C/O and N/O ratios in PNe with [WC] central stars

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Abstract

PNe around [WR] central stars (WRPNe) constitute a particular photoionized nebula class, representing about 10-15% of the PNe with known progenitor. We have studied 14 of them, detecting a large number of optical recombination lines (ORLs) from different ions of O and C (O^{+}, O^{++}, C^{++}, C^{+3}). This allows us to determine the C/O ratio, which is of paramount importance to constraint stellar evolution models. We have compared the obtained N/O and C/O ratios obtained with those derived from stellar evolution models, and we estimate that about half of our PNe have progenitors with initial masses similar to or larger than 4 $M_{\odot}$. These results are consistent with the results obtained from an independent analysis by Górny & García-Hernández (2013).

Observations

Table 1. Log of observations

Instrument	MIKE@6.5m Magellan
Spectral Res.	10.8 (blue) – 12.8 km s^{-1} (red)
Main Aim	Detect faint C and O ORLs
Details	García-Rojas et al. (2012, 2013)
Analysis	**PyNeb** (Luridiana et al. 2012)

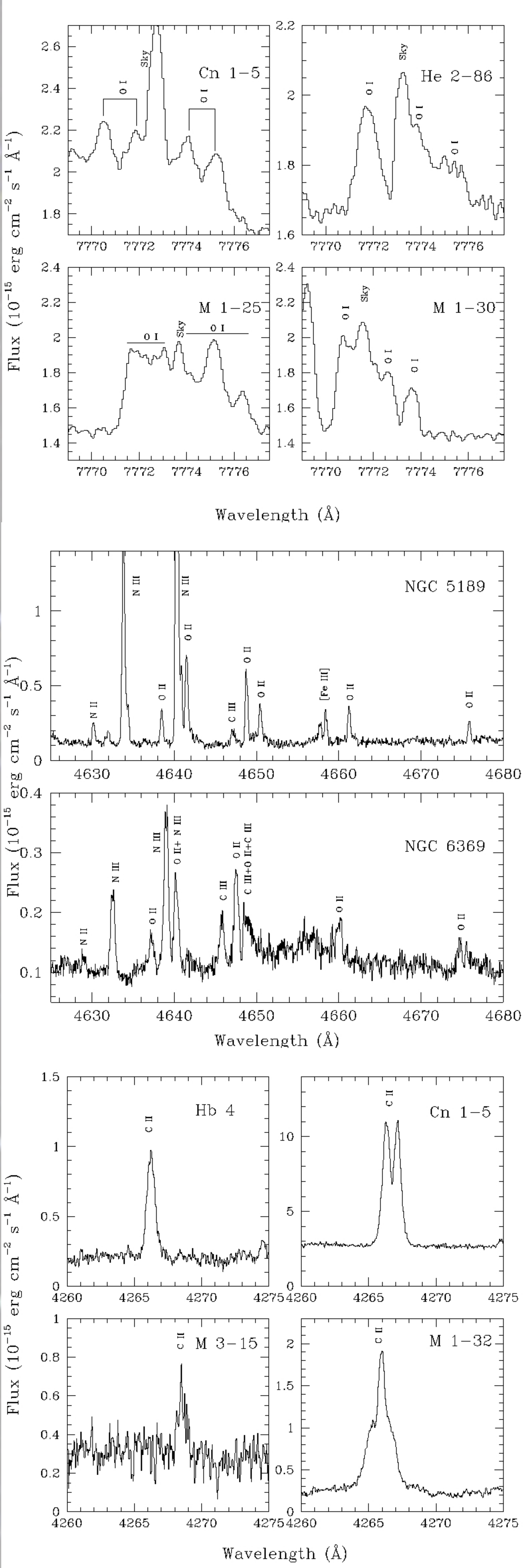

Figure 1. Section of the spectra showing RLs of multiplet 1 of O I (upper panel), multiplet 1 of O II and multiplet 1 of C III (middle) and multiplet 6 of C II (lower panel) for some PNe of our sample. Note the high velocity components in M1-32 (see C/O section).

N/O ratios

N/O ratios were computed from CELs. In Fig 2. (upper panel) we see that between one and three PNe are Peimbert's Type I (Peimbert 1990). Our sample is, on average, more N-rich, than the sample by Henry et al. (2004). This might be due to a slightly higher initial mass (M_i) of the progenitors, as found by Peña et al. (2013) who, from kinematics of Galactic WRPNe, found that they are located in a disk thinner than that of average PNe, hence, they are younger and, probably, with higher M_i.

Lower panel of Fig 2. shows the N/O ratios vs. N/H. The N enrichment through the CN-cycle is apparent. Predictions of stellar evolution models are shown. Our PNe are in between two sets of models with different metallicities, being the lowest metallicity PNe older and, probably, with M_i~1.5 $M_{\odot}$, and the most metallic ones, younger and with M_i≥ 4 $M_{\odot}$.

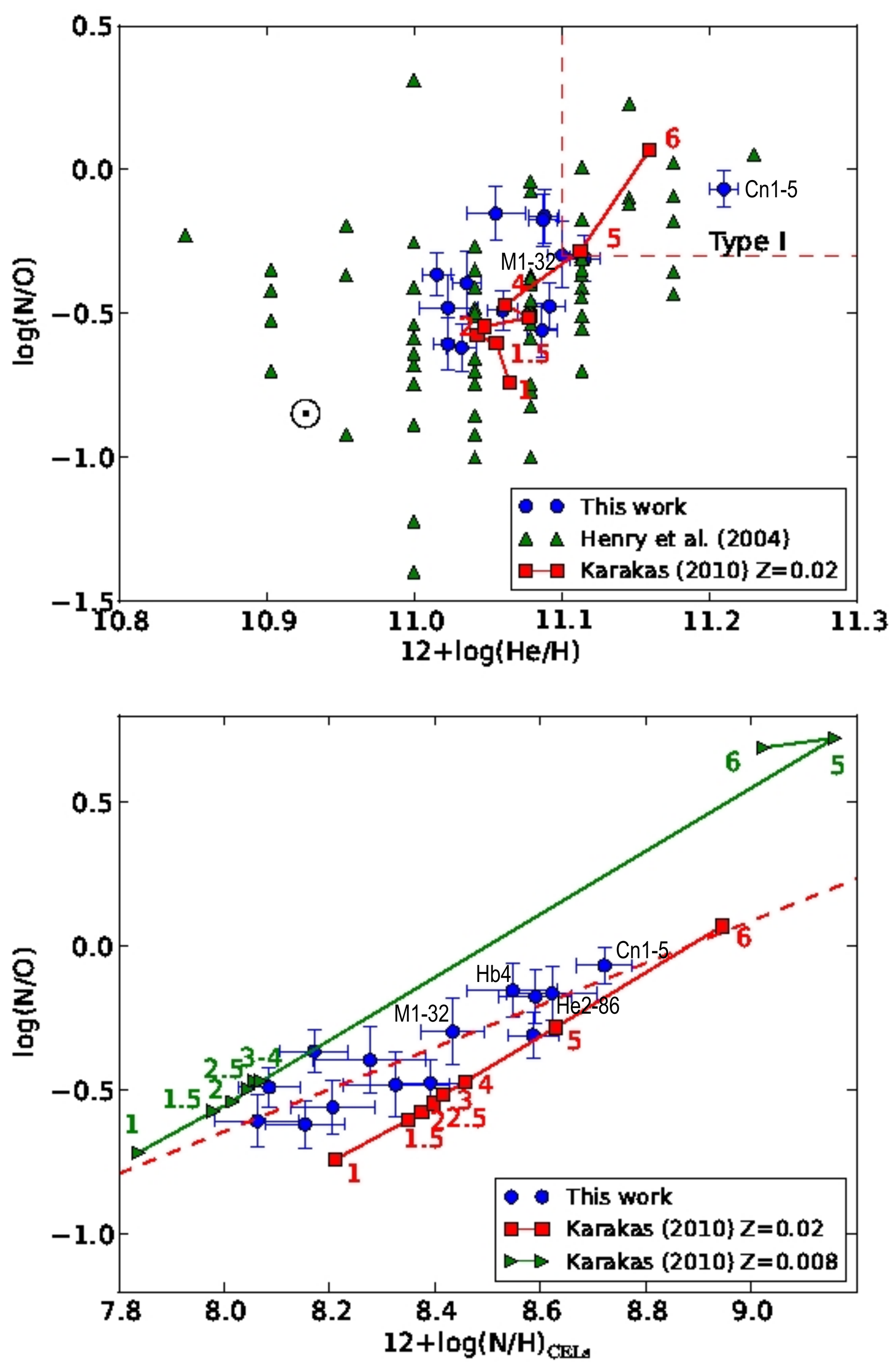

Figure 2. *Upper panel*: N/O ratio vs. He/H . The solar values are shown. *Lower panel*: N/O ratio vs. N/H for our PNe. Predictions of stellar evolution models by Karakas (2010) are included.

C/O ratios

Accurate determination of C/O ratios in PNe is of paramount importance to constraint the occurrence of different nucleosynthesis processes in AGBs, as well as to put limits to the M_i of PN progenitors by comparing them with theoretical AGB evolution models.

We computed C/O ratios from RLs of O I, O II, CII and C III (see García-Rojas et al. 2013). In Fig. 3 we show the C/O ratios vs. C/H, which are compared to different sets of stellar evolution models. It is evident that C-rich objects (C/O > 1) are produced by stars with M_i from 1.5 to 5 $M_{\odot}$. The case of M1-32, which shows an extremely large C abundance and high-velocity bipolar outflows, is somewhat striking and deserves further study (see Poster B16 by Rechy-García et al.) On the other hand, O-rich objects (C/O < 1) seem to descend from stars with M_i between 1 and 1.5 $M_{\odot}$ with the exception of Hb4 and He2-86, which in the N-diagram as PNe coming from stars with M_i> 4 $M_{\odot}$.

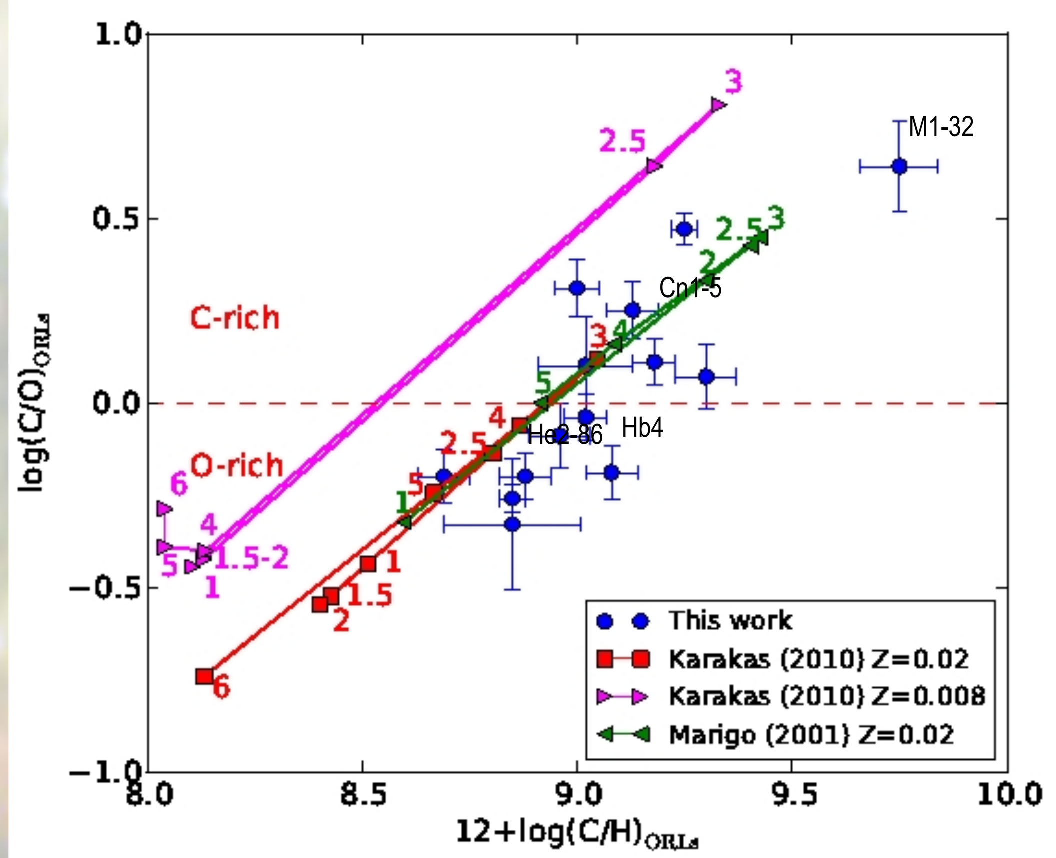

Figure 3. C/O ratio vs. C/H for our PNe. Predictions of stellar evolution models by Karakas (2010) and Marigo (2001) for stars with different M_i and metallicities are included.

C/O ratios and dust features

The C/O ratio is also useful as its value in the atmospheres of AGB stars determines the composition of the grains formed. In particular, C/O ratios would help to understand the origin of double-chemistry (DC) PNe, which show simultaneously both carbon- and oxygen-based dust (e.g. PAHs and amorphous/crystalline silicates, respectively (see Perea-Calderón et al. 2009 and Guzmán-Ramirez et al. 2011 for details of DC PNe).

8 PNe of our sample present DC features in their IR spectra. 5 have C/O < 1 and 3 have C/O > 1. The PNe with C/O < 1 show the typical DC *Spitzer* spectrum (very weak PAHs bands and crystalline/ amorphous silicates) while those with C/O > 1 display very unusual *Spitzer* spectra with strong PAH bands and very weak cristalline silicates features (see Perea-Calderón et al. 2009). Abundances obtained here and in the sample of Górny & García-Hernández (2013) are consistent with DC PNe being the descendants of high-metallicity and relative massive (~3-5 $M_{\odot}$) AGB stars experiencing hot bottom burning (HBB).

Further precise determinations of the C/O ratios in a complete sample of DC PNe are needed to learn about the dominant mechanism of PAHs formation (HBB deactivation and/or hydrocarbon chemistry within O-rich shells).

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