Detection of a Magnetized Disk Around a Young Protostar

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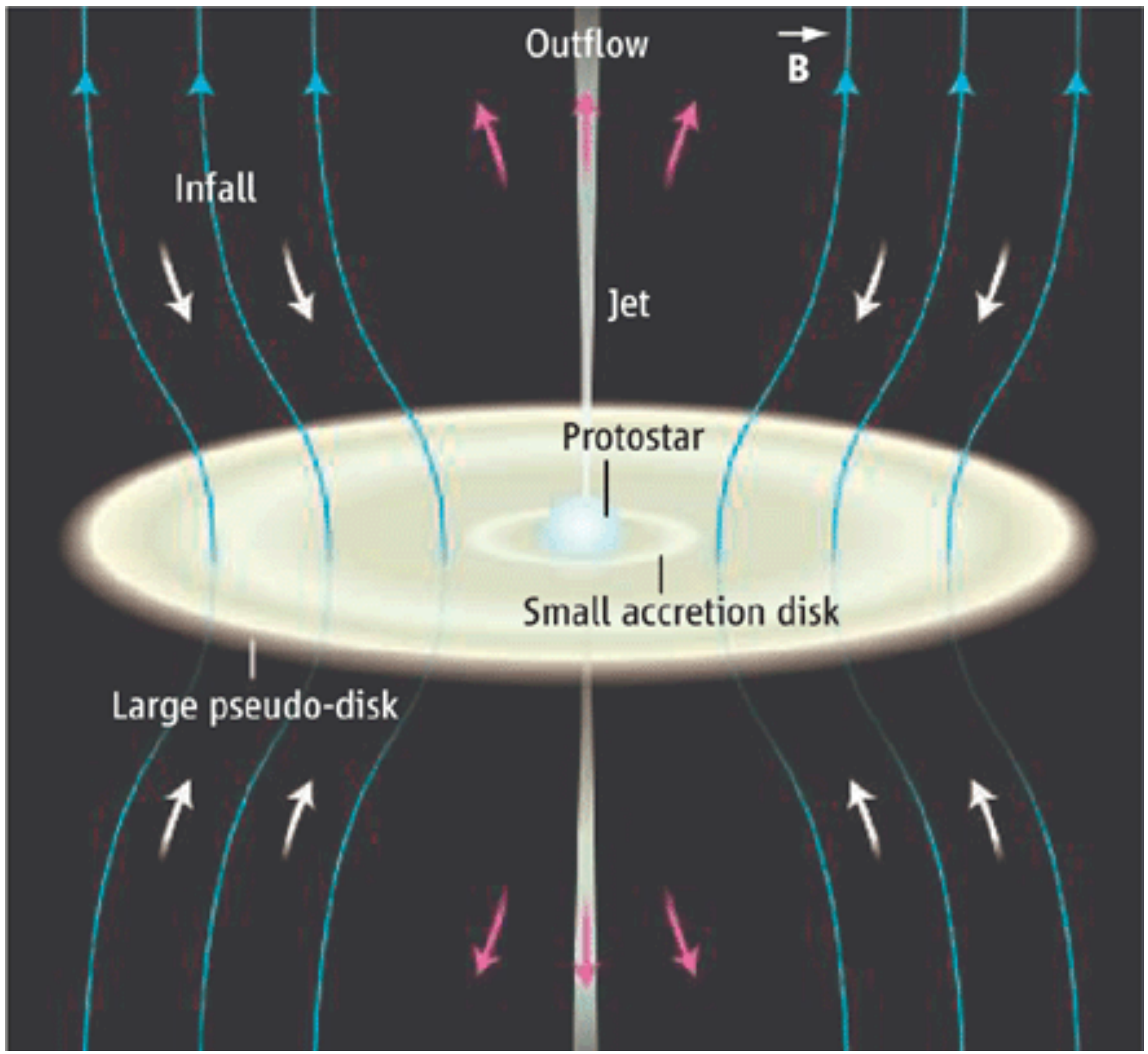
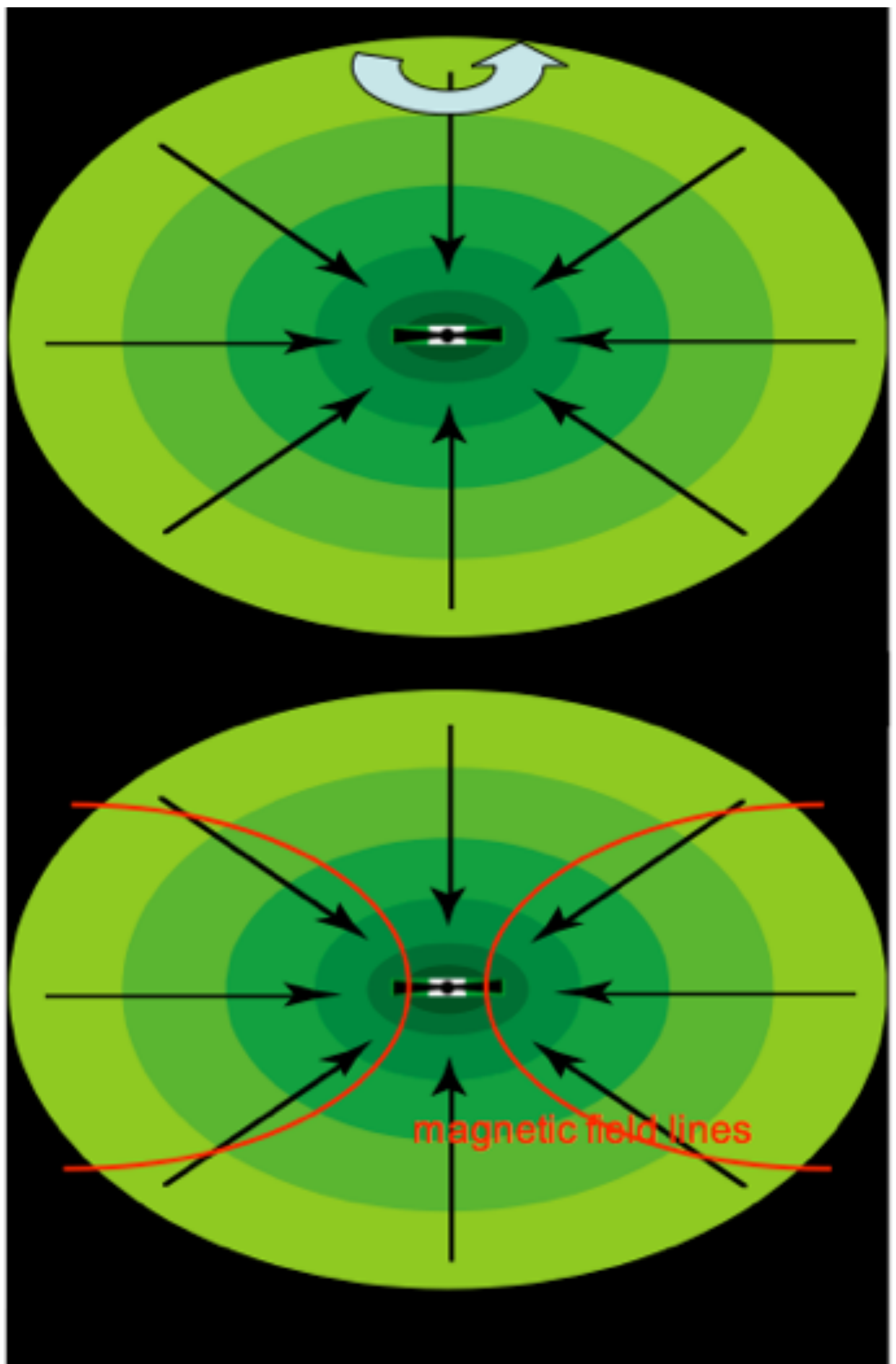
Standard Paradigm of Magnetically Regulated Star Formation



Crutcher 06

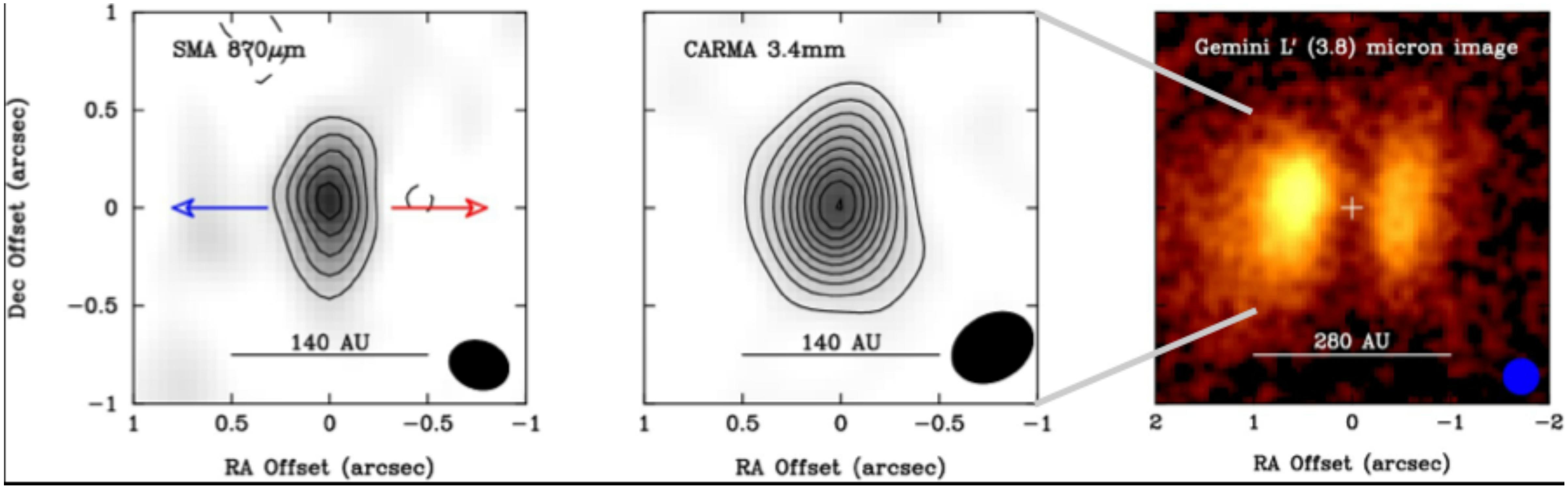
Magnetic Fields can Impede Disk Formation

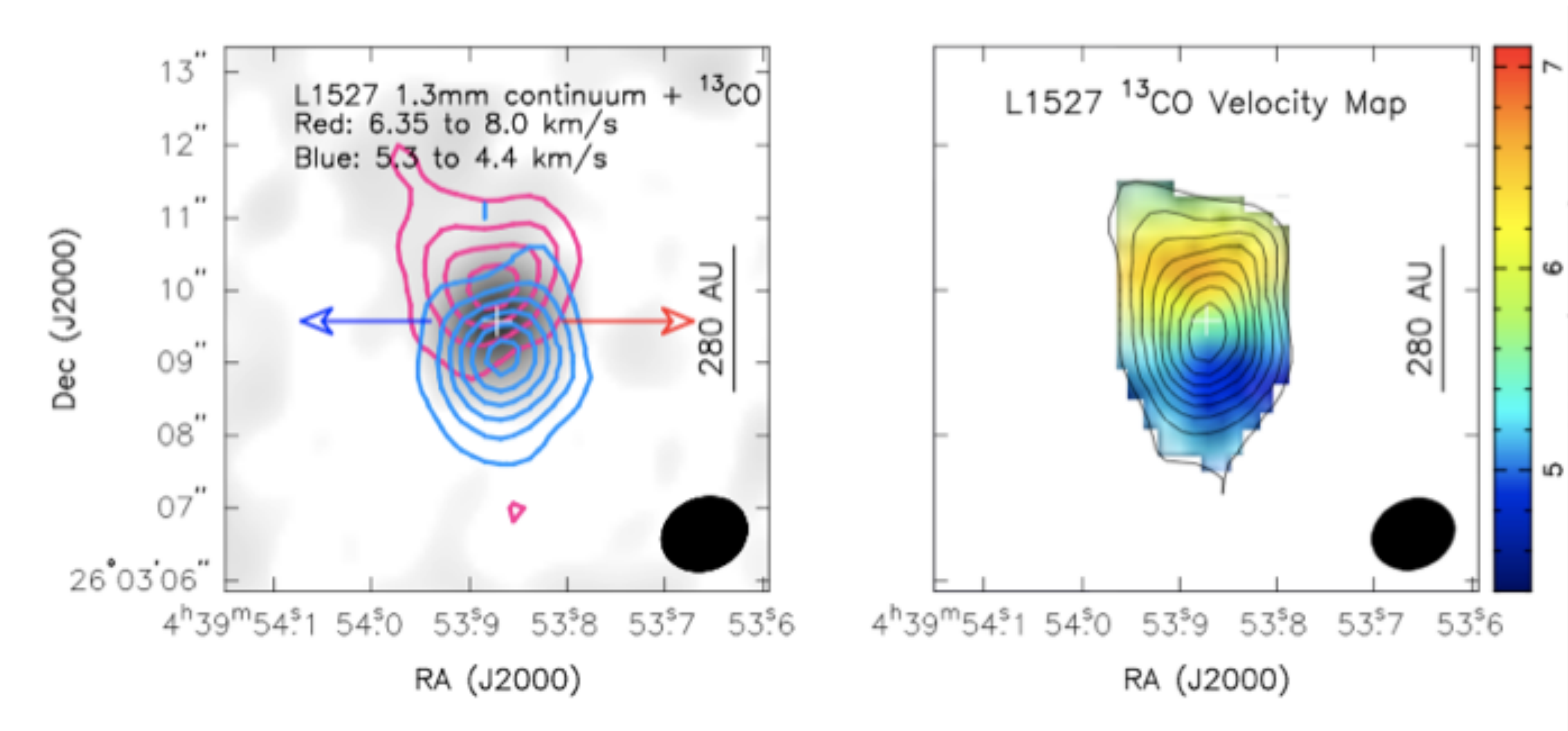


- Disks form from the collapse rotating cores due to conservation of angular momentum
- But, fast rotating disk and slowly rotating envelope are interconnected magnetically THRU *magnetic braking*
- Thus, disk formation is not guaranteed
- And only small disks can be formed

Slide courtesy Zhi-Yun Li; See Li+ 2014 PPVI

L1527: Total Intensity



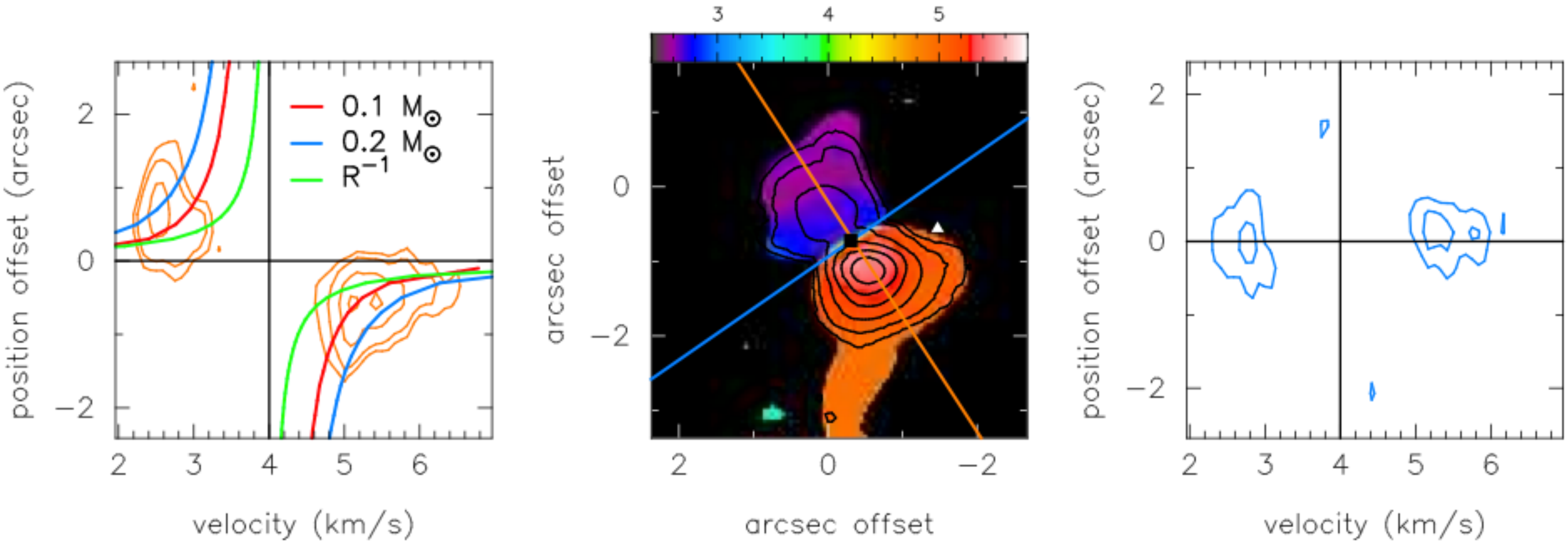


L1527

Tobin+12

See also: Poster by Yen

VLA 1623A: Total Intensity



Murillo +13: ALMA C18O 2 ->1 observations of VLA1623 A and fitted models.

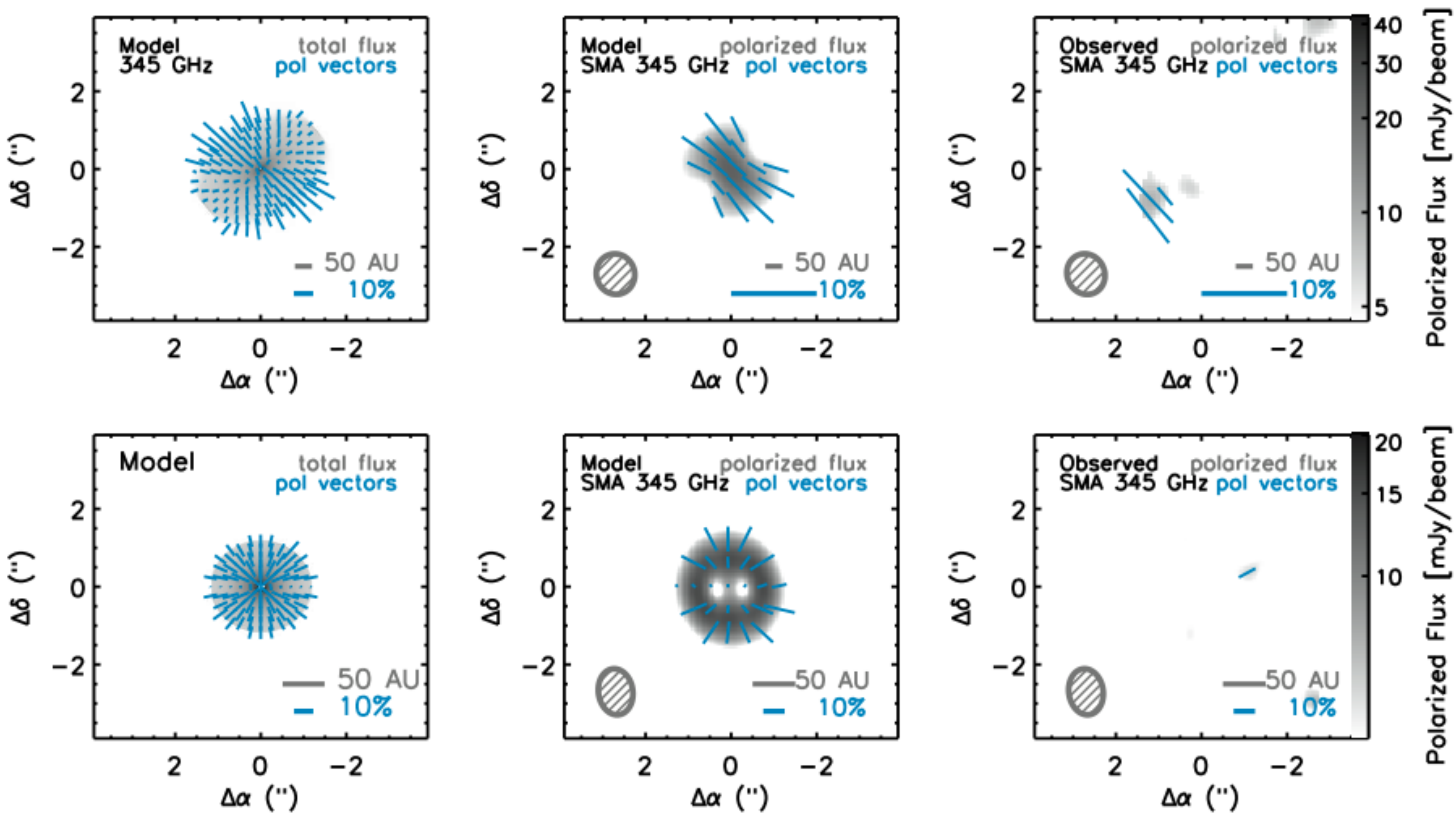
Disk is 50 AU in size

Also, Yen and his collaborators have made extensive studies in more than 17 YSOs with both SMA and ALMA follow up.

Challenges in Detecting the Magnetic Field Structures in these Disks?

- Extremely difficult to detect magnetic fields
  - sensitivity ~ with SMA and CARMA need a few 100 mJy sources
  - structure ~ inclination can play an important role
  - grain alignment ~ depends on grain properties, external conditions such as B field, radiation, densities etc.

Previous Observations

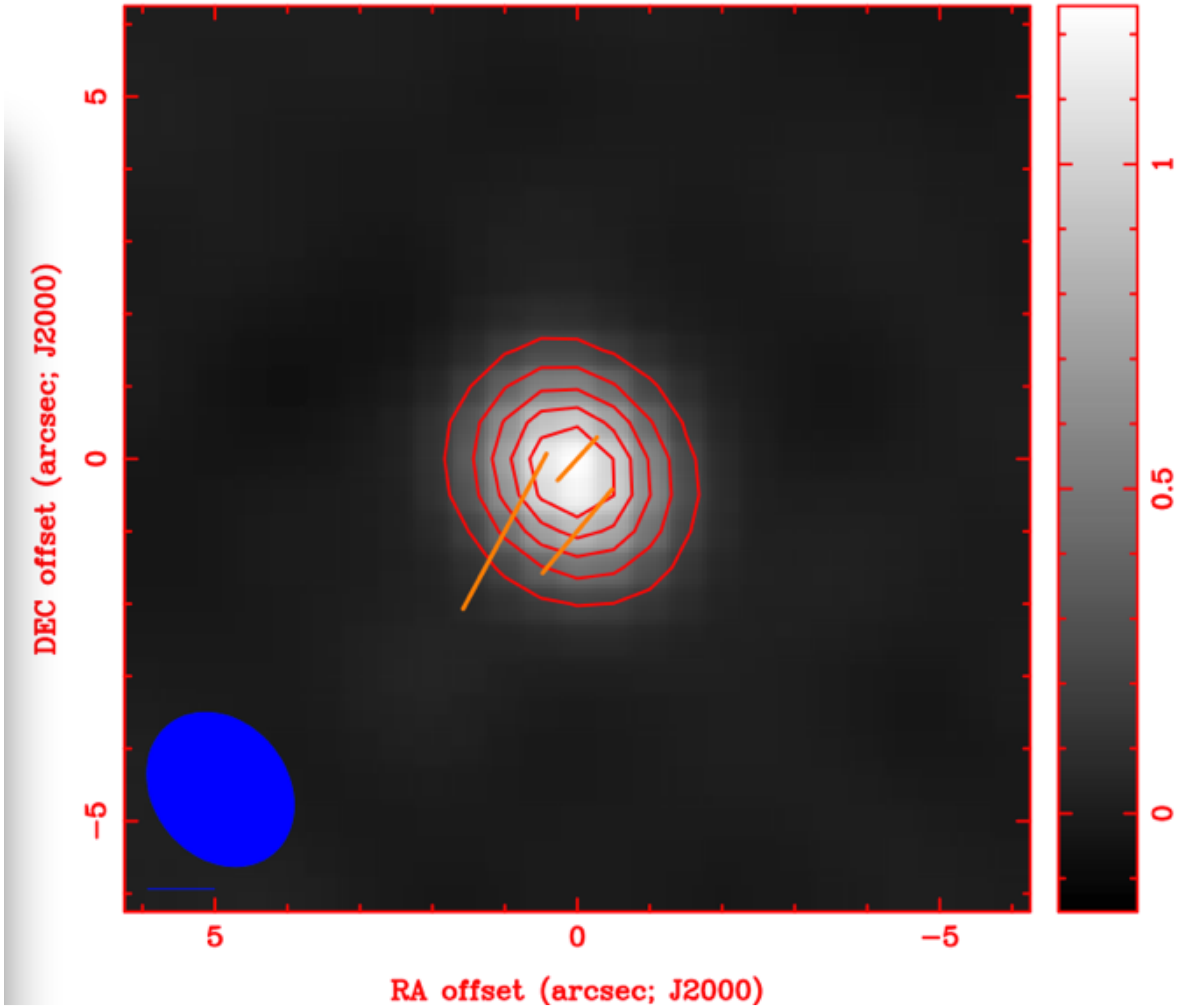


No detections in HD 163296 and TW Hya
Hughes+ 09

HL Tau: SMA

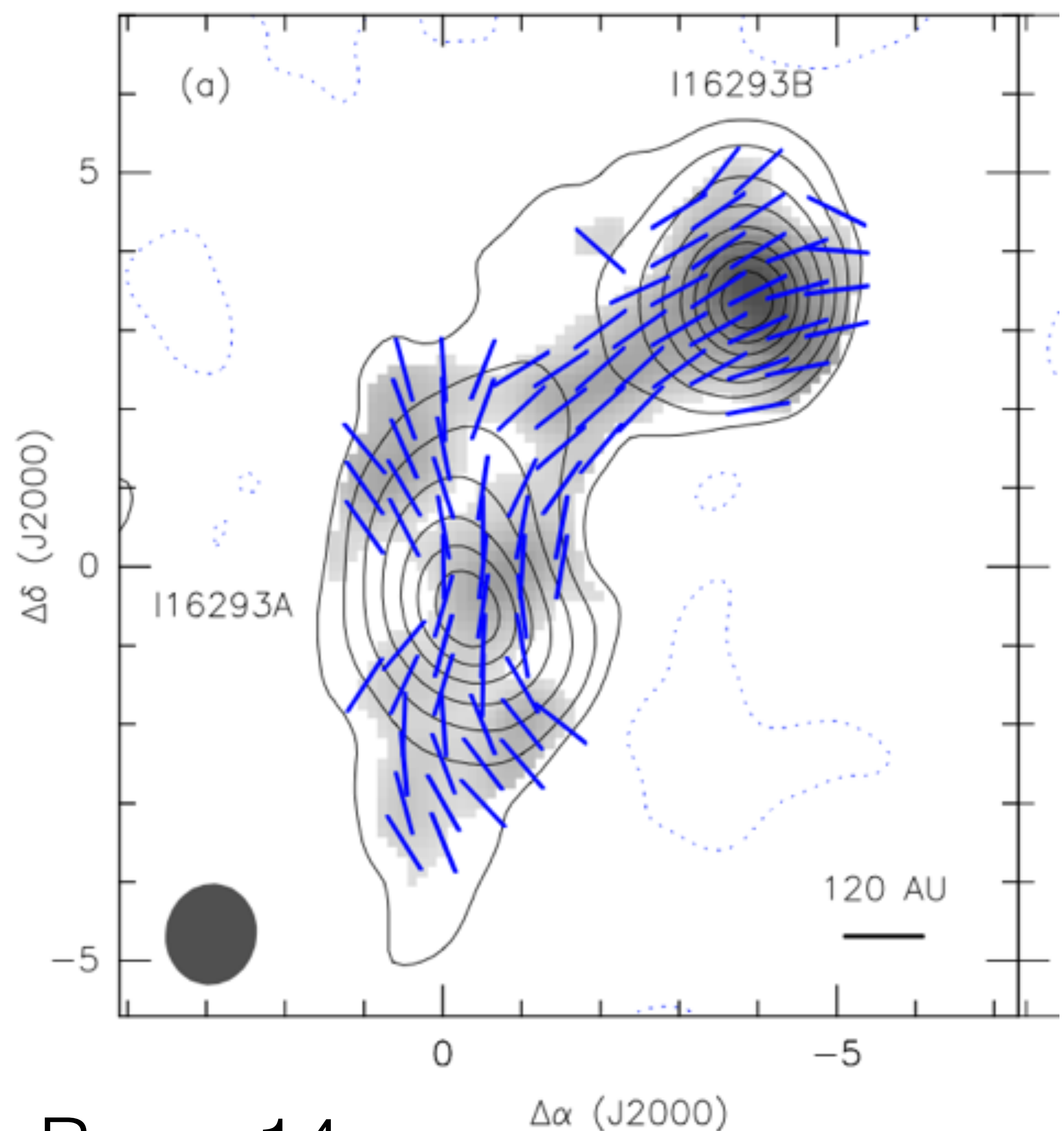
SMA 0.87 mm

P= 0.86+/-0.4%



Magnetic Field Structure in IRAS 16293

- SMA combined array observations
- Resolution is 1.2” compared to 2.5” from the compact array observations reported in Rao+ 09
- Emission from the envelope (extended structure) and the disk (compact structure) is intermixed and we need to separate the two.

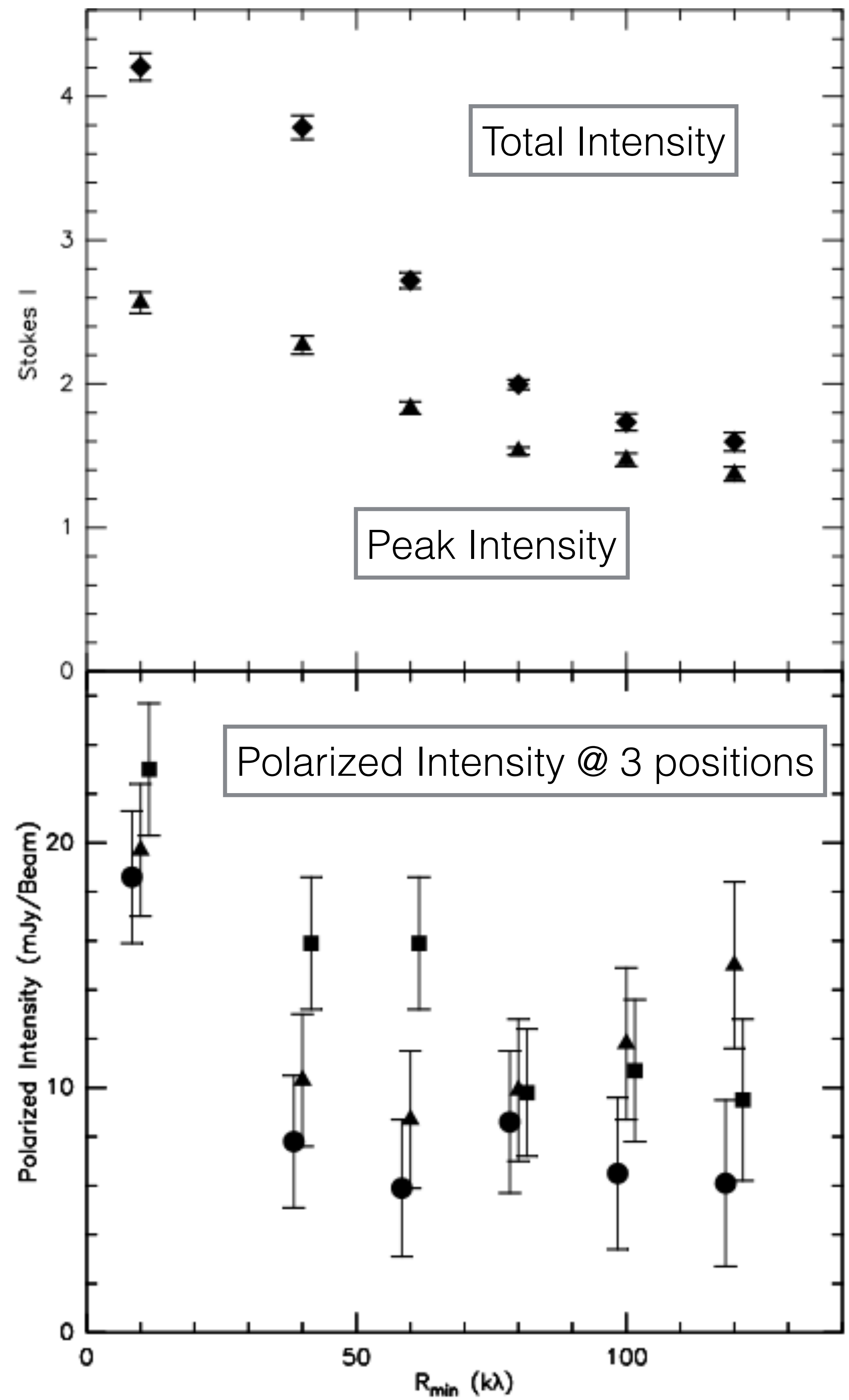


Rao+ 14

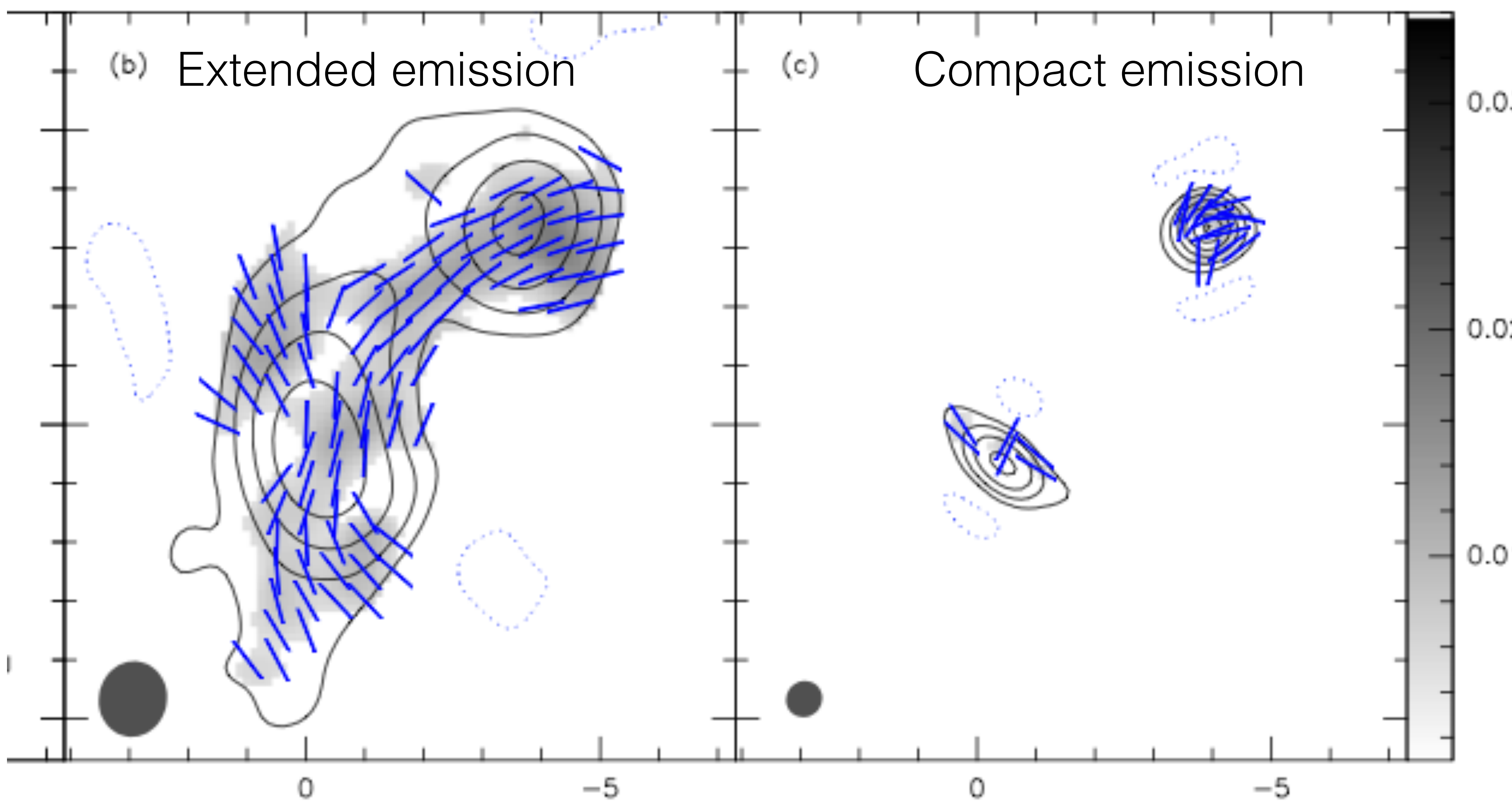
Separating the Extended Emission and the Compact Emission in I16293B

- Make images by having a lower cutoff in u-v distance.
- Both Stokes I (total and peak) and polarized intensity decrease initially
- Beyond 80 k lambda, the emission is constant
- Implies that the emission from the envelope is resolved out and that we are only looking at the disk
- Numbers for disk size and flux consistent with EVLA and ALMA observations of I16293B

Rao+ 14



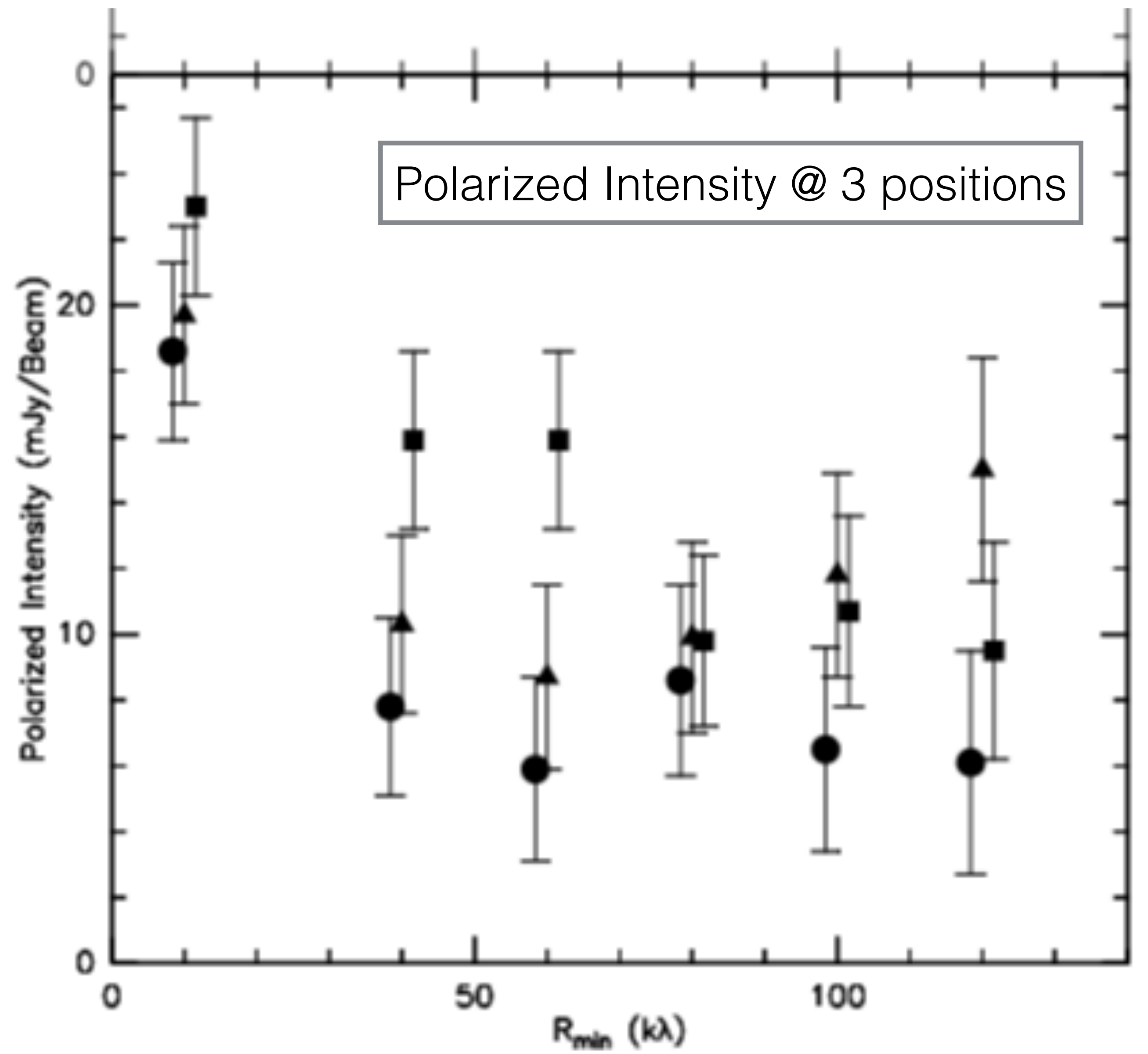
Emission at Various Scales



Rao+ 14

Polarized Flux Density Analysis

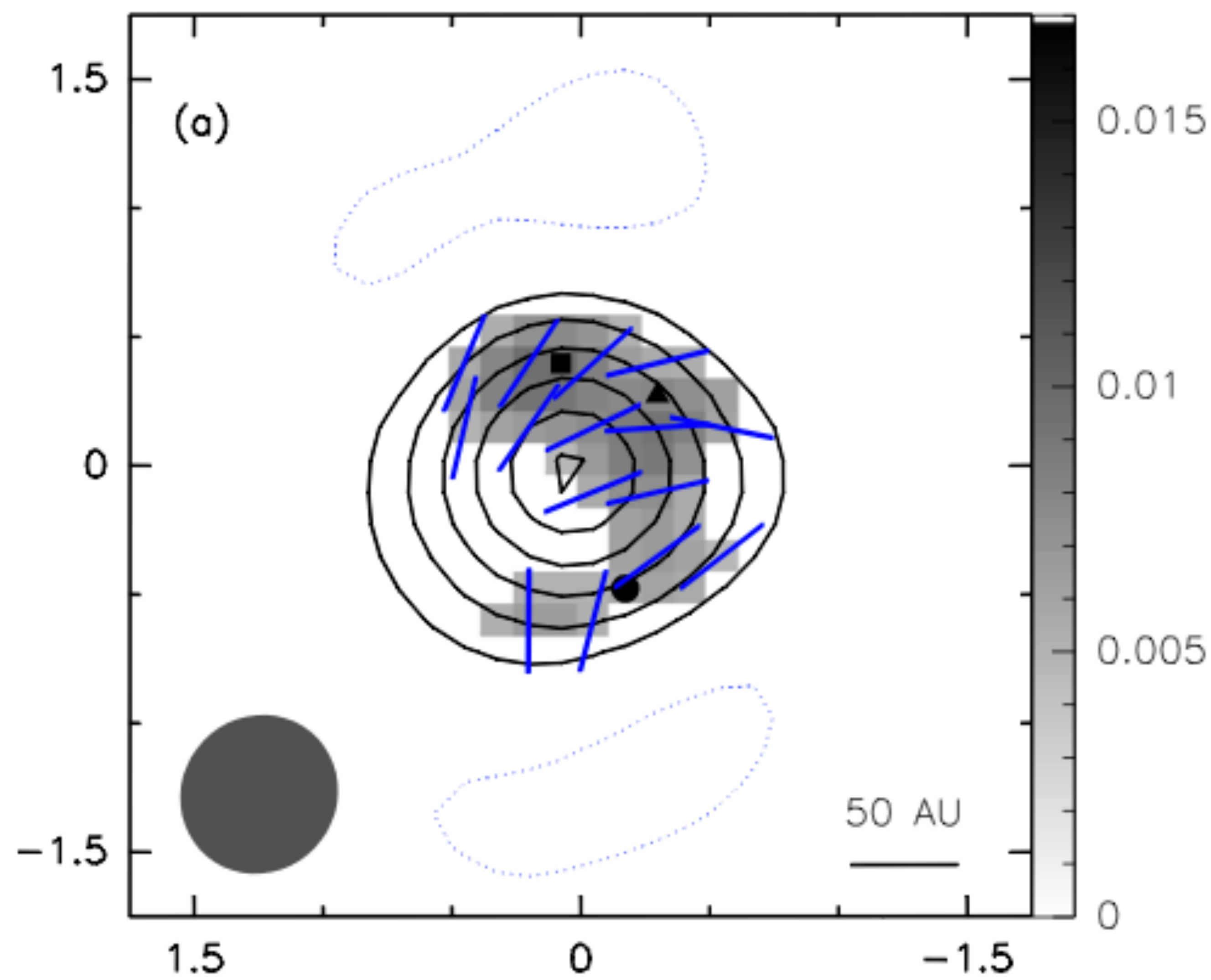
- Stokes I, Q, U may have different distributions. Need care.
- Compare with synthetic gaussians of Q,U



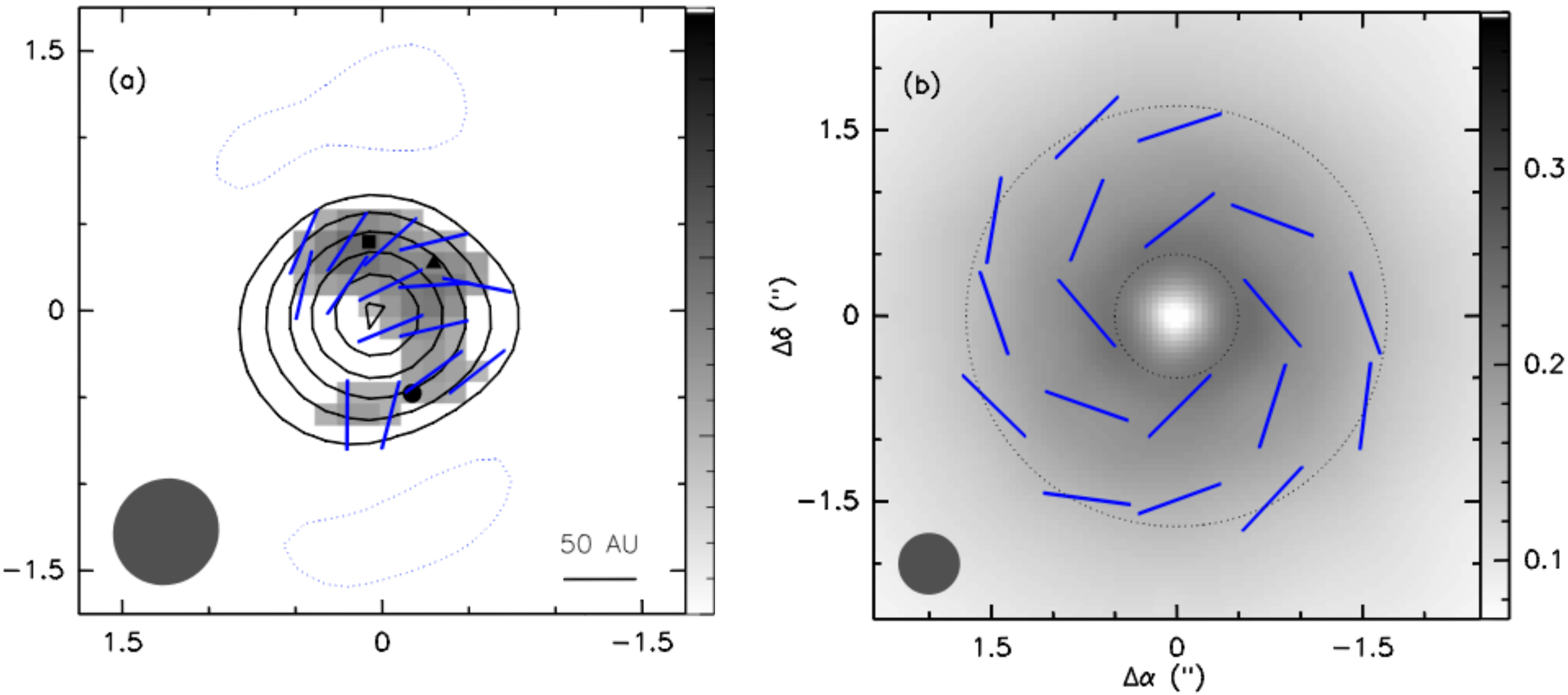
Rao+ 14

Polarization Structure in the Disk surrounding IRAS16293B

- The polarization structure is considerable different when compared to what we had when looking at the total emission
- In fact it has an azimuthal or partial ring structure
- Suggestive of a toroidal magnetic field that is being wrapped up by the rotation of the disk.



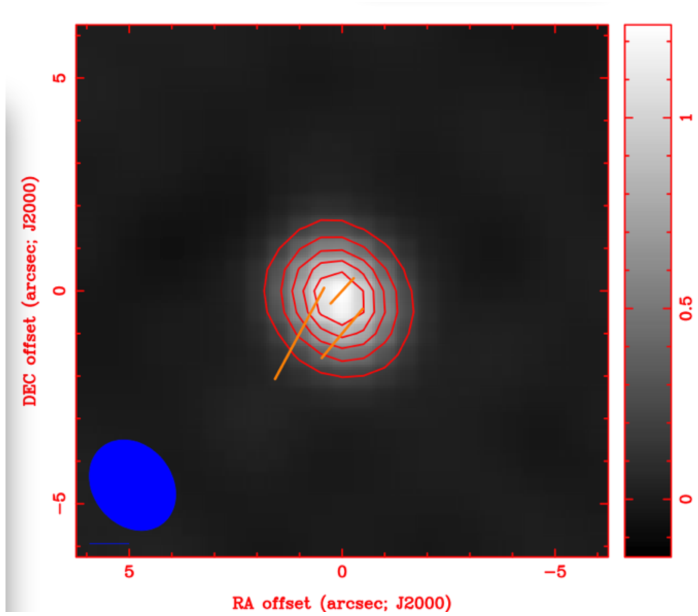
Comparison with Simulations



distance ~ 140 pc; t_collapse ~ 1.94x10^4 years

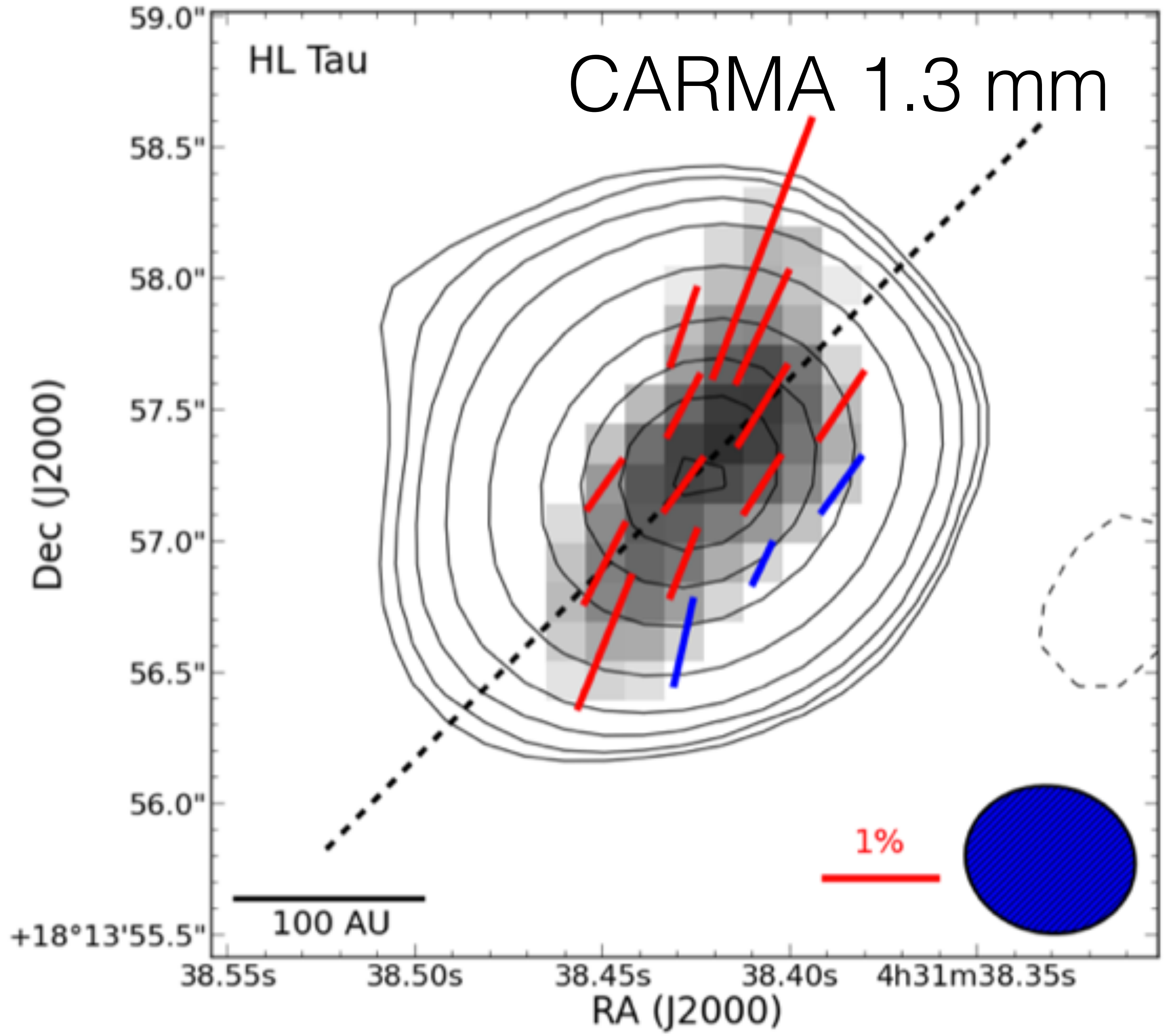
Hennebelle & Ciardi 09; Padovani+ 12

HL Tau: CARMA



SMA 0.87 mm

Red Vectors: >3σ detections
Blue Vectors: 2-3σ detections



Stephens et al. in prep

Summary

- We have made the first detections of the magnetic field structure in the circumstellar disk.

- While theoretical studies show that disk formation is difficult in the presence of magnetic fields, they also show that other non-ideal MHD processes may be able to allow disk formation. (Li+ 14; PPVI)

- ***FUTURE***:

    - SWARM with full bandwidth along with SMA low instrumental polarization.

    - ALMA Cycle 2 polarization observations