THE “RADIO HORIZON” EFFECT AS A POSSIBLE EXPLANATION OF THE PLANETARY AURORAL RADIO EMISSION PHENOMENOLOGY

A. Lecacheux*

Abstract

The aim of this study is to propose a framework for explaining, in a comprehensive way, some aspects of auroral radio emissions from giant planets, which still lead to controversy. Indeed, in the cases of Jupiter and Saturn, the questions of the exact radio source locations with respect to the auroral active regions, of the beaming and polarisation of radio emissions, and of the origin of fine structures, observed at various time scales in the dynamic spectrum, remain problems mostly unsolved so far. As commonly accepted, we assume that planetary radio emissions are radiated by mildly relativistic electrons moving along auroral magnetic field lines, through cyclotron maser amplification process. Then, in a low density, magnetised plasma, — as the auroral zones are thought to be —, radio emission is radiated near the local electron gyro frequency, at large angle from the magnetic field, at a frequency just above the cut off frequency of the X-mode. Because of this cut off, the radiation cannot propagate freely, but is reflected towards the outward half space. In first approximation, the reflection layer is shaped like the iso-surfaces of the planetary magnetic field intensity. The plane tangent to the iso-surface delineates the “radio horizon” for the distant observer. The result is a very complex optical system, in which several kind of propagation effects can occur, including refraction and diffraction by both large and small scale inhomogeneities of the medium. In particular, edge focusing will develop along caustical surfaces, leading to possible strong changes of the observed properties (by diffraction), when observed from large distance at low elevation from the horizon. To support this view, three new results are presented, which combine space and ground based observations. The first result comes from the analysis of a large series of Jupiter's Io-DAM “great arcs” (about 2000 events), measured from Wind/WAVES and ground based, Nançay data, over the period 1994–2002. Assuming that the radiation corresponding to those ”great arcs” is that of the Io Flux tube itself [Riddle, 1983], one find that the radio emission can reach the observer whenever the line of sight is within 10° from the radio horizon, in each of the four possible configurations (Io's footprint at east or west limbs, in northern or southern hemispheres). The second result comes from a re-analysis

* *Observatoire de Paris, LESIA, UMR CNRS 8109, 92195 Meudon, France*

of the January 2004 HST/Cassini joint observations of Saturn's auroral emissions, at both UV and radio wavelengths [Kurth et al, 2005]. A careful comparison of available UV images with the SKR dynamic spectrum, measured at Cassini, indicates that the radio emission was intensified whenever an active auroral region was crossing the limb (i.e. the radio source came close to the radio horizon), as viewed from Cassini direction. The third result comes from direct determination of SKR arrival directions by using direction finding capability of the Cassini/RPWS experiment. By analysing the four first Cassini's closest approaches to Saturn, radio measurements suggest [Lecacheux, 2005] that observed SKR active field lines are mainly issued from eastern and western parts of the auroral oval. In discussing these results, we then suggest that visibility of the planetary radio emission, associated with an active auroral region, might be mainly determined by the passage of the line of sight through a diffracted part (a caustics) of the radio beam being refracted above the "radio horizon" of the observer. In order to check the magnitude of such propagation effects, we present a few simulations, based on various available methods. Diffraction and catastrophe theory may be first applied, in order to predict what kind of caustics is involved: one find that the expected phenomenology, when radiation is observed over a wideband spectrum, is basically due to multiple images of the radio source in the space domain and appears as nested sets of diffraction fringes in the time-frequency domain. The thin phase screen approximation may then serve, with some limitations, to quantify the contrast and appearance of those fringe systems. Finally, by using enhanced ray tracing technique as well as by searching eulerian solutions (direct wave front determination) of light propagation in an inhomogeneous, anisotropic optical medium, the various estimated effects can be illustrated. Complex and rapidly changing structures in the time-frequency domain are to be expected, depending on the radio source extent and on the relative motion of the source with respect to the observer. They might correspond, in totality or in part, to most of the modulations observed at various time and frequency scales ("arcs", "lanes", sub-second drifting features known as S-bursts, etc...). The "radio horizon" scenario might also help us to understand the high level of dependence of emission properties on small changes in observer's direction (narrow beaming and planetary spin modulation effects). Further consequences on planetary radio emission phenomenology are discussed.

References

Kurth, W.S., et al., An Earth-like correspondence between Saturn's auroral features and radio emission, *Nature*, **433**, 722–725, 2005.

Lecacheux, A., "2D-images of SKR radio sources by using Cassini/RPWS", oral presentation, EGU 2005 session PS6, Vienna, 28 Apr. 2005.

Riddle, A. C., Identification of radio emission from the Io flux tube, *J. Geophys. Res.*, **88**, 455–458, 1983.