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Effects of the hot stellar component on derived physical parameters of the Carina Nebula

Víctor Robledo-Rella[1] and Miriam Peña
Instituto de Astronomía, UNAM,
Ap. Pos. 70-264, México, DF 04510, Mexico

1. Introduction, observations, extraction of the spectra and reddening corrections

Studies of extragalactic (un-resolved) H II regions, usually rely on assumptions about the underlying stellar absorption to estimate the reddening corrections needed to derive physical conditions of the ionized gas and to infer parameters of the ionizing stars (Robledo-Rella & Firmani 1990). We have addressed the problem of estimating *quantitatively* the effects of the hot star spectra on derived physical (nebular and stellar) parameters of galactic H II regions.

We present results from spatially integrated spectroscopy (3 600–10 200 Å) of three regions in the Carina Nebula. We used the *CTIO* 1.5m telescope with Cassegrain spectrograph and a 348×576 thinned CCD with ~12 Å FWHM resolution. A 7.5′ slit was aligned N-S and we 'drifted' the telescope over three selected regions ($\sim 7' \times 7'$ each), referred hereafter as Car-NW, Car-SE (which contains η Car) and Car-SW. The telescope tracking rate formula is given by Robledo-Rella & Conti (1994). Within these three regions are five O3 stars, η Car, one WN7+abs star, and ten stars earlier than O9 (Massey & Johnson 1993 and references therein).

The data were reduced using standard procedures with IRAF. Sky subtraction was done using 'pure-sky' frames close to the nebula. We extracted the spectra in two different ways: *(i) .all* case: extraction of the whole spectrum, including both the nebular emission and the exciting stars' spectra; and *(ii) .neb* case: before the extraction, we 'removed' from the CCD the spectra of 31 (previously defined) 'exciting' stars.

We derived our own extinction law, $f(\lambda)$, using the observed Balmer and Paschen line-decrements, and assuming that $f(\lambda)$ for Carina is not much different from the standard extinction law between Hα and Hβ. Our results are presented in Table 1, where we compare them with previous results by other authors.

2. Physical parameters and discussion

We ignored spatial temperature fluctuations and computed the electron temperature, T_e, electron density, n_e, and ionic abundances using line-emissivities provided by Stasińska (private communication). Total abundances were derived using the ICFs of Kingsburgh & Barlow (1994). See Table 1.

[1]Visiting Astronomer, CTIO, NOAO, operated by AURA, under cooperative agreement with the NSF

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Table 1. Physical parameters for Carina.[a]

	NW .all	NW .neb	SE .all	SE .neb	SW .all	SW .neb	error	$\langle SE_{PTPR} \rangle$ [b]
$c(H\beta)$	1.02	1.01	0.73	1.01	1.01	1.00	±0.09	0.65–0.94
R	4.0	4.1	5.4	4.2	4.3	5.0	±0.1	4.1[c]
A_V	2.27	2.24	1.64	2.26	2.21	2.40	±0.20	2.21[c]
$F(H\beta)_0$	1.26	1.25	1.00	1.47	0.94	0.93	±0.11	1.56
$N_{S\,II}$	100	100	300	200	75	100	$^{+100}_{-\dots}$	300
$T_{O\,III}$	10.1	9.6	–	10.0	9.7	9.1	±0.5	8.6–8.9
$T_{N\,II}$	9.8	9.7	20.4	12.6	11.2	11.1	±1.4	8.8–10.3
O/H	8.42	8.35	7.77	8.05	8.19	8.28	±0.14	8.30 (8.37)
N/H	7.08	7.19	7.47	7.21	7.17	7.23	±0.07	7.46
S/H	6.63	6.63	6.41	6.53	6.56	6.53	±0.07	6.93 (6.90)
Ne/H	7.89	7.70	6.90	7.23	7.47	7.56	±0.20	7.49
Ar/H	6.43	6.34	5.98	6.13	6.17	6.21	±0.14	–

[a] Gives the logarithmic reddening correction factor, $c(H\beta)$, ratio of total to selective extinction, R, total visual extinction in mag, A_V, and total de-reddened Hβ flux, $F(H\beta)_0$, in units of $10^{-13}\,erg\,cm^{-2}s^{-1}arcsec^{-2}$ (our final slit aperture was $5'' \times 6.4'$). n_e in cm^{-3}, T_e in kK. Abundances (assuming $t^2 = 0$) are given as 12+log(X/H).

[b] Average of common slit positions from Peimbert, Torres-Peimbert & Rayo (1978). Abundances are for $t^2 = 0$. Dennefeld & Stasińska (1983) values are given in parenthesis.

[c] Adapted from Tapia *et al.* al. (1988) for several stars within Car-SE.

Car-SE seems to be deficient in O/H (~ 0.2–0.3 dex), and to have a larger N/O ratio (~ 0.2–0.3 dex) compared to Car-NW and Car-SW. Part of this difference may be due to possible over-estimation of T_{OIII} (even in the *.neb* spectrum) due to scattered light contamination in [OIII] λ 4363 coming from the wide Hγ arising in η Car.

The stellar component produces different effects in the Balmer lines depending on the spectral type of the embedded stars: if the region is dominated by early O-type stars (as in Car-NW), one would under-estimate the observed Balmer fluxes by $\sim 10\%$ for lines redder than Hγ and by up to 50% for higher members of the series. On the other hand, if there are stars with strong emission lines (as in Car-SE), the effect is reversed and would lead to over-estimated Balmer fluxes by as much as 50%.

For Car-SE, the inclusion of the stellar component yields an under-estimate of O/H by ~ 0.30 dex and an over-estimate N/H by ~ 0.20 dex. For Car-NW however, ionized only by early O-type stars, we would over-estimate O/H by ~ 0.10 dex with their inclusion.

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