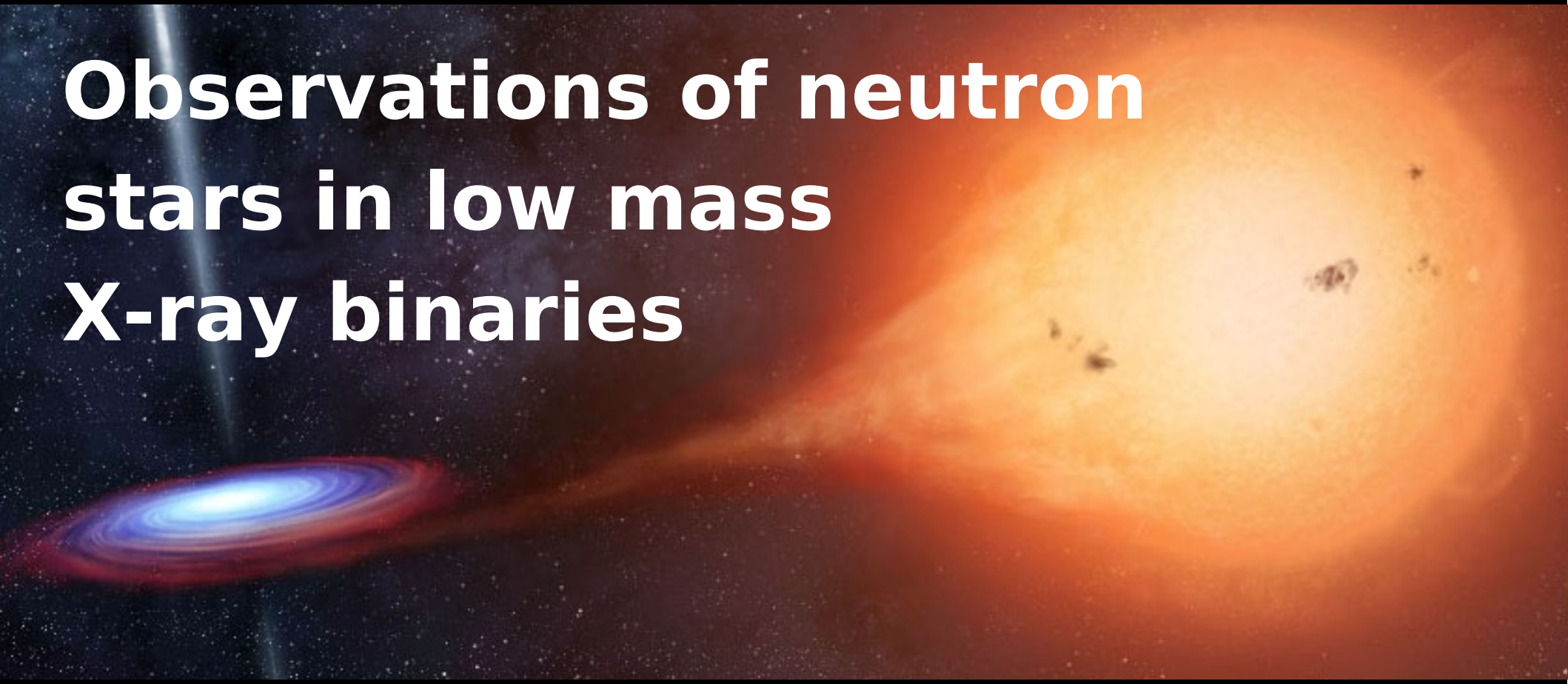


Observations of neutron stars in low mass X-ray binaries

M. Revnivtsev

IKI, Moscow, Russia

Neutron stars in galaxies

- ***Single (isolated) NS***
- ***NS in binaries***

(LMXBs, HMXBs)

Accretion in binaries allows us to probe different aspects of NSs

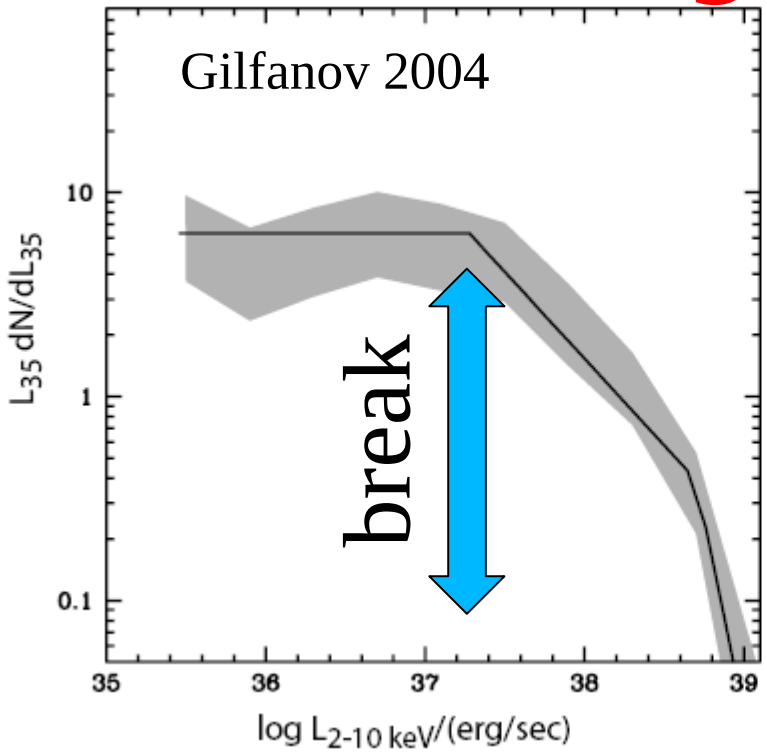
1)NS mass/radius

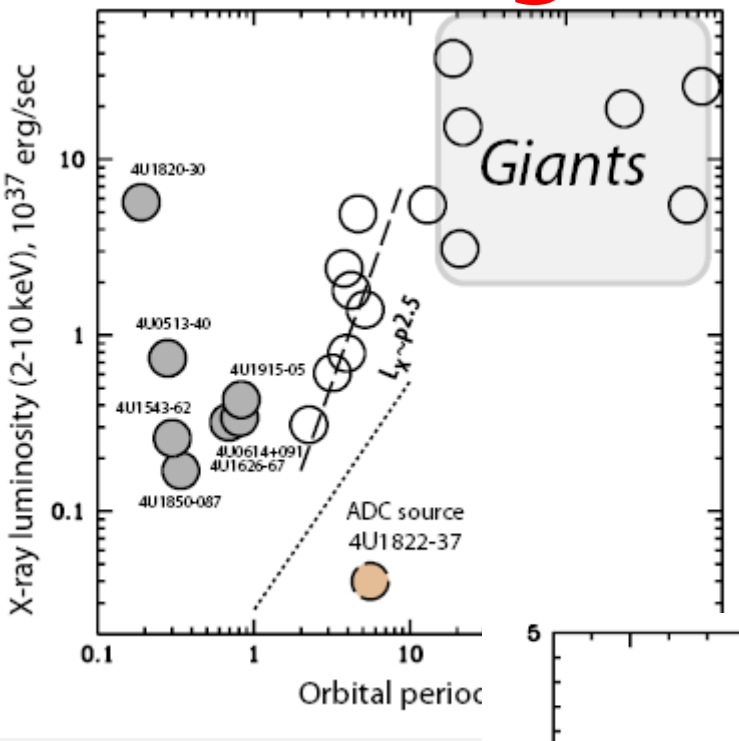
2)NS magnetic field

3)...

Giants and main sequence companions. Diagnostics of age

Revnivtsev et al. 2010



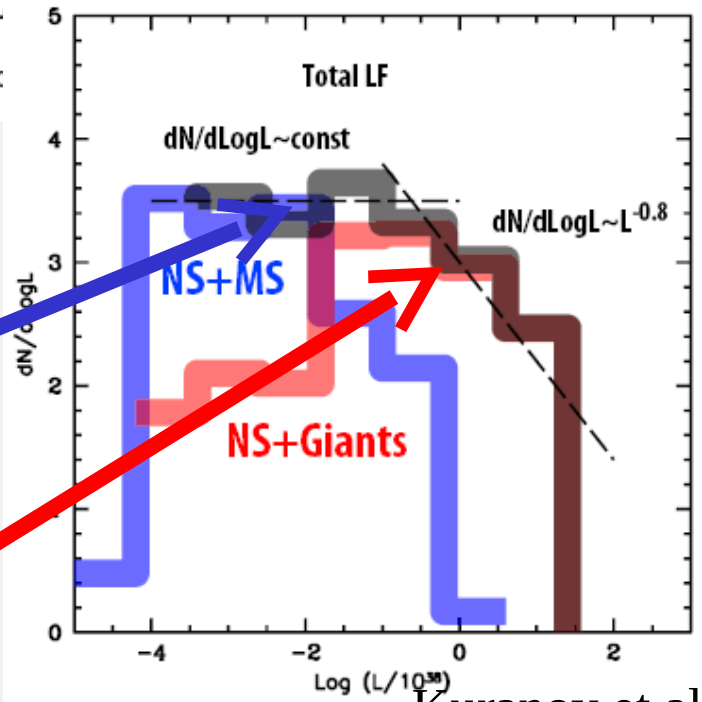


Break in LF of LMXBs is due to MS-Giants transition

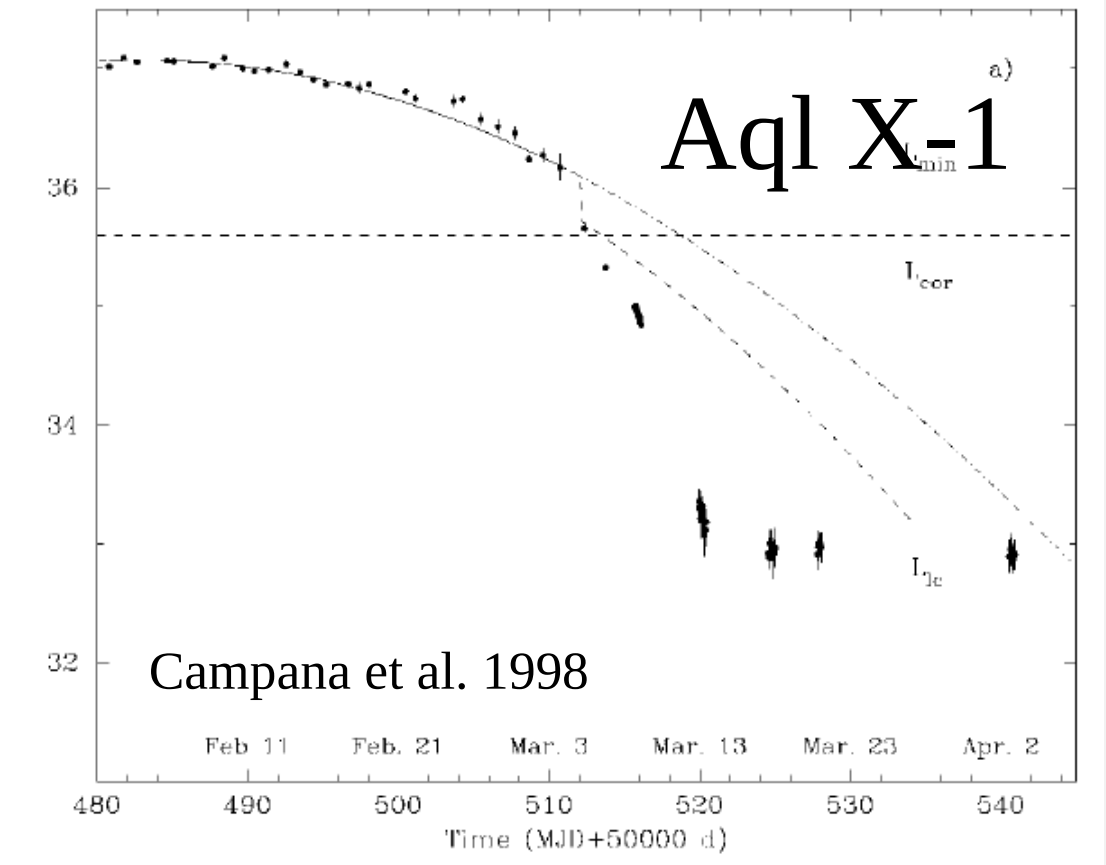
$$n(L_x) \propto \frac{1}{L_x}\frac{dN}{d\log P}\frac{d\log P}{d\log L_x} \sim \frac{1}{L_x}\frac{dN}{d\log P}$$

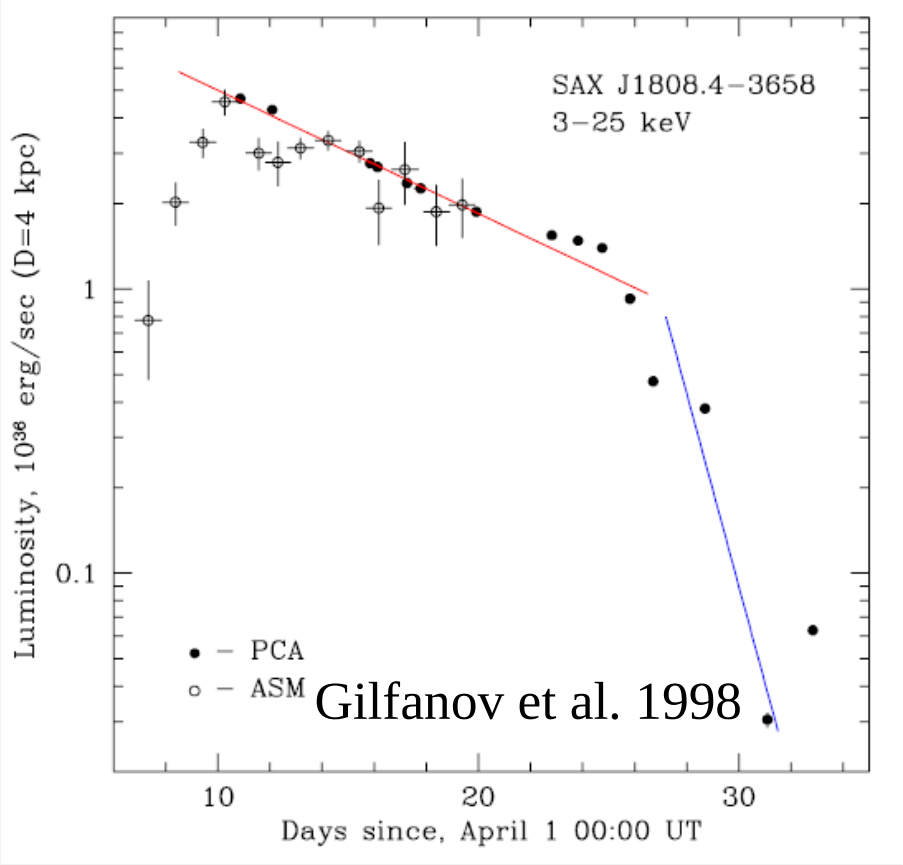
$$\tau \propto L_x^{-1}$$

$$\frac{dN}{dL_x} \propto \frac{1}{L_x P}\frac{dP}{dL_x} \propto \frac{1}{L_x^2}\frac{d\log P}{d\log L_x} \approx L_x^{-2}$$



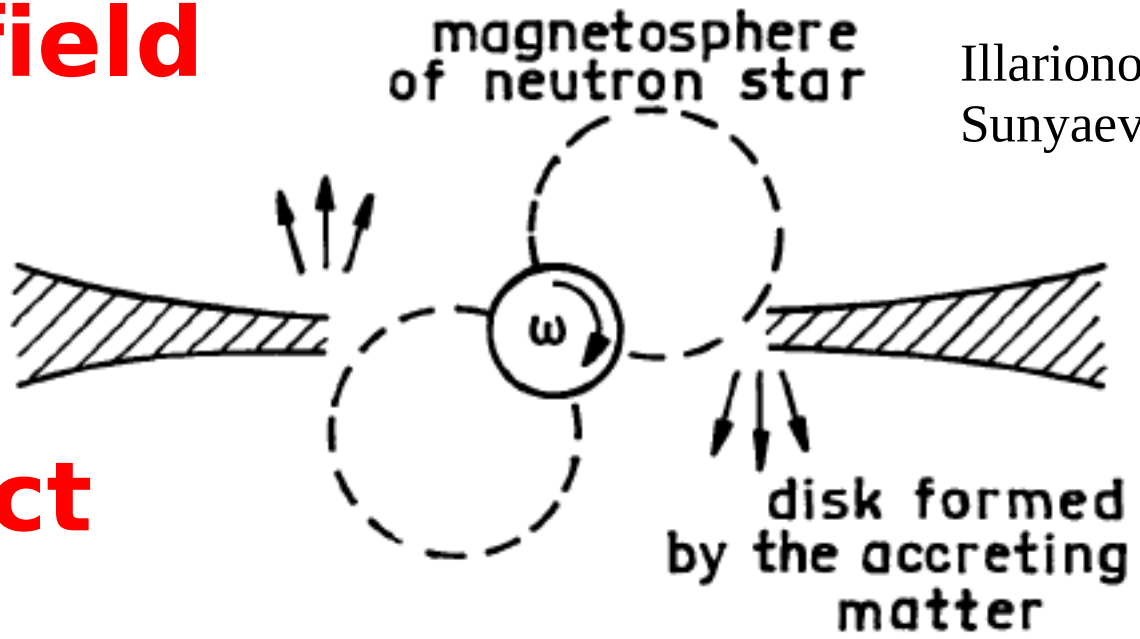
Kuranov et al.



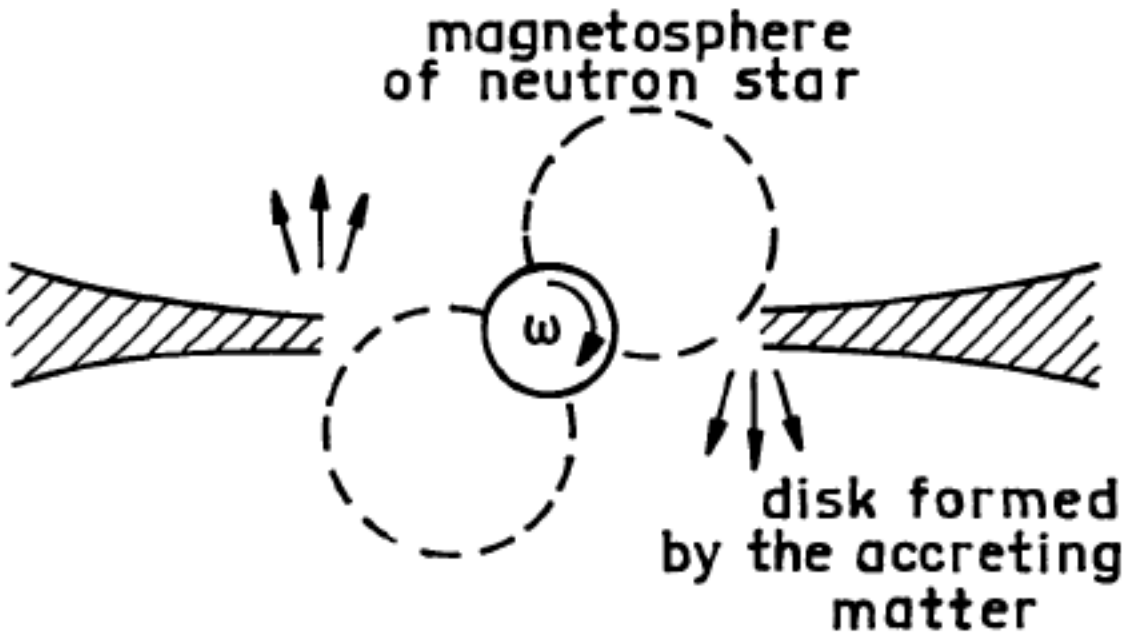


NS magnetic field

Pulsations,
Propeller effect

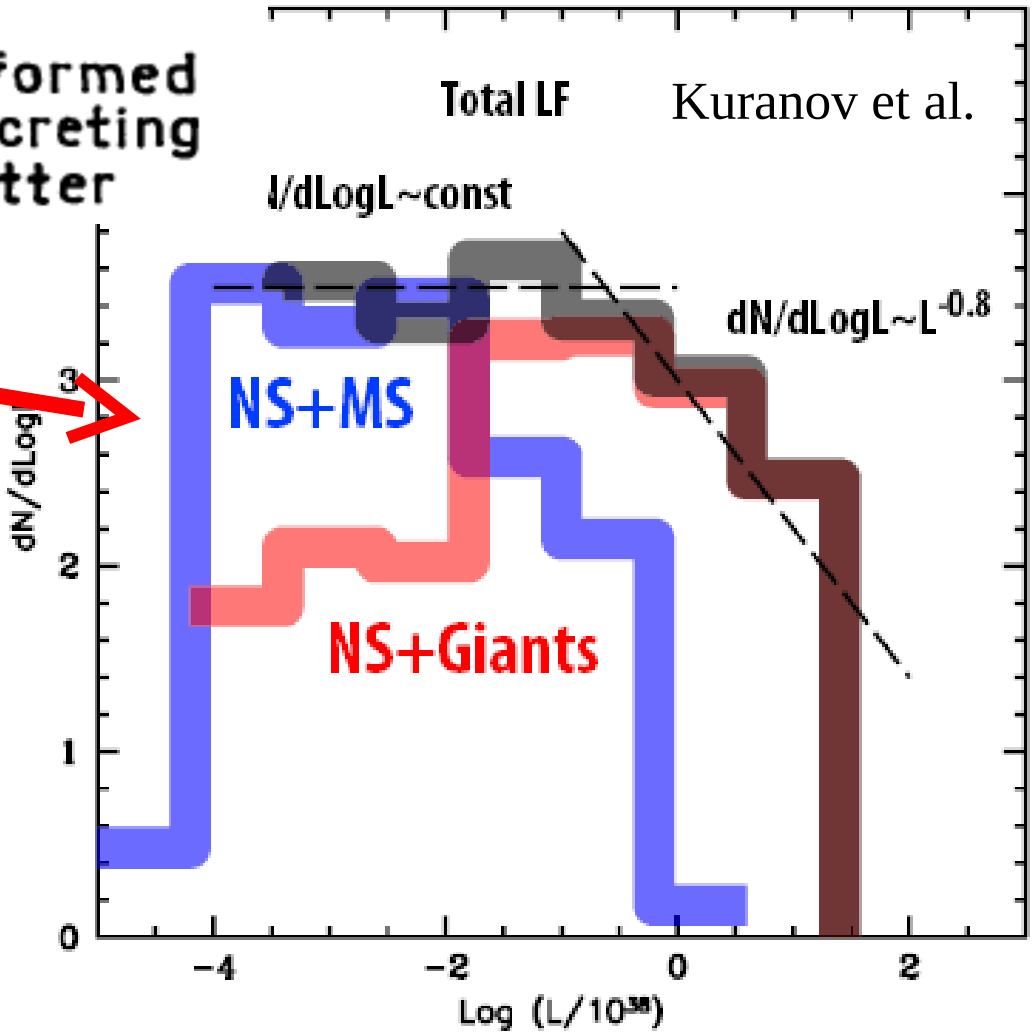


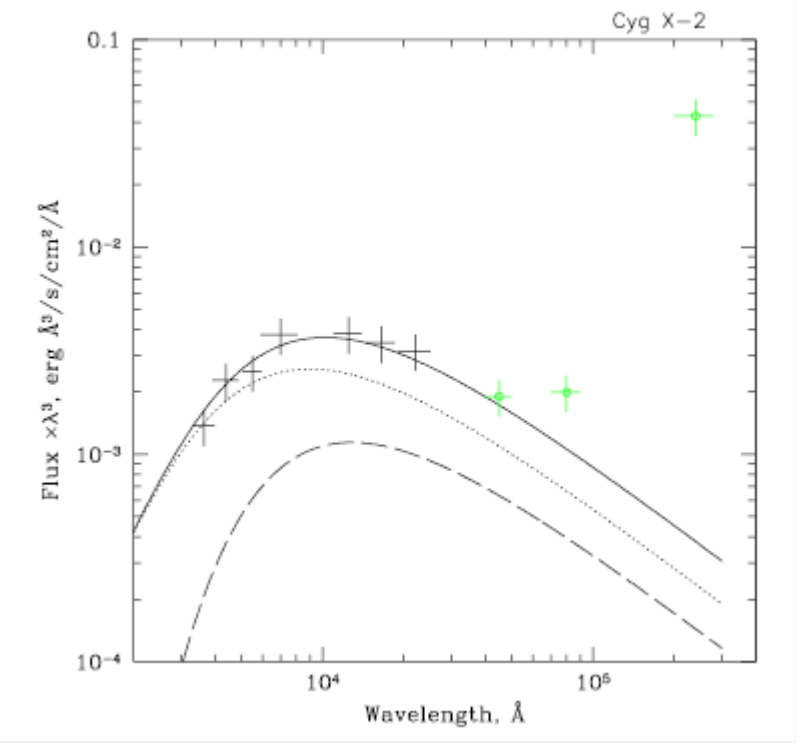
Illarionov,
Sunyaev 1975



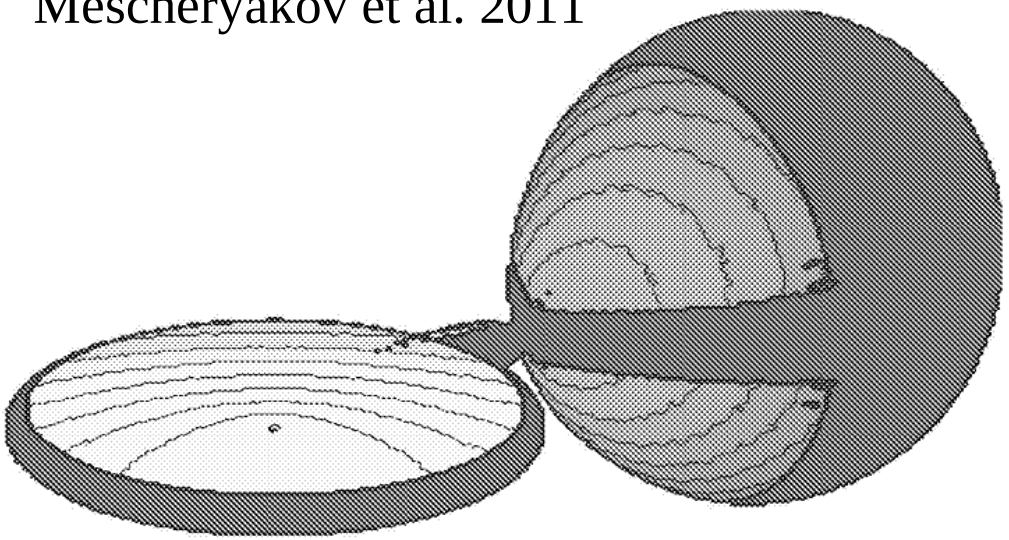
Propeller effect

Detection of this effect is not possible yet due to problems with finding low Lx LMXB





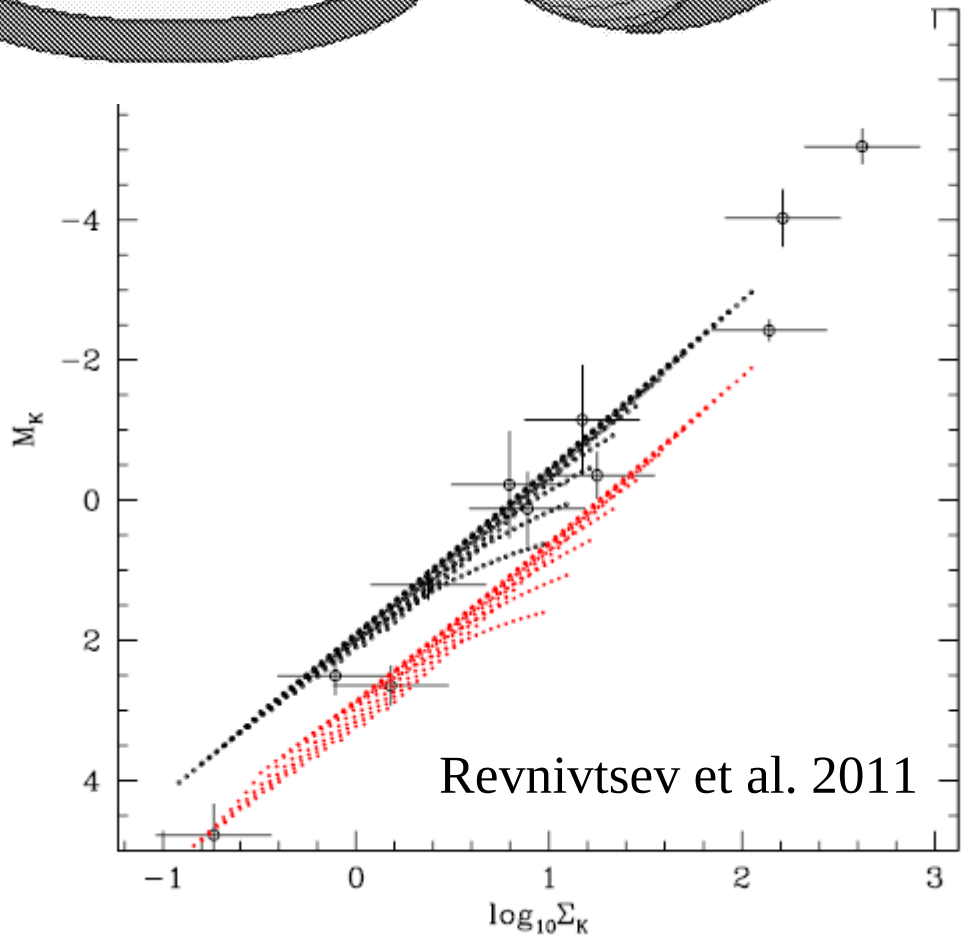
O'Brien et al. 2002
Mescheryakov et al. 2011

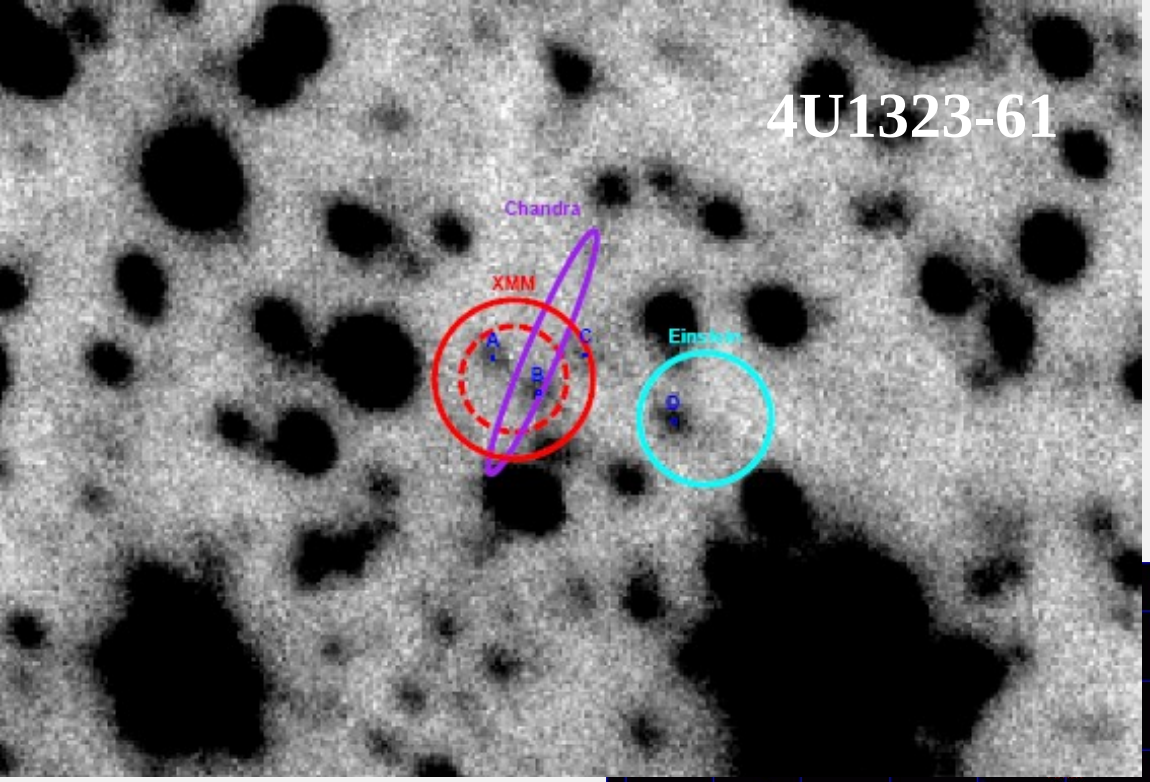


Problems of finding low-Lx LMXBS

K

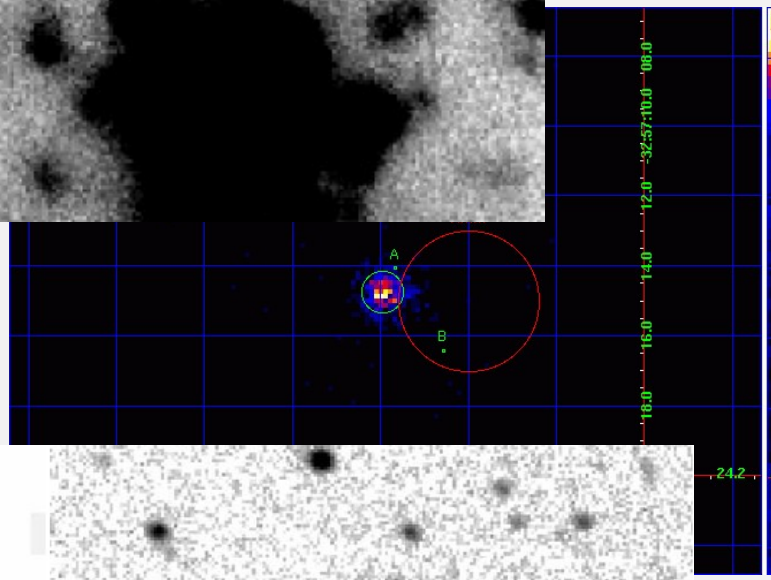
M down to ~4-5!

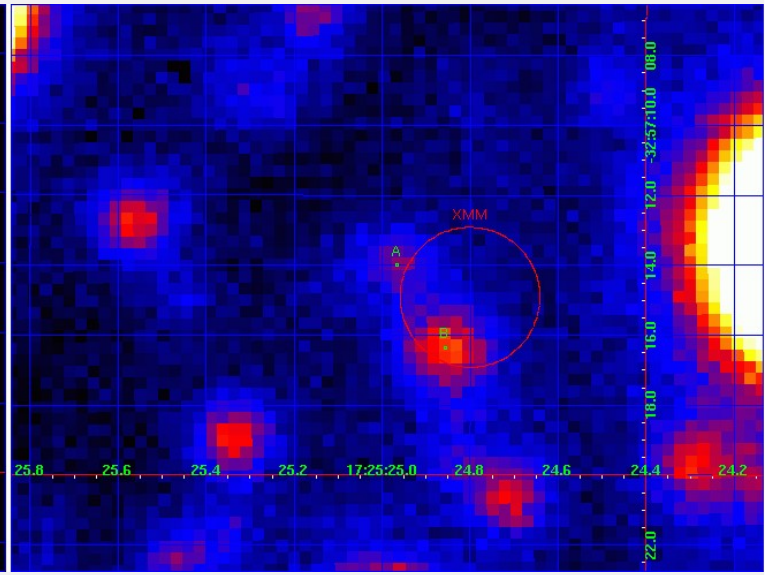


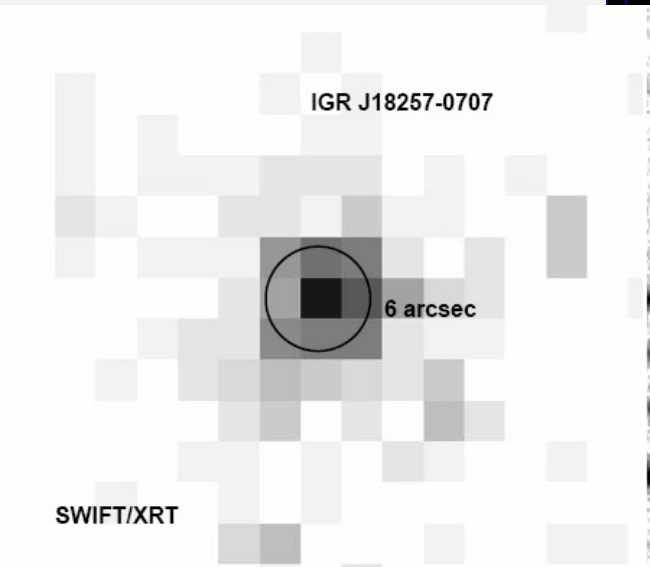


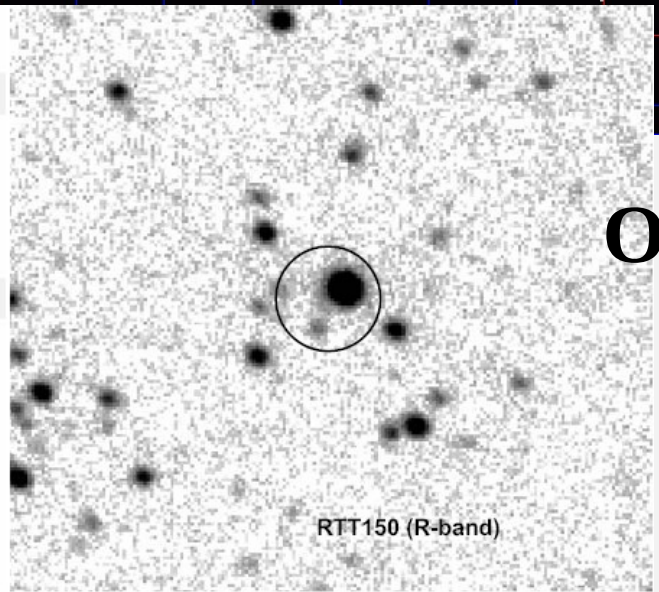
Ongoing project -hunt for low Lx LMXBs

IGR J17254



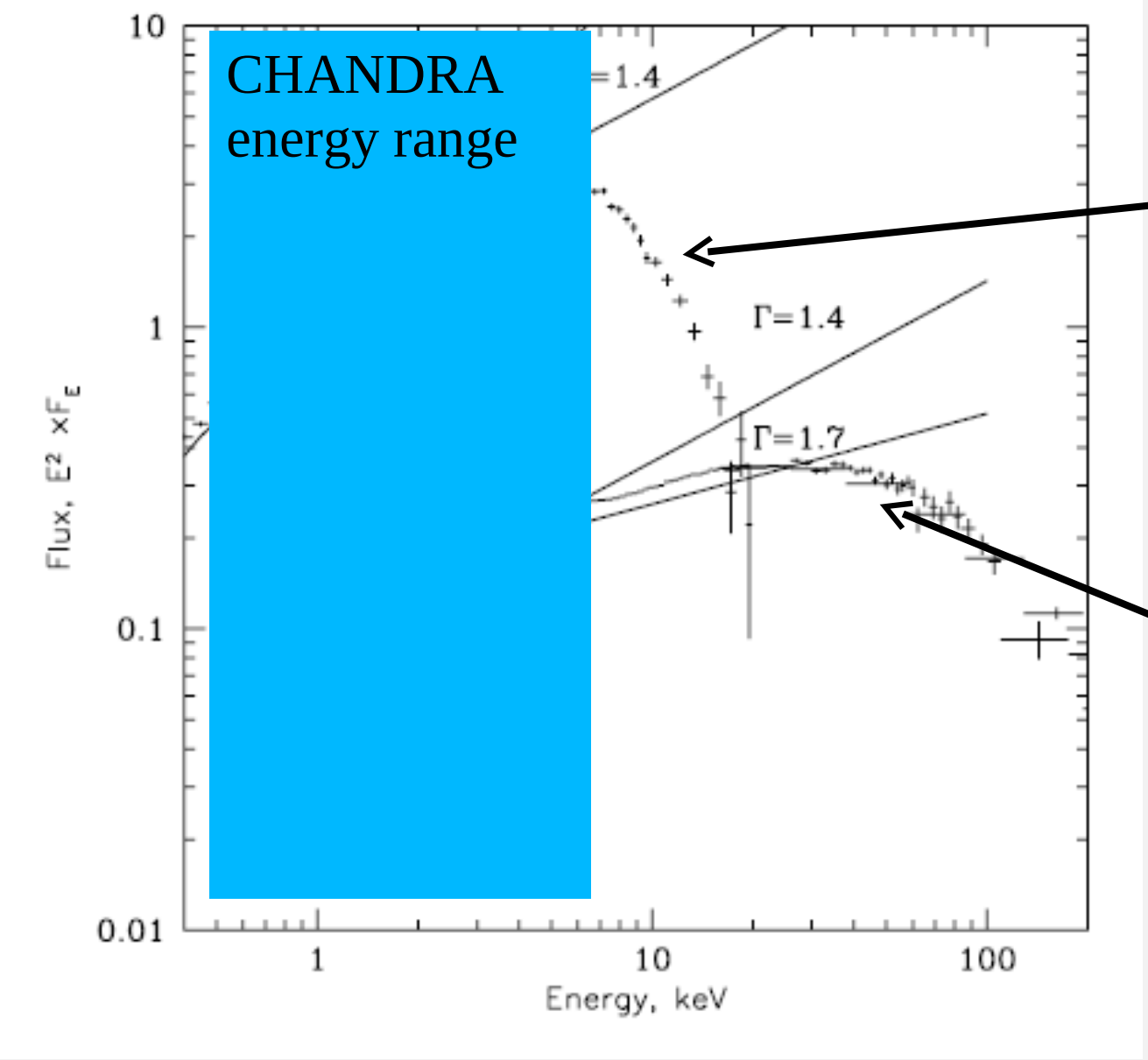






One of the INTEGRAL/ CHANDRA/HRC sample

X-ray emission of NS LMXBs

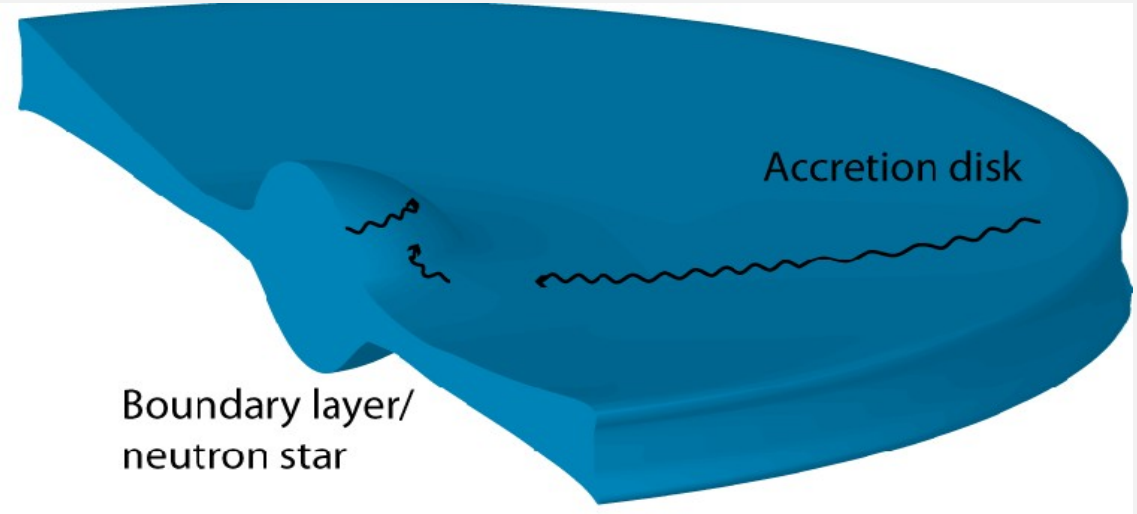


Optically thick emission

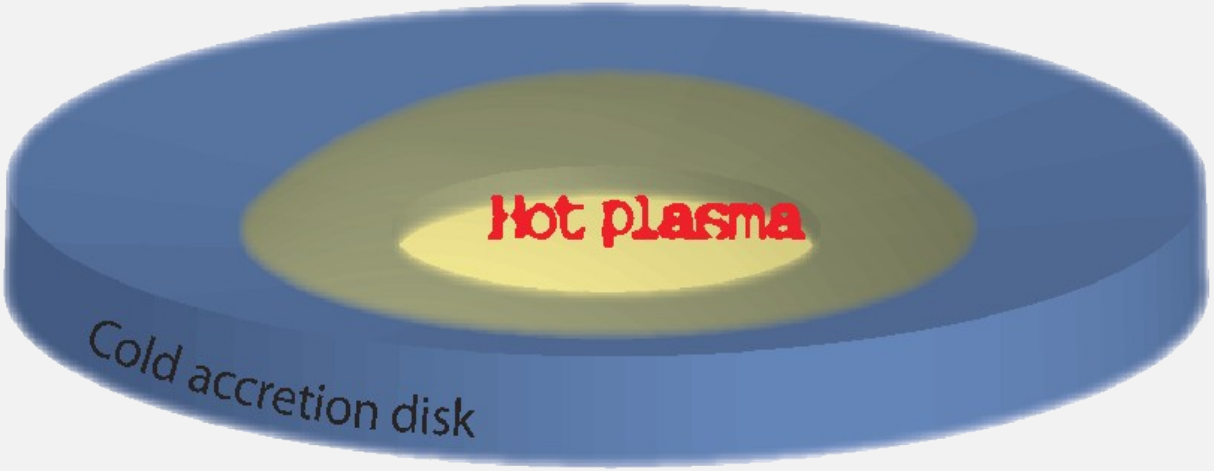
Optically thin emission

X-ray emission of NS LMXBs

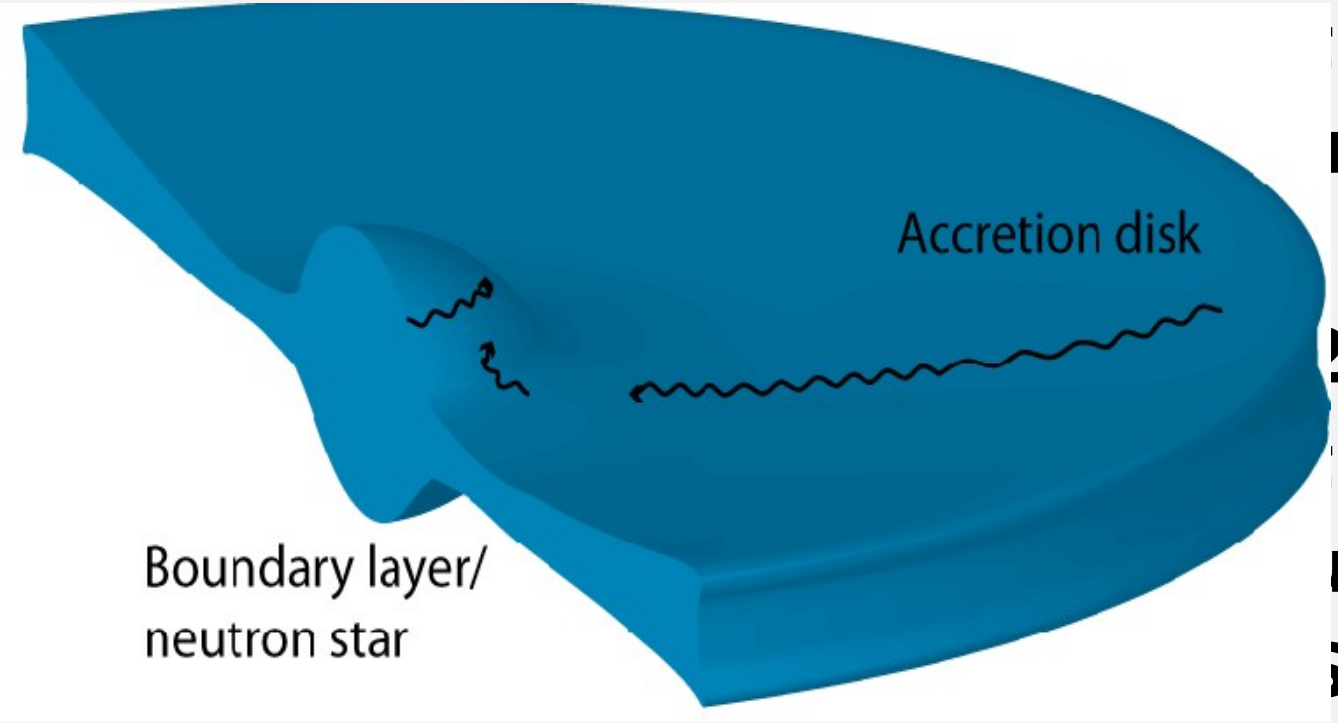
High/soft state



Hard/low state



Naive accretion disk/boundary layer scheme

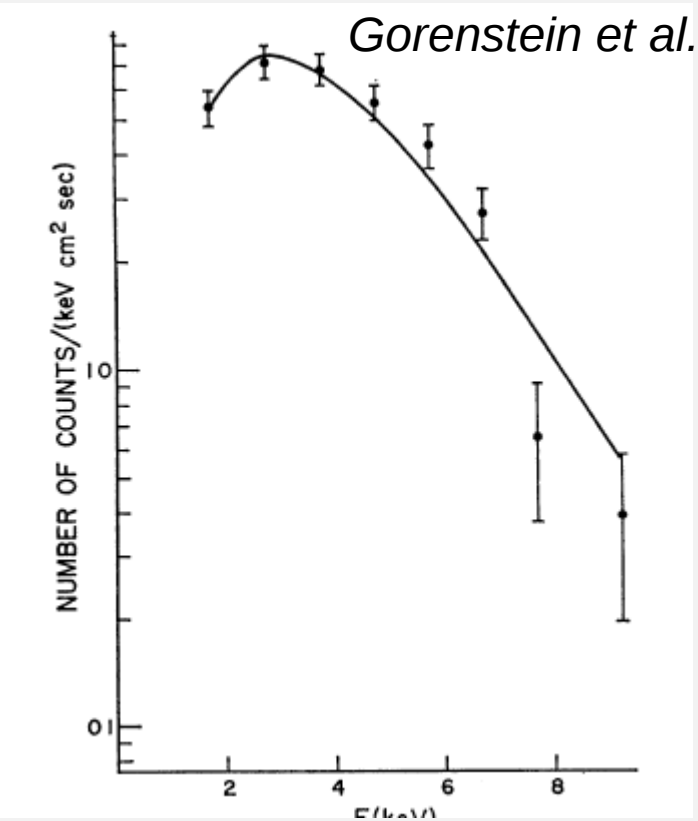


1. Matter rotates in the disk, moves inwards

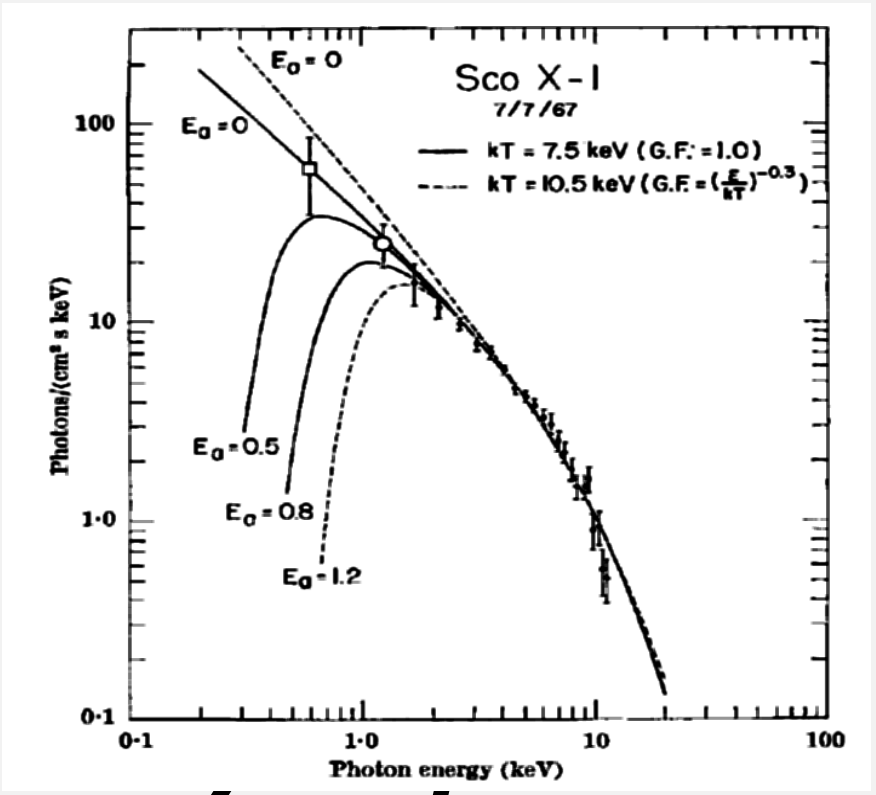
2. Then it goes into the BL, drifts up/downwards. Settles to the NS surface

Sco X-1

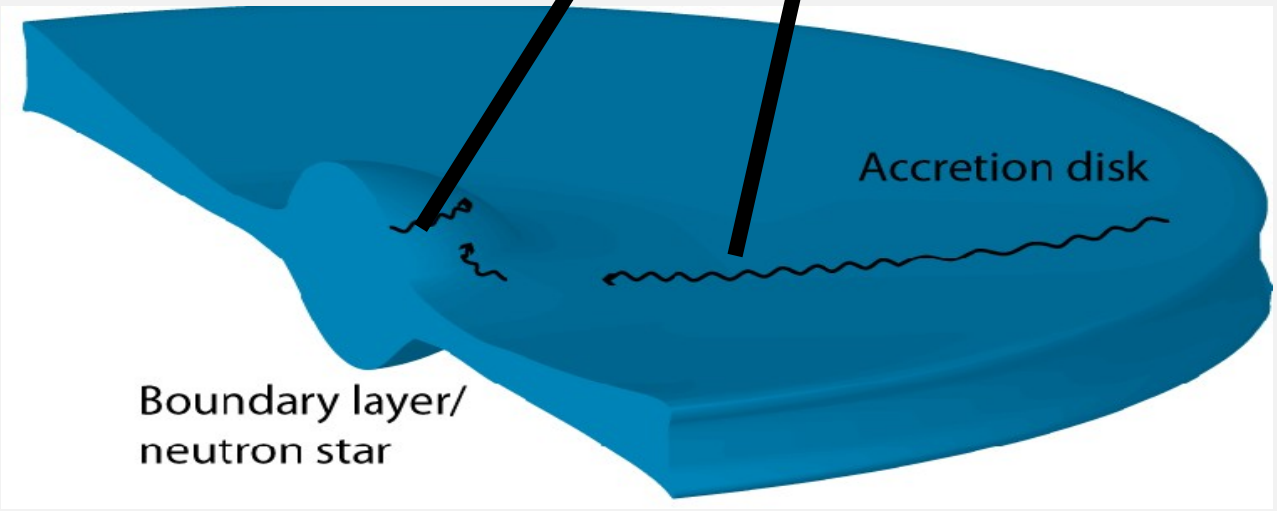
Gorenstein et al. 1968

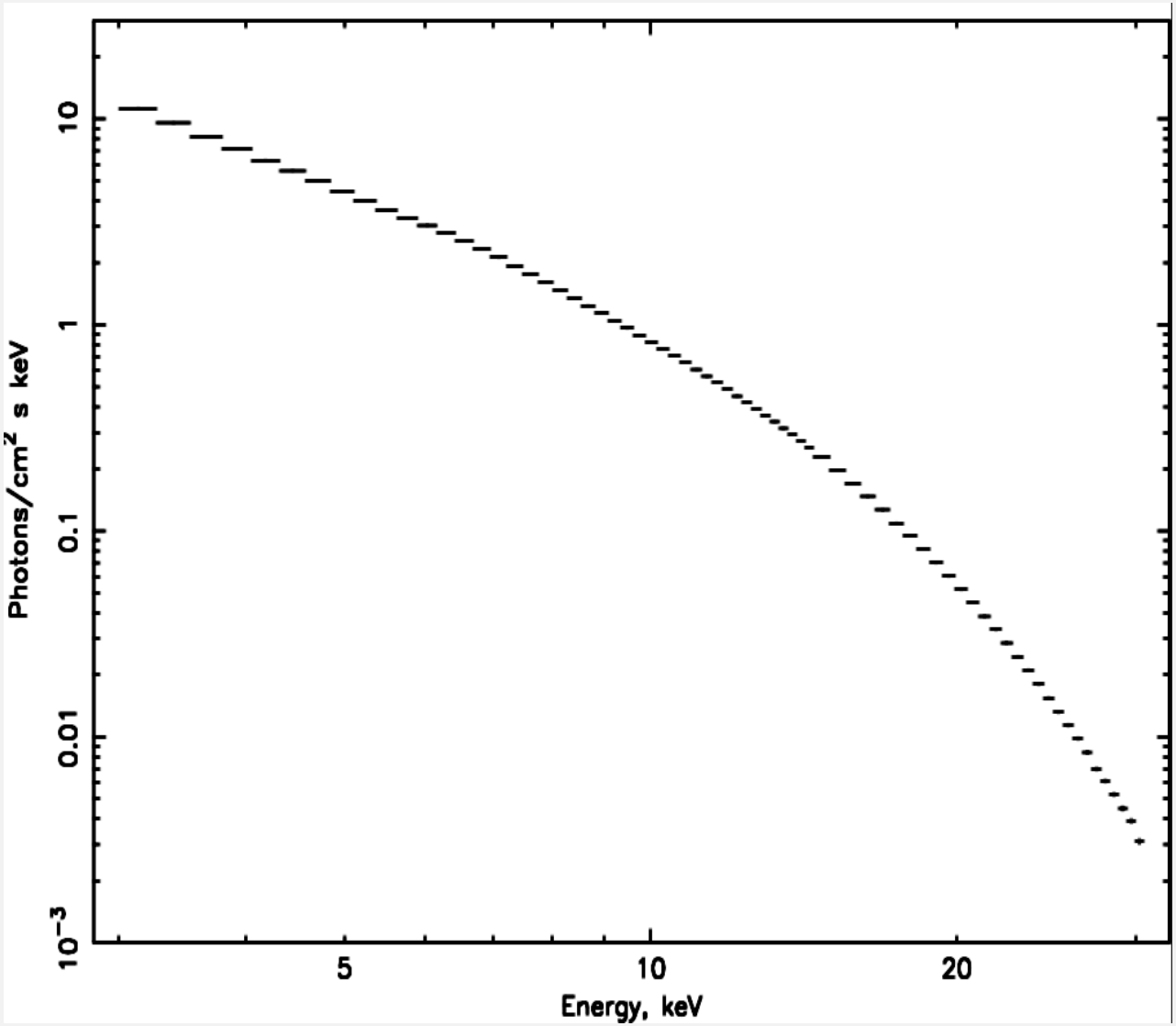


Rappaport et al. 1969



Rocket measurements (~100-300 cm²)





Sco X-1

Latest satellite measurements (~6400 cm2)

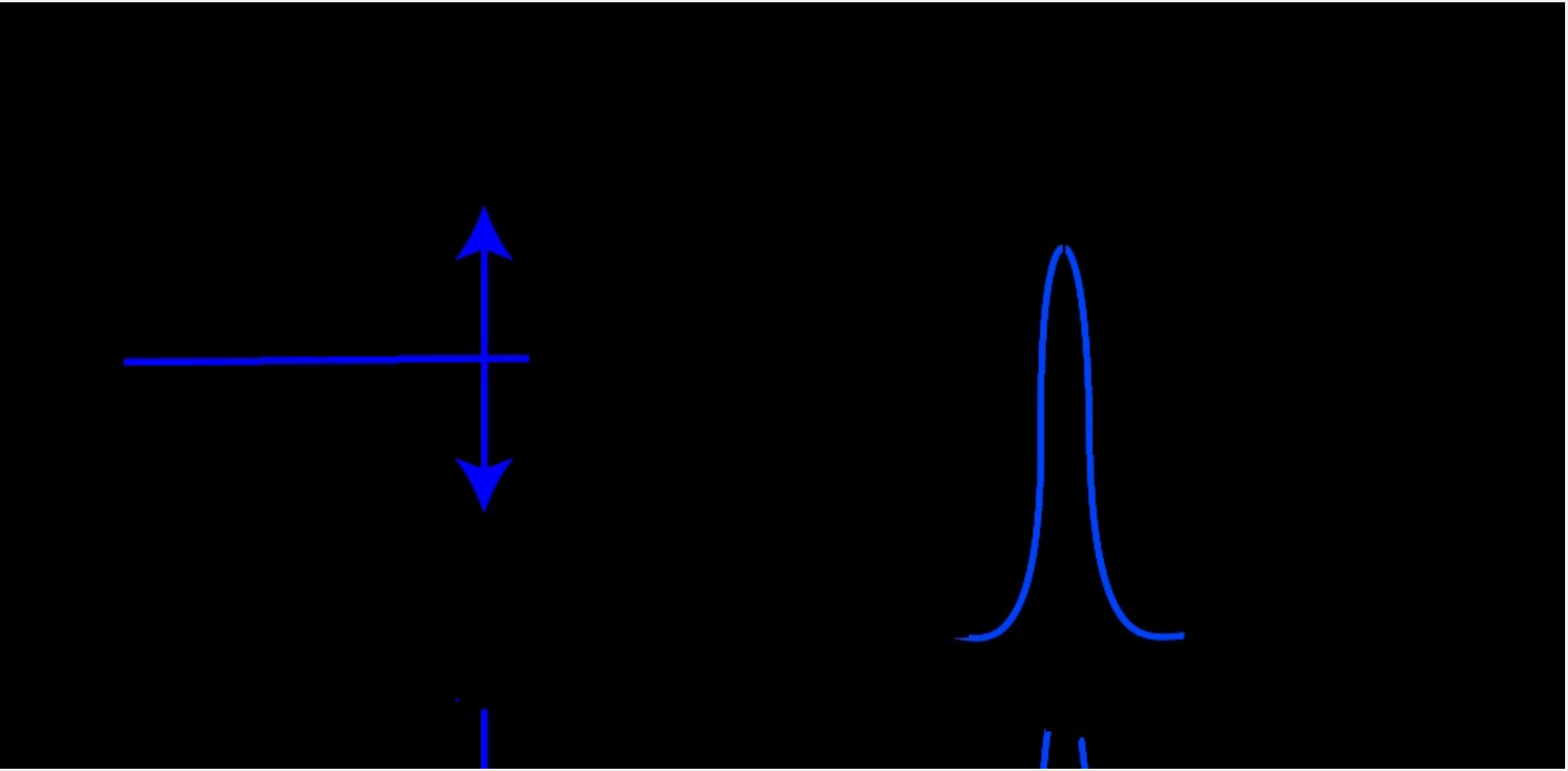
Separation of two components is far from obvious

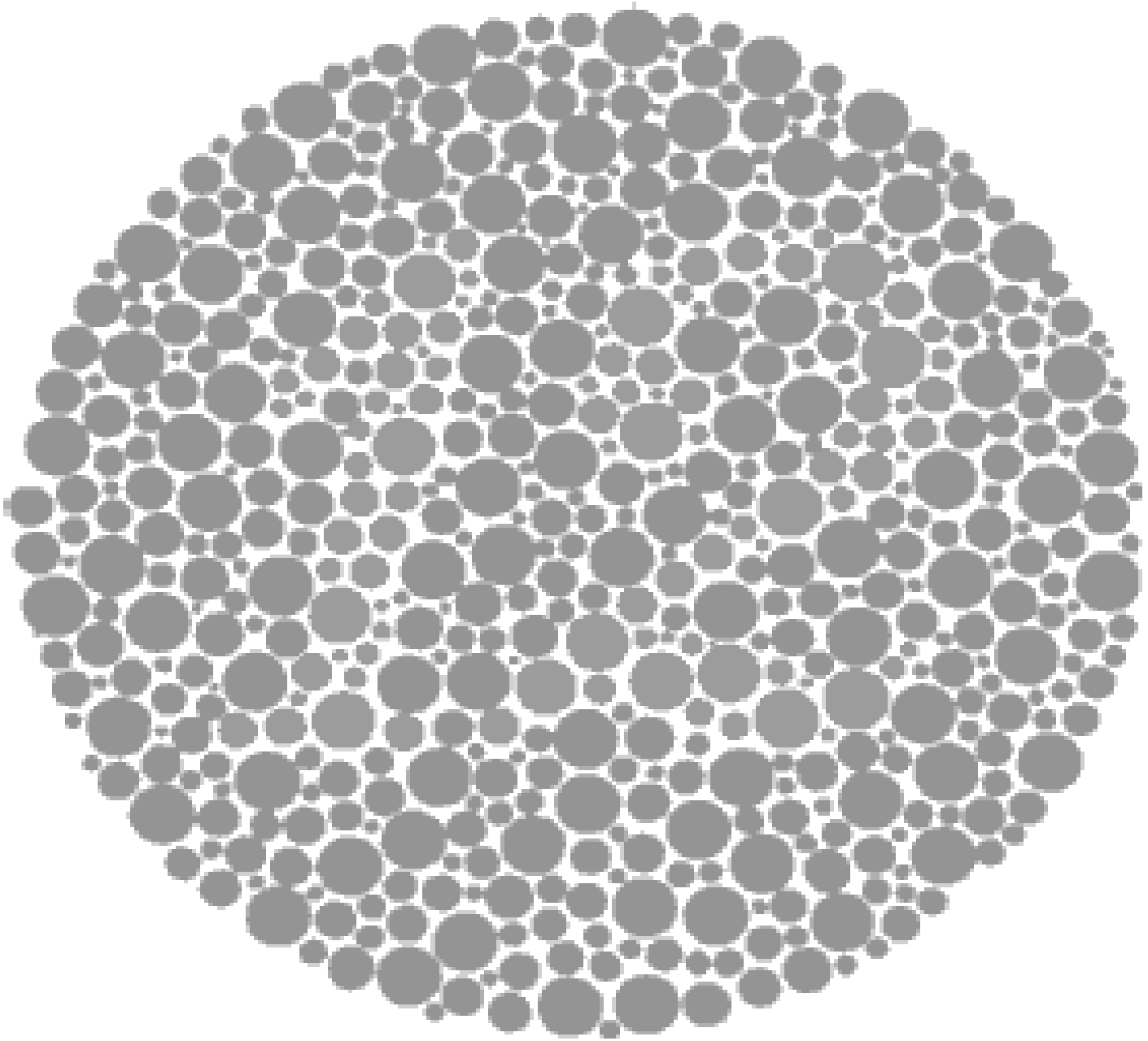
mple chi2 approach for separati

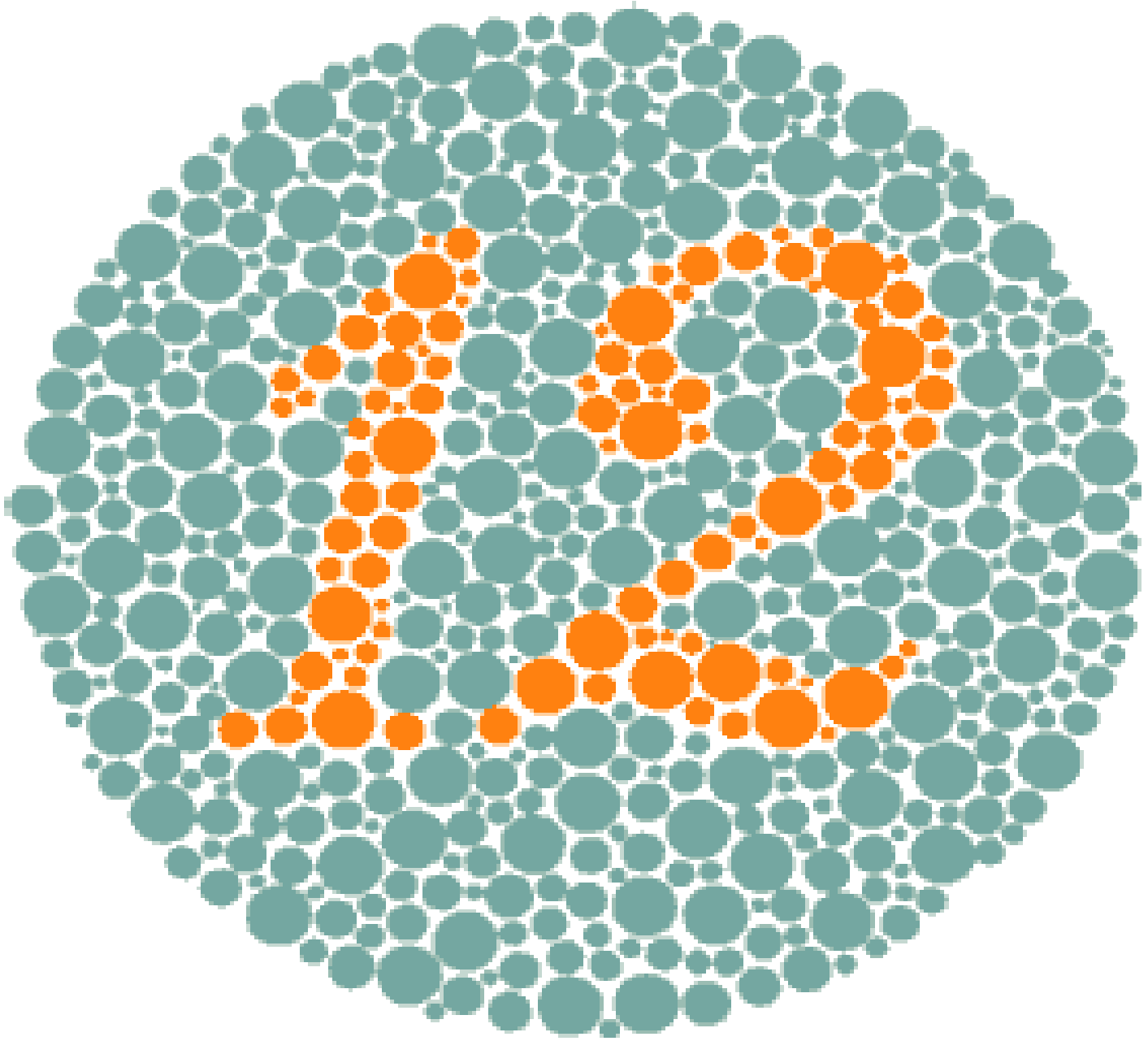
pectral components is not accept

Approach from different direction:

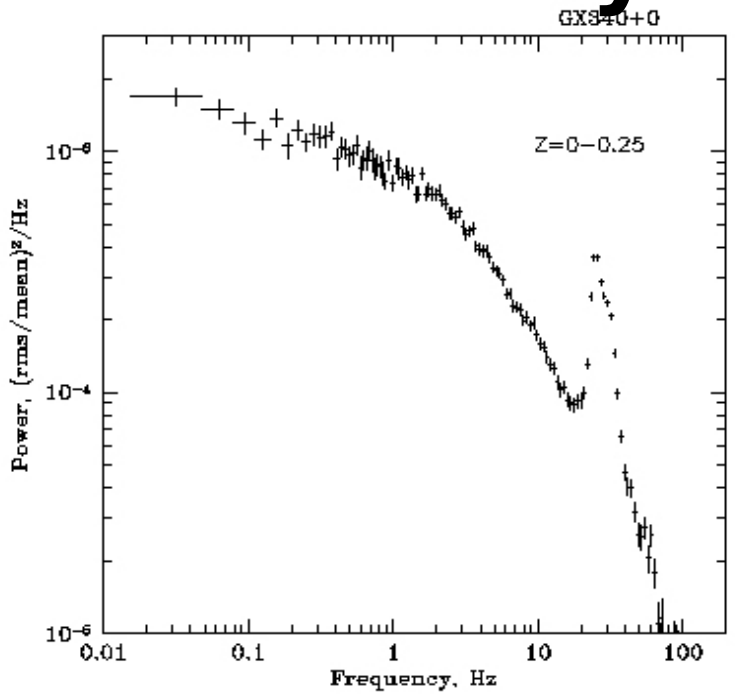
Fourier frequency resolved spectroscopy

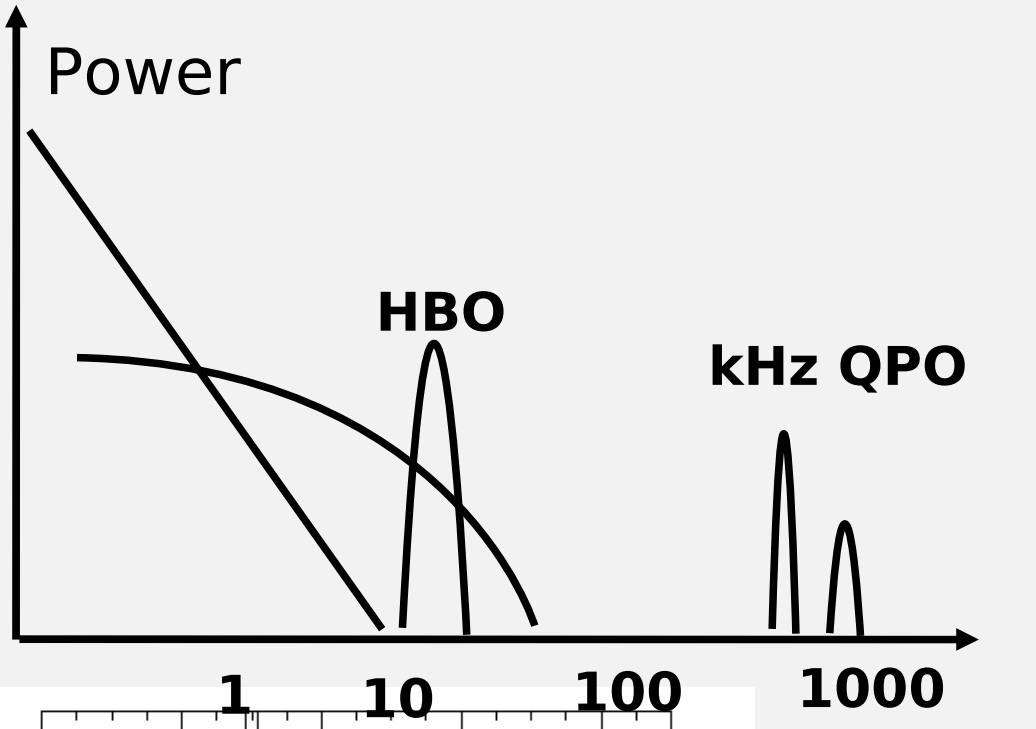


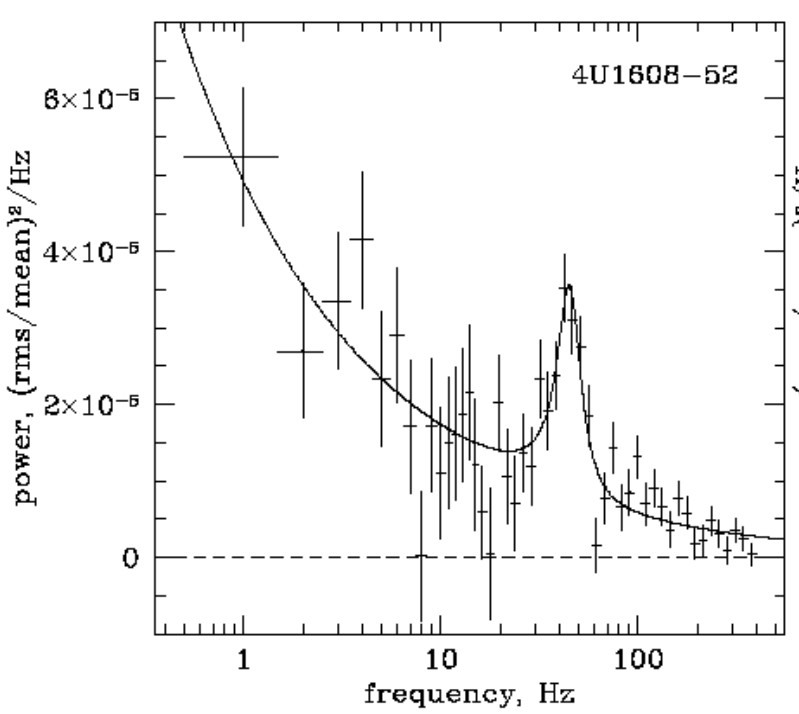


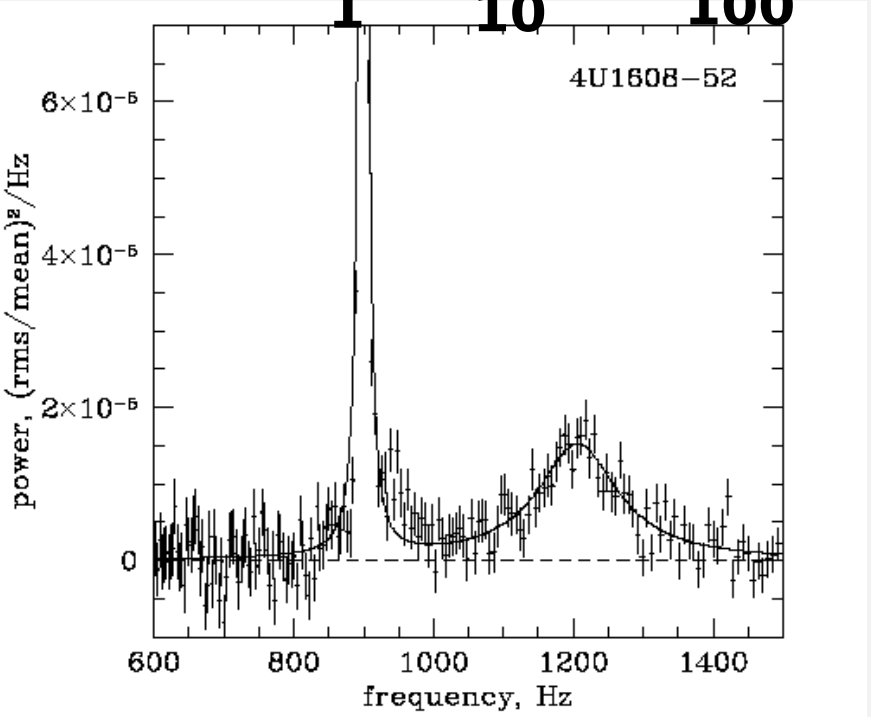


Variability of bright NS LMXBs

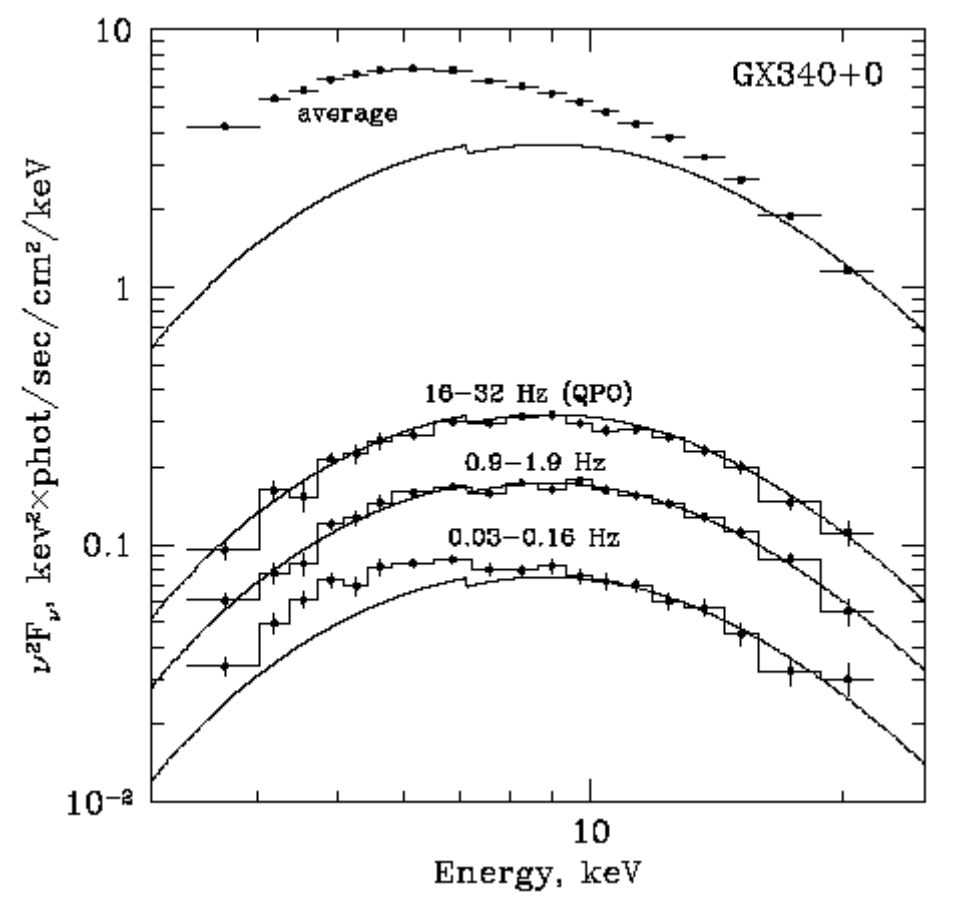


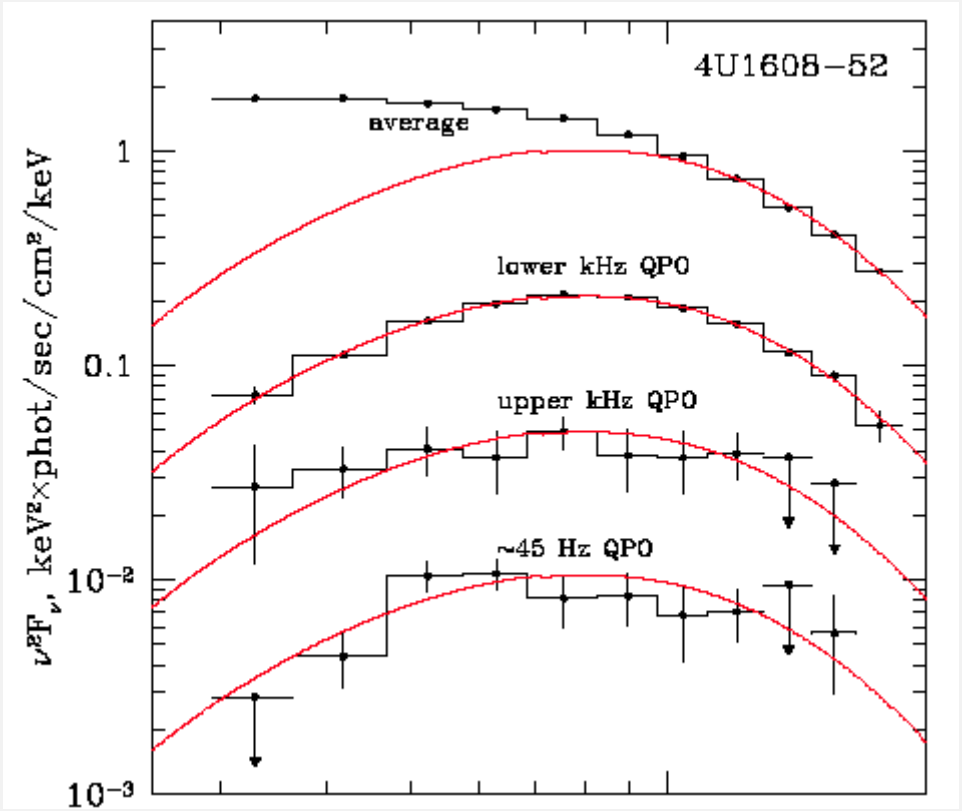






Frequency resolved spectra of bright LMXBs



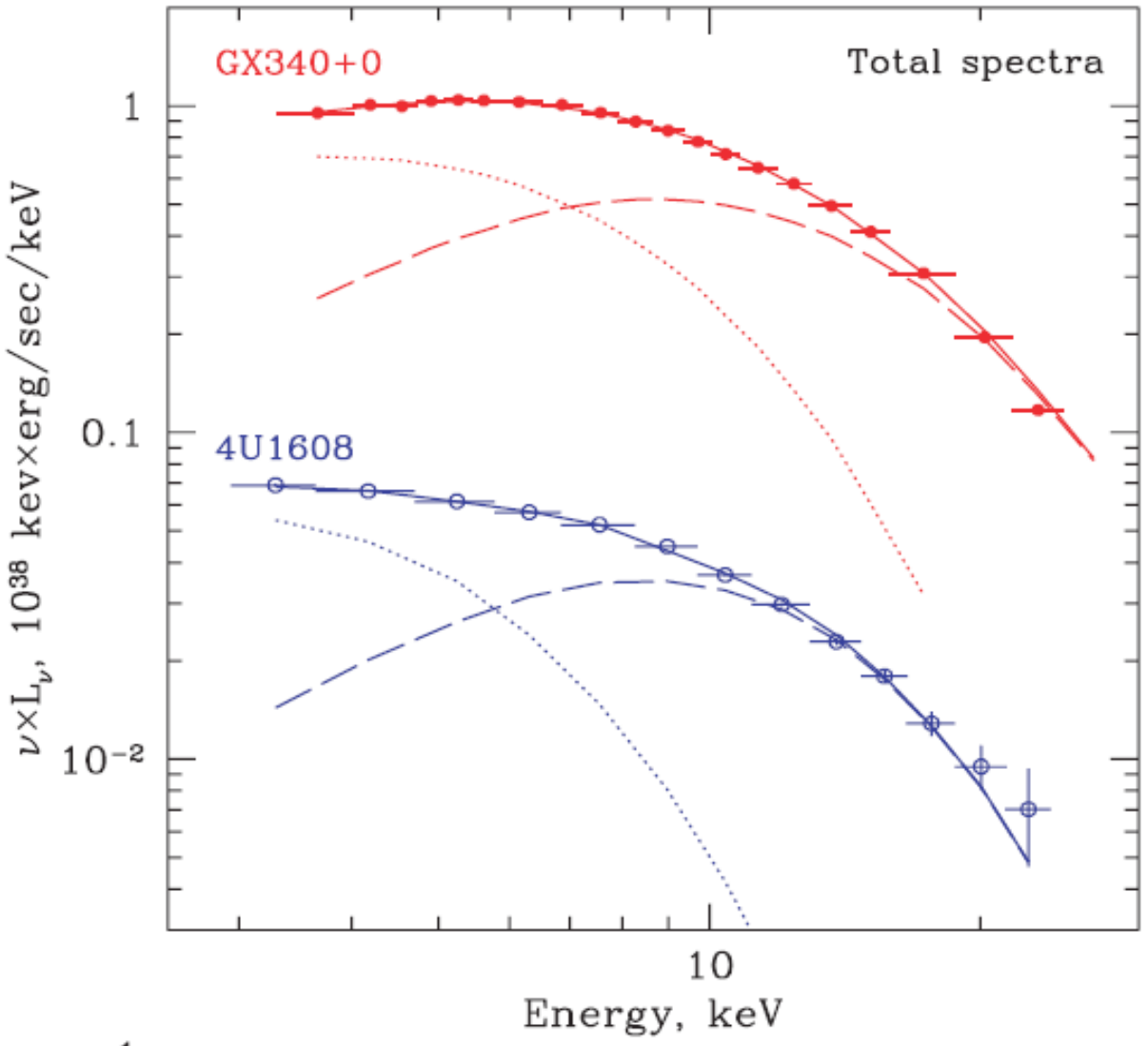


Energy, keV

Frequency resolved spectra

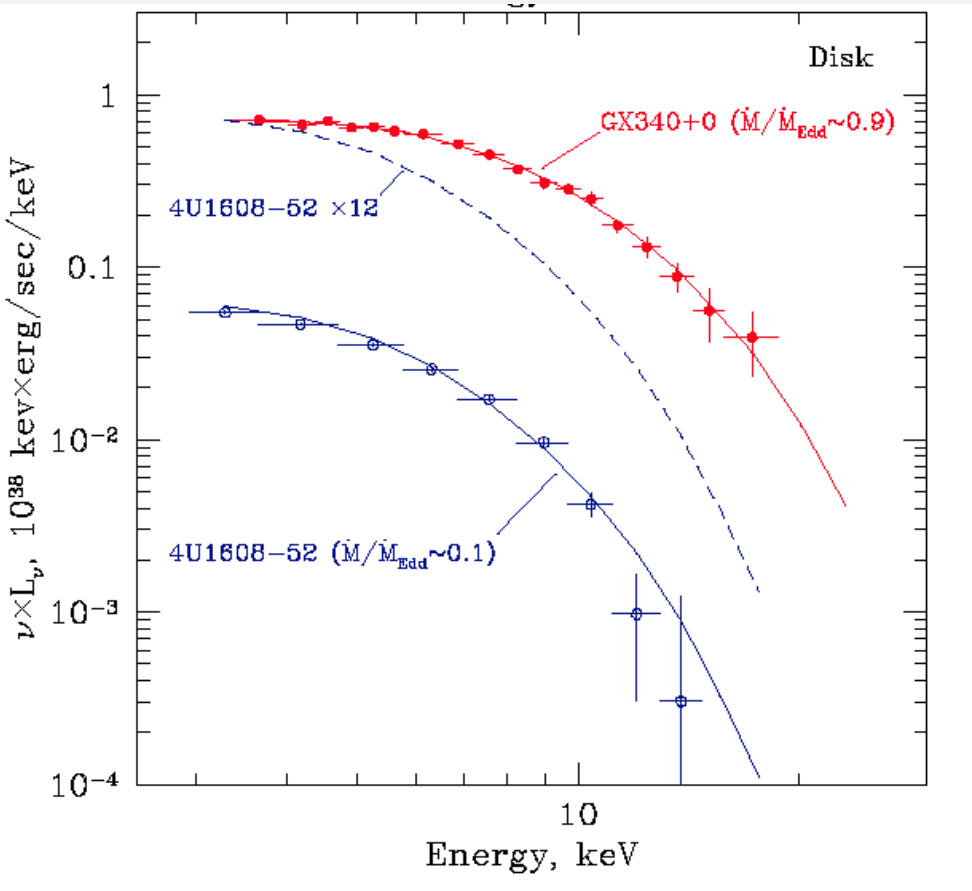
1. Coherence ~1
2. Time(phase) lags <<1
3. Achromatic – do not depend on frequency

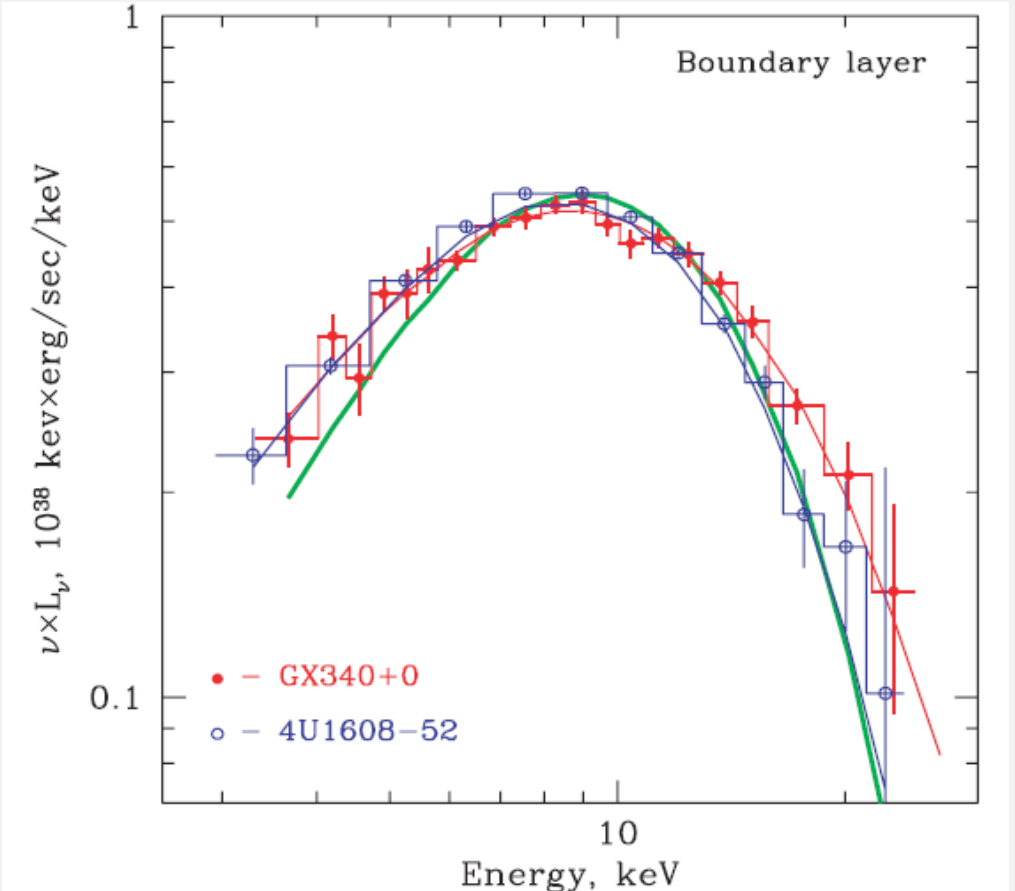
Almost unique interpretation - variability of one spectral componen as a whole



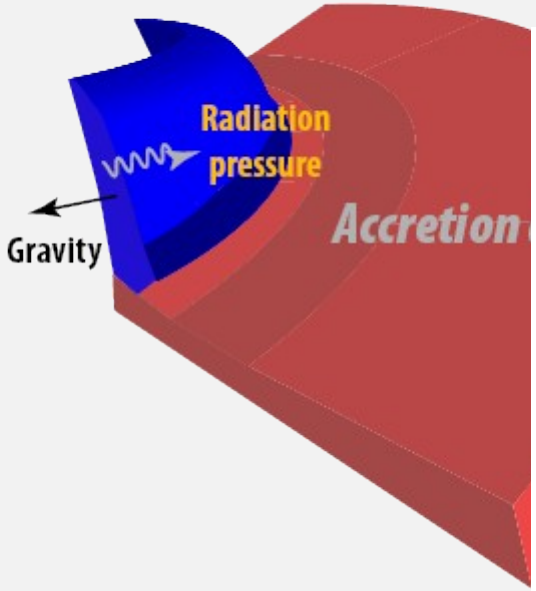
Factor 10 in LMXB luminosity:

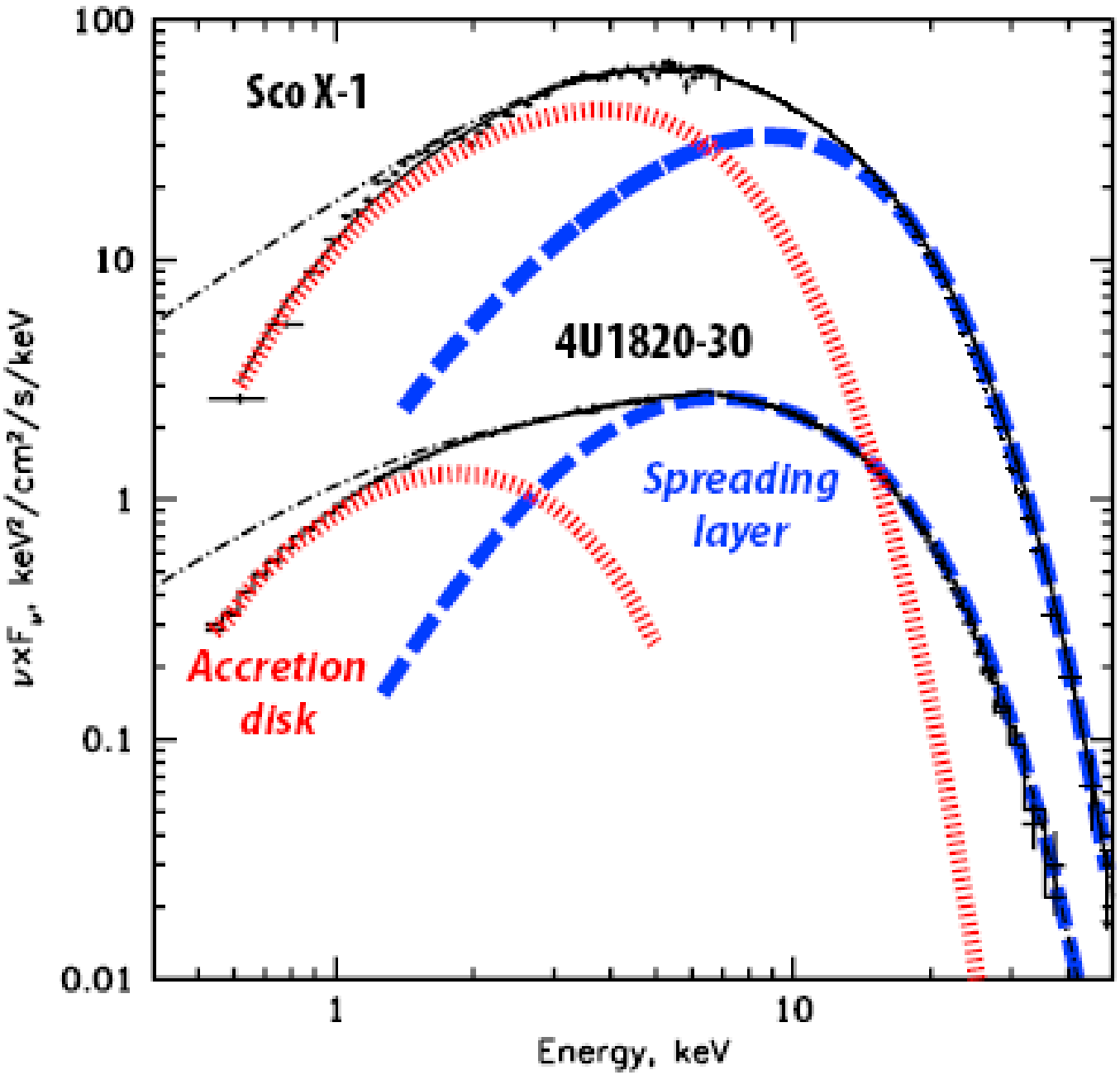
1) Temperature of AD changes ~accordingly
2) Shape of the boundary layer spectrum is ~constant



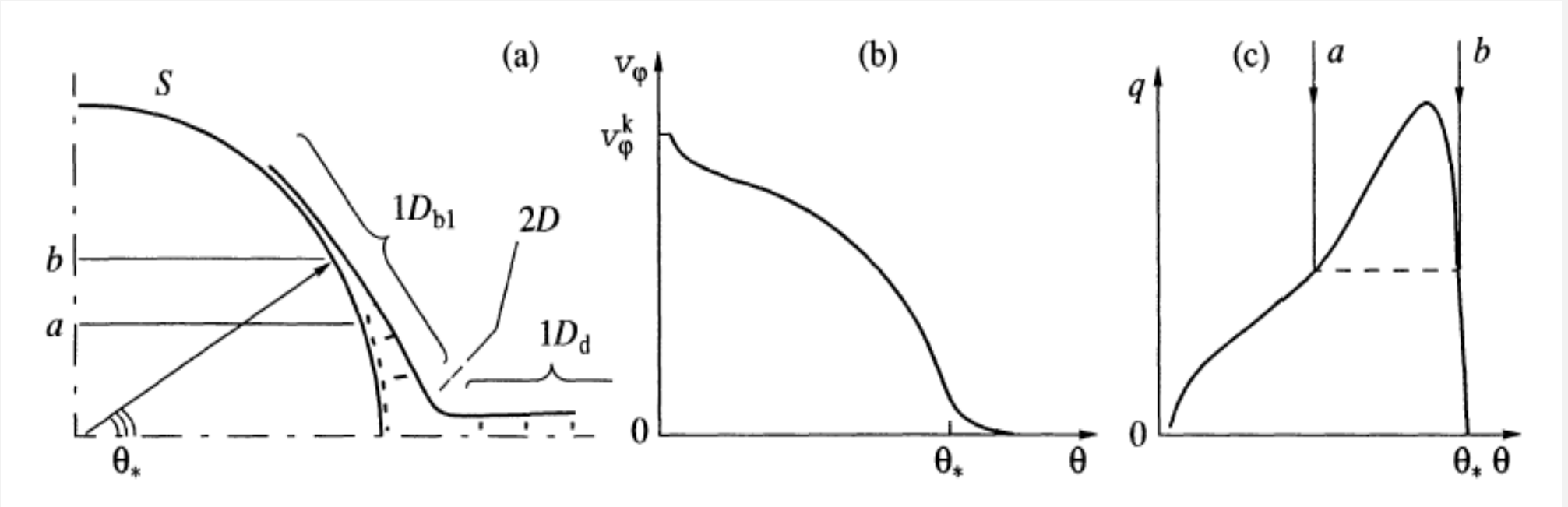


Spreading layer



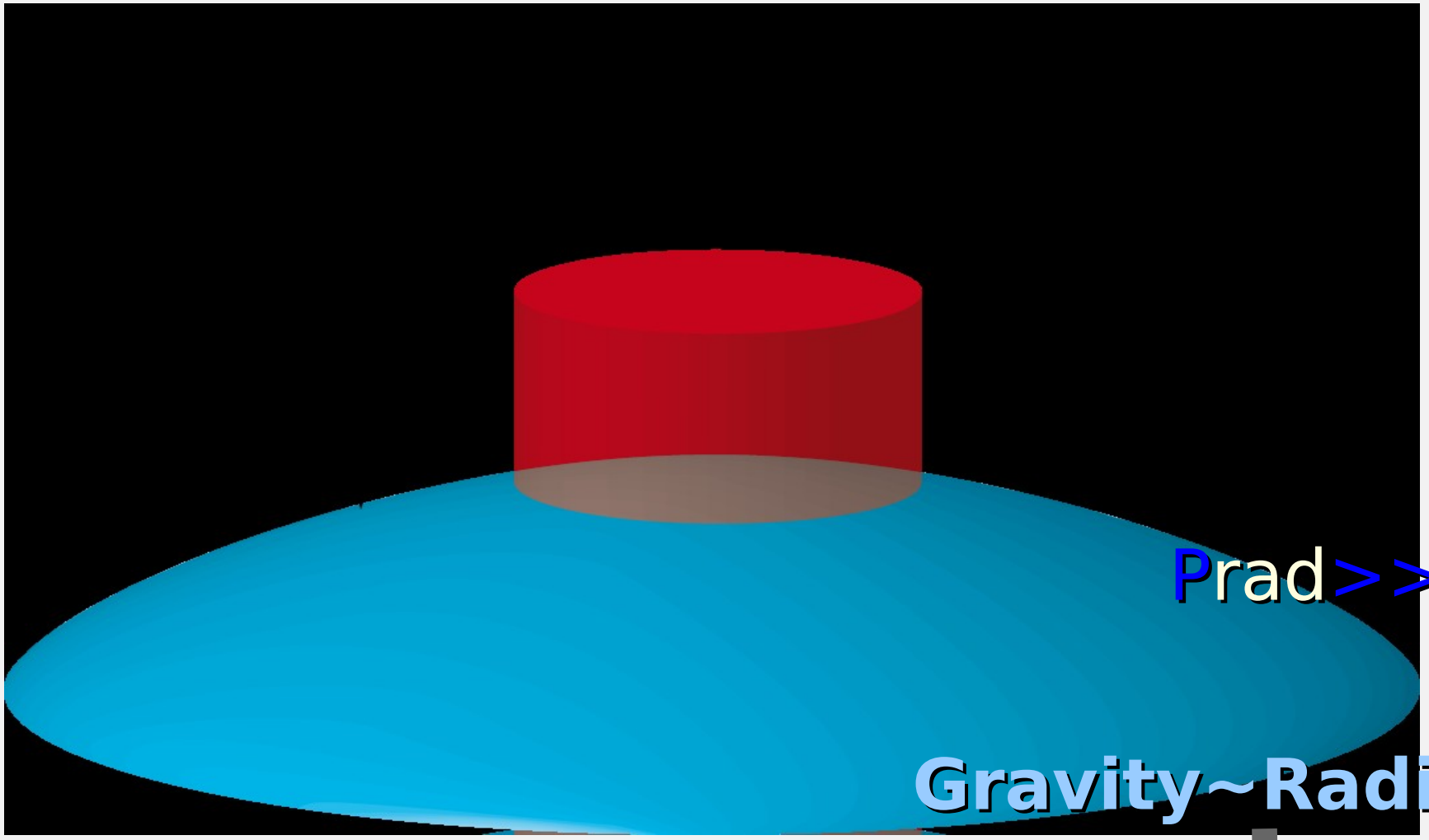


Boundary/spreading layer (Inogamov & Sunyaev 1999)



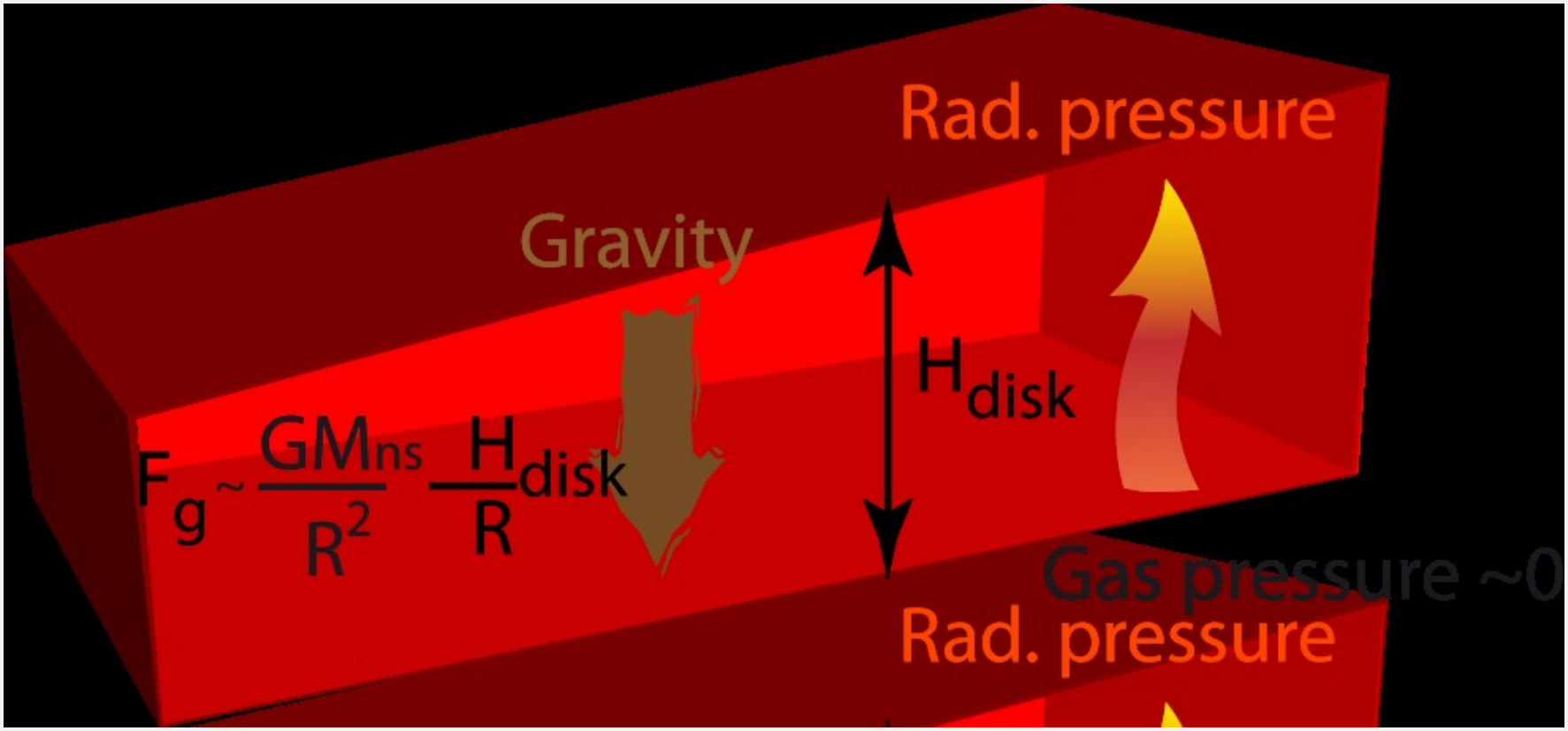
- **Radiation dominated**

Boundary layer statics



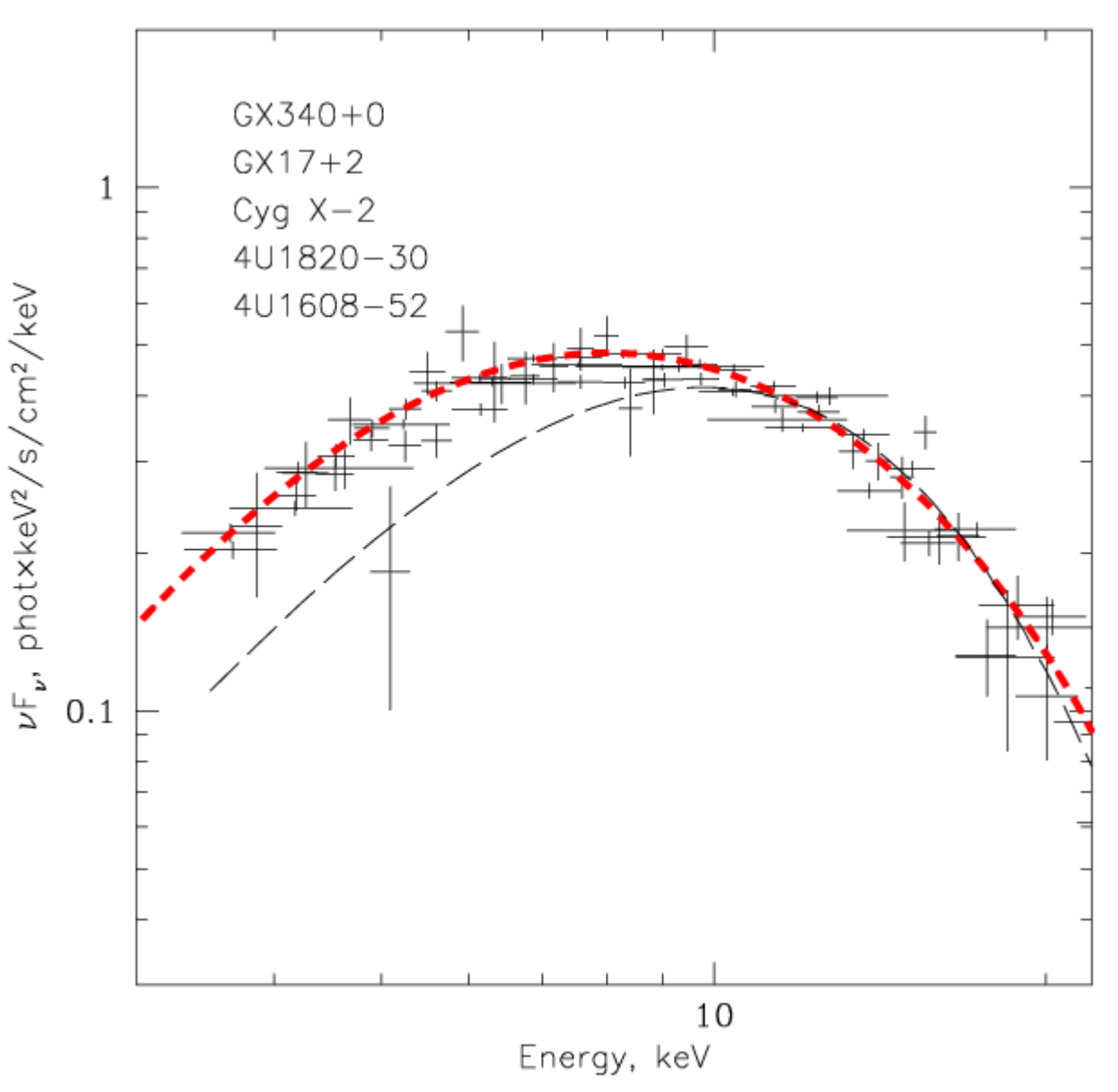
Eddington limited flux

Accretion disk statics is different!



Variations in Mdot -> T –> height of the disk

Boundary layer spectrum

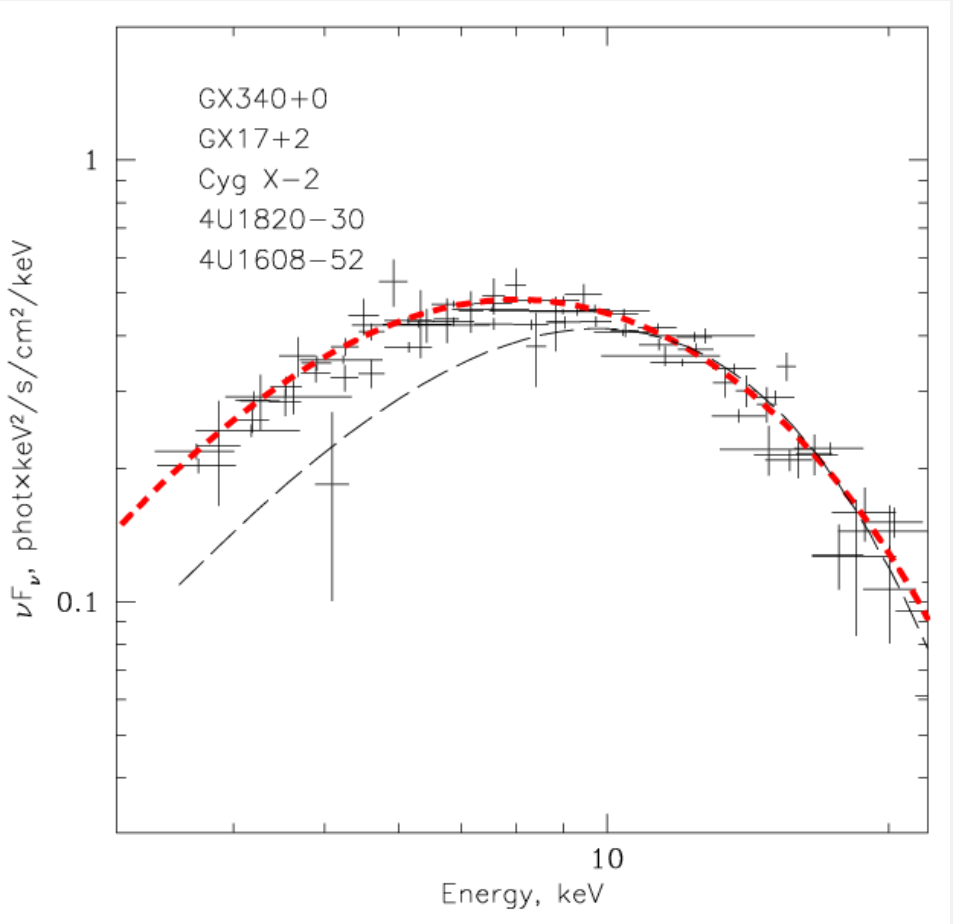


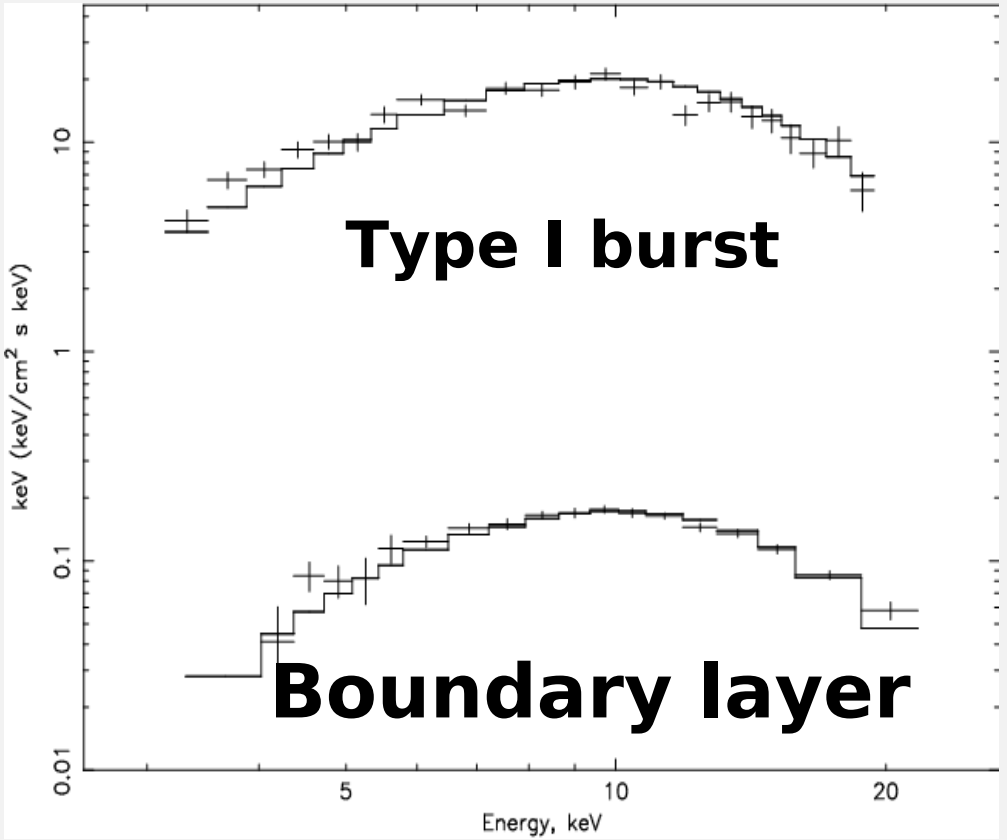
5 different sources

Accretion rate differs ~10 times

Color temperature kT ~ 2.4 keV

Eddington limited spectra of BL/NS





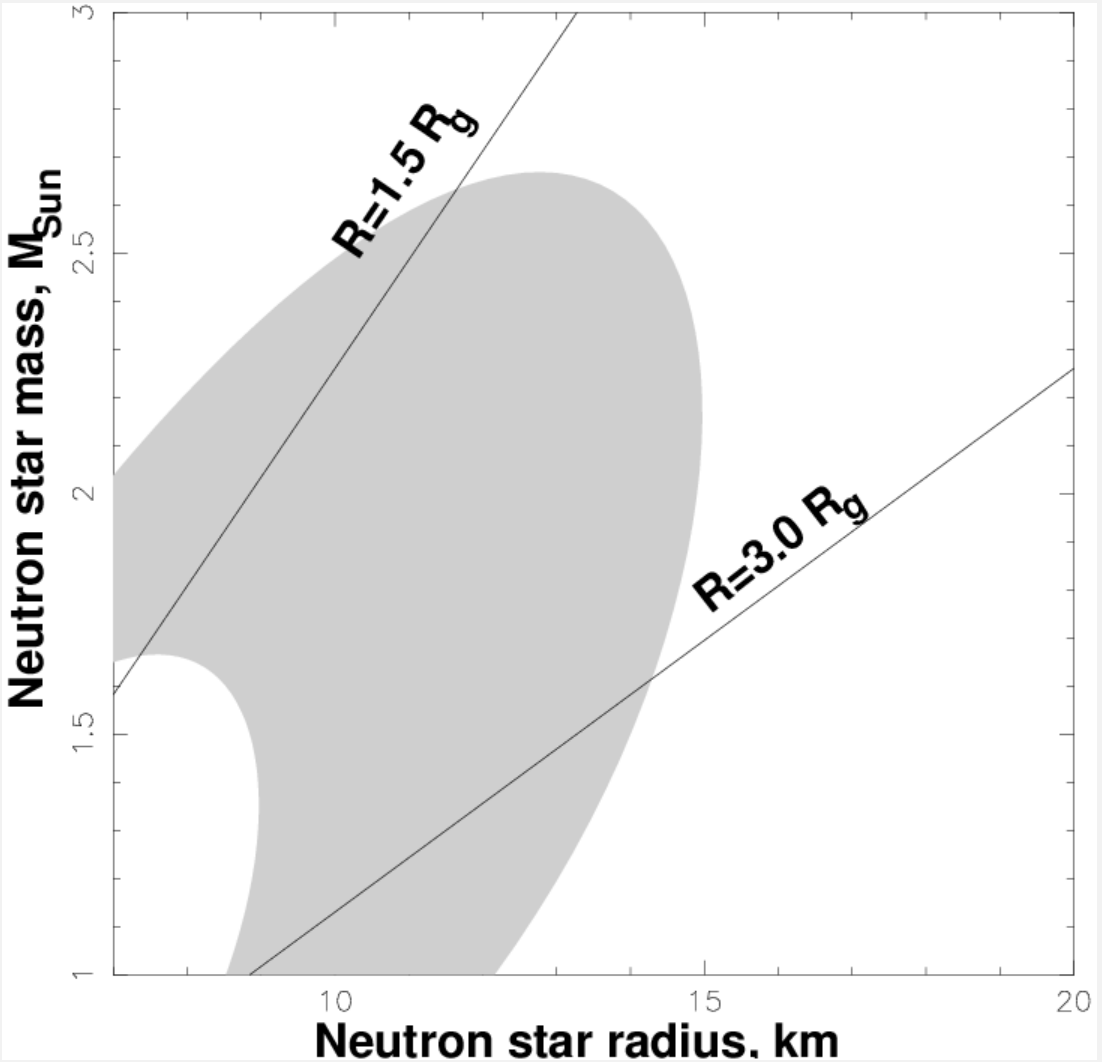
Neutron star parameters

Measurement of Eddington flux value in optically thick case

4 -2

GR corrections

$T \sim GM R$



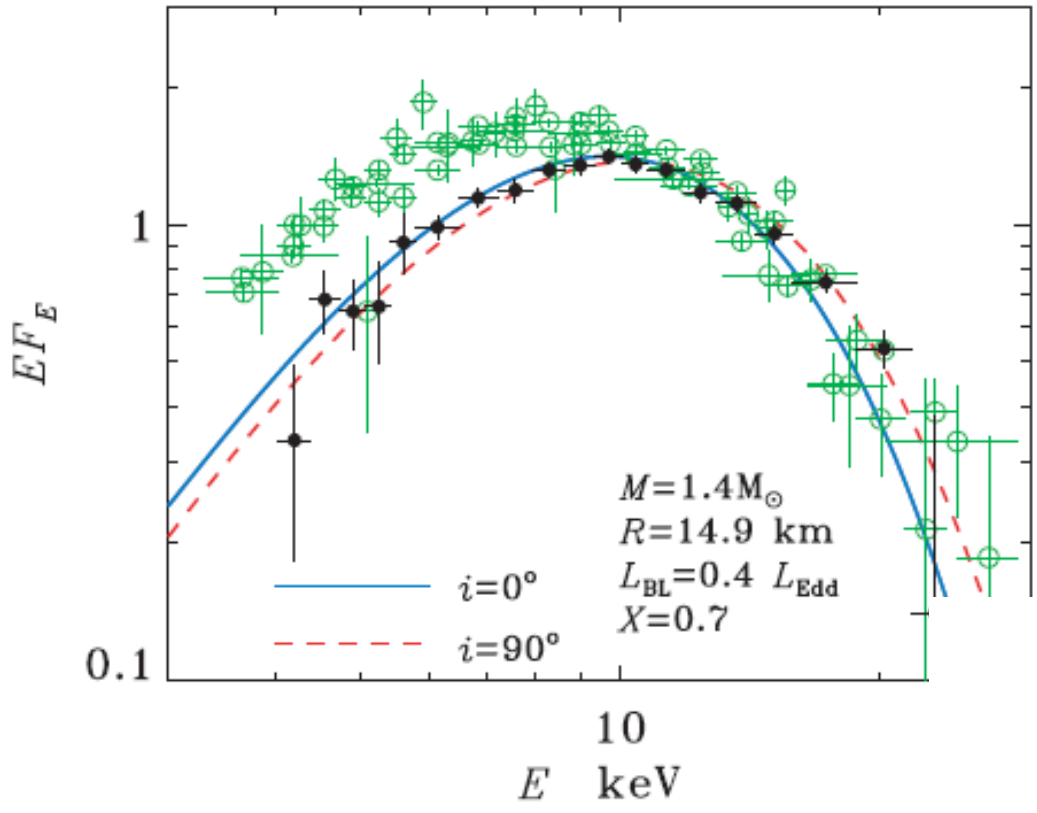
Complications:

1) Hardening factor

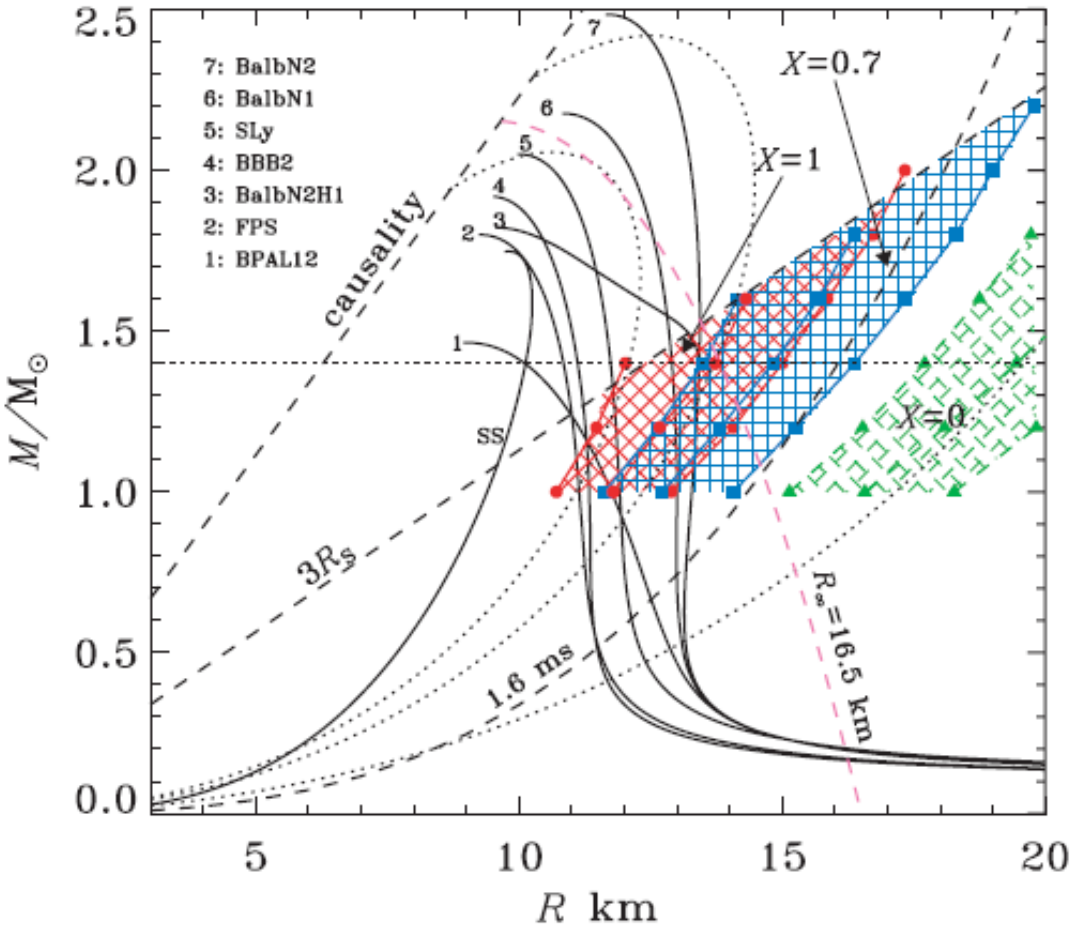
2) Centrifugal force

Revnivtsev, Gilfanov 2006

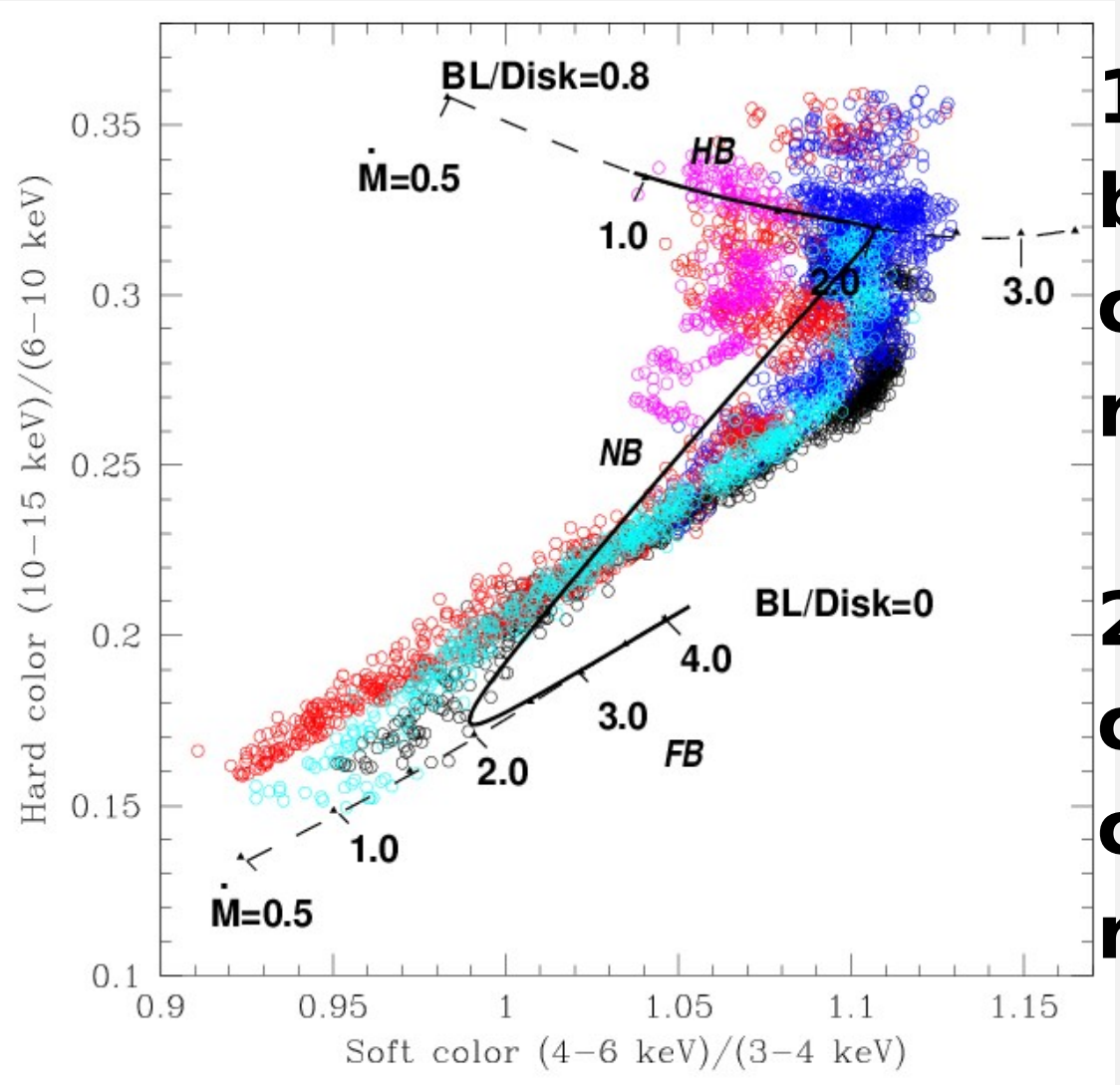
More accurate model of spreading layer spectrum



Suleimanov & Poutanen 2006



Z track

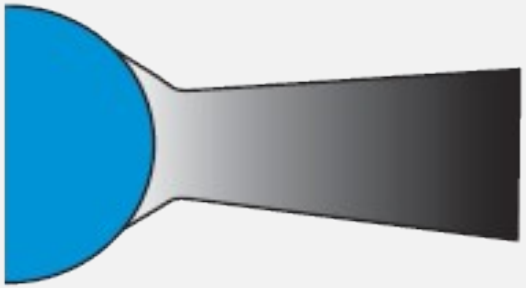


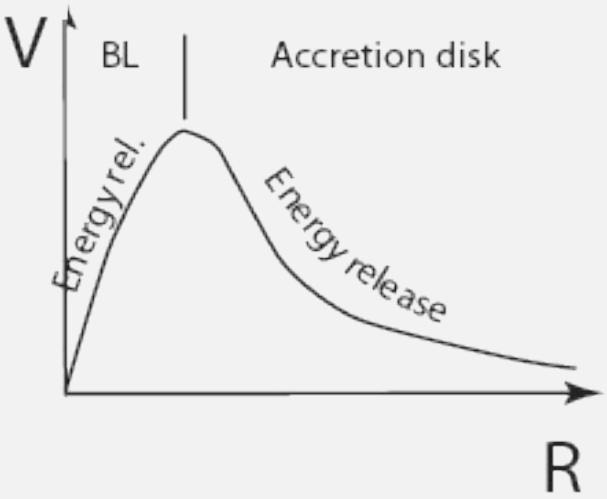
1. Decrease of the boundary layer component is the main reason for “Z-like” shap

2. The drop of the BL component occurs at certain mass accretion rate ~ close to MEdd

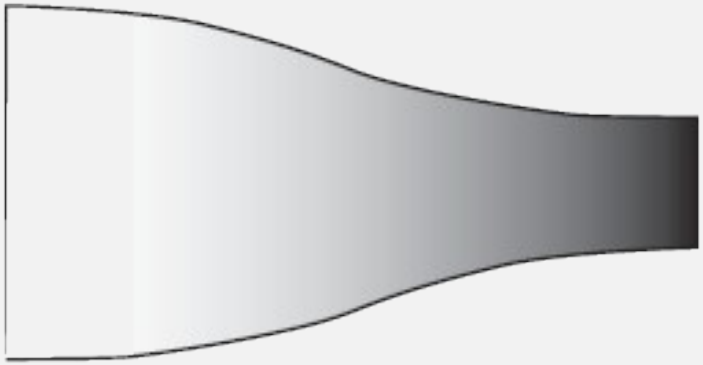
Accretion disk + BL scheme

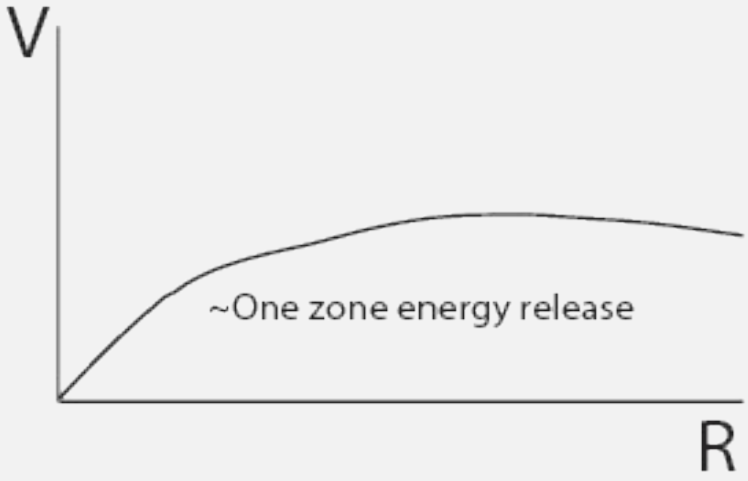
Mdot<Edd





Mdot~Edd

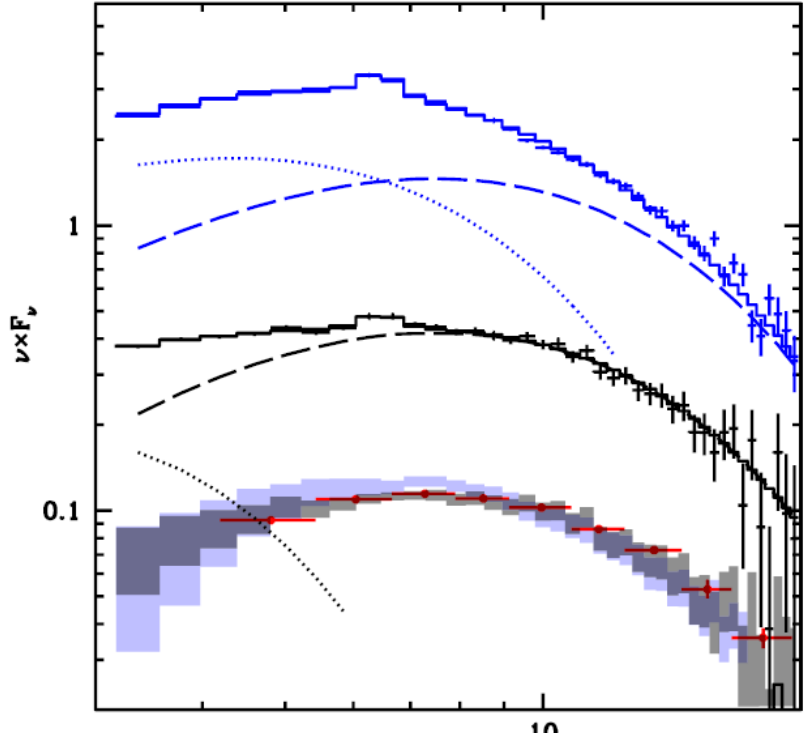


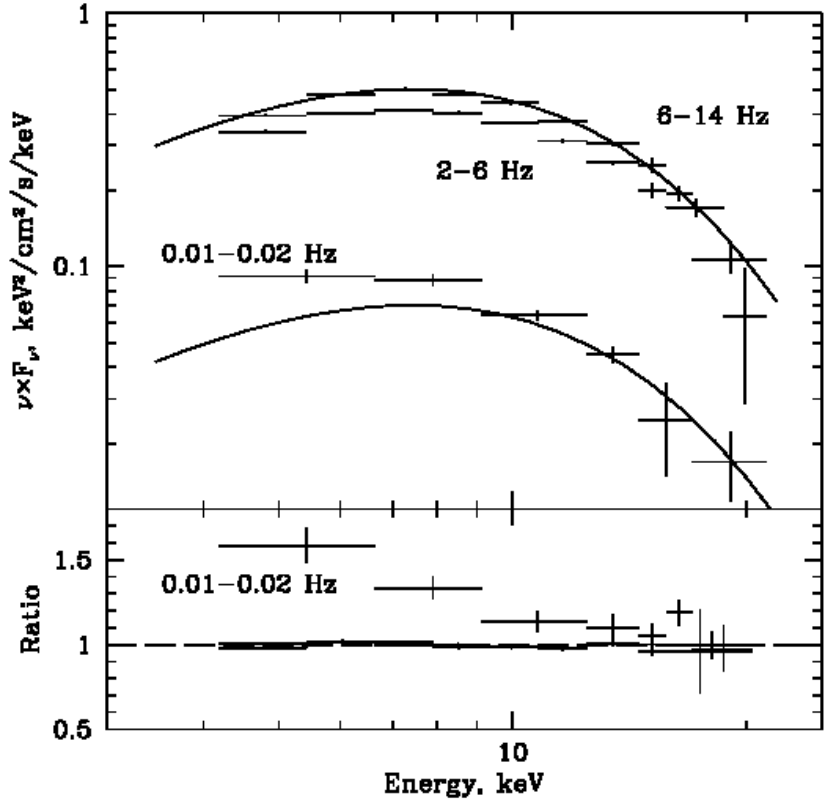


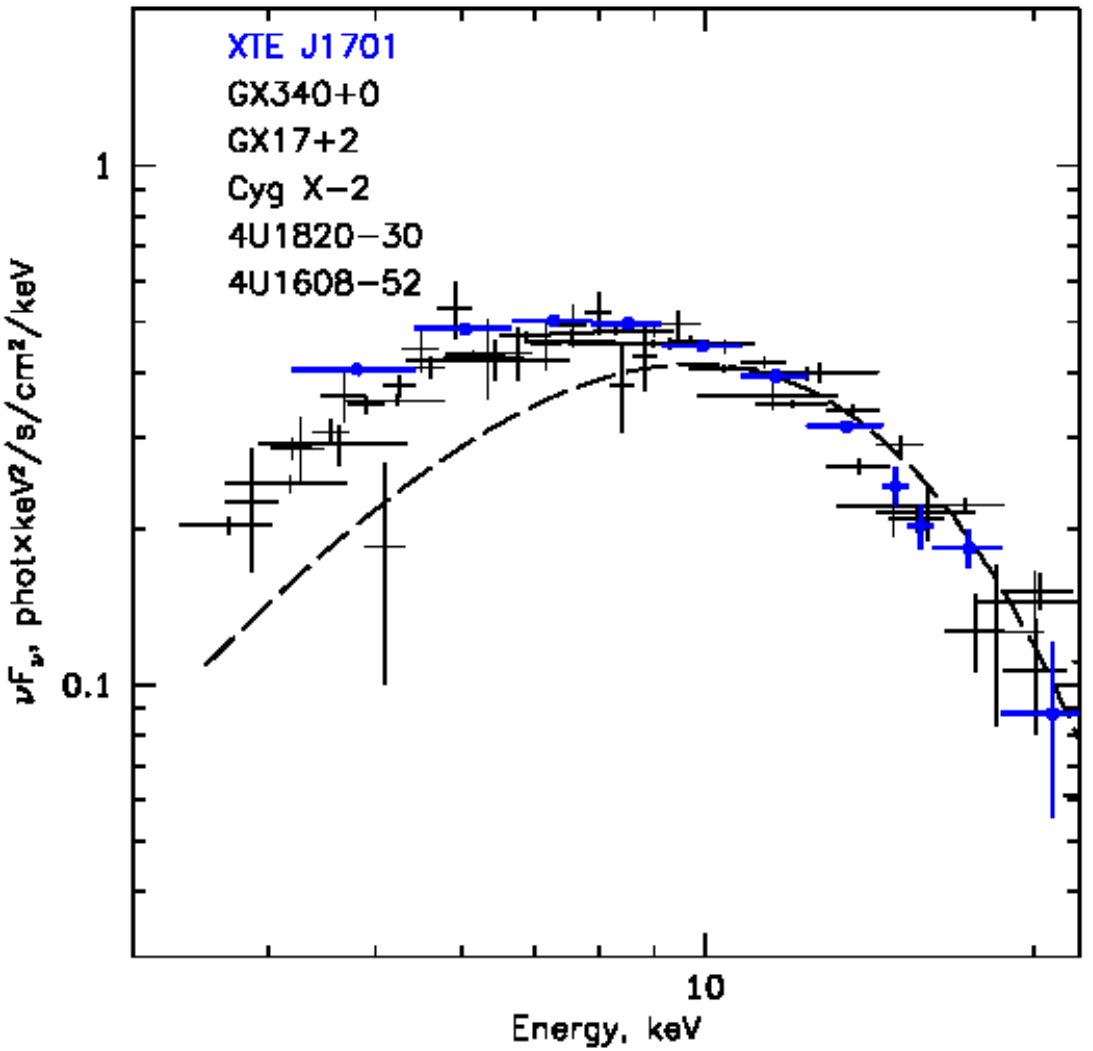
Here BL and AD are different

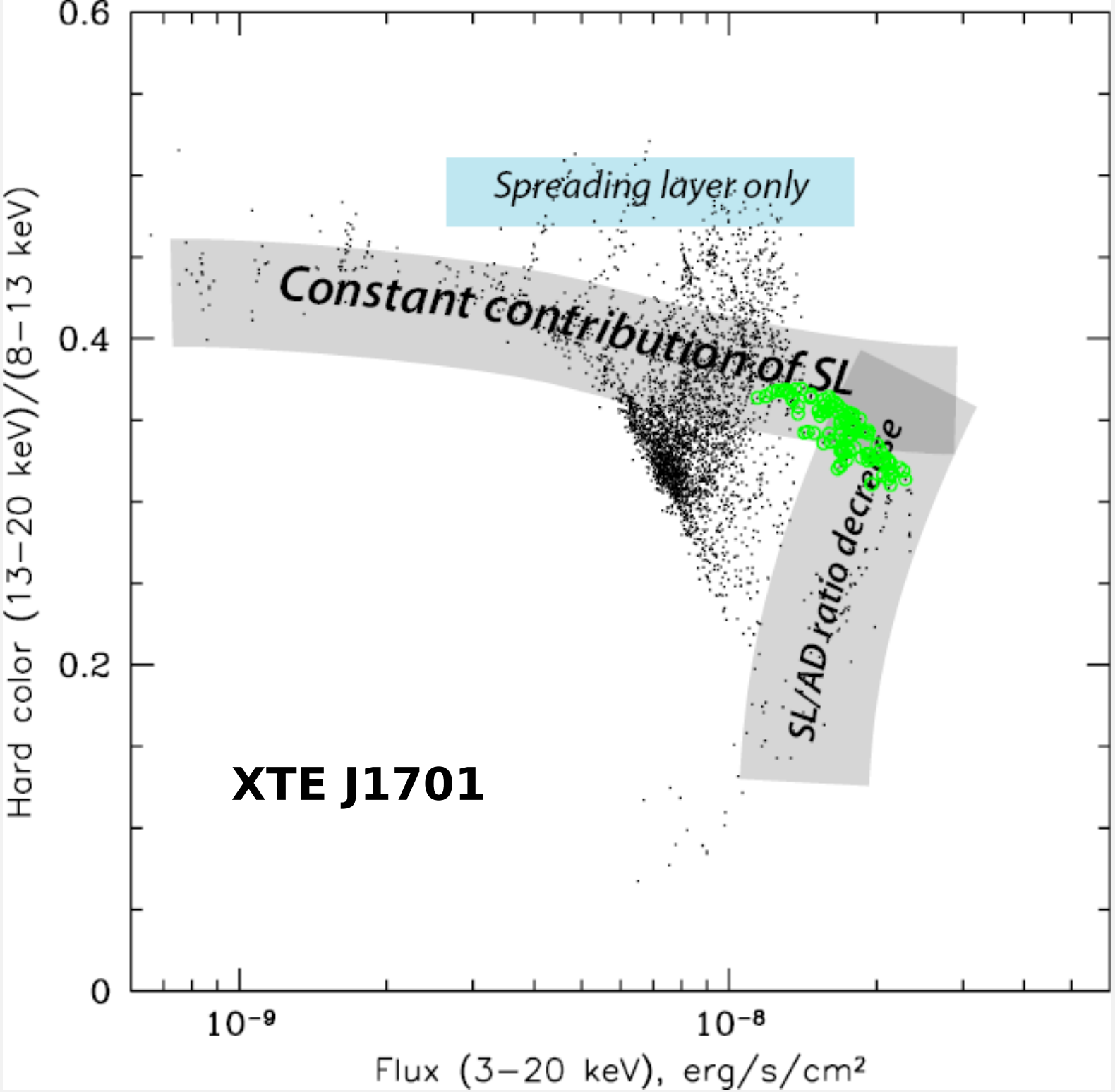
Here – not

XTE J1701 Z- and atoll- in one place








Spreading layer only
Constant contribution of SL
SL/AD ratio decrease
XTE J1701
Hard color (13–20 keV)/(8–13 keV)
Flux (3–20 keV), erg/s/cm²
0.6
0.4
0.2
0
10⁻⁹
10⁻⁸

Summary

1. **Boundary/spreading layer is important contributior to X-ray emission of NS**
2. **BL/SL surface flux is Eddington limited**
3. **This provides us important tool to measure masses and radii of NS!**

Due to accretion to neutron stars in LMXBs we now close to touch:

1. **Age of population (MS-Giants transition in LMXB LF)**
1. **Mean magnetic field of old NS (cutoff of the LMXB LF at low Lx?)**