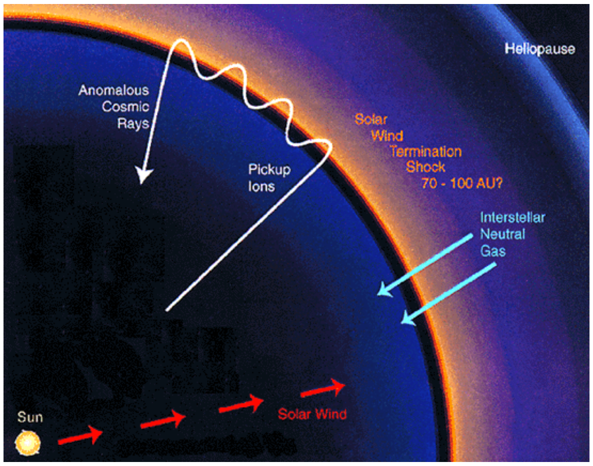
# The Heliopause...a question of balance!




Somewhere out beyond Pluto the particles flowing out from the sun in the 'solar wind' encounter a dilute gas called the interstellar medium (ISM). The sun is traveling through space at a speed of about 26 km/sec, and so from the sun's frame of reference, the ISM appears to be flowing past the solar system at this same speed. The solar wind can be thought of as a gas that exerts a pressure on the ISM, and similarly, the ISM exerts a pressure on the solar wind by virtue of its temperature and density.

The distance to the Heliopause is determined by the balance of pressure between the outflowing solar wind and the incoming ISM.

A relationship between these pressures yields the approximate formula shown to the right, where:

V = speed of the solar wind in cm/sec,
R = distance from the sun in AU.
D = solar wind density at 1AU in particles/cc,
M = the mass of a typical ISM atom in grams,
n = density of the ISM
T = temperature (Kelvins), of the ISM,

k = Boltzmann's constant $1.38 \times 10^{-16}$ ergs/degree.

Solar Wind Pressure = ISM thermal pressure

$$M V^2 \frac{D}{R^2} = n k T$$

For example, let's select:

V = 400 km/sec so that V = $4 \times 10^7$ cm/sec  D = 5 particles/$cm^3$
M = mass of hydrogen atom = $1.6 \times 10^{-24}$ grams  n = 0.01 particles/$cm^3$
T = 100,000 Kelvins.

Then: $(1.6\times10^{-24}) \times (4 \times 10^{7})2 \times (5.0) = (0.01)\times (1.38 \times 10^{-16}) \times (100{,}000) \times R^2$

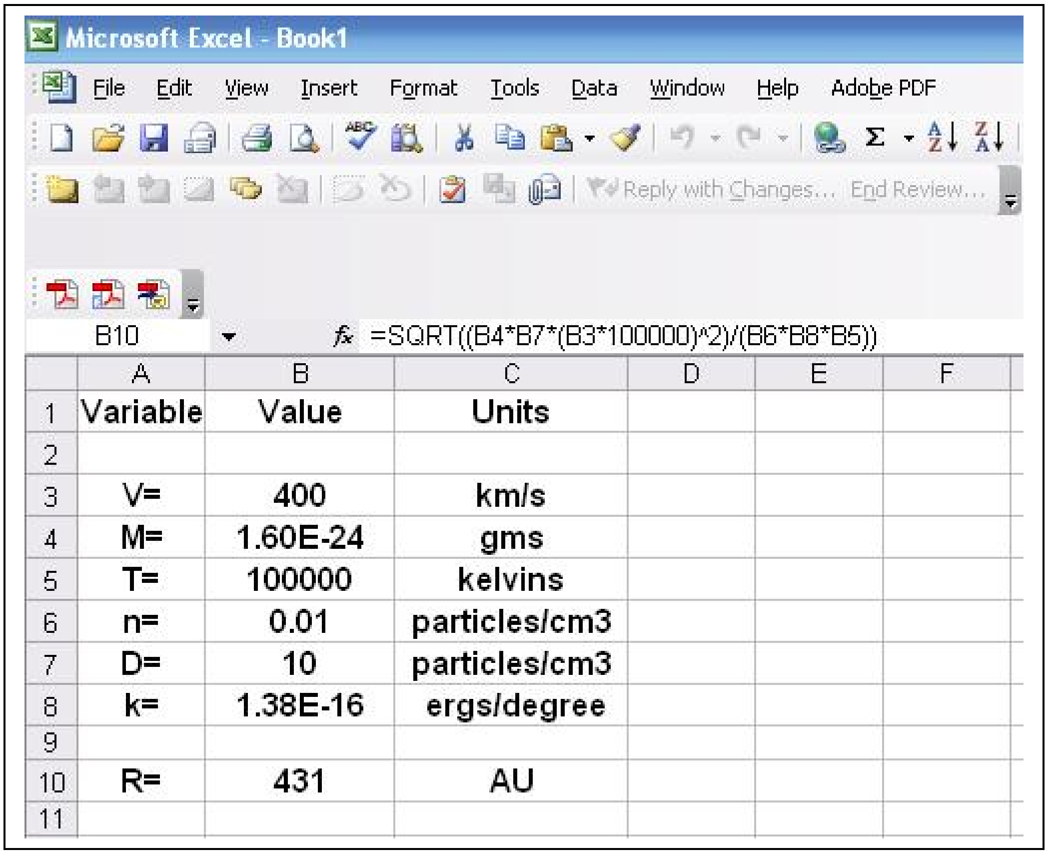
And so : $R = (1.3 \times 10^{-8} / 1.38 \times 10^{-13})^{1/2}$

= 306 AU to the heliopause from the sun. Note the distance to Pluto is about 40 AU!

## Inquiry Problem:

Data from the Voyager spacecraft suggest that the Bow Shock lies just beyond a distance of 100 AU from the sun, but probably not more than 200 AU. With the help of an Excel Spreadsheet, enter the bow shock distance formula into one of the columns. Can you find a range of distances to the heliopause that is consistent with plausible solar wind properties for V between 400 - 800 km/sec; T between 50,000 - 200,000 K and D between 2 - 20 particles/$cm^3$ ?

## Answer Key: A sample Excel page.




B10 =SQRT((B4*B7*(B3*100000)^2)/(B6*B8*B5))

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Variable | Value | Units | | | |
| 2 | | | | | | |
| 3 | V= | 400 | km/s | | | |
| 4 | M= | 1.60E-24 | gms | | | |
| 5 | T= | 100000 | kelvins | | | |
| 6 | n= | 0.01 | particles/cm3 | | | |
| 7 | D= | 10 | particles/cm3 | | | |
| 8 | k= | 1.38E-16 | ergs/degree | | | |
| 9 | | | | | | |
| 10 | R= | 431 | AU | | | |
| 11 | | | | | | |

The MS-Excel Formula Bar contains the solution for R in Astronomical Units (AU) as a function of the input variables defined in Column A. The values adopted for the example are shown in Column B with the indicated units in Column C. Note that the value for V in km/s has to be converted into cm/s which is why the formula shows B3*100000.

The resulting value for R is shown in Cell B10.

By varying V, n, D and T students can see how the distance to the heliopause varies. It is suggested that students do an on-line literature search to find out what values for these quantities are commonly cited by researchers. They should always cite the reference using proper citation formats, when creating a report on this project. **Values between 120 and 200 AU are reasonable, but students should be encouraged to do a GOOGLE search on the 'Heliopause distance' to explore other published estimates.**