SOME EXTENDED RADIO SOURCES IN MONOCEROS

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Summary

High resolution observations at 178 MHz have been made of the galactic plane near $l^\Pi = 205^\circ$. The structure of the Rosette Nebula is in agreement with high frequency work; from the present results in conjunction with data at 38 MHz an electron temperature of 8600 K is derived for the Nebula. The Monoceros Nebulosity, whose structure has been resolved for the first time, is discussed in detail; its properties suggest that it is a supernova remnant. Other objects observed in the region are discussed more briefly.

1. Introduction. A high resolution survey at 178 MHz of large sections of the northern sky has been carried out at the Mullard Radio Astronomy Observatory using a pencil-beam telescope (Crowther & Clarke 1966) with a beam-width between half-power points of 24 arcmin in R.A. and 18 sec (52\(\degree\) 10\('\) 8\('\)) in declination $\delta$. Complete maps have been published already (Caswell, Crowther & Holden 1967) and in the present paper detailed consideration is given to a region near $l^\Pi = 205^\circ$, $b^\Pi = 0^\circ$, extending from R.A. 06$^h$ 10$^m$ to 06$^h$ 50$^m$ and from declination +02$^\circ$ to +08$^\circ$.

The contours of brightness temperature at 178 MHz for this region are shown in Fig. 1, where the scale is nearly equi-angular. The contour interval is 24 K; an unresolved source with a peak response of one contour interval would have a flux density of $0.88 \times 10^{-26}$ sec (52\(\degree\) 10\('\) 8\('\)) w m$^{-2}$ Hz$^{-1}$. The zero level corresponds to a brightness temperature of 220 K.

The most striking object in the region is the Rosette Nebula at R.A. 06$^h$ 29$^m$, $\delta +05^\circ$ (1950.0); this is discussed in Section 2. The extended source north following the Rosette Nebula is the Monoceros Nebulosity (Section 3). This was first observed at radio wavelengths by Davies (1963) but a more detailed analysis may now be made since the structure has been resolved at 178 MHz. In Section 4 the H II region Sharpless 280 and other faint sources are discussed.

2. The Rosette Nebula. The Rosette Nebula is an ionized hydrogen region which has been studied at both optical and radio wavelengths (e.g. Minkowski 1949, 1955; Shajn & Hase 1952; Menon 1962; Bottinelli & Gouguenheim 1964; Hill 1967). At optical wavelengths it is roughly circular having diameter 2\(\degree\) with a marked decrease of brightness towards the centre. The excitation is provided by six hot stars, of spectral types 05 to 09V, close to the centre of the Nebula (Minkowski 1949; Johnson 1953; Osterbrock & Stockhausen 1966). The edge of the Nebula is fairly sharp as expected in ionization bounded H II regions. Elephant-trunk' structures and globules are visible, but there is no evidence of filaments (see, for instance, the photograph reproduced by Bottinelli & Gouguenheim (1964)).
distance, about 1 kpc, is uncertain because of interstellar absorption (Raimond 1966).

At radio wavelengths the most exhaustive study is that of Menon (1962) who made observations with the N.R.A.O. 27 m radio telescope at 2940 MHz, at which frequency the half power beam width was 16'. Menon found that the radio brightness agreed well with the optical features, there being a clearly defined edge to the Nebula and an intensity minimum in the centre. On the assumption that the temperature was constant throughout he estimated the electron density to be \( \leq 3 \text{ cm}^{-3} \) near the centre increasing to 20 cm\(^{-3}\) at a radius of 16', then decreasing slowly to \( \approx 13 \text{ cm}^{-3} \) at about 42' from the centre and sharply thereafter, corresponding to the boundary of the Stromgren sphere. The total ionized mass derived from this model was \( \approx 11 \text{,000 M}_\odot \). Further observations by Hill at 2650 MHz with a telescope of half power beamwidth 3'75 has shown that the emission is concentrated in a shell whose inner and outer radii are 23' and 53' respectively, the volume emissivity being a maximum at the inner edge.

The half power beamwidth of the 178 MHz telescope is 24'\times28' at declination +05° and the numerical data given by Menon were therefore convolved with a suitable function to reproduce the structure that would have been found with this resolution at 2940 MHz. Comparison of this map (Fig. 2) with that shown in Fig. 1 shows that the structure of the Nebula remains substantially unaltered over this frequency range. The central intensity minimum at 178 MHz can be seen more clearly in Fig. 3. Various explanations have been suggested for this feature (see, for instance, Kahn & Menon 1961; Vandervoort 1963; Mathews 1966) but the present observations do not enable any test to be made of these theories.
The flux density at 178 MHz has been obtained by integration of the brightness temperature across the Nebula after subtraction of a uniform galactic background component. The mean value of the latter was estimated to be \((375 \pm 5)\) K and the flux density of the Rosette Nebula \((200 \pm 20) \times 10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}\).

![Diagram](https://academic.oup.com/mnras/article-abstract/141/1/57/2602680)

**Fig. 2.** The brightness distribution of the Rosette Nebula derived by Menon at 10 cm convolved to the beamwidth of the 178 MHz pencil beam aerial. The contour interval is 0.25 K.

To investigate the radio spectrum of the Nebula, all observations made with telescopes having half power beam widths less than 1° have been listed in Table I. The flux densities have been corrected to the scale of Conway, Kellermann & Long (1963) whenever sufficient information was available. These data have been plotted in Fig. 4 where it can be seen that there is considerable uncertainty in the spectrum because of the errors associated with each point. It is clear, however, that the spectrum is thermal and the flux density at 85 MHz indicates that the Nebula is optically thin at this frequency.

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Flux density ((10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}))</th>
<th>Scaling factor (see text)</th>
<th>Corrected flux density ((10^{-26} \text{ W m}^{-2} \text{ Hz}^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuzmin et al. (1960)</td>
<td>3125</td>
<td>(300 \pm 30)</td>
<td>0.89</td>
</tr>
<tr>
<td>Menon (1962)</td>
<td>2940</td>
<td>(301 \pm 30)</td>
<td>1.00</td>
</tr>
<tr>
<td>Hill (1967)</td>
<td>2650</td>
<td>219</td>
<td>---</td>
</tr>
<tr>
<td>Bottinelli et al. (1964)</td>
<td>2315</td>
<td>(265 \pm 53)</td>
<td>---</td>
</tr>
<tr>
<td>Bottinelli et al. (1964)</td>
<td>1430</td>
<td>(292 \pm 58)</td>
<td>---</td>
</tr>
<tr>
<td>Hill (1967)</td>
<td>1410</td>
<td>201</td>
<td>---</td>
</tr>
<tr>
<td>Westerhout (1958)</td>
<td>1390</td>
<td>(260 \pm 65)</td>
<td>0.79</td>
</tr>
<tr>
<td>Wilson (1963)</td>
<td>960</td>
<td>(342 \pm 34)</td>
<td>0.95</td>
</tr>
<tr>
<td>Davis et al. (1965)</td>
<td>400</td>
<td>(250 \pm 44)</td>
<td>1.22</td>
</tr>
<tr>
<td>Holden (1967)</td>
<td>178</td>
<td>(200 \pm 20)</td>
<td>1.00</td>
</tr>
<tr>
<td>Mills et al. (1958)</td>
<td>85</td>
<td>250</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Further spectral information may be obtained from unpublished maps (Baldwin, private communication) of the region at 38 MHz, at which frequency the Nebula is observed in absorption, implying that it is optically thick. The Nebula is partially resolved by the 38 MHz pencil-beam aerial (whose half-power beam width is 45' in R.A. and 45 sec (52° 16' - 8°) in declination) and it has been possible to determine...
whether this structure is consistent with work at high frequencies. There is good agreement in R.A. but in declination, the absorption dip at 38 MHz extends further to the south—this latter feature is probably associated with the low temperature region to the south of the Nebula which can be seen in Fig. 1. In determining the 38 MHz absorption flux density, the integration was performed assuming that the structure is the same as that at higher frequencies. An absorption flux density of $-95 \pm 20 \text{ Wm}^{-2} \text{ Hz}^{-1}$ was obtained.

From these data, it is possible to estimate the electron temperature within the Nebula.

At 178 MHz, the Nebula is optically thin and hence

$$S = \frac{2k}{\lambda^2} \int k(\nu) T_e \, ds \, d\Omega$$

**Fig. 3.** Cuts at constant right ascension across the Rosette Nebula (1964 coordinates).

**Fig. 4.** The spectrum of the Rosette Nebula.
Some extended radio sources in Monoceros

where $k(\nu)$ is the absorption coefficient of free–free emission and $T_e$ is the electron temperature.

The absorption flux density at 38 MHz is

$$S_{38} = \frac{2k}{\lambda^2} \int (T_0 - T_{FG} - T_e)(1 - e^{-\int k(38) \, ds}) \, d\Omega$$

where $T_0$ is the total background radiation which would be observed in the absence of the Nebula and $T_{FG}$ is the foreground radiation between the observer and the source. The relationship between $k(178)$ and $k(38)$ is known:

$$k(\nu) = (\text{constant}) \nu^{-2} T_e^{-3/2} (35.4 + \log_e (T_e^3 / \nu^2))$$

(Field (1967)—after Scheuer (1960)) and hence, knowing $T_0$ and $T_{FG}$ the equations can be solved for $T_e$. In this analysis it is assumed that the electron temperature and electron density are constant throughout the source. In the present case, there is less than 5 per cent error in the final answer if it is assumed that at 38 MHz the Nebula is a sphere rather than a spherical shell. A radius of 12.2 pc, derived from Menon’s observations, was used.

$T_0$ has been estimated by scaling the local background temperature at 178 MHz to 38 MHz using the galactic spectrum derived by Purton (1966). This gives $T_0 = 16,000^\circ$K. $T_{FG}$ has been estimated in two ways. Bridle (1968) has derived the emissivity of the Galaxy at 10 MHz and $I^{II} = 140^\circ$ in the region of the Sun. Using the galactic spectrum of Purton, this emissivity corresponds to $T_{FG} = 2300^\circ$K at 38 MHz assuming that the distance of the Rosette Nebula is 1 kpc and the emissivity of the Galaxy is the same in directions $I^{II} = 140^\circ$ and $I^{II} = 205^\circ$.

Field (1967) has estimated the brightness temperature of the local spiral arm at 38 MHz by several different methods and at $I^{II} = 190^\circ$, this estimate is 4400$^\circ$K. The position of the Rosette Nebula relative to the local spiral arm is not known and thus 4400$^\circ$K is an upper limit to $T_{FG}$.

In view of the uncertainty in $T_{FG}$, the results are best presented as a table of electron temperatures and the corresponding values of $T_{FG}$.

<table>
<thead>
<tr>
<th>$T_e$ (°K)</th>
<th>$T_{FG}$ (°K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>550</td>
</tr>
<tr>
<td>9000</td>
<td>1800</td>
</tr>
<tr>
<td>8000</td>
<td>3000</td>
</tr>
<tr>
<td>7000</td>
<td>4100</td>
</tr>
<tr>
<td>6000</td>
<td>5200</td>
</tr>
</tbody>
</table>

Taking $T_{FG}$ as 2300$^\circ$K, the present data give an electron temperature of 8600$^\circ$K with an uncertainty of the order of 1000$^\circ$K. This value of $T_e$ is in excellent agreement with the theoretical estimates of the electron temperatures of H II regions (Kahn 1963).

3. The Monoceros Nebulosity. At optical wavelengths the Monoceros Nebulosity is an irregularly bright thin ring of emission of approximate diameter 3°.5, north following the Rosette Nebula. Examination of the prints of the Palomar–National...
Geographic Society 48" Sky Survey reveals fine filaments on the north and preceding edges and a mottled nebulosity on the south and following edges.

At radio wavelengths a source was first detected in this region by Davies (1963) at 237 MHz. The higher resolution of the present observations has enabled the structure of this source to be resolved in detail (see Fig. 1). The structure is illustrated more clearly in Fig. 5 in which cuts at constant right ascension between R.A. 06h 35m and 06h 44m (1964 coordinates) have been made; at earlier right ascensions the cuts are confounded by the Rosette Nebula. From these cuts it is immediately obvious that the radio emission is peaked sharply at the northern edge, $\delta \approx 07^\circ 5$; there is no corresponding maximum along the southern edge, $\delta \approx 04^\circ$. In unpublished maps at 178 MHz of the region to the north of the Monoceros Nebulosity (Caswell, private communication) the lower temperature beyond the northern edge of the Nebulosity extends at least 2$^\circ$ further north. Thus, the region between declination 04$^\circ$ and 08$^\circ$ and R.A. 06h 30m to 06h 44m has a brightness temperature in excess of the galactic background, this difference ranging from $\approx 70^\circ K$ in the centre to $\approx 140^\circ K$ at the northern edge. The radio contours of the region are shown superposed on the Sky Survey prints in Fig. 6; the agreement between optical and radio features is good, the radio emission being strongest in the region where there is optical filamentary structure. After allowing for the finite resolution in the radio observations there is good agreement between the optical and radio features, strongly suggesting that they are related.

The region bounded by the Nebulosity contains three sources listed in the 4C catalogue (Gower, Scott & Wills 1967); details are given in Table III.

<table>
<thead>
<tr>
<th>4C Number</th>
<th>R.A.</th>
<th>Declination</th>
<th>4C flux density ($10^{-26}$ Wm$^{-2}$ Hz$^{-1}$)</th>
<th>Pencil beam flux density ($10^{-26}$ Wm$^{-2}$ Hz$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>04·25</td>
<td>06h 33m 25·6</td>
<td>04° 35·8</td>
<td>4·5</td>
<td>—</td>
</tr>
<tr>
<td>05·29</td>
<td>06h 42m 36·7</td>
<td>05° 33·8</td>
<td>7·3</td>
<td>8·1</td>
</tr>
<tr>
<td>08·21</td>
<td>06h 30m 30·0</td>
<td>08° 15·0</td>
<td>3·7</td>
<td>—</td>
</tr>
</tbody>
</table>

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Pencil beam flux densities were not obtained for 4C 04:25 as it was confused by
the Rosette Nebula, nor for 4C 08:21 as it was more than 3° from the centre of
the primary beam and lay in a region of complex structure. As these sources have been
observed with the 4C interferometer, it is likely that they have angular diameters,
≤3′. There is also a weak source at R.A. 06h 39m, declination 04° 15′, of flux
density 2.4 × 10^{-26} \text{ w m}^{-2} \text{ Hz}^{-1}, which was observed by the pencil beam catalogue but
which is not in the 4C catalogue.

Except for the features discussed above, the Nebulosity has a circular appearance
with bright edges which suggests that the radio structure may be interpreted as a
shell of emission. This type of structure is particularly pronounced towards the
northern edge. Shell sources of different relative thicknesses were therefore con-
volved with the beam of the 178 MHz aerial and compared with a typical cut across
the Nebulosity at R.A. 06h 37m 5, perpendicular to the shell structure. This cut and

![Graph](https://example.com/graph.png)

**Fig. 7.** A comparison between the observed brightness distribution of the northern half of the
Monoceros Nebulosity and those expected for uniformly emitting shells having shell thick-
nesses 4 : 1 (full line) and 3 : 1 (dashed line).

shell models for which the ratios of outer radius to shell thickness were 3 : 1 and
4 : 1 are shown in Fig. 7; the latter shell model is in good agreement with the
observations. The convolution shifts the maximum of the original shell emission
towards the centre by a distance of the order of the half power beam width. This
was taken into account in the original model and explains why the maximum of the
radio emission appears to lie within that of the optical emission.

The flux density has been obtained by integrating the sky brightness temperature
over the Nebulosity. The flux density of an object of 4° in diameter in the galactic
plane is difficult to estimate accurately because the structure of the background
emission can change considerably over this angle. A uniform background temperature
of 310°K was assumed and a flux density of 343 × 10^{-26} \text{ w m}^{-2} \text{ Hz}^{-1} derived.
A change in the average background temperature of 10°K would alter the flux
density by 40 × 10^{-26} \text{ w m}^{-2} \text{ Hz}^{-1}. The best value for the flux density of the
Monoceros Nebulosity at 178 MHz is therefore 340 ± 60 × 10^{-26} \text{ w m}^{-2} \text{ Hz}^{-1}.

The radio spectrum of the Nebulosity is difficult to estimate since few high
resolution studies of the region have been made. At 1415 MHz, Davies quotes a
brightness temperature of 0.75°K at the preceding edge. At this frequency the beam
width of the 76 m telescope is 15′, compared with a shell thickness of ≈30′ and the
beam width of the 178 MHz telescope of 24′ × 27′. Thus the brightness temperature

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which could be observed with a beam width of \(24' \times 27'\) would be less than \(0.75\, ^\circ K\) and the spectral index of the preceding edge between 178 and 1415 MHz is therefore greater than \(0.5\).

Below 178 MHz the only evidence available is unpublished work at 38 MHz (Baldwin, private communication). The Monoceros Nebulosity is seen in emission, having a brightness temperature up to \(3000\, ^\circ K\) in excess of that of the galactic plane. The beam width used in the 38 MHz observations at these declinations is \(45' \times 66'\), so this temperature should be compared with a mean temperature of \(85\, ^\circ K\) for the Nebulosity at 178 MHz. This provides an estimate of the spectral index between these frequencies of 0.3. The available data thus suggests that the Monoceros Nebulosity has a non-thermal spectrum in the frequency range 38 to 1415 MHz, which may become less steep at low frequencies. It lies at low galactic latitudes \((b = 0\, ^\circ)\), has a large angular diameter and a well-defined shell structure on its northern edge. All the evidence thus indicates that the Monoceros Nebulosity is the remnant of a supernova.

The spectrum of a supernova remnant can be used to determine whether its radio emission could result from electrons which have the same electron energy distribution as galactic electrons. The ratio of the outer diameter to the shell thickness for the Monoceros Nebulosity is \(4:1\) and the magnetic field within the shell will therefore be enhanced by about this amount (van der Laan 1963). If galactic electrons were responsible for the emission, the slope of the spectrum of the Nebulosity between 200 and 800 MHz should therefore be similar to that of the galactic background between 50 and 200 MHz. The galactic spectrum between 13 and 404 MHz has been determined by Bridle (1967) (see also Purton 1966): it has a value of \(\approx 0.4\) between 50 and 200 MHz. The spectral index of the Nebulosity between 200 and 800 MHz is not known; it is \(>0.5\) between 200 and 1400 MHz but as the galactic spectrum steepens above 300 MHz it could be \(0.4\) between 200 and 800 MHz. It is thus possible that the emission results from electrons having the same energy distribution as the galactic electrons and which are moving in the enhanced magnetic field of the shell region but flux density measurements of the Nebulosity at intermediate frequencies are needed in order to verify this.

The distance of the Nebulosity is uncertain. As it has galactic longitude \(l = 205\, ^\circ\), it is unlikely to be further than 6 kpc from the Sun. The linear dimensions of the galactic supernova remnants for which distances are known are all less than 10 pc, with the exception of the Cygnus Loop which is \(\approx 50\, pc\). Even very old supernova remnants are likely, on present evidence, (see Bingham (1967) for discussion) to be considerably less than 300 pc in extent. The large angular size of the Nebulosity would therefore place it considerably closer than 6 kpc to the Sun, for even at a distance of 1 kpc, its linear diameter would be 70 pc.

It has been suggested (see, for instance, Westerlund (1966)) that supernovae are associated with regions in which there is a concentration of H I and O and B stars. Such a concentration in the Monoceros region at a distance of 1 kpc has been discussed by Raimond (1966). The Nebulosity could therefore be part of a complex at this distance. Raimond further notes that an upper limit of \(6 \times 10^6\) years can be placed on the age of the stars from a study of the colour–magnitude diagram and that the Rosette Nebula could be a region in which a second generation of stars are being formed. Supernova are formed from highly evolved stars and thus the Monoceros Nebulosity could have resulted from an explosion, within the last 100,000 years, from one of the first generation stars.
Fig. 6. The optical field in the region of the Monoceros Nebulosity and the Rosette Nebula.  
(© 1957, National Geographic Society–Palomar Observatory Sky Survey.)

Fig. 8. The optical field in the region of the H II region Sharpless 280. The dotted contour lines are more than 3° from the beam centre of the survey.  
(© 1957, National Geographic Society–Palomar Observatory Sky Survey.)

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In his study of the velocity distribution of the H I, Raimond observed a cloud with a radial velocity of \( \approx 40 \text{ km s}^{-1} \) in the same direction as that of the brightest radio emission. This velocity is of the same order as that of the expansion velocity of old supernova remnants such as the Cygnus Loop (116 \text{ km s}^{-1}, Minkowski (1964)) and as it occurs where the shell is pronounced, i.e. in the region where the shock wave may have reached a region of increased density, the two features could be related.

It is however surprising, that if the Nebulosity is an old supernova remnant, it has still preserved its circular structure in spite of having swept up the interstellar medium, particularly as it may lie in a region in which the interstellar density is high. The other surprising feature is that the shell on the northern edge is thick, which would suggest that the shell is still expanding with a highly supersonic velocity, i.e. \( \gg 20 \text{ km s}^{-1} \) (van der Laan 1963).

At a distance of 1 kpc the radio luminosity of the Nebulosity at 178 MHz is \( 3 \times 10^{15} \text{ W Hz}^{-1} \text{ ster}^{-1} \), similar to that of IC 443 and the Cygnus Loop.

The ancient Chinese, Korean and Japanese records (Ze-Zong & Shu-jen 1966) list two possible supernovae in the Monoceros region, those of A.D. 437 and of A.D. 837 (for the latter there is a misprint in the galactic longitude cited by Ze-Zong & Shu-jen). The relationship between estimates of the apparent magnitudes of these at maximum and the present angular diameter of the Nebulosity suggests that neither is related to it, unless the original supernova outburst was quite exceptional in its absolute magnitude or expansion velocity.

In summary, there is sufficient evidence to identify the Monoceros Nebulosity as a supernova remnant. It is fairly close, probably at about 1 kpc, but its age cannot be satisfactorily determined at present. Measurements of the proper motion of the optical filaments would help to resolve this problem.

4. \textit{H II} regions and extended structure.

(a) Sharpless 280. A coincidence has been found between the region of enhanced emissivity lying to the south of the Rosette Nebula and the H II region Sharpless 280 (Sharpless 1959). The radio contours are shown superposed on the appropriate Sky Survey print in Fig. 8.

The background emission has a pronounced gradient in this region which affects the position of the observed maximum of the radio emission. To estimate the radio angular diameter and the position of the centre of the source, a cut at declination \( 02^\circ 4 \) was made: a uniform sloping background across the nebula was then assumed and the source redrawn. (The true maximum of the source precedes that shown on the map by \( \approx 20 \) seconds of time: this considerably improves the coincidence between the optical and radio emission.) From the observed half power width of the source and knowledge of the beam width in R.A. (24') an angular width of \( \approx 24' \) was obtained. The width of the optical emission region is \( \approx 24' \) so that the radio and optical measurements are in good agreement. A similar procedure was carried out in declination, the cut being made at R.A. \( 06^h 33^m \) but here it was necessary only to remove a uniform background. A radio half power width of 42' was derived, this again being in fairly good agreement with the optical width which is estimated as \( \approx 30' \). The radio source therefore appears to be slightly bigger than the optical source but because of the uncertainties in estimating the optical width and the effect of the background temperature at radio wavelengths the difference may not be significant.

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The mean zero level in the region was estimated to be $320^\circ$K: a flux density of $18 \pm 2 \times 10^{-28}$ W m$^{-2}$ Hz$^{-1}$ was then obtained by integrating the sky brightness temperature over the source.

In the region of this diffuse nebulosity there are two B stars, whose parameters, obtained from the Smithsonian Catalogue (1966), are given in Table IV.

<table>
<thead>
<tr>
<th>Number</th>
<th>R.A.</th>
<th>Declination</th>
<th>Classification</th>
<th>$m_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1114069</td>
<td>06$^h$ 31$^m$ 39$^s$</td>
<td>02$^\circ$ 25$'$ 7</td>
<td>B5</td>
<td>8.4</td>
</tr>
<tr>
<td>1114075</td>
<td>06$^h$ 31$^m$ 47$^s$</td>
<td>02$^\circ$ 34$'$ 4</td>
<td>B2</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Raimond has made an extensive study of the O and B stars in this region: the two B* stars are at the same distance as the exciting stars in the Rosette Nebula. It will therefore be assumed that this is an H II region ionized by the very hot stars and that it lies at a distance of 1 kpc.

The maximum excess brightness temperature observed in the region is approximately $140^\circ$K. The nebula is therefore optically thin and the emission measure is $2.3 \times 10^3$ cm$^{-6}$ pc assuming $T_e = 10^4$K. A cloud of mean angular diameter 33$'$ at a distance of 1 kpc has a linear diameter of 10 pc and if it is assumed that the nebula is a uniformly dense spherical object then the mean emission measure corresponds to a line of sight through the nebula of $4/3 R$, where $R$ is the radius. The electron density is then 18 electrons cm$^{-3}$ and the mass of the H II region 210 M$\odot$.

(b) *Further sources in the region.* At R.A. 06$^h$ 46$^m$, declination +06$^\circ$ 5, there is an extended object whose integrated flux density is $13 \pm 2 \times 10^{-28}$ W m$^{-2}$ Hz$^{-1}$ (assuming a zero level of $340^\circ$K). This does not appear in the 4C catalogue and there is no evidence of optical emission in the Sky Survey prints. The maximum excess brightness temperature, as observed by the 178 MHz telescope, is $100^\circ$K and its half power width, after convolution by the beam, is 30$'$ $\times$ 52$'$. Without more evidence, it is not possible to draw further conclusions.

The remaining 11 4C sources in the region covered by the map shown in Fig. 1 were found to have the same flux densities (within the limits of error) as those obtained with the 4C interferometer and the angular diameters of these sources are therefore not greater than about 3$'$. In conclusion, it should be remarked that, although in general there are no abrupt gradients of brightness temperature in the region, there are two intensity minima present, one of which is very pronounced. This latter minimum, which is approximately 1$'$ in diameter, lies to the south of the Rosette Nebula and has brightness temperature $\sim 100^\circ$K less than the surrounding medium. The other smaller minimum is at R.A. 06$^h$ 23$^m$, declination +05$^\circ$ 5 and is $\sim 75^\circ$K cooler than the surrounding medium.

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*Mullard Radio Astronomy Observatory,*
*Cavendish Laboratory,*
*Cambridge.*
1968 *April.*

* Raimond classifies one of these stars as an O star.
References


