GRMHD/RADIATIVE TRANSFER MODELS OF BLACK HOLE ACCRETION FLOWS

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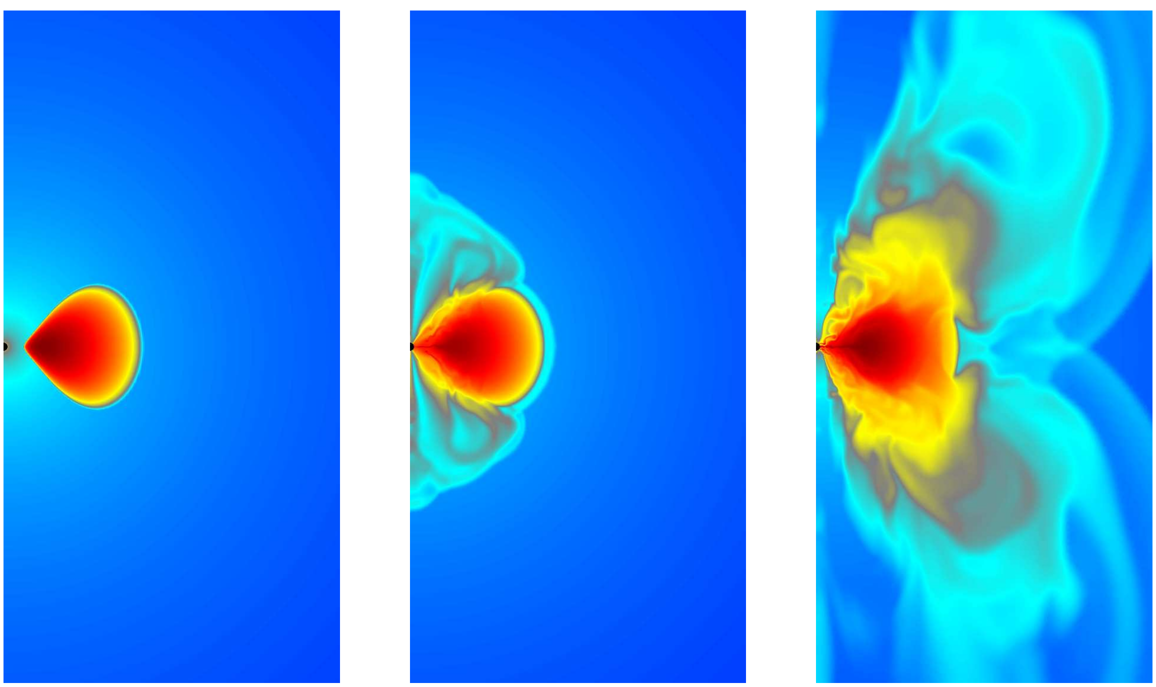
Magnetohydrodynamic Models in Full General Relativity



color shows log(density)

GRMHD Model Assumptions

- Fluid approximation
- Ideal MHD
- Nonradiative (good for Sgr A*)
- Conservative scheme
- Axisymmetric (no hot spots...)
- Limited initial conditions (torus radius, field strength, geometry)
- Numerical issues with low density regions (floors)

Radiative Transfer

- simulation data from single slice ("frozen fluid")
- integrate radiative transfer equation

$$\frac{\nu^2}{2\pi}\frac{d}{d\lambda}\left(\frac{I_\nu}{\nu^3}\right) = -\alpha_\nu I_\nu + j_\nu$$

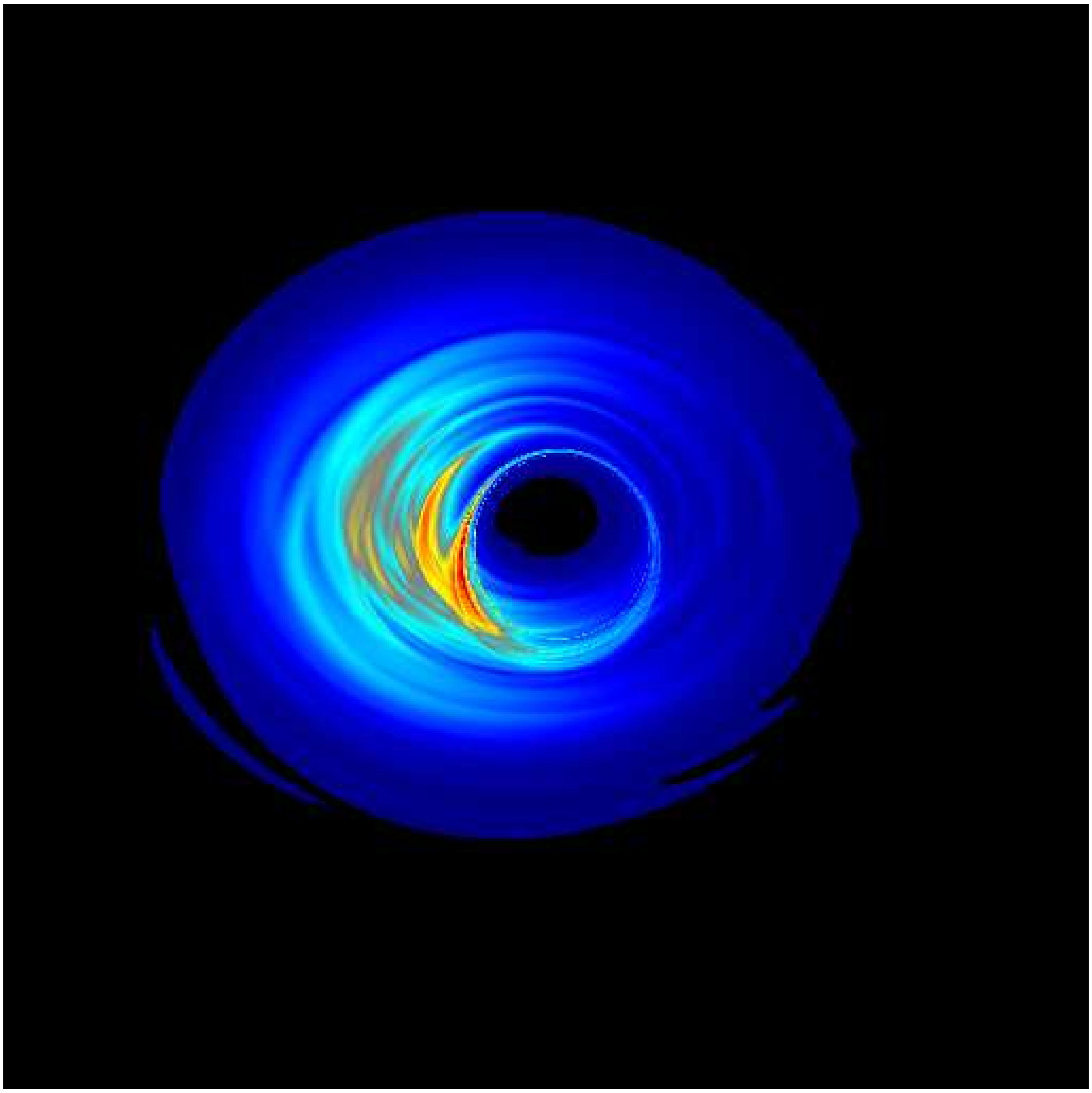
along geodesics:

$$\frac{dx^\mu}{d\lambda} = k^\mu$$

$$\frac{dk_\gamma}{d\lambda} = \Gamma^\mu_{\gamma\nu} k_\mu k^\nu.$$

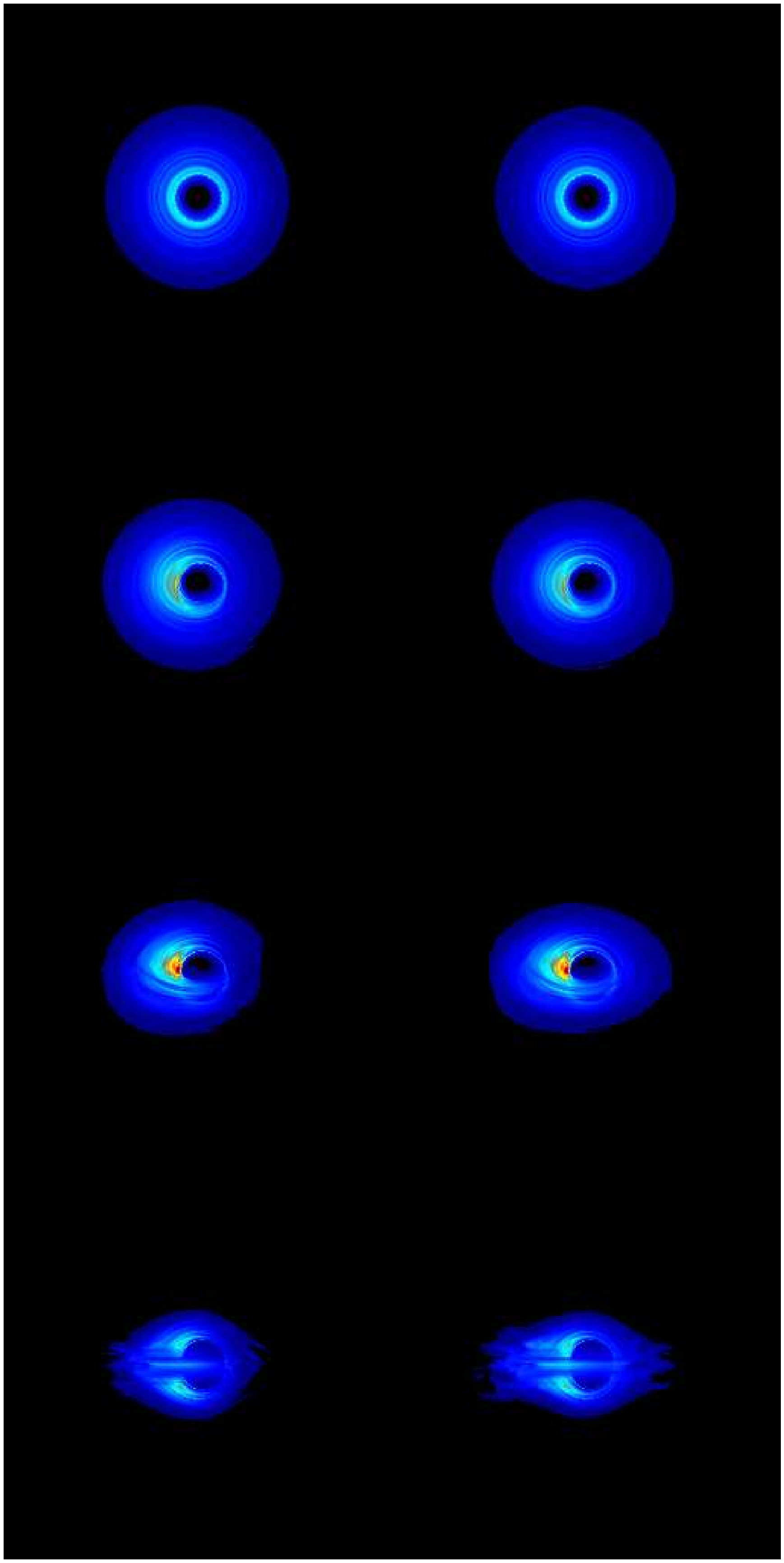
- Assume thermal electron distribution with $T_e = T_p$.
- Self-consistent: electron cooling time is long.
- Use either direct calculation of emissivity (Leung et al. 2007), or fitting formula (Wardzinski-Zdziarski, Mahadevan et al.). No angle-averaging.
- Scale density so that flux matches Sgr A* at 1mm. Accretion rate is then $\dot{M} = 4 \times 10^{-9} M_\odot\,\mathrm{yr}^{-1}$.
- Fix inclination.

Image Model of Sgr A* at 1mm

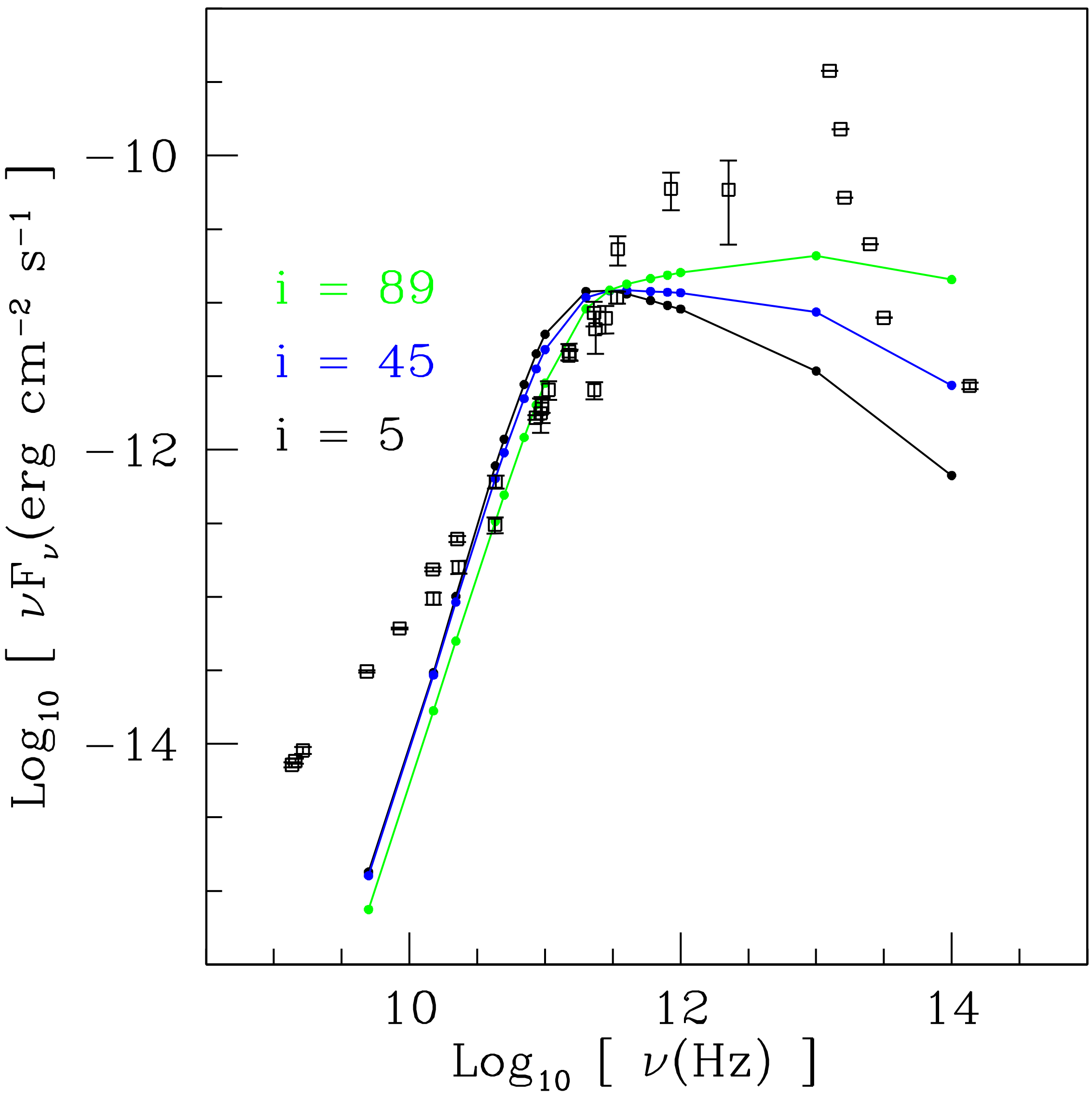


synchrotron emission; $\dot{M} = 4 \times 10^{-9} M_{\odot}\mathrm{yr}^{-1}$; $i = 45^{o}$; $a_* \simeq 0.93$

Noble, Leung, Gammie, & Book 2007



Model Spectrum of Sgr A*

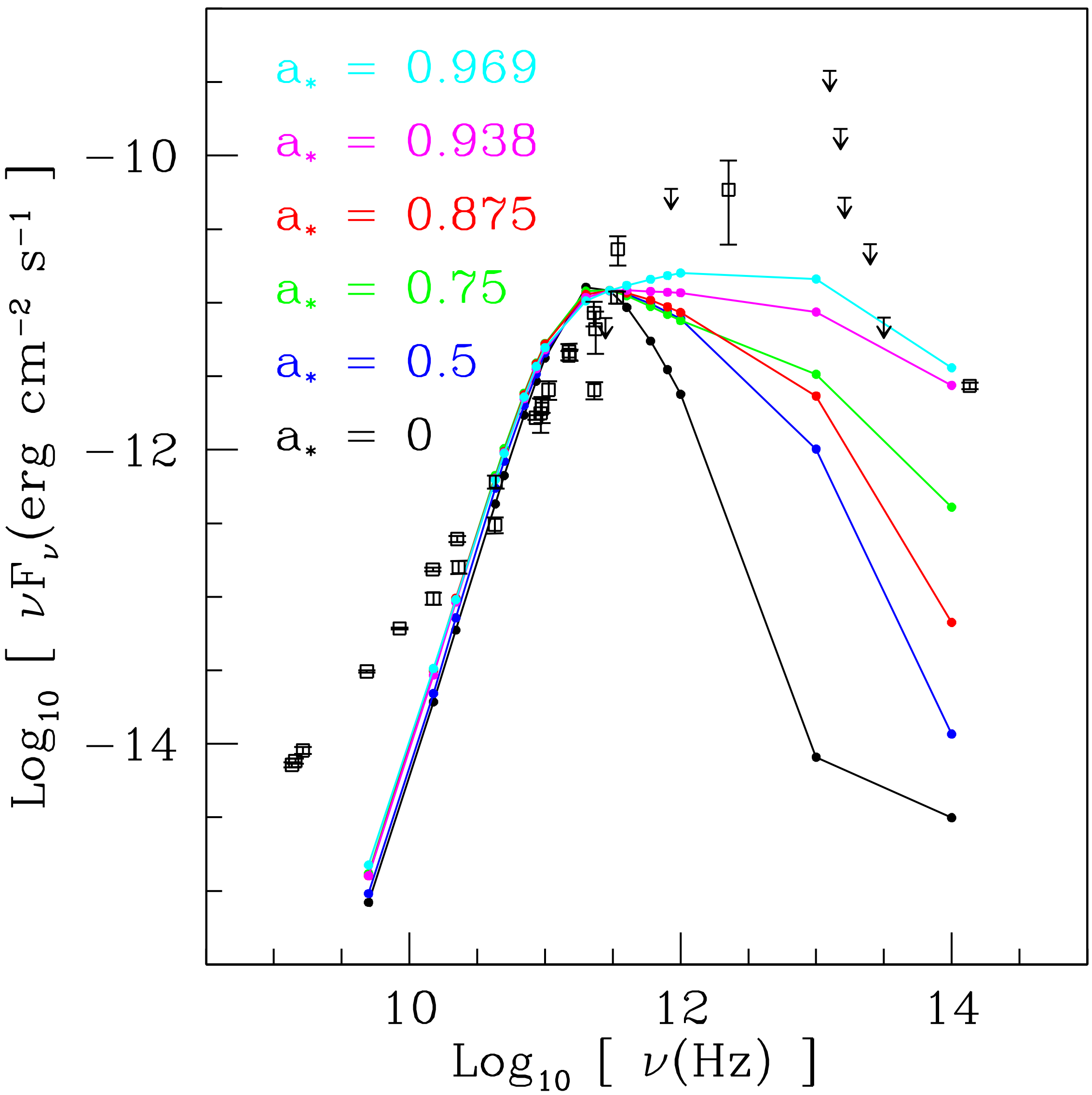


spectrum vs. inclination

$\dot{M} = 4 \times 10^{-9} M_{\odot} \mathrm{yr}^{-1}$; $a_* \simeq 0.93$

Noble, Leung, Gammie, & Book 2007

Model Spectrum of Sgr A*

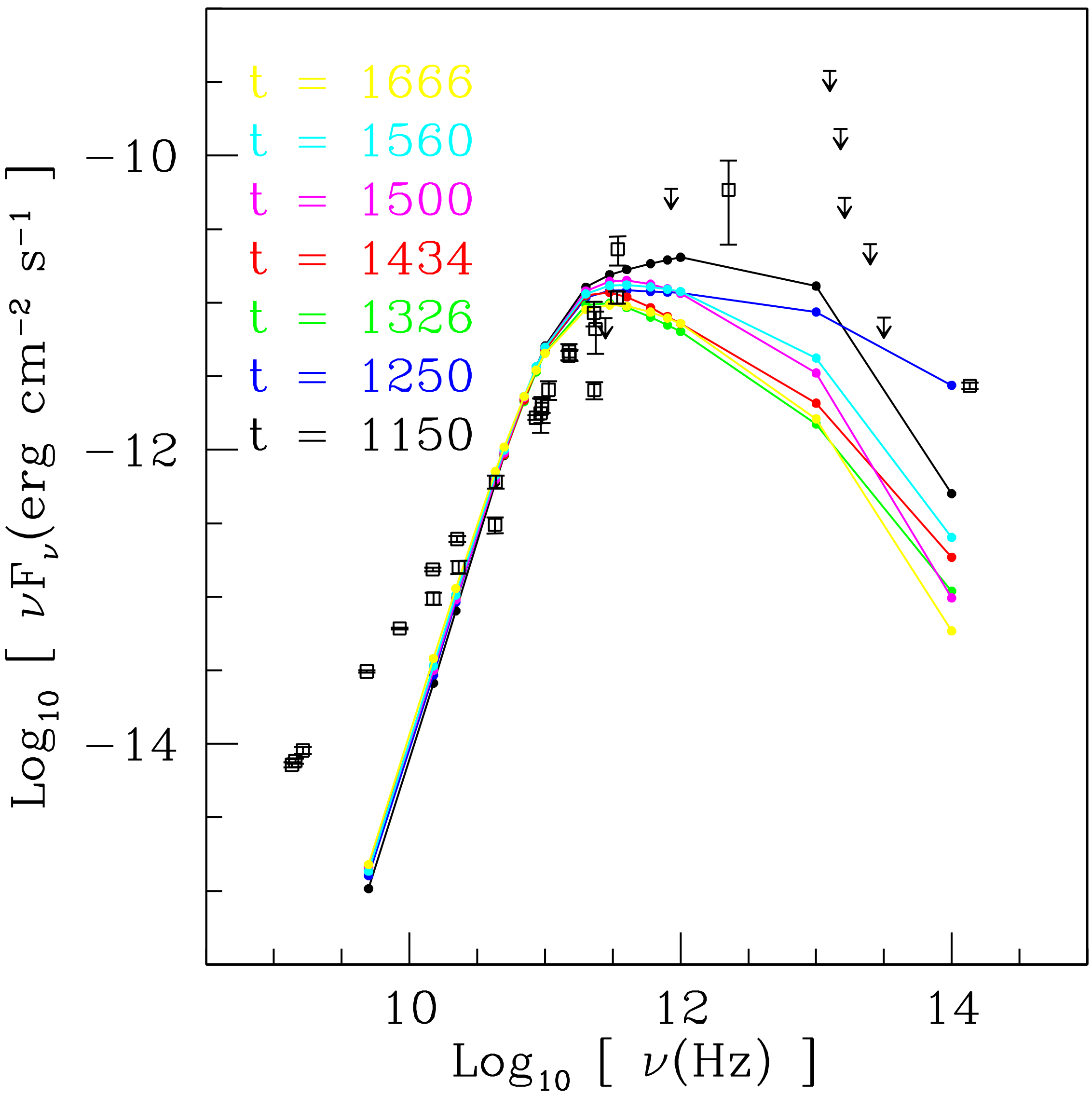


spectrum vs. spin

$\dot{M} = 4 \times 10^{-9} M_{\odot} \mathrm{yr}^{-1}$; $i = 45^o$

Noble, Leung, Gammie, & Book 2007

Model Spectrum of Sgr A*



spectrum vs. time

$\dot{M} = 4 \times 10^{-9} M_\odot \mathrm{yr}^{-1}$; $i = 45^o$; $a_* \simeq 0.93$

Noble, Leung, Gammie, & Book 2007

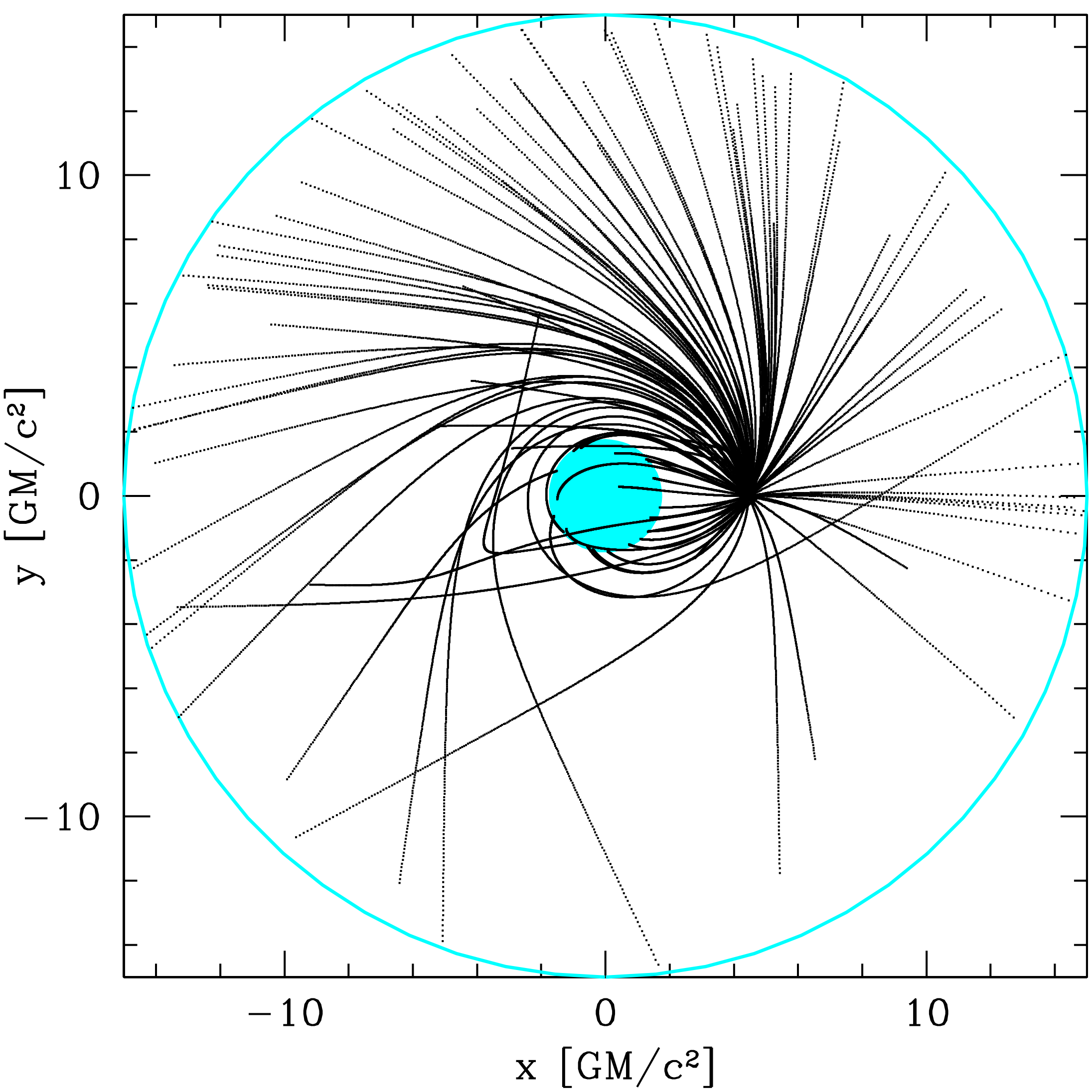
Future Prospects

- Proper treatment of time variability
- Electron energy equation
- 3D
- Compton scattering
- Polarized radiative transfer
- *Precision bothrology!*

HARM available at

`http://rainman.astro.uiuc.edu/codelib`

Isotropic Emission in Plasma Rest Frame



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