Magnetic fields in the cores of Taurus/B213 from JCMT BISTRO survey (preliminary results)

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Collaborators
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and

JCMT BISTRO team
LDN1495/B213 in Taurus: distribution of dense gas and YSOs

→ L1495/B213 is one of the most prominent filaments in nearby clouds in Gould belt.

→ well-studied
→ Length ~ 10 pc
→ Mass > 700 $M_{\text{sun}}$
→ ~40 YSOs,
→ ~20 dense cores

(Hacar & Tafalla 2011, Hacar+ 2013)

→ Agents governing the connection between low density ISM, filaments, cores, and star formation in them?

Distribution of regions and their cores. C$^{18}$O (black contour: 0.5 K km/s) and N$_2$H$^+$ (red contour: N2H+). Solid & open stars: Class I/Flat & Class II/III (Rebull+ 2010). Distance ~130 pc (Dzib+ 2019)
B-fields at larger scales based on optical and NIR polarimetry

At ~ pc to ~several pc scales B-fields are organized; either perpendicular to the dense filaments or aligned parallel to the low density striations. SCUBA-POL2 FOV: 16’ diameter. Column density map is from Gould belt Survey (Palmeirim+ 2013; http://gouldbelt-herschel.cea.fr/archives)
Log of POL2 observations: 2 fields

<table>
<thead>
<tr>
<th>Date of observation</th>
<th>No. of sets</th>
<th>Sequence number</th>
<th>$\tau^a$</th>
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<tbody>
<tr>
<td>2018 Nov 23</td>
<td>4</td>
<td>17,20,25,28</td>
<td>0.05,0.05,0.04,0.04</td>
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<tr>
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<td>5</td>
<td>26,29,43,44,48</td>
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<td>1</td>
<td>54</td>
<td>0.07</td>
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<tr>
<td>2018 Nov 08</td>
<td>1</td>
<td>41</td>
<td>0.06</td>
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<tr>
<td>2018 Nov 06</td>
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<td>56,57</td>
<td>0.04,0.04</td>
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<td>2018 Feb 17</td>
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<td>2018 Jan 20</td>
<td>1</td>
<td>46</td>
<td>0.04</td>
</tr>
<tr>
<td>2018 Jan 19</td>
<td>1</td>
<td>15</td>
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<tr>
<td>2018 Jan 15</td>
<td>1</td>
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<td>2018 Jan 02</td>
<td>1</td>
<td>43</td>
<td>0.04</td>
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<tr>
<td>2017 Nov 23</td>
<td>1</td>
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<tbody>
<tr>
<td>2018 Dec 06</td>
<td>4</td>
<td>18,22,28,44</td>
<td>0.04,0.03,0.05,0.05</td>
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<tr>
<td>2019 Jan 08</td>
<td>1</td>
<td>11</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Each field with 20 sets with exposure time of 14 hr

Two fields with 28 hrs Mosaicking

Achieved sensitivity (at 12” gridsize)
rms intensity $\sim$0.7 mJy/beam
rms PI $\sim$0.7 mJy/beam
Fragmented chain of cores

SCUBA-POL2 Stokes I map

3 prestellar, 2 protostellar, and 1 Class III (Bracco+ 2017)

<table>
<thead>
<tr>
<th>Object</th>
<th>Evolutionary stage</th>
<th>RA (J2000)</th>
<th>Dec (J2000)</th>
<th>Abbreviation in text and figures</th>
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<tbody>
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<td>HGBS-J041937.7+271526$^{a,e}$</td>
<td>Prestellar</td>
<td>04$^h$19$^m$37.7$^s$</td>
<td>+27°15′20.0″</td>
<td>Miz-2</td>
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<tr>
<td>HGBS-J041923.9+271453$^{e}$</td>
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<td>04$^h$19$^m$23.9$^s$</td>
<td>+27°14′53.0″</td>
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<td>Miz-8b$^{a,c}$</td>
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<td>Class 0/I</td>
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<td>J04194148+2716070$^{d}$</td>
<td>T Tauri</td>
<td>04$^h$19$^m$41.5$^s$</td>
<td>+27°16′07.0″</td>
<td>T Tauri</td>
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</tbody>
</table>
Mosaic image, binsize=12"

(a) B-field map on I map
(b) PI map, yellow contours at PI/DP= 2.5, 3, 4

Within 8arcmin mosaic, sensitivity uniform

(c) I vs PI
   PI b/n ~1.4 and ~4 mJy/beam
   - weakly polarized intensity
   - mean DPI ~0.7 mJy/beam

Vectors with different SNR in P/DP
Blue: 2.5 to 3 & red > 3
Complex B-fields inside core scales of \(\sim 0.01\) to \(\sim 0.06\) pc

Background and contours: Stokes I
Criteria: \(I/DI > 10\), \(P/DP > 2.5\)

- \(P/DP\) Green 2.5 to 3; Red > 3
B-fields inside core scales of \(~0.01\) to \(~0.06\) pc

P/DP
Green 2.5 to 3
Red > 3
Distribution of B-fields in cores

B-fields vs filament long axis (135 deg) and large scale B-fields (32 deg)

K04166: mean B-field PA (40 deg) and outflow PA (30 deg) aligned

K04169: mean B-field PA (130 deg) and outflows PA (64 deg) misaligned

B-fields at cores scales follow bimodal distribution with respect to large scale B-fields
Examine the correlation among
B-fields vs Velocity gradients (VG)
B-fields and Intensity gradients (IG)

Velocity centroid maps of N2H+ (1-0), 93.2 GHz, IRAM 30-m, HPBW = 26.5” (Punanova+ 2018)

Vlsr depends linearly on the 2D surface coordinates:

\[ v_{\text{LSR}} = v_0 + a \Delta \alpha + b \Delta \delta \]

**Magnitude of gradient:**
\[ \mathcal{G} \equiv |\nabla v_{\text{LSR}}| = (a^2 + b^2)^{1/2}/D \]

**Direction of gradient:**
\[ \theta_\varphi = \tan^{-1} \frac{a}{b} \]

Goodman et al. (1993)
K04169 – protostellar core

Red: VG and IG
Blue: B-fields

Arrow → direction matter flow or direction of gravitational potential
VG vs B
Miz8b - starless core

IG vs B
Miz2 – prestellar core

VG vs B

IG vs B

Miz2 – prestellar core
Summary

- One of the most sensitive observations (28 hrs) reaching the sensitivity $\sim 0.7$ mJy/beam (14")
- Weakly polarized intensity 1.4 to 4 mJy/beam with P/DP $> 2.5$
- Traced B-fields in the pre/protostellar cores of B213
- Coherent and ordered B-fields at larger scales $> 1$ pc
- Complex B-fields at core scale of 0.01 to 0.06 pc – bimodal with respect to B-fields of larger scales
- B-fields are governed by gravitational infall in protostellar cores? B-fields are shaped by material flows in starless cores?

Detailed analyses for K04166
- Magnetically regulated star formation?
- B-fields coherent with those of larger scales
- Outflows aligned with B-fields

Eswaraiah, Furuya, Li, Keping, +BISTRO team (in preparation)