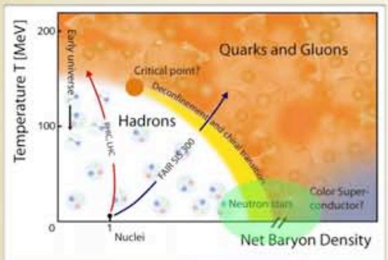
The High Time Resolution Spectrometer aboard the International X-ray Observatory

Didier Barret (CESR Toulouse), Shunji Kitamoto (Rikkyo University), Mariano Mendez (University of Groningen), Jon Miller (University of Michigan), Frits Paerels (Columbia University), Tod Strohmayer (Goddard Space Flight Center), Phil Uttley (University of Southampton), Joern Wilms (University of Erlangen-Nuremberg) on behalf of the HTRS working group

Abstract: The High Time Resolution Spectrometer (HTRS) will provide the International X-ray Observatory with the capability to observe with >90% throughput bright X-ray sources (up to ~10 Crabs) with ~150 eV spectral resolution (at 6 keV) and microsecond time resolution. We review the potential of the HTRS observations of accreting neutron stars and stellar mass black holes to constrain the properties of matter at supra-nuclear densities and to probe the strongest gravity fields.

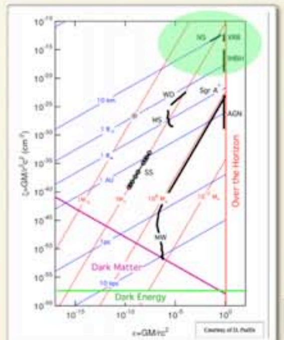
Why look at accretion powered neutron stars and stellar mass black holes?

Because neutron stars probe the low temperature-large density region of the QCD phase diagram



Determining the equation of state of cold matter requires measuring the mass-radius relation of neutron stars, using X-rays generated at their surface or their vicinity.

Because both probe the strongest gravitational fields and the most extremely curved spacetimes in the Universe

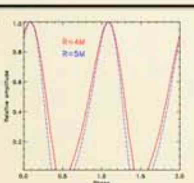
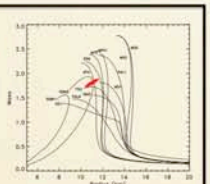


Understanding how strong gravity works and testing our understanding of General Relativity require observations of X-rays generated, close to the horizon of the black hole or the surface of the neutron star.

Key science drivers for the HTRS

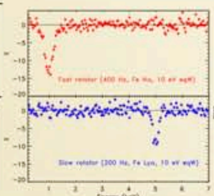
The equation of state of dense matter

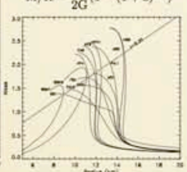
Cycle waveform of burst oscillations depends on neutron star compactness. Fitting of the waveform yields M and R. The HTRS will be able to observe type I X-ray bursts of up to 10 Crab intensity.

Redshifted absorption features expected during type I X-ray bursts. The ~150 eV spectral resolution of the HTRS will enable to detect those features, even if smeared by rotation. The redshift yields M/R.

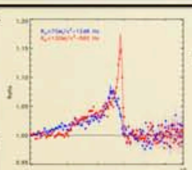
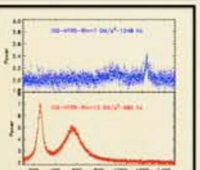
$$M/R = \frac{c^2}{2G}(1-(1+z)^{-2})$$





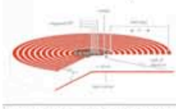
The HTRS will enable to track the inner disk radius from fitting the Iron line profile and from high frequency quasi-periodic oscillations. If the orbital nature of the kHz QPO can be demonstrated, then the neutron star mass can be readily derived.

$$M = \frac{32.2}{(\nu_K/1000\ \text{Hz})}(R_{in}/R_g)^{-3/2}\ M_\odot$$

The HTRS characteristics

Energy range	0.3-20 keV
Time resolution	10 micro-seconds
Energy resolution	<150 eV @ 6 keV
1 Crab count rate	~200 000 counts/s
Count rate capability	>10 Crab
Deadtime & pile-up	<1% @ 1 Crab

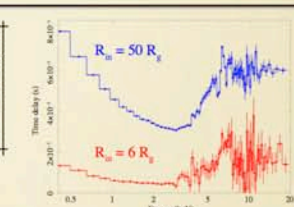



The HTRS is based on Silicon Drift Detectors (SDD). The main advantage of SDD is their small physical size and consequently the small capacitance of the anode, which translates to a capability to handle very high count rates simultaneously with good energy resolution. The HTRS is an array of 37 hexagonal SDDs, placed out of focus, such that the focal beam from the IXO mirror is spread as uniformly as possible over the array.

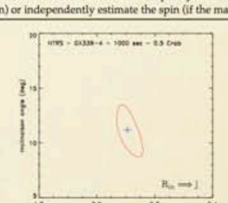
List of fellows supporting the HTRS in IXO: D. Altamirano, A. Baykal, S. Bhattacharyya, T. Belloni, E. Cackett, P. Callanan, D. Chakrabarty, C. Done, K. Ebisawa, M. Gilfanov, E. Gogus, E. Gourgoulhon, J. Homan, W. Hermsen, P. Jonker, E. Kalemci, Ph. Kaaret, E. Kendziorra, M. van Kerkwijk, M. van der Klis, W. Kluzniak, C. Kouveliotou, D. Lai, J.P. Lasota, T. Maccarone, K. Makishima, S. Mereghetti, C. Miller, C. Motch, J.F. Olive, S. Paltani, I. Papadakis, J. Paredes, J. Poutanen, D. Psaltis, N. R\'ea, R. Remillard, M. Revnivtsev, J. Rodriguez, R. Rothschild, A. Santangelo, L. Stella, M. Tagger, J. Tomsick, H. Tsunemi, Y. Uchiyama, A. Watts, R. Wijnands, J. in't Zan't, A. Zdziarski. **To receive informations about the IXO-HTRS, please send an email to Didier Barret (didier.barret@cesr.fr). Thanks.**

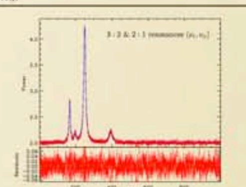
Accretion in extreme gravity

The HTRS will enable to measure X-ray reverberation lags in accreting compact objects, in particular by looking at the response of the iron line reflection and disc thermal reprocessing. Time lags provide a yardstick in the disk, probe strong gravity and accretion geometry (e.g. disk inclination). Thanks to its low energy threshold, the HTRS will measure lag spectra from below 1 keV, where the reprocessed disk component dominates.

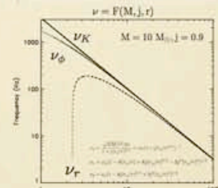


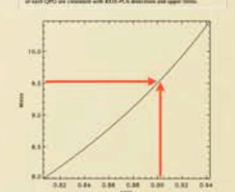
Fitting of the Iron line profile will provide accurate measurements of the inner disk radius (hence black hole spin). Consistency checks will be possible by analyzing the corresponding Fourier power spectrum. Identification of QPO frequencies with General Relativistic Frequency would make possible to measure the mass of the black hole (if the spin is known) or independently estimate the spin (if the mass is known).





$$\nu = F(M, j, r)$$





The HTRS will detect high frequency phenomena on their coherence timescales. The cycle waveform, which it will be possible to reconstruct statistically, depends on the Doppler shifts associated with the local linear velocity of the radiating matter in the emitting blob or spot, convolved with curved spacetime propagation effects. If the frequency of the orbit is known, modeling of the waveform yields the mass M of the compact object.