

Title: Detection and Implications of Horizon-Scale Polarization in Sgr A*

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Abstract: The Event Horizon Telescope has measured compact emission in Sgr A* and M87 at resolutions comparable to their event horizons. Polarimetry with the EHT enables a powerful extension of this work, mapping magnetic field structures via the highly polarized synchrotron emission that is thought to dominate the compact emission. Sgr A* provides an especially attractive target for linear polarization studies with the EHT because it is unpolarized at the longer wavelengths where facility instruments are available. I will report on polarimetric results from our 2013 campaign, which demonstrate a sharp increase in the linear polarization fraction and variability of Sgr A* with increasing baseline. These data allow rich model-independent inferences about the polarization images and morphology and reveal that polarization is a sensitive probe of intrinsic variability.

Detection and Implications of Horizon-Scale Polarization in Sgr A^{*}

Michael Johnson (CfA)

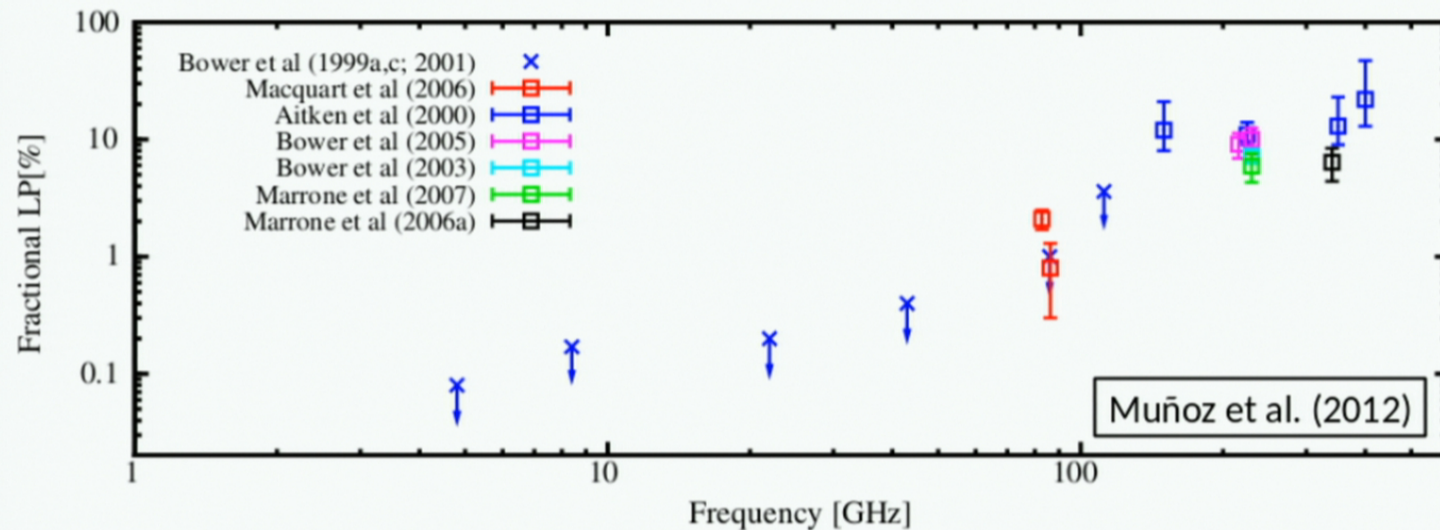
with Vincent Fish, Shep Doeleman, Dick Plambeck, Dan Marrone, Michael
Kosowsky, Kazunori Akiyama, Ru-Sen Lu, John Wardle, Mel Wright

EHT2014

November 10, 2014



Polarization of Sgr A*

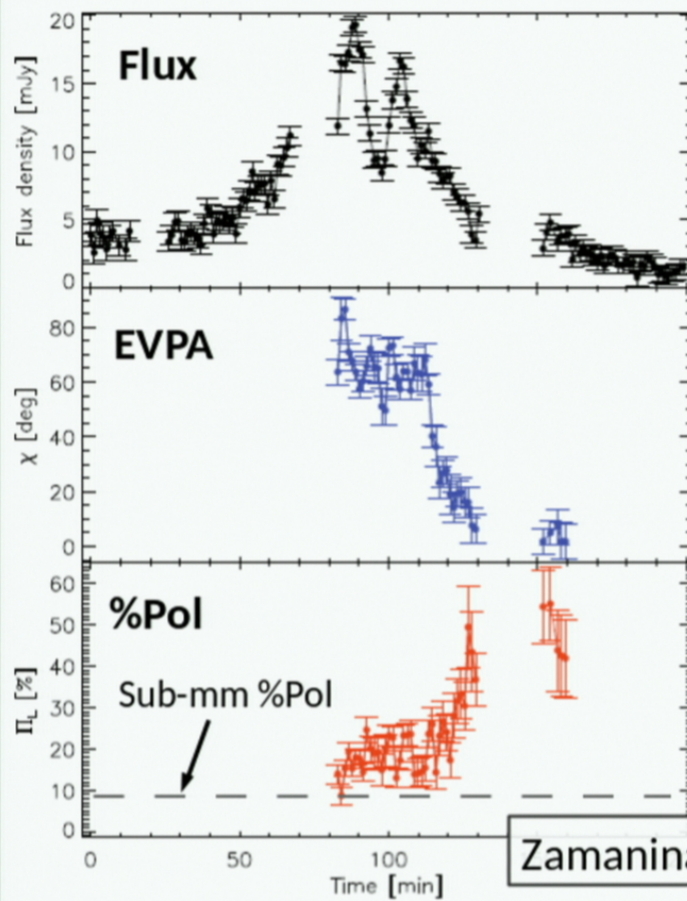


Linear polarization only detected above ~100 GHz

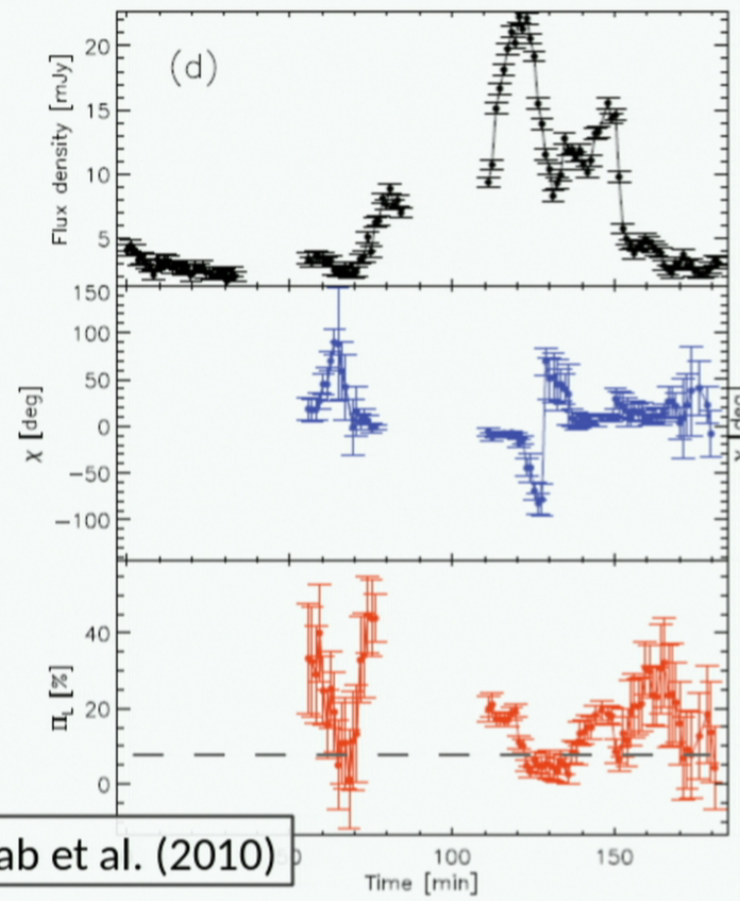
LP & RM too high for ADAFs, RM possibly too low for a jet
(e.g., Quataert & Gruzinov 2000, Bower+ 2003;2005, Marrone+ 2007, Li+ 2014)

Previous polarization measurements have been limited to ~1'' resolution

Near-Infrared Flares – Highly Polarized!



Zamaninasab et al. (2010)



Simulated Polarization Maps at 230 GHz

Magnetized Keplerian
+ Ray Tracing

Semi-Analytic RIAF
+ Ray Tracing

3-D GRMHD with PRT

(c2)

Connected-element interferometry is only sensitive to the **image-averaged** polarization

The ~7% polarization of Sgr A* could be:

1. Low intrinsic polarization (optically thick, non-thermal)
2. Unassociated polarization component
3. Disordered Fields in Turbulent Flow
4. Ordered Fields Threading the Emission Region with Changing Direction

Need VLBI to unambiguously distinguish among these possibilities

Bromley et al. (2001)

Broderick & Loeb (2006)

Shcherbakov & McKinney (2013)

Fractional Polarization

$$\frac{R_1 L_2^*}{R_1 R_2^*} \approx \left(\frac{G_{2,L}}{G_{2,R}} \right)^* \left[m e^{-2i\phi_2} + \underbrace{D_{1,R} e^{2i\phi_{12}} + D_{2,L}^*}_{\text{Instrumental "Leakage" (Spurious Polarization)}} \right]$$

Intrinsic fractional polarization

Unknown, but stable, phase

Idea: Phase reference (weak) cross-hand visibilities to (strong) parallel-hand visibilities

A baseline-based closure quantity

Fractional polarization is a good measurable: amplitude and phase

Immune to scatter broadening

Fractional Polarization

Measure fractional polarization in the visibility domain:

$$\check{m}(\mathbf{u}) \equiv \tilde{\mathcal{P}}(\mathbf{u})/\tilde{\mathcal{I}}(\mathbf{u})$$

$$\tilde{\mathcal{P}}(\mathbf{u}) \equiv \tilde{\mathcal{Q}}(\mathbf{u}) + i\tilde{\mathcal{U}}(\mathbf{u})$$

Not Fourier conjugate to fractional polarization in the image domain:

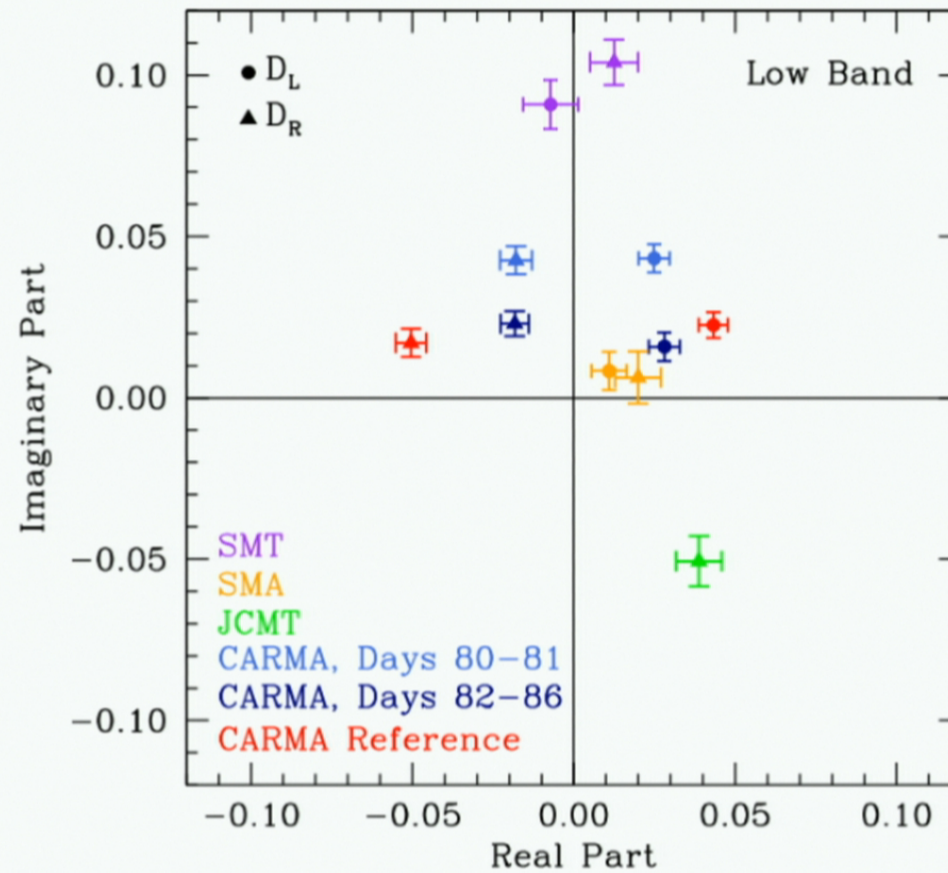
$$m(\mathbf{x}) \equiv \mathcal{P}(\mathbf{x})/\mathcal{I}(\mathbf{x})$$

Idea:

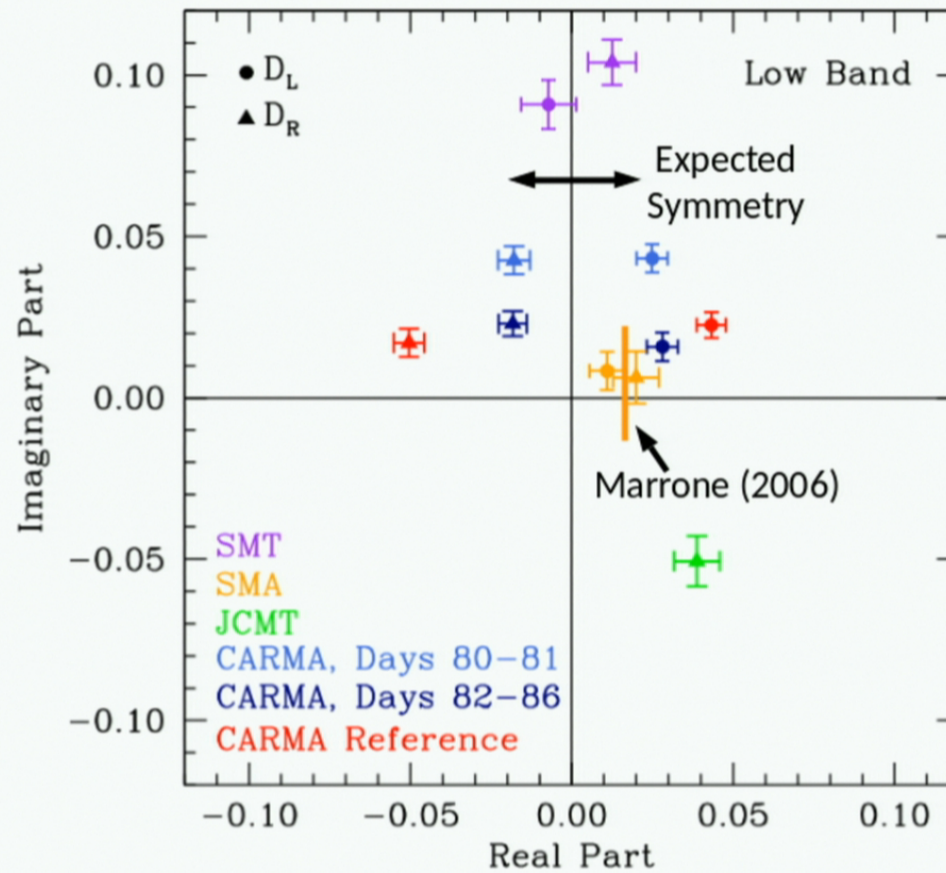
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The Inferred Leakage Terms

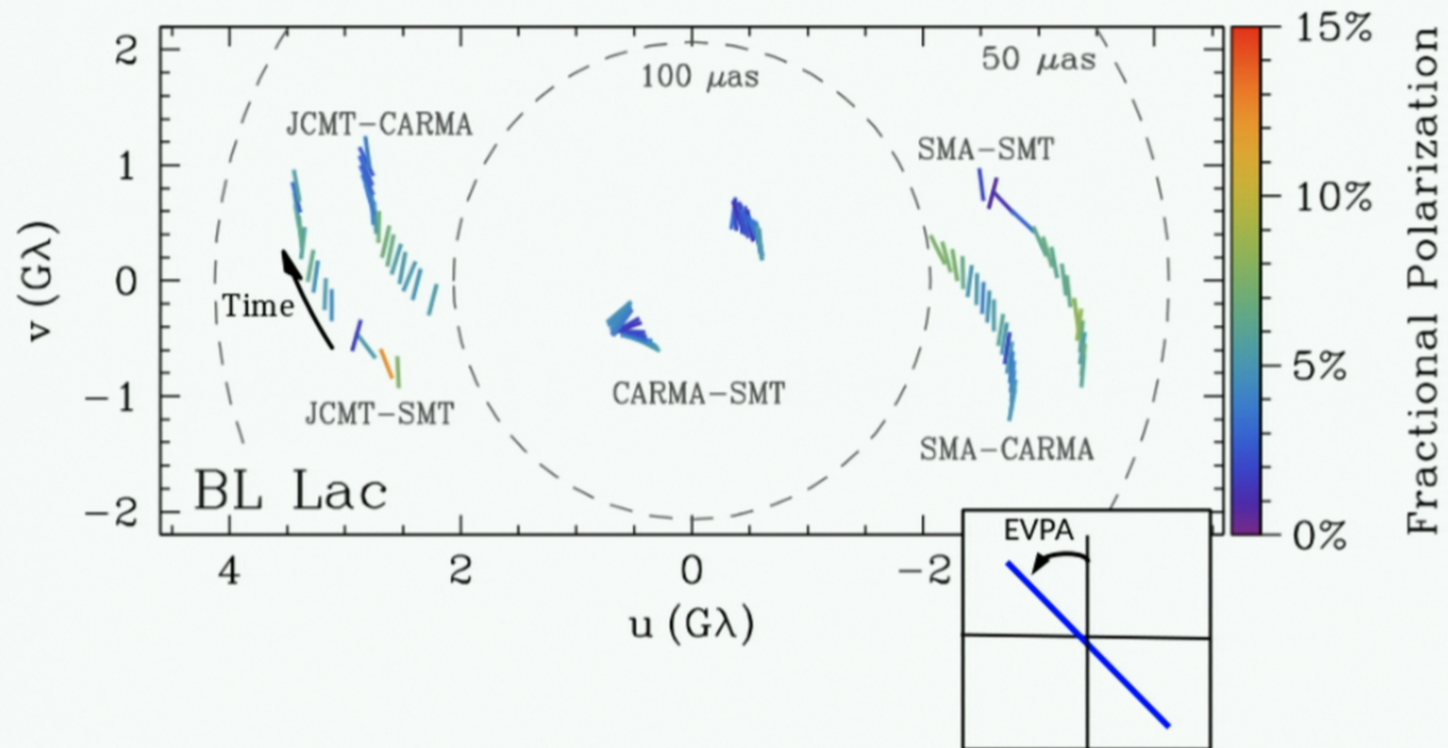


The Inferred Leakage Terms



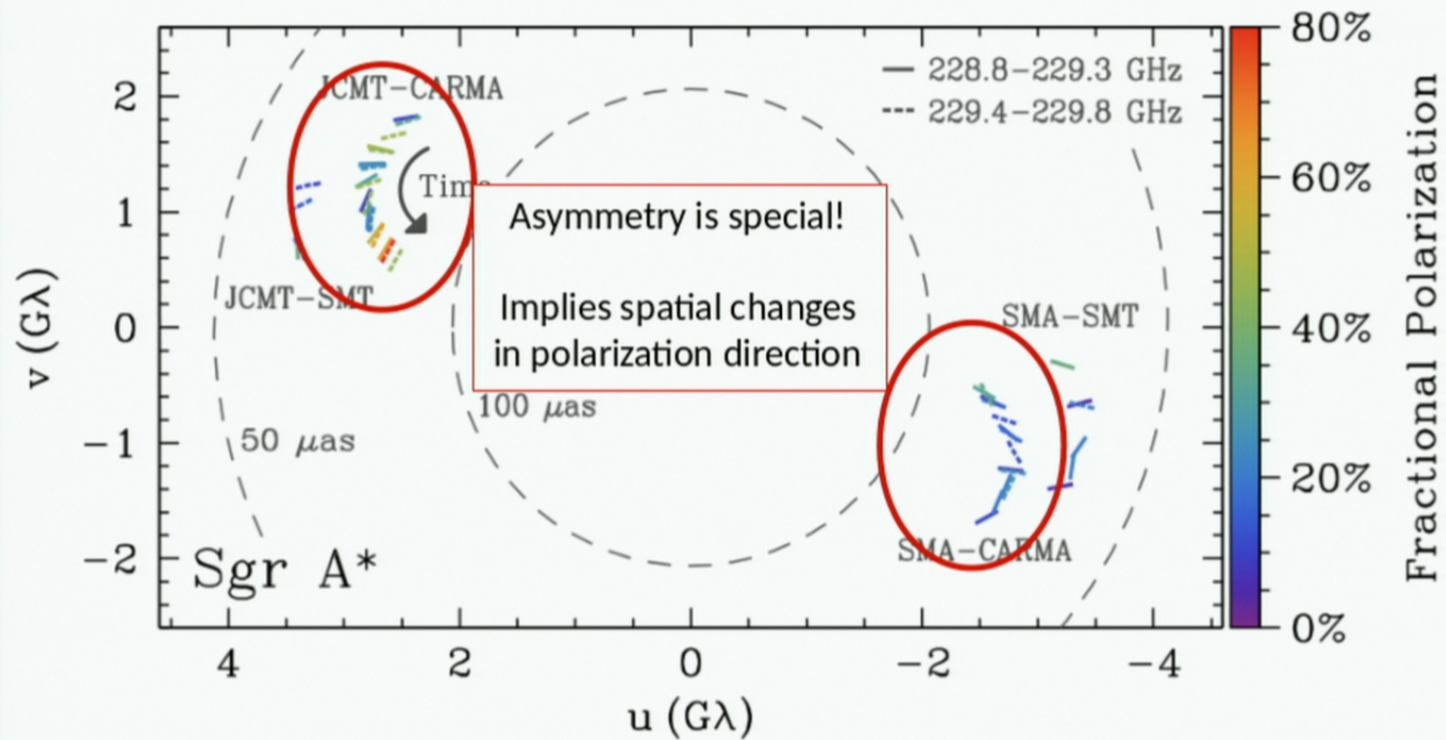
BL Lac

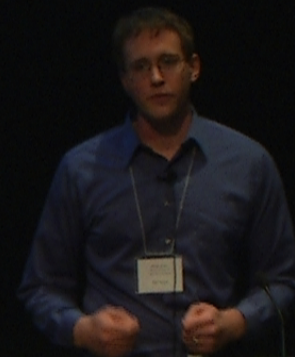
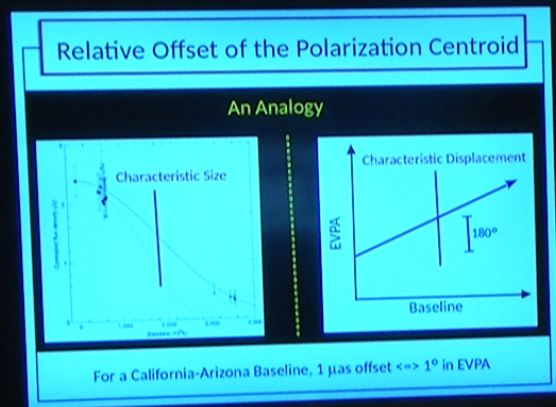
2013 EHT Data



Sgr A*

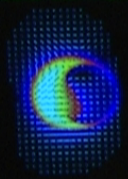
2013 EHT Data



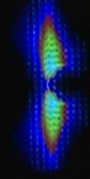


Ordered Fields Near the Event Horizon

Sheared Fields in Keplerian Flow

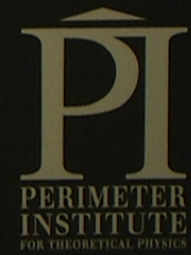


Poloidal Fields in Jet-Launching Region



Magnetically-Arrested Disk

Simulations Courtesy of Avery Broderick and Jason Dexter



Summary

Polarization with the EHT is now yielding first results

For Sgr A*:

- High polarizations require ordered magnetic fields near the event horizon
- Implies optically thin ($\tau \lesssim 1$), synchrotron emission
- Polarized emission is closely aligned with the total emission
- Variability is dominant

Rapid progress in polarimetric imaging and time-domain studies

Imaging is not required to effectively study variability



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