Polarimetry with the Event Horizon Telescope

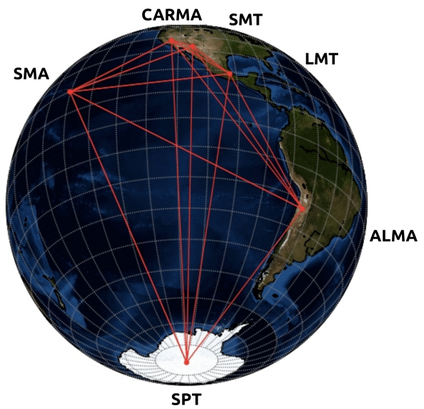
The Event Horizon Telescope Collaboration

The Event Horizon Telescope

The Event Horizon Telescope (EHT) is a global 1.3-mm VLBI array achieving angular resolutions of tens of *micro*-arcseconds — sufficient to image the event horizons of nearby supermassive black holes. Results include:

- Measuring the size of the event horizon of Sgr A*[1]
- Detecting time variability in the Schwarzschild-radius scale emission of Sgr A*[2]
- Measuring the size of the accretion disk powering the jet of M87, providing an estimate of black hole spin[3]

Polarization with the EHT can probe the magnetic field structure in these environments and is also sensitive to relativistic effects that are not apparent in unpolarized flux, such as parallel transport in the curved spacetime.[4,5]



The Event Horizon Telescope including projected site additions in 2015, as seen by Sgr A*. The SMA critically anchors the E-W baselines. (Credit: L. Vertatschitsch)

Polarimetric VLBI

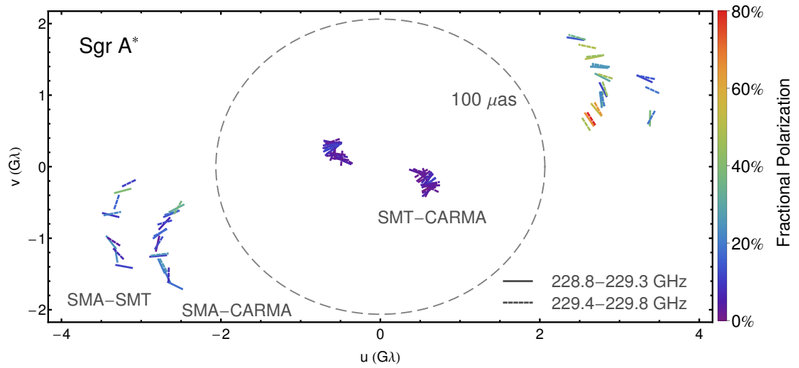
Cross-hand visibilities carry linear polarization information. Fractional polarization estimates then phase reference these measurements to parallel-hand visibilities, providing:[6]

- A good VLBI observable: amplitude and phase
- Two measurements per baseline: $\langle R_1 L_2^* \rangle$ and $\langle L_1 R_2^* \rangle$
- Immunity to scatter broadening and gain fluctuations

Intrinsic fractional polarization — Parallactic Angle

$$\frac{R_1 L_2^*}{R_1 R_2^*} \approx \left(\frac{G_{2,\mathrm{L}}}{G_{2,\mathrm{R}}}\right)^* \left[m e^{-2i\phi_2} + D_{1,\mathrm{R}} e^{2i\phi_{12}} + D_{2,\mathrm{L}}^*\right]$$

Unknown, but stable, phase — Instrumental "Leakage"



Measured fractional polarization with baseline for Sgr A* during one day. The polarization strength and direction are shown by the color and direction of the plotted ticks. The polarization fraction and variability increase sharply on the Hawaii baselines, which have resolutions of ∼6 Schwarzschild radii.

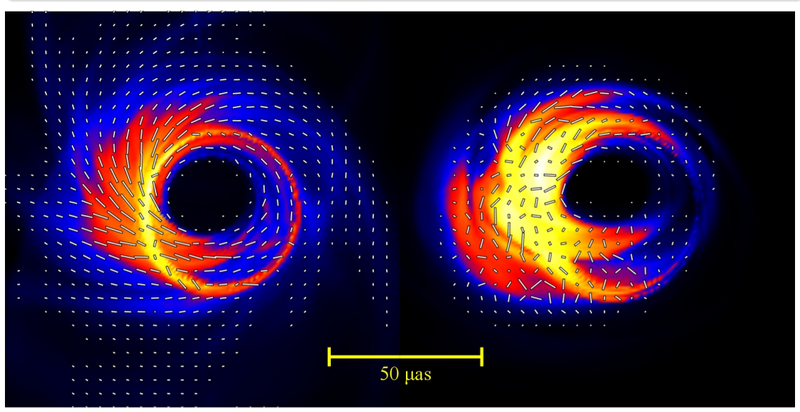
Magnetic Fields at the Event Horizon

The submillimeter emission from Sgr A* is[7,8,9]

- Energetically dominant (the "submillimeter bump")
- Synchrotron
- Partially optically thin

Yet, connected-element arrays measure only a ∼7% linear polarization fraction at these frequencies.[10,11] These comparatively low polarization fractions could indicate a disordered magnetic field within the turbulent emitting plasma or unresolved ordered magnetic fields with a low beam-averaged polarization.

Addressing these questions requires angular resolution matched to the emission region. Preliminary EHT results (see above Figure) suggest a highly ordered field threading the emission region, with significant structural variations.

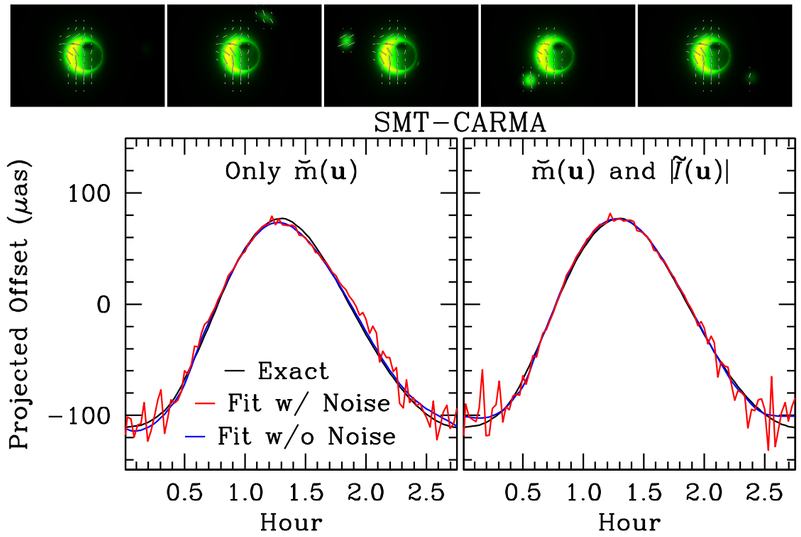


Simulated images and polarization maps at 230 GHz for two models of Sgr A* that are consistent with all non-polarimetric EHT data. In the left figure, the emission arises from a "magnetically-arrested" accretion disk, while the right figure shows a standard MRI-dominated disk (courtesy J. Dexter).

Relative Astrometry via Polarimetric VLBI

Polarimetric EHT data are excellent for variability studies.[12] Because fractional polarization carries phase information, it is well-suited to astrometry of flaring structures. The natural phase reference is the bright quiescent flux.

- No assumptions needed about quiescent structure or time-variability (e.g., periodicity)
- Only require that the flare be compact and polarized
- Only a single baseline is required
- Astrometric accuracy of $\lesssim$5 μas with current SNR



Exact and inferred displacement of a "hot spot" orbiting Sgr A* using synthetic data on the shortest and least-sensitive EHT baseline (SMT-CARMA). Thermal noise reflects 100-second integrations with current sensitivity.

References

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