Mountains on neutron stars

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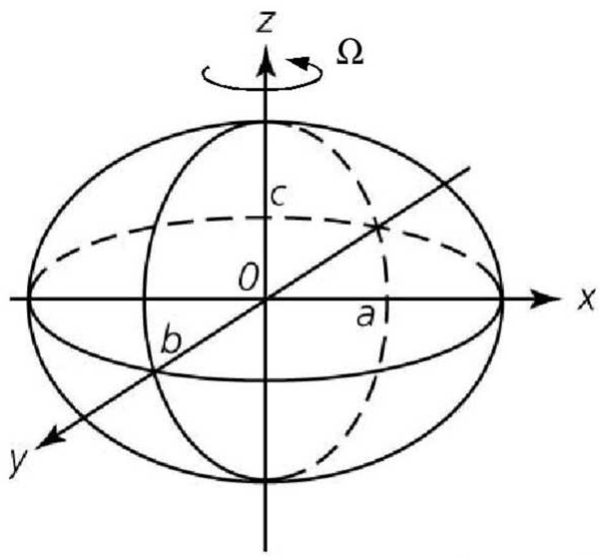
Gravitational waves

- A crustal asymmetry in a rotating neutron star can lead to a time varying quadrupole
- $I_0 = \frac{2}{5} M R^2$



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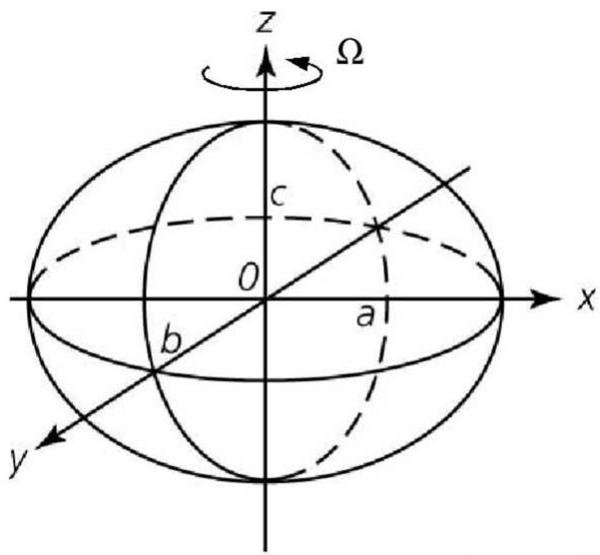

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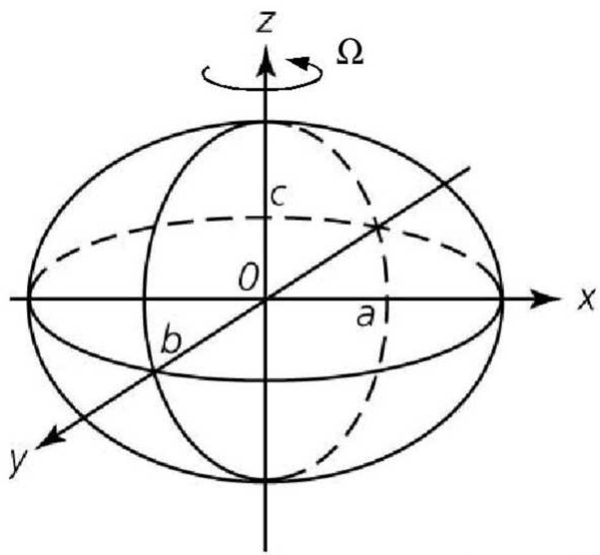
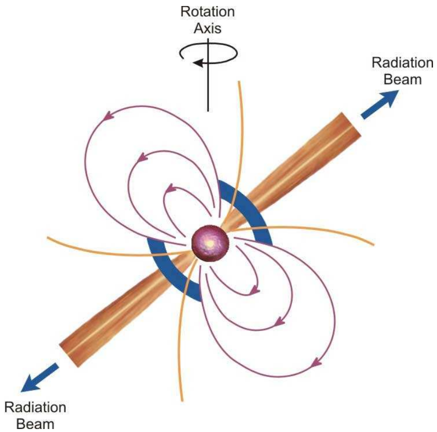
- $\epsilon = \frac{I_x - I_y}{I_0} = \frac{b-a}{2(a+b)}$
- $\frac{dE}{dt} \approx \frac{32G}{5c^5} \epsilon^2 I_0^2 \Omega^6$



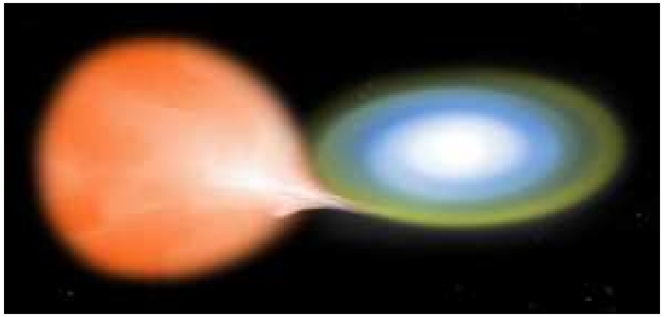
Astrophysical mountains

Isolated Pulsars



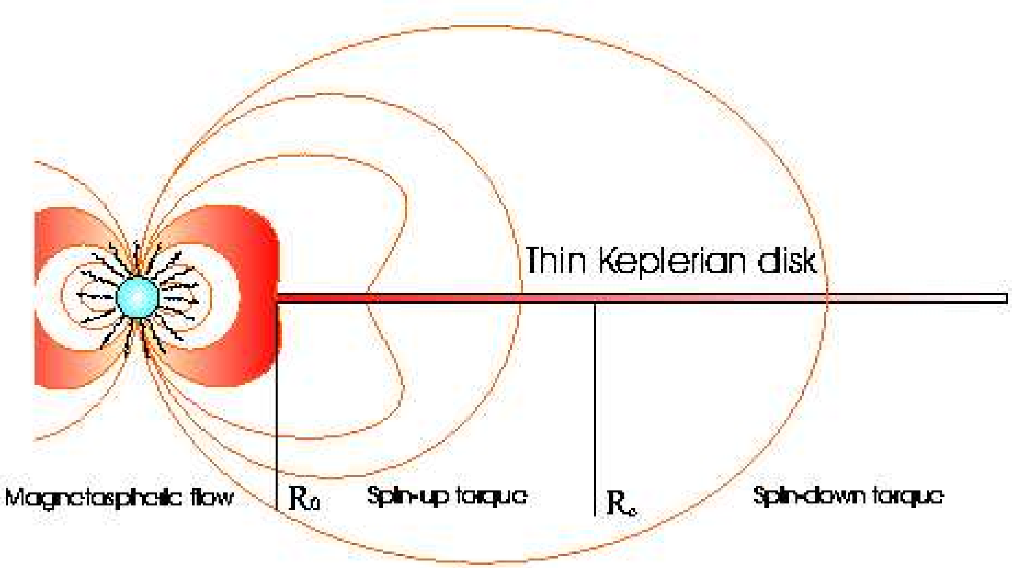
- assume spindown entirely due to GW
- $\dot{P}P^3 = -\frac{32G}{5c^5}\epsilon^2 I_0 (2\pi)^4$
- $\epsilon \approx 10^{-4}$ (Crab)

Accreting Systems



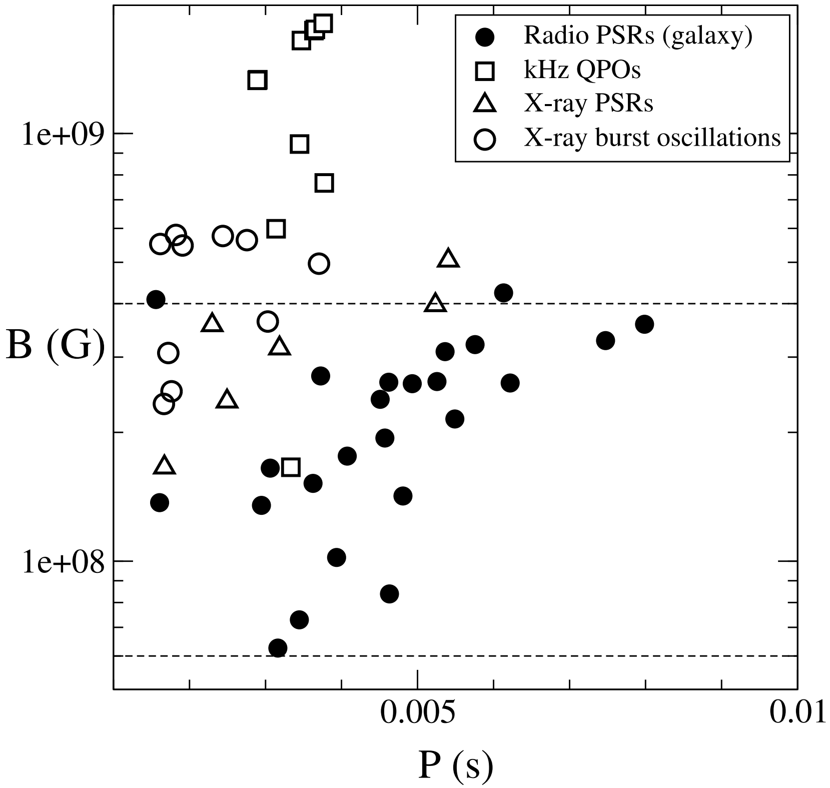
- assume accretion torque is balanced by GWs
- $\epsilon \approx 10^{-7}$
  for $\nu_e = 300$hz

Standard accretion model



- Interaction at magnetospheric radius R_0
- Spin up torque $\dot{J} = \dot{M}\sqrt{GMR_0}$

The case for gravitational waves



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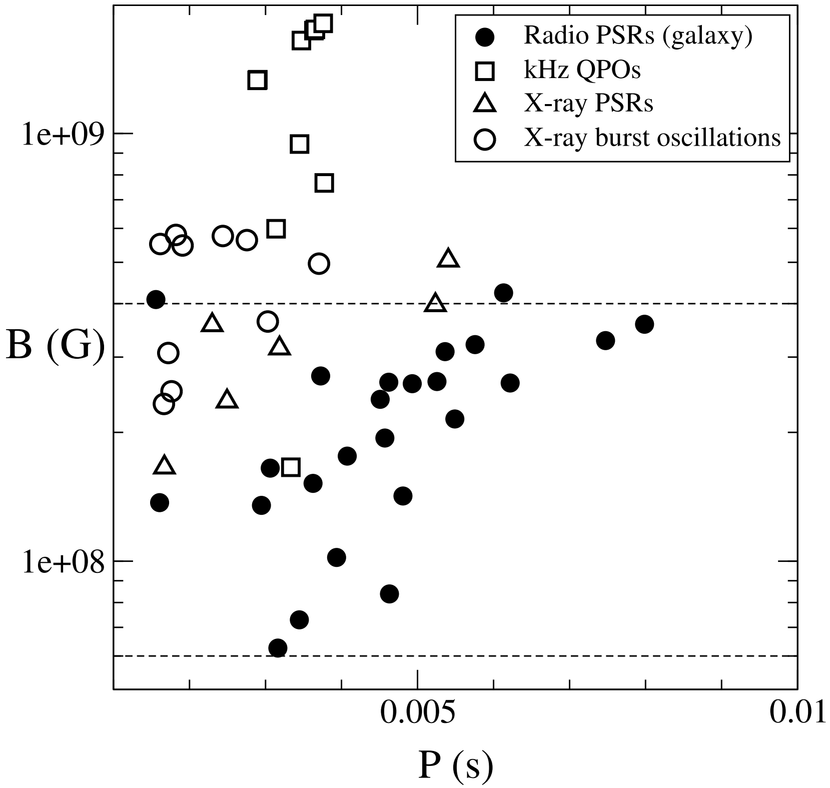

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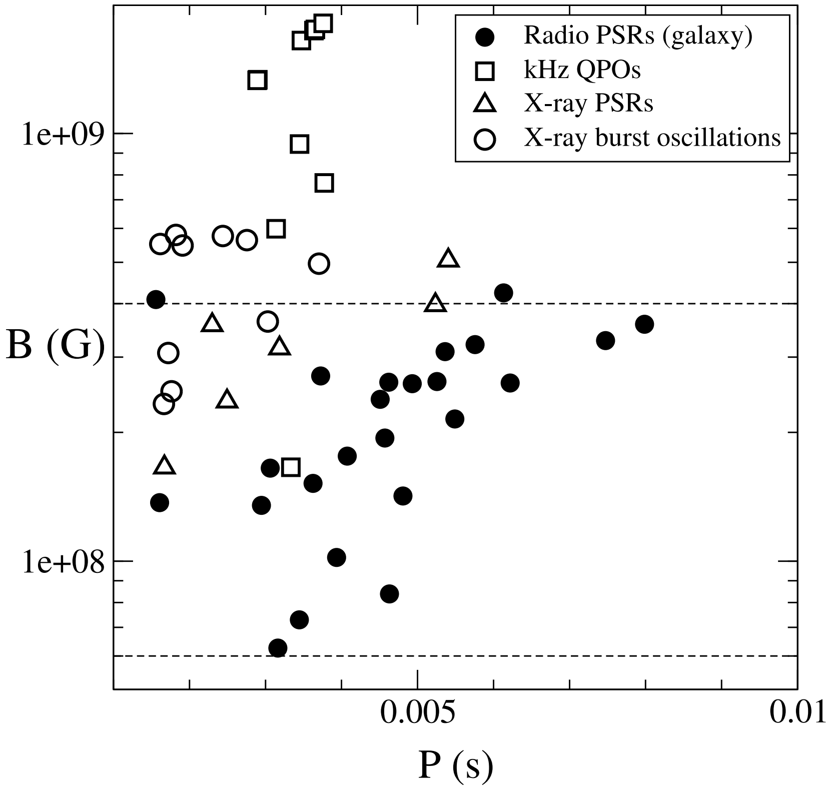

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- - crustal asymmetry
  - r-modes
  - magnetic mountains

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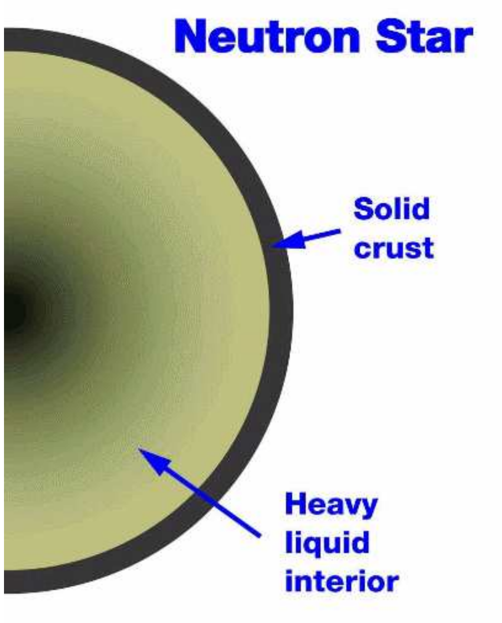
- Need to model the spin equilibrium and spin evolution to produce templates
- Need to understand what kind of “mountain” the crust can sustain

Maximum mountain

- Elastic matter in the crust



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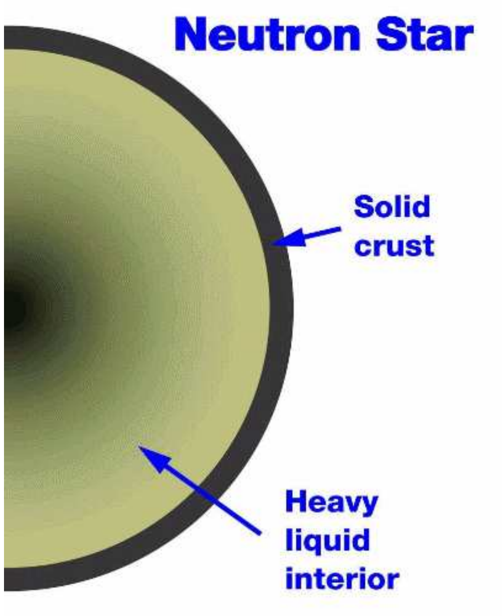

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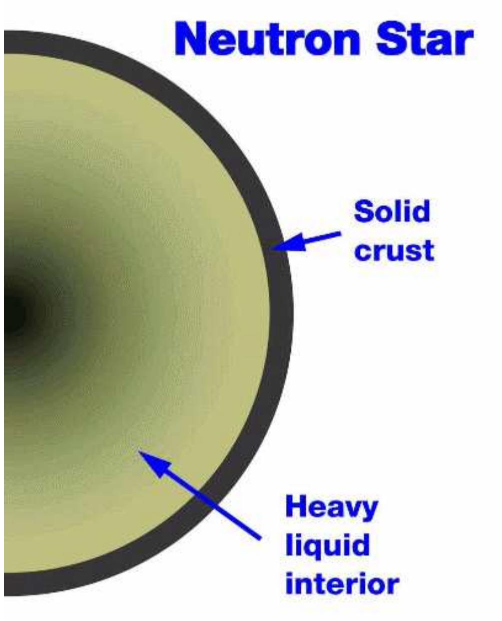

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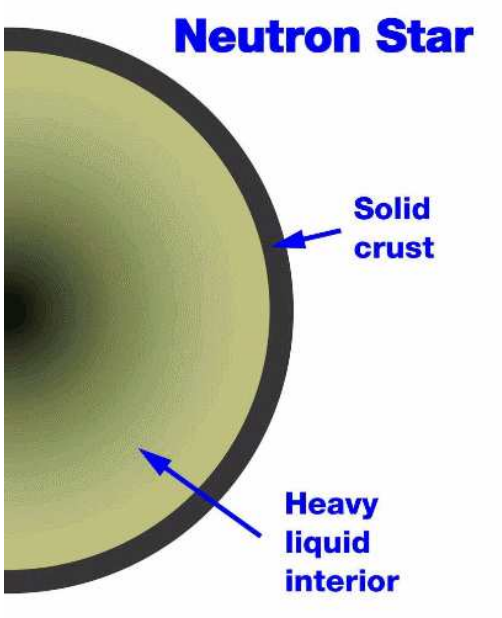

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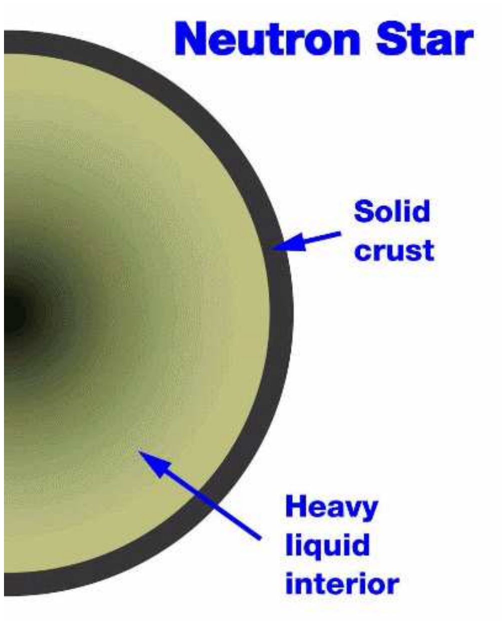

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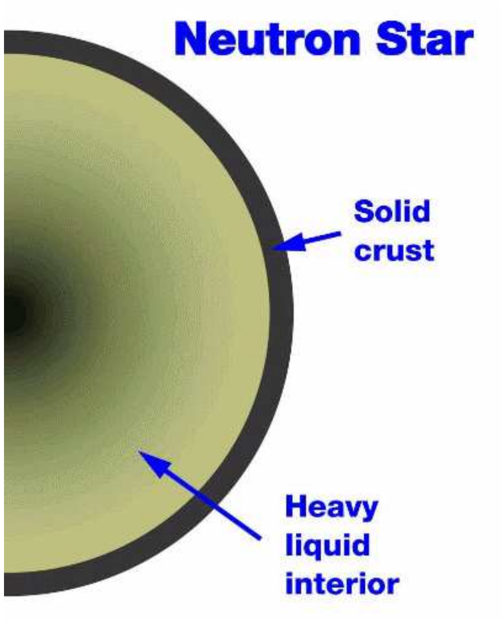

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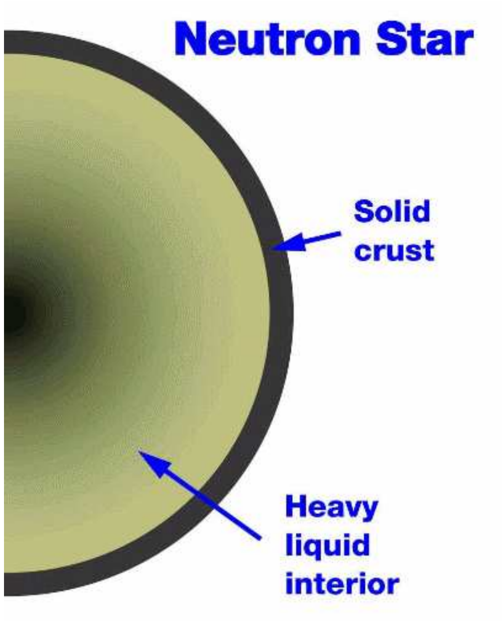

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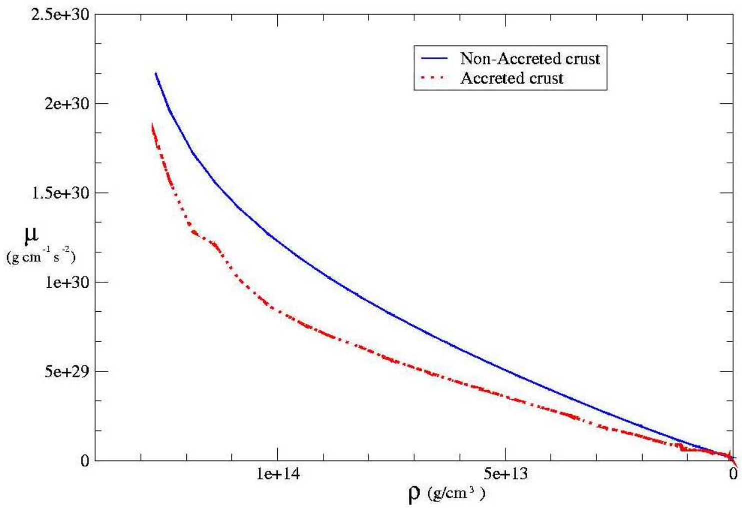
Accreted vs. non-accreted



- Composition determines EOS and shear modulus

$$\mu = 0.1194 \left(\frac{3}{4\pi}\right)^{1/3} \left(\frac{1 - X_n}{A} n_b\right)^{4/3} (Ze)^2$$

	Accreted crust	Non Accreted crust	Accreted crust
Mass	$1.4M_\odot$	$1.4M_\odot$	$1.6M_\odot$
Radius	12.56km	12.3km	12.3km
Crust Thickness	1.76km	1.5km	1.5km

Boundary Conditions

Two possibilities at the crust core interface:

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  Can use Newtonian core or Relativistic core
- Perturb the core
  -Continuity of the tractions
  -$t^a = T^{ab}\hat{n}_b$

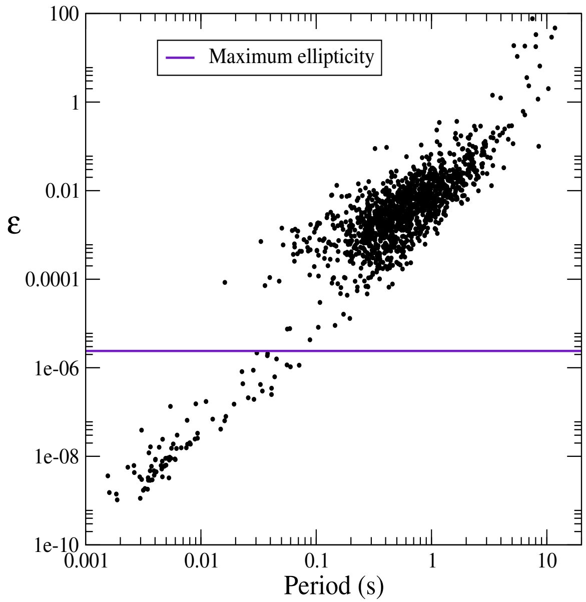
Maximum mountain

Is an accreted or a non-accreted crust stronger?

- $\epsilon = 2.4\ 10^{-6}$ Non-Accreted crust (Isolated Pulsar)
- $\epsilon = 1.3\ 10^{-6}$ Accreted crust (Accreting Neutron Star)

	M ($M_\odot$)	R (km)	crust thickness (km)
Accreted	1.4	12.56	1.76
Non-Accreted	1.4	12.3	1.5

Maximum mountain



$\epsilon \approx 10^{-6}$(theory)

GWs could balance accretion but:

- breaking strain poorly constrained ($\sigma_{max} \approx 10^{-5} - 10^{-2}$)

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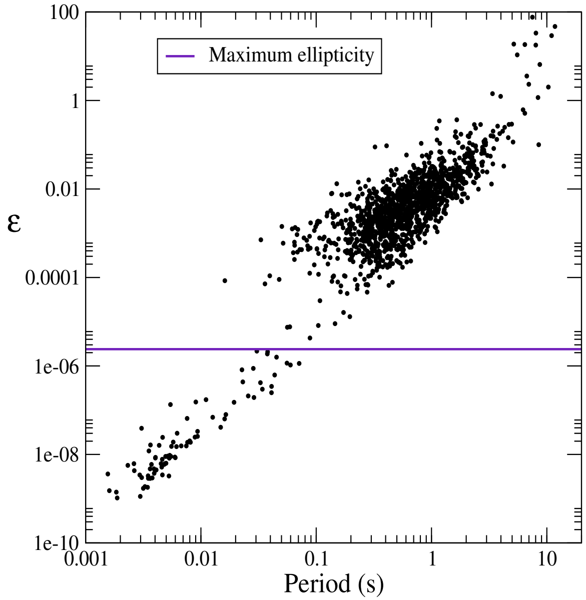

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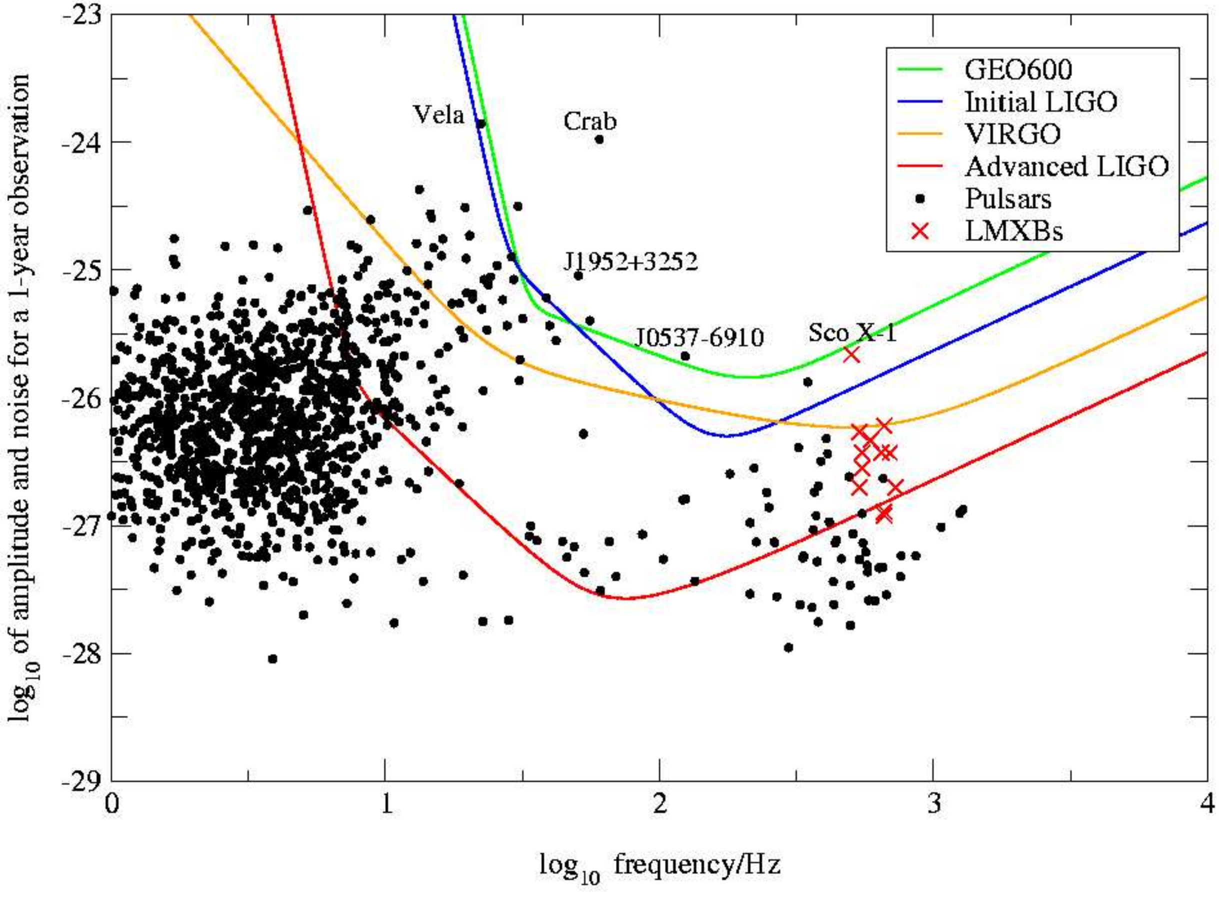
- accretion models can explain LMXB spin equilibrium without GWs

Detecting mountains with LIGO



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- Exotic states of matter..solid cores?
  A deformation of the core could be a strong source of GWs..
- Calculation in fully relativistic elasticity needed.
- Magnetic mountains
  $\epsilon \approx \frac{B^2 R^4}{G M^2} \approx 10^{-11}$ for B=10^{12}