Fragmentation of high line-mass filaments as revealed by ALMA: the integral shaped filament in Orion A

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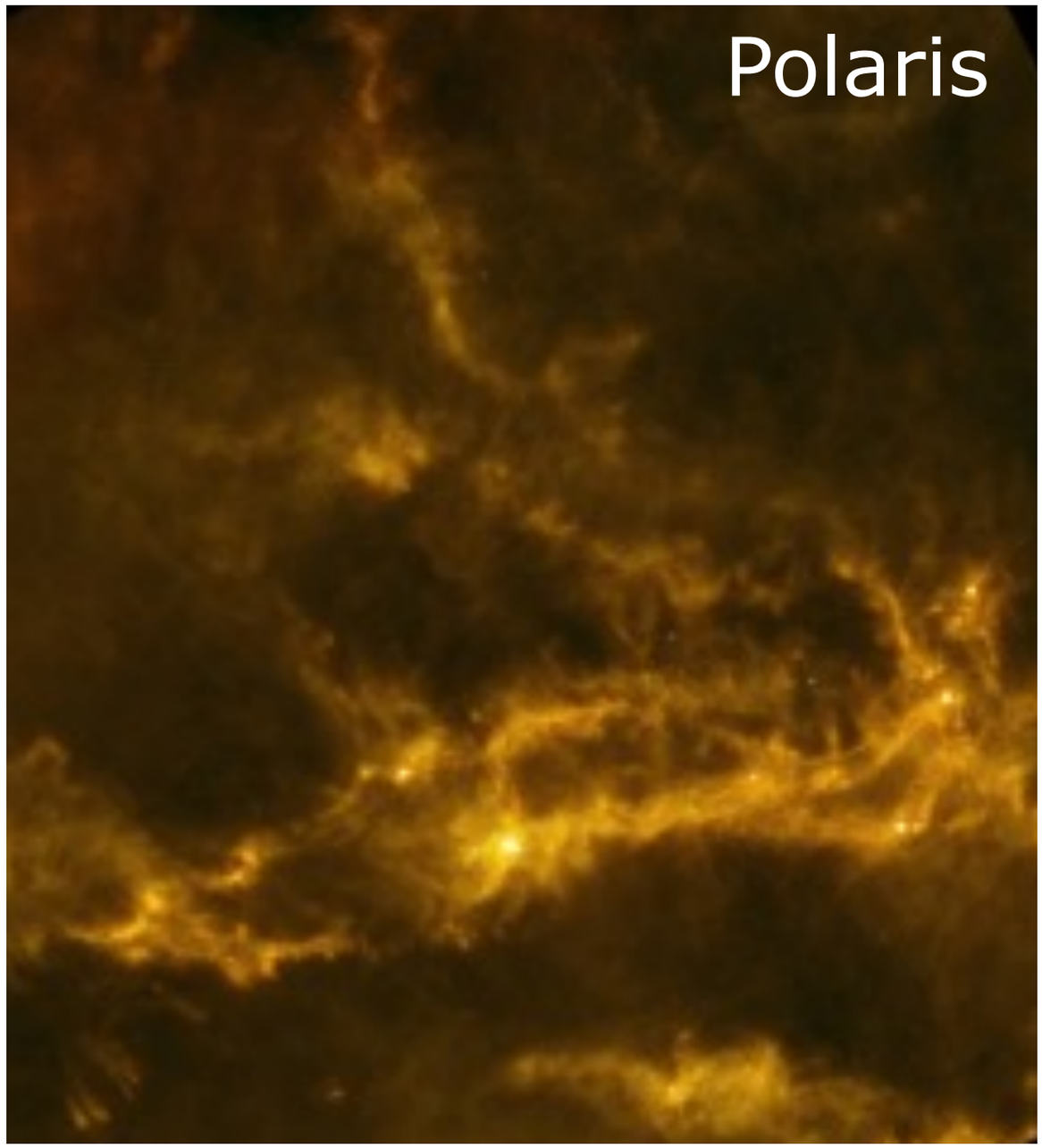
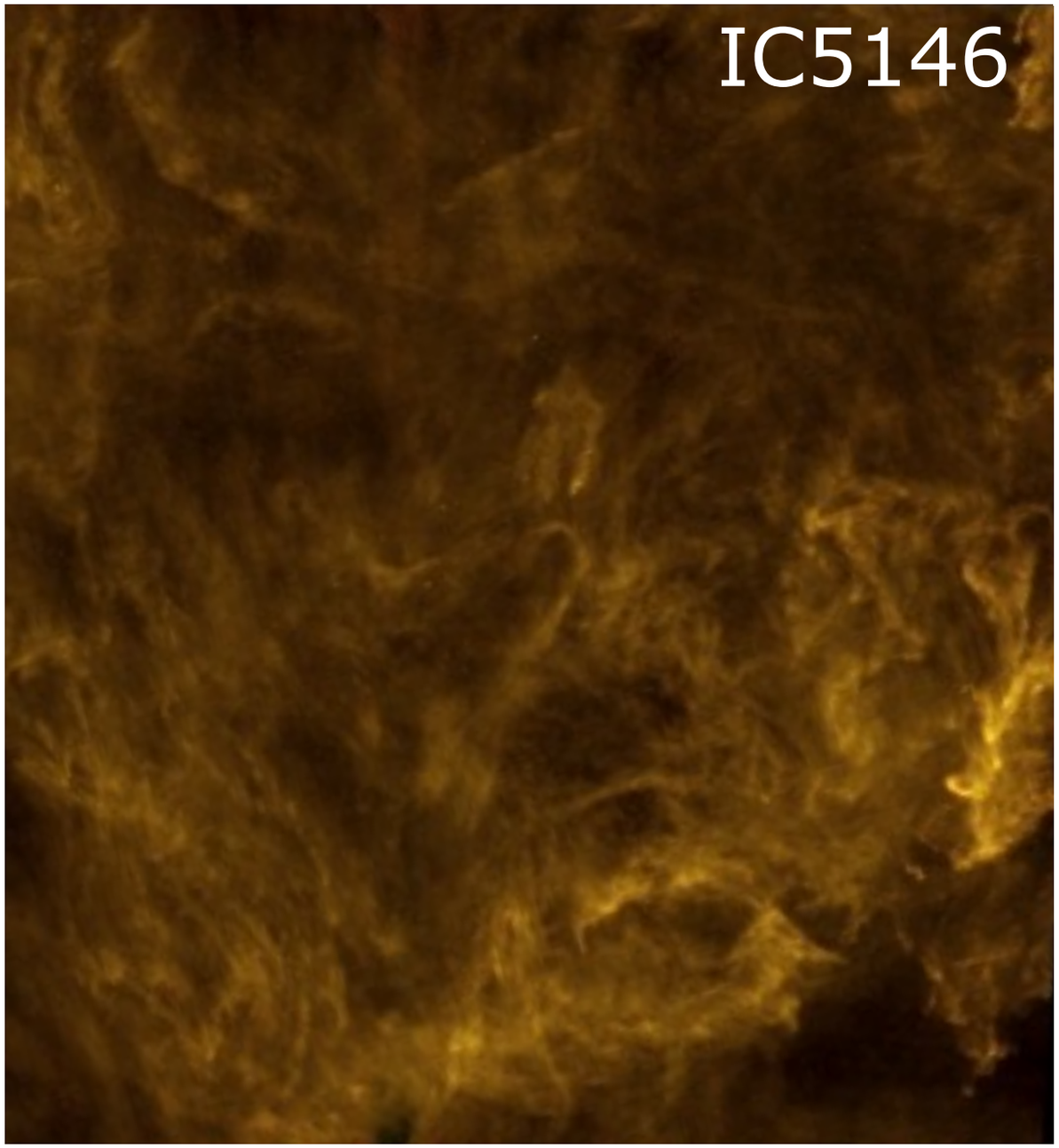
ABSTRACT

We study the fragmentation of the most nearby high line-mass filament, the integral shaped filament (ISF) in the Orion A molecular cloud. We have observed a 1.6 pc long section of the ISF with the Atacama Large Millimetre/submillimeter Array (ALMA) at 3 mm continuum emission, at a resolution of ~3″ (1 200 AU). We identify from the region 40 dense cores with masses on the order of a solar mass. The nearest neighbour separation distribution of the cores does not show a preferred fragmentation scale; the frequency of short separations increases down to our resolution limit. We apply a two-point correlation analysis on the dense core separations and show that the cores are significantly grouped at separations below ~17 000 AU and strongly grouped below ~6 000 AU. In addition, the two-point correlation function indicates periodic grouping of the cores into groups of ~30 000 AU in size, separated by ~55 000 AU. The groups coincide with dust column density peaks detected by *Herschel*. These results suggest a two-mode fragmentation in which the maternal filament periodically fragments into groups of dense cores. The strong increase of separations below 6 000 AU may be related to the regime of significant core-to-core interactions. We also find that the protostars in the northern ISF are grouped at separations below ~17 000 AU. The stars with disks do not show significant grouping in the ALMA-covered region. This suggests that the grouping of dense cores is partially retained over the protostar lifetime, but not over the lifetime of stars with disks. This is in agreement with protostars being ejected from the maternal filament by the slingshot mechanism, a model recently proposed for the ISF by Stutz & Gould. The separation distributions of the dense cores and protostars may also provide an evolutionary tracer of filament fragmentation.

Key words. ISM: clouds - ISM: structure - stars: formation - ISM: individual objects: OMC-2 - Radio continuum: ISM

Filamentary structures in molecular clouds





Herschel Gould Belt survey (70um-500um)

Filamentary structures in molecular clouds

基本的なパラメータ

* length: 0.1 - 100 pc
* width: ~ 0.1 pc ?
* mass: 1- 10^5 M_{sun}
* line-mass: < 1000 M_{sun}/pc

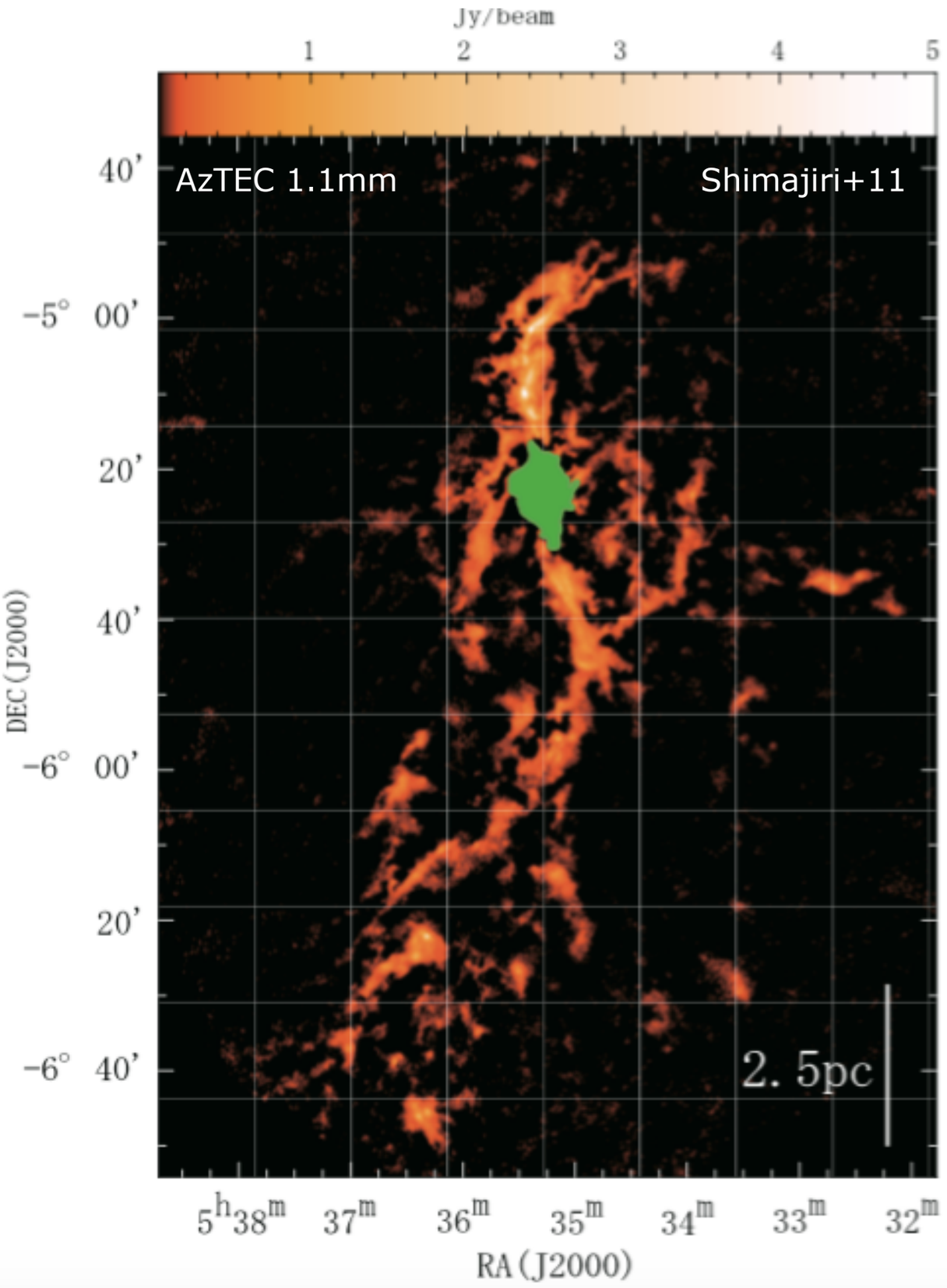
ここでは特に

high line-mass filamentsに着目

* line-mass: ~ several 10^2 M_{sun}/pc
* high-mass star, cluster formation
* strong global gravitational potential
  →fragmentation & gravitational collapse

Orion A molecular clouds

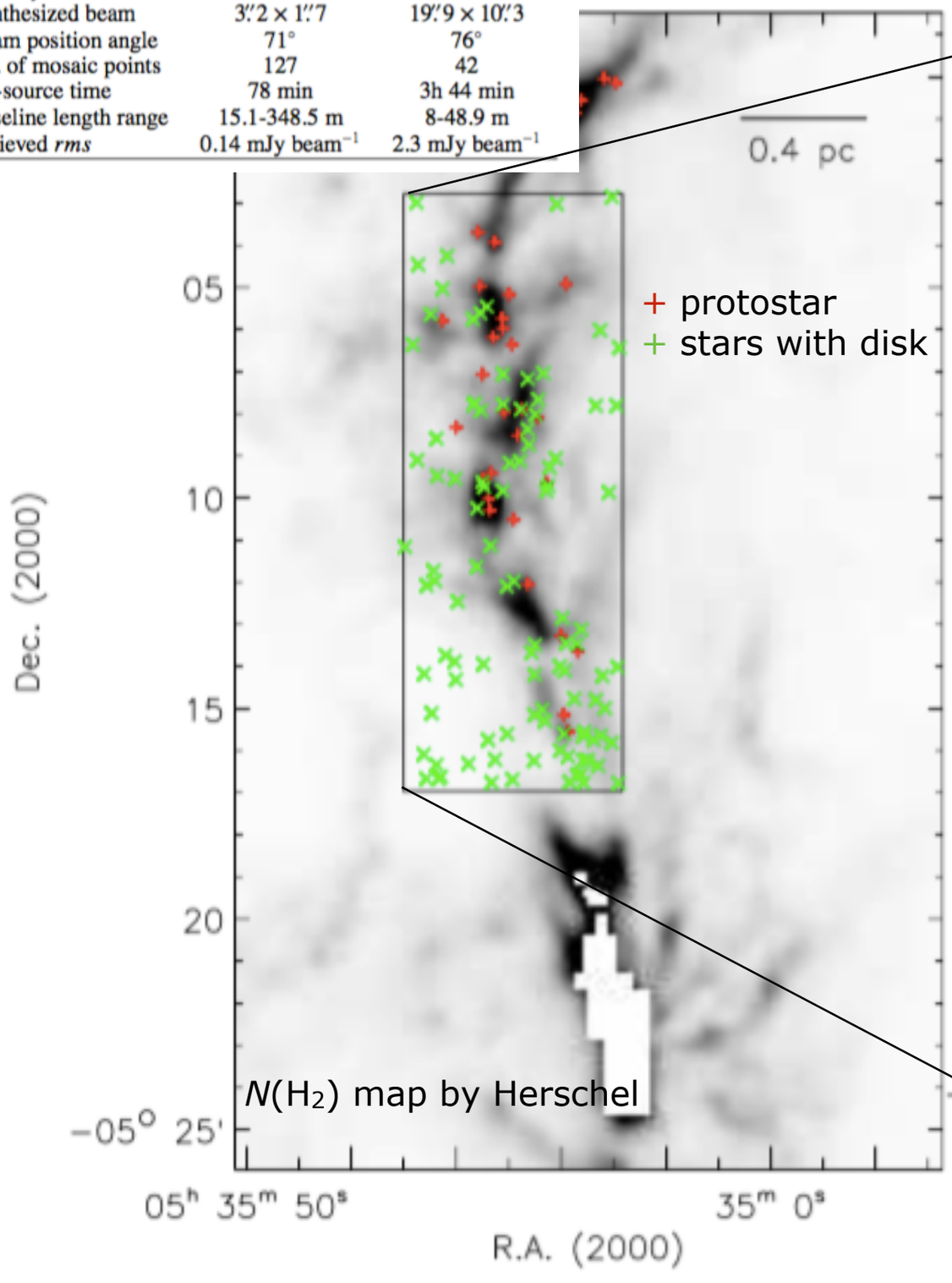
* d ~ 420 pc (3” ~ 1200 AU)
* line-mass ~ 385 M_{sun}/pc
* young stellar population is well studied
  →Spitzer, Herschel

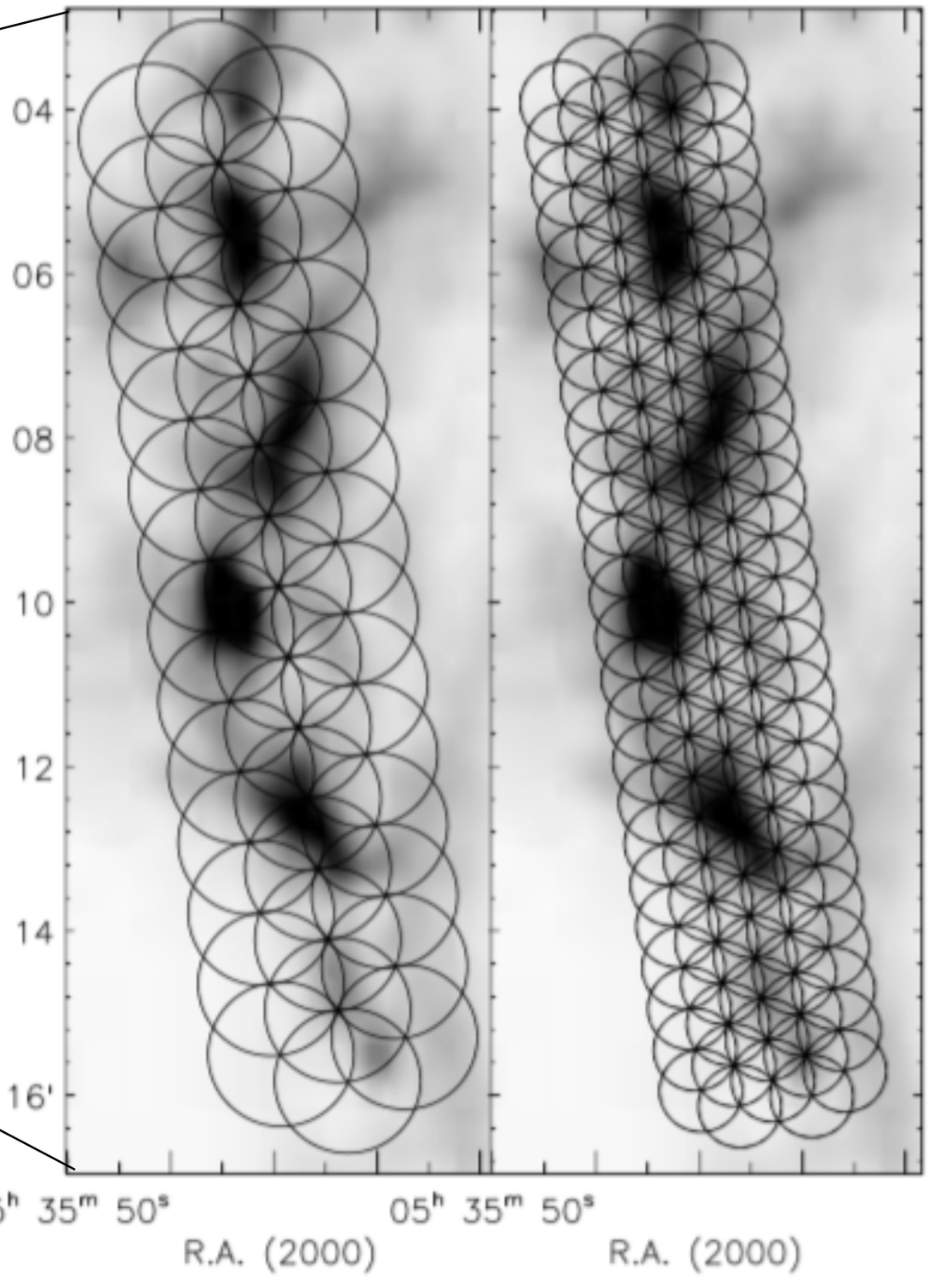


ALMA Observation in 3mm continuum

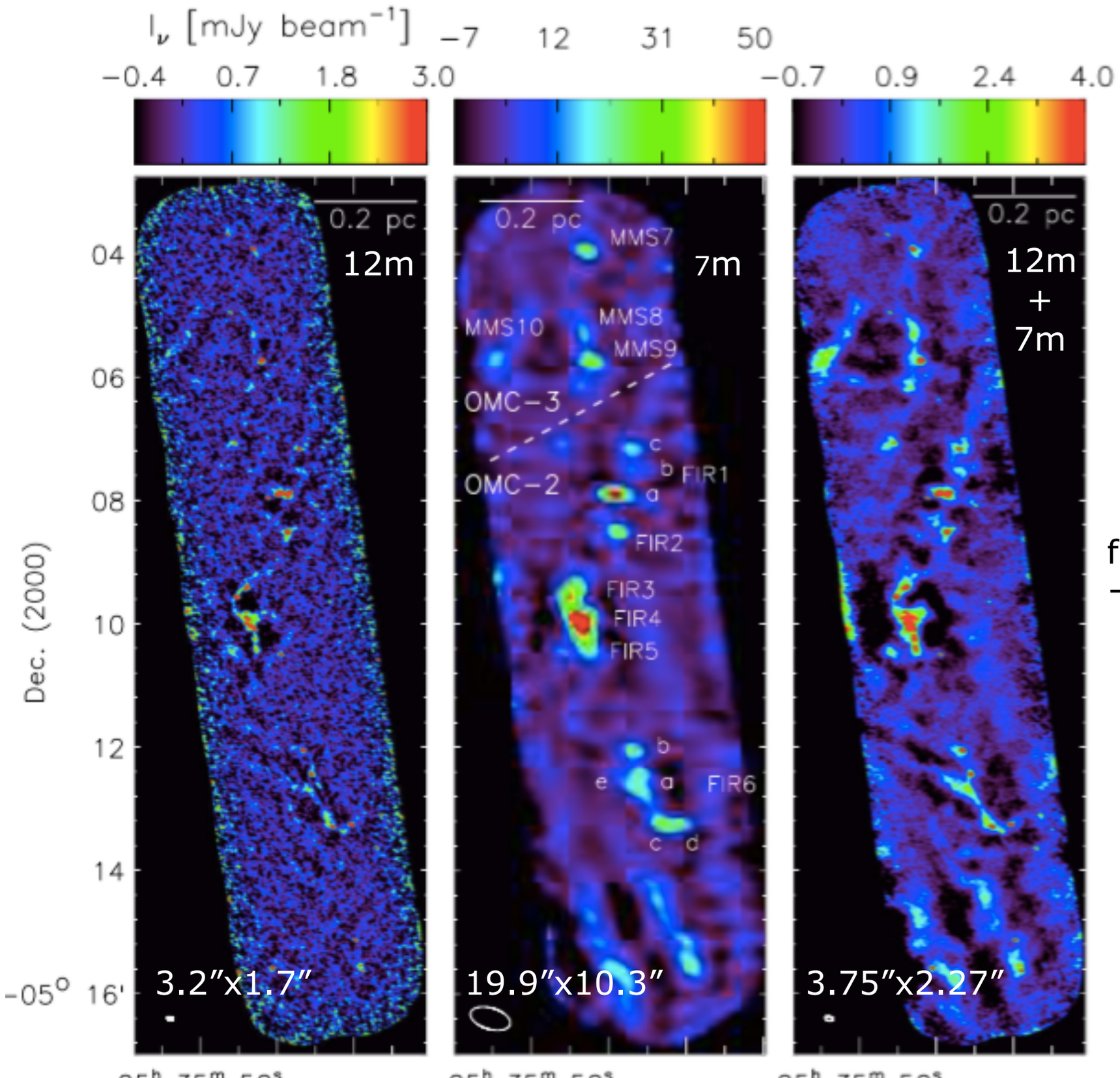
Table 1. Parameters of the ALMA observations

Parameter	12-m array	7-m array
Primary beam	~60″	~105″
Synthesized beam	3.″2 × 1.″7	19.″9 × 10.″3
Beam position angle	71°	76°
No. of mosaic points	127	42
On-source time	78 min	3h 44 min
Baseline length range	15.1-348.5 m	8-48.9 m
achieved *rms*	0.14 mJy beam^{-1}	2.3 mJy beam^{-1}



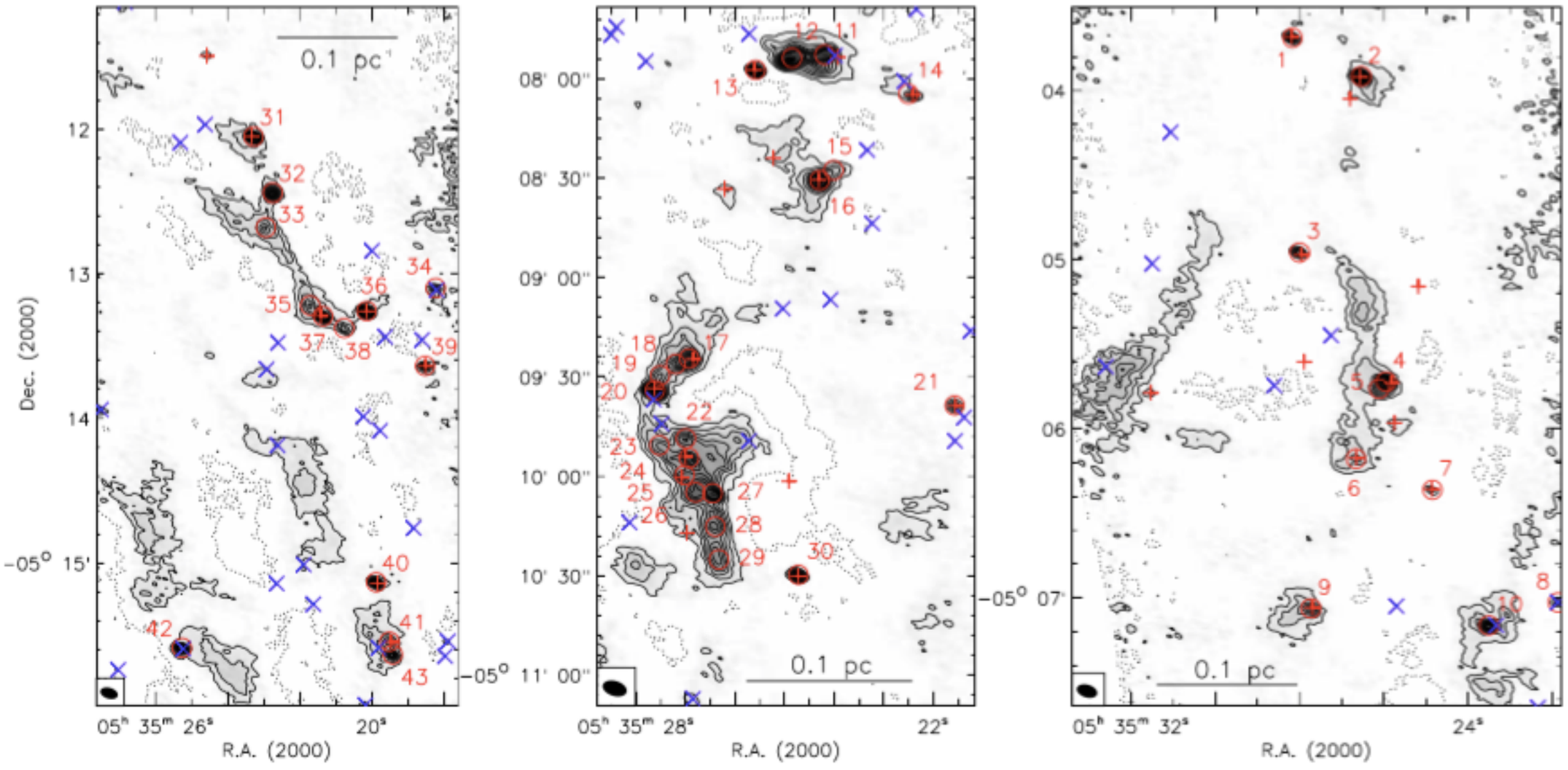


3mm continuum image



fitting by gaussclump
→**40 dense cores**
(0.2 -2.6 M_{sun})

3mm continuum image

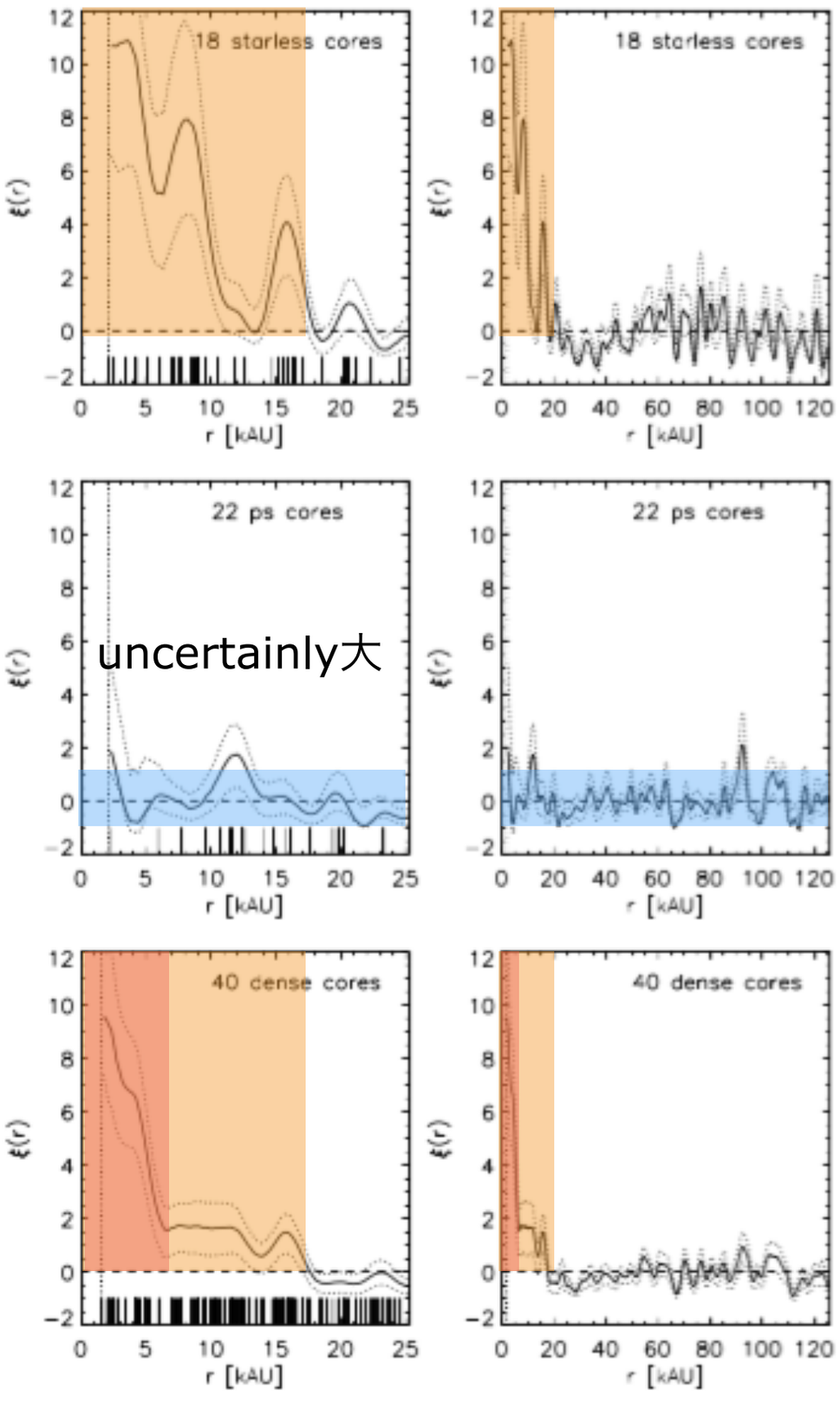


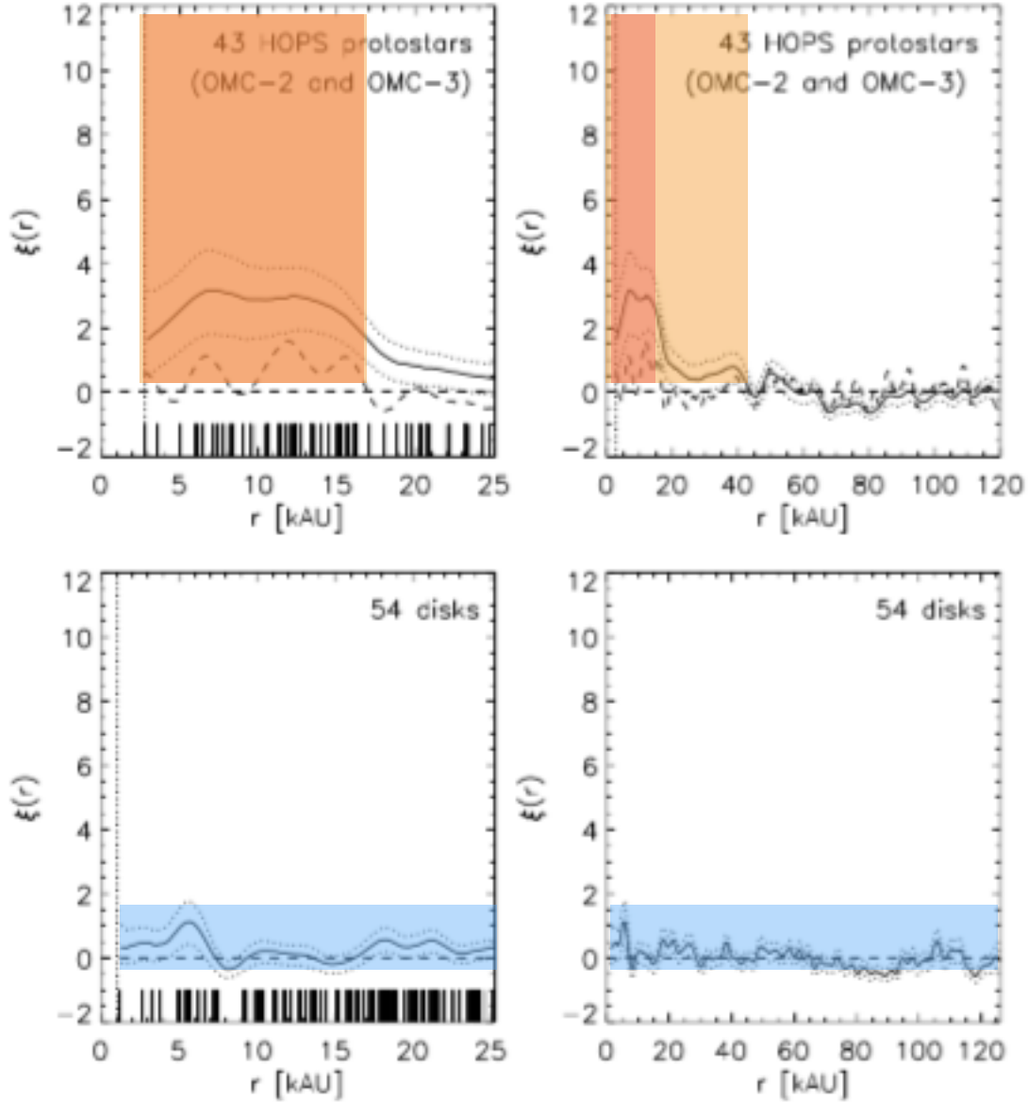
○ dense core
\+ protostar
X stars with disk

0.1 pc ~ 20000 AU

Objects	Number	< d_{nn} > [AU]	median d_{nn} [AU]	< M > [$M_\odot$]
All dense cores	40	7000	4 200	0.9
Starless cores	18	10 500	4 200	1.3
Protostellar cores	22	13 800	12 300	1.3
Protostars	34	10 200	10 400	-
Stars with disks	54	8 700	6 600	-

Two-point correlation





starless cores, dense cores, protostars
→grouping below 6000 - 17000 AU
(0.03 -0.08 pc)

protosteller cores, star with disk
→~random distribution

Discussion

two-point correlation

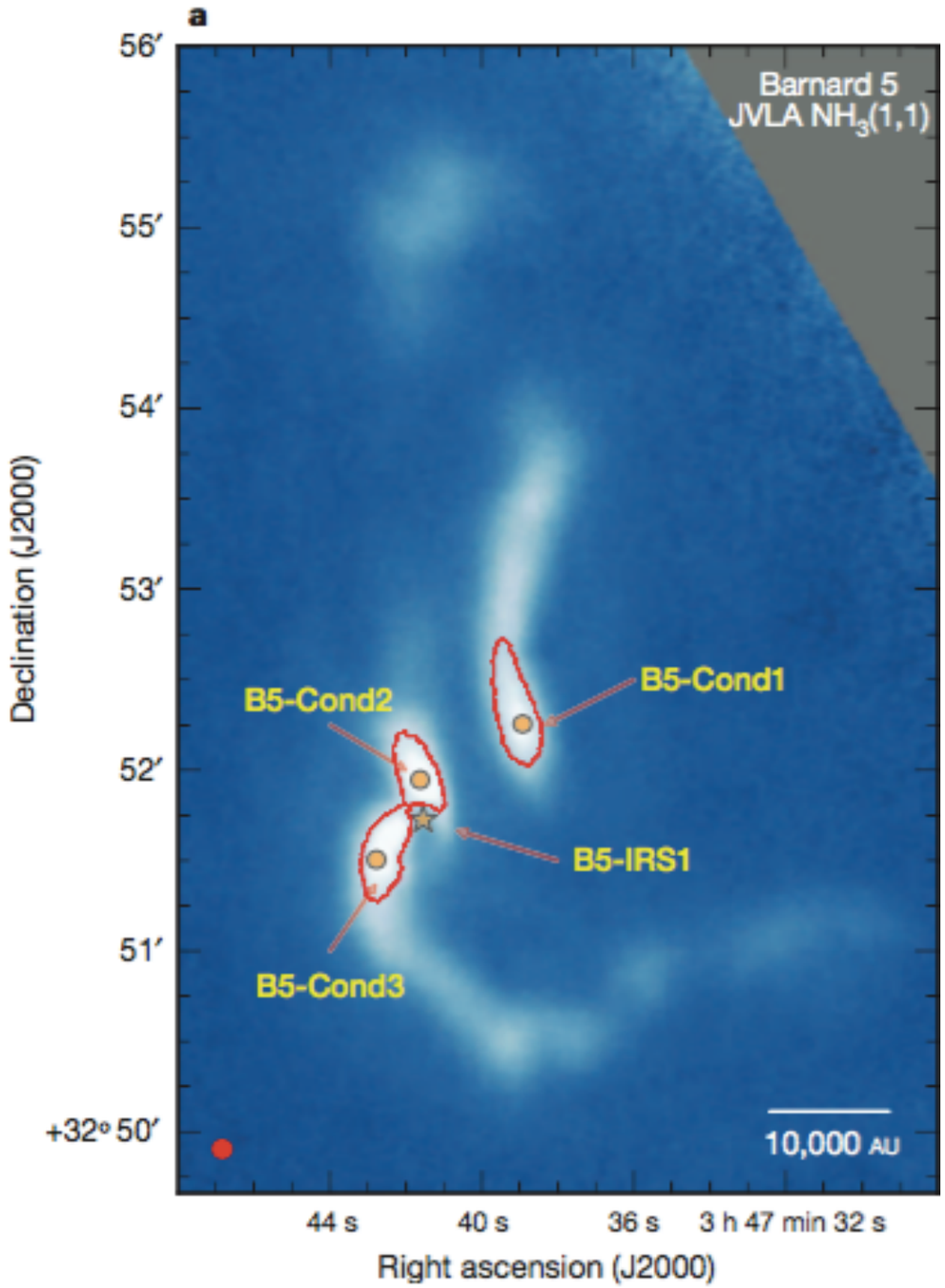
- 小さいスケールほど高い
- シミュレーション・他の観測との比較

  → 3000-4000 AU以下のスケールで重力が効いている

  → starless coreやdense coreでの増加は重力によるもの？

  →最近は5000AUスケールで重力的に束縛されたコアの例も
- なぜprotostellar coreではgroupingの兆候がない

  →進化の過程でgroupingを失った？

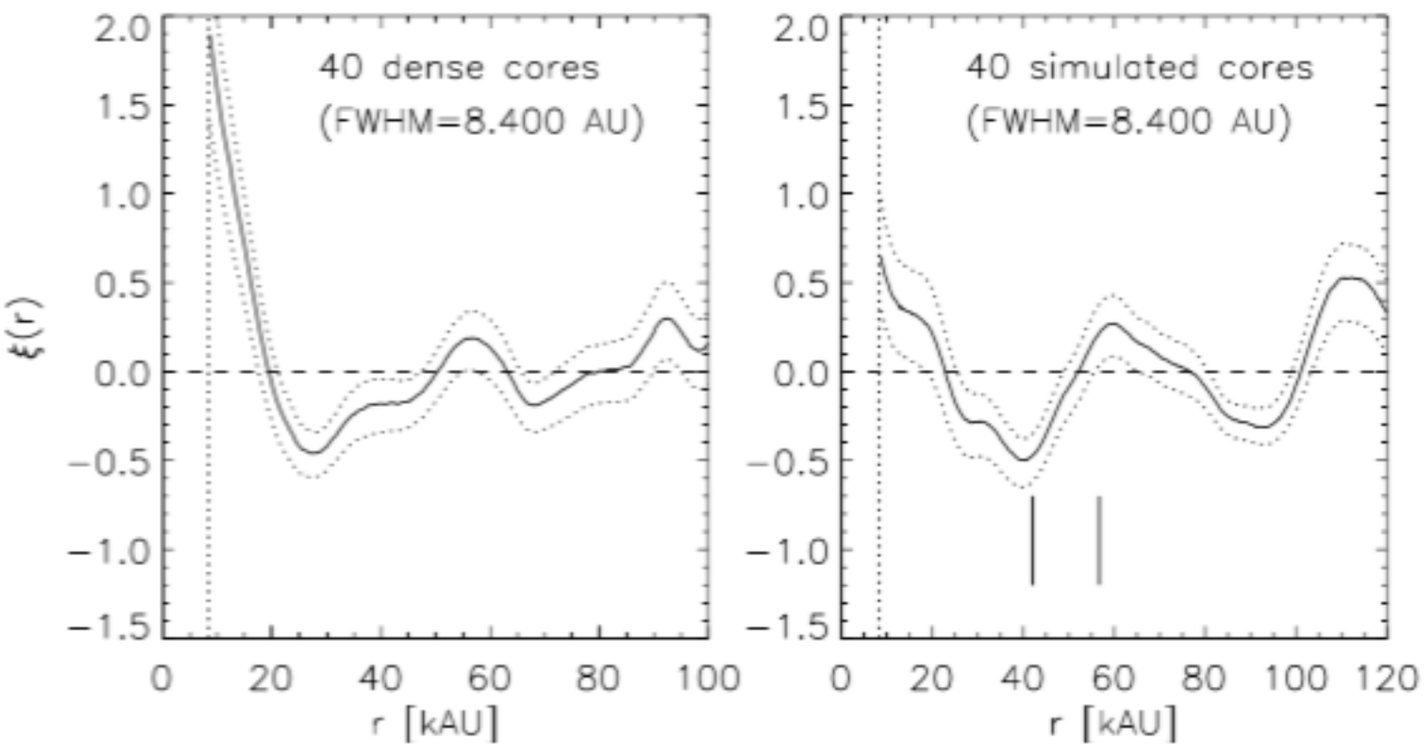


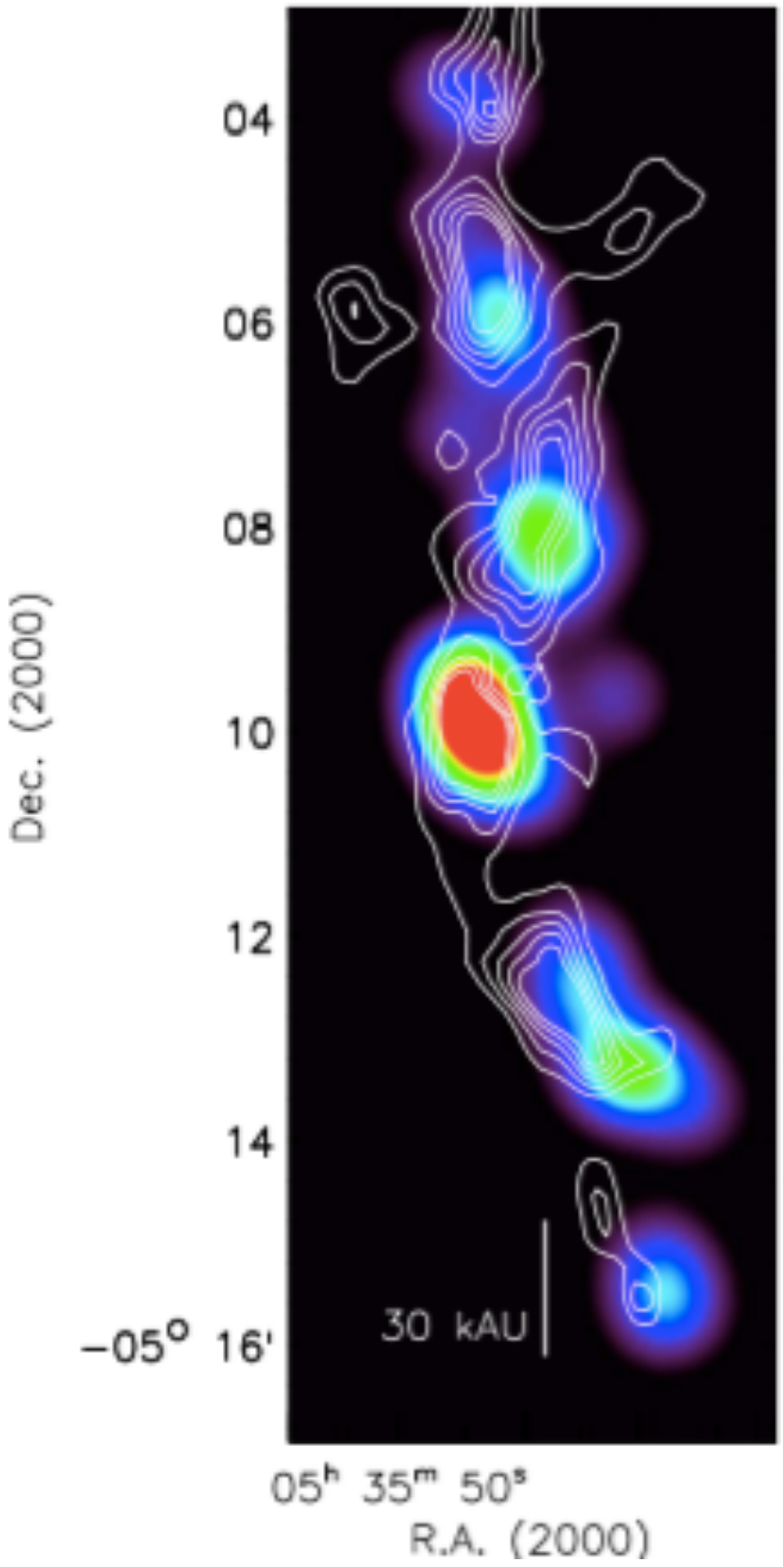
Pineda+15

Discussion

large scaleでのtwo-point correlation

- より大きいスケールのtow-correlationは不定性大
- スムージング(20” = 8400 AU)をかけてtow-correlationを見てみる
  - → 20000-40000 AUでnagative
  - → 55000 AUでピークが見えている
  - → 30000 AU程度のgroupの周期的な分布に対応
  - → これはHerschelのダストの分布とも一致





Discussion

Fragmentation in filaments

- 2つのfragmentationモデルの共存

  →filamentが周期的に分裂するcylindrical fragmentation mode

  →そのグループがさらに個々のcoreとなるspherical fragmentation mode

  →これらのmodeは~40000 AUのスケールを境に変わるように見える

  (Jeans' fragmentation scale ~ 10000 AU)

- なぜprotostellar coreではgroupingの兆候がない

  → Stutz & Gould (2015)のモデル

  → protostar/starが形成していく中で、gasとdecouple

  → groupingの情報を失う

Summary

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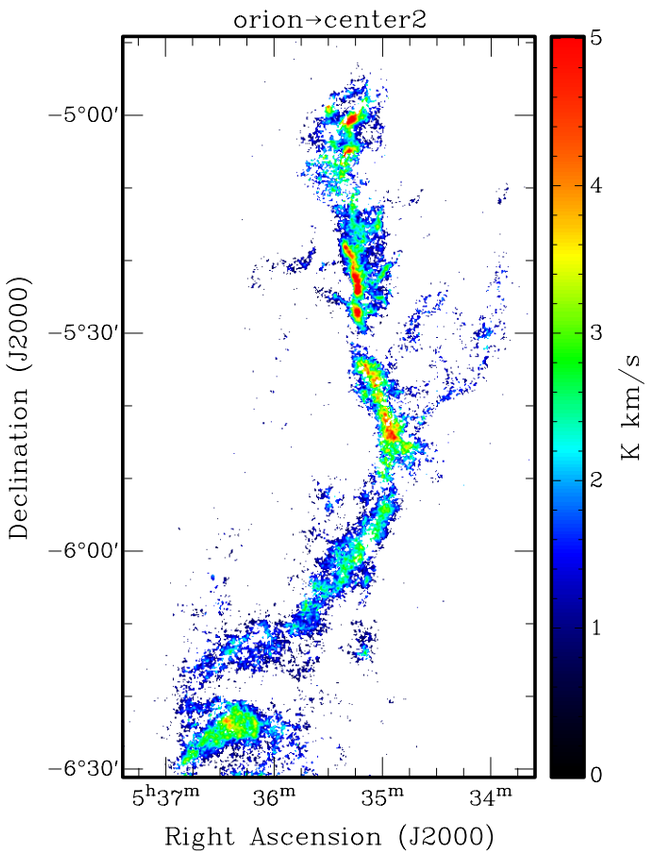
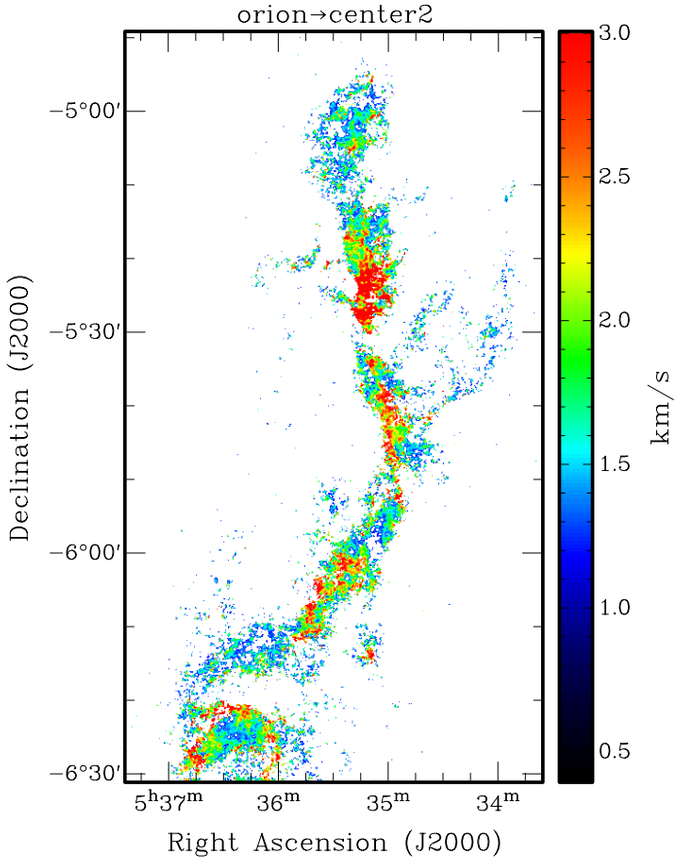
NRO star formation project

$C^{18}O$
integ. int. map



$C^{18}O$
dV map



N_2H^+
integ. int. map