Diffuse Aurora


1. Introduction
2. Where do the particles come from?
3. How do they become diffuse aurora
4. Remote sensing the magnetosphere
5. Unstructured quiet time H+ aurora
6. Structure in the diffuse aurora
7. Opportunities for future studies
8. Final thoughts

Diffuse Aurora

A Few Details
Images from rom http://spaceweb.oulu.fi/~jussila/aurora/
Diffuse Aurora
Diffuse Aurora

20070313 093154 AUGO NORSTAR and THEMIS Imagers

630 nm  428 nm  558 nm  BW
09 -  07 -  07 -  frame 18
Diffuse Aurora
Diffuse Aurora

0100
0210
0320
0430
0540
0650
0800
0910
1020
1130
1240
1350
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Introduction
Fig. 1. Schematic of auroral distribution modified slightly from Akasofu (1966). Note that the original figure was constructed on the basis of ground-based observations made before global imaging from space was possible. As such, it incorporates a mixture of diurnal (local time) and temporal (universal time) variations.
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Show SNKQ Movie
Diffuse Aurora
Diffuse Aurora

FAST Orbit 05849 - 980213
IES and EES data from CDAWeb

Magnetic Latitude (Degrees)

Energy (keV)

Energy Flux (erg/sec/cm²)

Energy Flux (eV/cm²/s/sr/eV)

Energy Flux (eV/cm²/s/sr/eV)

Energy Flux (eV/cm²/s/sr/eV)

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IES and EES data from CDAWeb

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Where do the Particles Come From?
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GEM Tutorial - Diffuse Aurora
Direction of Grad B for T87 + Dipole < Kp range : 0 >

Electric Field from Volland-Stern Potential
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\[ \mathbf{v}_D = \frac{\mathbf{E} \times \mathbf{B}}{B^2} + \frac{m}{2q} \left(2v^2_\parallel + v^2_\perp\right) \frac{\mathbf{B} \times \nabla \mathbf{B}}{B^3} \]
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Electric Field from Volland-Stern Potential

Electrons with $\mu = 60$ eV/nT

Electric Field from Volland-Stern Potential

Electrons with $\mu = 400$ eV/nT
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How does this become Diffuse Aurora?
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IES and EES data from CDAWeb

Kappa

Pitch Angle (Degrees)

radial distance (Re)

Magnetic Latitude (Degrees)

Energy Flux (erg/sec/cm^2)

Energy Flux (eV/cm^2/s/sr/eV)

Energy Flux (eV/sec/cm^2)

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98U103 Gillam-Hankin NORSTAR/CANOPUS MSP

630 nm

486 nm (H-beta)

UT (hh)

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980103 Gillam-Hankin NORSTAR/CANOPUS MSP

630 nm

486 nm (H-beta)

UT (hh)
Diffuse Aurora

980103 Gillam-Hankin NORSTAR/CANOPUS MSP

558 nm

486 nm (H-beta)

UT (hh)

03 04 05 06 07 08 09 10 11 12

2500 1166 517 241 107 50

20 16 11 8 3 0

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980103 Gillam-Hankin NORSTAR/CANOPUS MSP

558 nm

486 nm (H-beta)

03 04 05 06 07 08 09 10 11 12

UT (hh)

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960216 Gillam-Rankin NORSTAR/CANOPUS MSP

630 nm

558 nm

486 nm (H-beta)

UT (hh)
Remote Sensing the Magnetosphere
Latitude of equatorward boundary of proton aurora is highly correlated with magnetic field topology near the CPS inner edge.
The brightness of the proton aurora tracks sudden changes in solar wind dynamic pressure.
Poleward boundary of the diffuse 630 nm (Oxygen “Redline”) emissions is an excellent proxy for the open–closed boundary.
Unstructured Quiet Time H+ Aurora
Diffuse Aurora

Gillam H-beta Intensity 921227
Diffuse Aurora

900119 630 nm
921227 630 nm
951124 630 nm

900128 630 nm
930428 630 nm
960122 630 nm

901210 630 nm
931209 630 nm
970207 630 nm

901218 630 nm
940105 630 nm
970309 630 nm

910114 630 nm
950225 630 nm
971120 630 nm

920126 630 nm
951001 630 nm
980104 630 nm
Diffuse Aurora

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921227 Gillam 630 nm Intensity

921227 Gillam H-beta Intensity

$|B|$ in nT
GOES 6

UT [hh]

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970206 Gillam 630 nm Intensity

970206 Gillam H-beta Intensity

|B| (nT)
GOES 8

UT (hh)

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Structure in the Diffuse Aurora
Diffuse Aurora

Proton (Hβ) auroral fading before EVERY substorm onset.
Diffuse Aurora

FSMI 061227

0600 0700 0800 0900 1000 1100 1100

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SNKO 070227

0800 0900 1000 1000
Diffuse Aurora

GILL 061102

0800 0900 1000 1100 1100

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Frames separated by 3 seconds

Vertical striations on keograms are a consequence of patches “flashing” on.

Whatever process is on one level aliasing with 3 seconds & the one second exposure time.

2007-03-13
Athabasca THEMIS ASI
Diffuse Aurora

Athabasca

Optical Pi2
Diffuse Aurora

Athabasca, AB, Canada

Legal, AB, Canada

2007-03-24 08:17:48 UT
2007-03-24 01:17:48 MST

Institute for Space Research
University of Calgary
Alberta, Canada
Reproduced from Figure 10 in Yamamoto, T., S. Inoue, and C. Meng, *Formation of auroral omega bands in the paired region 1 and region 2 field-aligned current system*, JGR, 102(2531-2544), 1997.
Diffuse Aurora
Diffuse Aurora

- Oct 29, 2003: $K_p = 7$
- Nov 9, 1998: $K_p = 7$
- Nov 27, 2002: $K_p = 6$
- Aug 17, 2001: $K_p = 5$
- Nov 4, 2000: $K_p = 3$
- Aug 27, 1998: $K_p = 8$
Opportunities for New Studies
Diffuse Aurora

Questions that need answering!

Proton Diffuse Aurora

Why does proton auroral fading occur in the 20 minutes prior to onset?
Is proton diffuse auroral precipitation structured?
What are the relative contributions of the various causes of proton precipitation?
Are inductive electric fields important in proton auroral precipitation near onset?
Are all discrete electron auroral arcs embedded in the proton aurora?
Is there such a thing as a discrete proton auroral arc?

Electron Diffuse Aurora

What determines structure in the electron diffuse aurora?
What is the role of CPS turbulence in diffuse auroral structure/brightness?
Develop a relationship between CPS conditions and electron auroral brightness.
Do processes such as BBFs play a role in diffuse auroral brightness?
Is there a diffuse auroral signature of mid-tail reconnection?
Develop a relationship between CPS conditions and electron auroral brightness.
What are the relative contributions of the various causes of electron precipitation?
Why is the poleward boundary of the diffuse electron aurora sometimes so sharp?
Is the redline poleward boundary always a good proxy for the separatrix?
Diffuse Aurora

Questions that need answering!

- Oct 29, 2003, $K_p = 7$
- Nov 9, 1998, $K_p = 7$
- Nov 27, 2002, $K_p = 6$
- Aug 17, 2001, $K_p = 5$
- Nov 4, 2000, $K_p = 3$
- Aug 27, 1998, $K_p = 8$
Frames separated by 3 seconds

Vertical striations on keograms are a consequence of patches “flashing” on.

Whatever process is on one level aliasing with 3 seconds & the one second exposure time.

Show THEMIS–Athabasca Movie

2007-03-13
Athabasca THEMIS ASI
Diffuse Aurora

Plasma physical mechanisms of DA precipitation

Athabasca University Geophysical Observatory

Instrument Complement

NORSTAR H-beta Imager
OMTI Multi-Spectral Imager
NORSTAR Rainbow Imager
NORSTAR Dense Array Imager (Narrow)
THEMIS Panchromatic Imager
OMTI Meridian Scanning Photometer
OMTI Induction Coil Magnetometer
NRCAN Fluxgate (at Meanook)
NRCAN Riometer (at Meanook)
NORSTAR Dense Array Imager (at Legal)

Fluxgate Mags
- MAGIC
- MACCS
- DMI
- AGI
- Athabasca U.
- IGPP-LANL
- McMac
- THEMIS GBO
- THEMIS EPO
- MEASURE
- NRCAN
- CARISMA

Proposed AUGO Campaign
CGSM/NORSTAR Context
Eric Donovan & Mike Greffen

Meanook (very near Athabasca in above map)
In the following plots I am stepping forward one orbit at a time starting from an orbit where the satellite passes through the night side over eastern Russia.

The contours show constant PACE latitudes from 50 to 80 degrees and longitudes separated by one hour of local time.

The orbit is shown in red (projected geographically to the surface which is not too bad for the orbit we are talking about. Magnetic midnight is indicated by the dashed white thick line from 50 to 80 degrees PACE.

The black dots indicate fluxgate mags in North America and
Diffuse Aurora

Orbit Number: 010

SWARM Overflight Simulation
Based on Champ Orbit parameters
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 011
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 012
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 014
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 015
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 016

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SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 017

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SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 018
Diffuse Aurora

SWARM Overflight Simulation
Based on Champ Orbit parameters

Orbit Number: 019
Considering just this one day in 2002, had all of the ASIs been operating that I expect will be operating by 2009 been running...

Champ would have passed though the FOVs of roughly 50 ASIs with one pass having continuous optical coverage from 55 degrees mlat (NORSTAR) to the magnetic pole (CHAIN) and passing though the FOVs of AMISR and PolarDARN.

WE can expect this number of conjunctions for all three SWARM satellites during most times of year. With three satellites and the quality of E and B observations that SWARM will provide this will be an unprecedented opportunity for studies of auroral electrodynamics.
Final Thoughts
Diffuse Aurora

Plasma Physics
What causes the precipitation??

Geospace Remote Sensing
What can we infer about geospace from the diffuse aurora?

Role in Dynamics
Is the diffuse aurora “important”?

ECH
Chorus
EMIC
Turbulence
Potential Difference
FL Curvature
MASER

OC Boundary
E- CPS inner edge
H+ CPS inner edge
Stretched-dipolar trans
Stretching
H+ pressure
Presence of MHD waves
Presence of waves

Loss of low E e-
Loss of high E e-
Loss of low E H+
Low of high E H+
Direct role in currents
Conductivity effects
Role in wave generation

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References
Diffuse Aurora

High Points

**Discovery & Early Exploration of the Diffuse Aurora**

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Diffuse Aurora

High Points

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Wing, S., Central plasma sheet ion properties as inferred from ionospheric observations, JGR, 103(6785-6800), 1998.

Friedel, R.,
Airborne Observations of Auroral Precipitation Patterns, JGR, 76(1746-1755), 1971.

Diffusion mechanisms


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Diffuse Aurora

High Points

Inferring things from diffuse auroral boundaries

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W. Imhof, Fine resolution measurements of the L-dependent energy threshold for isotropy at the trapping boundary, JGR, 93(9743-), 1988.


Diffuse Aurora

High Points

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V. Sergeev, E. Sazhina, N. Tsyganenko, J. Lundblad, and F. Søraas,
*Pitch-angle scattering of energetic protons in the magnetotail current sheet as the dominant source of their isotropic precipitation into the nighttime ionosphere*, PSS, 31(1147-1155), 1983.

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