NEUTRON STAR OSCILLATIONS FROM STARQUAKES

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Glitches

Sudden increase in the spin rate of pulsars

- Younger pulsars
  ($\sim 10^3 - 10^6$ years)

- Typical sizes:
  $\frac{\Delta \Omega}{\Omega} \sim 10^{-8}$ for Crab,
  $\frac{\Delta \Omega}{\Omega} \sim 10^{-6}$ for Vela

Glitch in Crab Pulsar: Espinoza et al. (2011)
Can make a naive estimate of emitted gravitational wave energy

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Then can assess detectability with

\[ h_{rss} = \frac{1}{r} \left[ \frac{20G \Delta E_{GW}}{c^3 \omega^2} \right]. \]
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**Crab:** find \( h_{rss} \sim 10^{-24} \text{ Hz}^{-1} \)

**Vela:** \( h_{rss} \sim 10^{-23} \text{ Hz}^{-1} \)

(compare Advanced LIGO: \( \sim 5 \times 10^{-23} \text{ Hz}^{-1} \) at 1kHz frequencies)
**STARQUAKES**

**A**

$\Omega_0$

Crust relaxed

**B**

$\Omega_{\text{critical}} (< \Omega_0 )$

Slows down, building up strain in crust...

**C**

Starquake!

Strain lost from crust

Out of equilibrium, oscillates

**D**

$\Omega_{\text{new}} (> \Omega_{\text{critical}} )$

New equilibrium, higher spin frequency

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Assumptions:
- Incompressible, completely solid
- Spins down completely before ‘glitching’
- Model glitch as sudden loss of strain
Which oscillation modes are excited by the glitch?

- Find initial data $\xi^{DC}$
- Find normal modes of Star D
- Project initial data against this basis of modes
We solve

\[
\rho \frac{dv_i}{dt} = -\nabla^i P - \rho \nabla^i \Phi + \mu \nabla^2 \xi_i,
\]

with the gravitational potential satisfying Poisson’s equation,

\[
\nabla^2 \Phi = 4\pi G \rho,
\]

and subject to the incompressibility condition

\[
\nabla_i \xi^i = 0.
\]
EXTENDING THE MODEL

Currently:
- Found initial data $\xi^{DC}$
- Can calculate normal modes of Star D

Extensions:
- Glitches at arbitrary rotation rate
- Elastic crust, fluid core