Dust scattering halo of the peculiar black hole binary 4U 1630-47

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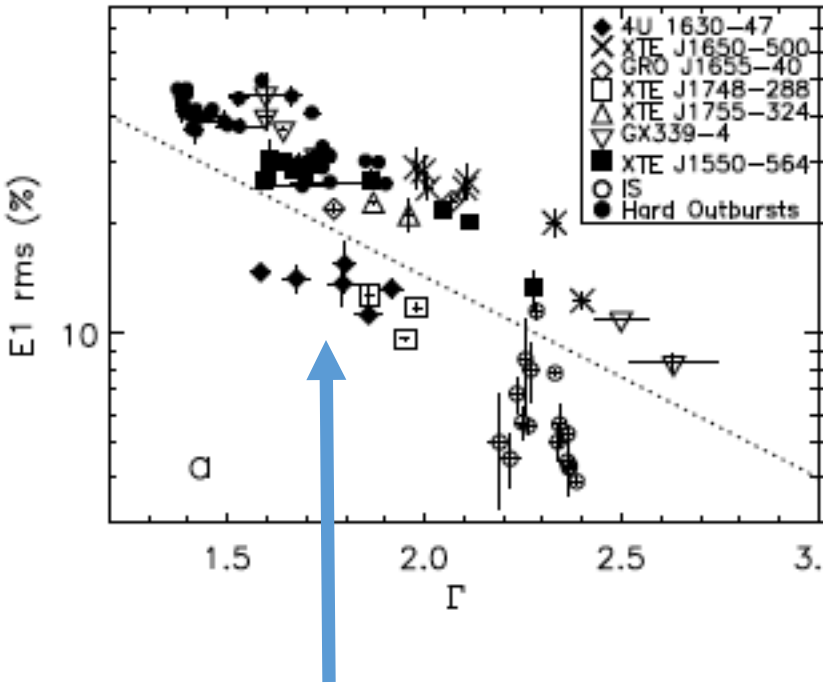
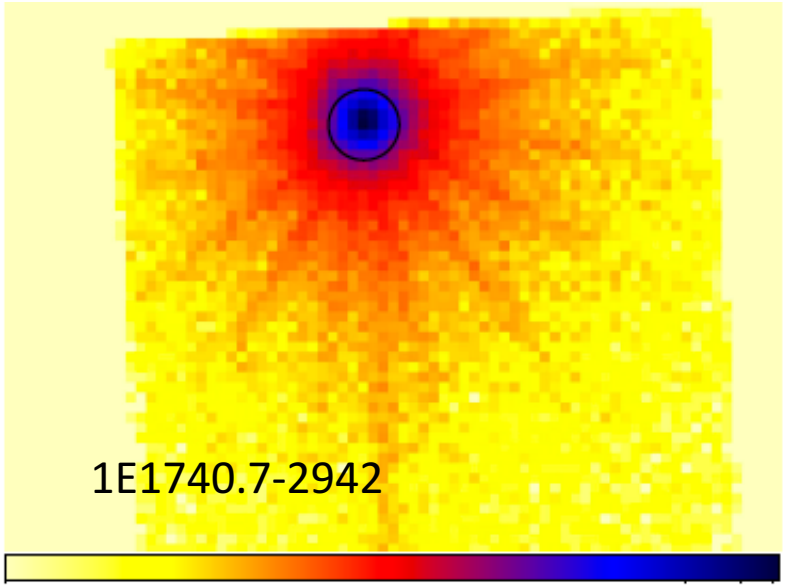
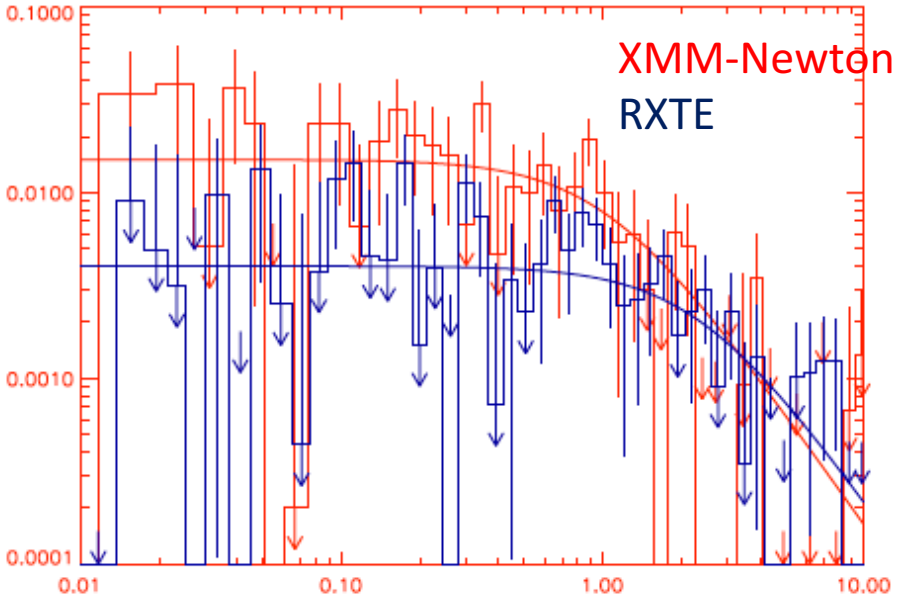
Motivation

Kalemci MQW6, 2006.

Kalemci PhD Thesis, 2002!







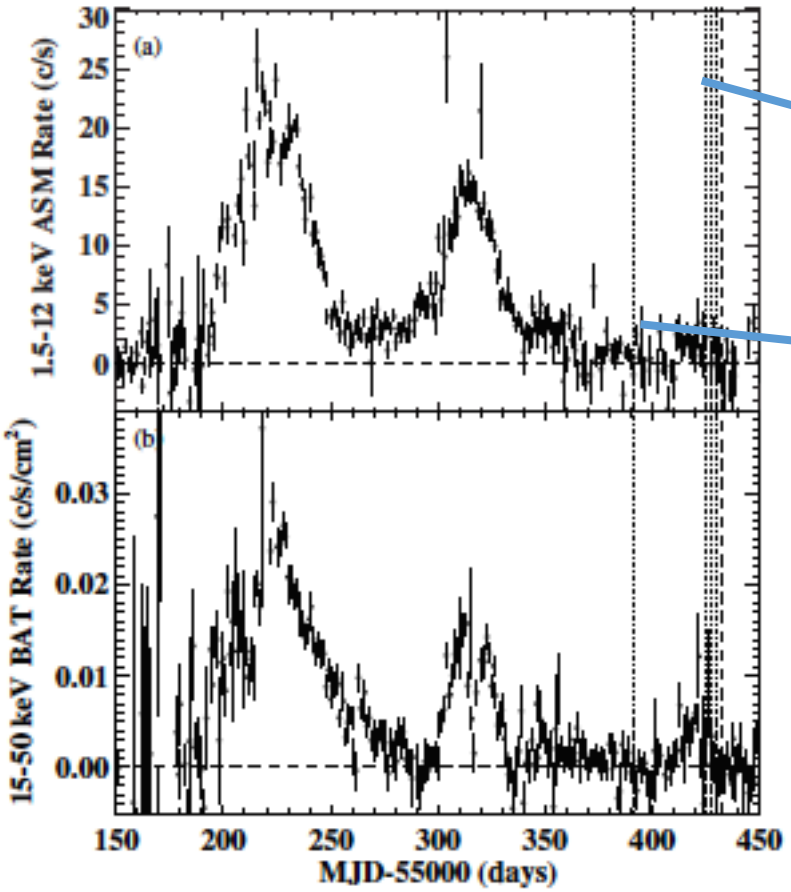
Outliers are high NH sources,
4U 1630-47 and XTE J1748-288

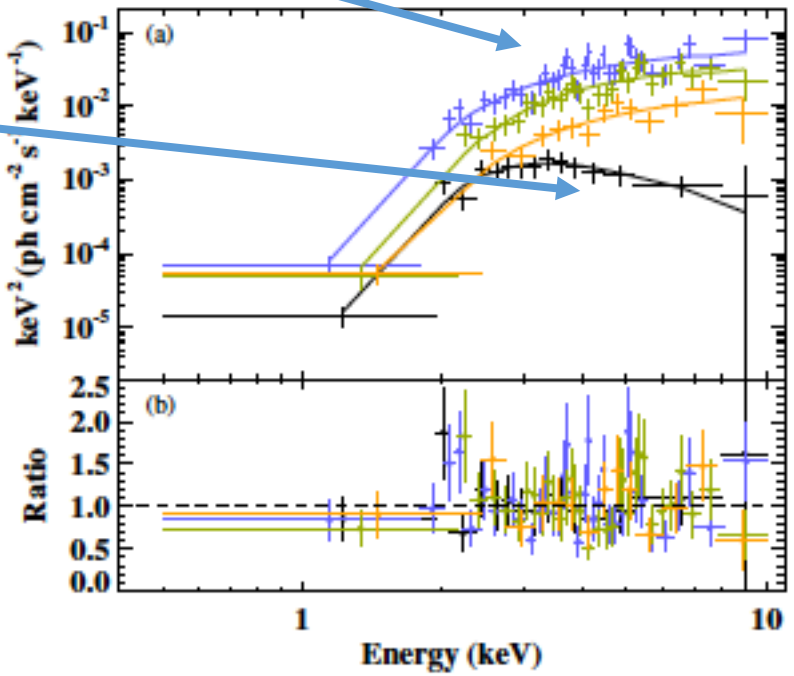
I claimed they have low rms because at low luminosities a dust scattering halo is present inside the FOV of RXTE.

4U1630-47

Soft state at **0.0003 L_{Edd} !** (10 kpc, 10 $M_\odot$)

See Armin Vahdat's poster (and Maccarone 2003, Kalemci 2013)





Tomsick et al 2014.

4U1630-47

peculiar HID, quite **soft**,
occasionally missing initial hard states

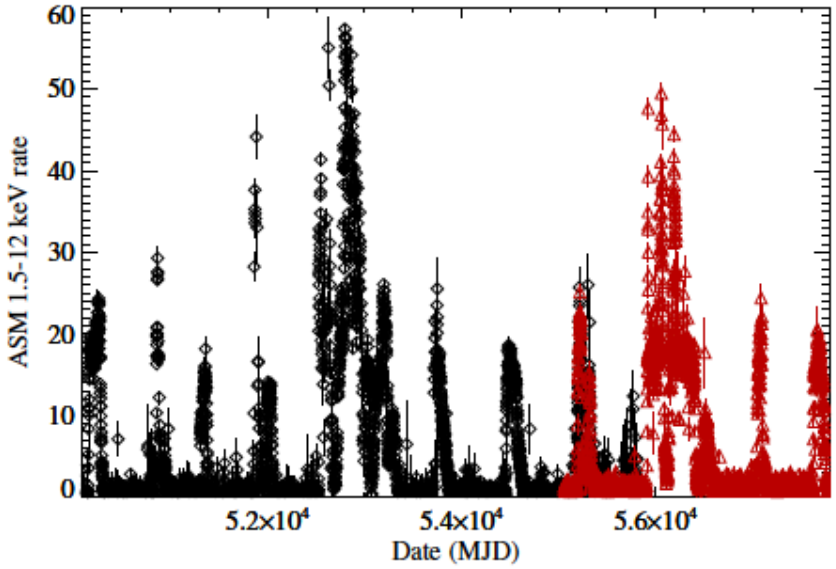
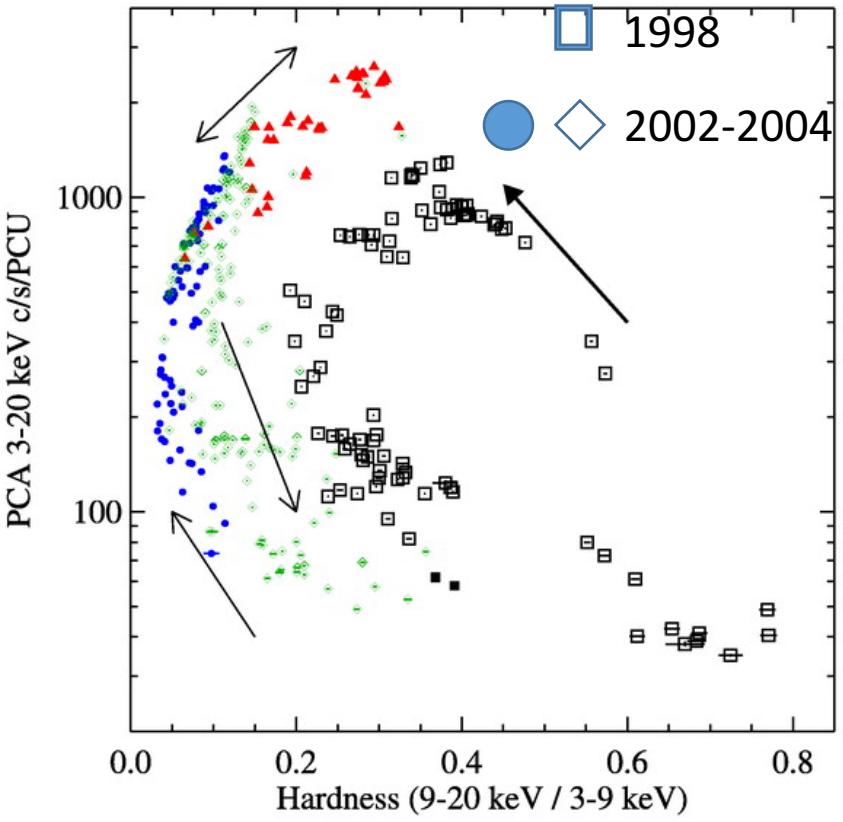


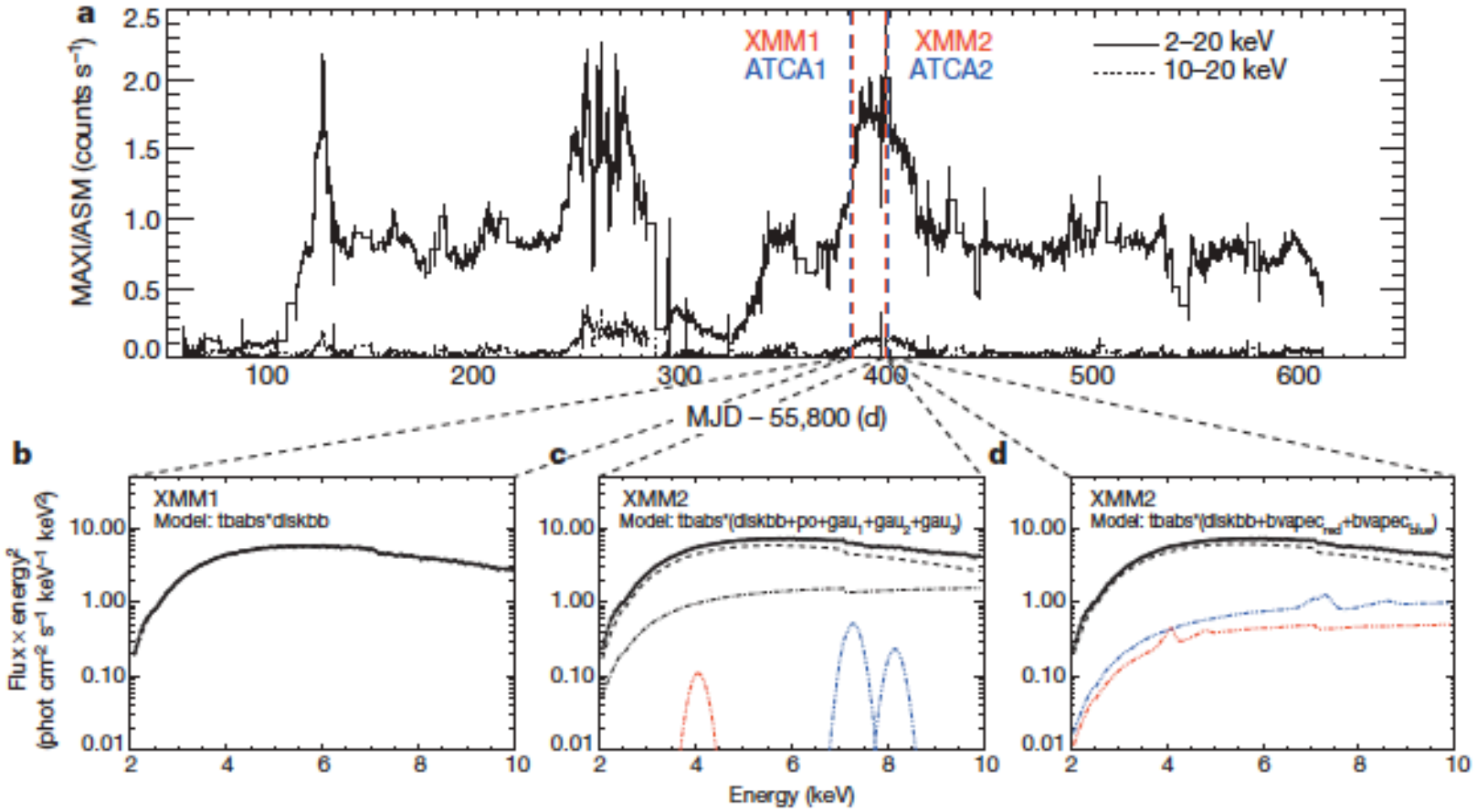
Figure 1. *RXTE* ASM (black points) in 1.5-12 keV band and MAXI (red points) in 4-10 keV band light curve of 4U 1630−47. MAXI rates are multiplied by 45 to match ASM rates.



Almost periodic outbursts,
small outbursts with occasional large outbursts.

Tomsick et al 2005.

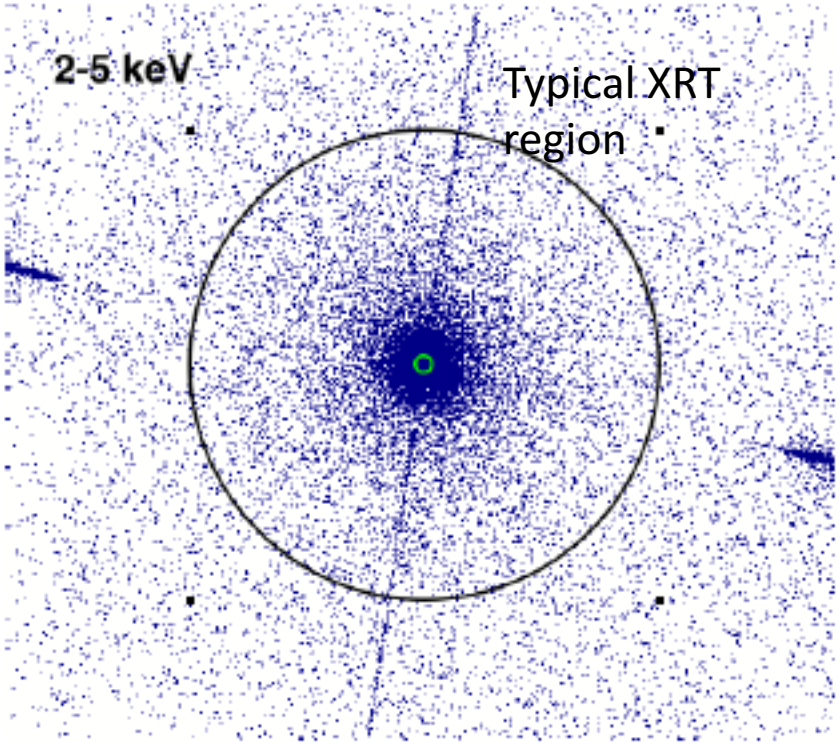
4U1630-47 Baryonic jets?

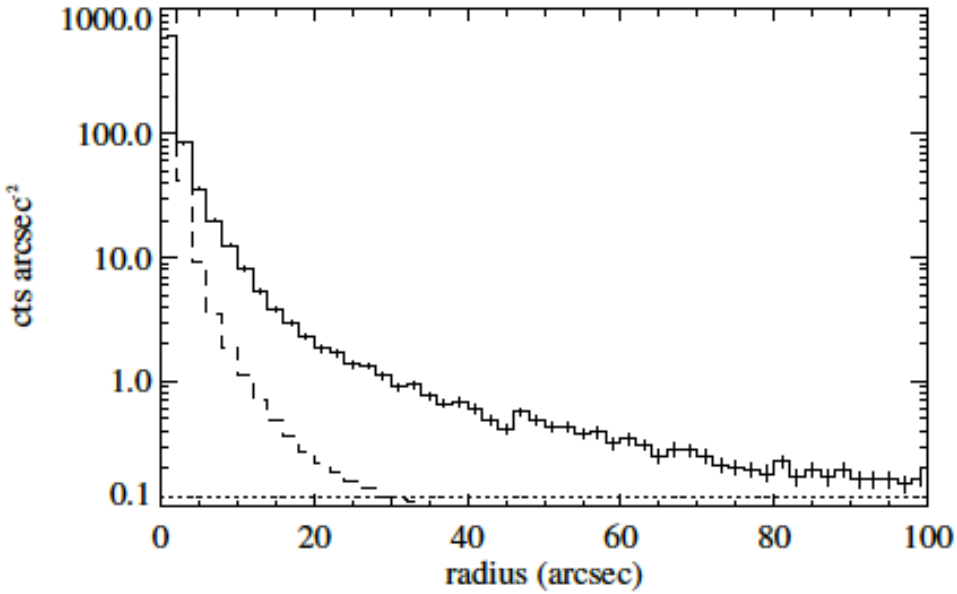


Diaz Trigo 13,
but also see Wang & Mendez 2016

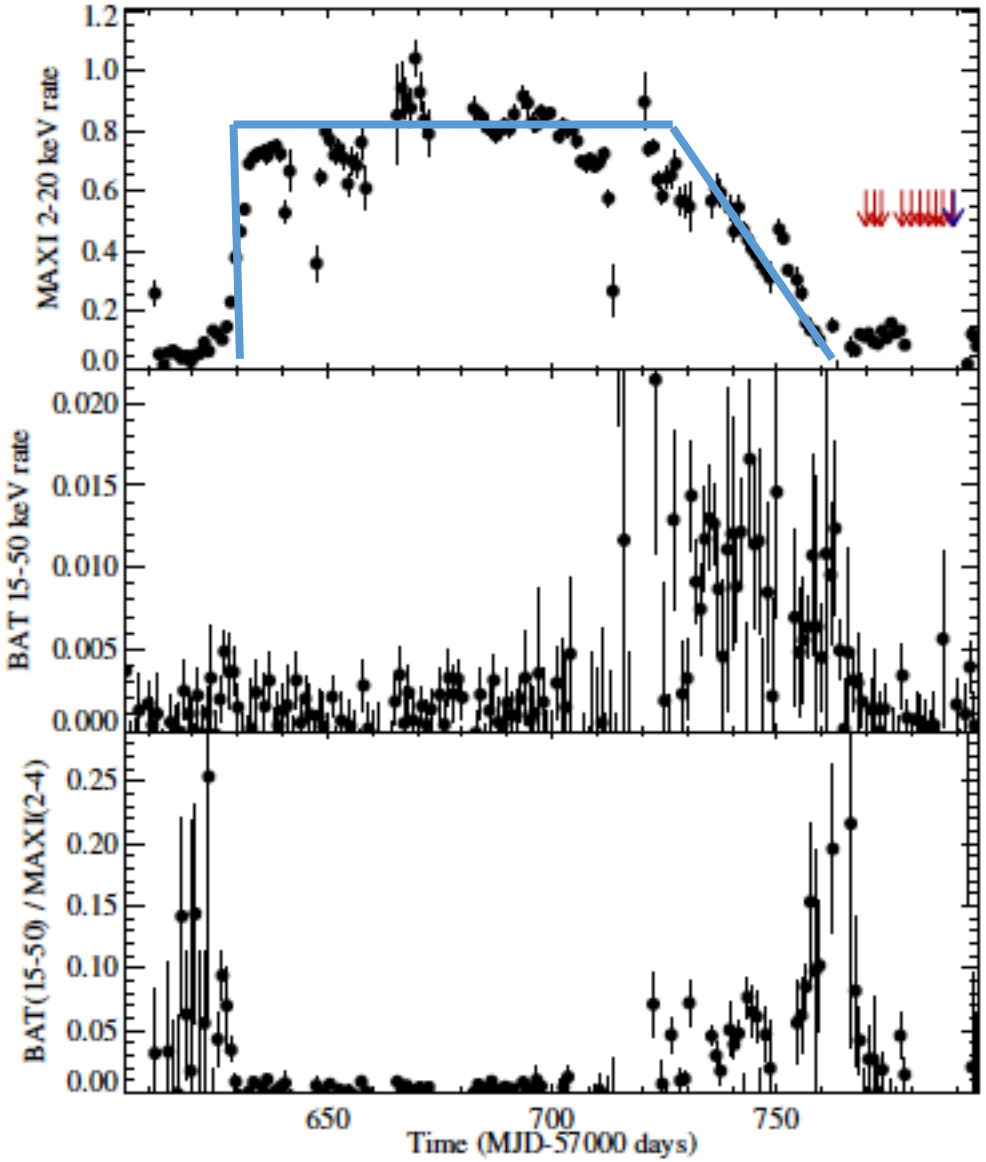
Idea….

- 4U 1630-47 is surrounded by heavy **local** gas and dust (AGB or Be binary)
- Because of the local stuff around, there must be a dust scattering halo!
- Lo and behold, both Chandra and Swift observations show the scattering halo!
- Got an additional Chandra observation at very low luminosity!





X-ray evolution in 2016-2017 outburst

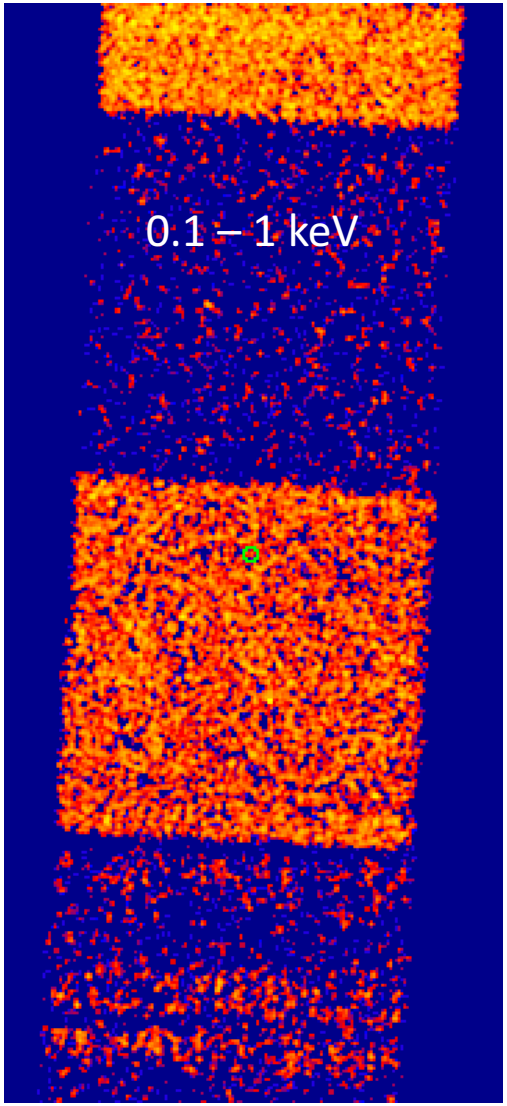


Missing early hard state
Decay hard state transition is not clear

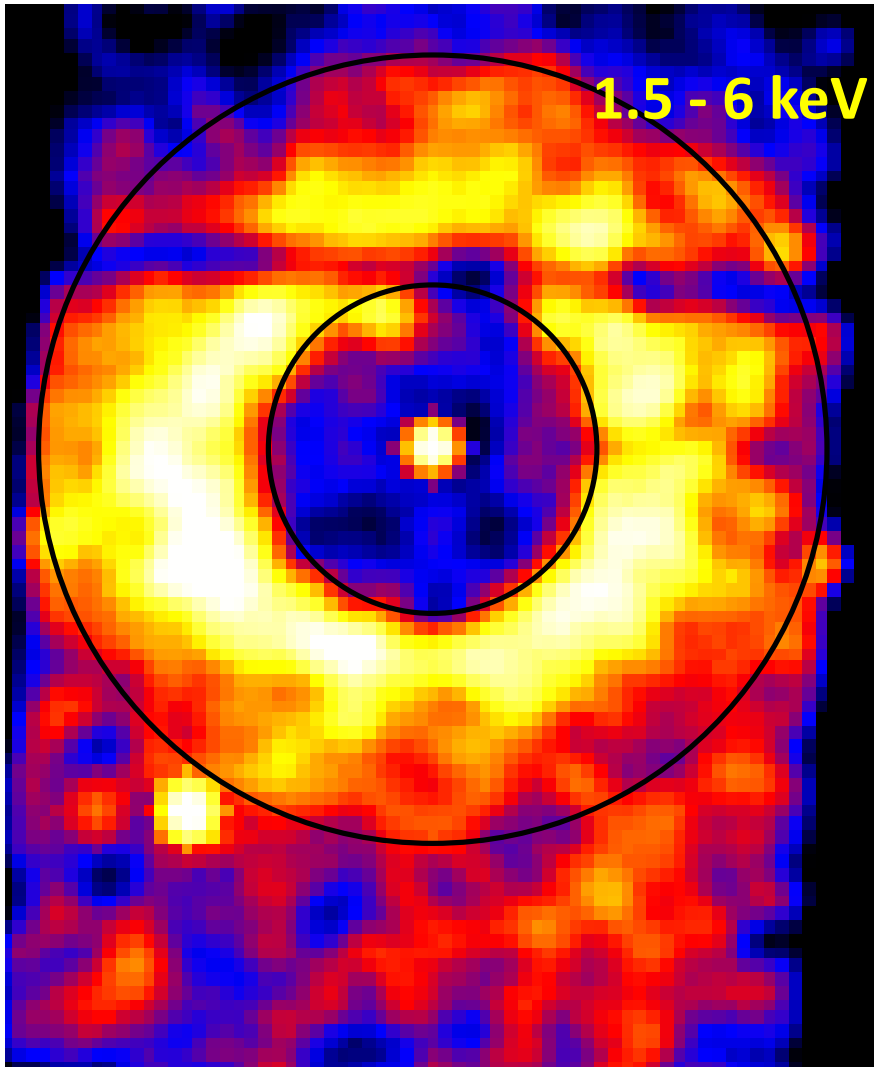
Due to visibility problems triggered late

But,
precise start and end points and a very sharp rise!

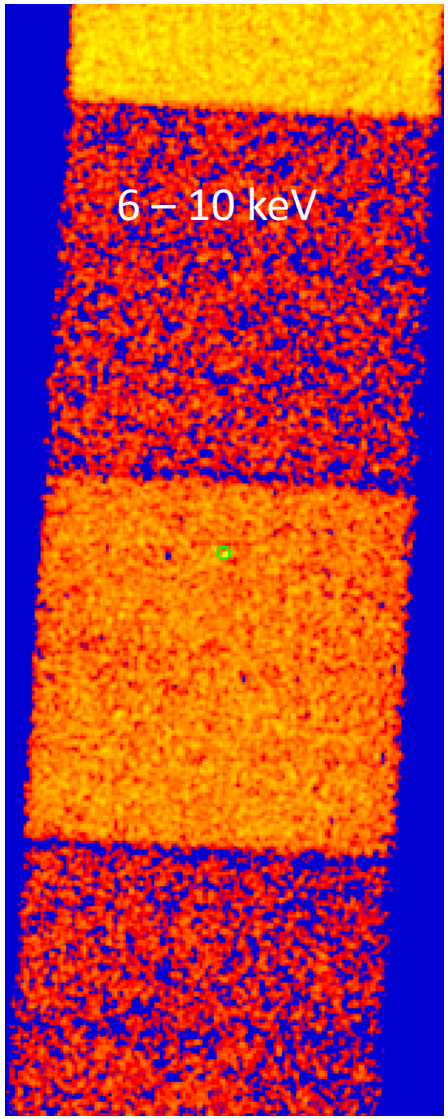
CHANDRA IMAGES



No sign of halo,
nor the point source



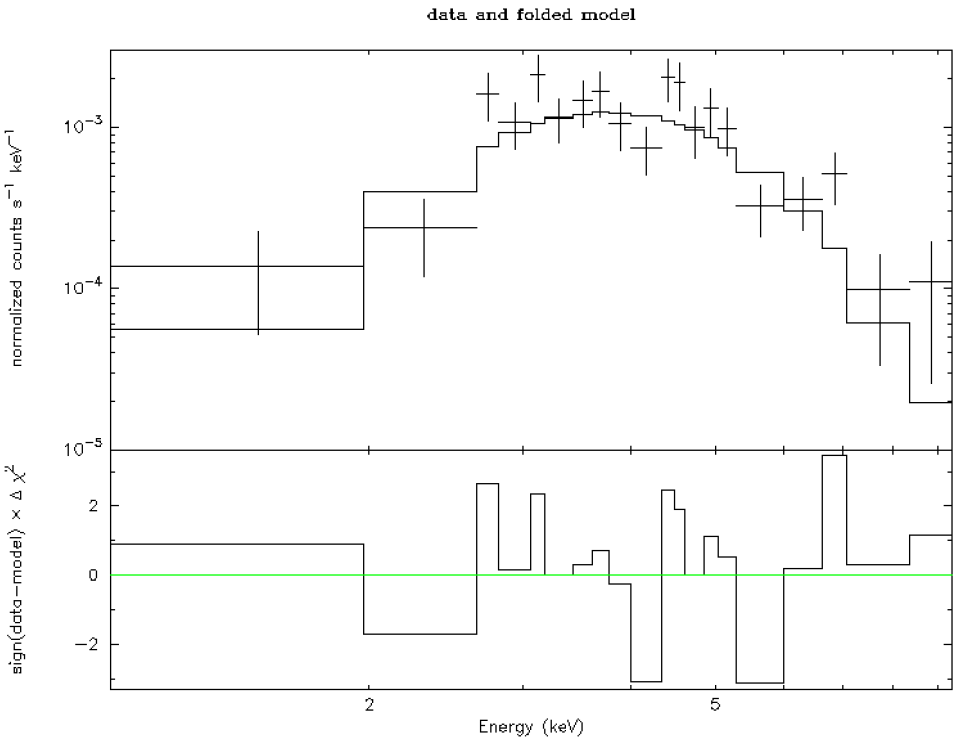
Pretty Chandra picture, JOERN!

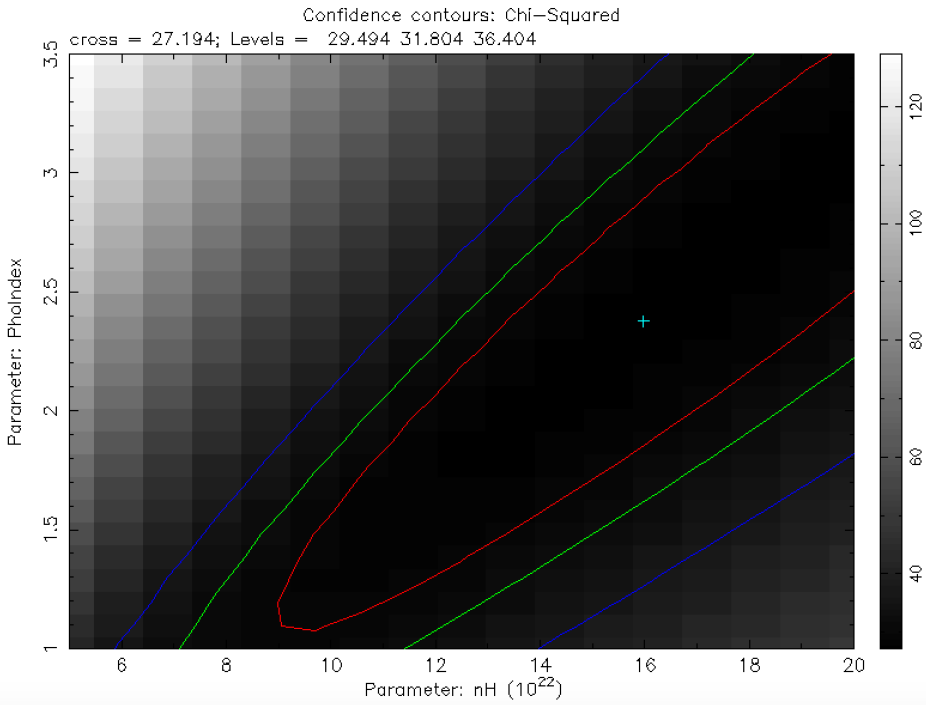


No sign of halo, point source detected.

Chandra spectrum of the point source

Point source

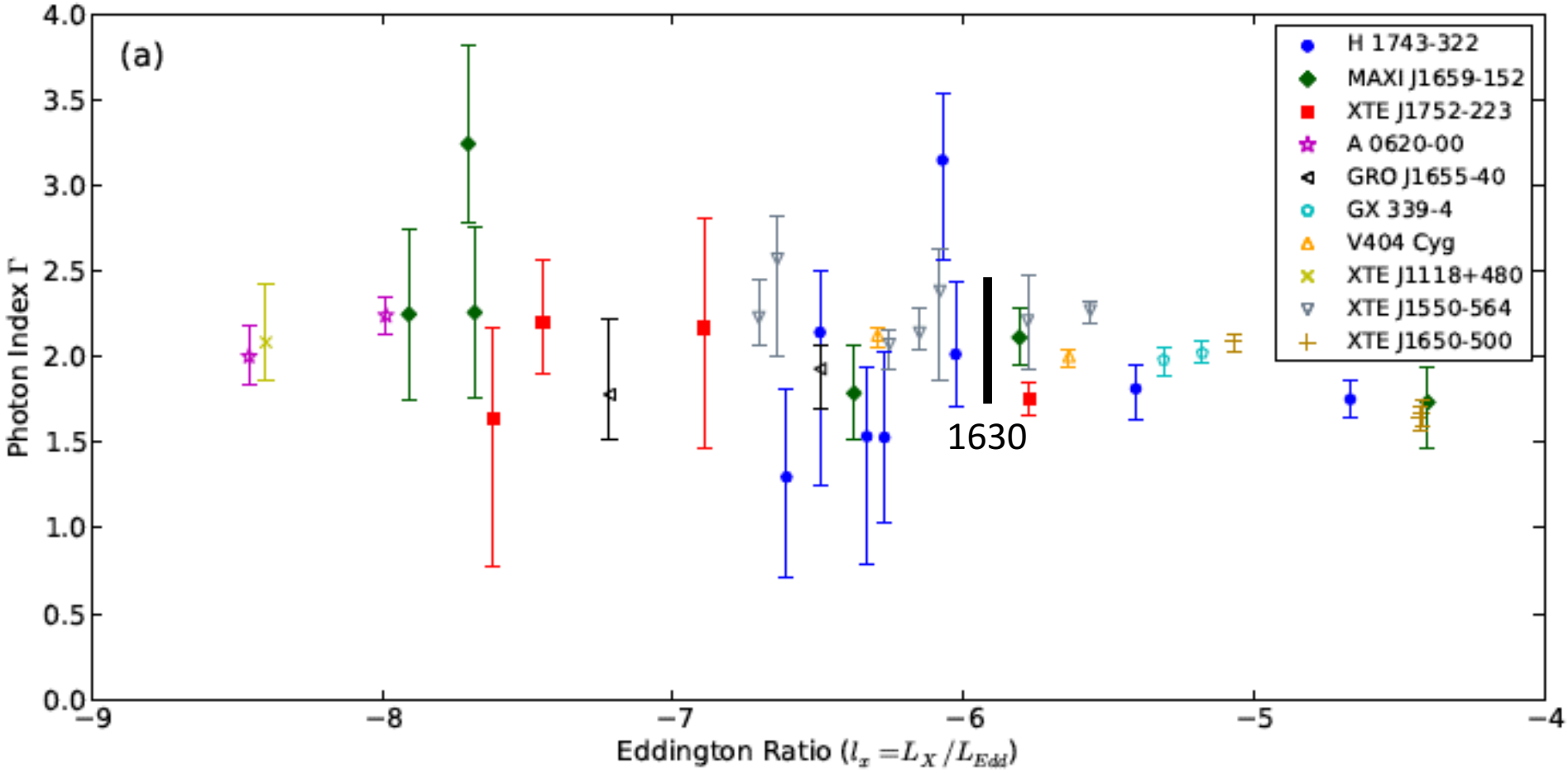




point source region: 8” circle
background region: annulus within 12’’-50”
2 – 10 keV flux: 1.25(-0.31+0.12) 10^{-13} ergs^{-1} cm^{-2} s^{-1}
Γ =1.85 ± 0.5 (if N_H fixed to 13)
Unabsorbed luminosity (M=x, d-y, ~2 10^{-6} L_{Edd}!!!)

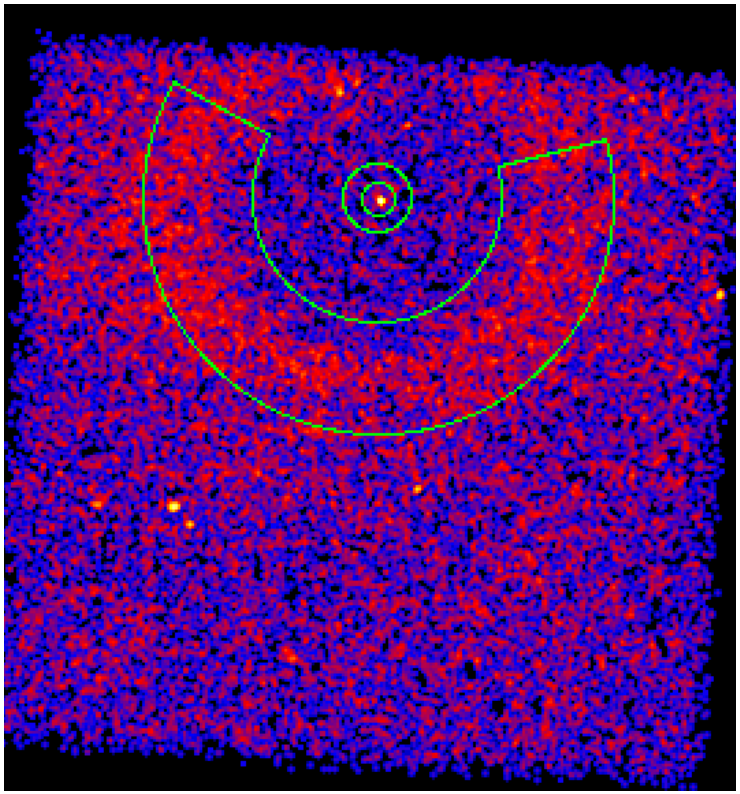
For typical 1630 N_H levels, spectral index < 2.5 consistent with both hard state and softened low luminosity BH.

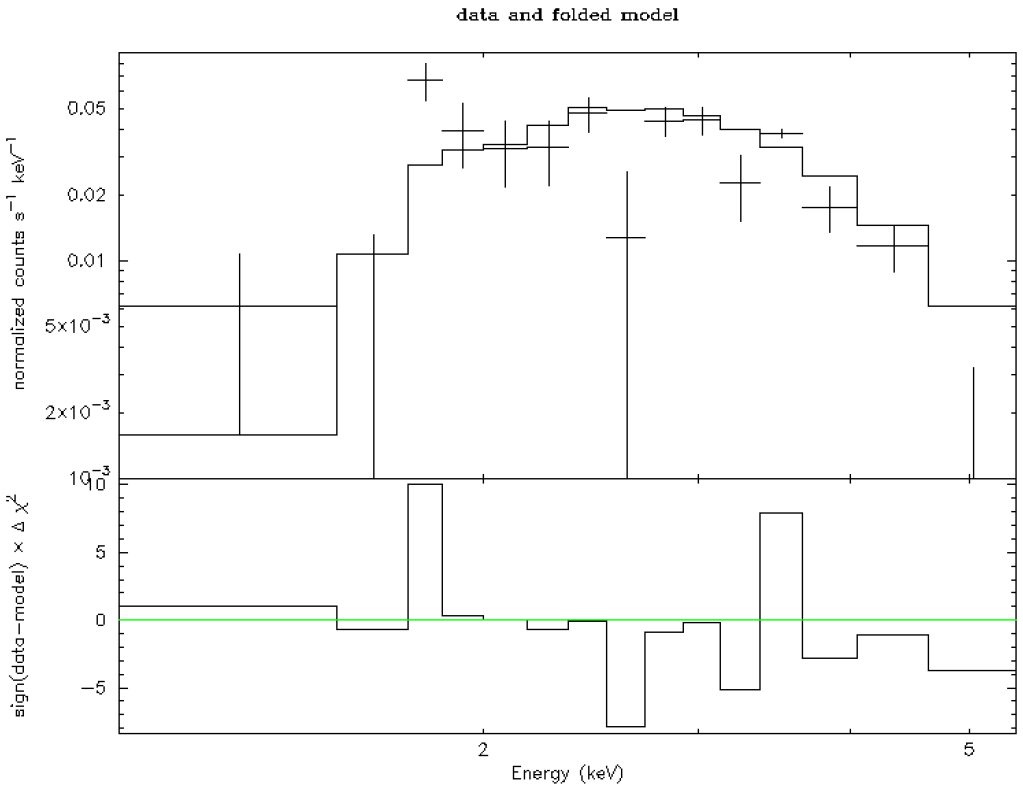
Plotkin spectral index towards Quiescence



Plotkin et al. 2013

Halo (Pie in ccd7 only)



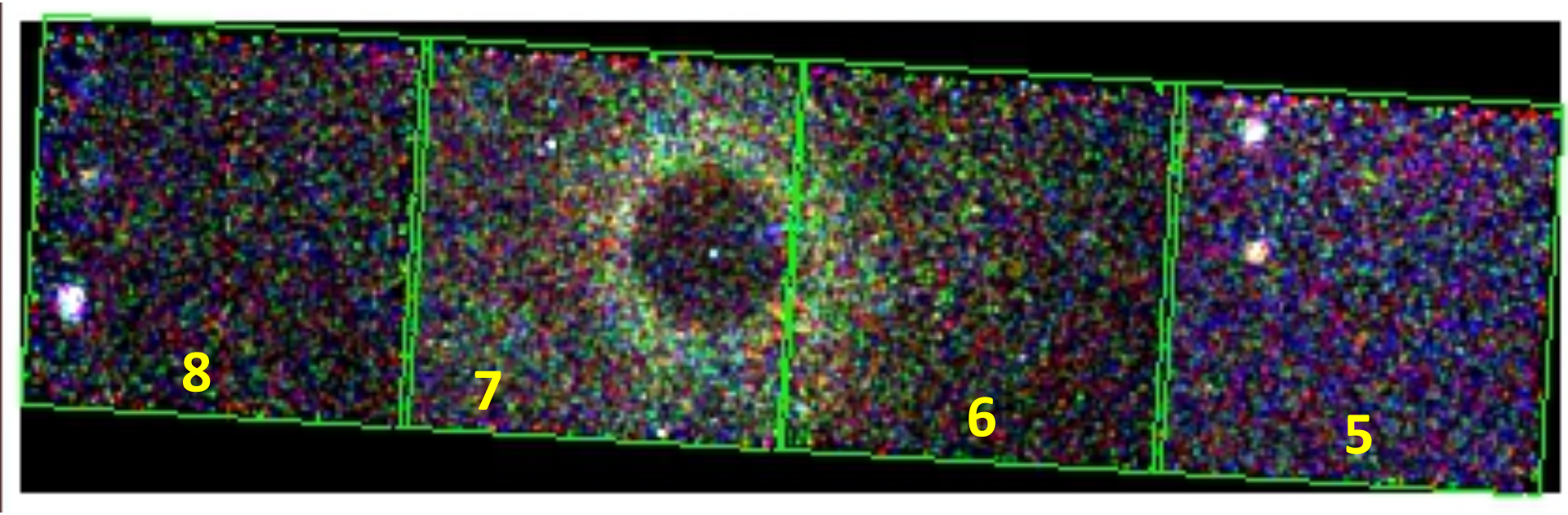


Halo spectrum
Background: annulus 12-25”
(try larger radii)

1-6 keV flux: 1.5 10^{-12} ergs cm^{-2} s^{-1}
Γ = 5.92 ± 0.24
Much stronger, much softer!!!

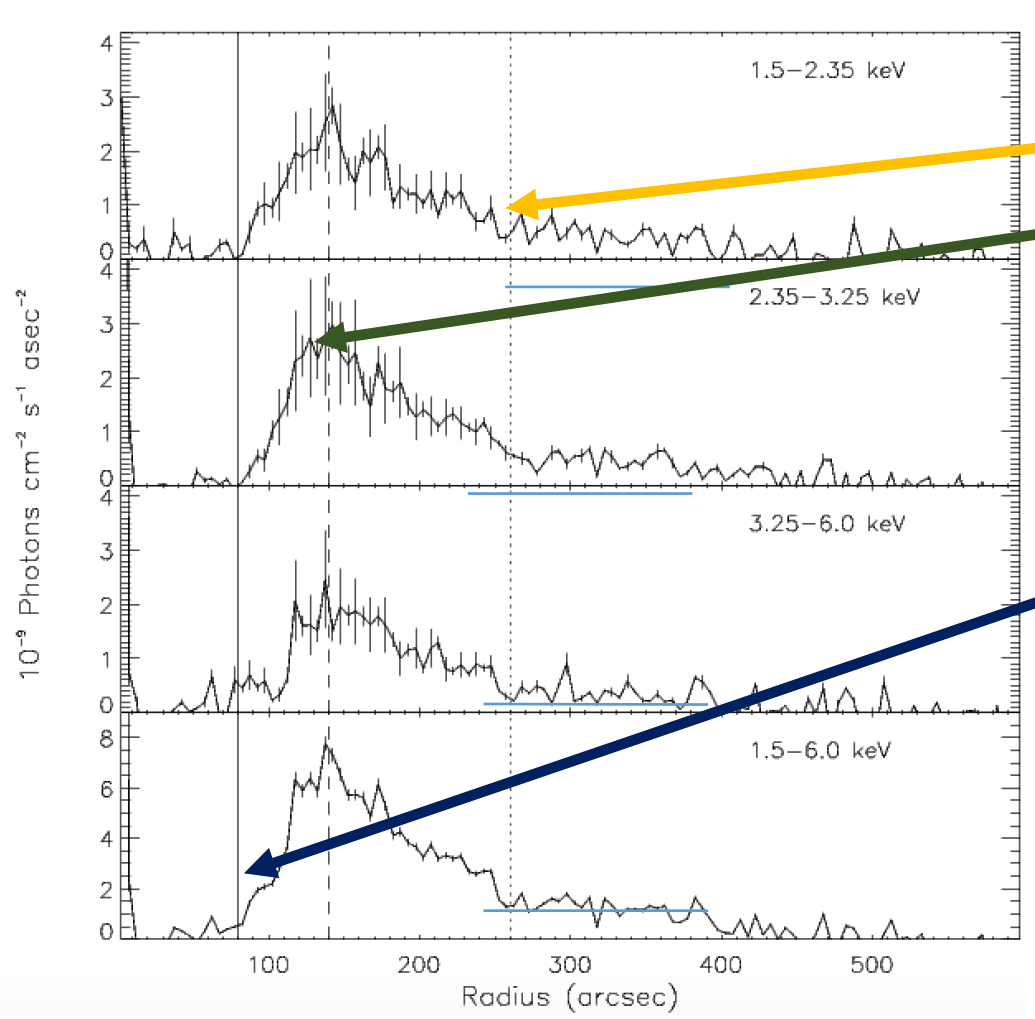
Fluxed RGB image

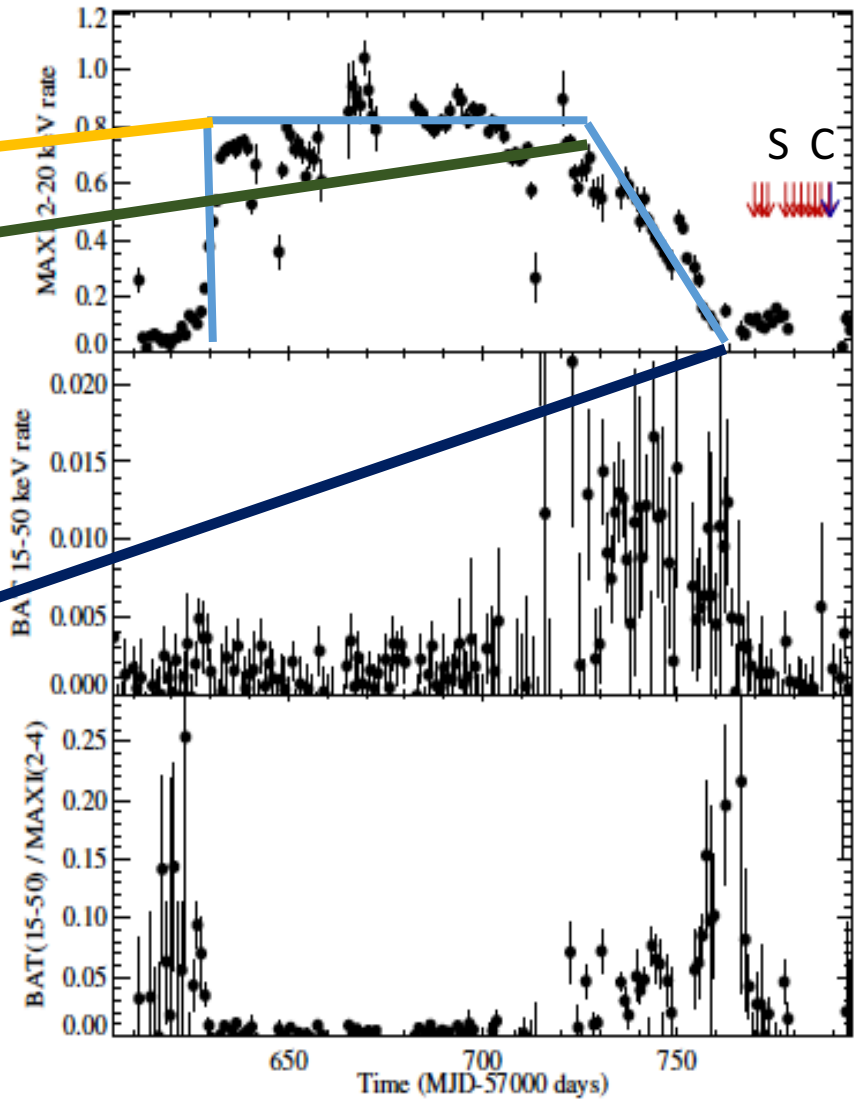
- R: 1.5 - 2.25 keV
- G: 2.25-3.25 keV
- B: 3.25-6 keV



Smoothed and binned to bring out the halo.

Surface Brightness Profile SBP

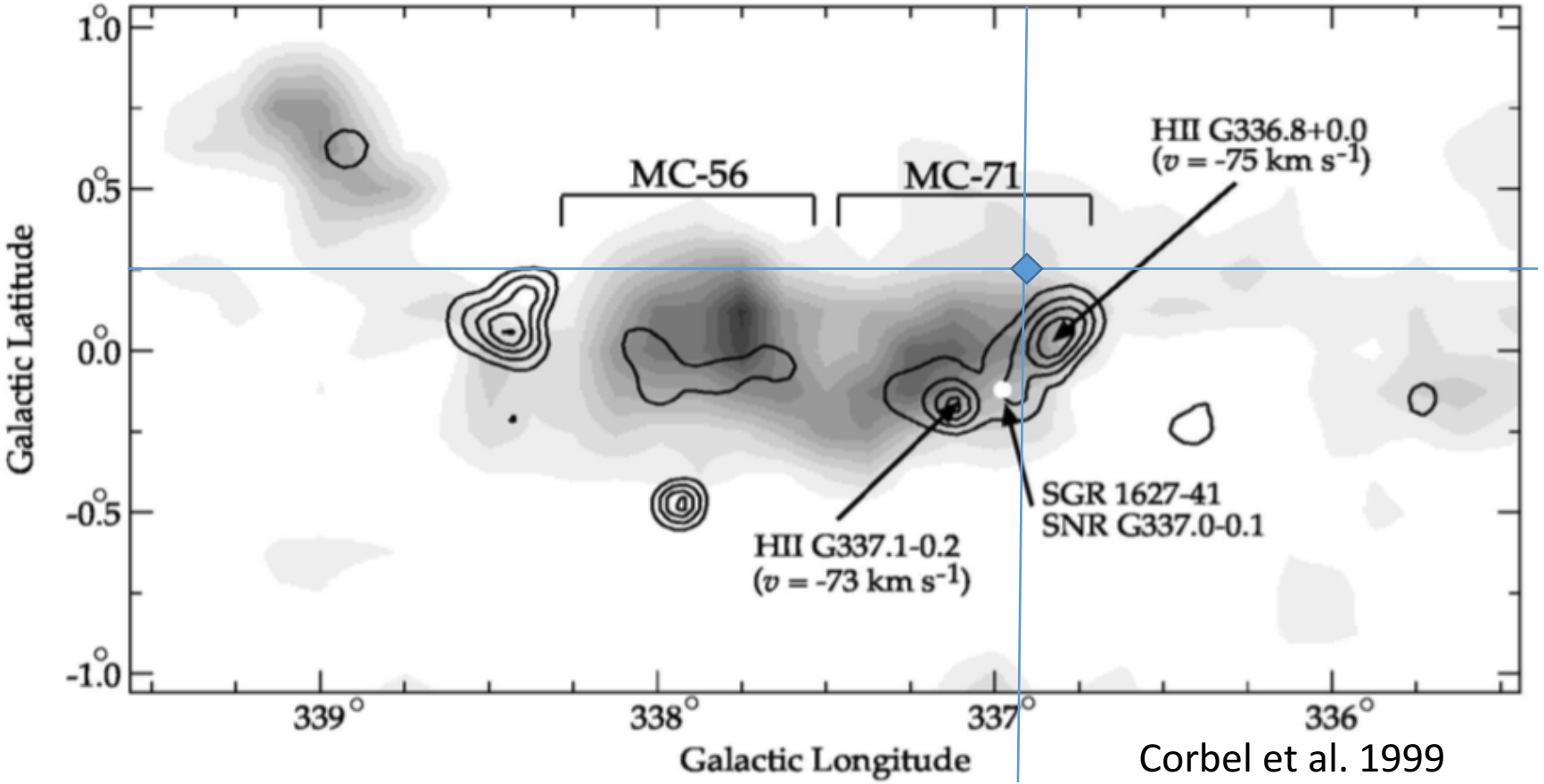




Distance to the source

Augusteijn 2001: N_H (MC-71) > N_H (4U 1630) < 11 kpc

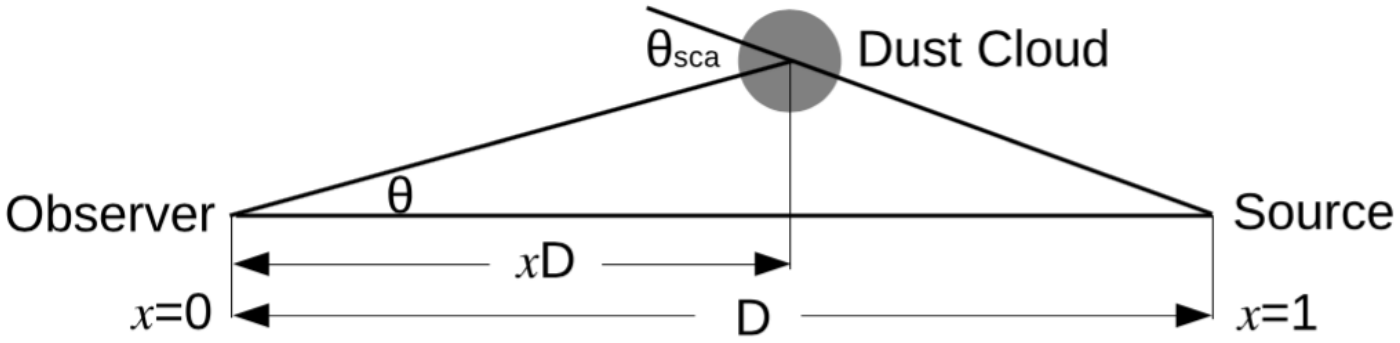
What IF 4U1630-47 is towards the edge of the cloud, but behind (to be properly discussed in a paper)



Corbel et al. 1999

The distance to 4U1630-47

Xiang et al.

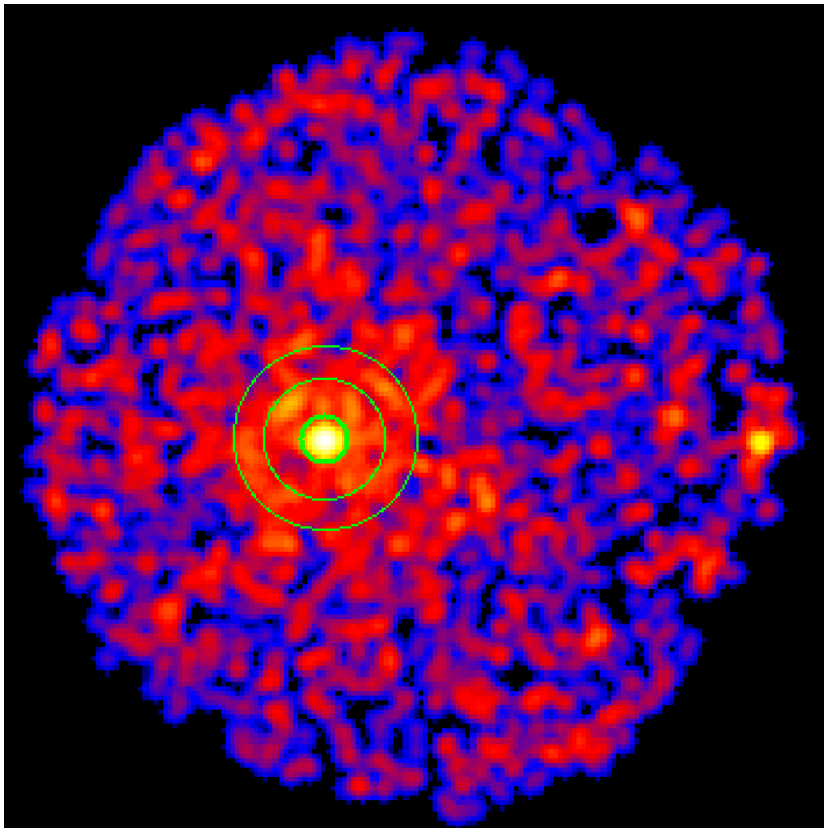


$$\Delta t \approx 1.4\,\mathrm{days}\,(xD/11\mathrm{kpc})\,(\theta/100'')^2\,(1-x)^{-1}$$

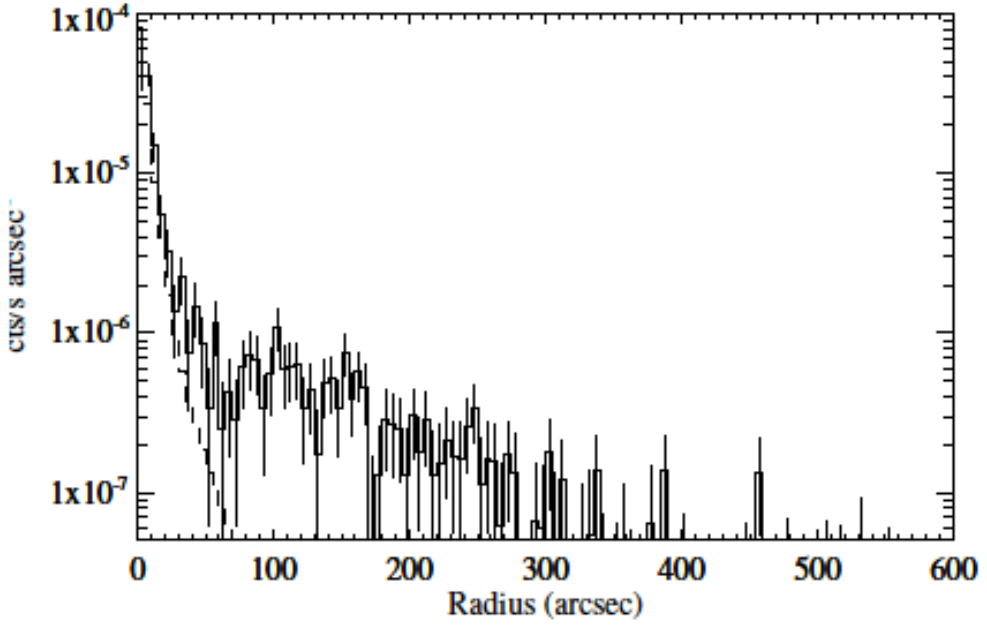
Chandra obs:	MJD 57789	Δt	θ	D
Outburst start	MJD 57630	160 d	260±10''	**11.48 kpc**
State transition	~MJD 57731	50-70 d	120±10''	**11.27 kpc**
Outburst end	~MJD 57760	30-40 d	90±10''	**11.26 kpc**

Difference can easily be understood with a reasonable thickness of the cloud and errors.

Can DSH explain very low luminosity soft state? No!



SWIFT XRT image of
anomolous soft state obs.



While using smaller regions and using background within DSH helps, the spectrum is still SOFT!

Γ **=4.25 ± 0.78** typical 47'' source region, outer back,

Γ **=3.60 ± 0.70** background within DSH, 20''

Conclusions and more speculation….

- We have observed a ring shaped DSH around the BH 4U1630-47
- Assuming the ring is caused by the X-rays scattered by the GMC 71 we determined a distance of 11.5 kpc
- DSH is strongly affecting low energy spectra during outburst decay (NICER, be careful!), yet not enough to explain the anomalous soft state observation.

If the source is only a few hundred pc away from the birth place, was there enough time for circularization and evolution as a LMXB?

A Be binary could solve this problem, as well as provide an explanation for the giant outbursts (Type I, II).

in case of LMXB, an evolved star and tidal-thermal instability driven super outburst is a possibility.

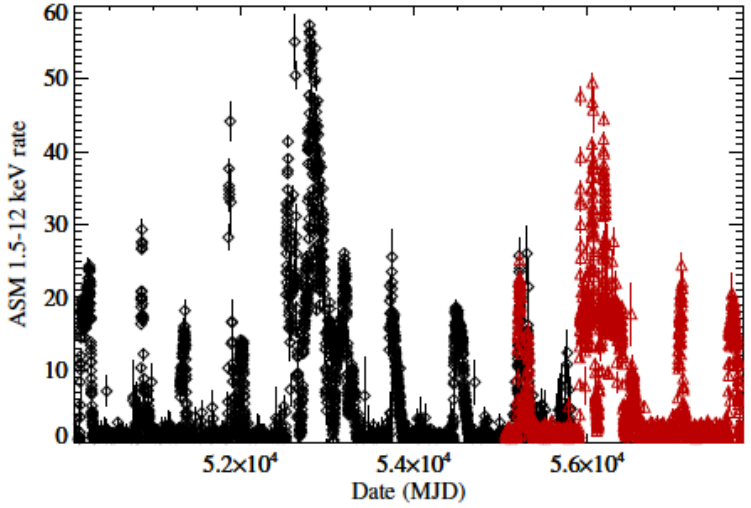
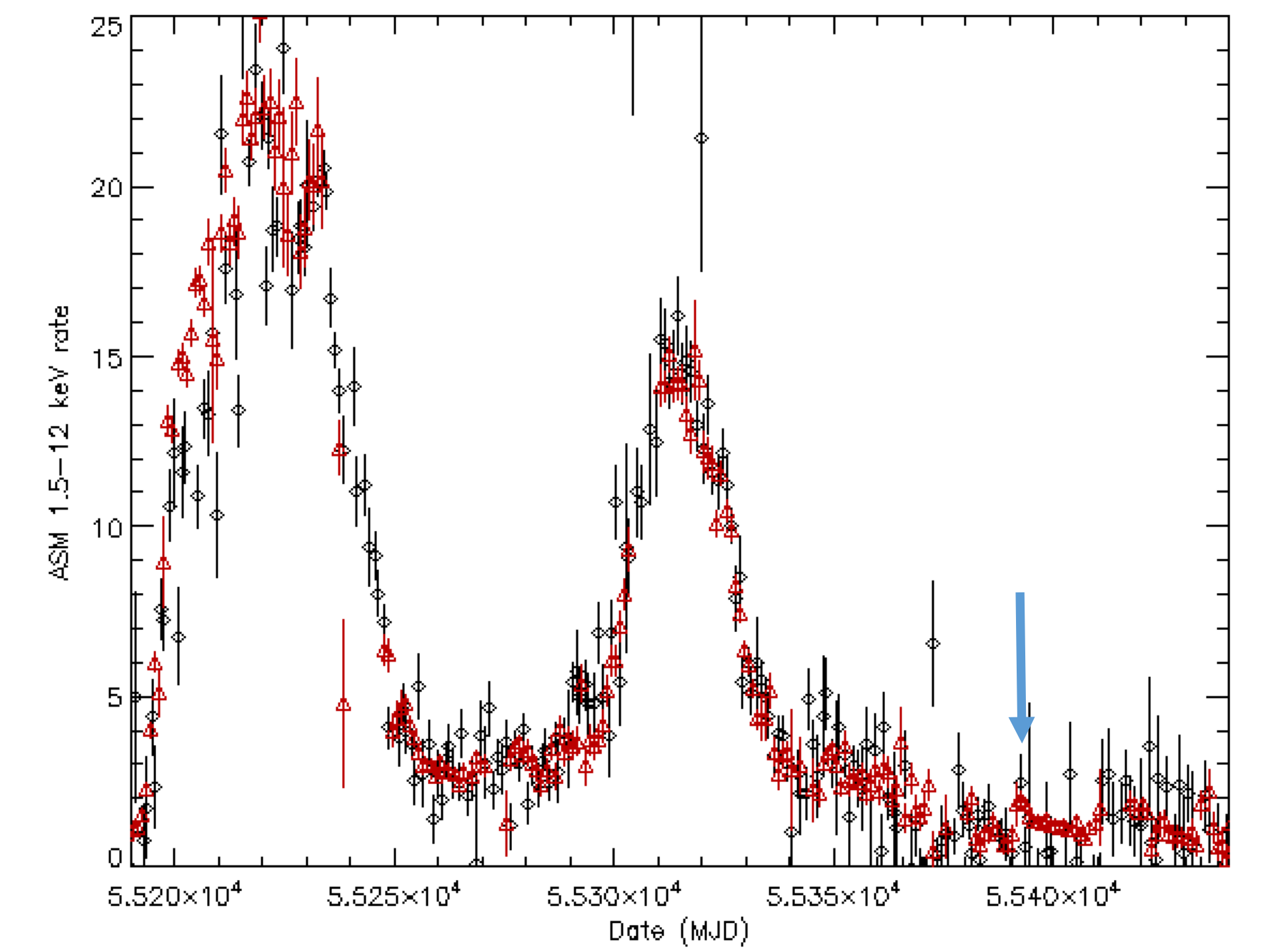
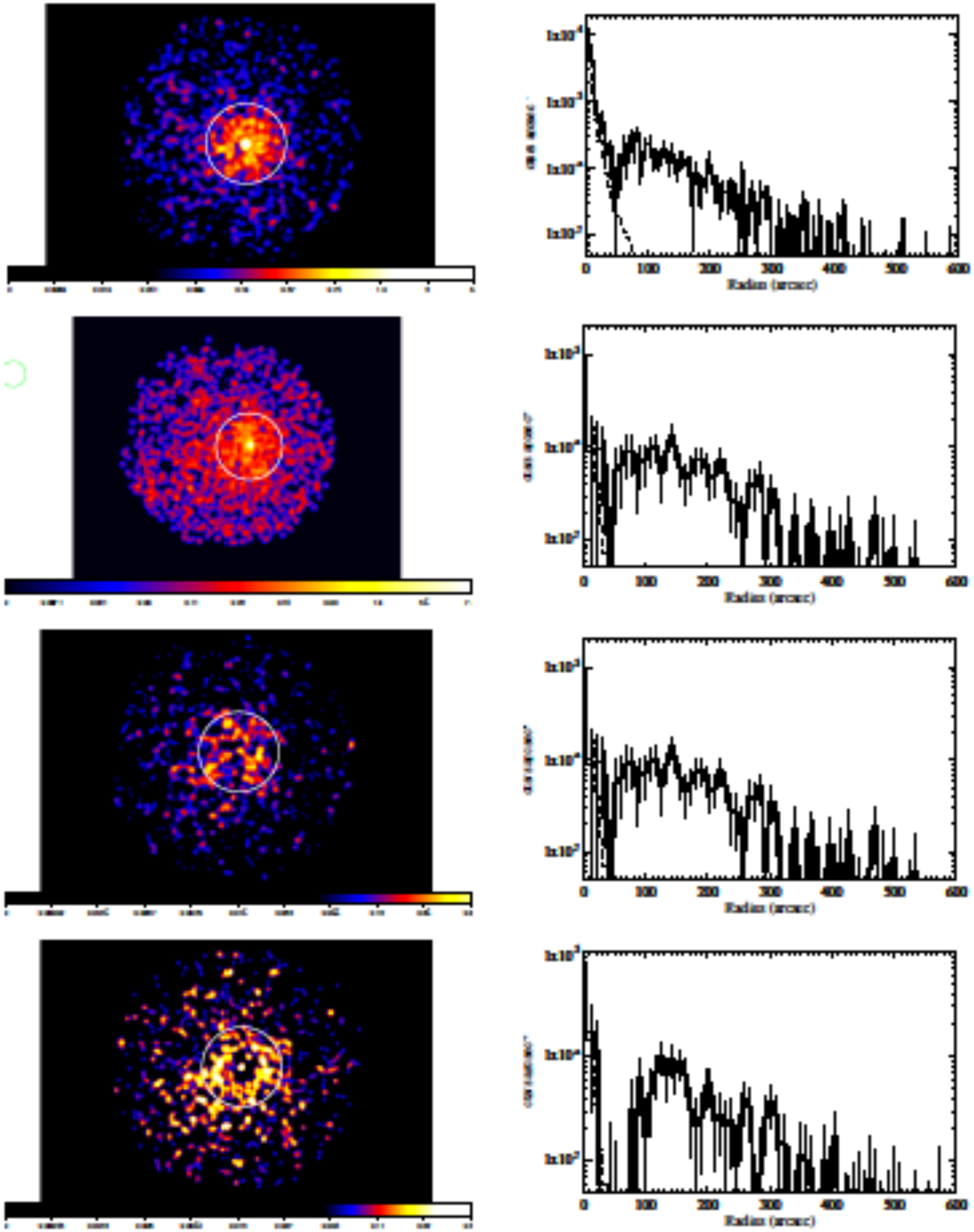


Figure 1. *RXTE* ASM (black points) in 1.5-12 keV band and MAXI (red points) in 4-10 keV band light curve of 4U 1630−47. MAXI rates are multiplied by 45 to match ASM rates.

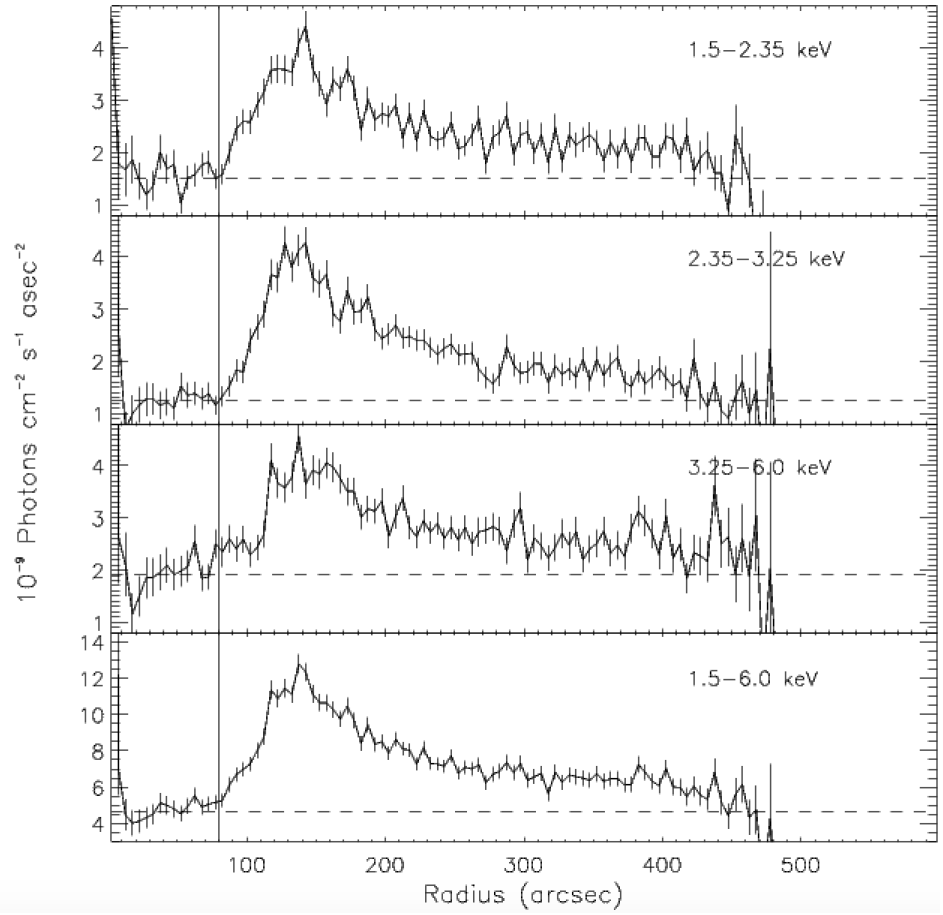

25
20
15
10
5
0
ASM 1.5–12 keV rate
5.520×10^4
5.525×10^4
5.530×10^4
5.535×10^4
5.540×10^4
Date (MJD)

SWIFT PROFILES

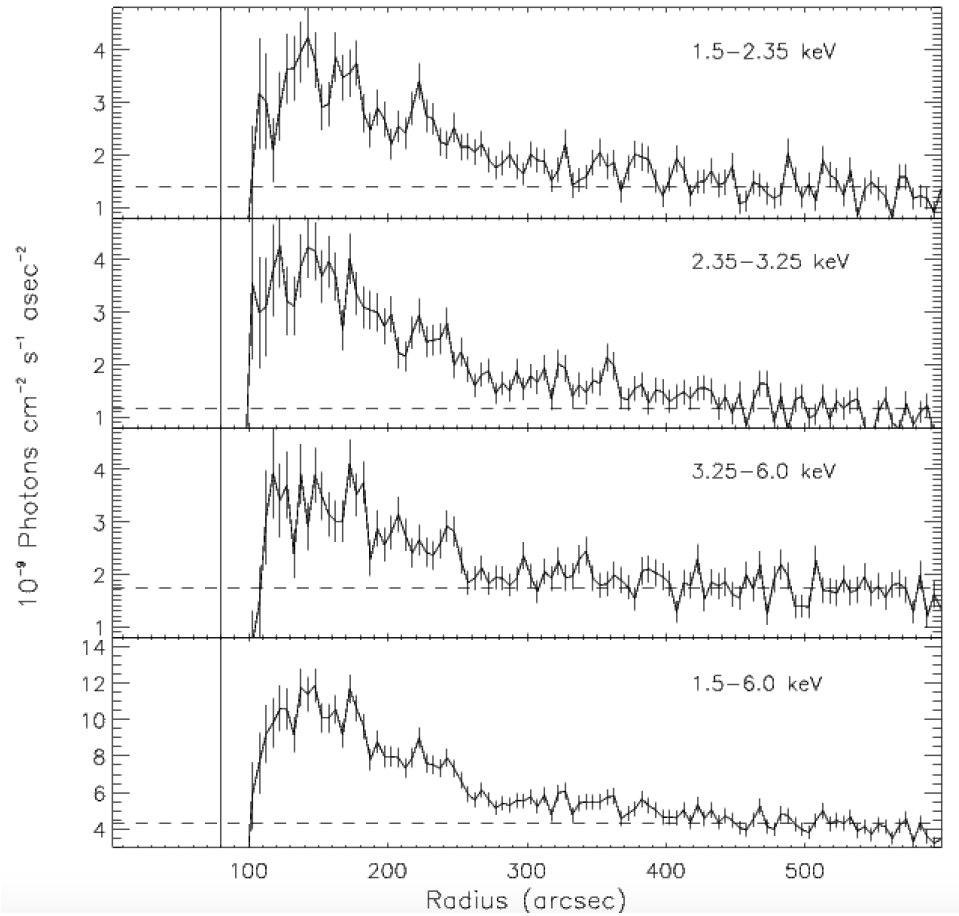


Chip by chip

Chip 7 (includes source)



Chip 6 (upper chip)

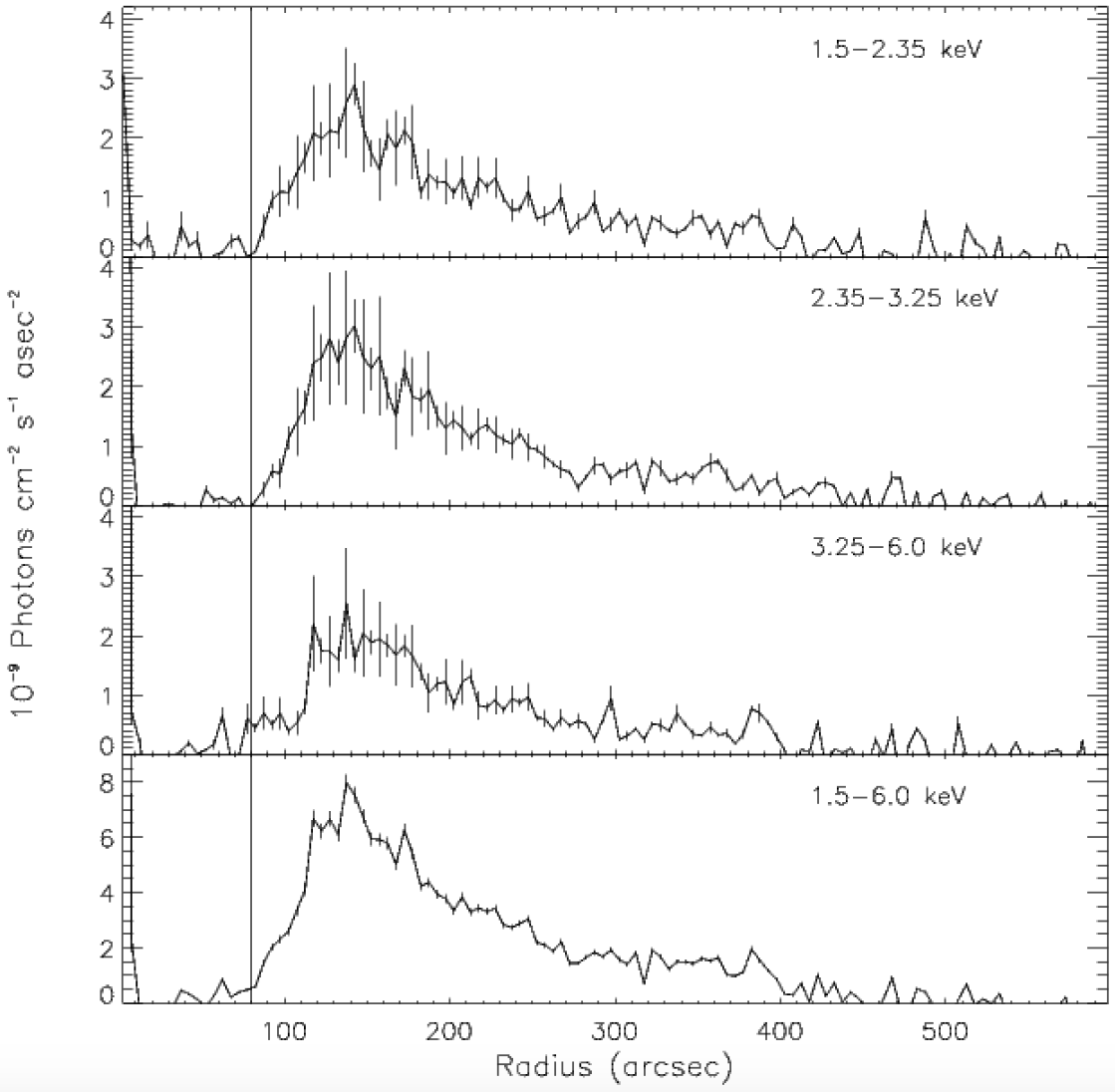


Chip 6, background taken as the average of 20''-60'', the hole around the source. Then the profile extends to 400''. Beyond 400'' chip has little area and the region is discarded. If we assume additional background in outer regions, then the ring may be cutting off between 250-300''

Chip 7 background determined from the average level between 450''-550''

NH differences and different BG variations are possible there!

Combined profile with the background discussed above.

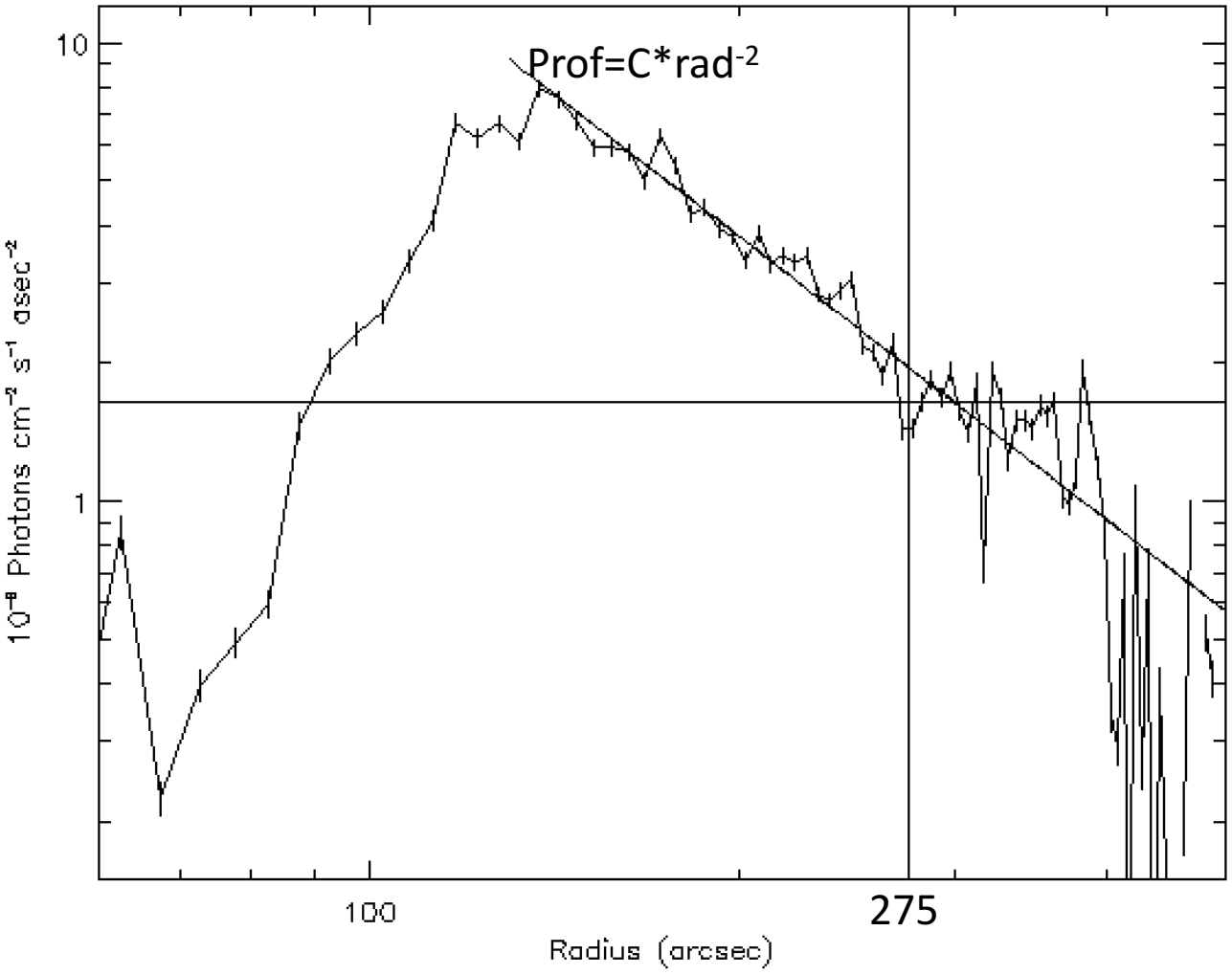


Flattening above 270’’

We can claim poor background determination and sharp cut off at 270’’, or an extended profile with a cut-off at 400’’.

Do not know how one can produce such an extended flat profile.

Log log plot.



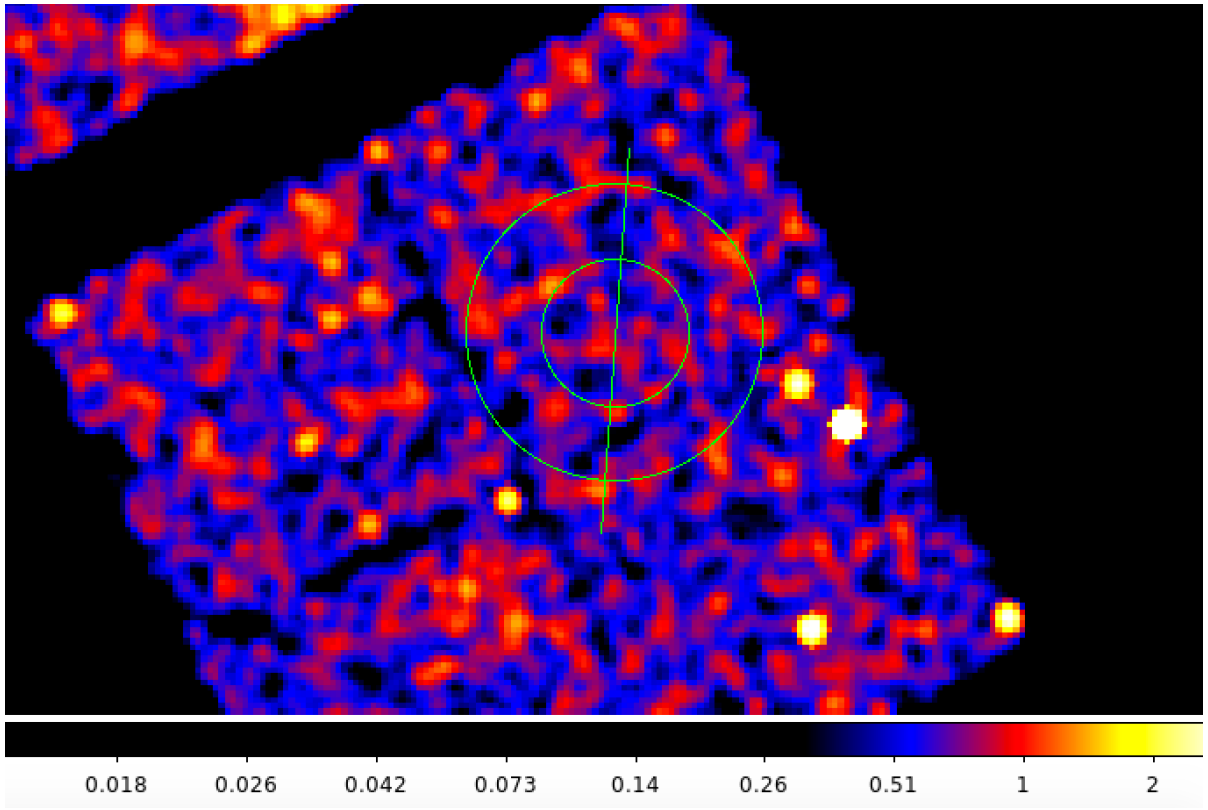
There is a flattening above 275''

Profile is consistent with power law >300''

can it be NH difference? No difference in profiles between low and high energy bands that I could see that can be explained by NH.

Need to understand profile formation!!!!

John’s Norma Arm observation



100’’ and 200’’ circles indicating the ring in 2017 obs.
Line shows the orientation of the chips in 2017 obs.

Halo spectrum, with larger background (12”-50)