Revista Mexicana de Astronomía y Astrofísica, **29**, 79-83 (1994)

SPATIALLY INTEGRATED SPECTROSCOPY OF THE GALACTIC H II REGION M8

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RESUMEN

Se presentan resultados preliminares sobre nuevas observaciones espectroscópicas de rendija larga (7.6 minarc) en el óptico (3700–10 100 A) integradas espacialmente de una porción central de la región H II galáctica M8 que incluye a la estrella excitadora HD 164794 (O4V). La rendija del telescopio se alineó N-S y se ajustó el guiado de modo de "barrer" un área de $\approx$ 7.6 minarc^2. El espectro se extrajo a lo largo de la dirección espacial, primero incluyendo junto con el espectro nebular, el espectro de las estrellas excitadoras (caso 1), y segundo excluyendo estos espectros estelares (caso 2). Los flujos en las líneas de la serie de Balmer son sistemáticamente mayores ($\sim$ 2 a 8 %) en el caso en el que se han excluído las extrellas excitadoras (caso 2). Los flujos en las líneas prominentes de [O III] y [S III] son prácticamente iguales en ambos casos, mientras que los de [O I], [O II] y [N II] son menores ($\sim$ 2 a 6 %) en el caso 2 respecto del caso 1. Estas diferencias podrían tener consecuencias en análisis de regiones H II gigantes extragalácticas donde no se resuelven las estrellas excitadoras.

ABSTRACT

We present preliminary results of new long slit (7.6 arcmin) optical (3700–10 100 A) spatially integrated spectroscopic observations of a central portion of the galactic H II region M8, including the exciting star HD 164794 (O4V). With the slit of the telescope aligned N-S we "scanned" an area of $\approx$ 7.6 arcmin^2. We extracted the spectra along the spatial direction, first including along with the nebular spectrum, the spectra of the exciting stars (case 1), and then excluding these stellar spectra (case 2). The line fluxes for the Balmer series are systematically bigger ($\sim$ 2 to 8 %) in the case where the exciting stars have been excluded (case 2). The fluxes in the prominent [O III] and [S III] lines are practically the same in both cases, while those of the [O I], [O II] and [N II] lines are smaller ($\sim$ 2 to 6 %) in case 2 than in case 1. These small differences, if real, cause the model-assigned Effective Temperature for the nebula be $\sim$ 1 to 2 % cooler in case 2 with respect to case 1 and may have some consequences on analyses of giant extragalactic H II regions where the exciting stars are not resolved.

Key words: **H II REGIONS — ISM: INDIVIDUAL OBJECTS (M8)**

1. INTRODUCTION

In order to accurately derive the physical conditions and related stellar parameters of giant H II regions in nearby galaxies (and of H II galaxies), the contribution in the "integrated light" from the embedded exciting

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stars to the nebular spectrum must be accounted for quantitatively. In some works, people just simply ignore the underlying stellar absorption even when noticing that the logarithmic reddening correction at Hβ C(Hβ) may have different values for different ratios of Balmer lines, Hα/Hβ, Hγ/Hβ,... (e.g., Robledo-Rella & Firmani 1990). To study this problem, we have observed (with the same technique, see § 2) a number of galactic H II regions, distributed all over the galactic plane, for which we know *a priori* the spectral types and luminosities of the exciting star(s). In future papers we intend to model the nebular emission in these objects in order to compare the predicted (mean) effective temperature of the ionizing star(s) with the values already known from stellar spectral types. This comparison will allow us to assess the validity of model assumptions on the basis of (quantitatively) estimating the stellar contribution to the integrated (nebular plus stellar) spectrum.

2. OBSERVATIONS

As part of this general project we observed two "subregions" in the galactic H II region M8; here we present early results only for the eastern-most subregion, which we have labelled M8-E and which contains the exciting star 9 Sgr (HD 164794, O4V; star No. 5 in Figure 1). This M8-E subregion does not include the Hourglass, which is further W from it (about 1 arcmin W from the W-side of M8-E). The observations were carried out with a 348 × 576 thinned GEC CCD and cassegrian spectrograph attached to the 1.5-m telescope at CTIO during 3 consecutive nights, from April 28 to 30, 1993. The slit was aligned N-S, corresponding to ≈ 7.60 arcmin × 5 arcsec on the sky. The achieved spectral resolution was not better than ≈ 10 A FWHM. The tracking rate of the telescope was adjusted so as to "scan" a desired length in R.A. in a given integration time (this being function of the spectral range we were looking at). The formula we derived to compute the tracking rate X in terms of the swept length D in R.A., the integration time t and the object's declination δ is:

$$X(\mathrm{timemin/min}) = 15 - \{D(\mathrm{arcmin})/[t(\mathrm{min}) \times \cos\delta]\} .$$

The R.A. at the beginning of the integration corresponding to the center of the slit was RA(2000)= 18h04m14s. The scanned length D was ~ 7.65 arcmin to the W. The declination δ(2000)= −24° 22' 52" was approximately constant during all integrations.

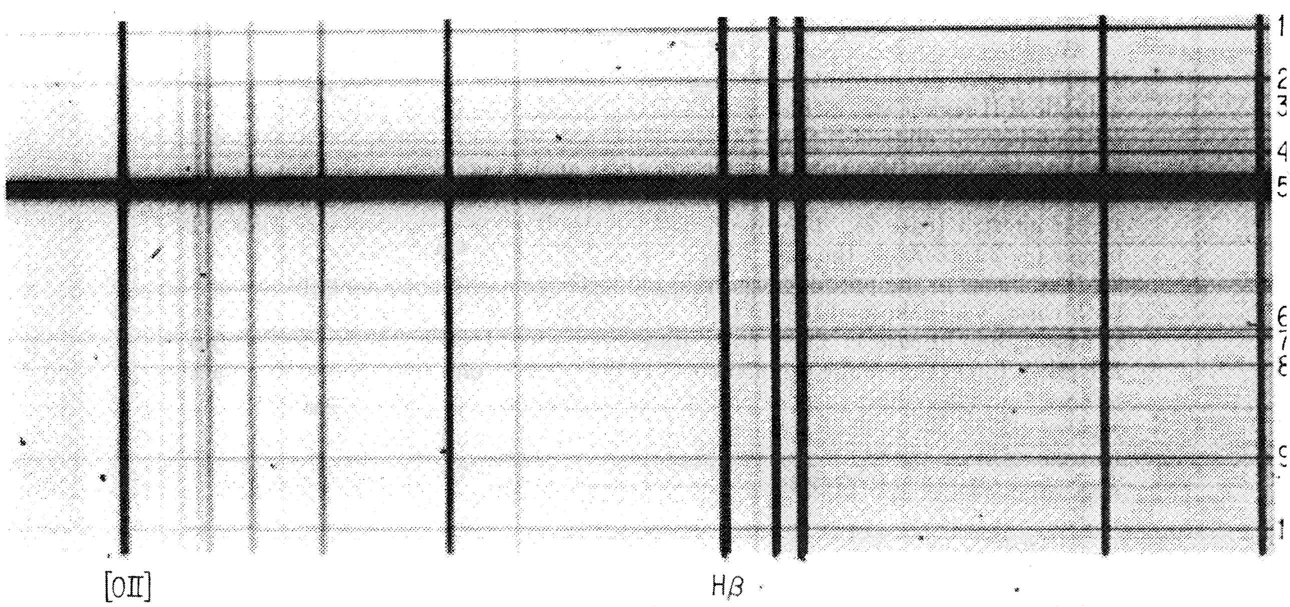


Fig. 1. Bias-, flat field-, illumination-corrected CCD"B" frame for the M8-E region. 10 stars are marked, which were "removed" in order to compute the M8-E.neb (nebular emission only) spectrum.

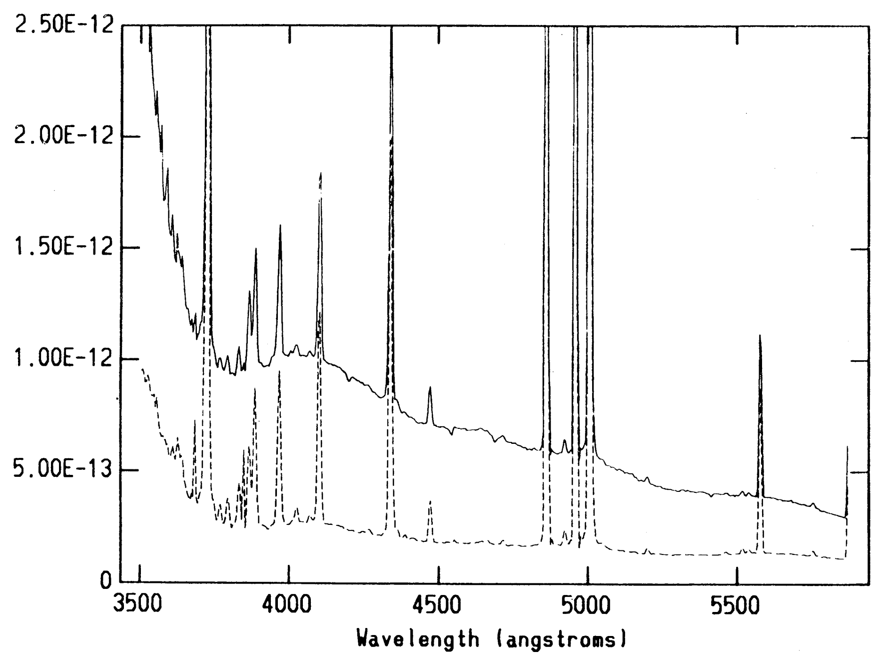
In order to cover the whole spectral range 3700–10 100 A we used three different setups (i.e., different gratings with the appropriate filters), called here Blue "B": 3700–5900 A, Yellow "Y": 5800–8000 A and Red "R": 7900–10 100 A, starting each exposure for the three spectral ranges as much as possible at the same osition within the nebula. In Figure 1 (above) we show our "B" CCD frame. As the extension of the whole ebula ($\sim$ 90 arcmin) in this case was much bigger than our slit length, we took "blank sky" frames close to but still outside) the nebula in order to subtract sky contributions.

3. DATA REDUCTION, ANALYSIS AND CONCLUSIONS

The data were reduced using the standard procedures within IRAF: trimming, bias subtraction, flat field orrection, illumination correction (crucial for our long slit program), "extraction of the spectra", λ calibration, tmospheric extinction correction and flux calibration. We have not done sky subtraction yet. Flux calibration 'as done using the standard star LTT4364 (Baldwin & Stone 1984). We did the "extraction" of the spectra in wo different ways: 1) Extracting along the spatial direction the whole spectrum, including both the nebular mission spectrum as well as the spectra of the exciting stars passing through the slit during drift. We called his spectrum "M8-E.all"; 2) Extracting only the nebular emission spectrum. For doing this we "removed" rom the whole 2D frame only the spectra of the exciting stars that had a continuum flux value at 4861 A (Hβ) reater than 5 % of the Hβ nebular emission value at both sides of the star. We then used a linear interpolation f the Hβ nebular emission between these two side-points over the pixels that were occupied by the star. The pectrum so obtained was called "M8-E.neb". There were 10 such stars, indicated in Figure 1. We took care in xtracting exactly the same number of pixels corresponding to the same region on the sky for our three spectral anges, both for M8-E.all and M8-E.neb. As an example, in Figure 2 we present the final λ and flux calibrated B" spectra obtained for M8-E.all (all-emission extraction) and M8-E.neb (only nebular-emission extraction), uperimposed over the same scale in wavelength and flux. As can be seen from this figure, both the continuum s well as the line intensities are different for M8-E.all and M8-E.neb.

In Table 1 we present a list with the most prominent lines in both spectra, the derived line fluxes given in rg cm^{-2} s^{-1}. The last column of Table 1 shows the ratio of the .all and .neb flux values. All the Balmer lines how larger ($\sim$ 2 to 8 %) flux values for the .neb spectra than for the .all spectra (as one would expect given he absorption Balmer lines in the stellar spectra). The bigger the quantum number in the Balmer series, the arger the difference between the .neb and .all values (see Table 1).

The fluxes for the [O III] and [S III] lines remain practically unchanged between the two extractions. The O I], [O II] and [N II] lines have smaller ($\sim$ 2 to 6 %) flux values in the .neb than in the .all spectrum.



'ig. 2. Plot of the M8-E.neb (dashed line) and M8-E.all (solid line) extracted spectra flux (erg cm^{-2} s^{-1} A^{-1}) vs. λ A) for the 'B" spectral range.

Table 1. Observed Line Fluxes and Line Ratios for M8-E.all and M8-E.neb[1].

λ	Ion	[F(λ)/F(Hβ)].all[2]	[F(λ)/F(Hβ)].neb[2]	F(λ).all/F(λ).neb
3727	[O II]	0.984 ± 0.031	0.937 ± 0.076	1.032
3869	[Ne III]	0.165 ± 0.012	0.166 ± 0.017	0.976
4102	Hδ	0.220 ± 0.027	0.236 ± 0.030	0.916
4340	Hγ	0.425 ± 0.052	0.435 ± 0.051	0.960
4861	Hβ	1.000	1.000	0.982
4959	[O III]	0.826 ± 0.033	0.818 ± 0.069	0.992
5007	[O III]	2.512 ± 0.083	2.481 ± 0.121	0.995
5577[3]	[O I]	0.169 ± 0.020	0.156 ± 0.022	1.064
5876	He I	0.120 ± 0.003	0.133 ± 0.031	0.886
6301	[O I]	0.0581 ± 0.0030	0.0540 ± 0.0047	1.057
6563	Hα	3.015	2.986 ±0.049	0.992
6584[3]	[N II]	0.333:	0.319:	1.025:
6716+31	[S II]	0.160 ± 0.032	0.164 ± 0.003	0.958
7136	[Ar III]	0.106 ± 0.026	0.119 ± 0.002	0.875
7816	He I	0.0382 ± 0.0020	0.0296 ± 0.0041	1.268
8346	Pa23	0.0506 ± 0.0088	0.0447 ± 0.007	1.112
8665	Pa13	0.0460 ± 0.0222:	0.0407 ± 0.0021	1.110
8915	He I	0.0325 ± 0.0058	0.0307 ± 0.0047	1.040
9069	[S III]	0.447 ± 0.060	0.432 ± 0.049	1.016
9229	Pa9	0.0596 ± 0.0098	0.0569 ± 0.0151	1.029
~9376[5]	?	0.0965 ± 0.016	0.0983 ± 0.0078	0.965
9464	He I (?)	0.0390 ± 0.0024	0.0420 ± 0.0100	0.912
9531	[S III]	1.451 ± 0.104	1.437 ± 0.155	0.992
~9797[5]	?	0.0508 ± 0.028	0.0513 ± 0.0033	0.972

[1] F(Hβ)/10^{-11} erg cm^{-2} s^{-1} (.all) = 5.704 ± 0.225; (.neb) = 5.807 ± 0.283.
[2] Uncertainties correspond to ± 3σ.
[3] Still contaminated by strong emission sky-line.
[4] Uncertain due to blending with Hα.
[5] Not identified by Osterbrock et al.1992.

The Paschen lines also show a similar behaviour. We do not clearly understand the physical reason for thes differences; the stellar spectrum does not show any particular feature at these wavelenghts. We need to stud more objects before we can safely conclude if these differences are real beyond our systematic errors. Howevei if real, the differences in line ratios (Table 1) would place this region in a slightly different position in th common three "diagnostic diagrams" (e.g., Veilleux & Osterbrock 1987): [O III]λ5007/Hβ vs. [N II]λ6584/Hα vs. [S II]$\lambda\lambda$6716+31/Hα; vs. [O I]λ6301/Hα. According to the models of Evans & Dopita (1985) for sola abundances, and using these three diagrams, we found (fitting the observed positions) a somewhat cooler (~ 300–500 K) model-assigned mean effective temperature $<T_{eff}>_{mod}$ for the .neb than for the .all spectrum being $<T_{eff}>_{mod}$ about 45 000 ± 800(!) K. This may at least in part account for some of the differences foun for a number of galactic H II between the $<T_{eff}>_{mod}$ values and the spectroscopic $<T_{eff}>_{spec}$ values know from the actual spectra of the exciting star(s) (Conti 1993). This work is part of ongoing systematic studie to determine fully sufficient conditions for modeling the nebular emission for a selected sample of galactic H I regions.

We acknowledge P.W. Morris for many useful comments on the manuscript. VR-R received a fellowshi from DGAPA, UNAM, for the elaboration of this work.

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DISCUSSION

ɭoman: a) Has Walborn classified the exciting star in M8? b) Does nebular contamination cause difficulties n classifying this star?

ɭobledo-Rella: a) Yes, Walborn (1972, AJ, 77, 312) gave two-dimensional classifications for both HD 164794 O4V ((f))] and HD 165052 (O6.5V), although HD 164740 is also another exciting star in this nebula. b) Nebular ontamination causes no difficulty for the two stars in which the He I emission lines are not very strong.

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