

Insight-HXMT observations on type-I & type-II X-ray bursts 慧眼对一型&二型X射线暴的观测

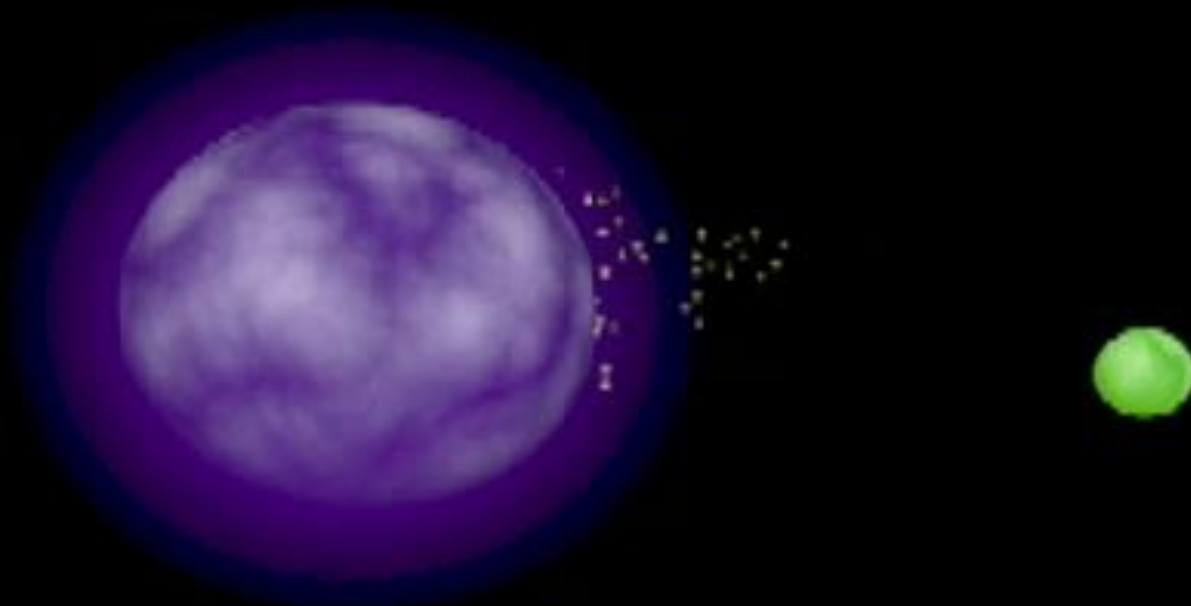
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On behalf of Insight-HXMT team

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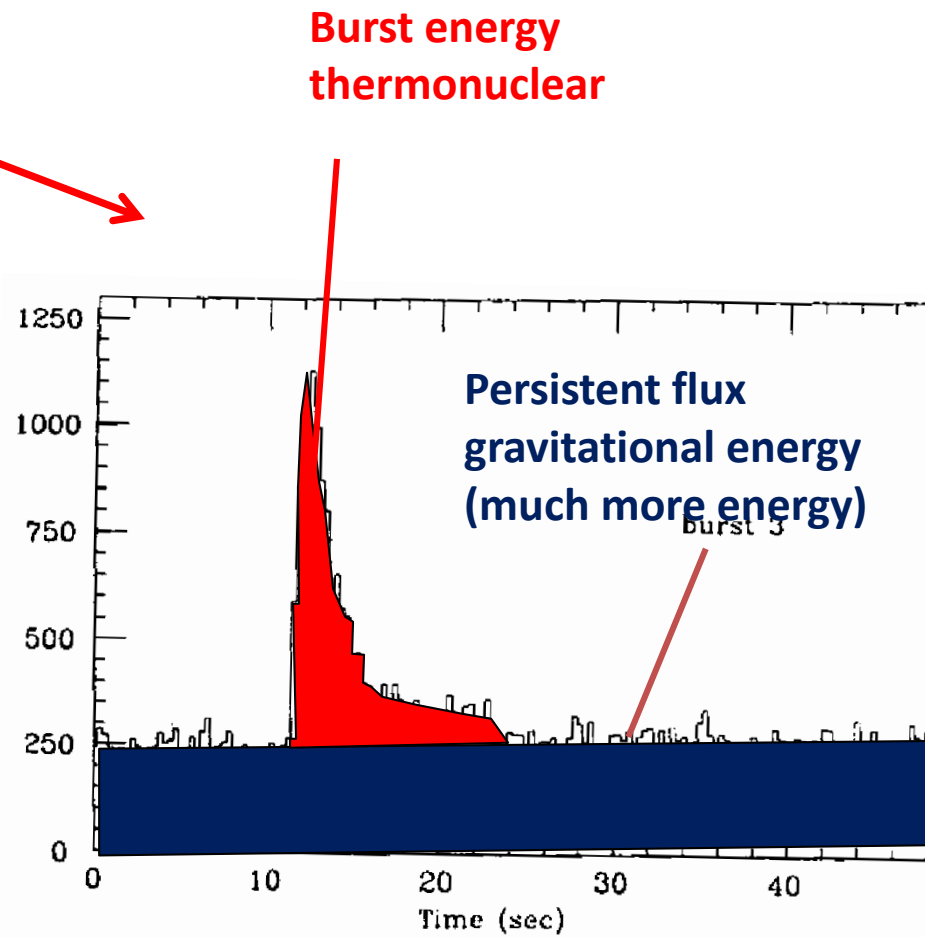
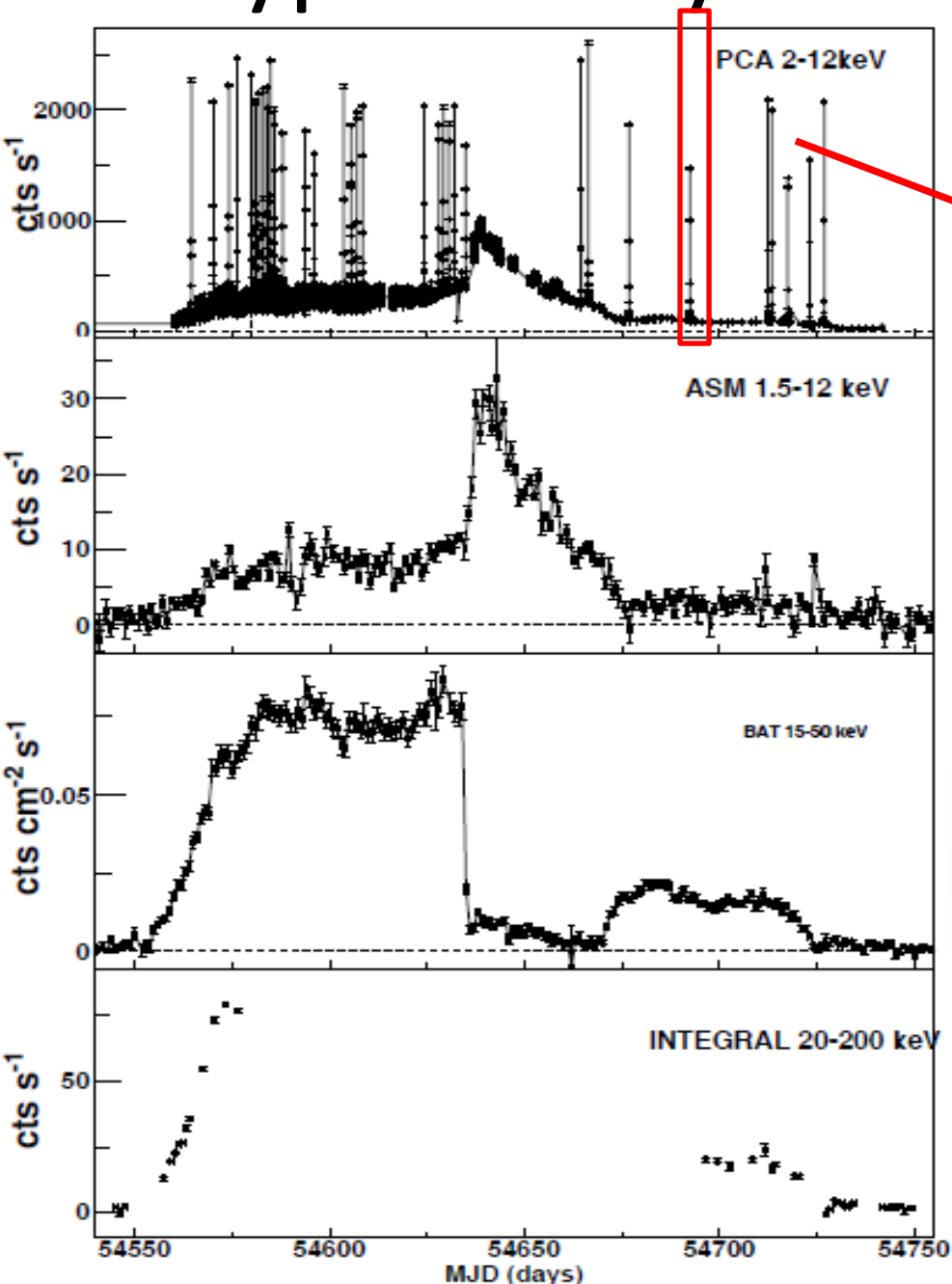
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陈玉鹏 高能物理研究所

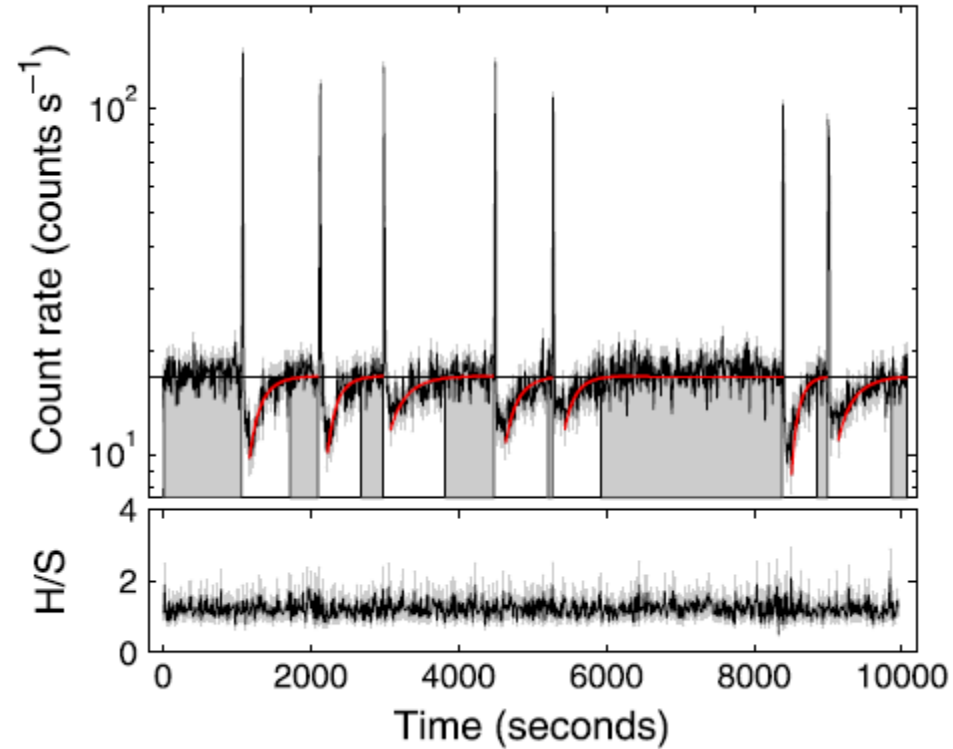
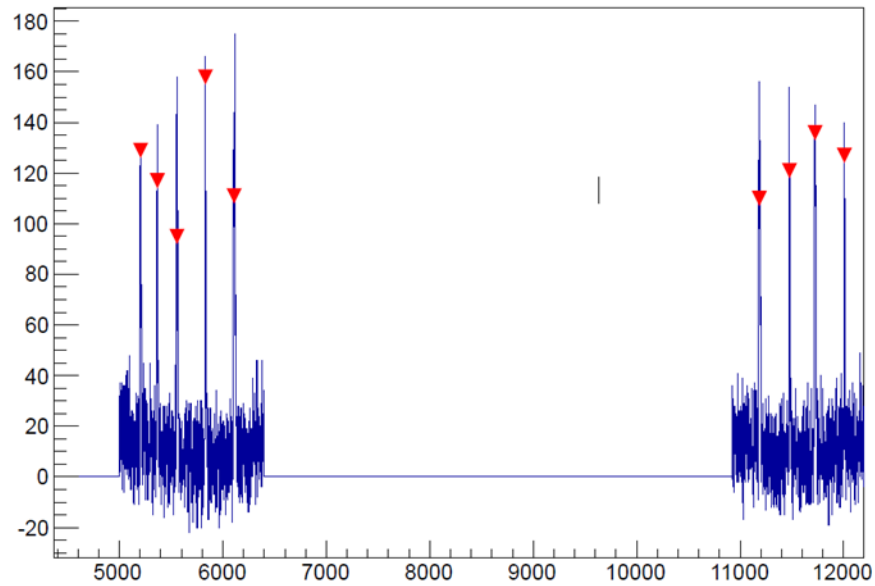




type-I X-ray burst 一型X射线暴



type-II X-ray burst 二型X射线暴



Younes et al. 2015

Rapid burster (MXB 1730-335) Bursting Pulsar (GRO J1744-28)

X-ray bursters

Frequent Outbursts of 10-100s duration
with lower, persistent X-ray flux inbetween

Type I bursts (~116 sources)¹

Thermonuclear

By far most of the bursters

Type II bursts (2 sources)

sudden increases accretion rate

Rapid burster (MXB 1730-335)

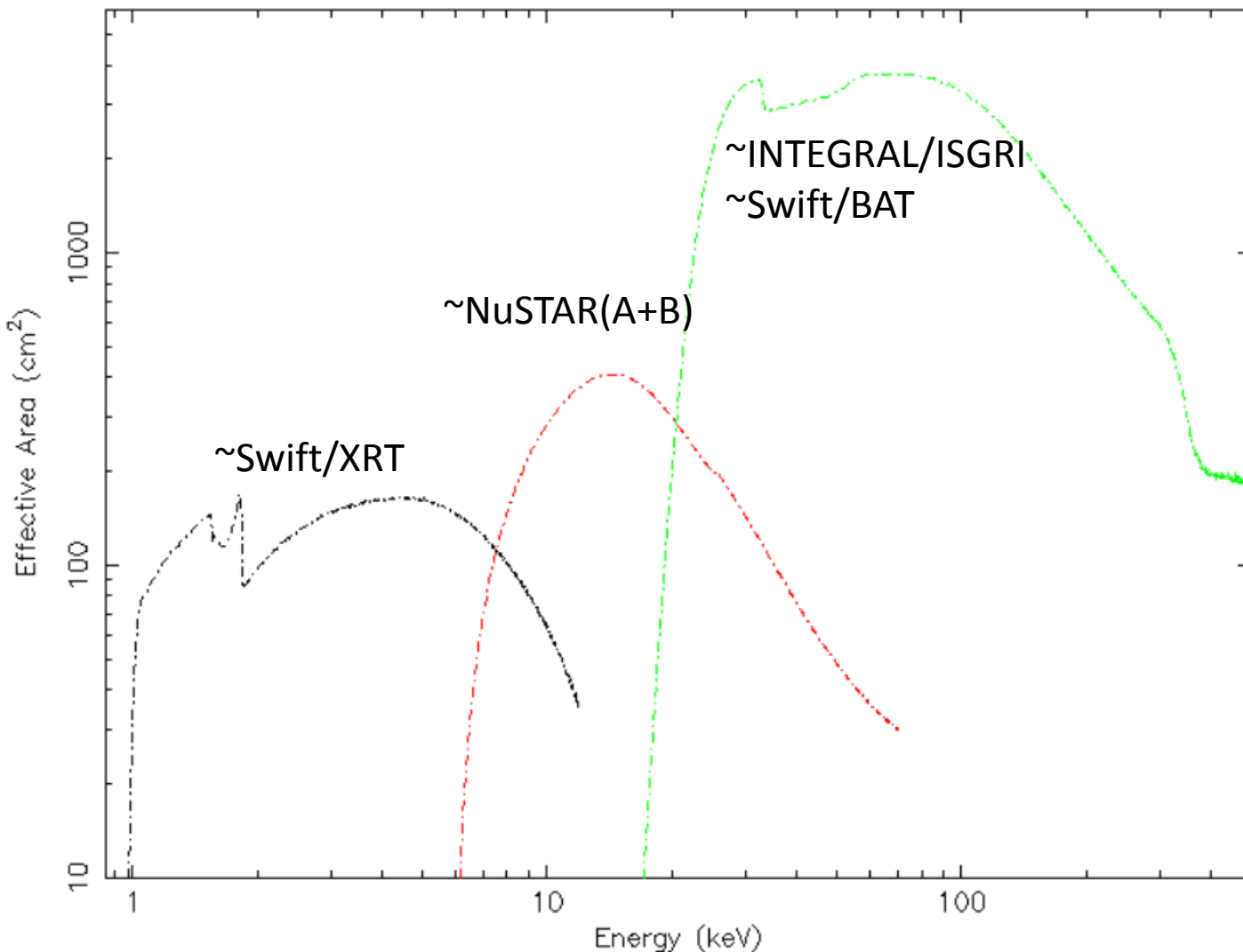
Bursting Pulsar (GRO J1744--28)

1. spectral softening in decay
2. $a > 30$ (the ration between outburst fluence and burst fluence)

1: <https://personal.sron.nl/~jeanz/bursterlist.html>

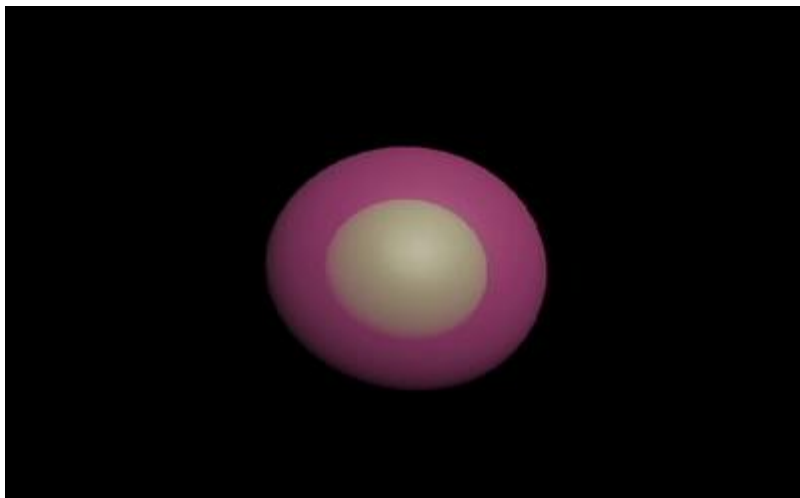
Insight-HXMT effective area (LE&ME&HE) 慧眼有效面积

Total Efficiency



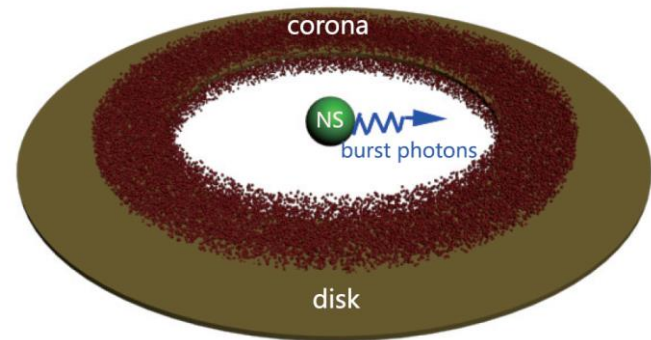
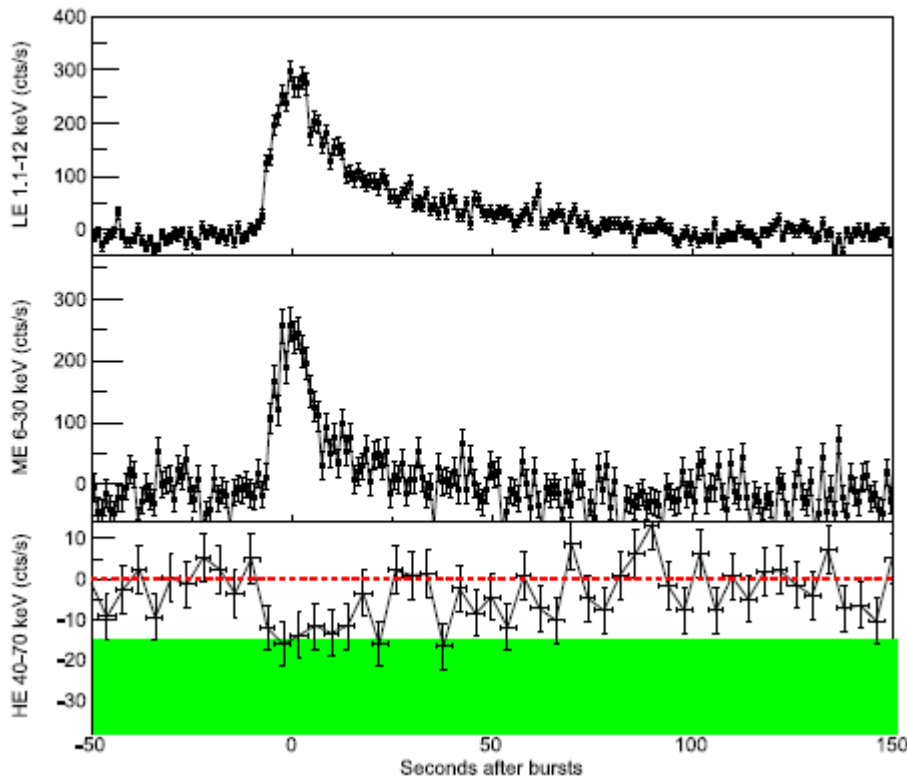
Type-I & type-II bursts by Insight-HXMT

- tens type-I bursts
 - Burst oscillations (4U 1608-52~614 Hz)
 - Photospheric Radius Expansion (4U 1608-52)
 - Hard X-ray deficit (4U 1636-536)
 - Enhancement of accretion emission (4U 1636-536 & 4U 1608-52)
 - Interplay between thermonuclear burst and accretion environments(4U 1608-52)
- ~800 type-II bursts
 - Broad-band spectra (Rapid Burster)



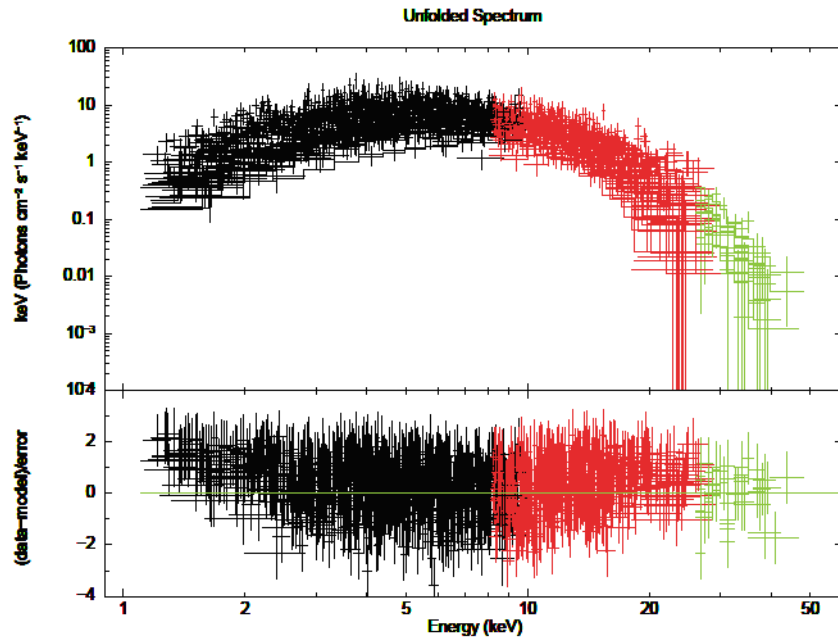
source	Type-I X bursts	Type-II X bursts
4U 1636-536	~10	
4U 1728-34	~10	
Rapid Burster		~800
4U 1608-52	~10	
Aql X-1	~5	
Cyg X-2	~10	
GS 1826-238		
GX 17+2		
4U 1702-429	~10	
4U 1730-22	3	

Hard X-ray deficit (4U 1636-536) 暴期间硬X辐射的缺失

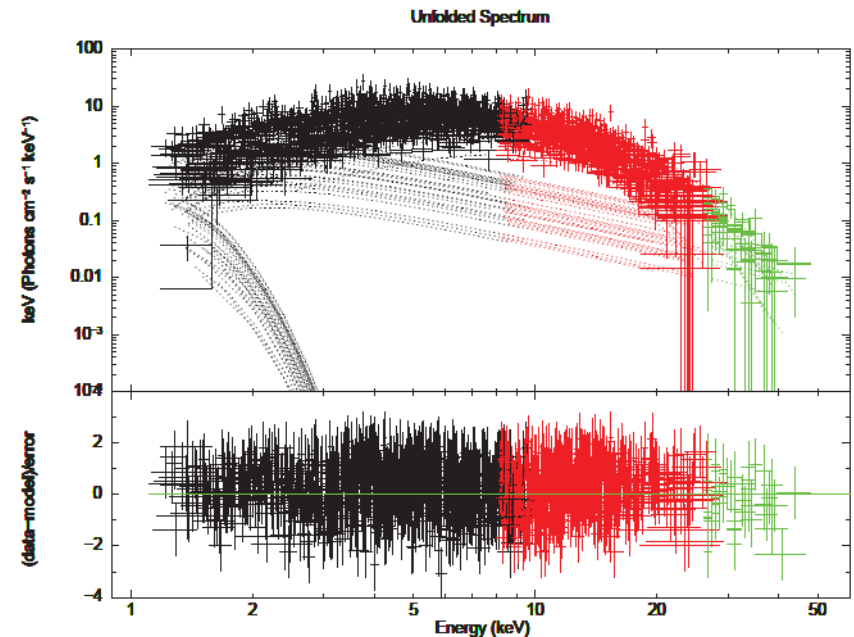


慧眼对4U 1636-536的一个热核暴观测中，即发现了暴期间冕的冷却（ ~ 6 sigma）。
First detection of corona cooling by Insight-HXMT from a single short type I burst.

Enhancement of accretion emission (4U 1608-52)



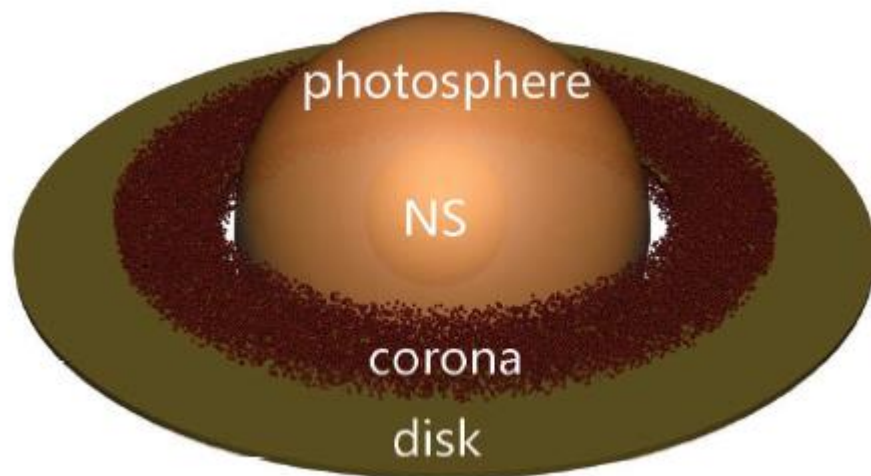
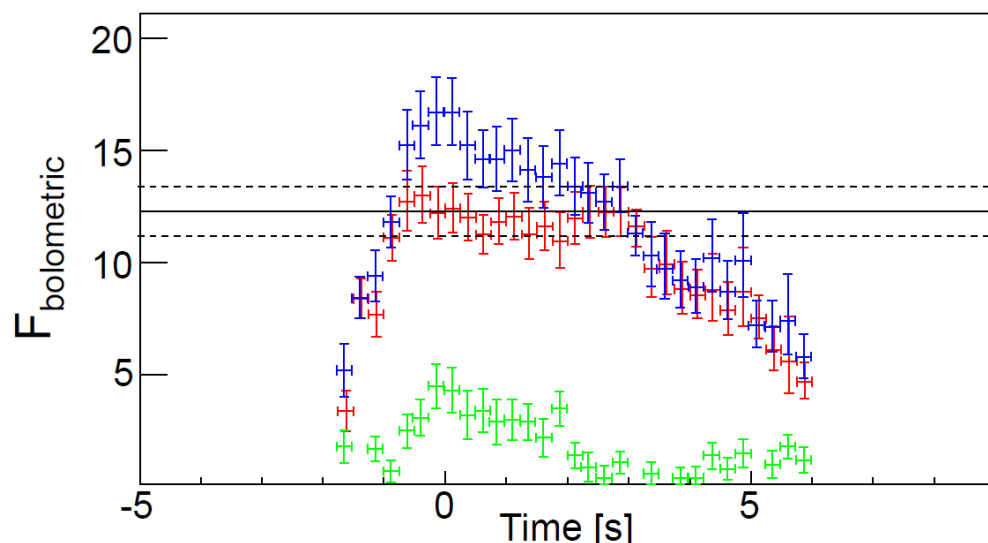
Blackbody model



F_a model: add a scaling (multiplication) factor to the pre-burst emission ($bb+f_a * F_{per}$)

慧眼在对4U 1608-52的热核暴观测中发现: 除了中子星表面的热辐射之外, 还有另外一个成分。该成分和热核暴的流量正相关, 其谱形和吸积辐射能谱相似, 该现象一般认为是热核暴引起的吸积率的增加。

An emission excess at soft X-rays: an enhanced pre-burst/persistent emission.

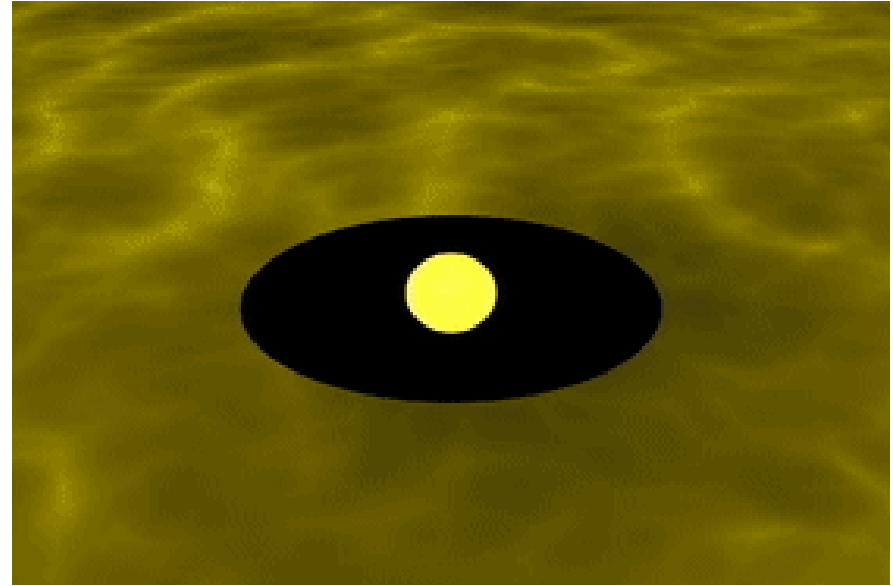
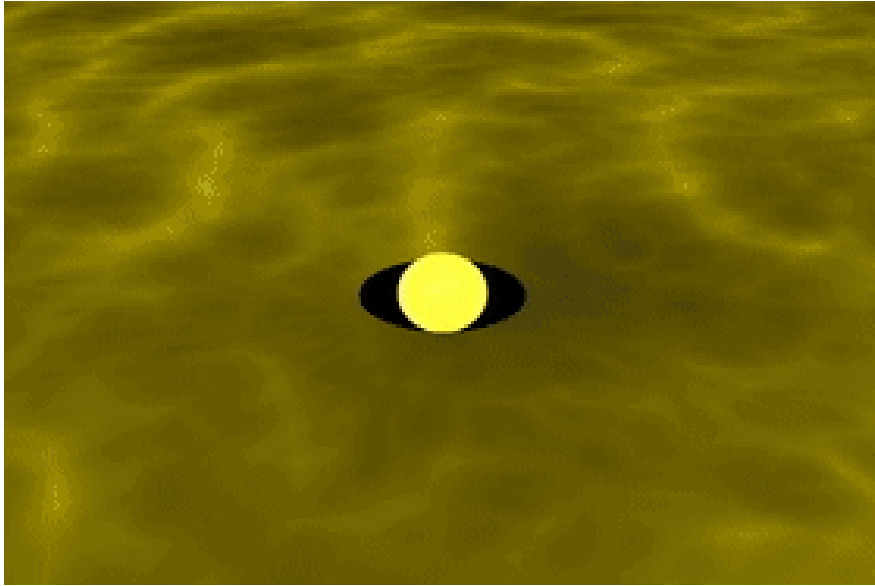


由于该热核暴的辐射半径超出了中子星表面，且达到爱丁顿光度，我们认为其吸积能释放区域在热核暴的半径之外，这是吸积盘内半径新的限制方法。

We find that the burst and enhanced persistent emissions sum up to exceed Eddington luminosity by ~ 40 percentages. We speculate that the enhanced persistent emissions is from a region beyond the PRE radius, or through the Comptonization of the corona.

盘冕成分在PRE半径之外

enhanced persistent emissions is from a region beyond the PRE radius, or through the Comptonization of the corona.

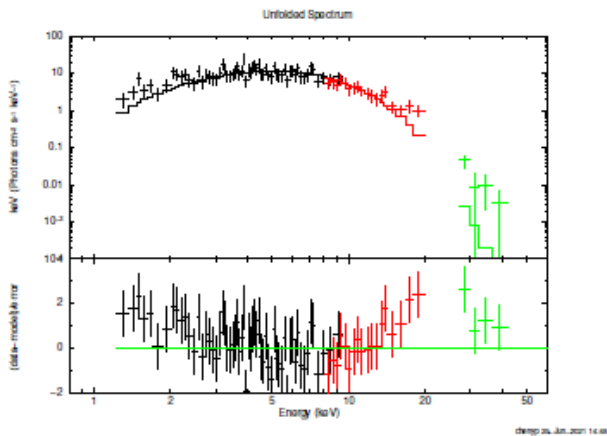


暴和吸积环境的相互影响

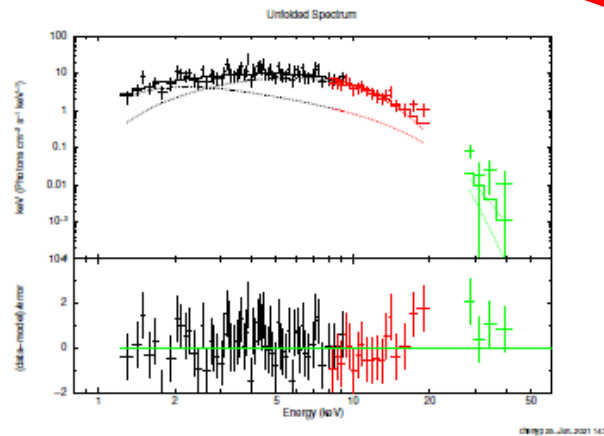
interplay between thermonuclear burst and accretion environments

convolution thermal-Comptonization model to fit outburst spectra

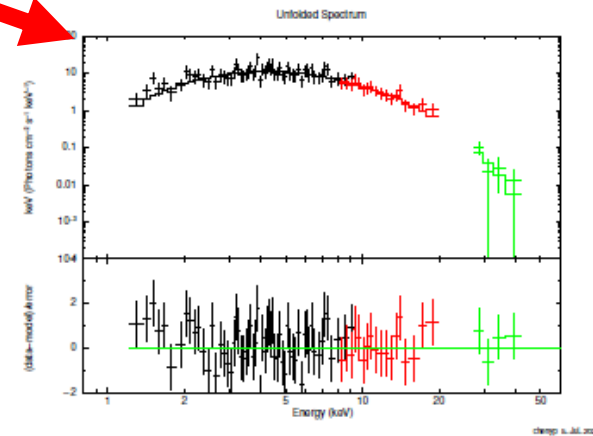
N_{H} 10^{22}cm^{-2}	τ	kT_e keV	f_{sc}	kT_{in} keV	N_{diskbb} 10^2	χ^2_{ν}
$1.00^{+0.01}_{-0.01}$	$10.5^{+0.3}_{-0.3}$	$3.13^{+0.01}_{-0.06}$	$0.69^{+0.04}_{-0.03}$	$0.71^{+0.01}_{-0.02}$	$8.25^{+0.70}_{-0.50}$	1750/1520



bb



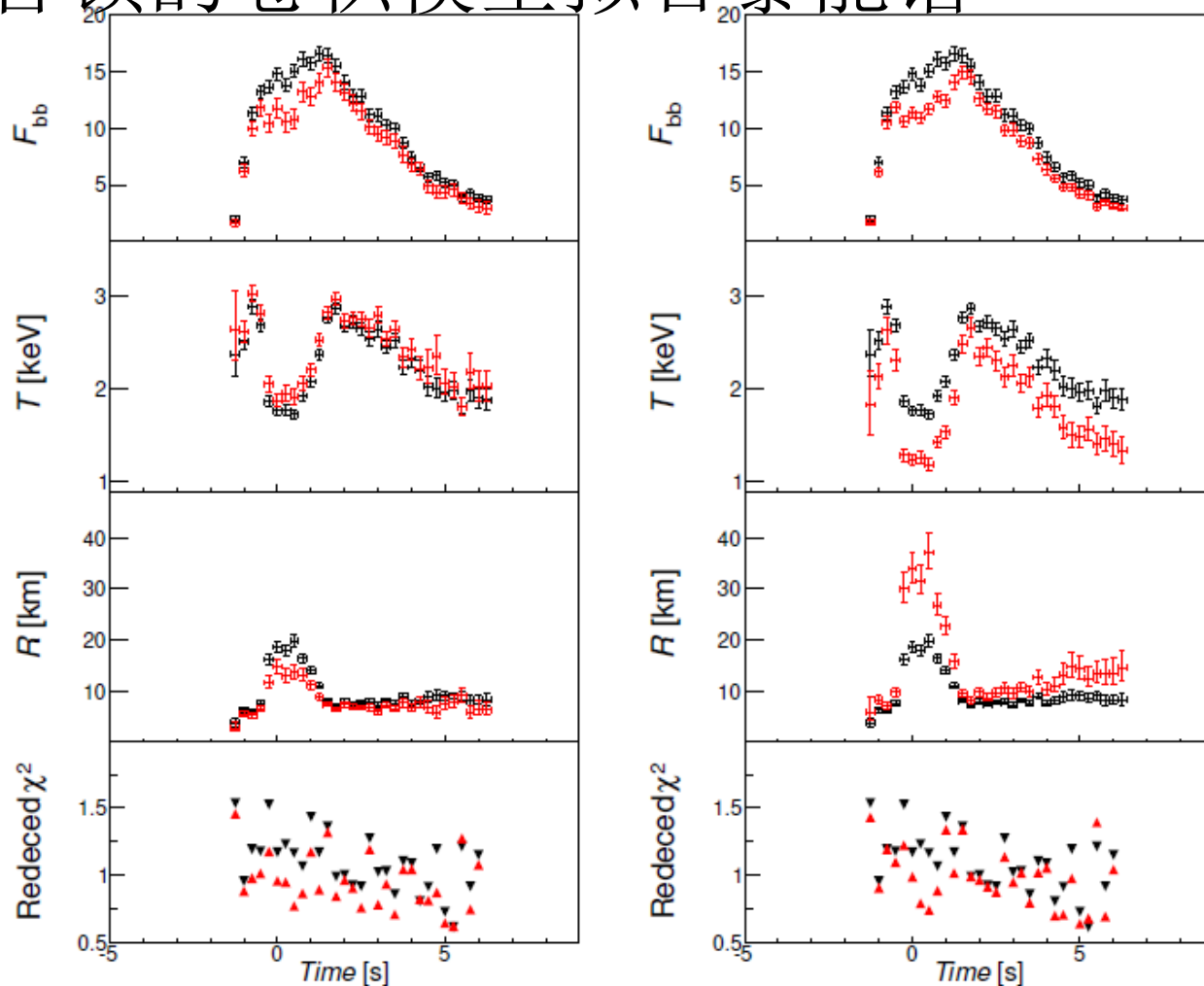
$bb + f_a * F_{\text{per}}$



thcomp * bb

convolution thermal-Comptonization model to fit burst spectra

热康普顿的卷积模型拟合暴能谱



$bb + f_a * F_{per}$

$thcomp * bb$

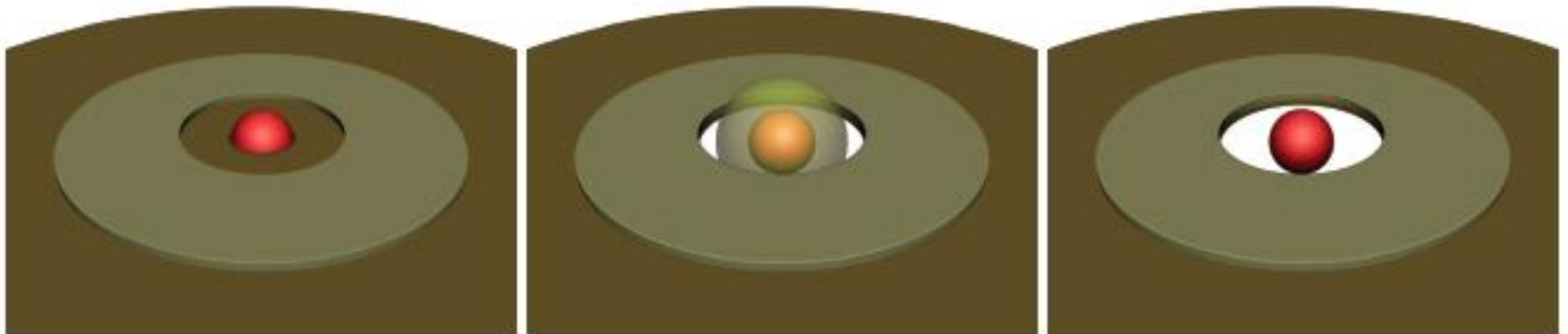
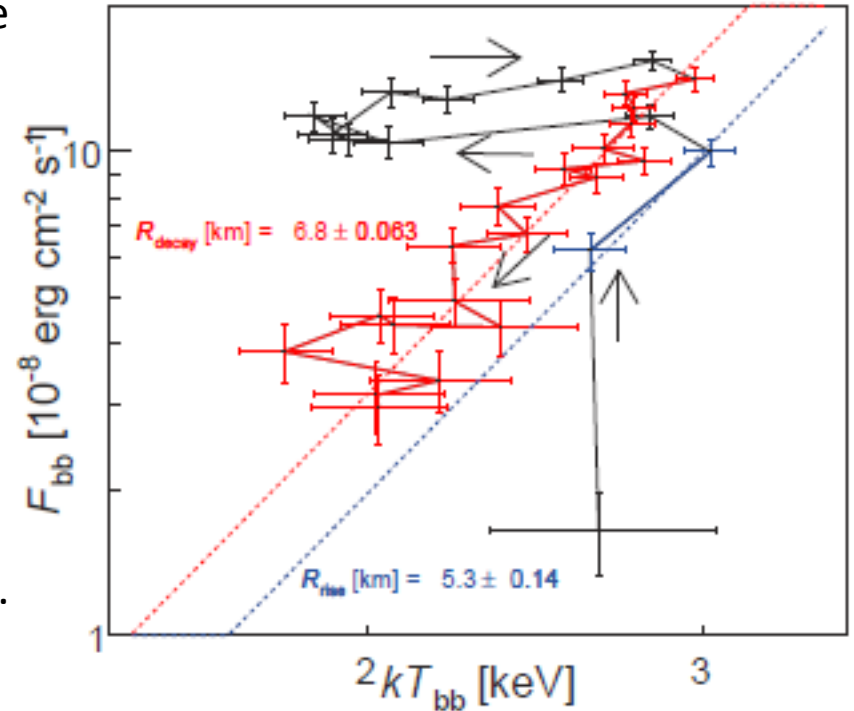
disk evaporation by the burst emission

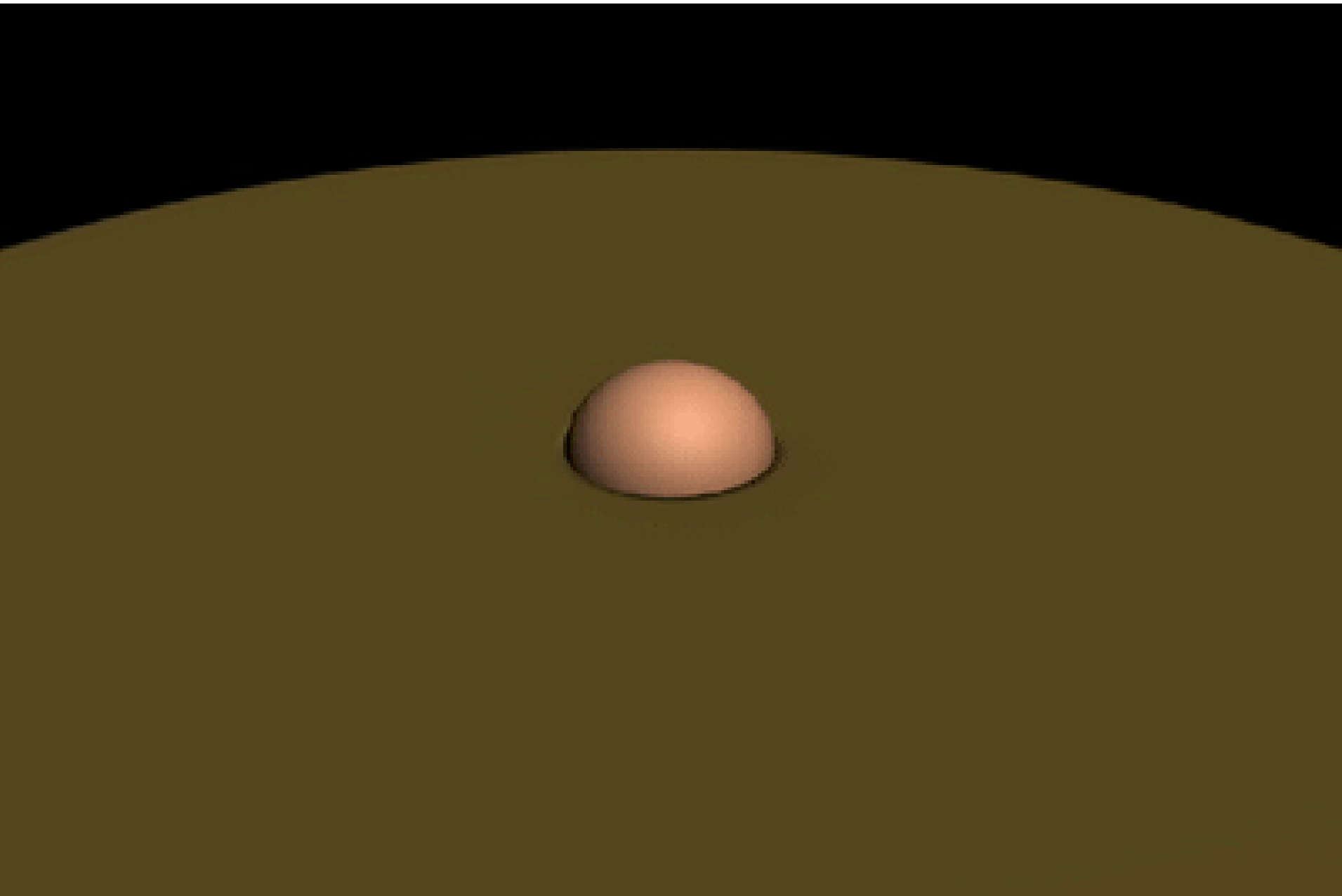
暴蒸发内盘

The obscured lower part of the NS surface by the disk is exposed to the Earth observer due to the inner disk evaporation by the burst emission.

The consistency between the fa model and convolution thermal-Comptonization model indicates the interplay between thermonuclear bursts and accretion environments.

it is widespread in bursts but covered up due to the low counts rate and narrow energy coverage.





Broad-band spectra (Rapid Burster)

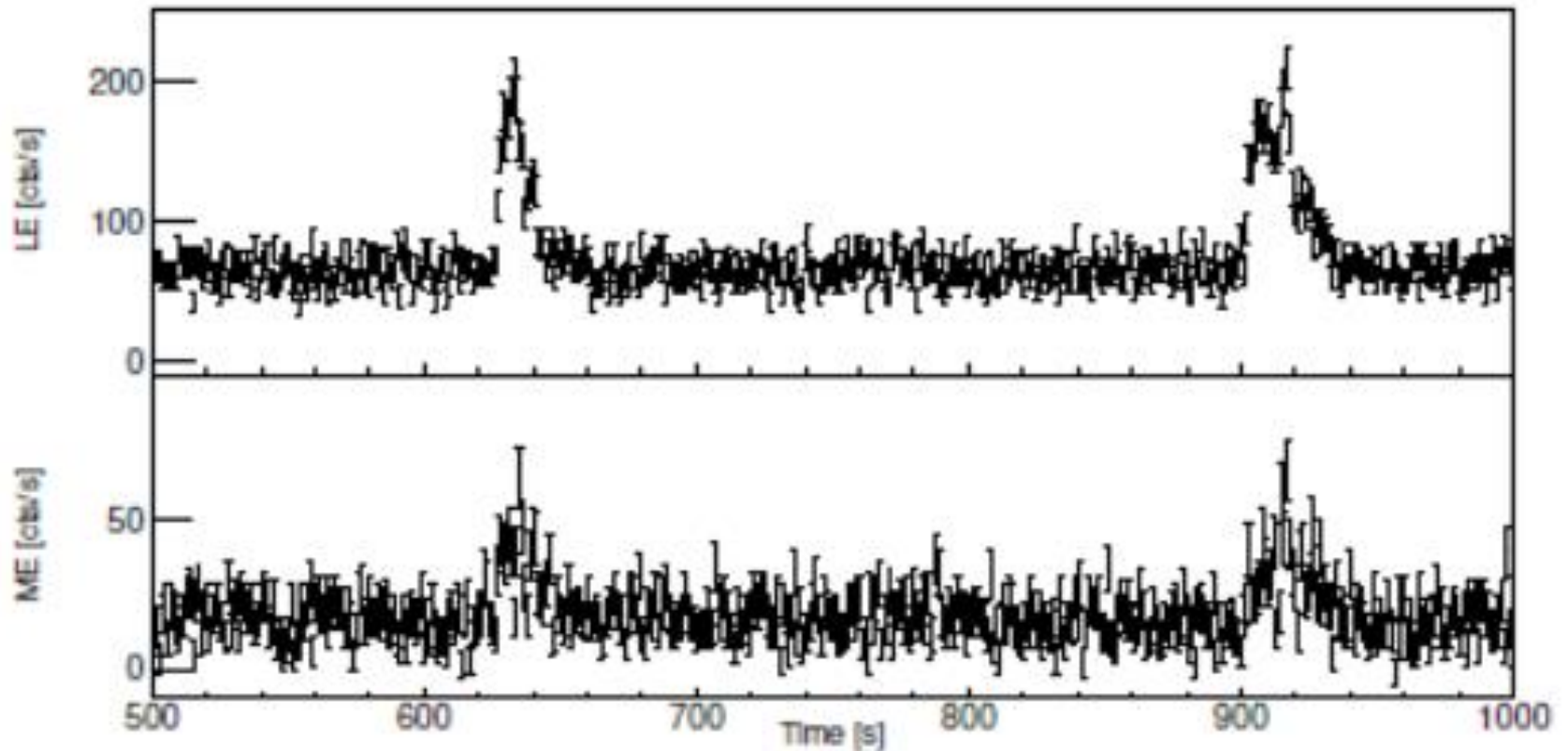
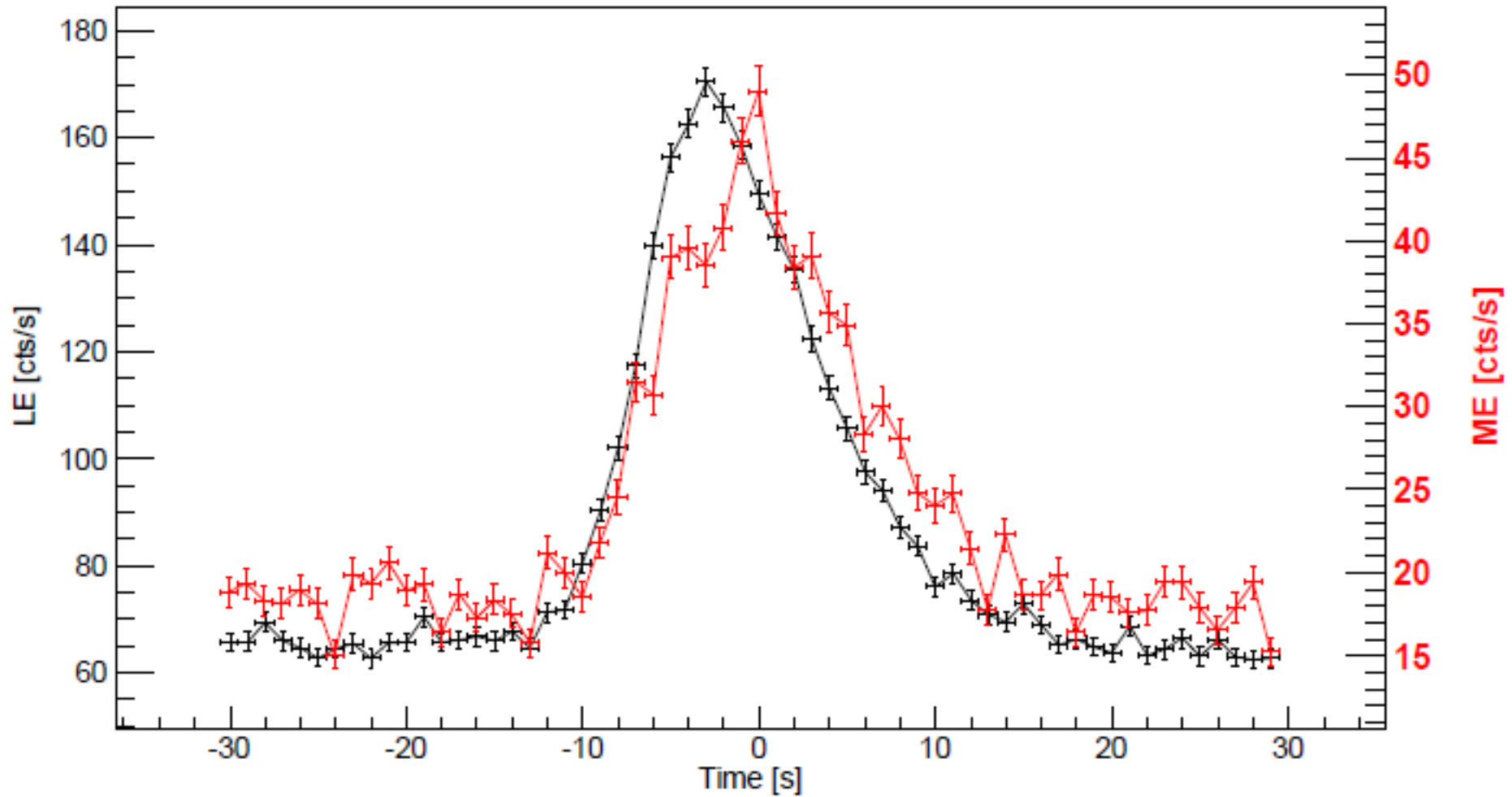
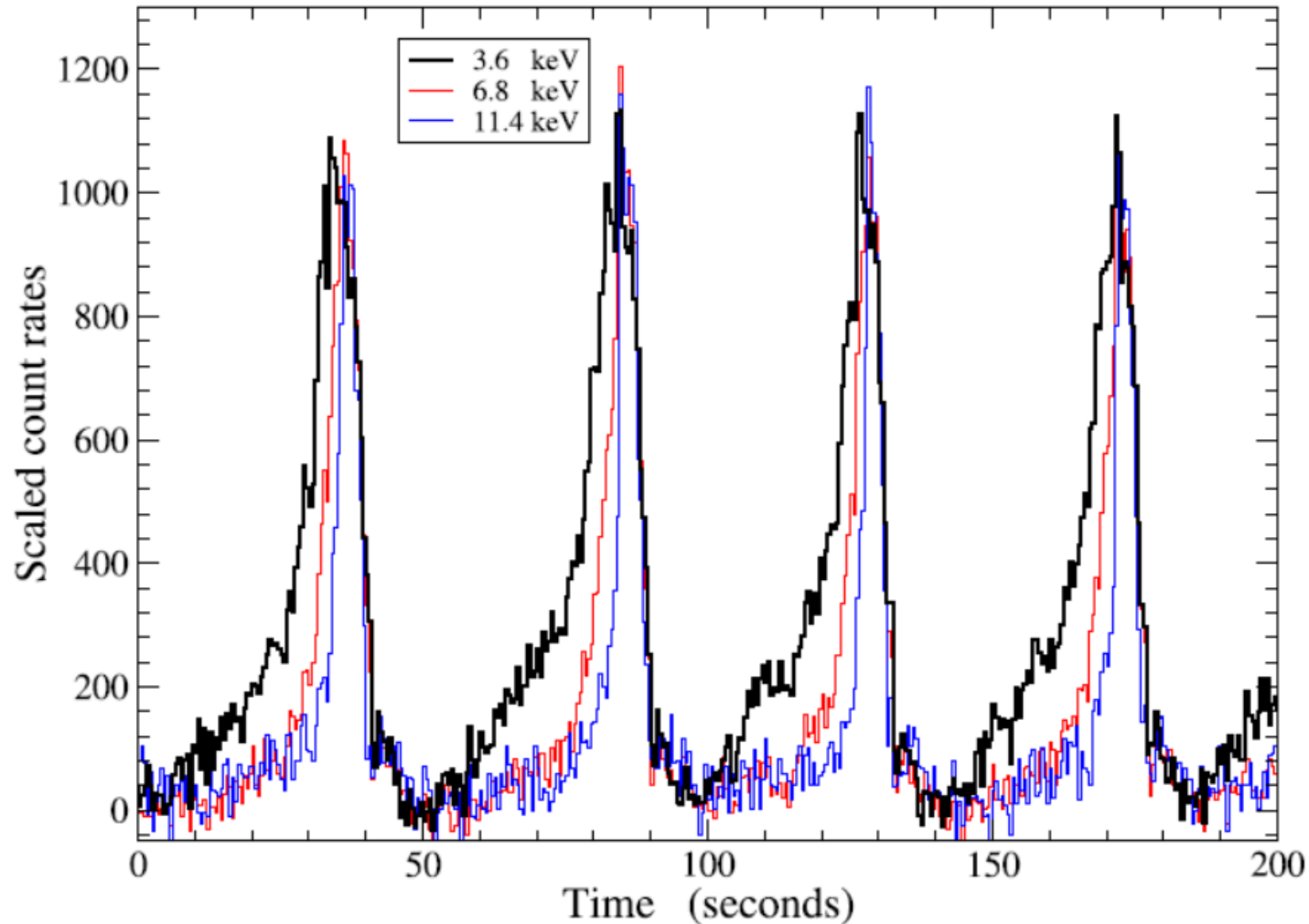


Figure 2. The light curve snippets of TOO1 (left) and TOO2 (right) at 1-10 keV and 10-20 keV are given in the top and bottom panels, respectively.

Stacked Ic (hard X-ray delay)



HXD in GRS 1915+105 & IGR J17091-3624



Mrk 110

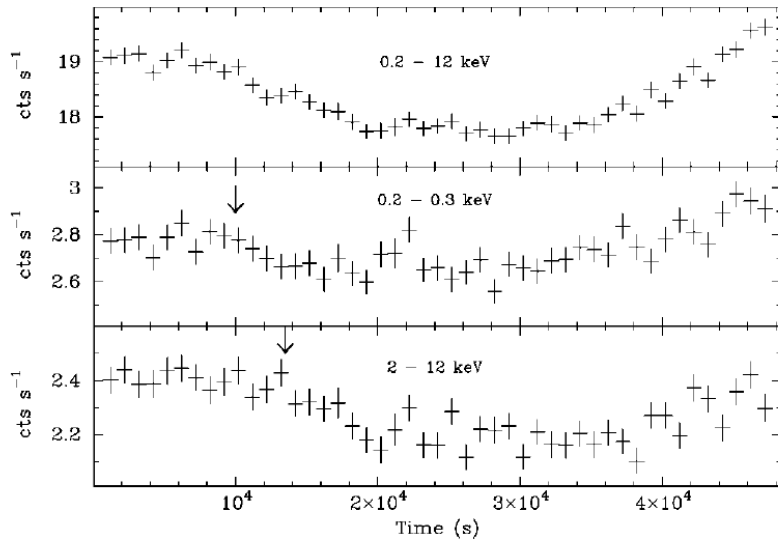


FIG. 1.—EPIC pn light curves (1000 s bin) of Mrk 110 in different energy ranges. The start of variability is indicated by downward arrows (see text)

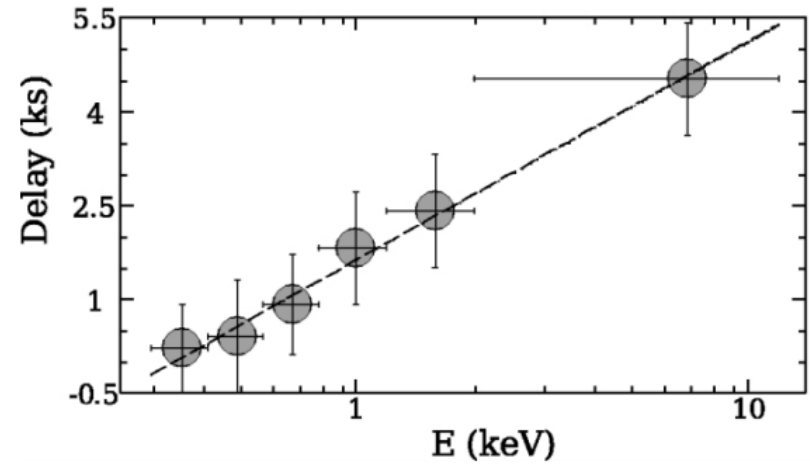
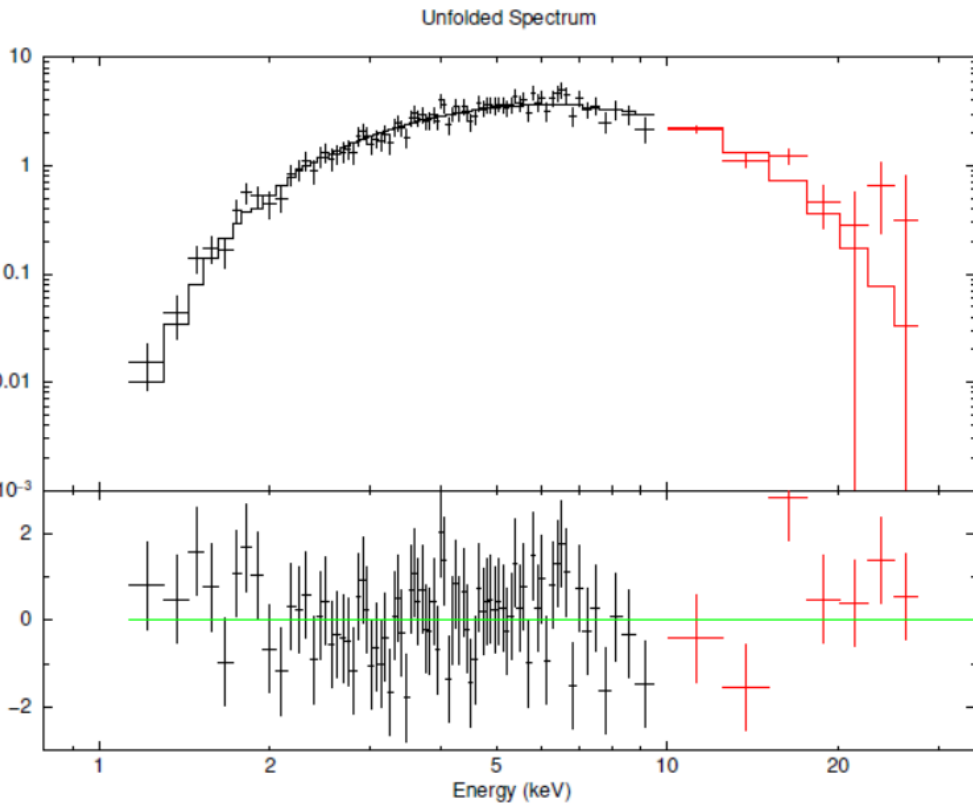


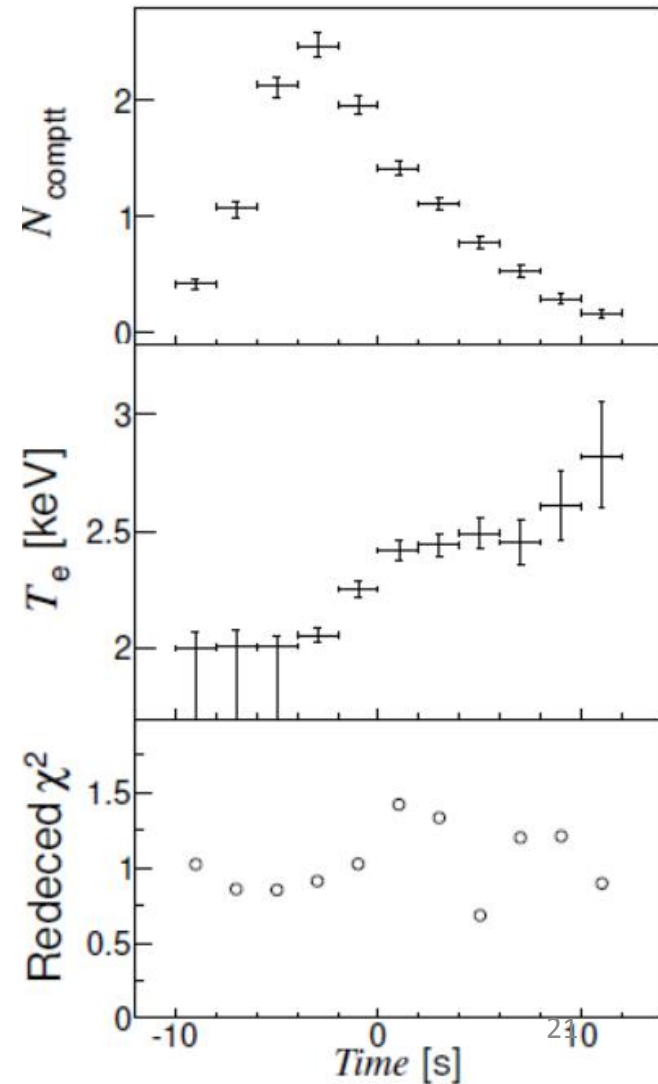
FIG. 3.—Energy dependence of lag between the light curves of energy 0.2–0.3 keV and higher energies.

Comptt ($\tau \sim 10$, $T_{\text{seed}} \sim 0.2 \text{ keV} \sim T_{\text{disk}}$)

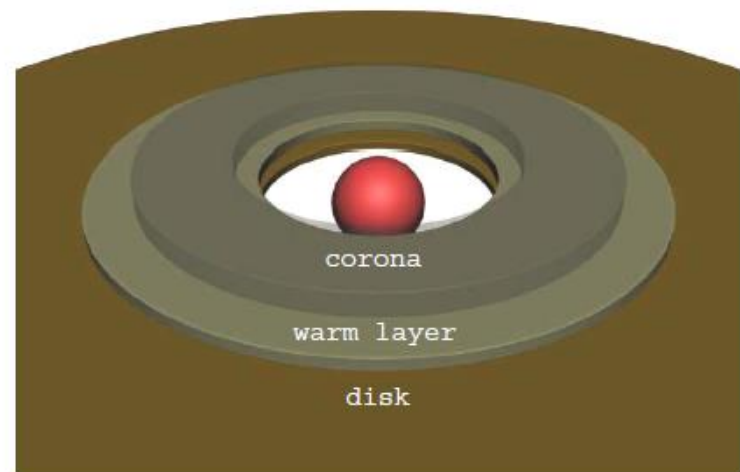
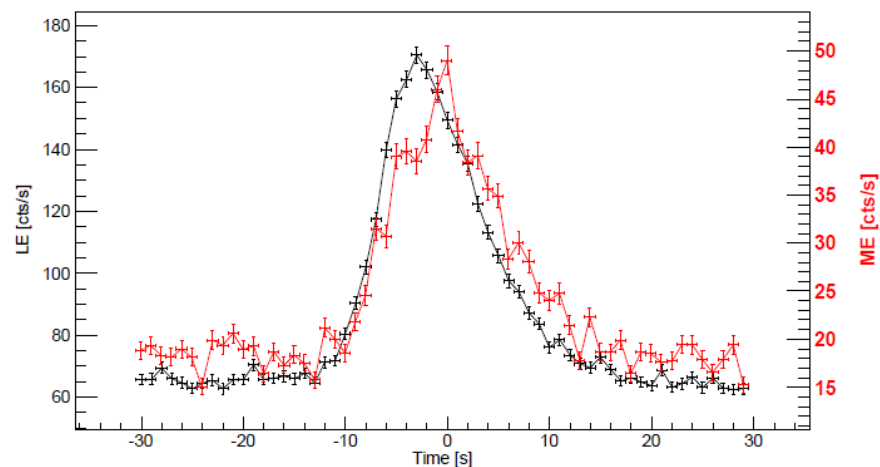


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led 1-30 keV spectra of the TOO1 burst at the peak flux observed by LE (black) and ME (red).



- 慧眼在对河内的二型X射线暴源Rapid Burster观测中，通过合并多个二型X射线暴，在暴间隔为100-200秒的二型暴中，发现其硬X射线辐射落后于软X射线的辐射大约3秒。
- 这是在中子星双星中第一次观测到这种硬延迟，之前的硬延迟都是在黑洞双星中观测到的。
- By stacking tens bursts, we find for the first time that the hard X-rays are lagging behind the soft X-rays by 3 s, which is first reported in NS XRB.
- 其能谱和康普顿散射模型符合，且电子温度在2--3 keV，光深在10左右。我们认为二型X射线暴的辐射和位于吸积盘和高能冕之间的热层（warm layer）有关（Zhang, S. N., et al., 2000, Science, 287, 1239）。
- Zhang et al. (2000) showed that the magnetic reconnection in the disk can produce a so-called warm layer, i.e., a corona with low temperature covering the cold disk



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