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.

Herschel Gould belt survey:

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

Aquila Rift, identified filaments with prestellar cores (blue triangles)
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
- \( \text{N}_2\text{H}^+ (1-0) \) 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 \( \mu \)m image
Circle colors: \( \text{N}_2\text{H}^+ (1-0) \) velocities
Circle sizes: \( \text{N}_2\text{H}^+ (1-0) \) velocity dispersion

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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

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

<table>
<thead>
<tr>
<th>Regions</th>
<th>$B_{pos}$ (DCF) ($\mu$G)</th>
<th>$\lambda$ (DCF)</th>
<th>$B_{pos}$ (ST) ($\mu$G)</th>
<th>$\lambda$ (ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub</td>
<td>94 ± 5</td>
<td>0.87 ± 0.05</td>
<td>75 ± 2</td>
<td>1.08 ± 0.03</td>
</tr>
<tr>
<td>Filament NE</td>
<td>31 ± 1</td>
<td>1.50 ± 0.05</td>
<td>34 ± 1</td>
<td>1.34 ± 0.03</td>
</tr>
<tr>
<td>Filament NW</td>
<td>34 ± 5</td>
<td>0.95 ± 0.14</td>
<td>25 ± 2</td>
<td>1.29 ± 0.10</td>
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<tr>
<td>Filament S</td>
<td>58 ± 4</td>
<td>0.66 ± 0.03</td>
<td>49 ± 1</td>
<td>0.79 ± 0.02</td>
</tr>
</tbody>
</table>

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

◇: Starless cores
☆: Protostellar cores
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.