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Chinese Astronomy and Astrophysics 29 (2005) 20–38

CHINESE
ASTRONOMY
AND ASTROPHYSICS

The Electromagnetic Field of a Slowly Rotating Magnetized Neutron Star in Saa's Gravitation Model with Torsion† ⋆

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Abstract The equations of the electromagnetic field of a slowly rotating magnetized neutron star in Saa's gravitation model with torsion are derived and their exterior solution is investigated. The following conclusions are obtained: first, there is a specific solution for the electromagnetic field when $A^{\hat{0}} = 0$; second, there is no solution at all when $A^{\hat{0}} \neq 0$. Therefore, we can judge whether or not torsion exists by observing the exterior electromagnetic field of the neutron star.

Key words: gravitation—stars: neutron—stars: magnetic field

1. INTRODUCTION

It is well known that intense gravitational fields exist in black holes, neutron stars and their neighborhoods. Such fields are generally studied using the general relativity theory, and accretion in the neighborhood of black holes has been a hot topic [1,2]. For neutron stars, CHEN Ci-xing et al.[3] studied the Boltzmann equation of a rotating and slowly collapsing neutron star within the framework of general relativity. However, as magnetic fields are widely present in neutron stars, we have to study the solution of Maxwell equations within the framework of general relativity and seek appropriate conclusions. In their early works, Ginzburg et al.[4], Anderson et al.[5] and Petterson[6] studied the electromagnetic field in the Schwarzschild spacetime, and their results indicated that the magnetic field resulting from the space-time curvature was stronger than that given by Newton's theory[7].

† Supported by Excellent Young Teachers Project of Ministry of Education and National Natural Science Foundation

Received 2003–11–20; revised version 2004–01–09

⋆ A translation of *Acta Astron. Sin.* Vol. 45, No. 2, pp. 141–157, 2004

DOI: 10.1016/j.chinastron.2005.01.003

Sengupta[8] reconsidered this problem and found expressions for the electric fields of neutron stars in the Schwarzschild background. Sengupta[9] also discussed the ohmic decay rate of magnetic fields of neutron stars in the same background, but his method did not describe the interior electromagnetic field of the star and applies only to the star's exterior space-time region. Nevertheless, using these approximations, Sengupta[9] pointed out that the intense gravitational effect apparently reduces the overall decay rate by several orders of magnitude. Later, Geppert et al.[10] reconsidered this problem further in detail. The above-mentioned authors discussed only non-rotating neutron stars, but most neutron stars are rotating. Muslinov et al.[11] studied the general relativistic effect resulting from rotation of neutron stars in the approximation of slow rotation. Later, Muslinov et al.[12] discussed the exterior solution of the magnetic fields of rotating magnetic stars with a similar method. In the same year Prasanna et al.[13] studied the properties of the electromagnetic field in the magnetosphere of rotating neutron stars within the framework of general relativity, Rezzolla et al.[14] discussed comprehensively the equations of the electromagnetic field in slowly rotating magnetized neutron stars and their interior and exterior solutions. All these authors were keen to conduct the discussion within the framework of general relativity.

Although the theory of general relativity has been a great success, it is not a perfect theory of gravitation: to be precise, it is not readjustable, it is not unitary, and it cannot avoid singularity. So people have sought to revise it. An example is the introduction of torsion by Cartan[15]: it is a natural improvement of general relativity, especially as its existence can be predicted by the string theory[16], the hopeful candidate for the unification of the four interactions. At the same time the torsion can be taken as a compensation field of local gauge transformation[17], and a gravitation theory with torsion can hopefully settle the problems of readjustment and unitarity. Unfortunately, so far there is no physical result showing that torsion can be used in basic physics, so there are many people who do not believe in its existence. On the other hand, people are continuing to propose further gravitation models with torsion and take Cartan's line of thought as part of the theoretical development of modern physics. Especially, starting from the requirement that the principles of least action and of least coupling be compatible, Alberto Saa[18] has proposed the so-called Saa's gravitation model with torsion.

In this paper, we try to study the electromagnetic field in a slowly rotating magnetized neutron star by using Saa's gravitation model with torsion.

2. EQUATIONS OF ELECTROMAGNETIC FIELD IN COMMON COORDINATES

Assuming that the matter relating to the magnetized neutron star is a fluid and there is an electromagnetic field, the total amount of action in Saa's gravitation model with torsion is:

$$\begin{aligned}\mathcal{A}_{\text{total}} = & -\frac{c}{2k}\int e^{2\Theta}R\sqrt{-g}d^4x - \frac{1}{c}\int e^{2\Theta}(\mu c^2+\mu\Pi)\sqrt{-g}d^4x - \\ & \frac{1}{c}\int e^{2\Theta}\left(\frac{1}{16\pi}F_{\mu\nu}F^{\mu\nu} - \frac{1}{c}J^\alpha A_\alpha\right)\sqrt{-g}d^4x\,,\end{aligned} \tag{1}$$

in which