

## Lesson 2: Auroral oval and precipitation within the oval

AGF-351

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Anita Aikio  
University of Oulu  
Finland

### Auroral zone

- Regions in which night-time auroras occur in the statistical sense.
- Within the auroral zones, auroras are observed by the naked eye on more than 50% of nights (if there are no clouds), even during years of low solar activity.
- They are centered roughly  $23^\circ$  from the geomagnetic poles and are  $\sim 10^\circ$  wide.

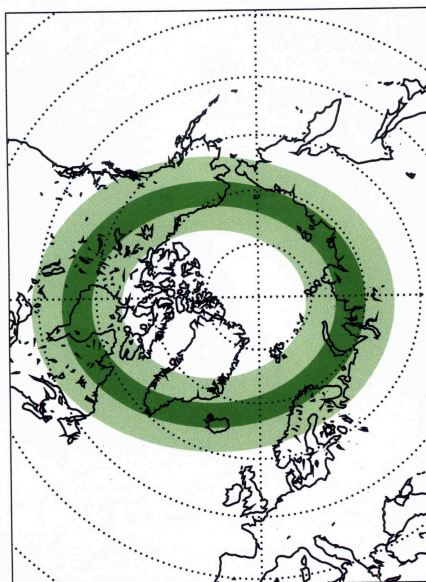


Figure from Kaila (1998).

## Auroral zone in the southern hemisphere

- Regions in which night-time auroras occur in the statistical sense.
- Within the auroral zones, auroras are observed by the naked eye on more than 50% of nights (if there are no clouds), even during years of low solar activity.
- They are centered roughly 23° from the geomagnetic poles and are ~ 10° wide.

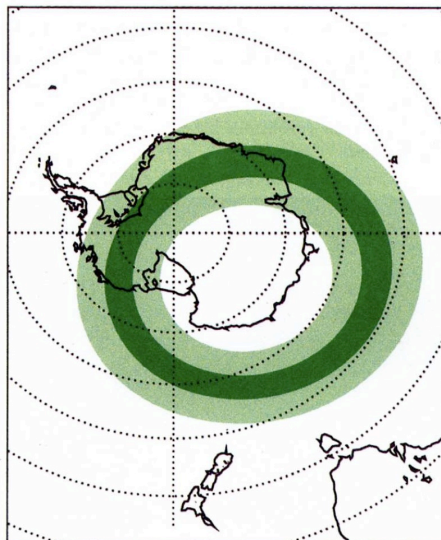
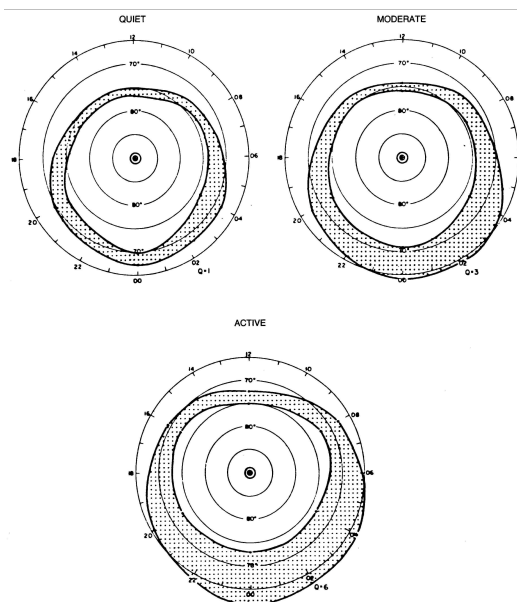
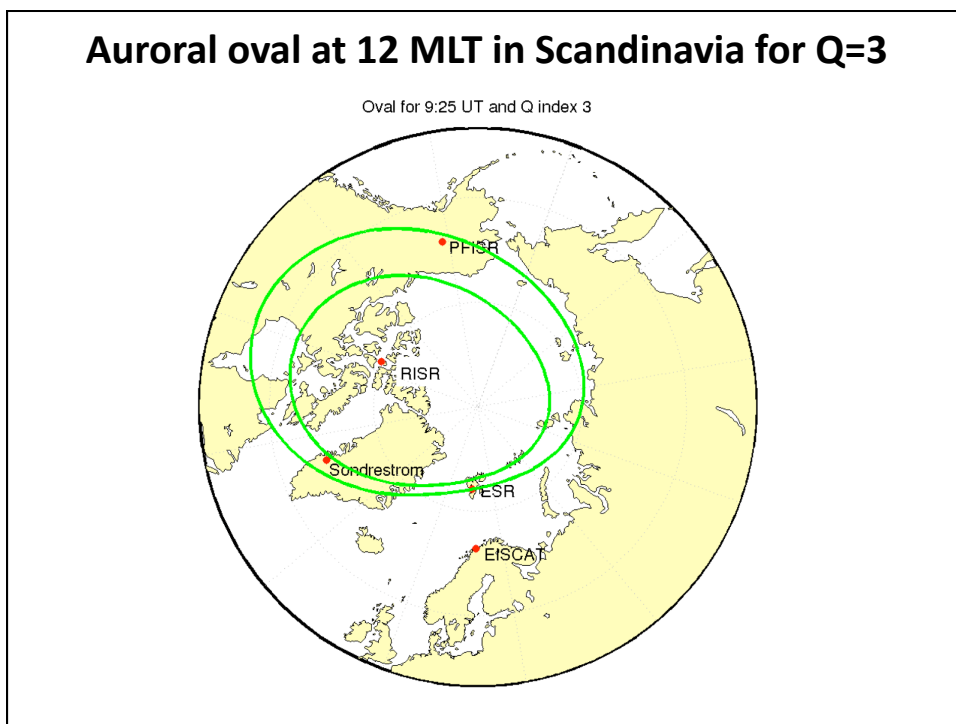
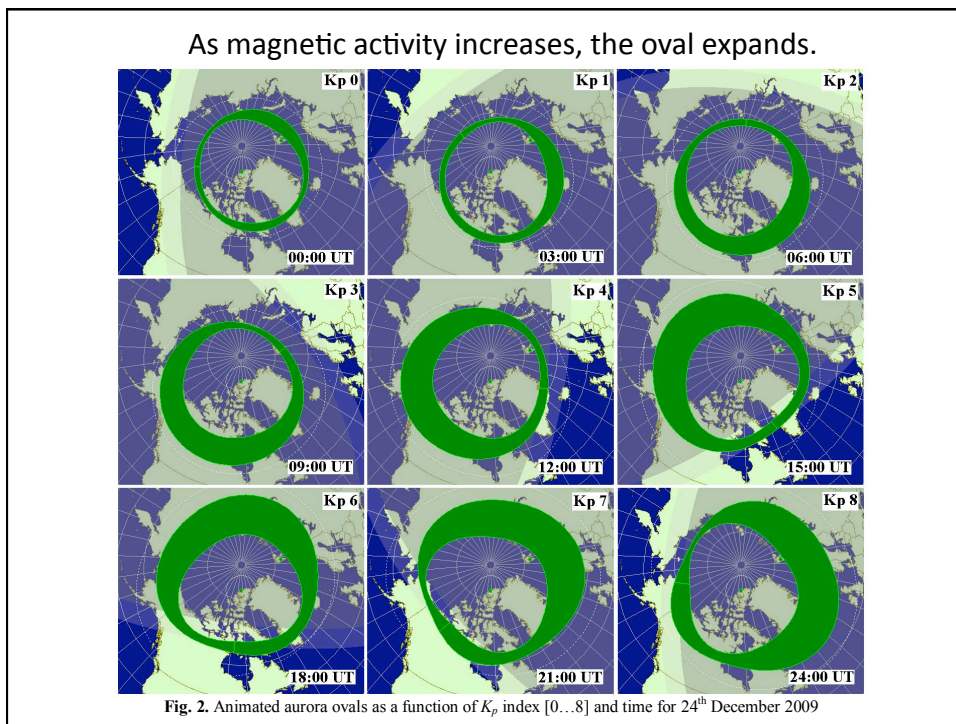


Figure from Kaila (1998).

## Auroral oval

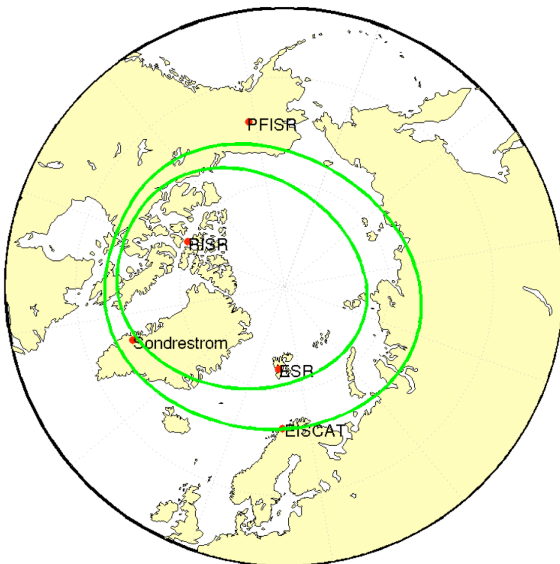
Based on observations during the International Geophysical Year 1956-57, the instantaneous distribution of auroral activity versus magnetic local time (MLT) and magnetic latitude (MLAT) was found to be an oval-shaped by Feldstein in 1963. The auroral ovals (one for each hemisphere) are continuous bands centered near 67° MLAT at magnetic midnight and near about 77° MLAT at magnetic noon. The figure shows the Feldstein and Starkov (1967) ovals for 3 different activity levels.





### Auroral oval at 20 MLT in Scandinavia for Q=3

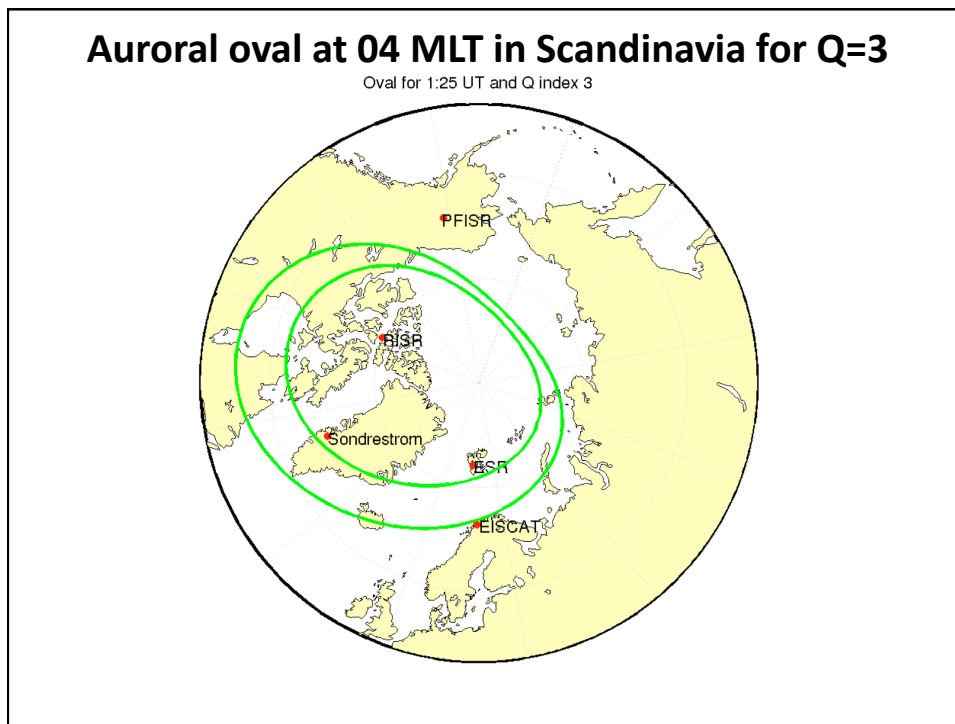
Oval for 17:25 UT and Q index 3



### Auroral oval at 24 MLT in Scandinavia for Q=3

Oval for 21:25 UT and Q index 3





But remember that there are other models for the oval too, like Hardy (1985) and Zhang and Paxton (2008)!

(Fred Sigernes is using both Feldstein&Starkov and Zhang&Paxton models on his KHO Auroral Oval Forecast web page )

In addition, it is known that the statistical model is not good during extremely disturbed conditions

... and statistics based on Kp index may not work during rapid substorm variations.

## Auroral oval and diffuse aurora

Originally, the oval was parametrized by the Q index, but modern versions use Kp or AL index. Equatorward of the oval, diffuse aurora exists and it is also included in the statistical models.

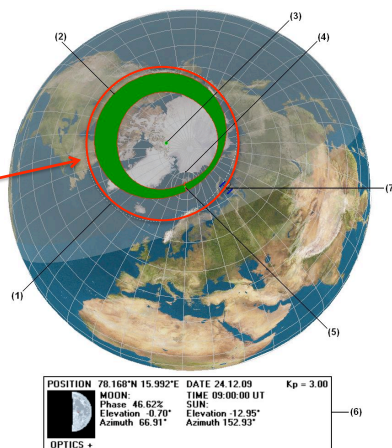


Fig. 1. SvalTrackII screen dump: (1) equatorward boundary of the diffuse aurora, (2) aurora oval  $K_p=3$ , (3) magnetic north pole, (4) field of view aurora observer, (5) observer location, (6) Moon and Sun information at local site, (7) position of the Rapideye 1 satellite. Time: 09:00 UT on 24<sup>th</sup> December 2009.

Figure from Sigernes et al. (2010).

## Diffuse and discrete aurora

### Discrete aurora:

- structured (e.g. arc)
- bright emissions

### Diffuse aurora:

- no (observable) internal structure
- relatively low luminosity
- spread fairly uniformly over a wide area, typically in the equatorward part of the oval
- RIGHT: Statistical locations of diffuse and discrete aurora as magnetic activity increases from 1 to 5. The lowest latitude shown is 60° MLAT (Sotirelis and Newell, 2000).

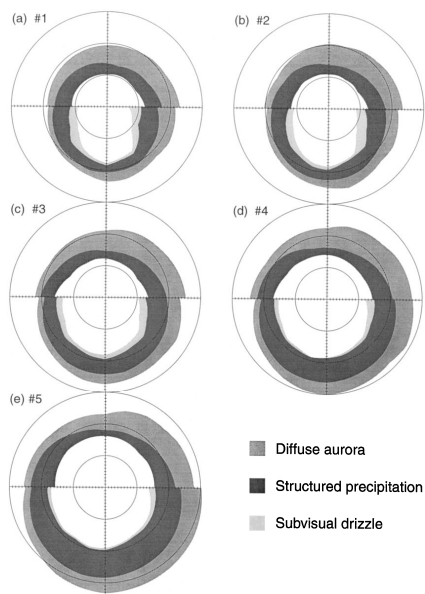
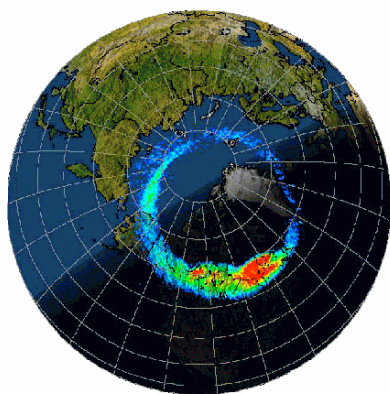


Figure 2. The average locations of the various auroral regions for the five different activity levels of the model. Noon is at the top with dusk at the left. Concentric circles are drawn at 60°, 70°, and 80° MLAT.

### The auroral intensities within the oval



UP: Instantaneous satellite measurement of auroral intensities in the oval (false colours).  
 RIGHT: Statistical energy fluxes of electrons by satellite measurements as the magnetic activity increases from 1 to 5 (Sotirelis and Newell, 2000).

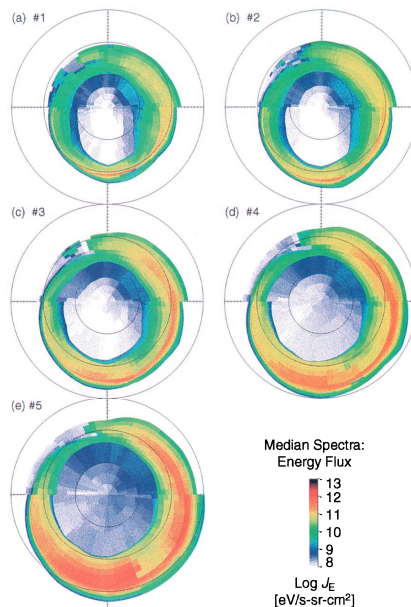
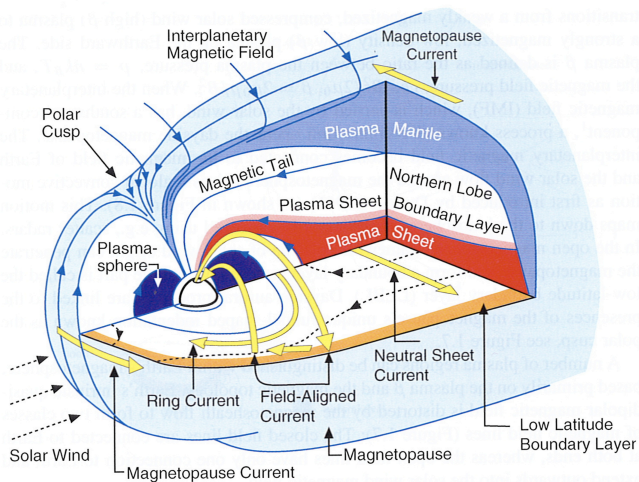


Plate 4. The log of the directional energy flux  $J_E$  (eV/s sr cm<sup>2</sup>) of electrons in the median model.

### Magnetosphere (3D view)

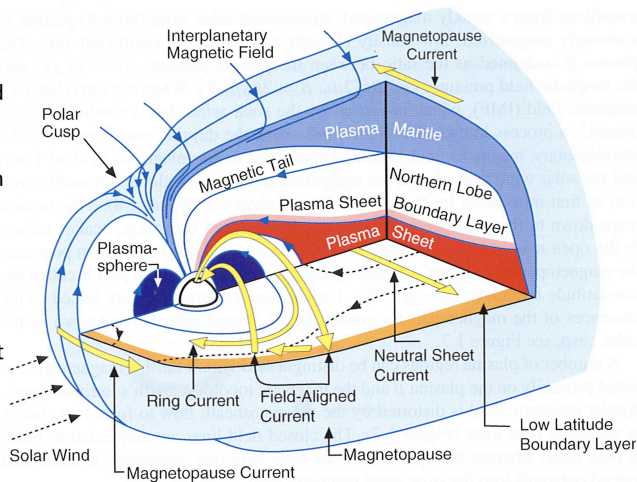
Which part of the magnetosphere corresponds to an auroral oval in the ionosphere?



## Magnetosphere (3D view)

**Plasma sheet** contains plasma that originally comes from the solar wind or from the ionosphere. It contains the most energetic plasma (electron energies typically 600 eV) in the magnetosphere.

**Plasma sheet boundary layer (PSBL)** is the outer region of the plasma sheet with electrons of typically 150 eV and field-aligned electron or ion beams are often found there.



## Origin of precipitation by DMSP satellites

### Precipitation Regions

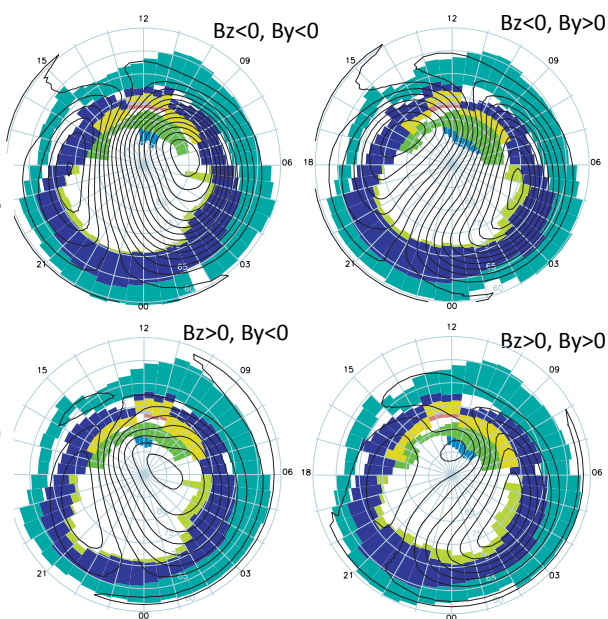
- Subvis
- P RN
- BPS
- OPLL
- CPS

Newell et al. (2004):  
**Nightside** oval is mainly CPS (central plasma sheet) and BPS (boundary plasma sheet) precipitation.

**CPS**: all electron spectra are similar, "unstructured".

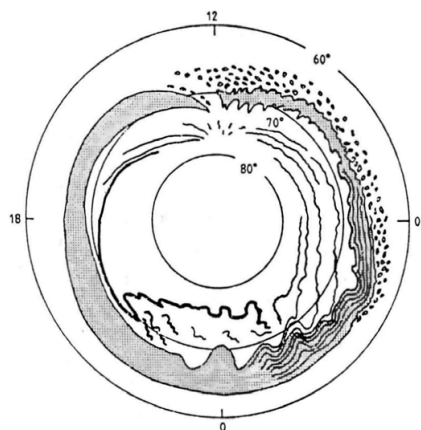
**BPS**: High variability, "structured".

These low-altitude (835 km) CPS and BPS regions are NOT necessarily the same as PS and PSBL in the magnetosphere.



## Auroral forms within the oval

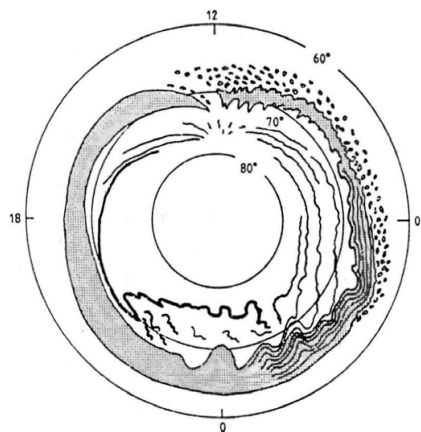
During the International Geophysical Year (IGY) (1957-58), space scientists all around the world coordinated their efforts to record the aurora from many places at the same time. More than 100 all-sky cameras were set up to watch the aurora. From the analysis of this data, two important concepts in auroral physics were born: "auroral oval" and "auroral substorm". One of the persons to make measurements was S.-I. Akasofu.



Schematic figure of aurora by Akasofu.

## Auroral forms within the oval

- Diffuse aurora equatorward of the main oval.
- Discrete auroral arcs
  - Homogenous bands
  - Curtains or draperies
  - Rayed arcs
  - Folds and curls
- North-south auroral arcs (streamers)
- Polar cap arcs (theta aurora)
- Omega bands
- Westward travelling surge and auroral bulge
- Auroral patches
- Pulsating or flickering aurora
- Cusp aurora
- Black aurora (usually stripes or arcs)



Schematic figure of aurora by Akasofu.

