

Simulating the Structure and Stability of Relativistic Neutron Stars

The groundbreaking detections of gravitational waves from neutron star mergers have underscored the significance of constructing and analyzing relativistic neutron star models to better understand the dynamics of extreme astrophysical phenomena. This project involves the study of the stability properties of such stars in general relativity, with the following sections in mind

1. Derive the TOV (Tolman-Oppenheimer-Volkoff) equations of static neutron stars. This will be followed by using linear perturbation theory to derive the oscillation equation governing radial vibrations of neutron stars.
2. Numerically solve the oscillation equation (which is of Sturm Liouville type) and producing the first few eigenfrequencies for a range of neutron star models.
3. Lastly the project will consider why these eigenfrequencies and associated eigenfunctions are useful in Relativistic Hydrodynamic applications.

The student must be proficient in writing code (in any programming language of choice). Some comfort with differential equations and numerical methods is helpful. Overall, this project is best suited for students who like applied maths/ODEs, eigenvalue problems, and turning physics into a clean computational pipeline.

Some references:

1. S. Chandrasekhar. Dynamical Instability of Gaseous Masses Approaching the Schwarzschild Limit in General Relativity. *Phys. Rev. Lett.*, 12:114–116, 1964. doi:10.1103/PhysRevLett.12.114.
2. J. M. Bardeen, K. S. Thorne, and D. W. Meltzer. A catalogue of methods for studying the normal modes of radial pulsation of general-relativistic stellar models. *Astrophys. J.*, 145:505–513, 1966. doi:10.1086/148791.
3. K. Kokkotas and J. Ruoff. Radial oscillations of relativistic stars. *Astron. Astrophys.*, 366:565, 2001 arXiv:gr-qc/0011093, [gr-qc].