Mini-groupwork 2, 2016

Space Physics, EF2240

In Figure 1 is shown 6 hours of data in the solar wind taken close to Earth by the WIND space probe, launched by NASA in 1994. In the figure are shown measurements of the magnetic field (in nT), and proton density (particles per cm^3) of the solar wind plasma on June 10, 2009. The coordinate system used is called GSE (Geocentric Solar Ecliptic), where $\hat{\mathbf{x}}$ points toward the sun, $\hat{\mathbf{z}}$ ”upwards/northwards” from the ecliptic plane and $\hat{\mathbf{y}}$ towards the evening side (see Figure 2). (The ecliptic plane is the plane in which the planets are orbiting the sun.)

a) Estimate the solar wind speed at around 09:00, using the magnetic field data.

b) We can now verify if the magnetic field is really frozen into the solar wind plasma by evaluating the magnetic Reynolds number R_M. Use the solar wind speed as the characteristic velocity. The characteristic length scale can be approximated by the length scale of a typical structure in the solar wind magnetic field, such as the one marked by an arrow in Figure 1. You can assume that the spacecraft velocity is very small compared to the solar wind velocity. The solar wind conductivity can be estimated by the so called Spitzer expression for the conductivity: $\sigma = 1.9 \cdot 10^3 \cdot T_e^{3/2}$ S/m, where T_e is the electron temperature given in eV.

c) Given that the magnetic field is frozen in to the plasma, we can ask if the magnetic field will determine the plasma motion or if the plasma motion will determine the magnetic field formation. To determine what is the case, we need to compare their energy densities. In the solar wind plasma the dominating kinetic energy is in the ordered motion of the radial flow away from the sun, (and not in the random thermal motion). The energy density of this motion is given by $\frac{\rho u_{SW}^2}{2}$ where ρ is the mass density of the solar wind, and u_{SW} is the solar wind velocity. Calculate this energy density and calculate the magnetic energy density (using typical magnetic field and density values from the data), and compare them. What conclusion can you draw regarding the frozen-in magnetic field from this value?

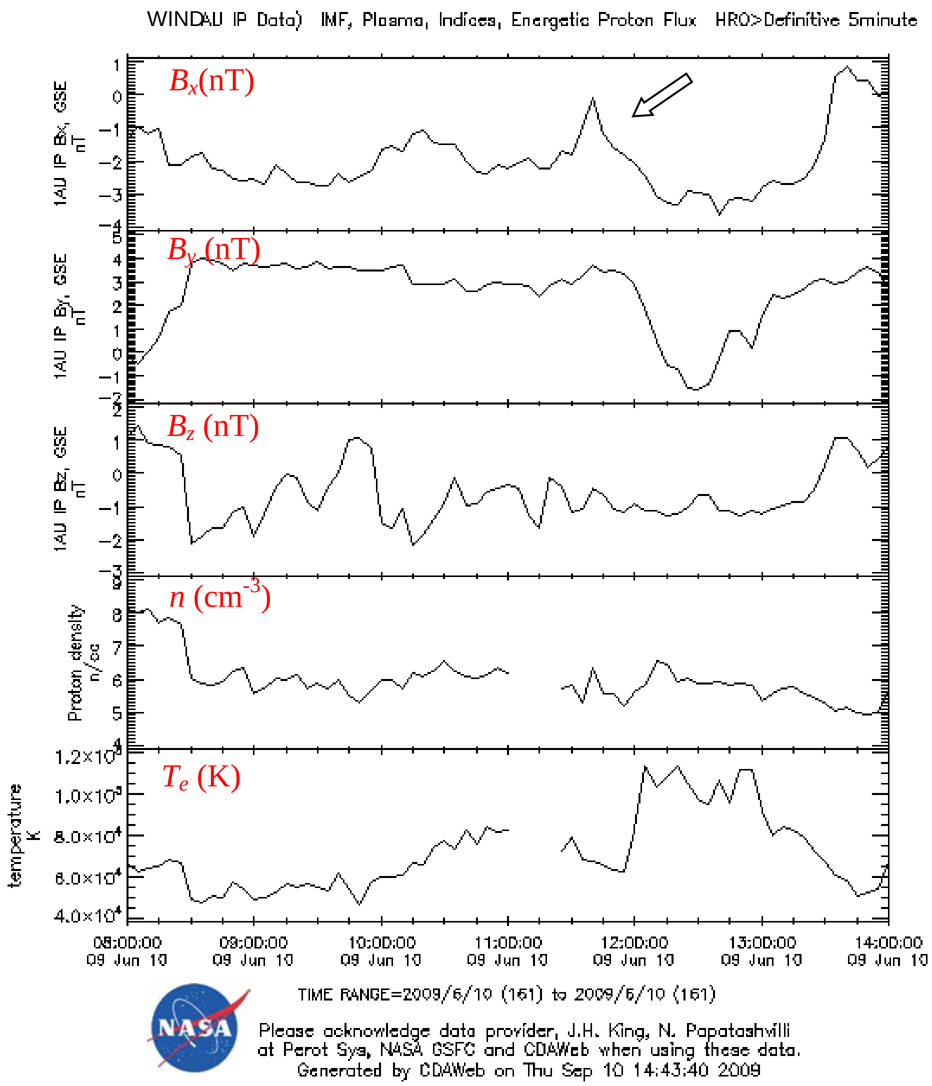

Figure 1

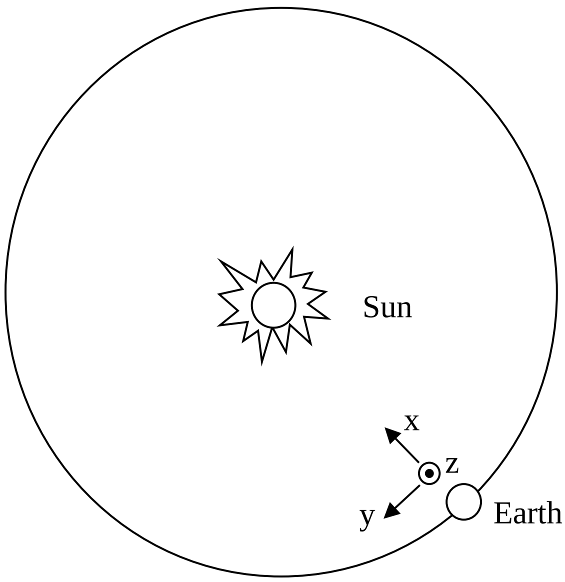

Figure 2