The influence of Small Scale Magnetic Field on the Polar Cap X-Ray Luminosity of Old Radio Pulsars

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The influence of small-scale magnetic field on the polar cap heating by reverse positrons is considered. We use the polar cap model with steady space charge limited electron flow. To calculate the electron-positron pairs production rate we take into account only the curvature radiation of primary electrons and its absorption in magnetic field. The reverse positron current is calculated in the framework of two models: rapid and gradually screening. It is shown that some pulsars are better described by the rapid screening model and some other pulsars have better agreement with calculation by the gradually screening model.

The polar caps of old radio pulsars are heated by reverse positrons. Such positrons emerge nearby the upper plate of the inner gap, are accelerated within it and hit to the neutron star surface causing the polar cap heating. The reverse positron current is calculated in the framework of two models: rapid [1] and gradual [2, 3] screening. In the first model electron-positron plasma rapidly screens the electric field above the inner gap that leads to a small reverse positron current and hence not so large polar cap heating. In the second model small electric field exists above the inner gap. It causes a substantial increasing of the reverse positron current and hence leads to a strong polar cap luminosity L_{pc}.

The result of calculation of L_{pc} for various ratios of small scale surface magnetic strength B_{sc} to strength B_{dip} of dipolar field is shown in Fig. 1. The polar cap luminosity L_{pc} calculated in the framework of the rapid screening model is shown by slant hatched region and calculated in the framework of the gradually screening model is shown by vertically hatched region.

The discrepancy between the calculated and observed values may be due to presence of some viscous force acting on positrons. The force may be related to the radiation closed inside the gap [11] or radiation coming from deep layers of a neutron star [12].

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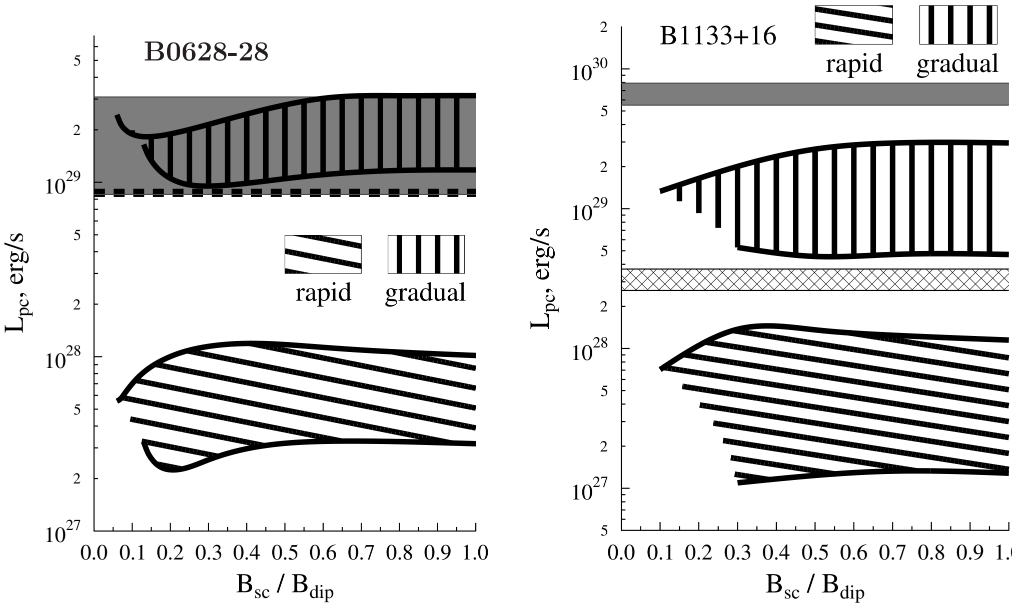

Figure 1: Left: the polar cap luminosity L_{pc} for B0628–28, $B_{dip} = 6.0 \times 10^{12} G$, $P = 1.24s$, $\tau = 2.8 \times 10^6$ years [4], inclination angle $\chi = 30°$ is taken from [5]. The observed L_{pc} range taken from [6] is shown by gray area, L_{pc} from [7] is shown by dashed line. Distance $D = 332^{+52}_{-40}$ pc is taken from [8]. Right: the polar cap luminosity L_{pc} for B1133+16, $B_{dip} = 4.26 \times 10^{12} G$, $P = 1.19s$, $\tau = 5.04 \times 10^6$ years [4], $\chi = 55°$ [9]. The observed L_{pc} value taken from [10] is shown by cross hatched area, L_{pc} range from [6] is shown by gray area.

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