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Multi-instrument study of the Jovian radio emissions triggered by solar wind shocks

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Abstract

The shocks in the solar wind, associated to coronal mass ejections (CME) or corotating interaction regions, are well known to trigger auroral emissions at the magnetized planets of the solar system. These auroral emissions cover a large range of wavelengths, from low frequency radio to X-rays. We concentrate on the reactions of the Jovian radio sources to the impinging of a fast solar wind shock. Many studies have been performed which shows a minor dependency of the Jovian radio emissions on the solar wind parameters, and in particular on the arrival of shocks. We use data from Nançay, Cassini and Galieo to perform a multi-instrument – and multi-point of view – study of the Jovian emissions triggered by solar wind shocks. We show that fast forward shocks have a clear and intense signature, with an onset on the dusk side of the magnetosphere. The fast reverse shocks also seem to have a particular, although less intense signature, with onsets on both sides of the magnetosphere.

1. Introduction

The shocks in the solar wind, associated to coronal mass ejections (CME) or corotating interaction regions (CIR), are well known to trigger auroral emissions at the magnetized planets of the solar system. Studies have even be performed which follows CME through the solar system by tracing the enhancements of the auroral emissions of the solar system planets [1]. The behaviour of the auroral sources in reaction to a shock differs depending on the planet – that is on its magnetosphere dynamics and on the detail of its interaction with solar wind – and depending on the wavelength. Most generally, the auroral emission intensity is modulated by the solar wind pressure, either dynamic or magnetic, but many other parameters may intervene or be modulated. We concentrate on the reactions of the Jovian radio sources to the impinging of a fast solar wind shock.

Jupiter's outer magnetosphere is sensitive to solar wind dynamic pressure variations. However, the relation of Jupiter auroral emissions to solar wind pressure is complex. Some theoretical models predict an anti-correlation between solar wind pressure and main auroral emissions [2, 3], but several observations have showed that auroral and radio emissions are enhanced during times of higher solar wind pressure [4, 5] or are triggered by interplanetary shocks [1, 6, 7, 8, 9]. Nevertheless, there are many uncertainties concerning the arrival of solar wind structures to Jupiter, which makes it difficult to determine with confidence if emissions occur during compressed or rarefied solar wind regions [7].

Contrary to Earth and Saturn, at which it has been quite straitghforward to establish the connection between the intensity of the radio emissions and the solar wind parameters, Jovian radio emissions are only slitghly dependant on the solar wind. This is easily explained by the fact that the dynamics of the giant magnetosphere of Jupiter is mostly determined by internal interactions (outgazing of the Io torus, interactions with the satellites) and only weakly by the interaction with the solar wind. Indeed, the brightest radio emissions from Jupiter are triggered by the interaction of Io with the Jovian magnetosphere. Nonetheless, there are also radio sources which are not related to satellite interactions. This type of emissions, called non-Io emissions, seems to respond to solar wind variations [4, 5, 6, 9].

2. Nançay stand alone study

In a recently published paper [10], we used a combination of Nançay observations of non-Io emissions and of solar wind parameters (magnetic field, velocity and density) propagated from Earth to Jupiter using the MSWiM code [11]. The main results of this study were that both fast forward (increase of the magnetic field and velocity) and fast reverse (increase of velocity but decrease of magnetic fied) shock in the solar wind triggered radio emissions. In case of reverse shocks, both dawn and dusk emissions are observed close to the time of arrival of the shocks. In case of forward shock, only dusk emissions are observed close to the shock arrival, and dawn emissions are observed 25 to 30 hours later.

3. Combined Nançay, Cassini and Galileo study

The study we perfom is both multi-platform – we use radio observations from Ground-based Nançay decameter array, Cassini RPWS and Galileo PWS – and multi-intrument, since we also use data from Cassini MAG magnetometer. This variety of data reveals itself important:

Nançay data are sparse (Jupiter is visible only 8 hour per day) and limited to frequencies above 10 MHz by Earth ionospheric cutoff, but have the best time and frequency resolution. Moreover, it provides full polarization states of the observations.

During the period selected for the study, Cassini is in the solar wind at a few hundreds Jovian radii in front of the Jovian magnetosphere. The Cassini spacecraft not only provides dynamic spectra from 16 MHz down to a few Hz, with more limited polarimetric capabilities, but the magnetometer measurements also provide a survey of the solar wind parameters, and in particular of the arrival of the shocks.

During the selected period, Galileo was on a long orbit and almost fixed in local time ($\sim$ 19:00 LT). Galileo provides a low frequency (<6 MHz) dynamic spectrum, which can be compared to that of Cassini, but with a 120° to 122° separation in longitude.

From these observations, we are able to confirm the previous results [10], and to study in more details the morphology and the angular motion of the radio sources associated with solar wind shocks.

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