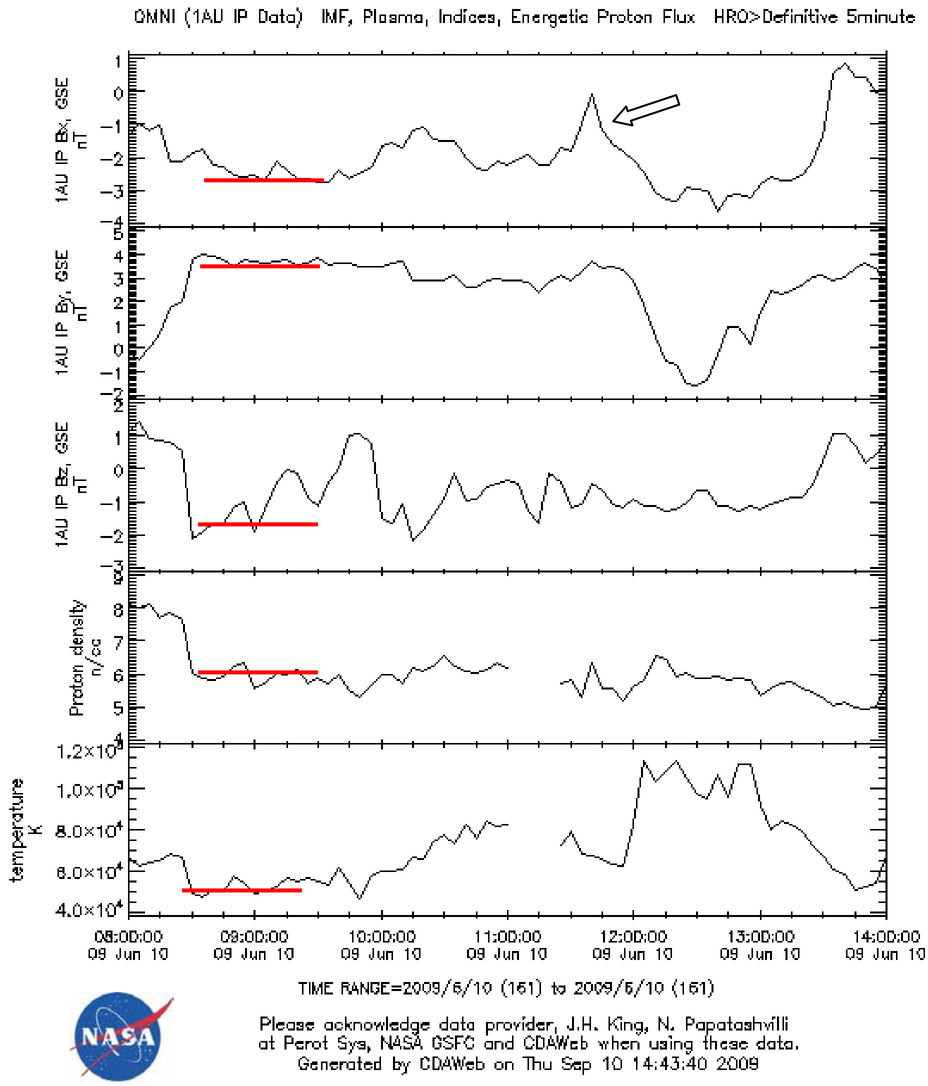
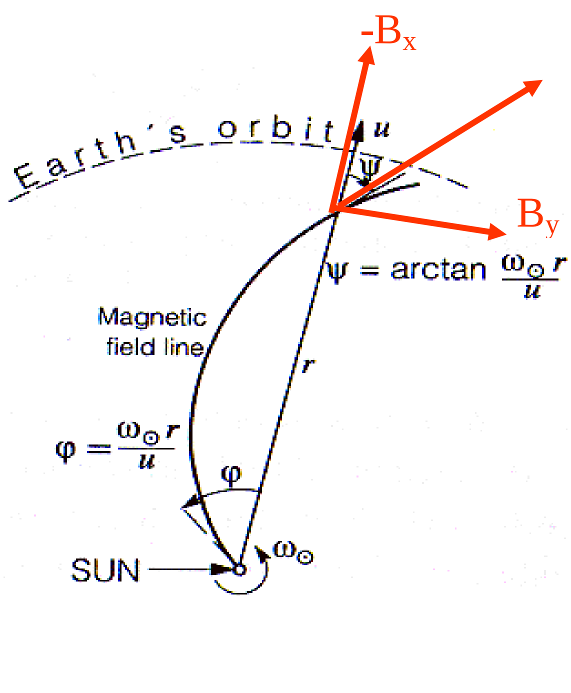
Minigroupwork 2, solutions, 2014

a)





$$\psi = \arctan \frac{\omega_{sun} r}{u_{sw}} \quad \Longrightarrow \quad u_{sw} = \frac{\omega_{sun} r}{\tan \psi}$$

$\omega_{sun} = 2\pi/T = 2.9 \cdot 10^{-6}\ s^{-1}$ (T = 25 days at equator)

$r = 1$ A.U. $= 1.496 \cdot 10^{11}$ m.

$\tan \psi = |B_y/B_x| \approx 3.6/2.6$ (from figure) ($\psi = 54°$)

With these figures I get $u_{sw} = 313$ km/s

b)

The magnetic Reynolds number is calculated by using typical plasma flow velocities v_c and typical length scales of magnetic field variations l_c

Use solar wind velocity obtained in a) for typical flow velocity. To obtain l_c, multiply the time t it takes the magnetic field structure (indicated in the figure), to pass over the satellite and use l_c, $= vt$. I get $l_c = 2.8 \cdot 10^8$ m.

Using a temperature of $5 \cdot 10^4$ K, we can evaluate the conductivity, remembering that the temperature should be given in eV. We get the conversion from

$$W = \frac{3}{2} k_B T$$

which gives the result that 1 eV corresponds to a temperature of 7729 K. We then get $T = 6.5$ eV, and

$\sigma = 3.1 \cdot 10^4$ S/m

Putting in the numbers I get

$R_m = \mu_0\, \sigma\, v_c\, l_c \approx 3.5 \cdot 10^{12} >> 1$

So the solar wind magnetic field is frozen into the plasma to a very good approximation.

c)

$\rho = n_e m_p = 6.1 \cdot 10^6 \cdot 1.67 \cdot 10^{-27} = 1.02 \cdot 10^{-20}$

Then the kinetic energy density is ($v = 313$ km/s):

$\rho v^2/2 = 5 \cdot 10^{-10}\ Jm^{-3}$

The magnetic energy density is (using values of figure)

$$\frac{B^2}{2\mu_0} = \frac{B_x^2 + B_y^2 + B_z^2}{2\mu_0} = (2.6^2 + 3.6^2 + 1.7^2)\cdot(10^{-9})^2 / 2\mu_0 = 9.0\cdot10^{-12}\ \mathrm{Jm}^{-3}$$

The ratio between the kinetic and magnetic energy densities is approximately 50, thus the plasma motion determines the magnetic field configuration, and not the other way around.