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LsPRESSO : "Large scale Plasma Radio Emission Simulation of Spacecraft Observations", Characterization of the Jovian Narrowband Kilometric Emission with Juno/Waves

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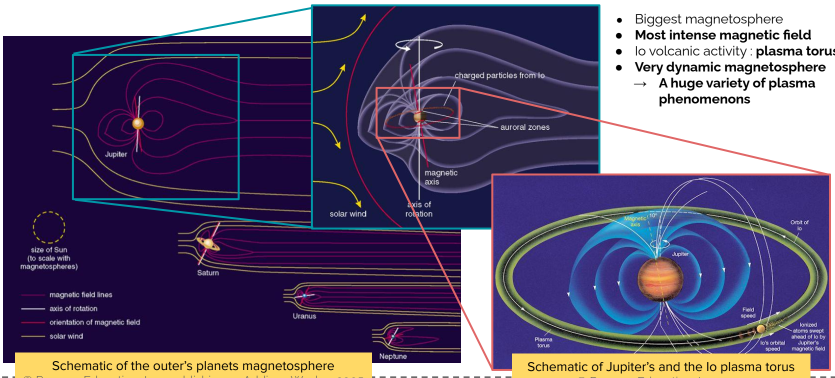
Aims

- Derive macroscopic constraints on the jovian narrow-band kilometric emissions generation mechanism, beaming & source localization :
  - We developed from scratch a large scale 3D geometrical model that simulate the observations of plasma radio emissions by a spacecraft
  - We perform a parametric study to identify the set of parameters and generation scenarios that produce compatible results with the Juno/Waves observations

Jupiter's magnetosphere : a giant natural plasma laboratory



Schematic of the outer's planets magnetosphere
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Schematic of Jupiter's and the Io plasma torus
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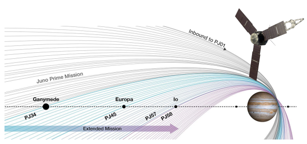
- Biggest magnetosphere
- **Most intense magnetic field**
- Io volcanic activity : **plasma torus**
- **Very dynamic magnetosphere**
  → **A huge variety of plasma phenomenons**

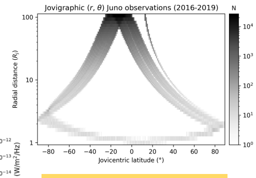
A lot of different **plasma processes** are **generating electromagnetic emissions in the radio spectrum**. Being able to **characterize radio emission and locate their radio-sources** allow us to perform **remote diagnostics of the plasma processes & the dynamic of the magnetosphere in the vicinity of the radio-sources**

The unique observations of the Juno spacecraft

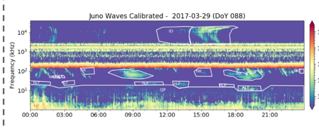


The Juno spacecraft orbit
Credit : NASA

- Mission duration : 2016 to 2026
- Polar orbit:
  → **observations at all latitudes & close flybys (~10 000 km)**



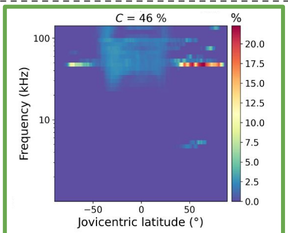
Radial & latitude distribution of the Juno observations for 2016 to 2019



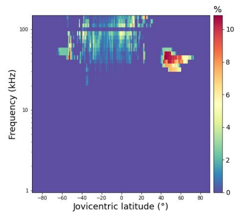
Radio observation of Juno with the Waves antennas [Louis et al. 2021]

Radio emissions produced in the plasma torus

- **nKOM** - narrowband kilometric radio emissions
  - source localization: inside the **Io plasma torus (IPT)**
  - frequency range: 10 - 160 kHz
  - **No confirmation on the generation mechanism** (probably conversion mode mechanisms)
- **Latitude & frequency distribution of the nKOM is very structured** with 2 distinct regions :
  - **Very localized maximum of occurrence in the high northern latitudes**
  - **Diffuse mimima of occurrences in the low latitudes** (around the centrifugal equator ~6.4°)



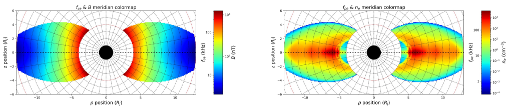
Best distribution simulated



Latitude & frequency probability occurrence distribution of the narrowband kilometric emissions for 2016 to 2019 [Louis et al. 2021]

LsPRESSO : a new method to constraints plasma radio emissions depending on their large scale beaming

- **Inputs :**
  - **Object :** Planet, environment
  - **Observer :** ephemerides, radio antennas property
  - **Generation scenarii :** emission frequency, beaming property
  - **Mode :** cutoff mode (ordinary or extraordinary)
- **Limitations :**
  - Radio waves straight line propagation
  - Permanent radio sources
- **Outputs :**
  - Observer simulated timeseries
  - Sources localization



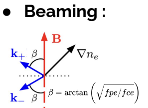
Meridian colormap of the plasma density & the magnetic field value

- **Usage :**
  - **Jupiter Medium Magnetosphere (4 to 13 Rj)**
  - **Juno/Waves observations from 2016 to 2019**

Generations scenarios for jovian plasma radio emissions

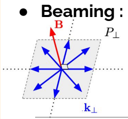
Scenario #1: Jones 1987

- **Beaming :**
- **Frequency** : f_{pe}



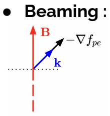
Scenario #2: Fung & Papadopoulos

- **Beaming :**
- **Frequency** : $2 f_{uh}$



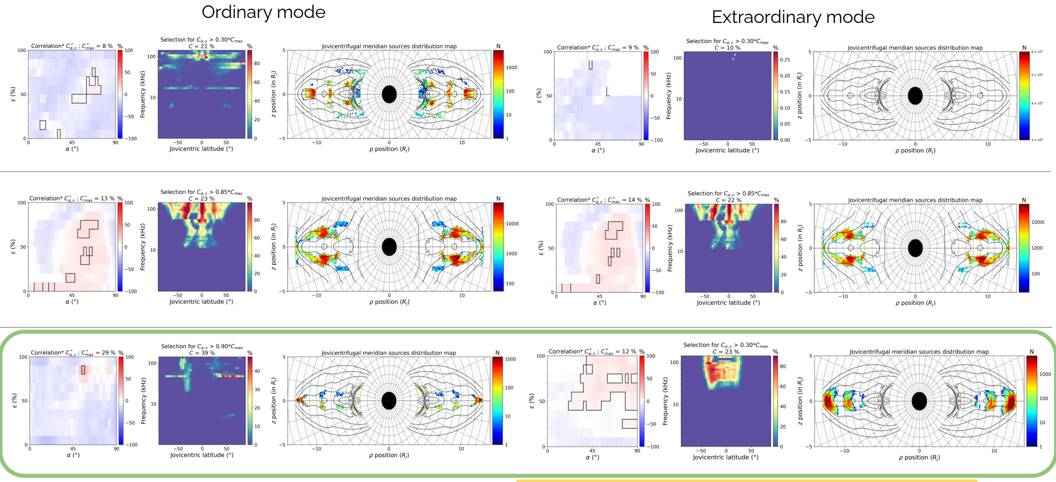
Scenario #3: Gradient directed fpe

- **Beaming :**
- **Frequency** : f_{pe}



Simulation of the Juno observation of the jovian narrowband kilometic emissions

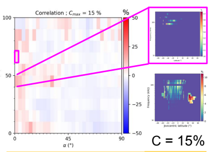
Ordinary mode — Extraordinary mode



Correlation parameter space, modeled distribution for the region contoured in the parameter space and meridian colormap with the active sources contoured for the 4 scenarios described in Sec. 4

- **2 parameters** involved in the **plasma emission generation:**
  - $angle(\mathbf{B}, \nabla n_e)$
  - $\varepsilon = percentile(\|\nabla n_e\|)$
- parameter space :
  - $\alpha \in [0, 90]^\circ$ with a step $\Delta\alpha = 3^\circ$
  - $\varepsilon \in [0, 100]\%$ with a step $\Delta\varepsilon = 10\%$

  ↳ 300 distributions per scenario



Correlation of the modeled distributions as a function of the parameters

Conclusions:

- We developed a **new method to characterize radio emissions at large scale based on the geometric distribution of the emission**
- The nKOM seems to be compatible with plasma radio emission **emitted at fpe**, **beaming along the opposite of the local frequency gradient**.
- The nKOM observed at **high latitude is compatible with ordinary mode radio emission** with their radio sources located in the inner part of the plasma torus (< 5 Rj)
- The nKOM observed **around the centrifugal equator is compatible with extraordinary mode radio emission** with their radio sources located near the centrifugal equator in the plasma torus
- **This method and model could be applied to plasma radio emissions produced by Saturn**