FORMATION OF THE SDC13 HUB-FILAMENT SYSTEM: CLOUD-CLOUD COLLISION IMPRINTED ON MULTISCALE MAGNETIC FIELD?

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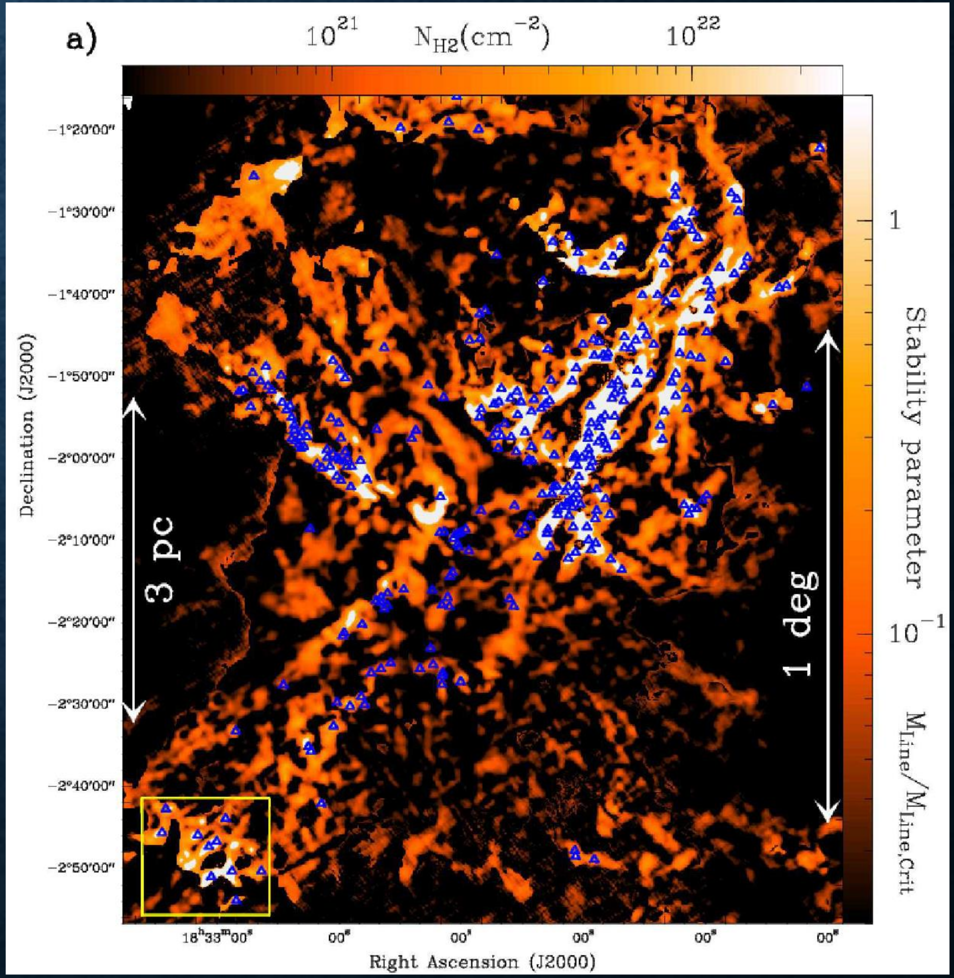
Interstellar Filaments: The potential site of star formation

- Stars appear to form within clustered environments.
- However, past studies mainly focus on the formation of single source, due to the limitation of instruments and computing power.
- Recently, the attention has been drawn to the large-scale star-forming environments.

Aquila Rift, identified filaments with prestellar cores (blue triangles)

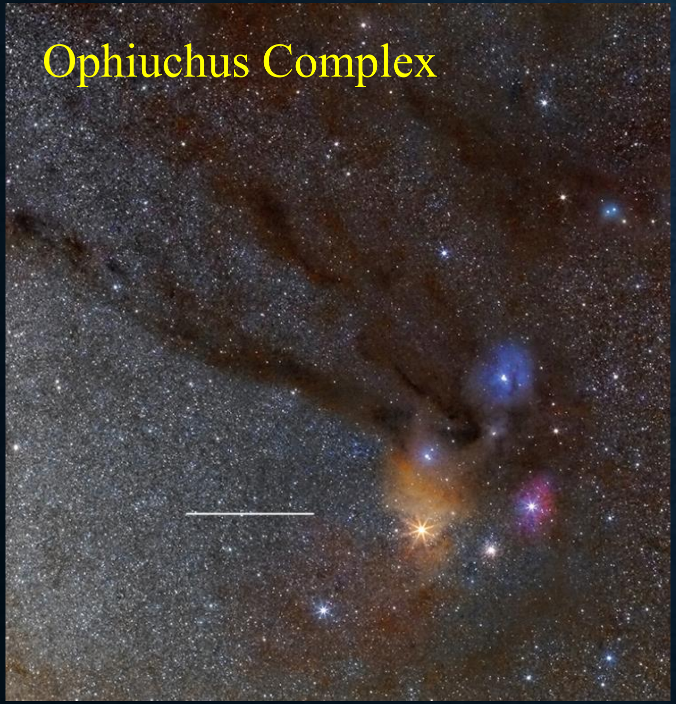


Herschel Gould belt survey:

- Stars predominantly form within dense filamentary clouds
- Density Threshold of prestellar cores : ~7 x 10^{21} cm^{-2} (Gravitational energy > 2 x Thermal energy)

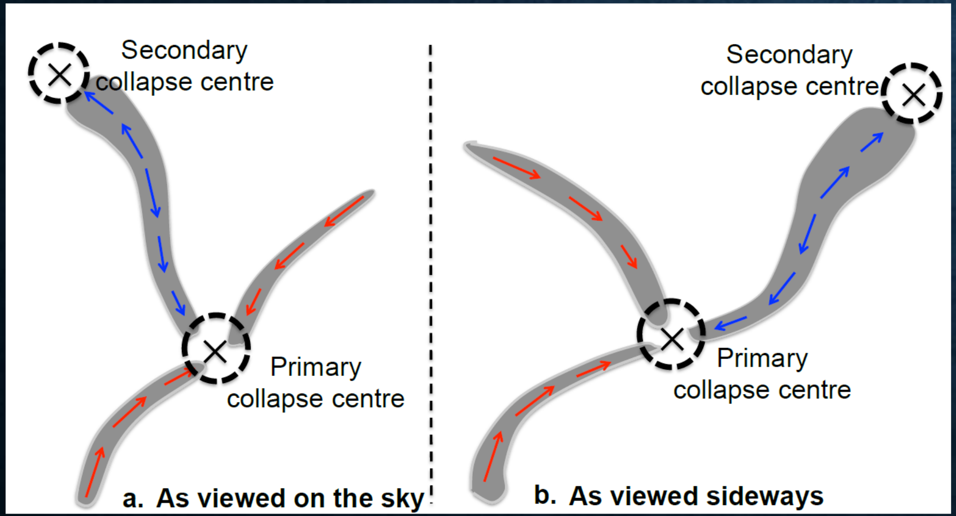
Hub-Filament System (HFS): The potential site of cluster formation

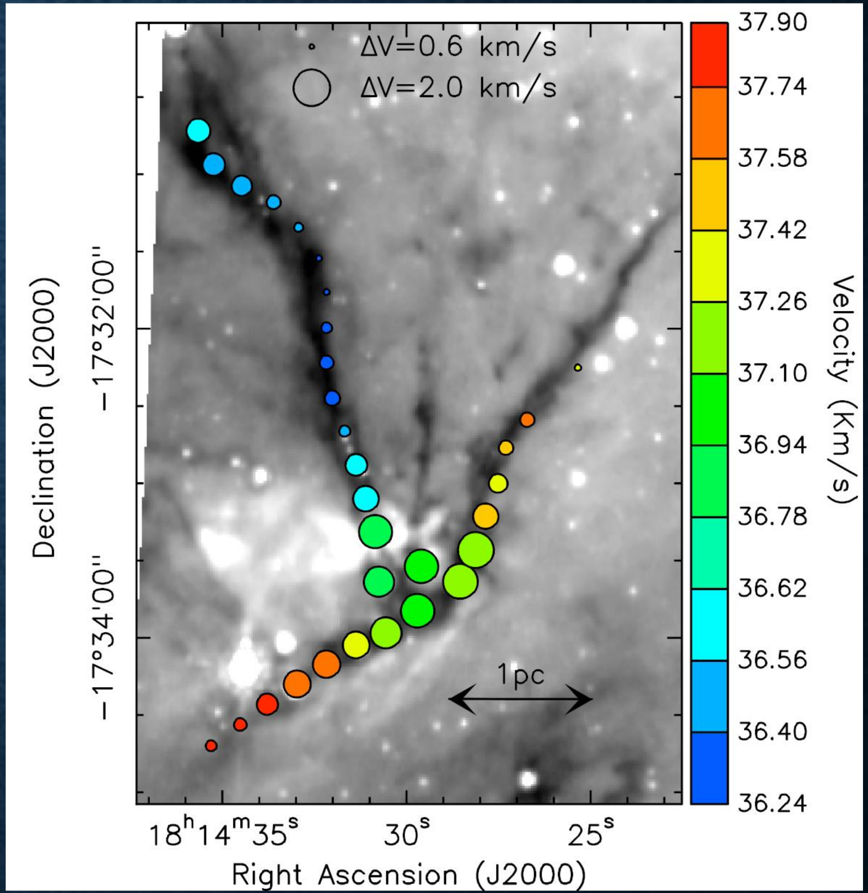
- Consisting of a dense hub, with several converging filaments
- Kumar et al. (2020): All nearby massive clumps ($L > 10^5 M_\odot$) at distances < 5 kpc are associated with HFSs.



Hub-Filament System SDC13

- Massive IRDC at 3.6 kpc
- 3 major filaments (+1 fainter filament) converging to the central hub
- N^2H^+ (1-0) observations (Peretto et al. 2014):
  - 1. Velocity gradient of 0.2—0.6 km/s/pc along the filaments
  - 2. Increasing velocity dispersion toward the center
- Longitudinally collapsing filaments?





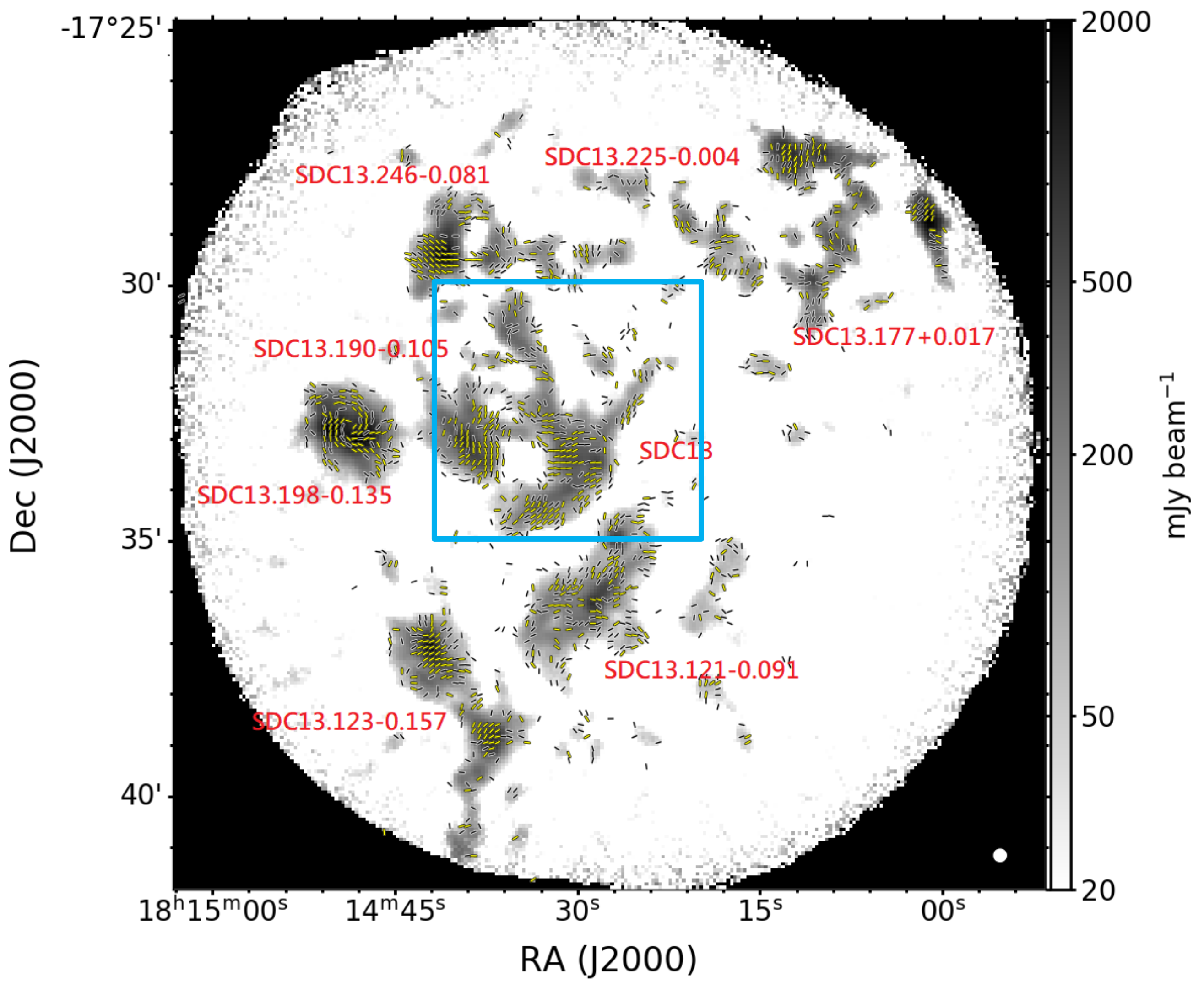
Grey scale : Spitzer 8 μm image
Circle colors: N^2H^+ (1-0) velocities
Circle sizes: N^2H^+ (1-0) velocity dispersion

POL-2 850 μm Polarization

- Polarization detected over a number of IRDCs
  - Yellow segments(3σ),
  - Black segments (2-3σ)

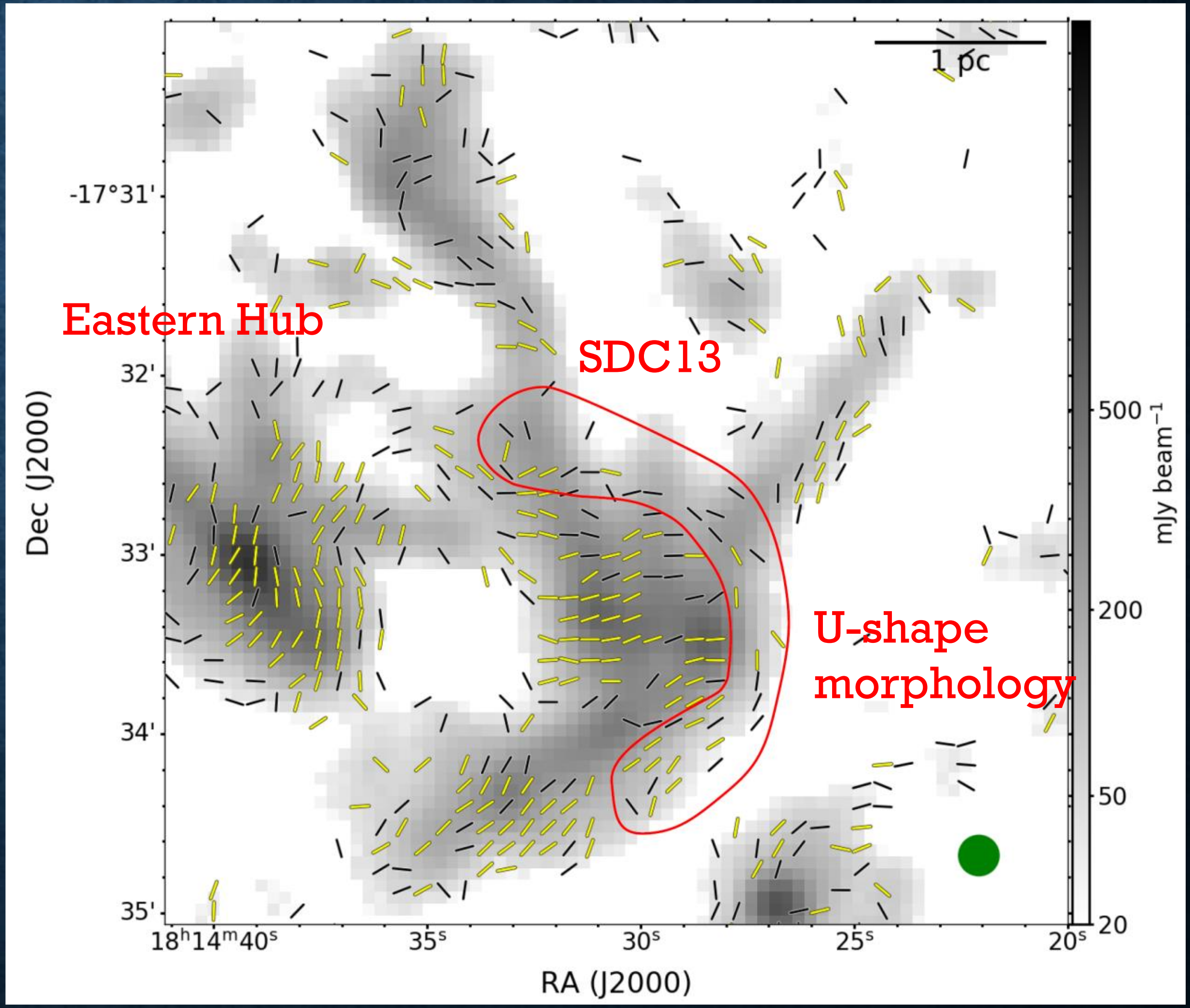
- The Y-shape SDC13 is clearly shown in the 850 μm continuum map

- Additionally, two faint bridges connecting the SDC13 to another cloud are present



POL-2 850 μm Polarization

- A patchy polarization map with non-detection gaps
  - Magnetic fields perturbed on cloud scale?
- Locally organized magnetic fields
  - Strong magnetic fields on core scale?
- “U-shape” magnetic field morphology along the western edge

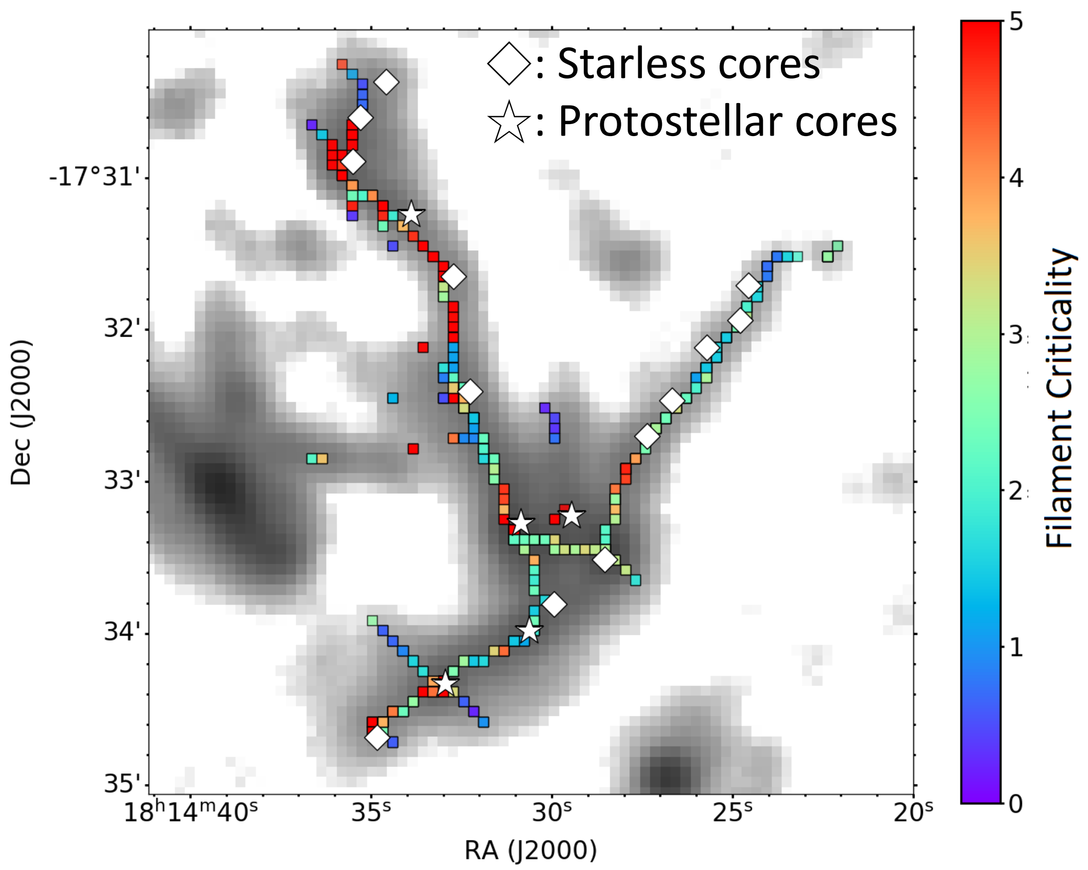


Global Stability

Regions	B_{pos}(DCF) (μG)	λ (DCF)	B_{pos}(ST) (μG)	λ (ST)
Hub	94 ± 5	0.87 ± 0.05	75 ± 2	1.08 ± 0.03
Filament NE	31 ± 1	1.50 ± 0.05	34 ± 1	1.34 ± 0.03
Filament NW	34 ± 5	0.95 ± 0.14	25 ± 2	1.29 ± 0.10
Filament S	58 ± 4	0.66 ± 0.03	49 ± 1	0.79 ± 0.02

- Magnetic field strength estimated using Davis-Chandrasekhar-Fermi (DCF) methods and Skalidis & Tassis 2021 (ST) method
- Mass-to-Flux ratio: trans- to supercritical

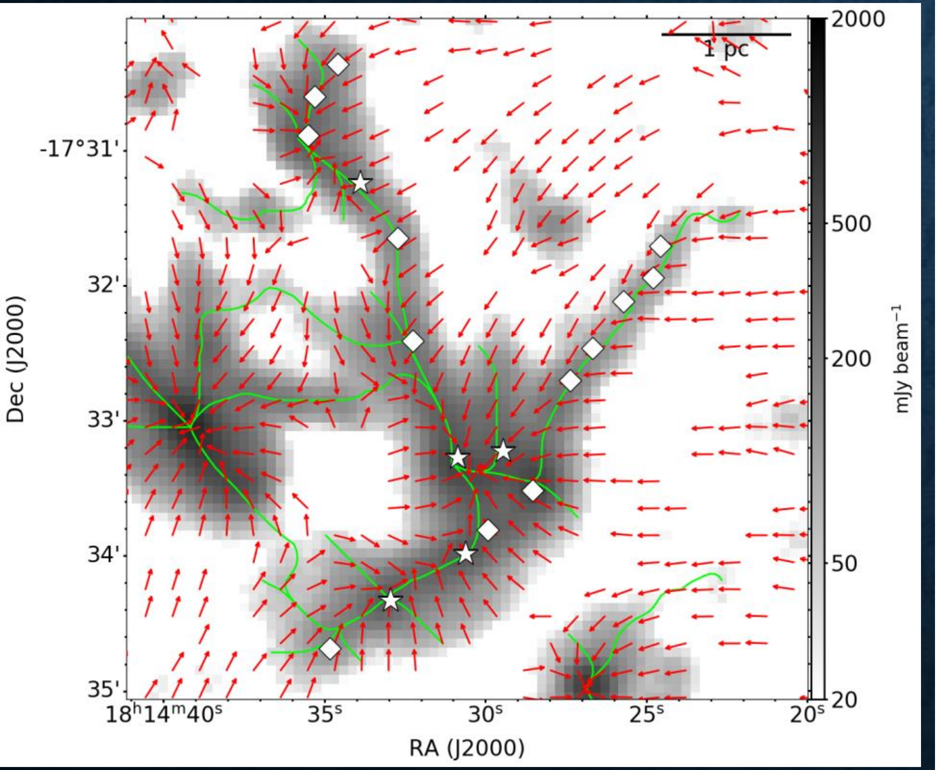
- Filament Criticality (Mass per Unit Length)
- Considering support from both turbulence and magnetic fields
- Mostly supercritical



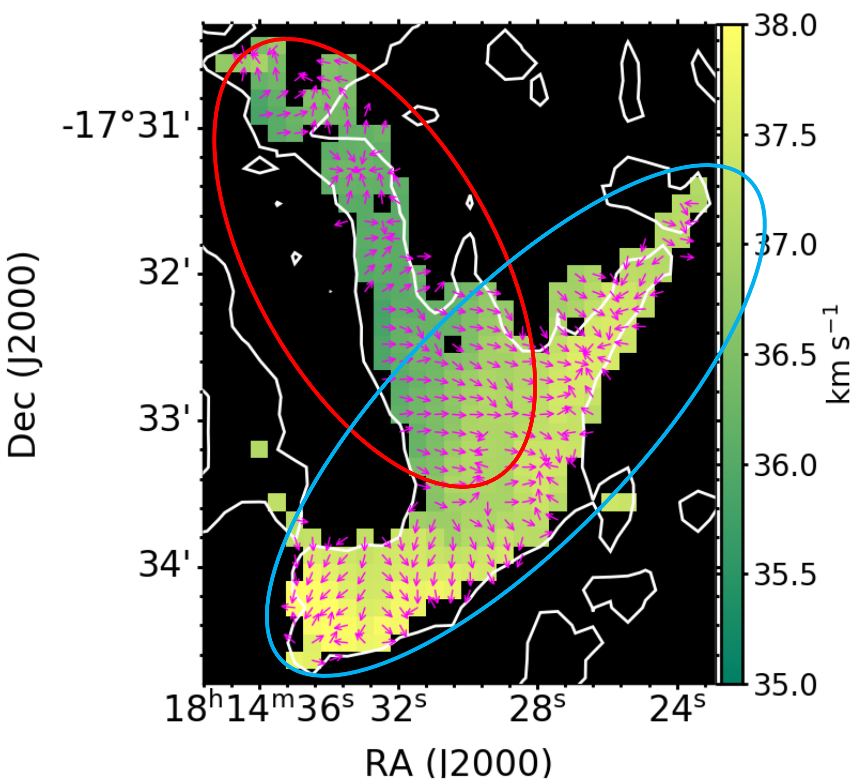
Local Gravity and Velocity Gradient

- Gravity: Converge onto filaments => toward dense cores and centers
- NH_3 Velocity: Globally northeastern (red circle) to southwestern (blue circle), but locally converge to filaments and dense cores

Gravitational Forces

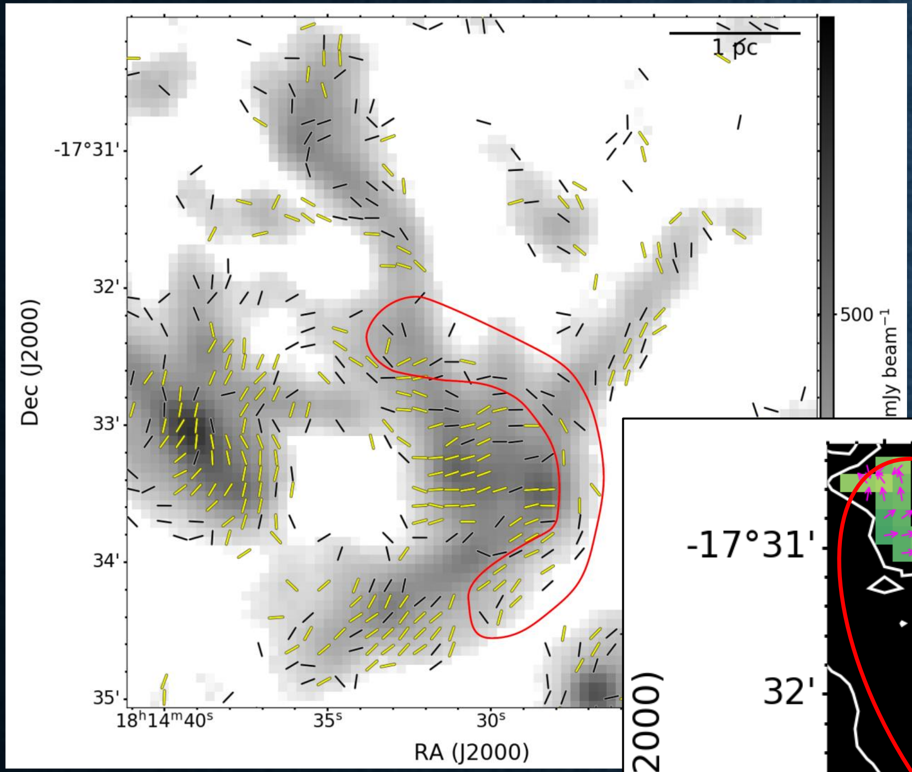


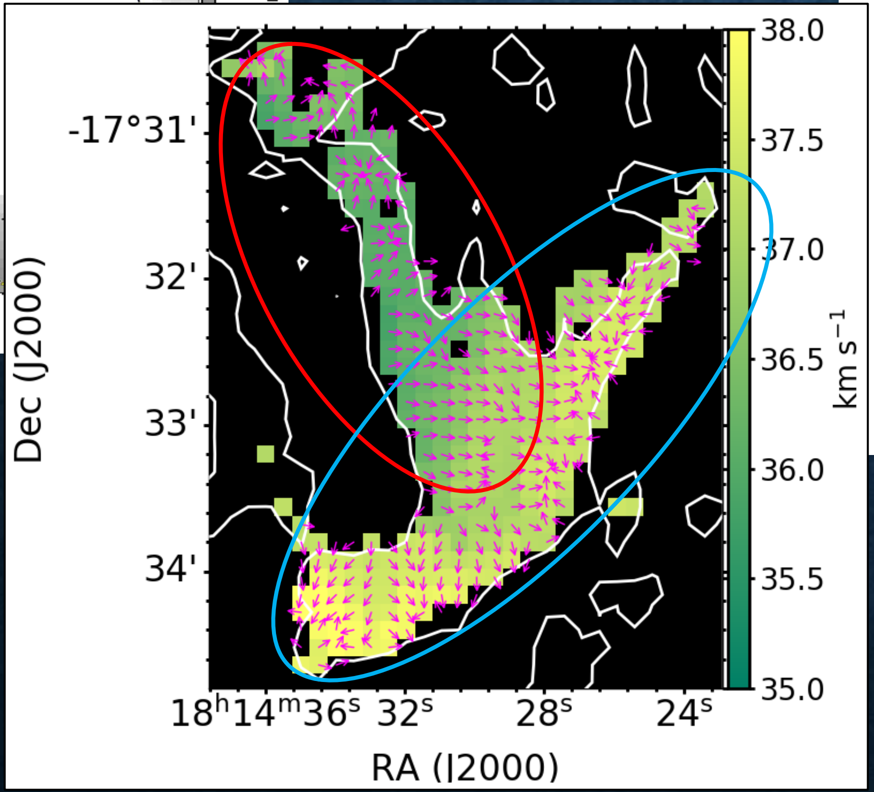
NH_3 centroid velocity map



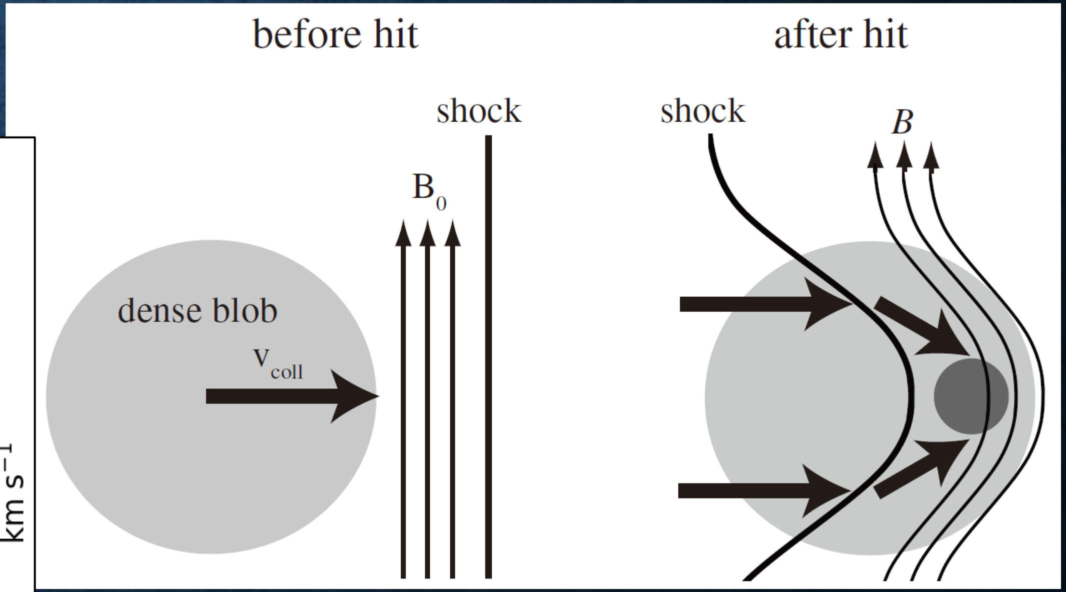
Red: Projected gravitational force
Green: Filaments (by DisPerSe)
Magenta: NH_3 Velocity Gradient
◇: Starless cores
☆: Protostellar cores

Possible Origin of the U-shape B-field?





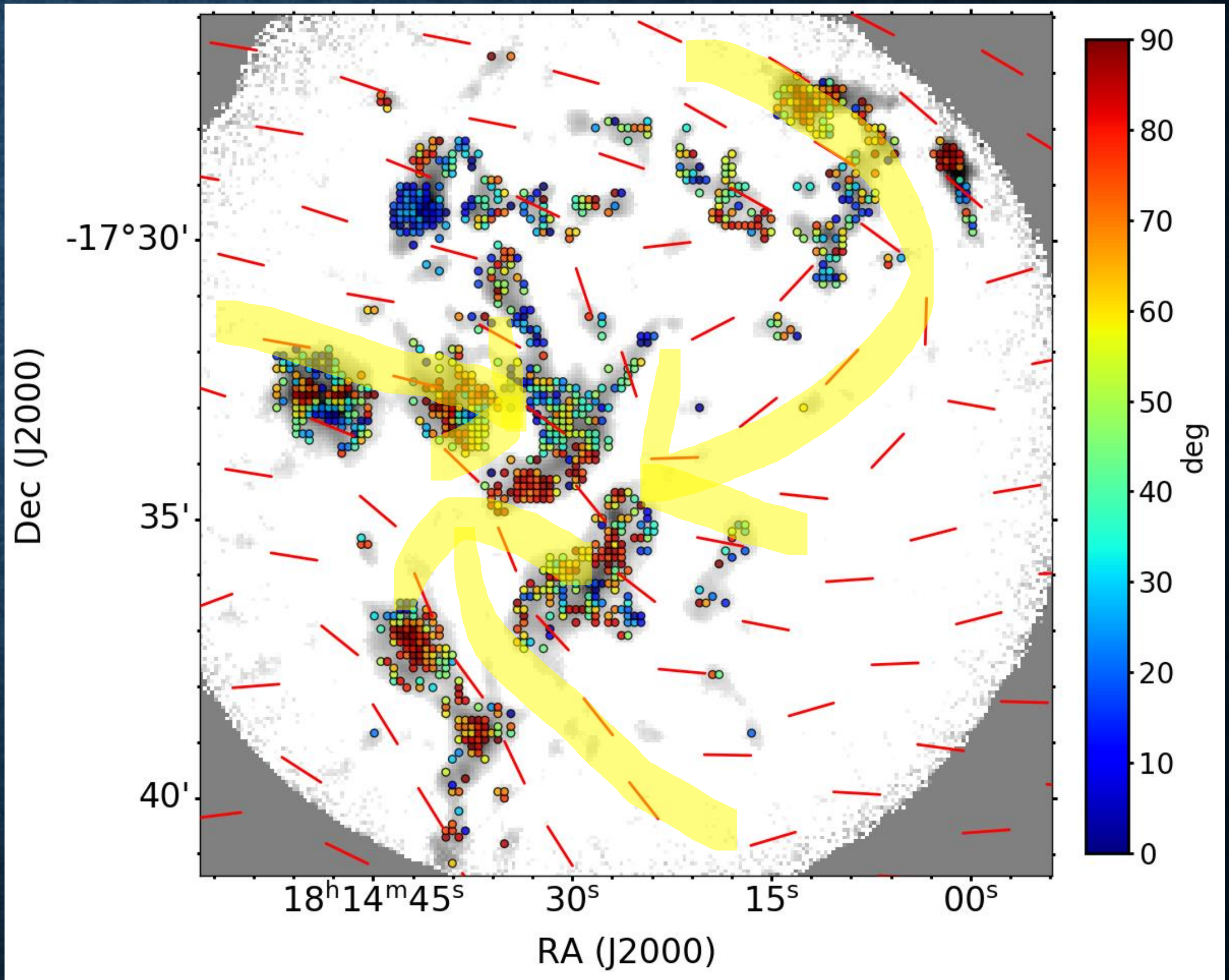
Schematics of the pinched magnetic fields during a cloud-cloud collision event (Inoue & Fukui 2013)



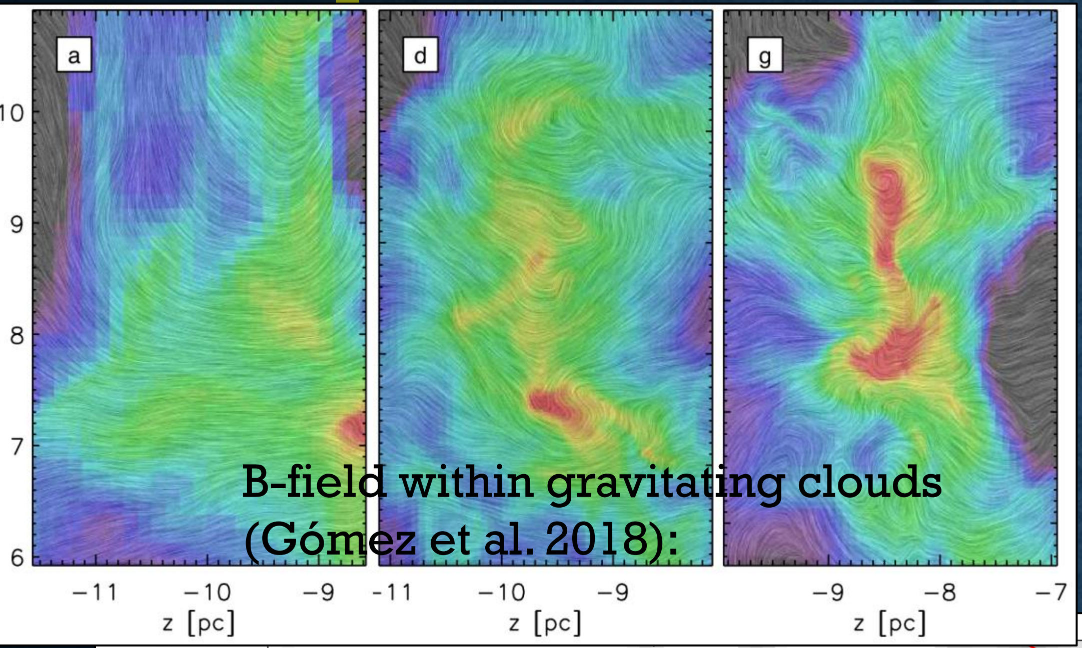
Large-Scale Magnetic Field

- Red Segments: 353 GHz PLANCK polarization
- Circles: Relative orientations between POL-2 and PLANCK polarization
  - Red: Perpendicular => Blue: Parallel

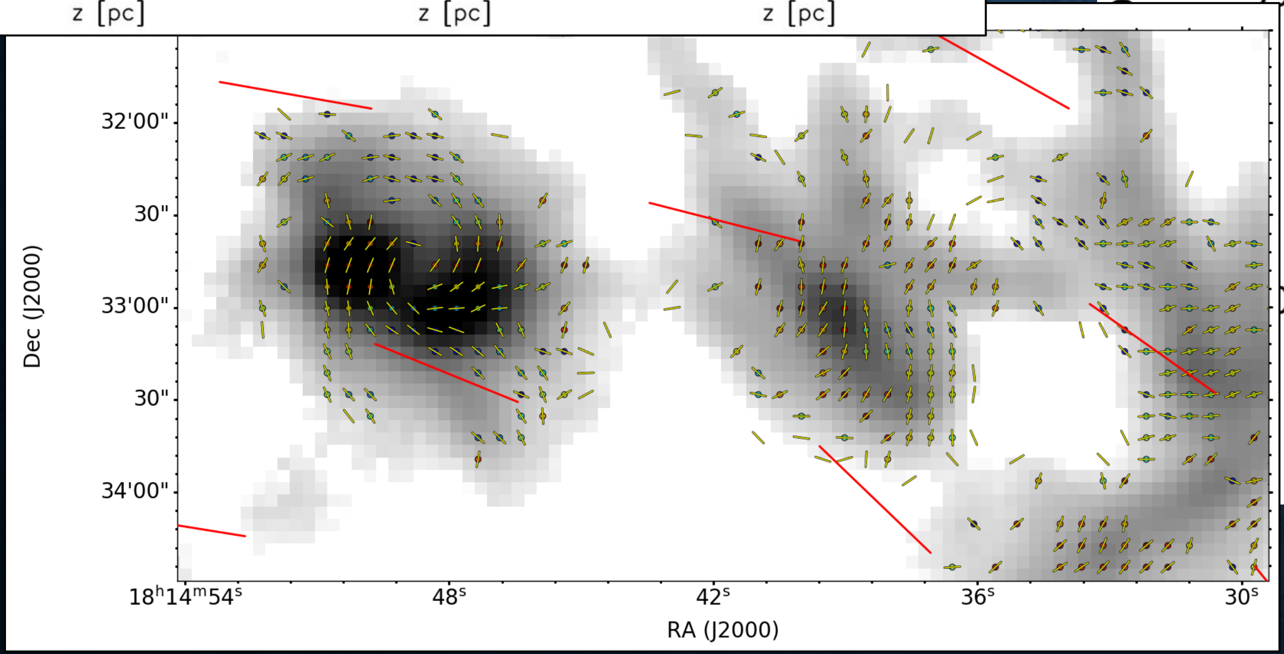
- A change from perpendicular to parallel over cloud scale, most likely due to cloud-scale event

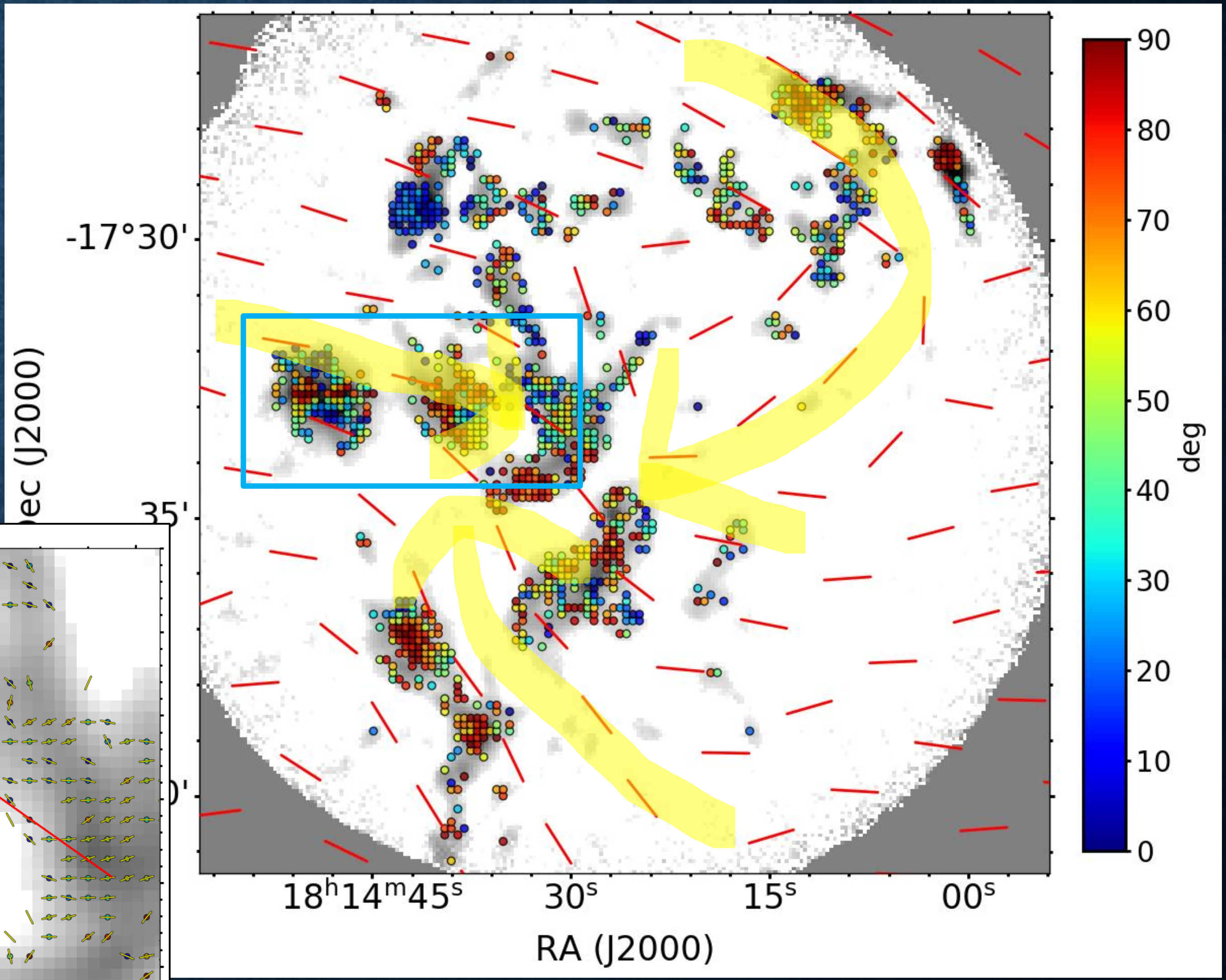


Large-Scale Magnetic Field



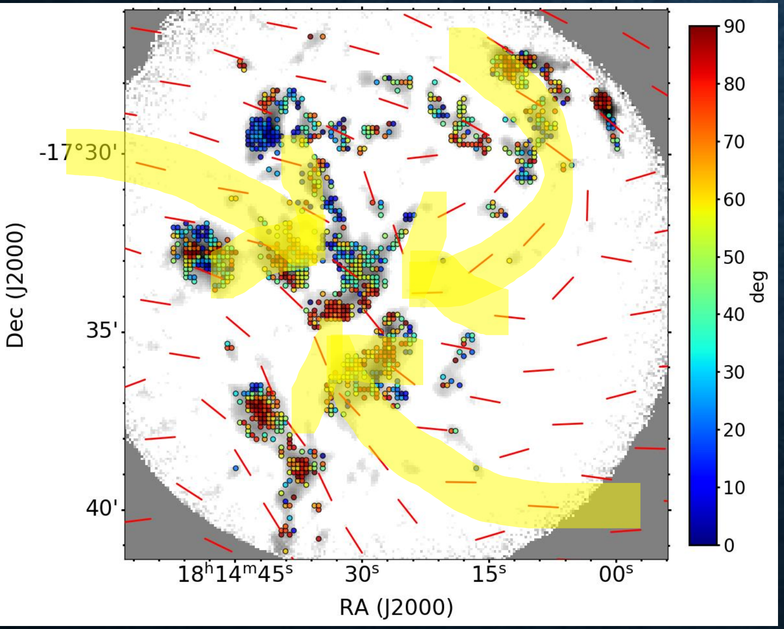
B-field within gravitating clouds
(Gómez et al. 2018):

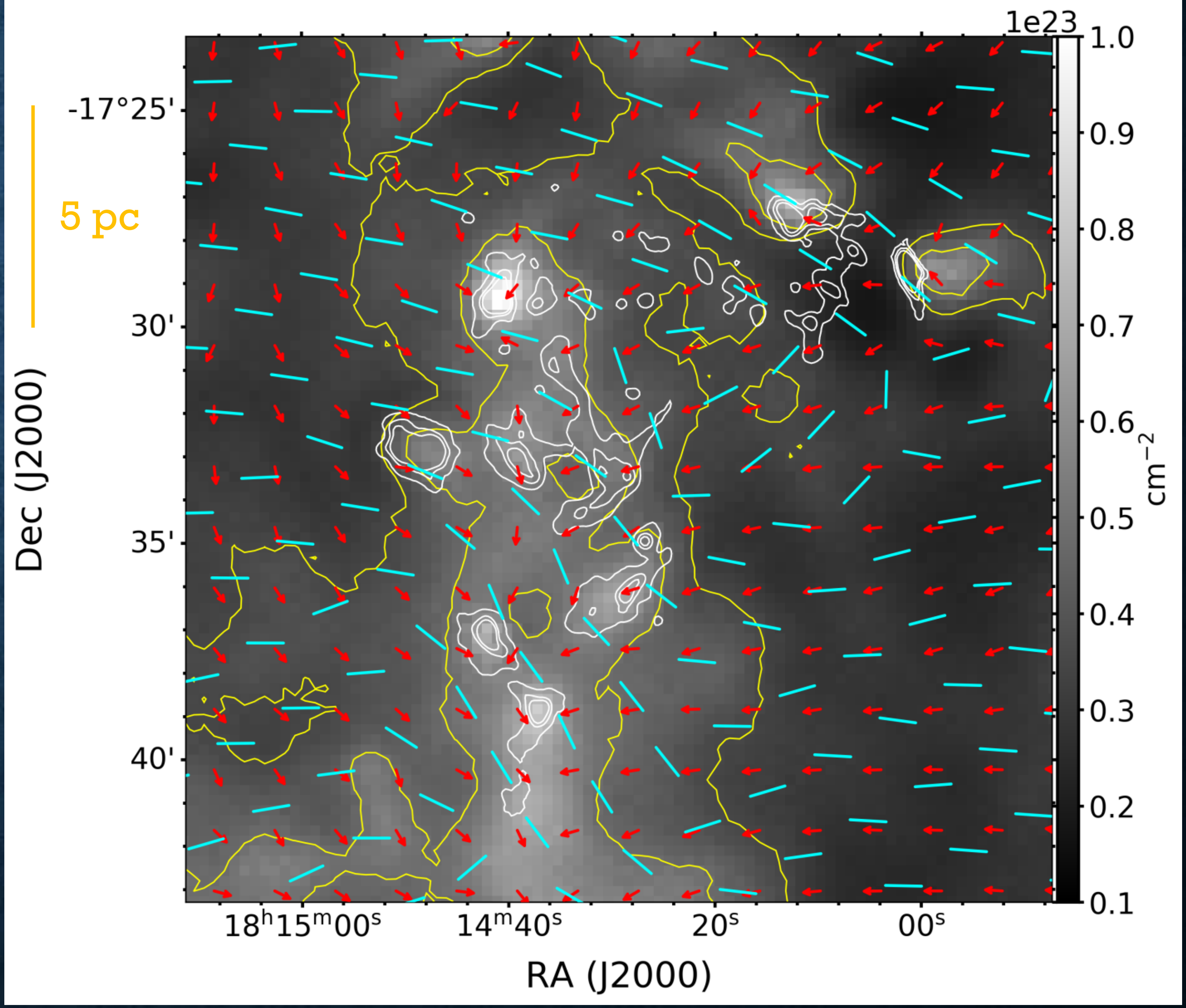




The Large-Scale Filament

- Herschel Column Density Contour:
  Showing a large-scale north-south filament
- JCMT Continuum Contour:
  Embedded in the center of the filament
- Gravity: Pointing toward/along the filament
- PLANCK B-Field: Winding around the filament

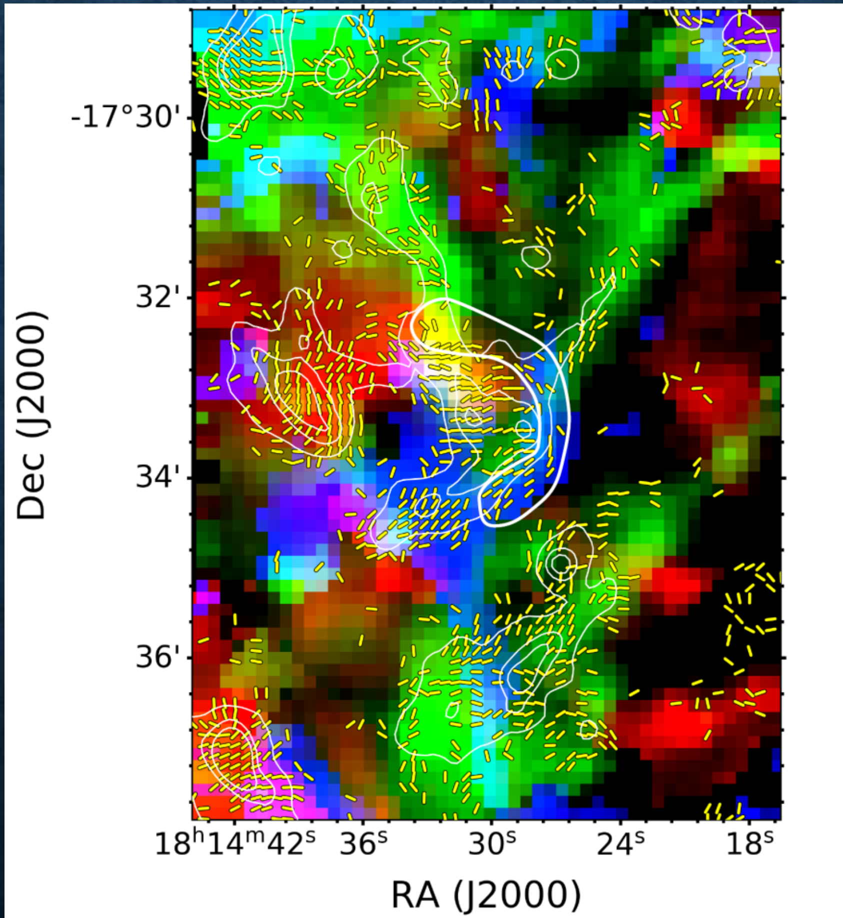




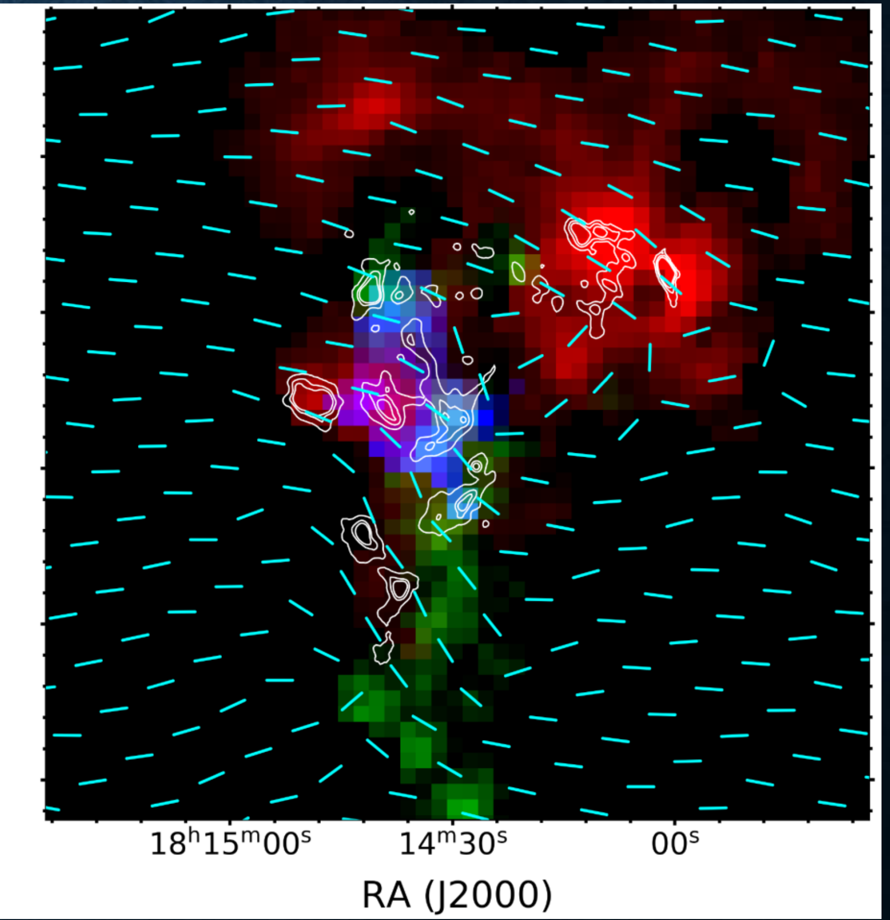
Nearby Giant Molecular Clouds associated with SDC13

- White Contour: JCMT Continuum
- Red (42-58 km/s):
  - Connecting to SDC13 from the north and east, winding along the PLANCK B-field
- Green(32-40 km/s):
  - The main body of SDC13, part of the north-south filament
- Blue: (5-20 km/s):
  - Connecting to SDC13 along the NW filament, overlapping with the U-shape B-field (thick line)

IRAM 30-m $C^{18}O$ (1-0) data (Williams et al. in prep)

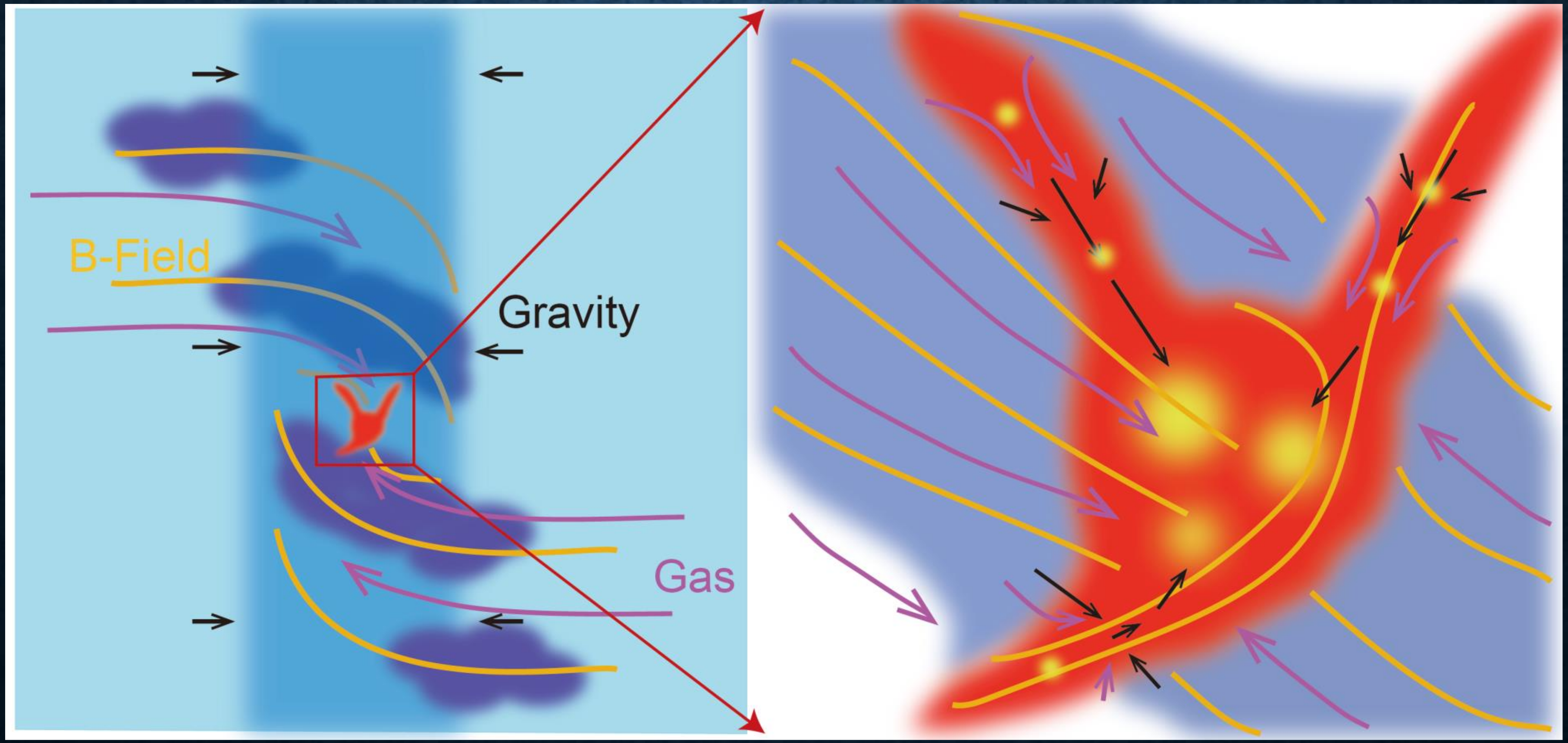


APEX ^{13}CO (2-1) data, Selected from the SEDIGISM survey GMC catalog (Schuller et al. 2021).



Possible Scenario

- 1. Large-scale gas flows, following B-fields, winding and converging into the large-scale filament
- 2. Colliding of the converging flows cause the initial Y-shape hub-filament system with bent B-field
- 3. After the shock energy dissipates, gravity take over the evolution of the hub-filament system



Caveats

- Low-density gas tracer data are still needed to reveal the structures among these GMCs (e.g., the bridge structure)
- Shock tracers to confirm the colliding event
- The above features might be difficult to detect, if the collision event occurs only in the early stage (dynamical age of ~5.2 Myr, Williams et al. 2018)

Summary

- Within SDC13:
  - POL-2 polarization data reveal a locally organized B-field with a pinched U-shape morphology
  - Globally, SDC13 is magnetically trans- to supercritical. The filaments within SDC13 are also supercritical
  - Filaments in SDC13 are likely collapsing, longitudinally and radially, driven by gravity.

- On large-scale
  - The large-scale B-field, traced by PLANCK, is parallel to the small-scale B-fields in the northeastern side of SDC13, but becomes perpendicular to small-scale B-fields in the southwestern side, where the U-shape feature is present.
  - The large-scale B-field appears to wind around a large-scale north-south filament, traced by Herschel.
  - Two GMCs are likely connecting to SDC13, along the B-field. One of the GMC show an U-shape arm, coincide with the U-shape B-field.
  - We propose a cloud-cloud collision scenario to explain the above features.