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An infrared study of southern dark clouds

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Abstract. We present the results of the analysis of near-infrared images of 14 southern hemisphere dark clouds taken at Las Campanas Observatory. All selected regions have associated IRAS sources. We based our study of the young stellar population associated with the clouds on our J, H and K_s calibrated images.

Key words. Stars: Infrared – Stars: Formation – ISM: Dark Clouds

1. Introduction

Dark clouds (DCs) are defined as regions of the sky where the apparent surface density of stars is much lower than that of the surrounding areas. A complete catalogue of northern DCs (-33° ≤ δ ≤ 90°) derived from visual inspetion of the PSS red and blue prints was published by Lynds (1962). This catalog has provided the basic reference for studies involving these objects.

As an extension of the Lynds's catalogue, Hartley et al. (1986) published a catalogue of 1101 new DCs with δ ≤ -33° obtained from visual inspection of ESO/SERC Southern J survey plates. Many of these DCs have been observed at different wavelengths. Persi et al. (1990) selected a sample of 482 small DCs (size ≤ 64 arcmin^2) in order to search for embedded IRAS sources. They found that approximately 50% of the sample contains IRAS sources. In addition using low resolution near-IR photometry, the authors found that a small number of these selected regions are associated with low-mass young stellar objects (YSOs) at different evolutionary stage. A survey in the NH_3 (1,1) line of 169 southern small and isolated DCs (globules) with diameters less than 10 arcmin was undertaken by Bourke et al. (1995), in order to determine the physical characteristics of these regions. Although half of these globules have been detected in ammonia, only 6% of the detected regions show strong emission. This result suggests that isolated dark clouds are less active sites of star formation to the cores in complexes studied by Benson & Myers (1989). A systematic search for millimeter dust continuum emission and CO molecular outflow from 35 southern small DCs associated with cold IRAS sources, was done by Henning & Leunhardt (1998). Eigtheen DCs were detected in the 1.3 mm continuum emission, and in 12 clouds the CO

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Table 1. List of the observed DCs

DC	IRAS	R.A.(J2000)	Dec.(J2000)	Density	MSX	1.3mm	CO
		h m s	° ′ ″				
DC260.7-12.4	07378-4745	07 39 17.2	-47 52 14.8	B	N		
DC249.4-5.1	07435-3430	07 45 26.4	-34 37 59.3	A	N	Y	Y
DC260.4-8.0	07591-4518	08 00 45.0	-45 27 18.0	B	N		
DC267.9+3.6	09169-4406	09 18 48.5	-44 19 24.8	A	Y		
DC283.8-3.4	10059-5948	10 07 33.4	-60 03 12.3	B	N	Y	Y*
DC286.2-1.3	10308-5924	10 32 40.9	-59 39 57.9	B	Y		
DC289.3-2.8	10471-6206	10 49 01.6	-62 22 15.3	A	N	Y	Y
DC289.9-3.2	10497-6242	10 51 39.8	-62 58 02.8	B	N	Y	Y*
DC287.1+2.4	10501-5630	10 52 14.9	-56 46 34.5	B	Y	Y	Y *
DC294.3-2.0	11306-6311	11 32 55.3	-63 27 58.7	B	N	Y	Y
DC294.5-1.6	11332-6258	11 35 31.9	-63 14 51.0	B	Y	Y	
DC296.2-3.6	11431-6516	11 45 34.0	-65 32 59.0	B	Y	Y	Y
DC295.0+1.3	11436-6017	11 46 02.3	-60 34 03.1	B	Y	Y	Y*
DC306.2+0.1	13158-6217	13 19 07.7	-62 33 43.5	A	Y		

line wings indicate the presence of molecular outflows.

All these observations show that the Hartley et al.'s catalogue of small dark clouds, contains dense globules of the type detected by Benson & Myers (1989) where very active low-mass star formation occurs as well as less dense globules with no trace of star formation. In order to study the young stellar population in these small DCs, we have undertaken a programme of near and mid-IR images of a selected sample of DCs from the Hartley's et al catalogue. We discuss here the results of near-infrared imaging of 14 DCs with IRAS counterparts, including dense globules detected in CO, NH_3 and 1.3 mm, and less dense globules with only far-IR emission.

2. Observations

J, H, and K_s images of 14 southern DCs were taken on the nights of 1999 January 3 to 7 with the Las Campanas Observatoy near-IR camera (Persson et al. 1992) on the 2.5m du Pont telescope. This camera provides a scale of 0.35"/pix. Using total exposure times of 300s , 200s and 180s in the J, H, and K_s filters, we obtained limits of 19.1, 18.3 and 17.5 mag. (3σ) respectively. Flux calibration was done by observing standard stars from the list of Las Campanas Observatory. Stellar photometry was performed using the DAOPHOT package (Stetson 1987) within IRAF with an aperture of 3". The list of the observed DCs is shown in Table 1.

3. Discussion

Our observed sample contains high and intermediate density clouds (Class A and B, see Hartley et al. (1986)) . Approximately 65 % have been detected at 1.3 mm continuum and in the ^{12}CO(2-1) line (Henning & Leunhardt 1998). Four of these DCs (marked with an asterisk in Table 1) are associated with a molecular outflow. We have used our $JHKs$ images in order to identify the YSOs associated with the DCs. Whitin the IRAS uncertainty ellipsoide no source with IR excess was found for DC 260.7-12.4, DC260.4-8.0, DC289.3-2.8 and DC289.9-3.2. The millimeter continuum emission detected in the last two DCs and the lack of near and mid infrared sources, suggest the presence of Class 0 young stellar objects in these clouds. Isolated sources with near-IR excess were found associated with DC267.9+3.6, DC 286.2-1.3, DC 294.3-2.0 and DC295.0+1.3 indicating that in these DCs, single low -mass stars are being formed. Figure 1 shows the K_s images of DC260.4-8.0, an example of

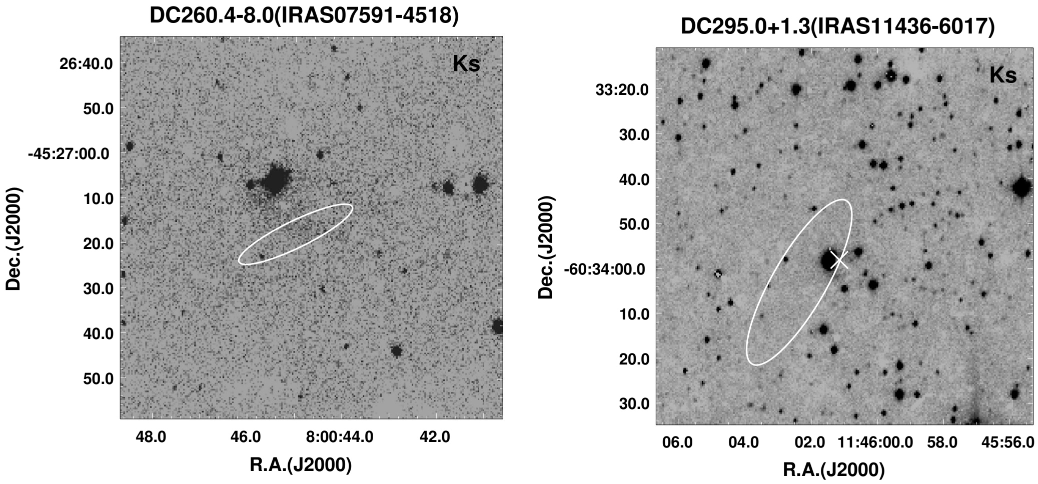

Fig. 1. K_s images of DC260.4-8.0 and DC295.0+1.3. The ellipsoide represent the IRAS uncertainty ellipse, while the position of MSX mid-IR source is indicated with the symbol X.

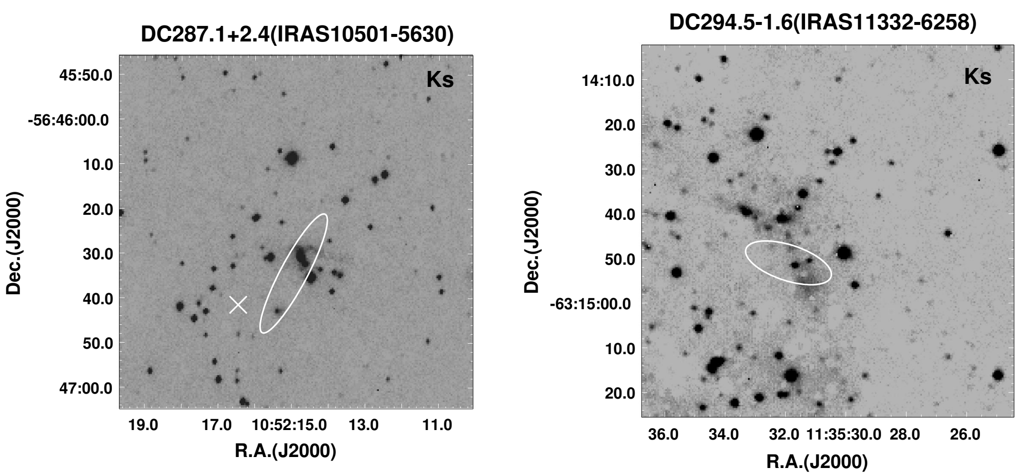

Fig. 2. K_s images of DC287.1+2.4 and DC294.5.0-1.6. The symbols are as in Fig. 1

dark cloud without near-IR excess source detected, as well as DC295.0.9+1.3 that has an isolated near-IR counterpart. Multiple sources with near-IR excess and small nebulosities were found in DC287.1+2.4 and DC 294.5-1.6 as shown in Figure 2.

For the YSOs, we derived the spectral energy distributions (SEDs) combining our near-IR photometry, with the mid-IR flux densities from MSX, the far-IR fluxes from IRAS and the millimeter continuum observations obtained by Henning & Leunhardt (1998). The SEDs of two of these sources are illustrated in Figure 3.

Particularly interesting it is the case of DC296.2-3.6, in wich a cluster of sources with IR excess is present as well as an infrared nebulosity. This DC is located at a distance of 3.6 Kpc in the far side of the Carina arm (see Figure 4). Accoding to Henning & Leunhardt

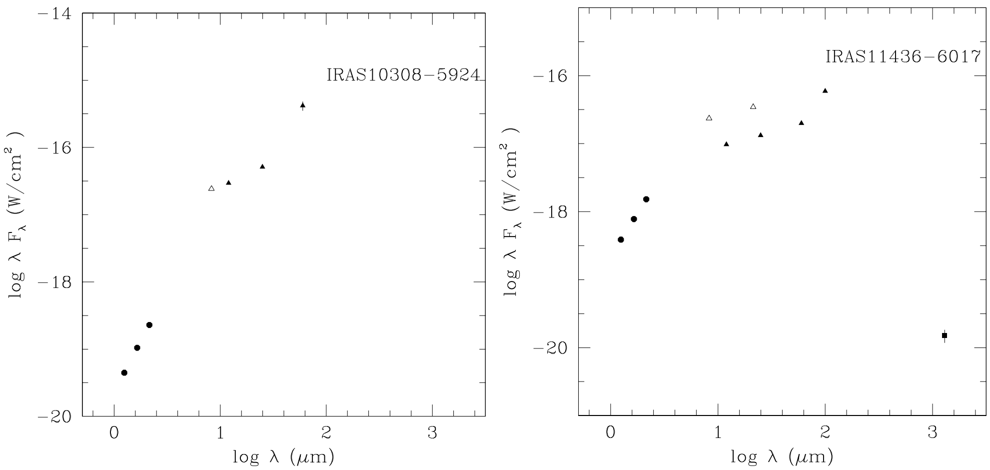

Fig. 3. Spectral energy distributions of IRAS10308-5923(DC286.2-1.3) and IRAS11436-6017(DC295.0+1.3).

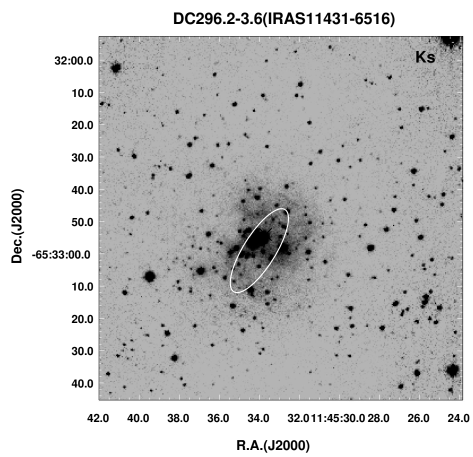

Fig. 4. K_s image of DC296.2-3.6. The symbols are as in Fig. 1

(1998) this cloud could be similar to the ρ Oph cloud core with an embedded cluster of low-mass YSOs, but seen at a much larger distance. We have recently re-observed several DCs of Table 1 at higher sensitivity and with higher spatial resolution in JHK_s bands using the Magellan telescopes at Las Campanas Observatory, and in the mid-IR using T-ReCS at the 8m Gemini South telescope. The results of these observations will be presented in a forthcoming paper (Persi et al. in preparation).

4. Conclusions

The southern hemisphere DCs reported by Hartley et al. (1986) does not represent an homogeneous sample of star forming regions. They include from very young globules with isolated embedded Class 0 objects to embedded clusters of low-mass YSOs,

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