

Modeling Gravitational Wave emission from LMXBs

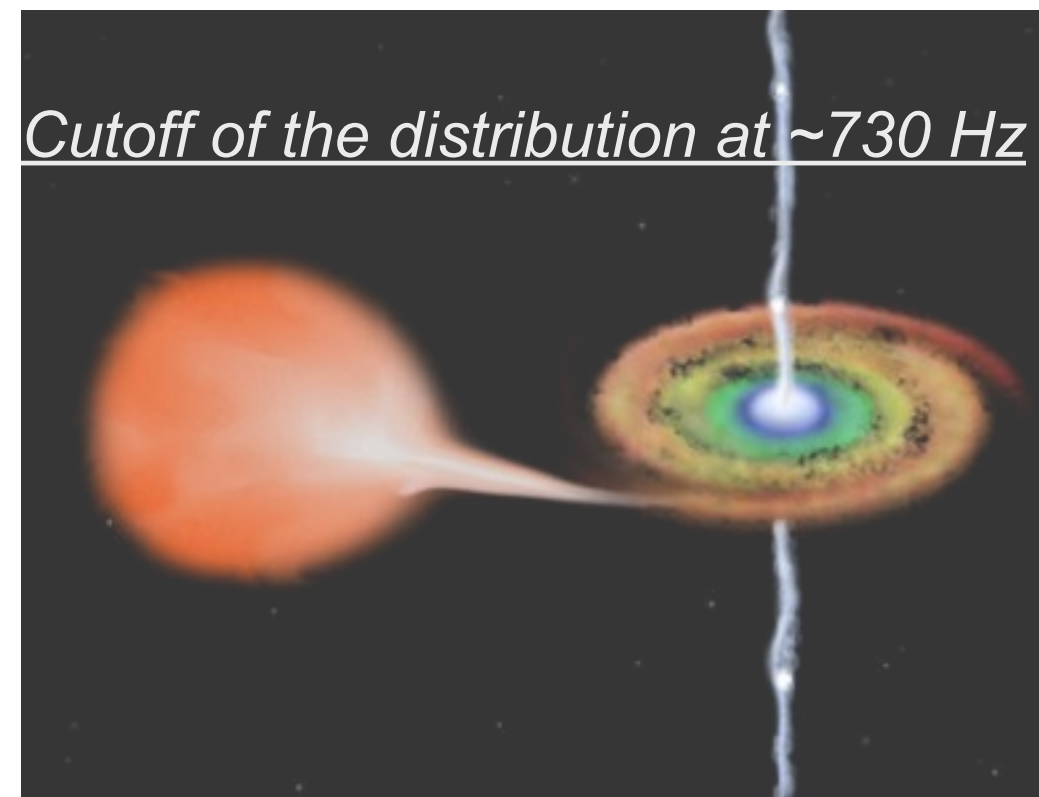
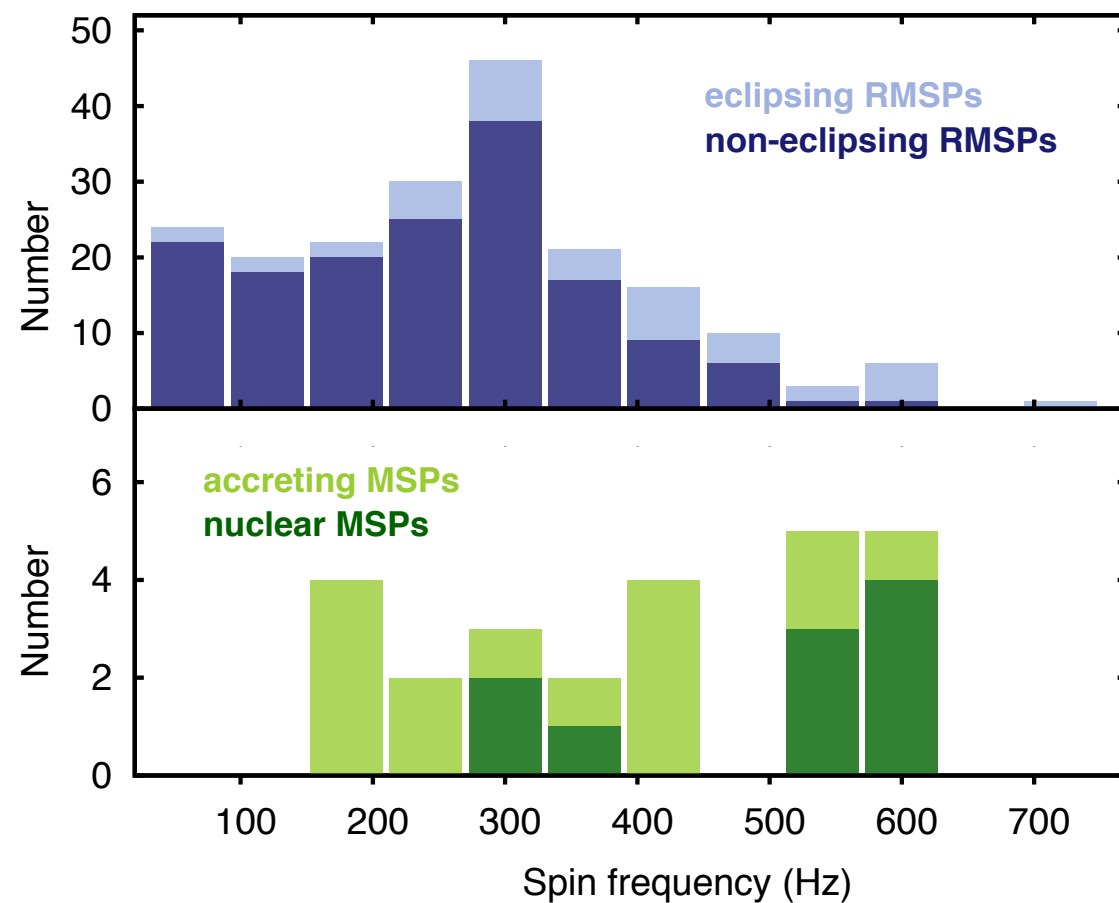
Brynmor Haskell



Polish Academy of Sciences

NICOLAUS COPERNICUS ASTRONOMICAL CENTER

GWs from Low Mass X-ray Binaries



(Chakrabarty et al 2003, Patruno 2010, Papitto et al. 2014)

■ Spin up halted well before breakup frequency

■ Disk/magnetosphere interaction?

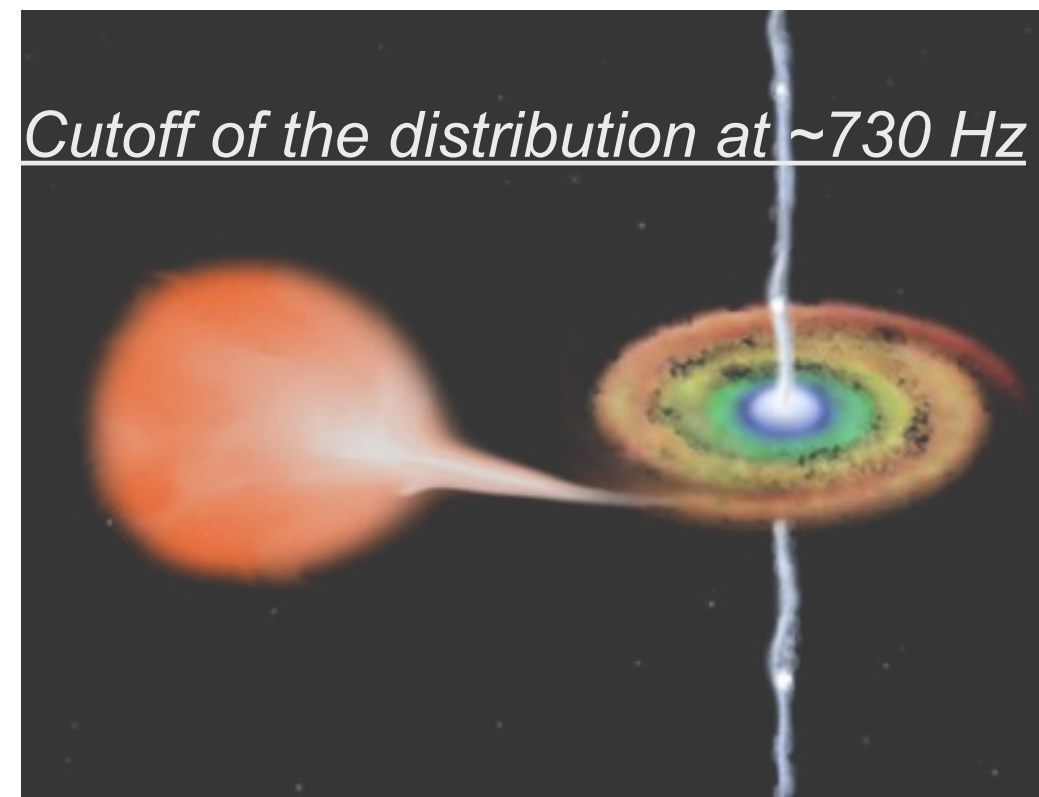
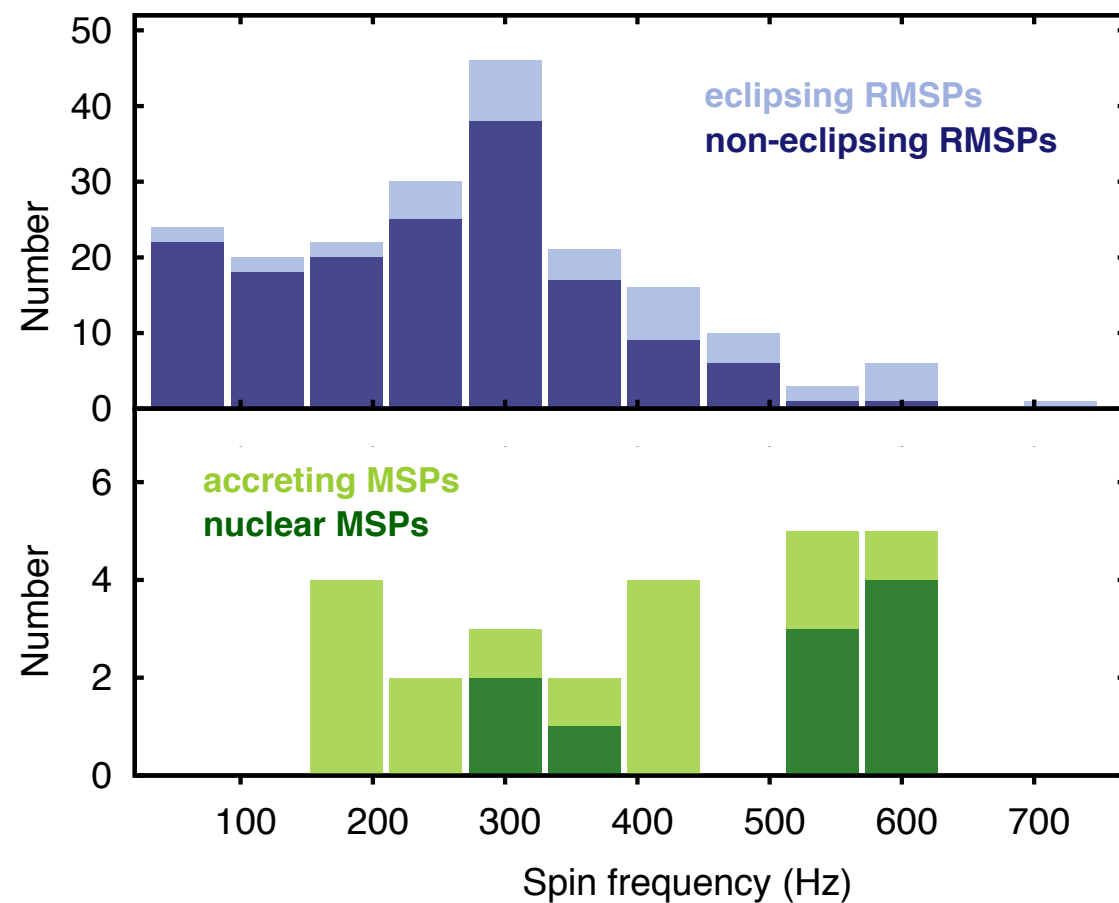
(White & Zhang 1997, Andersson, Glampedakis, BH & Watts 2006, BH & Patruno 2011, Patruno, D'Angelo & BH 2012, Ferrigno et al. 2013)

■ GWs!: “mountains”, unstable modes, magnetic deformations

$$\epsilon \approx 10^{-7}$$

(Papaloizou & Pringle 1978, Wagoner 1984, Bildsten 1998, Andersson 1998, Cutler 2002, BH et al. 06, BH et al. 08, Payne & Melatos 05)

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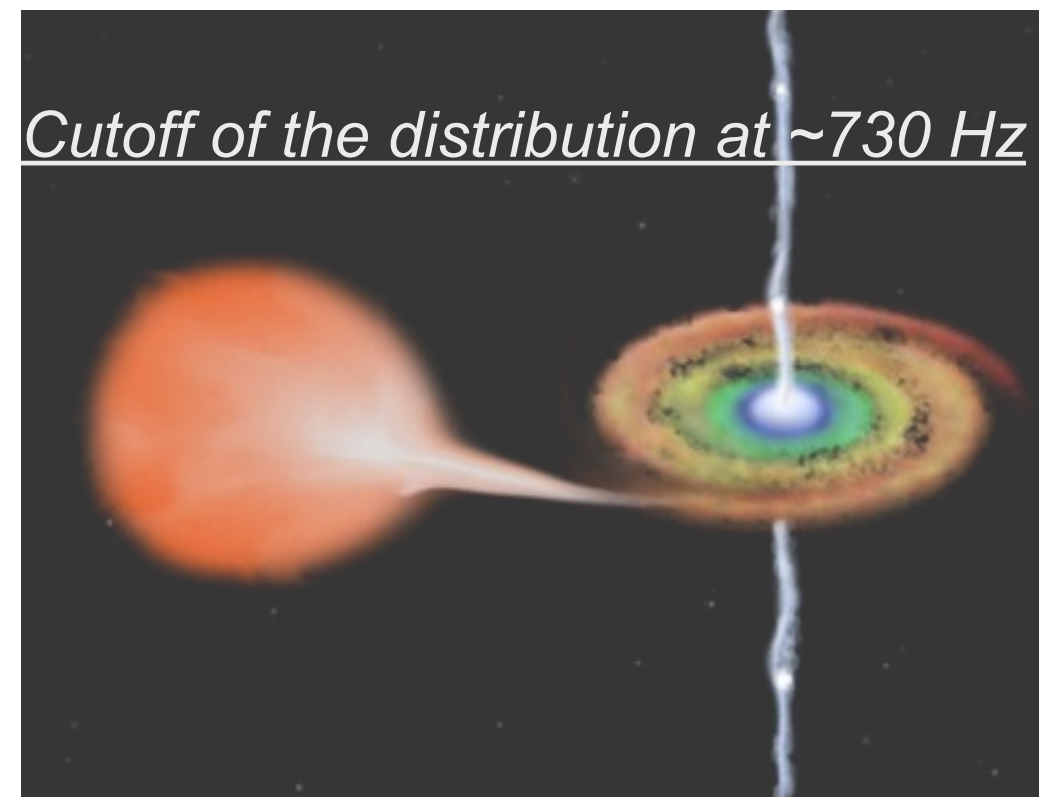
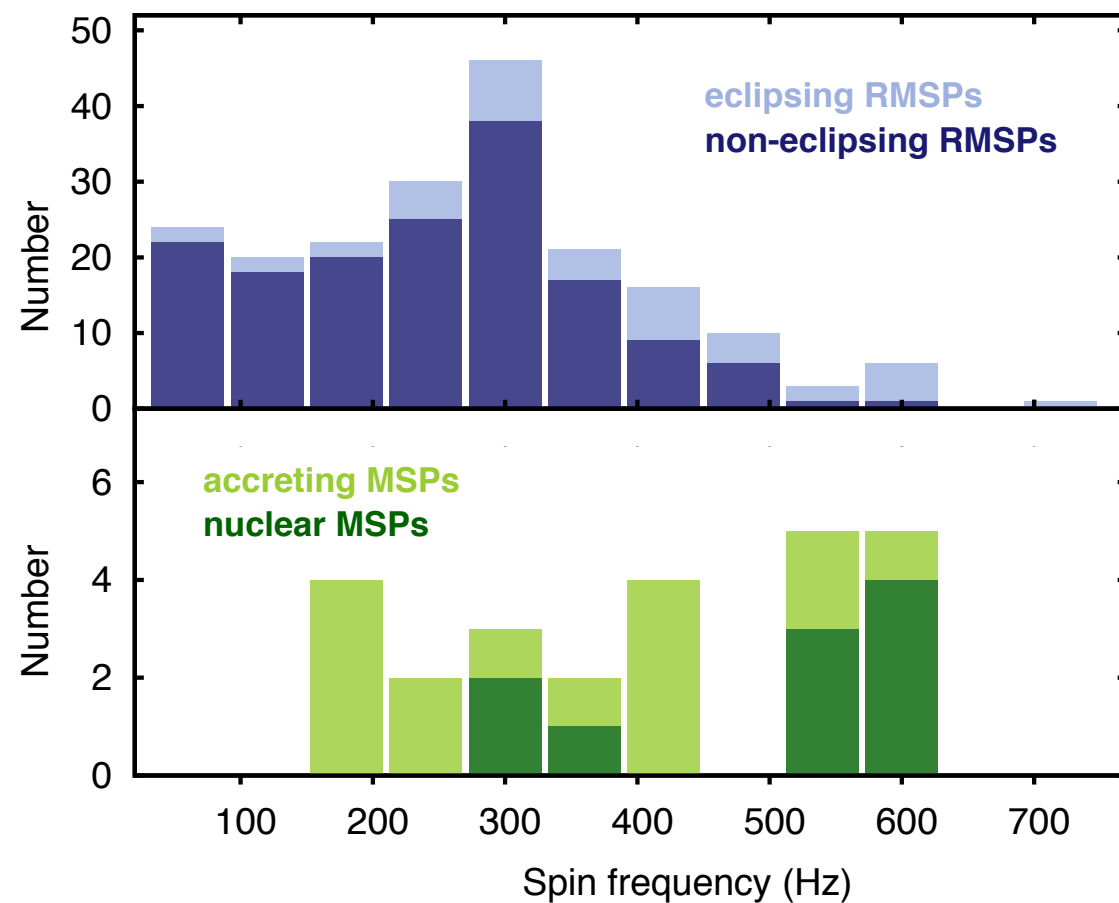
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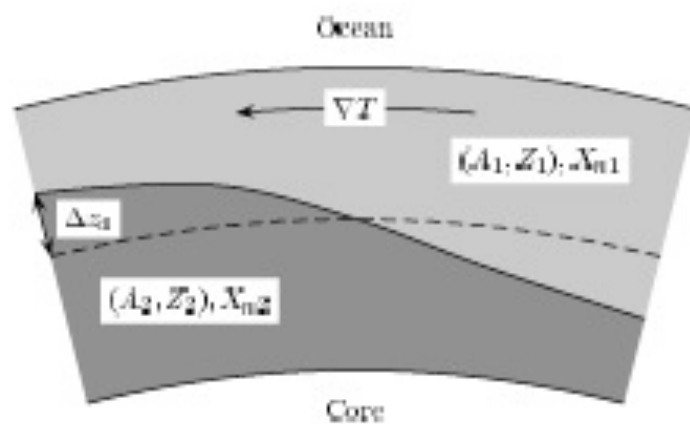
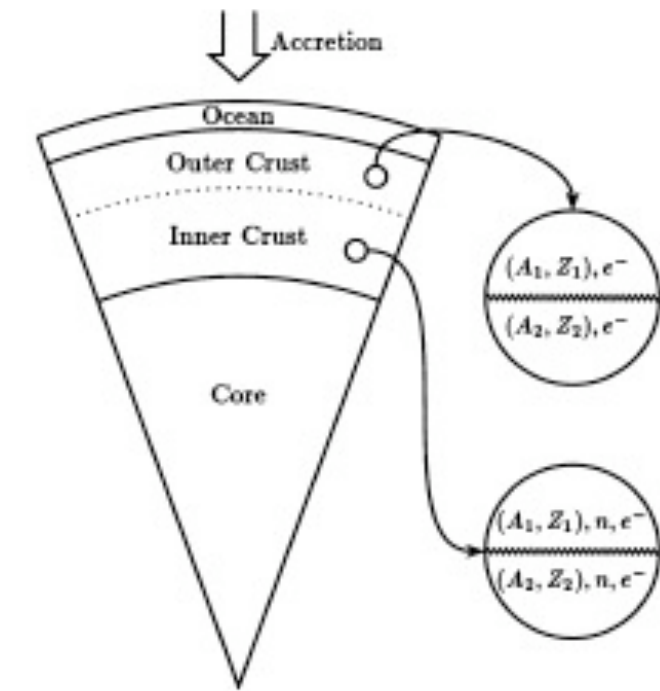
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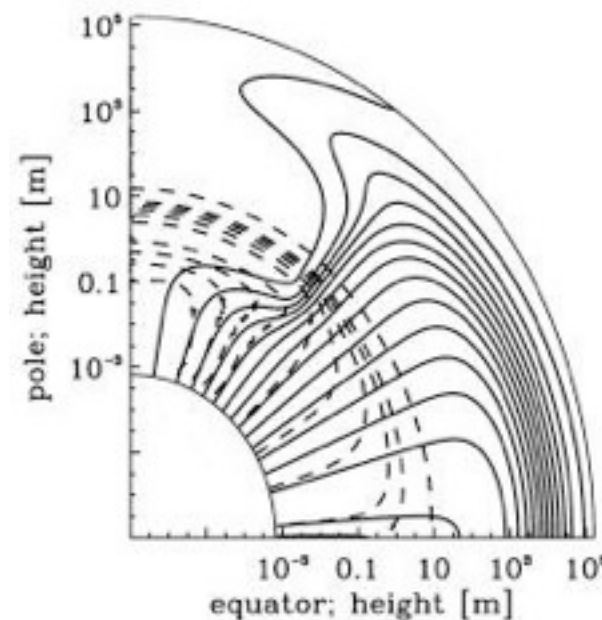
Mountains on LMXBs

■ Mountains from 'wavy' capture layers in crust



(Ushomirsky, Cutler, Bildsten 2000)

■ Magnetic mountains



Payne & Melatos 2005,
Priymak et al. 2011,
Mukherjee et al. 2012

Crustal (thermal and magnetic) mountains

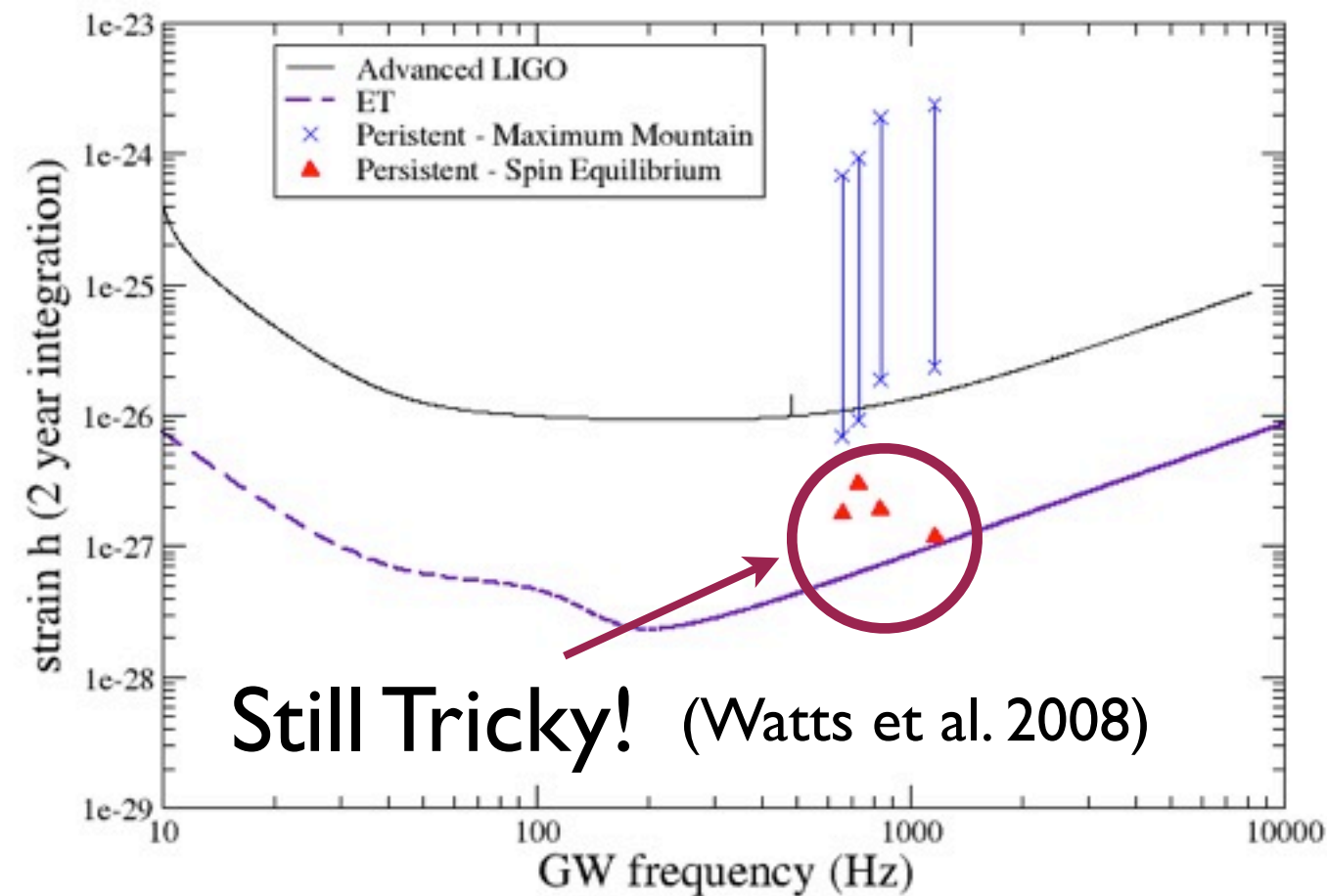
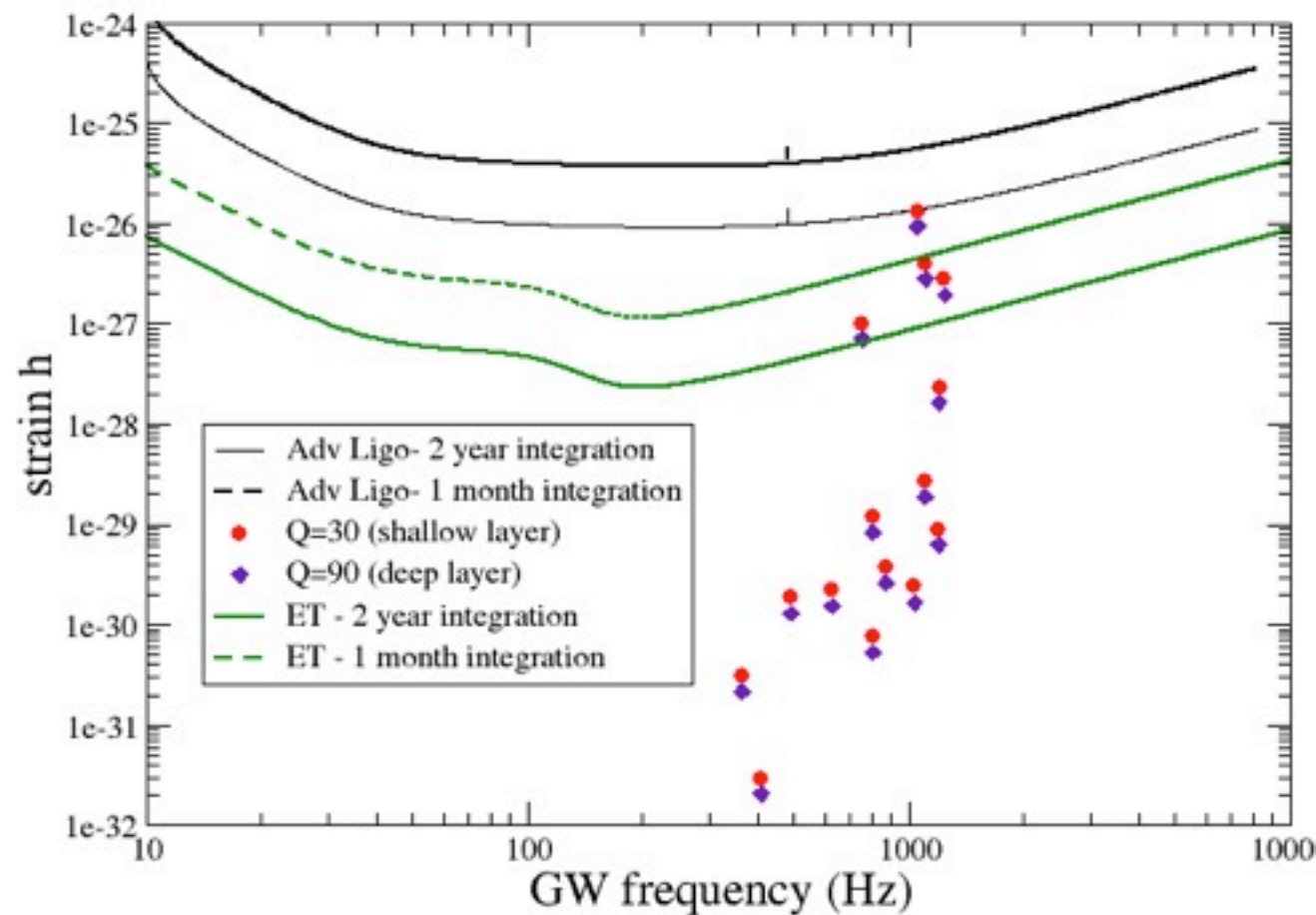
- Mountain accumulates during outbursts
- Does it dissipate between outbursts?

Source	ν (Hz)	d (kpc)	$\langle \dot{M} \rangle$ ($10^{-10} M_{\odot} \text{ yr}^{-1}$)	Δt (d)	Ref.
SAX J1808.4–3658	401	3.5	4	30	Patruno et al. (2009)
XTE J1751–305	435	7.5	10	10	Miller et al. (2003)
XTE J1814–338	314	8	2	60	this work
IGR J00291+5934	599	5	6	14	Falanga et al. (2005)
HETE J1900.1–2455	377	5	8	3000	Papitto et al. (2013b)
Aql X-1	550	5	10	30	Güngör, Güver & Eksi (2011)
Swift J1756.9–2508	182.1	8	5	10	Krimm et al. (2007)
NGC 6440 X-2	204.8	8.5	1	4	this work
IGR J17511–3057	244.9	6.9	6	24	Falanga et al. (2011)
IGR J17498–2921	400.9	7.6	6	40	Falanga et al. (2012)
Swift J1749.4–2807	518	6.7	2	20	Ferrigno et al. (2011)
EXO 0748–676	552	5.9	3	8760	Degenaar et al. (2011)
4U 1608–52	620	3.6	20	700	Gierlinski & Done (2002)
KS 1731–260	526	7	11	4563	Narita, Grindlay & Barret (2001)
SAX J1750.8–2900	601	6.8	4	100	this work
4U 1636–536	581	5	30	pers.	this work
4U 1728–34	363	5	5	pers.	Egron et al. (2011)
4U 1702–429	329	5.5	23	pers.	this work
4U 0614+091	415	3.2	6	pers.	Piraino et al. (1999)

(BH, Priymak, Patruno, Oppenoorth, Melatos & Lasky 2015)

“Thermal” mountains

■ Persistent sources promising

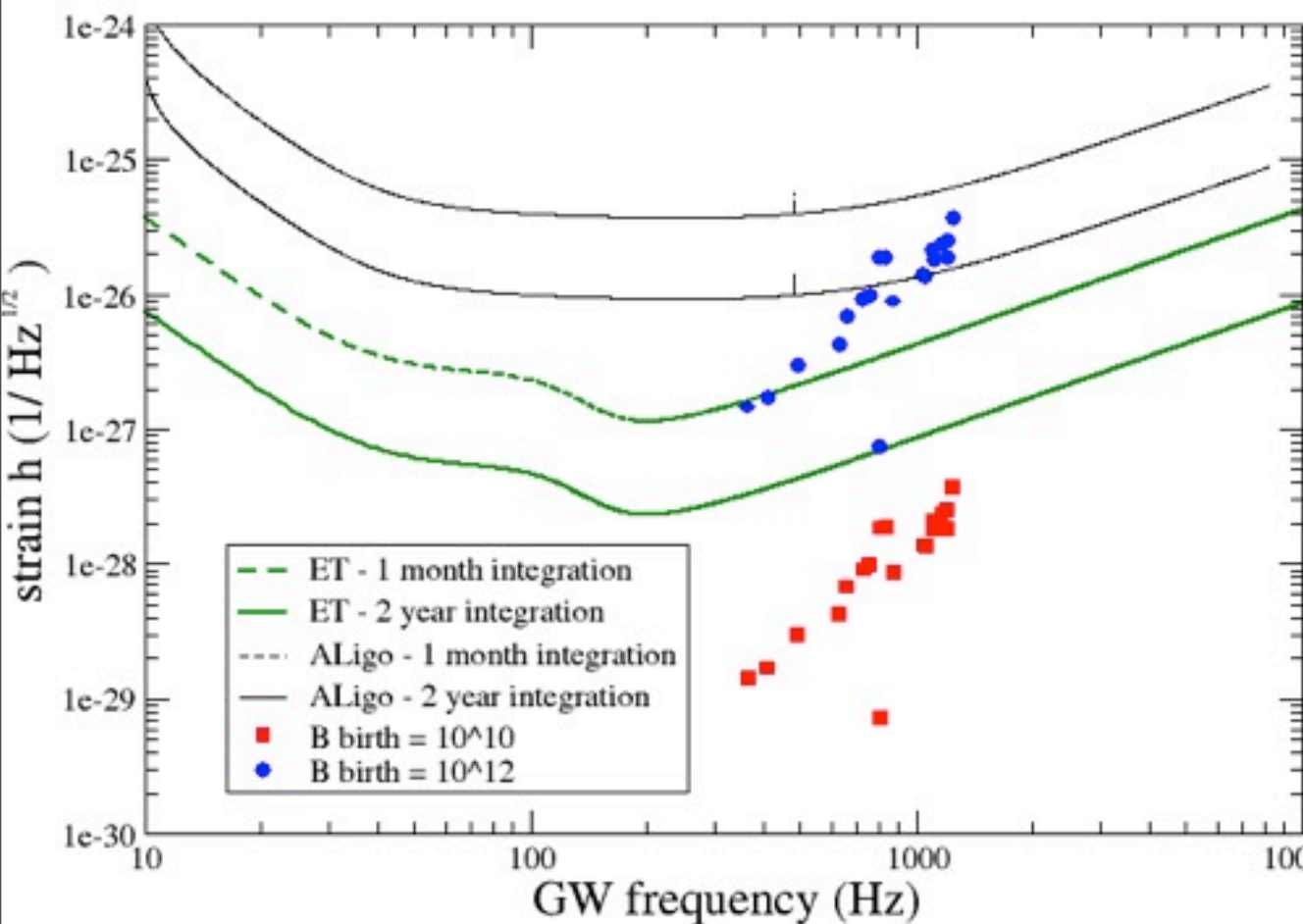


(BH, Priymak, Melatos, Lasky, Patruno & Oppenorth, 2015)

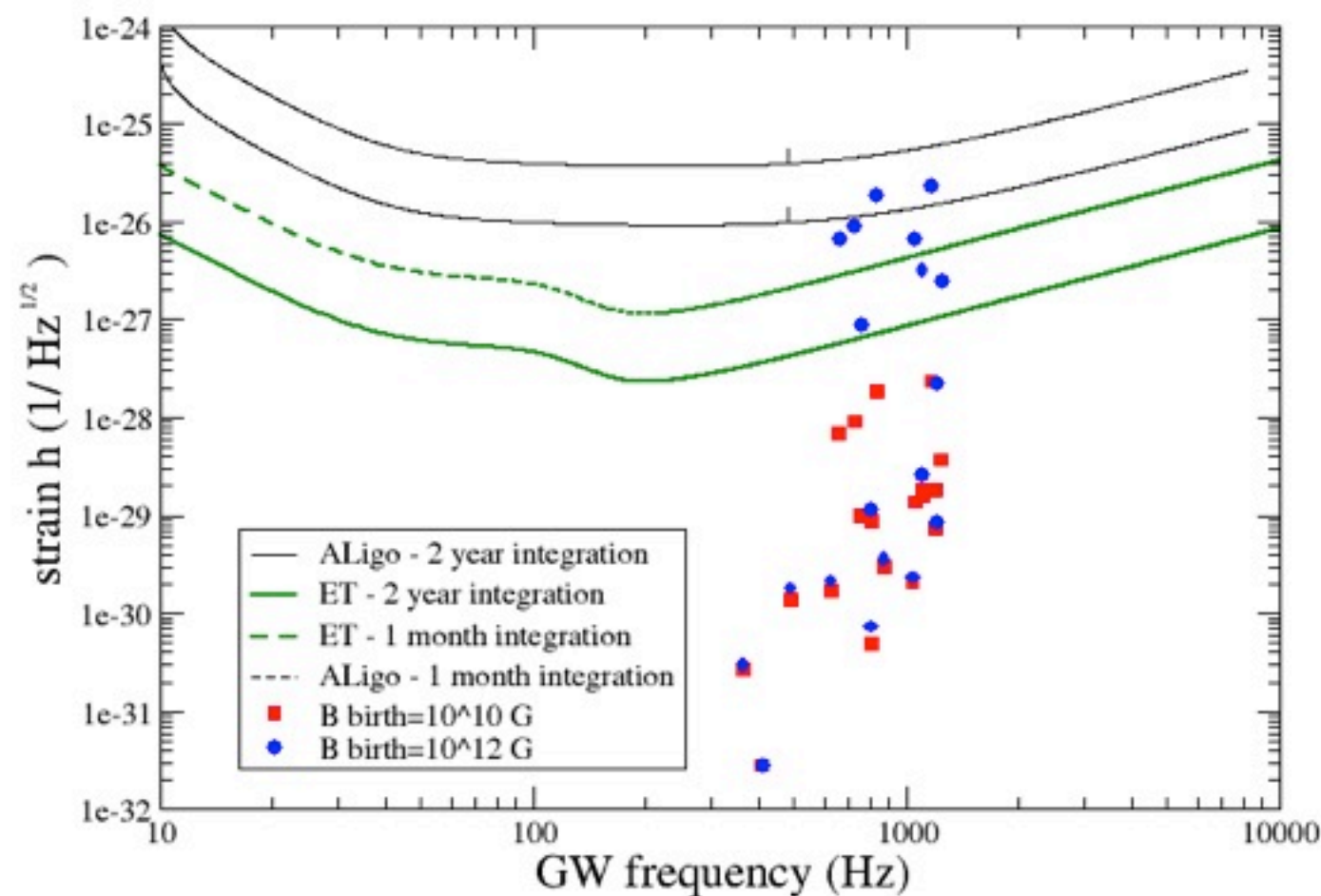
Magnetic mountains

- Only systems with strong fields detectable
- Possible cyclotron features

(BH, Priymak, Patruno, Oppenoorth, Melatos & Lasky 2015)



Maximum

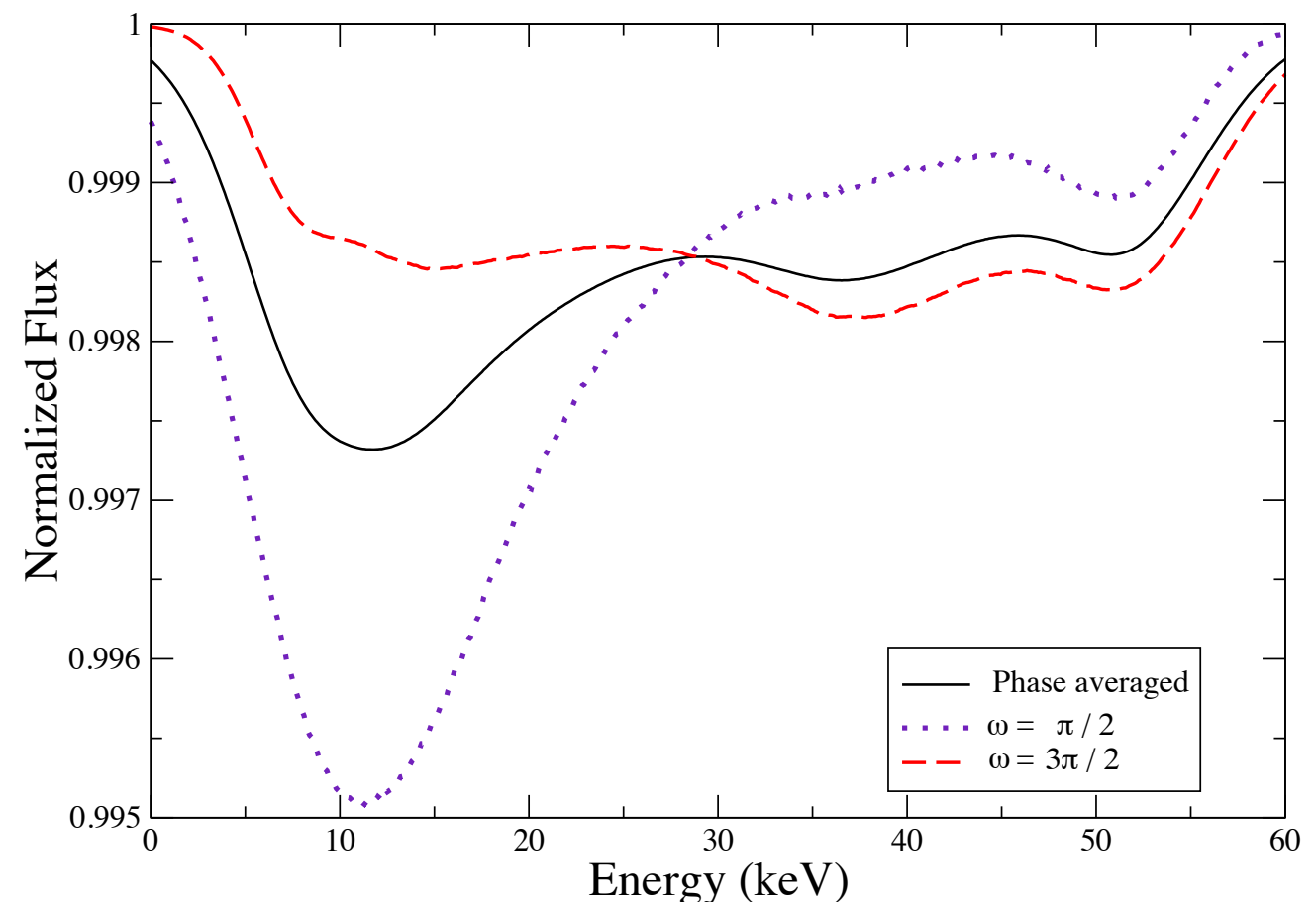
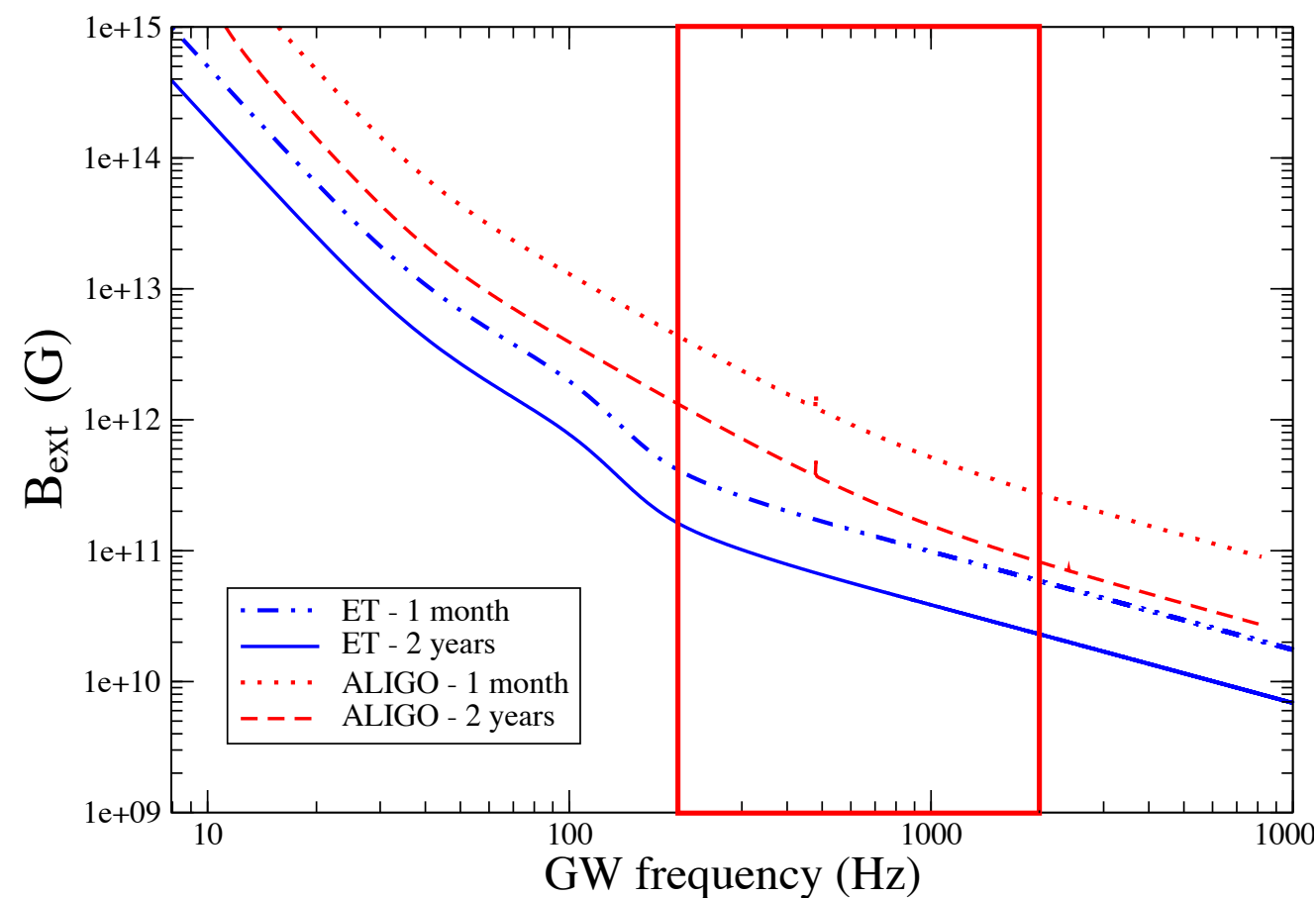


Transient

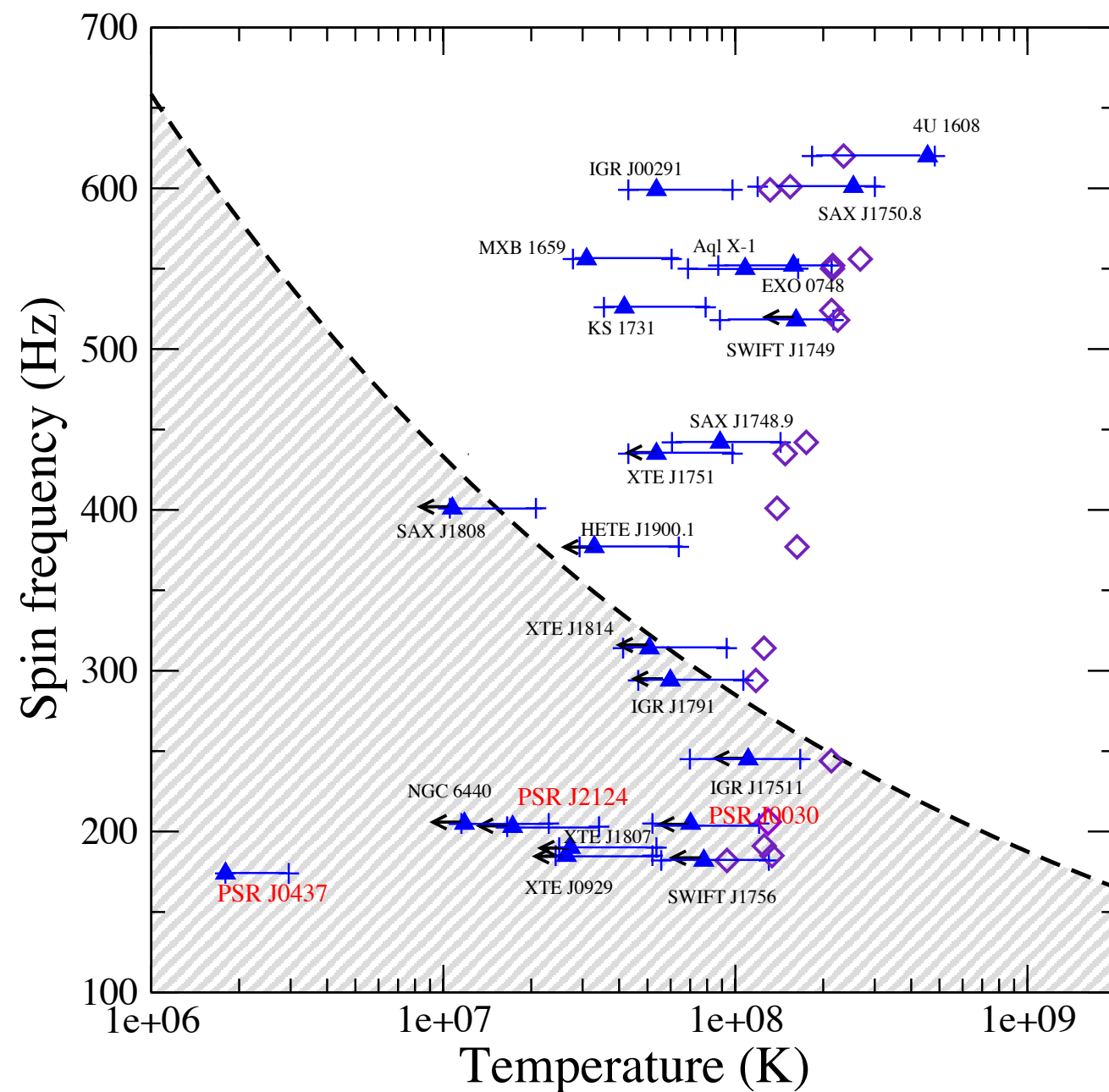
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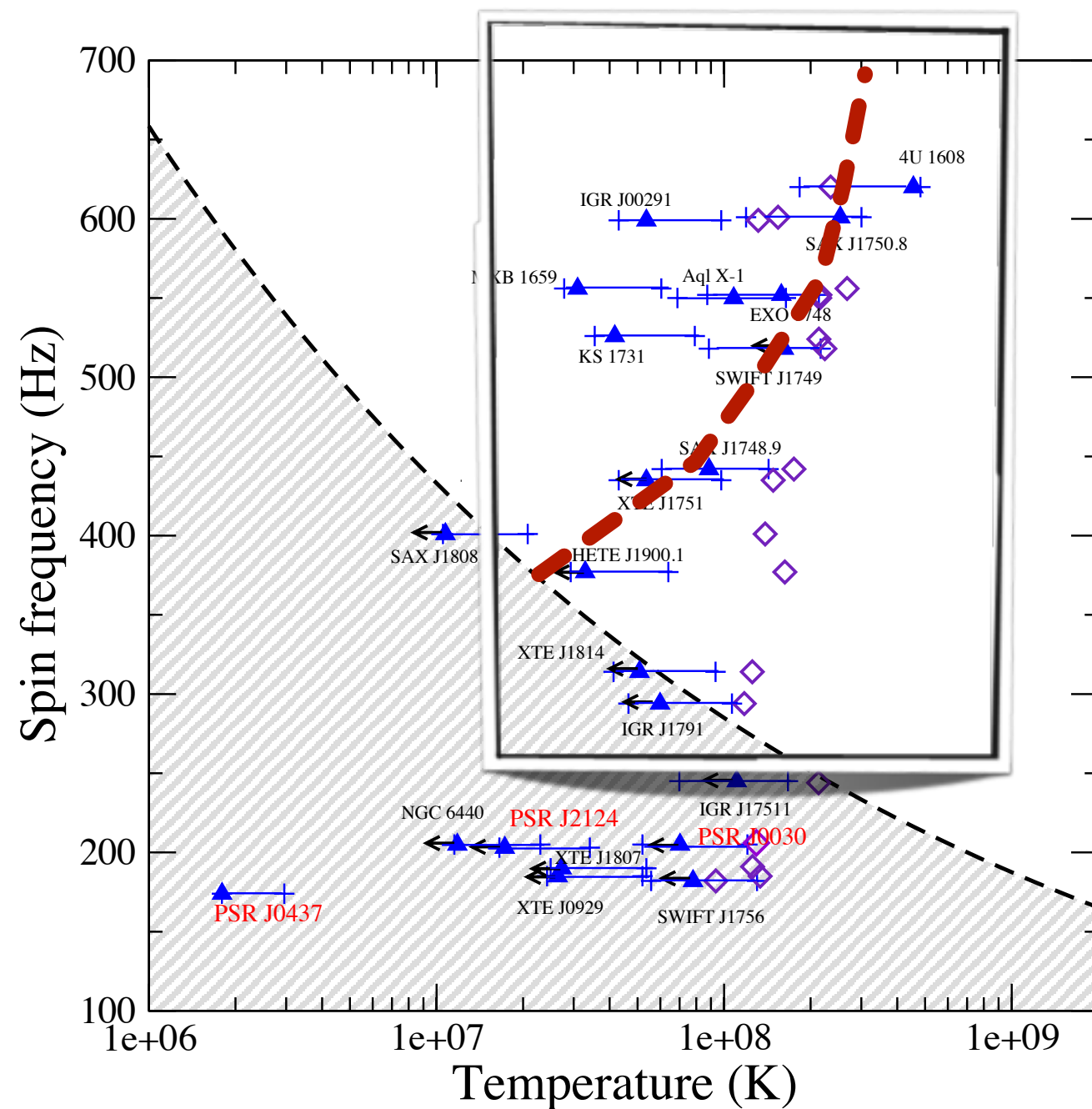
Spin equilibrium - r-modes?



[Ho, Andersson & BH (2011), BH, Degenaar & Ho (2012), Mahmoodifar & Strohmayer (2013), Haskell et al. (2015)]

- ‘minimal’ window not consistent with observations!
- most stars too cold for spin equilibrium - possible for hotter, faster, systems?
- need either enhanced viscosity, or very small saturation amplitude $\alpha \approx 10^{-6} - 10^{-9}$
- Vortex Flux tube interaction
BH, Glampedakis & Andersson (2014)
- Phase transitions
Alford, Han & Schwenzer (2015)
- Resonances
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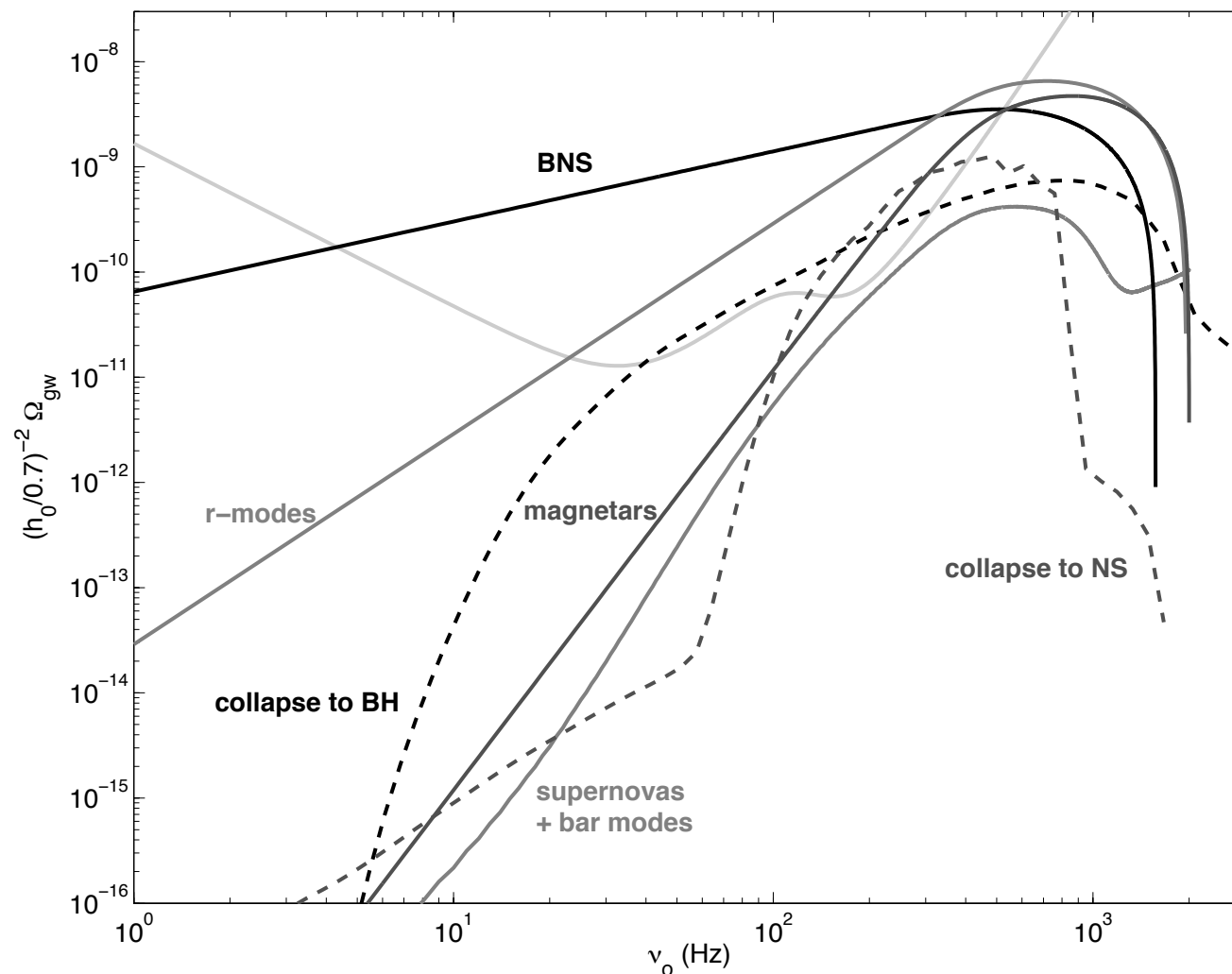
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Stochastic background of gravitational waves

- System gets stuck emitting GWs!
Long emission time (10^8 years) - stochastic background

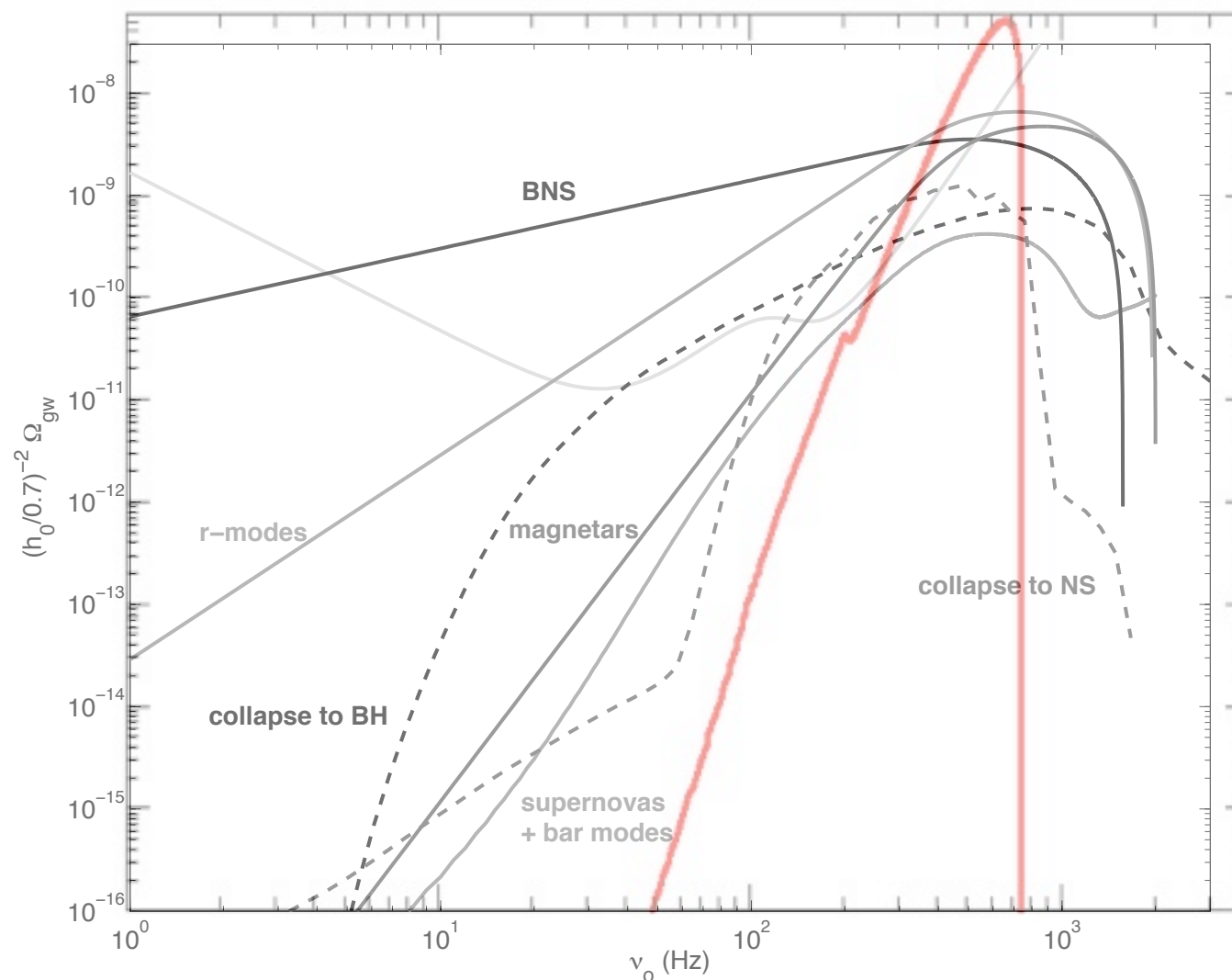
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Conclusions

- NSs in LMXBs are interesting sources of continuous GWs
- Spin equilibrium **ONLY** an upper limit
- Accurate modelling of the physics in the sources is needed for waveforms