Near-Infrared Study of Large Bok Globules

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Abstract

We present results from a near-infrared study of CB 3, CB 34, CB 39 and CB 54 as a part of an ongoing project, which is set to determine how Bok globules form, evolve and disperse.

Our observations have revealed the presence of active star formation in CB 3, CB 34 and CB 54, by the discovery of new knots in the H_2 1-0 S(1) emission line images.

We have discovered no indication of star formation in the Bok globule CB 39 which may suggest that this globule is in an early stage of evolution. Meanwhile the globules CB 3, CB 34 and CB 54 are obviously in their later stages of evolution.
KEYWORDS: *infrared: ISM – stars: formation – ISM: jets and outflows – ISM: clouds*

1. Bok Globules

Bok globules are dark patches on the sky against the background of stars, which have small angular extent and were stated as possible sites of star formation (Bok & Reilly, 1947). This statement has been confirmed recently by the work of Yun & Clemens (1990), who actually found manifestations of active star-formation in some globules.

The Catalouge of Northern Bok Globules has been published by Clemens & Barvainis (1988, hereafter CB88). The average catalogue members are small ($\approx$0.7 pc in diameter), with average masses of $\approx 10\,M_\odot$ and nearby ($d \leq 600$ pc; Bok, 1977; Leung, 1985; Launhardt & Henning, 1997). But CB88 contains some objects (e.g. CB 3, CB 34, CB 39, CB 54, CB 205) which are situated beyond 1 kpc and therefore are bigger in size ($\approx$2 pc) and larger in mass up to $120\,M_\odot$ in the case of CB 205 (Launhardt & Henning, 1997; Huard et al., 2000).

The importance of Bok globules is that they are sites of low-mass star formation (see Yun & Clemens, 1990; Khanzadyan et al., 2002). This is very important, because if there are some 10^5 globules in our Galaxy (Clemens et al., 1991), and we assume an average lifetime of 10^6 yrs and mass of $10\,M_\odot$ for them

(Launhardt & Henning, 1997), then a total mass of $10^{10}\,M_\odot$ could be processed through them during the lifetime of the Galaxy. This leads us to the conclusion that many field stars including our Sun, as well as T-Tauri stars may find their origin in Bok globules (Yun et al., 1997; Launhardt & Henning, 1997).

LBG vs. SBG: Large Bok Globules (LBGs) are sites for multiple and high-mass star formation, which tends to be a continuous process rather than a relatively instantaneous event like star formation in Small Bok Globules (SBGs) (Knee & Sandell, 2000; Motte et al., 1998). In LBGs powerful outflows, ejected from protostars interact with the globule material and are detectable even at the outskirts. In contrast to SBGs, which are nearby, outflows are not detected due to low column density and big outflow extent. So by detecting outflows from LBGs we are able to trace them back to the globule and associate with protostars (Khanzadyan et al., 2002).

2. Observations and Data Reduction

Observations of Bok globules were carried out during the nights of 7-10 December, 2000 using the Omega Prime (Bizenberger et al., 1998) infrared camera installed on the Calar Alto 3.5m telescope, Almeria, Spain. Omega Prime is equipped with a Rockwell 1024 × 1024 pixel HAWAII array detector. It provides a pixel scale of 0.4 arcsec/pixel and a total field of view of 6.8 × 6.8 arcmin^2 on the sky. Table 1 summarizes the observations.

Table 1: Log of the observations.

Object Name	R.A. (2000)	Decl. (2000)	Observed in Filters	seeing (arcsec.)
CB 3	$00^h28^m46^s$	$+56°42'06''$	K_s, H_2	1.5, 1.4
CB 34	$05^h47^m02^s$	$+21°00'10''$	J, H, K_s, H_2	1.5, 1.4, 1.2, 1.8
CB 39	$06^h02^m00^s$	$+16°31'00''$	K_s, H_2	1.7, 1.4
CB 54	$07^h04^m21^s$	$-16°23'18''$	J, H, K_s, H_2	1.5, 1.7, 1.6, 1.9

The data reduction and mosaicing proceeded through standard routines using several IRAF packages. In the later stage several packages from STARLINK software, such as CCDPACK and KAPPA, has been used for comparison of results and for correcting the array defects (Khanzadyan et al., 2002).

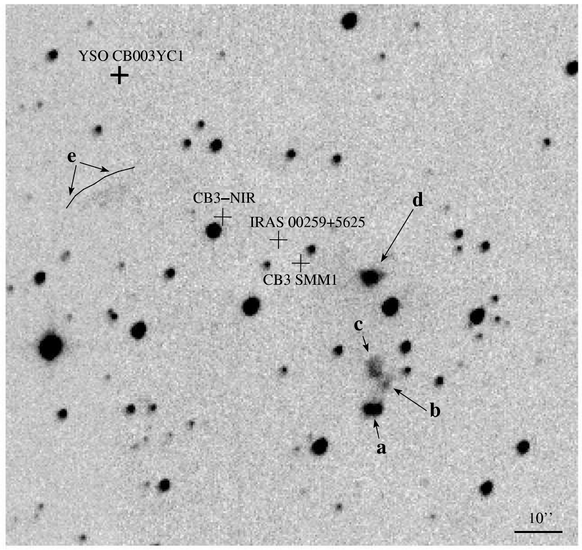

Figure 1: The central part of globule CB 3 in H_2 + cont. Newly found objects are labeled by letters **a** to **e**. The relative positions of several known sources are indicated on the image. The total integration time of this frame is 1120 seconds.

3. Results and Discussion

We found new H_2 excited objects in CB 3 marked by letters **a** to **e** in Fig. 1. The globule is excluded from the Bok globule study by Launhardt & Henning (1997) due to its large distance and mass, although it has a mass of $\approx$110 $M_\odot$, whereas CB 34 and CB 205, which are included, have masses of $\approx$80 $M_\odot$ and $\approx$120 $M_\odot$ (Huard et al., 2000).

CB 34 displays extremely well aligned chains of knots extending from submillimetre cores till the outskirts of the cloud, where they disappear without any trace of terminating bow shocks, due to lower density there (see Fig. 2).

CB 39 has several VLA sources in it and does not show any outflow activity (see Fig. 3), which may suggest relatively early stage of evolution.

The new near-infrared knots in CB 54 prove the active nature of cloud and indicate the advanced stage of its evolution (see Fig. 4).

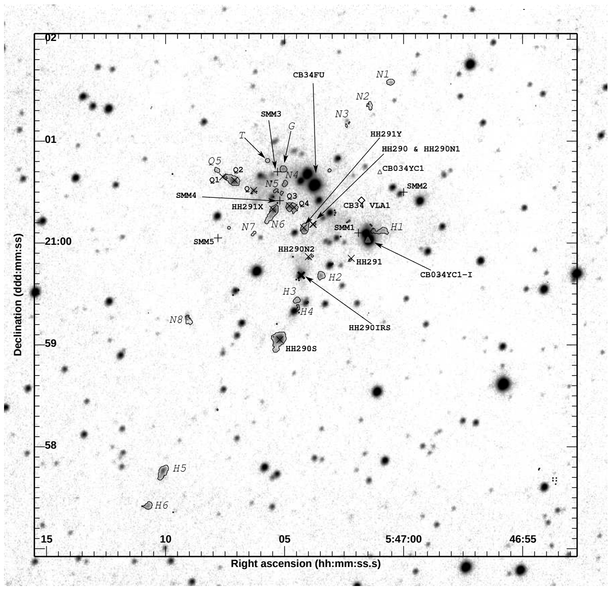

Figure 2: The central part of CB 34 in H_2. Total integration time of this frame is 3800sec. Crosses are SMM objects from Huard et al. (2000) and the asterixs are HH objects and H_2 knots discovered by Moreira & Yun (1995). CB34 VLA1 is marked by a diamond (Yun et al., 1996). The YSOs CB034YC1 and CB034YC1-I (triangles) are from Yun & Clemens (1994). Our discovered objects are indicated as chains of letters H and N as well as G and T. A further Q knot has been found – Q5.

4. Summary

CB 3, CB 34 and CB 54 are in advanced stage of evolution. We have discovered outflows from all of them by detecting their interaction with their environment.

We discovered no indication of active star formation in CB 39, which may suggest that the globule is in an early stage of evolution.

We suggest to classify CB 3 as a typical member of LBGs and therefore to connect it to the main evolutionary scenario of Large Bok Globules, if it exists.

Is there any sequence of LBGs and SBGs? Possibly LBGs are separate group of objects and should be treated apart from SBGs.

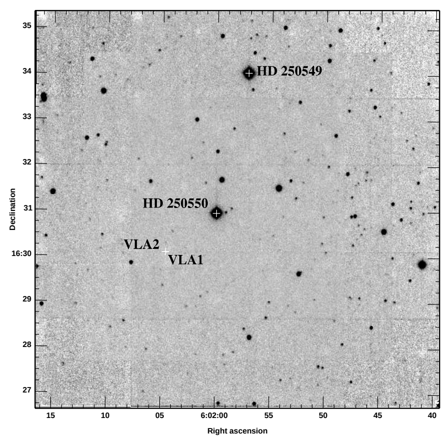

Figure 3: CB 39 in H_2 with total integration time of 1120 seconds.

Acknowledgements

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References

Bizenberger, P., McCaughrean, M.J., Birk, C., Thompson, D., Storz C., 1998, SPIE 3354, 825

Bok, B.J., Reilly, E.F., 1947, ApJ 105, 255

Bok, B.J., 1977, PASP 89, 597

Clemens, D.P., Barvainis, R.E., 1988, ApJS 68, 257

Clemens, D.P., Yun, J.L., Heyer, M.H., 1991, ApJS 75, 877

Huard, T.L., Weintraub, D.A., Sandell, G., 2000, A&A, 362, 635

Khanzadyan, T., Smith, M.D., Gredel, R., Stanke, T., Davis, C.J., 2002, A&A 383, 502

Knee, L.B.G., Sandell, G., 2000, A&A 361, 671

Launhardt, R., Henning, Th., 1997, A&A 326, 329

Leung, C.M., 1985, Protostars and Planets II, eds. Black, D.C. & Matthews, M.S., Univ. of Arizona Press, Tucson, p.104

Moreira, M.C., Yun, J.L., 1995, ApJ 454, 850

Motte, F., Andre, P., Neri, R., 1998, A&A 336, 150

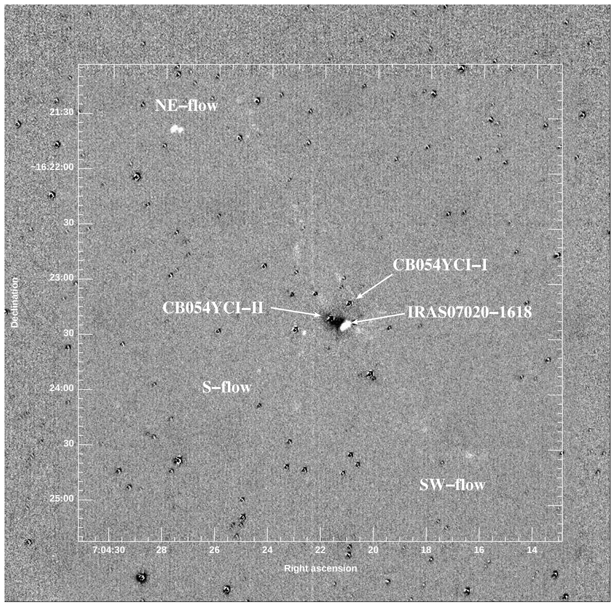

Figure 4: CB 54 in H_2-Continuum. Total integration in H_2 is 2700 seconds.

Yun, J.L., Clemens, D.P., 1990, ApJ 365, L73
Yun, J.L., Clemens, D.P., 1994, ApJS 92, 145
Yun, J.L., Moreira, M.C., Torrelles, J.M., Afonso, J.M., Santos, N.C., 1996, AJ 111, 841
Yun, J.L., Moreira, M.C., Alves, J.F., Storm, J., 1997, A&A 320, 167