"All-sky" survey of Planck cold clumps

------- A joint legacy project with the JCMT, the TRAO 14-m and KVN telescopes

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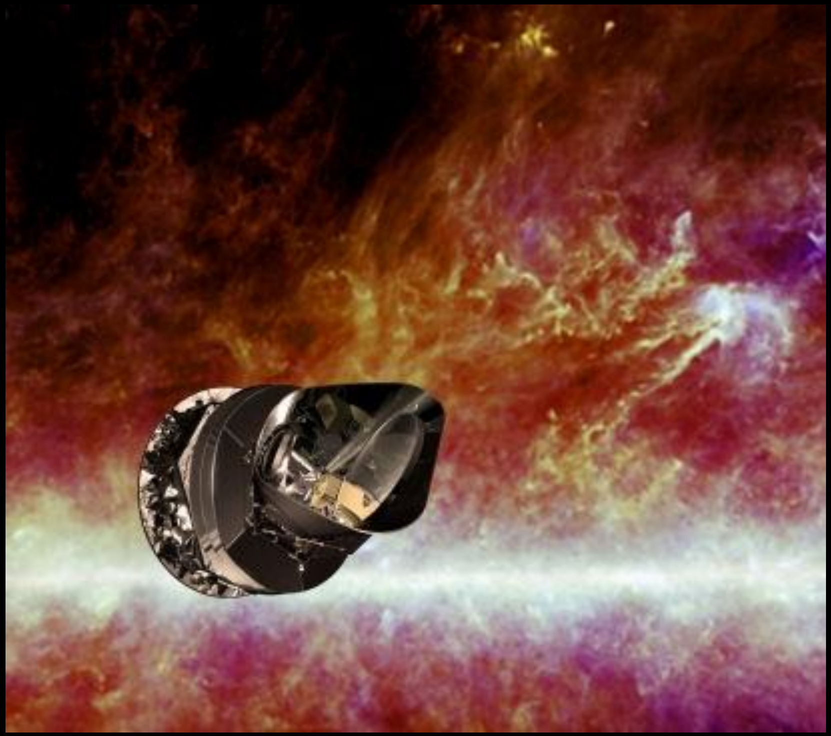
Outline:

- 1. Motivation of this legacy survey
- 2. Pilot observations and Preliminary results
- 3. A joint legacy project with the JCMT, the TRAO 14-m and the KVN telescopes

1. Motivation

- 1.An "all-sky" survey of cold clouds (outer Galaxy, High-Lat. Clouds), complementary to other surveys (e.g. Gould belt, Galactic plane)
- 2. Statistical studies of the properties of molecular clouds across the whole Galaxy
- **3. Formation and evolution of Starless/Prestellar Cores**
- **4. Search for First Hydrostatic Core**
- **5. Search for massive prestellar cores**
- **6. Fragmentation of massive Prestellar Clumps**
- **7. The role of turbulence and magnetic field in cloud and core formation and evolution.**
- **8. Properties of filamentary clouds**
- **9. and so on ……**

What are Planck cold clumps?



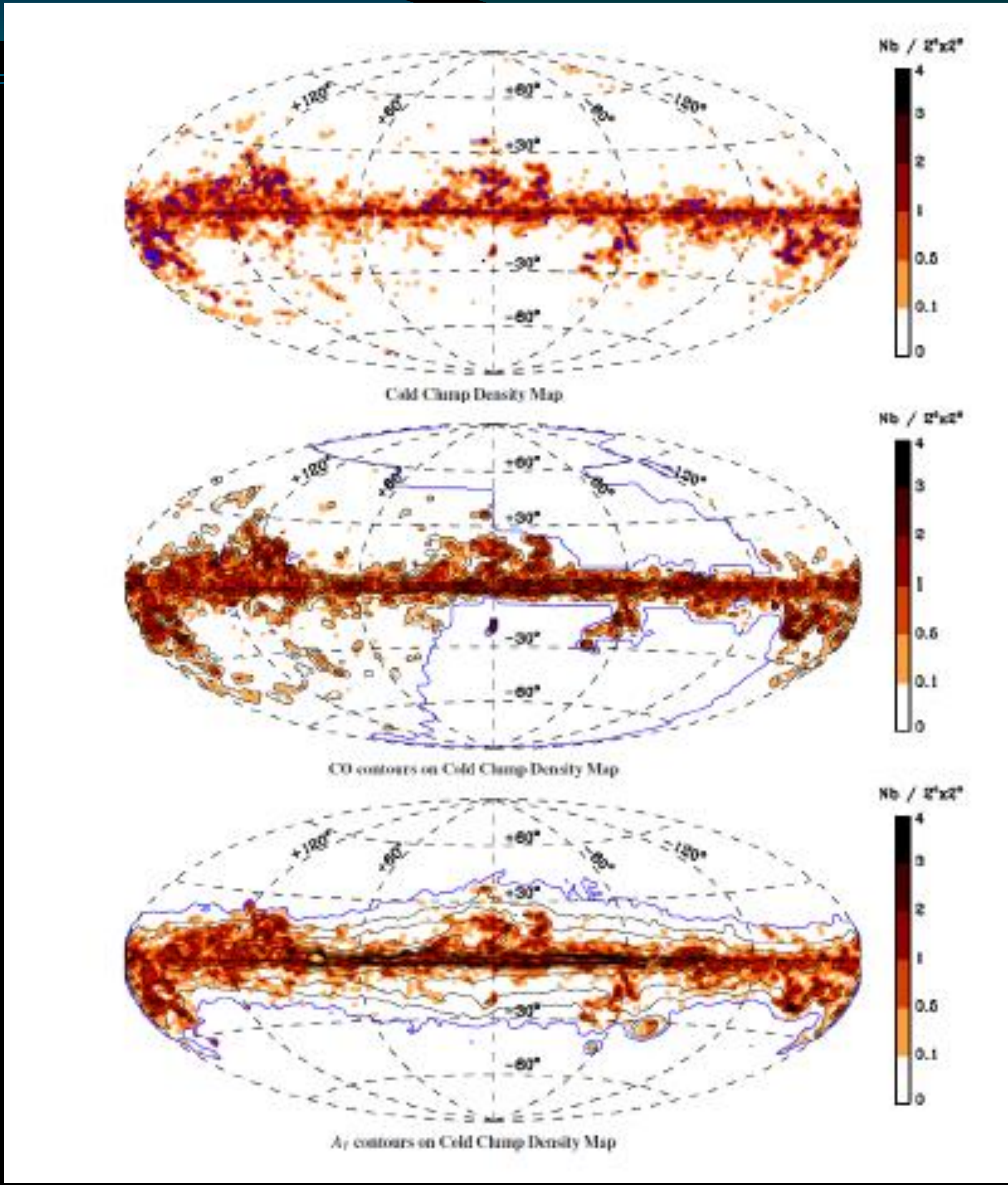
Planck is a third generation space based cosmic microwave background experiment, operating at nine frequencies between 30 and 857 GHz

a blackbody at T = 6K, the coldest dust temperature found inside Galactic dense cores, peaks at 850 GHz

Planck Galactic Cold Clumps (PGCC), 13188 cold clumps (Planck collaborations et al. 2015)

the early cold core (ECC) sample: 915 sample

Td<14 K, SNR>15



Planck collaborators et al. (2011)

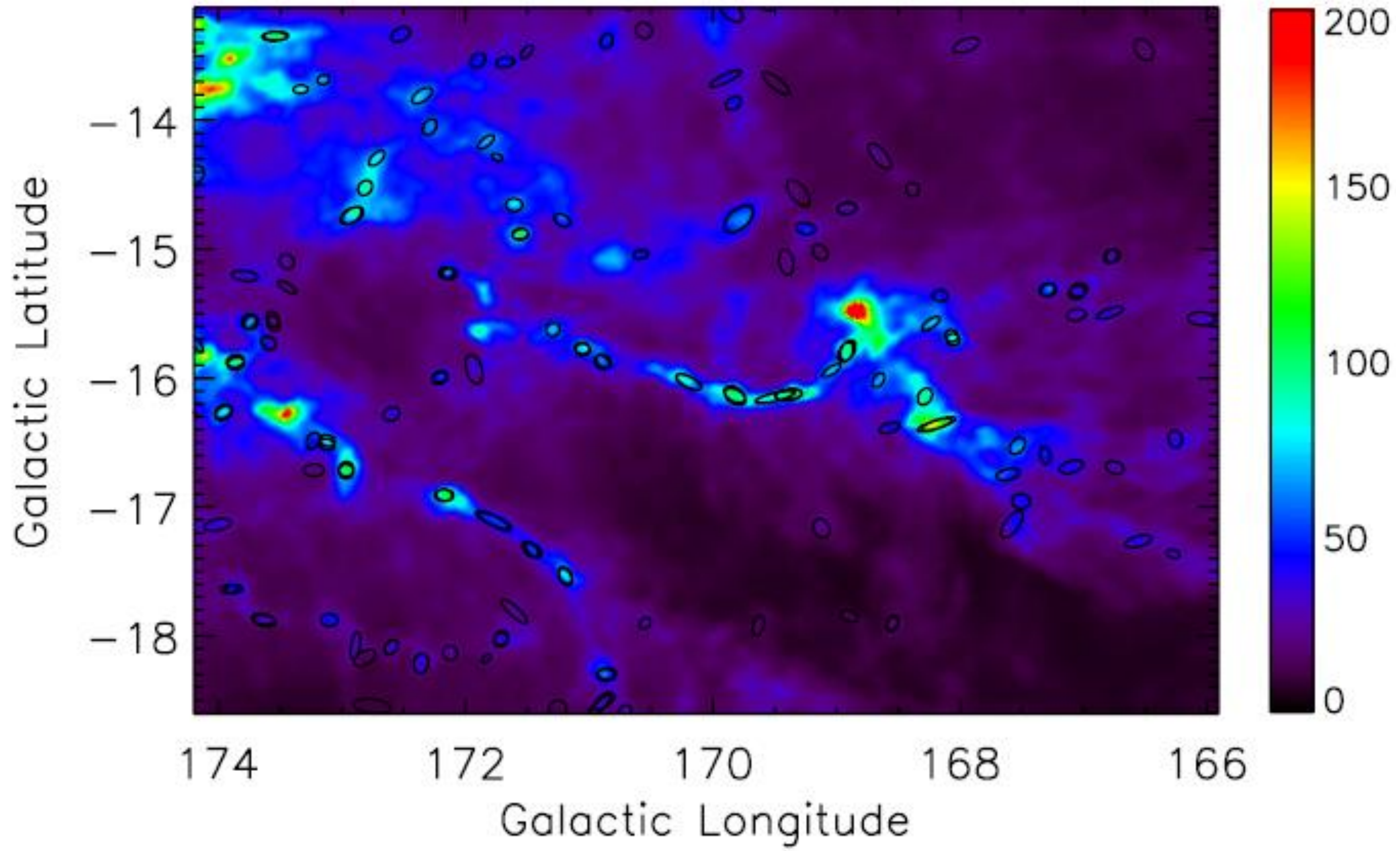


Fig. 8. *Planck*-HFI map at 857 GHz (in MJy sr^{-1}) of the Taurus cloud area, showing the location and extent (at one FWHM) of the C3PO cold sources. C3PO cold sources are clearly distributed along the filaments of submillimetre dust emission, also known to be the coldest regions in IRAS colours (Abergel et al. 1994).

Planck collaborators et al. (2011)

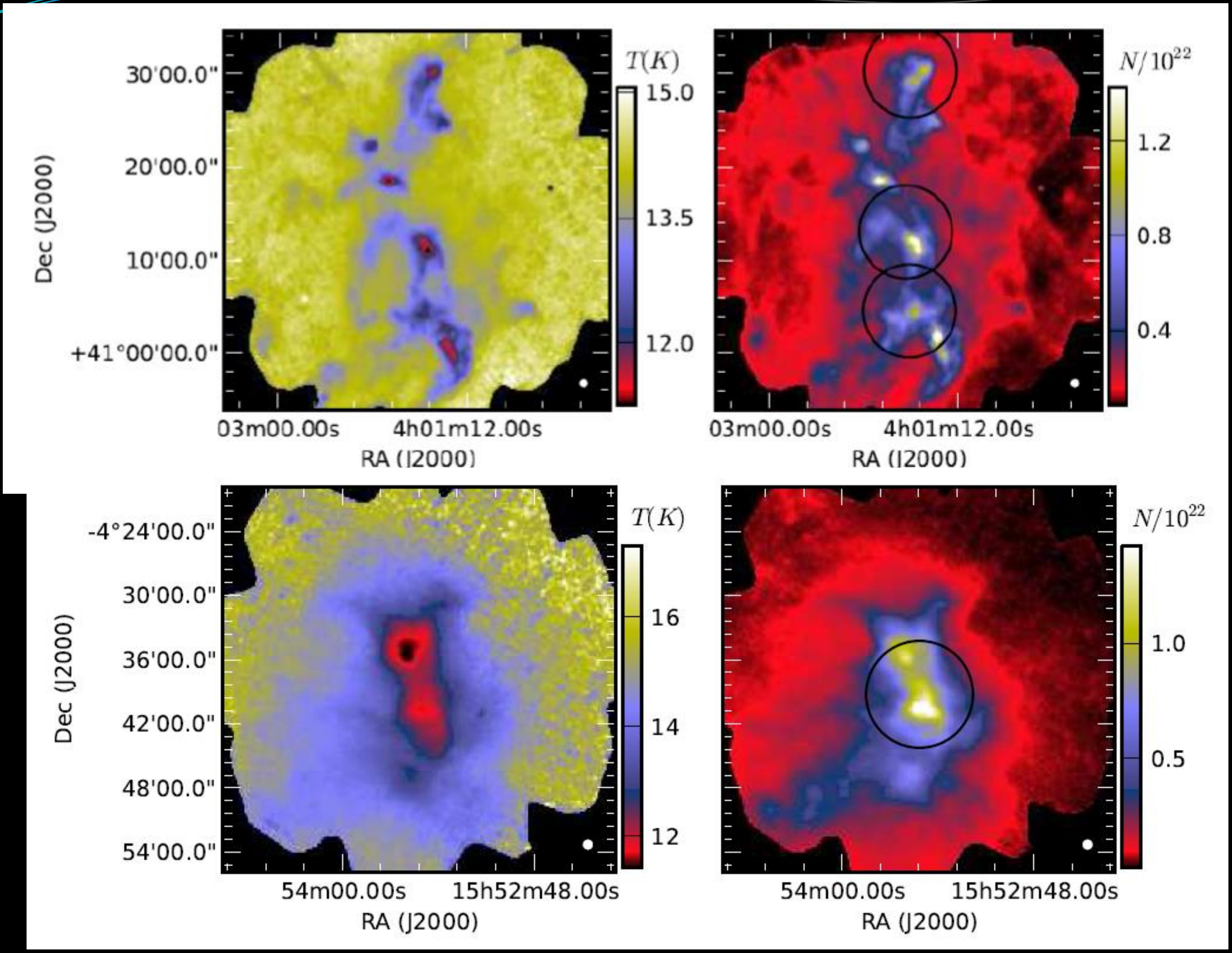
Table 9. Statistical description of the distribution of physical properties of the *Planck* C3PO catalogue of cold clumps.

Quantity	Min.	Median	Max.
T_c [K]	7	13	19
N_H [cm^{-2}]	10^{20}	2×10^{21}	2×10^{23}
Size [pc]	0.2	1.2	18
Ellipticity	0.4	0.8	1
Mass [$M_\odot$]	0.4	88	2.4×10^5
Mean density [cm^{-3}] . .	10^2	2×10^3	10^5

Notes. Notice that the minima and maxima of each quantity are not associated with the same objects. See Fig. 21 to get a better understanding of the correlations between some of these physical quantities.

Planck collaborators et al. (2011)

Planck cold clumps in Herschel images



(Juvela, M. et al. 2013)

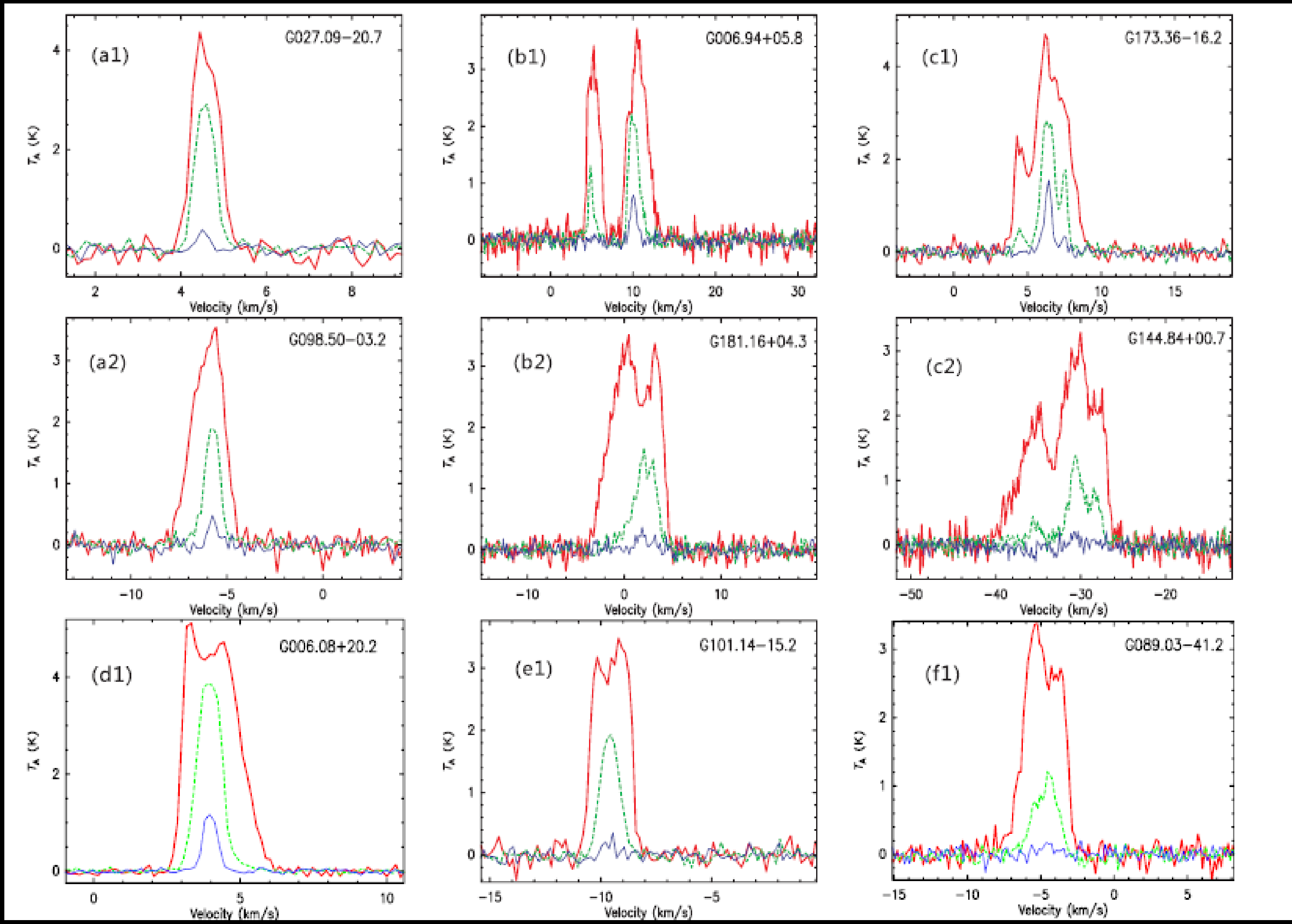
2. Pilot observations and Preliminary results

Table 1: Summary of the observations

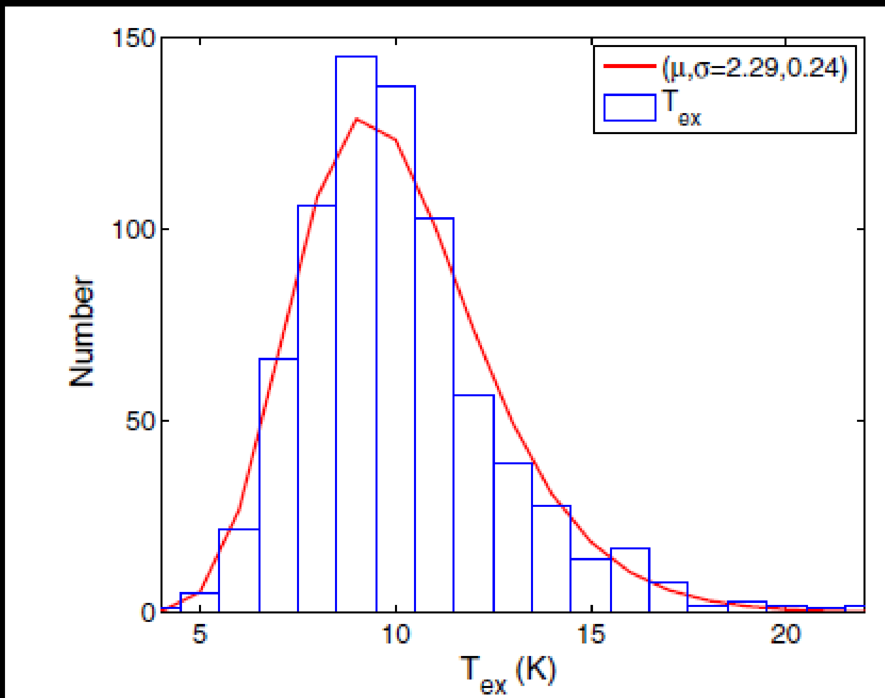
Telescopes	Tracers	Aims	Status	Data analyst
PMO 13.7-m	J=1-0 of ^{12}CO, ^{13}CO, $C^{18}O$, HCN and HCO^{+}	dense clumps	674 PCCs surveyed	Yuefang Wu's group
CSO 10-m	J=2-1 of ^{12}CO, ^{13}CO, $C^{18}O$	CO depletion & outflows	20 PCCs mapped	Tie Liu
APEX 12-m	J=2-1 of ^{12}CO, ^{13}CO, $C^{18}O$	CO depletion & outflows	proposal accepted	
NANTEN2 4-m	^{12}CO (4-3) & (7-6)	shock evidence	proposal accepted	
IRAM 30-m	J=2-1 of ^{12}CO, ^{13}CO & $C^{18}O$ J=1-0 of HCN, HCO^{+} & N_2H^{+}	starless cores; chemistry	24 PCCs mapped	Yuefang Wu's group
Mopra 22-m	J=1-0 of HCN, HCO^{+} & N_2H^{+} SiO (2-1), HC_3N (10-9)	chemistry	30 PCCs mapped	Maria Cunningham's group
Effelsberg 100-m	NH_3 (1,1) & (2,2); HC_7N (21-20)	kinetic temperature & chemistry	proposal accepted	
The SMA	continuum and molecular lines at 230 GHz band	fragmentation & kinematics of G207.3-19.8	proposal accepted	
The SMA filler	continuum and molecular lines at 230 GHz band	Origin of the protostellar outflow in G192.3 a proto brown dwarf or a first hydrstatic core?	2 tracks awarded; 1 track has completed	Qizhou Zhang
KVN filler	22 GHz H_2O maser, 44 GHz CH_3OH maser HCO^{+}, HC_3N & N_2H^{+}	masers and dense gas	40 hrs awarded	
SCUBA-2/JCMT	850μm continuum	Pilot survey	SASSy time for ~100 PCCs	Mark Thompson's group

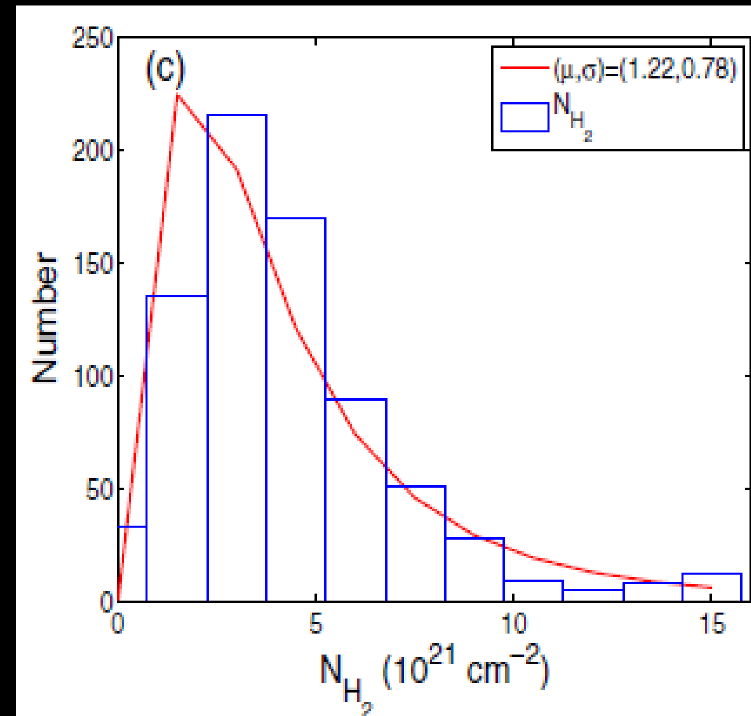
PMO 13.7-m observations

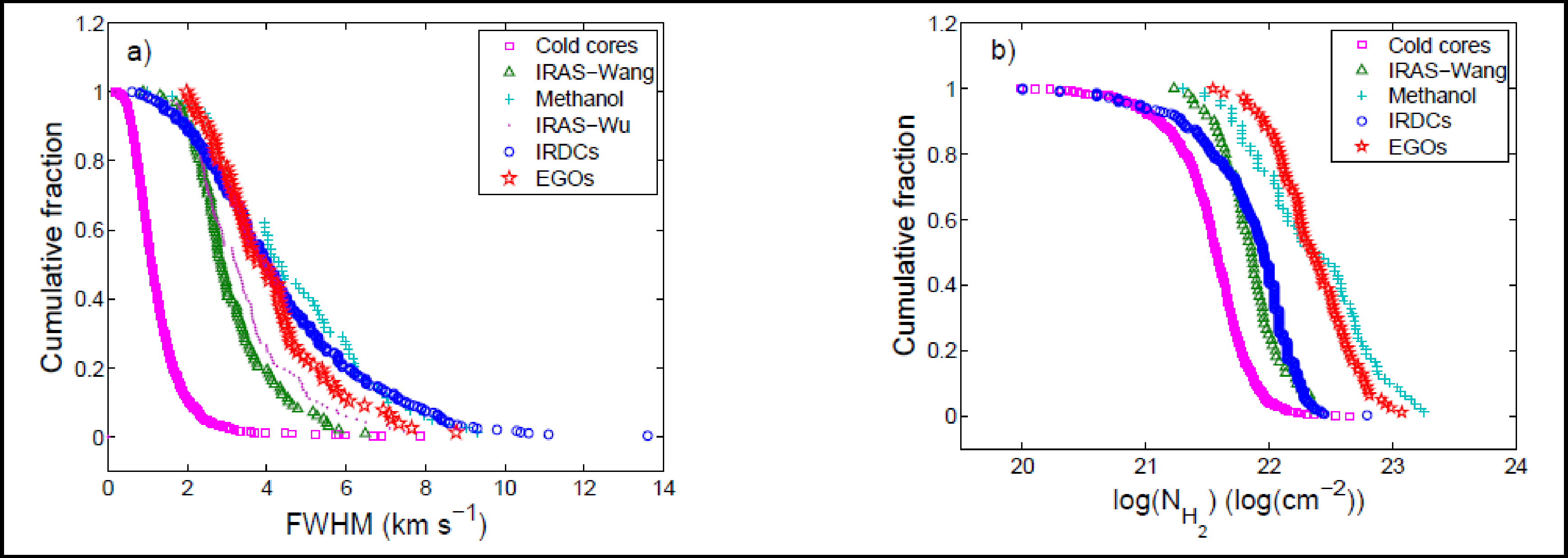
Red: 12CO (1-0)
Green: 13CO (1-0)
Blue: C18O (1-0)

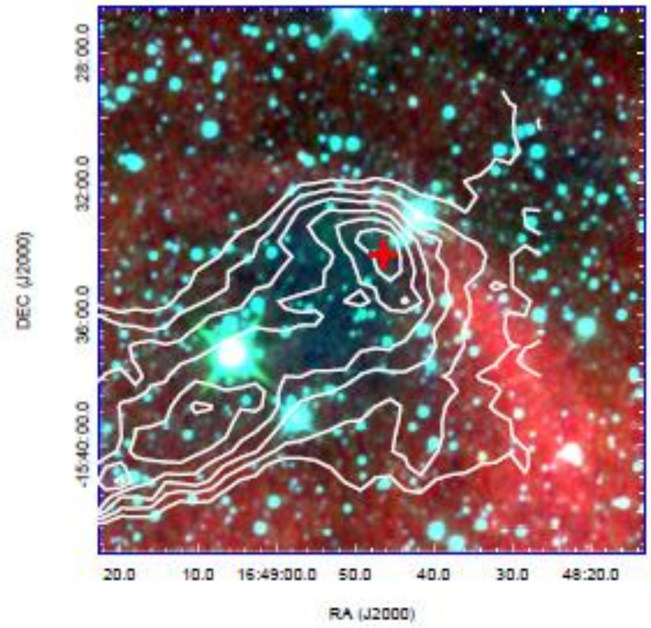


(Wu & Liu et al.2012. ApJ, 756, 76)

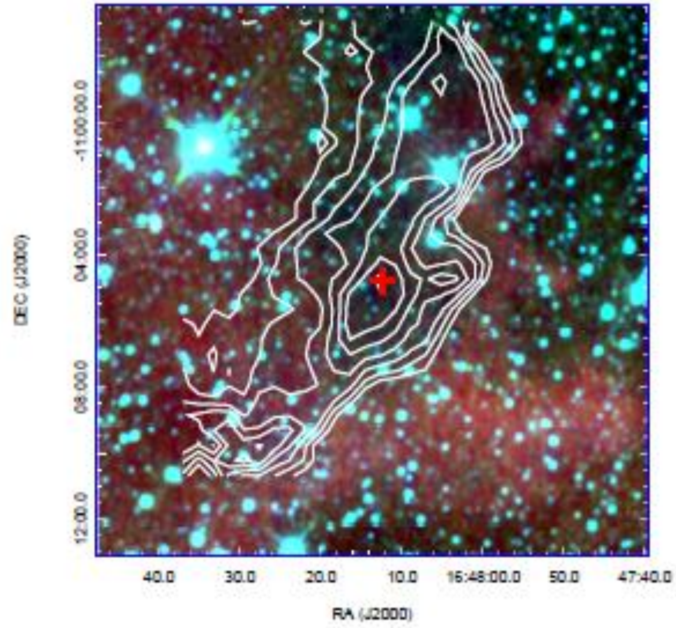

(μ,σ=2.29,0.24)
T_ex
Number
T_ex (K)
150
100
50
0
5
10
15
20


(c)
(μ,σ)=(1.22,0.78)
N_H2
Number
N_H2 (10^21 cm^-2)
250
200
150
100
50
0
0
5
10
15

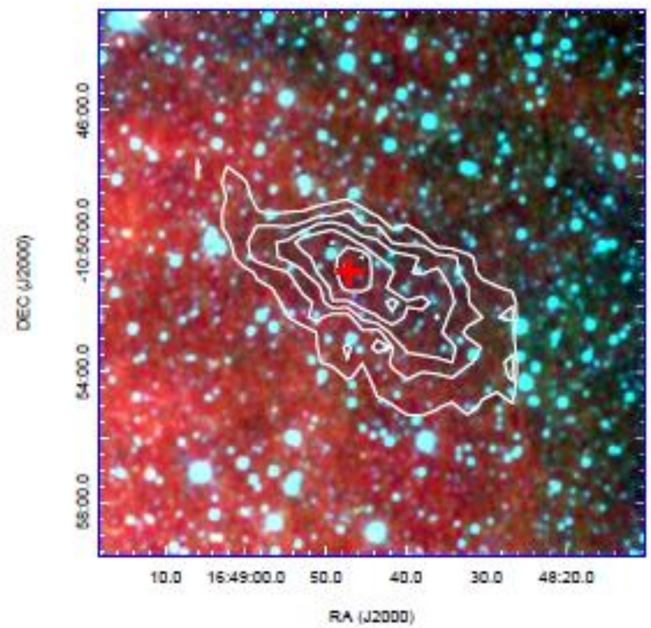

a)
Cold cores
IRAS−Wang
Methanol
IRAS−Wu
IRDCs
EGOs
Cumulative fraction
FWHM (km s^{-1})
b)
Cold cores
IRAS−Wang
Methanol
IRDCs
EGOs
Cumulative fraction
log(N_{H_2}) (log(cm^{-2}))



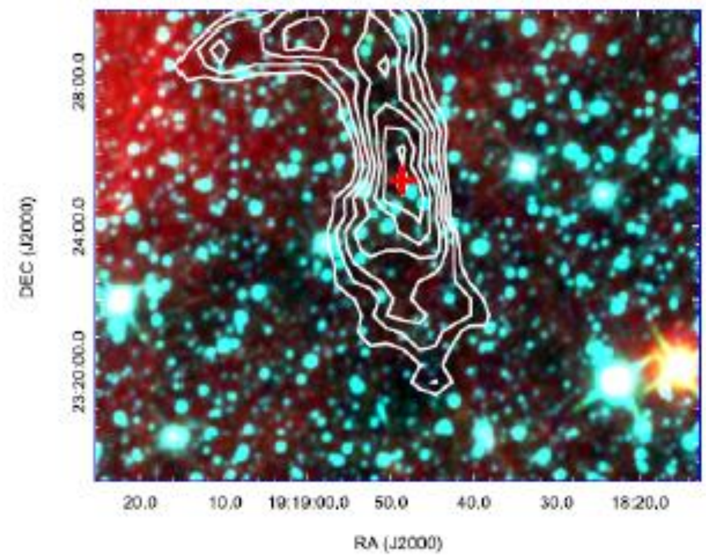
DEC (J2000)
28:00.0
32:00.0
36:00.0
-15:40:00.0
20.0
10.0
16:49:00.0
50.0
40.0
30.0
48:20.0
RA (J2000)



DEC (J2000)
-11:00:00.0
04:00.0
08:00.0
12:00.0
40.0
30.0
20.0
10.0
16:48:00.0
50.0
47:40.0
RA (J2000)

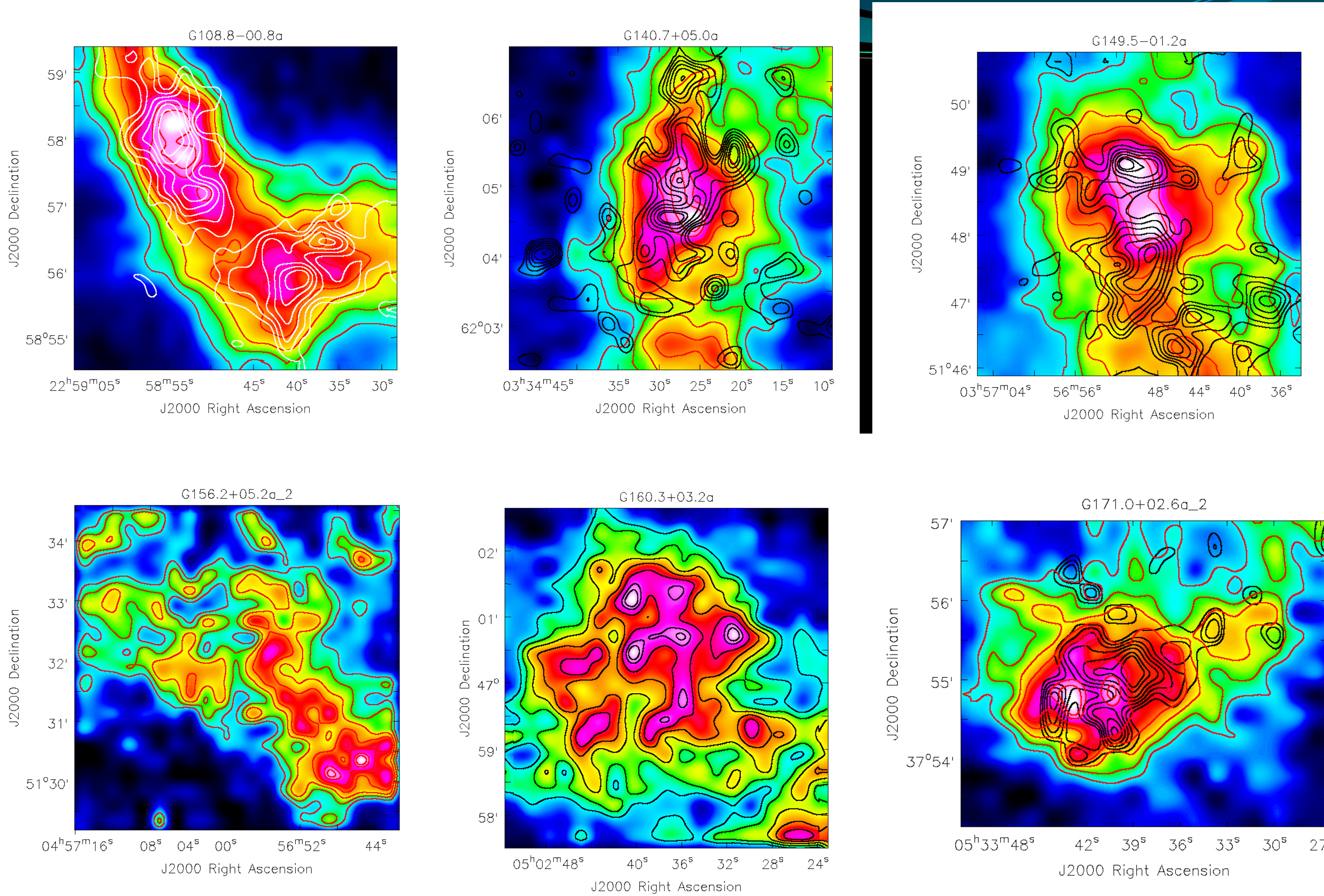


DEC (J2000)
46:00.0
-10:50:00.0
54:00.0
58:00.0
10.0
16:49:00.0
50.0
40.0
30.0
48:20.0
RA (J2000)

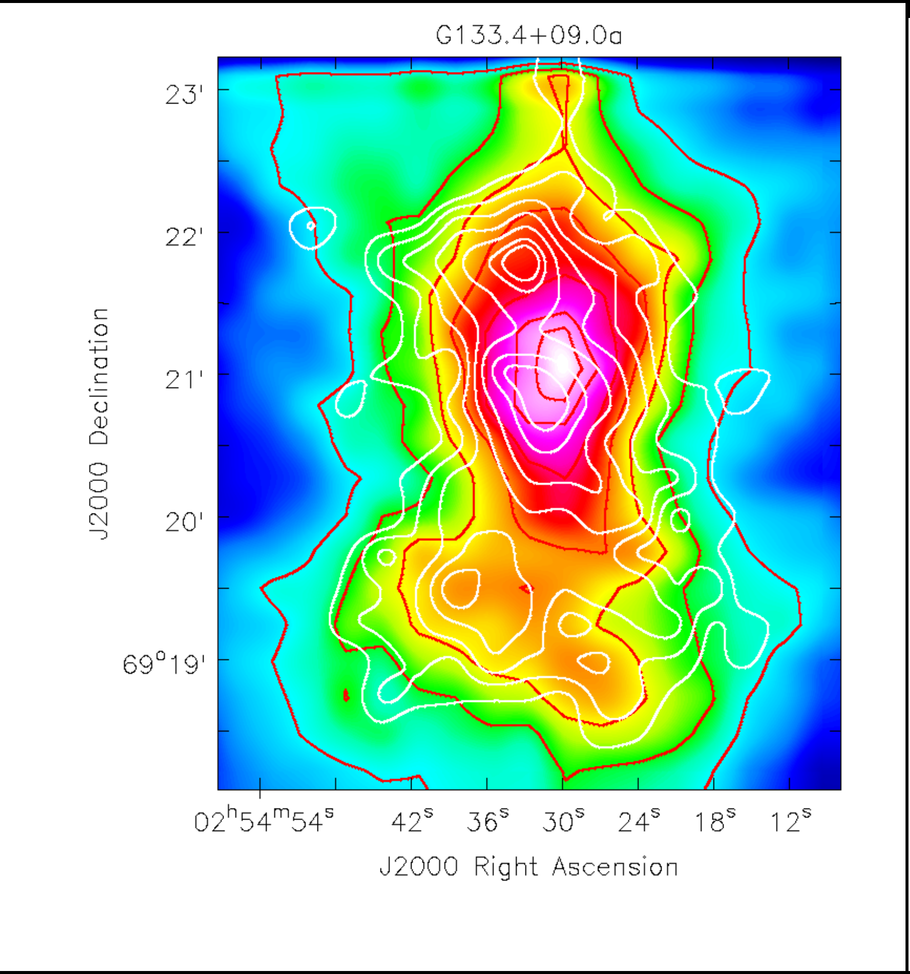


DEC (J2000)
28:00.0
24:00.0
23:20:00.0
20.0
10.0
19:19:00.0
50.0
40.0
30.0
18:20.0
RA (J2000)

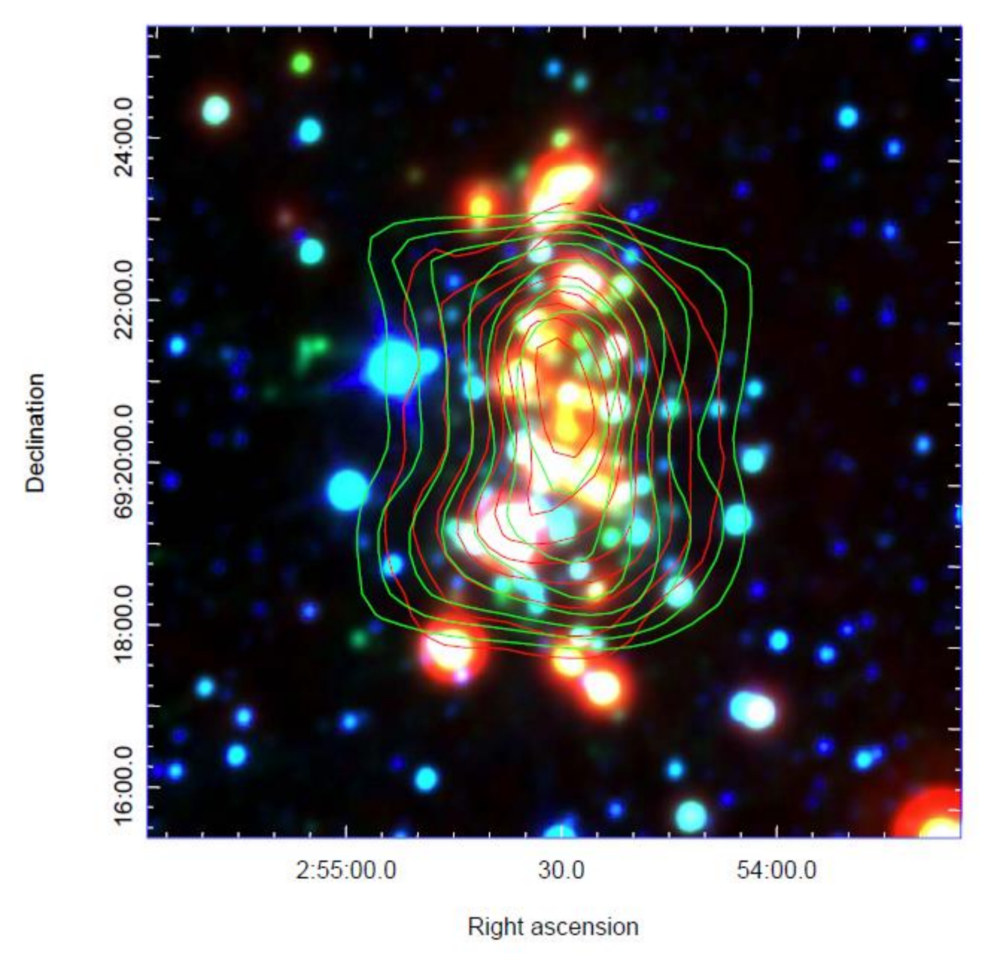
CSO observations of PCCs: background images: 13CO (2-1)



G133.4+09.0



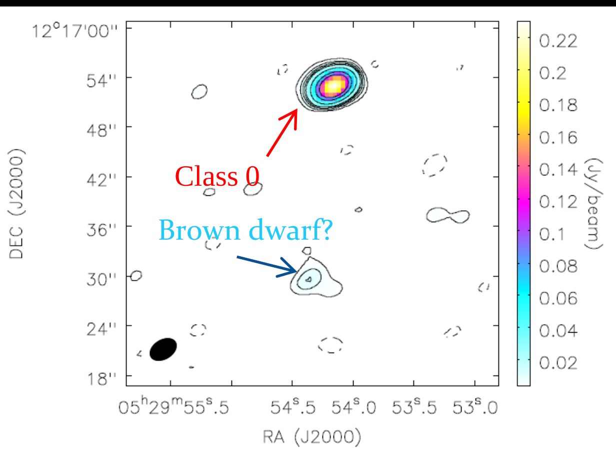
G133.4+09.0a
23'
22'
21'
20'
69°19'
J2000 Declination
02h54m54s
42s
36s
30s
24s
18s
12s
J2000 Right Ascension



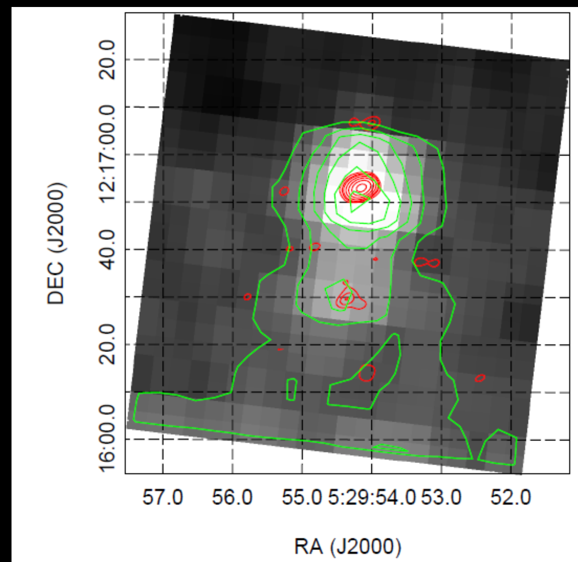
24:00.0
22:00.0
69:20:00.0
18:00.0
16:00.0
Declination
2:55:00.0
30.0
54:00.0
Right ascension

Planck cold clump G192.3-11.8: containing two very low luminosity objects (Vellos)

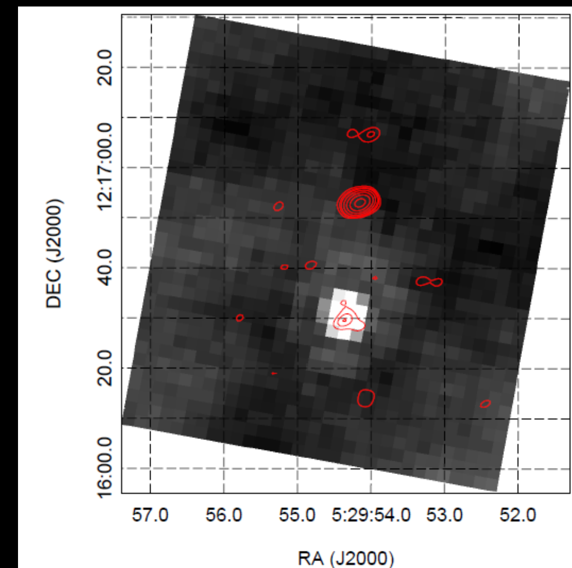
SMA 1.3 mm



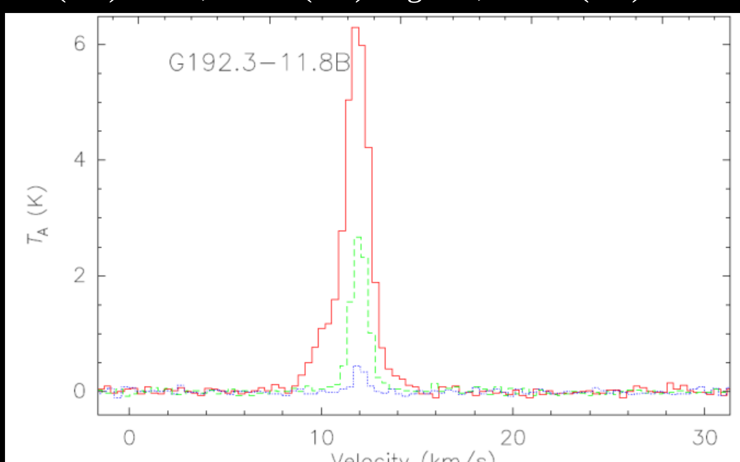
SMA 1.3mm in red, Spitzer 70 micron in green



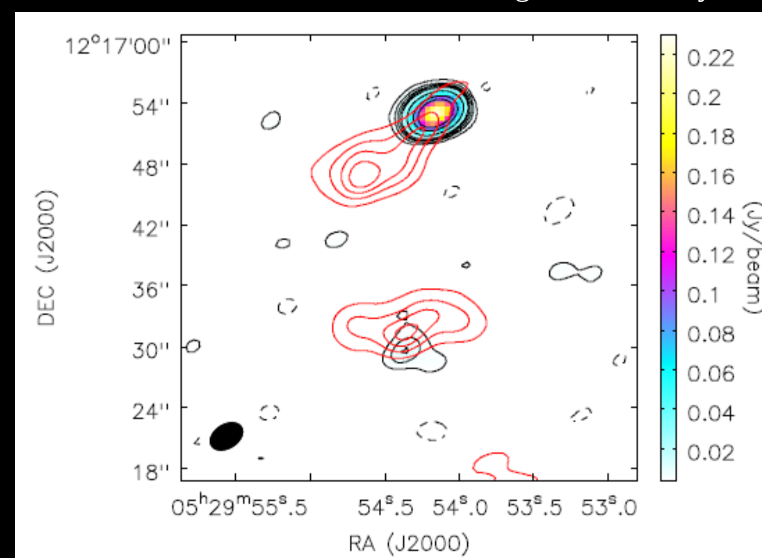
SMA 1.3mm in red, Spitzer 24 micron in grey image



CO (2-1) in red, 13CO (2-1) in green, C18O (2-1) in blue



SMA 1.3 mm in color and black contours, CO integrated intensity in red contours



IRAM 30-m observations

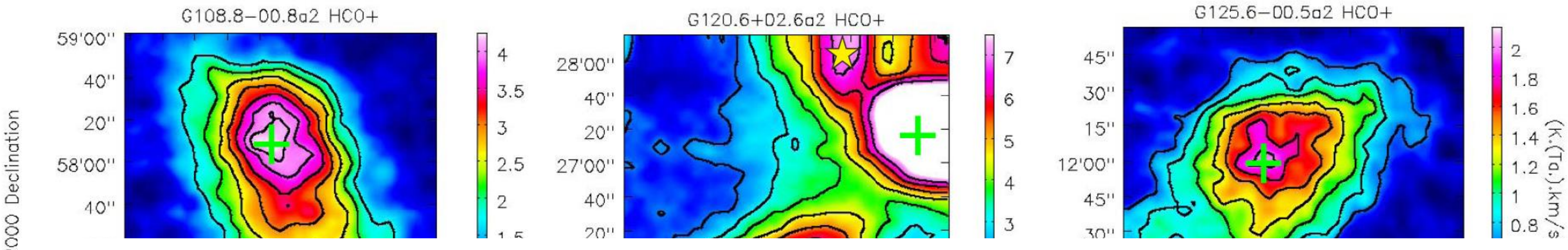
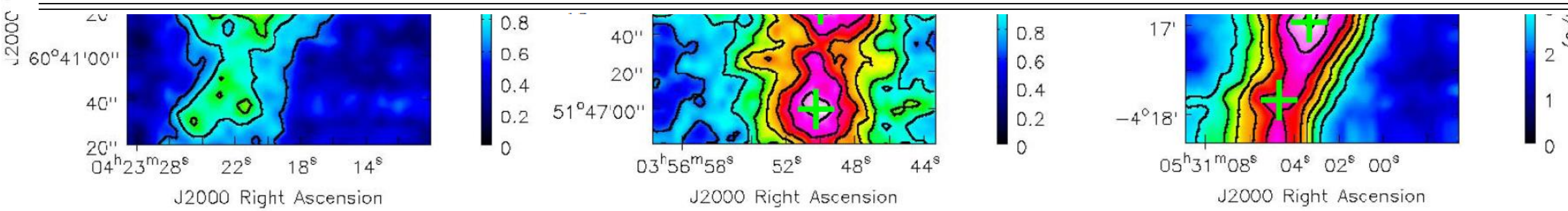
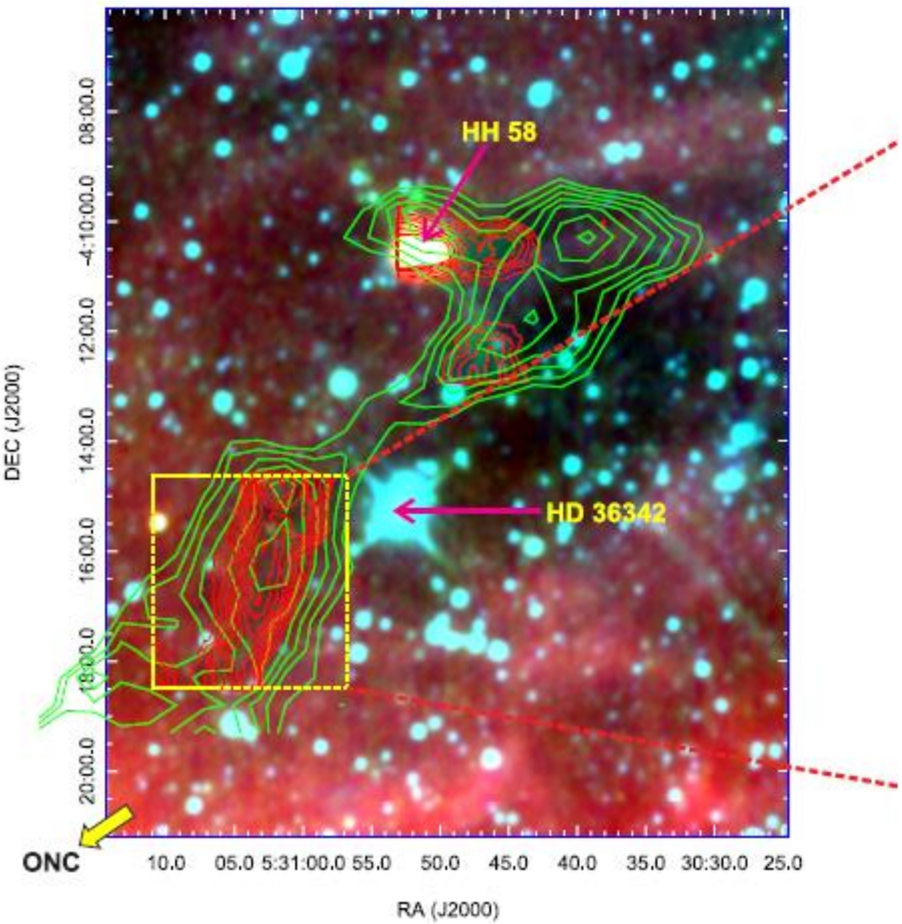
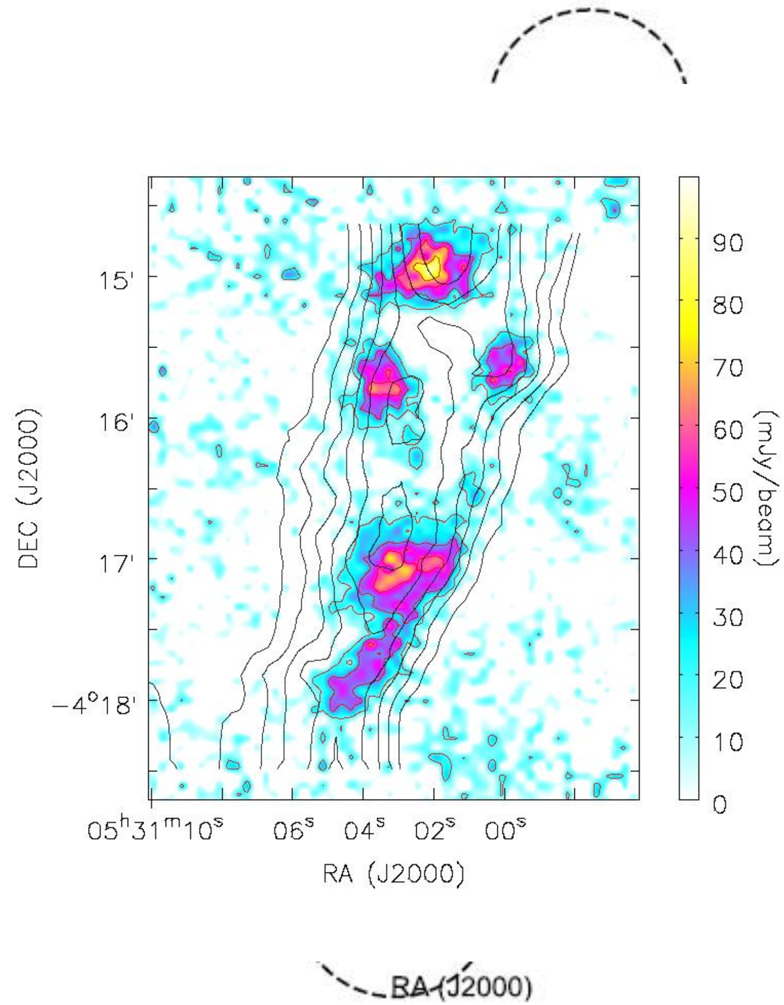


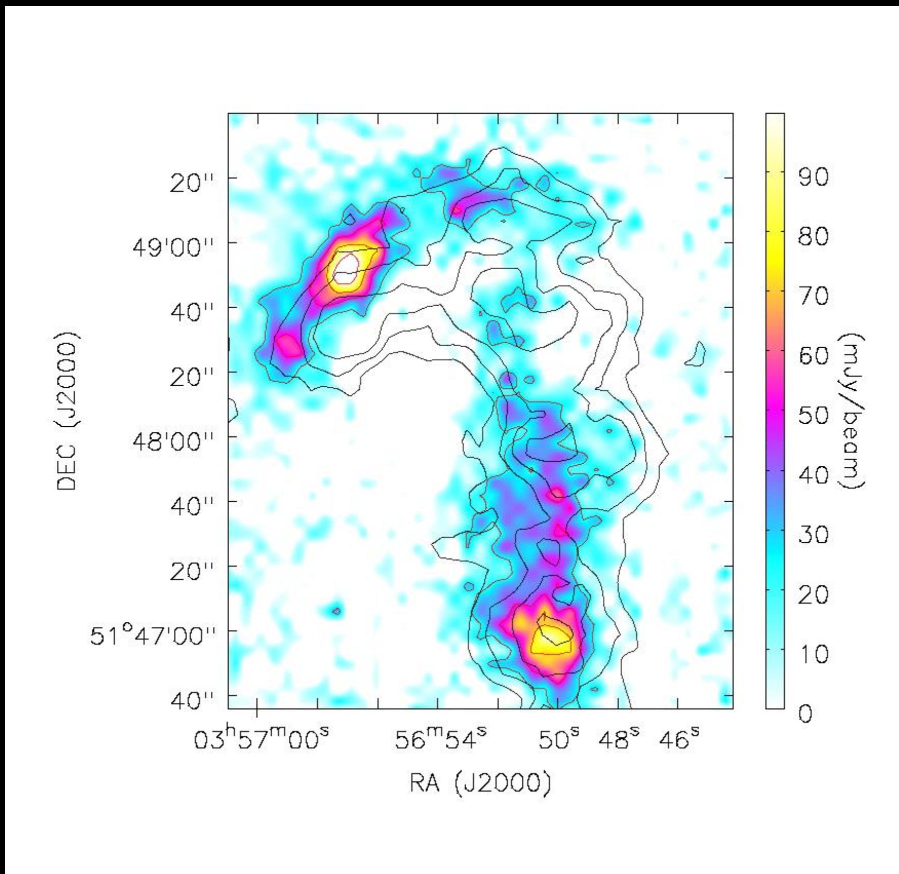
Table 1: The properties of the Planck cold clumps that have been mapped by the IRAM 30 m telescope

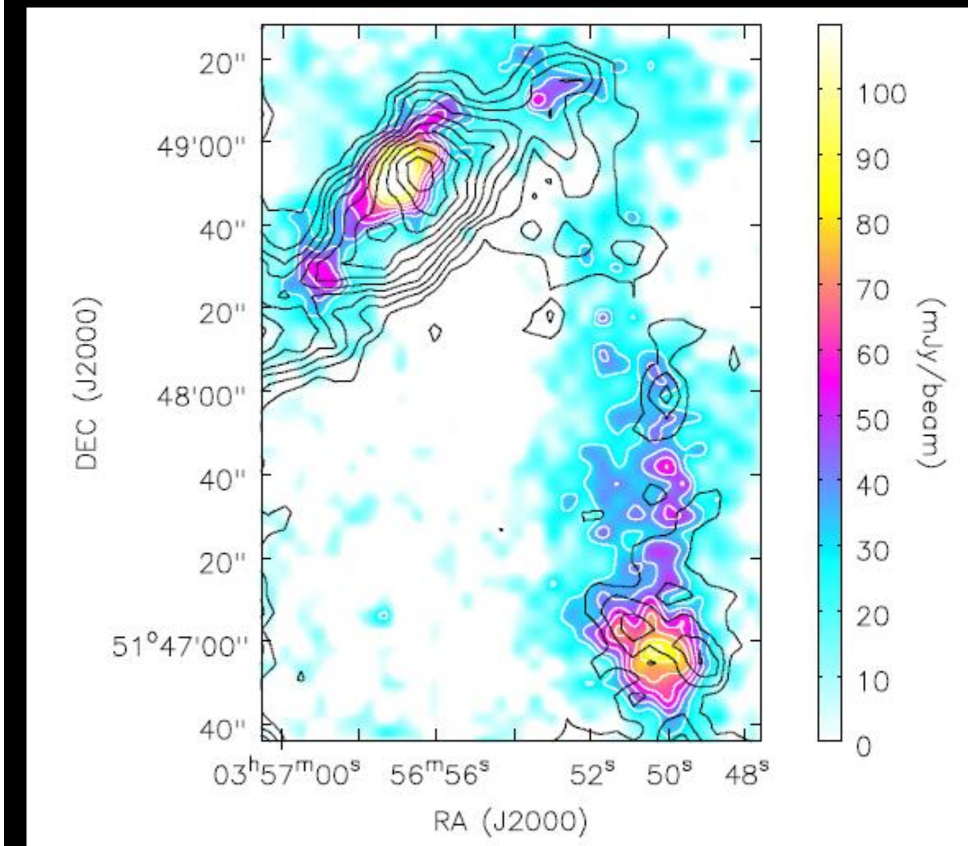
Name	RA[a] (J2000)	DEC[a] (J2000)	V_{lsr}[b] (km s^{-1})	ΔV[b] (km s^{-1})	D[c] (kpc)	R[d] (pc)	M_{vir}[e] ($M_\odot$)	N_{vir}[f] (10^{22} cm^{-2})	map grid[g]
G108.8-00.8a2	22:58:54	58:57:45	-49.5	2.1	5.4	1.7	1576	0.9	8×8
G120.6+02.6a2	00:29:36	65:26:40	-17.7	2.3	1.8	0.5	601	3.5	two 6×5
G125.6-00.5a2	01:14:50	62:11:55	-14.37	1.3	1.5	0.5	160	1.3	5×5
G146.1+07.8a3	04:23:21	60:41:50	-11.6	1	1.3	0.4	81	0.9	5 × 5
G149.5-01.2	03:56:53	51:48:10	-7.5	1.9	0.9	0.3	∼500[h]	4.2	8×9
G207.3-19.8a2	05:31:03	-04:16:30	11.7	1.4	0.414	0.2	∼300[h]	4.3	8×12




HH 58
HD 36342
ONC
DEC (J2000)
RA (J2000)
08:00.0
-4:10:00.0
12:00.0
14:00.0
16:00.0
18:00.0
20:00.0
10.0
05.0 5:31:00.0 55.0
50.0
45.0
40.0
35.0
30:30.0
25.0


DEC (J2000)
RA (J2000)
15'
16'
17'
−4°18'
05h31m10s
06s
04s
02s
00s
(mJy/beam)
90
80
70
60
50
40
30
20
10
0
RA (J2000)





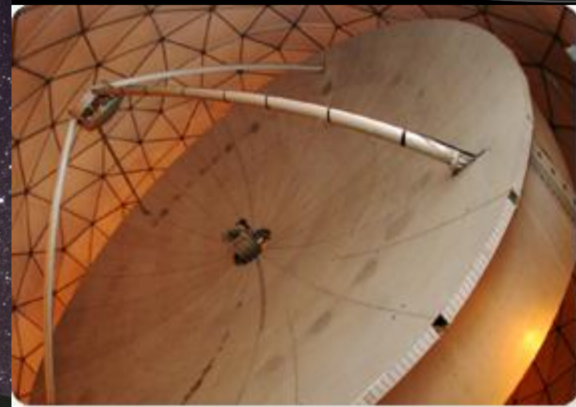
Black contours: Left: HCO+ (1-0), Right: N2H+ (1-0)

color images: 850 micron continuum

What we have learned from pilot observations?

- 1. All Planck cold clumps are in molecular clouds. In general, Planck cold clumps are really cold but not dense.
- 2. A small fraction of Planck cold clumps are associated with protostellar objects or protostellar clusters. But the majority of the Planck cold clumps are starless and may be at prestellar phase.
- 3.Some Planck cold clumps are highly fragmented and structured. They are ideal targets for studies of core formation and evolution.
- 4. Planck cold clumps contain various kinds of objects from low-mass cores to giant molecular clouds and thus everyone working on star formation or ISM can be benefited from an unbiased survey.

3. A joint proposal for the JCMT, the TRAO 14-m and the KVN telescopes




KVN연세대
KVN울산
KVN제주도
KVN연세대
KVN제주
KVN울산

Why JCMT?

- 1. Largest single-dish sub-mm telescope
- 2. Excellent mapping machine for both continuum and molecular lines:

  Largest bolometric array (SCUBA-2)

  16 pixels HARP receiver
- 3. Polarization measurement capabilities
- 4. Large overlap in sky coverage with ALMA & SMA

1. Observe 850 micron continuum with SCUBA-2 toward thousands of Planck cold clumps (PCCs). Now we are doing a pilot observation with SCUBA-2 toward ~100 PCCs. For a Pong900: 15 arcmin map in 850 *micron* continuum with SCUBA-2, we need 15 minutes to achieve an rms level of 10 mJy under grade 3 weather condition. 250 hrs per year for 1000 PCCs, three years for 3000 PCCs?

2. Follow-up observe SCUBA-2 sources with TRAO 14-m telescope (SEQUOIA) in 12CO/13CO/C18O (1-0). We have already done a pilot survey with the PMO 14-m telescope, in which we have mapped about ~500 PCCs. 500 hrs per year for TRAO 14-m?

3. Follow-up observe SCUBA-2 sources with HARP/JCMT in 12CO (3-2) & 13CO (3-2). Jiggle observations towards continuum peaks?

4. Single-pointing observations toward SCUBA-2 continuum peaks with KVN single dish telescopes in dense gas (HCN,HCO+,N2H+ (1-0)?) and masers (water & methanol) simultaneously.

5. Continuum Polarization measurements with SCUBA-2 POL2

6. Follow-up observations with other ground-based telescopes (e.g. NRO 45-m, APEX, IRAM-30m, GBT, SMA, ALMA…)

Thanks!