Scientific highlights on accreting black hole X-ray binaries from *insight*-HXMT

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On behalf of Insight-HXMT collaboration team

The 10th FERO meeting, 03/30-04/01, 2022, Toulouse, France
Overview to the *Insight*-Hard X-ray Modulation Telescope (HXMT)
Science Payload

- **High Energy Telescope (HE)**
  - 20-250 keV for pointing; 0.2-3 MeV for Gamma-ray monitoring; Geometrical area of ~5100 cm²

- **Medium Energy Telescope (ME)**
  - 5-30 keV for pointing; Geometrical area of ~952 cm²

- **Low Energy Telescope (LE)**
  - 1-15 keV for pointing; Geometrical area of ~384 cm²
Core Science

- To observe X-ray binaries in broad energy band and study the dynamics and emission mechanism in strong gravitational or magnetic fields;

  - Large Area (5000 cm$^2$)
  - High time resolution (25us)
  - Wide energy band:
    - Hard X-ray Energy (~250 keV)
    - Low Energy (~1 keV)
  - No PileUp

> 30 keV
Total Exposure Map (06/2017 -- 09/2021)

> 80 Ms
**Summary of the Observations** (07/2017 -- 09/2021)

<table>
<thead>
<tr>
<th>Obs. Mode</th>
<th>Source Type</th>
<th>No. of sources</th>
<th>No. of the Obs.</th>
<th>Exp. Time (ks)</th>
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</thead>
<tbody>
<tr>
<td>Pointing (&gt; 60 Ms)</td>
<td>SNR</td>
<td>2</td>
<td>48</td>
<td>3700</td>
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<td></td>
<td>Isolate pulsar</td>
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<td>157</td>
<td>4240</td>
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<td></td>
<td>Black hole XRB</td>
<td>15</td>
<td>948</td>
<td>16070</td>
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<tr>
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<td>neutron star XRB</td>
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<td>1133</td>
<td>24210</td>
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<td>extragalactic</td>
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<td>123</td>
<td>1680</td>
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<td>objects</td>
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<td>blank sky</td>
<td>21</td>
<td>442</td>
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<td>others</td>
<td>18</td>
<td>153</td>
<td>4640</td>
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<tr>
<td>Small Sky Survey (&gt;20 Ms)</td>
<td>Crab</td>
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<td>Vela</td>
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<td>70</td>
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<td>Cygnus</td>
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<td>2</td>
<td>50</td>
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<td>Galactic Plane</td>
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<td>2489</td>
<td>14760</td>
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</tbody>
</table>

> 20%
HXMT observations of bright BH X-ray binaries

- Swift J1658.2-4242
- MAXI J1348-630
- EXO 1846-031
- MAXI J1820+070
- MAXI J1535-571
- GX 339-4
- MAXI J1820+070
Scientific highlights from HXMT

MAXI J1820+070
MAXI J1348-630
What is the quantitative interpretation of HID?
4th polynomial fit for the peak fluxes

$\tau_{\text{fit}}$

Weng et al. 2021, ApJL
Cross-correlations of the lightcurves

Soft X-ray lags the hard X-ray/UV for ~10 days

Weng et al. 2021, ApJL
The “truth” of the HID is the "time lag" between radiations of the accretion disk and the corona.

Weng et al. 2021, ApJL
MAXI J1820+070

Type-C QPO observed up to 250 keV

1. Soft lags instead of hard lags
2. A light-travel time lag of ~1 s corresponds to a size of ~10^4 Rg for a 10 solar mass BH
3. QPO frequency is constant at different energies.

Ma, ..., Bu, et al. 2021, Nature Astronomy
LT precession of small-scale jet
MAXI J1820+070

You, ..., Bu, et al. 2021, Nature Communications

Hard state
Model: \( \text{tbabs} \times (\text{diskbb} + \text{relxillCp} + \text{xillverCp}) \times \text{constant} \)

In the rise phase, increasing fraction of photons that illuminate the disk; In the decay phase, decreasing fraction of photons illuminate the.

You, ... , Bu, et al. 2021, Nature Communications
Jet-like corona

Lamppost geometry

The system is characterized by two parameters: corona position and bulk velocity

You, ... , Bu, et al. 2021, Nature Communications
Application of jet-precession model in MAXI J1631-479

MAXI J1820+070

Broadband variability behaviors in 1-150 keV

High-energy noise (> 30 keV) is more variable on shorter timescales!!

harder photons from more inner region have larger lags

In-homogeneous hot flow/corona?

Fast transition between Type-C and -B QPOs in \( \sim 10 \) s

Liu, Huang, Bu, et al. 2022, submitted
From C to B, soft emission increases, while hard emission decreases.
Fast recurrence of type-B QPOs

From B to no-B, soft X-ray flux decreases, while spectral index remains the same.
Could both type-C and -B QPOs be generated by the LT precession of the jet?
Summary

- Small-scale jet precession model is a promising model in explaining the high energy (> 30 keV) timing properties of type B/C QPOs.
- Observed time-lag between radiations of the accretion disk and the corona leads naturally to the hysteresis effect and the “q”-diagram.
- HXMT has great advantages in the broadband variability study.
- *Everything we are not clear yet, we are counting on eXTP*