Alignment Between Flattened Protostellar Infall Envelopes and Ambient Magnetic Fields

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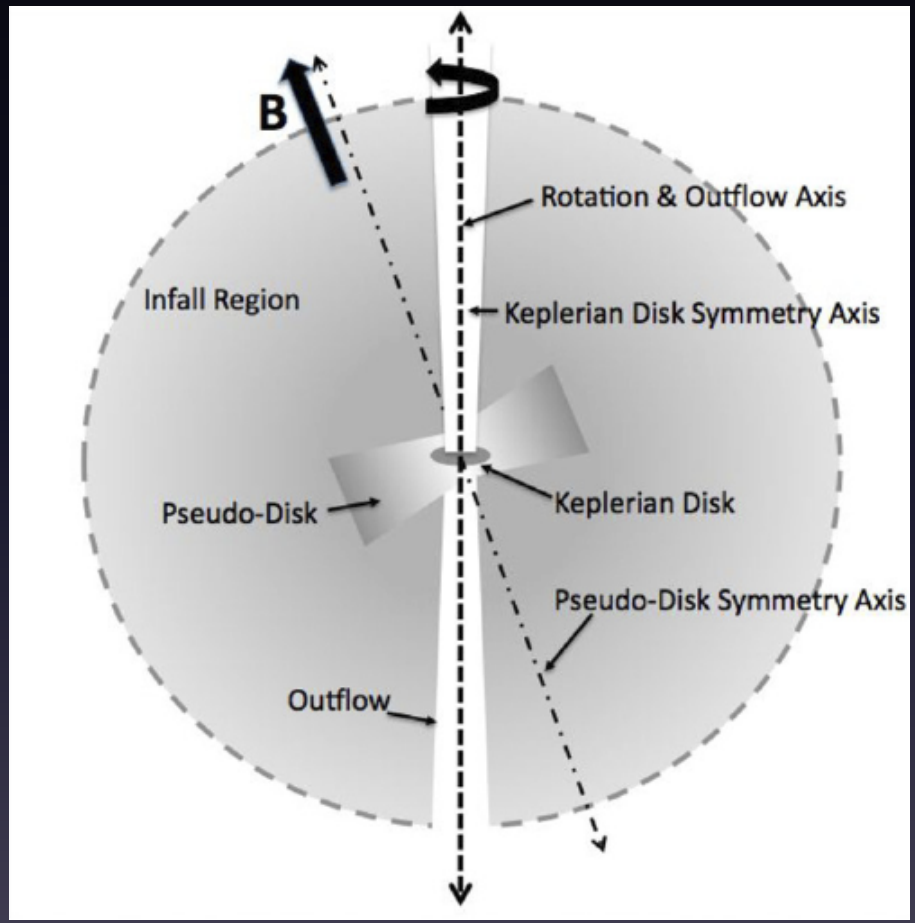
Magnetically Regulated Core Collapse (e.g. Allen et al. (2003a,2003b))

1. Existence of Pseudodisk (flattened infall envelope)
2. Magnetic field pinched within infall region
3. Pseudodisk axis $\|$ to magnetic field axis
4. (Outflow $\|$ to B-field and pseudodisk)
   - cf. Joos et al. (2012), Hull et al. (2013)



Davidson et al. (2011)

SHARP

- SHARP operates at the CSO
- SHARP adds polarimetric capability to SHARC-II camera
  - Simultaneous Horizontal and Vertical polarization
  - 350 μm and 450 μm
- SHARP Survey of Low-Mass Protostellar Cores
  - We chose simple, easy-to-understand sources
  - Nearby, single, isolated, inclinations near to plane of sky(*)

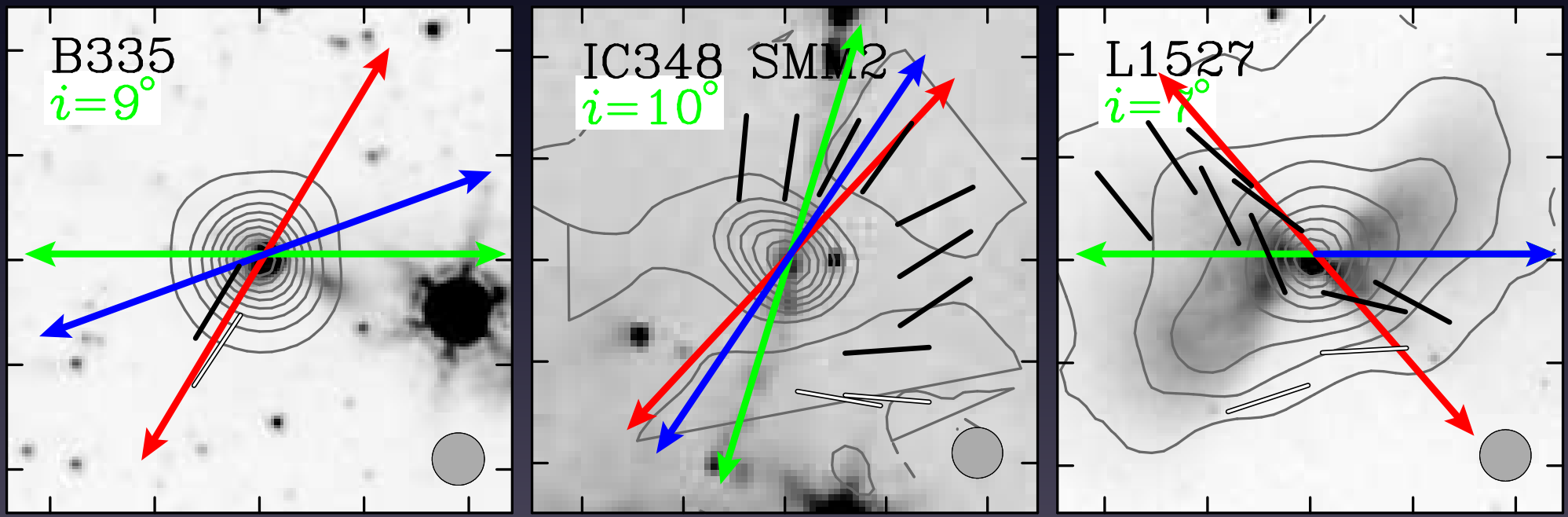
SHARP Survey of Low-Mass Protostellar Cores

- Paper I: Davidson et al. (2011)
  - B335, IC348 SMM2, L1527

red - mean magnetic field

green - outflow axis

blue - pseudodisk symmetry axis



SHARP Survey of Low-Mass Protostellar Cores

- Paper II: Chapman et al. (submitted)
  - L483, L1157, L1448-IRS2, Serp FIR1

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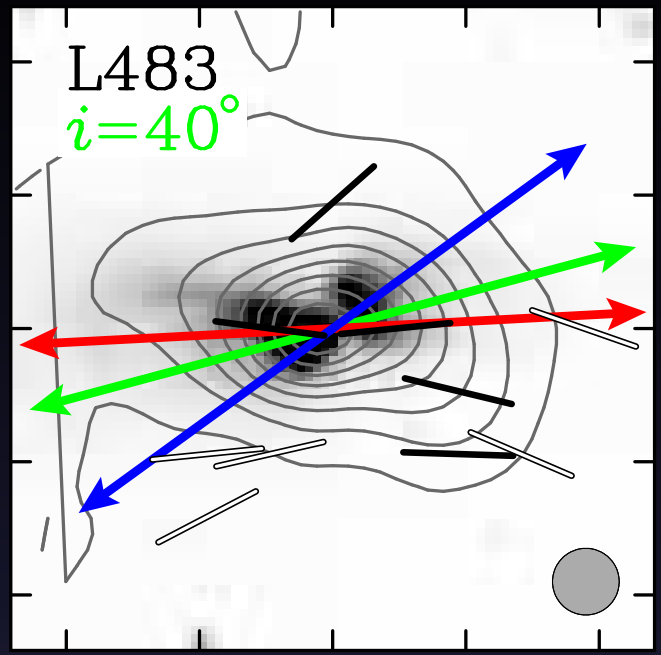
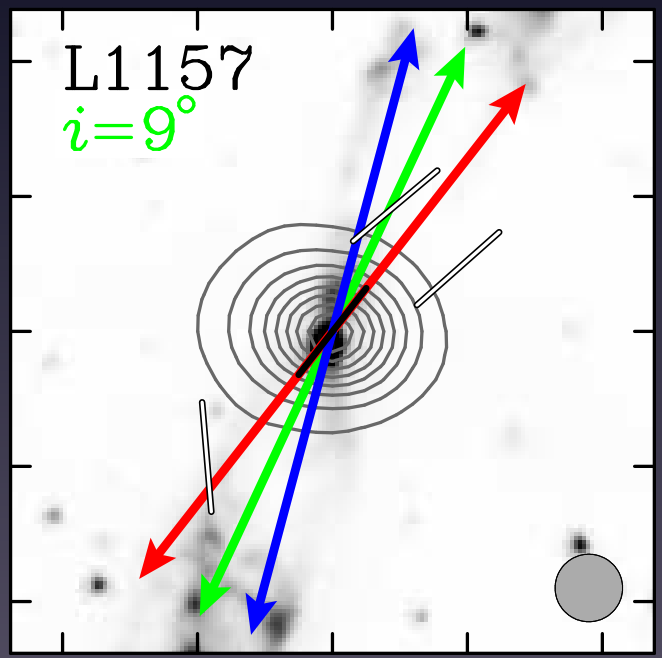
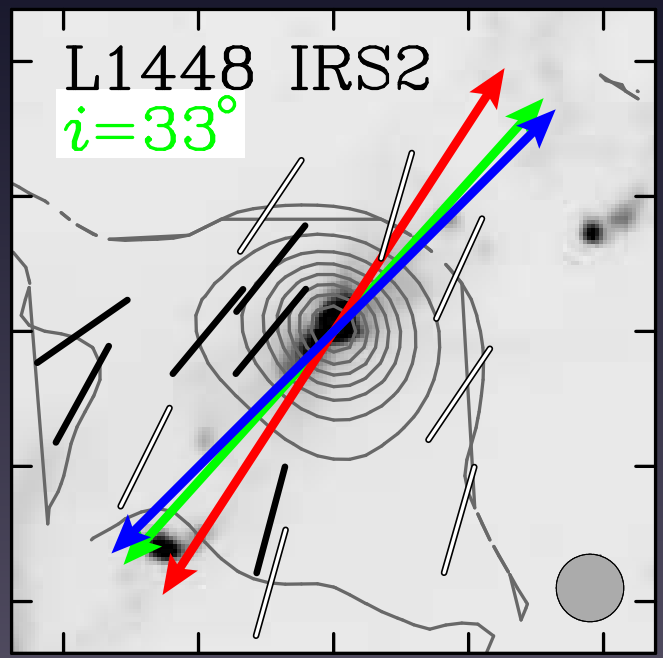
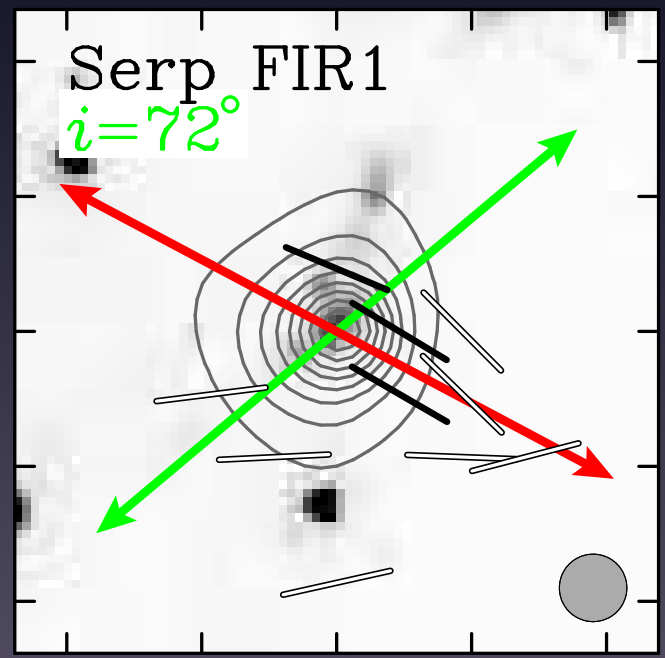
blue - pseudodisk symmetry axis









SHARP Survey of Low-Mass Protostellar Cores

Remarks

- The blue (pseudodisk symmetry axis) and green (outflow axis) are very well correlated.
  - Mean difference in angle is 12°
- blue (pseudodisk) somewhat aligned with red (mean magnetic field direction)
  - less than 45° in 6/7 sources
  - 7th source (Serp FIR1) has high inclination

Analyze

- *proxy 1*: Inclination of outflow = inclination of pseudodisk
- *proxy 2*: Outflow angle = pseudodisk angle in Serp FIR1

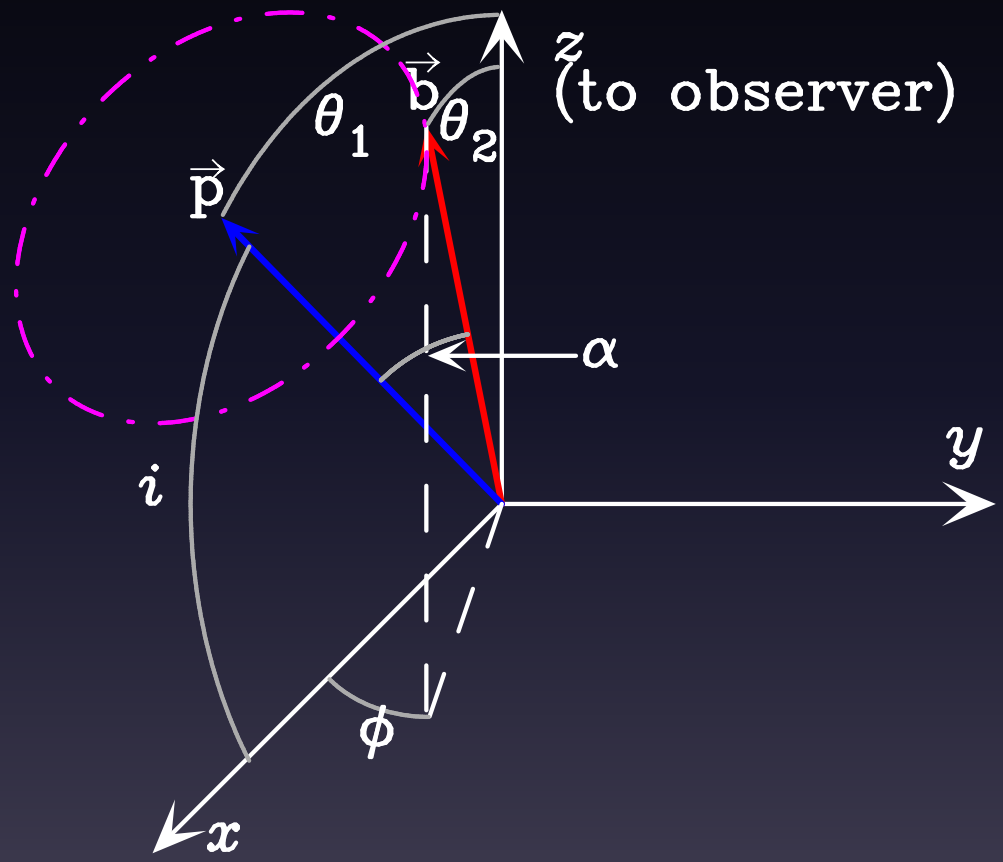
Future

- Unreduced data: L1551-NE, HH211-MM, B1-C

Importance of Inclination Angle

- Projected Separation ϕ is a function of:
  - Inclination i
  - 3D separation α
  - Rotation ϕ'

$$\tan\phi = \frac{\tan\alpha \sin\phi'}{\sin\theta_1 + \cos\theta_1 \tan\alpha \cos\phi'}$$



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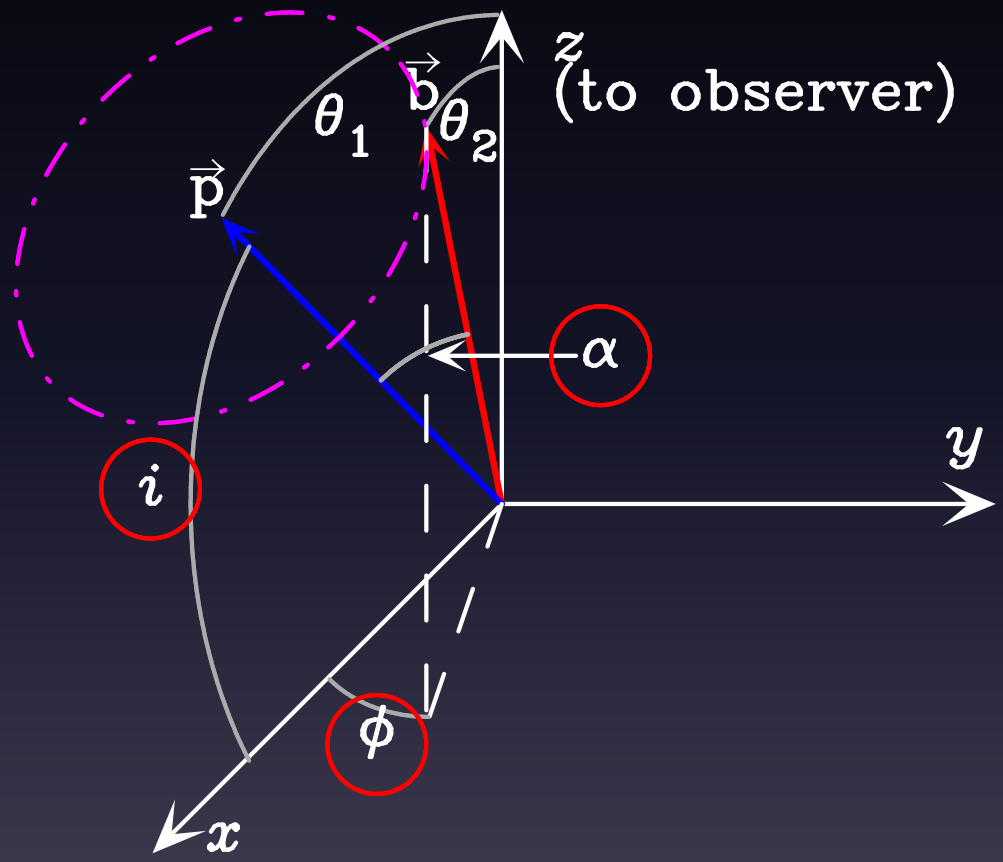
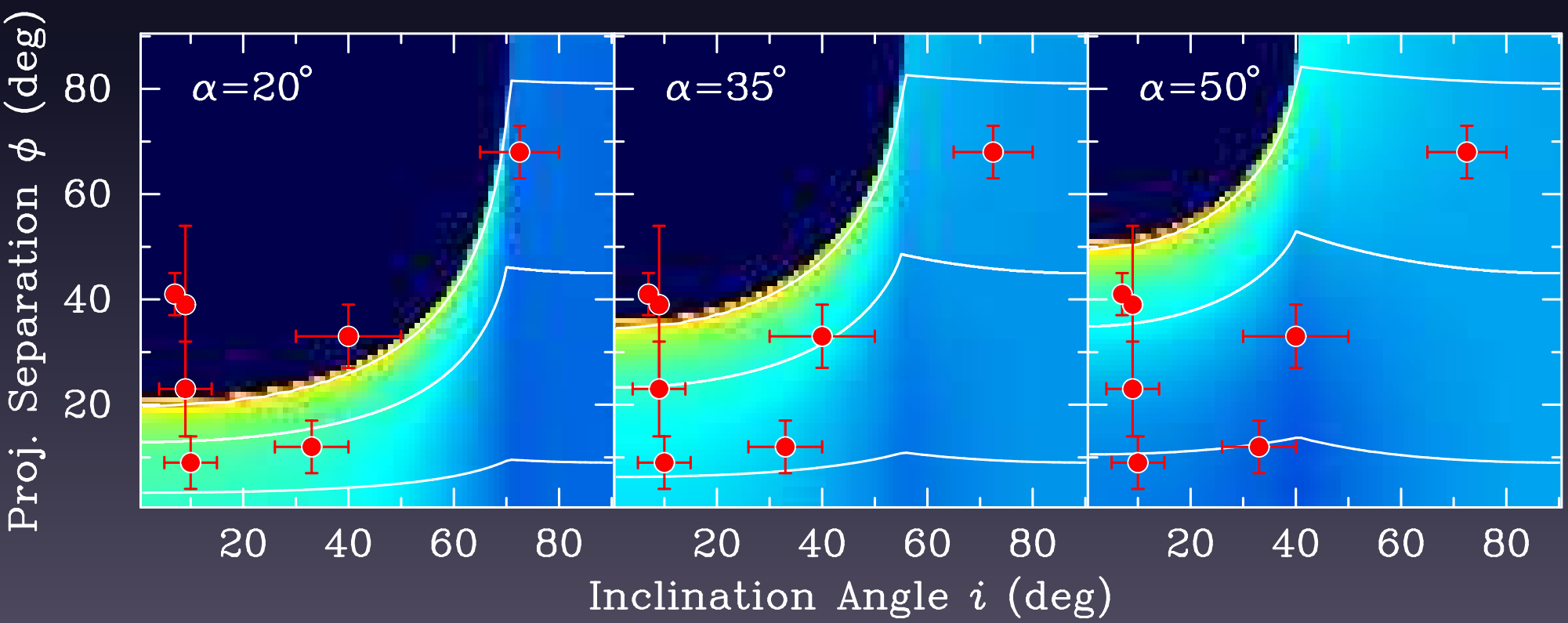


Results

- Compute projected separation between magnetic field and pseudodisk for all 7 sources
- From simple chi-squared minimization best-fit $\alpha = 36.1°$
- We estimate the probability of obtaining $\alpha \leq 36.1°$ by pure chance is 5%
- Folding in errorbars, $\alpha < 40°$



Combining Sources

- Each source has only a few vectors $\geq 2\sigma$
- Each source has other vectors of lesser significance

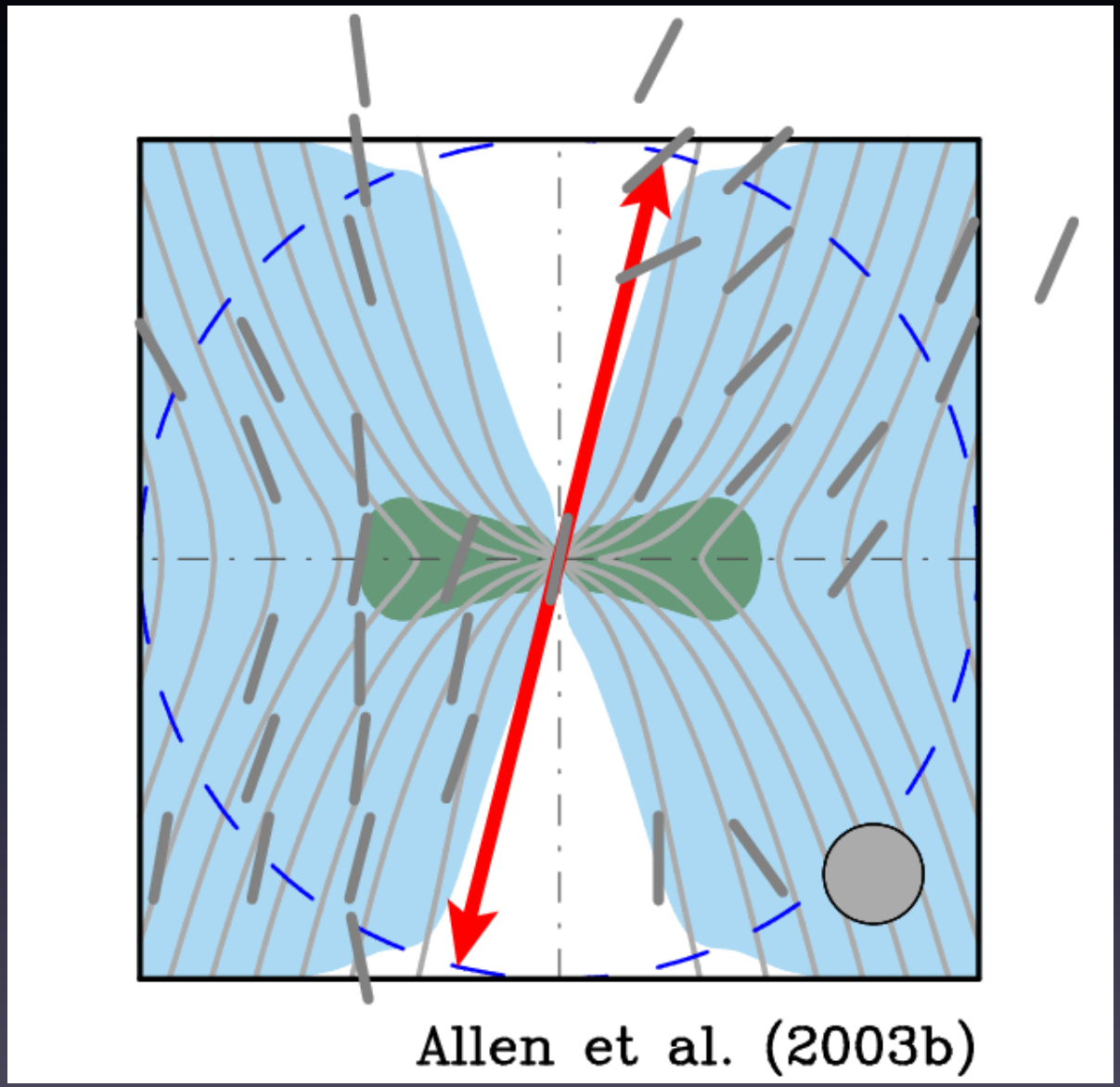
Why not utilize *ALL* the information on each source?

Compare with magnetically regulated core collapse model

- Ignored Serp FIR1 (high outflow inclination)
- Rotated each source so pseudodisk was horizontal
- Scaled each source by its infall radius
- Computed the source average map
  (weighted average of rotated, scaled maps)

Source Average Map

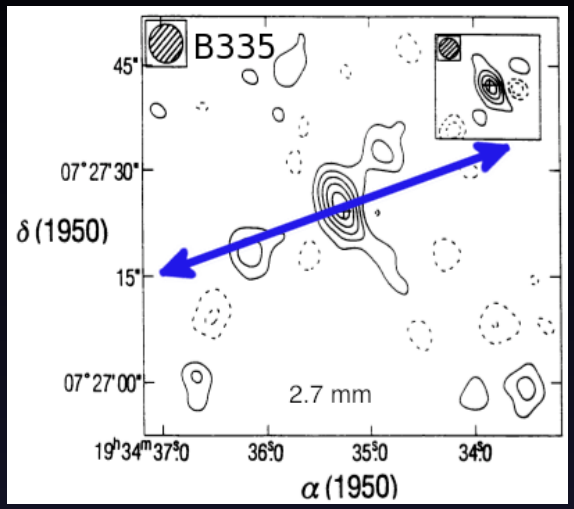
- Mean field angle 166°
- Hints of a pinch
- 35 vectors
  - $13 \geq 3\sigma$
  - $22 \geq 2\sigma$



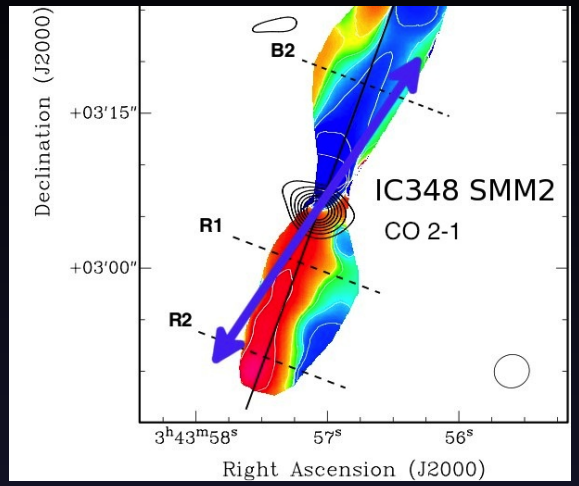
Summary

- We have now observed 7 low-mass, isolated sources
- The outflow axis is well aligned with pseudodisk axis
  - mean difference is 12°
- Pseudodisk preferentially aligned with *B*-field
  - $\alpha < 40°$; 5% probability due to chance
- Combining sources into a single map improves S/N and supports results of magnetic field alignment with pseudodisk

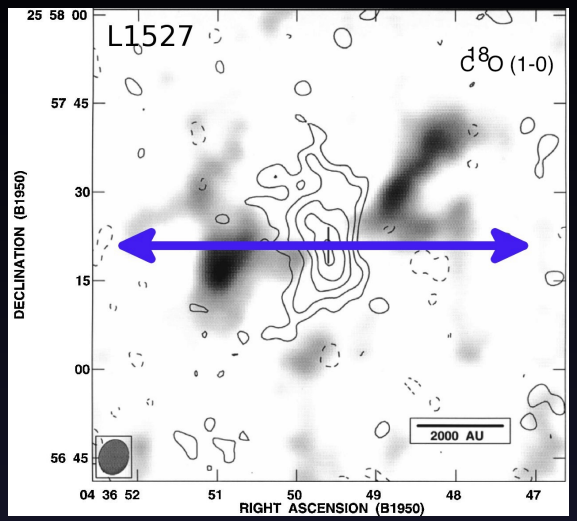
Pseudodisks



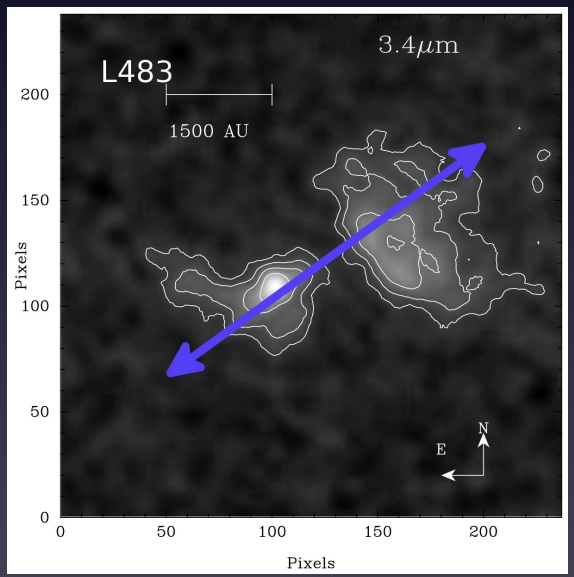
Chandler & Sargent (1993)



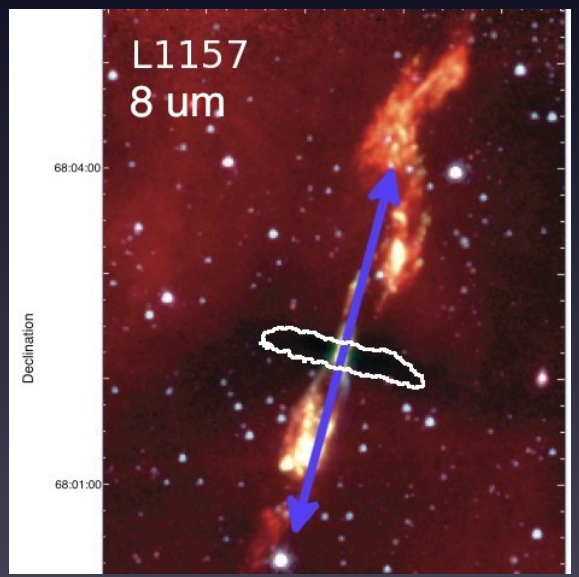
Pech et al. (2012)



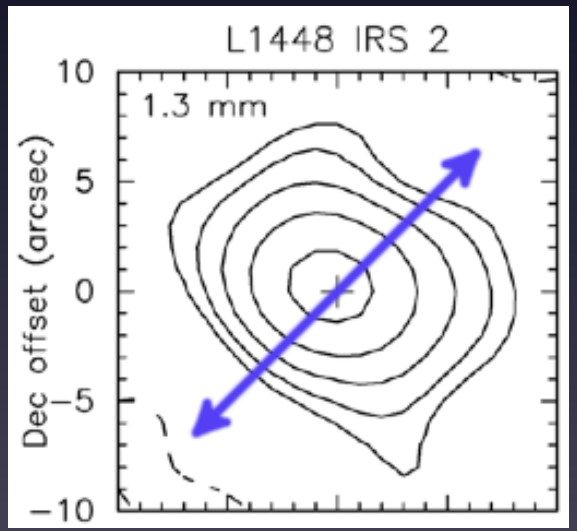
Ohashi et al. (1997)



Fuller & Wooten (2000)



Looney et al. (2007)



Kwon et al. (2009)

Vector Separation