Pulsar Magnetic Field Oscillation Model and Verification Method

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Abstract

We constructed the magnetic field oscillation model (hereafter the MO model) by analogizing the periodically reversing phenomenon of the solar magnetic field to pulsars. Almost all kinds of pulsar radiation phenomena are best explained using the MO model, especially polarization characteristics, glitch, generation rate, the geodetic precession of pulsars and the configuration of pulsar-wind nebula of the Crab. The MO model also provides a satisfactory explanation of other characteristics of pulsars, e.g., interpulse, spin-down, pulse nulling, beat and pulse drift, the loss rate of the rotating energy, and the accuracy of frequency. We present six verification methods for the MO model. In addition, we predict that the pulsar PSR B1913+16 will not disappear from our line of sight after the year 2025, which is antithetical to the prediction made by some astronomers.

Key words: Pulsars, Oscillations, Radiation mechanisms, Polarization
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1 Introduction

In studies of pulsars, three models have been discussed in detail: the oscillation, the orbiting binary system, and the lighthouse model. Once the oscillation and the orbiting binary system were ruled out on the basis of calculation results, the lighthouse model came to be widely accepted. The idea of analogizing the reversing phenomenon of the solar magnetic field to magnetic variables (Kienle, 1950; Babcock, 1958) has been proposed previously; however, it hasn't been taken seriously in the study of pulsars. Our study demonstrates that the magnetic field oscillation model (hereafter MO model) can be constructed by analogizing the reversing phenomenon of solar magnetic field to pulsars, and that the MO model provides a satisfactory explanation of the radiation characteristics of pulsars. This paper comprises our research results together with six methods for testing the validity of the MO model.

This paper explains the various observed characteristics of pulsars using the MO model. The reasons why the magnetic fields of pulsars reverse rapidly are beyond the scope of this paper, and will be considered in a separate paper.

2 MO model

We know that the solar general magnetic field reverses every 11 years, representing an oscillating period of 22 years. The MO model considers that the pulse radiation of pulsars originates from oscillations of the magnetic field, just similar to that of the Sun.

The MO model believes that the magnetic field of pulsars oscillates in a similar way to that of the sun, although with a much higher frequency. The rate of the magnetic flux change is very high during reversals of the magnetic field. Therefore, a very high ring-shaped induction voltage is generated during this period. If this induction voltage is calculated using the sine law, the peak value of the induction $E_{max} = \pi Bd/2P$. Supposing that the diameter of the pulsar is $d = 10^4$ m, the oscillation period is $P = 1$ s, the peak value of the magnetic field within the pulsar is $B = 10^8$ T, the induction electrofield intensity on the surface of the pulsar is $E_{max} = 1.56 \times 10^{12}$ V/m. If the change of the magnetic field is similar to a square wave, the electrofield intensity will be much higher.

The effect of induction voltage means that the charged particles around pulsars are accelerated along the circle until approaching the speed of light, at which point sync radiation is generated. Because the radiation only occurs in some moments (for example, near points b and d in Figure 1 when the magnetic field changes faster), the observed radiation is shown in the form

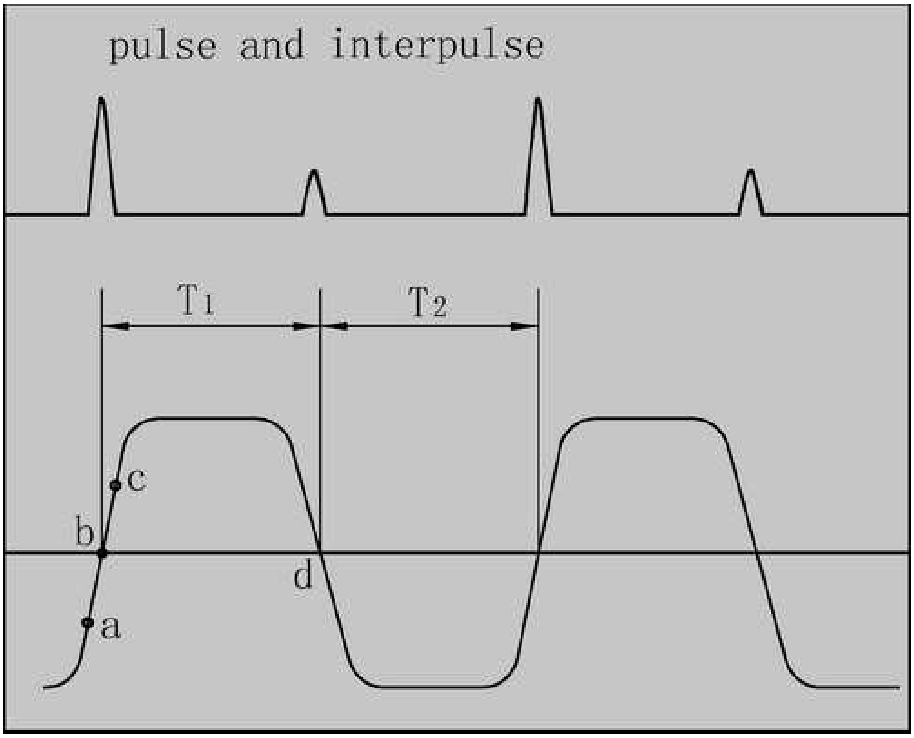

Fig. 1. Magnetic field oscillation and pulse radiation

of pulse. In a period, only one or two of the strongest pulses can usually be received. However, it cannot be eliminated that more weak components appear, such as the Crab pulsar on which there are five peaks to be observed (Moffett & Hankins, 1996).

The effect of induction voltage means that the pulse radiation is also potentially generated on the surface of pulsars, similar to the process of the generation of lightning.

The sun is a common main-sequence star. As the solar magnetic field oscillates, other main-sequence stars should also oscillate. In addition, the earth, although markedly different from the sun, also shows periodic reversals in its magnetic field. These observations lead us to believe that oscillations in the reversals of magnetic fields are a shared characteristic of all celestial bodies, including planets, main-sequence stars, white dwarfs and pulsars. The characteristics of the magnetic field oscillation of pulsars is nothing more than an extremely short time-scale of oscillation resulting from extreme physical conditions.

The latest discovery of the ultracool dwarf radiation (Hallinan et al., 2007) also indicates that the pulse radiation is not peculiar to neutron stars. For this reason, we guess that the radiation and the photometric change of all kind of celestial bodies are driven by reversal oscillation of their magnetic fields. After analyzing, we've found there is no strong evidence to negate our guess, but there are many evidences to support us.

Table 1
The oscillation time-scales of different Celestial body

Celestial body	Oscillation time-scale
earth	about 500,000 years
sun	about 22 years
magnetic variable and ultracool dwarf	several hours
white dwarf	several seconds to 1,000 seconds
pulsar	several milliseconds to seconds

Table 1 shows the oscillation time-scales of different celestial bodies.

We don't yet have a satisfactory understanding of why the magnetic fields of stars are able to oscillate. Nevertheless, the following discussion shows that the observed characteristics of pulsars are able to sufficiently explain their oscillatory nature.

3 Discussion

3.1 Polarization phenomenon

It is very difficult to use the lighthouse model to explain the reversion of rotation direction in some circular polarizations. In contrast, the MO model provides a sound explanation of such phenomena, as shown in Figure 2. According to the MO model, the accelerated particles revolve around pulsars along the latitude. As we know, these particles are able to radiate circularly polarized wave along the axial direction and as a linearly polarized wave along the plane of the equator. If our line of sight is superposed with the axial line, the circular polarization can be seen, whereas if our line of sight is perpendicular to the axis, the linear polarization can be seen. If the line of sight is neither perpendicular nor parallel to the axis, the elliptical polarization can be seen. Therefore, the polarization characteristic depends on the angle between the spin axis and the line of sight. Because the rays must pass through the pulsar's external magnetosphere when traveling away from the pulsar, the light wave generates Faraday rotation, leading to a change in the polarization parameter. The time at which the rays pass through the magnetosphere is the period when the magnetic field reverses. At this time, the intensity of the magnetic field is alternately weakening and strengthening. Therefore, Faraday rotation changes the position angle of the linear polarization to an S form.

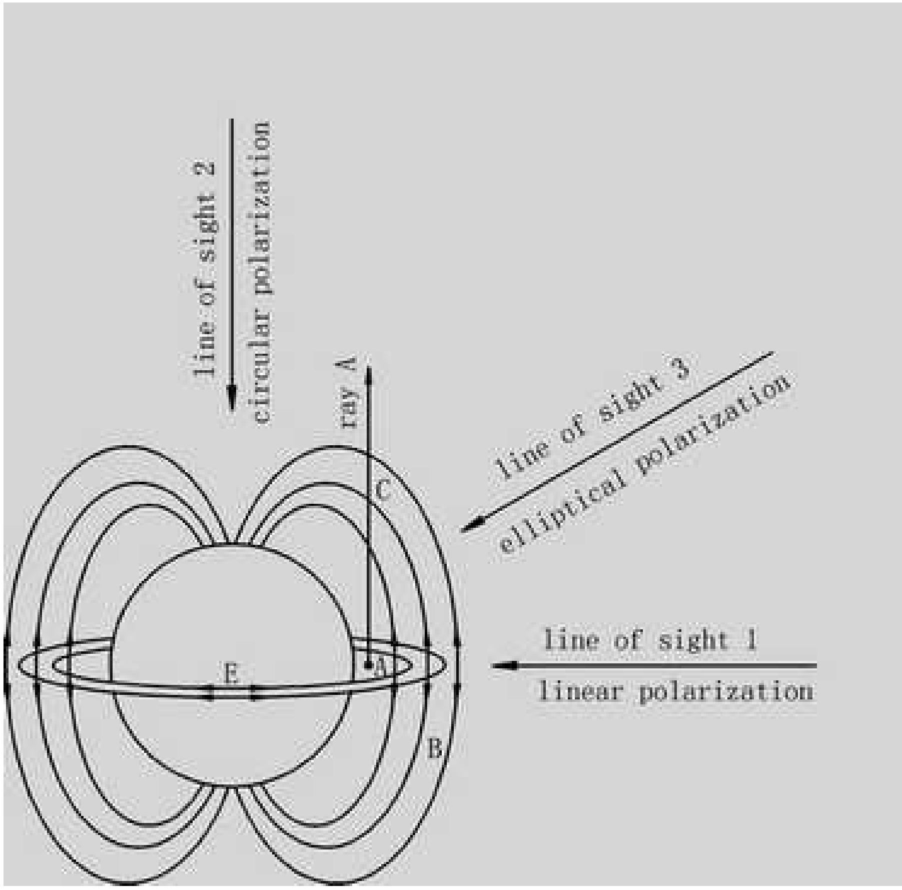

Fig. 2. Relationship between the spin axis, line of sight and polarization characteristics

The rotation direction can also reverse in the circular polarization. Of course, the magnetic field does not vary exactly according to sine, and it is not certain that the radiation appears exactly when the magnetic field reverses through the zero point. Accordingly, the actual change in the polarization is much more complicated.

As shown in Figure 2, the radiation of the linear polarization can retain its high linear polarization degree when the ray passes through the magnetosphere transversally, though its position angle changes in the S form. However, when ray A in region C passes through the magnetosphere transversally, the anisotropic properties can change the circular polarization into elliptical polarization. Therefore, the observed circular polarization degree is always lower.

3.2 Configuration of pulsar-wind nebula

If there is a pulsar within a supernova remnant, it will be possible to view a pulsar-wind nebula(PWN) using the Chandra telescope. The lighthouse model states that the radiation particles of pulsars are distributed in a configuration that resembles two cones placed tip to tip, as shown in the upper-left panel of Figure 3. When this structure is observed from direction B, not only the hyperbola bright faculae shown in panel B can be seen, but the pulse signal from pulsars can also be received. If observed from directions A or C, only the PWNs can be seen, as in panels A and C in Figure 3; no pulse signal is received because the beams of light do not sweep over the earth in these two cases.

The picture of the supernova remnant taken by the Chandra telescope does not support the conjecture of the lighthouse model.

3.2.1 In all of the remnants within which pulsars have been found, such as Crab and Vale, the bright hyperbola faculae shown in panel B of Figure 3 has not yet to be found.

3.2.2 In all of remnants within which no pulsars have been found, the faculae shown in panels A and C of Figure 3 have not yet to be found either.

According to the MO model, during reversal of the magnetic field the speed of the particles is extremely high. When the particles are accelerated circularly within the equatorial plane, they move outward under the influence of inertial force, while the magnetic field goes through zero point with a very weak intensity. Accordingly, a rotiform particle distribution forms around pulsars. In addition, the MO model predicts that the magnetic axis of pulsars always basically aligns with its spin axis. Therefore, trumpetshaped magnetic lines should occur near the poles, and some particles should flow out from the polar region along the magnetic lines to form an axial particle distribution. Figure 4 shows a distinct rotiform and axial configuration, and the pulsar is located in the center of the nebula disk rather than at the apex of two coins. This image strongly supports the validity of the MO model.

The MO model can well explain the filaments and the annular structures in PWN. The particles around a pulsar move outward by the action of an annular induced electric field. Where the particles are dense, each particle obtains less energy and the moving speed is lower, whereas, where the particles are thin, it can get more energy and the moving speed is higher. That is, the denser the particles, the lower the speed; the thinner the particles, the higher the speed. In this way, the thin particles chase the dense particles and accumulate to form a lot of filaments. Then, the filaments accumulate to form denser annular structure. The filaments and the annular structures are very clear in

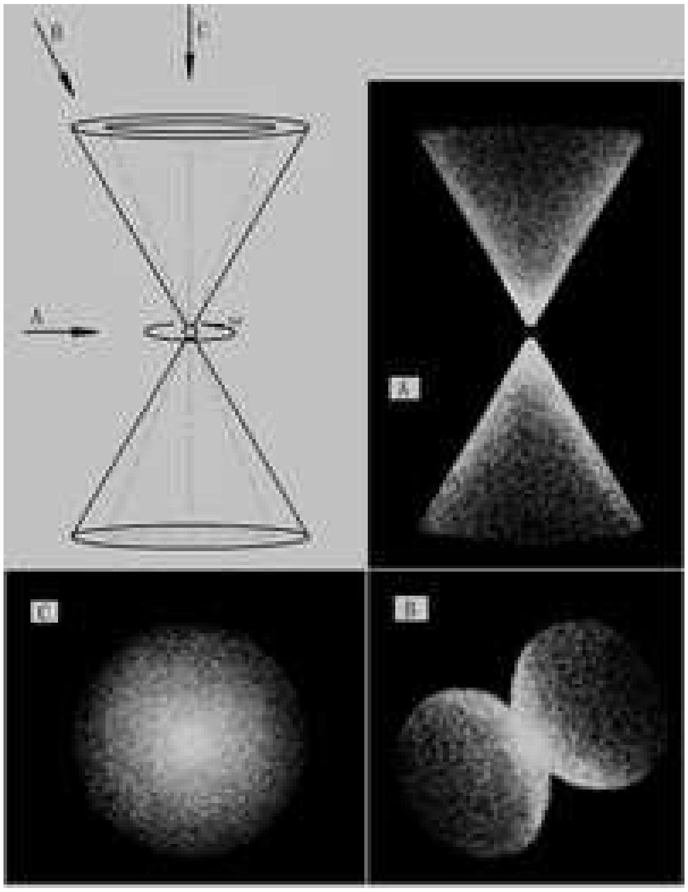

Fig. 3. Configuration of the PWN

Crab and Vela nebulas.

3.3 Frequency and stability of the frequency

At first glance, it is almost unimaginable that the reversal frequency of the pulsar magnetic field is so high; however, as long as we consider that the reversal period shows a positive correlative with the stellar capacitance and induction capacity, and a negative correlative with the rotating speed and temperature, then a millisecond-level oscillating period is plausible for pulsars.

Our proposal is that the factors that control reversals of the stellar magnetic field are the stellar components, geometric dimension, rotating frequency, temperature, and charge radiant rate, rather than the very random behavior of eddies. Because these factors have very high long-term stability, the reversal frequency of the stellar magnetic field must have a very high long-term stability. If one insists on explaining the origin and reversal of the magnetic field using eddy-current generator theory, it would be problematic to explain both

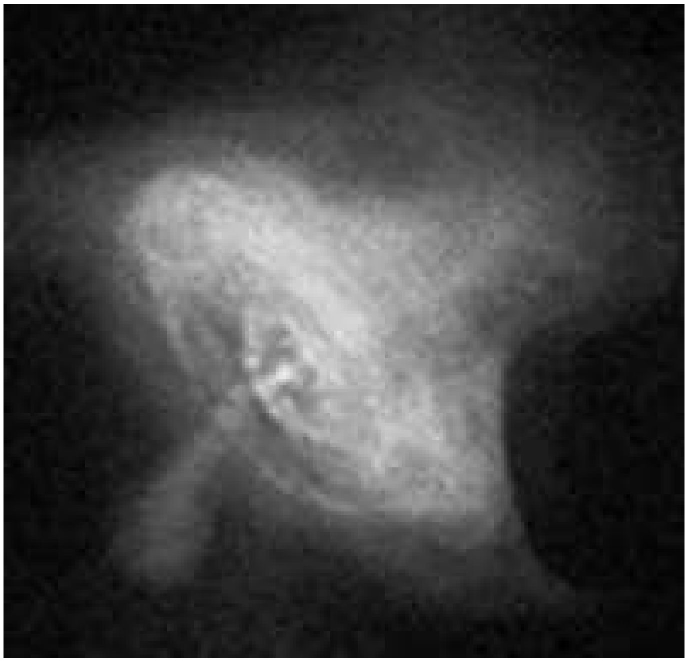

Fig. 4. PWN of Crab (Weisskopf et al., 2000)

the frequency stability of the pulsars and the frequency stability of the solar cycle.

On earth, the fundamental reason for the lower frequency accuracy of all kinds of electromagnetic oscillations is that there is no way to completely eliminate environmental interference. On pulsars, there is no such environmental interference at all: they are all isolated systems within empty space. Therefore, it is normal for pulsars to have a very high accuracy in frequency. The accuracy of the sun's oscillation is possibly degraded by nuclear reactions that take place within the sun. In the absence of nuclear reactions within pulsars, the oscillation of magnetic field to be powered by only rotating energy means that a very high accuracy is easily maintained.

It is important to ask why the accuracy of the solar magnetic field period is lower than that of pulsars. One of the reasons is that there are just 11 periods (22 half- periods) in which to record oscillations in the solar magnetic field. If only 11 signal periods of a pulsar are considered, the resulting period accuracy is also very low, probably approximately the same as that of the solar period. This indicates that there is no clear difference between the short-term stability of the sun and that of pulsars. There is presently no way of knowing the long-term stability of the sun. Once we are able to make billions of records of solar periods, we will be able to calculate the long-term stability of the sun and the solar periods to a very high degree of accuracy.

There is no comparability between the short-term stability of the solar period and the long-term stability of a pulsar period. Therefore, the validity of the MO model can be assessed by comparing these two features.

3.4 Glitch

The lighthouse model considers that the glitch is the result of a sudden change in the period of rotation. The model provides three explanations of why the period of rotation changes, but problems remain with these explanations.

Impact of extraneous objects. If the change in the period of rotation is considered to result from the impact of extraneous objects, there is no way of explaining the recovery of the rotating velocity after it has sped up.

Change in the rotating inertia. If it is considered that the change in the period of rotation results from the change in rotating inertia, we must consider (1) why the rotating velocity always increases first and then decreases, (2) why it always increases rapidly but decreases slowly, and (3) why no adverse phenomenon takes place. It is very difficult to explain these questions. In addition, before and after the glitch, the moment of momentum is conservative, yet the rotating energy is not conservative. It is necessary to transform other energy into the rotating energy. During the slow recovery process, the increased part of the rotating energy has to be completely transformed into other forms of energy. It is very difficult to associate this reversible energy transformation with a catastrophic event such as an impact or starquake.

Exchange of momentum between the inner matter and the outer shell. If the exchange of momentum between the inner matter of pulsars and the outer shell cause periodic glitch, there must be a differential rotation between the inner and outer matter. However, differential rotation contradicts the fixed inclination, unless the magnetic field is only installed on the thin shell and has nothing to do with the inner matter, the lighthouse model cannot justify itself.

In contrast to the lighthouse model, the MO model provides a much more simple explanation of the glitch. The MO model considers that the frequency of pulsar oscillation is most closely related to atmospheric temperature. When the temperature rises, the frequency also increases. The main cause of the period glitch is the sudden change in the magnetospheric temperature of pulsars, mainly caused by the impact of extraneous objects. These catastrophic events result in a rapid increase in temperature followed by a slow decline. Accordingly, the oscillation frequency always increases rapidly and then decreases slowly. The recovery speed of the frequency depends on the recovery speed of the temperature. If more heat is produced in the atmosphere and the heat diffuses into the inner part of the pulsar, a clear change occurs in the temperature of the celestial body and the frequency will not recover completely.

The collision of extraneous objects can lead to a change in the rotating period with increasing temperature. This change generally features a sudden increase rather than a slowing down. Because most extraneous objects are the outer substances of pre-stars, as with the planets of the solar system, their rotating direction is identical to the direction of pulsar rotation. Therefore, collision will inevitably accelerate the rotation rate of a pulsar. It is hypothesized that the oscillation frequency shows a positive correlation with the rotating frequency. In this case, the collision will first cause the rotation velocity to suddenly increase, and then the sudden increase of the rotation velocity results in a sudden increase of the oscillating frequency. This sudden increase in oscillating frequency cannot recover. That is, the glitch caused by the collision can be divided into two parts: a recoverable part and an irrecoverable one.

Starquakes can also cause glitch; however, in this case it first leads to a direct and immediate change in both the rotating period and temperature, followed by an indirect change in the oscillating frequency via the changes in rotation and temperature.

3.5 Birth-rate of pulsars

Observations of the Galaxy indicate that a supernova outburst is unable to create a large number of pulsars. The difference between estimates of the lighthouse model and observations is one digit. If the MO model is accepted, there is no such difference because the MO model does not recognize those pulsars that are concealed because their beams of light do not sweep over the earth. Therefore, the number of pulsars estimated by the MO model is far smaller than that estimated by the lighthouse model. The number of pulsars estimated by the MO model is more approximate to the number actually observed.

3.6 Spin down and age

The fact that the pulsar period increases over time and that calculated ages are consistent with observed ages is considered to represent solid evidence of the validity of the lighthouse model; however, as long as we consider that the oscillating frequency of the magnetic field shows a positive correlation with its rotating velocity, these observations are also entirely consistent with the MO model.

3.7 Pulse nulling, beat and pulse drift

Some pulsars have pulse nulling, beat, or pulse drift. The MO model provides two explanations for the occurrences of these phenomena.

The first reason is the change of the magnetosphere environment. The condition of the magnetosphere is not uniform, with structures similar to sunspots drifting within the magnetosphere. This heterogeneity can lead to continuous changes in the electromagnetic environment of the sparking region. At times, when it is easy to spark, the pulse will appear early; however, at times when it is not easy to spark the pulse will appear a little late. The continuous change in the electromagnetic environment can lead to a change in the strength of the single pulse. The pulse fluctuation is occasionally strong enough to have nulling. The resulting pulse fluctuation is largely random. Nevertheless, if the period of the change in electromagnetic environment is close to an integral multiple of the pulse period, phenomena termed beat or pulse drift will appear. The frequency of the pulse will directly reflect the oscillating frequency of the magnetic field, and the periods of the beat or the pulse drift will provide indirect information on changes in the period of the electromagnetic environment.

The second reason is the defilade function of pulsars. If the pulsar has a hard shell and anomalous structures such as hills on its surface, radiation will occur at places where it is easy to spark. If the sparking spots are fixed to smaller regions, they will be obscured from sight when the pulsar rotates and the regions are located on the back of the celestial body; pulse nulling will then appear. If the sparking region is larger than 180° in longitude, only the fluctuation in the pulse strength occurs, with no defilade phenomenon. The pulse frequency of pulsars shows a positive correlation with spin frequency, although the two are generally not equal and sometimes they can be significantly different. If the pulse frequency happens to be close to an integral multiple of the pulsar rotating frequency, beat phenomenon will also appear.

It is noteworthy that beat or pulses drift is a typical modulation phenomenon between waves. When two waves with different frequencies modulate, if one period is close to another, the drift will appear; if the difference of two periods is an integral multiple, beat will appear. However, only a few pulsars show the clear modulation feature and the spin modulating effect might be very slight for the most of pulsars. A significant example for slight modulation is the 1/60 Hz signal in Crab (Čadež et al., 2001). We insist that the 1/60 Hz signal is the spin signal, though it has been explained as free precession effect.

Beat and pulse drift demonstrate that there are at least two periodic phenomena with different frequencies on a pulsar; however, a basic hypothesis of the lighthouse model is that all of the substances and magnetic field on pulsars should co-rotate with the stellar body. According to this hypothesis, there is only one frequency: spin frequency. Nevertheless, a second hypothesis that is invoked when the lighthouse model explains drift is that particles in the magnetosphere revolve relative to the magnetic axis. These two hypotheses are clearly contradictory. As the MO model does not require a hypothesis of magnetosphere co-rotation, no self-contradiction occurs.

3.8 Rate of energy loss in rotating

According to the MO model, the factor that controls particle acceleration is the rate of change of the magnetic flux, rather than the strength of magnetic induction. When the magnetic field density changes through the zero point, the majority of the magnetic energy changes into electric field energy to accelerate the particles; the rate of energy utilization is much greater than that described in the lighthouse model. It is therefore possible that the intensity of the pulsar magnetic field is much weaker than that predicted by the lighthouse model. During reversal of the magnetic pole, the magnetic field energy first changes into electric field energy, with part of the electric field energy being radiated out or taken away by particles before most of the electric field energy changes back into magnetic field energy. Therefore, only a small part of the energy radiated out or taken away is needed to be supplemented with the rotating energy.

In addition, the MO model doesn't recognize dipole radiation, and the previous method used to estimate the magnetic field intensity no longer has any effect. After taking these changes into account, it is necessary to use a new method to estimate the rate of the loss of rotating energy. During the time that it takes a new estimation method to be formulated, the question of the rate of the loss of rotating energy is not a sound or sufficient reason to reject the MO model.

3.9 Interpulse

It is difficult to explain the interpulse using the lighthouse model, especially the interpulse of the Crab pulsar. From Figure 4, the angle between the spin axis and our line of sight is estimated to be about 60°. According to the lighthouse model, it should have no interpulses at this angle. Howevere, the Crab pulsar does have an interpulse. Therefore, the image of the Crab pulsar does not support the validity of the lighthouse model.

According to the MO model, the Lorentz force generated by pulsar rotation can force the electrons to reciprocate along with radius direction. This reciprocating motion can influence its electromagnetic environment anywhere within or outside of a pulsar. Periodic variations in sunspots reflect periodic changes in the electromagnetic environment. If similar variations in electromagnetic environment occur on pulsars, the pulse radiation parameter would be affected. Therefore, the parameter at point b in Figure 1 would differ from that at point d. In other words, the parameter of the odd pulse differs from that of the even pulse; this is the odd-even difference. In addition, if T_1 is not strictly equal to T_2, or if the slope of the magnetic flux variation at point b is not equal to the slope at point d, the odd-even difference is also generated. The odd-even difference has four kinds of representations: peak value difference, phase difference, shape difference, and polarization difference.

As we known, on average, sunspot numbers in odd periods are larger than those in even periods. If the record curve of sunspots is folded taking a period of 22 years, an interpulse appears that is similar to those of pulsars. This indicates that when the magnetic fields of stars oscillate and reverse, there will be odd-even differences in the observed data. If the radiation of pulsars originates from oscillations in the magnetic field, we would then have a satisfactory explanation for the interpulse.

The MO model predicts that the odd-even difference exists in any pulsar radiation. Nevertheless, it is true for most pulsars that the odd-even difference is so large that only the strongest interpulse is able to be observed. The MO model predicts that if the signal-to-noise ratio can be greatly increased, many new examples of interpulses are sure to be found.

Owing to interpulses mostly appearing on the young pulsars, we guess that the negative charges can be accelerated much more easily than the positive ones escaping from celestial body, it can result in the superabundance of positive charges and a departure from electrical neutrality on the old pulsars, consequently, so great odd-even difference would occur that the interpulse would be too small to be seen. In other words, it is the excursion degree of electrical neutrality that controls that the odd-even difference is great or small and whether the interpulse can be detected .

3.10 Micropulse

It is difficult to explain the fine structure of a pulse with reference to the lighthouse model. Assuming that the fine structure of each pulse corresponds to the fine structure of the radiation region, our calculations show that even if completely coherent radiation is generated in all of the fine regions, just as would occur if the array was composed of many lasers, it is impossible to generate such a fine micro-pulse.

The scattering law of laser beams is

$$\tan\beta = \frac{2\lambda}{\pi d}, \tag{1}$$

where β is the divergence angle, λ is the wavelength, and d is the diameter of the emission region.

According to equation (1), the smaller the beam diameter of the emission region, the larger the divergence angle. When the beam divergence angle β and its wavelength λ are known, the lower limit of the geometry dimension of the emission source can be calculated.

Taking PSR B1133+16 as an example, its period is 1.188 s. At the 1.65 GHz waveband, the narrowest micro-pulse width is 2 μs (Popov et al., 2002), and the ratio of the micropulse width to the pulse period is 1.68×10^{-6}; therefore, the beam divergence angle is limited to $\beta \leq 6.06 \times 10^{-4}$ degree. If the micropulses correspond to microstructures of the radiation source, the diameter of the microstructures is $d \geq 10.8$ km, which is impossible.

Special attention is drawn to the fact that the calculation above is based on completely coherent radiations. In fact, it is impossible to have completely coherent radiations in the emission region because only homogeneous light can be coherent, whereas pulsars radiate according to the power-law spectrum. For incoherent radiation, the calculation should be performed according to the area light source. Therefore, the beam divergence angle is much larger than that given above, which is not at all likely to have a micropulse with a very short time-scale.

According to the MO model, the signal of pulsars is a real time-domain signal, as with lightning radiation on earth. The characteristic of this kind of signal is that the greater the propagation distance, the weaker the signal, but the fine structure of a pulse is retained in its entirety.

3.11 Acceleration of particles

According to the lighthouse model, the charged particles are accelerated in the inner gap or the outer gap; however, there is considerable doubt concerning the presence of the so-called inner gap or outer gap. It is known that particle movement in the accelerating region neutralizes the original accelerating field. To maintain the strength of the electro field, it is necessary to supplement it with energy. The supplementary energy must be equal to that taken away by the particles. The process of the energy transformation is as follows: stellar kinetic energy ⇒ magnetic energy ⇒ potential energy of the accelerating electro field ⇒ particle kinetic energy. In these three steps, it is considerably doubtful as to whether the second step of the energy transformation is possible, as it is very difficult to explain how the energy flows continuously into and out of the small space near the magnetic pole.

According to the MO model, during reversal of the magnetic field the induced electromotive force is generated around pulsars. This induced electromotive force is the power required to accelerate the particles. The process of the energy transformation is as follows: stellar kinetic energy ⇒ magnetic energy ⇒ circle-induced electro field potential energy ⇒ particle kinetic energy. Every step in this process is certainly possible; oscillation of the solar magnetic field is completely consistent with this process although its frequency is very low. In terms of explaining particle acceleration and the energy supplement, the MO model is more credible than the lighthouse model.

3.12 Magnetic inclination

A basic hypothesis of the lighthouse model is that the magnetic inclination is non-zero; however, a simple analysis demonstrates that the magnetic inclination of a neutron star generated from a supernova explosion is equal to zero.

Before a supernova explosion, the density of inner matter within the pre-star is higher than that of the outer matter. During the explosion process, the matter of the star collapses inwards the center. As the outer matter is less dense, the contraction rate in the radius direction is higher. According to the conservation of angular momentum, after collapsing the outer angular velocity is higher than the inner one. This relative rotation between different layers means that the magnetic inclination eventually reaches zero.

The hypothesis that the inclination is non-zero requires that the magnetic field is inserted onto the solid, and that the attached body of the magnetic field does not have differential rotation; otherwise, the magnetic inclination would disappear.

The fact that the magnetic inclination is incompatible with the differential rotation is a problem for the lighthouse model because pulsars are commonly considered to have a thin shell that contains liquid, and it is therefore difficult to avoid differential rotation. The MO model is not affected by this problem, as it considers that the magnetic inclination is equal to zero.

Monaghan (1968) and several other researchers studying magnetic stars once stated that magnetic dipole radiation can cause the magnetic poles to move.In fact, this is polar motion and it is suitable for pulsars.

For pulsars, the change law of the magnetic inclination is

$$\dot{\theta} = \frac{\dot{P}}{P \tan\theta}, \tag{2}$$

or

$$\dot{\theta} = \frac{1}{2T \tan\theta}, \tag{3}$$

where θ is the magnetic inclination, $\dot{\theta}$ is the derivative of θ, $\dot{P}$ is the derivative of period and T is the characteristic age.

The equations (2) and (3) show that the magnetic inclination decreases quite rapidly when a pulsar has both a small characteristic age and a small magnetic inclination.

For example, Crab pulsar's characteristic age is about 1,240 years, and the angle between the spin axis and our line of sight is 60° (Weisskopf et al., 2000). We are sure that the magnetic inclination is also 60°, otherwise, we can not see its light beam. Substituting these data into equation (3), we find that the magnetic inclination should decrease by about 0.013° per year. If this result is authentic, the life of Crab pulsar must be less than several thousand years. If the result were not authentic, the lighthouse model which is the calculating base might be also not authentic.

The MO model considers that the moment of momentum of pulsars can be transferred to the outer mass by electromagnetic induction; there is neither magnetic dipole radiation nor the subsequent problem caused by dipole radiation and polar motion.

4 Verification method

The MO model differs significantly from the lighthouse model, and their radiation characteristics are also different. On the basis of these differences, it is easy to determine which of the two models is more reliable. six verification methods are presented below.

4.1 Effect of precession

According to the lighthouse model, the profile and the flux are strongly related to the precession angle in a binary system. On this basis, Jenet & Ransom (2004) predicted that the profile of PSR J0373-3039A would evolve considerably and it would disappear entirely over a period of 15 to 20 years. Kramer (1998) also predicted that PSR B1913+16 would disappear from our sight after the year 2025.

However,the MO model think that only the polarization parameters are strongly related to the precession, but the profile and flux are only weakly related to the precession. After the precession of the spin axis, the polarization characteristics will evolve considerably, but the flux and profile will merely show a bit little change. Therefore, the MO model makes two predictions that differ from those of the lighthouse model:

First, the polarization characteristics could evolve considerably even though the evolution of profile and flux were not obvious. Second, all pulsars will not be out of our line of sight even if the precession is very great.

After finding PSRJ0737-3039A/B, it was commonly believed that its profile could rapidly evolve. But we once predicted that its profile could not evolve obviously. At that time, we once discussed our prediction with several astronomers, but no body laid stress on our prediction. Mow, The observational results reported by Manchester (2005) are clearly consistent with our prediction.

After twenty years, whether the PSR B1913+16 disappear or not will finally determine which model is better, the lighthouse model or the MO model.

4.2 Effect of magnetic inclination evolution

The calculating result which is based on the lighthouse model shows that the evolution rate of Crab's magnetic inclination is about 0.013° per year. It is so rapid that the change of profile must be detected after hundreds years. In contrast with the lighthouse model, the MO model thinks that the magnetic inclination of pulsars is neglectable, and the profile would be changeless. After several hundred years, if the anticipative change of the profile hadn't occurred, the lighthouse model should be ruled out.

4.3 Relationship between the characteristics of polarization and the direction of the spin axis

The images of PWNs taken using the Chandra telescope (e.g. Figure 4) can help to estimate the direction of the spin axis of some pulsars from the shapes of PWNs. The relationship between the characteristics of polarization and the direction of the spin axis is given in Figure 2. This enables us to determine the relationship between the shape of PWN and the polarization. The predictions of the MO model are as follows. If PWN is cigar-shaped, as with PSR J0205+6449, the radiation will be linear polarization and the oscillation plane of the electric vector is averagely parallel with the cigar. If the shape of PWN is round, as with PSR B0540-69, the radiation will be low-level circular polarization, and if the shape of PWN is elliptical, as with the Crab, the radiation will be elliptical polarization. This relationship between polarization and the spin axis could be used to verify the MO model.

4.4 Sweep delay effect

According to the lighthouse model, when the light beams sweep over the different points on the revolving orbit of the earth, such as the spring equinox and the autumnal equinox, a time delay should exist. In other word, the light beams sweep over the autumnal equinox and the spring equinox in turn, even if the distances of two points to pulsar are absolute equal. After correcting the arrival time to the barycenter of the solar system, there is still a very small sine variety in the arrival time data. For example, the maximum delay of PSR J2144-3933 is as much as 0.24 μs. It is very difficult to measure such small time delay, but as long as the arrival time data is accumulating continuously and calculation accuracy is also improving, this measurement should be possible in the future. In contrast, the delay of far pulsars can be neglected. Therefore, correcting the revolving orbit of the earth using the data of distant pulsars can help to detect the time delay of near pulsars. This sweep delay is the most direct evidence of the lighthouse model. If this sweep delay can't be observed using methods that are highly precise enough, then the lighthouse model can be rejected.

4.5 Stability of the 1/60 Hz signal of Crab

The MO model thinks that the 1/60 Hz signal of Crab (Čadež et al., 2001) is caused by the spin modulation and the 1/60 Hz signal should surpass the 1/0.033 Hz pulse signal in stability of frequency. Therefore, making a comparison between two signals in the stability of frequency is a Verification method.

4.6 Interpulse in the young neutron stars

We guess that the SGRs are young neutron stars with weaker magnetic field. Usually, their magnetic field is oscillating, but the radiation is too weak to be observed. Only when some substances flied-out as the neutron stars forming return and bump the celestial body, and gamma radiation bursts, the oscillation of weaker magnetic field could be detected as a modulating signal. thus, we predict that all of the radiations of SGRs have the interpulse. According to the above discussionthe interpulse is closely related to the age, but has nothing to do with look angle. Therefore, we also predict that if a pulsar will be discovered in the SN 1987A in the future, it must have interpulse. If these two predictions could be proved, the guess in which the interpulse had nothing to do with the look angle would be proved at the same time. It could only be explained by the MO model, and the lighthouse model would be impuissant.

5 Conclusions

Compared to the lighthouse model, the MO model is better able to explain all kinds of radiation characteristics of pulsars, especially the characteristics of pulse polarization, the microstructure of profile, the glitch, the configuration of PWN. Although the reason why the oscillation of the magnetic field of pulsars remains unknown, its observation characteristics lead us to believe that the magnetic field oscillation should be the source of pulsar radiation.

The MO model is incapable to explain the reason of magnetic field oscillation, much less calculate the time-scale of oscillation. Therefore, a novel theory on the origin of stellar magnetic field is needed to support the MO model.

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