

The correlations between the spin frequencies and kHz QPOs in Neutron Stars in LMXBs

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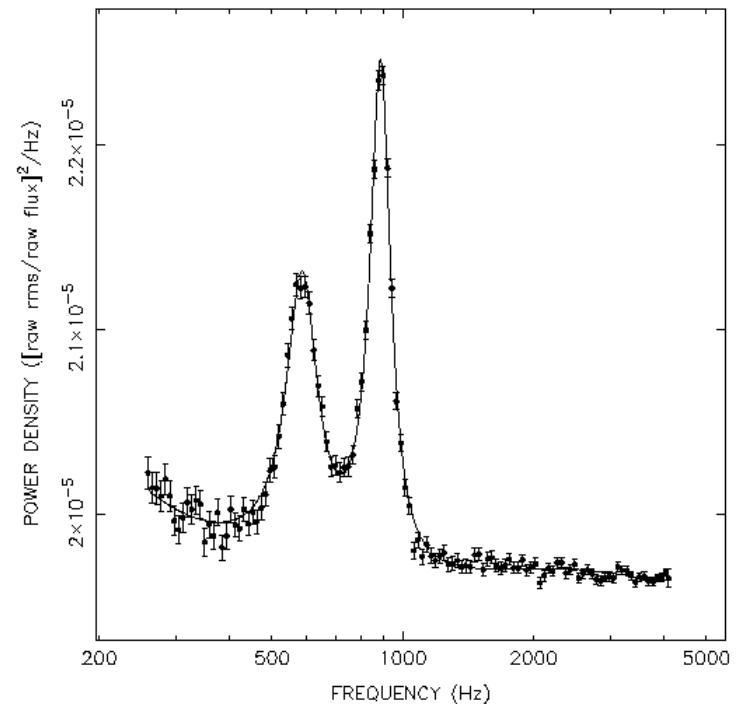
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kHz QPO

- $\sim(300\text{-}1300)$ Hz
- Often in pairs
- The upper-frequency
- The lower-frequency
- ~ 30 (21)

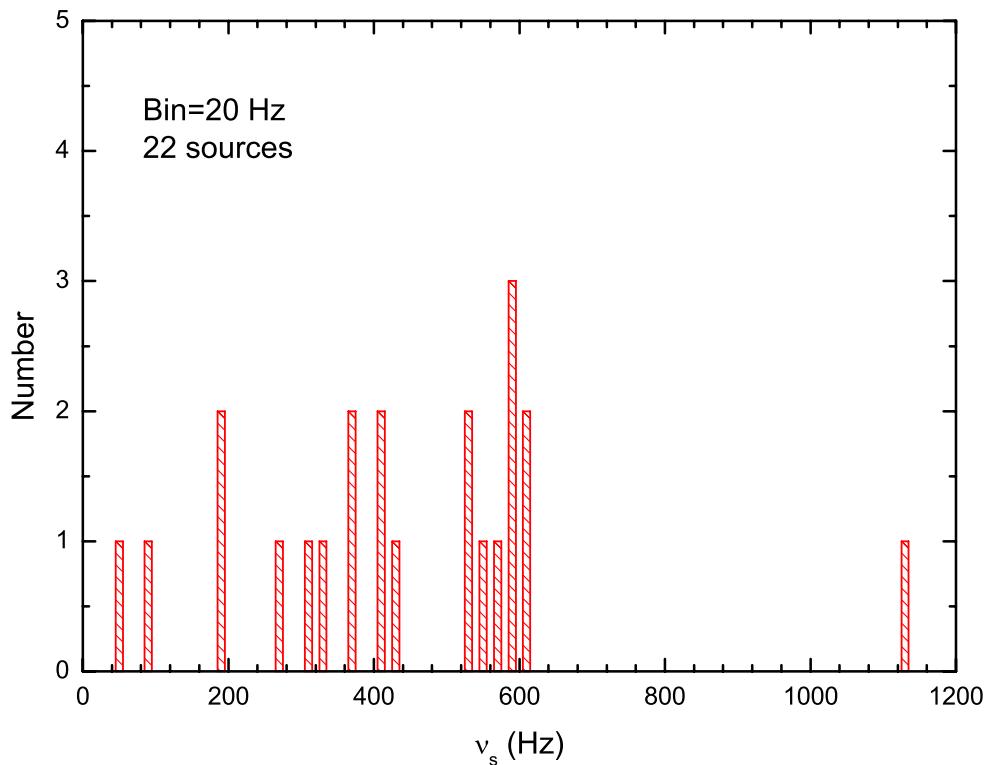
(van der Klis 2006)



Sco x-1, van der Klis et al 2006

Spin frequency

- X-ray pulsations 7
- Type-I x-ray bursts 16
- $16 + 7 - 2 = 21$
(Wijnands 2005)



Sources	$\nu_1^{(1)}$ (Hz)	$\nu_2^{(2)}$ (Hz)	$\Delta\nu^{(3)}$ (Hz)	$\nu_2/\nu_1^{(4)}$	$\nu_{burst}^{(5)}$ (Hz)	$\nu_{pulse}^{(6)}$ (Hz)	References
Millisecond pulsars (7)							
IGR J00291+5934	-	-	-	-	-	599	1
XTE J0929-314	-	-	-	-	-	185	K
XTE J1751-305	-	-	-	-	-	435	K
XTE J1807-294	127-360	353-587	179-247	1.51-2.78	-	191	2,3
SAX J1808.4-3658	499	694	195	1.39	401	401	K,4
XTE J1814-338	-	-	-	-	314	314	K
HETE J1900.1-2455 ^a	-	-	-	-	-	377	5
Z sources (8)							
Sco X-1	544-852	844-1086	223-312	1.26-1.57	-	649 [†]	M,B,K
GX 340+0	197-565	535-840	275-413	1.49-2.72	-	412 [†]	B,K,P,6
GX 349+2	712-715	978-985	266-270	1.37-1.38	-	752 [†]	B,K,7
GX 5-1	156-634	478-880	232-363	1.38-3.06	-	368 [†]	B,K,P,8
GX 17+2	475-830	759-1078	233-308	1.28-1.60	-	584 [†]	B,K,P,9
Cyg X-2	532	856	324	1.61	-	658 [†]	B,K,P
Cir X-1	56-226	229-505	173-340	2.23-4.19	-	176 [†]	10
XTE J1701-462	620	909	289	1.47	-	699 [†]	11
Atoll sources (16)							
4U 0614+09	153-823	449-1162	238-382	1.38-2.93	-	345 [†]	B,K,P,12,13
XB 1254-690	-	-	-	-	95	-	14
4U 1608-52	476-876	802-1099	224-327	1.26-1.69	619	-	M,B,K,15
4U 1636-53	644-921	971-1192	217-329	1.24-1.51	581	-	B,K,P,16,17
4U 1702-43	722	1055	333	1.46	330	-	K,P,18
4U 1705-44	776	1074	298	1.38	-	826 [†]	B,K,P
4U 1728-34	308-894	582-1183	271-359	1.31-1.89	363	-	B,K,P,13,19
KS 1731-260	903	1169	266	1.29	524	-	B,K,P
4U 1735-44	640-728	982-1026	296-341	1.41-1.53	-	755 [†]	B,K,P
XTE J1739-285 ^a	-	-	-	-	1122	-	20
A 1744-361 ^a	-	-	-	-	530	-	21
SAX J1750.8-2900 ^a	-	-	-	-	601	-	K,22
4U 1820-30	790	1064	273	1.35	-	818 [†]	B,K,P
Aql X-1 ^a	-	-	-	-	549	-	B,K,P
4U 1915-05	224-707	514-1055	290-353	1.49-2.3	270	-	B,K,P
XTEJ2123-058	849-871	1110-1140	261-270	1.31-1.31	-	854 [†]	B,K,P
Other sources (4)							
EXO 0748-676 ^a	-	-	-	-	45	-	K,23
MXB 1659-298	-	-	-	-	567	-	K,24
MXB 1743-29	-	-	-	-	589	-	K,25
SAX J1748.9-2021	-	-	-	-	410	-	K,26

Beat-frequency model

- (Strohmayer et al. 1996)

$$\nu_2 - \nu_1 = \nu_s$$

- (Miller et al 1998 ApJ)

$$\nu_2 - \nu_1 = \frac{1}{2} \nu_s$$

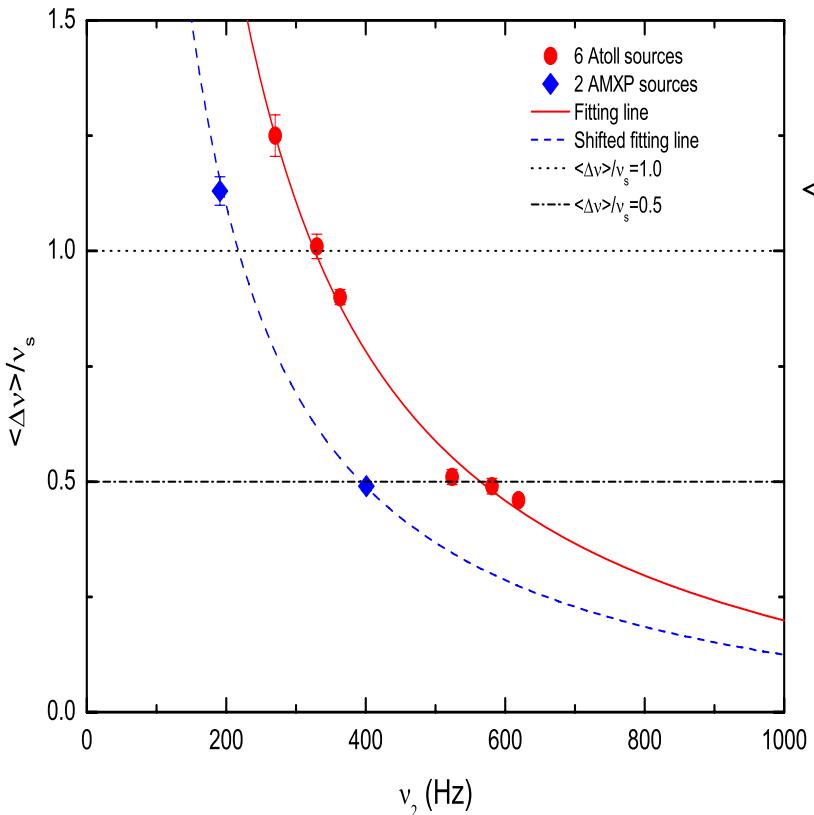
Our results: I

Sources*	$\langle \Delta\nu \rangle (\sigma)^{(1)}$ (Hz)	$\langle \Delta\nu \rangle / \nu_s^{(2)}$	$\nu_{2\min} / \nu_s^{(3)}$
Millisecond pulsar			
XTE J1807-294	215(5.9)	1.13	1.8
SAX J1808.4-3658	195(4.0) ^a	0.49	1.7
Atoll source			
4U 1608-52	287(7.2)	0.46	1.3
4U 1636-53	286(9.6)	0.49	1.7
4U 1702-43	333(8.7)	1.01	3.2
4U 1728-34	327(5.8)	0.90	1.6
KS 1731-260	266(8.7)	0.51	2.2
4U 1915-05	338(12.1)	1.25	1.9

$$\nu_{2\min} / \nu_s > 1.3$$

- To estimate the **upper limits** of spin frequency of neutron stars with twin kHz QPOs!
- A condition of detecting twin kHz QPOs?

Our results: II



Linear correlation in 6 Atoll:

$$\langle \Delta\nu \rangle / \nu_s = -(0.19 \pm 0.05) + (389 \pm 21) \text{Hz} / \nu_s$$

Shift a factor 1.5 on y direction

(Linares et al. 2005; van Straaten et al. 2005)

Linear correlation rather than
cumulating around 0.5 and 1

Discussions

- Spin frequency plays a role in the twin kHz QPOs production.
- Spin frequency corresponds to an averaged magnetosphere radius, where the long-term accretion rate matched with the magnetic field.
- Correlate to the evolution of magnetic field and spin-up history?

Thanks!