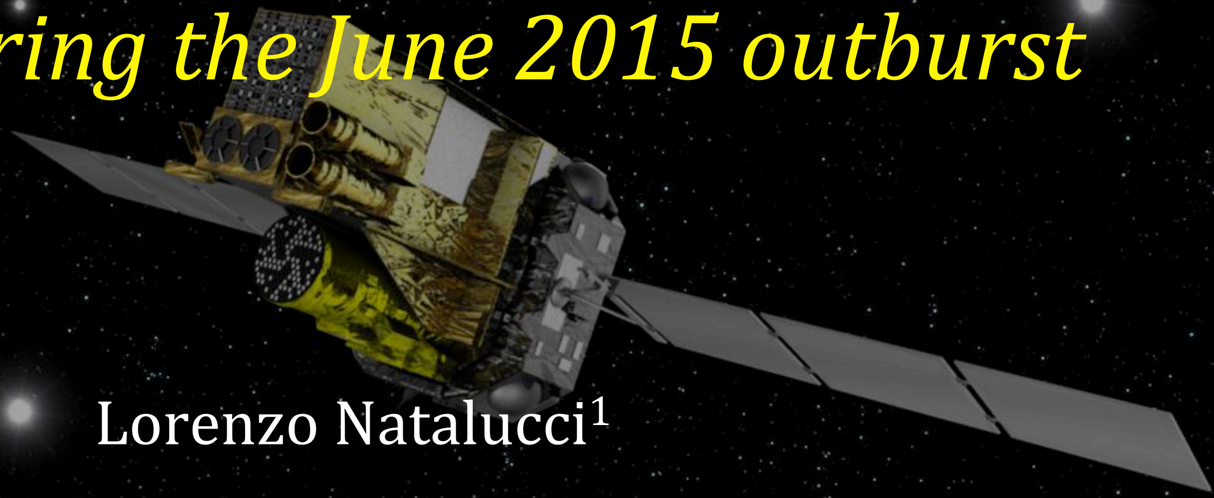
High energy spectral variability of V404 Cygni during the June 2015 outburst



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V404 brief history

- ✓ First time detection with Ginga in 1989 (Makino+89; Kitamoto+89)
- ✓ 2-300 keV spectra obtained with Roentgen on Mir-Kvant (Sunyaev+91)
- ✓ Optical follow-up and identification (Wagner+1989; Casares+93)
- ✓ Two previous outbursts in 1938 and 1956, identified in archival optical data
- ✓ Observed multiple times during quiescence:

  X-ray (Bradley+07,Rana+15)

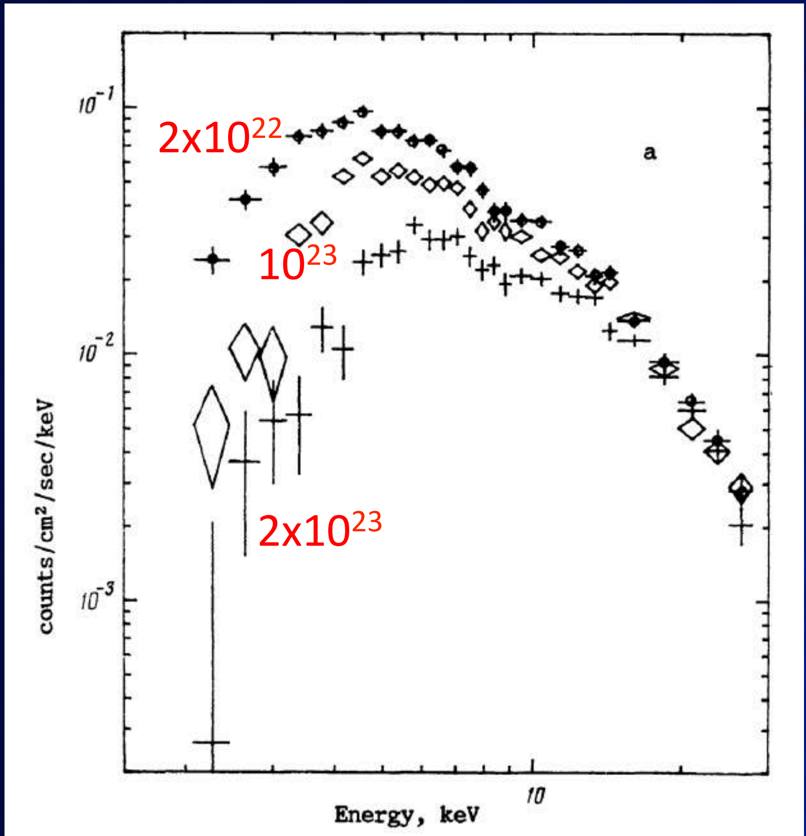
  multiwavelenght (Hynes+09)
- ✓ Swift and MAXI detection on 2015, June 15
- ✓ Multiwavelenght follow-up reported in many ATELs and in a few recent papers appeared on astro-ph

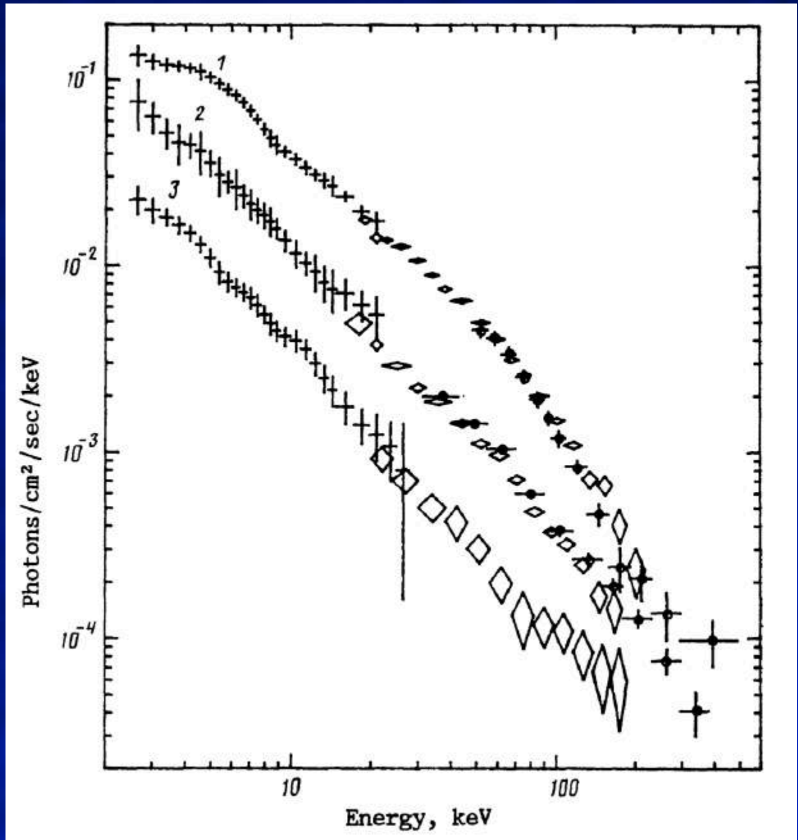
V404 Id

Black Hole mass: ~9 to12 M_{Θ}
Orbital period: 6.5 days
Companion star: K0IV (1 M_{Θ})
Distance: 2.39±0.14
Inclination: ~56 to 67^{O}
X-ray *quiescent* luminosity: ~10^{32} cgs

- ✓ One of the highest quiescent luminosities found in Black Holes
- ✓ Strong variability observed at all frequencies. Radio flux variations are on time scales of minutes
- ✓ The high energy spectrum, reported for the 1989 outburst is hard even at high luminosities (> ~0.1L_{Edd})

Spectral variability during the 1989 outburst



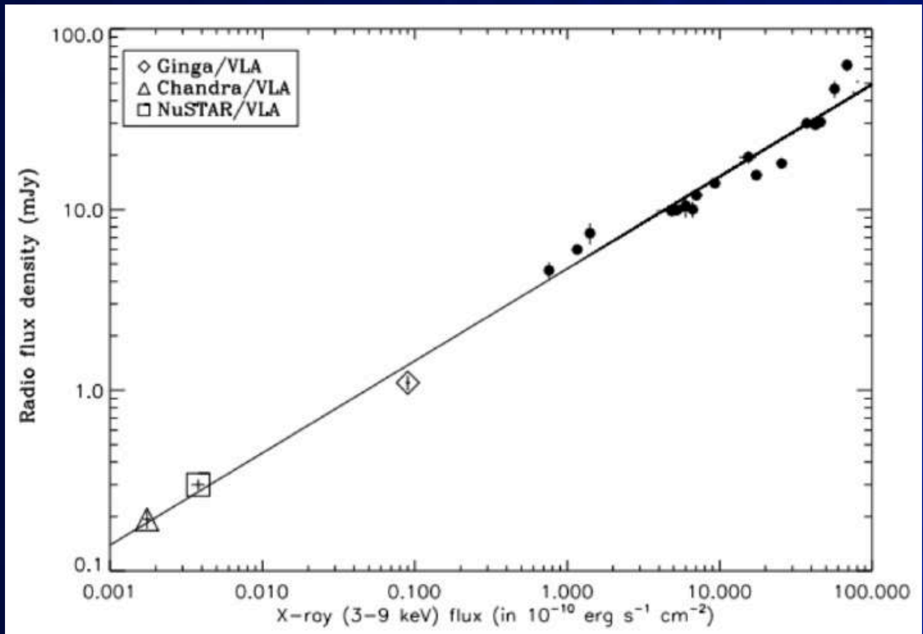


Sunyaev+91
Kvant/TTM observation
9-10 June 1989, variability in absorption

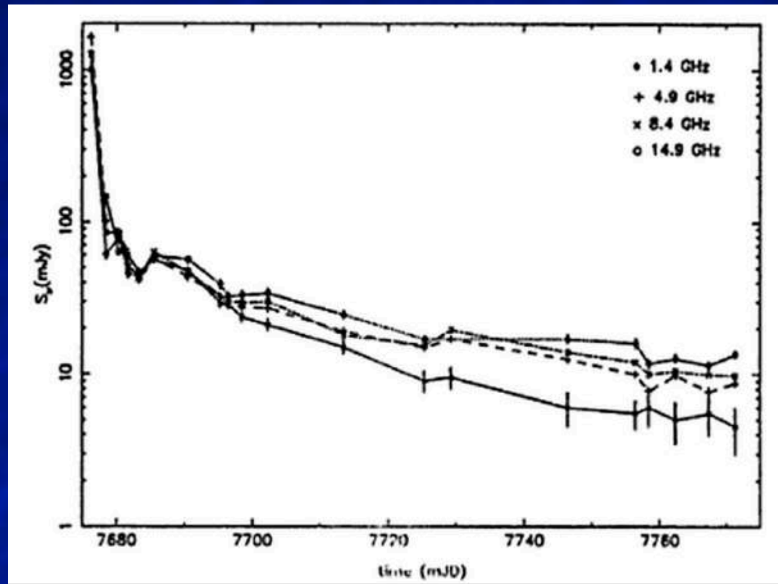
Hard spectra detected with TTM, HEXE and Pulsar X-1

Radio/X-ray correlation for V404 Cygni

✓ Strong radio flux detections show evidence for jet-like emission



Radio/X-ray flux correlation
Corbel+08, Rana+15

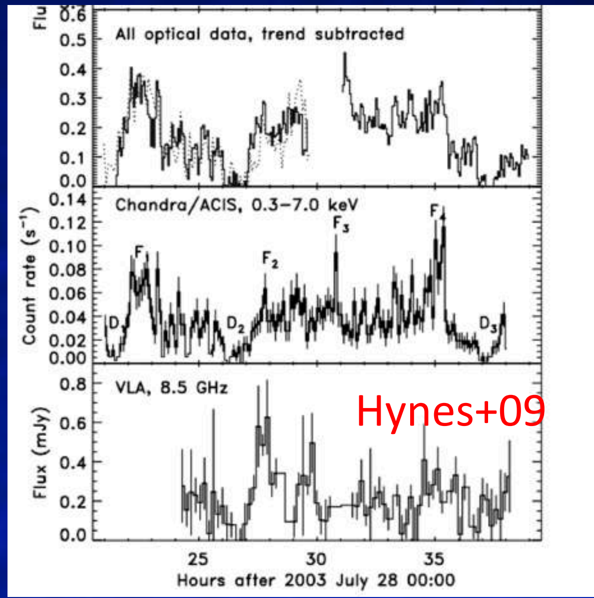


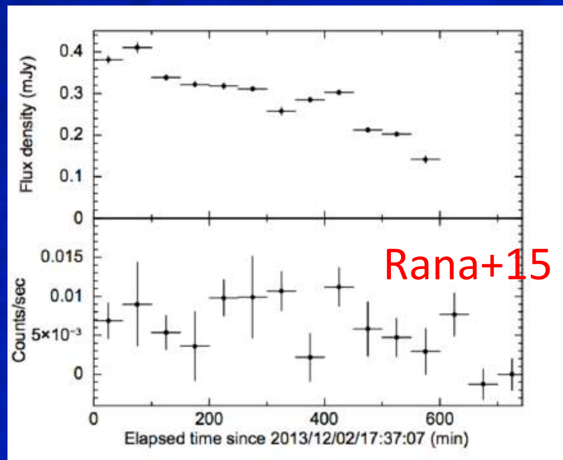
Radio LC of the 1989 outburst
Han & Hjellming 1990

High energy observations of quiescent emission

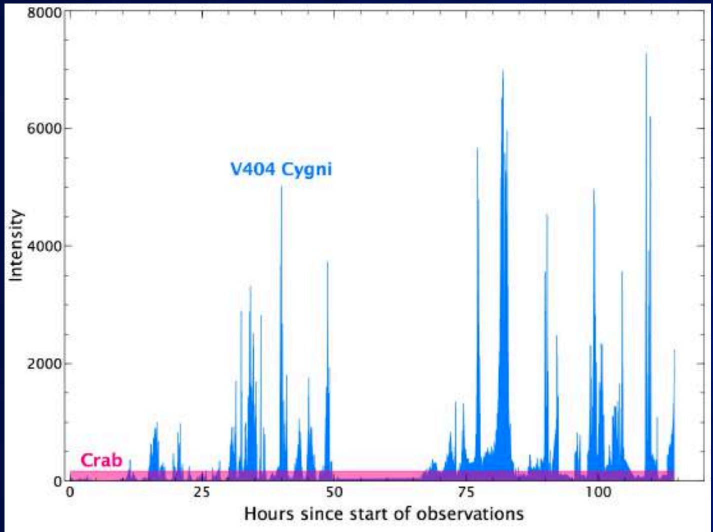
- ✓ Previous observations by *ROSAT ,Asca,BeppoSAX, Chandra, XMM*.
- ✓ Quiescent luminosity reported as ~10^{33} erg/s (varying across the observations)
- ✓ Power-law spectrum (Γ ~ 2)
- ✓ *XMM* observation (Bradley+04) places upper limit on Fe line EW
- ✓ No strong ionized lines in the *XMM* or *Chandra* data (Hynes+09)

- ✓ The recent *NuSTAR*+VLA simultaneous observations report no evidence of correlated variability with radio flux during observation (Rana+15)
- ✓ Similar variability timescale in soft and hard X-rays (*XMM-Newton*+*NuSTAR*)



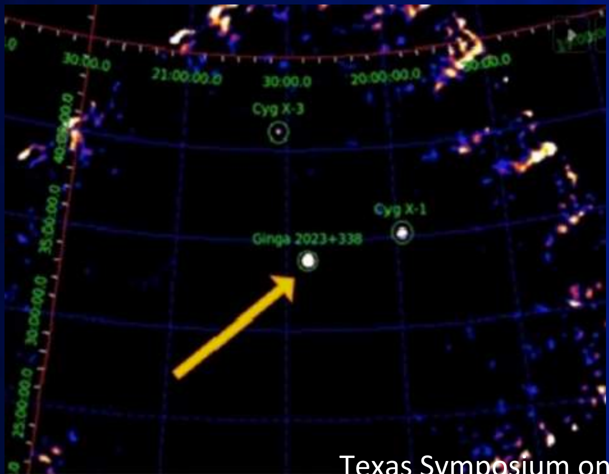


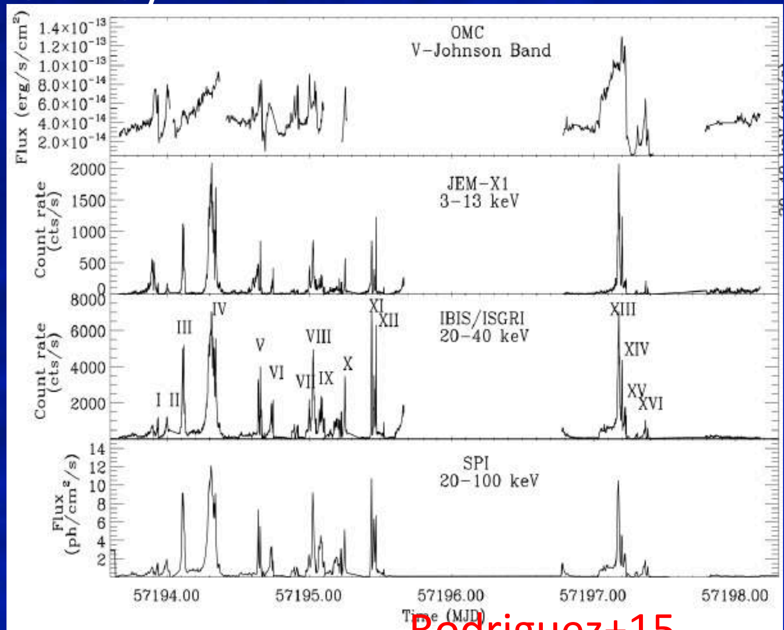
The 2015 outburst – the INTEGRAL monitoring



- ✓ INTEGRAL started to monitor the source on June17
- ✓ Strong X-ray/soft gamma-ray flares reaching ~50 Crab in intensity
- ✓ Optical flaring correlated with X-ray flares in a complex way

IBIS/ISGRI Light curve (17-22 June) *Credit:* ESA

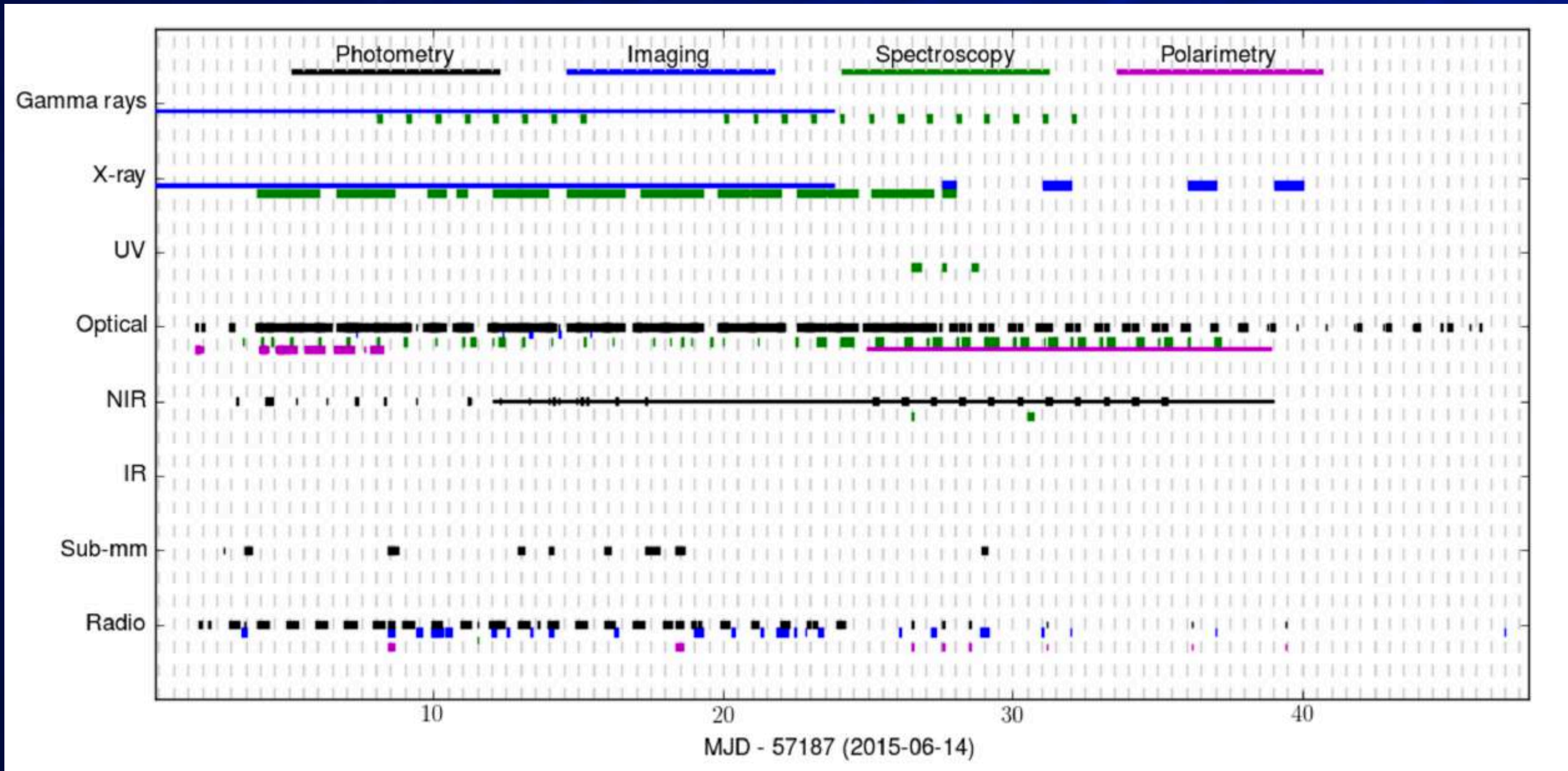




INTEGRAL Light curves (20-25 June)

Multi-wavelength follow-up

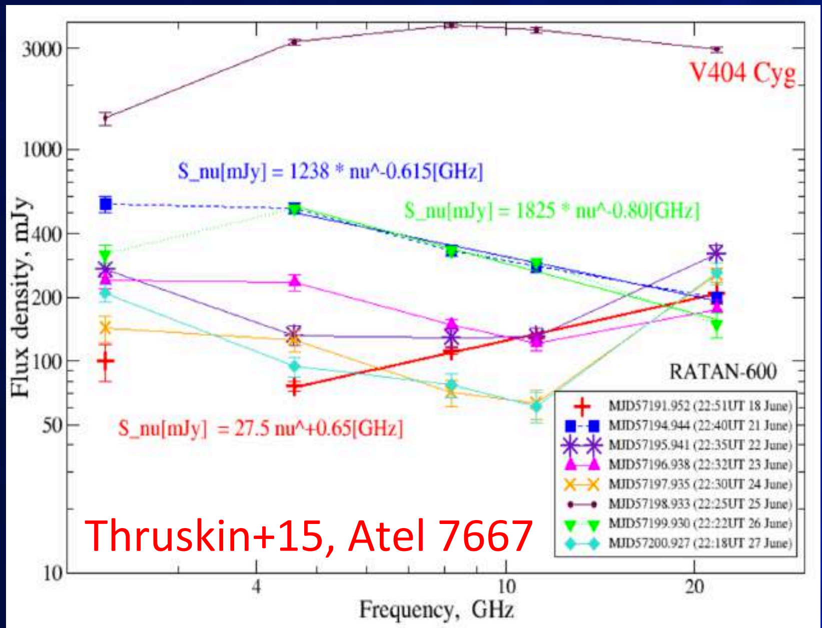
- ✓ Fantastic opportunity to follow-up; instrumentation much more performant than was available in 1989



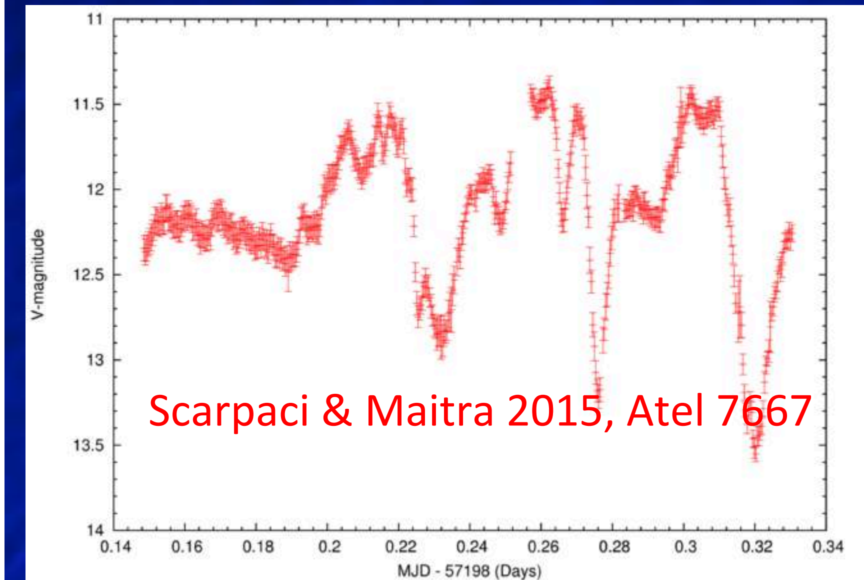
Credit: http://deneb.astro.warwick.ac.uk/phsaap/v404cyg/data/all.png

Radio & optical data

- ✓ Radio spectra point to optically thick synchrotron radiation probably from a compact jet



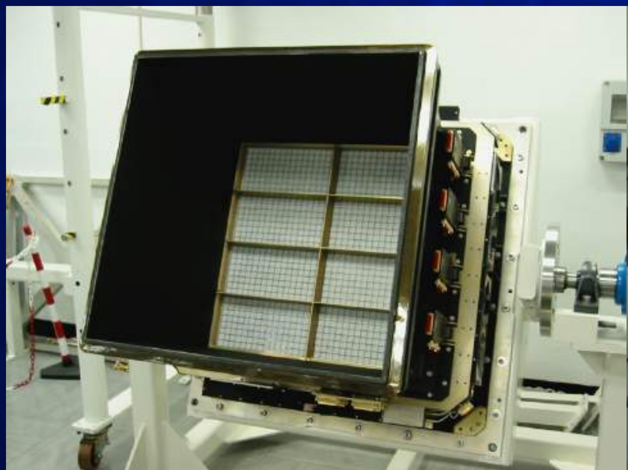
Spectra obtained with the RATAN-600 radio telescope



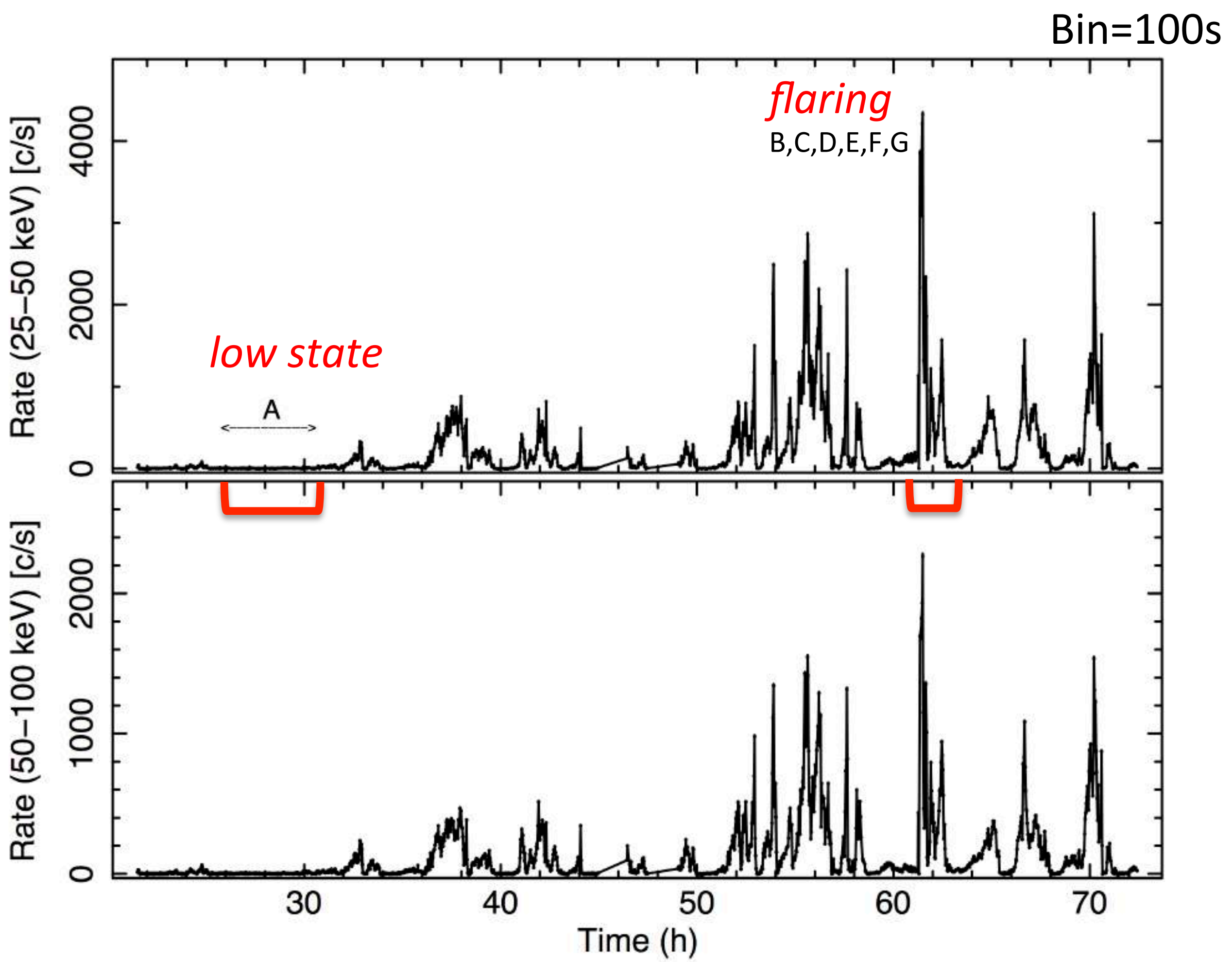
Optical LC from WCO

Spectral variability with IBIS and SPI

- ✓ Analysis of orbit 1554, period: June 17-20. Using OSA v10.1
- ✓ High count rates in ISGRI produce frequent gaps in the TLM data stream at the highest fluxes. The gaps duration is of the order of a few (~2-4) seconds.
- ✓ Our spectral analysis attempts to use both IBIS and SPI data in the 20-300 keV band. The two instruments are cross-calibrated, using Crab model spectrum on March 2015 data



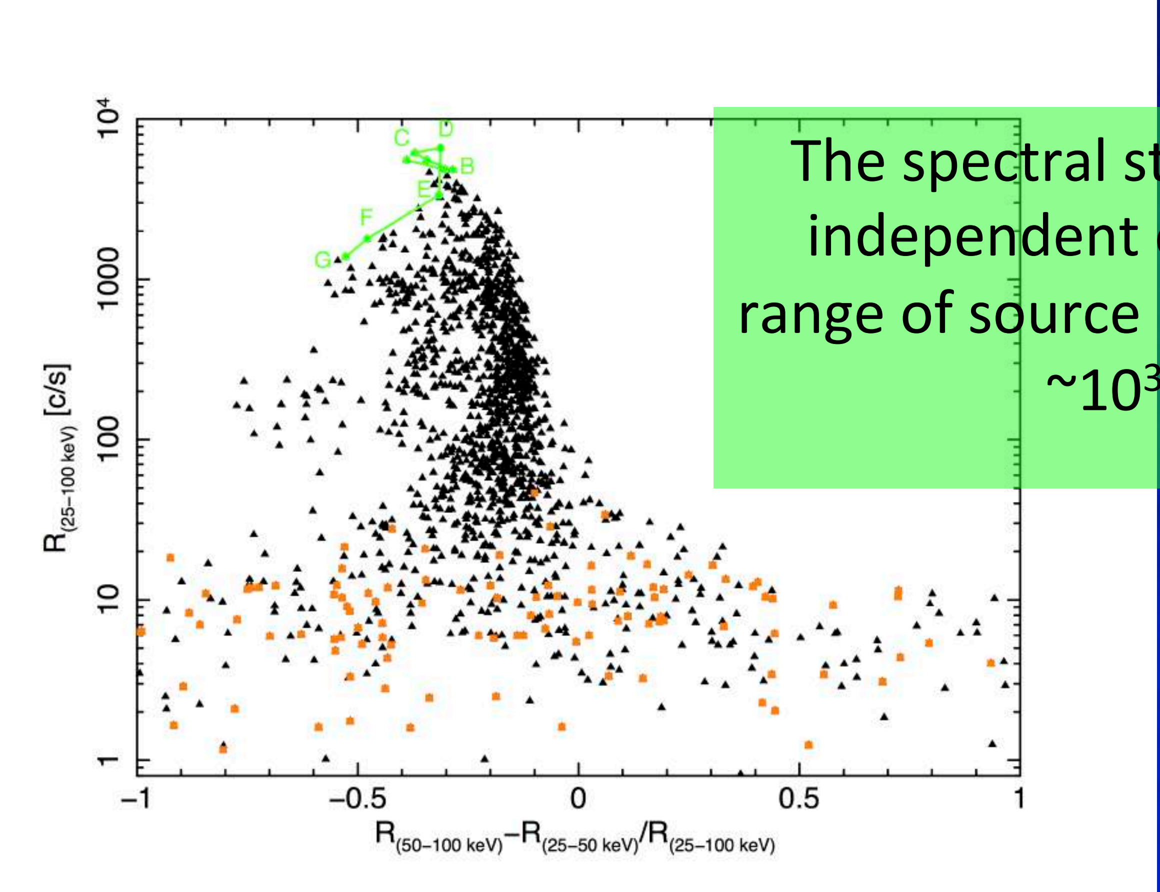
IBIS/ISGRI Light curves, orbit 1554



Start Time MJD 57190 21:30:45

Hardness variations: the HorseHead

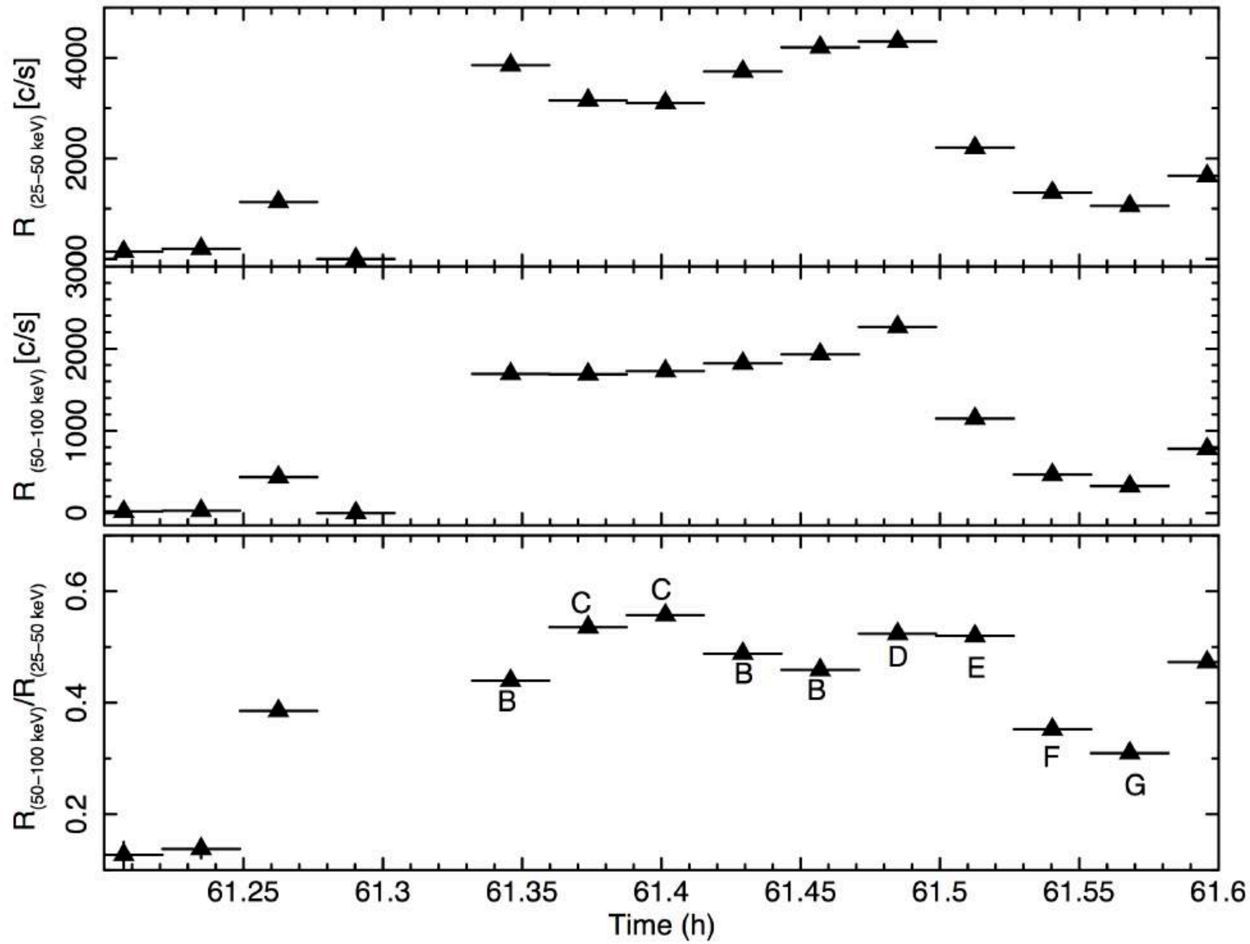
- ✓ At low fluxes (<0.1 Crab) the hardness variations are much wider
- ✓ More stable at intermediate fluxes. Positively correlated with flux up to ~2 Crab
- ✓ But within a single flare,harder spectra occur at higher fluxes



The spectral state seems rather independent of flux for a wide range of source luminosities (above ~10^{36} erg/s)

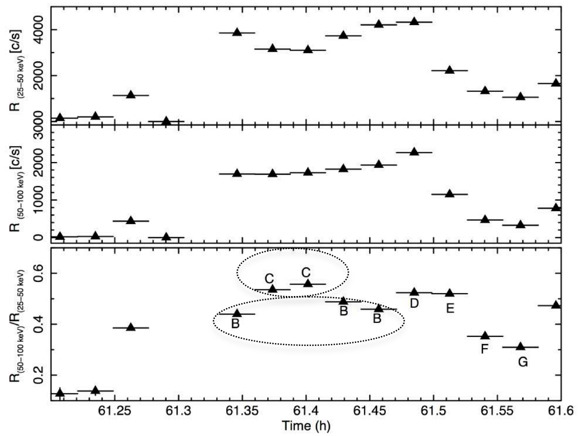
Natalucci+15

Zooming on a bright flare



Fits with thermal Comptonization

- ✓ All spectra are well fit by *comptt* model (thermal plasma with disk seed photons)
- ✓ Spectrum C is better fitted by a direct continuum plus reflection (*xillver*)
- ✓ Seed photon temperature is very high for all spectra. Similar results using *eqpair* (Coppi 1999)



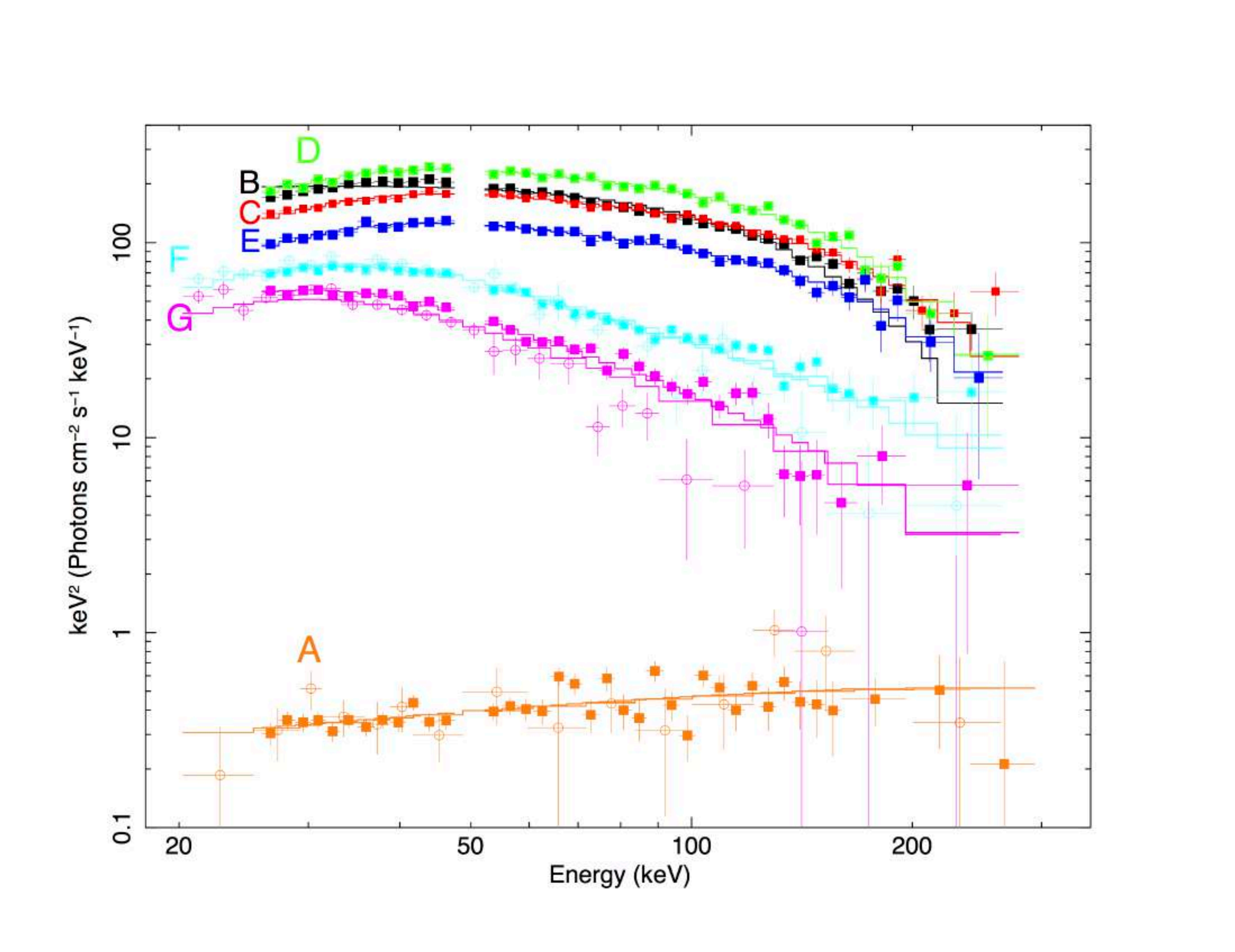
Results of spectra fitting using the *comptt* model.

Spec.Id[a]	$kT_0(keV)$	$kT_e(keV)$	τ	Flux[b]	χ^2/dof
B	7.05 ± 0.2	42^{+7}_{-4}	$0.7^{+0.1}_{-0.2}$	5.5	25.8/38
C	7.4 ± 0.2	40^{+5}_{-3}	1.0 ± 0.16	5.0	54.9/39
C_R^c	$8.6^{+1.0}_{-1.4}$	42^{+8}_{-18}	0.9 ± 0.3	5.0	40.3/36
D	7.2 ± 0.3	34^{+3}_{-2}	1.2 ± 0.2	6.6	42.0/37
E	7.4 ± 0.3	41^{+11}_{-5}	$0.9^{+0.2}_{-0.3}$	3.5	37.9/38
$F^{(*)}$	6.4 ± 0.2	182^{+8}_{-93}	< 0.09	1.73^d 1.76^e	91.5/73
$G^{(*)}$	6.0 ± 0.3	63^{+88}_{-33}	< 0.7	1.17^d 1.04^e	101.3/66

Note. — [a] Fits with IBIS and SPI spectra are marked by $^{(*)}$. In all other cases, only IBIS data have been used. [b] Flux values in units of 10^{-7}erg s^{-1} cm^{-2}, in the 20-200 keV range. [c] Fit with added reflection component (see text for more details). [d] Flux measured by IBIS. [e] Flux measured by SPI.

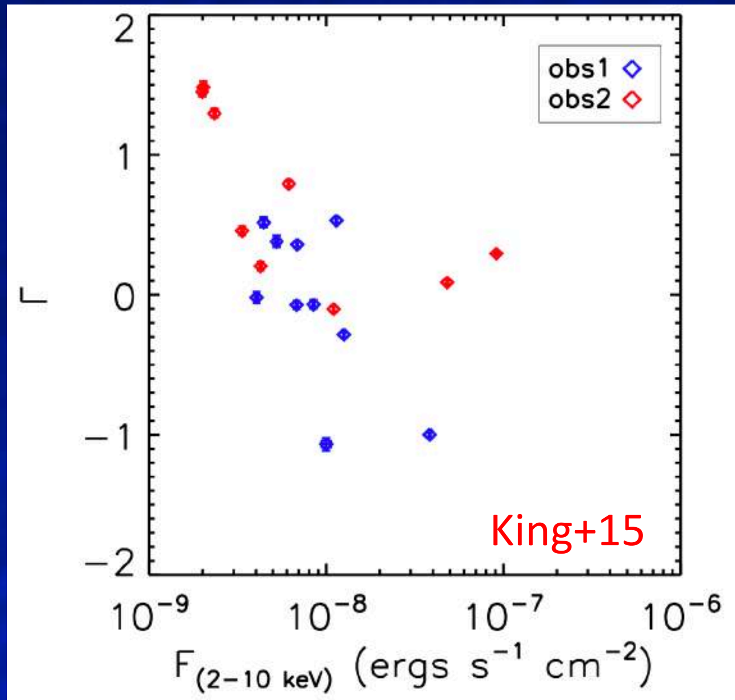
Natalucci+15

Low state vs. flaring spectra



The high energy variability

- ✓ At hard X-rays, the variability is characterized by strong variations of the hardness ratio down to timescales of ~10s or less, as detected by *INTEGRAL*
- ✓ The hard X-ray variability must be correlated to the central accreting source. Possible contribution by jet?
- ✓ The source is also much variable in the soft X-rays, but the origin could be different. Two recent *Chandra* observations show that this can be mostly explained by variable absorption in the outer disk



Slope vs flux variability in the Chandra observations (22-23 June)

Conclusions

- ✓ We reported on the analysis of the initial phase of the V404 Cygni outburst, using the IBIS and SPI instruments
- ✓ V404 Cygni exhibits a strong variability up to the hardest X-ray energies. The origin of the variability is still unclear, but most probably related to the central accreting source.
- ✓ The variability picture and spectral behaviour at high energies is consistent with the results for the previous outburst (Sunyaev+1991)
- ✓ The spectra at the highest fluxes seem well described by a thermal corona with ~40 keV temperature.
- ✓ Using a single component model for the direct emission, the seed photon temperature is constrained to be ~7 keV (too high to originate within the accretion disk).
- ✓ A more complete analysis is ongoing