PROBE THE CENTER OF NEUTRON STARS WITH ASTRO-H SOFT X-RAY SPECTROMETER

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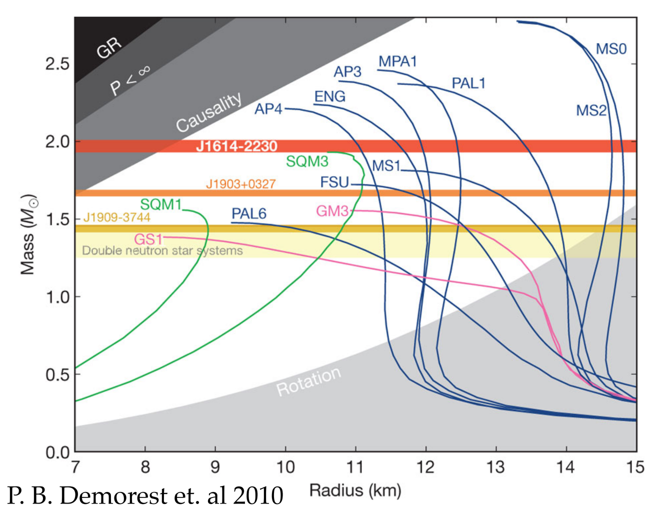
1. Motivation - How Matter Interacts In Extremely Dense Environments?



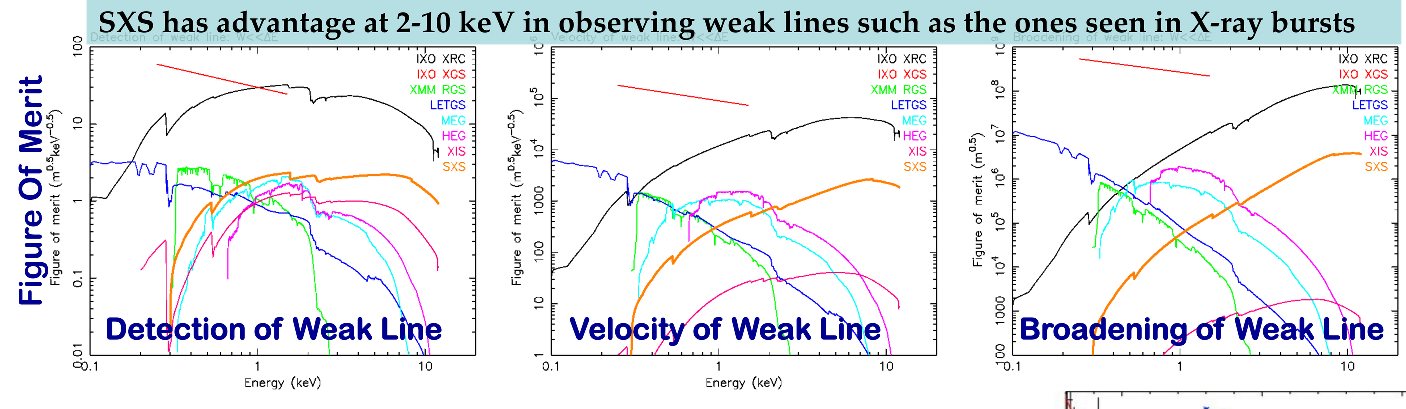
P. B. Demorest et. al 2010

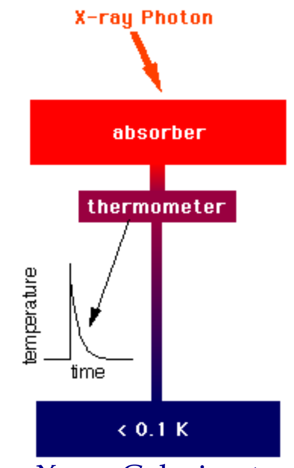
40 years after their discovery, the internal structure of neutron stars is still a puzzle. Understanding the equation of state (EOS) of the matter at the core of neutron stars is the key to probe interactions of matters in extremely dense environments (Lattimer & Prakash 2001), an experiment that is currently impossible in terrestrial laboratories.

To attack this question, we simply need to measure the masses and radii of neutron stars, two quantities that depend directly on EOS. Precise mass measurements have been done using relativistic orbital effects for neutron stars in binaries. Radii measurements, however, are extremely difficult due to the small sizes of neutron stars relative to their distances.

2. High Resolution Spectroscopy with Soft X-Ray Spectrometer (SXS)

SXS has advantage at 2-10 keV in observing weak lines such as the ones seen in X-ray bursts

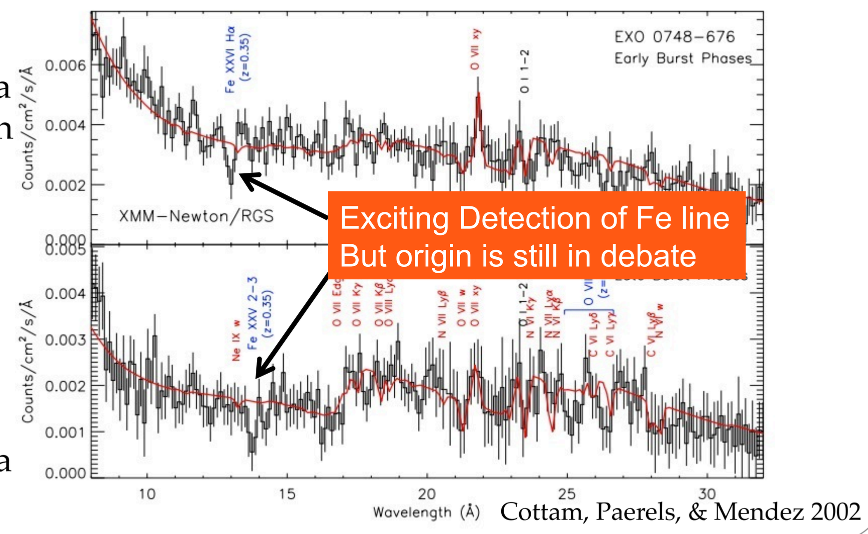




X-ray Calorimeter

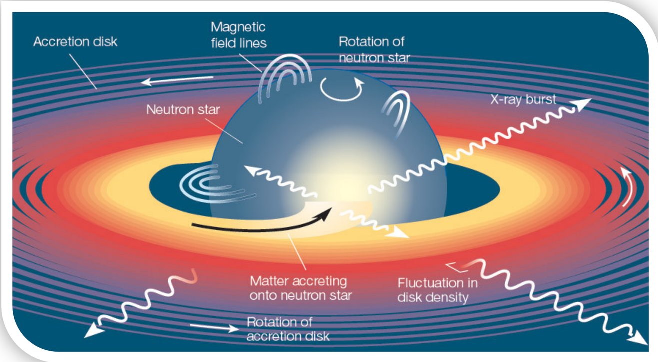
If we can detect absorption lines or edges in neutron star spectra and identify their rest wavelengths, the mass and radius relation can be inferred from the gravitational redshift
$1+z = (1-2GM/Rc^2)^{-1/2}$.

SXS onboard Astro-H uses a state-of-the-art X-ray calorimeter spectrometer at the focus of a high-throughput X-ray telescope. The X-ray calorimeter is a low-temperature sensor that measures the energy of each X-ray photon as heat with extraordinary precision, and allows high-resolution spectra to be obtained from extended sources without degradation.



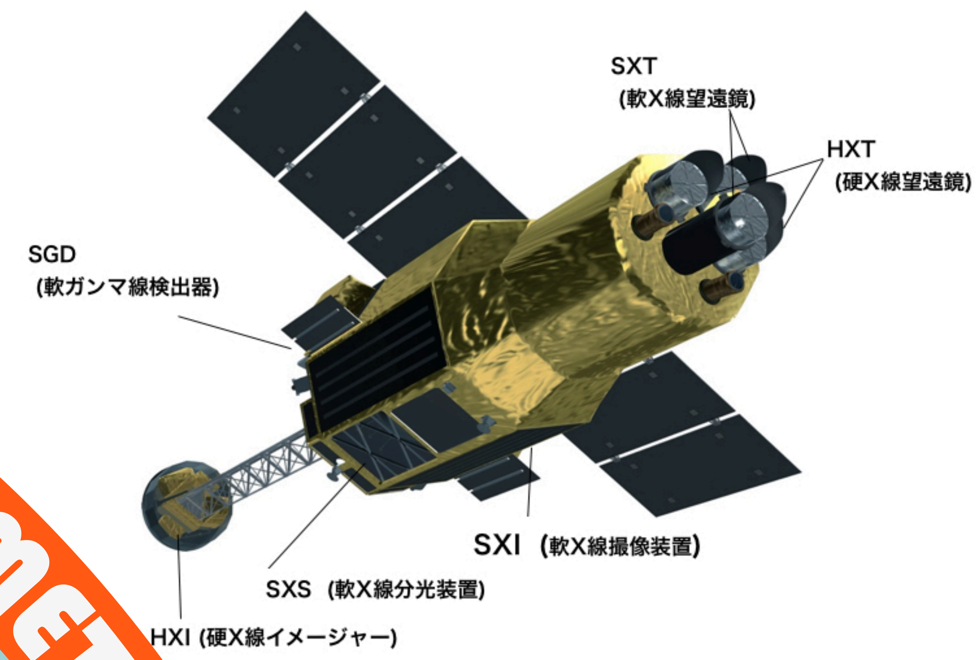
Cottam, Paerels, & Mendez 2002

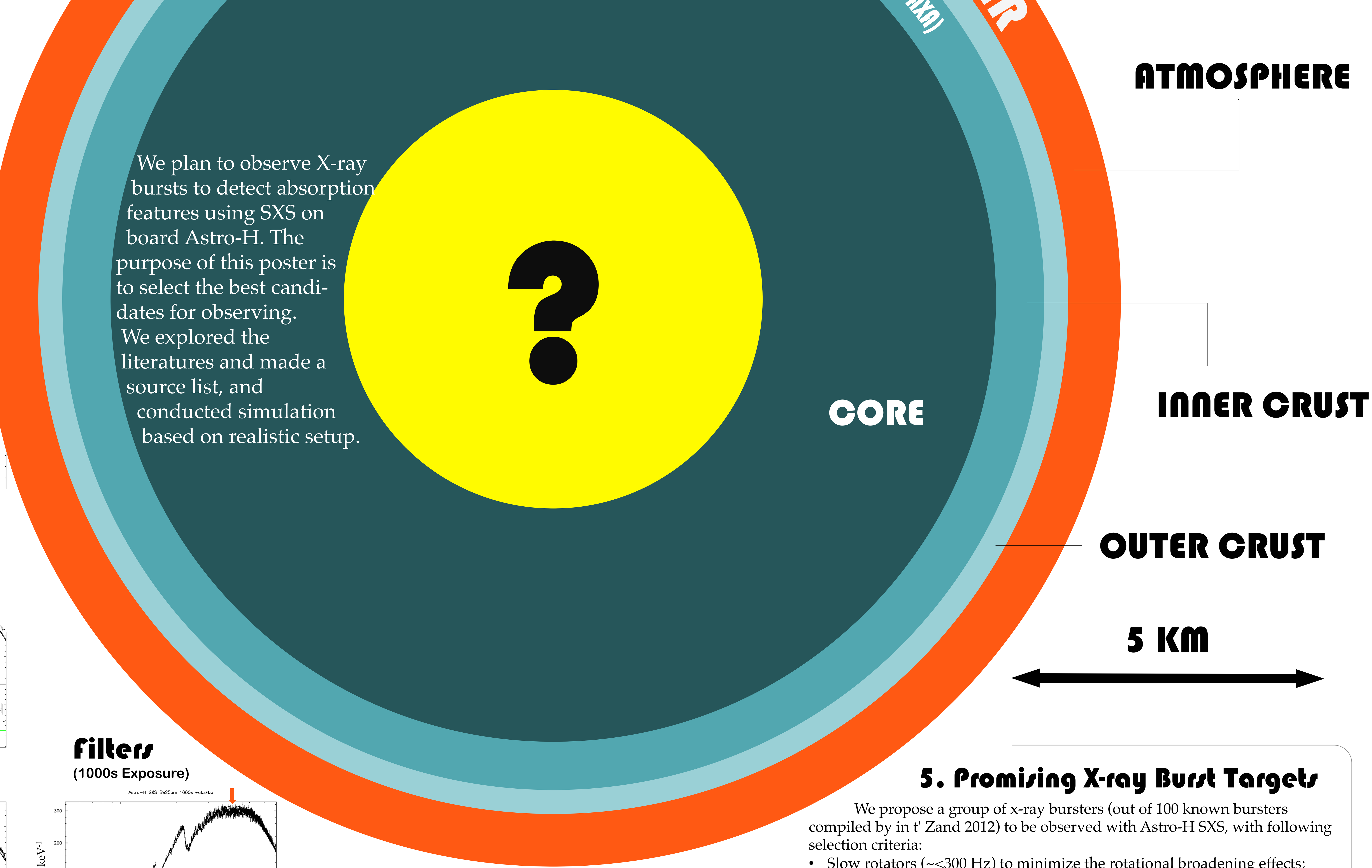
3. X-Ray Bursts from Neutron Stars



X-ray bursts originate from unstable nuclear burning of accreted matter on the neutron star surface. They are observed in Low Mass X-ray Binaries (LMXB), where a neutron star has a companion of < 1 solar mass. They show timing and spectral features that can be used to constrain the mass, radius and spin frequency of the same neutron star.

X-ray bursters are the most promising places to observe absorption features. In order to observe spectral lines in X-ray, the presence of heavy elements in the neutron star atmosphere and significant thermal emission from the surface are needed (Ozel & Psaltis 2003). X-ray bursters are accreting neutron stars in LMXBs, where heavy elements are continually replenished by accretion from the donor, and the thermonuclear burning provides 10 times energy than persistent flux. In contrast, for non-accreting neutron stars, the heavy elements would sink beneath the photosphere on time scale of 1 s due to the strong surface gravity of neutron stars (Bildsten et al. 2003).





We plan to observe X-ray bursts to detect absorption features using SXS on board Astro-H. The purpose of this poster is to select the best candidates for observing. We explored the literatures and made a source list, and conducted simulation based on realistic setup.

4. XSPEC Simulation Of X-ray Bursts

Model: wabs*bb*gabs*gabs

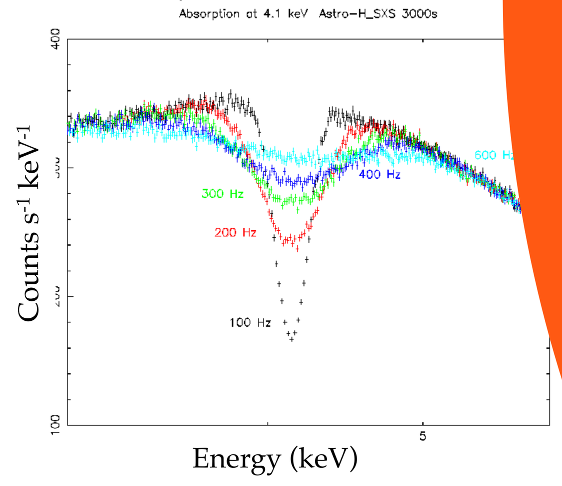
Wabs = 10^{21} cm^{-2}
$T_{blackbody}$ = 1.8 keV

2 gaussian absorption lines:

- 0.95 keV, EW = 0.013 keV (EXO 0748-676 spin = 45 Hz)
- 4.1 keV, EW = 0.158 keV (4U 1608-522 spin = 620 Hz)

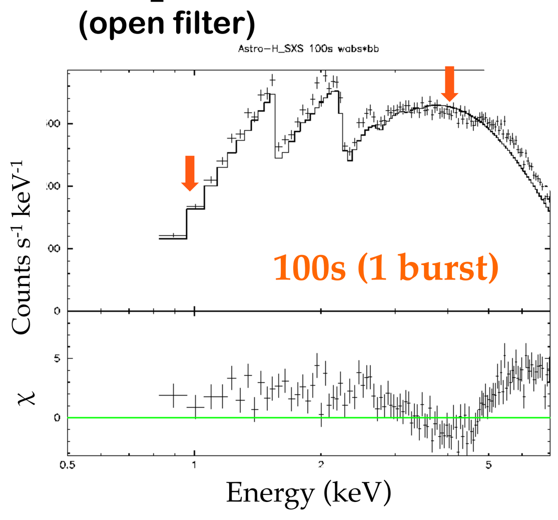
NS Spin

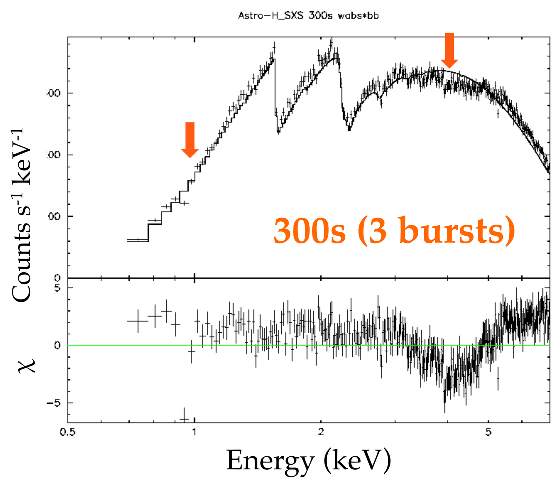
Absorption 4.1keV

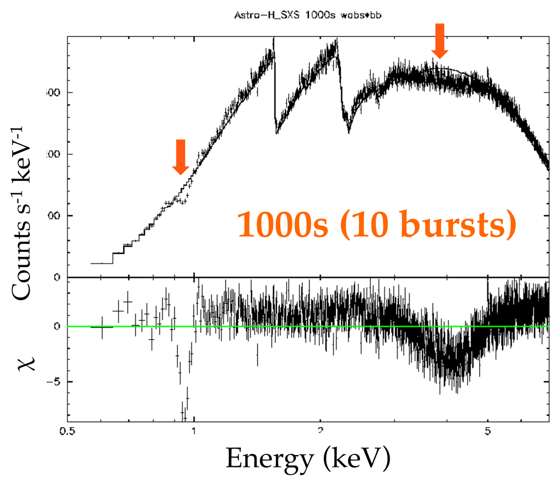


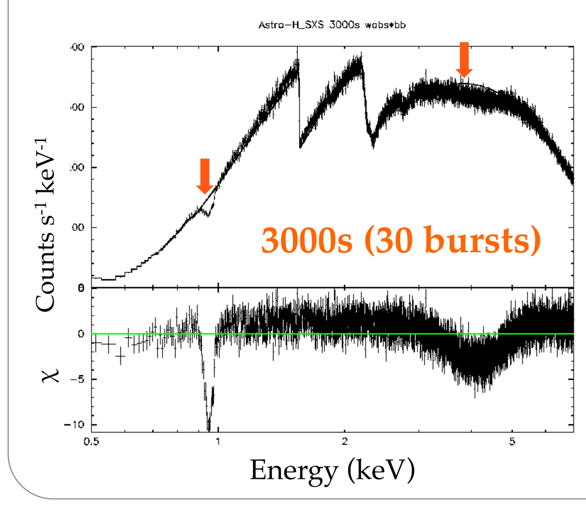
Exposure Time

(open filter)



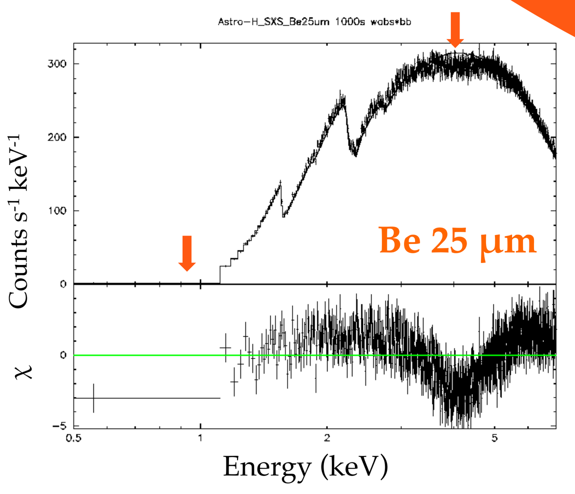


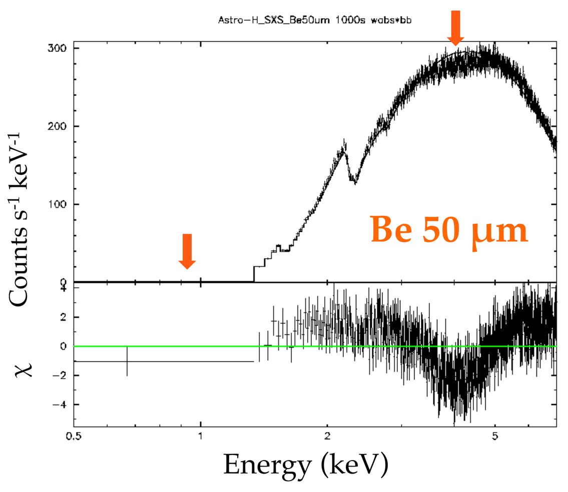


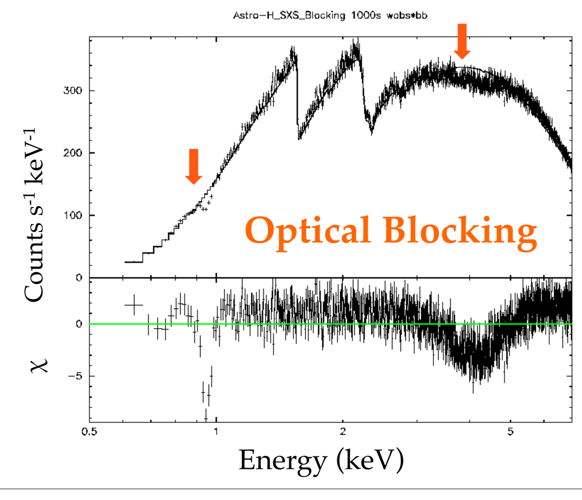


Filters

(1000s Exposure)



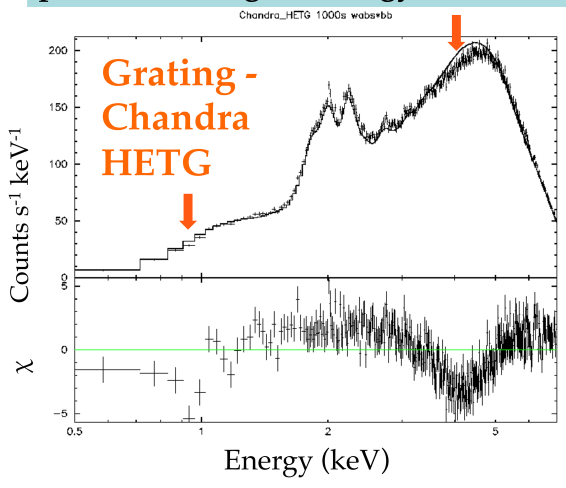


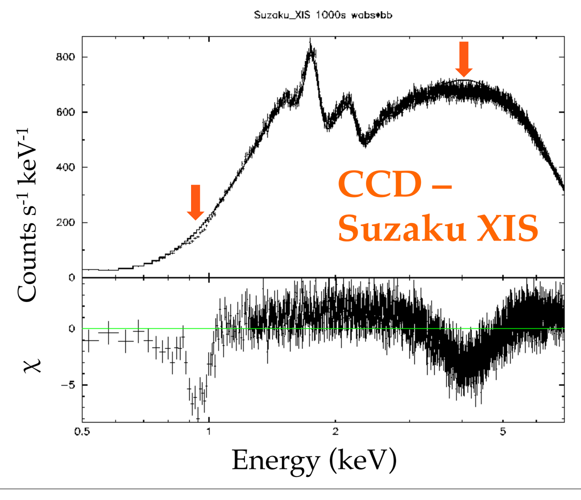


Compare with Grating & CCD

(1000s Exposure)

SXS show similar ability as grating & CCD at soft energy (<2keV) but more powerful at higher energy





5. Promising X-ray Burst Targets

We propose a group of x-ray bursters (out of 100 known bursters compiled by in t' Zand 2012) to be observed with Astro-H SXS, with following selection criteria:

- Slow rotators (~<300 Hz) to minimize the rotational broadening effects;
- High enough burst rates (if known) to ensure at least one burst to be observed during a 100 ks observation (mean burst rate > 0.036 hr^{-1});
- We also included any objects with previously identified features.

Object	Spin (Hz)	Burst rate (hr^{-1})	Absorption (keV)
EXO 0748-676	45, 552	0.24	0.95 [1]
4U 1254-69	95?	0.064	
4U 1608-522	620	0.068	4.1 [2]
4U 1636-536	581	0.22	4.5 [3]
IGR J17191-2821	294		
IGR J17480-2446	11		
IGR J17511-3057	245		
XTE J1814-338	314	0.23	
4U 1915-05	270	0.12	

[1] Cottam el al. 2002, [2] Nakamura et al. 1988, [3] Waki et al. 1984

Sample Observing Plans

4U 1608-522 (Peak flux = 4.55 Crab)
Count rate = 3.5E+03 cps
(PIMMS, 0.5 - 8.0keV, open filter)
CPU Load= 794% (200% available)

Plan	Obs. Eff	Hp+Mp cps
Open	0.77	49.03
Mask central 9 pixels	1.0	63.67
ND filter	0.08	5.11

References

Bildsten, L., Chang, P. & Paerels, F. 2003, ApJ, 591, L29.
Cottam, J., Paerels, F. & Mendez, M. 2002, Nature, 420, 51
Demorest P, Pennucci T, Ransom S, Roberts M and Hessels J 2010 Nature, 467, 1081
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Lattimer, J. M. & Prakash, M. 2001, ApJ. 550, 426
Nakamura, N., Inoue, H., & Tanaka, Y. 1988, PASJ, 40, 209
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