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Imaging Jupiter Radiation Belts at Low Frequencies

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Abstract

The ultra-relativistic electrons, trapped in the inner radiation belts of Jupiter, generates a strong synchrotron radio emission (historically known as the jovian decimeter radiation (DIM)) which is beamed, polarized (∼20% linear, ∼1% circular) and broadband. It has been extensively observed by radio telescopes/probes and imaged by radio interferometers over a wide frequency spectrum (from >300 MHz up to 22 GHz). This extended emission presents two main emission peaks constantly located on both sides of the planet close to the magnetic plane. High latitude emissions were also regularly observed at particular frequencies, times and in particular observational configurations.

This region of the magnetosphere is "frozen" due to the strong magnetic field (∼4.2 G as the equator) and therefore is forced to rotate at the planetary period (T≈9h55m). Due to the tilt ($\sim 10^o$) between the spin axis of the planet and the magnetic axis (which can be seen as dipolar in first approximation), the belts and the associated radio emission wobble around the planet center.

The analysis of the flux at different frequencies highlighted spatial, temporal and spectral variabilities which origins are now partly understood. The emission varies at different time scales (short-time variations of hours to long-term variation over decades) due to the combination of visibility effect (wobbling, beaming, position of the observer in the magnetic rotating reference frame) [1], [2] and intrinsic local variations (interaction between relativistic electrons and satellites/dust, delayed effect of the solar wind ram pressure, impacts events) [3], [4], [5].

A complete framework is necessary to fully understand the source, loss and transport processes of the electrons originating from outside the belt, migrating by inward diffusion and populating the inner region of the magnetosphere. Only a few and unresolved measurements were made below 300 MHz and the non-systematic observation of this radio emission, at different epochs only provided, each time, glimpses of the spectral content in different observational configurations. As the synchrotron emission frequency peaks at $\nu_{max} \propto E^2B$ (with ν_{max} in MHz, E, the electron energy in MeV and B, the magnetic field in Gauss), the low frequency content of this emission is associated with low energy electron populations inside the inner belt and the energetic electrons located in regions of weaker magnetic field (at few jovian radii). Therefore, there is much interest in extending and completing the current knowledge of the synchrotron emission from the belts, with low frequency resolved observations.

LOFAR, the LOw Frequency ARray (LOFAR) [6], is a giant flexible and digital ground-based radio interferometer operating in the 30-250 MHz band. It brings very high time ($\sim \mu$s), frequency (∼ kHz) and angular resolutions (∼1") and huge sensitivity (mJy). In November 2011, a single 10-hour track enabled to cover an entire planetary rotation and led to the first resolved image of the radiation belts between 127-172 MHz [7,8]. In Feb 2013, an 2×5h30 joint LOFAR/WSRT observing campaign seized the state of the radiation belts from 45 MHz up to 5 GHz. We will present the current state of the study (imaging, reconstruction method and modeling) of the radiation belts dynamic with this current set of observations. LOFAR can contribute to the understanding of the physics taking place in the inner belt as well as possibly providing a fast and a systematic "diagnostic" of the state of the belts. The latter represents an opportunity to give context and ground-based support for the arrival of JUNO (NASA) scheduled in July 2016 and also for future missions, such as JUICE (ESA), at the vicinity of Jupiter by the exploration of its icy satellites.

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