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SCATTERED LIGHT IN GALACTIC H II REGIONS[1]

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RESUMEN

Encontramos que la luz dispersada por polvo en los espectros de Carina, M8, y M20 contribuye con 50 a 70% del contínuo puramente nebular. Por otro lado, el contínuo estelar contribuye con $\sim$ 50% del contínuo total.

ABSTRACT

We find that dust-scattered light is the dominant contributor (50–70%) to the continuum in the *pure* nebular spectra (bright stars excluded) of NGC 3372 (Carina), M8 and M20. On the other hand, the stellar spectra contributes only about 50% of the continuum when the stars are included. This high contribution of scattered light should be taken into account when deriving the age and stellar content from observed Equivalent Widths ($W_{\mathrm{H}\beta}$) in spatially resolved GEHRs and H II galaxies.

Key Words: **DUST, EXTINCTION — H II REGIONS — ISM: INDIVIDUAL (CARINA, M8, M20)**

1. INTRODUCTION

We present results obtained from long-slit spatially-integrated visual-NIR spectroscopy of 3 subregions in Carina and 2 subregions in M8 and M20. With this drift-scanning technique we aligned N–S the largest slit ($5'' \times 7.5'$ on the sky) and adjusted the telescope tracking rate so to scan a selected subregion ($\sim 7'$ in RA) over each nebulae. We scanned $\sim$ 150 arcmin^2 in the center of Carina (including η Car) and $\sim$ 100 arcmin^2 in the centers of both M8 and M20. We used CTIO 1.5-m Telescope and Cassegrain spectrograph covering from 3600–10 200 Å ($\sim$ 12 Å FWHM), with 15–30 min exposures (depending on the observed $\Delta\lambda$ range). The 2-D spectra represent then an E–W average of all the emission (nebular plus stellar) arising within each scanned subregion. Data reduction was made with IRAF using standard procedures, however, we made two different extractions:

.all includes both the nebular and stellar spectra of stars crossing the slit during the scan;

.neb in which we "removed" from the CCD the spectra of all stars having a continuum flux at λ4861 $\geq$ 5% of the Hβ nebular emission around the star. We then filled-up these CCD spaces interpolating at each λ the nebular emission at both sides of the removed stellar spectra. We also subtracted a small contribution (less than 5%) of instrumental scattered light inside the spectrograph.

Previous results of the *.all* vs. *.neb* effects on derived physical parameters (extinction, de-reddened Hβ surface brightness, electronic density and temperature, and ionic and total abundances) for the 3 Carina subregions are given by Robledo-Rella & Peña (1999), while similar results for M8 and M20 subregions, including the spectral types of removed stars, and the effect on the Balmer line fluxes, are given by Robledo-Rella (2000). We merged the 1-D spectra from the Carina, M8 and M20 subregions to form what we will hereinafter call Car Reg, M8 Reg and M20 Reg, respectively. They correspond to the spectra we would obtain (with the same equipment) if each nebula were about 170 times farther away ($\sim$ 440 kpc for Carina).

One of the goals of this work is to quantify the effect of embedded stars on integrated (nebular plus stellar) spectra of giant extragalactic H II regions (GEHRs). The effect on the observed Balmer line fluxes (F_λ) increases at shorter wavelengths, with $F_\lambda^{neb}/F_\lambda^{all} \gtrsim 1.25$ at Hδ (Robledo-Rella 2000). However, the extrapolation to GEHRs is hampered by extinction of the observed Balmer F_λ, so we decided to use Equivalent Widths (W_λ), which are not affected by extinction.

2. RESULTS AND DISCUSSION

In this short communication we present and briefly discuss the *.neb* and *.all* Balmer F_λ and W_λ of Car Reg, M8 Reg and M20 Reg. We measured F_λ and W_λ, of Hα to Hδ in emission by fitting a Gaussian to each line and interpolating the continuum at both sides of the line. Our results are pre-

[1]Based on observations from CTIO, a division of NOAO, which is operated by AURA, Inc. under agreement with NSF.

TABLE 1

BALMER LINE OBSERVATIONS

	Car Reg		M8 Reg		M20 Reg		atomic
	.neb	*.all*	*.neb*	*.all*	*.neb*	*.all*	10^4 K
F_λ (10^{-11} erg s^{-1} cm^{-2})							
Hδ	1.28	1.46	1.53	1.46	0.35	0.29	0.26
Hγ	2.76	3.14	2.97	2.98	0.73	0.68	0.47
Hβ	6.88	7.44	6.96	7.16	1.73	1.68	1.00
Hα	37.8	38.5	29.9	30.0	7.72	7.73	2.85
W_λ (Å)							
Hδ	18	12	76	23	21	8	281
Hγ	46	28	162	56	50	21	546
Hβ	141	82	450	174	150	69.0	1360
Hα	816	464	1990	1077	791	454	4900
CONTINUUM CONTRIBUTION[a] (%)							
Hδ	94	42	73	68	92	55	
Hγ	92	47	70	65	91	54	
Hβ	90	46	67	62	89	53	
Hα	83	44	59	46	84	43	

[a]Of dust-scattered light for *.neb*; of starlight for *.all*.

sented in Table 1, with estimated errors of less than 10%. We interpolated the continuum atomic emission coefficients given by Brown & Mathews (1970) to compute the ratio of the atomic continuum emission to the intensity of Hβ ($i_c^a/I_{H\beta}$) for a nebula at 6, 10 and 14 kK, in the low density limit ($N_e \ll 10^4$ cm^{-3}), consisting of pure H and 10% of He, with no dust. These coefficients include continuum contributions from free-free and free-bound transitions of H I and He I (we neglected He II at these temperatures) and H I two-photon emission. We used the effective recombination coefficients of H from Péquignot, Petitjean, & Boisson (1991) to estimate the intrinsic Balmer line intensities relative to Hβ (at 10 kK; Table 1). In this manner, we estimated the "atomic" W_λ^a we would expect for this hypothetical nebula (free of dust), and we present our results in the last column of Table 1. Similar results for $W_{H\beta}^a$ have been computed by O'Dell, Hubbard & Peimbert (1966, 1150 Å) and by Sánchez & Peimbert (1991, 1600 Å).

Using Table 1, we estimated the fraction of dust scattered continuum in the *.neb* continuum,

$$i_c^d/(i_c^a + i_c^d) = 1 - \ (W_\lambda^{neb}/W_\lambda^a),$$

and the stellar fraction in the *.all* continuum,

$$i_c^\star/(i_c^a + i_c^d + \ i_c^\star) = 1 - r(W_\lambda^{all}/W_\lambda^{neb}),$$

where $r = F_\lambda^{neb}/F_\lambda^{all}$. Both results are given under the *.neb* and *.all* headers, respectively, in the last part of Table 1.

Obviously, we did not remove in our *.neb* frames all the stars crossing the slit, specially for the crowded Carina subregions. From the 2-D spectra, we estimate that the contribution from these non-removed stars to the continuum in our *.neb* spectra could explain up to about 20% of the fractions we list in Table 1. Even so, our results indicate that about 70% of the *.neb* continuum in Carina and M20 is due to dust-scattered light (i_c^d), while in M8 it reaches up to about 50%. Similar results have been reported by Sánchez & Peimbert (1991) for M8 and by O'Dell et al. (1966) for M20. Evidence for a strong component of scattered light in the optical continuum of M42 (Orion) has been given by O'Dell, Walter, & Dufour (1992). The stellar continuum ($i_c^\star$) on the other hand, comprises only about 50% of the *.all* continuum. Except for Hδ in Car Reg, i_c^d correlates with $i_c^\star$, as expected. All three nebulae also indicate that the fraction of scattered-light increases toward the blue, what would indicate that the dust scattering cross section (or the albedo) increases with decreasing wavelength. This scattered continuum contribution must be taken into account when deriving the age an stellar content from the observed $W_{H\beta}$ of spatially resolved GEHRs and H II galaxies.

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