A comprehensive study of Compton shoulder in High Mass X-ray binaries with gratings onboard Chandra

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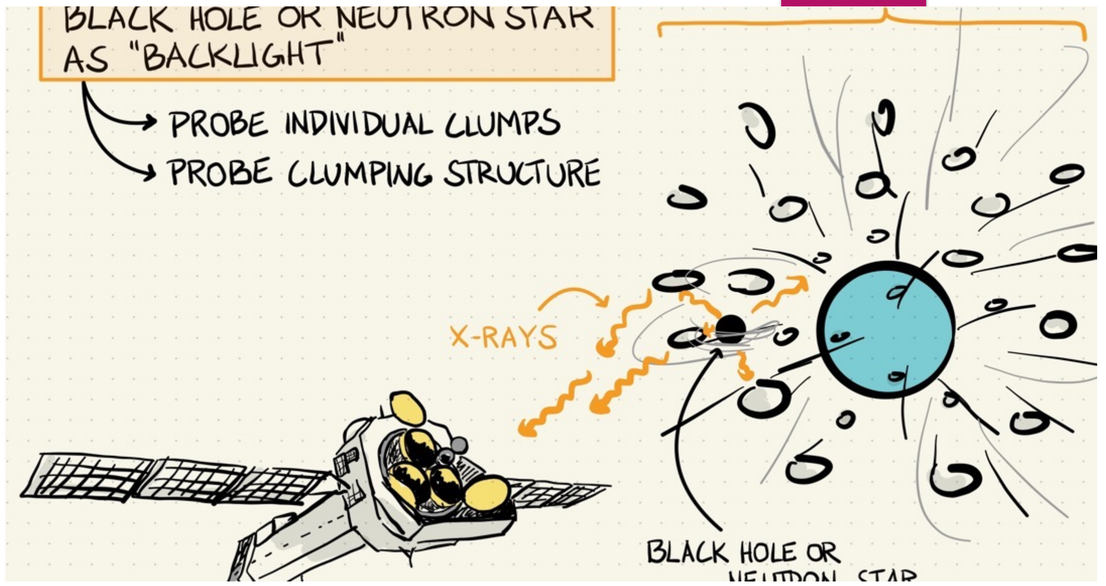
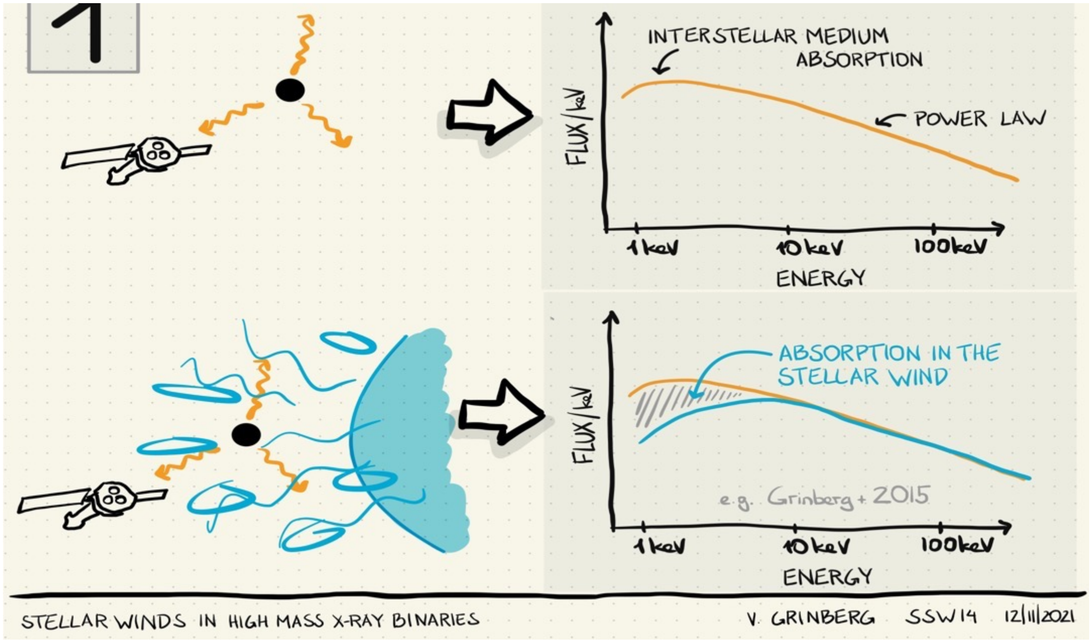
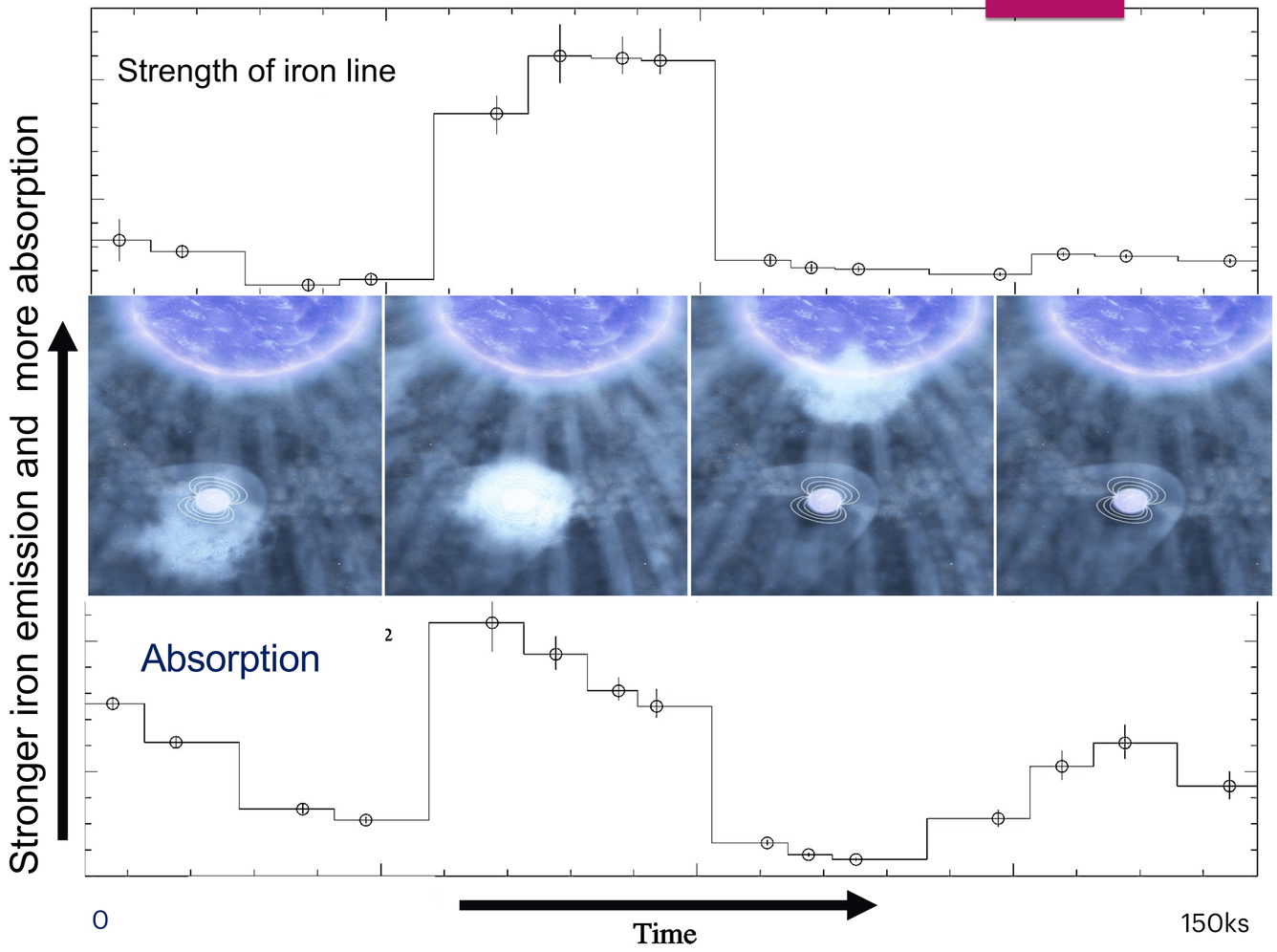
High mass X-ray binaries to probe wind structure

SKETCHES BY VICTORIA GRINBERG





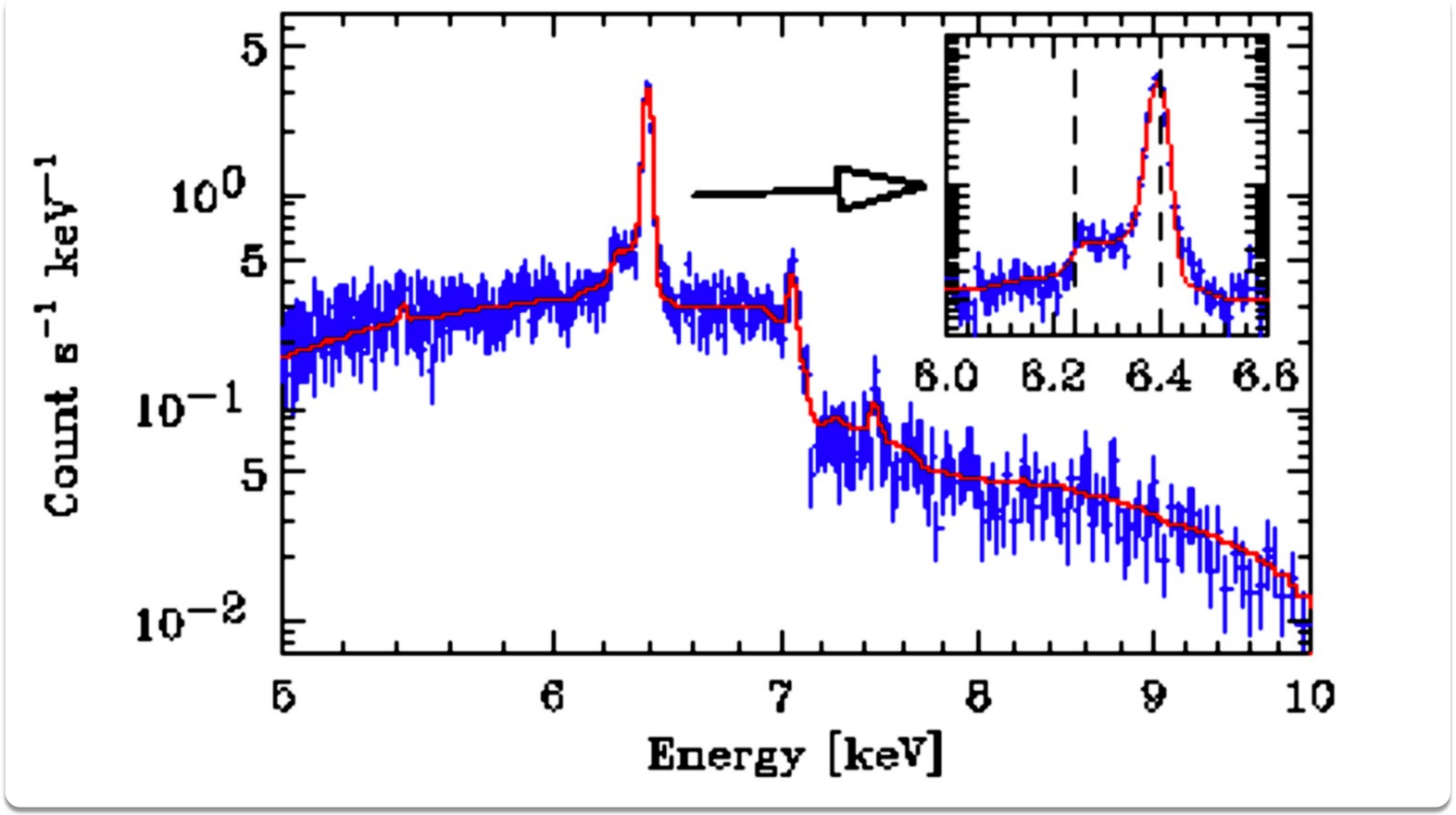
Clumpy winds in HMXBs

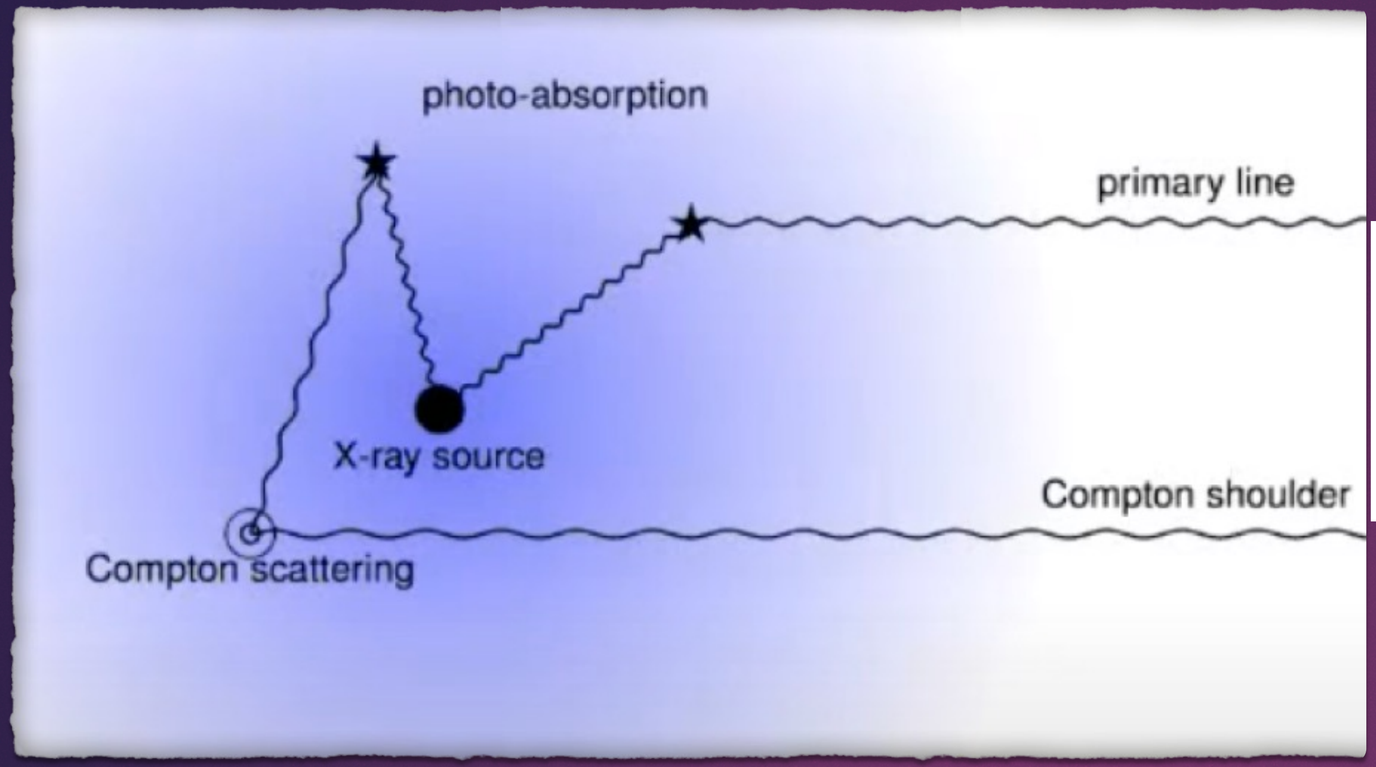


Pradhan 2014, Bozzo 2014

What is a Compton shoulder ?

GX 301-2: Watanabe 2003



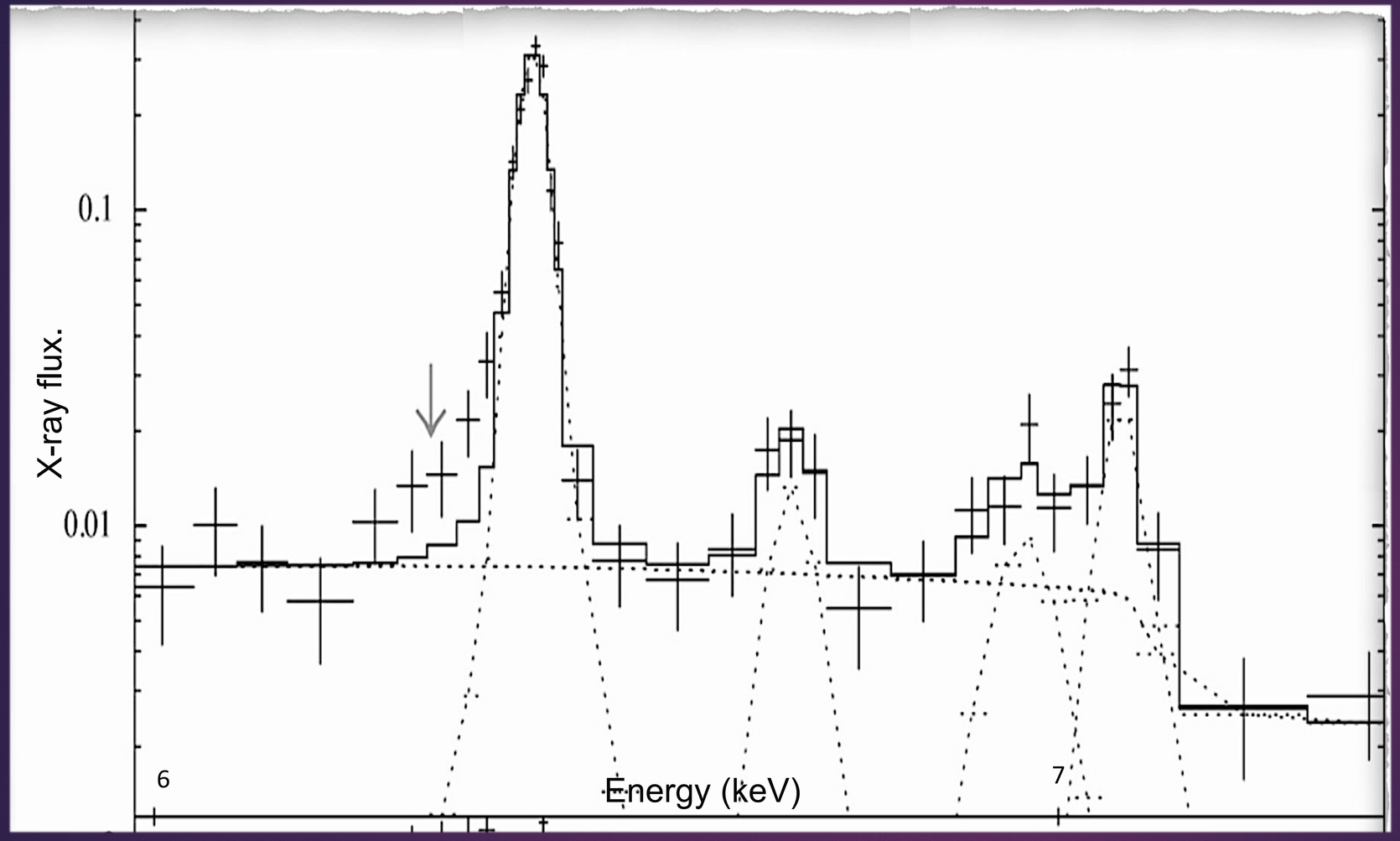


$$E_1 = \frac{E_0}{1 + (E_0/m_e c^2)(1 - \cos\theta)}, \qquad (1)$$

where E_0 is the energy of the incoming photon, E_1 is the energy of the outgoing photon, θ is the angle between the incoming and outgoing photons, and $m_e c^2$ is the electron rest-mass energy

During the scattering event, the photon transfers some of its energy and momentum to the electron, causing it to recoil. As a result, the scattered photon has lower energy than the original photon, and it is deflected at an angle from its initial path.

Pic credit: Ralf Ballhausen



OAO 1657-415
(Pradhan 2019)

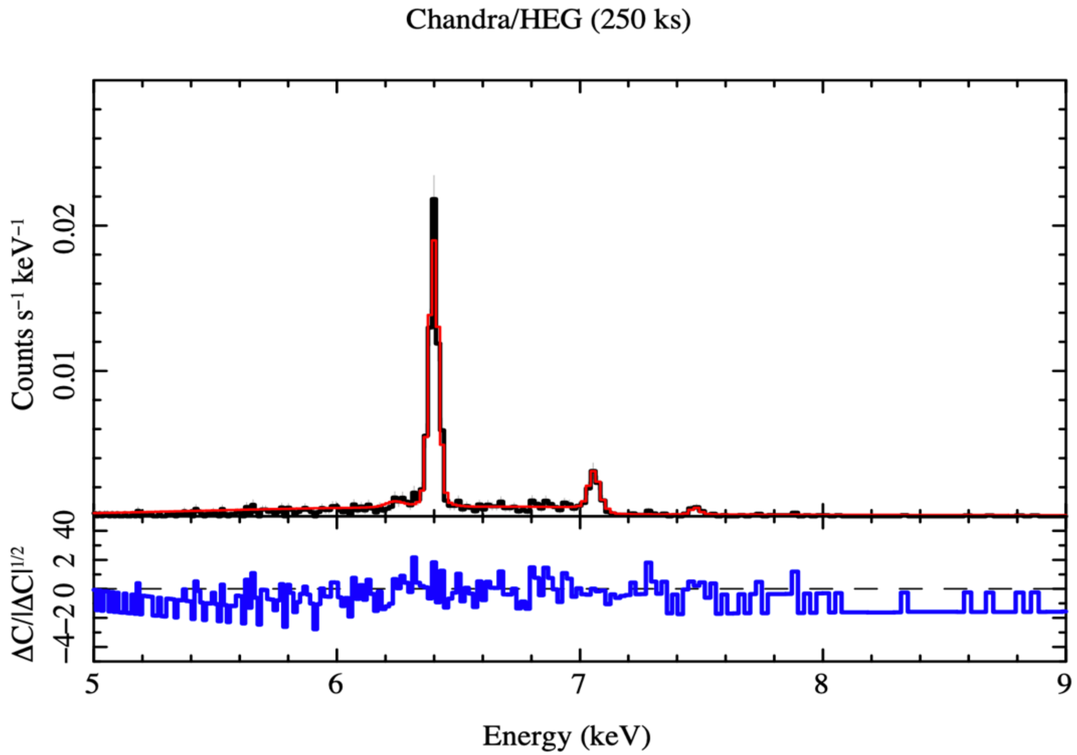
Why so few?

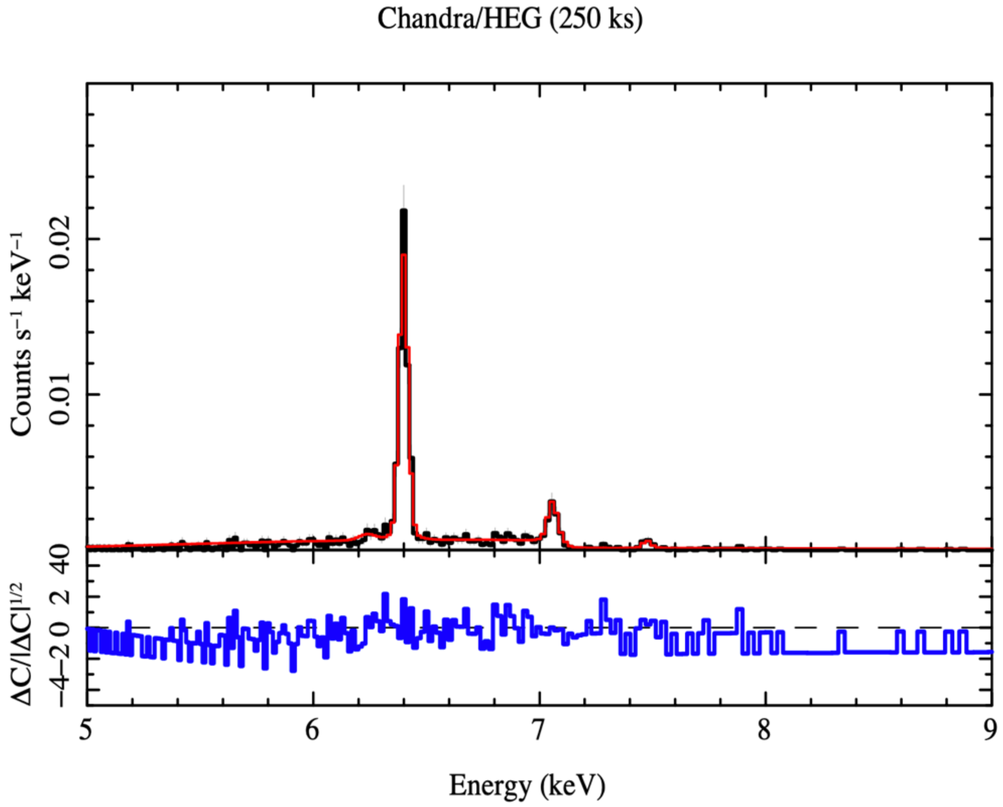
- Need high resolution spectrum: gratings, microcalorimeter
- Dependent on geometry of absorbers, opacity, electron temperature, abundances etc

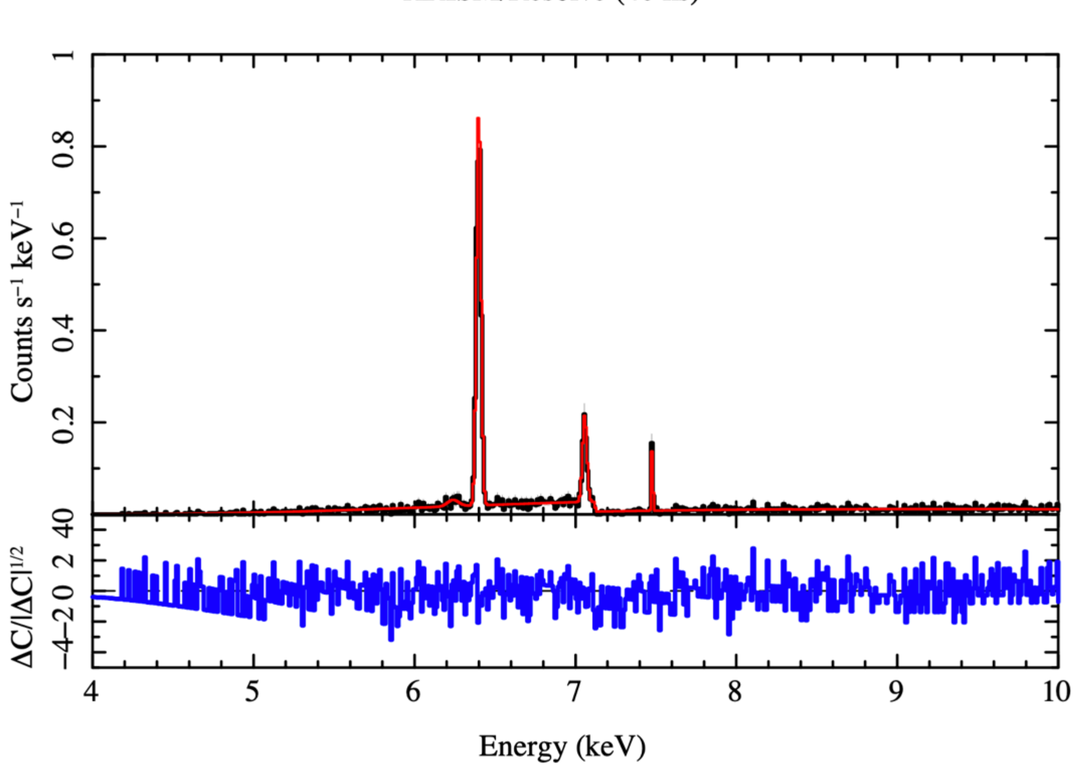
A curious case of IGR J16318-4848

A curious case of IGR J16318-4848

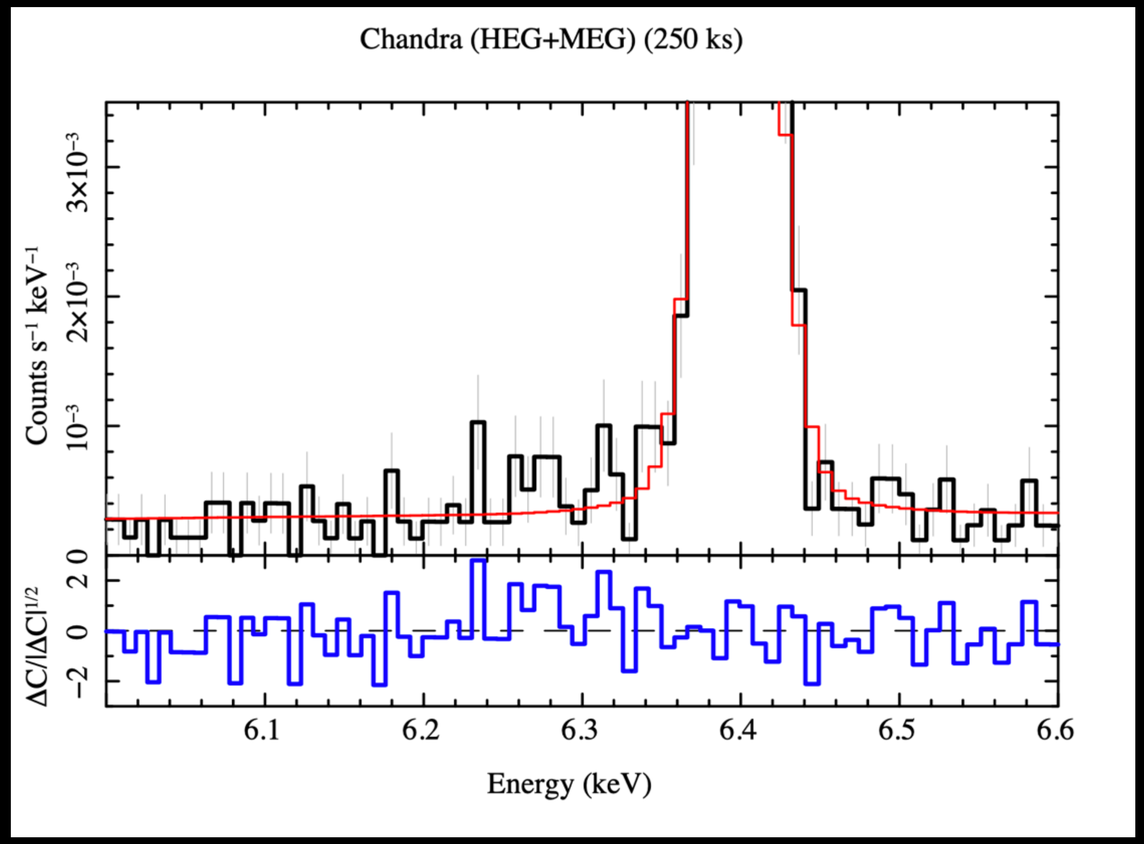
- Highly absorbed HMXB +Very strong iron line
- Small velocity of ~150 km/s (imply iron lines are formed close to the compact object – and not spread over stellar wind)
- Very less fraction of Compton shoulder (< 4%: Ballhausen 2020)

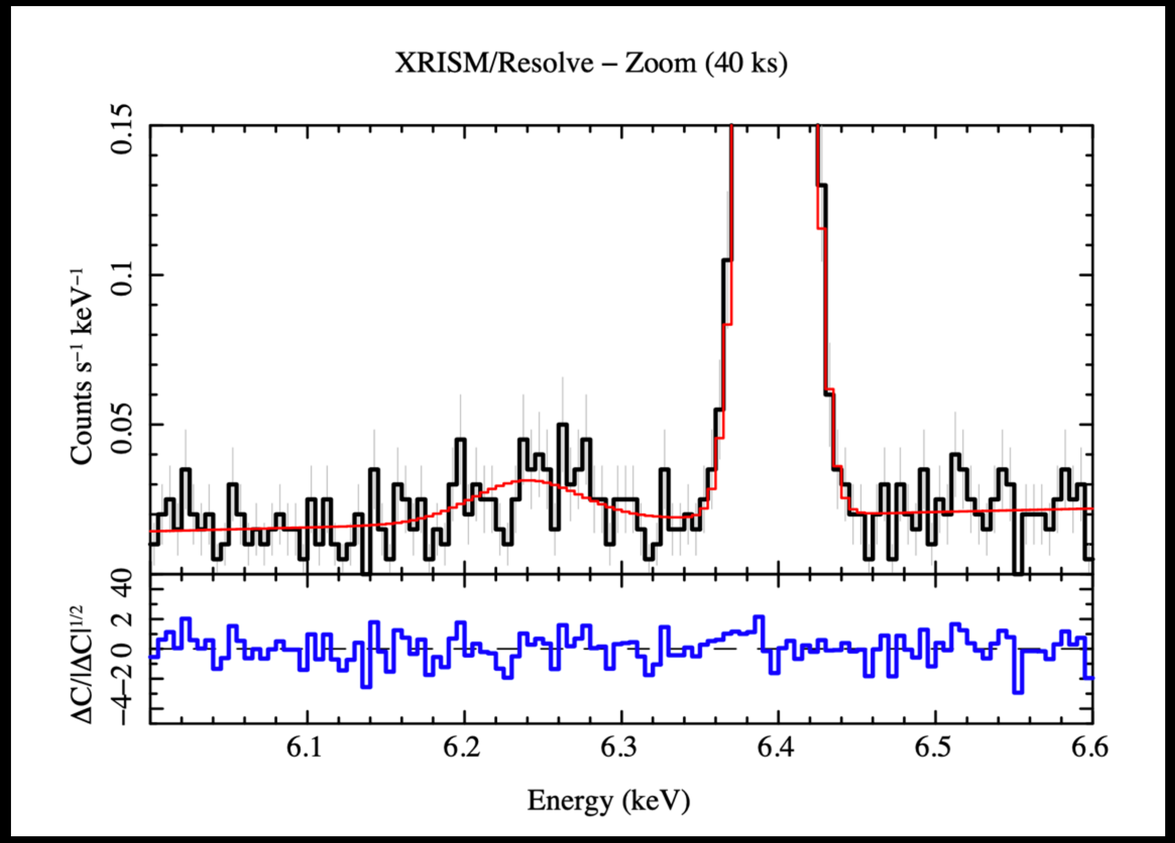



Chandra/HEG (250 ks)
Counts s⁻¹ keV⁻¹
0.01
0.02
ΔC/|ΔC|^1/2
−4 −2 0 2 4
5
6
7
8
9
Energy (keV)


XRISM/Resolve (40 ks)
Counts s⁻¹ keV⁻¹
0.2
0.4
0.6
0.8
1
ΔC/|ΔC|^1/2
−4 −2 0 2 4
4
5
6
7
8
9
10
Energy (keV)

Zooming in

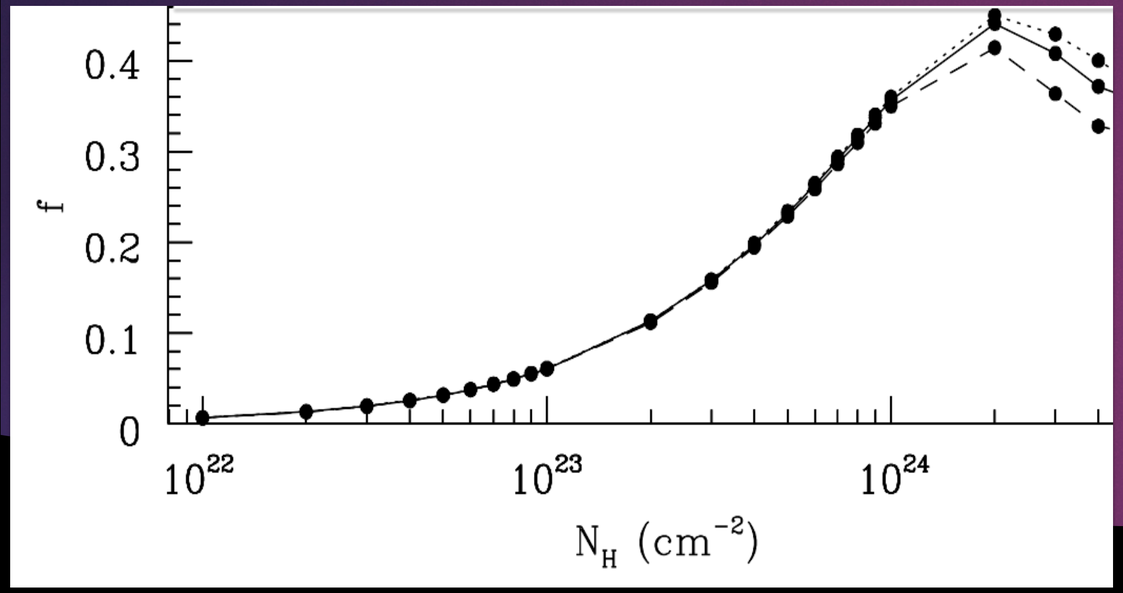

Chandra (HEG+MEG) (250 ks)
Counts s⁻¹ keV⁻¹
10⁻³
2×10⁻³
3×10⁻³
ΔC/|ΔC|^1/2
−2 0 2
6.1
6.2
6.3
6.4
6.5
6.6
Energy (keV)

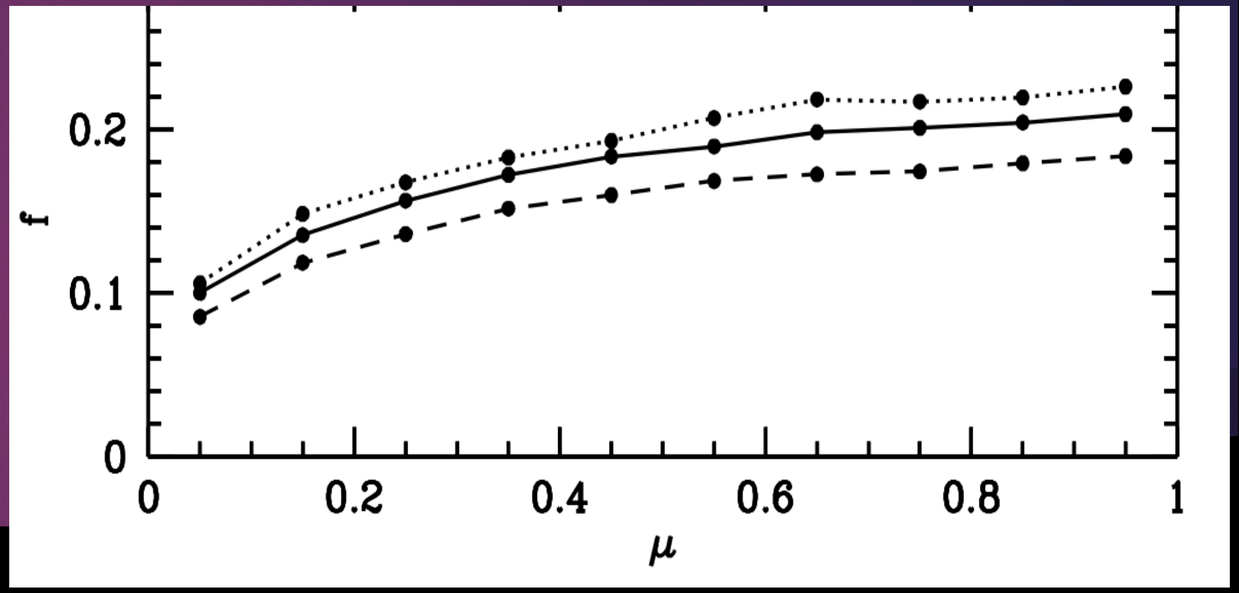

XRISM/Resolve – Zoom (40 ks)
Counts s⁻¹ keV⁻¹
0.05
0.1
0.15
ΔC/|ΔC|^1/2
−4 −2 0 2 40
6.1
6.2
6.3
6.4
6.5
6.6
Energy (keV)

Why is the Compton shoulder so low?

- Dependent on geometry (Matt 2002)
- Dependent on electron temp (Watanabe 2002)
- Absorbers are dusty (Ballhausen 2020)

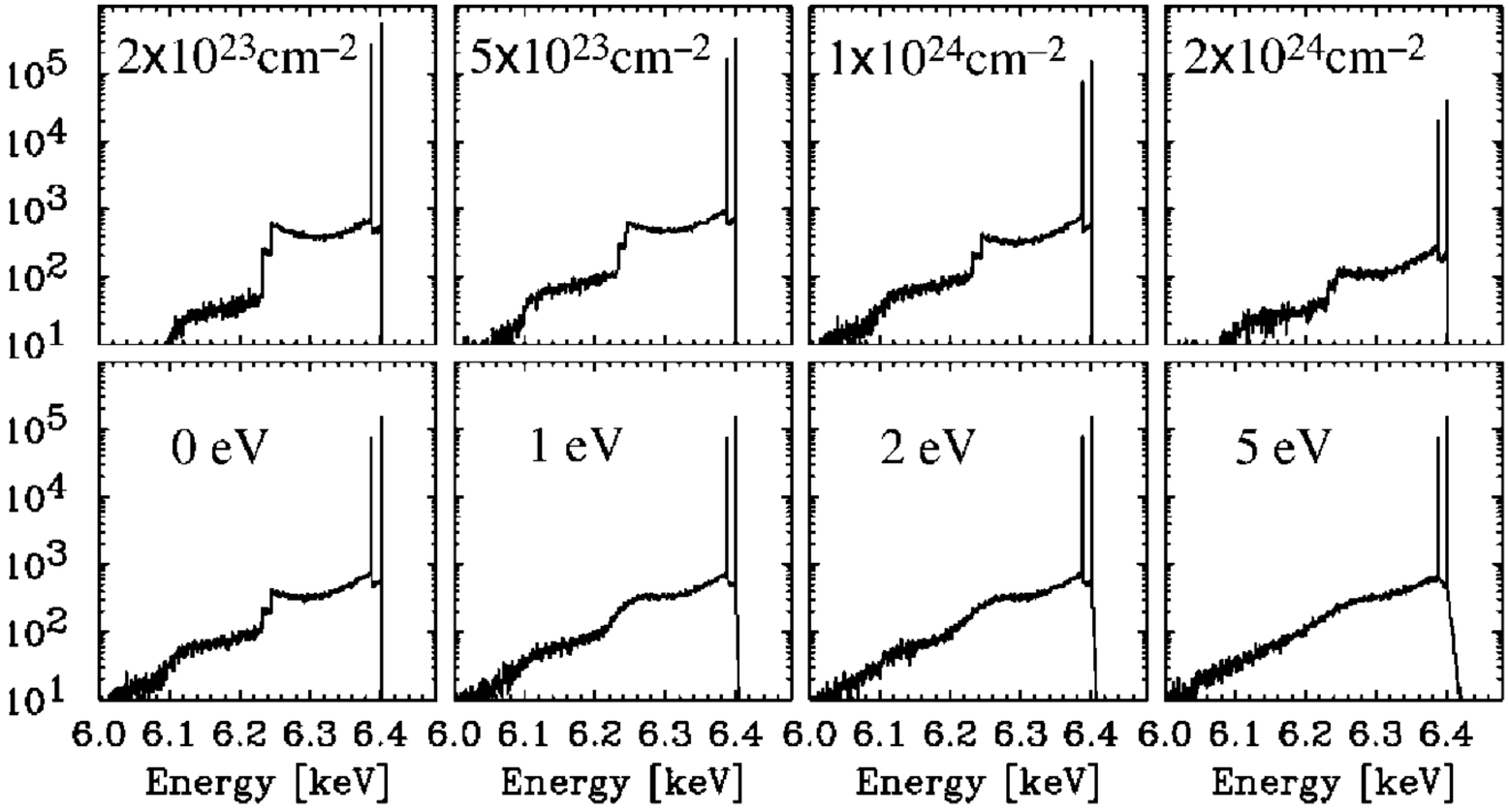
Geometry dependent (spherical versus slab)





Matt 2002

Dependent on electron temperature



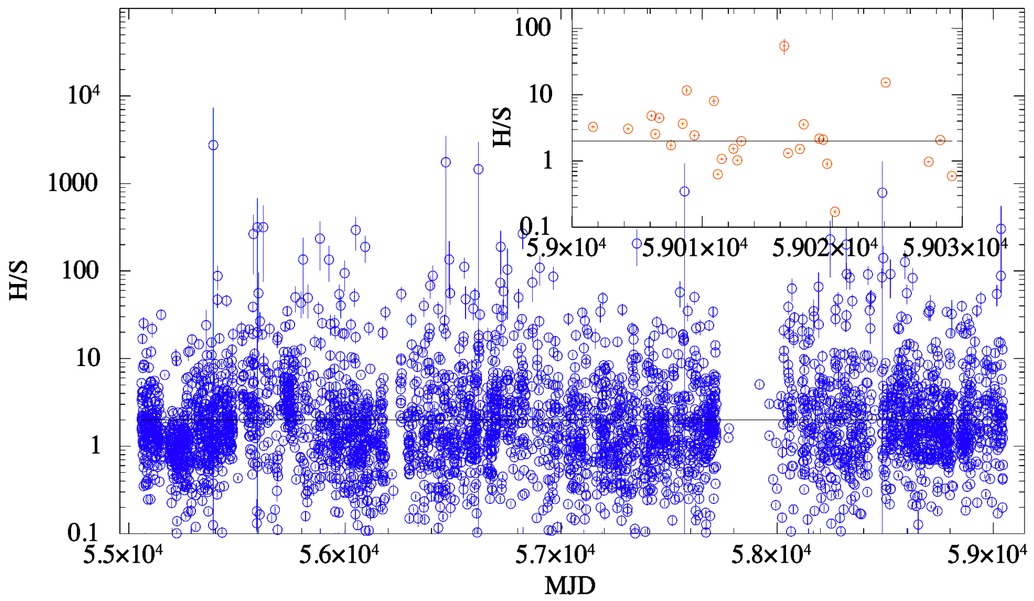
Watanabe 2003

Dust changes the optical depth

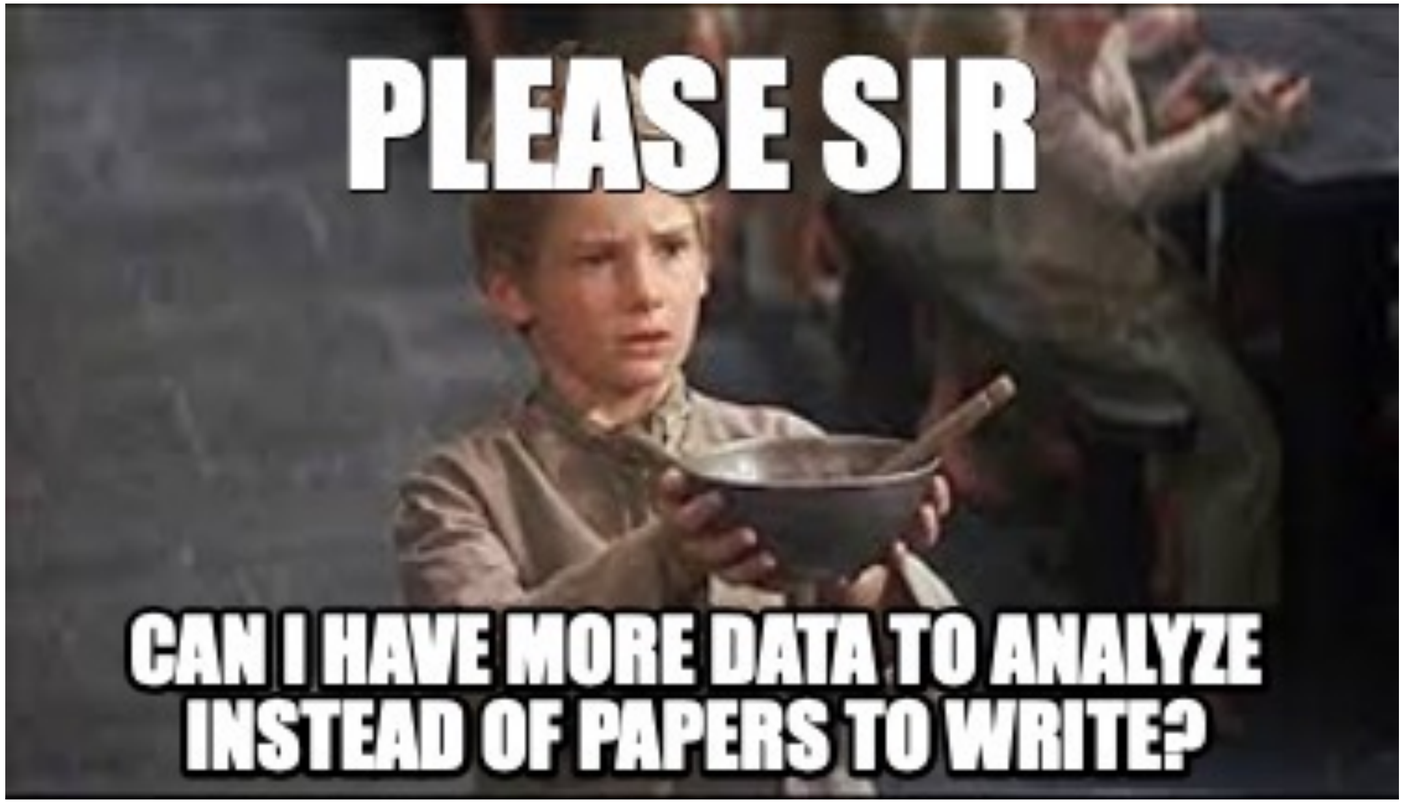
Self-blanketing effect: Atoms in the interior of dust grain are partially shielded by atoms on the surface, reducing the optical depth of dust grains versus gas (Fireman 1974).

Future work

- More data: Cycle 25 – IGR J16320–4751. Other archival data analysis e.g., hardness-ratio resolved analysis (right, plot of GX 1+4)
- XRISM: Better resolving power for large photon collecting area



Long term variability of GX 1+4 with MAXI/GSM


PLEASE SIR
CAN I HAVE MORE DATA TO ANALYZE
INSTEAD OF PAPERS TO WRITE?