Waves from Waves

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Context/Motivation

Asteroseismology

Most stars oscillate, but only very compact stars are likely to lead to relevant GW signals.

Need to understand the dynamics of "neutron stars".

Plausible scenarios

- strongly asymmetric core collapse leading to pulsating remnant
- dynamical instabilities (bar-mode)
- secular (gravitational-wave/viscosity) instabilities

Focus on gravitational-wave driven instability of f/r-modes.

Issues

- Is an instability present?
- Can the unstable mode grow to large amplitude?
- How does the source evolve?
- Are "persistent" sources possible (eg in LMXB)?

Key question

Can we hope to use GW data to probe neutron star physics?

EU Network overview

Within EU funded Network the SOTON, SISSA, Thessaloniki, Meudon, Jena and Portsmouth groups collaborate on issues concerning GW instabilities.

Radiation reaction

Numerical implementation of backreaction, aimed at understanding how unstable modes affect "background" star.

- perturbative framework for long-term evolutions of fast spinning stars
- implement mass/current multipole radiation reaction (spectral method)
- nonlinear "perturbations without perturbations"

D.I. Jones, U. Sperhake, L. Villain, G. Faye, P. Papadopoulos

Differential rotation

Neutron stars are born differentially rotating. Radiation reaction may drive the star towards non-uniform rotation.

- onset of secular quadrupole f-mode instability for attainable spins
- need to deal with co-rotation points and understand continuous spectrum
- shearing instabilities?

A. Watts, S. Yoshida, L. Rezzolla

Rotating relativistic stars

Need relativistic models to study "realistic" equations of state, and also to model GWs beyond "the quadrupole formula".

- calculate inertial modes (do r-modes even exist?)
- formulate outgoing-wave boundary condition for fast spinning stars?
- perturbative time-evolutions

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Superfluid stars

Mature NS are likely to contain (several) superfluid components that may be weakly coupled. Models must allow for "independent" motion.

- rotating models allowing for different rotation rates and entrainment
- effect of entrainment on pulsation modes (avoided crossings)
- understand superfluid inertial modes

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Magnetic fields

NS have sizeable magnetic fields that may affect the fluid motion. Internal field configuration virtually unknown (core may be superconducting!).

- "Stokes drift" leads to winding up of poloidal field and generation of a sizeable toroidal component
- Ekman/Alfvén boundary layer

K. Glampedakis, L. Rezzolla

Phenomenology

Under what circumstances can the instability be astrophysically relevant? Are the associated GWs detectable?

- effect of r-mode instability on newly born and accreting NS
- exotic phases of matter: hyperons, deconfined quarks
- strange star behaviour may be radically different (Wagoner scenario works!)

D.I. Jones, K. Kokkotas, N. Stergioulas, J. Miller

Morale

To solve this problem we need to understand many extremes of physics.
Don't expect a reliable answer soon!
In fact, we are likely to need observations to help put constraints on theory!