Long-term occurrence features of Jupiter's auroral radio emissions

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ABSTRACT

It is known that Jupiter's auroral radio emission (hereafter JAR) shows long term variations with the time scale of about a decade. The variations were first considered to be initiated by the solar activities in 1960's, however, longer term analyses in 1970's showed the variations relate with the Jovicentric declination of the earth (De). So far, their plausible causalities are considered to be brought by 1) De relating to amount of reachable rays to the earth, and 2) the geocentric declination of Jupiter relating to incidence angle of the radio wave to the terrestrial ionosphere (see Oya et al., 1984; Kawauchi et al., 2002). However, considering solar cycle dependence on the terrestrial auroral radio activity (e.g. Kumamoto et al., 2003), the solar activity control may not be negligible for the long term variations. The similar possibility, thought the opposite sense, is also implied for occurrence of Saturn's auroral short-term radio burst (Maruno et al. in this issue). Furthermore, so far we have not known well long term relationship between JAR and Jupiter's substorm-like process which may be controlled by Io's volcanic activity.

In order to assess the previously proposed causalities and the other effects, we have investigated occurrence features of JAR using the radio wave data observed outside the terrestrial ionosphere; i.e., by the WIND satellite for about 20 years after 1995. We have derived occurrence rates for 0.7 – 13.9 MHz around Jupiter's occultation periods using the data acquired with the WAVES instrument (Bougeret et al., 1995). Jupiter's auroral radio emissions in the frequency range above and below 3MHz are called as DAM and HOM, respectively. The analyzed results are controversial; i.e., the yearly occurrence rates show almost monotonous decrease from 1995 to 2005, then gradual increase after 2005, but change to somewhat complex nature with increase and decrease for DAM, and almost similar nature appears for HOM. It does not seem to correspond to variations of De and solar activities, but implies that some other or multiple causalities control the long term variations. The occurrence rates for Io-related DAM and non Io-related DAM show relatively high correlation (γ ~0.78). This implies that some common control factors affect the occurrence of Io-related and Non Io-related DAMs, and one of the possible candidates is Iogenic volcanic gas source rate which has showed roughly similar variation nature to the JAR occurrence rates.

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ABSTRACT

In order to investigate control factor(s) of Jupiter's long & short-term magnetospheric variations, we have investigated occurrence features of Jupiter's auroral radio emission using the radio wave data observed by the WIND satellite for about 20 years. We have derived occurrence probabilities from the data observed in the frequency range of 0.5 to about 14MHz (i.e., DAM & HOM) around Jupiter's occultation periods. The result is controversial & interesting; i.e., the yearly occurrence probabilities show almost monotonous decrease from 1995 to 2005, then gradual increase after 2005, but after 2009 change to somewhat complex nature with increase and decrease. It does not seem to correspond to variations of De and solar and/or solar wind activities, but implies that some other or multiple causalities (such as Io's plasma source rate) control the long term variations.

Jupiter's auroral radio emissions

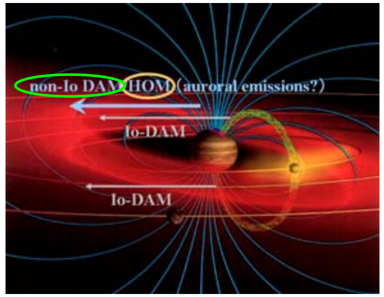


Fig. 1 Schematic view of Jupiter's electromagnetic/ plasma environment (after J. Spencer)

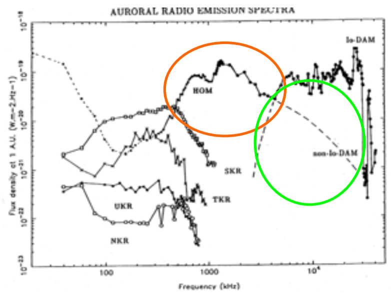


Fig.2 Power spectrum of planetary non thermal radio emission.（Zarka, 1992）

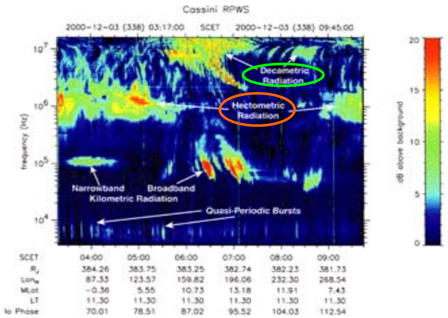


Fig.3 f-t diagram measured by Cassini.（Gurnett et al., 2002）

Long-term variations of DAM

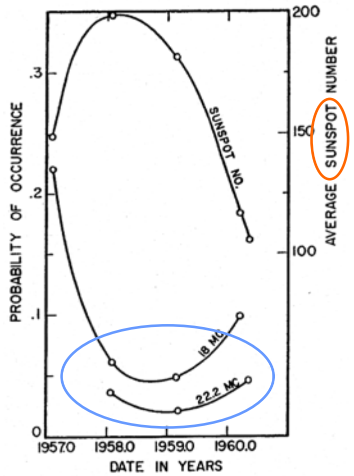


Fig.4 Relation of DAM occurrence and sun spot number（Carr+, 1961）

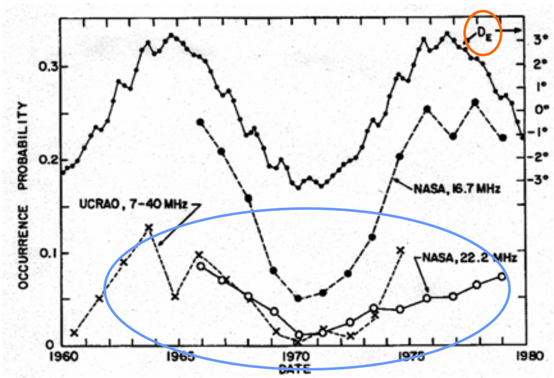


Fig.5 Relation of DAM occurrence and De（Carr+, 1983）

Negative-correlation with SSN

（～ by ionospheric condition?）

Positive correlation with Jupiter's declination of the earth

（～ by ray-emitting direction?）

Long-term variations of DAM

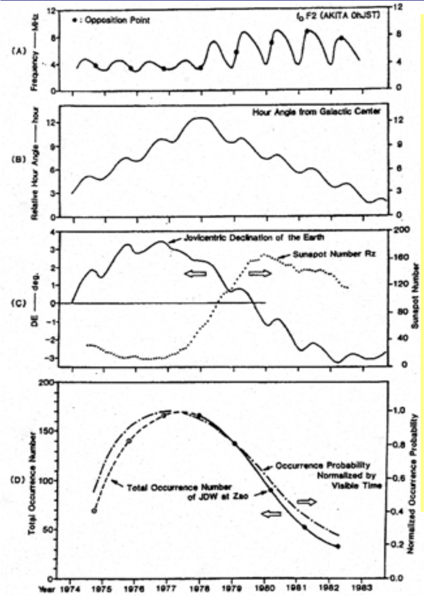


Fig.6 Relation of (D)DAM occurrence and (A)foF2, (B)deviation angle from galactic center, (C)SSN and De（Oya+, 1984）

Oya+(1984) **from the 1974～1982 data**

＋Terr. Ionospheric shielding by solar var.

＋variation of galactic back-ground

＋variation of Jupiter's ionospheric condition by solar var.

Kawauchi+(2002) **from the 1974～2001 data**

•De: effective for non Io-DAM

（De:+/- ➞ Occ. Prob. +/-）

non effective for Io-DAM

•Effect of Terr. Ionospheric shielding: ～40%

･Effect of var. of Galactic back-ground level ～5%

Correlation between HOM/DAM & solar wind

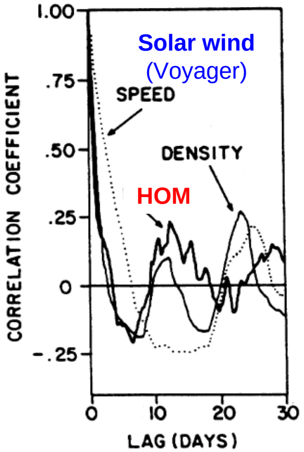


Fig.7 Autocorrelation coefficients for HOM & solar wind (Desch & Barrow, 1984)

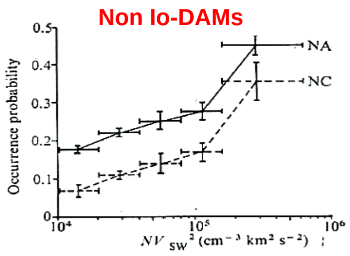


Fig. 8 Correlations between non Io-DAM & solar wind (Terasawa+, 1978)

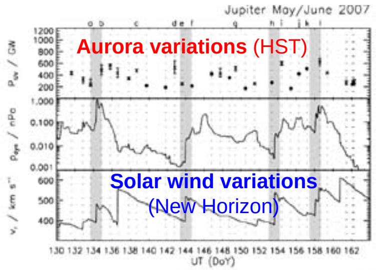


Fig.9 Relation between Jupiter's UV aurora & solar wind parameters (Clarke+, 2009)

Positive-correlation with solar wind parameters or shocks

Non-Solar Wind controlled variations in HOM

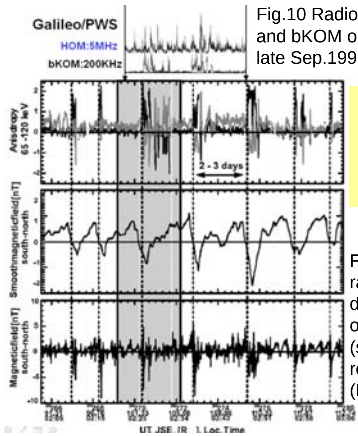


Fig.10 Radio intensities for HOM and bKOM observed by Galileo in late Sep.1996. (Louarn+, 1998)

HOM shows short-term correlation with internal-events

Fig.11 Anisotropies in the radial and corotational directions (top), s-n comp. of magnetic field (smoothed:middle, high resolution:bottom). (Kronberg+, 2005)

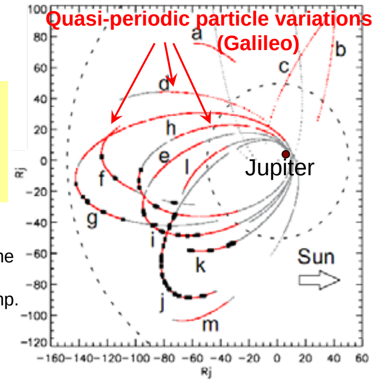


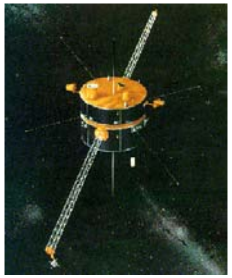
Fig.12 Locations of observed 'Quasi-periodic variations. (Kronberg+, 2009)

PURPOSE of this study

1. **Revealing time variability of Jupiter's auroral nature using radio emissions; especially long term (years)**
2. **Revealing control factor(s) of the time variabilities**
   Solar activity? / Solar wind? / Just apparent (e.g. De)? / the other(s)?

Tool: WIND/WAVES

Advantages: 1. Long-term & 2. Not-affected Terrestrial Ionospheric shielding



WIND: launched on Nov. 1, 1994

WAVES: Radio and Plasma Wave Investigation

·Radio Receiver Band 1&2 (RAD1&2)

Inputs: Ey(100m)+Ex(15m), Ez(12m)

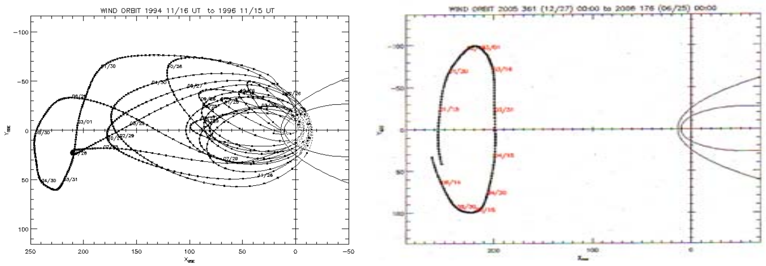
Frequency range: 0.05 MHz - 13.825 MHz

No. channels: 256 each for RAD1 & RAD2

Bandwidth: 4KHz(RAD1), 50 kHz(RAD2)

Sensitivity: 7 nV/√Hz (Bougeret et al.,1995)

Fig.13 WIND satellite and the orbits



Data analysis

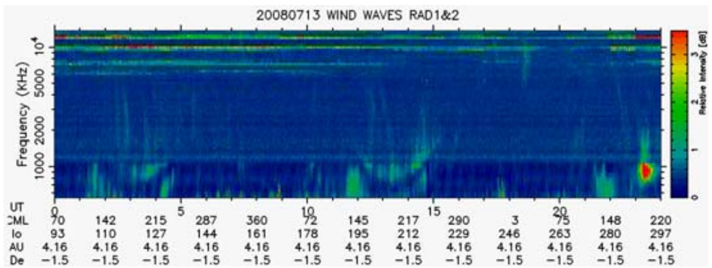


Fig.14 An example of one day f-t diagram observed with WIND/WAVES

･Procedure

1. **Detection of "events" from *f*−*t* diagram（>bg level+0.4dB）**
2. **Occurrence =event occ. period / observable period**

   #observable time : not include the period of solar radio emissions

･Period: Every opposition period (±2months) for 1995～2013

Results: DAM

・Apr.～Aug., 1995

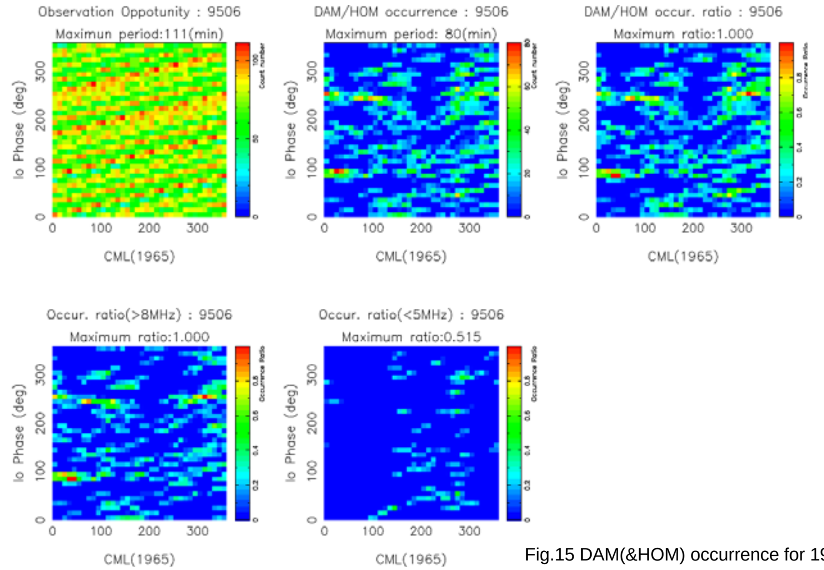


Fig.15 DAM(&HOM) occurrence for 1995

Results: DAM

・Sep. 2000～Jan. 2001

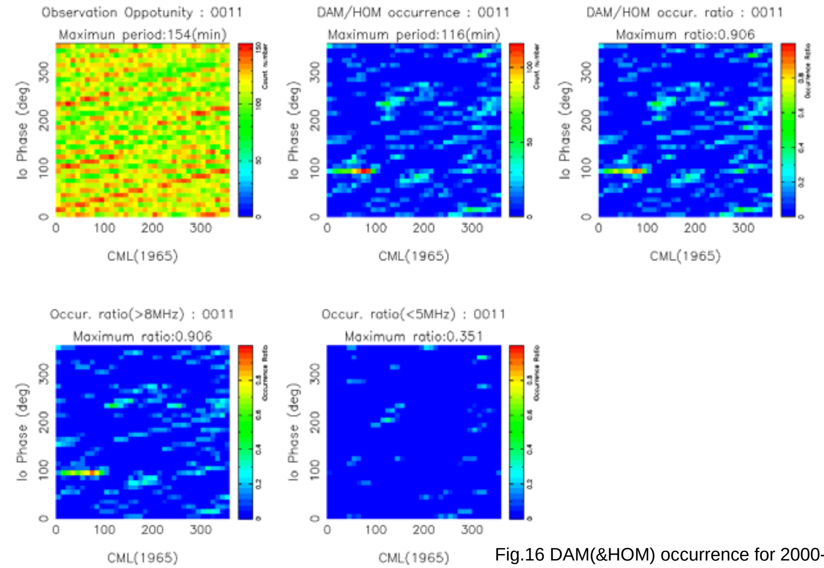


Fig.16 DAM(&HOM) occurrence for 2000-2001

Result: DAM

・Feb. 2006～ July 2006

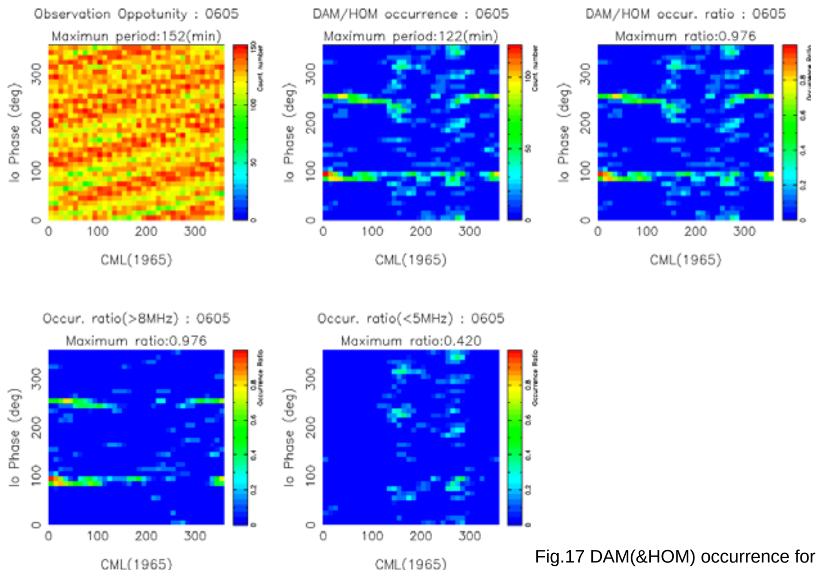
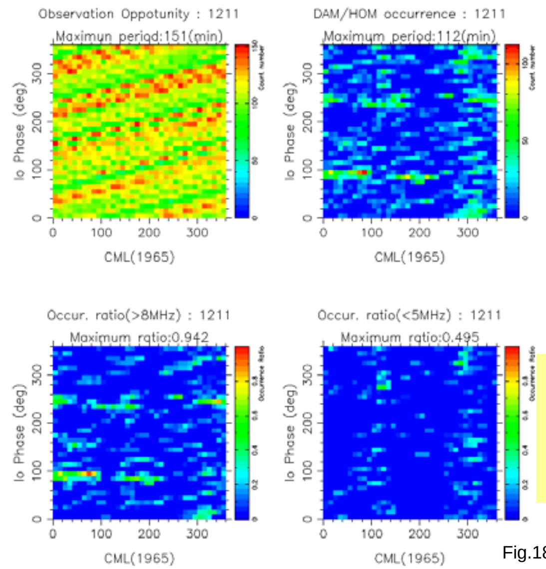


Fig.17 DAM(&HOM) occurrence for 2006

Result: DAM

・Sep. 2012～Feb. 2013



・f>8MHz: Strong Io control
Weak CML control

・f<5MHz:Strong CML control
& long term CML variation

Fig.18 DAM(&HOM) occurrence for 2012-2013

Result : DAM occurrence prob.

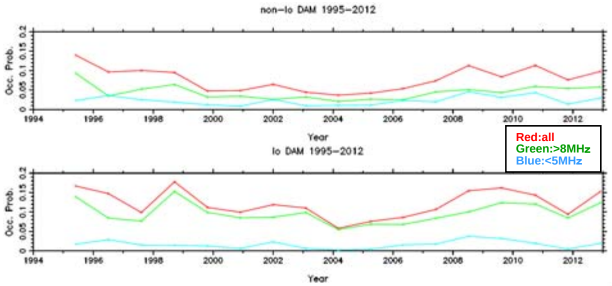


Fig.19 Io DAM/HOM (top) & non-Io DAM/HOM (bottom) occurrence rates in 1995-2013.

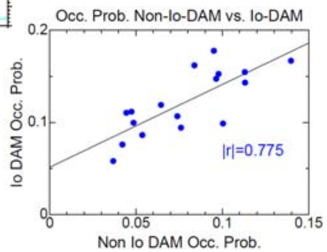


Fig. 20 Scatter plot for the non-Io DAM & Io-DAM occurrence prob.

・non clear De or Solar activity control

・ Io-DAM & non Io-DAM show somewhat similar variation

➔ Some common causality affects activities of both Io- & Non Io-DAM?

Result : HOM occurrence prob.

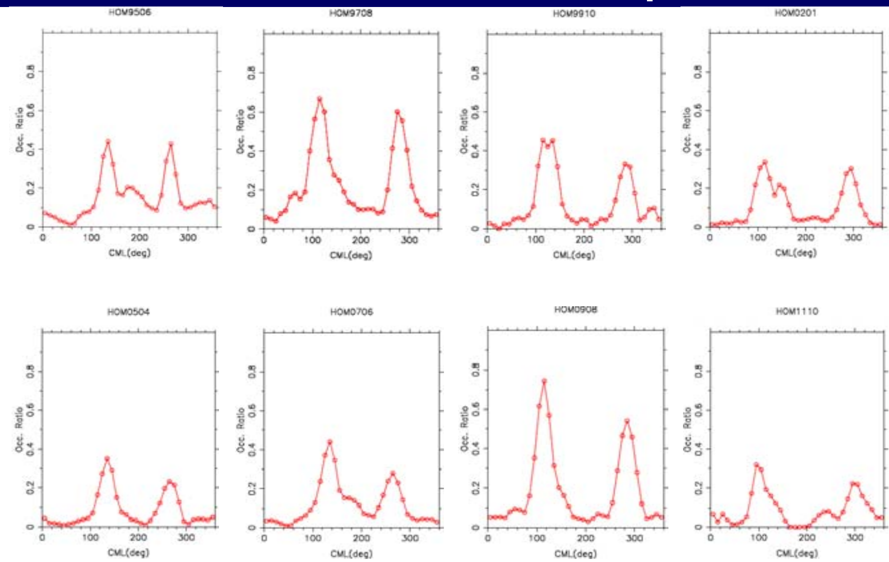


Fig.21 Yearly occurrence variation of HOM.

Characteristics of HOM occurrence

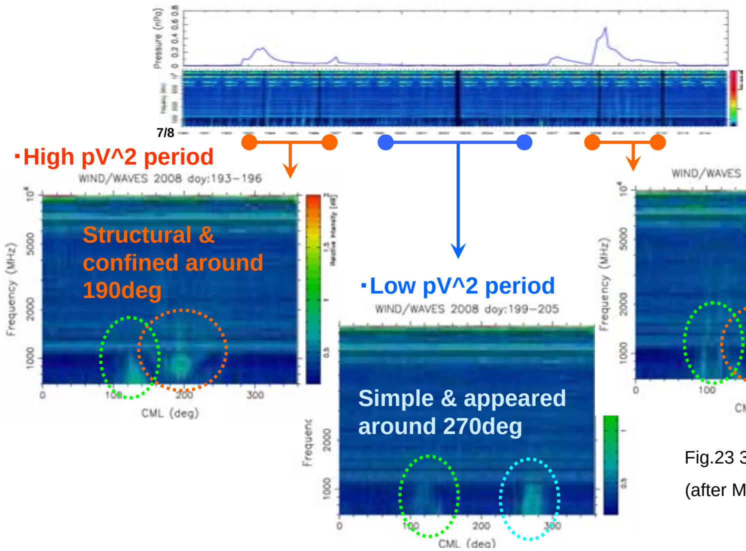


Fig.22 Mean feature (CML depend.) for high & low solar wind pressure periods.

Fig.23 3types of HOM (after Misawa+, 2011)

・HOM show different spectra between high & low solar wind pressure periods.

➔ 3 type HOMs: 1)solar wind(SW), 2)non-SW-1, 3)non-SW-2(~quasi regular)

Result: DAM & HOM

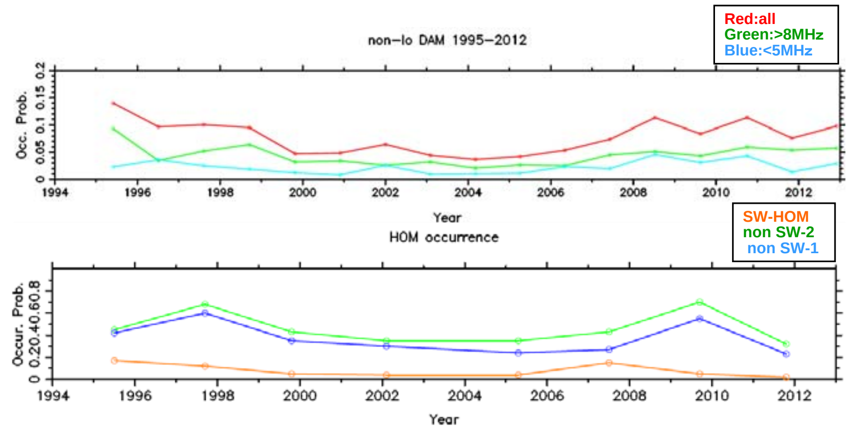


Fig.24 Occurrence variations of non Io-DAM & HOM

・Variation trends of non-Io DAM & non SW HOM are roughly similar.

Result : DAM summary

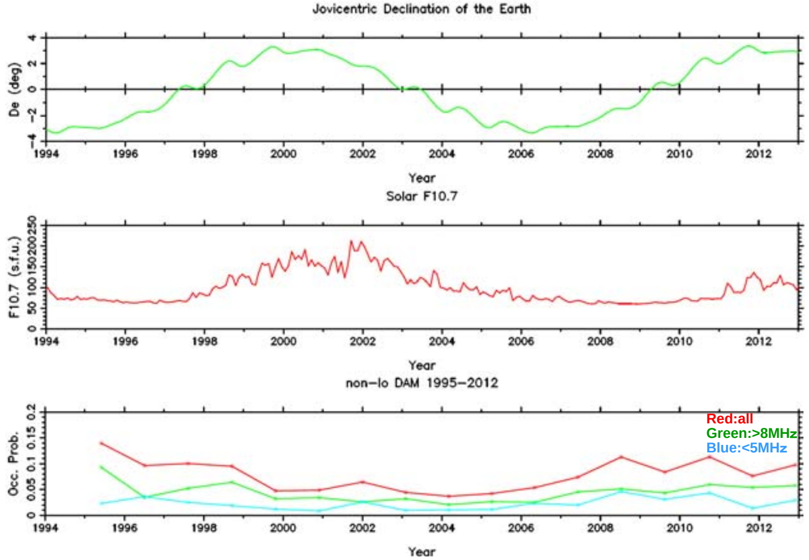


Fig.25 Variations of De, Solar F10.7 and non-Io DAM occurrence prob. De and F10.7 show in-phase variation, while the radio wave occurrence rates are roughly independent of both of them.

Relation with Solar wind pressure

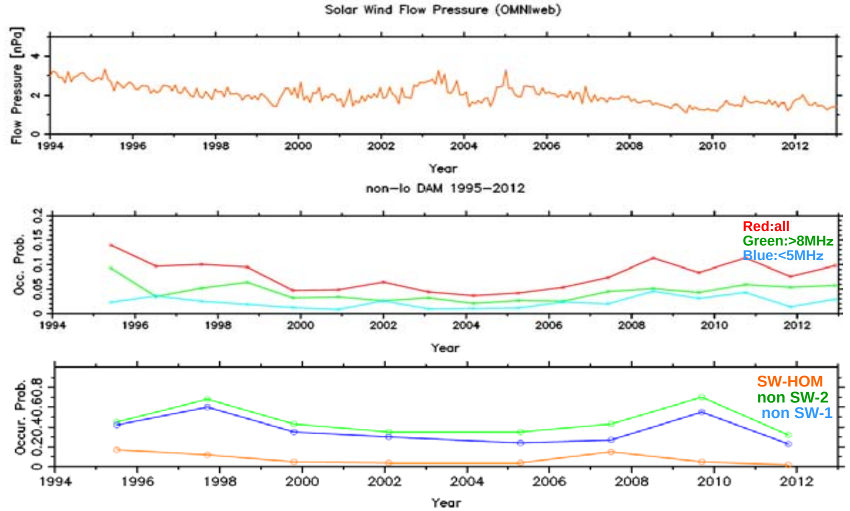


Fig.26 Occurrence variations of non Io-DAM & HOM and SW pressure.

・Solar wind also does not a main control factor for non Io-DAM & non SW HOM (& "SW HOM"??).

Relation with the Jovian plasma

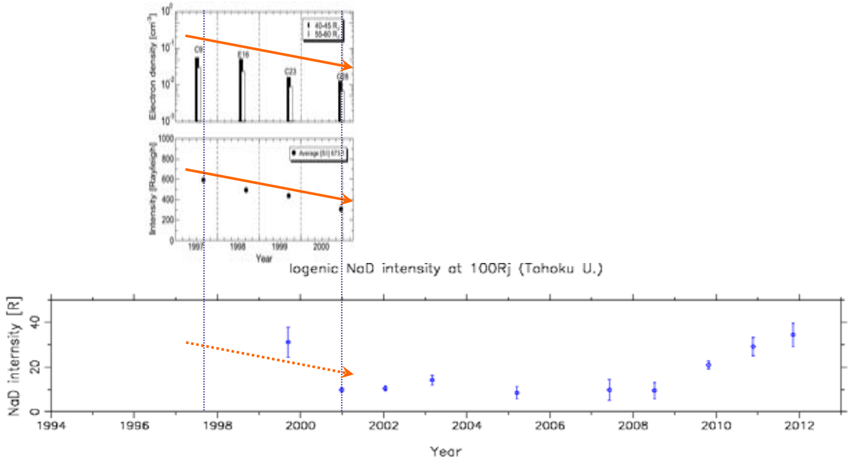


Fig.27 (Top) Variations of Jupiter's electron density in the plasma disk derived from Galileo/PWS, (Middle) Io Plasma Torus SII emission intensity derived from ground-based observation (Nozawa+, 2005), and (Bottom) mean Iogenic Na-D emission intensity at 100 Jovian radii derived from ground-based observation (courtesy of M. Yoneda, 2010, 2013).

Relation with the Jovian plasma

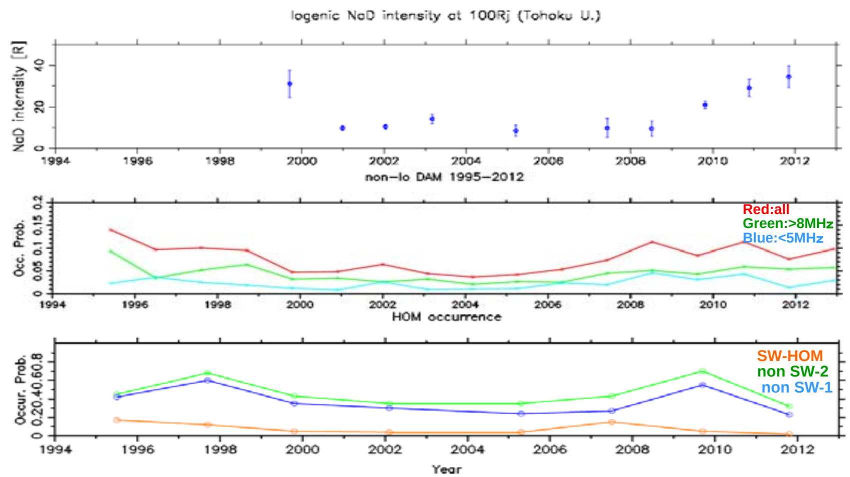


Fig.28 Variations of Iogenic sodium intensity (top) and non-Io DAM & HOM occ. Prob. (middle & bottom).

・Some relation?

Summary

- Analuses of time variation of Jupiter's auroral radio emission using WIND/WAVES

  [Analysis] using the data around every Jupiter's opposition period

  [Result] no 11 or 12-year systematic variation inferring Solar activity or De variation➔ different origin

  non Io DAM&HOM and Io-DAM show similar variations

  ➔ controlled by common factor(s)?

- Relation between expected causalities & radio emission occur.

  ･Pattern of occur. （＼＿／＾）

  ･Solar wind （＼／＼＿）･･･×

  ･Solar UV： （＿／＼＿／）･･･×

  ･Magnetspheric plasma: （?＼＿／?）･･･(○)？

  ･De： （／＼＿／^）･･･×

  ･･･ Magnetosphereic plasma is the main causality?

  ➔ suggesting the plasma variation positively control the activity.

- Future works：1. More continuous plasma monitor

  2. Additional assessments of other Jupiter phenomena