A CCD Hα Survey of Nearby Southern Spiral Galaxies

Stuart D. Ryder and Michael A. Dopita, Mount Stromlo and Siding Spring Observatories, Private Bag, Weston ACT 2611

Abstract: Some initial results of a flux-calibrated CCD Hα imaging program of bright, nearby southern spiral galaxies are presented. Very few southern hemisphere spiral galaxies have ever been completely imaged in Hα, let alone with a CCD. This survey (which mainly uses the MESSS0 1.0-m reflector with an f/3.5 focal reducer) will, when combined with spectrophotometry of the H II regions thus revealed, allow us to trace the chemical evolution of each galaxy. Furthermore, since the absolute Hα flux is a reliable measure of the high-mass star formation rate in a galaxy, such observational data will permit us to test the predictions of the various star formation theories.

1. Introduction
An enormous amount of information about star formation in spiral and irregular galaxies can be obtained from just one wavelength of the electromagnetic spectrum, the Hα line at 6563 Å. It is somewhat surprising that to date the only major Hα imaging survey is that by Hodge and Kennicutt (1983a), which consists of narrowband Hα interference-filter photographs taken with an image tube camera on the KPNO 2.1-m and 92-cm telescopes. A total of 10632 HII regions in 125 galaxies were catalogued. Lynds (1974) had earlier published Hα photographs of 41 galaxies. Despite the now widespread availability of CCDs, no similar survey on such a scale has yet been undertaken to utilise both their higher quantum efficiency and photometric precision. This is most likely due to their usually small field coverage on large-aperture telescopes. One major deficiency of both the Hodge and Kennicutt and the Lynds surveys is that only 17% of the galaxies surveyed lie south of the celestial equator. In an effort to rectify this situation, we have commenced an Hα interference-filter CCD imaging program of nearby southern spiral galaxies using focal reducers on both the MESSS0 1.0-m telescope and the 3.9-m Anglo-Australian Telescope.

The uses of such a survey of H II regions are many and varied. The Hodge and Kennicutt survey has allowed for a statistically significant study of the H II region populations in galaxies. The H II region luminosity function (LF) has been shown (Kennicutt et al. 1989) to follow a power law of the form:

\[ N(L) \propto L^{-2.65} \]

with either a turnover or a cutoff at \( \sim 10^{39} \) erg s\(^{-1}\). Early Hubble type galaxies have fewer H II regions at all luminosities, a steeper LF, and a more pronounced turnover. Recent CCD studies of H II regions in local group irregulars (Hodge et al. 1988, 1989a, 1989b, 1990) have tended to back these findings. A properly flux-calibrated Hα survey can also be used to estimate a galaxy’s present-day star formation rate, as demonstrated by Kennicutt (1983).

In the next section, we outline the observation and data reduction procedures. Then to illustrate some of our initial results, we derive the H II region luminosity function for the Magellanic-type barred spiral galaxy NGC 1313.

2. Observational Program
We are presently studying a sample of bright southern spiral galaxies satisfying the following criteria:

- Declinations in the range +15° to −90°
- Velocities < 1700 km s\(^{-1}\)
- Inclinations < 50°
- Diameters > 3 arcminutes
- Absolute magnitudes spanning the range −17 to −23.

The CCD observations are carried out on the MESSS0 1.0-m telescope, using an f/18 to f/3.45 focal reducer (Dopita and Hart 1976) to produce an 8.3′ × 12.5′ field of view, slightly vignetted. This arrangement permits the larger galaxies to be imaged with a single pointing, at a resolution of 1″. The more distant and fainter galaxies in the sample can be imaged using the same setup on the MESSS0 2.3-m telescope, in order to provide a similar spatial resolution for all the galaxies. Higher resolution narrow-band imaging of several local gas-rich galaxies is being carried out on the 3.9-m Anglo-Australian Telescope, using Taurus II as a focal reducer.

We have available four 75-mm diameter Hα filters, each with a 15Å bandpass, to cover continuously the velocity range −350 to +1750 km s\(^{-1}\). These filters are narrow enough to exclude the [N II] λ6548, 6583 lines, but can cause problems if the rotational velocity gradient across a galaxy is large. Typically, three 1000s exposures are obtained per galaxy using the appropriate Hα filter, followed by two 500s exposures through a 55Å-wide red continuum filter centred on 6676Å. A number of Magellanic Cloud planetary nebulae are observed each night to provide a flux calibration, using the spectrophotometry of Meatheringham and Dopita (1990). At least three twilight flatfield images per filter are also obtained each night.

After overscan subtraction and flatfielding, the multiple images are combined so as to eliminate cosmic ray events. The underlying continuum in the Hα images is removed by scaling and subtracting the red continuum image. Digital aperture photometry of the planetary nebula standards is used to flux-calibrate the data, after corrections are made for atmospheric extinction and the effects of temperature, filter tilt and beam focal ratio on the measured filter transmission function (Billhoff 1966). Finally, corrections for Galactic foreground extinction, and extinction within the galaxies and H II regions themselves should be estimated and applied in order to yield absolute fluxes and luminosities.

3. The H II Region Luminosity Function in NGC 1313
We have catalogued 158 distinct H II regions in the barred spiral galaxy NGC 1313 (Figure 1) down to a threshold of \( \sim 2 \times 10^{-16} \) erg cm\(^{-2}\) s\(^{-1}\) arcsec\(^{-2}\). Most of the nebulosity below this level takes the form of a diffuse background, with no discernible structure. For each region, the flux within a 10″ aperture has been measured, and then the contribution from the sky background removed. The value of the sky background is determined from an annulus surrounding the aperture using an appropriate algorithm, depending on whether nearby objects contaminate the sky annulus. These fluxes have been corrected for Galactic reddening only at this stage (0.10 mag at Hα according to Burstein and Heiles (1984)), and then converted to

Downloaded from https://www.cambridge.org/core, IP address: 54.70.40.11, on 24 Apr 2019 at 16:08:52, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/S1323358000025005
luminosities assuming a distance of 3.7 Mpc (Tully 1988). The luminosity distribution of the H II regions has been binned logarithmically, and is plotted in Figure 2.

The turnover in this function below \( \log(L) = 37.6 \) is mainly a result of incompleteness in our counts as faint H II regions drop below our detection threshold or blend in with brighter objects. The four brightest H II regions could be unresolved complexes of H II regions, or genuine 'giant' (30 Doradus-type) H II regions which seem to be a feature of Sc–Irr galaxies. At the other end of the range (\( L \lesssim 10^{37} \) erg s\(^{-1}\)) are those H II regions ionised by one or only a few OB stars; for comparison, the Orion nebula has an \( \text{H}\alpha \) luminosity of \( 10^{37} \) erg s\(^{-1}\) (Kennicutt 1984).

If we now plot the LF on a logarithmic scale (Figure 3), we find that the upper (complete) part of the LF, having \( \log L > 37.6 \) is indeed well fit by a power law of the form in equation (1), with a power law index of \( a = -1.9 \pm 0.1 \). Interestingly, this is intermediate between the values \( a = -2.1 \) and \( a = -1.75 \) derived by Kennicutt et al. (1989) for the Sc galaxy M101 and for the LMC respectively. Our H II region luminosity function is therefore consistent with NGC 1313 being a Magellanic-type barred spiral (de Vaucouleurs and Freeman 1972). The number of bright (\( L > 5 \times 10^{37} \) erg s\(^{-1}\)) H II regions, normalised in terms of both galaxy luminosity and surface area, is also consistent with the trends with Hubble type found by Kennicutt et al. (1989). By combining this empirical H II region luminosity function for NGC 1313 with theoretical estimates of the Lyman continuum luminosities, lifetimes and initial mass function of the ionising O and B stars, we will soon be in a position to determine the present-day rate of massive star formation in NGC 1313.