STUDY OF THE MODELLED OCCURRENCE VARIABILITY OF THE JOVIAN DECAMETRIC EMISSIONS

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Abstract

A recent paper by Galopeau et al. [2004] investigates the variation of the cyclotron maser instability efficiency at the footprint of the Io flux tube as a function of the jovicentric longitude. The authors derive a model which allows to determine the regions of high occurrence probability of the Io-controlled decametric emissions in the Central Meridian Longitude (CML) – Io phase diagram. In addition to this study we discuss the location of the modelled occurrence regions versus the jovicentric declination of the Earth. Our analysis is compared to the results of previous studies mainly based on ground observations. We show that the modelled and observed occurrence regions are found to present similar movements in the CML-Io phase diagram.

1 Latitudinal beaming of Jovian decametric emissions

Ground-based studies of Jovian decametric (DAM) radiations performed over the past fifty years reveal distinct variations in the DAM morphology. These changes are depending on the declination of the Earth with respect to the Jovigraphic equatorial plane which is called Jovicentric declination of the Earth (hereafter D_E), ranging between $-3.3°$ and $+3.3°$ over Jupiter's 11.9-year solar revolution period. Therefore both the system III Central Meridian Longitude (CML) and the relative occurrence probability for decametric activity are observed to vary significantly as D_E changes over this interval [see Carr et al., 1983, and references therein]. Fig.1 shows the CML-Io-phase diagram, which describes the DAM occurrence regions versus CML and Io-phase. Several zones of enhanced occurrence have been labelled 'sources'. We mainly distinguish four sources, the so-called Io-controlled emission, Io-A, Io-B, Io-C and Io-D [Genova, 1987].

Several studies have estimated the variation of the Jovian DAM activity versus the Jovicentric declination. For the Io-controlled emissions, like Io-A, Io-B and Io-C, the main

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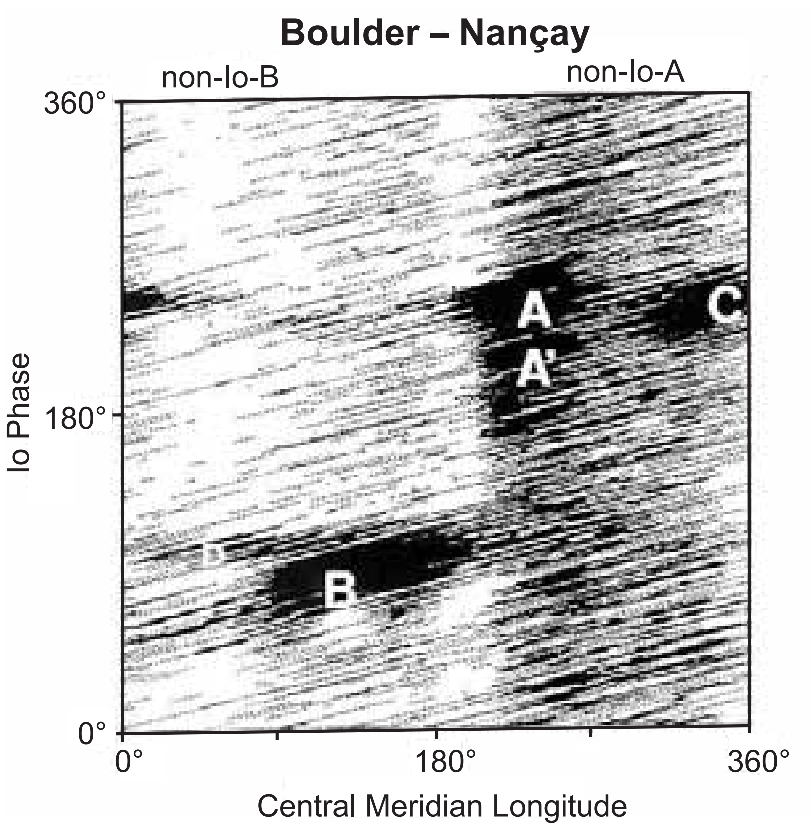

Figure 1: The CML and Io phase diagram associated to the occurrence of the Jovian decametric emissions. The well-known region of high probability of occurrence are indicated [adapted from Genova,1987].

investigations are based on observations obtained by three stations as listed in Table 1. The Io-D source is not taken into consideration in our analysis because previous studies did not show a shift of this source in declination. The periods which are reported in the table 1 are founded on studies of: (a) Lecacheux [1974] for the Boulder observations, (b) Thieman et al. [1975] for the Florida station, and (c) Boudjada and Leblanc [1990] for the Nançay Decametric Array.

Table 1: Jovian Decametric Stations

Station	Period Start Year	Period End Year	Frequency Start MHz	Frequency End MHz
Florida - Texas (USA)	1957	1975	18 - 20	22
Boulder - Colorado (USA)	1960	1971	10	40
Nançay (France)	1978	1988	10	40

The so-called "D_E effect" has generally been interpreted in terms of a latitudinal dependence of the Jovian DAM radiation in angular width , in location, and in intensity. Fig.2

(lower panel) displays D_E as a function of the CML of the half-probability of occurrence of the Io-A source. The shaded region in Fig.2 (upper panel) approximates the shape and angular dimensions of the part of the emission beam accessible to the Earth.

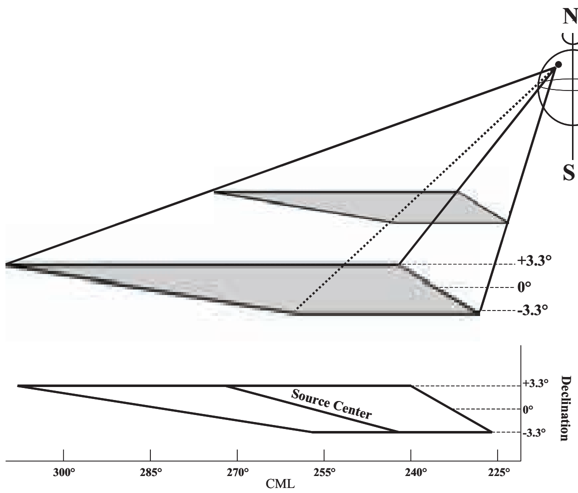

Figure 2: Schematic model (upper panel) showing how the angular width of the Io-A source emission is changing over Jupiter's 11.9-years solar revolution period. The shaded region is derived from the occurrence probability of Io-A source as displayed in the lower panel [adapted from Carr et al., 1970].

2 Active longitudes generated by the CMI mechanism

As shown in Fig.1, a great part of the Jovian DAM activity is modulated by two dominant parameters: the planetary rotation and the orbital phase of Io. The first one indicates that the occurrence probability of the radiation depends on the observer's longitude while the second factor points to a control of part of the radio emission by Io. A major part of the previous studies were interested by the relationship between the DAM occurrence and the phase associated to the Io satellite position [Genova and Aubier, 1985, and references therein].

The originality of the theoretical approach of Galopeau et al [2004] lies in the not referenced fact that, for the first time, it explains why the so-called Io-controlled sources are occurring at some specific longitudes, i.e. from 90° to 200° CML, and from 210° to 270° CML. Within the framework of the cyclotron maser instability [Wu and Lee, 1979], the authors calculate the maximum growth rate of radio waves amplified by this mechanism as function of the jovicentric longitude of the Io satellite. As shown in Fig.3, it emerges that some longitudes, called hereafter 'active longitudes', in the northern and southern Jovian hemispheres favor the radio decametric emission and lead to a higher occurrence probability. The 'modelled' and the observed CML-Io-phase diagrams are shown in Fig.3 and Fig.1, respectively. One can note that:

• The modelled Io-A source position is found, on average, in the region where it is currently observed.
• The longitude spreading of Io-B source is similar to the observed one, however the average position in the Io-phase is different.
• The Io-C source totally fits the same region as the observed one with a particular feature: It is prolonged towards lower longitudes which correspond to the Io-A source region.

3 Motion of Io-source regions

During one Jovian solar revolution period, the Jovicentric declination of the Earth varies between $-3.3°$ and $+3.3°$. We calculate the variation of the modelled source regions in the case of the Io-A, Io-B and Io-C sources. It is possible to estimate for each source how the related curve (represented by two or three points) is changing versus D_E. In the case of the Io-A curve, we consider three points: the beginning, the middle and the end. For each point, we calculate the shift in CML and Io-phase for the three values of the declination. The shift average value of Io-A source and the corresponding error bar (± one sigma) is given in Table 2. We summarize, in the same table, the main previous investigations and the corresponding shift in CML and Io-phase for each source.

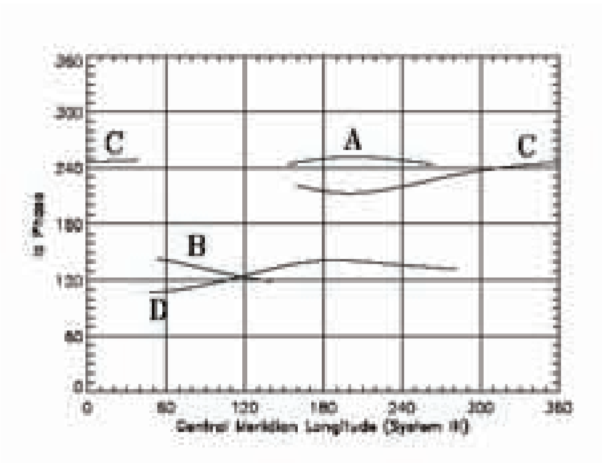

Figure 3: The Io-controlled source regions as deduced from the active longitude model [Galopeau et al., 2004].

The combination of our results and previous ones shows that the variation of the slope in longitude and in Io-phase is in agreement, taking into account the error bar on our estimations. On the one hand, all sources are found to have similar motions in Io-phase, i.e. the slope is usually negative when the declination D_E increases. On the other hand Io-A source, contrary to Io-B and Io-C, has a positive slope when D_E varies from $-3.3°$ to $+3.3°$.

Table 2: Shifts of the CML and Io-phase over Jupiter's 11.9-year solar revolution period

Source	Shift in CML	Shift in Io-phase	Observations	Authors
Io-A	2.11		Florida-Texas: 1957–1965 f=18–20 and 22 MHz	Gulkis and Carr [1966]
	5.31		Florida: 1957–1969 f=18 MHz	Carr et al. [1970]
	1.4		Boulder: 1960–1971 f=10 – 40 MHz	Lecacheux [1974]
	3.4		Nançay, Boulder and Voyager f=10 – 40 MHz	Barrow et al. [1982]
		-2.7	Florida 1957–1975	Thieman et al. [1975]
	+4.0	-0.7	Nançay 1978–1988	Boudjada & Leblanc [1990]
	1.44 ± 0.67	1.00 ± 1.20	Modelled source	This paper
Io-B		-2.5	Boulder 1960–1968	Conseil [1970]
		-1.2	Boulder 1960–1971	Lecacheux [1974]
		-0.6	Florida 1957–1975	Thieman et al. [1975]
	-1.50 ± 0.94	-1.50 ± 0.94	Modelled source	This paper
Io-C		-2.0	Boulder 1960–1971	Conseil [1970]
		-2.03	Florida 1957–1975	Thieman et al. [1975]
		-1.6	Nançay 1978–1988	Boudjada & Leblanc 1990
	-0.88 ± 0.76	-0.55 ± 1.38	Modelled source	This paper

4 Conclusion

The main outcomes, after combining our results with the previous ones, are:
(a) The Io-B source region is shifting to lower values in CML and Io-phase. This means that when D_E is at about $+3.3°$ this source is earlier observed and the occurrence area is more larger. The Jovian Northern hemisphere, from where Io-B source is emitted, is inclined towards the direction of the Earth and in this case the probability of Io-B occurrence is increasing.
(b) Io-A and Io-C are found to "converge/overlap" and "diverge/separate" when the declination attains high and low values, respectively. This can be interpreted as the effect of the beams coming from different hemispheres.
These results show that the modelled occurrence of DAM emissions is in agreement with previous observed ones. More detailed analysis of the longitude active model is discussed by Galopeau et al. [2006]. Furthermore, recent work of Imai [2002] also shows that the Jovicentric declination of the Earth influences the so-called modulation lanes associated

to the sources located in the Northern hemisphere.

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