Examination,
Space Physics EF2240

2008-10-25, 08.00-13.00

ALLOWED ON THE EXAM:

- All material handed out on the lectures (including Fälthammar and Lyons)
- All material from the home page (including lecture notes)
- Your own notes
- Standard physics and mathematics formula collections or primers
- Calculator and writing equipment

NOTE

There is a maximum of 100 p on this exam. The maximum points for each subproblem is indicated. To your results will be added your bonus points earned during the course. The grades will then be given by the following intervals:

Grade:	A:	119-135
	B:	101-118
	C:	84-100
	D:	69-83
	E:	50-68

Motivate your answers carefully, and be careful about units!

1.

a) Figure 1.1 shows a blackbody curve obtained by a computer simulation of a solar flare [from Allred et al., 2006]. What temperature does the blackbody curve correspond to? *(Hint: 1 Å = 0.1 nm)* (*5 p*)

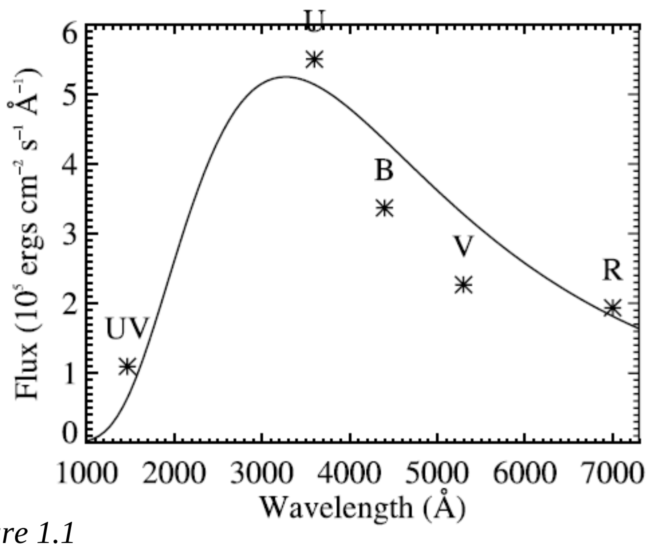

Figure 1.1

b) Figure 1.2 shows a large solar flare (Earth's size indicated in the figure). If a typical electron gyro frequency of the plasma that fills the magnetic field loop is 3 GHz, estimate the total magnetic energy of the loop. (*10 p*)

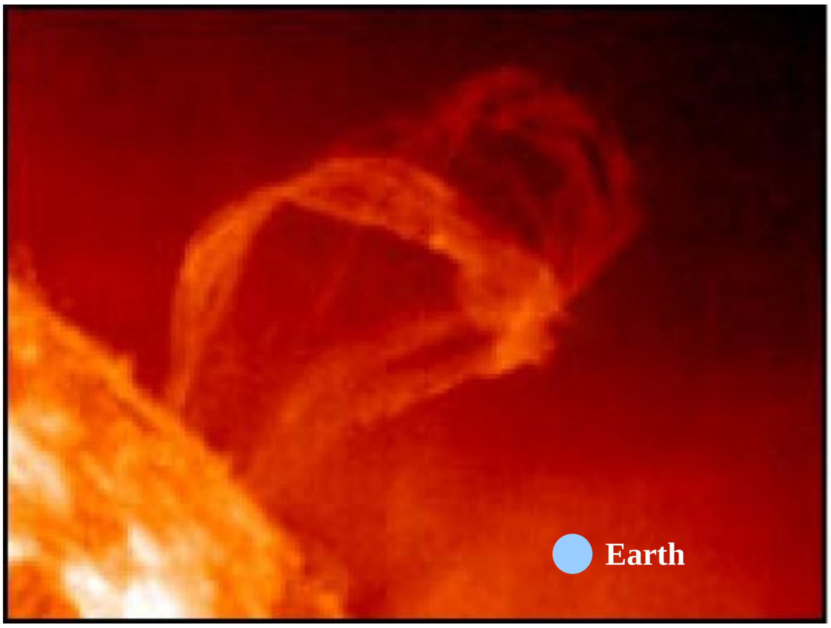

Figure 1.2

c) Estimate the gyro radius of a proton in the solar flare. (*5 p*)

2.

Figure 2 shows 48 h of solar wind data measured by the ACE spacecraft from June 7 and 8, 2000. The top panel shows the proton density in particles/cm^3, the bottom panel shows the solar wind speed in km/s. Between around 09:30 and 16:00 on June 8, a small Coronal Mass Ejection (CME) passes the spacecraft. Estimate how much the standoff distance of Earth's magnetosphere changes as it is hit by the highest density part of the CME, compared to what it was at the beginning of June 7. Give your answer in Earth radii (R_E). (*20 p*)

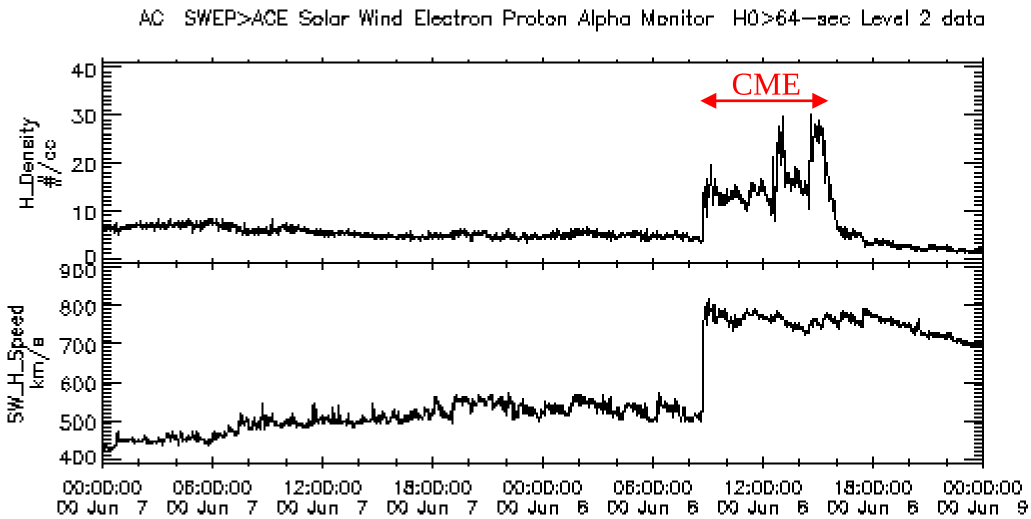

Figure 2

3.

The interplanetary current sheet (sometimes called the neutral sheet current) is the region close to the ecliptic plane where the polarity of the interplanetary magnetic field changes sign (see Figure 3). Assume that between distances of 0.1 and 1 A.U. (astronomical units) from the sun, the magnetic field is parallel to this sheet (apart from some small-scale variations), and has the same constant absolute value on both sides of the current sheet. If this value is 8 nT, how much current floats in the interplanetary current sheet between 0.1 and 1 A.U.? (*20 p*)

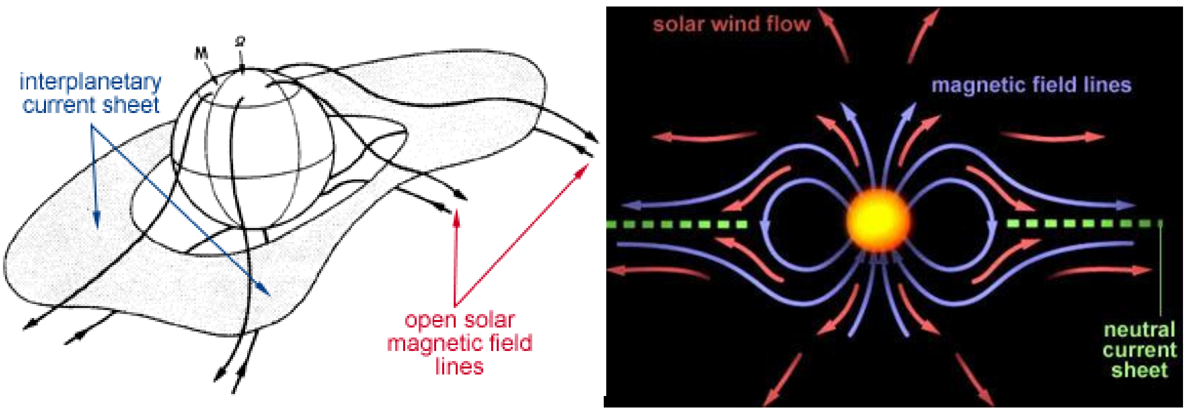

Figure 3

4.

Near the equator, the geomagnetic field is perpendicular to the gravitational force $F_g = mg$ (see Figure 4).

a) Calculate the plasma drift velocity due to the gravitational force at an altitude of 1000 km for an electron and for an Oxygen ion. (*Hints: The atomic weight of Oxygen is 16 amu. The gravitational acceleration g at 1000 km altitude is 7.3 ms^{-2}.)* (*10 p*)

b) What is the ratio of the gravitational drift of the Oxygen ion in 4. a) to the E×B drift due to an electric field of 10 mV/m, in the same direction as the gravitational force, at the same altitude in the equatorial plane. (*10 p*)

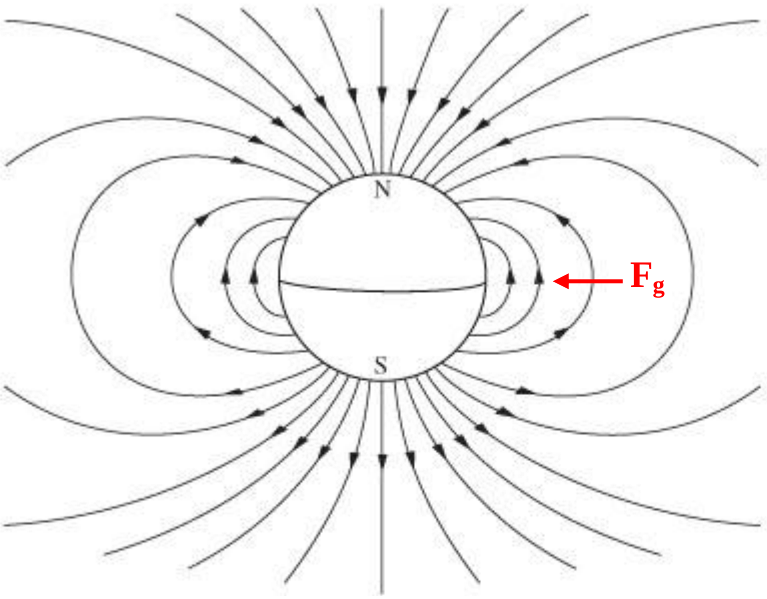

Figure 4

5.

Figure 5 shows the electron density (solid curve) as a function of altitude of the Venus ionosphere, measured by the Mariner 10 spacecraft [from Bauer and Hartle, 1974]. Assume (unrealistically) that the atmosphere has a constant temperature of 400 K. Assuming also that the atmospheric absorption coefficient is 10^{-24} m^2, that the atmosphere consists only of CO_2 and that the ionospheric electron density maximum corresponds to a Chapman layer, determine

a) the scale height of the Venus atmosphere. (*5 p*)

b) the neutral atmosphere particle density at the Venus surface. (*15 p*)

(Hints: the atomic weights of Carbon and Oxygen are 12 amu and 16 amu, respectively. The gravitational acceleration at the Venus surface is 8.87 ms^{-2}.)

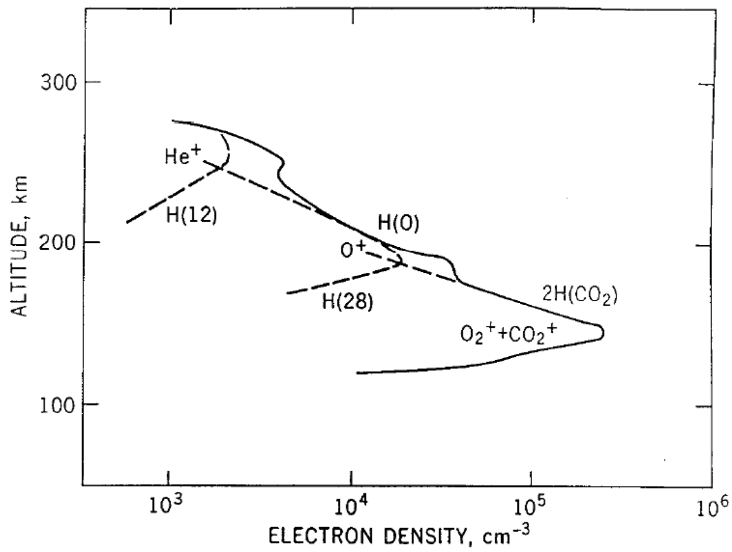

Figure 5

Examination,
Space Physics EF2240

2009-10-21, 14.00-19.00

ALLOWED ON THE EXAM:

- All material handed out on the lectures (including Fälthammar and Lyons)
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NOTE

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	D:	66-80
	E:	50-65

Motivate your answers carefully, and be careful about units!

1.

Figure 1 shows model results of photospheric magnetic field strengths from a simulation of a pair of sunspots. Assuming that the plasma density is constant at 10^{19} cm^{-3}, estimate the lowest temperature of the sunspots, if the undisturbed photosphere has a temperature of 6400 K. (Note that 1 Gauss = 10^{-4} Tesla.) *(5 p)*

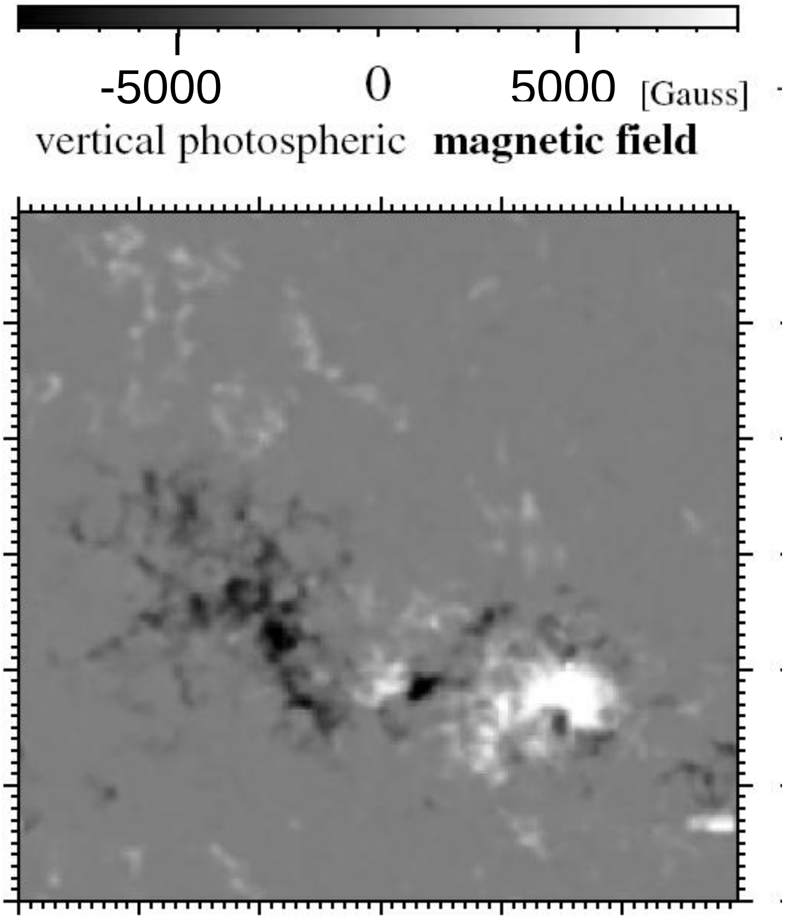


Figure 1

b) At what wavelength will the maximum intensity from the sunspots be emitted? *(5 p)*

2.

a) Figure 2a shows Voyager 2 measurements of the electron density of the Jupiter dayside ionosphere as a function of altitude above the surface. The surface of Jupiter is defined as the region where the pressure of the neutral gas is 1 bar = 100 kPa. It is still not known if the main ionospheric layer with the peak at around 1900 km altitude is associated with ionization of atomic hydrogen or molecular hydrogen. Supported by a calculation, state which alternative you believe is correct.

In Table 2b are given values of ionization cross sections $\bar{\sigma}$ (the same as the absorption coefficient called a_a in Fälthammar), for various wavelength intervals of the incoming solar EUV radiation. Use the values in the range 504-804 Å. Assume that the layer can be described by a Chapman profile, and that the neutral atmosphere is exclusively made up of either molecular or atomic hydrogen. Assume (somewhat unrealistically) that the temperature in the Jupiter atmosphere is constant with altitude and has a value of 300 K. The gravitational acceleration at the Jupiter surface is 23.1 ms^{-2}. *(15 p)*

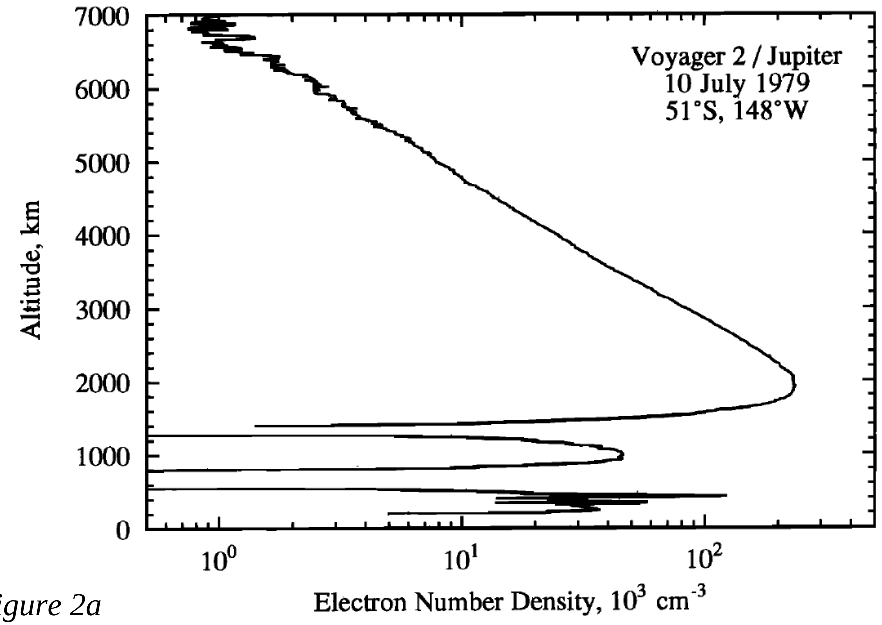


Figure 2a

Electron number density in Jupiter's ionosphere derived from Voyager 2 radio measurements at occultation exit. Altitude reference is the 1-bar equipotential surface defined by *Lindal et al.* [1981]. *(Hinson et al., 1998)*

MEAN CROSS SECTIONS AND FLUXES

$\bar{\sigma}(H_2)$	($\lambda < 504$)	1.7×10^{-18} cm^2
$\bar{\sigma}(H_2)$	($804 > \lambda > 504$)	6.1×10^{-18} cm^2
$\bar{\sigma}(He)$	($\lambda < 504$)	3.3×10^{-18} cm^2
$\bar{\sigma}(H)$	($912 > \lambda > 804$)	5.0×10^{-18} cm^2
$\bar{\sigma}(H)$	($804 > \lambda > 504$)	3.0×10^{-18} cm^2
$\bar{\sigma}(H)$	($\lambda < 504$)	6.0×10^{-19} cm^2
$\bar{\mathfrak{F}}_\infty$	($\lambda < 504$)	6.7×10^{8} ph/cm^2/sec^a
$\bar{\mathfrak{F}}_\infty$	($804 > \lambda > 504$)	4.0×10^{8} ph/cm^2/sec^a

Table 2b (Gross and Rasool, 1964)

b) Assuming that the main peak electron density maximum is representative for the whole dayside, estimate the minimum nightside electron density at 1900 km altitude, assuming that the ionosphere is corotating with Jupiter. Calculate the result for both assumptions; the layer consisting of either atomic and molecular hydrogen. The recombination coefficients for these two cases are given in Table 2c (entries 9 and 13), in units of cm^3s^{-1}. What can you say about the nightside electron density compared to the dayside one? *(10 p)*

Recombination	(9) $H_2^+ + e \rightarrow H' + H''$	$\alpha_9 = 10^{-8}$
	(10) $HeH^+ + e \rightarrow He + H$	$\alpha_{10} = 10^{-8}$
	(11) $He^+ + e \rightarrow He$	$\alpha_{11} = 10^{-12}$
	(12) $H_3^+ + e \rightarrow H_2 + H$	$\alpha_{12} = 10^{-8}$
	(13) $H^+ + e \rightarrow H$	$\alpha_{13} = 10^{-12}$
	(14) $H + H + X \rightarrow H_2 + X$	$\alpha_{14} = 10^{-32}$
	(15) $H + e \rightarrow H^- + h\nu$	$\alpha_{15} = 10^{-16}$

Table 2c (Gross and Rasool, 1964)

3.

a) Figure 3 shows values of the solar wind proton density and velocity close to Saturn, measured by the Cassini spacecraft on its way to Saturn, in the year 2004. Use these values to estimate the variation in Saturn's magnetospheric standoff distance during the period from which the measurements were taken. Ignore any effects from internal plasma pressure in the Saturn magnetosphere, and give your answer in Saturn radii. Saturn's magnetic dipole moment is $4.6 \cdot 10^{25}$ Am^2, and its radius is 60 268 km. *(10 p)*

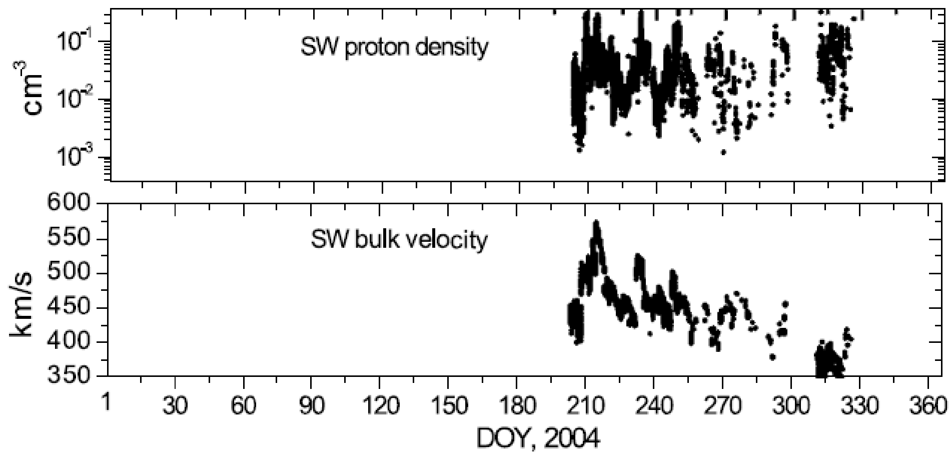


Figure 3a. Solar wind velocity and density profiles measured by the Cassini spacecraft (Rucker et al., 2008). (DOY = Day of Year).

b) From the data in Figure 3, determine the variation in the solar wind spiral angle (Parker angle) at Saturn orbit during the time the measurements were taken. (The distance from the sun to Saturn is 9.5 AU.) *(10 p)*

c) Figure 3b shows Cassini measurements of the magnetic field strength from the same time period. Using maximum and minimum values from Figures 3a and 3b, estimate the variation in the Alfvén velocity in the solar wind close to Saturn. *(5 p)*

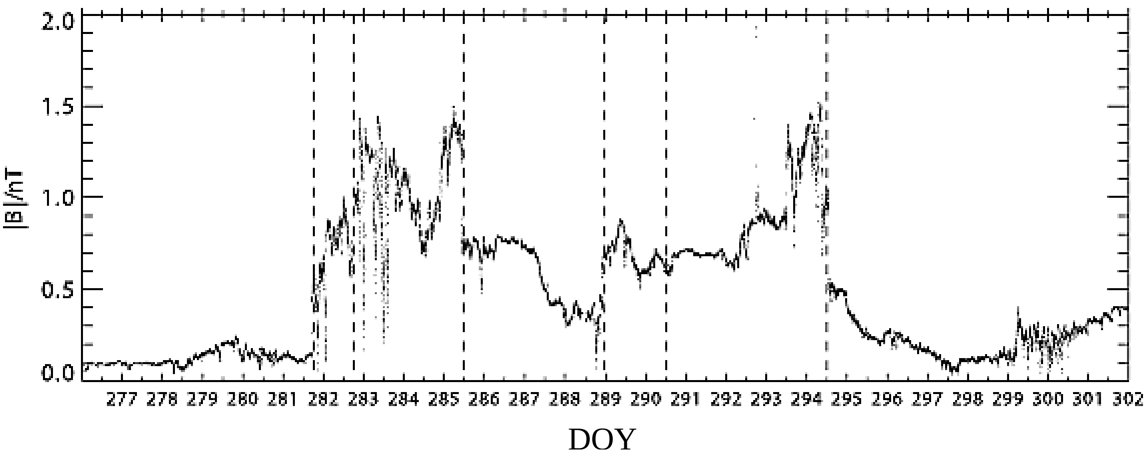


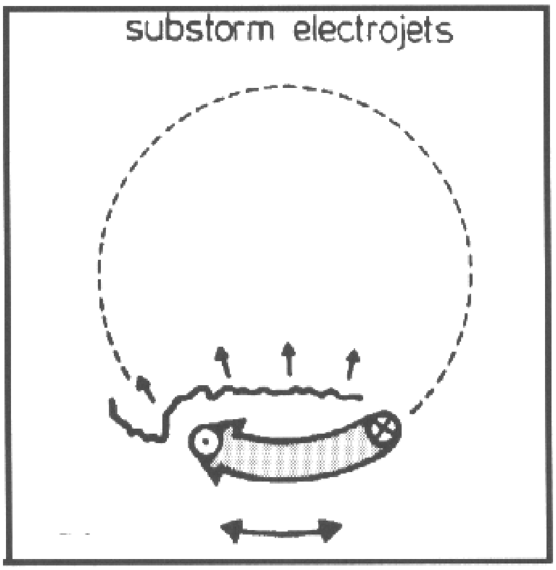
Figure 3b. Solar wind magnetic field measured by the Cassini spacecraft (Jackman et al., 2004). (DOY = Day of Year).

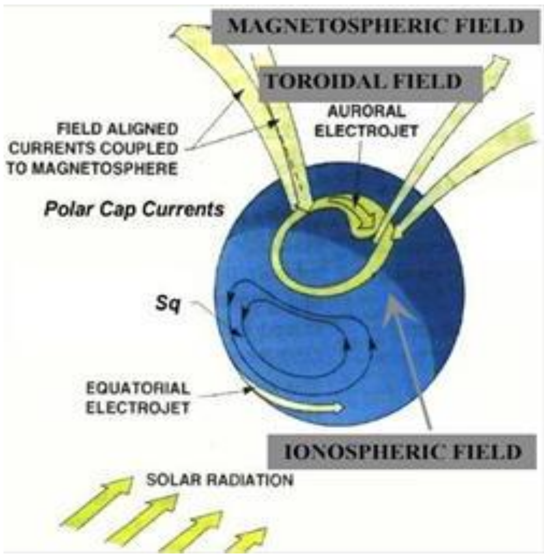
4.

The auroral (substorm) electrojet is the name of the current floating in the nightside auroral oval, where the conductivity is enhanced due to ionization caused by energetic auroral electrons. Model the auroral electrojet as a sheet of current 10 km thick in the direction along the magnetic field (assumed to point vertically downward), 500 km in the north-south direction and 5000 km in the west direction. Assume that the electrojet carries a total current of 8 MA in a westward direction, uniformly distributed within the current sheet.

a) If the Hall and Pedersen conductivities are $\sigma_H = 5 \cdot 10^{-4}$ S/m , and $\sigma_P = 3 \cdot 10^{-4}$ S/m, use the relation between the current density and the perpendicular electric field ($\mathbf{i}_\perp = \sigma_P \mathbf{E}_\perp + \sigma_H \frac{\mathbf{B} \times \mathbf{E}_\perp}{B}$) to determine the direction and strength of the electric field in the current sheet. *(10 p)*

b) If the north-south component of the magnetic field below the current sheet is 0 nT, what is it just above the current sheet (magnitude and direction)? *(10 p)*





5.

Let the geomagnetic field be represented by a dipole field. Consider a plasma in the equatorial plane at a geocentrical distance of 5 R_E with density 10 cm^{-3}, consisting of 1 eV protons and 10 keV electrons with close to 90° pitch angle in the equatorial plane. Calculate the current density for the ring current carried by these particles. If the cross-section area of the current is 1 $R_E \times 1$ R_E , what is the total current? How is the magnetic field from this current directed - does it enhance or decrease the geomagnetic field close to the Earth's surface? The current density **j** for a particle population is given by $\mathbf{j} = qn\mathbf{v}$, where q, n, and $\mathbf{v}$ are the particle charge, density, and velocity, respectively. *(20 p)*

Don't forget to fill in the course evaluation on the course home page!

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Space Physics EF2240

2010-10-21, 08.00-13.00

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1.

On the day of May 11, 1999 (known as ‘the day the solar wind disappeared’) the solar wind velocity and density decreased to very low values. Figure 1, on the next page, shows solar wind data from the ACE spacecraft from three days, where day number 131 corresponds to May 11, published in a paper by Smith *et al.* [2001]. The solar wind velocity is given in the panel denoted by V_R (in kms^{-1}), and the proton number density in the panel denoted by N_P (in cm^{-3}).

a) Estimate the maximum standoff distance of the Earth magnetosphere for this time, and compare it to the standoff distance at the beginning of day 130. *(10 p)*

b) What is the minimum and maximum Parker spiral angle during the times shown in Figure 1? *(10 p)*

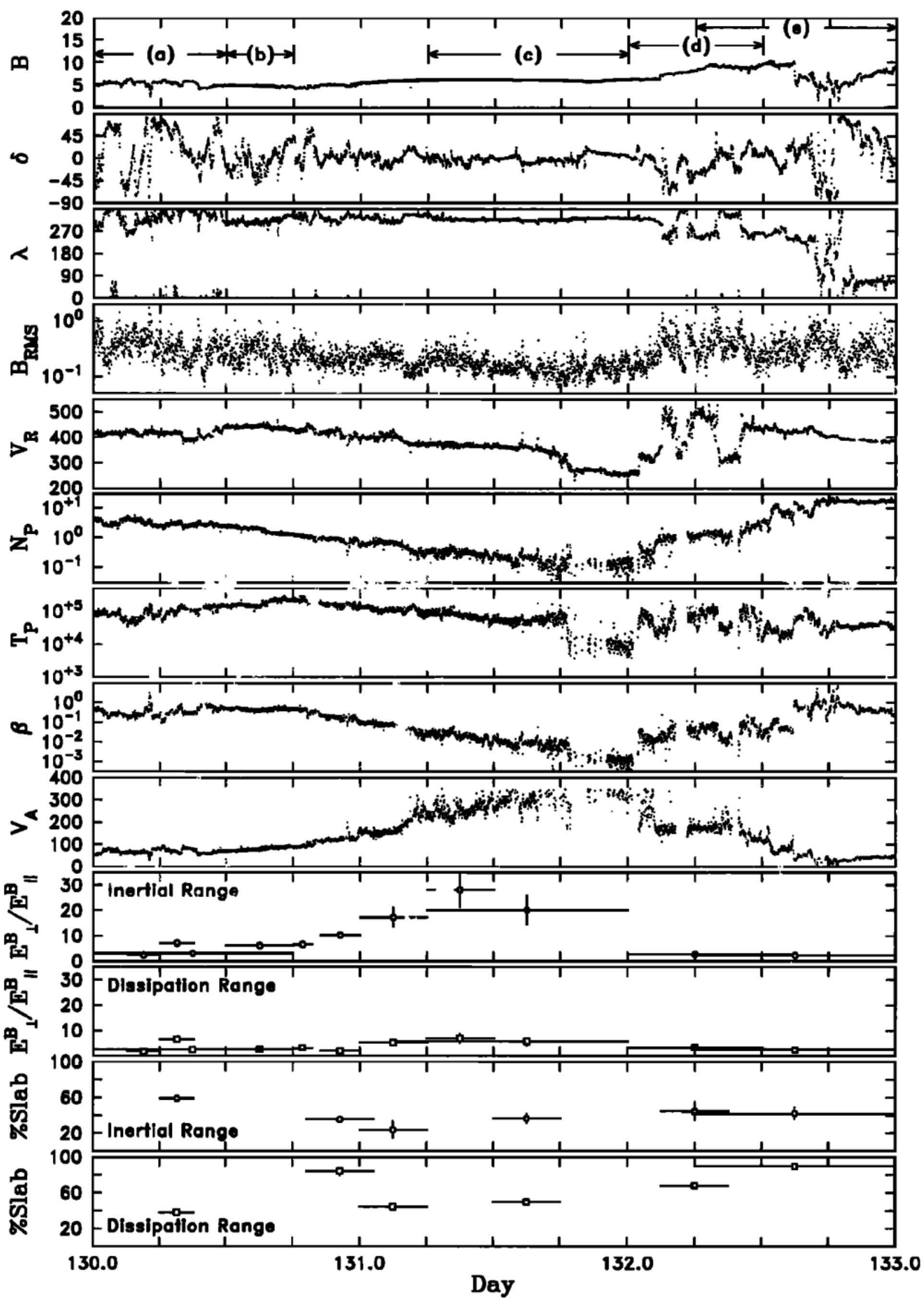

Figure 1. Days 130 through 132, 1999, when the solar wind density is observed to drop to 0.1 p cm^{-3}. IMF intensity B (nanoTeslas), IMF longitude δ (degrees), and IMF latitude λ (degrees), as well as RMS level of the IMF fluctuations B_{RMS} (nanoTeslas) are provided by the MAG instrument. The radial component of the wind speed V_R (km s^{-1}), proton density N_P (cm^{-3}) and proton temperature T_P (Kelvin) are provided by the SWEPAM instrument. The proton β and Alfvén speed V_A (km s^{-1}) are computed from data supplied by both instruments. The anisotropy of the IMF fluctuation spectra $E_{\perp}^{B}/E_{\parallel}^{B}$ in the inertial range and dissipation ranges are shown along with the anisotropy of the wave vector (expressed in terms of percent slab component in the inertial and dissipation ranges).

2.

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3.

An electron with an energy of 1 keV is positioned at point 1 on a particular field line of the geomagnetic field (see Figure 3), where the magnetic field strength is B_1 = 4000 nT. At that point, the electron has a pitch angle of α_1 = 20°. As the particle gyrates around the field line, it also moves along it down towards the atmosphere. If it will reach point 2, it will collide with the neutral particles of the atmosphere. The magnetic field strength increases monotonically along the field line and at point 2 it is B_2 = 50 000 nT. Particles that will make it down to point 2 before they mirror are said to be in the (atmospheric) loss cone.

a) Determine the loss cone angle for particles at point 1. *(6 p)*

b) The electron is not originally in the loss cone. How much would you need to increase the parallel velocity of the electron for it to be in the loss cone, if you keep the perpendicular velocity constant? *(7 p)*

c) This increase in parallel velocity for auroral particles is believed to be obtained by an electric field parallel to the geomagnetic field. How big would the electric potential drop need to be? (You can assume that the acceleration takes place in a small region at point 1.) *(7 p)*

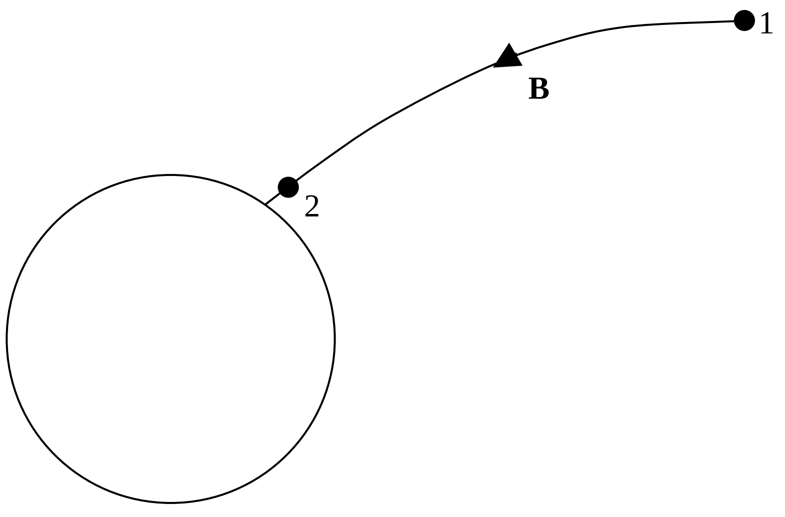

Figure 3.

4.

a) If you consider your own body to be a black-body radiator, what is the wavelength at which the highest intensity of electromagnetic waves is emitted. What kind of an electromagnetic wave is this? (*Hint:* 0 K = -273 C). *(5 p)*

b) We usually think of sunspots as black, since they appear so when observed close to the intense emissions from the undisturbed solar surface. But what colour are they really, if we assume that they have a temperature of 4200 K? *(5 p)*

c) The emitted power per unit area *P*, from a black-body radiator is

$$P = \sigma_{SB} T^4$$

where σ_{SB} is the Stefan-Bolzmann constant. Calculate the decrease (in percent) of total emitted power from the Sun due to a large, circular sunspot with a radius of 100 000 km. *(5 p)*

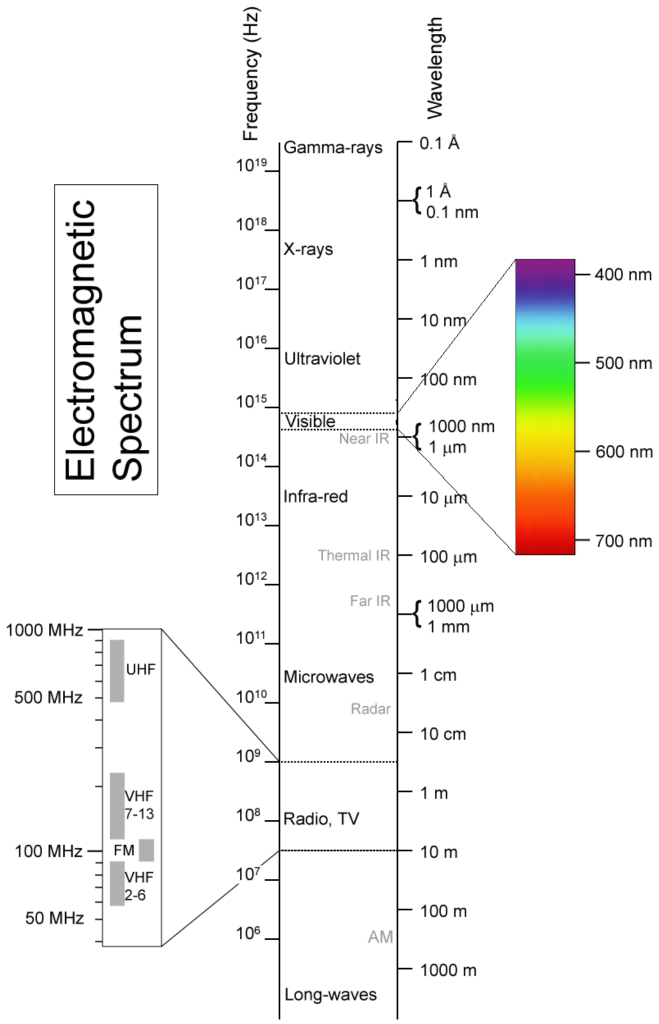

Figure 4. The electromagnetic spectrum.

5.

The ionograms in Figure 5 show recent measurements of the plasma frequency f_{pe} (black solid curve) as a function of altitude in km, performed at Pruhonice, Czech Republic. The first measurement (top part of the figure) is taken at a local time of 18.30, just before sunset, and the second measurement (bottom part of figure) is performed at 20.30, local time.

a) Calculate the maximum electron density for both times. This maximum corresponds to the F2-layer. *(5 p)*

b) The time variation of the electron density at a certain ionospheric altitude is different, depending on if the ions are molecular or atomic. In the first case we talk about a *Chapman layer*, where the time variation (in the absence of ionospheric winds) is given by

$$\frac{dn_e}{dt} = q - \alpha n_e^2$$

whereas in the second case we talk about a Bradbury layer, where the time variation is given by

$$\frac{dn_e}{dt} = q - \beta n_e$$

Use the measured densities at the altitude corresponding to the dayside F2-layer to determine if the layer is best modelled by a Chapman layer, where the ions are molecular oxygen O_2^+, or a Bradbury layer consisting of atomic oxygen ions O^+. Use the following values for the recombination coefficient α, and attachment coefficient β:

$\alpha = 3 \cdot 10^{-14}\ m^3 s^{-1}$
$\beta = 1 \cdot 10^{-4}\ s^{-1}$

(20 p)

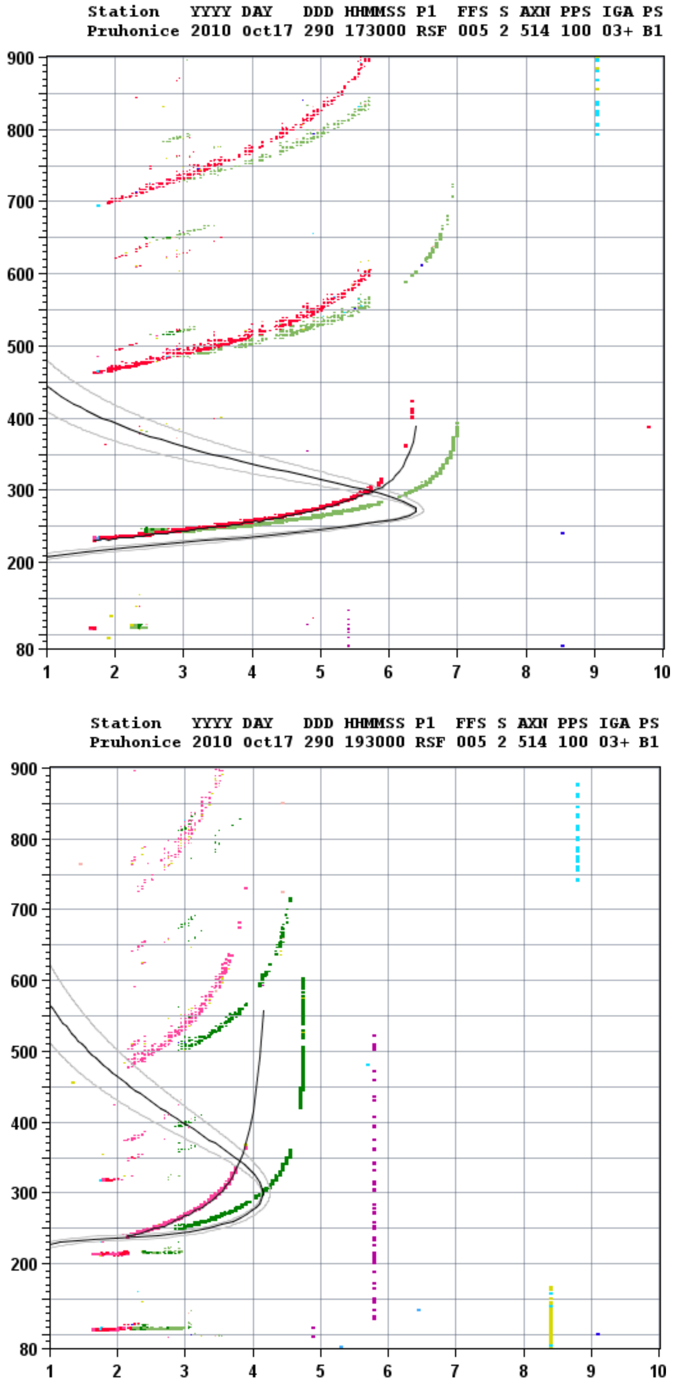

Figure 5. The black curve indicates the plasma frequency (given on the horizontal axis in units of MHz), as a function of altitude (given on the vertical axis in units of km).