ARE MAGNETIC FIELDS AND OUTFLOWS ALIGNED IN PROTOSTELLAR CORES?

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CARMA Science Symposium
University of Chicago
Chicago, Ill.
Misalignment of B-fields and outflows

IRAS 16293

NGC 1333-IRAS 4A

B-field

Outflow

Rao+ 2009

Girart+ 2006
CARMA
Combined Array for Research in Millimeter-wave Astronomy

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

- SIS mixers
- Orthomode transducer
- Waveguide circular polarizer
- WBA13 I.F. amplifiers (1-9 GHz)
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-Champaign**
  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

37 sources
Triples number of interferometric polarization maps

~300 observing hours
CARMA C, D, & E arrays

1 – 4” resolution
10X higher resolution than CSO & JCMT
Probes intermediate region between ~0.1 pc (single-dish) and ~100 AU (ALMA)
TADPOL results

See also: Stephens+ 2013, ApJL, 769, L15
TADPOL results

NGC 1333-IRAS 4A

NGC 1333-IRAS 4B

2''

2''
TADPOL results

L1527

NGC 1333-IRAS 2A
TADPOL results

Ser-emb 8

3"

Image of a map with various contours and labels.
Outflow vs. B-field: distribution

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

**Simulation:** outflows & B-fields are randomly oriented

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

**KS-test results:**
- 20º cone ruled out (p-value ~ 10^{-15})
- Misaligned (0.33) and random (0.33) cannot be ruled out

(updated version: July ‘13)
Summary

• 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

• CARMA 1 mm polarization system is online and accepting proposals

• Data release coming soon!

• TADPOL first results: ApJ, 768, 159
• TADPOL survey (CARMA key project): tadpol.astro.illinois.edu
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