

Imaging Accretion Disks Around Kerr Black Holes

Jeremy Schnittman

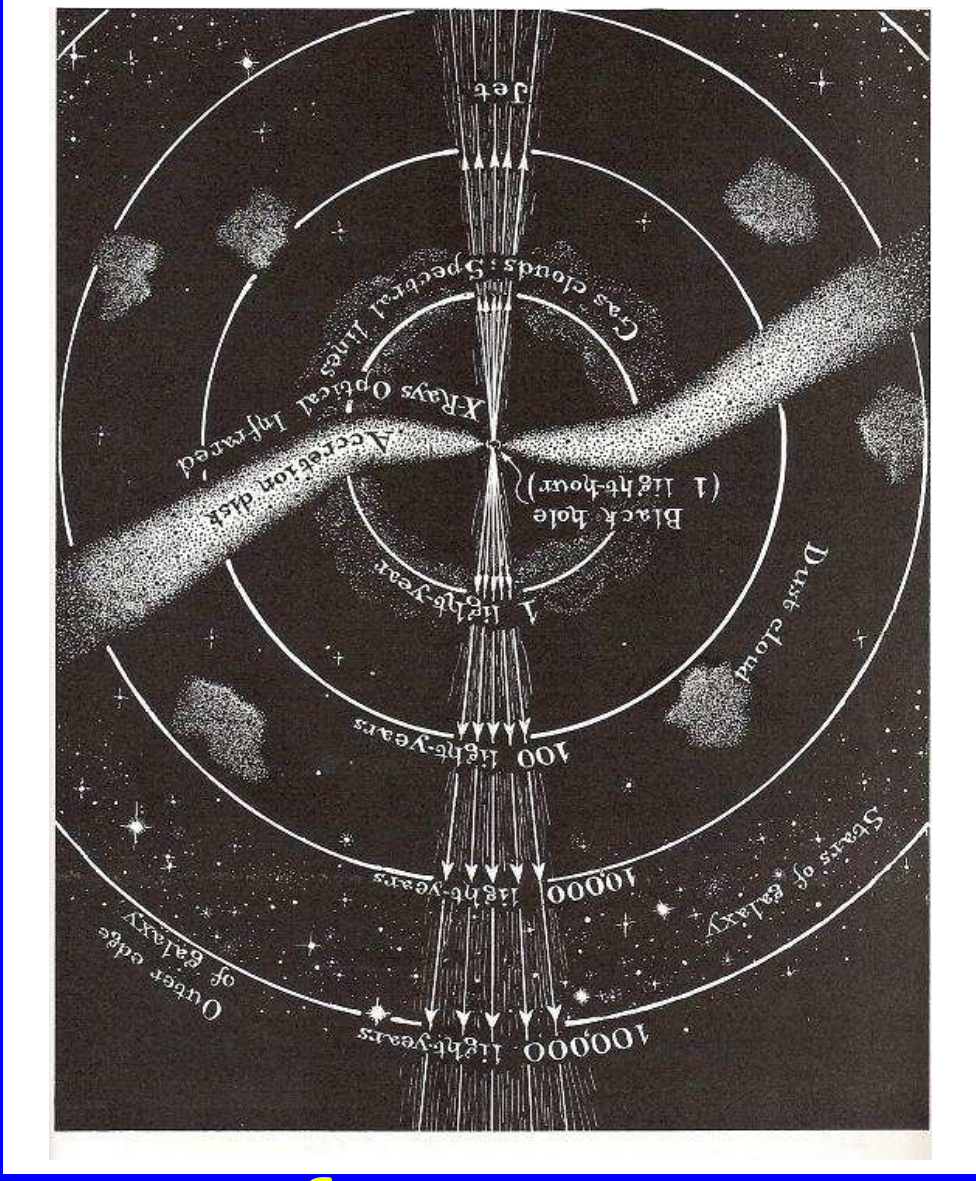
MIT Course 8.224: Exploring Black Holes

March 16, 2005

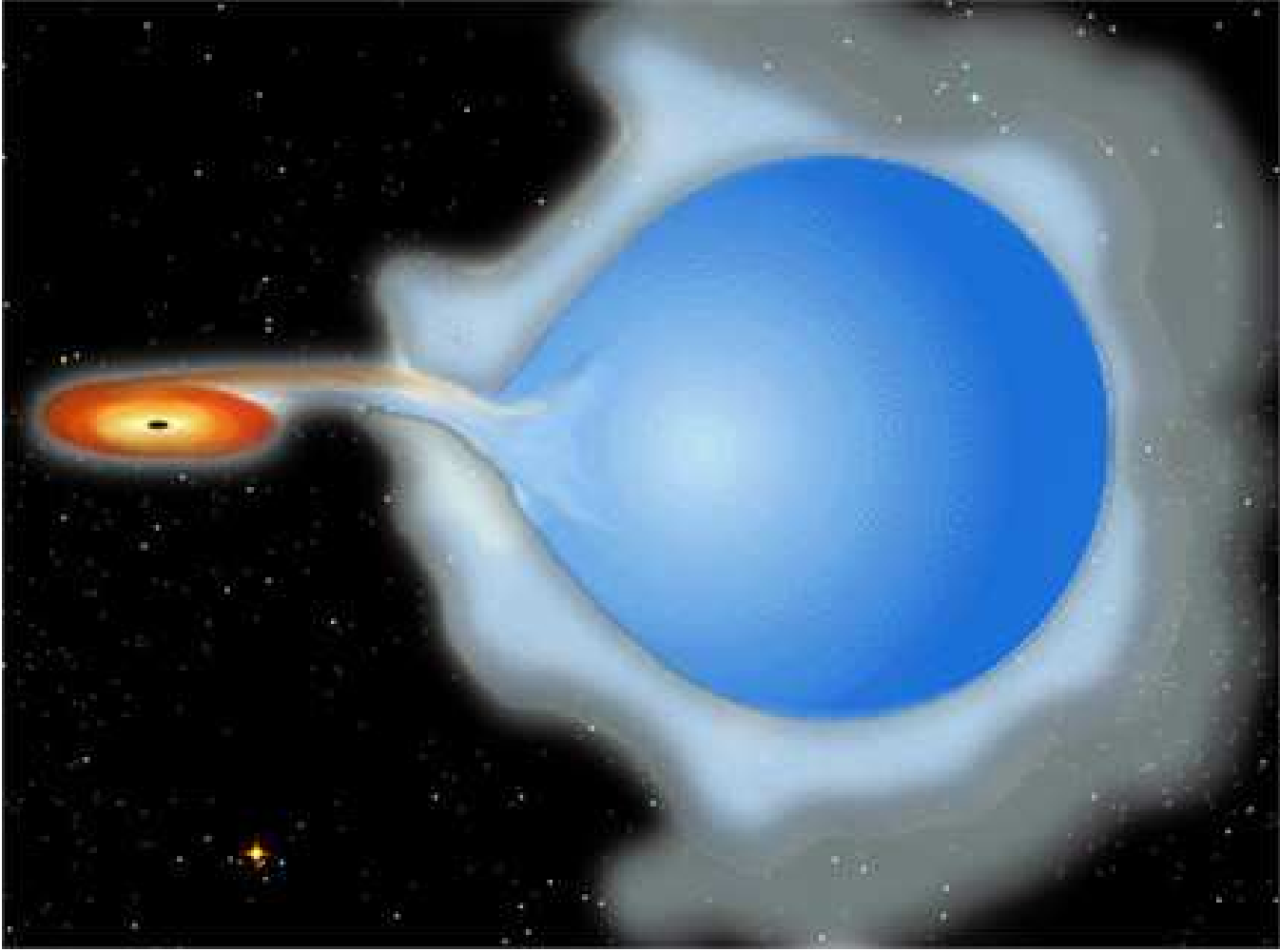
Outline

- Observations- What Can We See?
- Ray Tracing
- Hot Spot Model
- Lighthouse Beaming
- Black Hole “Sounds”
- Gravitational Lensing
- Foggy Lighthouse
- The Future...

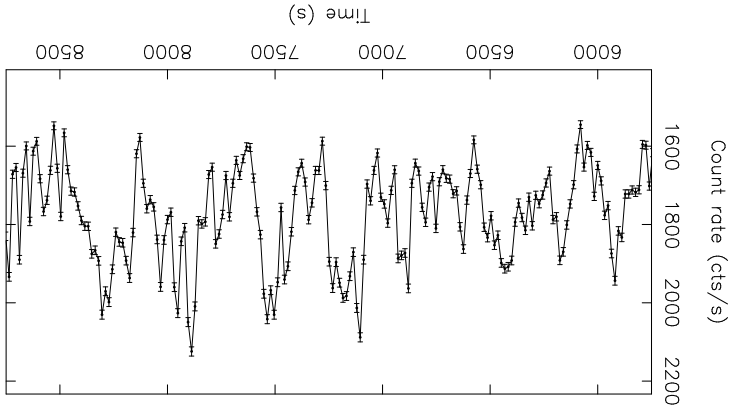
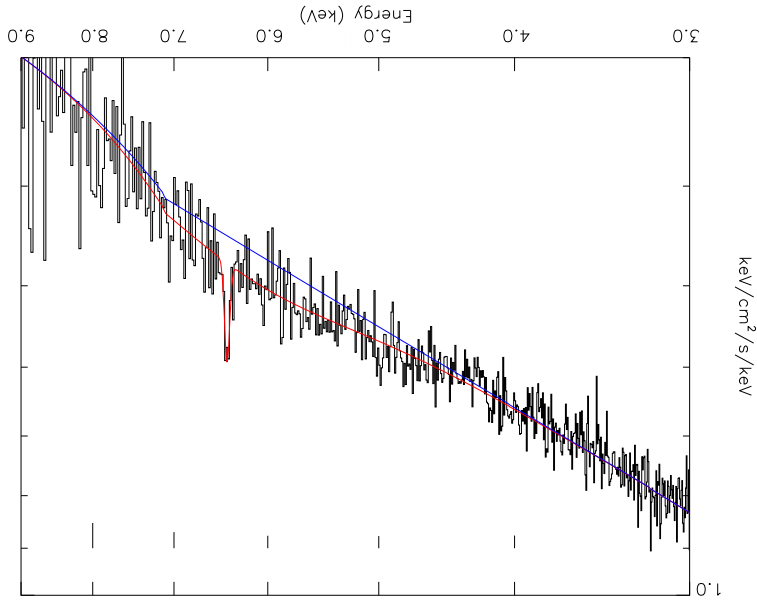
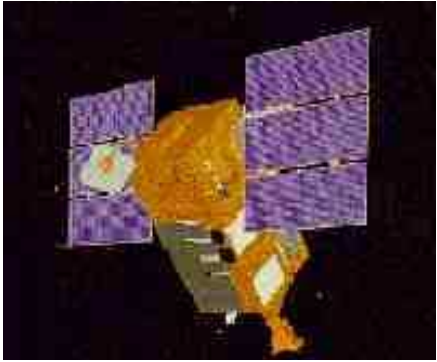
Black holes are actually REALLY tiny



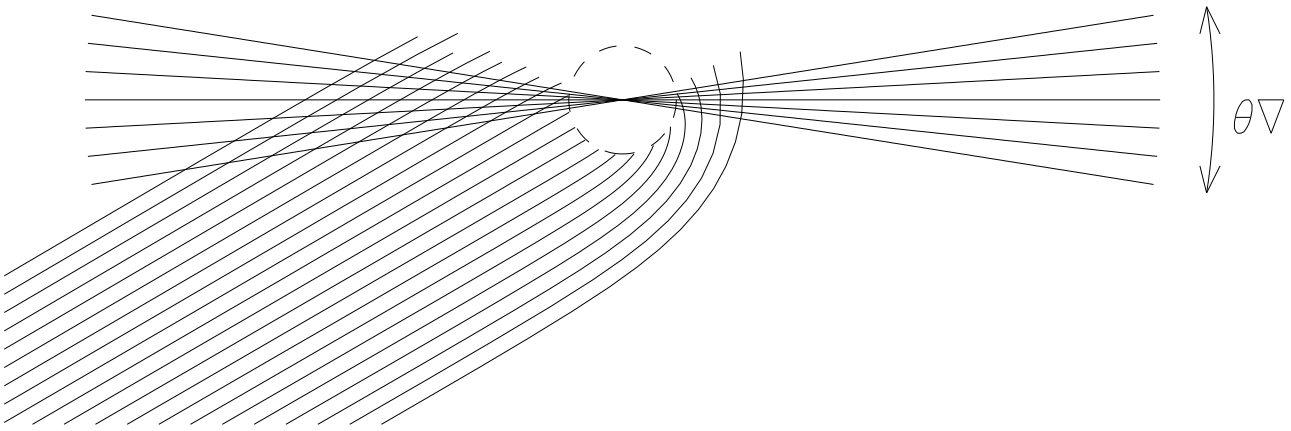
We can “see” black holes with the radiation
that comes from the surrounding gas



X-ray telescopes can be used to measure the spectrum or light curves from black holes



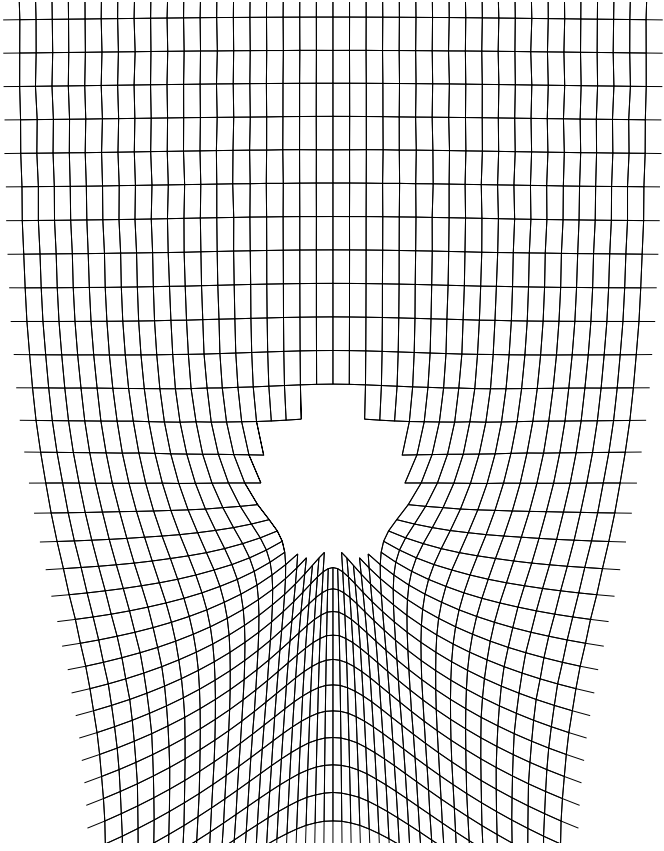
Ray Tracing / Hot Spot Model



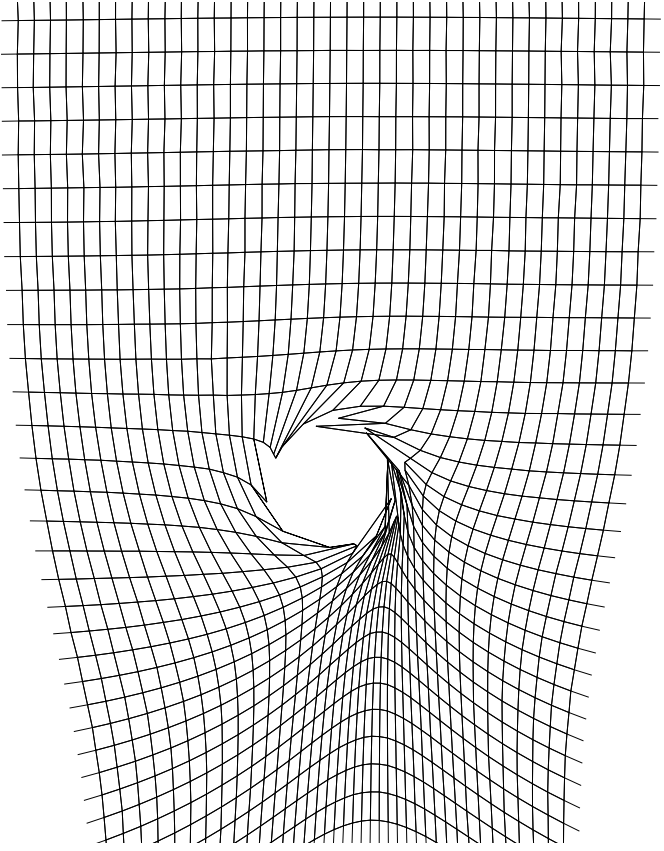
We ray-trace photons backwards in time from a distant observer through a fixed grid

Gravitational lensing focuses the photons around the black hole

Schwarzschild

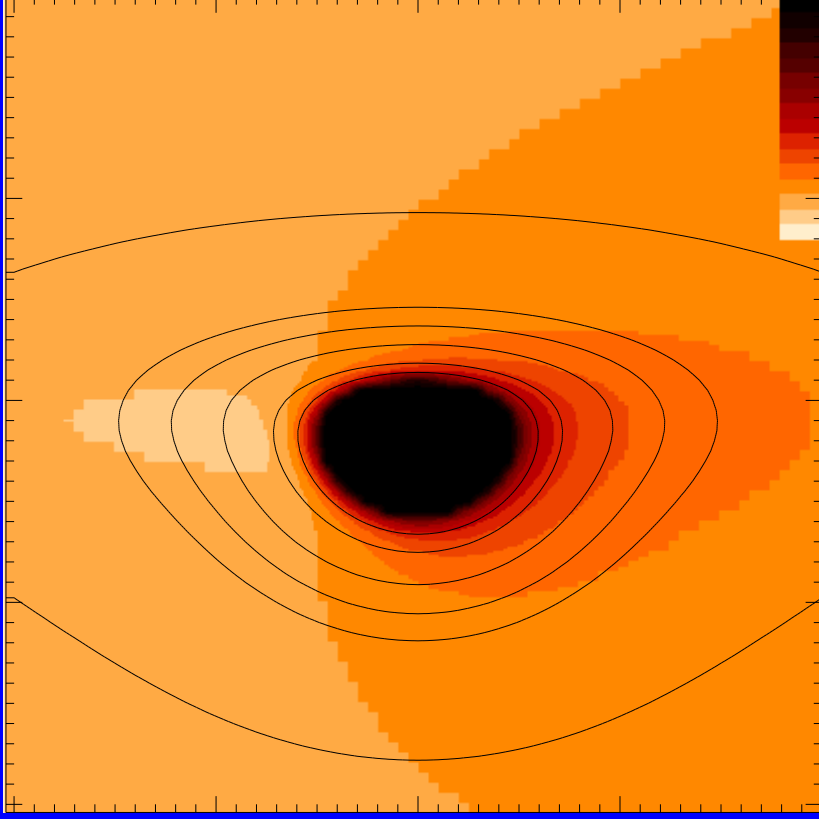


Kerr

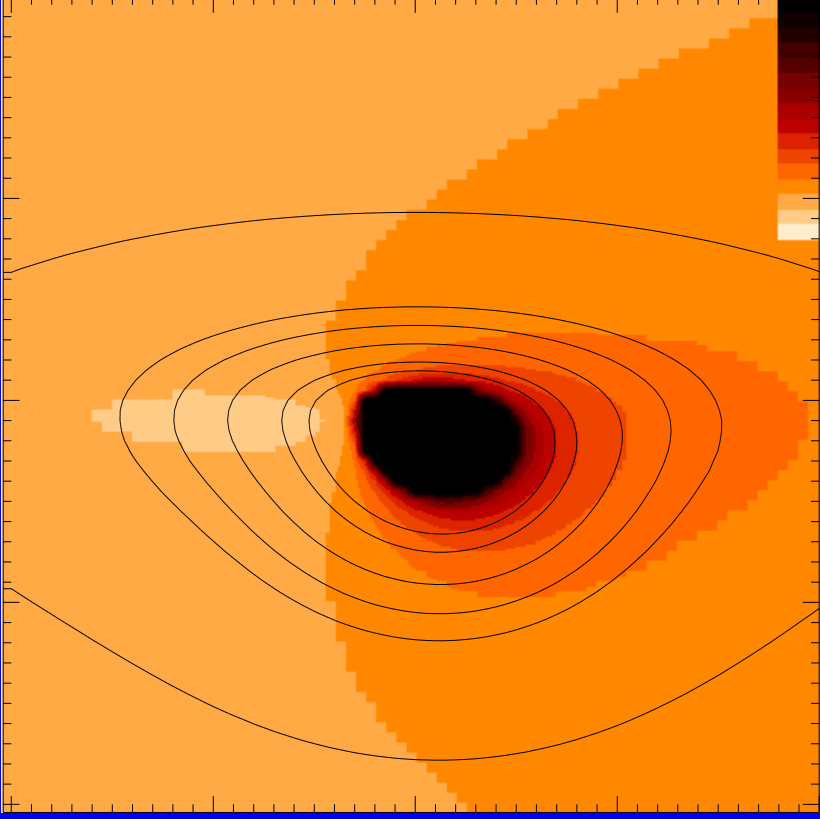


X-rays emitted from the disk produce a
relativistically redshifted image

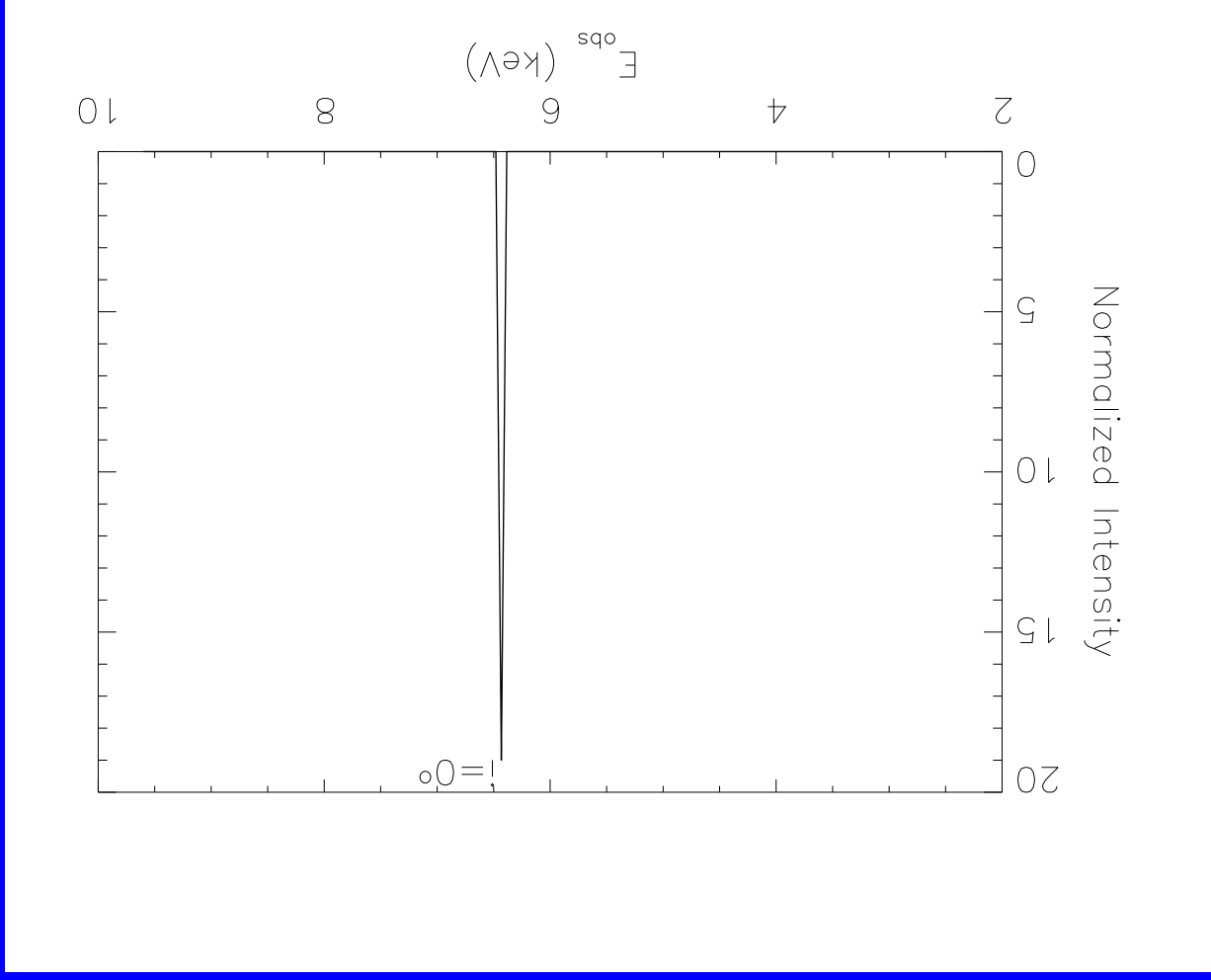
Schwarzschild



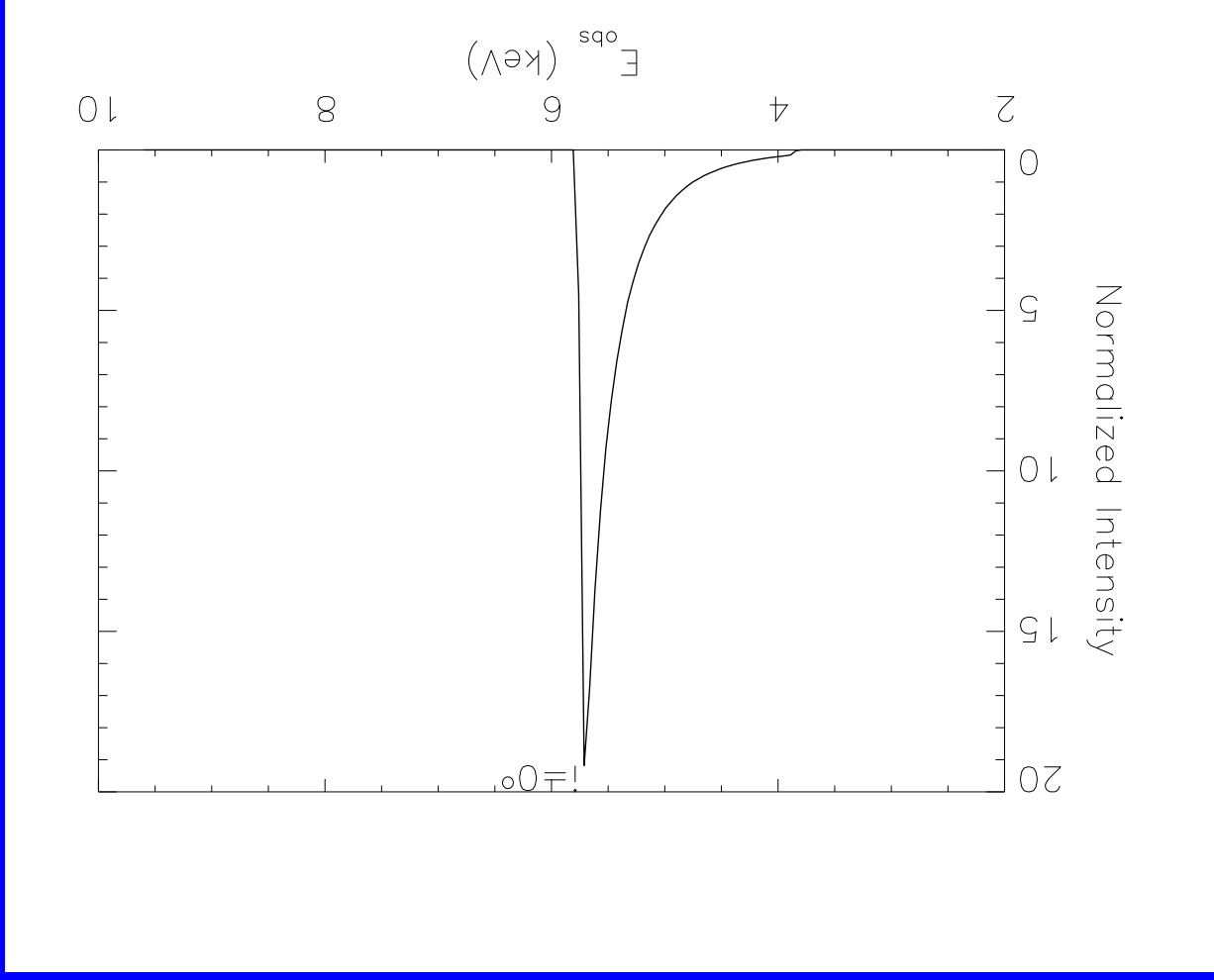
Kerr



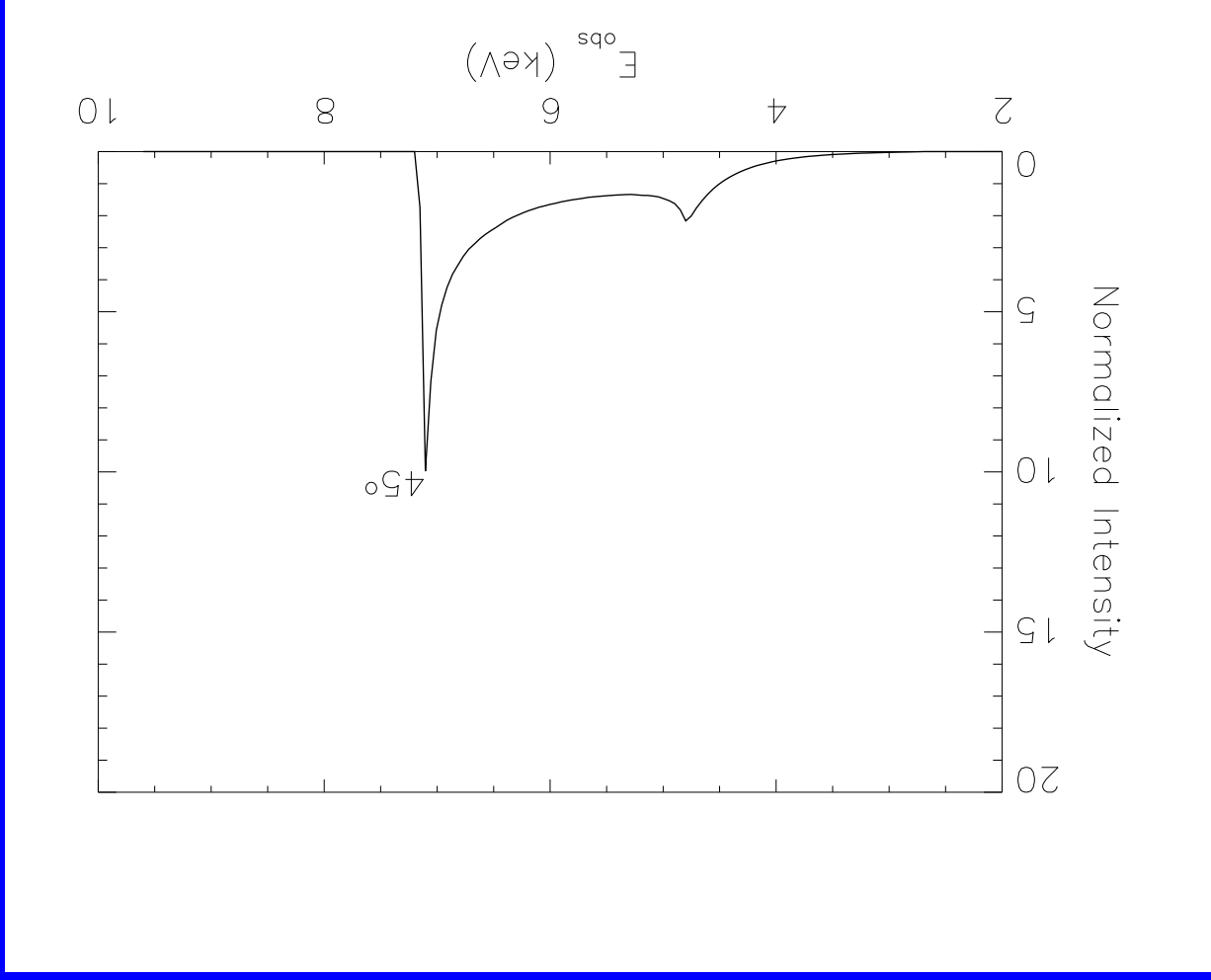
Adding up all the photons with different redshifts gives the X-ray spectrum



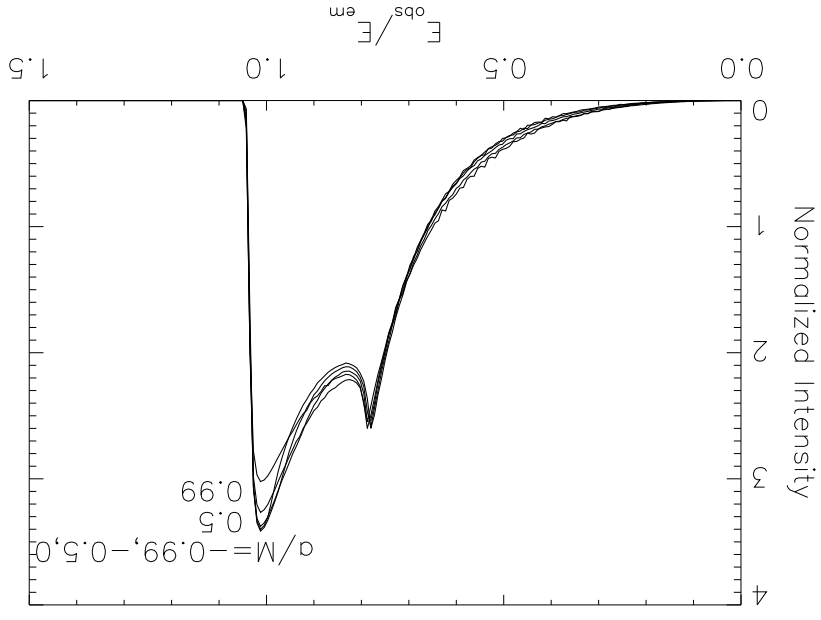
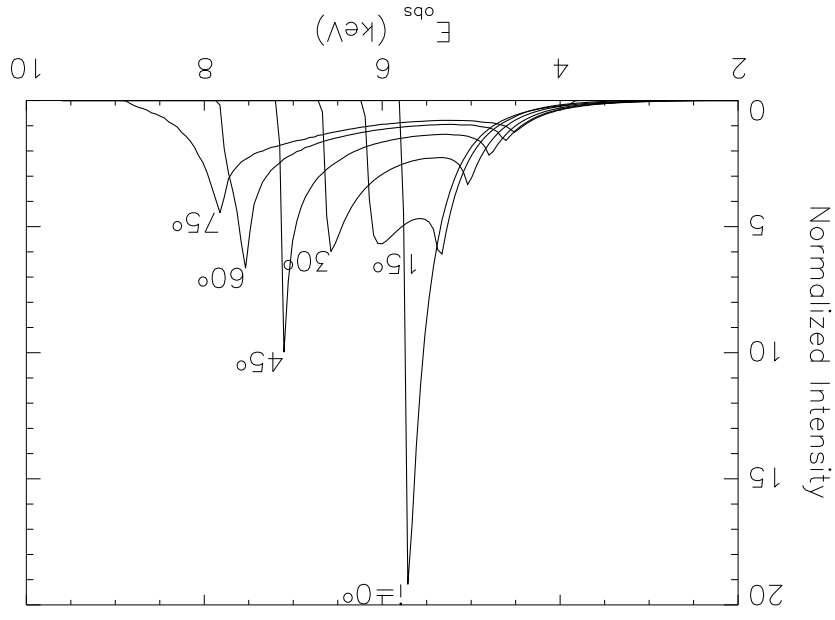
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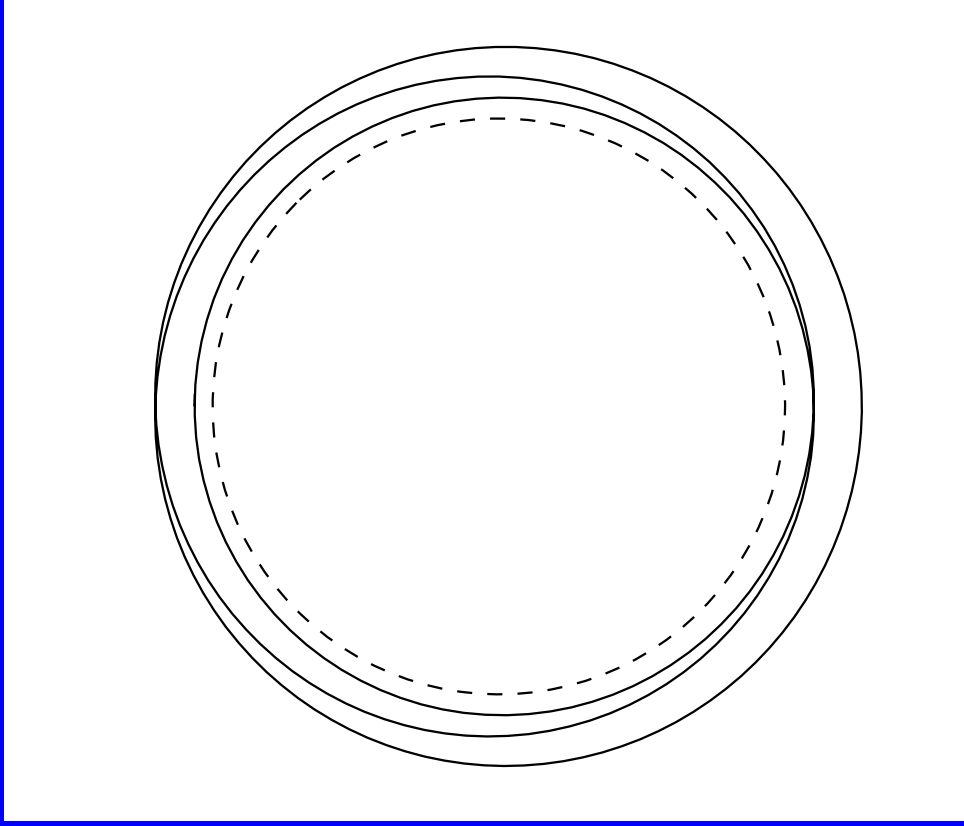
Adding up all the photons with different redshifts gives the X-ray spectrum



The broadened emission lines are sensitive to inclination but not spin



**Light curves are calculated by integrating
emission from hot spots orbiting along
geodesic orbits**

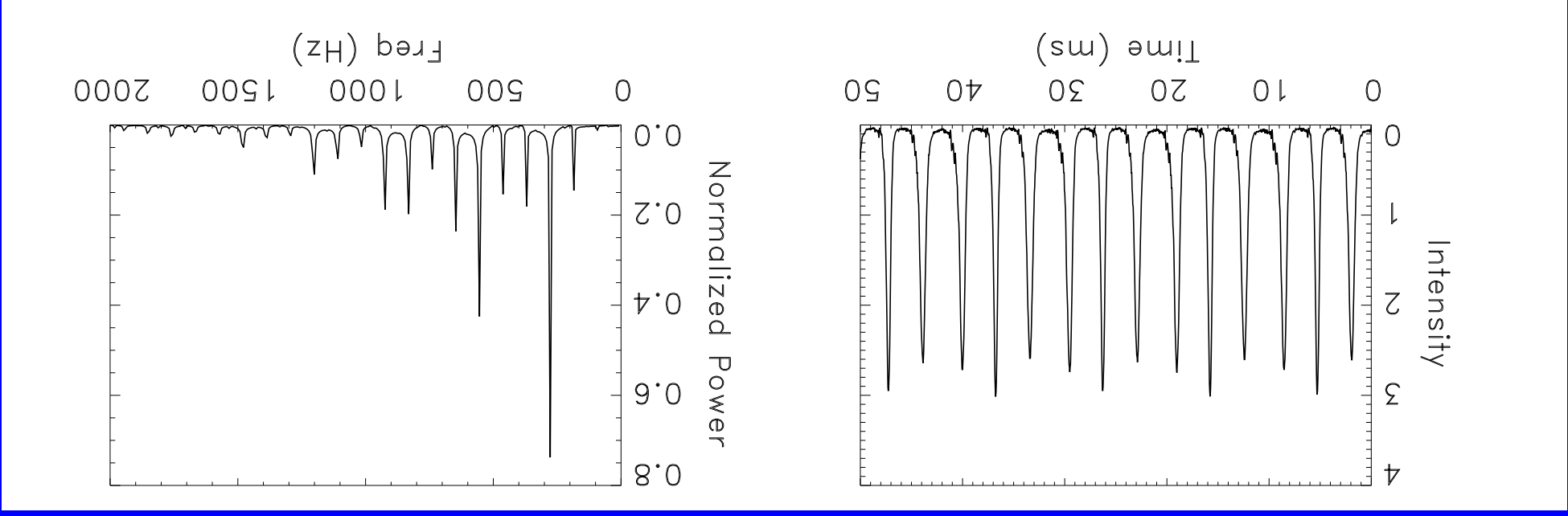


Black Hole Sounds

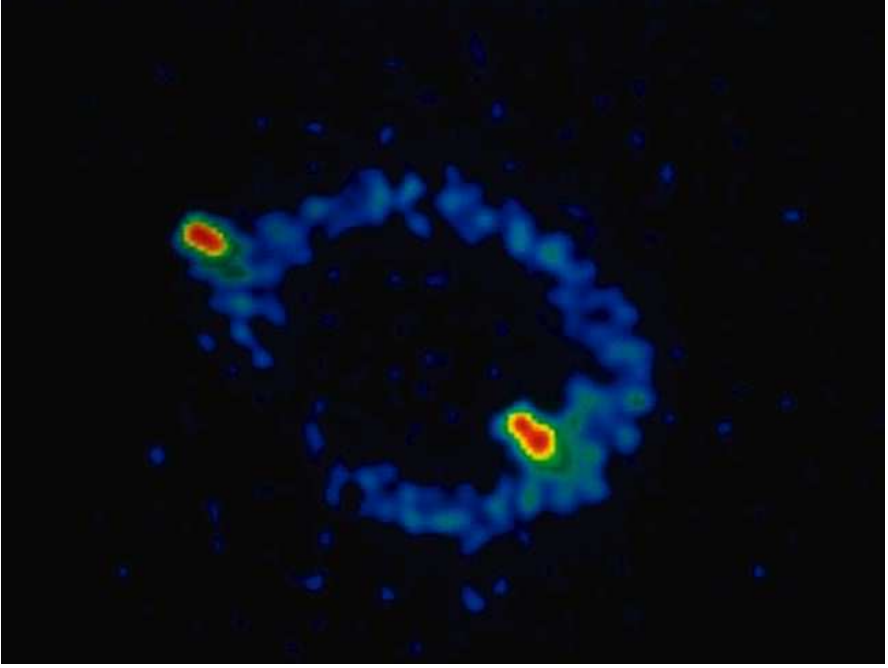
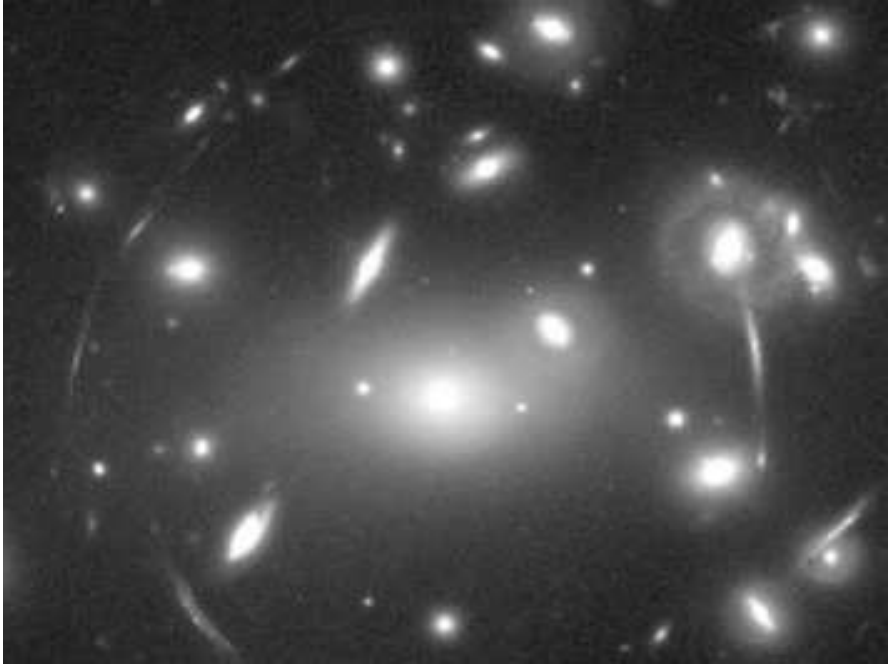
The X-ray light curves can be thought of as
 sound waves, with beats and harmonic
 overtones

$$M = 10M_{\odot} \quad a/M = 0.5 \quad r/M = 4.887$$

$$\nu_{\phi} = 285 \text{ Hz} \quad \nu_r = 95 \text{ Hz}$$



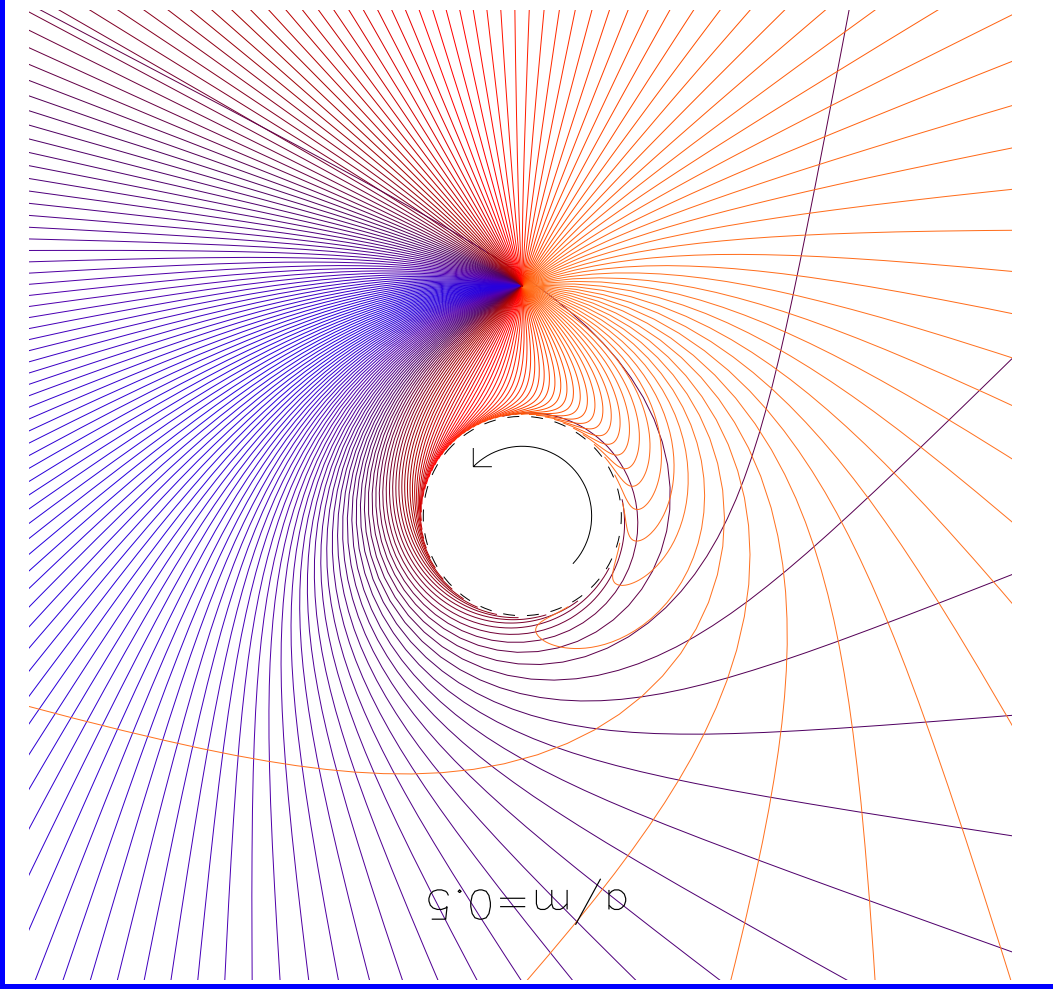
Gravitational Lensing

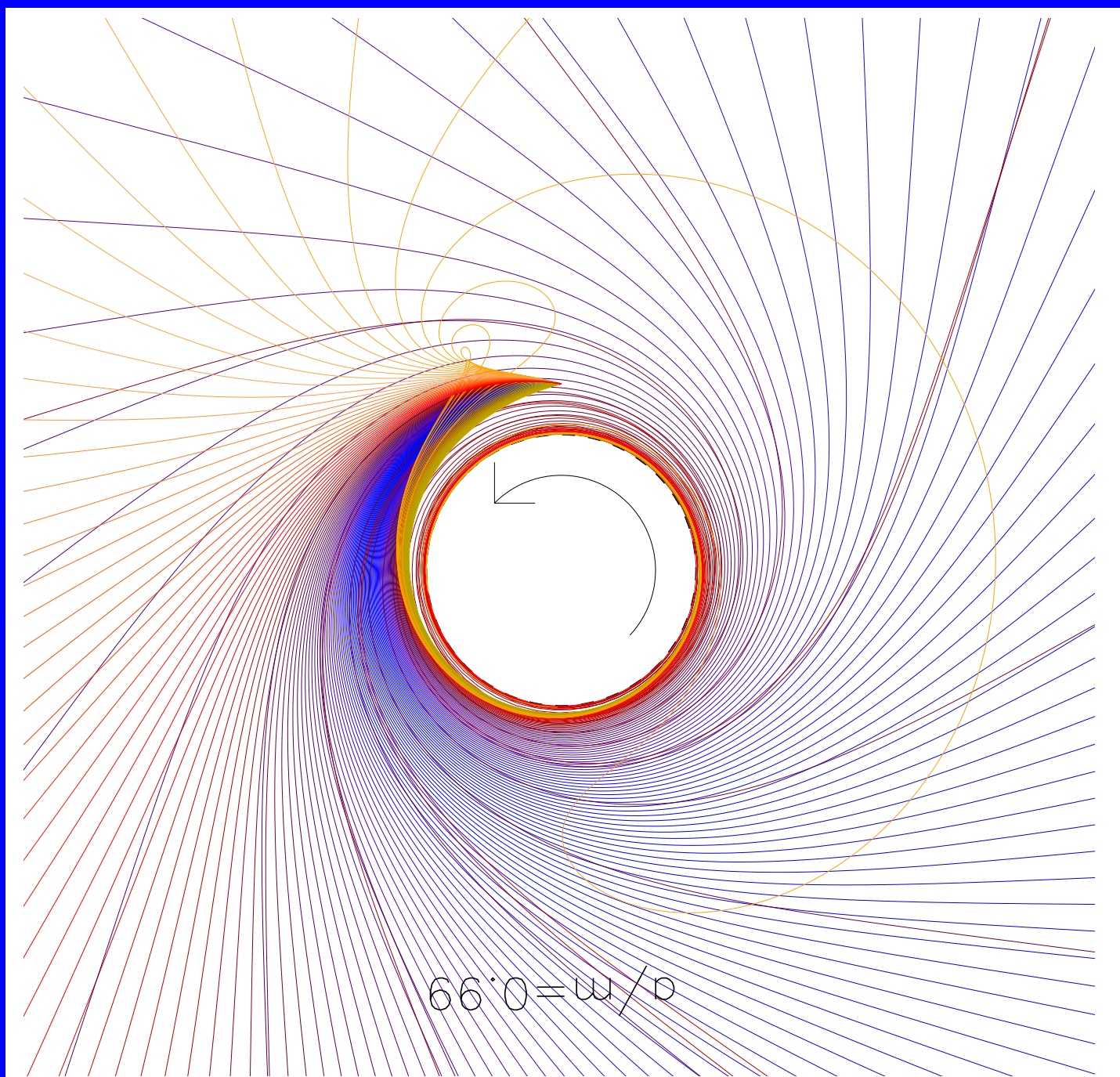


Just like massive galaxies, black holes can warp
background images

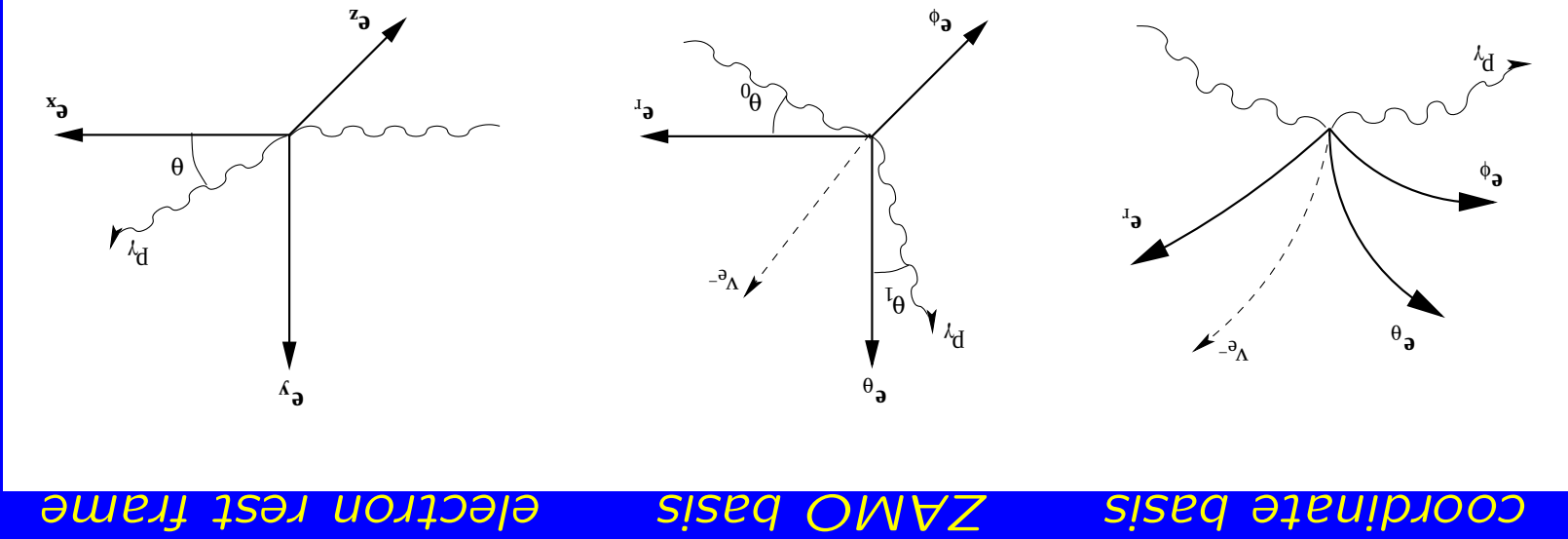
Electron Scattering

Photons are ray-traced from the emitter's
reference frame to a distant observer

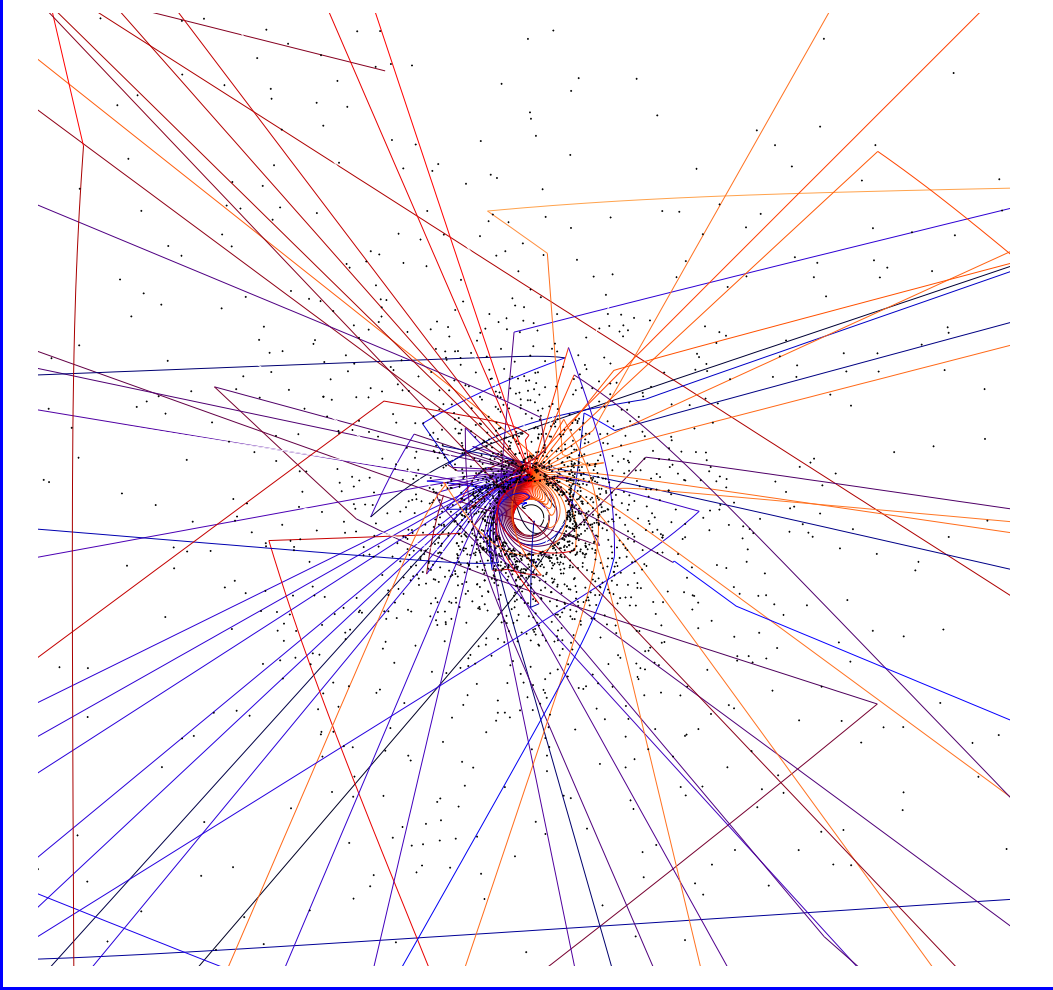




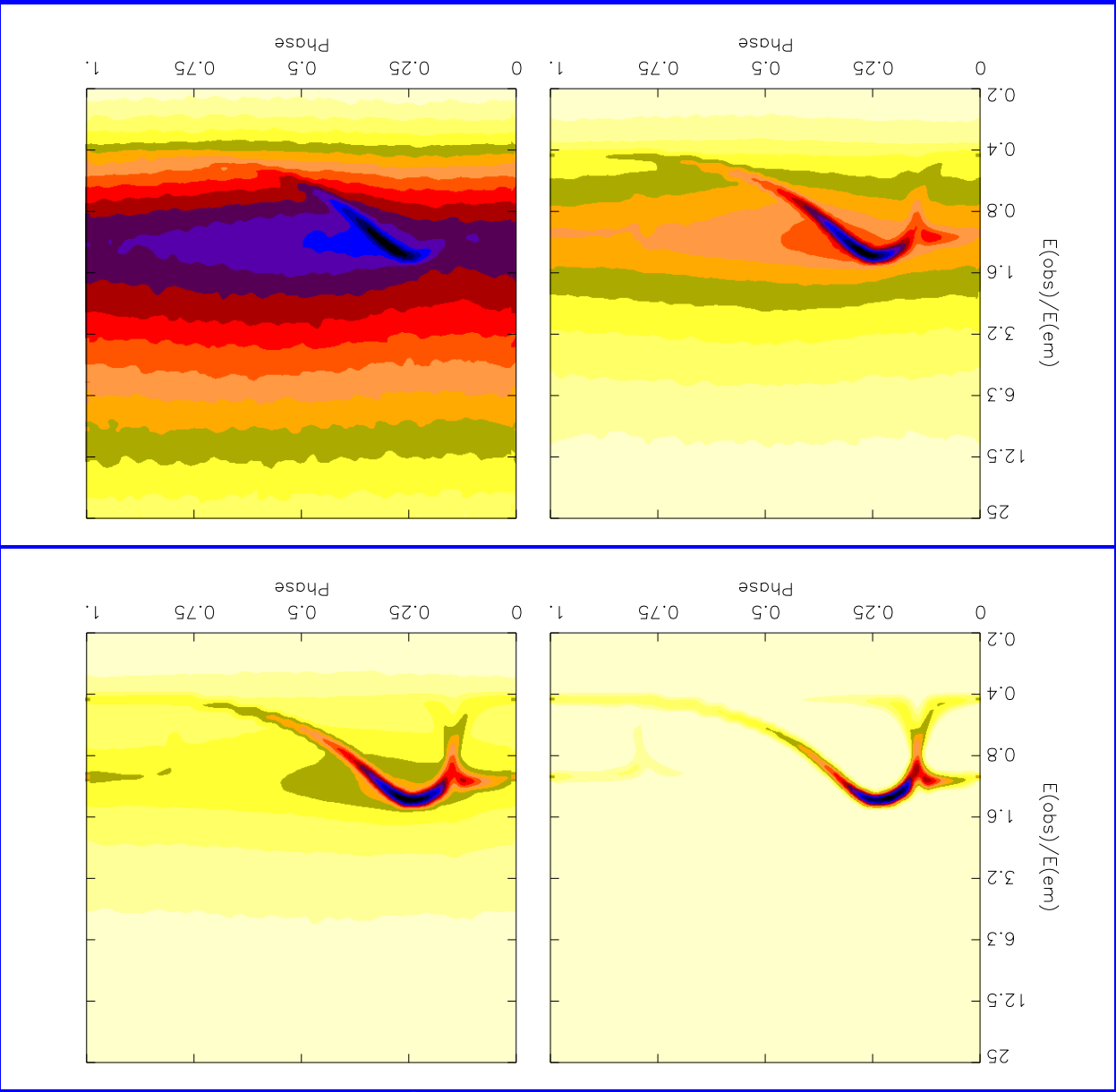
Photon-electron scattering is computed in the rest frame of the electron



Most of the scattering events occur close to the hot spot, where the corona is hottest



The hot spot spectra get smeared out in time and energy



We are just beginning to combine spectral and timing observations to probe spacetime around

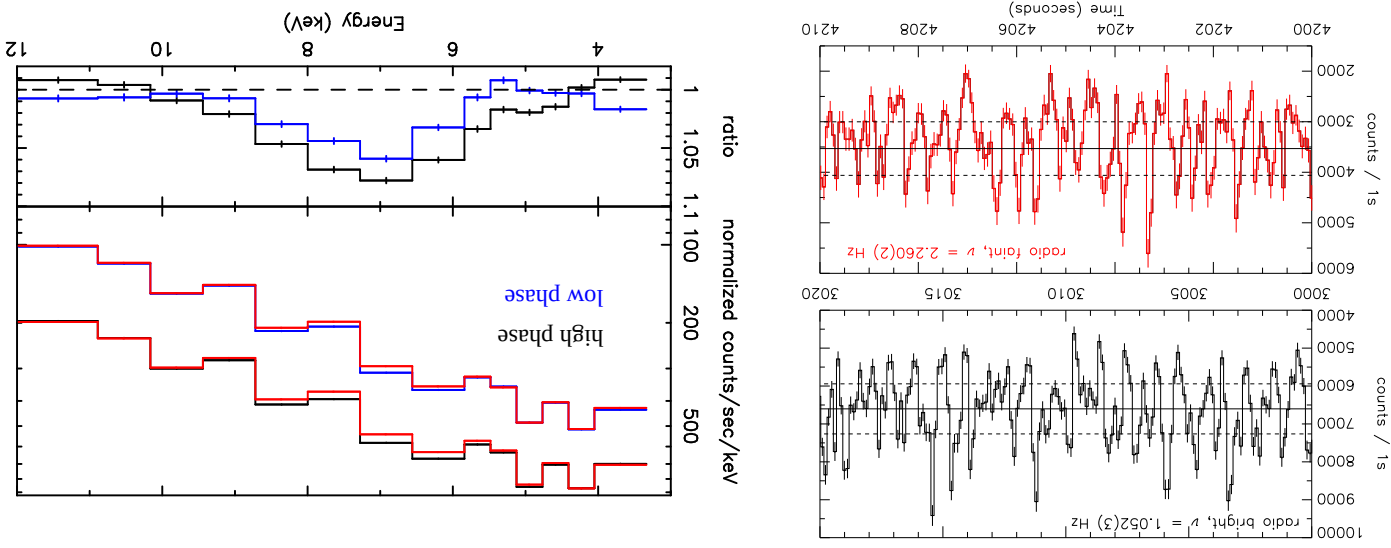
black holes

EVIDENCE FOR A LINK BETWEEN FE $K\alpha$ EMISSION LINE STRENGTH AND QPO PHASE IN A BLACK HOLE

J. M. MILLER^{1,2} AND J. HOMAN³

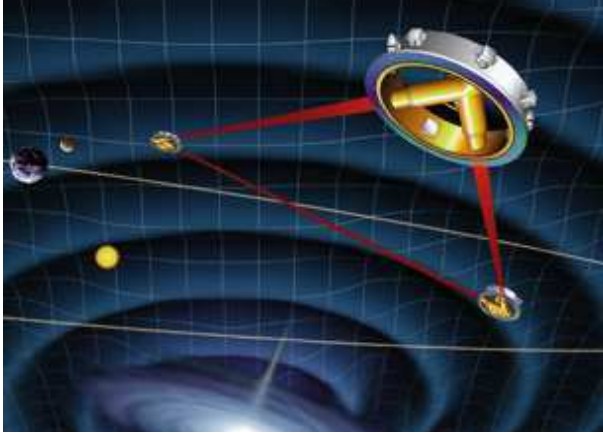
Subject headings: Black hole physics – relativity – stars: binaries – physical data and processes: accretion disks

Draft version November 9, 2004



The future of black hole exploration is defined by NASA's "Beyond Einstein" program

Astro – E2(2005) Constellation – X(2011) LISA(2010)



<http://universe.nasa.gov>