**International Journal of Advanced Research in Physical Science (IJARPS)**
*Volume 8, Issue 4, 2021, PP 20-25*
*ISSN No. (Online) 2349-7882*
*www.arcjournals.org*

# Decrease of Total Energy of Cosmic Rays Emitted by Pulsar due to Magnetic Radiation (The Theoretical Research)

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**Abstract:** *The decrease of total energy of the cosmic rays with time emitted by pulsar due to magnetic radiation is studied in this paper. The theoretical formulae for the decrease of total energy of cosmic rays with time are derived and discussion by using the theory of magnetic dipole radiation. In addition, the decrease values of the total energy of cosmic ray for pulsar .P.SR 0531+21 are calculated. The numerical results are given:* $-0.000232\times10^{60}\mathrm{ev}/yr$. *.i.e the decrease of total energy of cosmic rays due to magnetic radiation is* $0.000232\times10^{60}(ev)$ *in one year*

**Keywords:** *Cosmic rays: total energy: decrease: magnetic radiation: pulsar.*

## 1. Introduction

The high rapidly rotating neutron star is one of the enormous accelerators of high energetic particle in the cosmos. So, we infer that the energetic cosmic rays iare possibly produced by a pulsar. Karakula et al (1974) had suggested a prediction of the theoretical model of the origin of cosmic ray emitted by pulsar according to the theory of Ostriker et al (1967-1969). The theory had obtained the total energy of cosmic rays emitted by the pulsar .The energy of cosmic rays calculated by using this theory may reach the observable order, Li (1988) had made the accurate corrective formula for the work of Karakula et al.. The total energy of cosmic rays calculated by using this corrective formula is lower than the work of Karakula et al.. In addition the total energy of the cosmic rays decreases with time gradually.. This paper examined the theory of the decrease of cosmic rays with time due to magnetic radiation dipole.

## 2. The Theoretical Formulae for Total Energy of Cosmic Rays Emitted from Pulsar

The formula for total energy emitted by the pulsar during its lifetime is given by Karakula et al according to the theory of Ostriker and Gunn, which can be written as [

$$E_t=\int_0^{E\max} N(E,E_z)EdE\approx1.5\times10^{35}\left(\frac{I}{\in^2}\right)^{\frac{1}{3}}E_z^{\frac{1}{2}}. \tag{1}$$

$$E_{\max}=4.16\times10^{11}E_Z^{1/3}. \tag{2}$$

Where $E_z$ is the energy produced from the early stage of domination of gravitational loss to the later stage of domination of magnetic loss: i. e, the energy $E_Z$ is occurred in the stage of the magnetic radiation

$$E = \frac{1.31\times10^{39}}{\varepsilon^{4/3} I^{1/3}} p\frac{dp}{dt} = \frac{1.31\times10^{39}}{\varepsilon^{4.3} I^{1/3}} p\dot{p}(eV) \tag{3}$$

Where P is the period of the pulsar at time t and $\frac{dP}{dt}$ is its rate of change, and I and $\in$ are the moment of inertia and cllipticity

The author Li (1988) had deduced an accurate corrective formula for the above formula (1) given by Karakula

$$E_{tot} = \int_0^{E_{\max}} N(E,E_z)EdE = 1.5\times10^{35}\left(\frac{I}{\in^2}\right)^{\frac{1}{3}} E_z^{\frac{1}{2}}.(1-1.054\times10^6 E_z^{1/3}) \tag{4}$$

In the formula (3) $P\frac{dP}{dt} = p\dot{p}$ is contributed from magnetic dipole radiation.

## 3. The Magnetic Dipole Equations and its Solution

It is as shown in the section 2 that the first stage is the dominant role of gravitational radiation loss in almost 81 year after pulsar was born, and then, the second stage of dominant role of magnetic radiation loss is transformed. The energy $E_Z$ is a most important parameter, which is the change energy in the magnetic radiation loss transformed from the early stage of gravitation radiation loss. It also is the function of total energy of cosmic rays .However the change of $E_Z$ dependent on the period P and its rate $\frac{dP}{dt}$ in the magnetic radiation. Hence the variation of total energy of cosmic rays dependent on $P\frac{dP}{dt}$ in the magnetic radiation. So it is necessary to solve the magnetic dipole equations in order to get $P\frac{dP}{dt}$ or $PP'$ in the magnetic radiation. Such equations and its solution can be written as Li (2020):

$$I\frac{d\Omega}{dt} = -\frac{2\mu^2\Omega^3}{3c^3}\sin^2\alpha\,, \tag{5}$$

$$I\Omega\frac{d\alpha}{dt} = -\frac{2\mu^2\Omega^3}{3c^3}\sin\alpha\cos\alpha\,. \tag{6}$$

We use $\Omega = 2\pi/P$. P is period of pulsar.`

The equations (5) and (6) become as

$$\frac{dP^2}{dt} = \frac{16\pi^2\mu^2}{3c^3 I}\sin^2\alpha\,, \tag{7}$$

$$\frac{da}{dt} = -\frac{8\pi^2\mu^2}{3c^3 IP^2}\cos\alpha\sin\alpha\,. \tag{8}$$

We use primary condition $t = 0$, $P = p_0$ $\alpha = \alpha_0$ $\mu = \mu_0$ in equation (7), we have

$$\mu_0{}^2 = \frac{3c^3 I}{32\pi^2 \sin^2 \alpha_0} P_0 \dot{P}_0 \quad (9)$$

In this section we study the magnetic radiation without magnetic decay $\mu = \mu_0 = \text{constant}$ in the equations (7)-(8)

Substituting (9) into the equations (7) and (8) , the equations (7) –(8) become as

$$\frac{dP^2}{dt} = 2\sin^2 \alpha P_0 \dot{P}_0 \csc^2 \alpha_0, \quad (10)$$

$$P^2 \frac{d\alpha}{dt} = -P_0 \dot{P}_0 \csc^2 \alpha_0 \sin\alpha \cos\alpha. \quad (11)$$

The equations (10)-(11) can be given

$$\frac{dP^2}{P^2} = -\frac{2\sin\alpha}{\cos\alpha} d\alpha, \quad (12)$$

Integrating the above equation

$$P = P_0 \left( \frac{\cos\alpha}{\cos\alpha_0} \right), \quad \Omega = \Omega_0 \left( \frac{\cos\alpha_0}{\cos\alpha} \right). \quad (13)$$

The equation (11) can be written by using (13.):

$$d\alpha = -\frac{\dot{P}_0}{P_0} \frac{\cos^2 \alpha_0}{\sin^2 \alpha_0} \left( \frac{\sin\alpha}{\cos\alpha} \right) dt,$$

$$\therefore \frac{d\alpha}{\tan\alpha} = -\frac{\dot{P}_0}{P_0} \cot^2 \alpha_0 dt.$$

Integrating the above equation

$$\int_{\alpha_0}^{\alpha} ctg\,\alpha d\alpha = -\frac{\dot{P}_0}{P_0} \cot^2 \alpha_0 \int_{t_0}^{t} dt, \quad (14)$$

$$\ln\left( \frac{\sin\alpha}{\sin\alpha_0} \right) = -\frac{\dot{p}_0}{p_0} \cot^2 \alpha_0 (t - t_0)..$$

This expression can be written as

$$\sin\alpha = \sin\alpha_0 \exp\left[ -\frac{\dot{P}_0}{P_0} \cot^2 \alpha_0 (t - t\ ) \right] \quad (15)$$

$$P = P_0 \sec\alpha_0 \left\{ 1 - \sin^2 \alpha_0 \exp\left| -2\frac{\dot{P}_0}{P_0} \cot^2 \alpha_0 (t - t_0) \right| \right\}^{1/2} \quad (16)$$

## 4. The Decrease of Total Energy of the Cosmic Rays with Time due to the Mag netic Radiation of Pulsar

It is as shown in the section 3 that the variation of $P\dfrac{dP}{dt}$ is the function of the energy $E_Z$ , which is the magnetic radiation energy loss transformed from gravitational radiation energy loss. Hence it is necessary to get the variation of $P\dfrac{dP}{dt}$ with time in order to get the energy $E_Z$ in the magnetic radiation. This may be obtained from solution of magnetic dipole equations in the previous section .

In the previous section 2 the equation (10) can be written as

$$2P\frac{dP}{\mathrm{dt}} = 2\sin^2\alpha P_0\dot{P}_0\csc^2\alpha_0,$$

The about equation can be reduce to the equation

$$P\frac{dP}{dt} = P\dot{P} = P_0\dot{P}_0\frac{\sin^2\alpha}{\sin^2\alpha_0}. \tag{17}$$

The equation (15) can be written as

$$\sin^2\alpha = \sin^2\alpha_0\exp\left[-2\frac{\dot{P}_0}{P_0}\cot^2\alpha_0(t-t\ )\right] \tag{18}$$

Substituting (18) into the equation (17), we obtain

$$P\dot{P}\ = P_0\dot{P}_0\exp\left[-2\frac{\dot{P}_0}{P_0}\cot^2\alpha_0(t-t\ )\right] \tag{19}$$

Substituting the above expression (18) into the formula (3) of the energy $E_Z$ ,, we obtain

$$E_Z = \frac{1.31\times10^{39}}{\varepsilon^{4/3}I^{1/3}}P_0\dot{P}_0\exp\left[-2\frac{\dot{P}_0}{P_0}\cot^2\alpha_0(t-t_0)\right] \tag{20}$$

Substitution of (20) into the corrective expression (4), and then, we obtain that total energy of cosmic ray emitted by pulsar decreases with time

$$E_{tot} = \int_0^{E_{\max}} N(E,E_z)EdE = 1.5\times10^{35}\left(\frac{I}{\epsilon^2}\right)^{\frac{1}{3}}E_z^{\frac{1}{2}}(1-1.054\times10^6E_z^{1/3}) \quad (4)$$

If we put primary time $t = t_0$ , the expression (18) can be written as

$$E_Z = \frac{1.31\times10^{39}}{\varepsilon^{4/3}I^{1/3}}P_0\dot{P}_{0\circ} \tag{21}$$

In which $P_0$ and $\dot{P}_0$ are values in the magnetic radiation or they are curry values

Hence the total energy is given by the above $E_Z$ .which also is the curry value

## 5. Numerical Results

It is well known that PSR0531+21(Crab) is a pulsar emitted cosmic rays. We calculate the case for decrease of the cosmic rays with time by using the date of this pulsar

$P_0 = 0.0030975(s)$, $\dot{P}_0 = 422.69\times 10^{15}$ Allen (1973) $\varepsilon = 2\times 10^{-4}$, Rees(1974) $\alpha = 59.2^0$ Davis & Goldstien (1970) $I = 4.5\times 10^{45}(m.s^2)$, Shapiro &Teukolsky **(1983)** $G = 6.67\times 10^{-8}$, $c = 3\times 10^{10}(s, t^{-1})$. Substituting these data into the formulas (20) , ,and then, into (4) and (21), we obtain the numerical results of Table.1 and 2 as follows:

**Table1.** *The current values obtained from observable data :* $P_0$ *and* $\dot{P}_0$

| $P_0\dot{P}_0 \times 10^{-15}(s)$ ) | $(E_Z)_0 \times 10^{14}(ev)$ | $(E_{tot})_0 \times 10^{60}\ (ev)$ |
|---|---|---|
| 13.9900245 | 14.0082115 | 1.6198455 |

**Table2.** *The theoretical values due to magnetic dipole radiation*

| $(P\dot{P})_M \times 10^{-15}(s)$ | $(E_Z)_M \times 10^{14}(ev)/yr$ | $(E_t)_M \times 10^{54}(ev)/yr$ | $\delta\,(E_t)_M \times 10^{60}(ev)/yr$ |
|---|---|---|---|
| 13.9860179 | 14.0019979 | 1.6196135 | -0.000232 |

## 6. Discussion and Conclusion

**(**1) In the Table.1 all values $P_0\dot{P}_0 \times 10^{-15}(s)$ ) $(E_Z)_0 \times 10^{14}(ev)$ $(E_{tot})_0 \times 10^{60}\ (ev)$ are calculated from the current observable values $P_0$ and $\dot{P}_0$. The total value of energy of cosmic rays is approximate value $1.6\times 10^{60} ev$ in the reference Li (1988)

(2.) The decrease of total energy of cosmic rays due to magnetic radiation is $0.000232\times 10^{60}(ev)$ in one year.

(3.) The limits of decrease of total energy of cosmic rays emitted from Crab pulsar due to magnetic radiation : $1.6198455\times 10^{60}(\text{ev}) \le E_t \le 0.$ as $0 < t < \infty$

(4) It can be seen from (15) that the inclination angle $\alpha$, decreases with time $t$ . $\alpha = 0$ as $t \to \infty$.. In addition it can be seen from (21) that $P\dot{P} = P_0\dot{P}_0$ as $\alpha = \alpha_0$ we can obtain the current values of energy $E_z$ and the total energy $E_t$ of cosmic rays. Moreover, the total energy decreases

with the magnetic inclination angle decrease. The total energy of cosmic ray decreases to zero as the magnetic inclination angle decrease to zero..

（5） We conclude that the origin of the cosmic rays come from some celestial bodies. The most important celestial body is pulsar. The total energy of cosmic rays emitted by pulsar decreases with time, which is determined by magnetic dipole radiation

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**Citation:** *Lin-Sen Li( 2021). Decrease of Total Energy of Cosmic Rays Emitted by Pulsar due to Magnetic Radiation (The Theoretical Research). International Journal of Advanced Research in Physical Science (IJARPS) 8(4), pp.20-25, 2021.*