Long-term variable nature of Jupiter's auroral radio emissions - II

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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. Furthermore, we have not known well long term relationship between JAR and Jupiter's substorm-like process which is considered to be controlled by Io's volcanic plasma variability.

In order to investigate control factor(s) of Jupiter's long-term magnetospheric variations, we have investigated occurrence features of JAR using the radio wave data for more than 25 years (1995~) observed by the WIND satellite. We have derived occurrence probabilities from the data observed in the frequency range of 1 - 14MHz for 4 months of every Jupiter's opposition periods. The results are interesting; i.e., the yearly occurrence probabilities show almost monotonous decrease from 1995 to 2005, then gradual increase from 2005 to 2010, but change to somewhat complex nature after 2010 with increase and decrease for non Io-related components. In addition, it should be noted that the occurrence probability in the 2015 opposition period is abruptly large and that in the 2020 opposition period is the largest in the past 25 years. It does not seem to correspond to simple variations of De and solar and/or solar wind activities those have been discussed as plausible causalities, but implies that some other or multiple causalities control the long term variations. In particular, the abrupt increase of the 2015 occurrence probability implies that the causality should have shorter time scale than the solar cycle and/or De variations. One candidate for such the causalities is Io's volcanic plasma variability. We have started to make the comparison between the JAR and Iogenic sodium emission variations, however it does not seem to be a simple correlation. As the next step, we plan to make further comparative analyses with shorter time resolution (currently yearly base, monthly base as the nest step) and a comparative analysis with Iogenic plasma variations instead of the neutral sodium gas variations(c.f. Morgenthaler+, 2023) including the JAR occurrence data after the 2020 opposition period.

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Abstract: In order to investigate control factor(s) of Jupiter's long-term magnetospheric variations, we have investigated occurrence features of Jupiter's auroral radio emission using the radio wave data for more than 25 years (1995~) observed by the WIND satellite. We have derived occurrence probabilities from the data observed in the frequency range of 1 to about 14MHz around Jupiter's opposition periods. The results are interesting; i.e., the yearly occurrence probabilities show almost monotonous decrease from 1995 to 2005, then gradual increase from 2005 to 2012, but change to somewhat complex nature with increase and decrease for non Io-related components. It does not seem to correspond to simple variations of De and solar and/or solar wind activities those have been discussed as plausible causalities, but implies that some other or multiple causalities control the long term variations.

Outline: 1. Review: Long-term occurrence variations of Jupiter's auroral radio wave
2. Result: Long-term variations of the auroral radio wave observed from WIND
3. Brief discussions: possible causes for the long-term variations

Jupiter's auroral radio emission(JAR): review

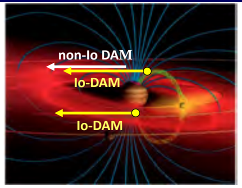


Fig. DAM & Io-DAM (after J. Spencer)

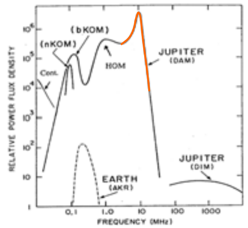


Fig. Schematic plot of Jupiter's non-thermal radio emissions.(Kaiser, 1993)

DAM: >3MHz

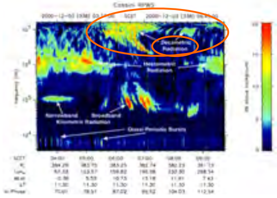


Fig. f-t diagram obs. by Cassini.(Gurnett+, 2002)

Long term variation of JAR: review

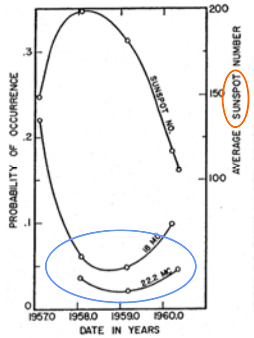


Fig.1 Relation of DAM occurrence and sun spot number (Carr et al., 1961)

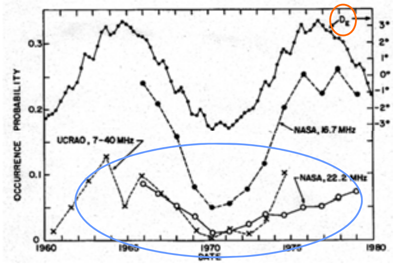


Fig.2 Relation of DAM occurrence and De (Carr et al., 1983)

太陽活動と反相関
(⇔地球電離層遮蔽・電波源状態・・・)

木星緯度(De)と正相関
(⇔ 電波放射角特性・・・)

Long term variation of JAR: review

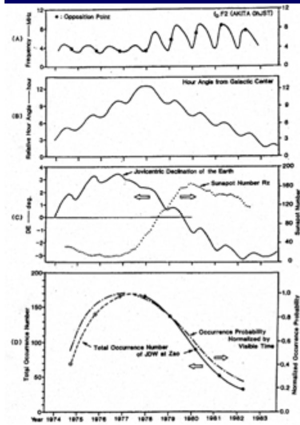


Fig.3 Relation of (D)DAM occurrence and (A)foF2, (B)deviation angle from galactic center, (C)SSN and De (Oya et al., 1984)

Oya et al.(1984):1974～1982年の解析

地球電離層遮蔽(太陽活動度大➔出現率低下:逆相関)

＋木星運行に伴う銀河背景放射の変動

＋木星電離圏状態変動(太陽活動)

河内他(2002): 1974～2001年の解析

・De: effective for non Io-DAM
(De:+/- → Occ. Prob. +/-: 正相関)
non effective for Io-DAM

・地球電離層による遮蔽の影響:～40%

・銀河背景放射強度変動の影響:～5%

Long term variation of External factors

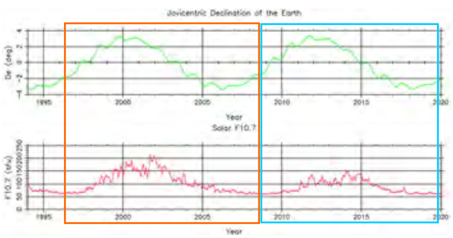


Fig.4 Long-term variation of De and F10.7. Solar cycle 23 & 24 show similar De variations, but different solar activities.

近年:Deと太陽活動が同様のフェーズで変化。しかし、太陽活動度はCycle 23~25で変化。
オーロラ電波出現への影響を調べるには良い機会。

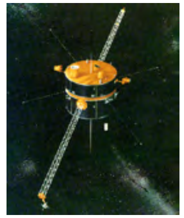
＋

電離圏外での観測の場合、地球電離層遮蔽の影響を受けない。

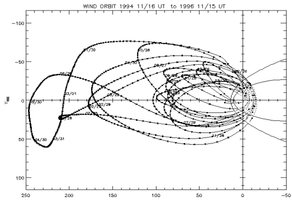
[目的] 科学衛星データ利用で木星オーロラ電波の長期変動様相とその変動要因を探る

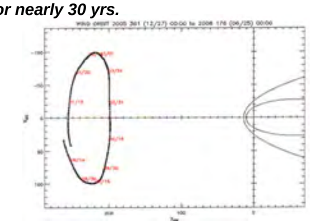
[データ] WIND/WAVES(1-14MHz) / 1995～2017(21)年 木星衝付近のデータ使用

Data source: WIND/WAVES

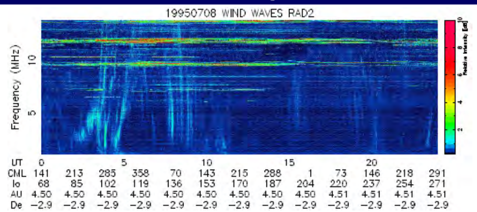


WIND: launched on Nov. 1, 1994
WAVES: Radio and Plasma Wave Investigation
・Radio Receiver Band 2 (RAD2)
Inputs: Ey(100m)+Ex(15m), Ez(12m)
Frequency range: 1.075 MHz - 13.825 MHz
Number of channels: 256
Bandwidth: 20 kHz
Sensitivity: 7 nV/Sqrt(Hz) (Bougeret et al.,1995)
#Δt 60sec
#Merit of WAVES data: highly sensitive & stable for nearly 30 yrs.





Data Analyses



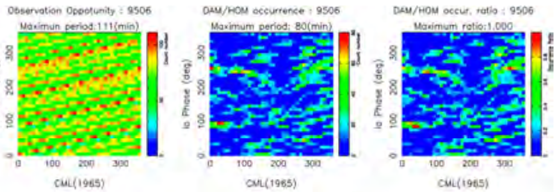
・手順:

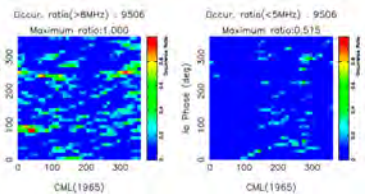
1. f–tダイアグラムからイベントを検出 (event: >bg level+0.5dB)。
2. 太陽バースト等によるイベント検出不可時間以外を可観測時間とし、イベント出現時間／可観測時間 から 出現頻度 を導出。

・解析期間:1995年～2020年の木星衝(～13ヶ月周期)の前後2ヶ月

Result:1

・1995年4～8月

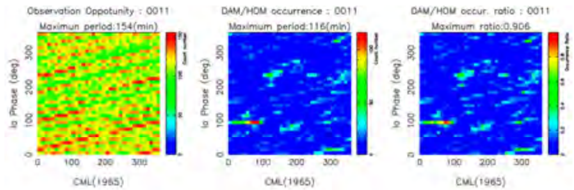


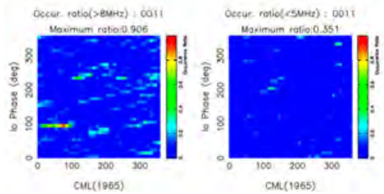


・解析補足:
CML10度×Io位相角10度のビンについて、観測時間、オーロラ電波の出現時間を積算し表示。

Result:2

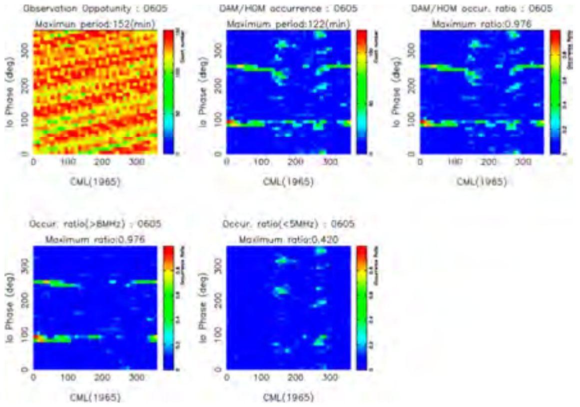
・2000年9月～2001年2月





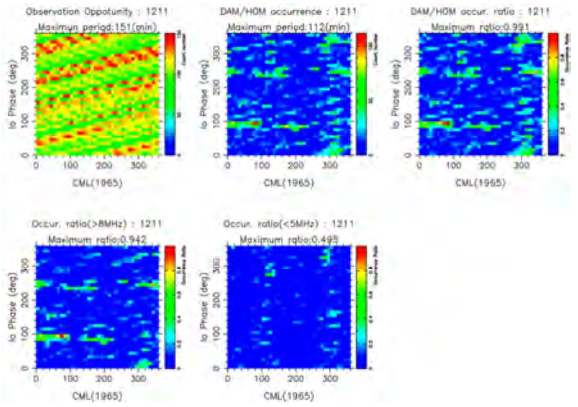
Result：3

・2006年2月～2006年7月



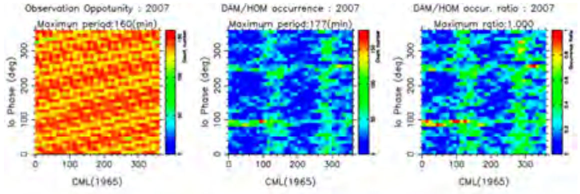
Result：4

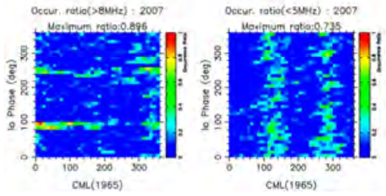
・2012年9月～2013年2月



Result：5

・2020年5月～2020年9月





・f>8MHz: Io control強
CML control弱
・f<5MHz: CML control強
& CML controlに長期変化

Result: Long term var. of JAR Occurrence

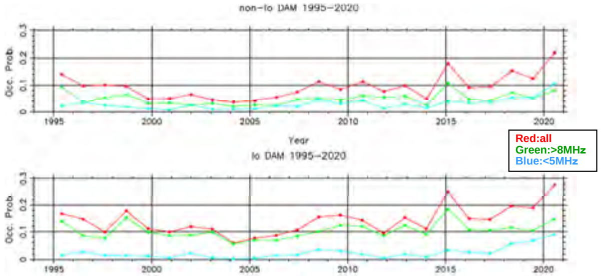


Fig. Io DAM/HOM (top) & non-Io DAM/HOM (bottom) occurrence rates in 1995-2017.

・Deや太陽活動に同期した規則的な(周期)変化は見られない。
より長い時間スケールでの変化が見える。

・ Io関連電波は非Io関連電波に較べ変化がやや大きいが、同様の変化傾向がある。

➔ 両者に太陽活動やDe以外の共通のプロセスが関与している可能性。

Discussion: DAM Long term var. vs De/F10.7

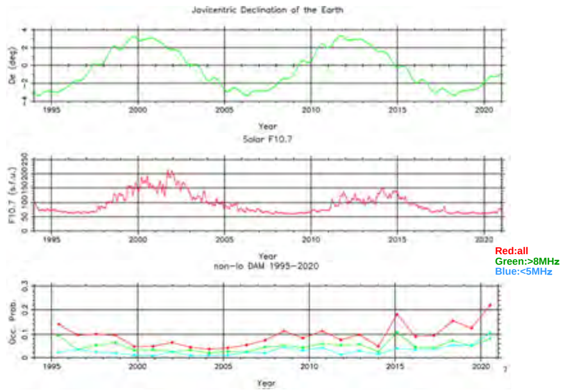


Fig. Variations of De, Solar F10.7 and auroral radio wave occurrence rate detected with the WIND/WAVES in 1995 - 2012. De and F10.7 show in-phase variation, while the radio wave occurrence rates are roughly independent of both of them.

Discussion: Long term var. of JAR vs Sol. wind

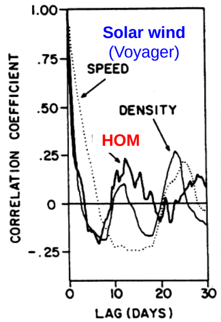


Fig. Autocorrelation analyses for HOM & solar wind
(Desch & Barrow, 1984)

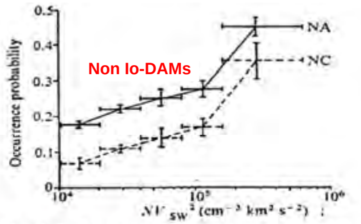


Fig. Correlations between non Io-DAM & solar wind
(Terasawa et al., 1978)

Discussion: Long term var. of JAR vs Sol. wind

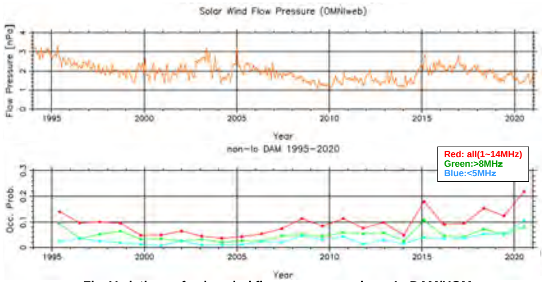


Fig. Variations of solar wind flow pressure and non Io-DAM/HOM

・太陽風動圧とオーロラ電波出現率の変化の相関は高くはない。
➔オーロラ電波出現率変動の主要因はDe,太陽活動以外の何物か・・・？

Discussion: Long term var. of JAR vs Io activity

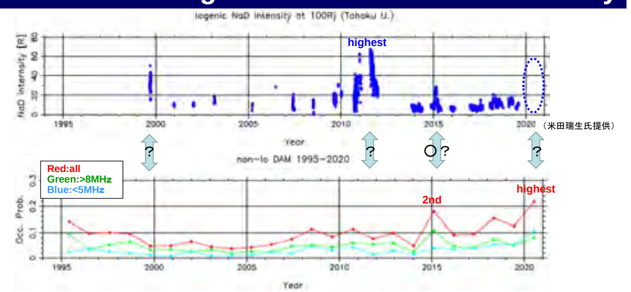


Fig. Variations of Iogenic sodium intensity (top) and non-Io DAM/HOM occurrence probability (bottom).

・2000~2010年頃までのNa発光量とDAMの出現は良相関。2015年のDAM出現の増加も定性的には合致。しかし、2012年以降のDAM高出現率はプラズマ源変動のみでは説明出来ず(?)。
➔ プラズマ源変動＋α（De？、外的要因）が出現率をコントロールか。

※ プラズマ密度と磁気圏活動の関係：
プラズマ量増加はサブストーム性現象発生頻度を増加さす (Kronberg et al., 2005)
←➔プラズマ量増加は磁気再結合率を低減する (Shay & Swisdak, 2004)

Summary

●オーロラ電波の長期変動解析　using　WIND衛星観測データ

[データ解析] 1995～2017年の木星衝前後約2月のデータ使用

[結果] 太陽活動やDe変化を示唆する11~12年周期変化はない➔別種の変動
非Io関連電波とIo関連電波で同傾向の変化 ➔ 共通要因による変動

●想定される長期変動要因とオーロラ電波出現率の関係

・電波出現の変動パタン:　[＼__／~~~~~]
・太陽UV照射：　[_／ ＼_／ ＼] ・・・×
・De：　[_／ ＼_／ ＼] ・・・×
・太陽風：　[~＼_／ ＼_ ／] ・・・×
・磁気圏プラズマ：　[?＼__／~(＼)?] ・・・△？
・・・　磁気圏プラズマ変化(＋α？)がオーロラ電波出現頻度変化に影響？
➔ プラズマ量変化が磁気圏活動を”positive”に制御する可能性を示唆。

●課題：　・他の木星現象(low HOM, optical・・・)の追加査定
・時間分解能を上げての出現頻度・相互比較評価
(・2021年以降の電波出現データの追加解析＆相互比較評価)