The Hα emission of the spiral galaxy NGC 7479

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Abstract. We use the catalogue of H ii regions obtained from a high quality continuum-subtracted Hα image of the grand design spiral galaxy NGC 7479, to construct the luminosity function (LF) for the H ii regions (over 1000) of the whole galaxy. Although its slope is within the published range for spirals of the same morphological type, the unusually strong star formation along the intense bar of NGC 7479 prompted us to analyze separately the H ii regions in the bar and in the disc. We have calculated the physical properties of a group of H ii regions in the bar and in the disc selected for their regular shapes and absence of blending. We have obtained galaxy-wide relations for the H ii region set: diameter distribution function and also the global Hα surface density distribution. As found previously for late-type spirals, the disc LF shows clear double-linear behaviour with a break at log $L_{H\alpha} = 38.6$ (in erg s$^{-1}$). The bar LF is less regular. This reflects a physical difference between the bar and the disc in the properties of their populations of regions.

1. Observations, data reduction and production of the H ii region catalogue.

The observations were made through the TAURUS camera on the 4.2m William Herschel Telescope on La Palma. The detector used was an EEV CCD 7 with projected pixel size 0”.279 $\times$ 0”.279. Observing conditions were good, with photometric sky and 0”.8 seeing. After standard reduction routines, we obtained the calibrated Hα continuum-subtracted image (Fig. 1) by subtracting an image through a non-redshifted filter to the image obtained through a 15 Å filter with central wavelength equal to the redshifted Hα emission from the galaxy and calibrating with observations of standard stars. As a selection criterion to construct the H ii region catalogue we specified that a feature must
contain at least nine contiguous pixels, each with an intensity of at least three times the r.m.s noise level of the local background. The r.m.s. noise of the background-subtracted Hα image is 15 instrumental counts, which means that lower limits to the luminosity of the detected H II regions, and to the radius of the smallest catalogued regions are, respectively, log L_{Hα} = 37.65 \text{ erg s}^{-1} and \approx 75 \text{ pc}. The detection and cataloguing of the H II regions were performed using a new program developed by C. Heller. The program identifies each H II region, measures the position of its centre, derives the area in pixels and the flux of each region, integrating all the pixels belonging to the region and subtracting the local background value. We catalogued 1009 H II regions in NGC 7479, and for all the H II regions we determined equatorial coordinate offsets from the nucleus and deprojected distances to the centre (in arcsec) using the inclination and position angles given by Laine & Gottesman (1998) (i = 51°, PA=22°). In Fig. 2 we show schematically the positions of the H II regions in the disc of NGC 7479, on a deprojected RA-dec grid centred on the nucleus of the galaxy.
2. Luminosity functions

The full count of H ii regions seen in Fig. 2 is presented in differential form, as a log-log plot in bins of 0.15 dex, in Fig. 3. The luminosity range in Hα is limited at the high end by the luminosity of the brightest detected region, and at the low end by our criteria for a detection. The limit of completeness is log L$_{H\alpha}$ = 38.0, so that the apparent broad peak in the distribution just below this luminosity is an artefact due to observational selection. The best single linear fit of the data to the points above log L$_{H\alpha}$ =38, corresponding to a power law

$$dN(L) = AL^\alpha dL,$$

has a gradient -0.83±0.06 (i.e. α=-1.83±0.06). We have also carried out a bi-linear fit, based on the evidence that at log L ~ 38.8 there is an apparent change in slope in the LF and we explained it as a manifestation of a transition in the physical properties of the regions, but in those cases the luminosity of the transition was always log L$_{Str}$ ~ 38.6 (~ 0.2 dex lower than in NGC 7479). As NGC 7479 is a barred
galaxy with unusually strong star formation in the bar, we tested the hypothesis that the differences in the LF might be due to this intense star formation activity under somewhat different physical conditions from those in the disc. To perform this test we constructed separately the LF’s for the 
H II regions of the bar and of the disc. The results are shown in Fig. 3 and the LF’s slopes are in Table II. In the LF for the 629 
H II regions detected in the disc (Fig. 5) the change in slope is cleaner than for the total LF and occurs at log $L=38.65\pm0.15$ (in 
$\text{erg s}^{-1}$). The change of slope, accompanied by a slight bump in the LF, has been detected in the seven galaxies so far examined in this degree of detail (see e.g. Rozas, Beckman & Knapen 1996, Knapen et al. 1993). Adding the value for NGC 7479 to the set of values previously

Figure 3. Luminosity function for the complete sample of H II regions from the catalogue with the best linear (a) and bi-linear fit (b), based on the previous experience with late-type spirals. (c) shows the bi-linear fit for the luminosity function of the H II regions of the disc; the change in slope is seen at log $L_{H\alpha}=38.65$. The luminosity function of the bar (d) is clearly less well-behaved than that for the disc.

measured for other galaxies, we find that the rms scatter in $L_{Str}$ in the
full set of objects is 0.08 mag. This low scatter can be explained if the IMF at the high luminosity end of the mass function changes little from galaxy to galaxy, i.e. varies little with metallicity. Another necessary condition is that the rate of emission of ionizing photons from a young stellar cluster rises more rapidly than the mass of its placental cloud, a condition which we have examined observationally (Beckman et al. 1999), and shown to hold. If we look at Fig. 3, where the LF for the 380 H II regions of the bar is presented, we can see clearly that the irregularity found in the total LF is due to the incorporation of the H II regions of the bar in the total LF. Clearly star formation conditions in the bar differ from those in the disc.

Table II. Luminosity limits, LF slopes and correlation coefficients for the two luminosity ranges (in erg s$^{-1}$) for the LF for the complete sample of H II regions from the catalogue and for the LF of the H II regions of the disc.

| range log L | α     | r   |
|------------|-------|-----|
| Total LF   | single linear fit | 38.1≤log L≤40.5 | -1.83±0.06 | 0.969 |
|            | bi-linear fit     | 38.1≤log L≤38.8 | -1.33±0.04 | 0.979 |
|            |                   | 38.8≤log L≤40.5 | -1.99±0.07 | 0.978 |
| Disc LF    | single linear fit | 37.9≤log L≤40.4 | -1.82±0.07 | 0.958 |
|            | bi-linear fit     | 37.9≤log L≤38.6 | -1.25±0.04 | 0.956 |
|            |                   | 38.6≤log L≤40.4 | -2.10±0.07 | 0.980 |

3. Other Statistical properties.

- The integral diameter distribution (number of regions with diameters greater than a given value as a function of diameter) is given in Fig. 4a. From our own and other published studies it has been found that the diameter distribution of the H II regions can be well fitted by an exponential of form $N(> D) = N_0 \exp(-D/D_0)$ where $D_0$ is a characteristic diameter, and $N_0$ is an (extrapolated) characteristic value for the total number of regions. From the observations represented in Fig. 4a, we obtain the values $N_0=5000±300$ and $D_0=110±2$ pc (with $H_0=75$ km s$^{-1}$Mpc$^{-1}$). $D_0$ has a value predicted for a galaxy of its measured absolute luminosity according to the observational plot of $D_0$ versus luminosity (Hodge 1987).

- The flux density distribution is shown in Fig. 4b. It was found by dividing the disc into rings using the values of P.A. and $i$ of
the galaxy (Table I). There is a clear trend to lower flux, with increasing radius, which clearly reflects the standard radial decline in surface density of each major component of this disc galaxy. This underlying radial flux density can be fitted by an exponential of form \( f(r) = B \exp(-r/h_{\text{H}\alpha}) \) from which we derive a value for the \( \text{H}\alpha \) scale length, \( h_{\text{H}\alpha} = (2.4 \pm 0.3) \text{ kpc} \).

4. Physical properties.

Using a distance to NGC 7479 of 31.92 Mpc we employed the standard theoretical formula (Spitzer 1978) relating the surface brightness of an \( \text{H}\\alpha \) region with its emission measure (Em), (assuming case B recombination and \( T \sim 10^4 \text{ K} \)) to calculate the Em of the \( \text{H}\\alpha \) regions. We performed this for a total of 39 regions, (22 in the disc and the rest in the bar), covering the full range of observed radii and chosen as isolated to minimize the uncertainties in calculating their luminosities due to the overlapping. Results are shown in Fig. 5a.

In Fig. 5b, we show the rms electron density (derived from the Em, \( < N_e >_{\text{rms}} = \sqrt{Em/r} \)) plotted against radius of the \( \text{H}\\alpha \) region. The general ranges and behaviour of Em and \( < N_e >_{\text{rms}} \) for NGC 7479...
agree well with those found by Kennicutt 1984 and by ourselves (Rozas, Knapen & Beckman 1996) for extragalactic H II regions. Due to observational selection, these tend to be more luminous and larger than Galactic regions.

We also computed the filling factors, using $\delta = (\langle N_e \rangle_{rms} / N_e)^2$. The implicit model is that an H II region is internally clumpy, so that the observed flux comes from a high density component, which occupies a fraction $\delta$ (filling factor) of the total volume; the rest of the volume is filled with low density gas which makes a negligible contribution to the observed emission line strengths.

To calculate $\delta$, we need to know the in situ $N_e$ for each region. We have not measured these values for NGC 7479, but have used a “canonical” mean value of $135 \, \text{cm}^{-3}$ obtained by Zaritsky et al. 1994 for 42 H II regions in a large sample of galaxies. The filling factors for the regions range from $4.3 \times 10^{-4}$ to $1.5 \times 10^{-3}$, a range which coincides well with those found for 4 galaxies in Rozas et al. 1996b.

Values of $\langle N_e \rangle_{rms}$ can also be used to estimate the mass of ionized gas, which range from $3000 M_\odot$ to $1.5 \times 10^6 M_\odot$. These physical properties, the emission of Lyman continuum photons and the equivalent number of O5V stars required to supply the luminosity of the regions are given in a more detailed paper (Rozas, Zurita & Beckman 1998).

![Emission measure versus radius (a.), $rms$ electron density versus radius (b.) for the 39 selected H II regions in NGC 7479.](image)

*Figure 5.* Emission measure versus radius (a.), $rms$ electron density versus radius (b.) for the 39 selected H II regions in NGC 7479.
5. Conclusions

The main results of the present work, where we analyze the statistics and properties of H II regions in NGC 7479 are summarized below.

- Using a high quality continuum-subtracted Hα image of the grand-design spiral NGC 7479, we have catalogued 1009 H II regions.
- The slope of the LF agrees broadly with slopes for other galaxies of comparable morphological types.
- We have found a change in slope in the LF of the H II regions of NGC 7479 that occurs at a luminosity slightly higher (≃ 0.2 dex) than that found in other galaxies of the same morphological type. Due to the intense star formation in the bar of NGC 7479, we decided to construct separately the LF’s for the H II regions of the bar and of the disc, finding:
  1. the LF of the disc is in no way different from that found in previous papers for galaxies of the same morphological type,
  2. The anomaly in the global LF is thus due to different star formation conditions in the bar. This must be due to the effects of gas dynamical parameters on the stellar IMF, and the physical conditions in the clouds.
- The integrated distribution function of the H II region diameters can be well fitted by an exponential function.
- The densities, filling factors and masses derived from the luminosities and sizes of a selected set of representative regions, through the range of observed luminosities for NGC 7479, are in agreement with those found in the previous literature on extragalactic H II regions.

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