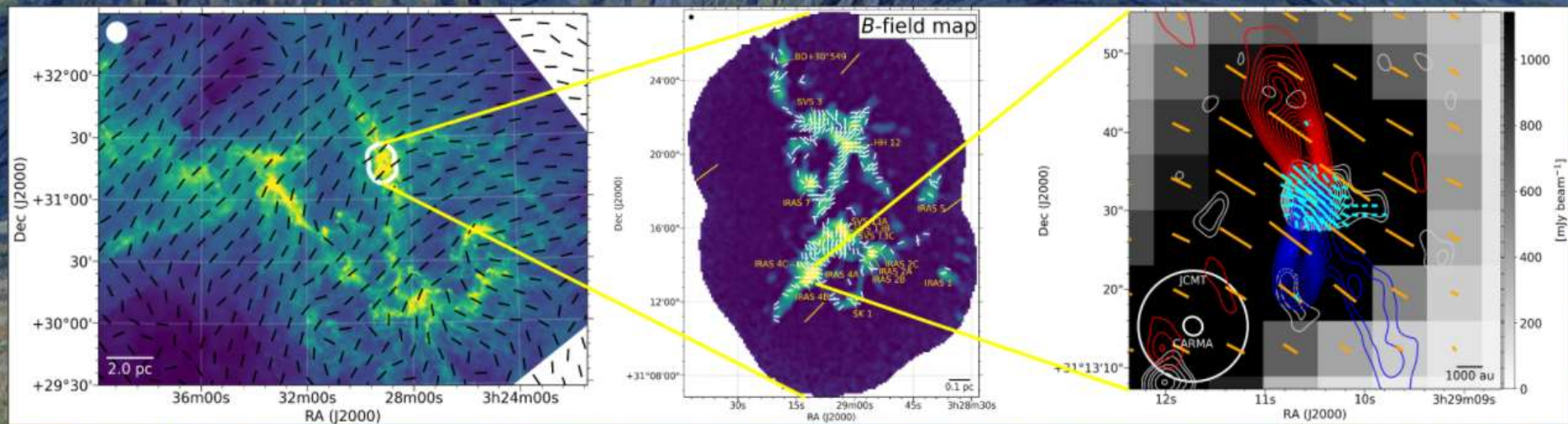


Multiscale magnetic field structure of NGC 1333 revealed by the JCMT BISTRO survey

Planck
10pc~1pc

JCMT
1pc~0.01pc

Interferometer
0.01pc~



Yasuo Doi and the BISTRO team

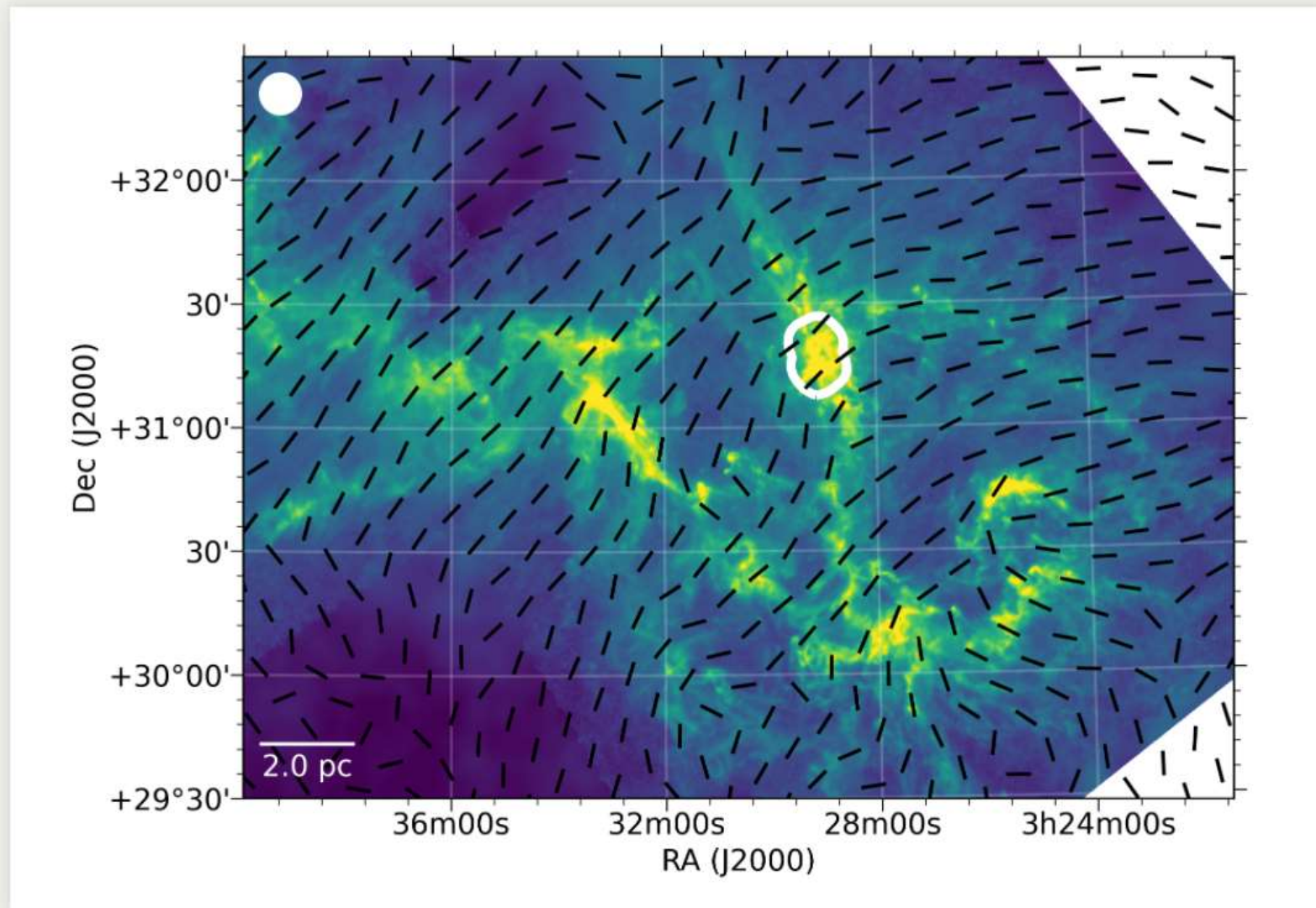
Contents:

Multiscale Magnetic Field Structure

- < 1 pc scale magnetic field tightly associated to molecular cloud filaments
- Distribution is perpendicular to the filaments
- Pinched magnetic field structure inside filaments
- The magnetic field should be bent at the time of the filament formation, and then keep its structure continuous down to the < 0.01 pc scale.
- $\ll 0.01$ pc ($\ll 1000$ au) scale magnetic field is affected by YSO formation

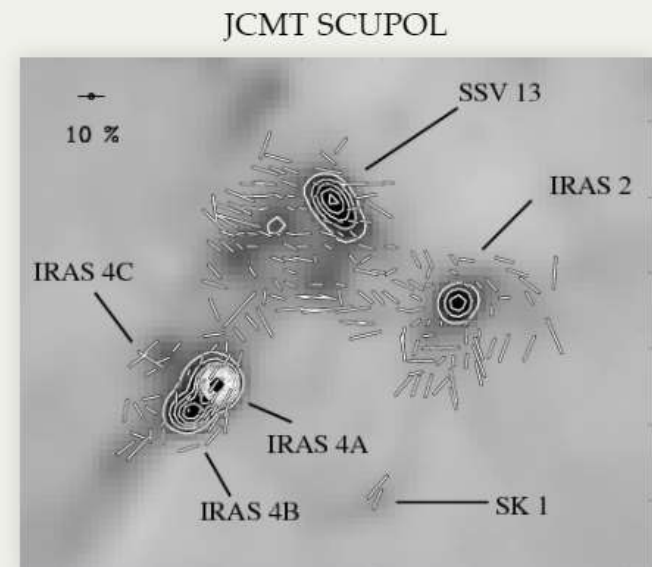
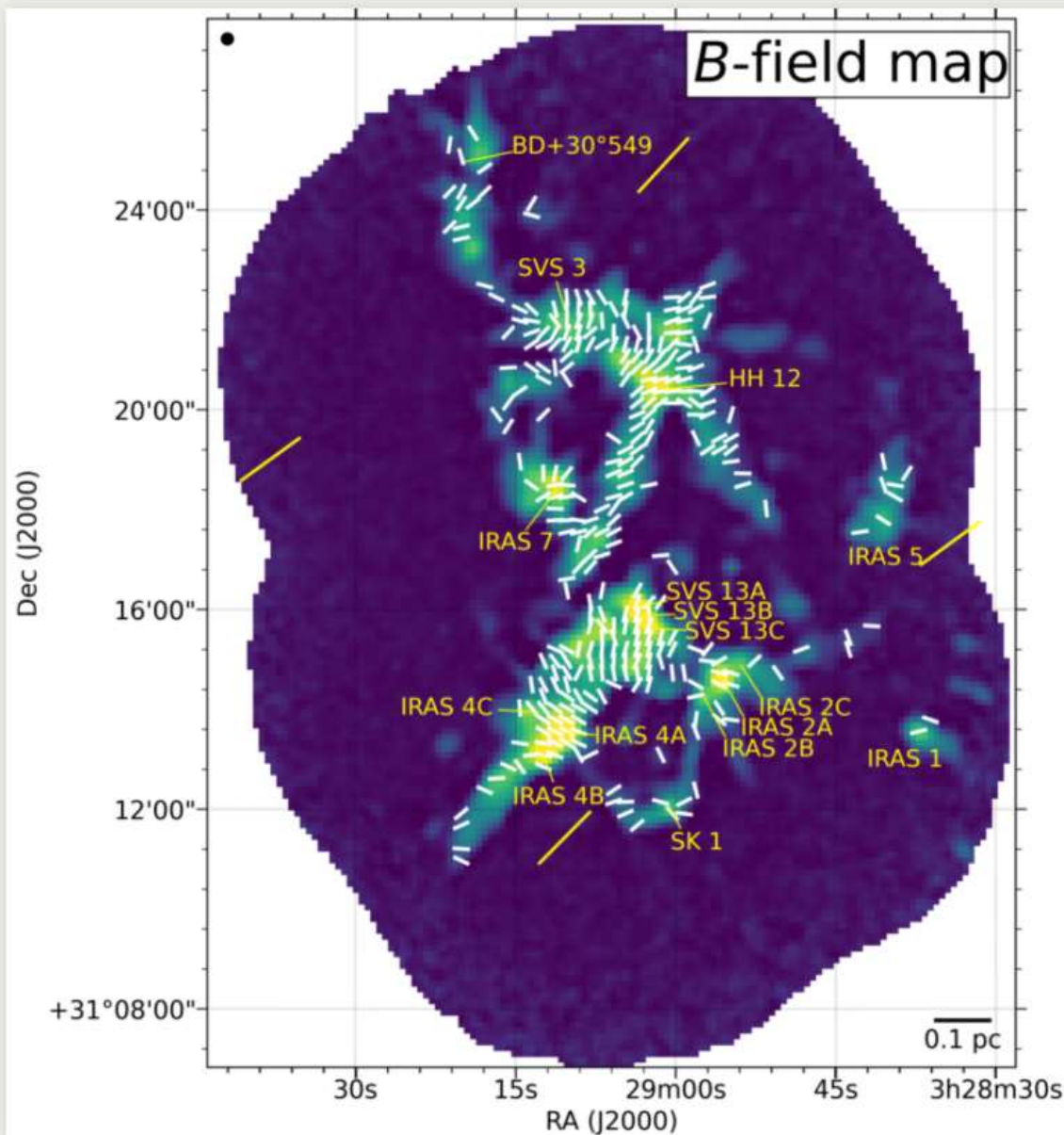
Large-scale magnetic field over Perseus

Smooth B -field observed by Planck (resolution ~ 1 pc)

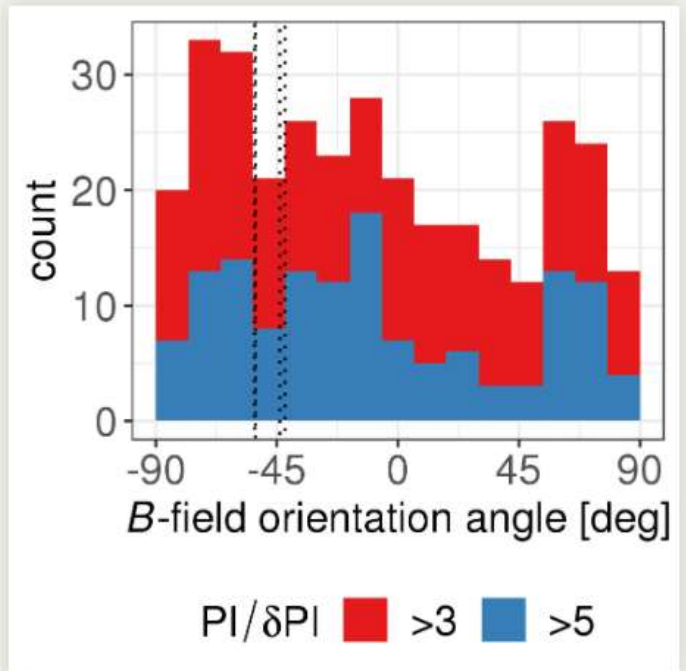
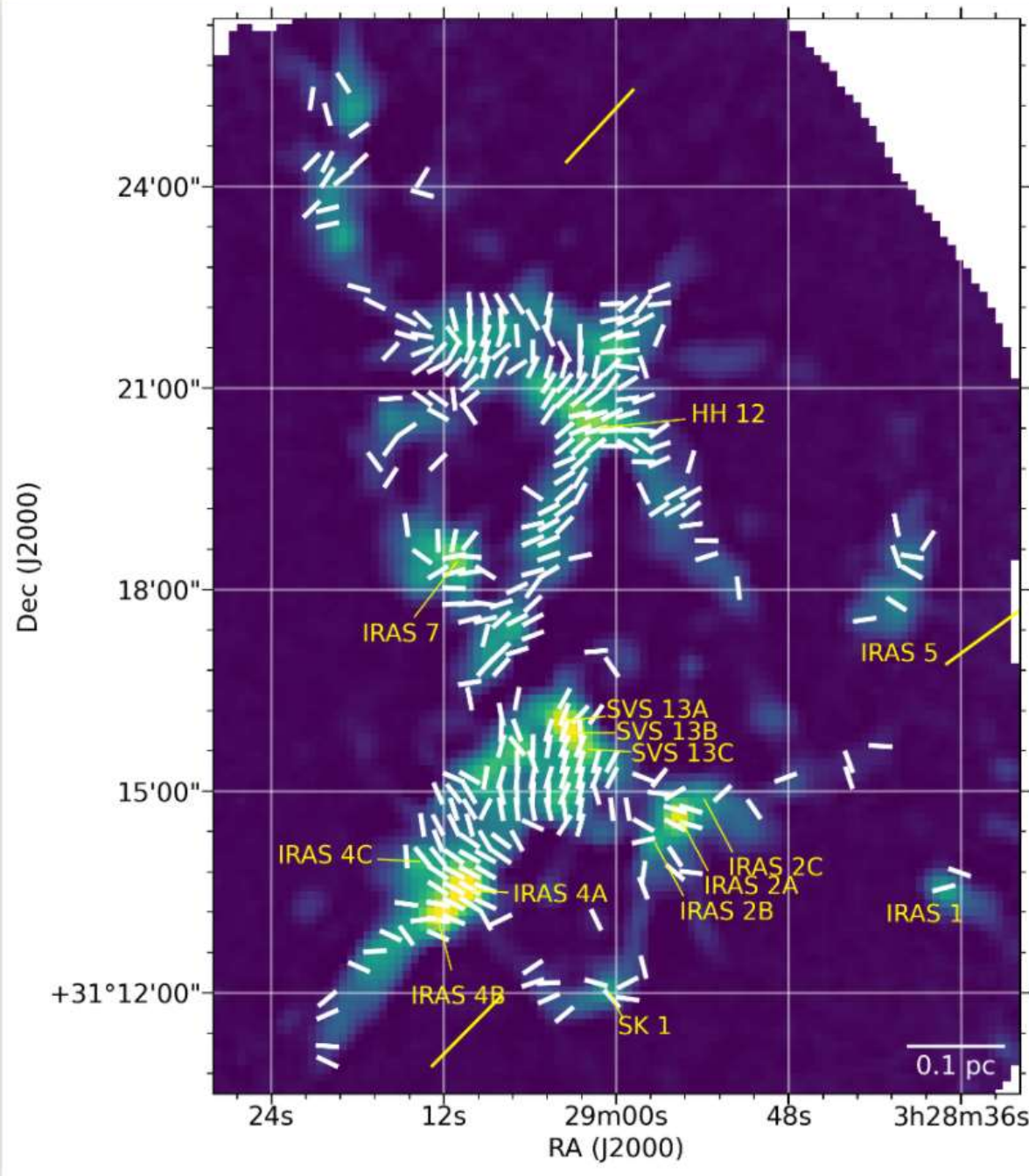


B-field in NGC 1333 obs. by BISTRO

- Resolution
 ~ 0.02 pc
- Massive filaments
($\geq 50M_{\odot}/\text{pc}$)
- *B*-field for the
whole region/
in filaments



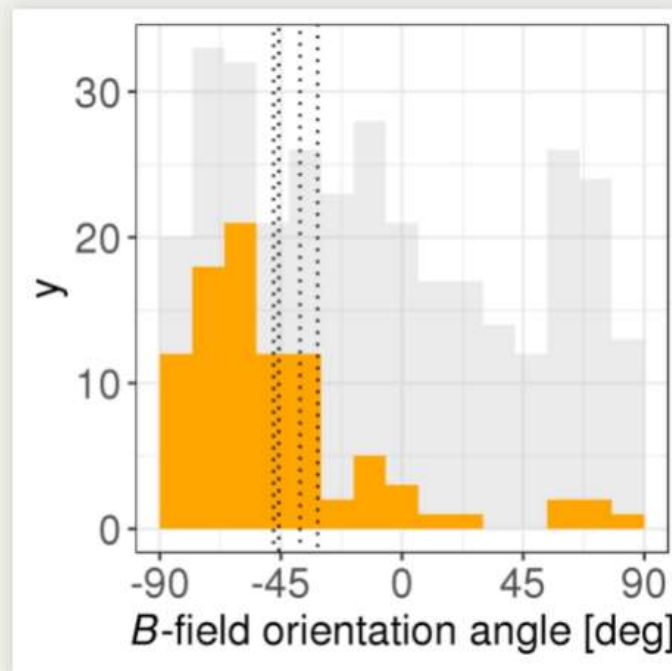
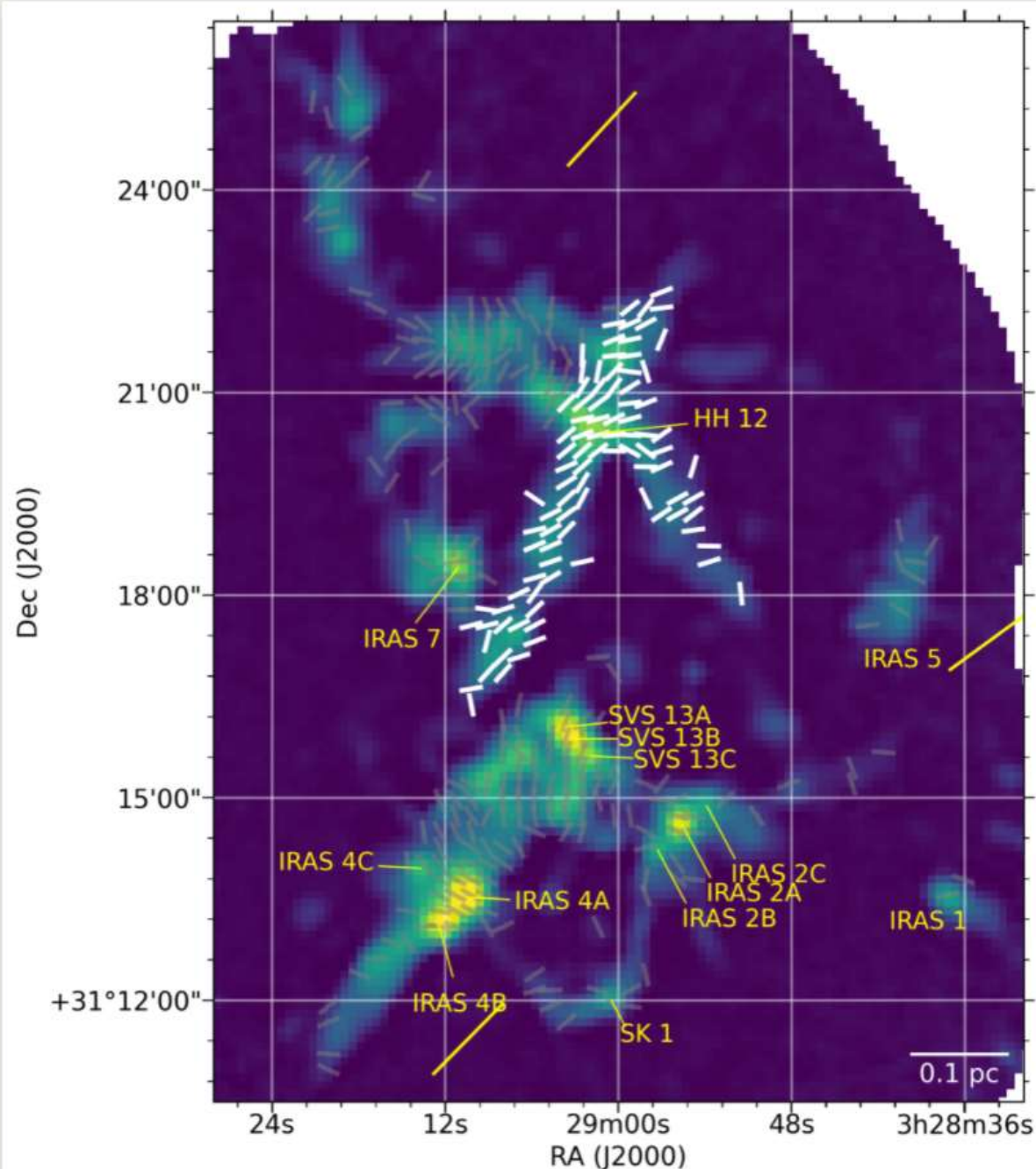
BISTRO B pos. angle



- Planck $-41^\circ \pm 8^\circ$
- JCMT $-46^\circ \pm 58^\circ$

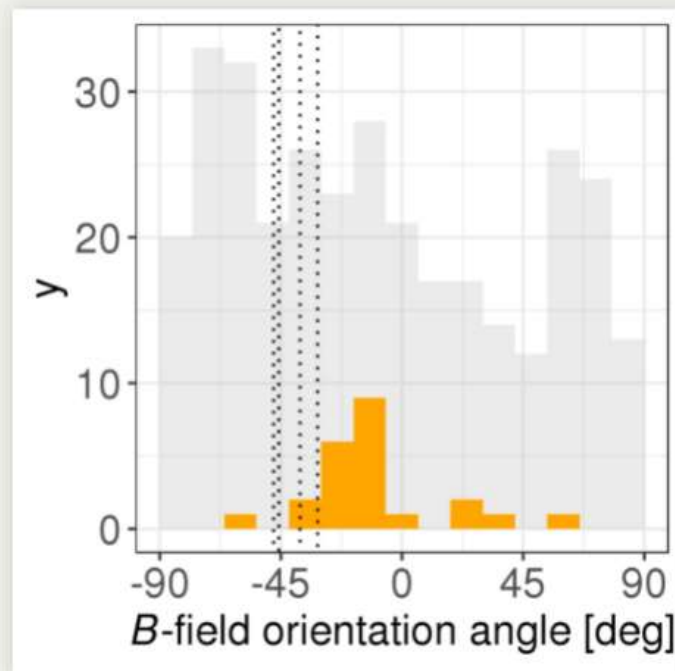
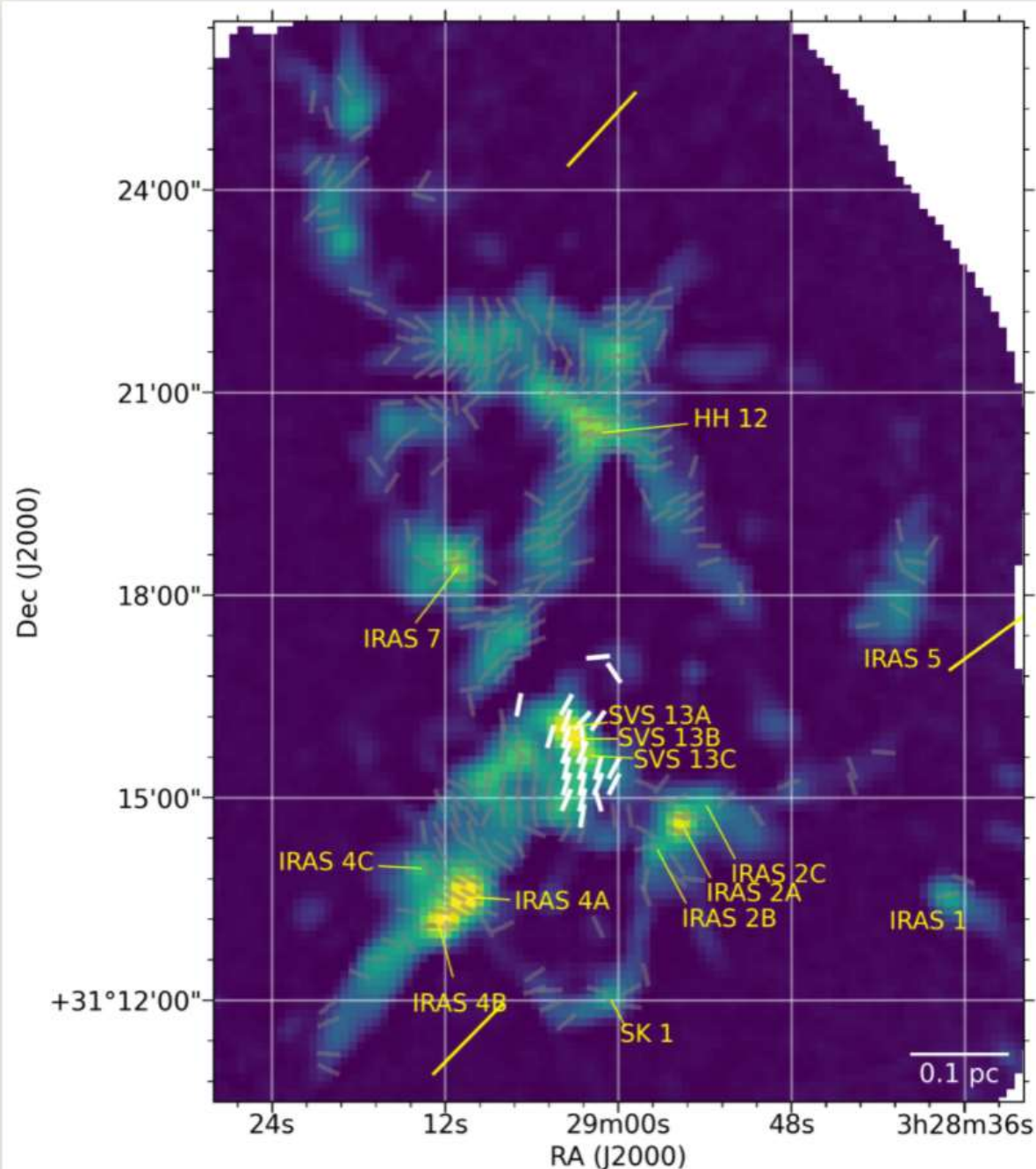
1: < 1 pc scale:
 B -field is random!!

BISTRO B pos. angle



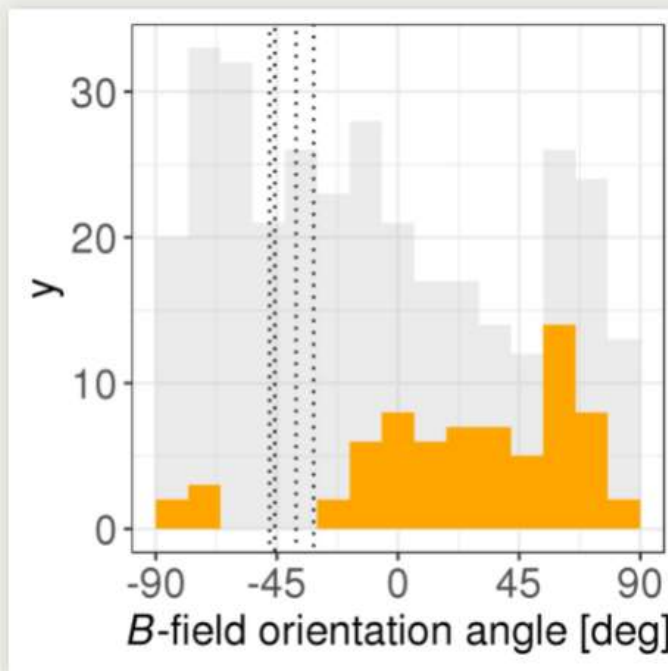
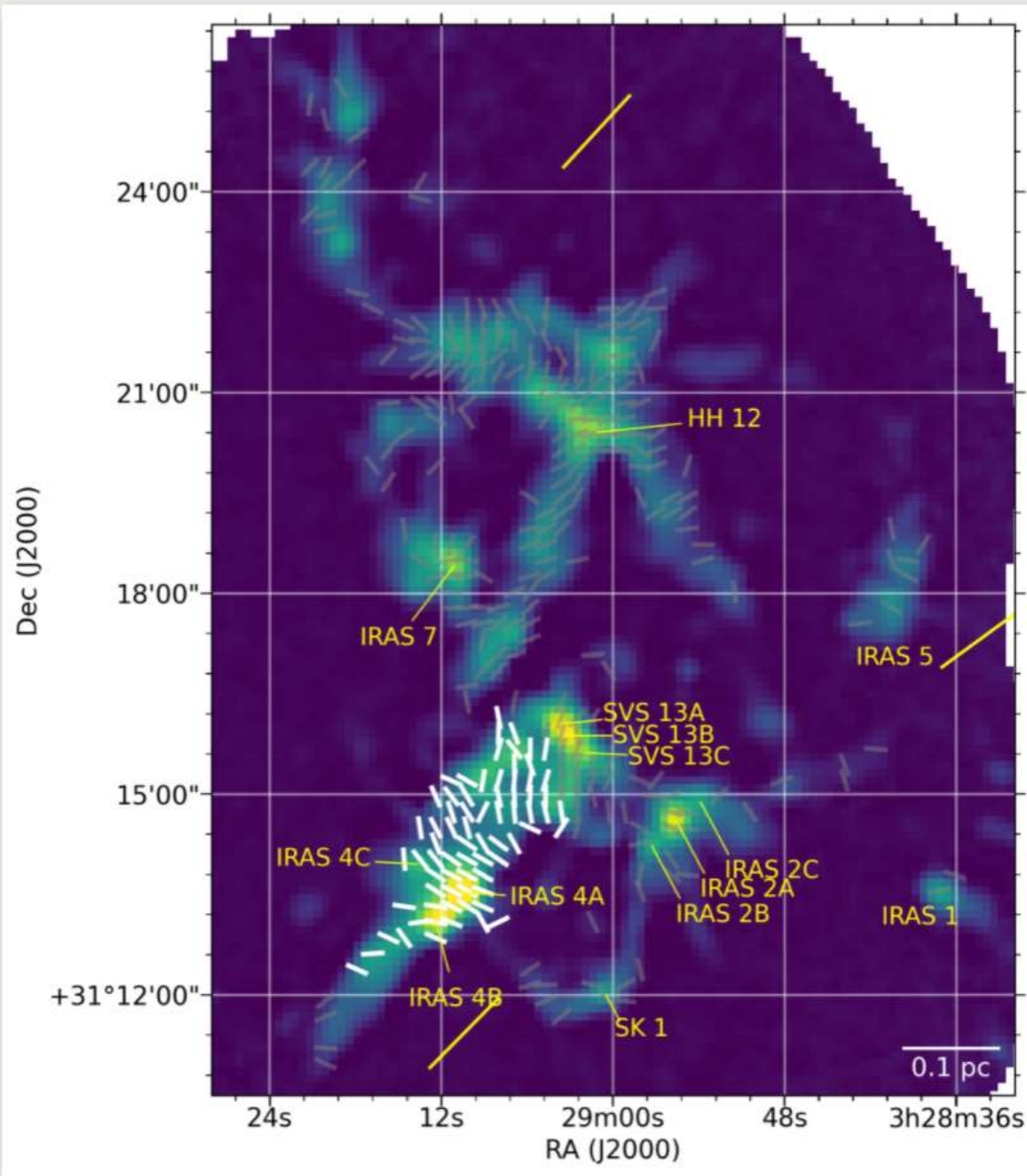
2: B -field aligns with
each filament at
different offset angles

BISTRO B pos. angle



2: B -field aligns with
each filament at
different offset angles

BISTRO B pos. angle

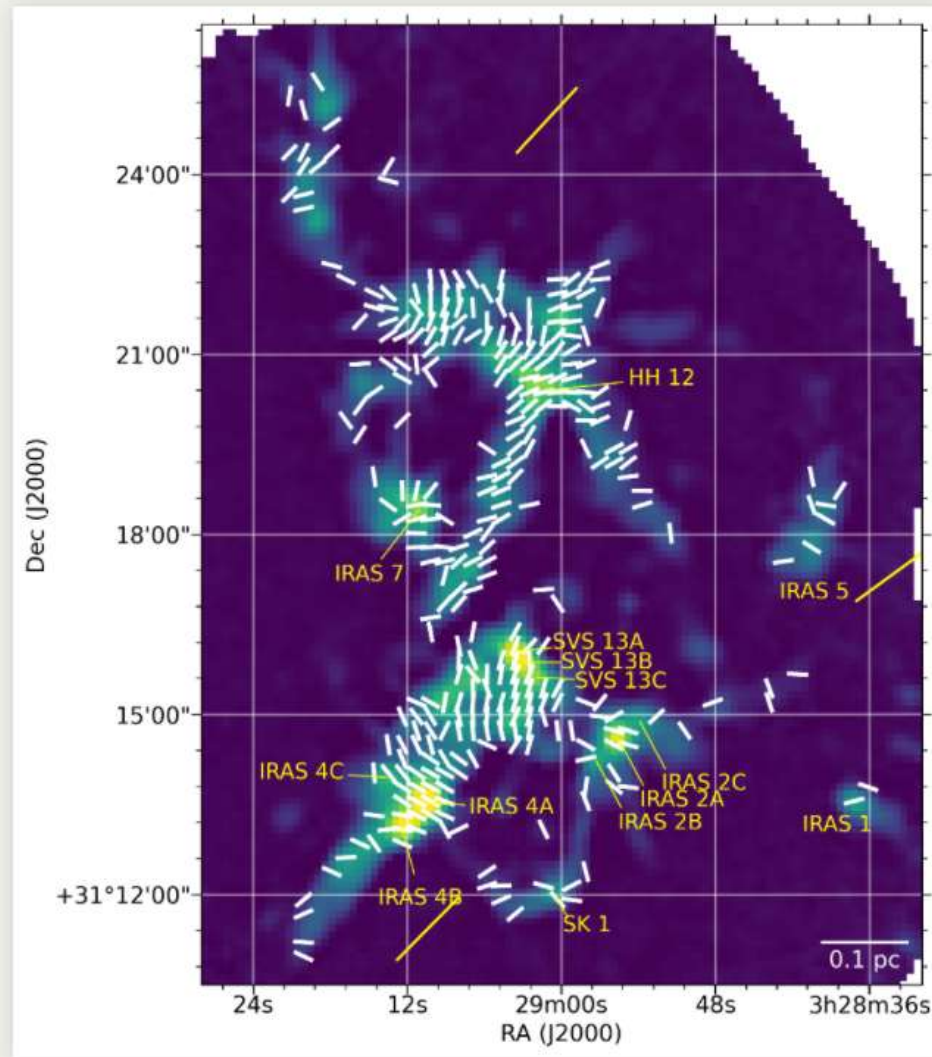
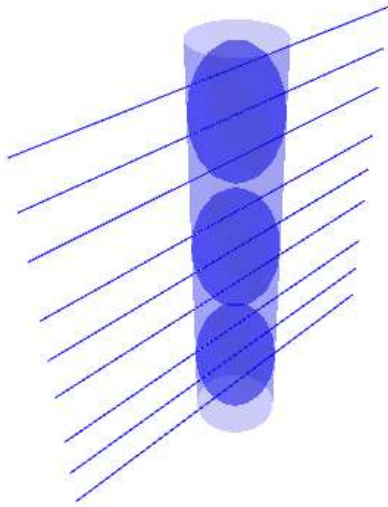


2: B -field aligns with
each filament at
different offset angles

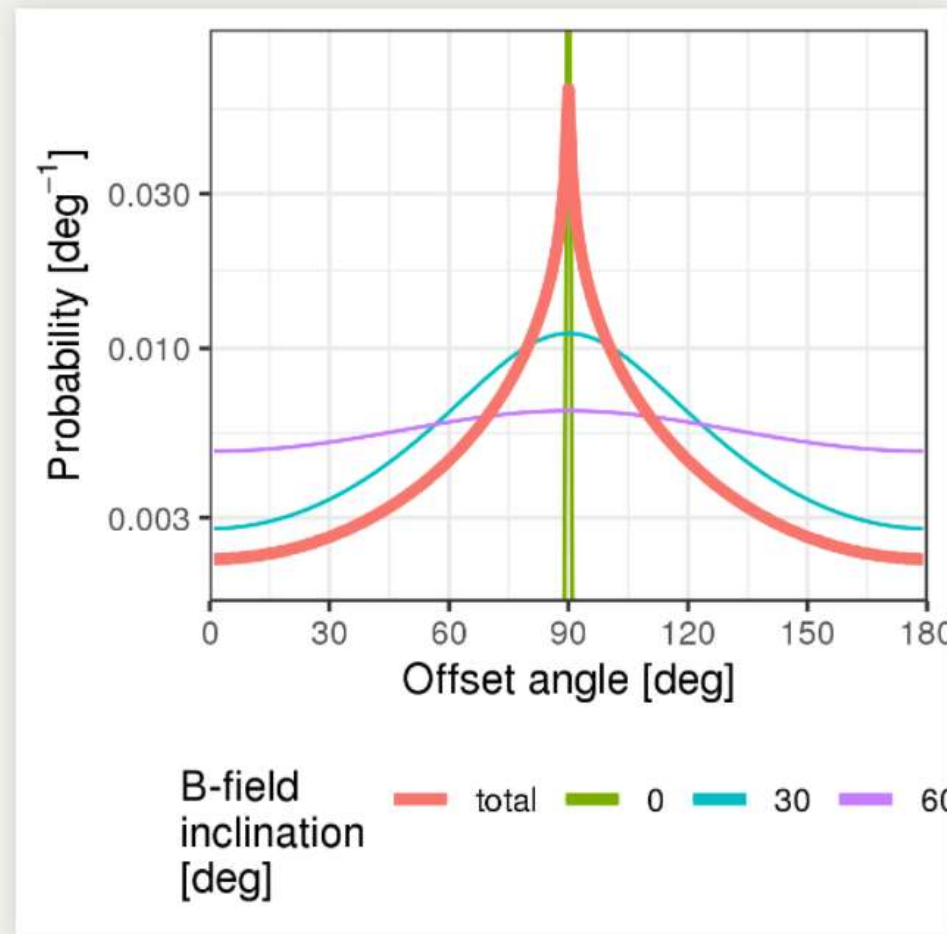
B-field alignment to filaments

3: 3D geometry of filaments and the magnetic field (Tomisaka 2015)

- Combination of simple structure can create complex geometry

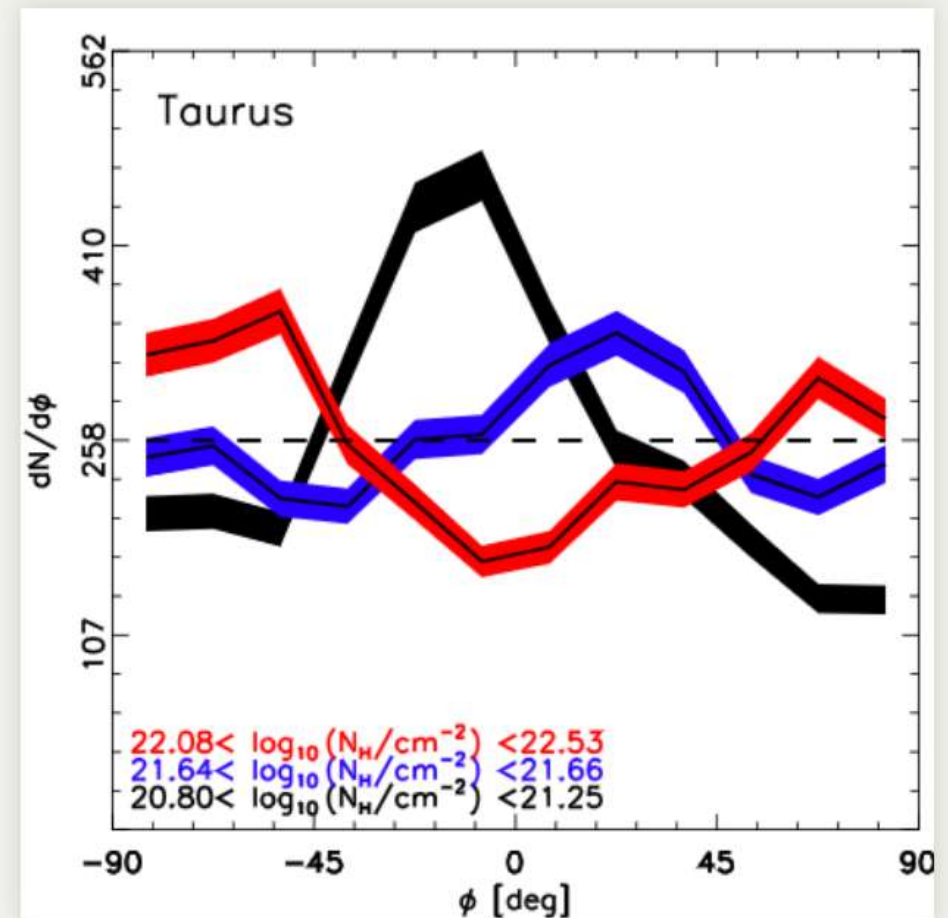
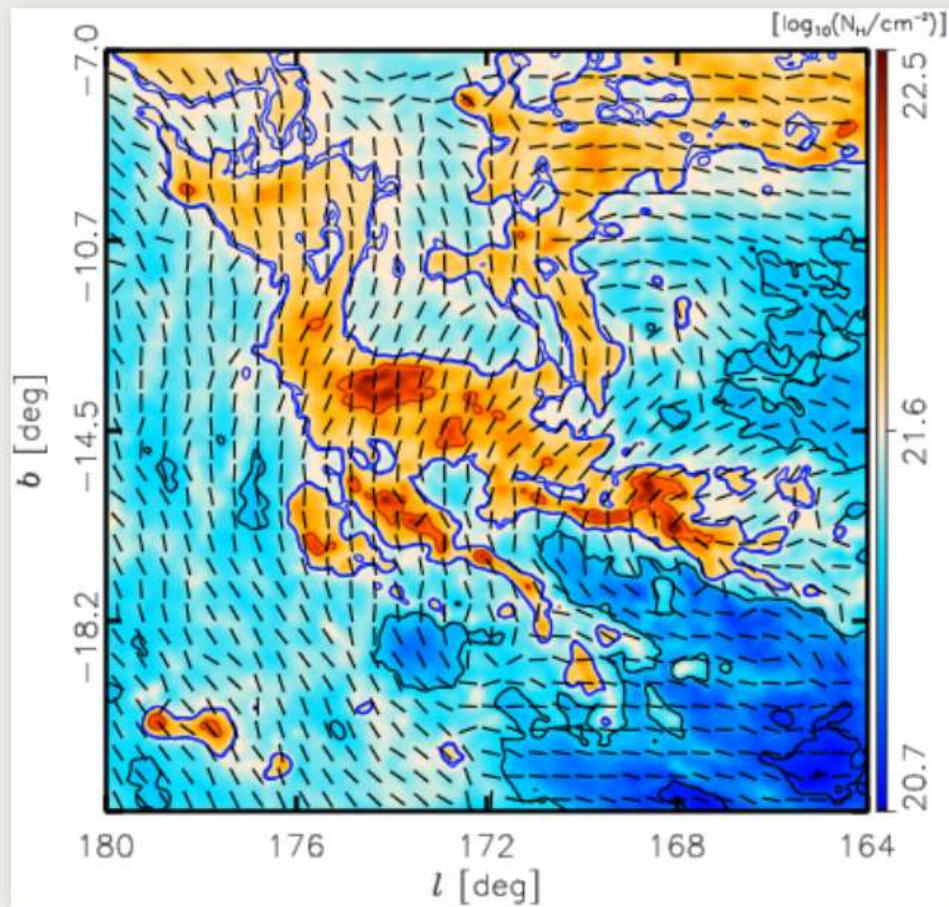


Projected offset angle between the magnetic field and the filament



Tend to be vertical -- consistent with Planck

Filaments alignment with B-field as seen by Planck

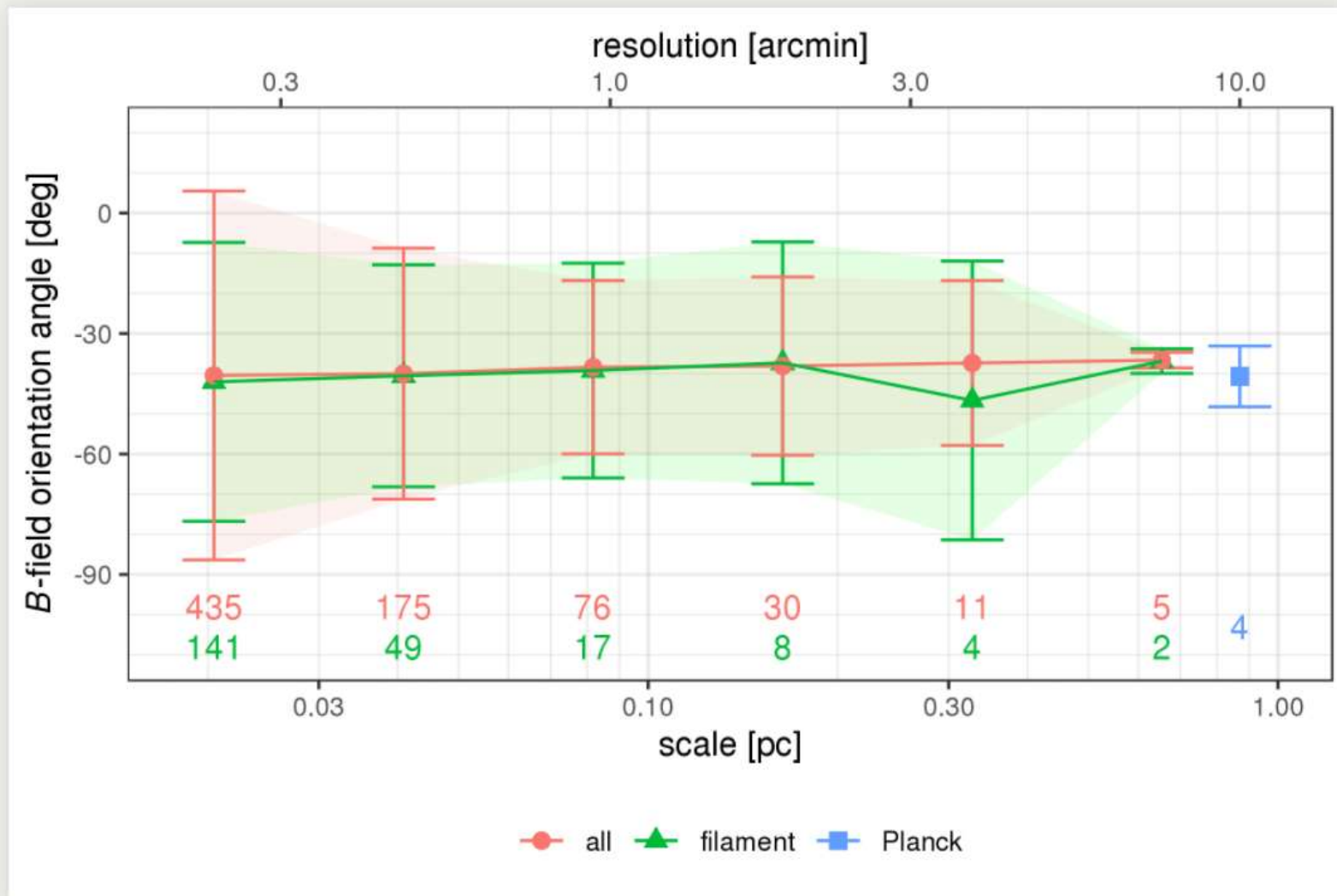


(Planck Collaboration+ 2016, A&A, 586, A138)

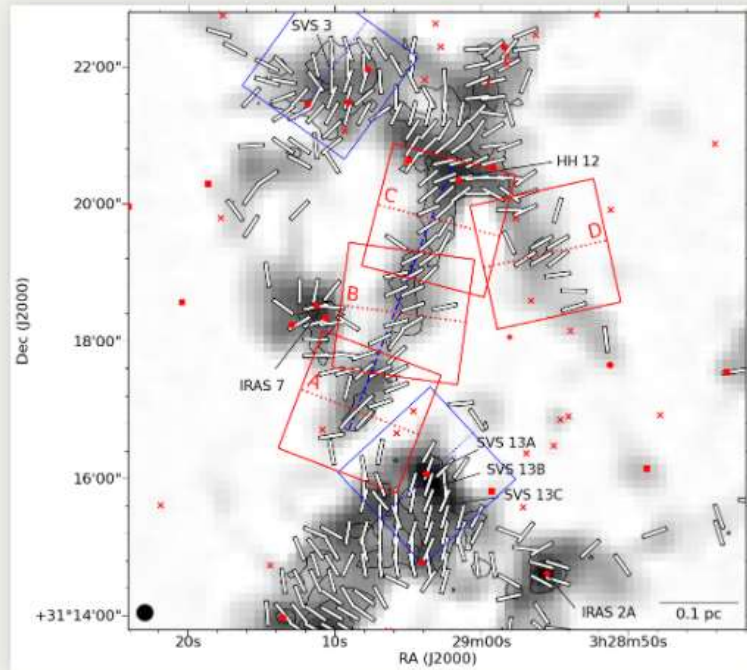
Scale dependence of B -field angle var.

- Increases at ~ 0.3 pc & constant on smaller scales

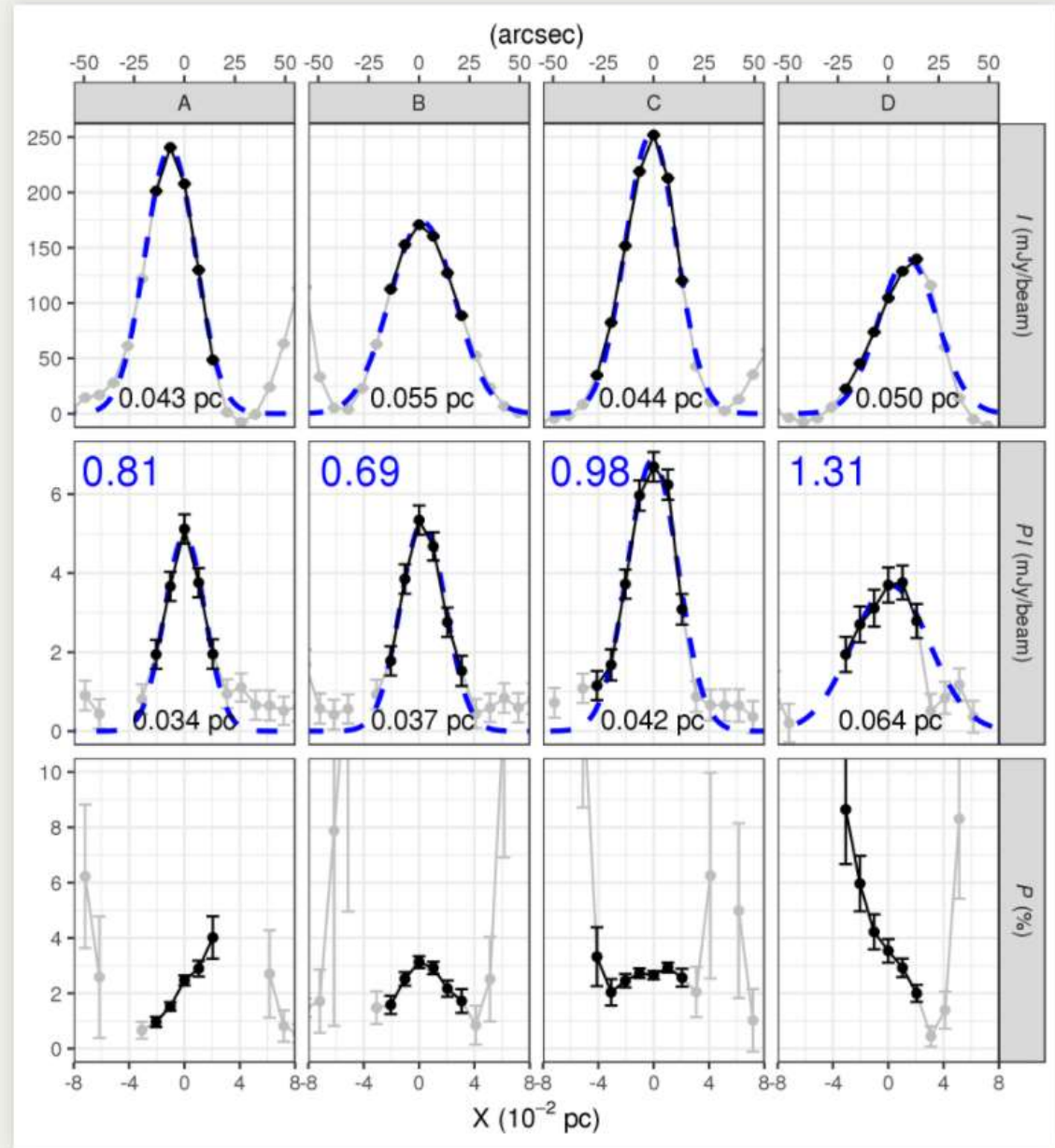
4: B -field structure change due to filament formation



Filament cross-sections



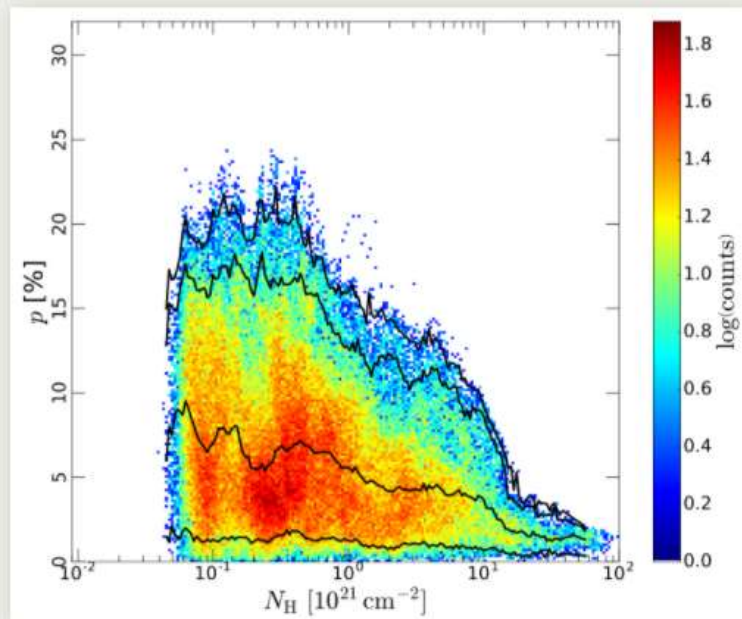
- PI is narrower than I
- $FWHM(PI)/FWHM(I) = 0.7 \sim 1.3$



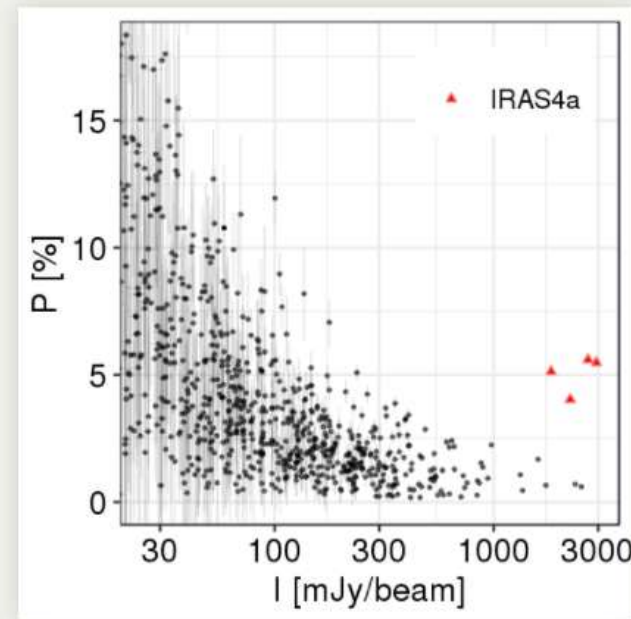
Anticorrelation between P and N_H

- inefficient alignment of dust particles in the cloud center
 - smaller radiation field • higher gas turbulent motion
 - PI cannot be sharper!!
- superposition of multiple ISM components
"geometrical depolarisation" inside the filament

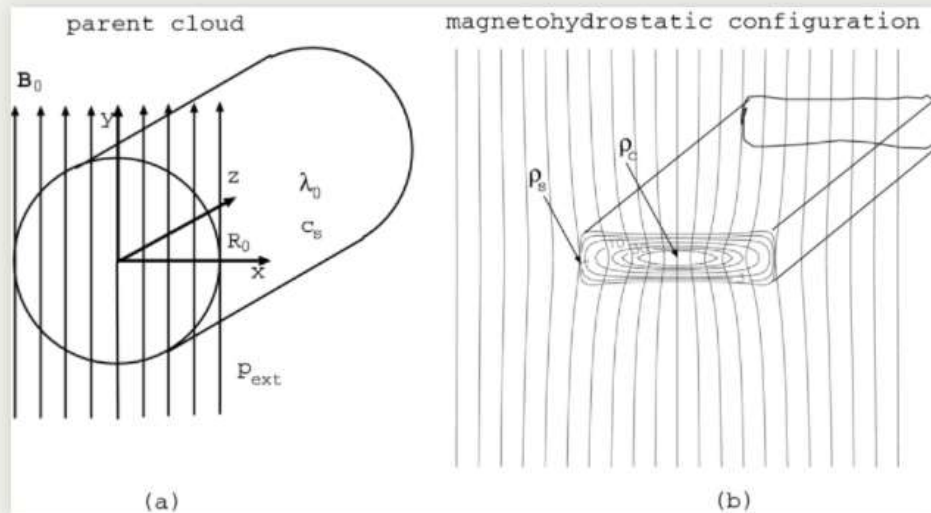
Planck 353 GHz



JCMT 850 μm



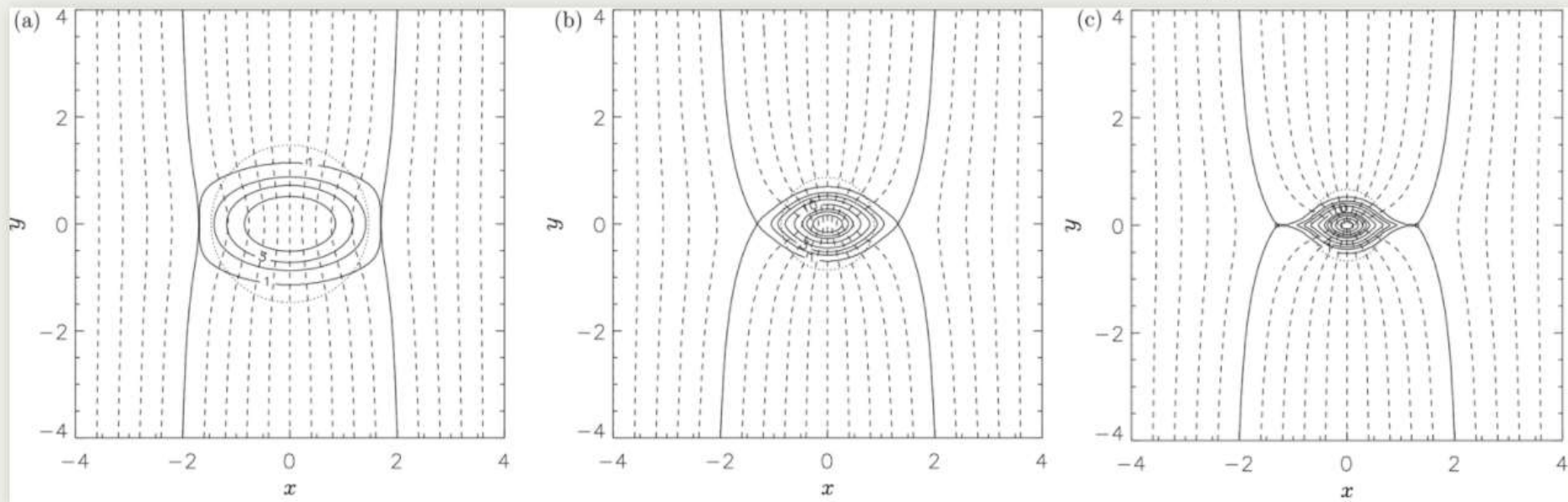
Pinched B -field inside filaments



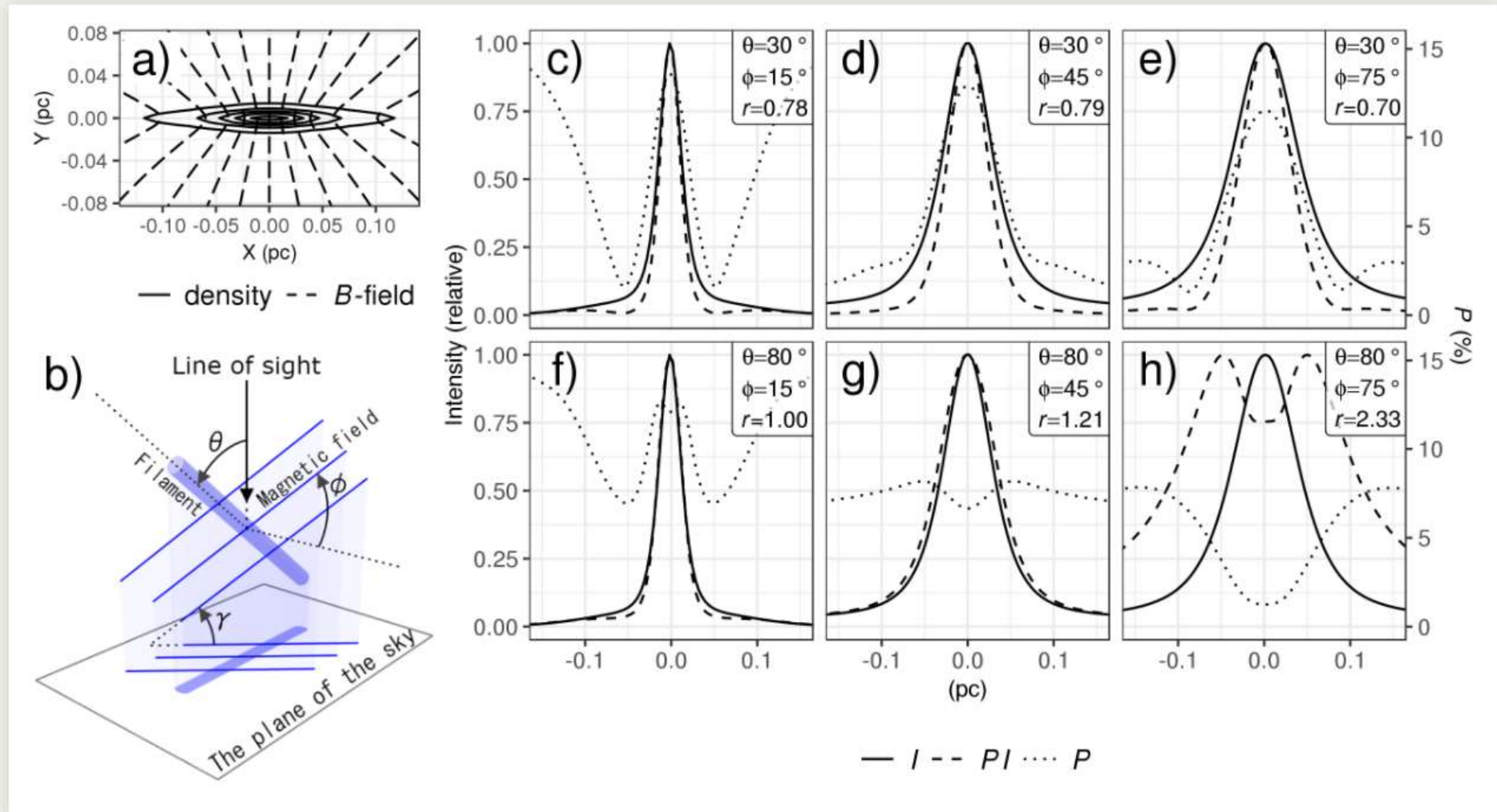
- MHD simulation by Tomisaka (2014)
- Equilibrium solution of filamentary (cylindrical) isothermal cloud with lateral magnetic field

small line mass $\leftarrow$

$\rightarrow$ large line mass



I & PI profiles at various viewing angles



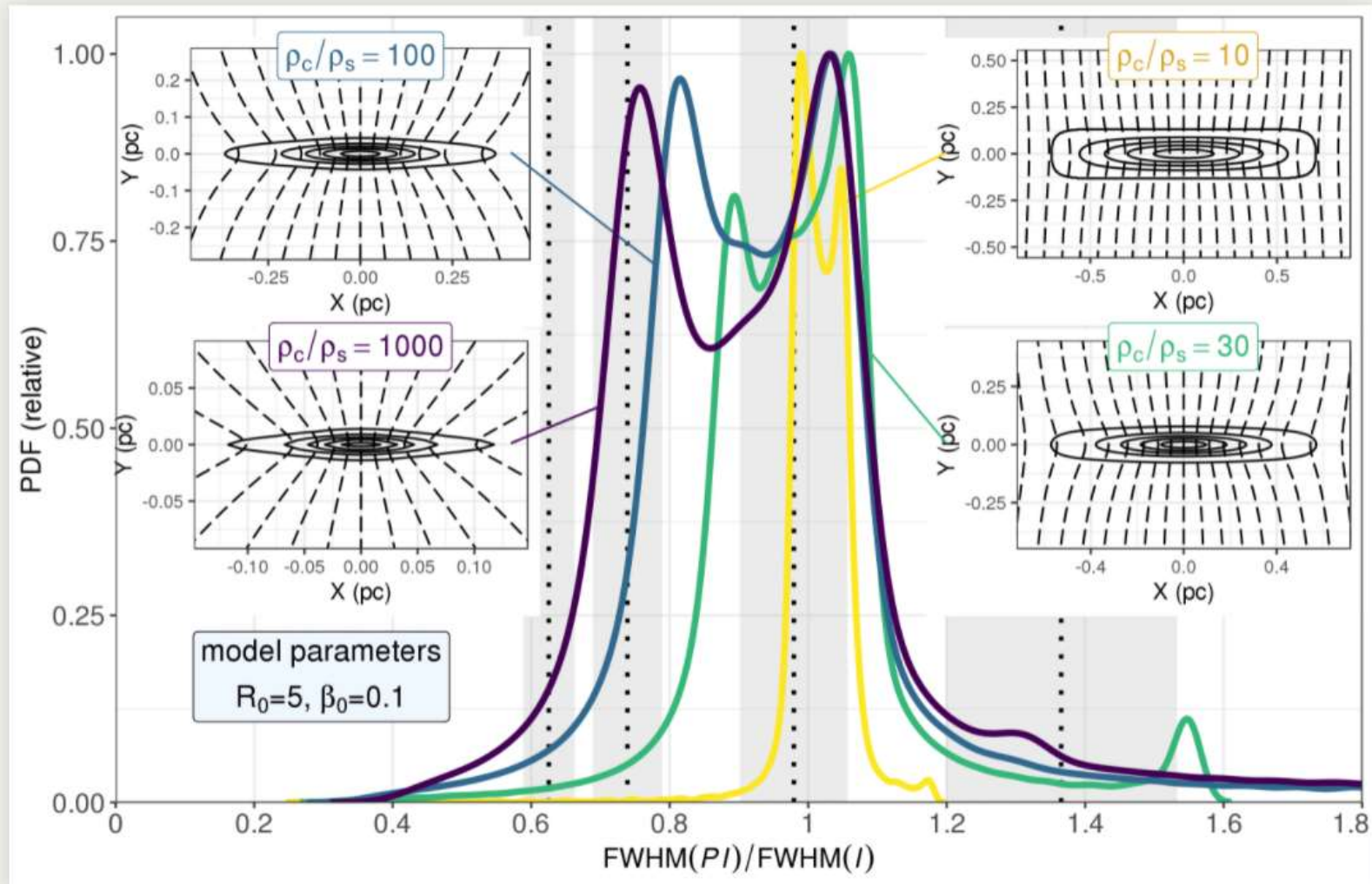
parameters:

$$R_0 = 5, \beta_0 = 0.1, \rho_c/\rho_s = 1000$$

Doi+ (2021)

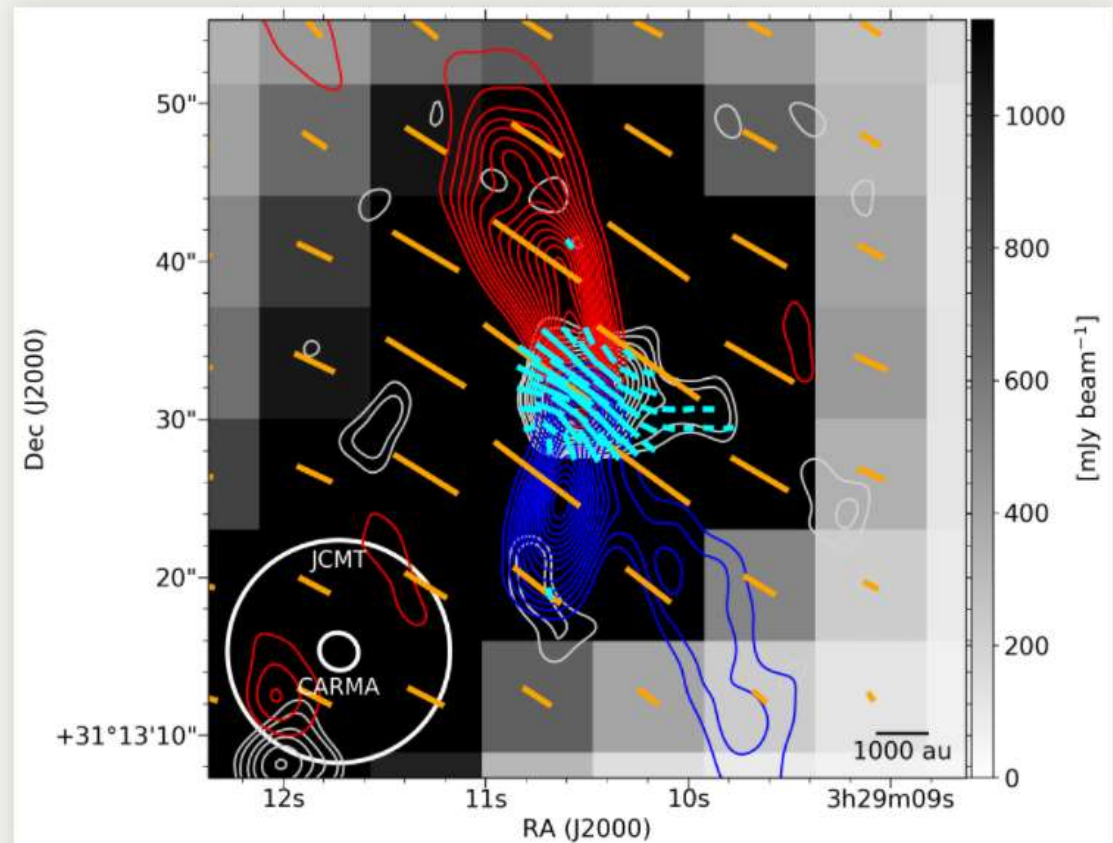
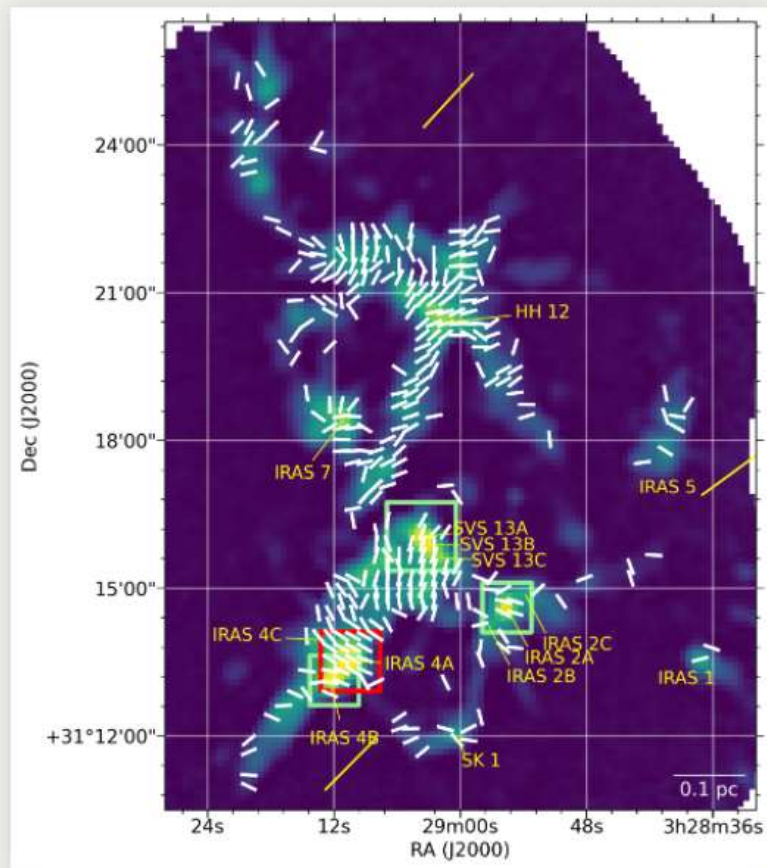
FWHM(PI)/FWHM(I) PDF

5. Pinched B -field in magnetically critical filaments



BISTRO vs. interferometric obs. (Hull+2014)

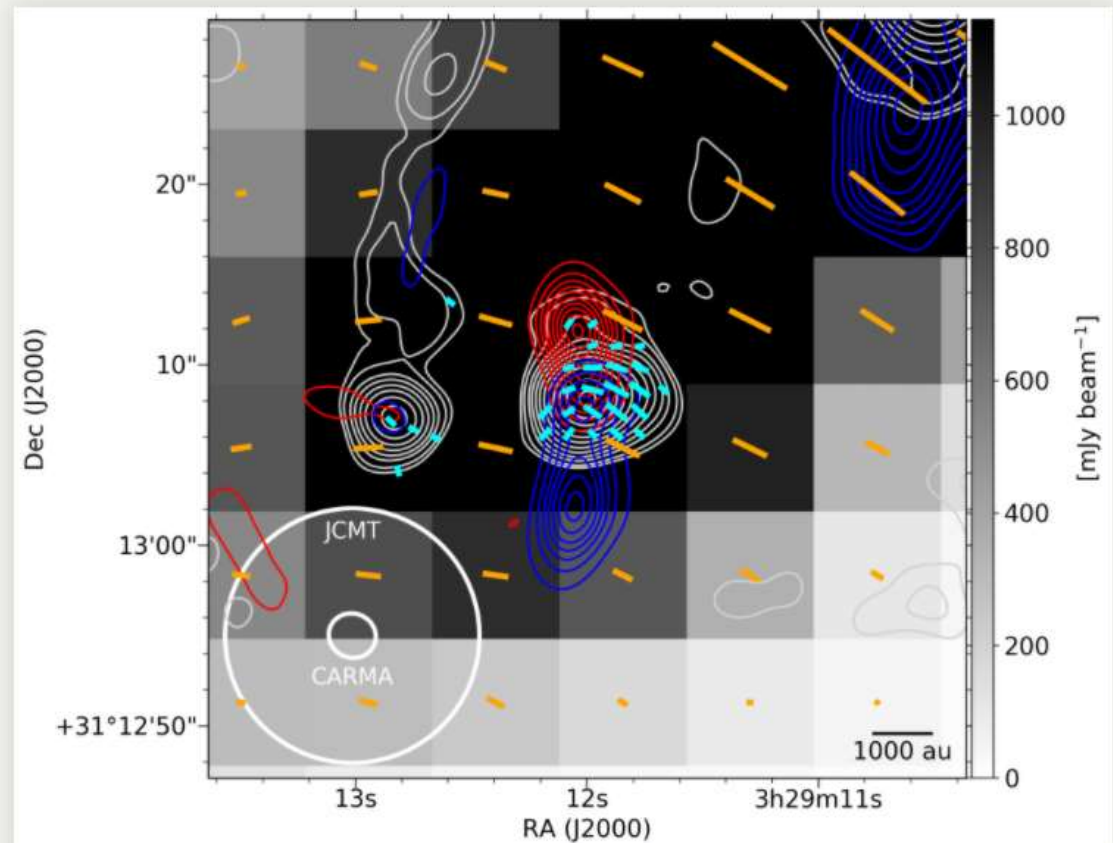
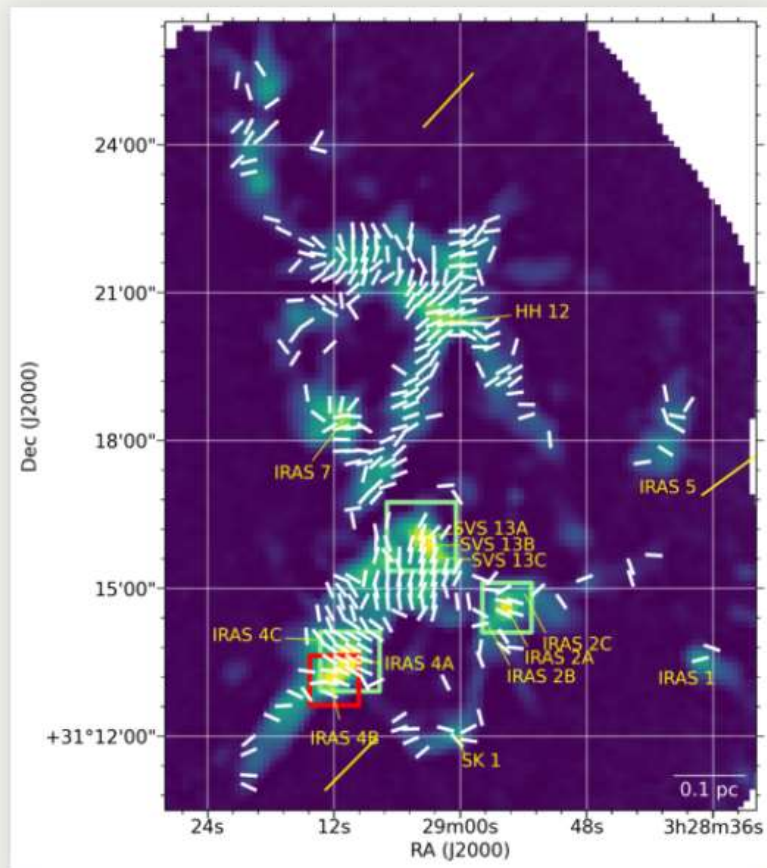
6. *B*-field structure is consistent down to < 0.01 pc or 1000 au



Doi+ (2020)

BISTRO vs. interferometric obs. (Hull+2014)

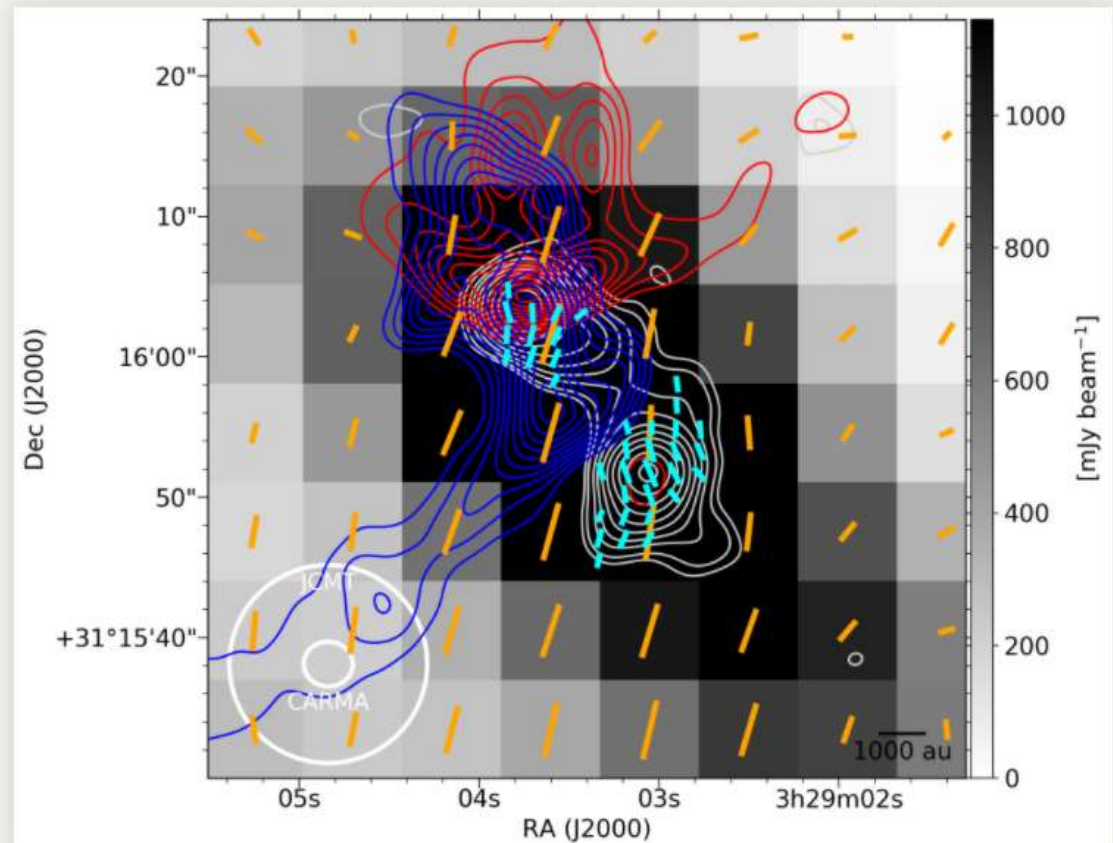
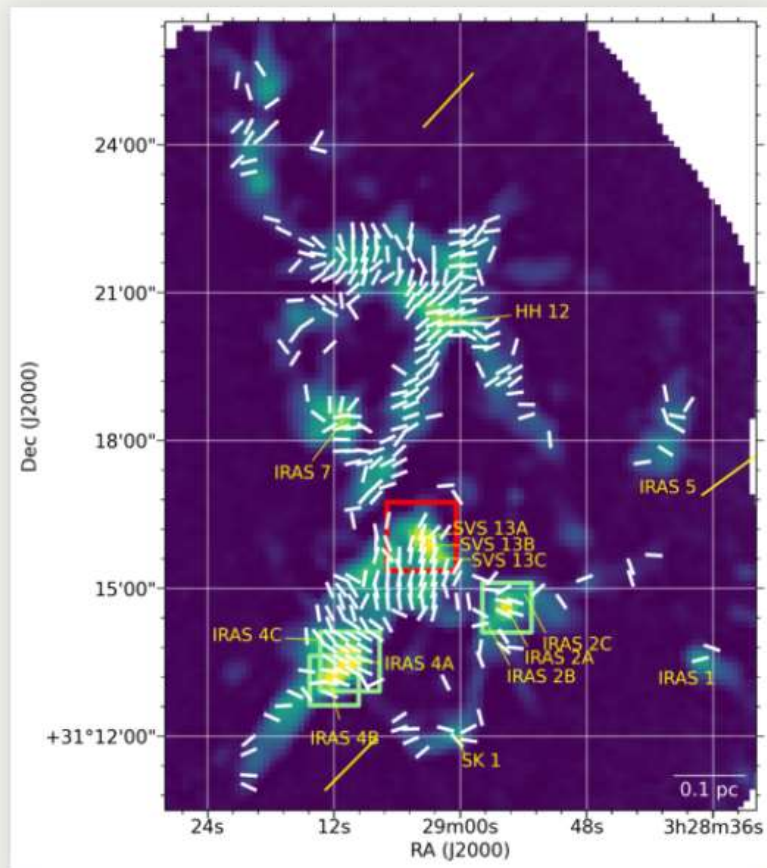
6. *B*-field structure is consistent down to < 0.01 pc or 1000 au



Doi+ (2020)

BISTRO vs. interferometric obs. (Hull+2014)

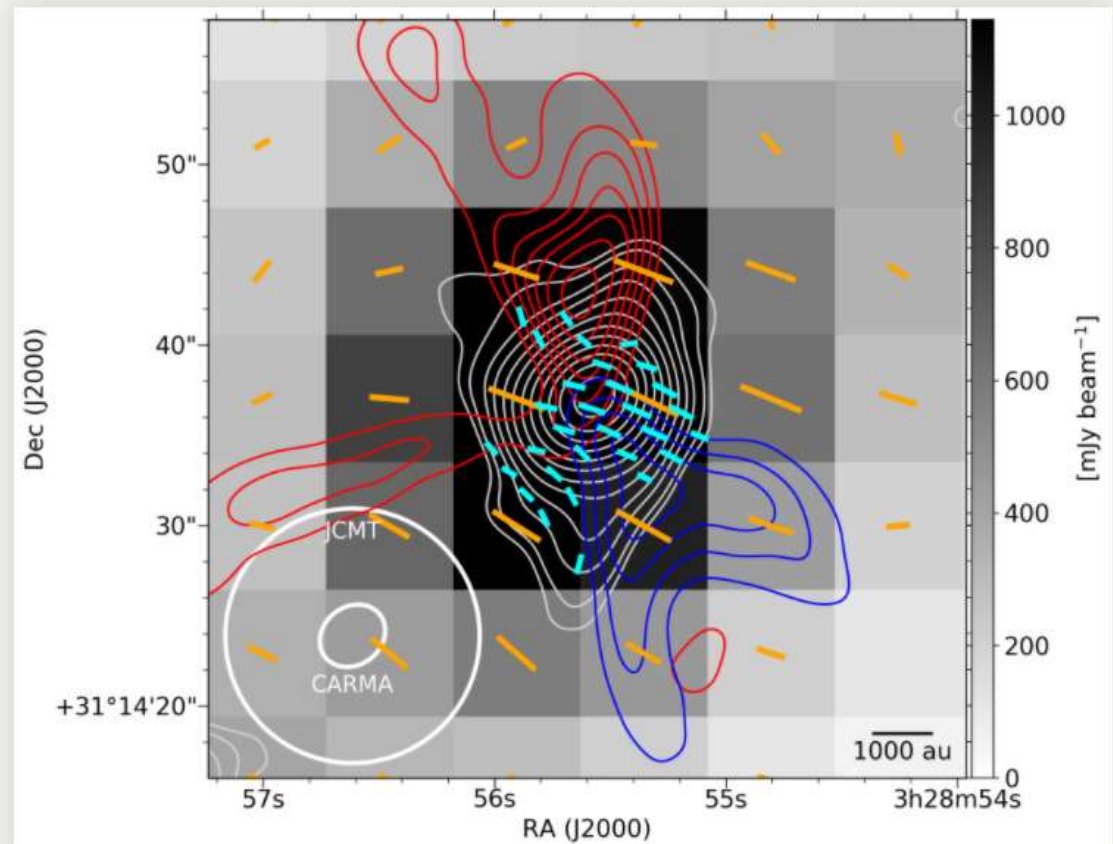
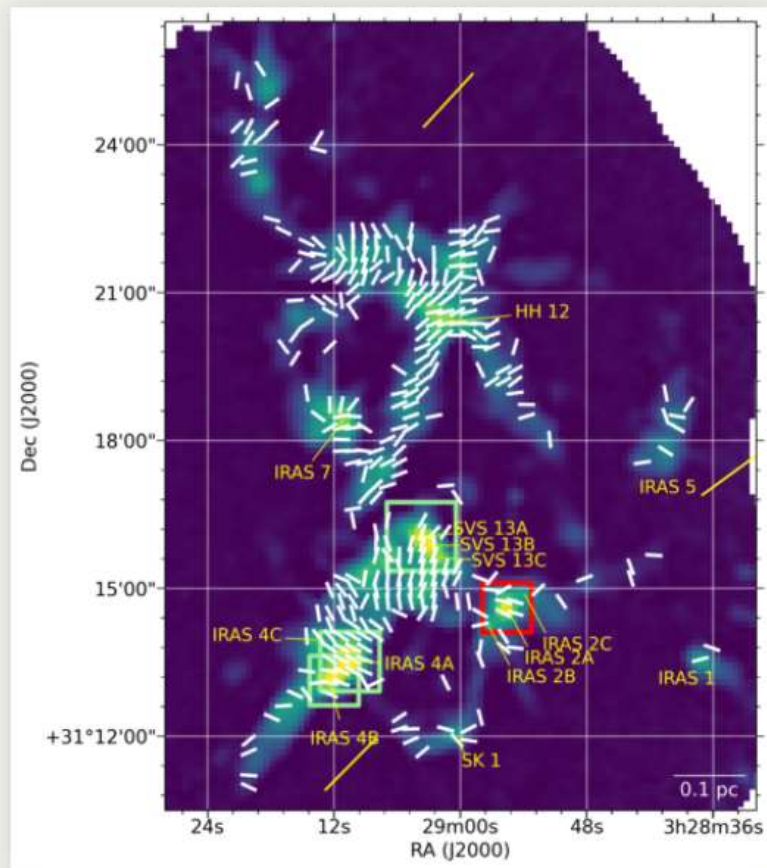
6. *B*-field structure is consistent down to < 0.01 pc or 1000 au



Doi+ (2020)

BISTRO vs. interferometric obs. (Hull+2014)

6. *B*-field structure is consistent down to < 0.01 pc or 1000 au

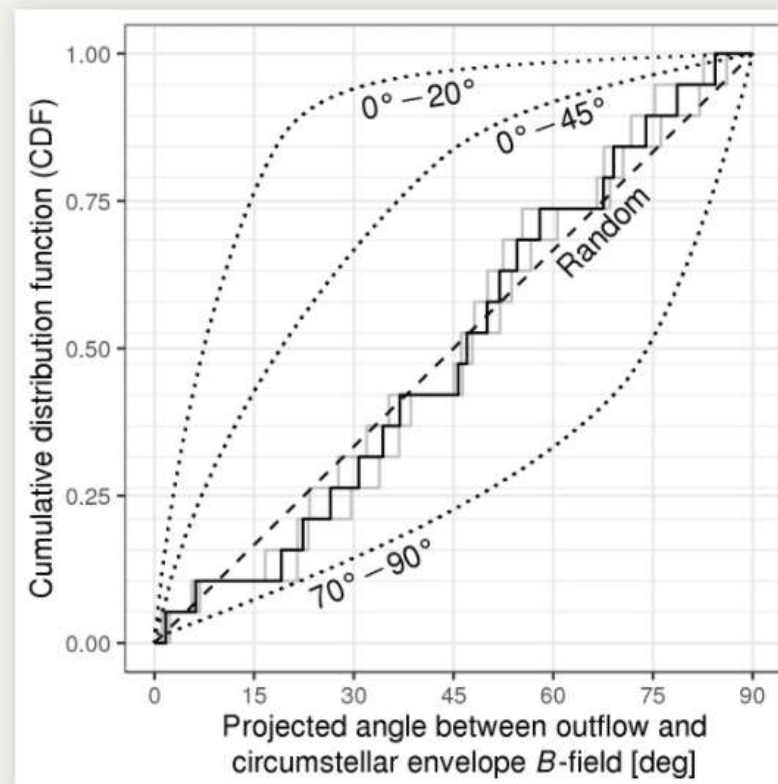
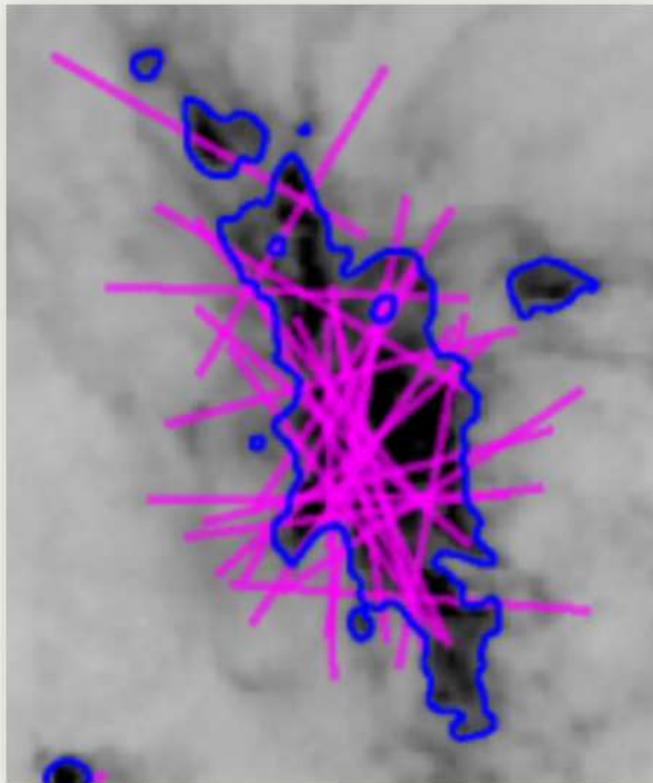


Doi+ (2020)

BISTRO vs. CO molecular outflows

- NO correlation between BISTRO B -field and the CO outflow direction (*cf.* interferometric obs.)

7. A significant change in the position angle at $\ll 1000$ au



Summary

Multiscale B -field structure in dense molecular clouds

- $< 1 \text{ pc}$: Magnetic field structure is changed (most probably) due to filament formation
 - Perpendicular B -field orientation in 3D space
 - Pinched B -field structure inside filaments due to cylindrical matter contraction
 - magnetically (near-)critical filaments
- $1 \text{ pc} \sim 0.01 \text{ pc}$: Maintains its distribution perpendicular to filament
- $\ll 0.01 \text{ pc}$: the YSO rotation axis does not match the larger-scale magnetic field orientation

Please refer to:

- Doi et al., 2020, *ApJ*, 899, 28
- Doi et al., 2021, *ApJL*, 923, L19
- (Doi et al., 2021, *ApJ*, 914, 122)