Polarimetry with SOFIA: the interplay between magnetic fields and kinematics in low-mass cores

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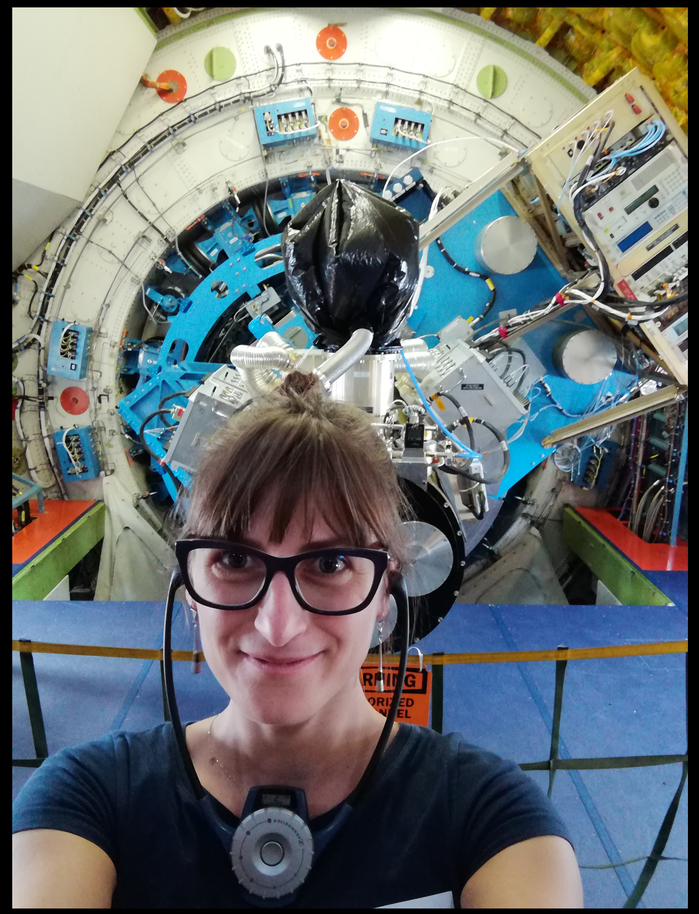
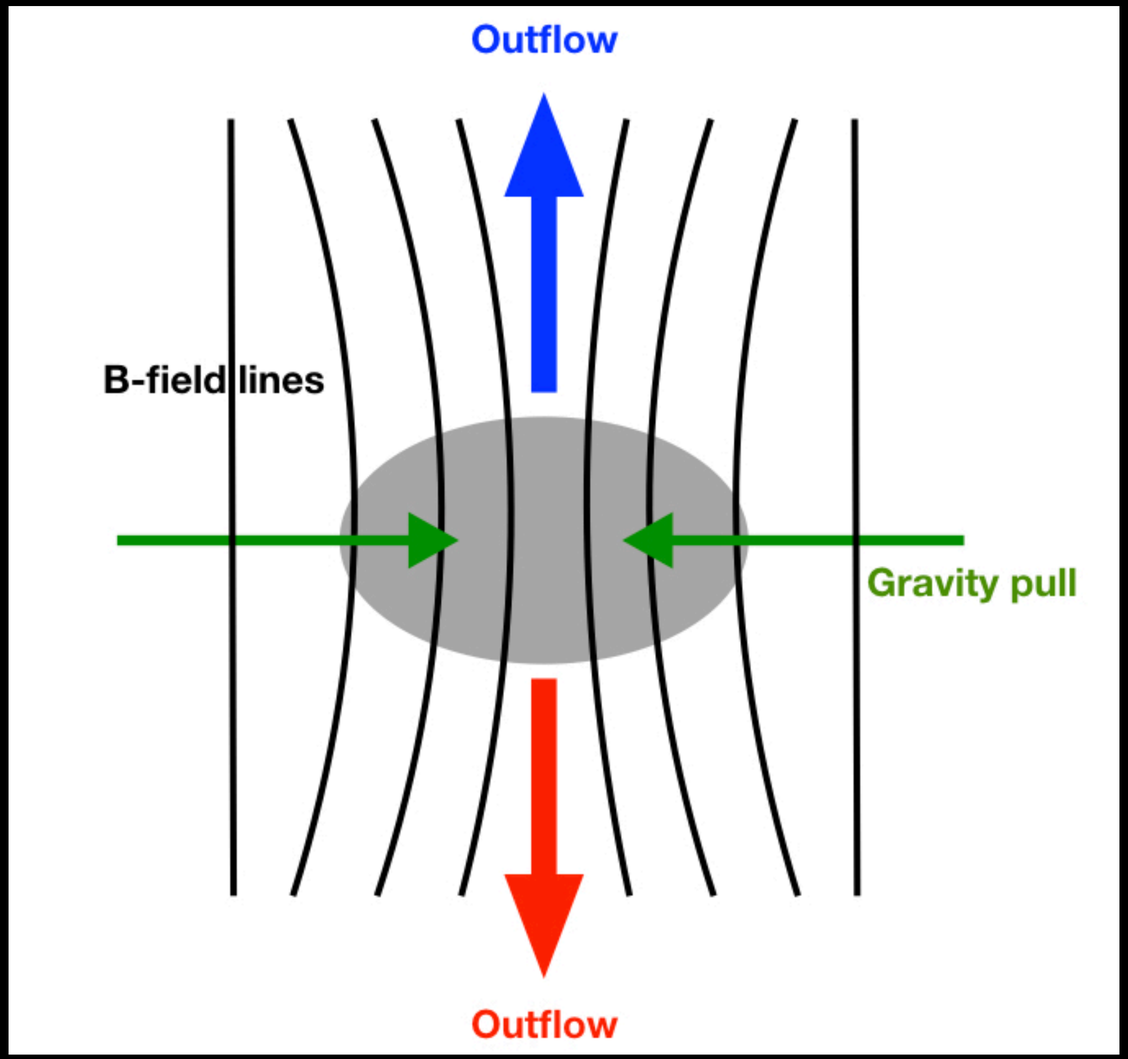
Congratulations!
We survived ALMA cycle 11 call for proposals!



AG Meeting 2019, Stuttgart

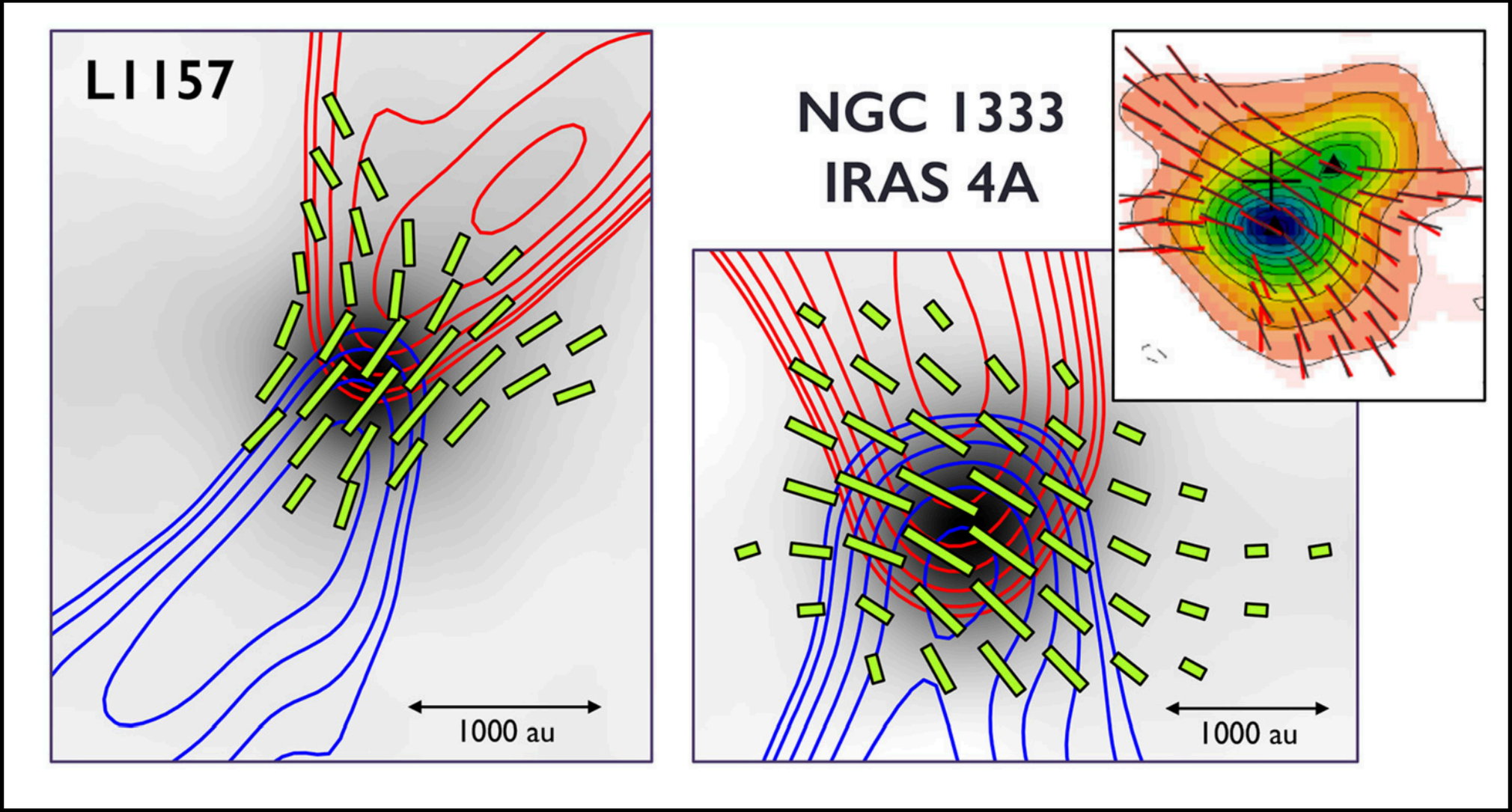
Polarimetry with SOFIA: the interplay between magnetic fields and kinematics in low-mass cores

B-fields in cores: theory



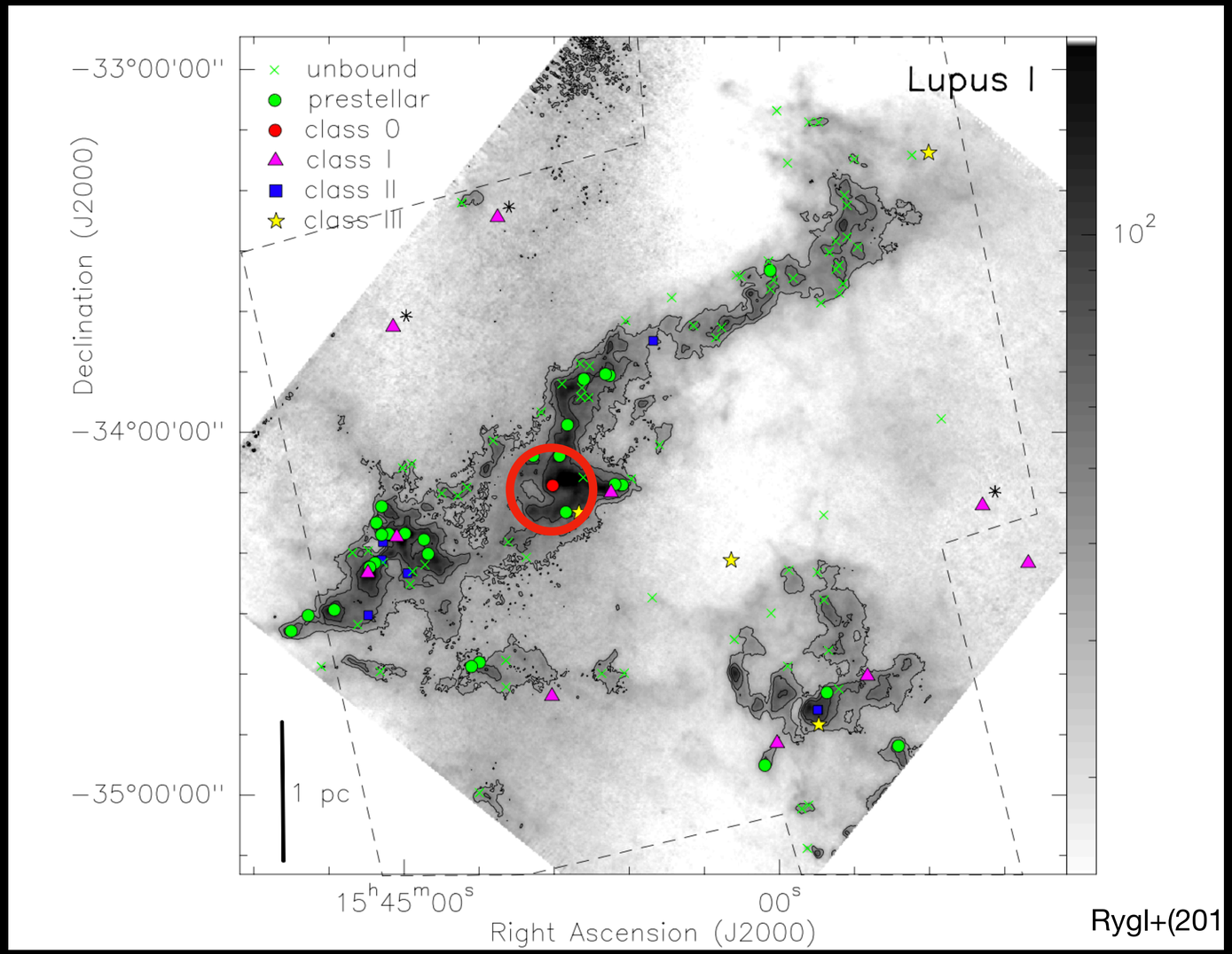
Mouschovias +(1991), Shu +(1994), Basu +(2009),…

B-fields: observations



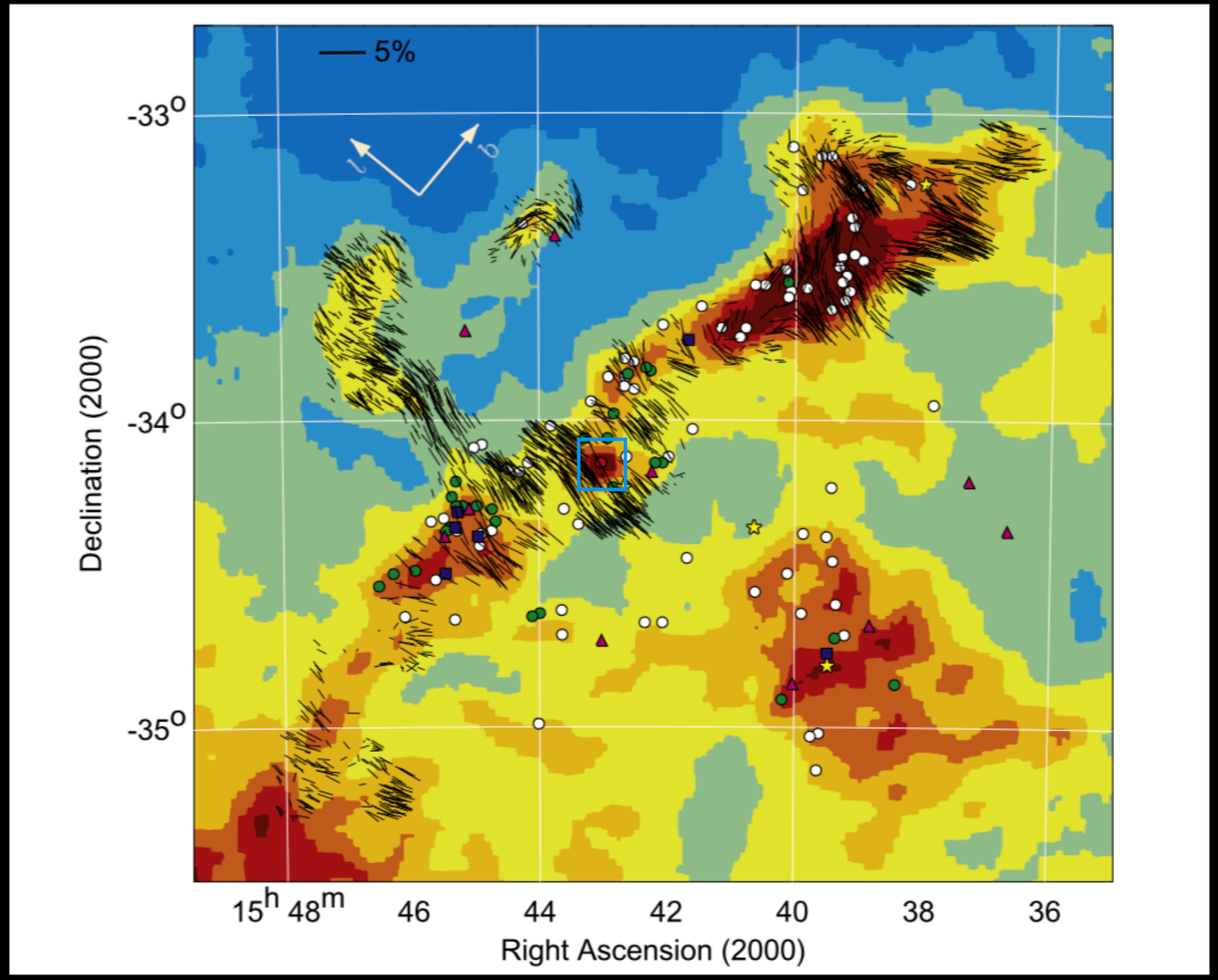
Girart et al. (2006), Hull et al. (2014), Hull et al. (2014), Stephens et al. (2013)

Lupus I



- The less evolved cloud of the Lupus complex
- A nearby (d~156 pc, Dzib+18) and young star forming regions

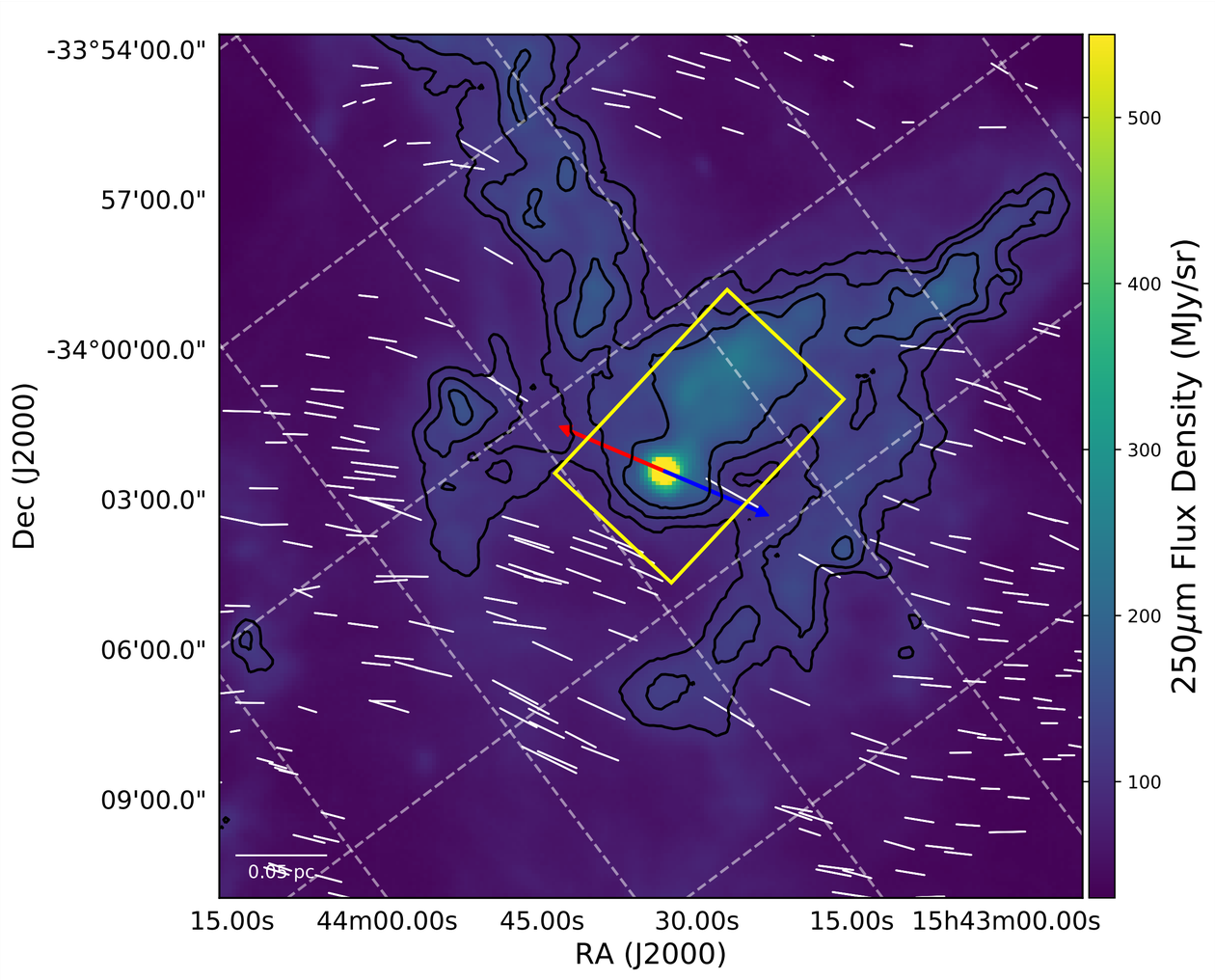
Optical polarisation

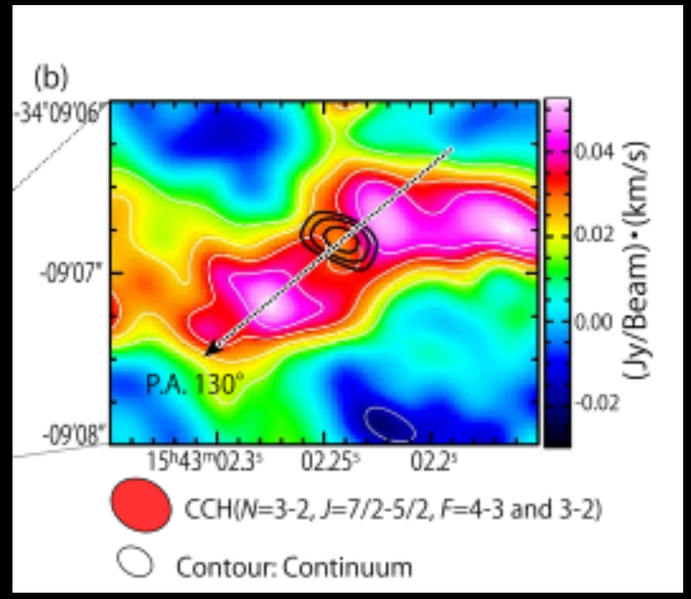


IRAS 100μm map with overlaying optical polarization (R-band) vectors (Franco&Alves, 2015)

Very ordered B-field!

IRAS 15398





Okoda et al. 2018

Mass: $0.007^{+0.004}_{-0.003} M_{sun}$

- A young class 0 object
- Driving a bipolar outflow

We wanted to investigate the magnetic field properties in early stages of star formation

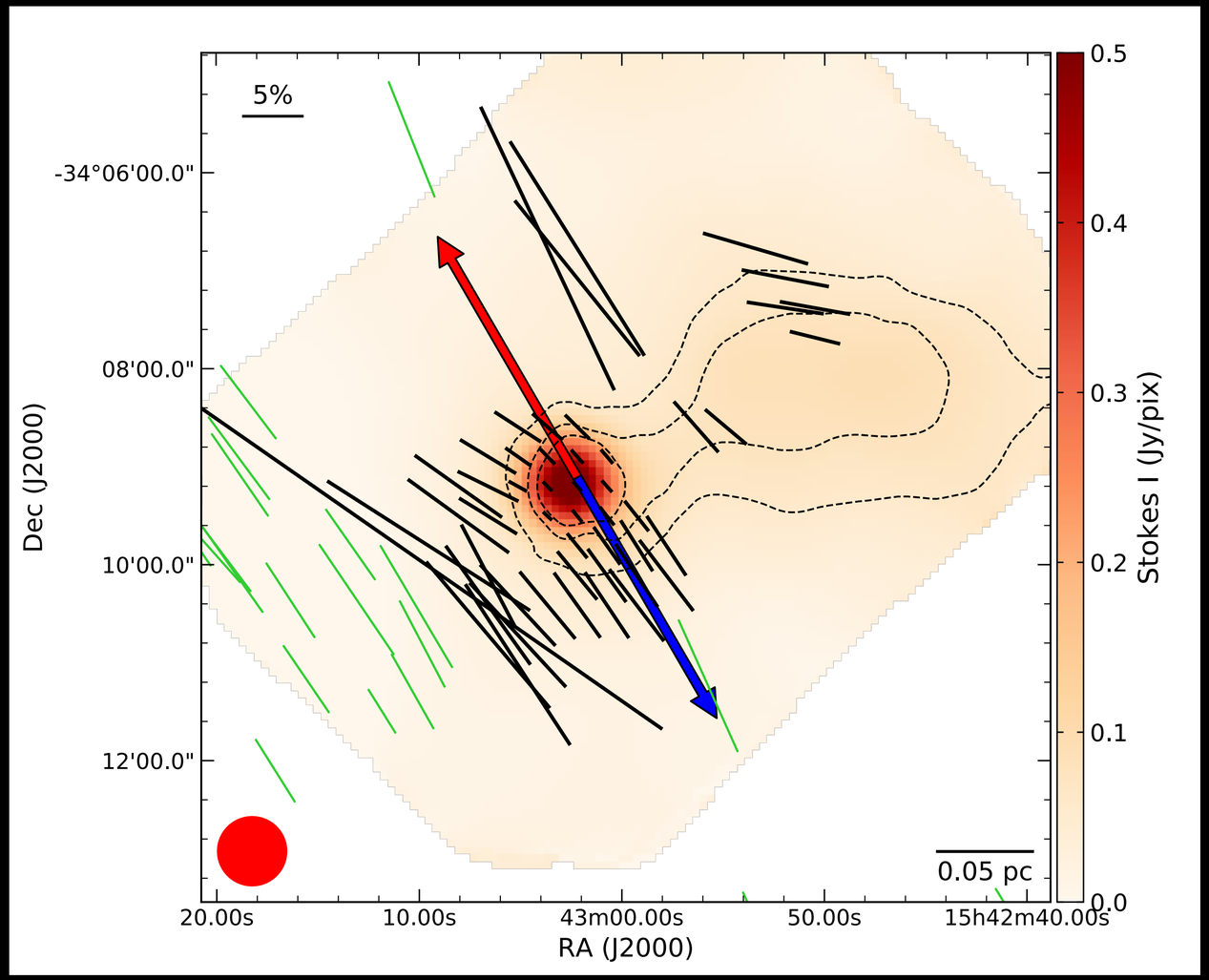
Observations

One of my first ever approved proposals!

06_0086 (DE)	Elena Redaelli (Max Planck Institute for Extraterrestrial Physics)	Polarimetry in B228	HAWC+

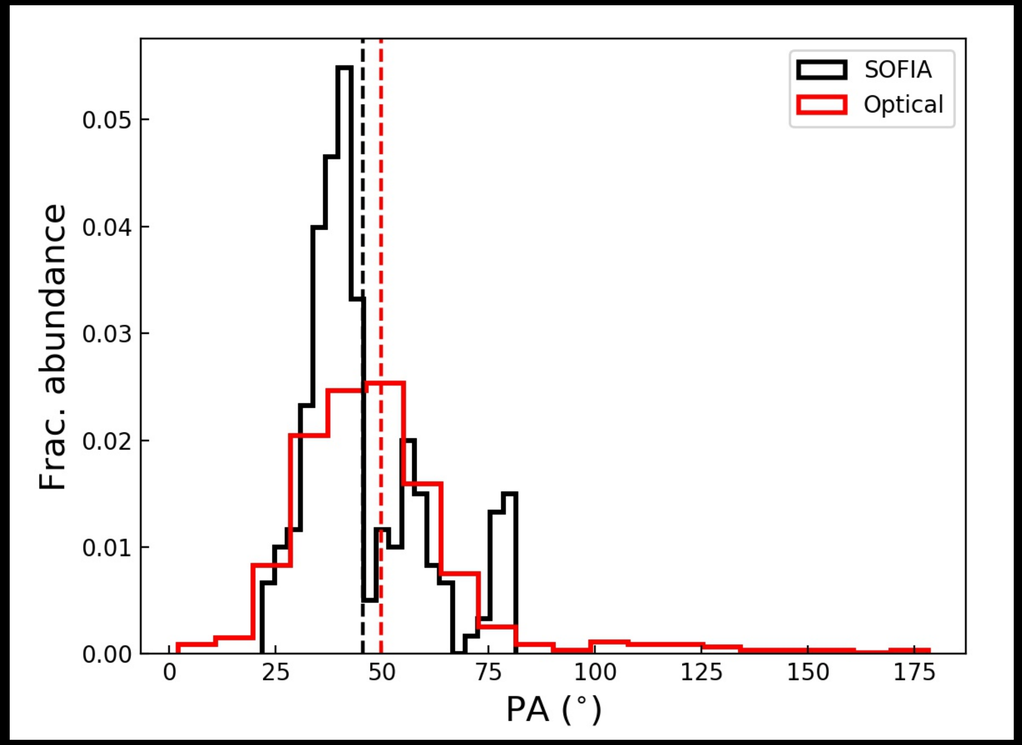
- We used the HAWC+ instrument in band E (214μm)
- The nominal FoV corresponds to 0.22x0.28 pc
- We asked for 5σ detection of 5% polarization (rms~0.5mJy/pix)
- The final integration time is ~2.5 h

Results

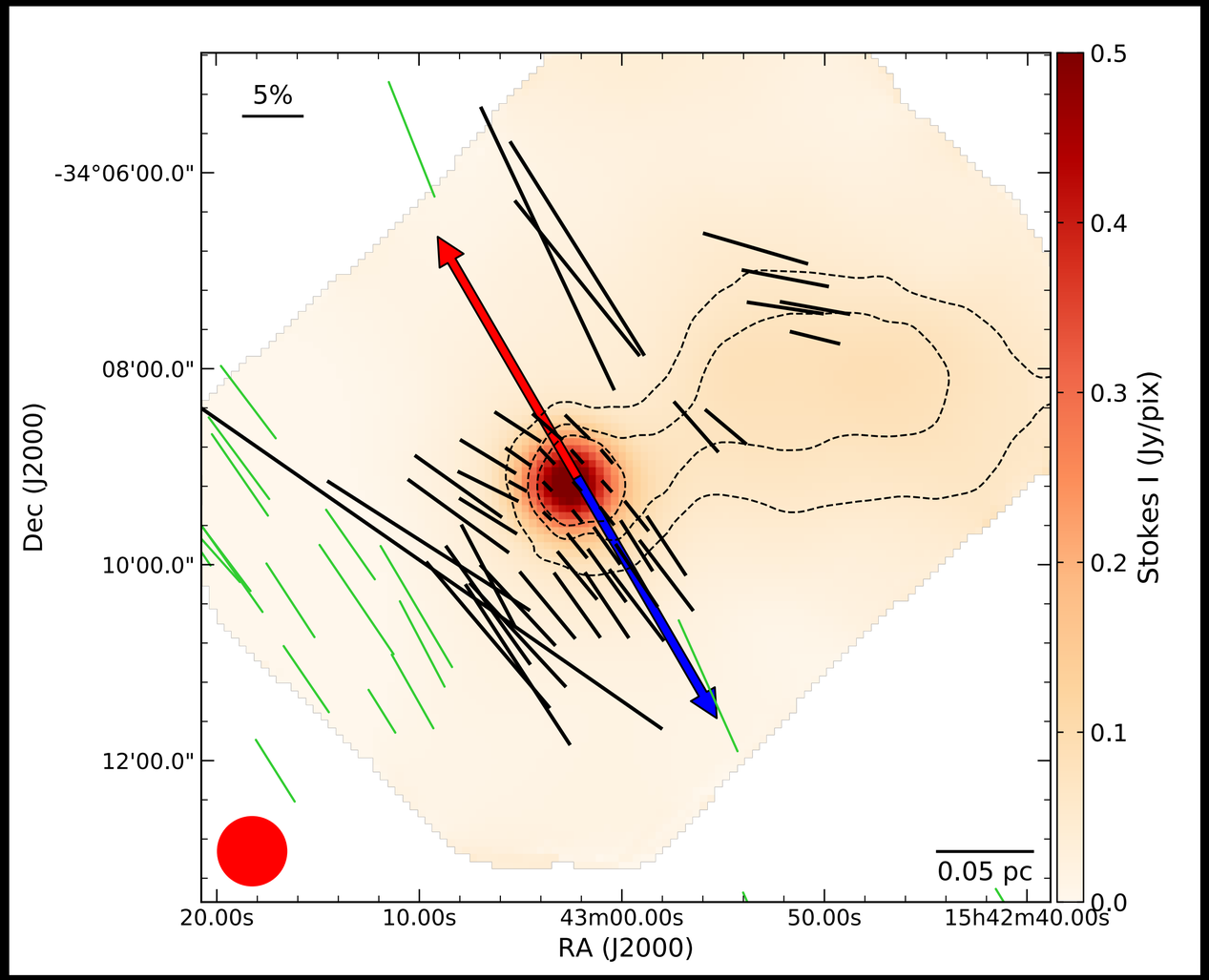


Black: SOFIA vectors,
Green: optical vectors

B-field vectors are aligned with the optical ones



Results



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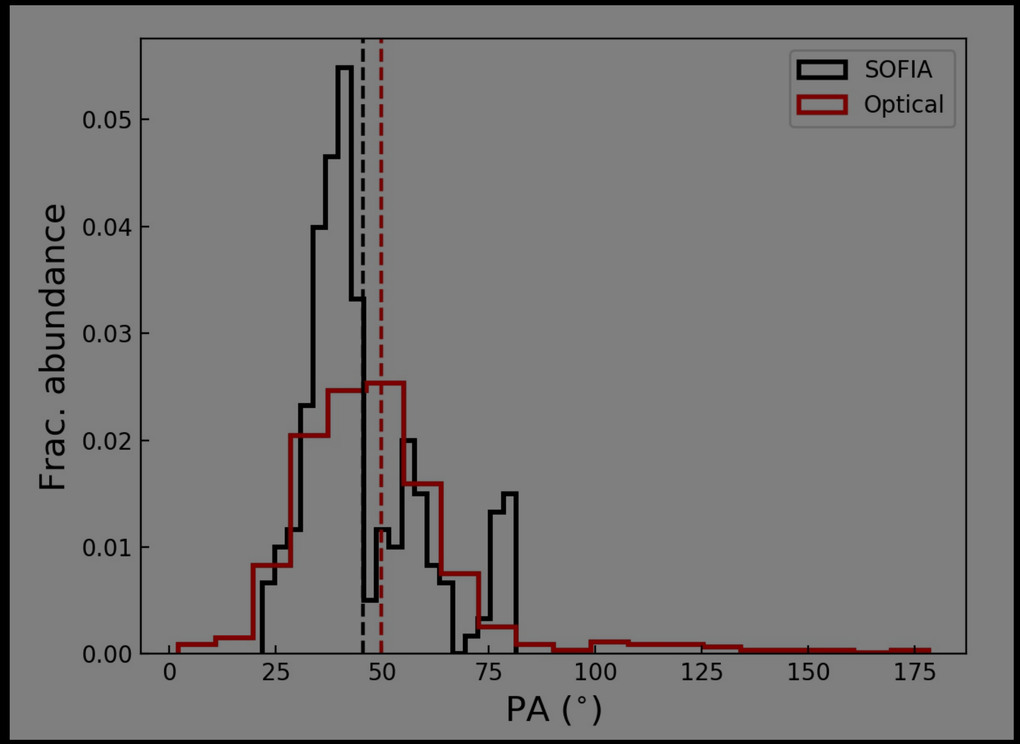
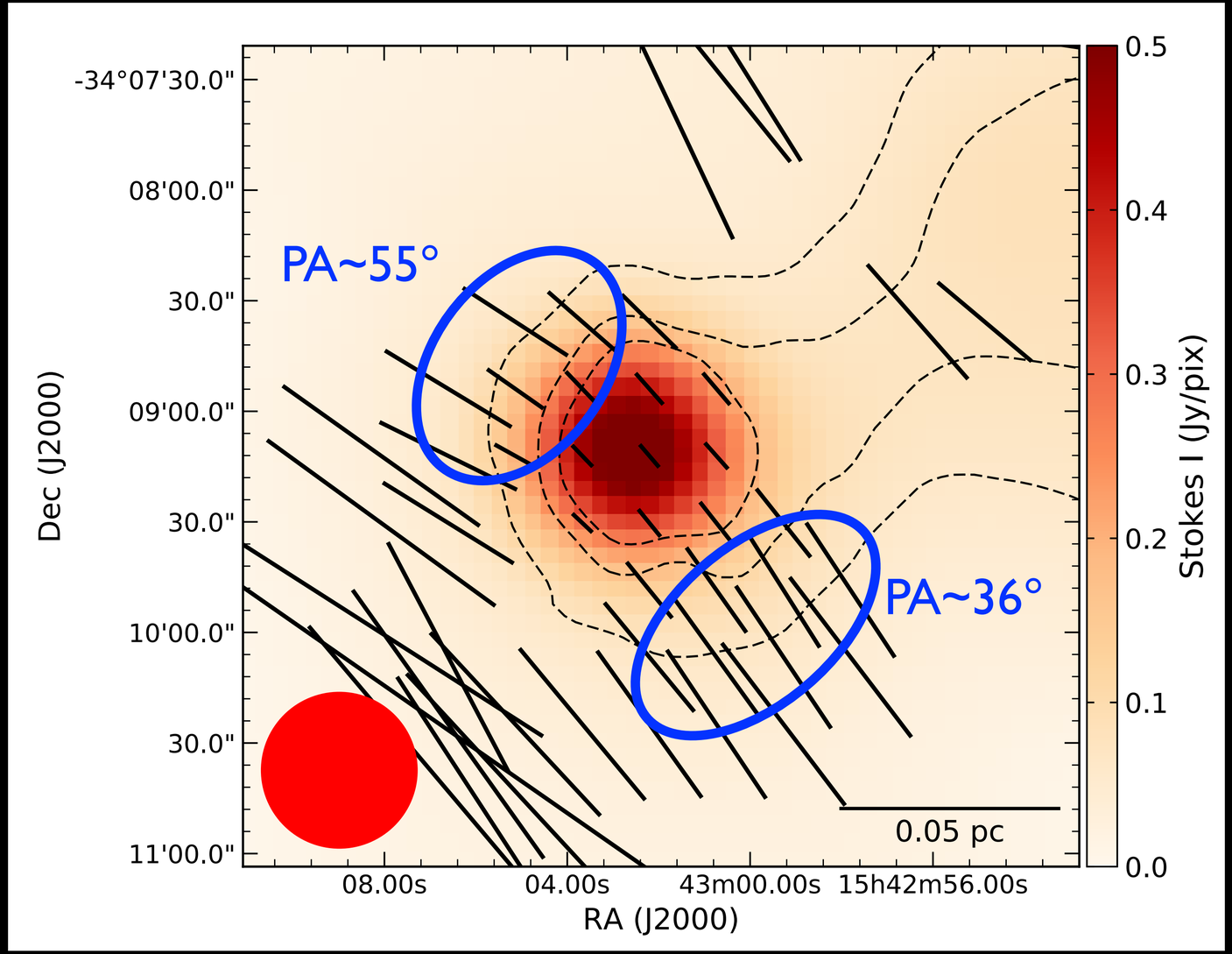
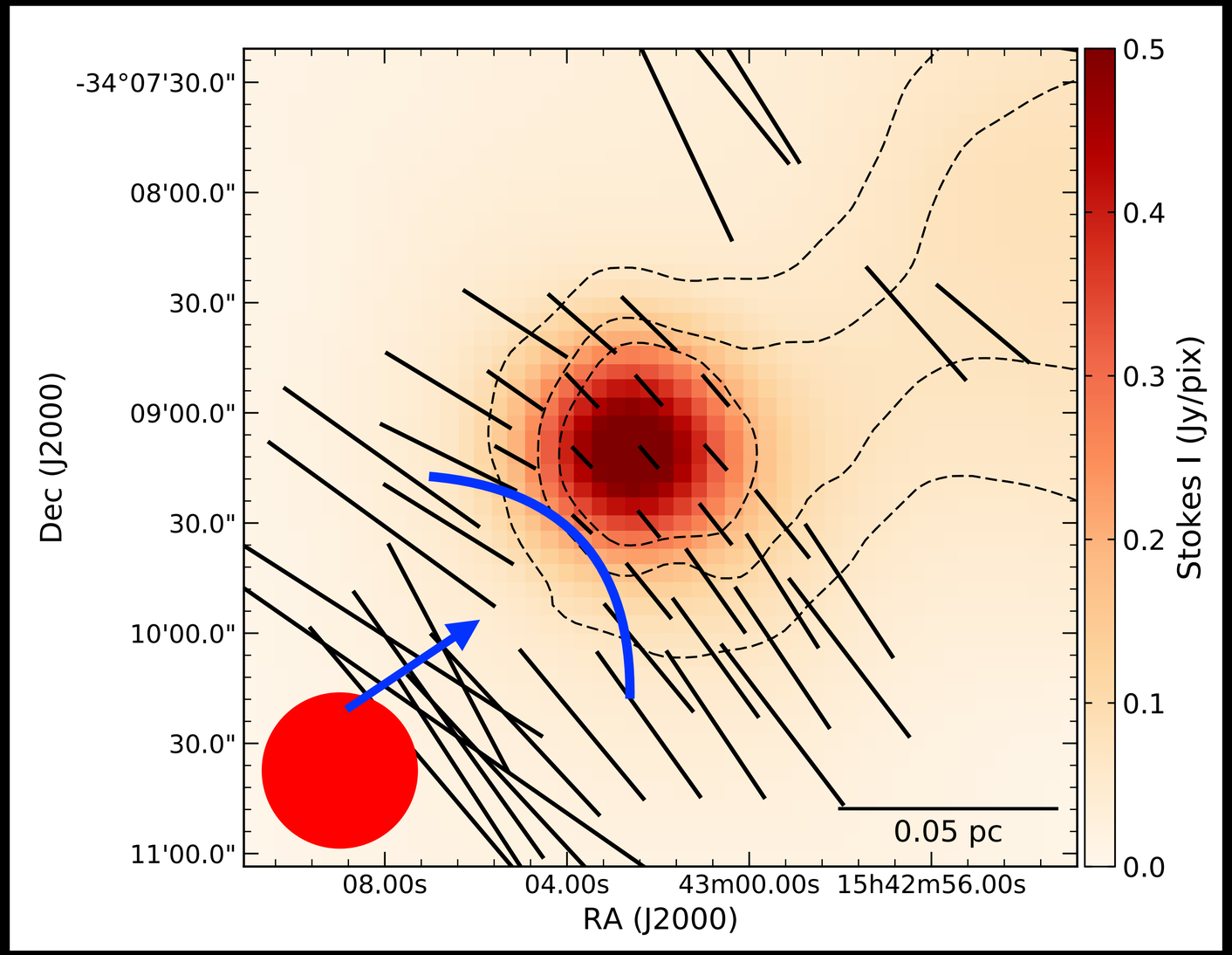


B-field is aligned with the outflow direction

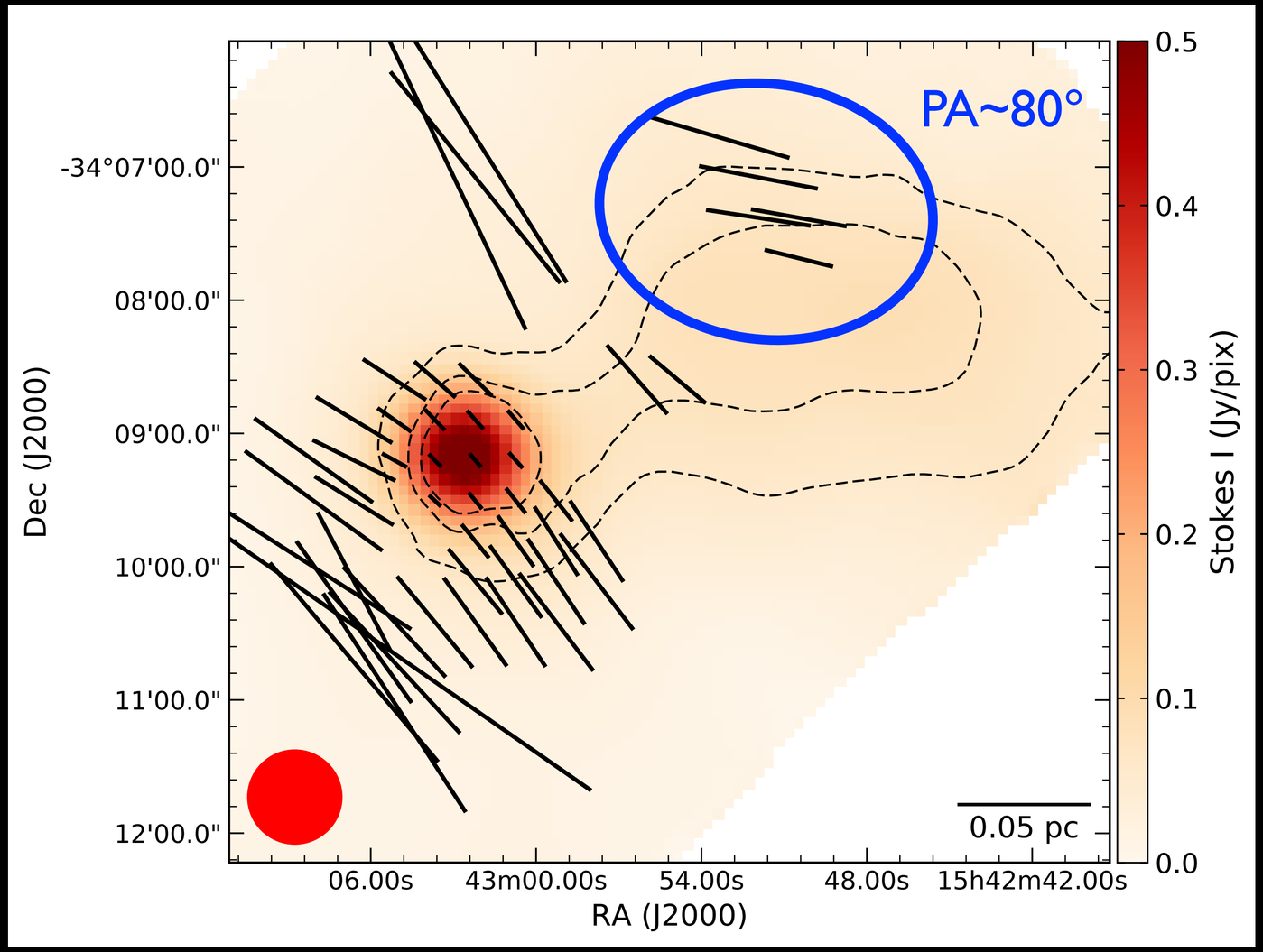
Hourglass shape



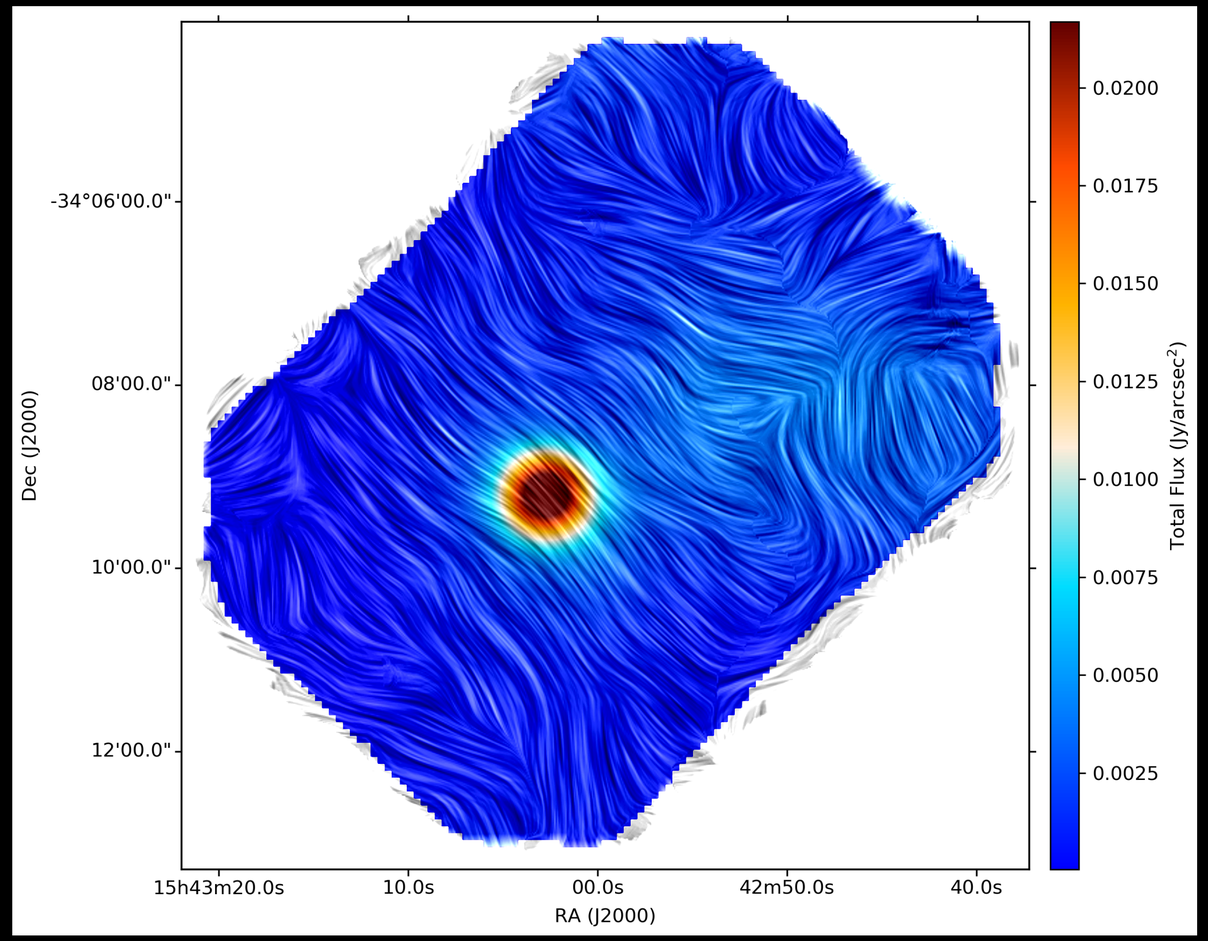
Hourglass shape



The filament

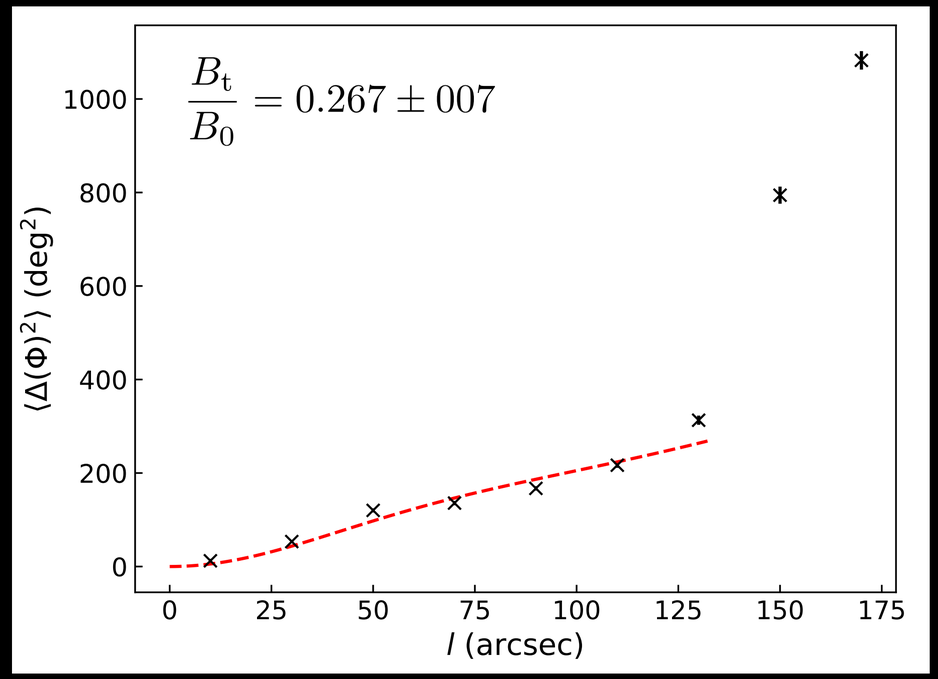


Magnetic field estimation



ADF analysis (Hildebrand, Houde+09)

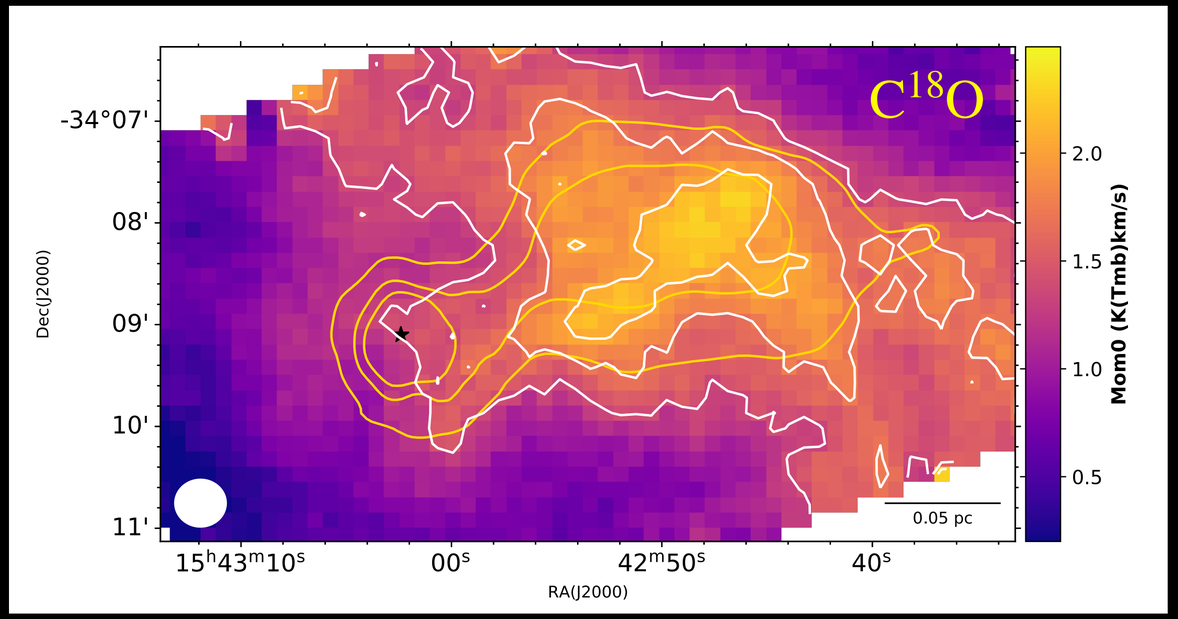
$$\langle \Delta\Phi^2(l) \rangle = 2\sqrt{2\pi} \left(\frac{B_t}{B_0} \right)^2 \frac{\delta^3}{\left(\delta^2 + 2W^2\right) \Delta'} \left[1 - \exp\left(-\frac{l^2}{2(\delta^2 + 2W^2)} \right) \right] + m^2 l^2$$



$$B_{\rm pos} = \sqrt{4\pi\mu m_{\rm H} n_{\rm H_2}} \frac{\sigma_V}{\delta\phi} \approx 80\,\mu{\rm G}$$

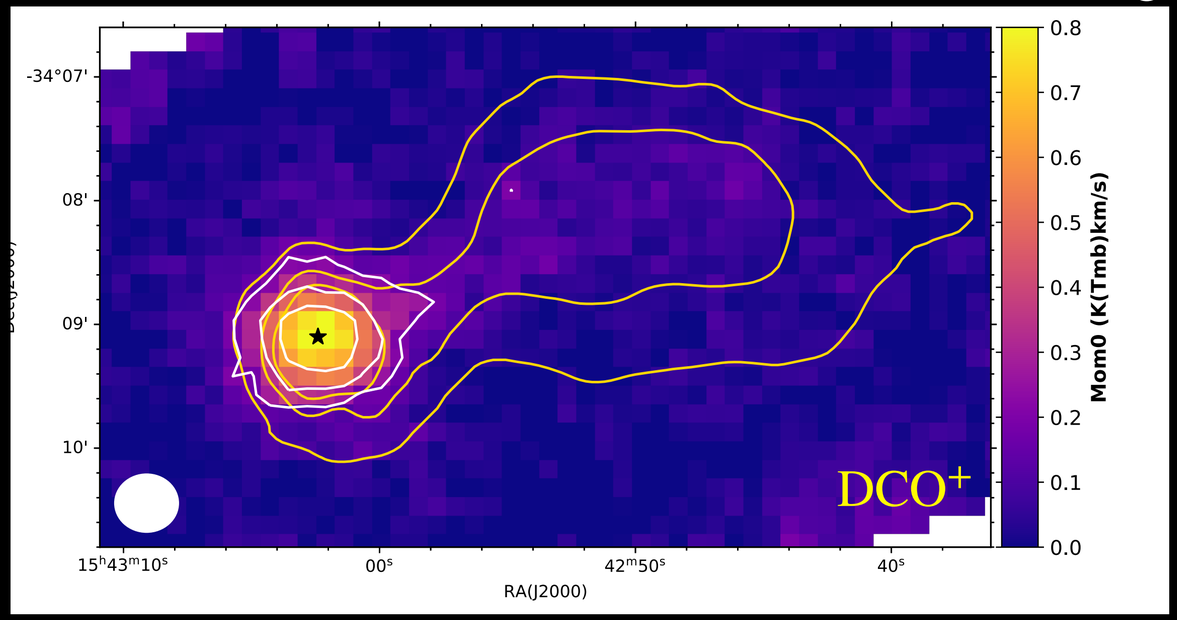
B-fields and kinematics

Farideh S. Tabatabaei
PhD candidate



$C^{18}O$:
Tracer of low-density gas

DCO^+:
Tracer of dense gas

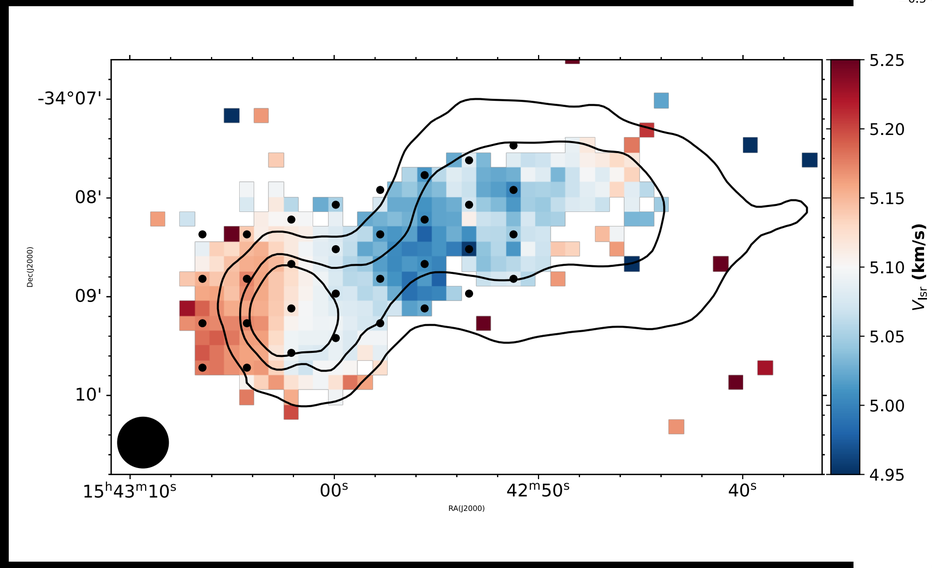


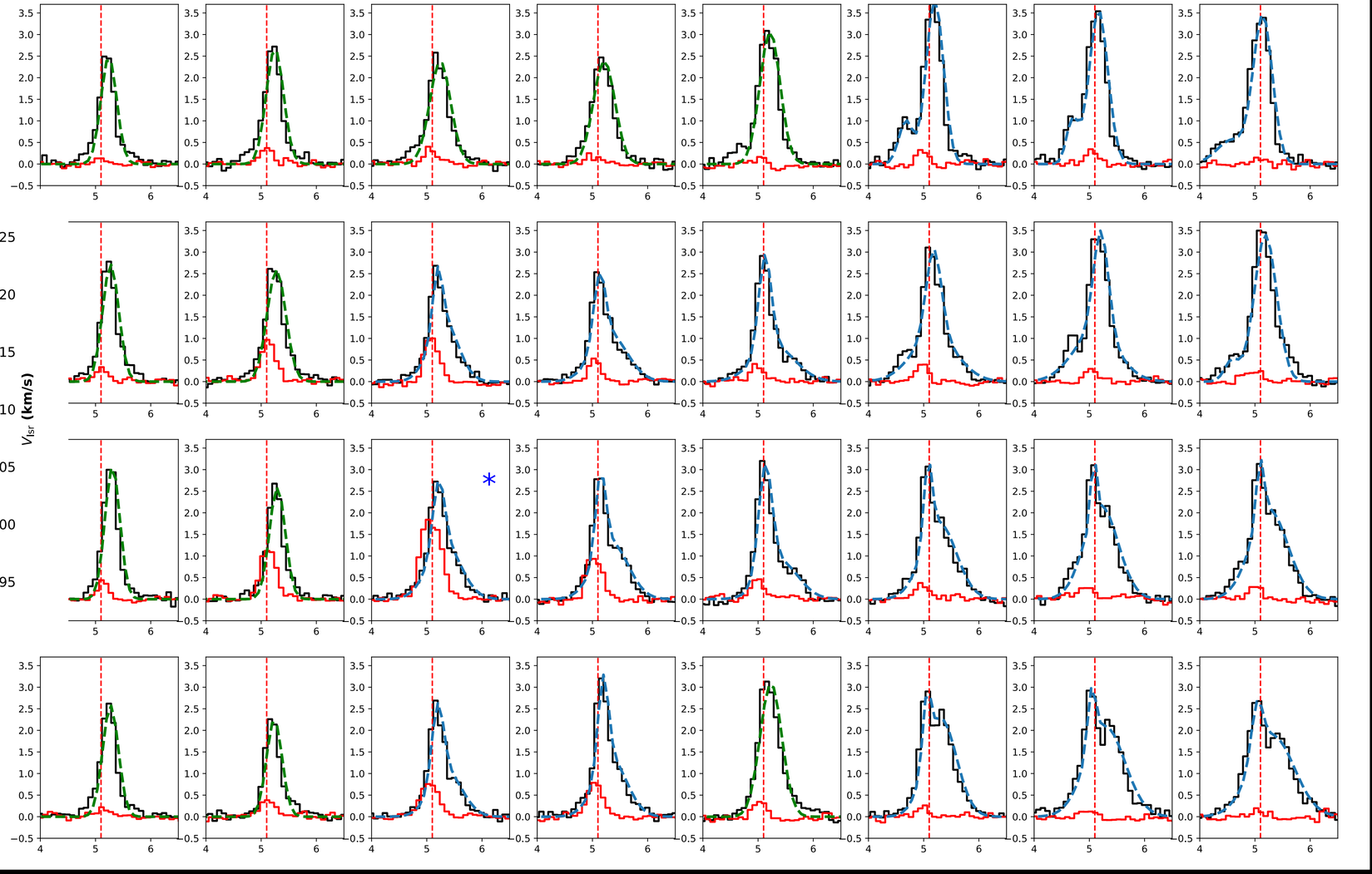
Data:

- APEX (PI 230)
- Angular resolution ~ 28”
- $C^{18}O$ (2-1) , 219.560 GHz
- DCO^+ (3-2), 216.113 GHz

B-fields and kinematics

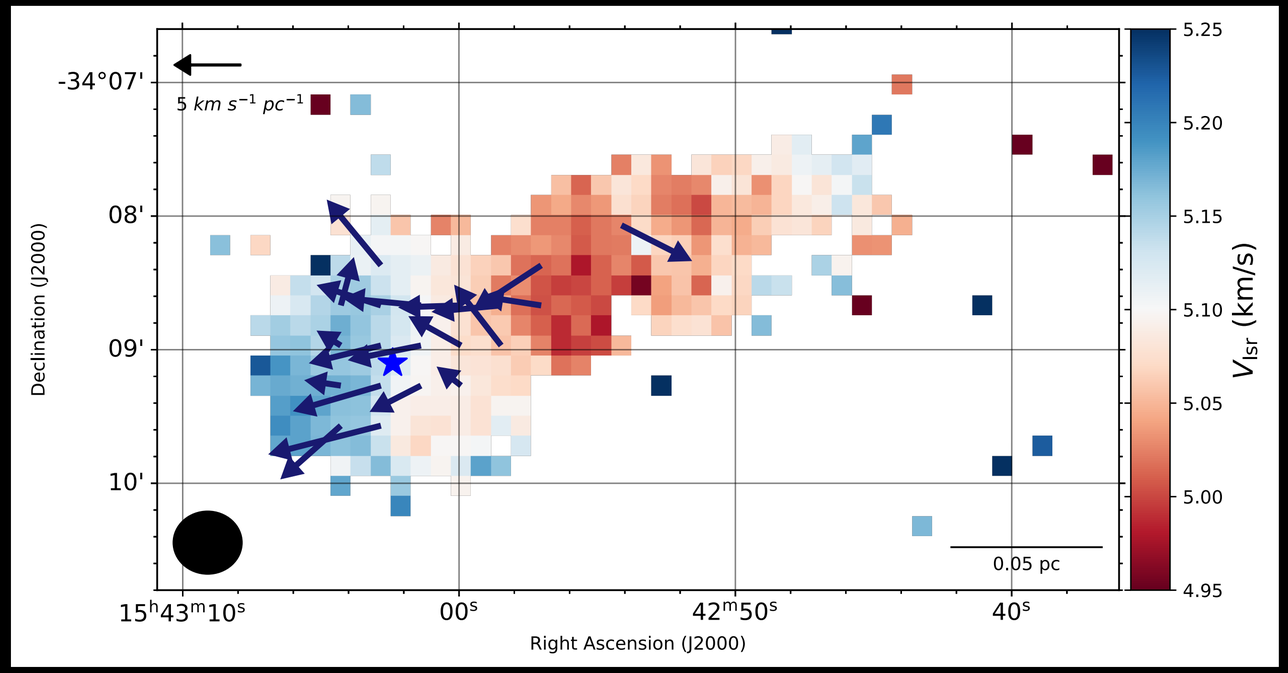
Red spectra: DCO^+
Black spectra: $C^{18}O$
Blue and Green Curve: $C^{18}O$ fit





Tabatabaei et al. (2023)

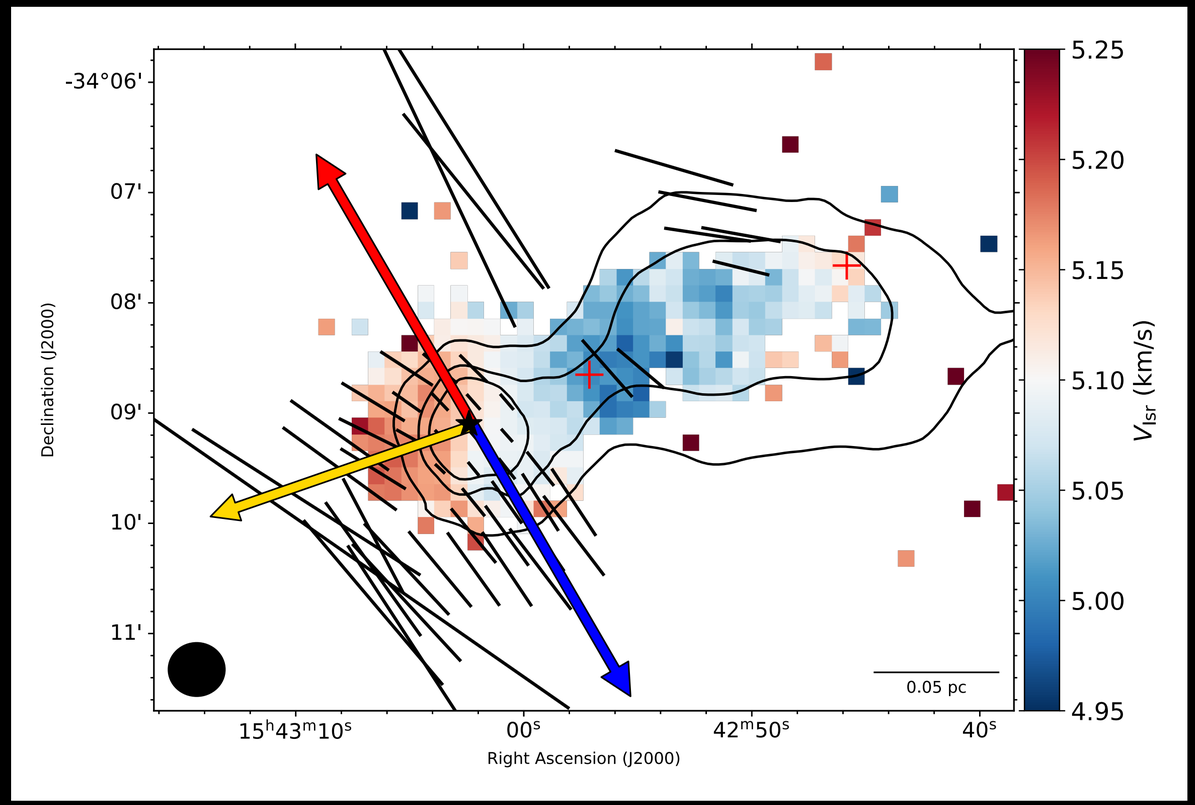
Velocity gradients



Mass accretion rate ~ $9.7 \times 10^{-7}\,\mathrm{M_\odot\,yr^{-1}}$

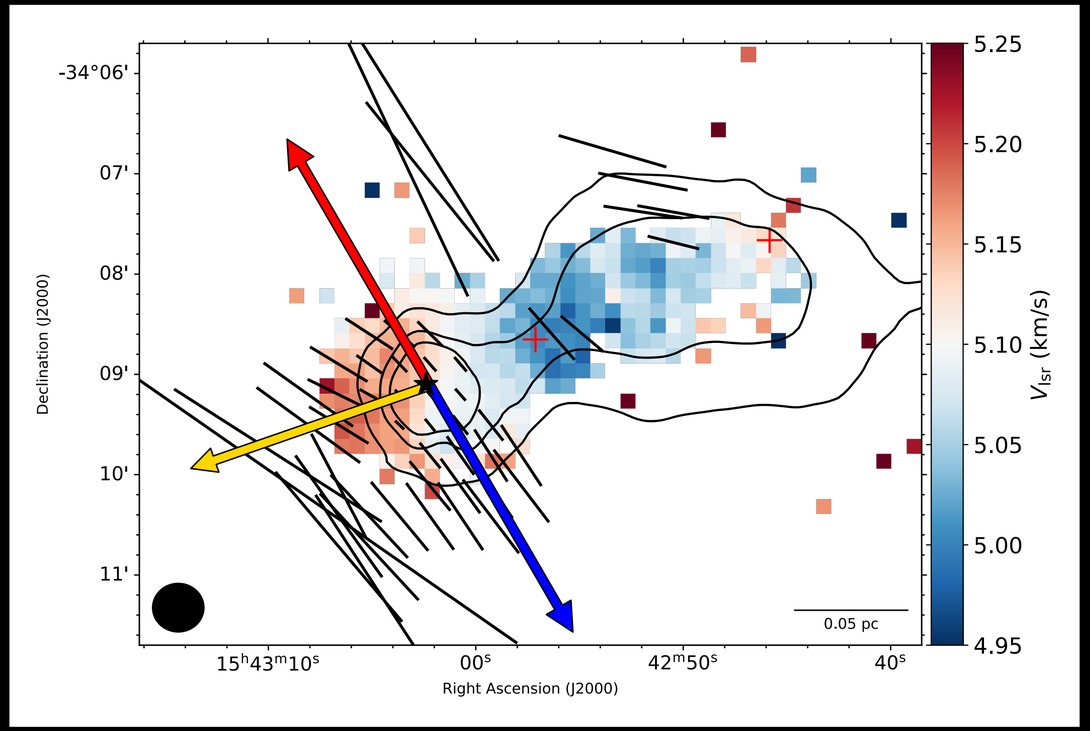
$\dot{M}_{\rm acc} = 10^{-6}\,\mathrm{M_\odot\,yr^{-1}}$ Pineda +2020

$\dot{M}_{\rm acc} = 3 \times 10^{-6}\,\mathrm{M_\odot\,yr^{-1}}$ Evans+2015



Conclusions

- The uniform magnetic field with hints of line bending suggest a protostellar evolution in a magnetic-dominated fashion
- The line observations reveal the core rotation and possibly some accretion of material along the filament that has bent the field direction



A wonderful synergy