Burst probe and HXMT mission

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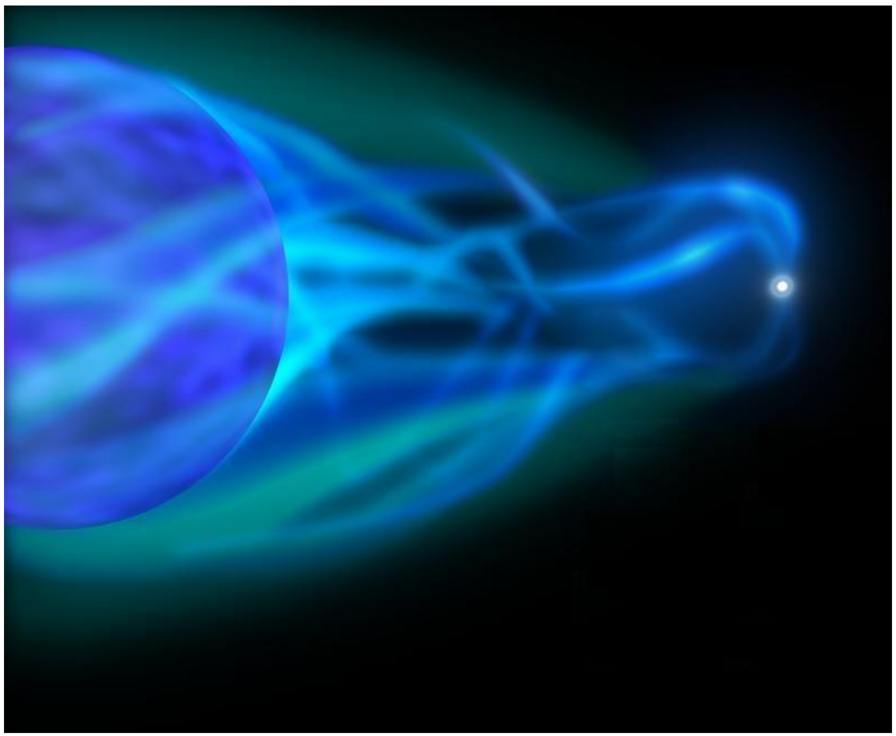
Outline

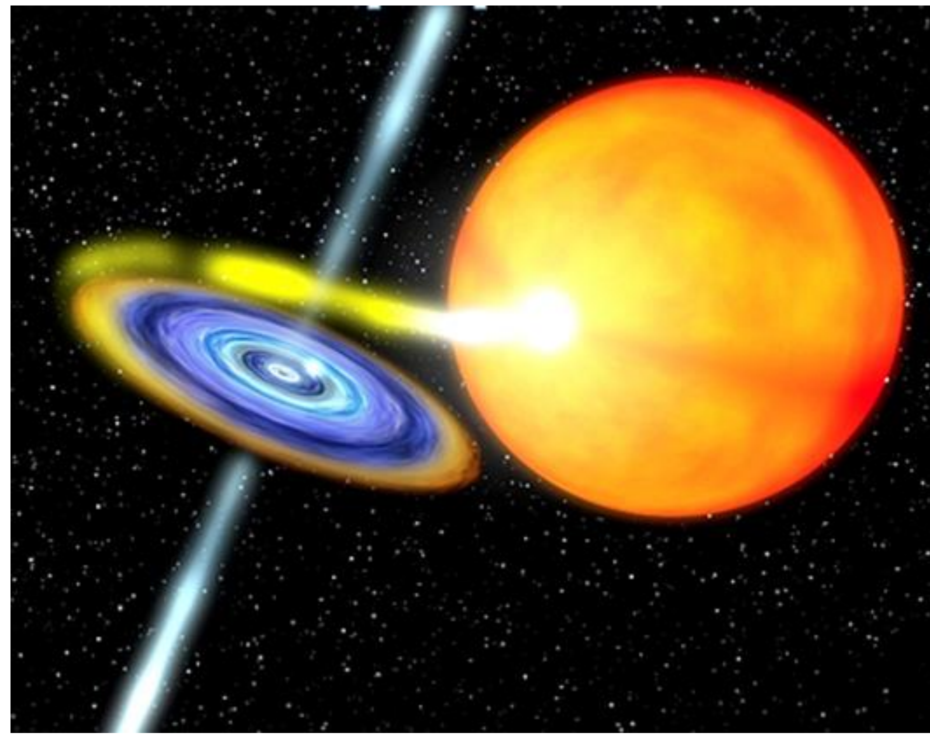
- Corona puzzle
- Proper probe
- State-of-art progress
- Issues be addressed
- HXMT mission
- Merits reside in HXMT

Corona puzzle

The classification of the X-ray binary systems

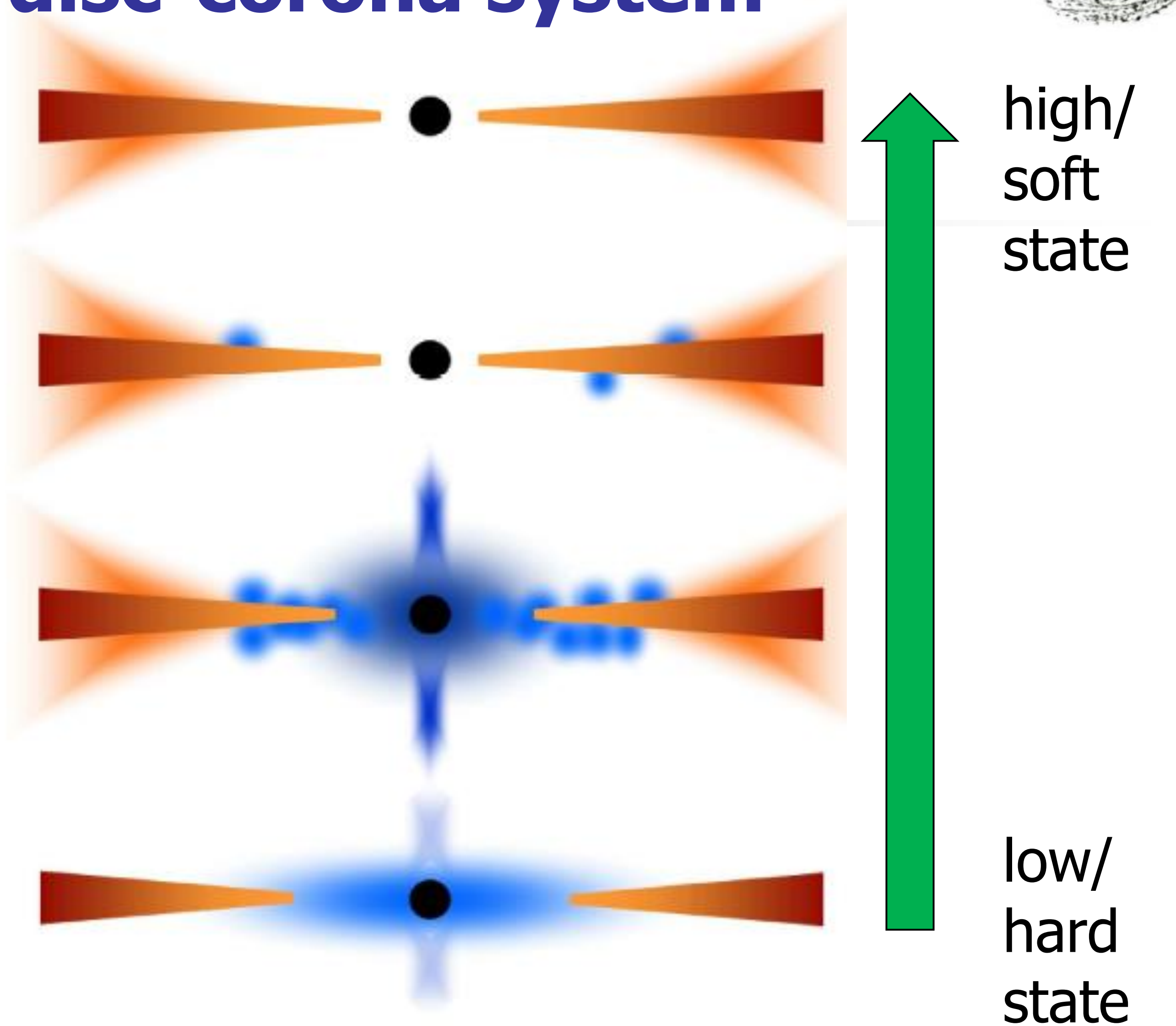


High-mass X-ray binaries
(wind-fed X-ray sources)



Low-mass X-ray binaries
(disk-fed X-ray sources)

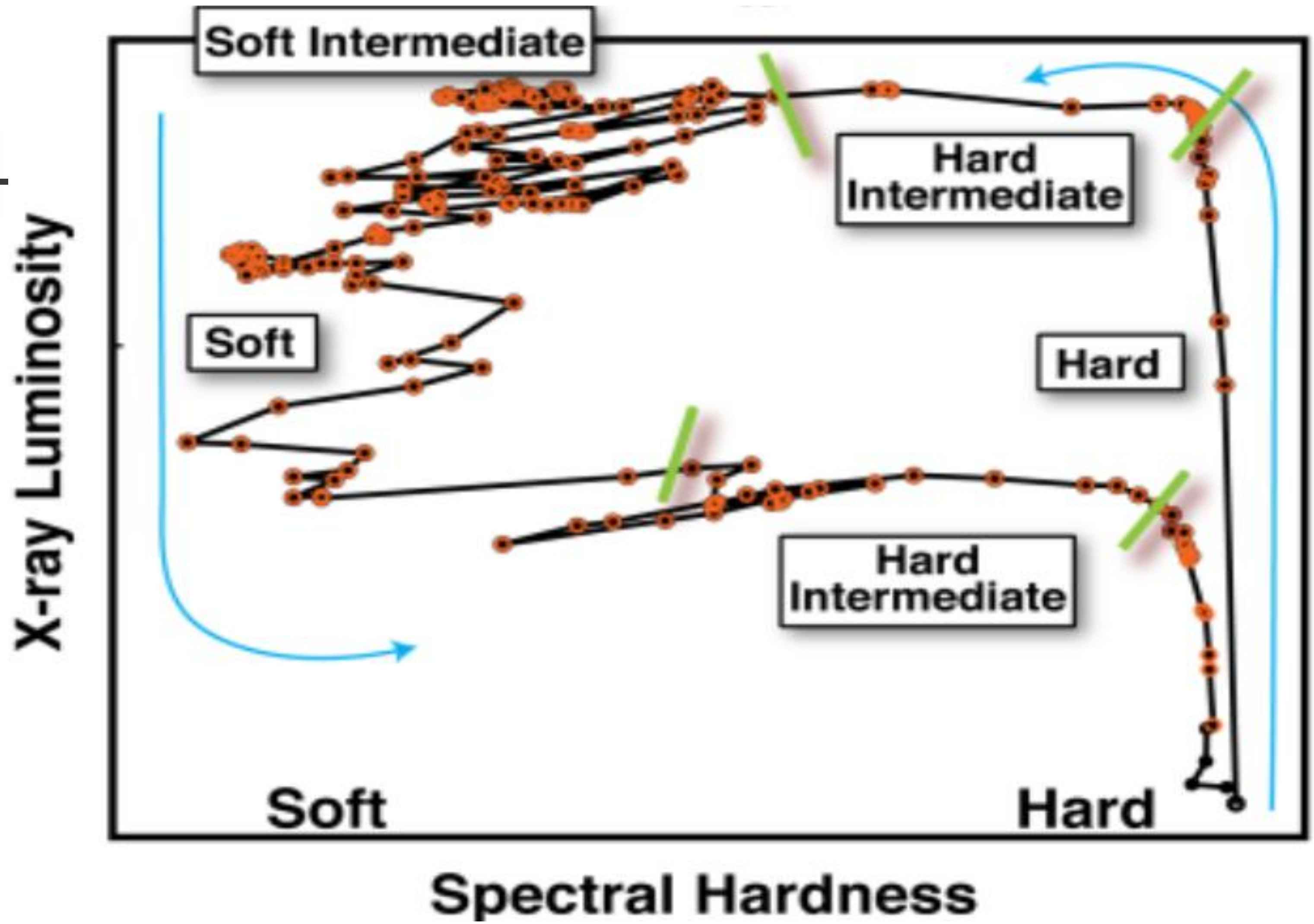
disc-corona system



accretion
rate

(Chris Done et al, 2007)

The evolution of the outbursts



A typical hard-intensity diagram of outburst evolutions (Tomaso Belloni 2010)

The corona puzzle

`*well known*' XRB corona:

WELL used in modelling, but *less KNOWN* in its nature

the formation mechanism?

Disk evaporation or magnetic re-connection

Intrinsic dynamic time scale?

Of hours or seconds

The corona puzzle

XRB corona:

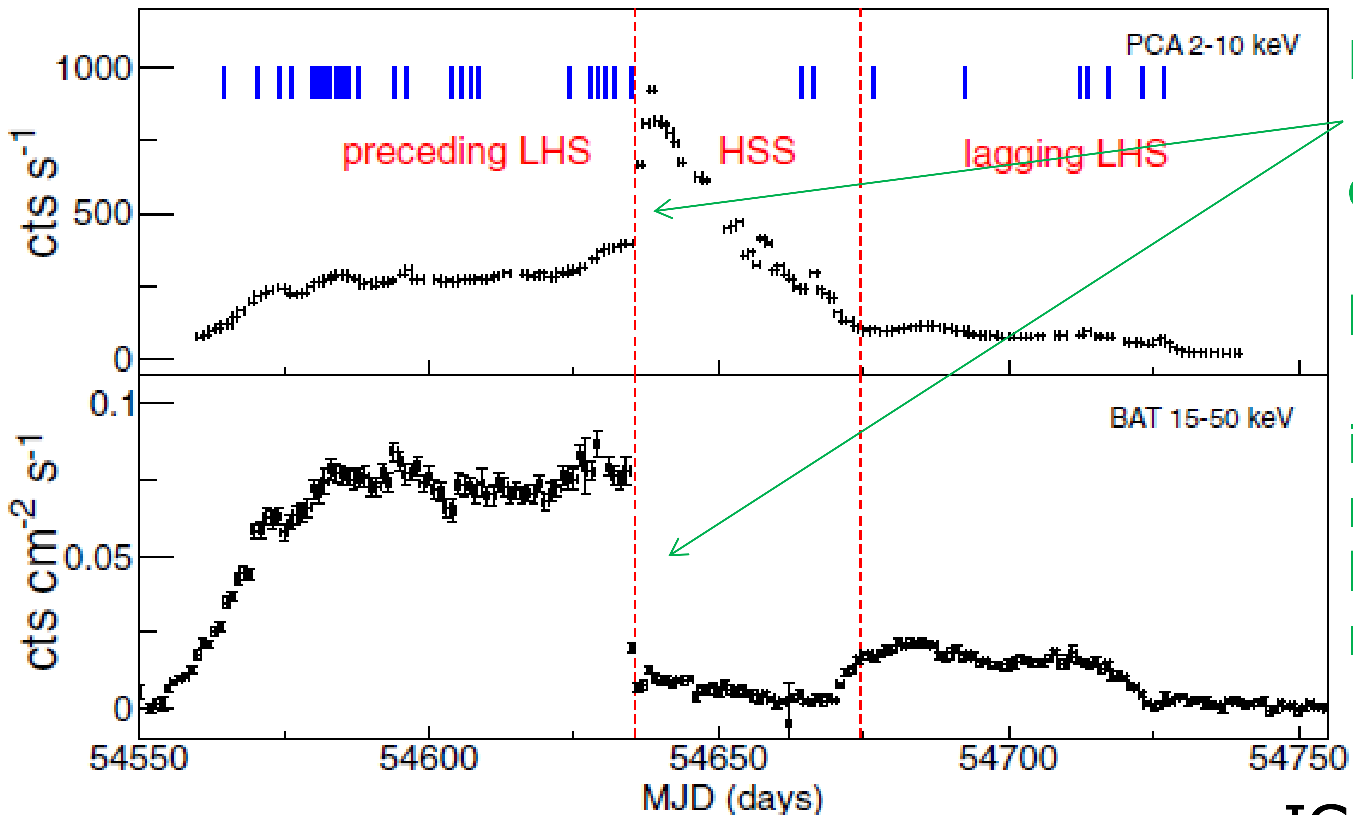
in definition, radiation inefficient hot flow

Lighted up mostly in case of the presence of Compton seed photons (soft X-rays)

Proper probe

Proper probe

XRB state transition(corona cooling)：



LH/HS transition:

cooling of the corona,

hours to days,

intrinsic to soft X-rays (disk viscosity) but not to hard X-rays (corona)

IGR J 17473-2721

Proper probe

Corona formation:

Even harder be addressed

largely suppressed with accompanied strong soft X-rays

Proper probe

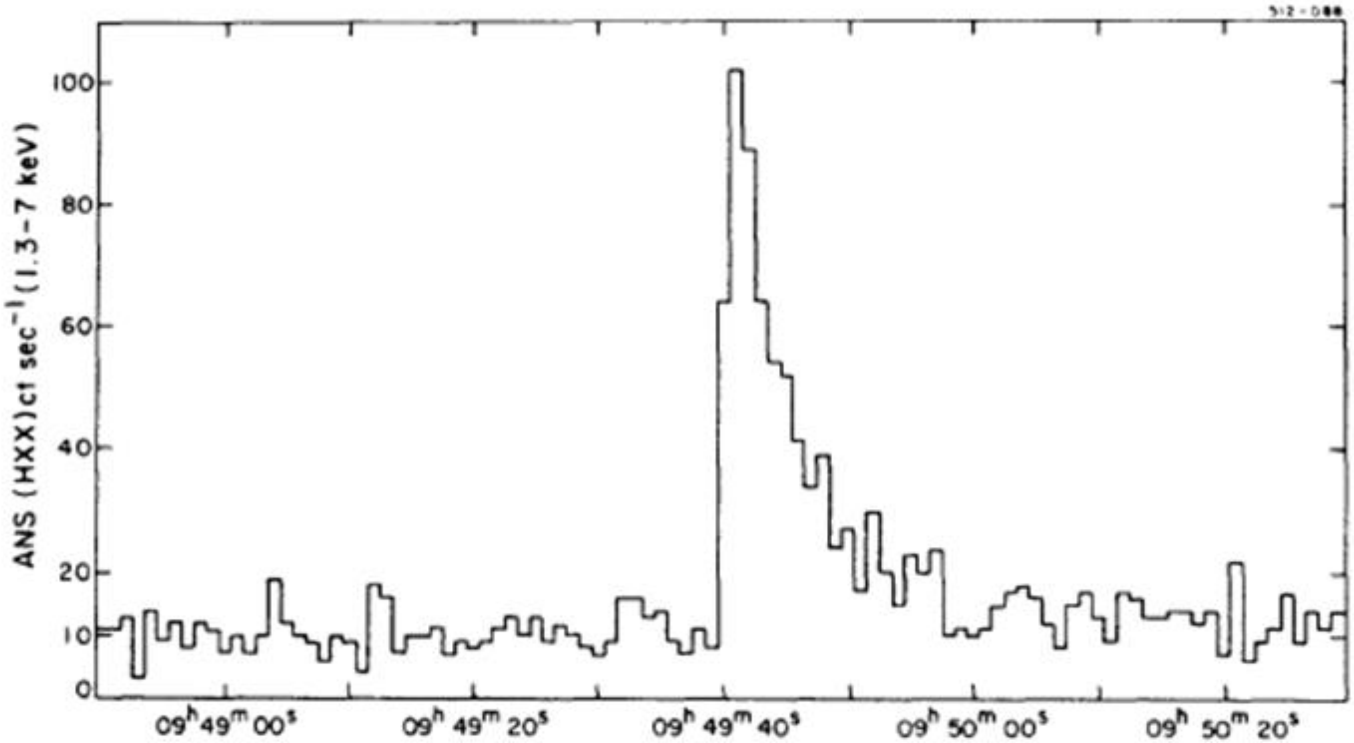
To decode the corona puzzle one needs the proper probe:

Intense soft X-rays & very short time scale

BH XRB: rare

NS XRB: the thermal nuclear flare (type-I bursts)

Proper probe: type-I burst



The first observed type-I burst （Grindlay et al，1976）

Proper probe: type-I burst

Physical process: thermonuclear explosions on the surface of neutron stars

color temperature: 2-3 keV

(corona temperature: ~ tens keV)

time scale: tens to hundreds of seconds

total energy: $10^{39} - 10^{40}$ ergs

proper probe: type-I burst

(Chen Yupeng et al ,2012)

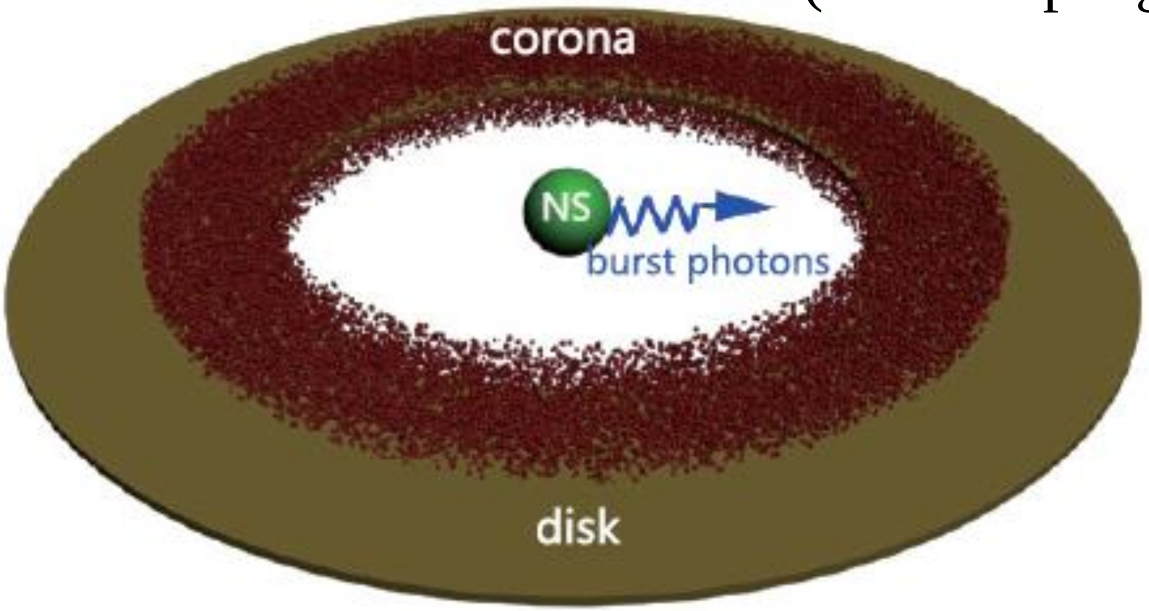
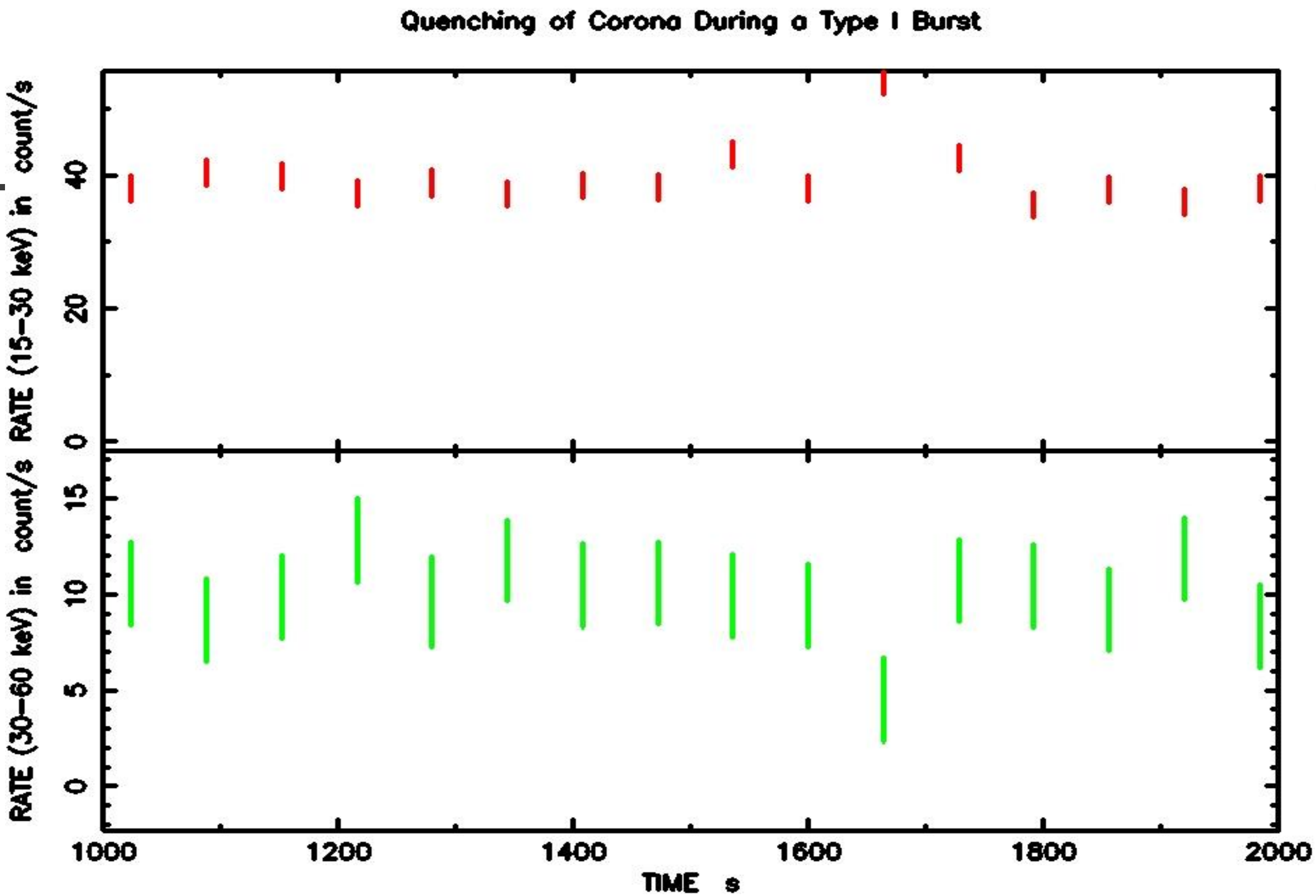


Figure 3. Illustration of the central region of an NS XRB, in which a corona is located around the disk and cooled by the soft X-rays from a type-I burst that occurred on surface of the NS.

The type-I bursts are located on the surface of neutron stars, which can be regarded as a shower of soft X-rays to cool the surrounding hot corona.

State-to-art progress

The pioneer research



Study of one burst from Aql X-1 in 2003: hard X-ray shortage of about 2 sigma level (Maccarone & Coppi, 2003, A&A, 399,1151)

Current researches

Papers published to this direction recently:

Zhang S., Chen Y.P., et al., 2009, A&A, 502, 231 — Outburst evolution in IGRJ 17473-2721

Chen Y.P. , Zhang S., et al., 2010, A&A, 510, 81 — Type-I bursts reside in this outburst

Chen Y.P. , Zhang S., et al., 2011, A&A, 534, 101 — Corona study in this outburst

Chen Y.P. , Zhang S., et al., 2012, ApJL, 752, 34 — Type-I burst as probe to corona in this outburst

Ji L. , Zhang S., et al., 2013, MNRAS, 432, 2773

Chen Y.P., Zhang S., et al., 2013, ApJL, 777,

Ji L., Zhang S., et al., 2014, ApJ, 782, 40

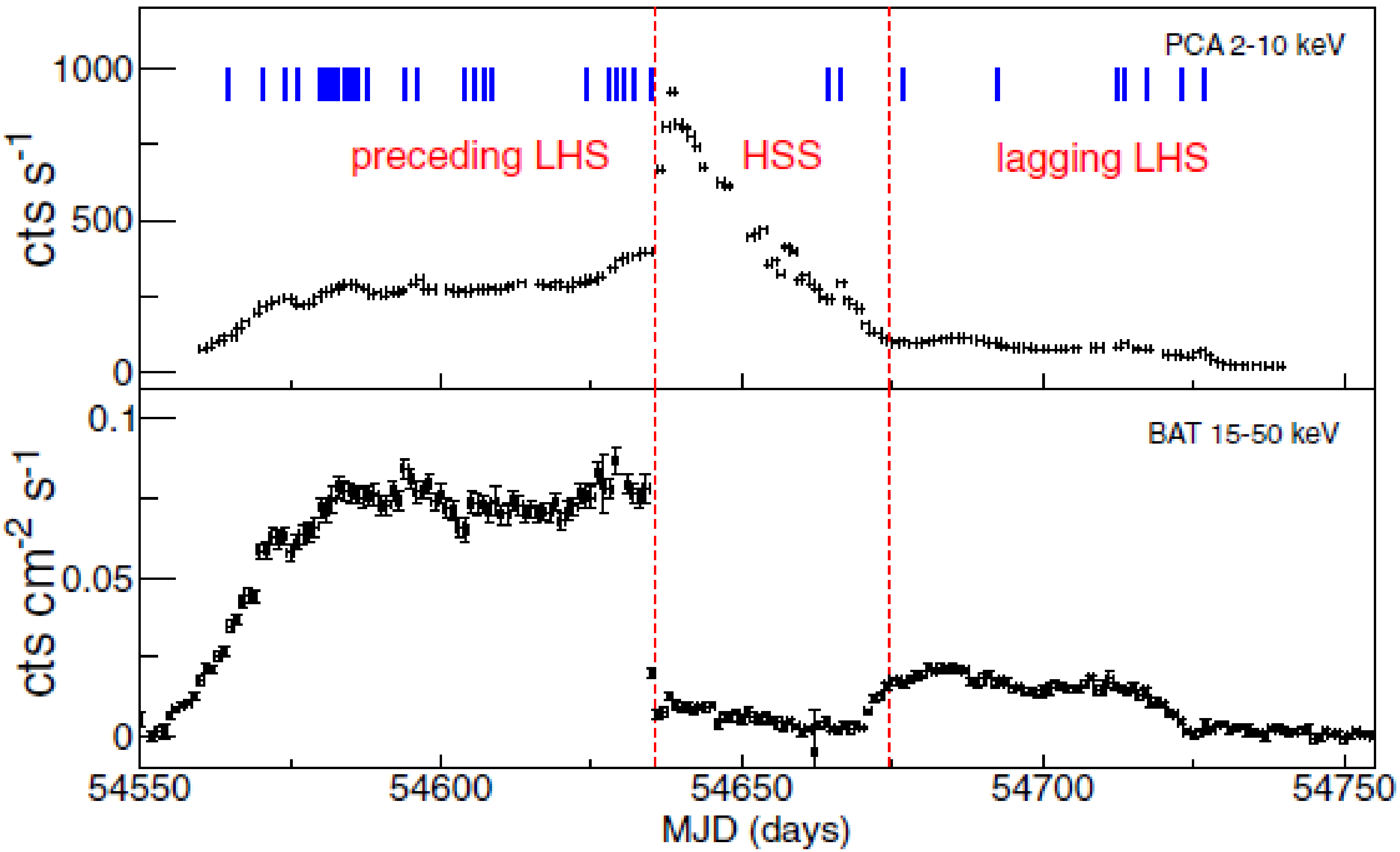
Ji L. , Zhang S., et al., 2014, A&A, 564, 20

— Universal of the result by investigating and providing a sample observed with hard X-ray shortage

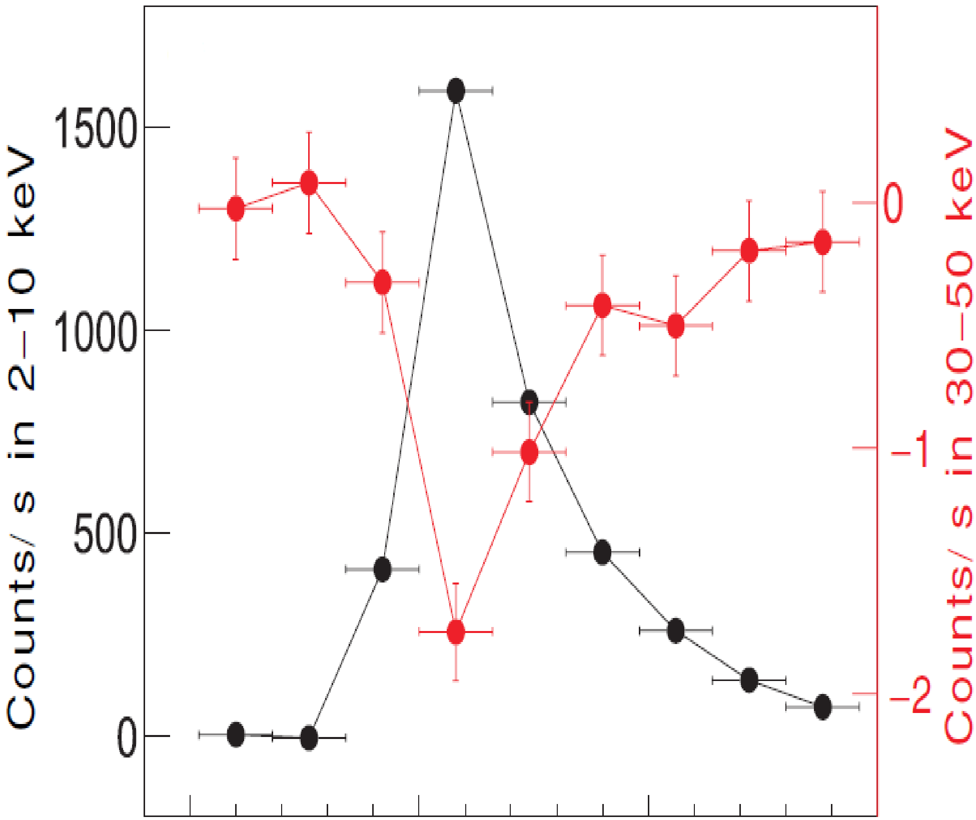
Ji L. , Zhang S., et al., 2014, ApJL, 791, 39 — Extension of the research to soft X-rays, discovery of fa dependence on spectral states

Ji L., Zhang S., et al., 2015, ApJL, accepted — Joint diagnostic on disk/corona based on fa evolution at soft X-rays and the hard X-ray shortage

The start of the entire story: IGR J17473-2721



RXTE/PCA light curve (2–10 keV, upper panel) and Swift/BAT light curve (15–50 keV, lower panel) covering the 2008 outburst of IGR J17473−2721 with a time resolution of 1 day.



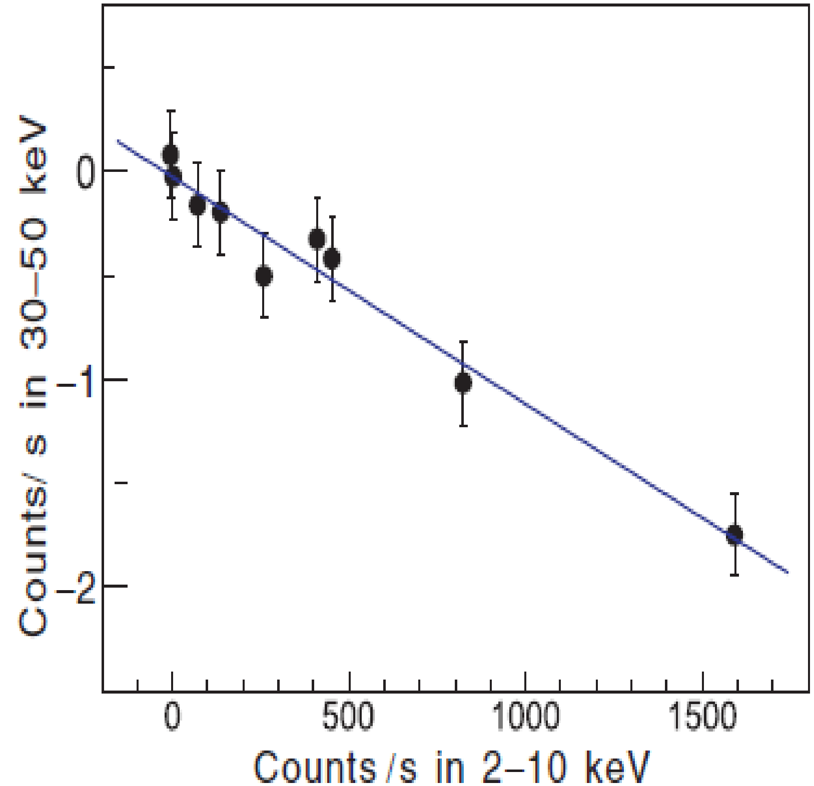


Figure 4. Linear fit to the data shown in the upper panel of Figure 2.

(Chen Yupeng et al., 2012, ApJL)

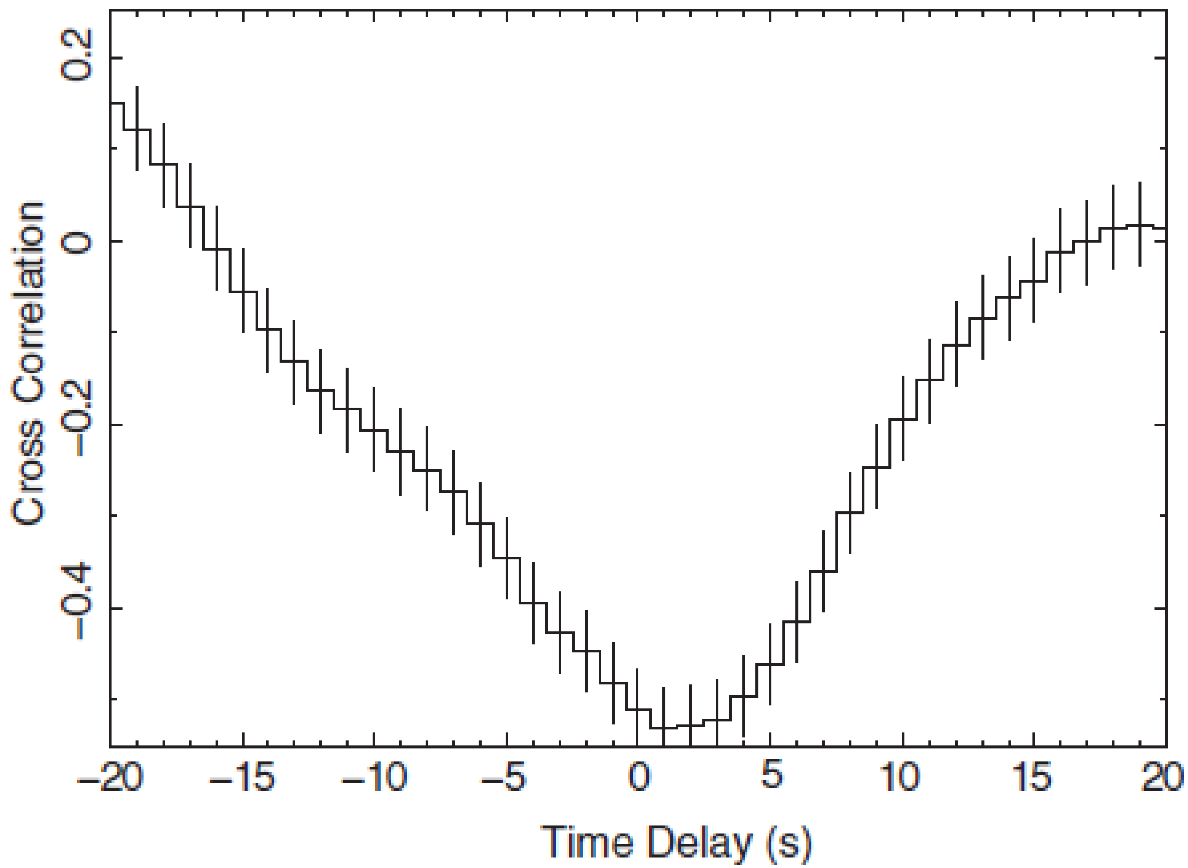


Figure 5. Cross-correlation between the 2–10 keV and 30–50 keV, with a time resolution of 1 s, for the combined burst in the preceding LHS.

Time delay between 2-10 keV and 30-50 keV :

0.7+-0.5 seconds

Universal of the observed phenomena : 4U 1636-536

During the low/hard state:

Shortage at 40-50 keV while bursting;

Time lag of 2.4+-1.5 seconds with respect to the soft X-rays.

(Ji Long et al., 2013, MNRAS)

Universal of the observed phenomena : the sample

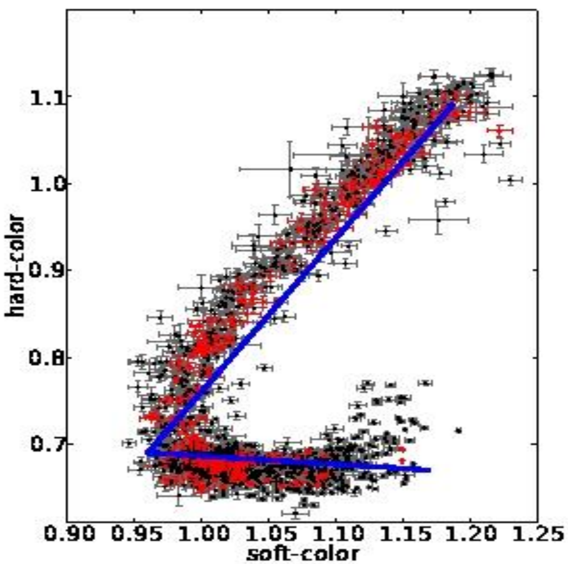
The findings are universal to NS XRBs?

Constitute an atoll sample by satisfying the selection criteria of,

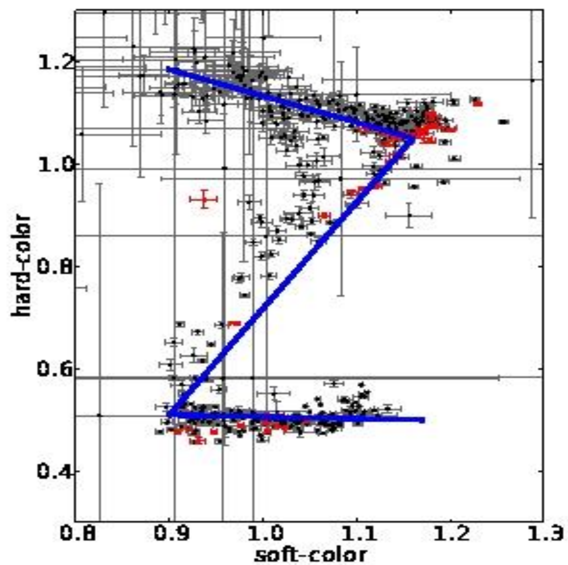
1， PCA hard X-ray count rate >0.2 ct/s
2, Burst number > 10
3, average burst temperature < 2.5 keV

A sample consists of 5 atoll sources:

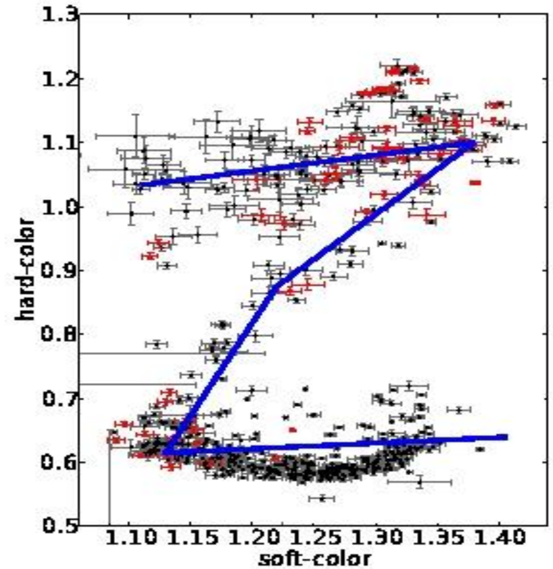
Aql X-1, KS 1731-260, 4U 1705-44, IGR J17473-2721, 4U 1636-536



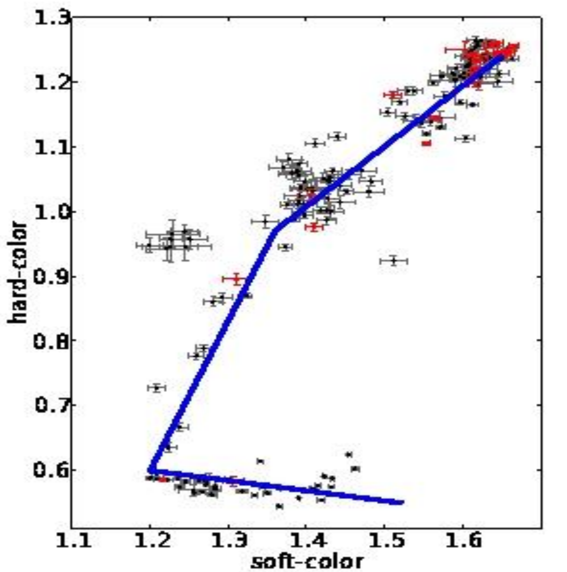
4U 1636-536



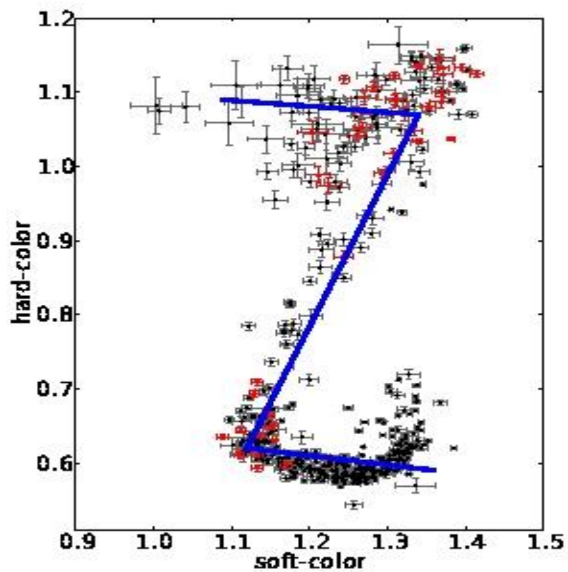
Aql X-1



KS 1731-260

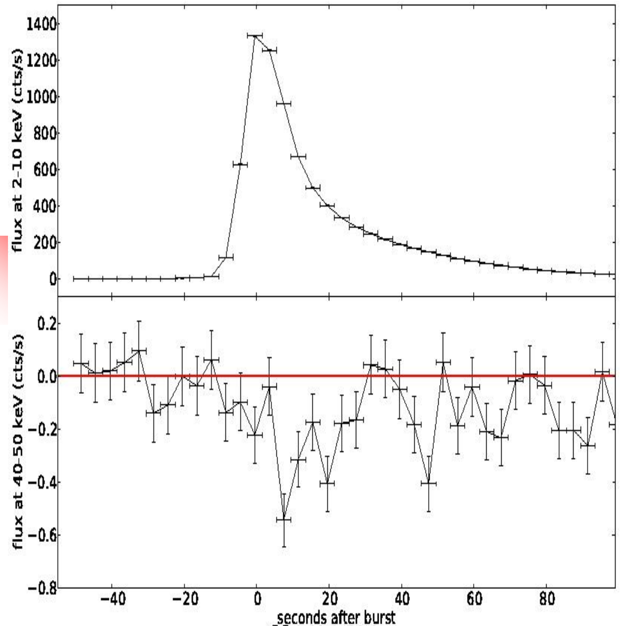


IGR J17473-2721

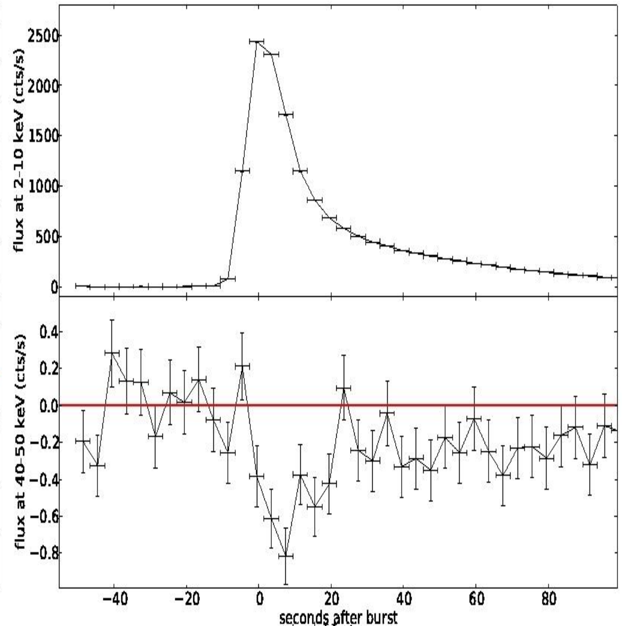


4U 1705-44

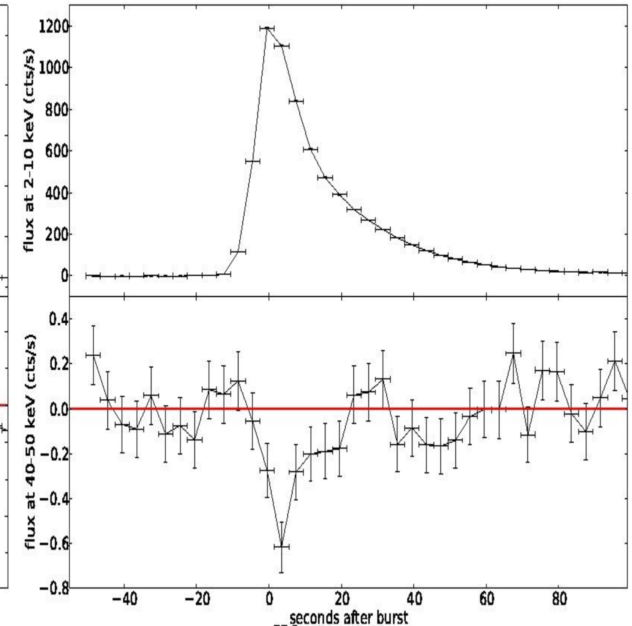
Only at extremely island state （Sz<1.5) the 40-50 keV count rate significantly larger than zero.



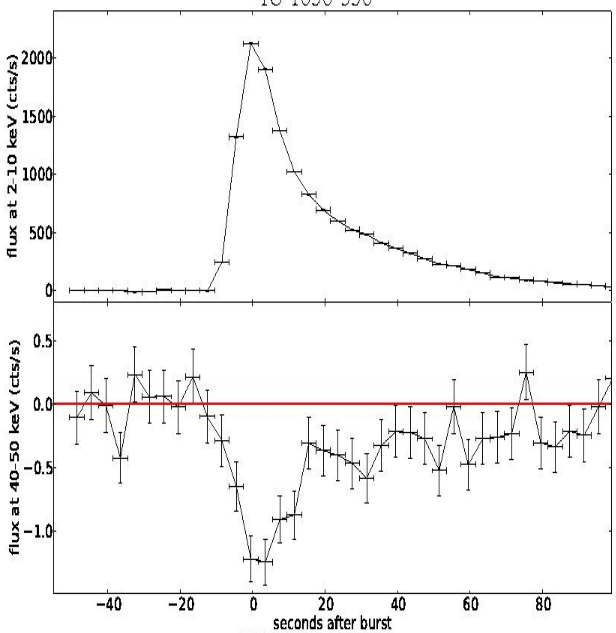
4U 1636-536



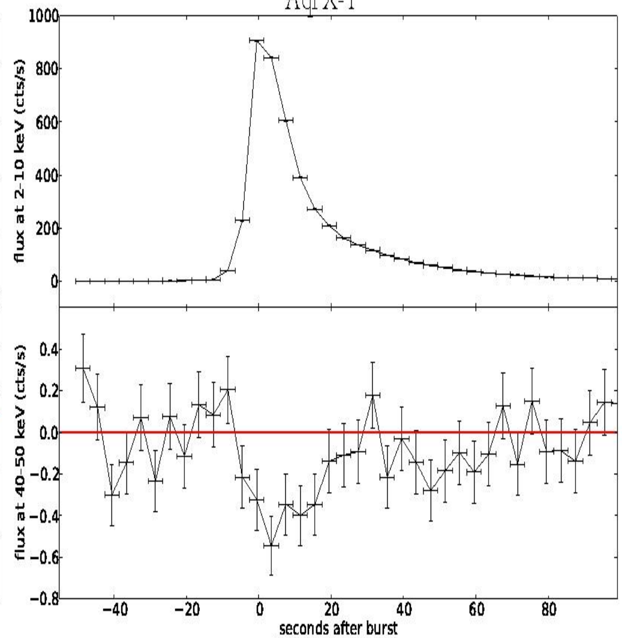
Aql X-1



KS 1731-260

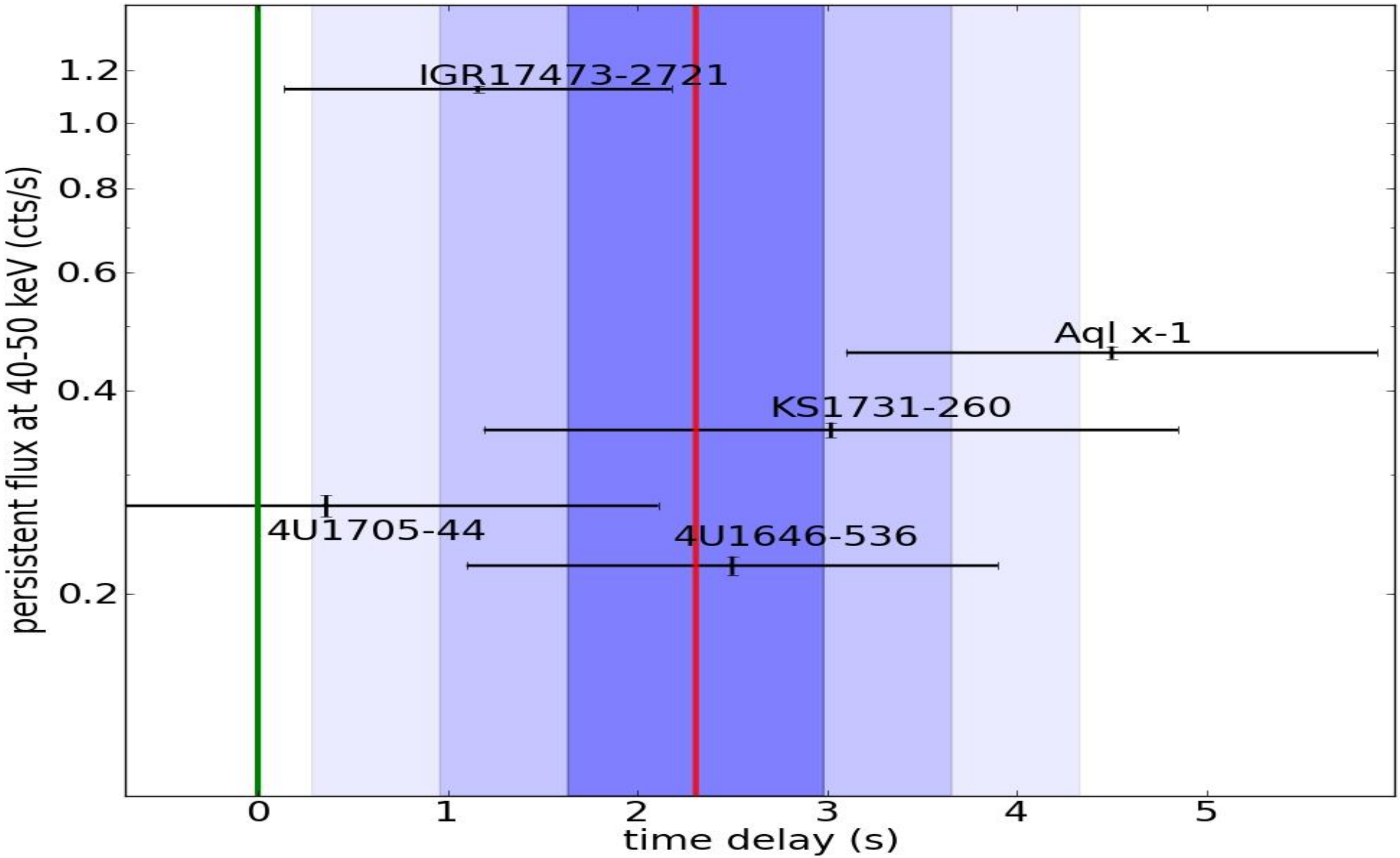


IGR J17473-2721



4U 1705-44

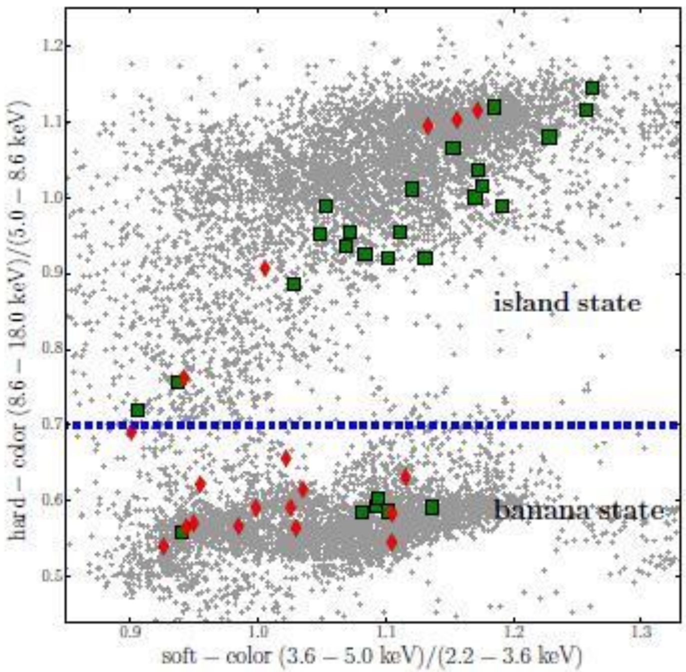
Hard X-ray shortage up to 100% are universal to the atoll sample, at significance levels of 4-10 sigma.

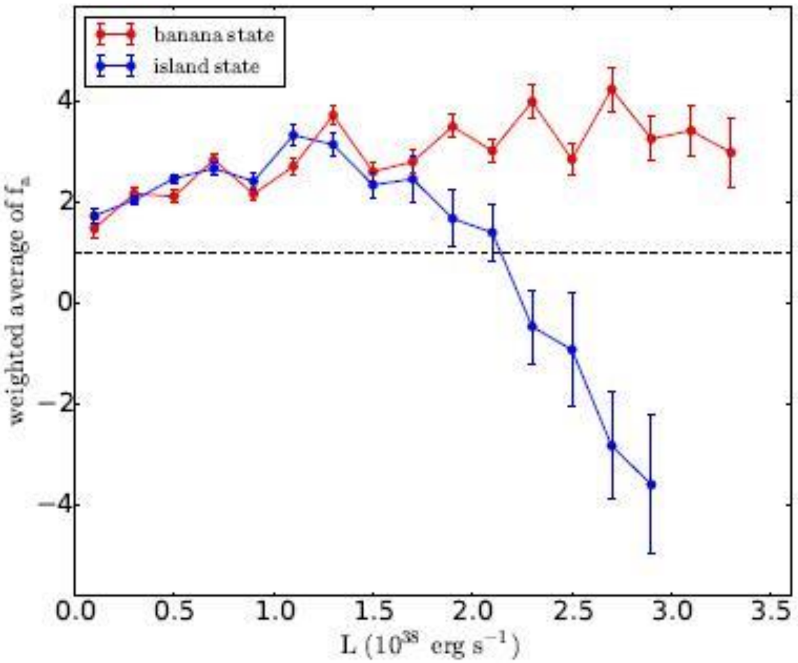


Time lags are universal to the atoll sample; an average over the sample gives 2.3+-0.7 seconds.

New chapter of the story: dependence of fa on spectral states

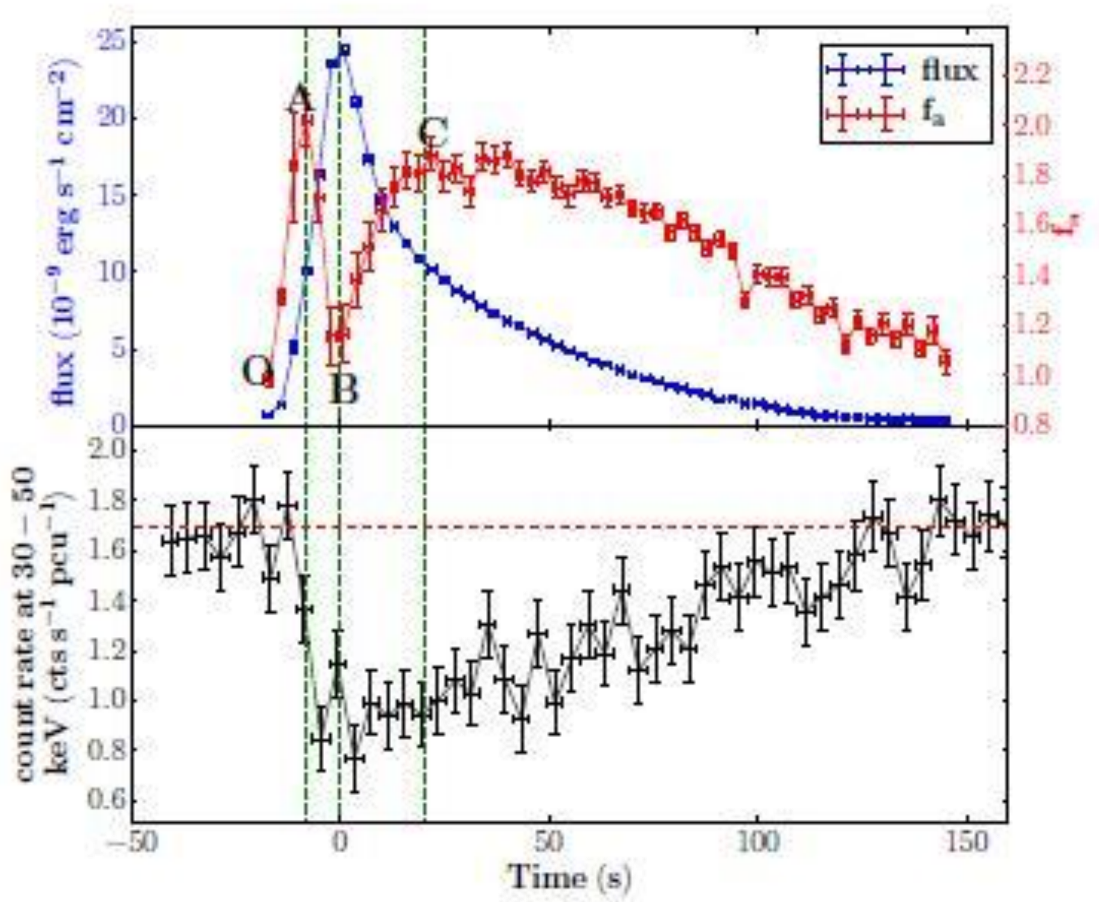
Dependence of the continuous emission (fa) with spectral state of the outburst: the case of 4U 1608-52





New chapter of the story: joint diagnostic at both hard/soft X-rays

The clock burster GS1826-238



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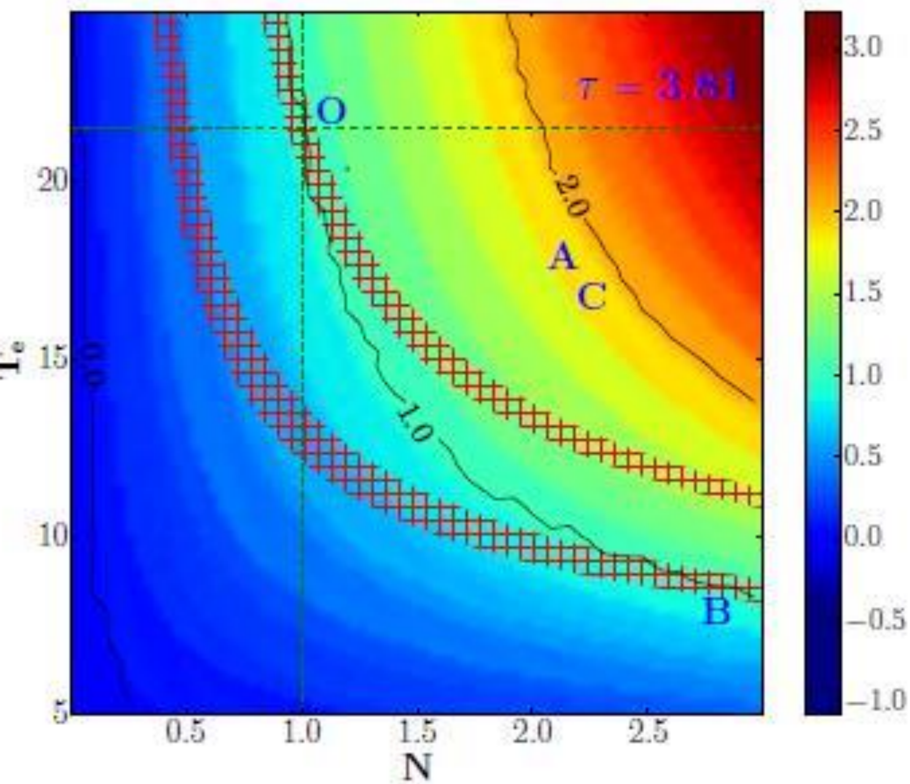
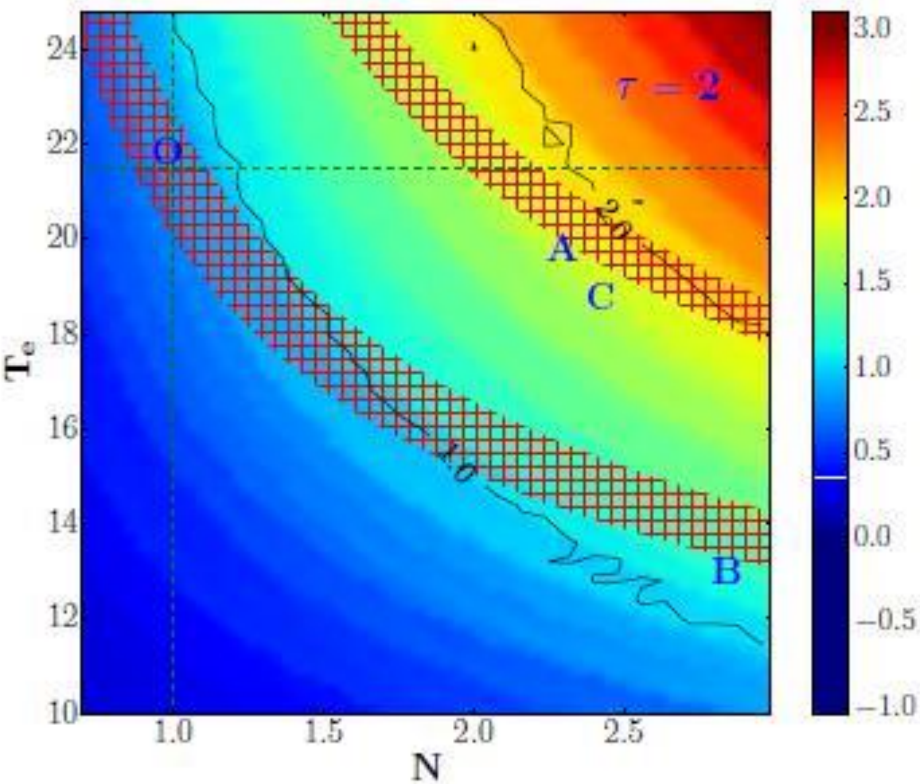




Issues be addressed

Hard X-ray shortage from cooling the jet?

1,Observationally, the hard X-rays in low/hard state of atolls are corona dominated;

2,The opening angle of the NS surface respect to jet too small for effective Compton cooling.

Energy budget of corona

Corona cooled from ~ 40 keV to ~15 keV under which hard X-rays not detectable to PCA

Corona blown away by burst radiation: shortage in hard X-ray suggests majority of the corona gone.

Dynamical time scale of corona

Observed with a delay of few seconds:

Compton cooling << 1 second.

Dynamical time scale a few seconds be intrinsic to corona recovery.

corona formation mechanism

Typical time scale:

1,Disk evaporation: > hundreds seconds

2,Magnetic re-connection: seconds or less

Corona/disk configuration

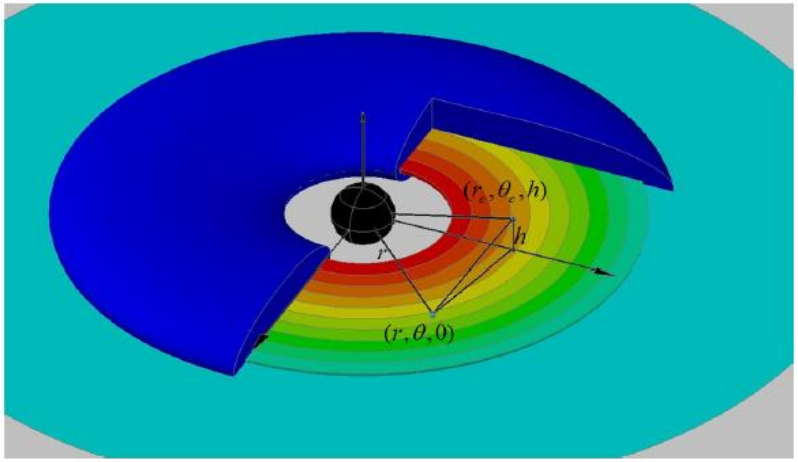
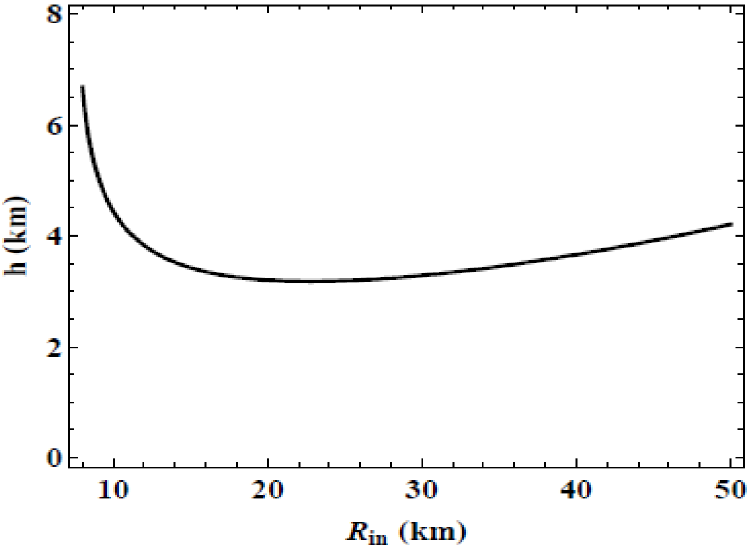


Figure 7. The NS-disc-corona system adopted in our analysis. The blue pancake represents the corona (in order to look at it more clearly, we cut a cross section). The colors in the annular rings show a cooling accretion disk at larger radii.



Size & location of corona (Reis & Miller 2013 ApJ 769 7):

A few Rg on top of the disk
(lags in soft X-rays due to reflection of the disk, reverberation mapping of AGN),

Other issues?

Spectral shape of the continuum emission during burst?

Evolution of the hard X-ray shortage along outburst?

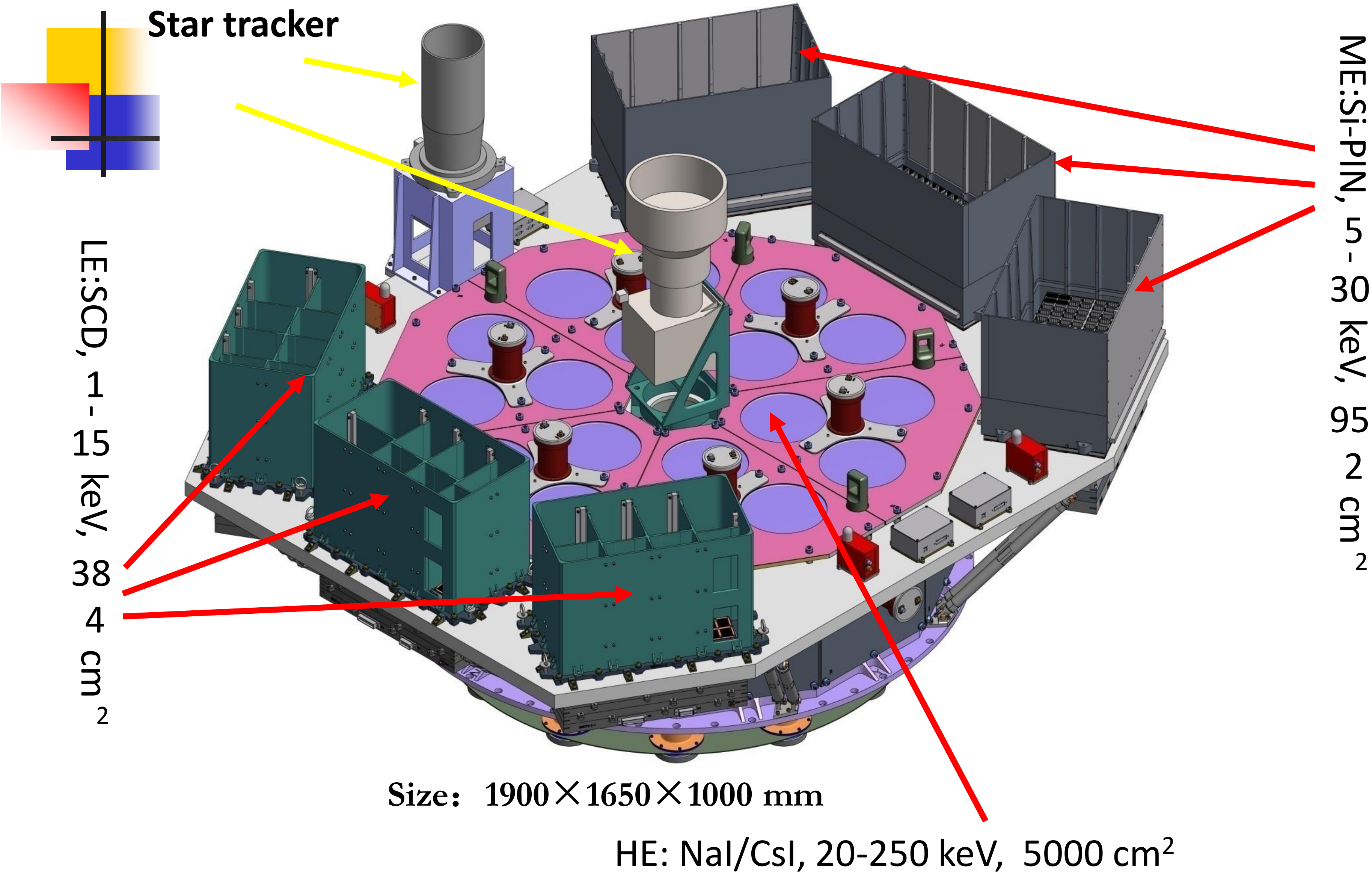
Missing of the hard X-ray shortage in some atolls?

Evolution of corona with jet monitored at radio band?

……

HXMT mission

HXMT payloads



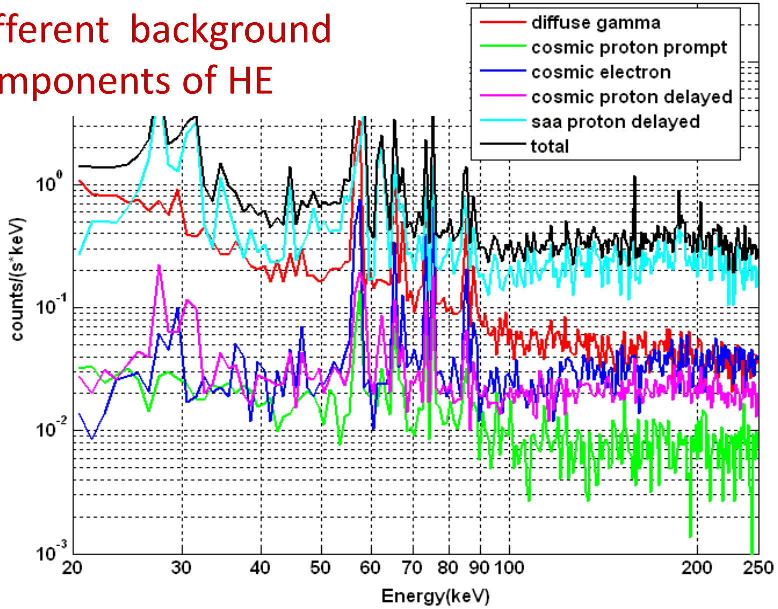
Characteristics of the HXMT Mission

Detectors	LE: SCD, 384 cm^2;ME : Si-PIN, 952 cm^2 HE : NaI/CsI, 5000 cm^2
Energy Range	LE: 1-15 keV;ME: 5-30 keV;HE: 20-250 keV
Time Resolution	HE: 25μs; ME: 180μs;LE: 1ms
Working Temperature	HE: 18±1℃; ME: -50~-20℃; LE: -80-45℃
Energy Resolution	LE: 2.5% @ 6 keV ME: 14% @ 17.8 keV HE: ≤16% @ 60 keV
Field of View of one module	LE: 6° ×1.6° ; 6° ×4° ; 60° ×3° ; blind; ME: 4° ×1° ; 4° ×4° ; blind; HE: 5.7° ×1.1° ; 5.7° ×5.7° ； blind
Source Location	<1' (20σ source)

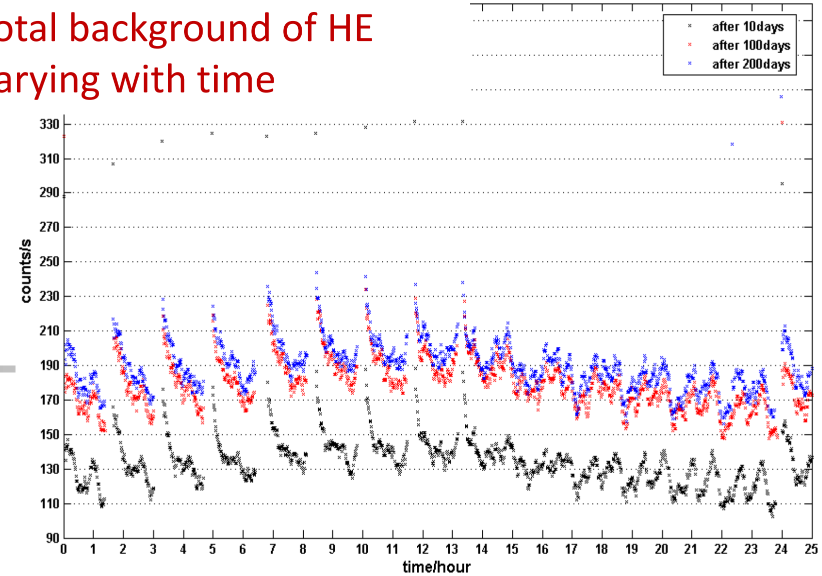
Characteristics of the HXMT Mission

Orbit	Altitude: ~550 km ; Inclination: ~43°
Attitude	Three-axis stabilized Control precision: ±0.1° Measurement accuracy: ±0.01°
Data Rate	LE: 3 Mbps; ME: 3 Mbps; HE: 300 kbps
Payload Mass	~1000 kg
Nominal Lifetime	4 years
Working Mode	Scan survey, small region scan, pointed observation

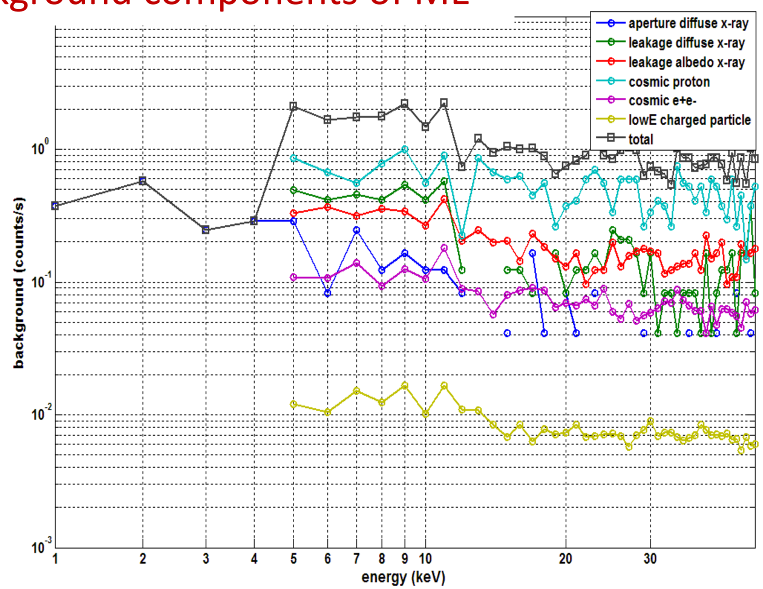
Different background components of HE



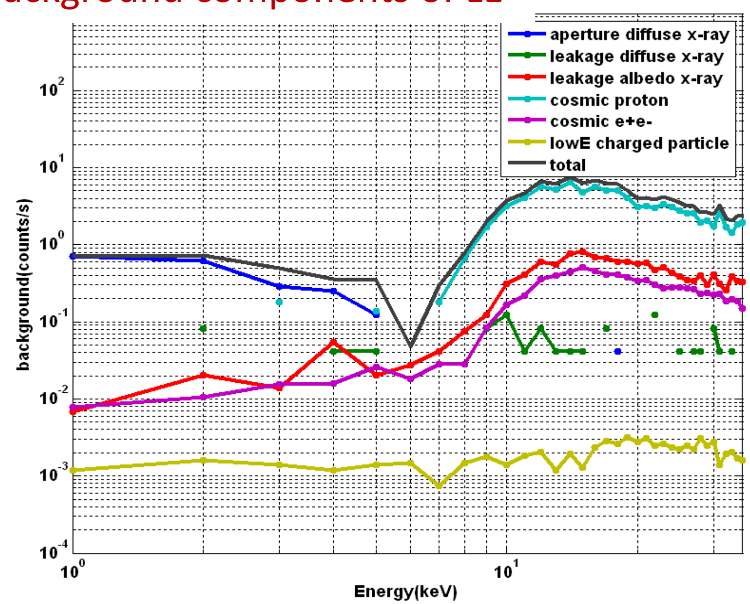
Total background of HE varying with time



Background components of ME

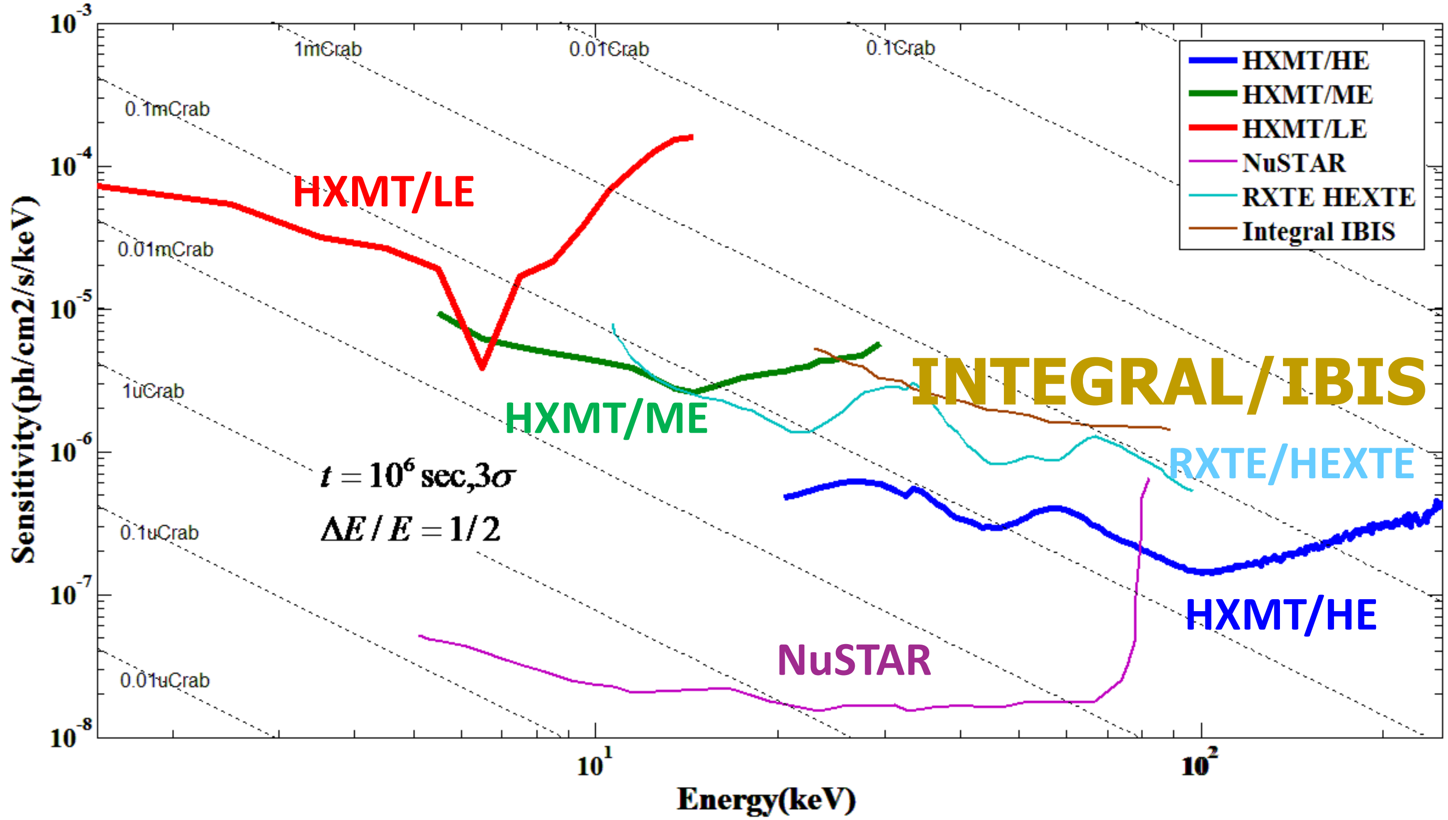


Background components of LE



Simulation of the in-orbit background of HXMT

Sensitivity



The sensitivities of the three telescopes of HXMT. The sensitivities of NuSTAR, INTEGRAL/IBIS and RXTE/HEXTE were reprinted from Koglin et al. (2005)[3].

Comparison between HXMT and other major hard X-ray telescopes

	HXMT	RXTE	INTEGRAL/IBIS	SWIFT	NuSTAR
Energy Band (keV)	LE: 0.8-15 ME: 5-30 HE: 15-250	PCA: 2-60 HEXTE: 15-250	15-10000	XRT: 0.5-10 BAT: 10-150	3-79
Detection Area (cm^2)	LE: 384 ME: 950 HE: 5000	PCA: 6000 HEXTE: 1600	2600	XRT: 110 BAT: 5200	847 @ 9 keV 60 @ 78 keV
Energy Resolution (eV)	150@ 6 keV 2500@ 20 keV 10000@60 keV	1200@6keV 10000@60 keV	8000@ 100 keV	150 @ 6 keV 3300 @ 60 keV	900 @ 60 keV
Time Resolution (ms)	LE: 1 ME: 0.18 HE: 0.012	PCA: 0.001 HEXTE: 0.006	0.06	XRT: 0.14, 2.2,2500 BAT: 0.1	0.1
Sensitivity (@100keV, 3σ, 10^5s, mCrab)	0.5	1.5	3.8	9	0.03 @ 20 keV

Sciences with HXMT

Large sky-area scan

- Diffuse X-ray emission: cosmic X-ray background; X-ray emission from the Galactic ridge and the Galactic center region
- Detection of new (transient) sources and constrain their broad band (1-250 keV) properties
- Follow up observation of gravitational wave bursts

Pointed observations

- X-ray binaries: multiwavelength temporal behaviors, broad band spectra and Fe emission line
- Monitoring of Blazars and bright AGNs

Merits reside in HXMT

Burst probe with HXMT

Advantages

- Coverage of a broad energy band (1-250keV)
- Large detection area at hard X-ray (5000 cm2 at above 20 keV)
- Good energy resolution at soft X-rays (below 15 keV, SCD)
- Free from pile up problem at soft X-rays (below15 keV, SCD)

Merits ?

- Measurement of the continuous emission prior to burst
- Measurement of the burst properties
- fa & hard X-ray shortage during burst

Simulations

Take the parameters from GS 1826-238, 4U1636-536 and IGRJ 17473-2721.

Models for Continuous emission (key parameters)

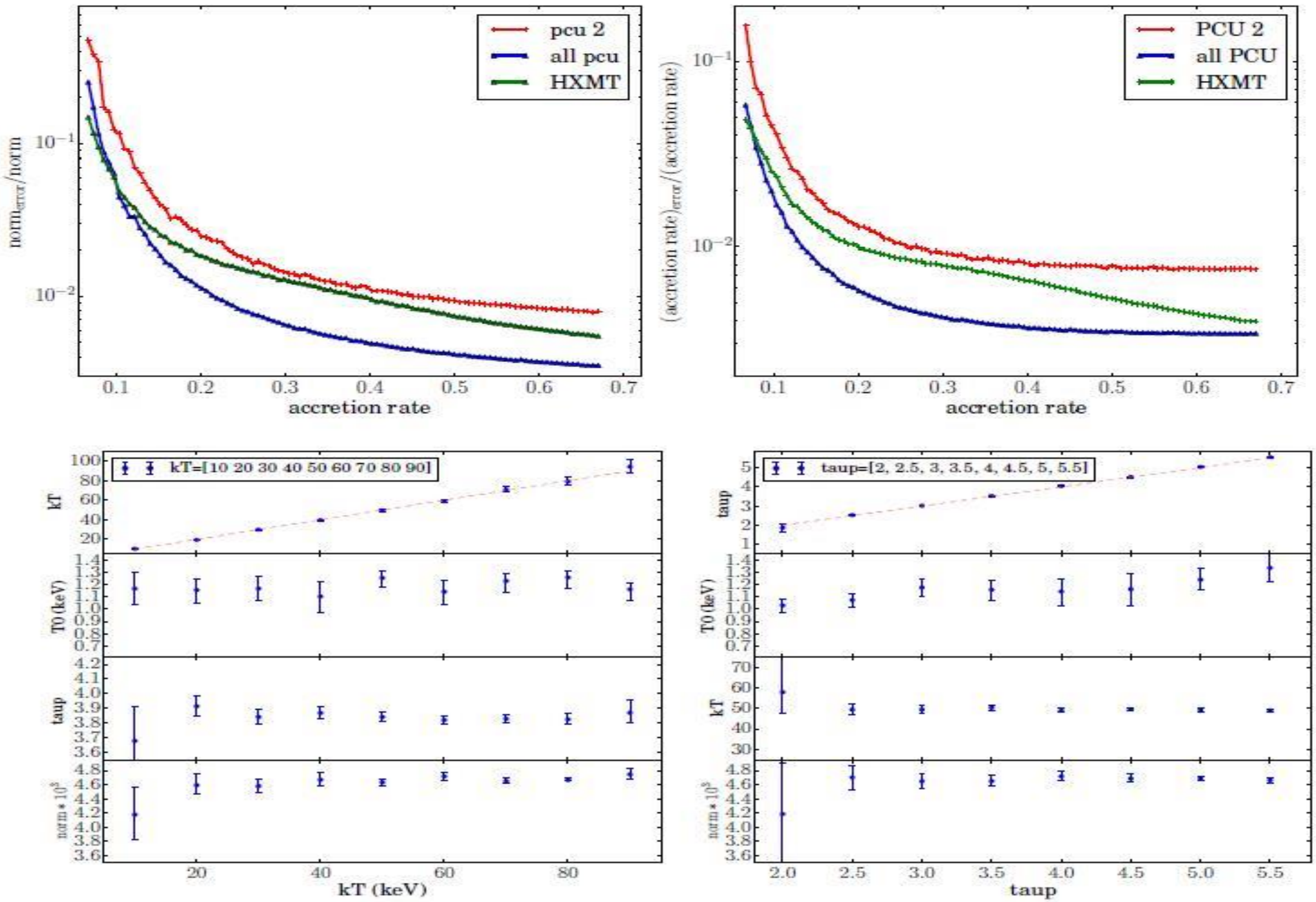
- soft X-rays: wabs*disko (norm., accretion rate)
- hard X-rays: Comptt (optical depth τ and corona Te)

Model for Burst: bbodyrad (temperature Te)

Model for burst + persistent emission

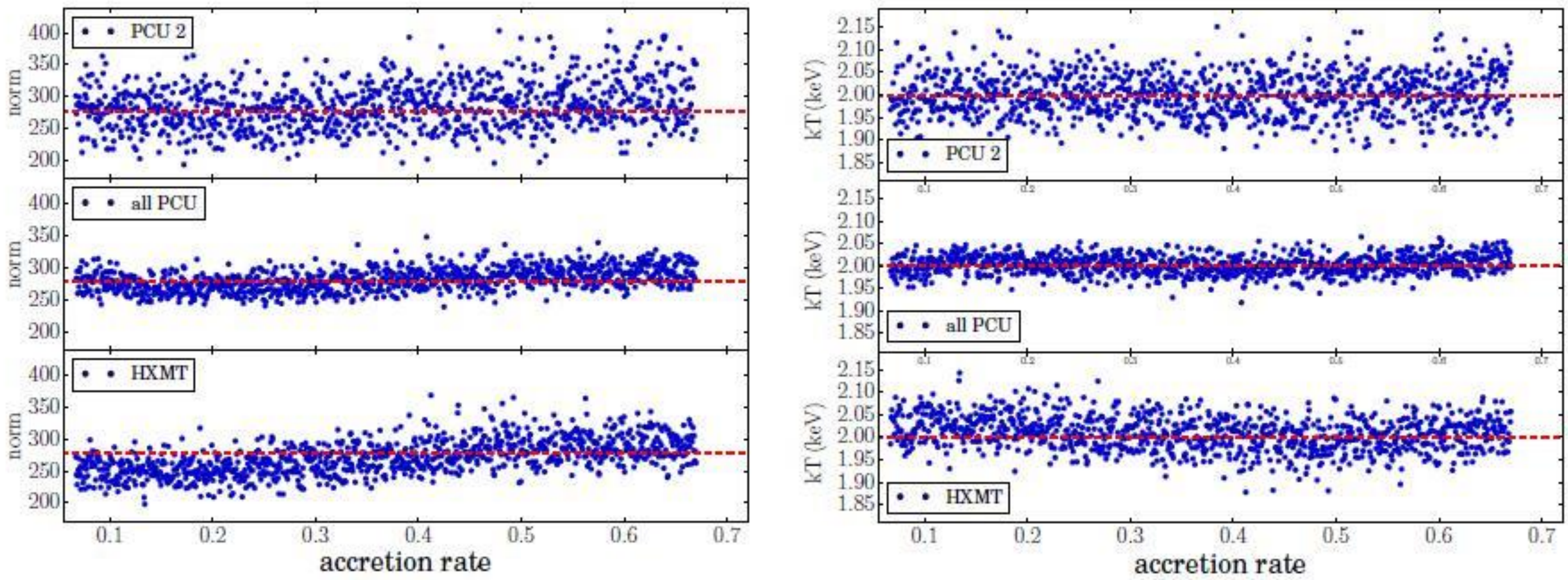
- soft X-rays: wabs*(bbodyrad+fa*disko) (fa)
- hard X-rays: wabs* cutoffpl (Ecut)

On the continuous spectrum

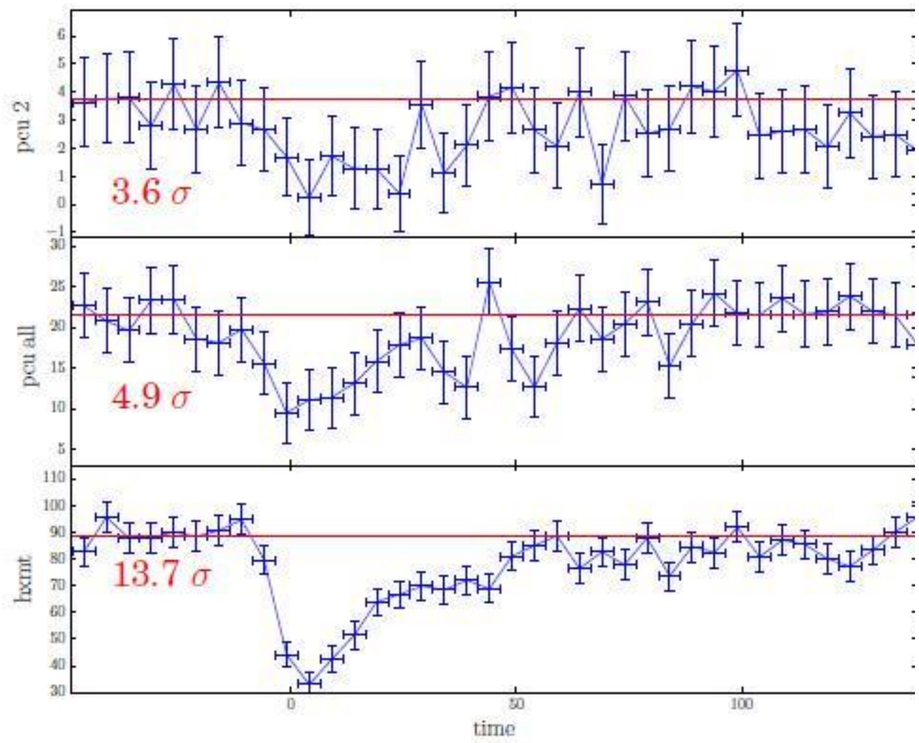


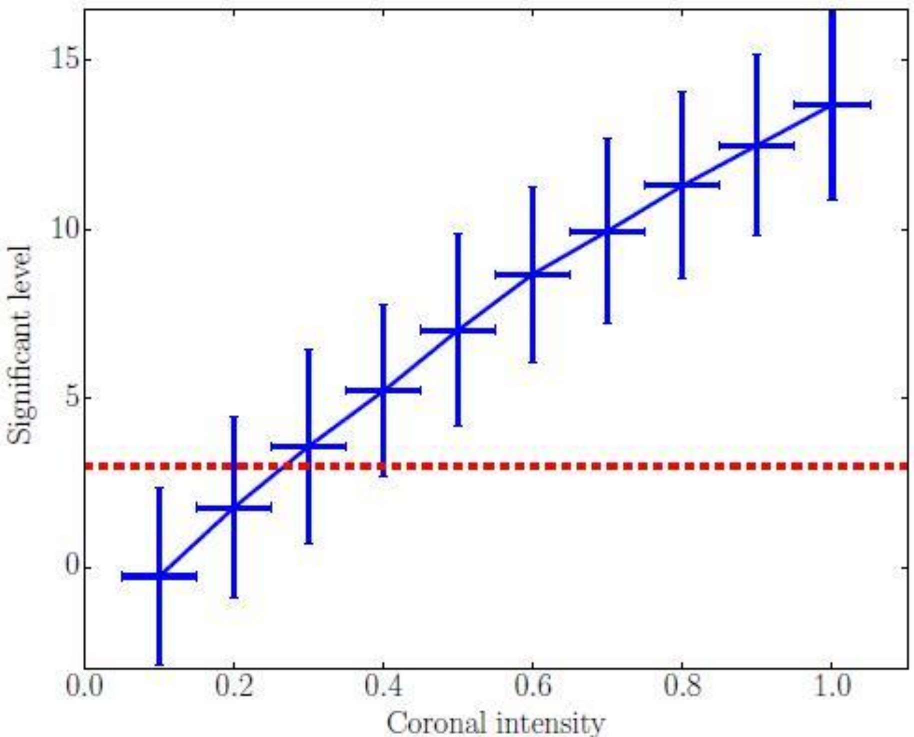
Parameters from GS 1826-238 & 4U1636-536

On the burst spectrum



On the hard spectrum of continuum + burst





Parameters from IGRJ 17473-2721

Merits with HXMT

1, precise measurement of the continuum spectrum prior to burst at hard X-rays.

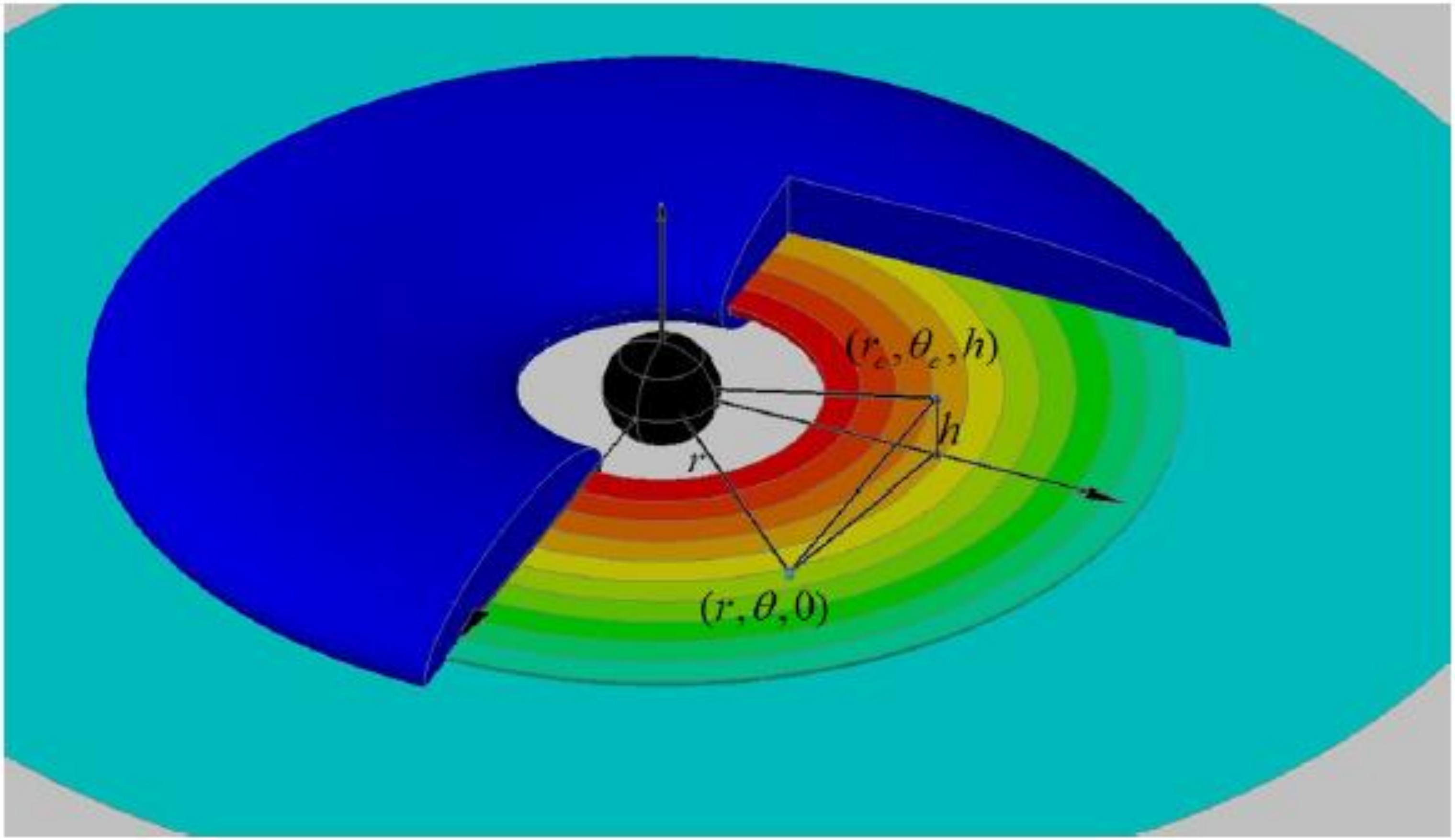
2, improvement on the statistics of hard X-ray shortages during burst.

->

more shortage sample; evolution with outburst

Thank you!

An application to XRB state transition



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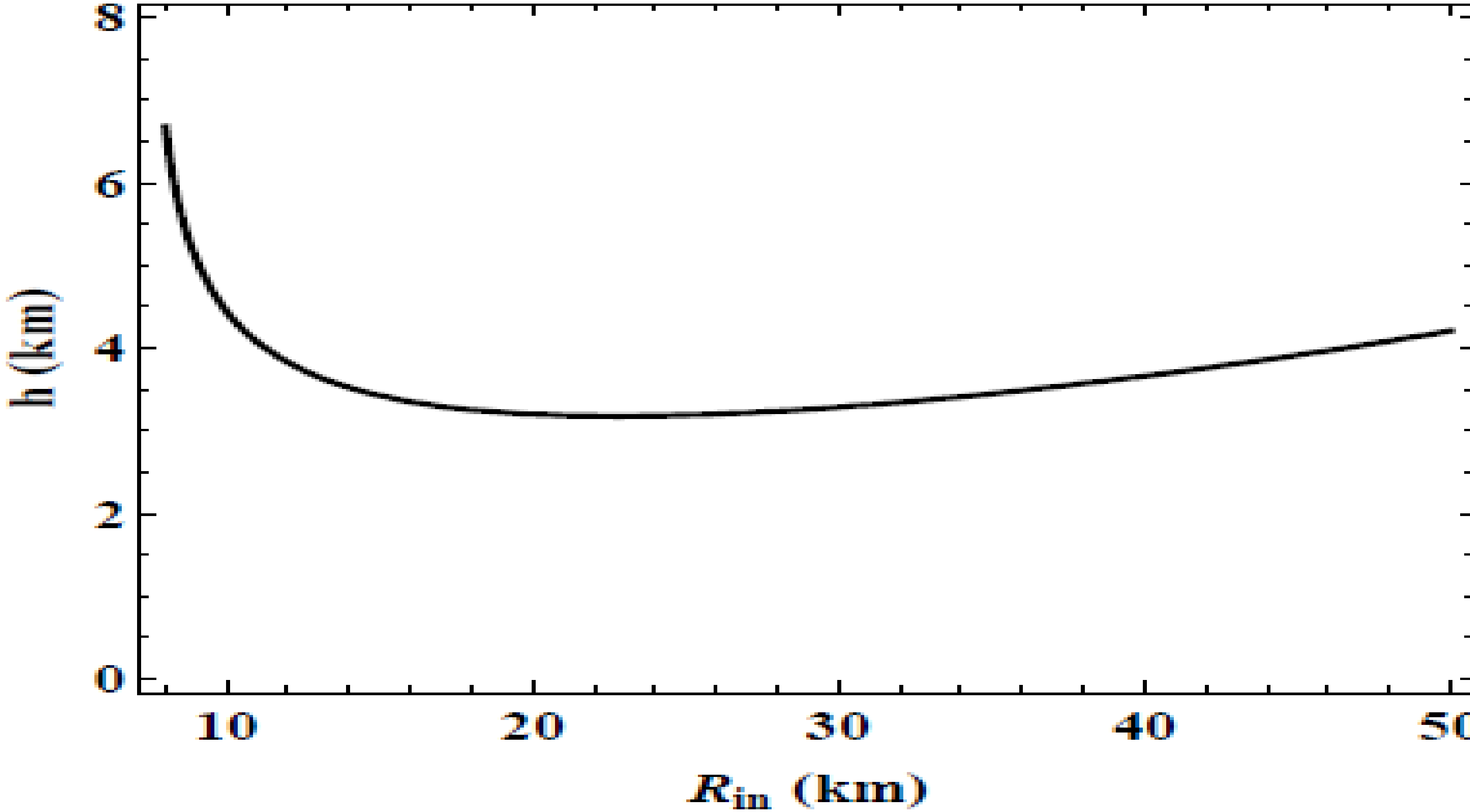


1,The corona is more likely cooled by disk emission at small inner radius

2,At a larger inner disk radius, in the LHS, the corona can be effectively cooled by disk emissions only if located in the vicinity of the disk.

Comparison to the cotemporary corona researches (Corona issue addressed recently in literature)

In Worpel, Galloway, & Price 2013 (astro-ph/1303.4824)
In 2-10 keV, the persistent emission can be promoted by a factor of a few compared to the pre-burst value.

Bust cooling of the corona that produce temporarily a inner disk? If so, it has to be evaporated again, otherwise the persistent emission increase after each burst;

Our findings show persistent emission change a lot while bursting, not a proper handling of a constant persistent spectral shape;

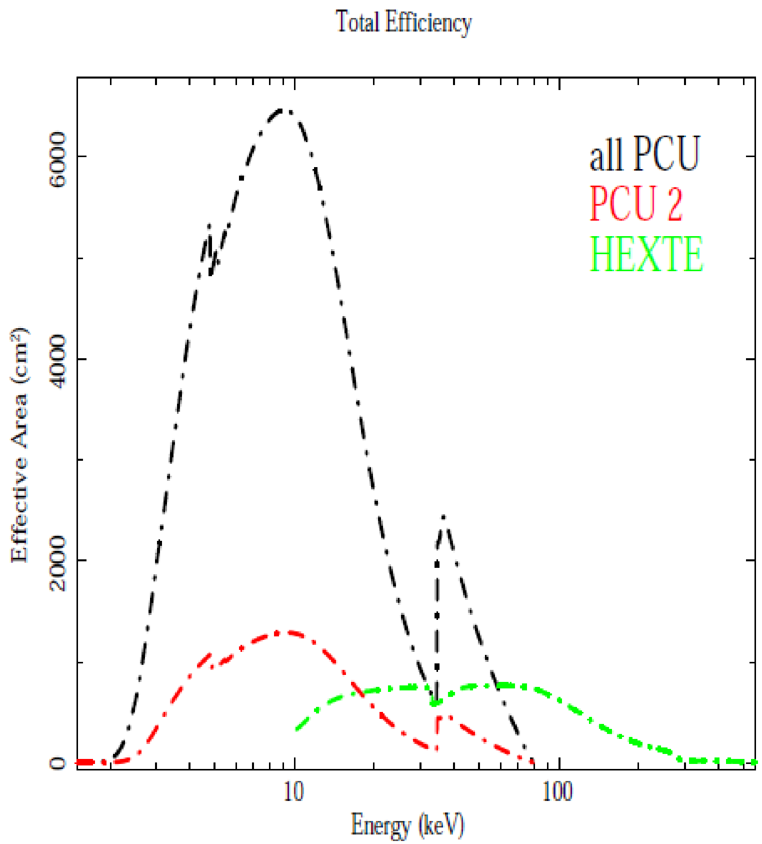
Comparison to the cotemporary corona researches (Corona issue addressed recently in literature)

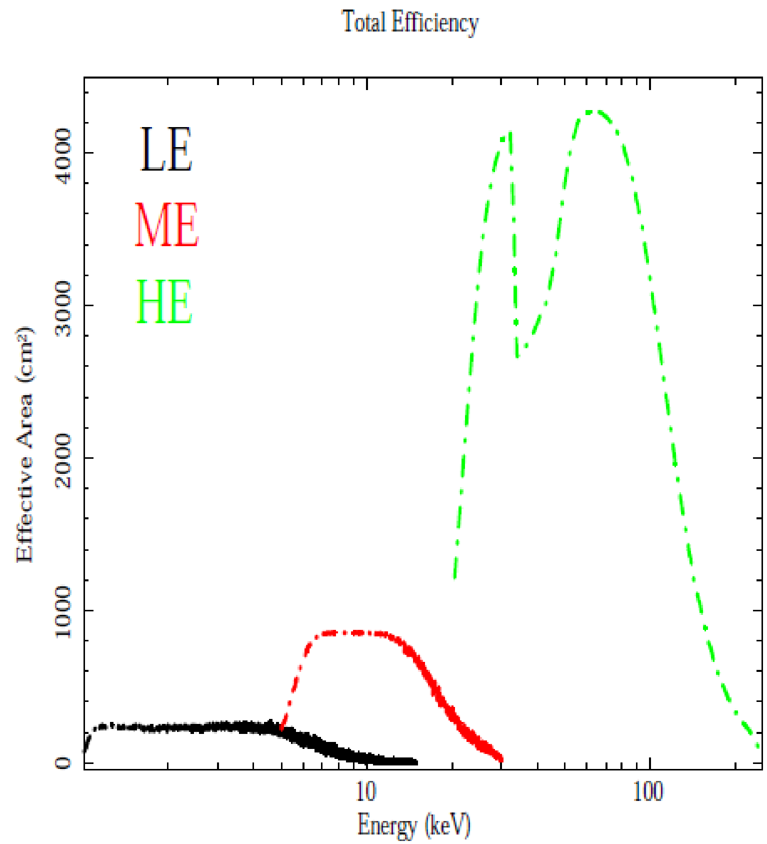
Size & location of corona : (Reis & Miller 2013 ApJ 769 7)
Highly compact

A few Rg on top of the disk (lags in soft X-rays due to reflection of the disk, reverberation mapping of AGN)
~20 Rg along the disk (microlensing effect for corona at X-ray of AGN)

Favor the scenario:

Emission by magnetic reconnection in the innermost disk
And/or
Process in the compact base of a central relativistic jet.





BCD： at 30-60 keV
PCA: about 1ct/s
HEXTE： about a factor of 10 higher.