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X-ray properties of the three megamaser AGNS:

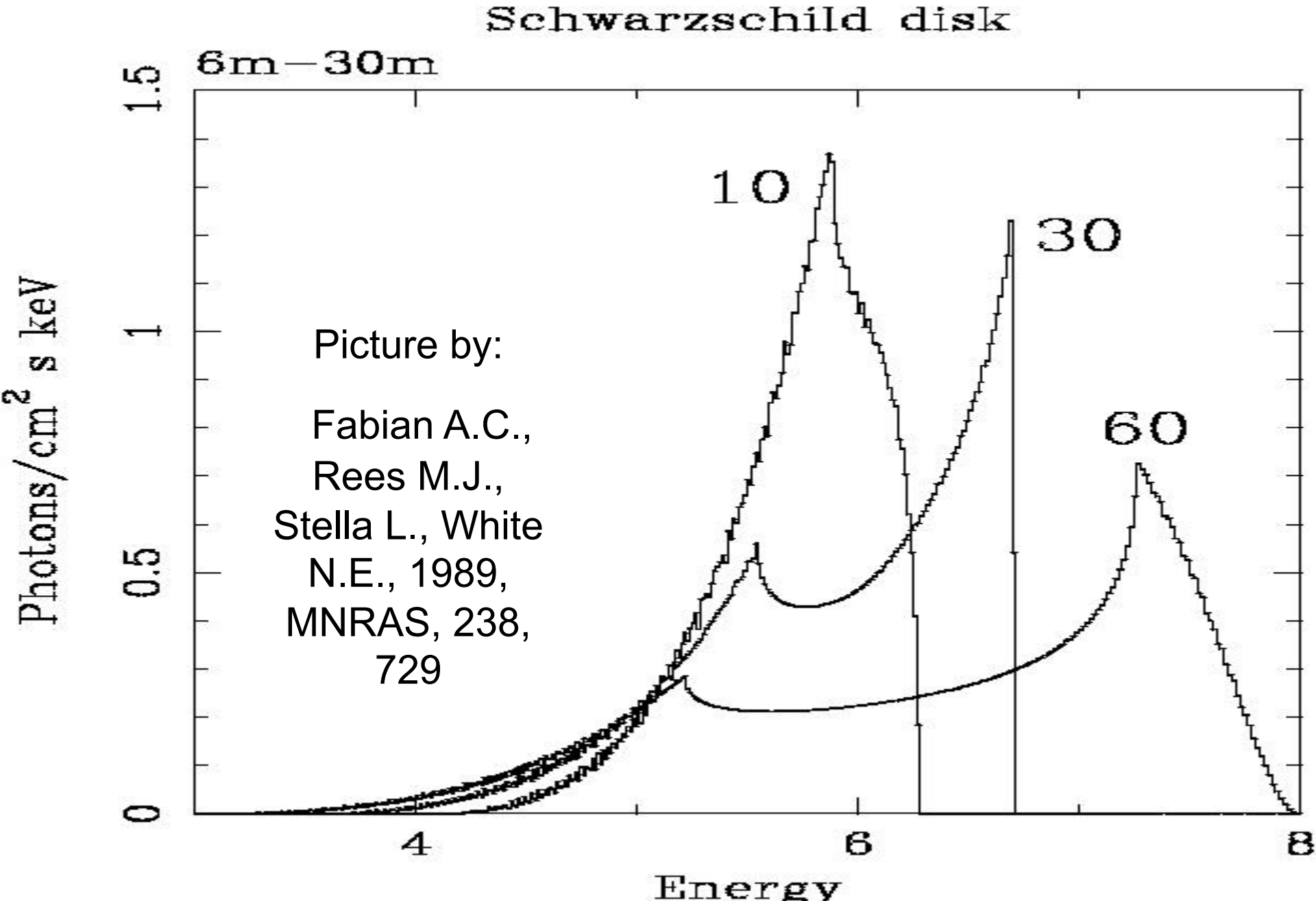
Comparative analysis of the NGC 1068, NGC 4258

and **NGC 1194** spectra

Mail goal: investigating the properties of the “centra engine” of NGC 1194

Main focus on: Fe-K lines (6.-7. keV) and primary hard X-ray continuum

Doppler + relativistic beaming + gravitational redshifting



NGC 1194

- z=0.013596
- RQ S1.9 AGN
- BH mass (6.5± 0.3)*10^7 solar masses
- nuclear megamaser disk ~ pc, (outer disk ~kpc well-ordered, Greene J. et al., arxiv1405.1430)
- kpc-scale jet
- Luminosities: lg(Lx)=43.2 (14-195 keV)
- Galactic absorbtion: 6.03*$10^{20}$$cm^{-2}$

NGC1194/ISGRI data (20-500 keV)

Table 1: *INTEGRAL*/ISGRI observation log for NGC 1194.

Data revolution	exposure time, ks	scw number	Observation time
098–099	212.6	88	02.08.2003–06.08.2003
207–210	441.8	125	24.06.2004–05.07.2004
336–342	161.1	60	16.07.2005–04.08.2005
456–462	214.5	59	08.07.2006–27.07.2006
570–582	526.0	177	14.06.2007–20.07.2007
659–699	399.2	124	07.03.2008–05.07.2008
700–718	204.1	63	05.07.2008–30.08.2008
1066-1068	11.4	7	07.07.2011–13.07.2011
Total	2170.7	713	02.08.2003–13.07.2011

XMM-Newton and Swift/XRT data LOG

Table 2: XMM-Newton observation log for NGC 1194.

observation date	camera	effective exposure time, s	total counts	count rate, cts
19.02.2006	MOS1	15634	380	0.023
dataset ID	MOS2	15629	376	0.027
0307000701	PN	12534	777	0.06
total		43798	1533	0.11

Table 3: *Swift*/XRT observation log for NGC 1194.

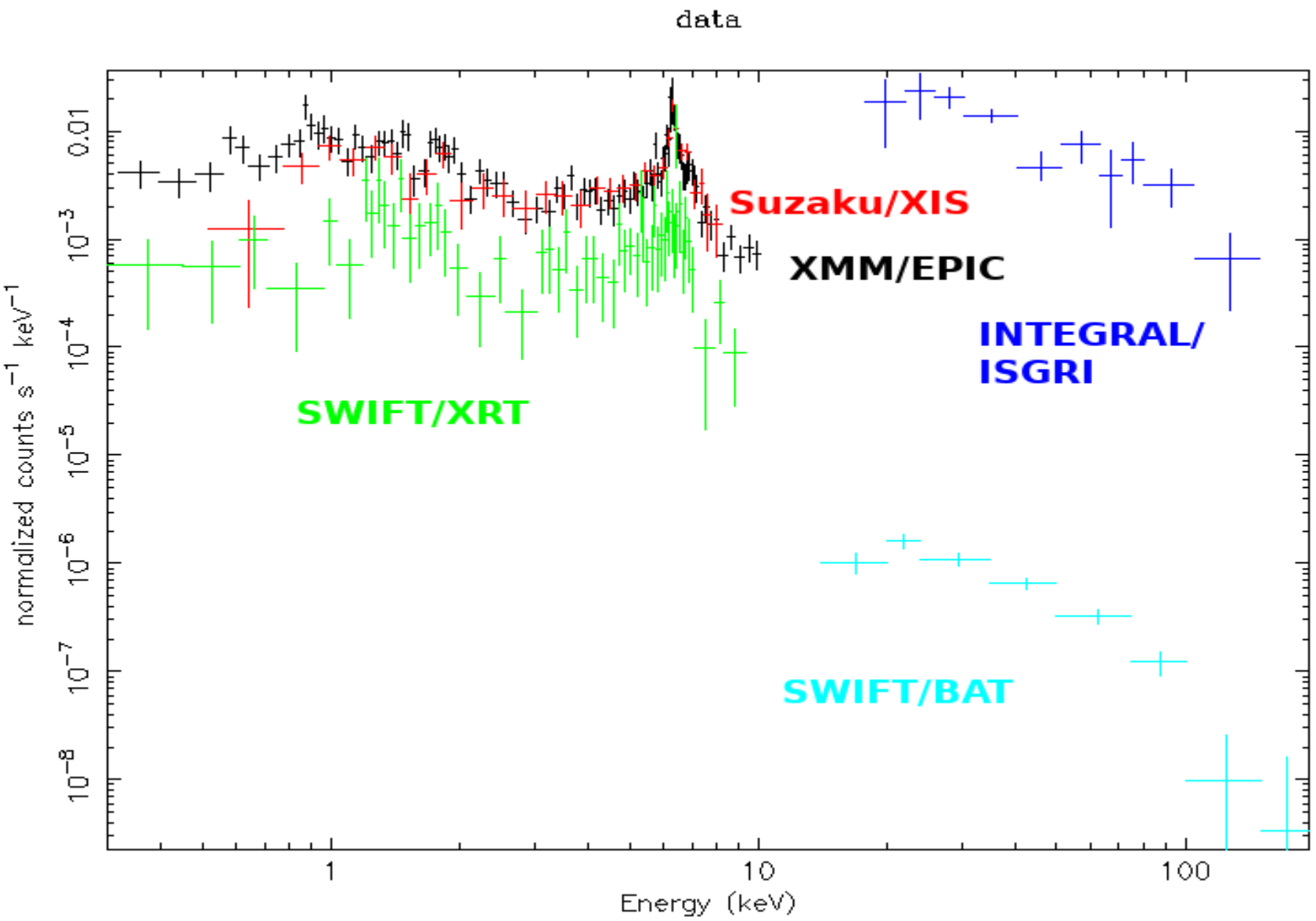
Data revolution	exposure time, ks	scw number	Observation time
000372	18.8	5	27.06.2008–28.02.2009
000496	1.6	2	19.06.2013–10.10.2013
Total	20.4	7	27.06.2008–10.10.2013

Suzaku/XIS data LOG

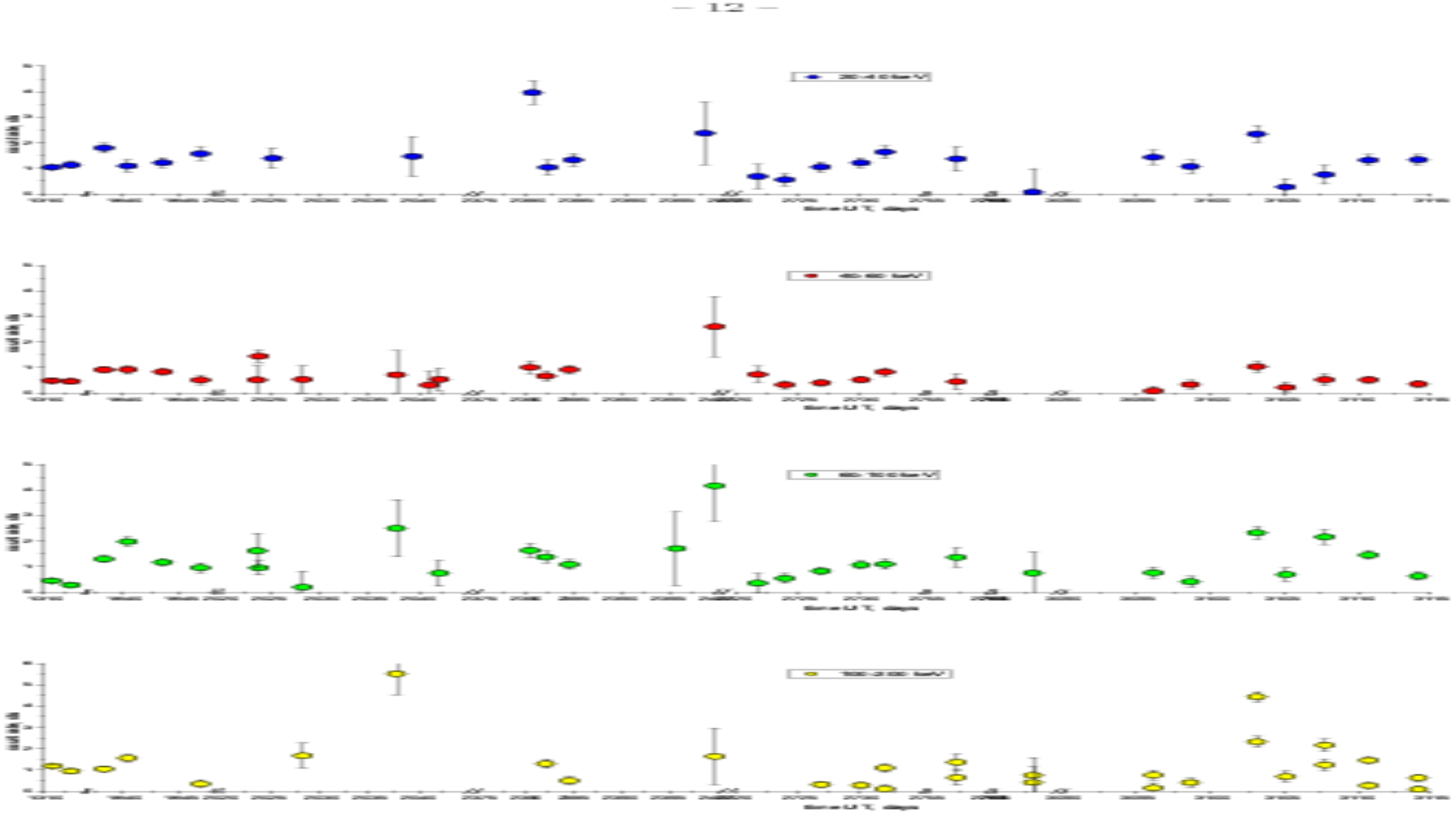
Table 4: Suzaku/XIS observation log for NGC 1194.

observation date	camera	effective exposure time, s	total counts	count rate, cts
2009.08.01	XIS0	50316.1	380	0.023
dataset ID	XIS1	50596.1	376	0.027
704046010	XIS3	50596.1	777	0.06
total			1533	0.11

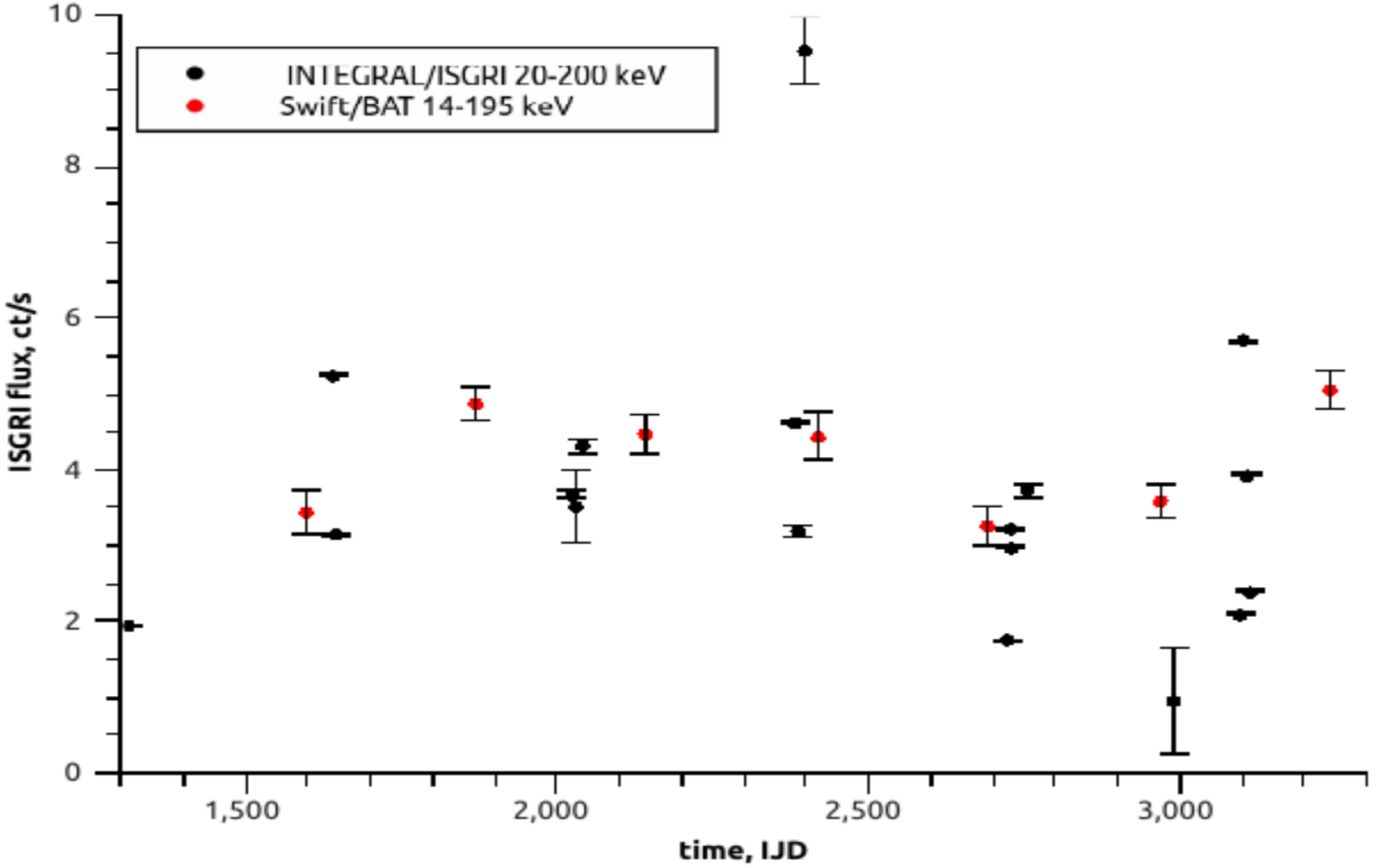
NGC 1194 folded spectra



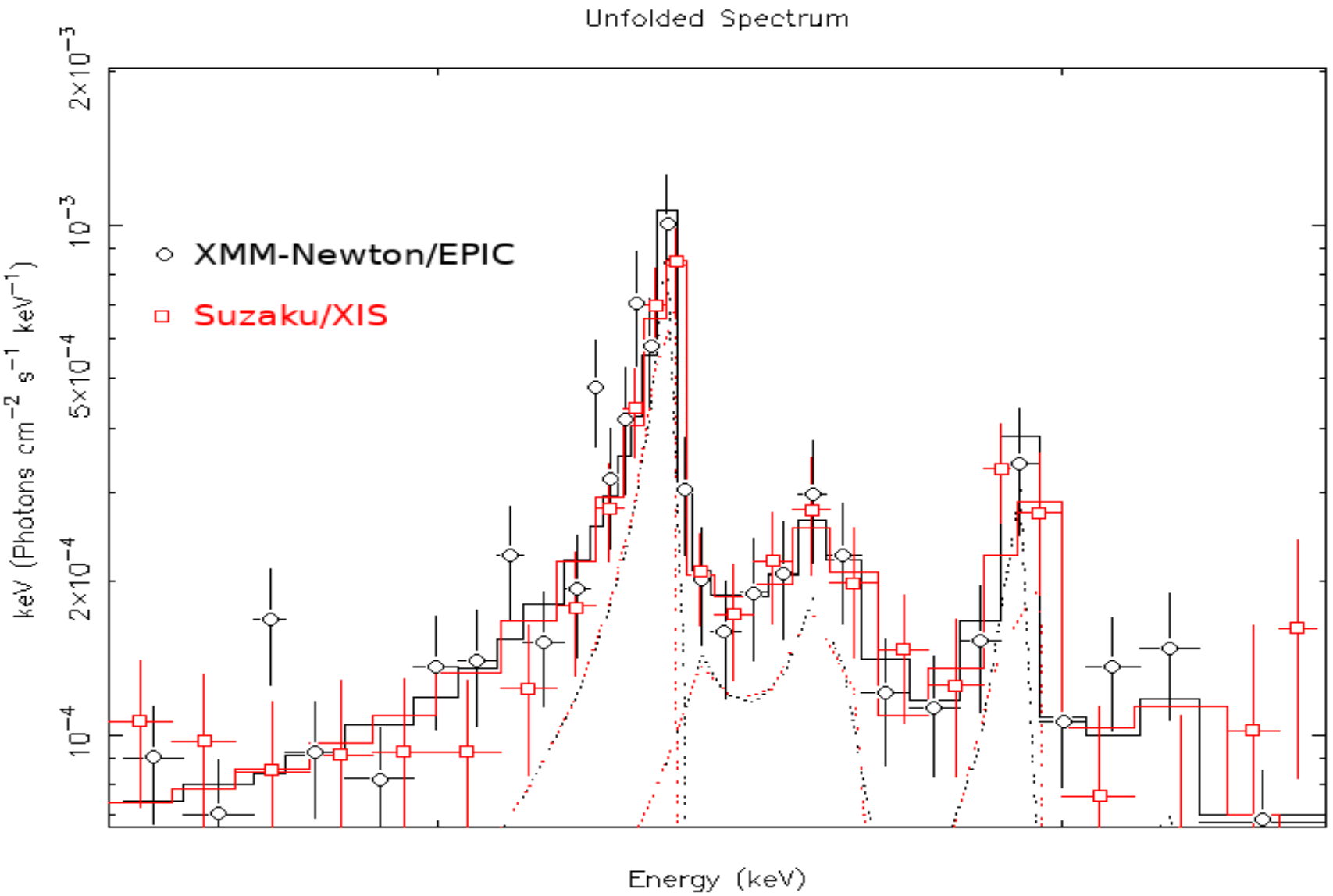
ISGRI ligtcurves (20-40, 40-60, 60-100 and 100-200 keV)



INTEGRAL/ISGRI (20-200 keV) and Swift/BAT (14-195 keV) lightcurves



Fe-K Emission lines



Emission lines: models and interpretations

1. double black hole system; the two lines with

energies slightly higher and slightly lower than initial one (Yu Q. , Lu Y. , 2001, A&A, 377, 17)

2. the first (6.37 keV) line is produced in the process of the Compton scattering of the second one (6.48 keV)

into the line-of-the-sight from some surface (for instance, the torus wall) (Wang J. et al. 1999);

3. lines (or rather one complex-shape two-horned line) are produced in the warped Bardeen-Petterson disk.

Fe-Kα,β Line parameters:

Table 7: Model parameters to the iron emission lines.

Model	Line energy, keV	i^o	R_{in}/R_{Sh}	σ, keV	EW, eV
4 * diskline	6.37±0.02	<8	$8^{+7.5}_{-5.5}$		603
$R_{in,1}$=$R_{in,3}$, $i_1 = i_3$	6.48±0.05	26^{+5}_{-4}	19^{+105}_{-18}		365
$R_{in,2}$=$R_{in,4}$, $i_2 = i_4$	6.97±0.04				457
R_{out}=1000	7.09±0.13				374
4 * diskline	6.38±0.02	<8	$6.5^{+9.5}_{-6.0}$		511
$R_{in,1}$=$R_{in,3}$, $i_1 = i_3$	6.47±0.04	44^{+10}_{-9}	485±123		364
$R_{in,2}$=$R_{in,4}$, $i_2 = i_4$	6.98±0.07				330
$R_{in,2}$=$R_{out,1}$, R_{out}=1000	7.03±0.11				298
pexmon + 2 * disklines		<8			550
$R_{in,2}$=$R_{in,1}$	6.46±0.09	23^{+6}_{-5}	24		300
$i_2 = i_1$	6.97±0.06				670

F-test values for line models:

double BH vs. reflection: 99%

warped disk vs. reflection 98.5%

Continuum models:

1. cutoffpl*zphabs + pexmon (absorbed +reflected)
2. cu*absori*zphabs +pexriv (ionized absorber/reflector)
3. cutoffpl * zphabs + pexrav1 * zphabs1 + pexrav2 * zphabs2 (double BH, additional disk, or warped disk → additional reflection)

Continuum fit

- Direct component is highly absorbed: $NH=1.08*10^{24}$ cm^{-2}
- Photon index is flat (in all models) 1.25 ± 0.04
- exponential cut-off at high energies: Ec>55 keV

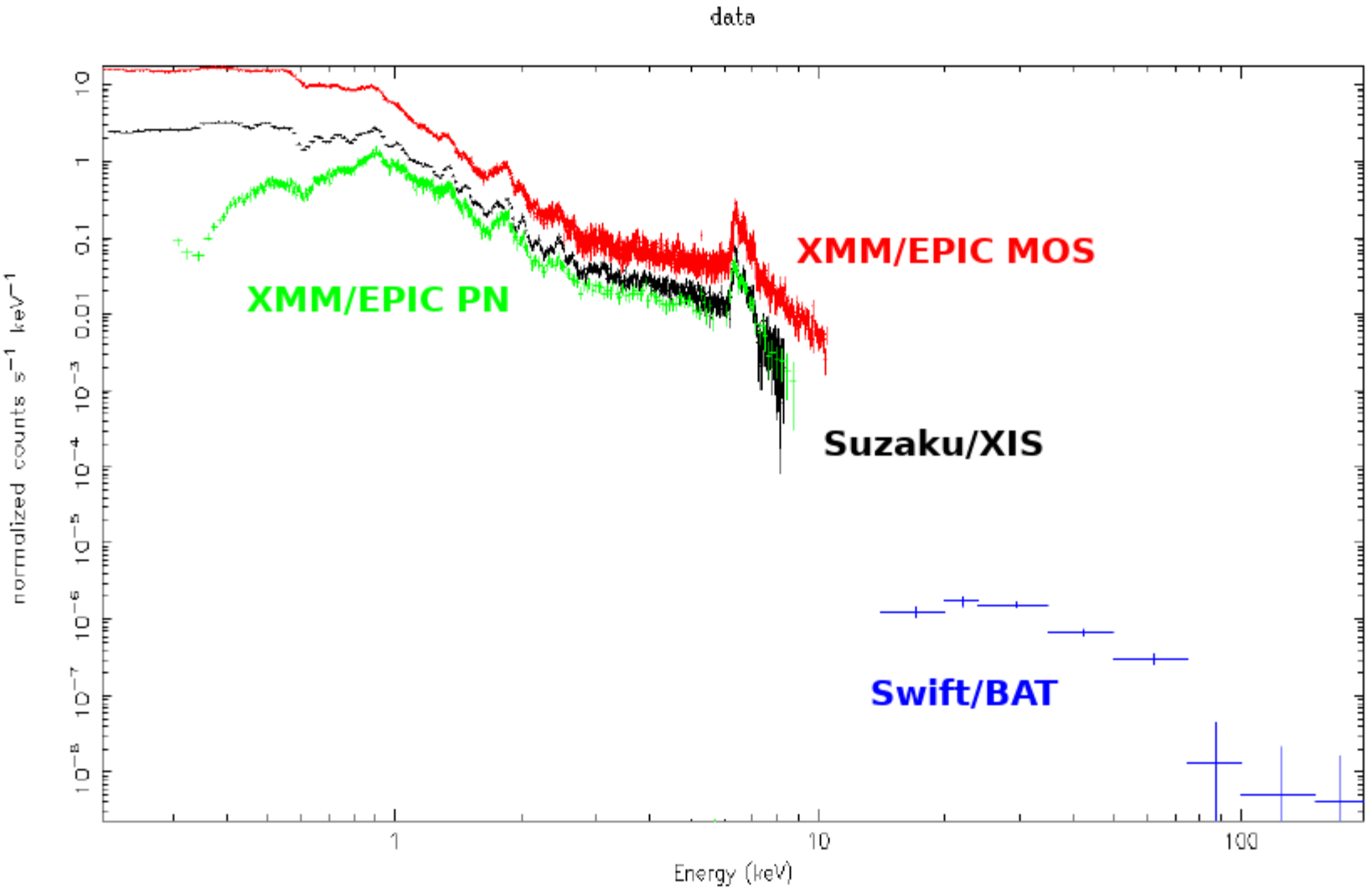
Comparison with the two “archetypal” AGNs

NGC 1068

- HBLR S2 type AGN
- z=0.003793
- RL/RQ - unambiguous structure
- Subnuclear megamaser disk (Wang J. et al., 2014)
- warped disk hypothesis in: Kumar P. The Structure of the Central Disk of NGC 1068: A Clumpy Disk Model
- $N_{Hgal}=3.5*10^{20}$ cm^{-2}

- RL AGN, S1.9 type
- SABbc host galaxy
- z=0.001494
- anomalous "X-ray arms"
- $M_{BH}=4.8*10^{7}M_{Sun}$
- Nuclear megamaser disk at 0.12-0.25 pc (Henkel J. et al., 2002)
- Galactic absorption $1.19*10^{20}$ cm^{-2}
- warped disk hypothesis: R.G.Martin The warped disc of NGC 4258

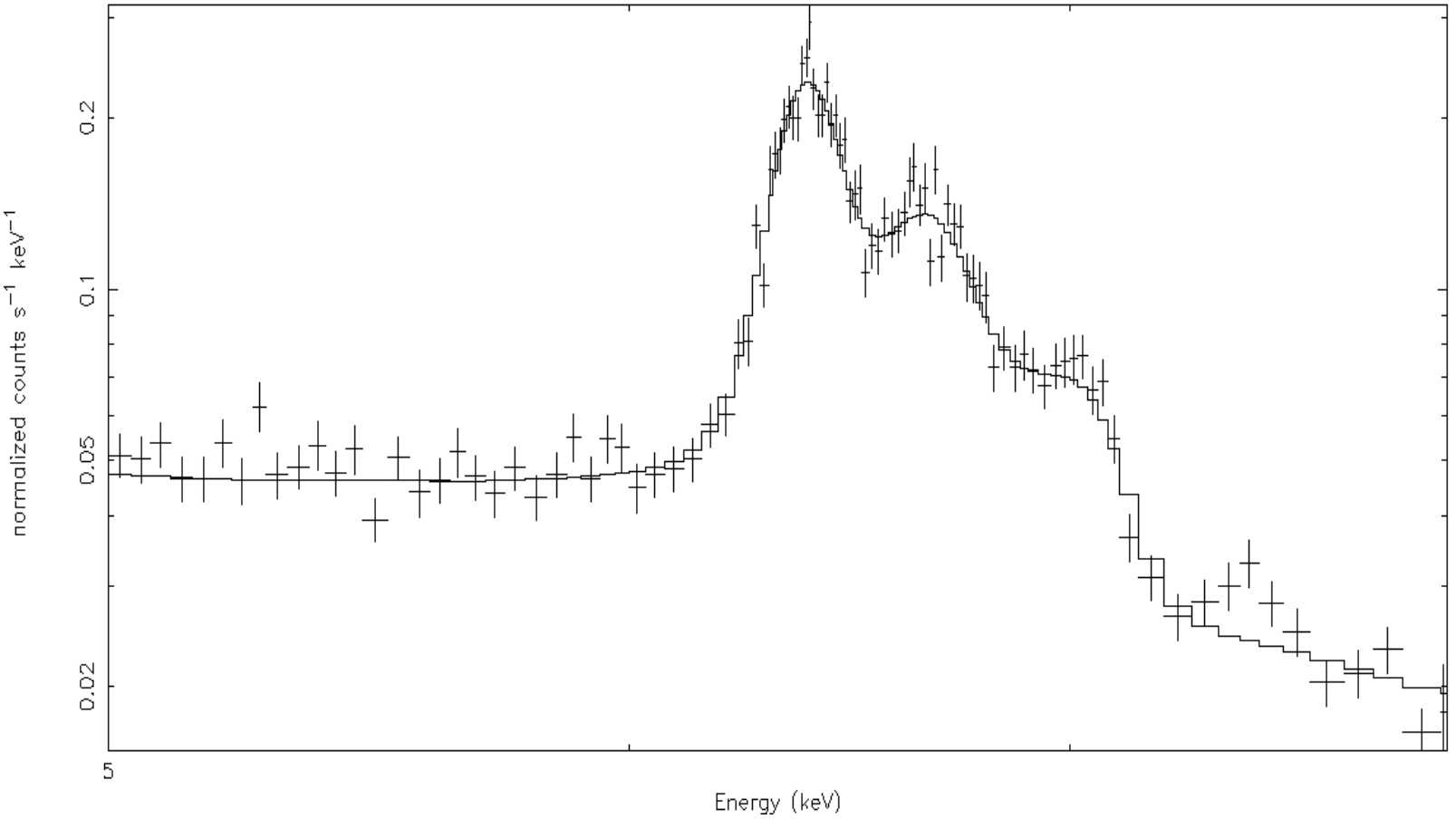
NGC 1068 spectra



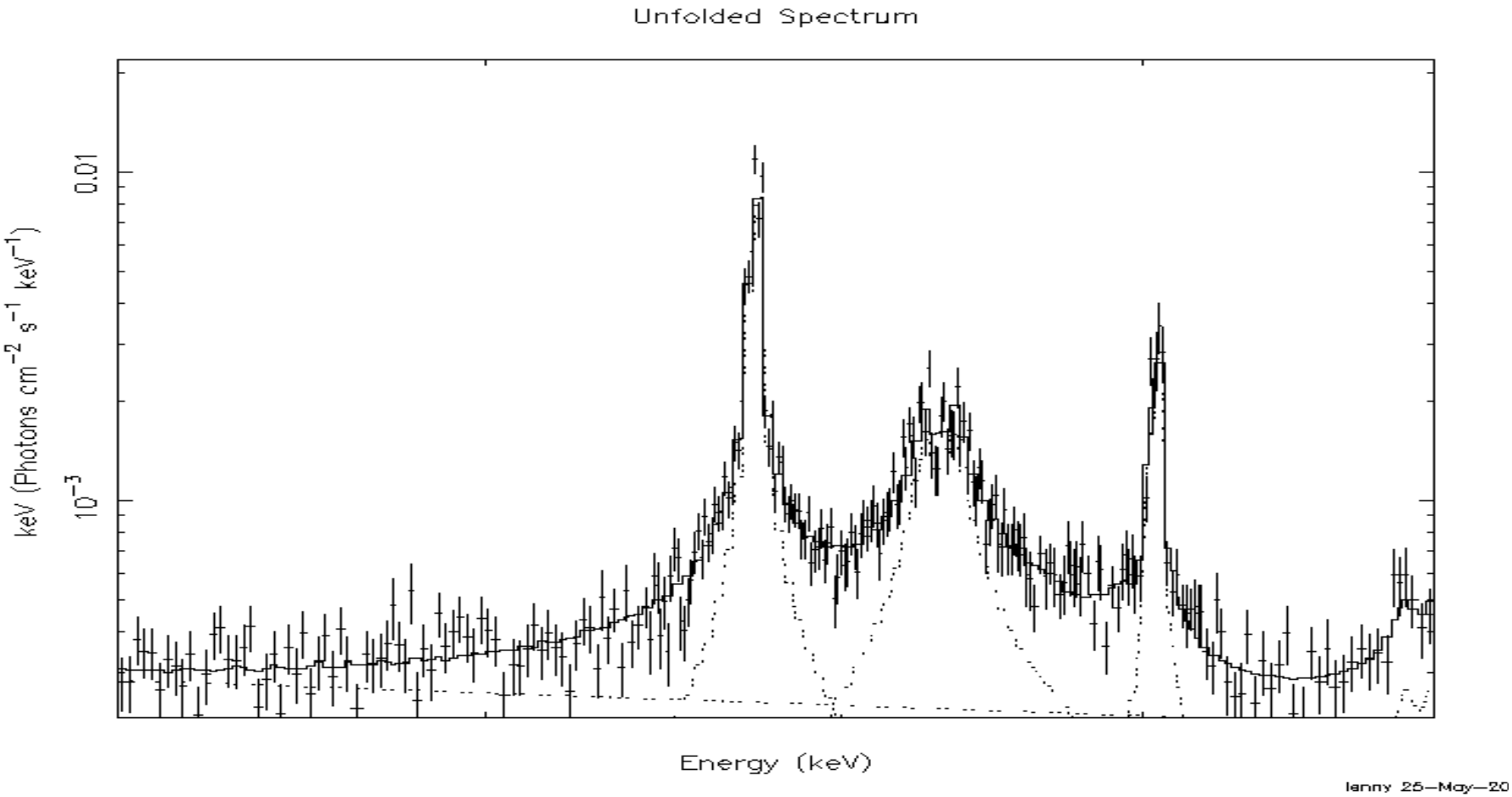
Continuum fit parameters

- model: pexrav*phabs+pexriv (Colbert E. et al. In AJ, 2002)
- Photon index 2.0-2.1
- inclination angle 63^{o}
- iron abundance ZFe=2.4ZSun
- absorption density >$9*10^{24}$ cm-2 of the primary emission

NGC 1068 emission lines: gaussian profiles...



… relativistic profiles



Line parameters

model: gauss+gauss+gauss

E_1=6.38±0.02, σ_1=0.001

E_2=6.66±0.01, σ_2=0.11

E_3=7.02±0.02, σ_3=0.02

E_4=7.44±0.09 χ^2=376.3/345

model: diskline+diskline+diskline

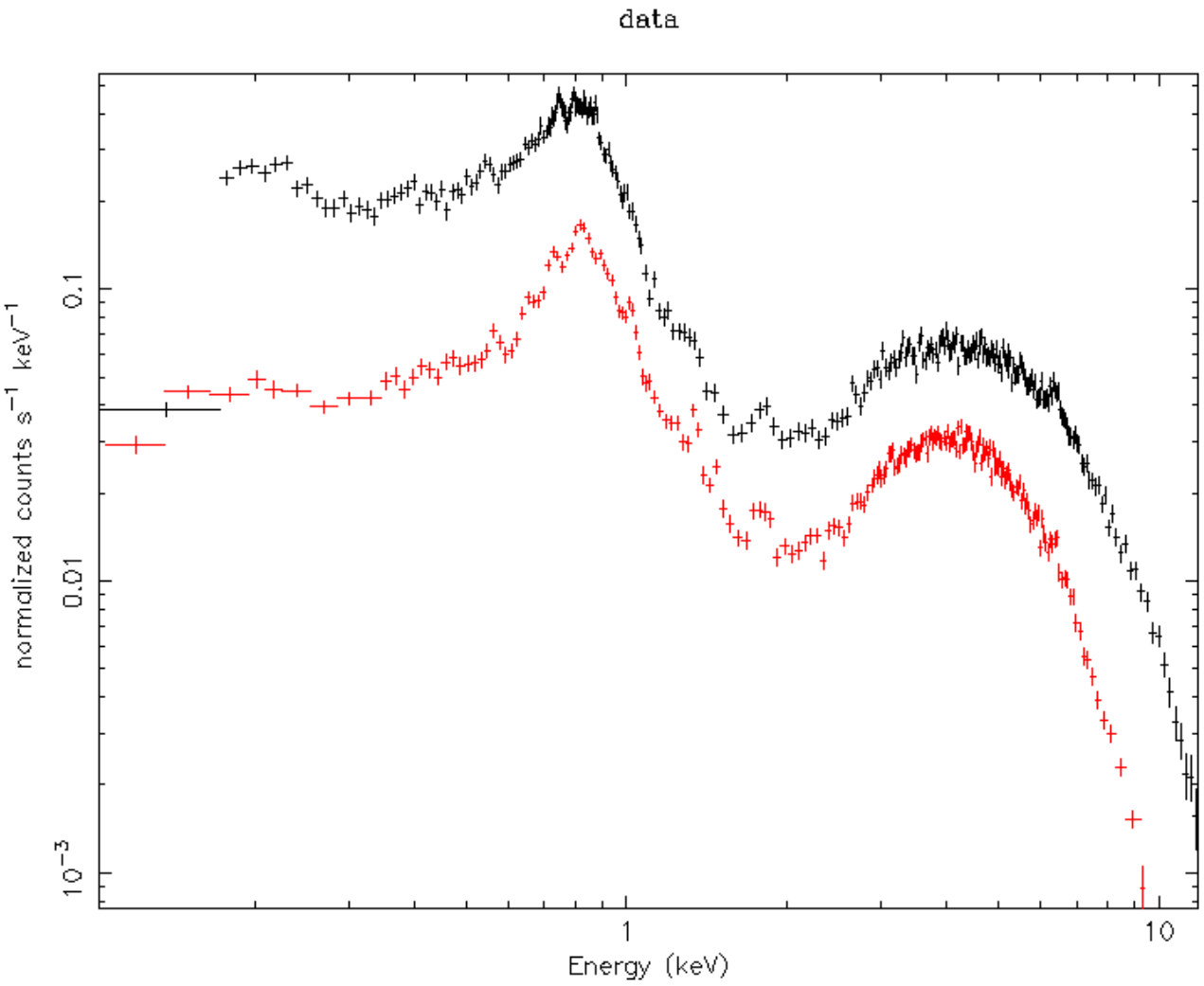
E_1=6.4±0.02, R_{in1}=R_{in3}=86.0±2.3, i_1=i_3=24^o±9.2

E_2=6.67±0.03, R_{in2}=6.0±5.0, i_2=13.6^o±3.2

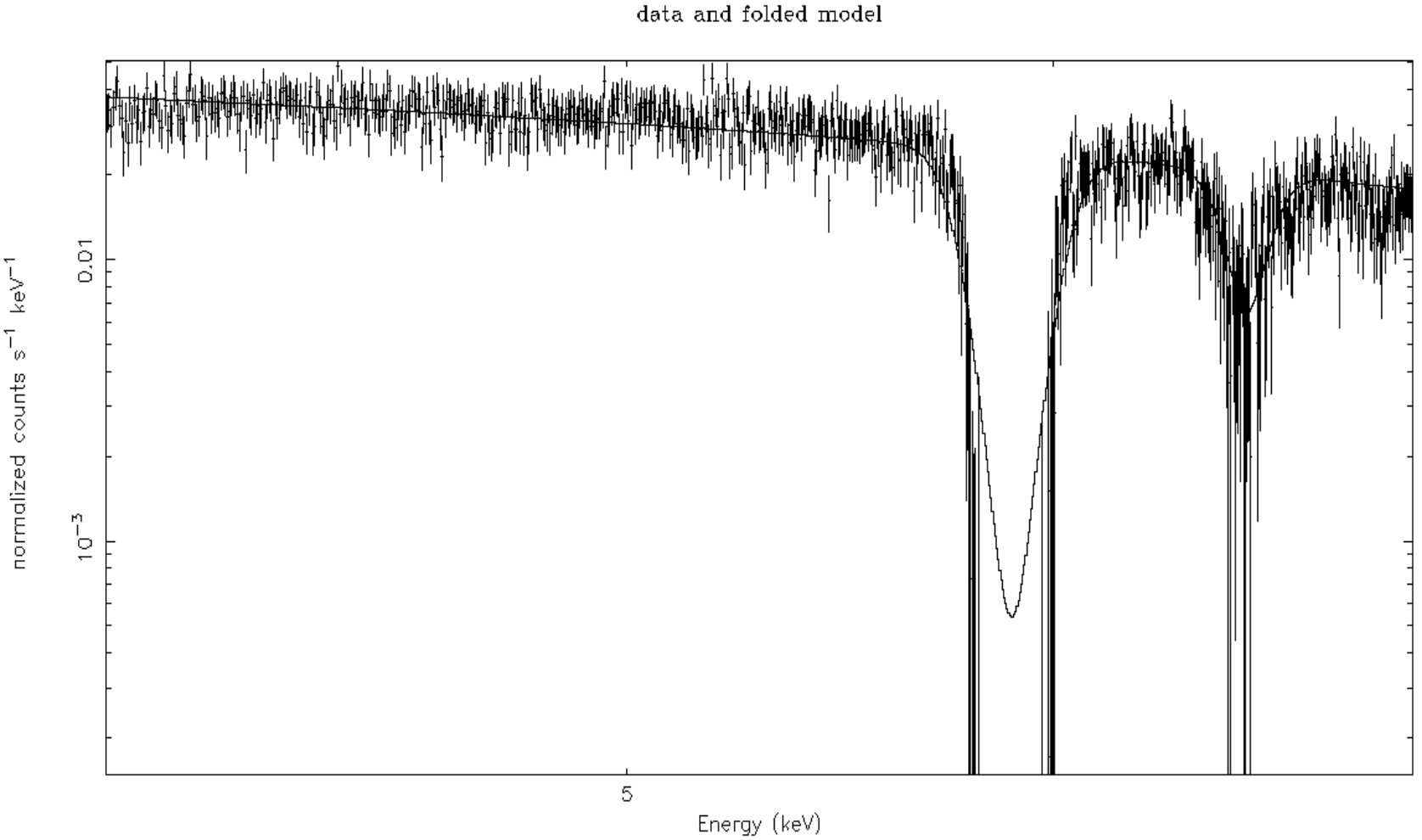
E_3=6.95±0.07

E_4=7.47±0.09 χ^2=375.0/345

NGC 4258: XMM/EPIC spectrum



NGC 4258: Suzaku/XIS spectrum



Continuum + lines fit parameters

- model: po*zphabs+zgauss
- Photon index 1.4-1.9 variable (Pietsch W., Reed A.M.)
- NH=$9*10^{22}$ cm^{-2}
- Emission lines at 6.45-6.57 keV variable...

… absorption lines (Suzaku/XIS): E_1=5.9±0.03, σ_1=0.03, s_1=$9.0*10^6$

E_2=6.52, σ_2=0.011, s_2=10^6

NGC 1194	NGC 1068	NGC 4258
RQ, weak radio jet	RQ/RL intermediate	RL
subnuclear megamaser, ~1 pc, regular	subnuclear megamaser, warped or clumpy	subnuclear megamaser, 0.1-0.3 pc, warped
complex relativistic Fe-K lines 6-7 keV	complex relativistic Fe-K lines 6-7 keV	weak emission or strong absorption lines between 5.5-7 keV
flat photon index 1.2-1.3, stable	2.-2.1 steep photon index, stable	1.4-1.9 variable photon index
high energy cut-off >100 keV	no cut-off	
probably ionized absorber/ reflector	ionized absorber/ reflector	

Current results

- NGC 1194 demonstrate peculiar shapes of Fe-K emission lines
- two possible explanations were proposed: double black hole and warped disk
- there are some similarities with the other warped disk candidate: NGC 1068 have complex shape of Fe-K emission lines, which can also be relativistic
- existing data is not enough to make a final choice between these two models
- More accurate numerical models of double BH system and warped disk reflector should be added to xspec soft to resolve such problems … (and some future plans...)

THANK YOU FOR YOUR ATTENTION!