XXIII Simposio Chileno de Física
Chile,22-24 noviembre 2022 Gravitación - Física del estado sólido - Física nuclear

Rotational deformation of neutron stars

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Introduction

Neutron stars are the densest objects in the universe after black holes, with densities surpassing that of atomic nuclei. Since 1969, astronomers have observed periodic fluctuations in different wavelengths, mainly radio and x-rays, which were called pulsars. The best explanation for these small objects in space with periods between 10^{-3} and 10^{1} seconds are rotating neutron stars. The timing of the pulses allows measuring their deceleration, also called spin-down, which is producing internal changes in the star. Also, in many pulsars, one observes sudden accelerations or spin-ups, also called glitches, which recover close to 1 % of the spin-down. The neutron star is composed of a solid crust of thickness ~ 1 km and a fluid interior with a radius close to 10 km, possibly containing superfluid neutrons. Two explanations for the spin-up event are discussed in the scientific literature. The first, given by Ruderman (1969) is the starquake, a sudden break of the crust due to the deformation produced by the spin-down. The second, given by Anderson & Itoh (1975), is the transfer of angular momentum from an internal superfluid to the rest of the star. In this work, I study the rotational deformation of neutron stars by spin down. This change in shape accumulates enough stress to break the crust and allows us to estimate the size, waiting times, and energy released from glitches produced by these starquakes. I conclude that starquakes cannot account for the high observed glitch frequency, but it could explain the size of a big glitch. On the other hand the crust has enough elastic energy ($10^{46} erg$) to feed the energy released by transfer of angular momentum ($10^{35} erg$). The large breaking strain $\sigma = 0{,}1$ inferred from simulations demands a 10 % of internal deformation, which for variation in centrifugal forces (or potential forces) take long times, a little less than the characteristic age in order to break the crust. Also, this large breaking strain and the deformation by rotation sets the size and shape of the maximum mountain and quadrupolar deformation that can hold the crust. We discuss how this rotating mountain and ellipticity can produce continuous gravitational waves.

Acknowledge: Research supported by CONICYT y FONDECYT. I am tremendously grateful to Cristóbal Espinoza and Rafael Fuentes for useful discussions and data provided about pulsars and glitches.

References

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