CCD Spectroscopy of P_γ (10939), P_δ (10049) and Corresponding Balmer Lines in 30 Doradus

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Understanding the physical and dynamical evolution of galactic and extragalactic H II regions requires a knowledge of the dust component and its distribution. To date the extinction A_V has been derived by various methods: optical and infrared line ratios, comparison of radio and emission line fluxes, stellar photometry, etc. In particular the intensity ratios of the strong and spectroscopically easily accessible Balmer lines H_α, H_β are frequently used to derive A_V via their decrement. Since these lines originate from different upper levels, the interpretation of the observed line ratios requires recombination line model calculations (cf. Osterbrock 1974) which in many extragalactic cases have failed to give consistent results (Ward et al. 1987, Malkan 1983, Rieke and Lebofsky 1981). This difficulty can be avoided by using multiplet line ratios originating from the same upper level so that the theoretical line ratios depend primarily on their relative transition probabilities.

There are only few candidates of multiplet lines of abundant atomic species with sufficient wavelength spacings to derive accurately the differential extinction, viz. the corresponding Paschen and Balmer lines P_γ (10939 Å) – H_δ (4102 Å), P_δ (10049 Å) – H_ε (3970 Å) (Aller and Minkowski 1956), and lines of [S II] at 10287, 10330, 10336, 10370 Å in the IR and at 4069, 4076 Å in the blue (Miller 1968). However, these line ratios have seldom been used (Wampler 1968, Miller 1973) because of the low efficiency in the IR wavelength region of electron multiplier photocathodes and because of the severe contamination with many atmospheric emission lines of OH (Osterbrock 1974).

The situation has changed with the availability of CCD detectors. Although also CCD detectors have low efficiencies in the IR region, they provide a significant advantage over the earlier spectrophotometry by allowing a correct elimination of the atmospheric emission lines from sky background exposures in two-dimensional long-slit spectrophotometry.

As with the INT/IDS CCD spectrograph combination at the La Palma Observatory (Greve et al. 1989), we have used the ESO 1.52-m telescope and BC spectrograph equipped with the GEC # 14 CCD detector and the grating # 28 which in 1st and 2nd order allows the detection of the IR and blue components.

Figure 1a shows the flat-field corrected IR image (30 min. exposure time) of a section of the 30 Doradus nebula in the Large Magellanic Cloud. The many strong atmospheric lines, particularly located at the short wavelength end, confuse the image. The sky-corrected, flux calibrated spectrum is displayed in Figure 1b showing the detection of P_γ (10939 Å), He I (10830 Å) and P_γ (10049 Å). The [S II] 10300 Å lines are absent, or very weak, because of the low metallicity of the LMC. The corresponding lines H_δ (4102 Å) and H_ε (3970 Å) of the blue wavelength region are displayed in Figure 2. Using the observed P_γ/H_δ and P_δ/H_ε line ratios and adopting a standard reddening curve we derive A_V = 2.0–2.5 mag. for this particular region of 30 Doradus.

Similar spectra with exposure times of ~10 minutes for the IR wavelength region have been obtained for the Orion nebula.

Despite the low efficiency of the CCD detector in the IR wavelength region ($0.91 < \lambda < 1.1$ μm), we conclude from our observations that significant research on galactic and extragalactic H II regions can be carried out with the available telescope-spectrograph-CCD detector combination. The observations open up the possibility of deriving ex-

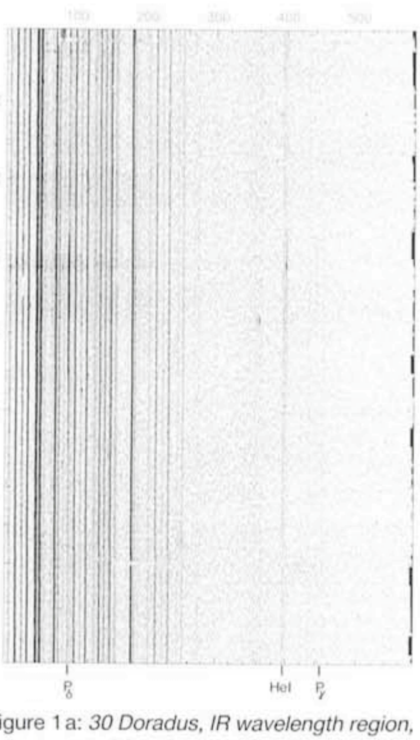

Figure 1a: *30 Doradus, IR wavelength region, not corrected for sky emission.*

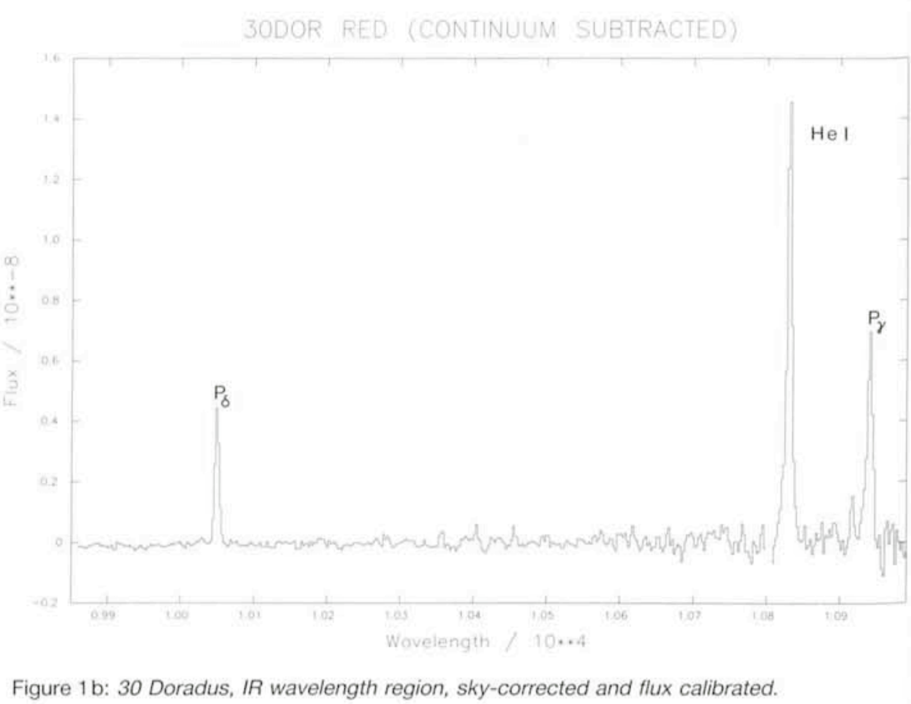

Figure 1b: *30 Doradus, IR wavelength region, sky-corrected and flux calibrated.*

tinction values without heavy reliance on recombination line model calculations. It is our intention in this context to investigate in proposed follow-up observations of galactic H II regions whether this observing technique gives consistent results when compared with data derived from the Balmer line decrement method.

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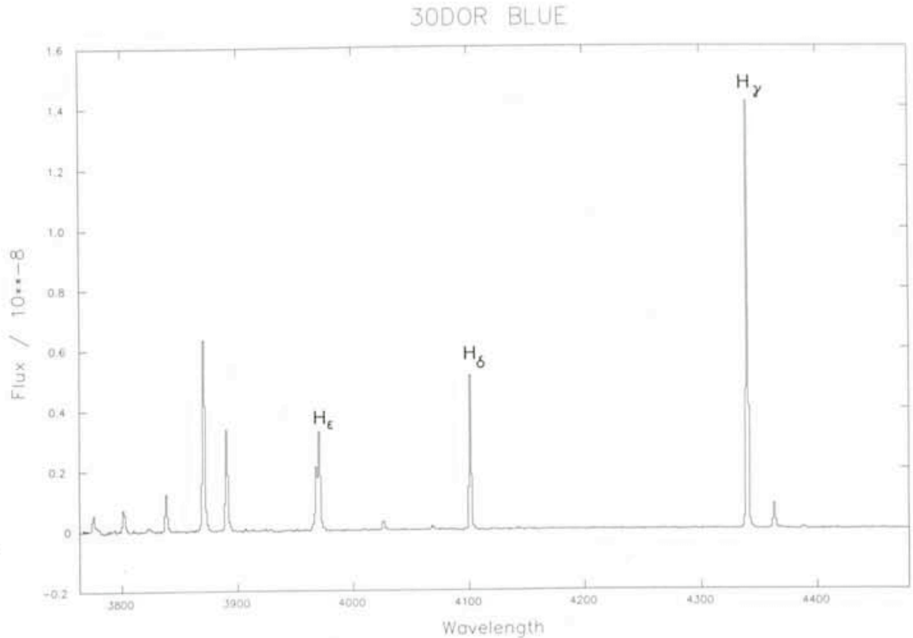

Figure 2: *30 Doradus, blue wavelength region, sky-corrected and flux calibrated. The Hε line is blended with the [Ne III] 3967 Å line.*

Star Formation in Dwarf Irregular Galaxies

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1. Introduction

Contrary to the more spectacular and appealing Spiral and Elliptical Galaxies, for a long time Irregular Galaxies have not been considered to deserve detailed studies. Only in the last decade, the difficulty found in the interpretation of the major evolutionary processes taking place in bigger, more complicated galaxies, has led to new interest in Irregulars, which should be easier to understand, for a number of circumstances. The structures of Irregular Galaxies appear, in fact, to be simple, with no combination of halo and disk phases and no special evidence of dynamical phenomena playing an important role. They contain a large amount of gas, easily detected by radio telescopes, which means that they are in a relatively early stage of the evolution. Besides this, their visible stellar content is young enough to indicate that Star Formation is active in these galaxies, several H II regions are present and allow the derivation of the metallicity, even at large distances. For all these reasons, Irregular Galaxies seem to offer a suitable ground for studying the basic phenomena controlling the evolution of galaxies.

Extensive studies by several authors have confirmed the above general features (see Viallefond, 1988, for a recent review), suggesting that Irregular Galaxies are presently the best candidates for the identification of the properties of primordial galaxies, which makes them particularly interesting from the cosmological point of view. On the other hand, the detailed study of the stellar content of Irregulars has opened some important questions on how the Star Formation processes have been operating in these systems. The Initial Mass Function (IMF) has been suggested to be considerably flatter than in our own Galaxy (Terlevich and Melnick 1983), but Matteucci and Tosi (1985) argued that a normal Salpeter function is more appropriate. As for the Star Formation Rate (SFR), according to Gallagher, Hunter and Tutukov (1984), Dwarf Irregulars are likely to have undergone a continuous, maybe even constant Star Formation, as seems the case for giant Irregulars and late type Spirals, while Matteucci and Chiosi (1983), on theoretical grounds, have rather suggested a bursting Star Formation Rate.

To try to answer these questions and to better understand the evolution of these galaxies, we have undertaken a project of CCD photometry of some Dwarf Irregulars in the Local Group. Our aim is to derive as deep as possible Colour-Magnitude (CM) diagrams to be compared with theoretical simulations performed with different prescriptions for the SFR and the IMF. In this respect, it is worth noting that the stellar content in these galaxies is not so crowded as to prevent a good resolution with optical telescopes, when adequate techniques for the data reduction are used. The relatively small distances ($m - M \lesssim 26$ mag) of Dwarf Irregulars in the Local Group allow to resolve their stellar content down to $M_v \simeq -1$ to 0, which corresponds to Main-Sequence stars of approximately 2 $M_\odot$. We will then be able to derive information on the SF which occurred over the last ~1 Gyr.

2. Data Acquisition and Reduction

Besides DDO 221 (WLM), for which results have already been published (Ferraro et al., 1989), the programme galaxies are DDO 70 (Sextans B), DDO 209 (NGC 6822), DDO 210 and DDO 236