Magnetic fields in Cepheus OB3 cloud complex

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Relative orientation between filament and magnetic fields: strong B-fields

Turbulence dominates over gravity
=> turbulence extends cloud along the B-fields

Stone+ (1998)

Gravity dominates turbulence
cloud contracts parallel to the B-fields

Nakamura & Li (2008; 2011)
B-fields vs filamentary cloud structure – Ophiuchus-Pipe region (see Li+ 2017)
Cepheus OB3 cloud complex
107 < l < 114 deg;
-2 < b < 5 deg
Distance: ~400 - ~600 pc

13CO map (Yonekura+ 1997)
– Vlsr ~ -10 km/s
– foreground component
  – at ~ -5 km/s
  – distance 300 pc

Various parameters of the clumps

<table>
<thead>
<tr>
<th>Clump</th>
<th>Size (pc)</th>
<th>(T ) (K)</th>
<th>(\tau_{\text{13CO}})</th>
<th>(N(\text{C}^{18}\text{O})) (10^{18} \text{cm}^{-2})</th>
<th>(N(\text{H}_2)) (10^{22} \text{cm}^{-2})</th>
<th>(n(\text{H}_2)) (10^3 \text{cm}^{-3})</th>
<th>M(LTE) (M_\odot)</th>
<th>M(vir) (M_\odot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1211</td>
<td>1.9</td>
<td>17</td>
<td>0.100</td>
<td>2.6</td>
<td>1.5</td>
<td>2.6</td>
<td>610</td>
<td>490</td>
</tr>
<tr>
<td>Cep A</td>
<td>1.2</td>
<td>22</td>
<td>0.055</td>
<td>4.6</td>
<td>2.7</td>
<td>7.6</td>
<td>410</td>
<td>1200</td>
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<tr>
<td>Cep F</td>
<td>1.4</td>
<td>12</td>
<td>0.124</td>
<td>1.4</td>
<td>0.8</td>
<td>1.9</td>
<td>180</td>
<td>240</td>
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<tr>
<td>Cep B</td>
<td>0.7</td>
<td>33</td>
<td>0.025</td>
<td>2.1</td>
<td>1.2</td>
<td>6.0</td>
<td>62</td>
<td>150</td>
</tr>
<tr>
<td>Cep E</td>
<td>1.5</td>
<td>17</td>
<td>0.064</td>
<td>1.7</td>
<td>1.0</td>
<td>2.1</td>
<td>250</td>
<td>390</td>
</tr>
<tr>
<td>Cep C(a)</td>
<td>1.2</td>
<td>17</td>
<td>0.037</td>
<td>1.4</td>
<td>0.8</td>
<td>2.2</td>
<td>120</td>
<td>610</td>
</tr>
<tr>
<td>Cep C(b)</td>
<td>1.9</td>
<td>17</td>
<td>0.099</td>
<td>3.6</td>
<td>2.1</td>
<td>3.8</td>
<td>820</td>
<td>970</td>
</tr>
<tr>
<td>Cep C(c)</td>
<td>1.0</td>
<td>17</td>
<td>0.089</td>
<td>3.0</td>
<td>1.8</td>
<td>6.1</td>
<td>180</td>
<td>430</td>
</tr>
</tbody>
</table>

Black contours: 13CO map (Yonekura+ 1997)
Blue contours: Av=2, 4 mag
Background image: extinction map (Dobashi+ 2005)
Clumps based on C18O data (Yu+ 1996)
Data

- **AIMPOL, R-band, 8’ (FOV)**
- **IMPOL, R-band, 2’**
- **TRIPOL, r’-band, 4’**

- archival polarization data (Heiles 2000)
- Optical photometry (BVRI-bands)
- 2MASS (JHKs-bands)
Vectors: exhibit bimodal distribution

R-band polarization vectors of ~300 stars on DSS R-band image

Contours: Herschel 500 µm dust emission
Separation of foreground and background stars

Green: Field stars (Heiles 2000) – 10 deg radius

GP: 79 deg toward LDN 1225

Two populations are present
NIR color-color diagram.

Blue: foreground stars with PA < 75 deg

Red: background stars with PA > 75 deg

Color-color diagrams:

\[ R_{\text{cloud}} = \frac{m_{\text{cloud}}}{m_{\text{normal}}} R_{\text{normal}} \]

R_{\text{normal}} = R_v = 3.1

<table>
<thead>
<tr>
<th>Color–color combination</th>
<th>( m_{\text{normal}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B – V)/(V – I)</td>
<td>–1.10</td>
</tr>
<tr>
<td>(B – V)/(V – J)</td>
<td>–1.96</td>
</tr>
<tr>
<td>(B – V)/(V – H)</td>
<td>–2.42</td>
</tr>
<tr>
<td>(B – V)/(V – K)</td>
<td>–2.60</td>
</tr>
</tbody>
</table>
Red: background with PA $> 75$ deg
Yellow: foreground with PA $< 75$ deg
Bimodal distribution of P and PA towards Cep A and Cep B

Contours:
Herschel 500um dust emission

Data from AIMPOL, R-band

Data from IMPOL, R-band
High resolution (6°) extinction map (Dobashi+ 2005). Polarization angles were converted from equatorial coordinates to Galactic coordinates using the relation given by Corradi et al. (1998).
14 stars from Heiles (2000) catalog:
- Gaussian Mean P: 2.55+/-.138 %
- PA: 116+/-.12 deg

202 stars observed in R-band:
- Gaussian Mean P: 2.97+/-.115 %
- PA: 112+/-.10 deg

Coherence: B-field 40 pc x 10 pc to 3 pc x 3 pc scale
But not with the large scale Galactic magnetic field

0.8 deg x 0.8 deg
B-field structure using mean PA from AIMPOL, IMPOL and TRIPOL. Background image: Herschel 500 um map.
B-field structure using mean PA from AIMPOL, IMPOL and TRIPOL. Background image: Herschel 500 um map
Magnetic fields, gravity and turbulence - result bimodal distribution

B-fields - guide gravitational contraction - result - B-field perpendicular to the filament

B-fields - channel sub-Alfvenic turbulence - result - B-field aligned with the cloud main axis.

Bimodal distribution - not seen - simulations with supersonic turbulence - random cloud/field orientations

Li+ (2013)
B-fields at clump and core scales around Cep A

(a) R-band polarization => B-fields perpendicular to the clump.

(b) and (c) Sub-mm 850 um polarization (JCMT/SCUBAPOL) => spiral B-field features, cloud collapsing (Curran & Chrysostomou 2007; Matthews+ 2009)
Summary & Conclusions

★ R-band polarimetry towards Cepheus OB3 cloud complex

★ Foreground and background stars exhibit bimodal distribution in both P & PA.

★ B-fields in Cepheus OB3 cloud aligned with the cloud structure (40 pc x 10 pc scale), but not with Galactic B-fields, while foreground B-fields follow Galactic B-fields.

★ B-fields vs turbulence (sub-alfvenic) => aligned B-fields with cloud axis

★ B-fields vs gravity => perpendicular B-fields wrt the cloud main axis

★ Further observations NIR and sub-mm wavelengths, along with molecular line observations are essential.