Comparing phase-resolved spectroscopy results from QPOs in low-mass X-ray binaries

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Low-Mass X-ray Binaries (LMXBs)

- Accretion disk
- Compact object
- Jet
- Roche-lobe overflow
- Low-mass companion star

Figure: ESO/L. Calçada
How does matter behave in strong gravitational fields?

Figure: ESO/L. Calçada
Inner Region of an LMXB

- Disk
- Corona
- Base of jet
- Lense-Thirring precession
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X-ray variability

Time (s) | Count/sec
---|---

Start Time: 12339 7:28:14:566
Stop Time: 12339 7:29:32:683

Bin time: $0.7812 \times 10^{-2}$ s
Inner Region of an LMXB

Disk

Corona

Base of jet

re-processing

blackbody

power-law

\begin{align*}
\text{keV}^2 \text{ (Photons cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1})
\end{align*}

\begin{align*}
\text{Energy (keV)}
\end{align*}
Inner Region of an LMXB

- Disk
- Blackbody
- Corona
- Re-processing
- Base of jet
- Power-law

X-ray variability

Graph:
- Energy (keV) on the x-axis
- keV² (Photons cm⁻² s⁻¹ keV⁻¹) on the y-axis
- Data points and curves indicating X-ray variability
Quasi-Periodic Oscillations (QPOs)

Power spectra show amount of variability at different frequencies in a light curve
Type B vs Type C QPOs

Type B’s:
stronger face-on

Type C’s:
stronger edge-on

(binary system inclination)

Schnittman, Homan & Miller 2006; Motta et al 2015 (images); Heil et al 2015b
Phase-Resolved Spectroscopy

- New technique allows us to effectively do phase-resolved spectroscopy of QPOs
- Details in paper -- arXiv: 1605.01753
Phase-Resolved Spectroscopy

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• Deviations from mean energy spectrum
• Spectral shape varying with QPO phase!
Type B QPO Spectral Variations

Parameters that vary:
1. PL index
2. PL normalization
3. BB temperature

- Blackbody variation is \( \sim 0.3 \) (110°) out of phase with power-law
- Power-law: large variation
- Blackbody: small variation
Type B QPO Interpretation

Jet-like precessing region
Type B QPO Interpretation

Jet-like precessing region
Jet-like precessing region
Our preliminary Type C results support a *disk-like* precessing region

Summary

• X-ray binaries are the best tool to study matter in strong gravitational fields
• Phase-resolved spectroscopy of QPOs can help break degeneracies between physical models
• Type B QPO in GX 339–4:
  – arXiv: 1605.01753
  – Interpretation: jet-like precessing region
• Type C QPO in GX 339–4:
  – Preliminary work, in prep
  – Interpretation: disk-like precessing region

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