Measuring black hole spin in AGN:
a few recent X-ray driven results

Giovanni Miniutti

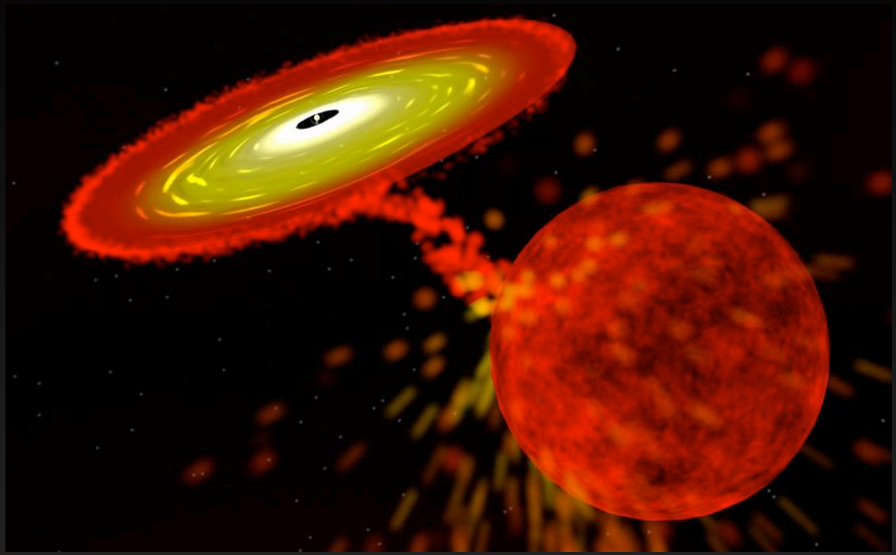
CENTRO DE ASTROBIOLOGÍA

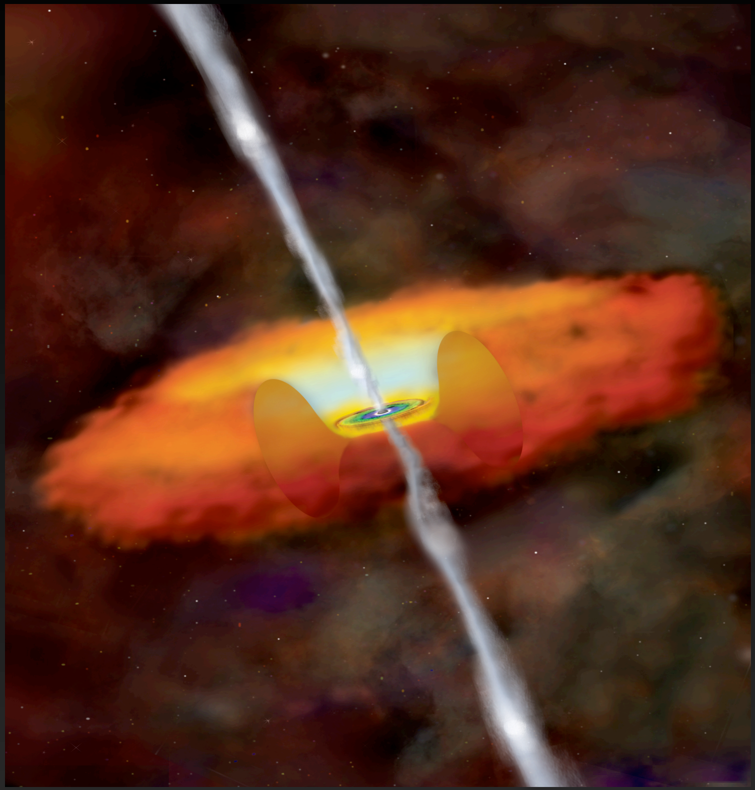
CSIC

INTA

Probing strong gravity around BH – Prague – Feb 2010

Accreting BHs



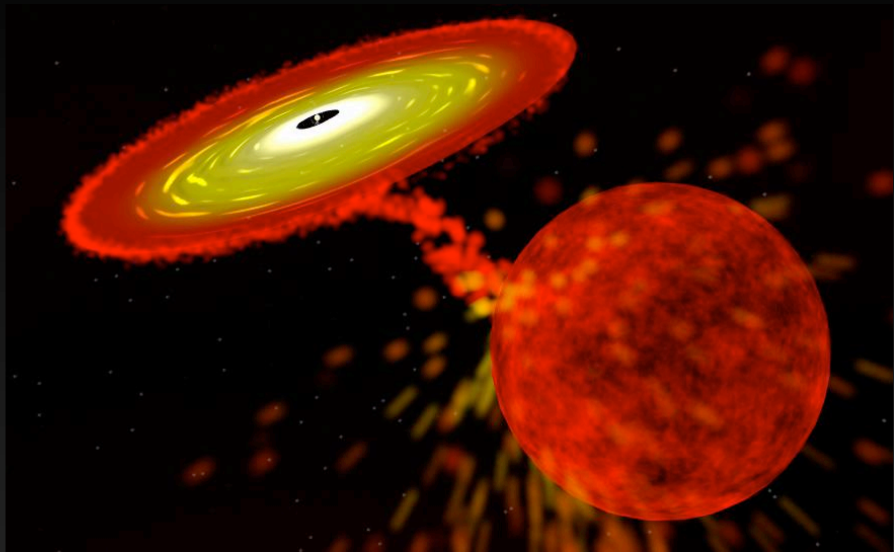


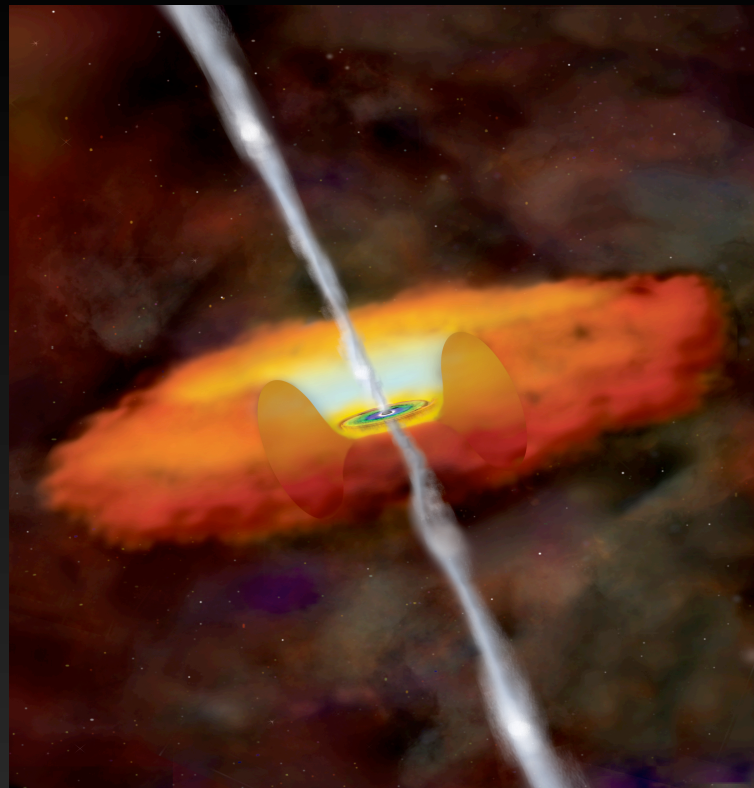
The two flavours of accreting BH:

stellar mass BHs scattered in galaxies (X-ray binaries)
supermassive BHs in the center of galaxies (AGN and quasars)

CENTRO DE ASTROBIOLOGÍA

Accreting BHs

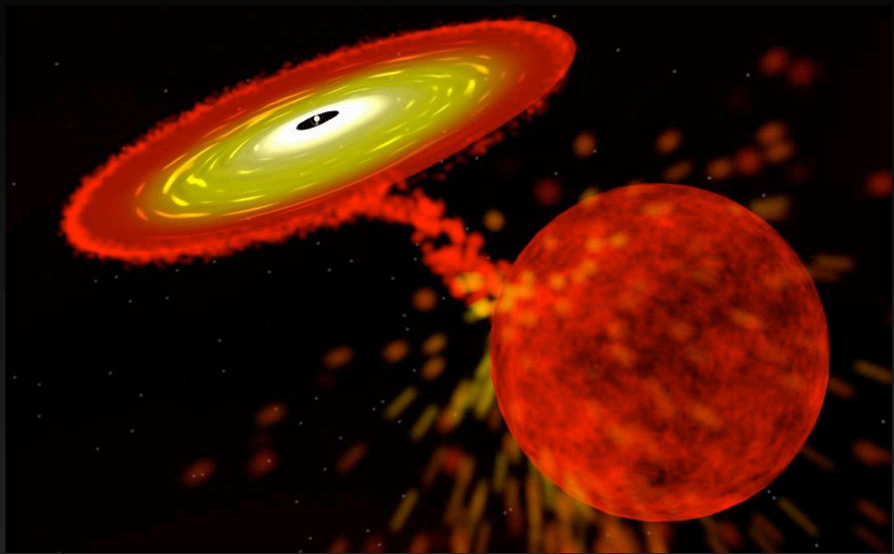


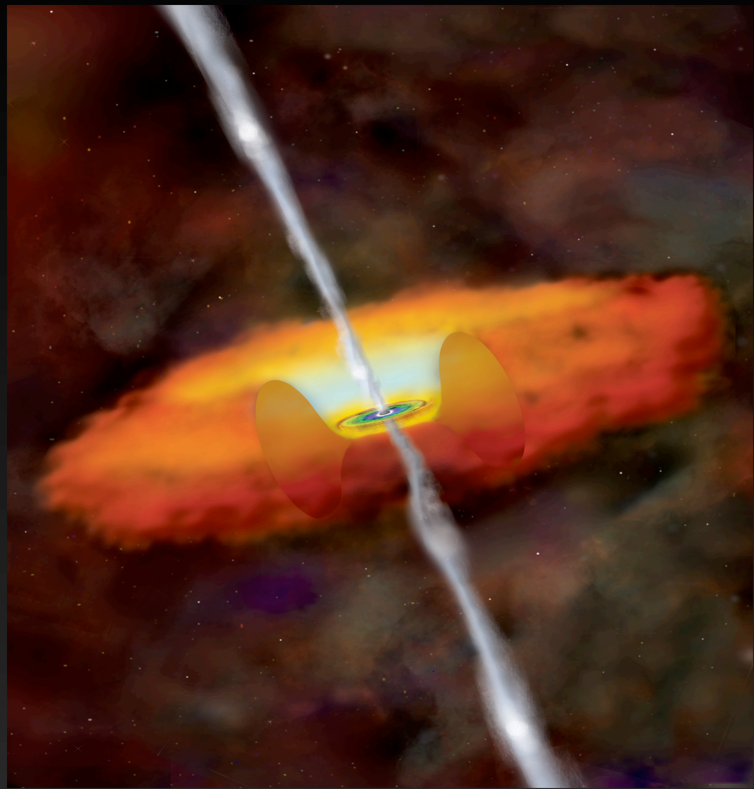


Why caring about the BH spin ?:

stellar mass BHs	dynamics of BH formation in supernovae
supermassive BHs	necessary condition for jets ?
	relative importance of mergers and accretion
	accretion modes (coherent vs chaotic)

Accreting BHs



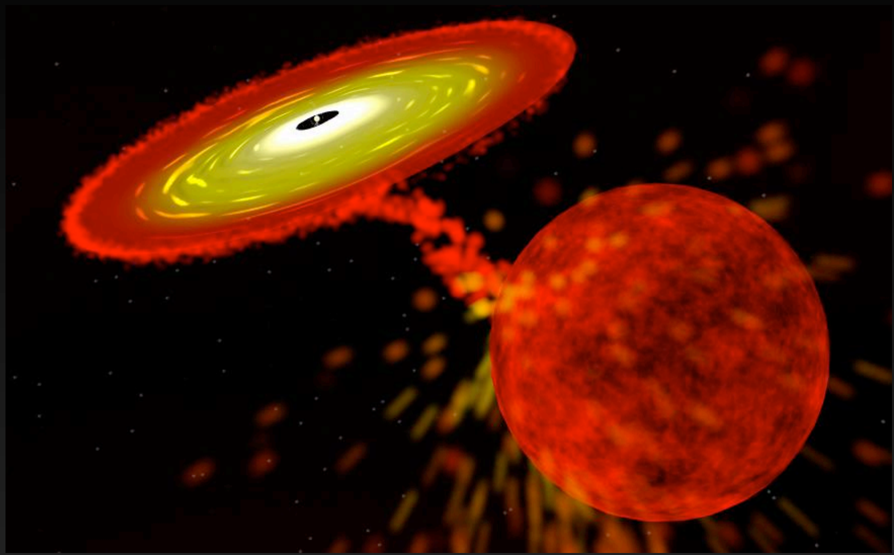


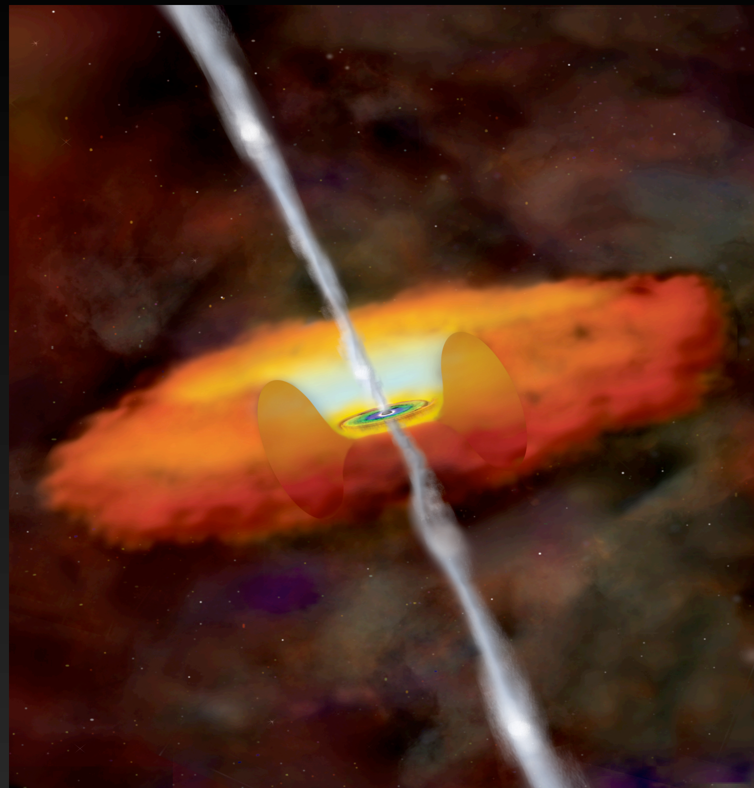
Why caring about the BH spin ?:

stellar mass BHs thermal continuum, Fe K lines, QPO
supermassive BHs thermal continuum, Fe K lines, QPO

CENTRO DE ASTROBIOLOGÍA

Accreting BHs



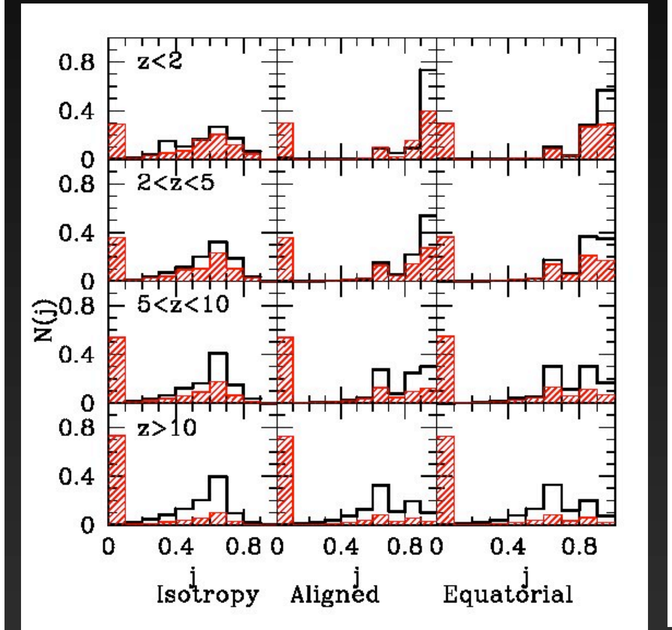


Why caring about the BH spin ?:

stellar mass BHs thermal continuum, Fe K lines, QPO
supermassive BHs ~~thermal continuum~~, Fe K lines, ~~QPO~~

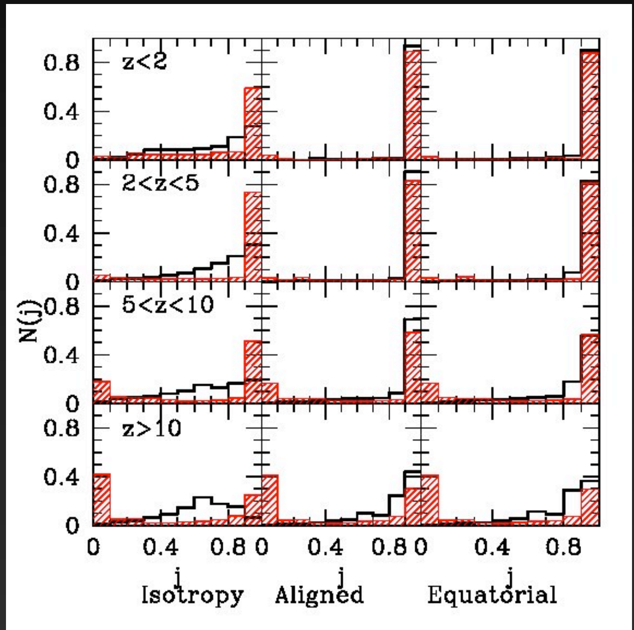
BH spin in AGN

mergers only
a ~ 0.7

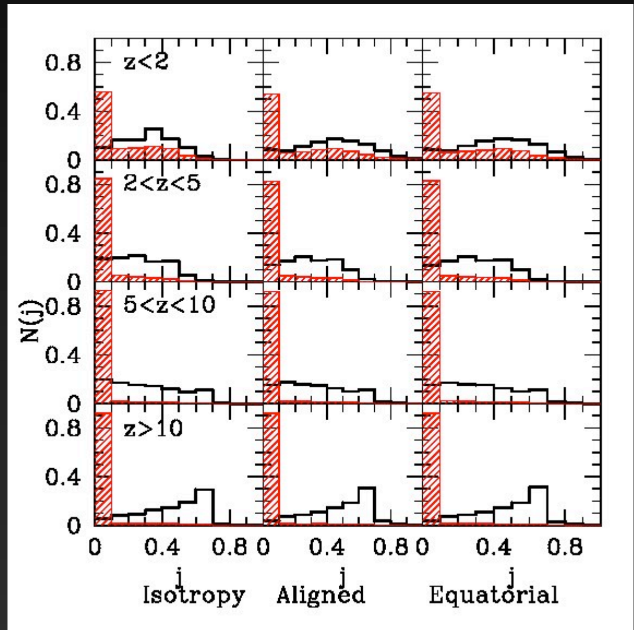


Berti & Volonteri 08

mergers + coherent
high a



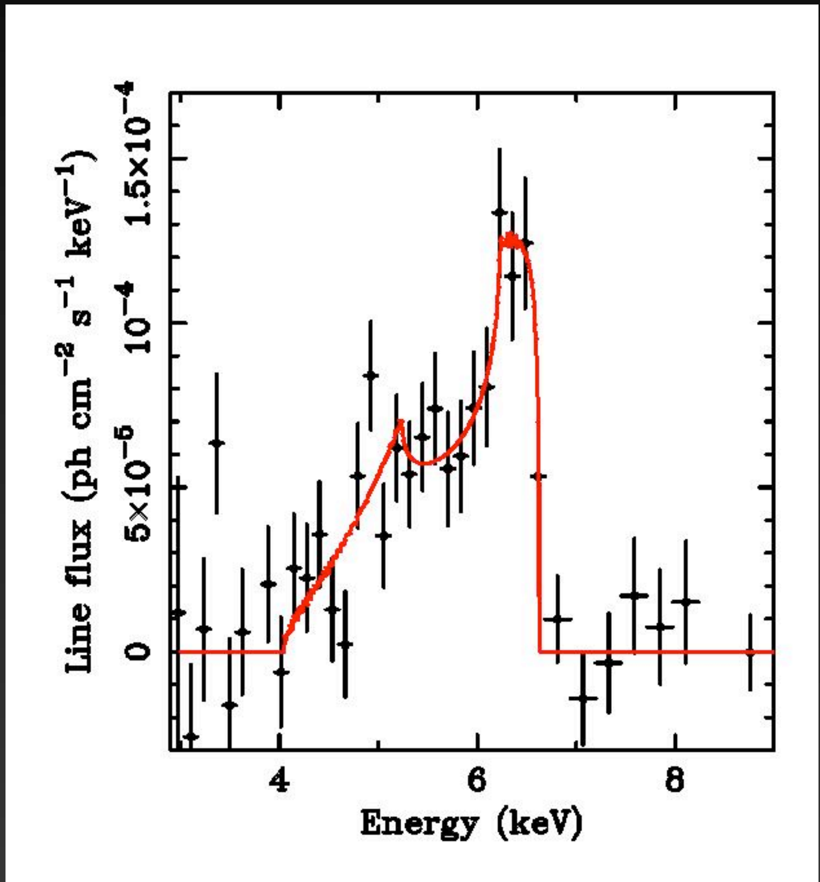
mergers + chaotic
low a



CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

First clear detection of relativistic Fe K line (Tanaka et al 95) and first evidences for a rapidly spinning Kerr BH (Iwasawa et al 96, 99)

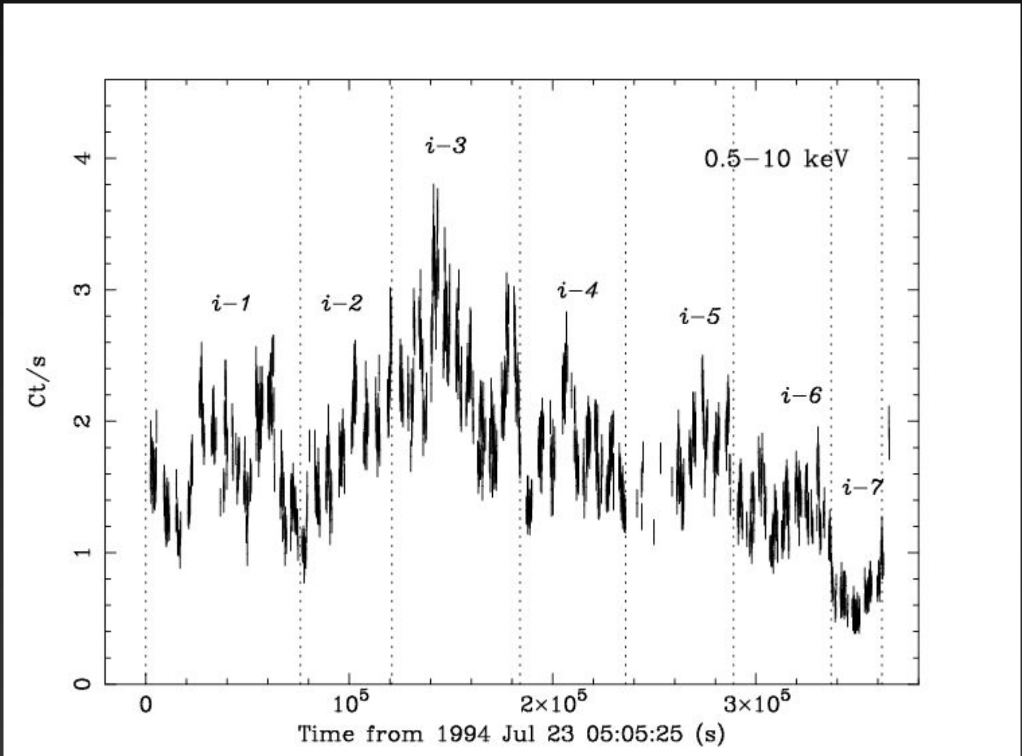


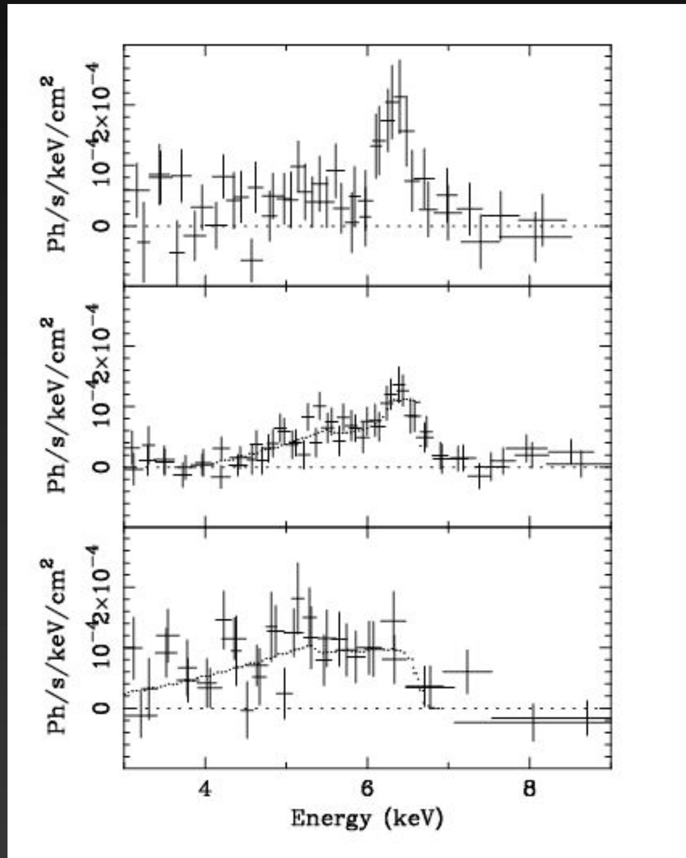
Tanaka et al 95

CENTRO DE ASTROBIOLOGÍA

The usual suspect: MCG-6-30-15

First clear detection of relativistic Fe K line (Tanaka et al 95) and first evidences for a rapidly spinning Kerr BH (Iwasawa et al 96, 99)

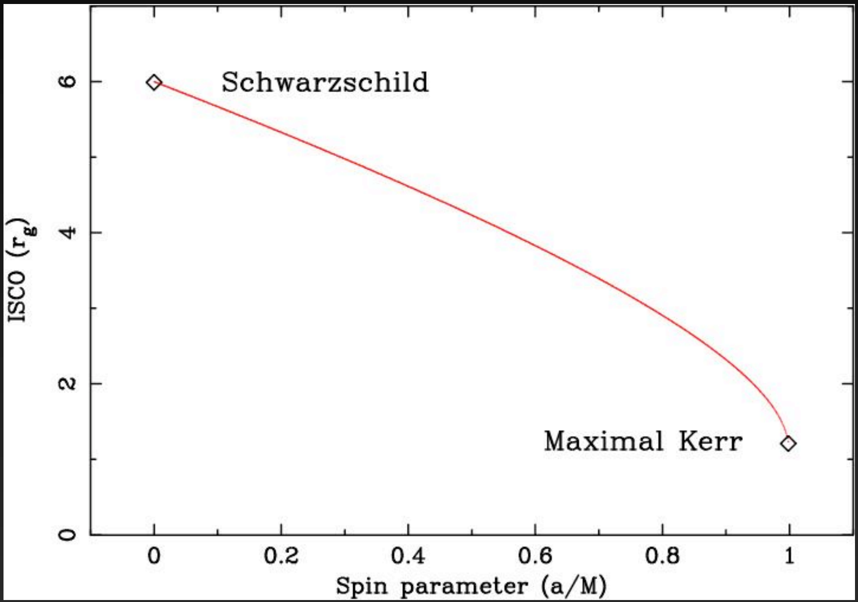


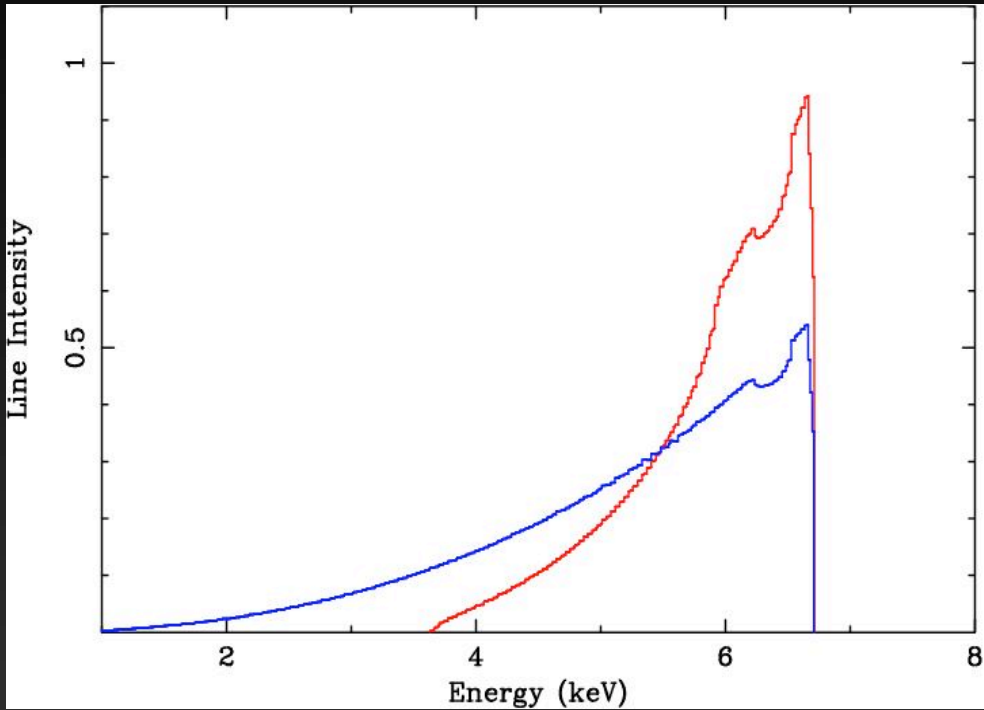


Iwasawa et al 96

The usual suspect: MCG-6-30-15

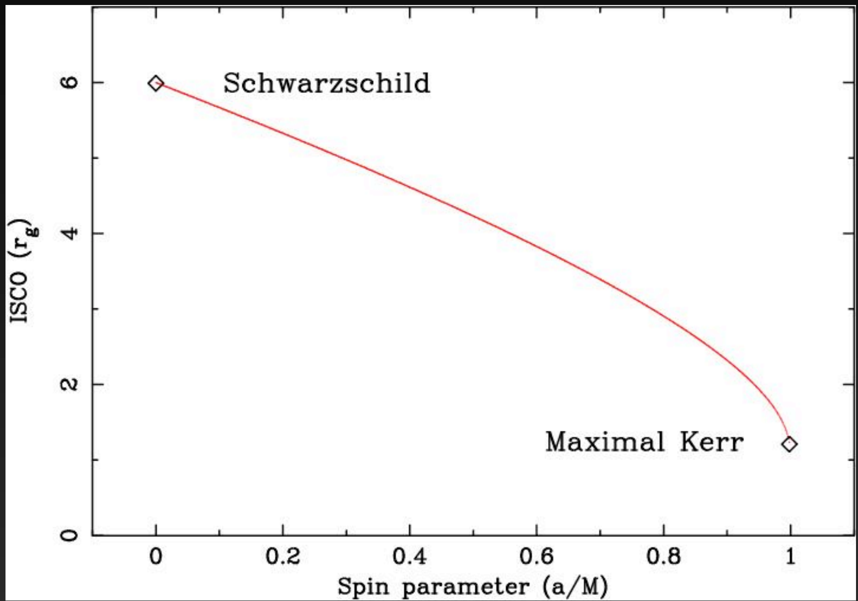
BH spin measurements rely on the id. ISCO ≅ R_{in}

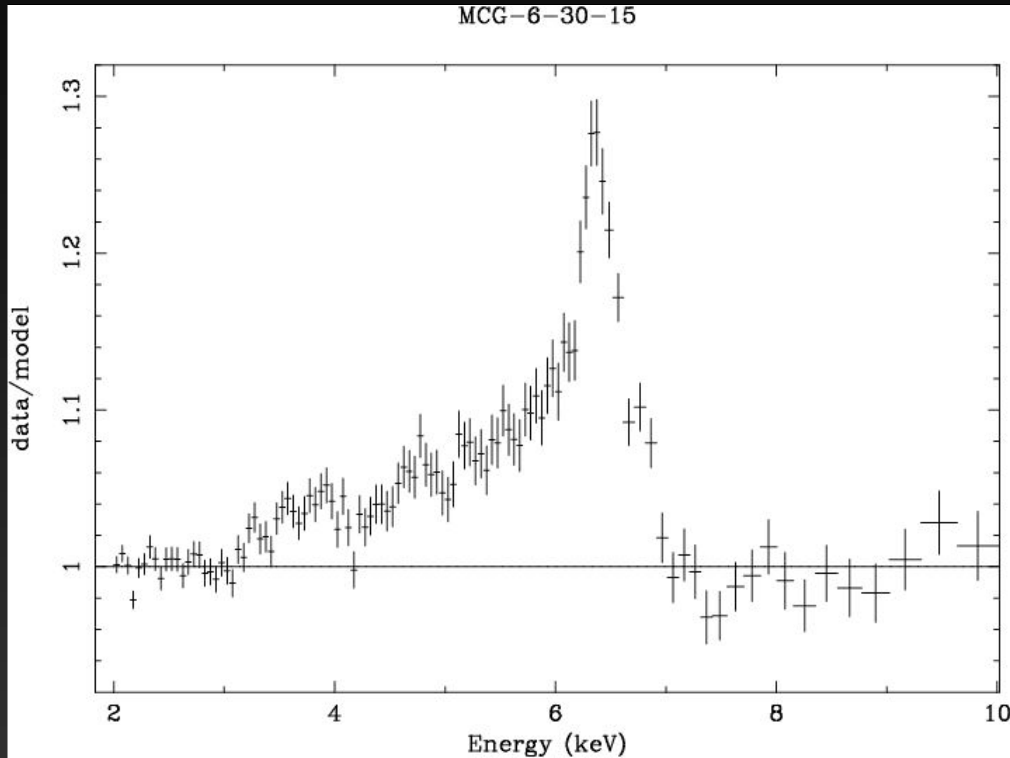




The usual suspect: MCG-6-30-15

BH spin measurements rely on the id. ISCO ≅ R_{in}



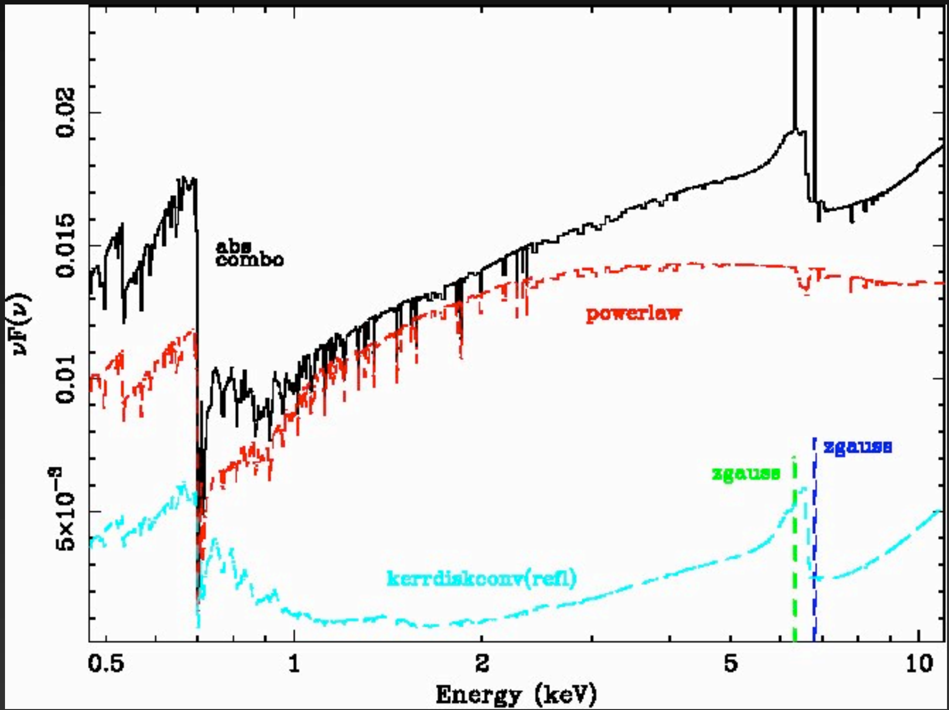


Fabian et al 02

Early results in MCG-6 indicate that $R_{in} < 2\ r_g$
which translates into a BH spin of a > 0.94

The usual suspect: MCG-6-30-15

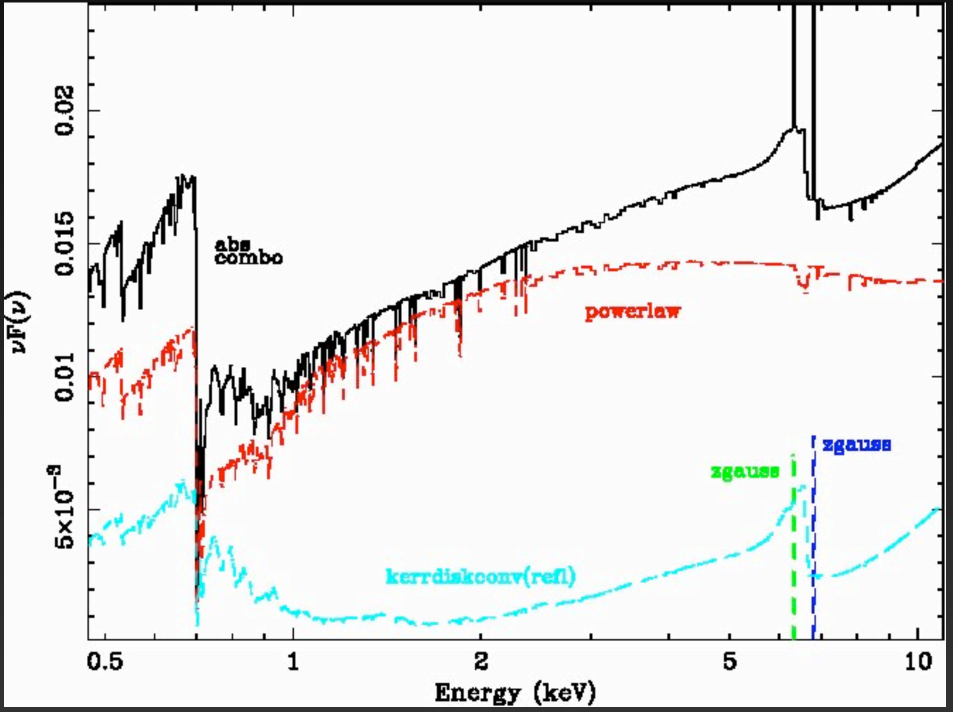
More recently, a detailed analysis by Brenneman & Reynolds (07) yields to a much more accurate spin measurement of a ≥ 0.987

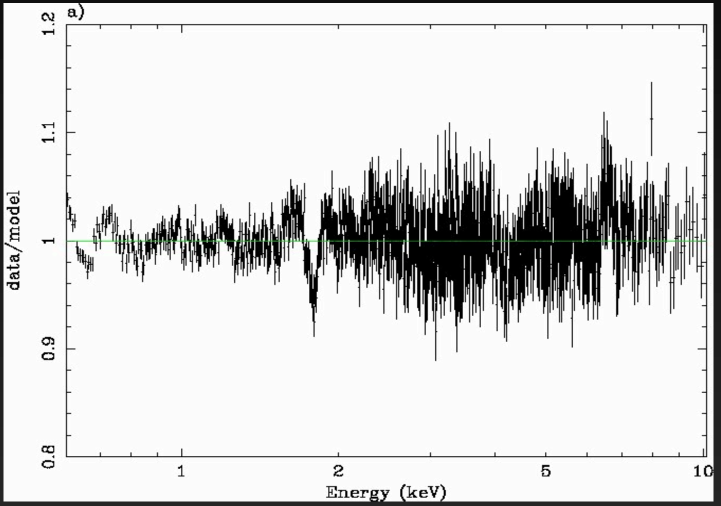


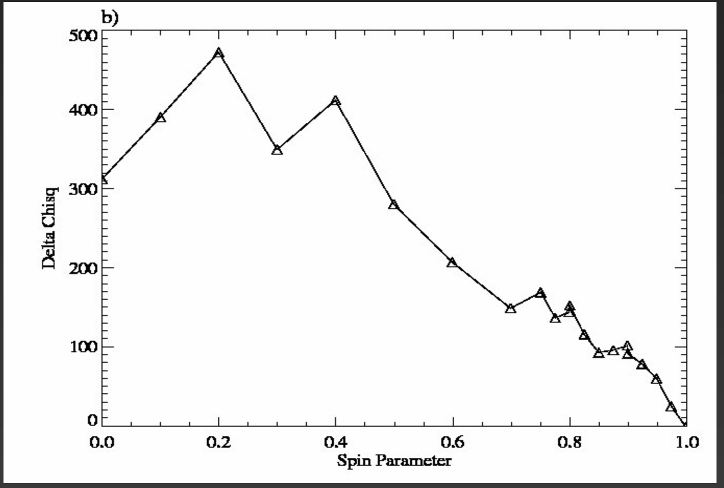
Brenneman & Reynolds 07
but see Miller et al. 09

The usual suspect: MCG-6-30-15

More recently, a detailed analysis by Brenneman & Reynolds (07) yields to a much more accurate spin measurement of a ≥ 0.987





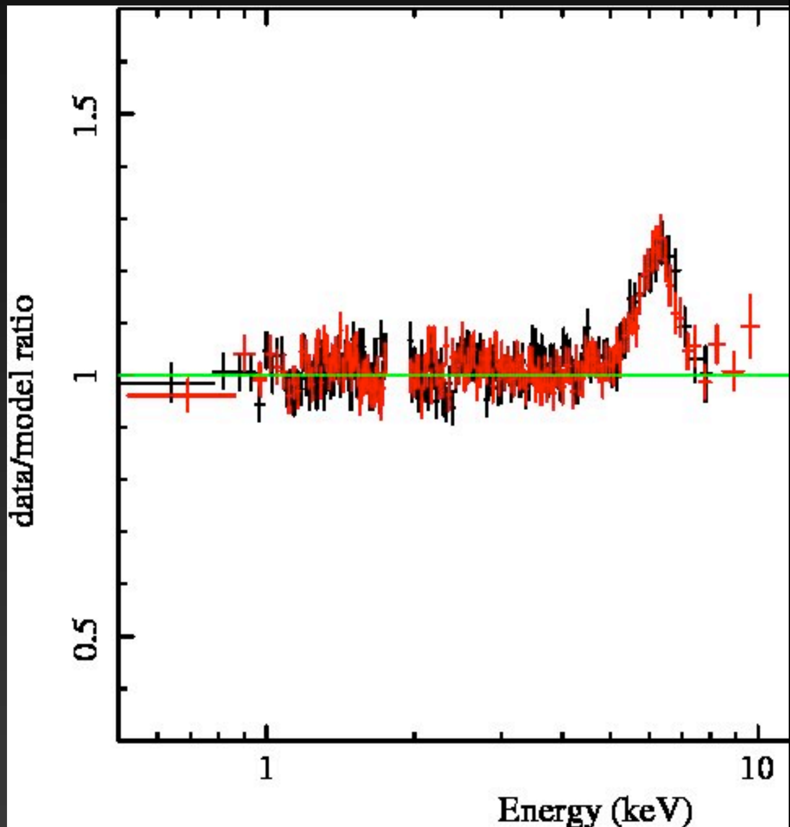


Brenneman & Reynolds 07
but see Miller et al. 09

Swift J2127.4+5654 with Suzaku

This is a NLS1 galaxy detected above 20 keV with INTEGRAL/IBIS (rare)

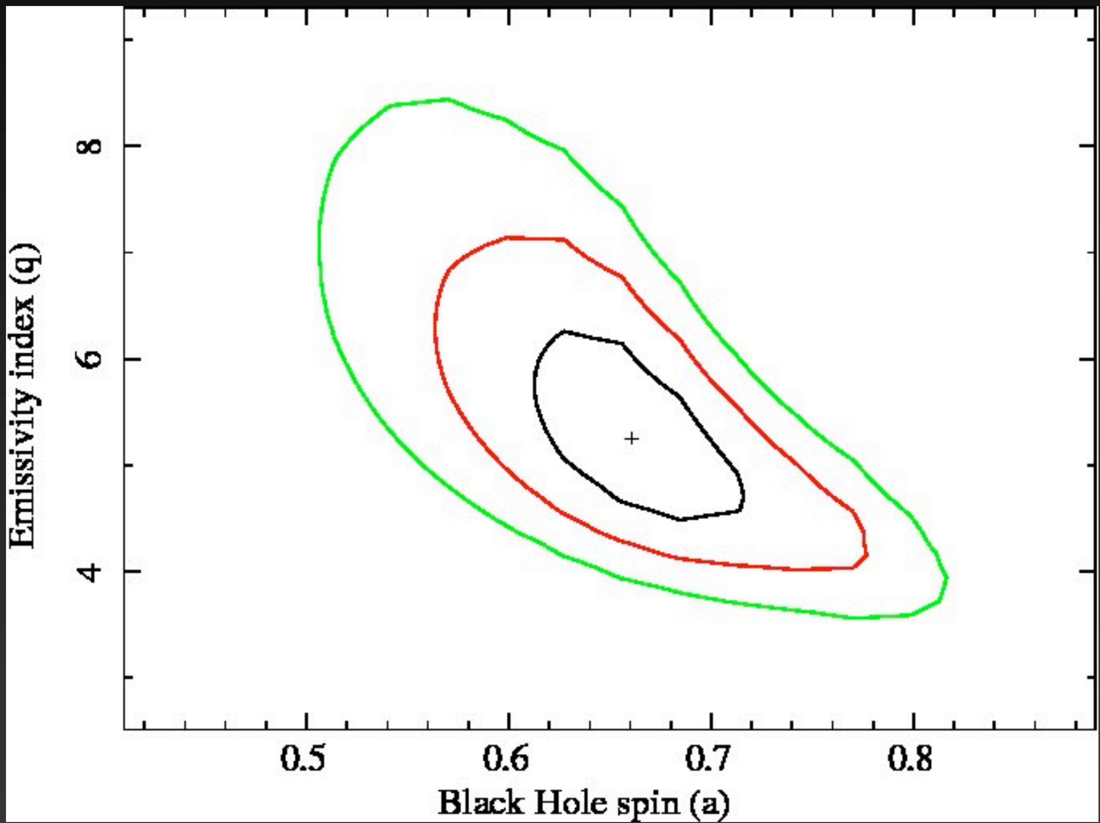
The hard X-ray flux (~ 2.5 10^{-11} in 20-100 keV) makes it a good Suzaku source (especially for the HXD)



GM et al 09

Swift J2127.4+5654 with Suzaku

modeling the XIS spectra with a relativistic line provides constraints on both emissivity index (steep) and BH spin (intermediate)



GM et al 09

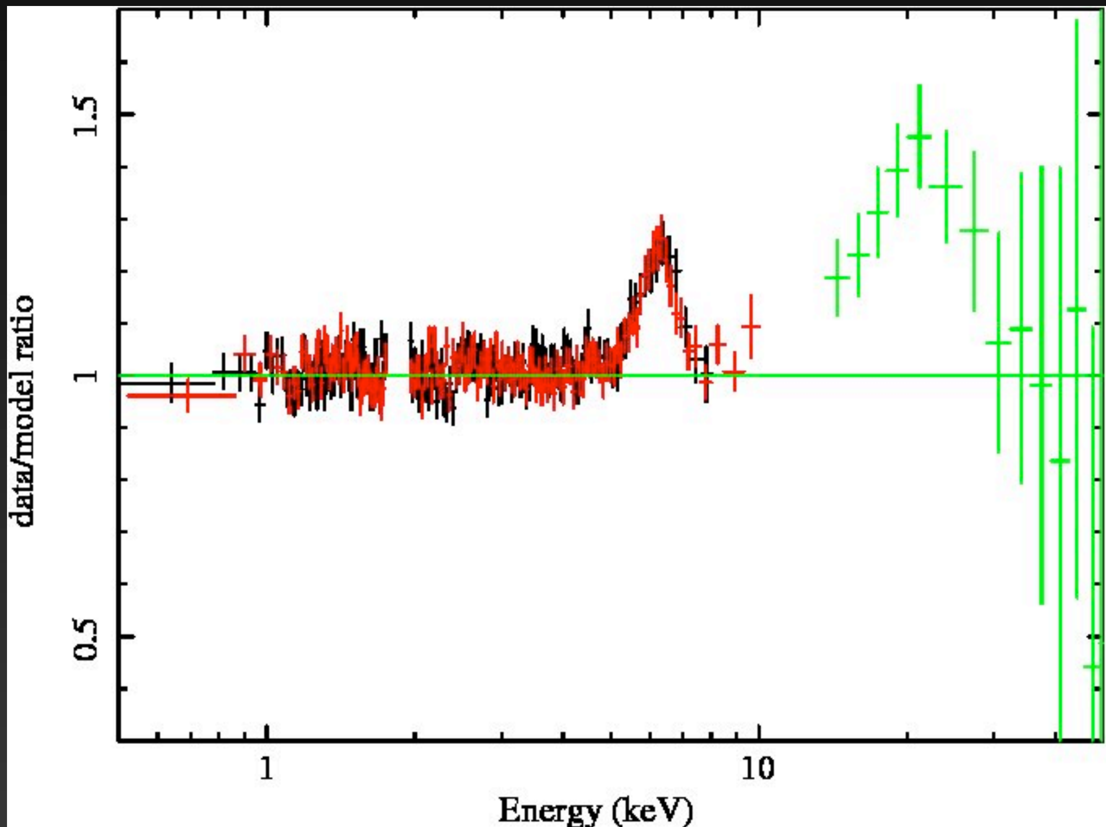
CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

The relativistic Fe K line should be associated with a full X-ray reflection spectrum which shows up at > 10 keV (Compton hump)

Swift J2127.4+5654 with Suzaku

The relativistic Fe K line should be associated with a full X-ray reflection spectrum which shows up at > 10 keV (Compton hump)

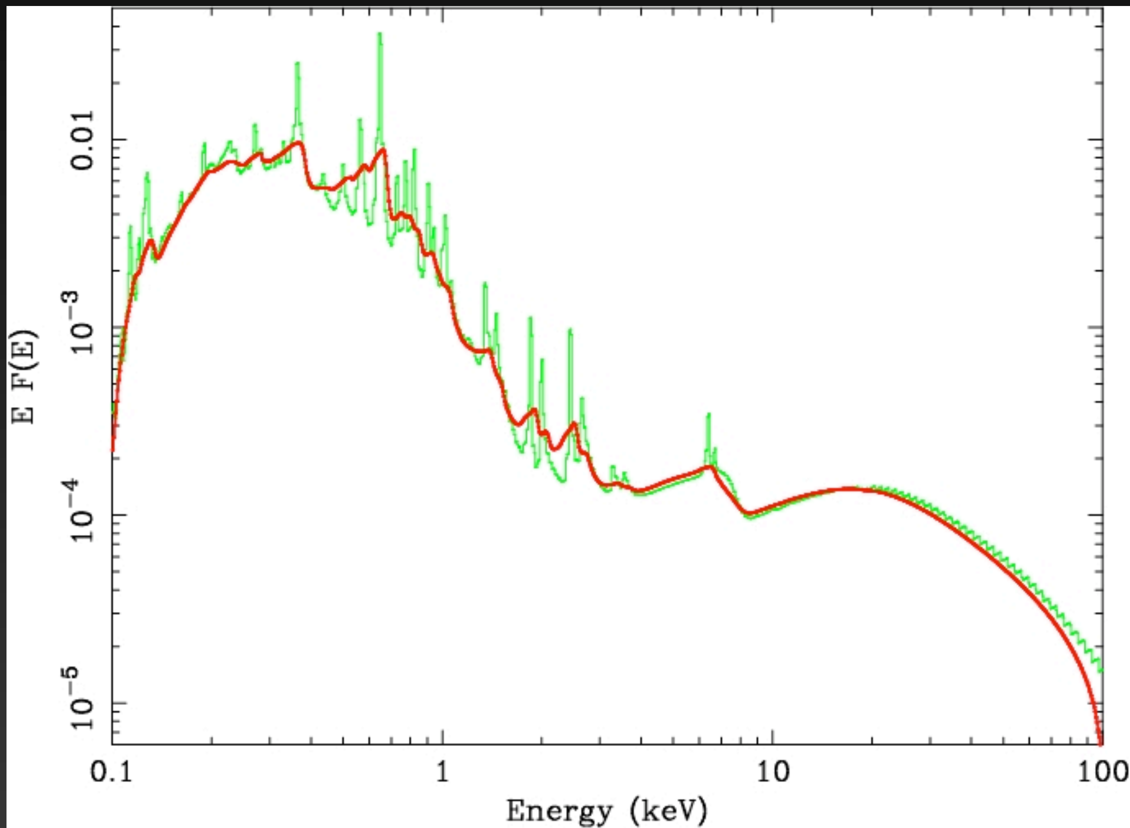


GM et al 09

CENTRO DE ASTROBIOLOGÍA

Swift J2127.4+5654 with Suzaku

We then used a ionized reflection model (Ross & ACF 05) to account for the whole broadband spectrum to get the spin



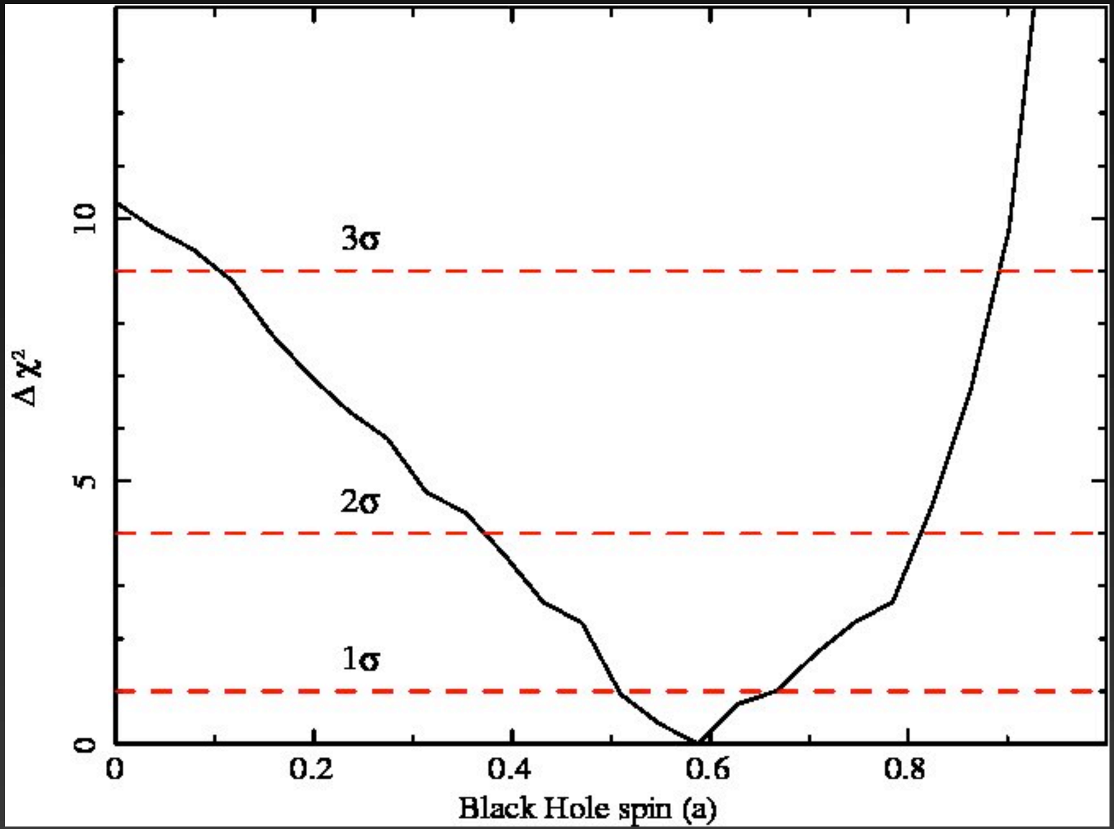
Ross & Fabian 05

Swift J2127.4+5654 with Suzaku

CENTRO DE ASTROBIOLOGÍA

The broadband analysis confirms results from Fe K diagnostics

a ~ 0 is excluded but just at the 3σ level
a ~ 0.998 is excluded at more than 5σ



GM et al 09

Swift J2127.4+5654 with Suzaku

BH accreting more than their own mass should be maximally spinning

this can then be excluded

a relatively recent major merger could result in an intermediate spin

a~0 cannot be excluded with very high significance

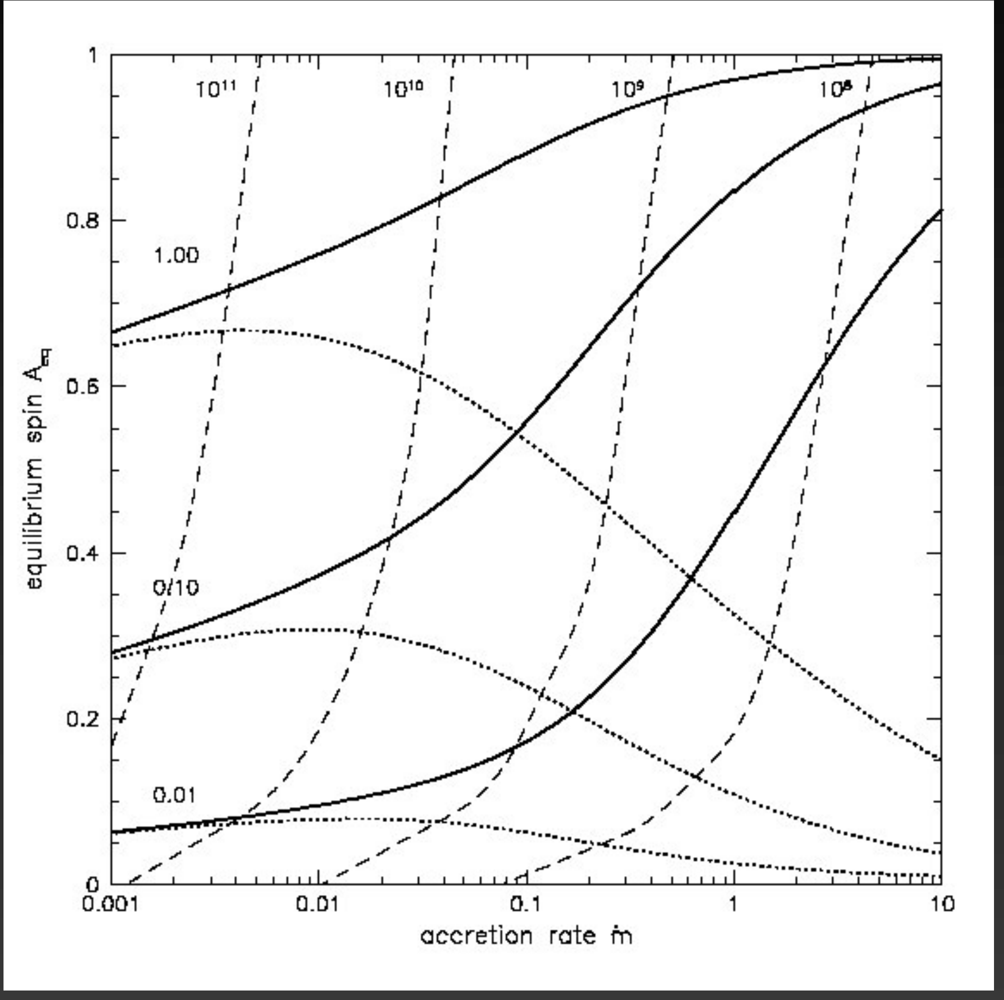
if we also consider that the spin may be 20% overestimated

it could be that BH growth proceeds here via chaotic accretion

a further possibility: magnetic extraction of rotational energy (BZ) ?

Swift J2127.4+5654 with Suzaku

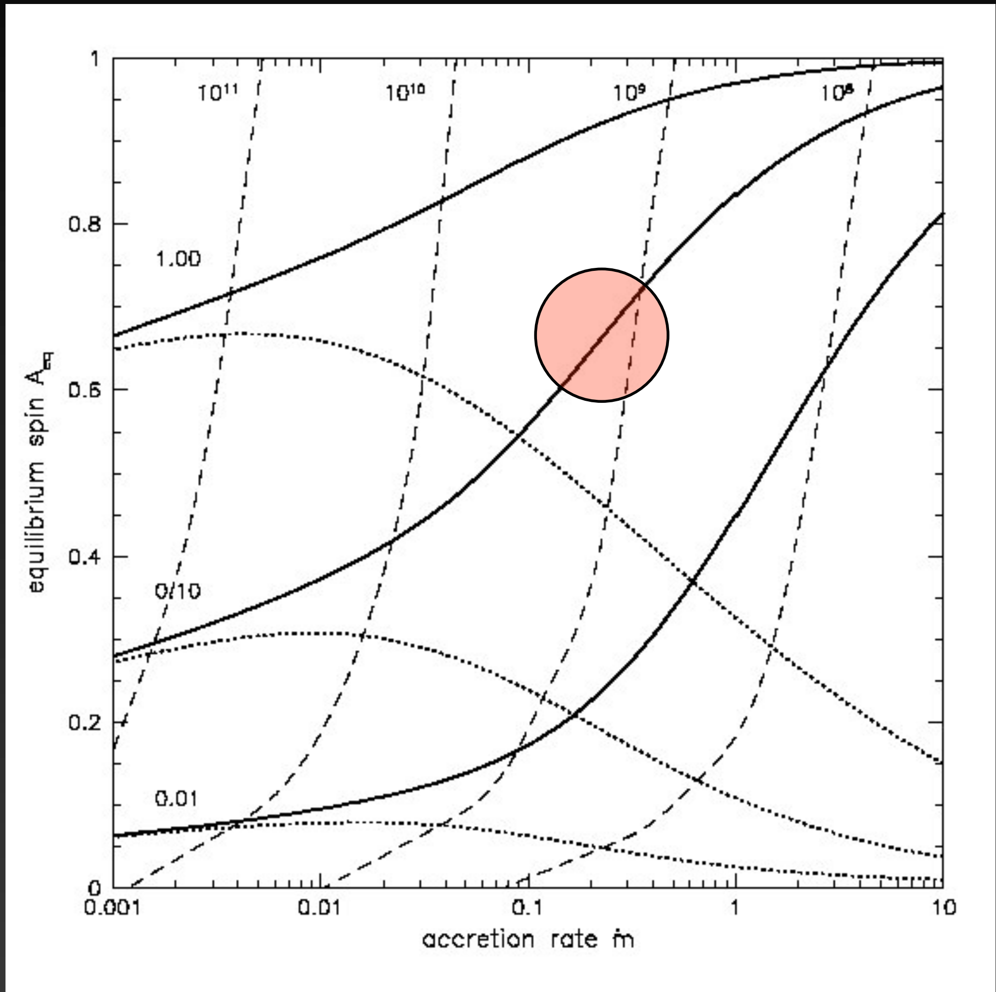
a further possibility: magnetic extraction of rotational energy (BZ) ?



Moderski, Sikora & Lasota 98

Swift J2127.4+5654 with Suzaku

a further possibility: magnetic extraction of rotational energy (BZ) ?



Indeed, if we consider a standard α ~0.1 disc coupled with the mass accretion rate of the object (~0.2) the system should reach an equilibrium value of a~0.5-0.6, not far from what we get

Moderski, Sikora & Lasota 98

Fairall 9 with Suzaku

Now a standard broad line Seyfert 1

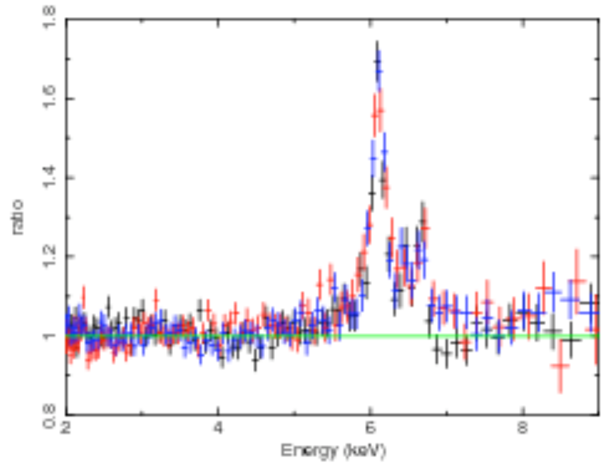
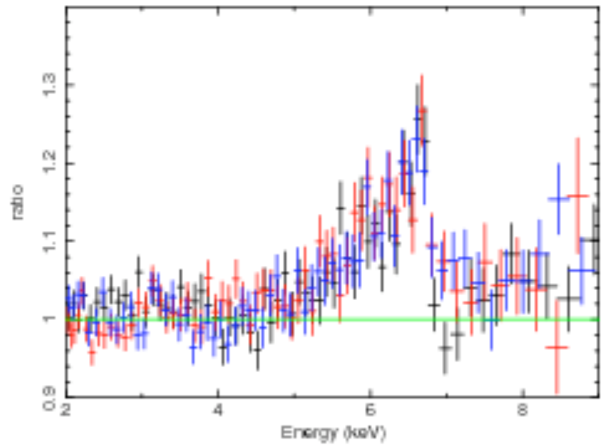


FIG. 2.— The plot above shows the data/model ratio in Fe K region that results from a simple power-law fit to the data. The narrow Gaussian peak near 6.1 keV (6.4 keV in the rest frame) is due to reflection from distant gas. A broad diskline component is also clearly present. The XIS0, XIS1, and XIS3 spectra are shown in black, red, and blue, respectively.



Schmoll et al 09

Fairall 9 with Suzaku

Now a standard broad line Seyfert 1

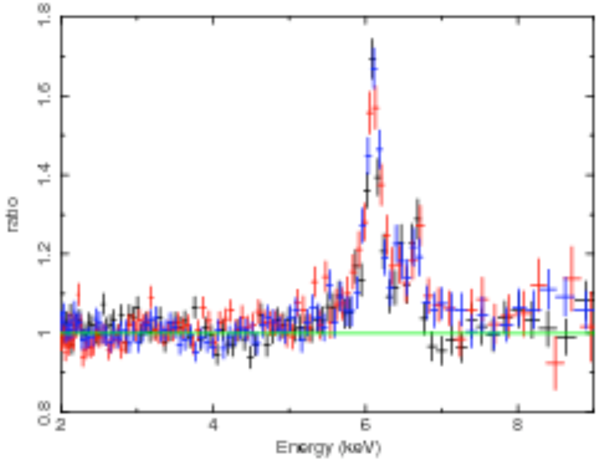
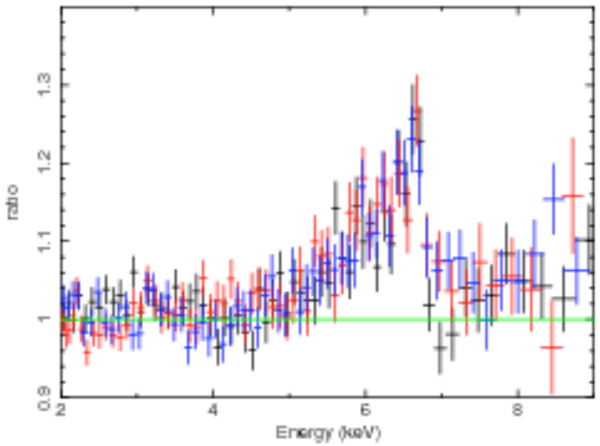
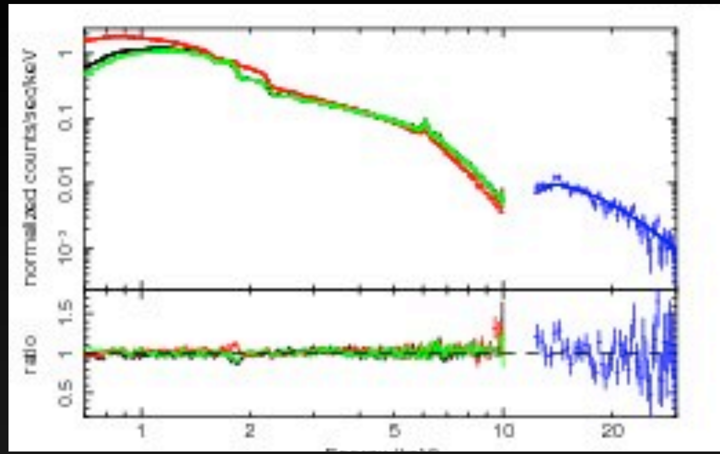
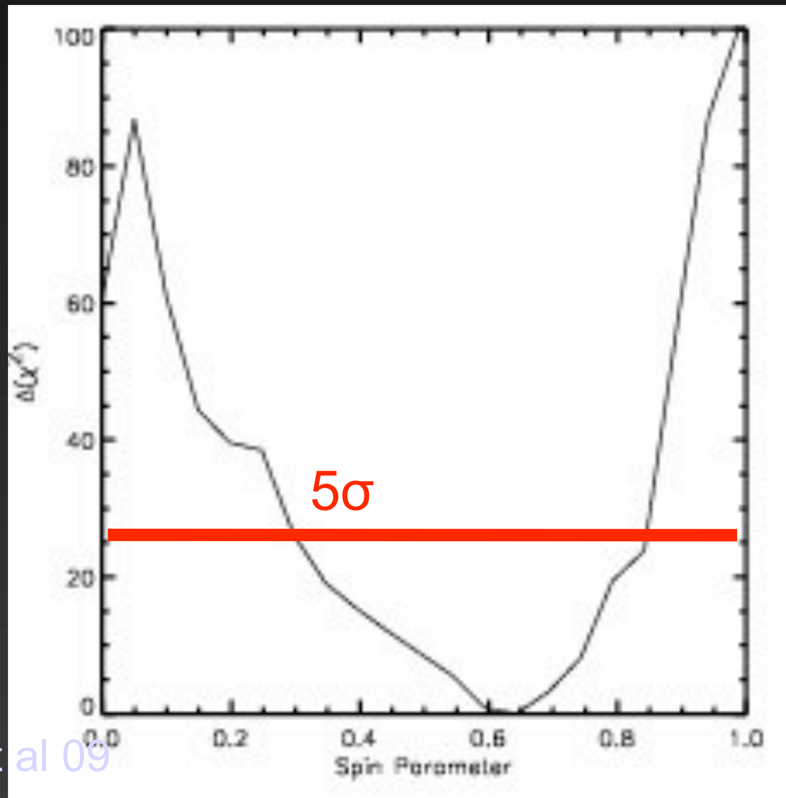


FIG. 2.— The plot above shows the data/model ratio in Fe K region that results from a simple power-law fit to the data. The narrow Gaussian peak near 6.1 keV (6.4 keV in the rest frame) is due to reflection from distant gas. A broad diskline component is also clearly present. The XIS0, XIS1, and XIS3 spectra are shown in black, red, and blue, respectively.



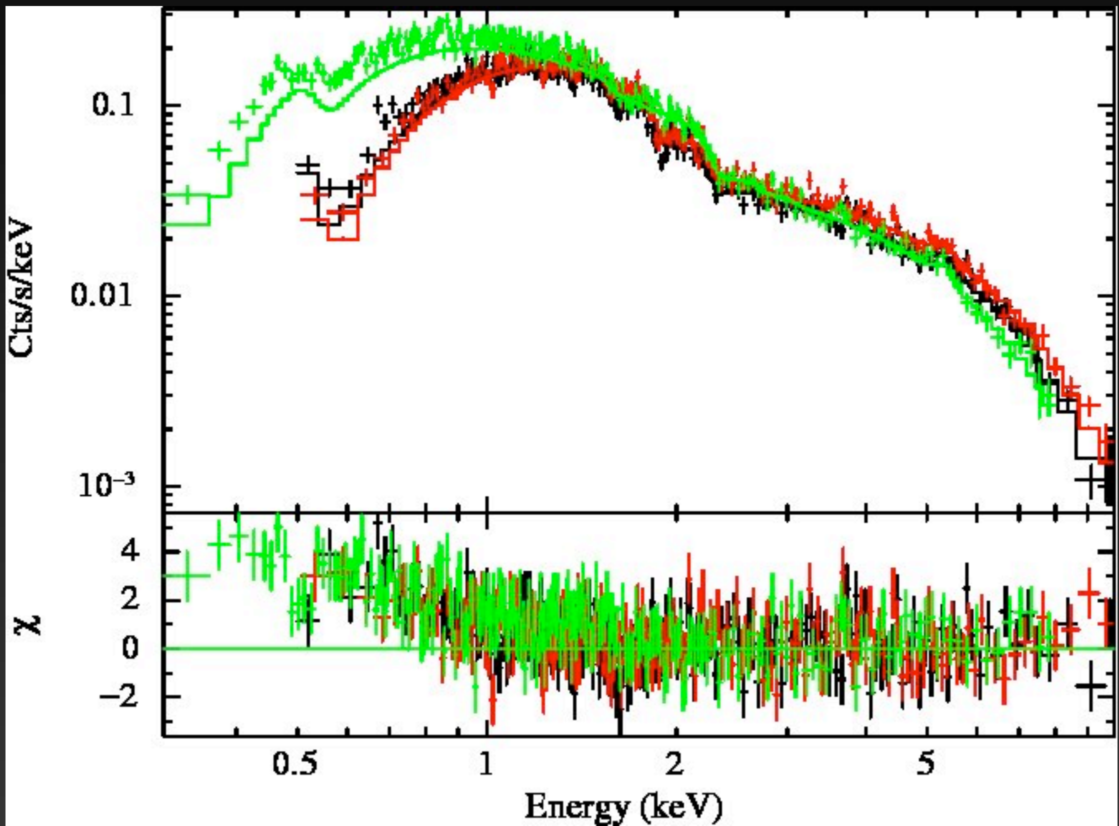


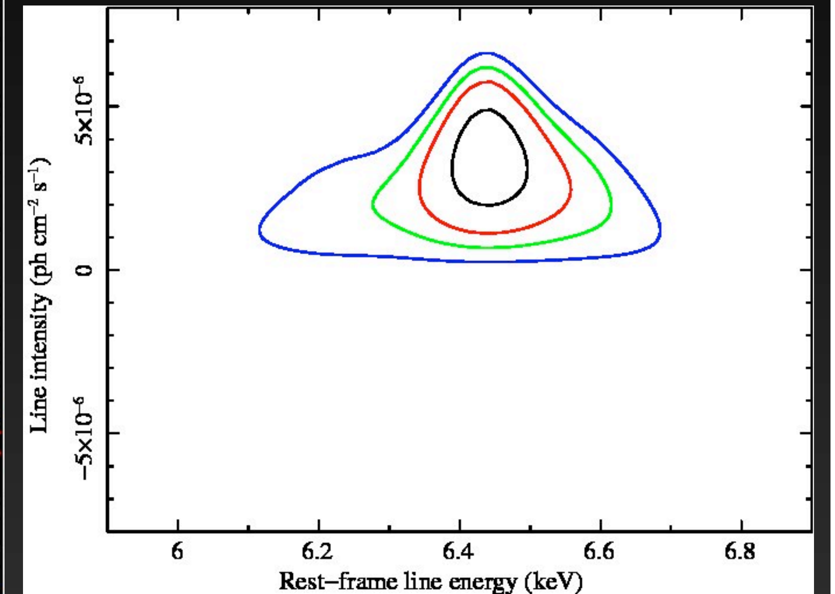


Schmoll et al 09

BH spin from soft excess: RBS 1124

Now a broad line luminous QSO (L / L_{edd} ~ 1 from x-rays)



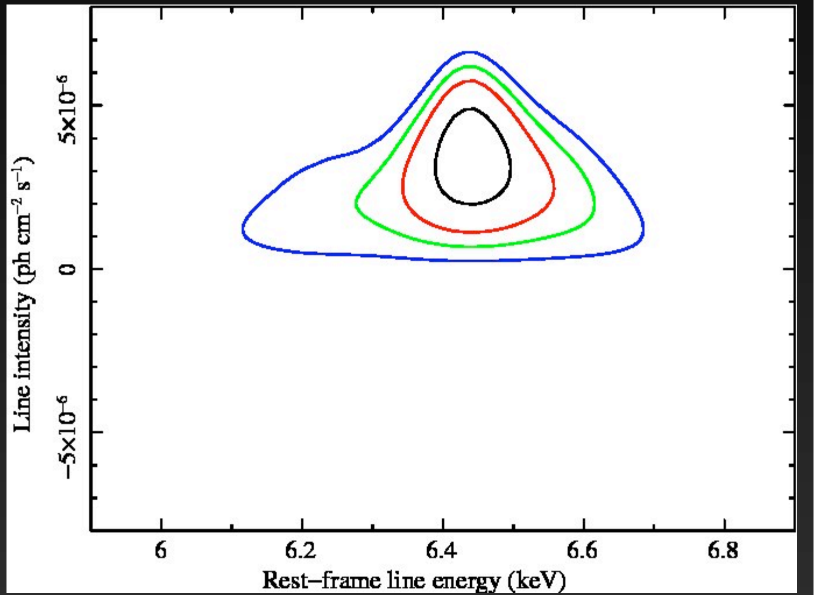


GM et al 10

BH spin from soft excess: RBS 1124

As far as the weak Fe K line is concerned, no need for reflection from within ~ 100 R_g

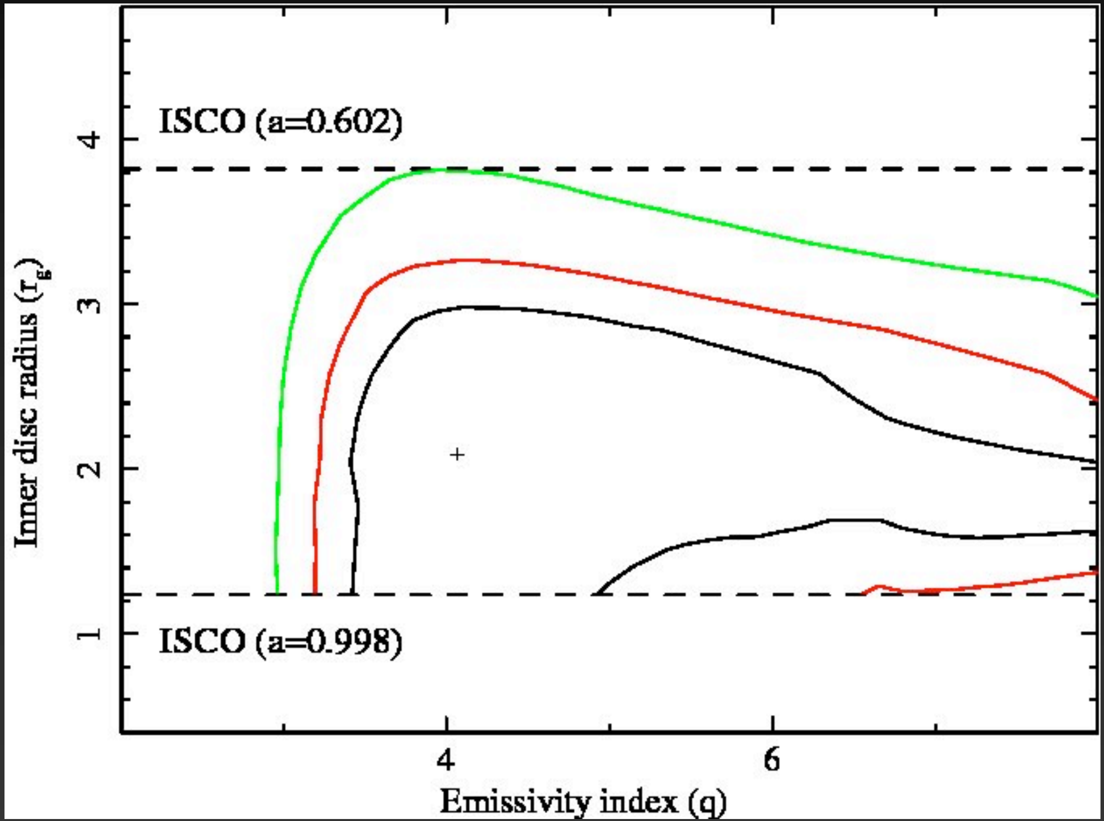
But what about the soft excess ?

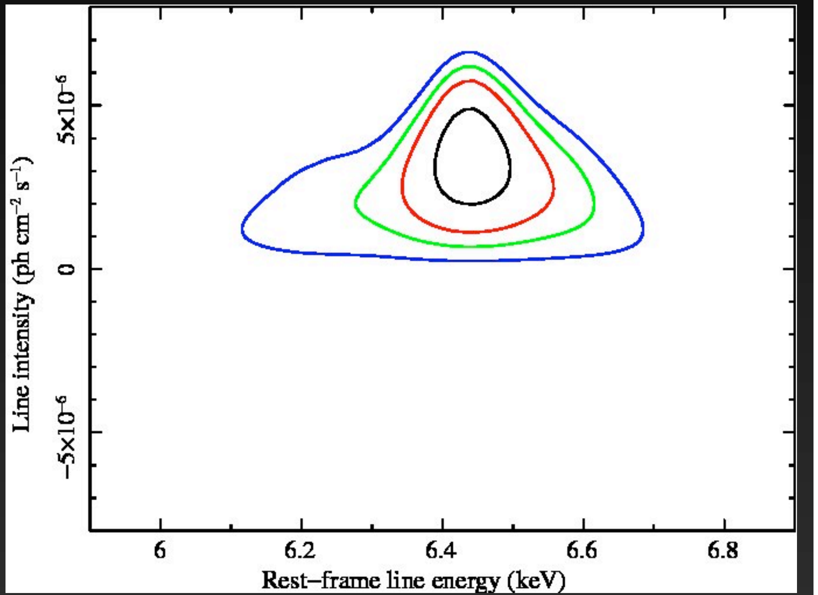


BH spin from soft excess: RBS 1124

As far as the weak Fe K line is concerned, no need for reflection from within ~ 100 R_g

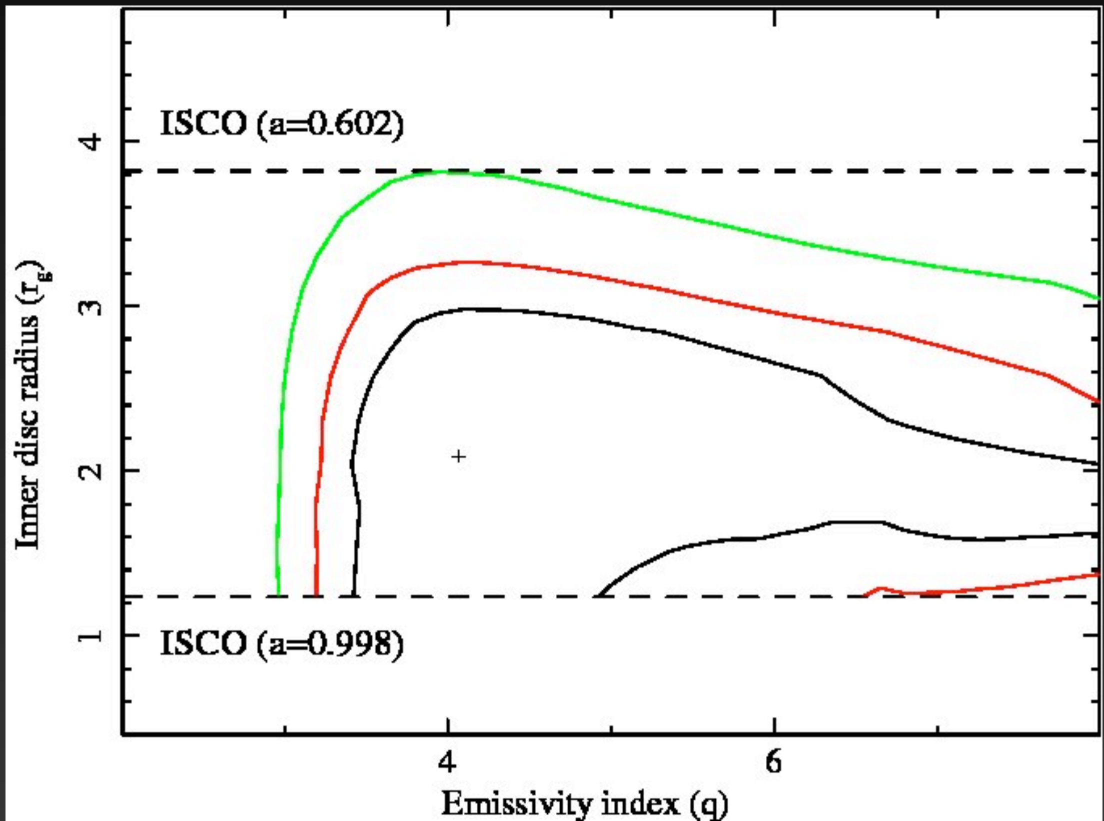
But what about the soft excess ?

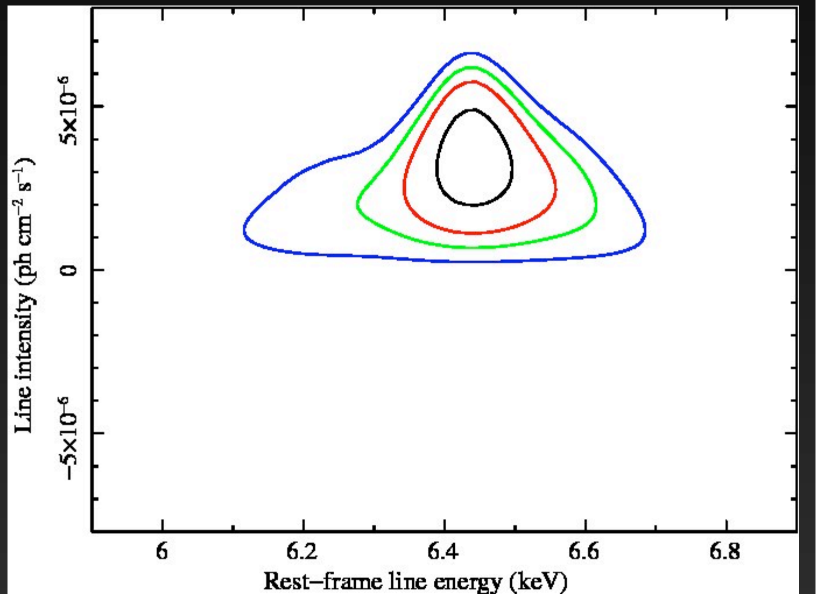




BH spin from soft excess: RBS 1124

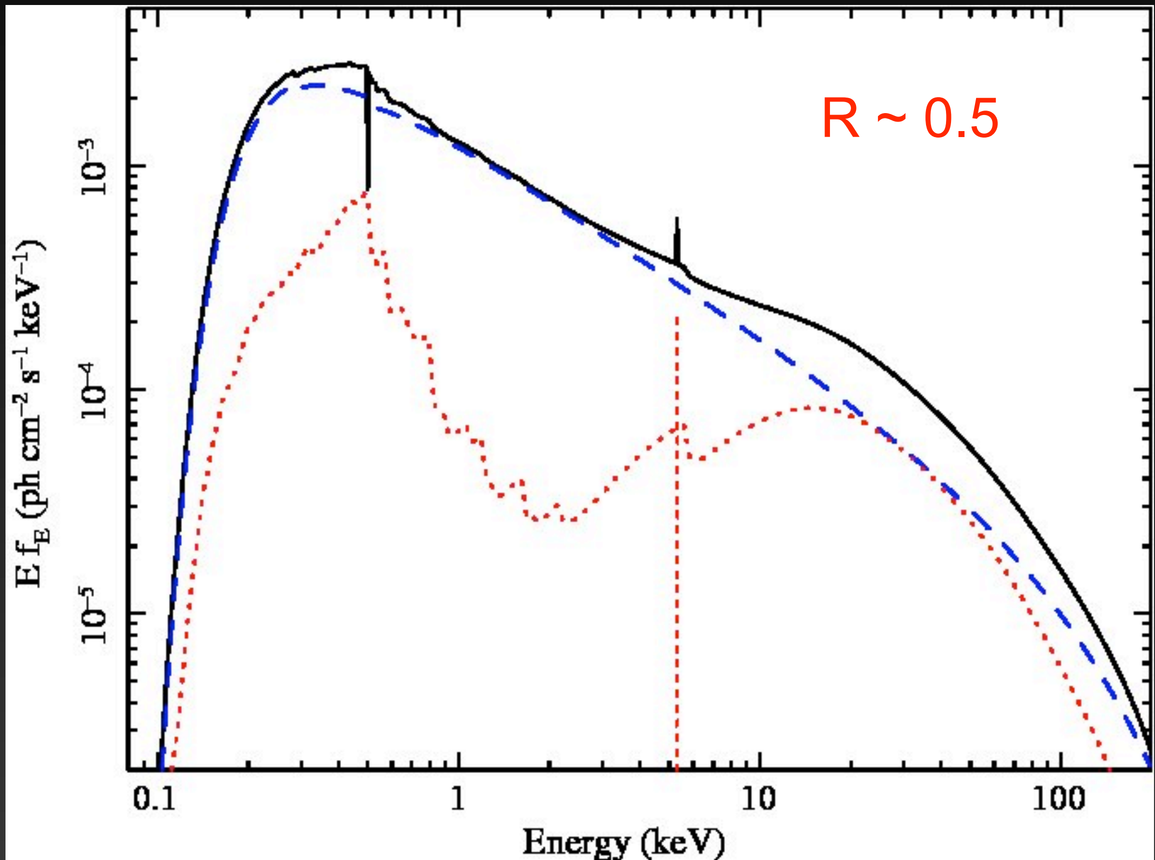
Soft excess and Fe K are consistent, but still… how can it be ?
Remember, the soft excess is weak in this object -> low R ? If so, the Fe K we are able to detect is just the blue peak, red wing buried in continuum





BH spin from soft excess: RBS 1124

Not surprisingly, this is what we get from the modeling (R~ 0.5)
Moreover L/L_{edd} ~ 0.7 (very efficient, disc should be at the ISCO)

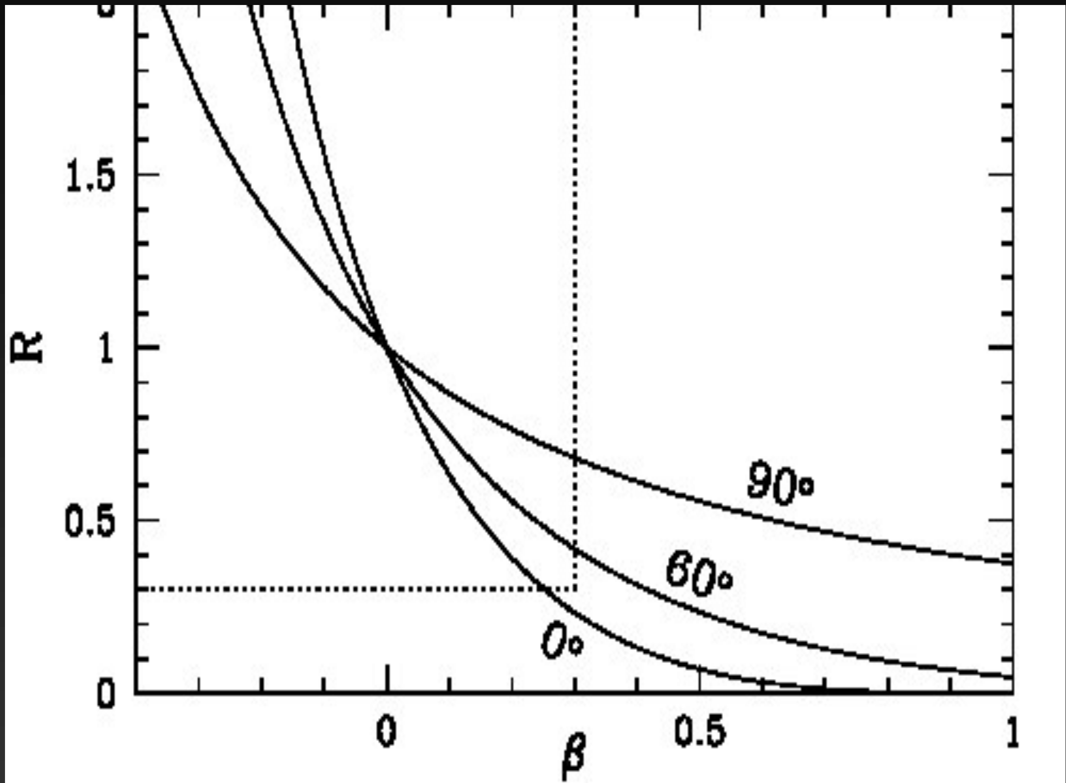


So, the right question to ask could be:

why such a low R ?

BH spin from soft excess: RBS 1124

The most natural answer (to me) is mild X-ray beaming



Beloborodov 99

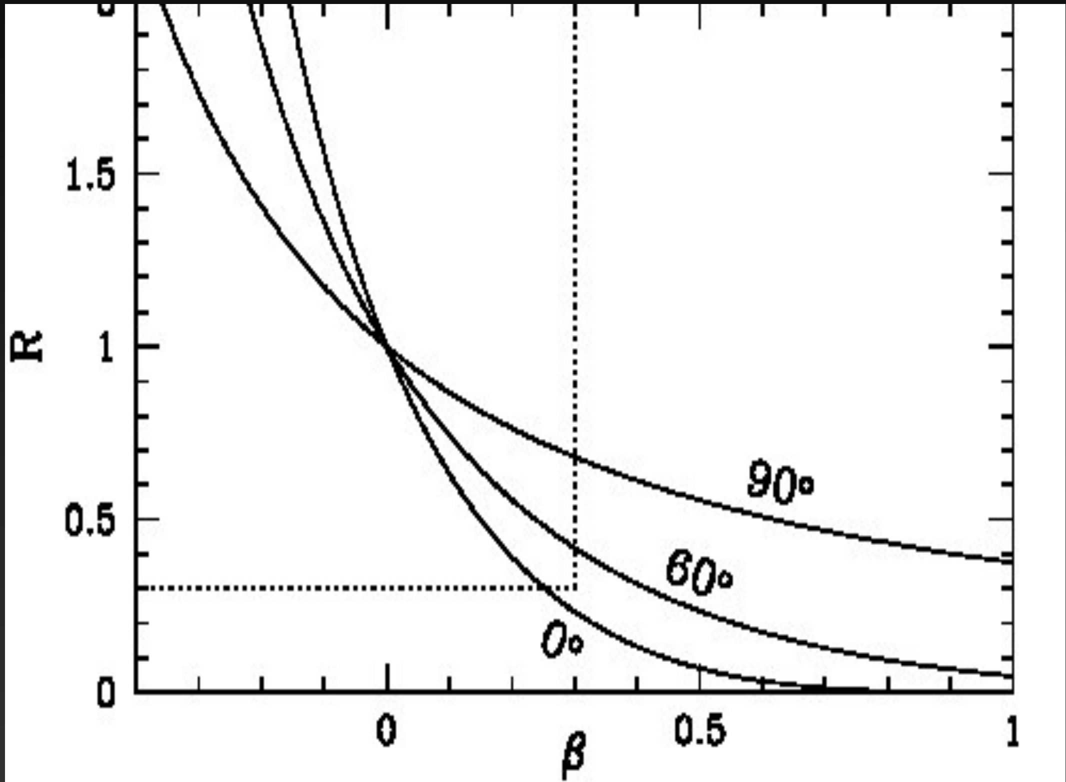
Moreover this would reduce the intrinsic X-ray luminosity by a factor

$[\ \gamma\ (1-\beta\ \cos i)\ ]^{-3} \sim 0.5$

leading to a more reasonable Eddington ratio ~0.4, more consistent with optical luminosity

BH spin from soft excess: RBS 1124

The most natural answer (to me) is mild X-ray beaming



Beloborodov 99

Moreover this would reduce the intrinsic X-ray luminosity by a factor
$[\gamma (1-\beta \cos i)]^{-3} \sim 0.5$

leading to a more reasonable Eddington ratio ~0.4, more consistent with optical luminosity

Thanks !!