太陽風

太陽風是一種由太陽表面吹出來的電漿流(plasma)，電子、質子與各類帶電原子核或離子雖然各自分開運動，但其整體還是保持電中性。太陽風可說是太陽大氣的延伸，其平均速率約為400 km/s。

太陽風中不但有電漿，由於太陽本身具有磁場，當太陽風吹出時，磁場亦會被太陽風帶著跑，即所謂的行星際磁場(IMF; Interplanetary Magnetic Field)。

太陽風大約在距離太陽不到0.1 AU處就已經加速成為超音速的電漿流，因此當太陽風吹過各行星時，會在行星的向陽面形成一激震波，稱之為艏震波(Bow Shock)。

Table 1. Statistical Properties of the Solar Wind at 1 AU

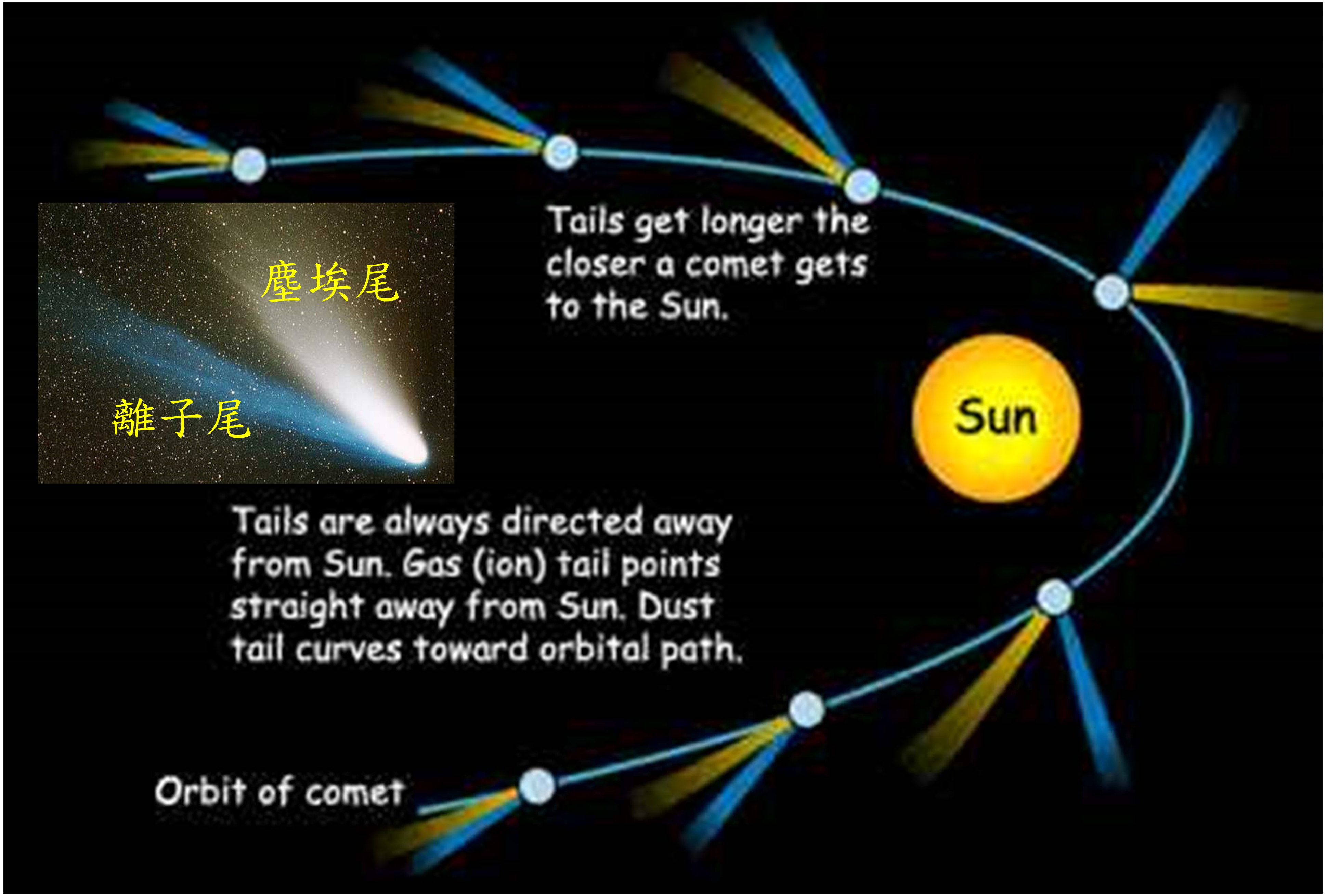
Parameter	Mean	STD	Most Probable	Median	5-95% Range
n (/cm^3)	8.7	6.6	5.0	6.9	3.0 – 20.0
V_{sw} (km/s)	468	116	375	442	320 – 710
B (nT)	6.2	2.9	5.1	5.6	2.2 – 9.9
A(He)	0.047	0.019	0.048	0.047	0.017 – 0.078
T_p (x10^{5}K)	1.2	0.9	0.5	0.95	0.1 – 3.0
T_e (x10^{5}K)	1.4	0.4	1.2	1.33	0.9 – 2.0
T_α (x10^{5}K)	5.8	5.0	1.2	4.5	0.6 – 15.5
T_e/T_p	1.9	1.6	0.7	1.5	0.37 – 5.0
T_α/T_p	4.9	1.8	4.8	4.7	2.3 – 7.5
nV_{sw} (x10^8/cm^{2}s)	3.8	2.4	2.6	3.1	1.5 – 7.8
C_s (km/s)	63	15	59	61	41 – 91
C_A (km/s)	50	24	50	46	30 - 100

n is proton density, V_{sw} is solar wind speed, B is magnetic field strength, A(He) is He^{++}/H^+ ratio, T_p is proton temperature, T_e is electron temperature, T_α is alpha particle temperature, C_s is sound speed, C_A is Alfven speed.

The Sun yearly loses ~6.8 x 10^{19} g to the solar wind, a very small fraction of the total solar mass of ~2 x 10^{33} g.

http://lasp.colorado.edu/reu/docs/solar_wind.jtgosling.ppt

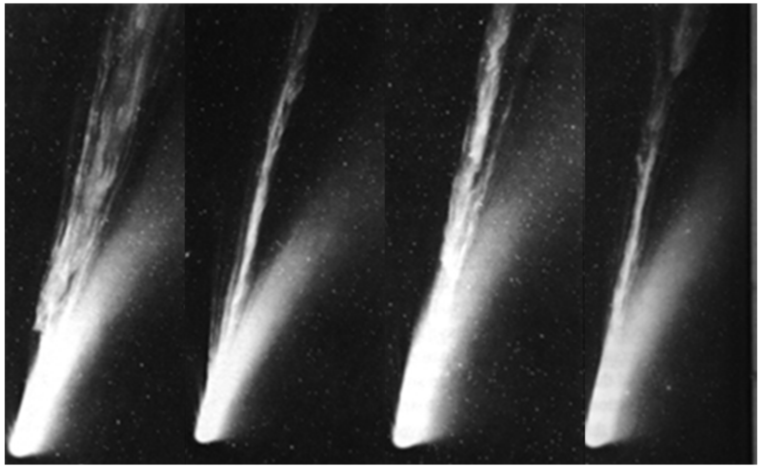
太陽風的證據——彗尾



http://www.portalsaofrancisco.com.br/alfa/cometas/imagens/cometas-34.jpg

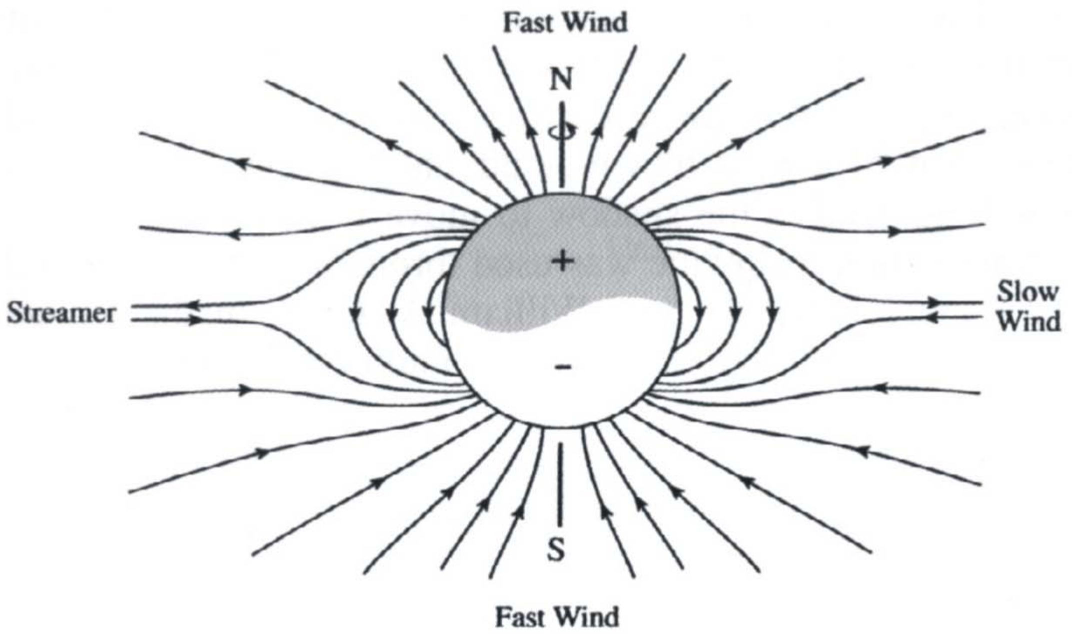
太陽風的證據---彗尾

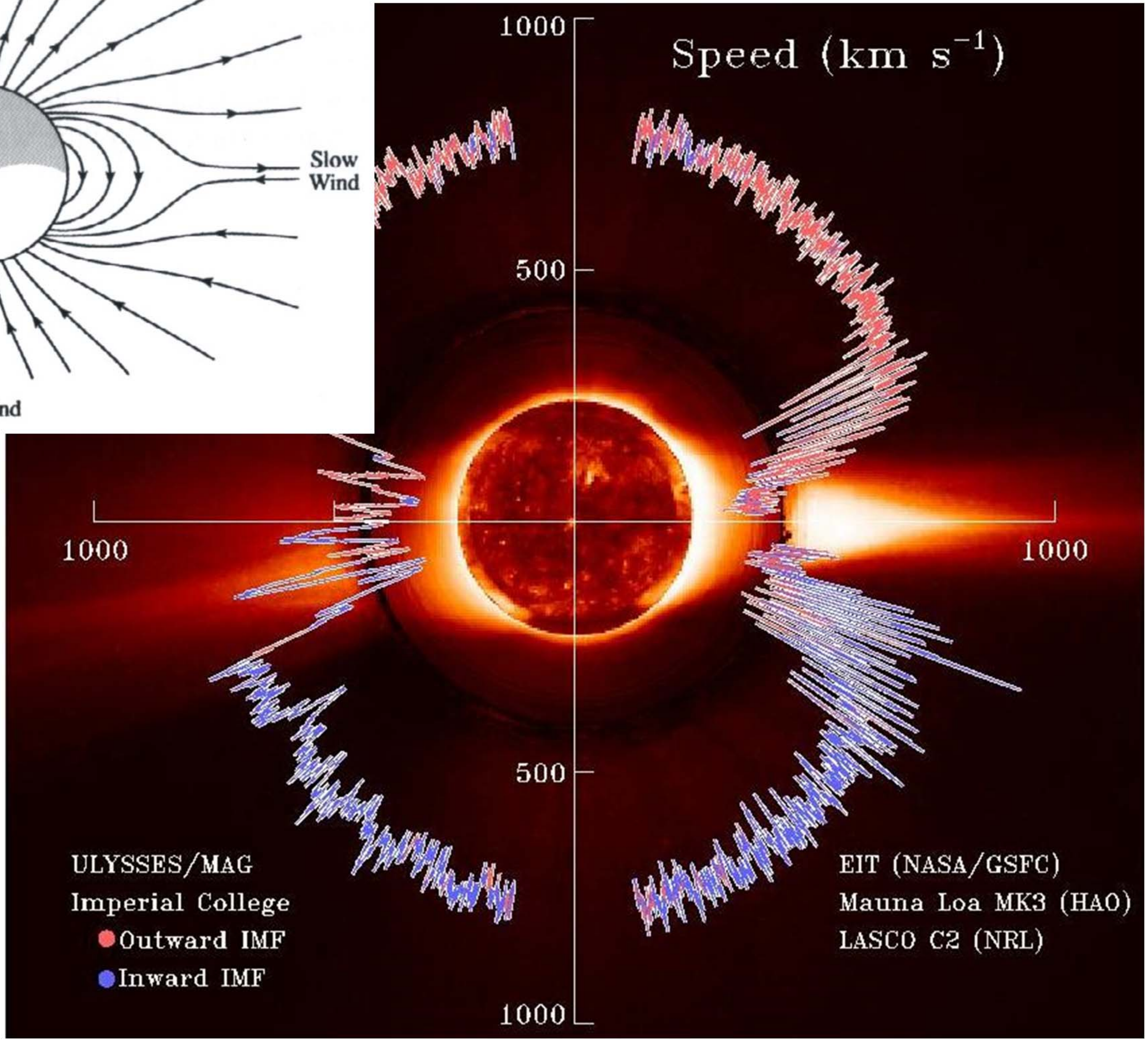
塵埃尾比較彌散且形狀彎曲，主要由塵埃顆粒組成，會同時受到太陽引力及太陽輻射壓力的影響。不同大小的塵粒受力不同，所以離開彗核的時間也不同，就會形成彎曲的塵埃尾，塵粒反射陽光而造成灰黃的顏色。



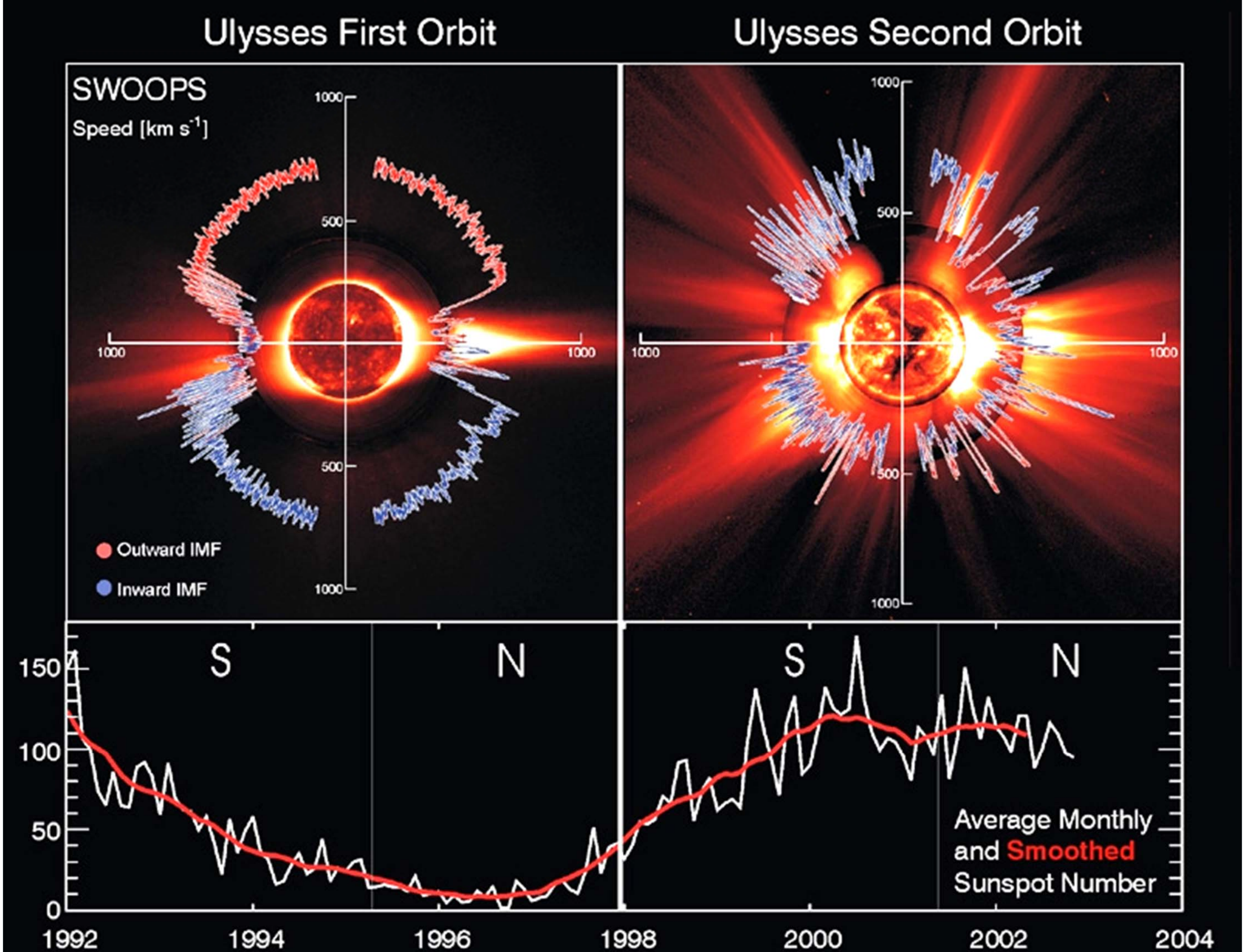
http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

離子尾形狀狹長，主要由氣體離子組成，不但受到太陽引力及輻射壓力的作用，同時還受太陽風及其磁場的影響。其中的一氧化碳離子吸收了紫外光後，會造成離子尾偏藍的顏色。在彗星運動的過程中，行星際磁場的變化常會造成離子尾的分叉、斷裂、再生。



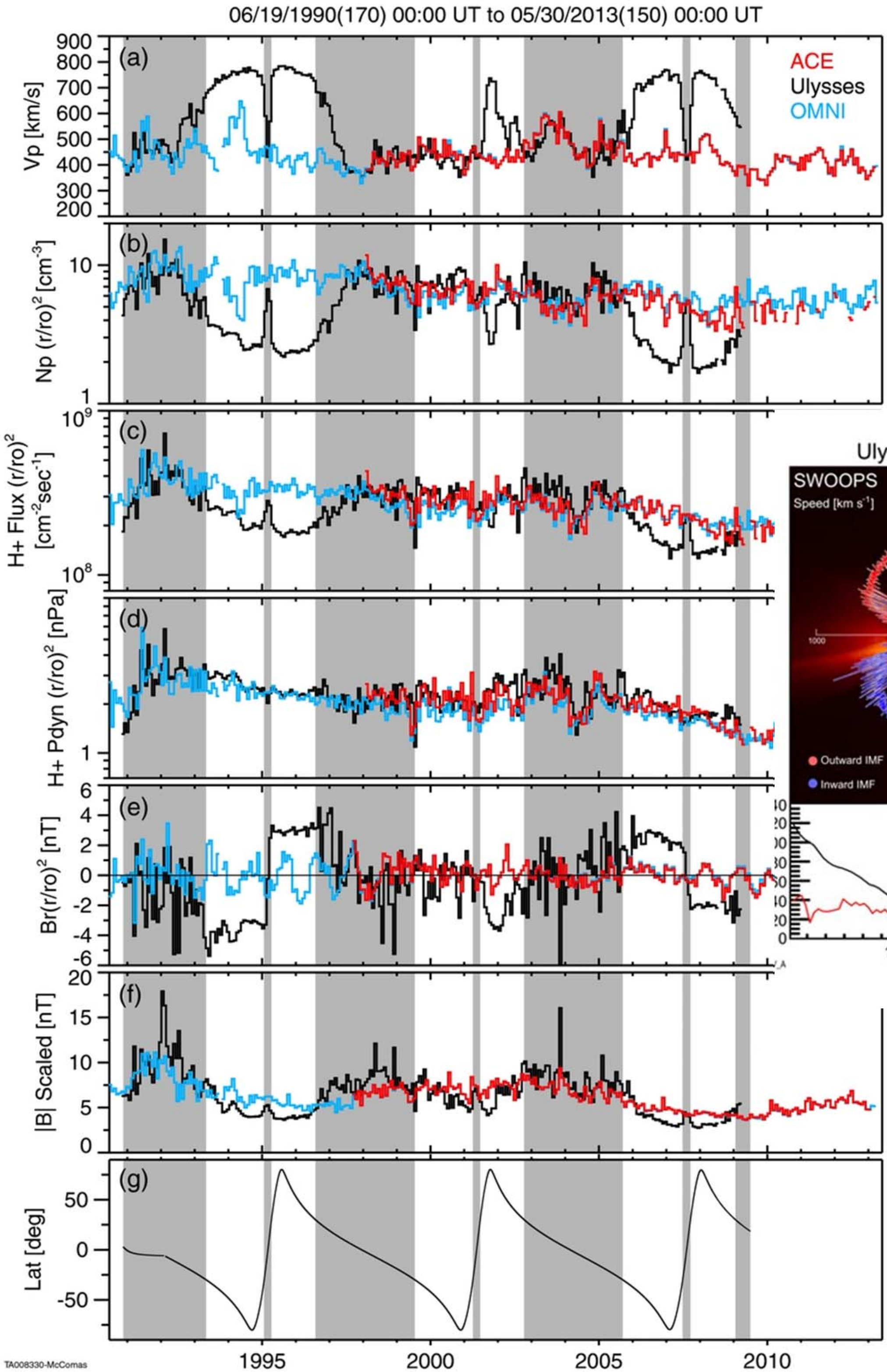


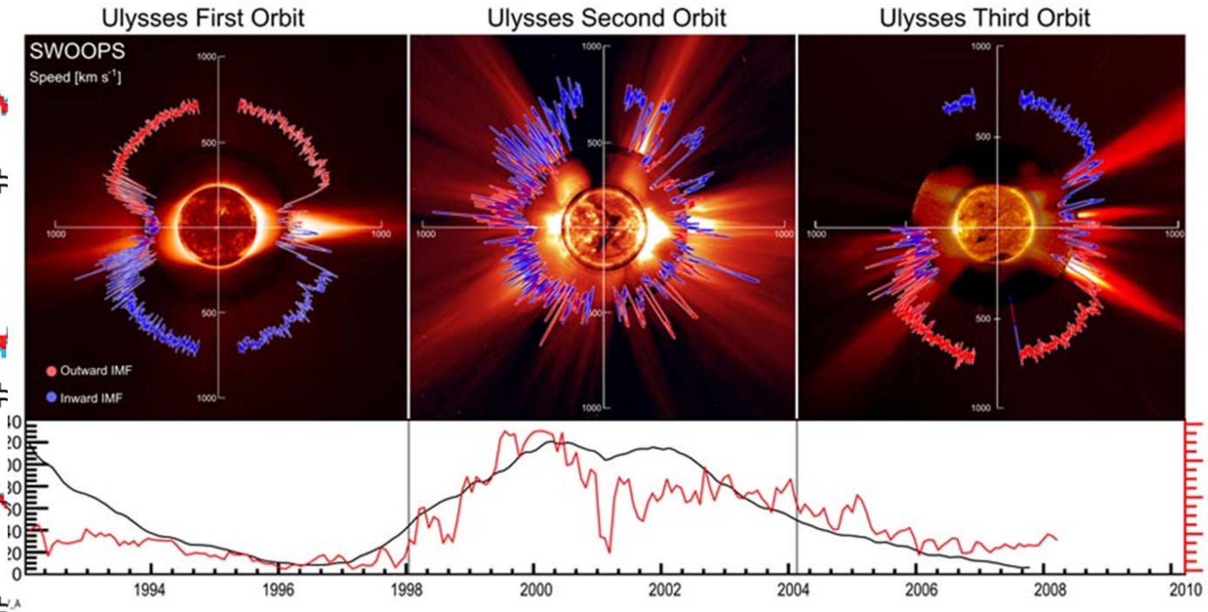
http://solarscience.msfc.nasa.gov/images/DialPlot.jpg



http://science.nasa.gov/media/medialibrary/2008/01/14/14jan_northpole_resources/swoops_wind.jpg

McComas et al., *Geophys. Res. Lett.*, 2003.





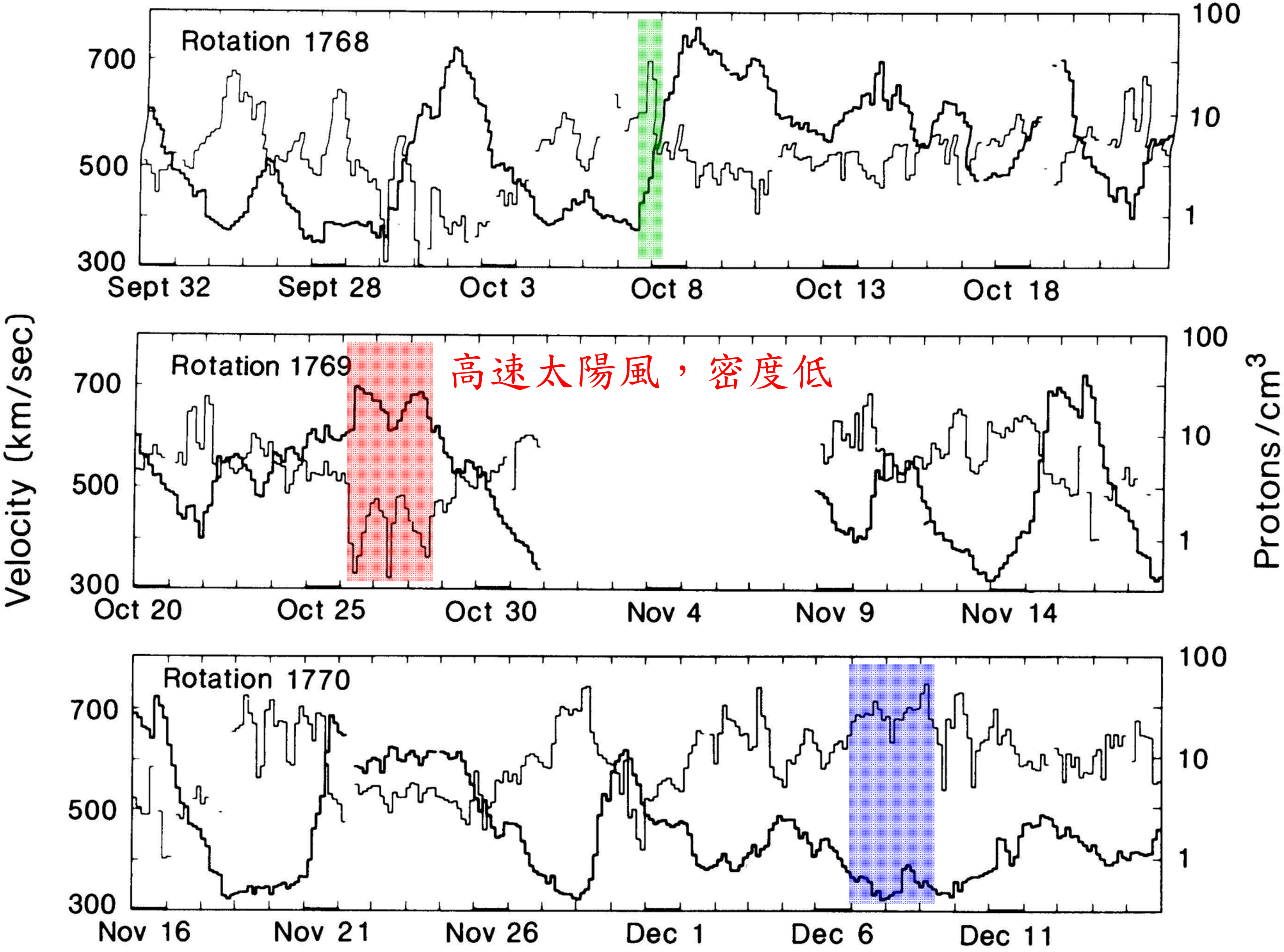
http://iopscience.iop.org/0004-637X/779/1/2/downloadHRFigure/figure/apj486711f2

Table 2. Average solar wind parameters at 1 AU, for the time around solar activity minimum.

	Slow wind	Fast wind
Flow speed v_P	250–400 km s^{-1}	400–800 km s^{-1}
Proton density n_P	10.7 cm^{-3}	3.0 cm^{-3}
Proton flux density $n_P v_P$	3.7×10^8 cm^{-2} s^{-1}	2.0×10^8 cm^{-2} s^{-1}
Proton temperature T_P	3.4×10^4 K	2.3×10^5 K
Electron temperature T_e	1.3×10^5 K	1×10^5 K
Momentum flux density	2.12×10^8 dyn cm^{-2}	2.26×10^8 dyn cm^{-2}
Total energy flux density	1.55 erg cm^{-2} s^{-1}	1.43 erg cm^{-2} s^{-1}
Helium content	2.5%, variable	3.6%, stationary
Sources	Streamer belt	Coronal holes

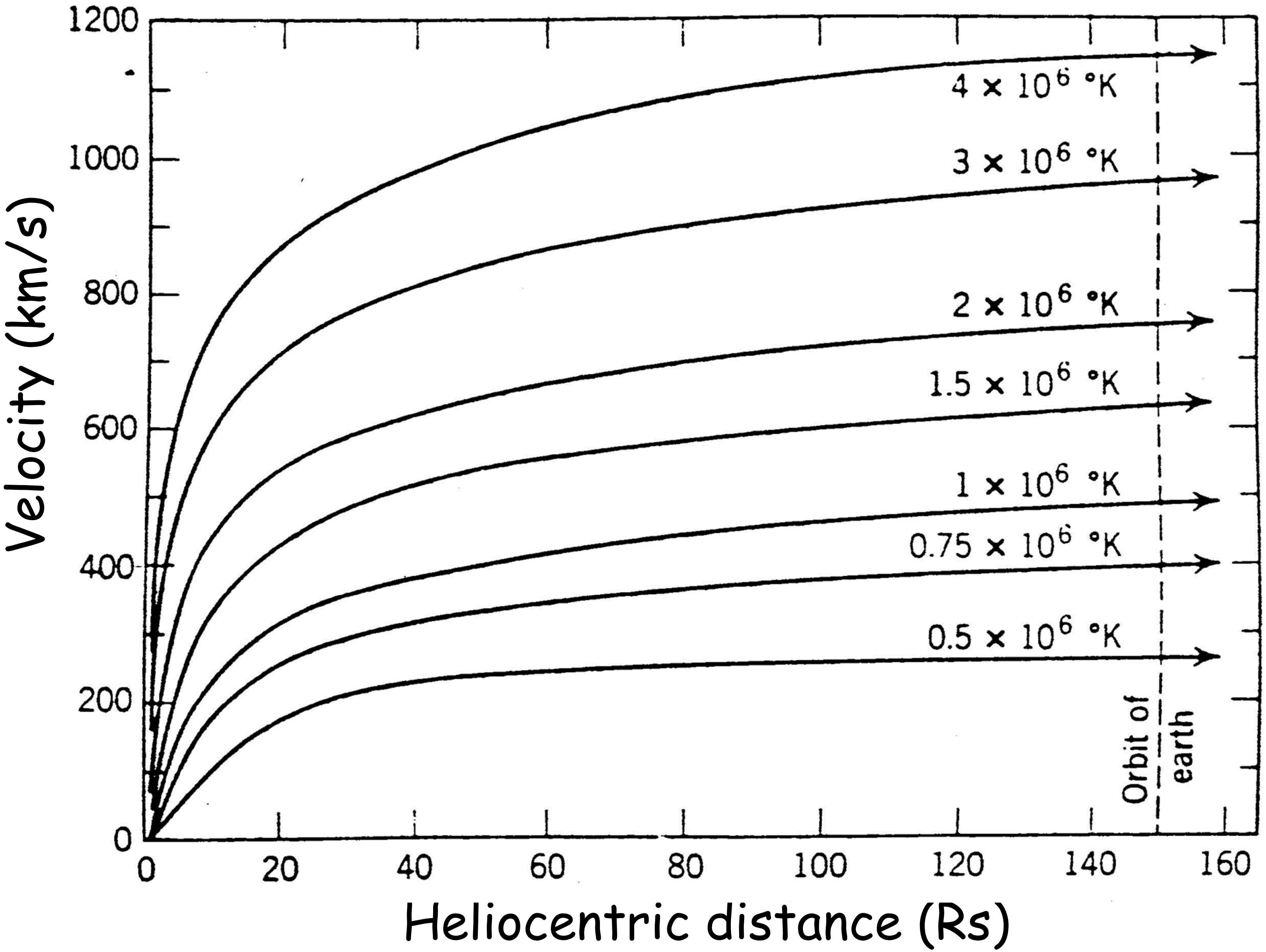
https://www.cfa.harvard.edu/~scranmer/ITC/eaaa_solar_wind_schwenn.pdf

粗線:速度　細線:密度　　高速太陽風的前緣有被壓縮的高密度高速太陽風

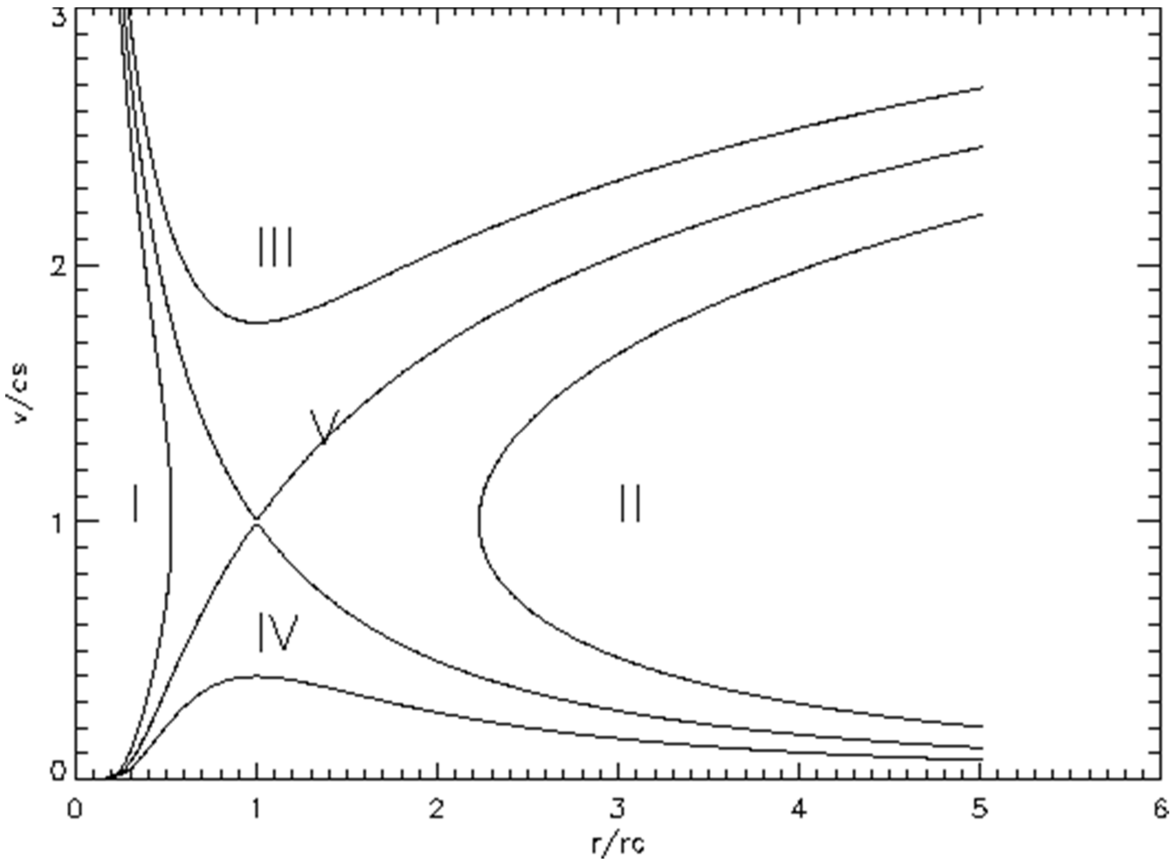


低速太陽風，密度高

Parker's Solar Wind Model



Parker's Solar Wind Model



Solution I & II are doubled valued and thus are unphysical.

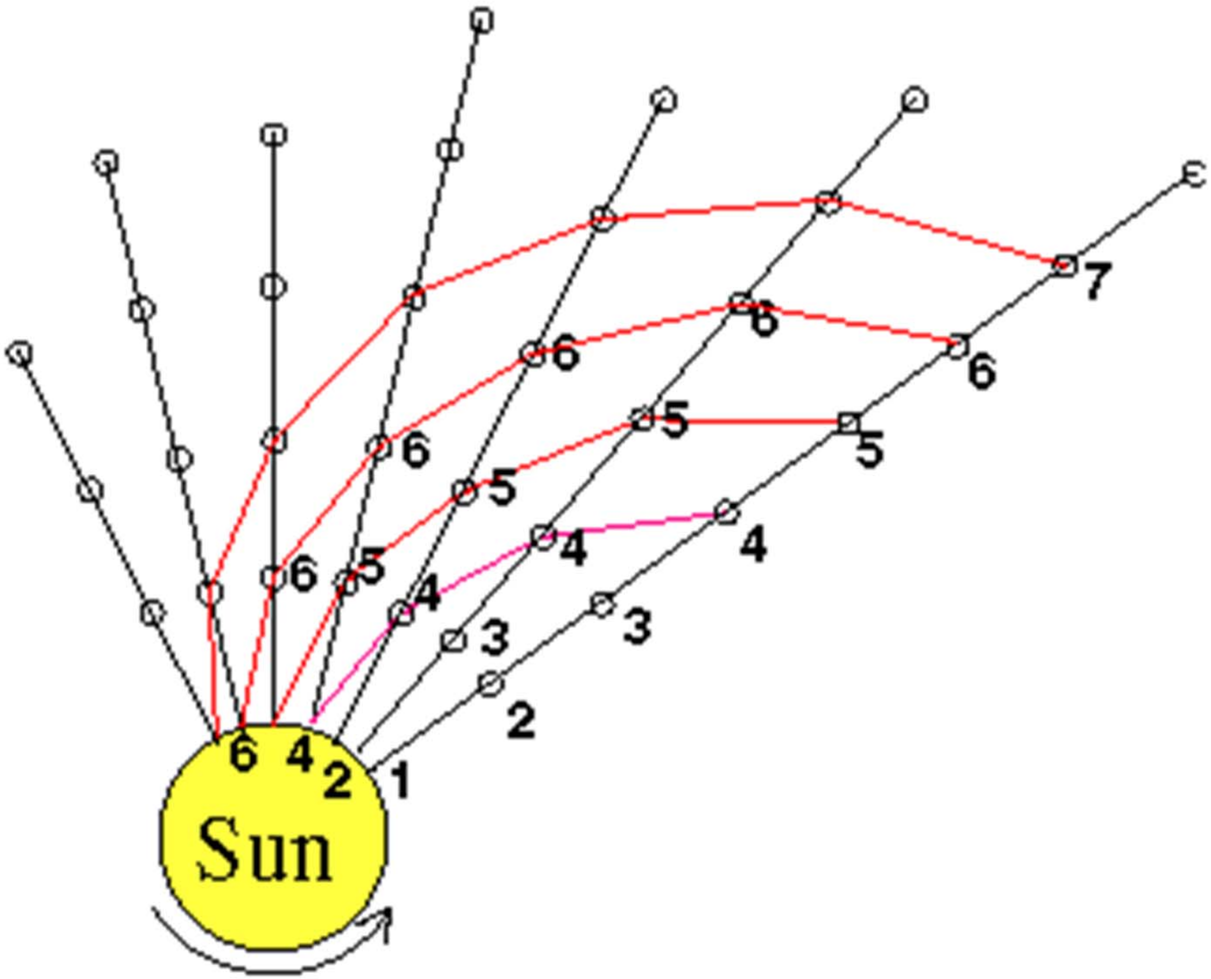
Solution III has supersonic speed at the Sun which is not observed.

Observations show that Solution V is correct.

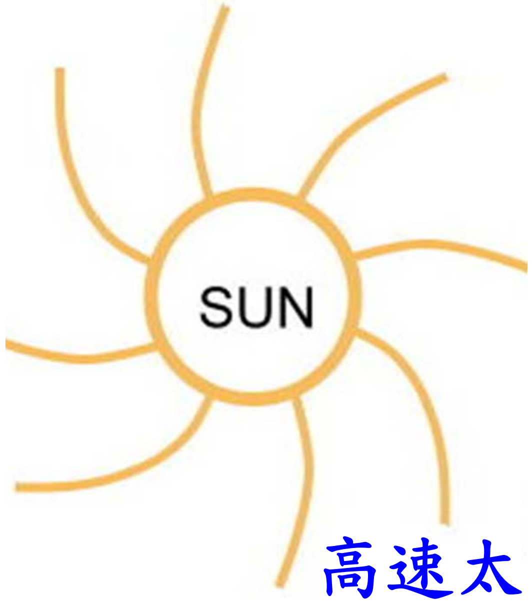
http://www-solar.mcs.st-andrews.ac.uk/~alan/sun_course/Chapter6/img51.gif

Parker Spiral

當太陽風吹出時，磁場會被太陽風拉著跑，由於太陽自轉，太陽磁場會以螺旋結構(稱之為Parker Spiral)分佈於太陽系中。

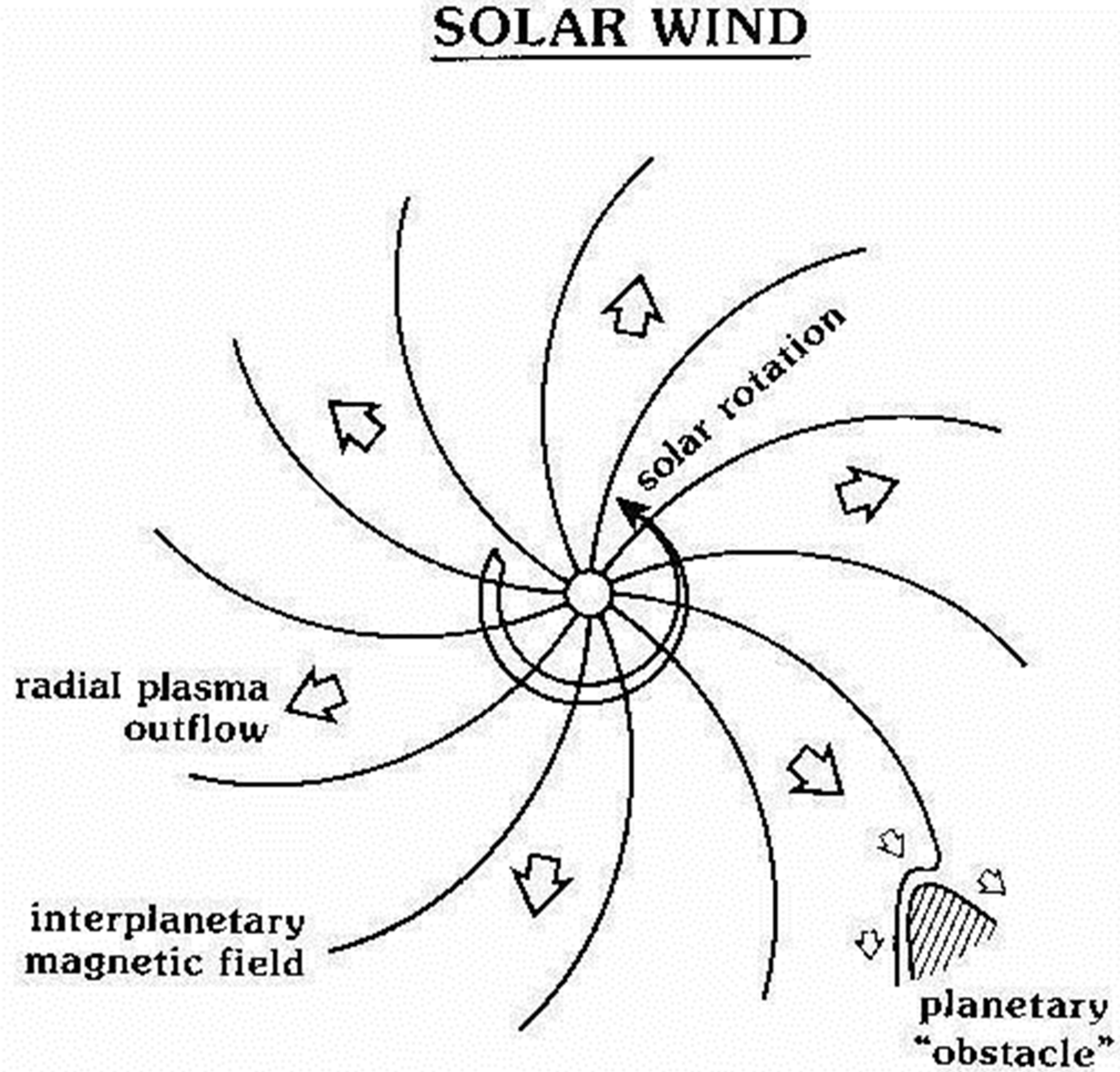


低速太陽風



高速太陽風

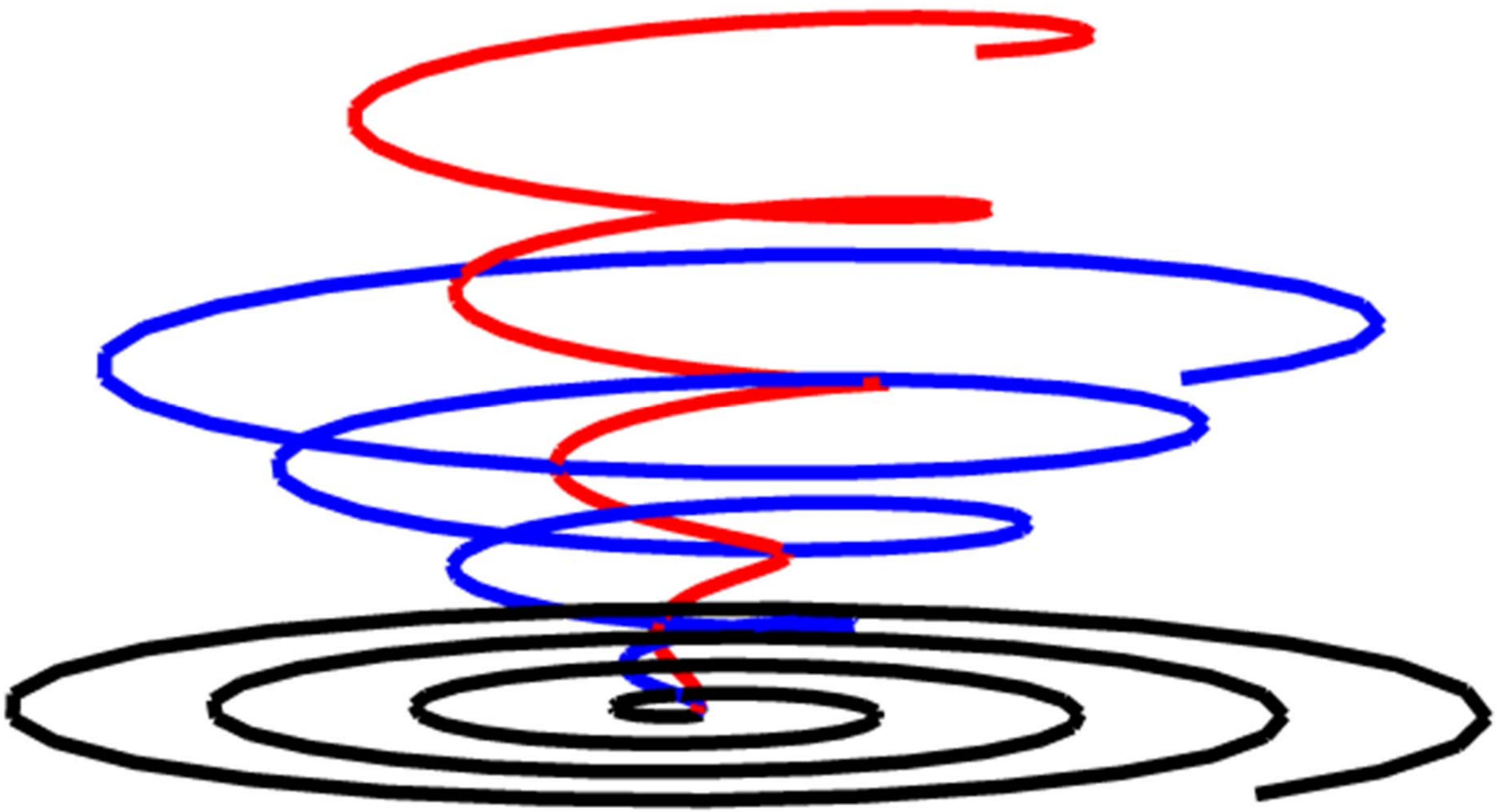
http://www.phy6.org/Education/wimfproj.html



http://pwg.gsfc.nasa.gov/istp/outreach/images/Gusts/windsprl.jpg

Parker Spiral

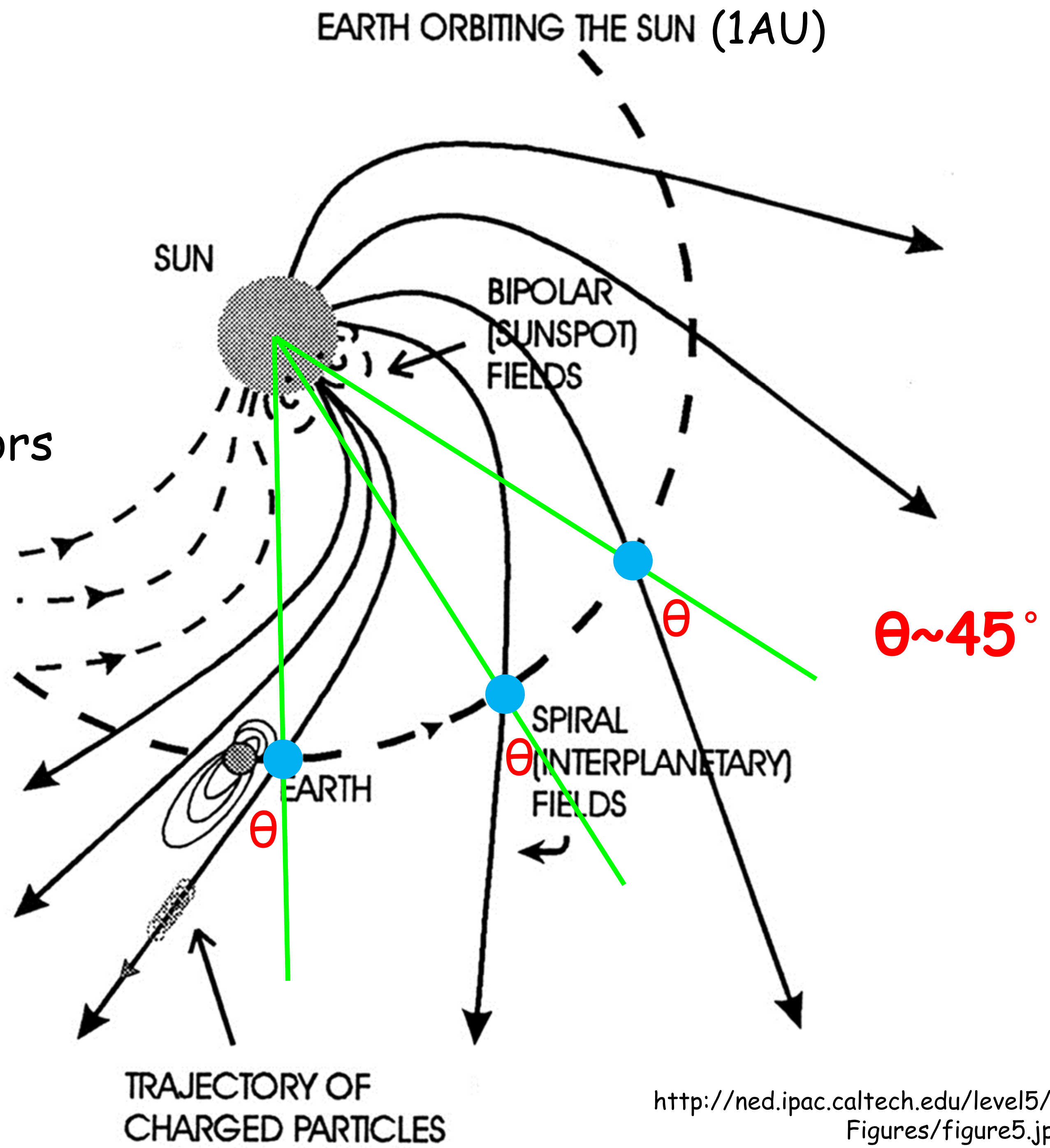
Ideal Parker spiral magnetic field lines between 0 and 25 AU for a solar wind speed of 450 km s^{-1}. Black, blue, and red lines show heliographic latitudes of 0, 30, and 60 degrees, respectively.



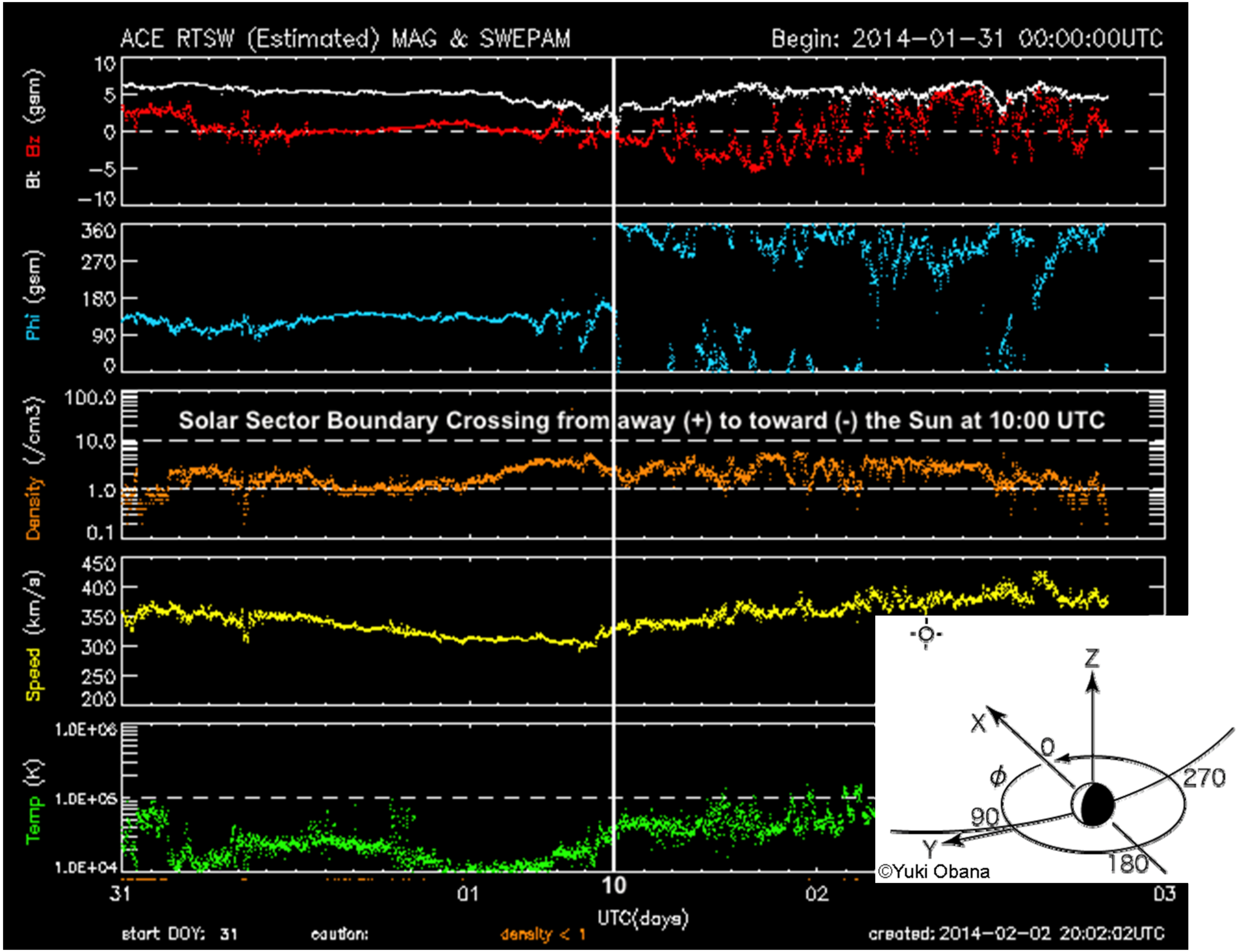
http://solarphysics.livingreviews.org/Articles/lrsp-2013-5/fig_3.html

Magnetic Sector Structure

magnetic sectors

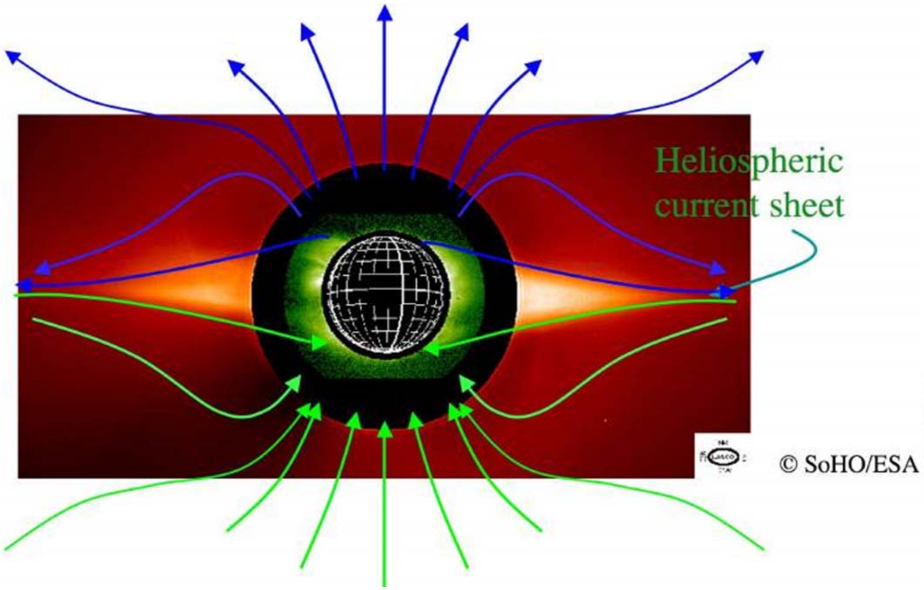


http://ned.ipac.caltech.edu/level5/March03/Vallee2/Figures/figure5.jpg

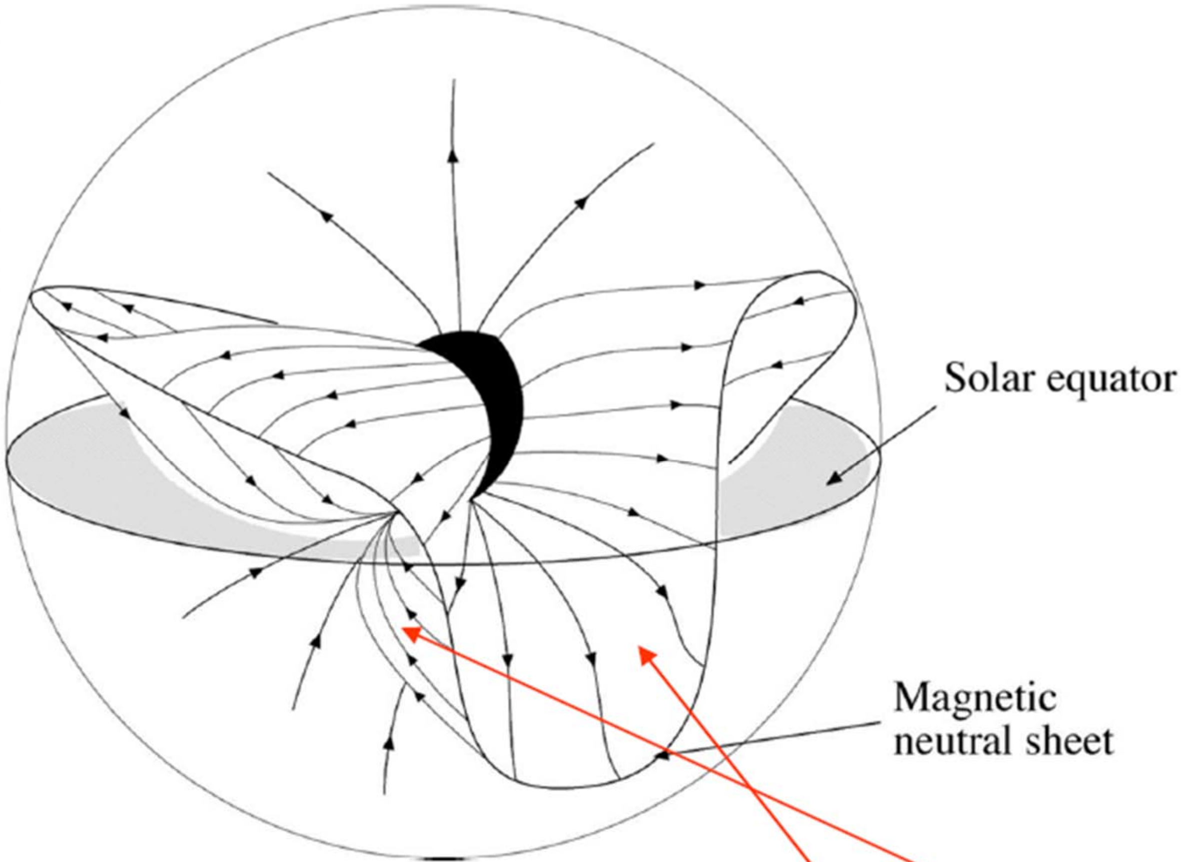


http://www.suspicious0bserverscollective.org/1/post/2014/02/solar-sector-boundary-crossing-on-february-1st-2014-research-notes.html

Heliospheric Current Sheet

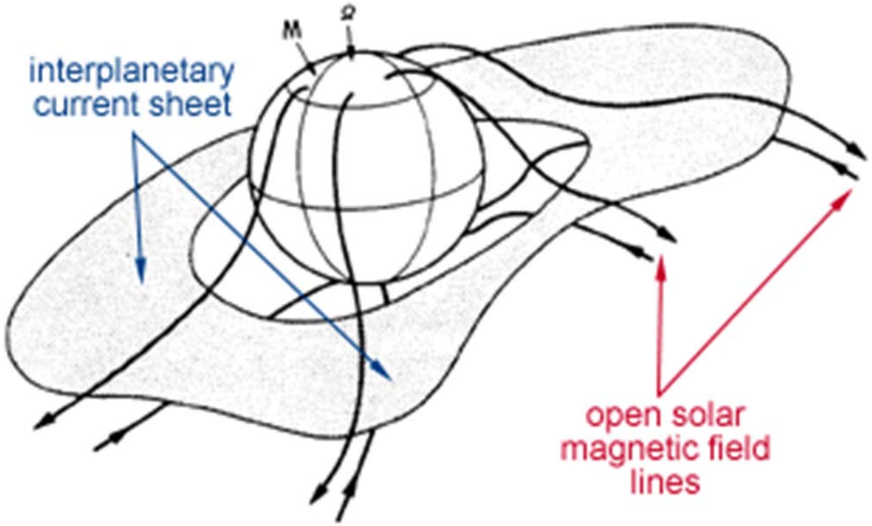


http://www.nmdb.eu/?q=node/135



"ballerina skirt"

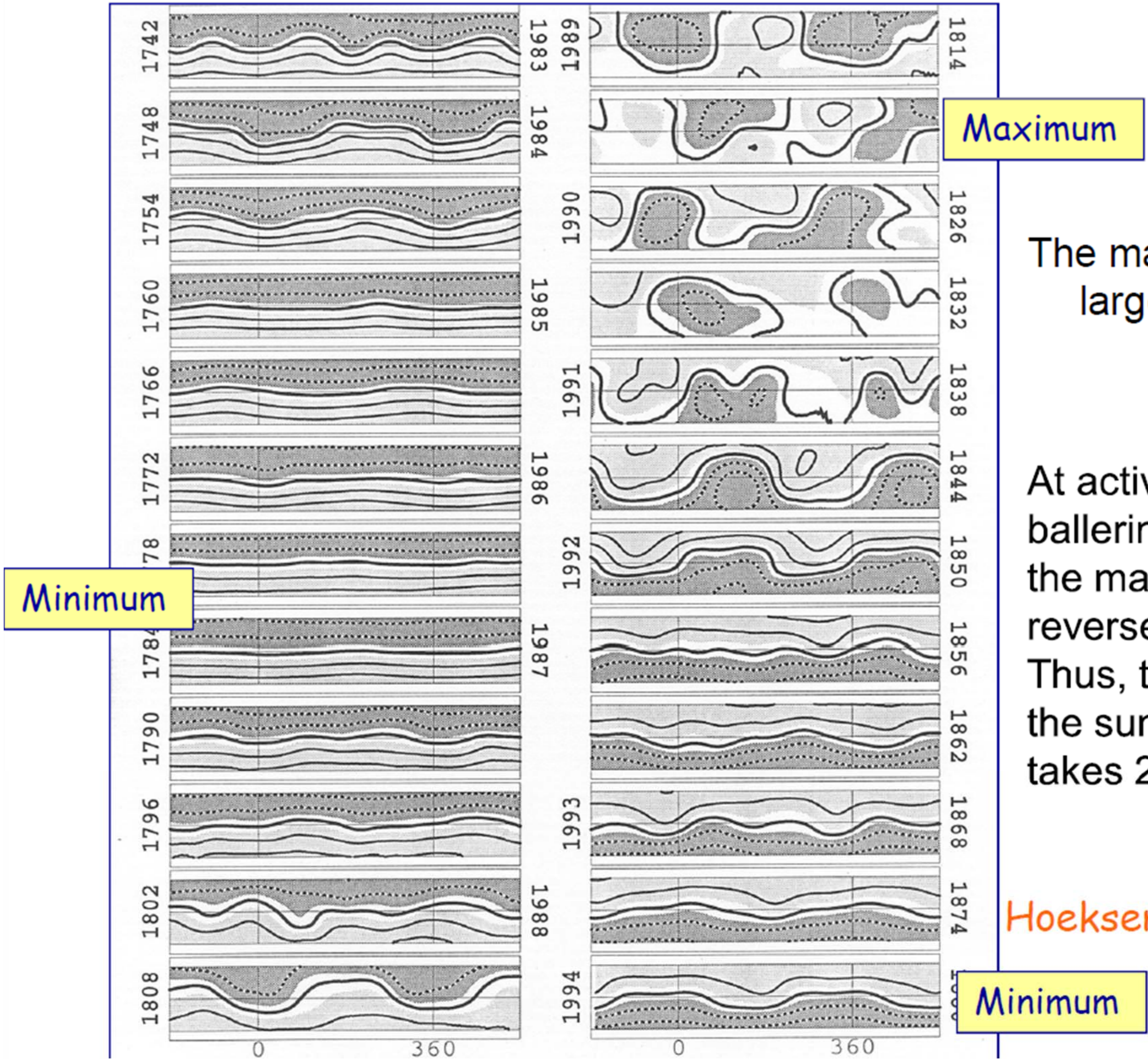
The Earth can be "toward" sector or in "away" sector



http://pluto.space.swri.edu/image/glossary/IMF.html

http://theory.physics.helsinki.fi~plasmainfo.html

The ballerina dancing through the solar cycle



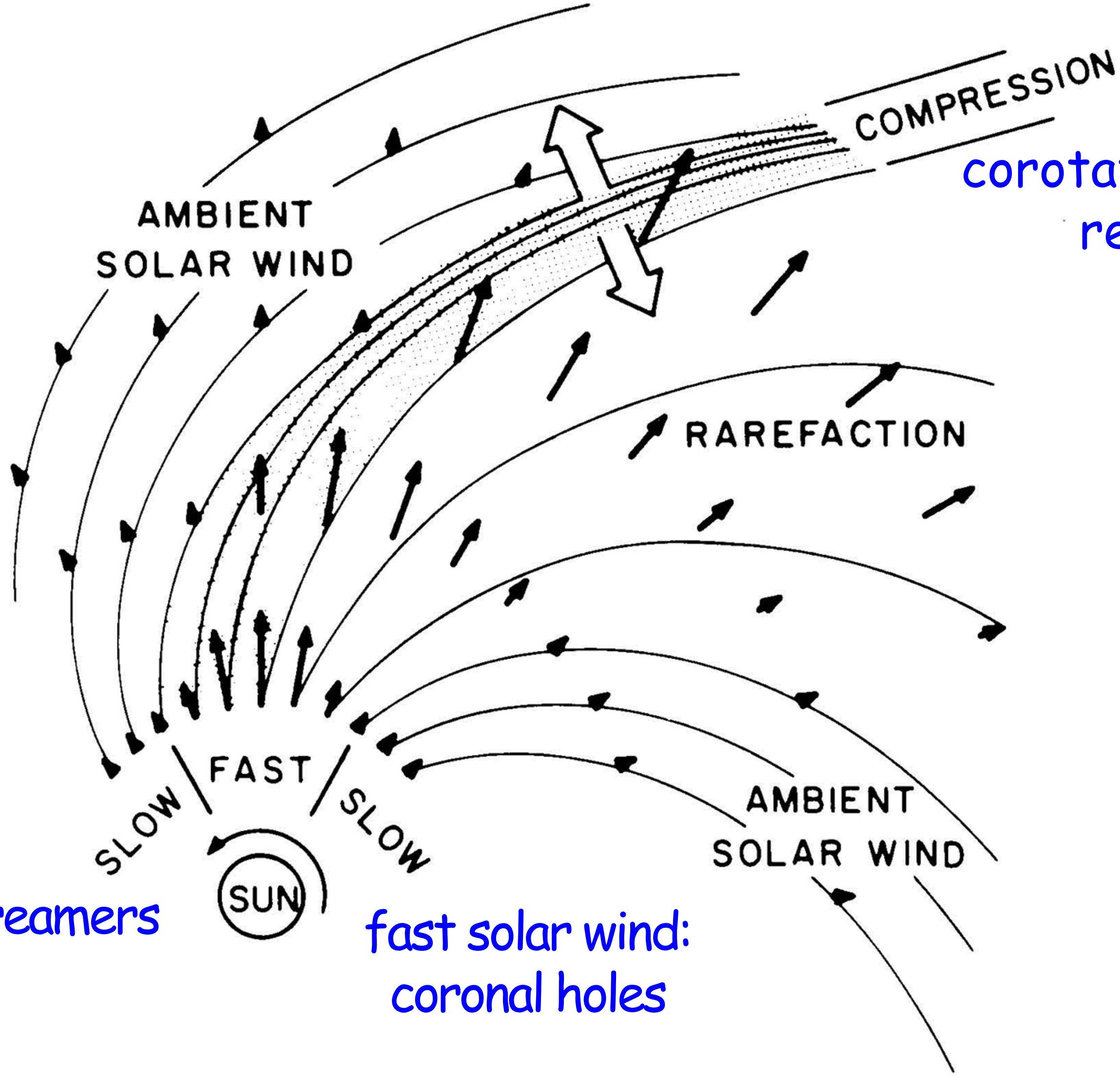
The magnetic topology of the large-scale heliosphere

At activity maximum, the ballerina skirt flips over, and the magnetic polarity is then reversed at next minimum. Thus, the magnetic cycle of the sun (the “Hale-cycle”) takes 22 years!

Hoeksema, 1995

http://theory.physics.helsinki.fi~plasmainfo.html

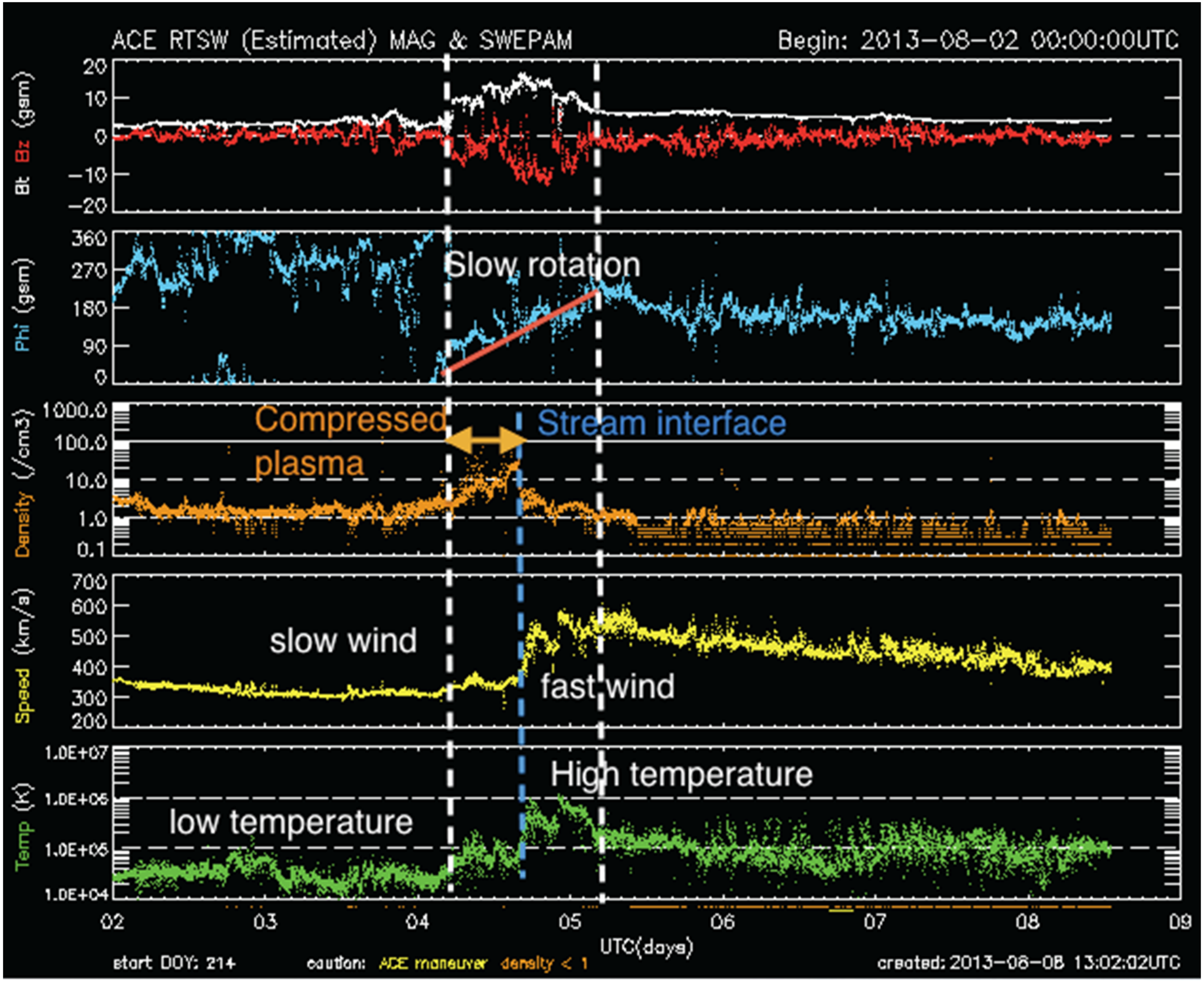
Interaction between Fast and Slow Solar Winds



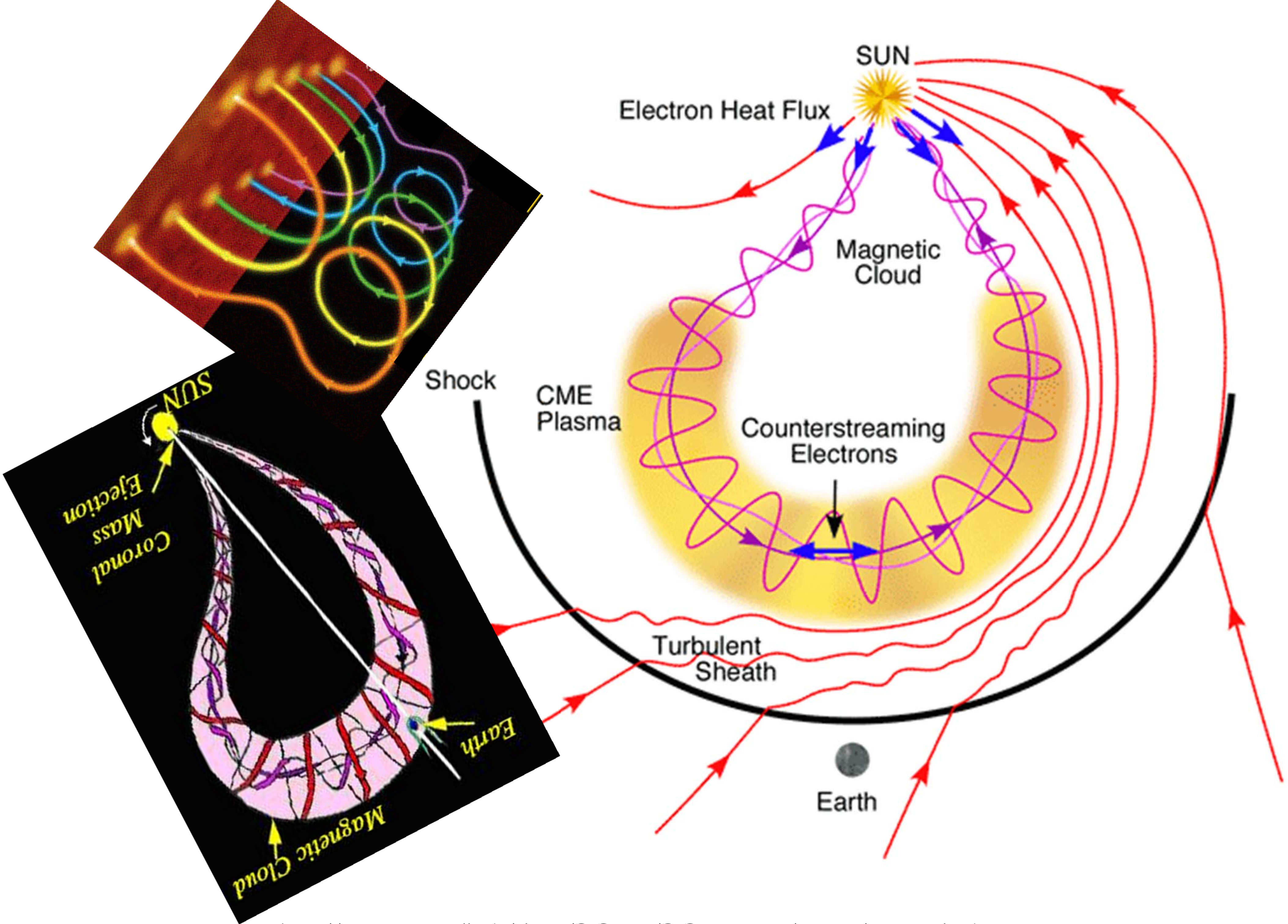
corotating interaction region (CIR)

slow solar wind: streamers

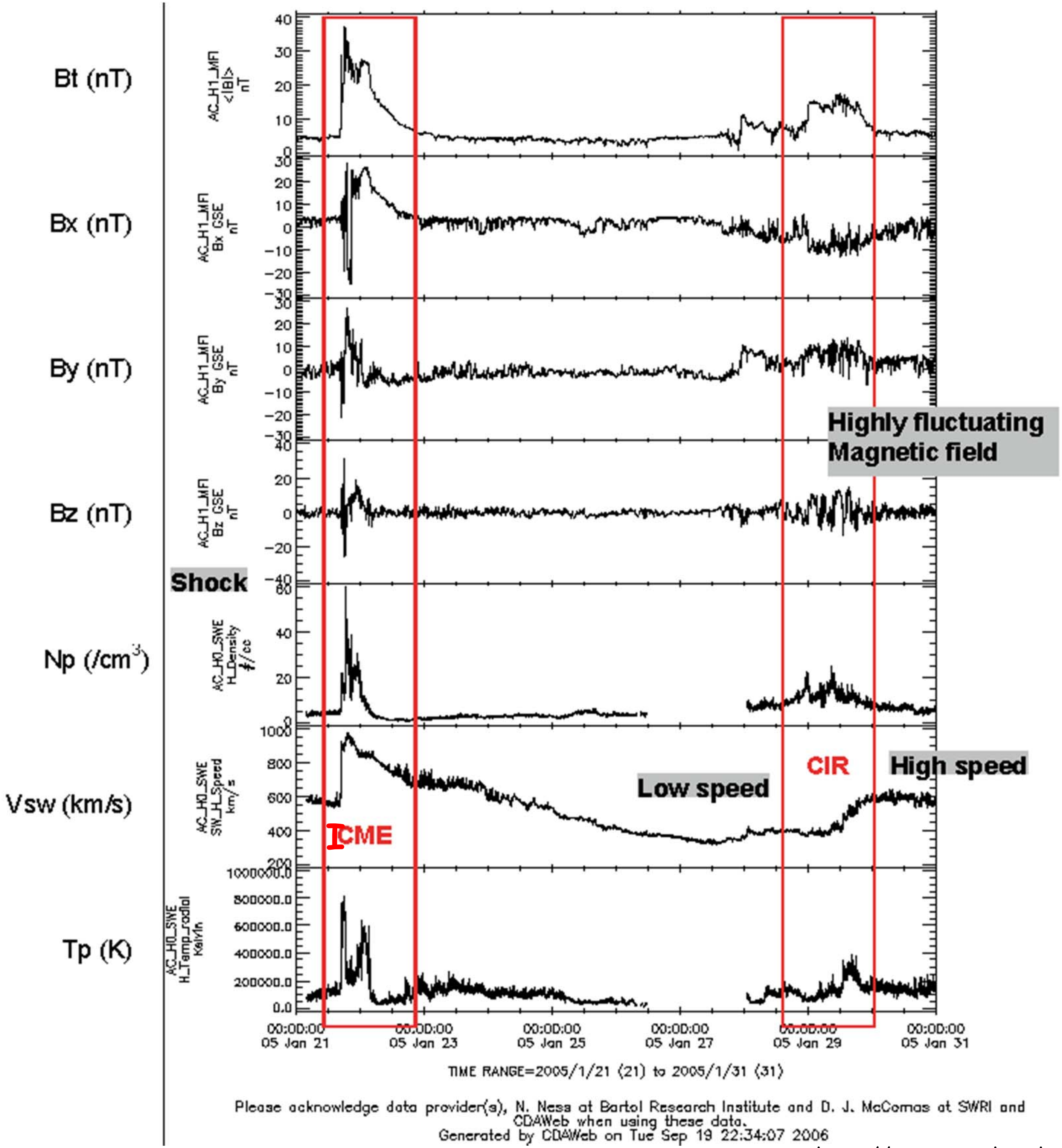
fast solar wind: coronal holes



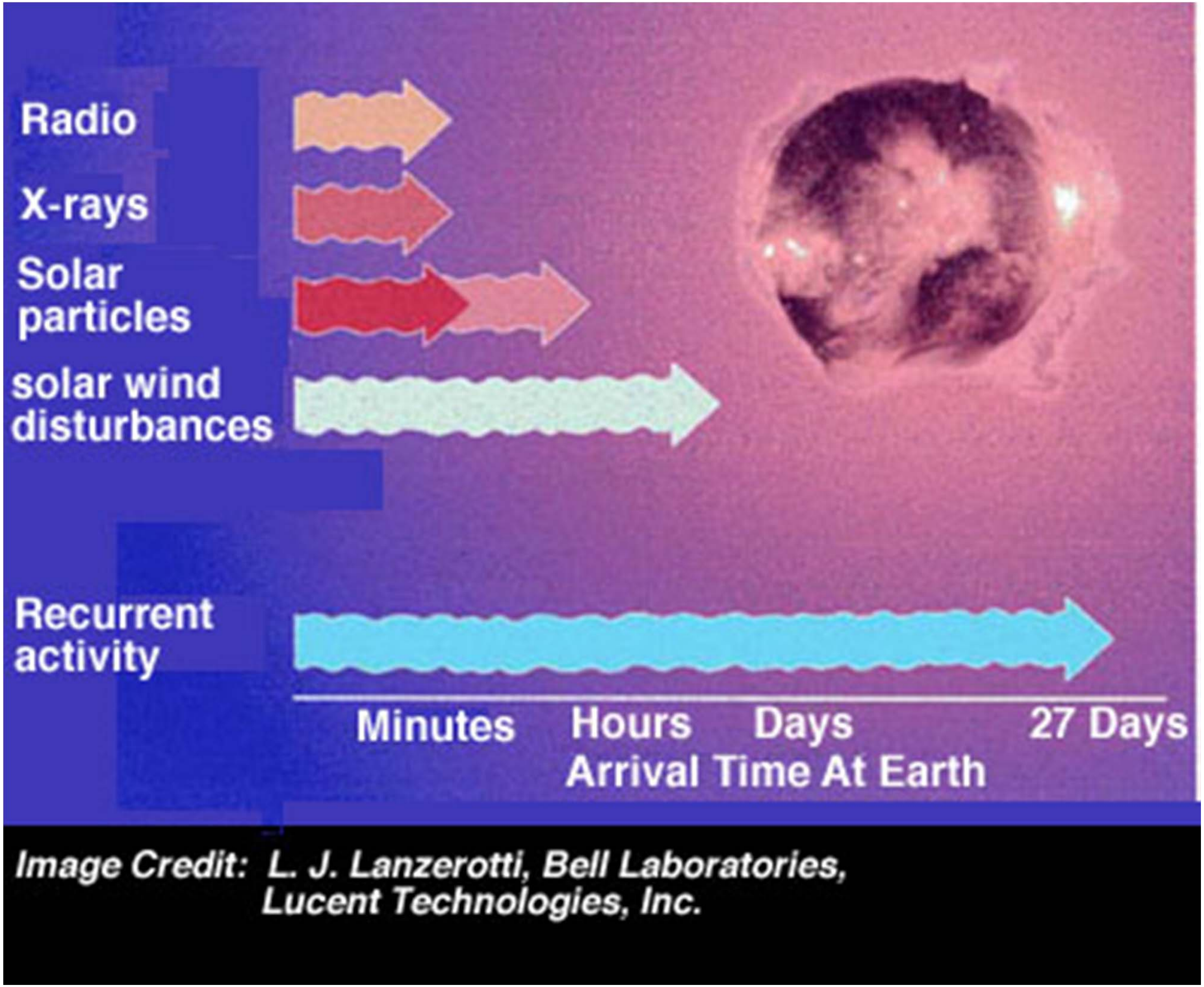
http://wis.kuleuven.be/CHARM/images/partners/20130919-eheroesschoolleuven.pdf



http://www.cac.cornell.edu/slantz/ECE5860/ECE586-Spr07/Images/magneticloud.jpg
http://ase.tufts.edu/cosmos/pictures/Sept09/Fig8_7.MagCloud.gif



http://www.serc.kyushu-u.ac.jp/gaikyo/manual.pdf



http://www.windows2universe.org/spaceweather/images/Lanzerotti_Arrival_time_med.jpg