Active Galactic Nuclei

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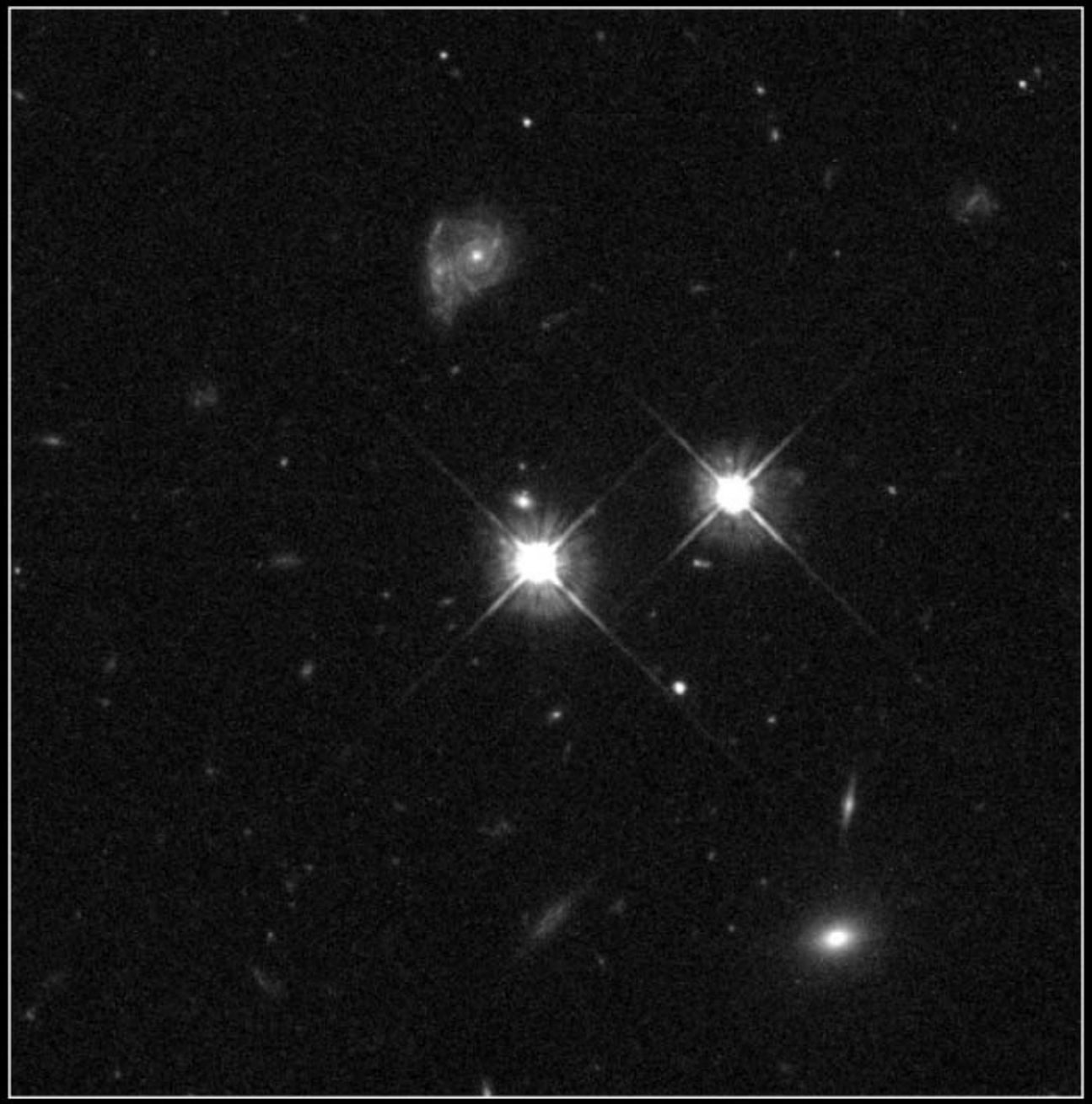
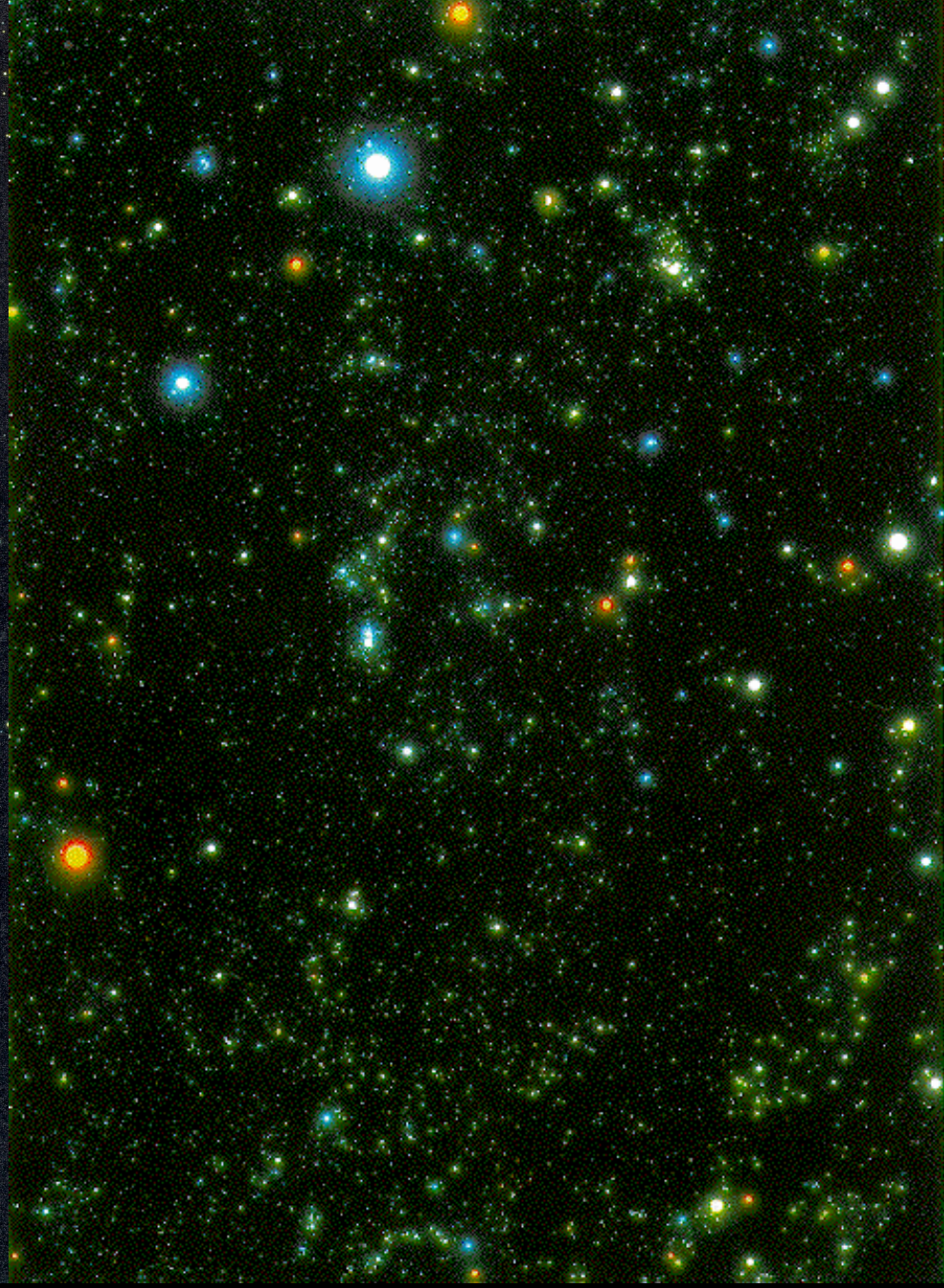


HST's 100,000th Observation HST • WFPC2

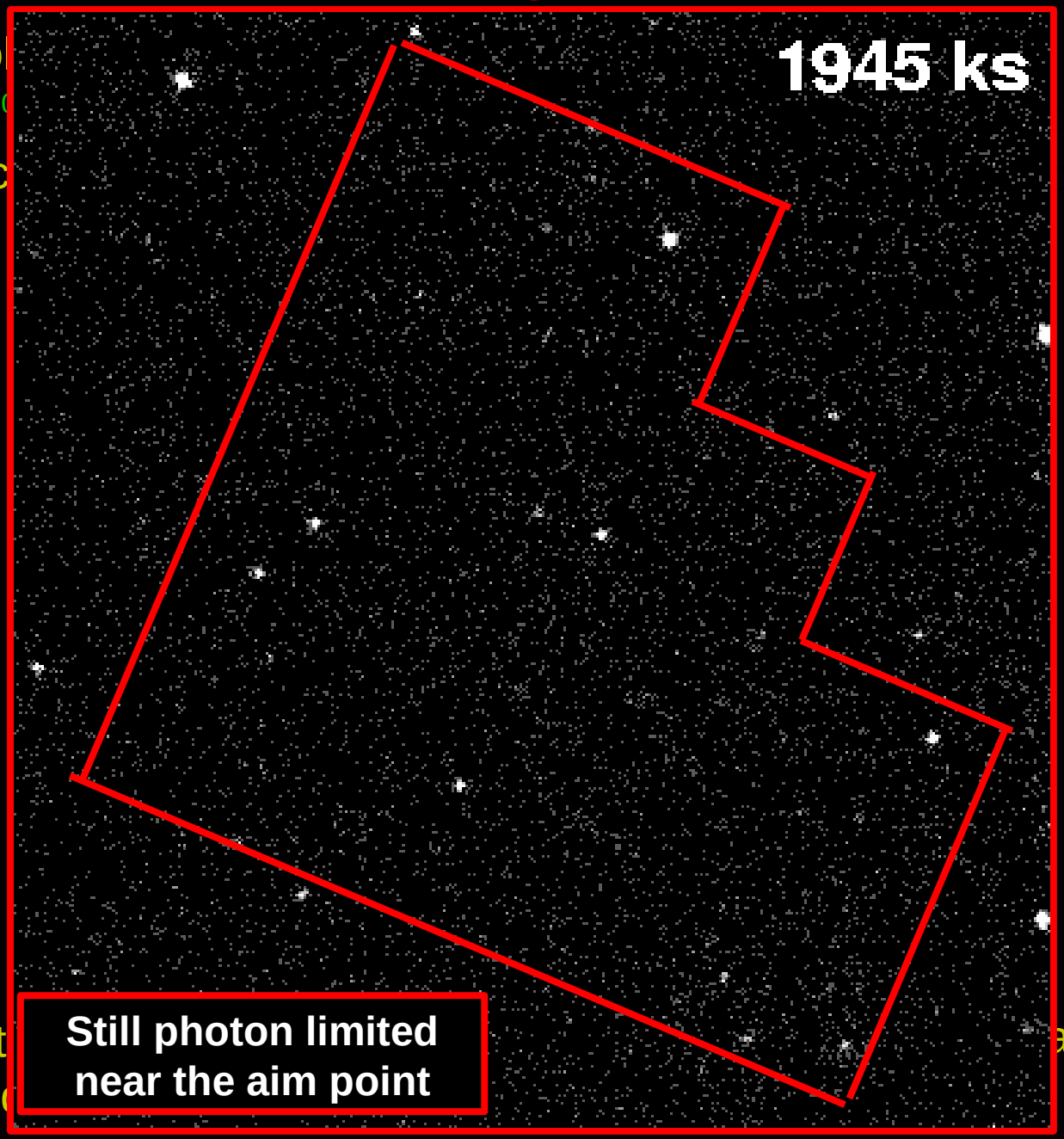
PRC96-25 · ST ScI OPO · July 10, 1996 · C. Steidel (CalTech), NASA



“True” col

0.5-2.0 keV 2.0-4.0

(447 arc



Still photon limited near the aim point

503 point ations

6 extende months

Active Galactic Nuclei

L. C. Ho

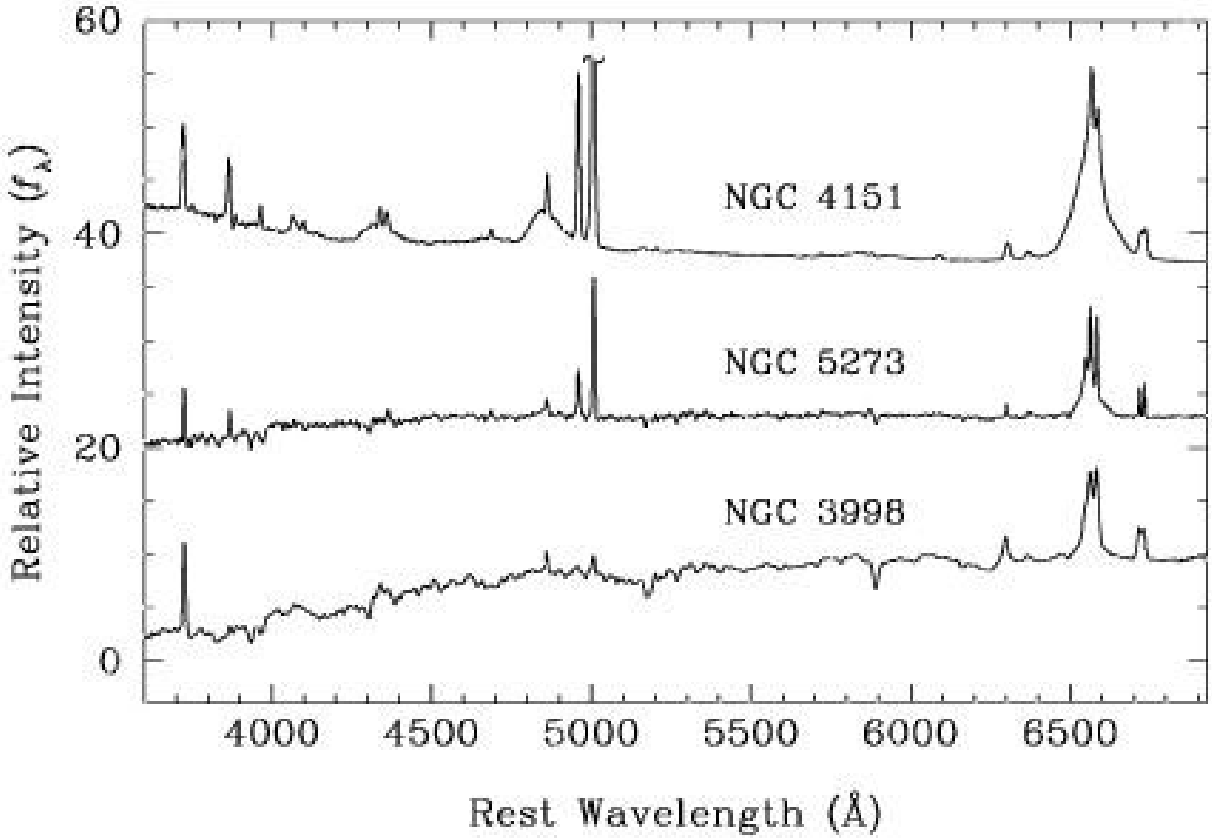
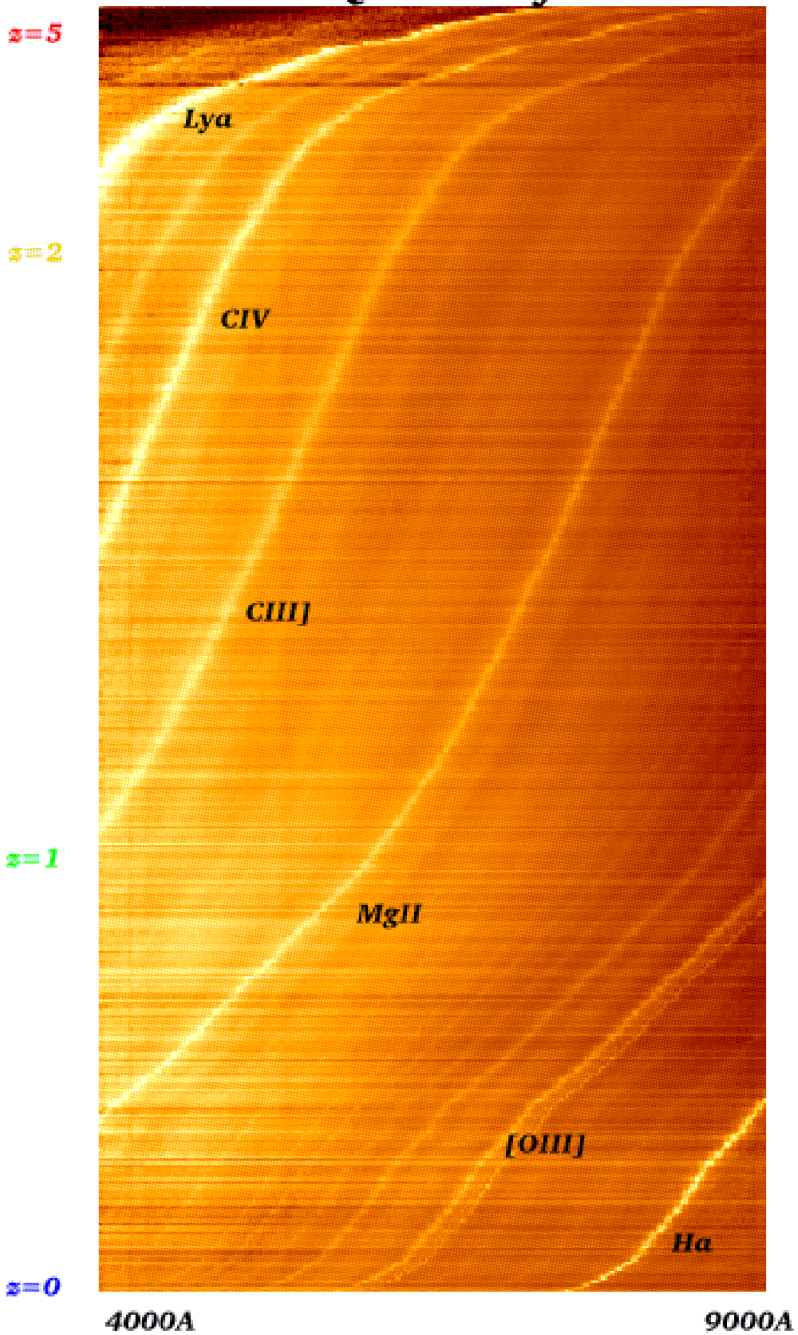


Fig. 1.2. Sample optical spectra of broad-line AGNs. NGC 4151 = "classical" Seyfert 1; NGC 5273 = typical low-luminosity Seyfert 1; NGC 3998 = LINER 1. (Based on Ho et al. 1993a and unpublished data.)

First 8000 Quasars from SDSS



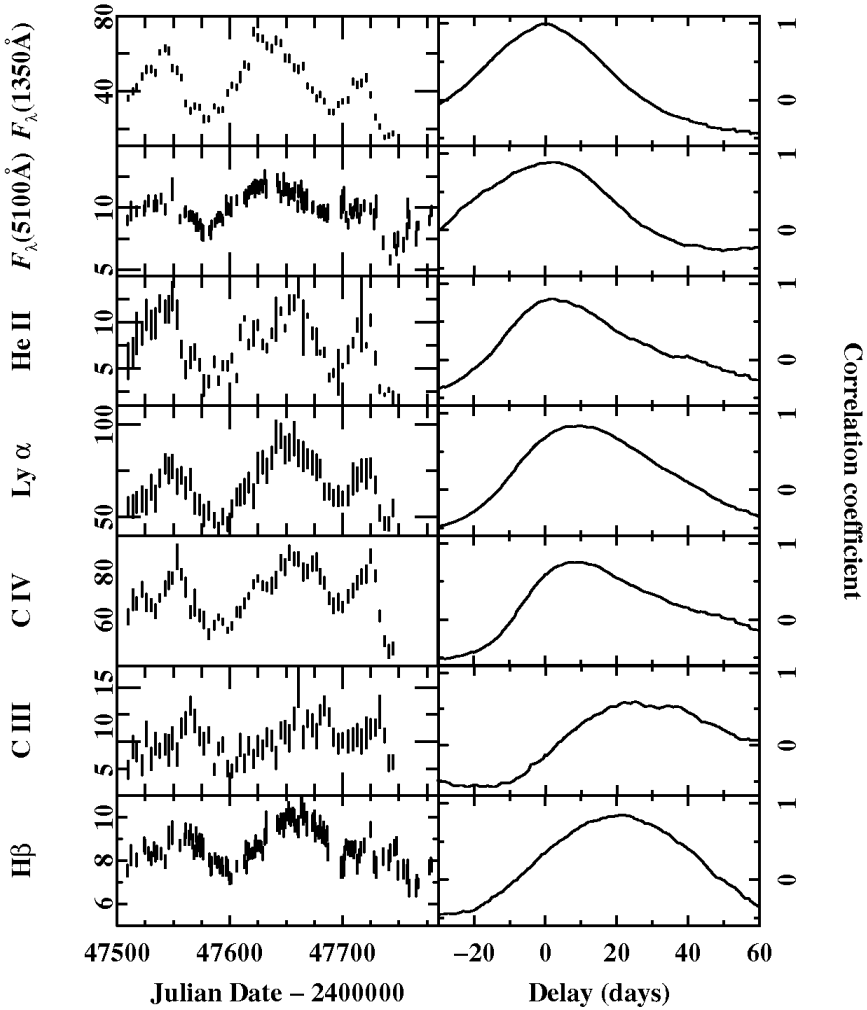


Figure 31. Light curves (left-hand column) and CCFs (right-hand column) for NGC 5548, from the first International AGN Watch monitoring project in 1988–89. From the top, the light curves are the UV continuum at 1350 Å, the optical continuum at 5100 Å, He II λ1640, Lyα λ1215, C IV λ1549, C III] λ1909, and Hβ λ4861. The continuum fluxes are in units of 10^{-15} ergs s^{-1} cm^{-2} Å^{-1}, and the line fluxes are in units of 10^{-13} ergs s^{-1} cm^{-2}. The CCFs are computed relative to the UV continuum at the top; the top panel is the UV continuum ACF. Data from Clavel et al.[14] and Peterson et al.[67].

Measuring masses

Gravitational constant

Mass

$$v^2 = \frac{GM}{r}$$

Velocity

radius

For circular motion; twice this for escape velocity

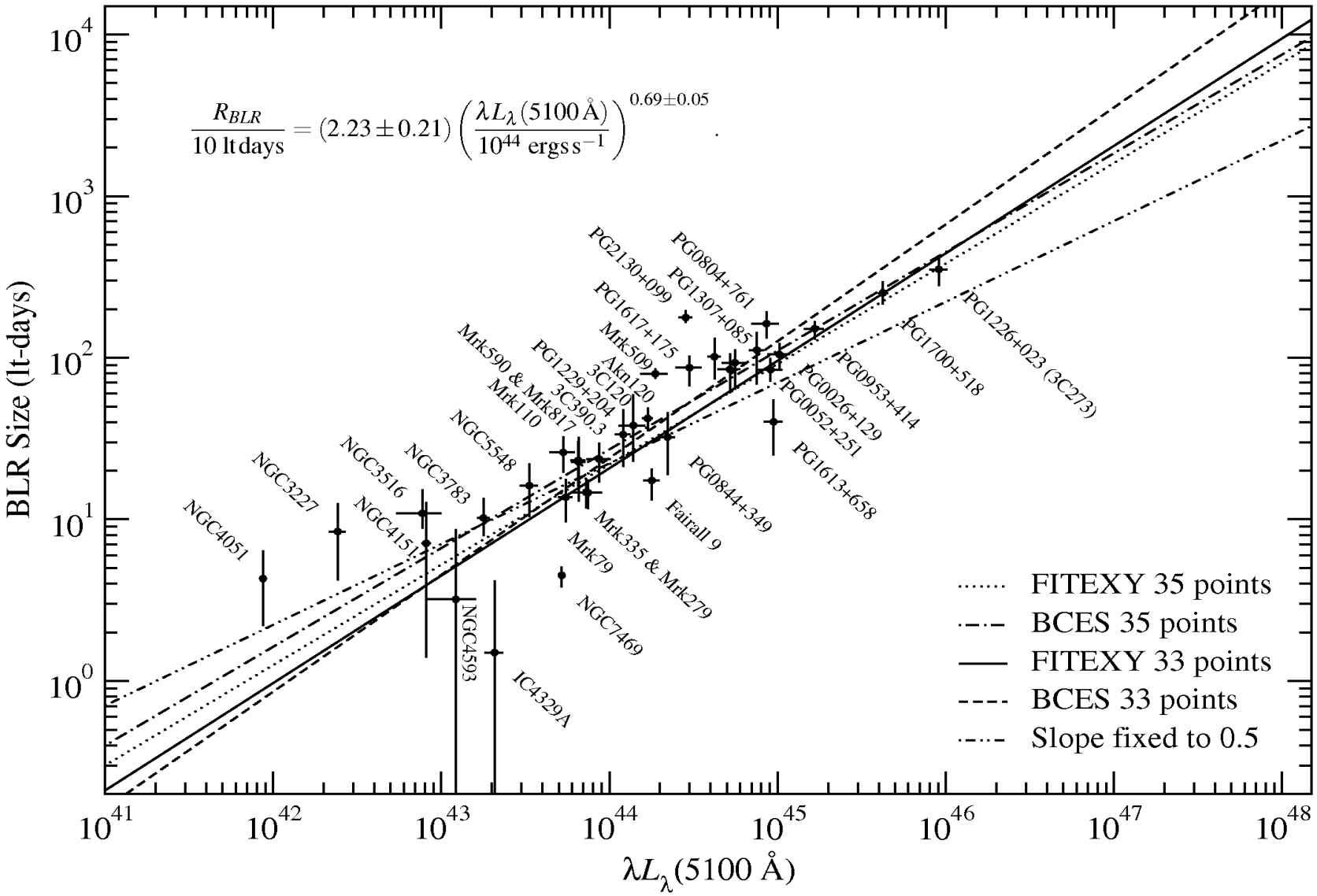
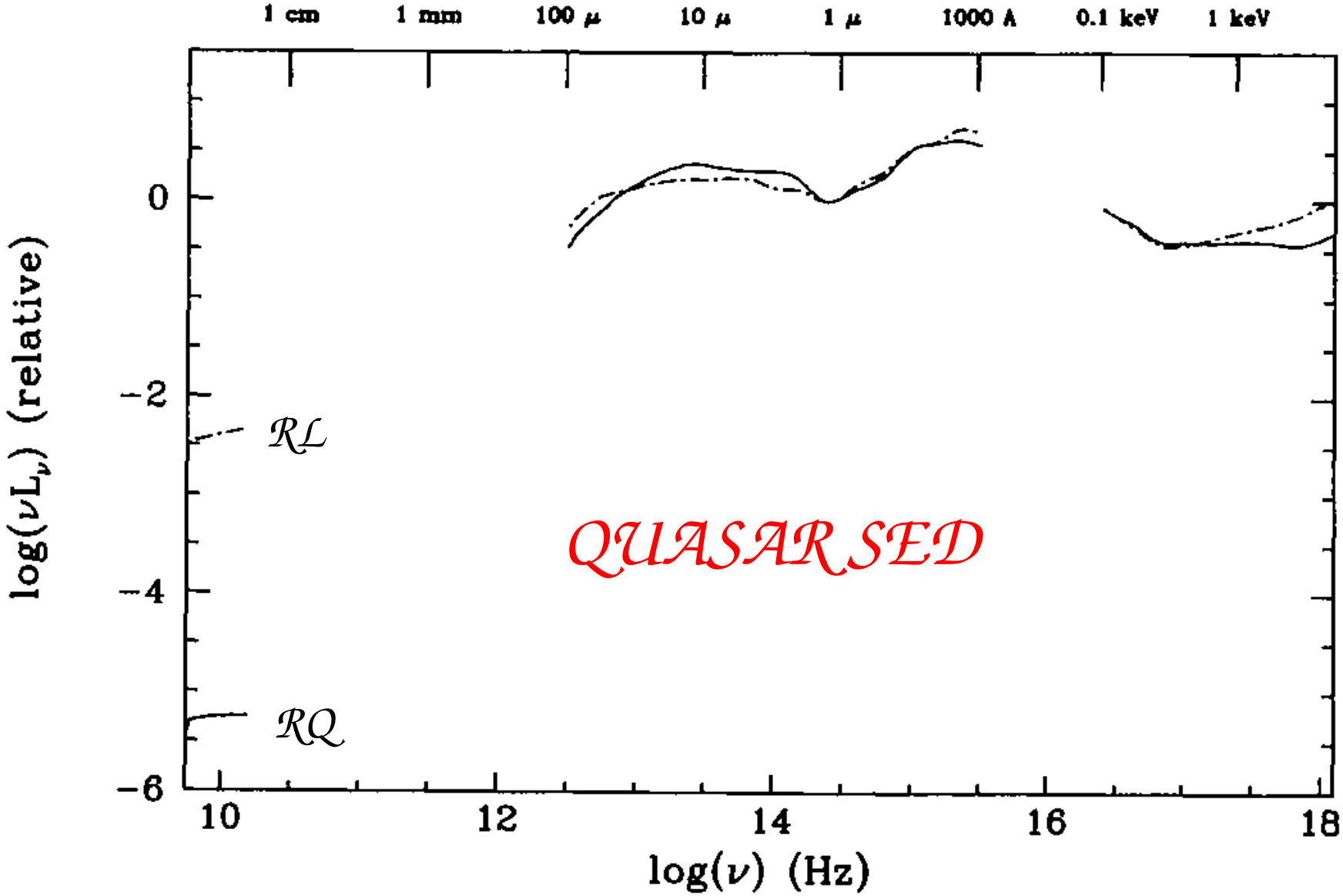
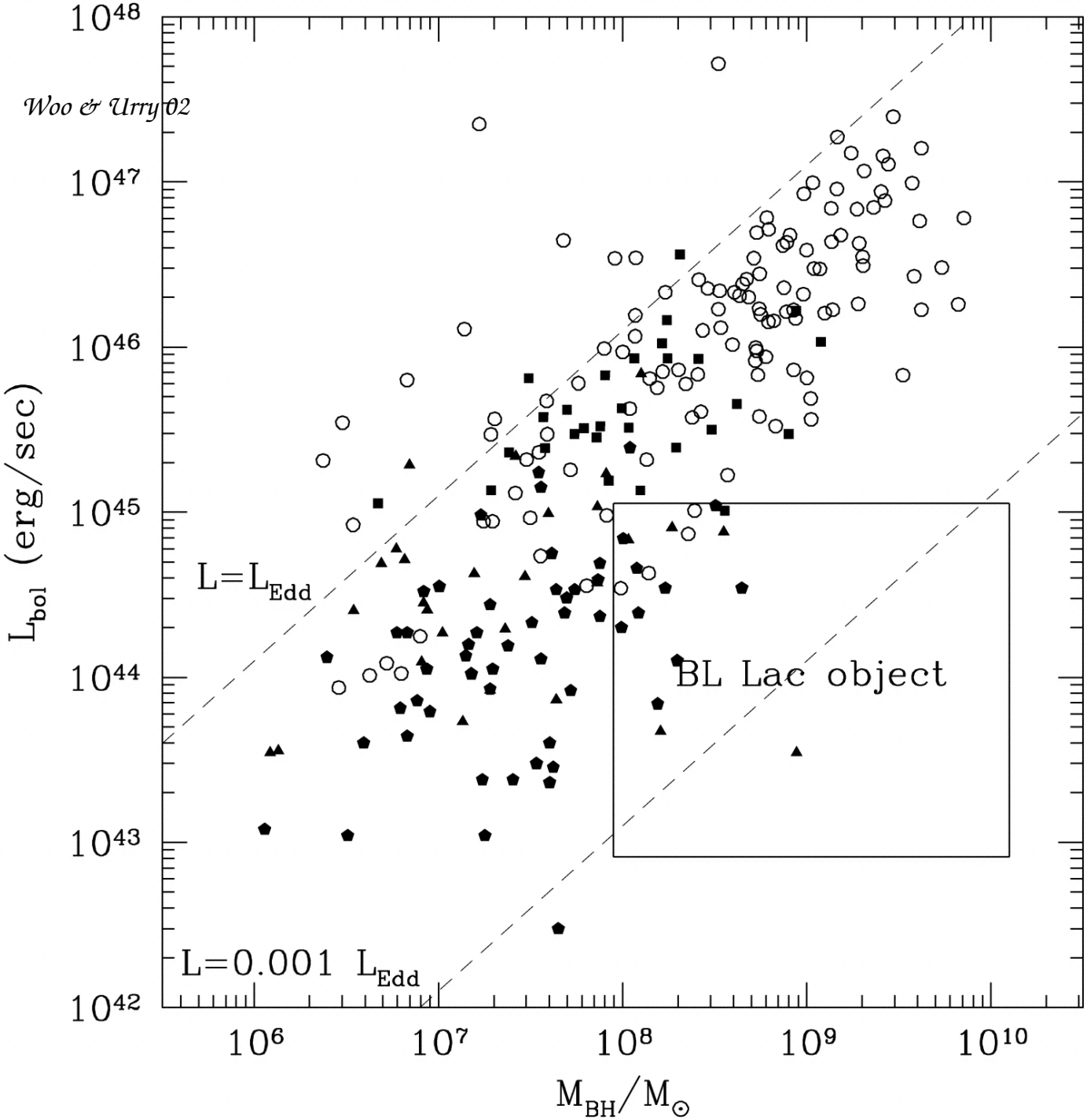


FIG. 2.— Balmer-line averaged BLR size plotted versus the λL_λ(5100 Å) luminosity (in units of ergs s^{-1}) on a larger scale. The BLR size of each data set is determined from the averaged Balmer-line time lags. Objects with multiple data sets have been averaged to one point per object. Five line fits are shown: dotted line - FITEXY using all 35 points; dot-dashed line - BCES using all 35 points; solid line - FITEXY excluding the 2 lower luminosity points; dashed line - BCES excluding the 2 lower luminosity points; dot-dot-dashed line - FITEXY excluding the 2 lower luminosity points and fixing the slope to 0.5.



Elvis+04

Norm at 1.2mu

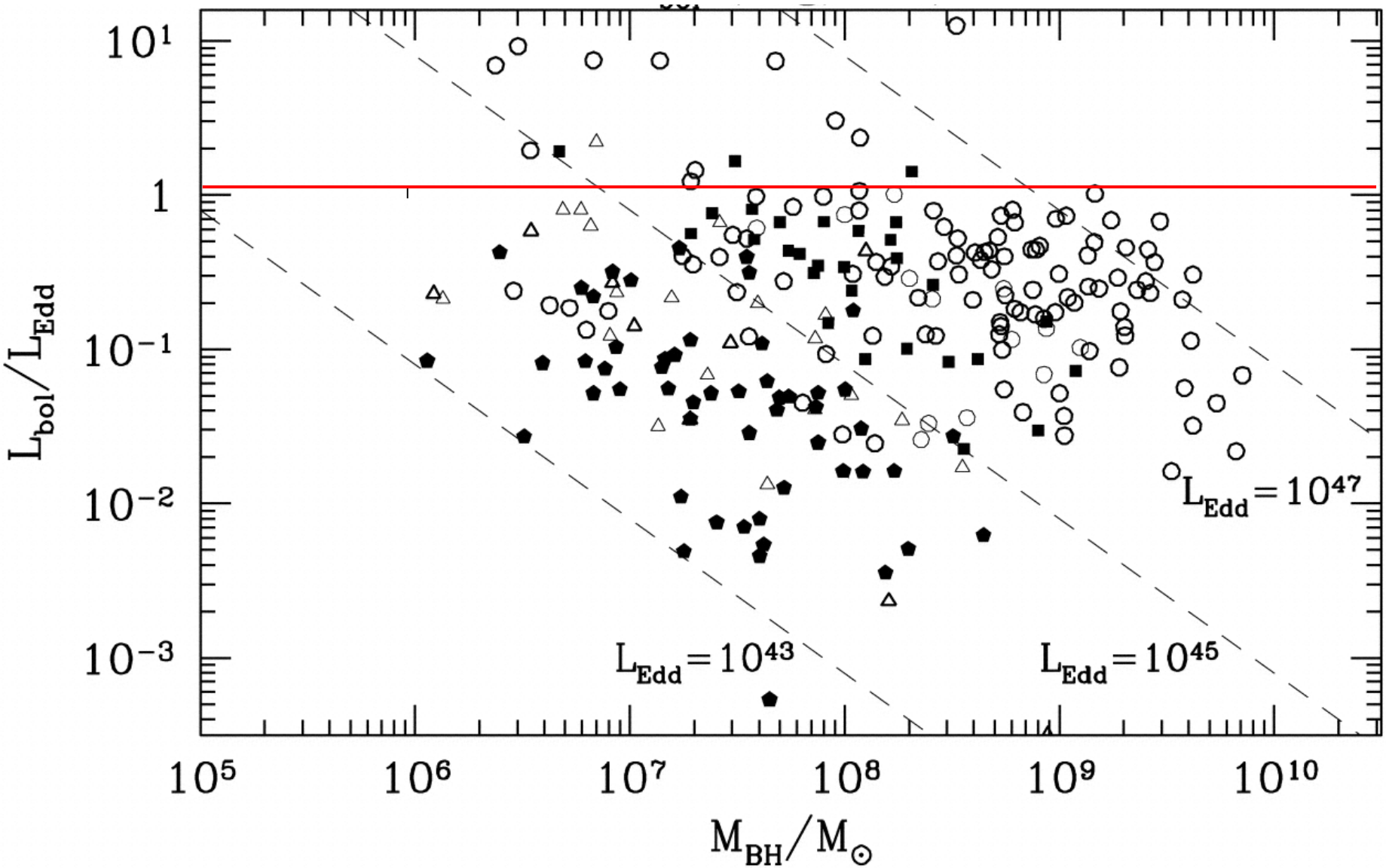

Woo & Urry 02
10^{48}
10^{47}
10^{46}
10^{45}
10^{44}
10^{43}
10^{42}
L_{bol} (erg/sec)
$L=L_{Edd}$
BL Lac object
$L=0.001\ L_{Edd}$
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
$M_{BH}/M_{\odot}$

The Eddington Limit

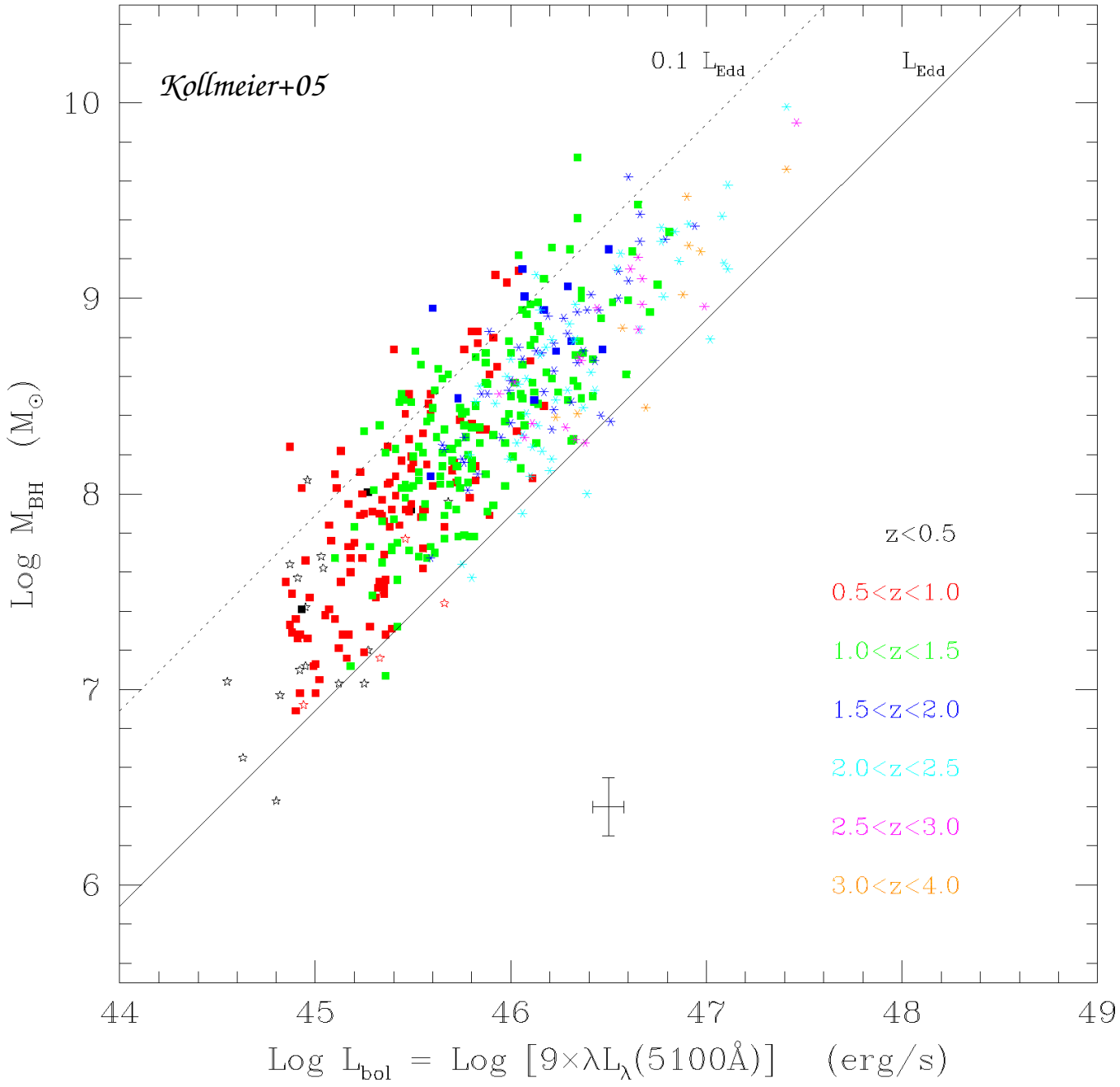
- *When outward radiation pressure on ionized electron balanced by inward grav force on proton*

$$\frac{L}{4\pi r^2 h\upsilon}\frac{h\upsilon}{c}\sigma_T = \frac{GMm_p}{r^2}$$

$$L_{Edd} = \frac{4\pi GMm_p c}{\sigma_T} \approx 10^{38} erg/s/M_o$$

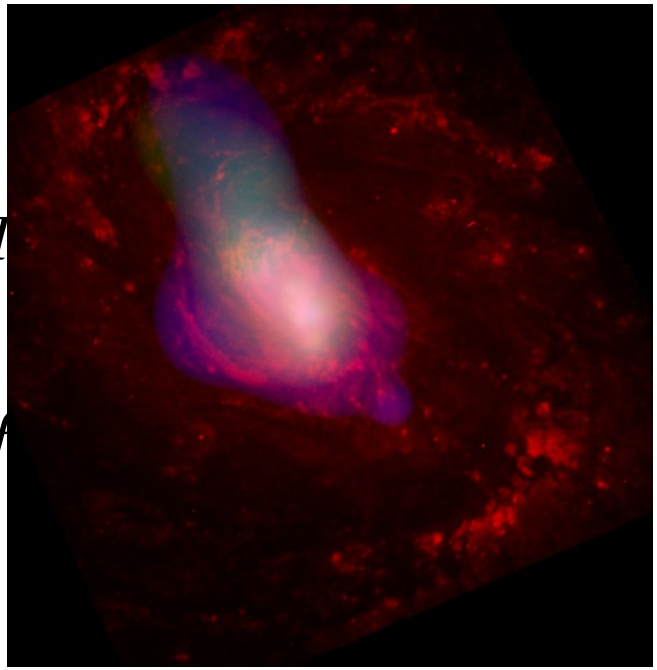


Quasars, from Woo & Urry 02


Kollmeier+05
0.1 L_Edd
L_Edd
z<0.5
0.5<z<1.0
1.0<z<1.5
1.5<z<2.0
2.0<z<2.5
2.5<z<3.0
3.0<z<4.0
Log M_BH (M_⊙)
Log L_bol = Log [9×λL_λ(5100Å)] (erg/s)
10
9
8
7
6
44
45
46
47
48
49

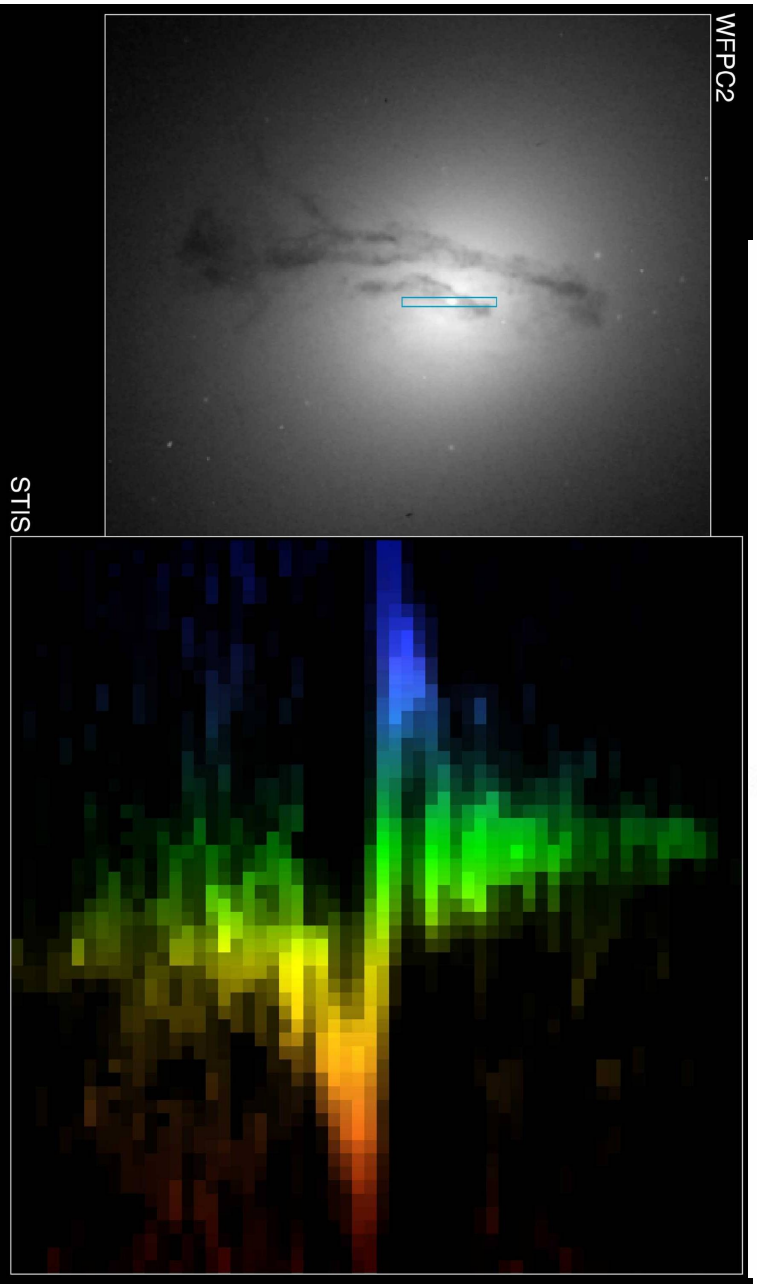
Types of AGN

- Most (90%) are radio-quiet
- Divided into unobscured ($N_H<10^{22}$) – Type I objects and obscured – Type II
- Obscured objects may outnumber unobscured ones 5:1 at low z (some of obscuration is a torus, but most is probably messy)
- Fraction of Type II quasars is an ongoing quest

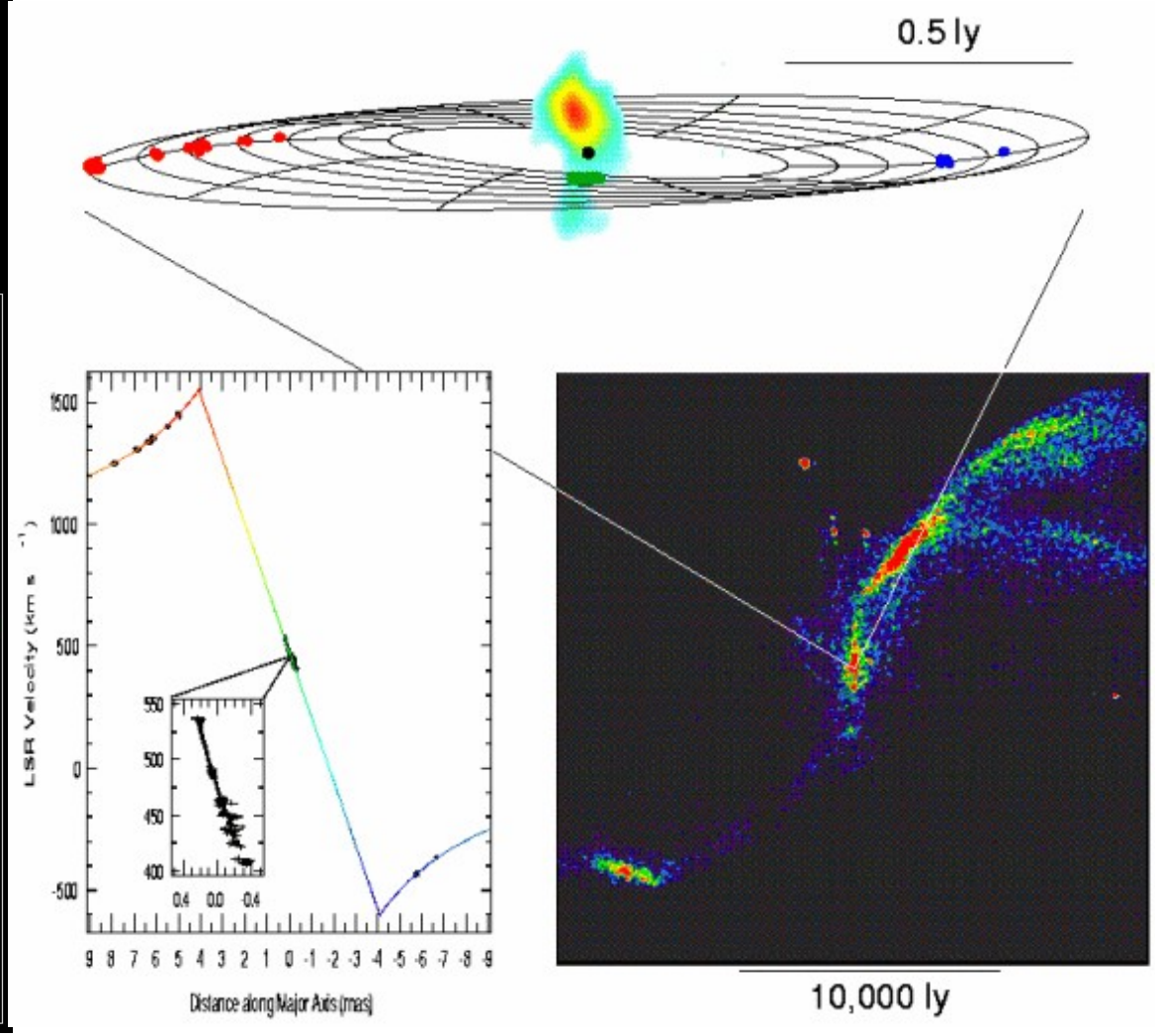


NGC1068

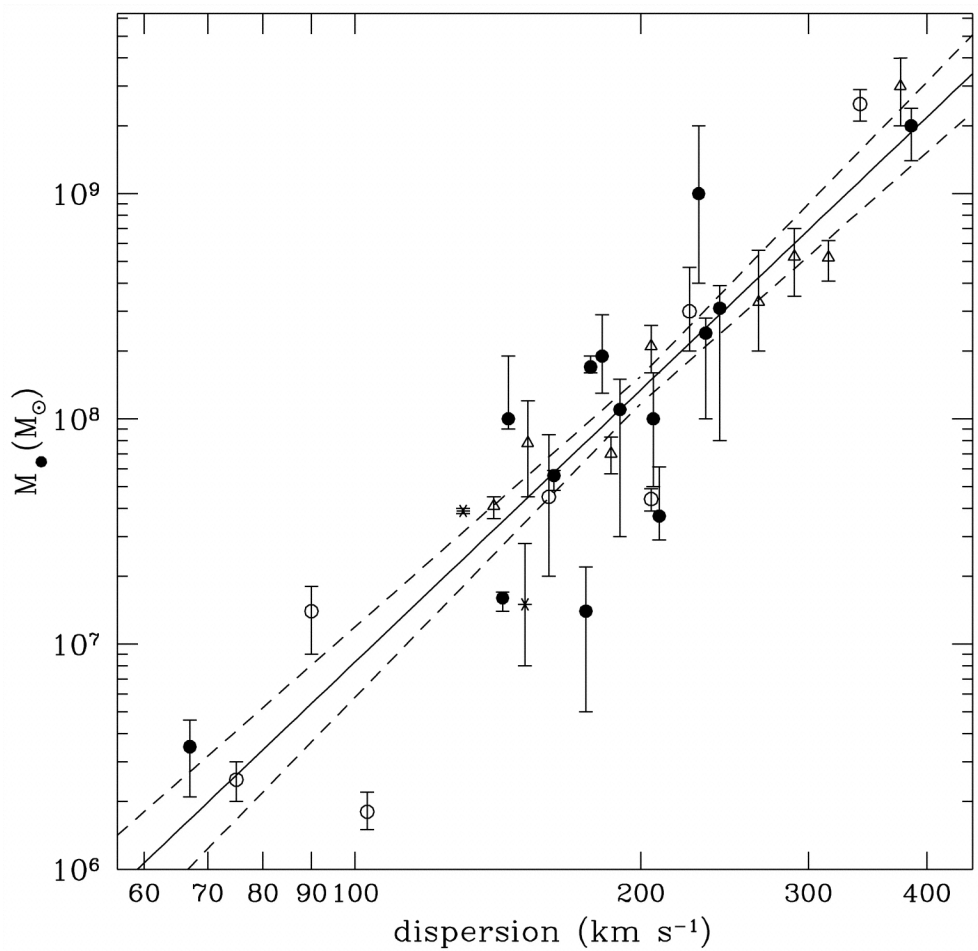
M84 HST



M106 Miyoshi et al 1995



Black hole mass vs stellar bulge velocity dispersion



Tremaine et al 2002

Accretion makes massive black holes

$$\varepsilon(1+z) = 0.1\rho_{\bullet}c^2$$

Soltan 82

Mean redshift

Radiative efficiency

$$\frac{4\pi I_{Bol}}{c} = \varepsilon$$

$$I_{Bol} = \kappa I_{XRB}$$

Possible effect of central black hole on galaxy

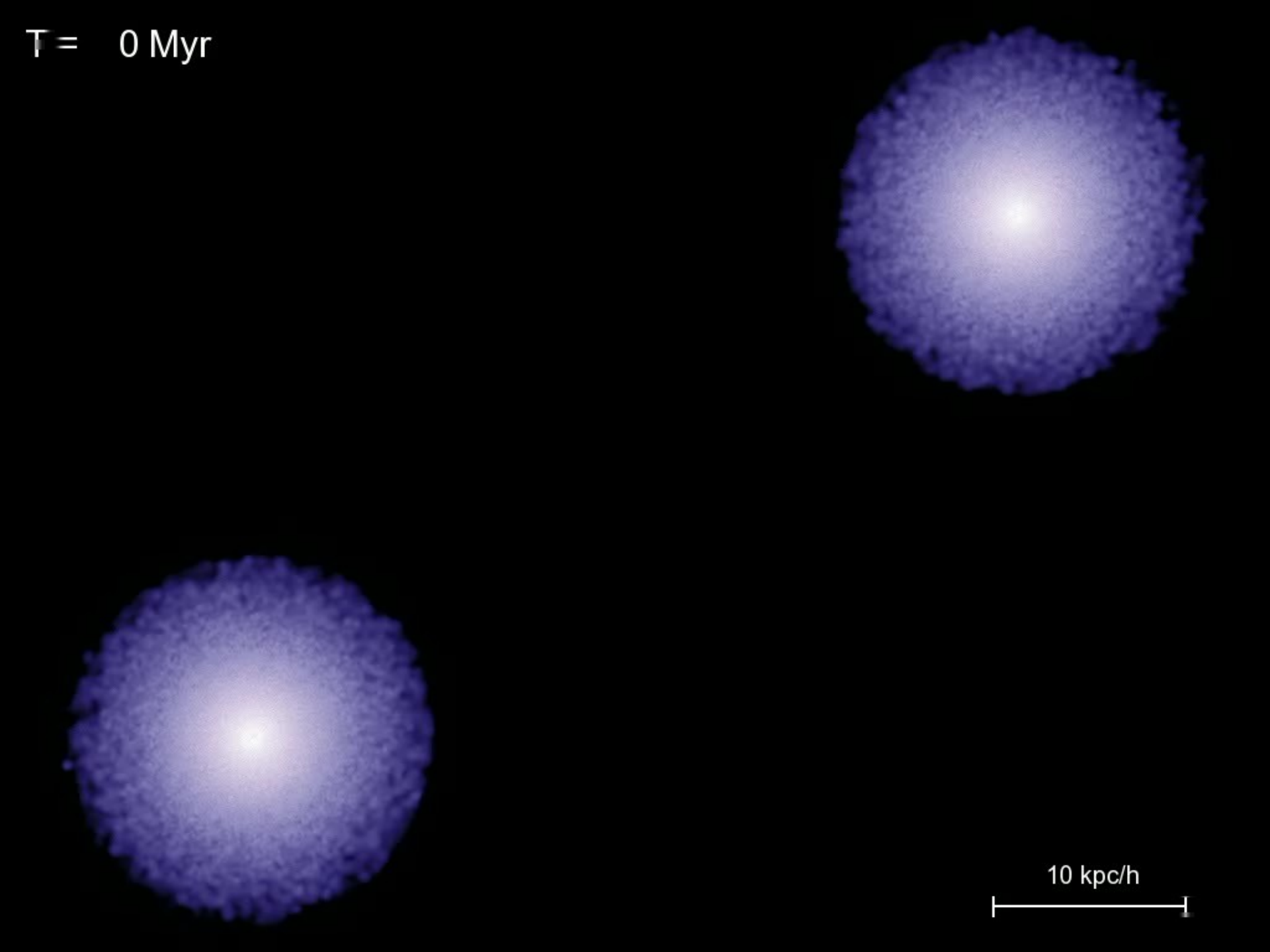
- BE of galaxy of mass $M \sim M \quad ^2$
- Mass of BH $\sim M/1000$

- Energy released during growth of BH
  $E_{BH} \sim 0.1 M_{BH} c^2 \sim 10^{-4} M c^2$

- Therefore $BE/E_{BH} \sim 10^4 (\quad /c)^2$

- Since $\quad < c/1000$, $BE \sim 0.01 E_{BH}$
- Conclude that BH can destroy galaxy

- *Fortunately, it is unlikely that BH destroy galaxies.*
- *They probably however do have strong influence on the growth of massive galaxies, eventually ejecting the gas available for star formation and so determining the total mass in stars.*
- *The interaction is probably either due to radiation pushing on dusty gas (winds) or to jets acting on hot gas.*
- *BH may thereby play a key role in galaxy evolution*


T = 0 Myr
10 kpc/h

REAFs Dominate
(Radiatively efficient accretion flows)

- *Dominant mode of SMBH in terms of GROWTH (Soltan-type arguments)*

- *Likely mode associated with AGN feedback (M-sigma relation)*

- *Inner radius of rad efficient disc is a few R_g*

Accretion Discs

- Viscosity causes angular momentum to flow out while mass flows in.
- Viscosity due to Magneto-Rotational Instability.
- For radiatively efficient, optically thick discs, flux emitted proportional to $1/r^3$
- So most emission from smallest radii
- Energy dissipated within disc emitted as quasi-blackbody emission from surface
- Magnetic energy dissipated above disc creates high temperature corona (and/or jet)
- Hot coronal electrons rapidly Compton scatter softer disc BB photons into a powerlaw spectrum seen as X-ray continuum

Standard (radiatively efficient) accretion discs

Surface flux

$$F(r) = \frac{3\dot{M}}{8\pi r^2}\frac{GM}{r}\left(1-\left(\frac{r_{in}}{r}\right)^{1/2}\right)$$

Integrates to give

$$L = \frac{1}{2}\frac{GM\dot{M}}{r_{in}}$$

(Remaining energy is orbital)

Spectrum rises as (frequency)$^{1/3}$ to max corresponding to inner temperature followed by Wien tail

These results are independent of viscosity

Further work requires knowledge of viscosity.

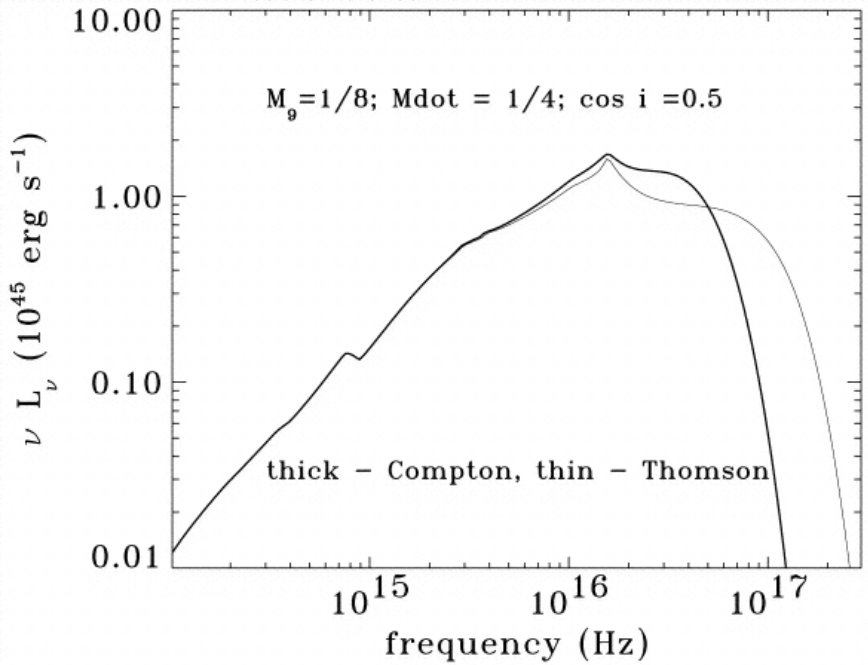
Often assumed that the shear stress is proportional to the local pressure, with const of proportionality =

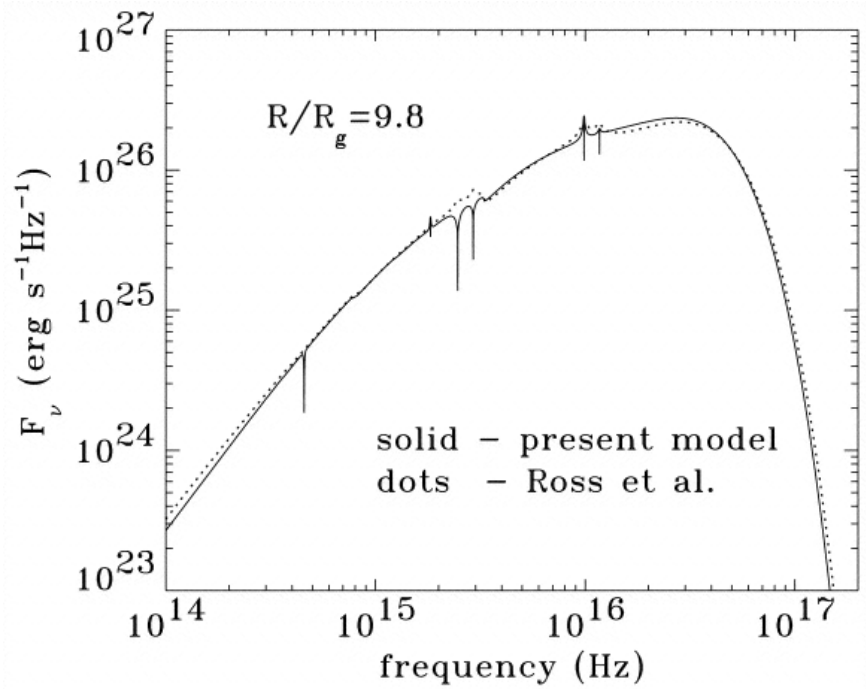
Viscosity believed due to the Magneto-Rotational Instability (MRI)

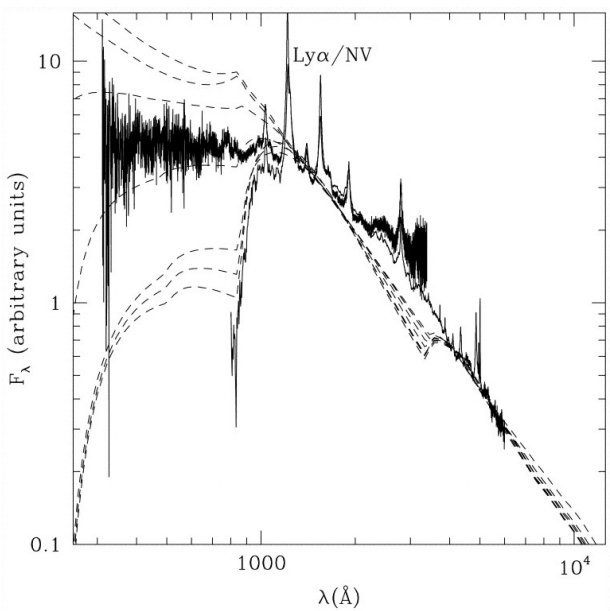
Pringle & Rees 72; Shakura & Sunyaev 73

Balbus & Hawley 90s; Frank, King & Raine book

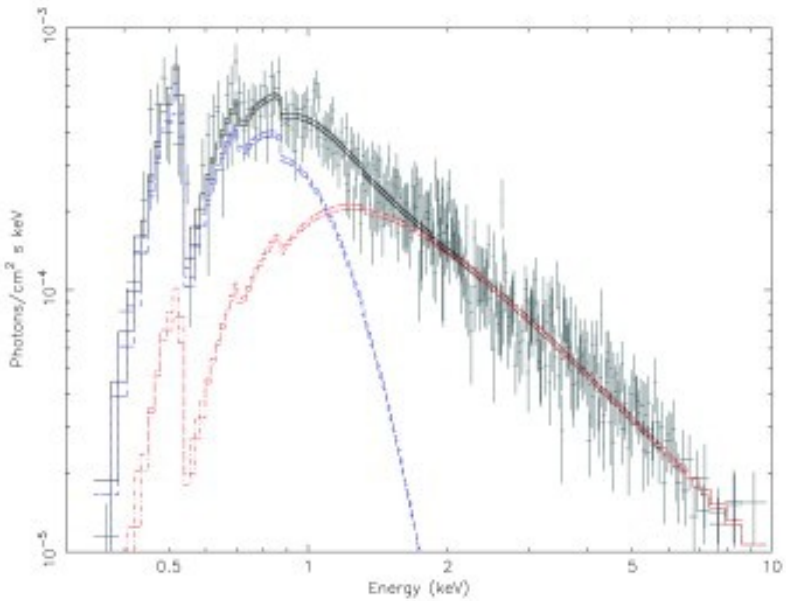
Blaes et al 01





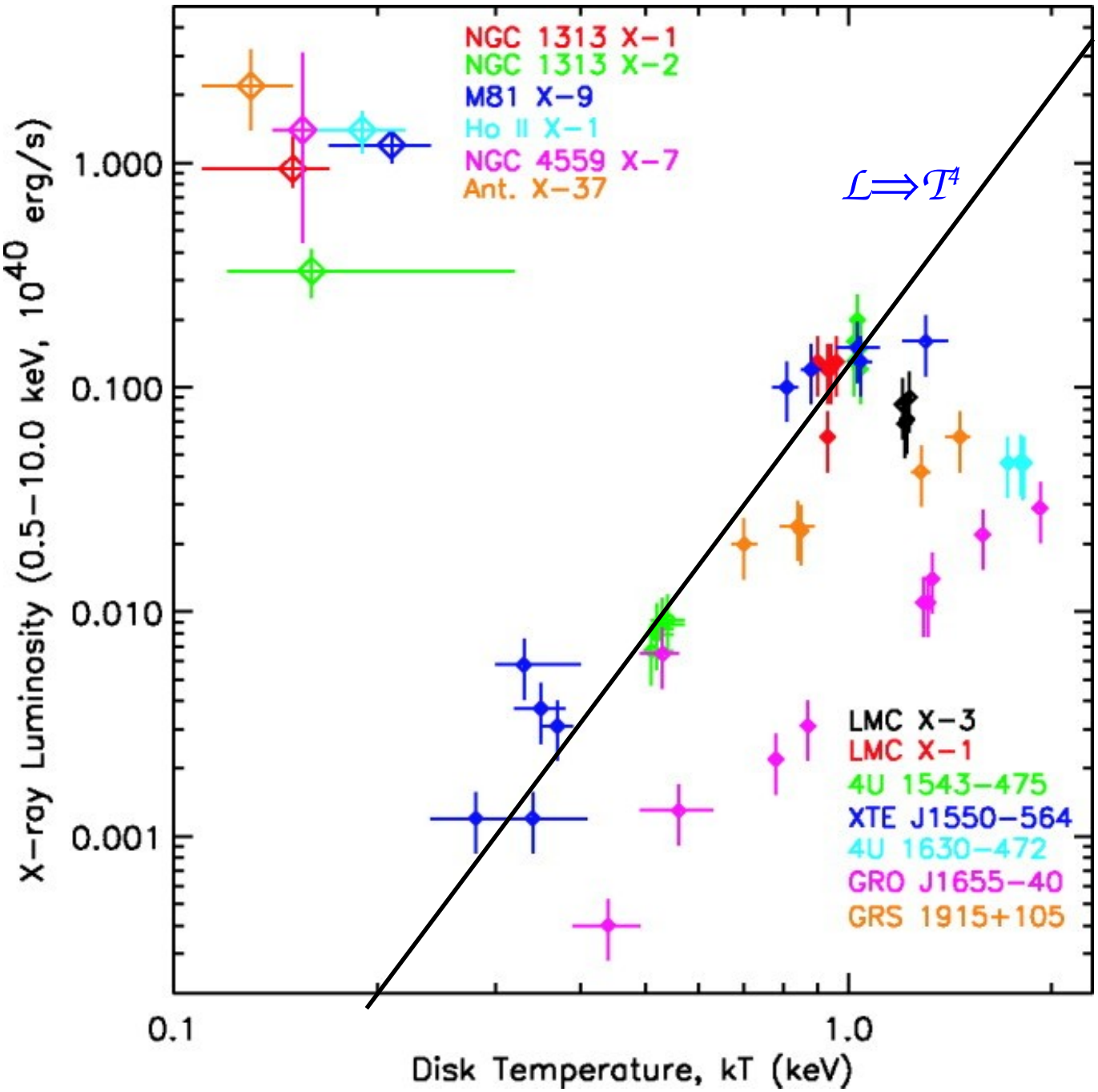


BB flux from disks
- Not straightforward!



3C273 Hubeny et al 00

ULX in NGC1313 Miller et al 03

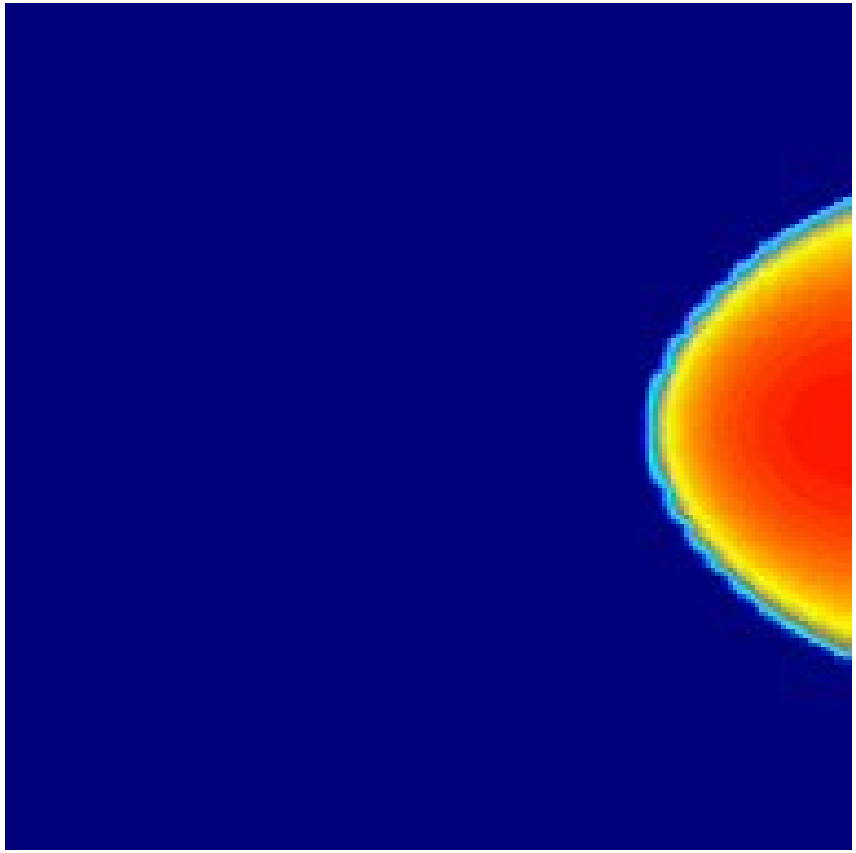


Miller
Fabian
Miller
2004

Accretion modes

- *Radiatively Efficient accretion (Shakura & Sunyaev 73, Pringle 81) is responsible for most BH growth*
- *When accretion rate below about* ^{2} *of Eddington rate then hot, optically thin, radiatively inefficient, solution is possible (Yi & Narayan 95, Rees+82)*
- *Jets are common at low accretion rates, taking much of the power as mechanical energy. Radiative efficiency of jets can be v low (<0.1%).*

Adiabatic accretion
Stone, Pringle & Begelman 01



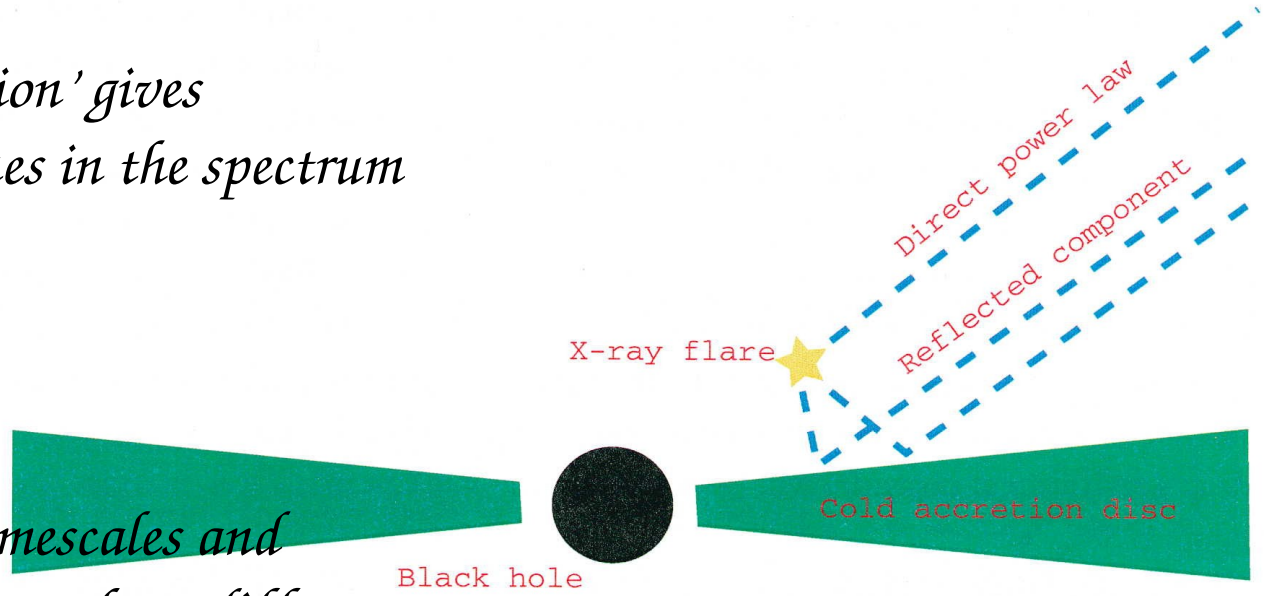
Computations of radiatively efficient disks much more difficult

Are they really Black Holes?

- *Most of the evidence shown so far involves velocities < 5000 km/s*
- *i.e. < few per cent of c*
- *"Massive object within small radius"*
- *Can we probe the strong gravity regime close to the bh?*
- *Need to use X-rays….*

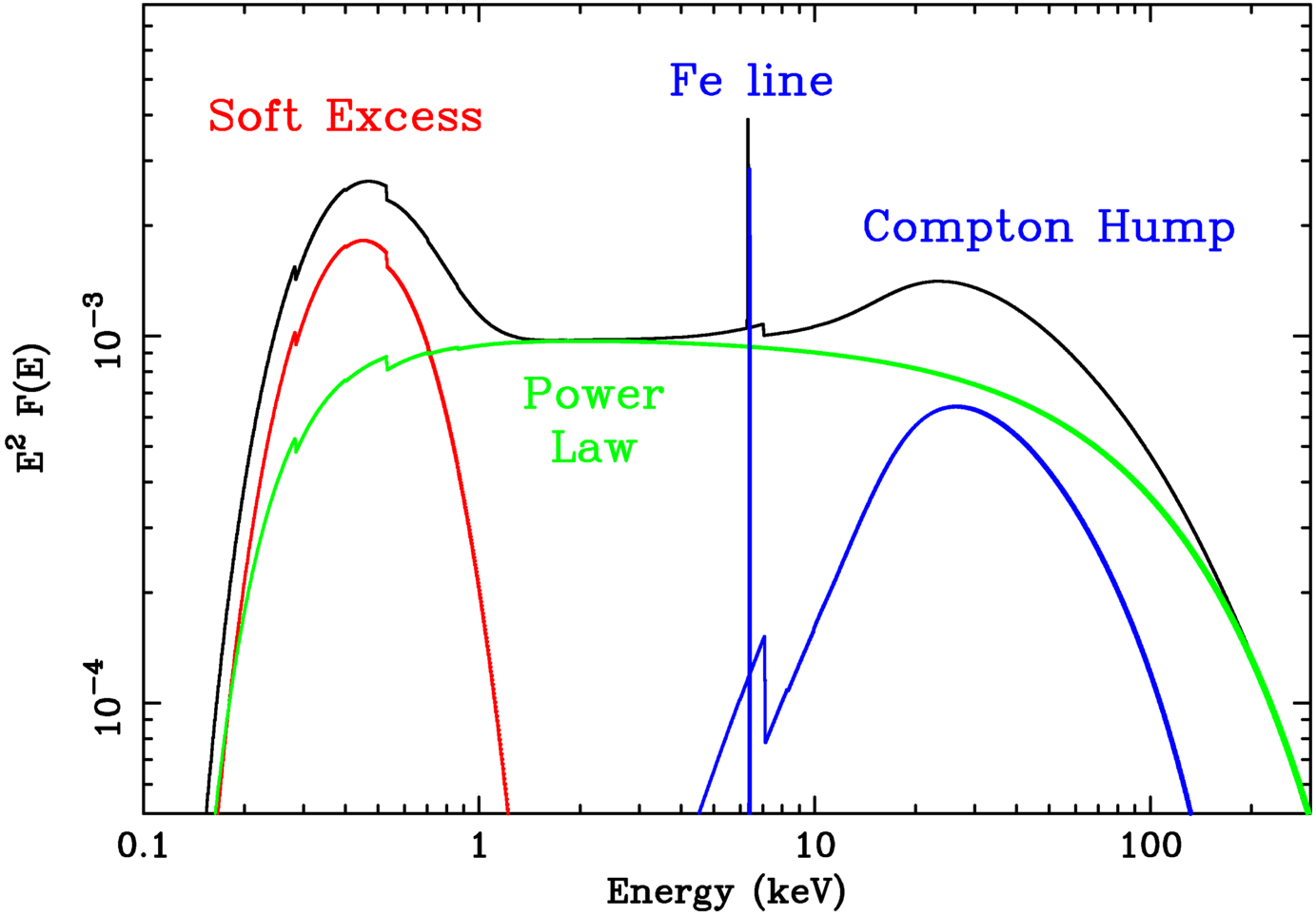
Clues from spectra and variability

- *X-ray 'reflection' gives important clues in the spectrum*



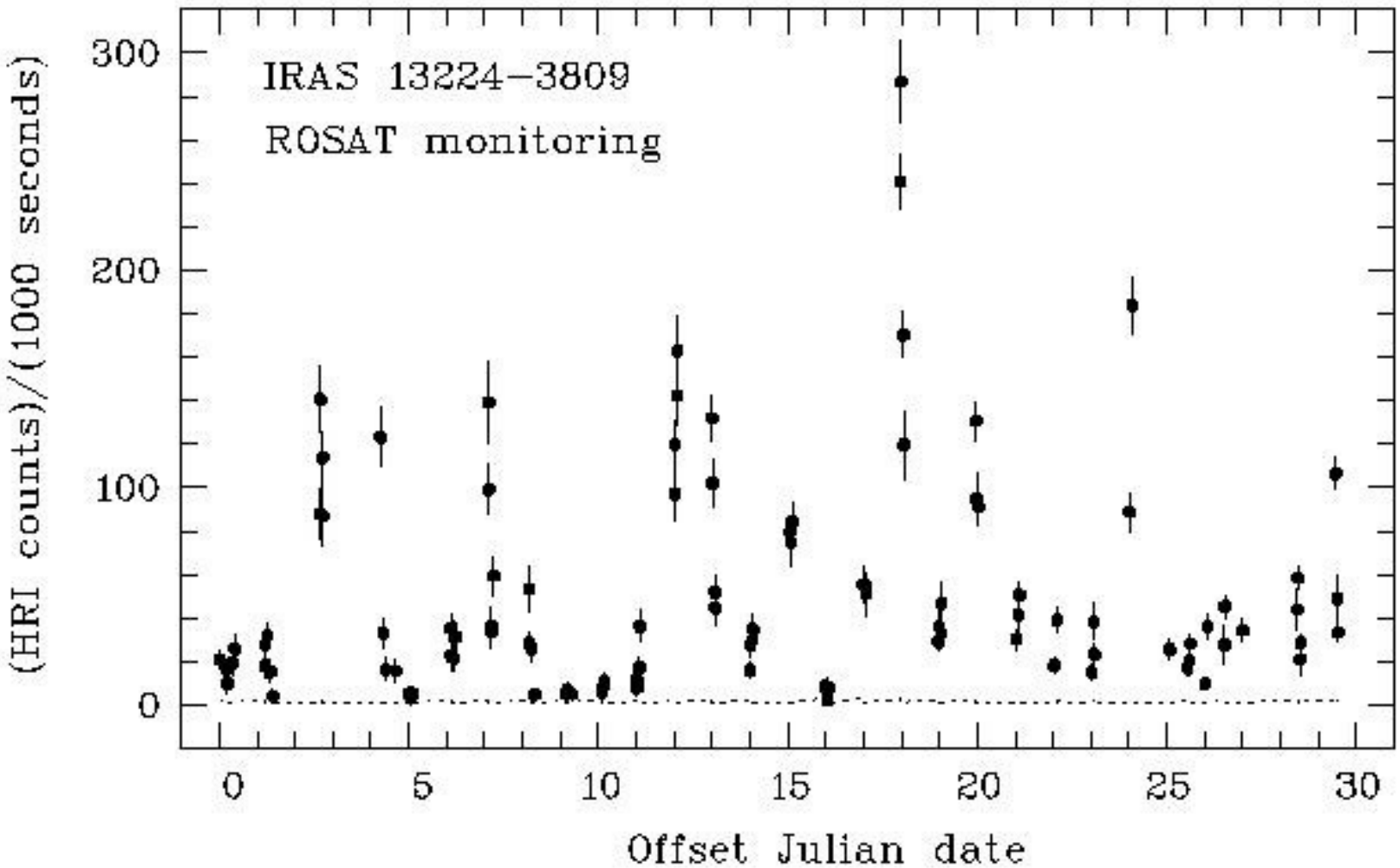
- *Variability timescales and spectral changes show different spectral components*

Components of an AGN (with Galactic absorption)

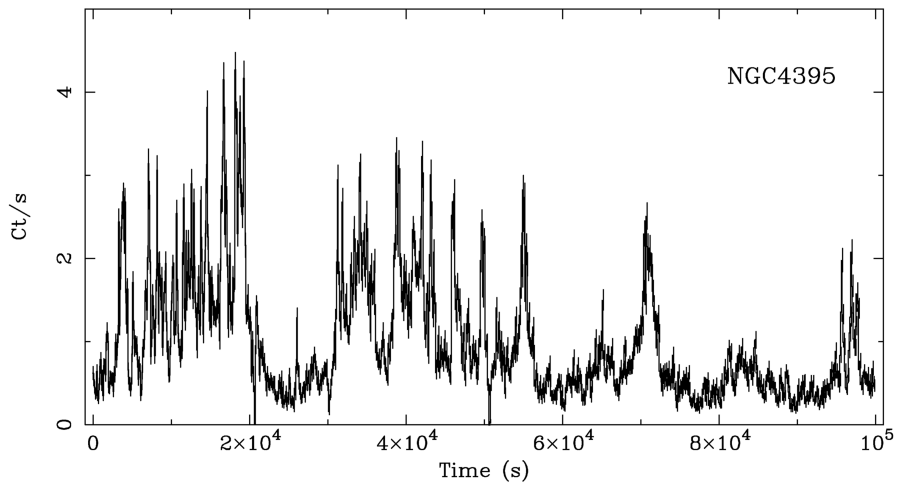


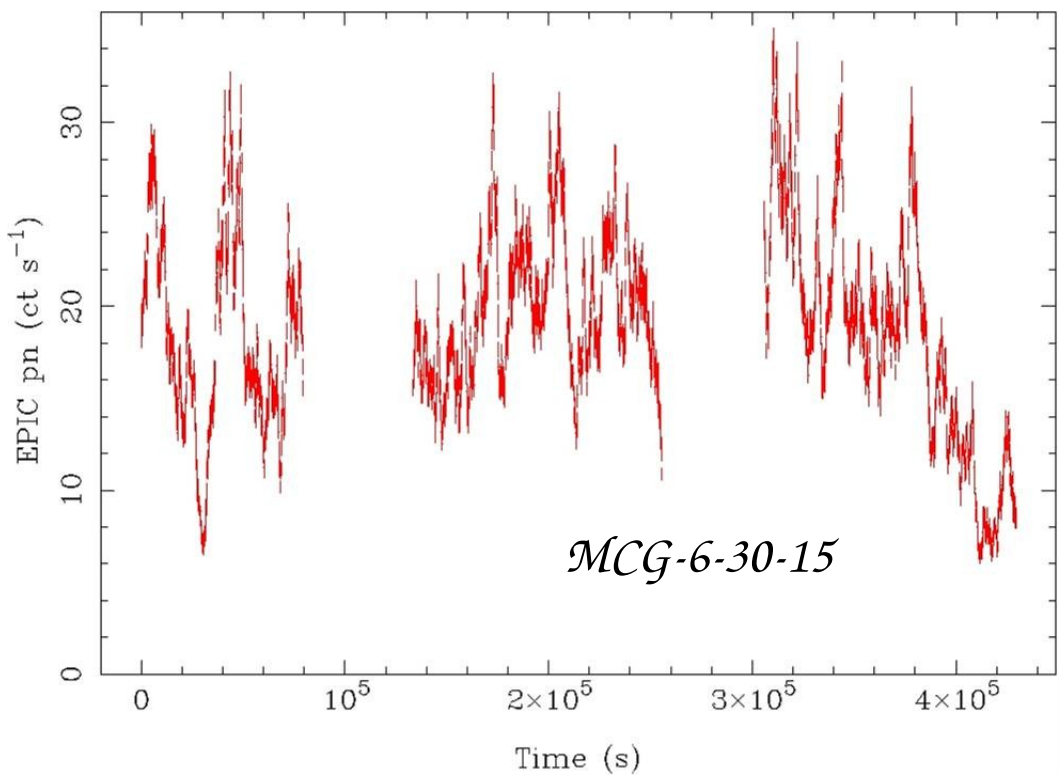
AGN variability can be extreme, particularly in X-ray band.

Peak here is 1e45 erg/s

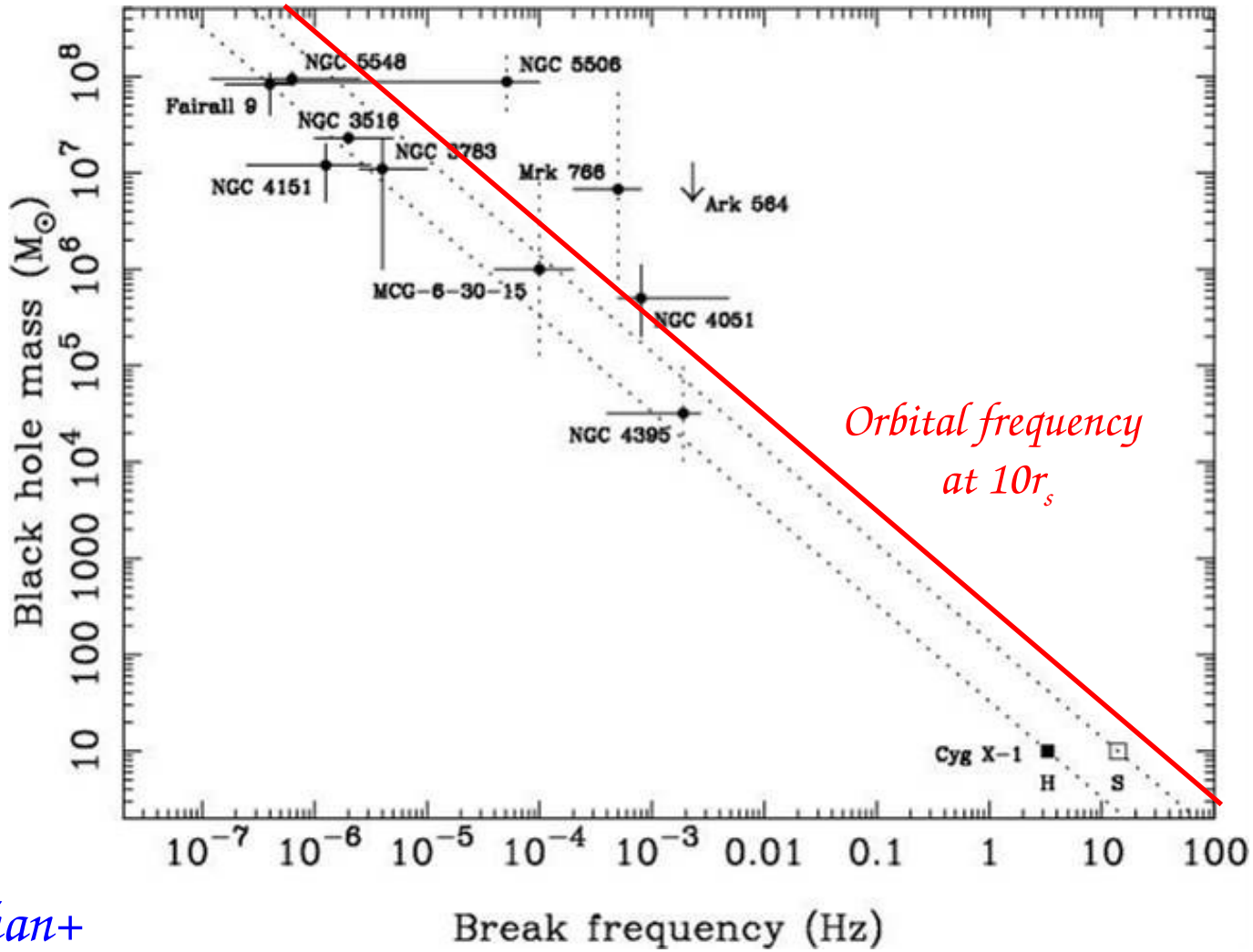


Rapid variability in AGN



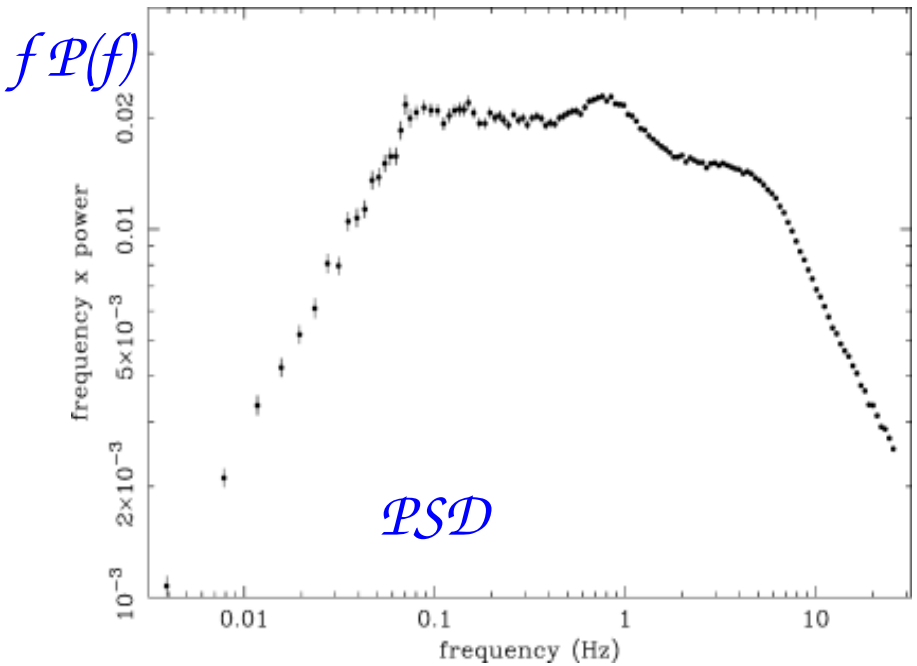


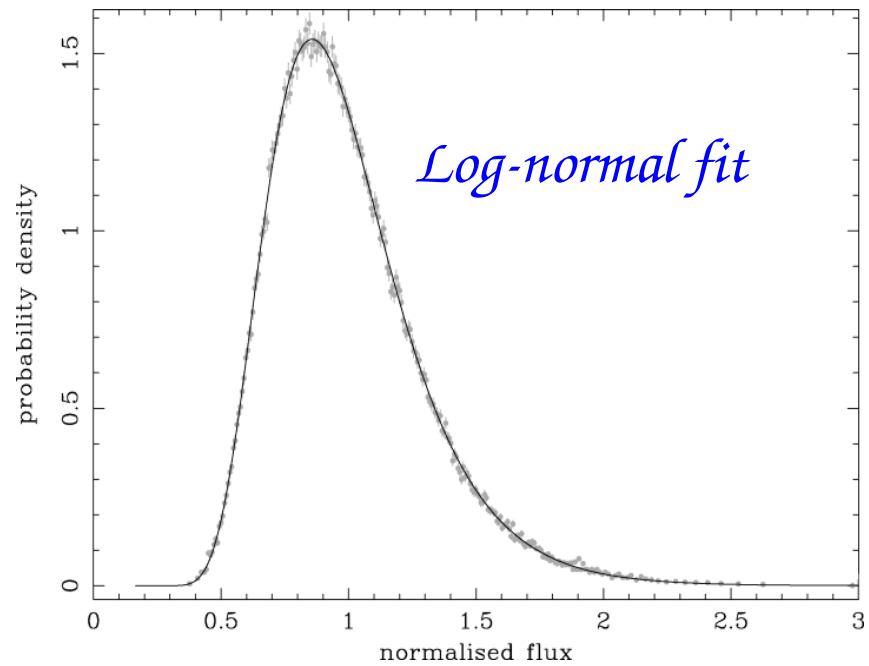
Emission dominated by innermost regions

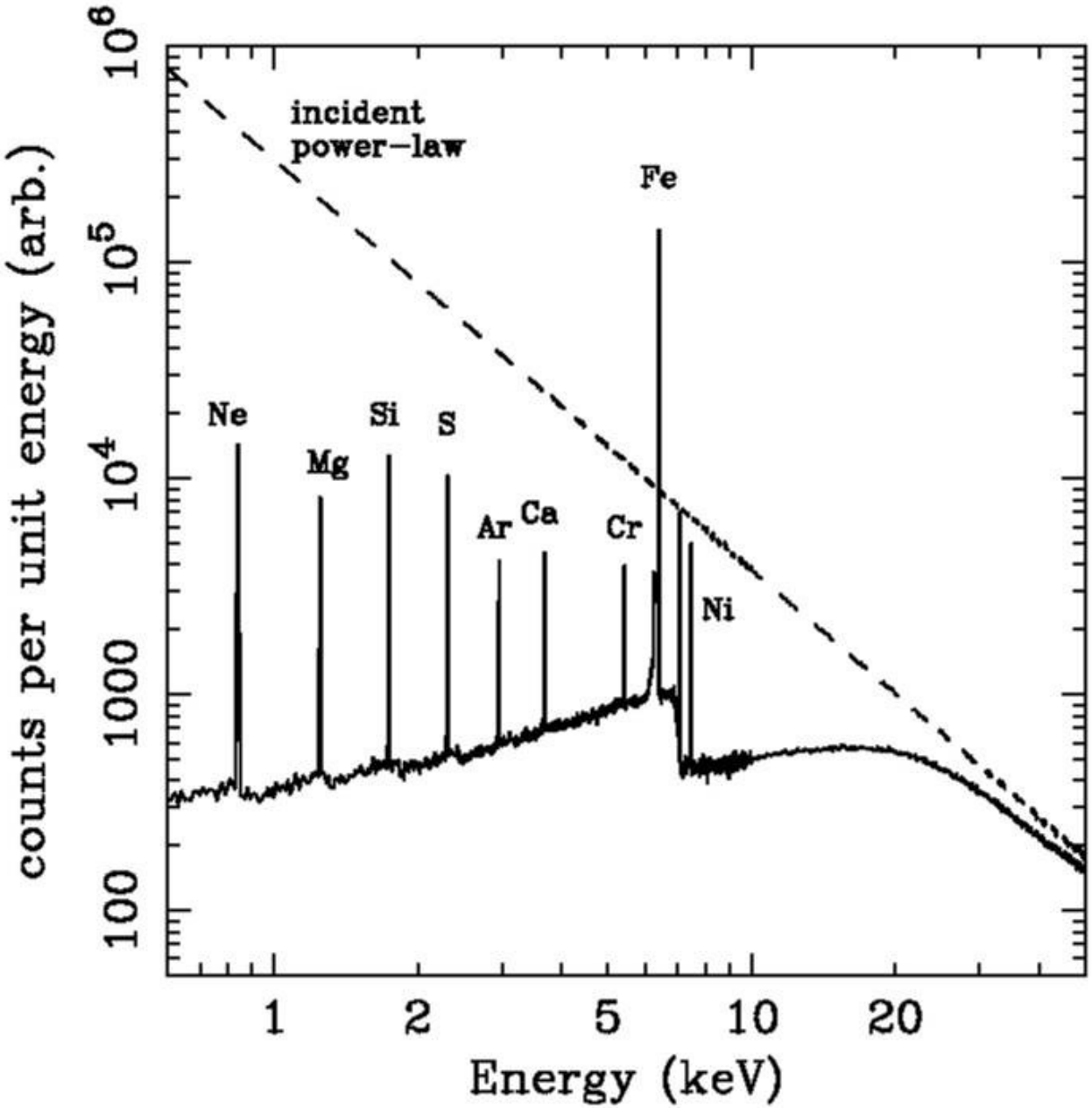


Vaughan+

Cyg X-1 low state (Uttley+05)

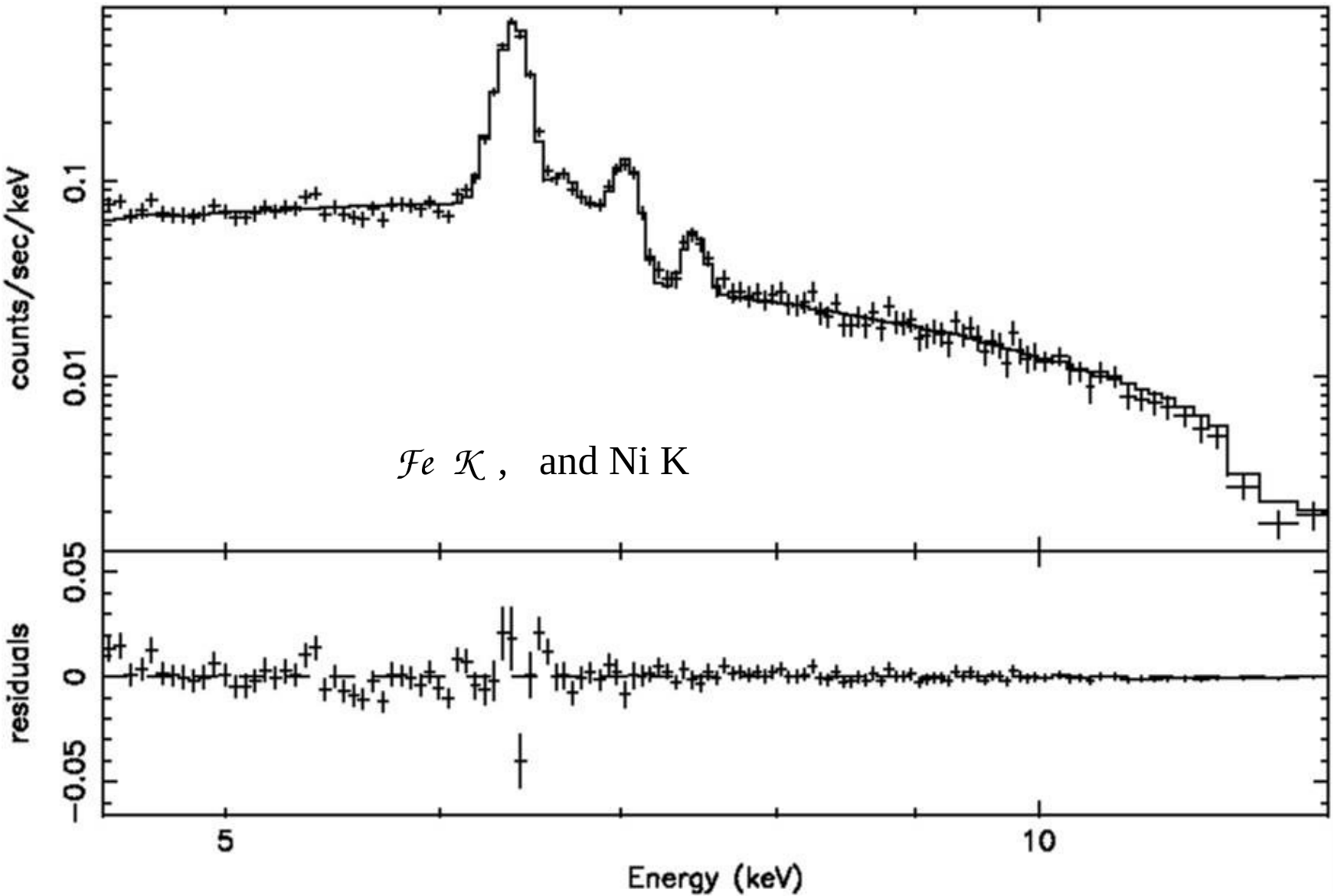






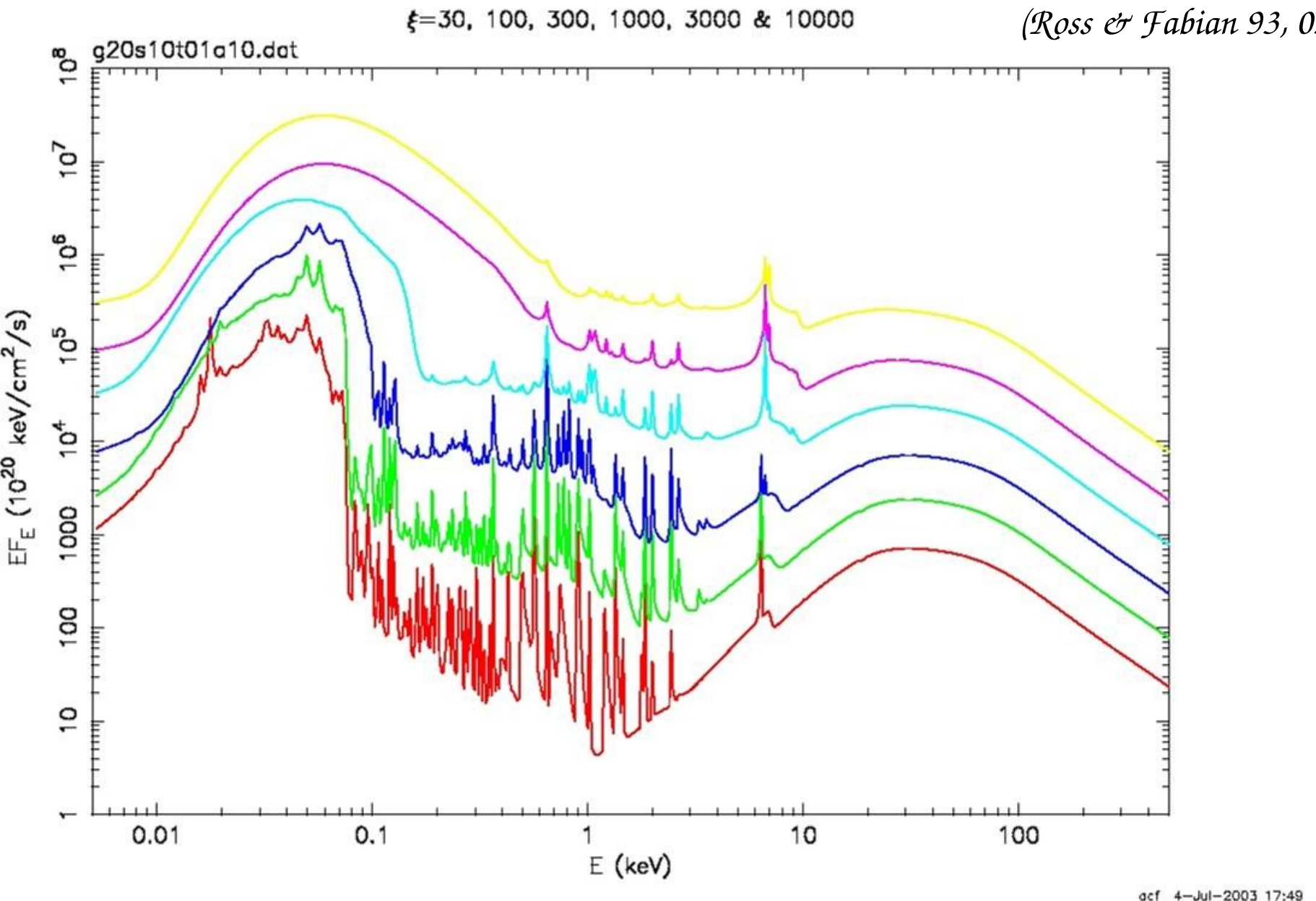
Reflection from cold matter

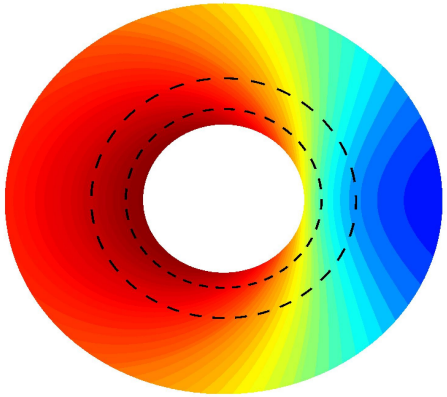
XMM-Newton spectrum of the Circinus Galaxy
Molendi, Bianchi & Matt 03

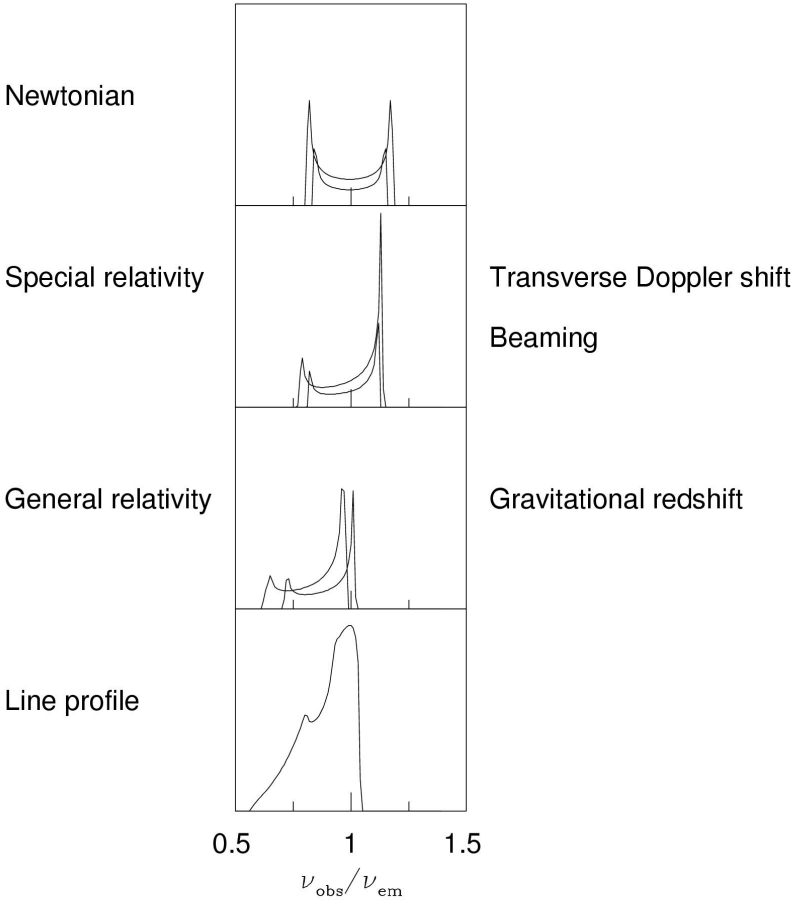


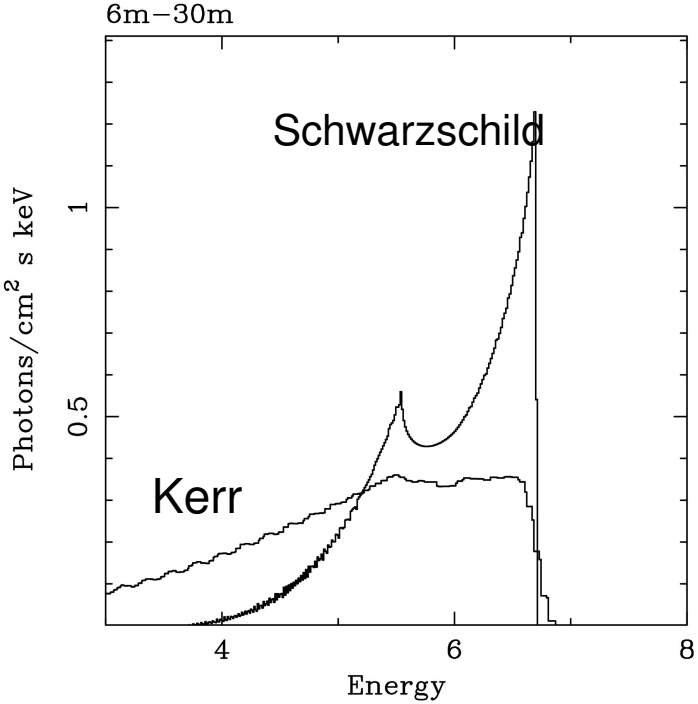
Reflection from photoionized matter

(Ross & Fabian 93, 03)

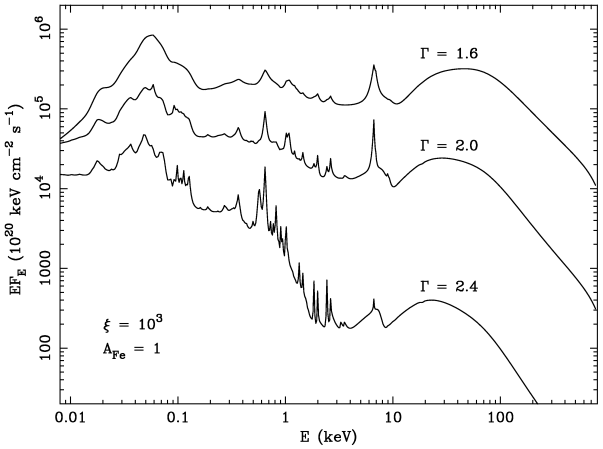




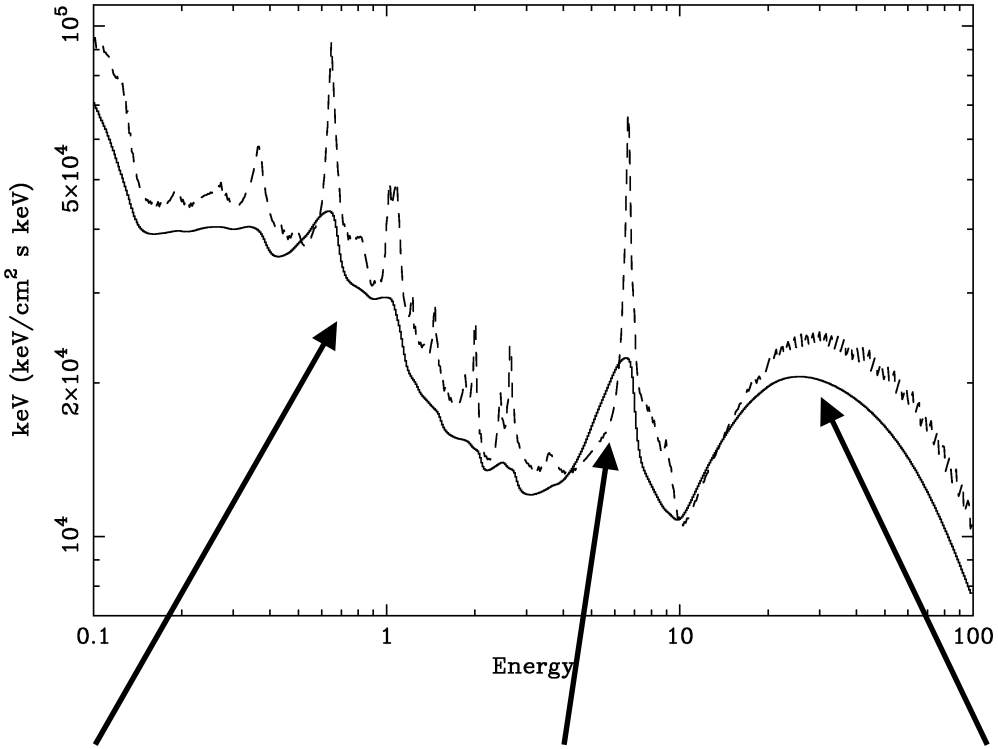




Fabian+89, Laor 90… Dovciak+04; Beckwith+Done05

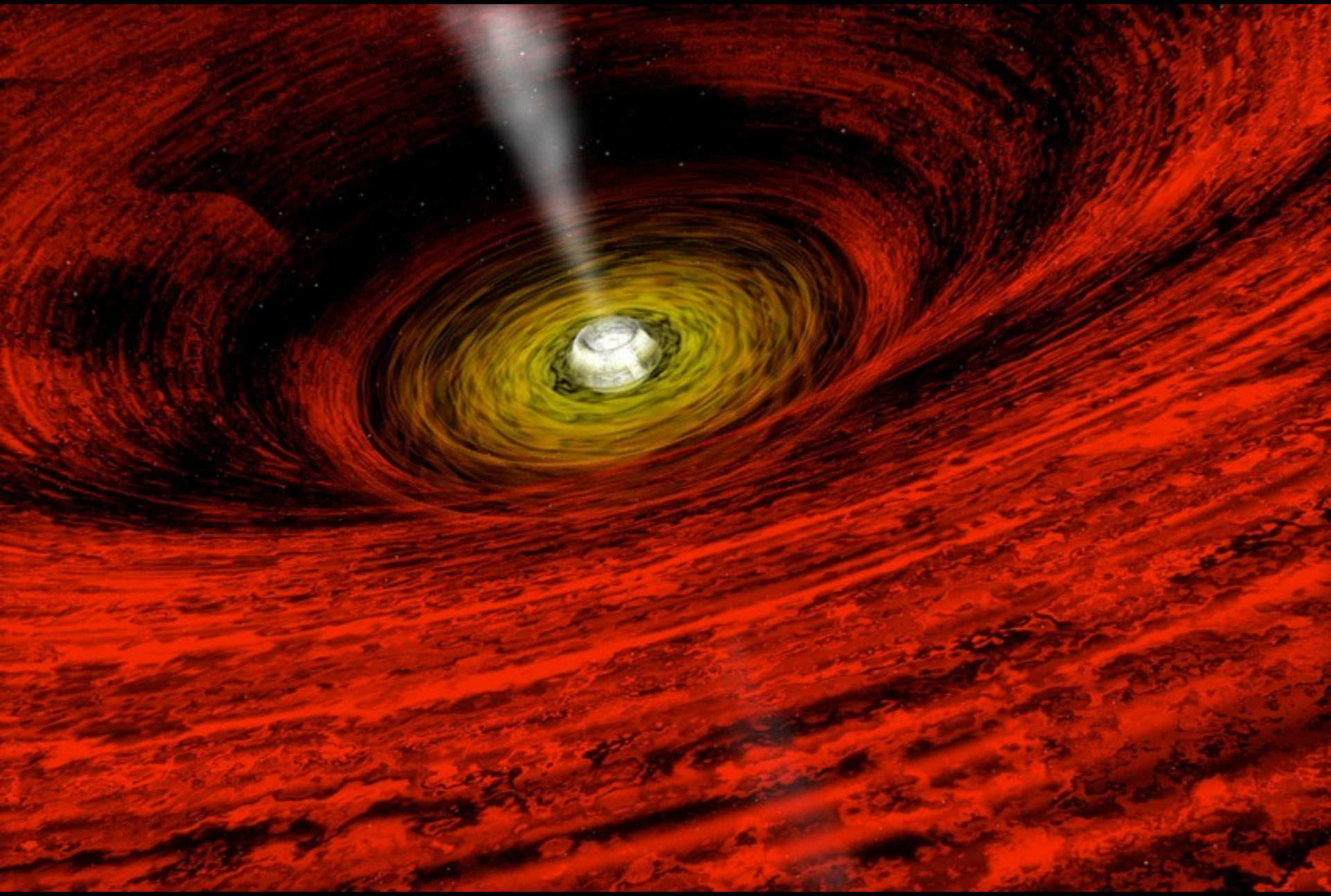


Vary spectral index

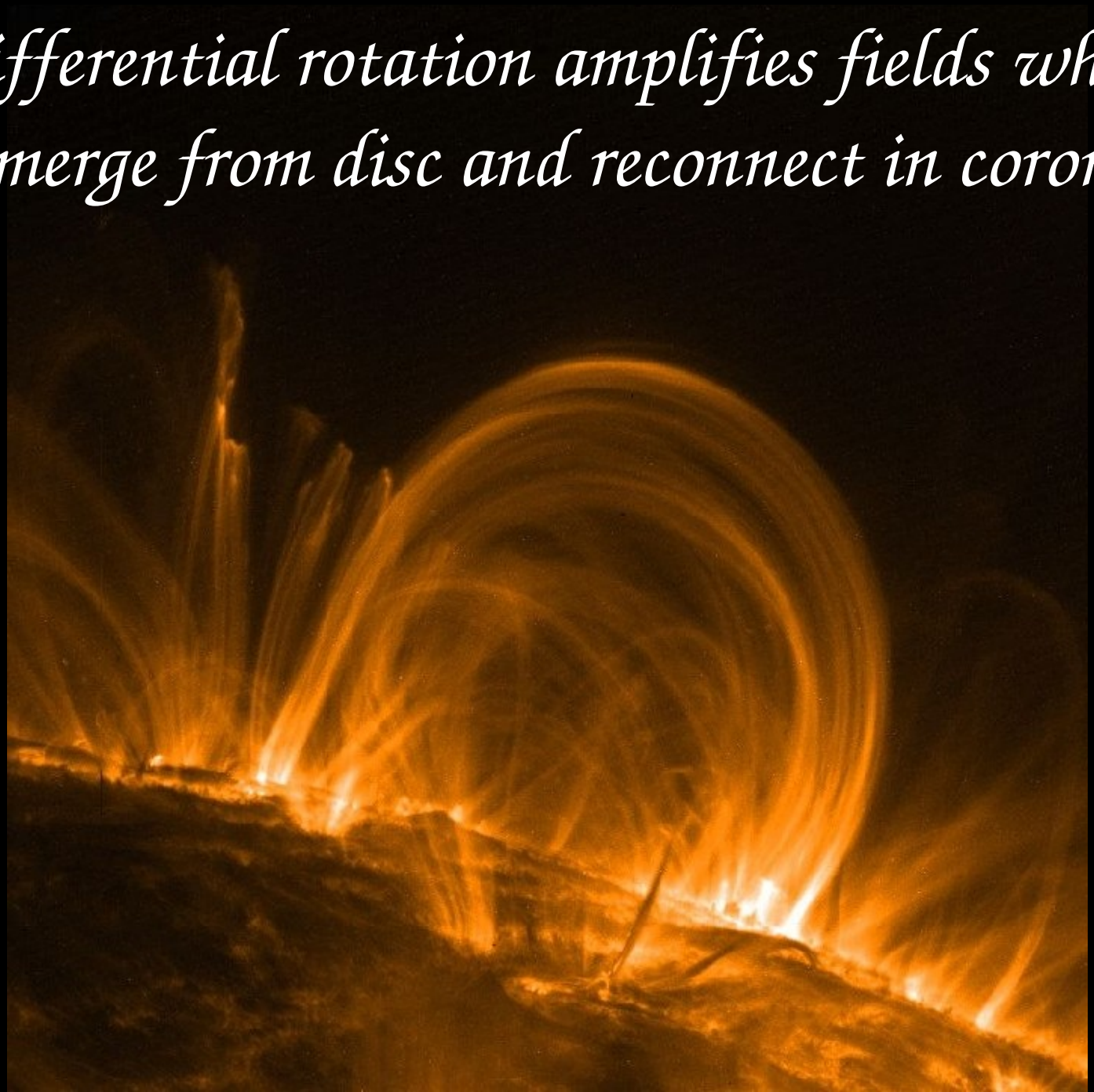


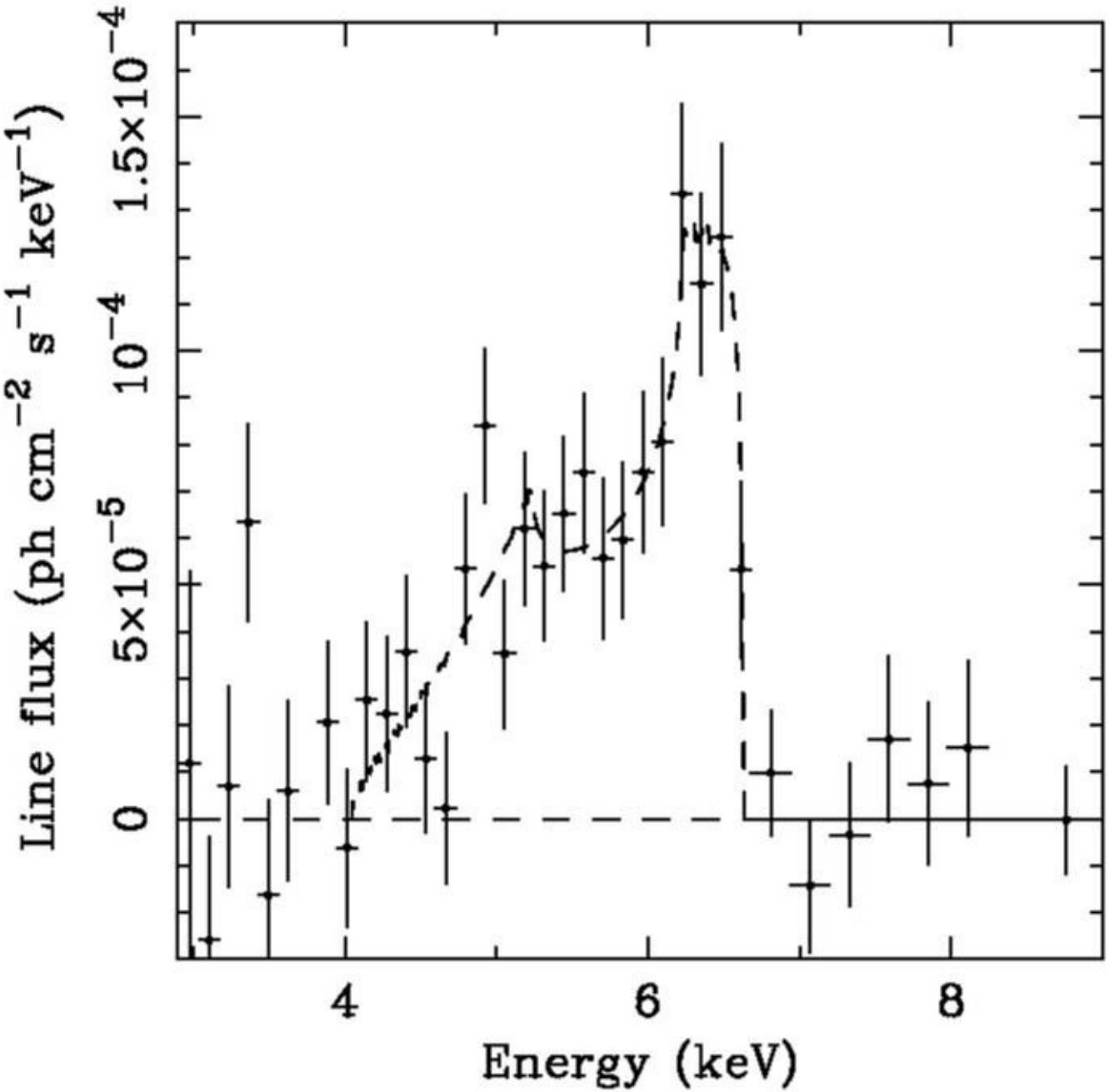
Add relativistic blurring

Soft excess – broad iron line – Compton hump



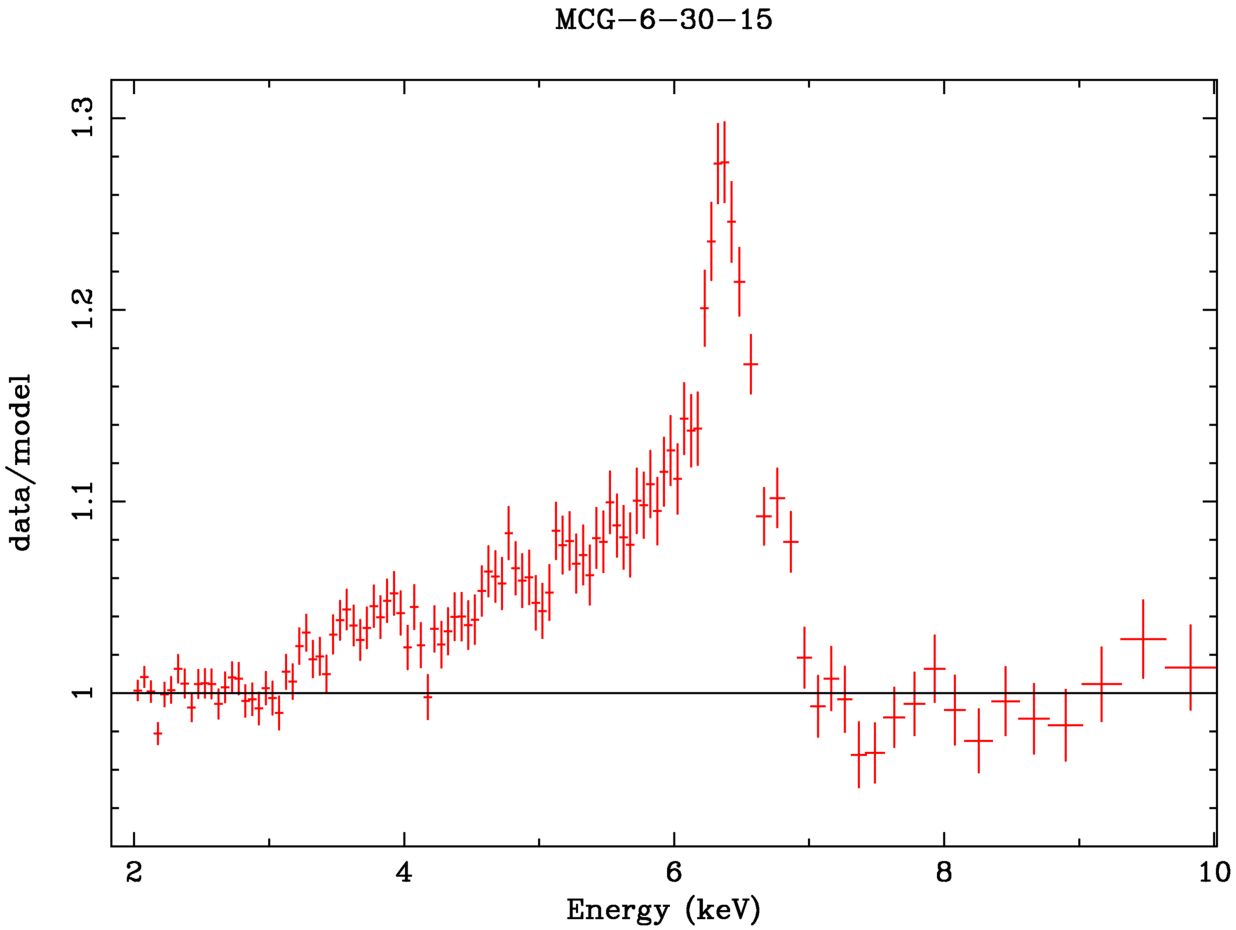
Differential rotation amplifies fields which emerge from disc and reconnect in corona





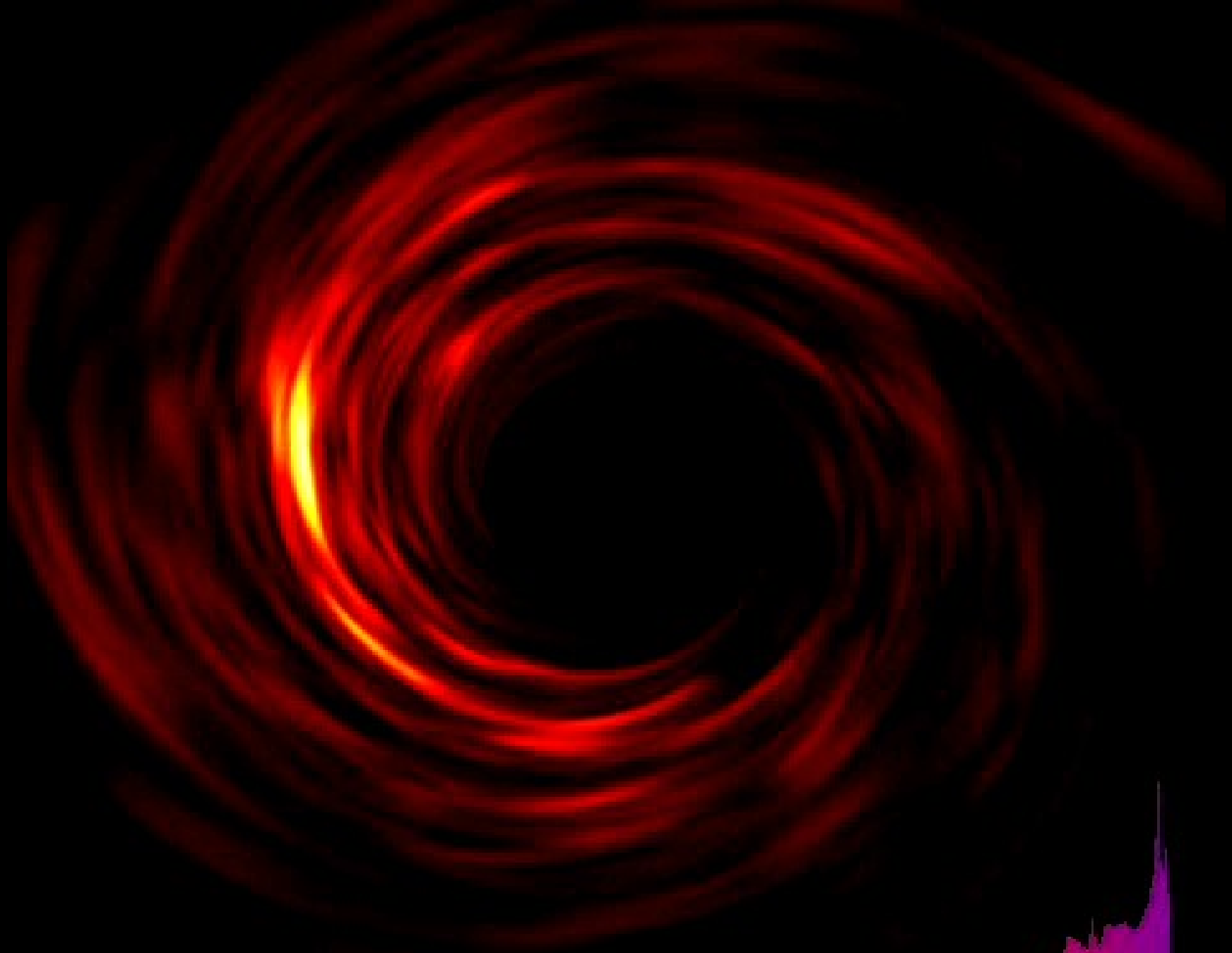
ASCA

Tanaka et al 1995

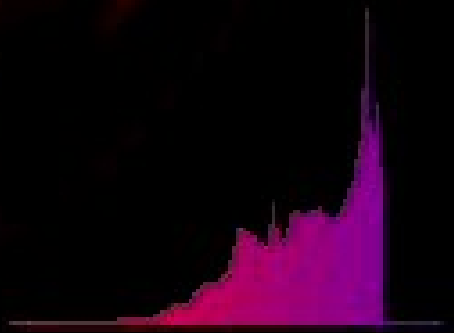


Very Broad Line ⟹ Spinning BH

Tanaka+ Iwasawa+ Wilms+ Fabian+



Armitage & Reynolds

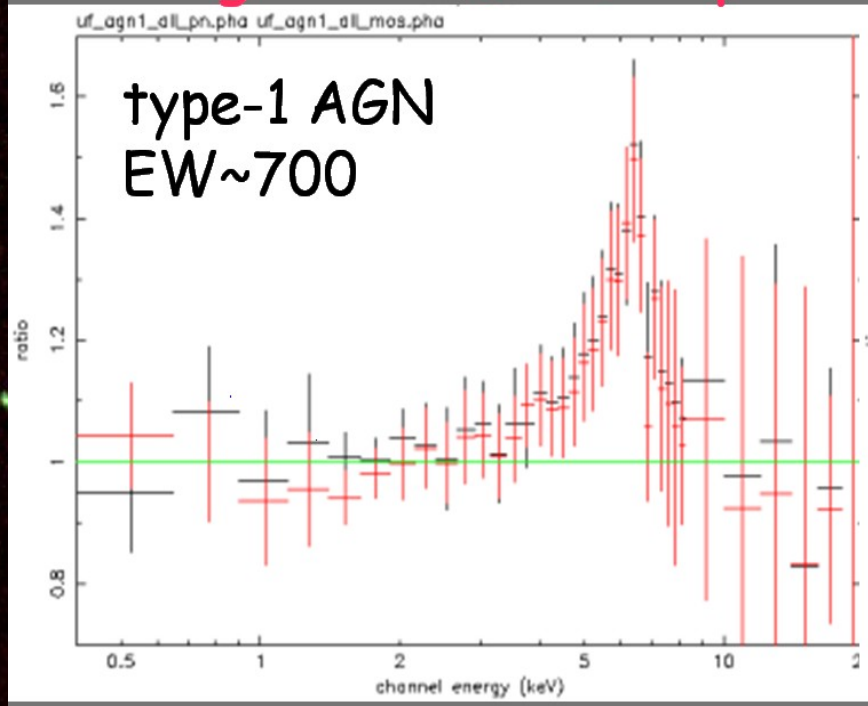


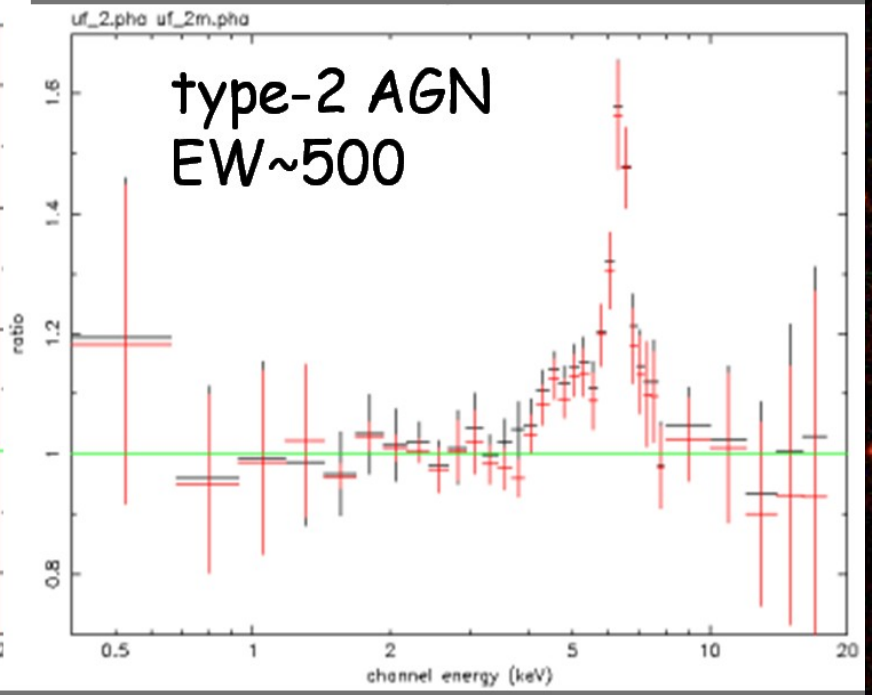
Lockman Hole

800 ks XMM-Newton observation

Hasinger

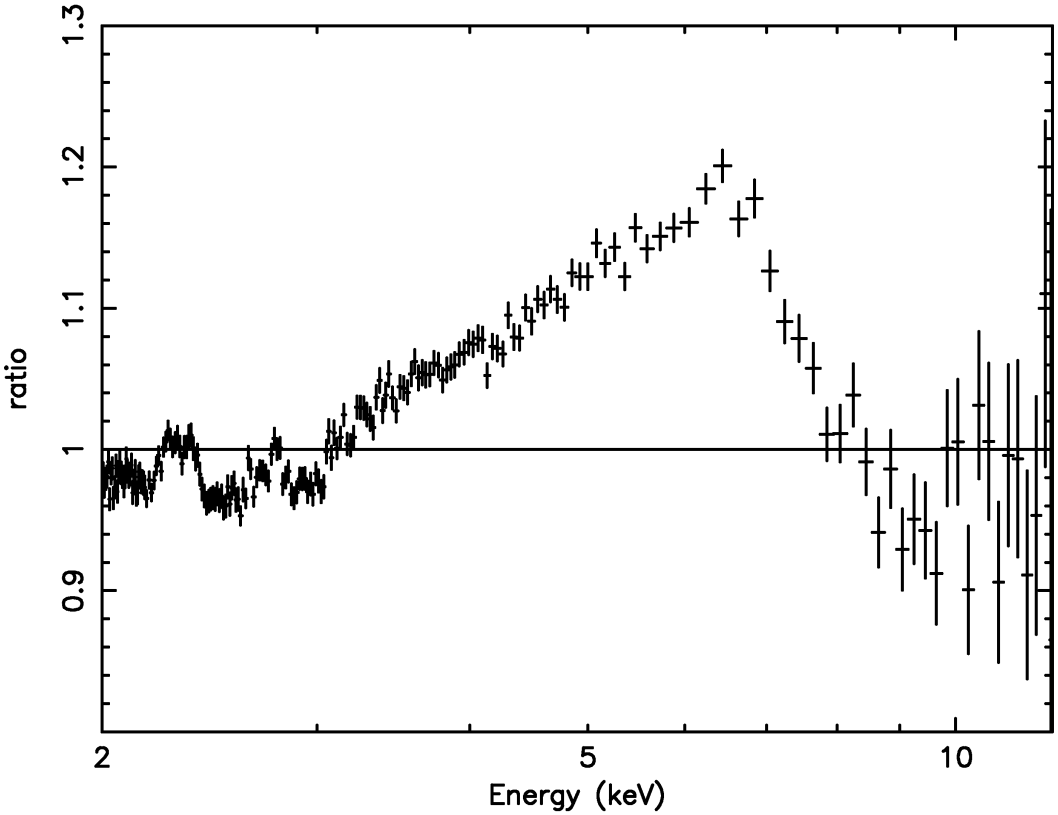
Average rest-frame spectra show relativistic Fe-lines





Streblyanskaya et al 2004

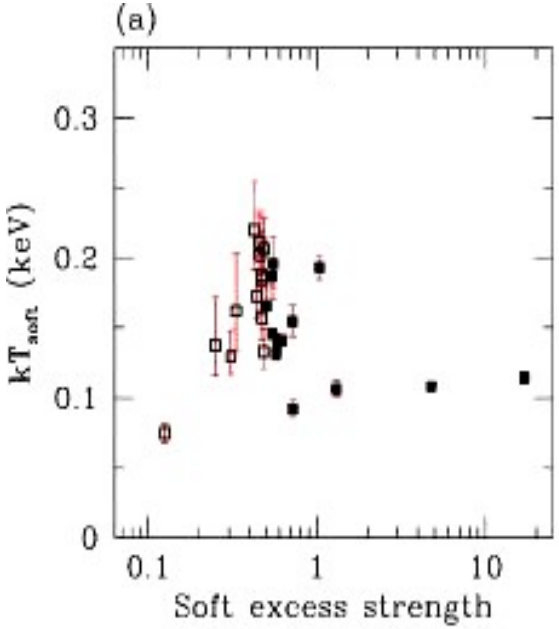
Galactic Black Hole GX339-4

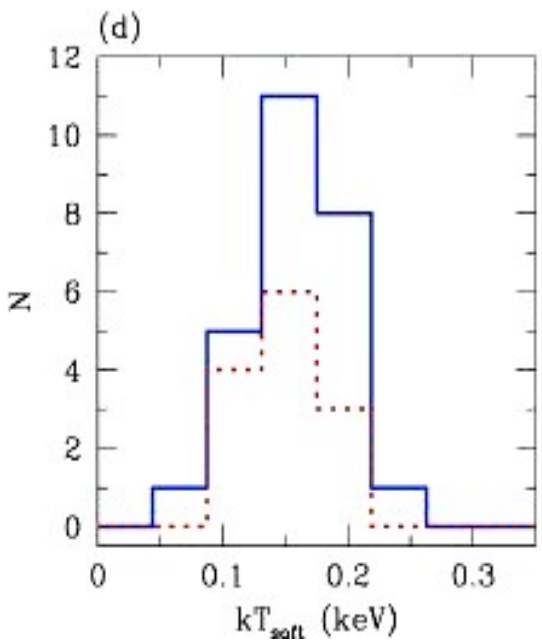


Very Broad Line ⟹ spinning BH

Miller+

The soft X-ray excess

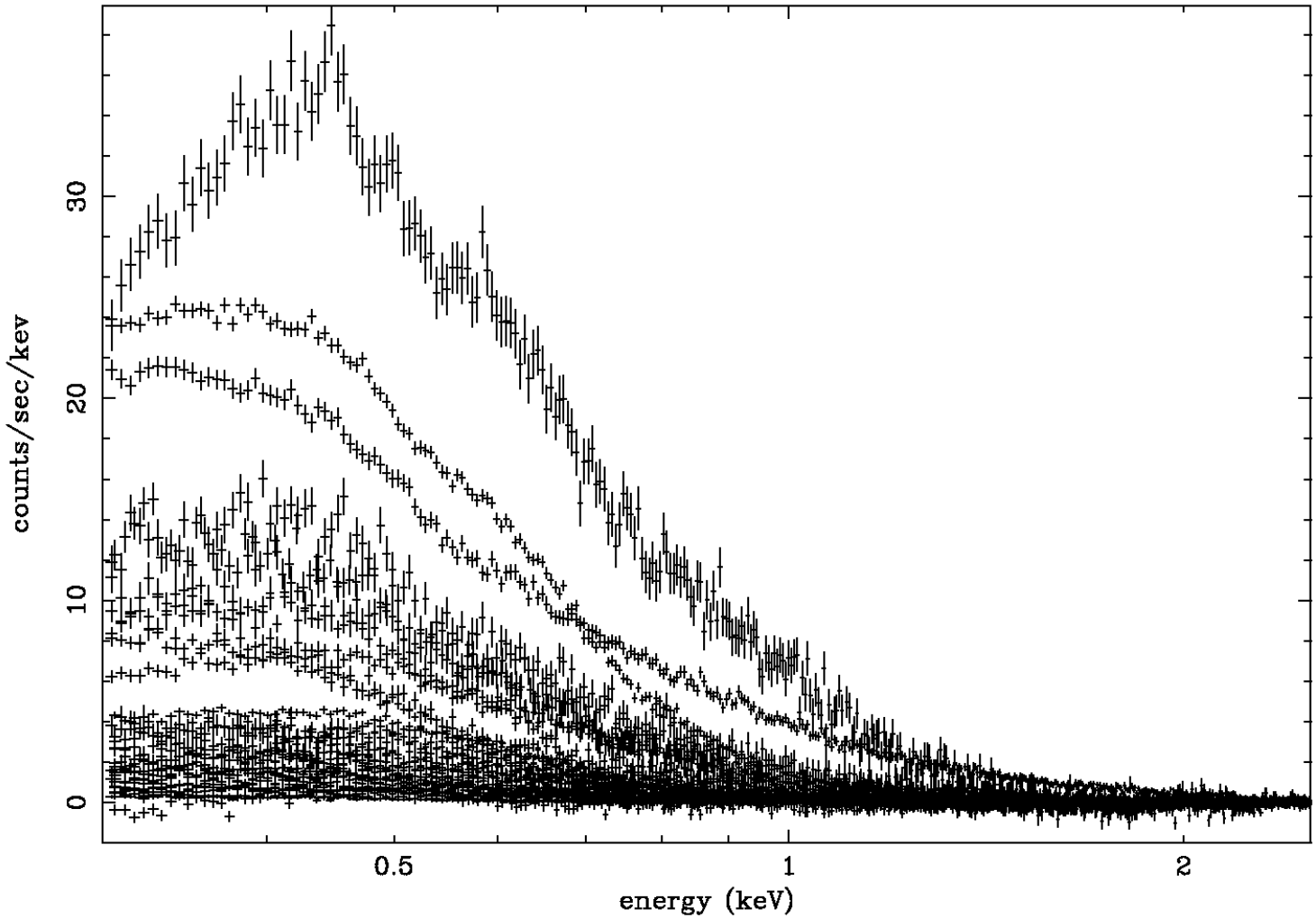




the soft excess in AGNs seems to have a "universal" temperature despite large differences in BH mass, hard spectral shape, accretion rates …
(Czerny+03; Gierlinski & Done 04)

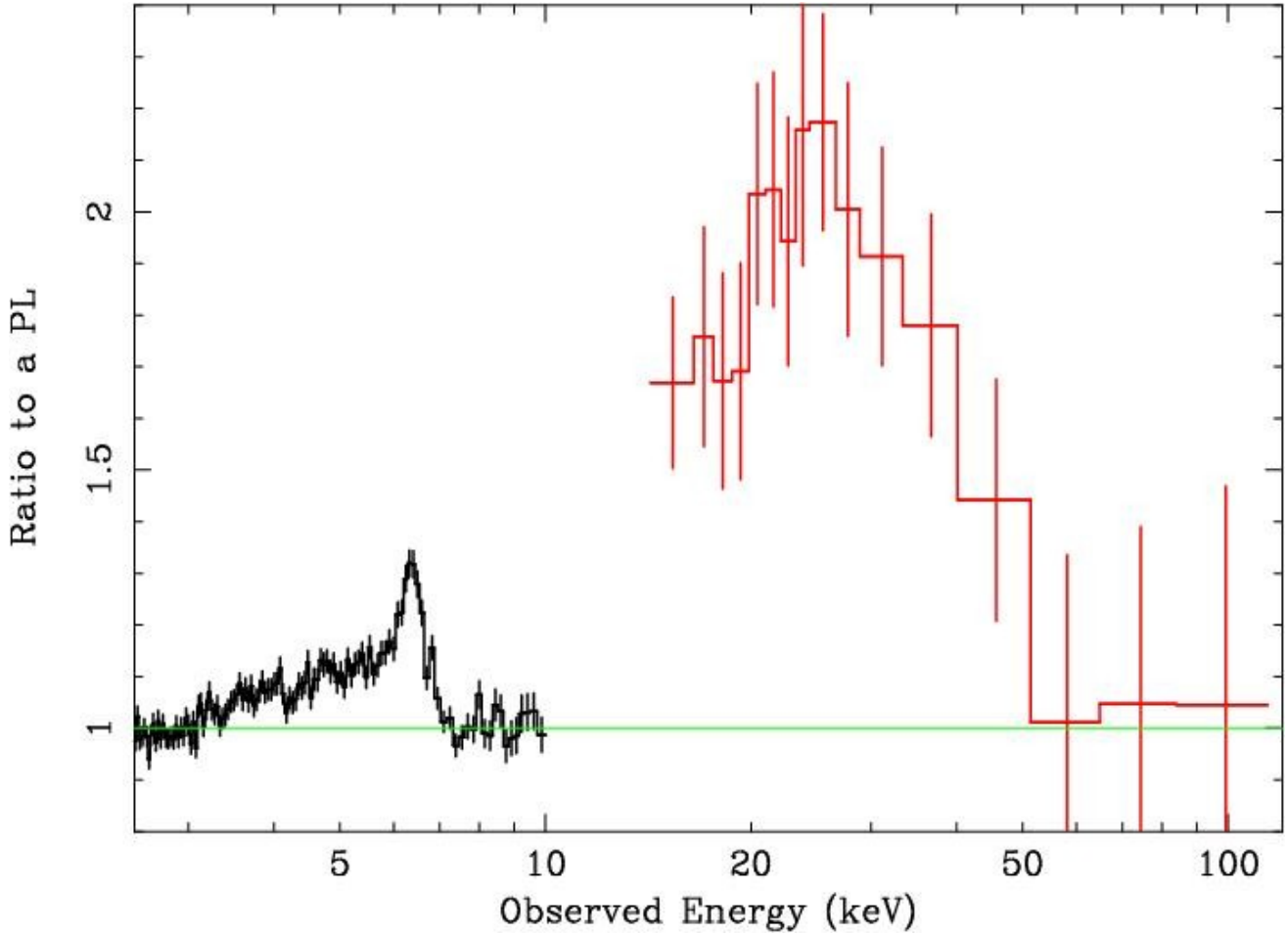
it could indicate that the process involved is not thermal as usually assumed but rather linked to atomic processes

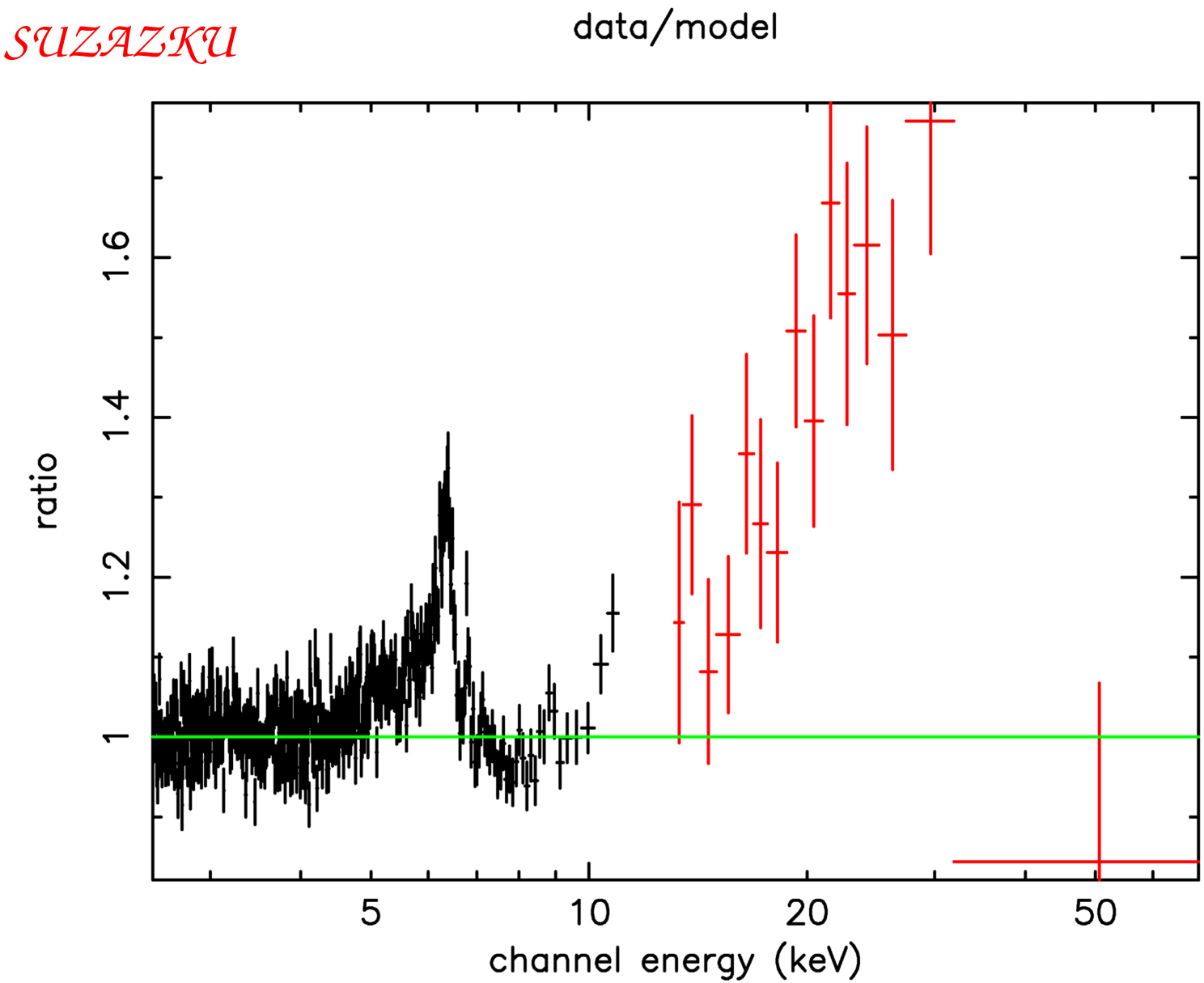
Can be EXPLAINED by REFLECTION
(Ross & Fabian 05; Crummy+05)



Crummy+05 22 PG QSO +12 Seyf1

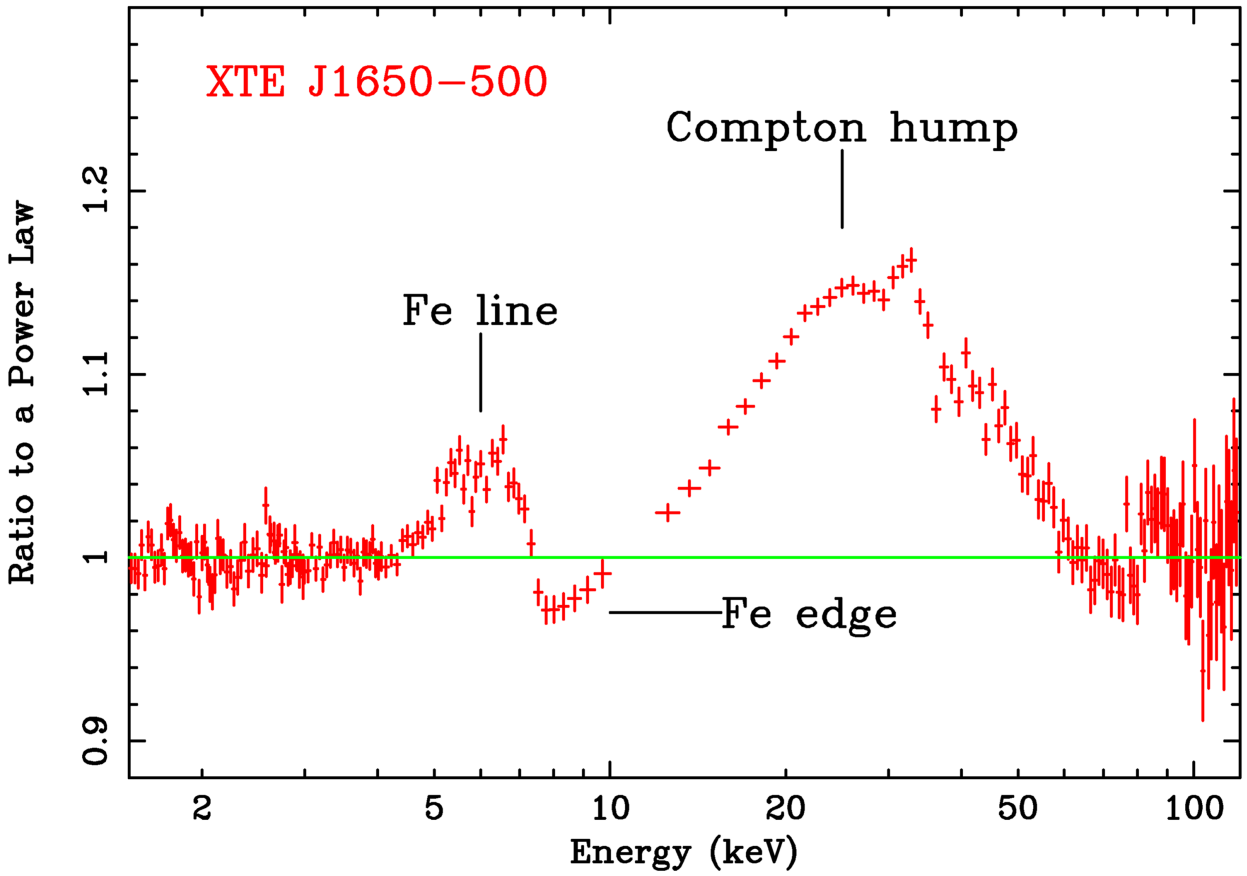
XMM pn + BeppoSAX PDS

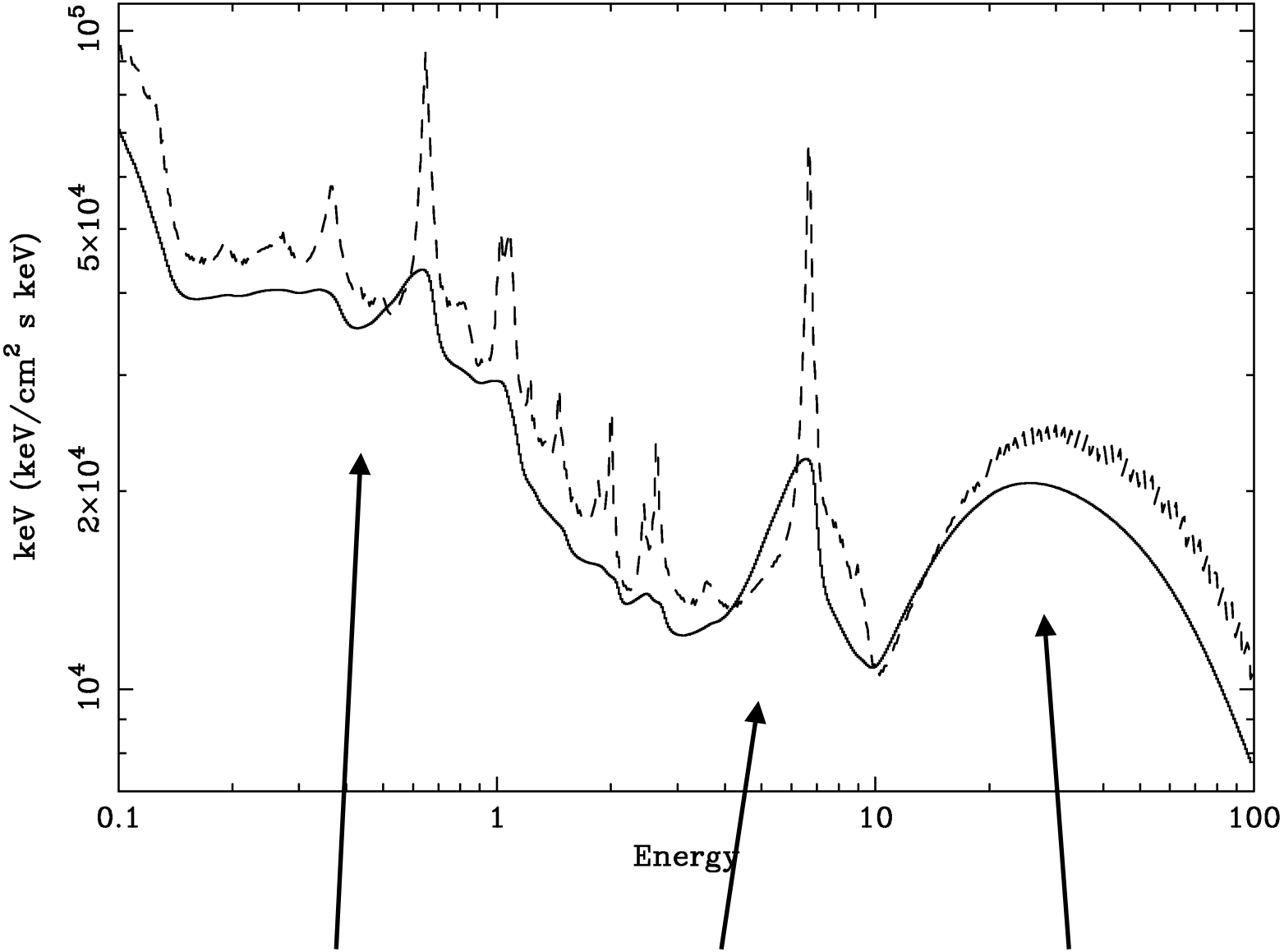



SUZAZKU
data/model
ratio
1
1.2
1.4
1.6
5
10
20
50
channel energy (keV)

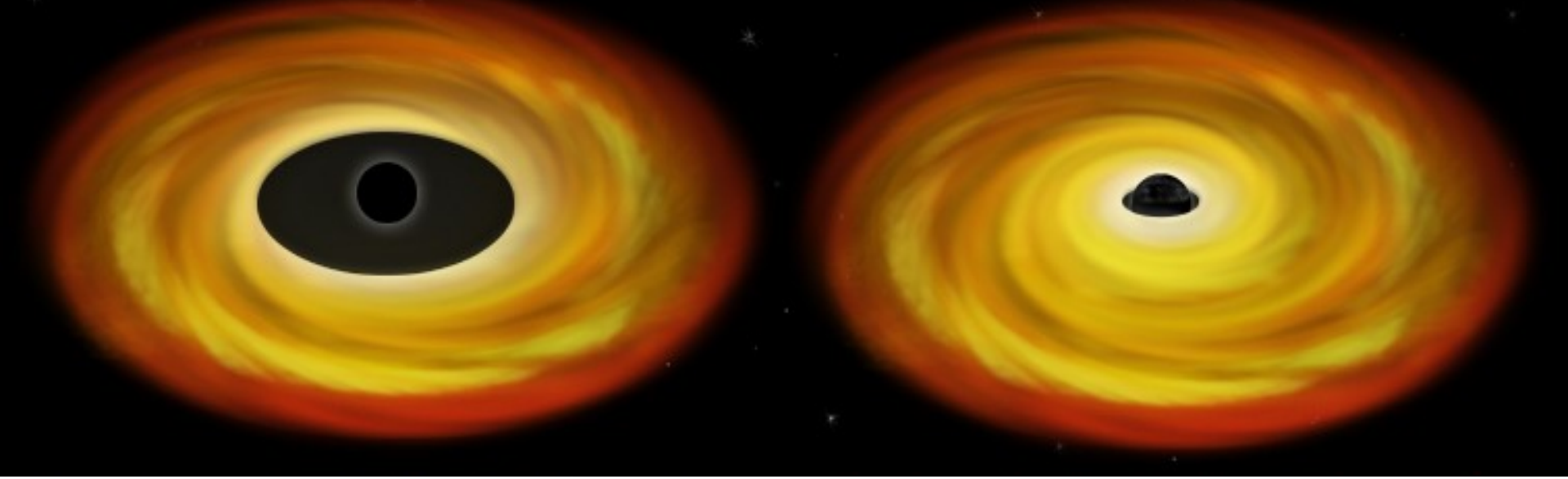
XTE J1650-500 from BeppoSAX

(G. Miniutti)

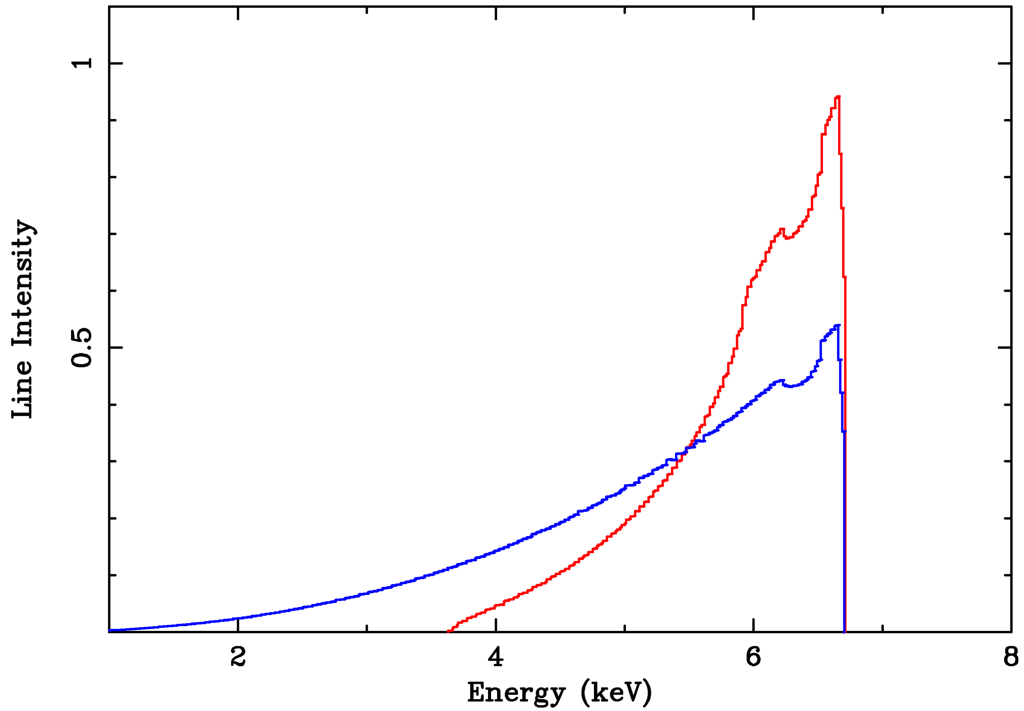


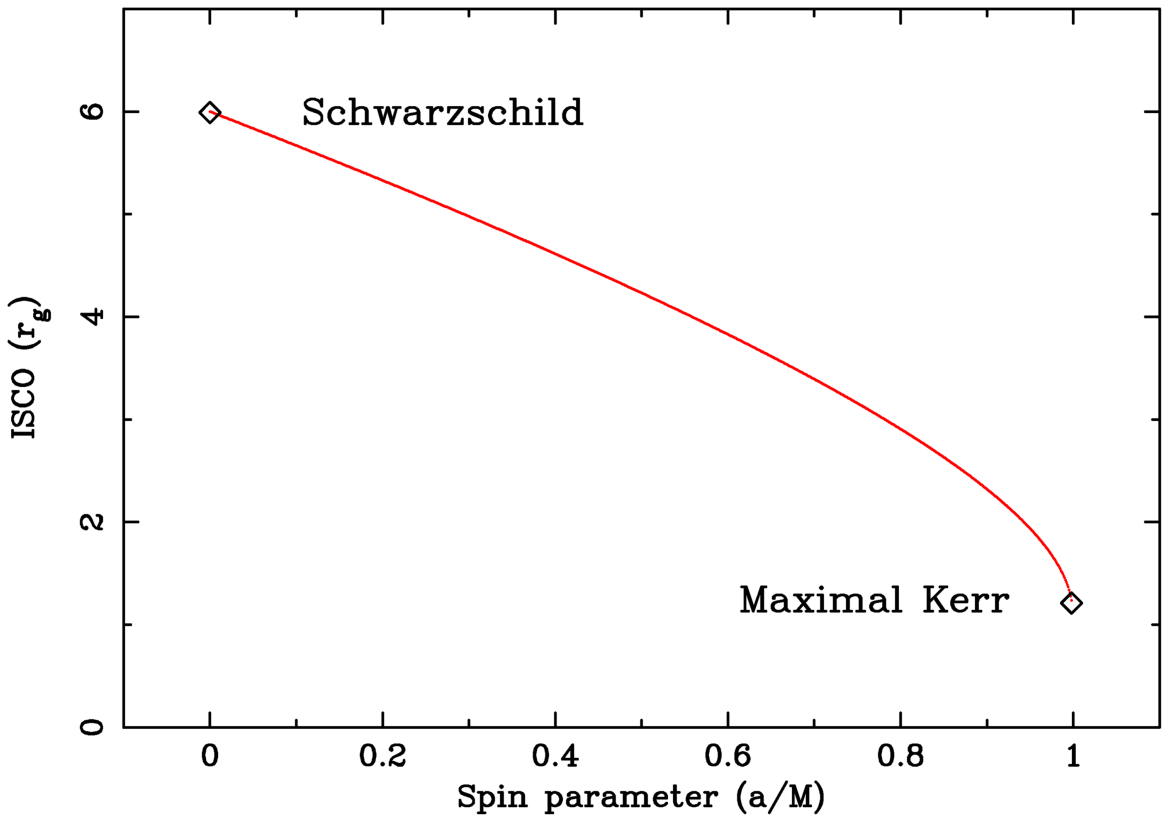


Soft excess – broad iron line – Compton hump



SPIN





Assumption: measurements of r_{ms} determine (or constrain) a

ISCO conjecture

- Measure R_{in} from spectra $\Rightarrow R_{ISCO} \Rightarrow$ spin?
- Maybe not, due to B decreasing R_{in} (Begelman & Reynolds, Gammie, Krolik, Hawley…)??
- BUT low ionization $\Rightarrow$ thin, slowly accretion disc, which is not plunging, so $R_{in} = R_{ISCO}$

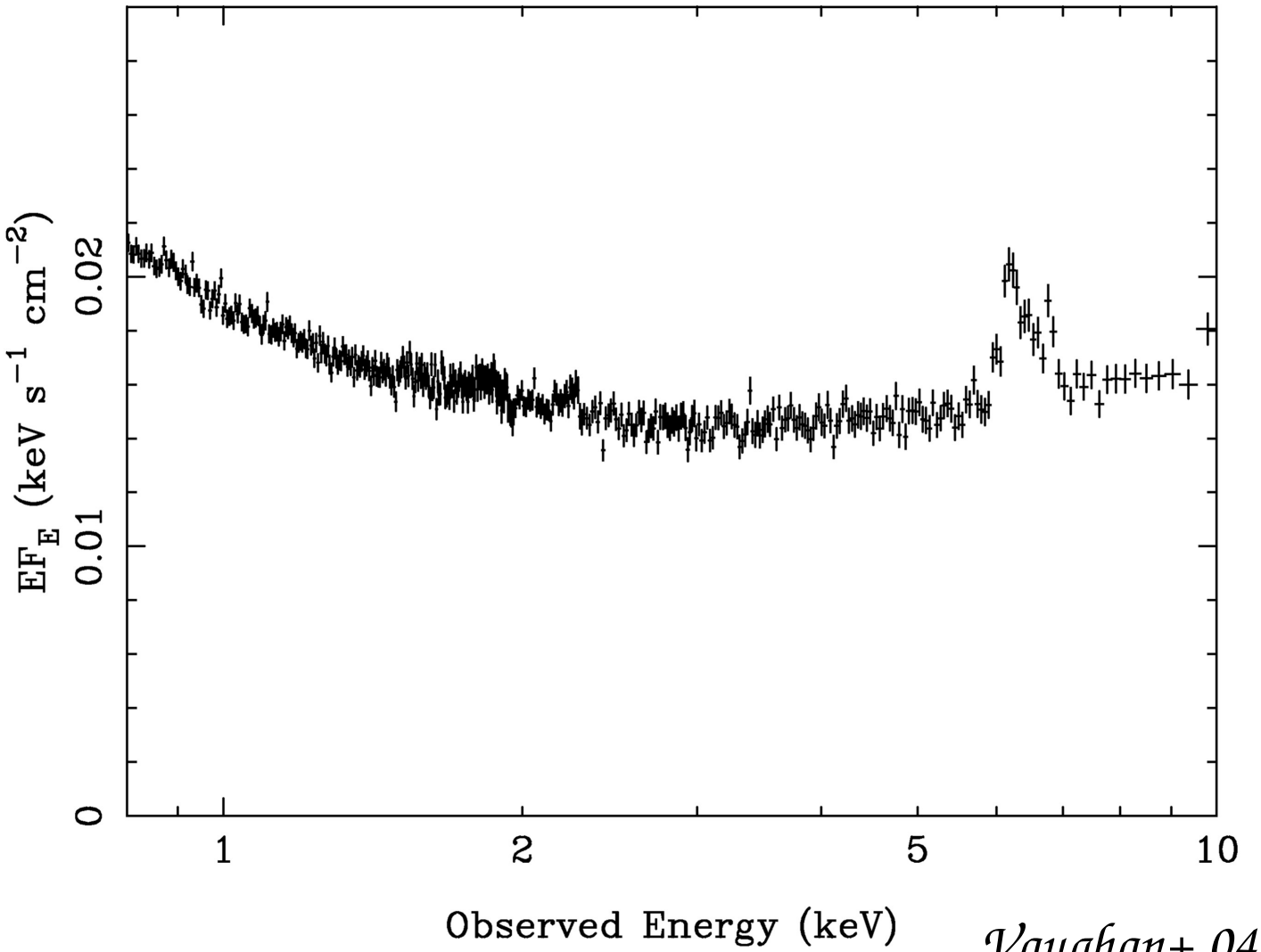
$$\frac{\xi}{100} = 3000\left(\frac{f}{0.1}\right)\left(\frac{v_{\mathrm{rad}}/c}{0.1}\right)$$

We conjecture that R_{in} measured from iron line is within $1r_g$ of R_{isco}

so red wing measures SPIN!

NO Broad Line (apparently)

Ark 120



Vaughan+ 04

Cautionary remarks

- *Narrow 6.4~keV components are expected from distant matter*
- *Iron line and reflection continuum need to be self-consistent and blurred together*
- *Warm, partial, outflow and other absorption components need to be considered*

- *Iron abundance could be a factor (high in MCG-6 and some NLS1, low in other objects)*

- *Going within $6GM/c^2 = 3R_g$ can make a large difference in increasing the blurring and so making features less obvious, particularly if abundances only less than solar*

Complex absorption

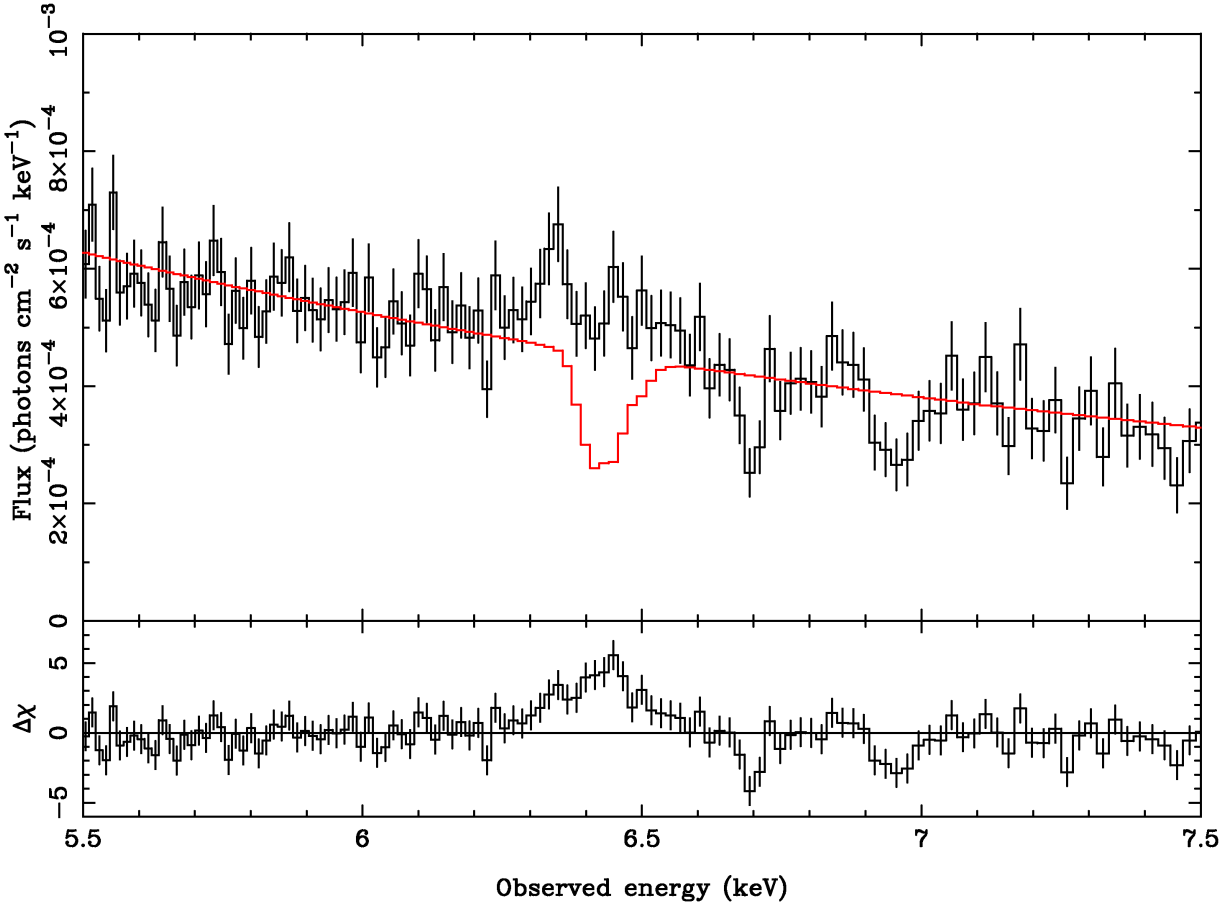
- *Spectral models can be made for many sources by using complex absorption (partial covering etc)*
- *These can be tested/rejected by:*

  higher spectral resolution

  broader bandwidth

  variability

Young+05

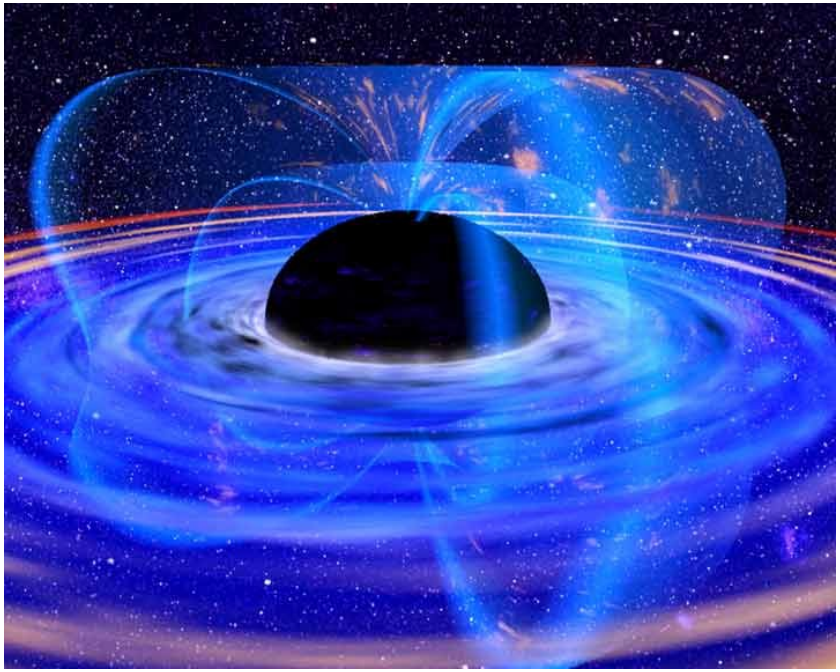


Chandra HETG

Constrains absorption by highly ionized species

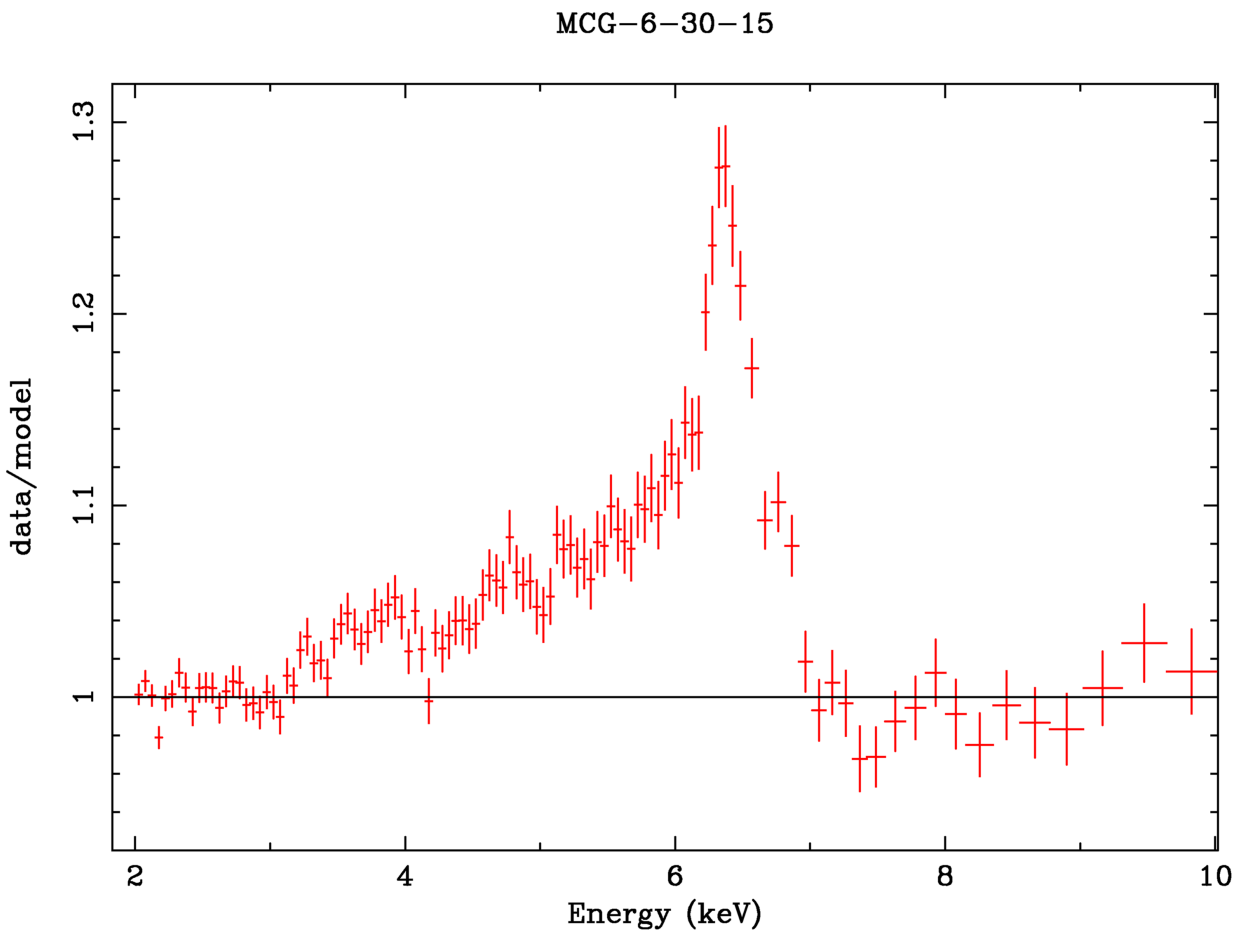
Implies that simple absorption models for red wing do NOT work

XMM-Newton observations of MCG-6-30-15 in the 2-10 keV band



Wilms et al 2002; Fabian et al 2002; Vaughan et al 2002; Fabian & Vaughan 2002; Ballantyne et al 2003; Reynolds et al 2003; Vaughan & Fabian 2004

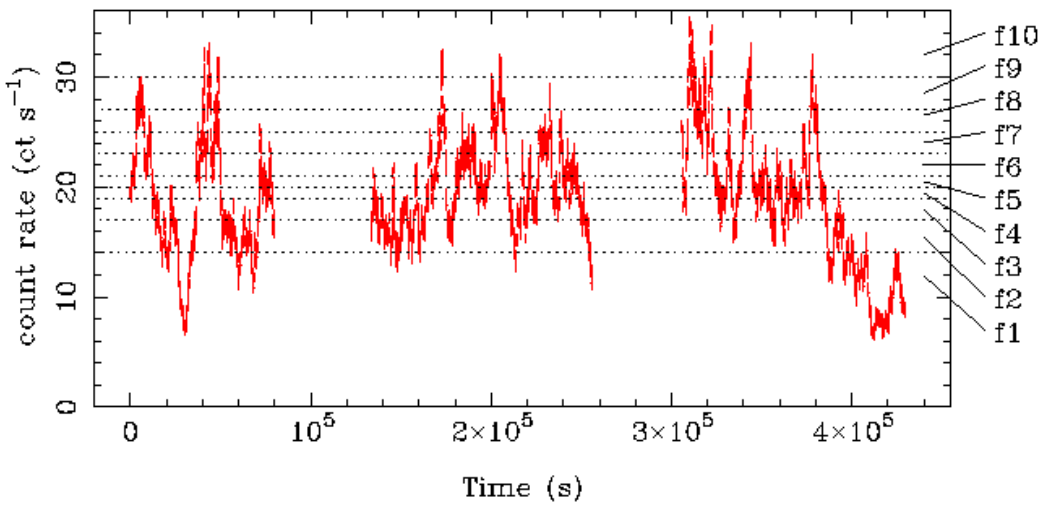
Understanding the spectral behaviour

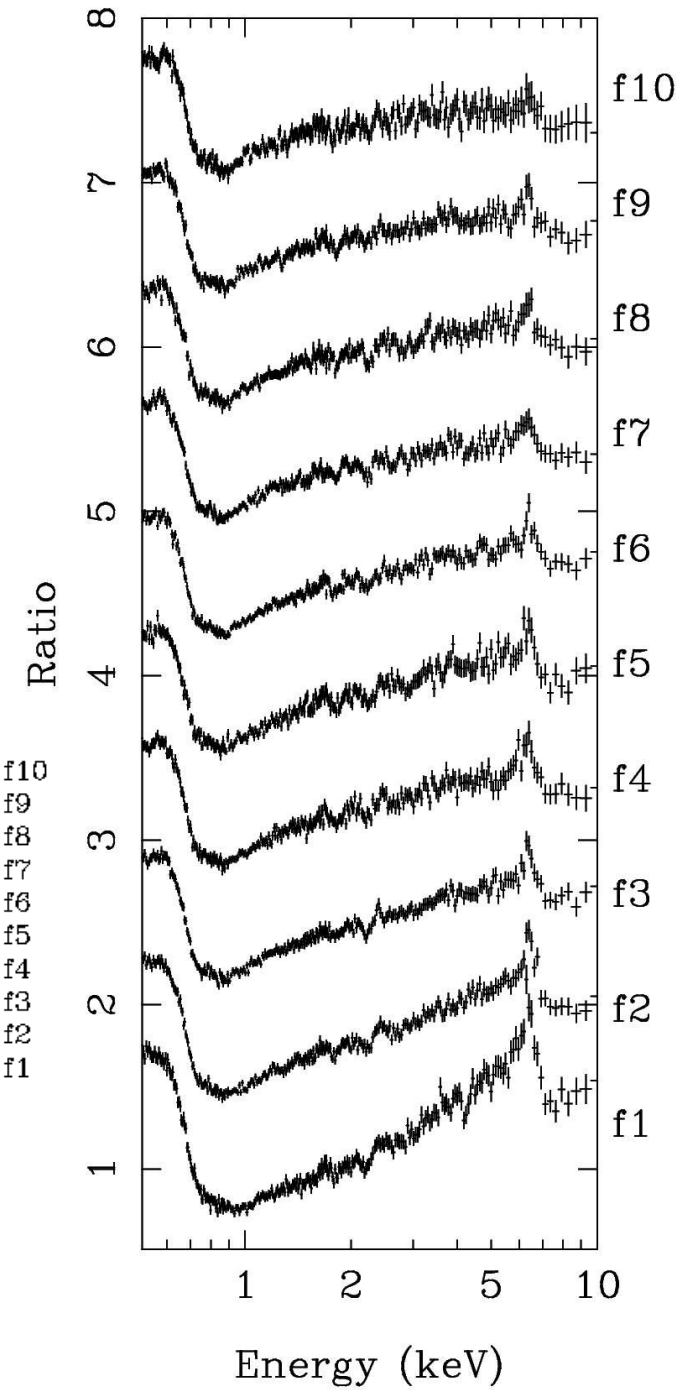


How does it vary?

Iwasawa+ Shih+ Fabian+ Vaughan+ McHardy+ Uttley+ Reynolds+

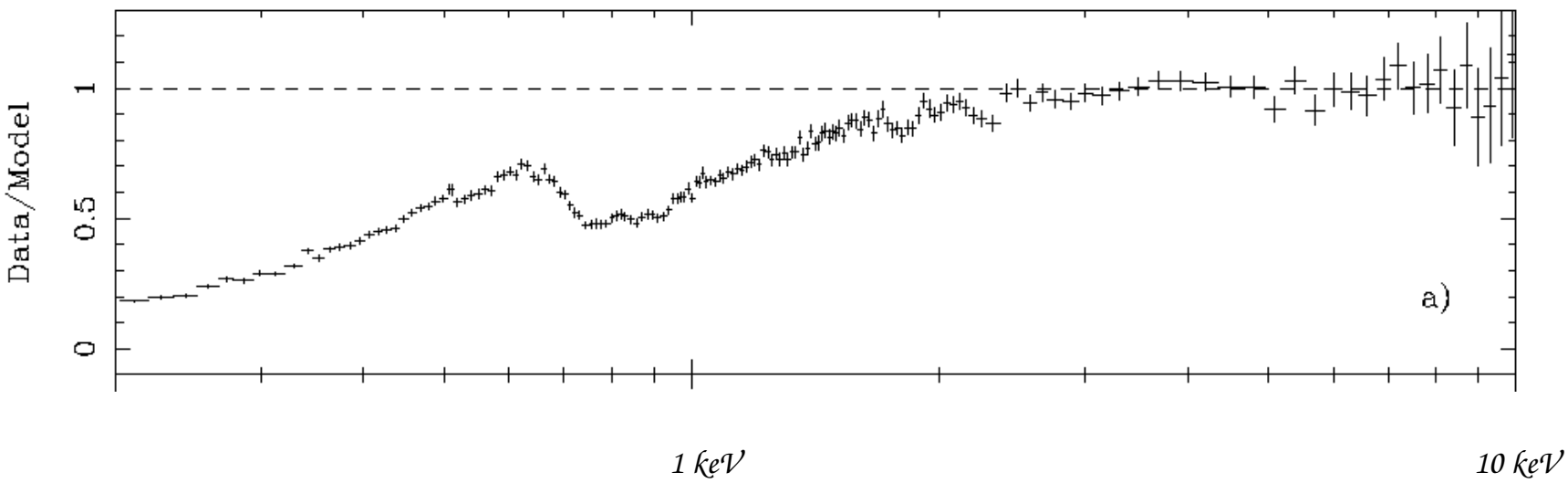
Spectral changes seen in 10 flux slices





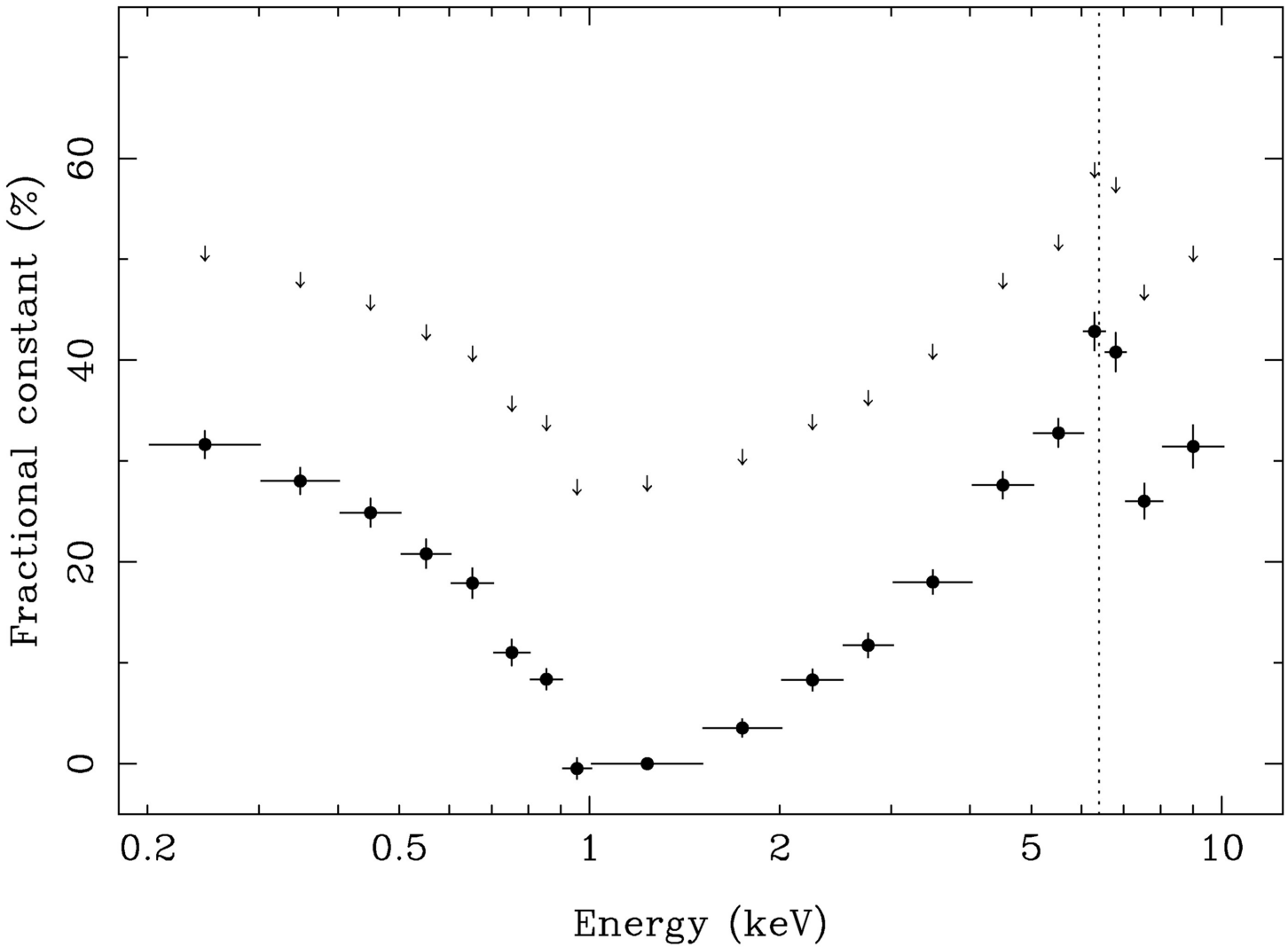
Difference spectrum: (High flux)-(Low flux)

is a power-law modified by absorption



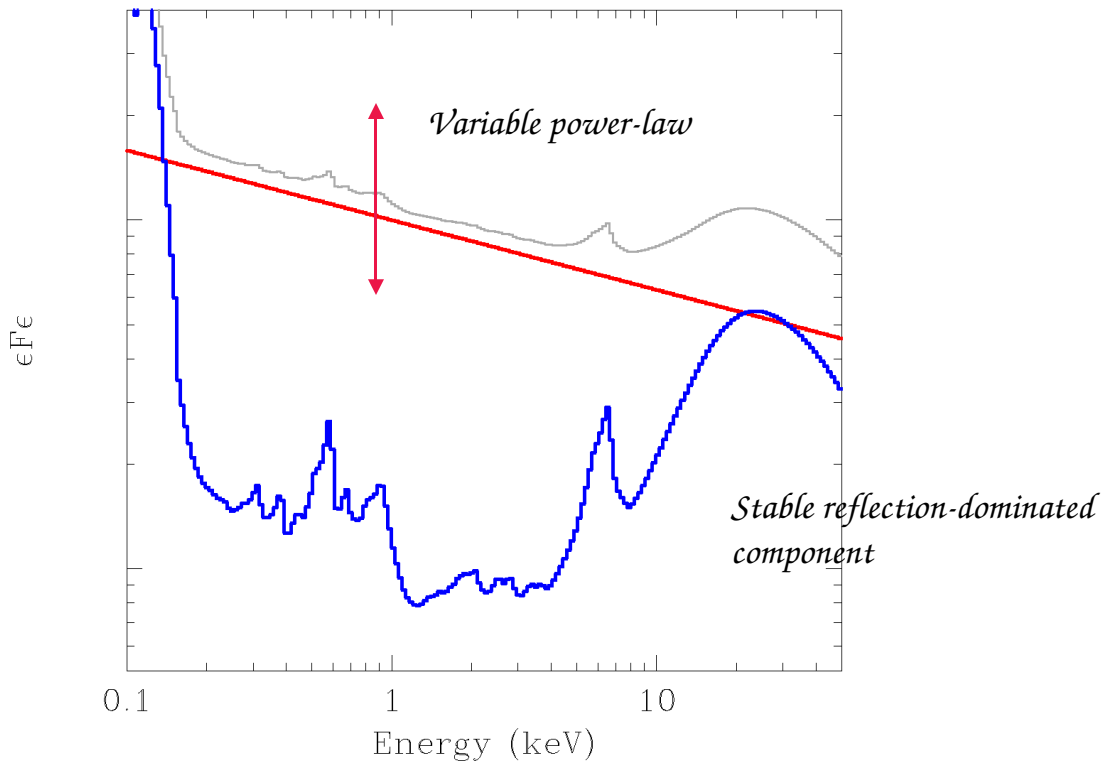
So we know which large scale features are due to absorption

Flux-flux variability



Vaughan+Fabian 04

Schematic picture of the two-component model



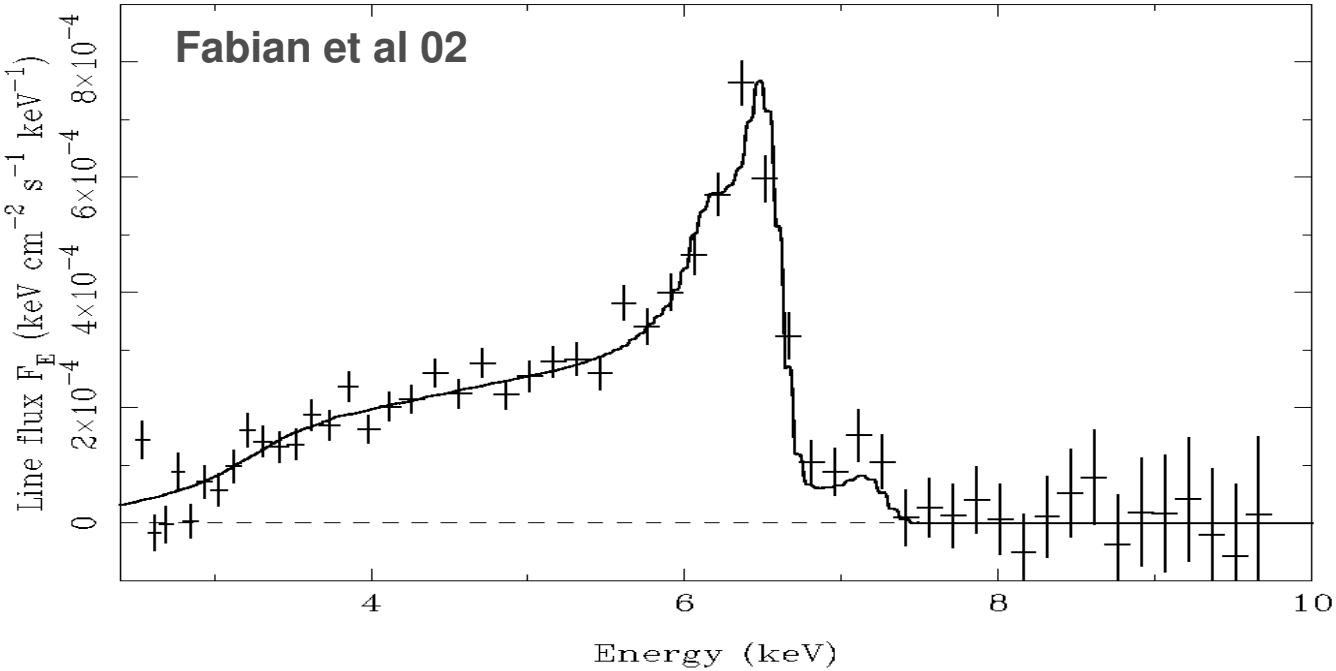
Summary of MCG-6-30-15 observations:

1. The broad Fe line

A broad Fe line is present in all flux states

Tanaka et al '95 – Iwasawa et al '96 - Guainazzi et al '99 – Wilms et al 01 – Fabian et al 02 …

Fe line red wing suggests a rotating Kerr black hole



Summary of MCG-6-30-15 observations:

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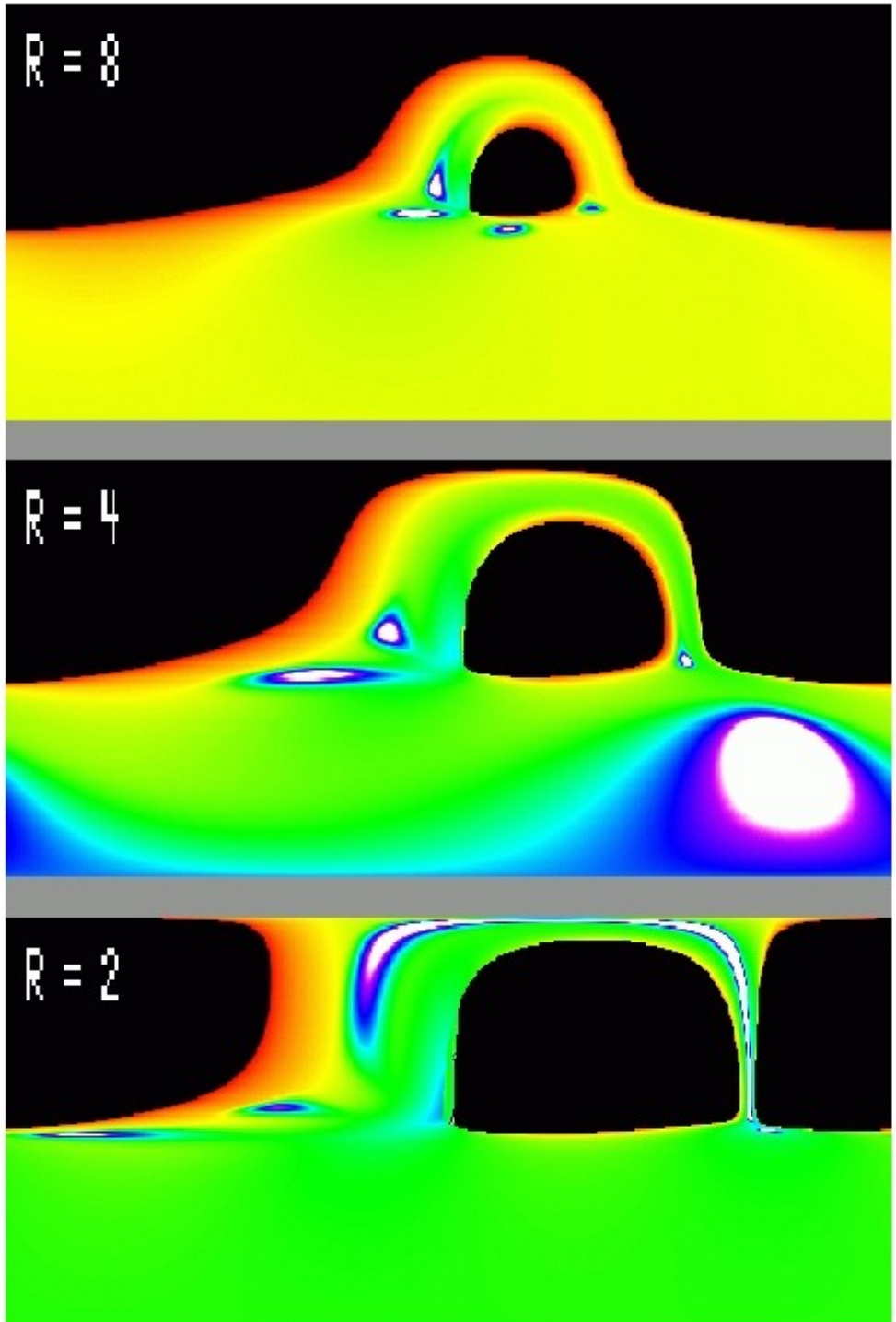
Fe line red wing suggests a rotating Kerr black hole

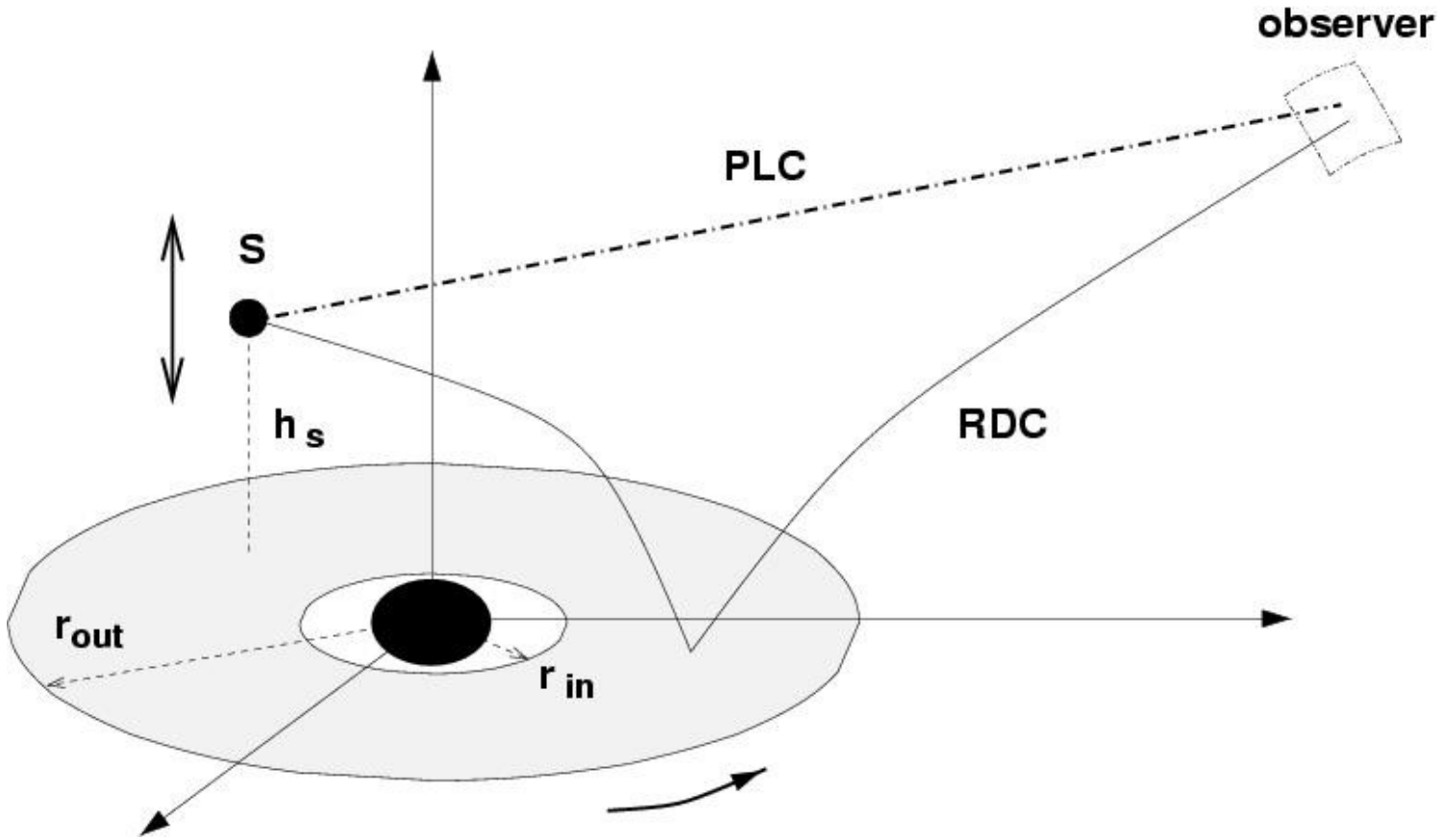
A steep emissivity profile is implied ($\beta > 3$)
possibly in the form of a broken power-law

The emissivity suggests the presence of a centrally concentrated primary source of hard X-rays

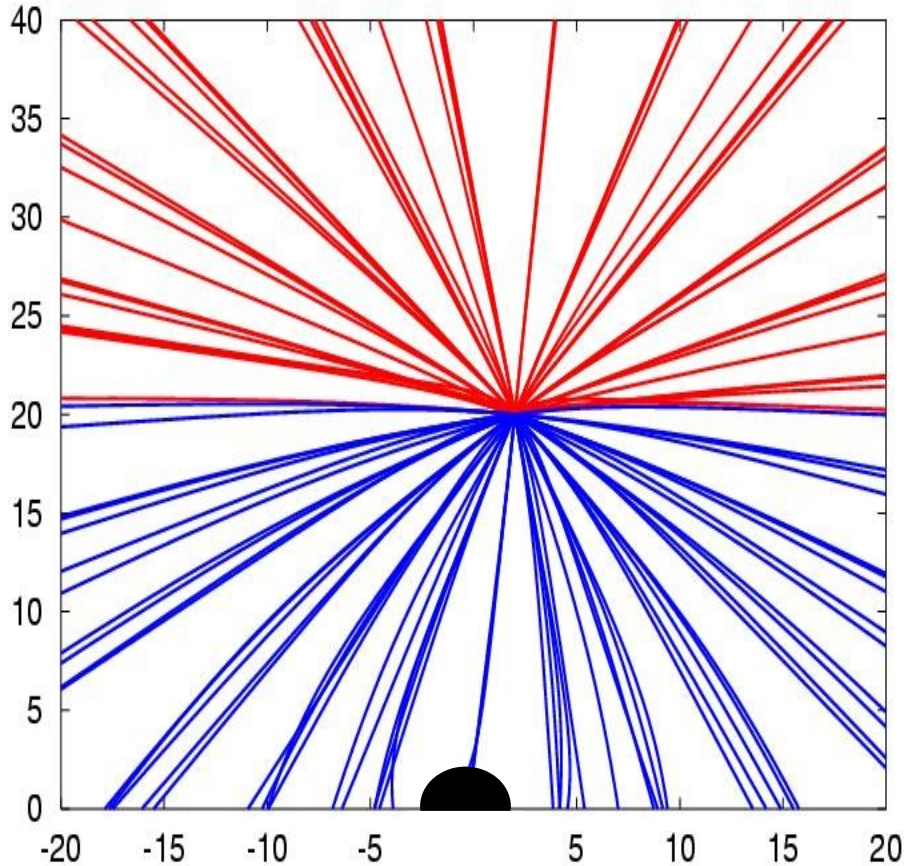
Kevin Rauch JHU

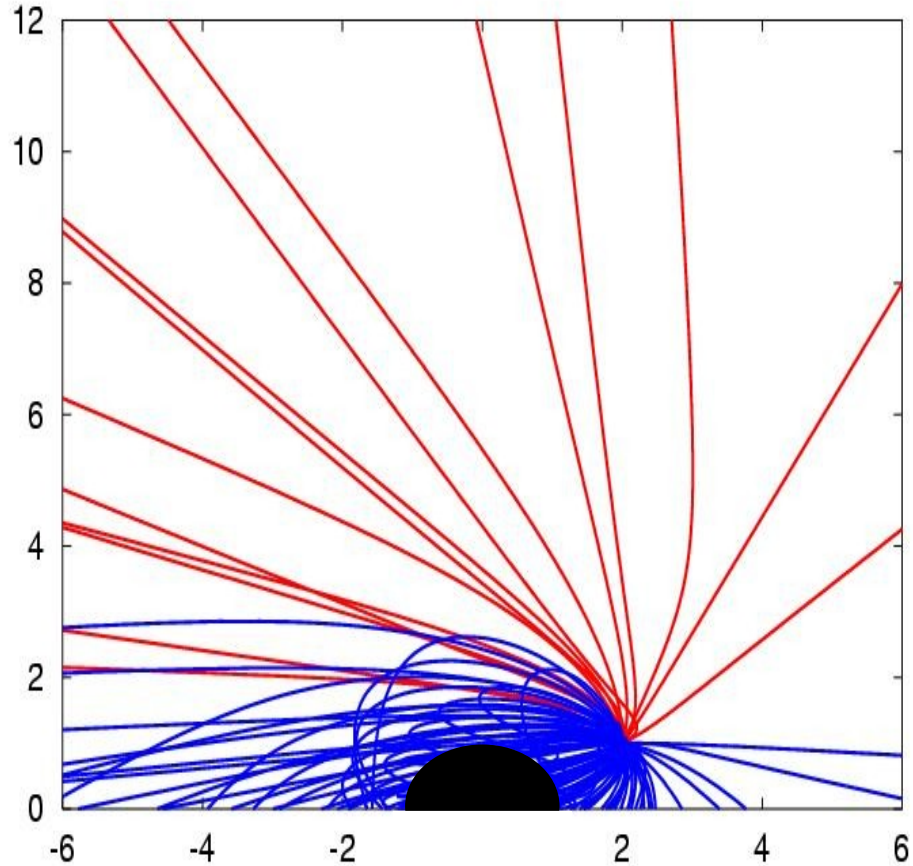


Light bending model in Kerr spacetime

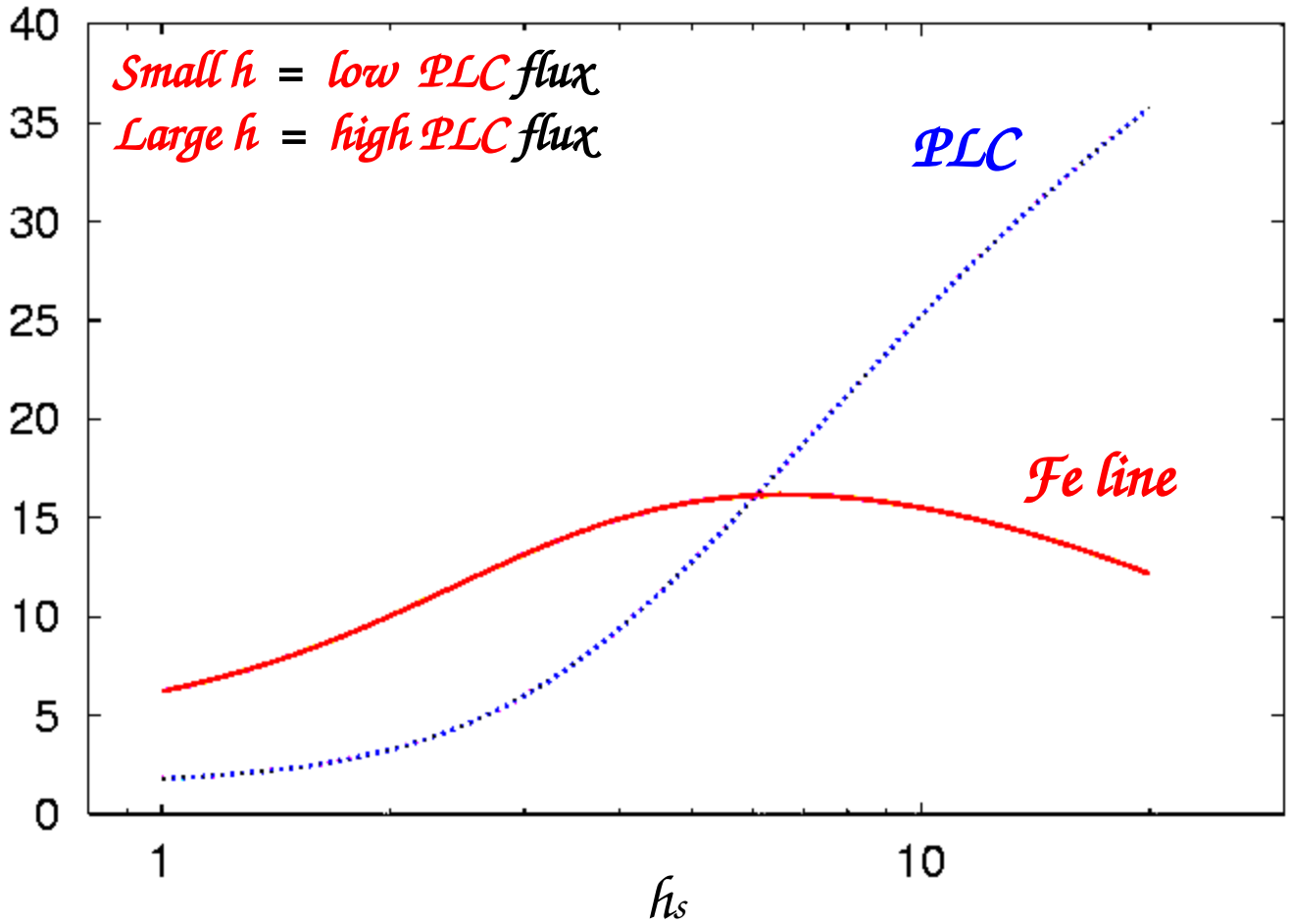


Miniutti et al 03; Miniutti & Fabian 04; earlier work by Matt et al

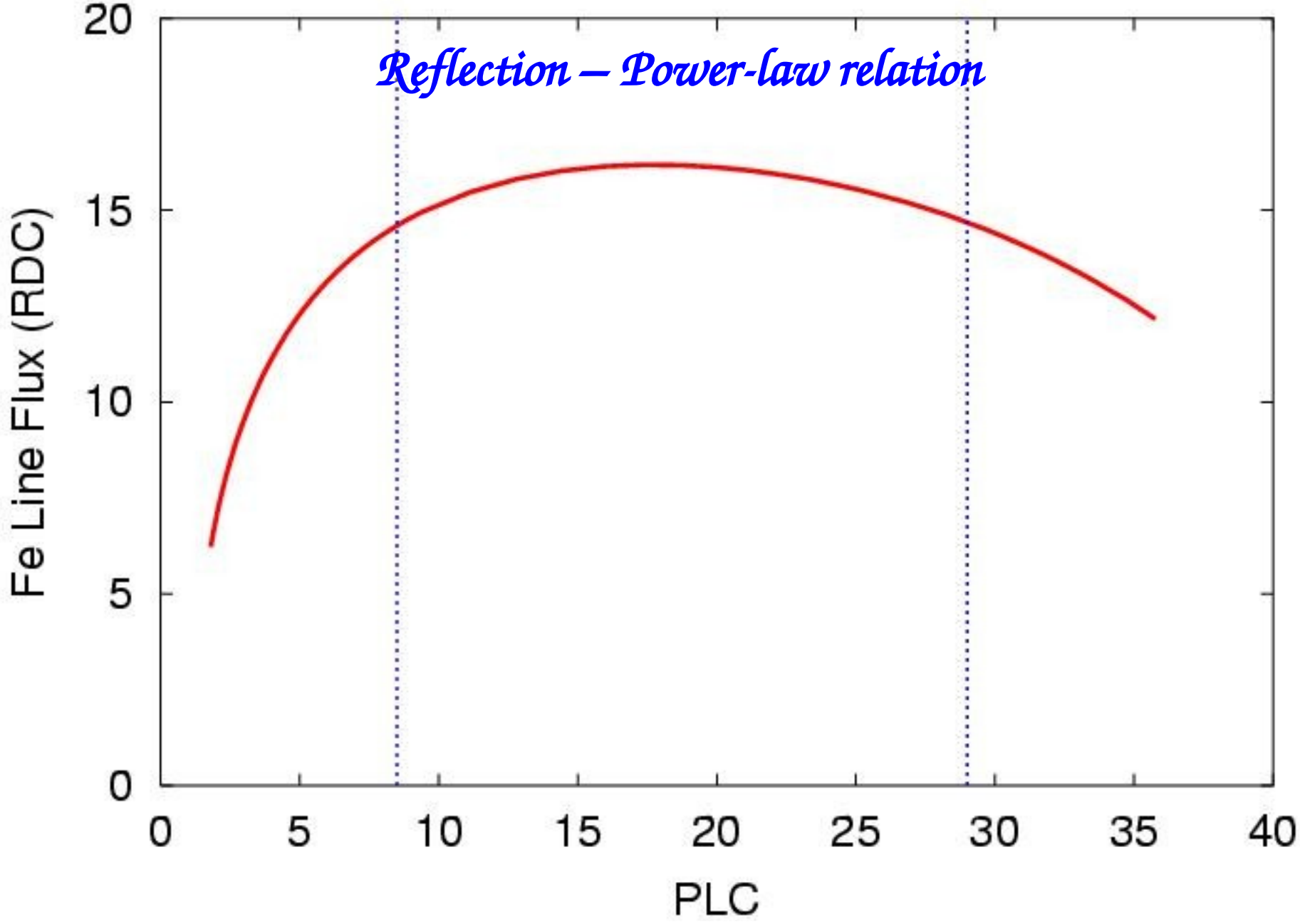

40
35
30
25
20
15
10
5
0
-20
-15
-10
-5
5
10
15
20

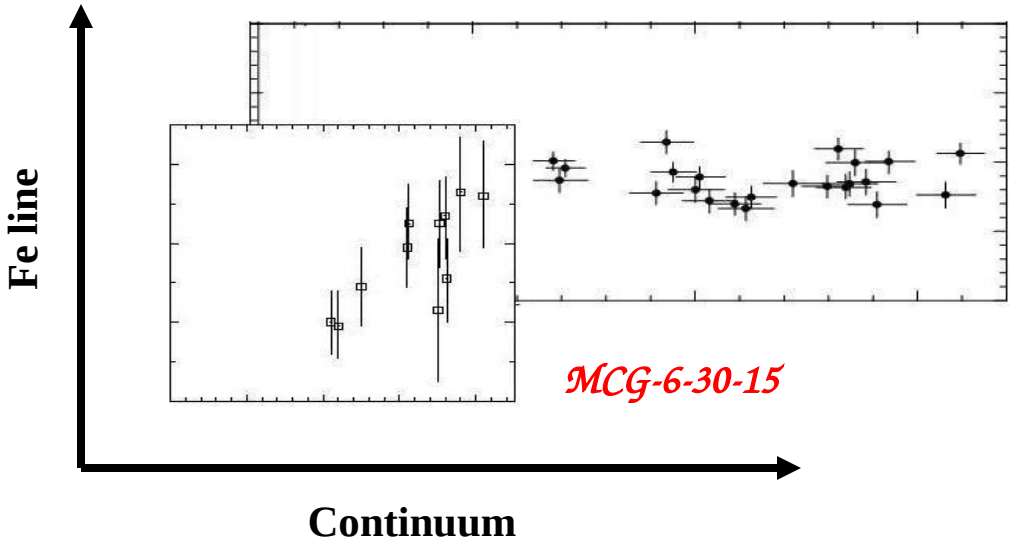

12
10
8
6
4
2
0
-6
-4
-2
2
4
6

PLC and Fe line variability induced by light bending when an intrinsically constant source changes height

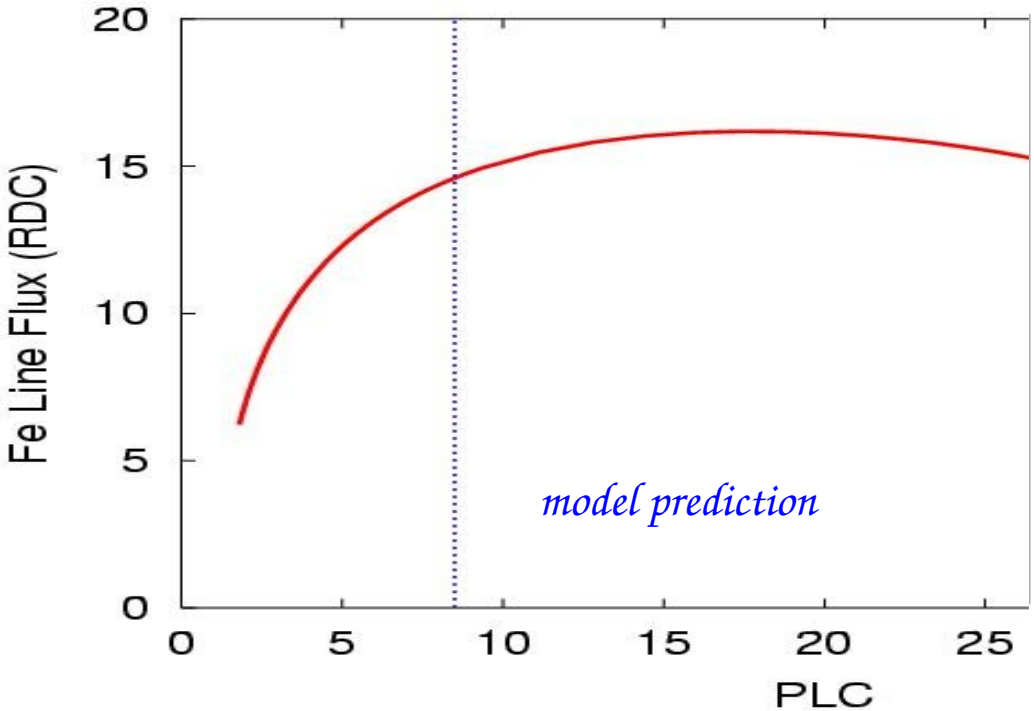


The Fe line varies with much smaller amplitude


Reflection – Power-law relation
Fe Line Flux (RDC)
PLC
0
5
10
15
20
0
5
10
15
20
25
30
35
40



Low flux results from Reynolds et al



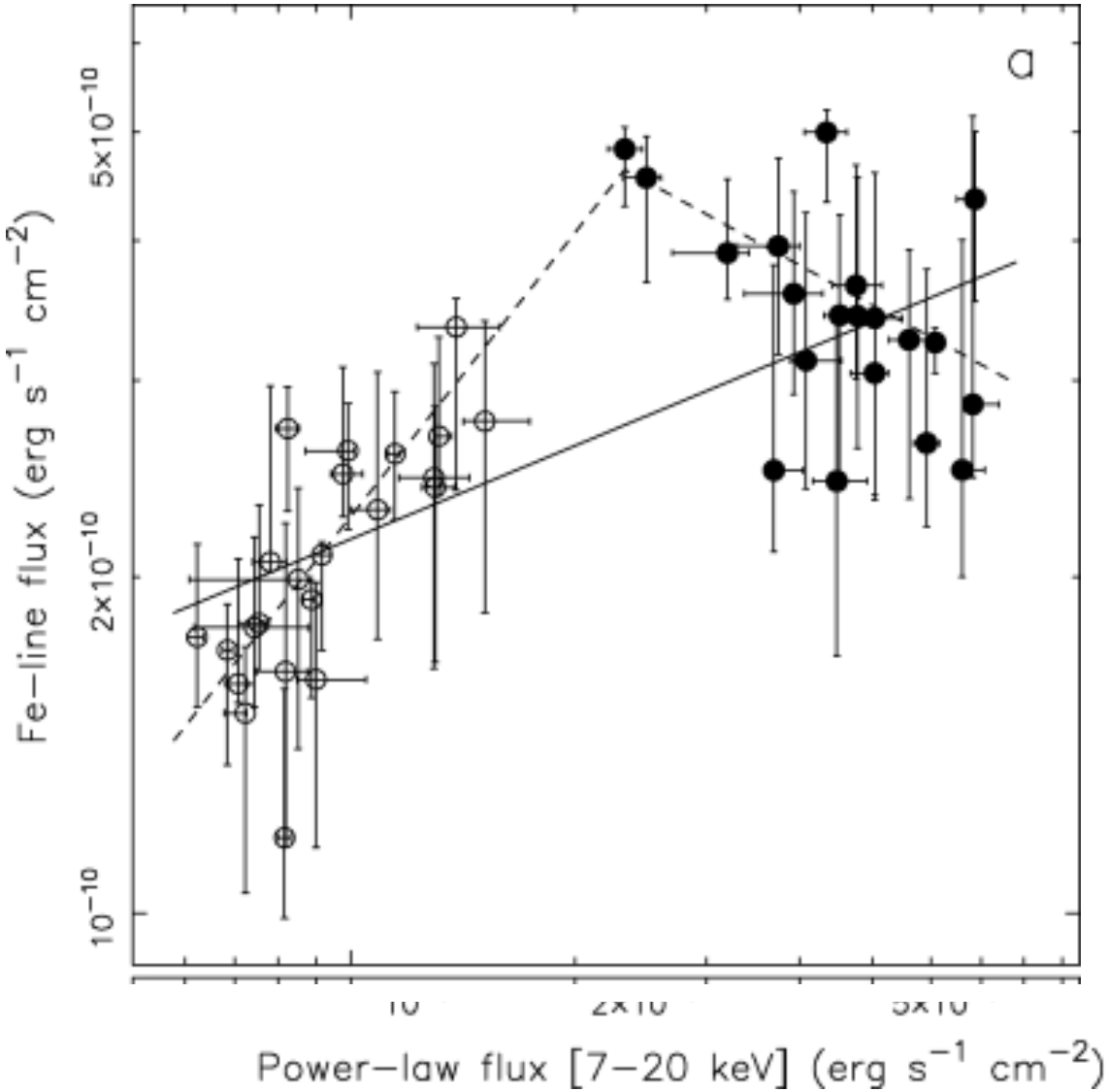
more details on the model:

GM et al, 2003, MNRAS 344 L22

GM & Fabian, 04

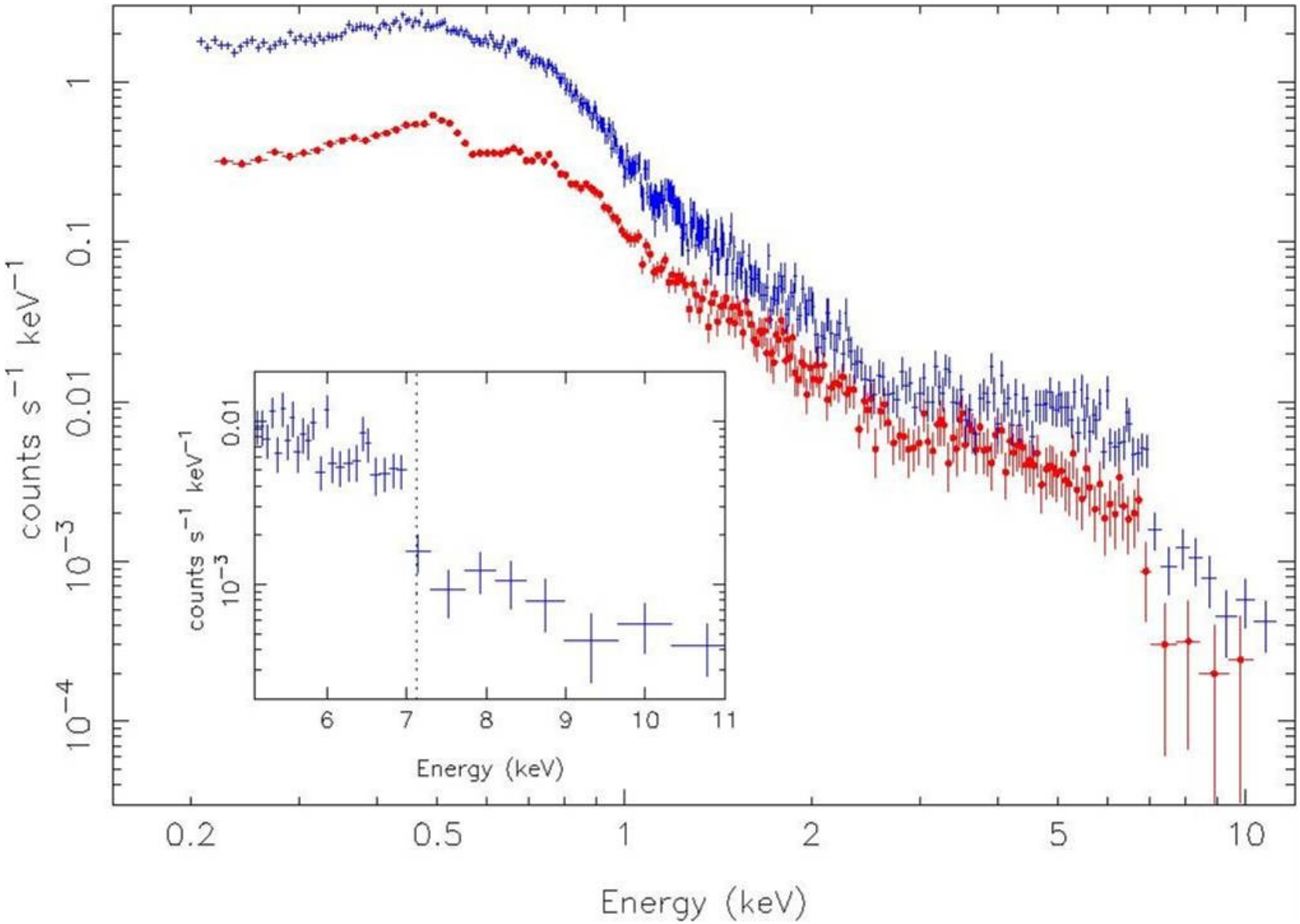
GM et al, 04

XTE J1650-500 during outburst

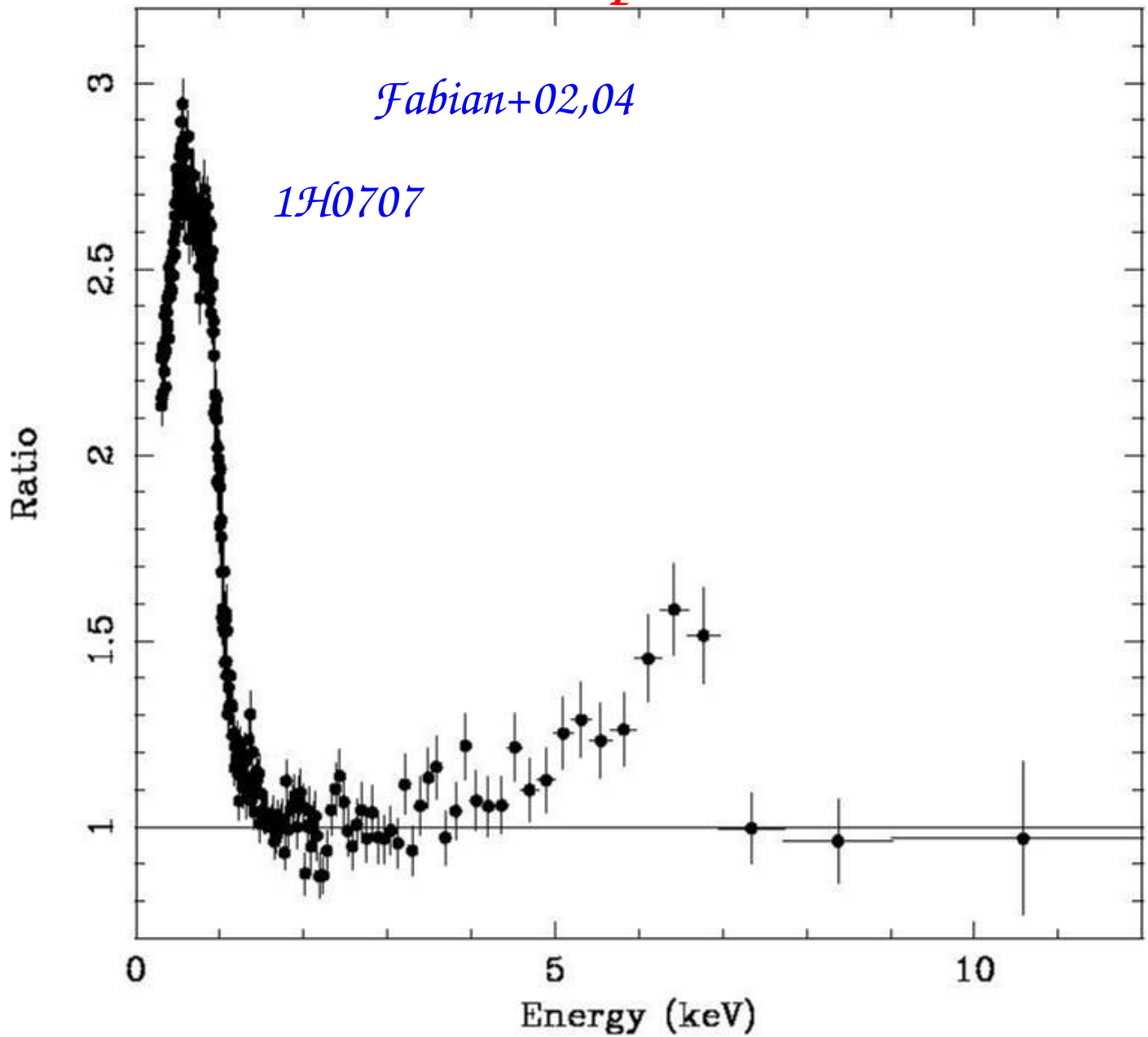


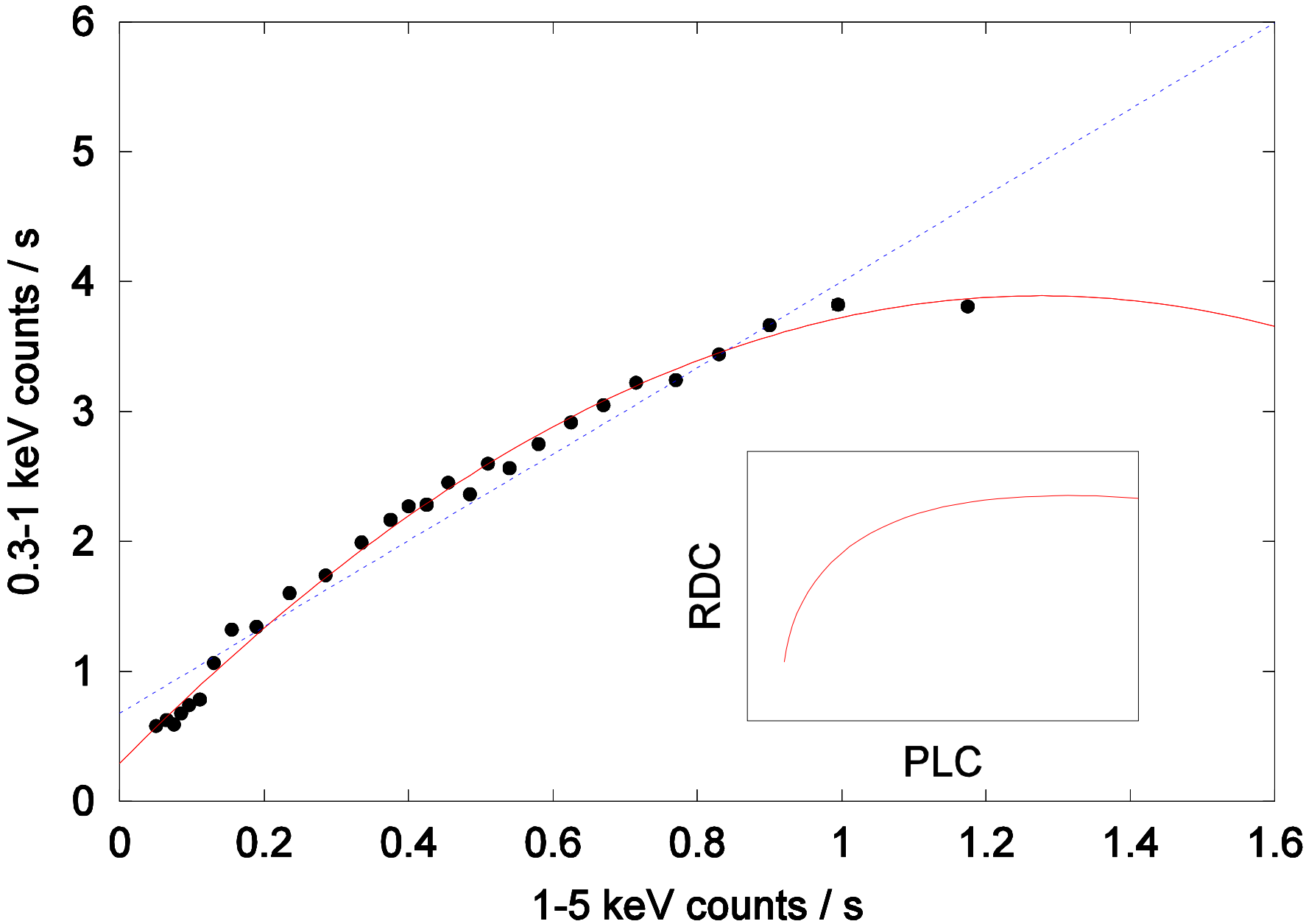
Rossi +05

1H0707 Boller+02; Gallo+04

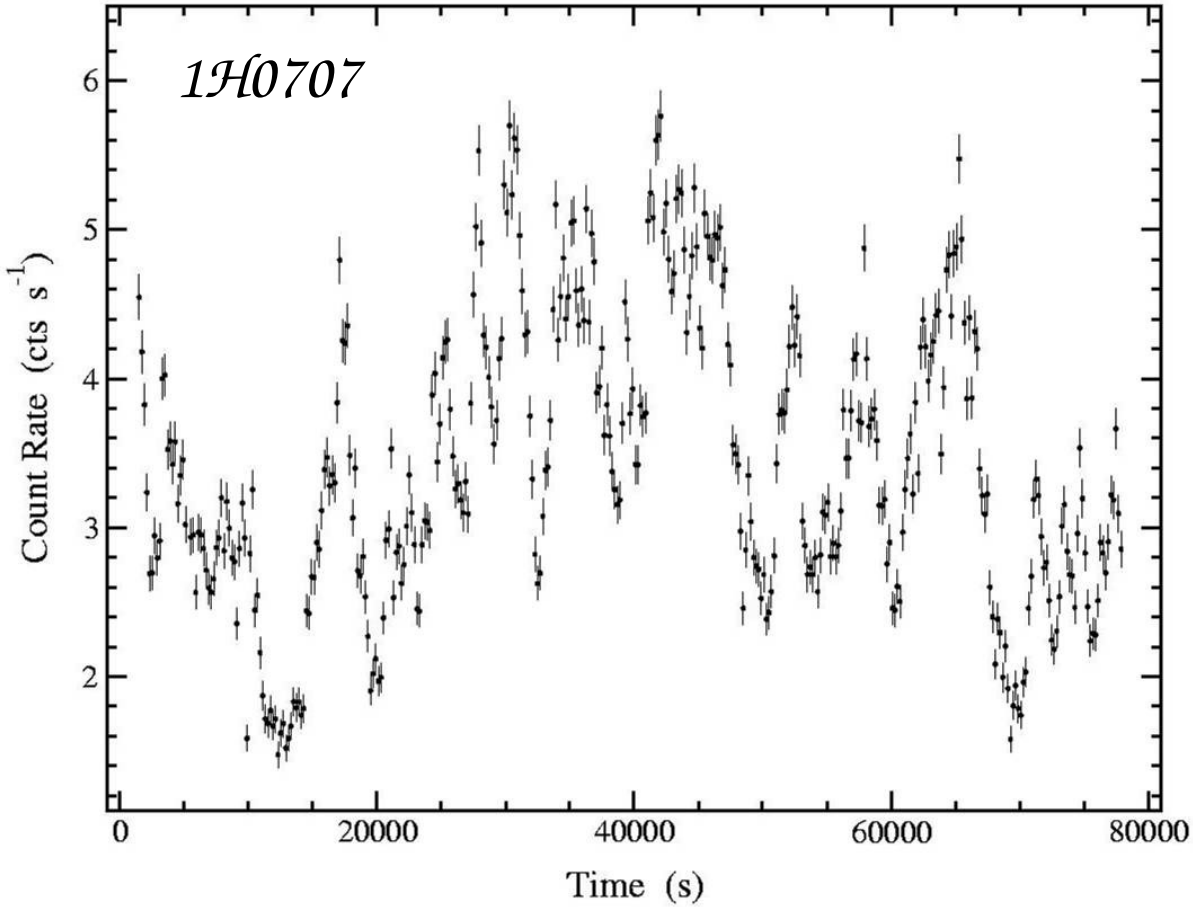


Is it absorption or a line?

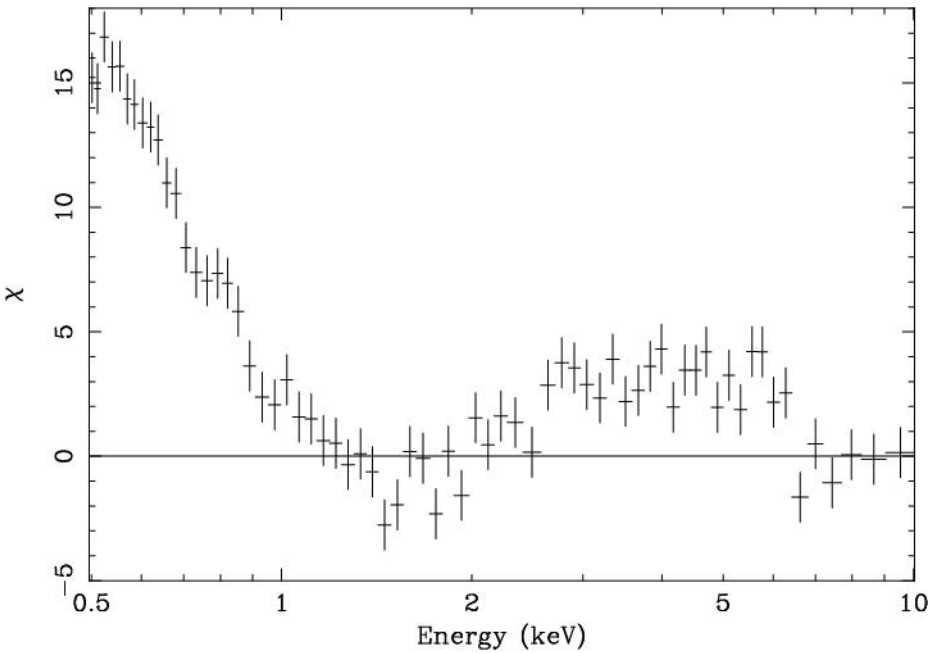


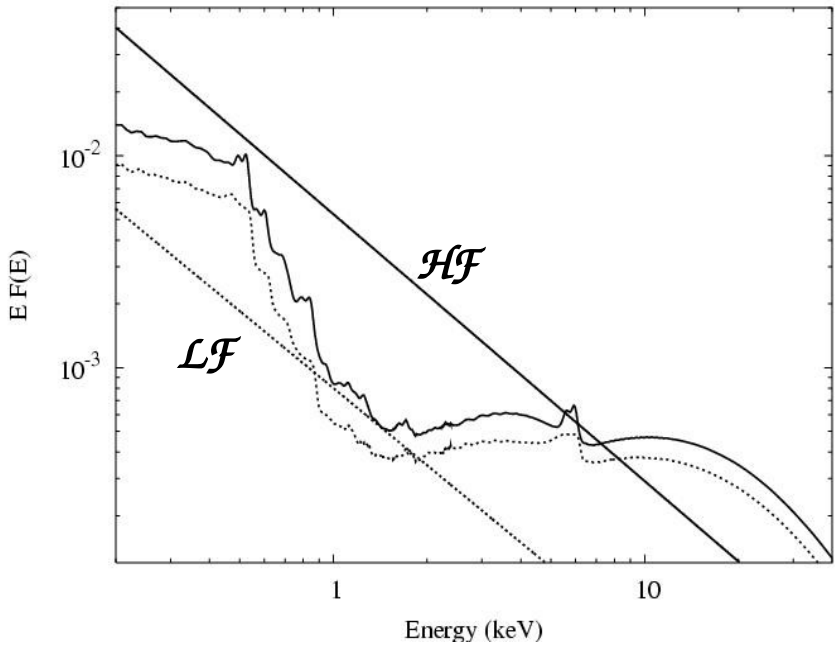

0.3-1 keV counts / s
1-5 keV counts / s
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
RDC
PLC

Rapid spectral variability of NLS1 explained by GR light bending effects if source within 6m



1H0439-577 *Pounds+04; Fabian+05*



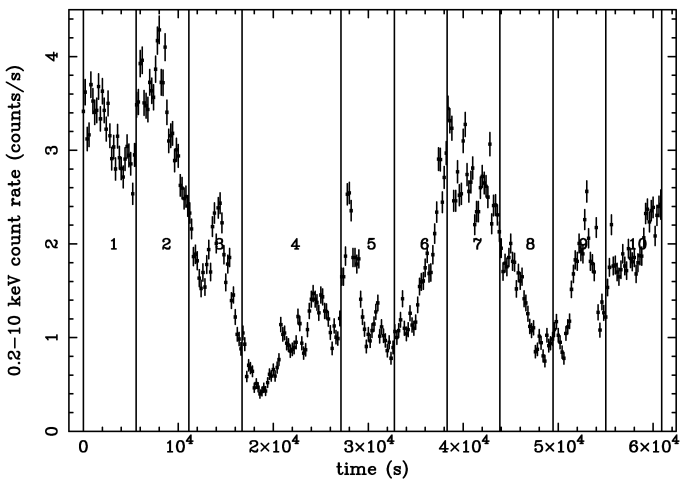


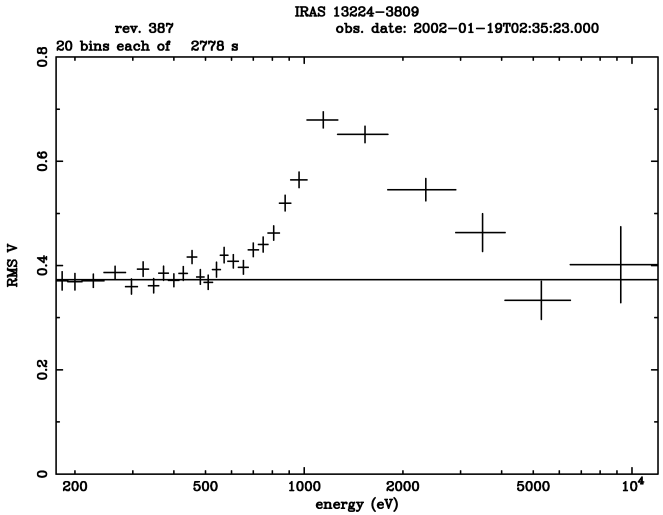
In lowest state the spectrum is almost completely reflection-dominated

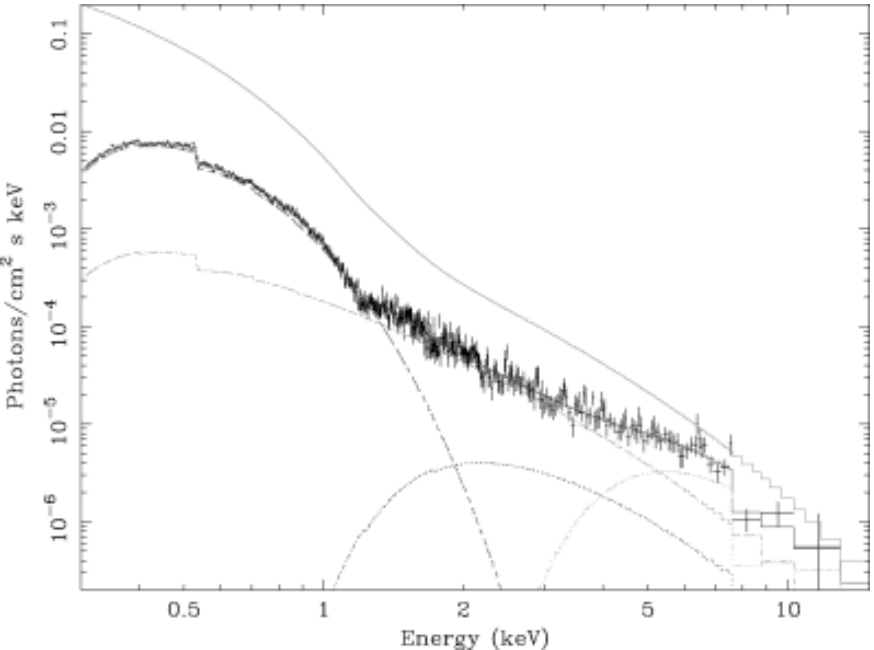
The reflection component requires strong relativistic blurring
(and implies the disc extends down to 2 grav radii)

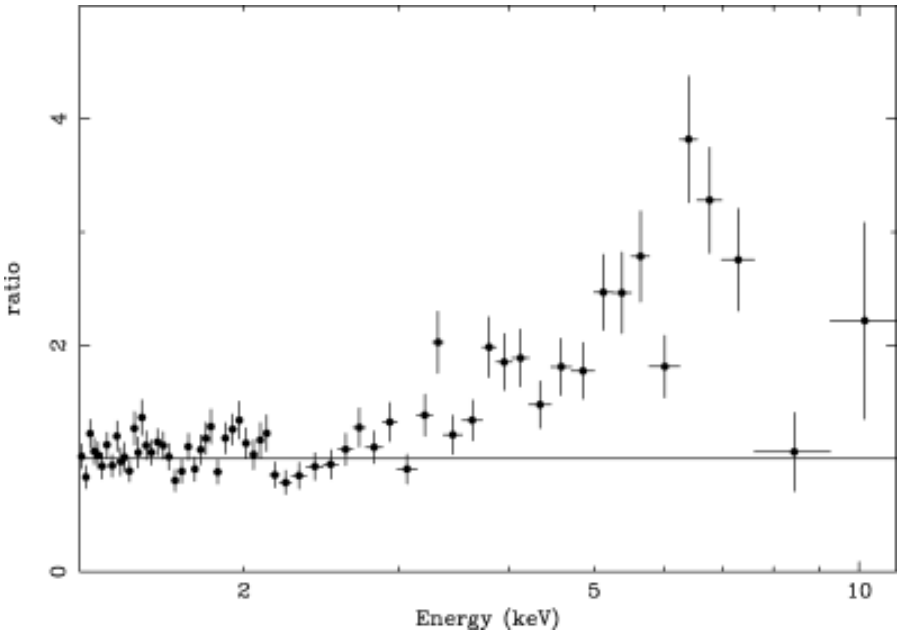
IRAS13224

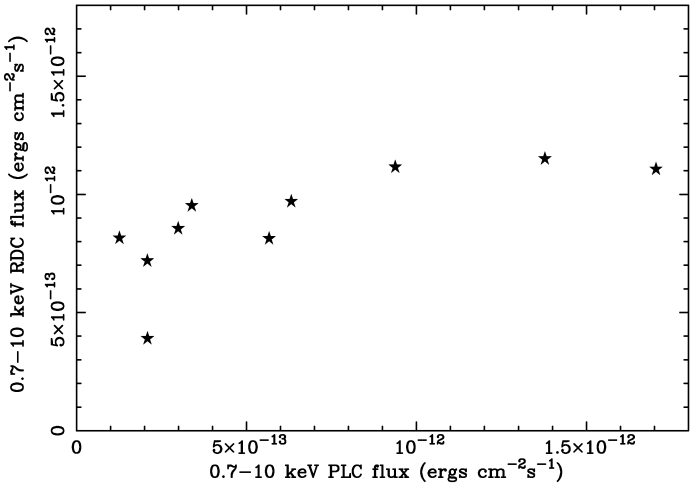
G Ponti et al (in preparation)

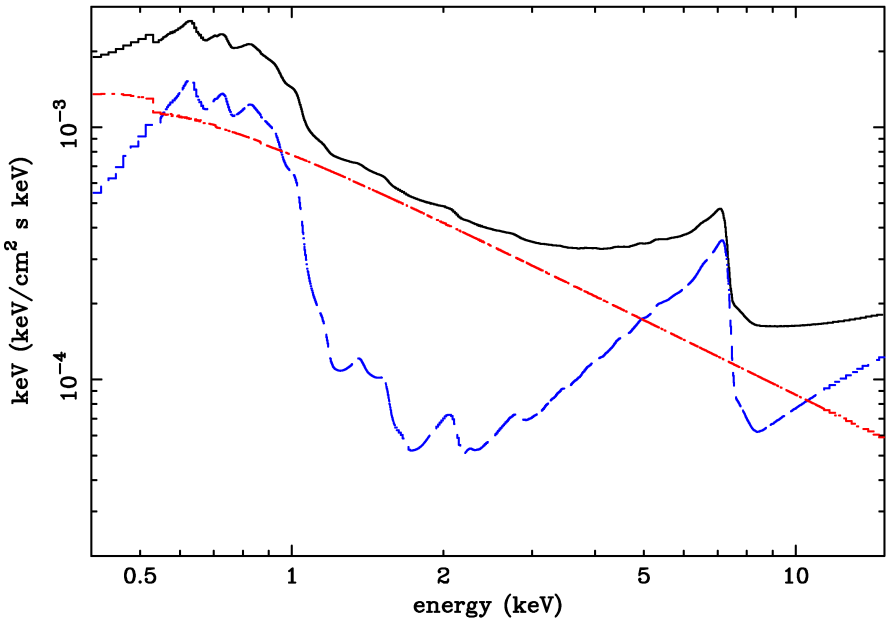


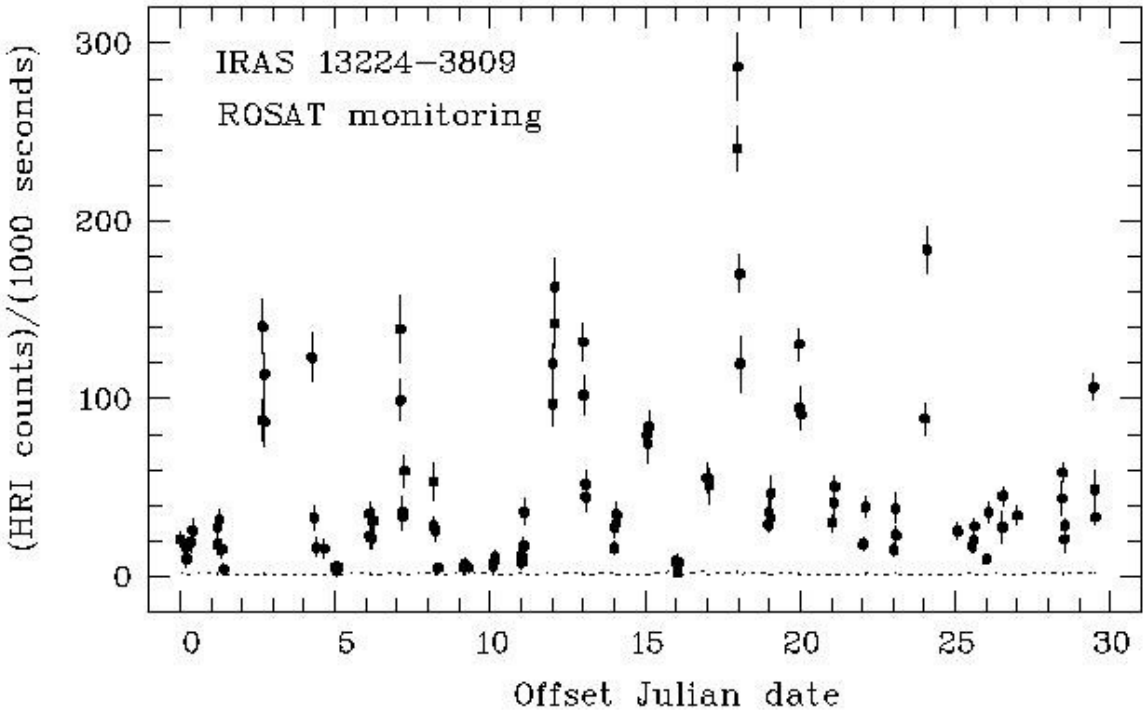







0.7−10 keV RDC flux (ergs cm^{-2}s^{-1})
0.7−10 keV PLC flux (ergs cm^{-2}s^{-1})
0
5×10^{-13}
10^{-12}
1.5×10^{-12}

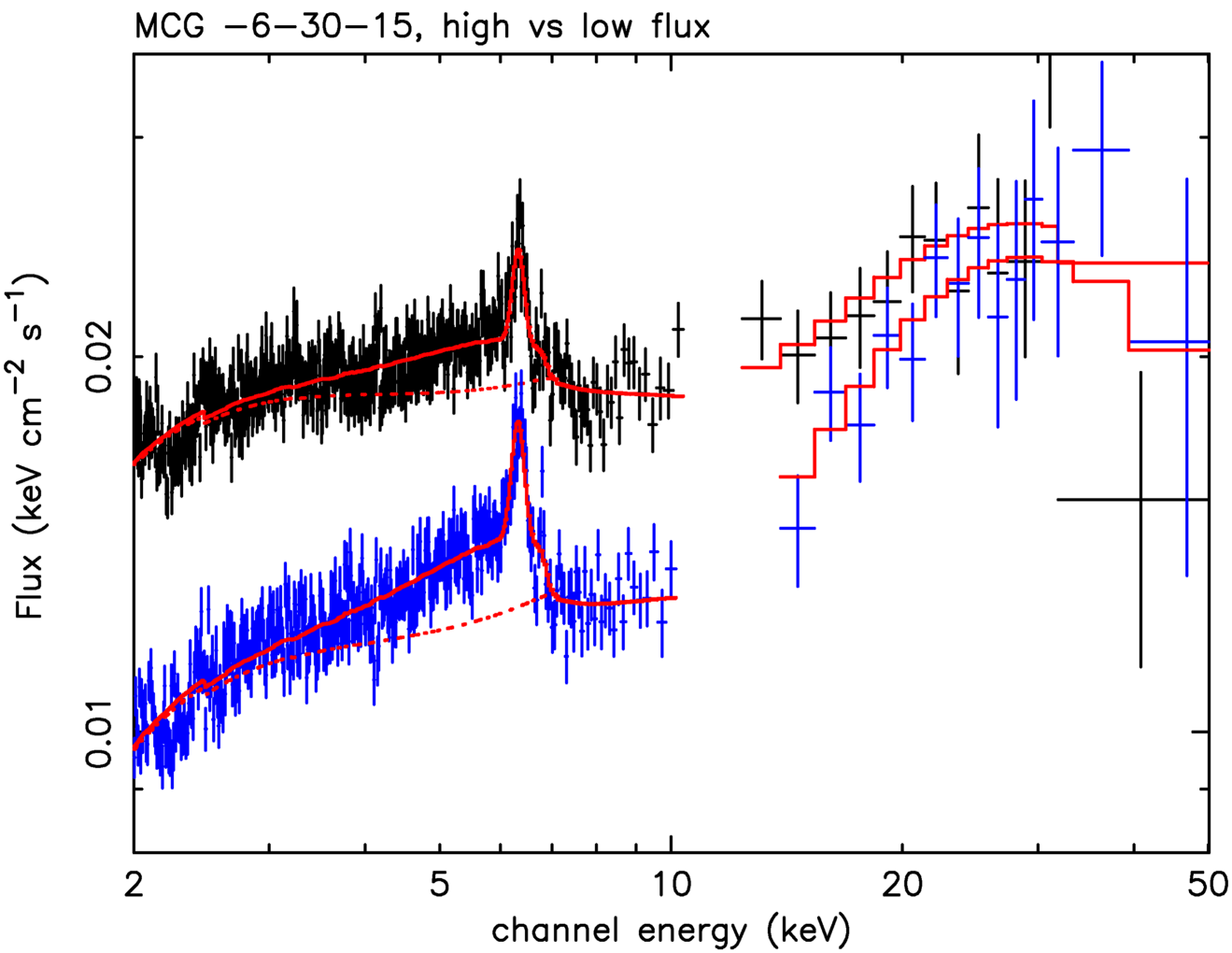

keV (keV/cm^2 s keV)
10^{-3}
10^{-4}
0.5
1
2
5
10
energy (keV)


IRAS 13224−3809
ROSAT monitoring
(HRI counts)/(1000 seconds)
0
100
200
300
0
5
10
15
20
25
30
Offset Julian date

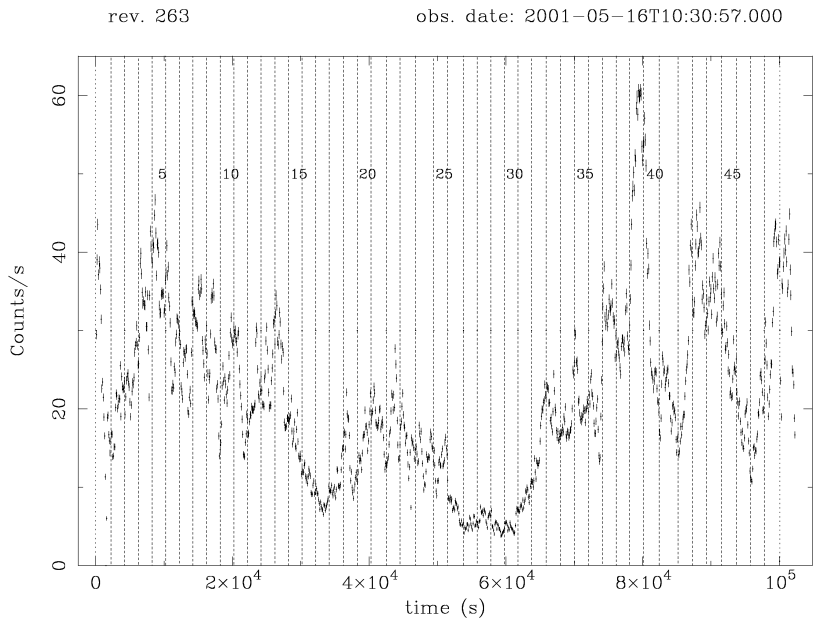
Broad lines and Spin

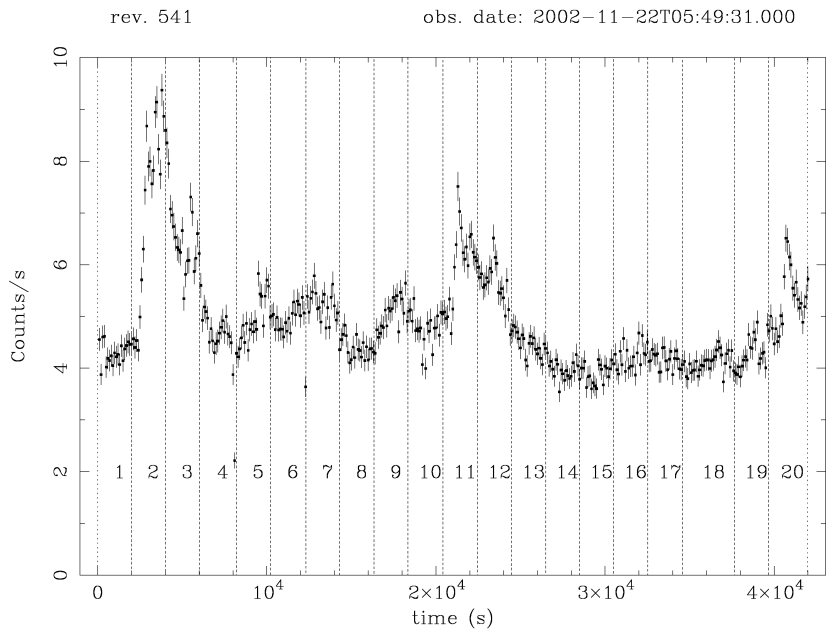
- *Moderate to high spin common (Volonteri+04)*
- *Therefore expect most emission to emerge from just a few* r_g
- *Light bending effects then not optional but must occur*

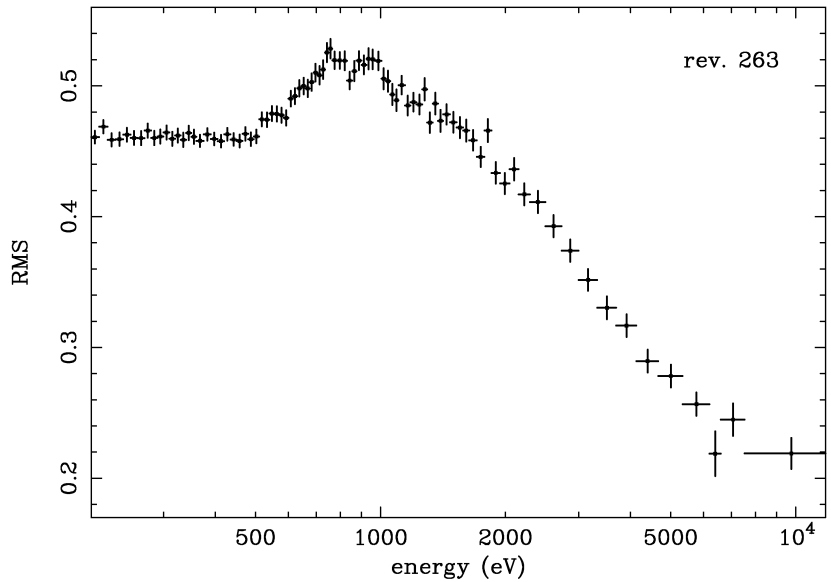
High flux spectrum and low flux spectrum

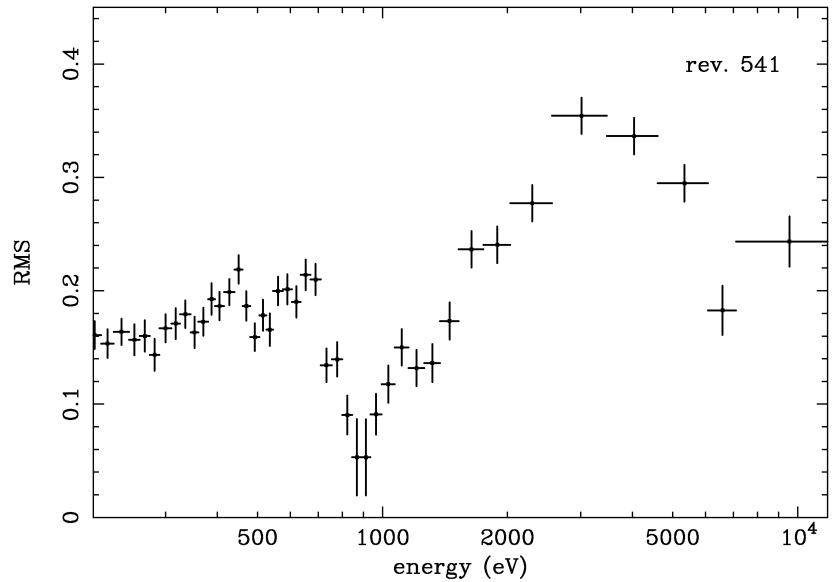


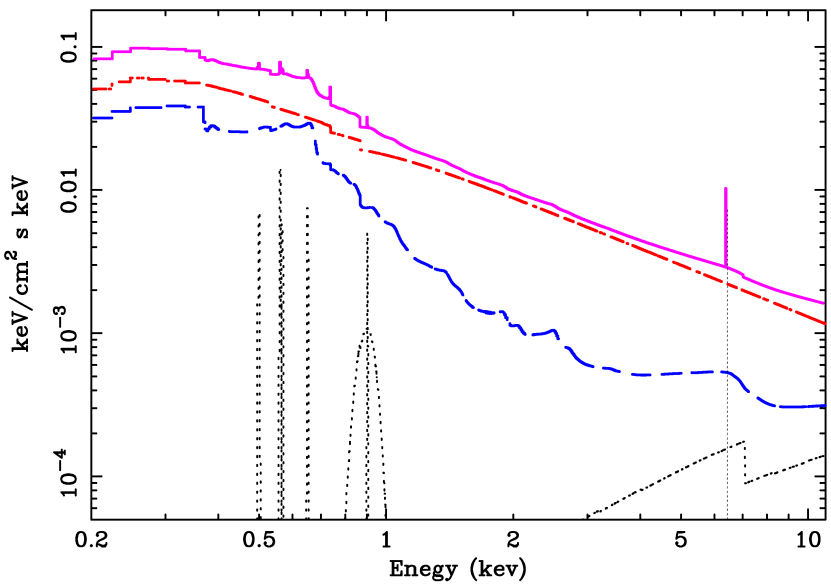
NGC4051
Ponti et al (MNRAS in press)

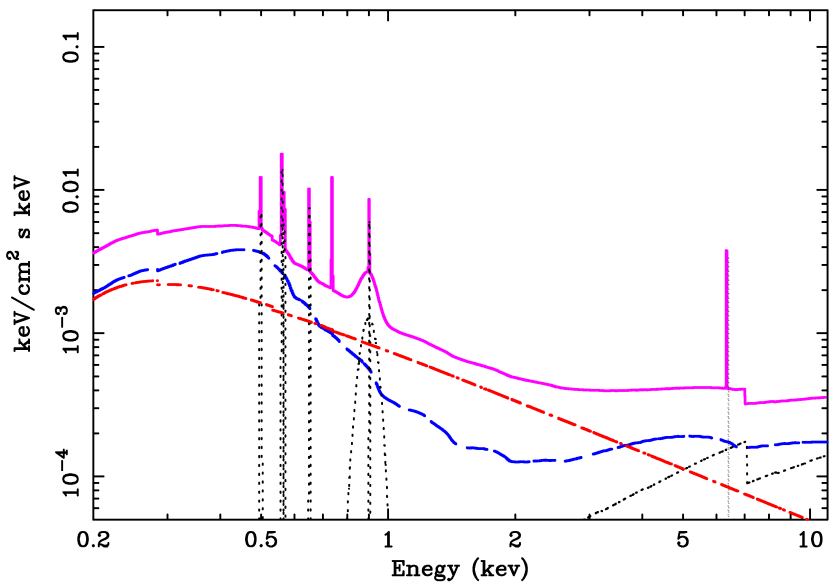


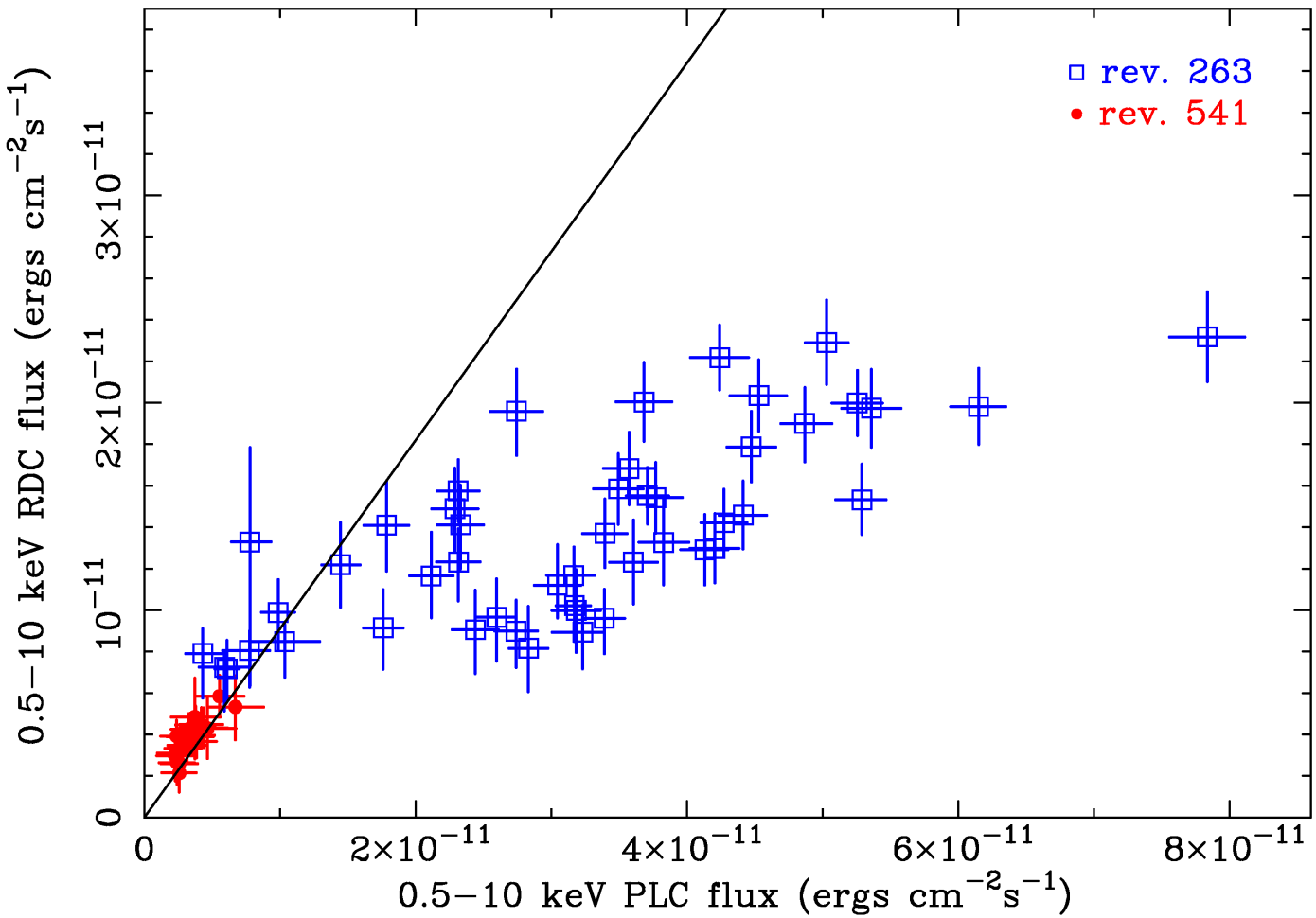


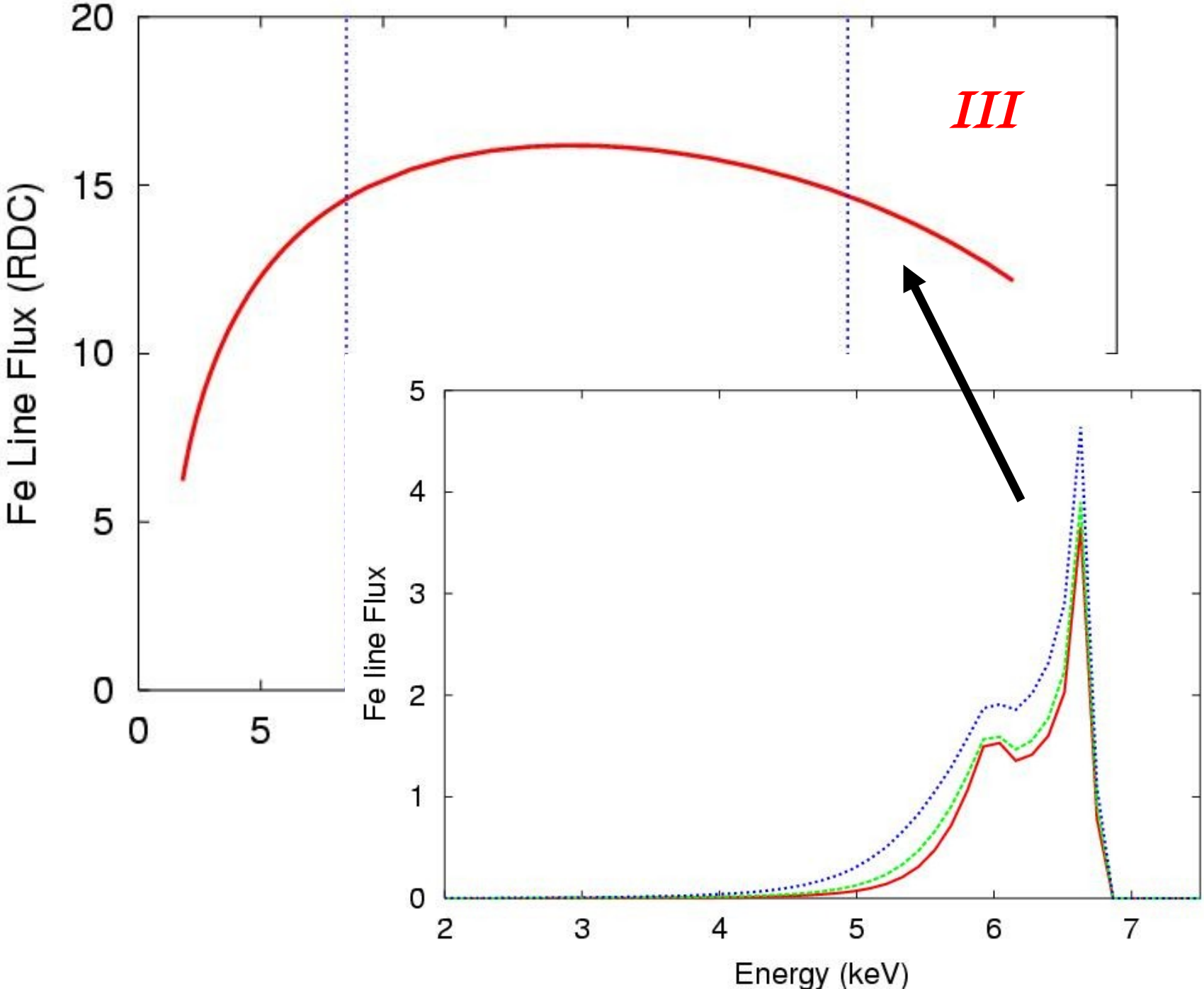

rev. 263
RMS
0.2
0.3
0.4
0.5
500
1000
2000
5000
10^4
energy (eV)

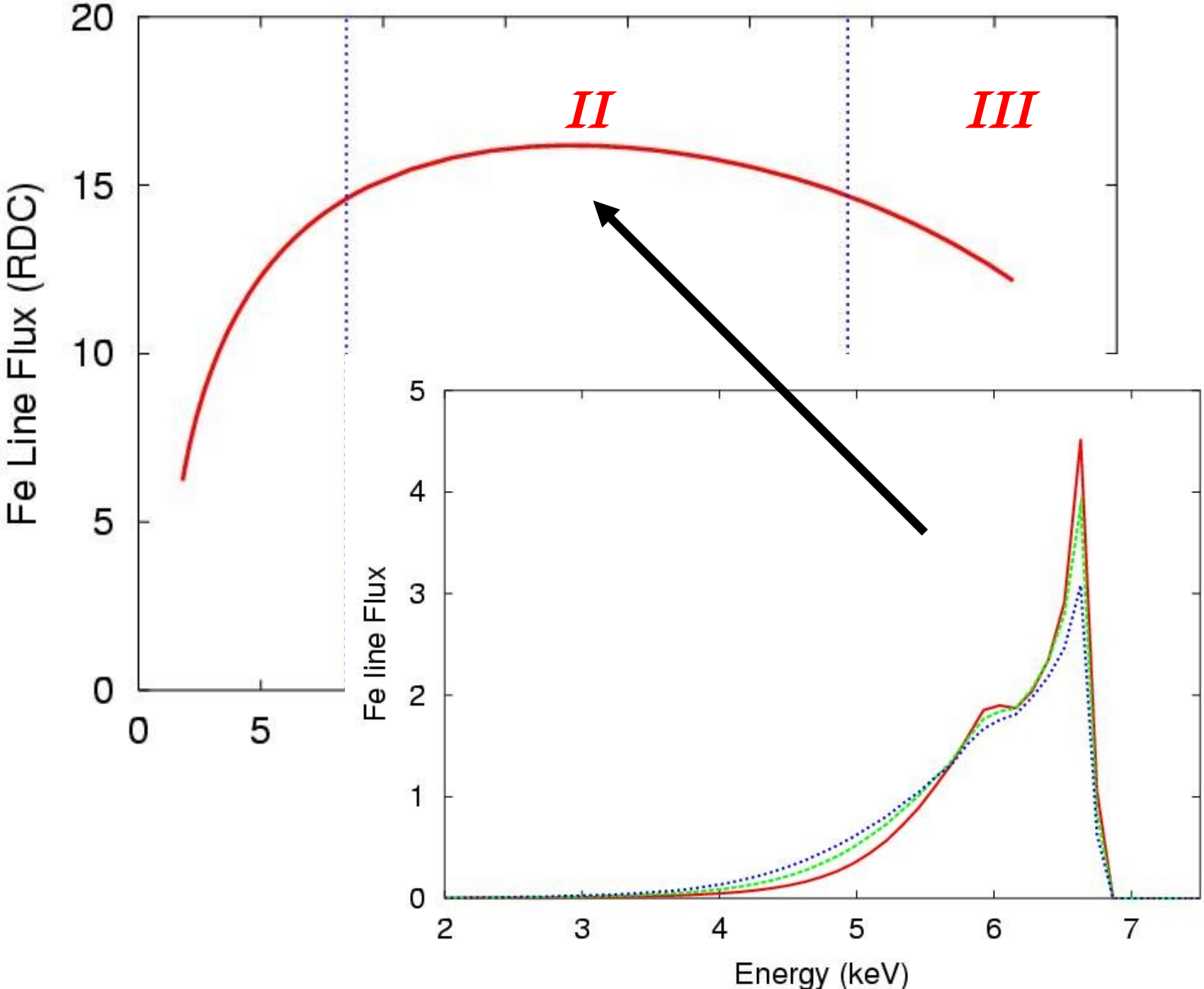

rev. 541
RMS
0
0.1
0.2
0.3
0.4
500
1000
2000
5000
10^4
energy (eV)

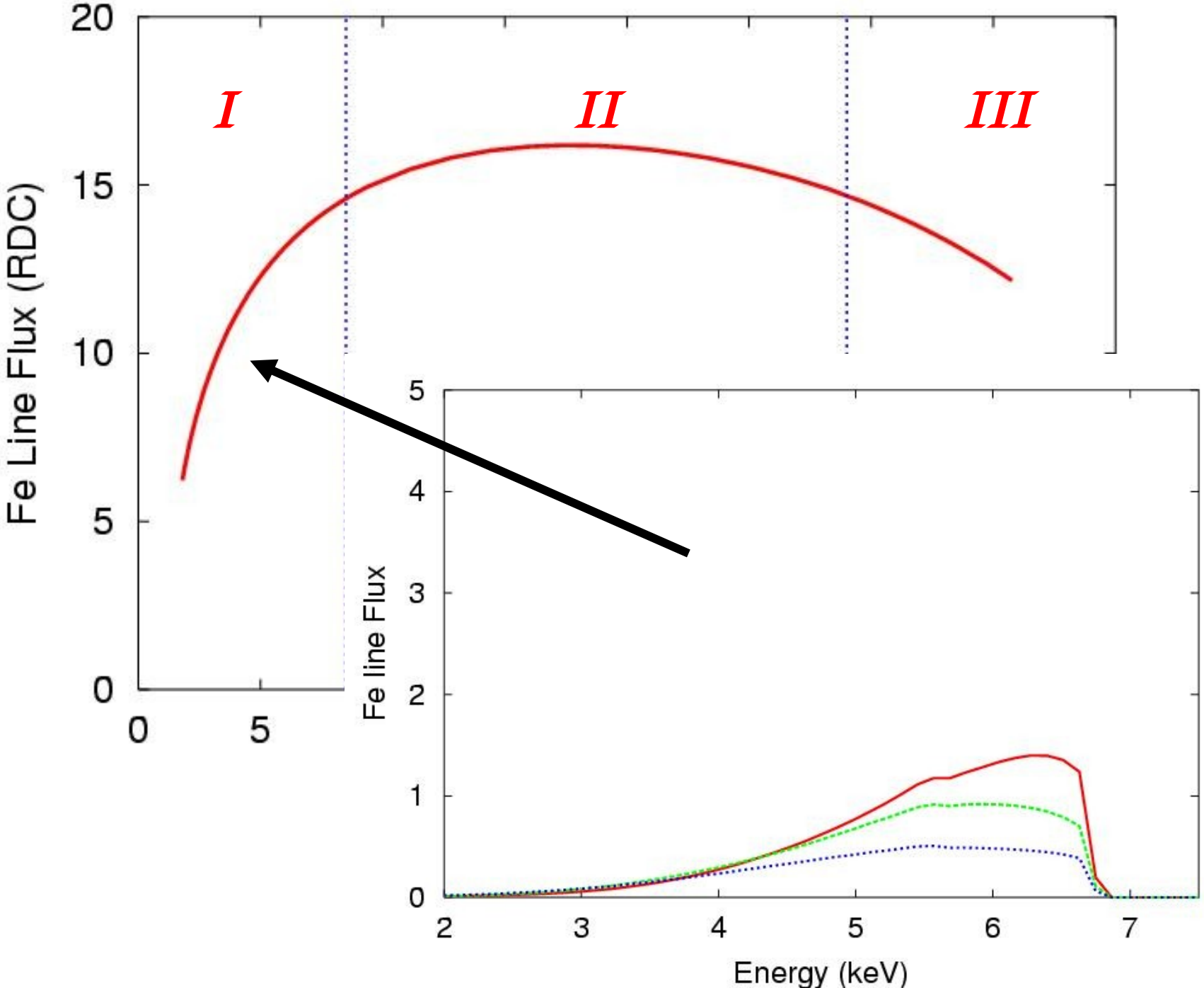

keV/cm^2 s keV
0.1
0.01
10^{-3}
10^{-4}
0.2
0.5
1
2
5
10
Enegy (kev)


keV/cm^2 s keV
0.1
0.01
10^{-3}
10^{-4}
0.2
0.5
1
2
5
10
Enegy (kev)


rev. 263
rev. 541
0.5−10 keV RDC flux (ergs cm^{-2}s^{-1})
0.5−10 keV PLC flux (ergs cm^{-2}s^{-1})
0
10^{-11}
2×10^{-11}
3×10^{-11}
0
2×10^{-11}
4×10^{-11}
6×10^{-11}
8×10^{-11}


III
Fe Line Flux (RDC)
20
15
10
5
0
0
5
Fe line Flux
5
4
3
2
1
0
2
3
4
5
6
7
Energy (keV)


Fe Line Flux (RDC)
20
15
10
5
0
0
5
II
III
Fe line Flux
5
4
3
2
1
0
2
3
4
5
6
7
Energy (keV)


I
II
III
Fe Line Flux (RDC)
20
15
10
5
0
0
5
Fe line Flux
5
4
3
2
1
0
2
3
4
5
6
7
Energy (keV)

Conclusions on broad Fe line

- A consistent model for the broad iron lines
  seen in some Seyferts and BHC
- involves both
  - strong gravitational redshift
  - and light bending
- indicating that much of the reflection and thus primary emission is occurring within a few gravitational radii of the event horizon

- Good evidence from several objects that BH is spinning (Kerr solution necessary)

- *Light bending model relevant when emission source is <20rg. Modelled close to axis. May be base of jet when eddington ratio is high?*

Clear broad iron line may need

- *accretion at high Eddington fraction*
- *high iron abundance*
- *little complex absorption*

XEUS / CON-X have the potential to maker MAJOR advances

Brightest lines are about 2 ph m^{-2} s^{-1}

Need sources with high L/L_{Edd} for broad lines (NLS1/GXRB)

Typically means

- BH mass of 10^6-10^8 Msun
- or timescales of 100s to 10^4s.

Therefore to study such BH on their

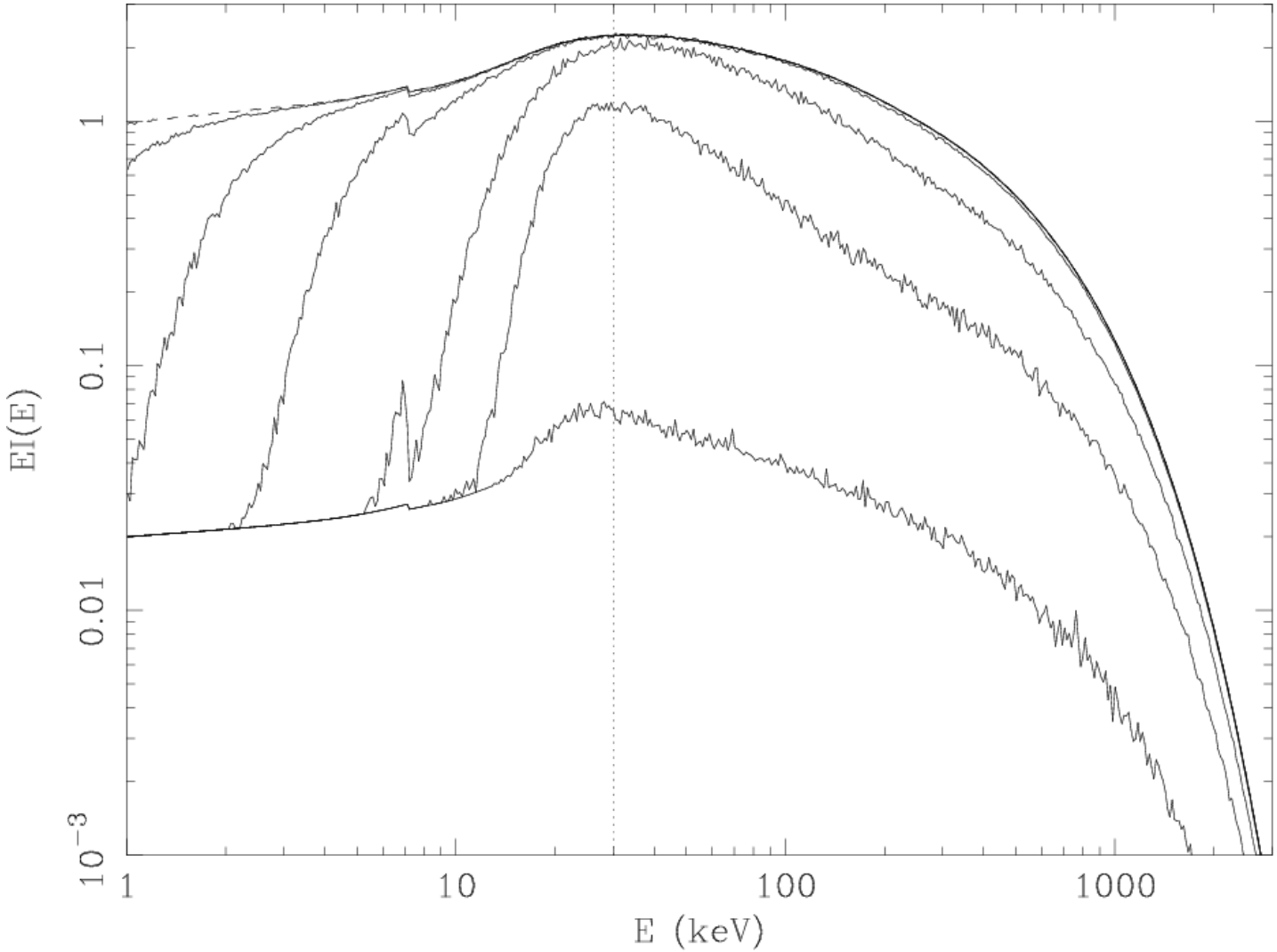
intrinsic variability
light crossing
inner orbital period

} timescales

⇒ effective collecting area at 6 keV of at least ~1m^2

Obscured AGN and the X-ray Background

Absorption of =2 power-law, including reflection component



Wilman & Fabian 1999

Cold absorption (ie neutral gas)

Absorbed AGN, particularly Compton-thick, are ***common***

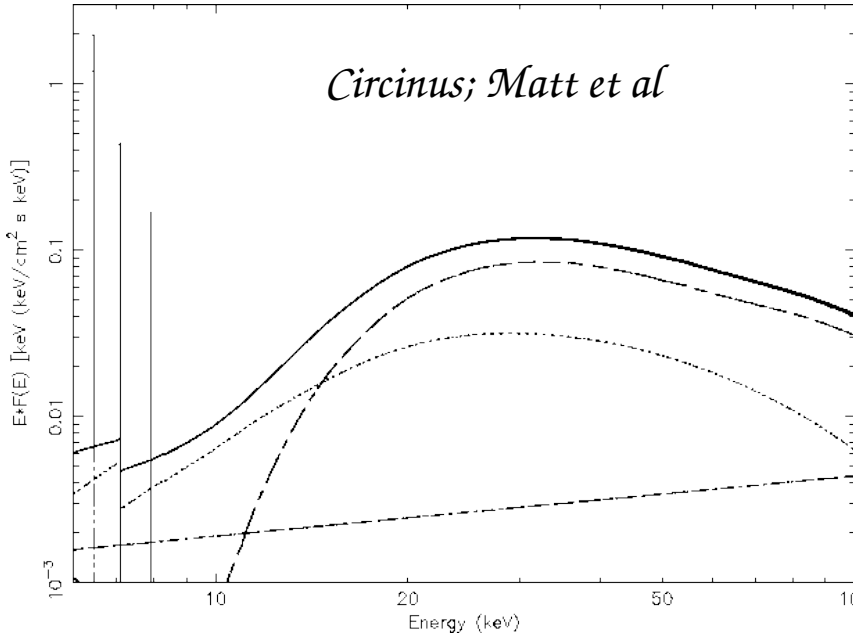
3 nearest AGN, NGC4945, Circinus galaxy and Centaurus A all have

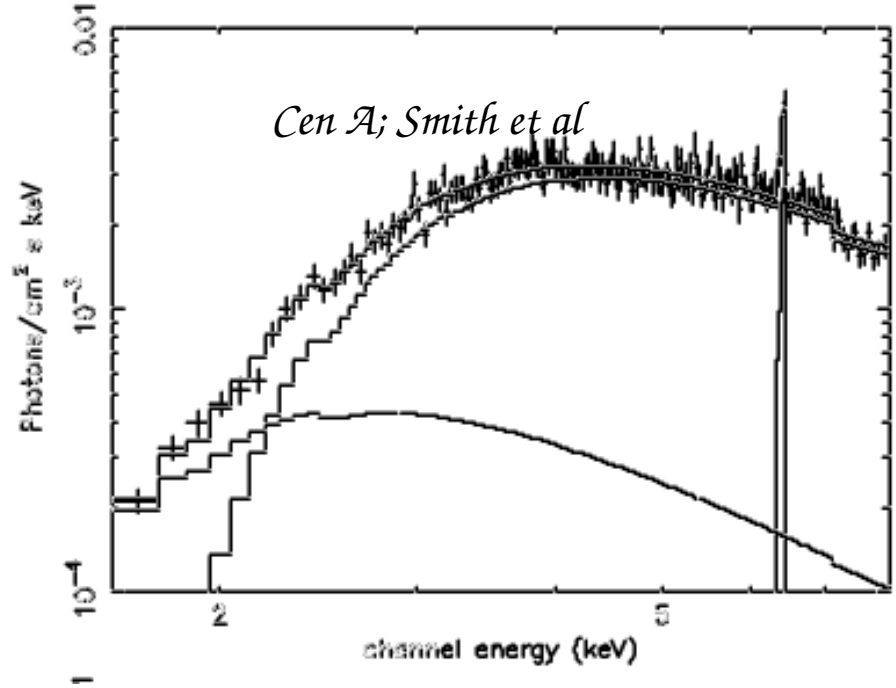
$N_H > 10^{23}$ cm^{-2}, the first 2 being

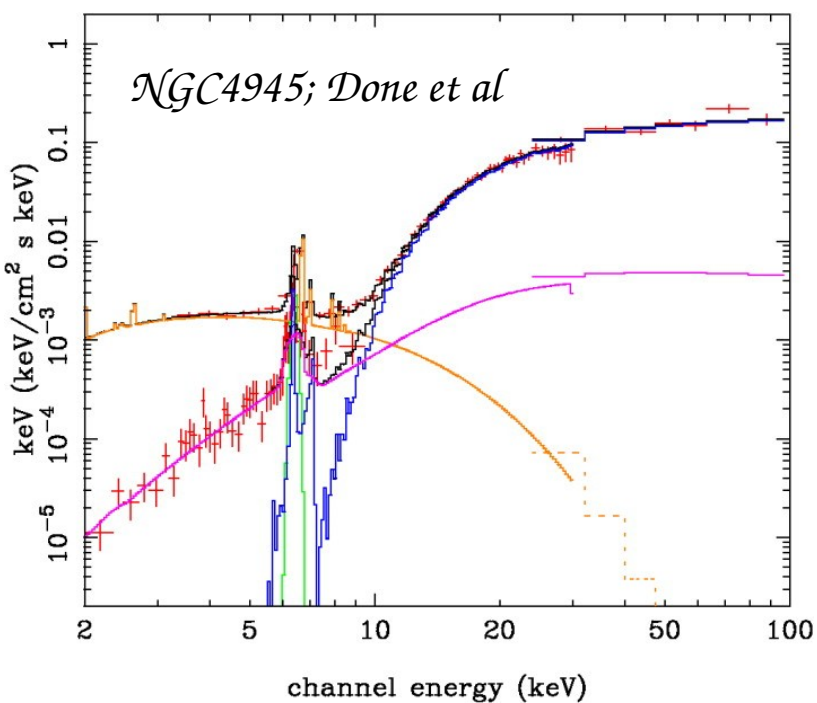
Compton thick with $N_H > 1.5 \times 10^{24}$ cm^{-2}.

3-5 times as many Seyfert II locally as Seyfert I AGN.

What about quasars and distant AGN?


Circinus; Matt et al
E*F(E) [keV (keV/cm^2 s keV)]
Energy (keV)


Cen A; Smith et al
Photons/cm^2 s keV
channel energy (keV)


NGC4945; Done et al
keV (keV/cm^2 s keV)
channel energy (keV)

Absorbed AGN, particularly Compton-thick, are ***common***

3 nearest AGN, NGC4945, Circinus galaxy and Centaurus A all have

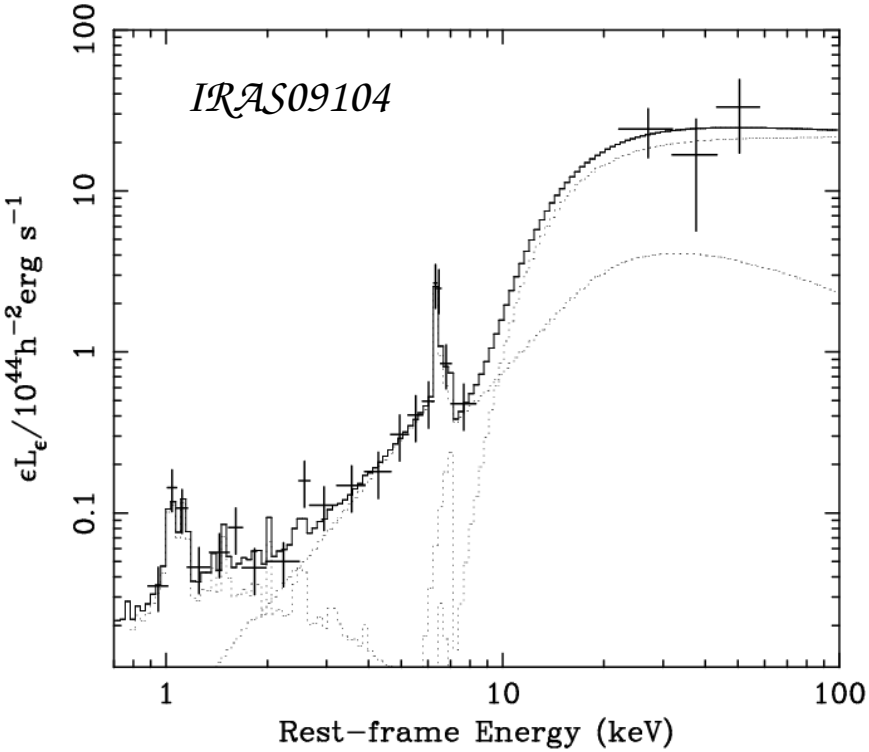
$N_H > 10^{23}$ cm^{-2}, the first 2 being

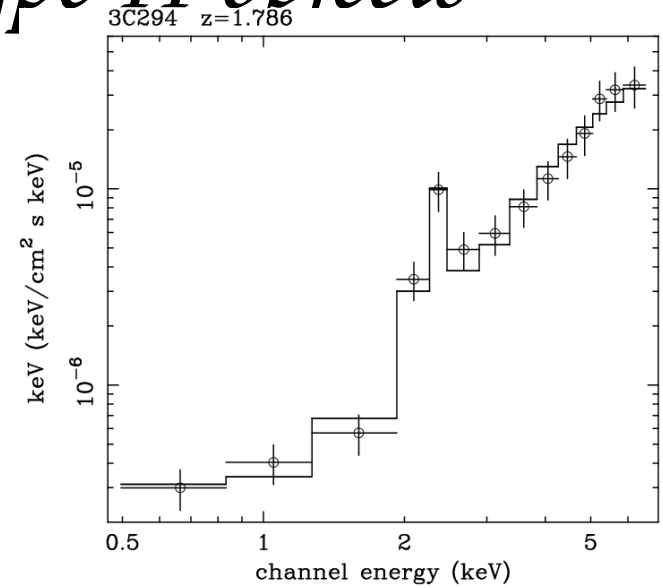
Compton thick with $N_H > 1.5 \times 10^{24}$ cm^{-2}.

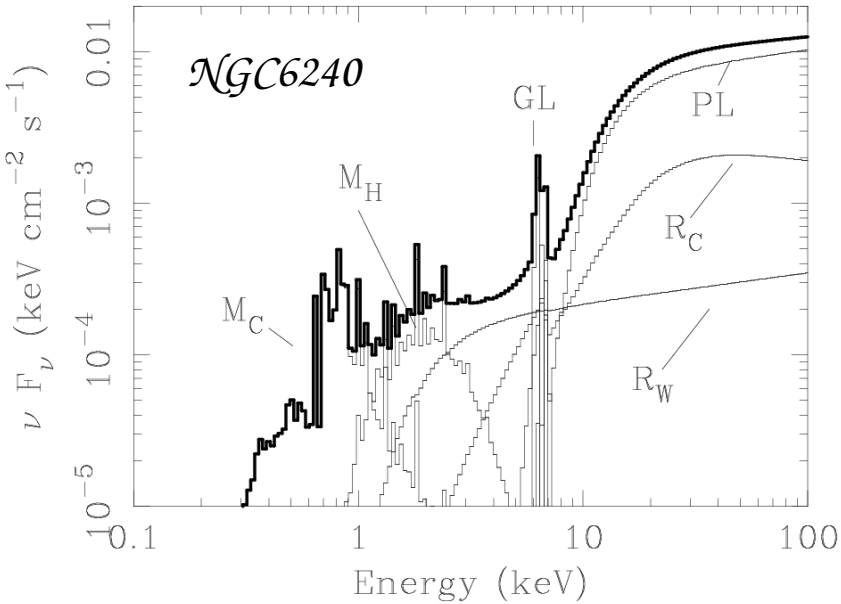
3-5 times as many Seyfert II locally as Seyfert I AGN.

What about quasars and distant AGN?

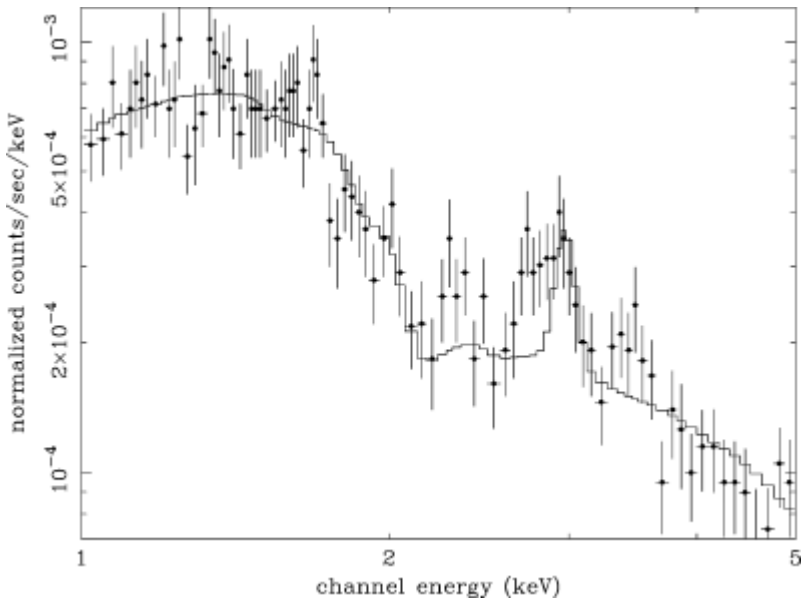
Some distant/powerful Type II objects

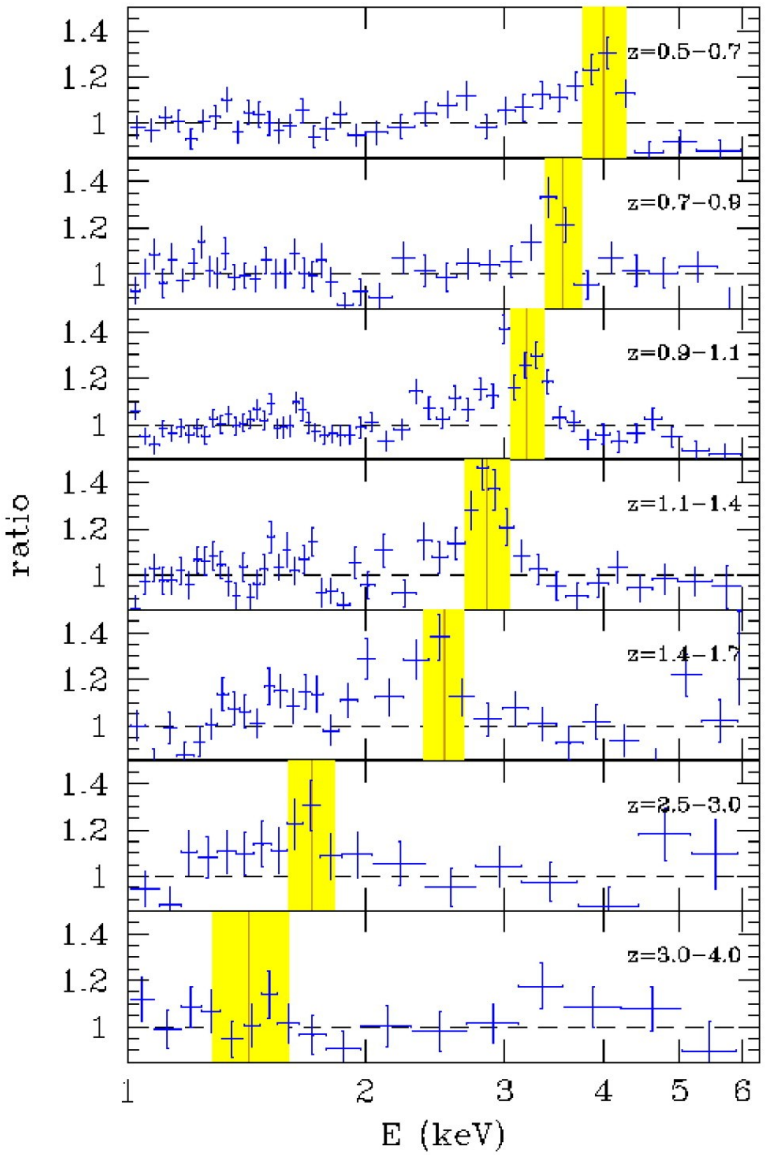






Brusa +05 CDF

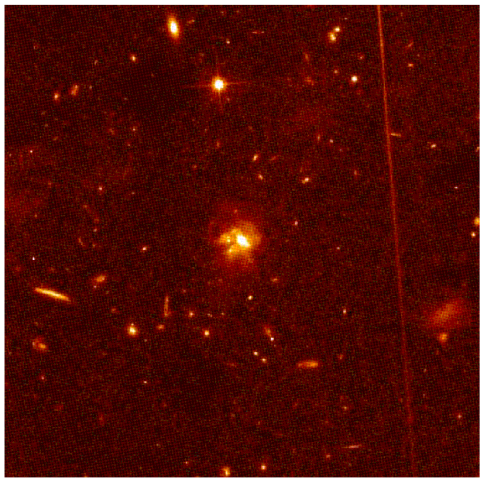


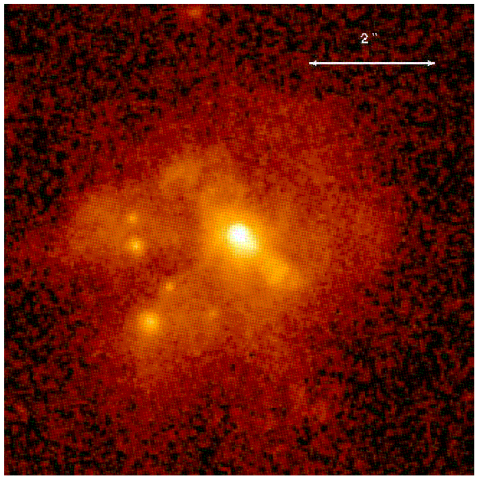


Comastri+04 z=1.4

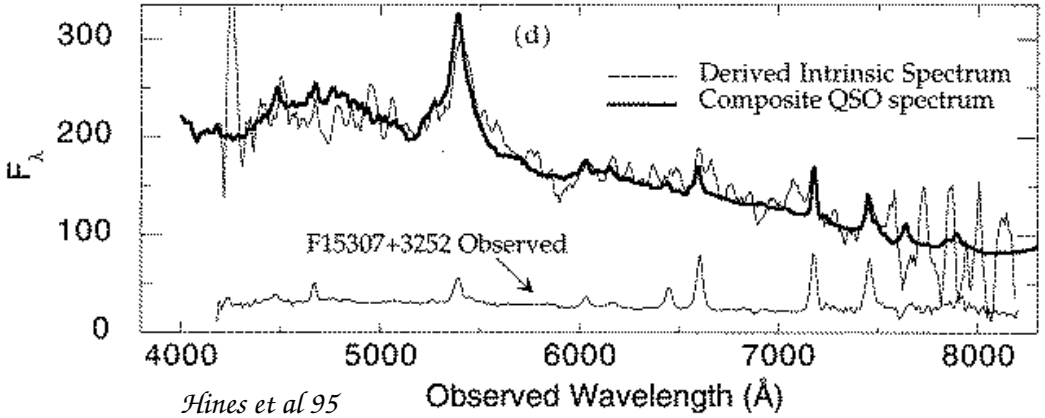
X-rays from the Type II quasar in the hyperluminous infrared galaxy IRAS F15307+3252

K. Iwasawa[1], C.S. Crawford[1], A.C. Fabian[1] and R.J. Wilman[2]

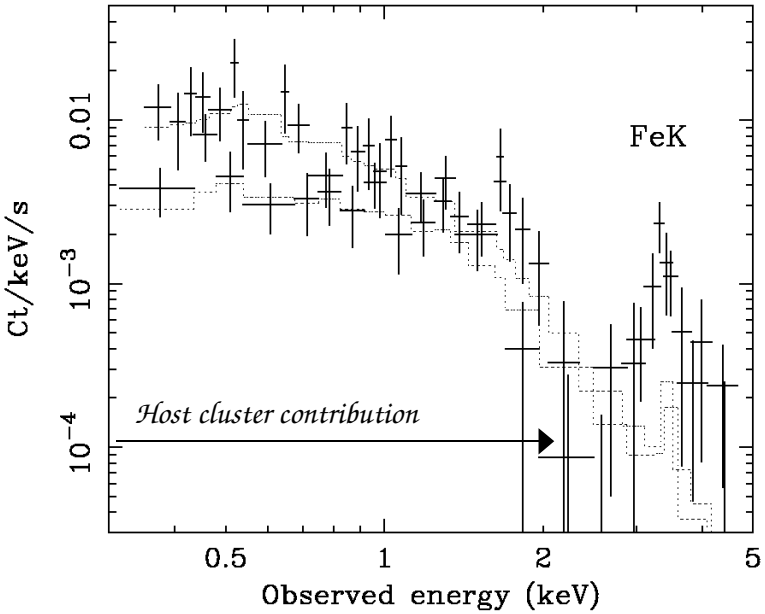




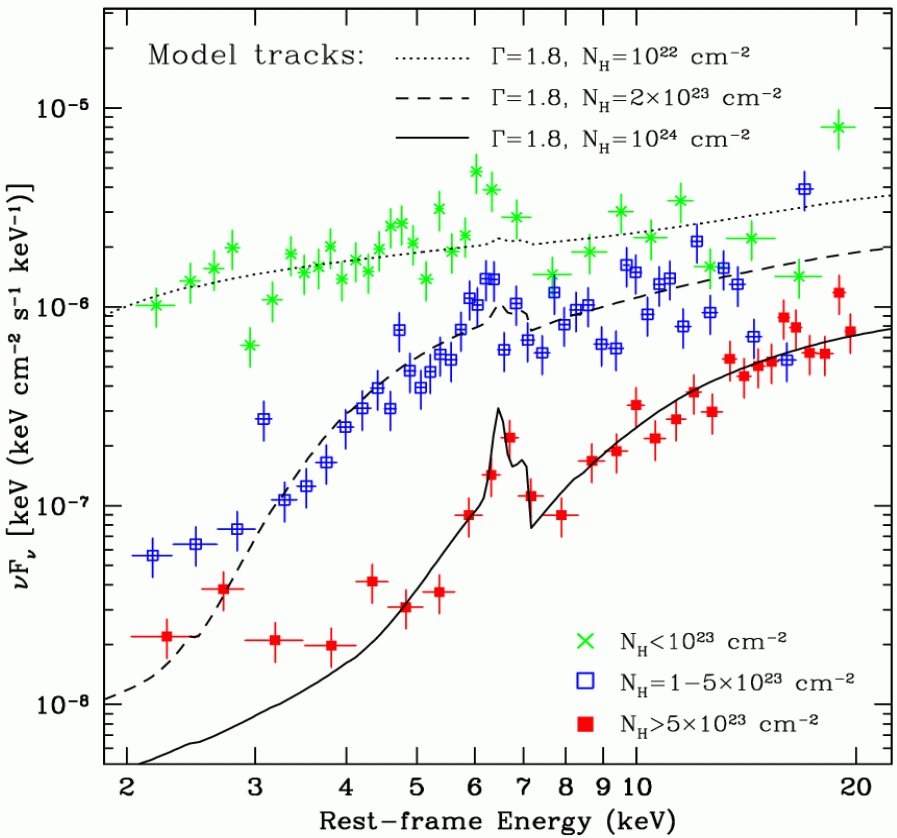
Fe K line is due to absorption of harder X-ray emission from obscured quasar nucleus



Hines et al 95

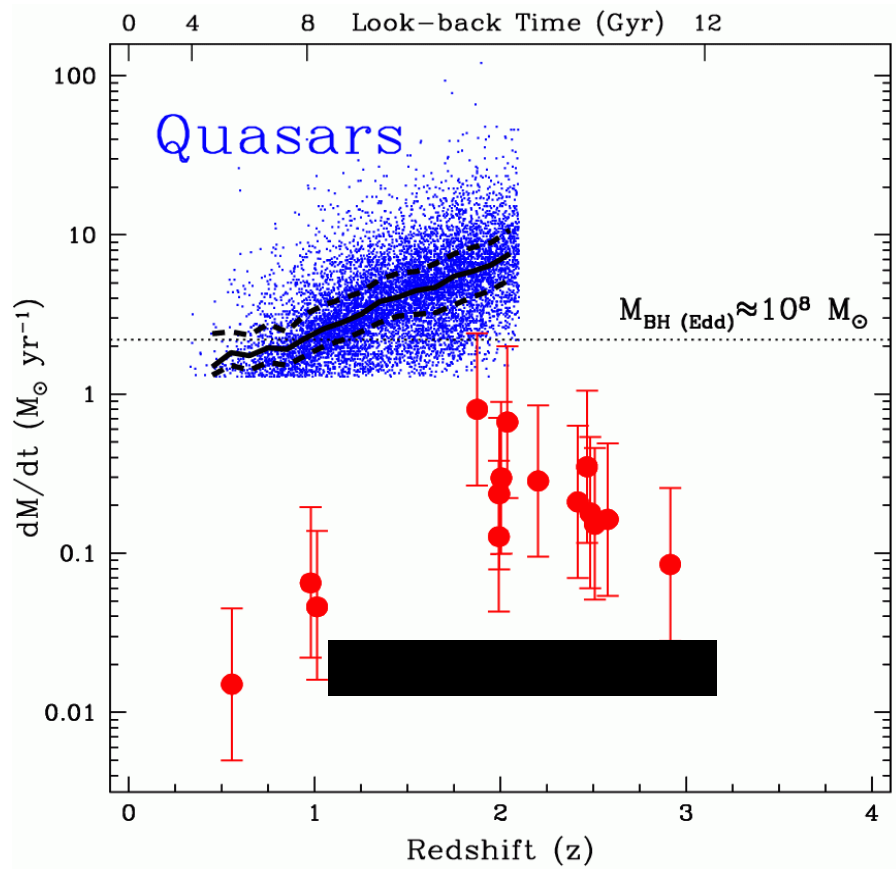


Obscured Black-Hole Growth in Massive Galaxies



Alexander et al., 2005

Stacked ~12Ms X-ray spectra: ~80% of the AGNs in massive SCUBA galaxies are obscured, some possibly Compton thick



Alexander et al., Nature, 2005

The properties of the AGNs in SCUBA galaxies are consistent with an obscured black-hole growth phase prior to an unobscured quasar phase

Ionized absorption

Ionization parameter

(sometimes divided by

hvc) measures

$$\xi = \frac{L}{nr^2}$$

balance between photoionizations and recombinations

< 30 gas is lowly ionized (eg CNO in high ion states)

>1000 gas is highly ionized (eg Fe in high ion states)

>10000 gas is completely ionized

Warm absorbers

Ionized gas along line of sight to nucleus

can be revealed by absorption lines and edges, particularly those due to OVII and OVIII (edges at 0.73 and 0.86 keV).

Seen in ~50% of Seyfert 1 spectra.

Columns, $N_H \sim 10^{22}$ cm^{-2} easily seen

Emission spectra complementary to emission spectra seen in Seyfert II galaxies

MCG-6-30-15

XMM RGS A.Turner et al

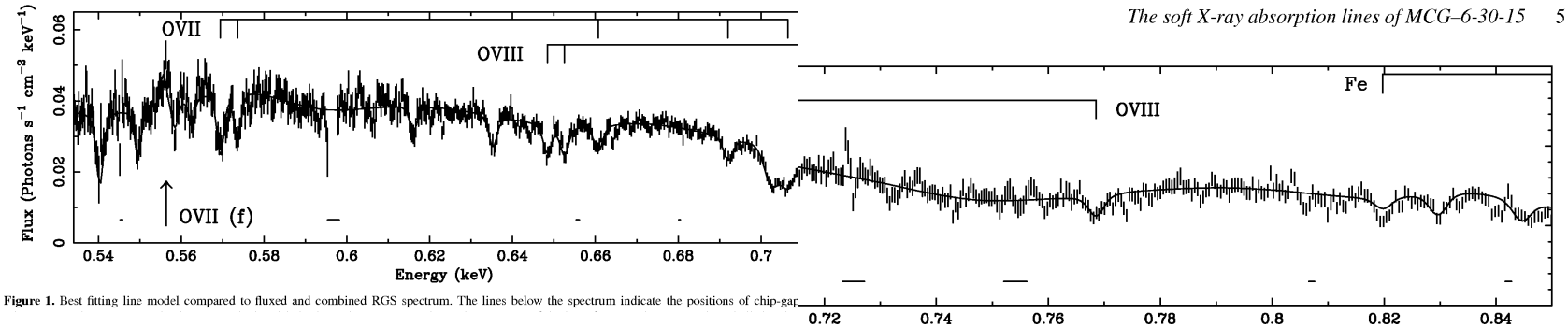
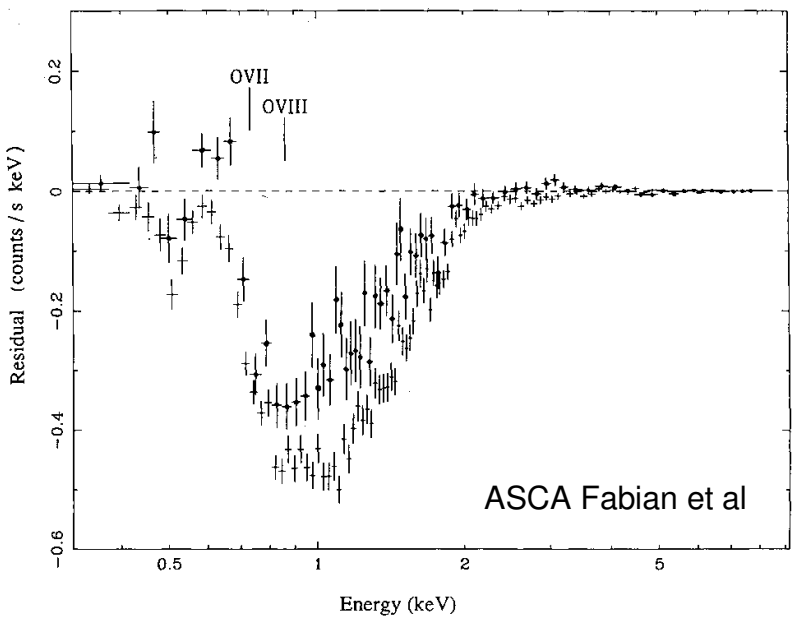


Figure 1. Best fitting line model compared to fluxed and combined RGS spectrum. The lines below the spectrum indicate the positions of chip-gap



NGC3783

TJ Turner et al ROSAT

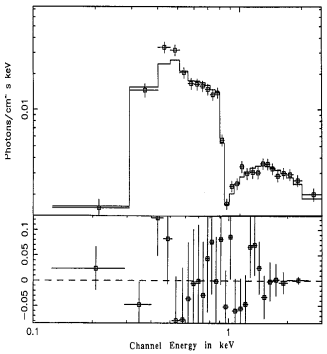


FIG. 3.—*Top:* Unfolded photon spectrum for the best-fit power-law plus
ge model to the mean spectrum. *Bottom:* Plot of the data-minus-model
iduals.

648

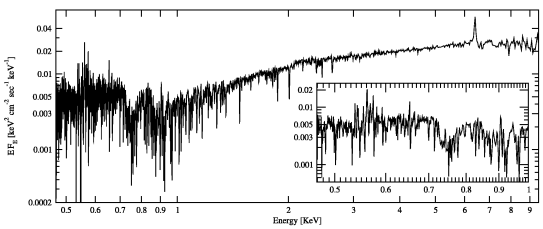
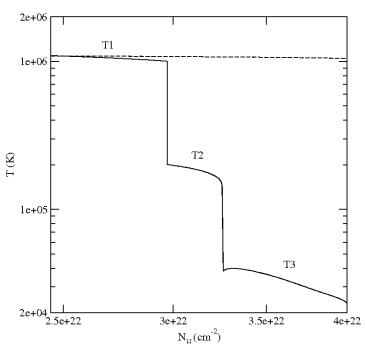


FIG. 2.—Combined MEG and HEG first-order 900 ks spectrum that was presented in Fig. 1 but shown here over the whole range in EF_E vs. energy format. Uncertainties are not shown for clarity. The warm absorber features are noticeable. The shape of this spectrum is consistent with previously published *ASCA* spectra (e.g., George et al. 1998). The insert focuses on the spectrum below 1 keV binned to 0.03 Å. No neutral oxygen edge is seen at 538 eV.



Goncaleves et al

Chandra HETG Kaspi et al

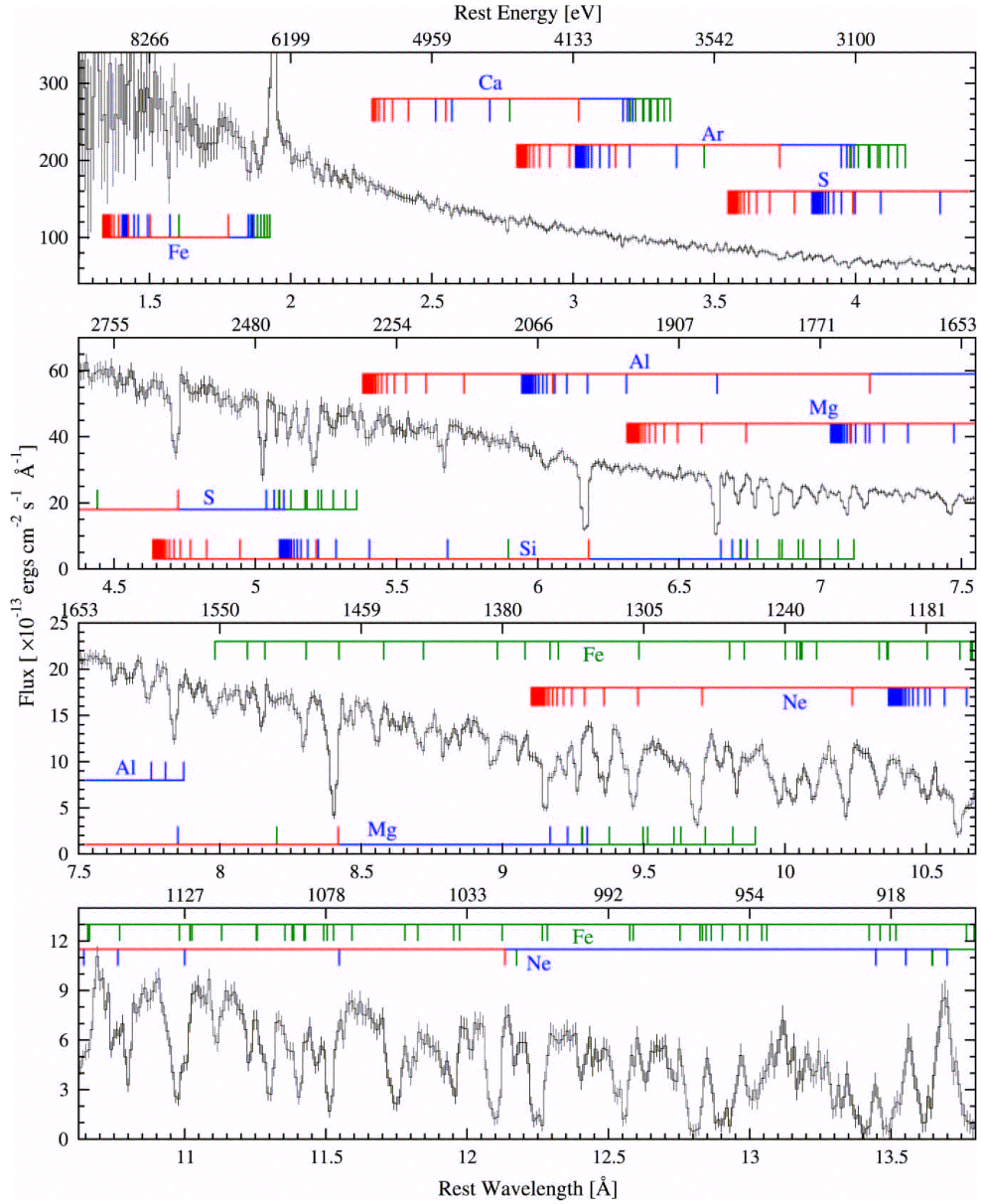
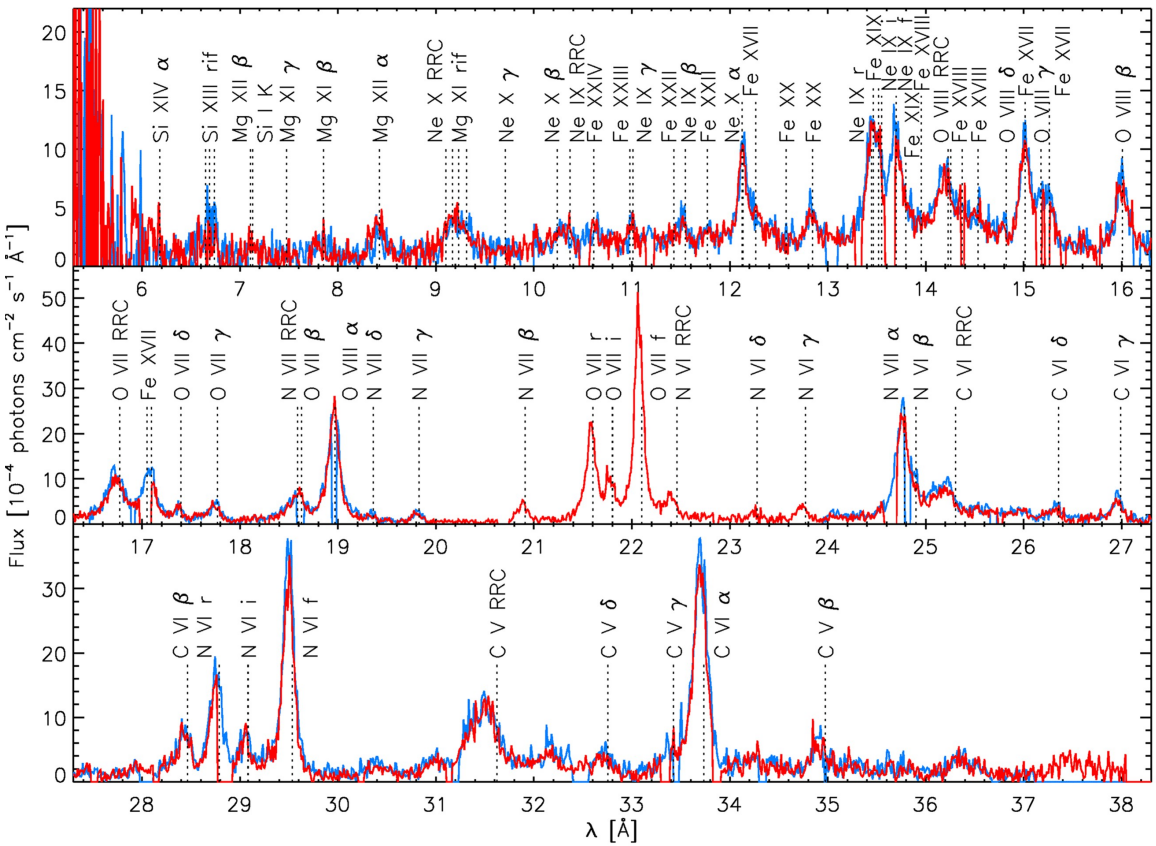
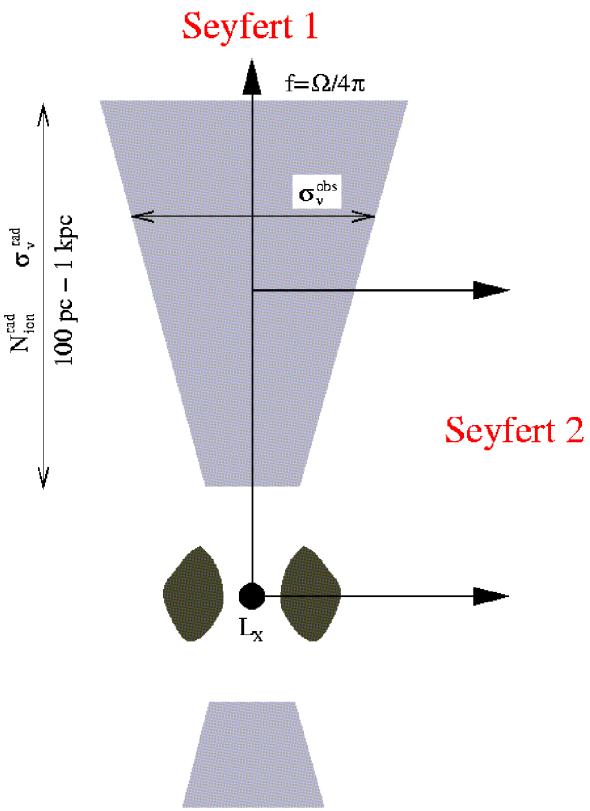


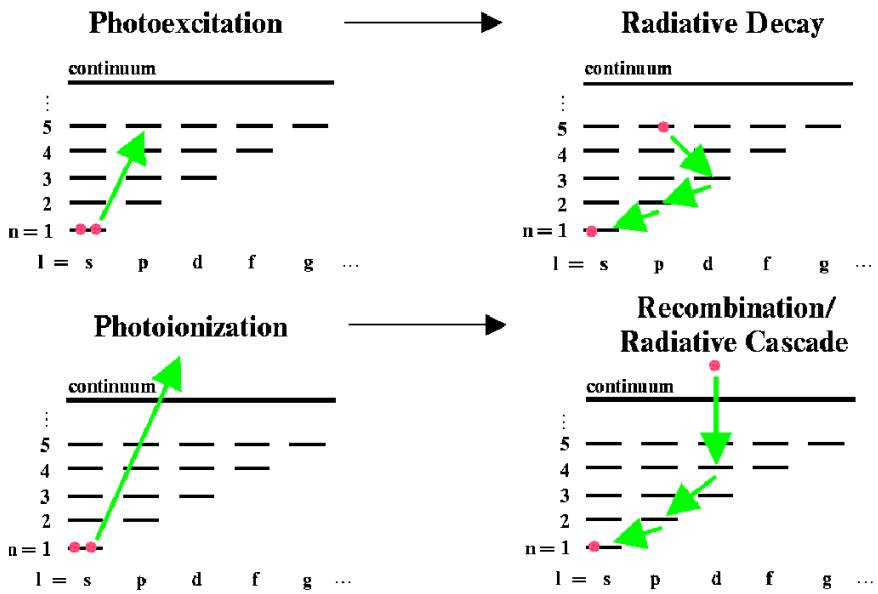
FIG. 1.—Combined MEG and HEG first-order 900 ks spectrum binned to 0.01 Å. Each data point has an error bar representing its 1 σ uncertainty. The H-like and He-like lines of the identified ions are marked in red and blue, respectively. Lines from other ions (lower ionization metals and Fe XVII–Fe XXIV) are marked in green. For each H-like or He-like ion the theoretically expected lines are plotted up to the ion's edge (not all lines are identified in the data). The ions' lines are marked at their expected wavelengths in the rest frame of NGC 3783, and the blueshift of the absorption lines is noticeable.

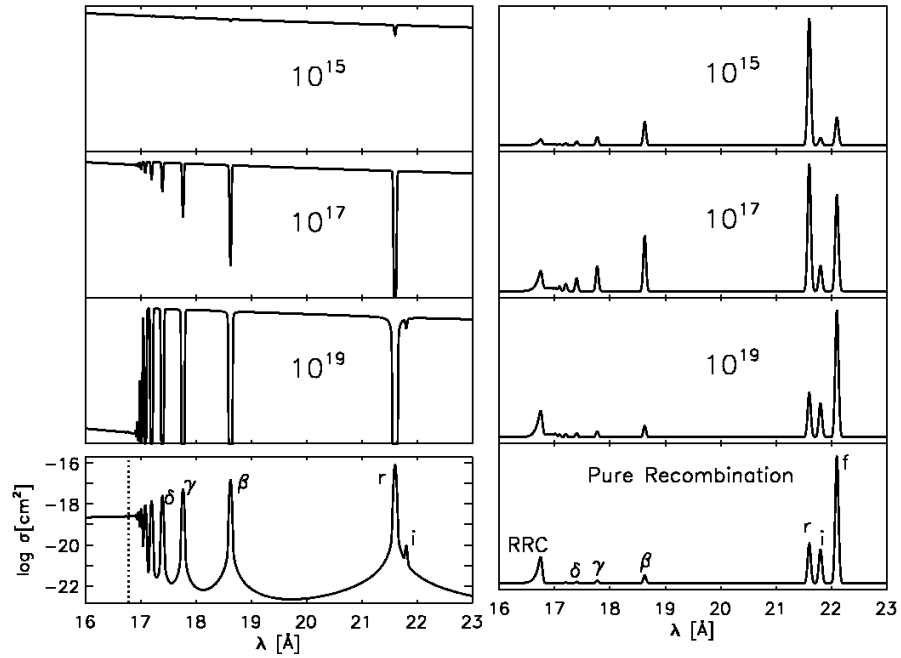
NGC1068



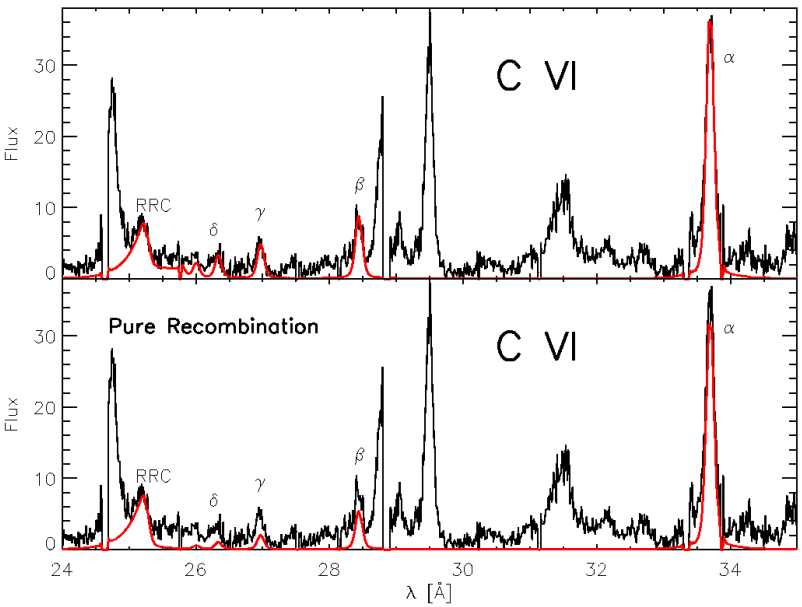


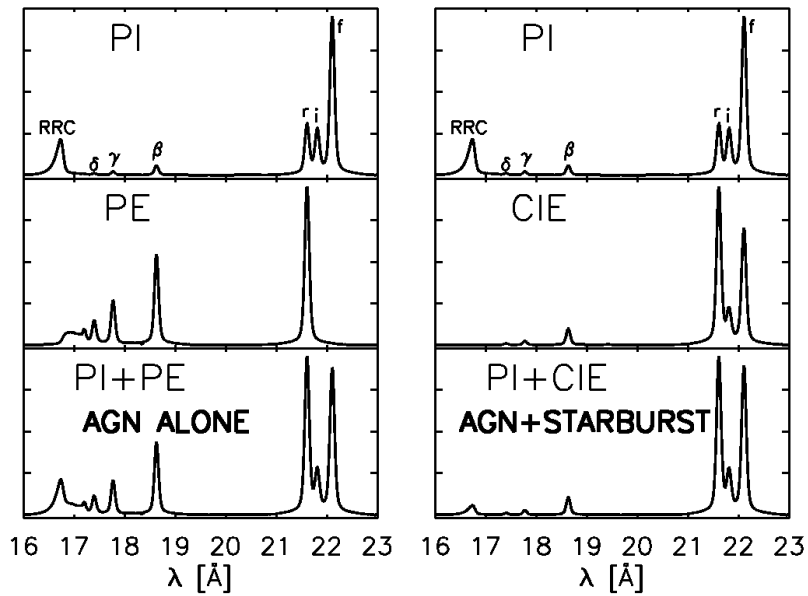
XMM RGS Kinkhabwala et al





Kinkhabwala et al





$$\xi = \frac{L_x}{nr^2}$$

$$\dot{M}_w = 4\pi f r^2 n m_p v$$

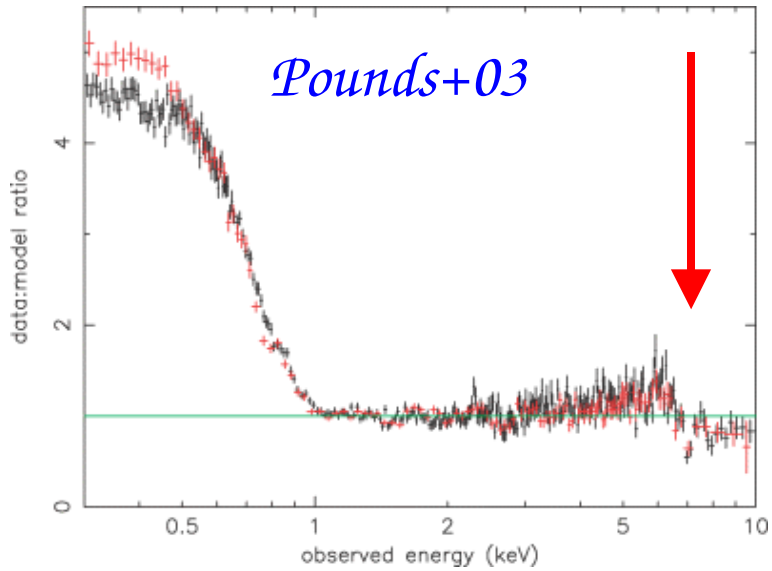
$$= 4\pi f \frac{L_x v}{\xi} m_p$$

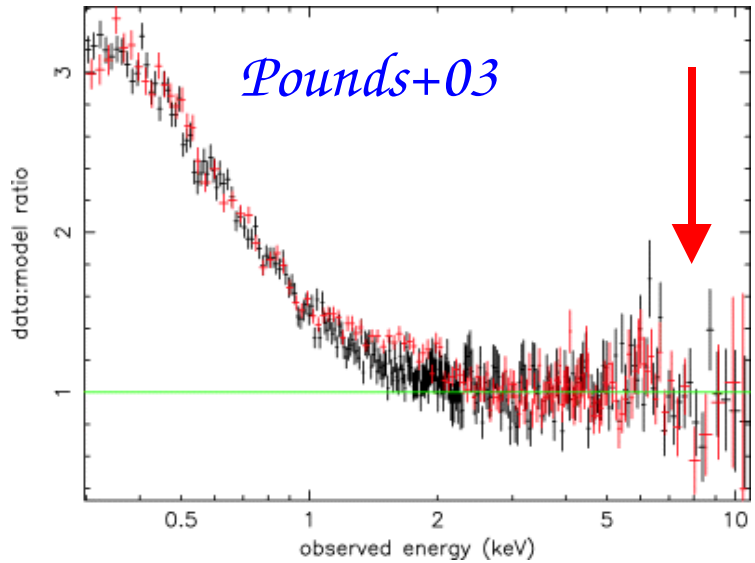
$$\frac{\dot{M}_w}{\dot{M}_a} = \frac{f v m_p c^2}{\xi} = 10^3 f \frac{v}{1000 km/s} \frac{100}{\xi}$$

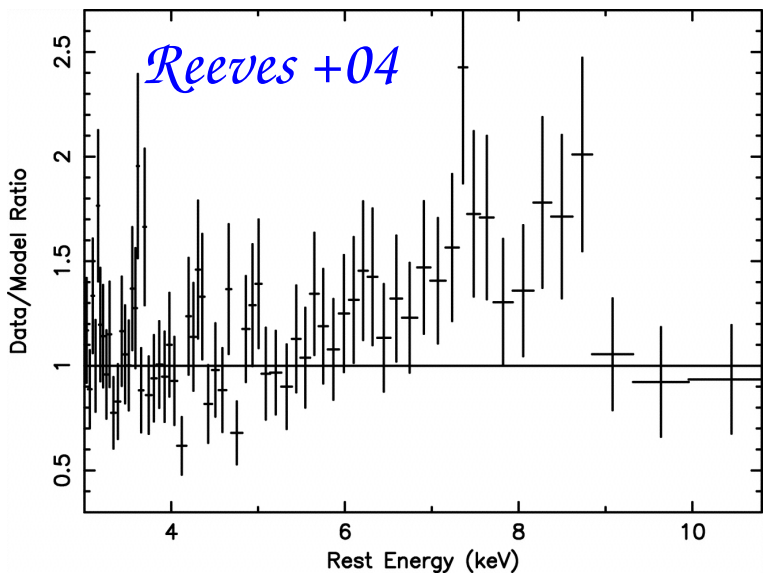
$$\frac{P_w}{P_a} = 10^{-2} f \left(\frac{v}{1000 km/s} \right)^3 \left(\frac{\xi}{100} \right)^{-1}$$

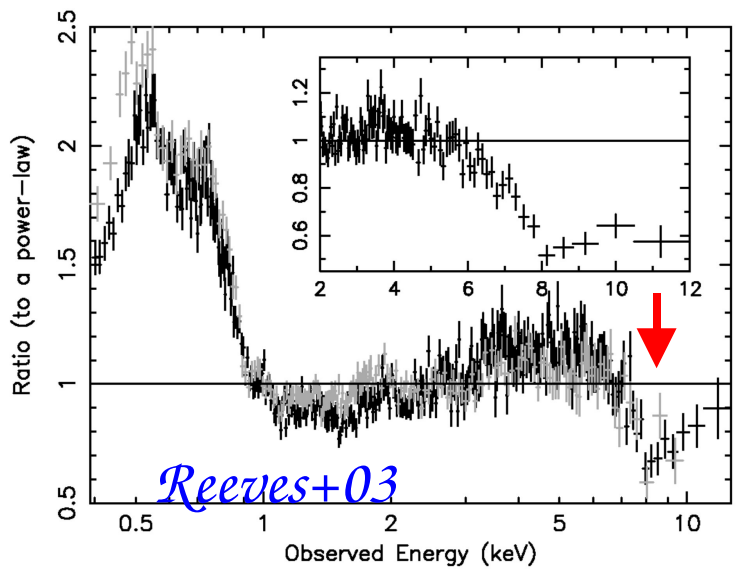
Conclude that flow likely to be clumpy (f<<1)

Blue-shifted absorption=fast outflows?

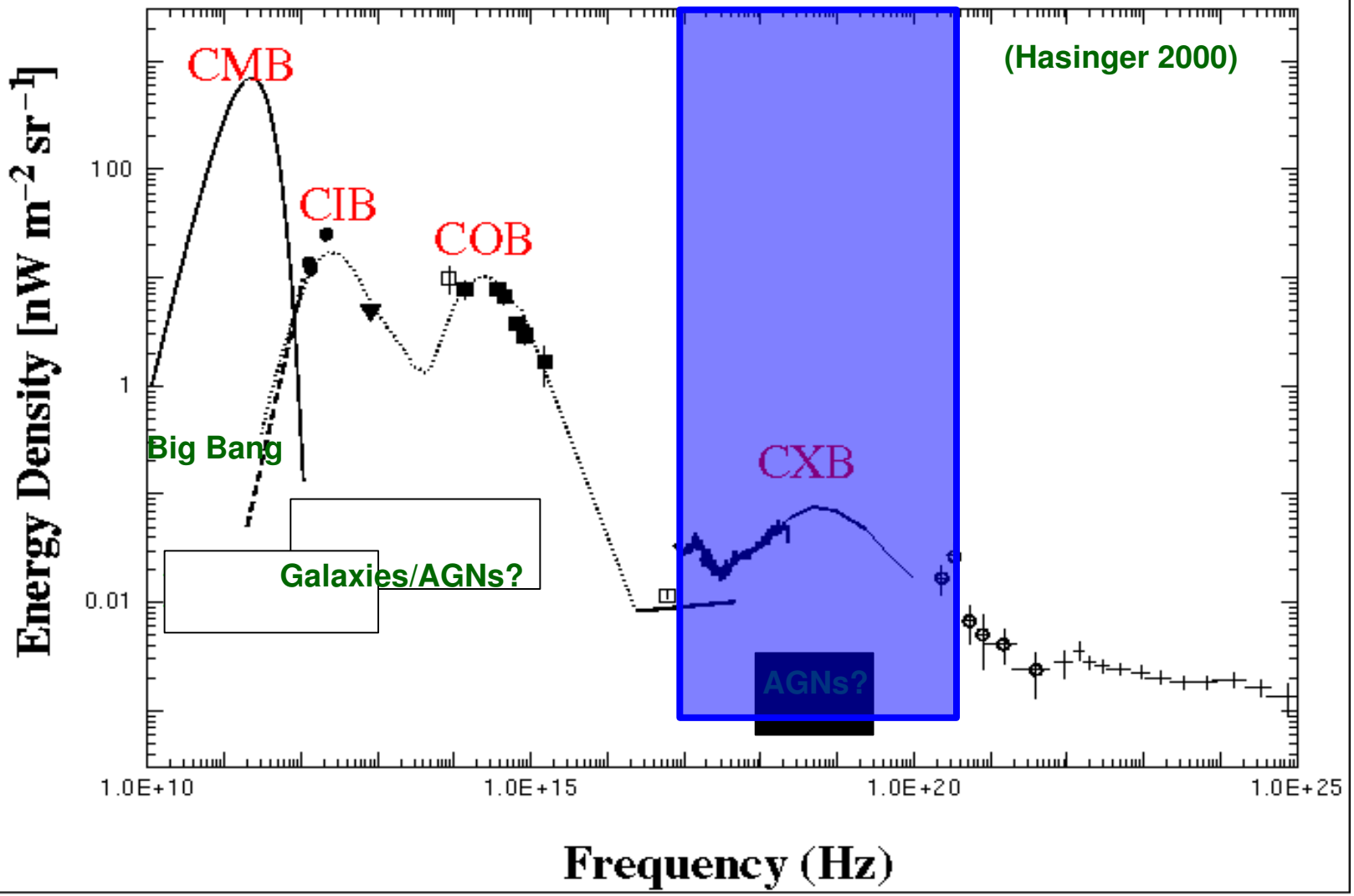


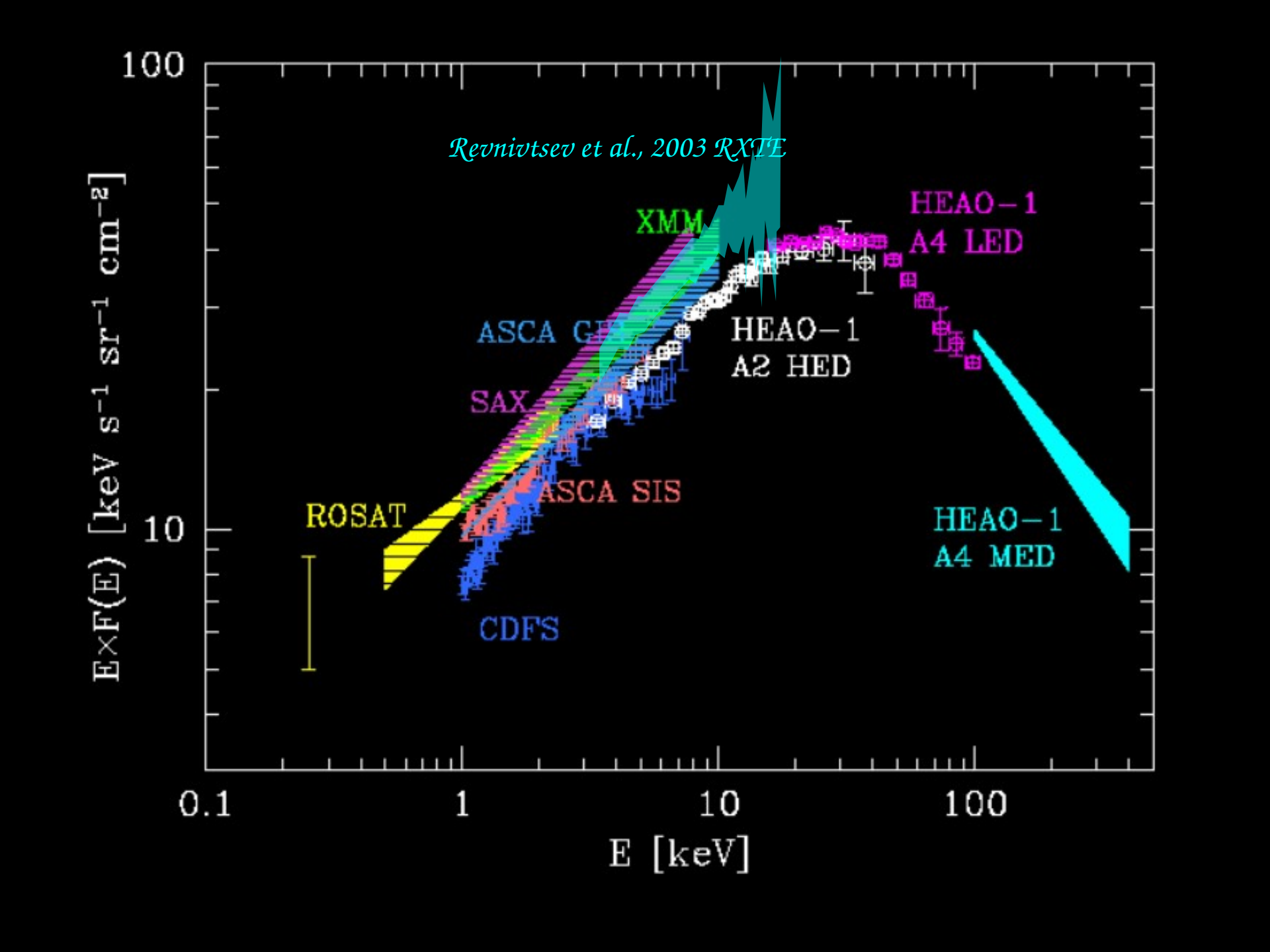




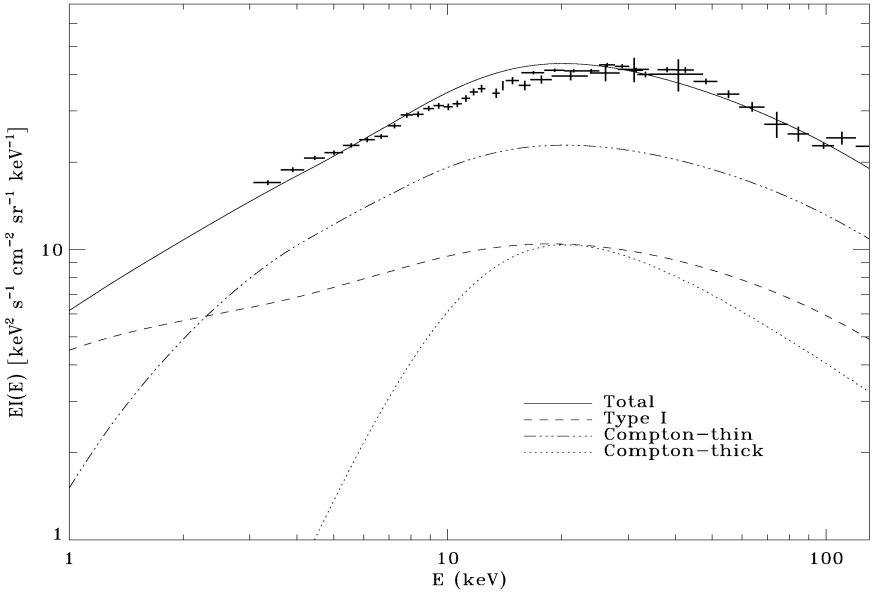


Cosmic Background Radiation



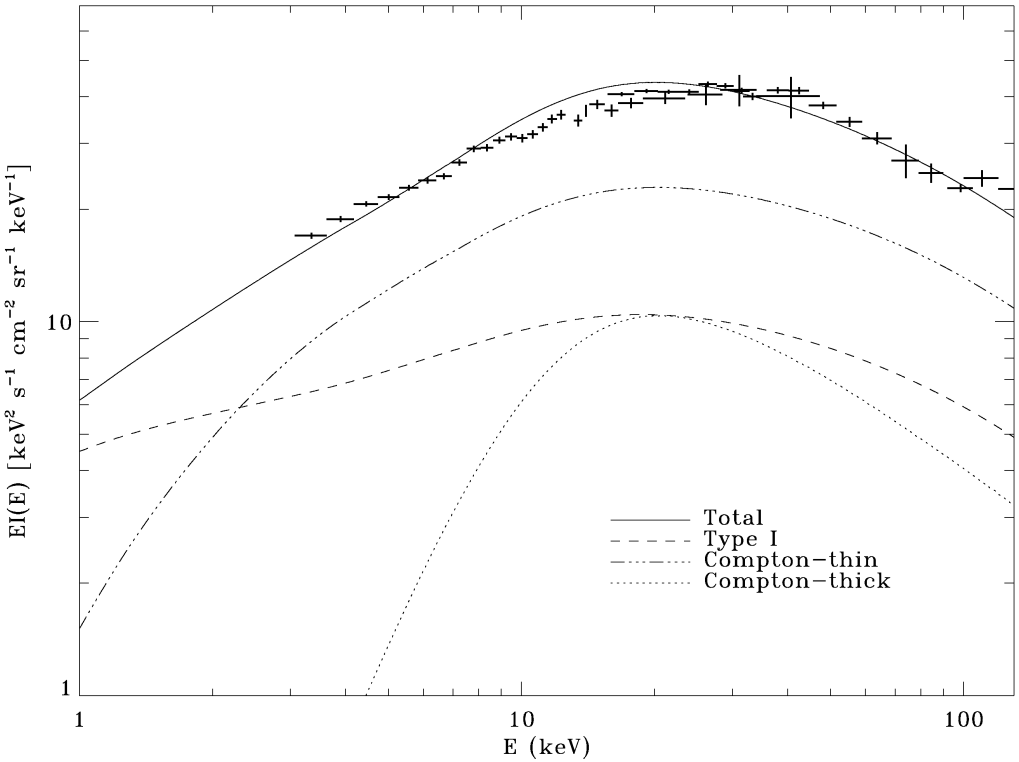

Revnivtsev et al., 2003 RXTE
XMM
HEAO−1
A4 LED
ASCA GIS
HEAO−1
A2 HED
SAX
ASCA SIS
ROSAT
HEAO−1
A4 MED
CDFS
100
10
0.1
1
10
100
E×F(E) [keV s⁻¹ sr⁻¹ cm⁻²]
E [keV]

Hard spectral shape of XRB explained by intrinsic absorption in component sources (Setti & Woltjer 89)



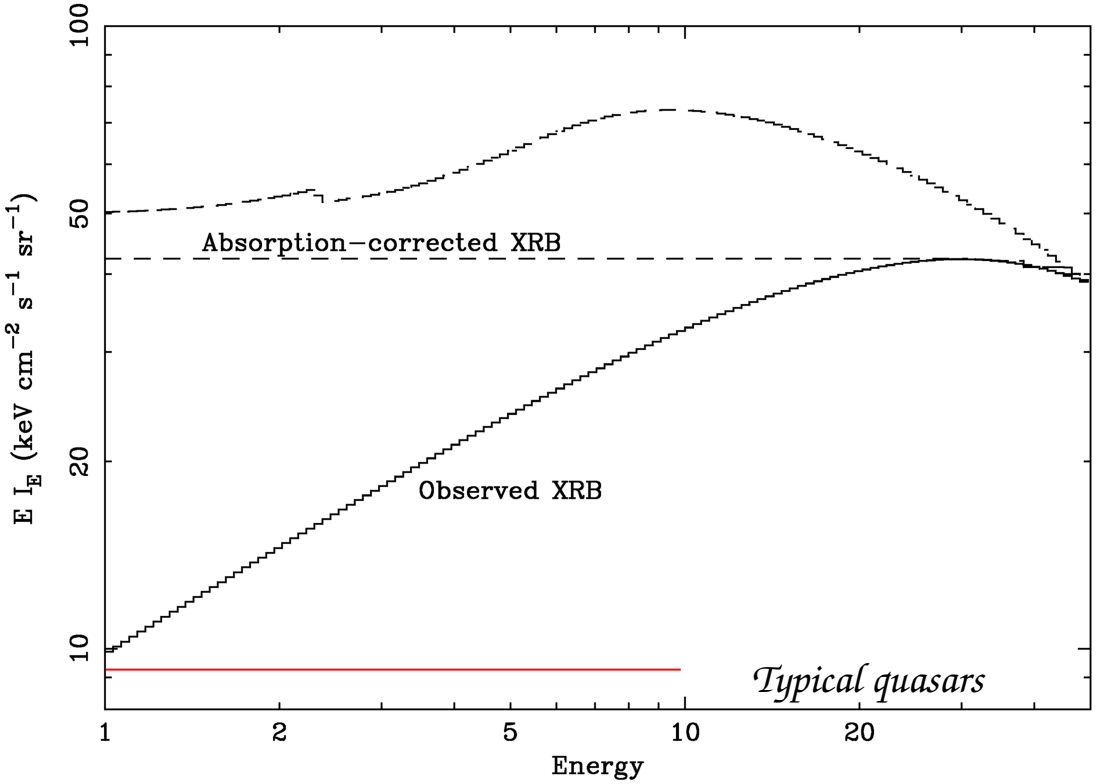
Model by Gandhi & Fabian 02; see also Madau et al; Comastri et al Gilli et al…

Gandhi & Fabian 02 (assumes Seyferts evolve like star-forming galaxies)



Note that Compton thick objects don't contribute significantly below 5 keV

MOST AGN emission must be absorbed!



Fabian & Iwasawa 1999

- *Probably more complex geometry for obscuration than simple unification torus model*
- *Star-formation in surrounding gas helps keep it inflated so has high covering factor?*

Accretion makes massive black holes

$$\varepsilon(1+z) = 0.1\rho_{\bullet}c^2$$

Soltan 82

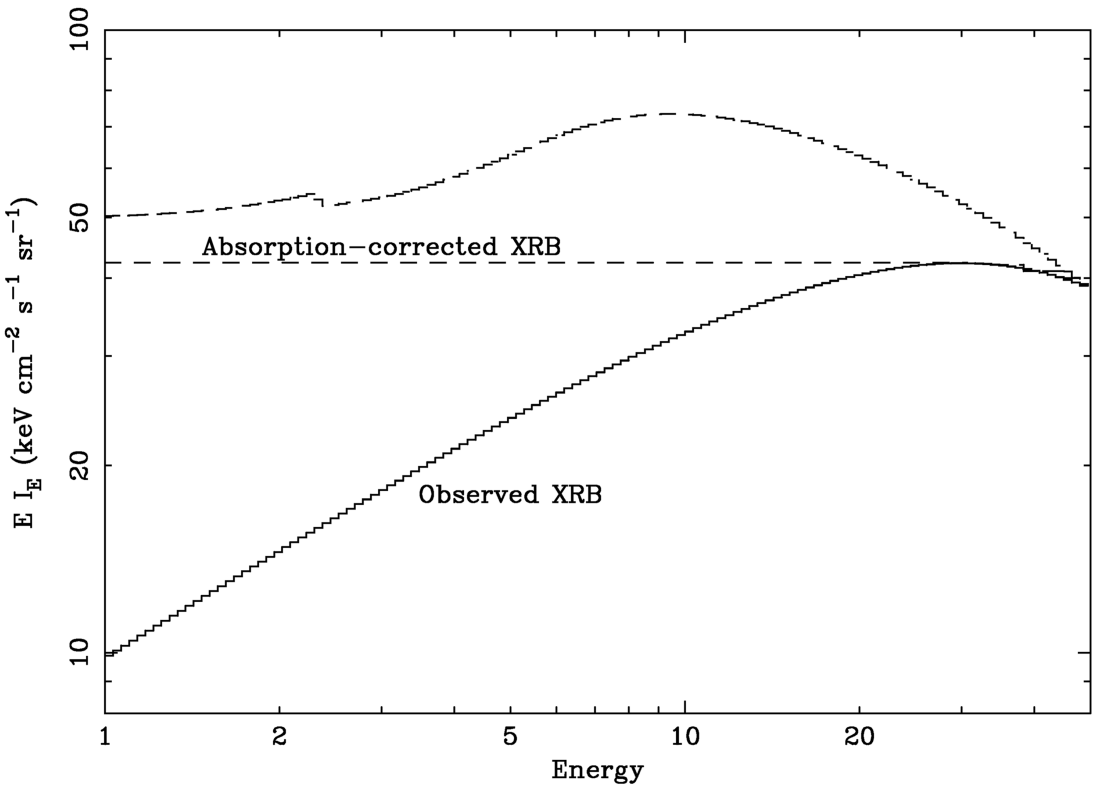
Mean redshift

$I_{Bol} = \kappa I_{XRB}$

Radiative efficiency

$$\frac{4\pi I_{Bol}}{c} = \varepsilon$$

$$I_{Bol} = \kappa I_{XRB}$$


100
50
20
10
1
2
5
10
20
Energy
E I_E (keV cm^-2 s^-1 sr^-1)
Absorption−corrected XRB
Observed XRB

- *Original guesses (FI99) assume z~2, ~30 (appropriate for quasars) seemed OK if efficiency ~0.1.*
- *Rework by Elvis et al (02) suggested need >0.15.*
- *But if ~3X10^{5} Msun pc^{-3} (eg Yu & Tremaine 02) then a major problem requiring much higher arises.*

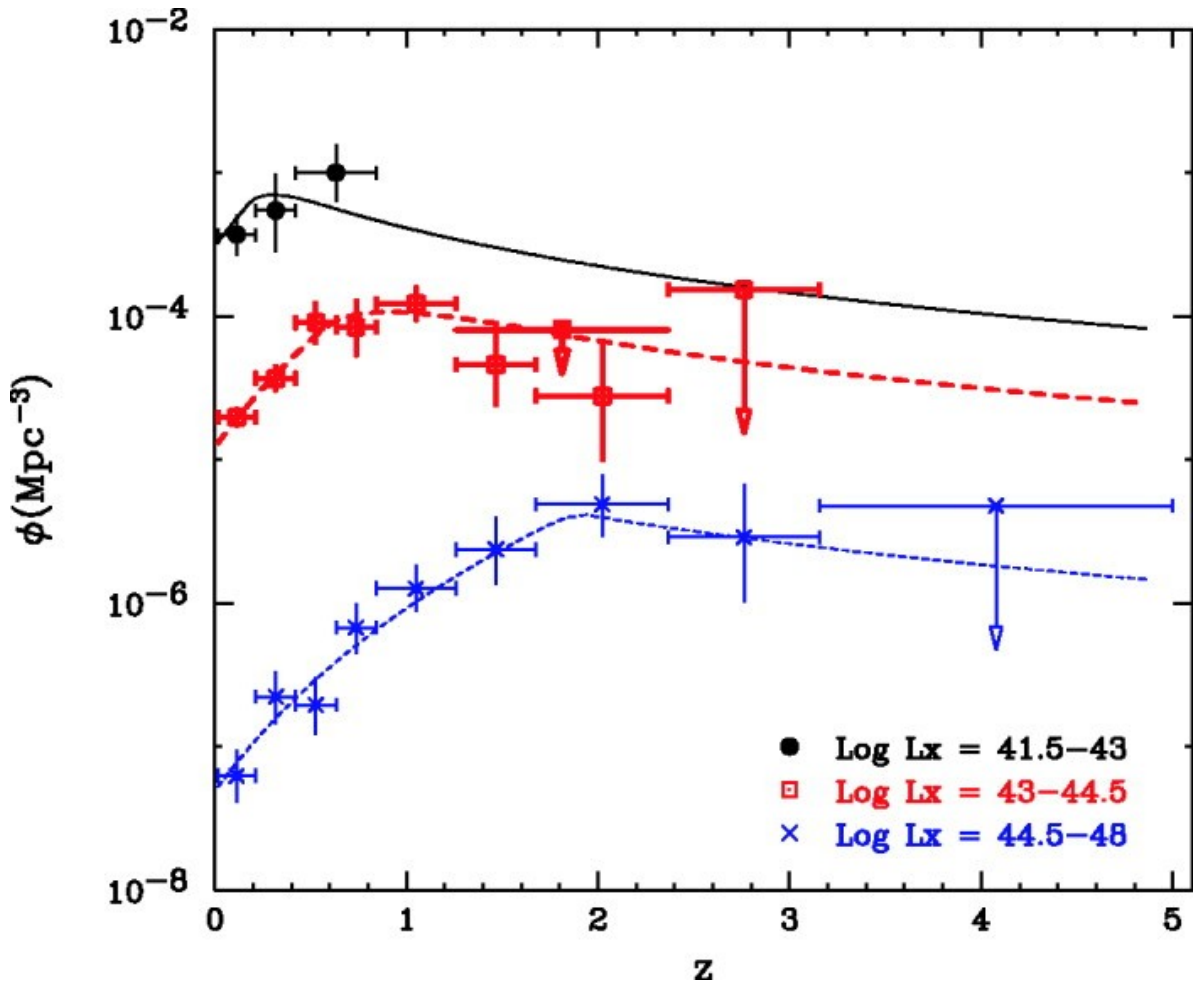
h=0.75

What (if anything) has gone wrong?

Chandra and XMM-Newton Deep Surveys

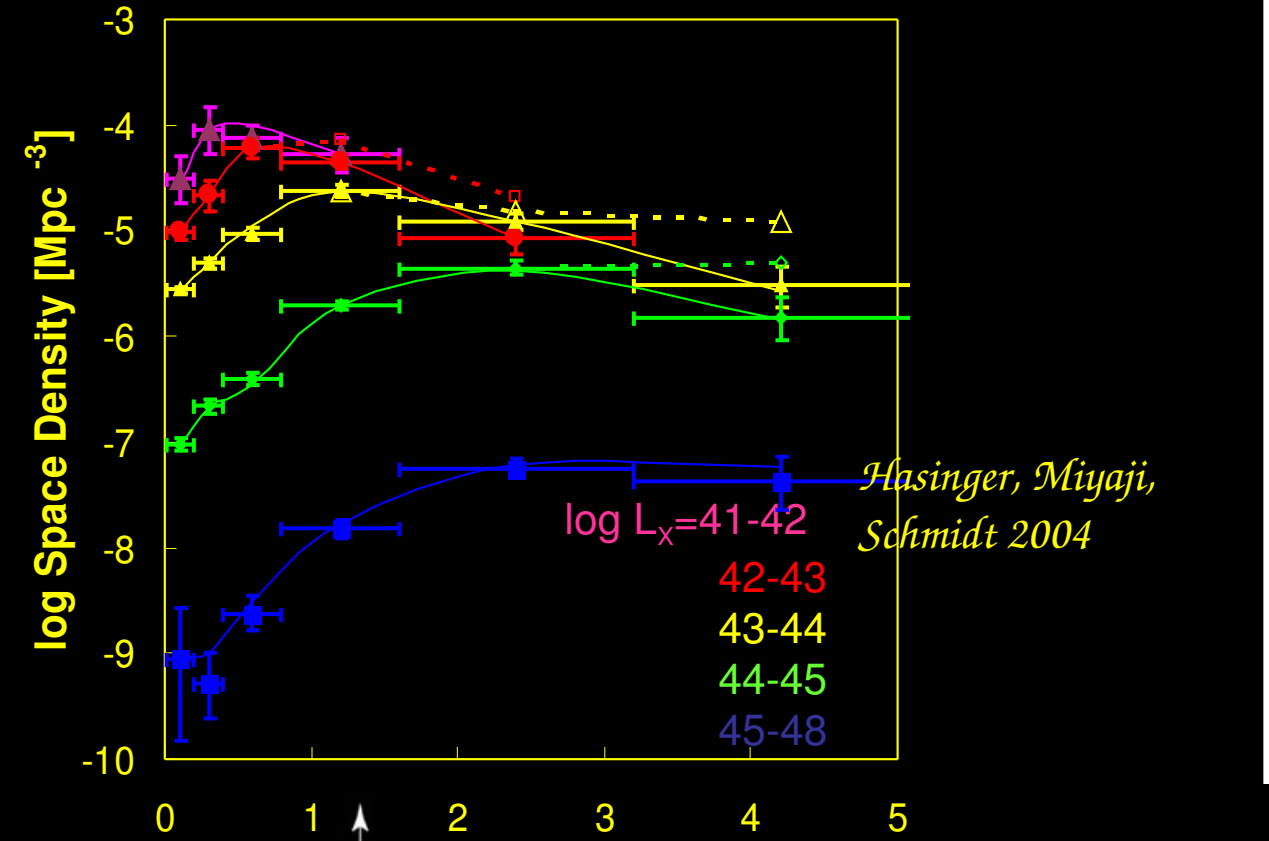
- *Confirm that point sources resolve most of the XRB in the 2-5 keV band (Mushotzky et al; Giacconi et al; Brandt et al; Barger et al; Hasinger et al; Alexander et al…)*
- *Many faint sources are hard due to absorption but generally find* $N_H<10^{23}$ cm^{-2}.
- *Dominant contribution from intermediate luminosity sources (L(2-10)<*10^{44} *erg* s^{-1}*) peaking at z~0.8.*
- *Are Compton thick sources rare? Has something changed since z~1?*

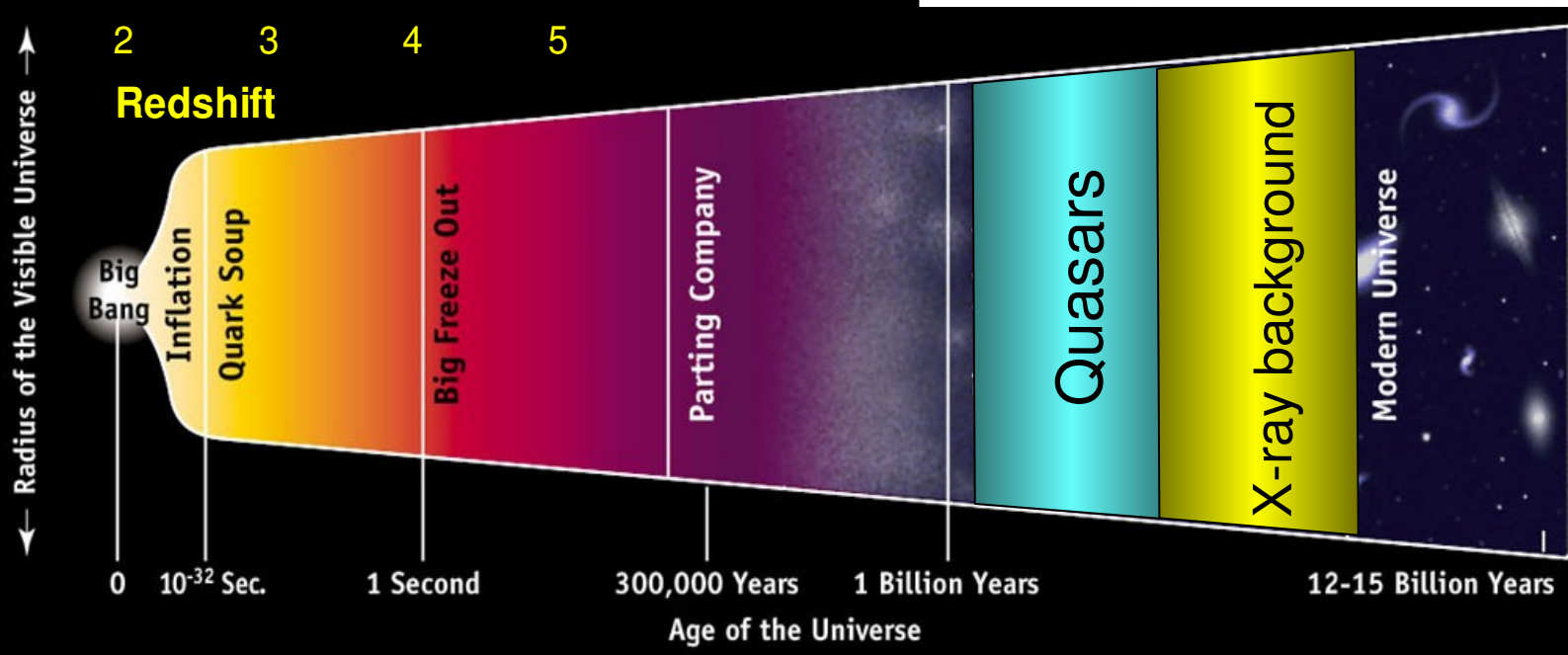
Similar results on the bright end from ASCA surveys (Ueda et al 03) and HELLAS (Fiore et al)



Ueda et al 2003

Rise and fall of quasars and AGN





Modifications assuming most absorbed AGN are Seyferts not QSO

- $L<3X10^{44}$ erg s^{-1} (this Seyfert/quasar boundary is a guess. Could be a continuous change. –What is a quasar?)
- Then ~15 and z~0.7
- This reduces • to ~4-5x10^5 (OK?)

Fabian 03 Carnegie Conference

Marconi et al 04 MN

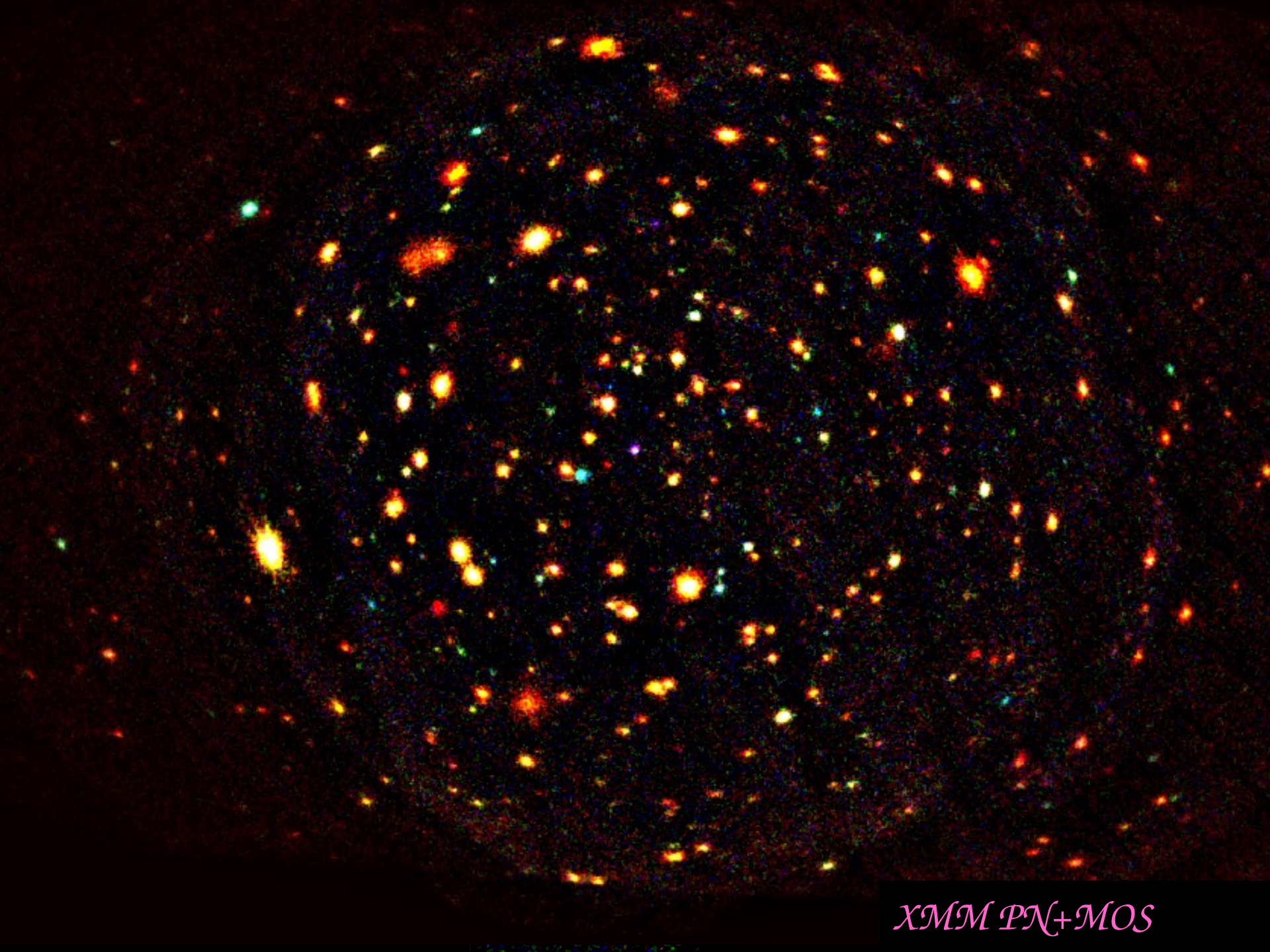
Ueda et al 03 ApJ 598 886

Shankar et al 04 MN

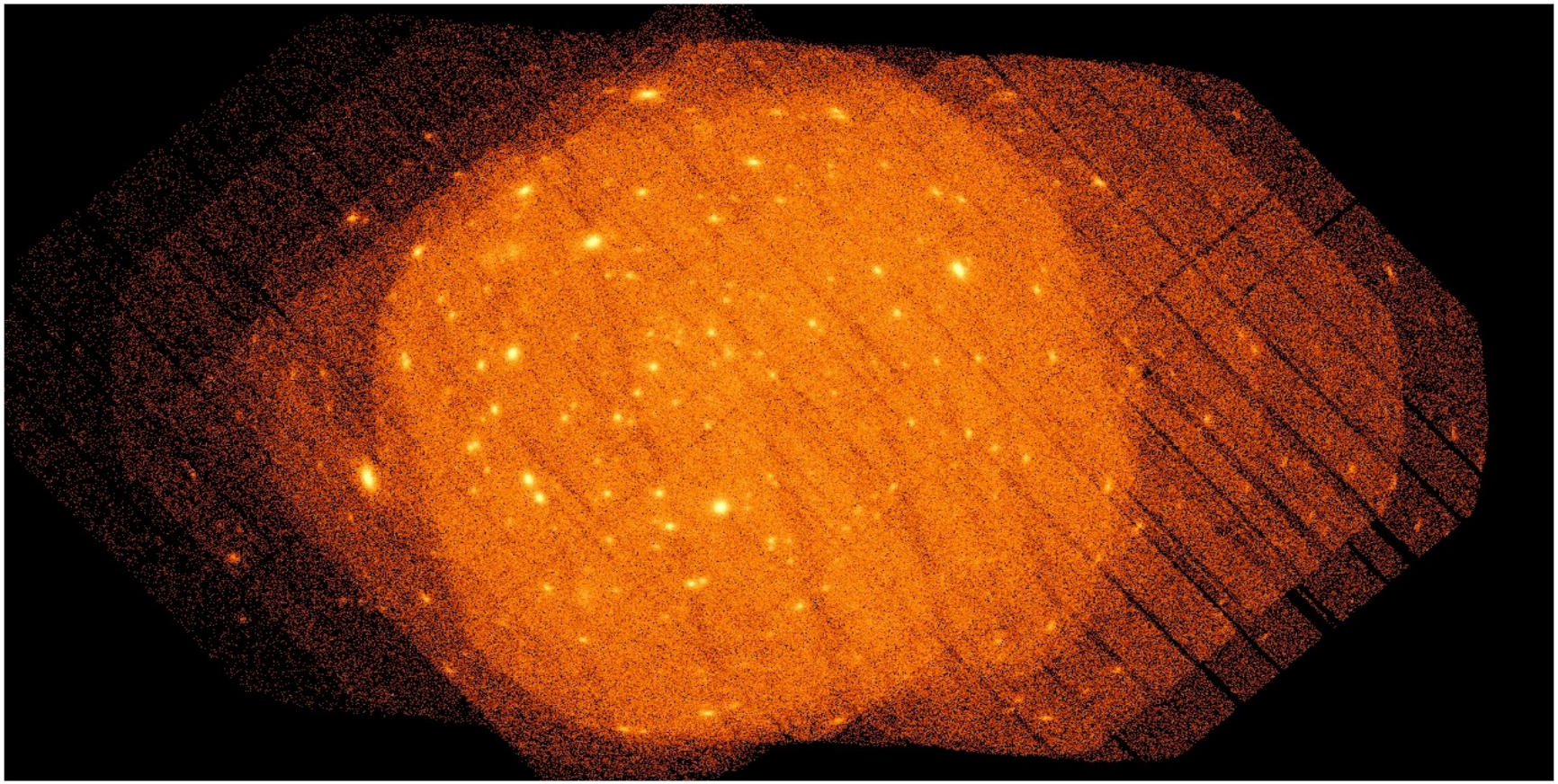
La Franca et al 05

Implications for AGN

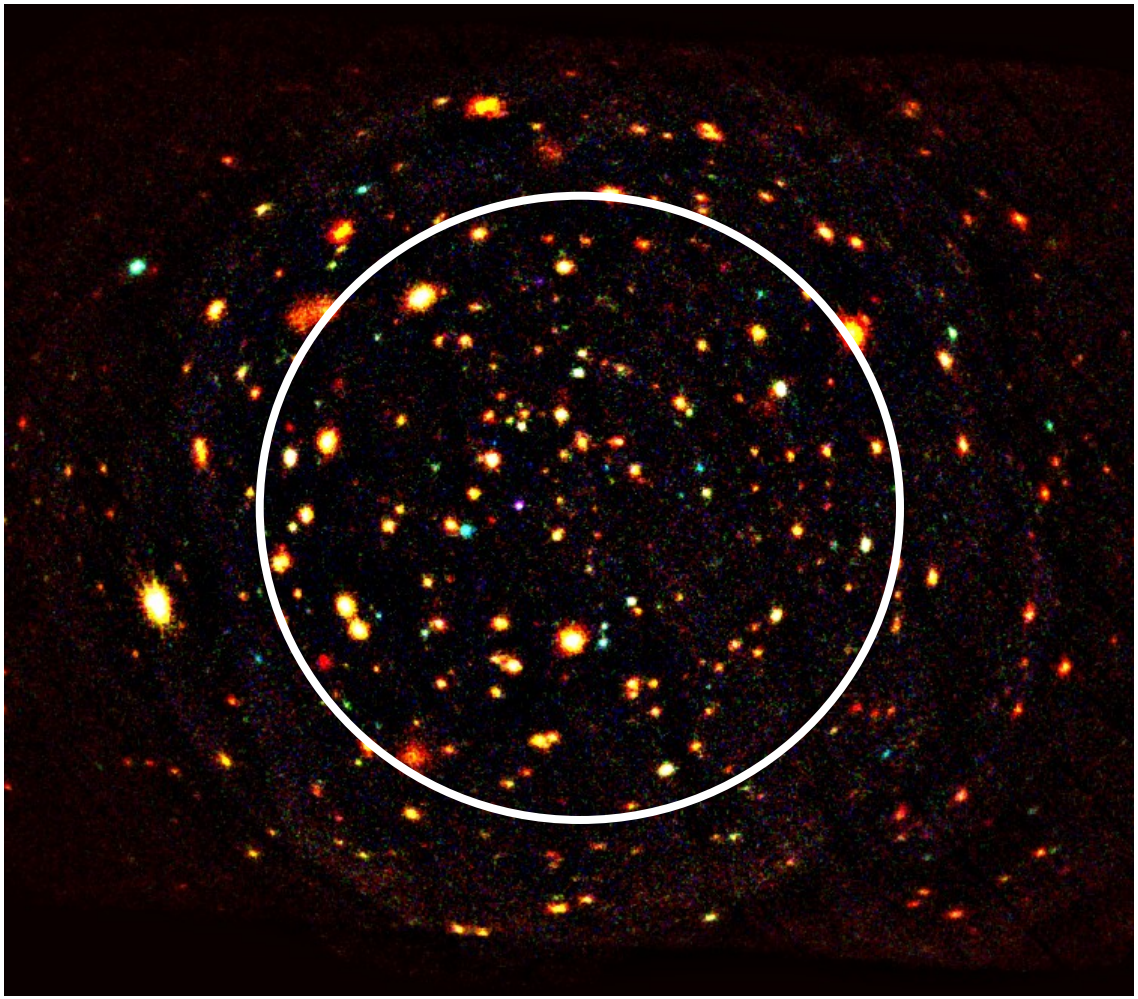
- *Most black hole growth is due to radiatively efficient accretion*
- *Most accreting gas releases most of its gravitational energy very close to the black hole*
- *Truncated discs, ADAFs, RIAFS etc only relevant for low accretion rates*


XMM PN+MOS

Do the spectra of the resolved sources stack to make up the XRB spectrum?



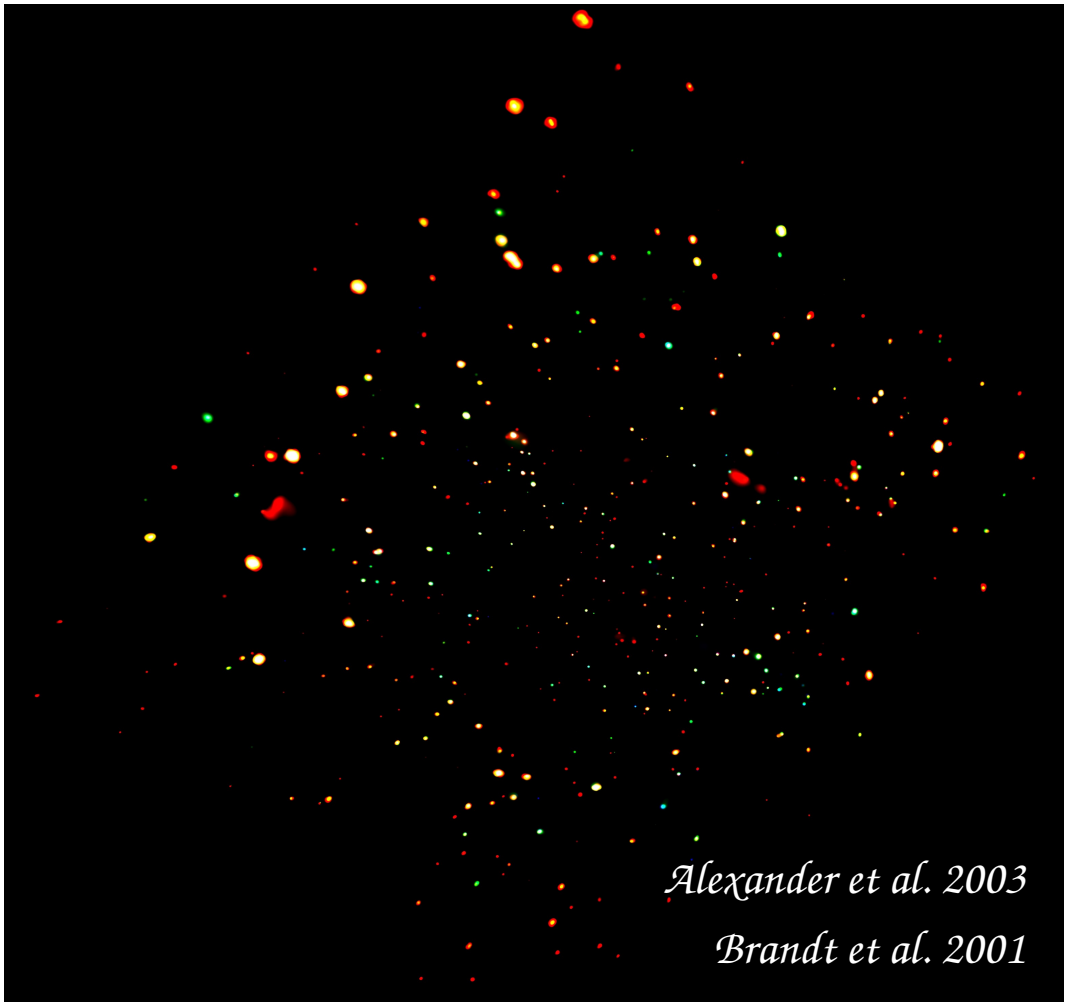
XMM-Newton Lockman Hole



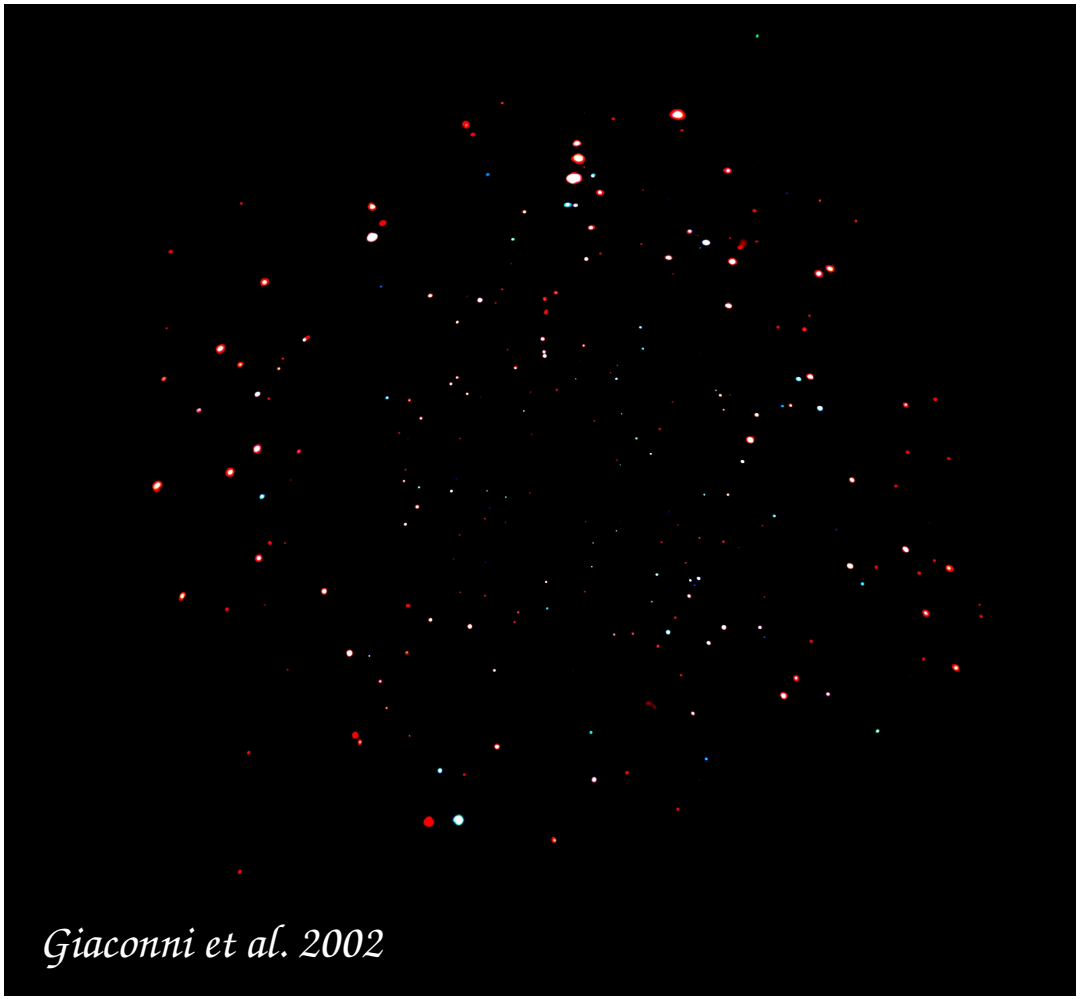
- 681 ks PN
- 858 ks MOS-1
- 878 ks MOS-2
- 314 arcmin^2 central portion
- 156 sources in catalogue
- 0.2-12 keV photometry in 7 narrow bands

Chandra Deep Field North

- ~2 Ms exposure
- 448 arcmin^2
- 503 detected sources
- 0.5-8 keV photometry in 5 bands

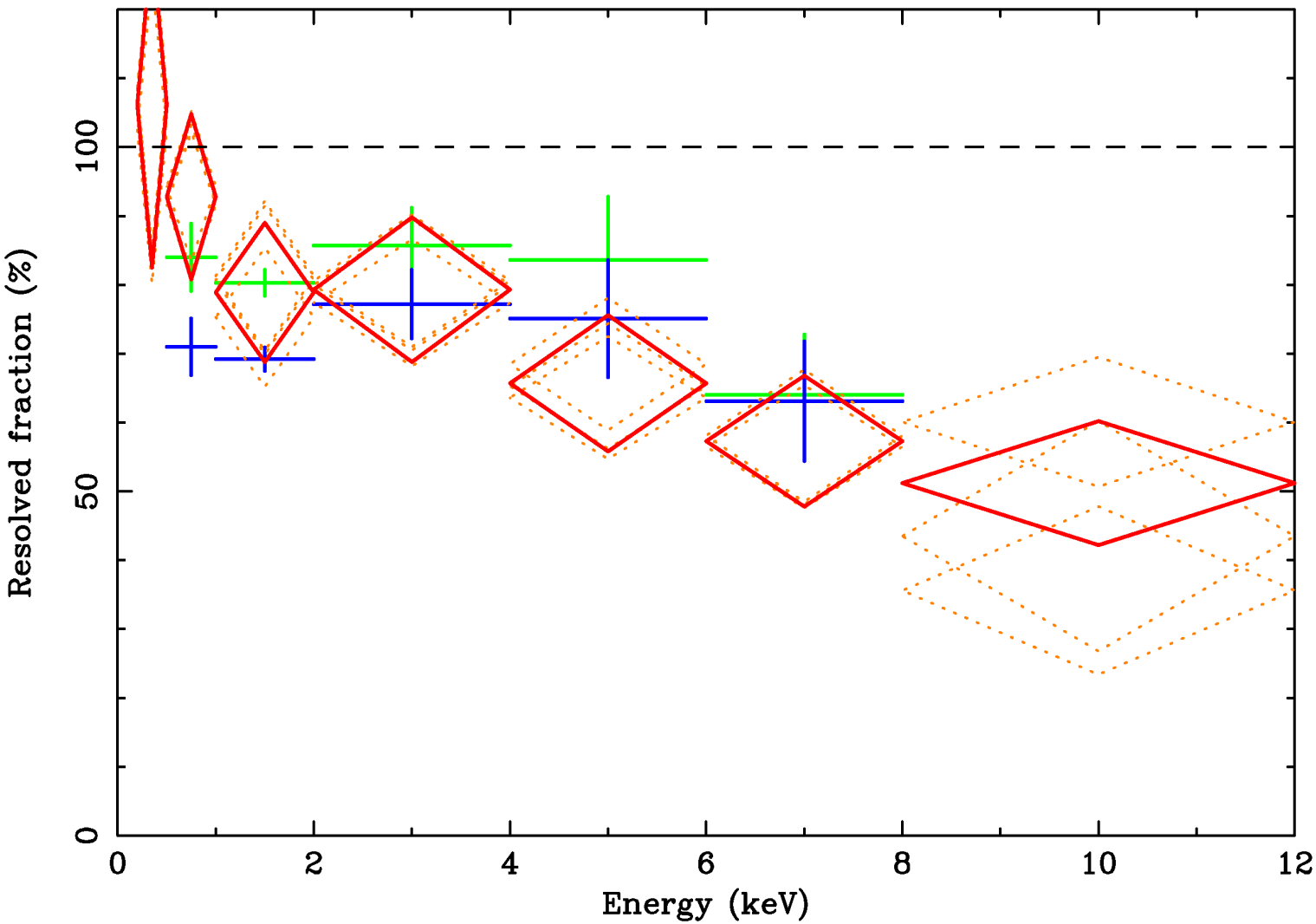


Chandra Deep Field South



- ~1 Ms exposure
- 391 arcmin^2
- 326 detected sources
- 0.5-8 keV photometry in 5 bands

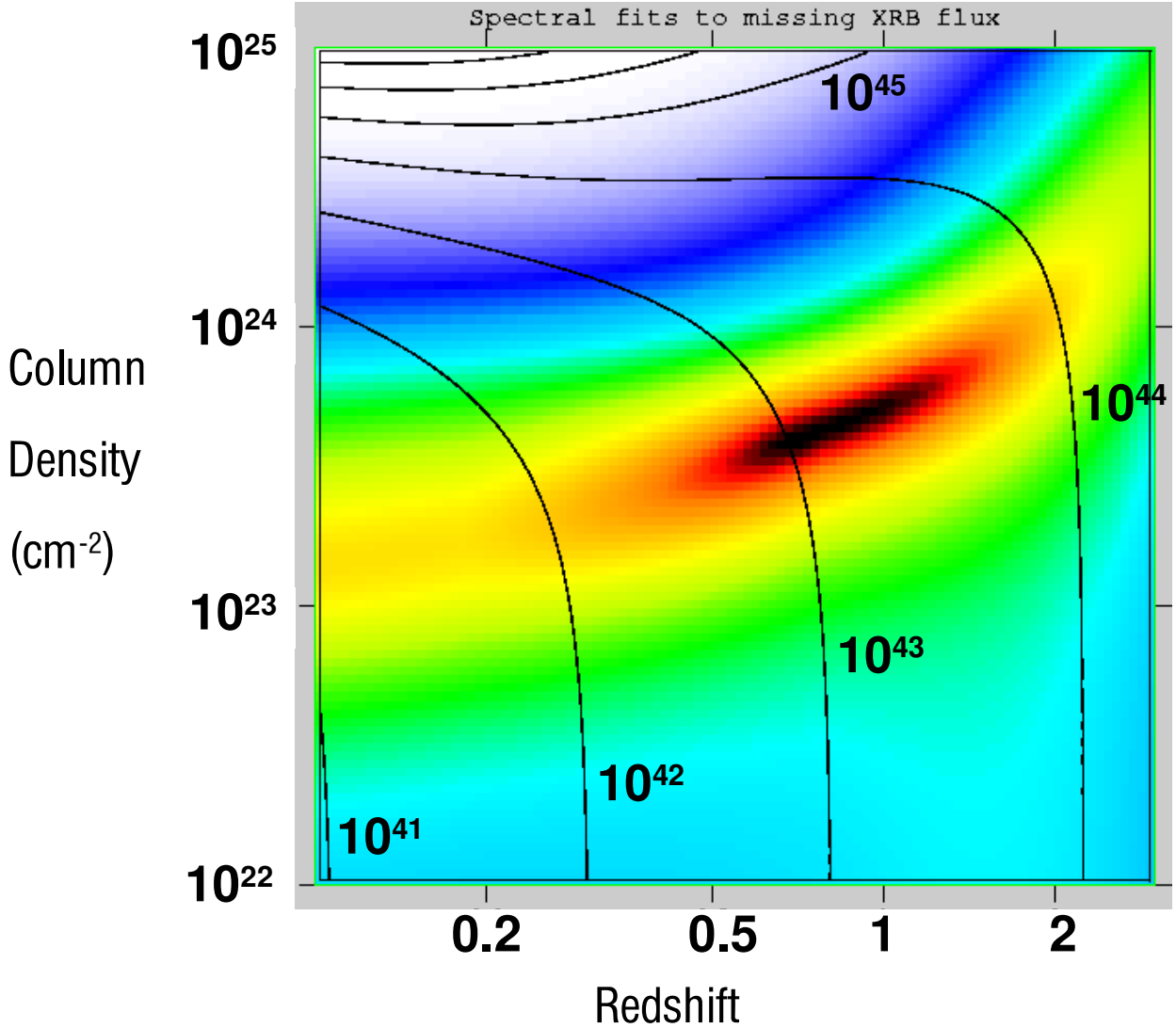
Resolved fraction



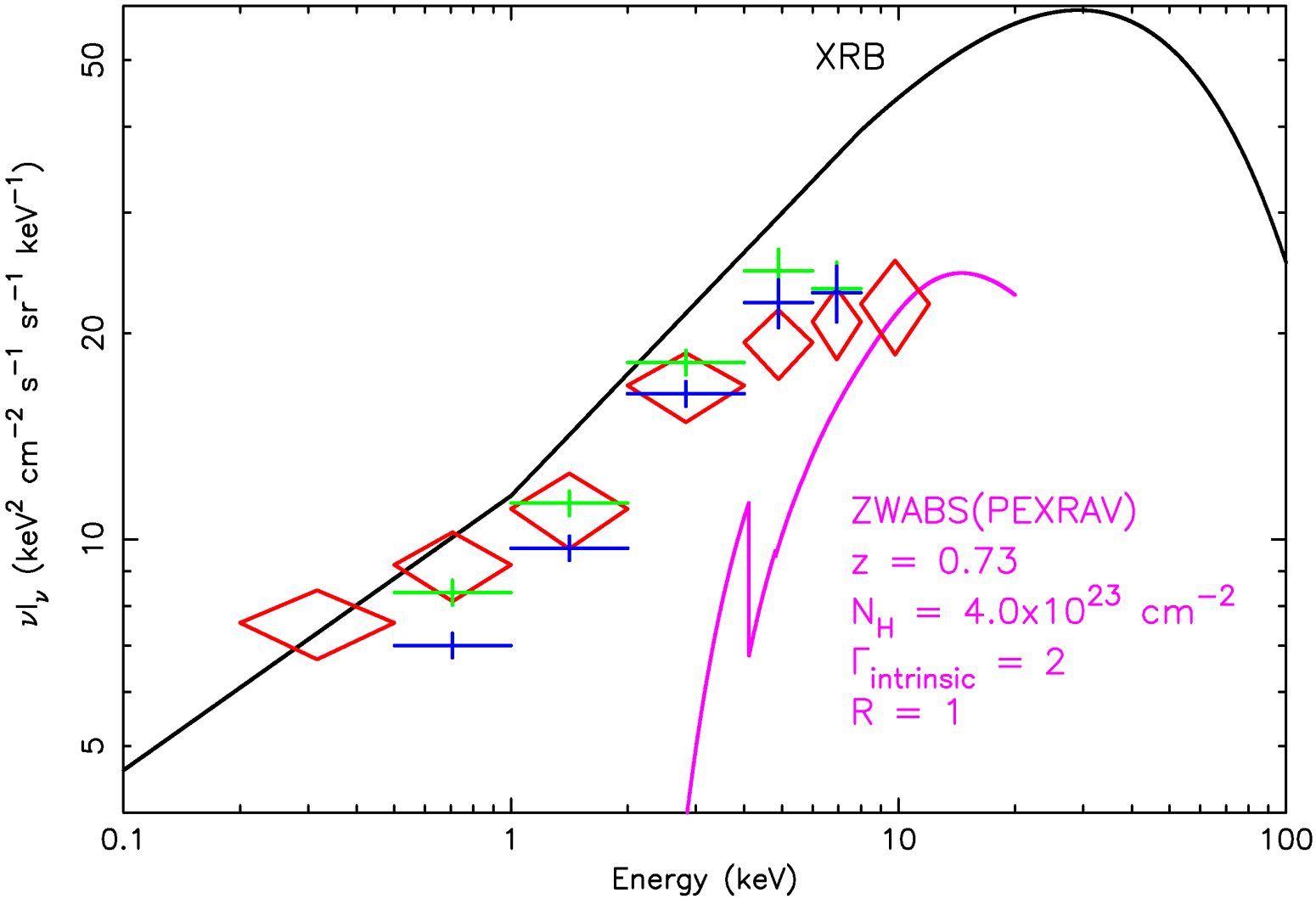
Modelling the missing flux

- *Subtract resolved flux from the known XRB spectrum and model the residual*
- *Simple obscured AGN model:* **ZWABS (PEXRAV)** *with* Γ*=2 power-law plus R=1 reflection component, with photoelectric absorption at the source redshift*
- *Grid over absorption column density and redshift and compute goodness-of-fit to residual*

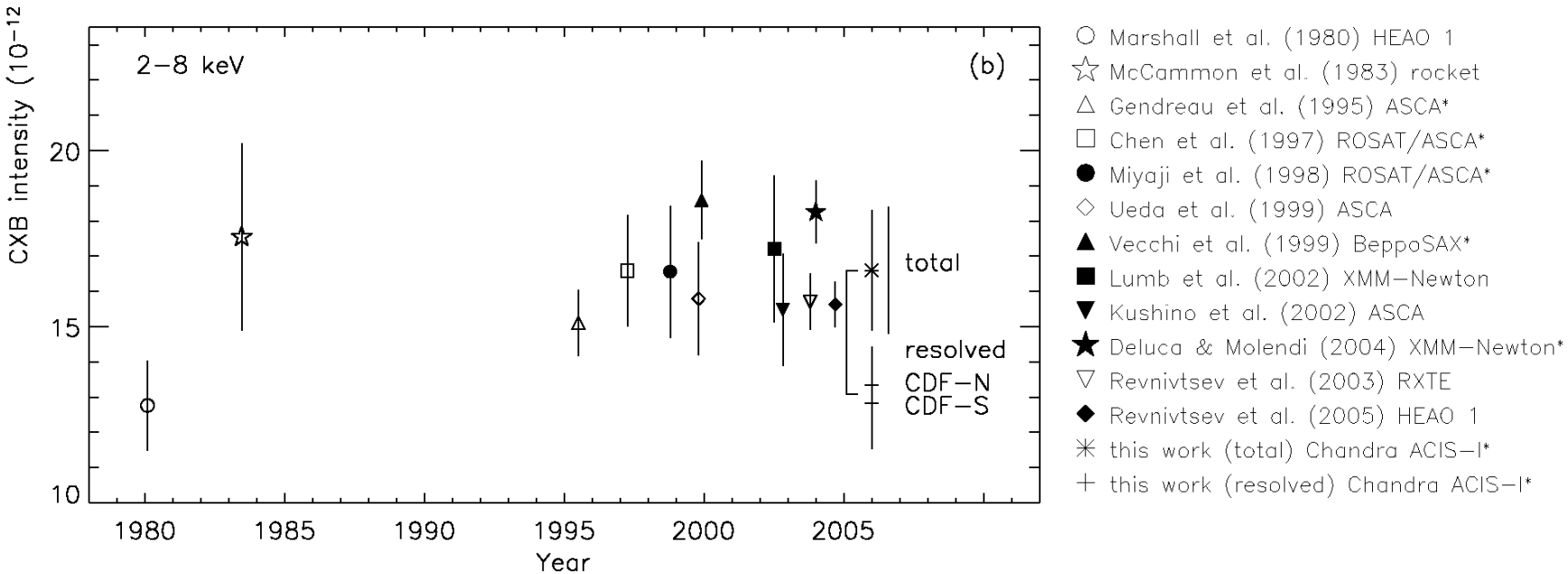
Properties of the missing AGN



Missing XRB component



Hickox & Markevitch (2005 astro-ph) summing unresolved XRB in CDF-N and S



Where are the sources?

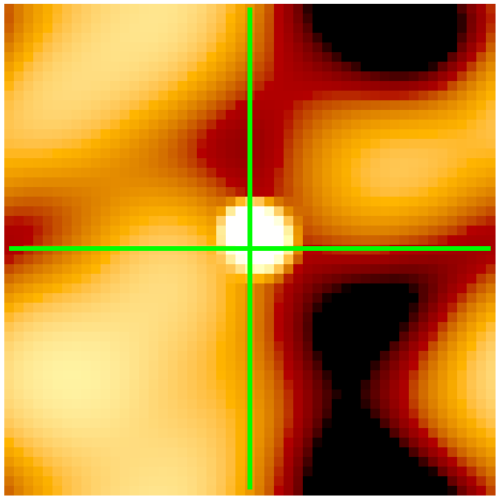
- Missing sources need to be highly-obscured AGN, with $N_H \sim 10^{23} - 10^{24}$ cm^{-2} at z ~ 0.5 - 1.5
- Unobscured rest-frame 2-10 keV luminosities need to be less than ~ 5×10^{43} erg cm^{-2} s^{-1} or else they should have been already detected in CDFs
- This suggests an obscured:unobscured ratio 3:1 similar to what we see in the local Universe

Great Observatories Origins Deep Survey (GOODS)

- *Multiwavelength deep-field survey campaign centred within the CDF-N (including HDF-N) and within the CDF-S (including the UDF).*
- *X-rays (Chandra), Optical (HST), IR (Spitzer) + ground-based observations*
- *The HST optical catalogues now complete with B, V, i and Z-band photometry down to ~27-28th mag (L* to z~6)*
- *We stack 10,000 optical sources in each of the CDF-N and CDF-S (~1000 yrs total X-ray exposure)*

Detection of X-ray emission

- Highly significant detection of X-ray emission when all sources are included in stacking: ~8-30σ in each of 0.5-1, 1-2, 2-4 keV bands of CDF-N and S
- Hard band detection less significant due to background and A_{eff} but 4.3σ and 2.8σ in 4-6 keV for the CDF-N and CDF-S (Z<~24th)



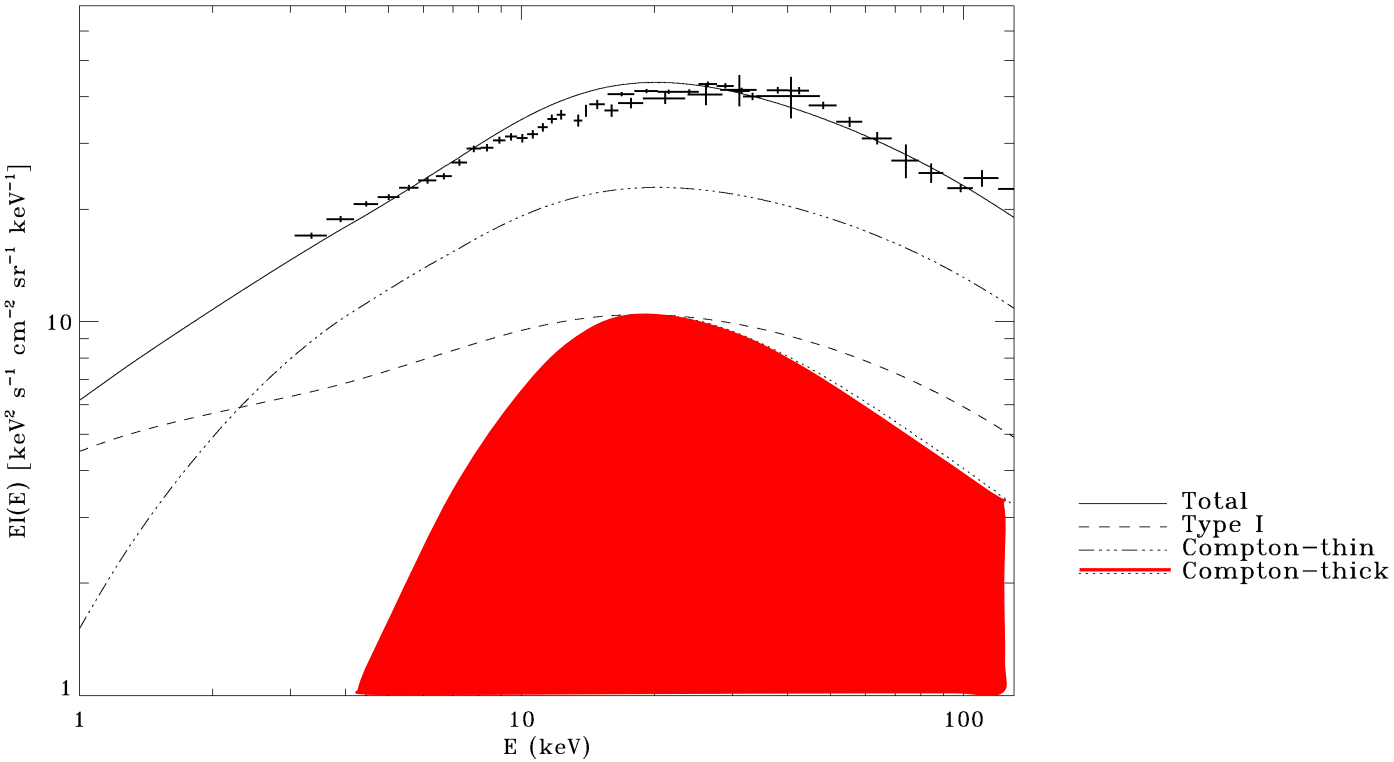
CDF-N Z<22nd mag

Smoothed image, log scale, 4-8 keV band

6-8 keV emission?

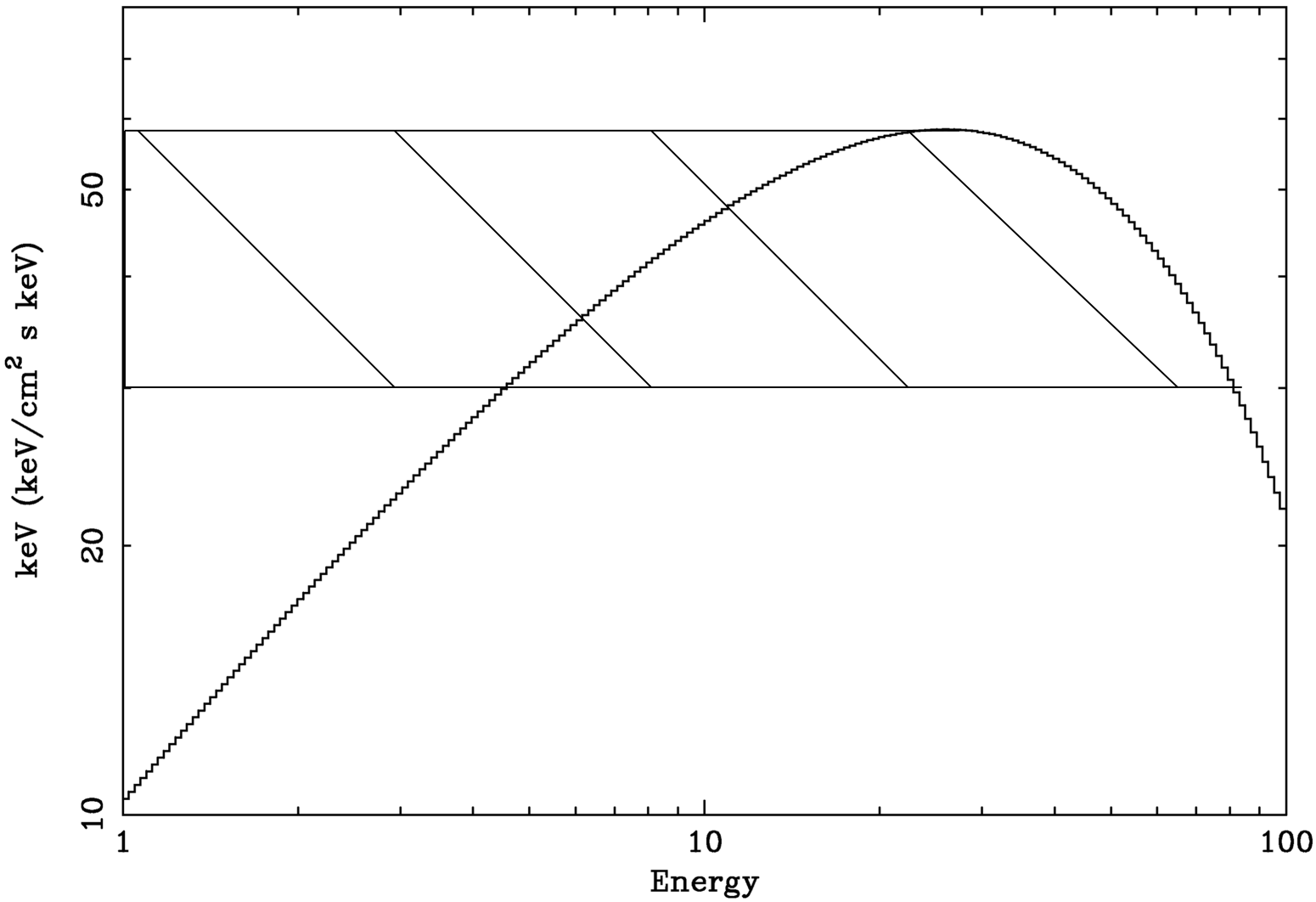
- Only see 1.2σ in CDF-N Z<23rd and 1.9σ in CDF-S Z<22nd… but…
- Background:source counts are 100:1 – even the entire missing XRB (40%) would only yield 2.1σ in the CDF-N and 1.4σ in the CDF-S
- We are searching for a very weak signal… the GOODS galaxies are only $2x10^{-18}$ erg cm^{-2} s^{-1} even in the 0.5-2 keV

Gandhi & Fabian 02
(assumes Seyferts evolve like star forming galaxies (Chary & Elbaz 02))



Note that Compton thick objects don't contribute significantly below 5 keV

~1/3 of XRB absorption-corrected energy density is in the 'missing component, which plausibly are Compton-thick Seyferts at z~0.5-1



Energy and mass

- *~1/3 of in Compton-thick Component?*
- *If at say <z>~0.7 rather than 2 and Bol correction is ~6% rather than 3% then intrinsic luminosity produced increases by ~1/6.*
- *Adds a similar fraction to local BH mass density (i.e. about 0.5-1x10^5 Msun Mpc^{-3} extra).*

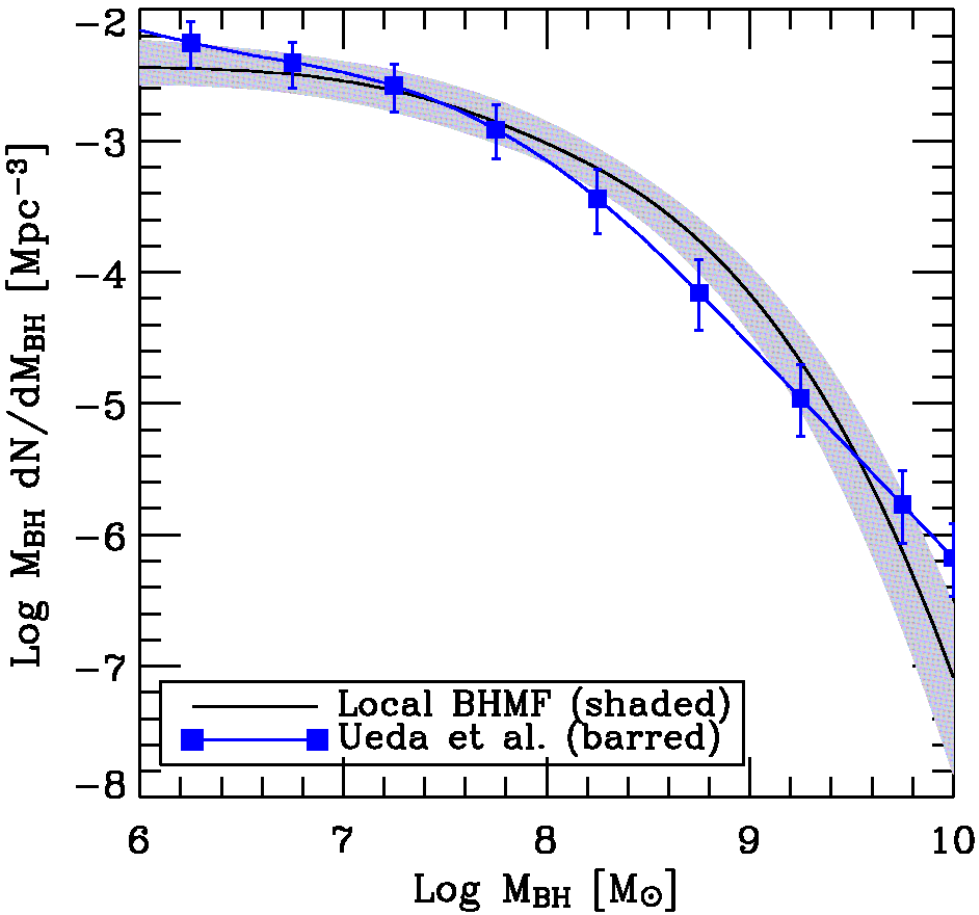
• *in units of 10^5 Msun Mpc^{-3}*

- *Unobscured quasars and Seyferts 2-3*
- *Obscured Compton –thin Seyferts 2*
- *Compton-thick Seyferts 0.5-1*

- *What of Compton thick quasars?*

Need better direct estimate of •
locally before can argue for high

Marconi+04



the $\pm 1\sigma$ uncertainty on the logarithm of local BHMF (see Fig. 2b).
luminosity function and accounting for the missing Compton Thick
; of 1000 realizations of the relic BHMF (see text). The local BHMF

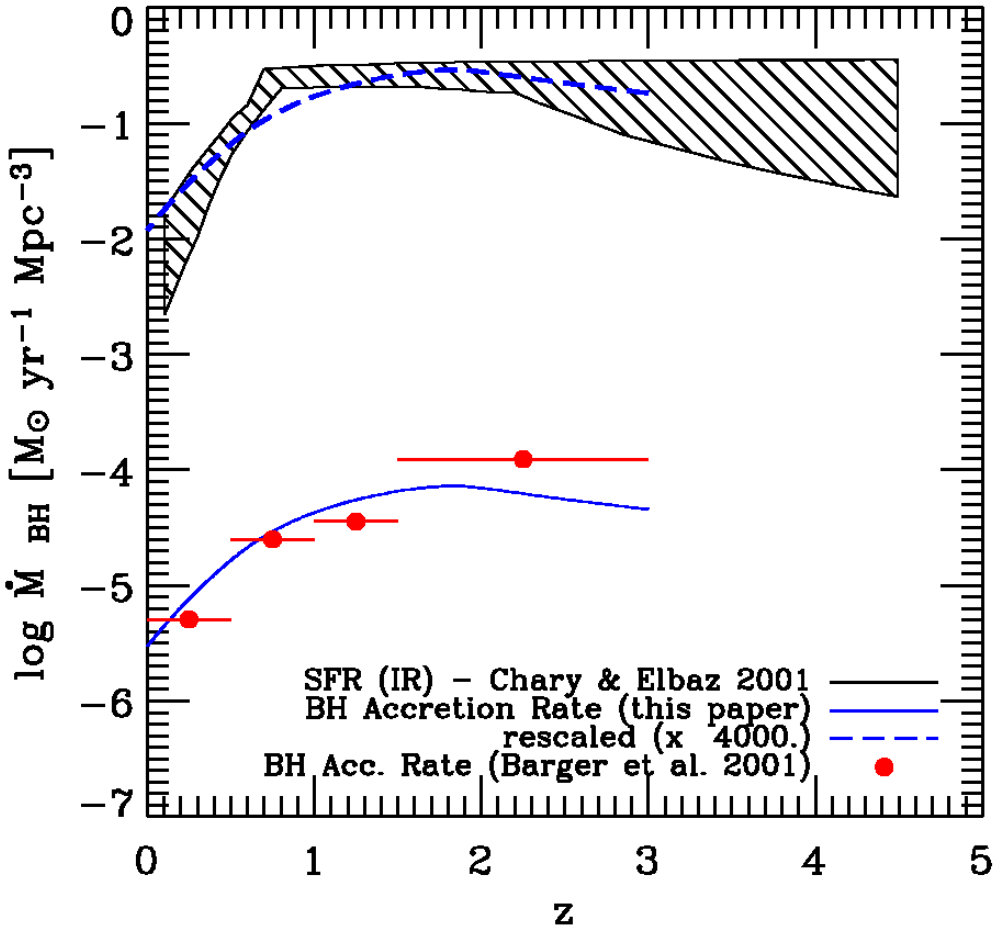


Figure 9. Cosmic BH accretion history compared with the estimate by Barger et al. (2001) and with the cosmic star formation rate by Chary & Elbaz (2001).

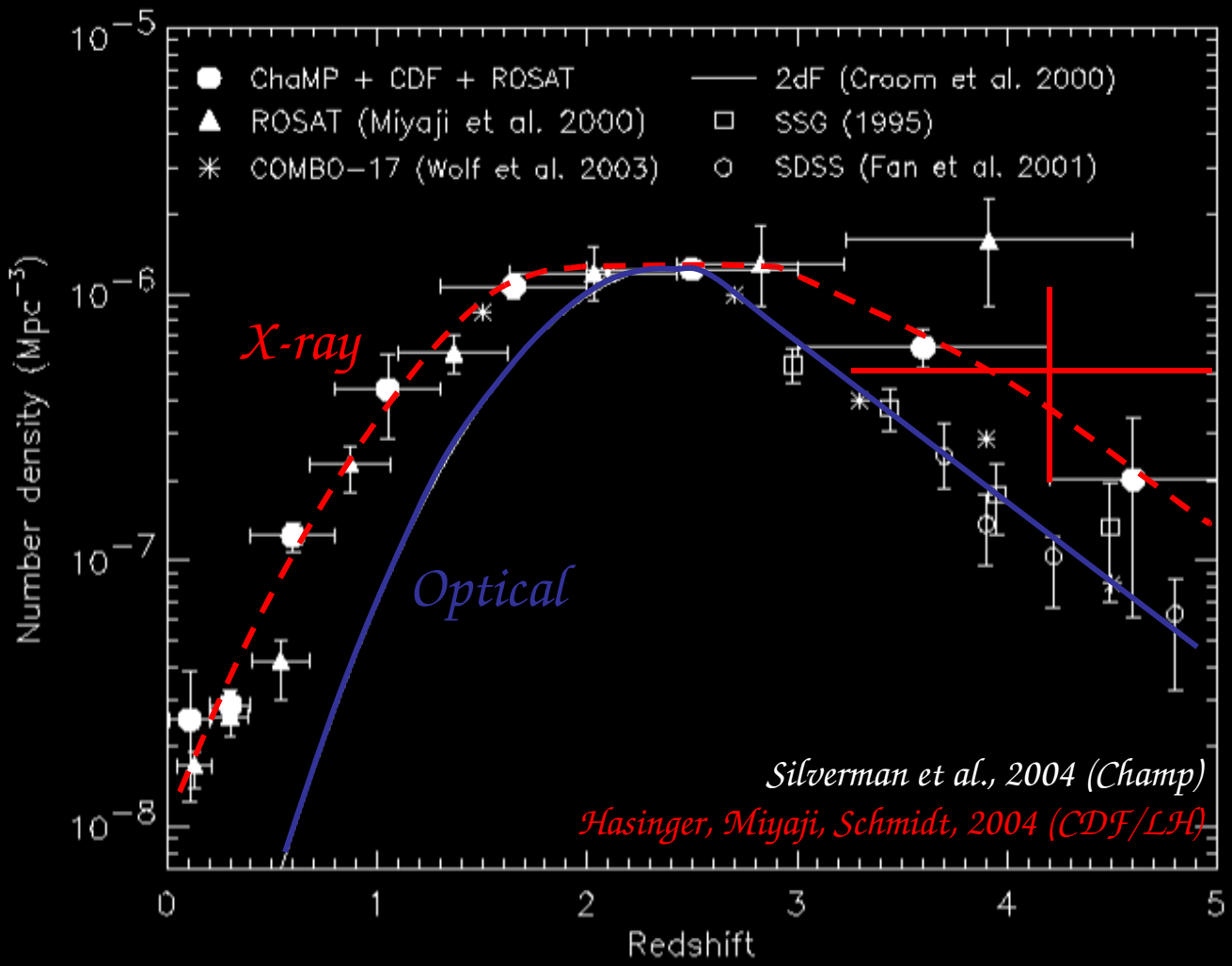
Summary

- X-ray Background resolved up to 6 keV.
- We are missing >40% of XRB intensity above 6 keV and most of XRB above 10 keV
- Missing fraction probably due to type II AGN

Some remaining issues for XRB

- *Hard shape of XRB spectrum*
-
- *What determines the cutoff energy?*
- *Reflection high??*
- *What causes the absorption?*

X-ray vs. Optical QSOs

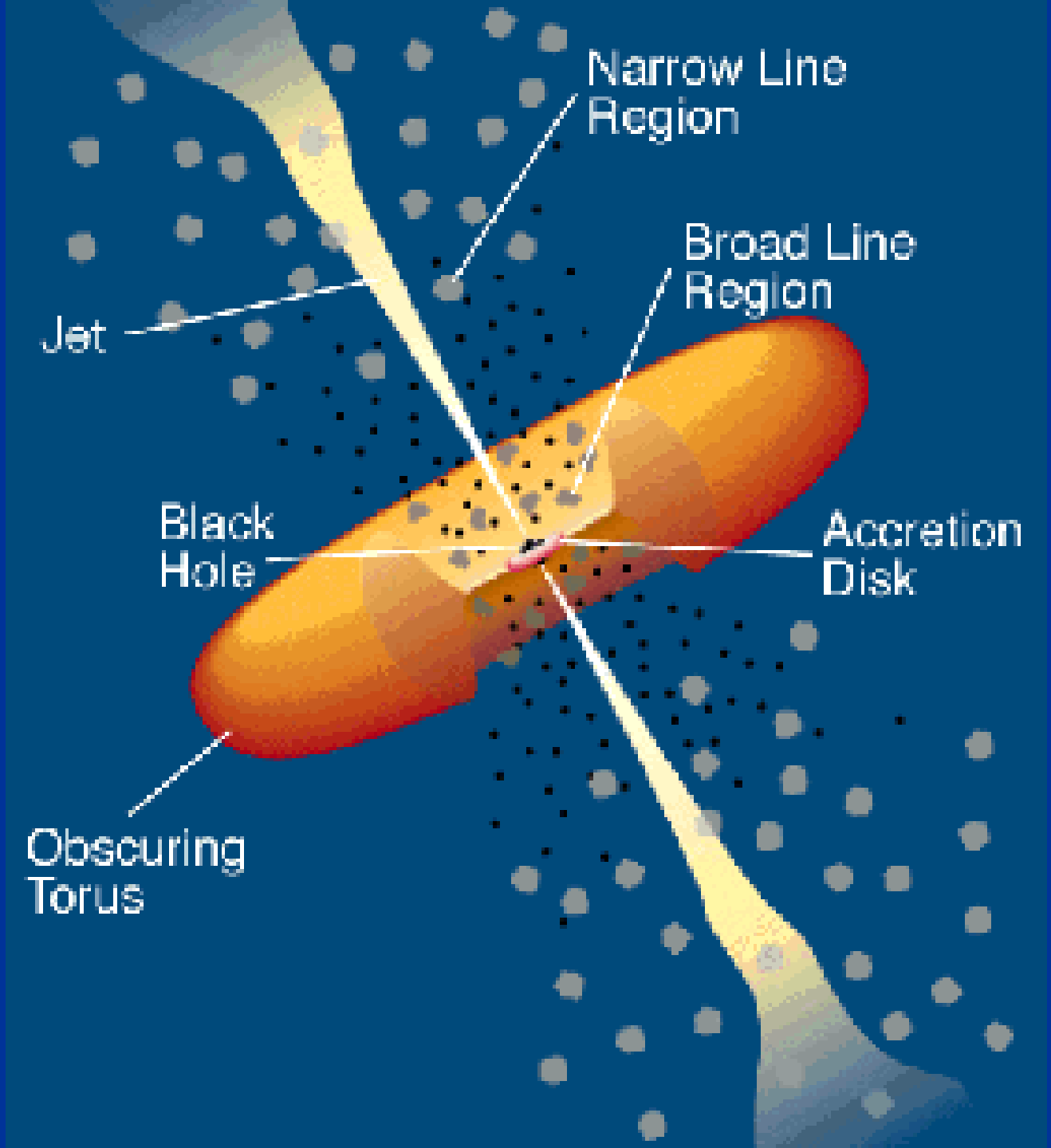


Very large solid angle deep surveys are required to discover z>5 QSOs

XMM/COSMOS

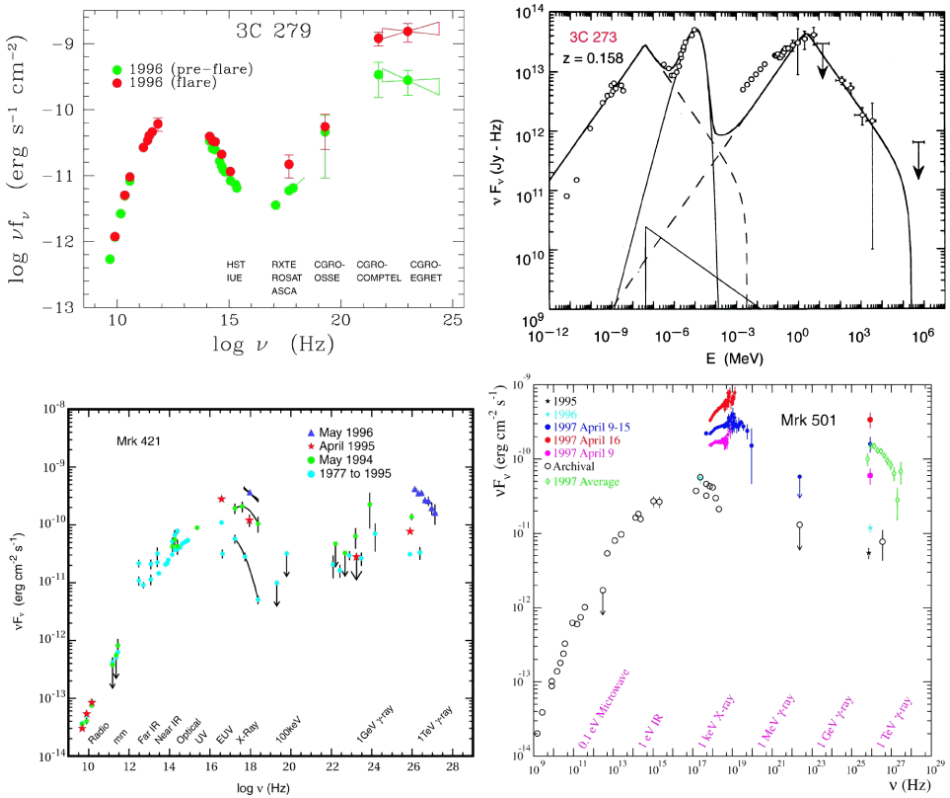
Alternatively from other wavebands

High-z decline now seen in X-rays at all luminosities!
Differences between X-ray and optical due to selection effects?


Narrow Line
Region
Broad Line
Region
Jet
Black
Hole
Accretion
Disk
Obscuring
Torus

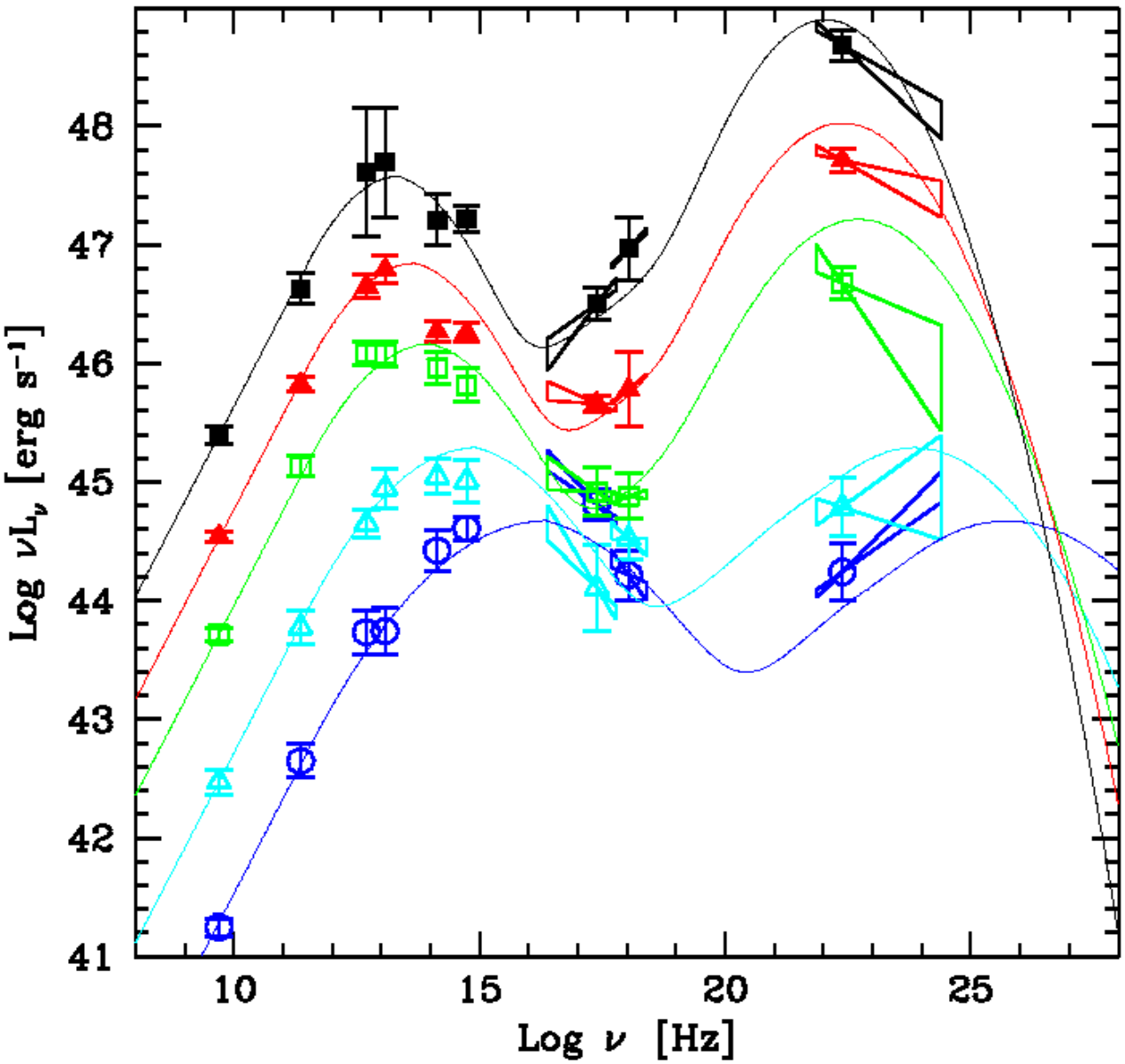
Radio-loud objects

- *Many parts of the spectrum are dominated by power-law jetted emission (synchrotron or SSC)*



Blazar sequence

Fossatti et al97



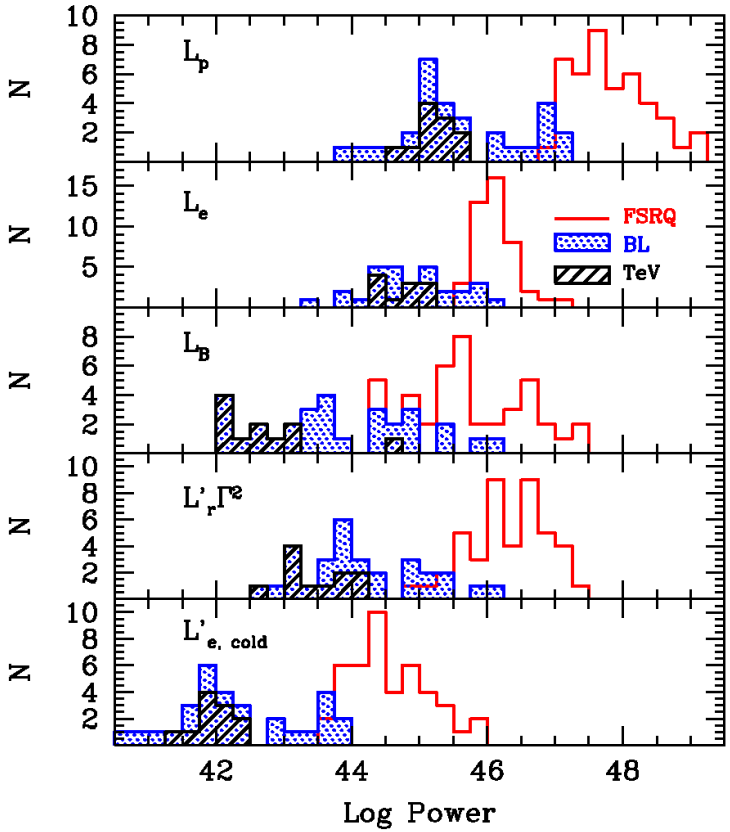


Figure 6. Distribution of jet powers for the blazars considered in Celotti & Ghisellini (2003). $L_{\rm p}$ is the power carried by protons assuming one proton per emitting electron; $L_{\rm e}$ is the power carried by the emitting electrons; $L_{\rm B}$ is the Poynting flux; $L'_{\rm r}\Gamma^2$ is the power radiated by the jet and $L_{\rm e,cold}$ is the power carried in the form of electron rest mass (without including the relativistic random energy of the particles).

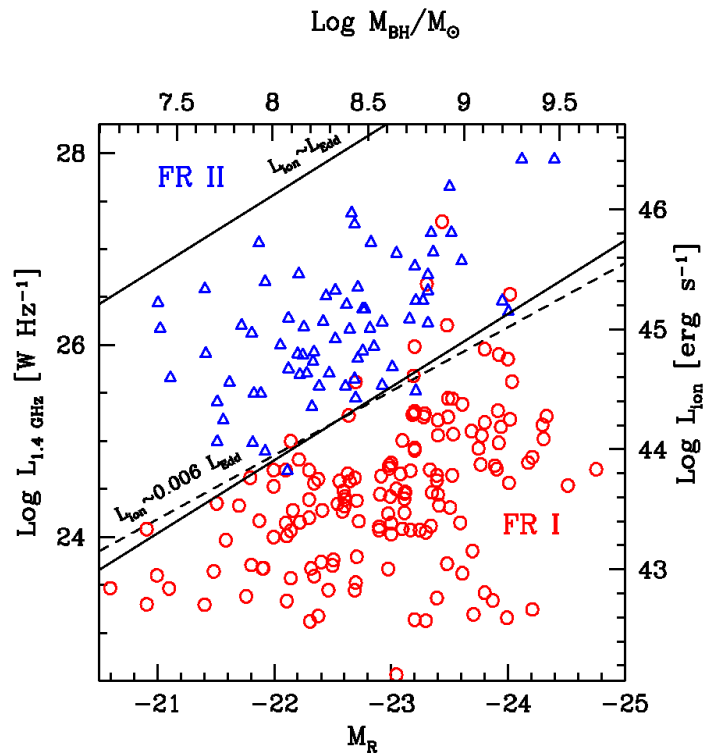
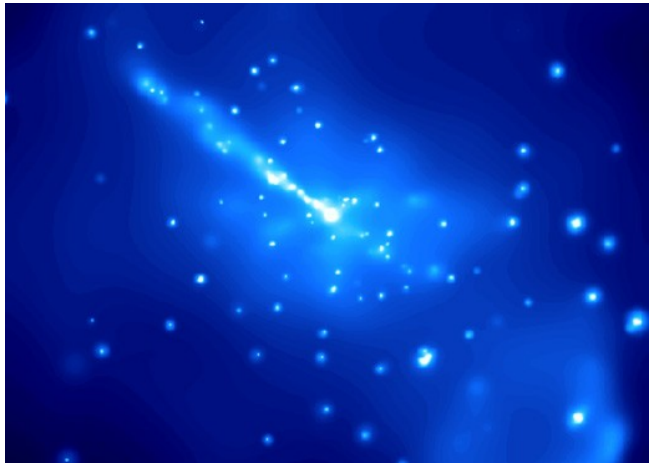


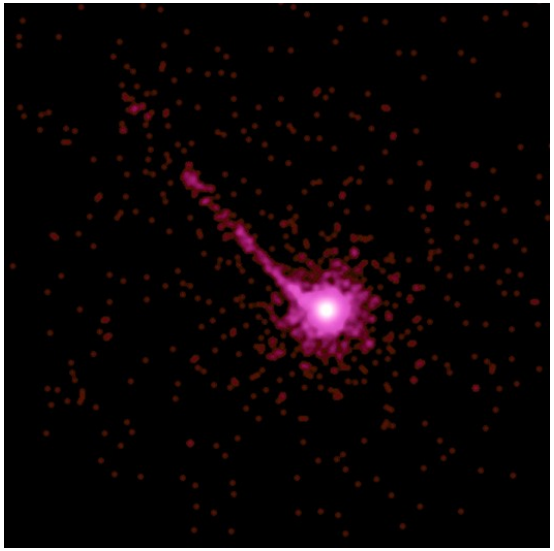
Figure 7. The radio jet power – host optical magnitude plane with the line sharply dividing FR I from FR II (dashed line, from Ledlow & Owen 1996). According to reasonably well established correlations this plane is equivalent to an accretion power vs black hole mass plane (right and upper axis). The central diagonal line represents $L_{\rm ion} \sim 6 \times 10^{-3} L_{\rm Edd}$. From Ghisellini & Celotti (2002).

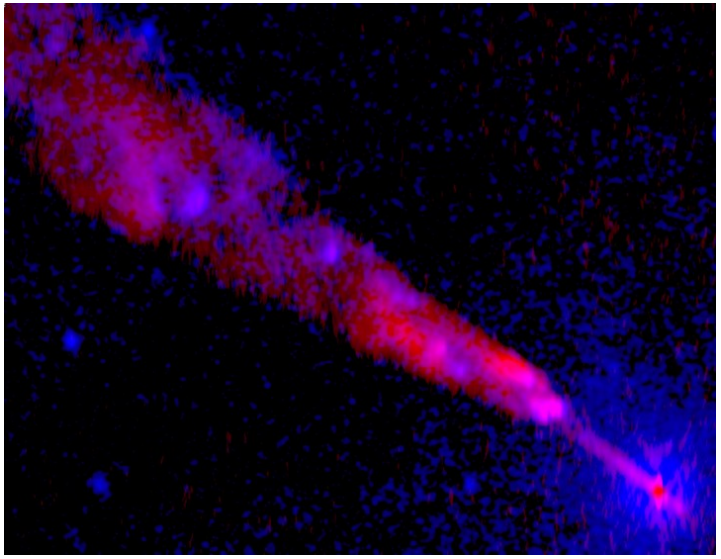
Ghisellini 03

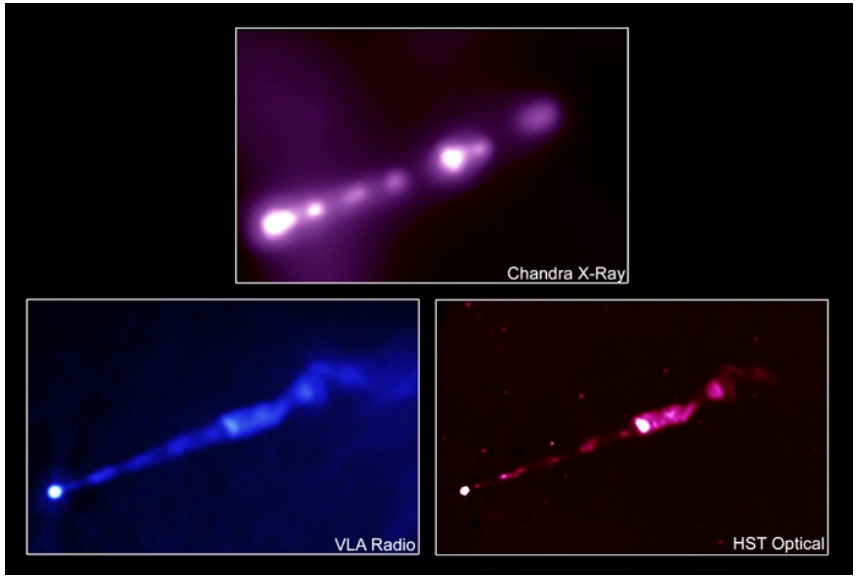
Some X-ray jets

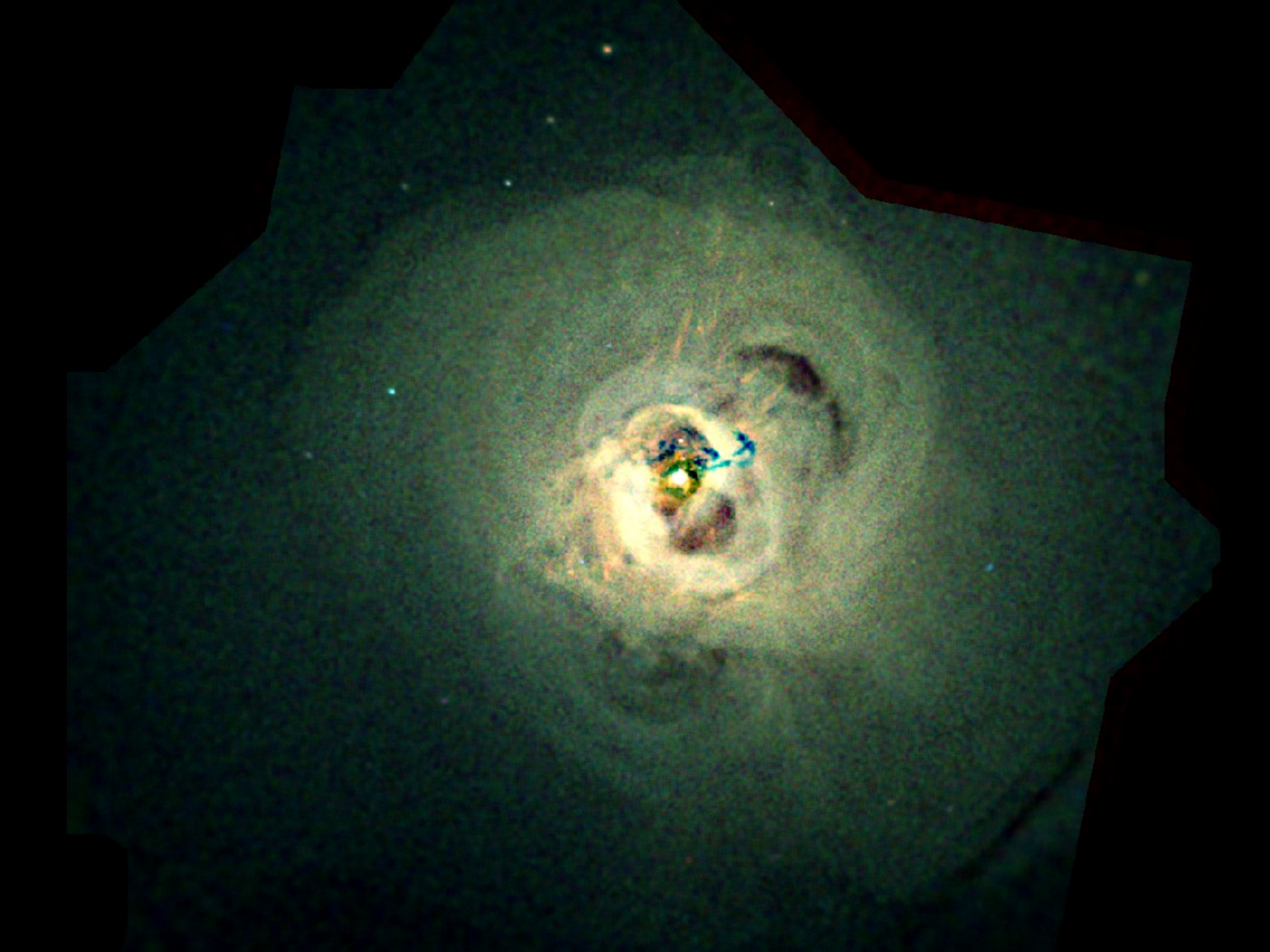


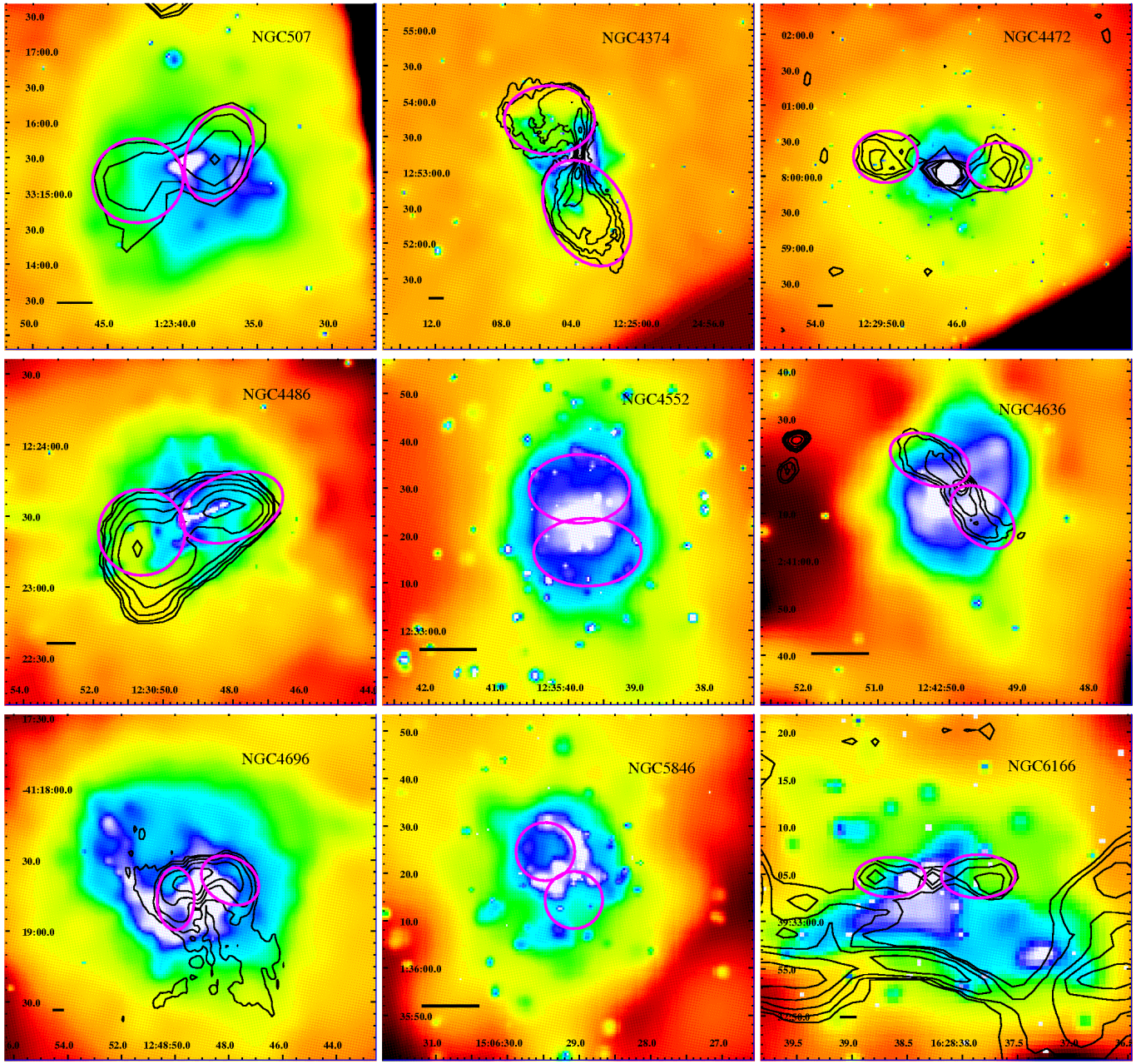
Cen A



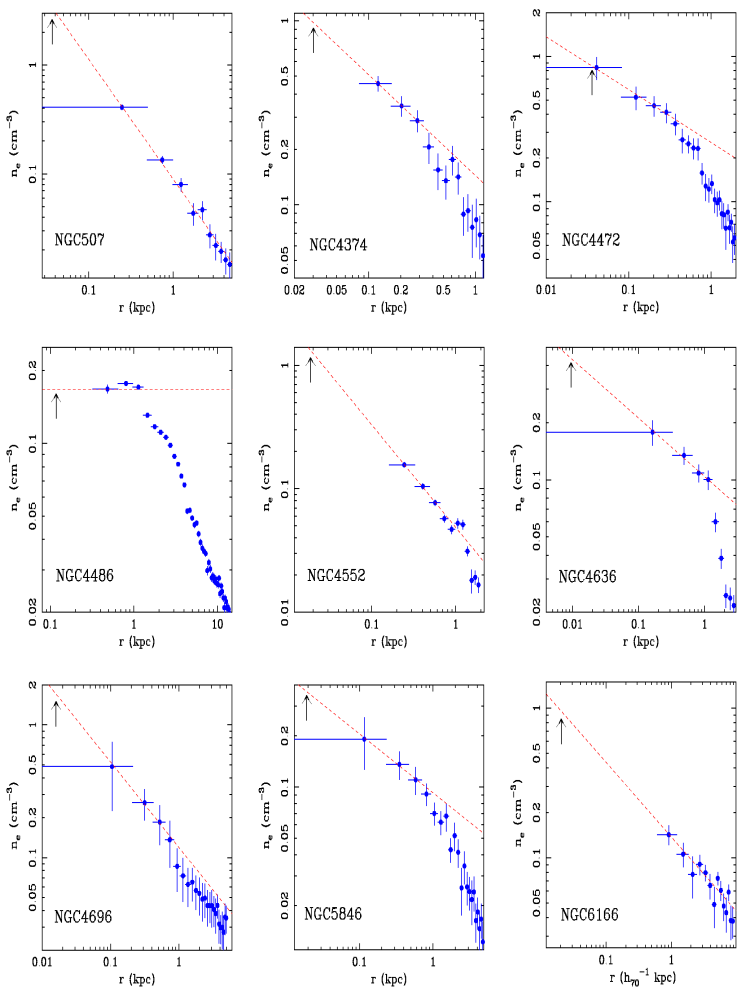


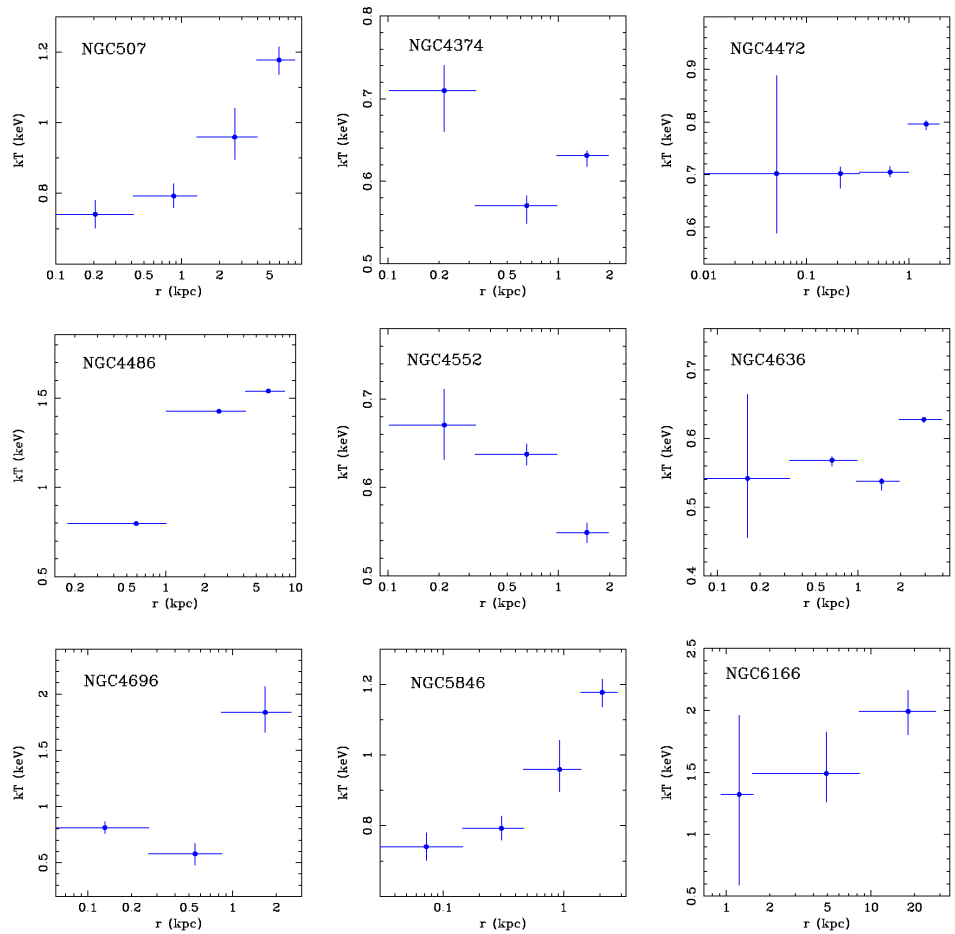




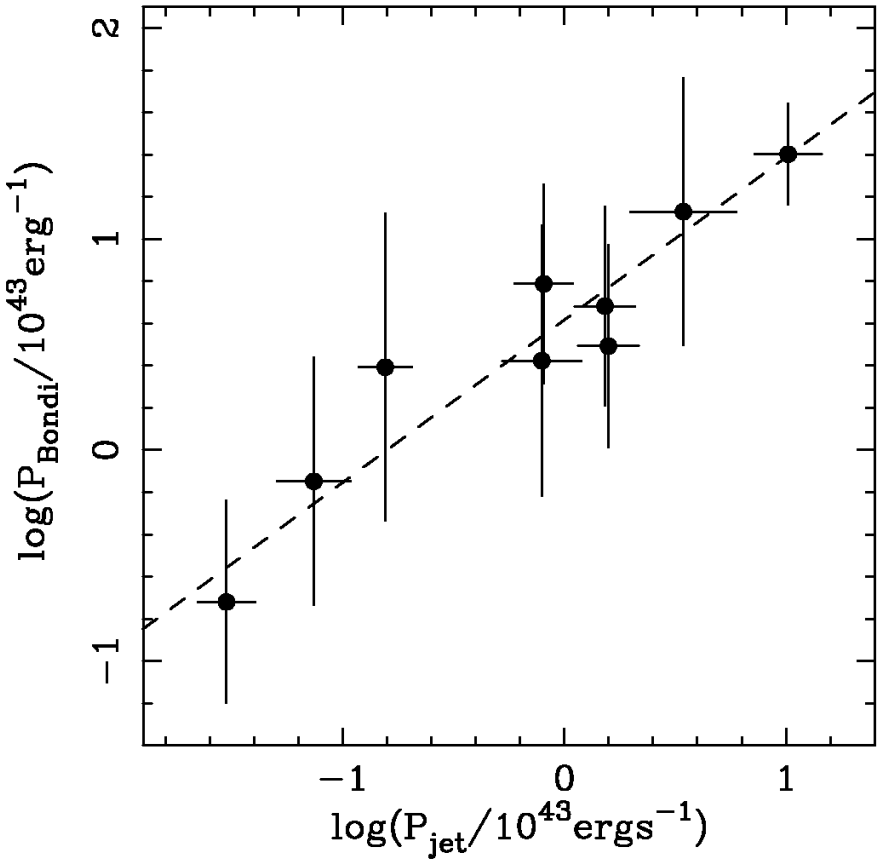

NGC507
NGC4374
NGC4472
NGC4486
NGC4552
NGC4636
NGC4696
NGC5846
NGC6166

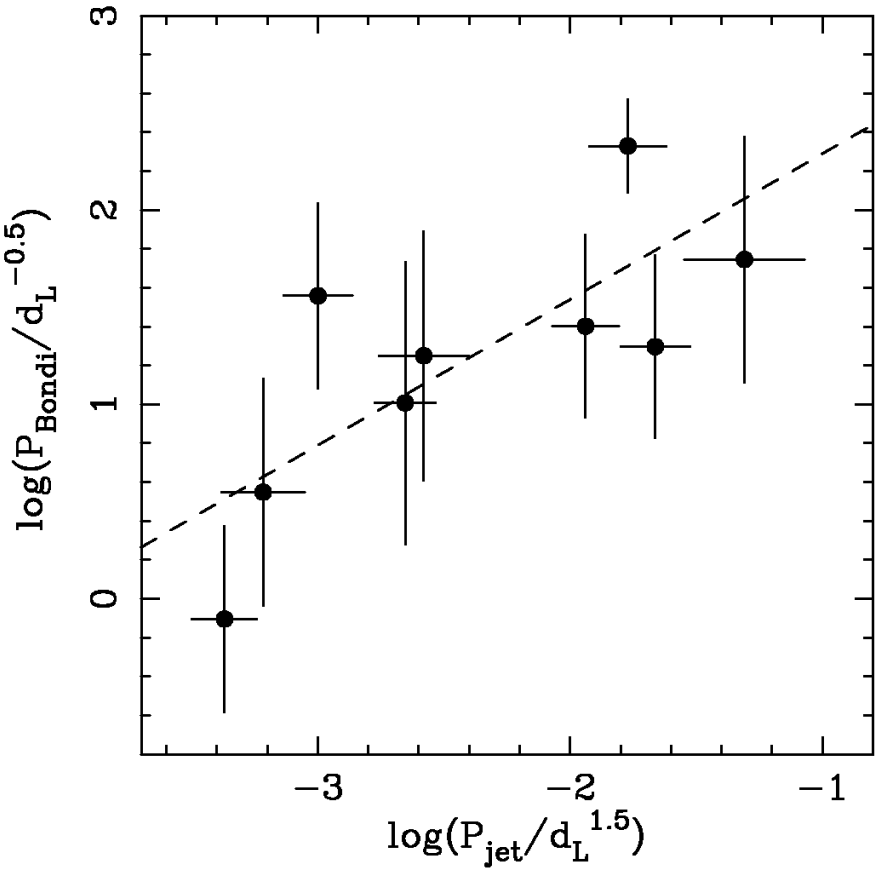
Temp and density profiles





Accretion power vs Jet power
Allen+06

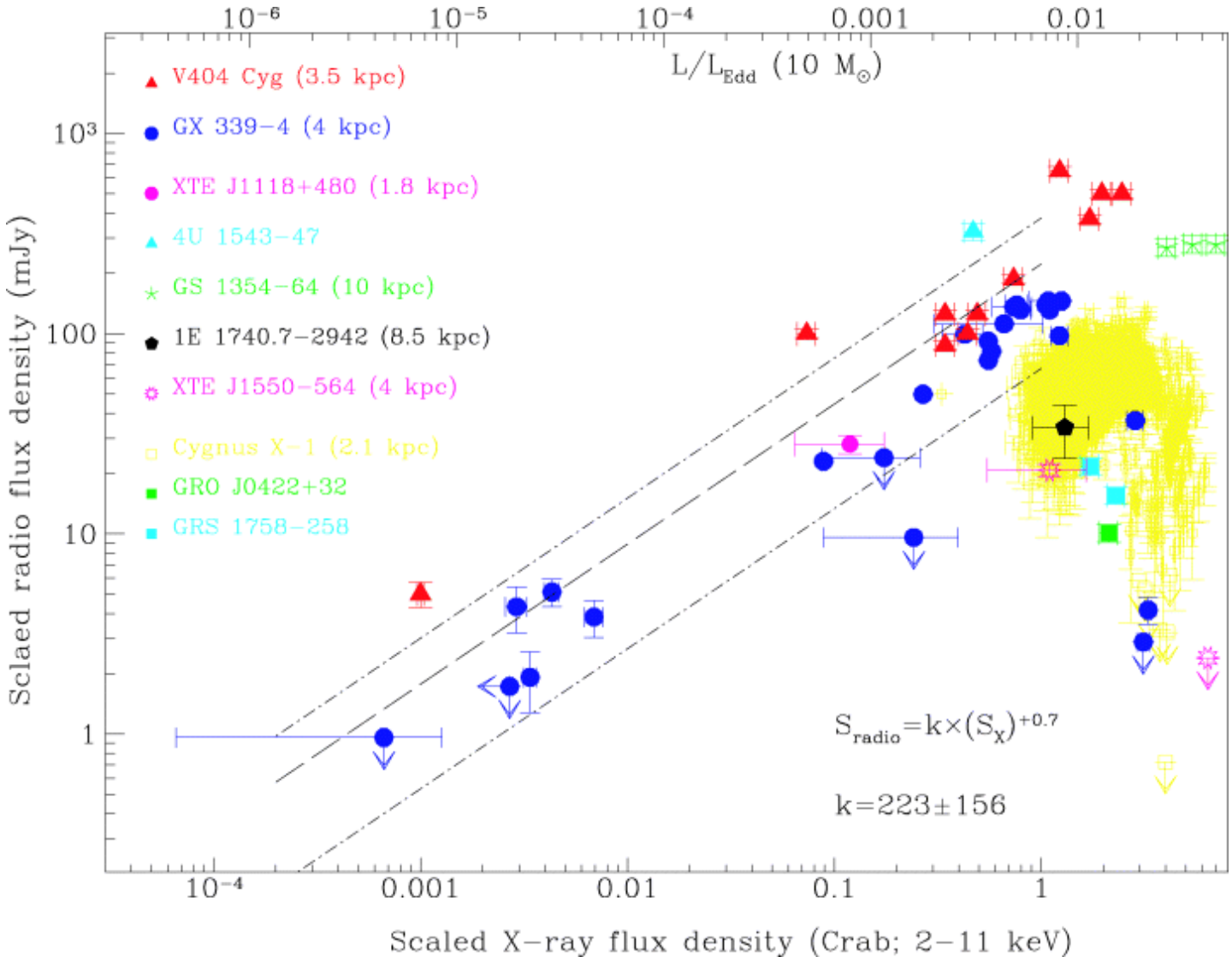




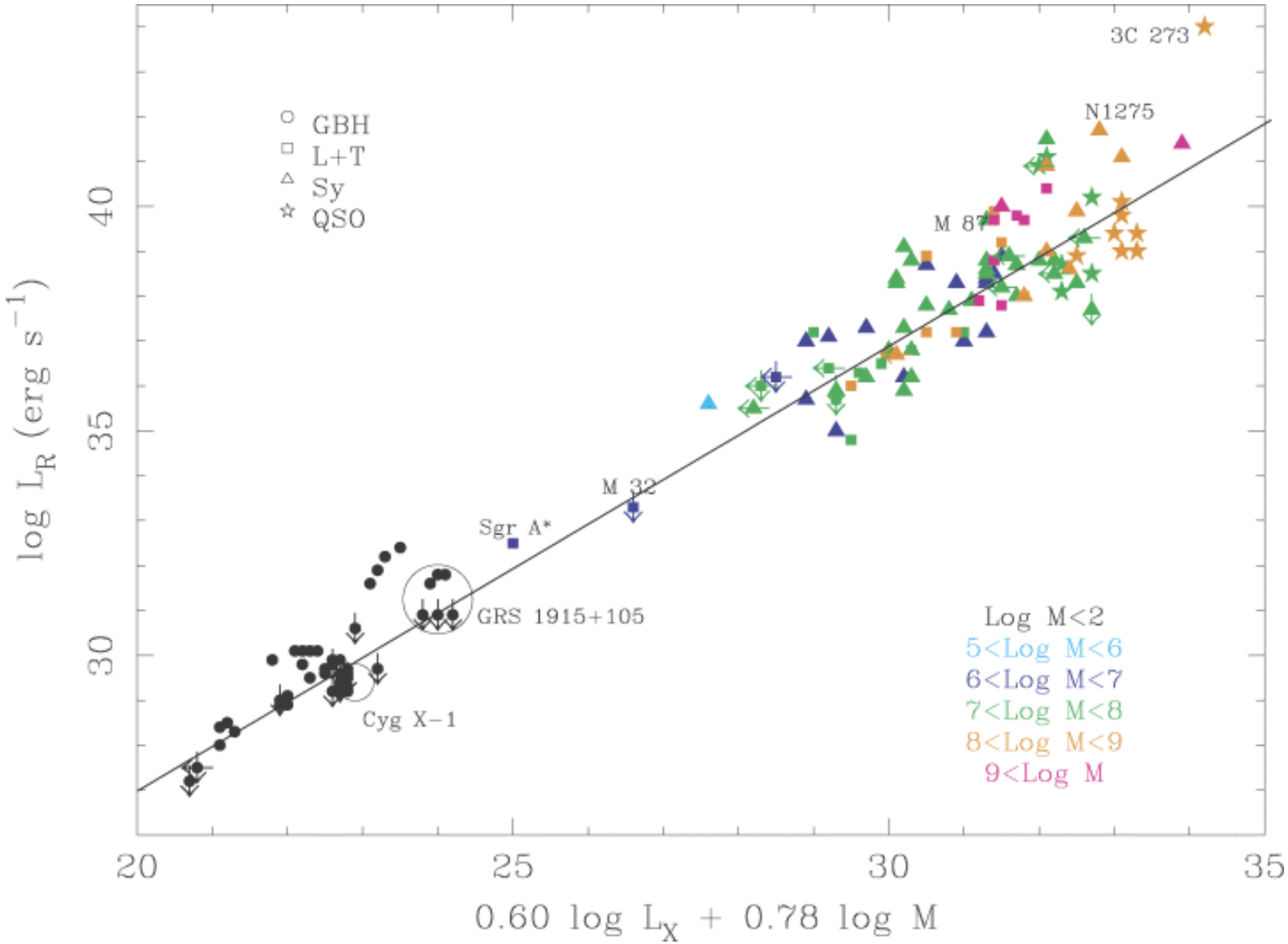
Summary

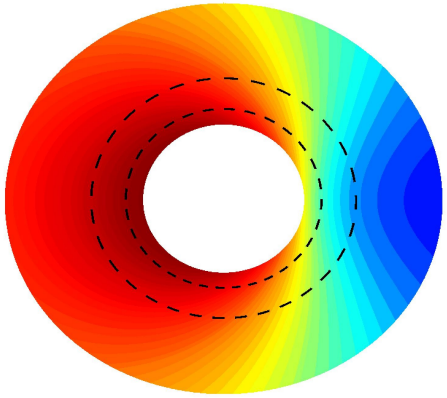
- *Jets likely to carry much power at low Eddington fraction*
- *Composition and acceleration of jets still remains uncertain*

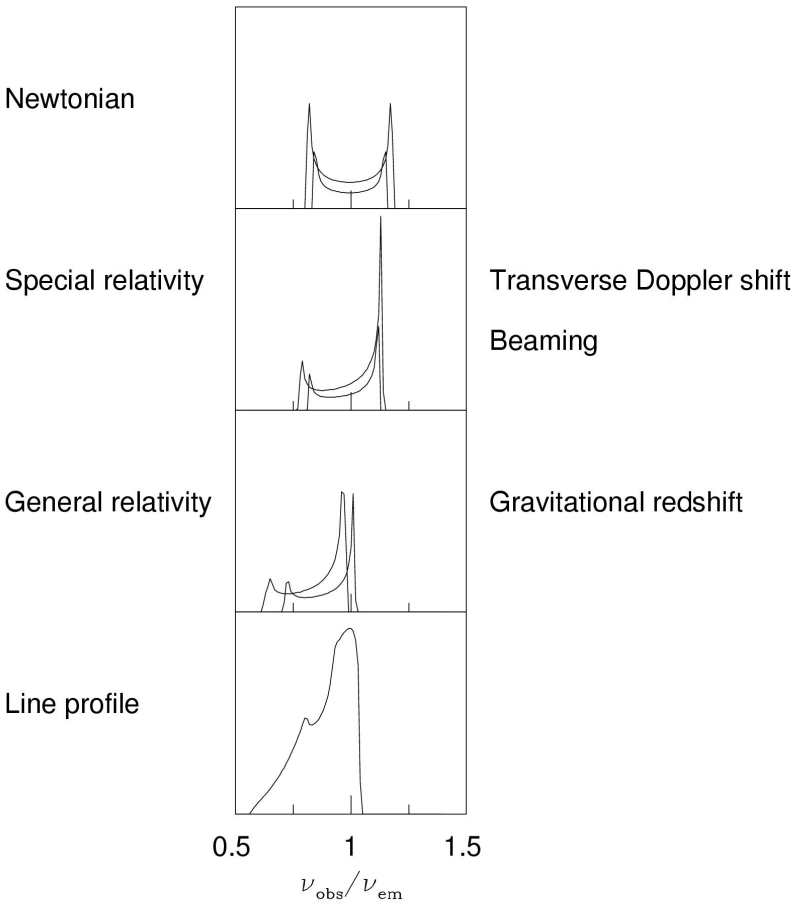
Gallo, Fender & Pooley 03
Jetted components in BHC?

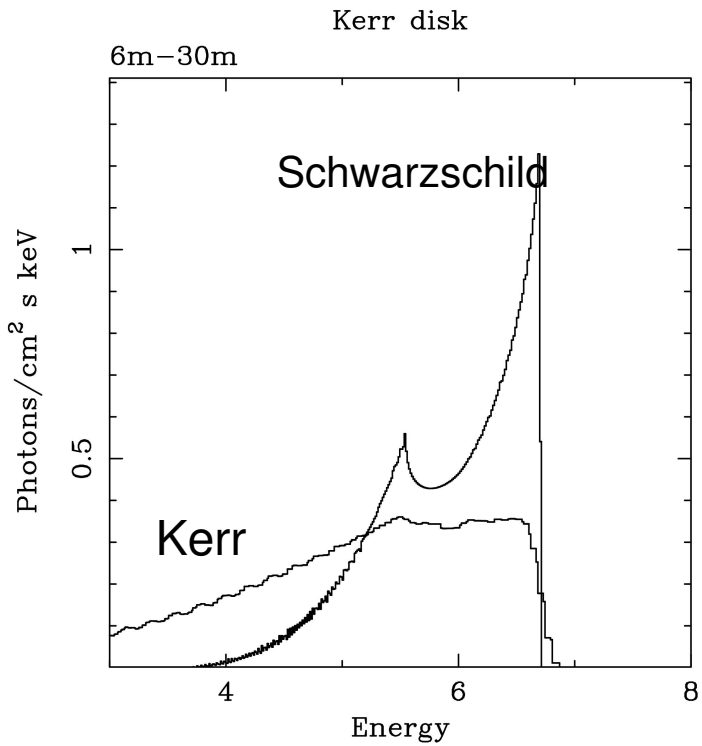


Merloni et al 03 show that correlation extends to AGN when mass accounted for (Fundamental plane)

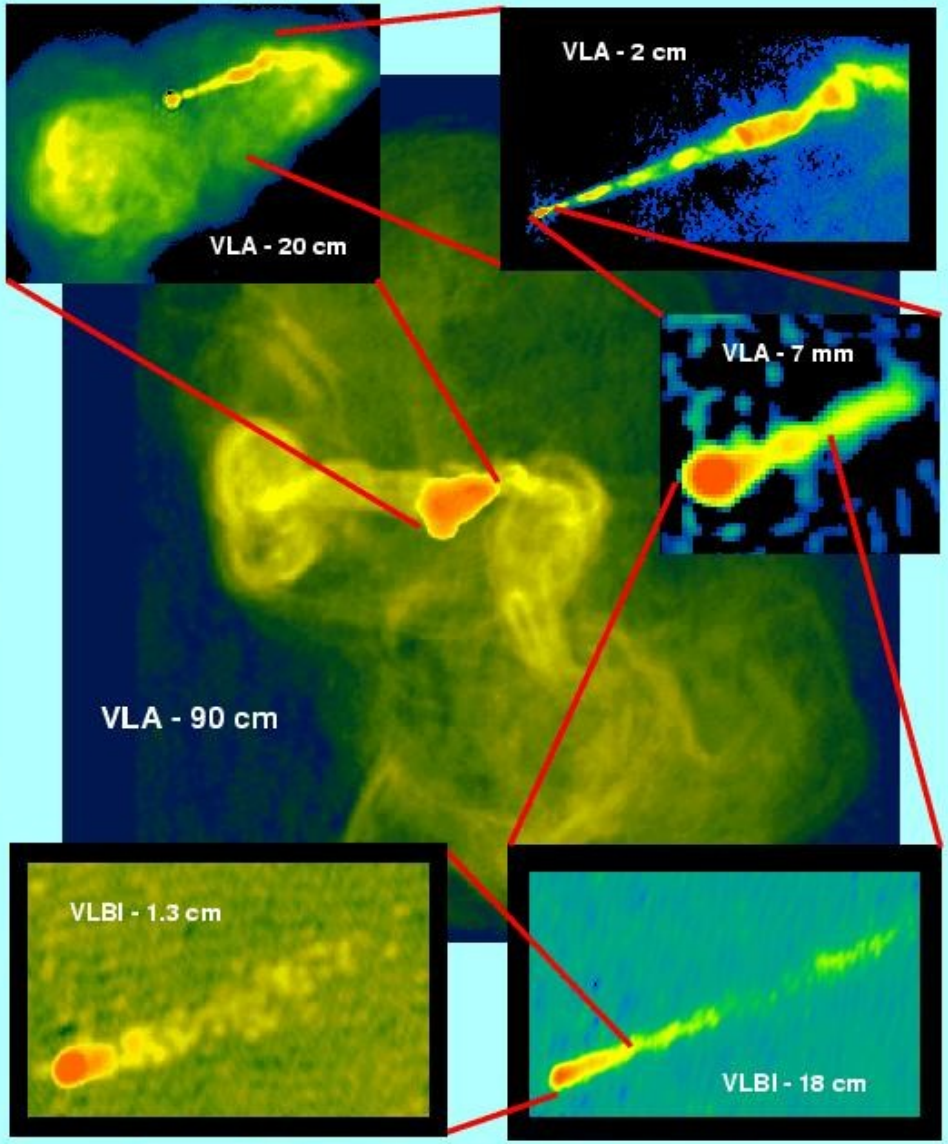




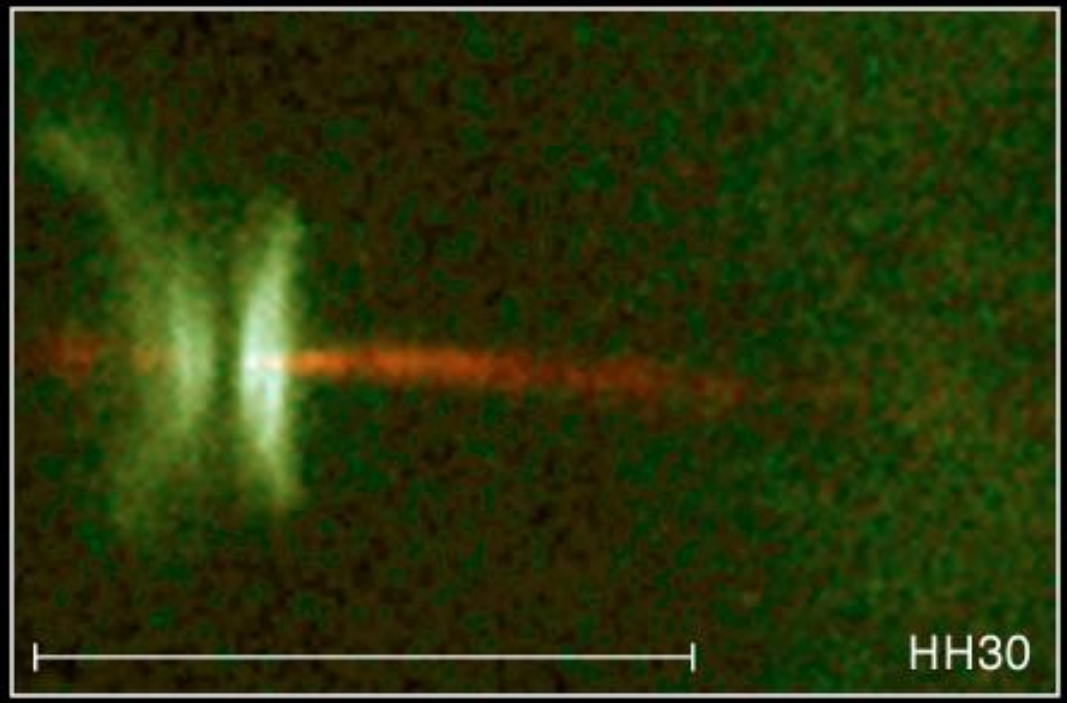

Newtonian
Special relativity
General relativity
Line profile
Transverse Doppler shift
Beaming
Gravitational redshift
0.5
1
1.5
ν_{obs}/ν_{em}

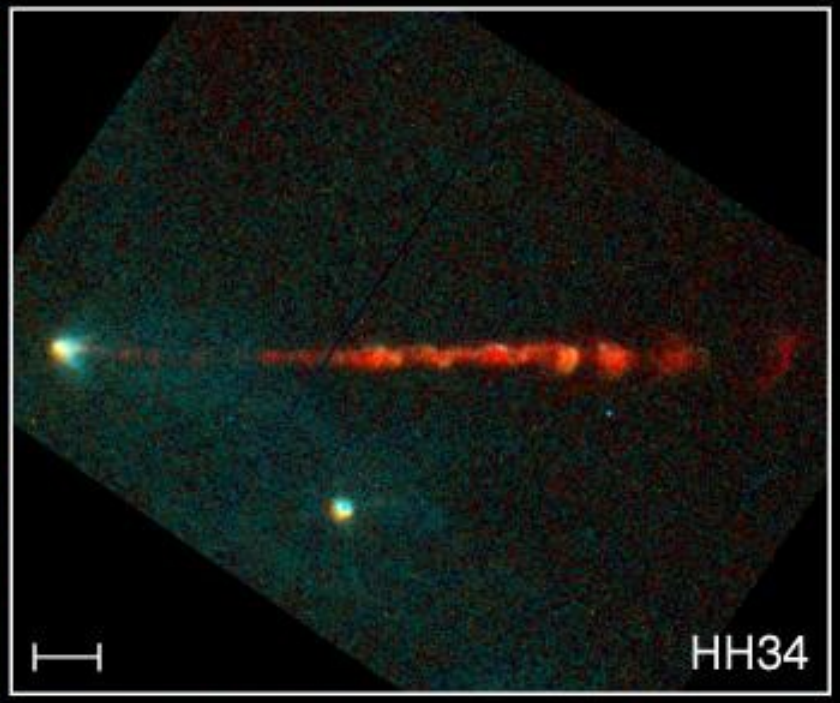

Kerr disk
6m−30m
Schwarzschild
Kerr
Photons/cm^2 s keV
0.5
1
4
6
8
Energy

M87 -- From 200,000 Light-Years to 0.2 Light-Year



Credit: Frazer Owen (NRAO), John Biretta (STScI) and colleagues.
The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.



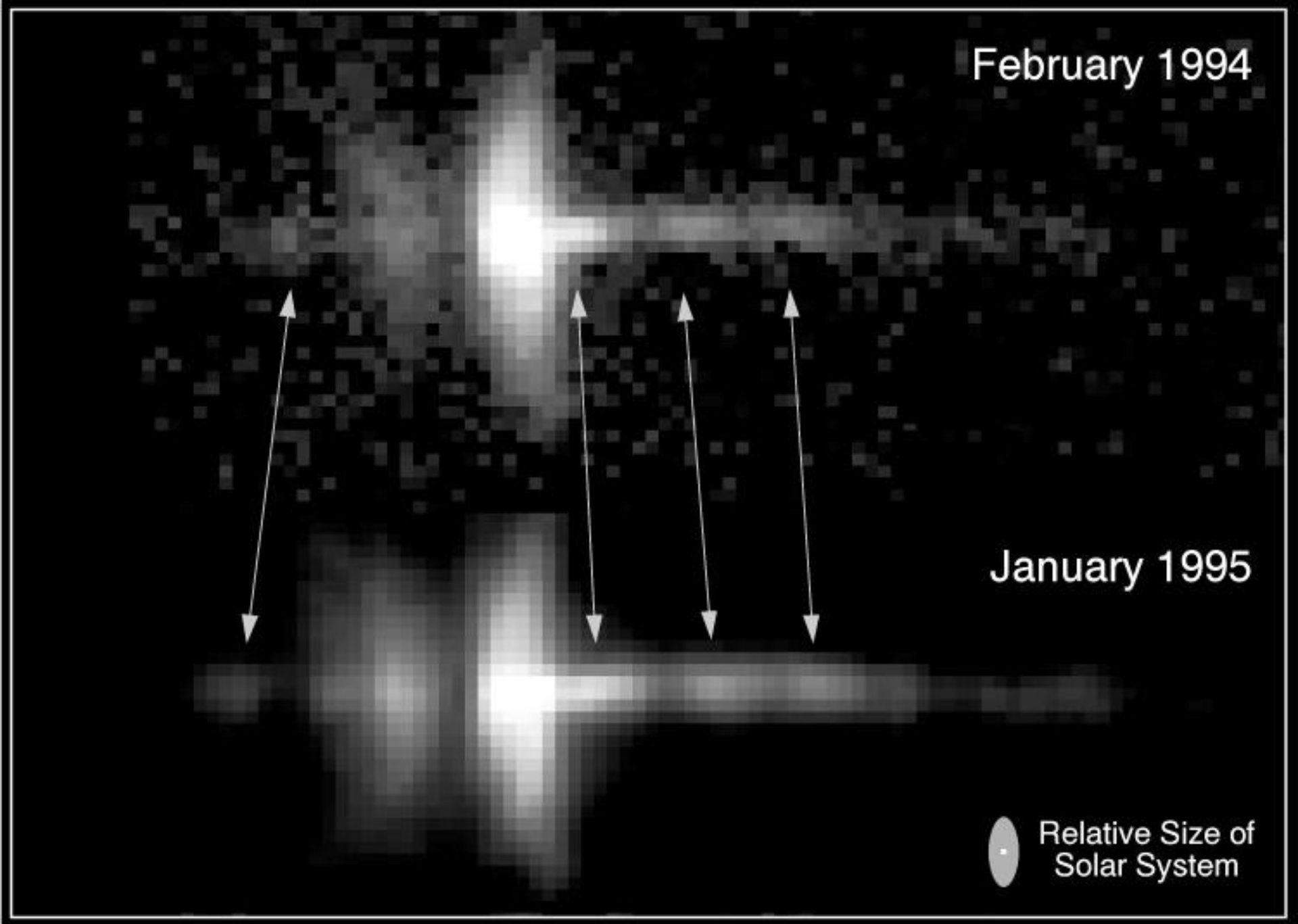


Jets from Young Stars

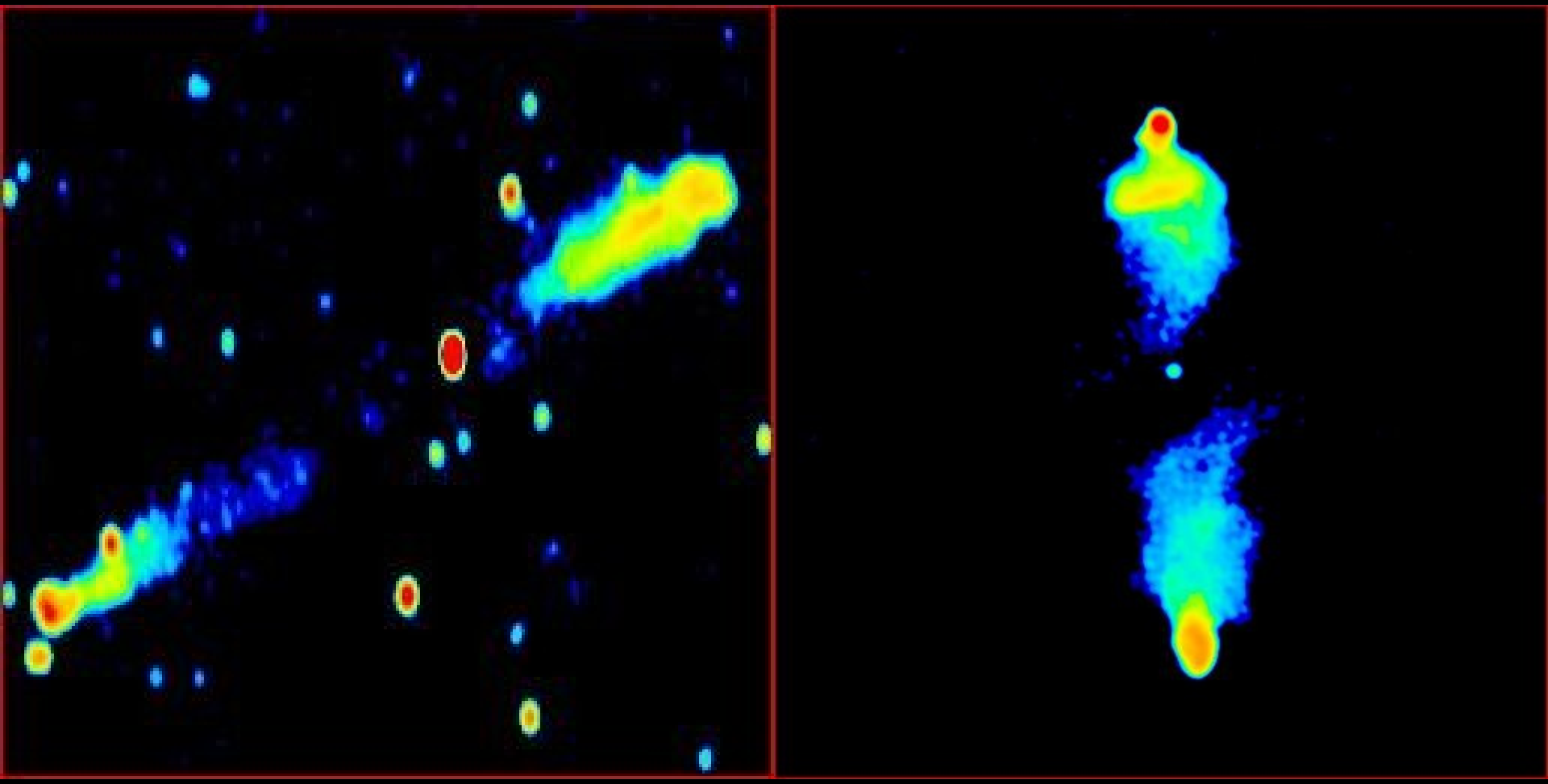
HST • WFPC2

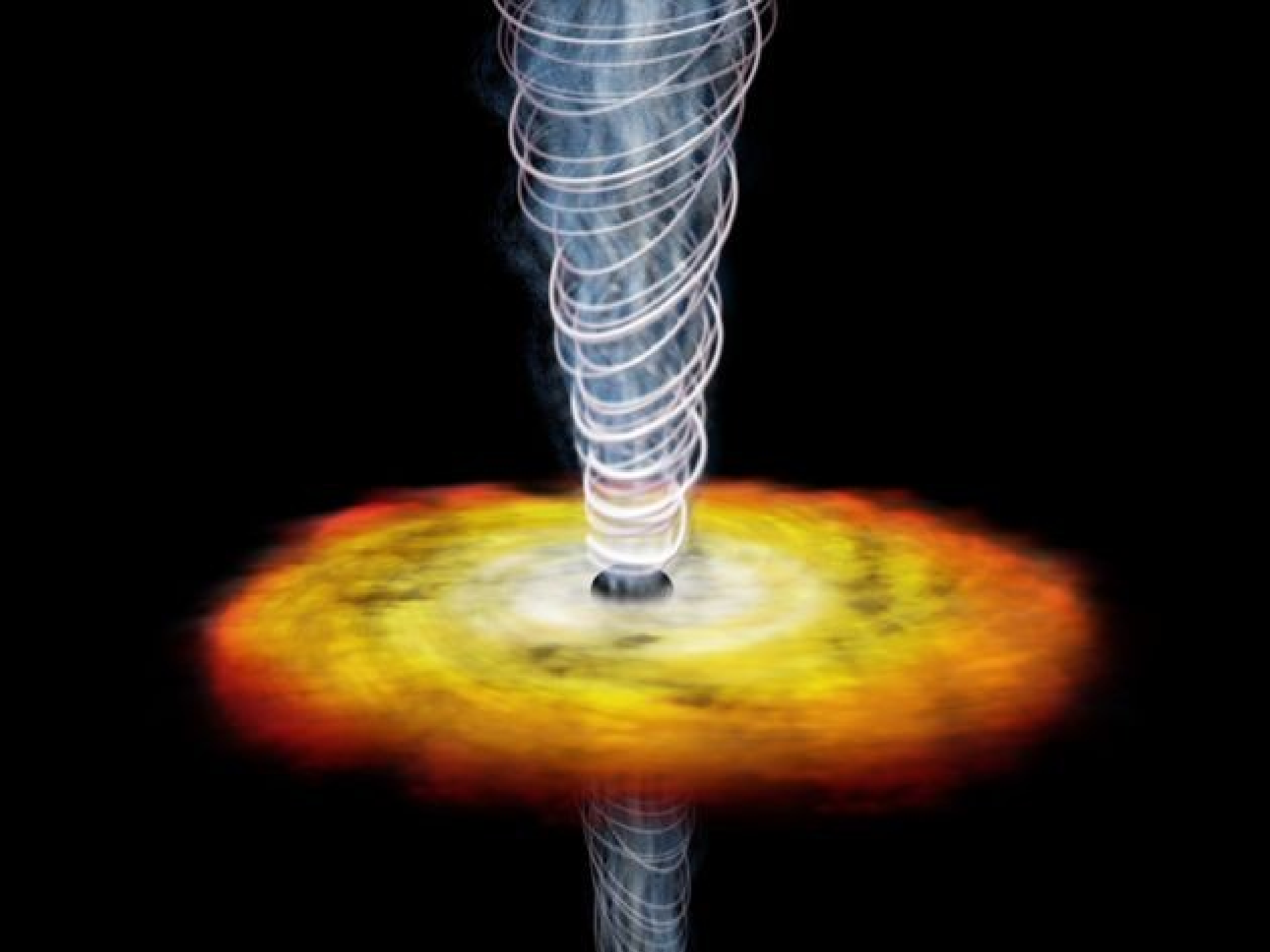
PRC95-24a · ST ScI OPO · June 6, 1995

C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA

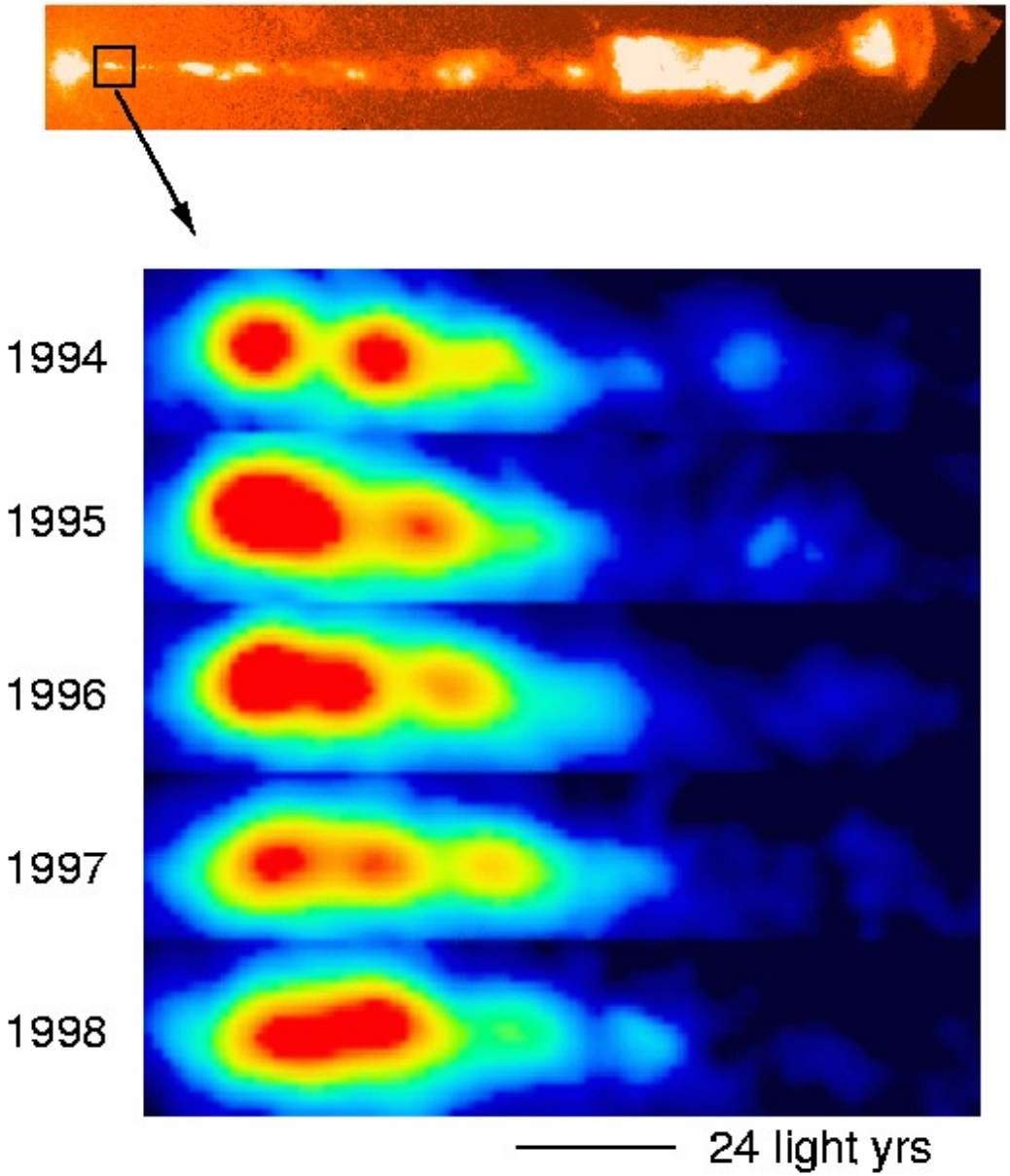


Stellar Disk and Jet Motion · HH30 HST · WFPC2

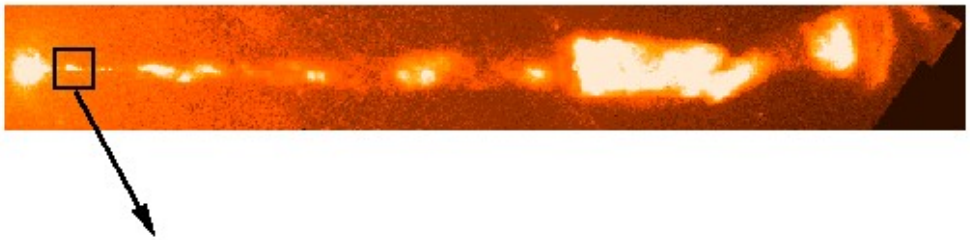


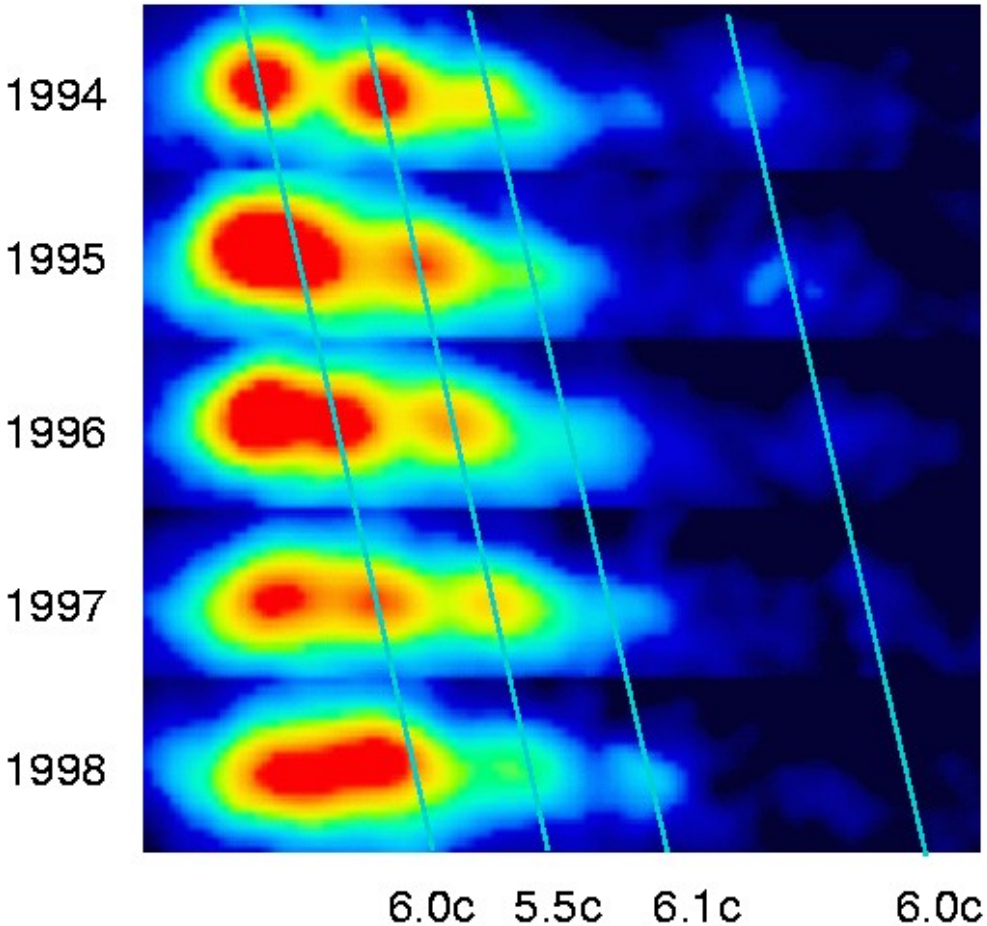


Superluminal Motion in the M87 Jet



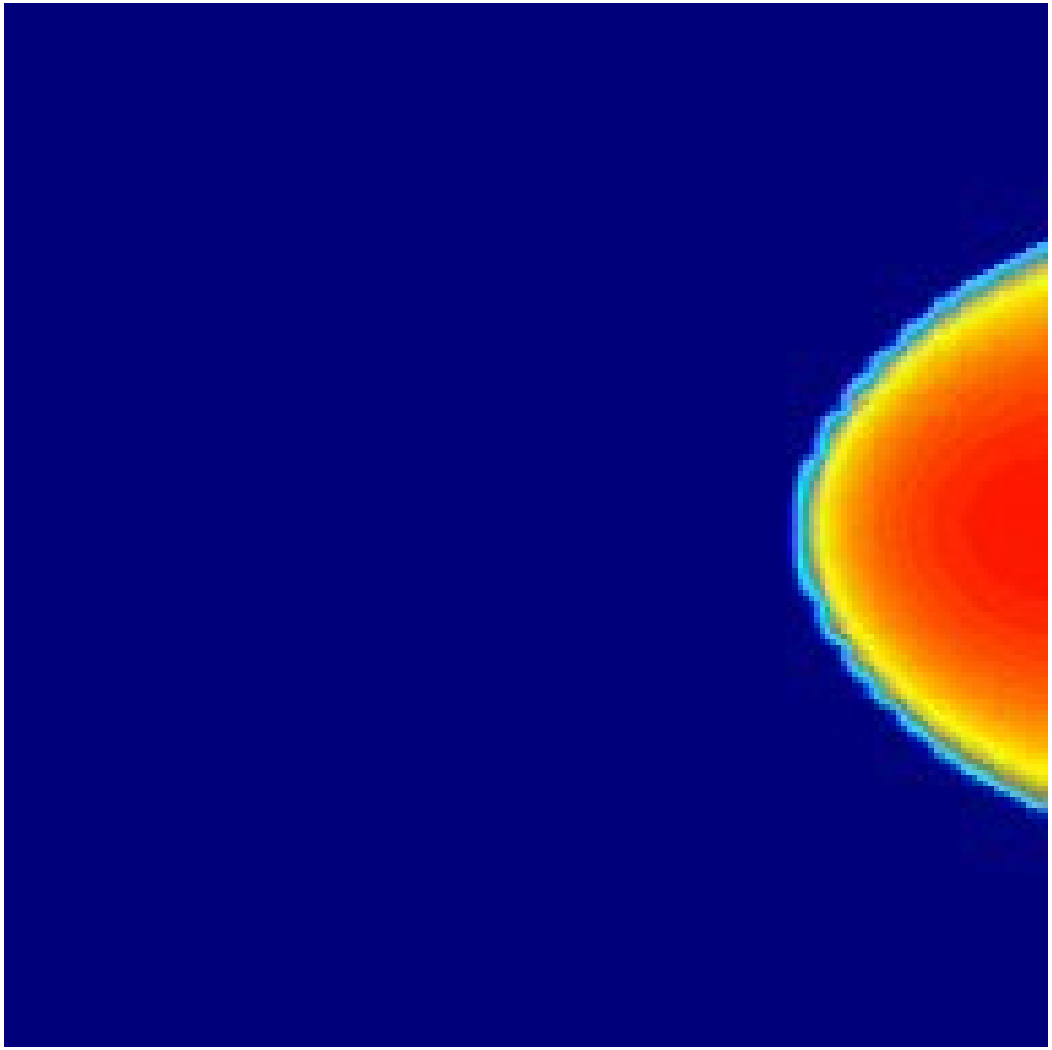
Superluminal Motion in the M87 Jet





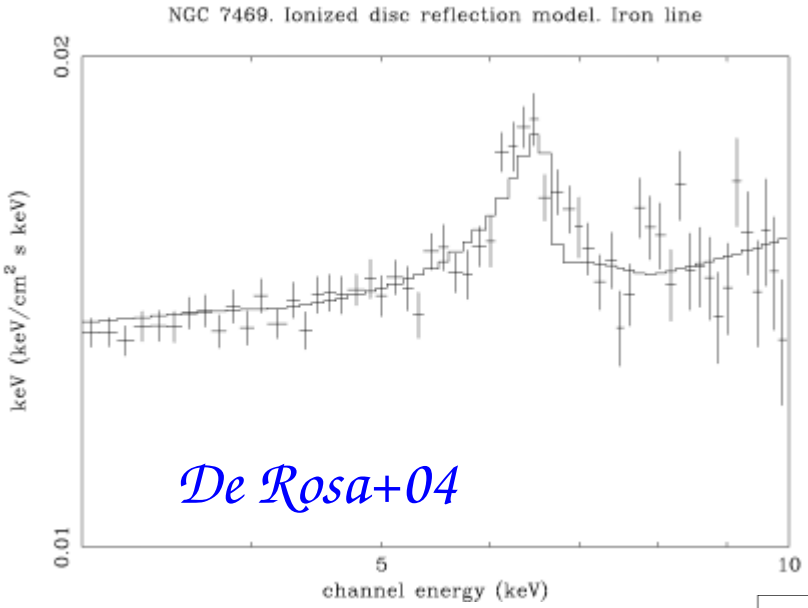
Adiabatic accretion

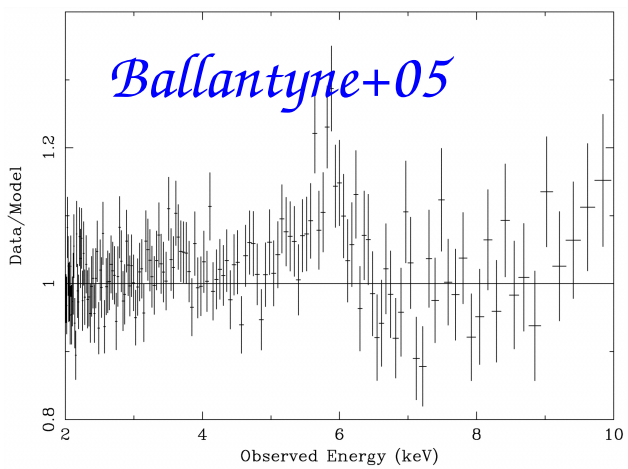
Stone, Pringle & Begelman 01

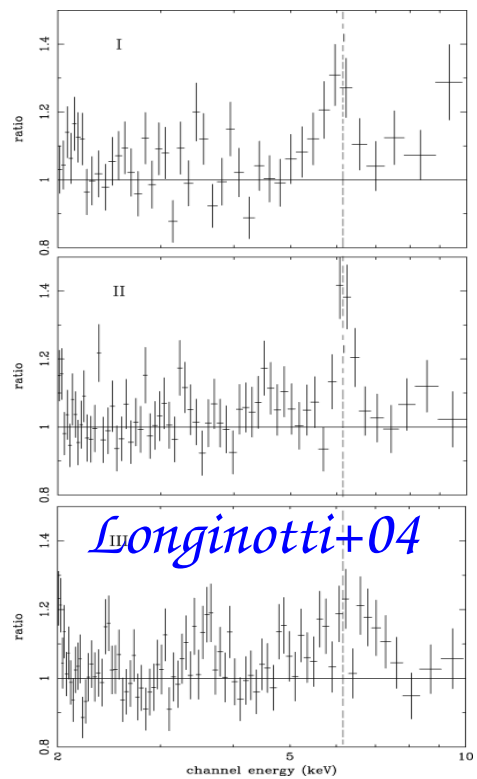


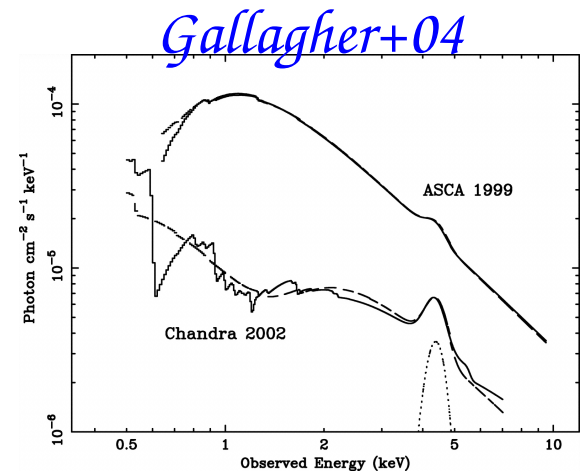
The XMM-Newton view of three X-ray weak quasars: Iron emission and strong ionized absorption

N. Schartel[1], P. M. Rodríguez-Pascual[1], M. Santos-Lleó[1], J. Clavel[2], M. Guainazzi[1], E. Jiménez-Bailón[1], and E. Piconcelli[1]



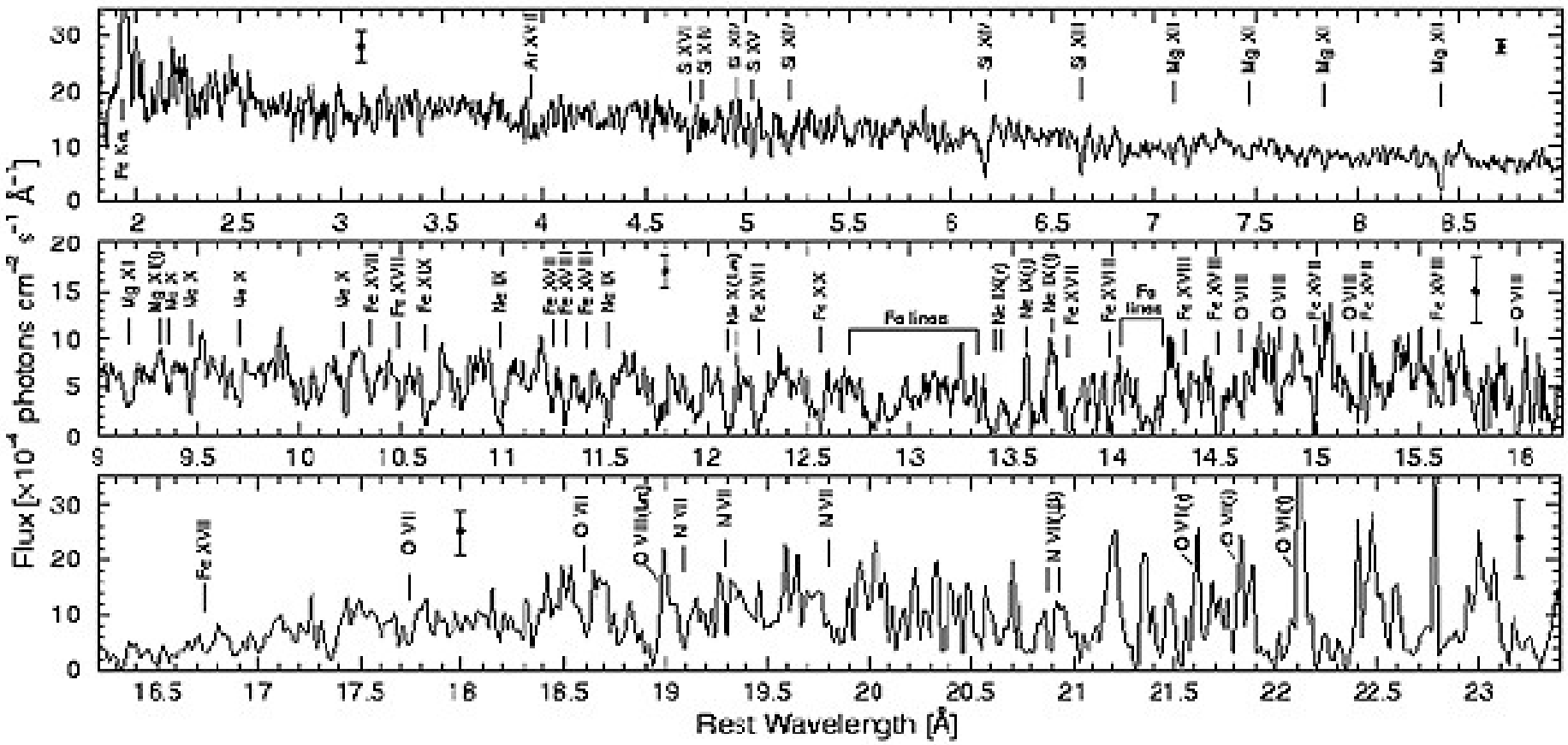




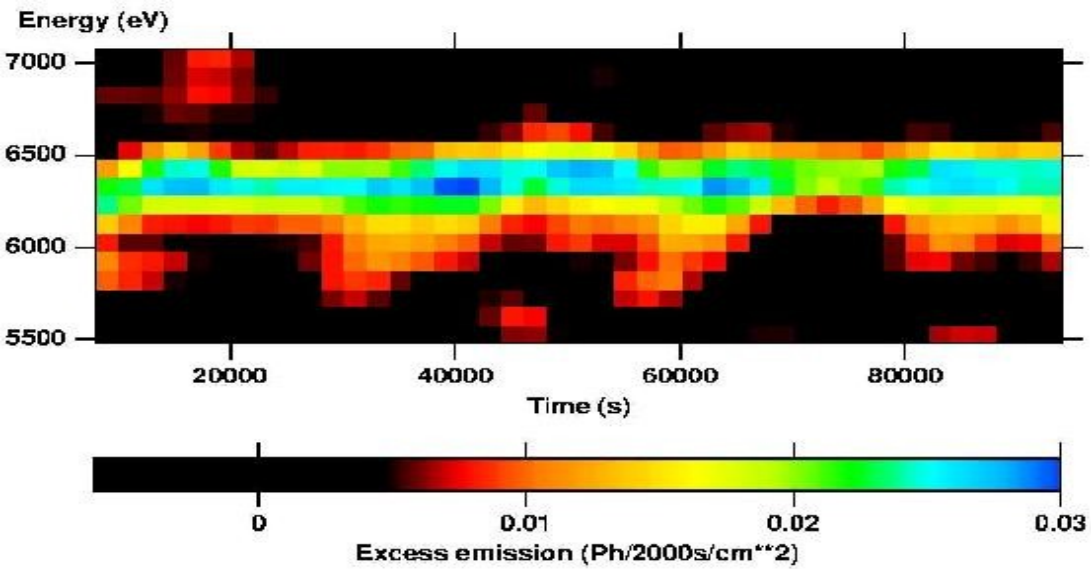


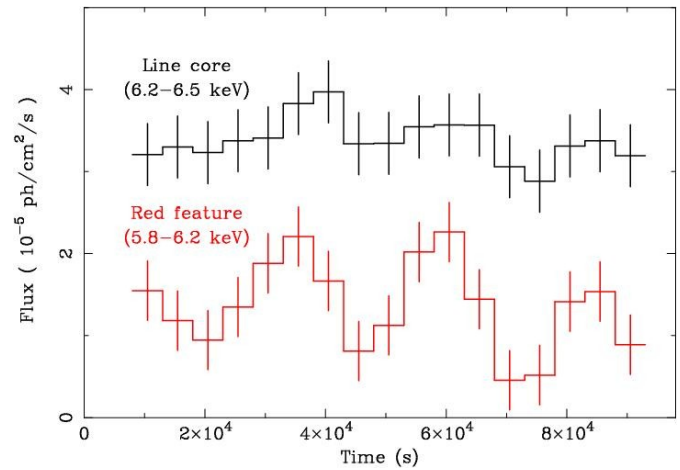
Broad iron lines?

NGC3783


Flux [×10⁻⁴ photons cm⁻² s⁻¹ Å⁻¹]
Rest Wavelength [Å]
Fe Kα
Ar XVII
S XVI
S XV
Si XIII
Mg XII
Mg XI
Mg X
Mg IX
Ne X
Ne IX
Fe XVII
Fe XVIII
Fe XIX
Fe XX
Fe lines
O VIII
O VII
N VII
N VI
O VI

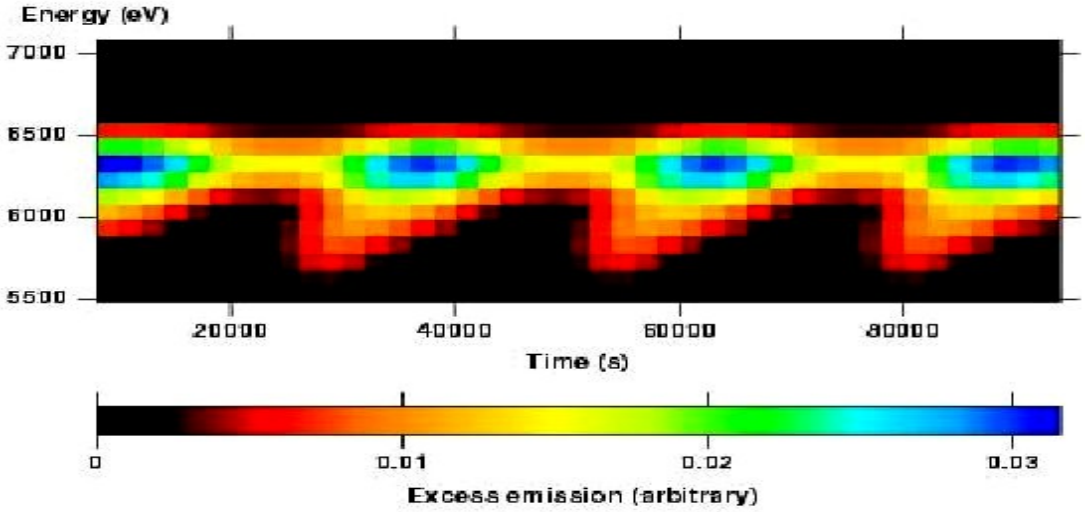
data

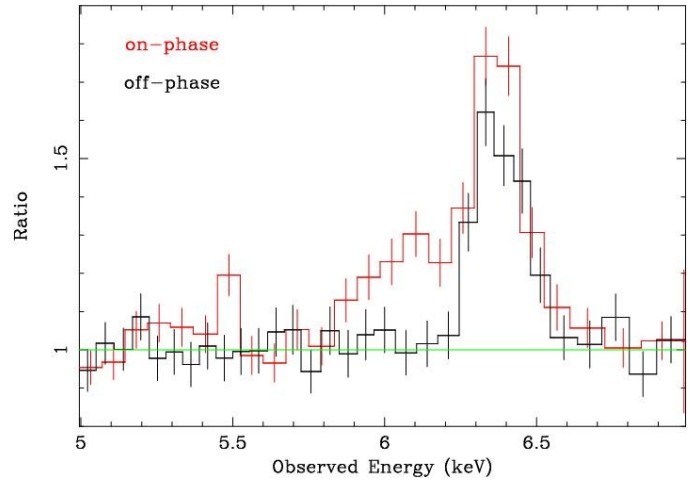


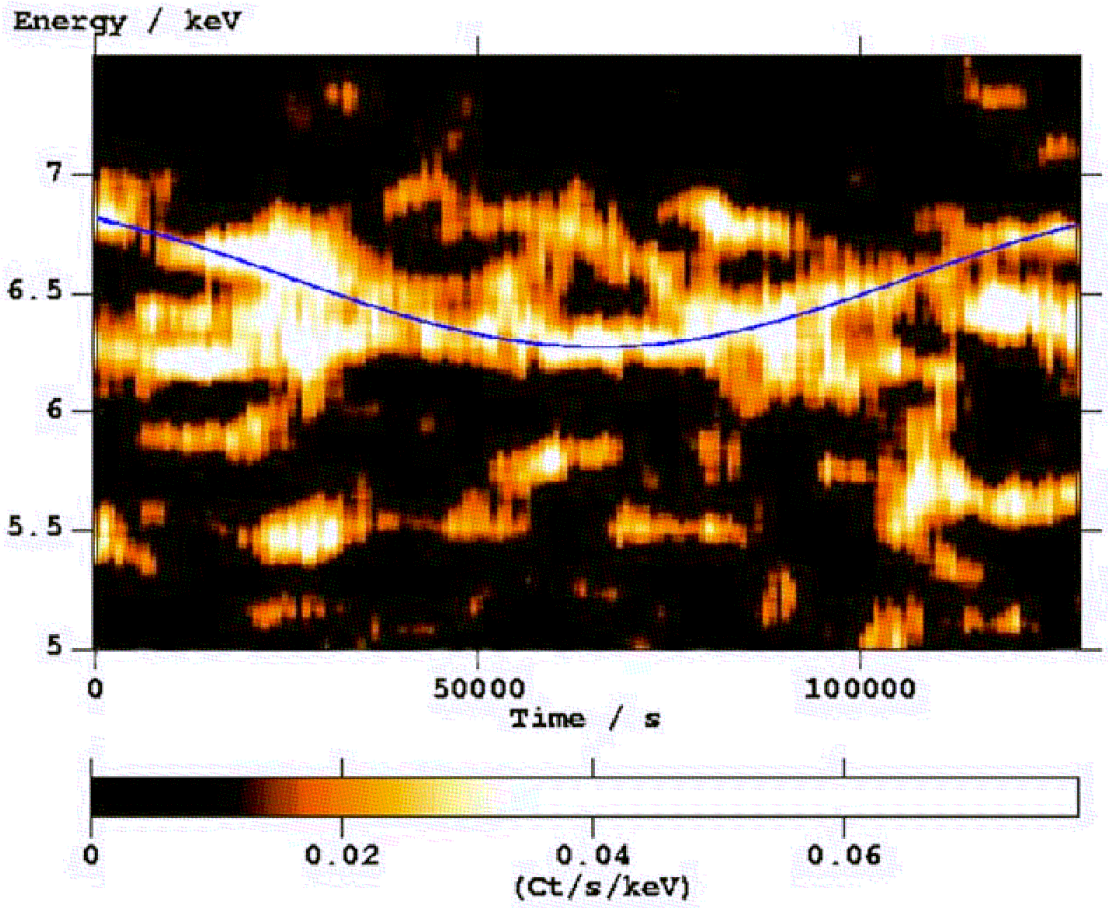


NGC3516
Iwasawa,
Miniutti
&
Fabian 05

model

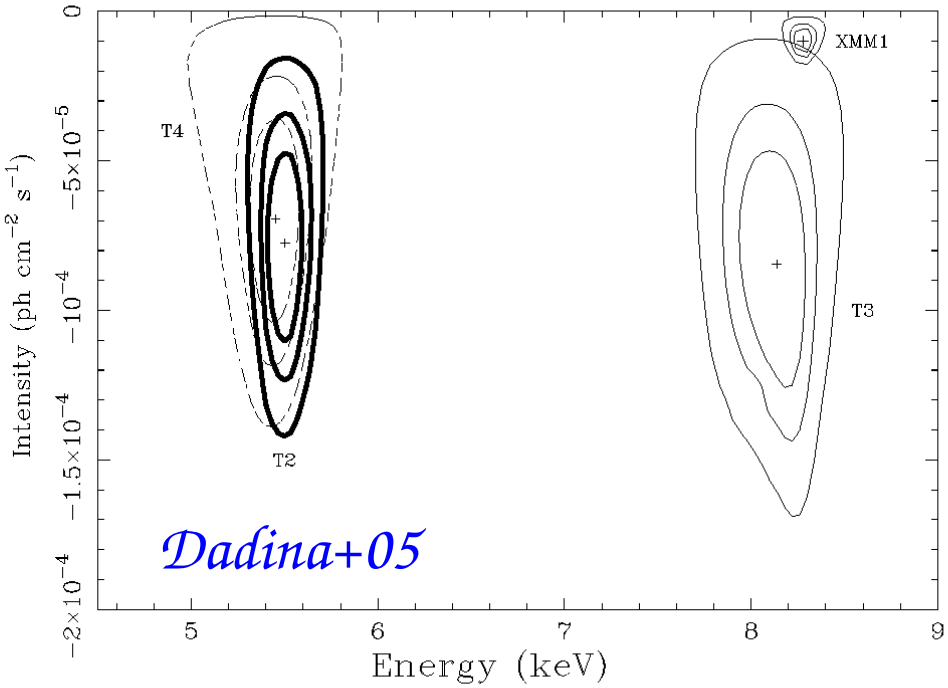


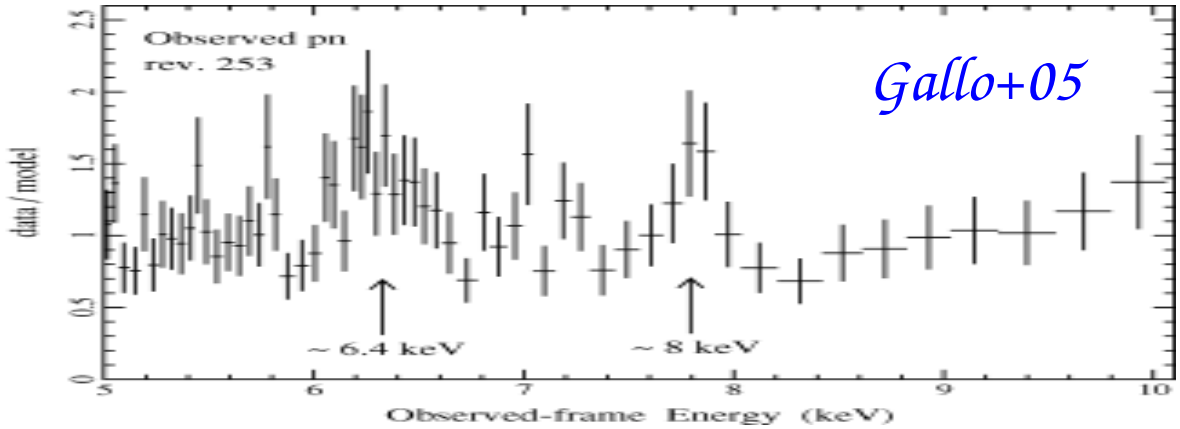




Mrk 766 Turner +05

Red+blue shifted iron lines





Several other examples