Of The Milky Way At The Center Black Hole

(CDFN: Barger et al. 2002; See also Giacconi et al. 2002 for CDFS)
Ferrarese & Merritt (2000)
Gebhardt et al. (2000)
Filled circles: high-proper motion stars within 0.1 pc

Open circles: earlier study by Genzel & Eckart

Squares: radial velocity study

Plummer model: $\rho(r) = \rho(0) \left(1 + \frac{r}{r_c}\right)^{-\alpha/2}$

$M_{bh} = 2.6 \times 10^6 M_\odot$

$\alpha_{dark} = 3$

$7 \times 10^{18} M_\odot pc^{-3}$

$0.00002 pc$

$\alpha_{dark} = 4$

$2 \times 10^{12} M_\odot pc^{-3}$

$0.005 pc$

$\alpha_{dark} = 5$

$6 \times 10^{11} M_\odot pc^{-3}$

$0.01 pc$

$\alpha_{lum} = 2$

$4 \times 10^6 M_\odot pc^{-3}$

(Ghez, et al. 1998)
X-ray Flares from Sgr A*  
(Baganoff et al. 2001)

During a flare, Sgr A*'s X-ray luminosity can increase by more than one order of magnitude.

This X-ray flare lasted a few hours. Significant variation in flux was observed over 10 minutes.
Geometry of the Inner 20 Schwarzschild Radii
Long-Term Radio Periodicity

(Folded light curve)

Power spectral distribution

(Zhao et al. 2001)
Implications of the radio periodicity

• This 106-day period is much longer than the dynamical time scale where the emission is produced.
• Strong internal coupling would require the disk to precess as a rigid body.
• It may be the signature of a precessing disk about a spinning black hole.

\[
P = \frac{\pi r_o^{2.5} r_i^{0.5}[1-(r_i/r_o)^{2.5}]}{5 a M [1-(r_i/r_o)^{0.5}]}
\]

Black Hole Spin:
\[a/M \sim 0.1 \ (r_i/3r_S)^{0.5}(r_o/30r_S)^{2.5}\]
Toward mm-submm wavelengths, the thin hot gas radiates predominantly via thermal synchrotron processes. Although the event horizon itself is not visible, the black hole’s shadow appears as a depression in the line-of-sight emissivity. Light from the infalling gas behind Sgr A* does not make it directly to us because of strong gravitational bending, or absorption by the black hole. The shadow’s size depends weakly on the metric (though its shape can change) and has a diameter of about 5 Schwarzschild radii. This image assumes no scattering by the intervening medium, and an ideal telescope resolution. At the distance to the Galactic center, this diameter corresponds to about 30 microarcseconds across.
Polarimetric Imaging with Sub-mm VLBI

The predicted size (~30 microarcsecs) of the mm-emitting region approaches the resolution of current radio interferometers. However, there are still too few single-dish telescopes that can operate at mm and sub-mm wavelengths.

In addition, there are two complications that really force the optimum imaging region to lie at or below ~0.7 mm:

[1] scatter-broadening of the image by the ISM. This is incorporated by smoothing the image with an elliptical Gaussian with a FWHM of

\[24.2 \, \mu\text{as} \times \left(\frac{\lambda}{1.3 \, \text{mm}}\right)^2\] along the major axis and

\[12.8 \, \mu\text{as} \times \left(\frac{\lambda}{1.3 \, \text{mm}}\right)^2\] along the minor axis (Lo et al. 1998).

[2] the finite achievable telescope resolution from the ground. This is added by convolving the smoothed image with a spherical Gaussian point-spread function of FWHM

\[33.5 \, \mu\text{as} \times \left(\frac{\lambda}{1.3 \, \text{mm}}\right) \left(\frac{L}{8000 \, \text{km}}\right)^{-1}\]

for an idealized global interferometer (Krichbaum 1996).
1.5 mm
(With Bromley and Liu 2001;
with Falcke and Agol 2000;
with Hollywood 1995)
Closing Thoughts

• Sgr A*’s spectral and polarimetric properties suggest emission from a small, hot, magnetized disk below 3-7 mm, but from a larger outflow region at longer wavelengths.

• The strong X-ray flares are probably induced by an enhancement of the accretion rate through the disk. The infrared flares appear to require at least some nonthermal emission---possibly stochastic particle scattering with the turbulent magnetic field.

• The 106-day radio periodicity may be due to precession with a/M ~ 0.1.

• Within 3-5 years, mm imaging may produce the first direct (visual) evidence of a black hole’s shadow. An analogous experiment at X-ray energies should reveal the black hole’s shadow changing dynamically during the evolution of an X-ray burst.