Contribution ID: **26**

Type: **not specified**

Modelling Superfluid Dynamics in Neutron Stars in 2D and 3D

Thursday 15 May 2025 10:45 (30 minutes)

Neutron stars are the collapsed cores of massive stars that have undergone a supernova explosion. They are the densest known astrophysical objects, with a mass typically 1.4 times that of the Sun compressed into a radius of approximately 10 km. Deep within the star, where the density exceeds the nuclear equilibrium density, neutrons become superfluid and protons become superconducting. As a result, the star's rotation and magnetic flux become are quantised into extremely thin vortices and fluxtubes respectively. These vortices pin to nuclear lattice sites or defects in the star's crust. When the star's rotation rate slows down, the vortices move outward to conserve angular momentum. At the same time, these vortices unpin and self-reorganise to release the stored angular momentum in catastrophic discrete events known as rotational glitches which are observed as an instantaneous increase in the observed rotation rate of pulsars. A complete theory of the micro and macroscale superfluid dynamics to explain this phenomenon does not yet exist and current theoretical models are hampered by an incomplete understanding of the interactions between superfluid vortices, fluxtubes and crustal nuclei. For this talk, I will be concentrating on some of our recent results in two-dimensionally modelling the vortex dynamics in a neutron-star using the point vortex model. The current focus of this work is to explore the behaviour of a lattice of vortices within a grid of pinning sites by statistically studying their collective unpinning behaviour as it undergoes linear spin down.

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