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A New Model of "Magnetar"

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Abstract. A new model is proposed to explain the main properties of anomalous X-ray pulsars and soft gamma-ray repeaters, in terms of drift waves in the vicinity of the light cylinder of a neutron star with a surface magnetic field $\sim 10^{12}$ G.

Several models of anomalous X-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs) have been put forward during the last 15 years: free precession of the solid neutron star (Carlini & Treves 1989), a neutron star with unusually strong magnetic fields $B_{dipole} \sim 10^{14} - 10^{15}$ G (a "magnetar") (Duncan & Thompson 1992), a single fast-rotating white dwarf with a strong magnetic field (Usov 1993), accretion onto a neutron star from the ambient medium (Israel, Mereghetti & Stella 1994; Mereghetti & Stella 1995). Now the accretion model and the magnetar are the most popular models. We propose here an alternative new model of AXPs and SGRs to explain the main properties of these objects.

We believe that the observed periods of the X-ray pulses are not the rotation periods of host neutron stars. A special type of electromagnetic waves — "drift waves" — can be generated in the outer layers of the pulsar magnetosphere (Kazbegi, Machabeli & Melikidze 1987). This mode is supplied by the energy of relativistic particles moving through the magnetosphere along magnetic field lines. Drift waves move across a local magnetic field, distort the dipole field structure, change the curvature of field lines and cause modulation of emission with the wave period. In the case of small angles between the rotation axis and the magnetic moment we will see almost continuous radiation and pulsed component. The period of such pulses,

$$P_{dr} = \frac{2\pi}{\omega_{dr}} = \frac{\lambda}{u_b}, \tag{1}$$

is determined by the beam drift velocity,

$$u_b = \frac{c^2\gamma_b}{\rho\omega_b}, \tag{2}$$

where ρ is the radius of curvature of the field line, γ_b is the Lorentz factor of beam particles and $\omega_b = eB/mc$ is the cyclotron frequency.

The wavelength λ can be identified with the radius of the light cylinder $r_{LC} = cP/2\pi$. Assuming $\rho = r_{LC}$, we find:

$$P_{dr} = \frac{eBP^2}{4\pi^2 mc\gamma_b}. \tag{3}$$

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The pulse periods for AXPs and SGRs are of order 10 s. So, if $\gamma_b = 10^6$, the following condition must be fulfilled:

$$BP^2 = 22.45\,Gs^2. \tag{4}$$

We suggest that the surface magnetic field is $B_s \sim 10^{12}$ G. Then $B \sim 10^3$ G for the dipole structure and distances $r \sim 10^3 R_{ns}$. The period of rotation of such a star should be $P_r = 0.15$ s. We obtain from Equation (3):

$$\dot{P}_{dr} = \frac{eB}{2\pi^2 mc\gamma_b} P\dot{P}, \tag{5}$$

and for the parameters considered, $\dot{P} = 7.5 \times 10^{-3} \times \dot{P}_{dr}$. AXPs and SGRs are characterized by values $\dot{P}_{dr} \sim 10^{-10}$, i.e., $\dot{P} = 7.5 \times 10^{-13}$.

The rate of loss of the neutron star's rotational energy

$$\dot{E} = \frac{4\pi^2 I\dot{P}}{P^3} \sim 10^{37} \text{ ergs s}^{-1}, \tag{6}$$

is sufficient to explain the X-ray luminosities of AXPs and SGRs and the injection rate of relativistic electrons in the ambient supernova remnant. The total rotation energy of such a neutron star ($\sim 10^{48}$ ergs) is quite enough to supply $\sim 10^4$ gamma-ray bursts during the life of this star.

We can see that our model allows the possibility of describing the main properties of "magnetars" within the framework of usual concepts of pulsar magnetospheres. This model is probably useful for the description of all radio pulsars with pulse periods $P > 5$ s.

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References

Carlini, A., & Treves, A. 1989, A&A, 215, 283

Duncan, R. C., & Thompson, C. 1992, ApJ, 392, L9

Israel, G. L., Mereghetti, S., & Stella, L. 1994, ApJ, 433, L25

Kazbegi, A. Z., Machabeli, G. Z., & Melikidze, G. I. 1987, Aust. J. Phys., 44, 573

Mereghetti, S., & Stella, L. 1995, ApJ, 442, L17

Usov, V. V. 1993, ApJ, 410, 763