Examination of the Relation between Jupiter's Inner Magnetosphere and Magnetic Reconfiguration Events

Misawa, H.(1), H. Kita(2) and F. Tsuchiya(1)
1:PPARC, Tohoku Univ., 2:ISAS/JAXA

ABSTRACT

It is known that Jupiter's synchrotron radiation (JSR) has information on dynamics of the deep inner magnetosphere. We have made JSR observations more than a decade, and has showed that JSR generally shows short term variations by more than several tens percent with the time scale of days to weeks. A plausible causality of such the short term variations is due to solar UV/EUV variations initially proposed by Brice and McDonough (Icarus, 1973) and observationally confirmed by several groups including us, which is so to speak an externally driving process. However, this scenario cannot be always applicable to any short term JSR variations, rapid flux variations with the time scale within a few days (hereafter RFV), and any other processes are required.

As a process which might explain RFV, an internally driving process, so-called 'substorm like event' is known (cf. Louarn et al., JGR, 2014). This phenomena is interpreted as a magnetic reconfiguration event occurred in the Jupiter's magnetotail region. Although it is revealed that major magnetic reconfiguration events generally affect the whole magnesphere from 10 to 80-120 Rj (Jupiter's radii), it has not been known whether the events affect the deep inner magnetosphere within a few Rj.

In order to reveal unknown dynamics of RFV, we have tried to examine relationship between the fast JSR variations and magnetic reconfiguration events. In this study we have used Jupiter's particular radio wave component in the hectrometer wave range (HOM) as an indicator of RFV, and have compared them with JSR total flux data observed with the Kashima 34m radio telescope of NICT at 2.3GHz and radio imaging data observed with the GMRT, India at 1.4GHz. A preliminary result shows a positive correlation between JSR variations and occurrence of the particular HOM, which implies RFV might be induced by rapid increase of radial diffusion and scattering of energetic particles to Jupiter at small L regions. For more confident confirmation, further JSR observations would be desirable using more sensitive radio receiving facilities at low frequencies (HF～low UHF), which enables us to examine RFVs with the electron energy for a few MeV～10 MeV.

Acknowledgement: We would greatly appreciate staffs of Kashima Space Technology Center, NICT, Japan and GMRT, India for supporting the observations of JSR.

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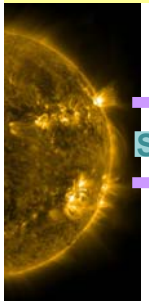
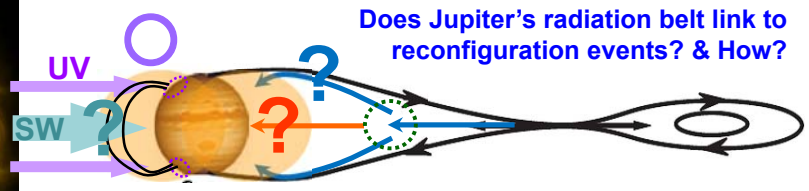




Does Jupiter's radiation belt link to reconfiguration events? & How?

Outline

- Introduction of Jupiter's radiation belt & synchrotron radiation
- Purpose of this study: investigation of cause of rapid variations
- Campaign observation of JSR using single dish & interferometer
- Preliminary results
- Tentative summary & beyond

Jupiter's Radiation Belt & Synchrotron Radiation (JSR)

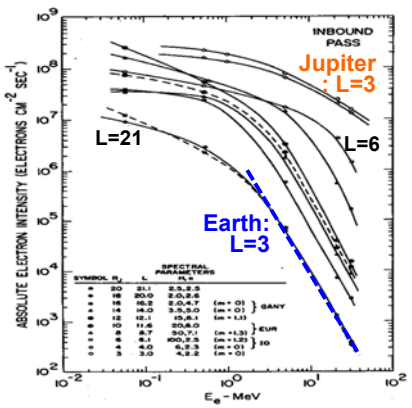
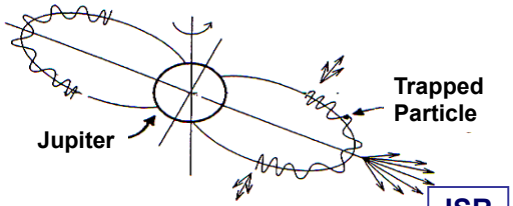


Fig. Electron intensity of Jupiter's magnetosphere measured by Pioneer 10 (Baker & Van Allen, 1976)



JSR flux: $\approx \Sigma E^2 B^2 sin^2\alpha$ ~ 5Jy

Fig. Schematic plot of JSR generation process.

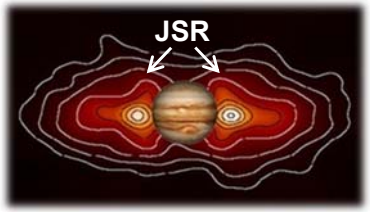


Fig. Radio image at 610MHz (Kita et al., 2015)

Recent Topics of JSR study

"Short term variation"
(time scale:~days to weeks)

Jupiter's Radiation belt

has long been thought as a stable region protected by the strong magnetic field…

Recent Observations of JSR

reveal evidences of short term variations

- Miyoshi et al., 1999
- Bolton et al., 2002
- Tsuchiya et al., 2011 etc.

Presence of some dynamic processes within the radiation belt.

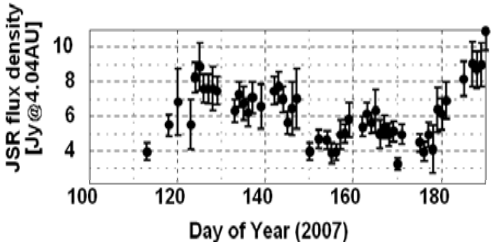


Fig. Daily JSR flux variations at 325MHz observed with IPRT. (Tsuchiya et al., 2010)

#325MHz JSR is generated by ~6MeV electrons

Fig. 1000m² antenna (IPRT) of Tohoku Univ.

Expected causalities of the short term variations

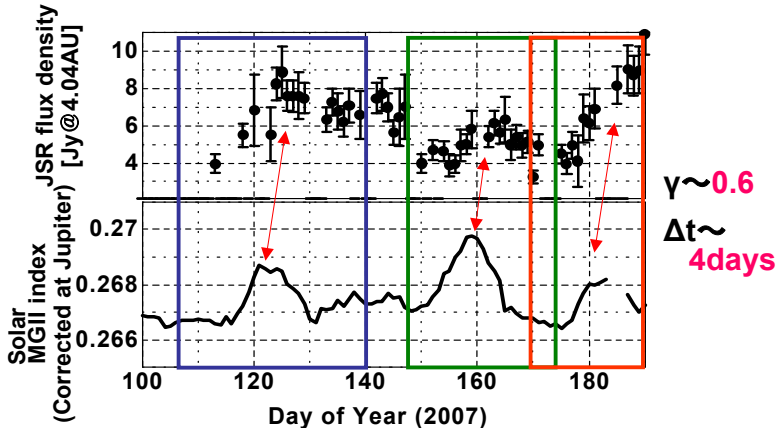


Fig. Daily JSR flux variations at 325MHz (after Tsuchiya et al., 2011)

✓Low frequency JSR variations are initiated by
1)solar activity (slowly varying) + 2) ?? (rapidly varying)

Characteristics? Causality(ies)? ➔Purpose of this study

Obs. result : Rapid Flux Variation (RFV) events

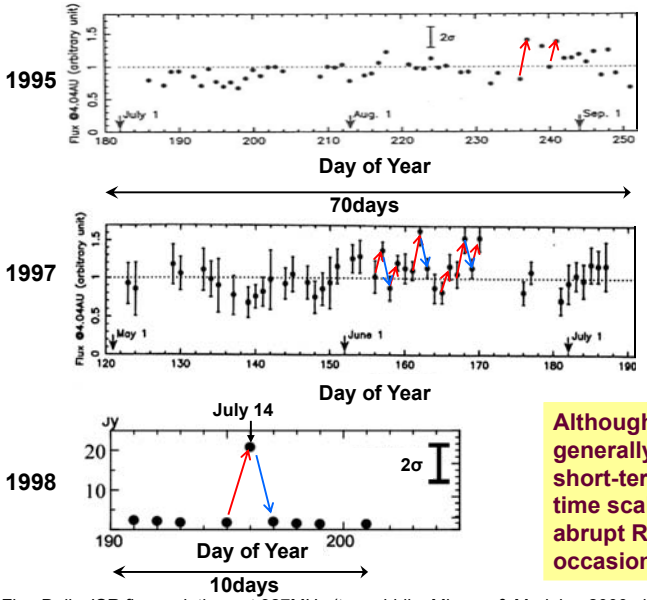


Fig. Daily JSR variations at 327MHz observed with the Nagoya Univ. 2000m² antenna

Although JSR@327MHz generally shows smooth short-term variations with the time scale of days-week, abrupt RFV events also occur occasionally.

Fig. Daily JSR flux variations at 327MHz (top,middle: Misawa & Morioka, 2000., bottom: Nomura, 2007)

Strangeness of RFV

[Expected causalities of JSR variations (relativistic particle variations in Juputer's radiation belt) and their time scales]

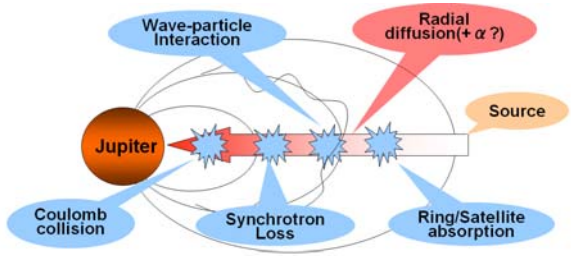


Fig. Schematic plot for expected source & loss processes

	τ (day)@JSR peak position
Radial diffusion	~1000 days (#1)
Synchrotron Loss	>100 days (#2)
Wave-particle interaction Loss	~10^5 days (#3)
Rings/satellites Loss	>1000 days / 10 days (#2)

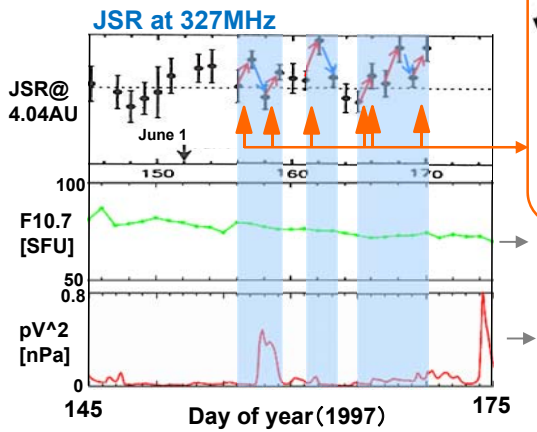
#1: Geoertz et al., 1978 #2: Hood, 1993 #3: Thorne, 1983

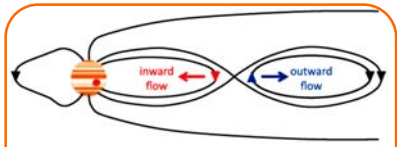
The expected time scales for JSR variations are much longer than the time scale of RFV!

➔ What the causalities??

Relation with solar & solar wind variations?

●1997 RFV events





Jup. magnetotail reconfiguration events confirmed by Vogt+(2014)
※ Particle propagation speed along B-line is expected to be >2.5hr/75Rj (Kasahara+, 2011)

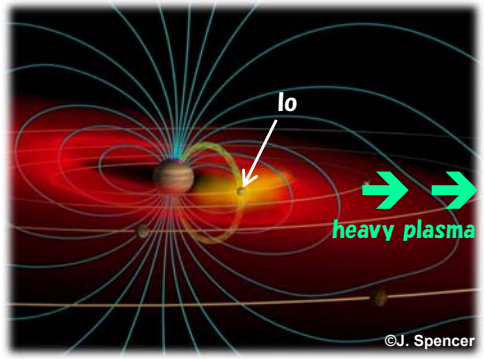
Solar F10.7 (proxy for solar EUV flux) corrected for Jupiter

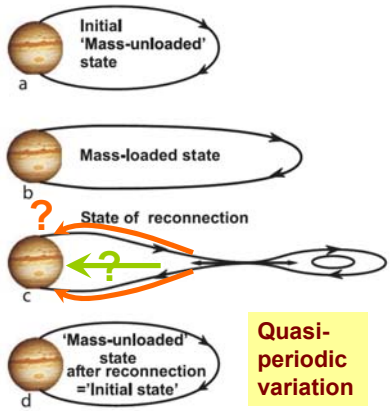
Solar wind dynamic pressure expected around Jupiter (Courtesy of C. Tao (NICT))

Fig. Daily JSR variation ratio at 327MHz, and solar F10.7 & solar wind pressure expected on Jupiter for the corresponding period.

No or weak relation between RFV events and solar / solar wind variations, but relatively higher correlation with reconnection events

Other candidates ➔ internally driven process?





Quasi-periodic variation

Fig. Schematic plot of "Substorm like event" (Kronberg et al., 2007)

Does RFV have any relation with internally driven process (magnetic reconfiguration process)?

～ rapid particle injection / rapid acceleration ??

Method of the examination

- **Observation of Rapid Flux Variations of JSR**
  - Sure confirmation of occurrence of RFV:
    - ➔ Regular obs. for JSR using a single dish antenna
      - ・・・=＞ NICT Kashima 34m antenna obs.@2.3GHz
  - Investigation of source region of RFV:
    - ➔ Campaign obs. for JSR using an interferometer
      - ・・・=＞ Giant Metre wave Radio Telescope(GMRT) @1.4GHz

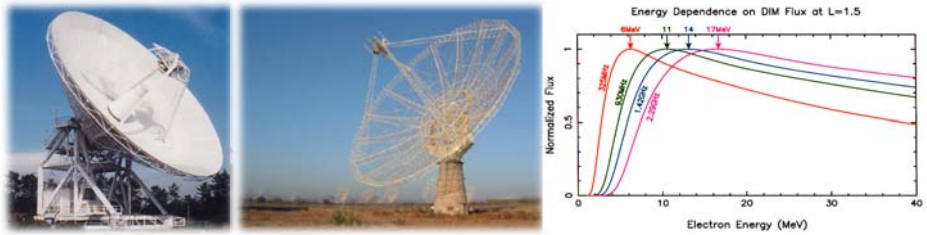
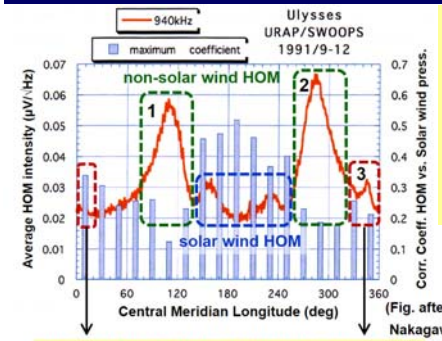


Fig. NICT 34m antenna (left), GMRT 45m × 30 antennas@India (mid) and Elec. energy dependence of JSR (right).

- **Confirmation of occurrence of internal events**
  - Using special HOM as an indicator of occ. of internal events.

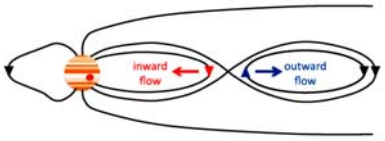
Indicator of occur. of inner process: HOM



(Fig. after Nakagawa+, 2000)

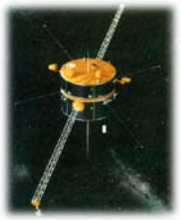
Special component of HOM (Jupiter's Hectometric Radiation) shows high correlation ($\gamma \sim 0.9$) with occurrence of magnetic reconfiguration events (and often quasi-periodic occurrence feature).

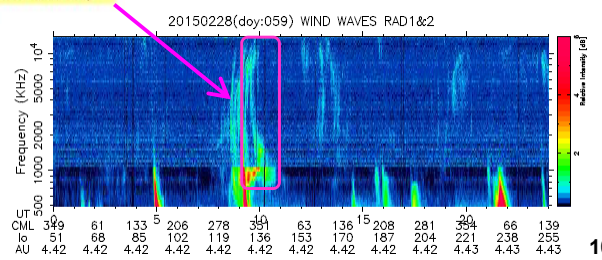
➔ A good remote indicator of occurrence of internally driven processes.



non-solar wind HOM relating with magneto-tail Reconnection; 3rd nsw HOM (Quasi-Periodic)

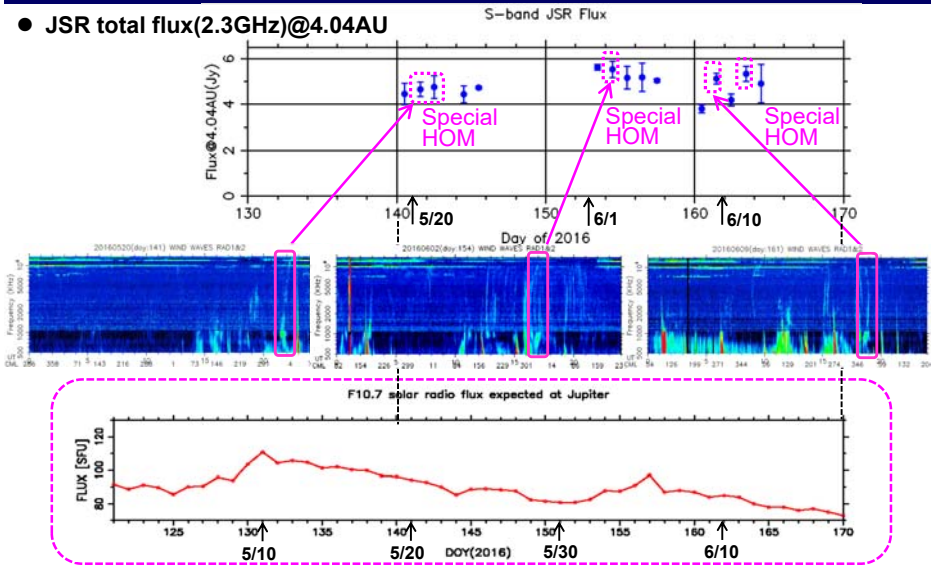
(Misawa+, MOP2018)





Preliminary result -1 : Daily JSR flux variation

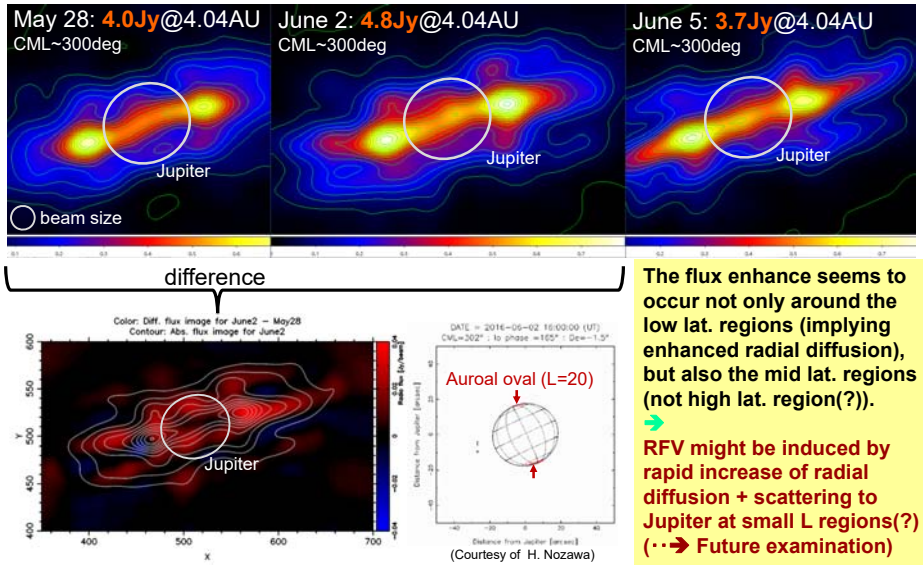
- **JSR total flux(2.3GHz)@4.04AU**



The daily JSR flux variations show positive correlation with occurrence of the special HOM suggesting occurrence of magnetic reconfiguration.

Preliminary result -2 : Radio image variation

- **JSR radio images@1.4GHz**



The flux enhance seems to occur not only around the low lat. regions (implying enhanced radial diffusion), but also the mid lat. regions (not high lat. region(?)).

➔

RFV might be induced by rapid increase of radial diffusion + scattering to Jupiter at small L regions(?) (・・➔ Future examination)

Fig. Daily radio images for May 28 ~ June 5 (upper panels) and the difference for June 2 – May 28 with an expected map of auroral oval area@L=20 (lower panels).

Summary (tentative)

●Purpose:

Investigation of characteristics of Rapid JSR Flux Variation event (RFV) & the relation between RFV and Jupiter's internal variation ~ magnetotail reconfiguration event.

●Preliminary results:

- **Positive correlation between RFV and occurrence of magnetic reconfiguration in the magnetotail region (implied by the 3rd HOM).**
- **RFV might be induced by rapid increase of radial diffusion + scattering to Jupiter at small L regions (??)**

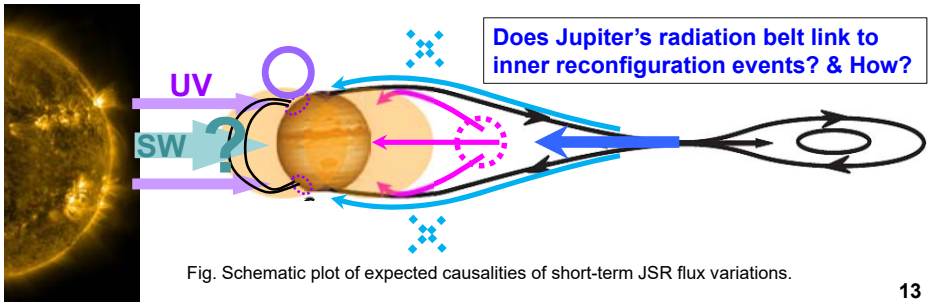


Fig. Schematic plot of expected causalities of short-term JSR flux variations.

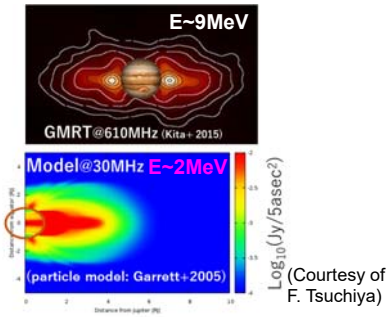
On going & Future investigations

●On going:

- **Additional radio image analyses have been made for the other campaign observations using GMRT and/or VLA in which internal driven processes might occur from the HOM data.**

●Future investigation:

- **Coordinated radio imaging study using GMRT and LOFAR(-NenuFAR) for several tens MHz to 1.5GHz, which enables to examine RFVs with the electron energy from a few MeV to 14MeV.**



(Courtesy of F. Tsuchiya)

Fig. Radio images of JSR at 610MHz(top: observation) & at 30MHz(bottom: model).

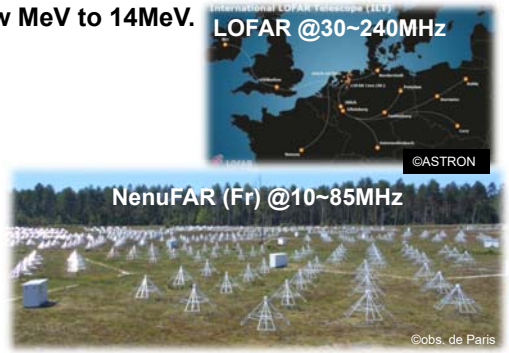


Fig. Station map of the **LOFAR** (top) and an photograph of **NenuFAR** of **obs. de Paris** in Nancay (bottom).

Acknowledgement

We are deeply grateful to staffs of Kashima Space Technology Center, NiCT, Japan, especially, M. Sekido, E. Kawai, H. Takefuji, S. Hasegawa and T. Kondo for their assistance on data acquisition and observation of JSR using the 34m radio telescope.

※ It's a great pity that the 34m radio telescope has finished its bright career suddenly in Sep. 2019 by the accidental hard attack of the typhoon 15 in 2019.

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