JCMT/POL-2 observations of Magnetic Field in massive filaments

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Collaborators and papers

- Collaborators:
- Kee-Tae Kim; Archana Soam; Pak Shing Li; Mika Juvela; Neal J. Evans II; James Di Francesco; Sheng-Yuan Liu; Jinghua Yuan; Ken’ichi Tatematsu; Qizhou Zhang et al. and the TOP-SCOPE team

- Papers:
- (1) Liu,Tie; Li, Pak Shing; Juvela, Mika et al., 2018, ApJ, 859, 151
- (2) Juvela, Mika; Guillet, Vincent; Liu, Tie; et al., 2018, A&A in press, arXiv:1809.00864
- (3) Liu, Tie; Kim, Kee-Tae; Liu, Sheng-Yuan; et al., 2018, submitted to ApJL
- (4) Soam, Archana; Liu,Tie; Juvela, Mika; 2018, to be submitted soon

Outline

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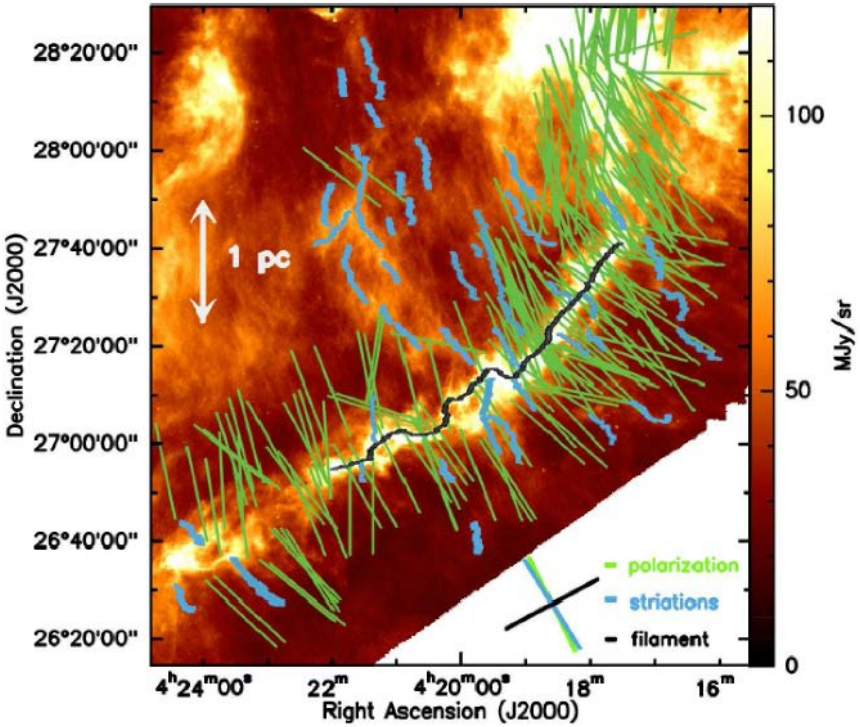
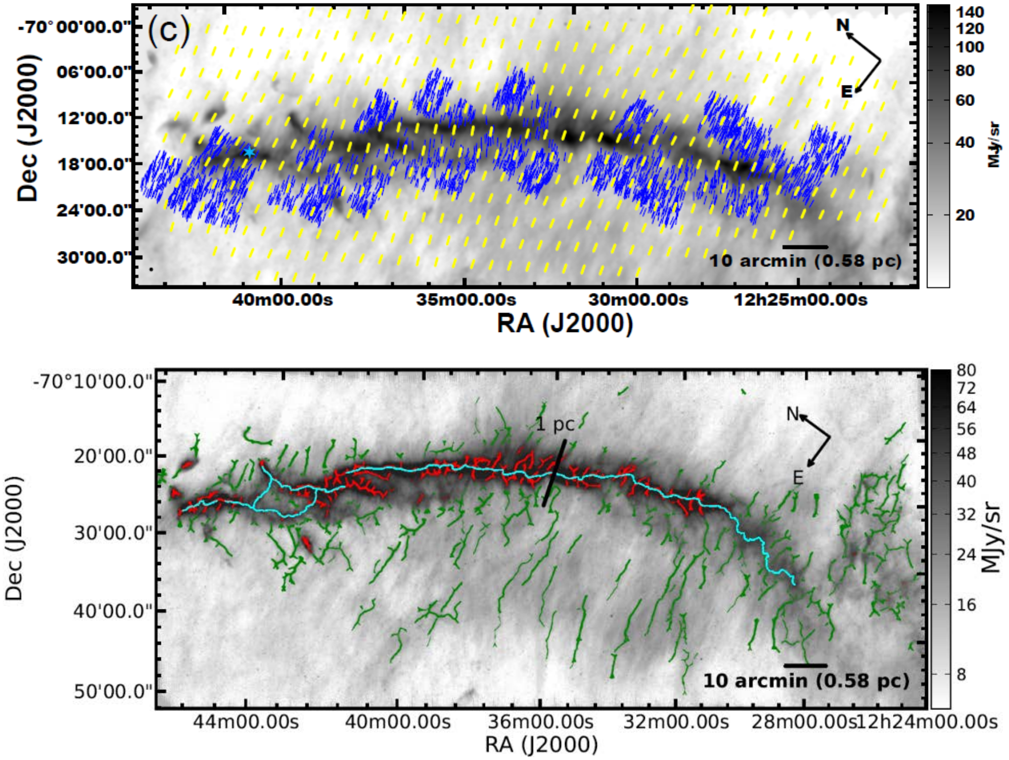
1. Introduction



Magnetic field in Taurus (*Heyer et al.*, 2008; *Chapman et al.*, 2011)

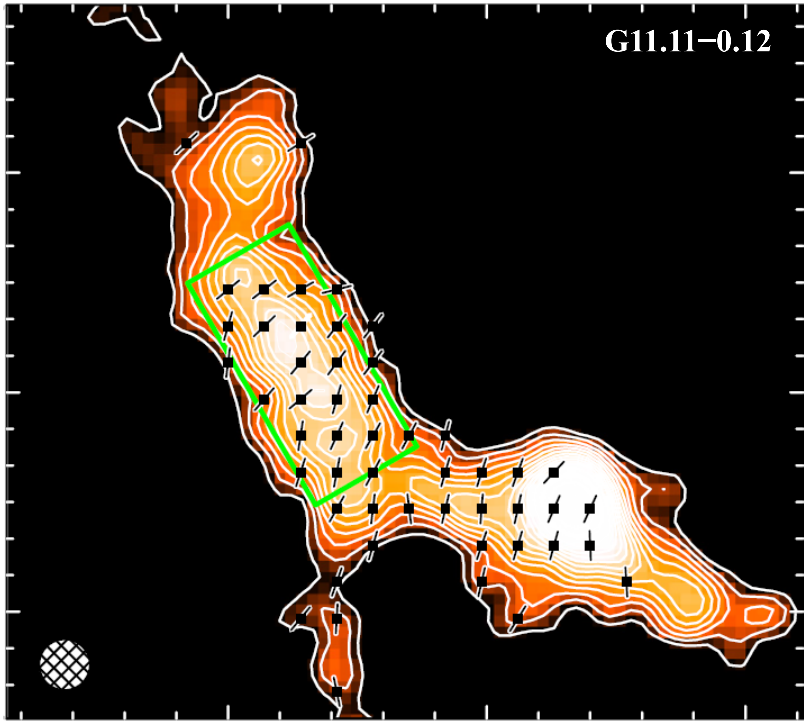


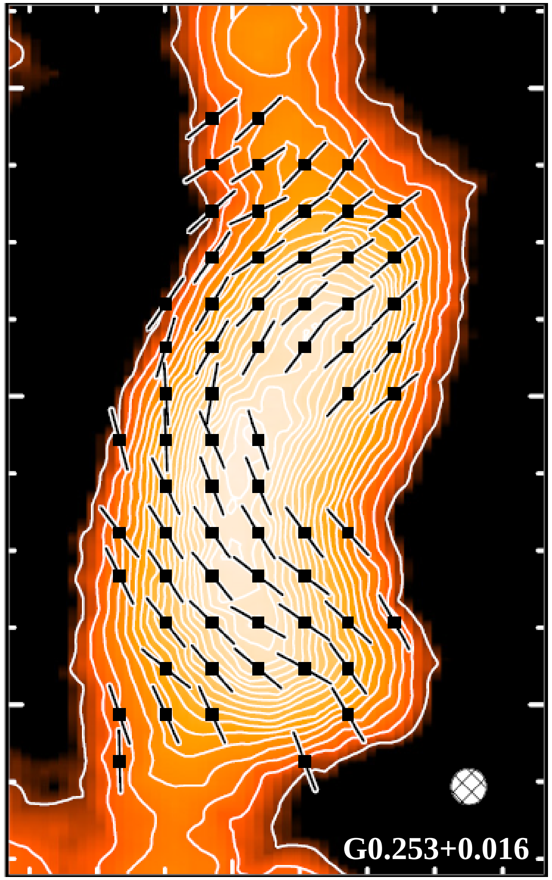
Magnetic field and striations in Musca (*Cox et al. 2016*)

The Herschel results emphasize the role of interstellar filaments in the star formation process (e.g., *Andre et al. 2013*). Polarization observations of nearby filamentary clouds suggested a scenario in which local interstellar material in this cloud has condensed into a gravitationally-unstable filament (with “supercritical” mass per unit length) that is accreting background matter along field lines through the striations (*Cox et al. 2016; see also Planck papers*).

How about distant and more massive filamentary clouds, where high-mass star formation is taking place and gravity may play a more important role?

Magnetic field in high-mass IRDCs





IRDCs G11.11−0.12 and G0.253+0.016 are strongly magnetized and that the strong magnetic field is as important as turbulence and gravity for HMSF (Pillai et al. 2015).

However, high-resolution dust polarization observations of IRDCs are rare. BISTRO survey @ JCMT and other polarization observations (e.g., BLASTPol, see Fissel et al.) are restricted to nearby clouds (d<1 kpc).

JCMT/POL-2 observations of massive filaments

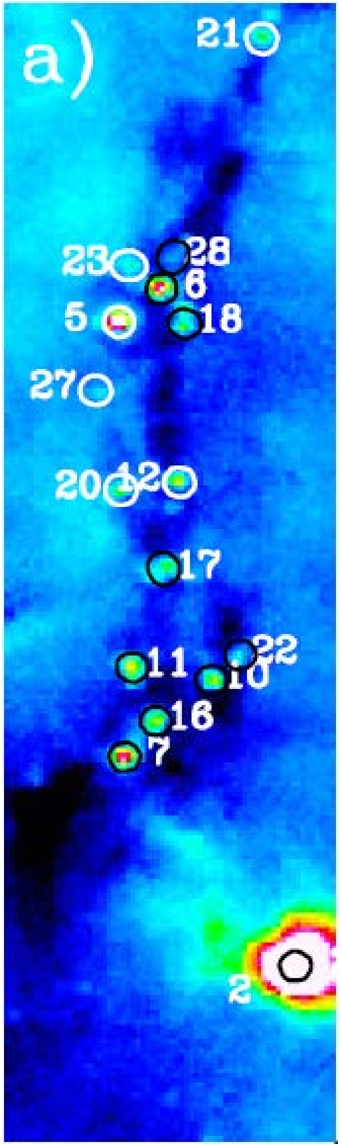
- (1) Motivation:

- What is the role of magnetic field in the formation and evolution of massive filaments?
- How important the magnetic field is in the formation of dense cores in filaments relative to the turbulence and gravity?

- (2) Targeted filaments in an evolutionary sequence:

- G16: A quiescent massive filament without star formation (observations ongoing)
- G35: A massive filament contains low-luminosity massive protostars (Liu et al., 2018; Juvela et al. 2018)
- G34: A massive filament contains hot molecular cores (Soam, Liu et al. 2018, to be submitted)
- G9.62: A massive filament close to expanding HII regions (Liu et al., 2018, submitted)

IRDC G035.39-00.33 (G35) ---A filament at very early stage to form high-mass stars



PACS 70 micron (*Nguy˜ˆen Lu’o’ng et al. 2011*)

- Distance: 2.9 kpc (Simon et al. 2006)
- Total mass of cloud: ~16,700 $M_{\odot}$ (Kainulainen & Tan 2013)
- High CO depletion factors (f_D~5–10; Jiménez-Serra et al. 2014) and a high deuterium fractionation of N2H+ (mean D_{N2H} =0.04 ± 0.01; Barnes et al. 2016), suggesting it is less evolved
- Substructures and resolved narrow fibers (Henshaw et al. 2013, 2014, 2017; Jiménez-Serra et al. 2014)
- Shock excited widespread narrow-linewidth SiO emission, indicating cloud-cloud collision (Jiménez-Serra et al. 2010)
- very low luminosity “Class 0”-like IR-quiet protostars (Nguyen Luong et al. 2011)

2. Observations and results

- Polarized 850 μm continuum data were obtained with the SCUBA-2/POL-2 instrument at the 15-m JCMT. The SCUBA-2/POL-2 observations of G035.39 (project code: M17BP050; PI: Tie Liu) were conducted from 2017 June to 2017 November. beam~14 arcsec; rms~1.5 mJy/beam

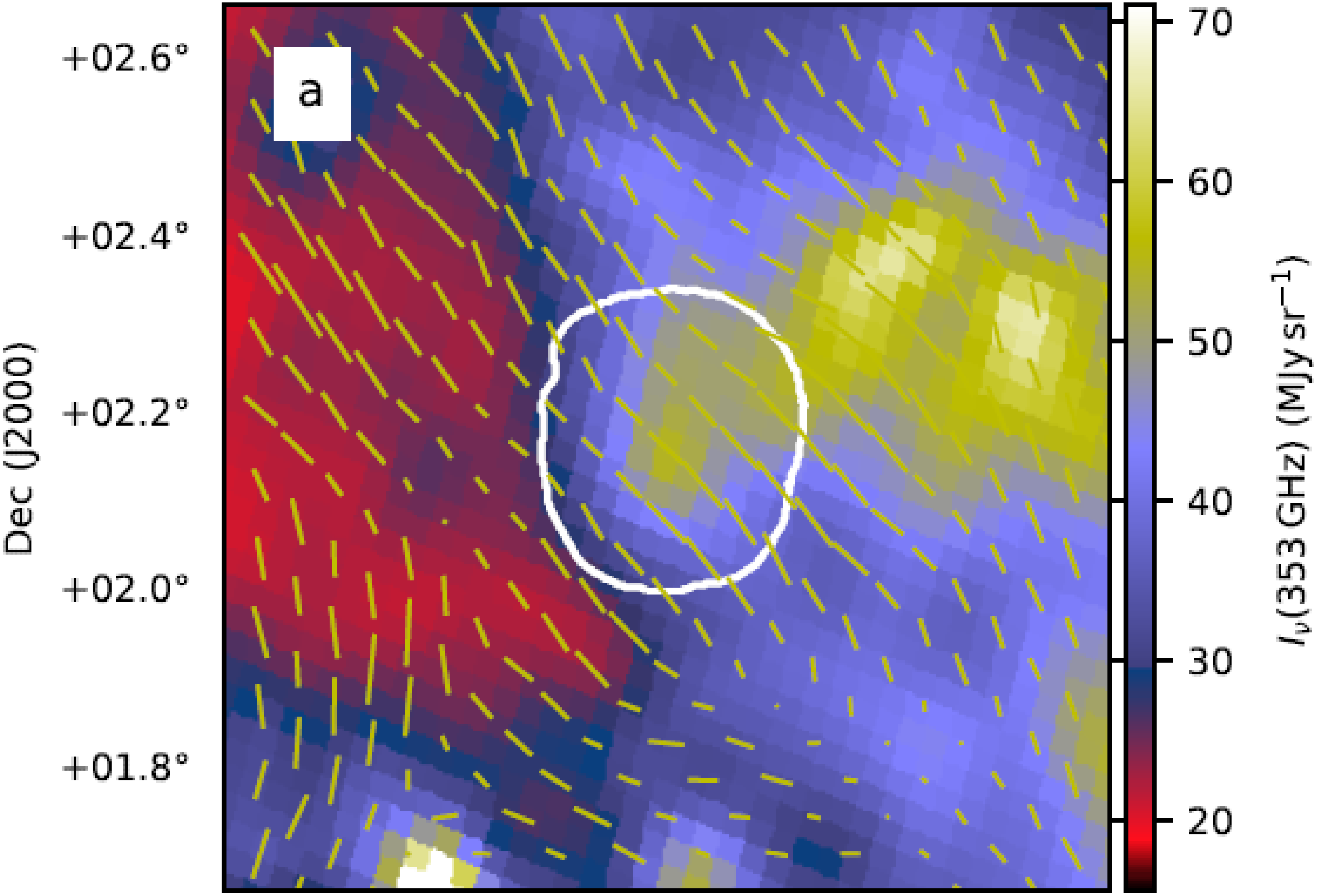
- The $C^{18}O$ (1–0) and ^{13}CO (1–0) mapping data are obtained at the 13.7-m TRAO telescope from the legacy survey program “TRAO Observations of PGCCs (TOP)” (Liu et al. 2018). The observations were conducted on 2017 March 17.

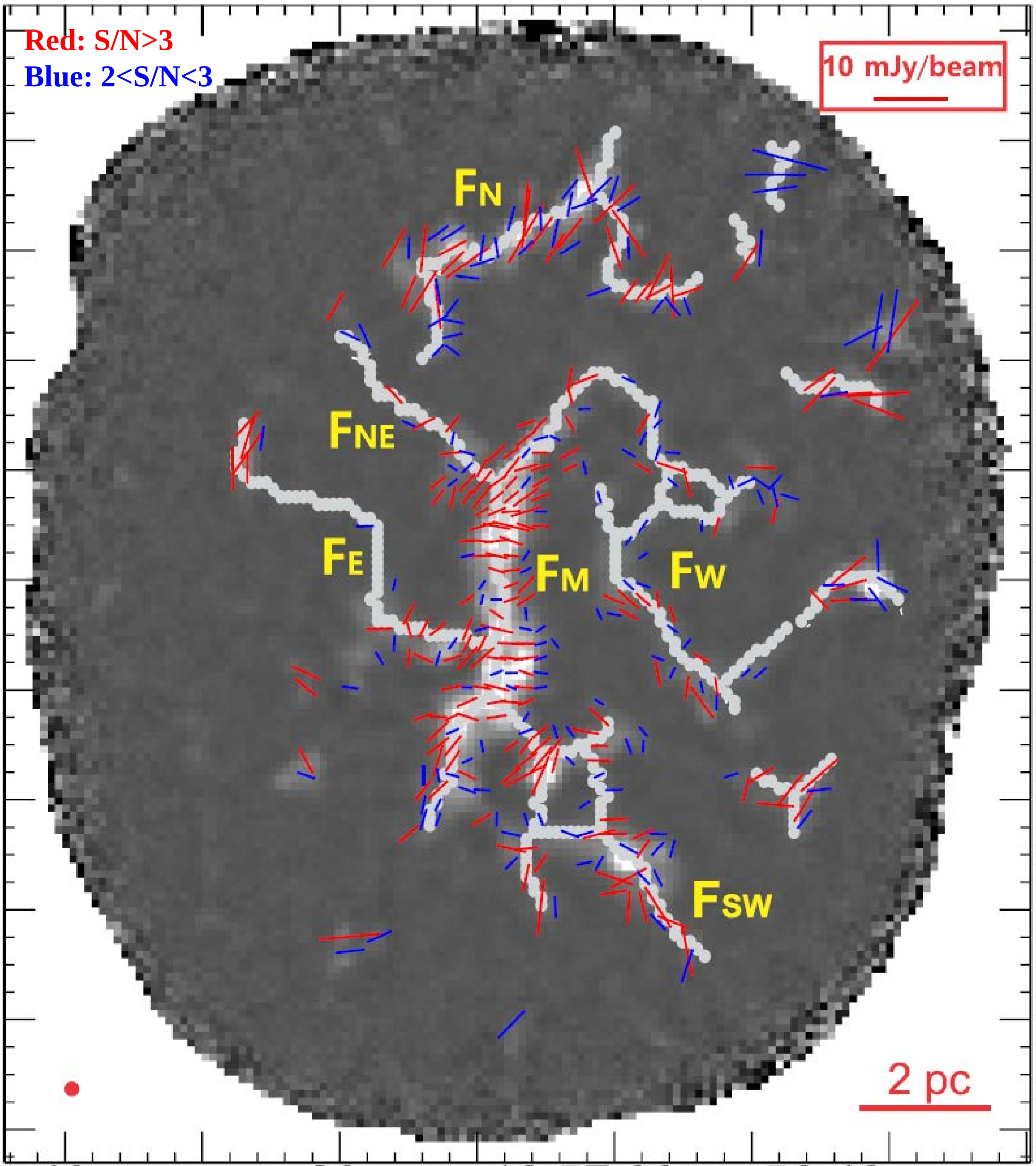
  map size: 30’*30’; beam~47’; rms~0.15 K in TA* @ 0.33 km/s resolution

- HCO+ (1–0), $H^{13}CO+$ (1–0), and H_2CO ($2_{1,2}$–$1_{1,1}$) were obtained toward a massive starless core with KVN 21-m telescope to check infall signature.

  Beam~23”-32”; rms~0.03-0.05 K @ 0.1 km/s

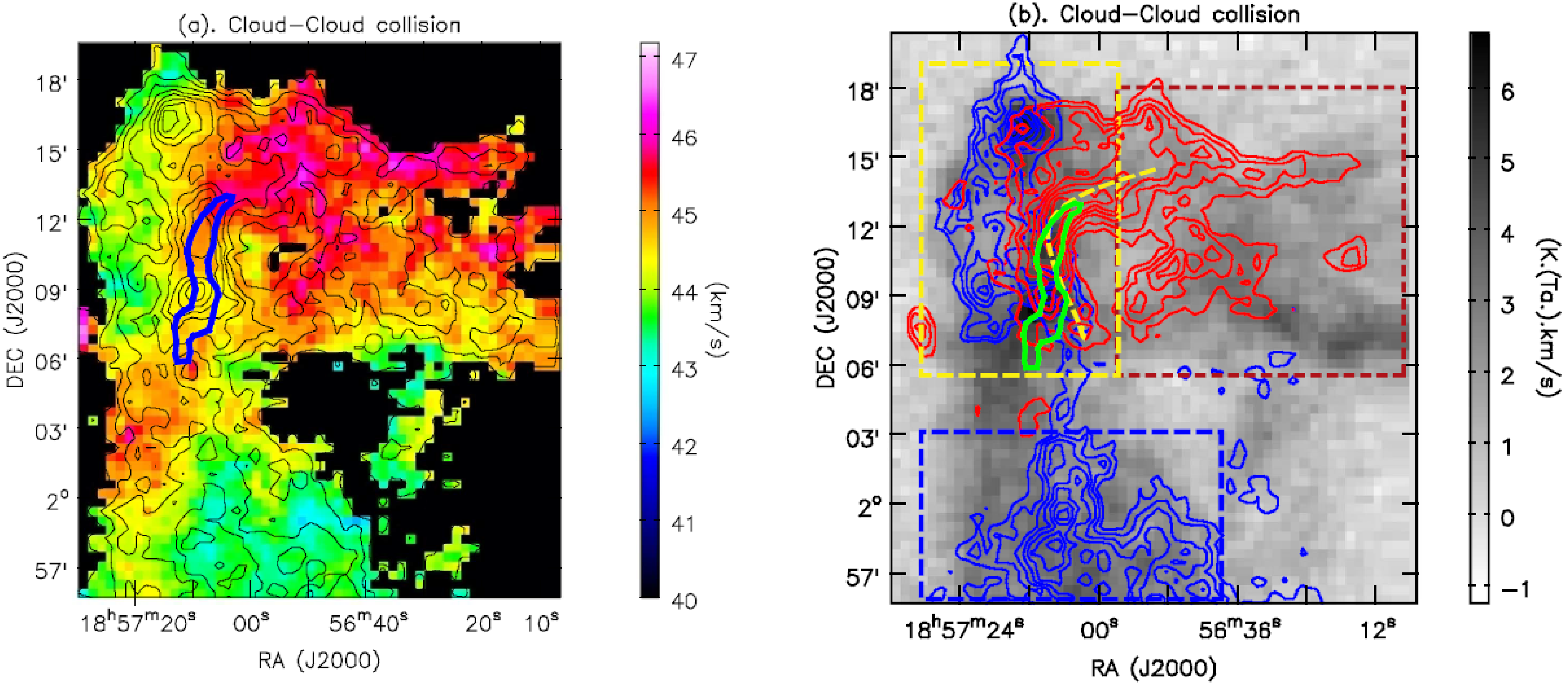
Planck polarization map at 353 GHz (Juvela et al. 2018)





POL-2 observations reveal a network of filaments and an ordered magnetic field

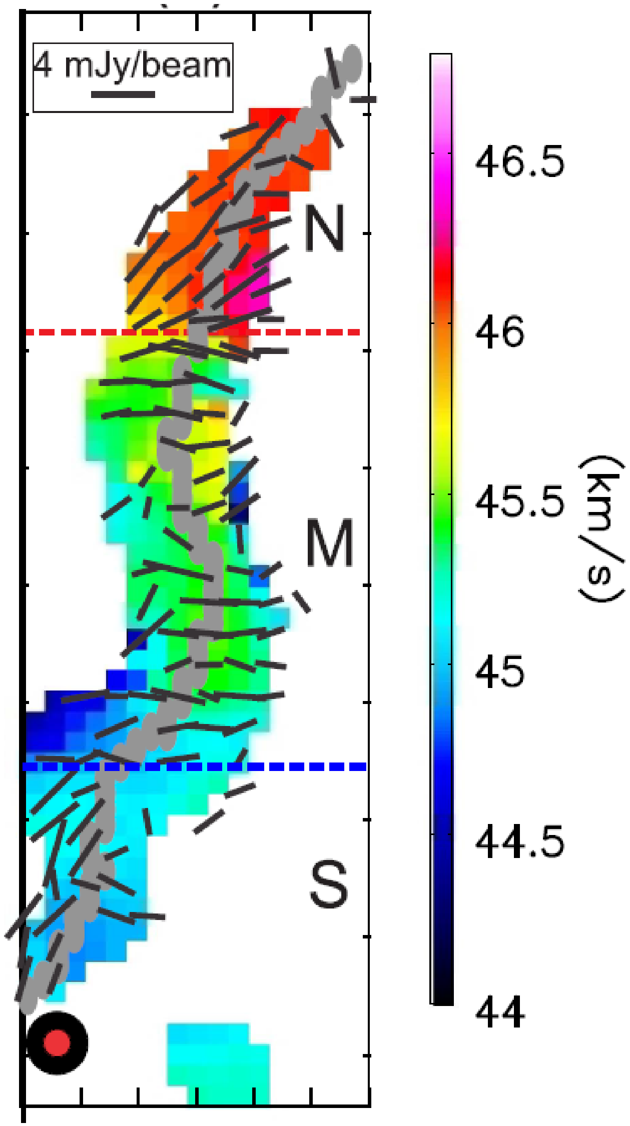
^{13}CO (1-0) emission reveals large-scale cloud-cloud collision



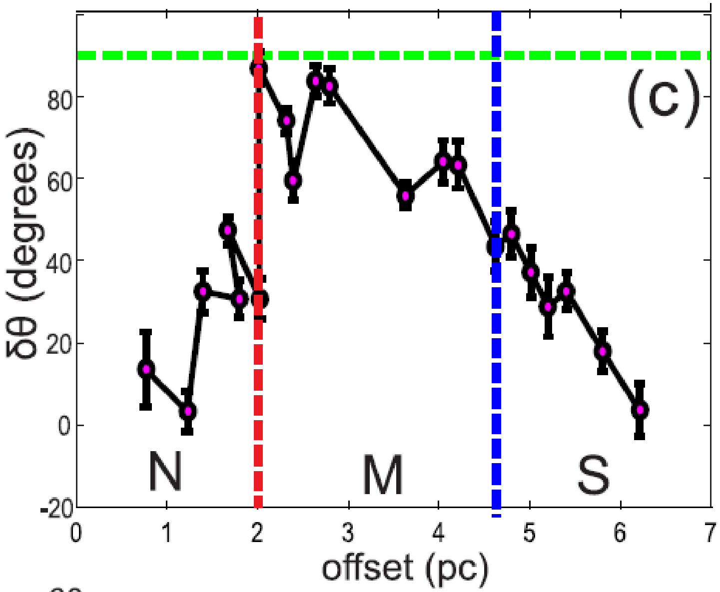
Previous findings of velocity gradients (Henshaw et al. 2014; Jiménez-Serra et al. 2014; Sokolov et al. 2017) and multiple velocity components (Henshaw et al. 2013) in the dense filament can be explained by the mixed gas distribution from the two larger-scale colliding clouds.

The cloud–cloud collision enhances the density in the interface, where the massive filament F_M has formed. The dynamical effect of the cloud–cloud collision may perturb F_M and trigger its fragmentation.

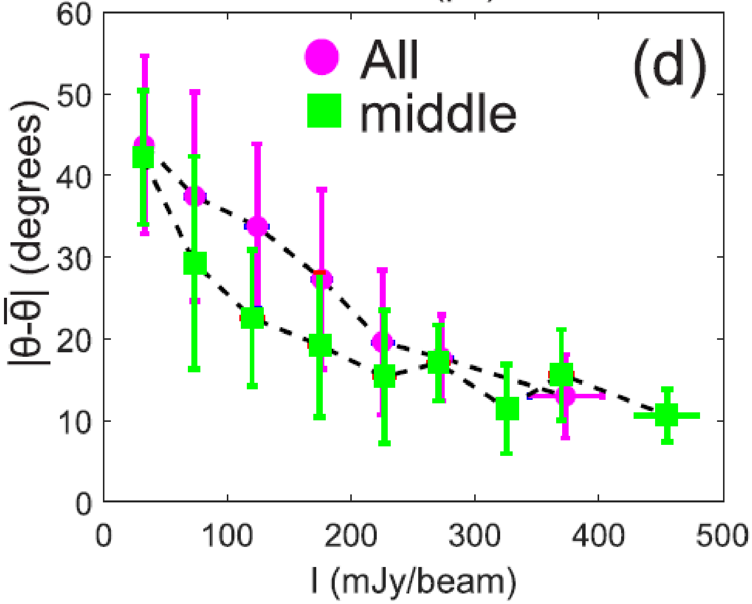
Magnetic field of the densest filament



B field vs. Velocity of $NH_3(1,1)$



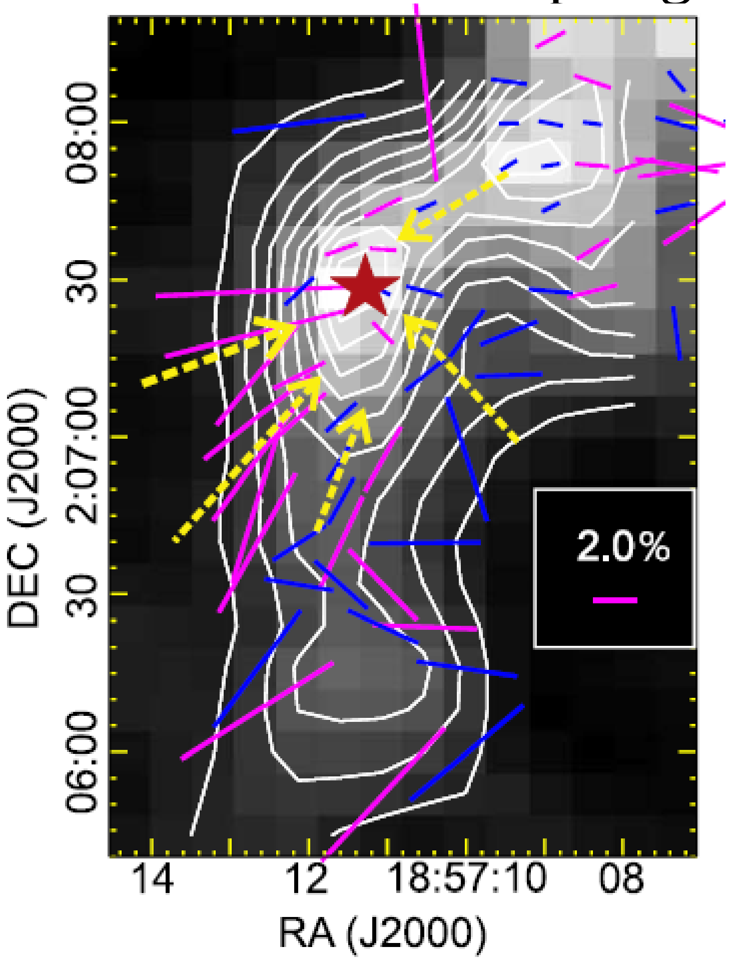
Relative orientations: B-field vs. skeleton



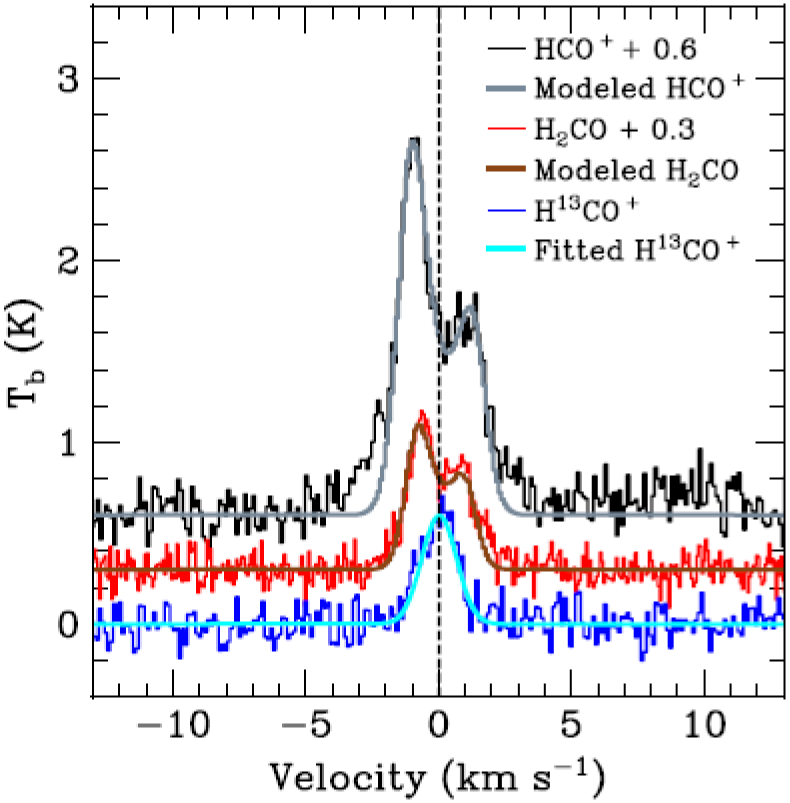
Relative orientations : B-field vs. mean angle in the middle part (86°)

Magnetic field perpendicular to the filament in dense regions and parallel to the filament in less dense regions.
Magnetic field is not strong enough to stabilize the filament and the dense clumps inside the filament.

A collapsing high-mass starless clump



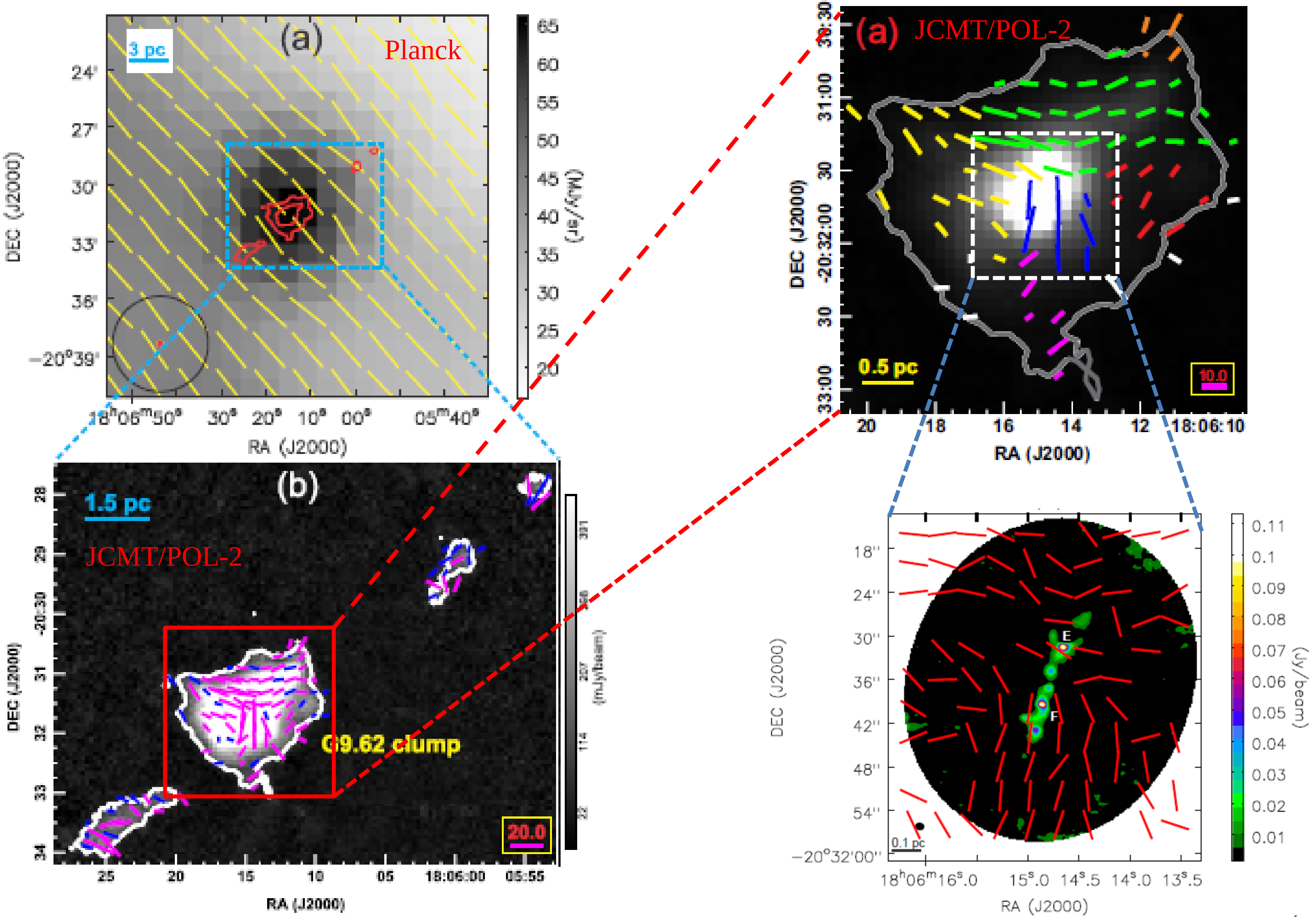
Pinched magnetic field hinting for accretion flows?



Collapsing signature in lines

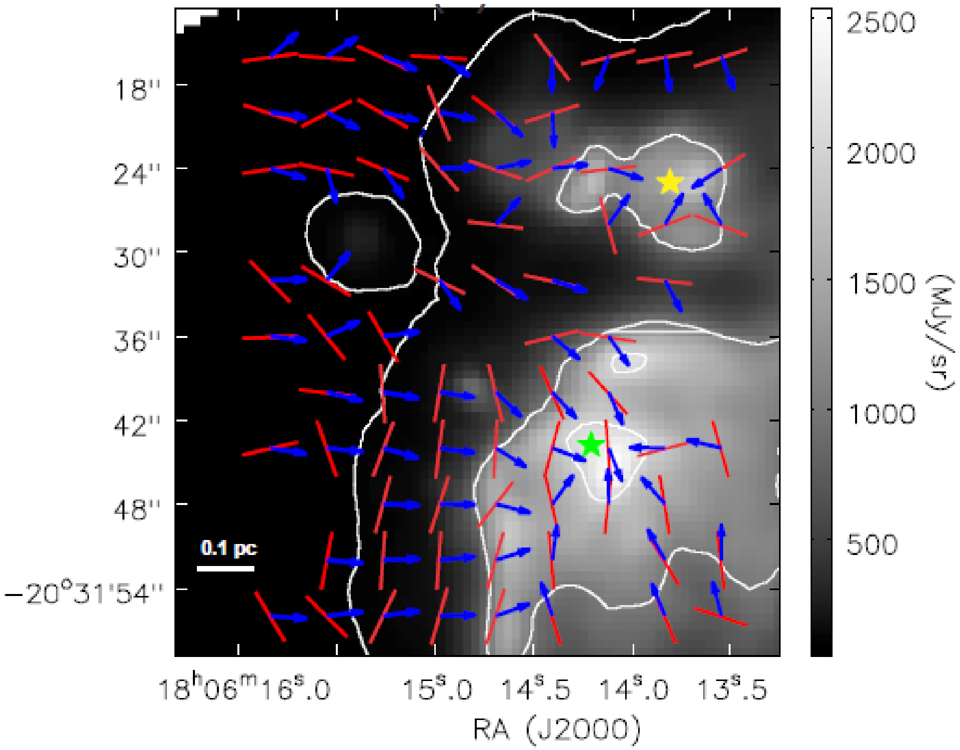
We firstly report a collapsing high-mass starless clump with pinched magnetic field: R~0.3 pc, M~ 200 $M_{\odot}$, V_{in}~0.3 km/s; Mass infall rate: $4*10^{-4}$ $M_{\odot}$/yr

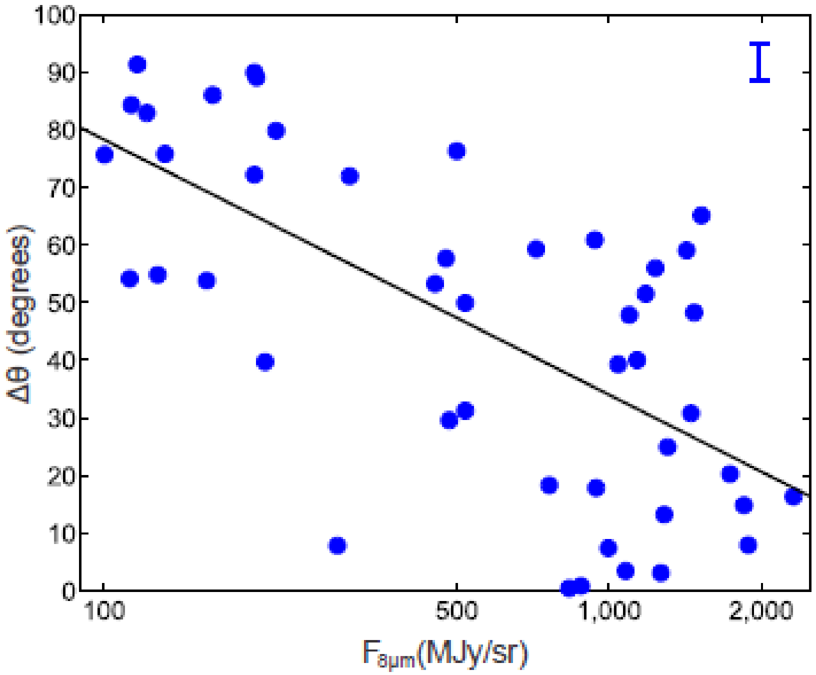
Structure formation regulated by magnetic field in G9.62 (Liu et al., 2018, submitted)



JCMT/POL-2 on ALMA 1.3 mm continuum (Liu et al. 2017)

Compressed magnetic field due to expanding HII regions?





Red: PoL-2 B-field segments
Blue: IRAC 8 micron intensity gradient
Color image: IRAC 8 micron PAH emission (PDRs)

Relative orientations between B-field and
8 micron intensity gradients (Δθ) vs. 8 micron intensity

Summary

- (1) JCMT/POL-2 is very powerful to reveal overall magnetic field in distant massive filaments
- (2) G35 contains a network of filaments; dense cores and high-mass protostars are formed in the densest filament.
- (3) Magnetic field tends to be parallel to the densest filament at its two ends but becomes perpendicular in the middle part. In low density regions, magnetic field is more likely pinched. Magnetic field is not strong enough to support filament or clumps against gravitational collapse.
- (4) B-field directions do not change much from large-scale to small-scale in massive filaments and usually perpendicular to the major axis of filaments (G35, G34, G9.62), indicating that B-field is dynamically important on cloud fragmentation.
- (5) Expanding HII regions is able to reshape magnetic field by compression (i.e., G9.62)