1. INTRODUCTION

The recent discovery of a cloud moving toward the Galactic center (Gillessen et al. 2012) creates a potential opportunity for testing models of Sgr A*. The >3 $M_\odot$ cloud will interact strongly with gas near pericenter at $r_p \simeq 300$ AU $\simeq 8000 G M/c^2$ ($M \equiv$ black hole mass), and may change the black hole accretion rate $M$. Since the structure of the cloud and the surrounding medium are uncertain, possible outcomes range from small changes in $M$ over timescales of decades to rapid, large changes in $M$.

The dynamical timescale at $r_p$ is $\tau_d = (r_p^3 / (GM))^1/2 = 0.5$ yr, and the viscous timescale $\tau_{vis} = (\alpha \Omega)^{-1}(R/H)^2 \approx 100$ yr $\gg \tau_{PhD}$, assuming $\alpha = 0.05$ and $H/R = 0.3$, i.e., a hot, radiatively inefficient accretion flow. After an initial transient phase while the flow circularizes—accompanied by transient emission—it is natural to think that the flow will settle into a steady state. The settling timescale could be as little as a few $\tau_d$, and so the steady state may arrive as soon as mid-2014. If the resulting flow can be modeled as a steady disk, the excess mass will drain away on the viscous timescale, i.e., the source will remain bright well into the 22nd century. It is therefore interesting to ask how changes in $M$ manifest themselves observationally.

Current observations of Sgr A* show $F_{\nu} \sim 0.5–1$ Jy at 1–50 GHz with a nearly flat spectral slope (Falcke et al. 1998); $F_{\nu} \sim \nu^\alpha$, with $\alpha = 0.17–0.3$. The spectral slope becomes flatter and variable at 230–690 GHz, with $\alpha = -0.46–0.08$ (Marrone 2006), which is commonly interpreted as signaling a transition from optically thick to optically thin synchrotron emission. The discovery of polarized emission (polarization fraction at level of a few percent) at level of a few percent) at $\nu < 4.4 \times 10^3$ erg s$^{-1}$ (Baganoff et al. 2003). We are not aware of secular trends in these observed properties of Sgr A*.

One model of Sgr A* that fits most observational constraints is our relativistic accretion model (Mościbrodzka et al. 2009), where submillimeter, IR, and X-ray emission arise in an optically thin, geometrically thick accretion flow close to the black hole. The spectrum and size of the source depend on the black hole mass ($M$), with $M > 2 M_\odot$ for modest increases in $\dot{M}$. Since Gillessen et al. have recently discovered a cloud moving toward Sgr A* that will arrive in summer 2013, $M$ may increase from its present value $M_0$. We therefore reconsider the “best-fit” accretion model of Mościbrodzka et al., which is based on a general relativistic MHD flow model and fully relativistic radiative transfer, for a range of $M$. We find that for modest increases in $M$ the characteristic ring of emission due to the photon orbit becomes brighter, more extended, and easier to detect by the planned Event Horizon Telescope submillimeter Very Long Baseline Interferometry experiment. If $M \gtrsim 8 M_0$, this “silhouette” of the black hole will be hidden beneath the synchrotron photosphere at 230 GHz, and for $M \gtrsim 16 M_0$ the silhouette is hidden at 345 GHz. We also find that for $M > 2 M_0$ the near-horizon accretion flow becomes a persistent X-ray and mid-infrared source, and in the near-infrared Sgr A* will acquire a persistent component that is brighter than currently observed flares.

Key word: Galaxy: center

Online-only material: color figures
model parameters are the source inclination \(i\), black hole spin \(a_\ast (0 \leq a_\ast \leq 1)\), \(T_i/T_e\), and \(M\). We fix \(M\) so that the 1.3 mm flux matches the observed \(\lesssim 3\) Jy.

The relativistic accretion models are not tightly constrained by the data, but they reveal the following: (1) face-on models that reproduce the millimeter flux would look like rings and therefore, in VLBI data, have dips in visibilities on fixed intermediate baselines, while existing observations suggest that the ring radius would need to vary to fit the data (Fish et al. 2011; see also Broderick et al. 2011). More nearly edge-on models are therefore favored; (2) models with \(a_\ast \gtrsim 0.98\) that reproduce the millimeter flux have a hot, dense inner disk that would overproduce X-rays via inverse Compton scattering. Lower spin, \(a_\ast \sim 0.9\), models are therefore favored; (3) the observed source size and flux fix the temperature of the emitting electrons \(T_e = F_\nu c^2/(4\pi k T_e^2\sigma T)(\sigma \equiv \text{rms size of the source on the sky})\) and this turns out to favor \(T_i/T_e \simeq 3\) models. The “best-fit” model from Mościbrodzka et al. (2009) has \(a_\ast \simeq 0.94, i = 85^\circ, M \equiv M_\odot \gtrsim 2 \times 10^{-3} M_\odot \text{yr}^{-1}\), and \(T_i/T_e \simeq 3\).

The relativistic disk model uses self-consistent dynamics and radiative transfer but is not unique. The electron distribution function is particularly poorly constrained. It is likely anisotropic, may contain multiple temperature components (Riquelme et al. 2012) and power-law components, and vary in functional form with time and position. Alternative accretion models (e.g., Broderick et al. 2011; Shcherbakov et al. 2010; Dexter et al. 2010) make different assumptions about the flow and/or distribution function and favor slightly different \(M, a_\ast\), and \(i\). These models may respond differently to an increase in \(M\).

Indeed, radically different models may also fit the data. The model dynamics depends on the initial magnetic field distribution; models with large vertical magnetic flux (e.g., McKinney et al. 2012) may respond differently to variations in the mass flux. Also, jet models for Sgr A* (Falcke & Markoff 2000; Loeb & Waxman 2007; Falcke et al. 2009) posit a luminous jet and a comparatively dim accretion disk. These may also respond differently to an influx of mass.

How, then, does our relativistic disk model respond to increases in \(M\)? In this Letter, we calculate the 1.3 and 0.87 mm flux, source size, and spectrum for the best-bet model over a range of \(M\). One question we seek to answer is whether a small increase in \(M\) would hide the event horizon (and the ring-like signature of the photon orbit, also known as the shadow or silhouette of the event horizon) underneath a synchrotron photosphere. This might prevent detection of the photon orbit by the planned Event Horizon Telescope (Doeleman et al. 2008). Another question is whether the increased \(M\) would make Sgr A* detectable in its quiescent state in the IR and X-ray. Below we describe variation of the flux and source morphology at 230 GHz (1.3 mm) and 345 GHz (0.87 mm) (Section 2), describe variation of the spectrum (Section 3), and finally discuss which features of the results are likely to be most robust (Section 4).

2. CHANGE OF Sgr A* SUBMILLIMETER LUMINOSITY AND SIZE FOR ENHANCED \(M\)

How do we naively expect the mm disk image size and flux to respond to changes in \(M\)? In our model, 1.3 mm emission in Sgr A* is thermal synchrotron emission from plasma with optical depth \(\tau_v \sim 1\), near the ISCO. The true electron distribution undoubtedly contains nonthermal components (e.g., Riquelme et al. 2012). Models with thermal + power-law distribution functions (e.g., Broderick et al. 2011) contain an O(1/3) nonthermal contribution to the flux at 1 mm, which hints at how uncertainty in the distribution function translates into uncertainties in the spectrum.

The thermal synchrotron absorptivity is \(\alpha_{\nu,i} = j_\nu/B_\nu\), where \(j_\nu = (\sqrt{2}\pi e^2 n_e v_e/3cK_2(\Theta_e^{-1}) (X^{1/2} + 2^{11/12} X^{1/6})^2 \exp(-X^{1/3}))\), \(X = v/v_e, v_e = 2/9(eB/2\pi m_e c)\Theta_e^2 \sin \theta, \theta\) is an angle between the magnetic field vector and emitted photon, \(K_2\) is a modified Bessel function of the second kind (Leung et al. 2011), and \(B_\nu \simeq 2\nu^2 \Theta_e m_e\). Near 1.3 mm, \(X \sim 1\), and the emissivity is nearly independent of frequency, so \(j_\nu \propto \nu m_e B\) and \(\alpha_{\nu,i} \propto \nu^3 n_e B \Theta_e^{-1} \). We will assume that \(n_e \propto M r^{-3/2}, \Theta_e \propto 1/r, \beta \propto \text{const.}\), so that \(B \propto M^{1/4} r^{-3/4}\) for \(r > GM/c^2\), and ignore relativistic corrections. Then for \(\tau_v \ll 1\) (or \(M \ll M_\odot\)), the source has size \(\sim GM/c^2\) and the flux \(F_\nu \sim (4/3)\pi (GM/c^2)^2 j_\nu \propto M^{7/2}/r^3\). For \(\tau_v \gg 1\), the source size is set by the photosphere radius \(r_{ph}\), where \(j_\nu \propto \alpha_{\nu,i} (r/dr) = 1\) (i.e., \(M \gg M_\odot\), but not so large that \(\Theta_e (r_{ph}) < 0.5\) so that our emissivity approximation fails). Then \(r_{ph} \propto M^{3/2}/\nu^2\), and the flux \(F_\nu \propto r_{ph}^2 B_\nu (r_{ph}) \sim M^{9/4}/\nu^3\).

These scaling laws, unfortunately, are not a good description of the variation of source size and flux with \(M\), for several reasons. First, relativistic effects are important; for \(M \sim M_\odot\) emission comes from close to the photon orbit and the source size is determined by Doppler beaming and gravitational lensing. Second, for the best-bet model at 1.3 mm \(\tau_v \sim 1\), so in a turbulent flow there is a complicated variation of the size of the effective photosphere with \(M\). Third, the emissivity is not precisely frequency independent near peak. We therefore need to turn to numerical models.

The best-bet model is taken from a survey of two-dimensional (2D) models. Here, we adopt the best-bet model parameters (\(a_\ast = 0.94, i = 85^\circ, T_i/T_e = 3\)) and use them to set parameters for a three-dimensional (3D) model (Shiokawa et al. 2012).\(^5\) We use the same data set as Dolenice et al. (2012), and choose three representative snapshots taken at times when the flow is quiescent (\(t = 5000, 9000\), and \(13,000\) \(GM/c^2\), where \(GM/c^2 = 20\) s). We then recalculate disk images and spectra for \(M = (0.5, 1, 2, 4, 8, 16, 32, 64) M_\odot\).

The 3D model with \(M = M_\odot\) is broadly consistent with observational data but is slightly more luminous at higher energies than 2D models (\(\beta\) is lower in the 3D models, and this changes the X-ray to millimeter color). The model is self-consistent only for \(M \lesssim 64 M_\odot\). At higher \(M\) the efficiency of the flow is \(>0.1\) and therefore our neglect of cooling in the GRMHD model is unjustified. At higher \(M\), the 1.3 mm photosphere lies outside the limited range in radius where \(dM/dr = 0\), so the emitting parts of the flow are not in a steady state.

The images and total fluxes emitted by the disk at 230 and 345 GHz are calculated using a ray-tracing scheme (Noble et al. 2007). To estimate the size of the emitting region, we calculate the eigenvalues of the matrix formed by taking the splitting, the major and minor axis eigenvalues, \(\sigma_1\) and \(\sigma_2\), respectively, are related by \(\sigma = \text{FWHM}/2.3\) to the FWHM of the axisymmetric Gaussian model used to interpret the VLBI observations. We use \(\sigma = (\sigma_1 + \sigma_2)/2\) to measure the average radius of the emitting spot.\(^5\)

\(^5\) A 3D GRMHD model parameter survey is too computationally expensive, and has a poor return on investment given the electron distribution function uncertainties.
Figures 1 and 2 show the variation of 230 and 345 GHz Sgr A* model images with $M$ (based on a single snapshot from the 3D GRMHD simulation). Evidently modest increases in $M$ make the ring-like signature of the photon orbit easier to detect. For $M \geq 8 M_0$, however, the ring (or black hole silhouette) is hidden beneath the synchrotron photosphere at 230 GHz. The silhouette survives to higher $M$ at 345 GHz, disappearing only at $M \geq 16 M_0$. For low $M$, the silhouette is also difficult to detect because the emitting region is too small.

Figure 3 shows the accretion flow image size ($\langle \sigma \rangle$, circle radii in Figures 1 and 2) and flux at 230 and 345 GHz as a function of $M$. The 345/230 GHz flux ratio increases with increasing $M$; this is caused by the shift of the synchrotron peak toward higher energies at higher $M$.

The following fitting formulas describe how $\sigma$ and $F_\nu$ depend on $M$:

\[
\langle \sigma \rangle_{230\text{GHz}} = \begin{cases} 
15.2 \times \left( \frac{M}{M_0} \right)^{0.38}, & \text{for } \frac{M}{M_0} < 2 \\
21.1 \times \log_{10}(\frac{M}{M_0}) + 13, & \text{for } \frac{M}{M_0} \geq 2 
\end{cases} \quad [\text{mas}]
\]

(1)

\[
\langle \sigma \rangle_{345\text{GHz}} = \begin{cases} 
12 \times \left( \frac{M}{M_0} \right)^{0.31}, & \text{for } \frac{M}{M_0} < 2 \\
19.7 \times \log_{10}(\frac{M}{M_0}) + 8.3, & \text{for } \frac{M}{M_0} \geq 2 
\end{cases} \quad [\text{mas}]
\]

(2)

\[
F_{230\text{GHz}} = \begin{cases} 
3.17 \times \left( \frac{M}{M_0} \right)^{1.03}, & \text{for } \frac{M}{M_0} < 2 \\
10.62 \times \log_{10}(\frac{M}{M_0}) + 3.8, & \text{for } \frac{M}{M_0} \geq 2 
\end{cases} \quad [\text{Jy}]
\]

(3)

\[
F_{345\text{GHz}} = \begin{cases} 
3.2 \times \left( \frac{M}{M_0} \right)^{1.3}, & \text{for } \frac{M}{M_0} < 2 \\
25.13 \times \log_{10}(\frac{M}{M_0}) + 0.54, & \text{for } \frac{M}{M_0} \geq 2 
\end{cases} \quad [\text{Jy}]
\]

(4)

The constants are nontrivial to interpret because they encapsulate the complexities of the accretion flow structure and relativistic radiation transport effects. The fitting functions are shown in Figure 3 as dashed and dotted lines.

Figure 4 shows the relation between two observables, $\sigma$ and $F_\nu$. The size is a linear function of the flux and increases more steeply at 230 GHz than at 345 GHz. We also provide two phenomenological scaling laws fitted to the data:

\[
\langle \sigma \rangle_{230\text{GHz}} = 1.72(F_{230\text{GHz}}/\text{Jy}) + 9.3 \quad [\text{mas}]
\]

(5)

\[
\langle \sigma \rangle_{345\text{GHz}} = 0.73(F_{345\text{GHz}}/\text{Jy}) + 9.2 \quad [\text{mas}]
\]

(6)

Note that these fits apply to the best-fit model only. For other $a_*$, $T_i/T_e$, or $i$, the scalings will be slightly different. If the source is optically thick, the source size–flux relation generally traces $T_e(r)$; in our model $T_e \propto 1/r$.

Equation (5) predicts a size increase of 9% in Sgr A* when the 230 GHz flux increases from 2 to 2.7 Jy. Taking into account observational and theoretical uncertainties this is consistent with the observed variations of source size, which increases by 6% as the flux increases from 2 to 2.7 Jy (Fish et al. 2011).
3. SPECTRA

Our model spectra are generated by thermal synchrotron emission in the submillimeter/far-IR bump and by Compton scattering in the X-rays. The spectral slope of flaring NIR emission and its high degree of linear polarization (Dodds-Eden et al. 2011) imply that it is synchrotron from a small, nonthermal tail of high-energy electrons that is not (but can be; see Leung 2010) included in our best-bet model.

What are the expected scaling laws? Again, $j_\nu \sim n_e B \sim M^{3/2}$. The luminosity around the synchrotron peak is $L_{\text{peak}} \sim 4\pi v_{\text{peak}} J_{\text{peak}} (GM/c^2)^3 \sim \dot{M}^{9/4}$, where $v_{\text{peak}} \sim M^{3/4}$ is such that $\omega_e GM/c^2 = 1$.

The emission rightward of the MIR/NIR is produced by Compton upscattered synchrotron radiation. The Thomson depth $\tau_{sc} = \sigma_{TH} n_e GM/c^2 \sim M$, the X-ray luminosity is expected to scale as $v L_{\nu}(v \approx 10^{18} \text{ Hz}) \sim L_{\text{peak}} \tau_{sc} \sim M^{13/4}$, assuming that X-rays are produced by singly scattered synchrotron photons.

What do the numerical models show? Figure 5 shows spectra emitted from the 3D disk model as observed at $i \approx 85^\circ$. The SEDs are calculated using a general relativistic Monte Carlo scheme (Dolence et al. 2009). The NIR luminosity $v L_{\nu}(v = 10^{14} \text{ Hz}) \sim M^{2.5}$, which is only slightly steeper than the expected dependence for the synchrotron peak, $v L_{\nu}(v \approx 10^{18} \text{ Hz}) \sim M^{3.25}$, agrees well with the expected scaling.

We conclude that Sgr A* would become a persistent MIR and X-ray source (above the present upper limits of 84 mJy in MIR, Schödel et al. 2011, and $2.4 \times 10^{33} \text{ erg s}^{-1}$ in X-rays, Baganoff et al. 2003) if $M > 2 M_\odot$. This is conservative in the sense that our models are strictly thermal. The addition of a high-energy nonthermal tail would only increase the MIR/NIR and X-ray flux.

We do not consider higher accretion rate models because for $M = 64 M_\odot (v L_{\nu}(v = 10^{18} \text{ Hz}) = 10^{39} \text{ erg s}^{-1})$, the model becomes radiatively efficient, $\epsilon = L_{\text{Bol}}/\dot{M} c^2 > 0.1$, and our neglect of radiative cooling in the 3D GRMHD model is unjustified.

Finally, notice that the MeV flux increases sharply with $M$. This suggests that electron–positron pair production by photon–photon collisions in the funnel over the poles of the hole would increase sharply (the pair production $n_e \sim L_{\gamma}^{2/3}$, Mościbrodzka et al. 2011). If this pair production is connected to jet production, then at high $M$ Sgr A* might also produce a jet.

4. DISCUSSION

In summary, we have used general relativistic disk models and relativistic radiative transfer to recalculate millimeter images and spectra for Sgr A* at a range of $M > M_\odot$. Our models predict the following: (1) if the 230 GHz flux increases by more than a factor of two, corresponding to an increase of $M$ by more than a factor of two, the central accretion flow will become a persistent, detectable, MIR and X-ray source; (2) the photon orbit, which produces the narrow ring of emission visible in Figures 1 and 2.
becomes easier to detect for modest increases in the 230 GHz flux; (3) the photon orbit is cloaked beneath the synchrotron photosphere at 230 GHz for \( \dot{M} \gtrsim 8 \dot{M}_0 \), or 230 GHz flux \( \gtrsim 13 \text{ Jy} \); (4) the photon orbit is cloaked at 345 GHz only at higher \( \dot{M} \gtrsim 16 \dot{M}_0 \), or 230 GHz flux \( \gtrsim 17 \text{ Jy} \); (5) the size of the source increases in proportion to the flux at both 230 and 345 GHz.

We suspect that almost any accretion model for Sgr A* with a spatially uniform model for the plasma distribution function will reach qualitatively similar conclusions, but that jet models may differ significantly. There are order-unity uncertainties in our model predictions due to uncertainties in the plasma model.

What range of changes in \( \dot{M} \) is reasonable? In our best-bet model, the mass at radii within a factor of two of the pericenter radius is \( \approx 10^{-1.5} M_\odot \), assuming steady mass inflow from \( r_p \) to the event horizon. The addition of even a fraction of the inferred cloud mass to the accretion flow in a ring near \( r_p \) could (eventually) increase \( \dot{M} \) by a factor of \( \sim 100 \). On the other hand, stellar winds supply mass in the neighborhood of the central black hole at \( \sim 10^{-3} M_\odot \text{ yr}^{-1} \). Models by Quataert (2004) and Shcherbakov & Baganoff (2010) suggest that most of this mass is ejected in the form of a wind, and that \( \sim 10^{-4.5} M_\odot \text{ yr}^{-1} \) to \( 10^{-7.3} M_\odot \text{ yr}^{-1} \) flows inward. A reasonable extrapolation of these models suggests that the accretion flow at \( r < r_p \) has a mass of \( \sim 2 M_\odot \); this is comparable to estimates of the mass of the inflowing cloud, so in this case we might expect a factor of two increase in \( \dot{M} \).
Figure 5. Model spectrum for various $\dot{M}/\dot{M}_0$. The $\dot{M}/\dot{M}_0$ is shown on the right-hand side. Observational points and upper limits are taken from: Falcke et al. (1998), An et al. (2005), Marrone et al. (2006), Melia & Falcke (2001), Schödel et al. (2011), and Baganoff et al. (2003). The black symbols in the NIR showing the flaring state are from Genzel et al. (2003). An example of X-ray flare is taken from Baganoff et al. (2001).

(A color version of this figure is available in the online journal.)

M.M. is supported by NASA grant NNX11AI96G. This work was supported by the National Science Foundation under grant AST 07-09246 and by NASA under grant NNX10AD03G. This work used the Extreme Science and Engineering Discovery Environment (XSEDE), which is supported by National Science Foundation grant number OCI-1053575.

REFERENCES

An, T., Goss, W. M., Zhao, J.-H., et al. 2005, ApJ, 634, L49
Baganoff, F. K., Bautz, M. W., Brandt, W. N., et al. 2001, Nature, 413, 45
Baganoff, F. K., Maeda, Y., Morris, M., et al. 2003, ApJ, 591, 891
Bower, G. C., Falcke, H., Wright, M. C., & Backer, D. C. 2005, ApJ, 618, L29
Broderick, A. E., Fish, V. L., Doeleman, S. S., & Loeb, A. 2011, ApJ, 735, 110
Dexter, J., Agol, E., Fragile, P. C., & McKinney, J. 2010, ApJ, 717, 1092
Dodds-Eden, K., Gillessen, S., Fritz, T. K., et al. 2011, ApJ, 728, 37
Doeleman, S. S., Weintroub, J., Rogers, A. E. E., et al. 2008, Nature, 455, 78
Dolence, J. C., Gammie, C. F., Mościbrodzka, M., & Leung, P. K. 2009, ApJS, 184, 387
Dolence, J. C., Gammie, C. F., Shiozawa, H., & Noble, S. C. 2012, ApJ, 746, L10
Falcke, H., Goss, W. M., Matsuo, H., et al. 1998, ApJ, 499, 731
Falcke, H., & Markoff, S. 2000, A&A, 362, 113
Falcke, H., Markoff, S., & Bower, G. C. 2009, A&A, 496, 77
Fish, V. L., Doeleman, S. S., Beaudoin, C., et al. 2011, ApJ, 727, L36
Gammie, C. F., McKinney, J. C., & Tóth, G. 2003, ApJ, 589, 444
Genzel, R., Schödel, R., Ott, T., et al. 2003, Nature, 425, 934
Ghez, A. M., Salim, S., Weinberg, N. N., et al. 2008, ApJ, 689, 1044
Gillessen, S., Eisenhauer, F., Trippe, S., et al. 2009, ApJ, 692, 1075
Gillessen, S., Genzel, R., Fritz, T. K., et al. 2012, Nature, 481, 51
Leung, P. K. 2010, PhD thesis, Univ. Illinois
Leung, P. K., Gammie, C. F., & Noble, S. C. 2011, ApJ, 737, 21
Loeb, A., & Waxman, E. 2007, J. Cosmol. Astropart. Phys., JCAP03(2007)011
Marrone, D. P. 2006, PhD thesis, Harvard Univ.
Marrone, D. P., Moran, J. M., Zhao, J.-H., & Rao, R. 2006, J. Phys.: Conf. Ser., 54, 354
McKinney, J. C., Techehovskoy, A., & Blandford, R. D. 2012, arXiv:1201.4163
Melia, F., & Falcke, H. 2001, ARA&A, 39, 309
Mościbrodzka, M., Gammie, C. F., Dolence, J. C., & Shiozawa, H. 2011, ApJ, 735, 9
Mościbrodzka, M., Gammie, C. F., Dolence, J. C., & Shiozawa, H., & Leung, P. K. 2009, ApJ, 706, 497
Noble, S. C., Gammie, C. F., McKinney, J. C., & Del Zanna, L. 2006, ApJ, 641, 626
Noble, S. C., Leung, P. K., Gammie, C. F., & Book, L. G. 2007, Class. Quantum Gravity, 24, 259
Özel, F., Psaltis, D., & Narayan, R. 2000, ApJ, 541, 234
Quataert, E. 2004, ApJ, 613, 322
Riquelme, M. A., Quataert, E., Sharma, P., & Spitkovsky, A. 2012, arXiv:1201.6407
Schödel, R., Morris, M. R., Muzic, K., et al. 2011, A&A, 532, A83
Shcherbakov, R. V., & Baganoff, F. K. 2010, ApJ, 716, 504
Shcherbakov, R. V., Penna, R. F., & McKinney, J. C. 2010, arXiv:1007.4832
Shiozawa, H., Dolence, J. C., Gammie, C. F., & Noble, S. C. 2012, ApJ, 744, 187