Which magnetic field scales are most responsible for regulating star formation?

A puzzle from clump formation to clump fragmentation

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The Puzzles of Star Formation II - 05/05/2025

We can already divide the puzzle into two:

Which magnetic field scales are most responsible for regulating star formation?

→ final outcome of clump fragmentation process

At which scales is it possible to probe the impact of magnetic fields?

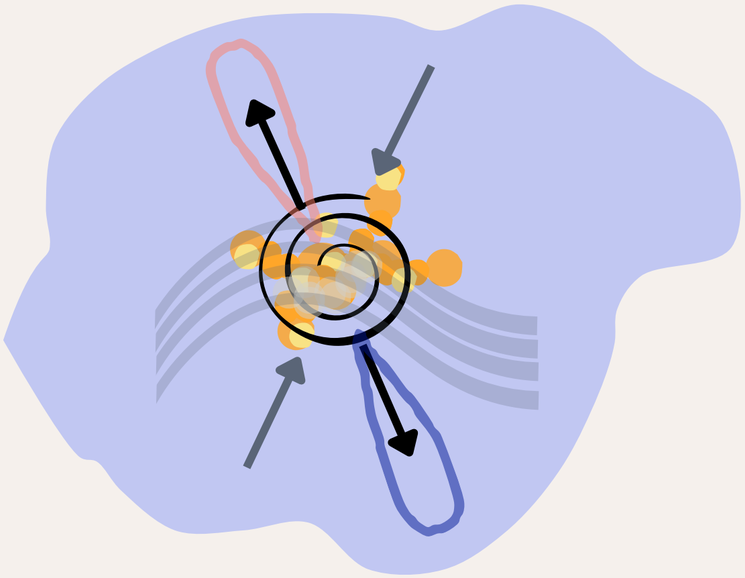
→ intermediate (hierarchical?) substructures forming during clump evolution

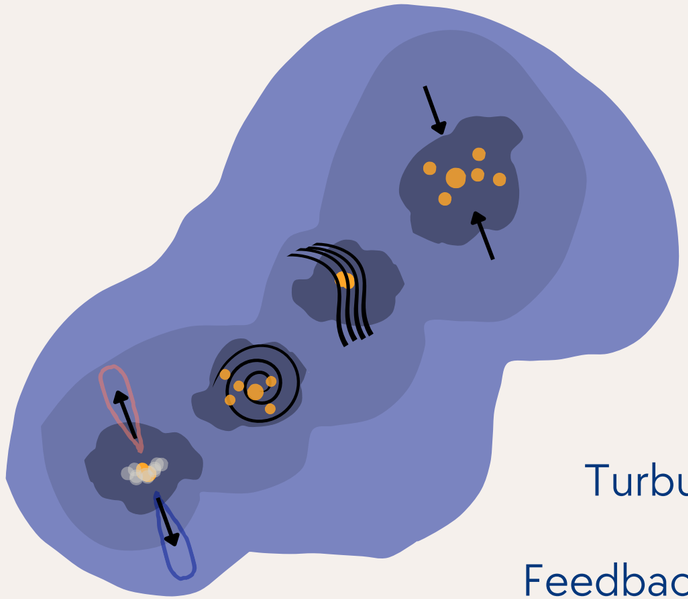
Also related to the scales that we can observationally probe

Probing magnetic fields in (high-mass) star-forming regions

Star formation is a multi-scale process

molecular clouds ~ 10 pc
clumps ~ 1 pc
fragments / cores ~ 1000 AU





The outcome is shaped by an interplay of forces

Gravity

Magnetic fields

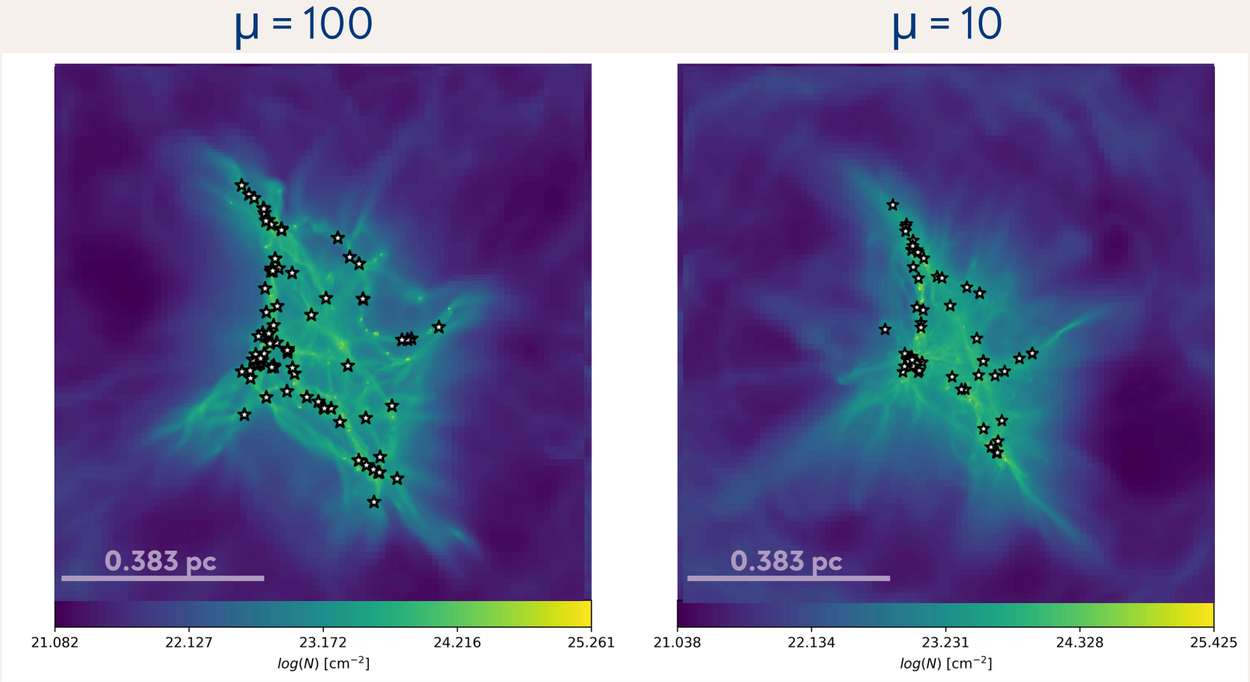
Turbulence

Feedback mechanisms

Why being puzzled? Evidence from numerical simulations vs. observations

From ~10 pc filaments to ~100 AU cores scales, numerical models suggest that, from the very early stages of star formation **magnetic fields provide support against gravity, influence the direction of gas flows, favor the formation of filamentary structures, and reduce the fragmentation** in comparison to weakly magnetized or non-magnetized environments

(e.g., Peters+2011, Hennebelle & Inutsuka 2019).



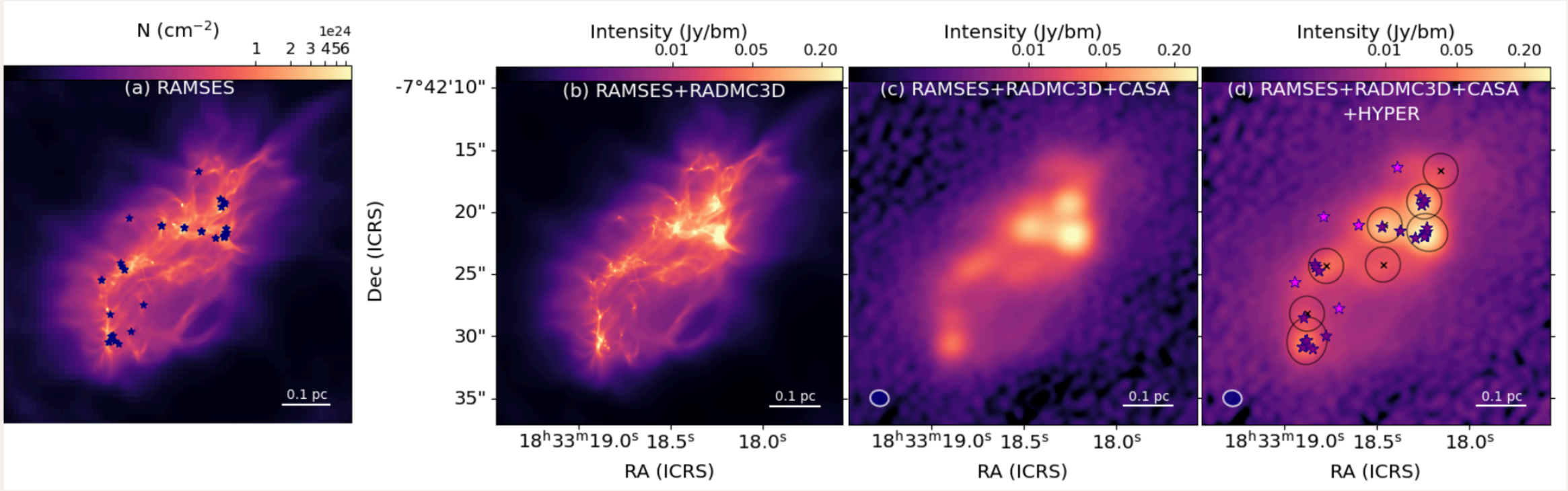
Lebreuilly+ (submitted)

vs. Pillai+15, Tang+19, Anez-Lopez+20, Palau+21, Beuther+24

We both find results in agreement and in contrast with numerical simulations

At which scales is it possible to probe the impact of magnetic fields?

From The Rosetta Stone Project (Coord. Traficante)



Lebreuilly+ (submitted)

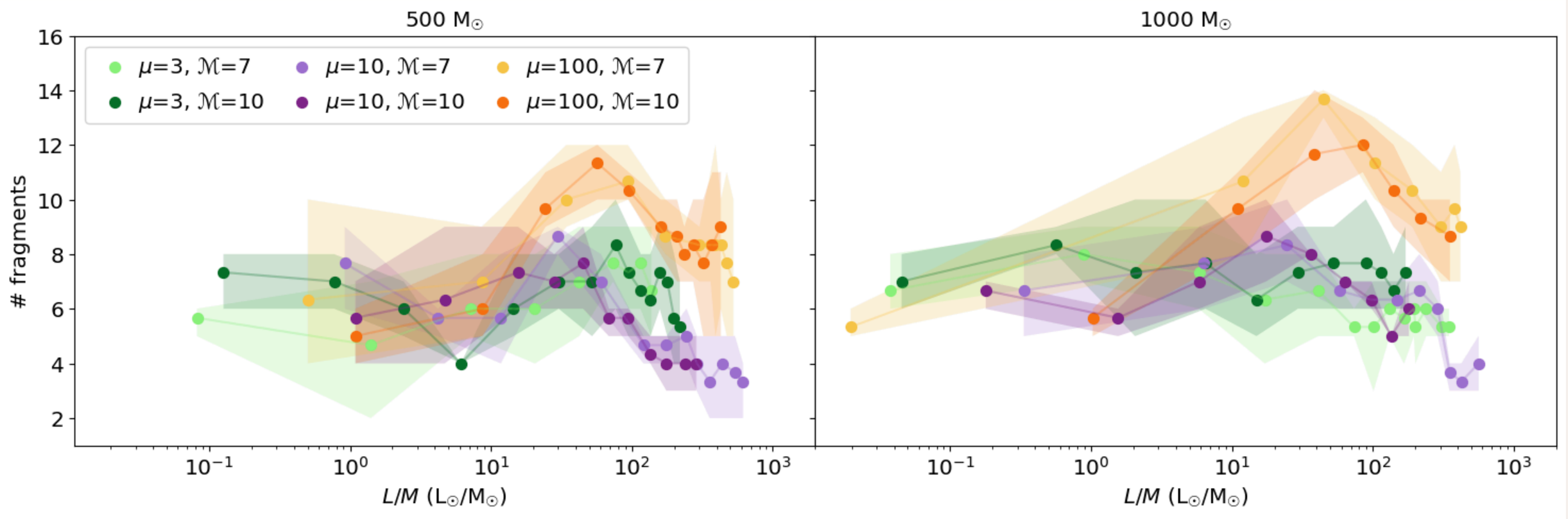
Tung+ (submitted)

Nucara+ (submitted)

Production of synthetic observations to test the impact of different environmental conditions of massive clump collapse on the fragmentation properties observed @~7000 AU

At which scales is it possible to probe the impact of magnetic fields?

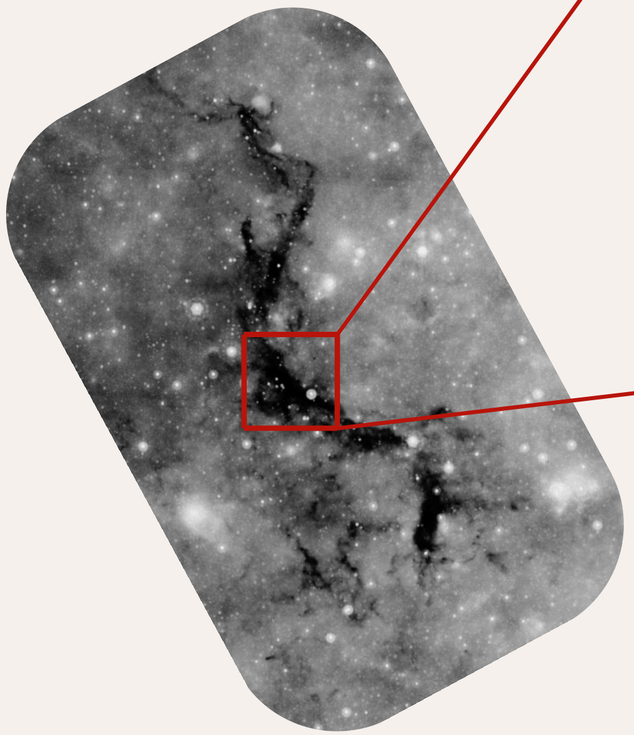
Evidence of clump-scale magnetic fields regulating fragment multiplicity



Synthetic observations @~7000 AU physical resolution (Nucara+ submitted).

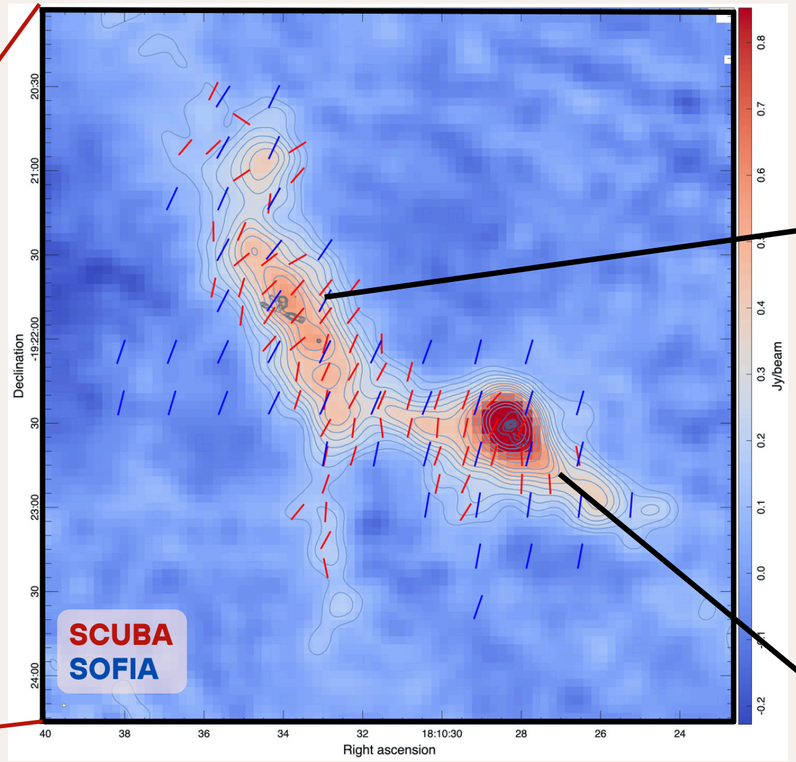
Soon @1000 AU to compare with ALMAGAL (Molinari+25, Coletta+25, Elia+ submitted)

Why being puzzled?
Fragmentation in G11

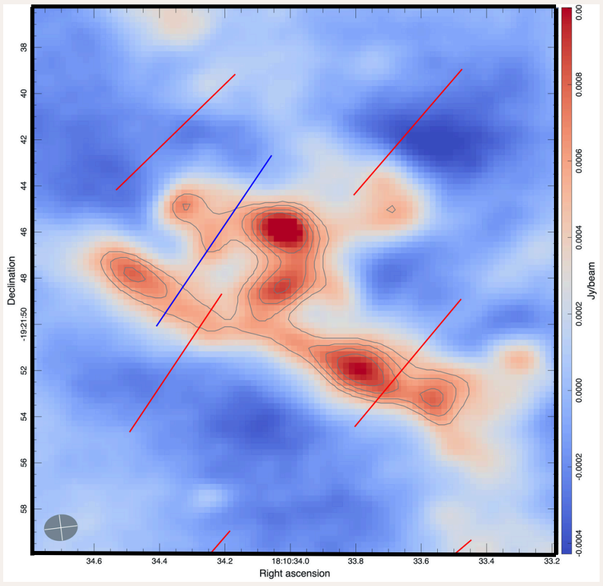


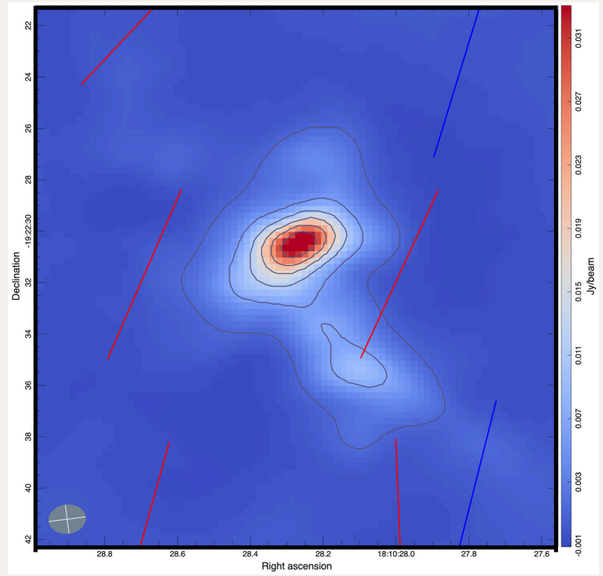
Spitzer Space Telescope
4.5/8/24 μm
Credit: NASA, JPL-Caltech/S. Carey (SSC/Caltech)

SCUBA 850 μm (Pillai+15)



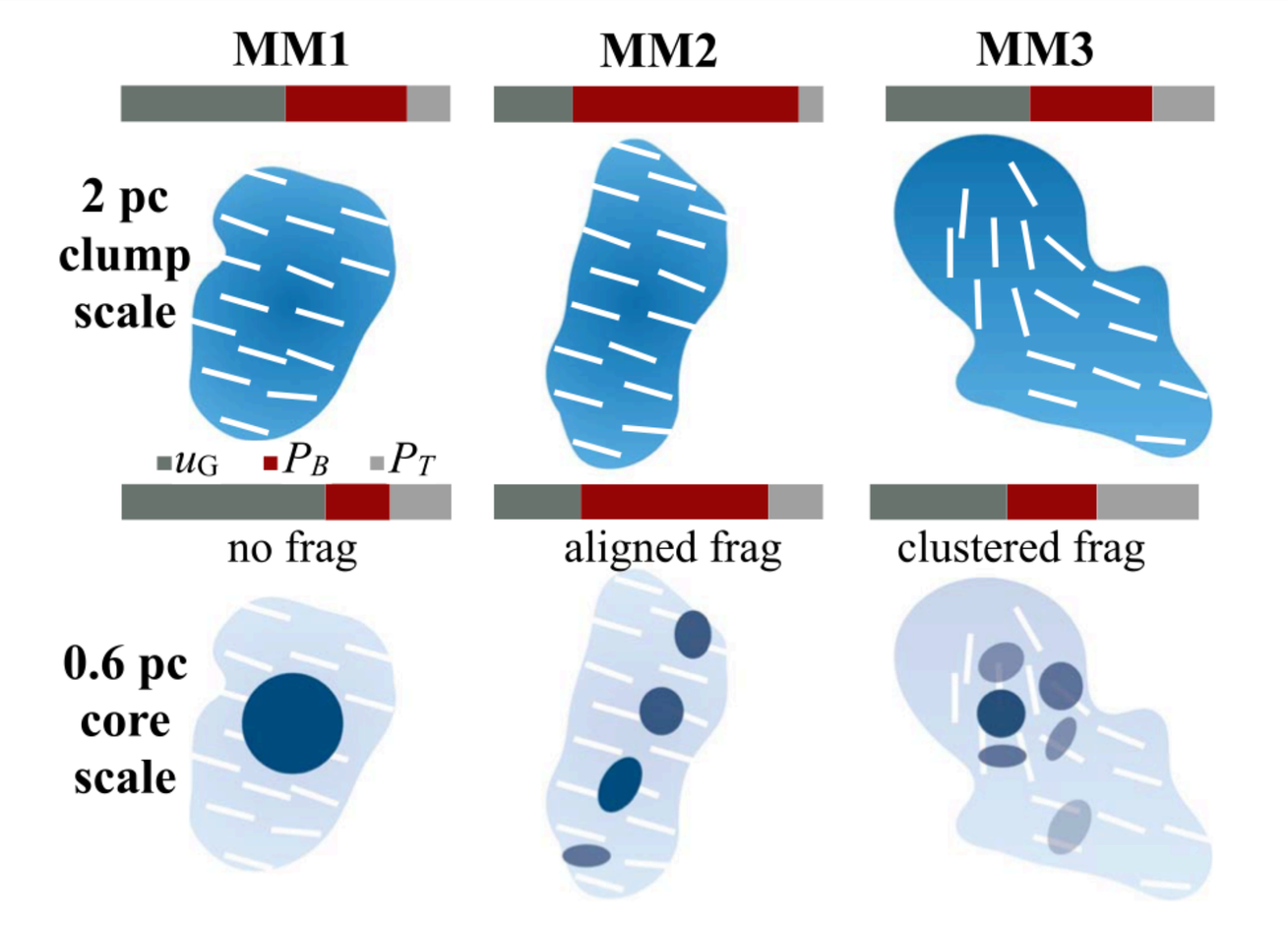
ALMA 1.3 mm



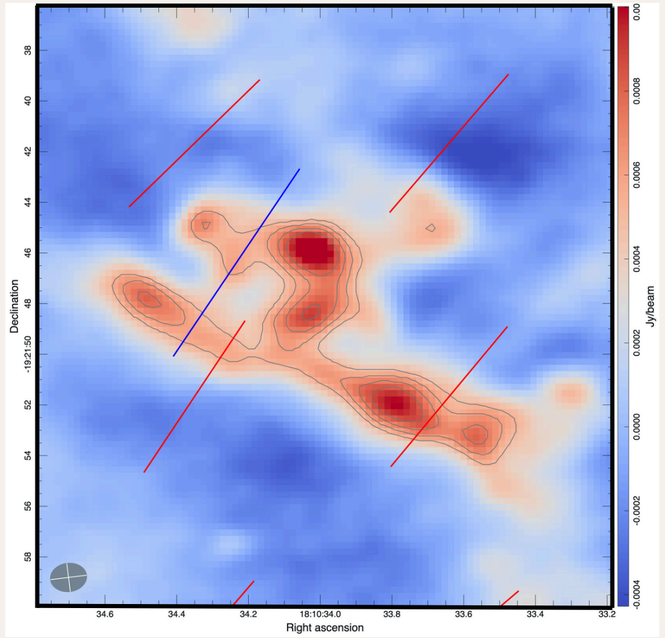


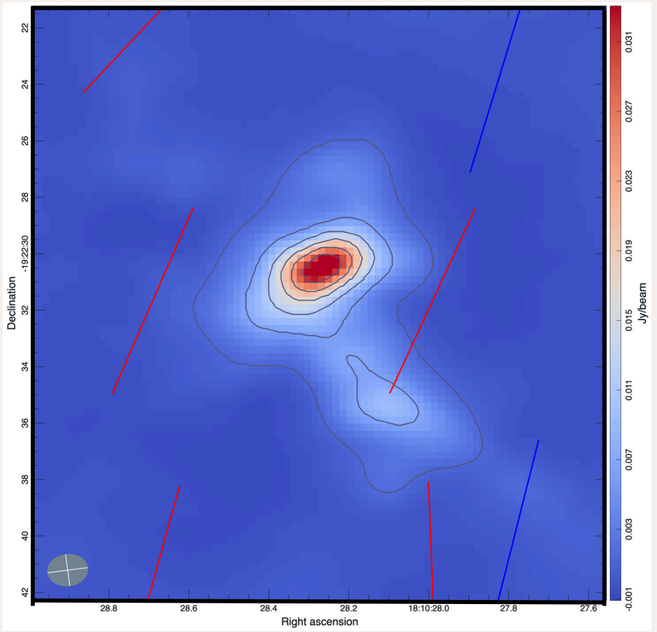
Cloud-scale magnetic fields in G11 do not seem to be regulating fragmentation within clumps → need to characterize clump-scale magnetic fields

Possible reason behind different fragmentation patterns



Tang+19





ALMA 1.3 mm

More about this puzzle:

- Multi-scale analysis

  higher resolution to constrain
  <1000 AU fragmentation properties

- Early evolutionary stages

  to avoid dominant impact
  of feedback mechanisms

- Synthetic observations (continuum + polarized emission)

  to trace magnetic fields
  orientation and characterize
  global vs. local properties