UNIVERSITY OF AMSTERDAM

Revealing the Nature of a Very Luminous Globular Cluster X-ray Source in M31 Galaxy

High Energy View of Accreting Objects: X-ray binaries Section
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Observation of Bo375 X-ray Source

Bo375 X-ray source was first discovered by Einstein High Resolution Imager (HRI) in 1979 during M31 survey observations. Later, it was also observed with ROSAT, ASCA, as well as many other on going X-ray satellites such as Chandra, XMM-Newton, Suzaku and Swift.

Di Stefano et al. (2002) conducted a Chandra survey of selected regions of M31, and found that the luminous source in their regions was associated with the globular cluster Bo375.

For more than 30 years, the source has been observed many times, and the luminosity has been found to be persistent all time (Lx > 4E38 ergs/s)

It is worth noting that the brightest GC X-ray source in our Milky Way galaxy is in the order of 10^37 ergs/s, indicating that there might be another class of X-ray sources which we do not see in our own galaxy.

Neutron Star or Black Hole?

what produces such high luminosity?

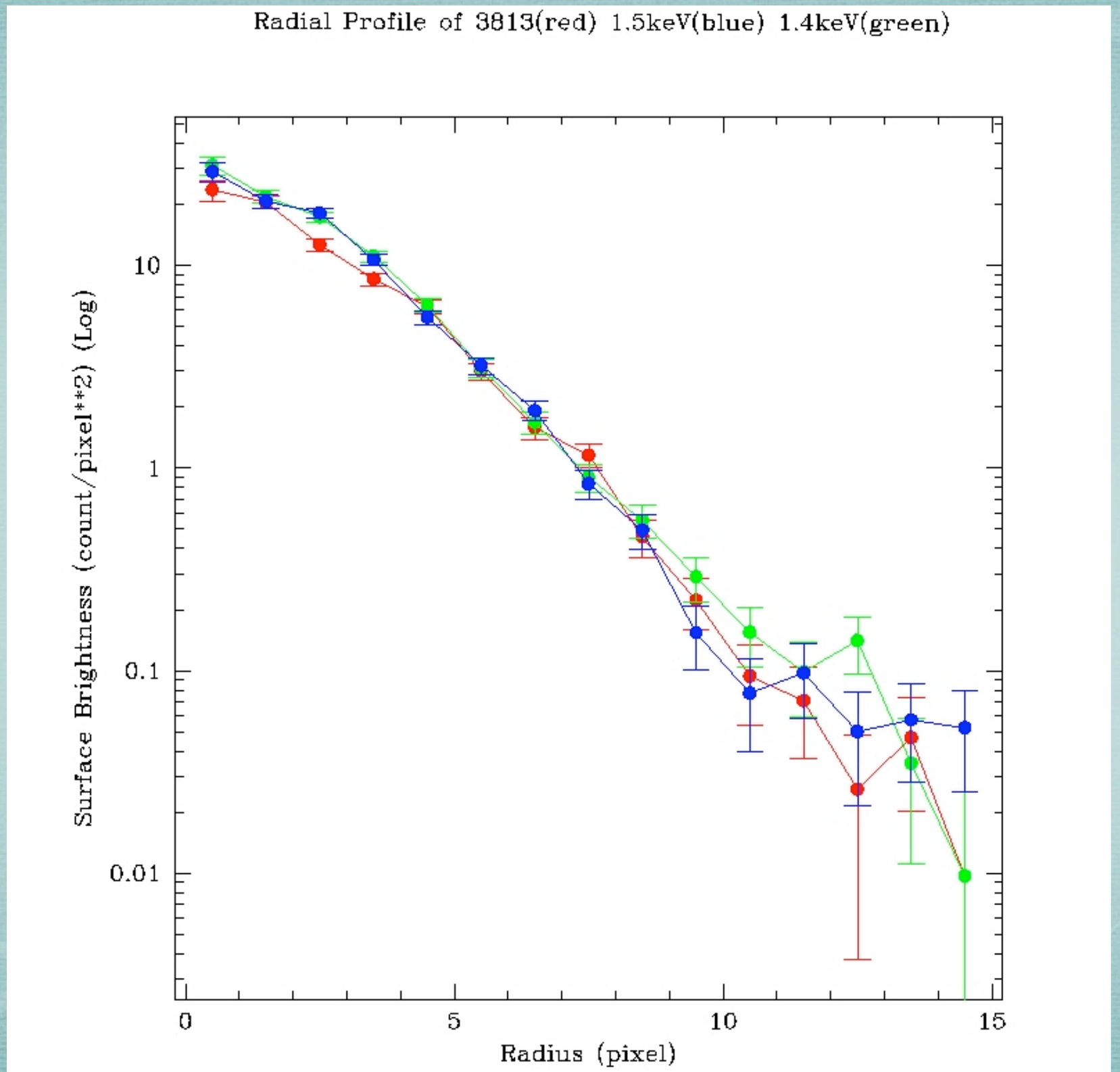
- the source might contain multiple components
- the source radiation might be beamed

Observation Log of Bo375

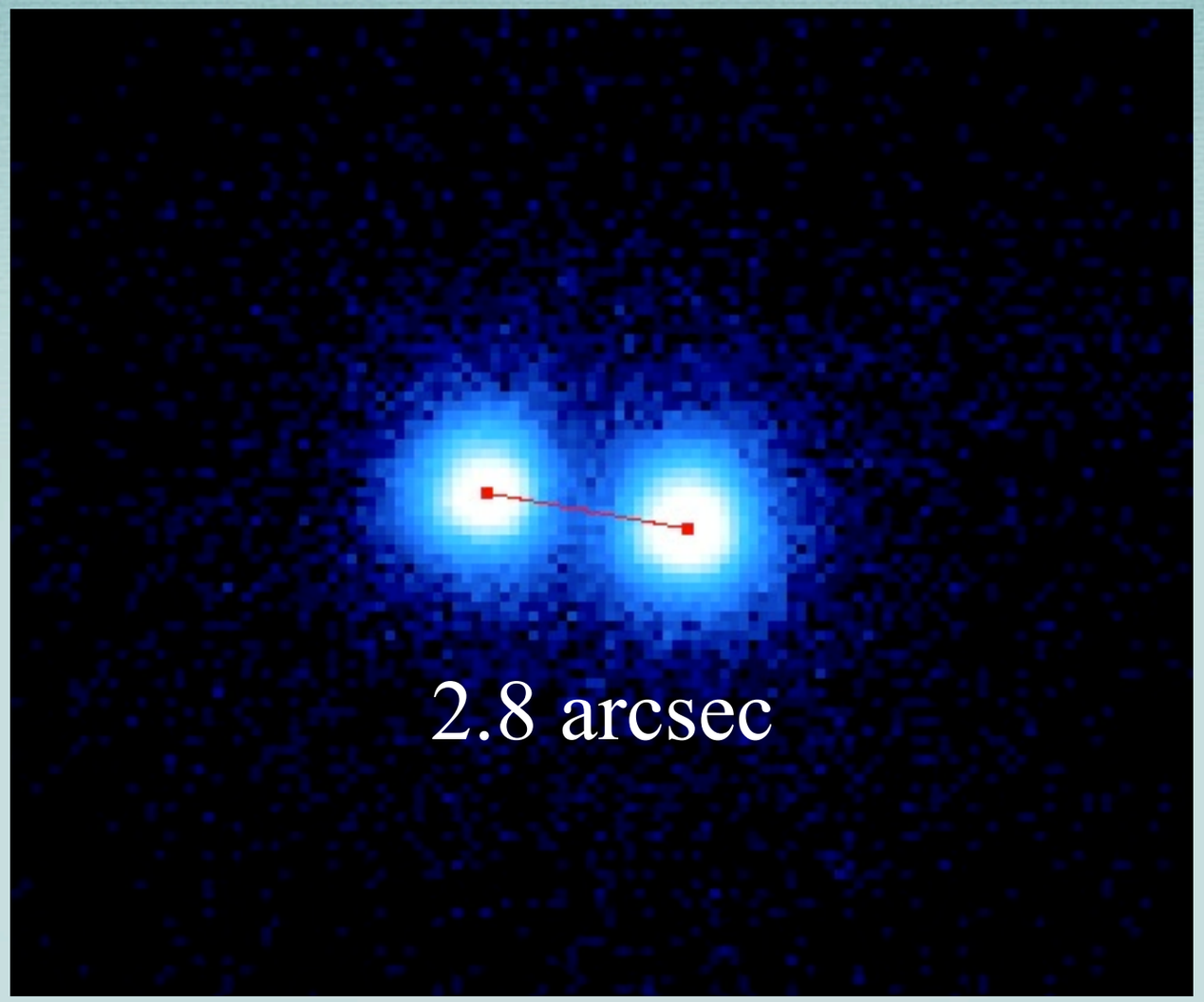
Date	ObsId	Observatory	Instrument	Exposure	Remark
2000 – 11 – 01	2052	Chandra	ACIS-S	13.9 ks	Pile-up
2003 – 09 – 10	3813	Chandra	HRC-I	4.6 ks	
2004 – 11 – 25	4541	Chandra	ACIS-S	25.6 ks	Pile-up
2004 – 11 – 26	6167	Chandra	ACIS-S	24.2 ks	Pile-up
2006 – 07 – 08	0403530201	XMM-Newton	EPIC-PN	13.3 ks	Timing Mode
2006 – 07 – 10	0403530301	XMM-Newton	EPIC-PN	18.0 ks	Timing Mode
2006 – 07 – 12	0403530401	XMM-Newton	EPIC-PN	16.2 ks	Timing Mode
2006 – 07 – 14	0403530501	XMM-Newton	EPIC-PN	14.9 ks	Timing Mode
2006 – 07 – 16	0403530601	XMM-Newton	EPIC-PN	18.0 ks	Timing Mode
2007 – 01 – 02	0402561201	XMM-Newton	EPIC-PN	63.2 ks	Imaging Mode
2007 – 02 – 04	701028010	Suzaku	XIS0 XIS1 XIS3	12.8 ks	
2007 – 02 – 06	701028020	Suzaku	XIS0 XIS1 XIS3	15.5 ks	
2007 – 02 – 11	701028030	Suzaku	XIS0 XIS1 XIS3	12.5 ks	
2008 – 05 – 28	22001	Swift	XRT	3.4 ks	
2008 – 06 – 01	28001	Swift	XRT	2.8 ks	
2008 – 07 – 26	28003	Swift	XRT	4.9 ks	

A series of Chandra HRC-I 1.0 ks observations from 1999 to 2002 were also used to construct the long-term lightcurve of Bo375.

Radial Profile of Bo375 Chandra Observation



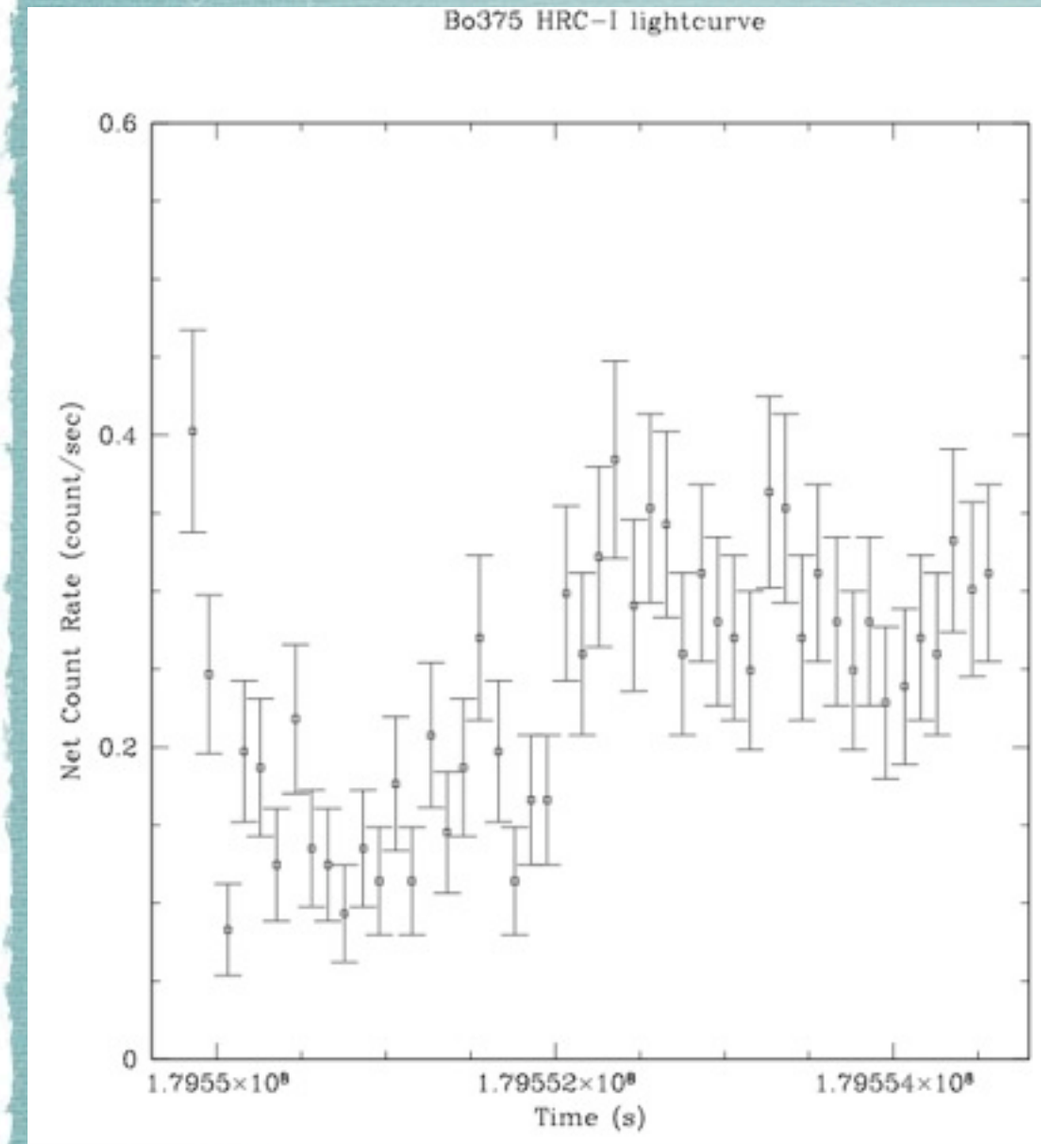
Example using M15

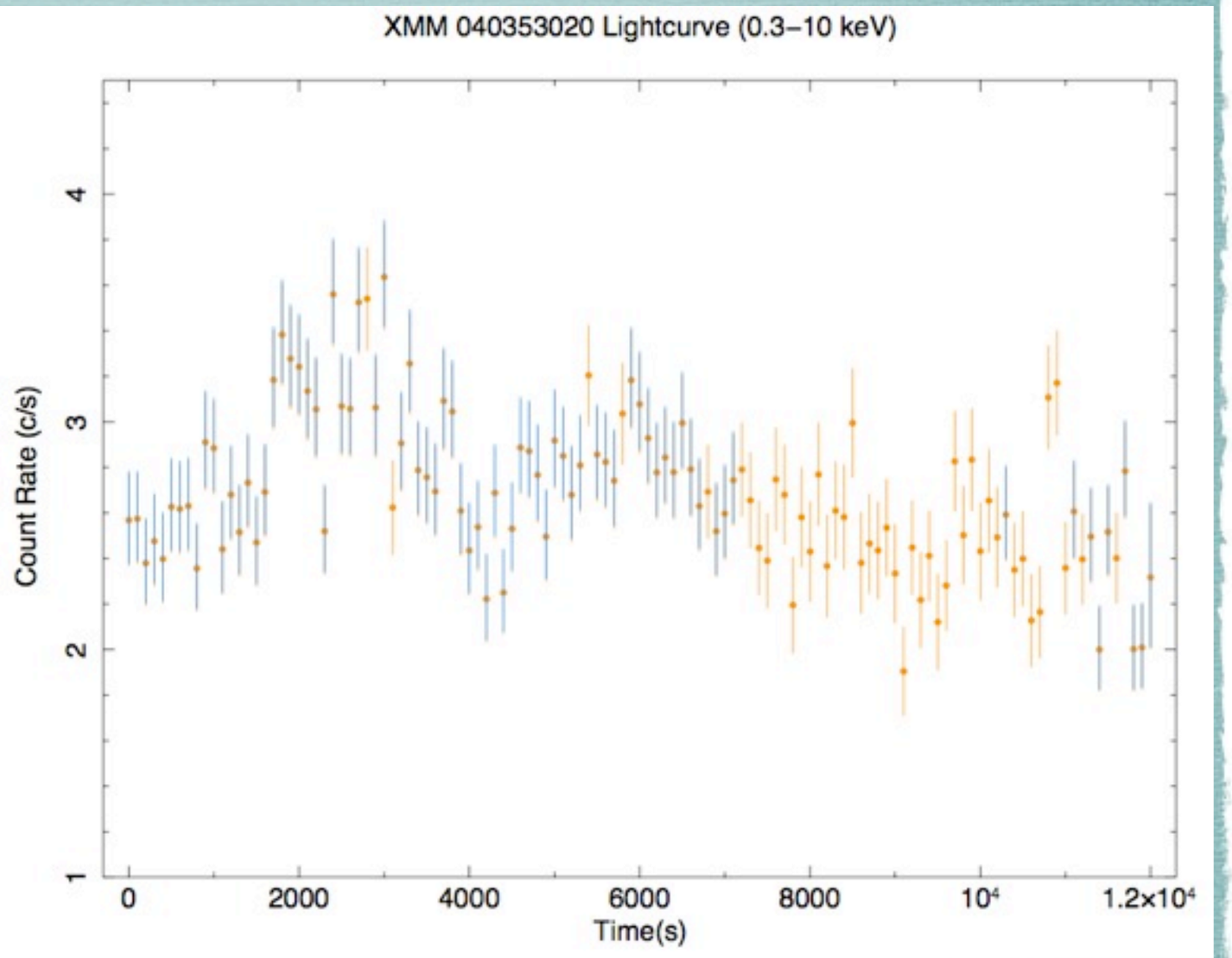


Assuming a distance of 9.98 kpc to M15, we can calculate the distance between these two sources. Apply the distance to Bo375 (distance to M31 is 780 kpc), the corresponding angular separation is 0.036”.

Using 0.5” as Chandra limit for angular resolution, that gives ~2pc.

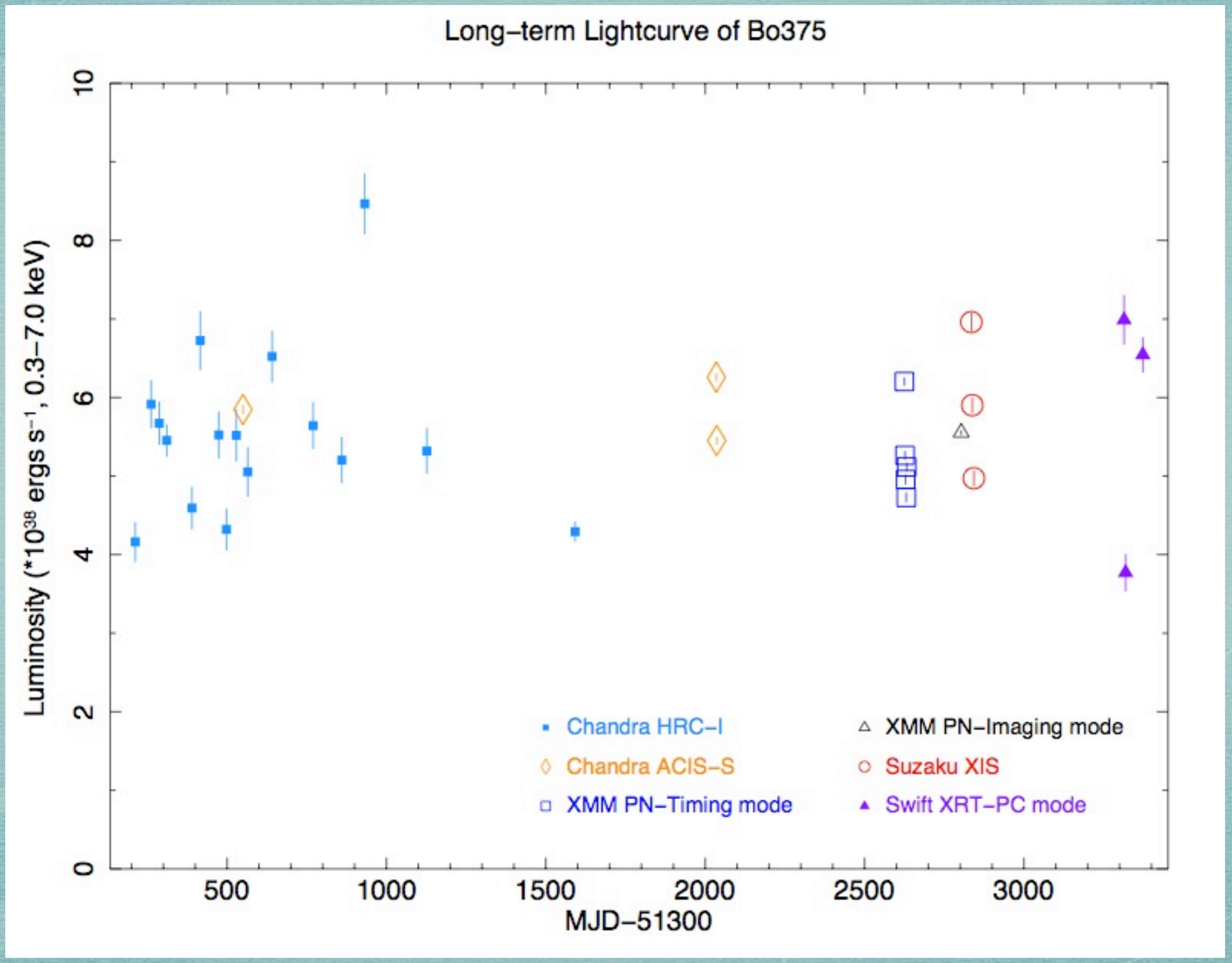
Short-term Lightcurve of Bo375



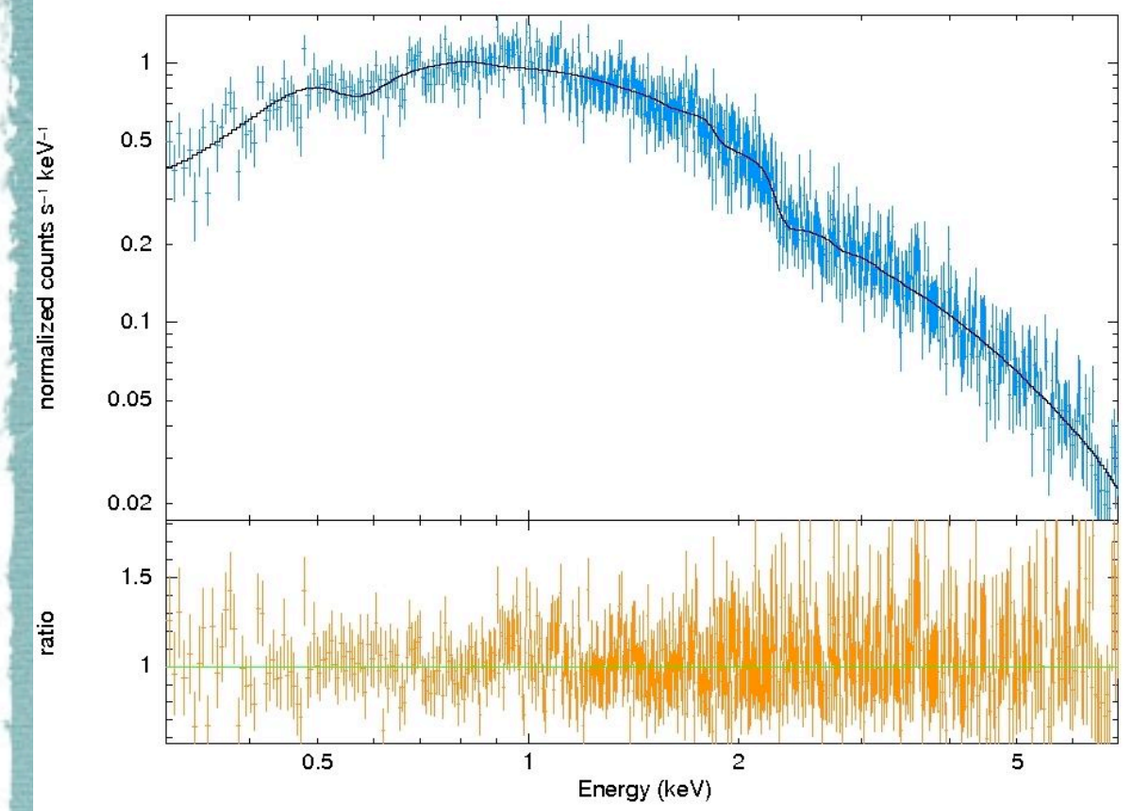


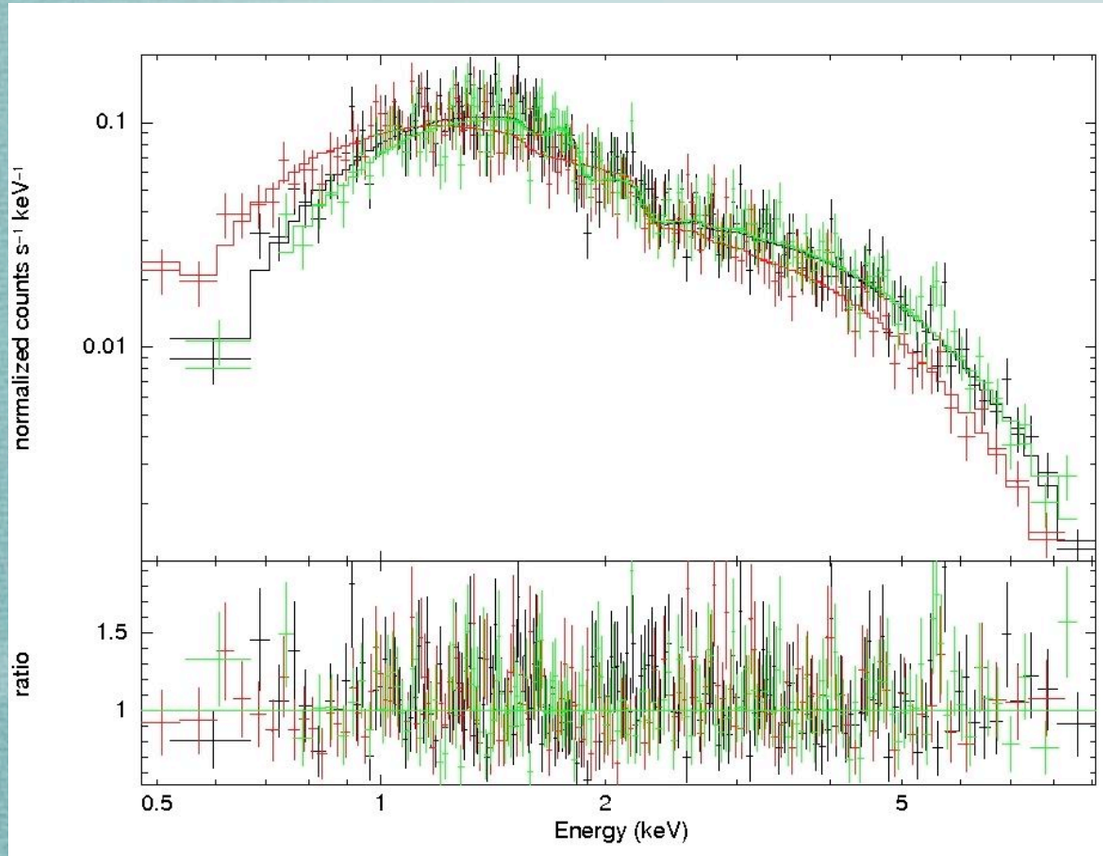
Chandra HRC and XMM-Newton PN-timing mode short-term lightcurves of Bo375 with 100 second time resolution.

Multi-Mission Long-term Lightcurve



XMM-Newton and Suzaku Spectra





The spectra are best fitted with an absorbed power law plus additional thermal component model.

ftest result shows that an additional thermal component is significant and required.

<-- Simultaneous spectral fit of Suzaku XIS0, XIS1 and XIS3 (0.3 – 10 keV) detectors of Bo375.

Pow+ BB Model

Gamma: ~1.83
kT: 0.92 keV
Flux: 9.2E-12 erg/s/cm^2
BB contribution: 22%
Effective Radius: ~40 km

Pow + Diskbb Model

Gamma: ~ 1.87
T(in): 1.66 keV
Flux: 8.8E-12 erg/s/cm^2
Diskbb contribution: 54%
Radius: ~15 km [cos(0)]

Not typical low/hard state. Although the photon index is similar, but the luminosity is too high.

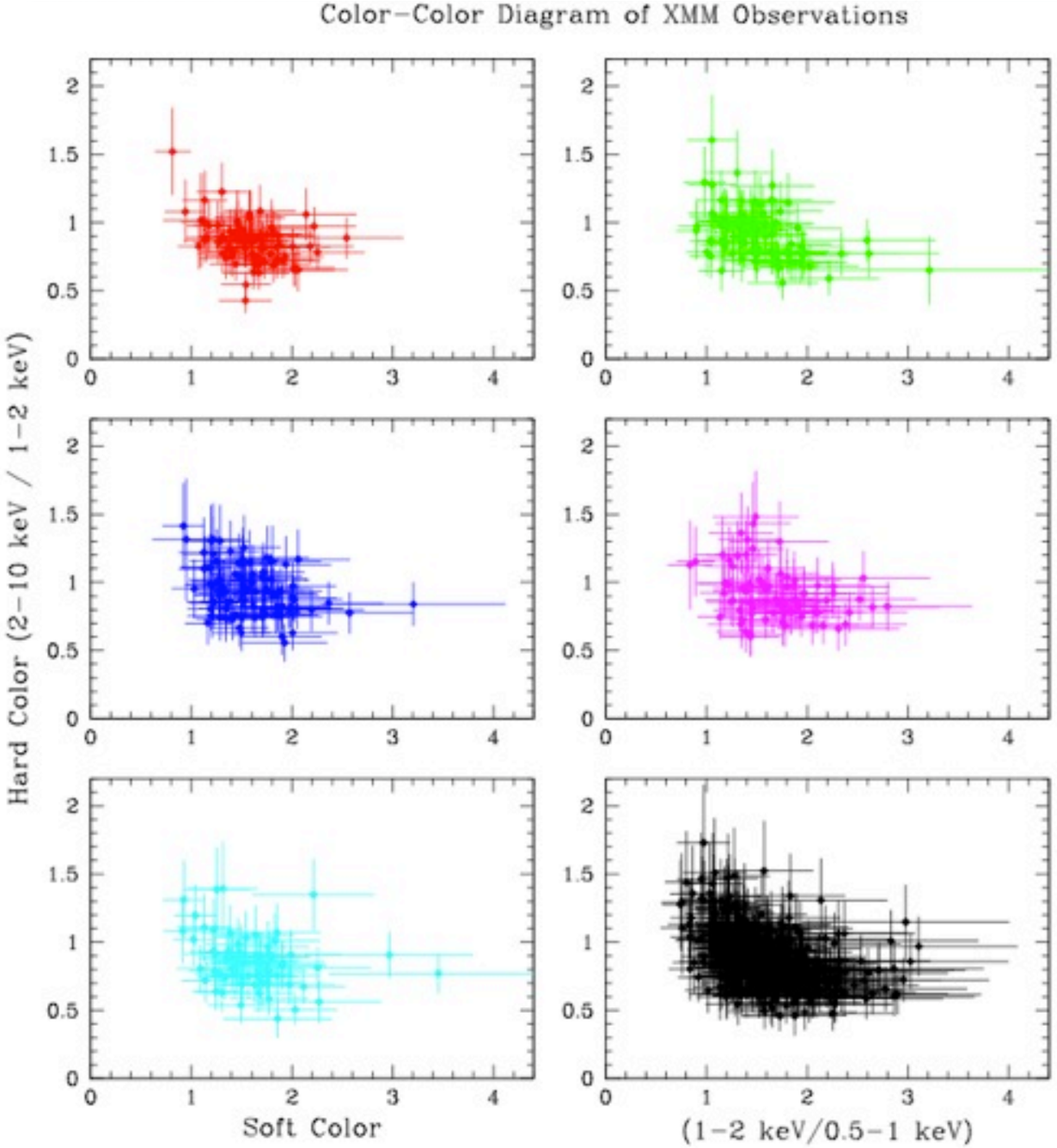
Not high/soft state, because the power-law contribution is too large.

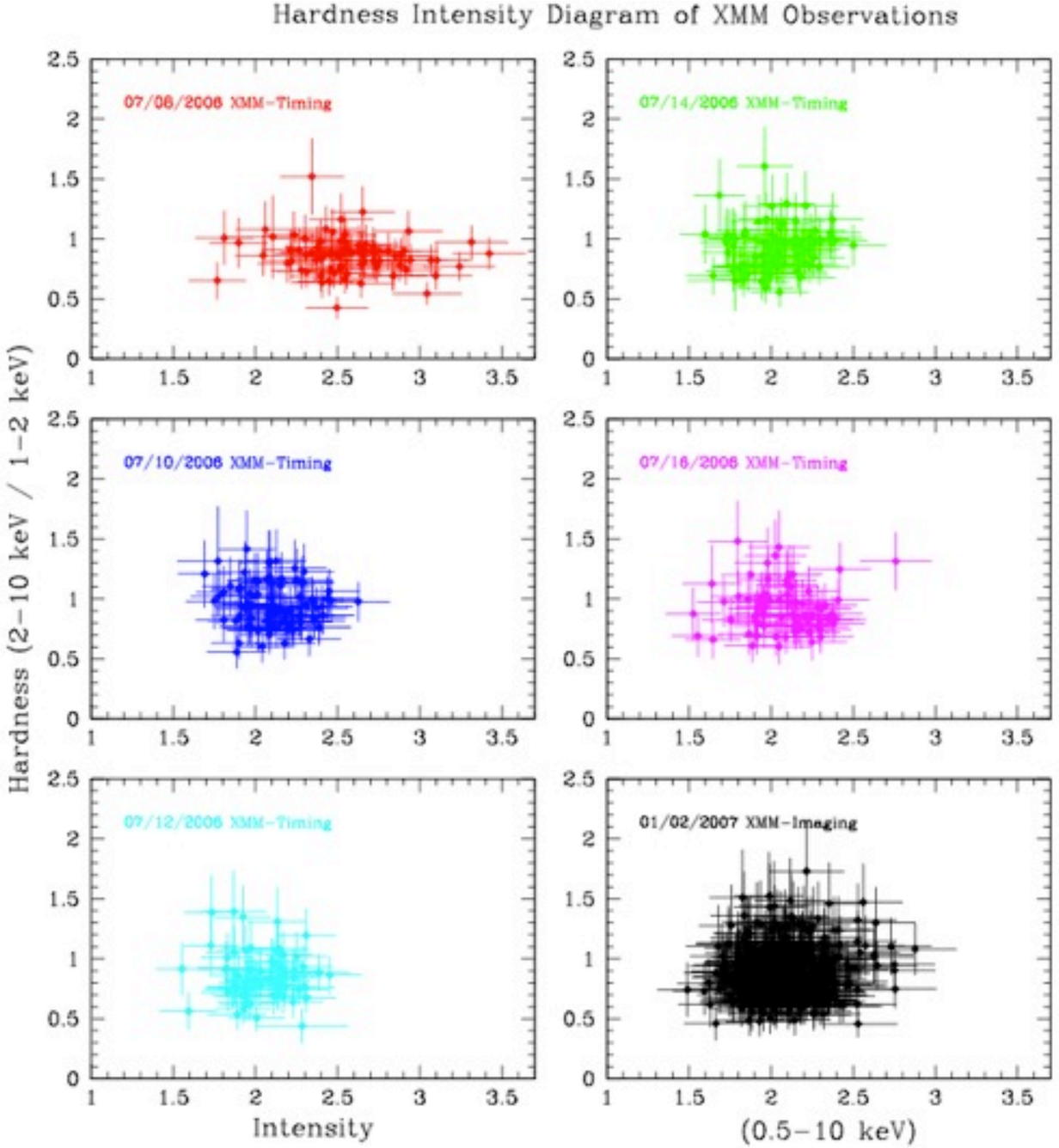
More likely to be "Very High" state, or "Intermediate Soft" state for a BH. (Horizontal branch for NS case)

Still unusual as typical Galactic BH do not stay at very high state for such a long time. Moreover, it does not have typical BH transient property.

Unusual for a NS to accretes at 3-5 super-Eddington for such a long time as well.

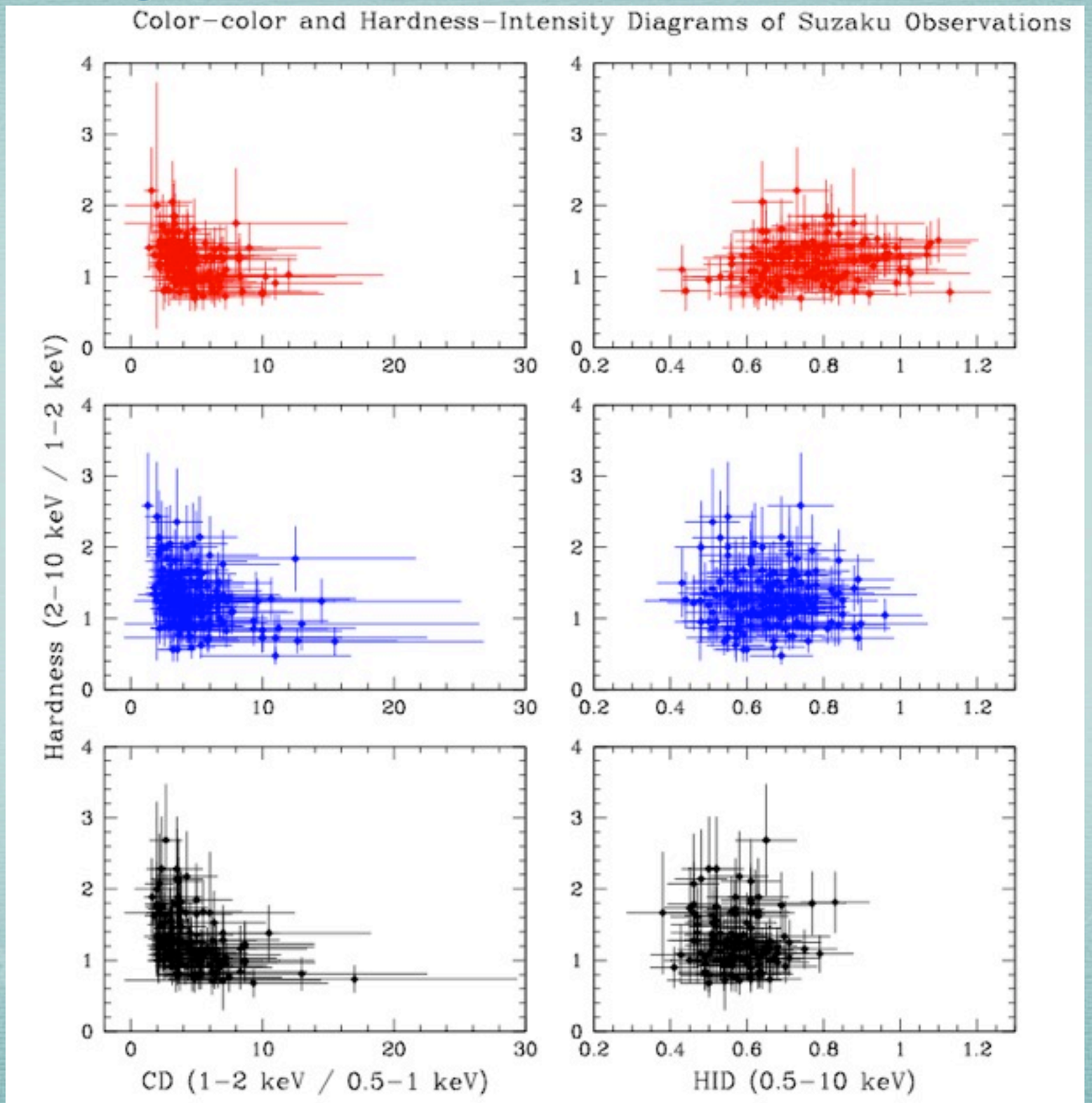
Color-Color and Hardness Intensity diagrams of XMM observations



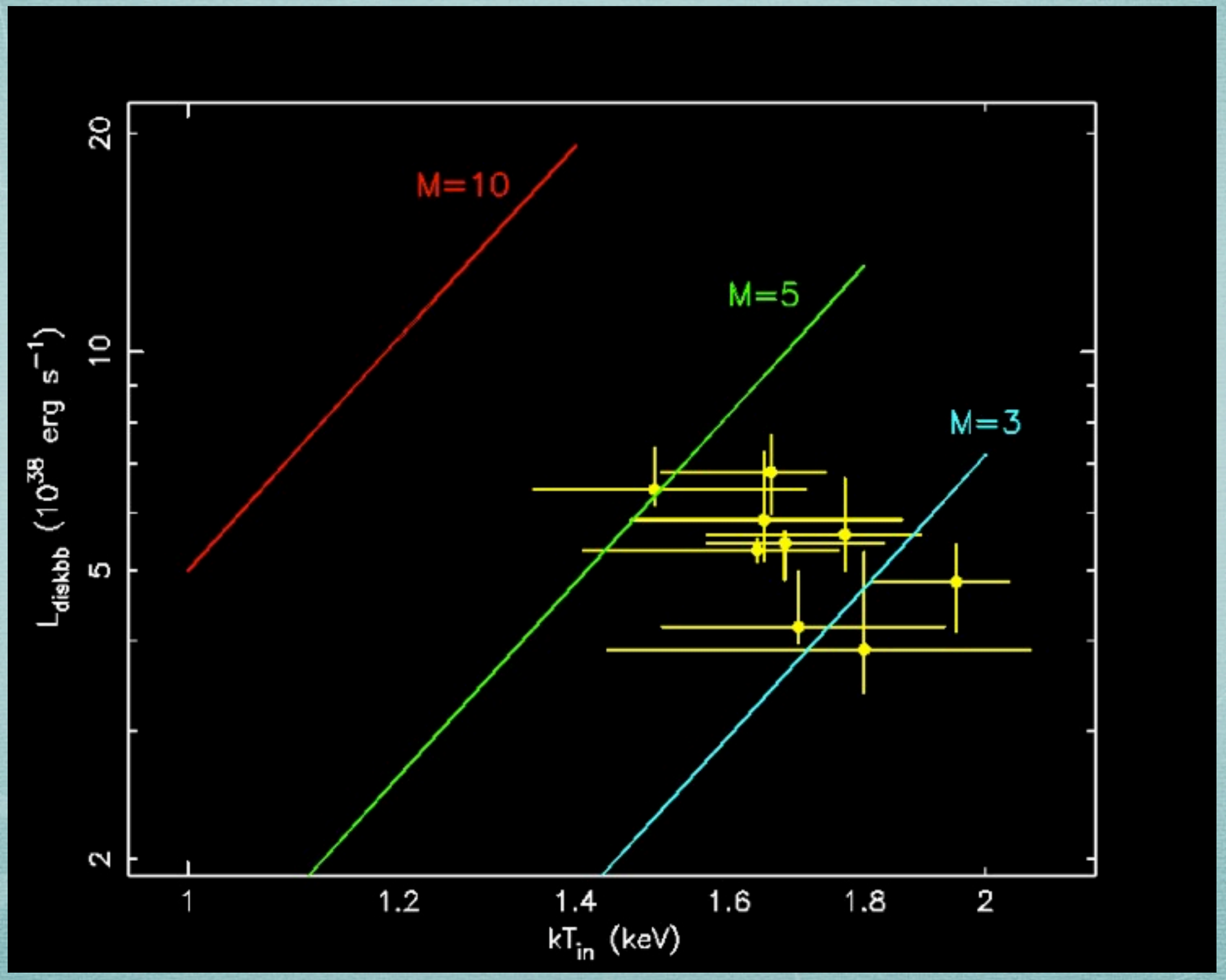


The hard color is the ratio of hard (2-10 keV) energy band over medium (1-2 keV) energy band.
The soft color is the ratio of the medium energy band over soft (0.5-1keV) energy band.
Total energy intensity is from 0.5-10 keV.

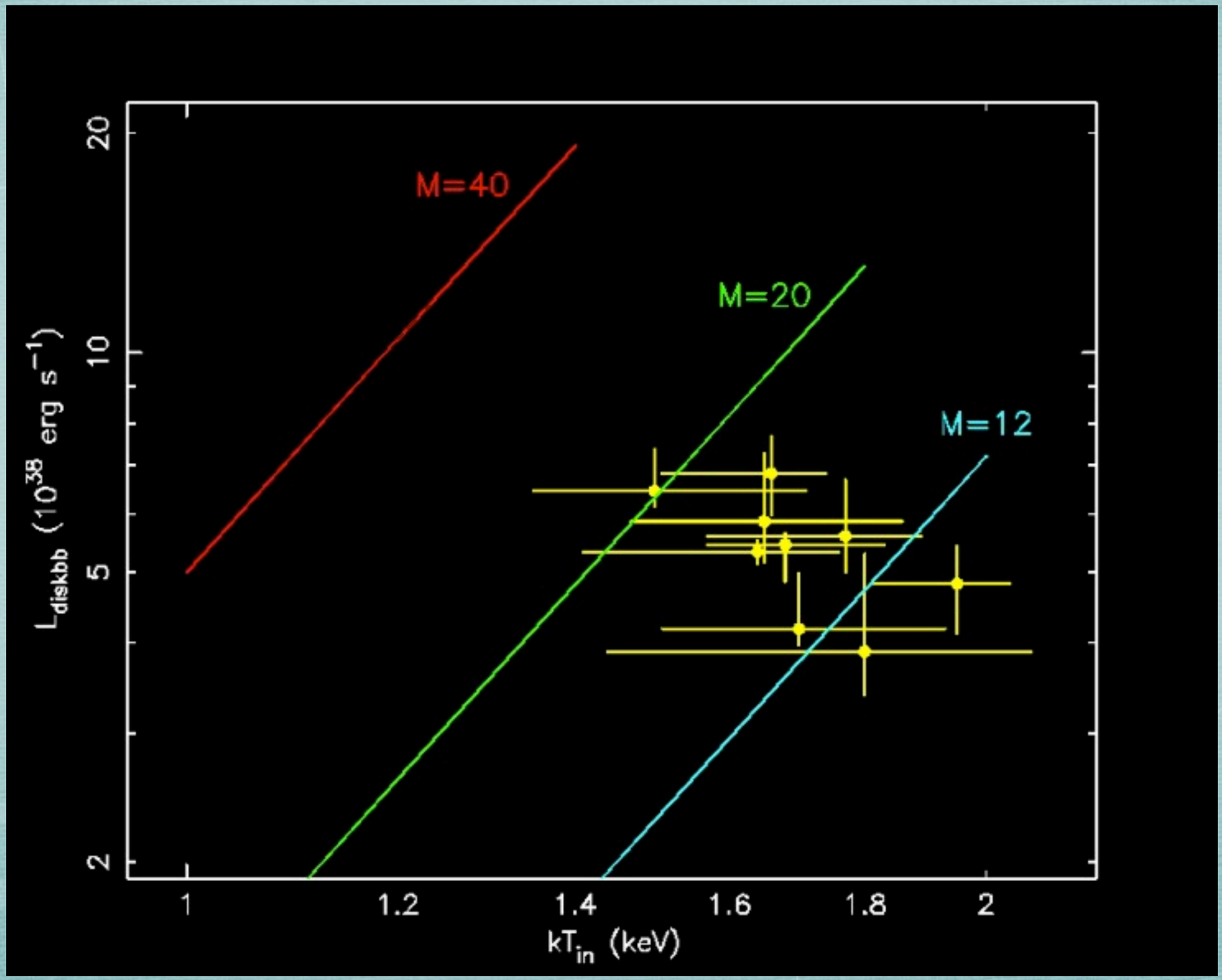
Color-Color and Hardness Intensity diagrams of Suzaku observations



Temperature-Luminosity diagram of Bo375 (Schwarzschild black hole)



Temperature-Luminosity diagram of Bo375 (Kerr black hole)



Summary

- Most luminous GC X-ray source in the local group. Not due to source superposition. Even if Bo375 contains more than one source, at least one dominates most of the energy output.

- Relativistic beaming is unlikely, because of the persistent source brightness, small short-term variability, and the significant fraction of thermal component found in the energy spectra.

- It might be a neutron star accreting in an unusual way, which produces at least 4 times super-Eddington luminosity and persistently bright for 30 years. (Horizontal branch for a NS)

- It might be a Schwarzschild black hole in the VH state, if it has a much smaller mass (3~4 Msolar) than we usually find in our own Galaxy. Or it could be a fast-spinning Kerr black hole.