 3500-7200 Å wavelength range, at 0.2 Å resolution was covered, allowing us to measure most of the important nebular lines for plasma diagnostic and kinematics. Data were reduced using standard IRAF procedures.

The analysis of our data has been partially presented in Peña et al. (2001). We have found the following results:

• A significant trend of the electron temperature ratio T_e[O III] / T_e[N II] decreasing with increasing excitation of the object, as measured by the O^{++}/O^{+} ratio, is found for WRPNe. At the high excitation end, T_e[N II] is larger than T_e[O III] by several thousands degrees. This is not expected from simple photoionization models of PNe, and might indicate the presence of additional heating mechanisms in the outer zones (shocks or turbulence for example). Future observations of a larger control sample of non-WRPNe will enable us to show whether such a behavior is also seen in these nebulae, giving some clues as to whether this additional heating mechanism can be due to the effect of the intense stellar winds from the [WC] central stars.

• Abundance ratios of O/H, Ne/O and N/O are normal for WRPNe and WELS and similar to non-WR disk PNe. In particular, we found a large dispersion in the N/O ratios for WRPNe indicating that there is no preferential stellar mass for the WR phenomenon to occur in the nucleus of a PN, confirming the finding by Górny & Stasińska (1995).

• We re-examined the relation between the nebular properties of WRPNe and the spectral types of the nuclei. Our data confirm the trend found by other authors, of the electron density decreasing with decreasing spectral type, which was interpreted as evidence that [WC] stars evolve from late to early [WC] types. However, the PNe K 2-16 and PM 1-188, with very late [WC] stars, do not follow the general density sequence, being of very low density for their spectral types. We suggest that their stars either underwent a late helium flash (the "born again" scenario) or that they have had a particularly slow evolution from the AGB, either due to their unusually small core mass or to an exceptionally long transition time from the tip of the AGB.

• The kinematical analysis shows that the [WC] stellar wind strongly affects the velocity field of the PN. Large expansion velocities and evidence of turbulence are found in WRPNe, in contrast with nebulae around WELS and non-WR central stars which present lower expansion velocities and no evidence of turbulence. In any case, it is found that expansion velocities are larger for old evolved PNe (less dense and with a hot central star) than for young PNe, which are denser and have cooler nuclei. This is such for PNe around [WC] stars, WELS and normal central stars.

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