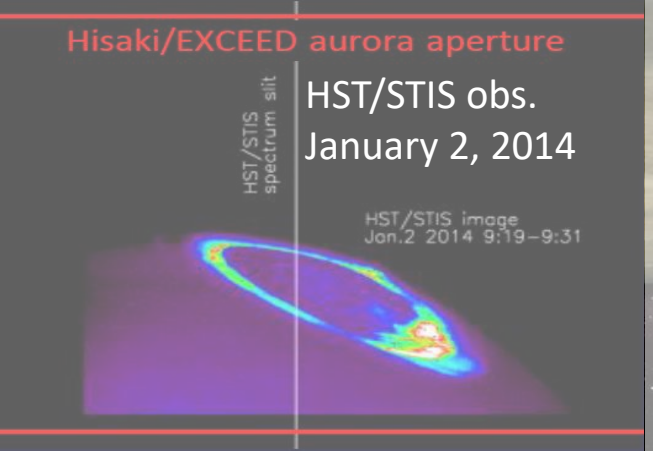


Planetary Space Weather Workshop,
Toulouse, Oct. 9-11, 2017

Variation of Jupiter's aurora observed by Hisaki/EXCEED

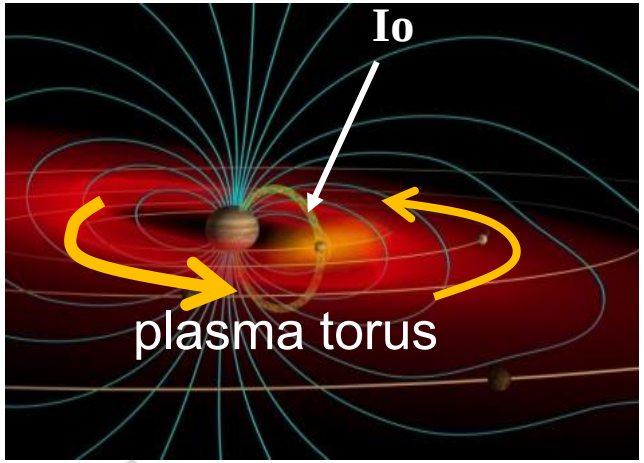
Chihiro Tao[1]

T. Kimura[2], H. Kita[3], F. Tsuchiya[3], G. Murakami[4], K. Yoshioka[5], S. V. Badman[6], N. André[7], A. Yamazaki[4], I. Yoshikawa[5], Y. Kasaba[3], and M. Fujimoto[4]

1. National Institute of Information and Communications Technology (NICT), 2. RIKEN, 3. Tohoku University, 4. ISAS/JAXA, 5. University of Tokyo, 6. Lancaster University, 7. IRAP/Université de Toulouse/CNRS

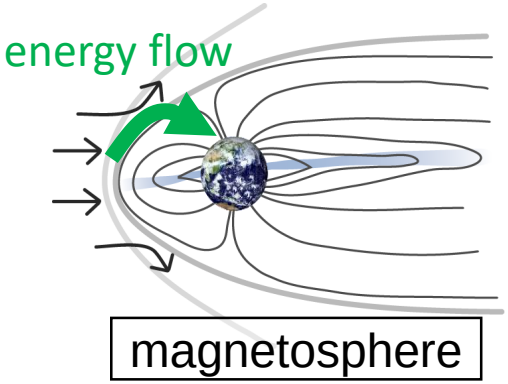
Jupiter's Magnetosphere

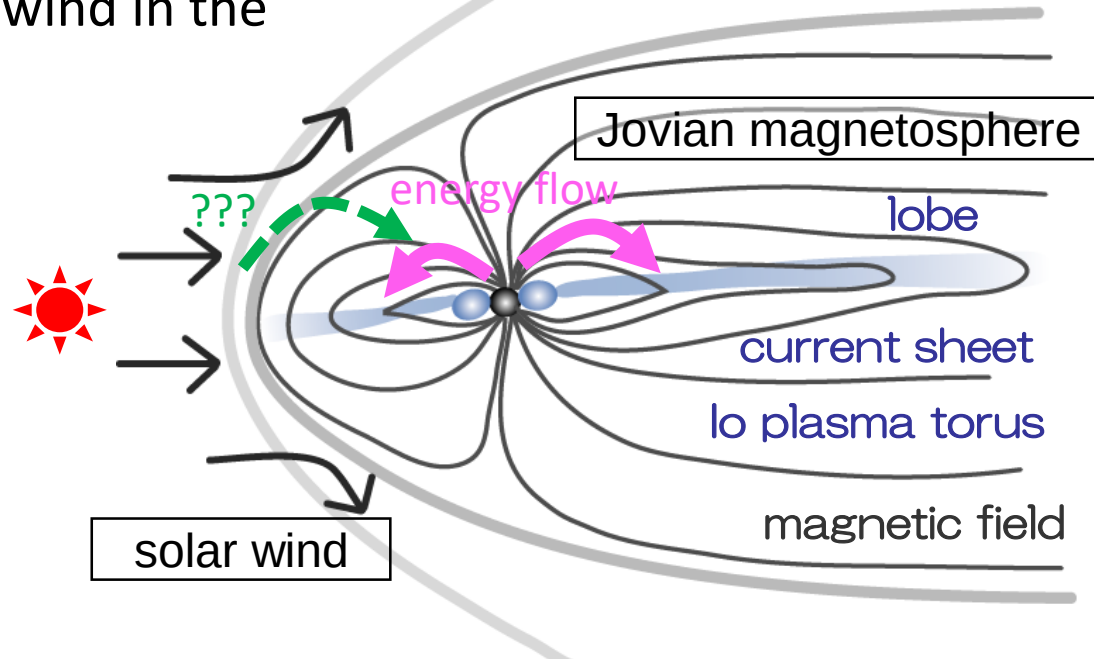
- Largest planet in the solar system, fast rotation
  (9h55m : rotation energy is x200,000 Earth's)
- Strong magnetic field (momentum x20,000 Earth's)
- Variable volcano of moon Io is main plasma source
- Momentum transfers from the planet to the magnetospheric plasma [e.g., Hill, 2001, Cowley and Bunce, 2001]



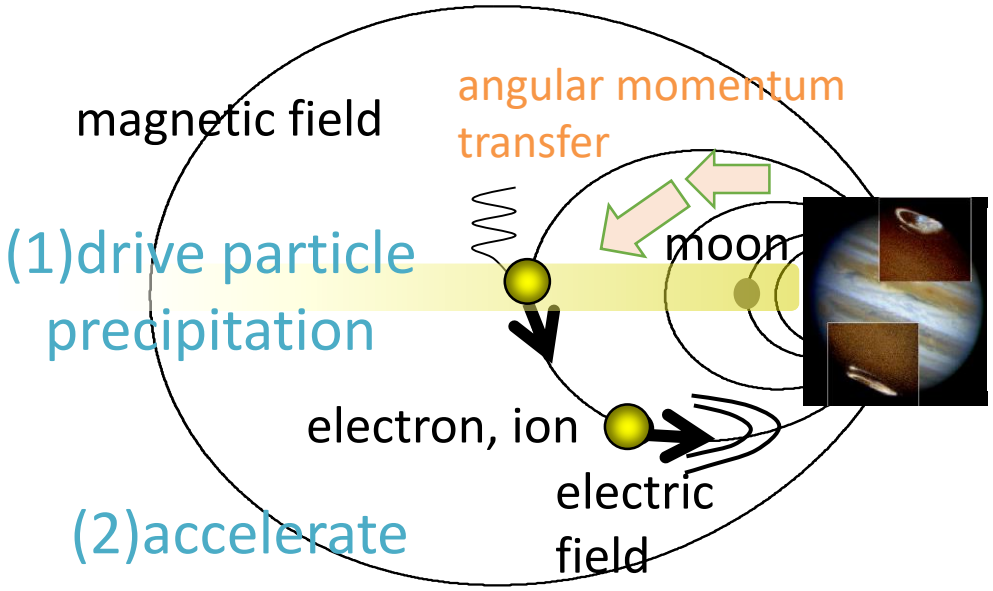
http://www.lowell.edu/users/spencer/

Q. What is the role of the solar wind in the system? Io plasma variation?
→ Aurora variation

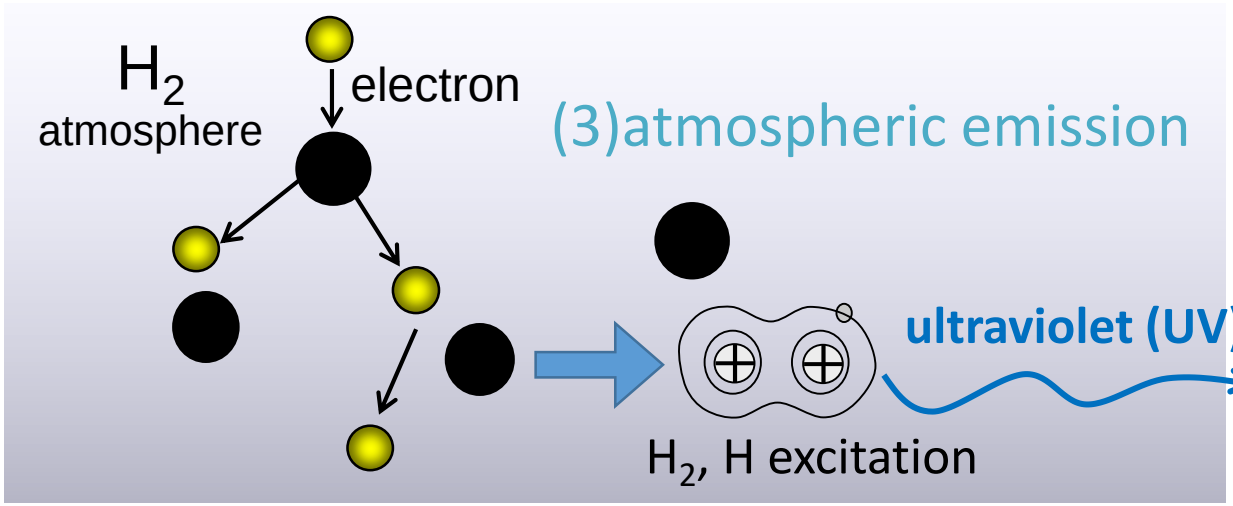


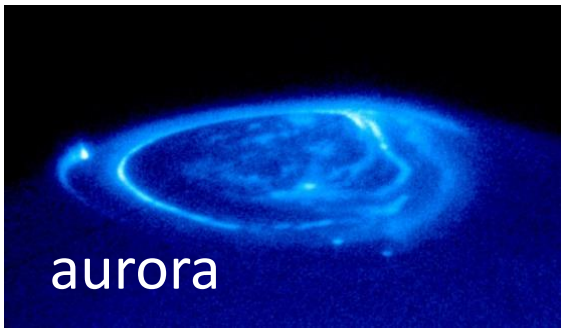


Jupiter UV Aurora



* Jupiter aurora reflects auroral electron precipitation and magnetospheric activities



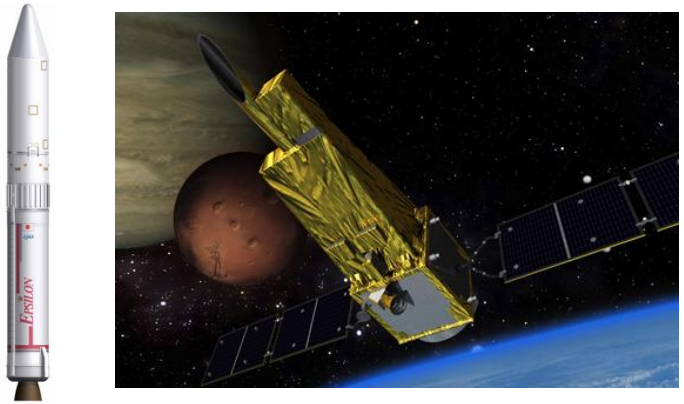


Hisaki/EXCEED

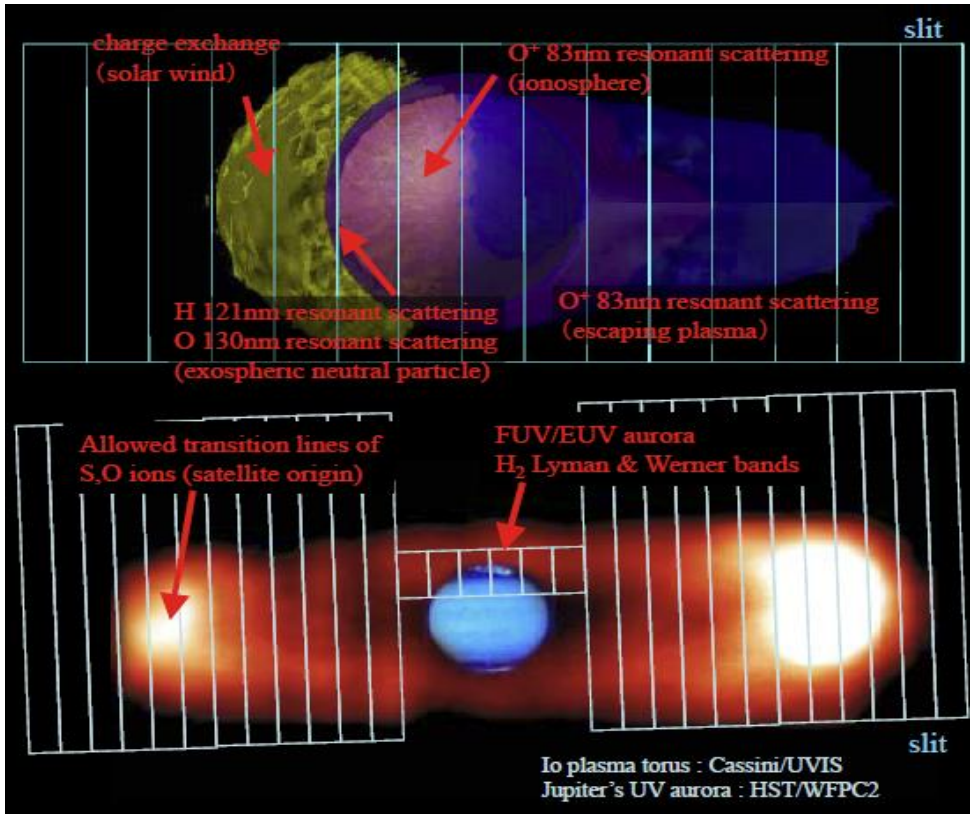
EXCEED (=Extreme Ultraviolet Spectroscope for Exospheric Dynamics) instrument is onboard “Hisaki”, a space telescope satellite by JAXA.

Targets of Extreme-ultraviolet (EUV) imaging spectrometer
(1) Atmospheric escape
from Venus, Mars, and Mercury
(2) Surrounding plasma and aurora
emissions from Jupiter and Saturn

Launch : September 14, 2013
→Long-term monitoring



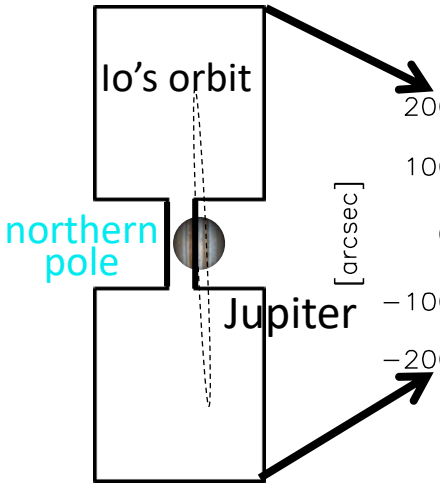
http://www.jaxa.jp/projects/sat/sprint_a/

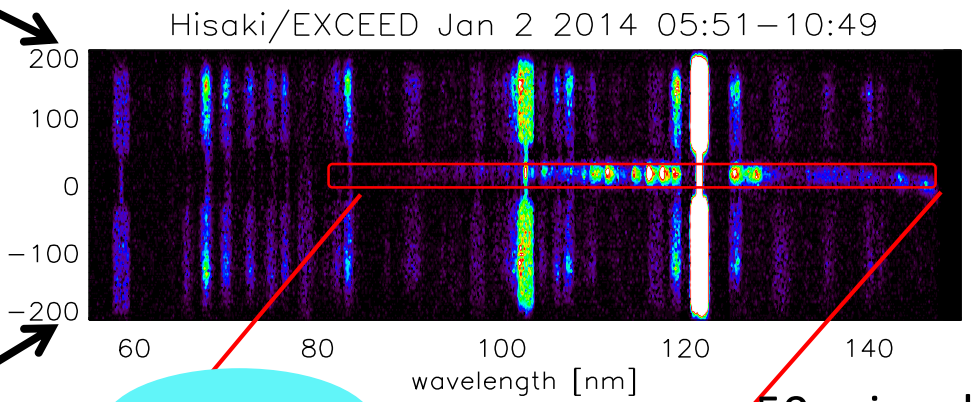


Dataset:

Method detail: Kimura et al. [2015GRL]; Tao et al. [2016bJGR]

Hisaki/EXCEED aurora observation

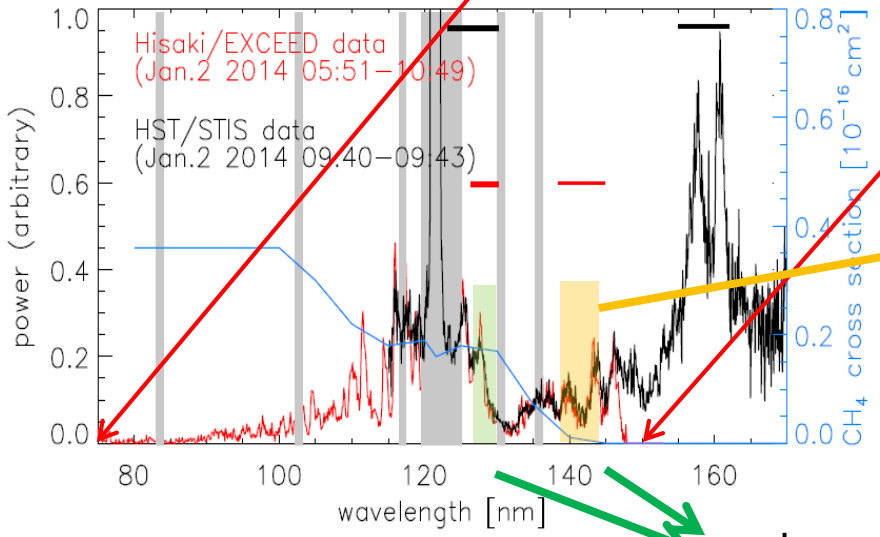




Wavelength 55-148 nm
FWHM 3 nm
Δx~17 arcsec
Pointing ±2 arcsec

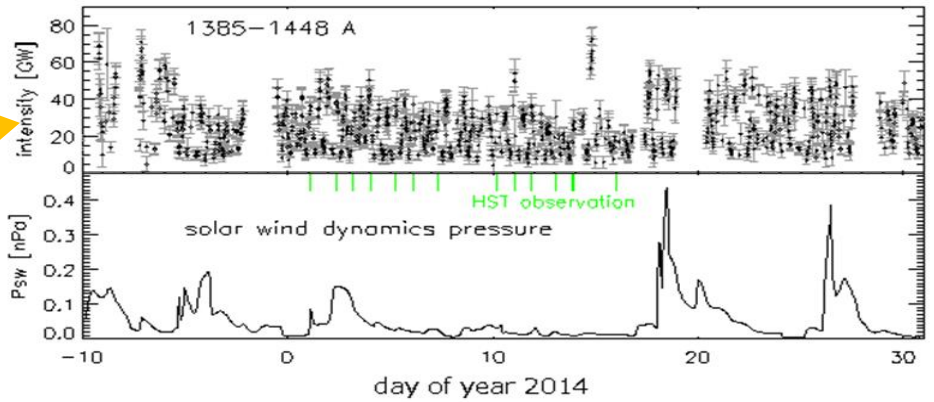
【Spectral Information】

Hisaki



50-min. obs. in each 106-min. orbit
(Aurora: 10-min. integration)

【Continuous Observation】



color ratio (CR) ∝ hydrocarbon absorption
→ auroral electron energy 【Auroral electron Information】

Hisaki Aurora Events

① Rotational variation (1 rot.~10 hours)

② Short-term enhancements (<1 rot.)

③ A few days variation

④ Several days variation

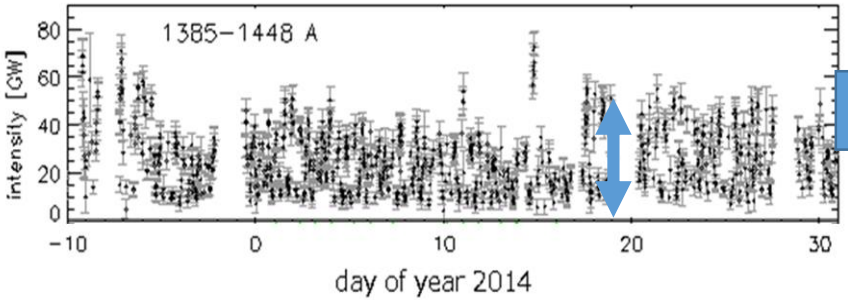
⑤ Several 10s days variation

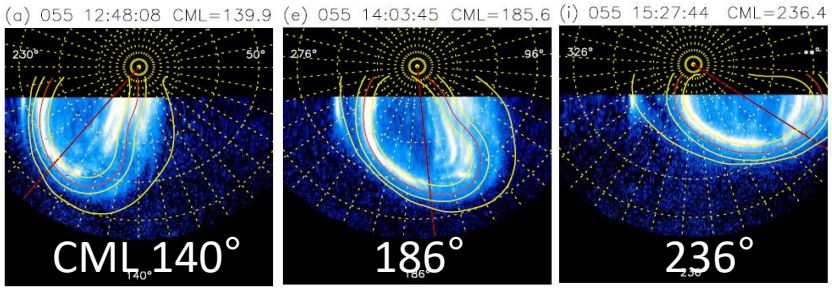
⑥ Statistical feature

CML dependence (~1 rot.) [Tao et al., 2016a JGR]

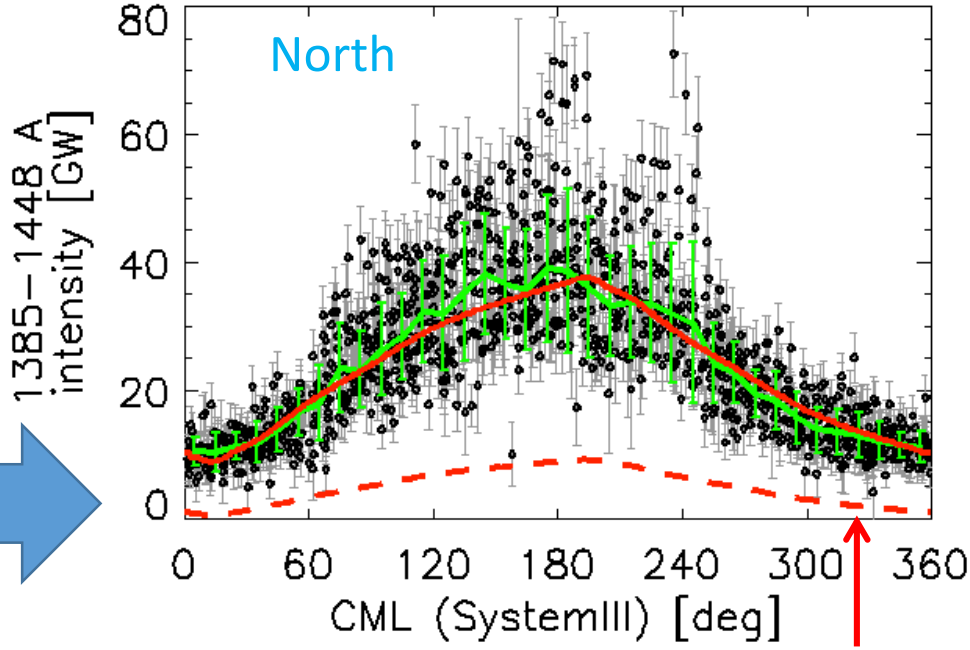
Appearance change of Jupiter aurora is due to the 10 deg. tilt of magnetic axis to the rotation axis.

Time variation of Hisaki aurora

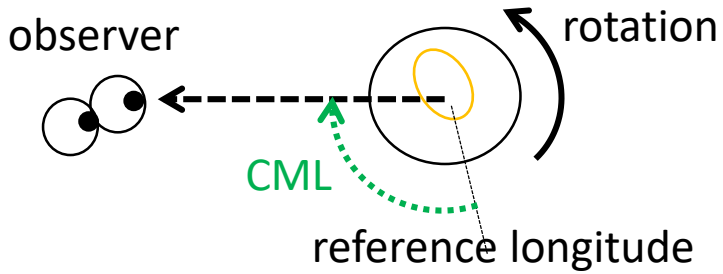




CML dependence of aurora aperture taken by Hubble Space Telescope [Nichols et al., 2009]



relative northern auroral based on VIP4 model [Connerney et al., 1998].

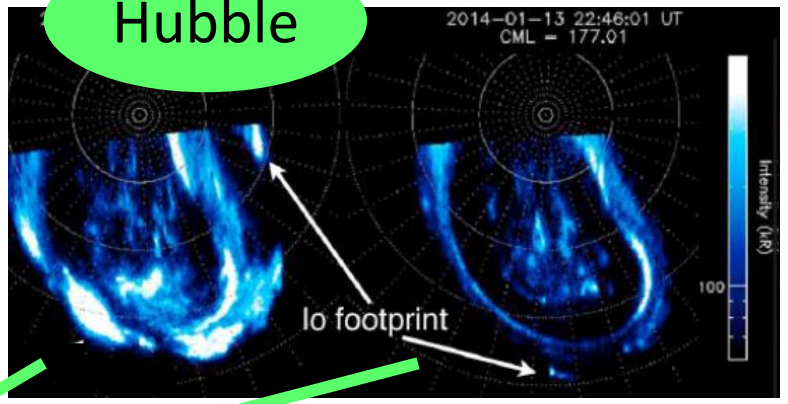


Short-term (<1rot.) Enhancements

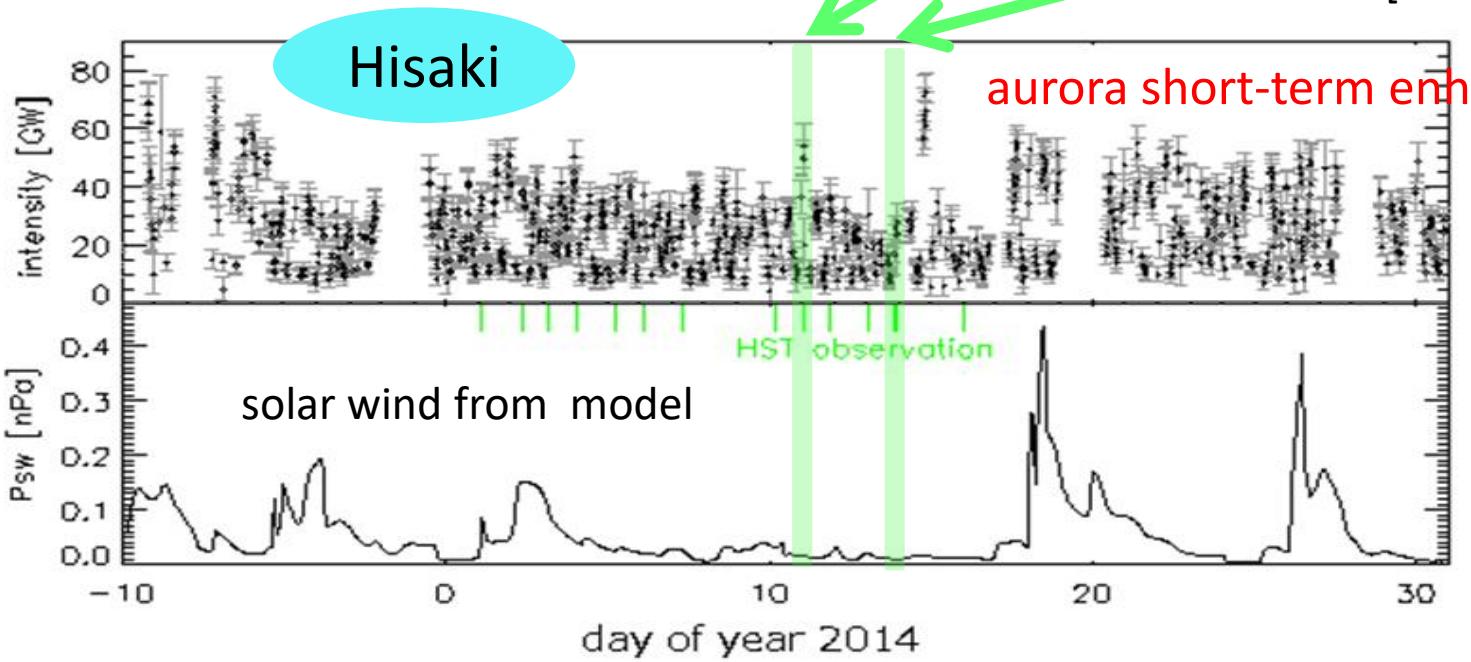
[Kimura et al., 2015 GRL]

Hisaki/EXCEED's continuous observation
+ Hubble Space Telescope (HST) image

→ Dynamic variation



[Kimura et al., 2015]



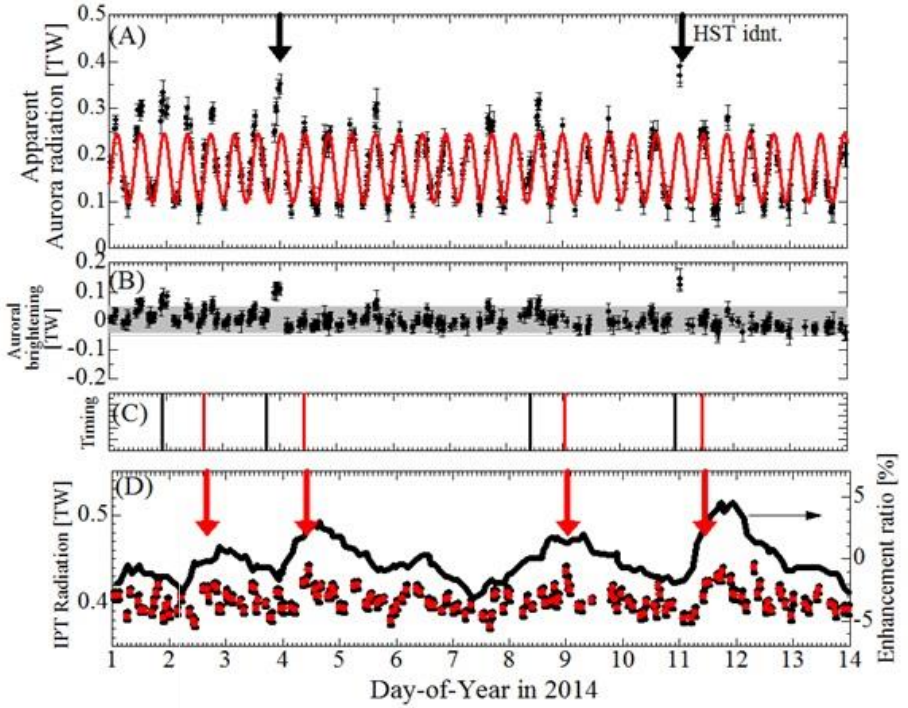
③ A few days variation

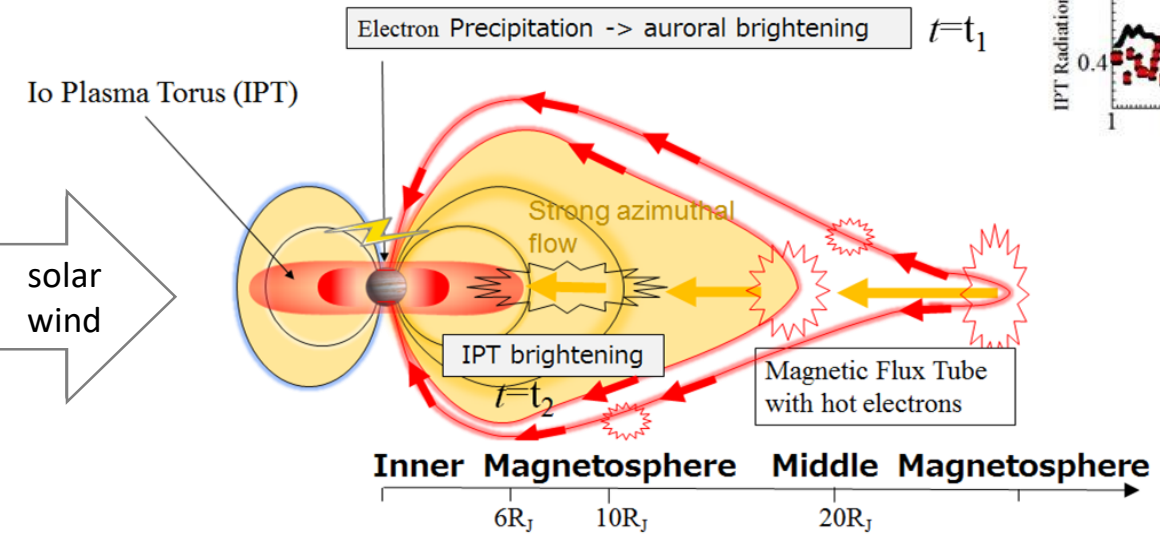
Energy coupling between middle and inner magnetospheres

Pairs of brightening of plasma in inner magnetosphere and aurorae

Brightening of aurora is earlier than that of that in the inner magnetosphere by several hours.

Evidence of inward radial transport of energy



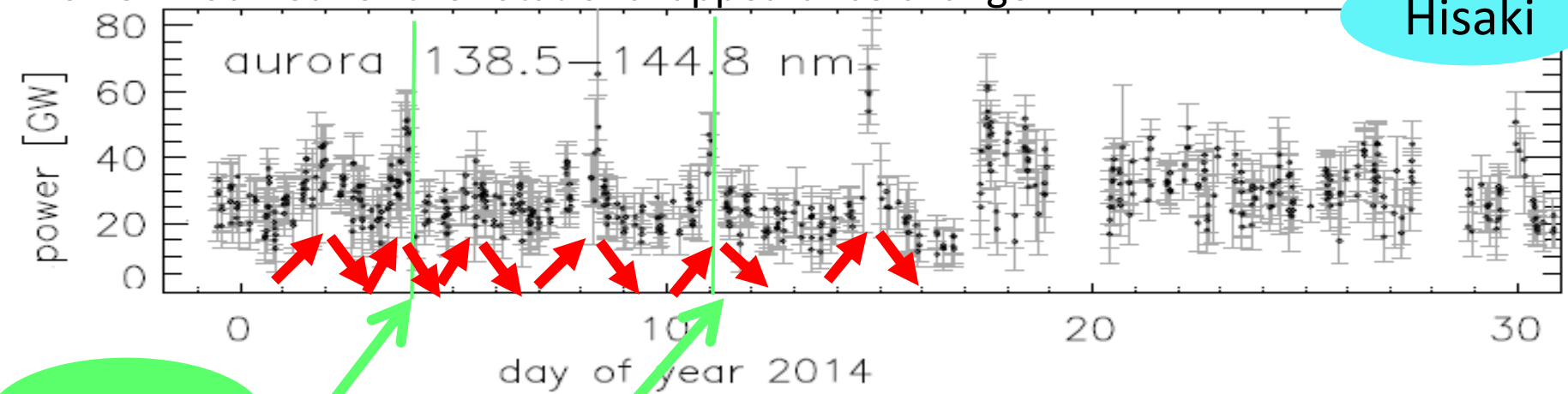


[Yoshikawa et al., 2016GRL, 2017EPS]

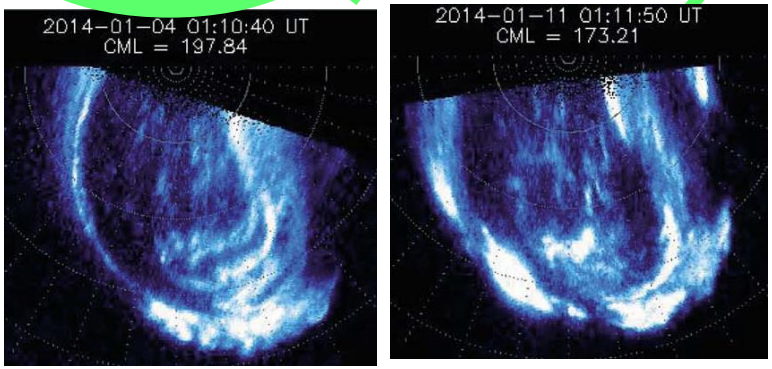
③ A few days variation

Short-time and daily variations

Power modified for the rotational appearance change

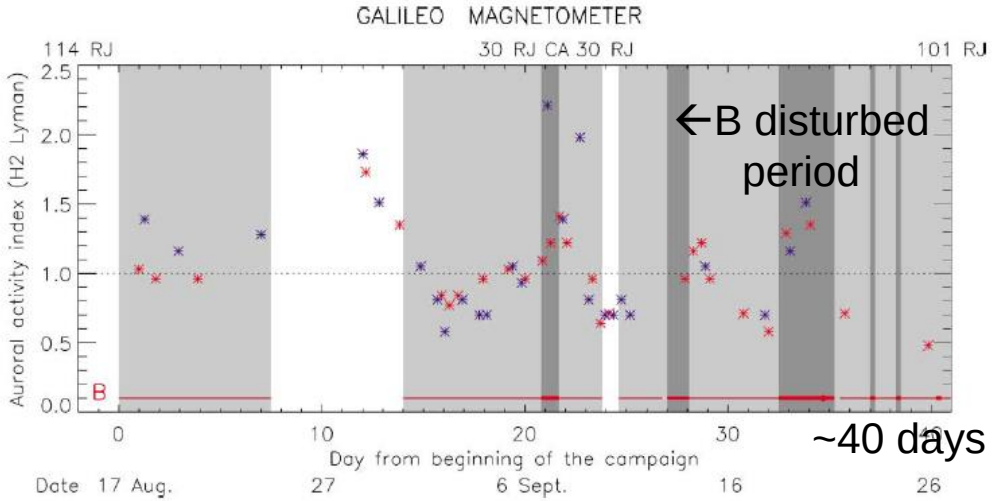


Hubble



[Kimura et al., 2015; Badman et al., 2016]

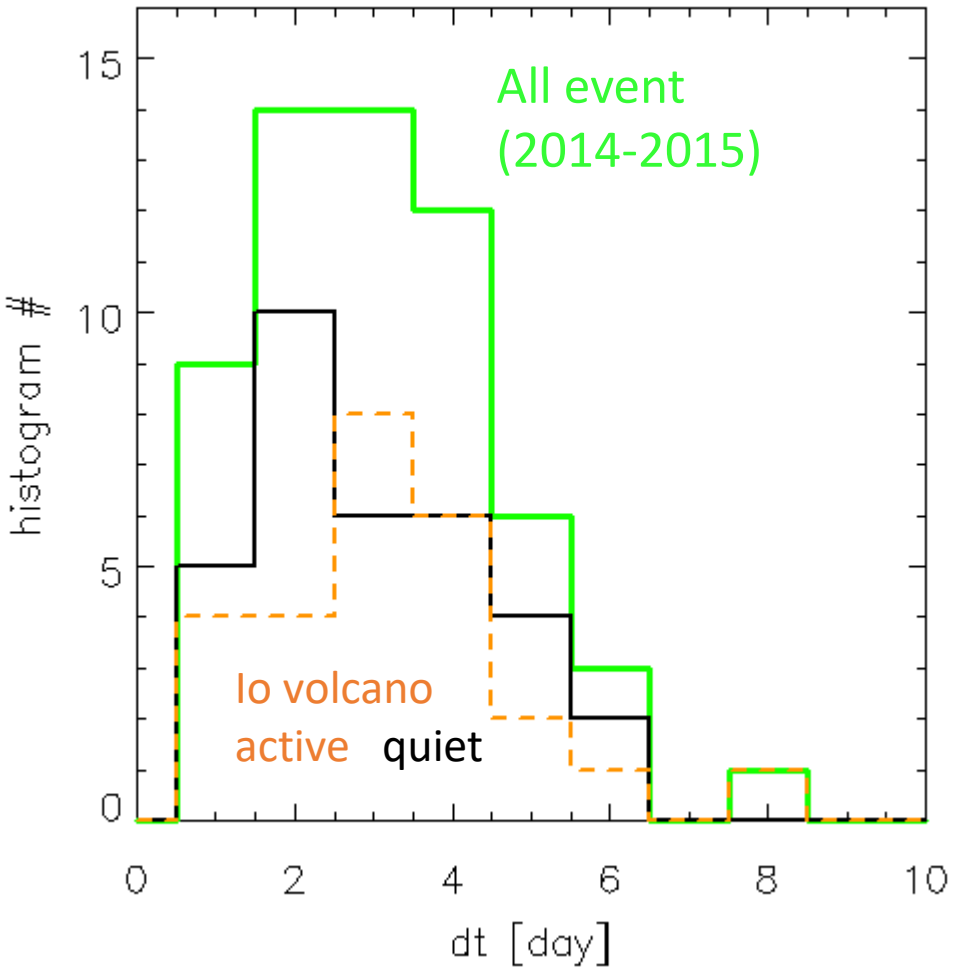
A few days–weeks variation of South/North aurora



~40 days

[Prange et al., 2001]

Periodicity analysis



Derived occurrence time separation seen in Hisaki: 0.8-8 days

Mean: 3.0 day, Median: 3.0 day

Standard deviation: 1.5 day

Not clear dependence of the aurora periodicity on solar wind dynamic pressure nor on the volcanic activity

cf. Comparable with…

5-10 days: aurora observed by IUE in Aug-Sep 1996 [Prange et al., 2001]

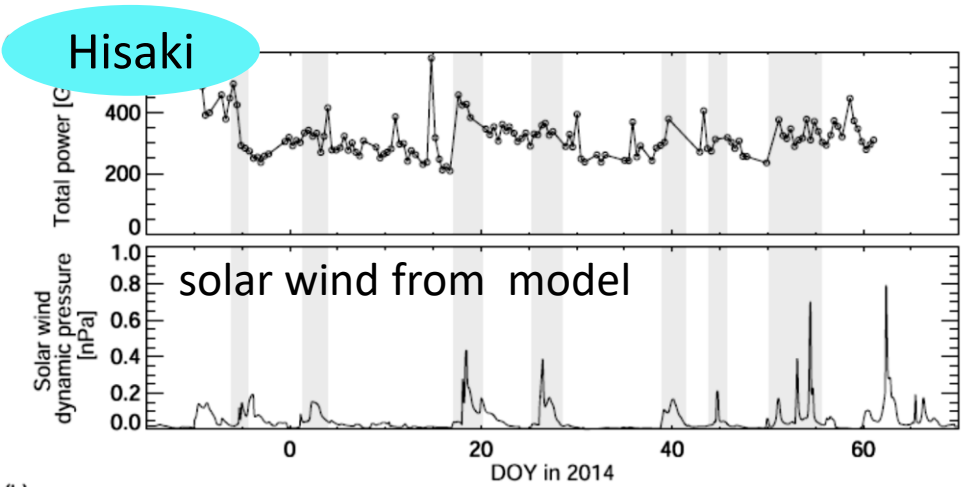
1.5-7 days: plasma spectra variation [Kronberg et al., 2009]

1-4 days: Magnetospheric reconnection feature seen by Galileo/MAG [Vogt et al., 2010]

④ Several days variation

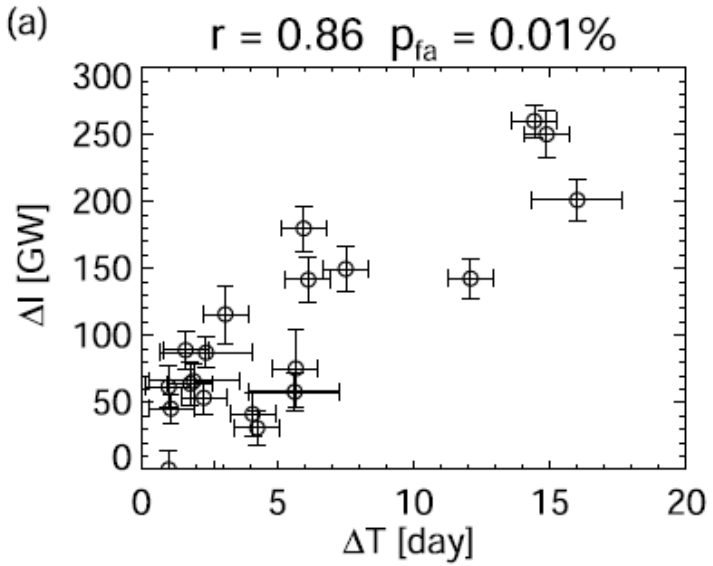
SW responses

[Kita et al., 2016 GRL]

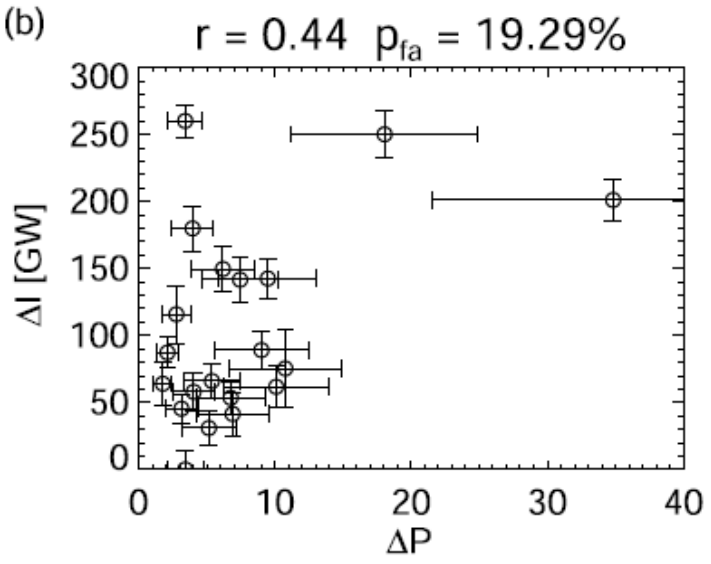


*Aurora intensity shows positive relation with solar wind dynamic pressure.
*The intensity has more correlation with the duration of solar wind quiet time before each enhancements.→ Importance of preconditioning

Intensity & SW quiet time



Intensity & SW pressure

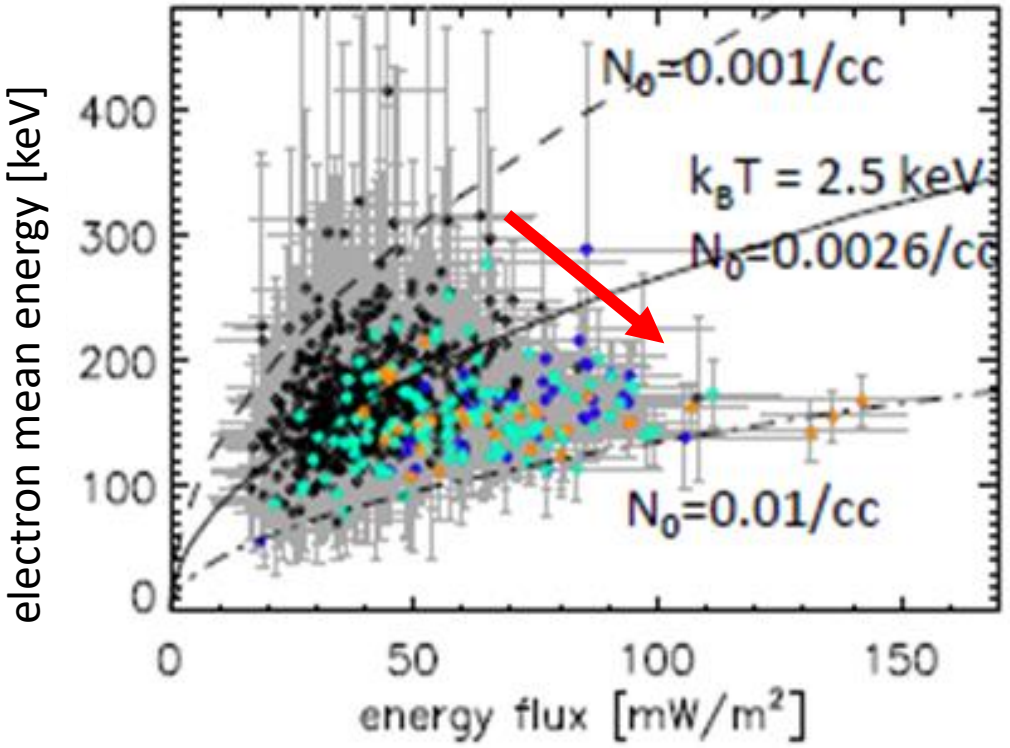


Parameter Relationship Variation

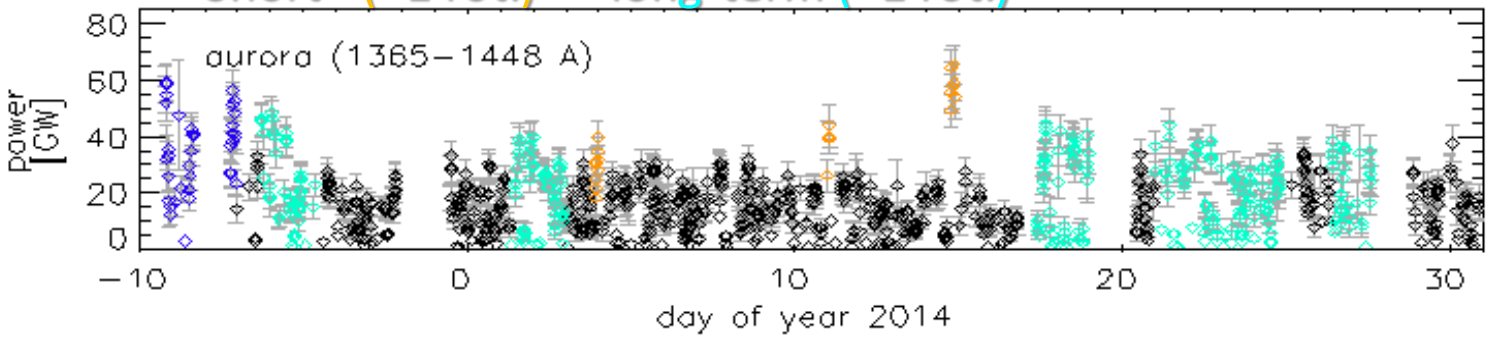
from Spectral Analysis
[Tao et al., 2016b JGR]

Positive relation among energy flux and energy
→ consistent with auroral electron acceleration theory (Knight relation).

Enhancement events are associated with source plasma variation



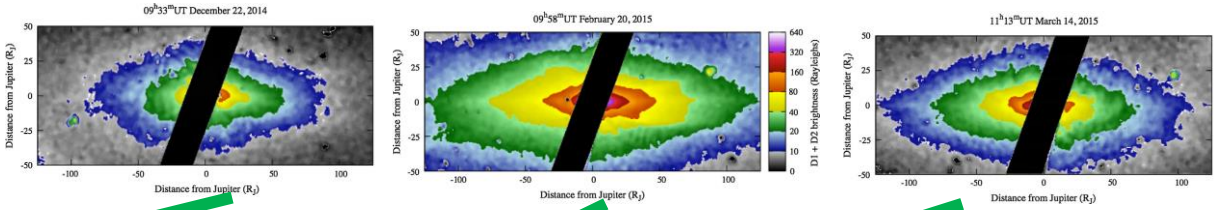
cf. Short- (<1 rot.) & long-term (>1 rot.) enhancements



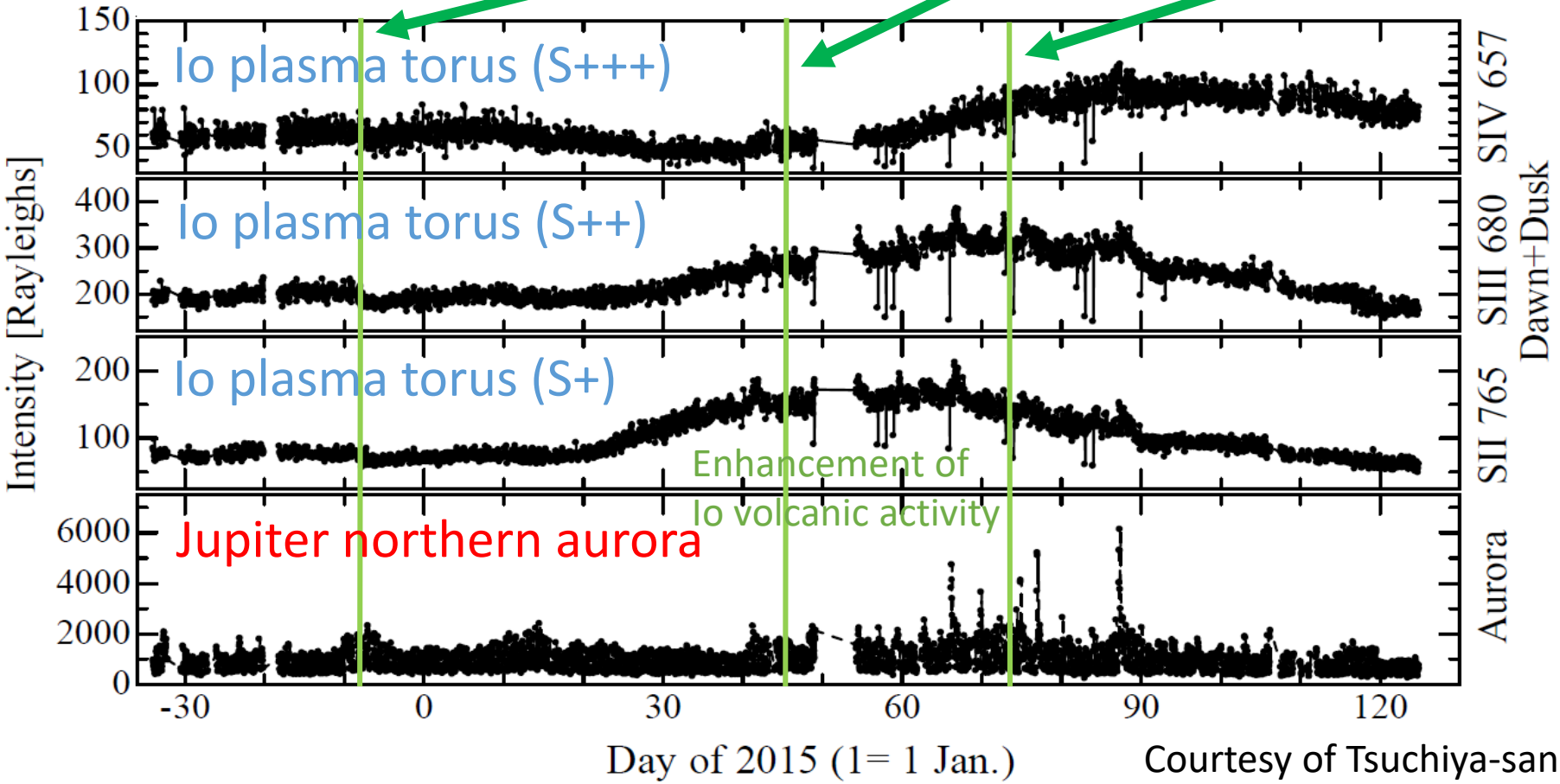
⑤ Several 10s days variation

2015 Io Plasma Torus Obs.

Sodium neutral
from ground obs.
[Yoneda et al., 2015]



Hisaki obs.

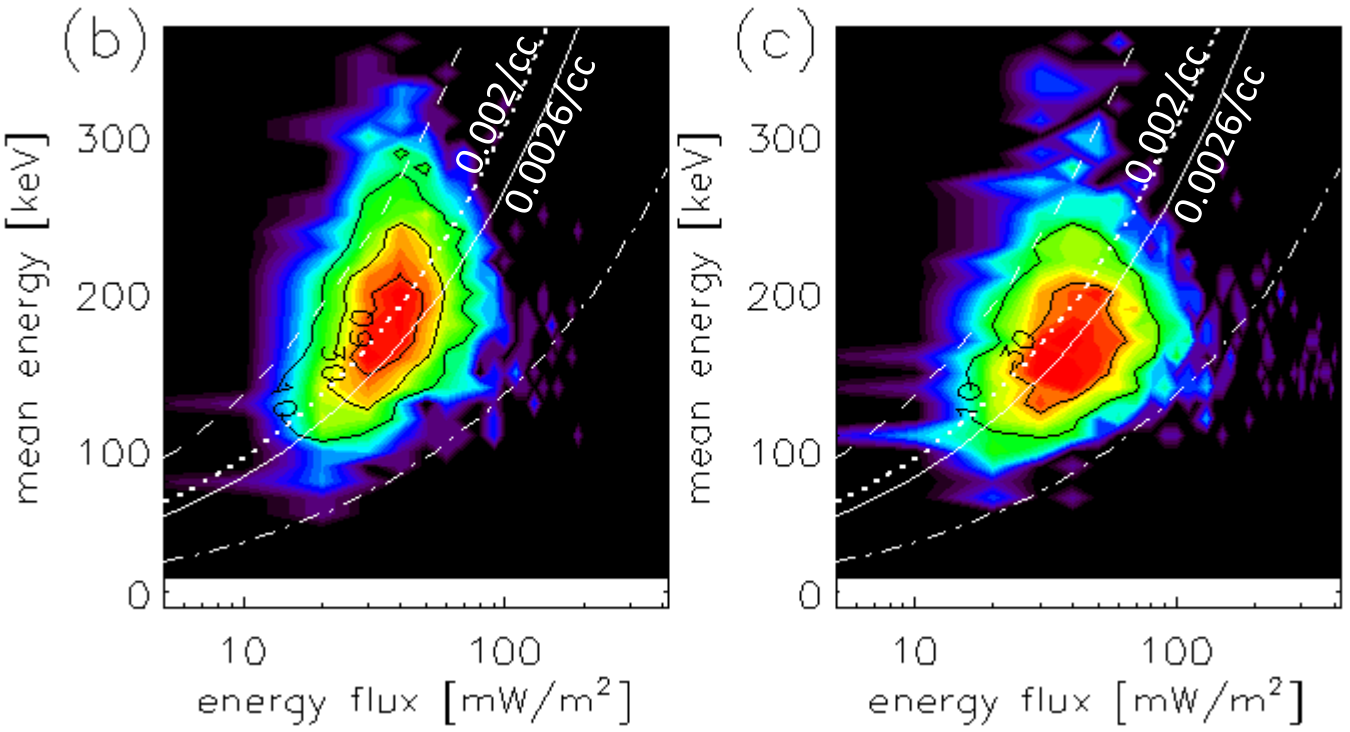


Courtesy of Tsuchiya-san

Parameter Relationship Variation 2

[Tao et al., submitted]

Io Volcano Quiet　　Io Volcano Active



During the Io's volcanic active time:

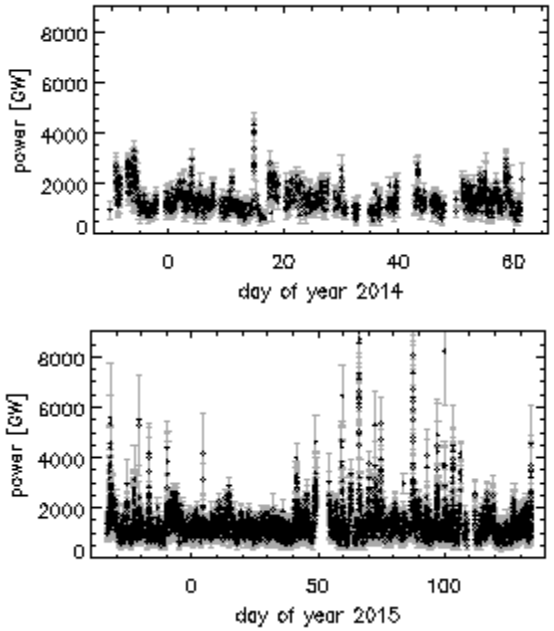
the relationship changes toward more energy flux and less energy part.

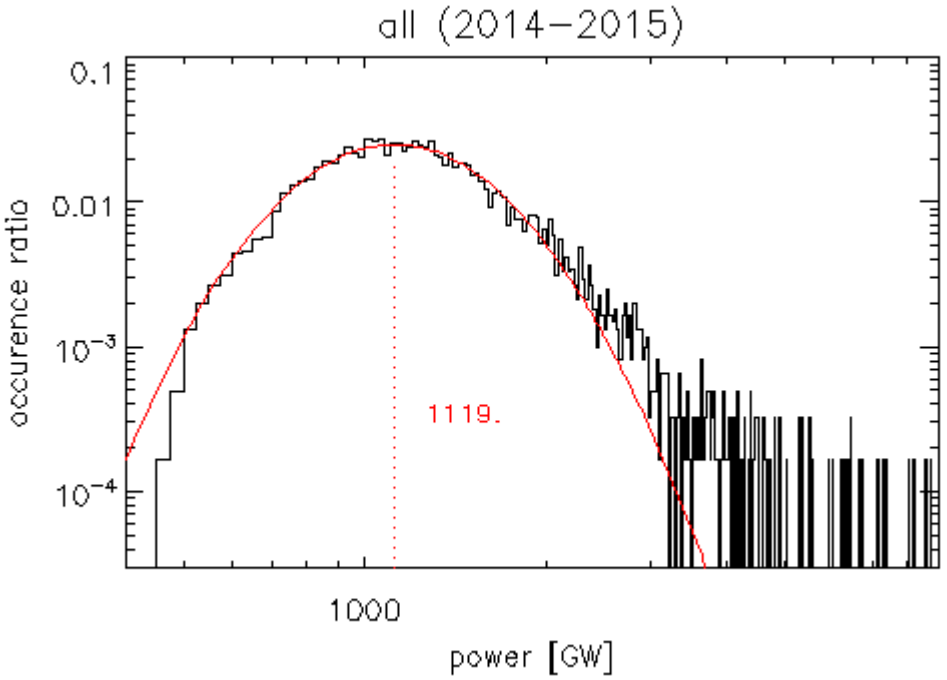
→ increase of source plasma (a few keV) density from 0.002 to 0.0026 /cc

→ popular magnetosphere plasma enough maintains MI current

Auroral power occurrence

Power @700-1800 A non-absorbed → as an indicator of input energy flux
with appearance modification by multiplying (north whole auroral area)/(area at the moment)





→ Log-normal distribution (red line)

Maximum occurrence: 1.11 TW Average: 1.40 TW

cf. HST obs. 1.2 TW in 2014 [Badman et al., 2016]; 0.8-5 TW in 2016 [Nichols et al., 2017]

Summary

Long-term Jupiter aurora monitored by Hisaki/EXCEED detects Jupiter's aurora & magnetospheric dynamics.

① Rotational variation (1 rot.) ② Short-term enhancements (<1 rot.)
③ A few days variation ④ Several days variation
⑤ Several 10s days variation ⑥ Statistical feature

Spectral information taken by Hisaki/EXCEED reveals:

(i) averaged auroral emission intensity is 1.4 TW.
(ii) the auroral enhancements over 1 rot. to several days are associated with the source current enhancement.
(iii) during Io volcanic event, energetic plasma (~a few keV) would also increase in the magnetosphere

Questions

1) Hisaki auroral observation is spatially- and mean energy analysis. Is the energy variation contributed by a decrease of the whole energy range, or a relative decrease (increase) of high (low) energy electrons, or a combination of them?
→ other methods would help: using radio emissions, H/H2 ratio analysis, …

2) How thermal electrons enhanced during the Io volcanic event?
→ relation with Io plasma torus parameters?

3) How these results are understood if Alfvenic acceleration is dominant as recent Juno observations suggest?