Response of Io Plasma Torus to middle magnetosphere of Jupiter

F. Suzuki [1]; (suzuki@astrobio.k.u-tokyo.ac.jp)

K. Yoshioka [1] ; G. Murakami [2] ; F. Tsuchiya [3] ; T. Kimura [4];

M. Kuwabara [1] ; R. Hikida [1] ; I. Yoshikawa [1]

[1]The University of Tokyo ; [2] ISAS/JAXA ;

[3] Tohoku University ; [4] RIKEN

Io Plasma Torus (IPT)

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The ionization of neutral material from Io's atmosphere produces a dense torus, called Io Plasma Torus.

◎ Extra ultraviolet(EUV) emissions

Various emission lines from the ions in the EUV wavelength range are excited by electron impact and were observed by spacecraft, such as Voyager and Cassini.

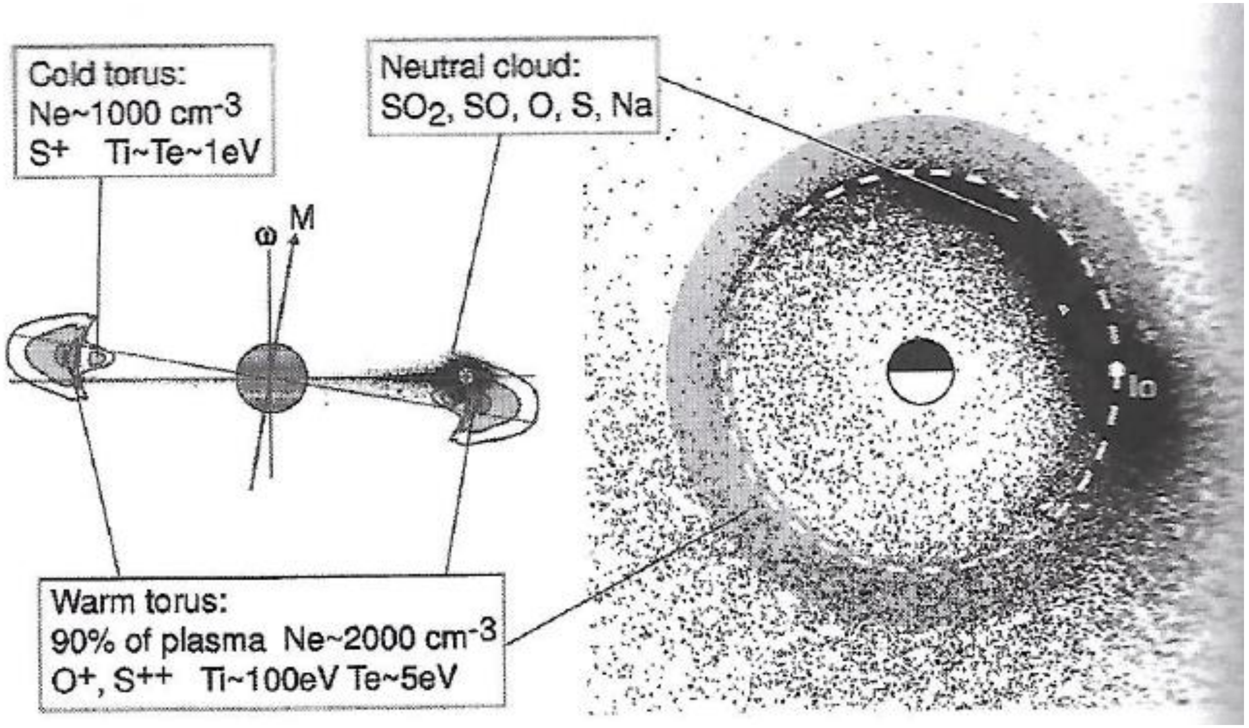


Fig. Cartoon of the Io plasma torus. [Thomas et al.2004]
Left: view from central meridian longtitude of 290˚
Right: view looking down over Jupiter's north pole.

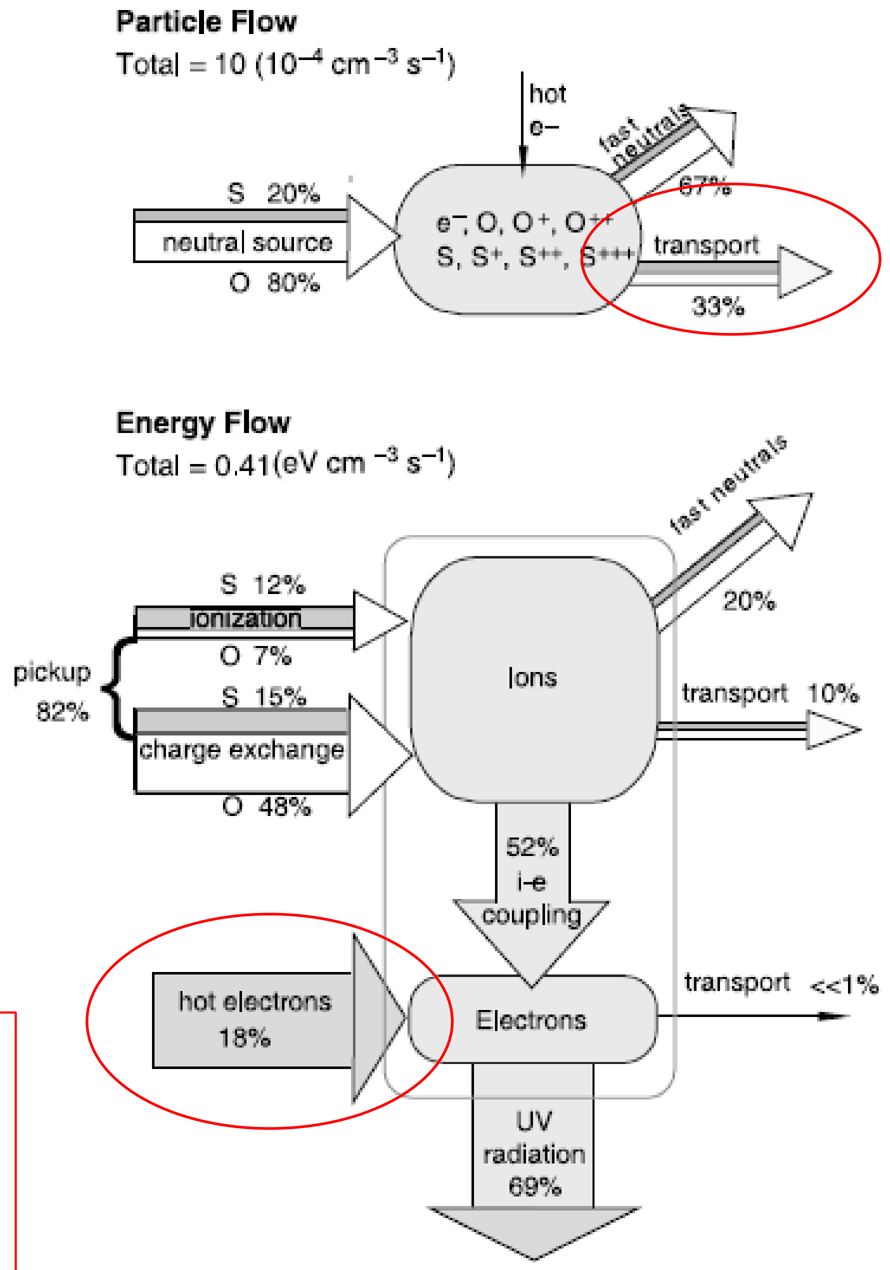
Open questions

◎What is the loss process for the remaining 1/3 of the total mass?

◎Where the ‘hot’ electrons get their energy?

※The energy picked up by fresh ions is Insufficient to maintain temperature of the hot electrons.

Inward and outward radial transport of plasma.
(e.g. interchange instability)



[Delamere and Bagenal 2003]

Simultaneous brightenings of the IPT and Jupiter’s Aurora

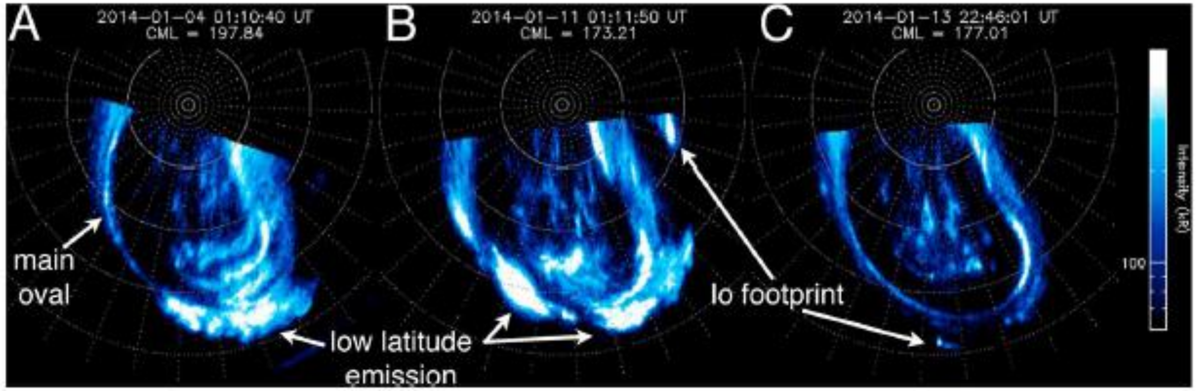


Fig. Auroral emmisions observed by Hubble Space Telescope.
[Kimura et al. 2015]

・IPT and aurora simultaneously brightened.
→The mechanism has not been resolved.
・This phenomenon suggests radial transport of plasma from middle magnetosphere to inner magnetosphere.

HISAKI/EXCEED

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・A space telescope dedicated for atmospheres/magnetospheres of planets.

HISAKI has an advantage of long-term and continuous monitoring of IPT and aurora at the same time.

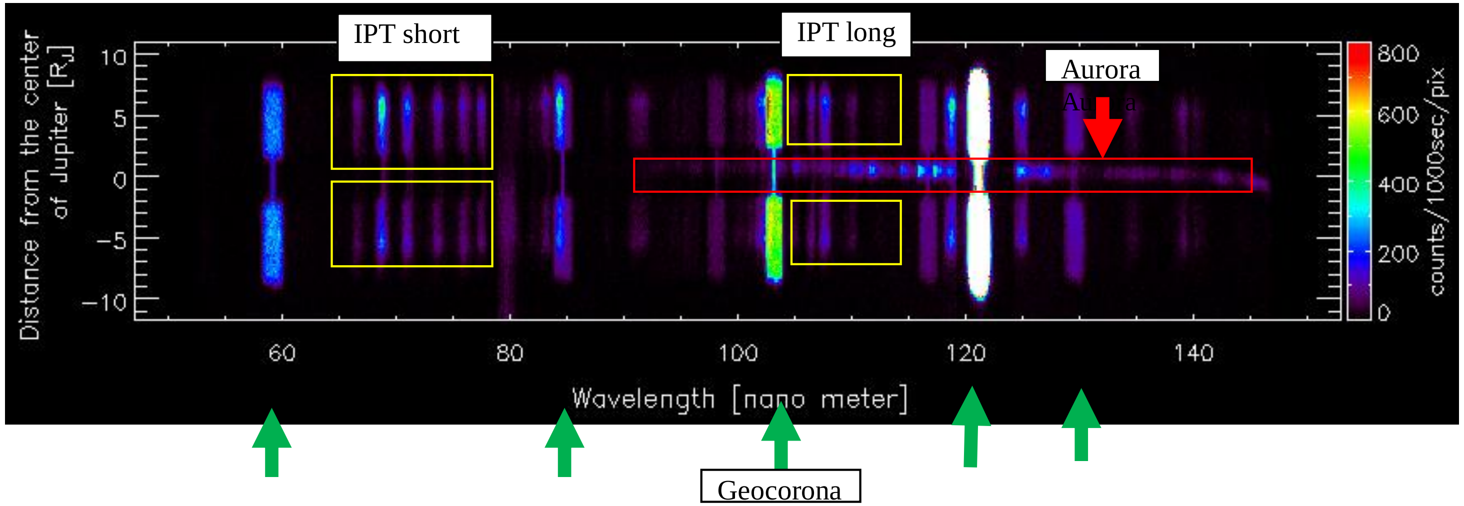


Fig. A spectral image obtained by EXCEED

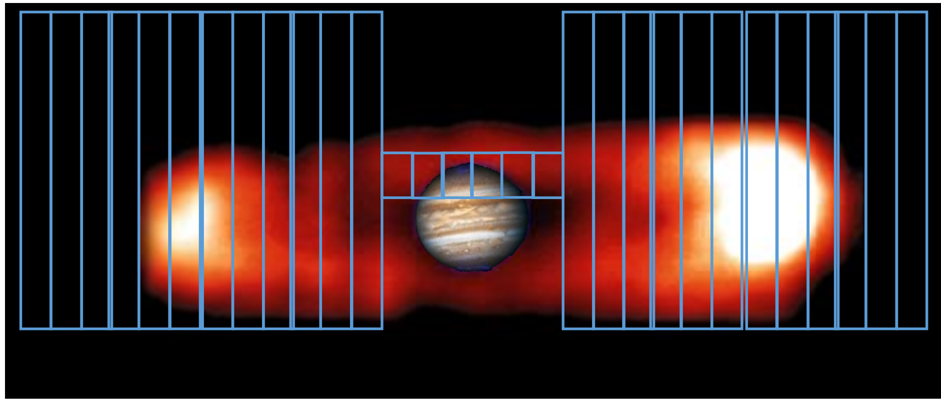


Fig. Schematic image of EXCEED’s observation of Jupiter with the ‘dumbbell-shaped’ slit.

Analysis

◎ Observation

・1st season: Dec. 2013～Feb.2014

・2nd season: Nov. 2014～May. 2015

※Io volcanic activity increased in 2nd season.

Rising Phase: DoY 20-60 in 2015

Declining Phase: DoY 60-100 in 2015

◎ Integrated wavelength range

・IPT short：650-780 Å

・IPT long：1050-1150 Å

・Aurora：900-1500 Å

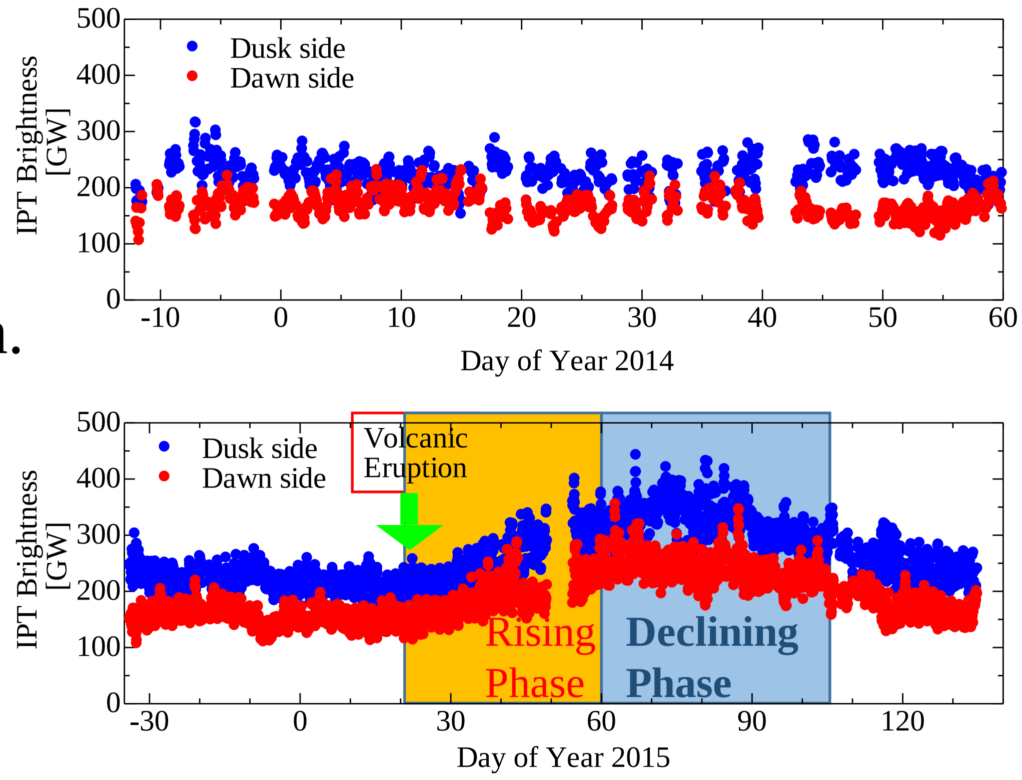


Fig. Time variety of IPT short in dusk side (blue) and dawn side (red).
Top: 1st season Below: 2nd season

Observation(1st Season)

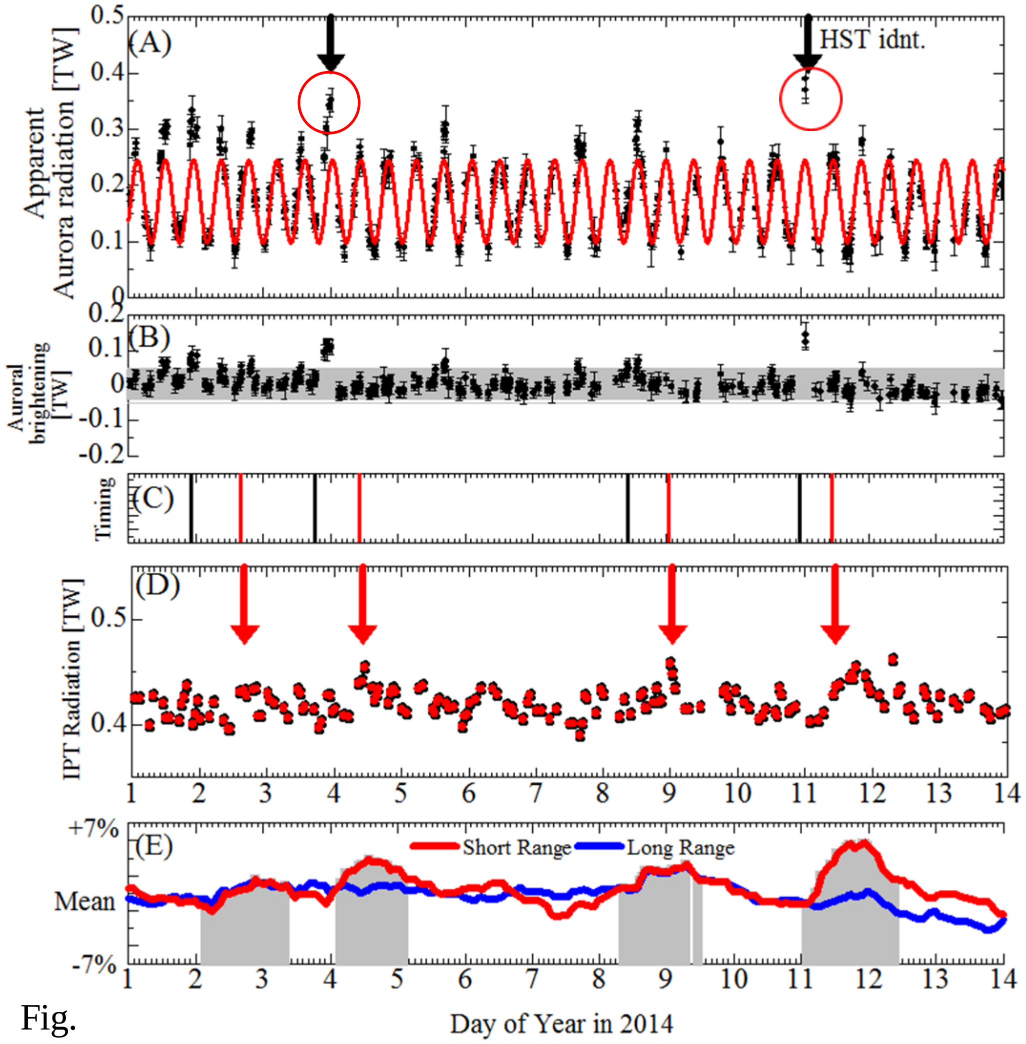


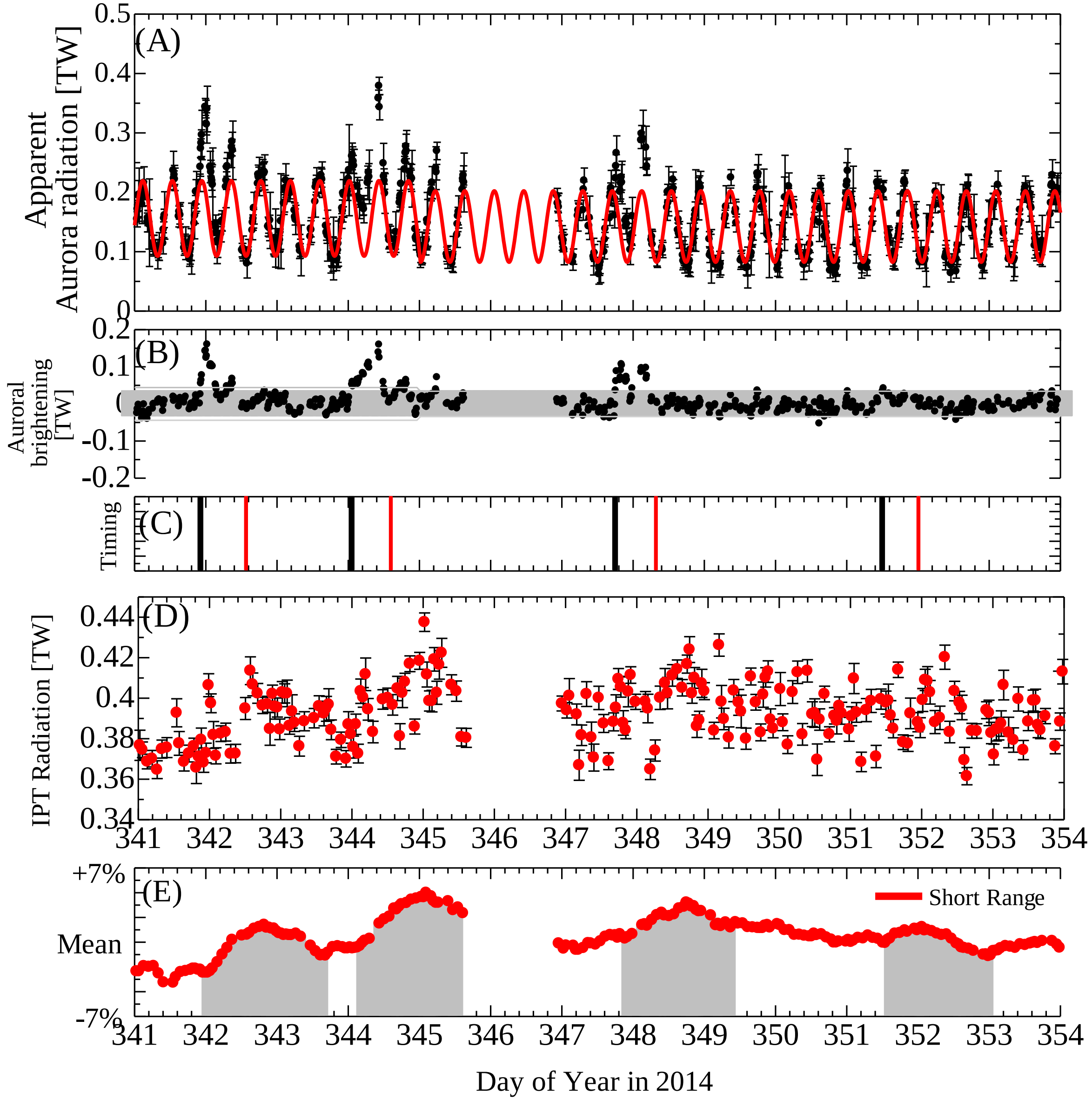
Fig.
(A)Time variation in aurora emission.
(B) The residuals from the sinusoidal function.
(C) The timing of transient brigtenings of aurora (black) and IPT (red).
(D) Time variation in IPT emission.
(E)20-hour moving average of IPT short (red) and IPT long (blue).

◎ IPT brightness increases 12 hours after the transient aurora brightening events.

◎IPT short brightens stronger than IPT long.
This is a signature of increase of the hot electrons.

◎9 pairs of brightenings were detected in 1st season.

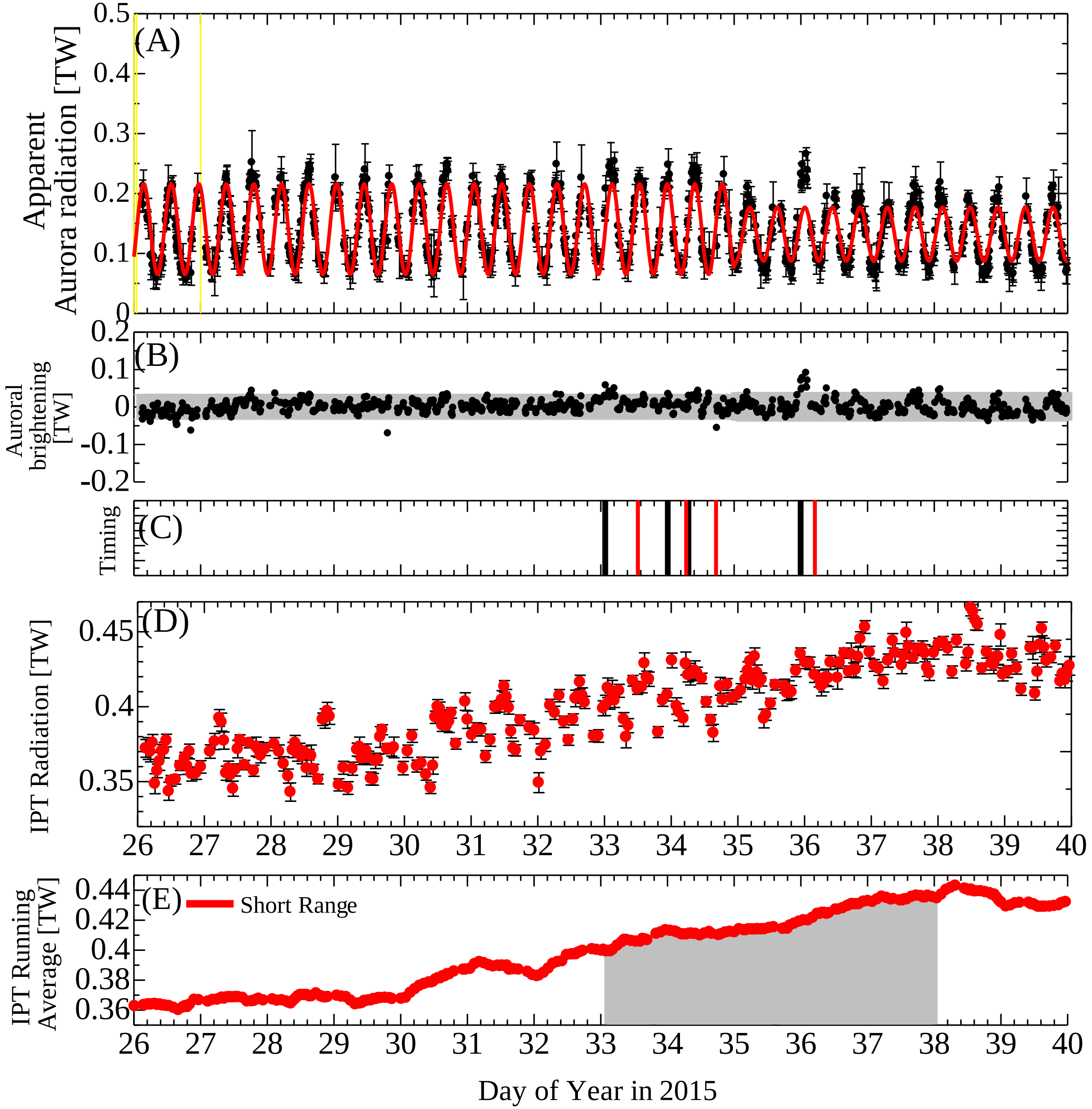
Observation(2nd Season)



Quiet phase during 2nd season

◎8 pairs of brightenings were detected in Quiet phase during 2nd season.

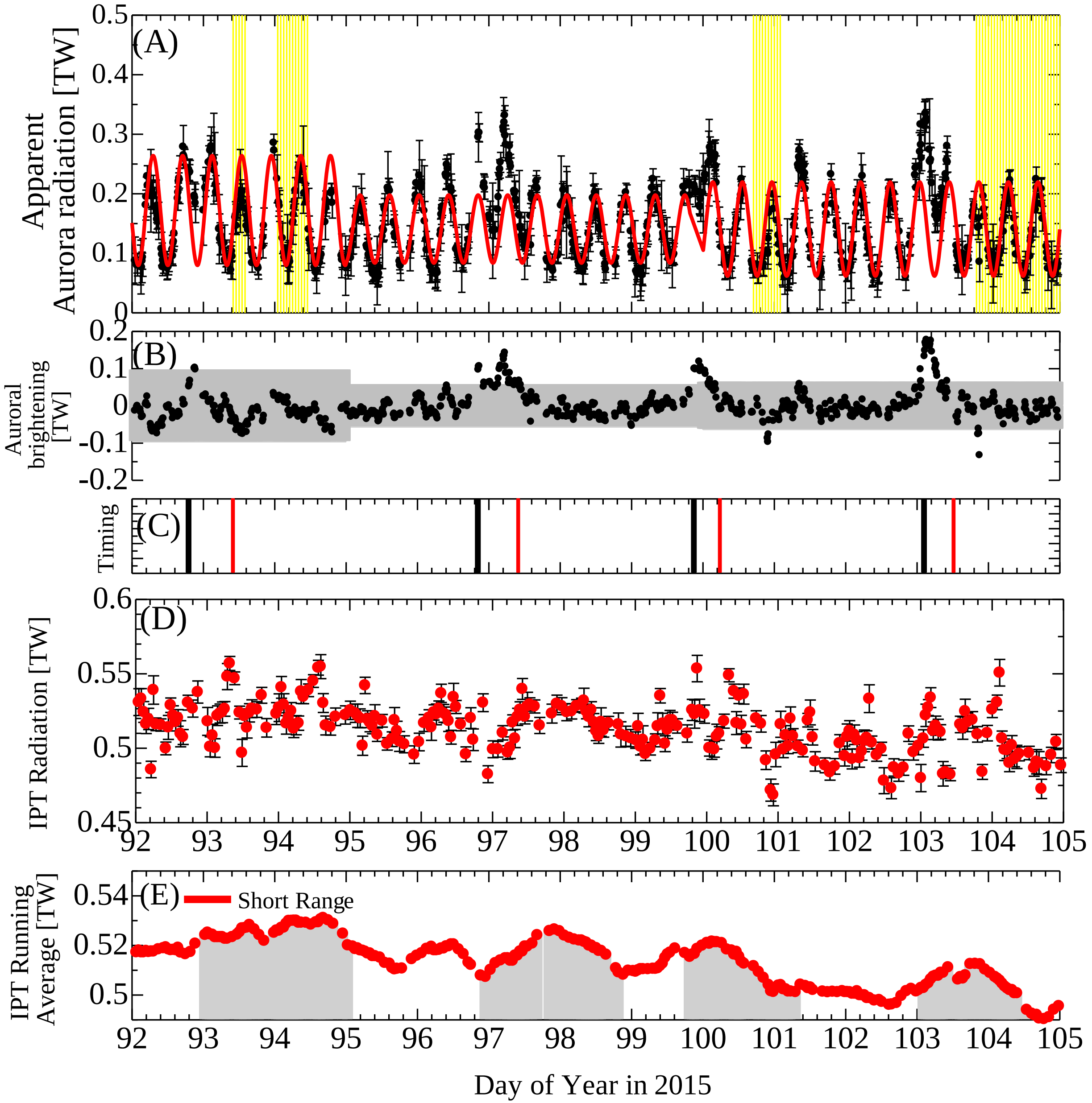
Observation(2nd Season)



Rising phase in 2nd season

◎6 pairs of brightenings were detected in rising phase.

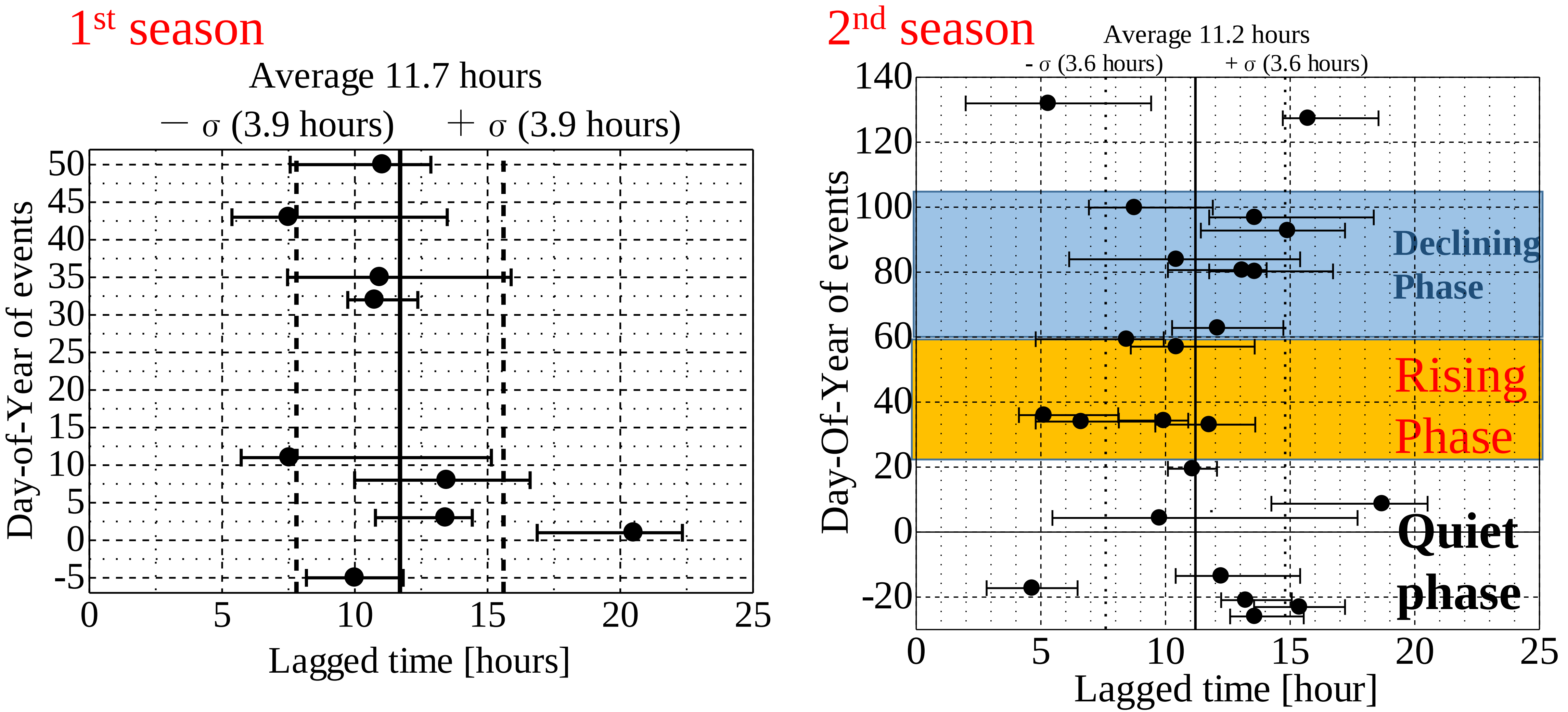
Observation(2nd Season)



Declining phase in 2nd season

◎11 pairs of brightenings were detected in declining phase.

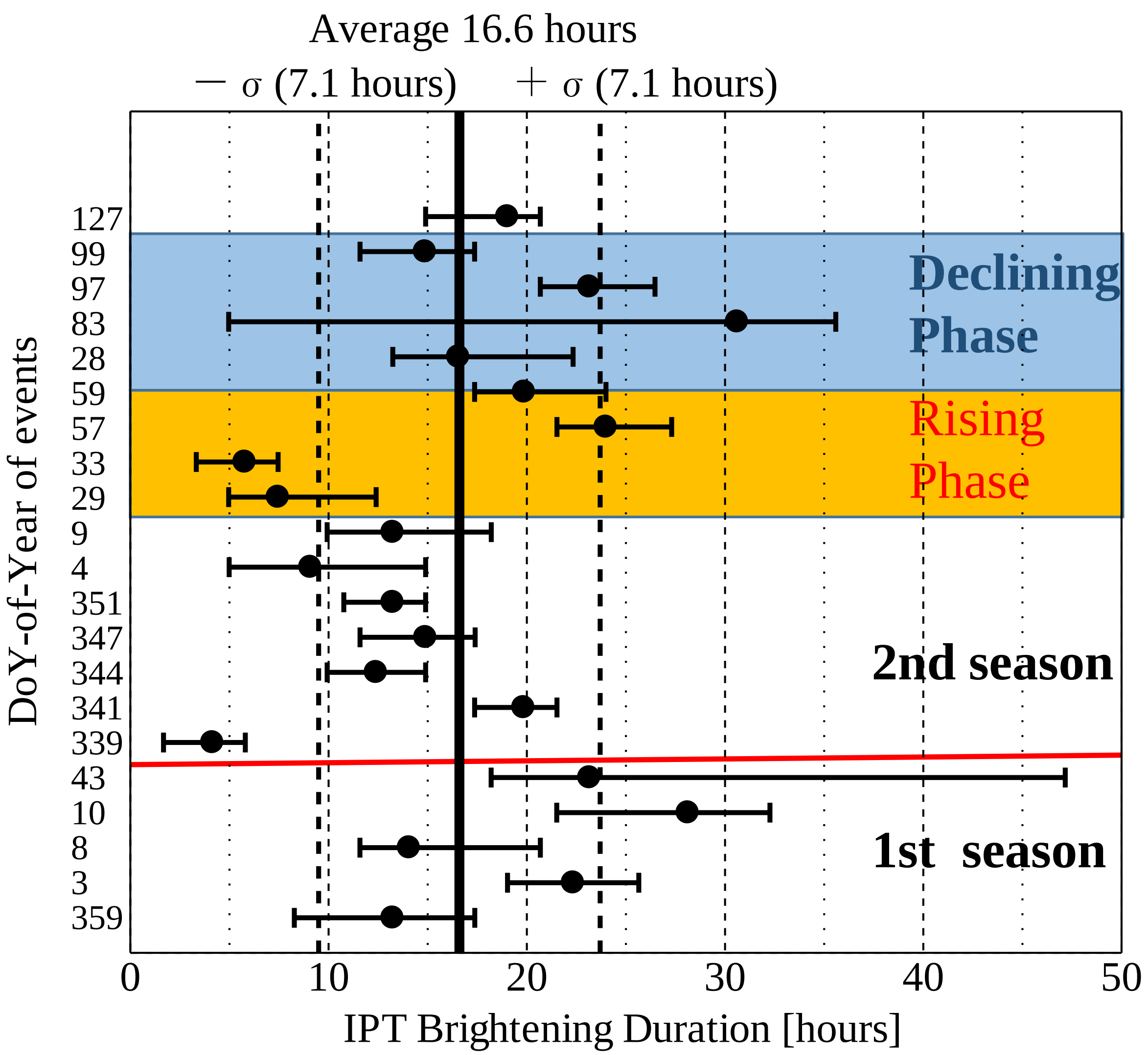
Result 1: Lagged time



Lagged time between IPT and aurora brightenings does not change during volcanic activity.

Result2：Duration of IPT brightenings

◎Duration of IPT brightenings is 16.6 hours on average.



Result3: Spatial structure of IPT brightenings

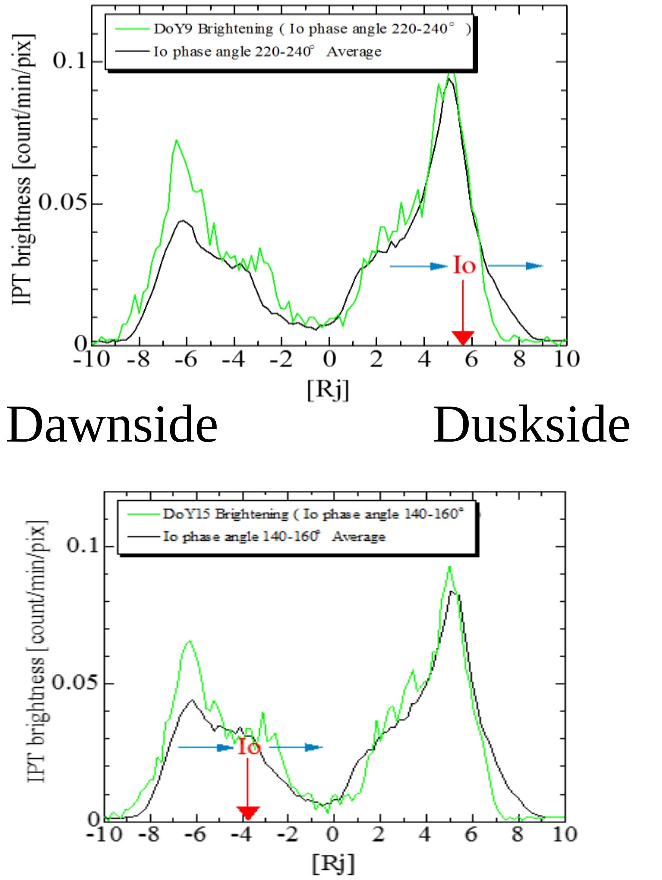
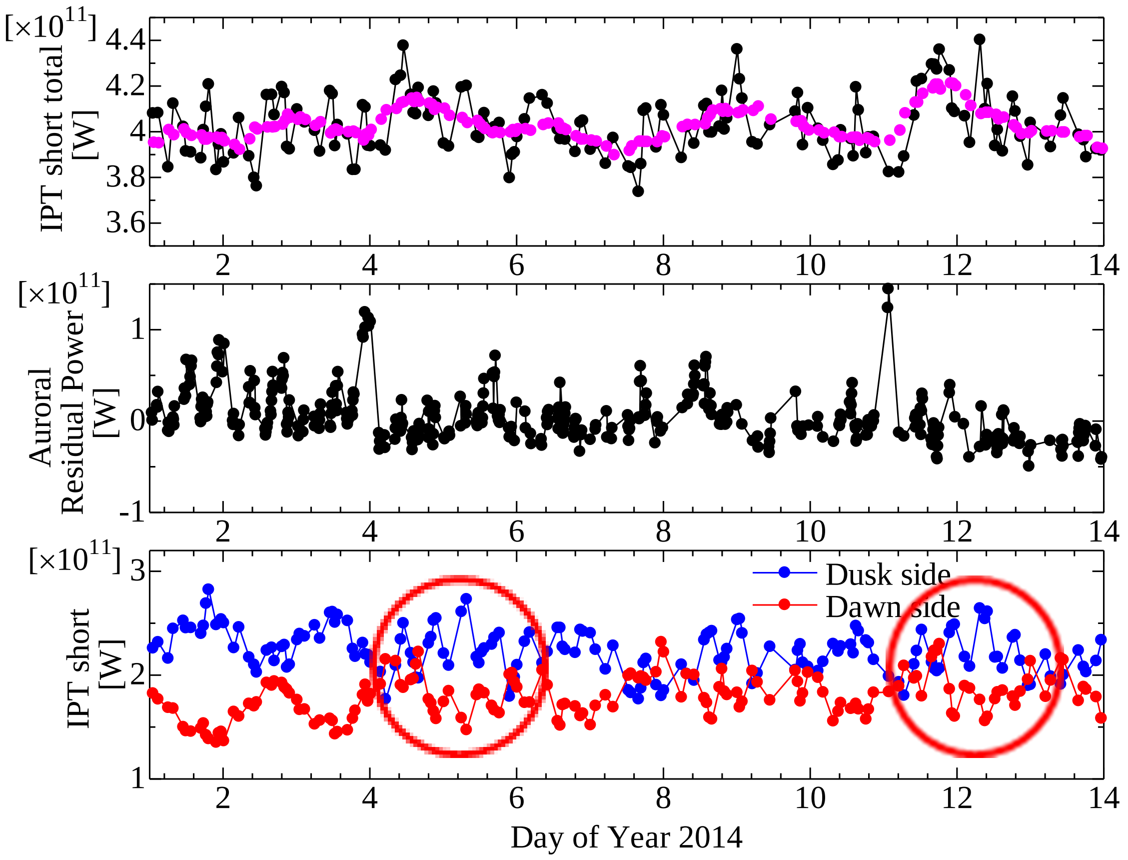


Fig. Radial profile of IPT on average (black) and during brightenings(green)



The 10-hour periodic variation increases after IPT brightenings.

Disccusion

Galileo's observation indicates that

▪the velocity of radial transport derived from interchange instability is 4 km/s.

▪the duration of interchange events is ~10 min.

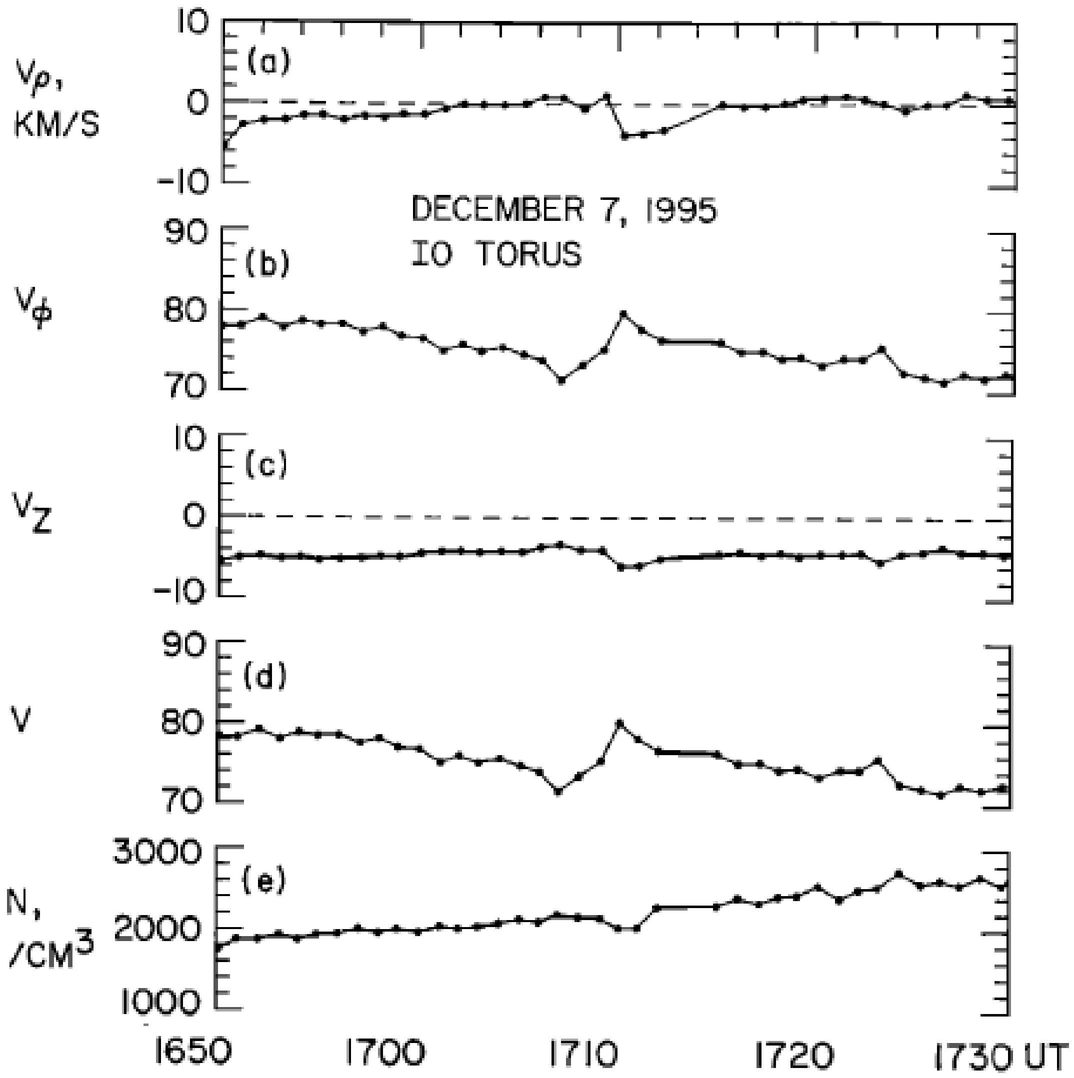


Fig.
A signature of an Interchange event observed by Galileo/PLS. [Frank and Paterson 2000]

Disccusion

If IPT brightenings are signatures of the interchange instability, we can conclude that

・the transport distance of the hot electrons is 2.4 Rj, if an interchange motion coincides with an auroral brightening.

・the duration of IPT brightenings is dominated by the collisional relaxation time of the hot electrons, which depends on temperature of the hot electrons.

Summary

According to the HISAKI observation, we have concluded that…

- electron temperature in IPT increases 12 hours after the transient auroral brightening events
- the duration of the IPT brightenings is over ten hours.

Investigation of this phenomenon has potential to reveal a radial transport process in Jovian magnetosphere.