Intermittent accretion-powered millisecond pulsars

A new piece of the puzzle of accreting neutron stars

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- Link between pulsing and non-pulsing LMXBs
- Consistent with moving spots around nearly aligned magnetic fields

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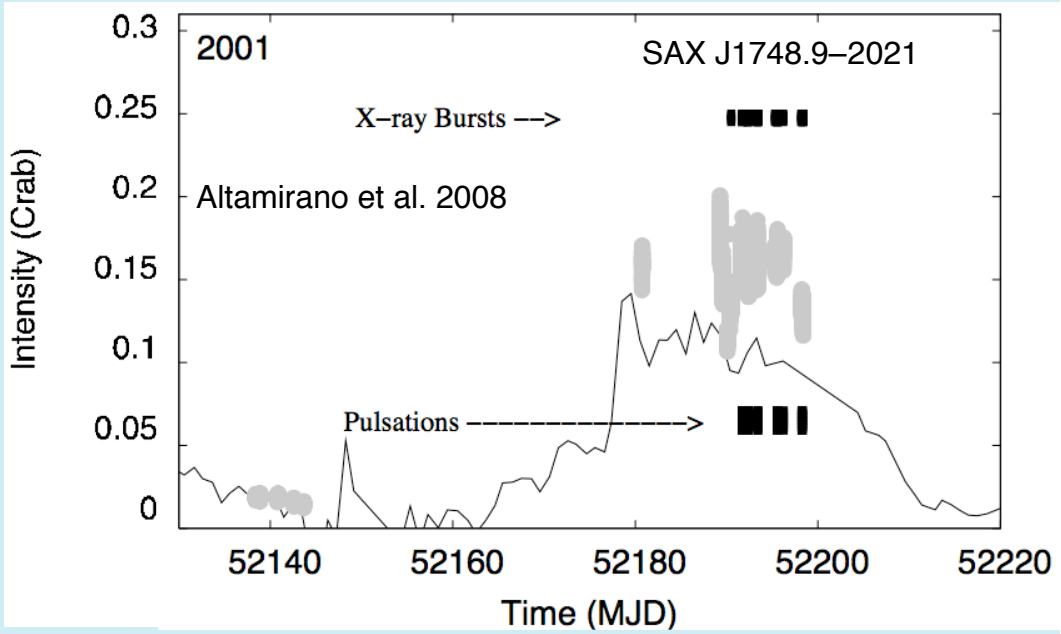
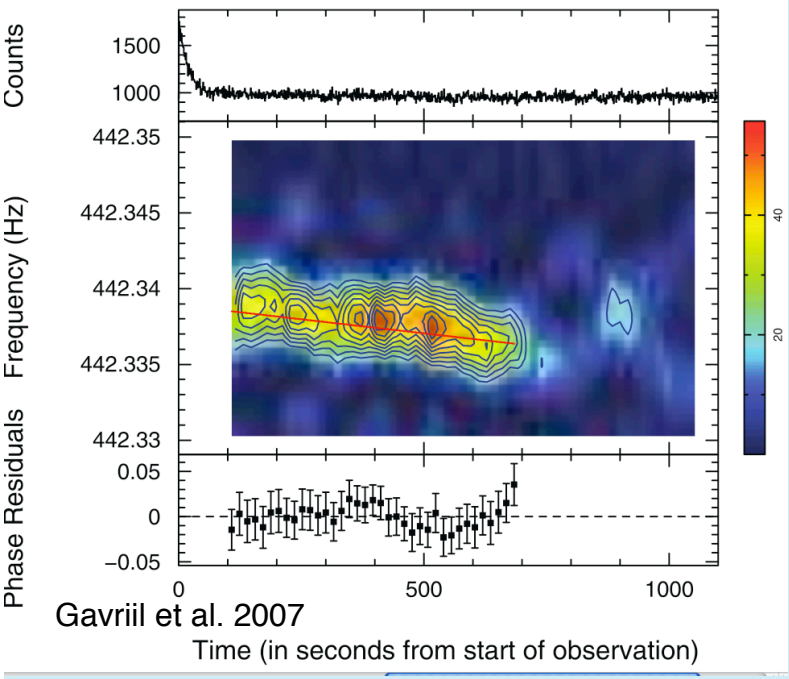
The Puzzle of Accreting Millisecond pulsars

- >80 known low-mass X-ray binaries containing a neutron star
- 9 LMXBs (all transients) displayed persistent millisecond X-ray oscillations
- No accretion-powered oscillations from others, including 13 from which we know the spin from nuclear-powered oscillations
- RXTE recently revealed a missing link, intermittent accretion-powered oscillations:



Intermittent APMSPs: a new piece of the puzzle



Gavriil et al. 2007

- SAX J1748-20

(Gavriil et al. 2007, Altamirano et al. 2008, Patruno et al. 2009)

< 3.5% rms oscillation amplitude in 11 intervals of ~ 200 sec in ~ 250 ksec of data

Upper limits on the first overtone are < 0.9%

Possible association with thermonuclear bursts

- HETE J1900-24 (Galloway et al. 2007)

0.5%-3% rms oscillation during first 2 months of 2 years of data

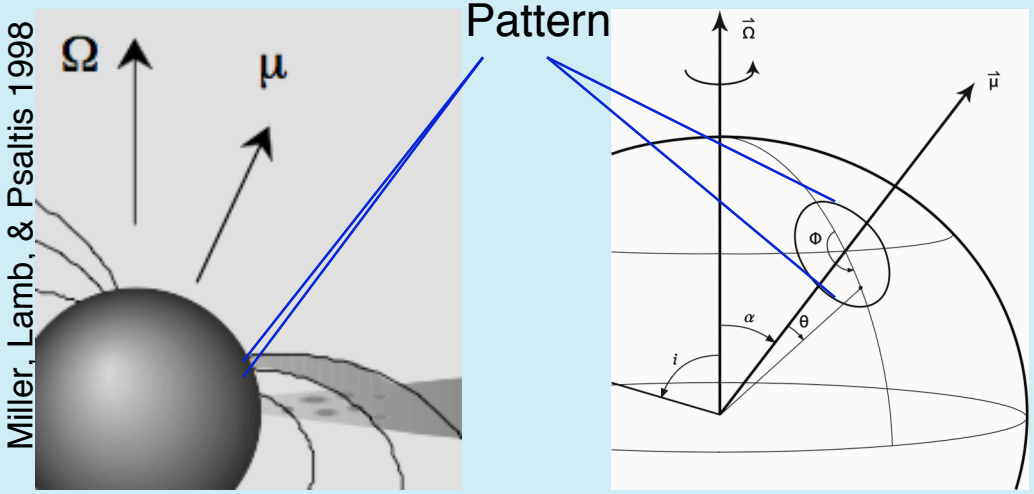
- Aql X-1 (Casella et al. 2008)

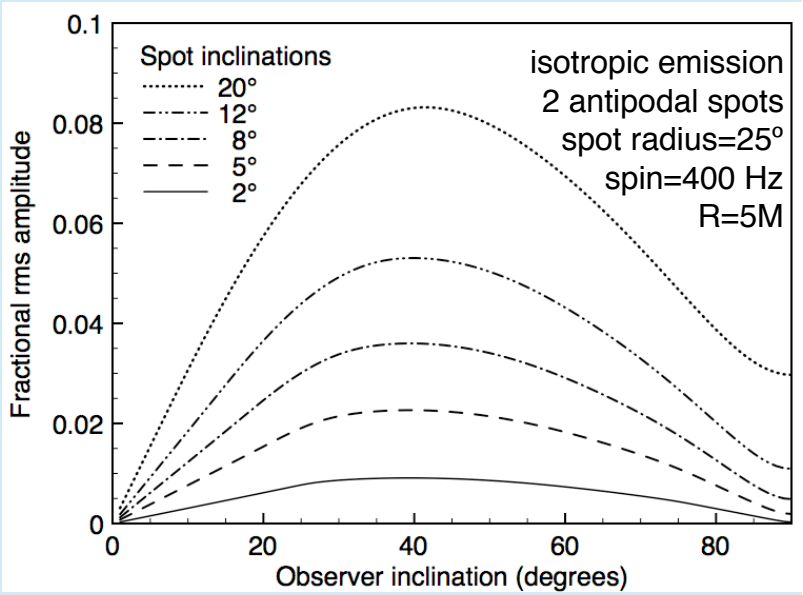
1.9% rms oscillation in 150 sec out of 500 ksec of data

Matching the pieces of the puzzle

Lamb et al, ApJL 705, 36 (2009); ApJ 706, 417 (2009)

Brightness Pattern





•We consider one or two (antipodal or on same hemisphere) circular isotropically-emitting bright spots of varying size and inclination with respect to the rotation axis, as well as different observer angles

•We use the Schwarzschild+Doppler (Miller & Lamb 1998) GR approximation to trace light rays from the neutron star surface to the observer, including special relativistic energy boosts and aberration, and time delays

Modest changes in the position of the brightness pattern on the stellar surface can cause sudden appearance and disappearance of pulsations (intermittency)

Current picture of intermittent APMSPs

- Careful studies of LMXBs with RXTE have revealed 3 intermittent APMSPs providing a *missing link between pulsing and non-pulsing sources*

- Pulsations appear and then disappear in timescales of minutes to hours, have small amplitudes (< 3.5%) and are highly sinusoidal (< 0.4%)

- This picture is consistent with modest wandering of emission regions on the surface of accreting neutron stars, if they are nearly aligned rotators. This *nearly-aligned moving spot* model also reproduces the relatively small amplitudes, sinusoidal waveforms, and large apparent phase variations in the persistent APMSPs, and predicts pulsation “dropouts” in some.

- This discovery opens a large window for future detections with RXTE and further improvements in our theoretical understanding of APMSPs