Variation of Jupiter's Auroral Electron Parameters Observed by Hisaki/EXCEED

Chihiro Tao[1,2], Tomoki Kimura[3], Fuminori Tsuchiya[2], Go Murakami[4], Kazuo Yoshioka[5], Atsushi Yamazaki[4], Hajime Kita[2], Ichiro Yoshikawa[5], Yasumasa Kasaba[2]
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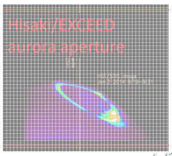
Hisaki collects a unique long-term dataset since its launch in 2013 (slides #2, 3). We analyzed Jupiter aurora spectra taken by a spectrometer EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) onboard Hisaki (slide #5). Using an auroral brightness ratio, called color ratio (CR), we derived characteristic auroral electron energy (slide #6). In addition, the less hydrocarbon absorption waveband provides the auroral electron energy flux, and then we obtained number flux or field-aligned current (slide #7). We applied this method to the previous three-year observations (slide #8).

The averaged auroral emission histogram shows the log-normal distribution with its averaged auroral emission intensity of 1.4 TW (slide #9). Average and variance of other aurora parameters are also derived (slide #10), which is comparable with the previous observation/estimation by other methods (slide #11). We found that auroral brightness enhancements over short (<1 rotation ~10 h) and long (a few days) durations are associated with the auroral electron number flux variation, rather than the energy variation (slide #12). During the Io volcanic active time in 2015, the auroral electron energy decreases and electron flux increases compared to the quiet time, which would be brought by increases of source thermal (~a few keV) electron density (slide #13).

Recent Juno observation suggests that these is no clear energy peak in the electron spectra at 10s–100s keV which is usually assumed for CR-energy estimations. Our auroral model shows that the CR values derived from the auroral spectra of kappa distributions is almost the same with those of Maxwellian or mono-energy spectra with the same mean energy of each profile (slide #14).



Symposium on Planetary Science, Tohoku Univ., 2017/2/20-22

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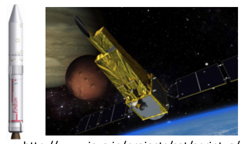
Introduction:

Hisaki/EXCEED

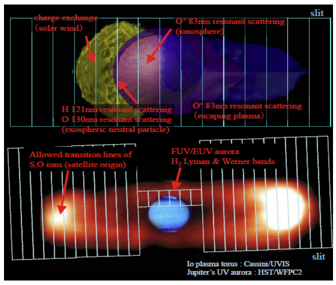
EXCEED (=Extreme Ultraviolet Spectroscope for Exospheric Dynamics) instrument is onboard "Hisaki", a space telescope satellite by JAXA.

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/



Jupiter Aurora Spectroscopy

Similar other facilities
* International Ultraviolet Explore (IUE): many years, 1978-1996
* Cassini UVIS during Jupiter flyby: several months in 2000-2001, continuously
* Hubble Space Telescope (HST), spectroscopy: 1997-, high spatial resolution
* Far Ultraviolet Spectroscopic Explorer (FUSE): a few, high spectral resolv. (0.22 Å)
* Juno UVS: close-up observation from Jupiter polar orbit

Hisaki: 2013-, continuously around opposition
+Io Plasma Torus monitoring simultaneously cf. IUE, HST, FUSE
+solar wind model with good input at 1 AU (ACE obs. 1996-) cf. IUE
+HST, X-ray telescopes, Juno, ground-based facilities cf. IUE, FUSE
+observe Jupiter in the similar view angle/distance cf. UVIS

→ It is useful to investigate the statistical feature and variations

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In this talk:

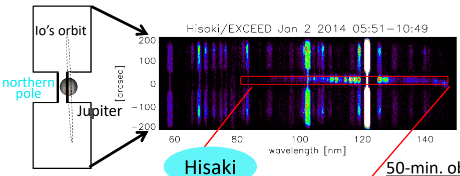
Hisaki/EXCEED data analysis:
(1) Statistical feature of auroral parameters (2014-2015)
(2) Variation during <1 rot. & a few days enhancements
(3) Variation during Io volcanic activity

Auroral modeling:
(4) Dependence of CR-energy relationship on spectra

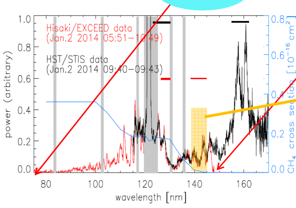
Dataset:

Method detail: Kimura et al. [2015GRL]

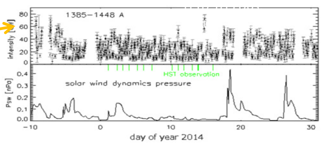
Hisaki/EXCEED aurora observation



Wavelength 55-148 nm
FWHM 3 nm
Δx~17 arcsec
Pointing ±2 arcsec
【Spectral Information】



50-min. obs. in each 106-min. orbit
(Aurora: 10-min. integration)
【Continuous Observation】

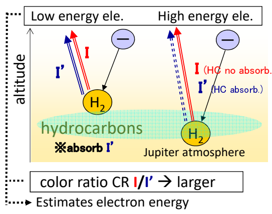


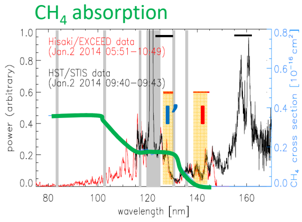
Analysis:

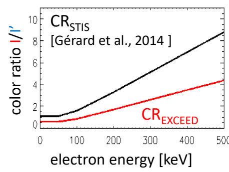
Method detail: Tao et al. [2016JGR]

Information from UV spectroscopy

Energy estimation using color ratio (CR)
[e.g., Yung et al., 1982, Livengood et al., 1993, Gérard et al., 2003]
Difference between emissions of hydrocarbon absorption *I* and less absorption *I'* is a indicator of depth of the auroral emission, i.e., auroral electron energy







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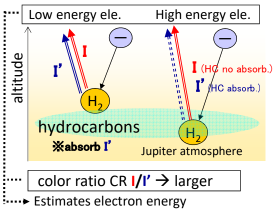


Less absorption band *I*

→ total input power or energy flux

→ number flux

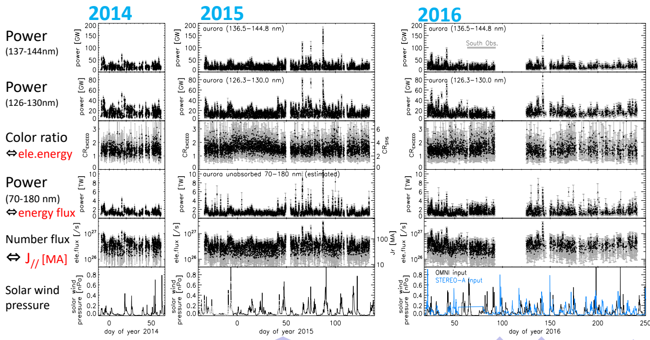
CR_{EXCEED} = I/I' → energy (⇔potential drop $\phi_{//}$) → number flux (⇔$j_{//}$)

$I_{(1385–1448\ A)}$ → total power → energy flux E_f

acceleration theory

magnetospheric parameter N_0, k_BT_0

Overview of 3-year dataset



Io vocano, large events [Yoneda et al. ,2016]

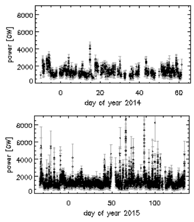
Small events [Yoneda et al.]

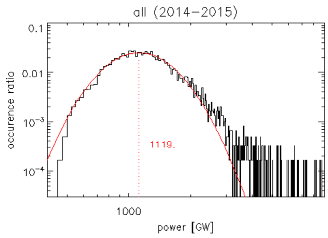
(1) Statistical feature of auroral parameters (2014-2015)

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: 1.1 TW Average: 1.4 TW

(1) Statistical feature of auroral parameters (2014-2015)

Parameter Values

2014-2015	Median ± 1σ	Mean ± 1σ
Power 138.5-114.8 nm [GW]	20.7±11.4	22.8±11.4
Power 126.3-130.0 nm [GW]	15.1±8.45	16.5±8.45
CR_{EXCEED}	1.51±0.35	1.56±0.35
Electron energy [keV]	178.±39.	183.±39.
Total power [GW]	962.±529.	1056.±529.
Electron Flux [MA]	54.2±30.0	59.2±30.0
Electron Flux [μA m^{-2}]	0.243±0.175	0.280±0.175
$j_{//0}(2.5/k_BT_0$[keV]) [nA m^{-2}]	3.42±3.03	4.07±3.03
Solar wind pressure [nPa]	0.032±0.082	0.061±0.082
System III longitude [deg.] for obs.	174. ±60.	175. ±60.
Appearance revised*1 total power [GW]	1276.±810.	1444.±810.

*1 appearance modified by multiplying (north whole auroral area)/(area at the moment)

(1) Statistical feature of auroral parameters (2014-2015)

Parameter Values

2014-2015	Medi	
Power 138.5-114.8 nm [GW]	20.7	
Power 126.3-130.0 nm [GW]	15.1	
CR_{EXCEED}	1.51	
Electron energy [keV]	178.±39	183.±39.
Total power [GW]	962.±5	1056.±529.
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Electron Flux [μA m^{-2}]	0.243±0.1	
$j_{//0}(2.5/k_BT_0$[keV]) [nA m^{-2}]	3.42±3.0	
Solar wind pressure [nPa]	0.032±0.0	
System III longitude [deg.] for obs.	174. ±6	
Appearance revised*1 total power [GW]	1276.	

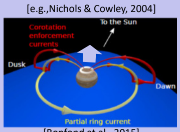
*1 appearance modified by multiplying (north whole auroral area

Total current from north pole.

Galileo obs.: 100 MA [Khurana, 2001]

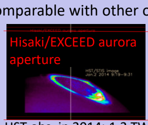
models: a few 10s-100 MA

[e.g.,Nichols & Cowley, 2004]



[Bonfond et al., 2015]

Comparable with other obs.



HST obs. in 2014: 1.2 TW [Badman et al., 2016]

past obs. 2-10 TW [Bhardwaj and Gladstone, 2000]

(2) Variation during <1 rot. & a few days enhancements

[Tao et al., 2016 JGR]

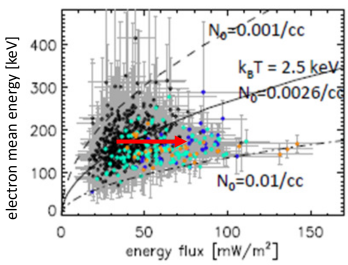
Parameter Relationship Variation

During enhancement events:

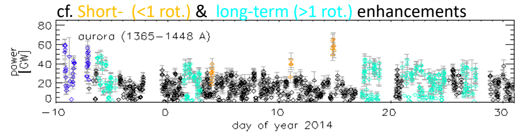
*Relationship between electron energy flux and energy shifts to high energy flux cases

→ source plasma variation

*Short and long-term variations show similar variation except for duration



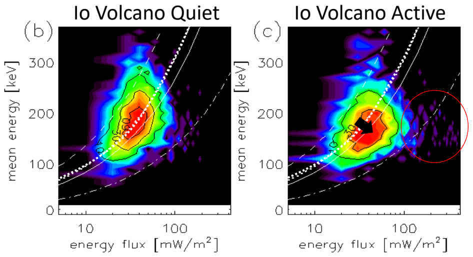
cf. Short- (<1 rot.) & long-term (>1 rot.) enhancements



(3) Variation during Io volcanic activity

Parameter Relationship Variation 2

[Tao et al., in preparation]



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

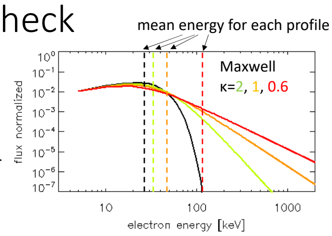
→ popular magnetosphere plasma enough maintains MI current → small CR

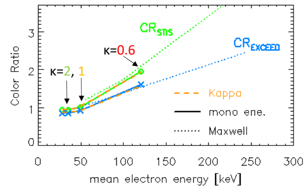
(4) CR-energy relationship

Auroral Model Check

Recent Juno observation suggests these is no clear peak in the electron spectra at 10s-100s keV [Mauk et al., 2016AGU] like "Maxwellian" which is assumed for CR-energy estimation.

Auroral model [Tao et al., 2011] shows that CR varies with kappa value of kappa distribution (right).
The obtained CR is almost the same with those of Maxwellian or mono-energy spectra with the same mean energy for each profile.





Summary

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

Spectral information taken by Hisaki/EXCEED reveals:

(1) Averaged auroral emission intensity is 1.4 TW.

(2) The auroral enhancements over 1 rot. to several days are associated with electron number flux change, rather than energy change.

(3) During Io volcanic active, electron energy decreases while number flux increases. Plasma (~a few keV) would also increase in the magnetosphere

(4) We also checked CR-energy relationship for different spectral profile.

EXPTECTATIONs to Juno obs.:

*Auroral particle spectra (statistical) -- Hisaki obs. comparison

*Auroral & magnetotail particle variations associated with auroral enhancements