Numerical Modelizing of Jovian Plasma Emissions

LESIA l'Observatoire de Paris | PSL

Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

SORBONNE UNIVERSITÉ CRÉATEURS DE FUTURS DEPUIS 1257 · cnrs · cnes

PNST 2022

A. Boudouma[1], P. Zarka[1,2], C. K. Louis[3,4], C. Briand[1], M. Imai[5]

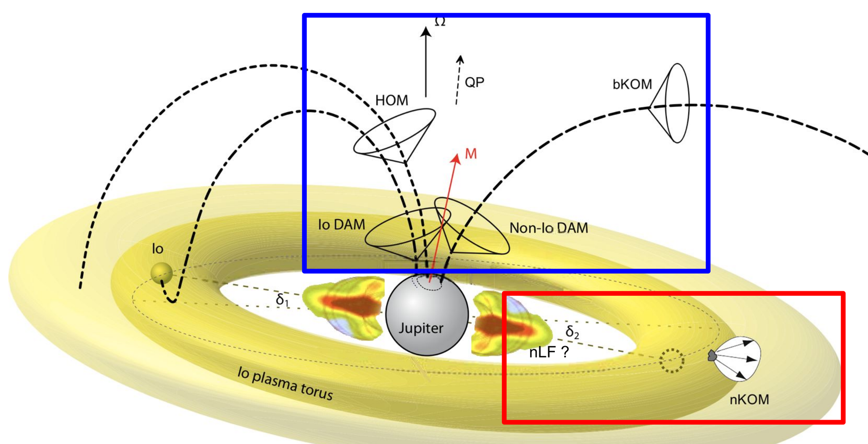
1 LESIA, Observatoire de Paris, CNRS, PSL, Sorbonne Universités, Universités de Paris, Meudon, France
2 Station de Radioastronomie de Nançay, USN, Observatoire de Paris, CNRS, PSL, Université de Orléans, Nançay, France
3 DIAS, Dublin, Irlande
4 IRAP, Toulouse, France
5 National Institute of Technology, Niihama College, Japan

Contact : adam.boudouma@obspm.fr

Aims

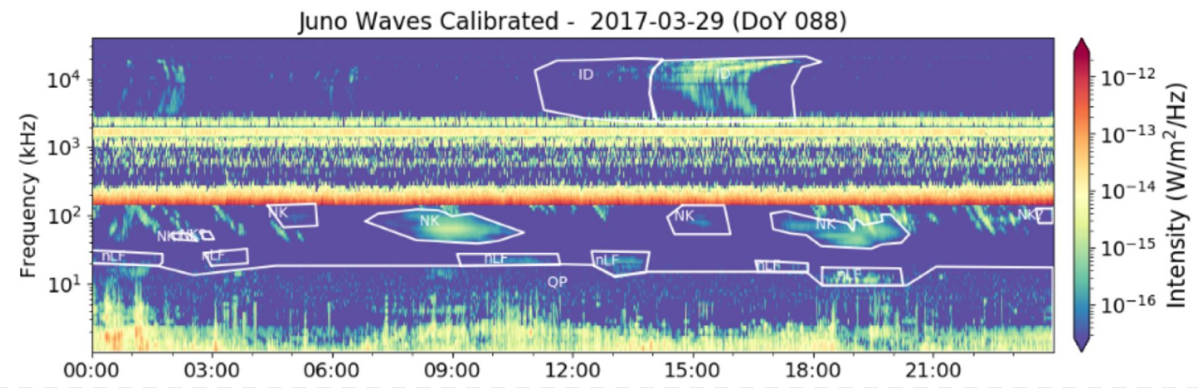
- Derive macroscopic constraints on the jovian emissions mechanism and distributions :
  - Modelize numerical plasma emissions latitude & frequency distributions from numericals and theoretical models
  - Identify and weight plasma emissions parameters on the distributions structures

1. Context



Jupiter & Io plasma torus representation with the jovian radio components

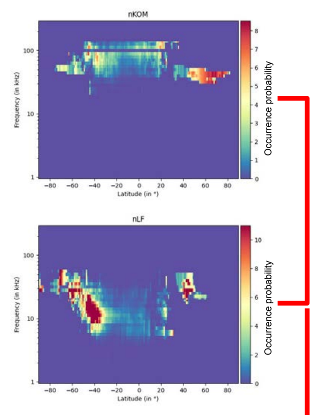
- Jovian radio emissions :
  - maser-cyclotron emissions
    - QP, bKOM, DAM, HOM
  - plasma emissions
    - nKOM, nLF ?
- Juno/WAVES characteristics :
  - **polar orbit** & **close flybys** (~10 000 km)
  - **calibrated data** from 2016 to 2019
  - **1 kHz - 40 MHz** radio observations
- Radio emissions structures are observed on a **dynamic spectra** :



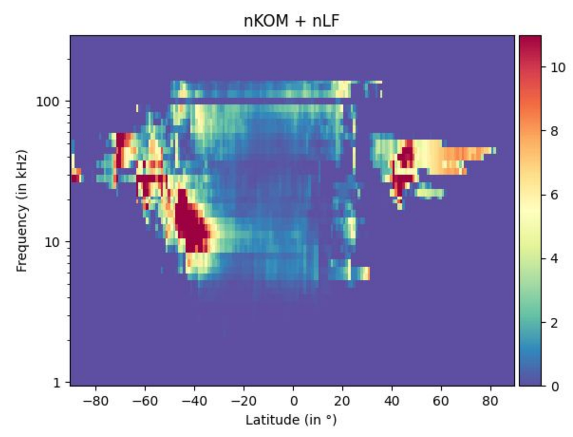
Juno/Waves 24h calibrated observations dynamic spectra with highlighted jovian component

2. Juno/Waves & nLF component

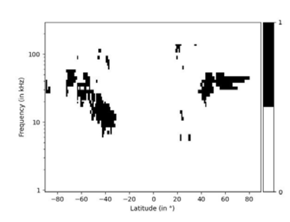
- **Latitude & frequency occurrence probability distributions :**
  - Computed with Juno calibrated data
  - Gives us information on the emissions beaming characteristics



- **nKOM & nLF** distributions share similar characteristics
- **nLF may be a plasma emissions**

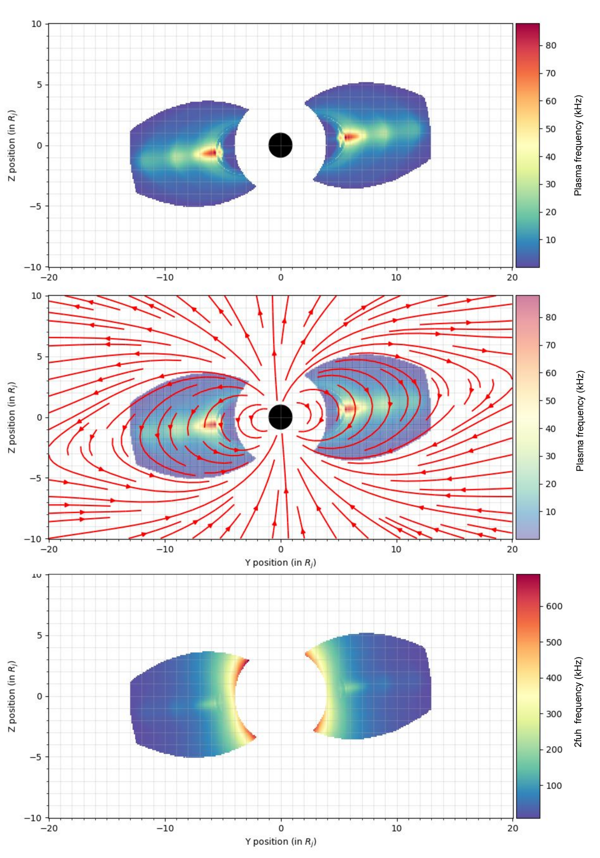


nLF, nKOM, nKOM+nLF latitude & frequency distribution from Louis et al. 2021



mask computed from the nKOM+nLF distribution highlighting the distribution structures

3. Numerical Models

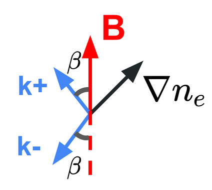


Meridian fpe colormap (in kHz), magnetic field lines & 2fuh colormap (in kHz) computed by the diffusive density model and the VIP4 magnetic field model

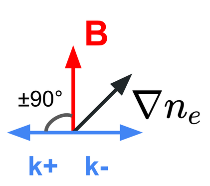
- Jupiter's intern magnetosphere :
  - **Plasma density** : diffusive density model [Imai 2016]
  - **Magnetic field + current sheet** : VIP4 [Connerney et al. 1998]
- Meshgrid parameters :
  - Volume : [-20, 20] Rj in (x,y), [-10, 10] Rj in z
  - Step : 0.1 Rj
- Constraints :
  - **Large scale** (0.1 Rj >> wavelength)
  - Plasma density model :
    - **cylindrical symmetry** (jovian centrifugal axis)
    - **restrained** to [4, 13] Rj & latitude < 80°

4. Parameters & Frameworks

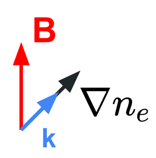
- Parameters involved :
  - $angle(\mathbf{B}, \nabla n_e)$: **emissions production**
  - $\|\nabla n_e\|$: **emissions propagation**
- Frameworks :
  - **Jones 1987 theory** :
    - frequency : f_{pe}
    - beaming :
      - $\beta = \arctan\left(\sqrt{fpe/fce}\right)$ angle with **B**
      - 2 beam in the plane $P = (\mathbf{B}, \nabla n_e)$



  - **Fung & Papadopoulos 1987 theory** :
    - frequency : $2f_{uh}$
    - beaming :
      - perpendicular to **B**
      - *we suppose 2 beam in the plane* $P = (\mathbf{B}, \nabla n_e)$

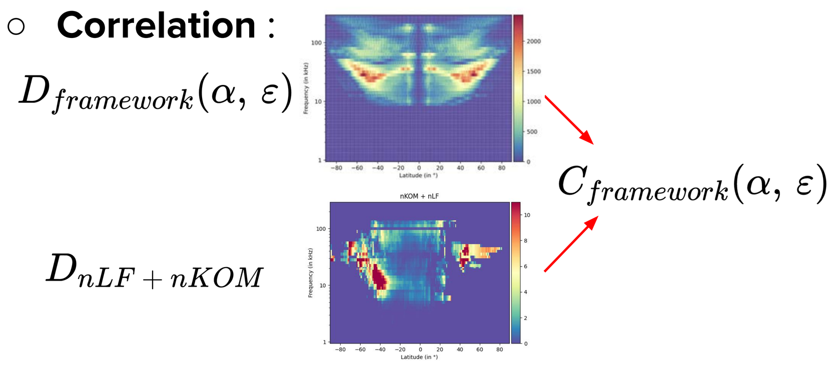


  - **Gradient directed emissions** :
    - frequency : f_{pe}
    - beaming : 1 beam along ∇n_e

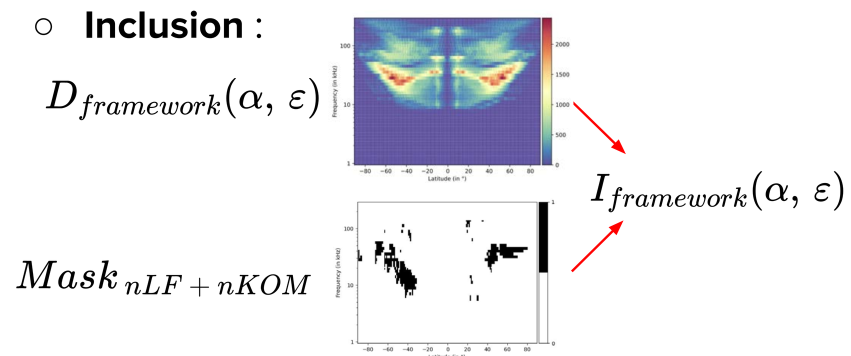


5. Distributions Comparison

- Quantitative comparison between numerical and observed distributions
  - **Correlation** :



  - **Inclusion** :



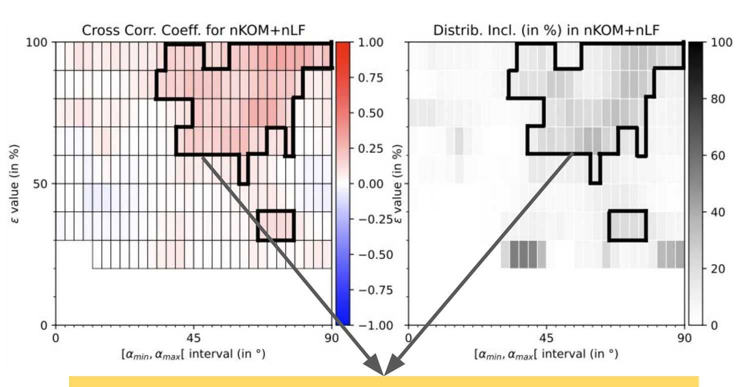
Study Hypothesis

- **Emissions Propagation**
  - Straight line (not altered by the plasma)
  - Screening by the plasma
- **Emissions Observation**
  - Infinity observer : **observation latitude = emission angle with the equator**
  - Juno observer : we consider a **sampled juno trajectory** ($\delta\theta_{Juno} = 1^\circ, \delta\varphi_{Juno} = 2^\circ$) & the emission is **intercepted by Juno if its angle with juno is** $< 1^\circ$

Parametric Study

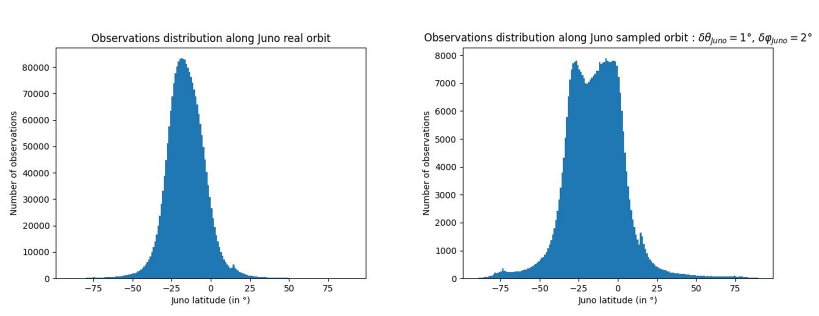
- Selection over 2 parameters :
  - $angle(\mathbf{B}, \nabla n_e)$
  - $\varepsilon = percentile(\|\nabla n_e\|)$
- For each framework :
  - $\alpha \in [0, 90]^\circ$ with a step $\Delta\alpha = 3^\circ$
  - $\varepsilon \in [0, 100]\%$ with a step $\Delta\varepsilon = 10\%$
  - ↳ 300 distributions per framework

6. Our Results



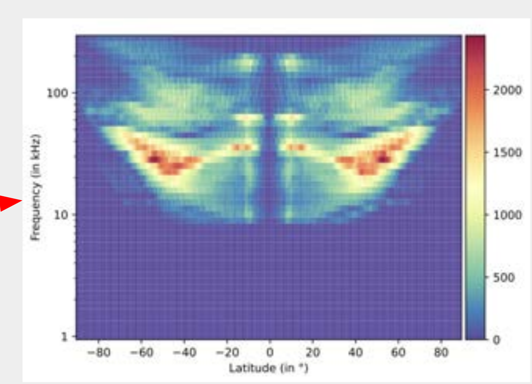
we merge the distributions where : $C > C_{threshold}, I > I_{threshold}$

- We set $C_{threshold} = 10\%, I_{threshold} = 10\%$ for all the cases except for cases 2 and 3 for the infinity observer condition where $C_{threshold} = 0\%, I_{threshold} = 0\%$

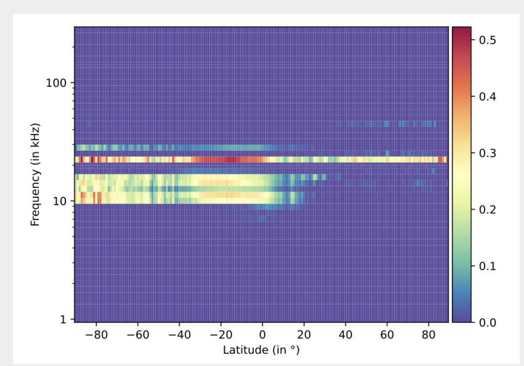


Case 1 : Fung & Papadopoulos framework

Infinity observer results : C = 44%, I = 35%

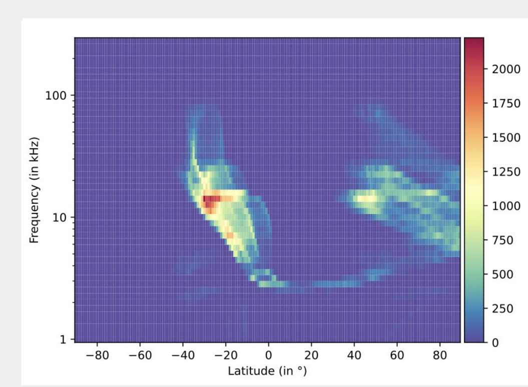


Juno observer results : C = 15%, I = 13%

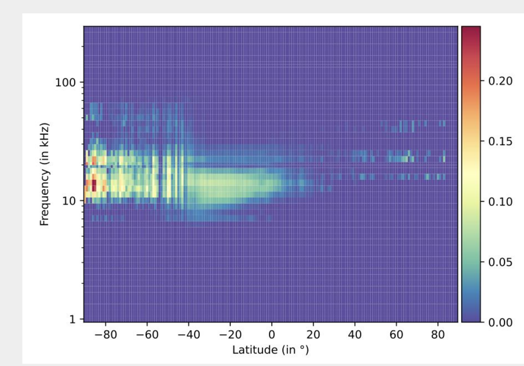


Case 2 : Jones framework

Infinity observer results : C = 4, I = 20

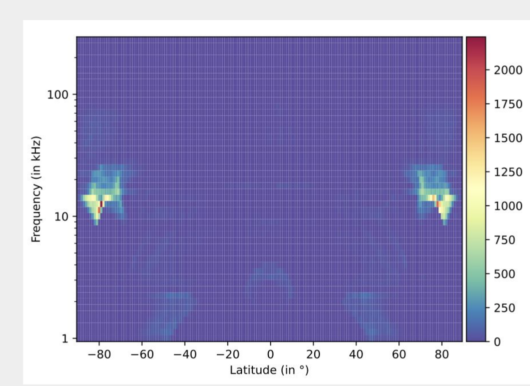


Juno observer results : C = 24%, I = 18%

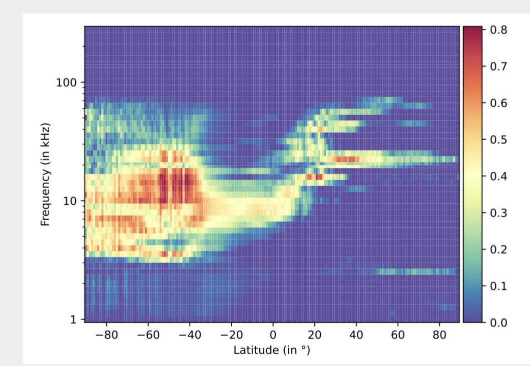


Case 3 : Gradient directed emissions framework

Infinity observer results : C = 5, I =3 %



Juno observer results : C = 31%, I = 14%



Conclusion :

- Different results between the Infinity observer & Juno observer cases : **Juno orbit effects on the observation cannot be neglected**
- Heavy numerical artifacts for Fung & Papadopoulos case when observed by Juno : **Juno interception criteria ($< 1^\circ$) may be too restrictive**
- Jones case results presents major differences with the observations :
  - **Low frequency** (< 30 kHz)
  - **High occurrence probability at high southern latitudes** (> 70°)
- Gradient directed emissions case shows the best result

Références :

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