The stars and gas in the region of N 63A (LMC)*

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Summary. N 63A is located in the cluster NGC 2030 of the LMC. From VBLUW observations of some cluster stars we derive $A_V = 0.6$ mag reddening in the direction of N 63A; the age of the cluster is estimated as $\sim 4 \times 10^6$ yr. VBLUW observations indicate the western knot of N 63A to be excited by an 05–9 main sequence star. The north-eastern and southern knots form the known SNR. Fabry-Perot observations indicate a velocity range of 100–300 km s$^{-1}$ for the SNR gas.

Key words: photometry – FP interferometry – stellar cluster – H II region – supernova remnants

1. Introduction

The nebula N 63A of the Large Magellanic Cloud (LMC) (Henize’s catalog, 1956; DEM 243 of Davies et al., 1976) is identified by Mathewson and Healey (1964) and Westerlund and Mathewson (1966) as a supernova remnant (SNR) of type II. From spectroscopic observations Danziger and Dennefeld (1974) and Dopita et al. (1977) concluded however that part of the nebula is photoionized. The comparison of Hα and [S II] pictures taken by Lasker (1976) reveals the ionized western knot of N 63A to be associated with a star believed to be the exciting star.

N 63A is one of the smallest SNRs of the LMC; recently it was studied by Danziger and Leibowitz (1985). The SNR is located near the center of the stellar cluster NGC 2030. From VBLUW observations of some cluster stars we derive the reddening in the direction of N 63A; from the Hertzprung-Russell (HR) diagram of this cluster we estimate its age. We use VBLUW observations to deduce the intrinsic colours, spectral type and absolute visual magnitude of the star inside the ionized region. From Fabry-Perot observations we derive the kinematics of N 63A and of the surrounding nebula N 63.

2. The Cluster NGC 2030

We have used the VBLUW photometer (Walraven and Walraven, 1960; Rijf et al., 1969; Lub and Pel, 1977), attached to the 90 cm Dutch telescope at European Southern Observatory, Chile, to measure the brighter members ($V < 15$ mag) of NGC 2030. The photometric data, not corrected for reddening, are given in Table 1; the stars are identified in Fig. 1. In Table 1, the apparent visual magnitude $V_j$ in the UBV system (denoted by the index $J$) is derived from the relation (Lub and Pel, 1983)

$$V_j = 6.889 - 2.5 [V + 0.039 (V - B)].$$

The absolute visual magnitudes $M_V$, also given in Table 1, are calculated using a distance modulus 18.6. From the positions in the VBLUW colour diagrams we identify the cluster stars as OB stars. With this identification we derived the individual reddenings $A_V$, given in Table 1; the average reddening in the direction of N 63A is $\langle A_V \rangle = 0.6$ mag. In the VBLUW system this reddening is equivalent to $A_V = 0.15$, $E(V - B) = 0.06$, $E(B - U) = 0.04$, $E(B - L) = 0.02$.

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* Based on observations collected at ESO, La Silla, Chile

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Table 1. *VBLUW* colours (system 1980) of stars of the cluster NGC 2030 containing N 63A; not corrected for reddening; observations Dec. 1980

<table>
<thead>
<tr>
<th>Star</th>
<th>(V)</th>
<th>(V-B)</th>
<th>(B-U)</th>
<th>(U-W)</th>
<th>(B-L)</th>
<th>(E(V-B))</th>
<th>(V_J)</th>
<th>(A_{V_J})</th>
<th>((B-V)_{0})</th>
<th>(M_{V_J})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log. intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-2.171</td>
<td>-0.032</td>
<td>-0.060</td>
<td>-0.009</td>
<td>-0.039</td>
<td>0.07</td>
<td>12.31</td>
<td>0.65</td>
<td>-0.31</td>
<td>-7.0</td>
</tr>
<tr>
<td>2</td>
<td>-2.806</td>
<td>-0.053</td>
<td>-0.045</td>
<td>-0.024</td>
<td>-0.036</td>
<td>0.05</td>
<td>13.90</td>
<td>0.42</td>
<td>-0.30</td>
<td>-5.7</td>
</tr>
<tr>
<td>3</td>
<td>-3.149</td>
<td>-0.032</td>
<td>-0.039</td>
<td>-0.008</td>
<td>-0.026</td>
<td>0.07</td>
<td>14.76</td>
<td>0.65</td>
<td>-0.31</td>
<td>-4.5</td>
</tr>
<tr>
<td>4</td>
<td>-2.552</td>
<td>-0.008</td>
<td>-0.042</td>
<td>-0.010</td>
<td>-0.020</td>
<td>0.10</td>
<td>13.26</td>
<td>0.85</td>
<td>-0.32</td>
<td>-6.2</td>
</tr>
<tr>
<td>5</td>
<td>-2.588</td>
<td>-0.038</td>
<td>-0.053</td>
<td>-0.012</td>
<td>-0.028</td>
<td>0.06</td>
<td>13.35</td>
<td>0.51</td>
<td>-0.29</td>
<td>-5.8</td>
</tr>
<tr>
<td>6</td>
<td>-2.834</td>
<td>-0.044</td>
<td>-0.060</td>
<td>-0.012</td>
<td>-0.034</td>
<td>0.05</td>
<td>13.97</td>
<td>0.42</td>
<td>-0.29</td>
<td>-5.1</td>
</tr>
<tr>
<td>7*</td>
<td>-2.436</td>
<td>-0.061</td>
<td>-0.086</td>
<td>-0.036</td>
<td>-0.046</td>
<td>0.04</td>
<td>12.97</td>
<td>0.34</td>
<td>-0.29</td>
<td>-6.0</td>
</tr>
<tr>
<td>8</td>
<td>-3.081</td>
<td>-0.037</td>
<td>-0.104</td>
<td>-0.014</td>
<td>-0.032</td>
<td>0.07</td>
<td>14.58</td>
<td>0.60</td>
<td>-0.31</td>
<td>-4.6</td>
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<tr>
<td>9</td>
<td>-2.932</td>
<td>-0.055</td>
<td>-0.075</td>
<td>-0.019</td>
<td>-0.046</td>
<td>0.05</td>
<td>14.19</td>
<td>0.42</td>
<td>-0.30</td>
<td>-4.8</td>
</tr>
<tr>
<td>10</td>
<td>-2.864</td>
<td>-0.029</td>
<td>-0.083</td>
<td>-0.015</td>
<td>-0.017</td>
<td>0.13</td>
<td>14.04</td>
<td>1.09</td>
<td>-0.31</td>
<td>-5.7</td>
</tr>
<tr>
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<td>-2.737</td>
<td>-0.060</td>
<td>-0.051</td>
<td>-0.032</td>
<td>-0.033</td>
<td>0.04</td>
<td>13.73</td>
<td>0.34</td>
<td>-0.29</td>
<td>-5.2</td>
</tr>
<tr>
<td>12</td>
<td>-3.091</td>
<td>-0.003</td>
<td>-0.082</td>
<td>-0.025</td>
<td>-0.051</td>
<td>0.11</td>
<td>14.61</td>
<td>0.94</td>
<td>-0.32</td>
<td>-5.0</td>
</tr>
<tr>
<td>13</td>
<td>-3.205</td>
<td>-0.034</td>
<td>-0.039</td>
<td>-0.004</td>
<td>-0.044</td>
<td>0.07</td>
<td>14.89</td>
<td>0.60</td>
<td>-0.31</td>
<td>-4.3</td>
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<tr>
<td>14</td>
<td>-2.982</td>
<td>-0.039</td>
<td>-0.025</td>
<td>-0.026</td>
<td>-0.040</td>
<td>0.06</td>
<td>15.32</td>
<td>0.51</td>
<td>-0.29</td>
<td>-3.8</td>
</tr>
<tr>
<td>15</td>
<td>-3.374</td>
<td>0.125</td>
<td>-0.460</td>
<td>-0.418</td>
<td>-0.386</td>
<td></td>
<td>17.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The positions of the stars and the nebulosity \(N\) are indicated in Fig. 1

a Possibly influenced by nearby star

Table 2. *VBLUW* colours (system 1980) of the H II region PLUS the star in N 63A (LMC) for different diameters of the diaphragm. Observations: 30/31 Dec. 1983

<table>
<thead>
<tr>
<th>Diaphragm ((d))</th>
<th>(V)</th>
<th>(V-B)</th>
<th>(B-U)</th>
<th>(U-W)</th>
<th>(B-L)</th>
<th>(V_J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log. intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.5</td>
<td>-2.852</td>
<td>0.002</td>
<td>-0.231</td>
<td>0.215</td>
<td>-0.203</td>
<td>14.0</td>
</tr>
<tr>
<td>16.5</td>
<td>-2.881</td>
<td>-0.001</td>
<td>-0.222</td>
<td>0.113</td>
<td>-0.189</td>
<td>14.1</td>
</tr>
<tr>
<td>11.6</td>
<td>-2.968</td>
<td>0.004</td>
<td>-0.215</td>
<td>0.170</td>
<td>-0.182</td>
<td>14.3</td>
</tr>
<tr>
<td>8.3</td>
<td>-3.123</td>
<td>-0.022</td>
<td>-0.168</td>
<td>0.110</td>
<td>-0.141</td>
<td>14.7</td>
</tr>
<tr>
<td>5.8</td>
<td>-3.442</td>
<td>-0.041</td>
<td>-0.171</td>
<td>0.048</td>
<td>-0.136</td>
<td>15.5</td>
</tr>
</tbody>
</table>

The picture of NGC 2030 by van den Bergh and Dufour (1980) shows a faint emission of the nebula N 63 in the outer regions of the cluster. A photometric measurement of the nebula at the position indicated in Fig. 1 reveals a brightness \(V_J \geq 17\) mag inside the diaphragm of 16·5 diameter; the photometric data are given in Table 1. In the reduction of the stellar photometry this nebular emission is not taken into account because of its low brightness.

We show in Fig. 2 the HR diagram of the observed cluster stars together with the empirical isochrones of the galactic cluster groups NGC 6231, NGC 2362, NGC 3766 taken from Mermilliod (1981a, b). Van Genderen et al. (1984) determined the age of NGC 6231 as 4 \(10^6\) yr. When comparing the LMC cluster NGC 2030 and the galactic cluster NGC 6231 the difference in abundance has little influence on OB stars, hence Fig. 2 suggests that NGC 2030 and NGC 6231 are of similar age, i.e. \(\sim 4 \times 10^6\) yr. This agrees with the range 3–6 \(10^6\) yr found by Copetti et al. (1985).

Our photometric data (Table 1) agree with the observations by van den Bergh and Dufour (1980). From kinematic arguments (radius of NGC 2030 \(\sim 17\) pc, assumed expansion velocity: \(10\) \(\text{km s}^{-1}\)) these authors obtain \(1.7 \times 10^6\) yr for the age of NGC 2030. However, kinematical ages are usually smaller than the ages obtained by other means (Blauuw, 1978; de Zeeuw and Brand, 1985).

3. Colours of the exciting star

The Hα, [SII] pictures by Lasker (1976) indicate a star coincident with the ionized western knot of N 63A. With the *VBLUW* photometer we obtained colours for the ionized H II region plus the star for different sizes of a circular diaphragm centered on the star. The photometric data, not corrected for reddening, are given in Table 2.

From the differential measurements we derived the intrinsic colours, spectral type and absolute visual magnitude \(M_{V_J}\) of the star. If we assume a uniform brightness \(i(N)\), per unit area, of the nebula inside the diaphragm of diameter \(d = 2r\), and denote by \(i(*)\)
Table 3. Intrinsic VBLUW colours for the star and the H II region of N 63A; corrected for reddening of \( A_V = 0.6 \) mag

<table>
<thead>
<tr>
<th>Object</th>
<th>( V )</th>
<th>( V-B )</th>
<th>( B-U )</th>
<th>( B-L )</th>
<th>( V_J )</th>
<th>( M_V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star</td>
<td>-3.26</td>
<td>-0.10</td>
<td>-0.05</td>
<td>-0.06</td>
<td>15.0</td>
<td>-3.6</td>
</tr>
<tr>
<td>H II</td>
<td>-2.85</td>
<td>-0.05</td>
<td>-0.16</td>
<td>-0.12</td>
<td>14.0</td>
<td></td>
</tr>
</tbody>
</table>

* For diaphragm \( d = 16.5' \)

the brightness of the star, then the intensity \( I(X, r) \) inside the passband \( X \) of the VBLUW system is

\[
I(X, r) = \pi r^2 i(N, X) + i(\ast, X).
\]

The values \( I(X, r) \) were derived from the observations using the equations of the photometric system (Lub and Pel, 1977). With a least square procedure we derived from \( I(X, r) \) the values \( i(\ast, X) \), \( i(N, X) \) which then were used to determine the intrinsic colours of the star and the H II region. We neglected the \( W \) filter because of the narrow passband and low intensities. The least square procedure was also performed neglecting the data obtained with the 57\'8 diaphragm because of uncertainties in the centering. We repeated the calculations adopting filling factors of 0.5–0.7 for the 16\'5 diaphragm thus taking into account the somewhat asymmetric structure of the H II region. We estimate the intrinsic colours and \( V_J \) of the star to be accurate within [0.06] and [0.5] mag, respectively.

The intrinsic colours of the star and the H II region (for \( d = 16.5' \), corrected for \( A_V = 0.6 \) mag reddening, are given in Table 3. The colours indicate a main sequence star of spectral type 0.5–9 with \( M_V = -3.6 \pm 0.5 \) mag using a distance modulus 18.6 (Feast, 1983). Assuming that the star is associated with N 63A, i.e. is not a background star, the luminosity is sufficiently large to ionize a H II region of \( ~4 \) pc diameter with \( 6 < n_e < 16 \) cm\(^{-3} \) (Panagia, 1973; Georgelin et al., 1975) (\( n_e \) is the electron density). Therefore this star can ionize the 6 pc knot (see dimensions in Sect. 4) assuming a lower density.

Although the errors in \( M_V \) and \( (B-V)_J \) are quite large, Fig. 2 indicates that this star is a fainter member of intensity NGC 2030. The intrinsic colours of the ionized nebula, given in Table 3, are typical for H II regions (Greve et al., 1982; Greve and Genderen, 1986).

4. Gas kinematics

The observations were obtained during a H\( \alpha \) survey of 68 nebulae of the LMC (Georgelin et al., 1983). They were performed at the 3.60 m ESO telescope at La Silla, Chile; the receiver was a two-stage RCA image tube. For details of the measuring method, see also Rosado et al. (1981, 1982).

The 8' field permits the analysis of both the N 63 diffuse region and the N 63A SNR, embedded in N 63. The interferometric technique gives two-dimensional velocity information which completes the results obtained by Dopita (1979) along two positions of an \( E-W \) slit. The large scale on the interferometer plate (46 mm\(^{-1} \)) associated with the chosen free spectral range (285 km s\(^{-1} \)) prevents confusion with density distortions.

The diffuse nebula: The mean velocity of the 6' diameter diffuse region is obtained from 220 measured points as \( 298 \pm 7 \) km s\(^{-1} \) (Fig. 3). This value is near to the velocity of 308 km s\(^{-1} \) for the H I layer determined by Rohlfs et al. (1984). Such a small velocity dispersion agrees with the young age of the ionizing cluster. The luminous stars of NGC 2030 do not sufficiently perturb the gaseous matter by their stellar winds to allow detection using this observing method.

The velocities of the western photoionized knot and the diffuse region are found to be equal. Figure 4 shows H\( \alpha \) contours from the H\( \alpha \) photograph by Lasker (1976) superimposed onto the interferometric rings. The 5' wide ring cuts across the intense 12' western knot, thus confirming a low velocity dispersion. The knot velocity is not contaminated by the motions of the SNR.

Figure 5 shows H I contours from Rohlfs et al. (1984) superimposed on a photograph taken by Davies et al. (1976). N 63 is located along the edge of a neutral plateau. With the assumption of a spherical symmetry an upper density limit \( n_H < 3 \) cm\(^{-3} \) can be evaluated. Lower H I densities should be found on the western edge of N 63. In young H II regions evolving on the edge of molecular clouds, we expect to find gas motions as a consequence of stellar winds, and, less importantly, of the "champagne evolution" described by Tenorio-Tagle (1979; et al., 1979; Deharveng, 1980). In N 63 neither gas motions nor an important absorption (see also Caplan and Deharveng, 1985) can allow such assumptions at the moment.
The SNR: The northern and south-eastern knots correspond to widenings of the ring reaching respectively 200 km s\(^{-1}\) and 140 km s\(^{-1}\). These knots correspond to the low-excitation region identified as a SNR from spectra by Danziger and Dennefeld (1974). This SNR coincides perfectly with the shell revealed in the \([S\, II]\) photograph taken by Lasker (1976) (Fig. 6).

We obtain the whole velocity range of N 63A using the Fabry-Perot method since the applied free spectral range is higher than the velocity enlargement. From Fig. 4 one can deduce the velocity limit from the well-visible avoidance zone. Therefore, the LSR velocity range within the SNR is found to be 100–300 km s\(^{-1}\). Previous determinations from slit spectroscopy (Dopita, 1979) fall within these limits.

N 63A also is an extended X-ray source of 3′ diameter (Mathewson et al., 1983) hence much larger than the optical emission; it is possible that some much fainter part of the SNR gas has not yet been detected optically along the line of sight of the diffuse gas.

5. Conclusions

We confirm that N 63A consists of two different objects: an intense photoionized knot (H\(\alpha\) region) and a SNR.

The kinematical data show that the ionized western knot is a part of the diffuse nebula N 63. This ionized region is excited by an
05–9 main sequence star with $M_V = -3.6 \pm 0.5$ mag belonging to the fainter members of NGC 2030. The age of this cluster is $\sim 4 \times 10^6$ yr. The cluster NGC 2030 is the ionizing source for the larger nebula N 63. We could not detect any motion of gas in the diffuse nebula caused either by supernova explosions or by stellar winds. This could be a consequence either of superimposed stellar and gaseous positions along the same line of sight, or of the faint emission from the expected moving layers.

The velocities in the SNR are in the range of 100–300 km s$^{-1}$. This velocity range is rather low compared to other SNR of the LMC. Some part of the gas, along the line of sight of the diffuse nebula N 63, remains still to be detected.

Acknowledgements. We are indebted to Dr. J. Lub who wrote the computer programs for various parts of the automatic data reduction, and to A. Viale for data measurements.

References


