I-Eccentricity-Q relation as the universal relation for rotating magnetized white dwarfs

DR. SOMNATH MUKHOPADHYAY
National Institute of Technology Tiruchirappalli, Tamil Nadu -620015.

XXIV DAE-BRNS HIGH ENERGY PHYSICS SYMPOSIUM 2020, NISER, ODISHA- 752050.
UNIVERSAL RELATIONS

• In classical physics, a Black hole is completely described by macroscopic classical parameters like Mass, Angular Momentum, Electric Charge etc. These parameters are independent of the microscopic degrees of freedom from which the black hole initially formed. Hence black holes have no hair.

• For a black hole the relations between its multipole moments depend only on the above mentioned macroscopic conserved parameters. Hence these relations are called Universal Relations.

• Recent studies have found that relations among certain multipole moments of rotating non-magnetized and magnetized neutron stars depend very weakly on the Equation of State (EOS) and hence are also universal. One of these is the I-Love-Q relation, where I is the Moment of Inertia, Love is the rotational love number and Q is the quadrupole moment.

• Recent investigations of the universality of the I-Love-Q relationship have also been performed for non-magnetized white dwarfs with degenerate electron gas EOS with and without electrostatic corrections. The universality has been achieved with good accuracy for various compositions of white dwarfs.

• In this work we study the universal relations of magnetized white dwarfs with Landau quantized degenerate electron gas in presence of Coulomb screening. We employ the magnetized relativistic Thomas-Fermi EOS. We consider four white dwarf compositions – $^4$He, $^{12}$C, $^{16}$O and $^{56}$Fe. We have also considered slowly rotating configurations in Newtonian Gravity.
\[ \ln I = -0.800188 + 0.412597 \ln \lambda \quad \ln Q = 1.55013 + 0.194545 \ln \lambda \quad \lambda = \frac{c^{10}}{G^4 M^5} \quad \bar{I} = \frac{c^4 I}{G^2 M^3} \quad \bar{Q} = \frac{c^2}{I^{(0)} \Omega^2} M^{(0)} \]
FIG. 19: Plots of logarithmic dimensionless moment of inertia with respect to logarithmic dimensionless quadrupole moment for different white dwarfs and different field strengths.

FIG. 22: Plots of normalized moment of inertia with respect to normalized quadrupole moment for different white dwarfs and different field strengths.
FIG. 21: Plots of normalized moment of inertia with respect to eccentricity for different white dwarfs and different field strengths.

FIG. 23: Plots of normalized quadrupole moment with respect to eccentricity for different white dwarfs and different field strengths.

\[
\text{Eccentricity} = \sqrt{1 - \left(\frac{\text{Polar radius}}{\text{Equatorial radius}}\right)^2}
\]
RESULTS AND DISCUSSIONS

- We find that sub- and super-Chandrasekhar magnetized white dwarfs with relativistic magnetized Thomas-Fermi EOS satisfy universality in the Moment of Inertia, Rotational Love number, Quadrupole Moment and Eccentricity to a fair degree of accuracy.

- The relative errors in the universality of the I-Eccentricity-Q relation is much less than that of I-Love-Q. Hence I-Eccentricity-Q can be regarded as a better universal relation than I-Love-Q for white dwarfs.

- The Iron-56 white dwarfs show slight deviations in both the I-Love-Q and I-Eccentricity-Q relationships. For the highest central magnetic field strength, the relative error ~1.5% for I-Love relation and ~3.5% for I-Q relation. This error reduces as the magnetic field strength reduces. The reason is due to the fact that larger the mass-number of the nucleus, larger is the Wigner-Seitz cell and hence larger is the trapped magnetic flux for the same magnetic field profile. Hence the effects of magnetic field energy and pressure can no longer be insignificant compared to the matter pressure. So we see the deviation in the trend.

Ref :
(ii) S. K. Roy et. al., PRD 100, 063008 (2019).
THANK YOU