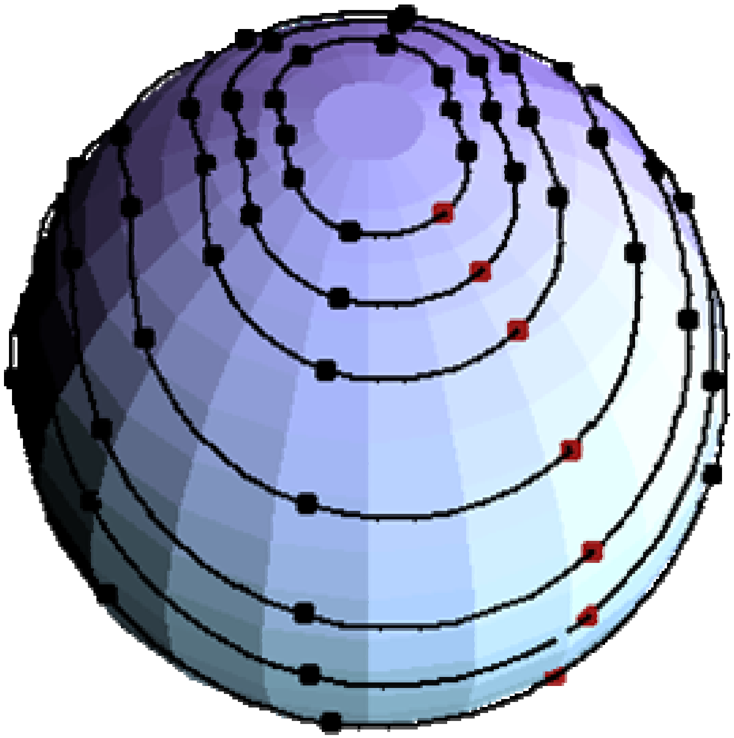
The r-modes look good again in accreting neutron stars

Ben Owen
with Mohit Nayyar

LIGO-G040353-00-Z

What is an r-mode?

- Dominated by Coriolis force
- Mainly velocity perturbation, little density perturbation
- Pushes buoys horizontally
- Extends down into core
- Has frequency comparable to spin frequency of star
- Has pattern speed prograde in inertial frame, retrograde in co-rotating frame
- Subject to gravitational radiation (CFS) instability

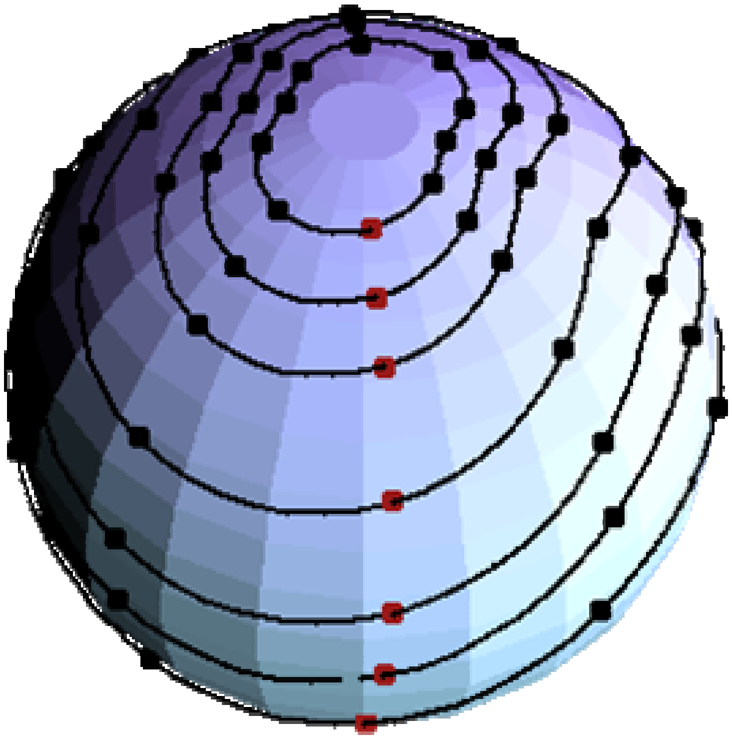


LIGO-G040353-00-Z

Why do we care?

Instability of r-modes could

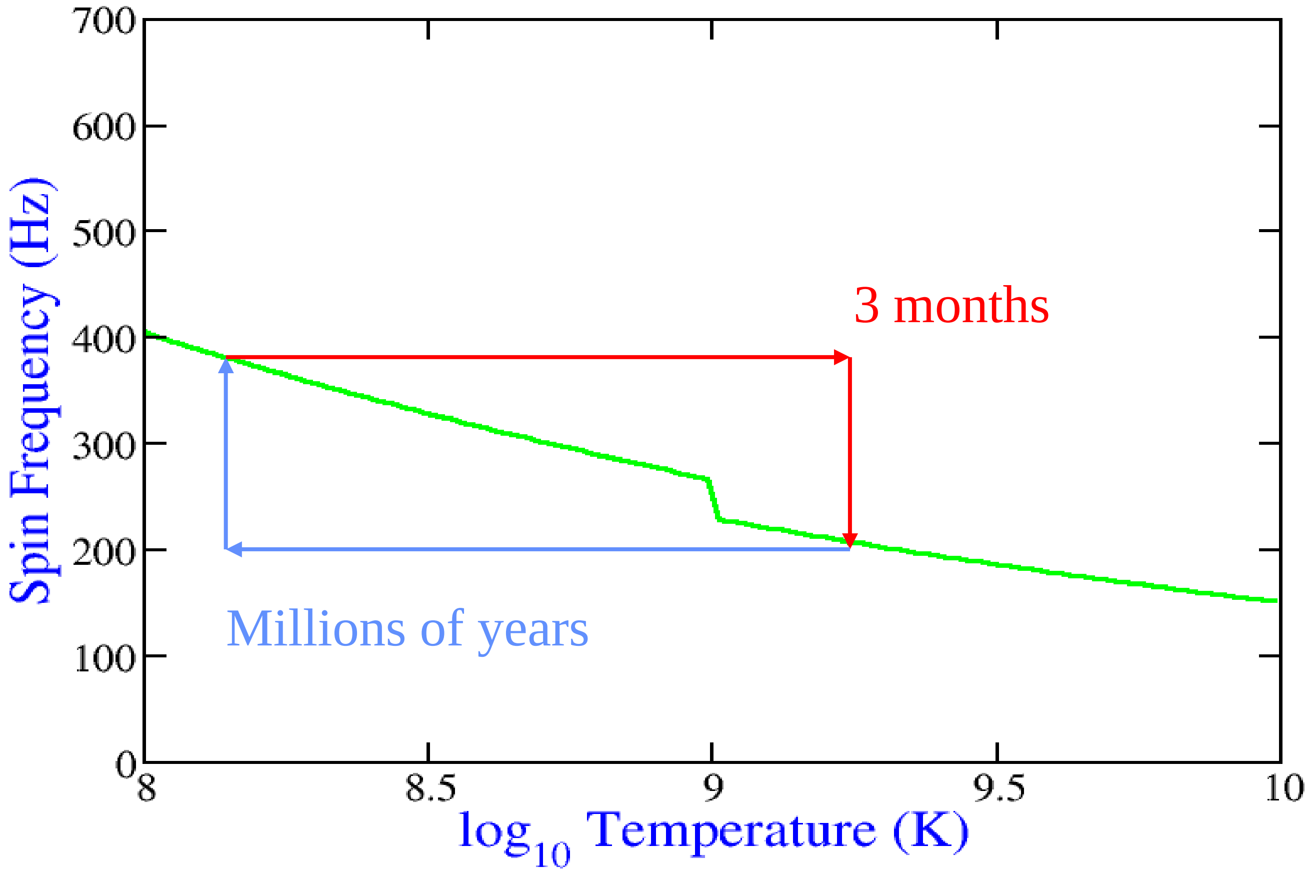
- survive in realistic neutron stars (with viscosity),
- explain why young neutron stars spin so slowly,
- explain why rapidly accreting neutron stars (LMXB) spin slowly and within a narrow band, and
- produce gravitational waves detectable by LIGO with noise a little better than SRD



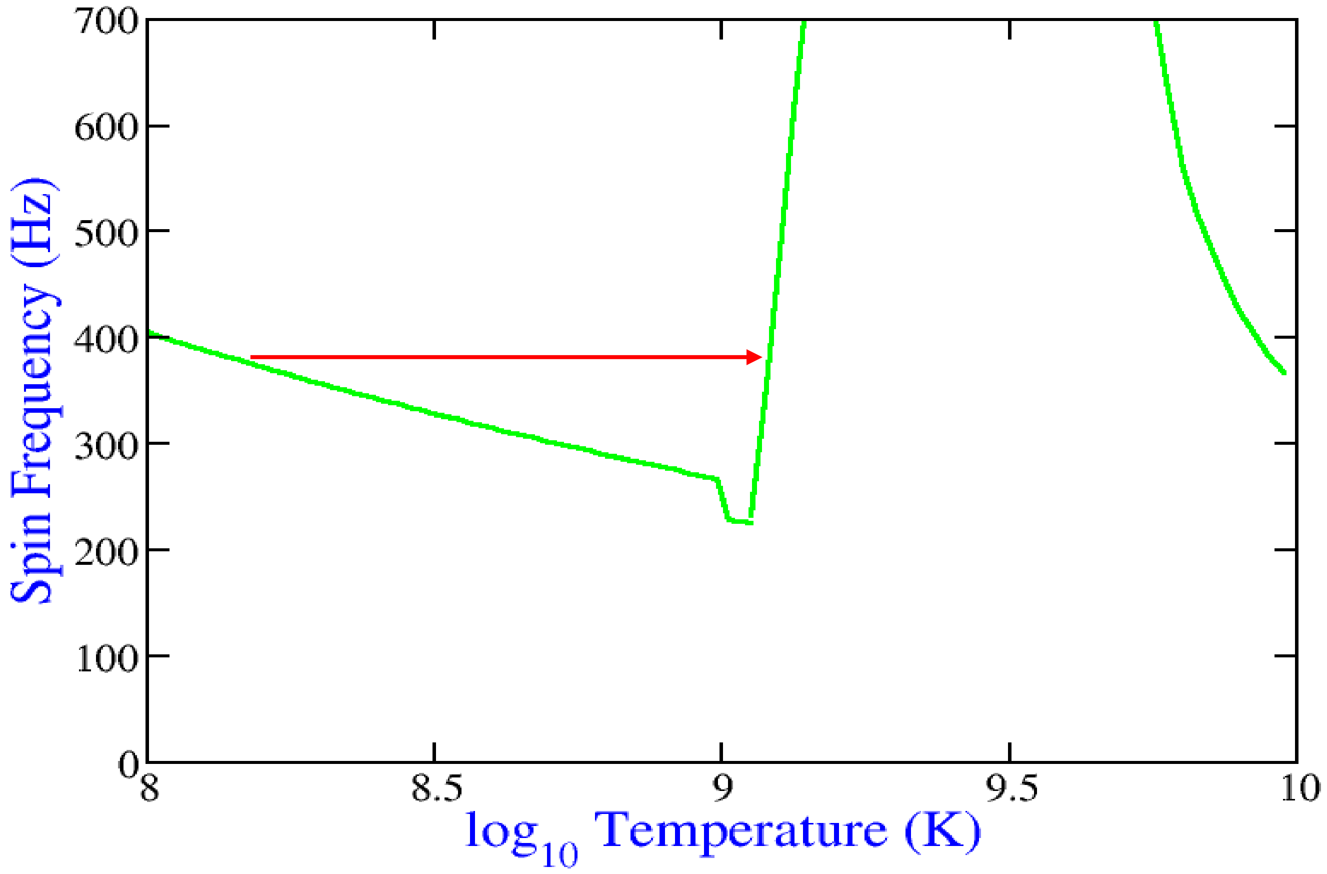
Context of this talk

- People kept saying the r-modes are dead (crust etc)
- Lindblom and I kept resurrecting them (melting etc)
- We thought the LMXB scenario was bad anyway for GW due to Levin's argument for thermal runaway
- Then we found something (bulk viscosity in hyperon core) that really was deadly (Peter Jones)
- Wagoner argued that it's actually good for GW in the LMXB scenario, though not for the young stars…
- But he used the least reliable part of our paper – is it really good if you do it right?

Thermal run-away



Thermal sit-there



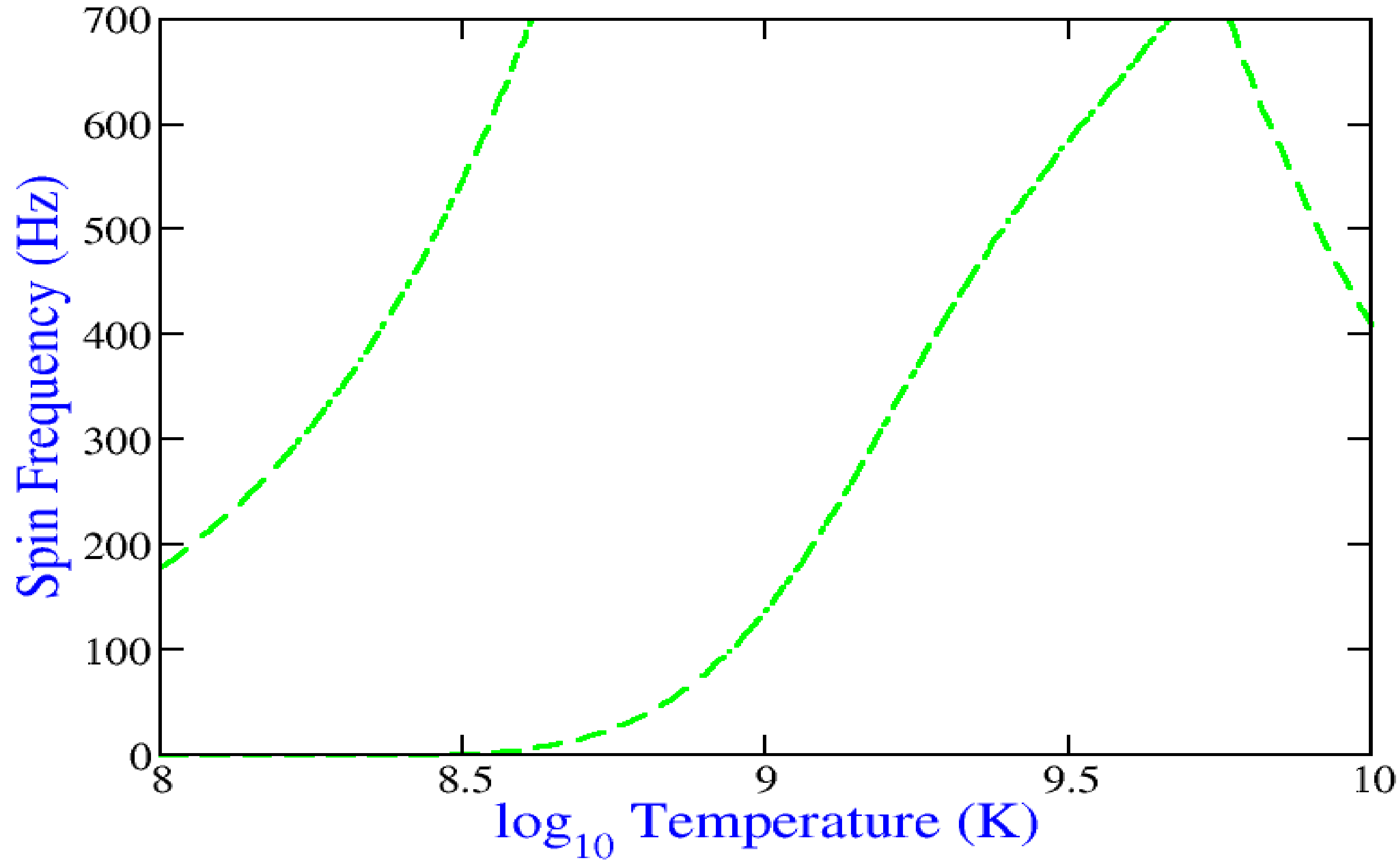
Where did that cliff come from?

- Hyperons are nucleons with a strange quark (e.g. Σ- = dds, 1200 MeV), might be formed at high density
- Similar things with other exotic matter, but we can measure lab numbers for hyperons
- High bulk viscosity by n n $\longleftrightarrow$ $p^+ \Sigma^-$ etc
- Comes from matching timescales
- Bulk viscosity coefficient ζ goes as $\tau / (1 + \omega^2\tau^2)$
- Usually $\omega\tau$ is large, so long τ (superfluid) reduces ζ
- Here $\omega\tau$ starts small, so superfluidity increases ζ!

Is it really there?

- Lindblom & Owen had sloppy treatment of superfluidity – use better one in Haensel et al.
- Haensel et al. were sloppy with rest of microphysics – use Lindblom & Owen but fix some minor errors
- Explore range of theoretical parameters consistent with laboratory measurements of (hyper)nuclei and astrophysical observations – is the cliff robust?

New instability curves



LIGO-G040353-00-Z

Conclusions

- Persistent emission of gravitational waves is robust
- Main parameter affecting cliff location is superfluid critical temperature of Σ^- - which is least known!
- Oh, and … a very popular equation of state has an error, and turns out to be physically impossible! (Glendenning K = 240 MeV when corrected gives maximum neutron star mass 1.3 solar masses)