Event-Horizon-Scale Structure in the Supermassive Black Hole Candidate at the Galactic Centre

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Abstract.

The cores of most galaxies are thought to harbor supermassive black holes, which power galactic nuclei by converting the gravitational energy of accreting matter into radiation. Sagittarius A* (Sgr A*), the compact source of radio, infrared, and X-ray emission at the center of the Milky Way, is the closest example of this phenomenon, with an estimated black hole mass that is 4,000,000 times that of the Sun. A long-standing astronomical goal is to resolve structures in the innermost accretion flow surrounding Sgr A*, where strong gravitational fields will distort the appearance of radiation emitted near the black hole. Radio observations at wavelengths of 3.5mm and 7mm have detected intrinsic structure in Sgr A*, but the spatial resolution of observations at these wavelengths is limited by interstellar scattering. Here we report observations at a wavelength of 1.3mm that set a size of 37^{+16}_{-10} microarcseconds on the intrinsic diameter of Sgr A*. This is less than the expected apparent size of the event horizon of the presumed black hole, suggesting that the bulk of Sgr A* emission may not be centered on the black hole but arises in the surrounding accretion flow.

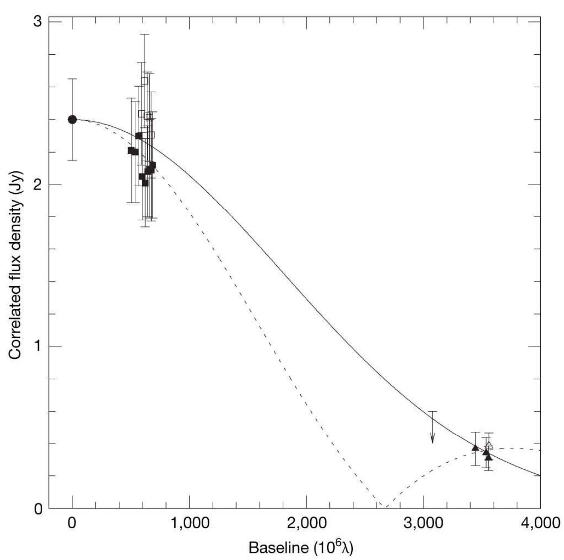

Figure 1 | Fitting the size of Sgr A* with 1.3 mm wavelength VLBI. Shown are the correlated flux density data on the ARO/SMT–CARMA and ARO/SMT–JCMT baselines plotted against projected baseline length (errors are 1σ). Squares show ARO/SMT–CARMA baseline data and triangles show ARO/SMT–JCMT data, with open symbols for 10 April and filled symbols for 11 April. The solid line shows the weighted least-squares best fit to a circular Gaussian brightness distribution, with FWHM size of 43.0 μas. The dotted line shows a uniform thick-ring model with an inner diameter of 35 μas and an outer diameter of 80 μas convolved with scattering effects due to the interstellar medium. The total flux density measurement made with the CARMA array over both days of observing (2.4 ± 0.25 Jy : 1σ) is shown as a filled circle. An upper limit for flux density of 0.6 Jy, derived from non-detections on the JCMT–CARMA baseline, is represented with an arrow near a baseline length of $3{,}075 \times 10^6\lambda$.

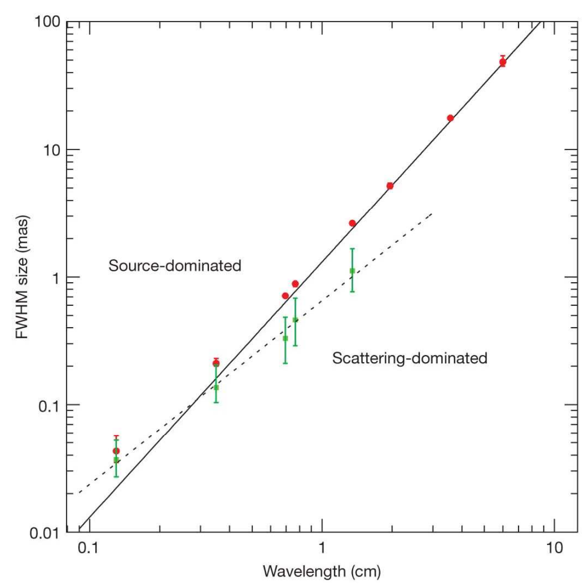

Figure 2 | Observed and intrinsic size of Sgr A* as a function of wavelength. Red circles show major-axis observed sizes of Sgr A* from VLBI observations (all errors 3σ). Data from wavelengths of 6 cm to 7 mm are from ref. 13, data at 3.5 mm are from ref. 7, and data at 1.3 mm are from the observations reported here. The solid line is the best-fit λ^2 scattering law from ref. 13, and is derived from measurements made at $\lambda > 17$ cm. Below this line, measurements of the intrinsic size of Sgr A* are dominated by scattering effects, while measurements that fall above the line indicate intrinsic structures that are larger than the scattering size (a 'source-dominated' regime). Green points show derived major-axis intrinsic sizes from 2 cm $< \lambda <$ 1.3 mm and are fitted with a λ^{α} power law ($\alpha = 1.44 \pm 0.07$, 1σ) shown as a dotted line. When the 1.3-mm point is removed from the fit, the power-law exponent becomes $\alpha = 1.56 \pm 0.11$ (1σ).