SPACE & ATMOSPHERIC PHYSICS POSTGRADUTE LECTURES – PROBLEM SHEET ON THE SOLAR WIND AND HELIOSPHERE 23 October 2017

1. The size of the heliosphere.

The distance of the heliopause from the Sun is determined by the point where a pressure balance occurs between the solar wind and the interstellar medium.

(a) Using the data from Table 1 below for the slow wind estimate the plasma, magnetic and dynamic pressures at 1 AU. Ignore the contribution due to helium. The dominance of the dynamic pressure that you should find is preserved all the way out through the heliosphere, a consequence of the solar wind remaining supersonic. So we can safely ignore the magnetic and plasma pressures in the solar wind when estimating the size of the heliosphere. Assuming that the solar wind speed remains constant and the density falls off as an inverse square law with distance allows you to use the 1 AU data to estimate the dynamic pressure at any distance from the Sun.

(b) Using the data from Table 2 below estimate the values of the same three pressures in the interstellar medium. Can you ignore any of the three here?

(c) Use the above information in a pressure balance calculation to estimate the distance to the heliopause.

Table 1 Characteristics of fast and slow solar wind

Property at 1 AU	Slow wind	Fast wind
Speed (v)	~400 km/s	~750 km/s
Number density (n)	~10 cm^{-3}	~3 cm^{-3}
Flux (nv)	~3×10^{8} cm^{-2} s^{-1}	~2×10^{8} cm^{-2} s^{-1}
Magnetic field (Br)	~3 nT	~3 nT
Proton temperature (Tp)	~4×10^{4} K	~2×10^{5} K
Electron temperature(Te)	~1.3×10^{5} K (>Tp)	~1×10^{5} K (<Tp)
Composition (He/H)	~1 – 30%	~5%

Table 2 Estmated properties of the interstellar medium (mostly from Opher et al., 2009)

Flow speed	26.3 km/s
Proton density	0.06 cm^{-3}
Proton temperature	6519 K
Electron density	assumed same as protons
Electron temperature	assumed same as protons
Magnetic field strength	0.4 nT (from Voyager 1)

2. Some data interpretation…

The figure overleaf shows a corotating interaction region observed by the Ulysses spacecraft at 5 AU from the Sun in 1992. The spacecraft was near enough to the equator that you don't have to worry about latitude effects.

From the top, the panels show the solar wind speed, the tangential and normal components of the solar wind velocity, the proton density (n_p), the proton temperature (T_p), the magnetic field strength (|B|), the azimuthal and meridional angles of the magnetic field, and finally the total pressure obtained by summing the magnetic field and plasma pressures. For the purposes of this discussion we can define the azimuth angle of the magnetic field ϕ_B as the angle obtained by projecting the vector onto the equatorial plane and measuring the angle that the projection makes to the radial direction taking positive in a right-handed sense. θ_B is the angle between the magnetic field vector and the equatorial plane.

(a) The figure shows four vertical dashed lines marking four boundaries in the CIR. These are labelled FS for forward shock, HCS for heliospheric current sheet, SI for stream interface – this is the contact surface between the two separate plasmas which started off as slow and fast near the Sun, and RW for reverse wave. Write down the principle features in the figure which you think led to the identification of these boundaries.

(b) The heliospheric current sheet, as discussed in the lectures, should lie in the centre of the band of slow solar wind. Can you explain why it appears here in the middle of an interaction region?

(c) Attempt to explain as many other features in the figure as you can.

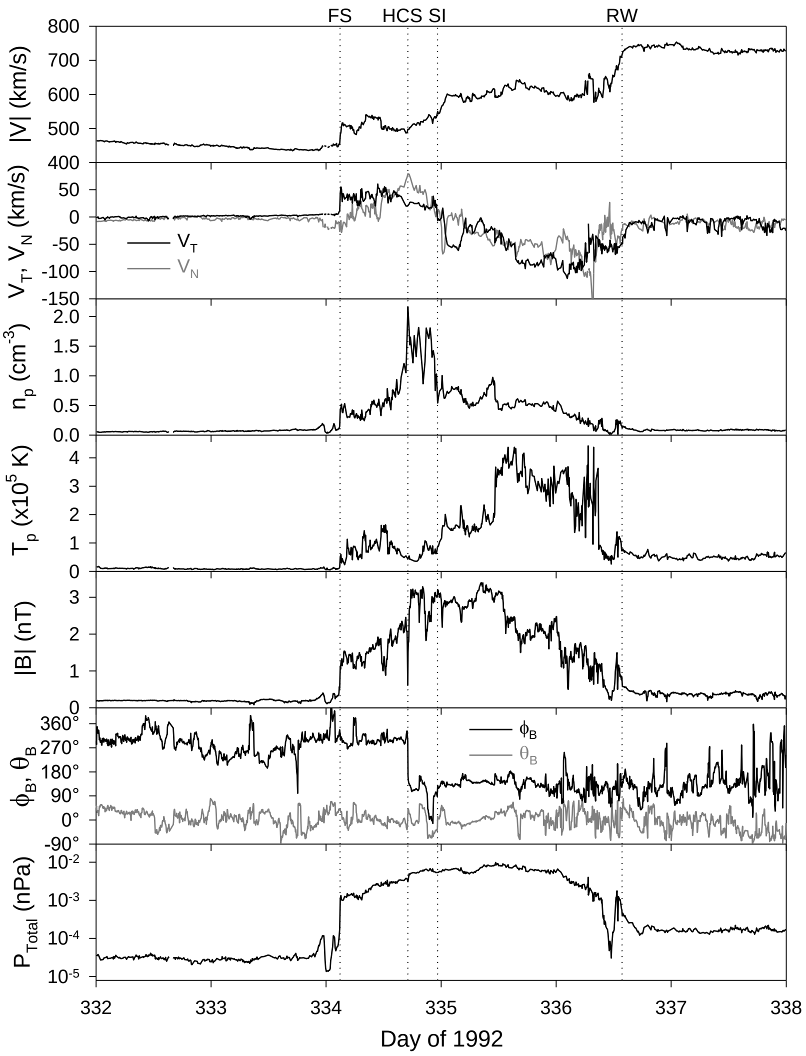

Figure 1 An example of a corotating interaction observed by Ulysses at 5 AU in 1992.