Observing Event Horizons with High-Frequency VLBI

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Motivations

Understand black hole physics
  accretion/outflow
  general relativity

Largest apparent event horizon:
  Sgr A*  $R_{sch} \sim 10 \mu\text{as}$
  M87 similar

Event horizon scale resolution possible with millimetre VLBI
  Hawaii-Chile and Europe-Chile: 30 $\mu\text{as}$ (230 GHz)
  20 $\mu\text{as}$ (345 GHz)

High-frequency observations needed due to scattering, opacity

Now: non-imaging VLBI observables
Future: imaging
General Relativistic Effects

Shadow

Doppler beaming

Photon orbit

Innermost stable circular orbit: 4 - 30 min (depending on spin)
General Relativistic Effects

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Telescopes
2007 Data

Correlated Flux Density (Jy) vs. Baseline ($x10^6 \lambda$)

- SMT-CARMA
- JCMT-CARMA
- JCMT-SMT
The Compact Emission is Small

Emission cannot be optically thick and centered on black hole

43 µas (measured)
37 µas (deconvolved)
Model Parameter Estimation

Broderick et al. 2009
2009 Data

large-scale component

JCMT-CARMA detections disfavour face-on disk models

compact component variable but constant size

asymmetric?
M87

More luminous class of AGN

More massive central black hole, known jet source

Innermost stable circular orbit $\sim 50 \mu$as

This scale is relevant for TeV photon generation and jet formation

43 GHz VLBA image (Walker et al. 2008)
Long VLBI detections may constrain jet models
Summary

Sgr A* has now been detected on all baselines between Hawaii, California, and Arizona

We can already place strong constraints on models of the emitting region

Variability seen in compact component, although no change in size

Future observations will be more sensitive...
- phased-array processor
- wider bandwidth

...and have greater angular resolution