Be/X-ray Binaries with LOFT


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Outline

• Yellow book science
  – Cyclotron Features and pulse to pulse variability
  – Centrifugal inhibition
  – Small Magellanic Clouds

• Importance of coordinated optical/IR observations

• Other open questions

• Summary
Be X-ray Binaries

- High B-field $10^{12-13}$ G
- Be Star surrounded by decretion disk
- Spin periods 1-1000s
- Elliptical orbits with periods of 10-1000 d
- Two classes of outbursts
  - Normal/Type I (orbitally modulated)
  - Giant/Type II (very bright)
  - Also faint persistent systems
- Most numerous HMXB
  - ~80 in Milky Way
  - ~60 in SMC
  - ~12 in LMC
Cyclotron Scattering Absorption Features

• Electrons interact with the magnetic field, producing line-like emission at the cyclotron energy.
• To be observed in X-rays, a B-field of $10^{12-13}$ G is required
• Discovered by Trumper (1977, 1978) in Her X-1 spectra

$$E_n = m_e c^2 \frac{\sqrt{1 + 2n(B/B_{\text{crit}}) \sin^2 \theta} - 1}{\sin^2 \theta} \frac{1}{1 + z}.$$
Pulse-to-pulse variations of cyclotron energy with LOFT

- Column is “breathing” on sub-pulse timescale
- With LOFT, single pulses have high enough statistics to derive cyclotron energy variations of a few percent
Pulse-to-pulse variability

- Consistent with long-term average spectral variations
- Two accretion regimes:
  - Local sub- and super-Eddington
Centrifugal Inhibition of Accretion

- Observe X-ray binaries to $L \sim 10^{33}$ erg s$^{-1}$
- Pulsations detected at $L < 10^{34}$ erg s$^{-1}$ for A0535+26 (Negueruela et al. 2000), 4U 1145-619, and A1118-615 (Rutledge et al. 2007)
- $L_{\text{cutoff}} \approx 2 \times 10^{38} \left( \mu/10^{30} \text{ G cm}^3 \right)^2 \left( P/1\text{s} \right)^{-7/3}$ erg s$^{-1}$

![Graphs and data points](images)
Continued Monitoring of SMC with LOFT

- 13 years of weekly monitoring with RXTE PCA
- Plotted luminosities are typical of “normal” outbursts (once per orbit)
- Giant outbursts are a factor of 10 brighter, but much rarer
- LOFT WFM can detect outbursts >0.1×10^{37} erg s^{-1} (red line) in a few days, similar to RXTE PCA sensitivity
- LOFT LAD can detect outbursts >0.01×10^{37} erg s^{-1} in ~10 ks, order of magnitude fainter than RXTE PCA
- Constrain M using Pdot Luminostiy correlation

Figure 4. The histogram of the estimated peak X-ray luminosities for the outbursts discussed in this work. The exceptionally large outburst from SXP2.37 is excluded from this plot.

Two populations of Be X-ray Binaries?

- Bimodal distribution consistent between SMC and MW+LMC
- Not predicted by SN models
- Iron-core collapse model predicts high eccentricities, e-capture model predicts low eccentricities

Knigge, Coe, & Podsiadlowski 2011
Importance of Multiwavelength Monitoring

K-band IR

20-50 keV pulsed flux

Spin Frequency

Orbital Phase

EXO 2030+375 H alpha spectra

July 1998

Aug 1997

July 1996

June 1993

Oct 1992

Sep 1998
Summary

• LOFT will enable pulse-to-pulse of cyclotron features for the first time.
• LOFT will enable studies of outbursts, quiescence, and outburst onsets.
• LOFT will continue monitoring the SMC, extending RXTE an order of magnitude fainter.
• To fully understand LOFT’s observations of Be X-ray binaries, supporting optical/IR observations are crucial.