

Origin of Jupiter's hectometric radiations (HOM) viewed from their polarization characteristics 木星 MHz 帯電波の発生源：偏波特性にもとづく考察

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It has been known that Jupiter's auroral radio emission in the hectometric wave range (HOM) is roughly classified into two type occurrence components. One is a component relating to solar wind variations (sw(solar wind)-HOM) appearing around CML (Central Meridian system III Longitude of an observer) $\sim 180\text{deg}$ when solar wind pressure enhances. The other one is generally more intense than sw-HOM and has no or weak relation with solar wind variations (nsw(non sw)-HOM) appearing around CML $\sim 110\text{deg}$ and $\sim 280\text{deg}$ (the 1st and 2nd nsw-HOM, respectively) when De (Jovicentric declination of an observer) $\sim -1\text{deg}$ (Nakagawa et al., 2000; Nakagawa, 2003). Recently, we found one more nsw-HOM component appearing around CML $\sim 340\text{deg}$ (the 3rd nsw-HOM), which highly correlates occurrence of magnetic reconnection events in Jupiter's magnetotail region (Misawa et al., 2018). This component is an important role for the studies of global magnetospheric dynamics of Jupiter since it is a possible remote marker of the reconnection events occurring in Jupiter's magnetosphere. However, due to difficulty in precise direction finding in the hectometric wave range, the radio source of this component (and also those of the other components), that is, location of transported energy input should be originated from the tail region, has been still unrevealed.

In order to investigate source location of each HOM component we have made their polarization analyses using the data provided by High Frequency Analyzer (HFA) which is a subsystem of Plasma Wave Experiment (PWE) onboard the Arase (ERG) spacecraft. Preliminary analyses show that the 3rd nsw-HOM is left-handed circular polarization. The result suggests that the 3rd nsw-HOM is radiated from the southern hemisphere by taking account of Jupiter's magnetic polarity. In addition, their arc-like spectral structures implies that the 3rd nsw-HOM is radiated dawn and/or dusk side hemispheres (both types were confirmed). The precise source examination by calculating expected observable rays using Jupiter's magnetic field models, and expected source regions of the other HOM components are deferred in future studies.

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木星数MHz帯電波の発生源: 偏波特性にもとづく考察 Origin of Jupiter's hectometric radiations (HOM) viewed from their polarization characteristics

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[Outline]

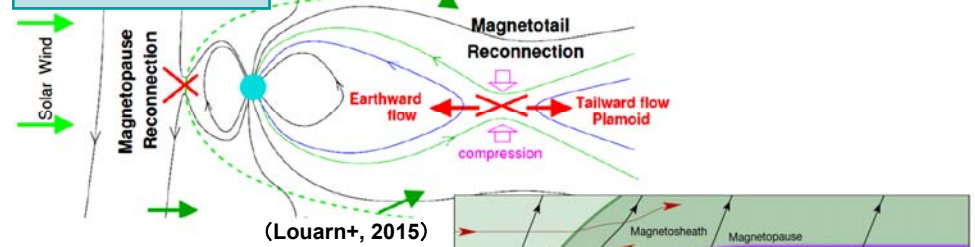
1. Review: Time variations of Jupiter's auroral radio emissions (especially HOM)
2. Result: Occ. char. of the 3rd nsw-HOM in relation with other parameters
3. Discussions: Expected source region of the 3rd nsw-HOM viewed from the polarization characteristics.

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Outstanding Questions on Jupiter's magnetosphere

EARTH:

Solar wind driven



Jupiter:

(mainly) Rotationally driven ...
Roll of logenic plasma?
Roll of solar wind variation?

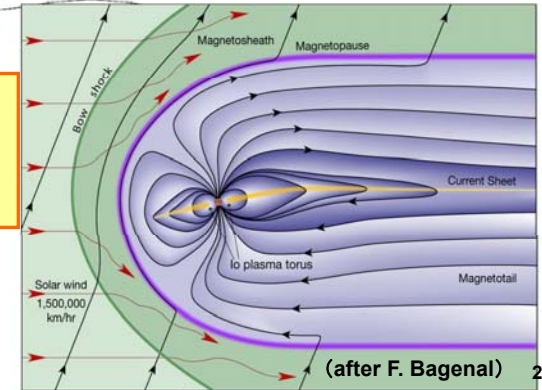
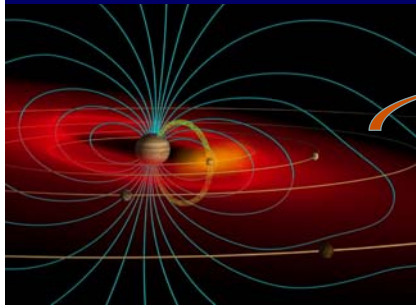


Fig. Earth's & Jupiter's magnetospheres

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Expected internal-driven process (IDP)



(after J. Spencer)

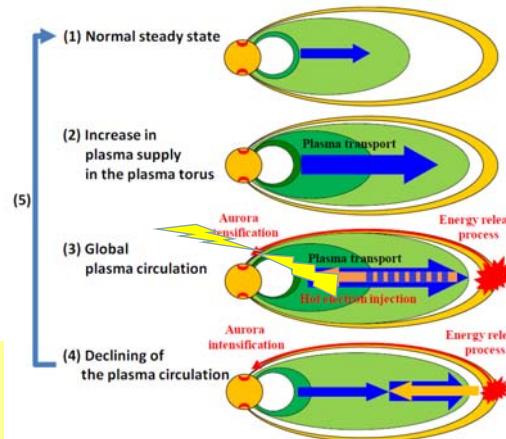


Fig. Schematic plots of expected sequence of Jupiter's internal driven process (Tsuchiya+, (2018))

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Subjects:

- ✓ What characteristics does IDP have? (phenomena, time scale,,)
- ✓ How does IDP globally affect to Jupiter's magnetosphere? (area, degree,,)

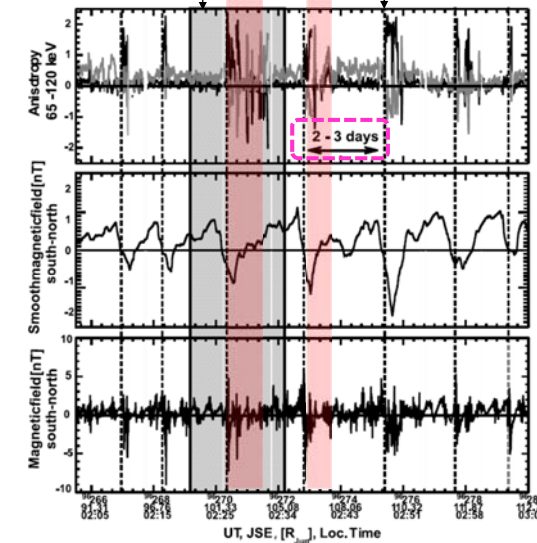
Signature of internal-driven process : QP nature

Galileo/PWS

HOM: 5MHz

bKOM: 200KHz

← Fig. Radio intensities for 5MHz HOM and 200KHz bKOM observed by Galileo in late Sep.1996. (Louarn+, 1998)



← Fig. Anisotropies in the radial and corot. directions (top), s-n comp. of mag. field (smooth & high res.) (Kronberg+, 2005)

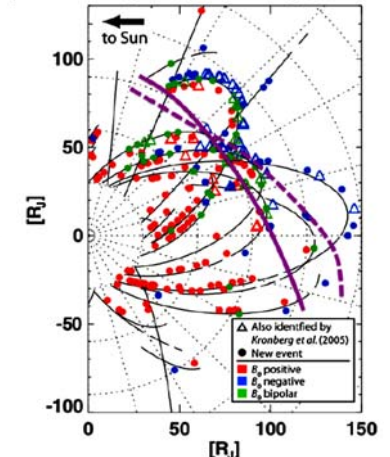


Fig. Positions of detected reconnection signature (Louarn+, 2015)

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Auroral radio emissions ~ a proxy of Jovian Mag. Activities

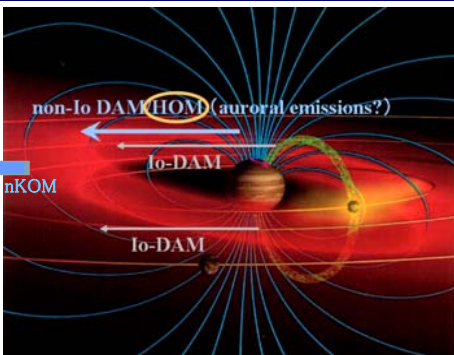


Fig. Schematic view of Jupiter's electromagnetic/plasma environment (after J. Spencer)

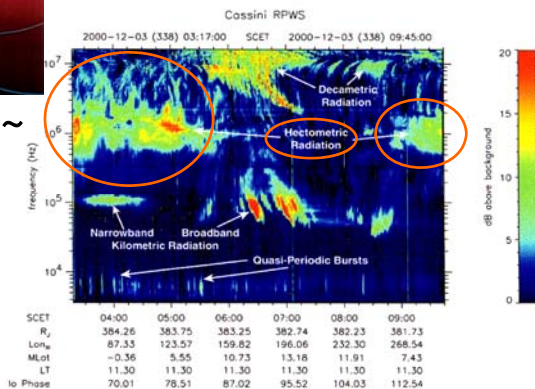


Fig. f-t diagram obs. by Cassini. (Gurnett+, 2002)

Characteristics of HOM : What is QP-HOM?

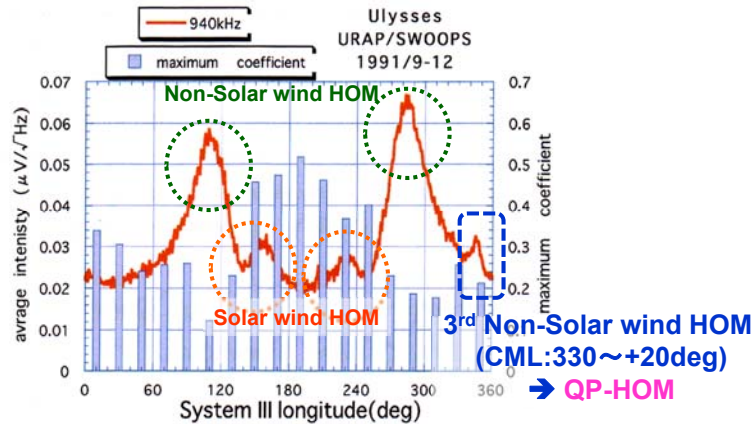


Fig. HOM occurrence dependence on CML and correlation coefficients for solar wind pressure (Nakagawa+, 2000)

HOM occurrence in 1996 (Galileo era)

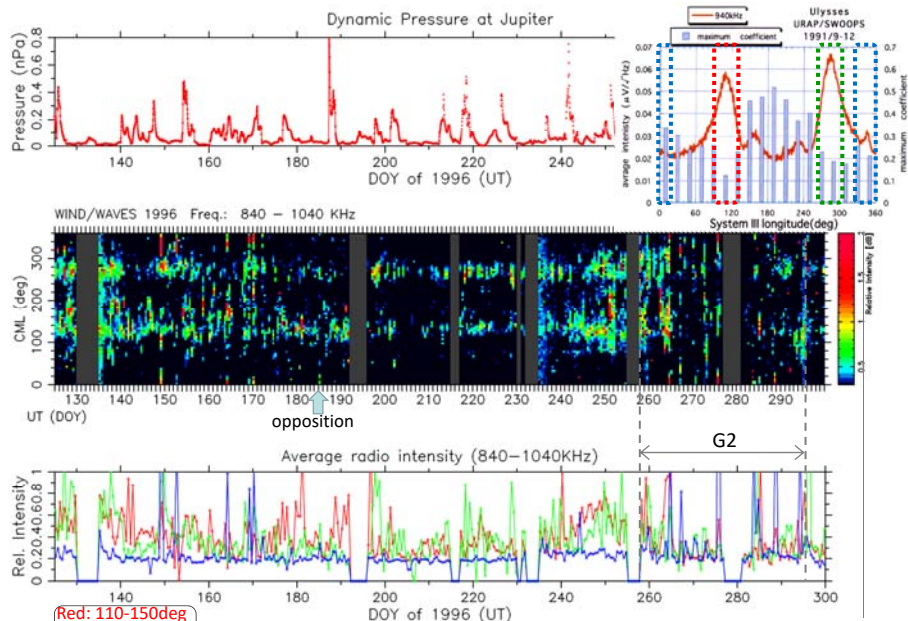


Fig. Solar wind pressure expected at Jupiter (Tao+, 2005), CML dependence of relative HOM intensities standardized at 4.04AU and nsw-HOM intensities.

Relation of the 3rd nsw-HOM occ. & recon. events

Table. Statics of the relation between reconfiguration (reconnection) events and occ. of the 3rd nsw-HOM

Orbit No.	Obs. period	No. of remarkable reconfig. event (Kronberg+, 2005)	No. of identified 3rd nsw-HOM (BG+2σ)	Matching rate ⁰ : HOM during remarkable reconfig. Event (%)	Matching rate ¹ : HOM during all reconfig. event (%)	Rate of remarkable reconfig. event without HOM ² (%)
G2	1996.9~10	14	14	86	93	14
G7	1997.4	0	0	-	-	-
G8	1997.5~6	6	10	40	90	17
C9	1997.7~9	4	2	100	100	50
C10	1997.9~10	4	5	40	60	25
E16	1998.7~9	3	2	100	100	0
Summary		31	33	67	88	19

- 0: Definition of "Matching" : the 3rd HOM events occurred within 10hrs with respect to the period of reconfiguration events
- 1: Reconfiguration events are referred from Vogt+, 2010.
- 2: The period of reconfiguration events when heavy solar bursts appeared are rejected from the statics.

- The 3rd nsw-HOM is identified as having QP nature in the Galileo era.
- The 3rd nsw-HOM appears when reconnection events occurs with 88% matching rate.
 - ➔ the 3rd nsw-HOM would be a proxy of indicators reflecting occ. of internal-driven process.
- Next step ... ➔ Where & How are the 3rd nsw-HOM generated ?
- The occ. of the 3rd nsw-HOM is not simultaneous with occ. of the 1st and 2nd nsw-HOM.
 - ➔ Energy sources ~ gen. regions and/or phys. cond. would be different. ... ➔ Future study.

New Question: What is the 3rd nsw-HOM?

Questions about origin of the 3rd nsw-HOM component

- Where are their source regions ?
- Why at CML=+330~+20deg ?

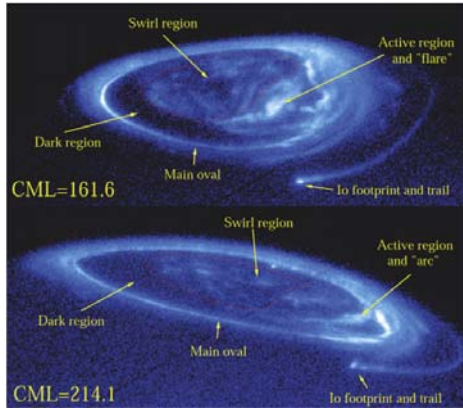


Fig. Jupiter's UV aurora (Grodent+, 2003)

- Auroral condition for N or S / E or W?
- Needs to consider rotational phase (CML)

Expected source @ $f \sim f_c$
 $\rightarrow h_{HOM} \sim 1R_J \sim$

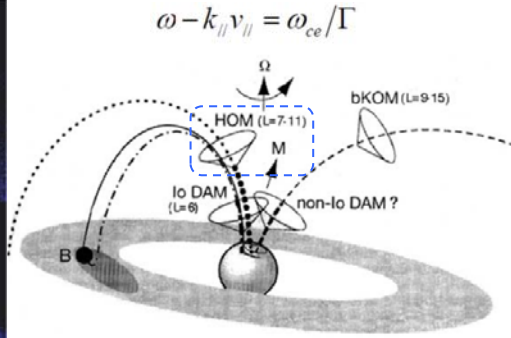


Fig. Expected source locations of Jupiter's radio emissions (Zarka, 2004)

- Needs to consider expected source height @ $f \sim f_c$

New Question: What is the 3rd nsw-HOM?

-Apparent features of aurora for each phase of nsw-HOM

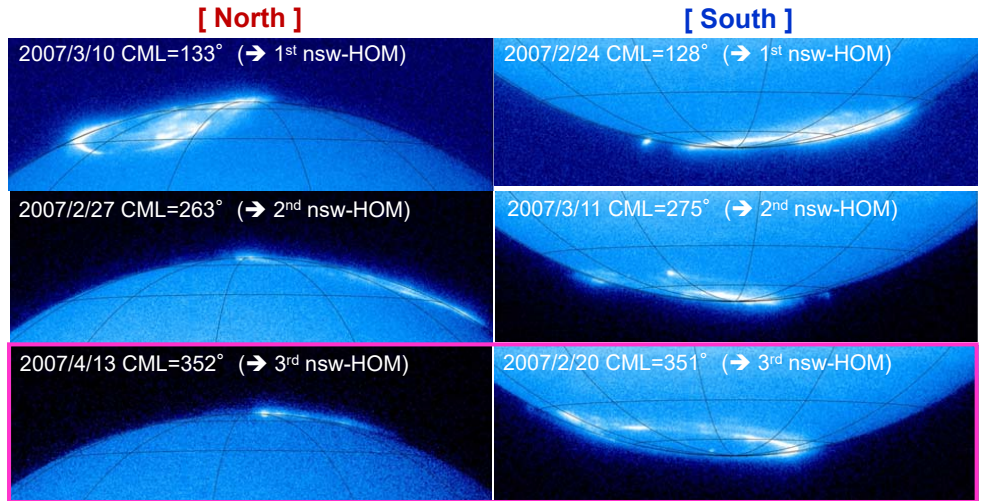


Fig. Jupiter's UV aurora images taken by HST for the campaign obs. period of New Horizon's Jupiter encounter in 2007.

- N or S? \rightarrow Polarization analysis (This study)
- # E or W? \rightarrow Adopting spectral feature

Expected source location: non Io DAM/HOM

- Source size: smaller than 5" (Erskine, 1976)
- Freq. Drift is same for Io & non Io-DAM (Boischot+, 1987) \rightarrow Dawn: B / Dusk: A,C

Source designation	CML range ^a	γ range ^a	Maximum frequency (MHz)	Dominant polarization	Arc curvature (vertex)	Notes
Io-D	0°-200°	95°-130°	18	LH	Early	Also called "fourth source"
Io-B	15°-240° (105°-185°)	40°-110° (80°-110°)	39.5	RH	Early	Also called "early source"
non-Io-B	80°-200°	0°-360°	38	RH	Early	Weak from above day hemisphere but strong when viewed from above night hemisphere
Io-A	180°-300° (200°-270°)	180°-260° (205°-260°)	38	RH	Late	Also called "main source"
non-Io-A	200°-300° (230°-280°)	0°-360°	38	RH	Late	Strong from above day hemisphere but weak when viewed from above night hemisphere
Io-C	280°-60° (300°-20°)	200°-260° (225°-260°)	36	RH and LH	Late	Also called "third source"
non-Io-C	300°-360°	0°-360°	32	RH and LH	Late	Moderately strong from above day hemisphere and very weak when viewed from above night side

Table. Definition of each DAM source & their characteristics (Carr, 1983)

^aNumbers in parentheses give widths at half-maximum for the major sources as observed from Earth at frequencies near 20 MHz.

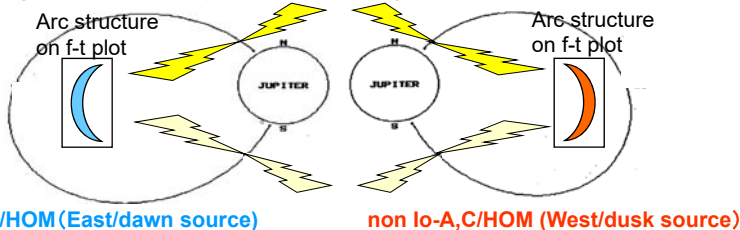


Fig. Schematic plots of each spectral feature of non Io-DAM / HOM emissions

Instrumentation for Polarization analysis

ARASE(ERG): launched on Dec. 20, 2016

PWE/HFA: Plasma Wave Experiment, High Frequency Analyzer

- Antennas: two pairs of dipoles with ~ 31m tip-to-tip length
- Freq. range: 10KHz-10MHz
- No. of steps: 479 (EE-LR(polarization) mode: interval=8sec)

(Kasaba+, 2017; Kumamoto+, 2018)



Fig. View of the ARASE(ERG) satellite ©ISAS/JAXA

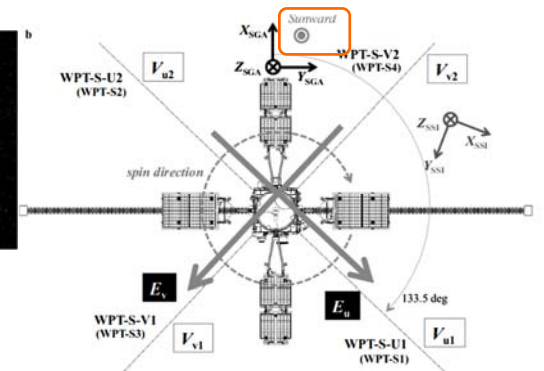
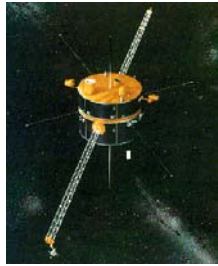


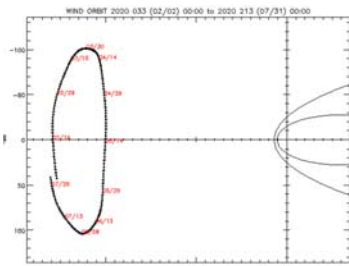
Fig. PWE WPT-S sensors viewed from the solar direction. (Kasaba+, 2017)

Instrumentation for f-t plot analysis



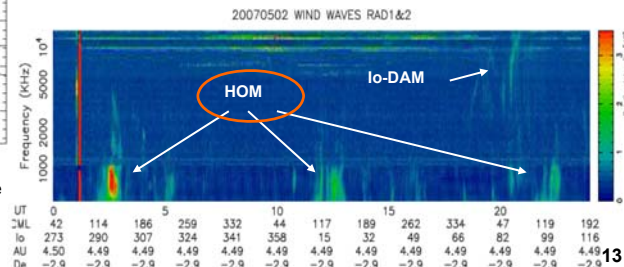
WIND: launched on Nov. 1, 1994
WAVES: Radio and Plasma Wave Investigation
 •Radio Receiver Band 1 (RAD1) & 2 (RAD2)
 Inputs: $E_y(100m)+E_x(15m), E_z(12m)$
 Frequency range: 20KHz-1.04MHz (RAD1),
 1.075MHz - 13.825 MHz(RAD2)

No. of channels: 256 each
 Frequency step: 4KHz(RAD1),
 50KHz(RAD2)
 Sensitivity: 7 nV/Sqrt(Hz) (Bougeret+,1995)



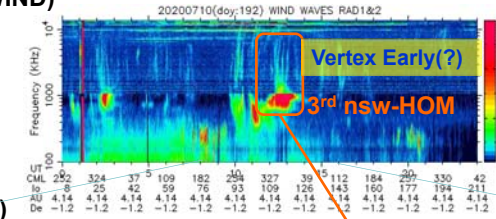
↑Fig. View of the WIND satellite and the orbit for Feb. 2020 to July 2020.

→ Fig. Example of WAVES data,



Polarization analysis: Preliminary results

One-day f-t plot (WIND)



8-h f-t & pol. (ERG)

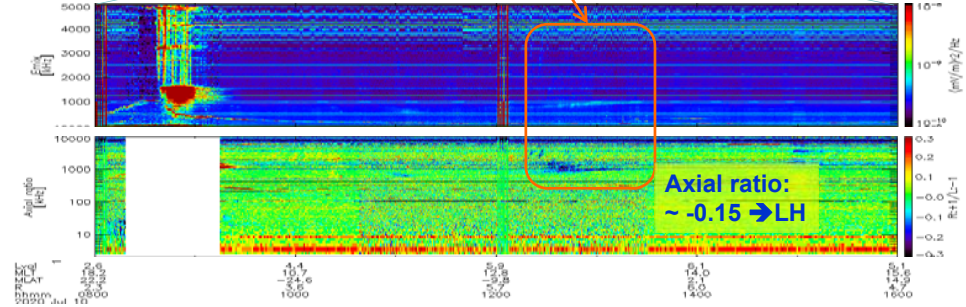
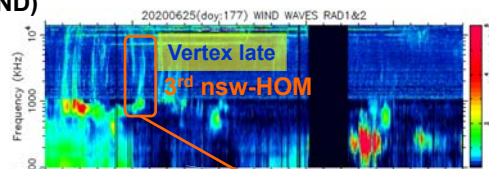


Fig. Polarization analysis(axial ratio: $RH=+1, LH=-1$) for the 3rd nsw-HOM observed on July 10, 2020 near Jupiter's opposition. The LH sense corresponds to Jupiter's southern hemisphere origin, and the seemingly vertex early arc structure implies Jupiter's east side origin.

Polarization analysis: Preliminary results 2

One-day f-t plot (WIND)



8-h f-t & pol. (ERG)

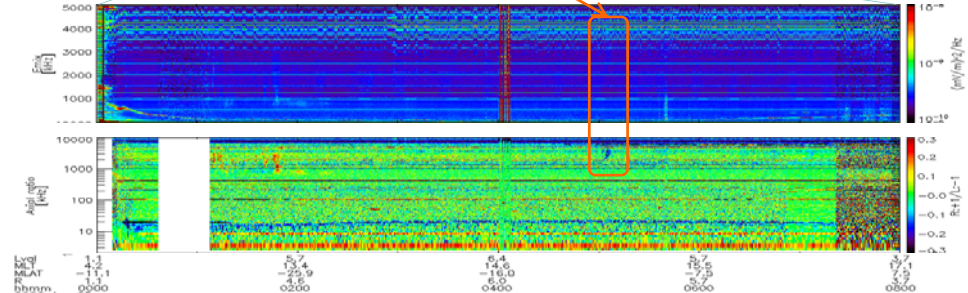
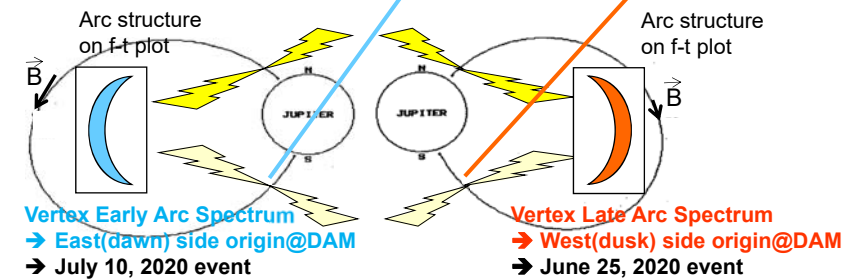
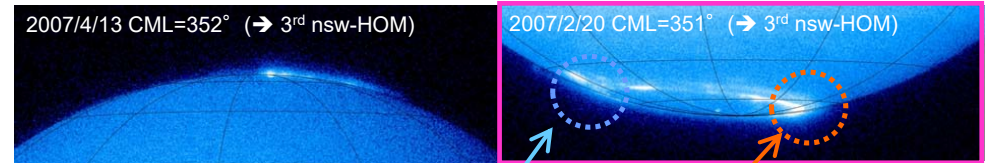


Fig. Polarization analysis(axial ratio: $RH=+1, LH=-1$) for the 3rd nsw-HOM observed on June 25, 2020 near Jupiter's opposition. The LH sense corresponds to Jupiter's southern hemisphere origin and the vertex late arc structure implies Jupiter's west side origin.

Discussions: Expected sources



- The 3rd nsw-HOMs, a proxy of indicator reflecting occ. of internal-driven process, are originated from east or west side of 'Southern' hemisphere where auroral activities are monitored relatively well.
- Next step : Why only southern? → Search for required conditions
 ... Investigations of wave generation/propagation cond. & energy input processes.
- The occ. of the 3rd nsw-HOM is not simultaneous with occ. of the 1st and 2nd nsw-HOM.
 → Energy sources ~ gen. regions and/or phys. cond. would be different. ... > Future study.

Summary

[Purpose] Elucidation of back-ground physical processes of Jupiter's HOM especially its new (3rd) non solar wind controlling components ("3rd nsw-HOM")

[Analysis] Investigation of HOM polarization data observed by the ARASE(ERG) satellite

[Results] The 3rd nsw-HOM shows the following natures.

- Polarization : LHCP (axial ratio ~ -0.15(elliptical)
- Spectral feature: Both vertex early & late arc structure
- ➔ Suggesting the 3rd HOMs originate from the Southern hemisphere, and dawn or dusk side region (both types were confirmed).

[Conclusions]

- ✓ The 3rd nsw-HOM would be generated by Jupiter's internal-driven process and originated from the Southern hemisphere and East or West side region.
- ✓ The clarifications of its precise source processes & the difference of the other nsw-HOMs are still future studies. (comparison with JUNO, (JUICE), and auroral images etc.)

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