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HUDO 1 AND HUBI 1: TWO PLANETARY NEBULAE IONIZED BY COOL [WC] CENTRAL STARS

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As part of our spectroscopic survey of planetary nebulae with [WC] nuclei (Peña et al. 2001), low- and high-resolution spectra of the planetary nebulae HuDo 1 (PN G 060.4+01.5, PM1-310) and HuBi 1 (PN G 012.2+04.9, PM1-188) were secured and analyzed. Both objects are ionized by very late [WC] central stars. We found that the objects belong to the galactic disk, with heliocentric radial velocities of -12 km s^{-1} (HuDo 1) and 57 km s^{-1} (HuBi 1). Both objects are heavily extinguished showing a logarithmic reddening, c(Hβ), of 2.04 for HuDo 1 and 1.22 for HuBi 1. Our data cover a wide wavelength range; therefore we obtained several plasma line ratios to estimate physical conditions and abundances. The derived electron temperature and density for HuBi 1 are 9,400$\pm$1,500 K and 800 cm^{-3}. This density is very low for a nebula around a [WC]-late star. HuDo 1 has N_e = 3300 cm^{-3}. We find log(O/H)+12 = 8.43 and 8.57, and N/O = 0.2 and 0.1 for HuDo 1 and HuBi 1 respectively, typical of disk PNe. Intense nebular He I recombination lines are detected for HuBi 1, this being the only PN excited by a very late [WC] star showing such an emission. The He$^+$ abundance derived for HuBi 1 is 0.11, which is indicating a large He enhancement in HuBi 1.

From the analysis of the stellar emission lines a [WC 10] spectral type is derived for both stars. This is consistent with a stellar temperature of about 30,000 K, although the HuBi 1 central star should be slightly hotter for providing the large amount of He^0 ionizing photons required to explain the nebular He I lines. Nebular and stellar parameters of HuDo 1 and HuBi 1 can be compared with those of other [WC 10] objects, such as M 4-18, He 2-113 and CPD$-56^0$8031. From this, we can conclude that, in spite of the fact that all the objects have the same spectral type, the central stars of HuDo 1 and HuBi 1 should be intrinsically fainter, and consequently of lower mass. This is an additional evidence showing that stars of different masses can go through the same WR stage.

The analysis of the the results reported above can be found in Peña (2005). In this work we want to discuss in more detail two interesting aspects of HuBi 1: its spatial structure as derived from our long slit spectra, and the possibility that its central star is variable. HuBi 1 is an interesting case study because it shows particularly intriguing aspects. Together with K 2-16 (PN G 352.9+11.4), these are the only objects ionized by very cool [WC] stars presenting an extended low-density nebula (Peña et al. 2001); and it has been suggested that such objects could be "born-again" planetary nebulae, but Peña et al. (2001) consider that they are PNe ionized by low-mass stars evolving slowly.

From Hα imaging Pollaco & Hill (1994) found that HuBi 1 consists of a faint extended nebula of 18″ in diameter surrounding a dense bright central zone, with apparently bipolar structure. On the other hand, K 2-16 consists of an extended shell like structure, with a diameter of 13.5″ (Acker et al. 1992). Peña et al. (2001) measured an electron density of 500 cm^{-3} for this object. All the other known PNe around late [WC] stars (including HuDo 1) are dense and compact, as it is expected for young PNe.

Figure 1 shows the spatial structures of Hα and [N II]λ6583 (left), [O III]$\lambda\lambda$5007 and 4959 (middle) and Hβ (right) emission lines in HuBi 1, as obtained from our low resolution spectrum secured on June, 2002. Hα and Hβ are extended showing two maxima at about 2″ at each side of the central star. This distribution coincides well with the bipolar structure along the E-W direction reported by Pollaco & Hill (1994). On the other hand the [N II] and [O III] lines appear concentrated and do not show the bipolar structure. Other lines showing bipolar structure are the He I ones. Our high resolution spectra show the same bipolar structure for the H and He lines and compact structure for the heavy-element lines, con-

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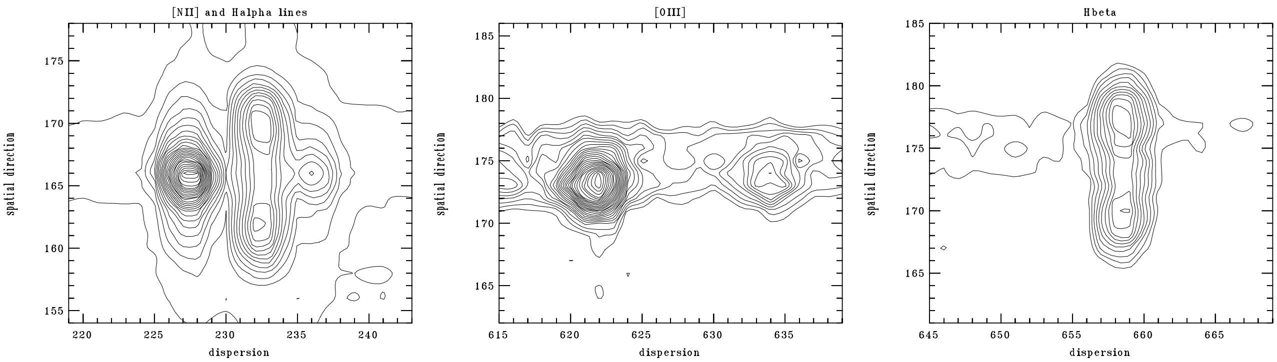

Fig. 1. Contour diagrams of Hα and [N II] (left), [O III] (center) and Hβ (right) for HuBi 1 obtained from our low resolution spectrum. Hα and Hβ present bipolar structure along the E-W direction showing two bright knots at about $2''$ at each side of the central star and very low emission in the center. The [N II] and [O III] lines are concentrated in the center.

firming that the structure presented in Fig.1 is not produced by the [WC] central star emission.

The difference in the spatial structure of H and He lines compared to those of the heavy element lines should be analyzed with much deeper imaging and spectroscopy. For the moment it can be said it resembles the difference found between the [O III] and the Hα images in the unusual planetary nebula A 78 where two well differentiated shells –the inner with strong [O III] emission and the outer with H emission– have been found (Medina & Peña 2000 and references therein). It is possible that a similar phenomenon is occurring in HuBi 1.

Another aspect which is interesting to investigate further is the possibility that the HuBi 1 central star could be variable. Peña (2005) pointed out that the stellar line intensities reported by different authors are different and they seem to be diminishing with time. Crowther et al. (1998) reported a dereddened log F(C III 5696)= -11.85, while Acker & Neiner (2003), from observations between 1994 and 1995, reported a value of -12.24. Peña (2005) measured log F(C III 5696)=-12.72 for the observations on September 2000 and a value of -13.50 for July 2002. Although much of the flux variations could be caused by the differences in the slit widths or the observing conditions, a systematic fading of the central star emissivity cannot be discarded. Therefore we have started a spectrophotometric follow-up of this object in order to analyze this possibility. In a few years we will have enough data for confirming or discarding this hypothesis.

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