Project title: Magnetars with superfluid core

Funding agency:

Department of Science and Technology, SERB

Duration:

Total 36 Months, 12 months more

Summary:

Neutron stars are excellent candidates to probe the dense matter. In the conventional picture, the extremely dense neutron star interior is mainly composed of neutrons, with a small amount of protons and electrons in beta equilibrium. It is also generally believed that the matter inside neutron stars is in superfluid phase owing to the Cooper pair formation by nucleons.

It is theoretically conjectured that neutron stars are associated with very strong magnetic fields ranging from 10^8 to 10^{16} G. Neutron stars with ultra-strong magnetic field strength exceeding 10^{13} G are categorized as special group, popularly known as magnetar. Anomalous X-ray pulsars and soft gamma-ray repeaters are classes of candidates identified as magnetars.

From the existing studies, it has been noticed that most of the researchers assume a priori that the magnetic field does not influence the superconductivity of protons, with the exception of several recent studies. However, if the fields are strong enough the cores of the flux tubes come into contact and the superconductivity is destroyed. In one of our recent studies the upper critical field for proton superconductivity inside neutron stars has been estimated within the Ginzburg-Landau theory including entrainment between proton and neutron condensates. Constructing models of neutron stars for realistic nucleonic equation of state, the volume occupied by the superconducting region has been derived from the microscopic calculations of proton pairing gap in dense matter. It has been observed that magnetars with surface field $B \geq 10^{15}$ G are either partially or completely non-superconducting, precise nature being dependent on the relation between the surface dipolar field and the field intensity at the crust-core boundary.

The quenching of proton superconductivity demands extensive theoretical studies of the interior configuration and composition of neutron stars. The problem is very important since the presence

(absence) of superfluid components has a strong impact on neutron star interior dynamics as well as many microscopic processes which might manifest in cooling, (anti-)glitch, postglitch relaxation, precession of neutron stars.

Consequently, the broad objective of this proposal is to find the implications of quenched superconducting phase inside the magnetized neutron stars on its dynamical properties and their consequences on the observed magnetar properties.

Key Words:

Compact objects – Neutron stars – Magnetars – Superconductivity – Cooling – Rotational Dynamics

Objective in Bullets:

- To study the neutrino cooling of magnetars with superfluid core
- To study the rotational dynamics of magnetars with quenched proton superconductivity
- To link the result with the observed properties of neutron stars: (anti)glitch, quasi periodic oscillation etcetera.

Outcome and Output:

The composition and equation of state of dense matter inside the neutron star is yet an interesting subject in view of the recent observations, mainly the observed neutron stars with mass close to 2 M_{sun} and rapid cooling of Cassiopea A. Such kind of matter cannot be obtained in our laboratory. So only way to study such highly dense matter is to relate the theoretical results with the observations of compact objects. Reach fields in this context are cooling, (anti)glitch of magnetar with/without superfluid matter inside compact objects. From this point of view the study mentioned in this project will enrich the theory of composition and interaction of highly dense matter which will be helpful to understand certain astrophysical observations. Briefly it will shed light on

1. Composition and EoS of highly dense matter
2. Presence or absence of superfluidity inside compact objects
3. The nucleon paring interactions
4. Effect of ultra-strong surface magnetic field on the interior of compact objects composition as well as other internal configuration such as rotational dynamics etc. from the comparison of theoretically obtained result with the current observations.