LIGO

The pulsar upper limits are already interesting!

Ben Owen

PENNSTATE 1855

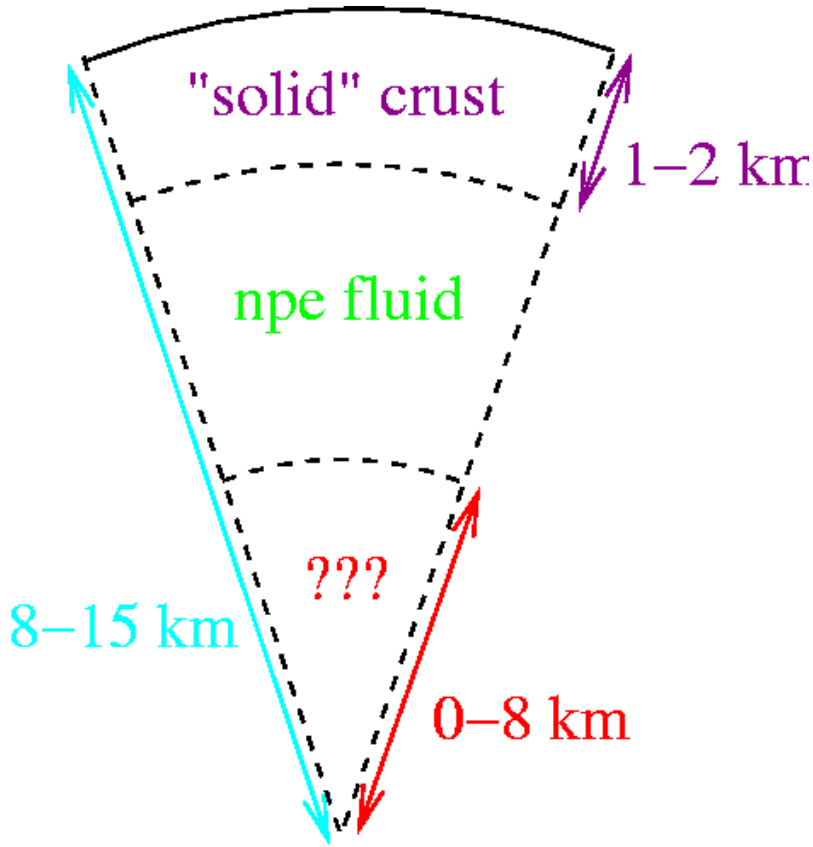
LIGO

How bumpy can neutron stars be?

- Ellipticity $\varepsilon = (I_{xx} - I_{yy})/I_{zz} \sim Q_{22}/I_{zz}$
- Elastic deformations
  - » Solid matter folded, spindled, and mutilated
  - » Max determined by breaking strain, shear modulus
  - » Traditional answer: ε_{max} ~ few x 10^{-7} (LIGO-S1 PRD 2004)
  - » New crazy answer: ε_{max} ~ few x 10^{-4} (Owen astro-ph/0503399)
  - » New not-so-crazy answer: $\varepsilon_{max} \sim 10^{-5}$ (Owen astro-ph/0503399)
- Hydromagnetic deformations
  - » Accreting matter (maybe not solid) bottled by magnetic field
  - » Max determined by field strength, matter conductivity (flow-thru)
  - » New answer: $\varepsilon_{max} \sim 10^{-5}$ (Melatos & Payne astro-ph/0503287)

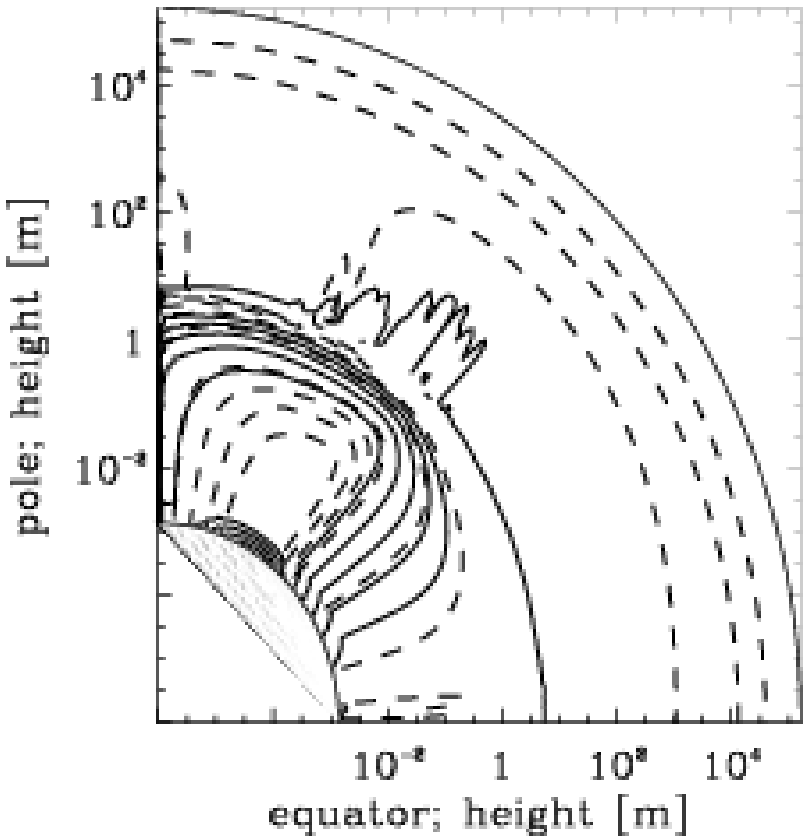
Elastic deformations

- Solid crust (all stars)
  - » Ushomirsky et al MNRAS (2000)
  - » Neutron-rich nuclei
  - » Conservative physics
- Solid core (hybrid star)
  - » Glendenning PRD (1992)
  - » Gradual phase transition
  - » (-) quark droplets in (+) baryonic background
  - » Up to 8km solid core
  - » Not-so-crazy physics
- All-solid (strange quark) star
  - » Xu ApJL (2003)
  - » s quark clustering
  - » Crazy physics



Hydromagnetic deformations

- Melatos & Phinney PASP (2000)
- Accreting ms pulsars only
- Accreted matter funnels towards magnetic pole
- Matter crosses field lines slowly (Ohmic diffusion)
- Depends on conductivity of matter at low density
- Field lines hold up mountain that would collapse under its own weight



Good news for searches

- S2 known pulsars
  - » 9 pulsars $\varepsilon <$ few x 10^{-4} (solid strange star) – mildly interesting
  - » (These have no competing spindown upper limit)
- S5 known pulsars
  - » (Extrapolating SRD sensitivity and 1yr integration time)
  - » 9 “original” pulsars $\varepsilon < 10^{-5}$ (hybrid star) – interesting!
  - » O(10) more have $\varepsilon < 10^{-5}$ and O(100) have $\varepsilon <$ few x 10^{-4}
- S5 all-sky
  - » Solid strange star ε_{max} visible in most of galaxy (beyond core)
  - » Hybrid star ε_{max} visible to few kpc (Gould belt, not galactic core)
- Detection: ε too big for normal star
- Many non-detections: render a model unlikely

Don’t party just yet…

- Many radio pulsars have $\varepsilon < 10^{-8}$ from spindown (probably even in globular clusters)
- How to get to ε_{max}?
- How to keep at ε_{max}?
- Stars with big ε don’t last long in the LIGO band
- Hydromagnetic: accreting millisecond pulsars in LMXBs have $\varepsilon \sim 10^{-7}$ from x-ray flux and torque balance; have we seen them all?

Conclusions

- Limits on $\varepsilon < 10^{-4}$ (S2) are already (mildly) interesting
- Limits on $\varepsilon < 10^{-5}$ (S5) get us to where we might detect something in a reasonable theory
- Enough non-detections will let us confront, though not rule out, some theories of dense matter