FYS 3610

EXERCISES WEEK 47

EXERCISE 1

a) Discuss the usage of the Reynolds number as an indicator of whether the frozen-in-flux concept is valid or not. Why does the frozen-in-flux concept (ideal MHD) break down locally near a reconnection site.

b) Point out what are the major differences between the Sweet-Parker and Petschek model of magnetic reconnection. What allows Petschek reconnection to proceed at such a high rate compared to a Sweet-Parker diffusion region?

EXERCISE 2

a) Describe the main concepts of the Cowley-Lockwood model of driving polar cap convection by transient reconnection?

b) Assume that IMF B_X and B_Y are both zero. Assume that IMF Bz has been steadily positive for several hours, that the polar cap is contracted, and that polar cap convection has calmed. I.e. the solar wind-magnetosphere coupling has been poor for a long time. Then IMF suddenly turns negative and maintains negative. Describe the ionospheric effect of this sudden transition in IMF. Put emphasis on flow generation, polar cap boundary motion, and how a new equilibrium will be achieved. About how long will it take until equilibrium of balanced magetopause and magnetotail reconnection has accomplished?

c) Starting out again with a quiet situation. The polar cap is circular with a radius of r = 1500 km. The ionospheric magnetic field is $B = 5 \times 10^{-5}$ T (roughly perpendicular to the Earth surface). Estimate the total amount of open flux.

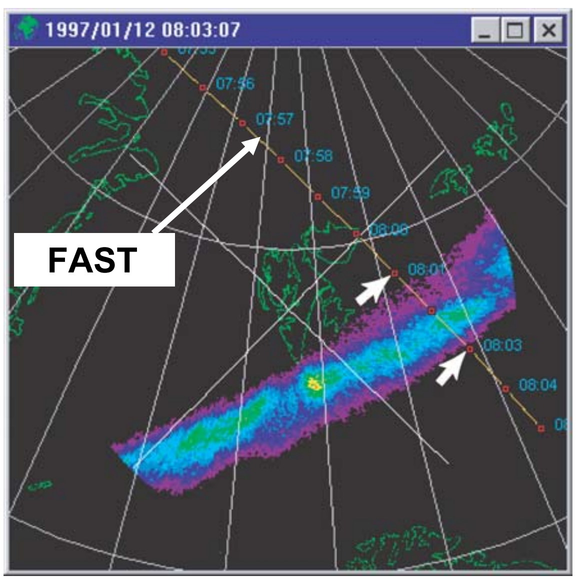
d) Assume that a reconnection pulse lasting 5 minutes adds 10% more open flux to the dayside. Estimate the voltage along the dayside reconnection line associated with this pulse.

e) Magnetopause reconnection between closed magnetic field lines and the draped IMF, takes place with a steady voltage of 100 kV for an extended period, while reconnection in the cross-tail current sheet takes place with a voltage of 20 kV. Describe the changes in the magnetosphere-ionosphere system that will take place while this situation persists. Initially the polar cap is a circle of radius 1500 km what radius will it have after 30 min? What do we call such an interval? (The ionospheric magnetic field is 5×10^{-5} T).

EXERCISE 3

Figure 1 illustrates crossing through the auroral cusp by the FAST satellite.

a) Describe the typical energy of incoming electrons and ions (pitch angle zero is down along the magnetic field line).
b) What are the most likely source for these particles.
c) Note the energy dispersion of ions which is taken as a characteristic of cusp precipitation. Can you provide an explanation for the energy dispersed ions (decreasing with latitude)?
d) dBz in panel b) of the FAST plot is magnetic field variation perpendicular to the orbital plane. Introduce position and direction of Birkeland current sheets from the positive and negative slopes. Where are the Birkeland currents located with respect to the auroral form. Comment your answer.



Oksavik et al., 2004 Ann Geophysicae

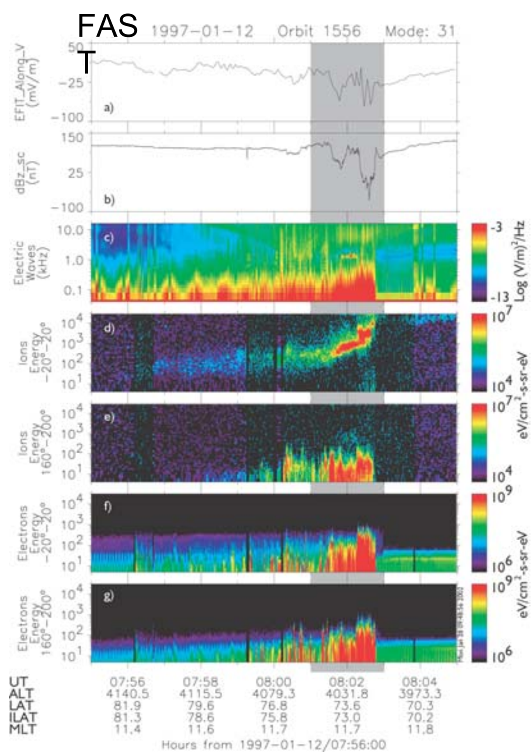


Figure 1 630.0 nm All-sky image from Ny-Ålesund. The straight yellow line indicates the FAST passage over through it, from which data are presented on the right.

EXAMPLE EXAM QUESTIONS

Cowley – Lockwood conceptual model of ionospheric convection:

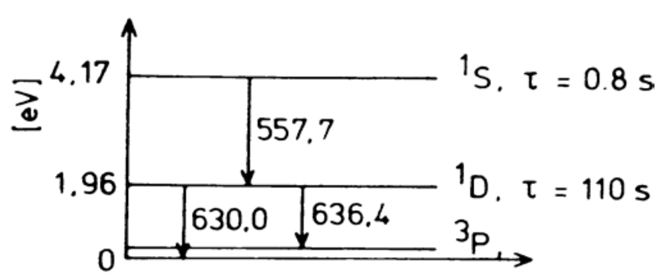
Can you give a description of the Cowley Lockwood model

1) Polar cap boundary. Adiaric, reconnection boundary
2) Give a description on the circulation pattern, from IMF interacts with the solar wind on the dayside, to reconnection in tail. (sketch in the noon-midnight meridian plane)
3) What is the basic idea behind transient generation of large scale flow
4) Explain figure 4a-e.
5) Relationship between polar cap potential and time varying magnetic flux.

Aurora:

Describe the Northern Lights Phenomenon.

1) Orientation of the Earth's magnetic field, and location of the Auroral oval.
2) Source
3) Auroral emission lines /bands (0.1 nm/2-3 nm vibration and rotation bands) (O and N2+)
4) Can you write up equations for excitation and ionization. What are typical energies of (e'= e - 36eV)
5) Atomic oxygen:



$$\Delta E = h\frac{c}{\lambda}$$

6) Height distribution of aurora (day/night). Why don't we see 630.0 nm low altitudes.
7) Describe Proton aurora.
8) Why is 630.0 nm more diffuse than 557.7 nm.

9) Definition of Rayleigh
10) Describe substorm auroras

Polarization arcs and magnetic deflections:

1) Height integrated currents in the ionosphere can be expressed as:

$$\begin{bmatrix} J_x \\ J_y \end{bmatrix} = \begin{bmatrix} \Sigma_P & -\Sigma_H \\ \Sigma_H & \Sigma_P \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

Define a coordinate system and describe the parameters involved.

2) Assume an east-west extended arc, that Σ_H and Σ_P are both zero outside the arc, that there is no field aligned current, and that E_y is the same inside and outside the arc.

Which primary currents is going to be set up in x and y direction, and which secondary currents are going to be set up.

3) Prove that the current along the arc then is given as

$$J_y^A = \left[\frac{\left(\Sigma_H^A\right)^2}{\Sigma_P^A} + \Sigma_P^A \right] \cdot E_y$$

What do we call this current near mid-night?.
Assume a line current and describe the characteristic signature of the magnetic deflection observable from ground. (insert typical values: 10mV/m, 30 mho, 10 mho → 1 A/m). (Amperes law)

4) Consider a more realistic case, where the height integrated conductivity is non-zero outside the arc, and that Birkeland –currents are allowed to float along the magnetic field lines.

5) Draw a map of a 2-cell ionospheric convection during steady IMF Bz south conditions. Draw the corresponding E-field. Where is the upward and downward Region1 currents located. Which one is related to auroral arcs. (Gauss law).