Survey of the Nançay Decameter Array's extended catalog for the possible control of Jupiter's decametric radio emissions by Europa

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Introduction

- The jovian Auroral Radio Emissions (AREs) are partially controlled by Io, Europa and Ganymede (Bigg, 1964; Menietti et al., 1998; Higgins et al., 2006; Higgins et al., 2007; Zarka et al., 2017; Marques et al., 2017; Louis et al., 2017; Zarka et al., 2018).
- This control may be indicated by nonuniform distributions of the emissions' occurrence as a function of the satellite's phase, and the observer's longitude in relation to the jovian Central Meridian Longitude (CML).
- The AREs are produced by the Cyclotron maser instability, and therefore, are detected by an observer when their beaming cones are located on the dusk or dawn limbs of Jupiter, at the observer's rest frame, due to the cone's large mid-aperture angle (Wu and Lee, 1979). There are four possible sources' locations: A, B, C, and D (**Figure 1**).
- The source of the observed emission is defined based on the emissions' dominant polarization sense, and their arc pattern formed on the dynamic spectra.
- The 29-year-long Nançay Decametric Array's (NDA) catalog has provided statistical evidences of control of the Jovian DAM emissions by Io and Ganymede and the possibility of further selection and analysis of various jovian radio components.

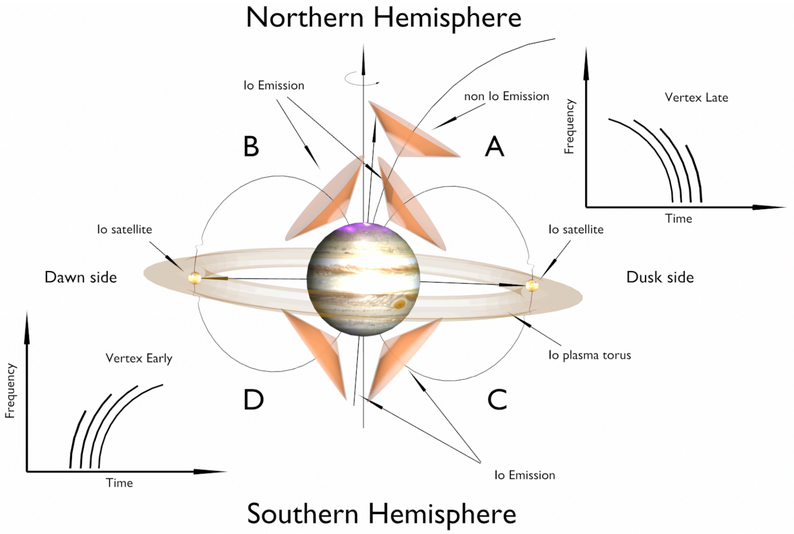

Figure 1: *Location of the beaming cones of the different components of the jovian satellite-induced radio emissions detected by an observer. The location is defi ned with regard to the observer position, which is out of the fi gure plane in the example. The emissions' dominant polarization indicates the hemisphere of origin and their arc pattern on dynamic spectra, the side of the source location. From Marques et al., 2017.*

- **This study is an extension of Zarka et al., 2017 and Zarka et al., 2018, and investigates the possible control of the jovian DAM emissions by the satellite Europa through the analysis of occurrence probability distributions of jovian DAM emissions observed by the Nançay Decameter Array (NDA) from 1990 to 2018.**

Methods

- The occurrence probability of the emissions induced neither by Io nor by Ganymede (non-Io and non-Ga) was calculated separately for each component (-A, -B, -C, and -D), and plotted (**Figure 2**) as:
  - a function of the Earth's longitude (in relation to the jovian Central Meridian Longitude - CML), and Europa's orbital phase (color plots, on the left);
  - a function of Europa's phase and the standard deviation of the probability values of the specific component's emissions (on the right).
- In the plots on the right in **Figure 2**, the standard deviation (σ) and mean were calculated over the entire phase interval alone, and its value varies for each component's plot.
- The prominent peaks of occurrence probability, in general $>1\sigma$, were highlighted.

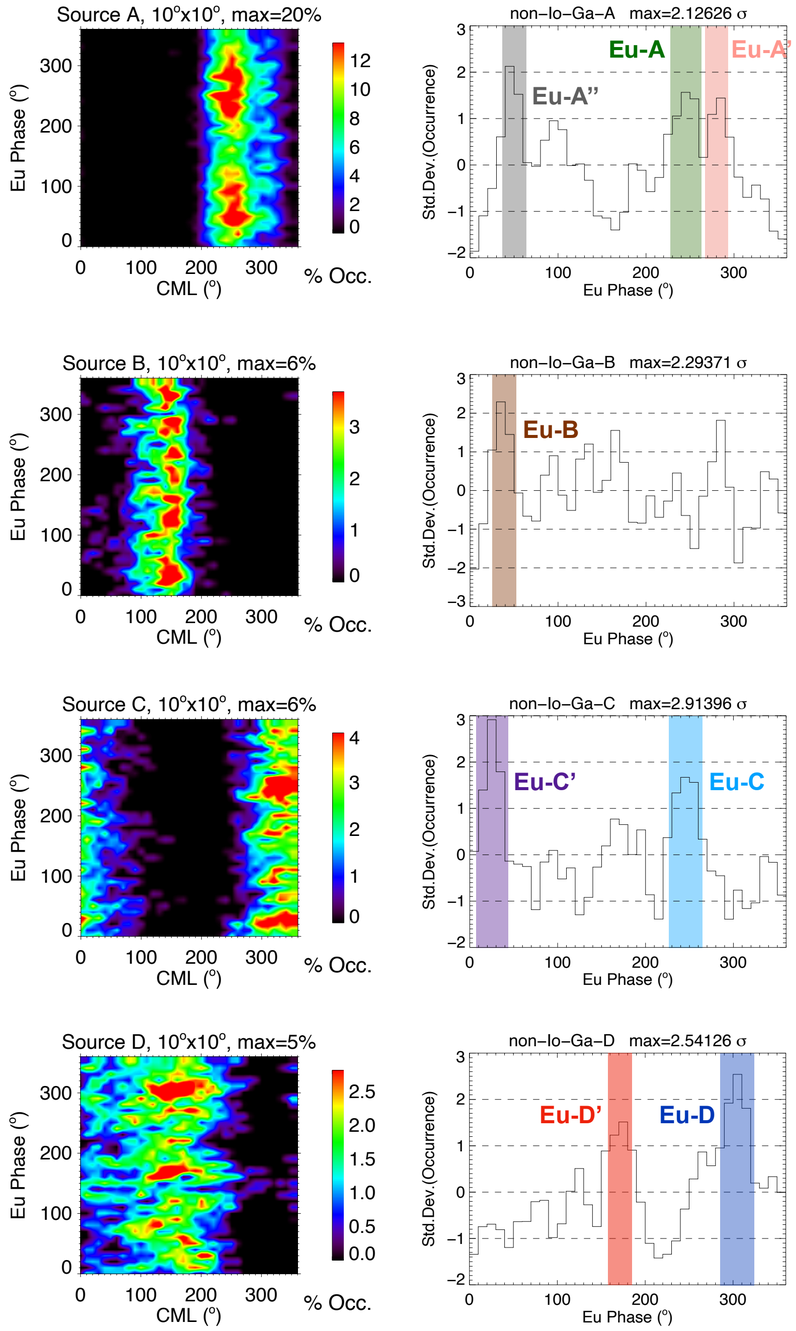

Figure 2: Distributions of *Occurrence probability of the NDA catalog's jovian decametric emissions not induced by Io nor by Ganymede, by components.*

Preliminary results

- The distribution of the selected emissions' occurrence probability in the *CML x Eu phase* plane was compared with the one obtained by Louis et al., 2017, with data from Cassini and the Voyagers 1 & 2 (**Figure 3**).
- **This comparison corroborates the possible identification of of part of the emissions in the peaks Eu-A, Eu-A', and Eu-C.**
- For this reason, we have selected only the emissions occurring within the CML and phase intervals corresponding to these peaks for analysis of their average maximum frequency, duration and intensity.

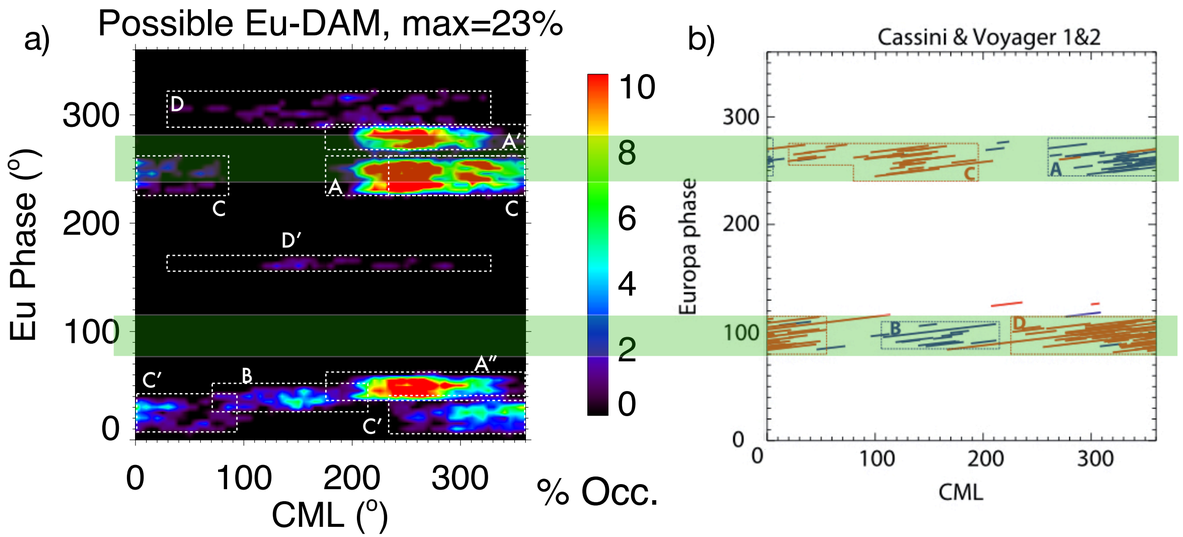

Figure 3: *(a) Distribution of occurrence probability of the possible Eu-DAM in the CML x phase plane. (b) Eu-DAM emissions observed on Cassini's and Voyagers' database, by Louis et al., 2017.*

- In total, 500 emissions were found occurring within the CML and phase intervals of the peaks called Eu-A, Eu-A', and Eu-C. Part of these emissions are possibly induced by Europa (Eu-DAM):
  - **253** possible **Eu-A** emissions (from the *A* source, *Northern* hemisphere - *Right-Hand sense* dominant polarization);
  - **162** possible **Eu-A'** emissions (from the *A* source, *Northern* hemisphere - *Right-Hand sense* dominant polarization);
  - **85** possible **Eu-C** emissions (from the *C* source, *Southern* hemisphere - *Left-Hand sense* dominant polarization).

Preliminary results

- From the distribution of maximum frequency, duration and intensity of these emissions (**Figure 4**) and their values of median, mean and standard deviation (**Table 1**):
  - The maximum frequency of the northern emissions are, in general, higher than the southern emissions';
  - There is a predominance of short-duration (t < 40 min) emissions in all the analyzed emission types;
  - The Eu-C emissions seem longer in time than the Eu-A and Eu-A' emissions.

Table 1: *Statitical parameters of the distributions of máximum frequency, duration, and intensity of the selected Eu-A, Eu-A', and Eu-C emissions.*

	n. emissions	Max. freq. (MHz)			Duration (min)			Intensity (dB)		
		Med.	Mean	Std.Dev.	Med.	Mean	Std.Dev.	Med.	Mean	Std.Dev.
Eu-A	253	25.0	24.4	3.40	29.0	38.4	33.7	2.19	2.21	0.757
Eu-A'	162	24.7	24.2	2.54	30.0	35.1	25.8	2.19	2.34	0.765
Eu-C	85	18.6	18.9	2.91	35.0	40.8	29.7	1.99	2.16	0.755

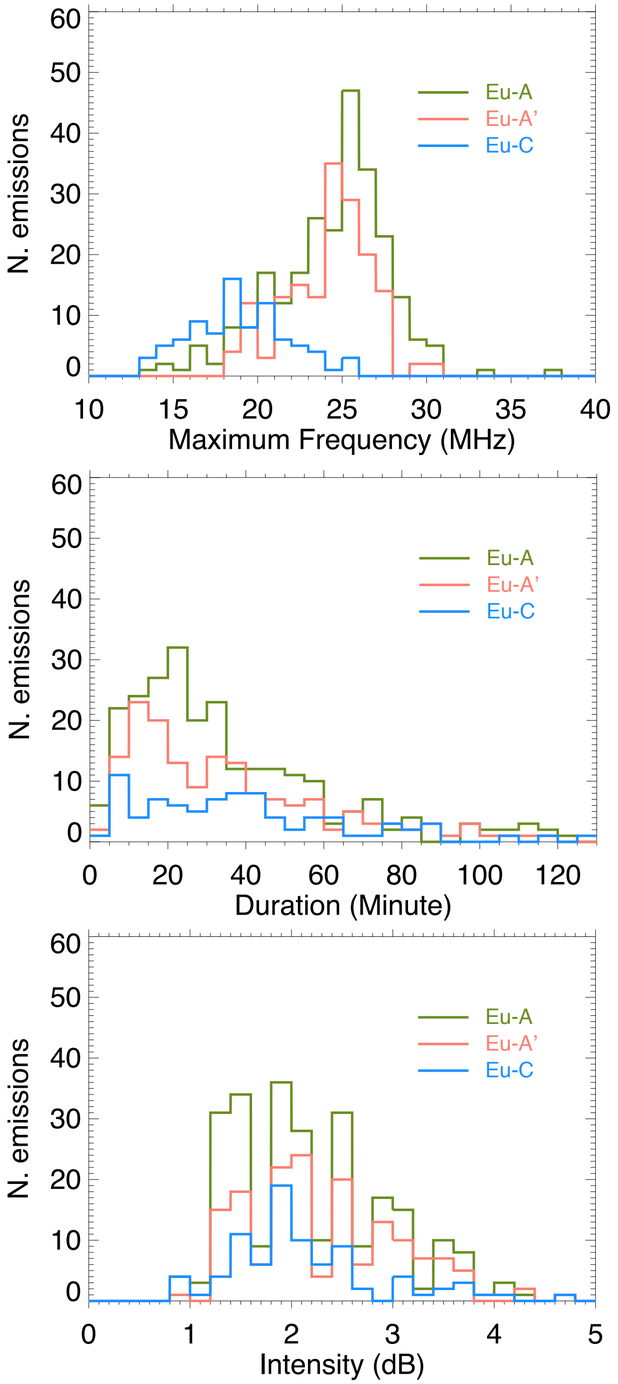

Figure 4: *Distribution of maximum frequency, duration and intensity of the selected emissions.*

Discussion

- The emissions' maximum frequency reflects the local electron cyclotron frequency at the sources in Jupiter.
- Therefore, the higher values of maximum frequency of the northern emissions, may result from the intense magnetic field at the northern anomaly of high-amplitude magnetic field on the jovian surface.
- The duration of the emissions observed by the NDA is an aspect of difficult evaluation since it is affected by:
  - The Earth's declination (Leblanc et al., 1993) ;
  - The distance variation between the Earth and Jupiter (Zarka et al., 2018);
  - The Earth's rotation since the array must be pointing to Jupiter to be able to detect the emissions.
- These factors explain the predominance of short-duration emissions in all the three types analyzed (Eu-A, -A', and -C).
- Considering that the duration of all emissions is affected equally, the emissions Eu-C seem, indeed, to have longer duration than the northern emissions.
- **More analyses are still needed in order to refine the selection of possible Eu-DAM emissions and to confirm our preliminary results.**

Further analyses

- We intend to refine the selection of the possible Europa-induced emissions through the analysis of the emissions' arcs on dynamic spectra, adding also low frequencies observations by WIND and comparing with Eu-DAM arcs simulation with ExPRES.

Acknowledgements

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