

Abstract

Neutron stars are fantastic laboratories for fundamental physics. With densities in the interior exceeding nuclear saturation density, they allow to probe aspects of the strong interaction that cannot be studied in terrestrial laboratories. Furthermore at such high densities the Fermi energies of the constituents is much higher than the thermal energy, and this leads to neutrons being superfluid and protons superconducting.

It is well known from terrestrial studies that a superfluid rotates by forming an array of quantised vortices, and the movement of these vortices can create ‘avalanches’ in the interior of the neutron star, and lead to observable phenomena, such as pulsar glitches.

In this thesis the motion of vortices, and their avalanches will be considered in a hydrodynamical context. First a hydrodynamical model for vortex pileup and avalanche propagation will be presented, then it will be applied to large glitches in the Crab and Vela pulsars.

The hydrodynamical stability of the system will also be considered, by studying oscillations of the superfluid neutron star. It will be shown that there are modes that can grow unstable in the laminar regime, but are stabilised if turbulence develops.

After this, an analysis of non-linear mutual friction, also applicable to the turbulent case, will be presented, and the onset of turbulence in laboratory analogues of neutron stars will be discussed.