Dayside Aurora as an Indicator of Asymmetric Solar Wind-Magnetosphere Energy Transfer

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Northern Hemisphere IMAGE WIC

Southern Hemisphere Polar UVI
Introduction (part 1)

- The dayside magnetosphere responds directly to incident interplanetary magnetic field (IMF) and solar wind energy

- Changes in the IMF and solar wind drive changes in magnetospheric and ionospheric convection

- Currents and (in the case of upward currents) aurora respond to these changes

→ Dayside aurora is a direct indicator of how the magnetosphere-ionosphere system responds to IMF and solar wind energy input
Introduction (part 2)

- Focus on afternoon sector – 15 MLT bright spot
- Region of persistent auroral emission centered near 15 MLT and 75 degrees latitude [Cogger et al., 1977; Liou et al., 1997]
- Caused by low energy (< ~ 1 keV) electron precipitation [McDiarmid et al.; 1975, Evans, 1985; Newell et al., 1996]
- Co-located with maximum in Region 1 upward field aligned current [Iijima and Potemra, 1987]
- Appearance and behavior influenced by solar wind and IMF [Murphree et al., 1981; Vo and Murphree, 1995]
- Can be structured and dynamic (string of pearls configuration) [Lui et al., 1987; Potemra et al., 1990, Rostoker et al., 1992]
- Varies with season: more likely in summer [Liou et al., 2001] → hemispheric differences
Introduction (part 3)

- Previous conjugate observations limited to small scales (in situ point measurements or ground based instruments) in at least one hemisphere [Dickinson et al., 1986; Mende et al., 1990; Burns et al., 1990, 1992; Vo et al., 1995]

- Fillingim et al. [2005] presented the first simultaneous images of dayside aurora from two global auroral imagers in opposite hemispheres (IMAGE WIC in northern hemisphere and Polar UVI in south)

- Addressed the issue of conjugacy of the dayside aurora on a synoptic scale for the first time
- Related differences in aurora to solar wind and IMF conditions
- Continuation of the work of Fillingim et al. [2005]
Spacecraft Orbits

**IMAGE**
Launch: Mar. 25, 2000
Apogee: 8 $R_E$
Period: 14 hours

**Polar**
Launch: Feb. 24, 1996
Apogee: 9 $R_E$
Period: 18 hours
Instrumentation

IMAGE Wideband Imaging Camera (WIC) & Polar Ultraviolet Imager (UVI) LBHS & LBHL

Temporal resolution
WIC: 10 second integration every 2 minutes
UVI: 18 & 36 second integration, cyclic

Spatial resolution
WIC: ~ 50 km
UVI: ~ 30 km

Spectral resolution
WIC: 140 to 190 nm – LBHS: 140 to 160 nm – LBHL: 160 to 180 nm –
NH: enhanced, unstructured emission in afternoon
SH: multiple spots; number, location, and intensity change
4 November 2002

Northern Hemisphere

Southern Hemisphere

NH: enhanced, unstructured emission in afternoon
SH: multiple spots; number, location, and intensity change
NH: enhanced emission in afternoon; variable intensity and location; single region

SH: multiple regions of emission; vary in intensity and location; different regions behave differently

Steady solar wind density and velocity

IMF

$B_X < 0$

$B_Y > 0$

$B_Z < 0$ (with some positive excursions)
SuperDARN Ionospheric Velocity Data

NH: large velocities pre-noon; moderate velocities in afternoon
SH: poor coverage; crescent shaped cell in afternoon, large v?
Interpretation

For $B_Z < 0$, strong $B_Y$
⇒ mirror image convection patterns

Strong flow shear, divergent $E_\perp$, $J_\perp$, strong $J_\parallel$
⇒ more discrete auroral structure (brighter?)

⇒ Hemispheric asymmetry

(from Clauer et al.)
Why Multiple Spots?

“String of pearls” configuration is consistent with being the result of a Kelvin-Helmholtz Instability (KHI) [Lui et al., 1989; Rostoker et al., 1992; Wei and Lee, 1993]

- KHI occurs at velocity shear; assumed to occur at equator
- Multiple spots only in one hemisphere, not both as expected

⇒ KHI occurs at high latitude near the ionosphere (in crescent cell) and depends on $|B_Y/B_Z|$ [cf. Ridley and Clauer, 1996]
22 October 2002

Northern Hemisphere

Southern Hemisphere

NH: latitudinally narrow emission, brightens near 19:40 UT
SH: broader, more diffuse emission; no noticeable change
22 October 2002

Northern Hemisphere

Southern Hemisphere

NH: latitudinally narrow emission, brightens near 19:40 UT
SH: broader, more diffuse emission; no noticeable change
22 October 2002

NH: very quiet from 17:45 to 19:15 UT; brightening near 19:40 UT; narrow MLT range (peaked)

SH: aurora brightens near 19:30 UT; diffuse in latitude and MLT

Steady solar wind density and velocity

IMF \( B_X > 0 \)
\( B_Y < 0 \)
\( B_Z < 0, > 0, < 0 \)
2 November 2002

Northern Hemisphere

Southern Hemisphere

NH: Sudden brightening at 14:10 UT;
SH: No change
NH: Sudden brightening at 14:10 UT

SH: No change

> 30% drop in solar wind dynamic pressure (related to brightening?)

Large IMF $|\mathbf{B}|$

(note change in scale)

Change from $+Y$ dominated to $-X$ dominated (radial) IMF (related to brightening?)
SuperDARN Data

NH: Large increase in dayside velocities in eastward direction
Large increase in velocity shear → could increase FAC
Response to solar wind/IMF change?

SH: Good data coverage; no increase in dayside velocities
Complex change in convection pattern; stagnation point?
No auroral signature
Simultaneous widespread brightening (< 15 MLT to 18 MLT) in both hemispheres at 19:47 UT (relatively conjugate)
Simultaneous widespread brightening at 19:47 UT in both hemispheres

Other brightenings and structure (and lots of it) non-conjugate

Solar wind density constant; velocity large with minor variations

IMF $B_x < 0$
$B_y < 0$ (mostly)
$B_z > 0$ w/fluctuations
Summary

Prediction: For $B_Y > 0$, afternoon aurora more structured [brighter] in the southern hemisphere
For $B_Y < 0$, afternoon aurora more structured [brighter] in the northern hemisphere

2 November 2002:
Brightening in north aurora absent in south for $B_Y > 0$
→ Large decrease in dynamic pressure and IMF rotation

25 October 2002:
Sporadic brightenings in north and south for $B_Y < 0$
→ High solar wind velocity and large $B_Z$ fluctuations

Seeing short-lived response to changes in solar wind and IMF and not quasi-steady state conditions observed on 4 November 2002
=> M-I system responds asymmetrically to solar wind variability