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# Fragmentation of the ALMAGAL dense clumps into young protoclusters


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# Overview

- ⭐ Intro: High-mass cluster-forming clumps fragmentation and key questions
- ⭐ ALMAGAL observations
- ⭐ Extraction of the Compact Source Catalog
- ⭐ Statistical and physical properties of the extracted core population
- ⭐ Preliminary correlations between estimated physical parameters of the cores and physical and fragmentation properties of the hosting clumps

# Clump fragmentation

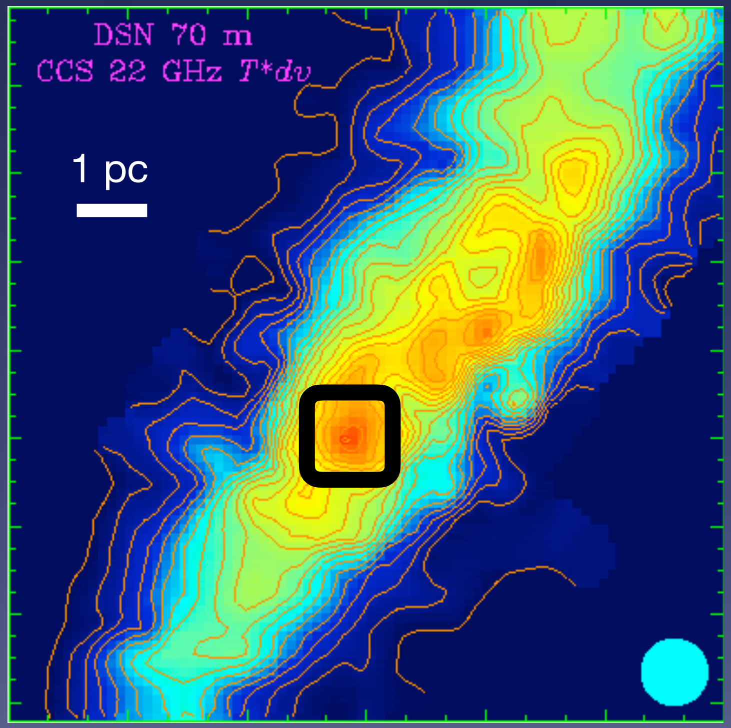
**Clumps**: dense gas and dust envelopes within molecular clouds, hosting star formation sites (compact cores).

$n \sim 10^3 - 10^6\ cm^{-3} \quad T \sim 20 - 70\ K$

$M \sim 10^2 - 10^4\ M_\odot \quad D \leq 1\ pc$

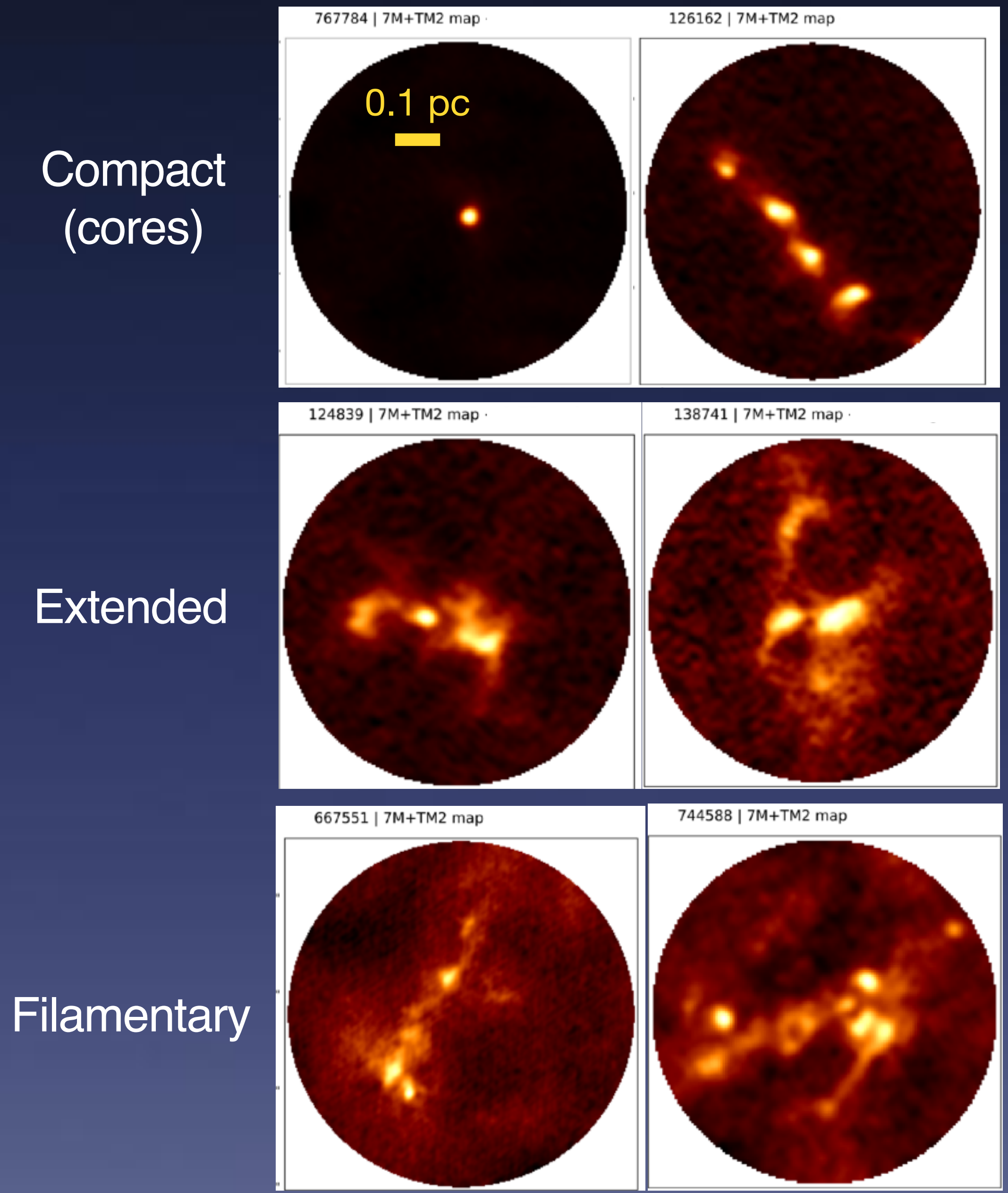
**Cores**:

$n \geq 10^6\ cm^{-3}$ T up to 100 K $D < 0.1\ pc$




*Clump (black contour)*
*in Taurus GMC*

**Dynamical fragmentation**
during free-fall
gravitational collapse
(see Stahler & Palla 2004)




*1.4 mm (220 GHz) continuum images of ALMAGAL clumps obtained with ALMA 7M+C2/C3 array*

# Key questions

- What are the typical clump fragmentation degree and spatial scales?
- How are compact fragments distributed in mass and size, and how this relates to the physical properties and environmental conditions of the hosting clump?
- How do cores gain their mass and how this process evolves with time?
- Which are the physical forces/ processes (e.g. gravity, turbulence) that dominate the fragmentation?

→

**High-mass star formation models:**

- Hierarchical fragmentation (e.g. Svoboda+19, Liu+21)
- Core (monolithic, *core-fed*) accretion vs competitive (*clump-fed*) accretion (e.g. Tan+14, Motte+18, Traficante+23)

# ALMAGAL observations (ALMA LP, PI: S.Molinari)

Sample: 1000+ dense clumps from Hi-GAL (900+, Elia+17,21) and RMS (100+, Urquhart+15)
Mass: $10^2 - 10^4\ M_\odot$
Distance: $2 < d < 8\ kpc$
Evolutionary stages: from IRDCs to HII Regions and ZAMS (i.e. from prestellar to protostellar)
L / M: $10^{-1} - 10^3\ L_\odot/M_\odot$
Surface density: $0.1 - 15\ g\,cm^{-2}$
Galactic locations: from the tip of the Central Bar to the outer spiral arms of the MW

**ALMA** Interferometer observations:

- Band 6 (continuum+lines), $\nu_0 = 220\,GHz \quad \lambda_0 = 1.4\,mm$
- Configurations: ACA-7M, C-2, C-5 (near sample, d < 4.5 kpc) | MRS: 3-29” | ang.res.: ~0.3”
  ACA-7M, C-3, C-6 (far sample, d > 4.5 kpc) | MRS: 2-29” | ang.res.: ~0.15”

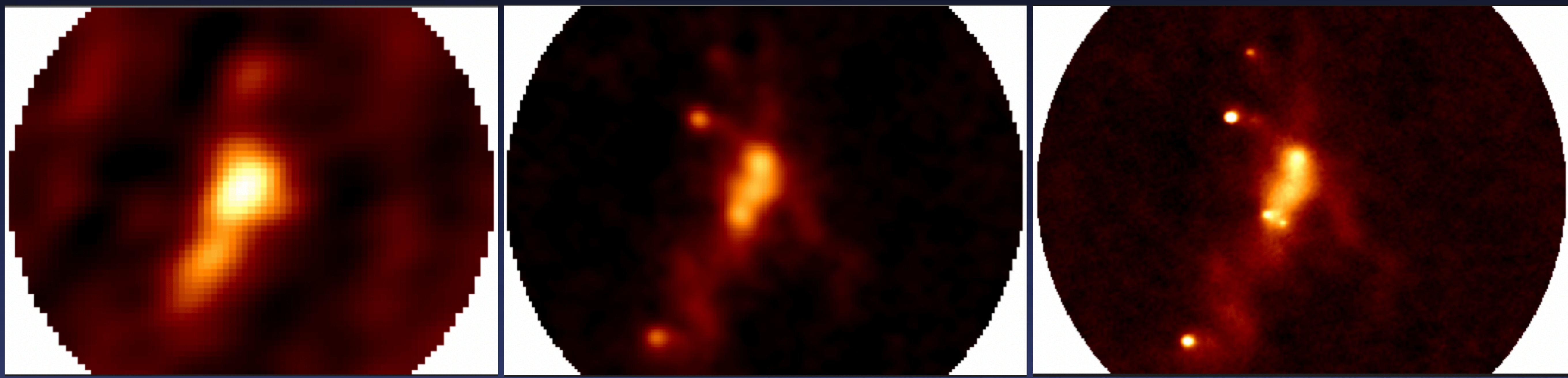
**—> ~1000 AU** homogeneous spatial resolution over the whole sample


*Atacama Large Millimeter/submillimeter Array (Chile)*

High-resolution observations are needed to identify, resolve and separate compact cores:

*Comparison of ALMAGAL continuum maps at different array configurations (near sample source 108933)*

| **ACA-7M** | → | **ACA-7M + C-2** | → | **ACA-7M + C-2 + C-5** |
|---|---|---|---|---|



| Angular \| Spatial resolution: | Angular \| Spatial resolution: | Angular \| Spatial resolution: |
|---|---|---|
| ~ 5" \| ~ 20000 AU (~0.1 pc) | ~1" \| ~ 3000 AU | **~ 0.3" \| ~ 1000 AU** |
| Large-scale structure | Medium/small-scale structure | Small-scale structure ↓ Higher fragmentation degree (**compact cores**) |

# Compact Source Catalog

## ALMAGAL Paper I (Coletta et al. in prep.)

- **Compact Source Extraction** performed on combined array continuum images with an implemented version of the CuTEx algorithm (Molinari+11,16)
- **Flux completeness analysis**: 4000+ synthetic sources with 10-15 different integrated flux levels injected in 60 fields —> Fcompl = ~1 mJy | Photometry accuracy (int. flux, size): < 20%

### Detection statistics

| sn-4 catalog | **sn-5 catalog** |
|---|---|
| Total detections: 9357 | **Total detections: 6321** |
| Clumps w/det.: 883 (88%) | **Clumps w/det.: 838 (83%)** |
| Average dets./clump: ~11 | **Average dets./clump: ~8** |
| Median dets./clump: 7 | **Median dets./clump: 5** |
| Nfrag range: 1 - 76 | **Nfrag range: 1 - 49** |
| Fint range: ~ 10^-4 - 1 Jy | **Fint range: ~ 10^-4 - 1 Jy** |

Preliminary results from unpublished material

*Stay tuned…*

# Conclusions

- ALMAGAL Compact Source Catalog:

  6321 cores in 838 clumps, Nfrag per clump = 1-49 (aver. 8, med. 5)

  D = ~1000-3000 AU

- ALMAGAL overall CMF:

  mass range: ~10^-2 - 10^2 Msun

  observed slope = -1.04±0.02 (6000+ cores in 800+ clumps)

  Sanhueza+19 (ASHES): -1.07±0.09 (300 cores in 12 70μm dark clumps)

  Pouteau+22 (ALMA-IMF): -0.95±0.04 / -1.02±0.05 (200 cores in W43)

- Preliminary inferred high-mass star formation scenario from core-clump correlations:

  gravity-driven, clump-fed competitive accretion

# Thank you!

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