1. The Reddening and Metallicity

1.1. Optical Spectroscopy

Non-optimal scheduling of a run on the 6.5-m MMT left us with an opporunity at the end of the night on UT 21 Nov 2003 to obtain optical spectroscopy of the H II region found in HIZSS 3 by Massey et al. (2003). primary goal was to determine the reddening from spectrophotometry of the Hβ relative to Hα, with a secondary goal of determining the oxygen abundance if the [O II] λ3727 could be detected despite the high reddening. The data were obtained with the MMT Blue Channel spectrograph using a 500 l mm−1 grating with a dispersion of 1.18Åpixel^{-1} using a 2688x512 CCD. The slit was opened to 3.5 arcsec, resulting in a resolution of 10 pixels (12Å). No blocking filter was used in order to maximize the through-put, a choice which we felt was safe given that first-order Hα would be contaminated by second-order light at 3280Å. While this proved to be a good choice for the H II region, our bluest flux standards (G191B2B and Feige 34) showed evidence of a 10% contamination in the red compared to the flux standard Hilter 600, which has a large Balmer jump. We relied upon two observations of the latter for the flux calibration. The observations were all made as 8 1200 sec integrations, with the slit of the spectrograph reset to the parallactic angle at the beginning of each integration.

The spectra were extracting using the trace of an observation a the nearby offset star as the template. There is obvious structure within the slit due to brightness variations of the nebula, and this structure changed with the rotation angle. We therefore measured the intensity of the strongest lines (Hα, Hβ, and [OIII] λ 5007) from each individual spectrum. However, N[II] λ6584 and [OII] λ3727 are so weak that they could only be measured on the co-added spectrum. We show the co-added the spectra in Fig. X. The spectra went deep enough to clearly detect [OII]. We show three pertinent regions in Fig. 1

The relative emission-line strengths are given in Table 1. We see that the line ratio [OIII] λ5007 to [OIII] λ4959 is 2.8, in good agreement with the 2.9 usually assumed. The actual Hα flux measured is only about one-quarter the total Hα luminosity measured from direct images by Massey et al. (2003), due presumably to slit losses necessitated by remaining at the parallactic angle (position angle $\sim$ 0 degrees) which prevented the slit from being aligned with the H II region (position angle $\sim$ 130 degrees; see Fig. 3 of Massey et al. 2003).

Using the Cardelli, Clayton, & Mathis (1989) reddening law ($A_{H\beta} = 3.609E(B-V)$ and $A_{H\alpha} = 2.535E(B-V)$) and an intrinsic ratio Hβ/Hα=0.350, we derive a value for $E(B-V) = 1.41 \pm 0.04$, where the error represents the standard deviation of the mean for the 8 individual ratios. We give the corrrected flux ratios in Table 1 as well.

Without detecton of the temperature-sensitive [OIII]λ4363 line, we must rely upon the quasi-empirical relations between other emission line ratios and oxygen abundance in order to get an approximation of the metallicity of HIZSS 3. We estimate this three ways:

(1) Classical R_{23} method. The R_{23} ratio

$$R_{23} = \frac{[\mathrm{OIII}]\lambda 5007 + [\mathrm{OIII}]\lambda 4959 + [\mathrm{OII}]\lambda 3727}{\mathrm{H}\beta} = 5.50$$

has been calibrated by Skillman (1989) for the case that the oxygen abundance is much lower than solar. Using his formula results in a value $\log O/H + 12 = 7.5$.

(2) R_{23} method modified by [OIII]/[NII]. Edmunds & Pagel (1984) use a modified version of the R_{23} method, which relies upon using the strength of the N[II]λ6584 line as an additional calibration of R_{23}. We find

$$\log \frac{[\mathrm{OIII}]\lambda 5007 + [\mathrm{OIII}]\lambda 4959}{[\mathrm{NII}]\lambda 6584} = 2.22,$$

yielding a value of $\log O/H + 12 = 7.8$.

(3) R_{23} method modified by [OIII]/[OII]. McGaugh (1991) instead calibrates the R_{23} value with the relative strengths of [OIII] and [OII]:

$$\log \frac{[\mathrm{OIII}]\lambda 5007 + [\mathrm{OIII}]\lambda 4959}{[\mathrm{OII}]\lambda 3727} = 0.35.$$

This yields a value of $\log O/H + 12 = 7.85$.

We conclude that the the $\log O/H + 12 \sim 7.8$, comparable to other metal-poor irregular galaxies in the Local Group, i.e., IC 1613 (log O/H+12=7.85, Talent 1980), WLM (log O/H+12=7.77, Hodge & Miller 1985), and Pegasus (log O/H+12=7.93, Skillman, Bomans, & Kobulnicky (sp?) 1997). For comparison, the oxygen abundances of the LMC ans SMC are 8.37 and 8.13, respectively (Russell & Dopita 1990), while that of the solar neighborhood is 8.70 (Esteban & Peimbert, 1995).

1.2. Narrow-band Imaging

The ESO observations provide another powerful way of determining the reddening to HIZSS 3, namely by comparing the flux of the H II region at Pβ (1.28μm) to that at Hα. This technique has been recently exploited to good advantage in a study of spiral galaxies by Jones, Elston, & Hunter (2002). The only complication is the lack of spectrophotometric standards in the NIR, necessitating the use of model atmospheres with JHK standards. We are indebted to L. Jones for correspondance and advice on this subject.

The UKIRT standards (Hawarden et al. 2001) FS 112 (G0) and FS 121 (K3) were observed through the ISAAC narrow band 1.28μm filter (NB1.28) and J_s filters, as was the HIZSS 3 field. We adopted the Kurucz (1992) Atlas 9 $\log g = 4.5$ 6000°K and 4750°K models for these two stars, and computed their average flux over the NB1.28 filter with respect to the Atlas 9 Vega model. We then scaled the fluxes using the catalog J and K values. The relative count rates agreed with the relative fluxes to better than 10%, giving us confidence in our procedure. In order to deterine an emission-line flux for a line-source, we must also take into account the width of the filter; we computed $\int T_\lambda d\lambda / T_{1.28\mu\mathrm{m}} = 194$, where T_λ is the transmission of the filter as a function of wavelength. (See Jacoby, Africano, and Quigley 1987, but beware of an error in equation 3, in which $F_N(i)$ is used in place of the correct quantity $F_(i)$). The Pβ count rate was then measured after aligning the J$_s$ image to Pβ, and subtracting after matching the PSFs by convolution and scaling. The derived flux at Pβ is 9.88×10^{-15} ergs cm^{-2} s^{-1}. The observed ratio $(\mathrm{P}\beta/\mathrm{H}\alpha = 8.7 \times 10^{-2})_{\mathrm{obs}} = 0.45$ (where the flux at Hα has been taken from Massey et al. 2003) can be compared to the intrinsic ratio $(\mathrm{P}\beta/\mathrm{H}\alpha = 8.7 \times 10^{-2})_{\mathrm{int}} = 5.71 \times 10^{-2}$ (Osterbrock 1974). Combined with the Cardelli et al. (1989) reddening law, we then derive $E(B-V) = 1.32$. This value is in very good agreement with the value found from our optical spectroscopy, $E(B-V) = 1.41$.

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Table 1. Relative Emission-line Strengths

Spectral Line	Uncorrected Flux	Corrected Flux
[OII]λ3727	0.033	0.60
[OIII]λ4959	0.10	0.35
[OIII]λ5007	0.29	0.98
Hβ	0.087	0.35
Hα	1.000	1.00
[NII]λ6584	0.0080	0.0080

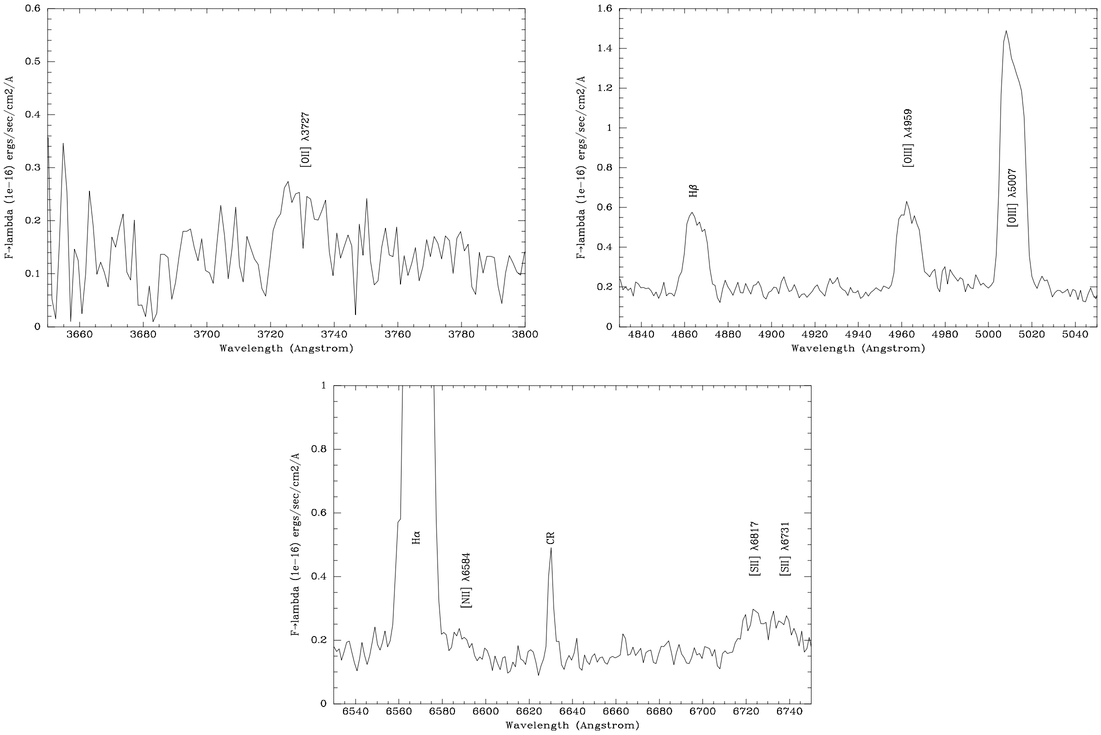

Fig. 1.— Three spectral regions in our summed spectrum of the H II region in HIZSS 3 are shown.