ISSN: 2998-2766

Iris Online

Journal of Sciences

DOI: 10.33552/IOJS.2026.02.000531

Iris Publishers

Review Article

Cosmic Baby, Neutron Star and the Extreme Precision

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Received Date: July 25, 2026

Published Date: August 05, 2026

Introduction

Discovery of Cosmic Baby (i.e. Swift J1818.0 – 1607) opens a new window in the form of "triaxiality "towards understanding the secrets of the Universe. Superstrong magnetic field (B ~ 8 x 1017 G) and high-speed rotation (with period P ~ s) make the magnetar as a valuable source to study the extreme precision. The binary millisecond pulsars, i.e. the red back (RB) and the black widow (BW), offer a new probe to understand the physics of extreme precision. Comparison of the estimated ellipticities of "RB" and "BW" with that of atomic clock hints the value of extreme precision will be beyond the presently accepted value (i.e. Atomic Clock case 10^{-18} – 10^{-19})

Among the compact stellar objects Neutron Stars are the densest manifestations of massive compact objects in our Universe. So, the knowledge of neutron star properties is essential a probe of understanding the high-density behavior for the baryonic matter in the region of beta equilibrium. Not only that, the precise gravitational mass and radius measurements of neutron star offer the astronomers / scientists to find the stability of its deformed state (due strong magnetic field and high-speed rotation). In particular, the double neutron star system (DNS) all of them have masses > 2.5 $M_\odot$ and exhibit equatorial deformation (i.e. ellipticity ϵ) ranging from 10^{-18} – 10^{-21}[1].

Neutron stars have different forms among which the most popular forms are "Pulsars" (pulsating star) and "Magnetar". In general, pulsars have typically [2-3].

(a) spin period (P) ~ 14 MS to 8.5 s,

(b) surface magnetic field (B) ~ 10^8 to 10^{12} G for older millisecond pulsars which is reaching up to (B) ~ 10^{14} – 10^{15} G for younger, highly magnetized ones known as magnetars.

(c) ellipticity (ϵ) ~ 10^{-9} to 10^{-6} which is the deviation from a perfect sphere.

While magnetar have spin period (P) typically ranging from 2 to 12 s; surface magnetic field (B) ~ 10^{14} to 10^{15} G and ellipticity (ϵ) ~ 10^{-6} to 10^{-4} [4-5].

Regarding estimation of deformation i.e. ellipticity (ϵ) of a magnetar Pauri [6] considered the recently detected magnetar i.e. pulsar Swift J1818.0 – 1607 (so called "Cosmic Baby" [7]) and in a calculation he showed that this cosmic baby is a "Triaxial Star" with age ~ 240 years and having ellipticity ~ 8.9424 x 10^{-3} such that it will exhibit its triaxiality for the next ~ 760 years [8-9].

The origin of this deformability in the case of pulsars, magnetars arise from their birth phase i.e. at the early phase of neutron stars, pulsars, magnetars these objects suffer from deformation and continue to exhibit this triaxiality for a period of ~ 10^6 –10^7 years in the case of pulsars and for a period of ~ 10^3 – 10^4 years in the case of magnetars [10].

A new view of this deformability appears in the case of compact binaries having millisecond pulsars. What happens is that the companion stars are after strongly irradiated by the pulsars, even the effective center of light from their barycenter can be displaced by accretion, resulting which the measurements of mass become uncertain. For example, recent discoveries of two types binary millisecond pulsars system (i.e. the red back (RB) and the black widow (BW) binary MSPs) through a series of optical spectroscopic and photometric observations suggest that

i. the companion or the secondary stars are light weight (i.e. ~ 0.1 $M_\odot$ in the case of "red back") or ultra-light weight (i.e. ~ 0.01 $M_\odot$ in the case of "black widow").

ii. they are strongly irradiated by pulsar wind and high energy radiation powered by the neutron star's rotational energy loss.

iii. they provide "long sought" link between millisecond pulsars (MSRs) and the low mass x-ray binaries [11].

In this context it is to be noted that the follow up of the optical observations of gamma ray pulsars (i.e. pulsars-like sources) especially the eclipsing binary systems hints that there is also exist two types of populations but that are differentiated by the companion masses — (a) black widow (BW) pulsar systems which have very low mass degenerate companions ($0.02\ M_\odot < M < 0.05\ M_\odot$), and (b) red back pulsar systems that have slightly more massive companions ($0.2 < M < 0.04\ M_\odot$). The significance is that the companions of these two types of pulsars are "ablated "by the pulses that heats and strips material off of the companion's surface into the surrounding medium. In other words, the companions in BW systems are degenerate stars which are highly "ablated". while the red back (RB) systems tend to be non-degenerate resulting which are less "ablated" companions [12].

Considering a total of 21 detected RB, BW, and double neutron star systems, having companion mass > 2.5$M_\odot$ Parui [13] calculated the deformation i.e. ellipticity of these stars and found their exhibited equatorial deformation (ϵ) ranging from $10^{-18} - 10^{-21}$. By subdividing means the range ($10^{-18} - 10^{-19}$) supports the ellipticity which is for the Atomic Clock Precision values [14 – 17], while another subdivision ($10^{-20} - 10^{-21}$) favors the possible further extreme precision values beyond that of Atomic Clock case. This means that

(a) all the considered 21 detected double neutron star systems having companion masses > 2.5 $M_\odot$

(b) the ellipticities of all these double neutron star systems are within $10^{-18} - 10^{-21}$, implying that

(c) all these massive neutron stars exhibit extreme precision which may be within that of the Atomic Clock case (i.e. $10^{-18} - 10^{-19}$) or

(d) beyond the atomic clock case (i.e. $10^{-20} - 10^{-21}$).

In other words, it can be said that

(e) beyond the Atomic Clock case further extreme precision is possible.

(f) double neutron star systems are the potential sources for measuring the extreme precision parameters.

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Citation: Ramen Kumar Parui*, Cosmic Baby, Neutron Star and the Extreme Precision. Iris On Journ of Sci. 2(2): 2026. IOJS.MS.ID.000531.
DOI: 10.33552/IOJS.2026.02.000531