POLARIZATION SCIENCE WITH **CARMA**

PROBING SMALL-SCALE MAGNETIC FIELDS IN STAR-FORMING REGIONS

Chat Hull

University of California, Berkeley

Radio Astronomy Laboratory

10 April 2013

Special Session: Polarization

ALMA 2013 Rocks!

Kona, Hawai'i

Outline

- **CARMA**
  - 1mm polarization system
- **Science results & future proposals**
  - TADPOL survey: protostellar polarization
  - Circumstellar disk polarization & formation
  - Other projects: Serpens, SgrA*

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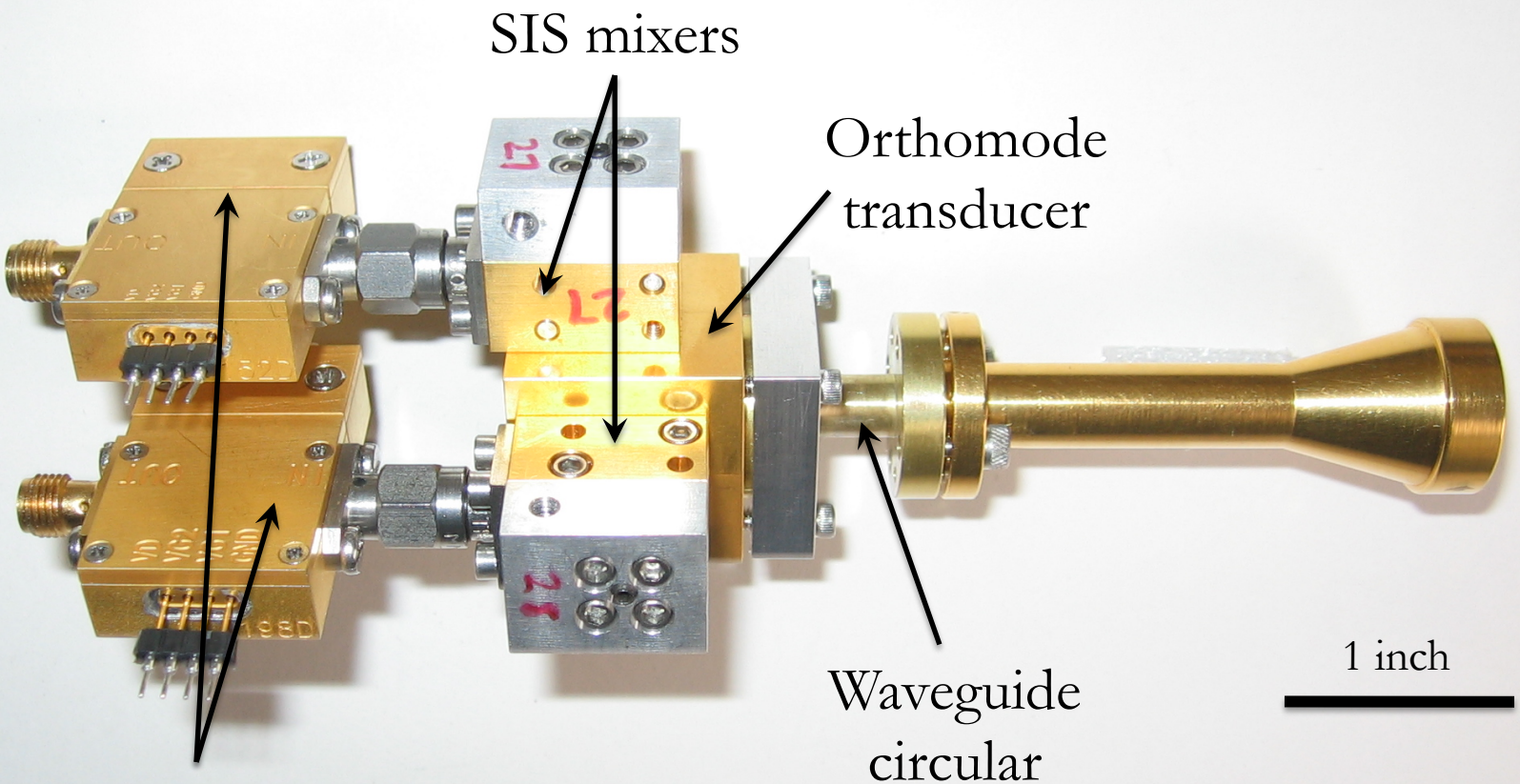
CARMA

Combined **A**rray for **R**esearch in **M**illimeter-wave **A**stronomy

Consortium: Berkeley, Caltech, Illinois, Maryland, Chicago

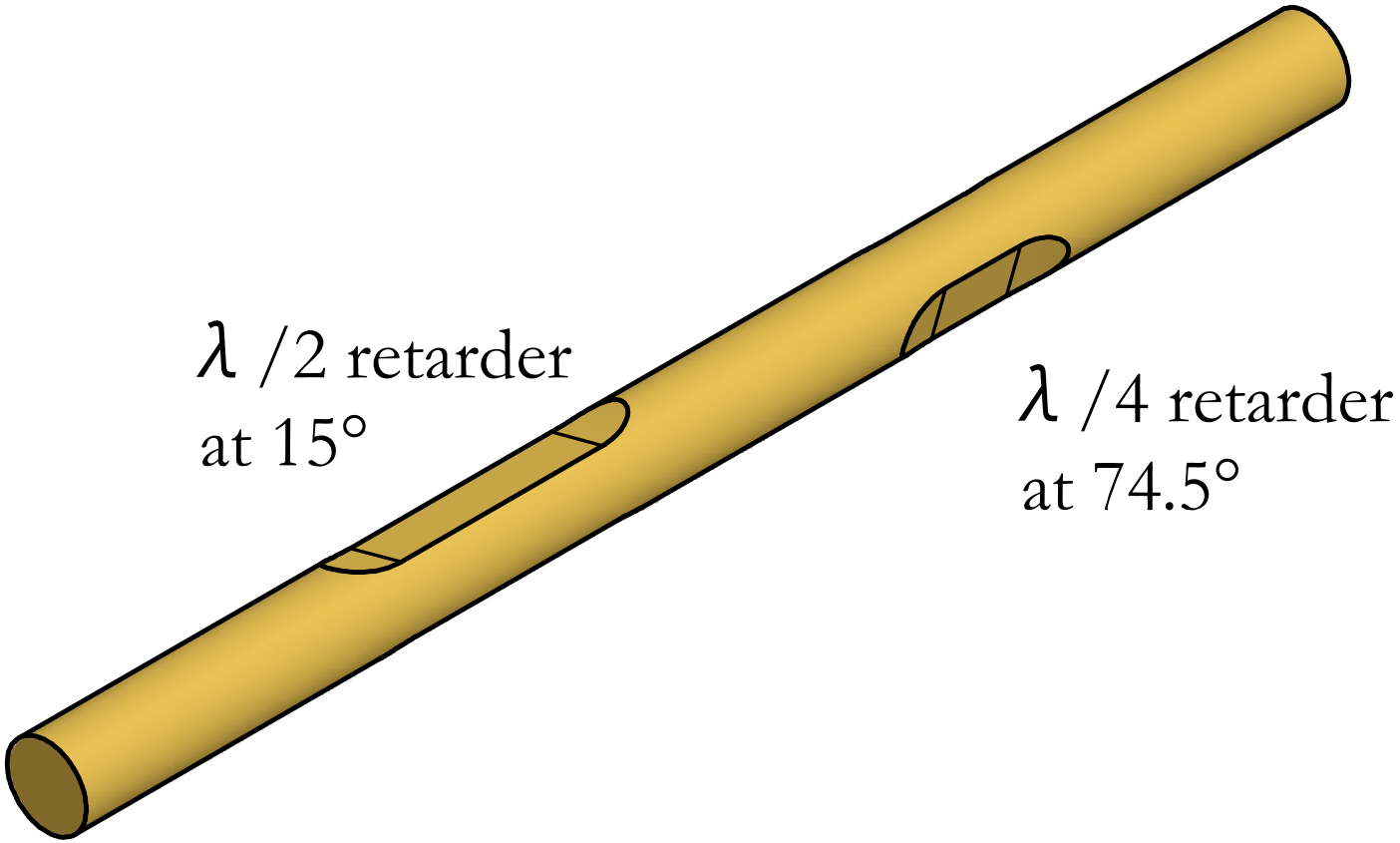
- 6 ×10-m, 9 × 6-m, 8 × 3.5-m telescopes
- Observations at 1 cm, 3 mm, and **1 mm (polarization!)**
- Located in Cedar Flat, CA (near Bishop)

1 mm dual-polarization receivers



Credit: Dick Plambeck

Wideband, 2-section polarizer



Polarizer simulation

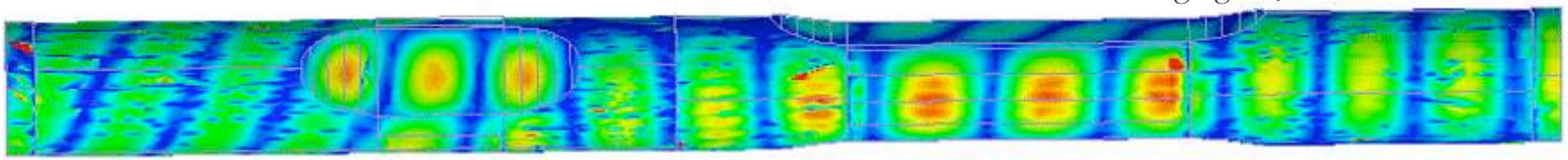
← Feed horn (sky)

OMT →

Plambeck & Engargiola, CARMA Memo #54

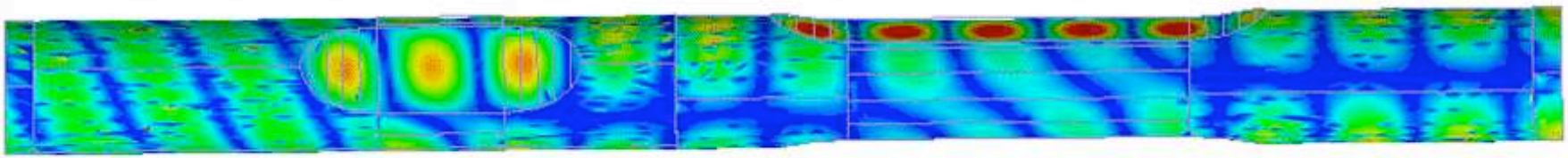
RCP

X



LCP

Y



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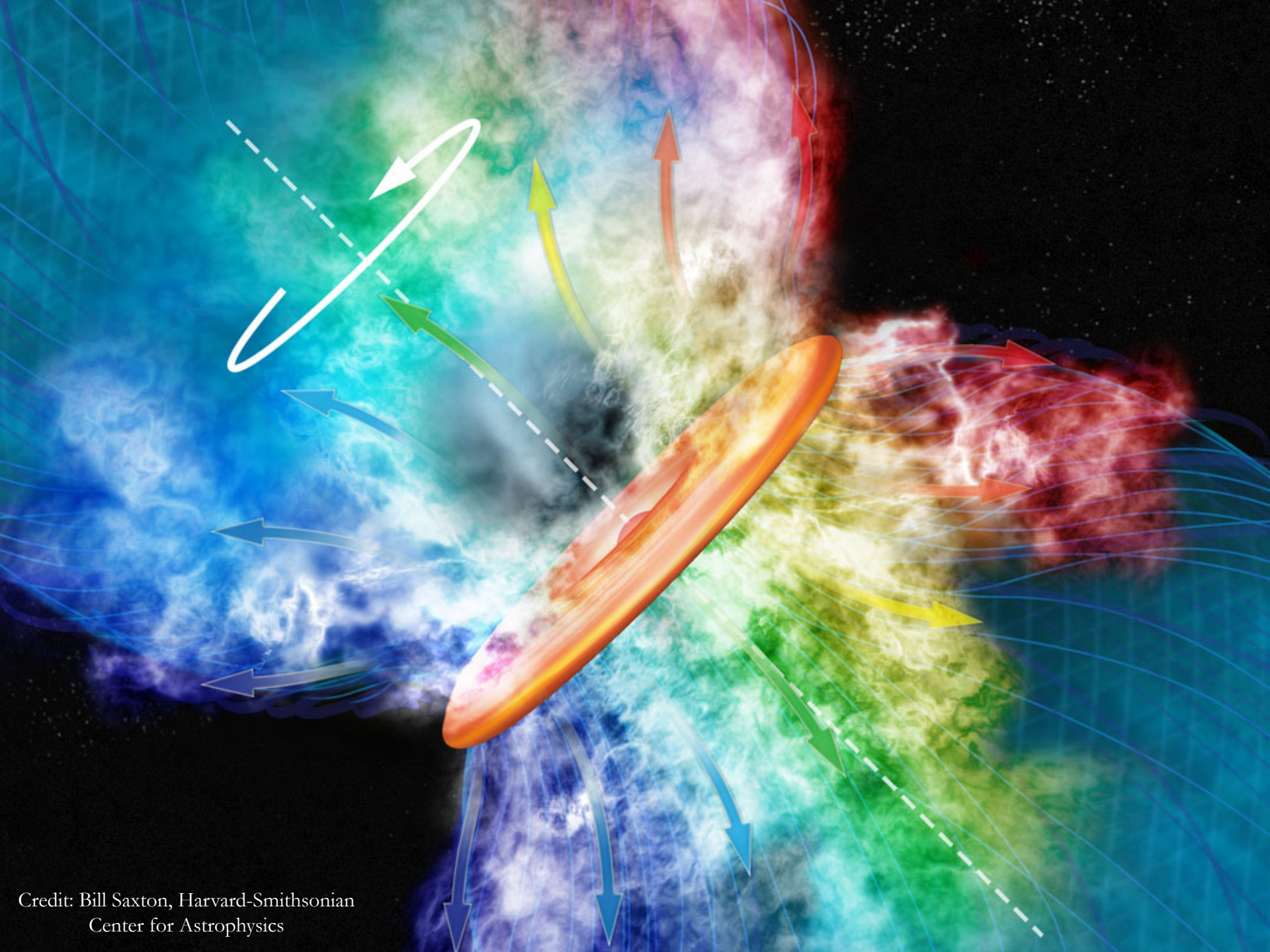
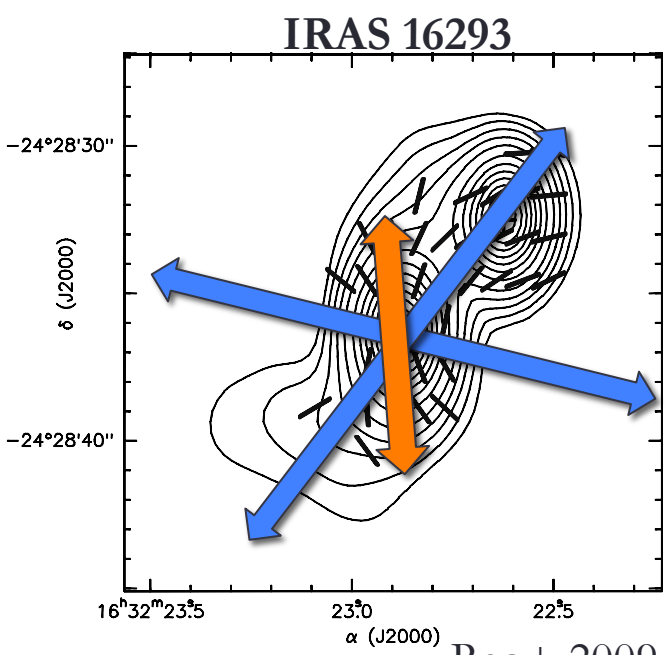
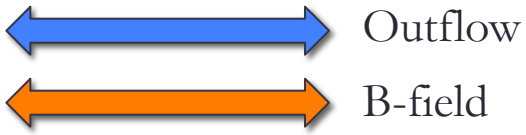


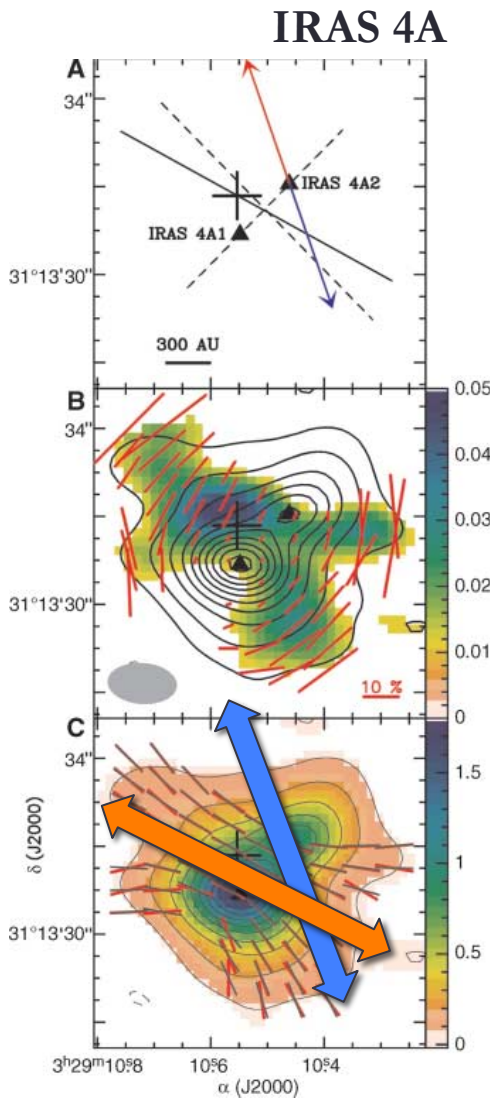
Credit: Bill Saxton, Harvard-Smithsonian Center for Astrophysics

Misalignment of B-fields and outflows



Rao+ 2009





Girart+ 2006

TADPOL collaboration

- **UC Berkeley**

  Chat Hull (PI), Dick Plambeck, Mel Wright, Carl Heiles, Geoff Bower

- **University of Maryland**

  Marc Pound, Alberto Bolatto, Katherine Jameson, Lee Mundy

- **Caltech**

  Thushara Pillai, John Carpenter, James Lamb, Nikolaus Volgenau

- **University of Illinois, Urbana-Champagne**

  Ian Stephens, Leslie Looney, Woojin Kwon, Dick Crutcher, Nick Hakobian

- **Other**

  Dan Marrone (Arizona), Meredith Hughes (Wesleyan), John Vaillancourt & Göran Sandell (USRA-SOFIA), John Tobin (NRAO), Jason Fiege (Manitoba), Erica Franzmann (Manitoba), Martin Houde (UWO, Caltech), Brenda Matthews (NRC-CNRC)

TADPOL survey

35 sources

Triples number of interferometric polarization maps

~300 observing hours

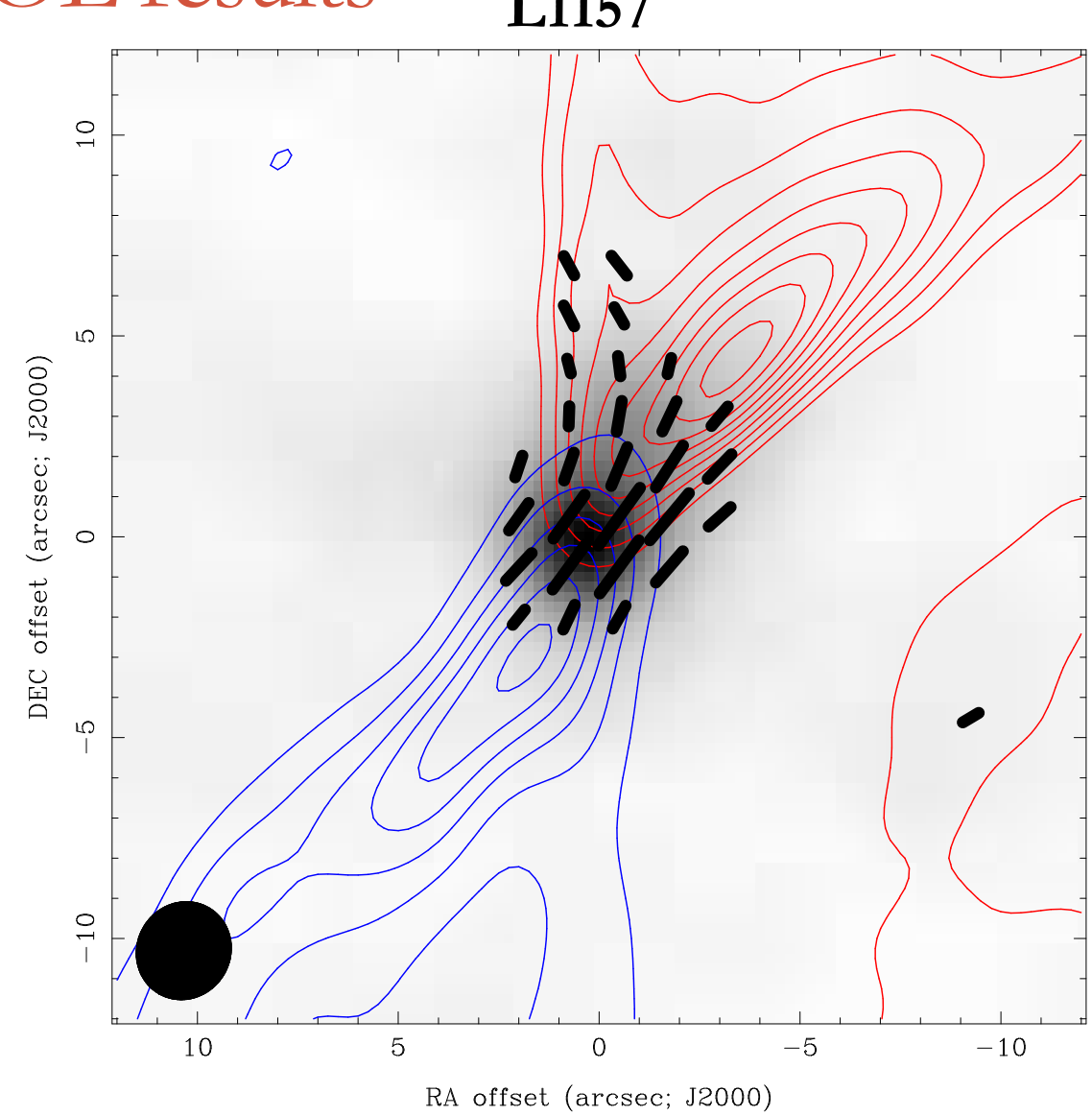
CARMA C, D, & E arrays

1 – 4″ resolution

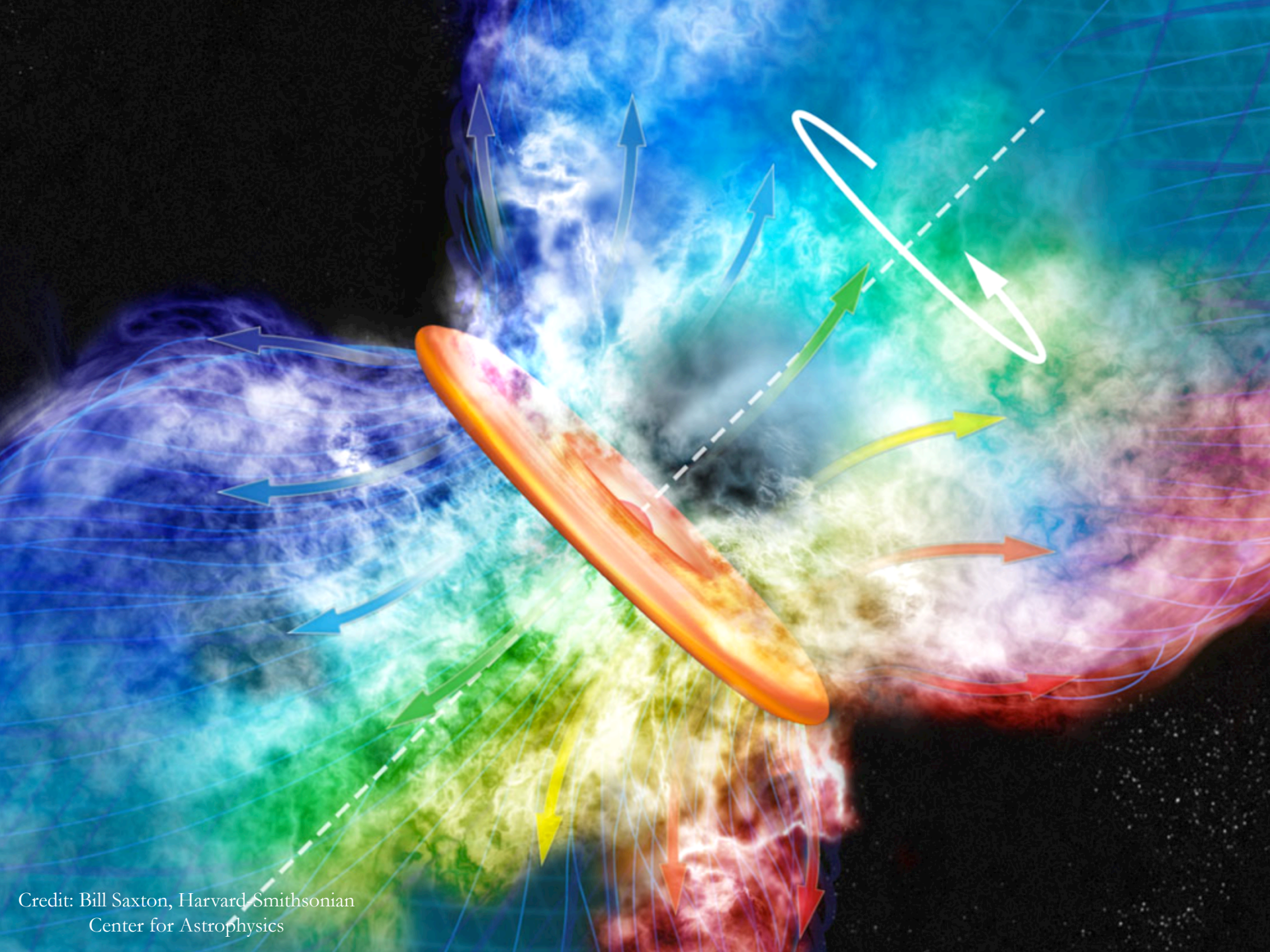
10× higher resolution than CSO & JCMT

Probes intermediate region between ~0.1 pc (single-dish) and ~100 AU (ALMA)

TADPOL results

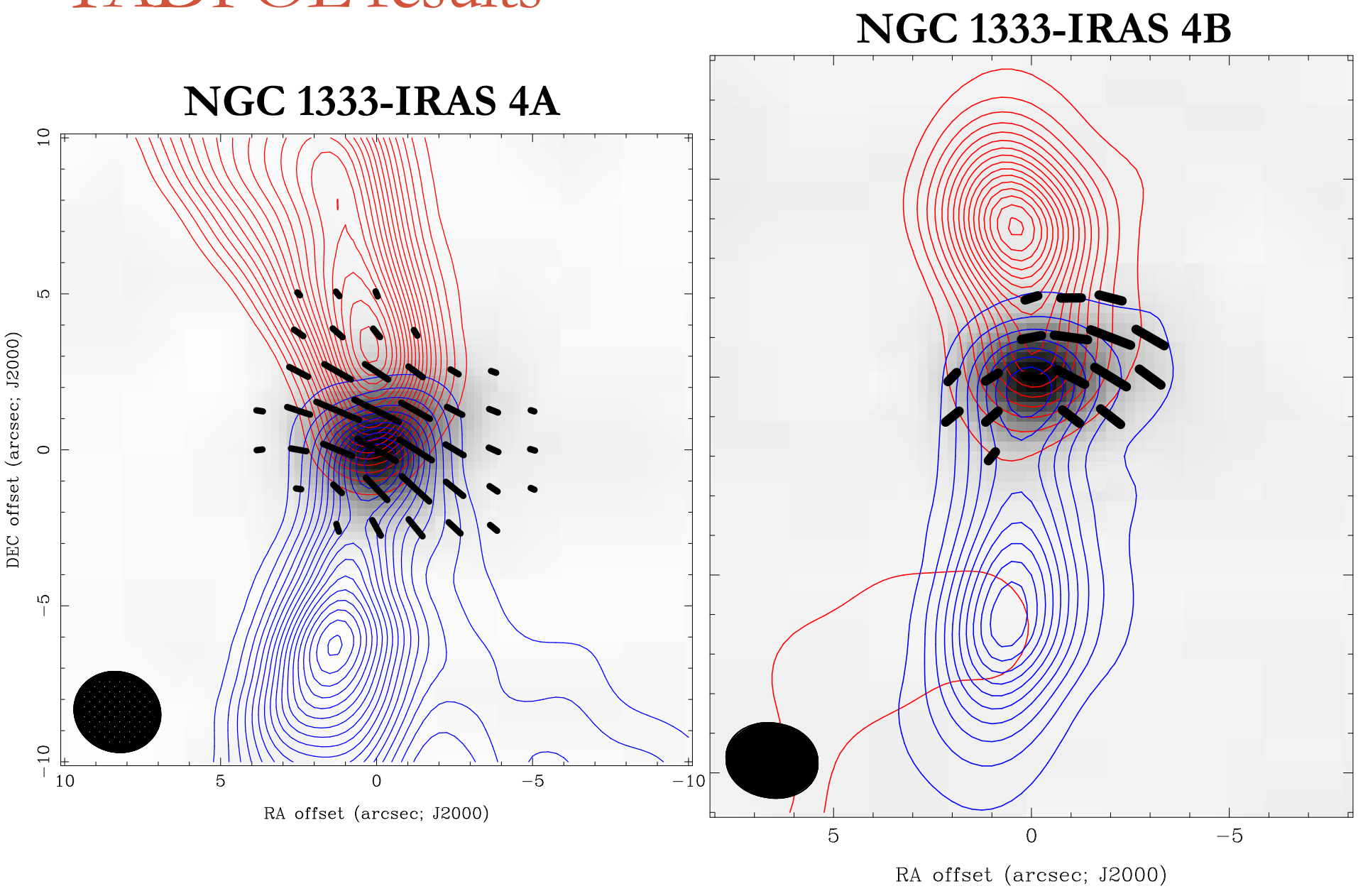


See also: Stephens, Looney, Kwon, **Hull** *et al.* 2013, ApJL, submitted



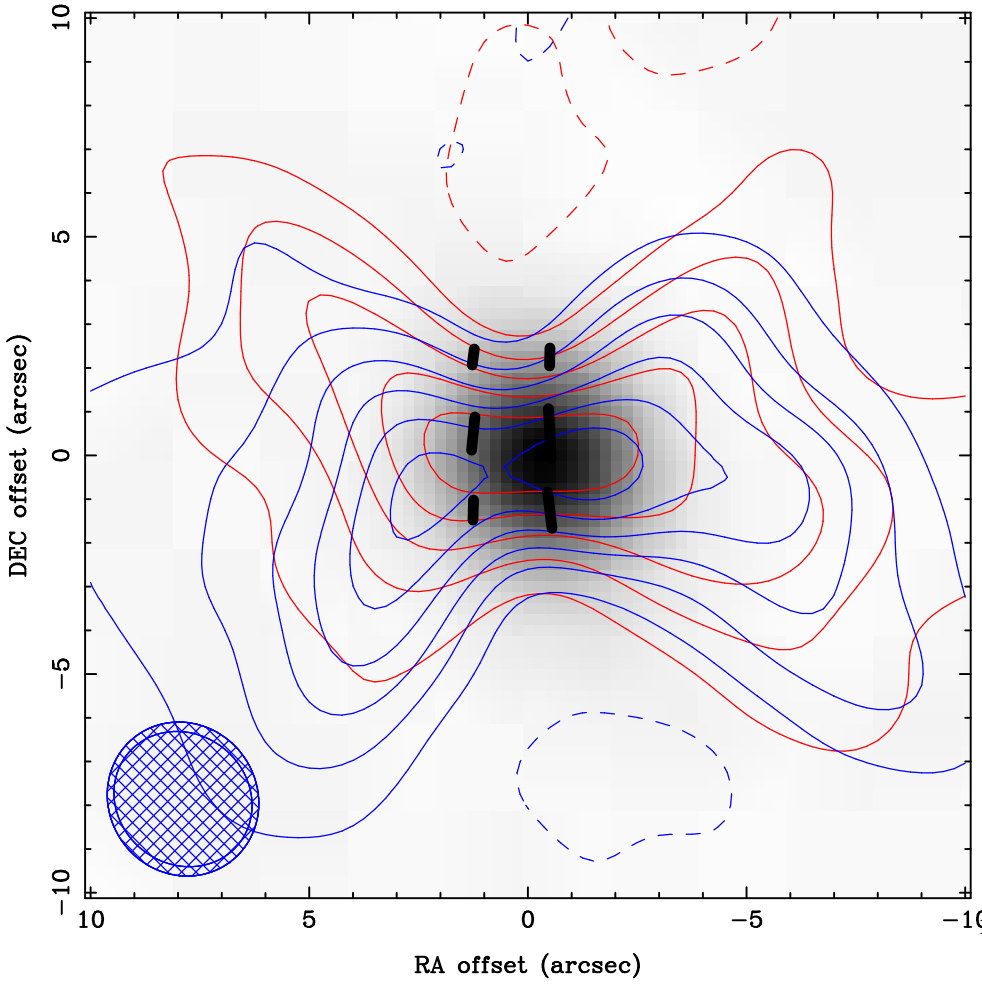
Credit: Bill Saxton, Harvard-Smithsonian
Center for Astrophysics

TADPOL results

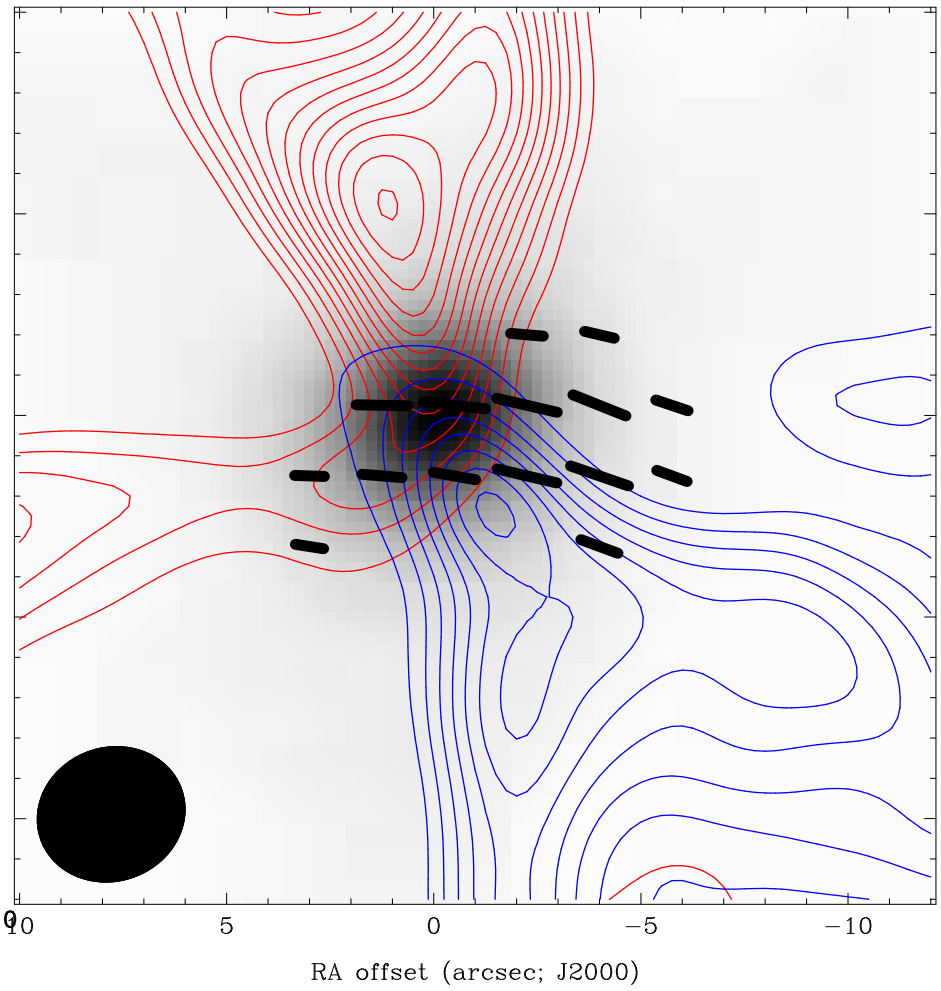


TADPOL results

L1527

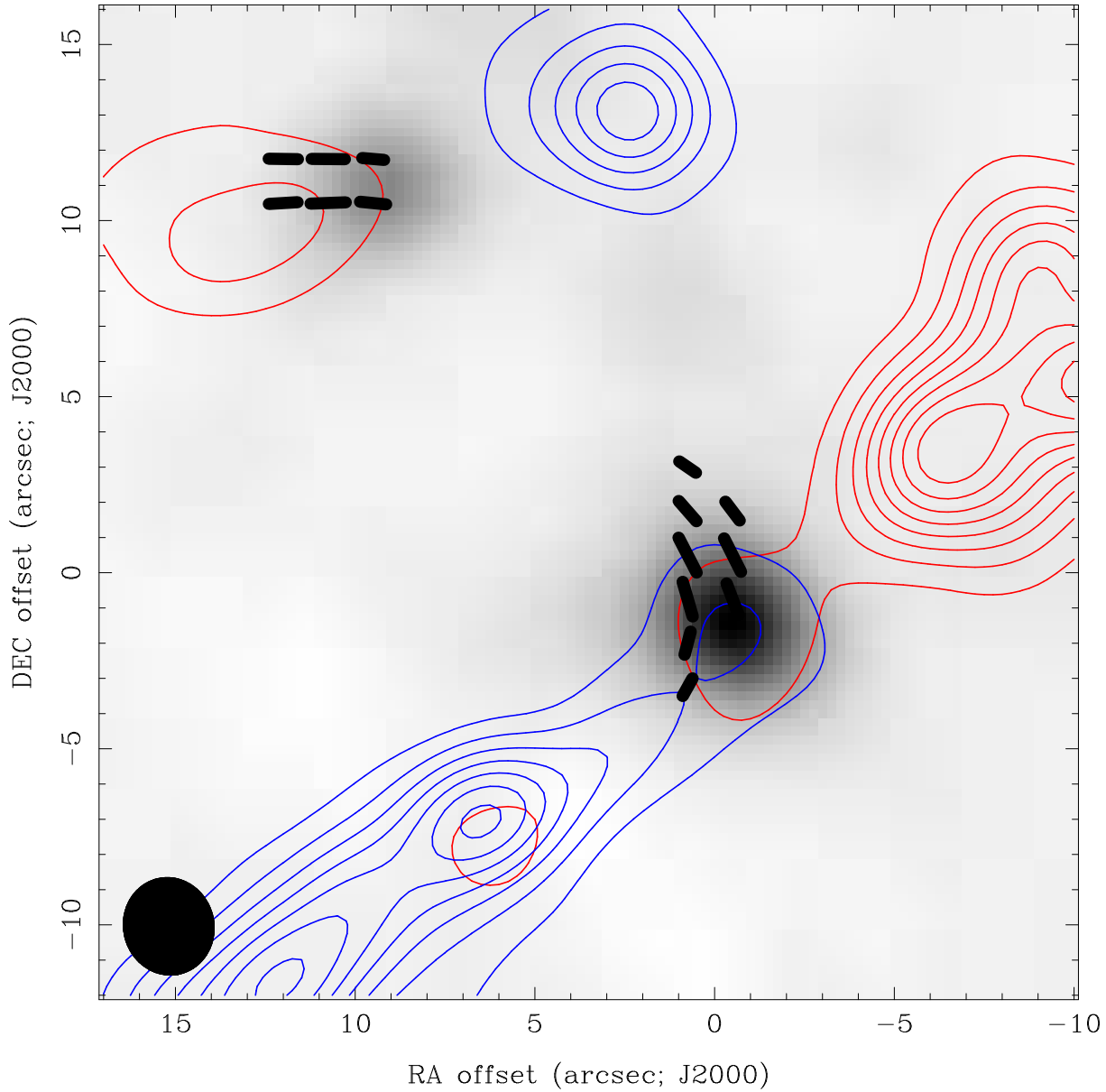


NGC 1333-IRAS 2A

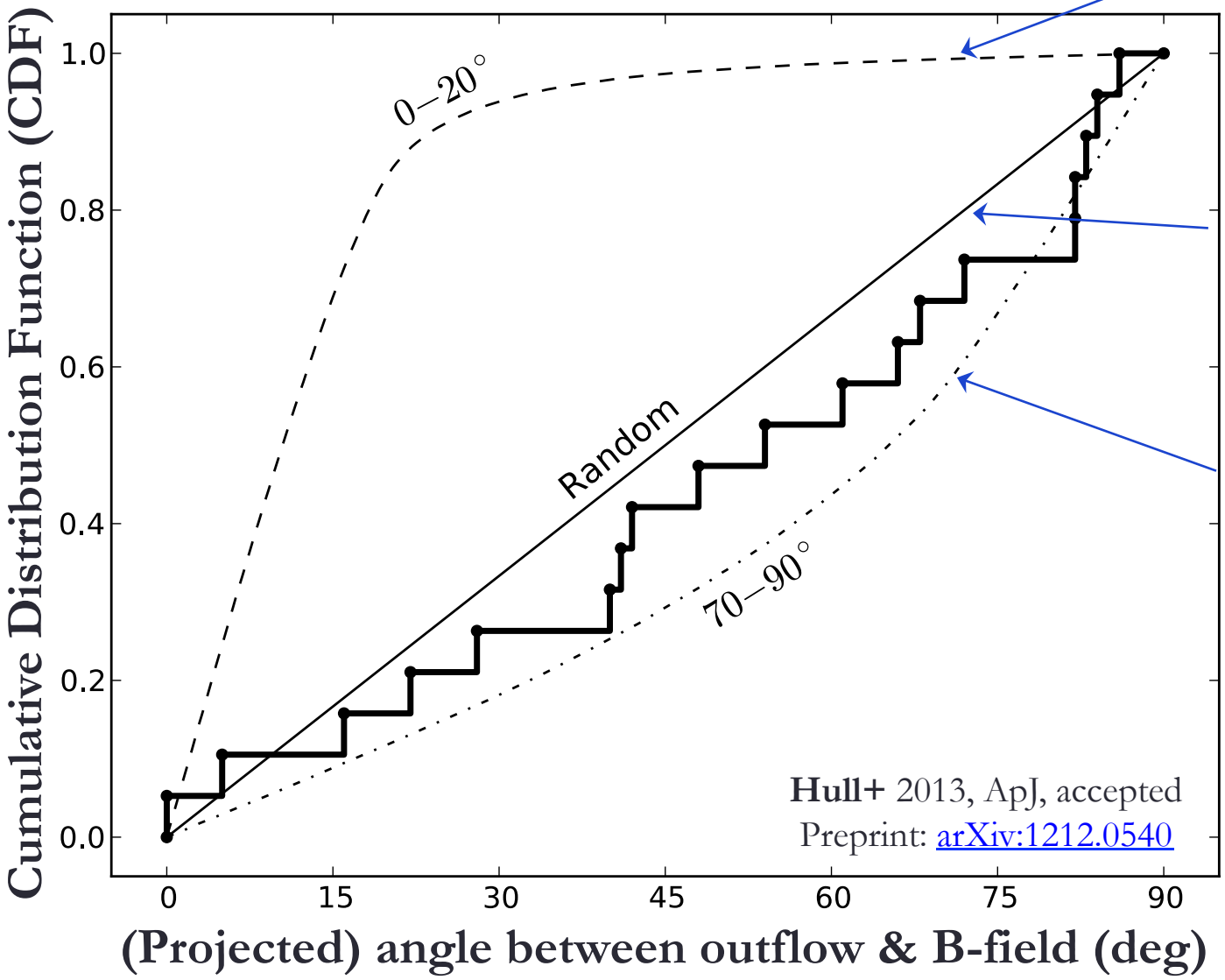


TADPOL results

Ser-emb 8



Outflow vs. B-field: distribution



Simulation: outflows & B-fields aligned within a 20° cone (tightly aligned)

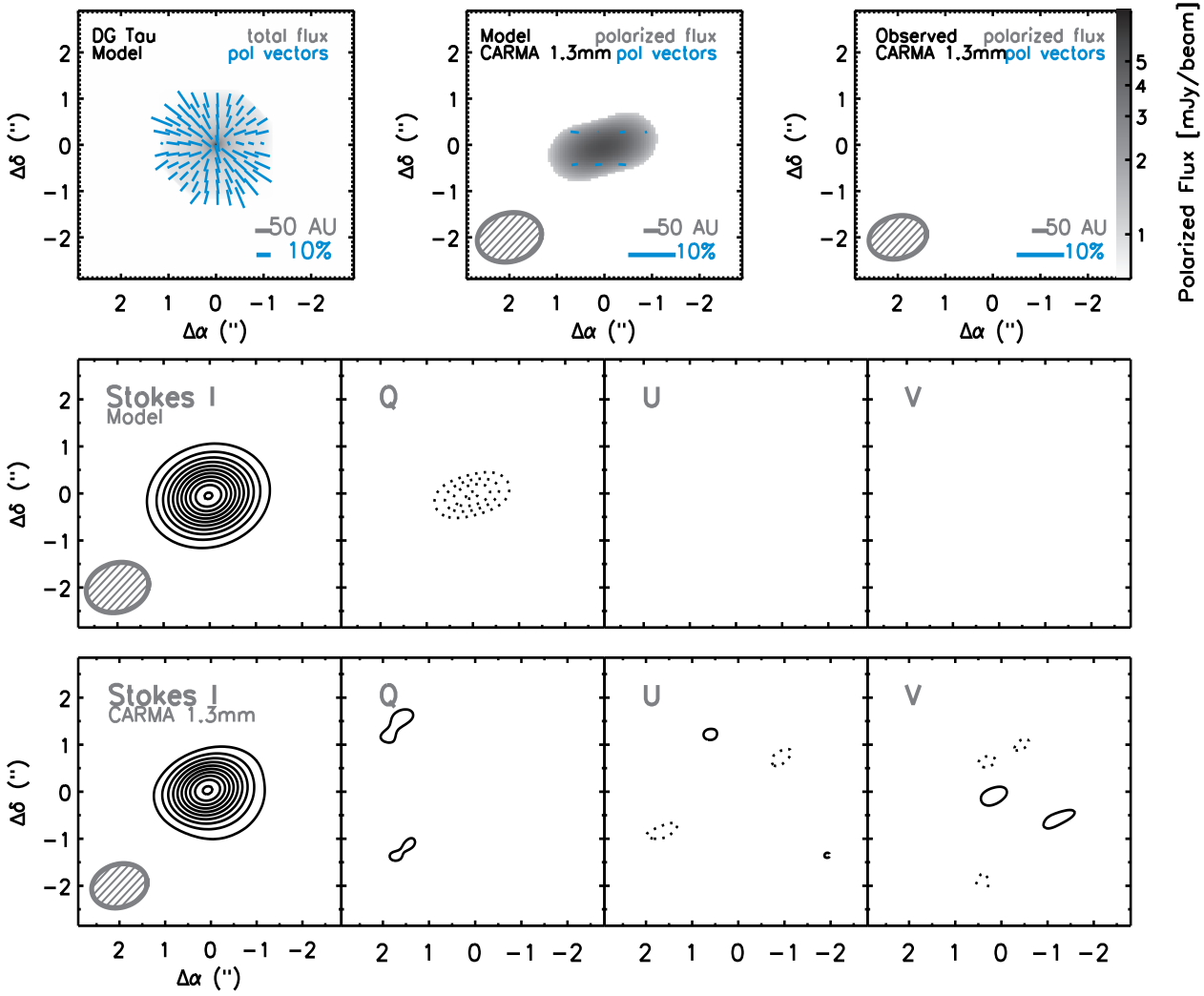
Simulation: outflows & B-fields are randomly oriented

Simulation: outflows & B-fields aligned between 70–90° (preferentially misaligned)

KS-test results:

- 20° cone **ruled out** (p-value ~ 10^{-9})
- Misaligned (0.79) and random (0.64) cannot be ruled out

Upper limits on circumstellar disk polarization

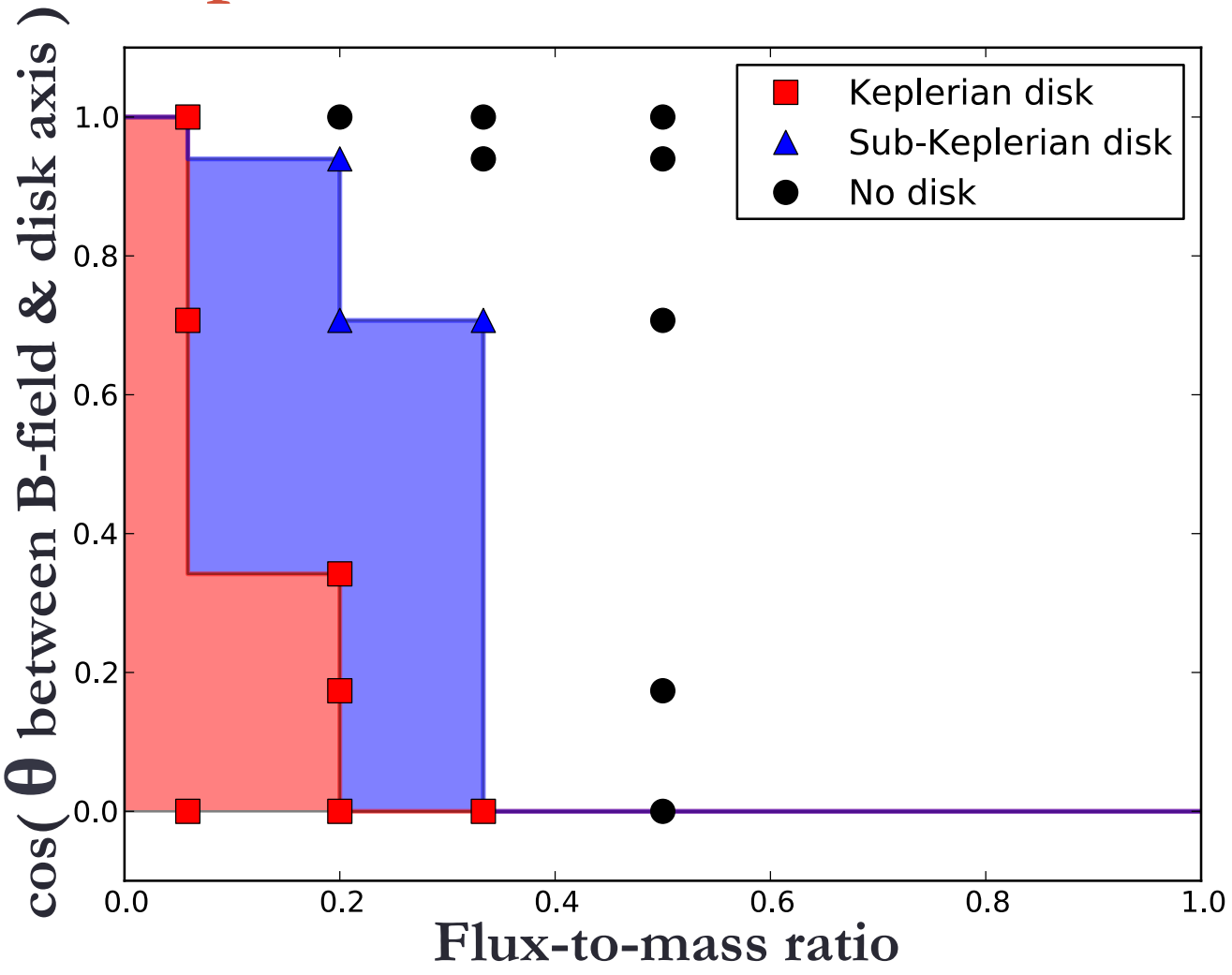


- CARMA + SMA results
- Disks are **not** strongly polarized at ~100 AU scales:

$$P < 0.5\%$$

Hughes, **Hull,** Wilner, & Plambeck 2013, AJ, 145, 115

Implications for disk formation



- Weak & misaligned B-fields in cores could aid disk formation
- Addresses "magnetic braking catastrophe"
- Points are from simulations in Joos+ 2012
- We find that ~10–50% of Class 0/I stars should form Keplerian disks

Krumholz, Crutcher, & **Hull** 2013, ApJL, 767, L11

Other projects

- **Filamentary B-field structure in Serpens**
  - Observing same field as ALMA (Mundy *et al.*)

- **Galactic center (SgrA*)**
  - Rotation measure, simultaneous with SMA
  - G2 cloud

Summary

- CARMA 1 mm polarization system is fully functional, and accepting proposals (next deadline is **next month** (May, '13))
- Wide array of science
- TADPOL results: B-fields are either **preferentially misaligned** (perp.) or **randomly aligned** with respect to outflows at the ~1000 AU scale
  - Thus, circumstellar disks are misaligned with fields in the cores from which they formed

- **TADPOL results:** arXiv:1212.0540
- **TADPOL survey** (CARMA key project): tadpol.astro.illinois.edu
- **Questions?** Email: chat@astro.berkeley.edu

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