

A Remark on “Forcedly Precession Neutron Star FRB180916.J0158+65” as a New Type Fast Radio Burst (FRB) Emission Source-Possibly be a Triaxial Pulsar?

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Abstract: Motivated on the paper in *Forcedly precessing neutron star, FRB180916.J0158 + 65, and FRB121102 —MNRAS497, 1001 – 1007 (2020)* by Sob'yanin [1] an attempt has been made to search the nature of the neutron star in FRB180916.J0158+65. Using the observed parameters at the time of discovery I calculate the deformability (i.e. ellipticity ϵ) due to the effect of internal magnetic field 6×10^{14} G and 2×10^{14} G inferred from the period activity 16.35 days and 157 days, respectively for rotational period 1s and found $\epsilon = 6 \times 10^{-4}$ and $\epsilon = 2 \times 10^{-4}$ accordingly. Considering the proposed limiting magnetic field for minimal deformation of a neutron star i.e. internal magnetic field $< 10^{16}$ G, forcedly precession, deformation $< (1 - 2) \%$ for treating spherical symmetry regime, it is possible for FRB180916.J0158+65 to satisfy the above conditions. It is concluded that the neutron star in FRB180916.J0158 + 65 is a “triaxial pulsar” which is a new type FRB emission source beyond the conventional / popular sources.

Keywords: fast radio bursts- radio continuum: transients- stars: neutron – stars: magnetars

1. Introduction

Discovery of fast radio bursts (FRBs) by Lorimer et al. [2,3] in 2007 and since then more than 800 FRBs have been detected by different telescopes till date. But it is not clear to the astronomers/ scientists the exact physics of emission sources. Our present knowledge from theoretical studies and observational facts hint that the burst duration is ~ 1 ms, wide range of emitted isotropic energies $\sim 10^{35}$ to $\sim 10^{46}$ erg, typically exhibit strong linear polarization. Regarding FRB emission sources — highly magnetized and relativistic plasma are the potential FRB sources. Regarding mechanism of coherent radio emission magnetars are the most promising sources of FRB.

In a recent paper- “Periodic fast radio bursts from forcedly precessing neutron stars, anomalous torque, and internal magnetic field for FRB180916.J0158+65 and FRB121102”–MNRAS **497**, 1001 – 1007 (2020) D N Sob'yanin [1] analyzed the properties of CHIME detected a repeating fast radio burst source FRB180916.J0158+65 as:

- The possible origin of this FRB is a freely precessing neutron star in the form magnetar having magnetic field strength of $\sim 10^{16}$ G.
- Two radio telescopes *Swift* and AGILE simultaneously observed this FRB and detect “ no high energy emission”.
- Absence of high energy emission i.e. non-detection of electromagnetic radiation from this source implies a constraint on the magnitude of the magnetic field as well as on the nature of the progenitor.
- Consideration of a forced precession of a neutron star in this context favors to explain the above puzzle.
- Forced precession neutron star i.e. a neutron star is not deformed and as a result the anomalous moment of

electromagnetic forces (induced by stellar rotation) appear that finally offer a non-zero anomalous torque.

- Correlating the observed 16.35 day period to the period of stellar precession they found (i) the inferred internal magnetic field $\sim 6 \times 10^{14}$ G for rotational period of the neutron star = 1s while (ii) for another possible 157 day period of this FRB the internal magnetic field value is $\sim 2 \times 10^{14}$ G.
- This model supports the hypothesis of FRB origin from the precessing neutron star.

This means that the requirement for a precessing neutron star that has capability to be a FRB emission source (i.e. origin of FRB) when its deformation due to the effect magnetic field and self-rotation is almost “zero” (i.e. can be treated as non-deformed) under the situation of internal magnetic field of $\sim 10^{14}$ G or less, period of rotation is = 1 s.

Looking back into their birth, neutron stars are one of the possible end points or remnants of the supernovae explosions. Due to conservation of angular momentum and magnetic flux, the rotation frequencies and magnetic fields of these are exceptionally amplified during the collapse such that new born neutron star possess (as a regular pulsar form) period of rotation ≈ 1 s and surface magnetic field $B_{\text{surface}} \sim 10^{12}$ G. In the case of even more extreme than regular pulsars i.e. magnetars the surface magnetic field values $B_{\text{surface}} \sim 10^{13} - 10^{15}$ G.

A neutron star with its rotational period (P) = 1s and its internal magnetic field (B_{internal}) $\sim 10^{14}$ G will suffer a deformation that can be measured by ellipticity (ϵ). In a numerical study of the magnetized deformation of a neutron star Rizaldy and Suluksono (2018) found significant results which indicate that:

- a) Balance between the gravity and magnetic field is different for various directions in the case of small mass i.e. low mass neutron star than that of massive one.
- b) In fact, gravity pull of the magnetic field on the z axis is significantly more than for the other axes. As a result, an oblate shape appears in low mass neutron stars. In the case of massive neutron stars their oblateness i.e. oblate shape is very much less in comparison to that of less-massive one. So, one can say the internal toroidal magnetic field component is more effective than the poloidal field component. According to Rizaldy and Sulaksono [4] the deformation associated to the poloidal field (i.e. $B_{\text{poloidal}} \approx 10^{14}$ G and 10^{15} G) and the corresponding corrections in ellipticity (i. e. $\epsilon \sim 10^{-4}$ – 10^{-2} , respectively) are negligible [5].

The interior of neutron star contains different compositions such as nucleons, hyperons and quark matters. In a study of the effects of strong magnetic field on the equation of state of neutron star matter, using fully general relativistic formalism on the structure of neutron stars [6 – 8] Gomes et al [9] found :

- i) For magnetic field strength at the center $B_c \leq 10^{18}$ G the magnetic field effects on the equation of state (EoS) of baryons and quarks do not have a significant role on the macroscopic stellar structure.
- ii) For star with mass $< 1.5 M_{\odot}$, surface magnetic field $\sim 2 \times 10^{16}$ G and central magnetic field $\sim 3 \times 10^{16}$ G the effects cause a deformation $> (1 - 2)\%$ on the star.
- iii) For surface magnetic field $\sim 5 \times 10^{16}$ G and central magnetic field $\sim (2 - 4) \times 10^{17}$ G the deformation is same i.e. $(1 - 2)\%$ for all neutron star's masses but independent of model and composition of the star.
- iv) A special situation arises in the case of limiting magnetic field for minimal deformation i.e. the situation of neutron star under the effect of a poloidal magnetic field that determines the limiting magnetic field strength such that the deformation i.e. the ratio between the polar and equatorial radii does not exceed $(1 - 2)\%$ then the magnetic neutron star falls in the spherical symmetry regime (i.e. as if “no deformation” satisfactorily but practically deformed under the effect of magnetic field.

The present paper advocates this special situation applicable for searching the nature of the FRB emission source. In the case of FRB 180916.J0158+65 can be the persistent radio source (PRS), as suggested by Sab'yamin, provided the neutron star is forcedly precessing under the internal magnetic field $\sim 10^{14}$ G, rotation period = 1s, no deformation i.e. the realistic deformation within the limit $< (1 - 2)\%$.

Considering the internal magnetic fields (B_{internal}) $\sim 6 \times 10^{14}$ G and $\sim 2 \times 10^{14}$ G for activity period of 16.35 day and another one of 157 day and using the formula [10 – 12]

$$\text{ellipticity } (\epsilon) = 10^{-8} (B_{\text{internal}} / 10^{12} \text{ G}) \dots\dots (1)$$

where the ellipticity ϵ such that the amount of deformation is under the effect of internal magnetic field (B_{internal}),

I calculate the ellipticity and found $\epsilon = 6 \times 10^{-6}$ and 2×10^{-6} , respectively. The estimated deformation values i.e. ellipticity lies within the range of ellipticity $\sim 10^{-6}$ for

“triaxial pulsar” when a pulsar exhibits its triaxial nature [13].

As the internal magnetic field strength $\sim 6 \times 10^{14}$ G (i. e. $< 10^{16}$ G), the deformation will be less than that of $(1 - 2)\%$ in the case of neutron star having its internal magnetic field $\sim 10^{16}$ G. This means that neutron star in FRB180916.J0158+65 satisfies the required conditions i.e.

- a) Internal magnetic field strength (i.e. 6×10^{14} G) which is $< 10^{16}$ G;
- b) No deformation (i.e. less than $(1 - 2)\%$) as because $(1 - 2)\%$ deformation under internal magnetic field is considered as spherical symmetric;
- c) The value of ellipticity $\epsilon \sim 10^{-6}$ which is for a triaxial nature of pulsar, for being a “Triaxial Pulsar”.

This implies that the neutron star in FRB180916.J0158+65 is a triaxial pulsar.

2. Conclusion

It is proposed that the associated neutron star with FRB180916.J0158+65 is a “Triaxial Pulsar”. This is a new type FRB emission source (i.e. PRS) beyond the conventional / popular FRB source models.

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