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ASTRONOMIE

OPEN-CLOSED CAVERN AROUND NEUTRON STAR IN BINARY SYSTEM[1]

R. K. Zamanov

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The analysis of the evolution of the massive binary stars [1,2] have shown that a substantial part of the neutron stars in binary systems must be in Ejector regime. In this case the surrounding plasma is stopped by the electromagnetic waves and the high energy particles produced by the neutron star (for details see [3]). A cavern forms around the neutron star, where the wind of the primary can not penetrate. Two forms of the cavern are possible – a closed cavern or an open cavern [4]. Here we shall show that at an eccentric orbit it is possible the cavern to be closed at the periastron and to be opened around the apastron. This can produce periodic radio outbursts from a neutron star in binary system.

On the boundaries of the cavern will be fulfilled

$$P_{\rm ram} + P_g = P_L, \tag{1}$$

where $P_{\rm ram}$ is the ram pressure of the primary wind, P_g is the gas pressure in this wind, and P_L is the pressure of the relativistic wind generated by the neutron star. We will consider that the walls of the cavern do not reflect the relativistic wind generated by the pulsar.

We will express the gas pressure in the wind of the primary as

$$P_g = P_* \left(\frac{R_0}{R_*}\right)^{-n-2}, \tag{2}$$

where R_0 is the distance from the primary, R_* is the radius of the primary, and P_* is the pressure at $R_0 = R_*$.

The back point of the cavern (the outermost from the normal star) is defined by the balance of the gas pressure and the pressure of the relativistic wind of the neutron star.

$$P_* \left(\frac{d+R}{R_*}\right)^{-n-2} = \frac{L_m}{4\pi c R^2} \tag{3}$$

where d is the distance between the components and R is the distance from the neutron star, L_m is its magneto-dipole luminosity, c is the speed of light. It is clear that $R_0 = d + R$ for the back point.

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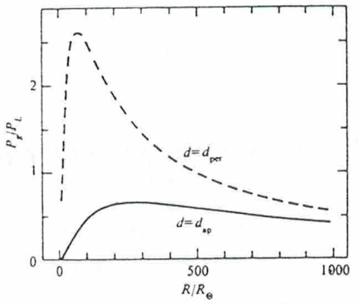

Fig. 1. The ratio P_g/P_L as a function of the distance from the neutron star. It is visible that at the periastron P_g/P_L reaches values greater than 1 and the cavern will be closed. At the apastron P_g/P_L is always less than 1 and the cavern will be opened. At the calculations it was adopted semimajor axis 0.4 AU, $e = 0.6, n = 1$ and $cP_* R_*^2 L_m^{-1} = 10.7$

If $P_g < P_L$ for every value of R, the cavern will be opened. If Eq.(3) has a positive solution, the cavern will be closed. The ratio P_g/P_L reaches a maximal value at $R = 2d/n$.

Using this we obtain that a closed cavern around the periastron and an open cavern, around the apastron, can be realized if

$$(4) \qquad \frac{16\pi c P_* R_*^{n+2}}{L_m} \cdot \frac{n^n}{(n+2)^{n+2}} \cdot d^{-n} \begin{cases} > 1 & \text{at } d = d_{\text{per}} \\ < 1 & \text{at } d = d_{\text{ap}}, \end{cases}$$

where d_{per} and d_{ap} are the distances between components at the periastron and at the apastron respectively. Equation (4) can be fulfilled if $n > 0$ and at appropriate values of the parameters P_*, R_*, L_m.

We must note that for $n = 0$ (isothermal wind) the possibility discussed here [illegible] not be realized.

At the change of the form of the cavern from closed to open, the size of the region dominated by the relativistic wind will increase and will probably cause an enhancement of the radio synchronous luminosity. It can be considered as a possible reason for the periodic radio outbursts observed from Cir X-1 [5] and from LSI+61°303 [6,7].

In Table 1 are shown binary parameters and the calculated values of the magneto-dipole luminosity necessary for a change of the cavern's form during every orbital period. Adopting $n = 1$ and $n = 2$, the expected magneto-dipole luminosities are of the order of $10^{36} - 10^{37}$ erg s^{-1}. This corresponds with the luminosities of the young neutron stars.

It was supposed [4] that the cavern's walls can reflect a part of the relativistic wind. In this case the transition from closed to opened cavern will be possible at lower values of the luminosity of the neutron star.

Table 1

The necessary magneto-dipole luminosities for an open-closed cavern

	LSI+61°303	Cir X-1
Semimajor axis	6×10^{12}	8×10^{12} cm
Eccentricity	0.6	0.6
Primary Sp	BOV	OB supergiant
R_*	7×10^{11}	2×10^{12} cm
P_*	2×10^{3}	1×10^{3} din cm^{-2}
n	1	2
L_m	$(4-16) \times 10^{36}$	$(2-40) \times 10^{36}$ erg s-1

The parameters of the stars are from [9–11].
The gas pressure is taken from [12].

To conclude we can say that the Ejector-Propeller model for LSI+61°303 [8] successfully explains the radio outbursts. But the proposed transition, from closed to an open cavern, can also be considered as a possible reason for a periodic modulation of the radio light curves from binary stars containing neutron star.

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National Astronomical Observatory Rozhen
POBox 136,
4700 Smoljan, Bulgaria