Constraining Theories of SiO Maser Polarization:
Analysis of a $\pi/2$ EVPA Change

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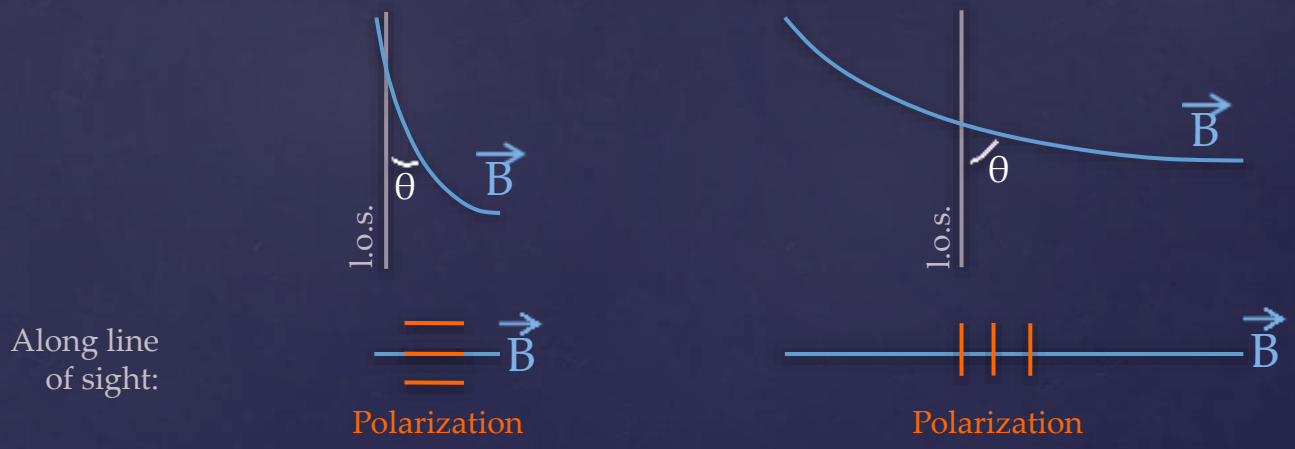
What Could Cause a π/2 EVPA Change?

- Critical Angle between LOS & Projected Magnetic Field
  - Goldreich, Keeley, & Kwan 1973 (GKK) for saturated J=1-0
  - Asymptotic limit $\Delta\omega >> g\Omega >> R >> \Gamma$ *

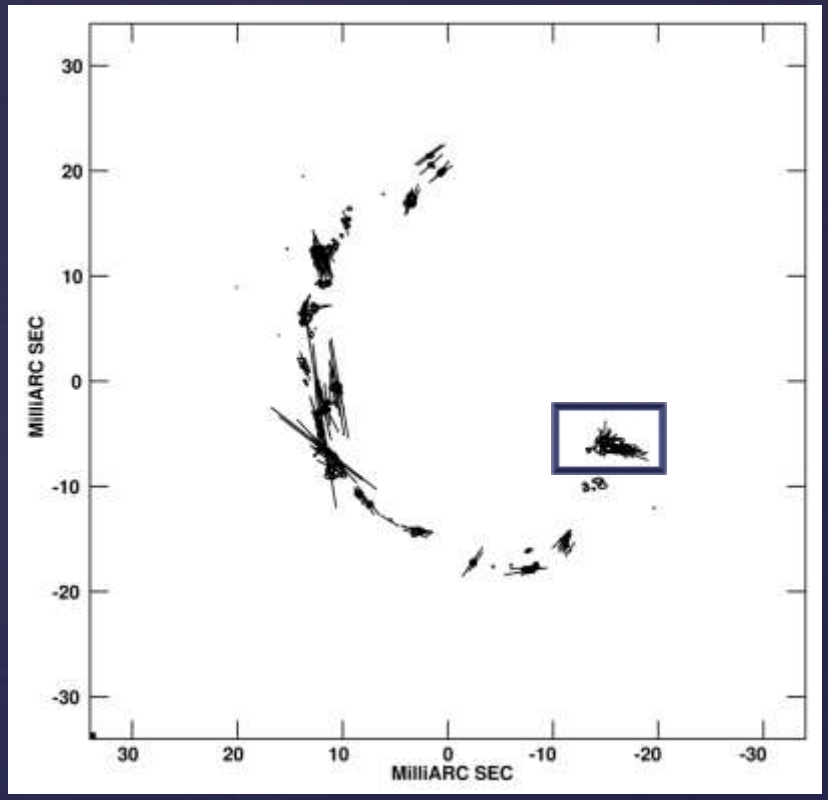


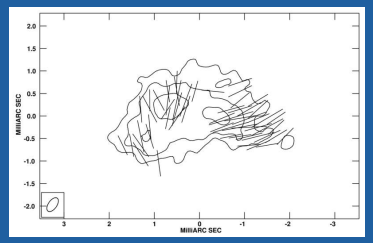
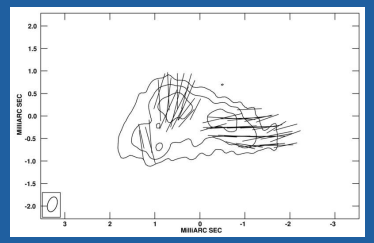
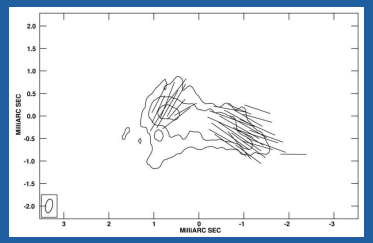
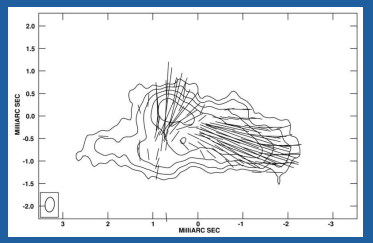
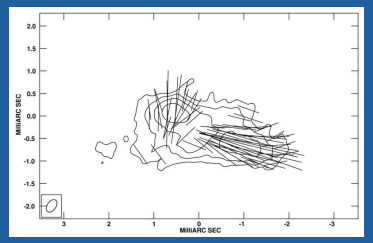
- Change in magnetic field orientation (Soker & Clayton 1999) due to local conditions
- Anisotropy mechanisms (Asensio Ramos et al. 2005)

* Kwan & Scoville 1974, Elitzur 1980, Nedoluha & Watson 1990, Elitzur 1992, Plambeck et al. 2003, Kemball et al. 2009

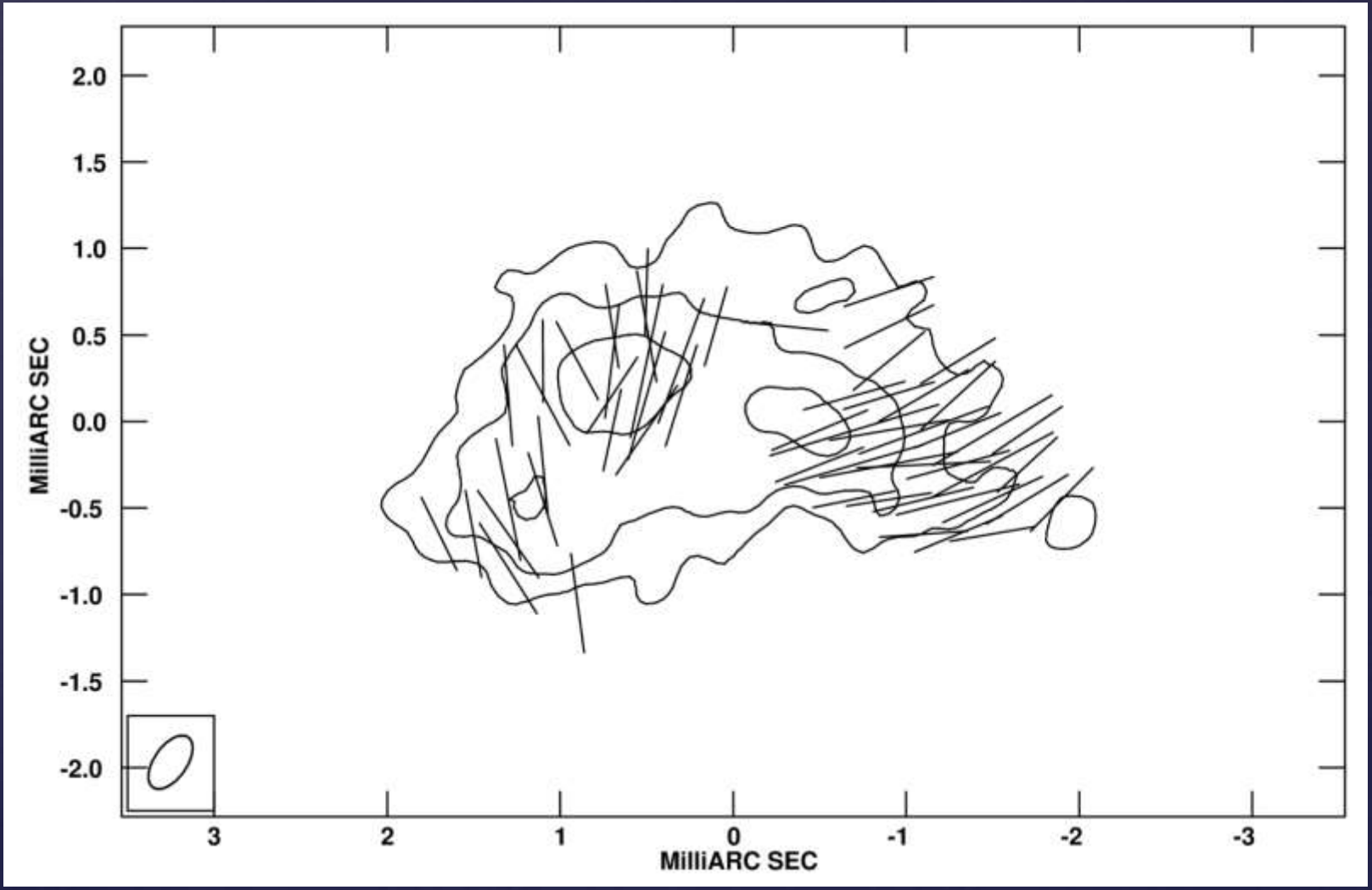
Multi-Epoch TX Cam Re-analysis: EVPA Rotation Feature

- SiO ν=1 J=1-0 [7 mm]
- Full Polarization
- Mira Variable TX Cam
- 5 Epochs (BD46AN-AR) from long-term VLBA Campaign (Diamond & Kemball 2003; Kemball et al. 2009; Gonidakis et al. 2010; Kemball et al. 2011)
- Re-analysis using Refined Circular Polarization Calibration (Kemball & Richter 2011)

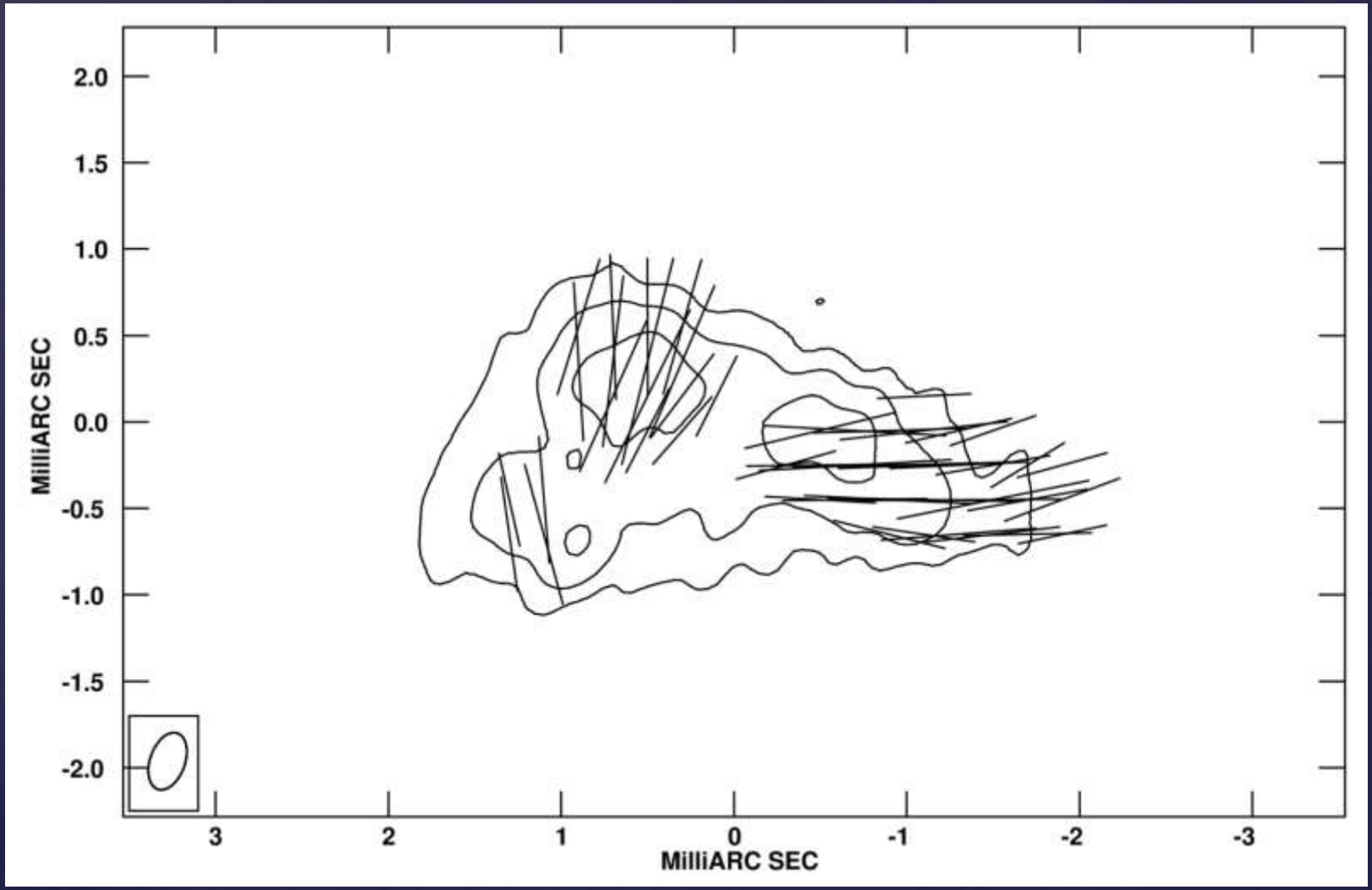


BD46AN



BD46AO



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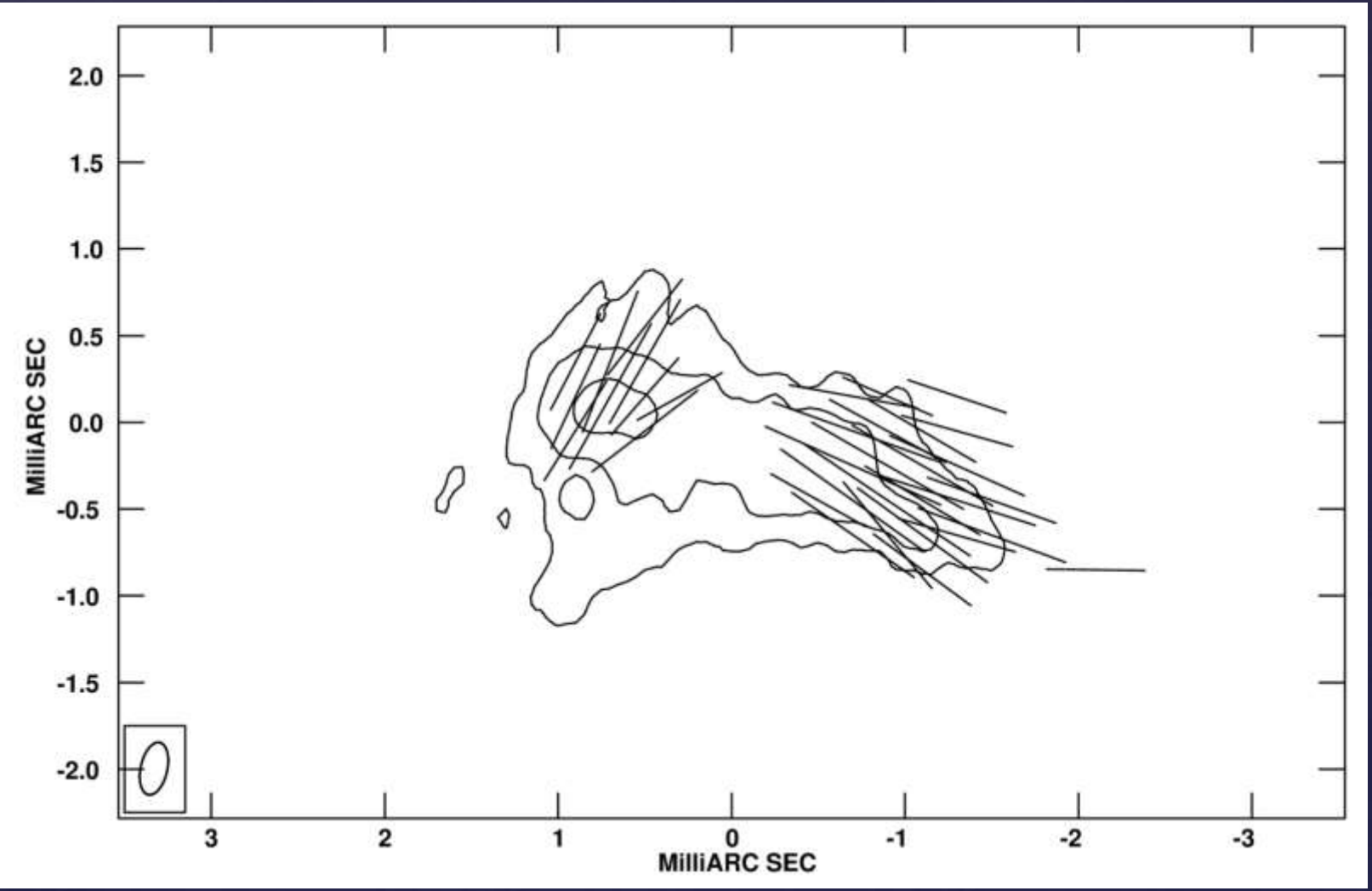

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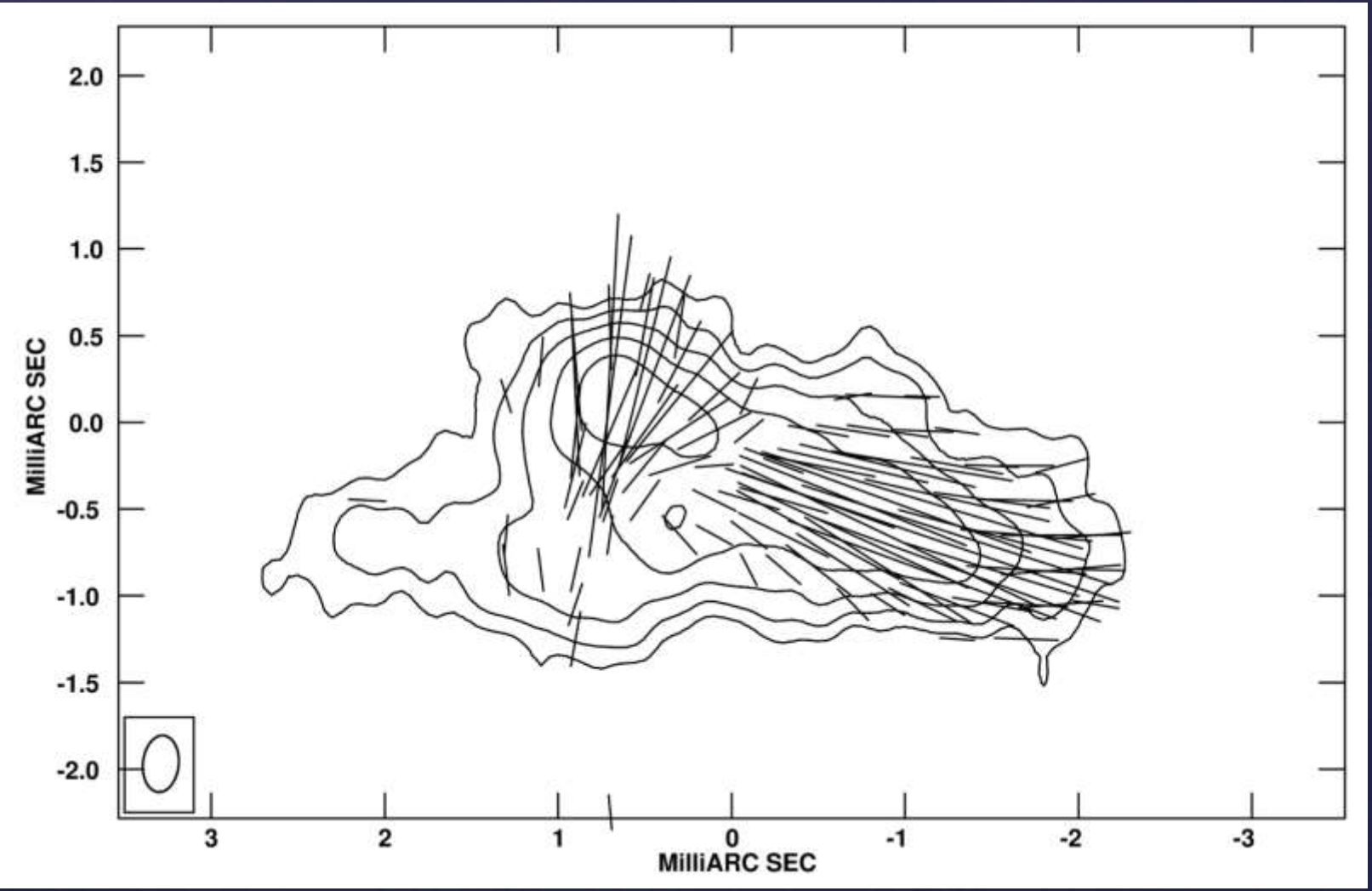

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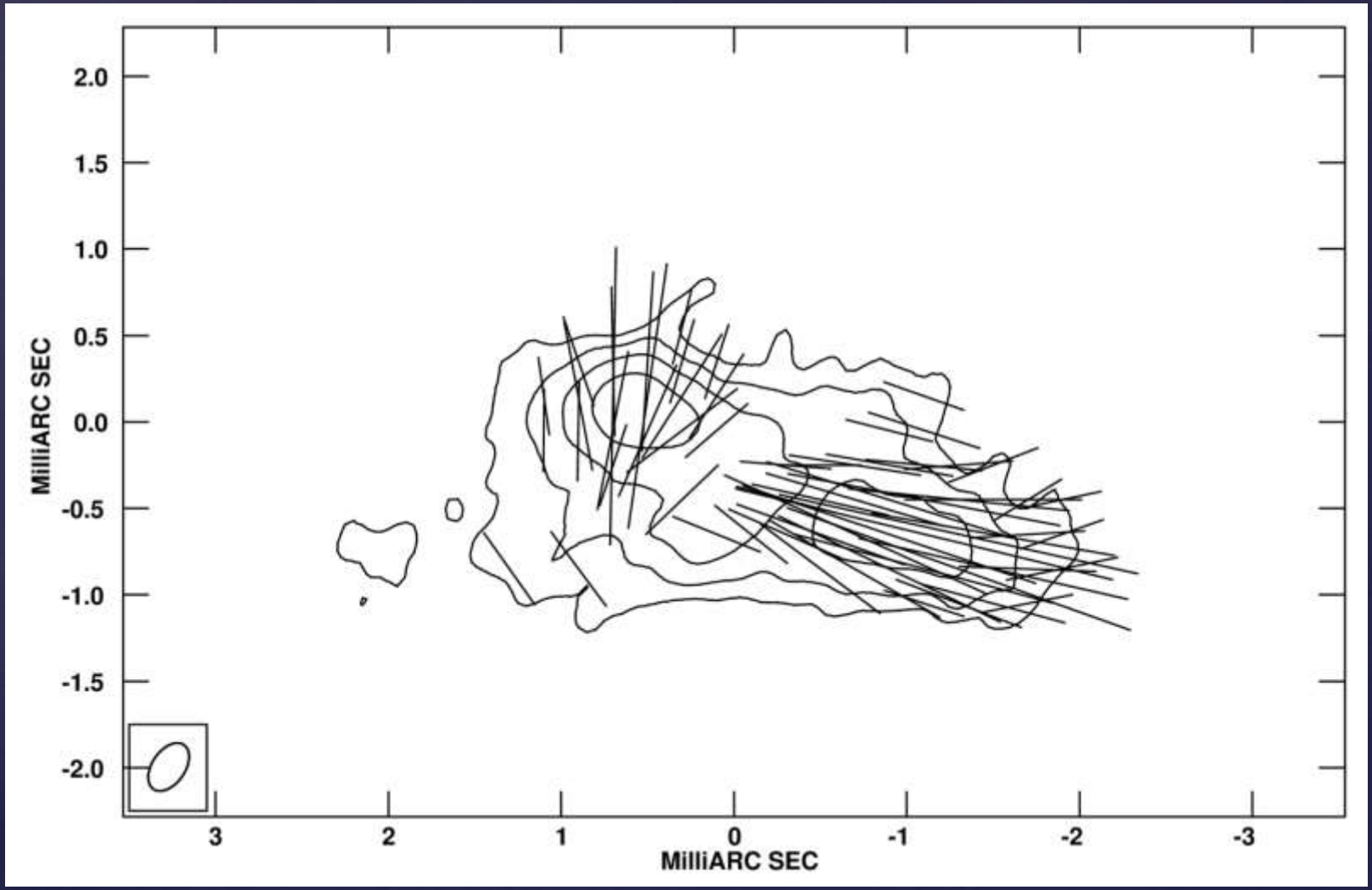
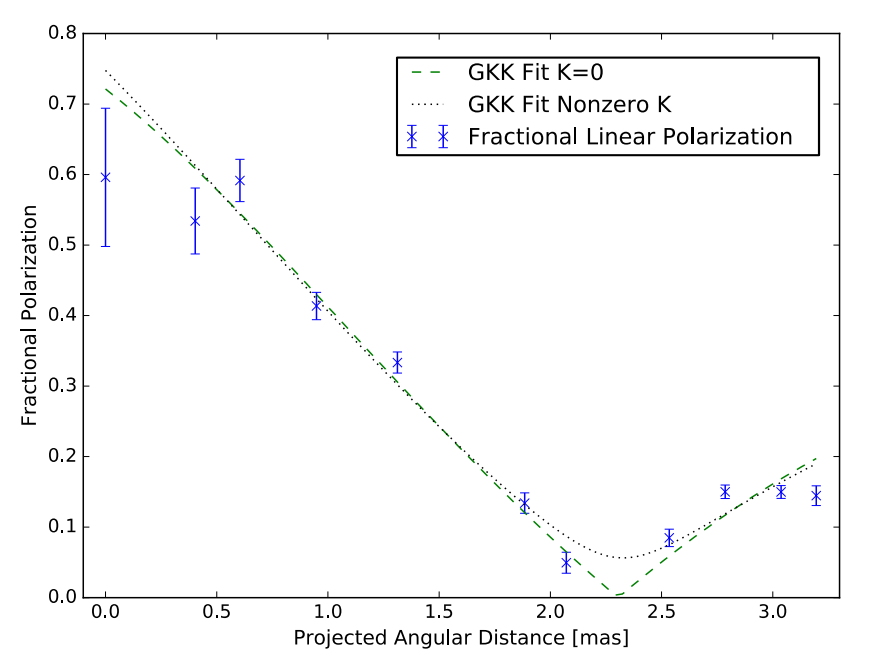


GKK m_l Profile

BD46AP



- $Y=Q_B/I$, $Z=U_B/I$, $V=0$

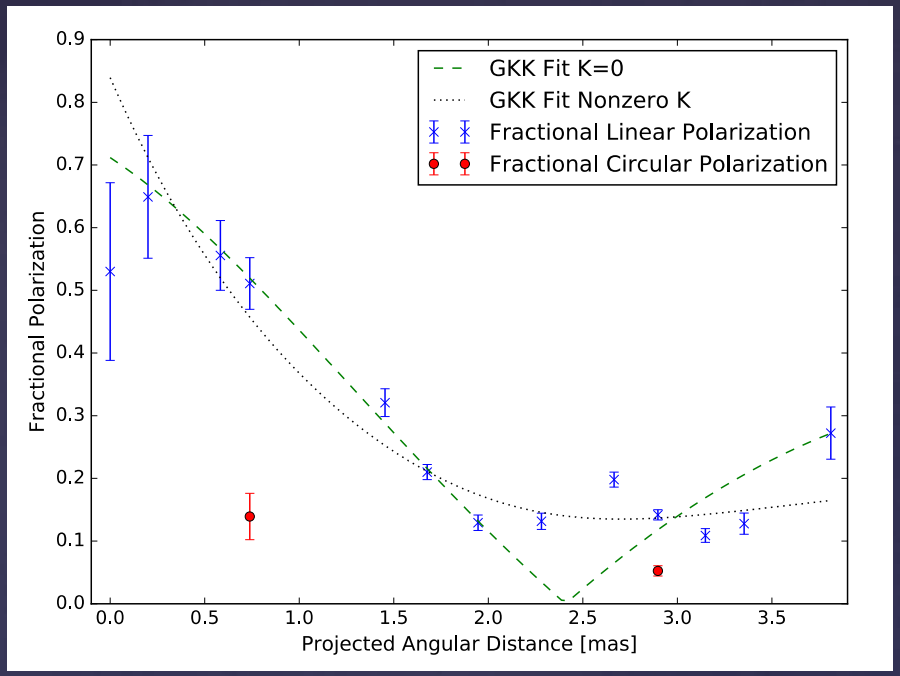
$$Y=\frac{3\sin^2\theta-2}{3\sin^2\theta},\quad Z=K,\quad \text{for } \sin^2\theta\le\tfrac{1}{3}$$

$$Y=-1,\quad Z=0,\quad \text{for } \sin^2\theta\ge\tfrac{1}{3}$$

- Approximate θ as quadratic function of projected distance

$$\theta=p_0\left(d^2-df^2\right)+p_1\left(d-df\right)+\arcsin\sqrt{2/3}$$

- K=0, fit for p_0, p_1, & df (dashed)
- Fit for p_0, p_1, df, and K (dotted)



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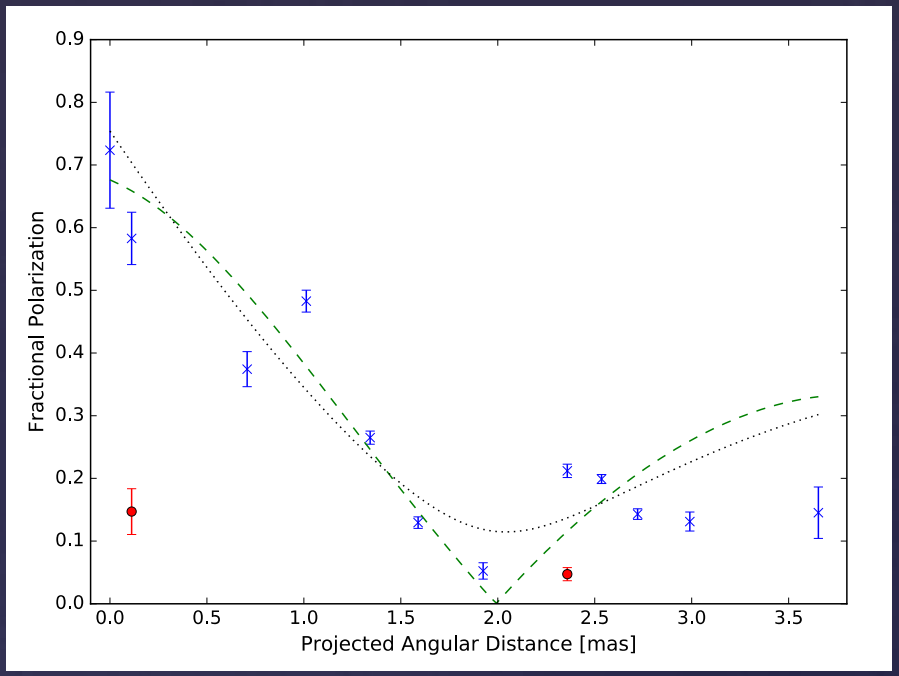

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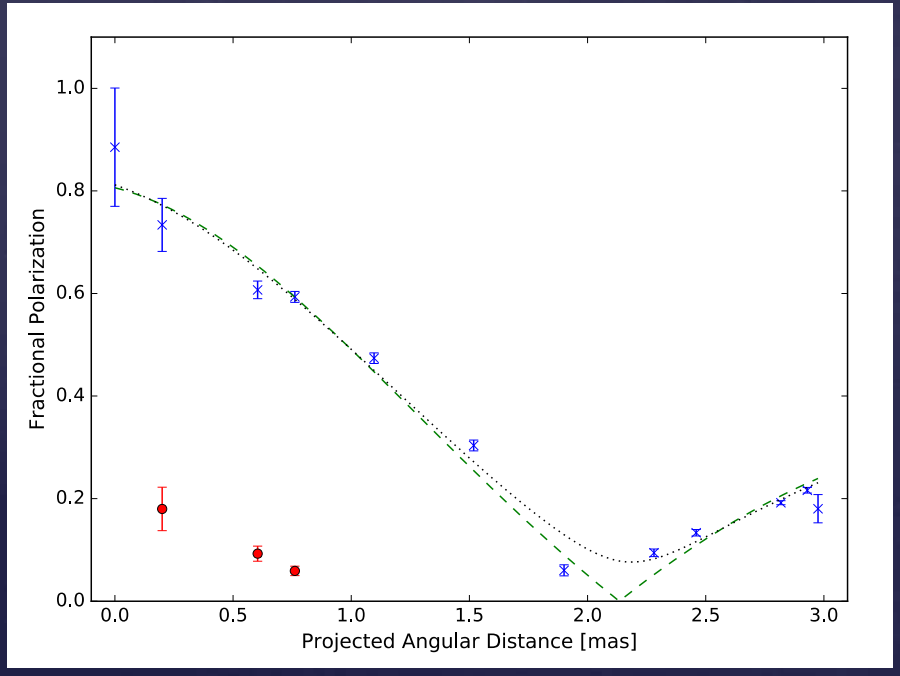

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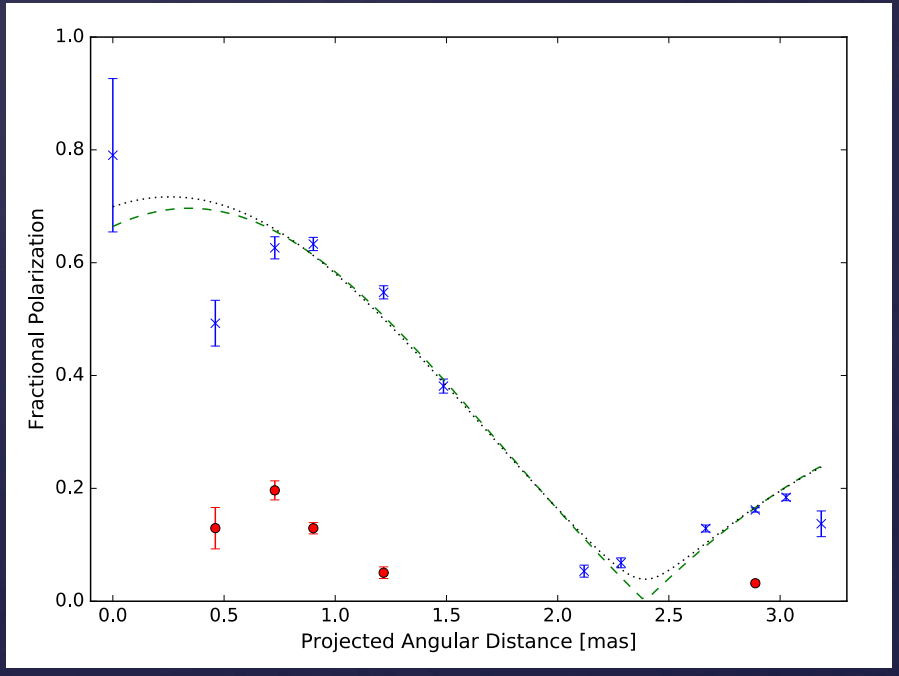


BD46AR

GKK EVPA Profile

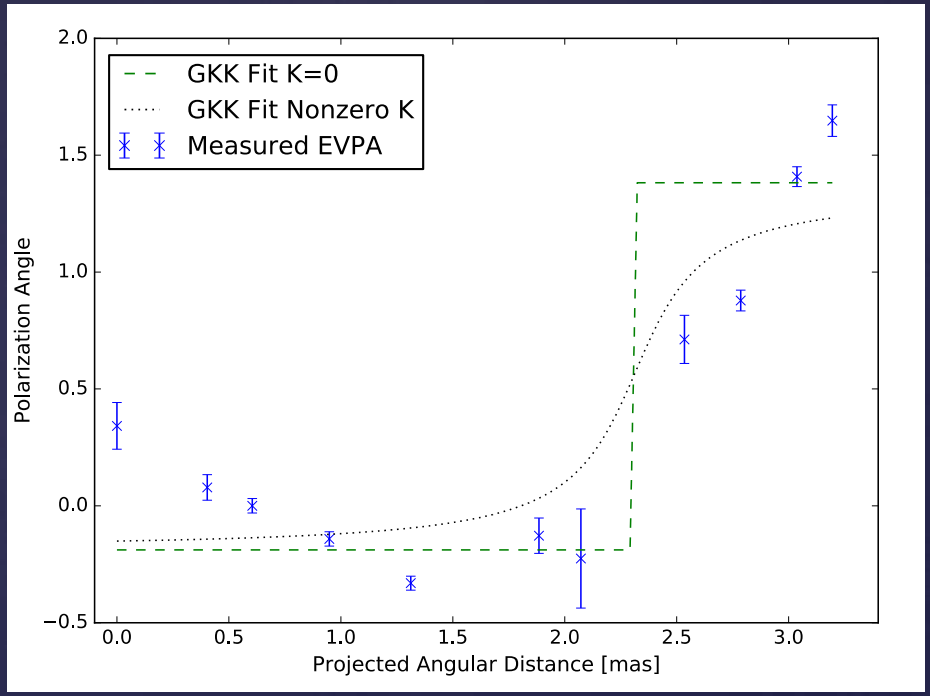
- EVPA

$$EVPA = \tfrac{1}{2}\arctan 2(Z, Y) + \gamma$$

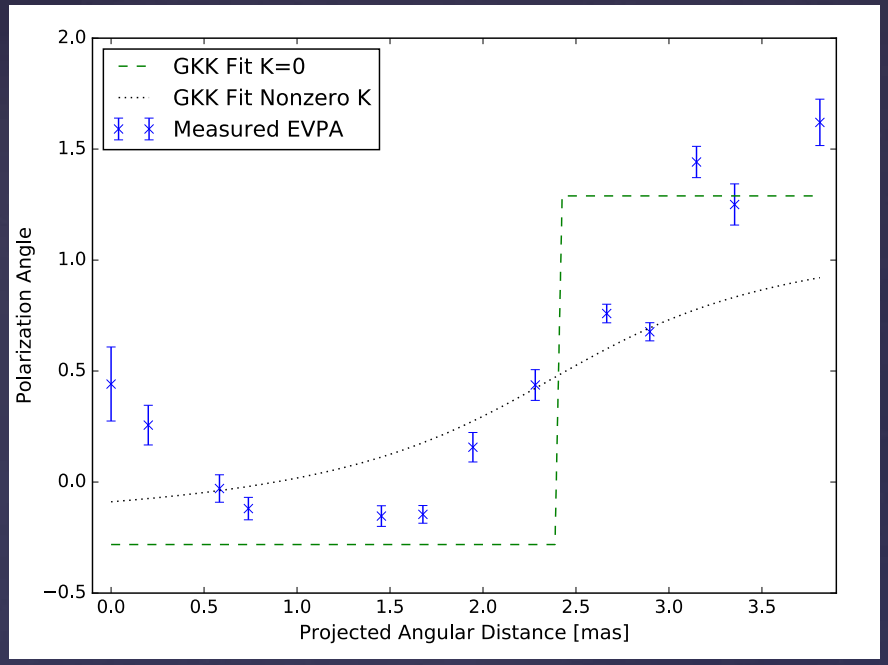
$$= \tfrac{1}{2}\arctan 2\left(K, \frac{3\sin^2\theta - 2}{3\sin^2\theta}\right) + \gamma$$

- GKK K=0 EVPA should be step function at θ~55°
- Actually smooth rotation*
- Nonzero K -> smooth rotation, smaller EVPA range
- Faraday Rotation?

BD46AP



*See Vlemmings & Diamond 2006



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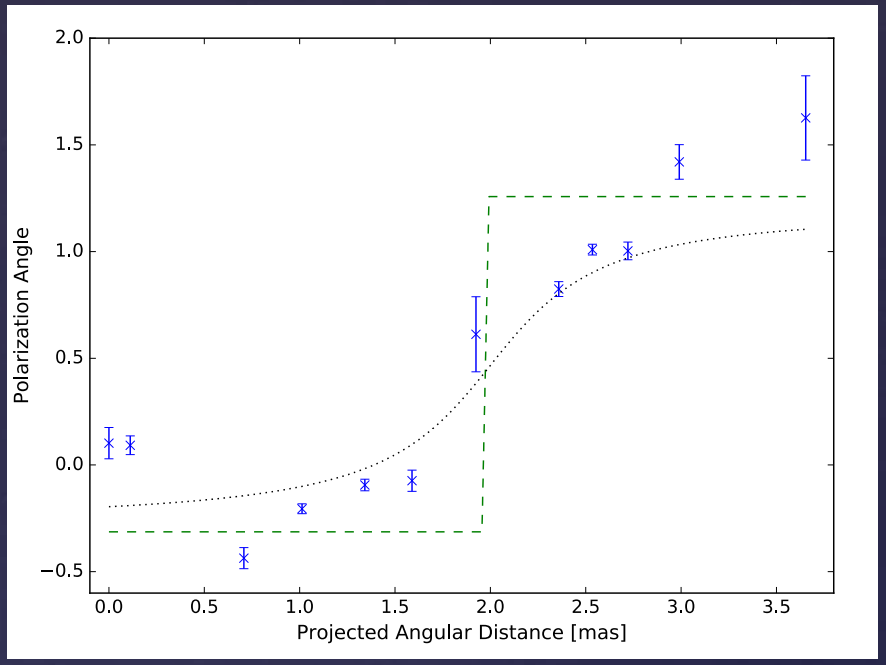

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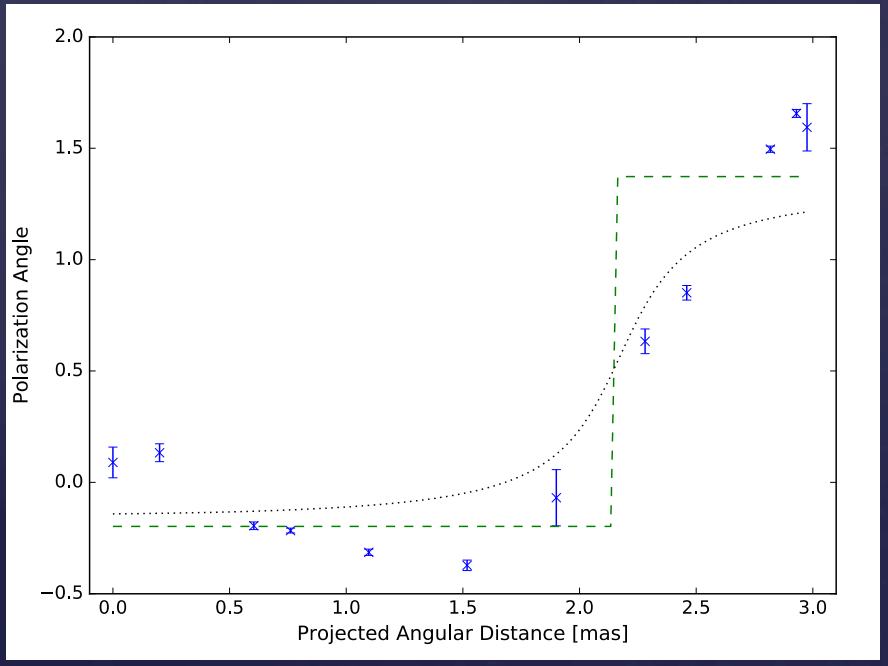

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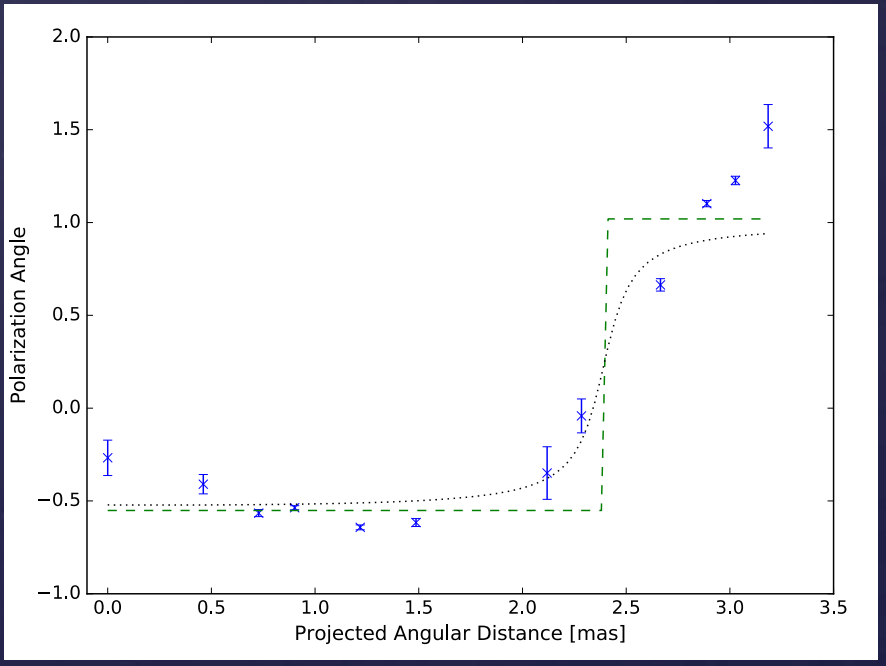

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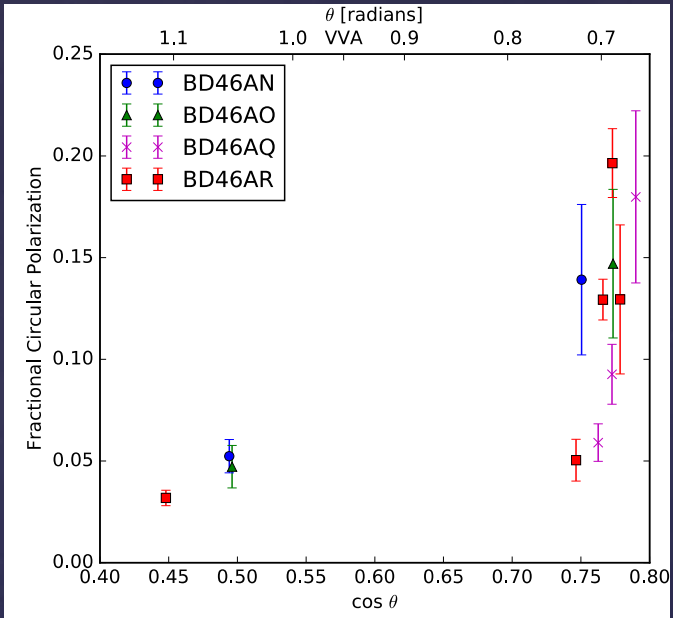
Circular Polarization & GKK



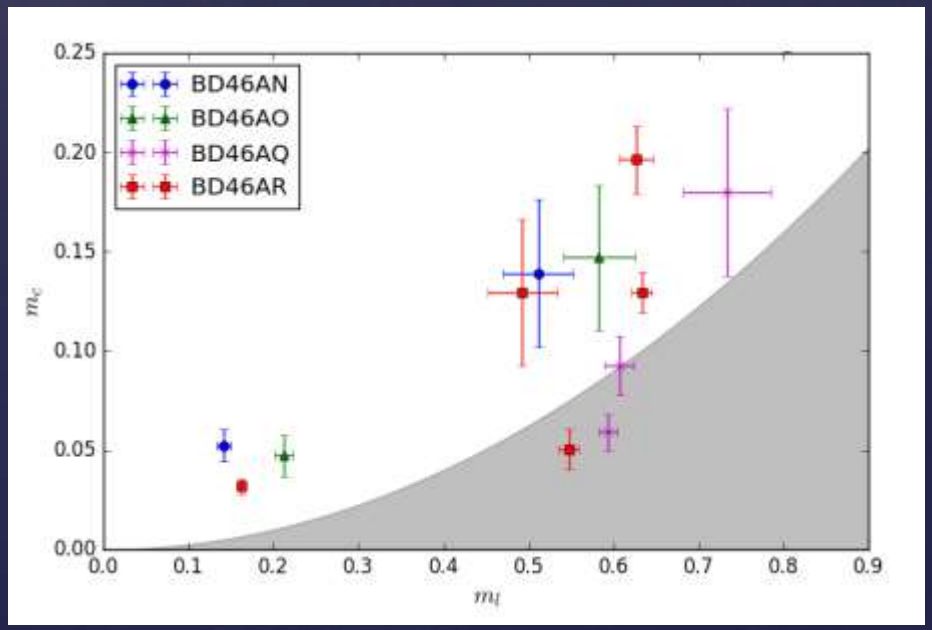
- θ from GKK fit
- Tendency toward higher m_c for higher cos θ
- Closest to Gray (2012) m_c approximately ∝ cos θ
- Predictions: ∝ 1/cos θ (Elitzur 1996) or peaked cos θ ~ 0.2 (Watson & Wyld 2001), GKK (1973) assumed Stokes V=0

Linear to Circular Conversion: Non-Zeeman Mechanisms

- Wiebe & Watson (1998) conversion by different optical axes or change in B orientation along line of sight

$$m_c < m_l^2/4$$

- Few points within limit
- Epoch averages also exceed limit



See also: Cotton et al. (2011)

Alternatives to GKK

- Local Magnetic Field Curvature
  - Would give smoother EVPA rotation
  - But why the m_l profile?
- Radial Change in Anisotropic Pumping Conditions
  - Asensio Ramos et al (2005)
  - Flip caused by anisotropy factor, w, crossing zero
  - Would be unpolarized when w=0
  - Don't expect EVPA rotation of over ~ 45°

Summary

- 5 epochs SiO ν=1 J=1-0 Full-Polarization VLBA Observations of TX Cam
- GKK limit $\Delta\omega >> g\Omega >> R >> \Gamma$
  - Good fit to GKK m_l profile for asymptotic solution
  - EVPA shows smooth rotation instead of sudden flip
  - Faraday Rotation?
- Linear -> Circular Polarization Conversion
  - Observations do not favor non-Zeeman mechanisms
- Local Magnetic Field Curvature
  - But why m_l profile?
- Anisotropic Pumping
  - Unclear EVPA profile