

Peculiar CNO photospheric abundances in the central star of NGC 2392

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Abstract. Using new, high signal-to-noise CFHT ESPaDOnS visual spectrograms, and archive IUE and FUSE UV spectrograms, together with state-of-the-art non-LTE hydrodynamical model atmospheres, we have obtained accurate He, C, N, O photospheric abundance determinations in the central stars of NGC 2392, IC 4593, and NGC 6826. We compare with the corresponding nebular abundances, taken from the literature. The central star of NGC 2392 shows high He, N, and very low C, O abundances. We propose that these peculiar abundances must have originated in a common-envelope phase of interaction with a close binary companion. If we assume that the companion is more evolved than the visible central star, this offers a way of solving the old mystery of the discrepant He II Zanstra temperature of NGC 2392.

Keywords. planetary nebulae: individual (NGC 2392, IC 4593, NGC 6826), stars: abundances, stars: atmospheres, binaries: close, stars: chemically peculiar, stars: evolution

1. Introduction

The Eskimo, NGC 2392, and its central star, have long been known to have some remarkable peculiarities: high nebular expansion velocity, too high He II Zanstra temperature, slow stellar wind, low mass loss rate, and, in particular, great strength of N lines and weakness of C lines in the central star spectrum (Méndez 1991). We have decided to undertake a reliable determination of He, C, N and O photospheric abundances, using modern observations and model atmospheres, and explore the possible evolutionary significance of the resulting abundances. We have also selected two “more normal” central stars, IC 4593 and NGC 6826, which bracket NGC 2392 in surface temperature.

2. Spectrograms and model atmospheres

High resolution ($R=68000$), high signal-to-noise ($S/N\sim 100$) optical spectra of NGC 6826, NGC 2392 and IC 4593 were obtained in 2010 using the echelle spectrograph ESPaDOnS with the 3.6m Canada-France-Hawaii Telescope at Mauna Kea. Each individual spectrum covers 40 orders from 3700 to 10500 Å. These optical spectra were complemented with archival IUE and FUSE spectra covering the UV range from 950 to 1900 Å.

We used the non-LTE, line-blanketed model atmosphere code CMFGEN (Hillier & Miller 1998). This solves the radiative transfer equation for a spherically symmetric wind in the comoving frame under the constraints of radiative and statistical equilibrium. Since the code does not solve for the wind structure from first (physical) principles, a velocity

Table 1. Central star (photospheric) and nebular abundances.

Object	T_{eff}	$\log g$	He/H	C abund	N abund	O abund
IC 4593 CS	41000 K	3.60	0.10	8.24	8.44	8.75
IC 4593 neb			0.10	7.68	8.65	8.77
NGC 2392 CS	43000 K	3.65	0.30	7.08	8.90	7.18
NGC 2392 neb			0.08	8.52	8.27	8.46
NGC 6826 CS	50000 K	3.85	0.10	8.64	8.30	8.78
NGC 6826 neb			0.10	8.68	7.76	8.60

structure must be chosen; we adopted a standard β -type law (Schaerer & Schmutz 1994). The main atomic processes and data sets are discussed in Hillier & Miller (1998). The atomic data are described in Table 2 of Dessart & Hillier (2010). Each model is prescribed by the stellar radius, the stellar effective temperature, the surface gravity, the mass loss rate, the velocity field (defined by β and the wind terminal velocity), the volume filling factor, f , characterizing the clumping of the stellar wind, and elemental abundances.

3. Abundances and interpretation

Because of space limitations, we do not show the model fits to stellar spectral features. We have successfully fitted a variety of features from different C, N, O ions. The derived parameters are listed in Table 1. The abundances are by number; in the cases of C, N and O, we tabulate the expression $12 + \log(\text{C}/\text{H})$, etc. The uncertainties are of the order of 0.2 dex. Nebular abundances are from Kwitter & Henry (1998), and Pottasch & Bernard-Salas (2010). The photospheric C, N, O abundances of IC 4593 and NGC 6826 are similar to, or higher than, the corresponding nebular abundances. The central star of NGC 2392 has very high N, and very low C, O abundances, while the nebular abundances of NGC 2392 are more or less normal (Pottasch *et al.* 2008).

Since the stellar He abundance is very high in NGC 2392, we are seeing H-depleted material at the stellar surface, clearly CNO-processed material, with enhanced N and depleted C, O. This must correspond to a situation where the mass loss that produced the PN has uncovered layers that belonged to the H-burning shell. See, for example, the profiles by Lattanzio *et al.* (1996). We interpret that the evolution of the central star was interrupted by interaction with a close binary companion, and that NGC 2392 was formed as a consequence of a common-envelope event. If we assume that the current central star is the less evolved of the two components, then the more evolved one would have to be a hot, perhaps accreting, compact stellar remnant. This would offer a way of solving the He II Zanstra discrepancy. A hot companion has been suggested many times; now the photospheric abundances have provided an additional reason to make the suggestion.

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