Near Infrared (JHK) Photometric Survey of NGC 7538

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\textbf{Abstract.} We describe results of the first large JHK imaging survey of the vicinity of NGC 7538. The survey used SQID on the 1.3 m telescope of the Kitt Peak National Observatory to cover about 230 arcmin\textsuperscript{2}. We identify and catalogue more than 600 near-infrared (NIR) sources to a limiting magnitude of $K = 15$, which corresponds to 1.4 $M_\odot$ stars for $A_k = 1.1$ mag at $d = 3.5$ kpc.

1. Introduction

In the last decade the development of infrared detectors has enabled probes of the interiors of molecular clouds not accessible at optical wavelengths. The discovery of embedded clusters containing many newly formed stars demonstrates the effectiveness of NIR imaging surveys for probing the embedded stellar populations of molecular clouds (e.g. Lada et al. 1991, Lada, Strom, & Myers 1993, Zinnecker, McCaughrean, & Wilking 1993). These studies show that the cluster mode of star formation contributes significantly to star formation in the galaxy.

Young embedded clusters offer unique opportunities to study the stellar IMF and its variation in space and time. Dense young clusters with ages of 10 million years or less probably have retained nearly all of their original stellar population (older clusters lose members due to evolution and dynamical interactions). The low mass members of these clusters are brighter than at any other time of their evolution and are thus easier to identify and count than stars in older clusters.

NGC 7538 is a visible HII region in the Perseus spiral arm and is probably part of the Cas OB 2 complex. Its distance is 2.2–4.7 kpc. It is a site of active star formation with several luminous IR sources ($L = 3000$–$30000 \ L_\odot$; $M = 10$–$20 \ M_\odot$). Bloomer et al. (1998), Werner et al. (1979), and Wynn-Williams,
Figure 1. The position of the observed fields (Left) and the star density contours (Right). Dark grey symbols: stars with infrared excess; grey symbols: main sequence stars; black symbols: stars above the reddening band. See also Figure 4.


Although the region around NGC 7538 is relatively well mapped at optical and radio wavelengths, there are no extensive published NIR surveys of the region. Here, we present the results of the first large JHK imaging survey of the vicinity of NGC 7538. The limiting magnitude is $K = 15$, which corresponds 1.4 M$_\odot$ for $A_k$=1.1 mag at $d = 3.5$ kpc. We show the infrared color-color and color-magnitude diagrams of the embedded cluster together with the ZAMS and the $10^6$ year isochrone. We also identify several pre-main sequence sources using the $(H - K) - (J - H)$ color-color diagram.

2. Observations

We acquired imaging data of NGC 7538 on 1993 Jun 4-10, with SQIID on the 1.3 m telescope of the KPNO. We took 12 dithered pairs of 5.4′ × 5.4′ images covering the HII region and its immediate vicinity. We observed two additional fields (1 dithered pair each) farther from the cluster to map the stellar density of the foreground and background populations. Figure 1 shows the position of the fields covering the cluster together with the detected IR sources.

We used standard IRAF routines for bias, flat-field, and background correction, and SEExtractor (Bertin & Arnouts 1996) for aperture photometry. We observed standard stars from the Elias at al. (1982) catalogue each night to perform the transformation into the standard photometric system. Figure 2 compares our photometry with previous results of common sources.

3. The NIR Extinction Law and Photometric Parameters

We use background stars to derive a reddening law as described in Kenyon, Lada, & Barsony (1998). Figure 3 shows the extinction measurements for stars with $K < 14$ mag. Stars without NIR excess emission yield $E_{J-H}/E_{H-K} = 1.69 \pm 0.04$. 

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Figure 2. Comparison between photometry found in the literature and our data. The black line represents the x=y. The numbers next to the symbols refer the number of the publication in the upper left corner of the figure.

Figure 3. The reddening law for the NGC 7538 region. The straight line fit has a slope $E_{J-H}/E_{H-K} = 1.69 \pm 0.04$. 

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Figure 4. The color-color diagram of the detected IR sources. Dark grey symbols: stars with infrared excess; grey symbols: main sequence stars; black symbols: stars above the reddening band. Solid line denotes the ZAMS of Siess, Dufour, & Forestini (2000), dashed lines denote the reddening band.

Figure 5. The color-magnitude diagram of the detected IR sources (see Figure 4 for color coding). Solid line denotes the ZAMS of Siess et al. (2000), dashed line shows the $10^6$ years isochrone.
Figures 4 and 5 show the color-color (Figure 4) and color-magnitude (Figure 5) diagrams of NGC 7538. We identify 238 sources with NIR excess (dark grey dots in Figure 4 and 5). Most of the NIR sources lie in three concentrations, which coincide with the highest contour levels in the stellar density map (Figure 1). This spatial distribution suggests the presence of a young embedded cluster associated with the H II region.

We fit the ZAMS of Siess, Dufour, & Forestini (2000) on the blue edge of the $(J - K) - K$ diagram of the detected IR sources to estimate $E_{J-K} = 0.55$ and $DM = 11.6$, which corresponds to a distance of about 2.1 kpc. This distance is lower than the most accepted, $d = 2.8 \pm 0.9$ derived by Blick, Fich, & Stark (1982), but is still within their error bars. We plan to check our findings with IR spectra which will yield distances and reddenings to individual objects.

We estimate $E_{H-K} = 0.186$ and $A_K = 0.333$ from $E_{J-K}$ using the equations of Bessel & Brett (1988). These values are also lower than the values from the literature, probably because the reddening values for individual sources have a large scatter due to the presence of the nebula.

4. Conclusions

- We detected 634 NIR sources in a JHK survey of NGC 7538
- 238 of these sources have infrared excess; most of them are concentrated in a small area which is probably an embedded cluster
- We derived the reddening law of the region, $E_{J-H}/E_{H-K} = 1.69 \pm 0.04$
- By fitting a ZAMS on the blue edge of the $(J - K) - K$ diagram of the NIR excess sources, we measured the reddening and the distance of the cluster. $E_{H-K} = 0.186$, $d = 2.1$ kpc

References