

Characteristics of solar wind control on Jovian UV auroral activity obtained from Hisaki EXCEED and ground-based observations

Hajime Kita[1]; Tomoki Kimura[2]; Chihiro Tao[3]; Fuminori Tsuchiya[1]; Atsushi Yamazaki[4]; Go Murakami[4]; Kazuo Yoshioka[5]; Hiroaki Misawa[1]; Takeshi Sakanoj[1]; Yasumasa Kasaba[1]; Ichiro Yoshikawa[5]; Masaki Fujimoto[4]
[1] Tohoku Univ.; [2] RIKEN; [3] NICT; [4] ISAS/JAXA; [5] The Univ. of Tokyo

Kita, H., et al. (2016), Characteristics of solar wind control on Jovian UV auroral activity deciphered by long-term Hisaki EXCEED observations: Evidence of preconditioning of the magnetosphere?, *Geophys. Res. Lett.*, 43, 6790–6798, doi:10.1002/2016GL069481. 1

Solar wind response of Jovian aurora

Jovian auroral emission results from M-I coupling current system

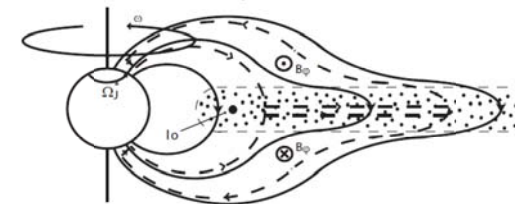
- Io supplies massive plasma to the magnetosphere
- Angular velocity decreases and corotation breakdown occurs around 15–40R_J
- The strong current system produces main auroral emission.

Cowley and Bunce [2001], Southwood and Kivelson [2001]

- Angular velocity of magnetospheric plasma increases when the Jovian magnetosphere is compressed by enhanced solar wind pressure, which decreases the field-aligned current.

→ Ionospheric wind becomes super-rotation?

→ Anti-correlation between intensity of aurora and solar wind pressure?



Solar wind response of Jovian aurora

- HST [Clarke et al., 2009], and IRTF [Baron et al., 1996]
 - Auroral power increases near the arrival of solar wind shocks.
 - Not consistent with theoretical expectation
 - However, the data set lacks of continuity
- Hisaki could find clear solar wind response of UV aurora. However, UV aurora does not always respond to the solar wind
 - It seems that the solar wind shock with long quiescent period causes large enhancement of UV aurora.

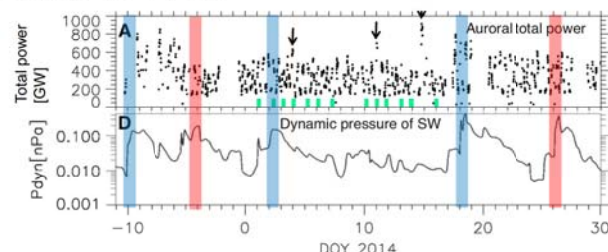


Figure. Time variation of Jovian EUV aurora obtained from HISAKI observations (modified from Kimura et al., [2015]). We can find clear solar wind response of EUV aurora (Blue hatched), but some times aurora do not respond to the solar wind (Red hatched) infrared aurora and solar wind dynamic pressure.

Purpose

- Cowley model expects that increase of the solar wind dynamic pressure is anti-correlated with the intensity of the UV aurora.
- However, observation showed that Jovian aurora increase with solar wind dynamic pressure [e.g. Baron et al., 1996; Nichols et al., 2009].
- Recent HISAKI observations showed that sometimes aurora does not respond to the enhancement of the solar wind dynamic pressure.

Purpose of this study

- ① Evaluate whether UV aurora increase or decrease with the variation of the solar wind dynamic pressure.
Try to find other control factors of Jovian UV aurora variation.
+
- ② Add observational evidence for the time variation of Jovian aurora from observation campaign in 2016 (Hisaki, Juno, IRTF)
 - IRTF: Infrared aurora intensity + spectrum → heating, wind velocity

HISAKI OBSERVATION CAMPAIGN IN 2014-2015

Dec. in 2013 – Feb. in 2014

Dec. in 2014 – Feb. in 2015

5

HISAKI EXCEED

- An earth-orbiting Extreme Ultraviolet (EUV) spectroscopic mission
- Wavelength 470 -1530 Å
- Spatial resolution 10asec
- Slit 140"slit (Dumbbell shaped)



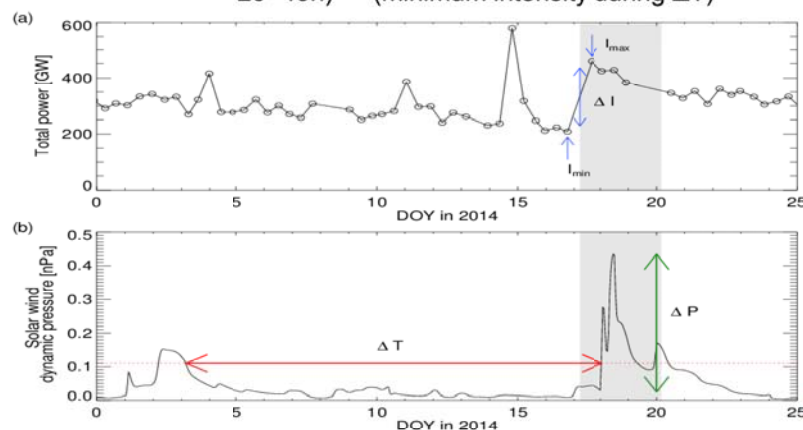
EUV data analysis

- Level 2 EUV spectrum data → Total power of Jovian northern aurora (L3)
 - Wavelength range: 900-1480 Å, Integration time:10min
- Correct longitudinal dependence
 - Plot each data along CML → calculate median every 6 degrees.
 - Fit cos function
- Exclude the longitude when aurora is difficult to see from the earth, (CML<100, CML>250), and calculate longitudinally averaged UV aurora.
- +
- Solar wind: 1D MHD model [Tao et al., 2005]

6

Definition of each parameter

- Duration of quiescent interval (ΔT): the period of $P < 0.11$ [nPa]
- Variation of solar wind dynamic pressure (ΔP): maximum during the period of $P > 0.11$ ÷ mean during the rarefaction region
- UV variation ΔI = (maximum intensity during the period of $P > 0.11$ +/- 20~40h) – (minimum intensity during ΔT)

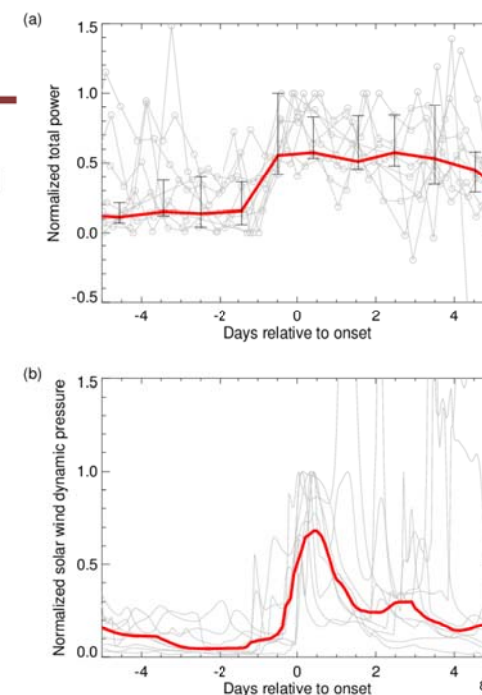


7

Superposed profile

- Cowley found that after an impulsive compression, the main oval dim because of the increased angular velocity of the equatorial plasma.
 - We made superposed epoch analysis for the event of $\Delta T > 5$ days.
- The data are aligned to the onset of dynamic pressure enhancement.
- Aurora does not dim during solar wind compression.

Figure (Top) superposed profile of EUV aurora. Red line indicates median profile for one-day window. Errorbars indicate Interquartile range. (Bottom) superposed profile of the solar wind dynamic pressure. Red line indicates median profile.

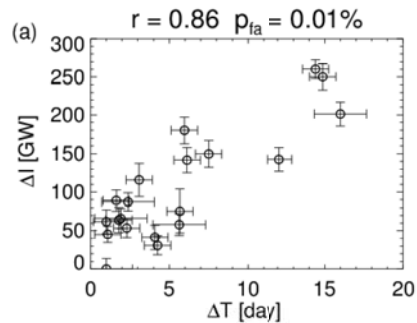


8

Correlation analysis

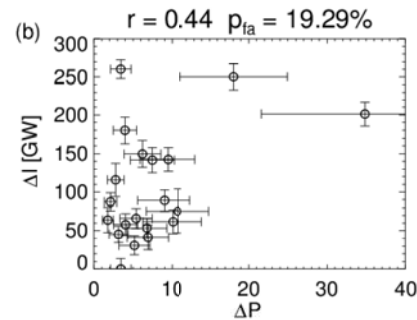
$\Delta T - \Delta I$

- Correlation coefficient (R) = 0.86
- False alarm probability: <1%
→ $\Delta T - \Delta I$ have correlation



$\Delta P - \Delta I$

- Correlation coefficient = 0.44
- False alarm probability: ~19%
→ $\Delta P - \Delta I$ do not have correlation



- EUV aurora depends on the duration of quiescent interval.**
→ some process related to mass loading??
→ More plasma supplied from Io and accumulated in the magnetosphere??

9

HISAKI OBSERVATION CAMPAIGN IN 2016

May. – Jul. in 2016

10

NASA Infrared Telescope Facility

IRTF

- Mauna Kea, Hawaii
- Diameter: 3m

CSHELL

- SP: High resolution single order spectrograph
- Slit width: 0.5 asec
- Resolution: $\lambda/\Delta\lambda = 43000$
- H_3^+ Q(1,0-) 3.953 μm
- IM: CVF filter
- Wavelength: 3.43 μm
- H_3^+ R(3,0), R(3,1), R(3,2), R(3,3)

- Mar 8, Mar 10, Mar 20, Mar 22
- CML 130~210

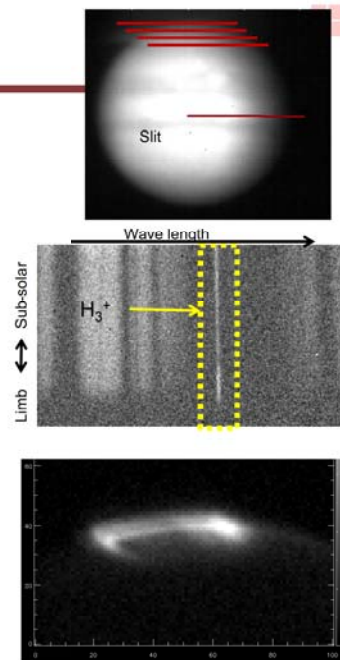
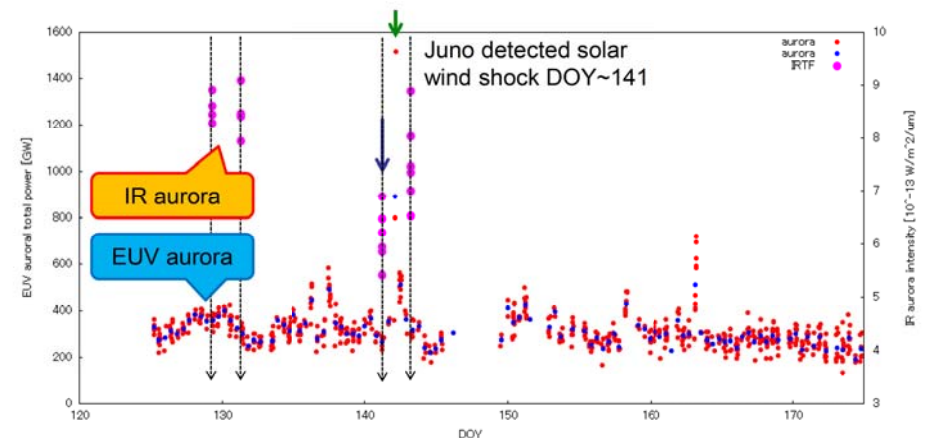


Fig. Example of visible guide camera (Top), H_3^+ emission line (Middle), and CVF filter image.

11

H_3^+ intensity variation

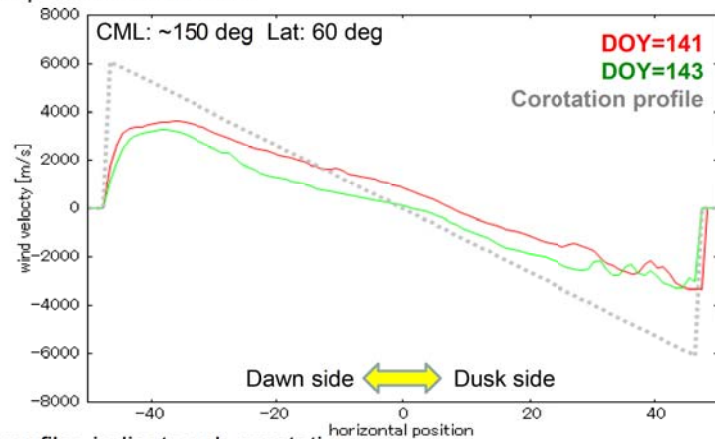


- After the shock arrival, UV an IR aurora became brighter.
- H_3^+ intensity roughly corresponded to the EUV auroral total power
- EUV aurora \leftrightarrow heating

12

H₃⁺ wind velocity variation

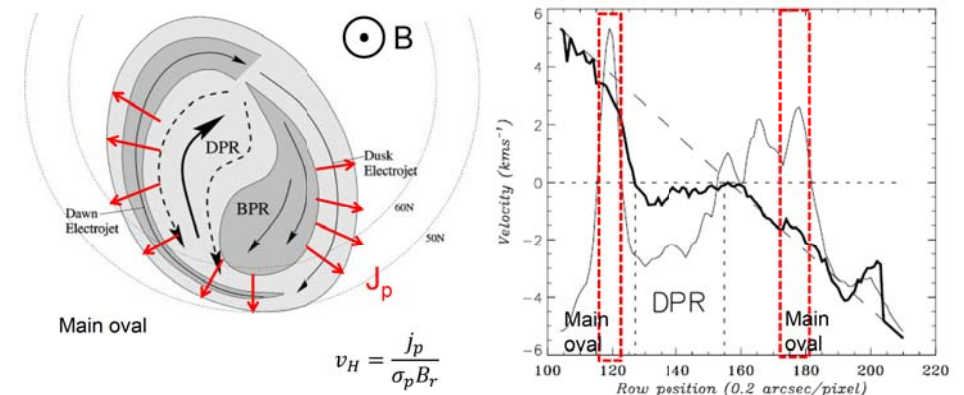
Ionospheric wind becomes super-rotation or sub-corotation when the solar wind dynamic pressure enhances?



- Both profiles indicate sub-corotation
- Thermospheric wind did not super-rotate when the solar wind dynamic pressure enhanced

13

Northern auroral wind system

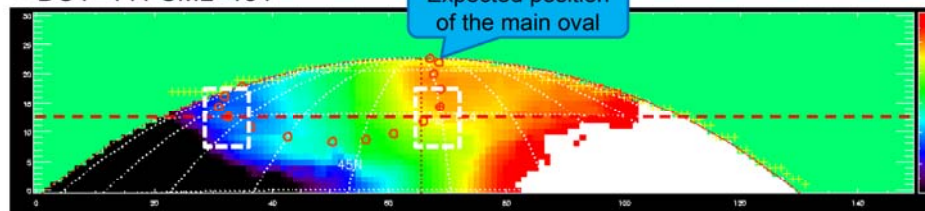


- Infrared observation result and proposed wind system [Stallard et al., 2001]
 - Pedersen current ⇔ Hall drift
 - EUV aurora ⇔ sub-corotation velocity???

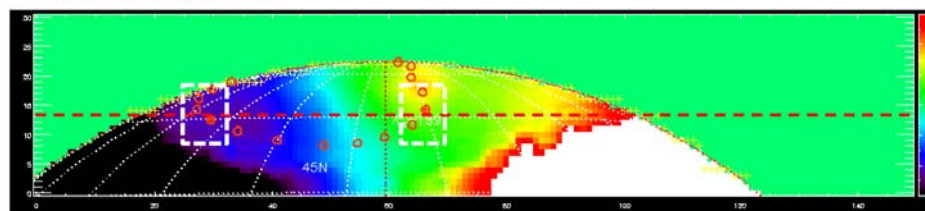
14

H₃⁺ wind velocity (corotation flame)

- DOY=141 CML=154



- DOY=143 CML=159

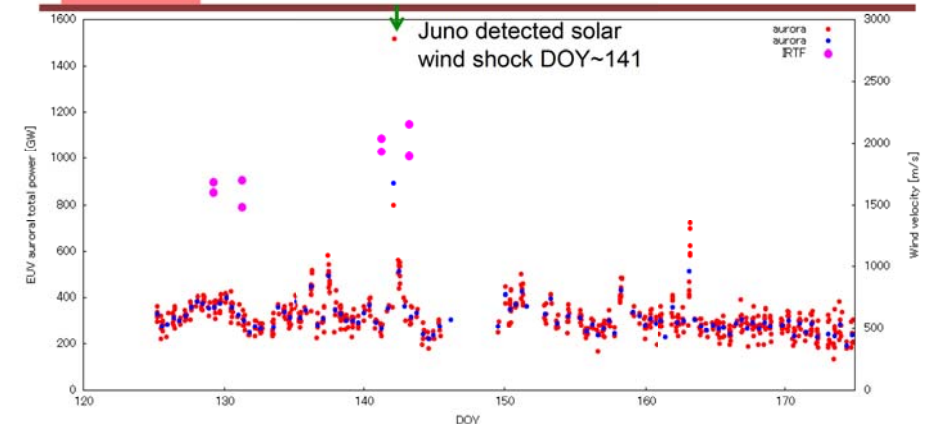


(Red: toward observer, Blue: away from observer)

- We focus on the velocity around the dawn and dusk side of main oval.

15

H₃⁺ wind velocity variation



- Averaged sub-corotation velocity between dawn and dusk side oval.
- We cannot see any difference between the shock arrival.
 - Sub-corotation velocity did not correlate with the EUV auroral total power (?)
 - Try again with IRTF-iSHELL (Slit viewer, high spectral resolution)

16

Summary and key questions



How to explain solar wind control on Jovian aurora??

Solar wind controlled auroral brightening should meet following points.

- Total power of UV aurora increases with a rise in the solar wind dynamic pressure
 - Auroral power enhancements clearly correlate with the durations of the quiescent interval of the solar wind (some process related to mass loading?)
 - Auroral power enhancements do not clearly correlate with the amplitudes of the dynamic pressure
- +
- IR auroral also increases with the dynamic pressure and total power of UV aurora → heating (IRTF obs. in 2016 and Baron et al., 1996)
 - Thermospheric wind velocity does not super-rotate when the solar wind dynamic pressure enhances
 - Sub-corotation velocity did not correlate with the EUV and IR intensity (?).

