NEUTRON STAR OSCILLATIONS FROM STARQUAKES

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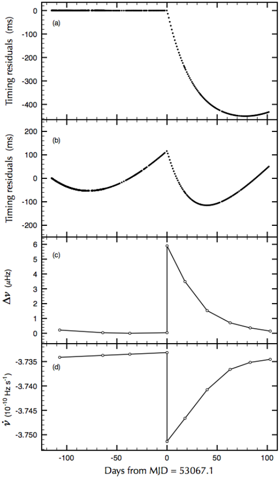
GLITCHES

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)

Energy estimates

Can make a naive estimate of emitted gravitational wave energy

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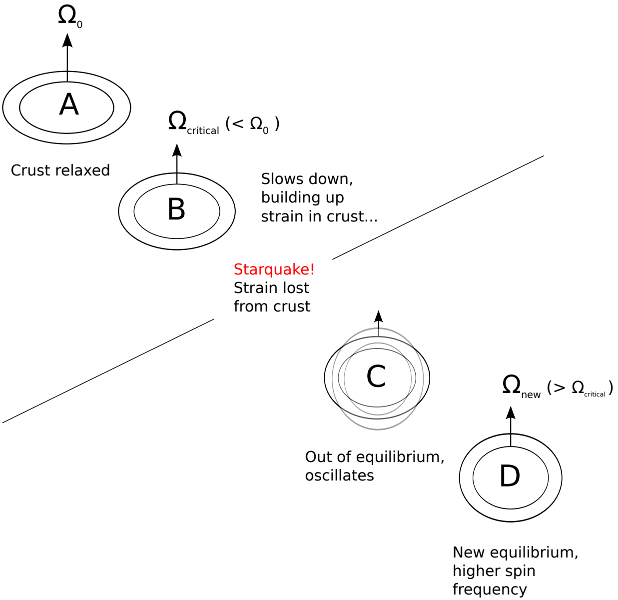
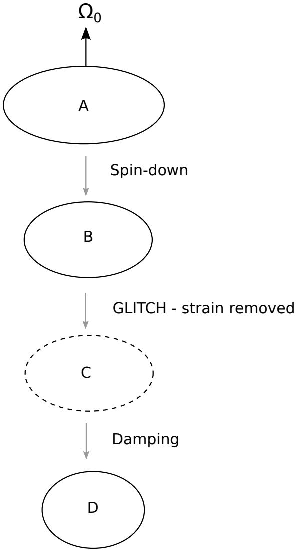
Crab: find $h_{\rm rss} \sim 10^{-24}$ Hz^{-1}
Vela: $h_{\rm rss} \sim 10^{-23}$ Hz^{-1}
(compare Advanced LIGO: $\sim 5 \times 10^{-23}$ Hz^{-1} at 1kHz frequencies)

Starquakes


Ω0
A
Crust relaxed
Ωcritical (< Ω0)
B
Slows down, building up strain in crust...
Starquake!
Strain lost from crust
C
Out of equilibrium, oscillates
Ωnew (> Ωcritical)
D
New equilibrium, higher spin frequency

TOY MODEL



Assumptions:

- Incompressible, completely solid
- Spins down completely before 'glitching'
- Model glitch as sudden loss of strain

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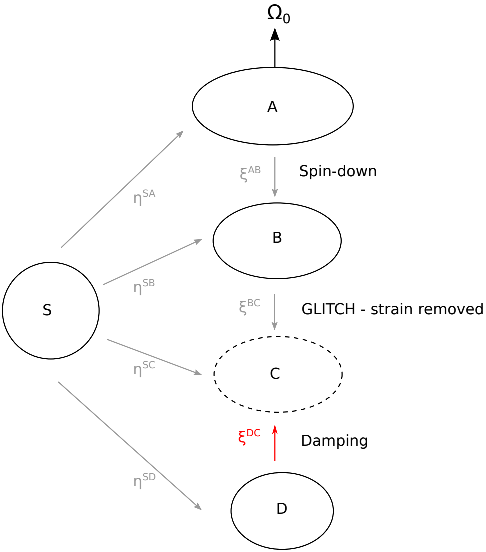

Which oscillation modes are excited by the glitch?

- Find initial data ξ^{DC}
- Find normal modes of Star D
- Project initial data against this basis of modes

EQUATIONS FOR THE MODEL

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 ξ^{DC}
- Can calculate normal modes of Star D

Extensions:

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