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Speed Down of Spin of Pulsar Under the Braking of Gravitational Radiation

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Abstract: *This paper studies the secular influence of gravitational radiation on the change of the angular velocity and period. of pulsar. The formula for the gravitational radiation is given. The variation of angular velocity and period with time and its radiation energy and radiation fux at the Earth are calculated by using the derived formulas. The numerical results are given in Table. The discussion and conclusion are drawn.*

Keywords: *Pulsar: gravitational radiation: angular velocity and period: Variation*

1. Introduction

The early stage of pulsar after formation, especially, 81 ages ago the gravitational radiation dominates this stage, the energy loss is the gravitational energy loss .The last stage is the magnetic radiation. The energy loss is the magnetic energy loss.. So when we consider the evolution of pulsar in the early stage ,we must consider that the results come from the energy loss due to gravitational radiation. However, in the last stage the pulsar still loses its energy, but the loss energy is very small. The gravitational energy loss of pulsar may results in the change of period and angular velocity. In this paper we study this topic.

2. The Change of Period and Angular Velocity of Pulsar under Braking of Gravitational Radiation Energy Loss

According to the theory of the material radiation, the total radiation includes dipole, magnetic dipole and quadruple radiation. A body proceeds quadrupole gravitational radiation, if its ellipticity $\in \neq 0$ The gravitational energy - loss can be transformed to the radiation power (Fang & Ruffini, 1983) [1]

$$\frac{d\varepsilon}{dt} = -\frac{G}{45c^6}\tilde{Q}_{\alpha\beta}^{\ 2} \ . \tag{1}$$

Where $Q_{\alpha\beta}$ is the quadrupole tensor of mass distribution of body

$$\dddot{Q}_{\alpha\beta}^{\ 2} = 18I^2 \in \Omega^6(1+15\sin^2\theta\ )\sin^2\theta. \tag{2}$$

When we take the special case $\theta = 90^0$

$$\dddot{Q}^{\ 2}_{\ \alpha\beta} = 288I^2 \in^2 \Omega^6. \tag{3}$$

Where I and $\in$ denote moment of inertia and ellipticity respectively.
Substituting (3) into equation (1)

$$\frac{d\varepsilon}{dt} = -\frac{32}{5c^5}GI^2 \in^2 \Omega^6. \tag{4}$$

This is consistent with the radiation power W_G given by Weber (1961) [2]

$$W_G = \frac{32GI^2 \in^2 \Omega^6}{5c^5} \tag{5}$$

The radiation flux is given by

$$\Phi = \frac{W_G}{4\pi d^2} \tag{6}$$

Where d is the distance from pulsar to the Earth.

If the gravitational energy - loss come from the rotational energy supplement $\varepsilon_{rot} = \frac{1}{5} I\Omega^2$ (for ellipsoid) the equation (3) can be written as

$$\frac{d\varepsilon}{dt} = \frac{d\varepsilon_{rot}}{dt} = -\frac{32}{5c^5} GI^2 \in^2 \Omega^6,$$

$$\therefore \frac{d\Omega}{dt} = -\frac{16}{c^5} GI \in^2 \Omega^5. \tag{7}$$

Integrating the above equation

$$\int_{J_0}^{J} \frac{d\Omega}{\Omega^5} = -\frac{16GI \in^2}{c^5} \int_{t_0}^{t} dt,$$

$$\Omega = \Omega_0 \left[1 + \frac{64G \in^2 I\Omega_0{}^4}{c^5} (t - t_0) \right]^{-1/4},$$

$$\therefore \Omega = \Omega_0 [1 + K(t - t_0)]^{-1/4}. \tag{8}$$

$$P = P_0 [1 + K(t - t_0)]^{1/4}. \tag{9}$$

Where $K = \frac{64G \in^2 I\Omega_0{}^4}{c^5}$. (10)

3. NUMERICAL RESULTS

This paper uses the formulas (5), (6) and (8), (9),(10) to calculate the radiation power and flux and the change of the period and inclination angle of PSR0531+21(Crab) under baking of gravitational radiation. For this pulsar its $P_0 = 0.033085(s)$ [3], $\Omega_0 = 189.91$(rad/s), $\epsilon = 2 \times 10^{-4}$ [4]

$I = 1.4 \times 10^{45} (g.cm^2)$ [5], $G = 6.67 \times 10^8$, $c = 3 \times 10^{10} (cm/s)$, , $d = 5 \times 10^{21} cm.$

Substituting the above data into the formulas (4), (5)and (7), (8). (9) we obtain $K = 1.2789 \times 10^{-11}$ and the numerical results are listed in Table

Table Numerical results

Pulsar	$W_G(egr/s)$	$\Phi(egr/cm^2)$	$P(t)(s)$	$\delta P(s)$	$\Omega(t)(rad/s)$	$\delta\Omega(rad/s)$
PSR0531+21	6.50×10^{41}	2.07×10^{-3}	0.03414	0.00329	188.04	-1.87

4. DISCUSSION AND CONCLUSION

(1) The solar radiation power is $1.87.\times 10^{33}$egr . Hence the Crab radiation power is large than that of the sun 1.7×10^{8}fold, but the solar flux is very small than that of Crab pulsar. Because the distance is very far from Crab to the Earth.

(2) It can be seen from Table that the period of Crab prolongs with time and angular velocity slow down due to the gravitational energy loss.

(3) In this paper the gravitational radiation refers to the present radiation and does not refer to the radiation in the early stage. According to the theory of Ostriker and Gunn[6] the influence of gravitational radiation is very large on the priod and angular velocity.

(4) When pulsar can not emits gravitational radiation or gravitatiomal wave i.e

(A) ellipcity € =0 spheroid. However € 2×10^{-4} can not zero in this paper.

(B) Magnetic inclination angle $\alpha = 0$ However $\alpha = 90^{0}$ in this paper

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