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Broad iron $K\alpha$ line feature

as seen by XMM-Newton in Modified Timing Mode

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Istanbul

The Goal(s)

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Spectral feature:

Study the iron line feature in Cygnus X-1

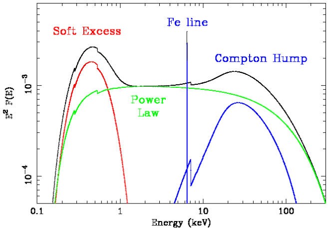
Instrumental:

Customize XMM-Newton to observe bright sources

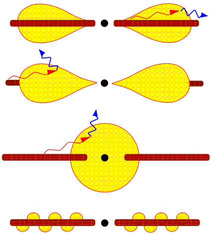
Accretion : physics behind

Physical processes:

- black body radiation (accretion disk)
- inverse compton scattering
- compton reflection, including iron line feature emergance



(Fabian et al., 2008)

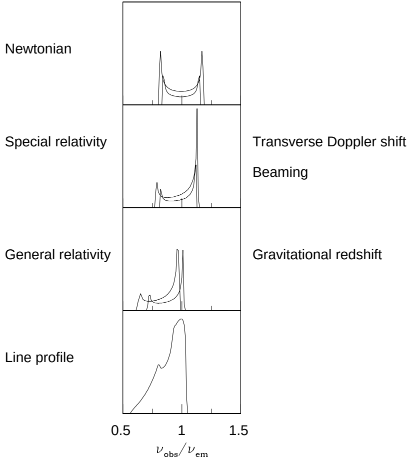


(Reynolds & Nowak, 2003)

Accretion: iron line broadening

Iron line evolution:

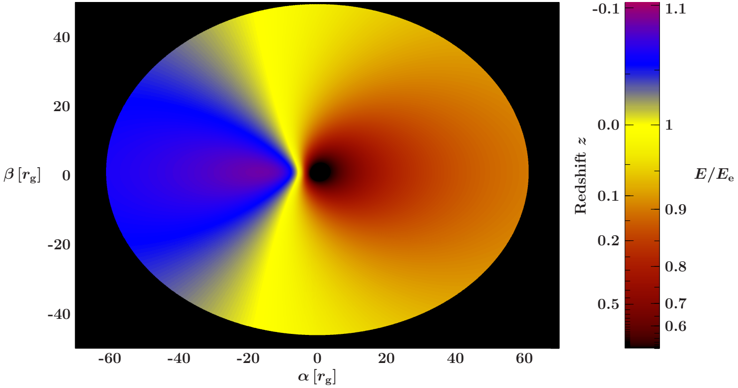
- non-relativistic effect - *Doppler with double peak*
- special relativity - *relativistic beaming*
- general relativity - *gravitational redshift*
- (inclination)
- (emissivity profile)



(From Fabian et.al, 2008)

Accretion: energy shift

What it looks like from our point of view...



(Dauser et al., 2010)

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Accretion: gains

Potential of revealing dynamics of BH system:

- spin
- inclination
- emissivity profile
- ionization state of the disk

Modified Timing Mode - why?

- Bright sources are cruicial for detailed understanding of accretion processes.
- Cygnus X-1 ∼300 mCrab

	Time res.	Live time[%]	Max. cps	mCrab
EPIC-MOS				
Large window	900 ms	99.5	1.8	0.6
Timing	1.5 ms	100.0	100	35
EPIC-pn				
Small window	6 ms	71.0	100	11
Timing	0.03 ms	99.5	800	85
Burst	7 μs	3.0	60000	63000

Telemetry limit problem!

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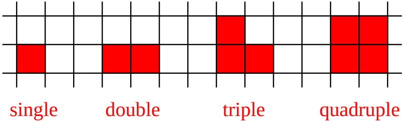
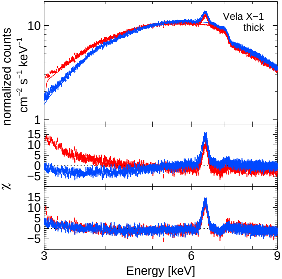
Modified Timing Mode

Steps of modified timing mode:

- switch off EPIC-MOS - increase in telemetry
- increase the lower energy threshold to 2.8 keV
- recalibration of the instrument (split events)



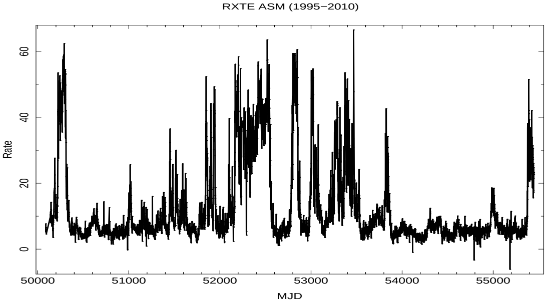


(S.Fritz, PhD Thesis Kendziorra et.al, 2004.)

Who is Cygnus X-1?

High Mass X-ray Binary system

- 8.7 $M_{\odot}$ black hole orbiting supergiant O9.7Iab
- wind accretion
- persistent source
- highly variable
- distance of 2.3 kpc

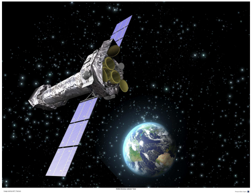


Cygnus X-1: observations

Simultaneous observations give us better constraints on:

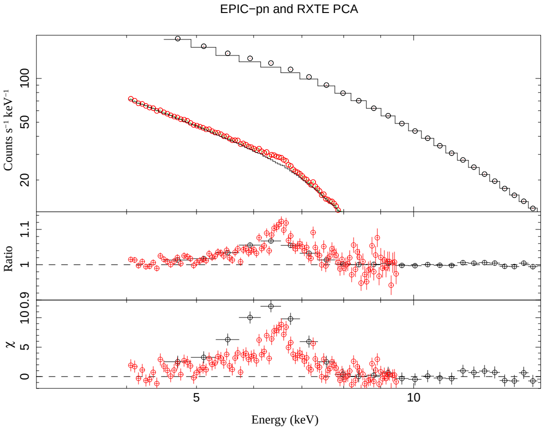
- continuum
- reflection components

Observatory	**XMM-Newton**	**RXTE**
Instruments	EPIC-pn	PCA/HEXTE
Exposure (ks)	10	7
Energy range (keV)	4-10	4-120
Mean (cps)	250	1100



Cygnus X-1: iron line feature

EPIC-pn and PCA data.
Excluding 5-8 keV during the fit, and replotting.
Broad Fe fluorescence line feature is clearly seen.



Cygnus X-1: fit model

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Model:

phabs*((bknpower*highecut)+diskbb+gaussian+relconv(1,reflionx))

- reflionx (ionization states and transitions) (Ross & Fabian 2005)
- relconv (relativistic effects near BH) (Dauser et al. 2010)
- diskbb (soft emission from the disk)
- gaussian for narrow iron line (Hanke et al. 2009)

Cygnus X-1: calibration

Model:

phabs*($Isis\_Active\_Dataset$)*((bknpower*highecut)+diskbb+gaussian+relconv(1,reflionx))

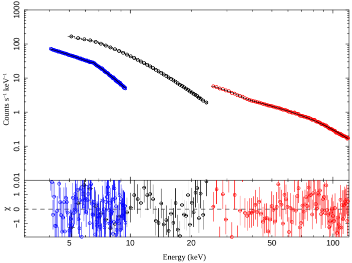
Calibration effects:

- cross-calibration constants
    - account for calibration differences for different instruments
- broken power law indexes Γ_1 and Γ_2
    - XMM-Newton and RXTE
- gain shift in energy
    - CTI overcorrection
    - X-ray loading

Fit results

Satisfied with:

- χ^2_{red} ~1.3
- Orbital inclination $i \sim 39°$ (Ninkov et al. 1987, Davis & Hartmann 1983)
- Emissivity ~ 2.4 (Miller et al. 2002)



Γ_{pca}	$1.96^{\pm 0.02}$
Γ_{pn}	$1.87^{\pm 0.01}$
diskBB [keV]	$0.45^{\pm 0.04}$
Ioniz.[erg cm s^{-1}]	$236^{\pm 15.0}$
Emiss. q	$2.36^{\pm 0.25}$
Spin a	$0.65^{\pm 0.20}$
i [deg]	$38.9^{\pm 3.0}$
$Const_{pca}$	1.37
$Const_{hexte}$	1.06

What we have

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Modified Timing Mode:

- EPIC-MOS switched off
- Lower EPIC-pn threshold increased to 2.8 keV
- recalibration of the instrument

Cygnus X-1:

- simultaneous XMM-Newton and RXTE observation
- relativistically broadened iron line
- convolved reflection model

The Next step(s)

3 more observations:

- simultaneous with RXTE
- longer exposure
- less variability in flux (Wilms et al. 2005)