太陽黑子分類

蘇黎世黑子群分類法

A	單極性黑子，沒有半影
B	雙極性黑子，但都有半影
C	雙極性黑子，其中一端有半影
D	雙極性黑子，兩端黑子都有半影，東西延長方向不超過10度
E	雙極性黑子，兩端黑子都有半影，東西延長方向在10度到15度之間
F	雙極性黑子，兩端黑子都有半影，東西延長方向超過15度
G	和E、F型相同的條件，但在兩端黑子的半影間沒有任何黑子
H	單極黑子，有半影，且最少直徑達2.5度
J	單極黑子，有半影，且直徑少於2.5度

http://content.edu.tw/senior/earth/tp_ml/sun/spotclass.htm

太陽黑子分類

威爾遜山磁性分類法

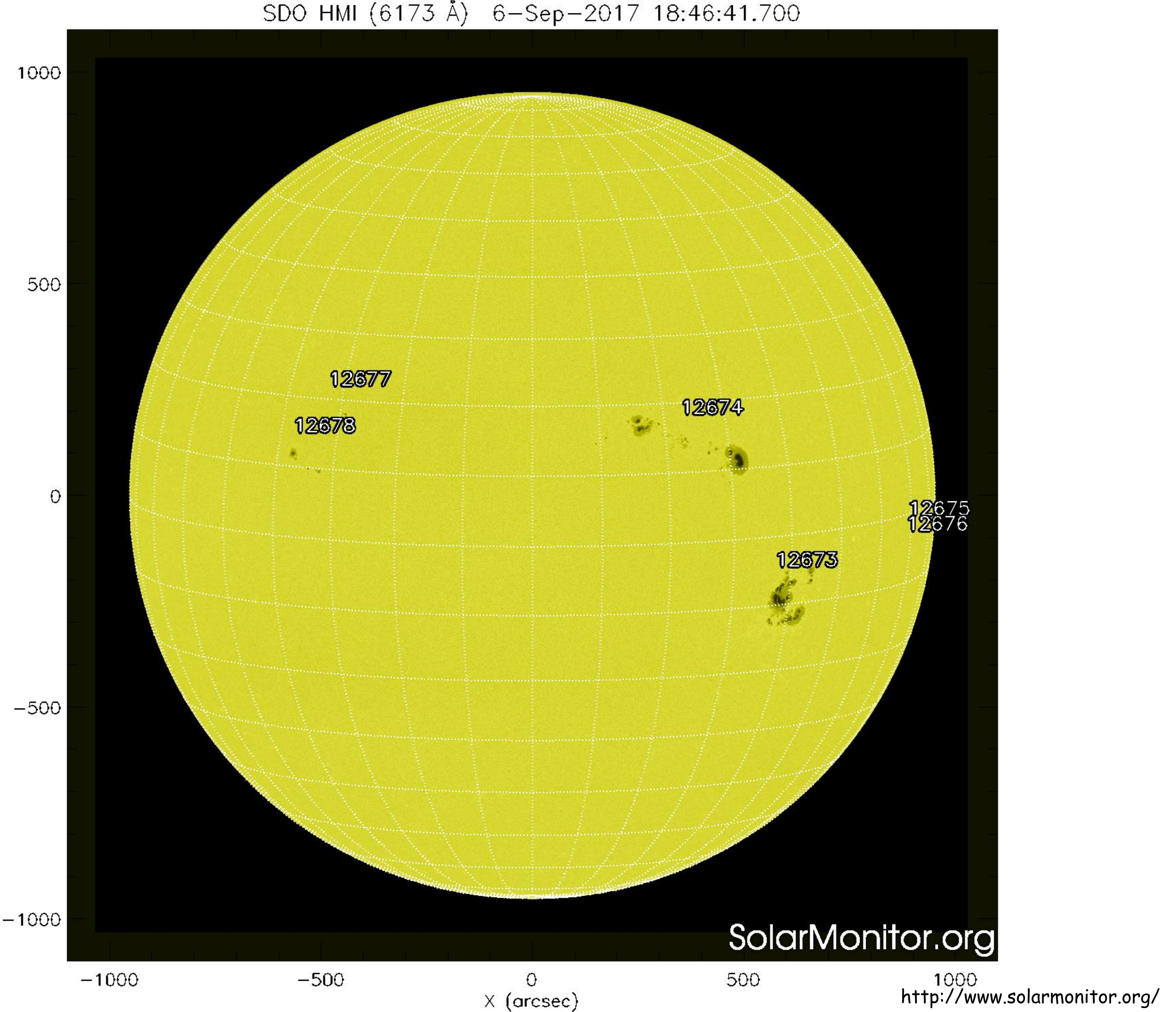
Alpha	單極黑子群
Beta	太陽黑子有正、負極者，而且兩者間可以簡單且清楚的區隔開
Delta	雙極性的黑子包含在一個本影中，有複雜的磁力輪廓線
Gamma	複雜的活動區，正負磁極不規則分佈，而無法分類為一個雙極性的黑子群者
Beta-Gamma	有雙極性的太陽黑子，但是兩極間沒有辦法以連續線將之分開來

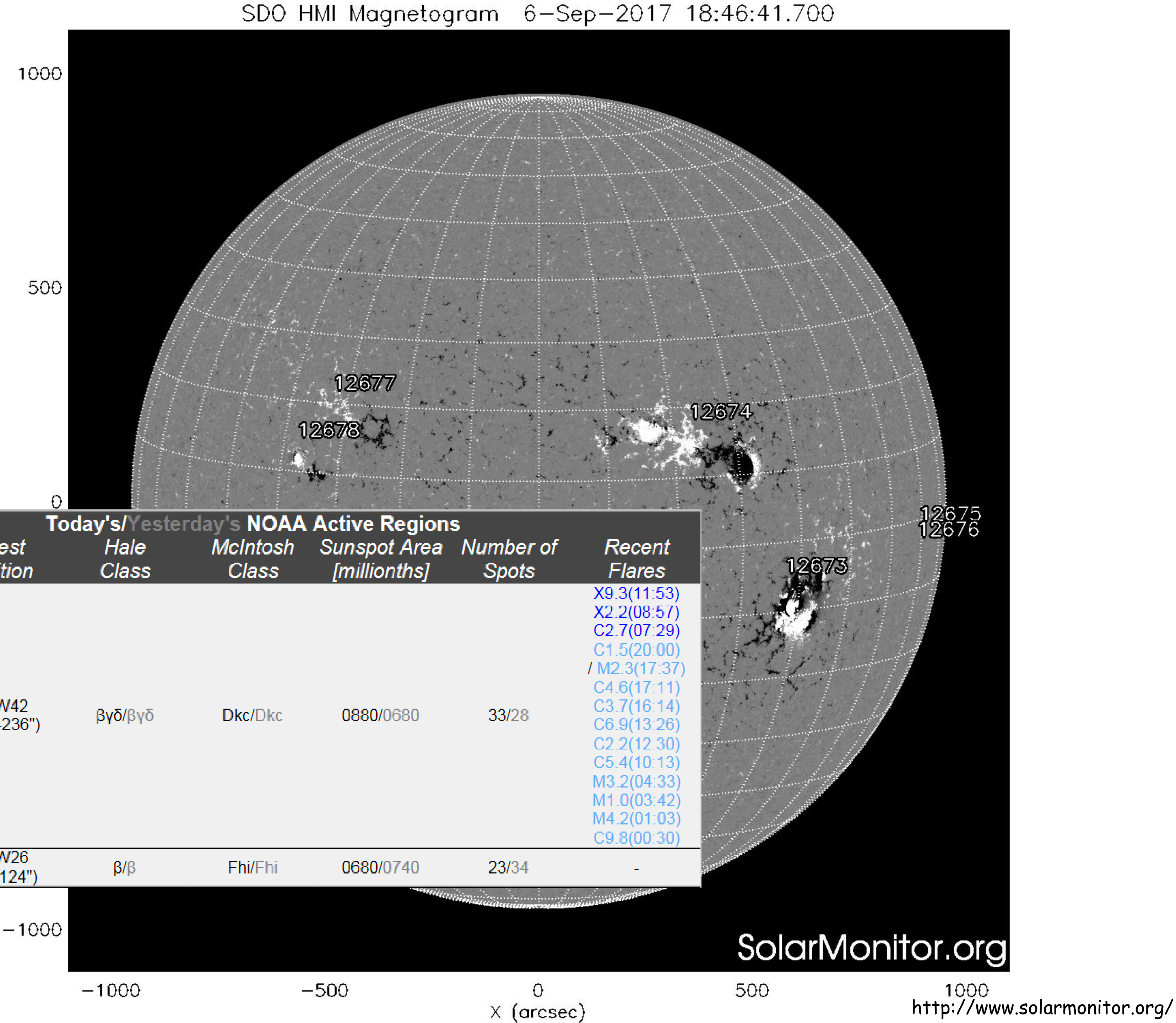
http://content.edu.tw/senior/earth/tp_ml/sun/spotclass.htm

Mount Wilson Sunspot Magnetic Classification

alpha: A unipolar sunspot group.
beta: A sunspot group having both positive and negative magnetic polarities (bipolar), with a simple and distinct division between the polarities.
gamma: A complex active region in which the positive and negative polarities are so irregularly distributed as to prevent classification as a bipolar group.
beta-gamma: A sunspot group that is bipolar but which is sufficiently complex that no single, continuous line can be drawn between spots of opposite polarities.
delta: A qualifier to magnetic classes(see below) indicating that umbrae separated by less than 2 degrees within one penumbra have opposite polarity.
beta-delta: A sunspot group of general beta magnetic classification but containing one (or more) delta spot(s).
beta-gamma-delta: A sunspot group of beta-gamma magnetic classification but containing one (or more) delta spot(s).
gamma-delta: A sunspot group of gamma magnetic classification but containing one (or more) delta spot(s).

http://www.spaceweather.com/glossary/magneticclasses.html

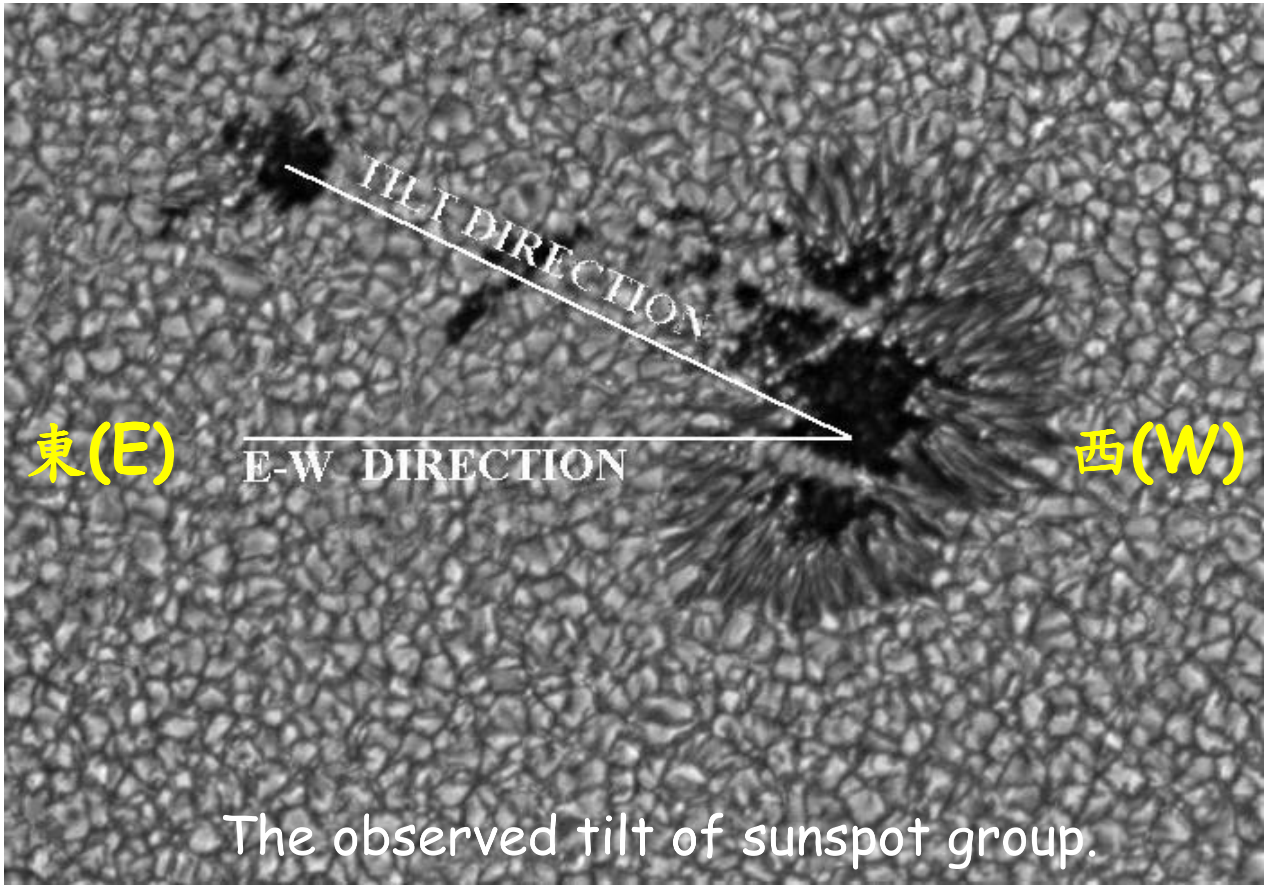

SDO HMI (6173 Å) 6-Sep-2017 18:46:41.700
1000
500
0
−500
−1000
−1000
−500
0
500
1000
X (arcsec)
12677
12678
12674
12675
12676
12673
SolarMonitor.org
http://www.solarmonitor.org/

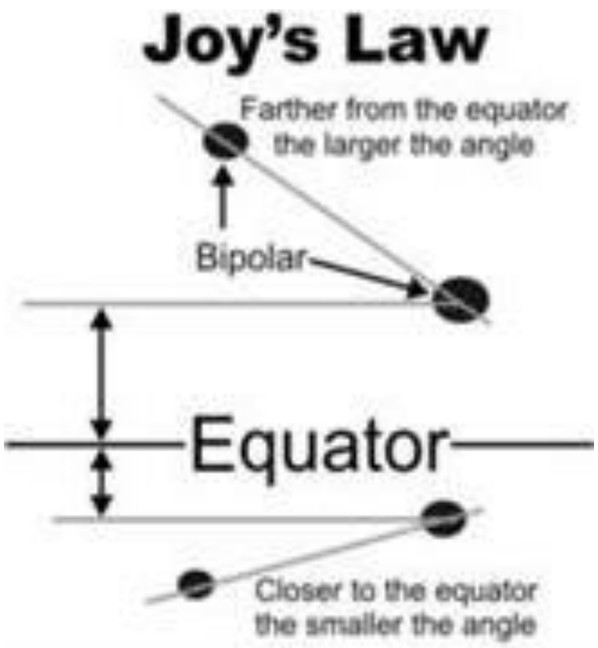


Today's/Yesterday's NOAA Active Regions

NOAA Number	Latest Position	Hale Class	McIntosh Class	Sunspot Area [millionths]	Number of Spots	Recent Flares
12673	S09W42 (630",-236")	βγδ/βγδ	Dkc/Dkc	0880/0680	33/28	X9.3(11:53) X2.2(08:57) C2.7(07:29) C1.5(20:00) / M2.3(17:37) C4.6(17:11) C3.7(16:14) C6.9(13:26) C2.2(12:30) C5.4(10:13) M3.2(04:33) M1.0(03:42) M4.2(01:03) C9.8(00:30)
12674	N14W26 (406",124")	β/β	Fhi/Fhi	0680/0740	23/34	-

Joy's Law



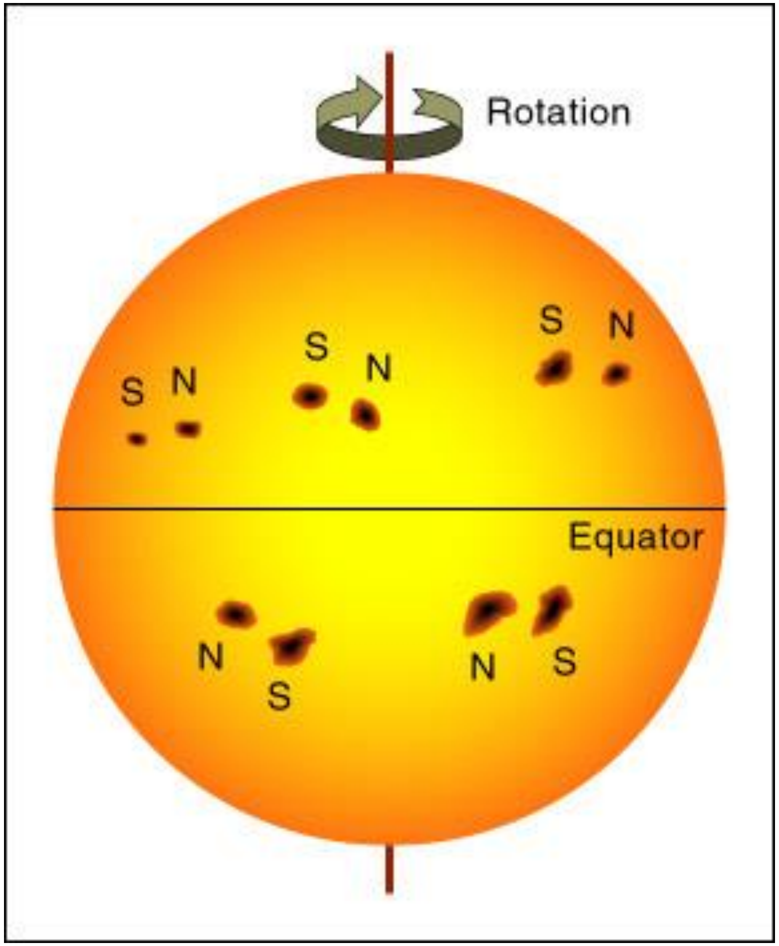


太陽黑子群因前導黑子較尾隨黑子靠近赤道而傾斜，傾斜角度隨緯度增加而增加，該傾斜現象稱之。

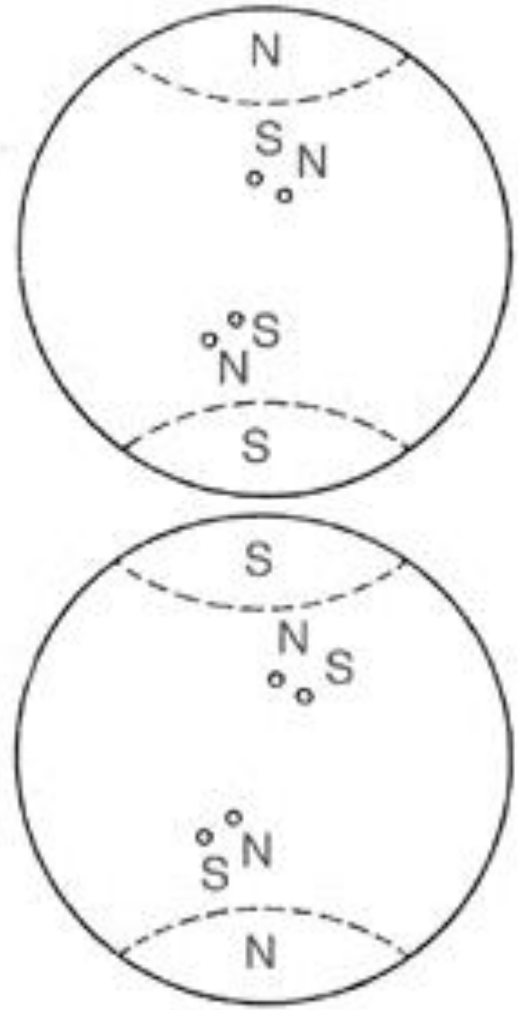
http://solarscience.msfc.nasa.gov/images/joys_law.jpg

http://www.e-huh.com/chapter%207%20the%20sun/chapter%207%20a%20new%20model%20of%20the%20sun_files/image004.jpg

Hale's Polarity Law



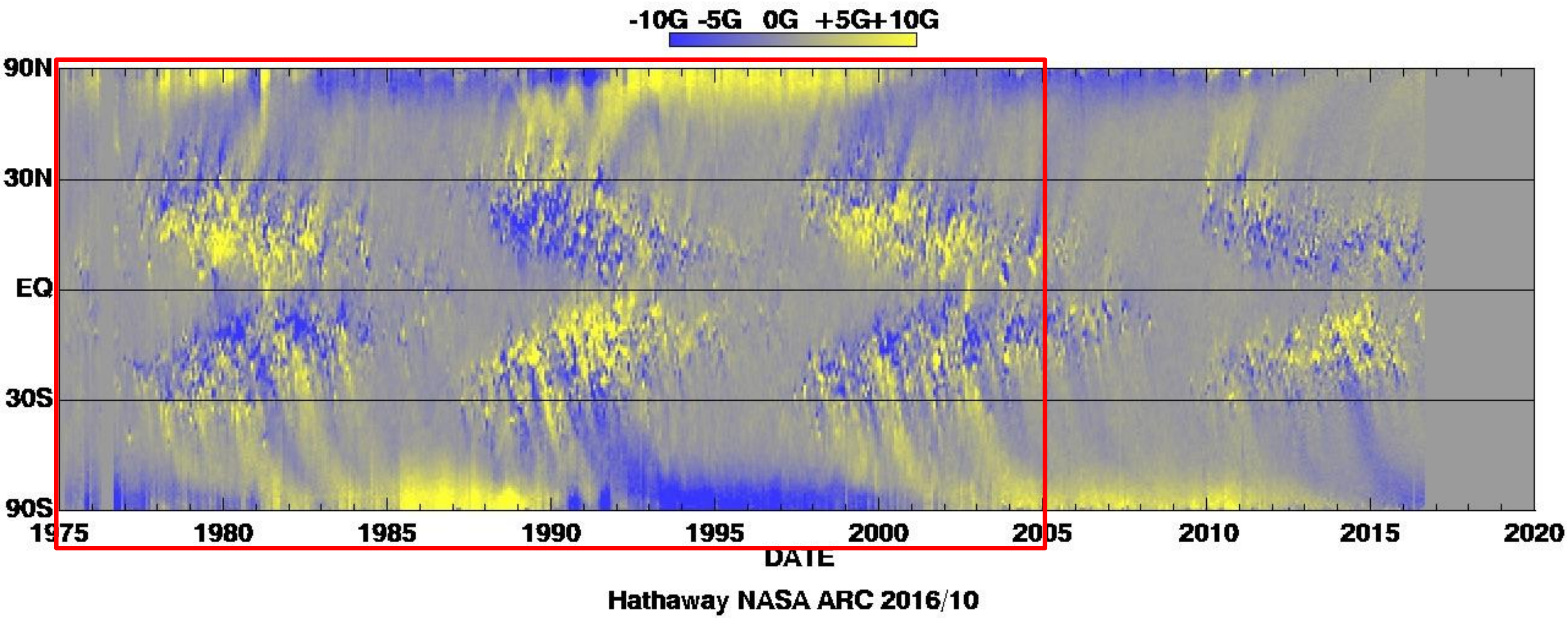
http://www.lcsd.gov.hk/CE/Museum/Space/EducationResource/Universe/framed_e/lecture/ch11/ch11.html



在同一週期中，北半球前導黑子的極性與南半球前導黑子的極性相反，下一個週期南北半球黑子的極性會反轉。

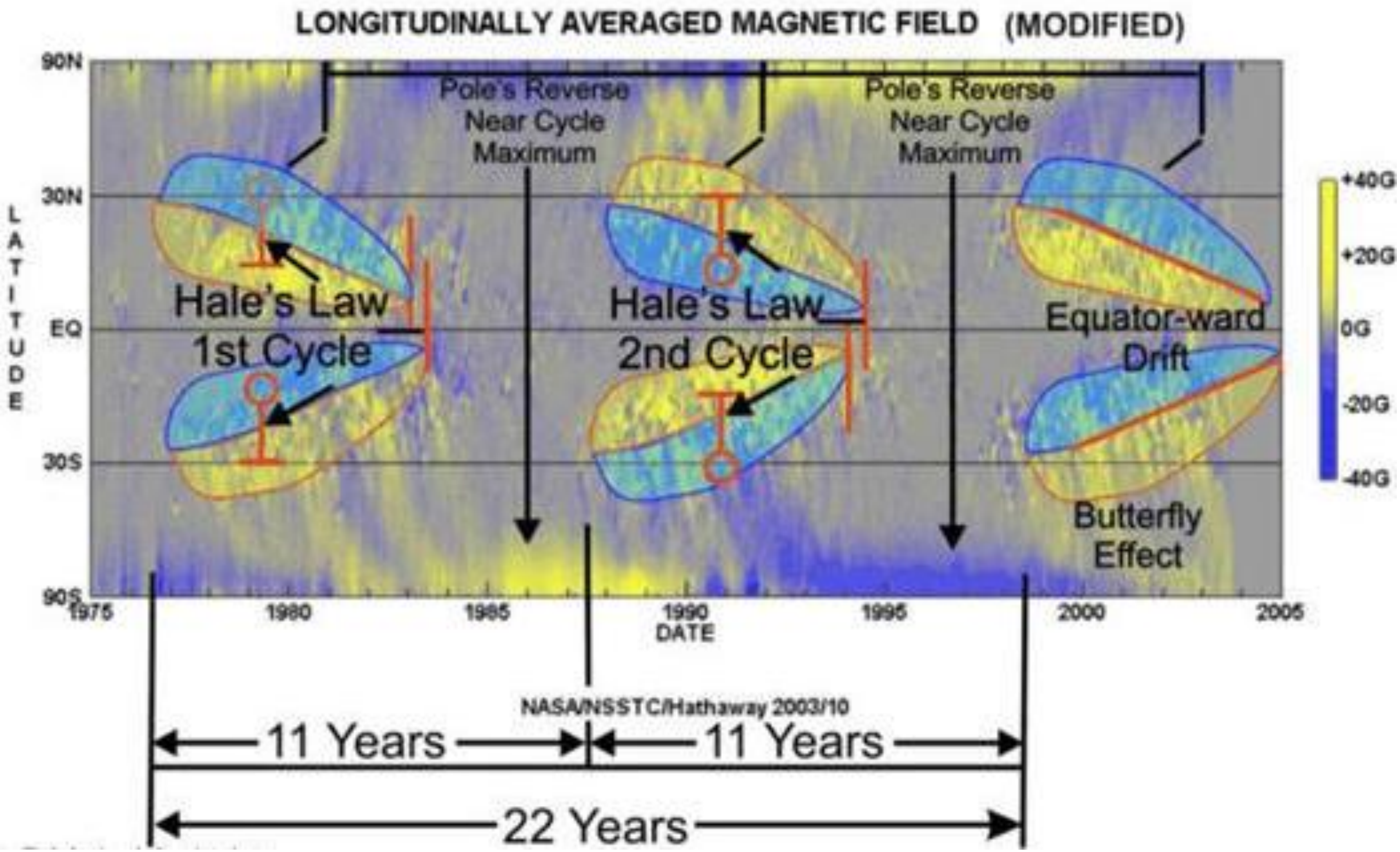
Hale's Polarity Law

Magnetic Butterfly Diagram



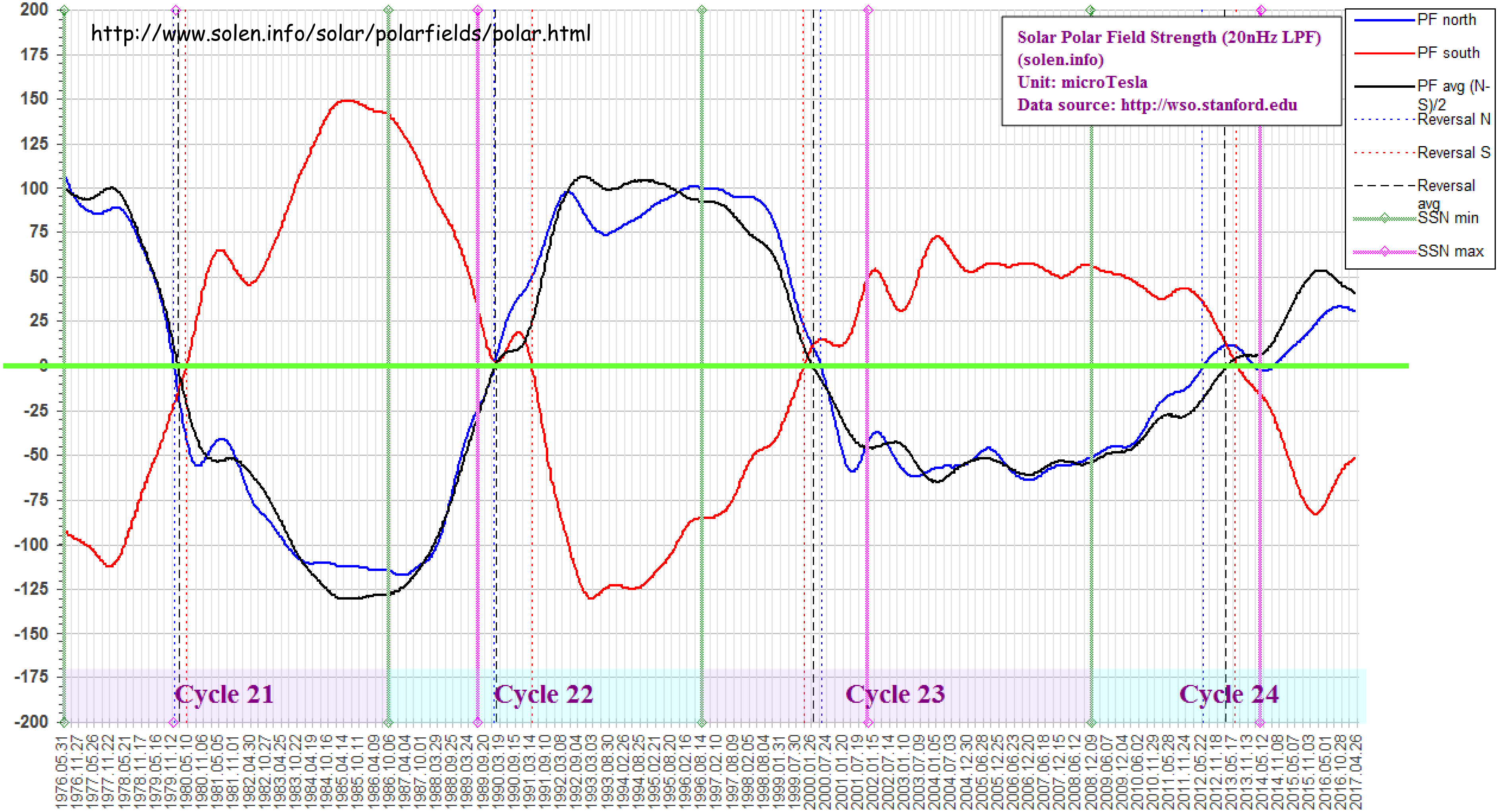
https://solarscience.msfc.nasa.gov/images/magbfly.jpg

Hale's Polarity Law



http://www.e-huh.com/chapter%207%20the%20sun/chapter%207%20a%20new%20model%20of%20the%20sun_files/image004.jpg

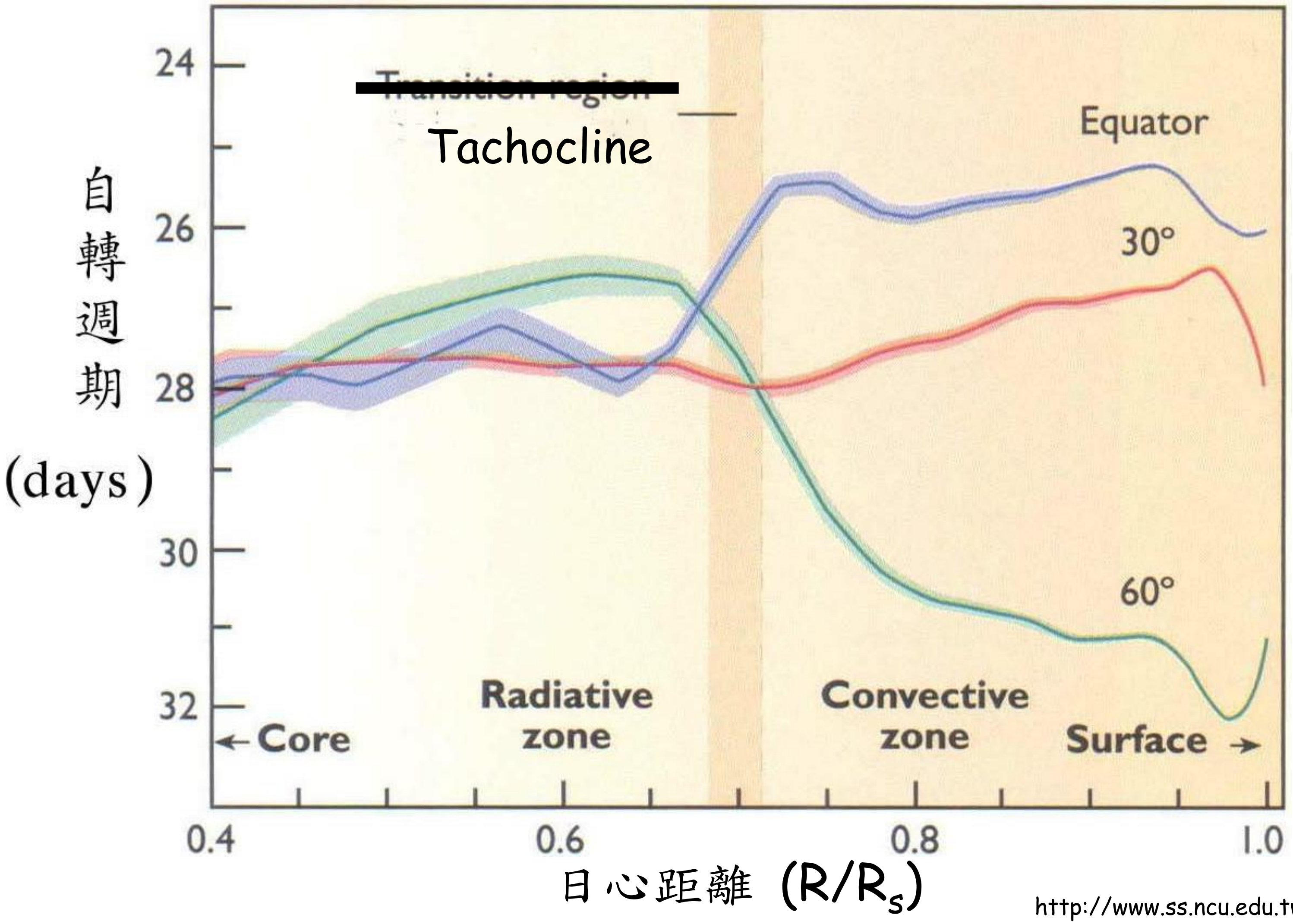
Solar Polar Fields



“The northern polar field reversed in June 2012 while the southern polar field reversed in July 2013. During the previous similar polarity reversal in 1989-1991 the northern polar field reversed 14 months prior to the southern polar field reversal, very similar to the situation during cycle 24.”

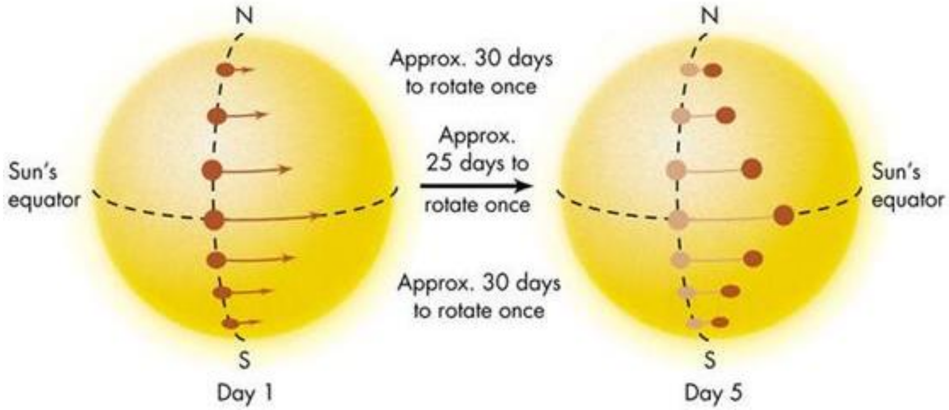
差動自轉(differential rotation)

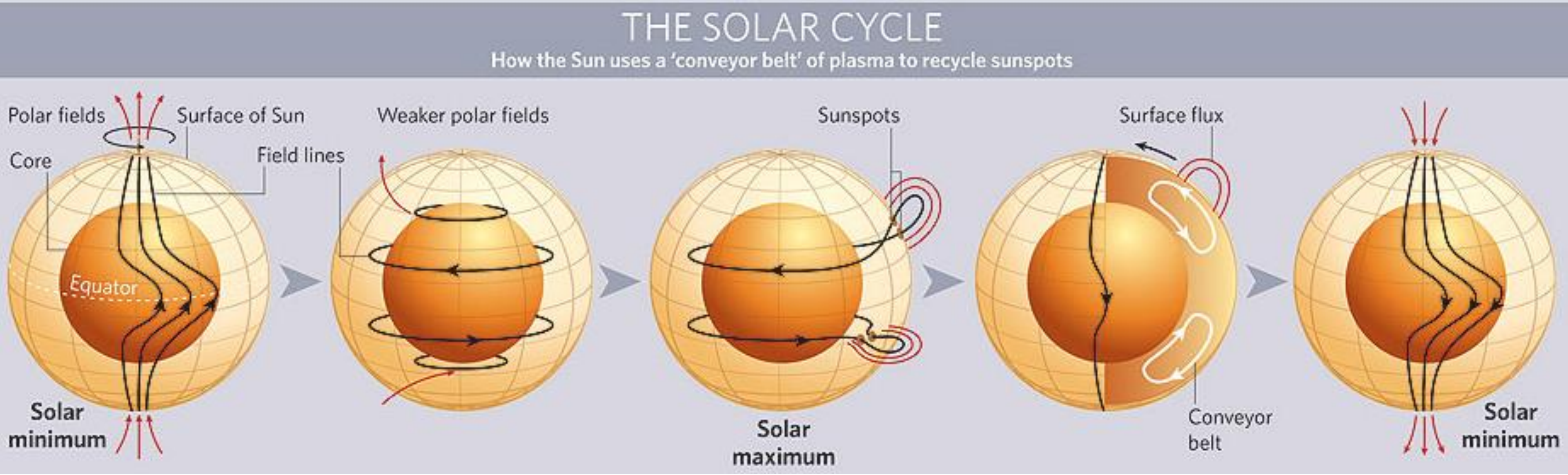
太陽平均約27天自轉一周，赤道區自轉速率較快約需25天，高緯區自轉速率較慢約需30天。太陽的核心和輻射層並無差動自轉。



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

差動自轉(differential rotation)

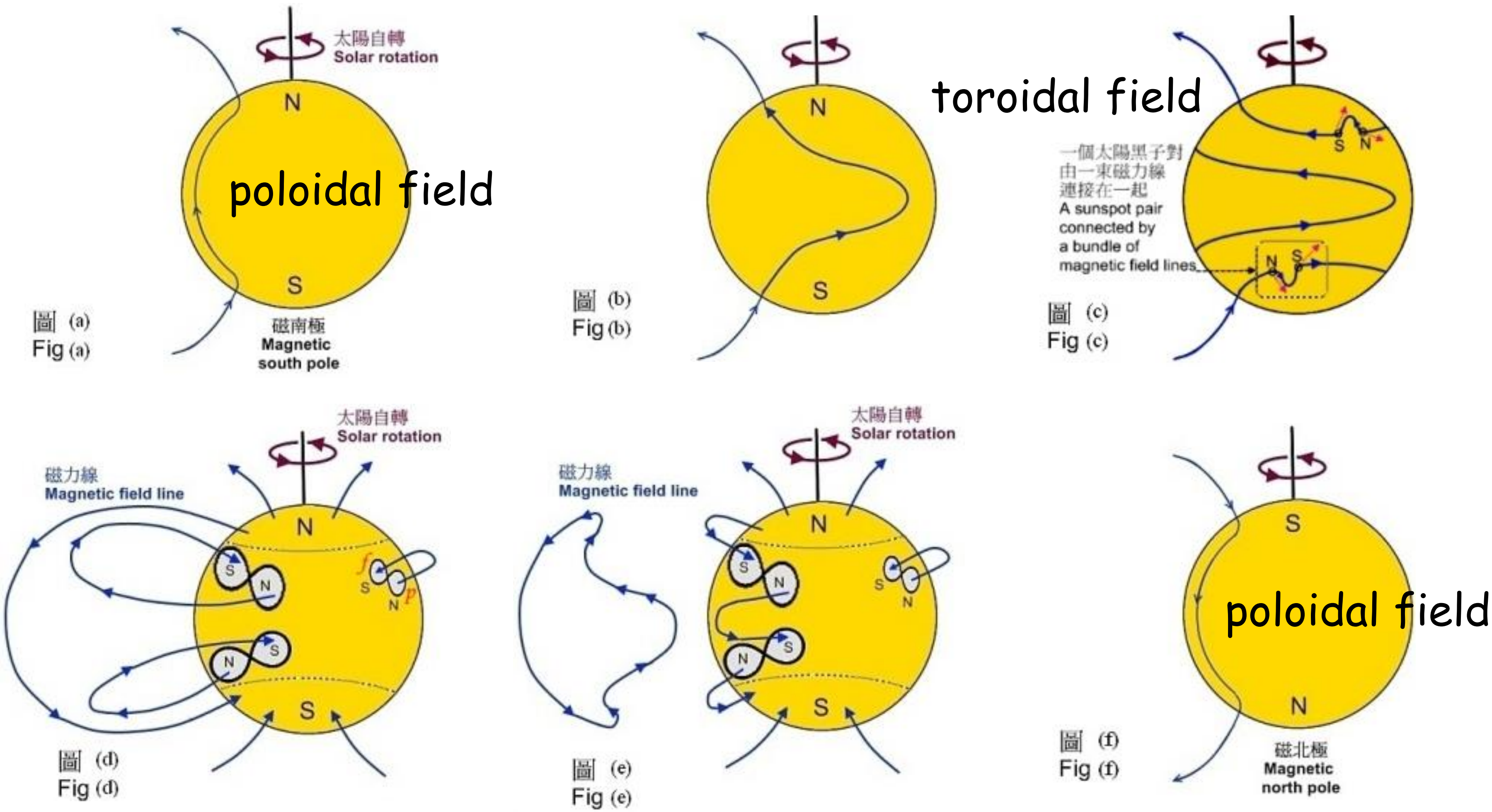




太陽差動自轉造成黑子數目有11年的週期變化、磁場極性有22年週期變化。太陽磁場每11年反轉一次，反轉時黑子數目最多。

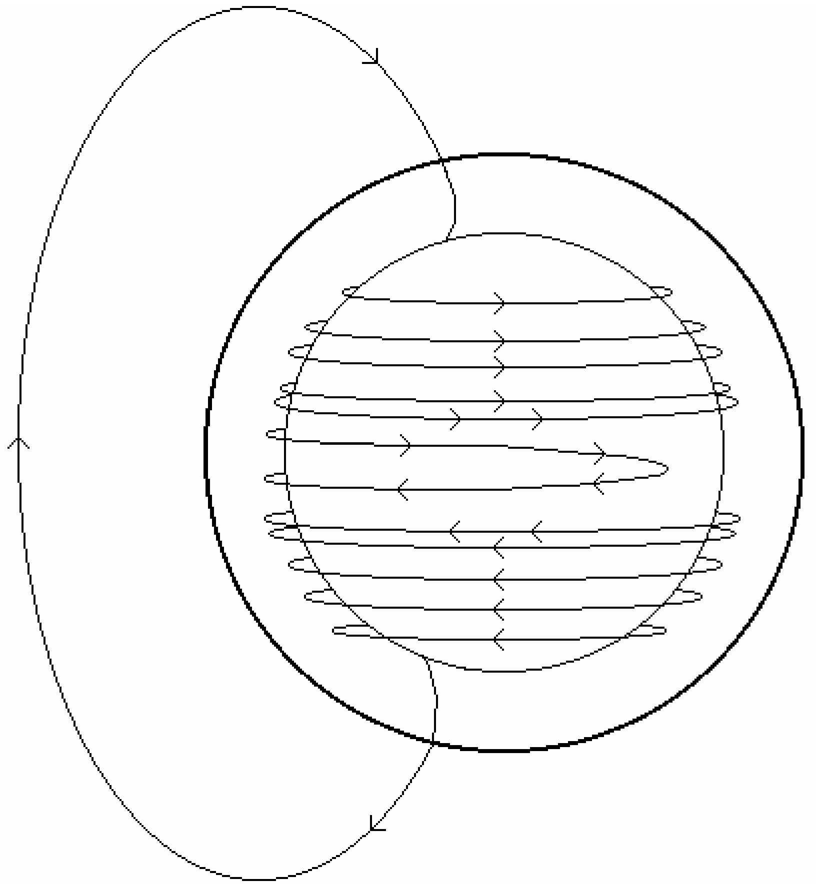
http://www.stil.bas.bg/IHY/lectur_1/l2fig/image003.jpg http://www.timmytelescope.com/outreach-materials/board05/sun_pole-reversal.jpg

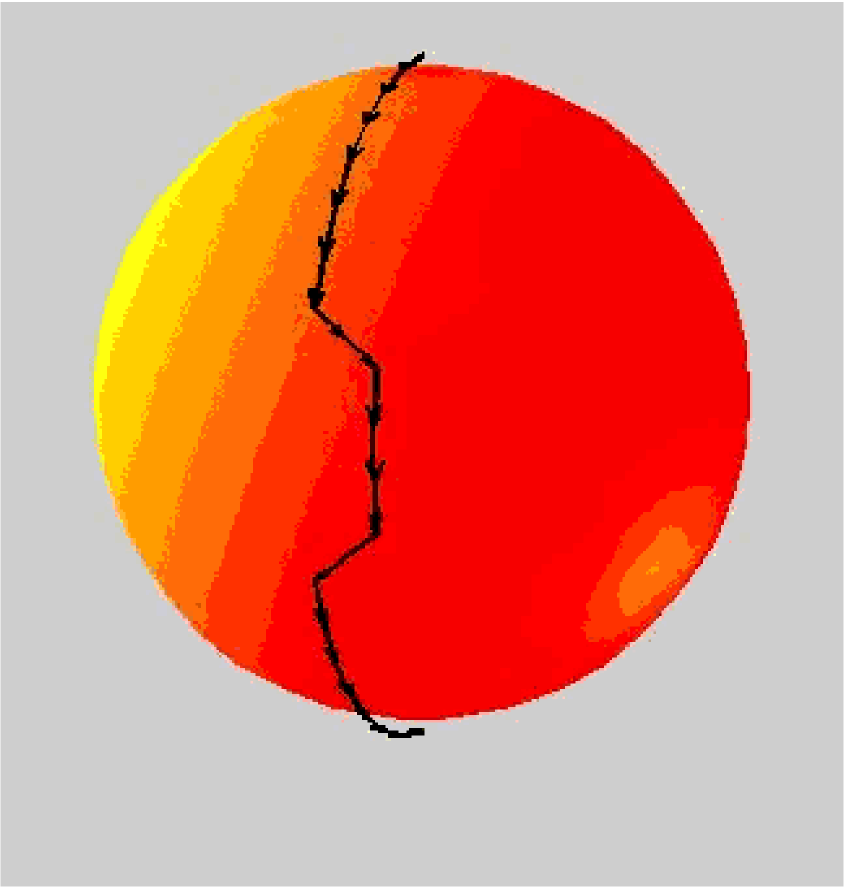
Solar Dynamo---Babcock Model



http://gb.weather.gov.hk/education/edu05spacewx/ele_babcock_c.htm

Ω-effect

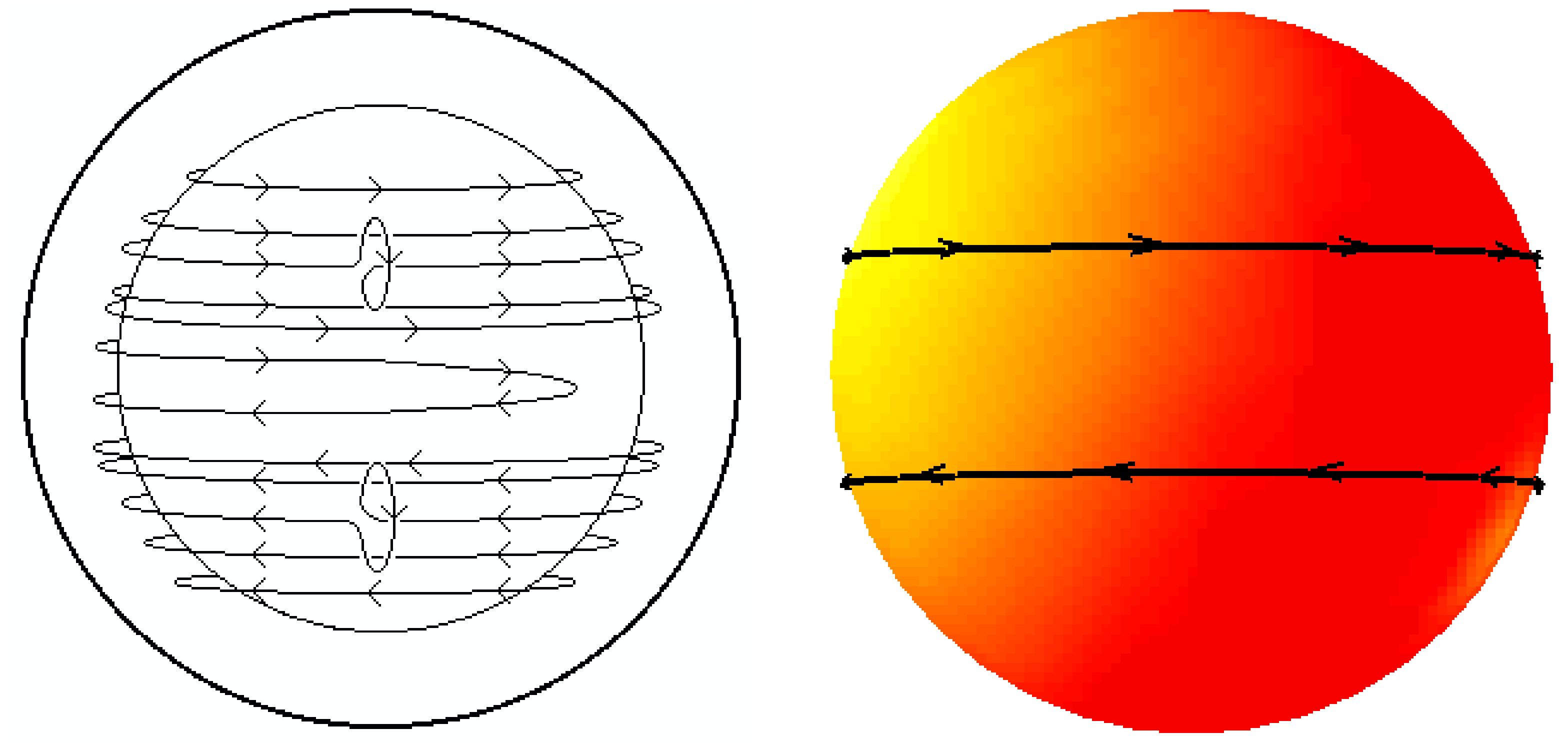




poloidal field → toloidal field
due to the differential rotation

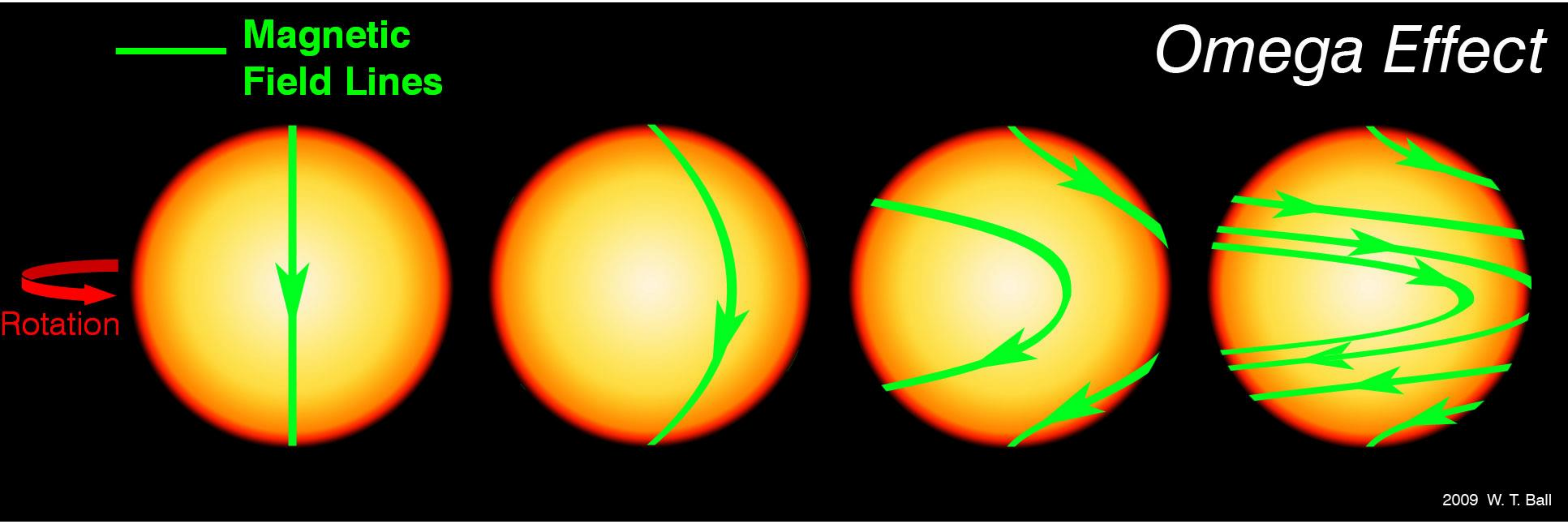
http://solarscience.msfc.nasa.gov/dynamo.shtml

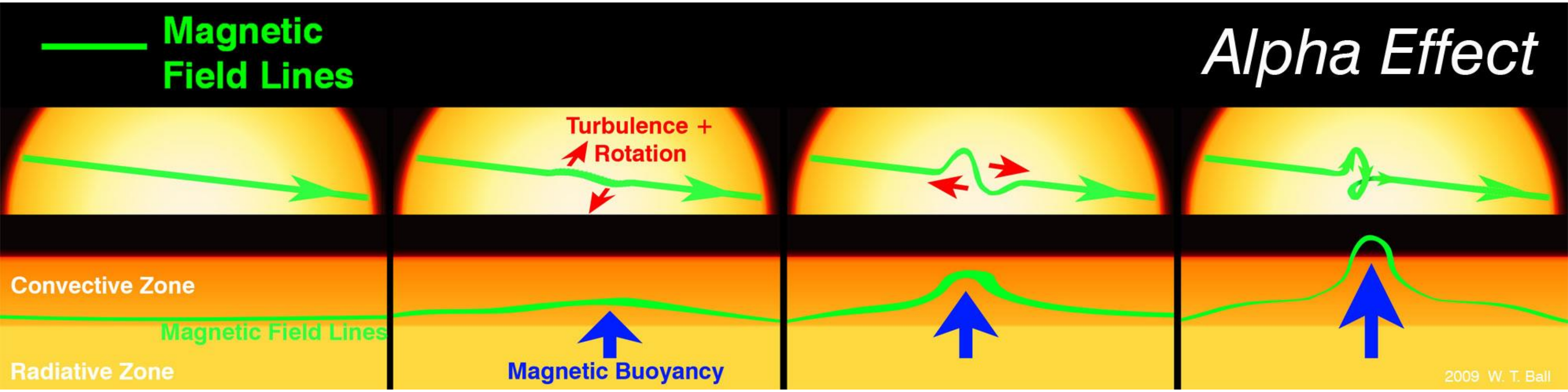
α-effect



twisting of magnetic field lines due to the rising magnetic flux tube from the deep

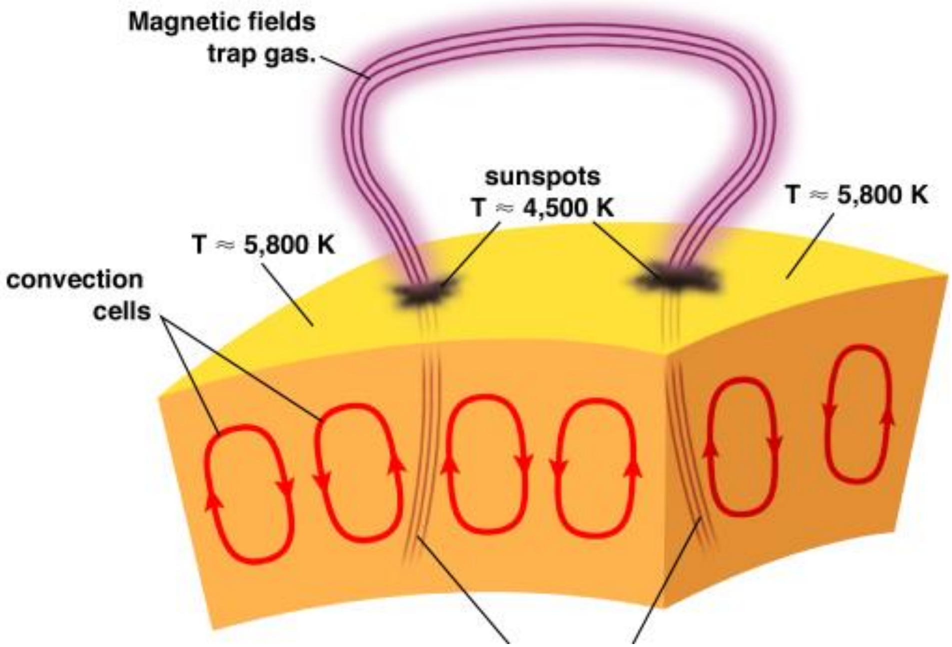
http://solarscience.msfc.nasa.gov/dynamo.shtml





http://astro.ic.ac.uk/research/solar-basics

磁浮力(magnetic buoyancy force)



氣壓

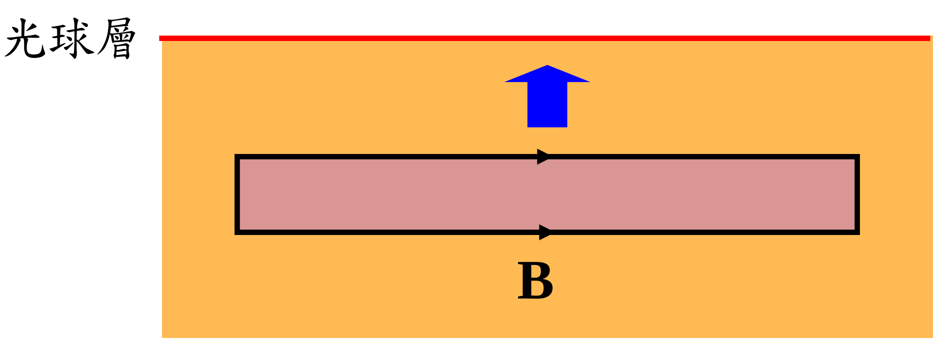
$$\because \frac{B^2}{2\mu} + P_{in} = P_{out}$$

磁壓

$$\therefore P_{in} < P_{out}$$

$$\because P = \rho RT$$

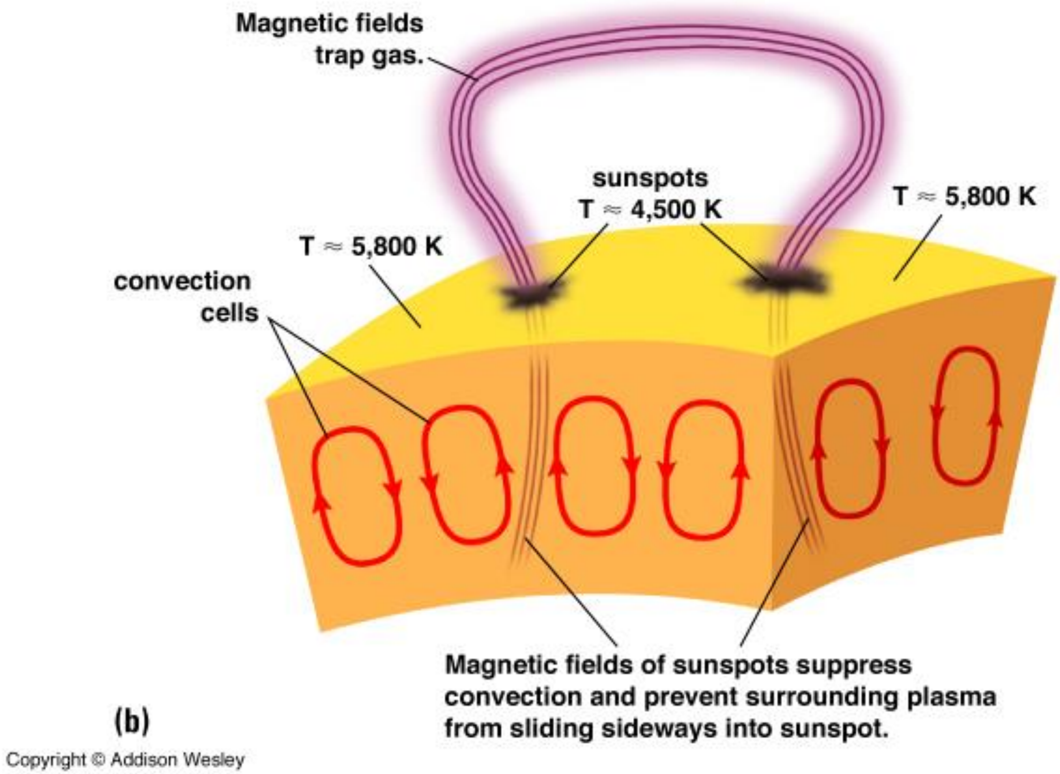
$$\text{if } T_{in} \approx T_{out} \Rightarrow \rho_{in} < \rho_{out}$$



磁通量管上升前

太陽對流層內各處的氣體壓力並不完全相同，若某處磁壓超過氣壓，就會像水裡的氣泡一樣受到一向上浮力的作用而浮出表面，因此磁力線連同電漿都冒出太陽表面，在磁力線集中穿過對流層頂進入光球層的地方形成黑子。

http://aeea.nmns.edu.tw/geo_home/GEO95/sunspots.htm

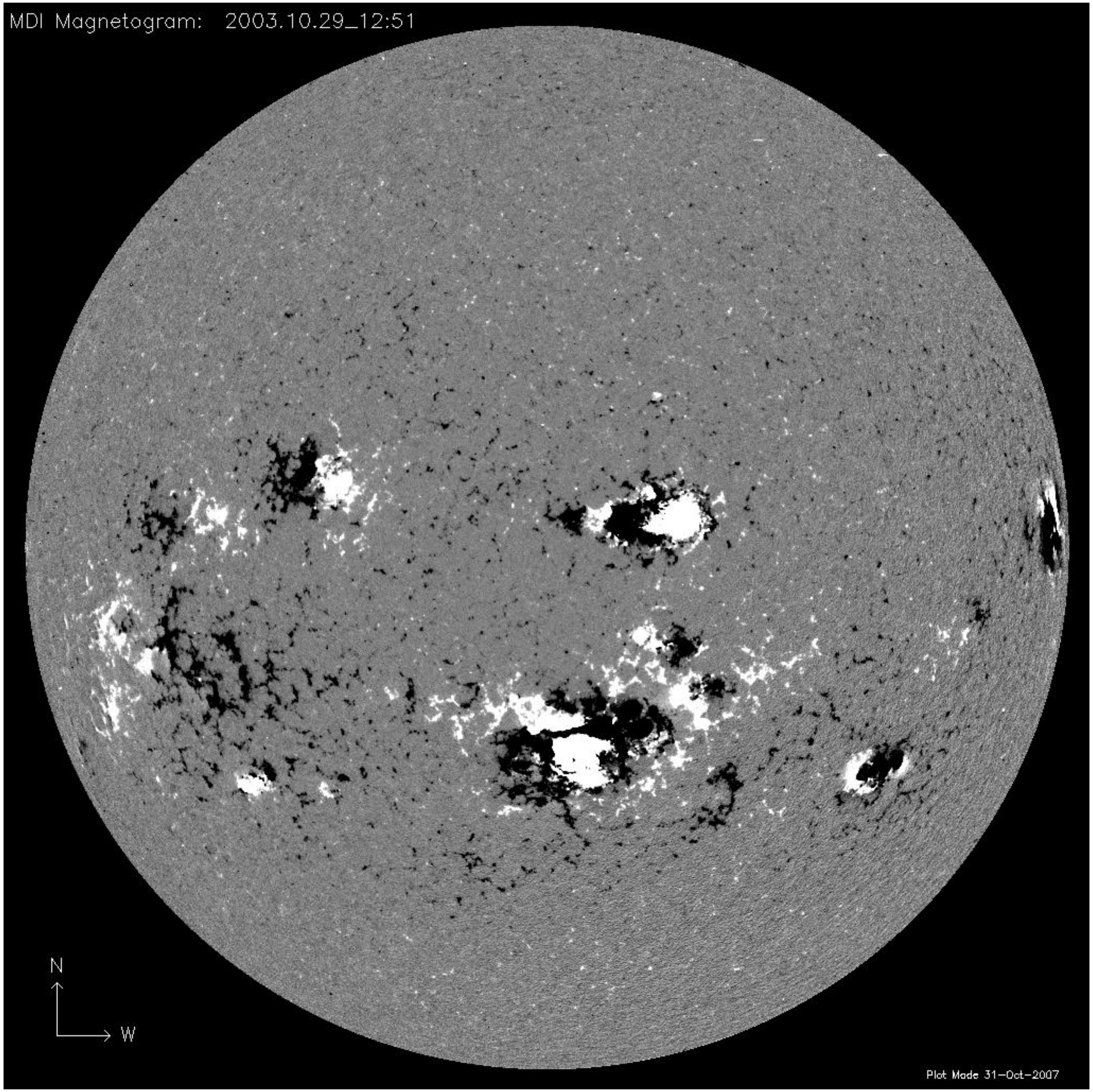


1908年美國天文學家George Ellery Hale發現黑子附近的磁場比太陽平均磁場高出約1000倍(地球平均磁場約0.5 Gauss，太陽平均磁場約1.0 Gauss，黑子則高達約1000 Gauss)，解釋了太陽黑子是由強磁場抑制對流能量傳輸所造成。

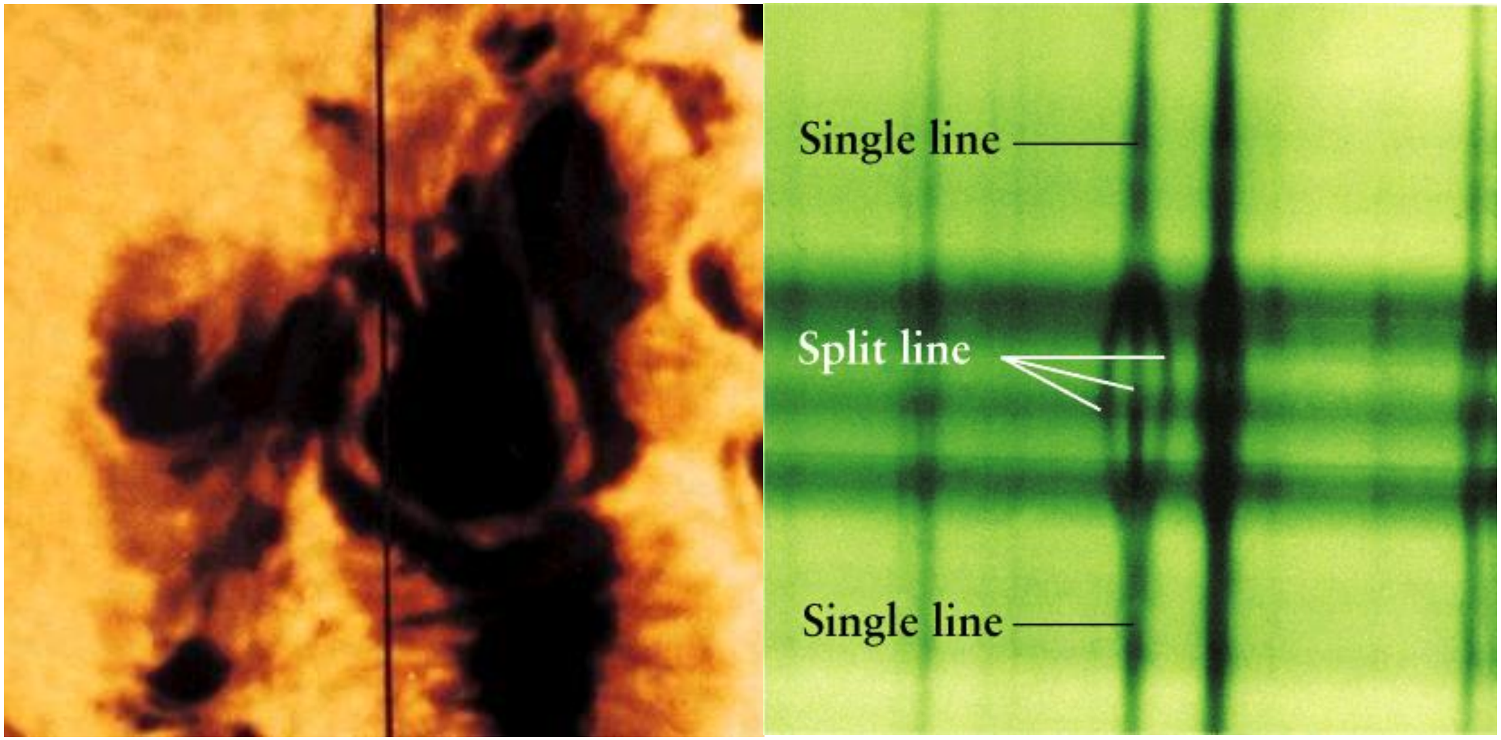
由於黑子區內的磁場抑制了來自光球層下方對流能束的能量傳輸，因而較少能量能傳至光球層，造成黑子區內溫度較低，對比上也較光球層暗。

http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/suninterior.htm
http://content.edu.tw/junior/earth/tn_gz/astro/sumsite/sun3a.htm#黑子的成因

光球層磁場--- line-of-sight magnetogram

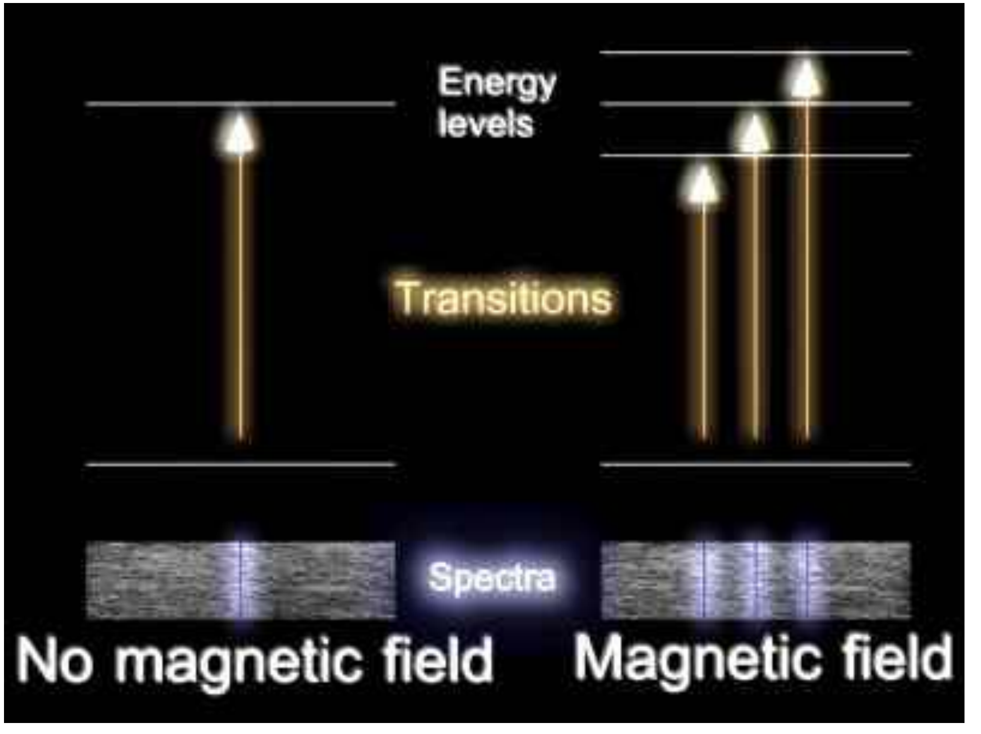


Zeeman Effect



Photospheric magnetic measurement is based on Zeeman effect: the splitting of a spectral line because of the presence of magnetic field.

Zeeman Effect

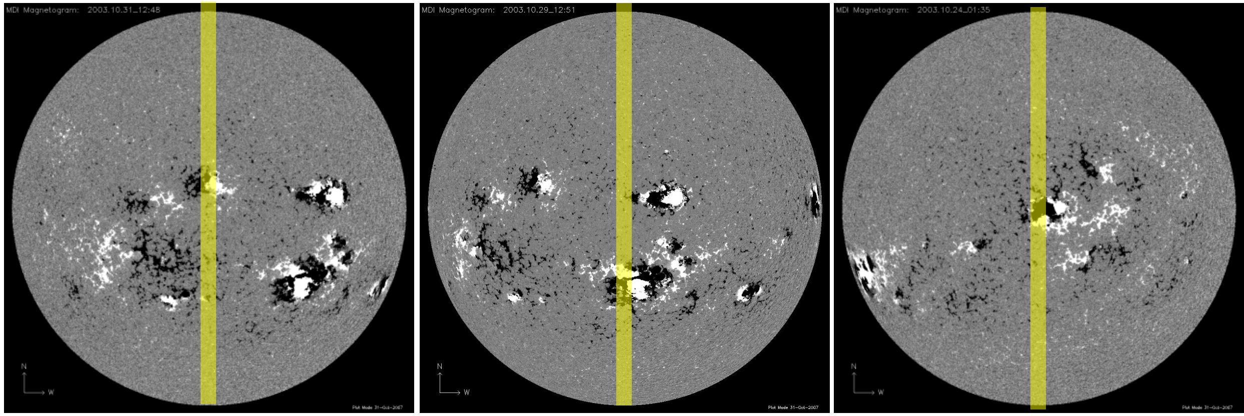


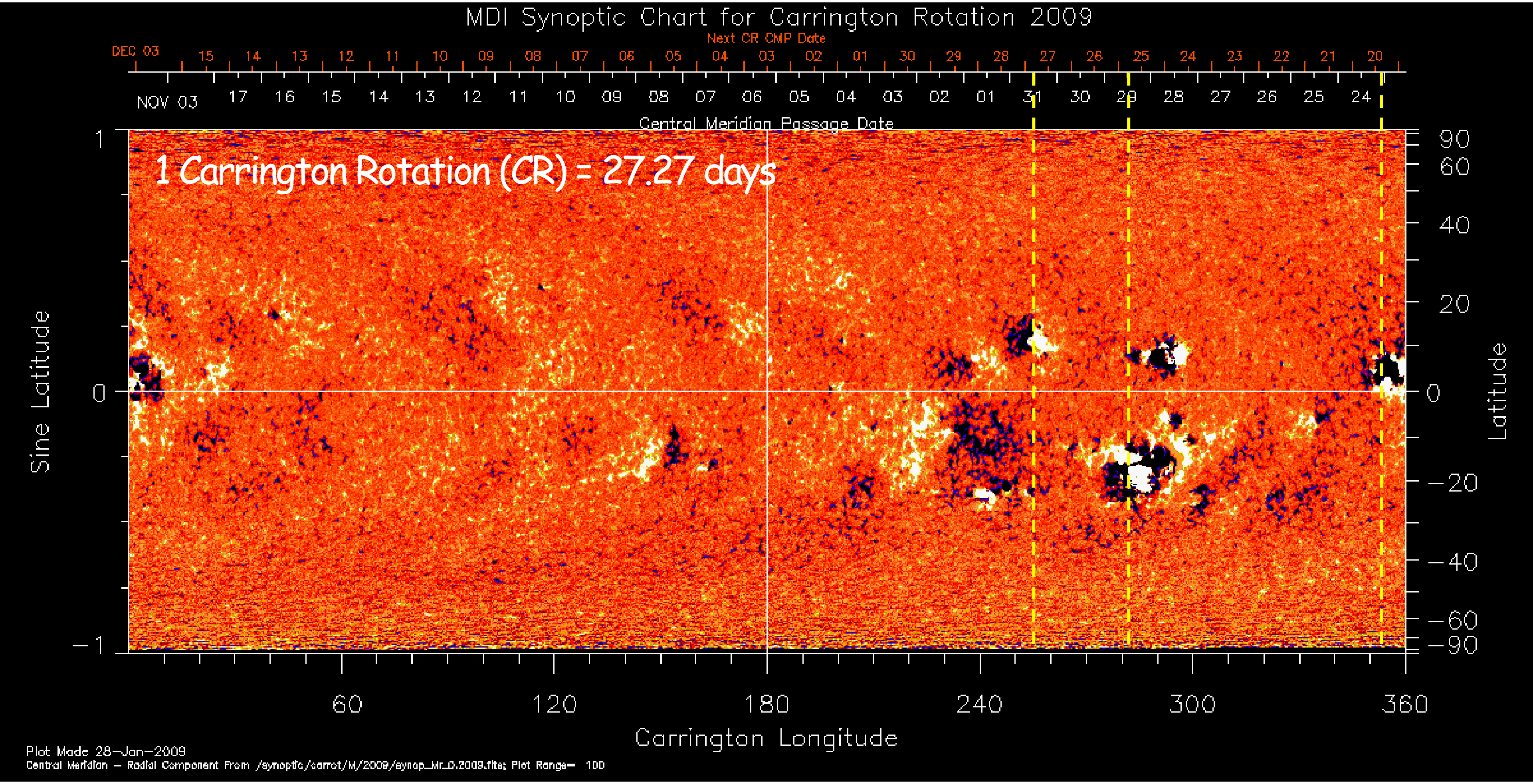
$$\Delta\lambda = 4.7 \times 10^{-13} \lambda_0^2 gB$$

λ_0: original wavelength
g: Lande factor, e.g., FeI 6173Å (g=2.5)
B: magnetic field strength

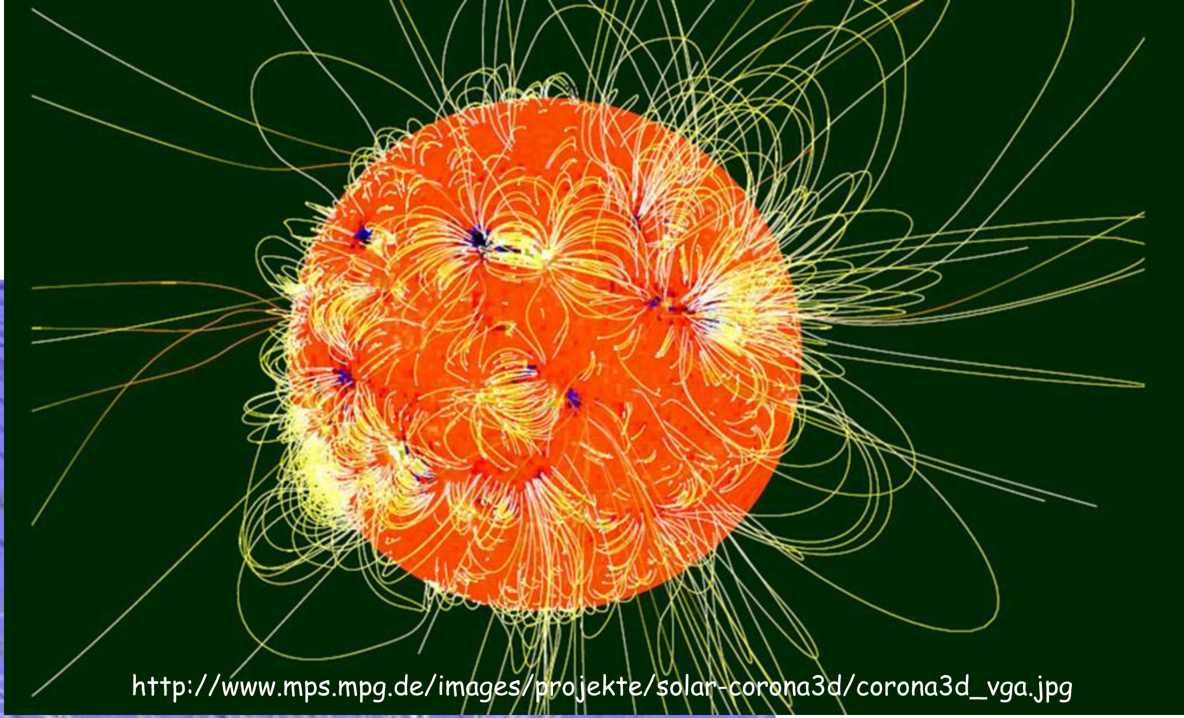
http://www.sr.bham.ac.uk/xmm/fmc2.html

Synoptic Chart

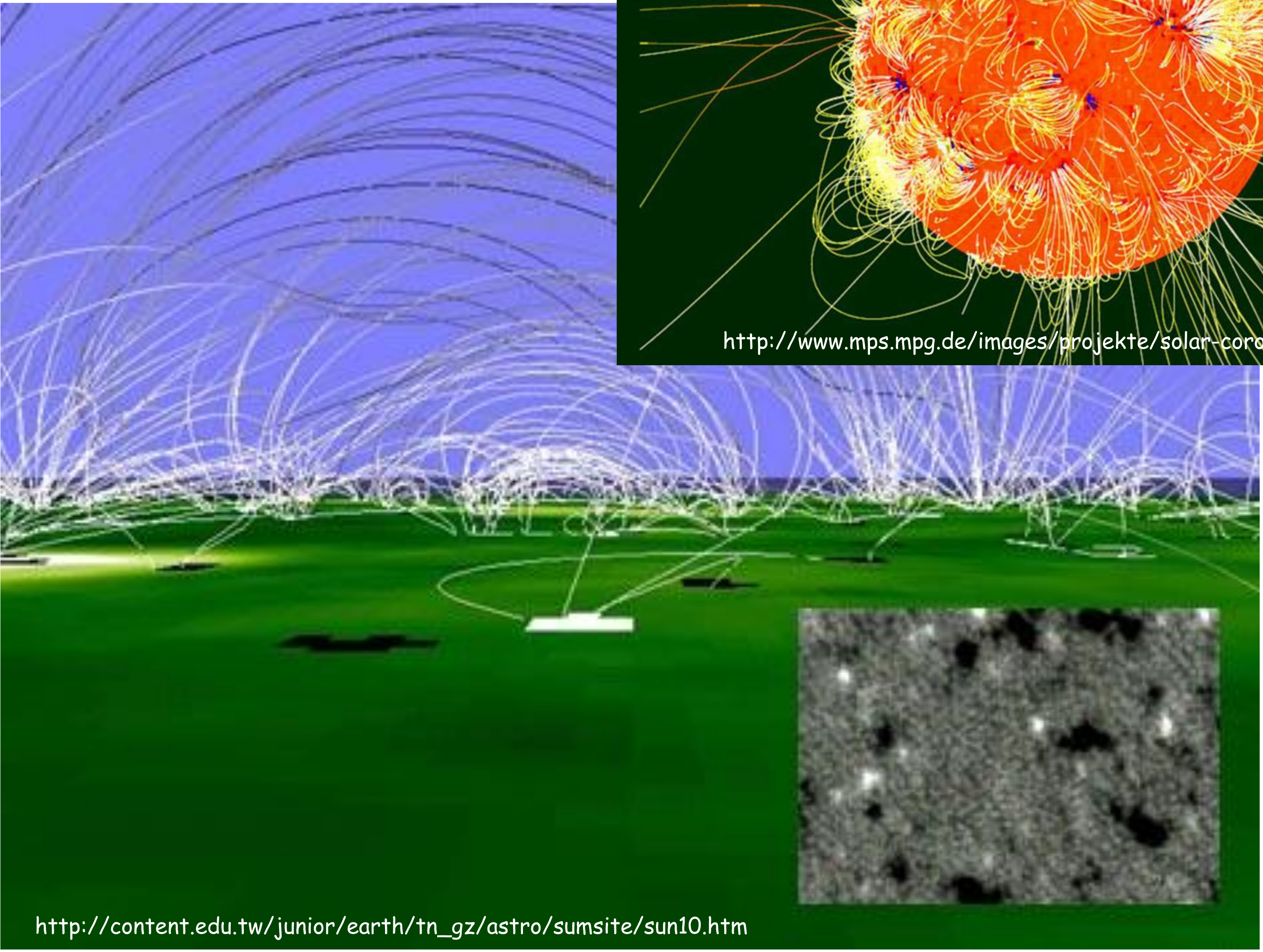




太陽磁場

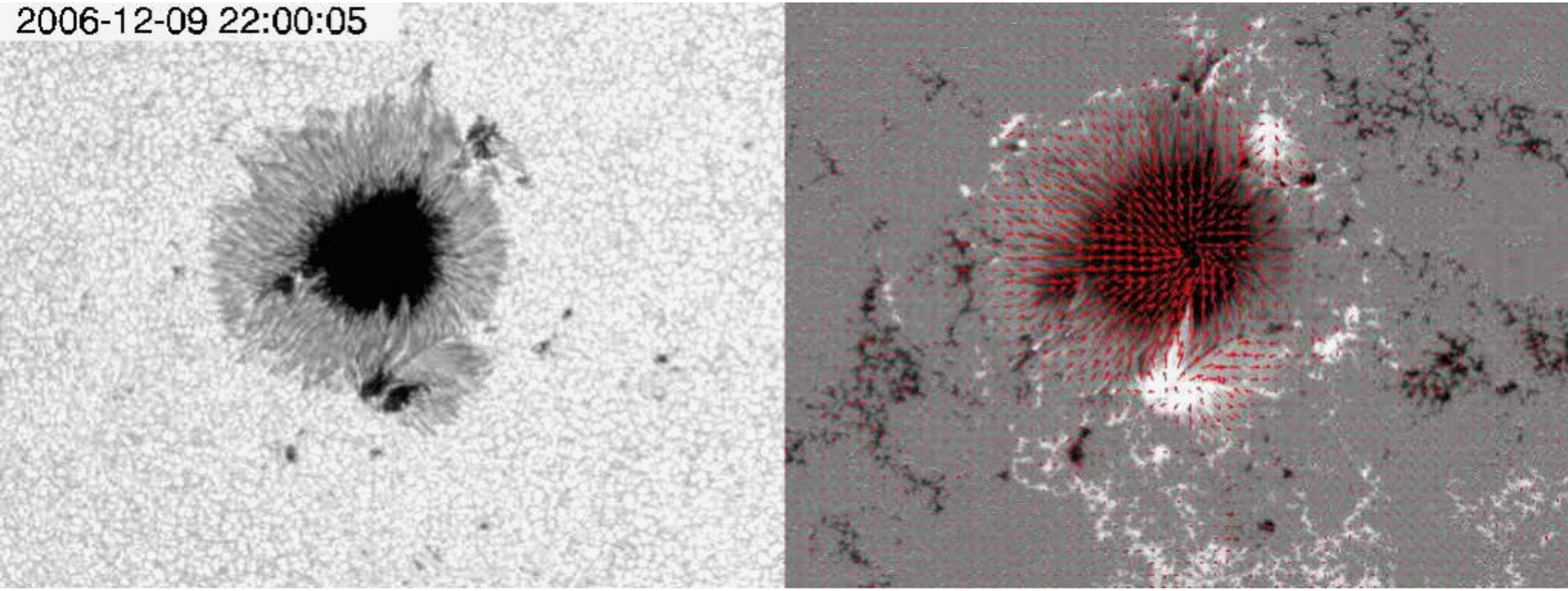


http://www.mps.mpg.de/images/projekte/solar-corona3d/corona3d_vga.jpg



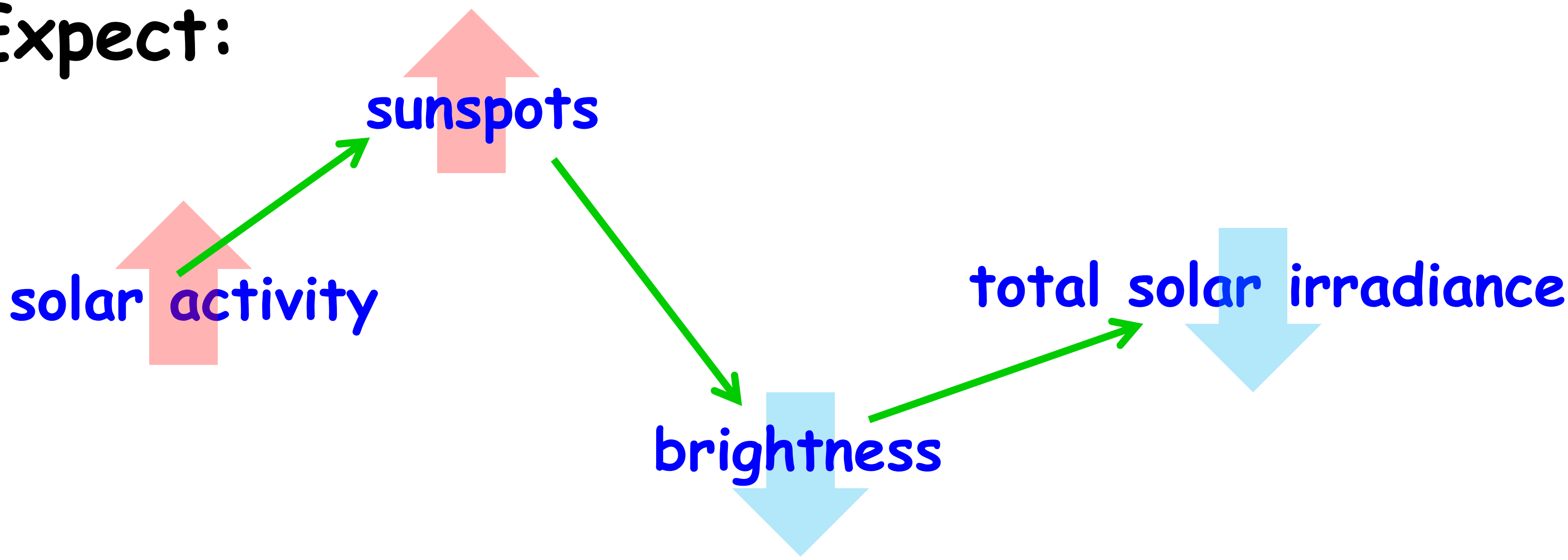
http://content.edu.tw/junior/earth/tn_gz/astro/sumsite/sun10.htm

光球層磁場--- vector magnetogram



http://science.nasa.gov/media/medialibrary/2007/04/24/24apr_hubble4sun_resources/hurricane_huge.gif

Expect:

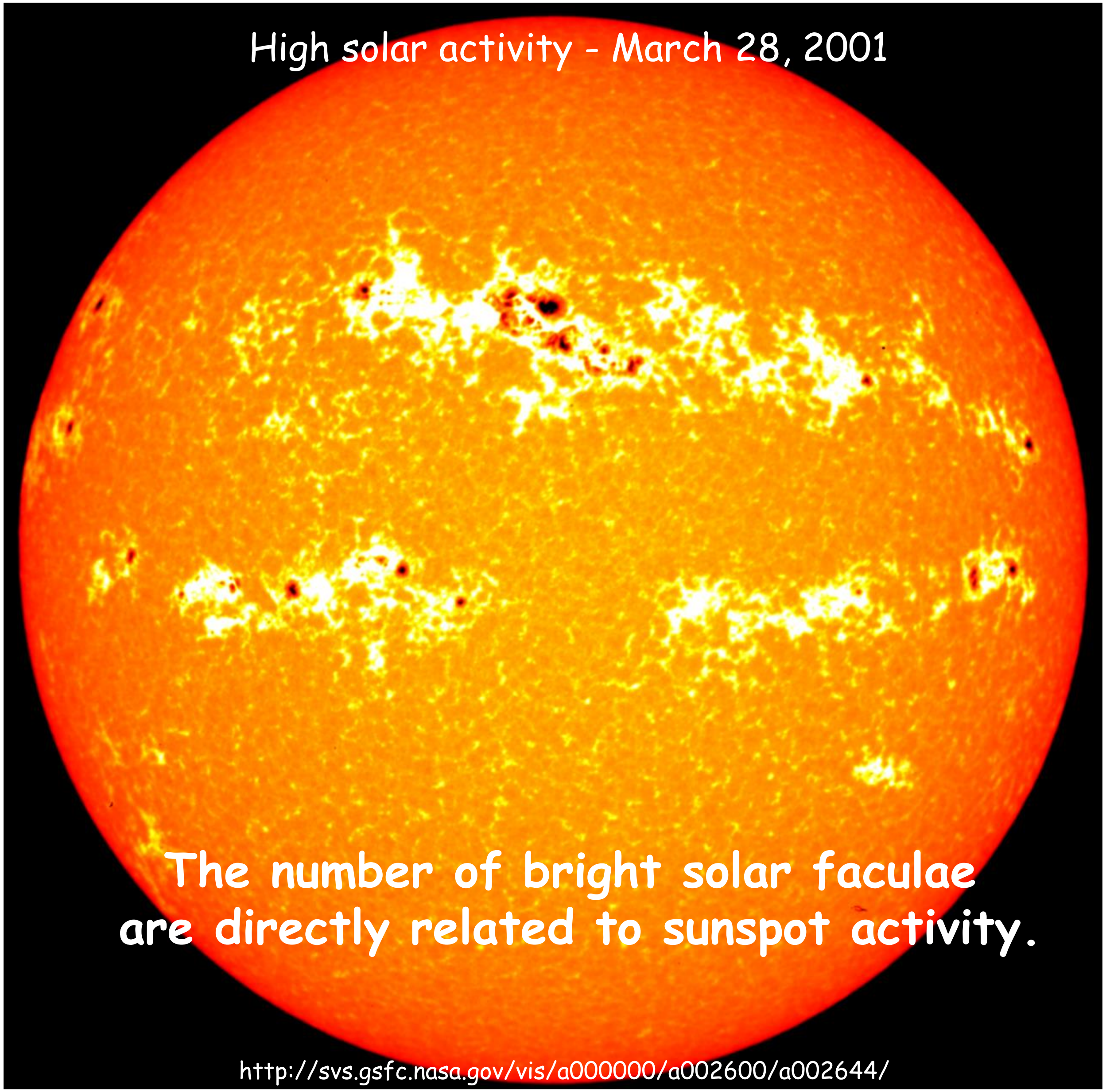


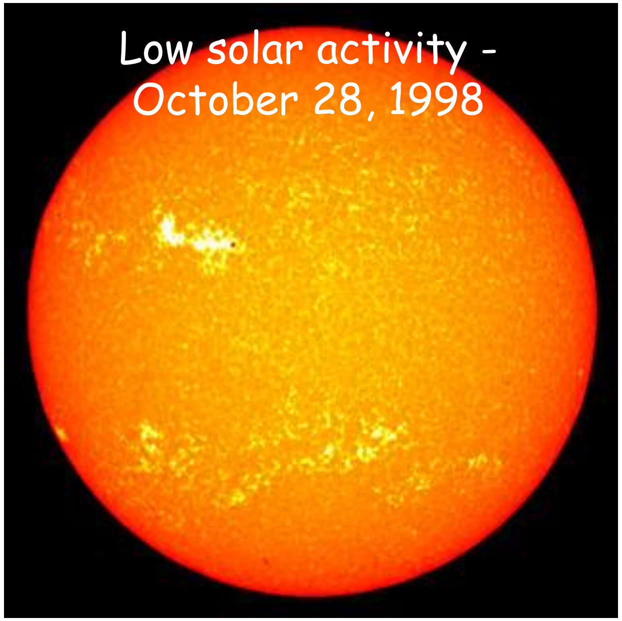
In reality:

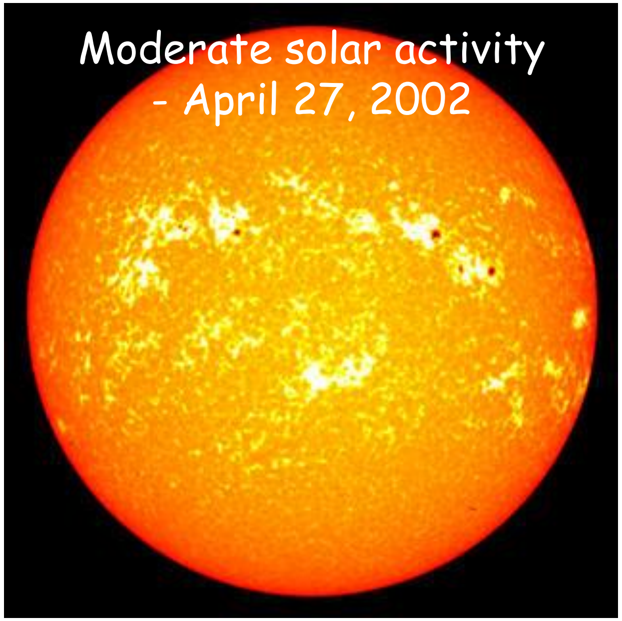
The total solar irradiance (TSI) increases by ~0.1% at sunspot maximum.

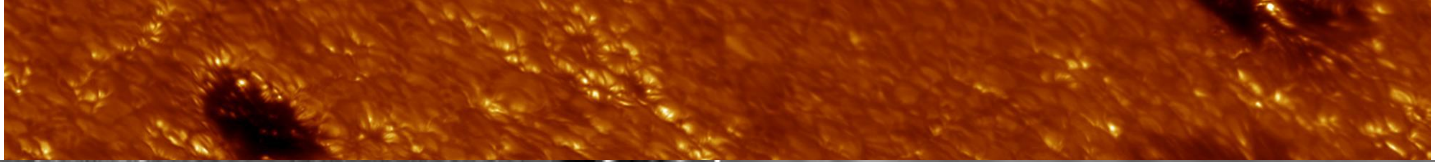
Why?

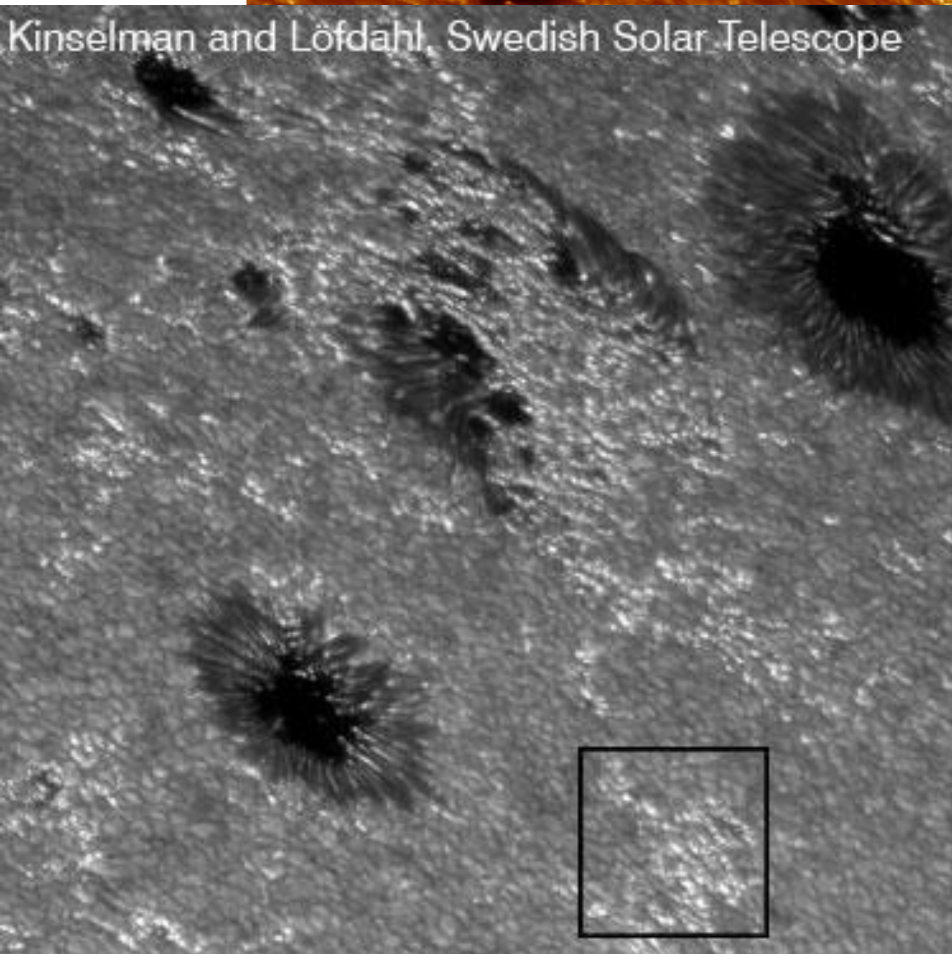
Faculae

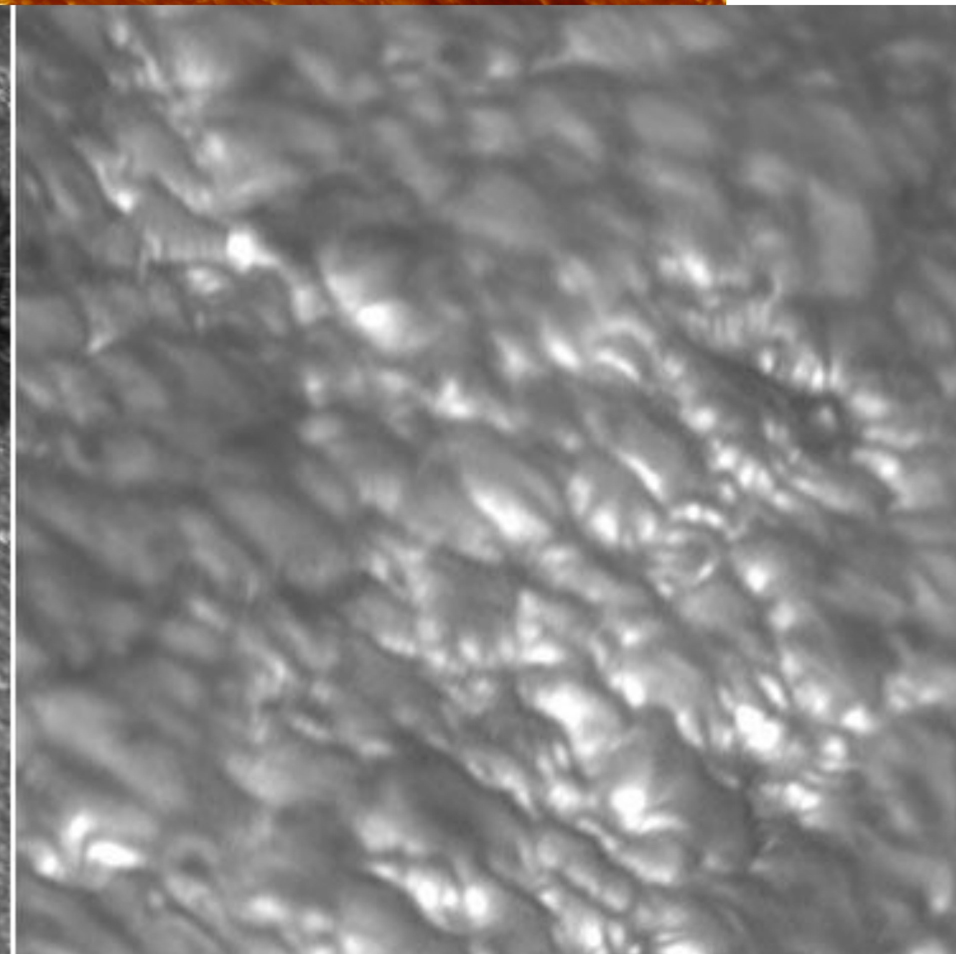

High solar activity - March 28, 2001
The number of bright solar faculae
are directly related to sunspot activity.
http://svs.gsfc.nasa.gov/vis/a000000/a002600/a002644/

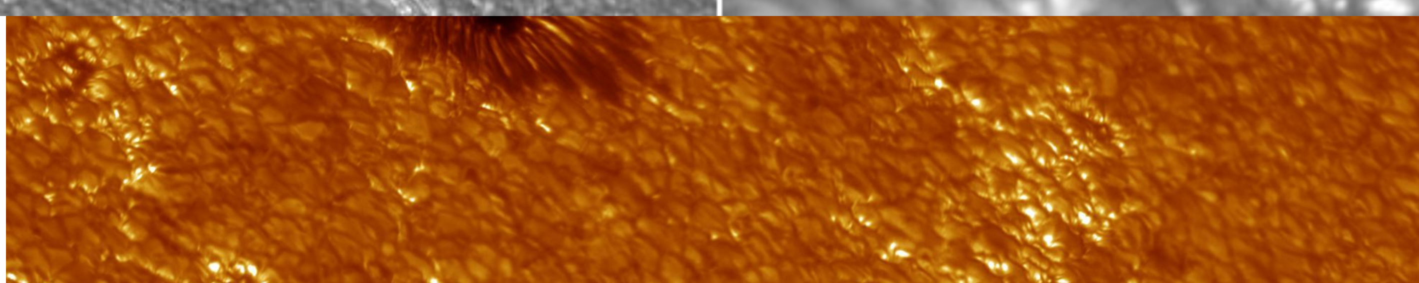

Low solar activity -
October 28, 1998


Moderate solar activity
- April 27, 2002



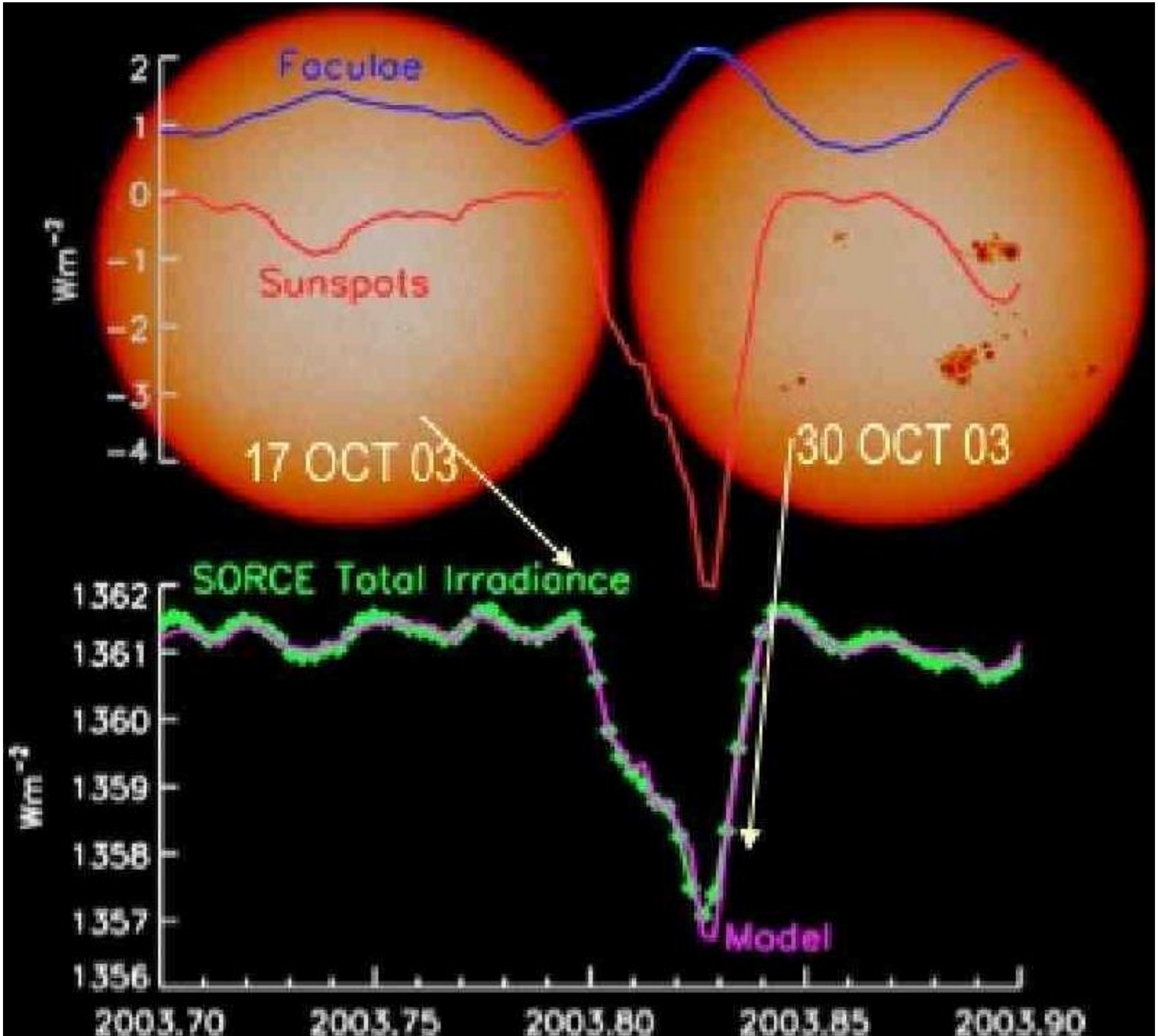


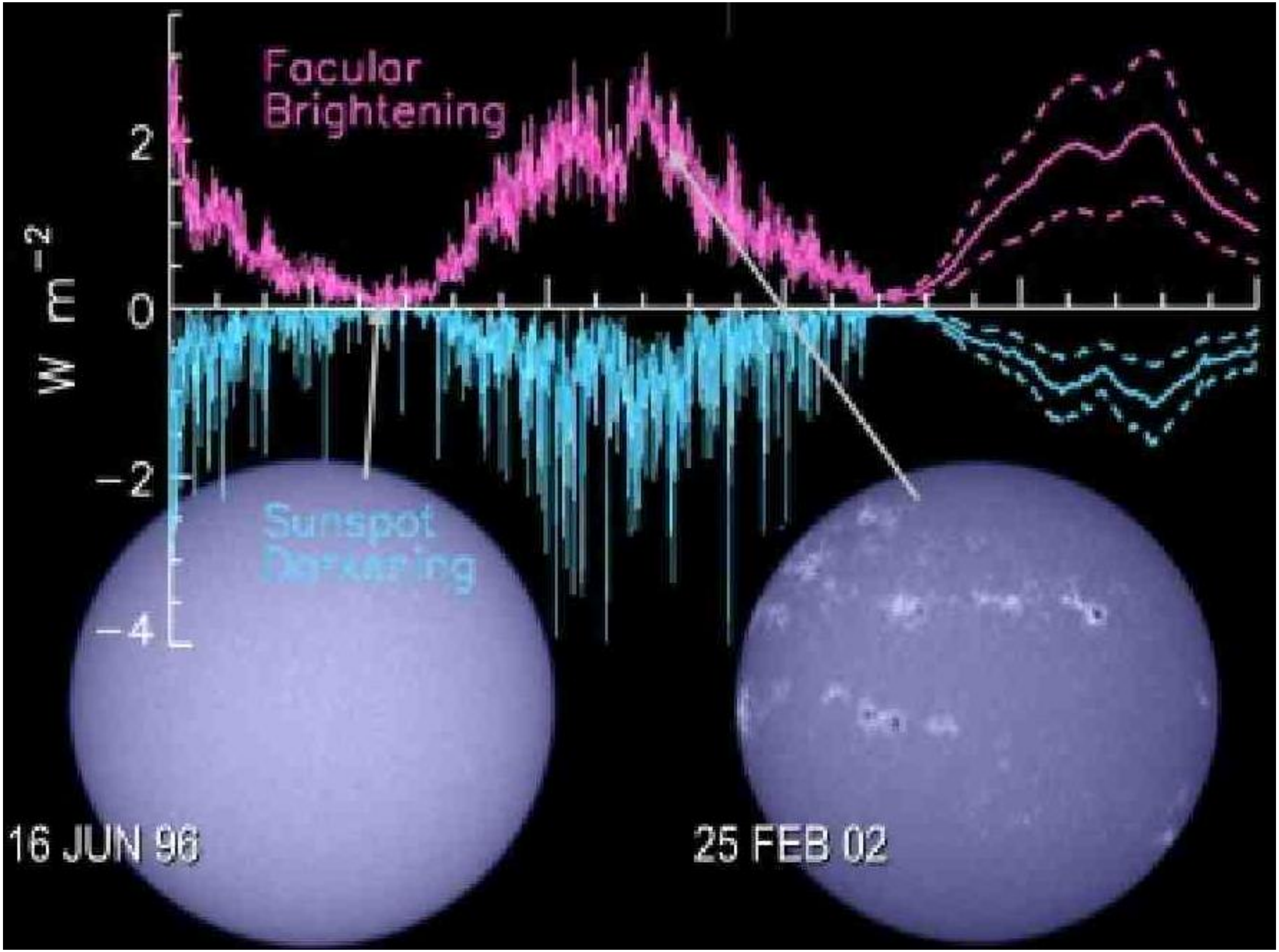




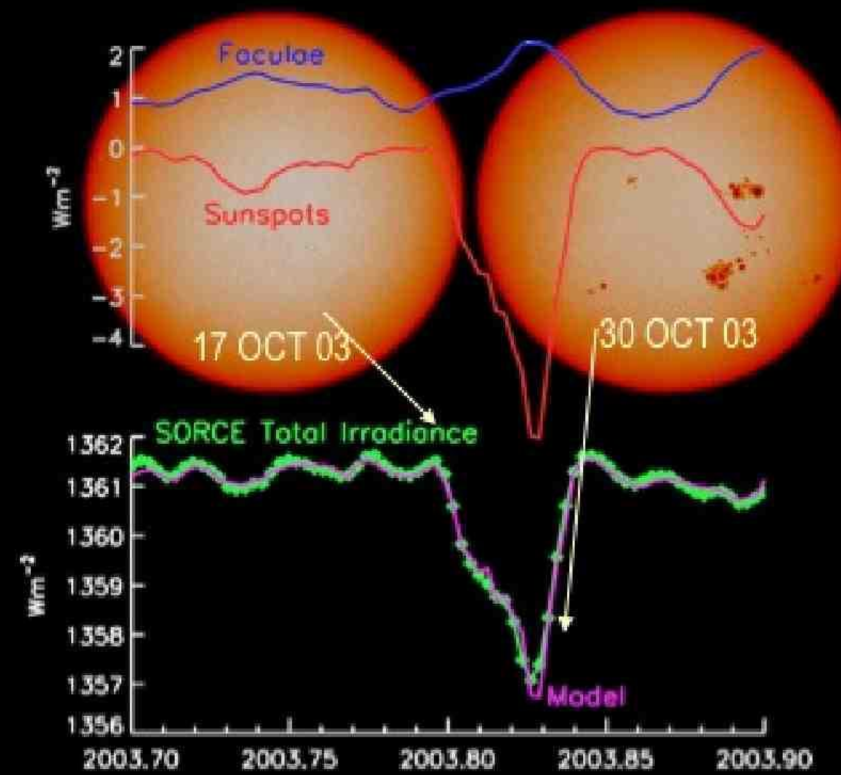
http://www.isf.astro.su.se/highlights/faculae-explained/

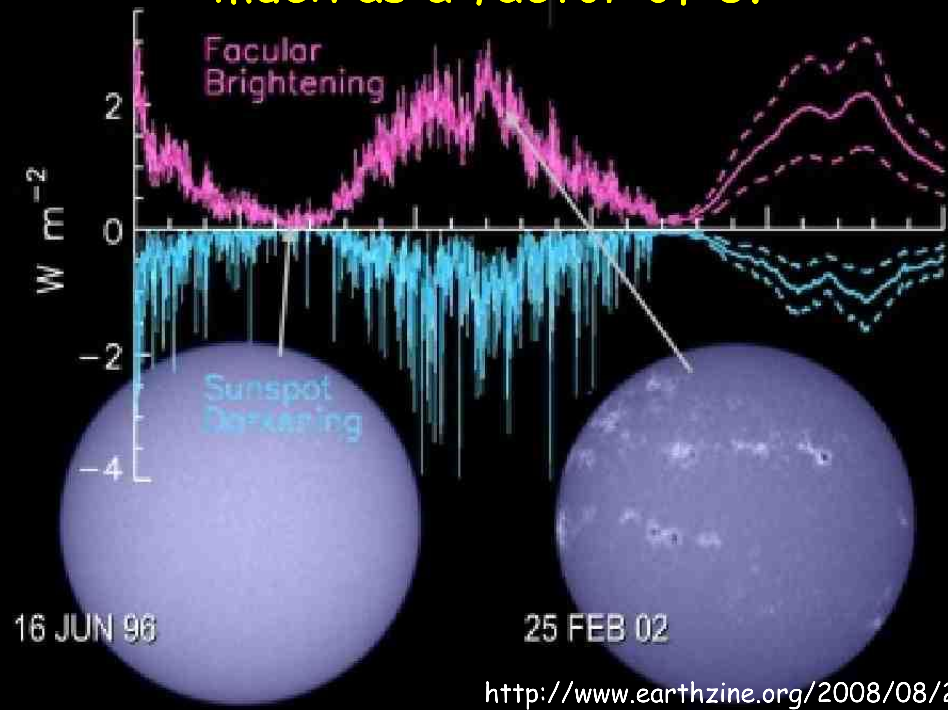
http://astro.ic.ac.uk/research/solar-basics


Faculae
Sunspots
Wm^{-3}
2
1
0
-1
-2
-3
-4
17 OCT 03
30 OCT 03
SORCE Total Irradiance
Model
Wm^{-3}
1362
1361
1360
1359
1358
1357
1356
2003.70
2003.75
2003.80
2003.85
2003.90


Facular
Brightening
W m⁻²
2
0
−2
−4
Sunspot
Darkening
16 JUN 96
25 FEB 02

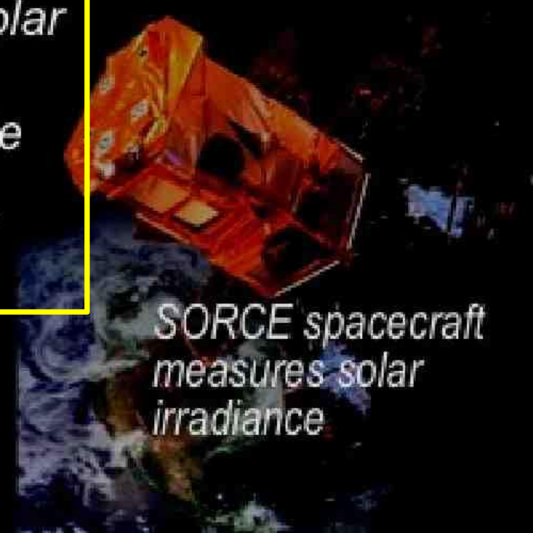
"There is an overall increase in total solar irradiance during the solar cycle because enhanced emission in bright faculae more than offsets (by a factor of ~2) the decreased emission in sunspots. However, when solar rotation carries large sunspots onto the face of the Sun visible at the Earth, short-term sunspot dimming can exceed facular brightening by as much as a factor of 5."





sunspots dominate faculae during solar rotation but…

faculae dominate sunspots during 11-year solar cycle



http://www.earthzine.org/2008/08/28/changing-sun-changing-earth/

→Sunspots are areas where the Sun's concentrated magnetic field deflects hot material flowing upward from the interior producing a cooler region.

→Faculae form where the magnetic field concentrates hot material flowing from the interior producing a hot spot.

→Faculae always form in areas surrounding sunspots. Faculae sometimes form along the boundaries between granules.

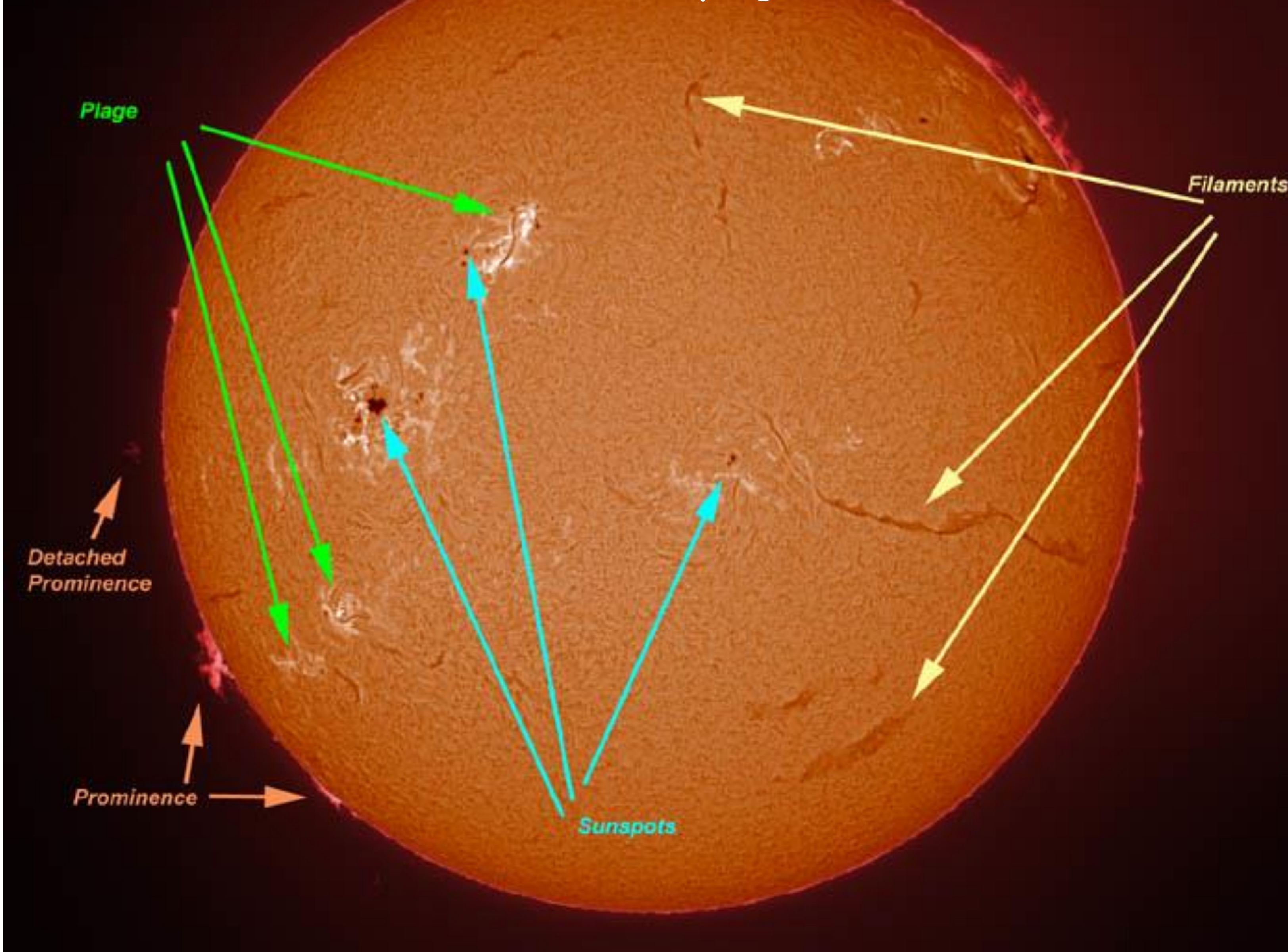
→Faculae are small-scale magnetic fluxes ranging from 0.1" to 1~2".

→The number of bright solar faculae are directly related to sunspot activity.

→The chromospheric counterpart of a facular region is called a plage.

https://suite101.com/a/solar-faculae-a62789 http://www.isf.astro.su.se/highlights/faculae-explained/
http://lasp.colorado.edu/sorce/news/2004ScienceMeeting/SORCE%20WORKSHOP%202004/SESSION_3/3_6_Berger.pdf

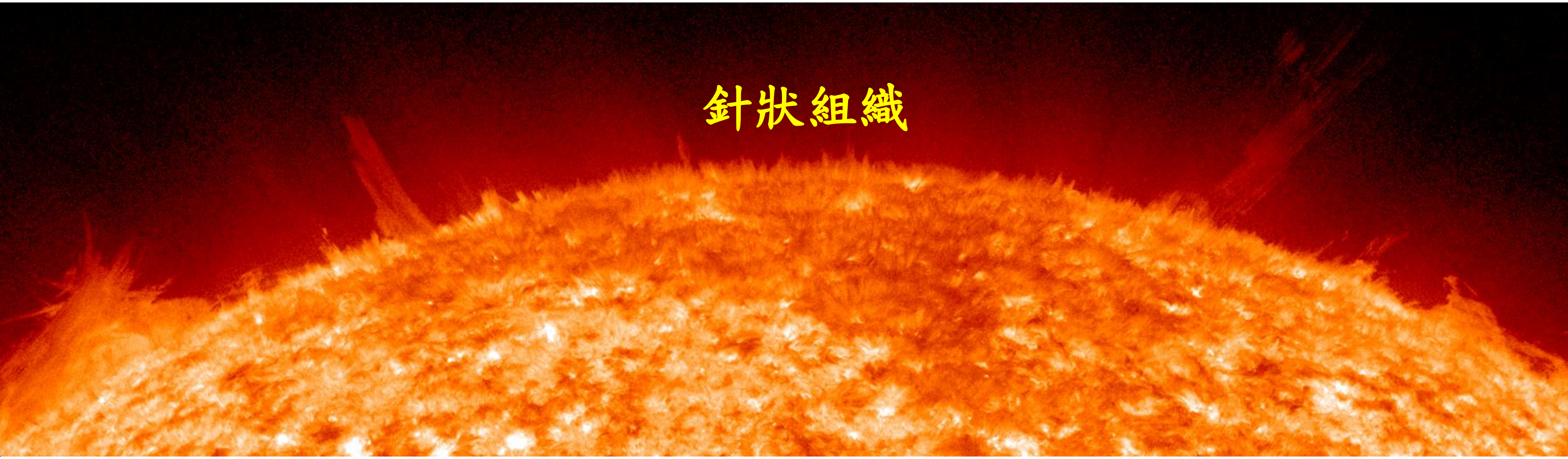
The chromospheric counterpart of a facular region is called a plage.



http://www.atscope.com.au/coronado/sunfeature.jpg

→色球層 (Chromosphere)

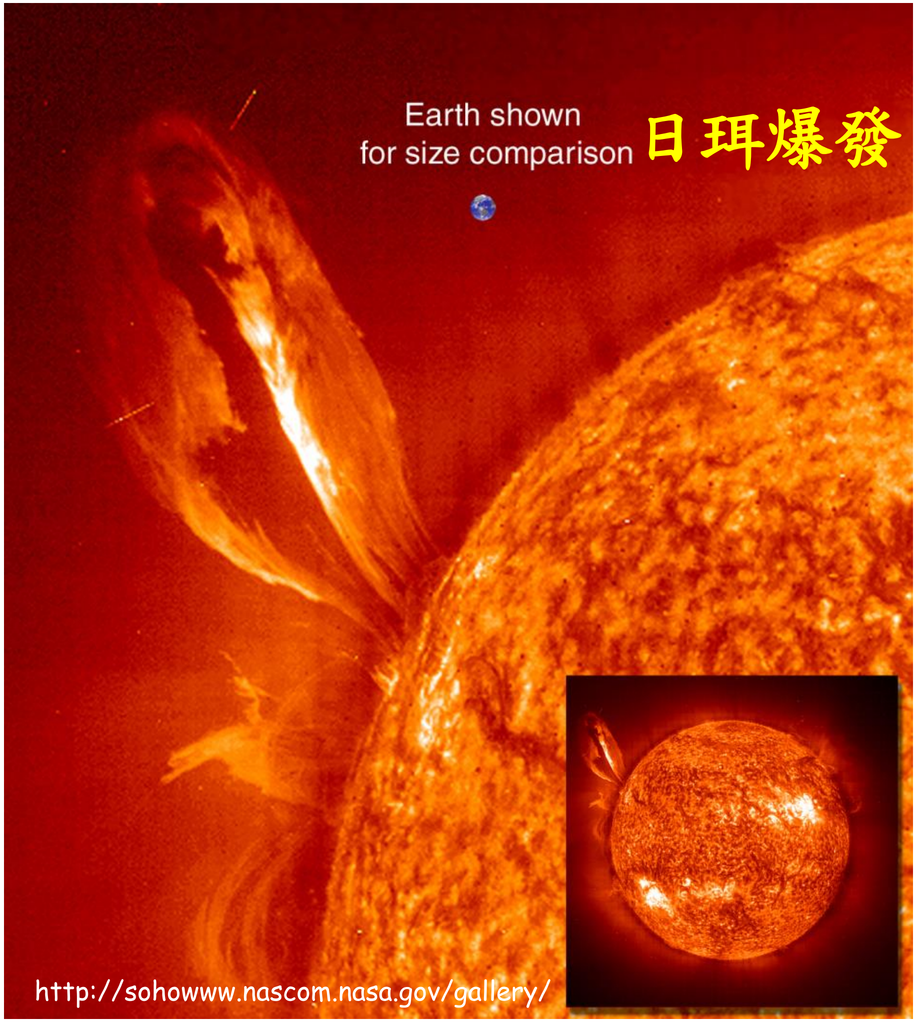
厚度約2000 km，溫度隨高度增加而上升(幾千到幾萬度K)。主要現象為:日珥(prominence)/暗紋(filament)，超米粒組織(super-granulation)，針狀組織(spicular)。

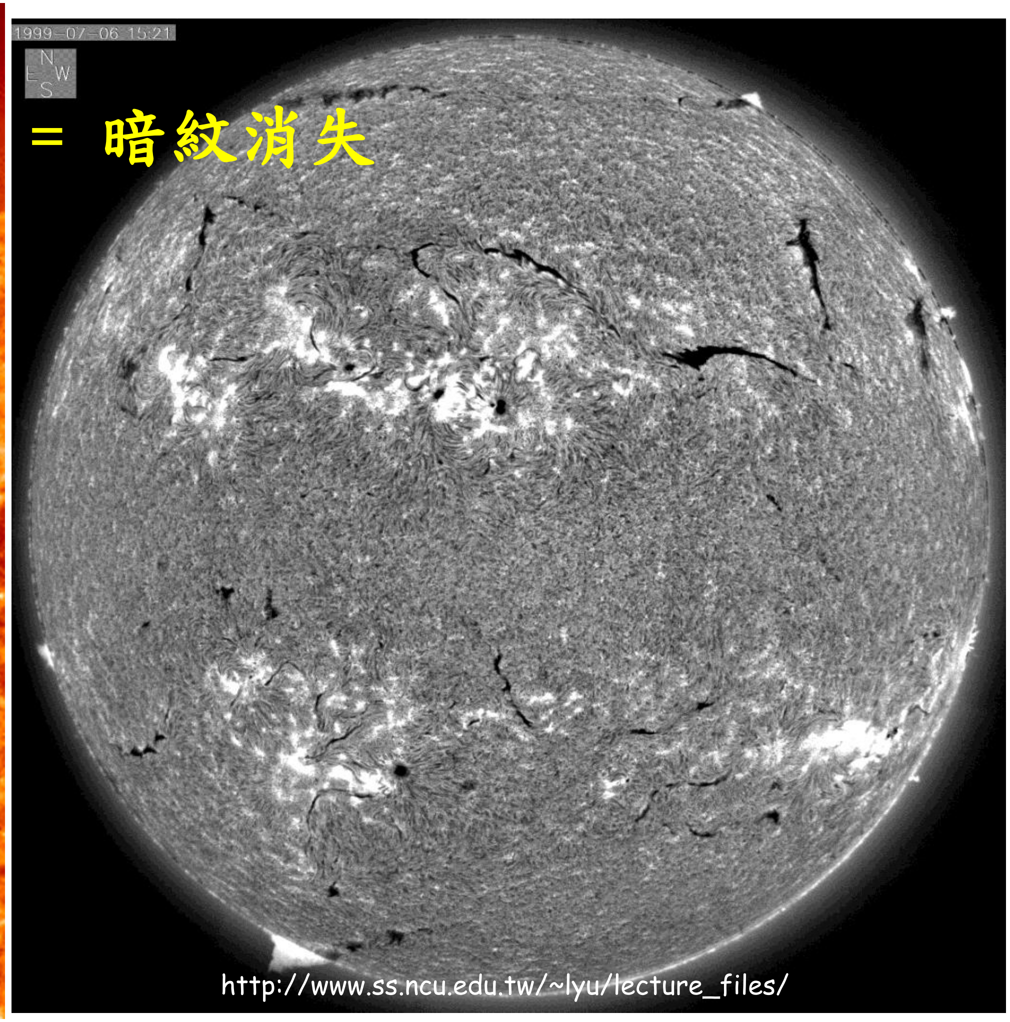


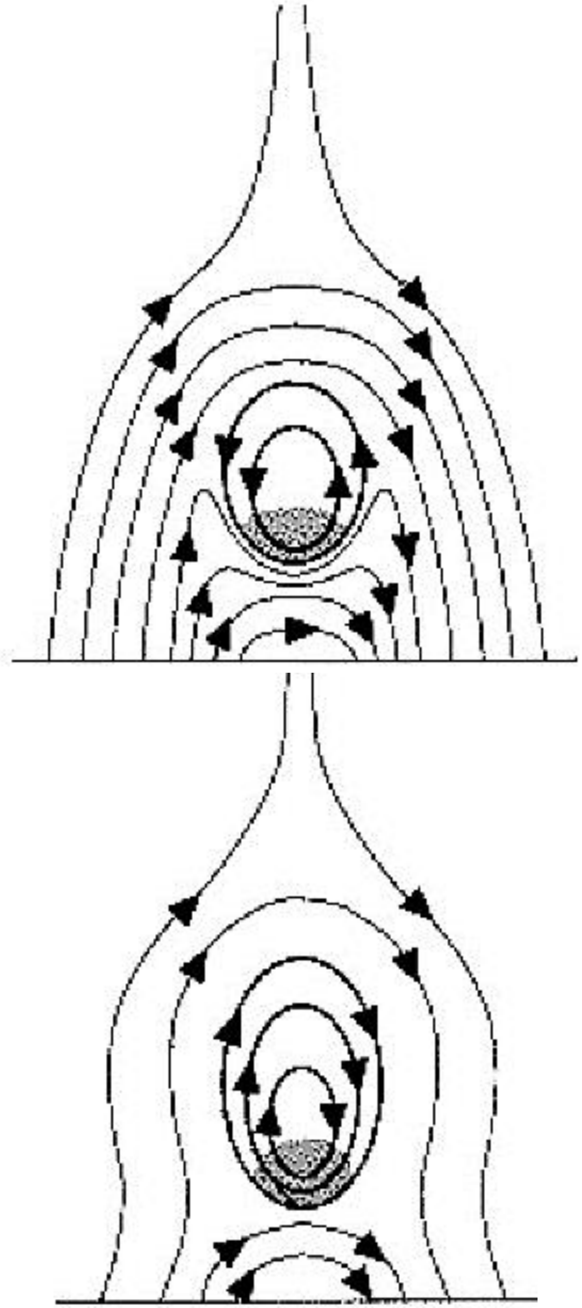
http://sdo.gsfc.nasa.gov/gallery/main.php

日珥/暗紋

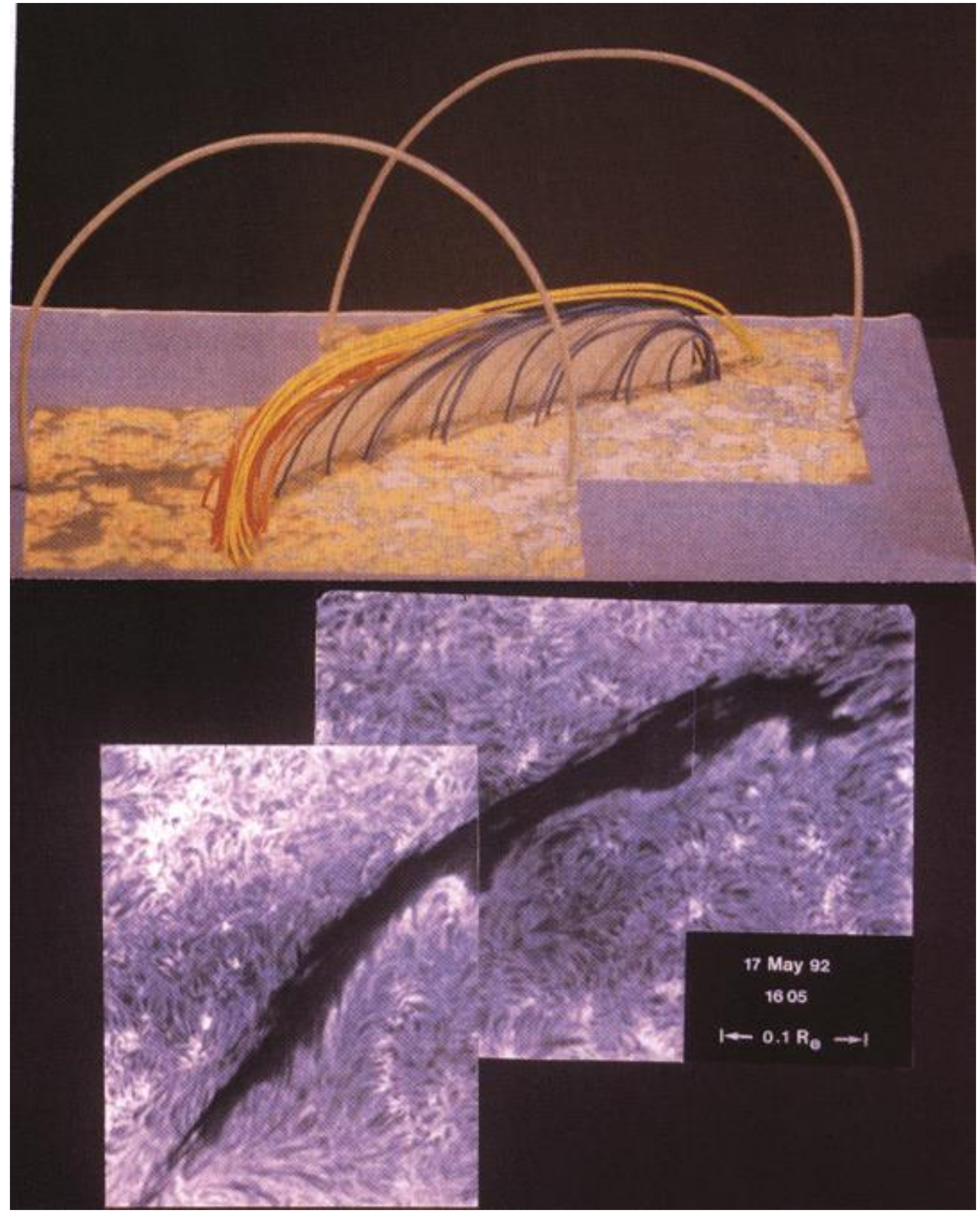
日珥是太陽的磁力線浮在光球層上方，電漿沿著磁力線運動，被束縛在此磁場結構中，形成低溫高密度的電漿結構。因此在黑暗的星空襯托下，日珥是一個光亮的結構。而相對光亮的光球層而言，日珥中低溫高密度的電漿結構，會遮住來自光球層的H-alpha光，而呈現黑色的暗紋結構。





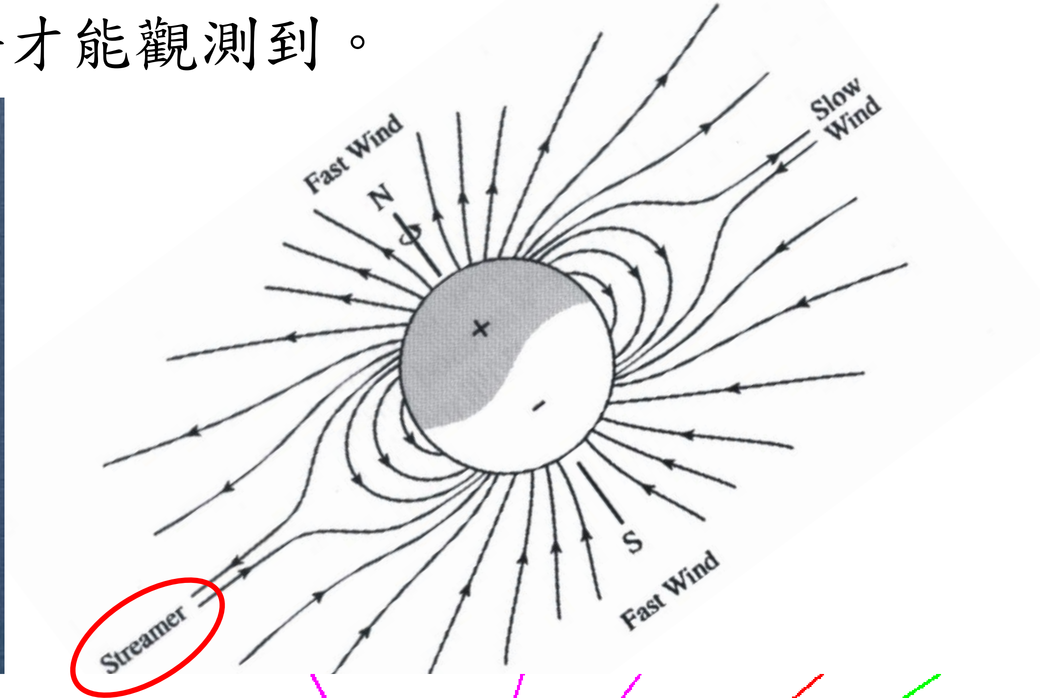


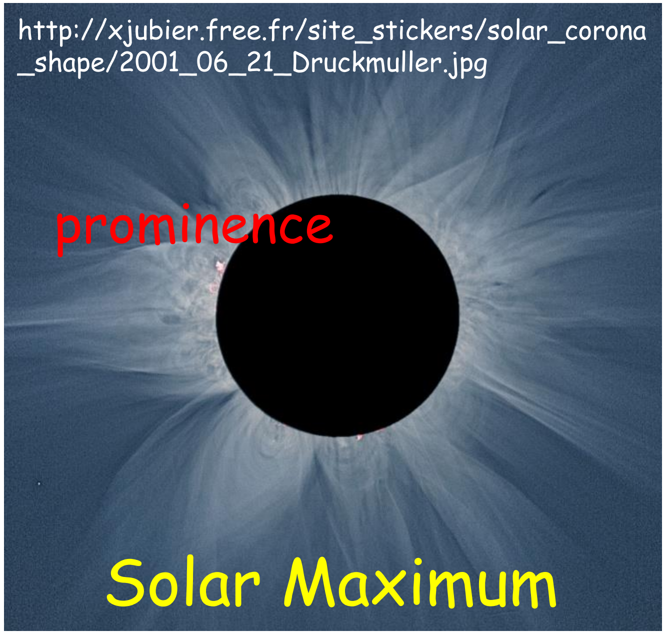
http://www.agu.org/journals/ja/ja0302/2002JA009588/

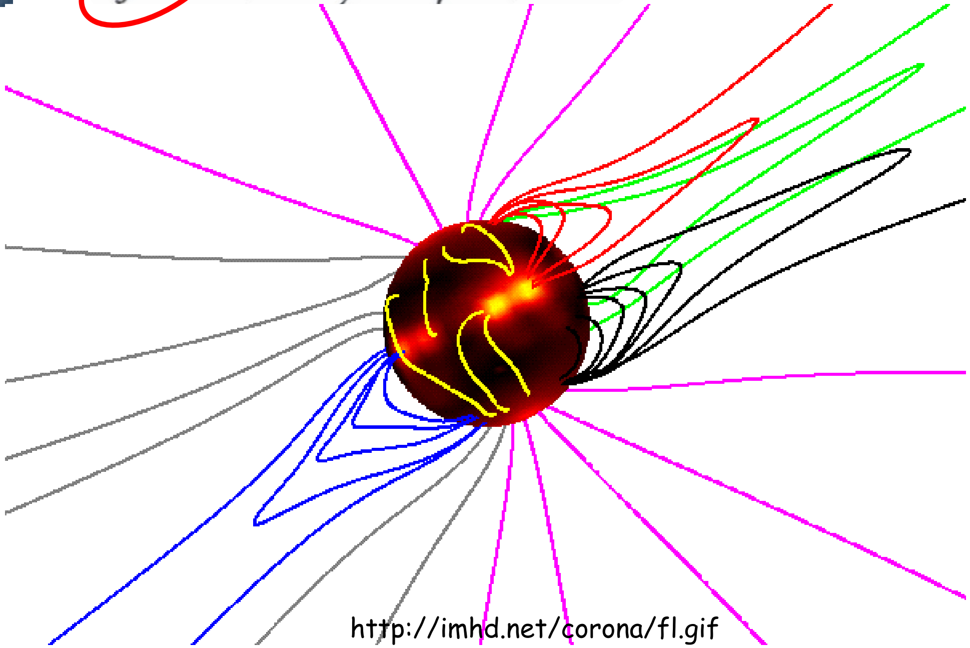


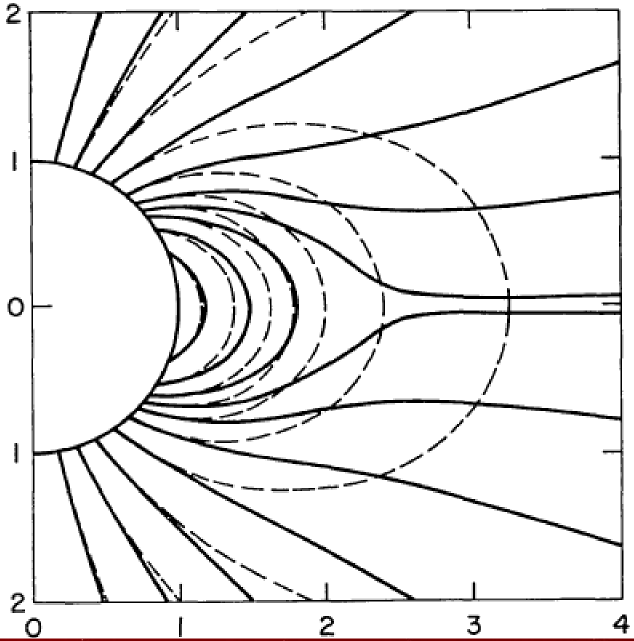
http://www.ss.ncu.edu.tw/~lyu/lecture_files/2002Spring/IntroSpace_exam/Solar_Fig/filament-B-model.gif

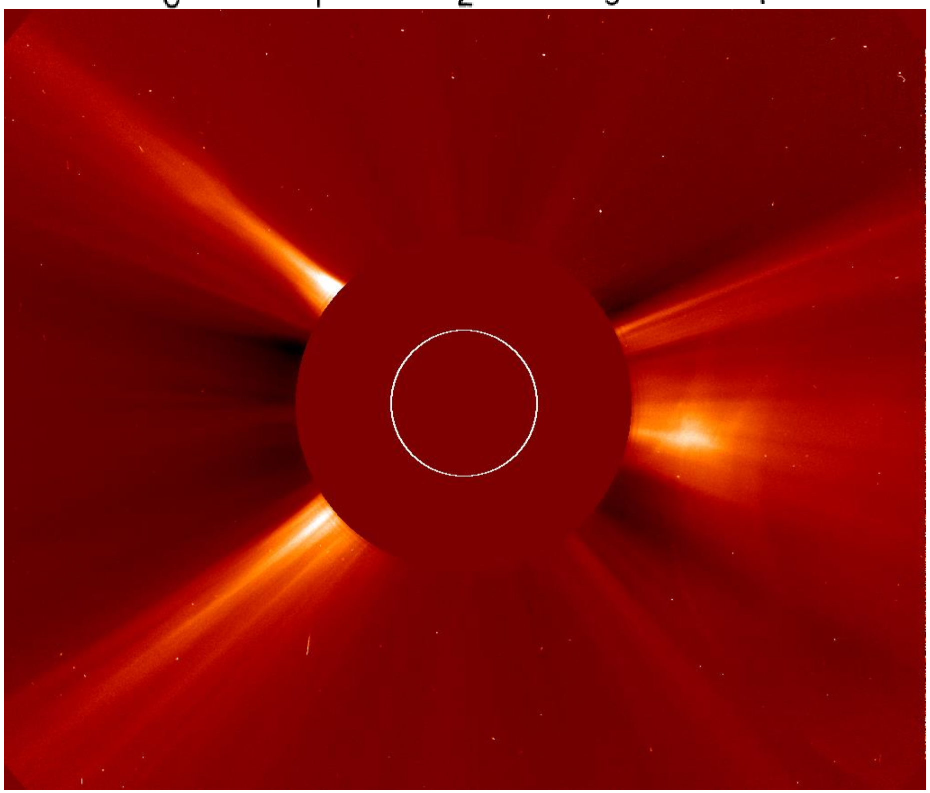
→日冕 (Corona): 溫度為百萬度K，密度非常稀薄，只有在日全食或使用日冕儀時才能觀測到。











Streamer

→a stable large-scale structure in the outer corona

→extending away from the Sun along the radial direction

→open magnetic field lines with opposite polarity

→current sheet in between

→associated with the heliospheric current sheet