# Transpolar arcs under a long-duration radial IMF interval: A case study

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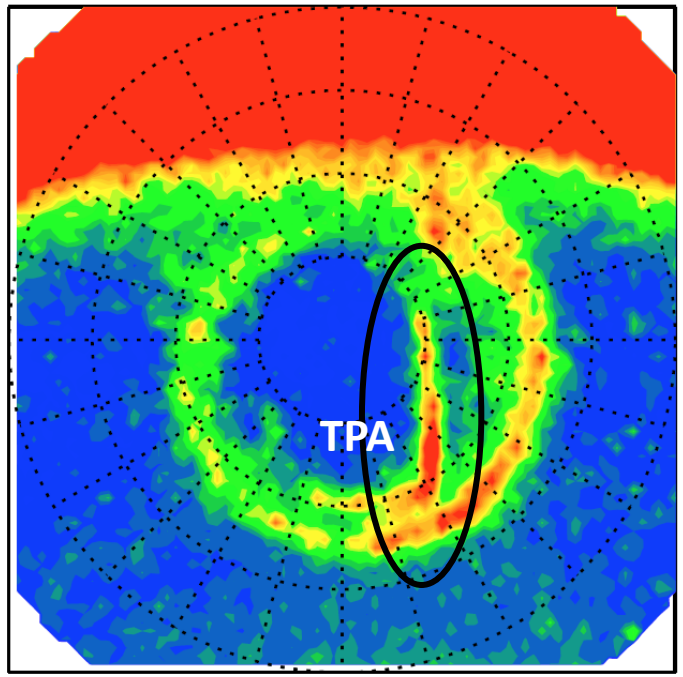
# Motivation (1/2)




Ex) Transpolar arc (Fear & Milan, 2012)

Transpolar arc (TPA): An optical auroral arc appearing at magnetic latitudes poleward of the main auroral oval

◆Interplanetary magnetic field (IMF) control of TPAs

- IMF $B_z$: Occurrence rate
  - Predominant occurrence during the northward IMFs → Low geomagnetic activity
- IMF $B_y$: Magnetic local time (MLT) location
  - IMF $B_y > 0$: Duskside (dawnside) MLTs in the northern (southern) hemisphere
  - IMF $B_y < 0$: Dawnside (duskside) MLTs in the northern (southern) hemisphere
- IMF $B_x$: Hemispheric asymmetry
  - One hemisphere where lobe reconnection is favored

❖Previous studies: TPAs in relation to the IMF $B_x$ coupled to northward IMFs

➢Controlling drivers that suppress TPAs → Difficult to determine the origin of the particles that produce the TPA

- ✓ Solar wind electrons with open field lines?
- ✓ Particles in the plasma sheet (or its boundary layer) with closed field lines?

# Motivation (2/2)

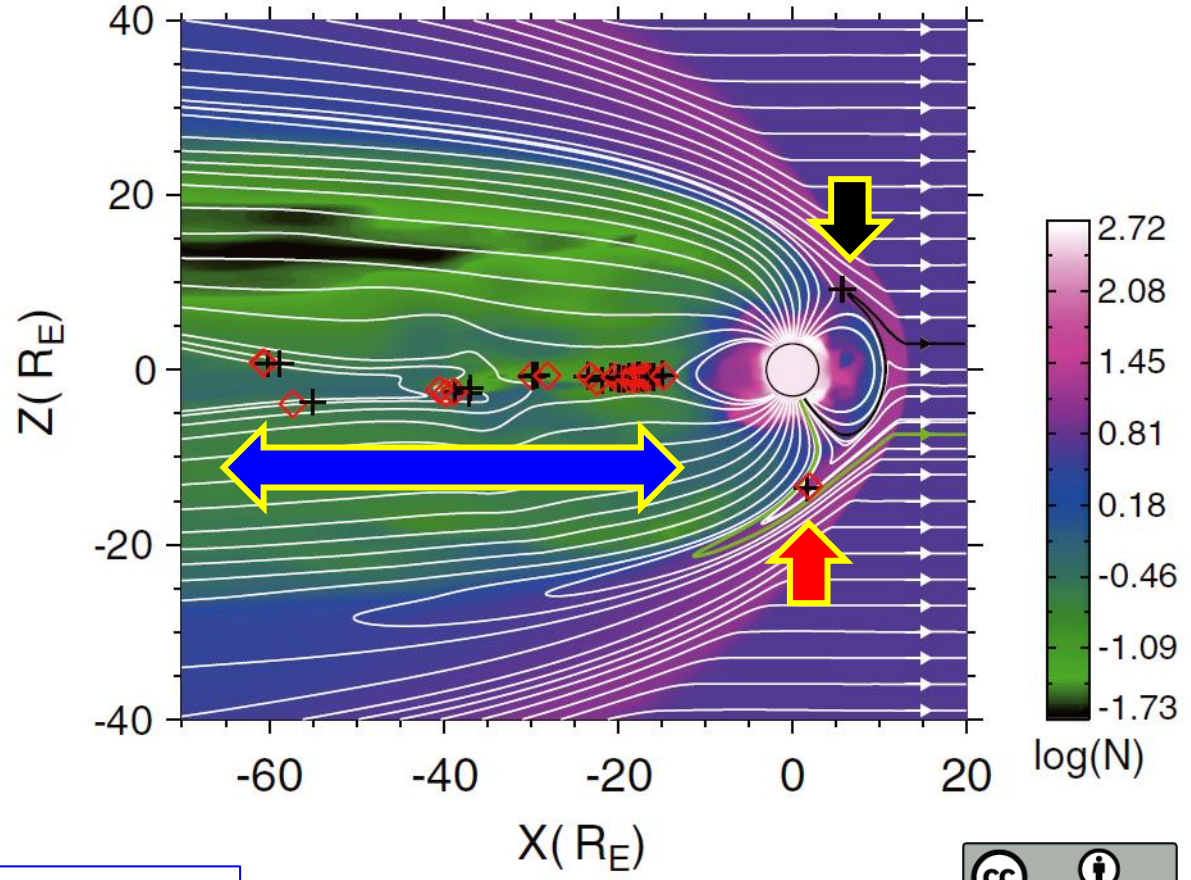
Solar wind-magnetosphere-ionosphere (S-M-I) system under radial IMF conditions

- IMF splitting/draping along the magnetopause
  - ➢ Different north-south IMF components in the opposite hemispheres along the magnetopause
- Magnetic reconnection regions
  - Sunward of the cusp (dayside magnetopause)
  - Tailward of the cusp (nightside magnetopause)
  - Magnetotail (plasma sheet/plasma sheet boundary layer)

❖Combining the terrestrial magnetic field configuration connected to the radial IMFs with auroral images, precipitating particle type, and the plasma convection pattern

➢ Provide more direct evidence for the particle sources that produce the TPAs

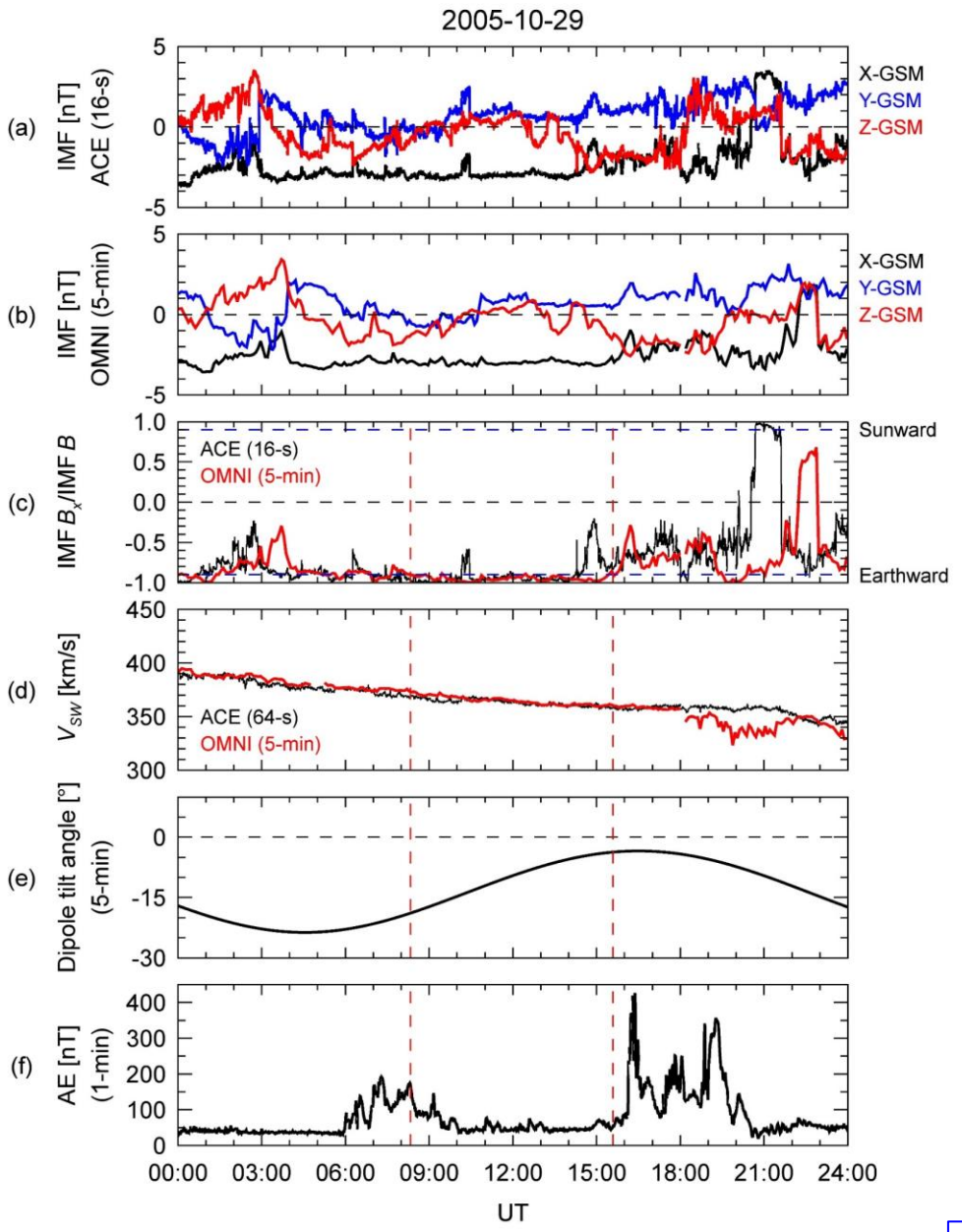
Ex) For sunward IMF conditions (Tang et al., 2013)



# Data Set

- IMF/Solar wind conditions
  - ACE: MFE (~16-s time resolution) & SWEPAM (~64-s time resolution)
  - OMNI: 5-min averaged data time-shifted into the nominal bow shock nose

- Auroral images
  - Cross-track scanned images of FUV emissions in Lyman-Birge-Hopfield (LBH) short band (~140-150 nm)
  - DMSP F16 (prenoon-premidnight local time sector): Special Sensor Ultraviolet Spectrographic Imagers (SSUSI)
  - TIMED (postnoon-postmidnight local time sector): Global Ultraviolet Imager (GUVI)
- Precipitating particle type
  - DMSP F13 & F16: Special Sensor for Precipitating Particles (SSJ/4 & SSJ/5)
- Ionospheric plasma convection pattern
  - DMSP F13 & F16: Special Sensor for Ions, Electrons, and Scintillation instruments (SSIES-2 & SSIES-3)




# Interplanetary/Geomagnetic Conditions

ISS
Institute of Space Sciences
Shandong University

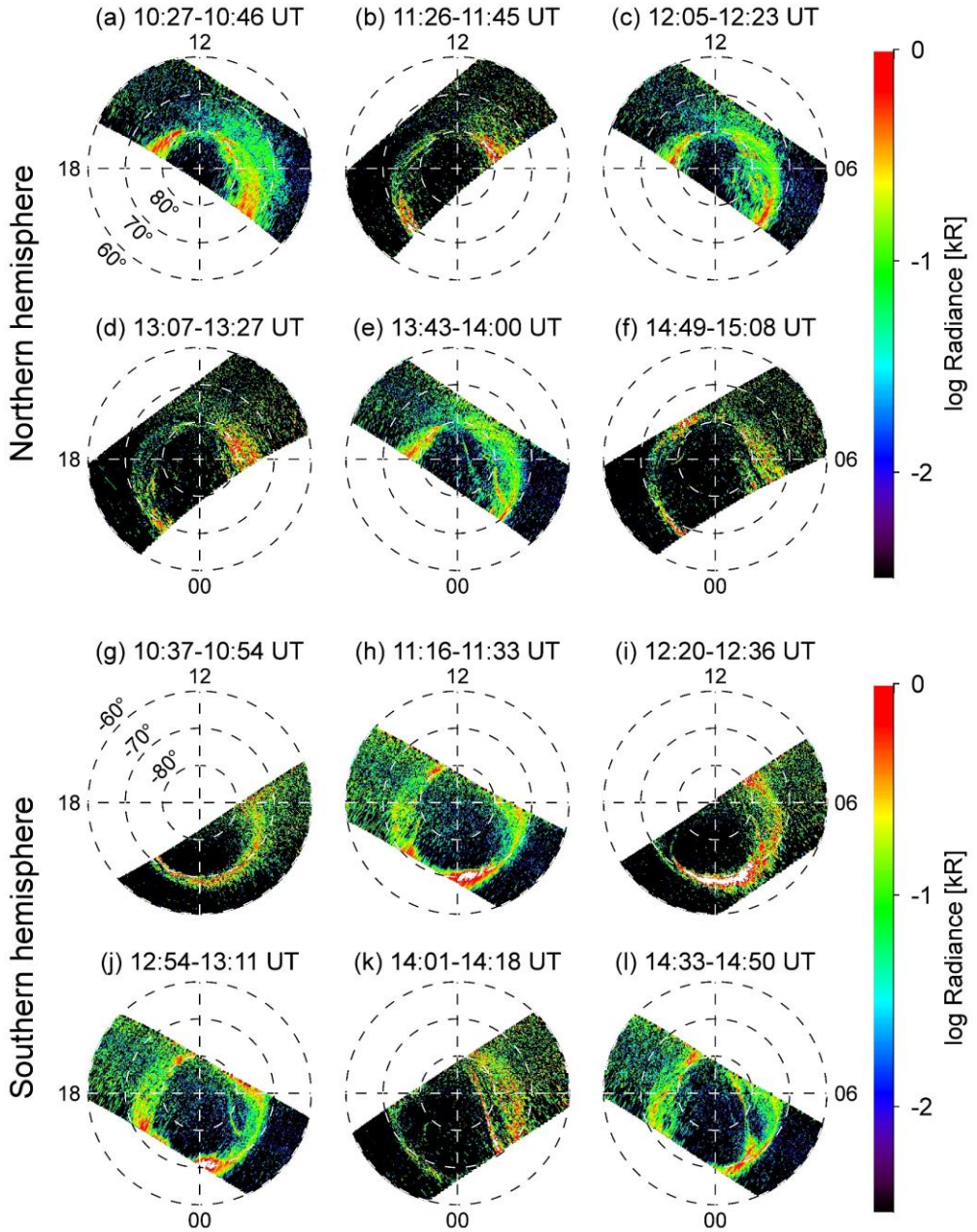
❖On 29 October 2005,

◆IMF $B_x$/IMF $B$ for OMNI (third panel)

➢ Long-duration earthward IMF (IMF $B_x$/IMF $B \leq -0.9$) interval: 08:22:30–15:37:30 UT (vertical dashed lines)

◆During this interval,

- Dipole axis: Become nearly orthogonal to the Sun-Earth line (dipole tilt angle: -20° → -4°)
- Auroral electrojet (AE) index: Very low (AE < 100 nT) regardless of the southward IMF conditions embedded in the IMF orientation
  - ➢ Small magnitudes of southward IMF → Not act on the auroral electrojet activity



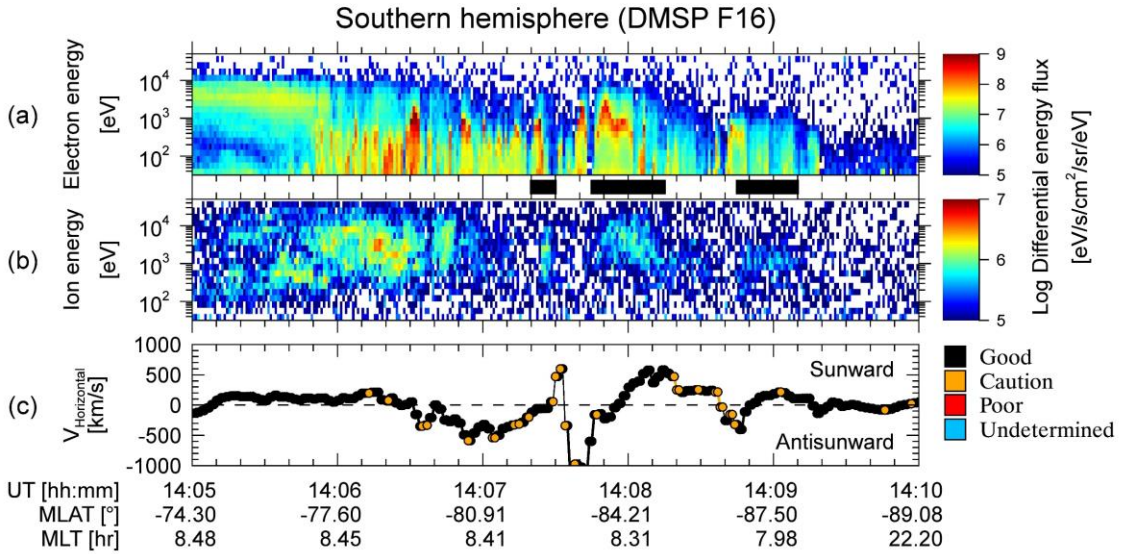

# Auroral Image

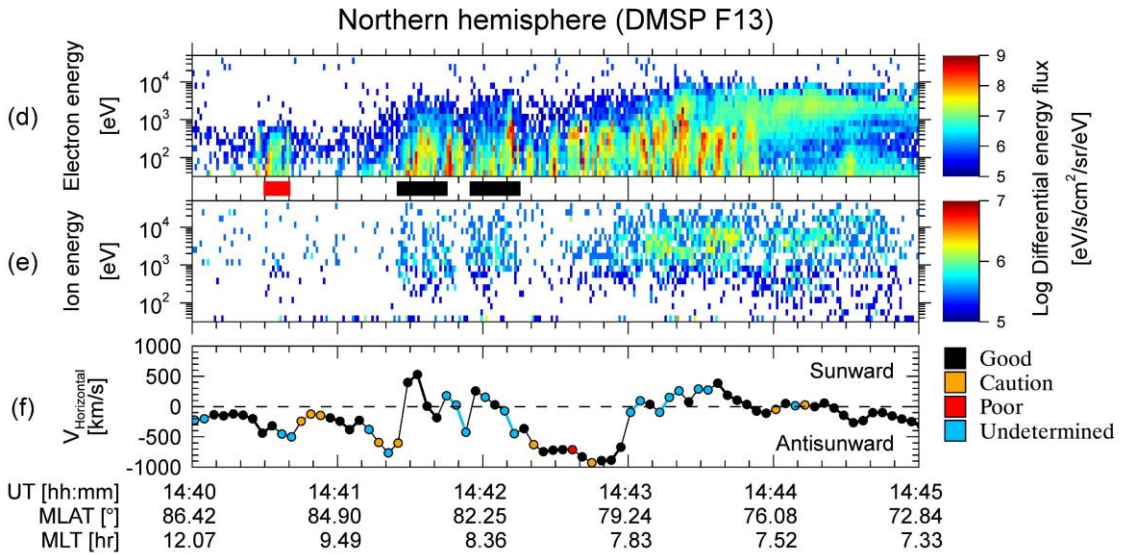
- Figures (a)-(f): Northern hemisphere (NH)
  - Figure (a): Local emission peak at ~80° MLAT near the dawnside (~0500 MLT) auroral oval
  - Figures (c) & (e): Two clear TPA structures (with ~1 kR near the dawnside oval & ~0.1 kR near the magnetic pole)
  - ✓ Figures (b) & (d): No TPA near the magnetic pole? → Limit of the field of view for auroral imager and/or the difference between the two instruments?
- Figures (g)-(l): Southern hemisphere (SH)
  - Figures (g) & (h): Auroral oval devoid of the TPA
  - Figures (i)-(l): A clear TPA structure with radiance of ~1 kR on the dawnside of the polar cap

➢ TPAs with radiance of ~1 kR: In both hemispheres

➢ TPA with radiance of ~0.1 kR: In the NH

# Precipitating Particles and Plasma Convection



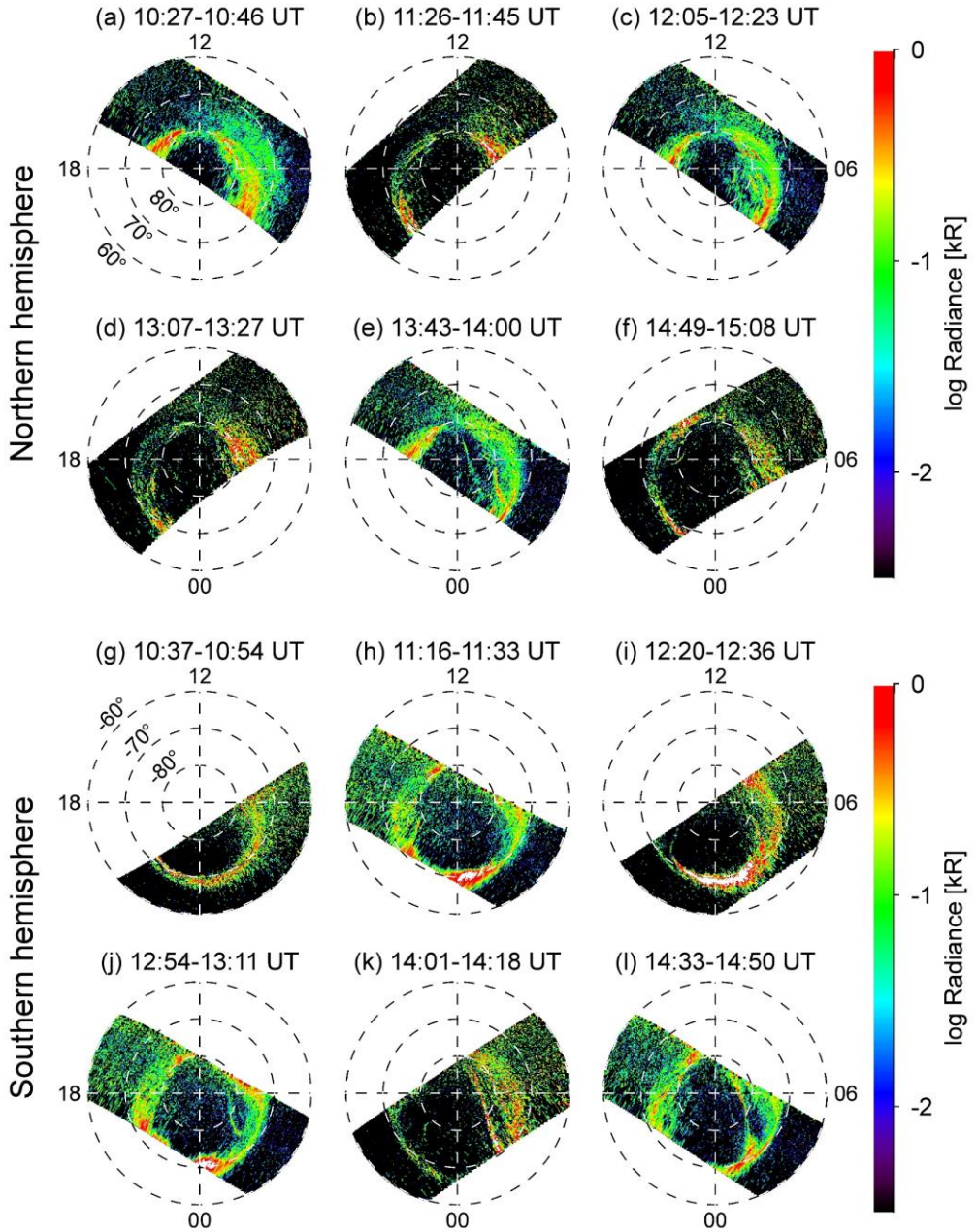




◆Figures (a)-(c): SH at 14:05–14:10 UT

- At ~14:07:20–14:07:30, ~14:07:45-14:08:15, & ~14:08:45-14:09:10 UT
  - Ion and electron (up to a few keV) precipitation
  - Sunward plasma convection

◆Figures (d)-(f): NH at 14:40–14:45 UT

- At ~14:41:25–14:41:45 & ~14:41:55–14:42:15 UT
  - A few keV ion and electron precipitation
  - Sunward plasma convection
- At ~14:40:30–14:40:40 UT
  - Electron-only precipitation (a few hundreds of eV)
  - Antisunward plasma convection




# Discussion (1/2)

❖Under the long-duration earthward IMF interval at 08:22:30–15:37:30 UT on 29 October 2005,

- TPAs with radiance of ~1 kR
  - In the NH: At 12:05–12:23 UT (Figure 2c)
  - In the SH: At 12:20–12:36 UT (Figure 2i)
  - ✓ ~3–4 h delay from the onset time of the earthward IMF conditions: Response time of the TPA formation to IMF orientation (Fear & Milan, 2012)

➢ Independent of the IMF orientation prior to the onset of the radial IMF interval

# Discussion (2/2)

❖ Under earthward IMF conditions,

◆TPAs (with radiance of ~1 kR) in both hemispheres

➢ TPA formation: Not limited to northward IMF conditions

- Precipitating electrons and ions & sunward plasma convection

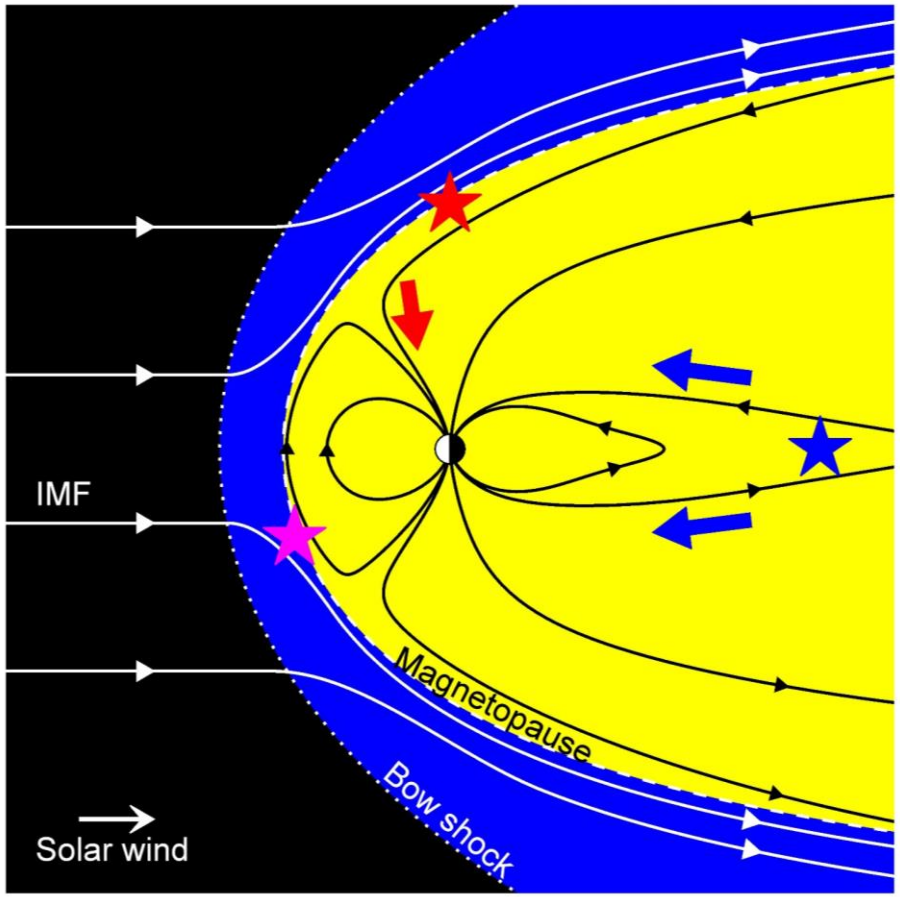
➢ Magnetotail plasma with closed field lines (star symbol and arrows in blue)

◆TPA (with radiance of ~0.1 kR) in the NH

➢ Nightside magnetopause reconnection

- Electron-only precipitation & antisunward plasma convection

➢ Solar wind electrons with open field lines (star symbol and arrow in red)




Schematic illustration of the terrestrial magnetic field configuration under purely earthward IMFs

# Conclusions

- TPAs occurring under a prolonged interval of radial IMF conditions

➢ Categorized into two different types according to the precipitating particles and plasma convection

  - Electron and ion precipitation with sunward plasma convection (in the SH)
  - Electron-only precipitation with antisunward convection & electron and ion precipitation with sunward convection (in the NH)

- TPA formation

✓ Not limited to northward IMF conditions

✓ On both closed and open field lines

❖ TPAs: Both direct and indirect processes of the solar wind energy transfer to the high-latitude ionosphere