ON A KLYSTRON MECHANISM OF GENERATION OF VIBRATIONS IN PULSAR MAGNETOSPHERE

YU. A. RYLOV

Institute of Space Research, Academy of Sciences, Moscow, U.S.S.R.

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Abstract. It has been shown that vibrations can be generated in the electron cap of the neutron star (Rylov, 1976, 1977; Jackson, 1976) under certain conditions. The mechanism of generation is like that in a klystron. The electron gas of the cap plays the role of the klystron resonant circuit. The electron beam penetrating the electron cap and returning to the star's surface plays the role of the klystron electron beam. The bunching electron stream along the magnetic axis acts like a strongly directed antenna. The conditions in which it is possible to generate these vibrations were also investigated. The energy of the accelerated primary electrons, the frequency of radiated radio-waves and the degree of the radiation directivity are evaluated.

1. Introduction

There are many different viewpoints on the method by which pulsars generate radio emission. Analyses of different models can be found in surveys by ter Haar (1972), Ruderman (1972) and Ginzburg and Zheleznyakov (1975). In most cases the authors start from observed data and try to invent a theory for the generation of radiowaves that could explain most of the data observed. In many cases no consideration is given to the physical mechanism of radiation or the method by which energy is supplied.

In the present paper I shall not try to guess a mechanism of radio emission that will satisfy the observational data. I shall start from a simple model. Let there be a rapidly rotating neutron star of radius $R = 10^6$ cm with a strong dipole magnetic field (magnetic field at the pole $H_p = 10^{12}$ gauss). For simplicity, let the rotational axis and magnetic axis be aligned. Let the conductivity of the star be infinite and permit it to eject charged particles from its surface. We are interested in the star's magnetospheric structure and in the physical processes in the magnetosphere. The rotating neutron star shows itself to be a powerful unipolar generator. The question is: 'Can vibrations obtaining energy from the unipolar generator arise in the magnetosphere?' If the answer is 'Yes', then what is the mechanism of irradiation of the vibration energy? The initial statements of the present model are the same as those considered in the model of Goldreich and Julian (1969) (see also Ginzburg and Usov (1972), Michel (1973), Scharlemann and Wagoner (1973), Julian (1973)), but the results are different from those of Goldreich and Julian (1969). The difference was explained in papers by Rylov (1976, 1977) and Jackson (1976).

It was shown in these papers that the magnetosphere of a rotating neutron star with a dipole magnetic field consists of electron caps on the star's poles and an equatorial proton–positron belt. The electron caps are separated from the belt by a vacuum. An electron cap contains only negatively charged particles. Any protons or positrons...
which are there have fallen onto the star's surface by the effect of gravity. The part of the electron cap which is outside the light cylinder is unstable. Electrons precipitate from the top of the cap. Outside the light cylinder the electric field dominates the magnetic field. Under the influence of the electric field the precipitated electrons pass from one magnetic surface to another and return to the star's surface along the new magnetic surface, increasing their energy. The electron trajectories are shown schematically in Figure 1. Electrons falling onto the star are hard enough to generate a flow of secondary protons and positrons. The positrons are hard enough to overcome the gravitational field of the star, and escape. Thus, the flow of electrons through the electron cap takes the form of a loop. In addition, a flow of escaping electrons moves along the magnetic axis and a flow of escaping positrons envelopes it. (This is shown schematically in Figure 1.) All these flows are ultra-relativistic.

Fig. 1. Scheme of electron flows and positron flows in the magnetosphere of a neutron star.