

The “TOP” “SCOPE”:

Follow-up surveys toward Planck Galactic cold clumps with ground-based radio telescopes

Ken Tatematsu (NAOJ)

on behalf of

SCOPE Planck Cold Clump collaboration

Coordinators for JCMT survey:

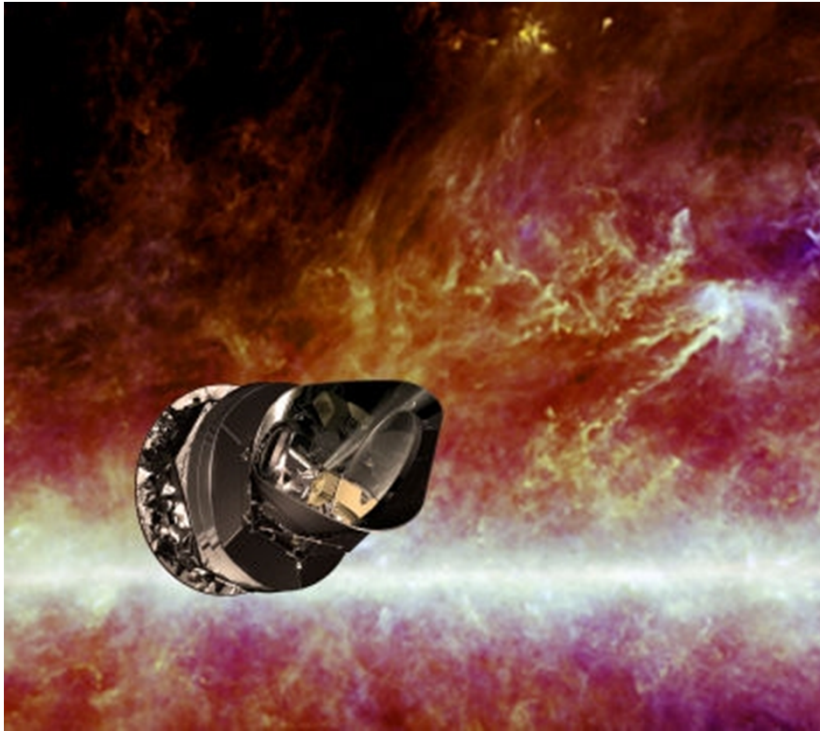
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1. Kee-Tae Kim will take the place of Tie Liu to coordinate Korean collaborators when Tie Liu leaves Korea in future.

Coordinators for Joint surveys:

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What are Planck galactic cold clumps?

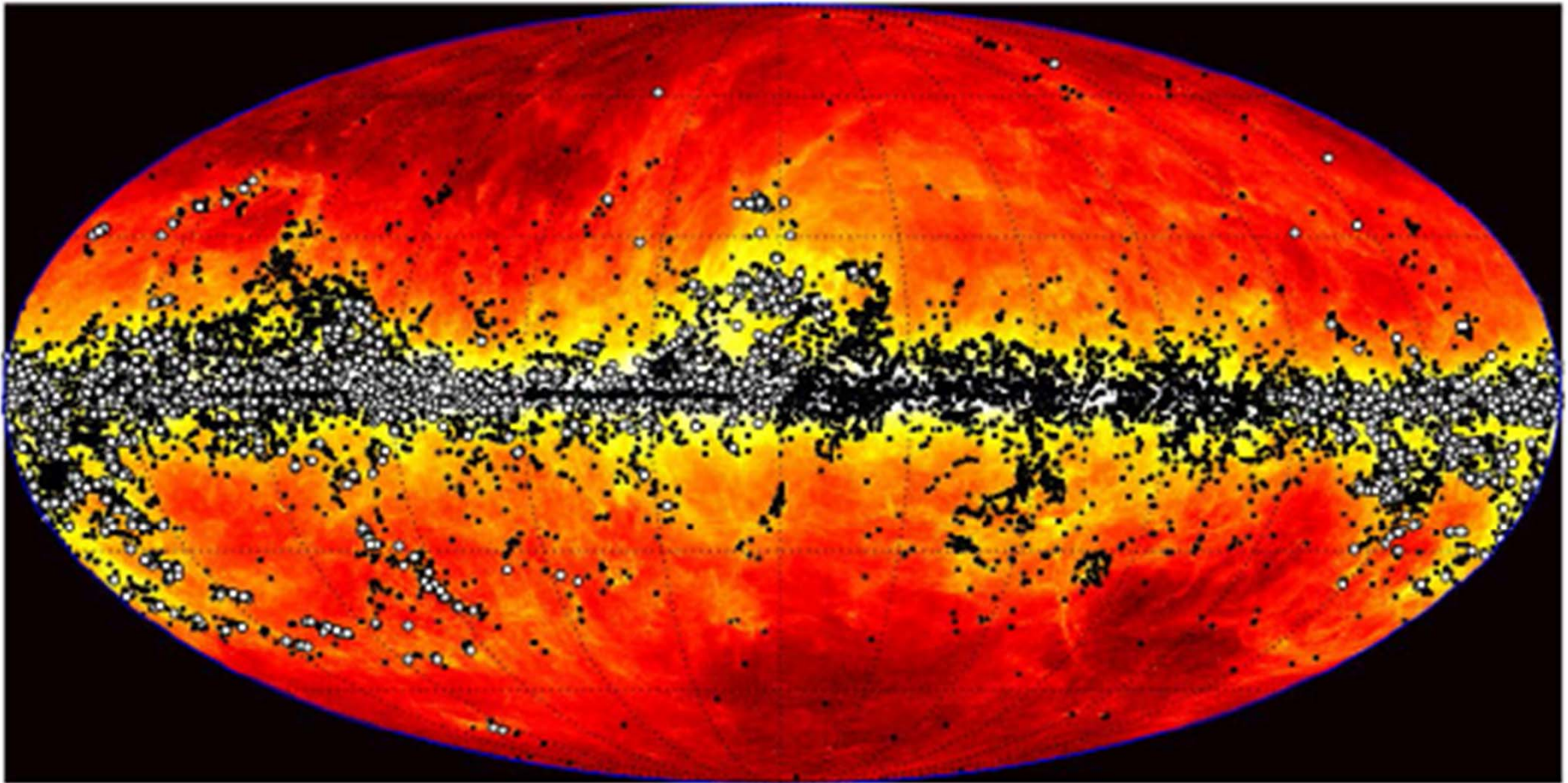


Planck is a third generation space based cosmic microwave background experiment, operating at nine frequencies between 30 and 857 GHz

Planck Catalogue of Galactic Cold Clumps (PGCC), *13188 clumps*

The early cold core (ECC) sample: *915*
sample *$T_d < 14$ K, $SNR > 15$*

Galactic distribution of targets



All-sky distribution of the 13188 PGCC sources (black dots) and the 2000 selected PGCC sources (open dots) overlaid on the 857 GHz Planck map.

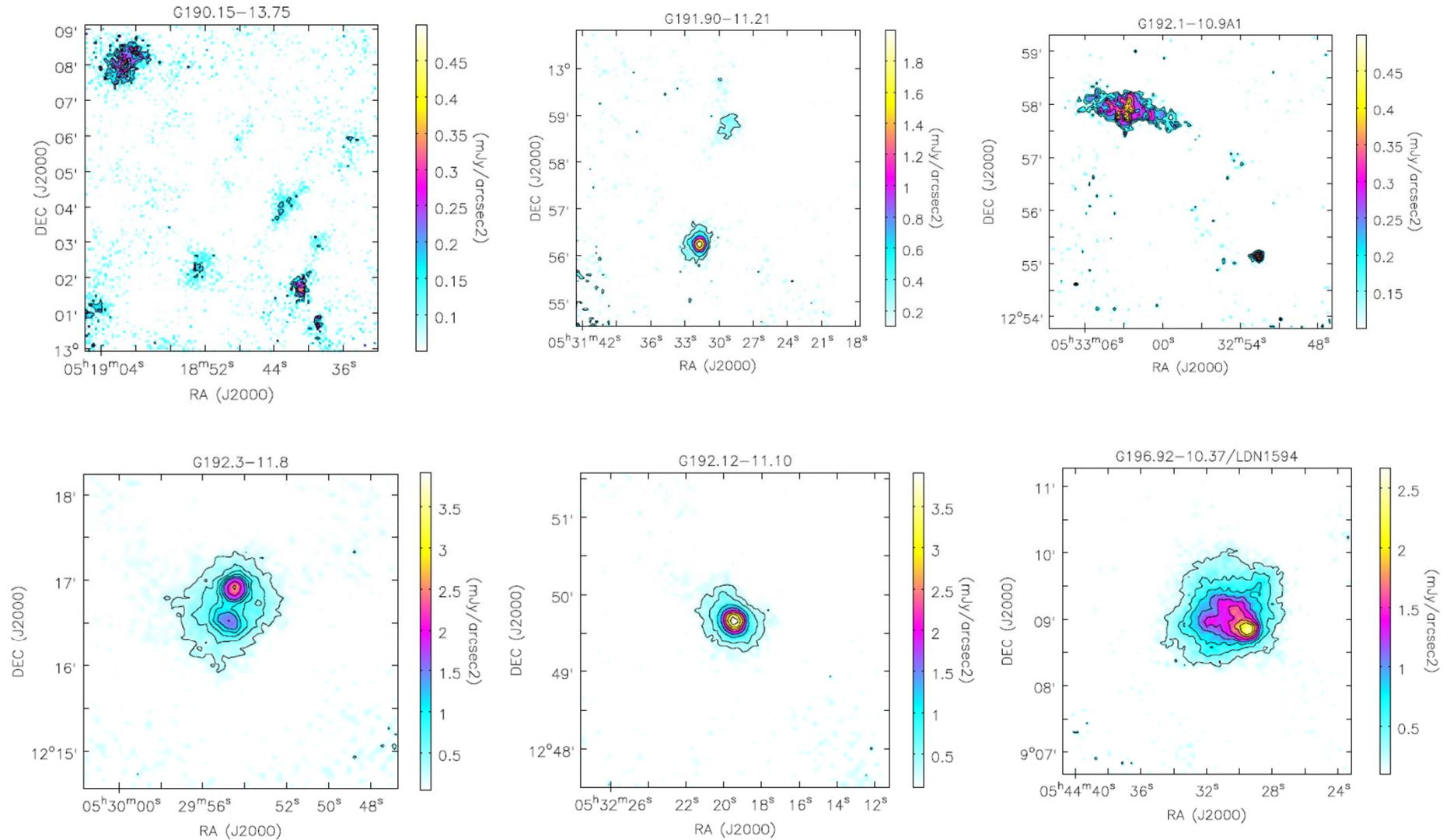
Status

- **1. PMO 14 m**
Line tracers: 12CO/13CO/C18O (1-0), HCN/HCO⁺ (1-0)
Status: ~1000 hrs awarded. 672 PCCs surveyed in single pointing. ~500 mapped in an area of 22arcmin*22arcmin, ~700 dense clumps detected, one third of which HCN/HCO⁺ (1-0)
TRAO observations of Planck cold clumps (TOP): 1400 hrs awarded, 100 mapped
- **2. CSO**
Line tracers: 12CO/13CO/C18O (2-1), 12CO (4-3), CI (492 GHz)
Status: 5 nights awarded, 20 PCCs mapped
- **3. IRAM 30 m**
Line tracers: 12CO/13CO/C18O (2-1) & HCN (1-0), HCO⁺ (1-0), N₂H⁺ (1-0)
Status: 30 hrs awarded. 24 PCCs mapped
- **4. Effelsberg 100 m**
Line tracers: NH₃ (1,1) & (2,2)
Status: 27 hrs awarded, 6 PCCs mapped
- **5. Mopra 22 m**
Line tracers: N₂H⁺ (1-0), N₂D⁺ (1-0), and so on
Status: 54 hrs awarded. 30 PCCs observed
- **6. APEX**
Line tracers: 12CO/13CO/C18O (2-1) & HCN (3-2)
Status: one proposal approved (30 hrs), 10 PCCs observed
- **7. JCMT/SCUBA-2**
SASSy+Pilot+2015B: ~200 PCCs mapped
2016A: ~300 PGCCs mapped
- **8. SMA** PGCC G192.32-11.88 and G207.3 mapped, proposals for PGCC G108.8 and G074.1 submitted
- **9. ASTE**
10 hrs for mapping G207.3
- **10. NRO 45-m**
~150 hrs in 2015B, 15 sources were observed
- **11. KVN : ~60 SCUBA-2 cores observed with filler time**

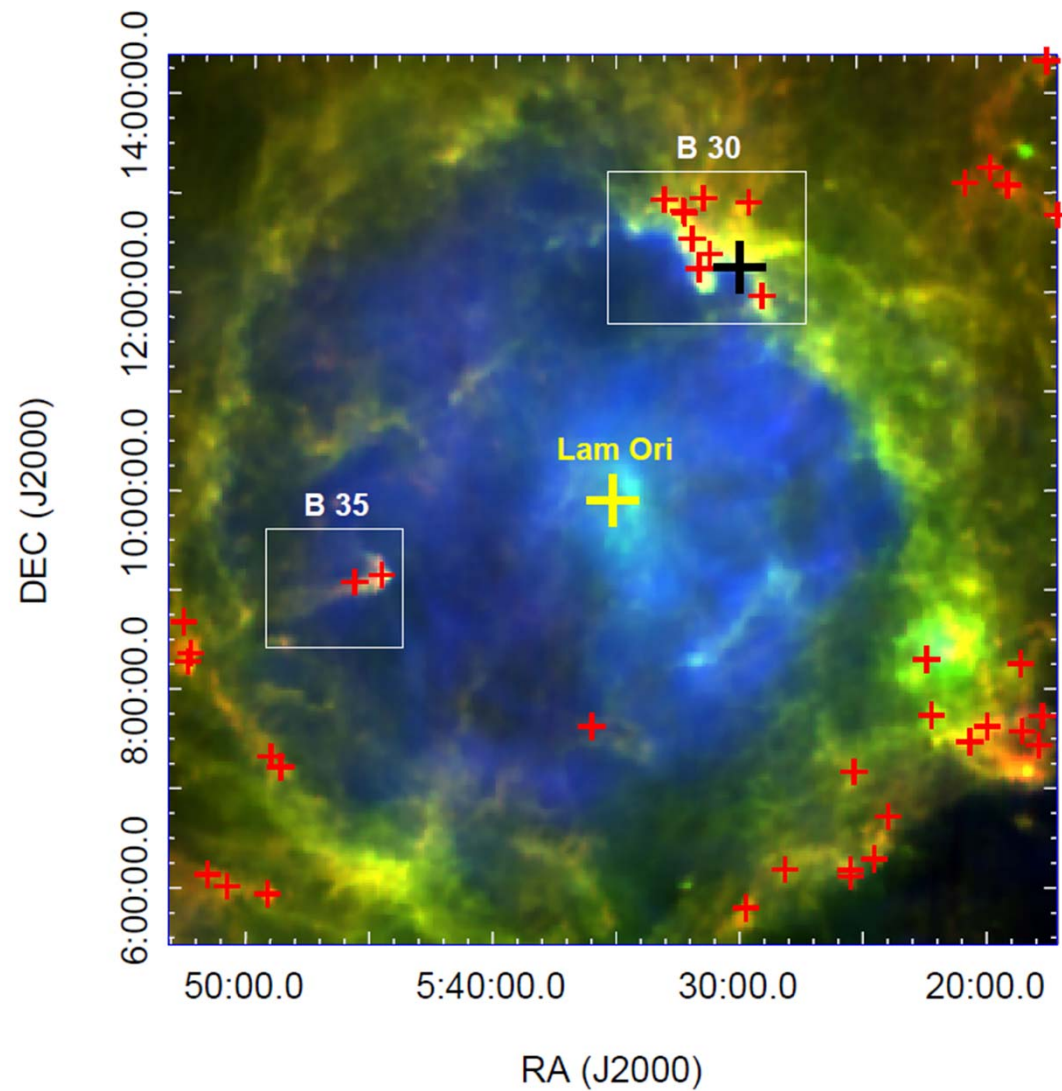
Status of JCMT survey in 2016A

- 303 observed in 2016A so far
- PMO selected sources: 37/60
- Herschel selected sources: 68/78
- Lamda Orion region: 11/49
- HINSA: 12/31
- MSBs for 180 PGCCs in Galactic Plane submitted (All GP PGCCs observed so far have detections)
- Need to select more than 600 PGCCs

PGCCs in Lamda Orion Complex



Highlight 2: Stellar feedback on core formation

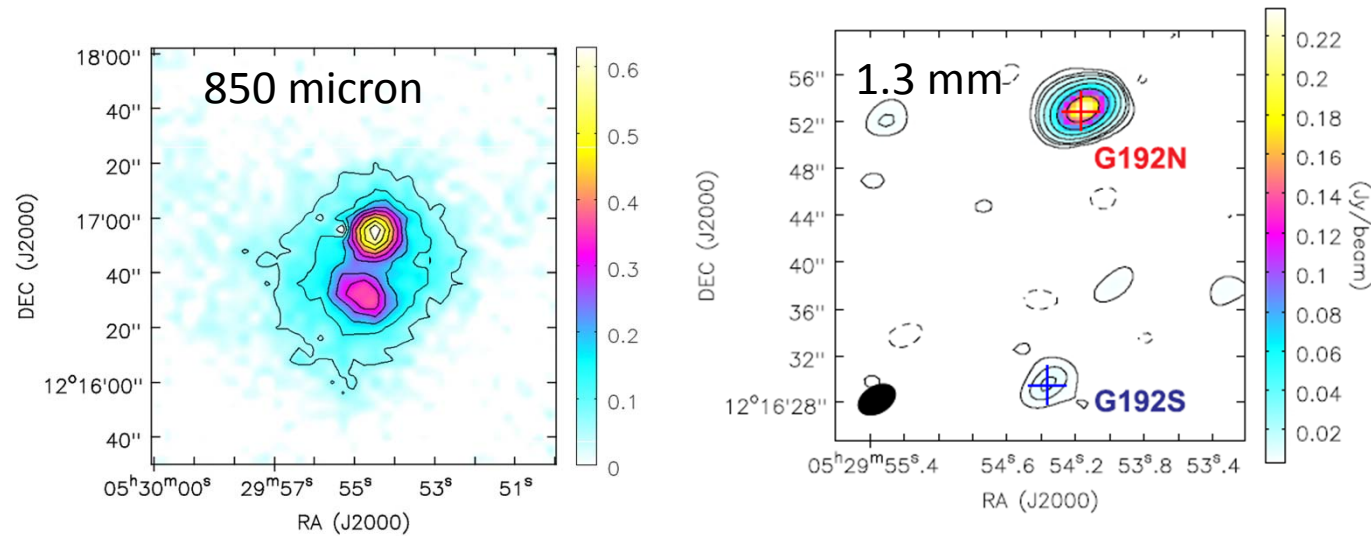


<20% with SCUBA-2 850
micron continuum
detections!!!

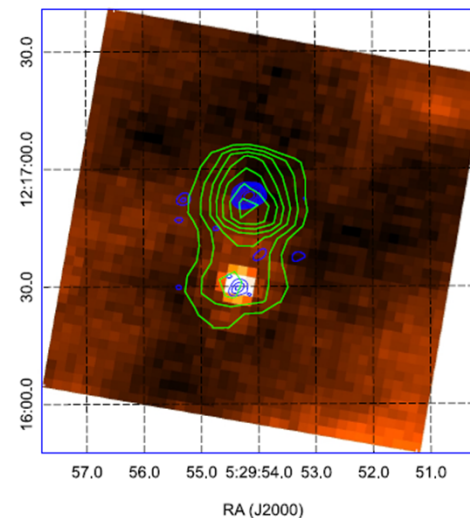
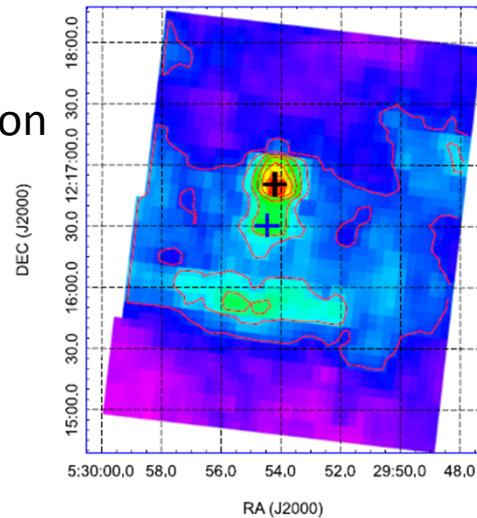
Suppressed dense core
formation!?

857GHz/100micron/Halpha

Highlight 3: brown-dwarf and very low-mass star formation (Liu+2016)



MIPS 70 micron



Green Contours: 70 micron
Blue contours: 1.3 mm
Color: 24 micron

Extremely young Class 0:

G192N: $M=0.43 M_{\odot}$ (JCMT); $M=0.38 M_{\odot}$ (SMA); $L_{\text{int}} \sim 0.2 L_{\odot}$

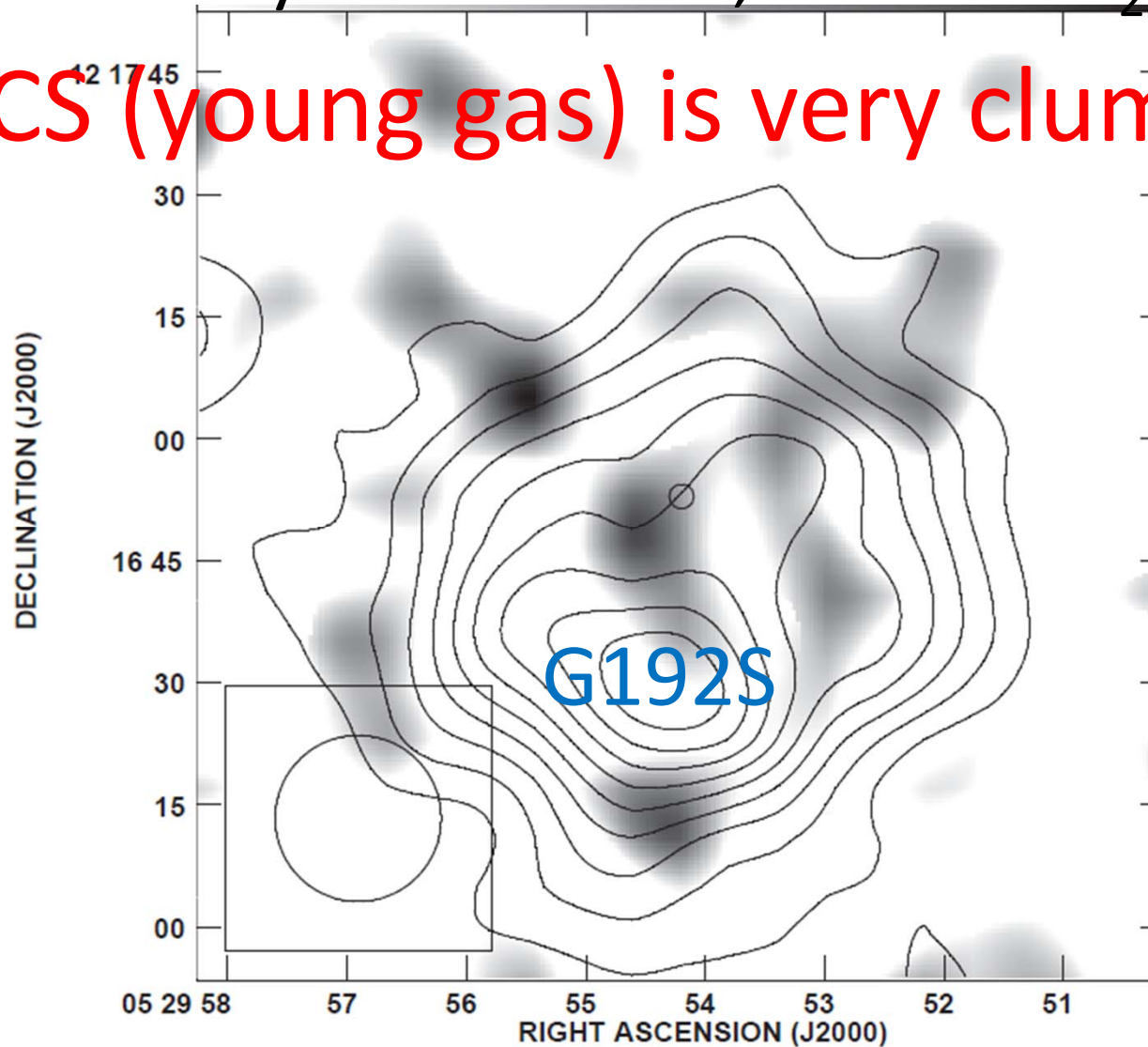
Proto-brown dwarf:

G192S: $M=0.23 M_{\odot}$ (JCMT); $M=0.02 M_{\odot}$ (SMA); $L_{\text{int}} \sim 0.08 L_{\odot}$

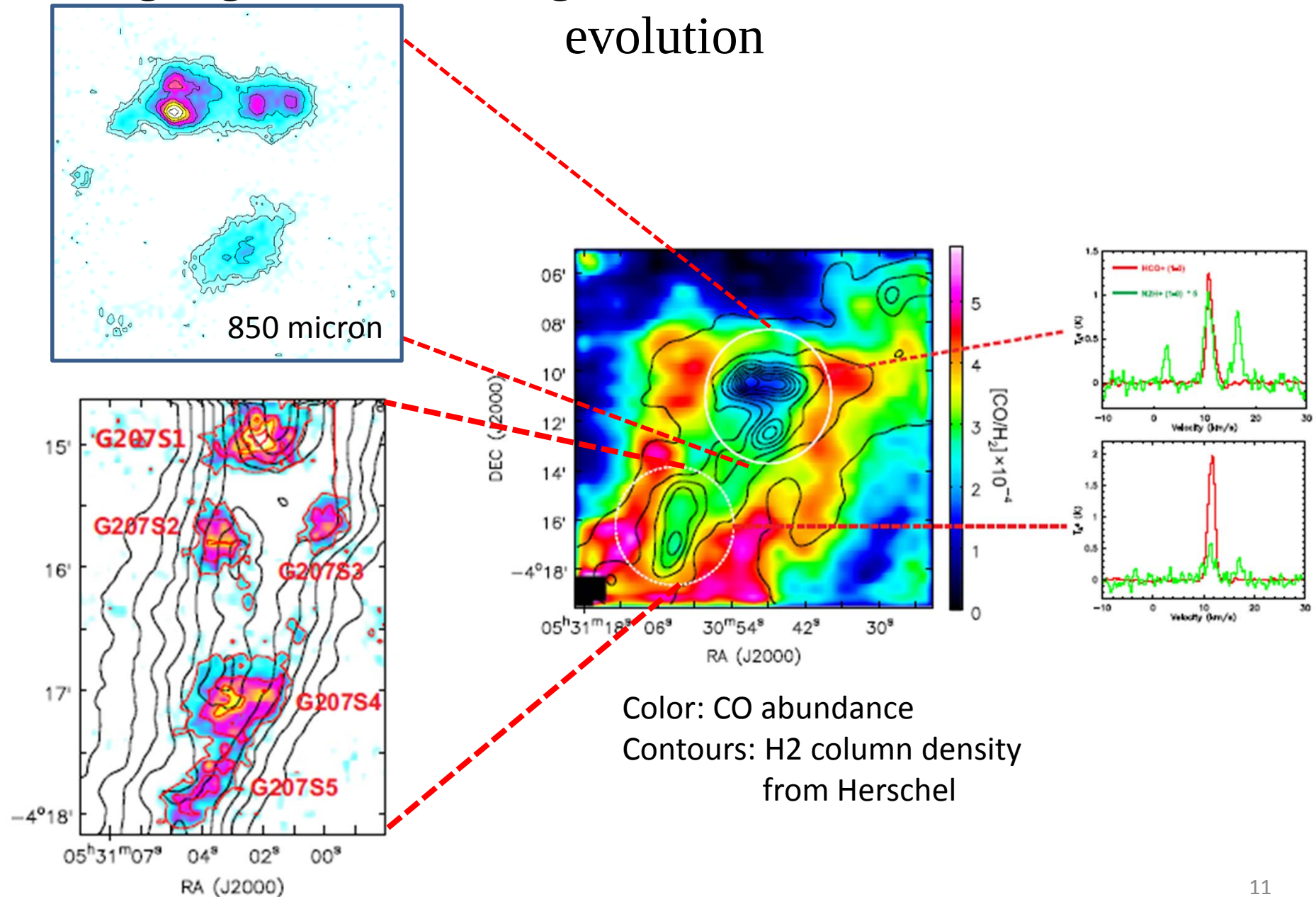
Nobeyama follow-up

Gray= CCS 82 GHz, contour= N_2H^+

CCS (young gas) is very clumpy



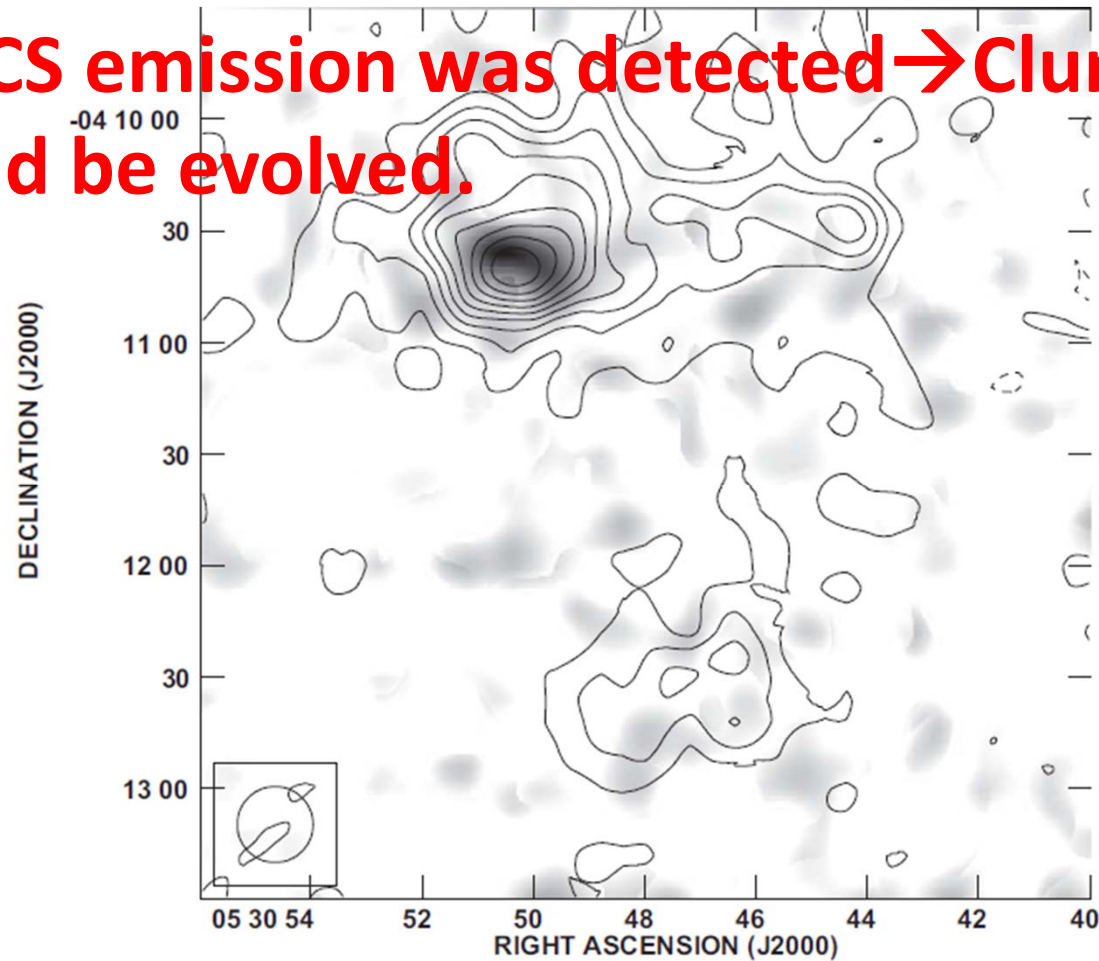
Highlight 4: initial fragmentation of filaments and core evolution



Nobeyama follow-up

Gray= HC_3N , contour= N_2H^+

- No CCS emission was detected → Clumps should be evolved.



NRO 45-m follow-up observations (Ken Tatematsu)

- 13 clumps were mapped in N_2H^+ , HC_3N , two CCS lines. **We detected 81 GHz CCS from 10 out of 13.** This detection rate **77%** is appreciably higher than 32% in 45 GHz CCS toward Orion A GMC (Tatematsu+10), although frequency and sensitivity are different. Suzuki+93 ' detection rate in CCS 45 GHz toward **nearby dark clouds is 27/49 (55%).** Our detection rate is close to theirs, or even more. **Planck cold clumps should be as young as nearby dark clouds.**
- 9 clumps were observed in DNC, HN^{13}C , N_2D^+ , $\text{c-C}_3\text{H}_2$ in single-pointing mode. Usually, DNC, HN^{13}C , $\text{c-C}_3\text{H}_2$ are easily detectable. **$\text{I}(\text{DNC})/\text{I}(\text{HN}^{13}\text{C}) \sim 1-4$, which is similar to value at TMC-1 and L1544.** Four out of nine were detected in **N_2D^+ 1-0 hyperfine!!!**
- 15 clumps were observed in 23 GHz NH_3 to measure T_{rot} (mostly 10-15 K).

Summary

- In order to make significant progress in understanding the early evolution of molecular clouds and dense cores in a wide range of Galactic environments, we are carrying out **unbiased “all-sky” surveys of 2000 Planck cold clumps** in J=1-0 of CO/¹³CO lines with TRAO 14-m telescope and 850 μm continuum with the JCMT/SCUBA-2. We are also actively developing **follow-up surveys/observations (SMT, KVN, FAST, NRO 45-m, SMA)** for these legacy surveys, which will allow us to deepen the investigation of the dense core or star formation in widely different environments at their earliest evolutionary phases.
- Our pilot observations have proved that Planck cold clumps are really interesting for studies of **initial conditions of star formation at their earliest evolutionary stages** in various environments.

Thanks!