A CLUSTER OF COMPACT RADIO SOURCES IN NGC 2024 (ORION B)

Luis F. Rodríguez and Yolanda Gómez
Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Apartado Postal 377 (Xangari), 58089 Morelia, Michoacán, Mexico; l.rodriguez@astrosmo.unam.mx, y.gomez@astrosmo.unam.mx

AND

Bo Reipurth
Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822; reipurth@ifa.hawaii.edu

Received 2003 June 28; accepted 2003 August 8

ABSTRACT

We present deep 3.6 cm radio continuum observations of the H II region NGC 2024 in Orion B obtained using the Very Large Array in its A configuration,1 with 0″2 angular resolution. We detect a total of 25 compact radio sources in a region of 4′ × 4′. We discuss the nature of these sources and its relation to the infrared and X-ray objects in the region. At least two of the radio sources are obscured proplyds whose morphology can be used to restrict the location of the main ionizing source of the region. This cluster of radio sources is compared with others that have been found in regions of recent star formation.

Subject headings: binaries: general — open clusters and associations: individual (NGC 2024) — stars: formation — stars: pre–main-sequence

1. INTRODUCTION

NGC 2024 is a prominent H II region located in the Orion B (L1630) star-forming complex at a distance of ~415 pc (Anthony-Twarog 1982). The H II region is sharply ionization-bounded to the south (Barnes et al. 1989). With a total flux density of ~60 Jy at centimeter wavelengths (Rodríguez & Chaisson 1978; Barnes et al. 1989), the H II region requires about 1048 ionizing photons per second to maintain its ionization, a flux that can be provided by an O9 zero-age main sequence star with a luminosity of its ionization, a flux that can be provided by an O9 zero-age main sequence star with a luminosity of ~5.0 × 105 L⊙. Until recently, the required emitting star had not been identified, but Bik et al. (2003) have proposed that the infrared source IRS 2b is an embedded late O or early B star responsible for the ionization.

A prominent dust lane is seen in optical images running across the region from north to south. This dust lane is also evident in molecular line observations of the region (i.e., Schulz et al. 1991). Mezger et al. (1988) identified six small-scale submillimeter condensations embedded along this dense ridge, suggesting that star formation is presently taking place there.

Clusters of near-infrared (Lada et al. 1991; Beck, Simon, & Close 2003; Haisch, Lada, & Lada 2000), mid-infrared (Haisch et al. 2001), and X-ray sources (Skinner, Gagné, & Belzer 2003) are known to exist in association with NGC 2024. Furthermore, a number of submillimeter continuum sources were found and studied by Mezger et al. (1988) and Visser et al. (1998). To provide a more complete census of the young stellar population in this region, we have undertaken deep, high angular resolution 3.6 cm observations in an attempt to detect a cluster of compact radio sources similar to those found in Orion A (Garay, Moran, & Reid 1987; Churchwell et al. 1987), NGC 1333 (Rodríguez, Anglada, & Curiel 1999), the Arches region near the Galactic center (Lang, Goss, & Rodríguez 2001), and in GGD 14 (Gómez, Rodríguez, & Garay 2000, 2002).

2. OBSERVATIONS

We have used the Very Large Array (VLA) of the NRAO1 in its A-array configuration to observe NGC 2024 at 3.6 cm. The region was observed on 2002 March 2, 3, and 8. Our phase center was at α(J2000.0) = 05h41m44s.9, δ(J2000.0) = −01°55′54″, with an adopted flux density of 5.18 Jy, and the phase calibrator was 0541−004 with average flux density of 0.748 ± 0.004 Jy over the three epochs of observation. The data were analyzed in the standard manner using the package AIPS of NRAO. The data were self-calibrated in phase. Individual images were made at each epoch to search for fast variability (on a timescale of days) between the epochs observed. To diminish the presence of extended emission, in particular, that originating from the very sharp ionization front of the H II region that is evident in Figure 1b of Barnes et al. (1989), we used only visibilities with baselines larger than 50 kλ, thus suppressing the emission of structures larger than ~2″. The images were restored with a circular beam of 0″24, the average value of the angular resolution of the individual maps made with the ROBUST parameter of IMAGR set to 0. The three maps were then averaged to obtain an rms noise of 15 μJy.

A total of 25 sources were detected in a region of 4′ × 4′. The distribution of these sources is shown in Figure 1. Following Fomalont et al. (2002), we estimate that in a field of 4′ × 4′ the a priori number of expected 3.6 cm sources above 0.1 mJy is ~0.6. We then conclude that probably one out of the 25 sources could be a background object, but that we are justified in assuming that practically all the members of the radio cluster are associated with NGC 2024. In Figure 2 we

1 The VLA is operated by the National Radio Astronomy Observatory, which is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.
show the positions of the radio sources overlapped on the red Digitized Sky Survey (DSS) 2 image of the region. From this figure it is evident that the cluster of radio sources is closely associated with the central parts of the dust lane that runs across NGC 2024.

In Table 1 we list the positions and flux densities of the sources, averaged over the three observations. We also note in column (5) whether they were found to be variable. The number given in parentheses for the variable sources is the ratio between the largest and smallest flux density observed. Finally, in the last three columns we list counterparts, when found. A counterpart was taken as such if its position was within 3'' of the radio position. The radio positions are estimated to be accurate to \( \sim 0.05 \) arcsec.

3. OVERALL CHARACTERISTICS OF THE SAMPLE OF RADIO SOURCES

Out of the 25 radio sources detected, 13 have a Two Micron All Sky Survey (2MASS) counterpart and 15 have a Chandra counterpart (Skinner et al. 2003). Only the brightest source in the radio cluster, VLA 19, had previously been reported at radio wavelengths (Snell & Bally 1986; Gaume, Johnston, & Wilson 1992; Kurtz, Churchwell, & Wood 1994). Only four of the 25 radio sources, VLA 8, VLA 12, VLA 17, and VLA 18, lack a previously reported counterpart.

Of the 25 sources detected, eight were found to be time-variable over the observed timescale of a few days (see col. [5] in Table 1). We searched for linear and circular polarization in the sample, and only one source (VLA 24) showed left-circular polarization at the 3% level. We measured the angular size of the sources using the AIPS task IMFIT, with a correction for bandwidth smearing. With the exception of sources VLA 8, VLA 13, and VLA 19, all sources were found to be unresolved, \( \theta < 0.2'' \).

We found radio continuum sources closely associated with three of the six far-infrared (FIR) submillimeter sources of Mezger et al. (1988), namely, FIR 4 (VLA 9), FIR 5 (VLA 10), and FIR 6 (VLA 14). All three sources are relatively weak and do not show time variability. Remarkably, none of these three radio sources have a near-IR or X-ray counterpart, suggesting very large extinction toward them.

Two close (\( \leq 2'' \)) double systems, formed by sources VLA 12 and 13, as well as VLA 15 and 16, respectively, are part of the cluster. Most probably they constitute physical binaries.

4. COMMENTS ON SELECTED INDIVIDUAL SOURCES

4.1. VLA 8

This source has no reported counterparts. It is one of the few sources that is clearly resolved, elongated in the north-south direction (see Fig. 3). Its deconvolved dimensions are \( 0\!.59 \pm 0\!.03 \times 0\!.25 \pm 0\!.02 \); P.A. = \( 177^\circ \pm 3^\circ \). These angular dimensions correspond to \( 170 \times 95 \) AU. One possible explanation is that we are observing a thermal radio jet (e.g., Rodriguez 1997) that could be powering the unipolar redshifted CO jet in the region (Richer, Hills, & Padman 1992), since both the radio source and the CO jet are well aligned and elongated in the north-south direction. However, the CO jet seems to emanate from a point about 1' south of VLA 8, a position much closer to VLA 10 (= FIR 5). Furthermore, the detailed shape of the source is curved, unlike most thermal jets, which are rather straight. This curved morphology is reminiscent of that seen in cometary H II regions or in ionized proplyds. It is known that the ionized Orion proplyds, when observed in the radio continuum (Henney et al. 2002), show an arc-shaped structure. Furthermore, the physical dimensions of VLA 8 are similar to those of the Orion proplyd LV 2 (Henney et al. 2002).
TABLE 1
PARAMETERS OF THE 3.6 cm VLA SOURCES

| VLA (1) | α(J2000.0) (2) | δ(J2000.0) (3) | Fluxa (mJy) (4) | Time Variable? (5) | 2MASS (6) | Chandra (7) | Other (8) |
|---------|----------------|----------------|----------------|-------------------|-----------|-------------|----------|
| 1       | 05 41 37.745   | -01 54 41.20   | 0.30           | N                 | HLP 2     |             |          |
| 2       | 05 41 37.858   | -01 54 31.82   | 0.16           | Y (1.9)           | SGB 78    |             |          |
| 3       | 05 41 41.346   | -01 53 32.54   | 0.28           | N                 | SGB 120   | HLL 52, BSC 69 |          |
| 4       | 05 41 41.385   | -01 54 44.64   | 0.26           | N                 | SGB 123   |             |          |
| 5       | 05 41 41.487   | -01 54 39.35   | 0.33           | Y (3.7)           | SGB 124   | HLL 87, BSC 65 |          |
| 6       | 05 41 43.446   | -01 56 42.74   | 0.10           | Y (6.5)           | SGB 147   | BCB IRS 24   |          |
| 7       | 05 41 43.559   | -01 53 56.67   | 0.20           | N                 | SGB 152   |             |          |
| 8       | 05 41 43.912   | -01 54 34.13   | 0.63           | N                 | M FIR 4, MC 89-4 |             |          |
| 9       | 05 41 44.136   | -01 54 46.04   | 0.33           | N                 | M FIR 5, LCGR FIR 5 4 |             |          |
| 10      | 05 41 44.221   | -01 55 41.32   | 0.11           | N                 | SGB 171   | HLL 77, HLP 22 |          |
| 11      | 05 41 44.827   | -01 54 25.16   | 0.22           | Y (1.6)           | SGB 182   | B IRS 2b     |          |
| 12      | 05 41 45.024   | -01 54 53.94   | 0.11           | N                 | SGB 183   |             |          |
| 13      | 05 41 45.056   | -01 54 54.73   | 0.24           | N                 | SGB 187   | IRS 2, KCW 206.543–16.347 |          |
| 14      | 05 41 45.168   | -01 56 00.56   | 0.29           | N                 | SGB 188   | BSC 93       |          |
| 15      | 05 41 45.492   | -01 54 28.70   | 0.24           | N                 | SGB 193   |             |          |
| 16      | 05 41 45.522   | -01 54 27.02   | 0.97           | N                 | SGB 196   |             |          |
| 17      | 05 41 45.554   | -01 55 25.86   | 0.27           | N                 | SGB 196   |             |          |
| 18      | 05 41 45.733   | -01 54 57.93   | 0.49           | N                 | SGB 200   |             |          |
| 19      | 05 41 45.809   | -01 54 29.92   | 17.4           | N                 | SGB 201   |             |          |
| 20      | 05 41 45.905   | -01 54 10.98   | 0.18           | Y (5.0)           | SGB 210   |             |          |
| 21      | 05 41 46.157   | -01 56 22.20   | 4.54           | Y (5.7)           | SGB 211   |             |          |
| 22      | 05 41 46.236   | -01 56 54.80   | 0.10           | N                 | SGB 212   |             |          |
| 23      | 05 41 46.570   | -01 54 46.88   | 1.17           | Y (6.2)           | SGB 213   |             |          |
| 24      | 05 41 48.224   | -01 56 02.01   | 8.60           | Y (2.2)           | SGB 214   |             |          |
| 25      | 05 41 50.983   | -01 55 06.97   | 0.24           | N                 | SGB 222   | HLP 29, HLL 98 |          |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

*a* Total flux density corrected for primary beam response. The flux density reported is the average of the three epochs observed.

*b* B = Bik et al. 2003; BCB = Barnes et al. 1989; BSC = Beck et al. 2003; HLL = Haisch et al. 2000; HLP = Haisch et al. 2001; KCW = Kurtz et al. 1994; LCGR = Lai et al. 2002; M = Mezger et al. 1988; MC = Moore & Chandler 1989; SGB = Skinner et al. 2003.

Clearly, additional observations are needed to establish whether this radio source is a thermal jet, a cometary H II region, or a proplyd. As we will see below, the fact that the arc “points” to the region where the ionizing star of the region is believed to be located favors the identification of this source as a radio proplyd.

### 4.2. VLA 9

This source has no reported near-IR or X-ray counterpart. It is associated with FIR 4, one of the small-scale submillimeter condensations reported by Mezger et al. (1988), and is thus likely to represent a deeply embedded protostar. It is associated with an infrared reflection nebula (Moore & Yamashita 1995) and a unipolar redshifted CO outflow (Chandler & Carlstrom 1996).

### 4.3. VLA 10

This source has no reported near-IR or X-ray counterpart, but it is associated with FIR 5 (Mezger et al. 1988). It could be the powering source of the unipolar redshifted CO jet studied by Richer et al. (1992) and Chandler & Carlstrom (1996), since it is located at the position from which this jet seems to originate. Wiesemeyer et al. (1997) present interferometric 3 mm continuum observations and show that FIR 5 separates into two clumps, FIR 5e and 5w. VLA 10 coincides precisely with FIR 5w. Lai et al. (2002) studied the detailed magnetic field structure around FIR 5.
4.4. VLA 12 and VLA 13

These two sources (see Fig. 4) form a close binary system separated by 0\arcsec9, which at 415 pc corresponds to 375 AU in projection. Source 12 has no reported counterpart. The source VLA 13 is angularly resolved, with deconvolved dimensions of 0\arcsec46/0\arcsec03 x 0\arcsec12/0\arcsec04, P.A. = 110\degr\pm 3\degr. Its arc-shaped morphology and the fact that it points to the region where the ionizing star of the region is believed to be located favors, as in the case of VLA 8, the identification of VLA 13 as a radio proplyd.

4.5. VLA 14

This source has no reported near-IR or X-ray counterpart. It is associated with FIR 6 (Mezger et al. 1988) and could be the powering source of a compact bipolar CO outflow found in this region (Richer 1990; Chandler & Carlstrom 1996), since the outflow emanates from a position coincident with VLA 14.

4.6. VLA 15 and VLA 16

Both these VLA objects are 2MASS and Chandra sources. They form a close binary system (see Fig. 5) separated by 1\arcmin7. The source VLA 15 coincides positionally with the infrared source IRS 2b, which has been proposed as the ionizing source of the NGC 2024 H II region by Bik et al. (2003). The source IRS 2b, first found by Jiang, Perrier, & Léna (1984) and Nisini et al. (1994), is located about 5\arcsec northwest of IRS 2. IRS 2 is the brightest near-IR source of this region (detected by us as VLA 19, see below). The source VLA 16 is not detected in the near-IR, but it is a Chandra source (Skinner et al. 2003).

4.7. VLA 17

This source has no reported counterparts. It is located exactly over the sharp ionization front that runs east-west (Barnes et al. 1989). It could be a bright knot in the ionization front, with no young star directly associated with it.

4.8. VLA 19

This is the brightest radio source in the cluster, with near-IR and X-ray counterparts. It was previously reported as a radio source by Snell & Bally (1986), Gaume et al. (1992), and Kurtz et al. (1994). We found no significant variability at the three epochs that we observed. However, our 3.6 cm flux density of 17.4 mJy is about twice the value of 8.9 mJy reported by Kurtz et al. (1994), from VLA observations taken 13 years before. This radio source coincides with the infrared source IRS 2 (Grasdalen 1974; Barnes et al. 1989). The radio source (Fig. 5) clearly shows structure. There is a bright, dominant component to the west, with a fainter extension to the east. At present, it is not possible to establish whether we are observing a binary source, an ultra-compact H II region, or a radio proplyd. Multifrequency observations at high angular resolution are needed to favor one of these possibilities.

4.9. VLA 21

This source is quite bright in the radio and exhibits large variation with a factor of 5.7. It has a Chandra counterpart.

4.10. VLA 24

This source, with 2MASS and Chandra counterparts, is the only one that showed evidence of polarization, showing left-circular polarization at the 3% level at all three epochs.
observed. It is also time-variable, with variations of about a factor of 2. The combination of fast time variability with circular polarization is an indicator of gyrosynchrotron emission (Feigelson & Montmerle 1999).

5. DISCUSSION

There are several mechanisms that can produce compact centimeter radio sources in regions of star formation. In regions of low mass star formation, thermal jets and gyro-synchrotron emitters can be present. In regions of high mass star formation we also have strong ionizing radiation available, and, in addition to the two mechanisms present in low mass star-forming regions, we can have ionized stellar winds, ultracompact H II regions, and radio proplyds. It is possible to distinguish between these various possibilities with high angular resolution, multifrequency observations made with the required sensitivity. For NGC 2024 we have available only the 3.6 cm observations presented here. We can, however, argue that because of its time variability and circular polarization, VLA 24 is most probably a young low-mass star showing gyrosynchrotron emission. In the case of sources VLA 2, 5, 6, 11, 20, 21, and 23, their fast time variability also suggests a gyrosynchrotron nature.

Sources VLA 8 and VLA 13 are probably radio proplyds given their morphology and orientation. If so, they can be used in an attempt to search for the ionizing source of the region. These two sources are also affected by bandwidth smearing, but the deconvolution made to correct for this effect clearly shows that they are truly extended. In Figure 7 we show an image that includes these two sources as well as other nearby sources. In this image we have passed two lines by each of the sources. These lines have position angles of ±3° with respect to the perpendicular to the major axes of the sources. The set of lines defines a four-sided region that includes sources VLA 15 (IRS 2b) and VLA 19 (IRS 2). Note that the 10 VLA sources in this figure are distributed in the plane of the sky approximately in an ellipse.

Over the years, a few examples of radio clusters associated with regions of recent star formation have been appearing in the literature (Garay et al. 1987; Churchwell et al. 1987; Becker & White 1988; Stine & O’Neal 1998; Rodríguez et al. 1999; Gómez et al. 2000; Lang et al. 2001). In Table 2 we summarize the parameters of these radio clusters. Although more such clusters should be studied in order to have a reliable statistical base, some interesting trends are evident. The diameters of the radio clusters are in the 0.2–0.7 pc range. The radio luminosity of the most luminous member is correlated with the bolometric luminosity of the cluster. We believe that sensitive, high angular resolution studies similar to that presented here are needed to establish whether these clusters are always present in other relatively nearby regions of massive star formation. If properly understood, these radio clusters could be an invaluable observational tool to study the stellar population of heavily obscured regions of star formation.

6. CONCLUSIONS

We have presented sensitive, high angular resolution (0\'02) VLA observations at 3.6 cm toward the NGC 2024 region of recent star formation. Our main conclusions are summarized below.
1. We detected a total of 25 compact radio sources in a region of 4′ × 4′. Only four of these sources do not have a previously reported counterpart at any wavelength. However, only one of the radio sources had been reported in the literature.

2. We found radio continuum sources closely associated with three of the six submillimeter sources in the region. Remarkably, none of these three radio/submillimeter sources has a near-IR or X-ray counterpart, suggesting very large extinction toward them.

3. Two of the sources (VLA 8 and VLA 13) are proposed to be radio proplyds whose study may help pinpoint the origin of the ionizing radiation in the region. Our attempts to do this suggest a region containing both VLA 15 (= IRS 2b) and VLA 19 (= IRS 2) as the area where the ionizing source is located.

4. The source VLA 19, the counterpart of IRS 2, is found to exhibit spatial structure, although its precise nature remains undetermined. We also detected a radio counterpart to IRS 2b, the object that has been recently proposed to be the ionizing source of NGC 2024.

5. Eight of the sources detected (VLA 2, 5, 6, 11, 20, 21, 23, and 24) show fast time variability and are probably young low-mass stars exhibiting gyrosynchrotron emission.

6. Two close (<2″) binary systems, formed by sources VLA 12 and 13 and VLA 15 and 16, respectively, are part of the cluster.

7. We have briefly discussed the parameters of other radio clusters found in regions of star formation and suggest that sensitive, high angular resolution studies of other relatively nearby massive star formation regions are likely to detect similar clusters.

We thank Will Henney for his comments on proplyds and Steve Skinner for providing us with his list of X-ray sources before publication. We are also grateful to George Herbig for calling our attention to the radio cluster in NGC 1579. L. F. R. and Y. G. acknowledge the support of Dirección General de Asuntos del Personal Académico (DGAPA), Universidad Nacional Autónoma de México (UNAM), and of Consejo Nacional de Ciencia y Tecnología (CONACyT) (México). B. R. acknowledges support from NASA grant NAGS-8108. The Second Palomar Observatory Sky Survey (POSS-II) was made by the California Institute of Technology with funds from the National Science Foundation, the National Aeronautics and Space Administration, the National Geographic Society, the Sloan Foundation, the Samuel Oschin Foundation, and the Eastman Kodak Corporation. The Oschin Schmidt Telescope is operated by the California Institute of Technology and Palomar Observatory. The 2MASS project is a collaboration between The University of Massachusetts and the Infrared Processing and Analysis Center (JPL/California Institute of Technology), with funding provided primarily by NASA and the NSF. This research has made use of the SIMBAD database, operated at the Centre de Données Astronomiques de Strasbourg (CDS), France.

REFERENCES

Anthony-Twarog, B. J. 1982, AJ, 87, 1213
Barnes, P. J., Crutcher, R. M., Bieging, J. H., Storey, J. W. V., & Willner, S. P. 1989, ApJ, 342, 883
Beck, T. L., Simon, M., & Close, L. M. 2003, ApJ, 583, 358
Bik, A., Lenorzer, A., Kaper, L., Comerón, F., Waters, L. B. F. M., de Koter, A., & Hanson, M. M. 2003, A&A, 404, 249
Chandler, C. J., & Carlstrom, J. E. 1996, ApJ, 466, 338
Churchwell, E., Wood, D. O. S., Felli, M., & Massi, M. 1987, ApJ, 321, 516
Gaume, R. A., Johnston, K. J., & Wilson, T. L. 1992, ApJ, 397, 363
Haisch, K. E., Lada, E. A., Piña, R. K., & Telesco, C. M., & Lada, C. J. 2001, AJ, 121, 1512
Henneby, W. J., O'Dell, C. R., Meaburn, J., Garrington, S. T., & Lopez, J. A. 2002, ApJ, 566, 315
Jiang, D. R., Perrier, C., & Lina, P. 1984, A&A, 135, 249
Kurtz, S., Churchwell, E., & Wood, D. O. S. 1994, ApJS, 91, 659
Lada, E. A., Evans, N. J., Depoy, D. L., & Gatley, I. 1991, ApJ, 371, 171
Lai, S.-P., Crutcher, R. M., Girart, J. M., & Rao, R. 2002, ApJ, 566, 925
Lang, C. C., Goss, W. M., & Rodríguez, L. F. 2001, ApJ, 551, L143
Meenten, K. M., & Reid, M. J. 1995, ApJ, 445, L157
Mezger, P. G., Chaisson, E. J., Kreyka, E., Wink, J. E., & Salter, C. J. 1988, A&A, 191, 44
Moore, T. J. T., & Chandler, C. J. 1989, MNRAS, 241, 19P
Moore, T. J. T., & Yamashita, T. 1995, ApJ, 440, 722
Nisini, B., Smith, H. A., Fischer, J., & Geballe, T. R. 1994, A&A, 290, 463
Richer, J. S. 1990, MNRAS, 245, 24P
Richer, J. S., Hills, R. E., & Padman, R. 1992, MNRAS, 254, 525
Rodríguez, L. F. 1997, in IAU Symp. 182, Herbig-Haro Flows and the Birth of Low Mass Stars, ed. B. Reipurth & C. Bertout (Dordrecht: Kluwer), 83
Rodríguez, L. F., Anglada, G., & Curiel, S. 1999, ApJS, 125, 427
Rodríguez, L. F., & Chaussion, E. J. 1978, ApJ, 221, 816

TABLE 2
PARAMETERS OF RADIO CLUSTERS IN REGIONS OF RECENT STAR FORMATION

| Region     | Luminosity ($L_{\odot}$) | Number of Members | Most Luminous Member* (mJy kpc$^2$) | Diameter (pc) | Reference |
|------------|--------------------------|-------------------|-------------------------------------|--------------|-----------|
| Orion      | ~2 x 10$^4$              | ~50               | 8.8                                 | 0.3          | 1         |
| NGC 1579   | ~2 x 10$^4$              | 16                | 0.6                                 | 0.3          | 2         |
| GGD 14     | ~10$^6$                  | 6                 | 0.2                                 | 0.2          | 3         |
| NGC 1333   | ~120                     | 44                | 0.3                                 | 0.7          | 4         |
| Arches     | ~10$^7$                  | 8                 | 122.8                               | 0.7          | 5         |
| NGC 2024   | ~5 x 10$^4$              | 25                | 3.0                                 | 0.5          | 6         |

* 3.6 cm flux density times distance in kpc$^2$.
Schulz, A., Guesten, R., Zylka, R., & Serabyn, E. 1991, A&A, 246, 570
Skinner, S. L., Gagne, M., & Belzer, E. 2003, ApJ, in press
Snell, R. L., & Bally, J. 1986, ApJ, 303, 683
Stine, P. C., & O’Neal, D. 1998, AJ, 116, 890
Visser, A. E., Richer, J. S., Chandler, C. J., & Padman, R. 1998, MNRAS, 301, 585
Wiesemeyer, H., Güsten, R., Wink, J. E., & Yorke, H. W. 1997, A&A, 320, 287