Science with the High Time Resolution Spectrometer on-board the International X-ray Observatory

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MG12-ATP2 session, Monday July 13th, UNESCO center
The Con-X and XEUS studies are being replaced by a single tri-agency study called the **International X-ray Observatory**.

- The result of this study is being submitted to the 2010 “Decadal Survey”, will be submitted to ESA Cosmic Vision (2010) and to the JAXA approval process.
- IXO is then competing in Europe for the first large mission slot (against LISA and the Jupiter mission).
- Launch date 2020-2021.
The IXO science payload

- Flight Mirror Assembly
- Representative Gratings
- Moveable Instrument Platform (MIP)
- Fixed Instrument Platform
- WFI/HXI
- HTRS
- XMS
- XGS Camera
- XPOL

20 m
1.5 meters
~ 3 m
The HTRS characteristics

- HTRS is based on Silicon Drift Detectors (SDD)
  - Placed out of focus, such that the focal beam from the IXO mirror is spread over the array
  - Combined with the IXO mirror, the HTRS provides 10-20 times larger count rates than the RXTE PCA, and an energy resolution about ten times better

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
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<tbody>
<tr>
<td>Energy range</td>
<td>0.3-20 keV</td>
</tr>
<tr>
<td>Time resolution</td>
<td>10 micro-seconds</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>&lt;150 eV @ 6 keV (−20°C)</td>
</tr>
<tr>
<td>1 Crab count rate</td>
<td>~200 000 counts/s</td>
</tr>
<tr>
<td>Count rate capability</td>
<td>&gt; 10 Crab</td>
</tr>
<tr>
<td>Deadtime &amp; pile-up</td>
<td>&lt;1% @ 1 Crab</td>
</tr>
<tr>
<td>Overall detector size</td>
<td>~ 2 cm²</td>
</tr>
<tr>
<td>Readout time</td>
<td>50-75 ns</td>
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</table>
Science with the HTRS

The High Time Resolution Spectrometer (HTRS) will provide IXO with the capability to observe the brightest X-ray sources of the sky

✓ accreting neutron star and black hole X-ray binaries, including X-ray bursters

Two science goals, under the matter under extreme conditions topic:

✓ Accretion in strong gravity
  ➡ Measuring the spin distribution of stellar mass black holes and probing strong field GR

✓ The equation of state of dense matter
  ➡ Tracking X-rays from the surface of NSs to determine their radii
Why care about BH spins?

- Accretion efficiency scales with spin from 10% for non spinning up to 42% for maximally rotating black holes

- BH launch jets which can shape galaxies, clusters
  - Tied to BH spins

- From a zero spin to a maximal spin, a black hole must double its mass
  - Not possible in a stellar binary
    - Current spin reflects that imparted at birth
    - A unique window on SNe/GRBs and the first BHs

- Put in the AGN context, spin may reflect the growth history of supermassive BHs

Miller (2009)
Securing spin measurements

- ~10 stellar mass black holes only - slightly larger spins preferred
  ✓ Addition 30-40 candidate black holes to be considered

Securing the spin measurements by:

✓ Sampling the source in multiple states with much better statistics
  ➡ Test the robustness of the models

✓ Correlating the spin inferred from energy spectra with timing measurements
  ➡ QPOs
  ➡ Reverberation mapping
  ➡ Low energy continuum spectroscopy
Improvements in spectra

~100 ksec - XMM-Newton

1 ksec - IXO-HTRS

Spins will be measured with an accuracy of ~1%

Miniutti & Fabian (2002)

Miller et al. (2008)
Improvements in timing

Detecting weaker features and known features on shorter timescales

\[ \nu = F(M, j, r) \] if \( j \) is known, \( r \) fixed (from resonant frequencies), then \( M \) can be derived
Burst oscillations

Dynamical Fourier PDS of a type I X-ray burst showing an oscillation at 364 Hz (from Strohmayer)

Simulated light curve of burst oscillations for increasing neutron star compactness

Spreading of a thermonuclear burning hotspot on the surface of a rotating neutron star. (from Spitkovsky)
X-ray burst oscillations

Constraints on mass and radius waveform fitting. The red ellipse shows the 95% confidence regions from 5 typical bursts. (Courtesy of Cole Miller).

Simulated X-ray light curve of a typical burst oscillation - Thanks to its unprecedented effective area, IXO will resolve individual pulses.

Courtesy of T. Strohmayer & M. C. Miller

Lundi 13 juillet 2009
Time resolved X-ray spectroscopy

The residuals for two simulated relativistically broadened Iron lines at two different inner disk radii (line parameters from Cackett et al. (2008))

Simulated Fourier PDS, assuming that the upper QPO is a Keplerian frequency at the same inner disk radii.

\[ M_{NS} = \frac{32.2}{(\nu_K/1000 \text{ Hz})} \left( \frac{R_{in}}{R_g} \right)^{-3/2} M_\odot \]

Absolute measures

Provided by Phil Uttley

Lag spectrum simulated for different inner disk radii

1 Crab
\[ \tau_{exp} = 100 \text{ ks} \]

\[ R_{in} = 30 \text{ km} \]

\[ R_{in} = 18 \text{ km} \]

\[ R_{in} = 12 \text{ km} \]
Combining multiple diagnostics

Various representative mass-radius relations on which IXO-HTRS constraints from a limited sample of NS are shown - redshifted absorption line predicted in the ashes of type I bursts, constraints from QPOs, and waveform fitting of type I burst oscillations.
Conclusions

IXO is the natural successor to Chandra (~2600 users) and XMM-Newton (~3000 users)

- Separate studies by ESA and NASA demonstrate that the mission implementation for a 2021 launch is feasible (part of Astro2010 Decadal Survey and ESA Cosmic Vision program)

Understand how black holes form, evolve, work, influence their surroundings is a key science goal of IXO

✓ by probing BHs at all scales under a wide range of conditions: from stellar mass BHs to the first BHs formed in the Universe - emphasis put on stellar mass BH spin measurements with the HTRS

Similarly, determining the equation of state of the densest matter observable in the Universe appears for the first time within reach

✓ by observing the brightest phases of NSs with the HTRS

The IXO-HTRS is a follow-up to the RXTE-PCA