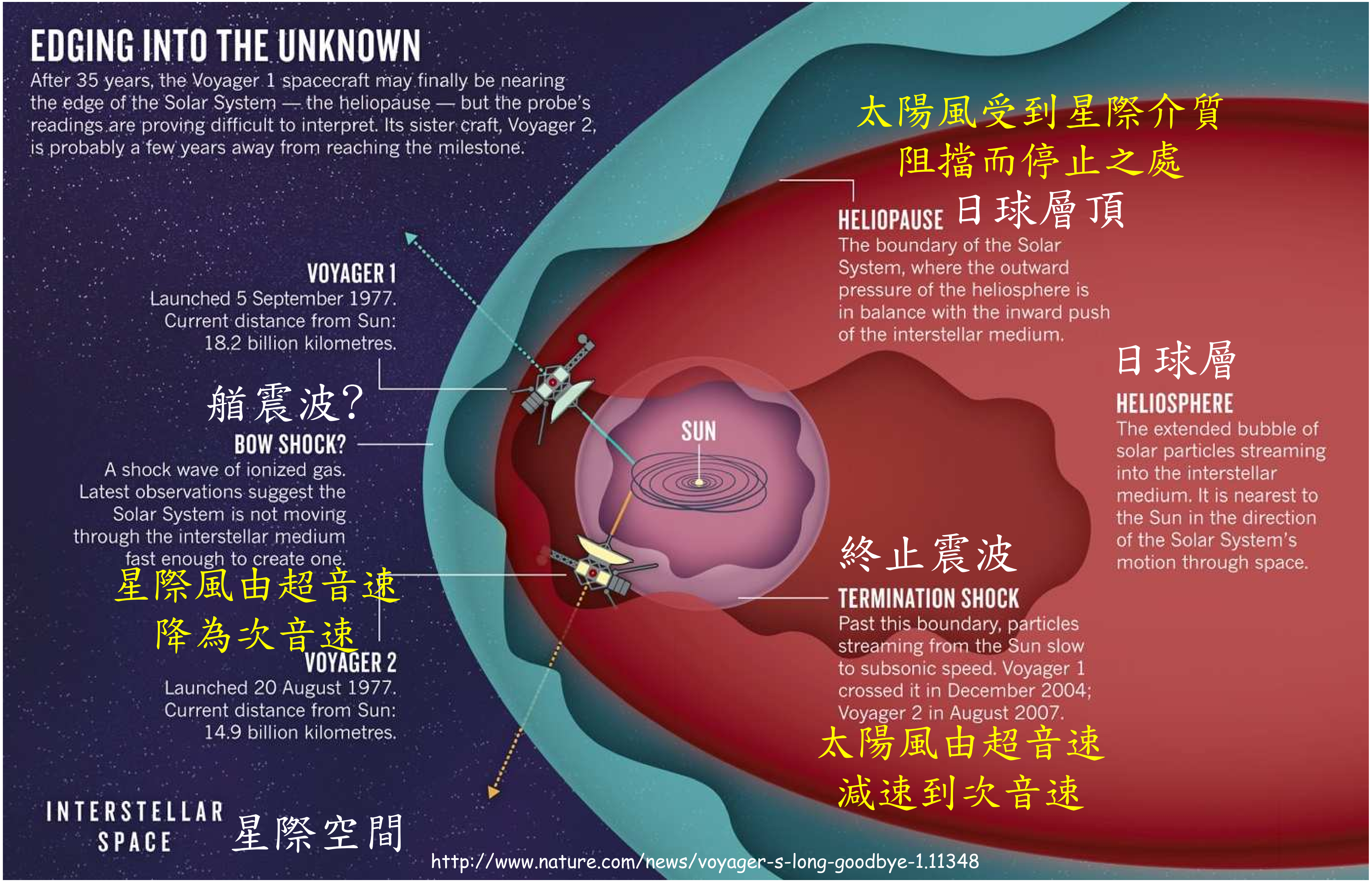
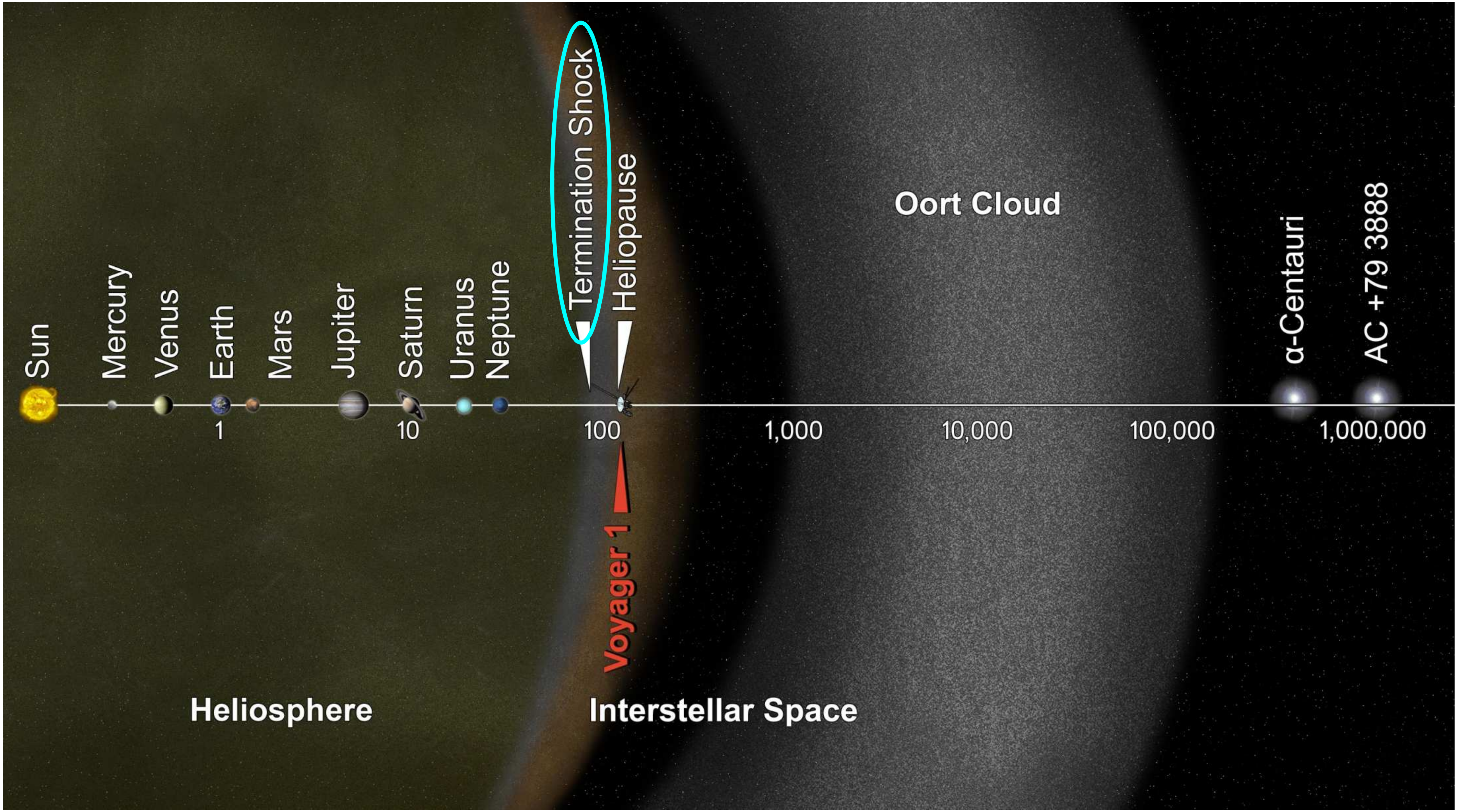
太陽風的終點

"太陽風減速→過渡→停止"
"星際風減速→過渡→停止"???

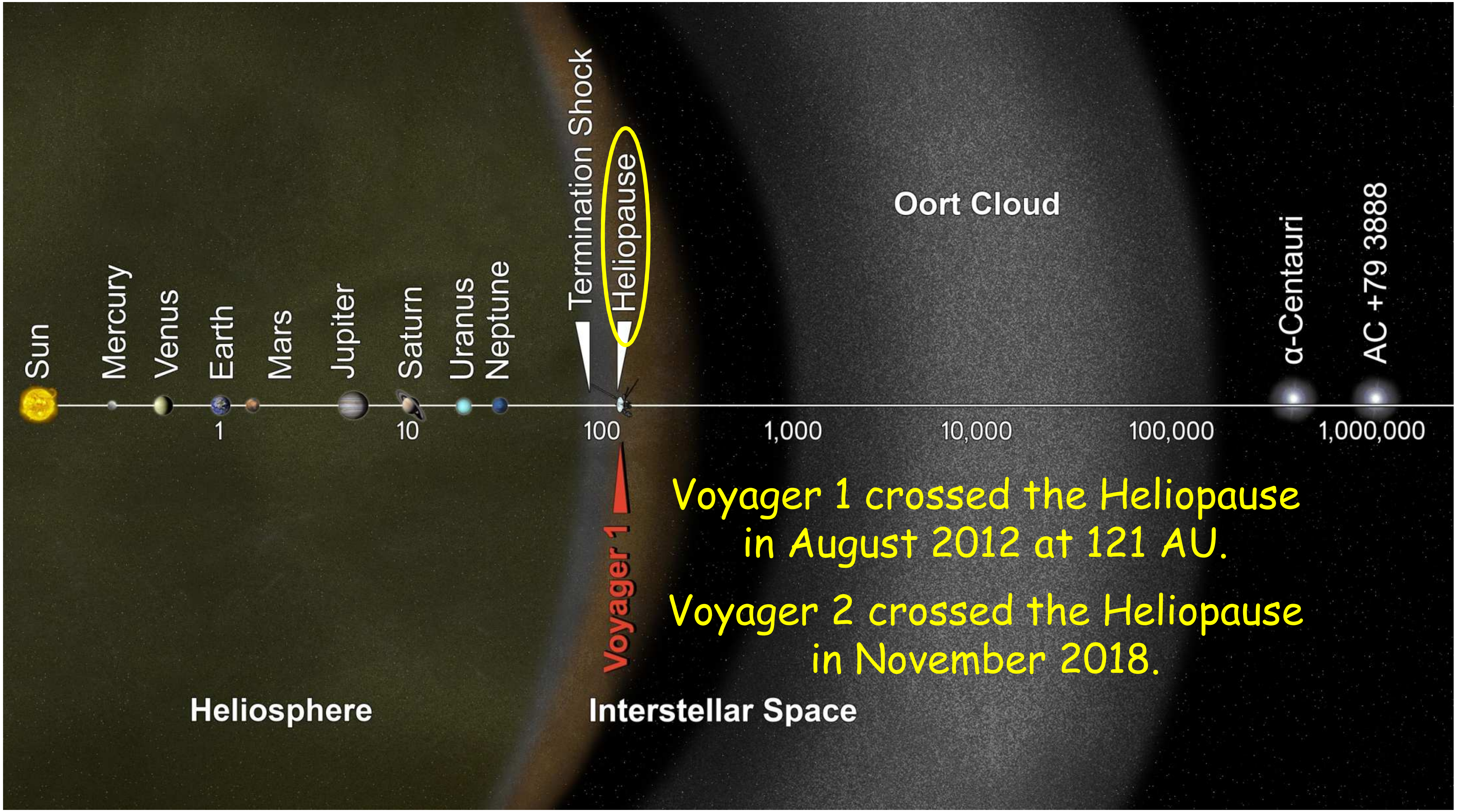


http://www.nature.com/news/voyager-s-long-goodbye-1.11348

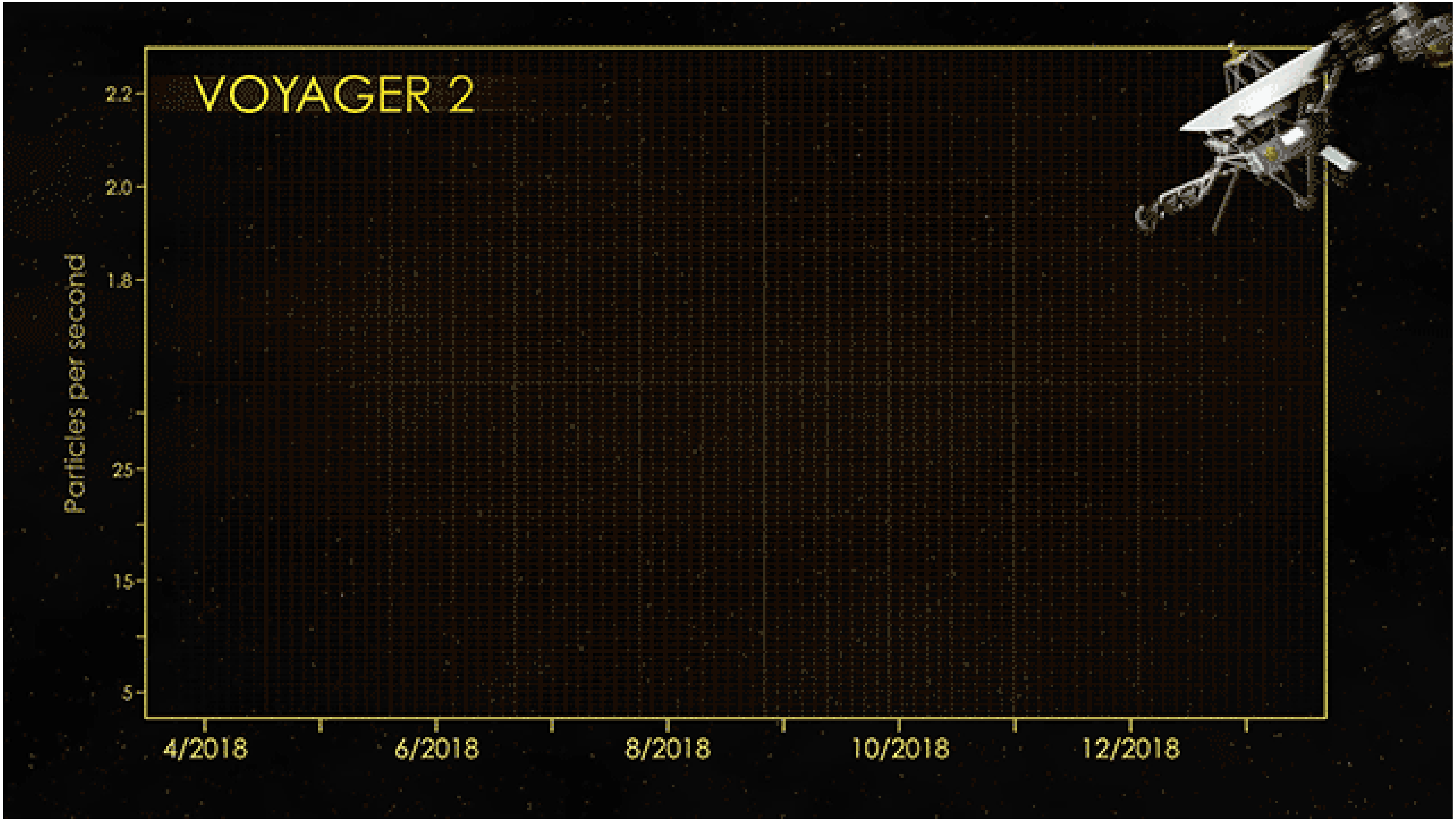
Voyager 1 crossed the termination shock in December 2004 at 94 AU.
Voyager 2 crossed the termination shock in August 2007 at 84 AU.



https://upload.wikimedia.org/wikipedia/commons/d/da/PIA17046_-_Voyager_1_Goes_Interstellar.jpg



https://upload.wikimedia.org/wikipedia/commons/d/da/PIA17046_-_Voyager_1_Goes_Interstellar.jpg



https://www.nasa.gov/sites/default/files/thumbnails/image/pia22924-640.gif

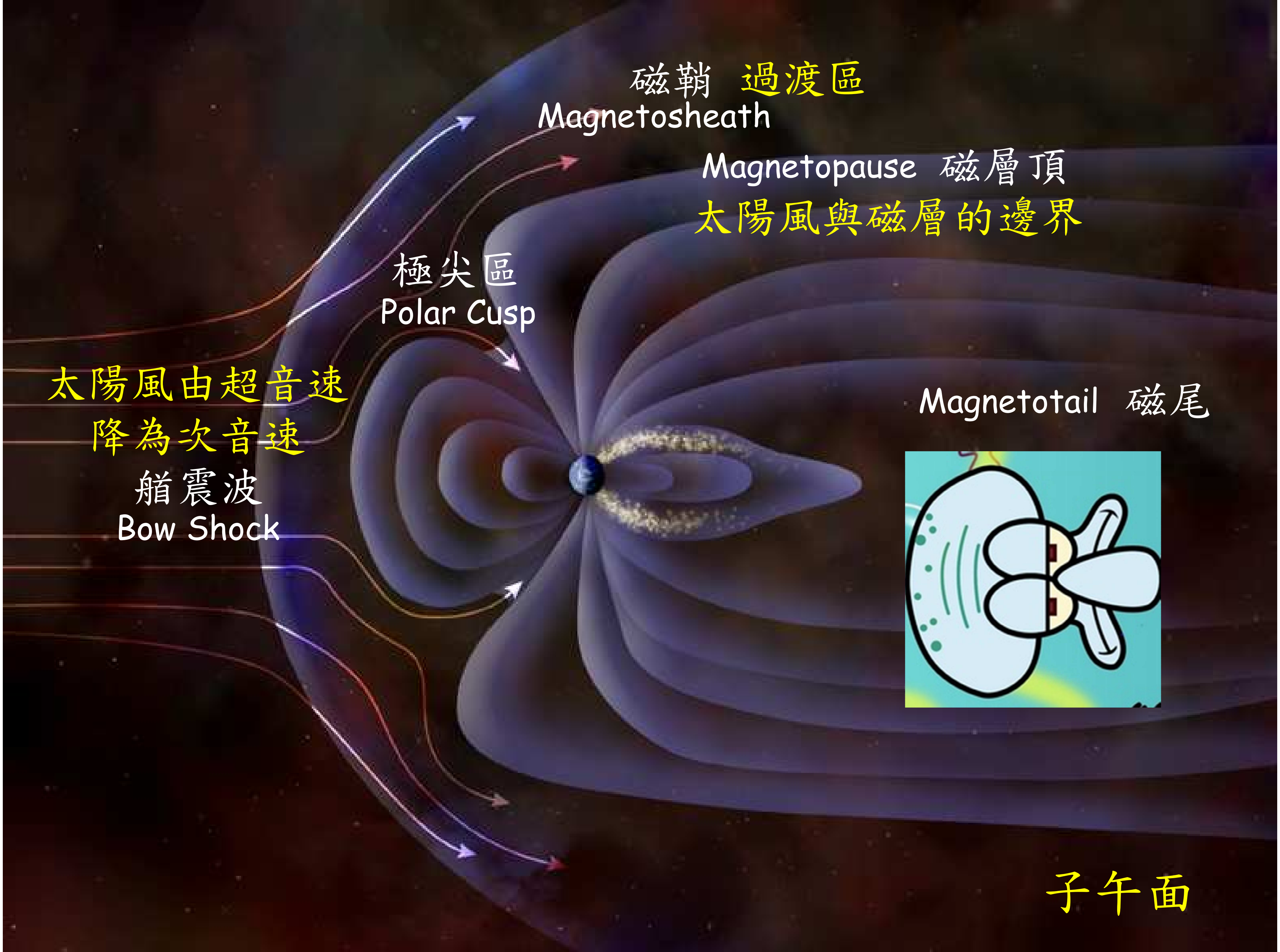
地球磁層

→磁層顧名思義是一個由磁場主導的區域，它並不是一個"層"狀結構。磁層頂為地球磁層的外邊界，是"地球磁場與電漿"和"太陽風磁場與電漿"交界的邊界層。但磁層與電離層之間兩者並無明顯的邊界。

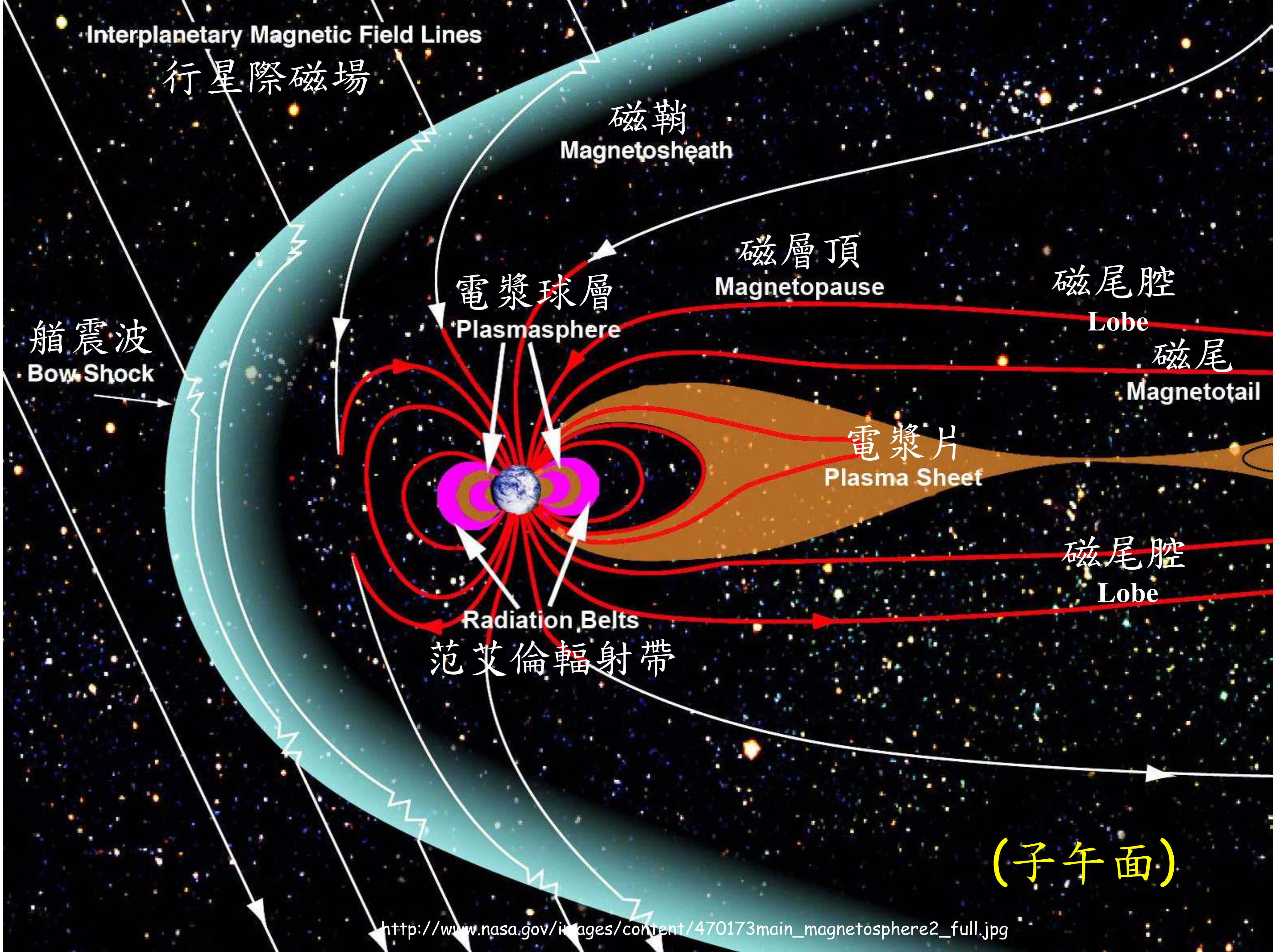
→磁層可視為完全游離的電漿態，磁層中的電漿大多數來自電離層，少數來自太陽風。電離層電漿中的主要正離子成份為氫離子及氧離子，而太陽風電漿中的主要正離子成份為氫離子及氦離子。

→當太陽風吹向地球時，地球原有的磁偶極場在向陽面會被壓的扁一點，而背陽面的地球磁場，則被拖拉成尾巴狀。整個地球磁場所佔據的勢力範圍，即為磁層。

為什麼地球磁場會由簡單的磁偶極場變形成為"日側被擠壓、夜側被拉長"的模樣? ←太陽風、地球磁層中的電流系統



http://www.halibutherald.com/wp-content/uploads/2010/03/earth_mag_auro_illustration_nolabel.jpg



http://www.nasa.gov/images/content/470173main_magnetosphere2_full.jpg

→艏震波(bow shock)

當高速的太陽風撞擊地球磁層時，因為受到地球磁場的阻擋必須停下來，於是太陽風速大減。當太陽風速由超音速減小到次音速的地方，就會自然的形成一個激震波。因為這個激震波的外型，與船在水中航行時，船首前方所形成的艏波(bow wave)很像，因此又稱為艏震波。

→磁鞘(magnetosheath)

介於艏震波與磁層頂之間的亂流區域。磁場擾動大，本區電漿可來自磁層及太陽風。

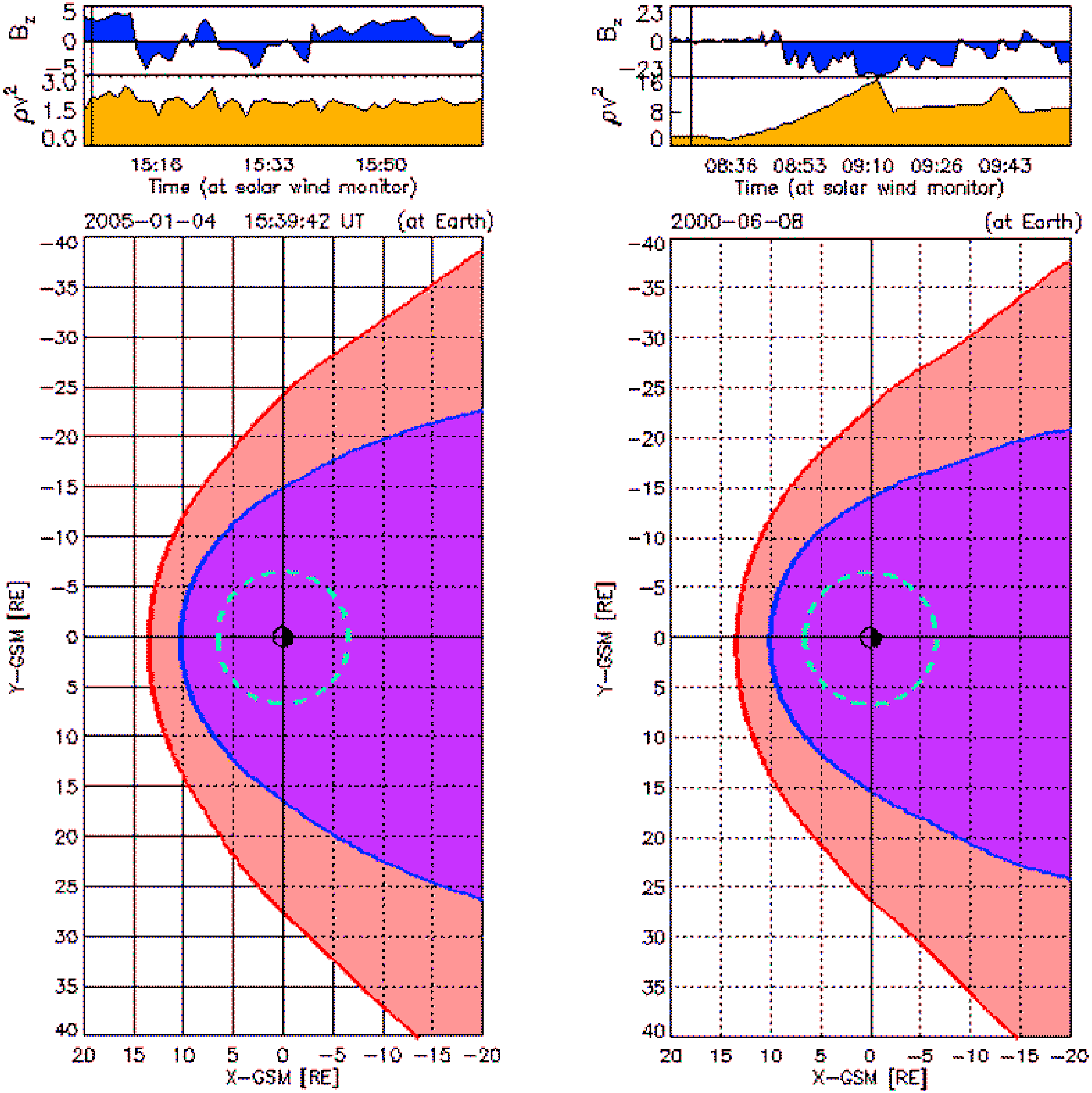
→磁層頂(magnetopause)

位於磁層與太陽風接壤處的明顯邊界。內側為磁層電漿，密度低、溫度高。外側為磁鞘電漿，密度高、溫度低。

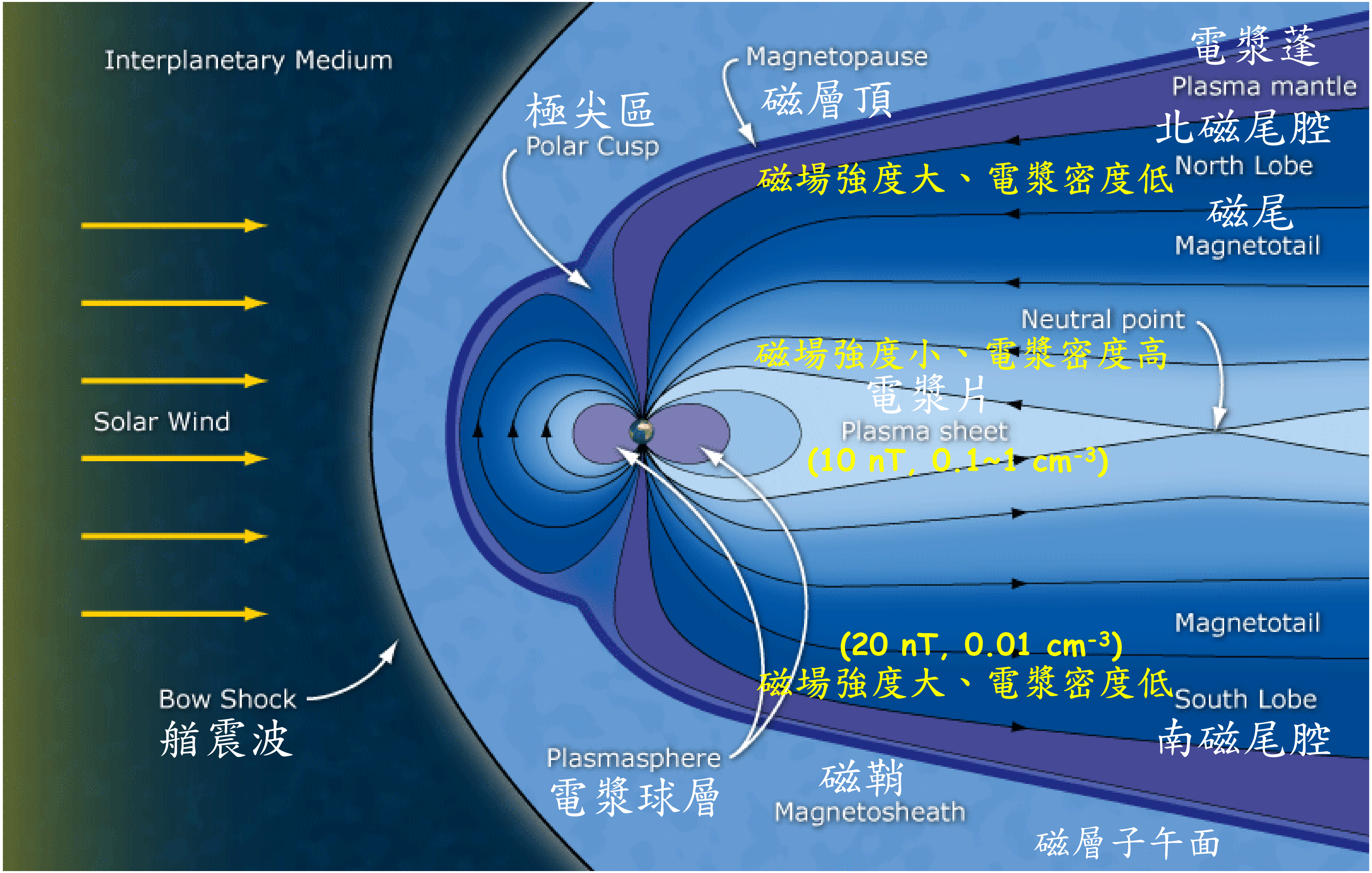
→極尖區(polar cusp)

位於南北磁極呈喇叭狀的區域，該區的磁場線與太陽風中的行星際磁場線相接，使得太陽風的電漿可沿著磁場線直接進入極尖區。

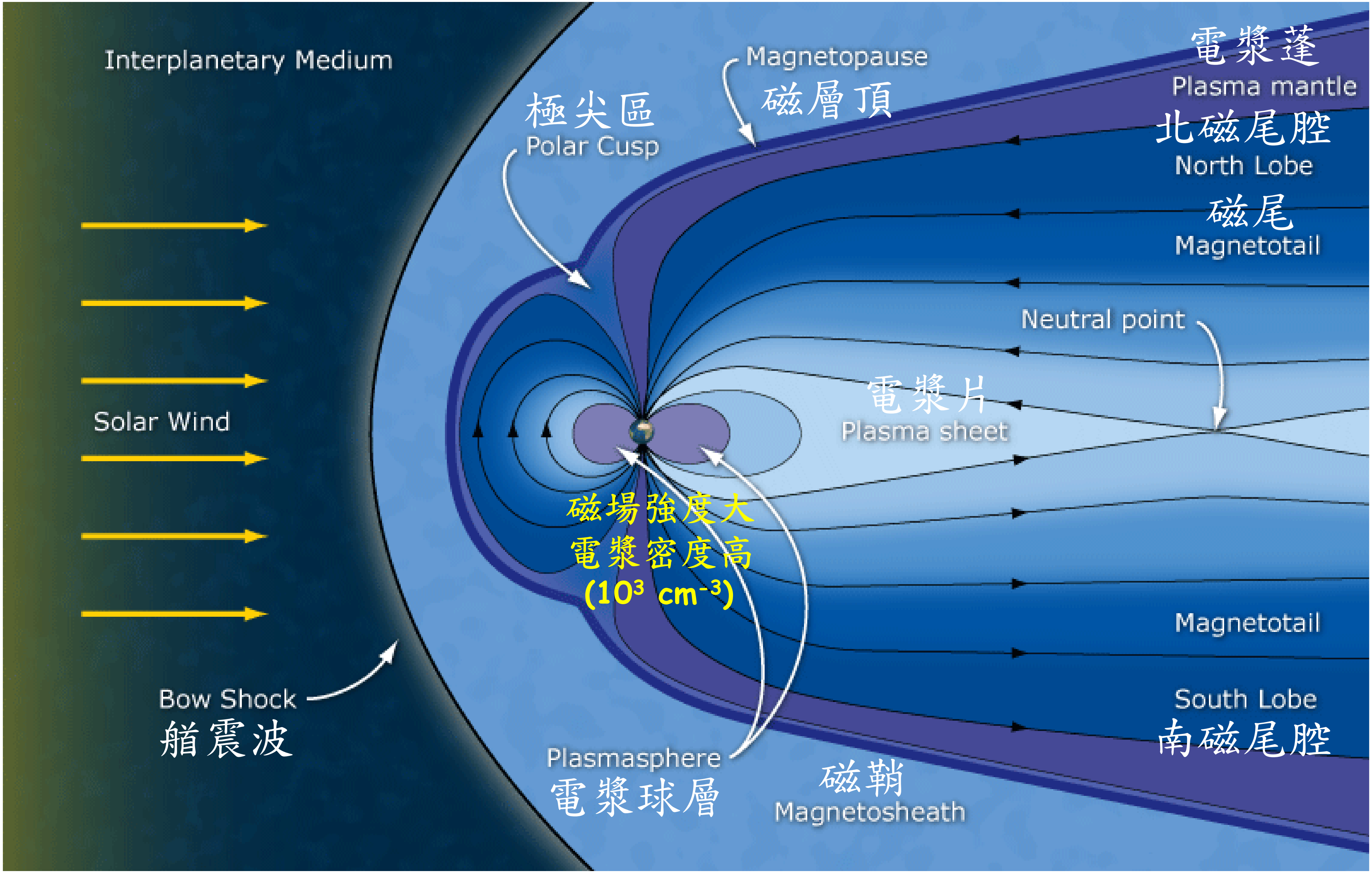
http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html



Credit: S.M. Petrinec, Lockheed Martin



http://www.weirdwarp.com/wp-content/uploads/2012/04/Earths-Magnetosphere.gif

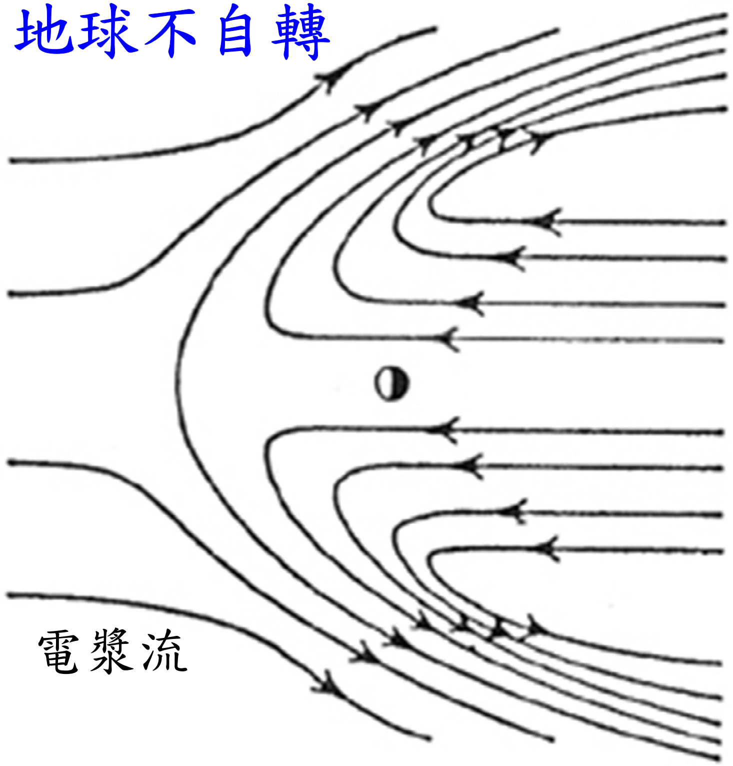


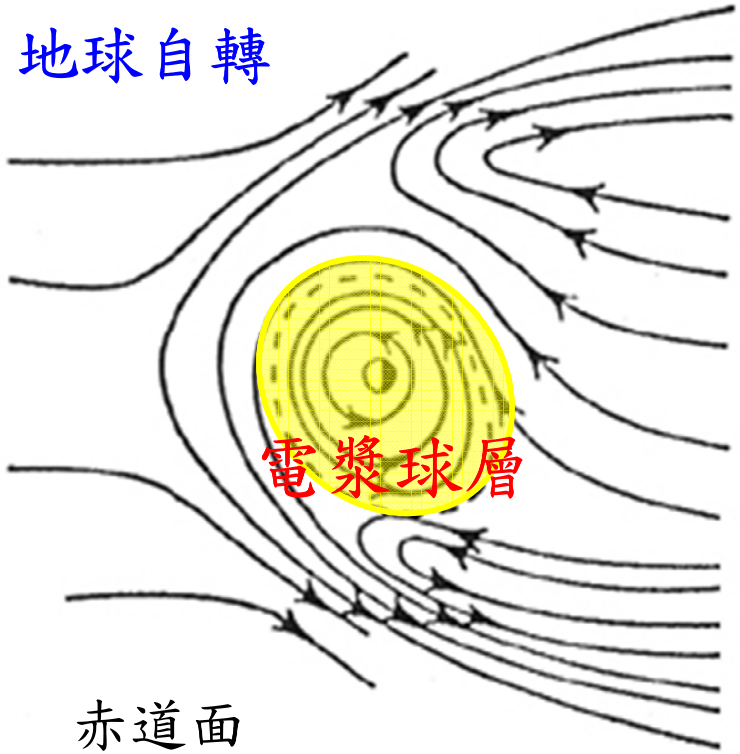
http://www.weirdwarp.com/wp-content/uploads/2012/04/Earths-Magnetosphere.gif

→電漿球層(plasmasphere)

離地球最近的內磁層區域，該區磁場很強、電漿密度也很高。其形成與地球自轉有密切的關係。電漿球層的電漿主要來自中、低緯電離層，少部分的高能粒子來自磁層，很少數的高能粒子來自磁尾電漿片及外太空。

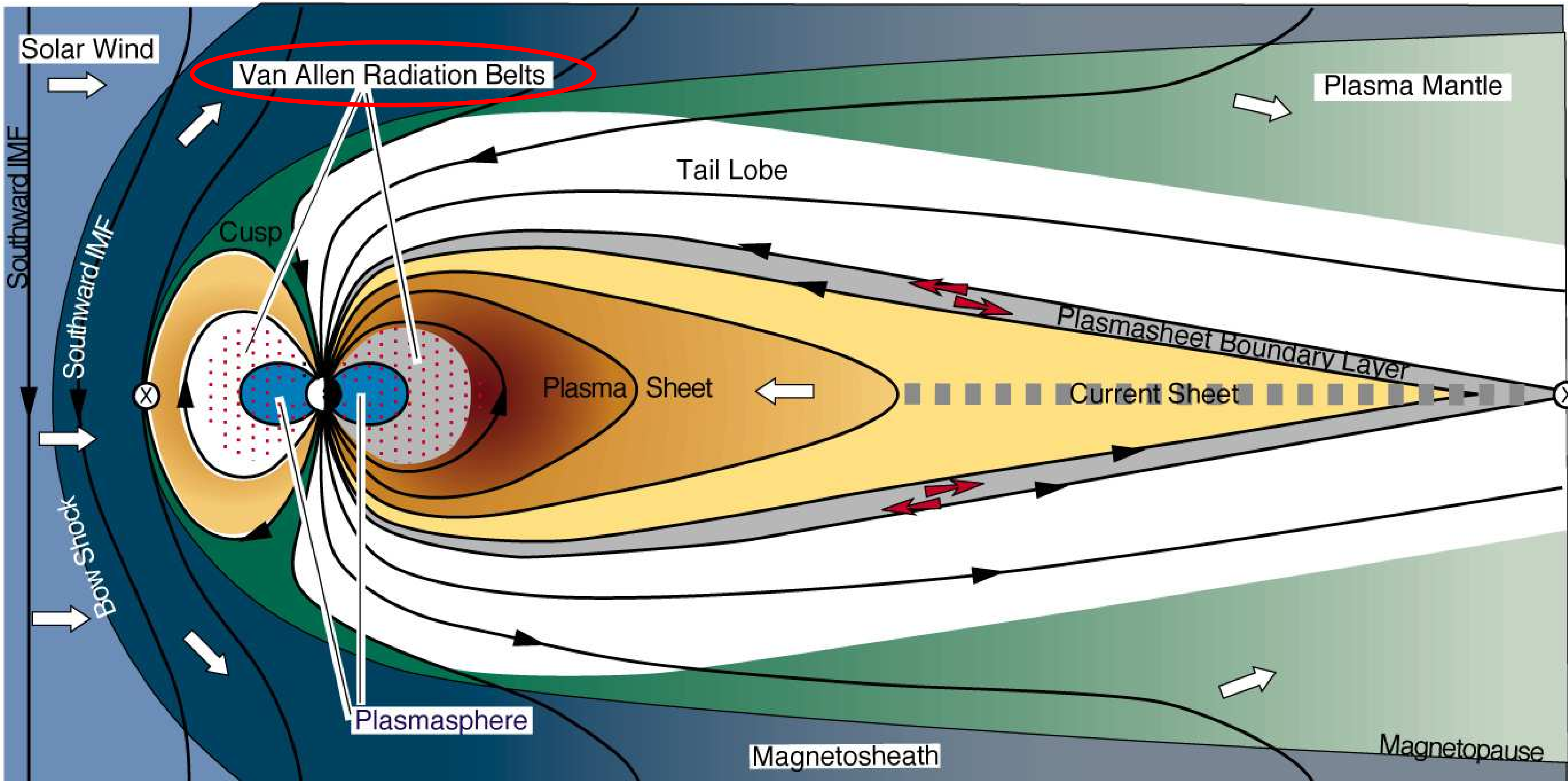
電漿球層頂(plasmapause)內外的電漿密度相差超過一千倍。電漿球層頂的位置決定了電漿球層的大小。電漿球層頂的位置會隨著太陽風所產生的晨昏方向的電場強度增強而內移，也會隨著磁層頂的位置內移而內移。行星自轉越快，電漿球層越大。





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

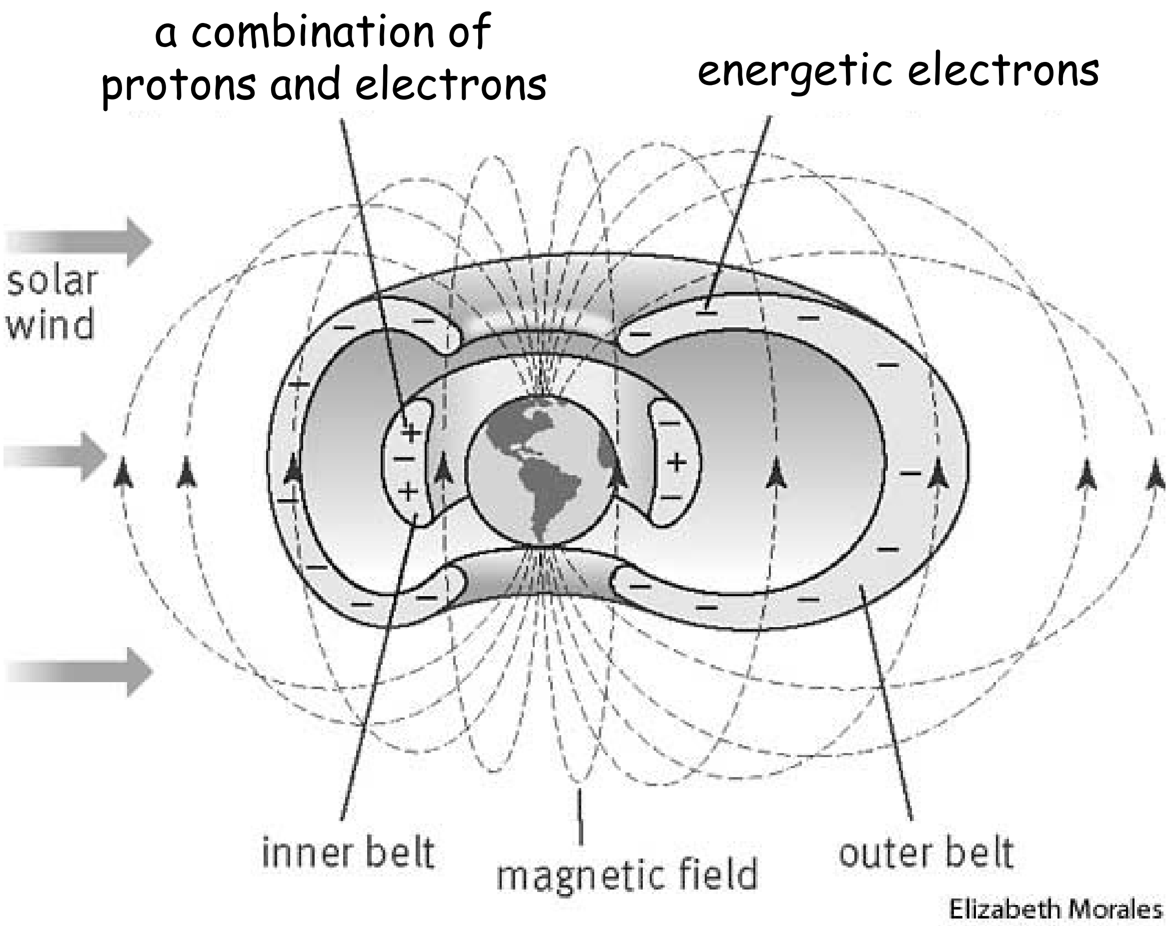
范艾倫帶



地球磁層子午面

http://space.rice.edu/IMAGE/livefrom/5_magnetosphere.jpg

→范艾倫帶(Van Allen Radiation Belt)



內范艾倫帶是因超新星爆炸產生的高能宇宙射線粒子打入磁層後，被電漿球層的強磁場束縛住，同時又與電漿球層內其他粒子碰撞，產生更多新的高能粒子而構成。

外范愛倫帶是由磁尾的電漿粒子(來自高緯電離層或太陽風)被磁尾區的晨昏電場加速後，灌進電漿球層中或其鄰近區域所構成。來自磁尾的高能粒子數量很多，但其能量不如超新星爆炸產生的高能宇宙射線能量高，因此無法深入到內范艾倫帶。

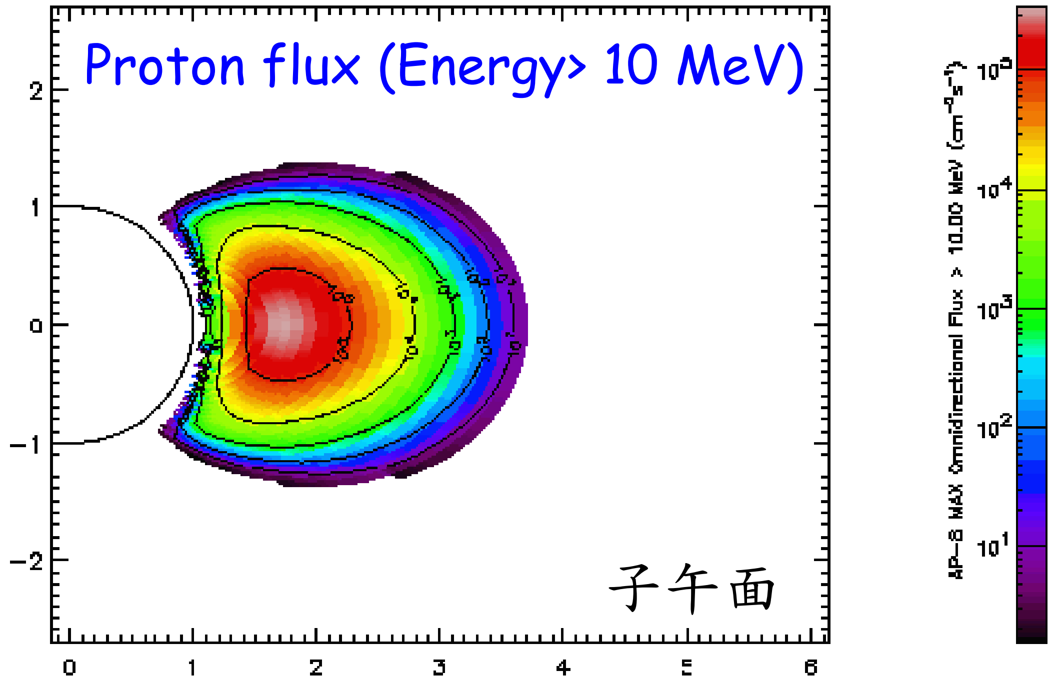
一般來說，內范艾倫帶裡的高能質子多，外范艾倫帶裡的高能電子多。

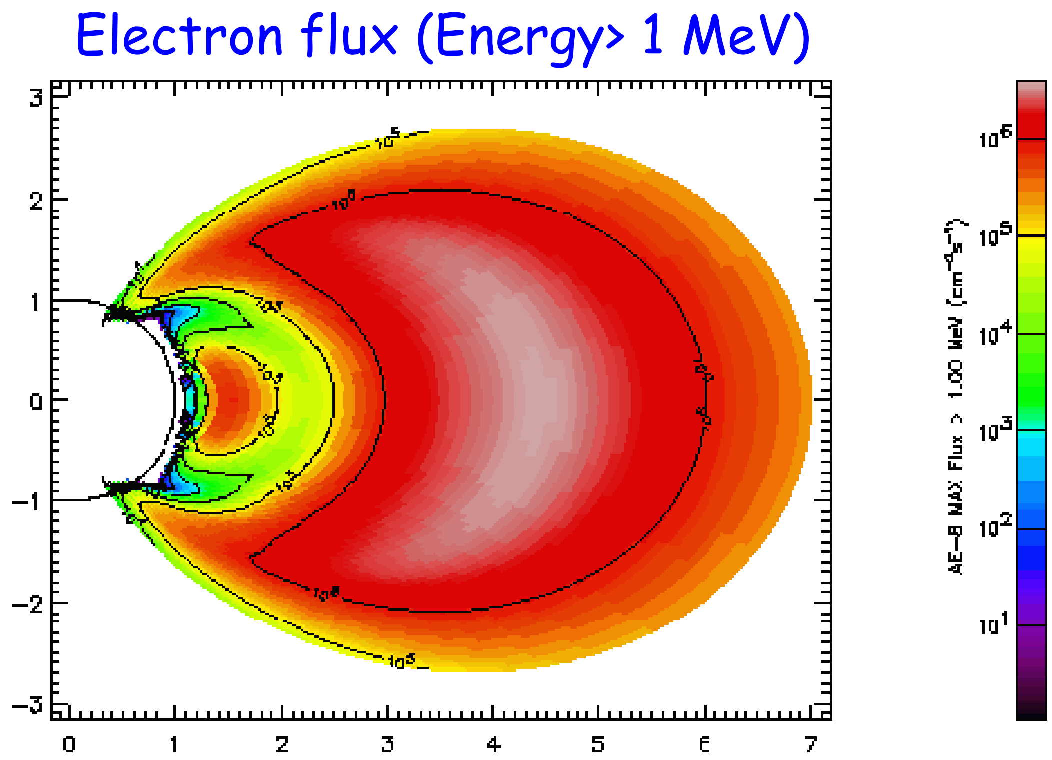
http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

內范愛倫帶約位於1~2個地球半徑上空，而外范愛倫帶約位於4~5個地球半徑上空。

電漿球層頂的平均位置約為5~6個地球半徑上空，但有時可內移至3~4個地球半徑。所以內范愛倫帶一定位在電漿球層內部，而外范愛倫帶有時在電漿球層內，有時則在電漿層頂外。

內、外范愛倫輻射帶的分野可由高能電子的分布圖看出來。

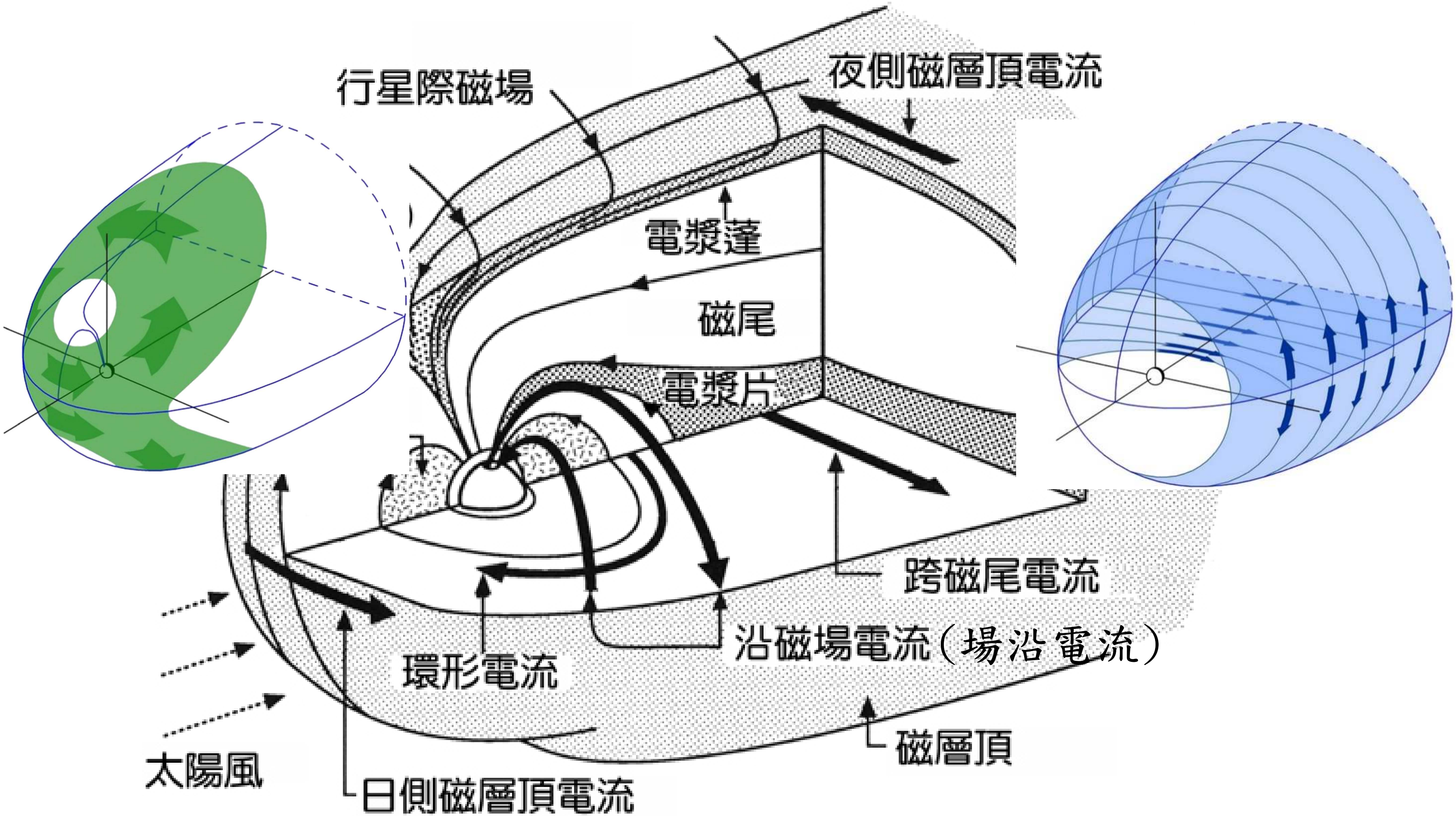




http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html

http://image.gsfc.nasa.gov/poetry/tour/AAvan.html

地球磁層電流系統



http://www.ss.ncu.edu.tw/~lyu/lecture_files/IntroSpace.html Credit: Ganushkina et al. (2018)

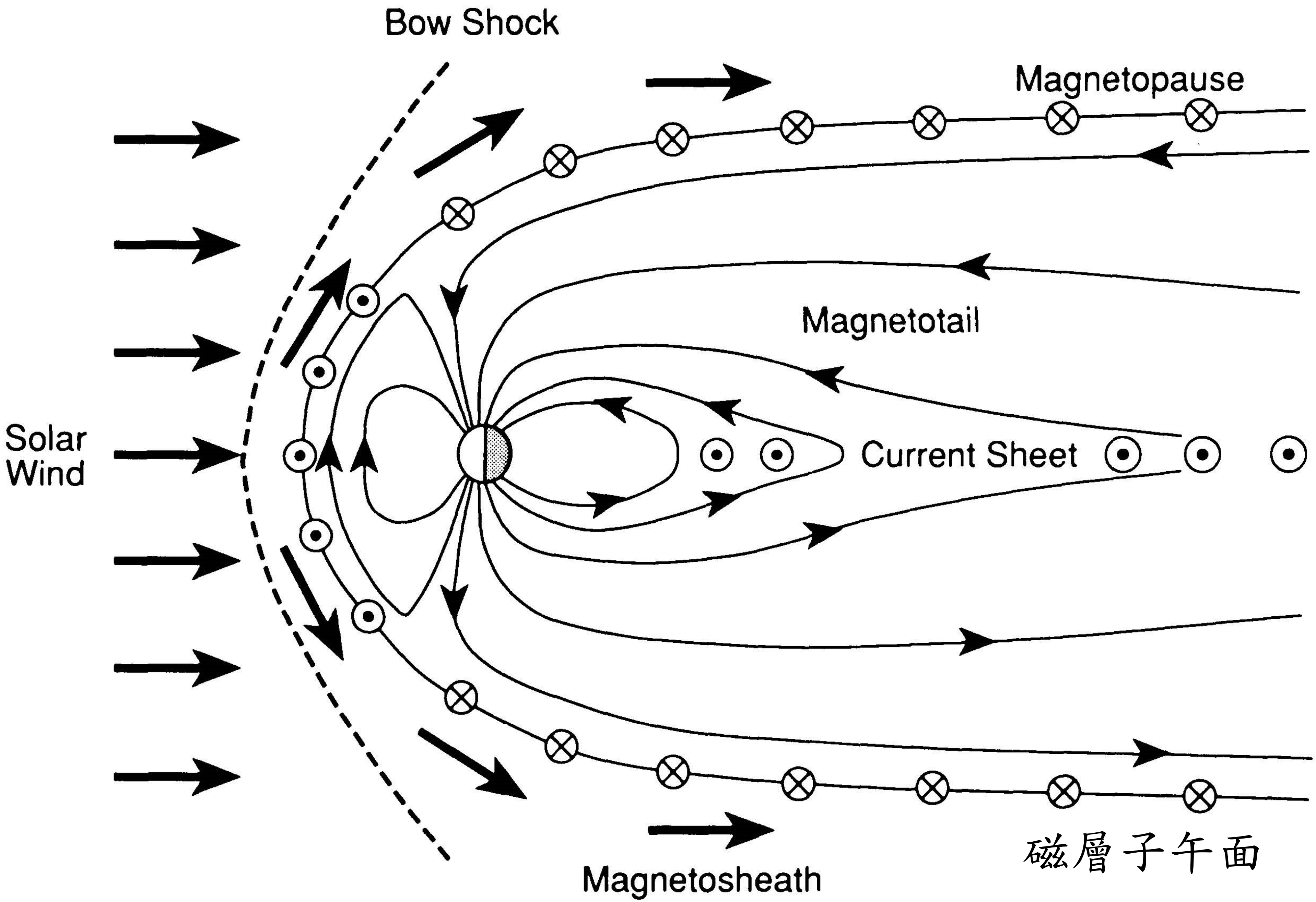
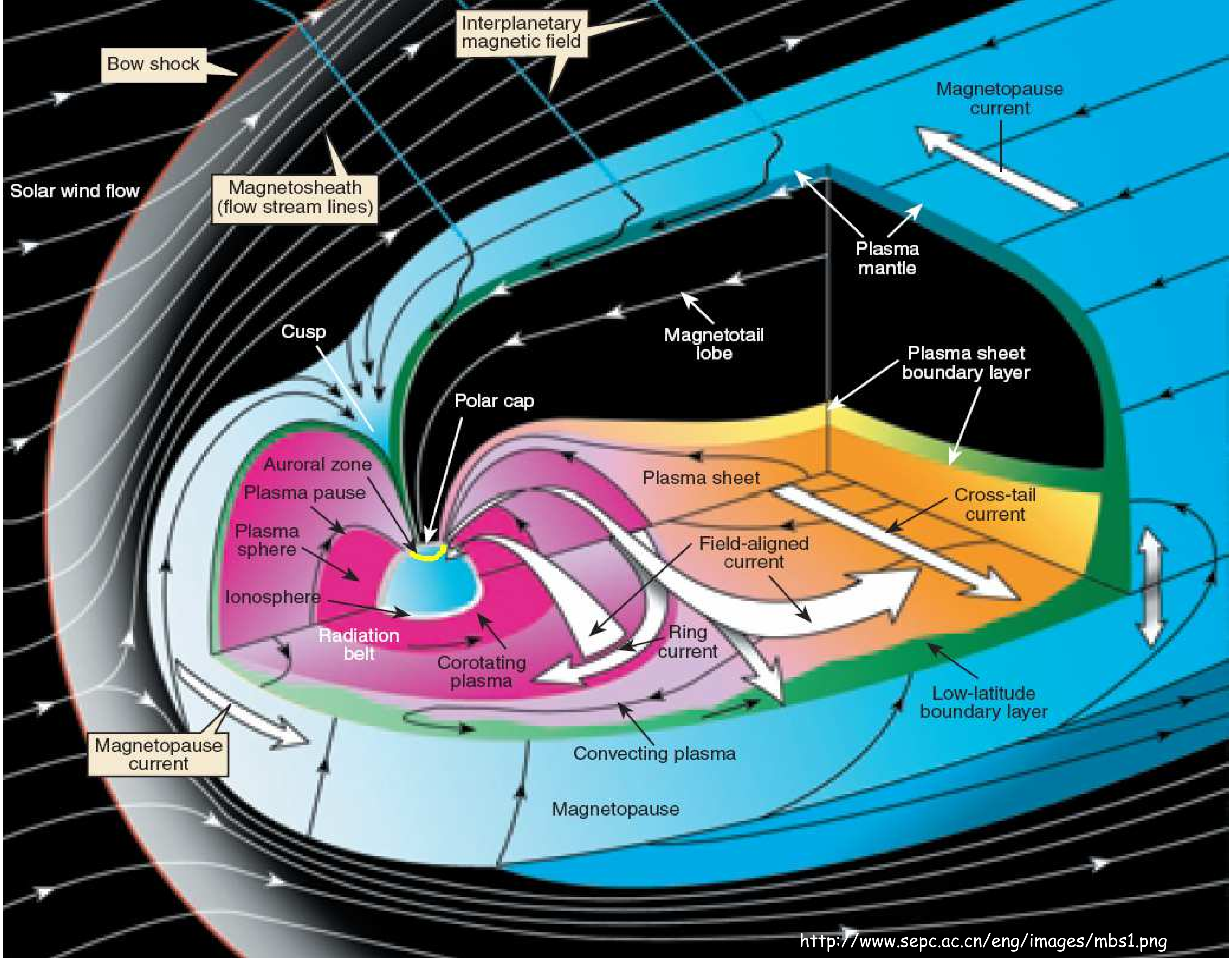
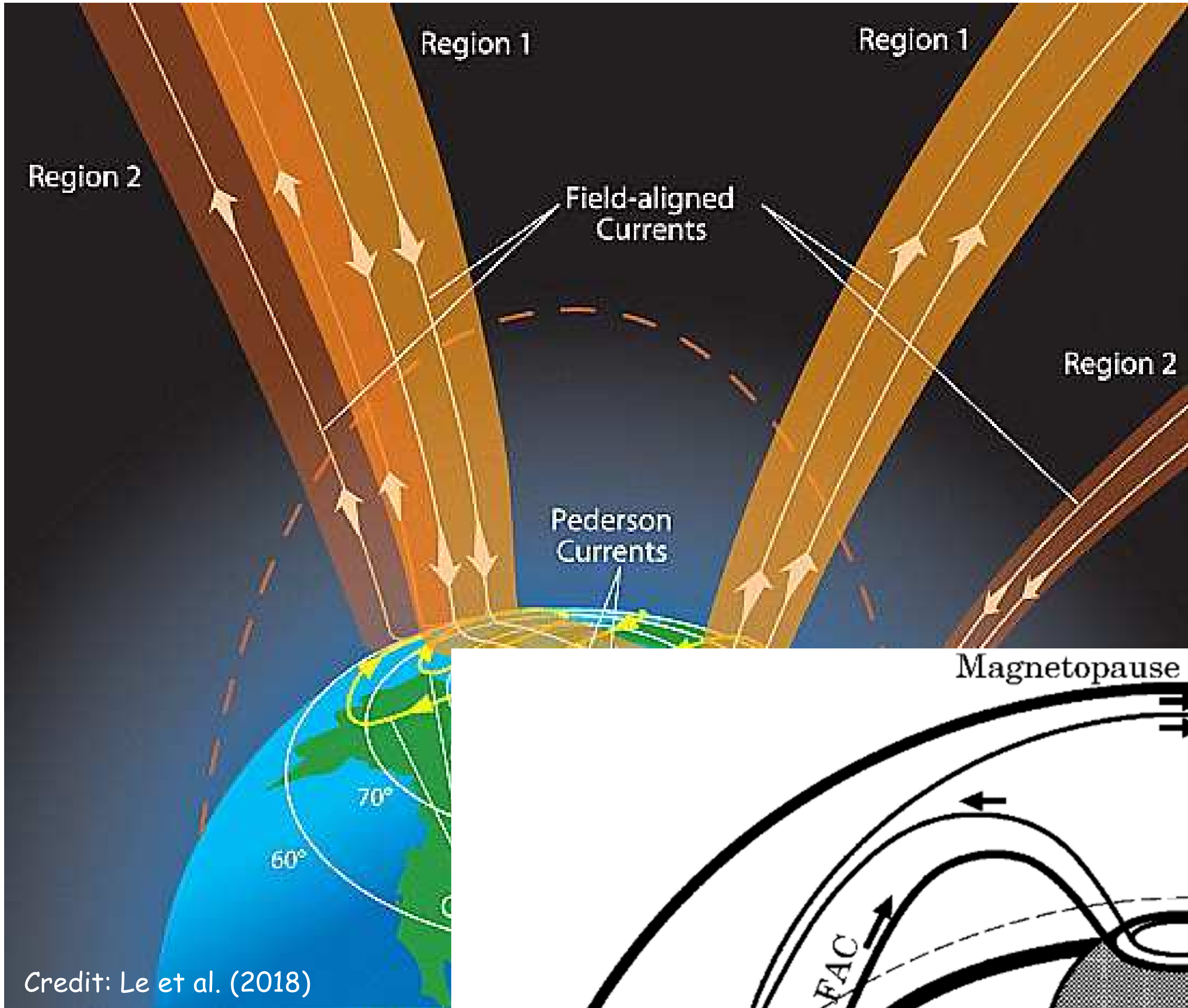


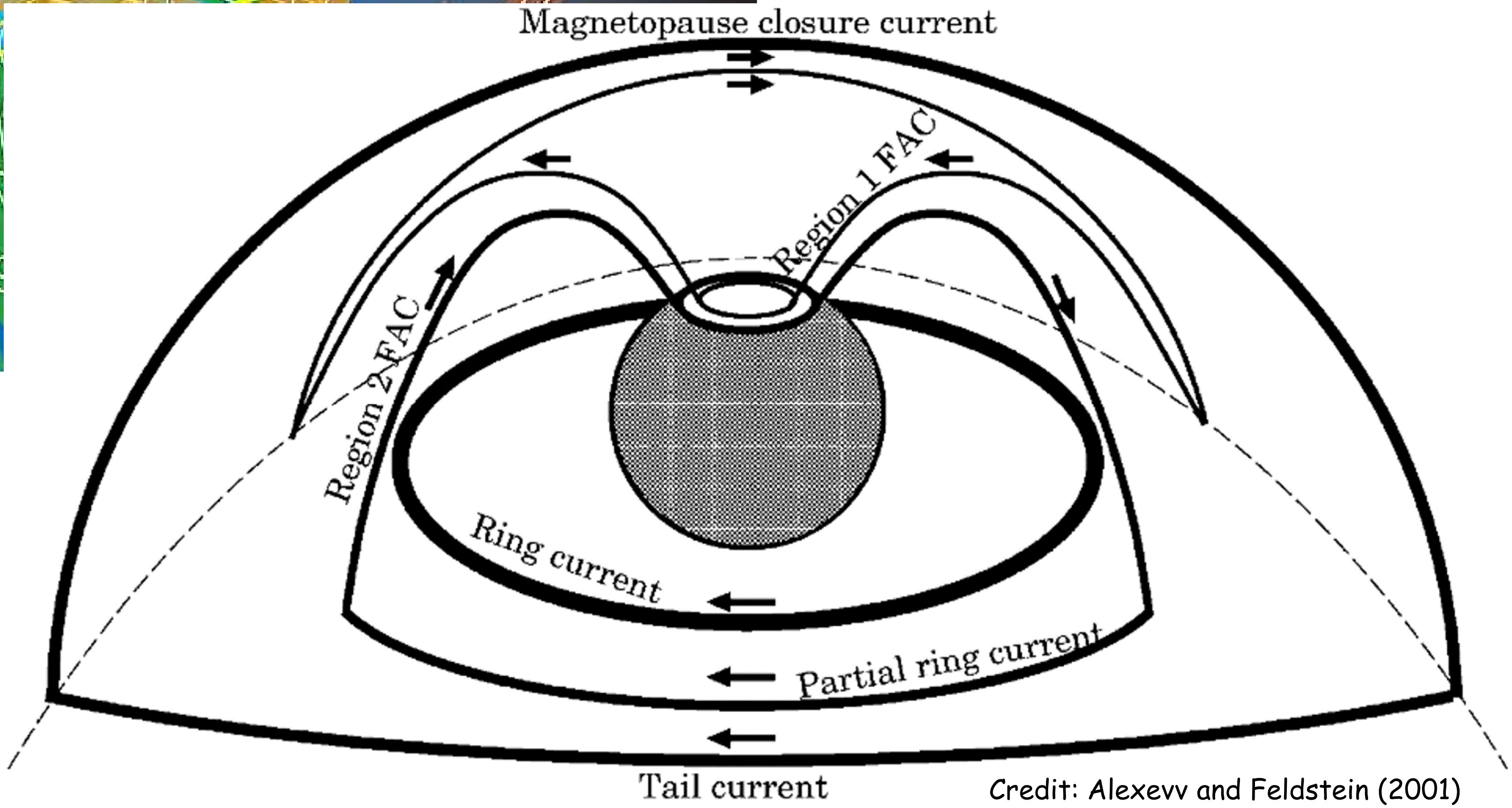
Fig. 9.1 in M. G. Kivelson and C. T. Russell (1995)



http://www.sepc.ac.cn/eng/images/mbs1.png



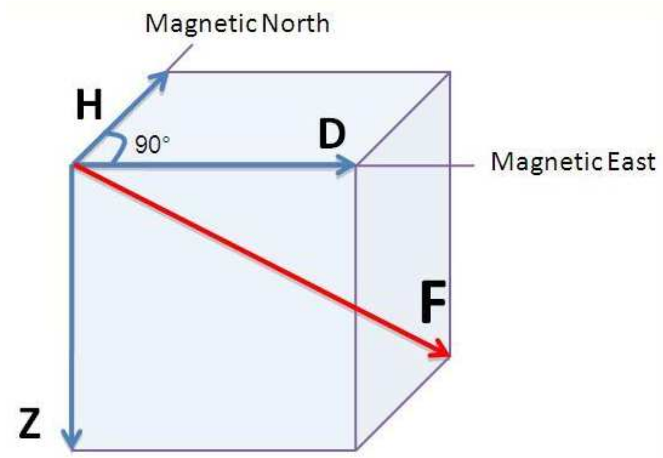
Credit: Le et al. (2018)

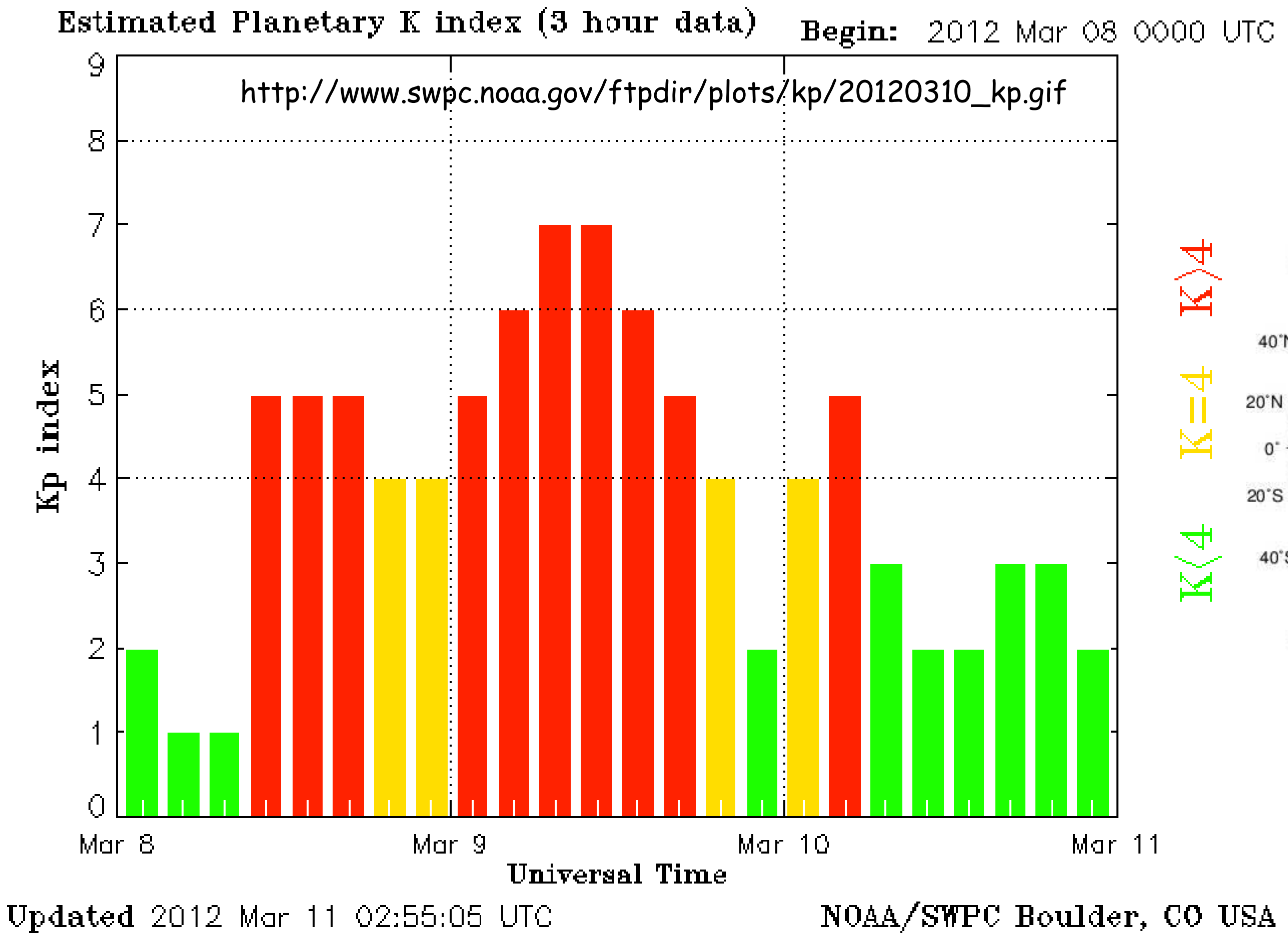


Credit: Alexevv and Feldstein (2001)

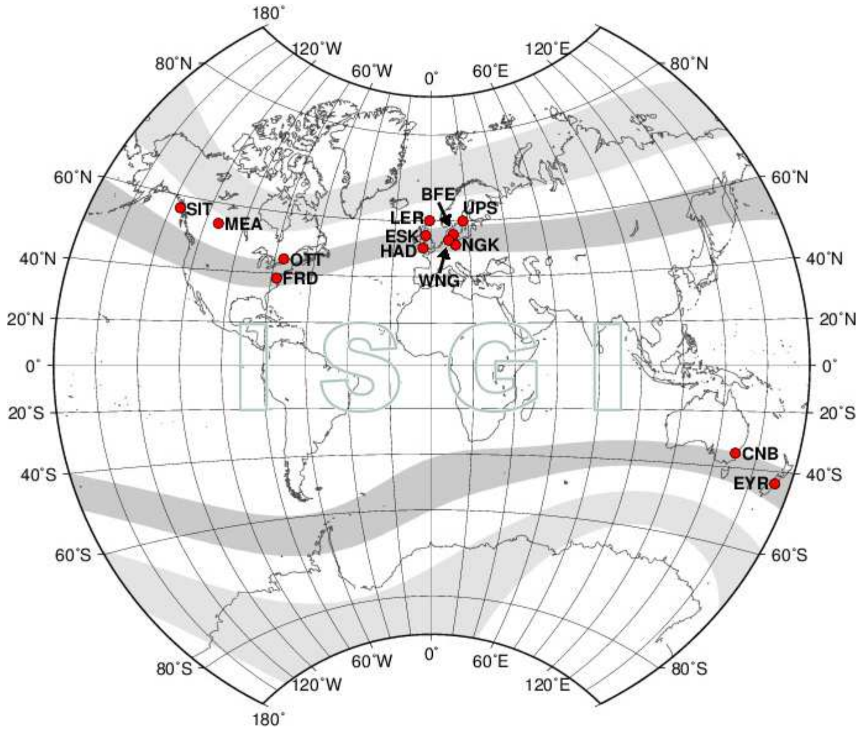
Kp Index

The Kp index is estimated from the average of the disturbance levels in the most disturbed horizontal magnetic field component (H or D) at 13 selected mid-latitude stations during three-hour period.





http://www.thecamino.com.ar/KPindex.htm



Credit: SIIG/ISGI

http://wwwuser.gwdg.de/~rhennin/kp.html

磁暴(magnetic storm)

→持續時間約3天至一個多星期

→影響地表中低緯度區域

→過程:

initial phase:

日側磁層頂內移，日側磁層頂電流強度增強，中低緯地表北向磁場分量增強

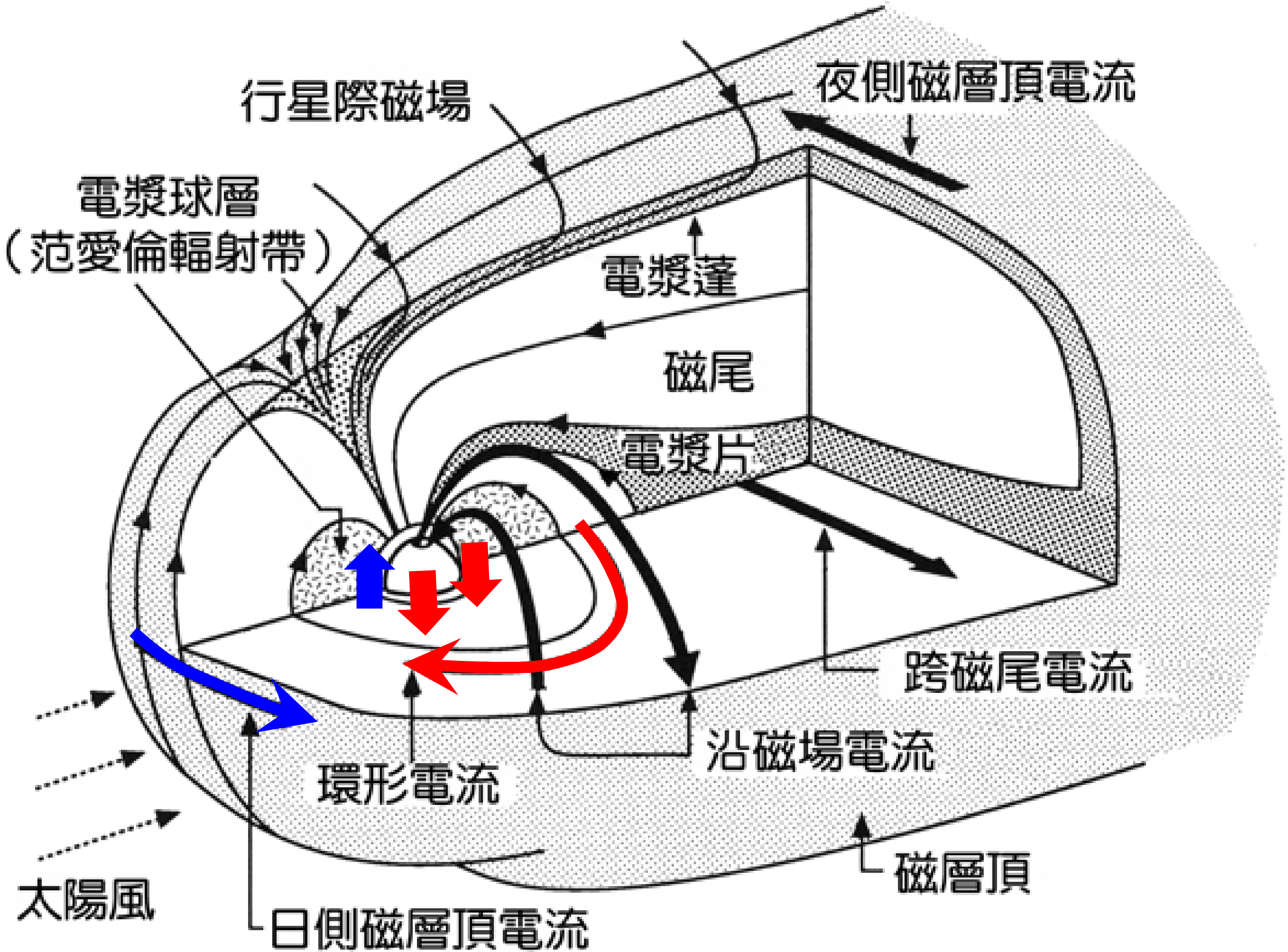
main phase:

電漿球層頂內移，范愛倫輻射帶的高能粒子數目增多，環形電流強度增強，中低緯北向磁場分量減弱

recovery phase:

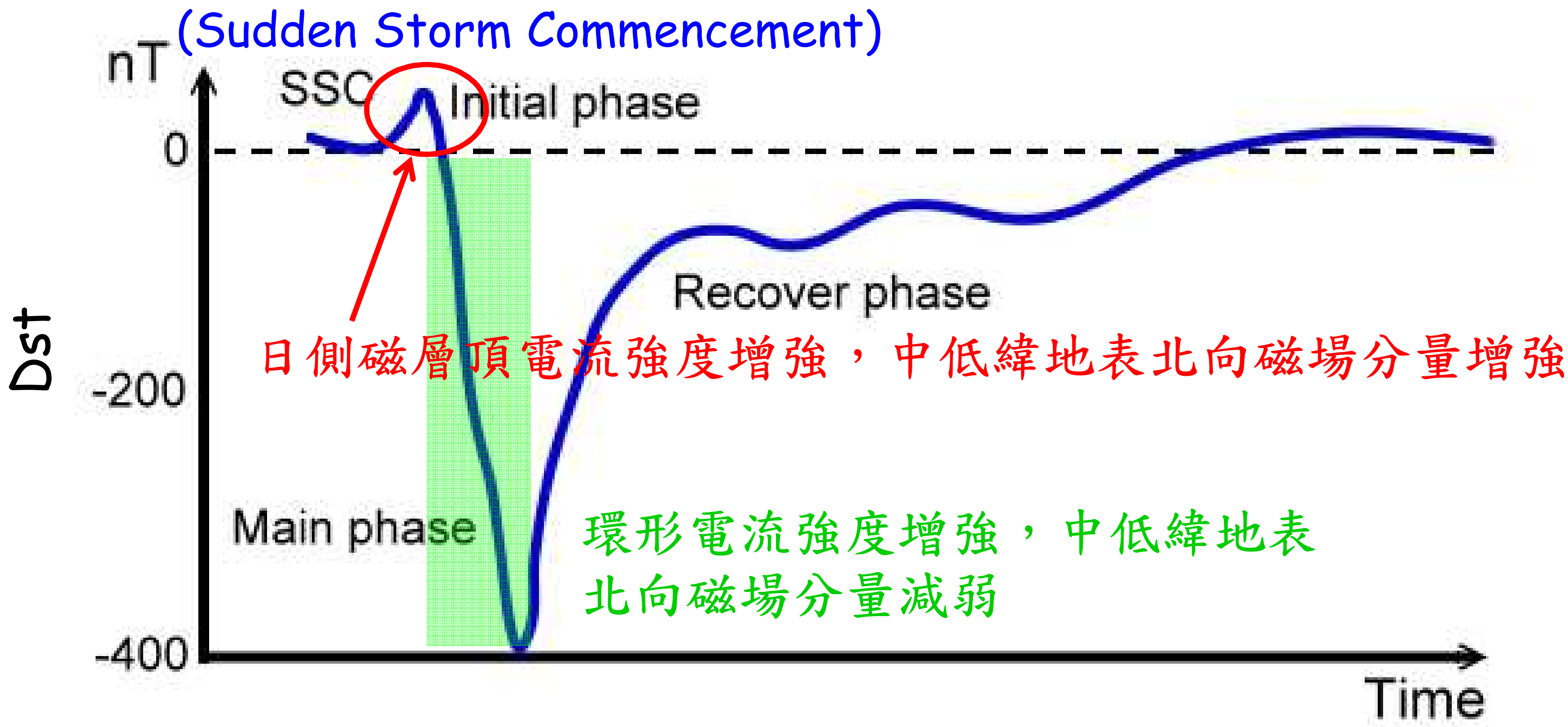
磁層頂與電漿球層頂還原到安靜期的位置

地球磁層電流系統



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

Dst (Disturbance Storm Time) Index

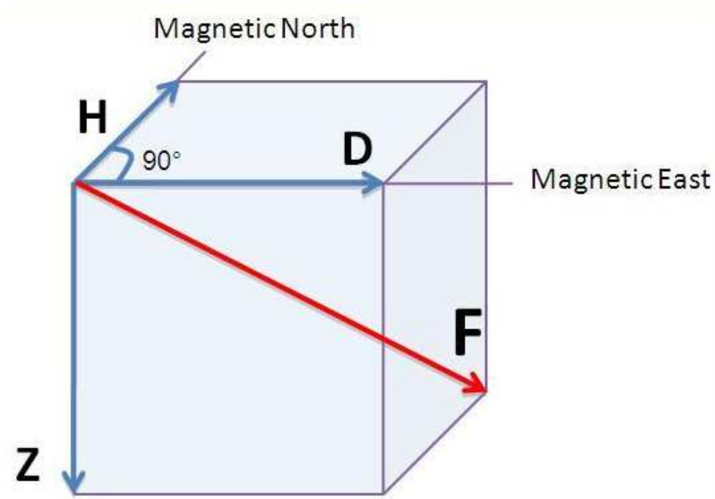


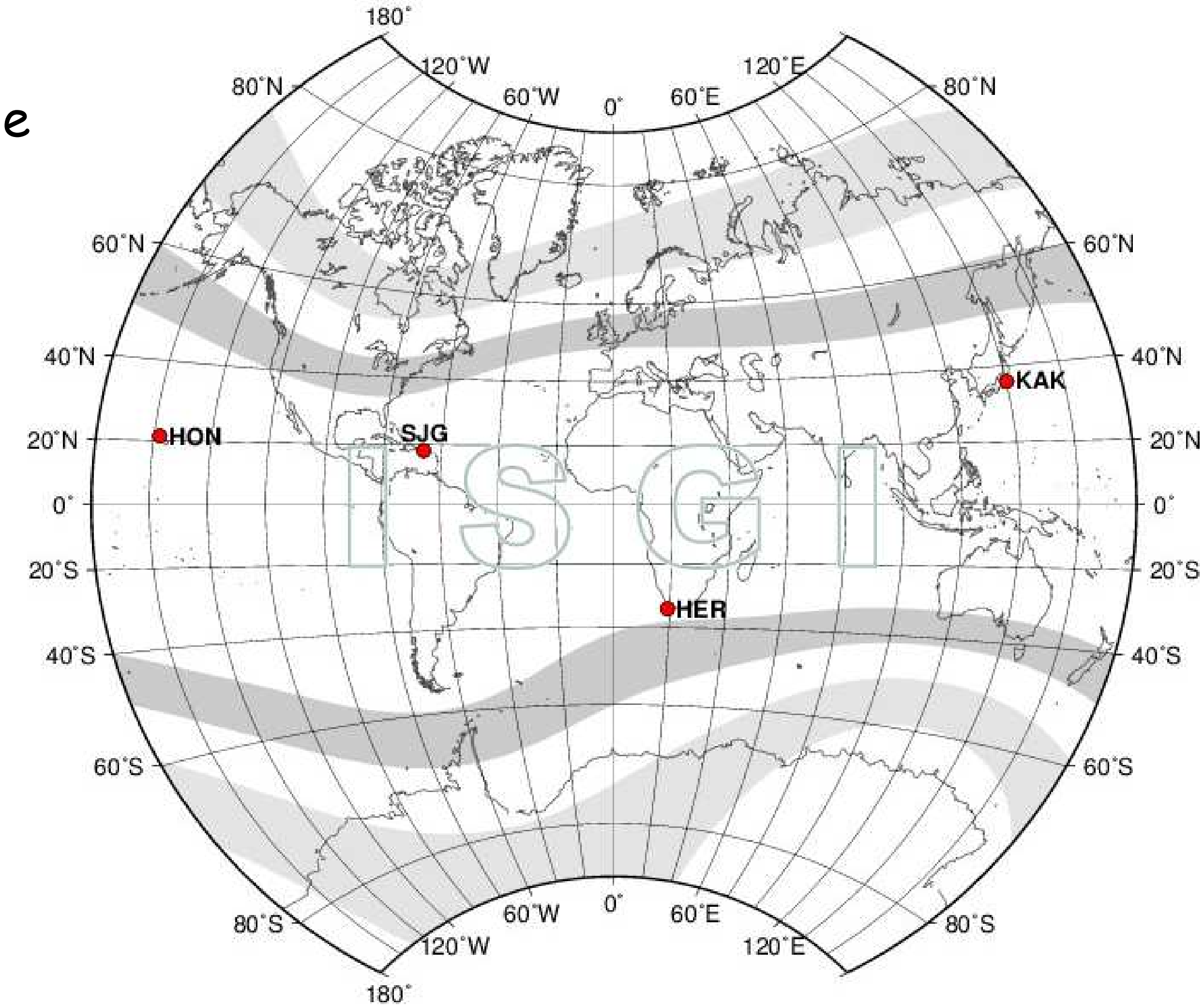
http://roma2.rm.ingv.it/en/themes/23/geomagnetic_indices/27/dst_index

Dst (Disturbance Storm Time) Index

Dst is derived from the average of H (northward) component disturbances of the geomagnetic field measured hourly at four low-latitude magnetic observatories and is expressed in nanoteslas.

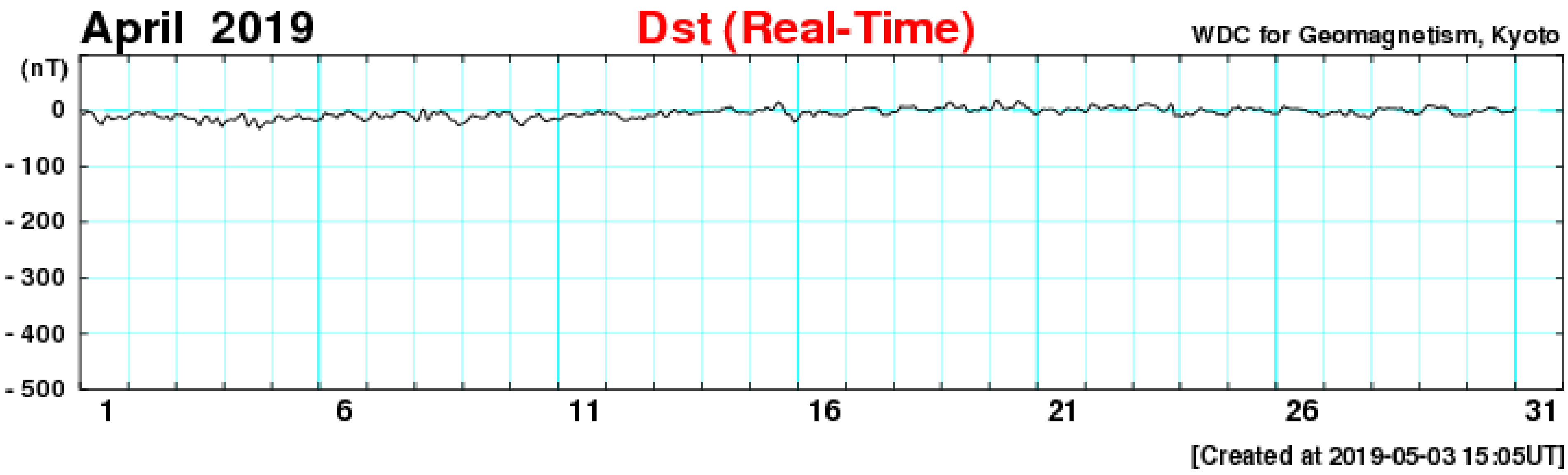
Dst is a geomagnetic index which monitors the world-wide magnetic storm level and has long been used as an indirect measure of the ring current.

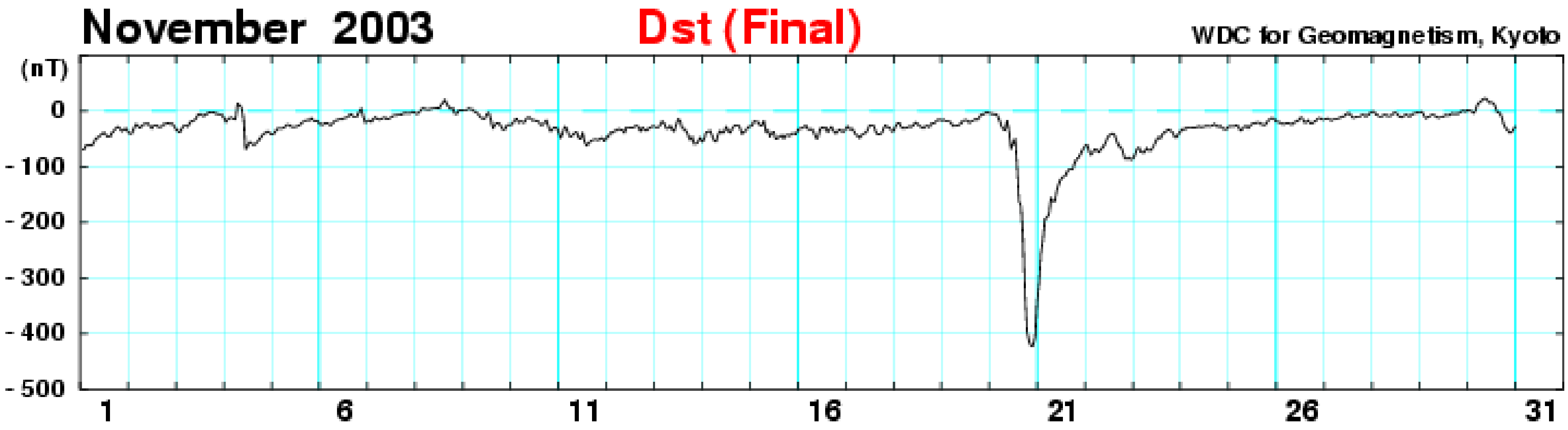




http://pluto.space.swri.edu/image/glossary/dst.html

Credit: SIIG/ISGI





http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html

磁副暴(magnetic substorm)

→持續時間約3小時

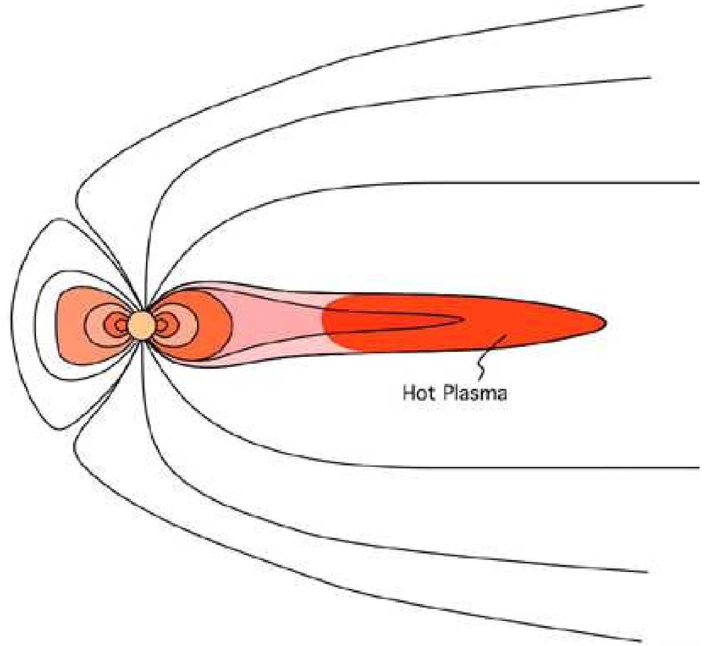
→影響地表高緯度區域

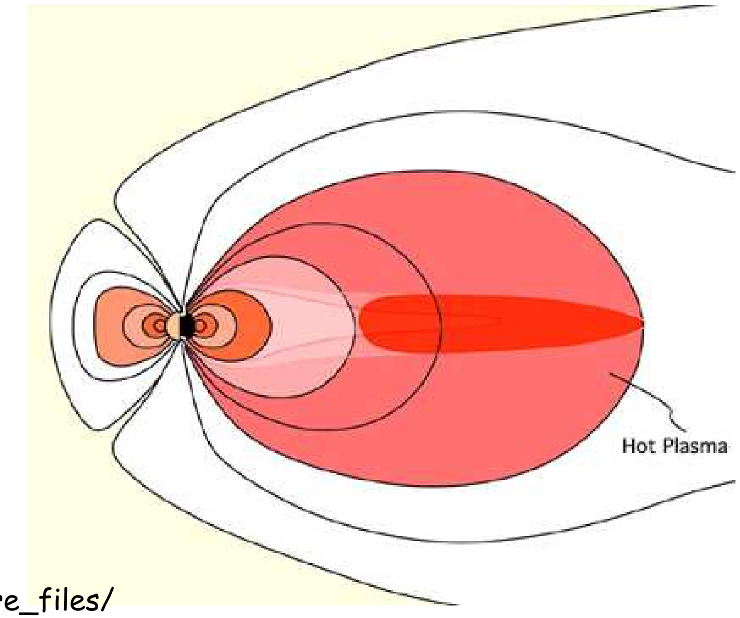
→過程:

grow phase:磁尾電漿片變薄，連原來接近磁偶極場區域的磁場也被拉長成磁尾的形狀，跨磁尾電流逐漸增強

expansion phase:磁尾電漿片變厚，磁場變成比較像磁偶極場的結構。

recovery phase:磁層還原為成長期以前的模樣

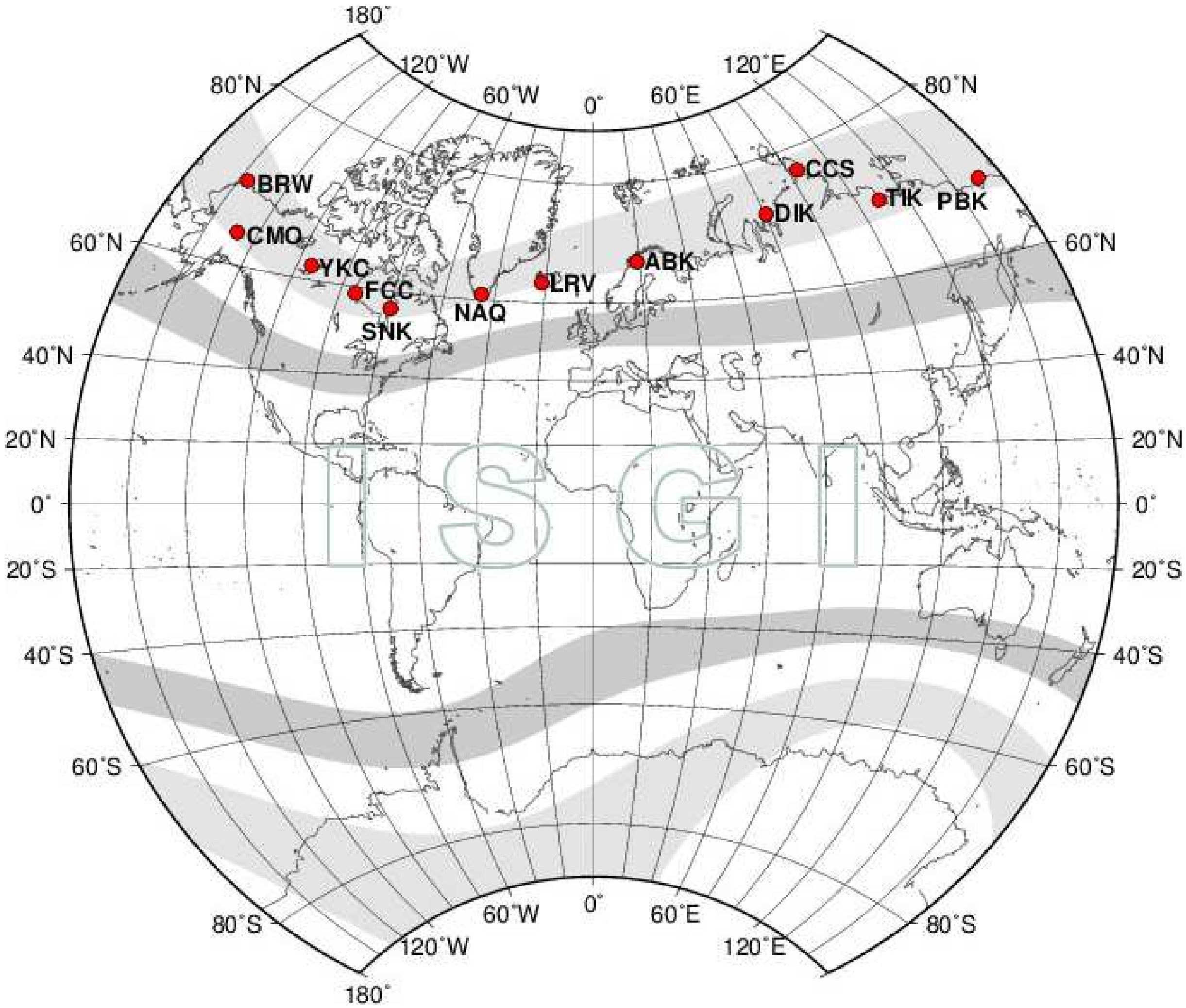


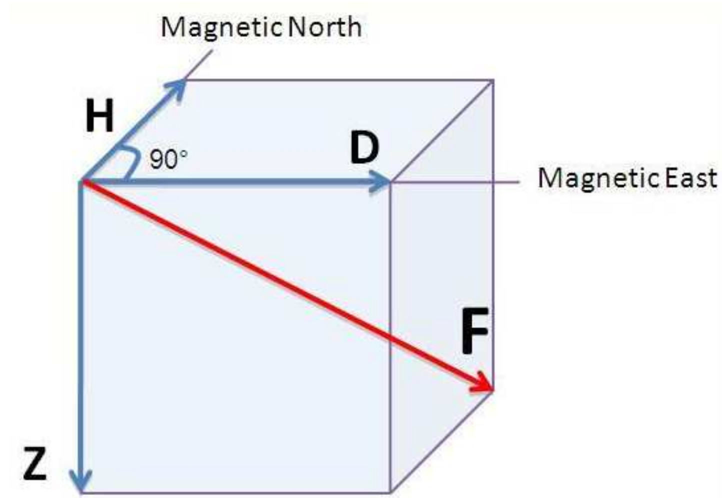


http://www.ss.ncu.edu.tw/~lyu/lecture_files/

AE (Auroral Electrojet) Index

The AE indices (AU, AL, AO, and AE) are derived from geomagnetic variations in the horizontal component during one-minute interval observed at selected observatories along the auroral zone in the northern hemisphere.

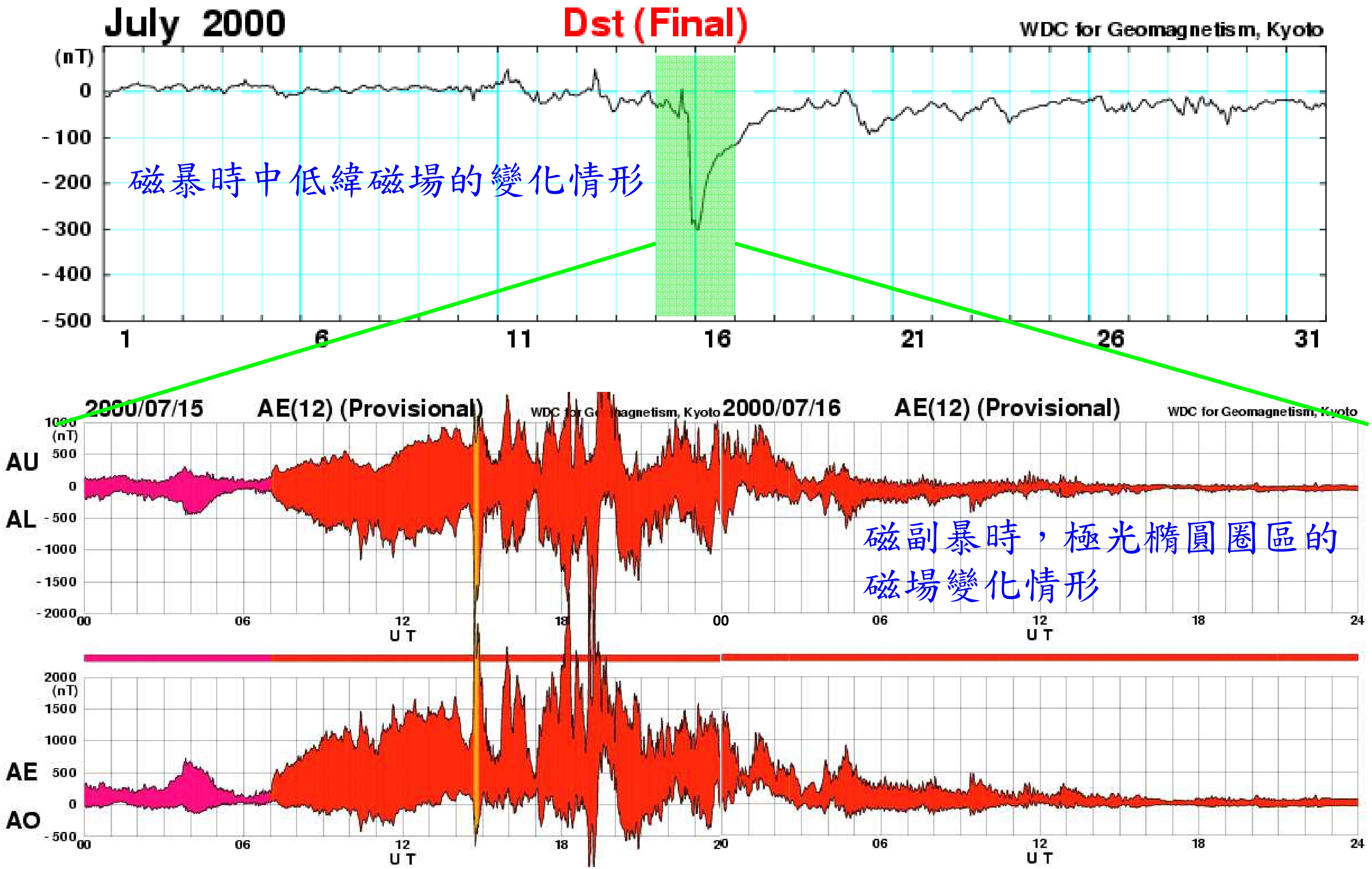




Credit: SIIG/ISGI

http://wdc.kugi.kyoto-u.ac.jp/aedir/ae2/AEObs.html

磁暴與磁副暴



磁暴時中低緯磁場的變化情形

磁副暴時，極光橢圓圈區的磁場變化情形

http://wdc.kugi.kyoto-u.ac.jp/aedir/index.html

http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html