



A New Compact Star—the "Triaxial Star"—and the Detection of a Cosmic Baby: A Possibility

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The "Triaxial Star" was first proposed by S. Chandrasekhar in 1969, but to date it has not detected. The Cosmic Baby, i.e., SwiftJ1818.0-1607, is the youngest magnetar. It's characteristic age is ~300 years, with a superfast spin period ~ 1.36s and a strong surface dipole magnetic field ~ 3×10^{14} G. Taking into account three facts:

- i) The ambipolar diffusion in the neutron star core is expected to be the dominant mode of field decay in the early evolution of magnetar (as long as the age much less than ~ 10^4 yrs.) ;
- ii) Magnetars's field decay is negligible as long as the core temperature is a few times of 10^8 K (i.e. $< 10^9$ K) ;
- iii) The coupling between the decay of internal magnetic field and the cooling is so strong in the early phase of Magnetar that it significantly slows down both processes but interior magnetic fields able to remain strong enough resulting the core temperature stays higher than several times 10^8 K for thousands years (at least 10^3 years proposed by Dall'Osso et al. [1]) we suggest the swift J1818.0-1607 is a triaxial magnetar i.e., simply Triaxial Star. Significance of our study is — continuous observation thus provides an opportunity for (a) detection of existence of a real Triaxial Star, (b) understanding of the evolution from strong to ultra-strong

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magnetic field of a neutron star and a magnetar , (c) the bizarre properties of newly baby magnetar,d)how the fast spin period and interior ultra-strong magnetic field turn the baby magnetar into a unique compact object possessing spontaneously broken axial symmetry and a potential source for measuring the properties of triaxially deformed neutron star (i.e. Magnetar) or triaxialstar. This author encourages the GW community to search the Triaxial Stars through electromagnetic counterparts during their observation of compact objects.

Keywords: Gravitational waves; triaxial star; neutron star; pulsar; magnetar.

1. INTRODUCTION

Chandrasekhar proposed the concept of a “Triaxially deformed” star in 1969 [2]. The classical solution of Maclaurin spheroids and Jacobi ellipsoids for self-gravitating and uniformly rotating, incompressible fluids in equilibrium yields two models of rapidly rotating stars. When the rotation of an equilibrium configuration is increased, the sequence of triaxial Jacobi ellipsoids diverges from that of the axisymmetric Maclaurin spheroids, and the ratio of kinetic (T) to gravitational (W) energy reaches $T / |W| \sim 0.14$ [3]. Because the configurations are no longer a precise ellipsoid in relativistic gravity or for compressible fluids, triaxially deformed rotating compact stars(or simply triaxial stars) are rather than ‘ellipsoids’. This triaxial model is very important in relativistic astrophysics because it includes fluid compressibility for modeling the realistic neutron star as an axisymmetric and uniformly rotating configuration associated with the equation of state (EoS) of high density nuclear matter [4,5].

Uryū et al. [6] discovered supra-massive triaxial solutions for relatively stiff (piecewise) polytropic equation of state (EoS) with tri-planar symmetry w.r.t. three orthogonal x, y, and z planes, the masses of which exceeded the maximum mass of the spherical solution but were always lower in comparison to those of axisymmetric equilibrium. They obtained the following results:

- a) The difference in the maximum masses of triaxial and axisymmetric equilibrium solutions depends sensitively on the equation of states (EoSs) ;
- b) In the case where this difference turns out to be only 10%, then it will be treated as strong evidence that the EoS of high density matter in the core of neutron stars becomes substantially softer [6].

Another crucial information about the conditions for a star collapsing into a black hole [8] is that supernova fall back accretion can spin up a

freshly formed neutron star with a strong magnetic field (B) of 5×10^{14} G as rapidly as $T / |W| \sim 0.14$ for 50 – 200s before the star collapses into a blackhole. This suggests that a triaxially deformed compact stars,, such as the recently formed neutron star discussed above, could form transiently from enormous stellar core collapse. Once such a triaxial star is produced, the massive volume of gravitational waves emitted allows us to extract attributes from high density nuclear materials. Using a realistic excess cross-power search technique the typical value [7] of the amplitude of gravitational waves produced by triaxial stars is

$$h \sim 9.1 \times 10^{-21} (30 \text{ Mpc} / D) (M / 1.4 M_{\odot})^{3/4} (R / 10 \text{ Km})^{1/4} f^{-1/5} \quad (1)$$

where D, M, R and f are the distance to source, the source mass, the mean radius, and the wave frequency in Hz , respectively. Piro and Thrane [9] estimated the detectability of gravitational waves produced by triaxially compact stars under the fall back accretion scenario for Advanced LIGO detector [10] ~ 17 Mpc.

A neutron star or magnetar can be deformed into a triaxial compact star by its intrinsic ultra-strong core magnetic field [11-13]. In this research we investigate the triaxiality of the magnetar Swift J1818.0-1607 taking into account the ellipticity's stability and the effect of internal strong core magnetic field.

The paper is organized as follows: In Sec.2.we describe the valuable observed parameters of the cosmic baby magnetar used in this work. The ellipticity of the baby magnetar in details are presented in Sec.3. Effects of the ambipolar diffusion on heating and cooling inside the magnetar core materials, resulting effects of super-strong inner magnetic fields are discussed in Sec.4. Role of ellipticity and interior strong magnetic fields towards the formation of triaxial magnetar are presented in Sec.5. In the end, we briefly concluded and discussed future prospects of the triaxial magnetar in Sec.6.

Table 1. Various early observed / measured parameters of Swift J1818.0 – 1607

Instruments	Observation based on	Typical properties	Value	Reference
BAT Radio Telescope	9 ms hard X-ray burst and long-lived outbursts	Characteristic age (shortest known)	~ 240 years	Esposito et al [16]
		Surface magnetic field	~ 2.7×10^{14} G	
		Dipolar magnetic field at poles	$\approx 7 \times 10^{14}$ G	
		Spin down Luminosity ($\dot{E}_{\text{rot}}$)	~ 1.4×10^{36} erg.s ⁻¹	
XMM Newton Telescope		Luminosity	~ 8×10^{34} erg.s ⁻¹	Enoto et al. [17]
		Coherent periodicity of x-ray signal	1.36 s	
Sardini Radio Telescope	Radio observation	Spin period derivative	~ 8.2×10^{-11} s.s ⁻¹	Champion et al. [18]
		Period derivative	~ 9×10^{-11} s.s ⁻¹	
		Spin Period	0.7333920 s	

2. COSMIC BABY

The Swift Burst Alert Telescope (BAT) on board the Neil Gehrels Swift Observatory [14] detected a typical characteristics of short burst from magnetar [15] on March 12, 2020, at 21:16:49 UT. The Swift X-ray Telescope (XRT) ultimately spotted a new un-catalogued x-ray source, Swift 1818.0–1607 which is presently known as Cosmic Baby, 64 seconds later. Table 1 shows the main parameters of this cosmic infant derived from the timing analysis of early data at the time of discovery.

Following a series of observations at multiple telescopes (including TMRT and NICER) some confirmed parameters of the cosmic baby magnetars were accessible till July 27, 2020. The rotation / spin period derivative, for example, is ~ 3.74×10^{-11} s⁻², the surface dipole magnetic field is ~ 3×10^{14} G, the spin down luminosity is ~ 1.1×10^{36} erg. S⁻¹, and so on. Although Chandra Observatory [19] began observing swift J1818.0–1607 less than a month after its discovery, its observations provided astronomers with the first high resolution x-ray picture of the cosmic baby. Nonetheless, practically all characteristics of the cosmic infant qualities vary greatly.

3. ELLIPTICITY OF COSMIC BABY MAGNETAR SWIFT J1818.0-1607

In 1992, Robert Duncan and Christopher Thompson [20] postulated the existence of magnetars to explain the features of transient

sources of gamma rays, i.e., soft gamma repeaters (SGRs). Magnetars are isolated young neutron stars with powerful magnetic fields that generate a wide range of high-energy emissions, from huge flares to quick radio bursts. The underlying hypothesis behind these unusual high-energy sources is that they could be ultra-strong magnetized neutron stars, magnetars with surface (dipole) fields in the 10^{14} - 10^{16} G range and core magnetic fields $>10^{16}$ G (at least one order of magnitude greater) [21, 22]. Because the density of the neutron star core is larger than or equal to 10^{15} g/cm³, the compact object has an anisotropic character [23], which means that the internal pressure can be divided into two parts: radial pressure (p_r) and transverse pressure (p_t), where p_t is orthogonal to p_r . The physical properties, stability, and structure of stellar matter are all affected by pressure anisotropy [24]. The ultra-strong internal magnetic field of stellar matter can also produce anisotropic pressure, which is the deformation of a rotating neutron star's spheroidal shape and the emission from it as a result of that deformation.

Cutler [25] initially identified the internal field structure of a neutron star as an effective and efficient source of GW emission when looking for strong gravitational wave (GW) emission. According to him, a magnetically distorted neutron star, that is, a neutron star with a strong internal toroidal field, forms a prolate shape, which has the best probability of being a strong GW emitter. As a result, the ellipticity (ϵ) of the magnetic deformation in the shape of star object is critical in the powerful GW source. In other

word, the stellar body's triaxiality is determined by its reliance on an internal strong magnetic field, the decay of the field strength, and the dynamical shape transition to a triaxial ellipsoid form.

A magnetar is a slowly revolving solitary neutron star with an extremely strong magnetic field in its interior ranging from 10^{16} – 10^{18} G and even up to 10^{20} G [26]. A magnetar, in general, is a triaxial stellar body [27], especially in its newborn period. The geometric distortion of the neutron star (or magnetar) generated by strong toroidal magnetic field is used to estimate its internal ultra-strong magnetic field (i.e., the toroidal magnetic field is larger than at least one order of magnitude greater than its surface dipolar magnetic field). As a result, magnetar ellipticity limitations can be employed to as a time or duration of GW emission. So, if the field is dipolar, then hydro-magnetic stresses, arising from non-radial gradients of the super-strong internal magnetic field, deform the magnetar (that is, between the magnetic poles and the equator), and the fractional difference (ϵ) between the principal moments of inertia can be expressed as [27-29].

$$\epsilon \sim \delta\rho R^5 / I_1 \approx 2 \times 10^{-9} (B_{\text{internal}} / 10^{10} \text{ T})^2 \quad (2)$$

where $\delta\rho$ = induced matter-density perturbation $\sim B_{\text{internal}}^2 / \mu_0 C_s^2$,
 R = the stellar radius,
 C_s = the isothermal sound speed ($= 3^{-1/2} c$, c being the velocity of light),
 B_{internal} = the characteristic magnitude of the internal magnetic field

- i) $\approx B_0$, if the internal magnetic field is confined to the stellar crust,
- ii) $B_0 \geq 10^{10}$ T, if it is generated deep inside the star (i.e. convective dynamo model [30],
- iii) $B_0 \leq 10^9$ T in the case of rotation powered pulsars,

B_0 being the neutron star surface dipolar field and $T = 10^4$ G.

According to Melatos [27], a) the hydrodynamic deformation in a magnetar is much larger in comparison to the elastic deformation arising from shear stresses in the crystalline stellar crust of a rotating neutron star; b) the principal axes of inertia in a rotating neutron star are oriented arbitrarily w.r.t. the magnetic axis of the external magnetic dipole field whereas in the case of a magnetar, the magnetic axis is approximately

parallel to one of the principal axes of inertia (say e_3), i.e., the alignment of magnetic axis is not exact to the inertia axis due to the complicated structure of the internal field near its generation site (i.e., a non-axisymmetry state remains).

4. ORIGIN AND DECAY OF CORE MAGNETIC FIELD OF SWIFT J1818.0-1607

Idealizing the magnetar as a neutron star with the shape of slightly deformed, homogeneous ellipsoid and having a small ellipticity

$$\epsilon = (I_1 - I_2) / I_3 \quad (3)$$

where I_1, I_2, I_3 are the principal moments of inertia of the neutron star such that I_3 is assumed to be aligned with the spin axis then using eqn. (3) we obtain the following constraint on the magnetar ellipticity [31] as

$$|\epsilon| < (5 / 3G)^{1/2} \{ C R^3 P_0 B_{\text{dipole}} / 2^4 \pi I \} \approx 3 \times 10^{-4} (B_{\text{dipole}} / 10^{14} \text{ G}) (P_0 / 1 \text{ ms}) \quad (4)$$

with fiducially standard neutron star properties of $I = 10^{45} \text{ g.cm}^2$, $R = 10 \text{ km}$, P_0 = initial spin period and the angle between the spin axis and the principal axis of the neutron star distortion $= \pi/2$ [32].

If we assume that magnetar's internal toroidal magnetic field component (B_{toroidal}) is the main cause of neutron star deformation then we can constrain the average value of this component by the relation [25].

$$|\epsilon| \sim 1.6 \times 10^{-4} (B_{\text{toroidal}} / 10^{16} \text{ G})^2 \quad (5)$$

and B_{toroidal} as [31]

$$B_{\text{toroidal}} < \sim 1.4 \times 10^{16} \text{ G} (B_{\text{dipole}} / 10^{14} \text{ G})^{1/2} (P_0 / 1 \text{ ms}) \quad (6)$$

Considering the observed dipolar magnetic field strength $B_{\text{dipole}} = 7 \times 10^{14} \text{ G}$ and spin period $P_0 = 1.36 \text{ s}$ of the Swift J1818.0-1607 we estimate the ultra-strong internal toroidal field strength $B_{\text{toroidal}} < \sim 10^{18} \text{ G}$. This value is consistent with the value $10^{17} - 10^{18} \text{ G}$ in the case of newly born proto-neutron stars [33 – 35] and also supports the model proposed by Dall'Osso et al. [36] that the internal magnetic field must be a very large initial value ($> \sim 10^{16} \text{ G}$) for the internal magnetic field decay.

4.1 The Decay of Core Magnetic field

Studies of magnetic field decay in the neutron star core [37,38] point to three distinct mechanisms that affect the evolution and dissipation of magnetic fields in the magnetar interior :ohmic dissipation, ambipolar diffusion and Hall drift. Specially, ohmic dissipation and ambipolar diffusion are directly active in dissipation, whereas Hall drift is indirectly active. Further research [39,40] shows that total energy conservation remains nearly the same after the Hall drift, implying that due to Hall diffusion, a new equilibrium configuration with lower total energy will arise in the magnetar interior. According to their findings, initial stable magneto-hydrodynamic configurations remain close to the new equilibrium configuration. Even yet, ambipolar diffusion in the neutron star core is projected to be the primary mechanism of internal field decay as long as magnetars are in their early phase evolution (i.e., ages less than $\sim 10^4$ years).

Another significant result was found in ref [39,40] about ambipolar diffusion at high temperature in the core of a neutron star (i.e. magnetar). Ambipolar diffusion actually drives a slow motion of charged particles (located amid neutrons in the core of a neutron star)that is in opposition to. In the stable neutron star medium, particle friction and chemical potential gradients work together. Inside the core two forms of ambipolar diffusion are active depending on their effect on chemical composition. Inside the core, two forms of ambipolar diffusion are active in terms of chemical composition: a) solenoid mode — only particle friction is used to counteract without disturbing chemical equilibrium. b) irrotational mode — disrupts the chemical equilibrium but does not evolve on time scales less than the β -reaction time-scale. Because the core magnetic field of neutron star (i.e. magnetar) is 10^{18} G (which is greater than 10^{16} G), the temperature in the magnetar core material will be greater than 10^9 K. The field degradation is not frozen in this scenario. This meansan that in the high-temperature zone, an equilibrium condition between heating and cooling may develop.

Using the relation for heating rate per unit volume through field decay

$$dU^+ /dt = (B^2 / 4\pi t_{\text{decay}}^{\text{(early)}}) \approx 3.69 \times 10^{19} \{ B_{16}^4 / T_9^2 (\rho_{15})^{2/3} \} \text{erg.cm}^{-3} \cdot \text{s}^{-1} \quad (7)$$

and the relation for cooling rate per unit volume through modified URCA reaction

$$dU^- /dt \approx 9.6 \times 10^{20} \cdot (T_9)^8 \cdot (\rho_{15})^{2/3} \text{erg.cm}^{-3} \cdot \text{s}^{-1} \quad (8)$$

and then equating the two rates Dall'Osso et al. [1] found the equilibrium temperature as

$$T_{\text{eq}} \approx 6.6 \times 10^8 \cdot (B / 10^{16} \text{ G})^{2/5} \cdot (\rho_{15} / 0.7)^{2/3} \cdot (L / 2 \text{ km})^{-1/5} \text{ K} \quad (9)$$

Where B_{16} , T_9 , ρ_{15} are in their usual notations, 'L' and 'a' are the characteristic scale of variation of the Lorentz force and the chemical potential, respectively, with $(L/a) \approx 9.6 T_9^4 (\rho_{15})^{-1/3} (L / 2 \text{ km})$ [38]. Comparing the obtained T_{eq} with the transition time $T_{\text{tr}} \approx 5.73 \times 10^8 (\rho_{15} / 0.7)^{1/12} \text{ K}$ (i.e. when β -reaction are very efficient in deleting the chemical equilibrium imbalance) they found T_{eq} is higher than T_{tr} (i.e. $T_{\text{eq}} > T_{\text{tr}}$) at magnetar interior core field environment where field decay occurs on the same time scale in both active modes. This means that magnetar core fields larger than that would be able to i) dissipate enough energy and ii) balance neutrino cooling in the early phase under the effective solenoidal and irrotational modes, which are still degenerate. It can be said that the field decay is negligible as long as the temperature is high enough (e.g. $> T_9$) and when the time scale of field decay occurs on the same time scale in both two modes. The significance of ambipolar diffusion is that it becomes active soon after the formation of magnetar and can prevent the cooling of magnetar core below a temperature $\sim 10^9$ K for a period of thousands yrs (at least 10^3 yrs) [1]. This means the decay of an internal magnetic field $\geq 10^{16}$ G couples with the magnetar cooling at the early stage.

5. ELLIPTICITY AND TRIAXIALITY OF SWIFT J1818.0-1607

Theoretically, a rotating neutron star will break its axial symmetry spontaneously when the rotational kinetic energy to gravitational binding energy ratio i.e. $T / |W|$ exceeds the critical value. When a rotating compact star is born from a core collapse supernova, it can also have a larger value of $T / |W|$. The ratio $T / |W|$ of a triaxial neutron star is basically constant, as is the triaxial sequence for increased compactness [41]. Except for swift J1818.0-1607, 30 magnetars have been detected to date. The spin or rotational durations of these 30 magnetars range from 2 – 10 s and their surface dipolar fields (derived from the periods, period derivatives) are $10^{13} - 10^{15}$ G [42]. However, Jawor and Tauris [43] demonstrated that

magnetar's initial period must be shorter than 2s. According to data analysis, magnetars are young, with most of them having characteristic spin down ages of less than a million years [44]. Because they are slow rotators, spin down energy losses are insufficient to power their emission. The dissipation and re-arrangement of their magnetic energy is thought to be another source. Magnetar interior structure, particularly the equation of state (EoS) and the cooling process in the presence of high density, strong gravity, and a strong magnetic field are significant in defining magnetar shape deformation and triaxial value [45 – 47].

According to numerical calculations, a newly created magnetar will have a strong magnetic field and a rapid rotation, resulting in stellar deformation [48,49]. As a result, a magnetar can release detectable gravitational waves; for example, a baby magnetar will spin down due to a magnetic dipole torque and gravitational wave quadrupole radiation. Electro-magnetic radiation is also produced by the magnetar's spin-down evolution. In other words, the dynamic evolution of magnetar spin down is related to the theoretical breaking index (n) in such a way that

- a) $n = 3$ when magnetic dipole radiation (i.e. electromagnetic phenomena) dominates the spin down of the magnetar;
- b) $n = 5$ when the GW radiation dominates the magnetar spin down.

The comparison of the observed spin-down light curves and their related models, on the other hand, allows us to restrict the neutron star's initial spin period (P_0), dipole magnetic fields (B_{dipole}) and ellipticity (ϵ) (i.e. magnetar). Magnetars with initial period $P_0 \sim 1$ ms and surface dipole magnetic field $B_{\text{dipole}} \sim 10^{14} - 10^{15}$ G, for example, often have the ellipticity $\epsilon \sim 10^{-3}$. However, the magnetar's theoretical minimum rotation period is $\sim 0.3-0.5$ ms [50]. The most appropriate relationships [51] include.

$$\log \epsilon = 3.79^{+0.52}_{-0.43} + (2.19^{+0.17}_{-0.15}) \log P_0 \quad (10)$$

$$\text{and } \log \epsilon = -22.50^{+2.15}_{-2.22} + (1.29^{+0.15}_{-0.14}) \log B_{\text{dipole}} \quad (11)$$

suggest that

- a) magnetar having a stronger magnetic field and / a slower spin period corresponds to the longer ellipticity;

- b) a longer rotation period corresponds to possession of a stronger magnetic field;
- c) the neutron star deformation is related to its surface dipole magnetic field to some extent.

But it is argued [52,53] instead of dipole magnetic field neutron star deformation may be induced by a strong internal magnetic field (B_{int}) in the stellar core through the relation

$$\epsilon \approx 10^{-8} (B_{\text{int}} / 10^{12} \text{ G}) \quad (12)$$

This relation hints the possession of a very strong internal magnetic field (i.e. $B_{\text{int}} \sim 10^{16} - 10^{17}$ G) is needed in order to obtain the ellipticity $\epsilon \sim 10^{-3} - 10^{-4}$ and also the required strength of the internal core magnetic field which should be at least 1 – 2 order of magnitude greater than the surface (i.e. external) magnetic field ($B_{\text{dipole}} \sim 10^{15}$ G).

5.1 The Triaxiality of swift J1818.0-1607

At the time of its discovery on 12th March 2020 the Swift J1818.0 – 1607 was appeared to the astronomers as a new un-catalogued x-ray source. Presently it is a confirmed magnetar [52]. The follow up observations suggest the following properties:

- i) rotational period = 1.36s
- ii) surface dipolar magnetic field = 3×10^{14} G
- iii) surface magnetic field at poles = 7×10^{14} G
- iv) spin down luminosity $\sim 1.1 \times 10^{36} \text{ erg.s}^{-1}$
- v) characteristic age ~ 300 years

Using equ. (4), (5), (6) and (12) and with the above parameters — as input we calculate the ellipticity, internal core magnetic field of Swift J1818.0-1607 and found $\sim 9 \times 10^{-3}$ and 8.9424×10^{17} G, respectively.

A numerical study [53] of magnetized deformation of neutron stars shows an interesting consequence for neutron stars with low masses, i.e., the effect of magnetic field is more prominent for internal magnetic fields $> 4 \times 10^{18}$ G. The equilibrium between gravity and magnetic field is notably different for different directions in the case of a modest mass rather than a big neutron star, according to Rizaldy and Sulakseno [53]. Even the magnetic field's gravitational force on the z-axis is substantially larger than on the other axes, resulting in the oblate-shape seen in low mass neutron stars. The oblate form is quite tiny in the case of a large

neutron star compared to a less massive one. To put it another way, the internal toroidal magnetic field outperforms the poloidal field. The poloidal field's deformation ($B_p \approx 10^{14}$ and 10^{15} G) and the accompanying adjustment in ellipticity (i.e. $\sim 10^{-4} - 10^{-2}$, respectively) are negligible [54].

Although the contemporary perspective of magnetized deformation of neutron stars (i.e. magnetars) is owing to the action of both the toroidal and the poloidal magnetic fields i.e. a mixed magnetic field, we only investigate the effect of a toroidal magnetic field in this. Our primary goal is to examine the ellipticity and stability of the deformed neutron star, magnetar Swift J1818.0–1607. In a realistic situation Heras [55] discovered the initial magnetic fields in the interior of a young neutron stars lay in the range 10^{14} – 10^{16} G in a comparative investigation of pulsars and magnetars. Because ambipolar is active, it inhibits both the decay of inner magnetic fields and the cooling of the neutron star i.e., the magnetar (because the effect is same for magnetars and neutron stars' magnetic fields, i.e., a mixed magnetic field). such that magnetar core temperature stays higher than several times 10^8 K for a period of few thousands of years (at least 10^3 years). This ellipticity of new born magnetar might not be changed too much during the period of thousand years. As the characteristic age of the Swift J1818.0 – 1607 is only ~ 300 years i.e. the baby phase compare to thousands years it will very certainly exhibit triaxiality, i.e., triaxial behavior, at least up to its age 1000 years.

This magnetar's estimated ellipticity is within the range for triaxiality, and it will remain at that value for several thousands of years if it exhibits triaxiality. As a result, we believe Swift J1818.0 – 1607 is a triaxial magnetar or simply a triaxial star.

6. CONCLUSION

If the ratio T/W surpasses a certain threshold, a freshly formed revolving neutron star can spontaneously violate its axial symmetry. Magnetars are an uncommon kind of somewhat slow-rotating neutron stars with extremely strong magnetic fields. A magnetic field with a component parallel to the rotation axis breaches circular conservation and introduces spontaneous symmetry breaking as a non-dissipative mechanism. The Swift J1818.0-1607 is a 300-year-old baby magnetar with an extremely powerful internal core magnetic field of

8.9424×10^{17} G. It has the shortest spin or rotating period of the 31 magnetars discovered, measuring 1.36 seconds. Its magnetic fields are not perpendicular to the rotational axes. The Swift J1818.0-1607's aforesaid features indicate that it is a good triaxial magnetar (compact object) for testing or studying the discovery of a triaxial star and its odd properties. Although its internal core magnetic field is too powerful, it has at least one slow decay mode via ambipolar diffusion that becomes active soon after its birth. Because this process can prevent the magnetar core from cooling below a few times 10^8 K (i.e., less than 10^9 K) for thousands of years, continuous observation of Swift J1818.0 - 1607 will allow us to better understand the evolution of magnetar magnetic fields.

The frequency of the produced continuous gravitational waves would be quite low because the spinning period of this magnetar is 1.36 s, which is within the range of 1-10 s [56-59]. This author asks the Gravitational Wave Community to regularly observe this triaxial infant magnetar (i.e., Swift J1818.0-1607) while observing compact objects via electromagnetic equivalents.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Dall'Osso S, Shore SN, Stella L. Early evolution of newly born magnetars with a strong toroidal field. MNRAS. 2009; 398:1869. DOI:10.1111/j.1365-2966.2008.14054.x
2. Chandrasekhar S. Ellipsoidal Figures of Equilibrium. Yale University Press, New Haven; 1969
3. Bonazzola S, Friebe J, Gourgoulhon E. 1998 Spontaneous symmetry breaking of rapidly rotating stars in general relativity. Astron. & Astrophys. 1998; 331:280. DOI: 10.48550/arxiv.gr-qc/9710121.

4. Friedman JL, Stergioulas J. Rotating relativistic stars. Cambridge University Press, Cambridge, UK; 2013.
5. Straumann N. General Relativity. Springer, Netherlands; 2013.
6. Uryū K, Tsokaros A, Baiotti L, Galeazzi F, Sugiyama N, Taniguchi K, Yoshida S. Do Triaxial supramassive compact stars exist? *Phys. Rev. D*. 2016;94:101302. DOI:10.1103/PhysRevD.94.101302.
7. Lai D, Shapiro SL. Gravitational radiation from rapidly rotating nascent neutron stars. *Astrophys. J.* 1995;442: 259. DOI:10.1086/175438.
8. Piro AL, Ott CD. Supernova fallback onto magnetars and propeller-powered supernovae. *Astrophys. J.* 2011;736: 108. DOI:10.1088/0004-637X/761/1/108
9. Piro AL, Thrane E. Gravitational Waves from fallback accretion onto neutron stars. *Astrophys. J.* 2012;761:63. DOI:10.1088/0004-637X/761/1/63.
10. Harry GM. (LIGO Scientific Collaboration). Alignment sensing and control in advanced LIGO". *Class. Quan. Grav.* 2010;27: 084006.
11. Lambi F S, Benkaiem D, Joyce M. On the generation of triaxiality in the collapse of cold spherical self-gravitating systems. *MNRAS*. 2015;449:4458. DOI:doi.org/10.1093/mnras/stv581
12. Rather IA, Rahaman U, Dexheimer V, Usmani AA, Patra SK. Magnetic deformation in Neutron Stars. in *Proc. DAE Symp in Nucl. Phys.* 2021;65:478.
13. Haskell B, Samuelsson L, Glampedakis K, Andersson N. Modelling magnetically deformed neutron stars. *MNRAS*. 2008; 385:531. DOI:10.1111/j.1365-2966.2008.12861.x.
14. Gehrels N, et al. The swift gamma-ray burst mission. *Astrophys. J.* 2004;611:1005. DOI:10.1086/422091
15. Evans PA, Gropp JD, Kennea JA, et al. Swift-BAT trigger 960986: Swift detection of a new SGR Swift J. 1818.0-1607. 2020;GCN circular #27373
16. Esposito P, Rea N, Borghese A, Coti-Zelati F. et al. A very young radio-loud magnetar *astrophys. J. Lett.* 2020;896:L30. DOI:10.3847/2041-8213/ab9742
17. Enoto T, Sakamoto T, Younes G. et al. NICER detection of 1.36 sec periodicity from a new magnetar. Swift J1818.0-1607. 2020;(Astronomer's Telegram # 13551)
18. Champion D, Desvignes G, Jankowski F. Spin-evolution of the new magnetar J 1818.0-1607. 2020;(A. Tel # 13559)
19. Blumer H, Safi-Harb S. Chandra observations of the newly discovered magnetar SWIFT J1818.0–1607. *Astrophys. J. Lett.* 2020;904:L19.
20. Duncan RC, Thompson C. Formation of very strongly magnetized neutron stars *astrophys. J.* 1992;392:L9. DOI:10.1086/186413
21. Paczynski B. GB 790305 as a very strongly magnetized neutron star. *Acta Astron.* 1992;42:145.
22. Thompson C, Duncan RC. soft gamma repeaters as very strongly magnetized neutron stars. *MNRAS*. 1995;275:255. DOI:10.1093/mnras/275.2.255
23. Ruderman A. Pulsars: Structure and dynamics. *Ann. Rev. Astron. Astrophys.* 1972;10:427. DOI:10.1146/annurev.aa.10.090172.002235
24. Dev K, Gleiser M. Anisotropic stars: Exact solutions. *Gen. Rel. Grav.* 2002;34:1793.
25. Cutler C. Gravitational waves from neutron stars with large toroidal B fields. *Phys. Rev. D*. 2002; 66:084025. DOI:10.1103/PhysRevD.66.084025
26. Lai D, Shapiro S. Cold equation of state in a strong magnetic field: effects of inverse beta –decay. *Astrophys. J.* 1991;383:745. DOI:10.1086/170831
27. Melatos A. Bumpy spin-down of anomalous x-ray pulsars: the Link with Magnetars. *Astrophys. J.* 1999;519:L77.
28. Goldreich P. Neutron star crusts and alignment of magnetic axes in pulsars. *Astrophys. J.* 1970;160:L11. DOI:10.1086/180513
29. deCampli W M. *Astrophys. J.* 1980;242:306.
30. Thompson C, Duncan RC. Neutron star dynamos and the origins of pulsar magnetism. *Astrophys. J.* 1993;408:194. DOI:10.1086/172580
31. Moriya TJ, Tauris TM. Constraining the ellipticity of strongly magnetized neutron stars powering super-luminous supernova. *MNRAS*. 2016;460:L55. DOI:10.1093/mnras/slw072
32. Cutler C, Jones DI. Gravitational wave damping of neutron star wobble. *Phys. Rev. D*. 2001;63: 024002. DOI:10.1103/PhysRevD.63.024002
33. Del Zanna L, Bucciantini N. Covariant and 3 + 1 equations for dynamo-chiral general

- relativistic magneto-hydrodynamics. MNRAS. 2018;479:657.
DOI:10.1093/mnras/sty1633
34. Cioffi R, Kastaun W, Kalinani JV, Giacomazzo B. First 100 ms of a long-lived magnetized neutron star formed in a binary neutron star merger. *Phys. Rev. D*. 2019;100:023005.
DOI:10.1103/PhysRevD.100.023005
35. Franceschetti K, Del Zonna L. General Relativistic Mean-Field Dynamo Model for Proto-Neutron Stars. *Universe*. 2020; 6:83.
DOI:10.3390/universe6060083
36. Dall'Osso S, Granot J, Piran T. Magnetic field decay in neutron stars: from soft gamma repeaters to 'weak-field magnetars' MNRAS. 2012;422:2878.
DOI:10.1111/j.1365-2966.2012.20612.x
37. Thompson C, Duncan RC. The soft gamma repeaters as very strongly magnetized neutron stars. II. Quiescent Neutrino, X-Ray, and Alfvén Wave Emission. *Astrophys. J.* 1996;473:322.
DOI:10.1086/178147
38. Goldreich P, Reisenegger A. Magnetic field decay in isolated neutron stars. *Astrophys. J.* 1992;395:250.
DOI:10.1086/171646
39. Pons JA, Link B, Miralles JA, Geppert U. Evidence for heating of neutron stars by magnetic-field decay. *Phys. Rev. Lett.* 2007;98:071101.
DOI:10.1103/PhysRevLett.98.071101
40. Pons JA, Geppert U. Magnetic field dissipation in neutron star crusts: from magnetars to isolated neutron stars. *Astron. Astrophys.* 2007;470:303.
DOI:10.1051/0004-6361:20077456
41. Zhou E, Tsokaros A, Rezzolla L, Xu R, Uryu K. Uniformly rotating, axisymmetric, and triaxial quark stars in general relativity. *Phys. Rev. D*. 2018;97:023013.
DOI:10.1103/PhysRevD.97.023013
42. Kouveliotou C, Stohmayer T, Hurley K, van Paradijs J, Finger MH, Dieters S, Wood P, Thompson C, Duncan RC. Discovery of a magnetar associated with the Soft Gamma Repeater SGR 1900+14. *Astrophys. J. Lett.* 1999;510:L115.
DOI:10.1086/311813
43. Jawor J A, Tauris T M. Modelling spin evolution of magnetars. MNRAS. 2022 ;509; 634
DOI:10.1093/mnras/stab2677
44. White CJ, Burrows A, Coleman MSB, Vartanyan S. *Astrophys. J.* 2022 ;396; 111.
45. Yakovlev DG, Gnedin OY, Gusakov ME, Kaminkar AD, Lavenfish KP, Potekhin AY. Neutron star cooling. *Nucl. Phys. A* 2005 ;752; 590.
DOI:10.1016/j.nuclphysa.2005.02.061
46. Chamel N, Haensel P. Physics of neutron star crusts living rev. *Relativity*. 2005; 11:10.
DOI:10.12942/lrr-2008-10
47. Bucciantini N, Pili AG, Del Zanna L. Modelling the structure of magnetic fields in neutron star: from the interior to the magnetosphere. *Proceedings of the 10th International Conference on Numerical Modeling of Space Plasma Flows*; 2015.
48. Lindblom L, Pwen BJ, Morsink SM. Gravitational radiation instability in hot young neutron stars. *Phys. Rev. Lett.* 1998;80:4843.
DOI:10.1103/PhysRevLett.80.4843
49. Doneva DD, Kokkatas KD, Prigouras P. Gravitational wave afterglow in binary neutron star mergers. *Phys. Rev. D*. 2015;92:104040.
DOI:10.1103/PhysRevD.92.104040
50. Koranda S, Stergioulas N, Friedman JL. Upper limits set by causality on the rotation and mass of uniformly rotating relativistic stars. *Astrophys. J.* 1997 ;488; 799.
DOI:10.1086/304714
51. Xie L, Wei DM, Wang Y, Jin ZP. Constraining the ellipticity of the newborn magnetar with the observational data of long gamma-ray bursts. *Astrophys. J.* 2022;934:125.
DOI:10.3847/1538-4357/ac7c13
52. Majid W A, Pearlman AA, Prince TA, Naudet CA, Bansal K. Flattening of Swift J. 1818.0 – 1607's spectral index via dual radio frequency observation with the Deep Space Newtork ". 2022 ;A. Tel # 13898.
53. Rizaldy R, Sulaksono A. Magnetized deformation of neutron stars. in *Proc. 3rd Padjadjaran Int. Phys. Conf. Symp., J. of Phys. Conf. Series*. 2018;1080:012031
54. Morasi S, Cioffi R, Schneider R, Stella L. Stochastic background of gravitational waves emitted by magnetars. MNRAS. 2011 ;411:2549.
DOI:10.1111/j.1365-2966.2010.17861.x
55. Heras R. Pulsars are born as Magnetars. *ASP Conf. Ser.* 2012;466:253.
56. Sieniawska M, Bejger M. Continuous gravitational waves from neutron stars: current status and prospects. *Universe*. 2019;2019:217.
DOI:10.3390/universe5110217

57. Ibrahim AY, Borghese A, Rea N, Cotzelati F. Deep X-Ray and radio observations of the first outburst of the young magnetar swift J1818.0-1607. *Astrophys. J.* 2023; 943: 20.
DOI:10.3847/1538-4357/aca528
58. Huang J-X, Lü, H-J, Rice J, Liang E-W. Gravitational –wave evolution of newborn magnetars with different deformed structures. *Phys. Rev. D.* 2022; 105: 103019.
DOI:10.1103/PhysRevD.105.103019
59. Uzuner Mete, Keskin Ö, Kaneko Y, Gögüs, Roberts OJ, Lin L, Baring MG, Güngör, Kouveliotou C, van der Horst AJ, Younes G. Bursts from high-magnetic-field pulsars swift J 1818.0-1607 and PSR J1846.4-0258. *Astrophys. J.* 2023;942:8.
DOI:10.3847/1538-4357/aca482

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