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JOVIAN ACTIVE LONGITUDES AND IO-CONTROLLED DECAMETER RADIO EMISSIONS

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Abstract. In the framework of the cyclotron maser instability, supposed to be at the origin of most auroral planetary radio emissions, we have developed a model allowing a theoretical location of the Io-controlled decameter radio sources (Io-A, Io-B, Io-C and Io-D) in the central meridian longitude-Io phase diagram. We have calculated the efficiency of this theoretical mechanism at the footprint of an active magnetic field line carried away by Io during a complete revolution of the satellite around Jupiter. We make the basic hypothesis that electrons are accelerated in the neighbourhood of Io and follow an adiabatic motion along an active magnetic field line carried by the satellite. We also assume that the source of free energy needed by the cyclotron maser instability to amplify the waves derives from a loss cone distribution function built up by electrons which have disappeared in Jupiters ionosphere. In the end we give evidence of the existence of some specific longitudes in the northern and southern hemispheres favouring the radio decameter emission and leading to a higher occurrence probability. Finally we analyse the effect of several parameters on the theoretical location of the sources in the central meridian longitude-Io phase diagram: jovicentric declination of the Earth, half-angle of the beaming cone, lead angle of the active magnetic field line and frequency of emission.

1 Introduction

Long term ground observations of the jovian decameter radio emission (hereafter DAM) show that the occurrence probability of the radiation depends on two essential parameters: the central meridian longitude (CML, System III) which is linked to the rotating magnetic field and the orbital phase of the satellite Io (Bigg 1964). The CML-Φ_{Io} diagram, which displays the occurrence of the emission as a function of the CML and Φ_{Io}, reveals several zones of enhanced occurrence probability which have been named Io-controlled sources: Io-A, Io-B, Io-C and Io-D (Carr and Desch 1976). In a recent paper (Galopeau et al. 2004), within the framework of the cyclotron maser instability, which is supposed to be the mechanism at the origin of most non-thermal planetary radio emissions, we showed that some longitudes in the northern and southern jovian hemispheres favour the radio decameter emission and induce a higher occurrence probability.

2 Theoretical model

The generation of planetary radio emissions (in particular the jovian decametric emissions) is attributed to the cyclotron maser instability (CMI) theory introduced by Wu and Lee (1979). This mechanism is a resonant coupling between right-handed electromagnetic waves (relatively to the local magnetic field) and an electron population forming a magnetized plasma. The source of free energy needed by the CMI is contained in a positive gradient in perpendicular velocity $v_\perp$ of the electron distribution function f; i.e. $\partial f/\partial v_\perp$ must be positive in certain domains of the momentum space (Le Quéau et al. 1884a, 1984b; Ladreiter 1991).

In our model, we assume that electrons are accelerated in the neighbourhood of Io's wake and follow an adiabatic motion along an "active" magnetic field line shifted by an angle δ relatively to Io. We also suppose that some electrons disappear by collision in Jupiter's ionosphere leading to a loss-cone distribution function supposed to be the source of free energy needed by the cyclotron maser instability to produce the radiation. We also suppose that the radiation generated by the CMI is emitted at the local gyrofrequency within a hollow cone of half-angle θ, the axis of which is parallel to the gradient of the local magnetic field modulus ∇B.

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3 CML-Io phase diagram

We compute numerically the maximum growth rate of the waves ω_i as a function of the jovian longitude of the active magnetic field line along which the radio emission is supposed to occur. The calculation is made for several frequencies for both hemispheres. With regard to the DAM radiation coming from the northern and southern hemispheres, the maxima of ω_i are around 130° and 200°, respectively, defining an "active" longitude range. Two conditions are needed for the radio emission to be observed at the Earths orbit: (i) the active magnetic field line must cross the CMI active domain linked to Jupiter, and in the same time (ii) the observer must be on the hollow cone representing the beaming of the radiation.

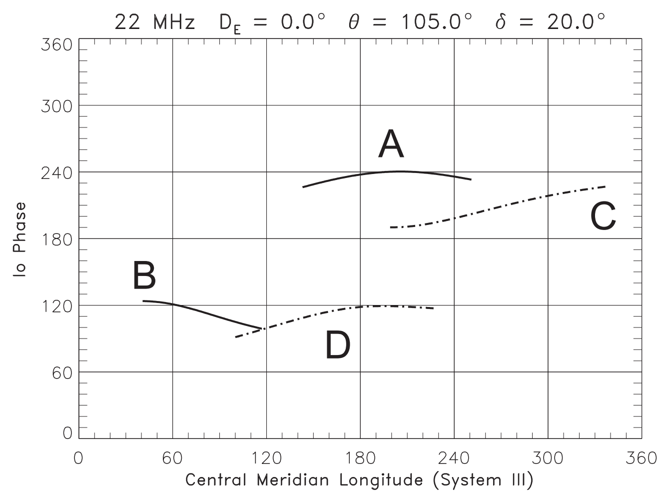

Fig. 1. Curves of high occurrence probability versus central meridian longitude and Io phase. Here the frequency is 22 MHz, the half-angle of the emission cone θ is 105°, the lead angle δ is 20° and the declination of the Earth $D_{\rm E}$ is 0°.

Four regions in the CML-$\Phi_{\rm Io}$ diagram (labelled A, B, C and D in Fig. 1) fulfill the two previous conditions and, in the same time, correspond to a maximum growth rate ω_i. These source zones can be compared to the source regions observed for the Io-controlled DAM radiation. We analyze the variation of the source occurrence region for different values of the following parameters: the lead angle δ of the active magnetic field line, the half-angle θ of the beaming cone, the observation frequency f, and the jovicentric declination of the Earth $D_{\rm E}$.

4 Conclusion

In the framework of the CMI theory, it is possible to prove the existence of an active longitude, rotating with Jupiter, and favoring the radio decameter emissions. From the model developed by Galopeau et al. (2004), we have investigated the role of some parameters on the CML-Io phase diagram. It is difficult to fit simultaneously the four observed sources, moreover our model only allows a right-hand polarization for the northern sources and a left-hand polarization for the southern ones. In our study, the location of the active longitude is governed mainly by the variation of ∇B at the footprint of the active magnetic field line.

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