CCS versus NH_3 in Bok globules - a possible age indicator?

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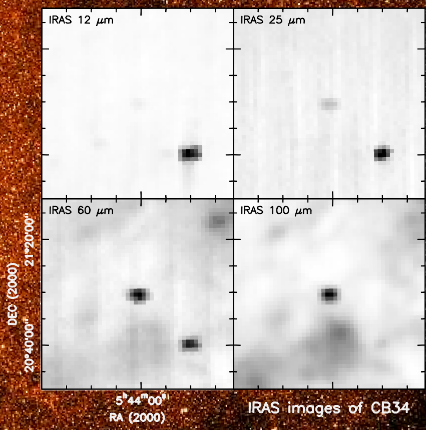
Abstract

Bok globules as relatively small and isolated molecular clouds are interesting targets for a study of isolated low-mass star formation. Because of different production mechanisms (Suzuki et al. 1992) the abundance of CCS is expected to be higher in cold and quiescent cloud cores and to decrease in time with ongoing evolution and star formation process inside the globules. In contrast, NH_3 tends to be more abundant in cores with star formation than in those without.
Therefore the CCS/NH_3 ratio has been proposed to possibly be a useful tracer of the cloud evolution process and an indicator for the age of the globules.

In order to investigate the role of this abundance ratio in more detail, a sample of 22 Bok globules in different evolutionary stages has been observed in the CCS (J_N=2_1-1_0) line at 22.344 GHz using the Effelsberg 100m Radio Telescope.
The aim of this study is to find out in which globules CCS emission is present at all, what the abundance ratio between CCS and NH_3 is and how this ratio correlates with other age indicators (e.g. molecular outflows, IRAS colours).



IRAS images of CB34

Characterization of the evolutionary stages (based on IRAS point source fluxes) according to Launhardt & Henning (1997):

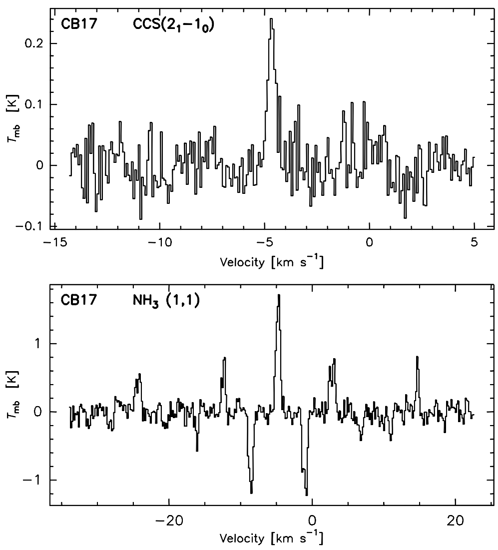
- Group 1 (protostellar cores): candidates for internally heated starforming cloud cores (infrared SED steadily rising from 12 to 100μm, but significantly broader than that of a single blackbody)
- Group 2 (pre-protostellar cores): candidates for young star-forming regions (SED steeply rising from 60 to 100μm; not detected at λ <60μm, no molecular outflows found)
- Group 3: candidates for evolved young stars with warm circumstellar dust (detected at least at 12μm, but not at 100μm, SED rising towards shorter wavelengths)
- Group 4: no associated IRAS point sources within the boundaries of the globule known.

Overview of the sample and first results of the CCS(2_1-1_0) observations

source	group[a]	associated IRAS source[b]	CO outflow[c]	v_{LSR} [km/s]	Δv [km/s]	$\int T_{mb}dv$ [K km/s]	T_{mb} [mK]	r.m.s. [mK]	N_{CCS} [$10^{12}cm^{-2}$]	N_{NH_3}[d] [$10^{12}cm^{-2}$]
CB3	1	00259+5625	y	-	-	-	<132	31	-	
CB6	1	00465+5028	-	-	-	-	<102	31	-	
CB12	2	01354+6447	-	-	-	-	<135	38	-	
CB17	2	04005+5647		-4.66 ± 0.01	0.44 ± 0.02	0.112 ± 0.003	236	36	3.3 ± 0.1	7.78 ± 1.11
CB22	4	-		-1.04 ± 0.01	0.14 ± 0.03	0.036 ± 0.005	234	37	1.0 ± 0.1	3.64 ± 0.87
CB23	4	-		4.87 ± 0.01	0.16 ± 0.03	0.064 ± 0.001	380	40	1.87 ± 0.03	10.1 ± 1.1
CB26	1	04559+5200		-	-	-	<140	38	-	
CB28	4	05036-0359	-	9.02 ± 0.02	0.28 ± 0.04	0.065 ± 0.009	221	39	1.9 ± 0.2	1.95 ± 1.18
CB34	1	05440+2059	y	0.29 ± 0.01	0.34± 0.04	0.041 ± 0.004	115	36	1.2 ± 0.1	
CB44	4	06047+1923		-	-	-	<124	44	-	
CB68	1	16544-1604	-	-	-	-	<130	38	-	12.7 ± 0.9
CB125	3	18127-1803		-	-	-	<132	43	-	6.01 ± 0.30
CB130	4	-		-	-	-	<95	34	-	17.9 ± 4.1
CB179	3	19018-0525		-	-	-	<111	33	-	
CB188	1	19179+1129	y	6.16 ± 0.02	0.51 ± 0.04	0.061 ± 0.005	111	34	1.8 ± 0.1	
CB222	2	20328+6351		-2.74 ± 0.01	0.41± 0.01	0.042 ± 0.001	98.1	24	1.24 ± 0.03	
CB224	1	20355+6343		-	-	-	<157	48	-	6.23 ± 1.17
CB230	1	21169+6804	?	2.43 ± 0.01	0.23 ± 0.04	0.063 ± 0.006	218	50	1.5 ± 0.2	
CB232	1	21352+4307	y	12.50 ± 0.01	0.26 ± 0.03	0.038 ± 0.003	138	42	1.1 ± 0.1	
CB243	1	23228+6320		-	-	-	<96	38	-	2.77 ± 1.04
CB244	1	23238+7401	y	4.19 ± 0.01	0.33 ± 0.05	0.052 ± 0.007	149	41	1.5 ± 0.2	9.64 ± 1.07
CB246	1	-		-0.65 ± 0.01	0.25 ± 0.03	0.122 ± 0.010	461	39	3.5 ± 0.3	7.70 ± 1.01

[a] Launhardt & Henning 1997 [c] Yun & Clemens 1992/1994 [b] Clemens & Barvainis 1988 [d] Lemme et al. 1996

Two examples of spectra obtained in Effelsberg for the Bok globule CB17, which shows no current signs of star formation.



Preliminary Results

Although NH_3 (1,1) emission is present in all globules of the sample, CCS was detected in 11 globules only. CCS has been sucessfully observed in

- 60% of the globules (three out of five) being quiescent cores without any internal infrared sources (group 4)
- 66% of the globules (two out of three) being quiescent, pre-protostellar cores with weak (or cold) internal infrared sources (group 2)
- 50% of the globules (six out of twelve) being protostellar, star-forming cores (group 1), and
- 0% of the globules with internal infrared sources being candidates for evolved young stars (group 3)

The quiescent globules of group 4 (which have not yet formed stars or may be not forming stars at all) tend to show particularly narrow lines.

References

Clemens & Barvainis 1988, ApJS 68, 257
Launhardt & Henning 1997, A&A 326, 329
Lemme, Wilson, Tieftrunk, Henkel 1996, A&A, 312, 585
Suzuki, Yamamoto, Ohishi, Kaifu, Ishikawa, Hirahara, Takano 1992, ApJ 392, 551)
Yun & Clemens 1992, ApJ 385, 21 and 1994, ApJ 92, 145

DSS2 (Red) image of CB188