High resolution imagery of the clumpy irregular galaxy Markarian 325 = NGC 7673

G. Coupinot and J. Hecquet Observatoire du Pic-du-Midi
J. Heidmann Observatoire de Paris

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Summary. High resolution imagery of the clumpy irregular galaxy Mkn 325 shows that some clumps have sizes \( \sim 300 \text{ pc} \) while some may still be unresolved and \( \leq 100 \text{ pc} \). In spite of dimensions comparable to — or even smaller than — those of the giant \( \text{H} \text{\textsc{ii}} \) complex 30 Doradus, one clump has a star formation rate 100 times higher.

1 Introduction

The galaxy NGC 7673 = IV Zw 149 = Mkn 325 = UGC 12607 = MCG 4-55-14 is a non-Seyfert Markarian galaxy exhibiting several bright compact spots (Vorontsov-Vel'yanov & Arhipova 1964; Sargent 1970; Zwicky 1971). Optical spectra are typical of \( \text{H} \text{\textsc{ii}} \) regions (Sargent 1970; Bottinelli et al. 1975). Its morphology shows an agglomeration of eight clumps scattered in a common triangular envelope, with tails and bridges, typical of clumpy irregular galaxies (Casini & Heidmann 1976a, b). \( UBV \) photometry by Huchra (1977) leads to \( U - B = -0.43 \) and to the very high absolute \( B \) magnitude \( -22.1 \) (with a Hubble constant \( 75 \text{ km s}^{-1} \text{ Mpc}^{-1} \)). Mkn 325 has also a wide 21-cm neutral hydrogen line and forms a physical stable pair with Mkn 326 which lies 95 kpc away (Bottinelli et al. 1975). In the far ultraviolet its clumps each radiate on the mean 120 times more than the giant \( \text{H} \text{\textsc{ii}} \) region 30 Doradus and as much as 5000 08V + 20000 B8I stars (Benvenuti, Casini & Heidmann 1980, 1982).

Here we present new data from high resolution imagery obtained from first-light photographs of the recently operating 2-m telescope at Pic-du-Midi.

2 Observations

Plates were taken in 1980 September at the \( f/25 \) Cassegrain focus of the Pic-du-Midi 2-m telescope behind an ITT F4708 single-stage image tube with a S-20 extended red photocathode. Exposures were 2–8 min, the scale 4 arcsec mm\(^{-1}\) and the seeing around 0.8 arcsec (Plate 1). The plates were scanned with the PDS microdensitometer of the Centre de Dépouillement des Clichés Astronomiques in Nice using a 40 \( \times \) 40 \( \mu \text{m} \) slit.
A set of flat field plates with known relative intensities were used to calibrate the system (Fig. 1). The tube can be used up to 15 mm from its centre. If we divide this region into three zones, the calibration curves obtained are similar to those from Tri-X film, have the same slope in their linear parts and can be superimposed by a translation. In order to obtain photometry at the 5 per cent level one should use the three different curves. We used the mean one instead, attaining an accuracy of 15 per cent. The set of isophotes obtained has then been deconvolved by a Fourier transform method with an apodizing filter (Coupino & Hecquet 1979). The smearing function used was taken as the sum of two Gaussians whose parameters were evaluated through fitting to the profile of a star in our field (40 arcsec north of clump I, Fig. 2). This restoration analysis gave a resolution of 0.5 arcsec for our 2-min exposure plate (Fig. 2).

Figure 1. Photographic densities versus distance from centre of image tube plates in mm for various uniform field exposures.

Figure 2. High-contrast deconvolved intensity isophotal map of Mkn 325 2-min exposure. Clumps are labelled A–J from west. North is up; 10 arcsec and 2 kpc scales are given. Resolution is 0.5 arcsec.
Plate 1. Pic-du-Midi 2-m telescope photograph of Mkn 325. One-stage image tube 2 min exposure. North is up, east left; 10 arcsec and 2 kpc scales are given. Seeing is 0.9 arcsec.
3 Sizes of the clumps

The gain in resolution over previous photographs gives interesting results. The strongest clump to the NE, which was described as elongated by Casini & Heidmann, is now resolved into two components, I and J, separated by 1.1 arcsec. At a distance of 49 Mpc, this corresponds to 260 pc (1 arcsec = 240 pc). More clumps appear distinctly. They are labelled in Fig. 2. The fat elongated main mass to the SW breaks down into a wavy conglomeration of five of them, B—F, separated by 1.2 arcsec or 280 pc. Some, like B or H, appear resolved with dimensions reaching 1.2–1.4 arcsec, i.e. ~300 pc. Some, like C, may still be unresolved, with sizes smaller than or comparable to 100 pc.

On our longer exposure photograph the isophotes include the peculiar faint 19th magnitude elongated object 0.4 arcmin to the north of and pointing towards the centre of Mkn 325 which was noted by Vorontsov-Vel’yaminov & Arhipova (1964). It is similar (Casini & Heidmann 1976b) to the one noted by Arp (1966) pointing towards the nucleus of UGC 5029 which is physically paired with Mkn 111 = Arp 300 (Casini, Deniszuk & Heidmann 1981). However, we cannot decide whether the isophotal link corresponds to a photographic effect or to a physical association.

4 Magnitudes of the clumps

As a first step we evaluated the relative intensities of the clumps using a model for the galaxy made up of a number of point sources spread by the smearing function plus a continuum background with surface brightness constant around each group of clumps but different from one group to the other. Then we measured the intensity of clump J in two ways: by comparing the intensity integrated over clumps I and J to that integrated over our field star or to total intensity of the whole galaxy. The magnitude of the star was found to be $B = 16.6$ from its diameter on the Palomar Sky Survey and using King & Raff’s (1977) relation. The magnitude of the galaxy was taken as $B = 13.4$ from Huchra’s (1977) value in a 41 arcsec diaphragm, close to the size of our region of integration. We use the B system, close enough to the response of the instrument, thus obtaining $B = 17.3$ for clump J by both methods. Table 1 gives the relative intensities and apparent magnitudes of the clumps.

The clumps are extraordinarily luminous. Their mean apparent magnitude is 17.5. With a galactic absorption $A_B = 0.31$ (de Vaucouleurs, de Vaucouleurs & Corwin 1976) this corresponds to a mean corrected absolute magnitude $-16.2$ or an intrinsic luminosity of $4.4 \times 10^8 L_\odot$. Similar results were obtained for the two other clumpy irregular galaxies

<table>
<thead>
<tr>
<th>Clump</th>
<th>Relative intensity</th>
<th>Apparent magnitude</th>
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<tbody>
<tr>
<td>A</td>
<td>0.30</td>
<td>18.6</td>
</tr>
<tr>
<td>B</td>
<td>0.62</td>
<td>17.8</td>
</tr>
<tr>
<td>C</td>
<td>1.37</td>
<td>17.0</td>
</tr>
<tr>
<td>D</td>
<td>0.82</td>
<td>17.5</td>
</tr>
<tr>
<td>E</td>
<td>0.88</td>
<td>17.4</td>
</tr>
<tr>
<td>F</td>
<td>1.50</td>
<td>16.9</td>
</tr>
<tr>
<td>G</td>
<td>0.36</td>
<td>18.4</td>
</tr>
<tr>
<td>H</td>
<td>0.20</td>
<td>19.0</td>
</tr>
<tr>
<td>I</td>
<td>1.07</td>
<td>17.2</td>
</tr>
<tr>
<td>J</td>
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<td>17.3</td>
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Mkn 7 and 8 by Börngen & Kallohogliam (1974). It is interesting to relate this luminosity to the information obtained on the early star content of Mkn 325 from IUE ultraviolet spectra (Benvenuti et al. 1980, 1982). The short wavelength (115–200 nm) spectrum of Mkn 325 included clumps B–H in the IUE slit and was interpreted as due to the radiation of $3.0 \times 10^4$ O8V + $8.0 \times 10^4$ B8Ia stars. Using, for example, Allen’s (1973) data on the optical luminosities of such stars, one finds that in the optical range the stars implied by the IUE observations radiate $4.4 \times 10^9 L_\odot$. On the other hand, from our present Pic-du-Midi observations clumps B–H radiate $3.1 \times 10^9 L_\odot$. The agreement is remarkable and gives further weight to the conclusion obtained from the IUE data that the clumps are hyperactive H II complexes in which star formation occurs on an exceptional scale.

5 Conclusion

High resolution imagery of the clumpy irregular galaxy Mkn 325 has shown that some clumps have dimensions ~ 300 pc while others may still be unresolved with diameters < 100 pc. The large ones are comparable in linear dimensions to the giant H II complex 30 Doradus in the Large Magellanic Cloud — see e.g. the 5000 GHz map by McGee, Brooks & Batchelor (1972, fig. 11), where 500 pc ~ 30 arcmin. The most interesting fact is that, in spite of having comparable — or even smaller — linear dimensions, a clump has undergone a burst of star formation producing on average a hundred times as many early type stars as 30 Doradus (Benvenuti et al. 1980, 1982). This leads to the working hypothesis that a clump is a complex of overall size similar to the large scale dimension of the 30 Doradus giant H II region — i.e. a few hundred pc — stuffed or packed with a hundred active regions each comparable in luminosity to the Doradus core, with sizes < 100 pc. Yet, smaller still more compact clumps could exist.

In order to test this model and to investigate the unusual physical conditions of such packing, further high resolution work on clumpy galaxies is contemplated with the Pic telescope and more especially with the Faint Object Camera of the Space Telescope (Heidmann 1979, 1980; Casini et al. 1980).

References

High resolution imagery of Mkn 325

