Review of ‘Observables of spheroidal magnetized Strange Stars’

Summary

Background

In general, we have a pretty good understanding of Main Sequence Stars and a description of their state and evolution through most of their lives. However, we are lacking a great descriptions for the extreme end events of Neutron Stars. Neutron Stars are the leftover core of a star after it experiences stellar collapse.

Being able to describe these types of stars brings us closer to understanding more about the climatic end and transition of main sequence stars as they collapse and then explode outward, ejecting material and light at vast high energies. These novae mark the end of the star and reveal the legacy of the progenitor (star):

- a slowly expanding cloud of hot gasses (Nebula),
- a small but compact and cool core (Neutron Star),
- or an empty void that curves spacetime (Black Hole)

ELI5

We have a good understanding of the overview for the life of a star: it’s birth and formation, it’s life as it burns hotter and cooler, and it’s climatic and cataclysmic end. When a star reaches the end of its life, it starts with an explosion of glorious bright light that causes what we see of the star in our night sky to shine brighter than any other star we can see.

Three fascinating things can happen next:

1. If the star wasn’t much bigger than our Sun, the stuff that made up the star drifts apart through space, slowly expanding and eventually creating beautiful clouds we can see with our telescopes. One of the most common and astounding examples of these *star-stuff clouds* are known as the Pillars of Creation.
2. If the star is a little bigger than our Sun, the star-stuff still drifts away and forms the beautiful clouds; but a smaller star is left behind. This smaller star is different from one the that created it because it consists solely of a single type of universal building block: neutrons. Neutron stars are almost a contradiction: they incredibly heavy but very small (compared to the original star) and the source of a vast amount of energy but very cold.
3. Finally, if the star is much bigger than our Sun, a Neutron star is still created, but it is so heavy that this time, it collapses under its own weight and creates an object we call a Black Hole. The Black Hole has a force of gravity so strong, that light can’t even escape its surface.

Why do we care about 'Strange Stars'?

Strange Stars are a sub-classification on Neutron Stars. Under the extreme pressures and intensities that exist inside Neutron Stars, we suppose that the core consists not of subatomic particles, but Strange Matter (SM or SQM for 'Strange Quark Matter'): quarks that come from the decomposed hadronic matter (neutrons). The study of quarks are of great interest in our path to understanding the minute building blocks that combine in masses to create the grand structures of life and the properties of our Universe.

The study of Neutron Stars has renewed with increased interest over the past decade, as another sub-classification has promisingly offered an alternative (and concurrent) method of visualizing and recording Gravitational Waves: Pulsars. A prime example of this research can be seen by NANOGrav's work with the Pulsar Timing Array, which has a local presence at Oregon State University through the work done by Dr. Xavier Siemens.

What's so interesting about this paper?

The authors of this paper make tremendous effort forward in deriving Equations of State (EoS) for these Strange Stars (SSs). What is notable about this physical system is that there are no solutions that provide the EoS for these SSs: either using exact calculations or perturbation theory in Quantum Chromodynamics.

Previous attempts to derive equations of state for magnetized Strange Stars arrive at two independent pressure equations. The independence of these equations prevent a coherent description of the macroscopic star and are highly dependent on the model.

This attempt uses the same concept as a launching point but derives a variation similar to the Tolman-Oppenhimer-Volkoff (TOV) equations by starting with an axially symmetric metric in spherical coordinates. These equations combine coherently to accurately describe observed properties of highly magnetized Neutron stars.

While these results are promising, they are not the end; they only offer a promising path forward, as the equations are still very model dependent.

The Physics of this Paper

There are four major topics of Physics present in this paper:

1. Thermodynamics (and Statisical Mechanics)
2. Quantum Mechanics
3. General Relativity
4. Nuclear Physics

Astrophyics

- https://en.wikipedia.org/wiki/Nova
  - https://en.wikipedia.org/wiki/Supernova

Nuclear Physics

- We're talking about a star that is made up of decomposed subatomic particles
  - quarks make up the subatomic particles
  - cores of SSs are proposed to be comprised of quarks
- https://en.wikipedia.org/wiki/Quark

Thermodynamics: Macroscopic and Microscopic

- (Stable) Stars need to be in stellar equilibrium: if they are not, they will evolve to reach what will be the new equilibrium.
  - this is what describes stellar evolution
- Equations of State let us discuss how changes of properties change the rest of the system
- We need Statisical Mechanics to describe the Microscopic contributions to the two separate pressure differentials.

Quantum Mechanics

- We describe (and limit) the energy of the quarks by using a model similar to *particle in a box*
  - MIT-Bag Model
  - quasi-free particles but with binding energy
- https://en.wikipedia.org/wiki/Quantum_chromodynamics

General Relativity

- Need a metric that describes the physical situation more than the idealization
- Axial symmetry, not spherical