R-mode instability and related phenomena

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Outline

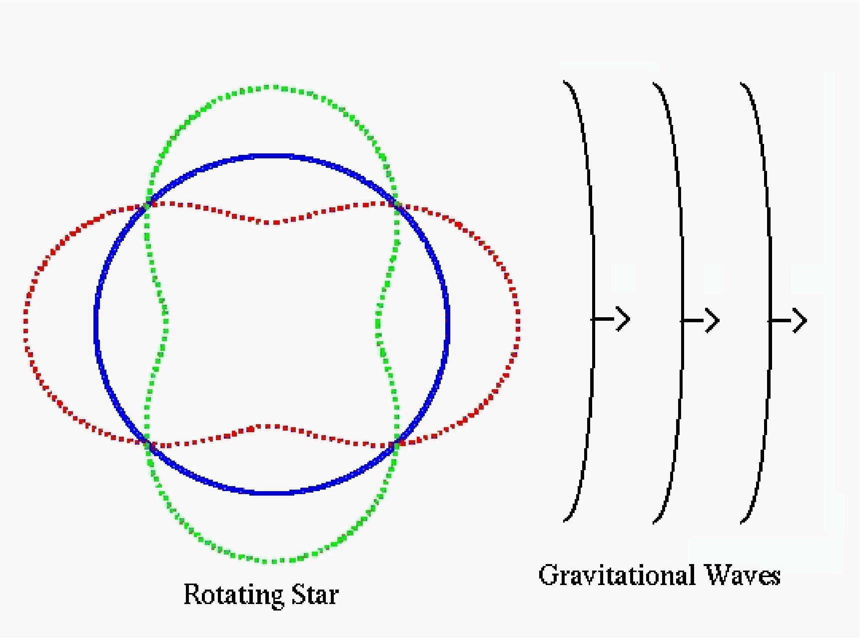
- Ways R-modes could be interesting
- What we did
- Conclusions

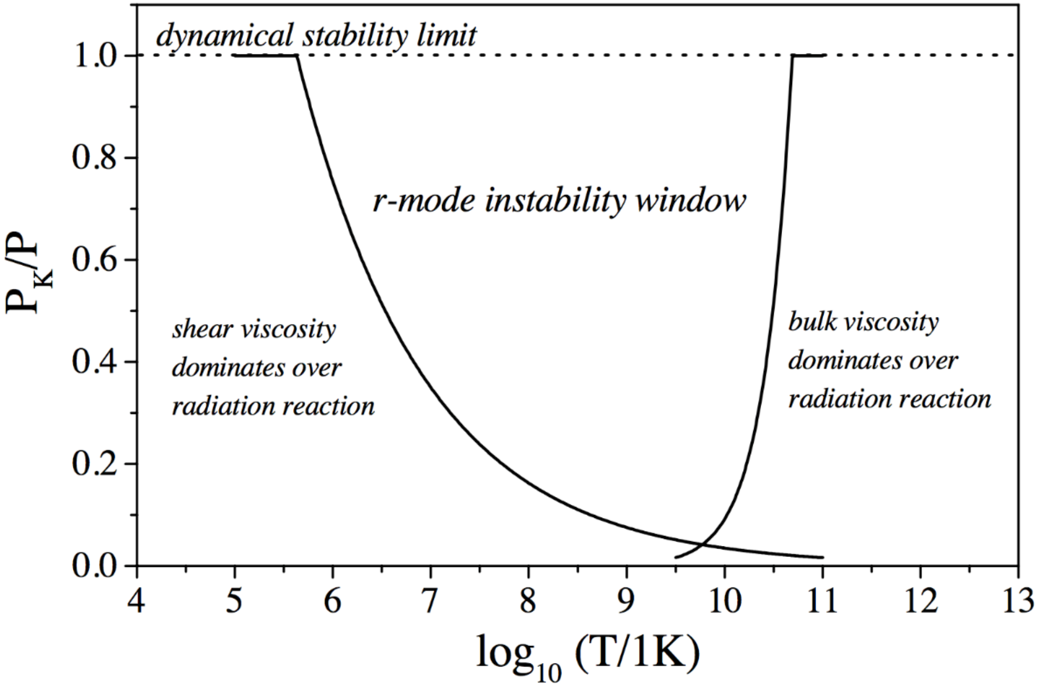
Way R-modes could be interesting

- R-modes can produce Gravitational waves
- direct way to probe the interior of compact stars

R-mode instability

- GR tends to drive all rotating stars unstable!
- Internal dissipation in the star can suppress the instability

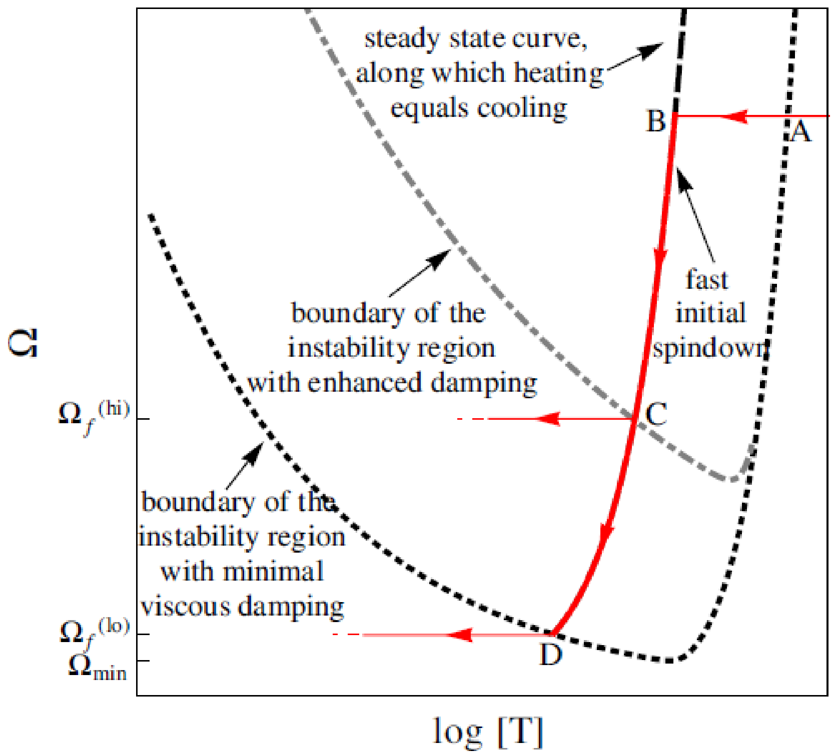




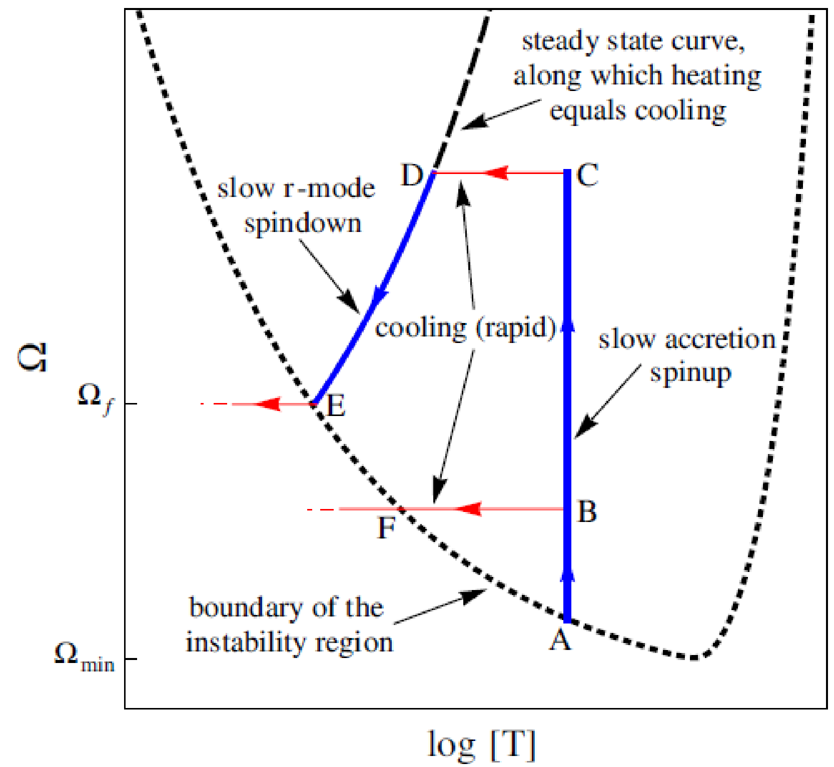
N. Andersson & K.D.Kokkotas, IJMPD, 2001
K.D.Kokkotas & K. Schweizer, EPJA, 2016

R-mode gravitational wave scenarios

$$h_0 = \sqrt{\frac{2^{15}\pi G}{3^6 5}} \tilde{J} M R^3 \frac{\chi^2 \Omega^3 \alpha}{D} .$$



newly formed compact stars
young sources



sources in LMXBs
millisecond pulsars

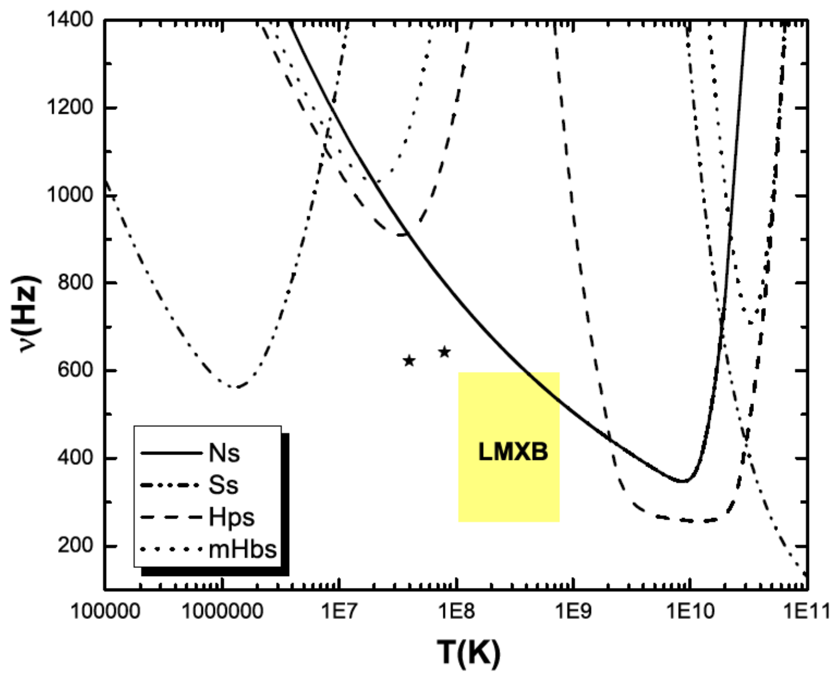
Alford et al. 2012

R-mode instability window

- competition between the destabilizing effect of GR and the damping effect of viscosity

- *dE/dt* >0, r-mode increase, GW emission
- *dE/dt* < 0, r-mode decrease, no instability
- critical condition $\frac{dE}{dt} = 0$

$$\frac{1}{\tau_{gw}} + \frac{1}{\tau_v} = 0$$



Pan et al., 2006
K.D.Kokkotas & K. Schweizer, EPJA, 2016

R-mode instability and GW emission

$$\frac{1}{\tau_{gw}} + \frac{1}{\tau_{v}} = 0$$

- $\frac{1}{\tau_{\xi}} = \frac{4\pi}{690}\left(\frac{\Omega^2}{\pi G\bar{\rho}}\right)^2 R^{2l-2}\left[\int_0^R \rho r^{2l+2}dr\right]^{-1}\int_0^R \xi\left(\frac{r}{R}\right)^2\left[1+0.86\left(\frac{r}{R}\right)^2\right]r^2 dr$
- $\frac{1}{\tau_{\eta}} = (l-1)(2l+1)\left[\int_0^R \rho r^{2l+2}dr\right]^{-1}\int_0^R \eta r^{2l}dr$
- $\frac{1}{\tau_{GW}} = \frac{32\pi G\Omega^{2l+2}}{c^{2l+3}}\frac{(l-1)^{2l}}{[(2l+1)!!]^2}\left(\frac{l+2}{l+1}\right)^{2l+1}\int_0^R \rho r^{2l+2}dr$

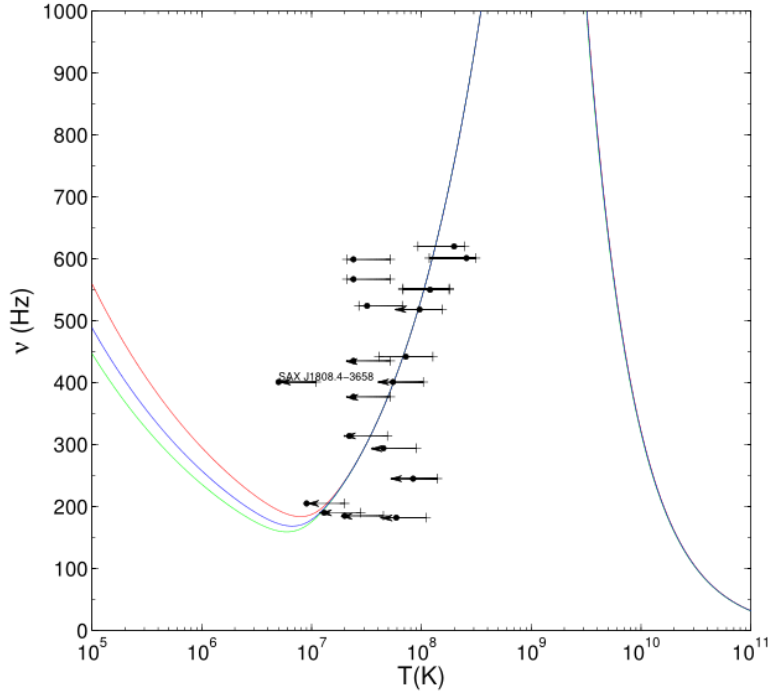
$$C_{\rm V}\frac{dT}{dt} = -L_{\nu} - L_{\gamma} + H,$$

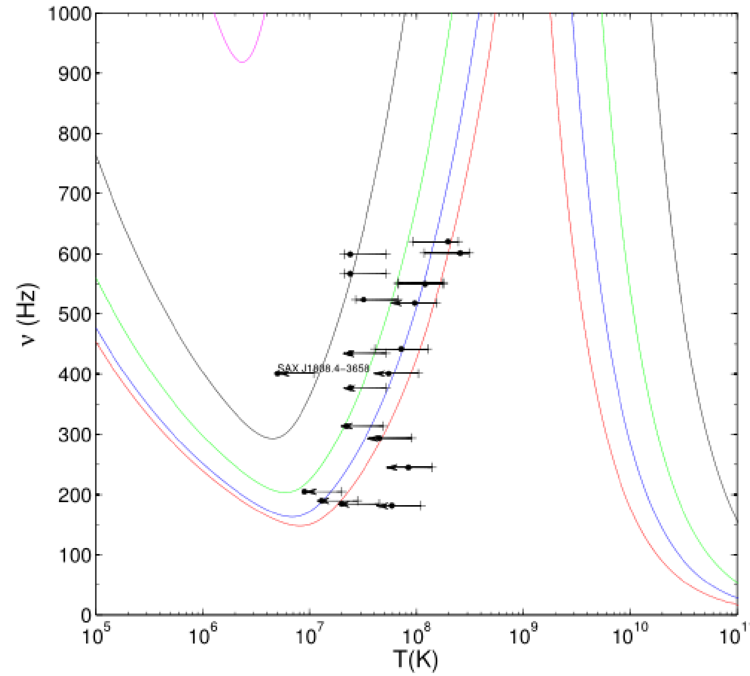
$$\frac{d\Omega}{dt} = -\frac{\Omega}{\tau_m} - \frac{2Q\alpha^2\Omega}{\tau_v},$$

$$\frac{d\alpha}{dt} = \alpha\left(\frac{1}{\tau_g} - \frac{1-\alpha^2 Q}{\tau_v} + \frac{1}{2\tau_m}\right)$$

- ✓ EOS
- ✓ Dissipation mechanisms
- ✓ R mode saturation amplitude α_{sat}
- ✓ Thermal evolution/Spin evolution

R-mode instability windows and EOS

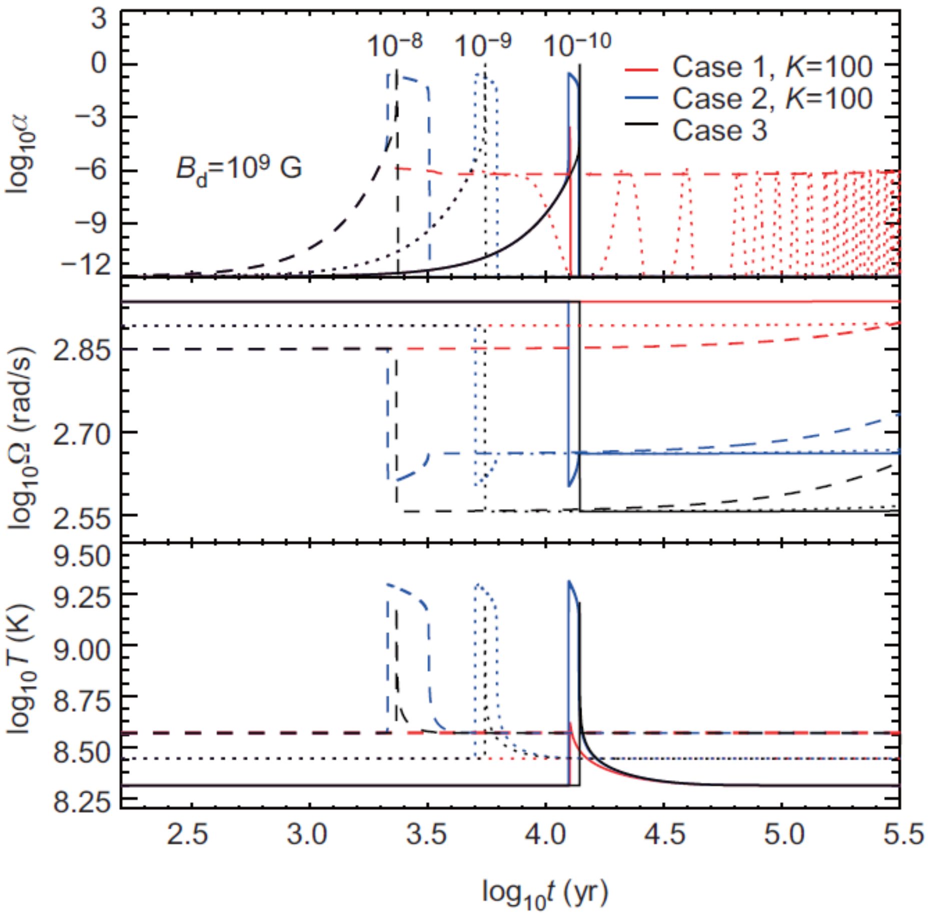


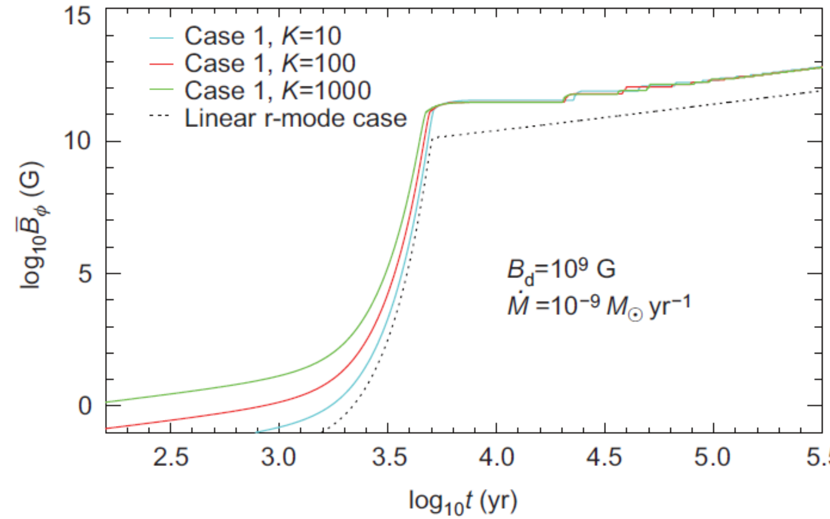


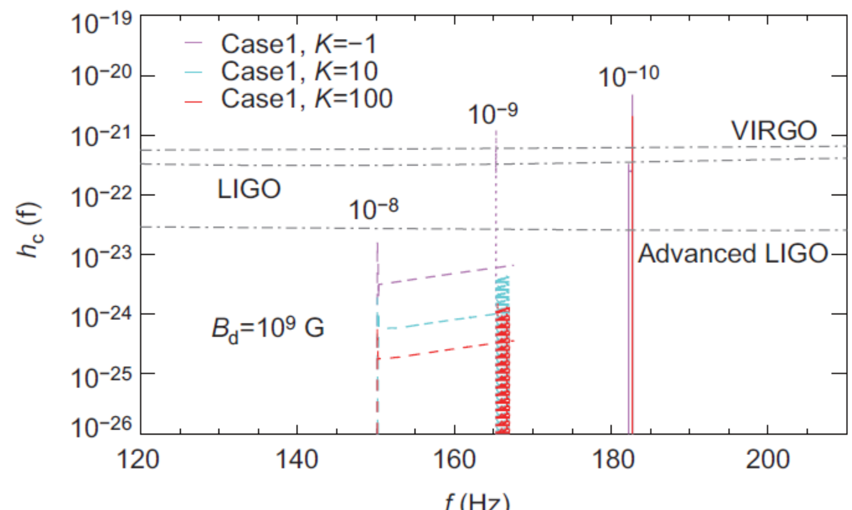
Wang et al. 2018, in preparation

- Constraints on interquark interaction parameters with GW170817 and two-solar-mass pulsar observations(Zhou et al. 2018, PRD)

R-mode instability and Dissipation mechanisms-magnetic damping

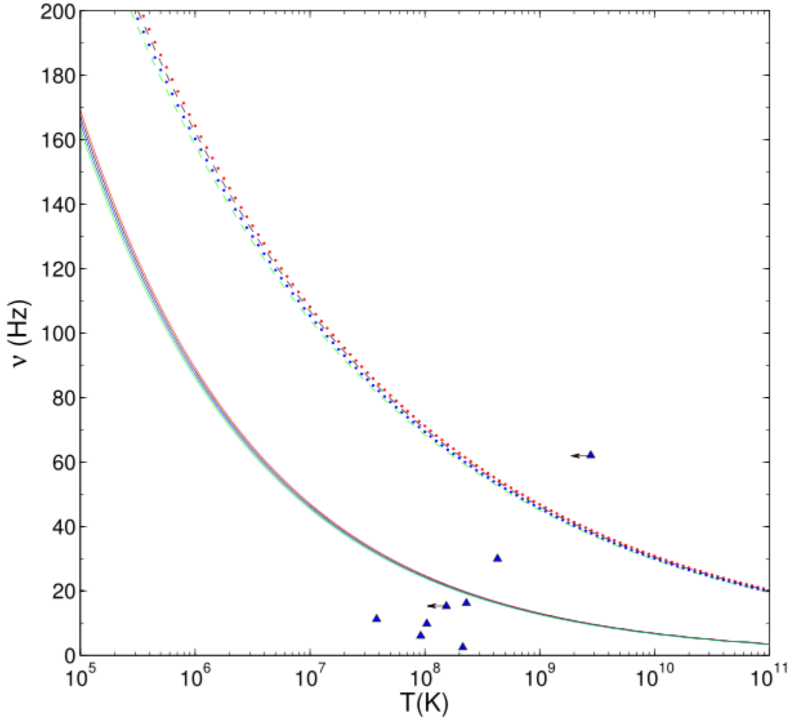


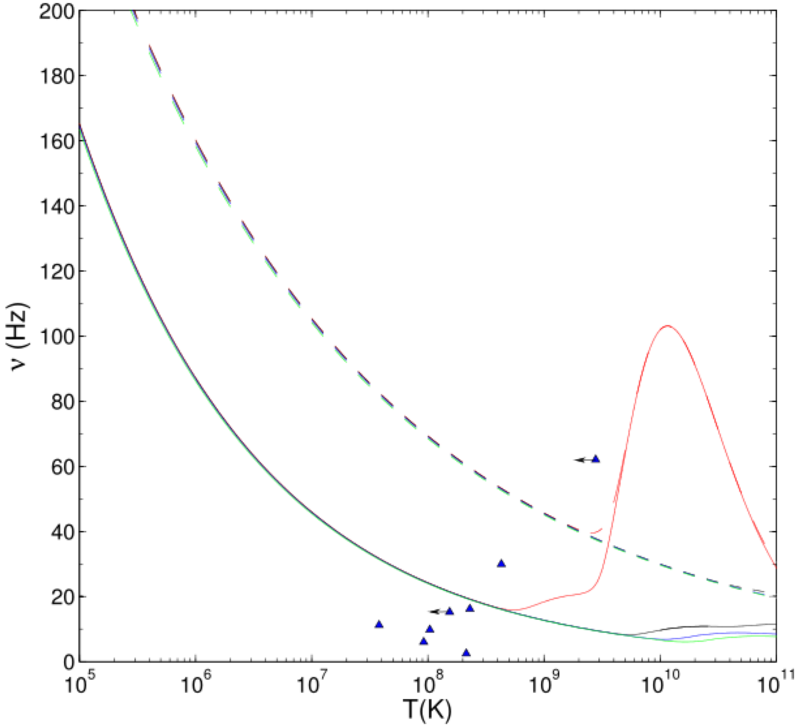




Cao et al.,2015,*Sci China-Phys Mech Astron*

R-mode instability and Dissipation mechanisms



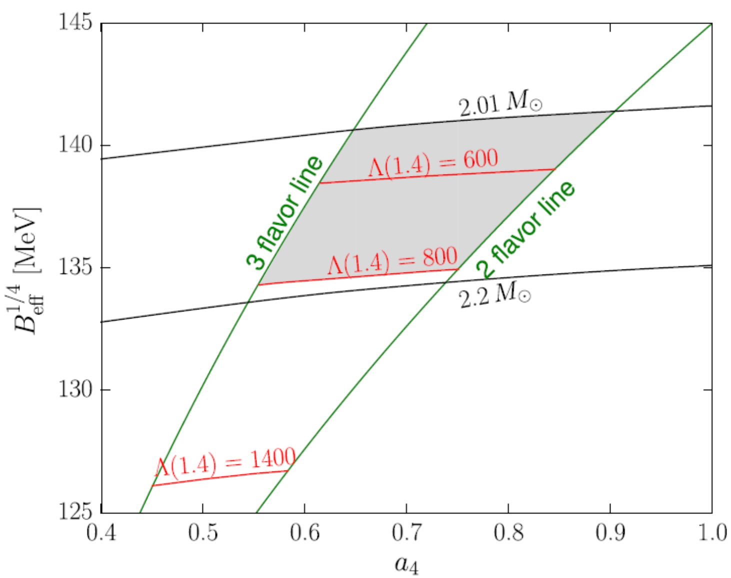


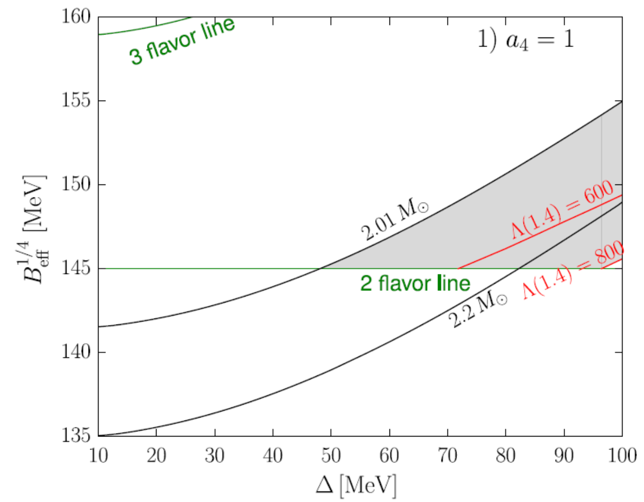
Surface rubbing and shear viscosity due to electron-electron scattering

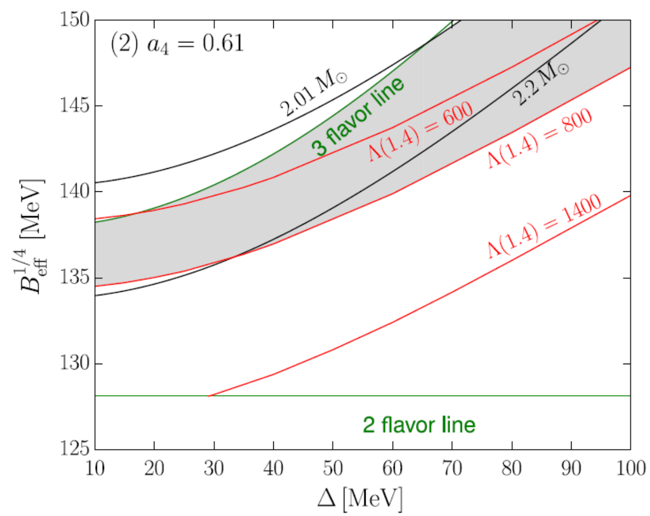
Wang et al. 2018, in preparation

Parameters of r-mode instability

- **Problem: model parameters** α_{sat} , Δ
- ✓ **Observation: constraint the parameters**



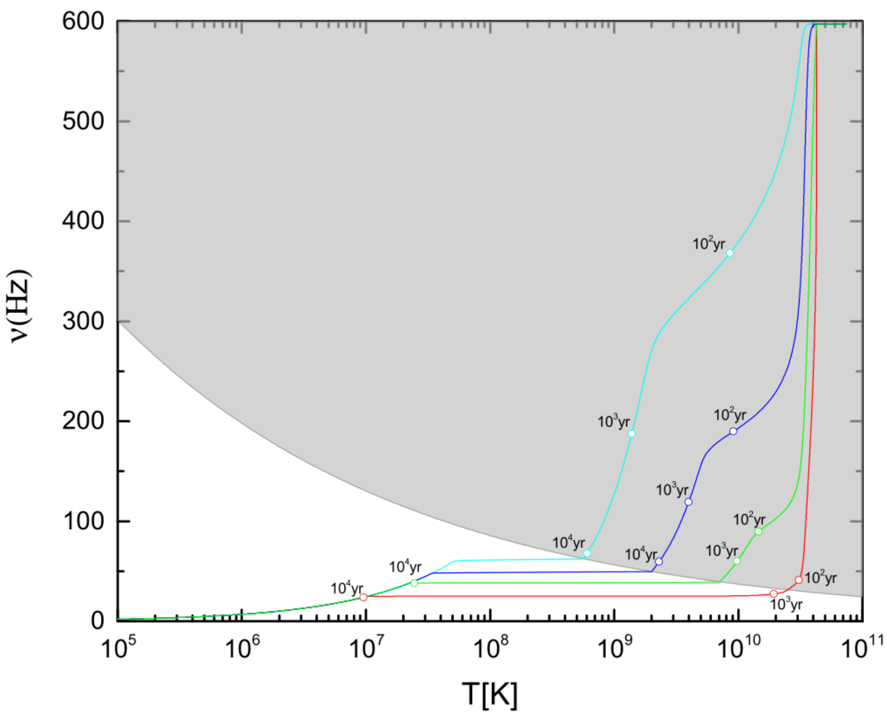


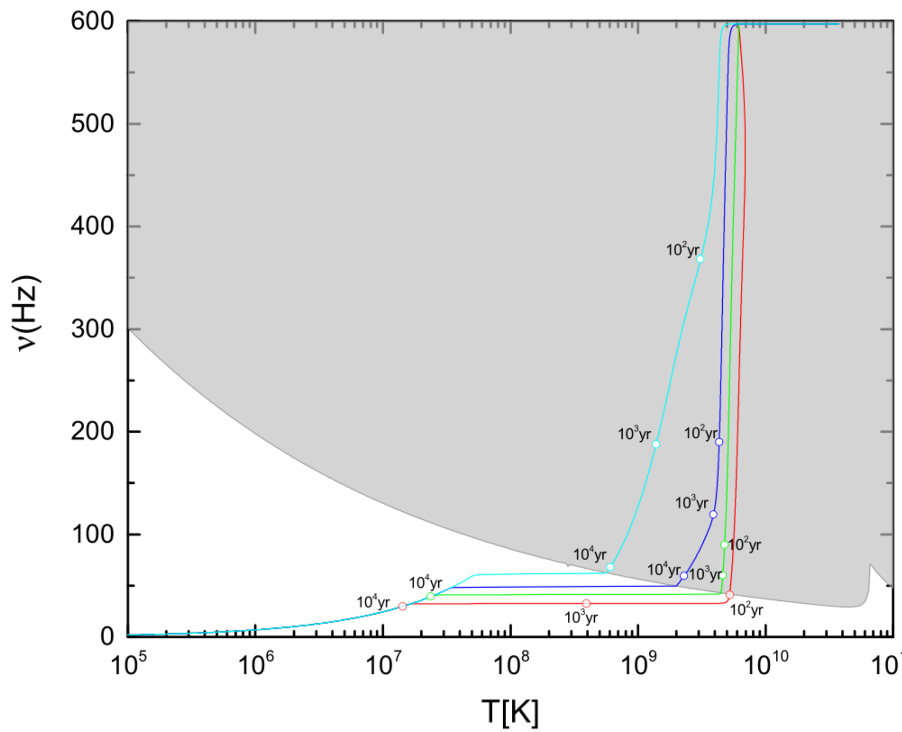


PSR J2215+5135 $M_1 = 2.27^{+0.17}_{-0.15}\, M_\odot$

Zhou et al.,2018, PRD

R mode saturation amplitude α_{sat}

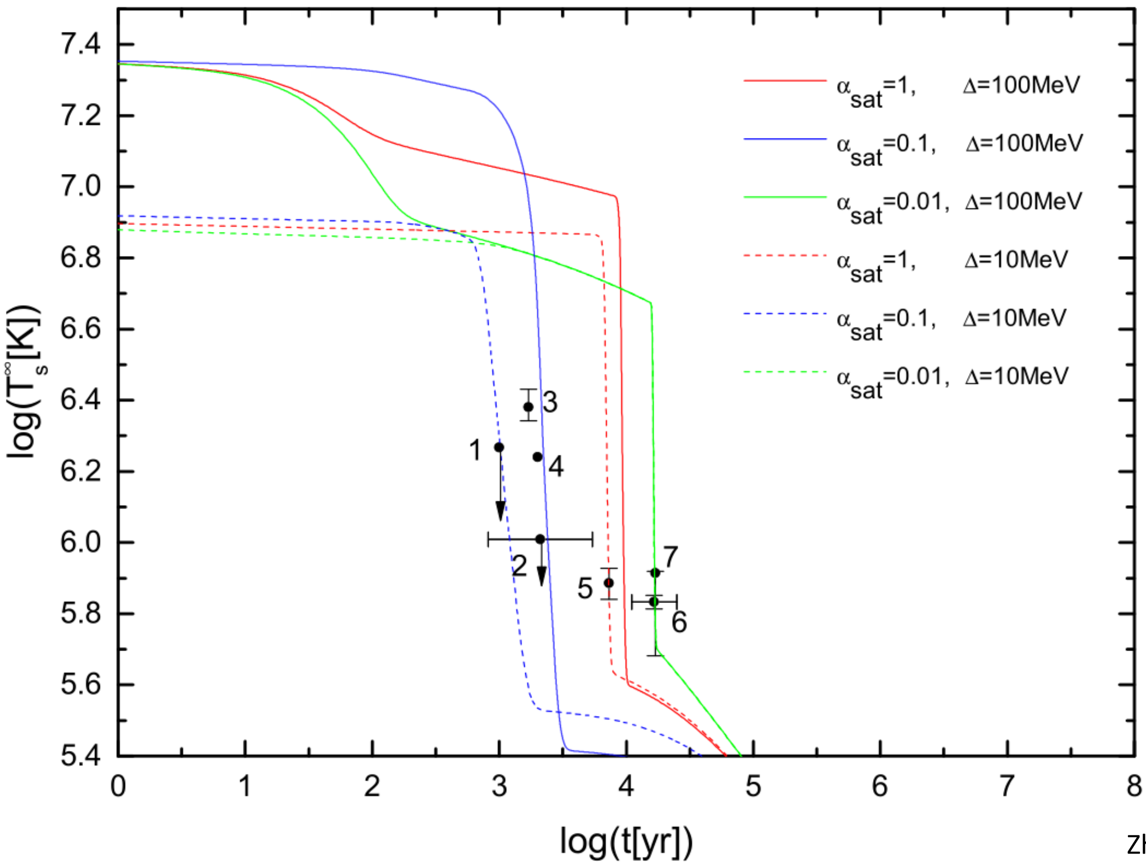




α_{sat}>0.01

Zhou et al. 2018, in preparation

R-mode instability and thermal evolution of young pulsars



Zhou et al. 2018, in preparation

Conclusion

- Using multiple observational data to constrain the model parameters in a reasonable regime
- A more realistic structure of compact stars
- N~7
- gravitational wave emission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