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Pulsar Theory of Chiu, Canuto and Fassio-Canuto

IN the theory proposed by Chiu *et al.*[1,2] the radio emission from pulsars, which has a brightness temperature[3] exceeding 10^{21} °K, is supposed to be radiation from electrons having kinetic temperatures $\sim 10^5$ °K. This is a surprising suggestion because it is believed that incoherent processes cannot produce brightness temperatures in excess of the effective temperature of the radiating particles. Indeed, the belief that such a limit applies to incoherent synchrotron emission[4] led to the dismissal of that mechanism for the pulsar radiation[3]. Hence it seems that this aspect of the new theory should be examined carefully.

This black body limit on the emission stems from the intrinsic relation between emission and absorption expressed in the relationship between the Einstein A and B transition probabilities. The actual emission and absorption coefficients j_ν, $\varkappa_\nu$ involve not only the A and B probabilities but also the populations of the upper and lower states of the transition. When the ratio of these populations corresponds to a temperature T_s, the ratio of the emission and absorption coefficients is equal to the Planck function,

$$\frac{j_\nu}{\varkappa_\nu} = \frac{2h\nu^3}{c^2} \frac{1}{\exp(h\nu/kT_s)-1} \qquad (1)$$

Here j_ν is the emission per unit volume per unit frequency interval at frequency ν, and per unit solid angle in a specified direction, while $\varkappa_\nu$ is such that the fraction of the radiation flux travelling in this direction, which is absorbed in a distance ds, is $\varkappa_\nu ds$.

As is clear from the equation of transfer, the surface brightness is always less than the ratio $j_\nu/\varkappa_\nu$ and tends to $j_\nu/\varkappa_\nu$ as the optical depth tends to infinity. Thus while j_ν and $\varkappa_\nu$ are related by equation (1) the brightness never exceeds the brightness of a black body of temperature T_s.

In the mechanism proposed by Chiu and Canuto the radio emission is a new form of electron–ion bremsstrahlung which occurs in strong magnetic fields. They seem to have computed the emission for equilibrium conditions only. For a temperature of 10^5 °K they claim that the emission is sufficient to explain the observed pulsar radio emission if the absorption is assumed negligible. But in equilibrium conditions the emission and absorption are related by equation (1), where T_s is now the kinetic temperature of the electrons. The absorption cannot therefore be neglected and it will limit the brightness temperature to 10^5 °K.

In ref. 2 there is an ingenious proof that the absorption is negligible, but this proof can hardly be taken seriously. It is argued that the important direction for propagation is along the field ($\theta = 0$), and that in this direction the absorption coefficient is zero. But there is no emission in this direction, as is clear from equation (3) of ref. 2. To avoid this the authors then argue that a wave propagating at an angle θ to the field can be resolved into two components, one propagating parallel to the field and one perpendicular to the field, and that the latter cannot propagate. In other words, a wave propagating at an angle θ to the field is actually propagating along the field!

In non-equilibrium situations, although the emission and absorption are related by equation (1) the state temperature T_s need not be a measure of the kinetic energy of the radiating electrons. Indeed, for inverted populations the temperature T_s may become negative and there will be amplification[5] (maser action). Evidently anticipating criticism of the type offered here, Chiu *et al.*[1,2] suggested that the population inversion needed might occur for this process as a result of oscillations of the star. They give no quantitative discussion of the matter, however, and certainly do not prove that the absorption will be less than in the equilibrium state. Because this is the central problem for any theory that attributes the pulsar radiation to low energy electrons, we feel that it must be discussed before this new theory is considered seriously for pulsars.

We may also remark that if, as Chiu *et al.*[1,2] suggest, the radiation occurs where the plasma frequency exceeds the wave frequency it will certainly be necessary to include the effect of the refractive index of the medium in the calculation of the emission, as has been done for synchrotron emission[6,7].

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Spin Down Effects in Neutron Stars

THE discovery[1–3] that pulsar periods are continually increasing has been fairly widely accepted as convincing evidence that the pulsar clock mechanism is based on the rotation of a neutron star. We wish to discuss within the framework of this model the sudden decrease of the period of *PSR* 0833–45 during the week February 24 to March 3, 1969 (ref. 4).

The slowing down of the rotation of a neutron star presumably occurs as a result of torques applied to it through its external magnetic field. We wish to point out that these torques need not necessarily be uniformly applied to the neutron star as a whole. We imagine