Black hole physics with IXO

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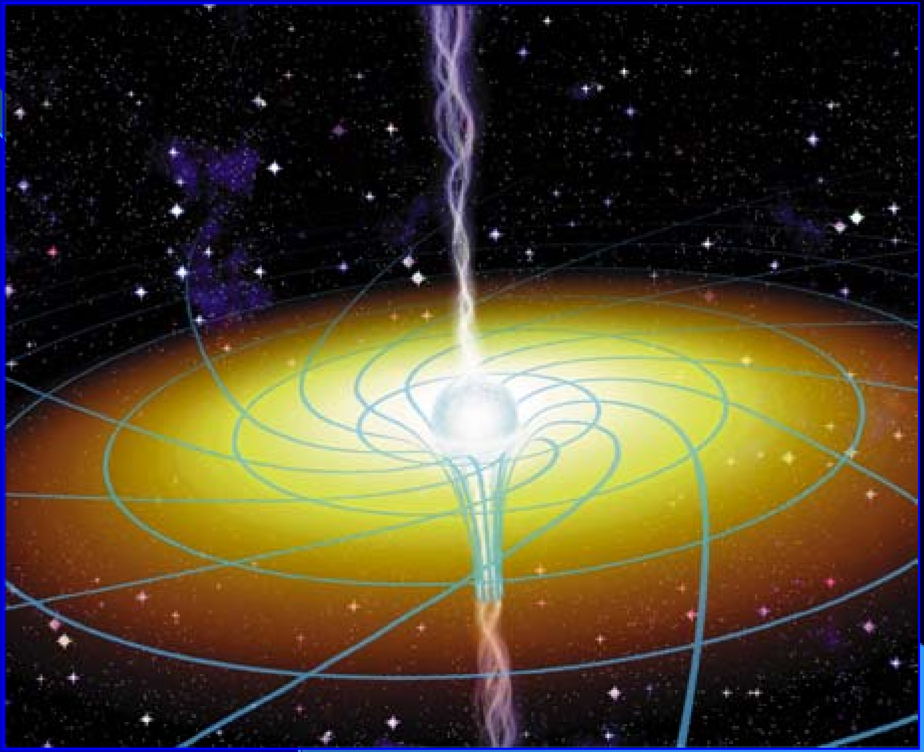


The GR/BH-Spin panel

- Fred Baganoff (MIT)
- Giorgio Matt (Rome)
- James Reeves (Keele, UK)
- Chris Reynolds (Maryland, Chair)
- Kim Weaver (NASA-Goddard)
- Andy Young (Bristol)

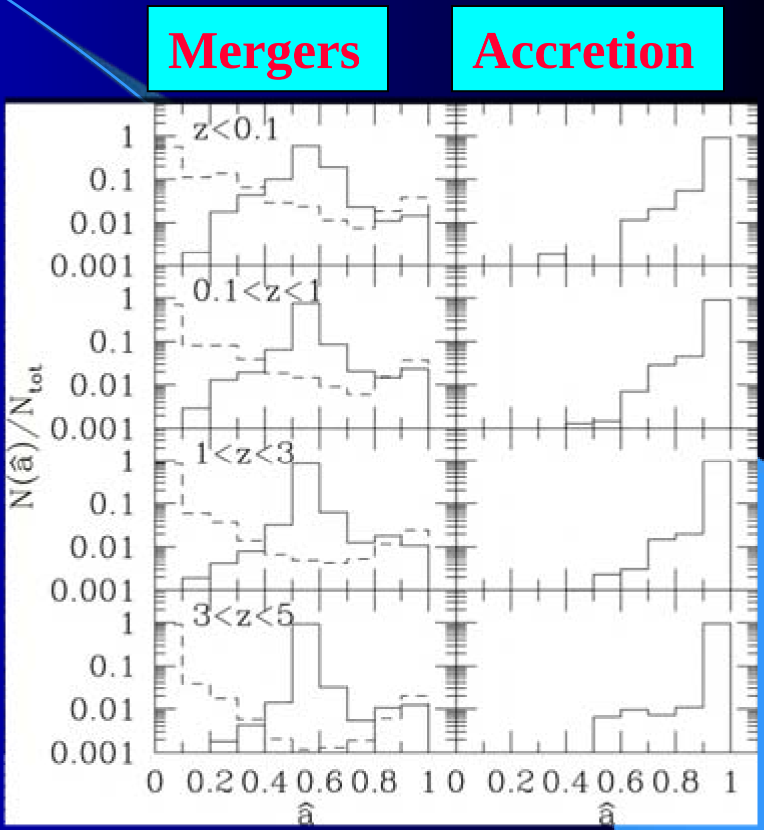
The two key questions…

<u>Key question 1</u> : What are the demographics of black hole spin?

Black hole spin probes formation event of black hole (in stellar-mass systems) and growth of black holes (in supermassive systems). For SMBHs can distinguish merger-driven evolution from accretion-driven evolution (important implications for LISA).

Spin may be the **prime mover** for relativistic jets from black hole systems…

IXO will determine spin for upto 300 supermassive black holes, as well as all accessible stellar-mass Galactic black holes that outburst.

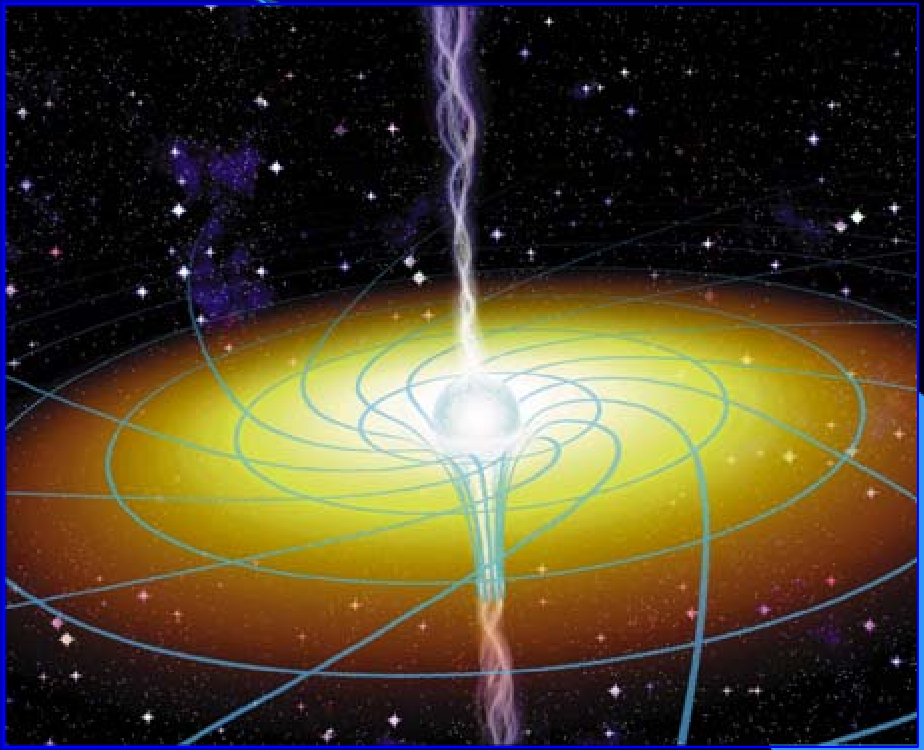


Volonteri et al. (2005)

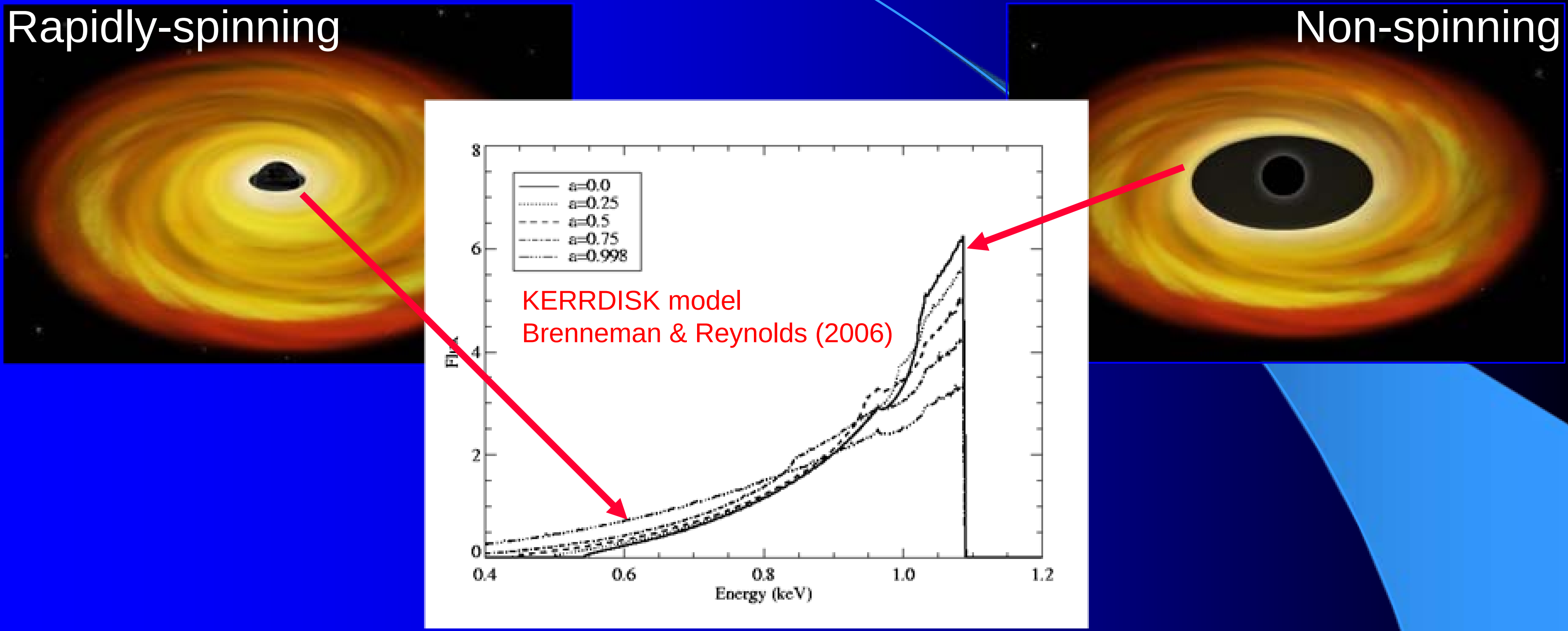
***Key question 2* : Is the space-time close to an isolated black hole really described by the Kerr metric?**

Theoretical physics is in a crisis… most physicists expect/hope that we will trip across a big surprise in either gravity or quantum theory.   Never been more important to test GR in strong field regime.

IXO can probe spacetime metric via rapid variability of the broad iron line…

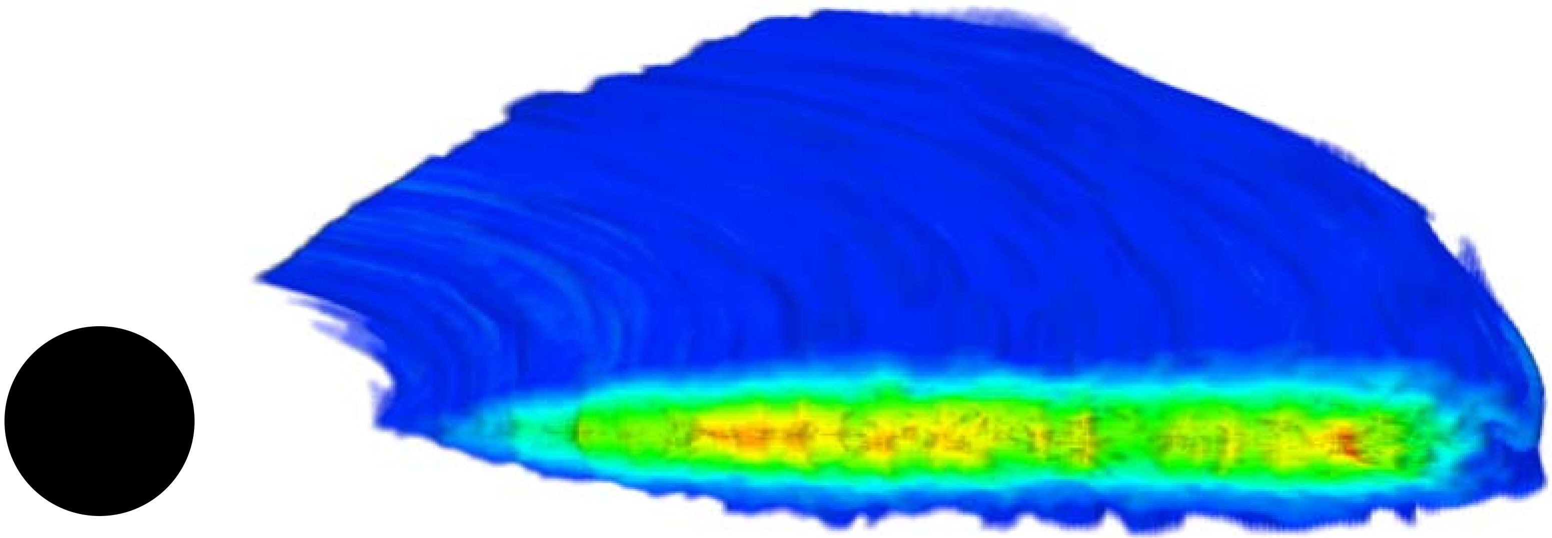


Spin from iron line profiles

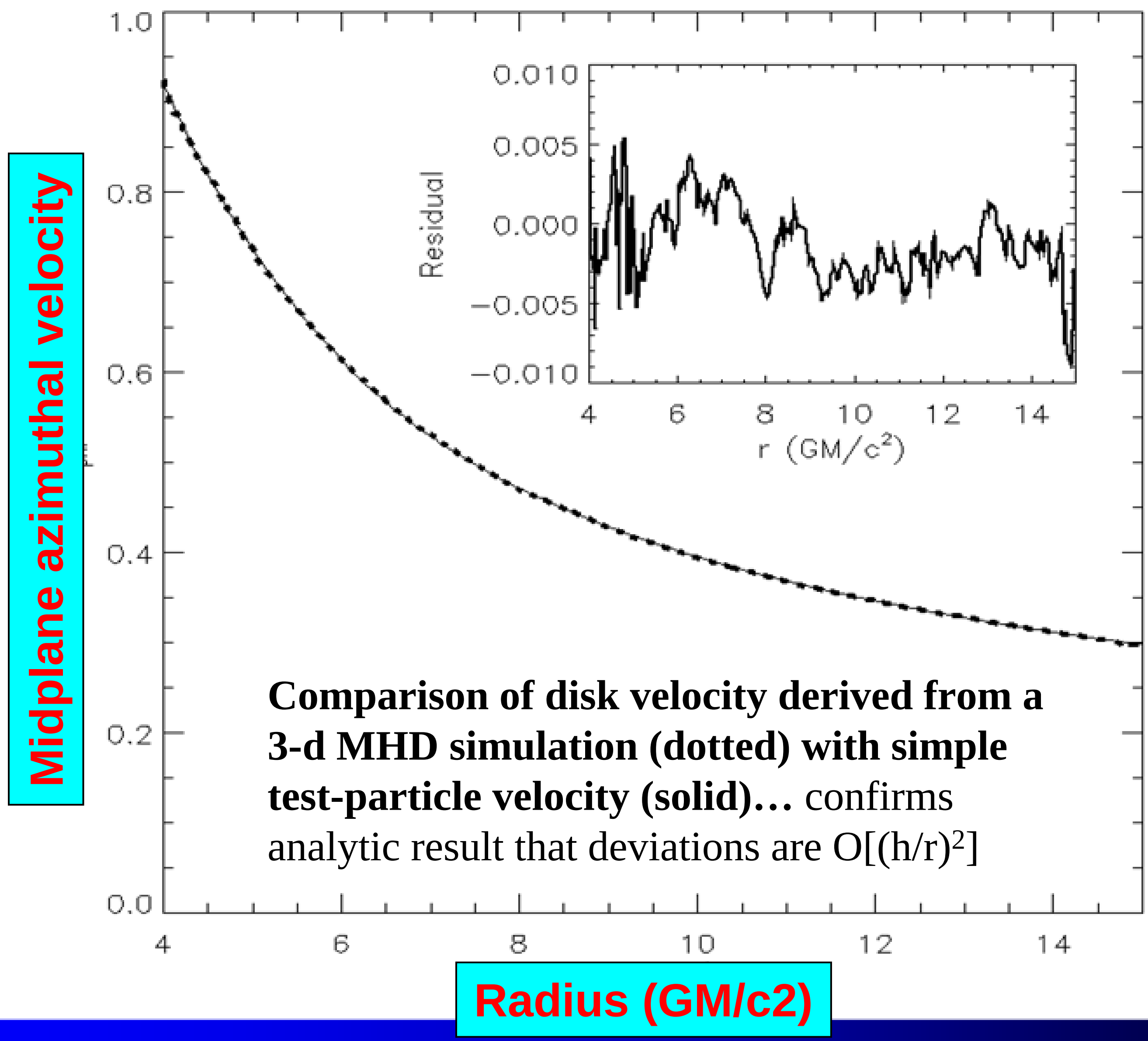


- **<u>Feature</u> :** Spin measurement independent of mass or distance
- **<u>Theoretical assumptions</u>** : Assume that disk is Keplerian and that the iron line truncates at the ISCO

3-d MHD simulation of thin disk (pseudo-Newtonian potential)



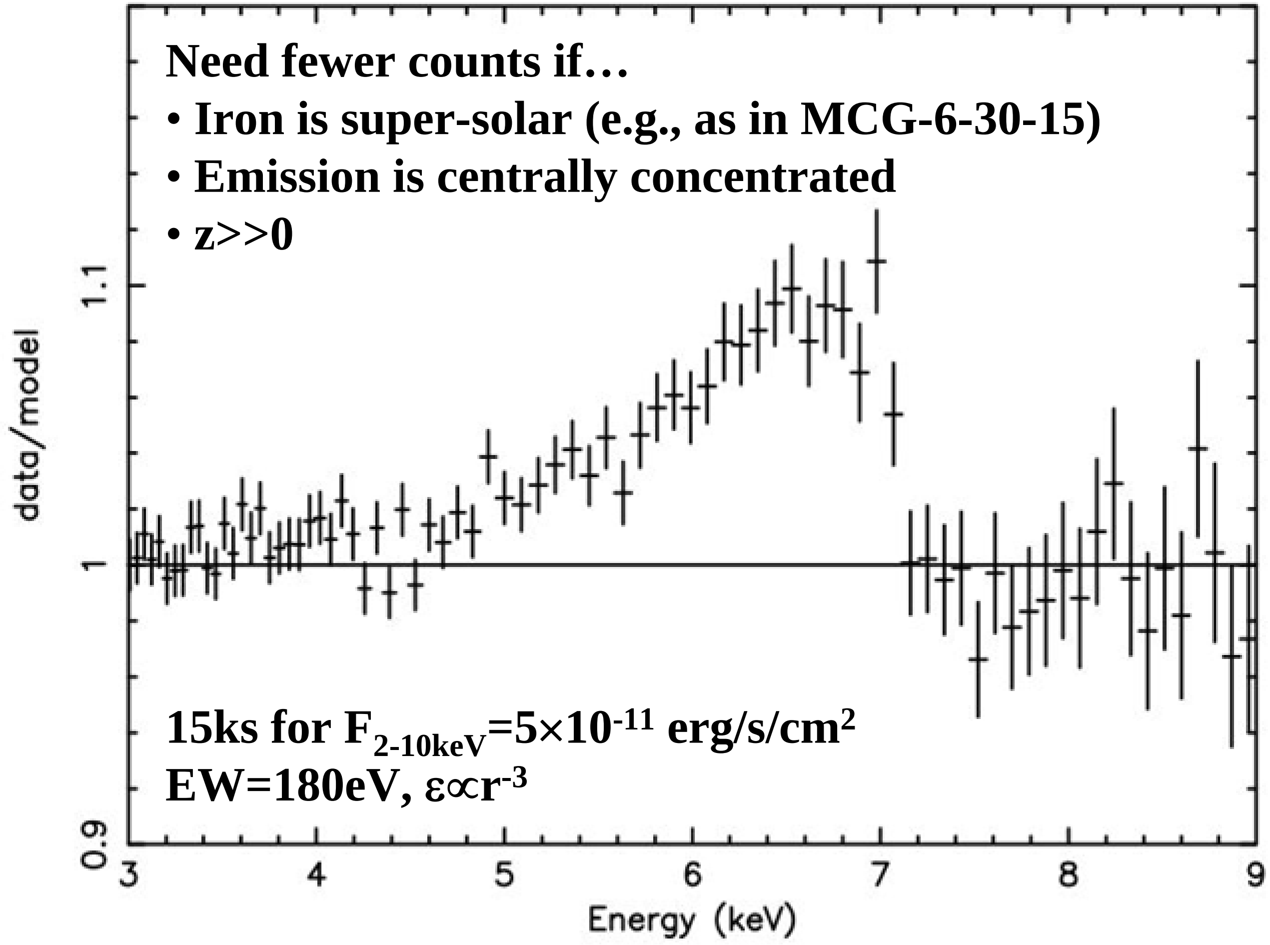
Run MHD3d_2hr
CSR & Miller (2008)
CSR & Fabian (2008)



Comparison of disk velocity derived from a 3-d MHD simulation (dotted) with simple test-particle velocity (solid)… confirms analytic result that deviations are $O[(h/r)^2]$

Con-X simulation with 1 million photons in 2-10keV band

Constrains a>0.90 for a_{model}=0.95



15ks observation for $F_{2\text{-}10keV}=5\times10^{-11}$ erg/s/cm^2

Comments about observing strategy…

- **One possible strategy : target known AGN on the basis of flux and the presence of a broad iron line… "run down log N - log S curve"**
- Using HEAO-A1 LogN-LogS…

$$N_{tot} \approx 140 \left(\frac{f}{0.5}\right)^{2/5} \left(\frac{n_{ph}}{10^6}\right)^{-3/5} \left(\frac{\Omega}{3\pi}\right) \left(\frac{T}{10^7\,s}\right)^{3/5}$$

  - f is fraction of sources with broad lines
  - n_{ph} is number of 2-10keV photons needed for individual measurement

- Need to refine/re-assess observing strategy as we learn more about AGN populations and X-ray spectra (e.g., from follow-up to the BAT survey)… goal will be to optimize constraints on models through mixture of
  - Local studies (running down logN-logS curve)
  - Targeted studies of high-z broad iron line sources
  - Targeted studies of interesting but under-represented minorities (e.g., radio-loud AGN, AGN in LSB galaxies).

Testing the kerr metric…

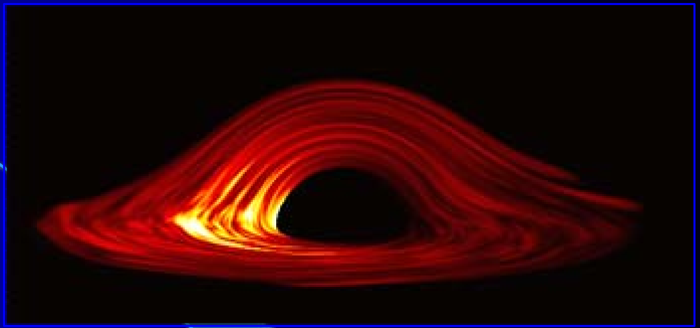
- Why is this worth doing?
  - GR is a fundamental pillar of physics and our basis for understanding the structure of space, time and gravity
  - BUT, it is essentially untested in the strong-field regime
  - Expected failure points are in the extreme regimes inside the event horizon… but it is important to stay open to surprises!

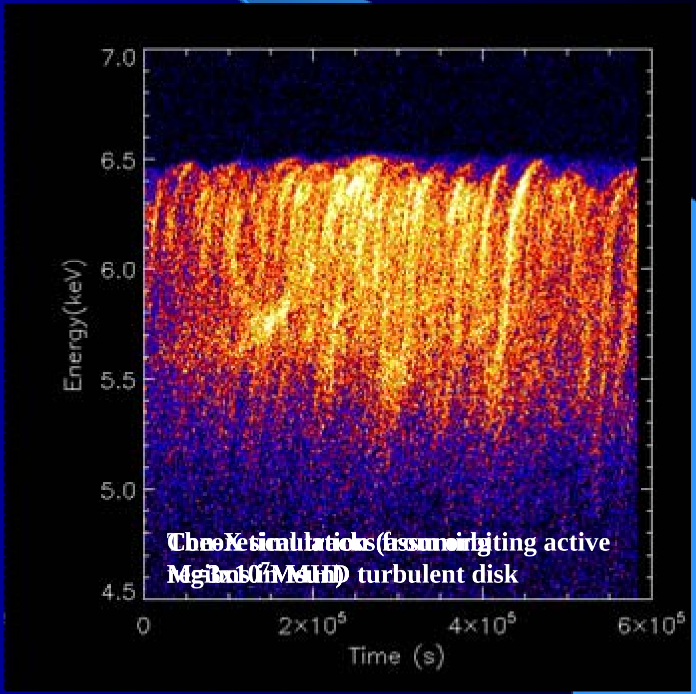
- Why is this hard (for us)?
  - We "see" the underlying gravity filtered through messy and uncertain astrophysical processes
  - May be hard to distinguish a breakdown of GR from a problem with our understanding of the astrophysics **(mind you… the SNe1a/dark-energy people pull this off!)**

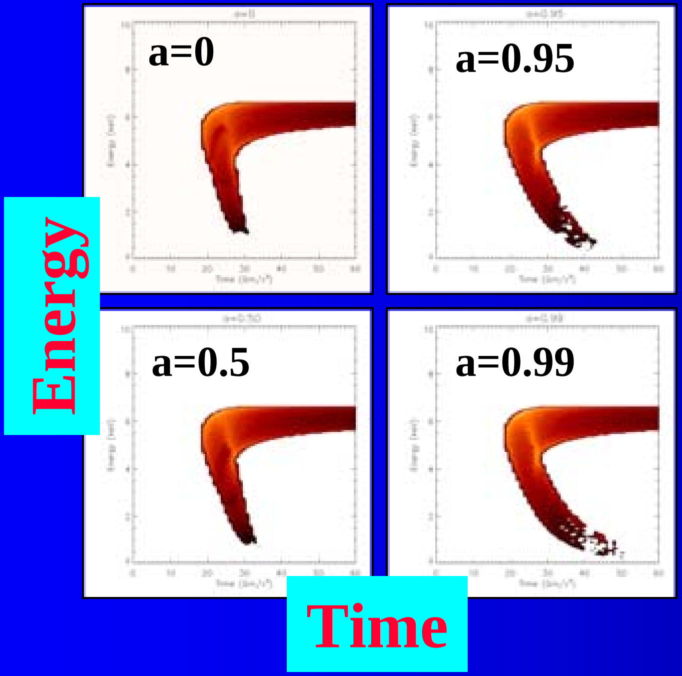
Example of astrophysical uncertainty… iron line variability qualitatively different depending upon X-ray source geometry…

• **<u>Disk-hugging corona</u>**: will see line variability as active regions orbit. Modeling "tracks" will probe whether relativistic frame-dragging has same radial dependence as the Kerr metric

• **<u>Base of a jet</u>**: will see relativistic reverberation delays. Extreme "Shapiro" delays can be compared with expectation from Kerr metric.



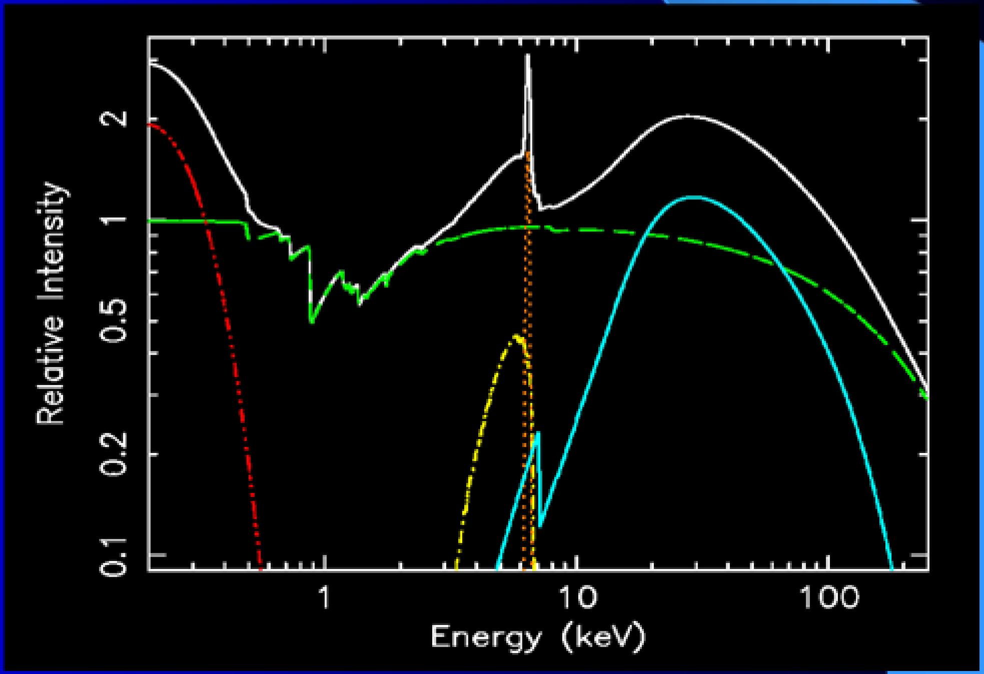




Utility of hard X-ray data

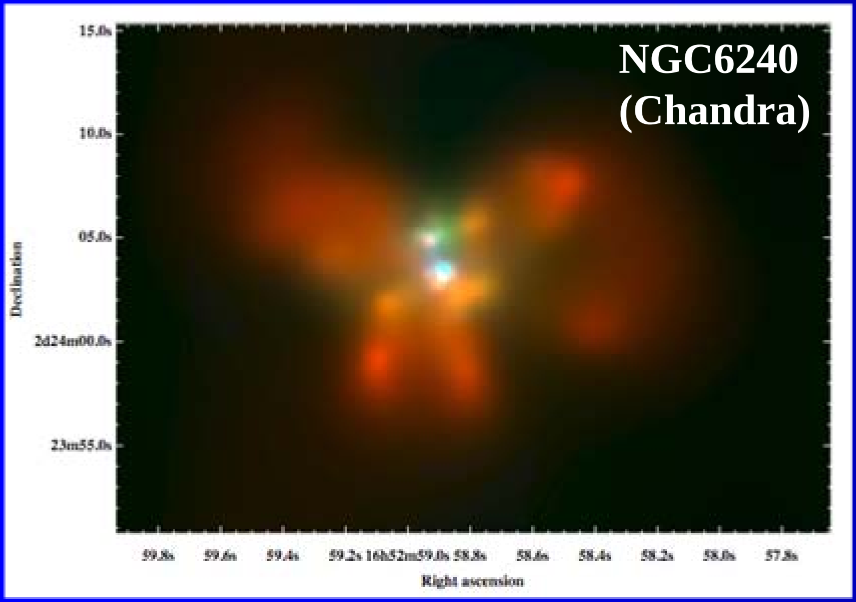
- E.G. 15ks observation of bright Seyfert galaxy ($F_{2-10}=5x10^{-11}$)
- Model includes
  - 3 zone warm absorber (set to MCG-6 parameters)
  - Reflection from ionized accretion disk (ξ=30, β=-3, i=30deg, W_{Fe}~100eV)
  - Convolve with variable spin model "kerrconv" (Brenneman & CSR 2006)
  - Assumes spin a=0.9 and disk truncated at ISCO
- Fitting just above 2keV
  - XMS alone ; a=0.77±0.17
  - XMS+HXD ; a=0.84±0.10

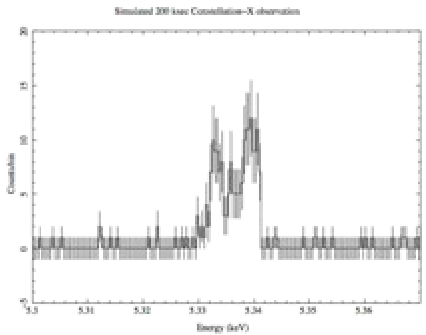
Sharp spectral features probably stable on timescales of <1 day. Thus, can tolerate simultaneous CCD+HXT data provided there was a high-resolution 0.5-10keV observation within ~1 day.



Opportunities offered by the WFI

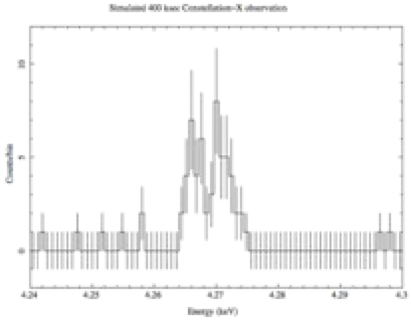
- Has little impact on primary science goals
- But will allow serendipitous discovery of binary AGN…





200 ksec @ z = 0.2

Expect 10+ SMBH binaries per WFI field of view



400 ksec @ z = 0.5

Courtesy Andy Young

Conclusions

- The two big issues…
  - Investigating the formation and evolution of black holes across the mass range using black hole spin
  - Testing predictions of GR in the strong-field region close to supermassive black holes (risky and difficult, but worth it).
- Speed and robustness of spin study dramatically aided by hard X-ray (10-50+keV) data
- Field of view not a driver (but will start to pick up serendipitous spectroscopic binary AGN in wide field deep surveys).