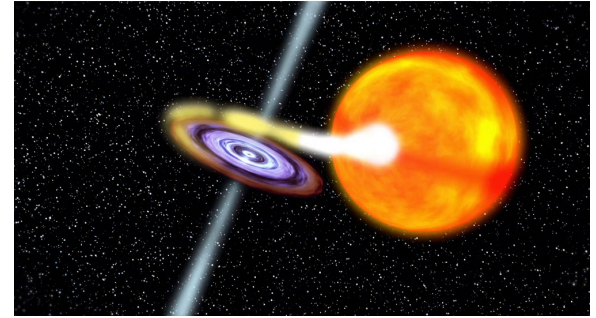
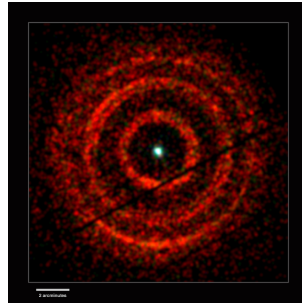
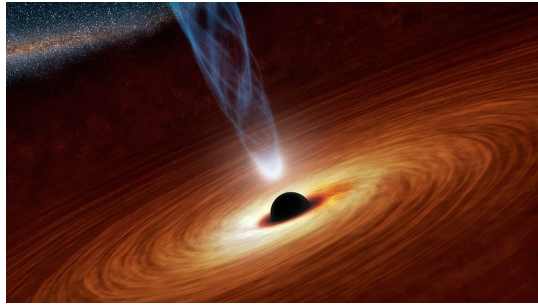




X-ray Timing

John Tomsick

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September 2018

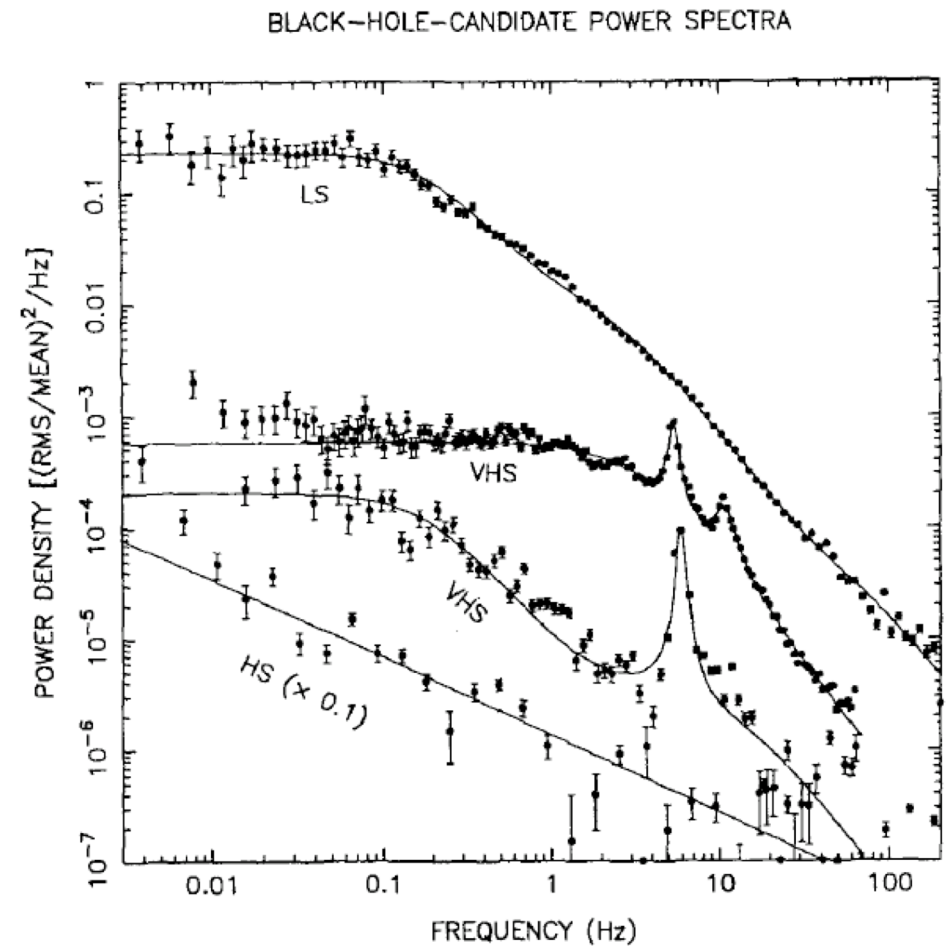


Outline

- Pre-Rossi X-ray Timing Explorer (RXTE)
- RXTE (1995-2011) discoveries
- Current and future
 - NICER and AstroSat (current)
 - STROBE-X (proposed)

Pre-RXTE

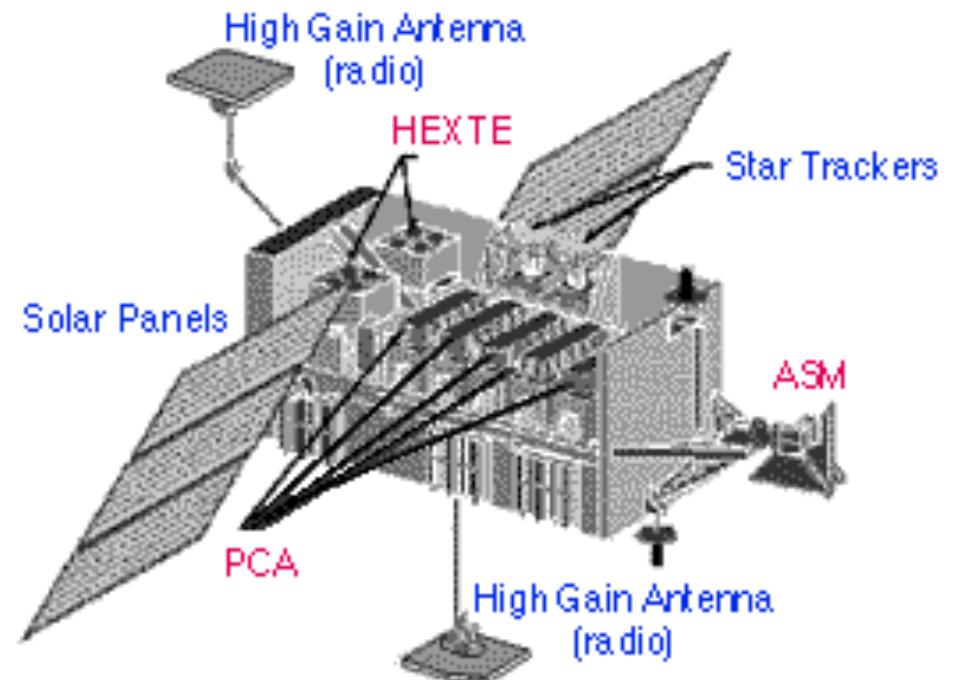
- Accreting black holes are variable
- Sometimes we see peaks in their power spectra
 - Quasi-periodic oscillations (QPOs)



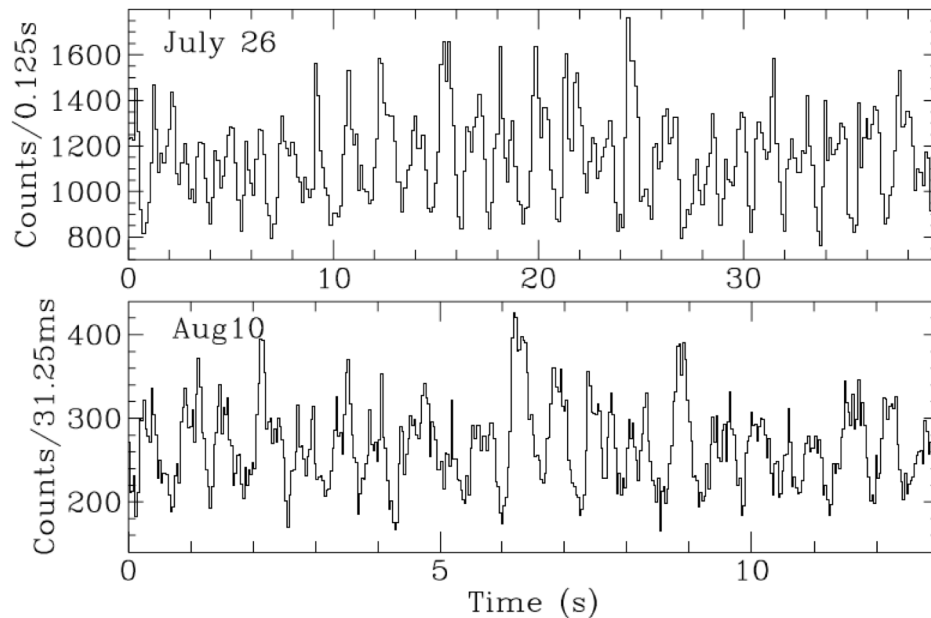
Van der Klis 1995

RXTE

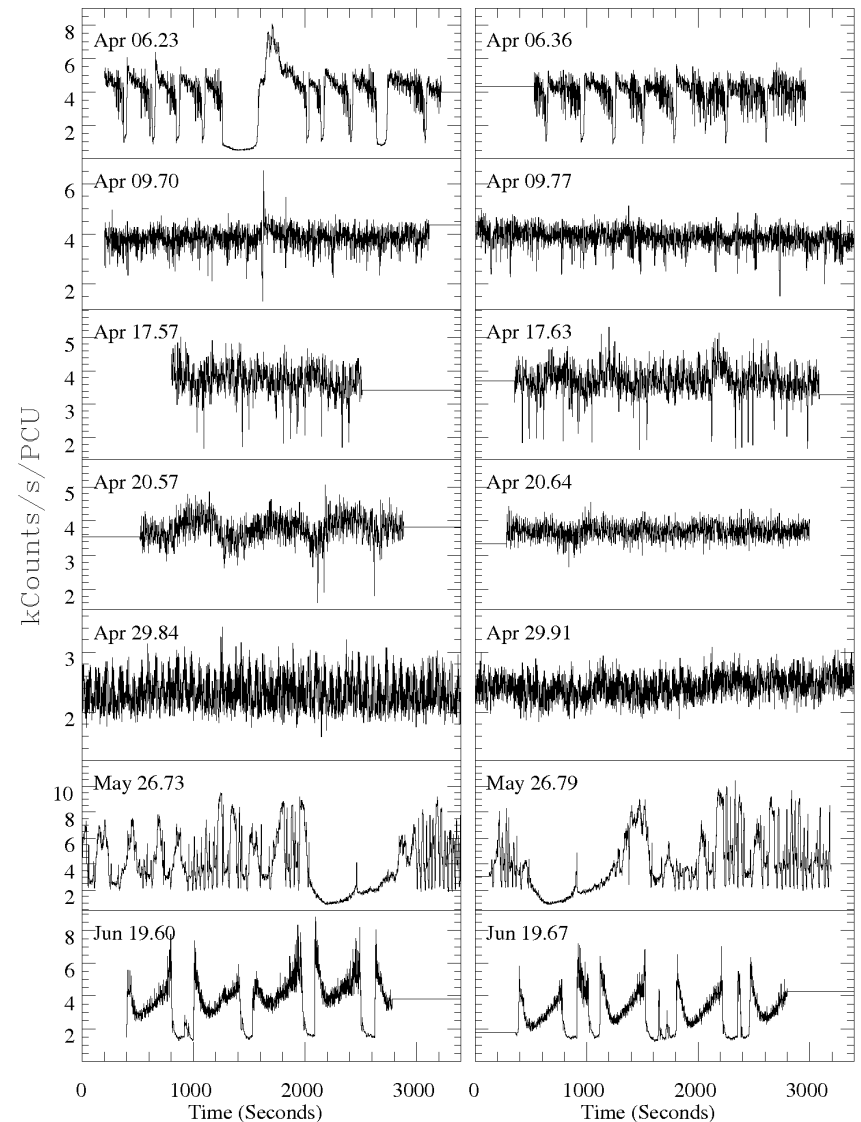
- Proportional counters operating at 2-60 keV
- Large effective area to collect lots of X-rays
 - $6500 \text{ cm}^2 = 0.65 \text{ m}^2$
- Special data packaging allowing for telemetry of all data even for very bright sources



RXTE example light curves

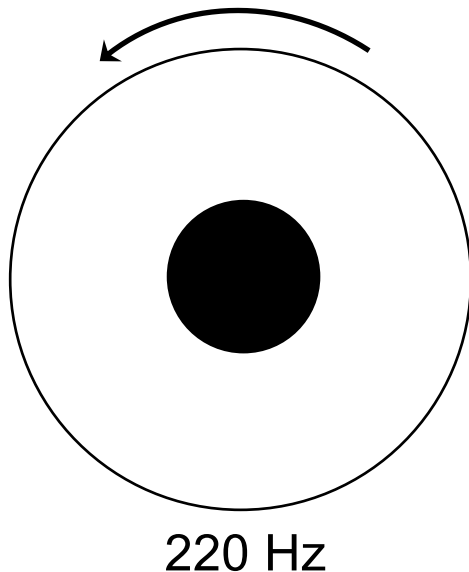


- Above: 1 Hz QPO
- Right: Many types of variability seen for GRS 1915+105

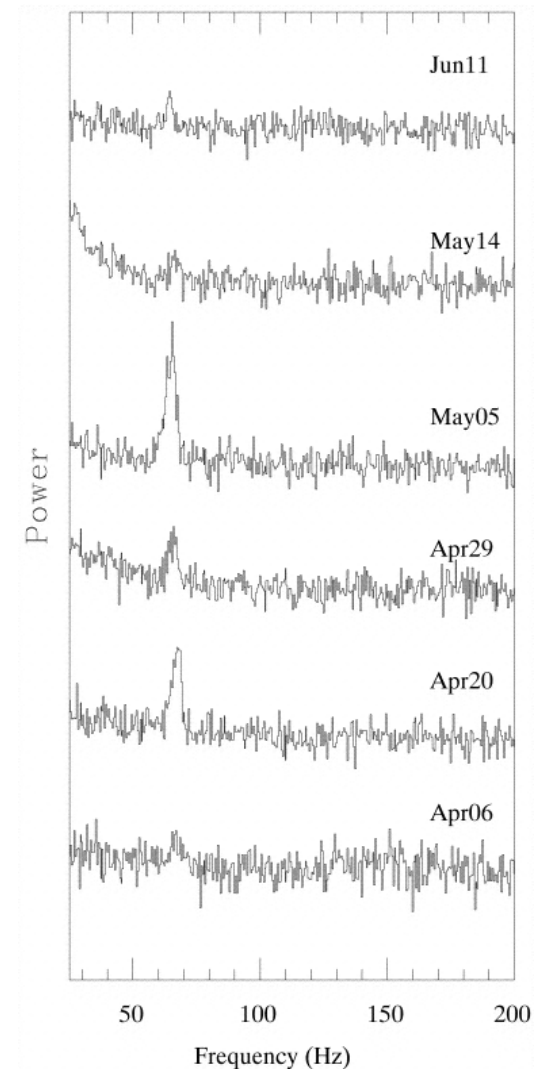


Discovery of High-Frequency QPOs

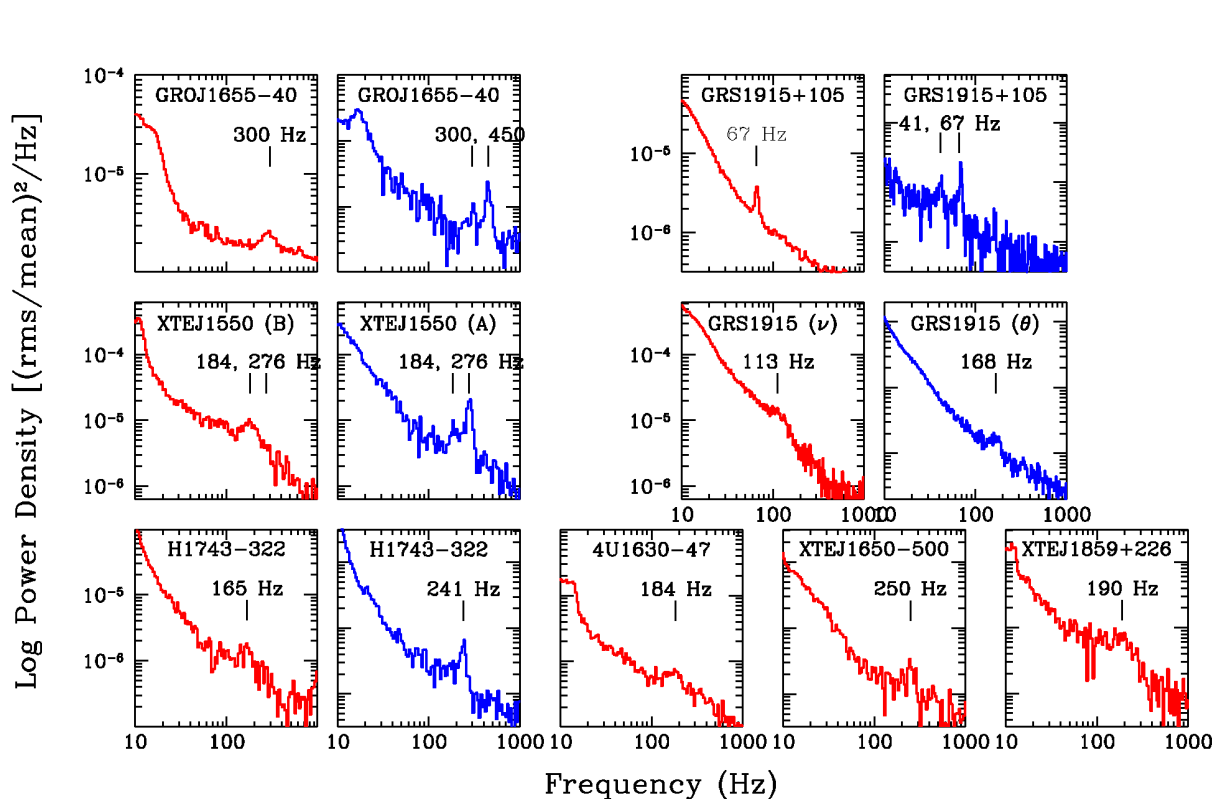
- GRS 1915+105: 67 Hz QPO at a stable frequency (Morgan et al. 1996, 1997)



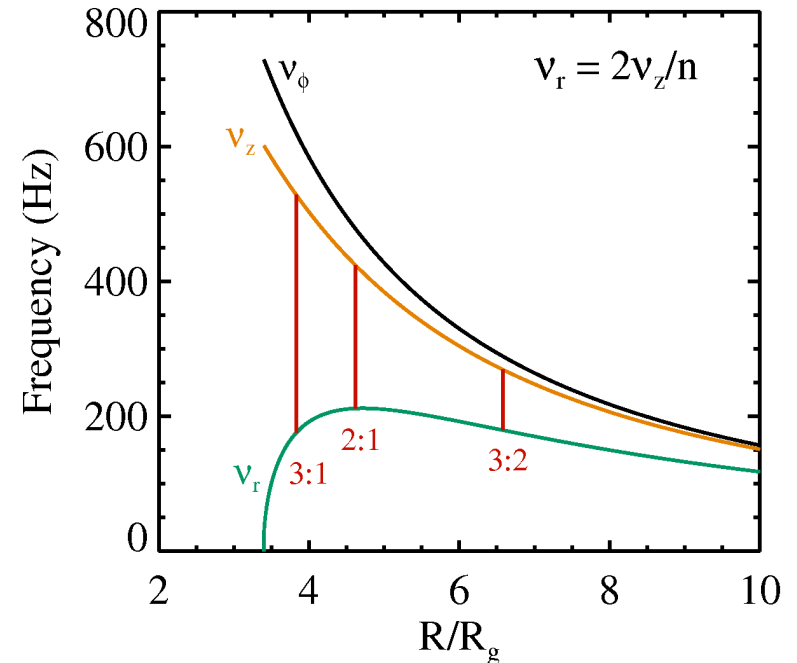
Although this is a “high” frequency, it is lower than the frequency at the ISCO for a non-rotating $10 M_{\text{sun}}$ BH.



HFQPOs



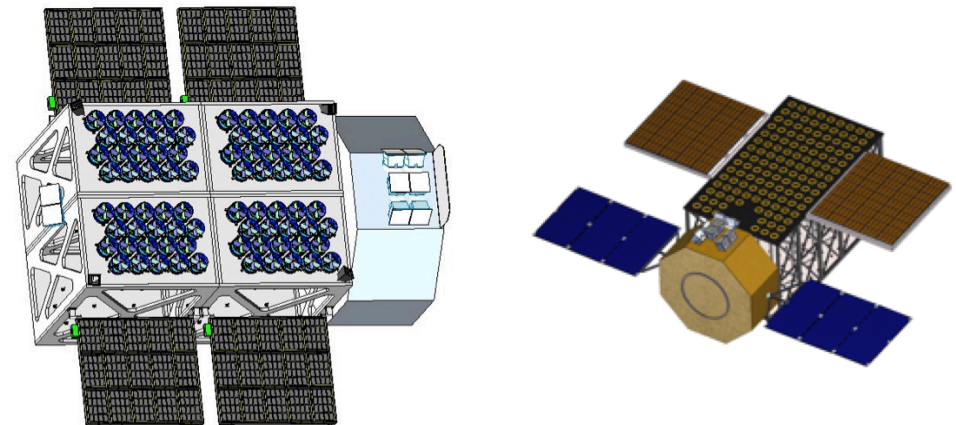
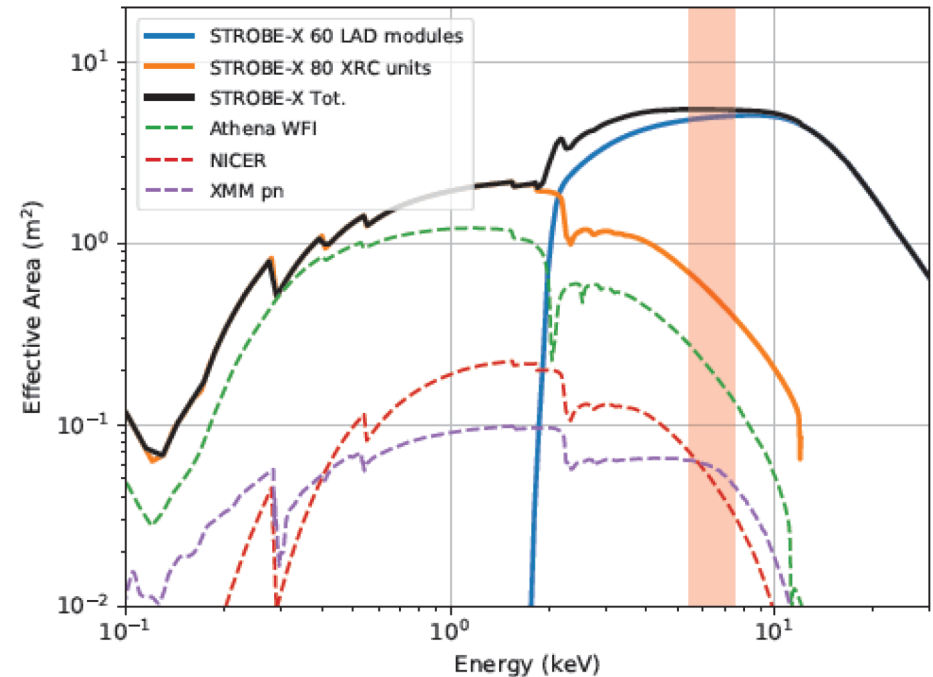
- Almost all of the HFQPOs that have been detected
- Remillard & McClintock (2007)



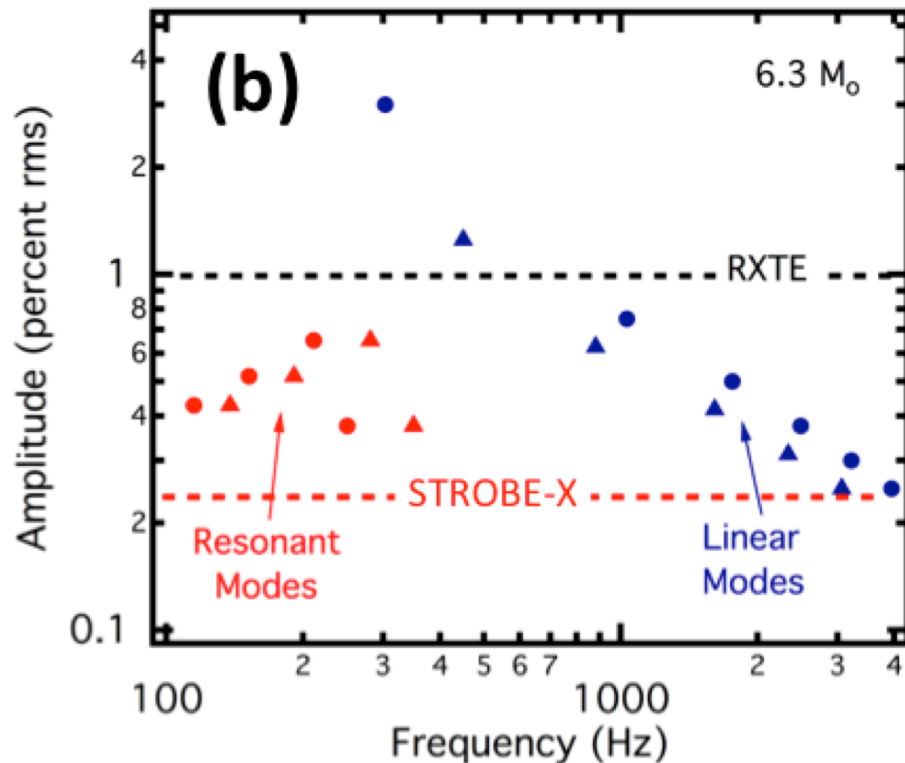
- 3:2 ratio of frequencies motivated the **epicyclic resonance model** (Abramowicz & Kluzniak 2001)
- A major motivator for future timing missions is to search for more resonances (2:1, 3:1, etc.)

Missions: Current and Future

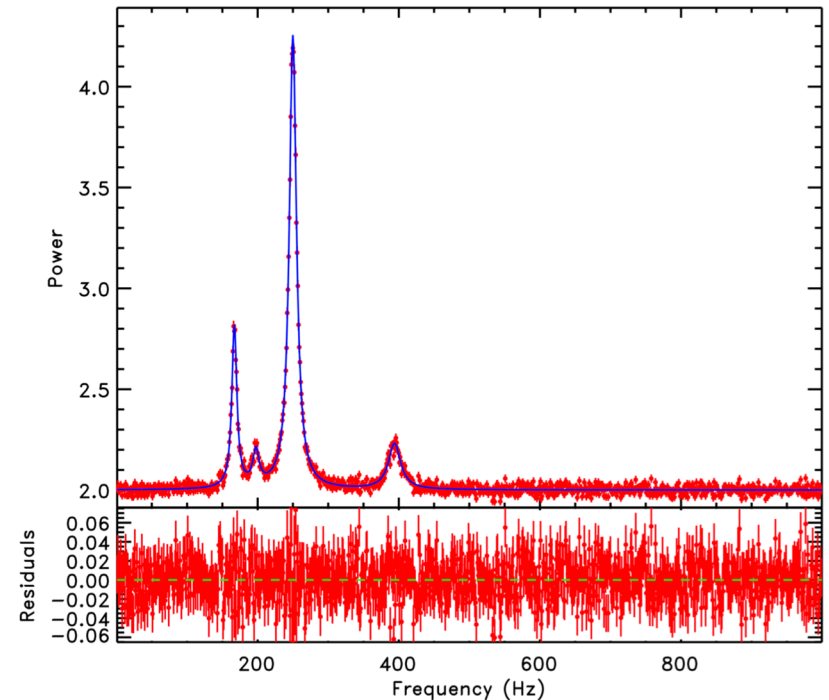
- **NICER**
 - Currently operating
 - Capable of finding new HFQPOs
- **STROBE-X**
 - Proposed mission with $>5 \text{ m}^2$ at 6 keV
 - X-ray Concentrator Array (scaled-up version of NICER)
 - Large Area Detector



STROBE-X vs. RXTE



- STROBE-X would be sensitive to other HFQPO modes



- Simulation of a power spectrum with 10x the effective area of RXTE