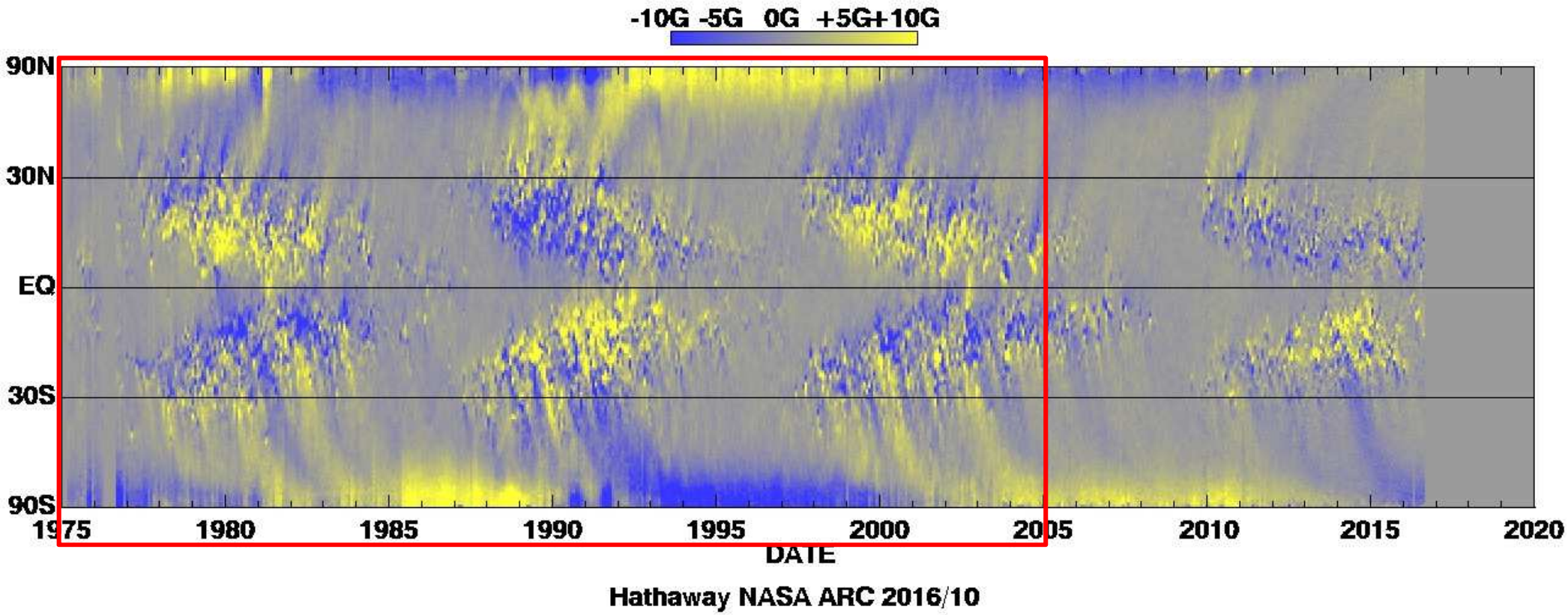
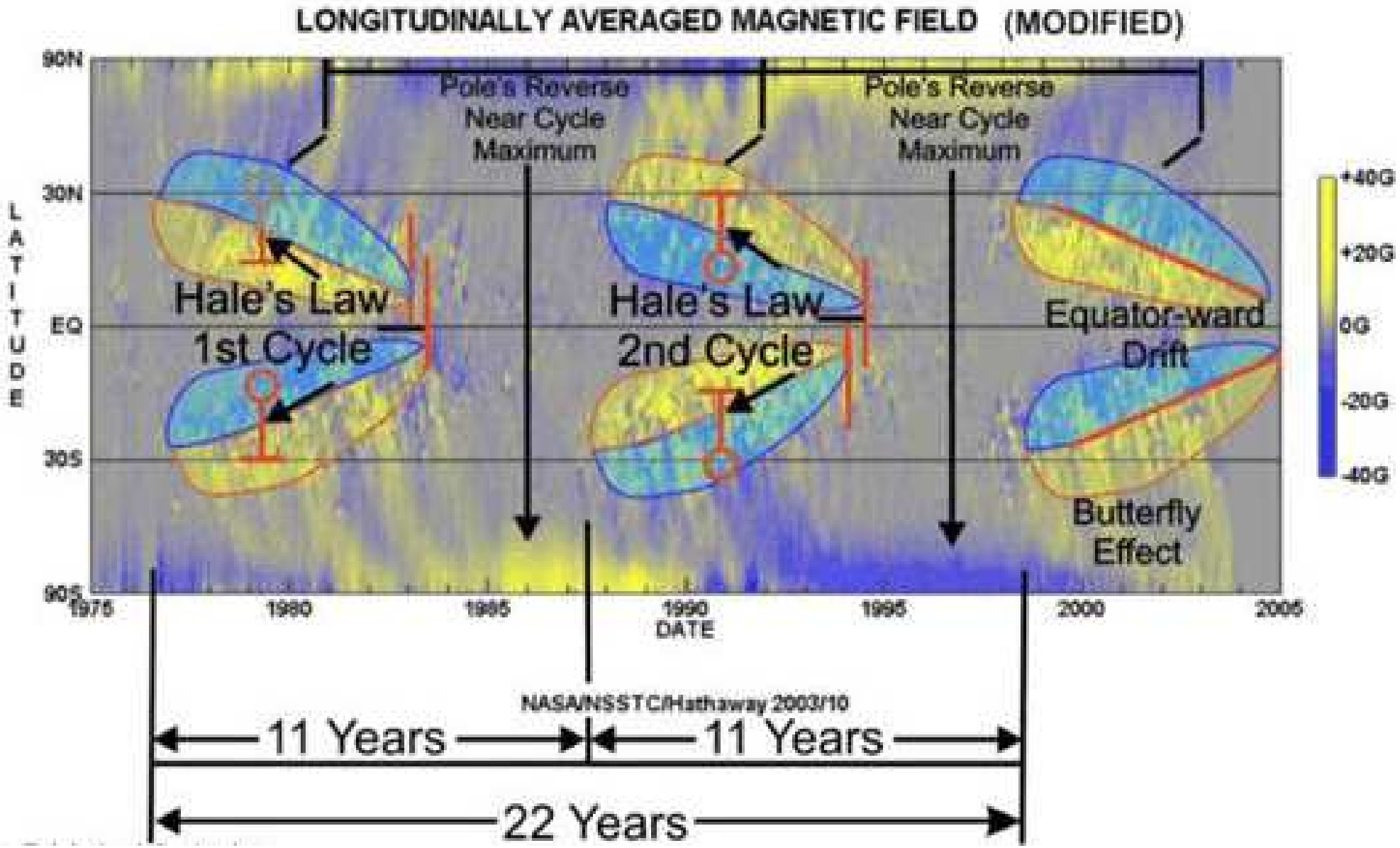
Magnetic Butterfly Diagram



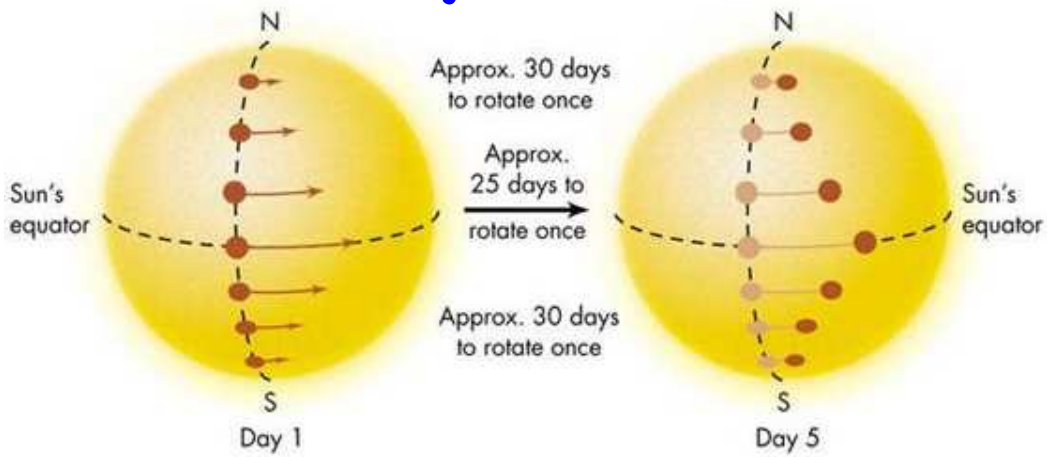
https://solarscience.msfc.nasa.gov/images/magbfly.jpg

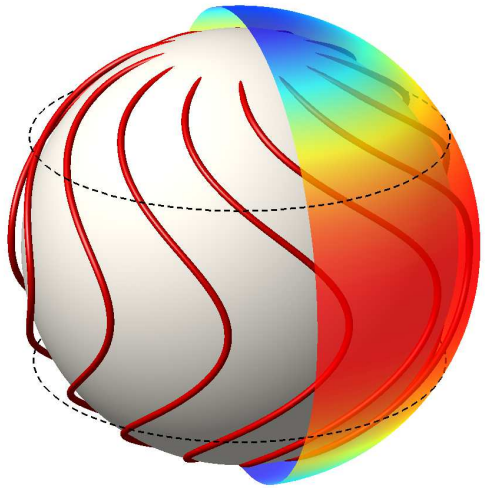
Magnetic Butterfly Diagram

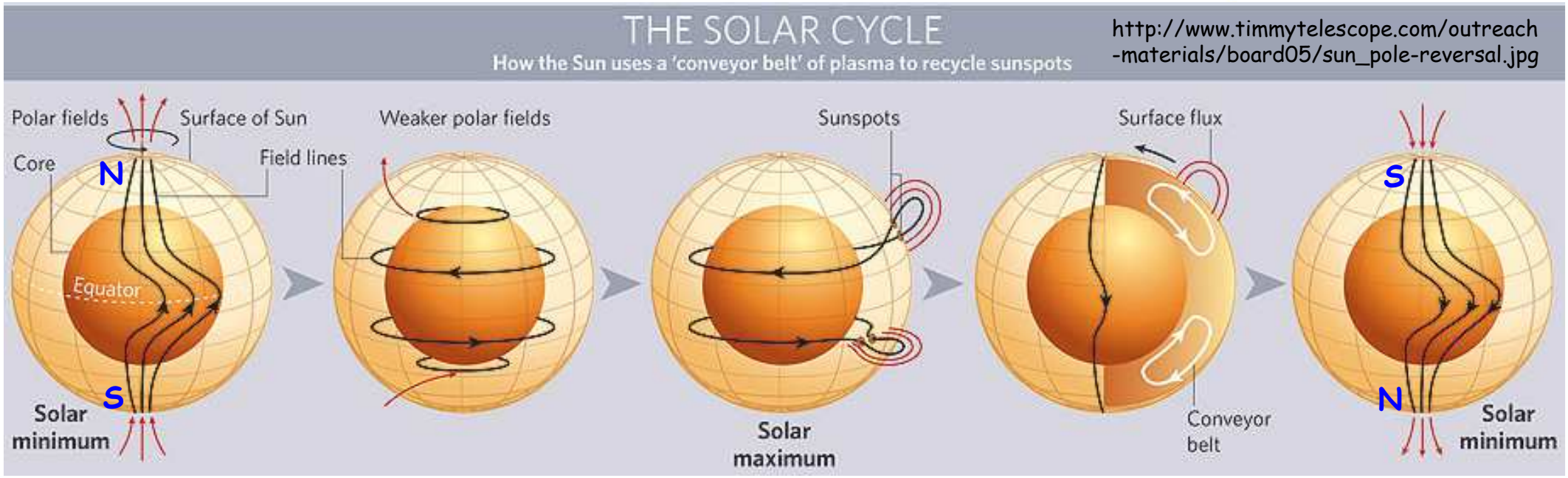


http://www.e-huh.com/chapter%207%20the%20sun/chapter%207%20a%20new%20model%20of%20the%20sun_files/image004.jpg

Solar Dynamo---Babcock Model







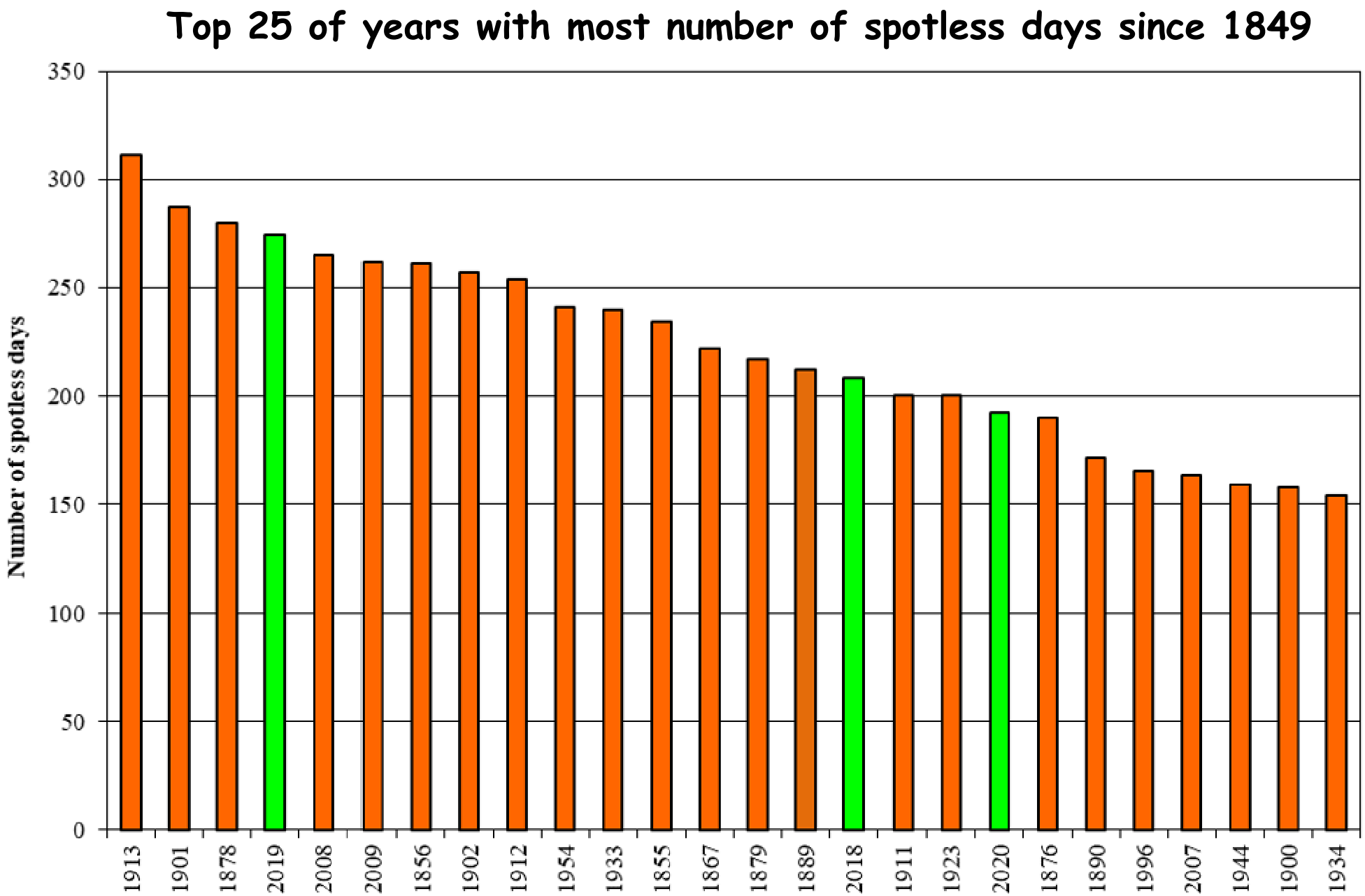
http://www.timmytelescope.com/outreach-materials/board05/sun_pole-reversal.jpg

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。

http://www.stil.bas.bg/IHY/lectur_1/l2fig/image003.jpg

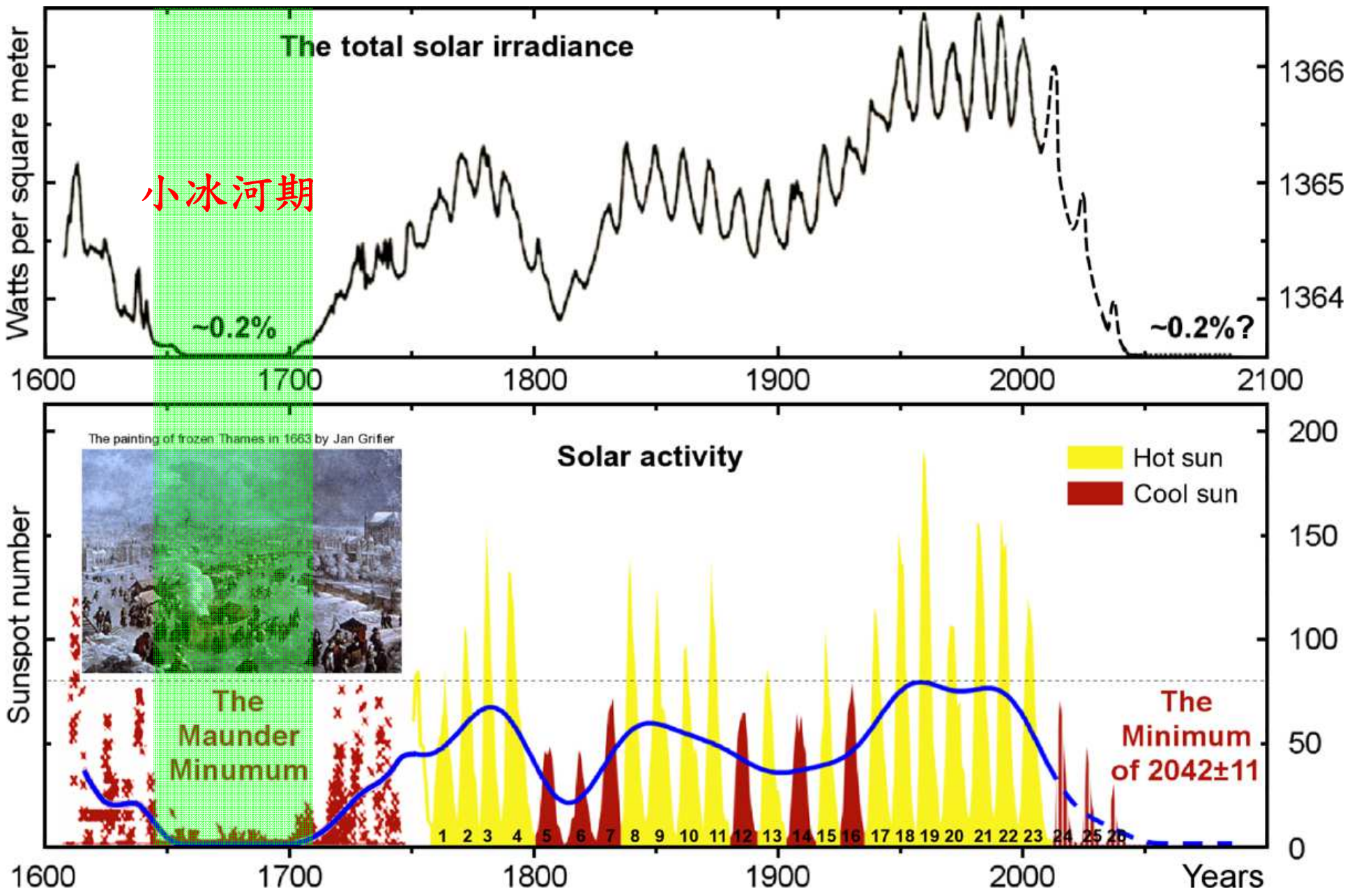
https://www.staff.ncl.ac.uk/toby.wood/files/2015/04/sphere3.png

Days of Spotless Sunspot



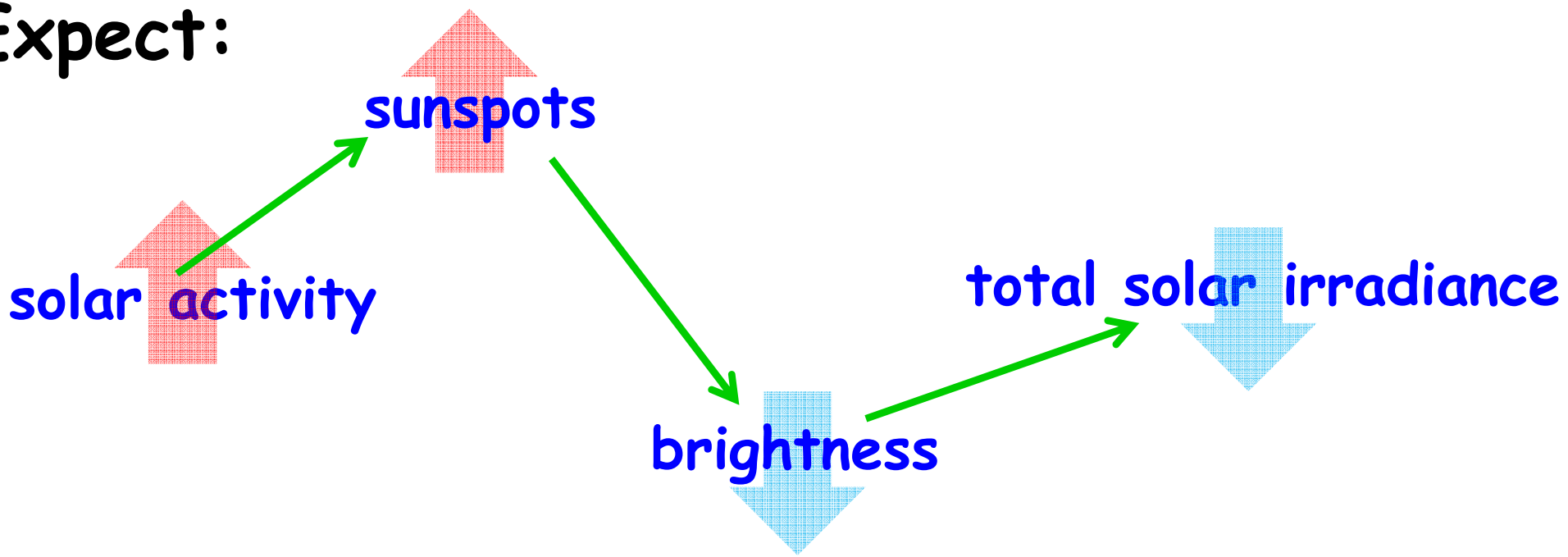
http://www.sidc.be/silso/IMAGES/GRAPHICS/spotlessJJ/SC25_year.png

Maunder Minimum (1645-1715)



http://www.gao.spb.ru/english/astrometr/sa_tsi_1600_en.jpg

Expect:

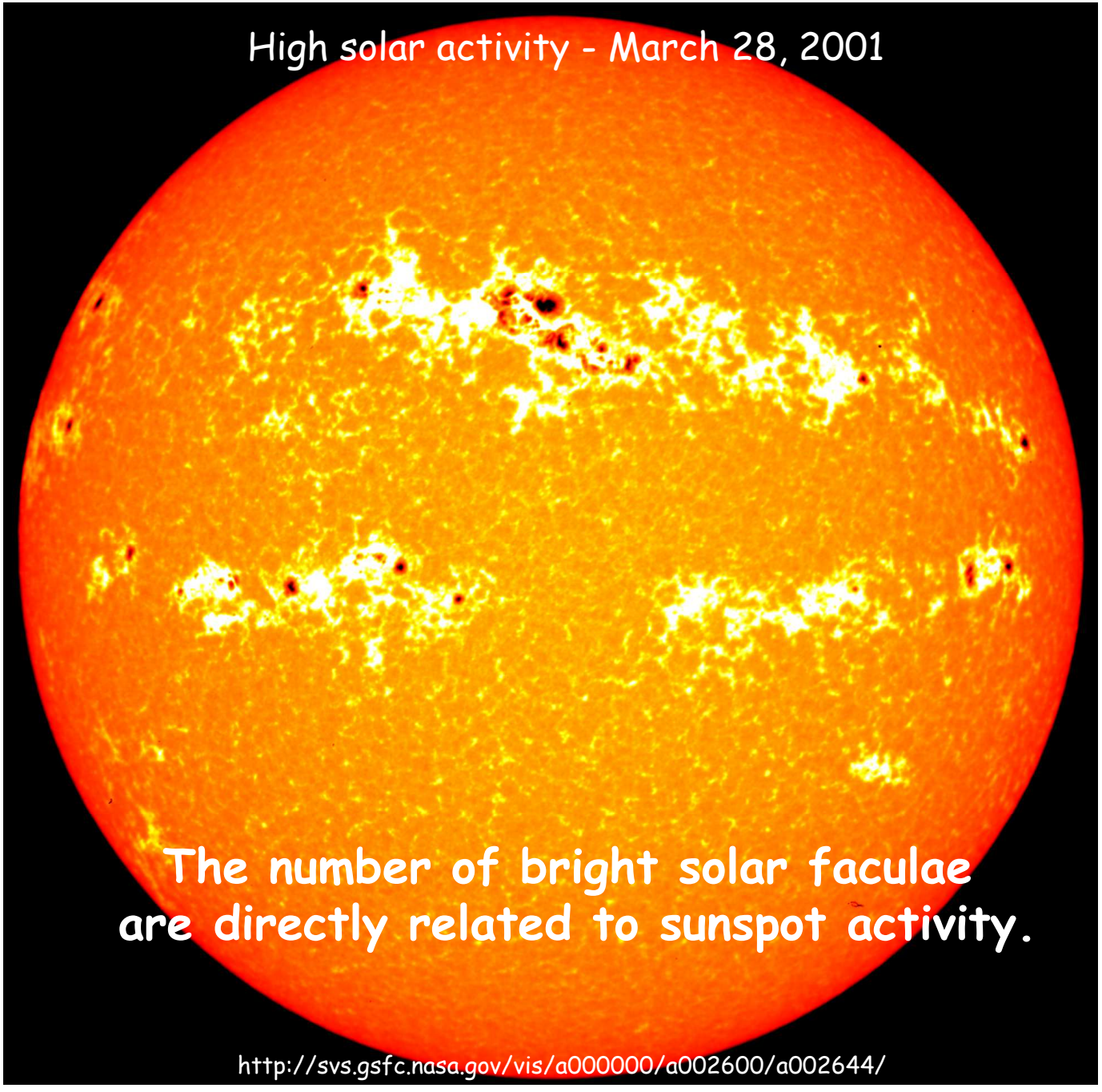


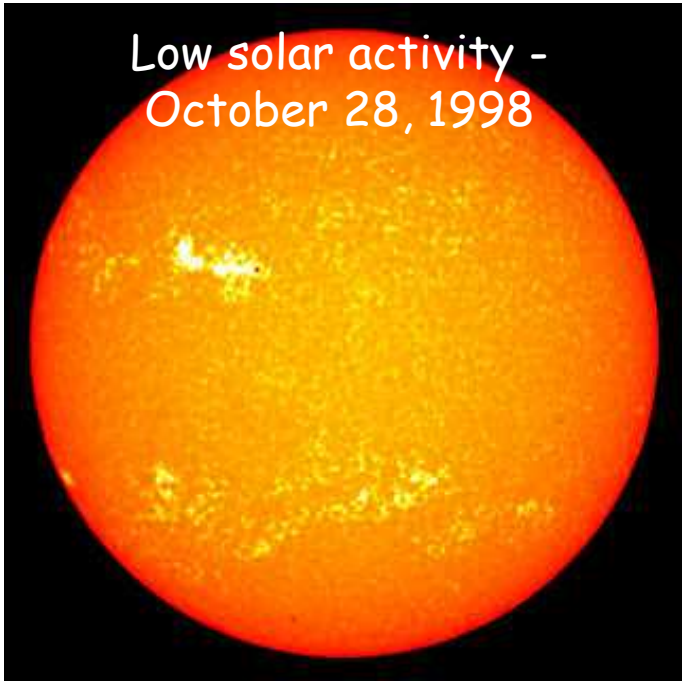
In reality:

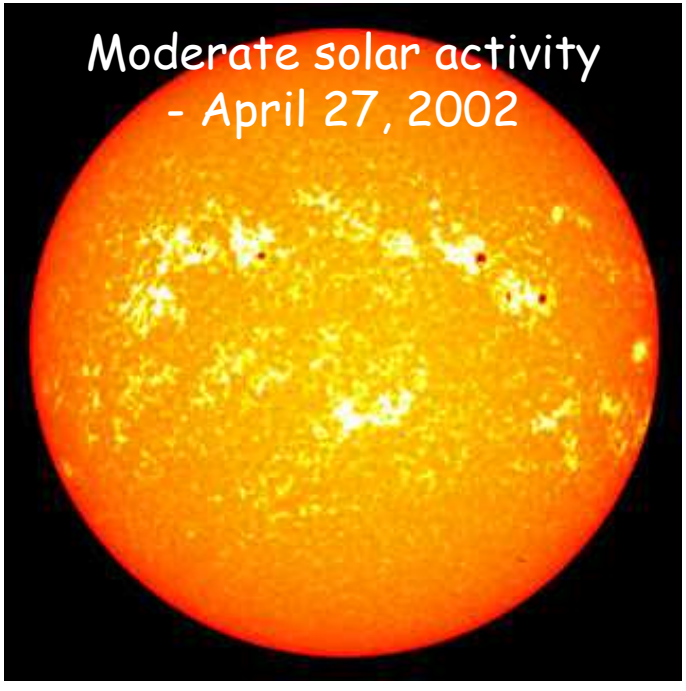
The total solar irradiance (TSI) increases by ~0.1% at sunspot maximum.

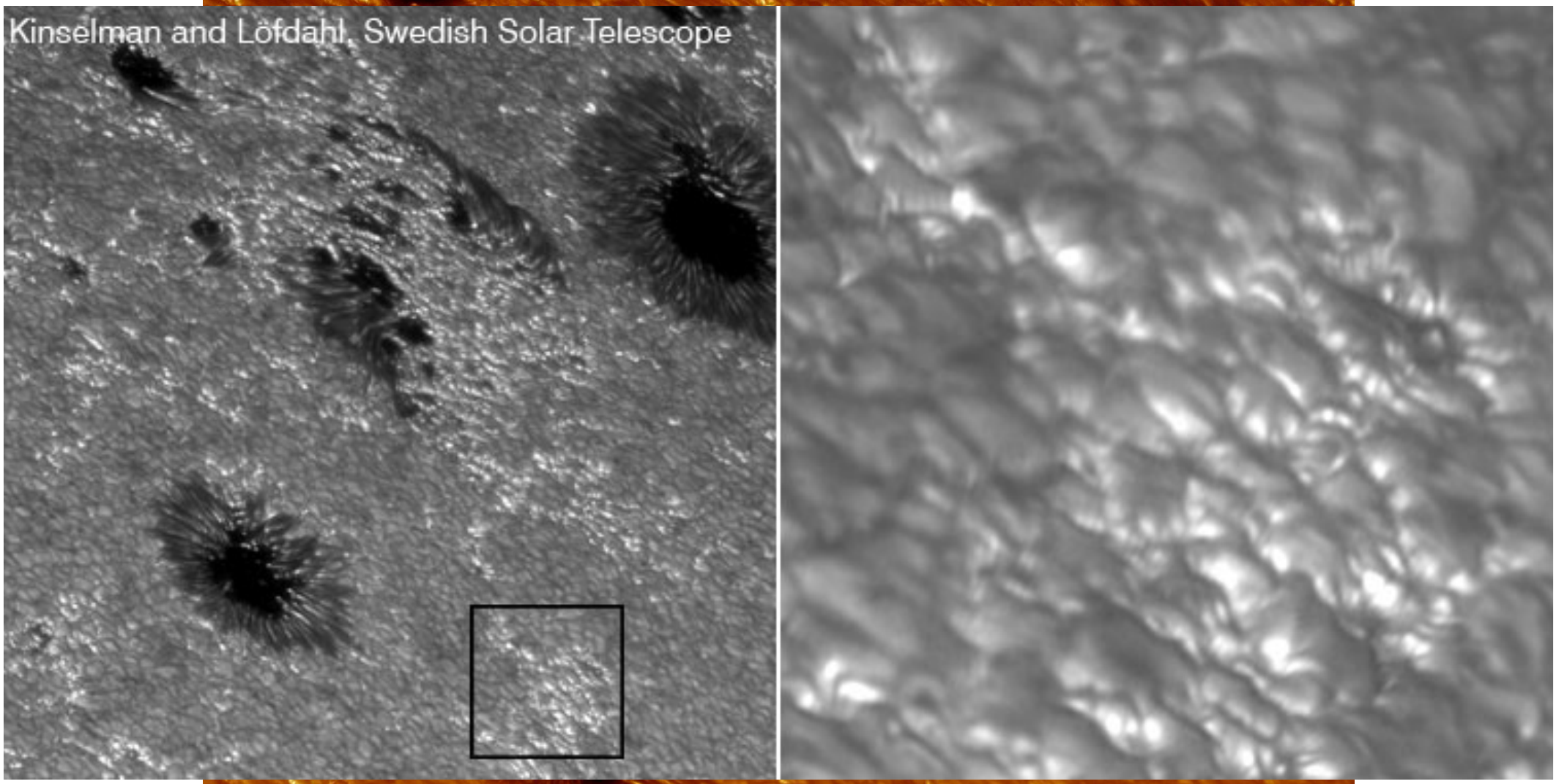
Why?

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

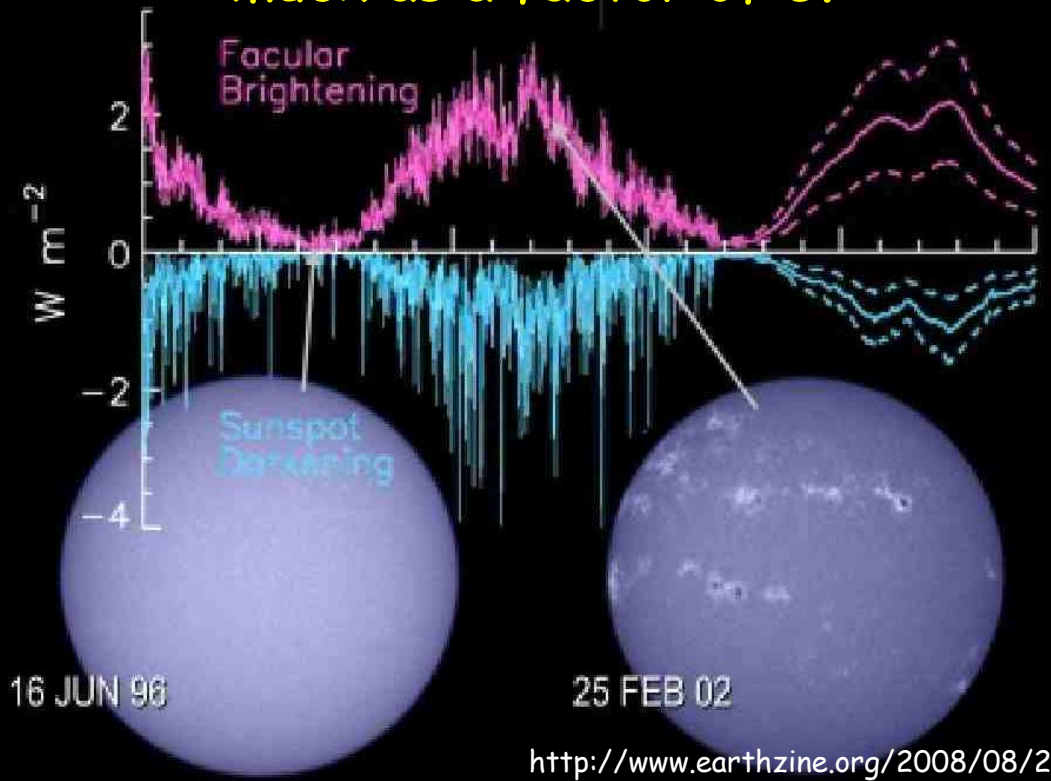

Moderate solar activity - April 27, 2002

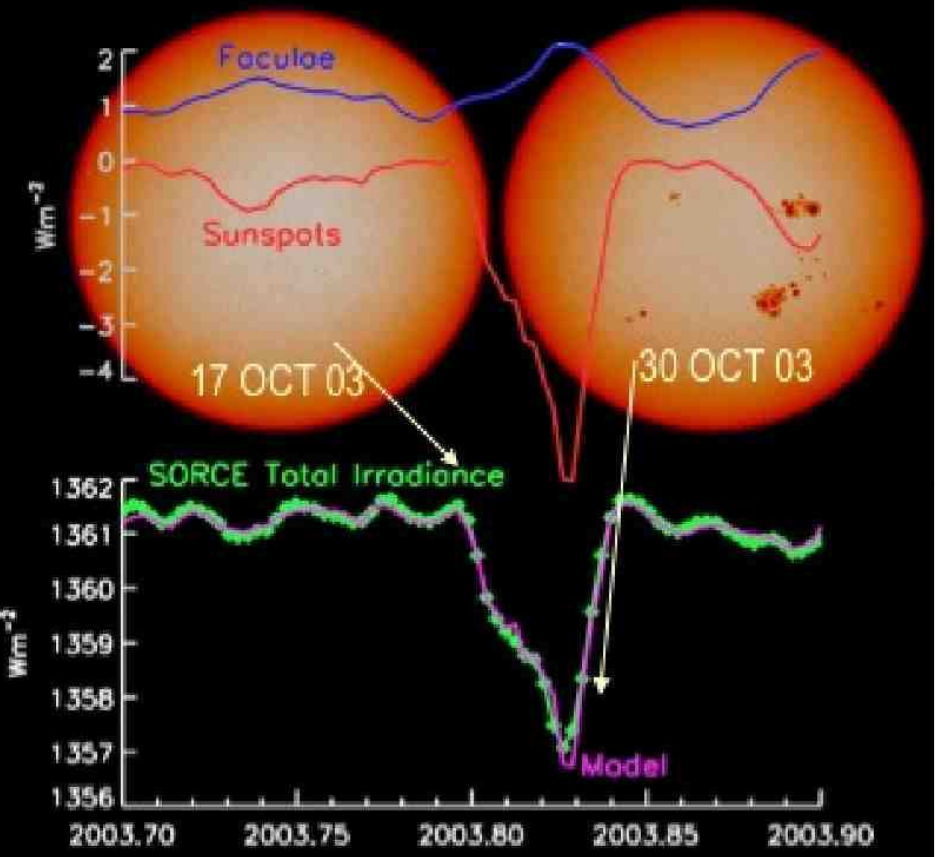


http://www.isf.astro.su.se/highlights/faculae-explained/

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

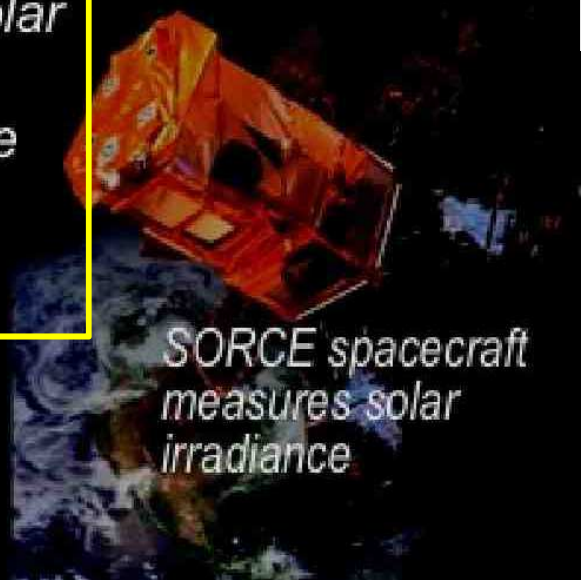
"There is an overall increase in total solar irradiance during the solar cycle because enhanced emission in bright faculae more than offsets (by a factor of ~2) the decreased emission in sunspots. However, when solar rotation carries large sunspots onto the face of the Sun visible at the Earth, short-term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





sunspots dominate faculae during solar rotation but…

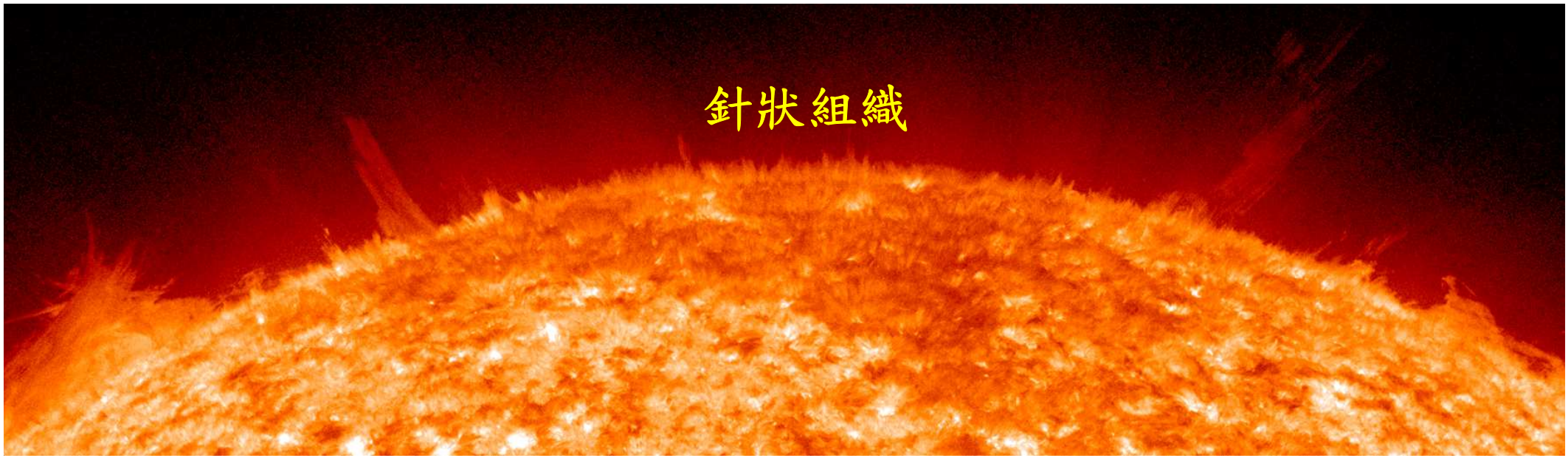
faculae dominate sunspots during 11-year solar cycle



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

→色球層 (Chromosphere)

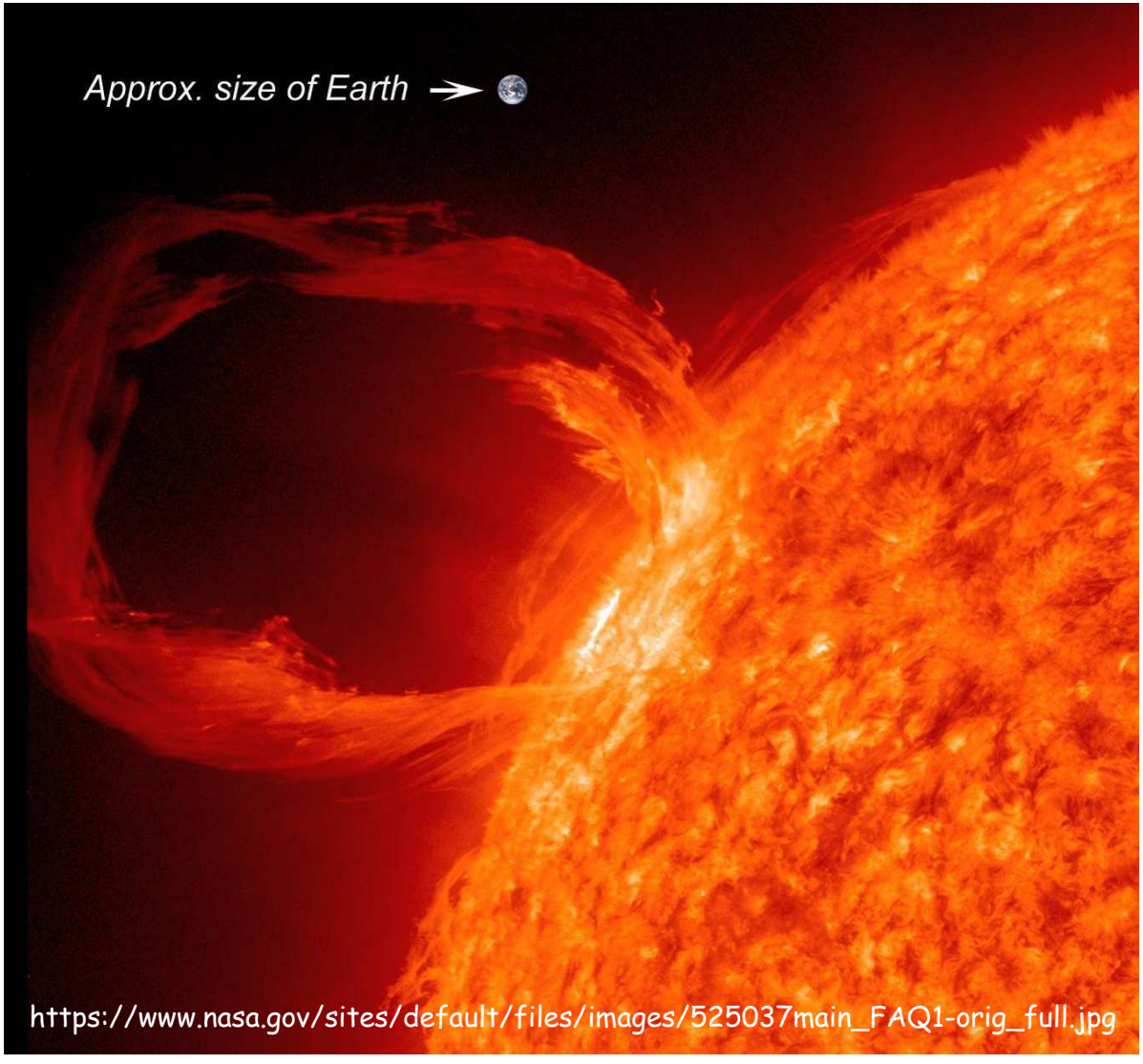
厚度約2000 km，溫度隨高度增加而上升(幾千到幾萬度K)。主要現象為:日珥(prominence)/暗紋(filament)，超米粒組織(super-granulation)，針狀組織(spicule)。



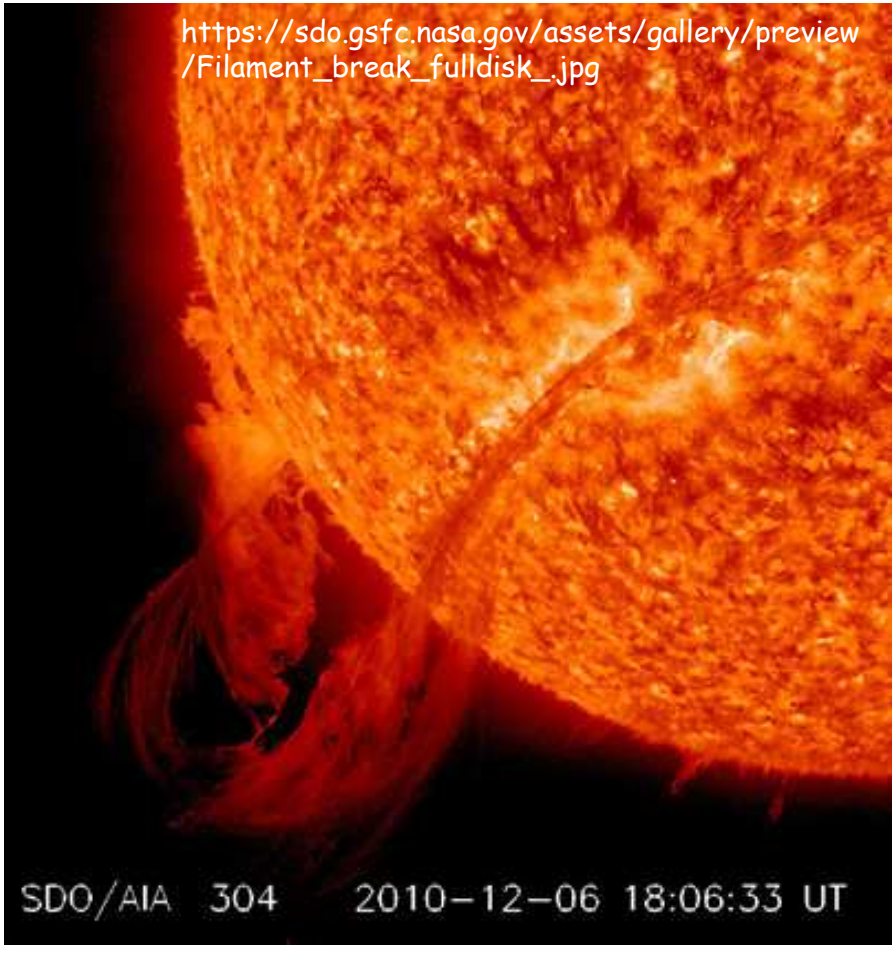
http://sdo.gsfc.nasa.gov/gallery/main.php

日珥/暗紋

日珥是太陽的磁場浮在光球層上方，被束縛在此磁場結構的電漿所形成的低溫高密度的結構。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。

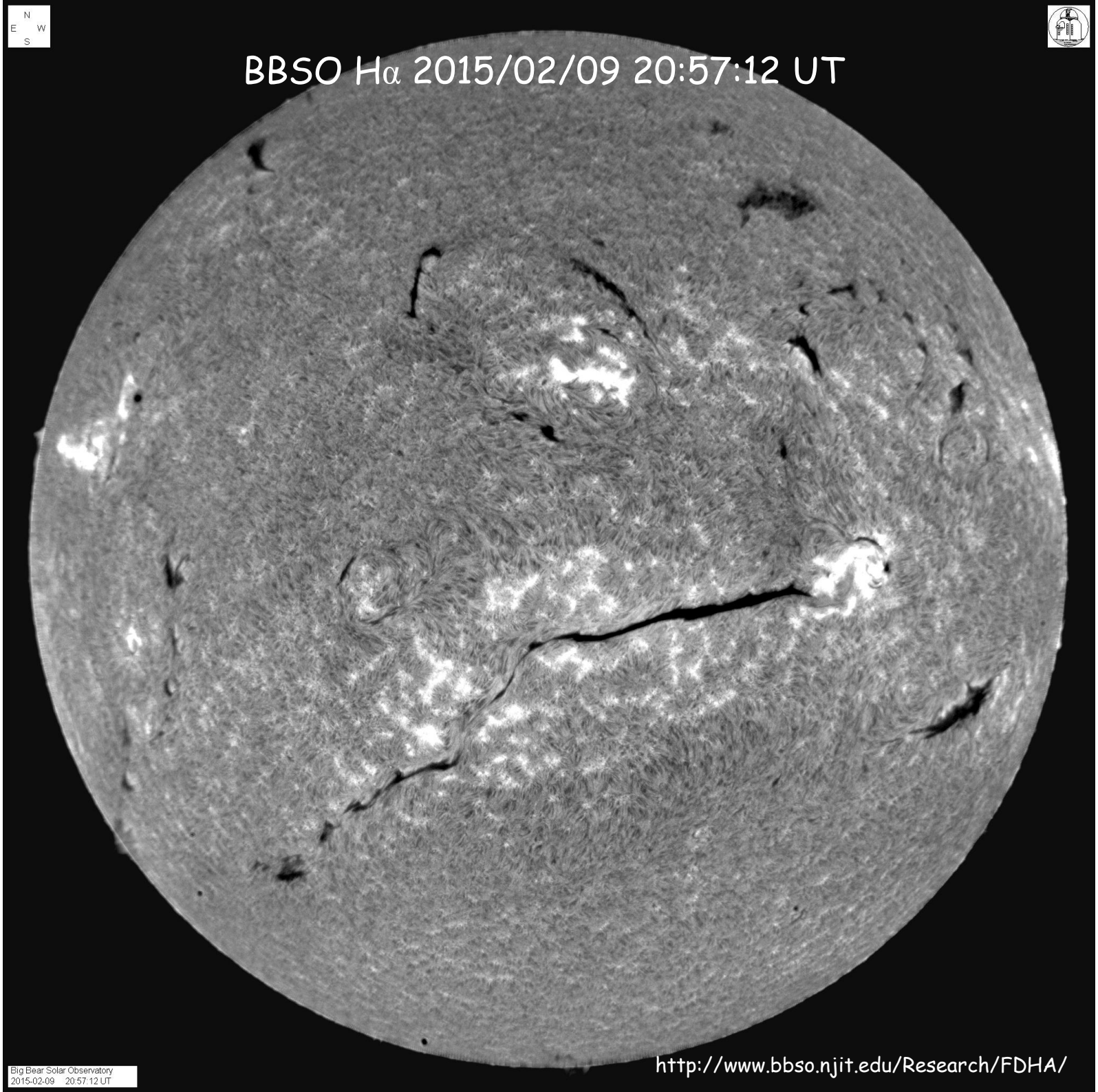


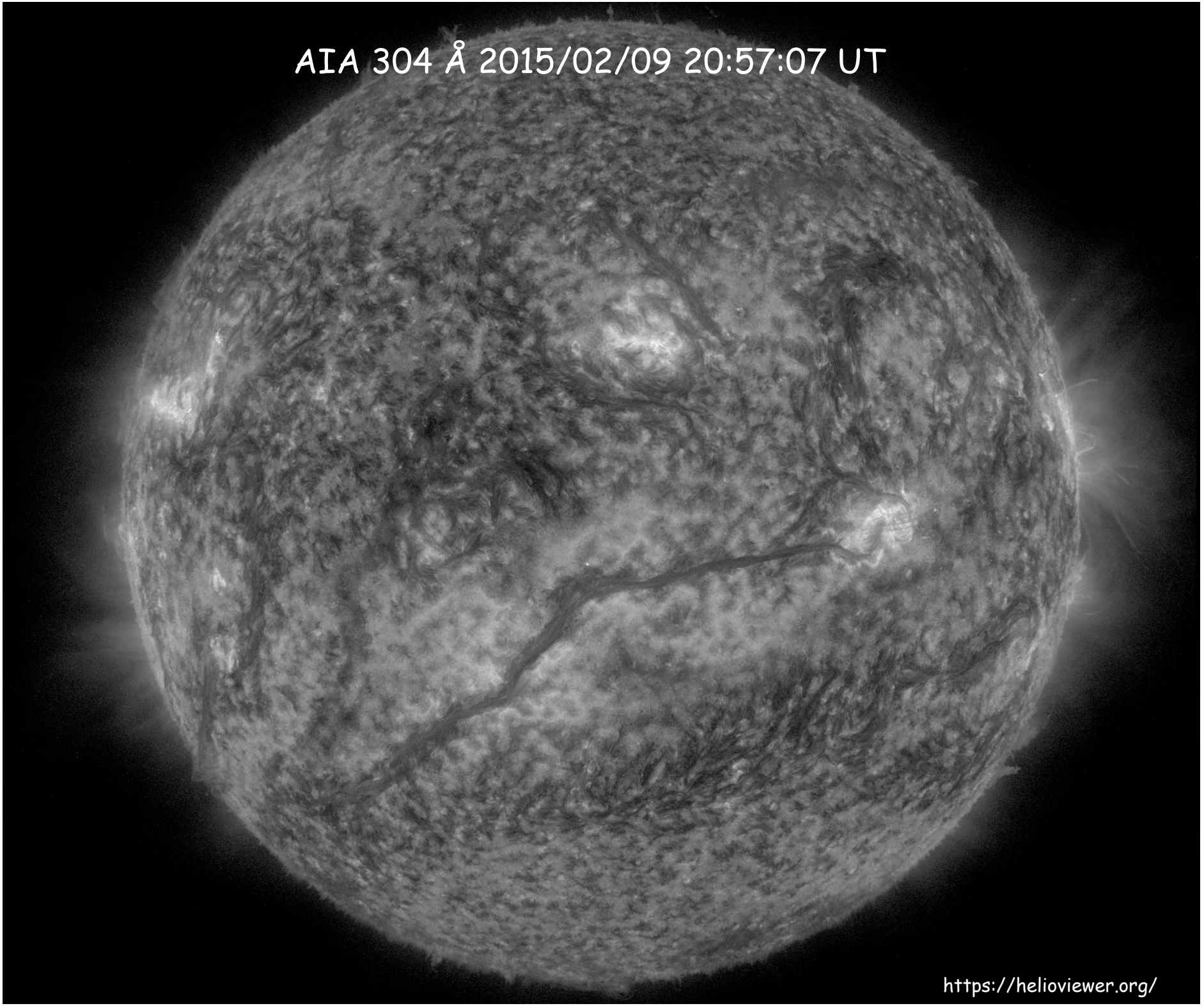
https://www.nasa.gov/sites/default/files/images/525037main_FAQ1-orig_full.jpg



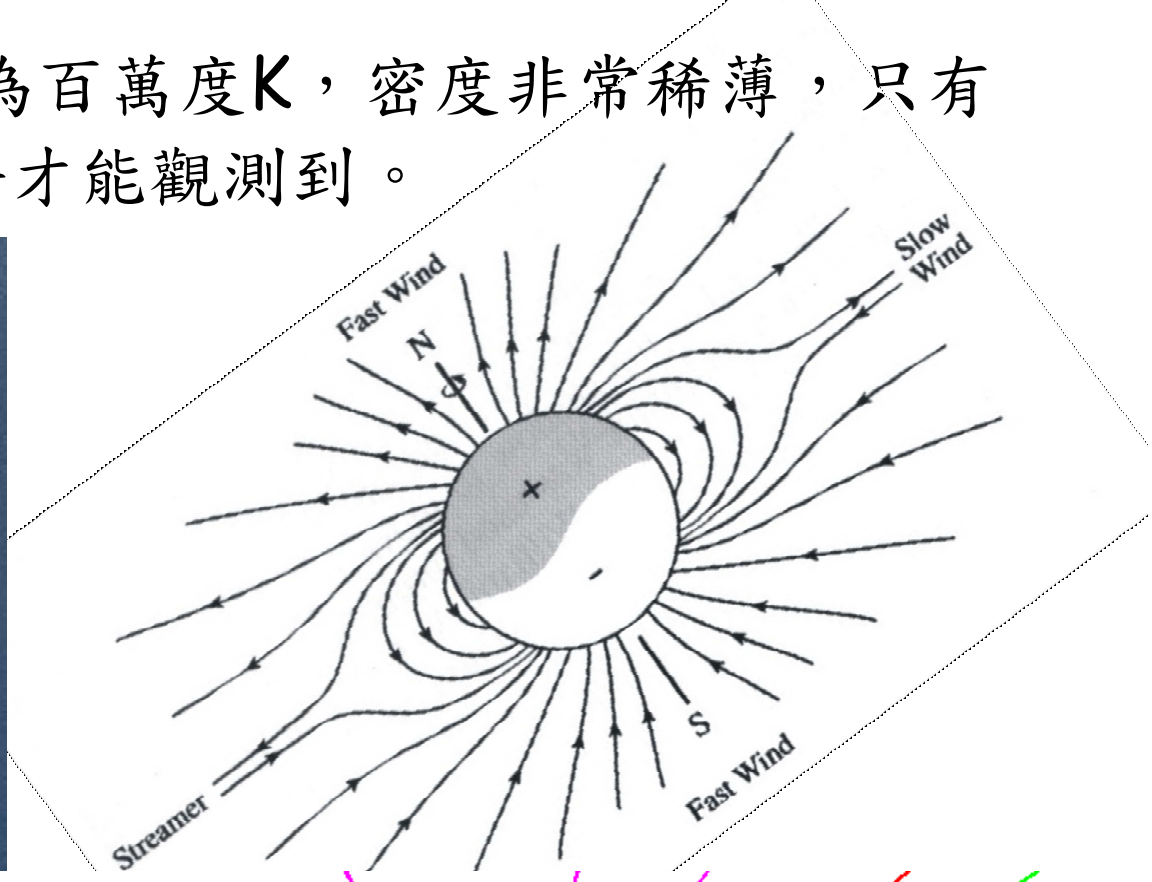
https://sdo.gsfc.nasa.gov/assets/gallery/preview/Filament_break_fulldisk_.jpg

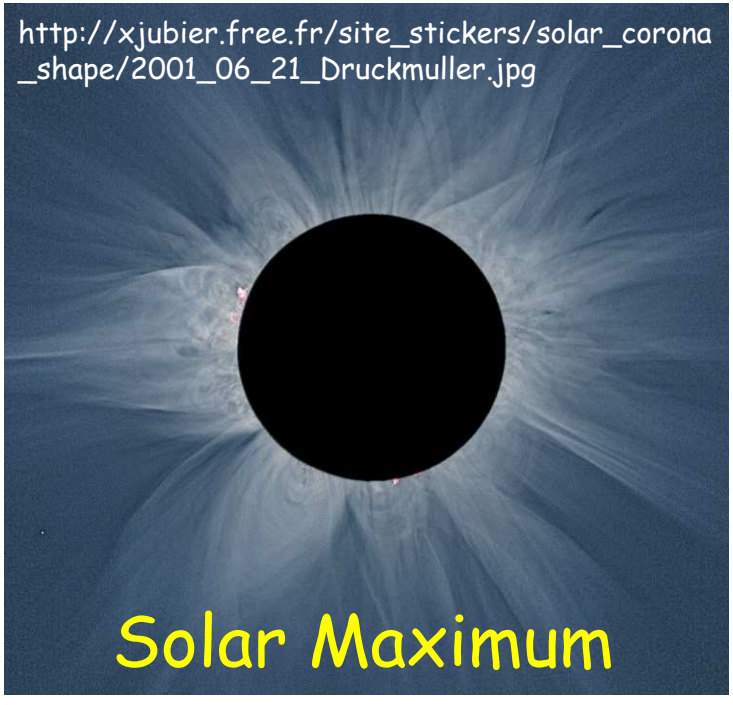
日珥爆發=暗紋消失

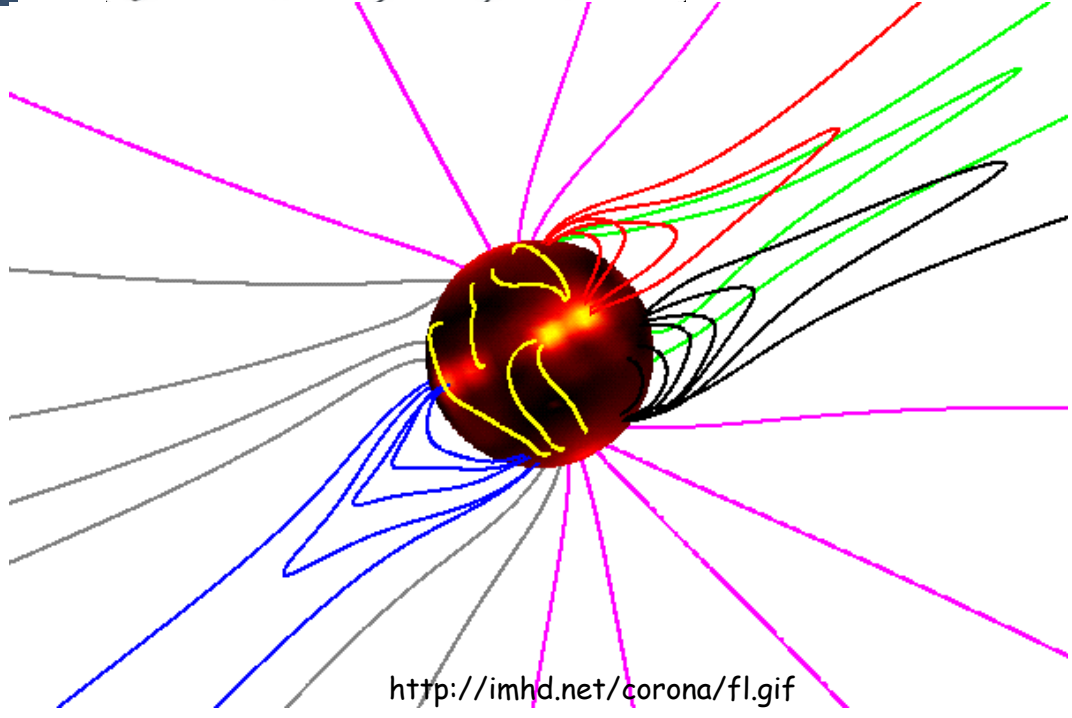

N
E W
S
BBSO Hα 2015/02/09 20:57:12 UT
Big Bear Solar Observatory
2015-02-09 20:57:12 UT
http://www.bbso.njit.edu/Research/FDHA/


AIA 304 Å 2015/02/09 20:57:07 UT
https://helioviewer.org/

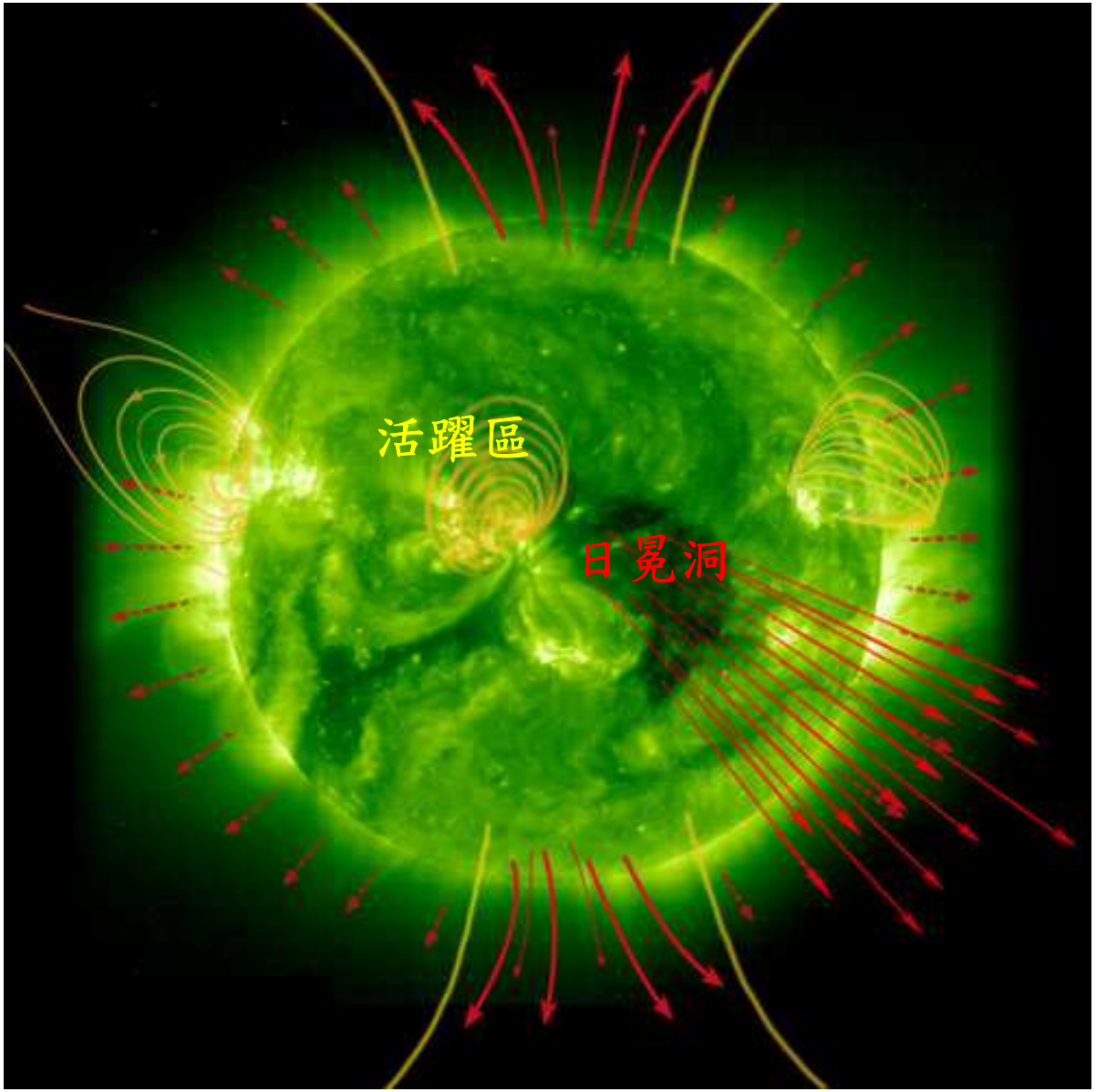
→ **日冕 (Corona):** 溫度為百萬度K，密度非常稀薄，只有在日全食或使用日冕儀時才能觀測到。





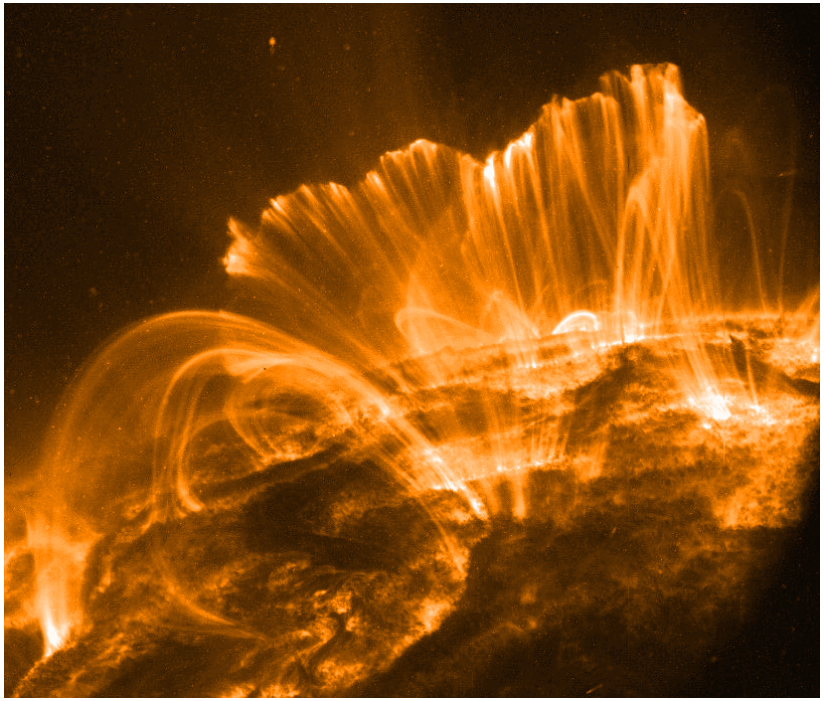


日冕洞及日冕環



日冕洞(coronal hole):
開放磁力線、電漿密度低、
快速太陽風

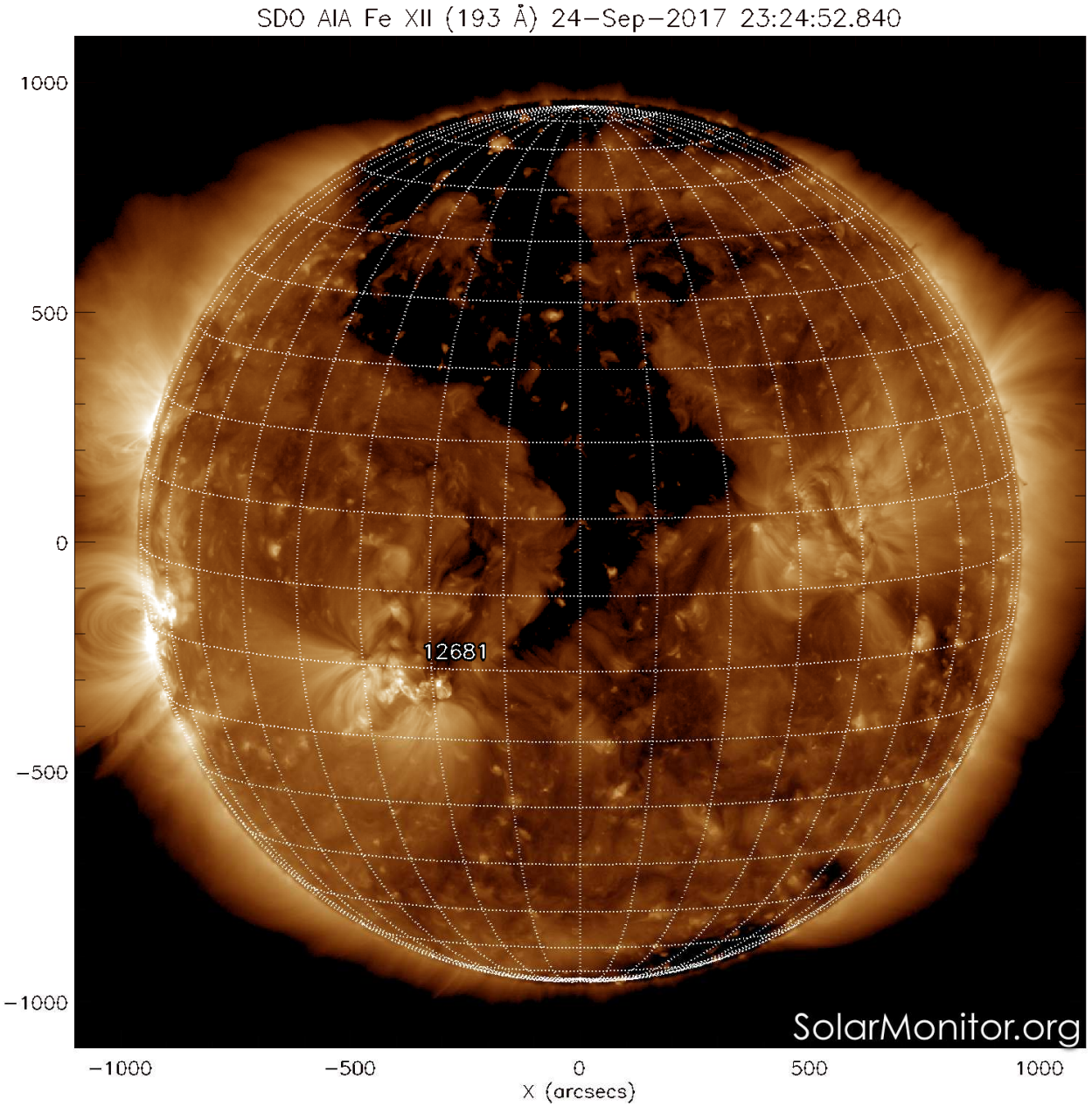
日冕環(coronal loop):
封閉磁力線、電漿密度高、
慢速太陽風



http://astro.berkeley.edu/~echiang/fluid/solarwind.jpg

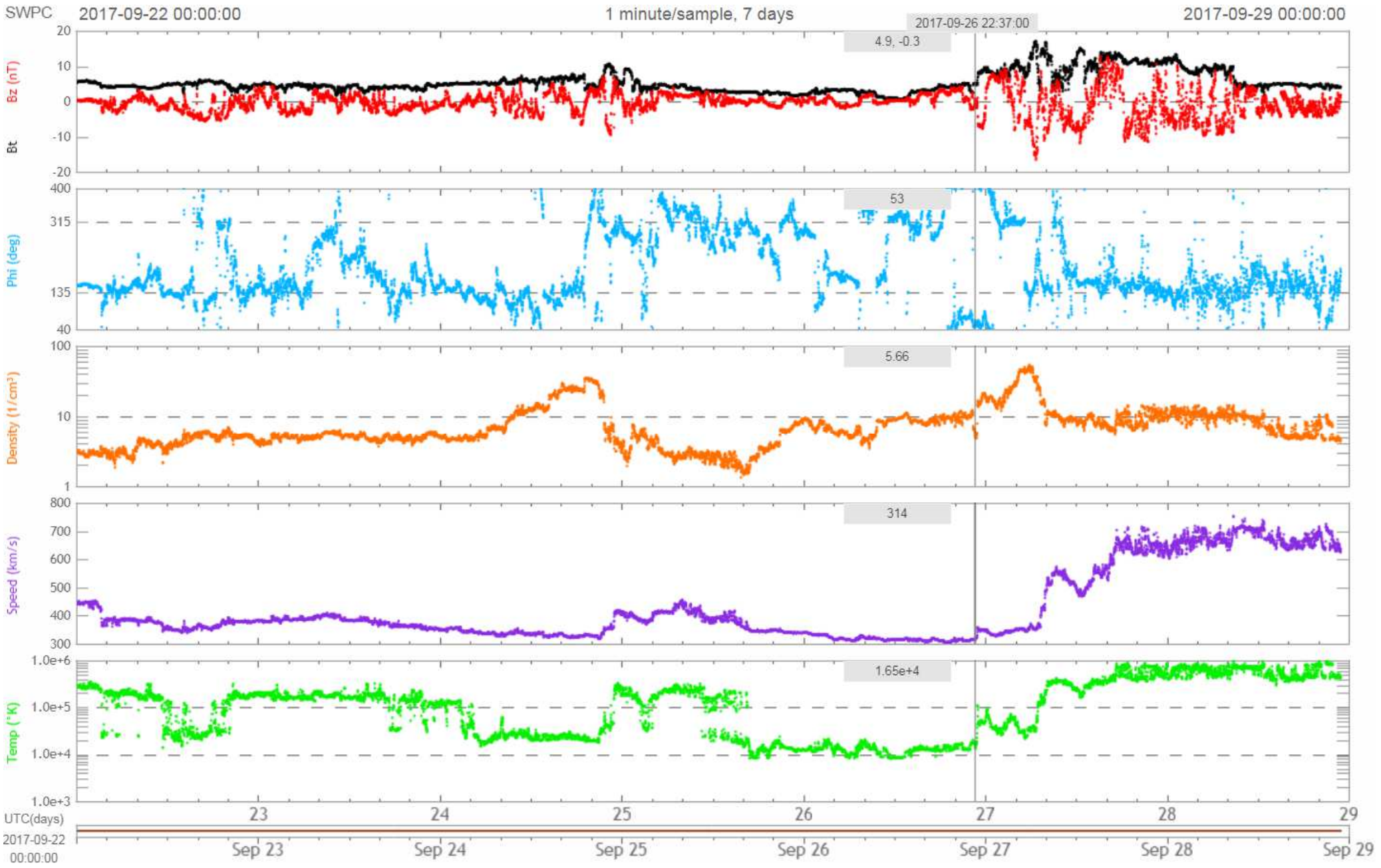
http://trace.lmsal.com/POD/

日冕洞 ⟶ 快速太陽風



http://www.swpc.noaa.gov/products/real-time-solar-wind

日冕洞 ⟶ 快速太陽風



http://www.swpc.noaa.gov/products/real-time-solar-wind

Solar Explosions

1970's –now: X-Ray Disk Observing
–No! Flares are coronal explosions

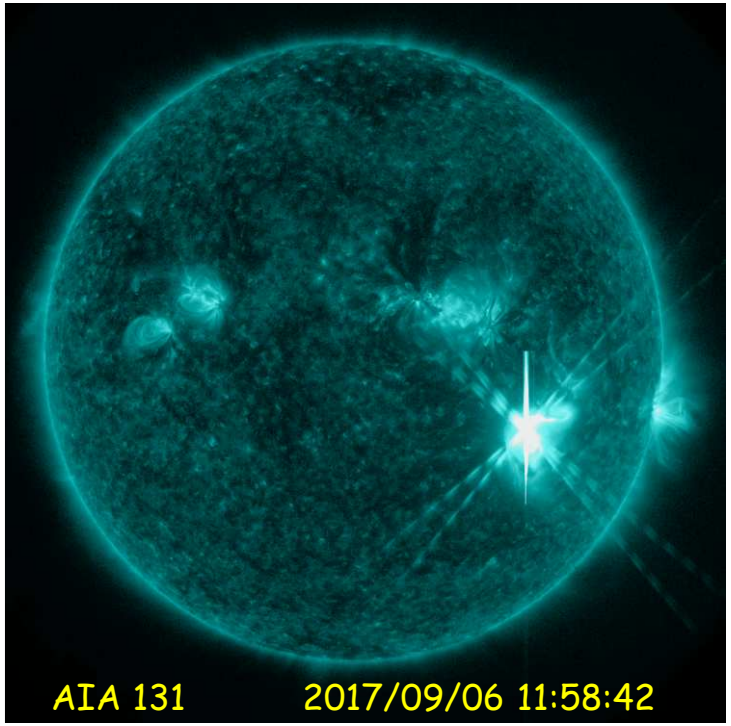
19th Century: Visual Disk Observing
–Flares are photospheric explosions

21st Century: Full Sun Observing (almost)
–Both are magnetic field explosions

Mid-20th Century: H-alpha Disk Observing
–No! Flares are chromospheric explosions

1980's –now: Visual Coronal Observing
–No! CMEs are the real explosions

太陽閃焰(solar flare)



→太陽短時間內巨大能量釋放的現象。

→幾乎都發生在太陽黑子附近。

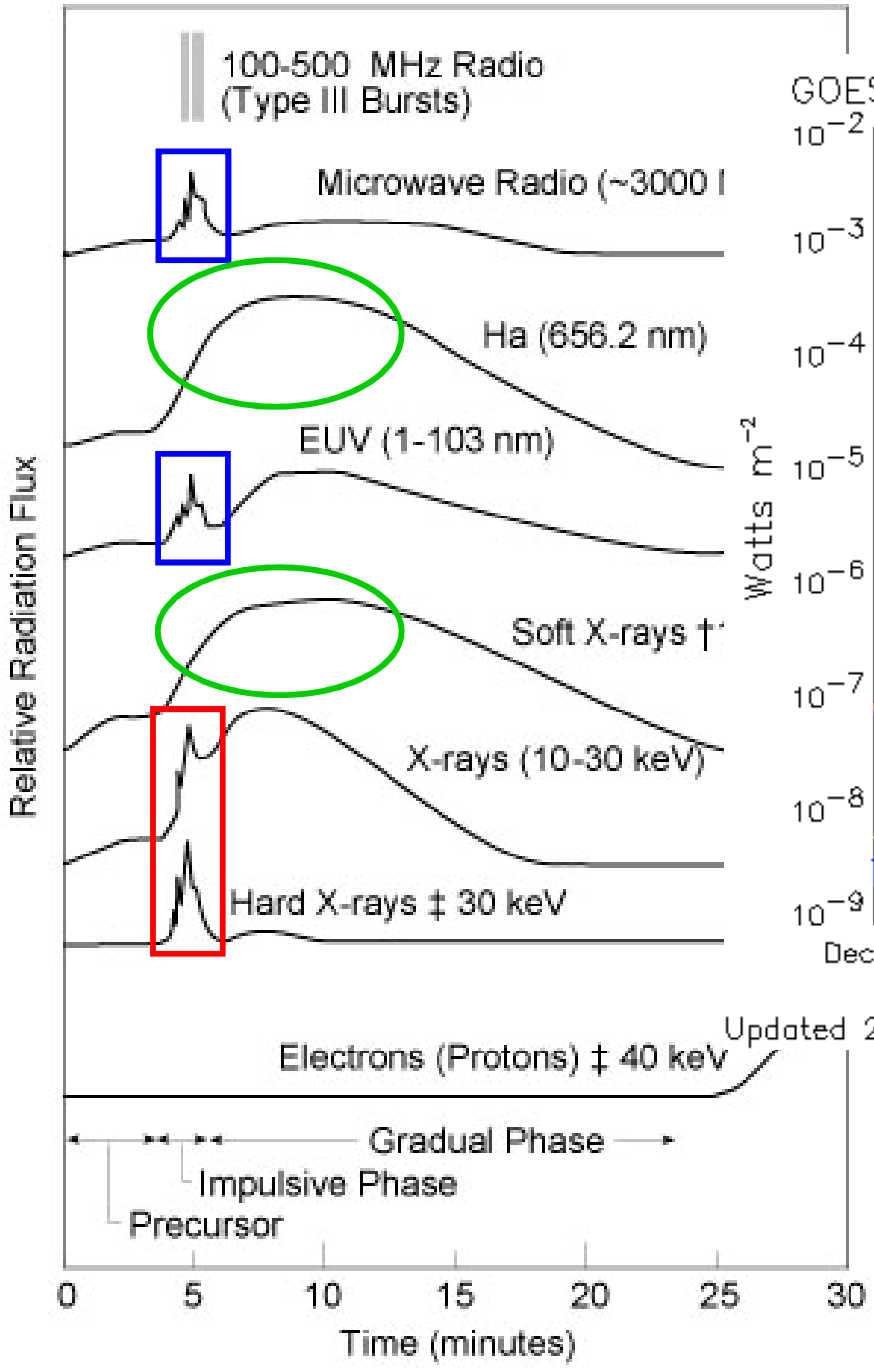
→閃焰出現後，可觀察到亮度突然增加(幾分鐘內即達到很亮的程度，而在不到一小時或幾小時內漸漸減弱)，在這段期間會輻射大量的X射線、紫外線、可見光、無線電，有時還會發射高能的γ射線和高能帶電粒子。

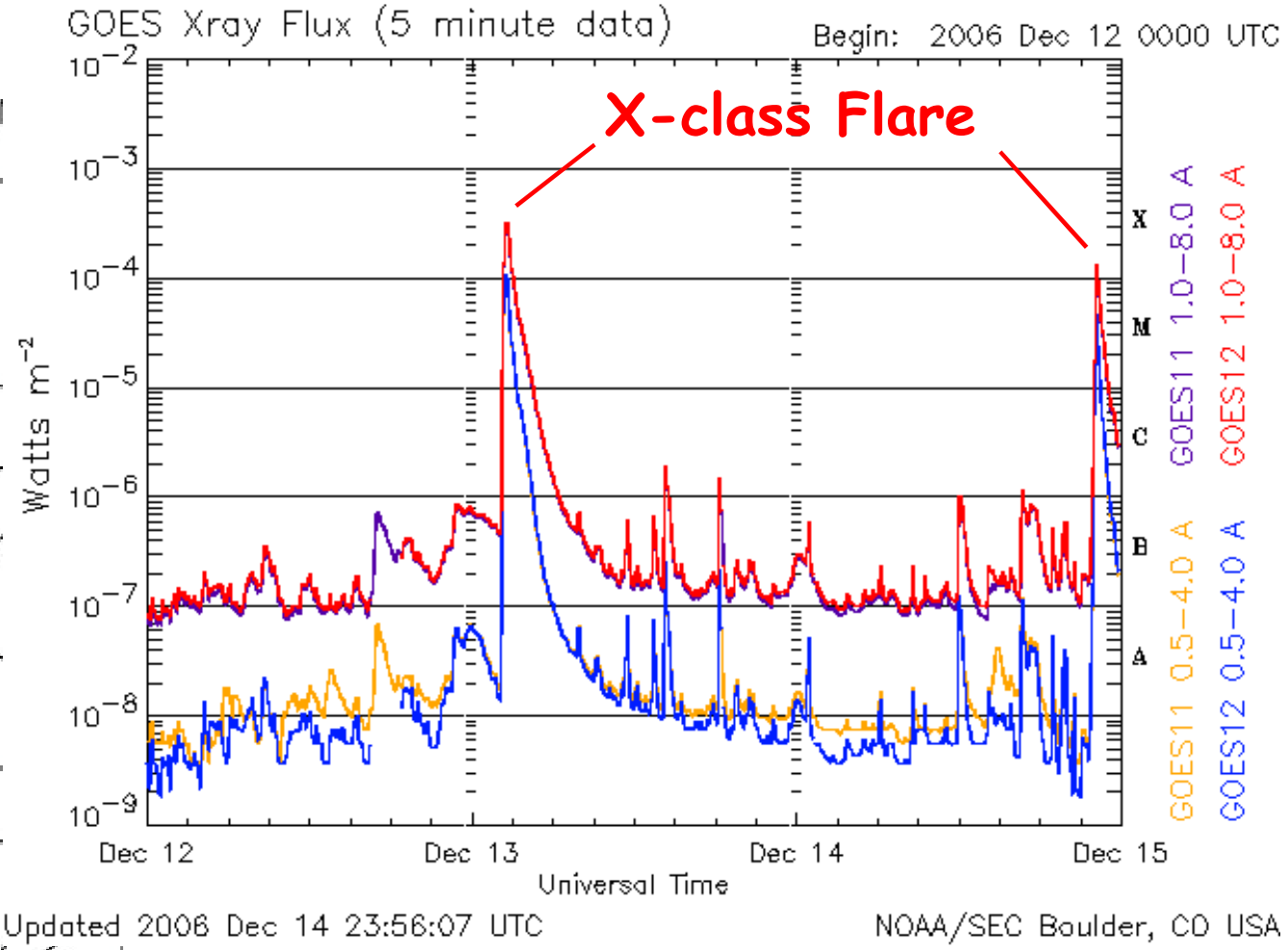
→太陽閃焰能放出10^{20}-10^{25}焦耳的能量。
(Note: one H-bomb: 10 million tons of TNT = 5 X 10^{16} Joules)
(Note: worldwide energy consumption/year = 10^{20} Joules)

→多數理論認為閃焰的發生是由於磁場嚴重扭曲，所儲存的巨額能量於瞬間釋放出來的。

http://www.phys.ncku.edu.tw/~astrolab/e_book/sun/sun.html#activities_sun

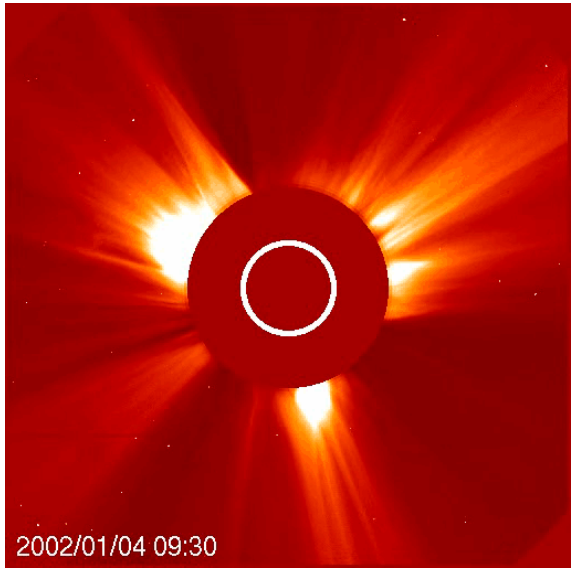
http://aeea.nmns.edu.tw/geo_home/geo_93/29-2.htm
http://web.fg.tp.edu.tw/~earth/learn/tasastro/ch083.htm

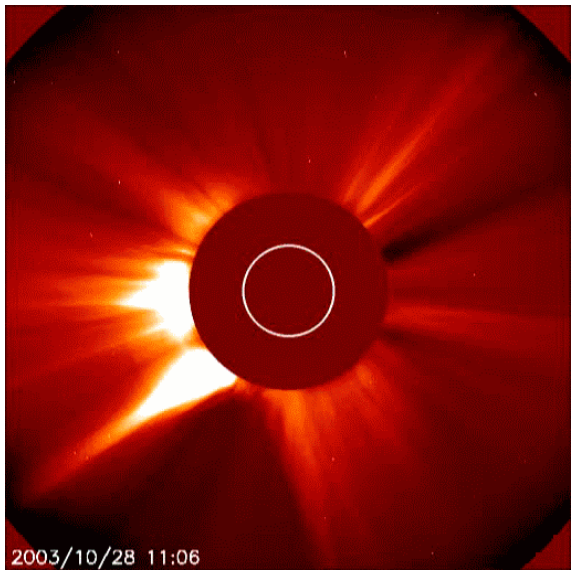




http://www.swpc.noaa.gov/Data/index.html

日冕物質拋射 (coronal mass ejection; CME)





→大量電漿伴隨著磁場從太陽日冕層向外拋射出的現象。

→大多數的日冕物質拋射都來自活躍區，經常伴隨太陽閃焰的發生。

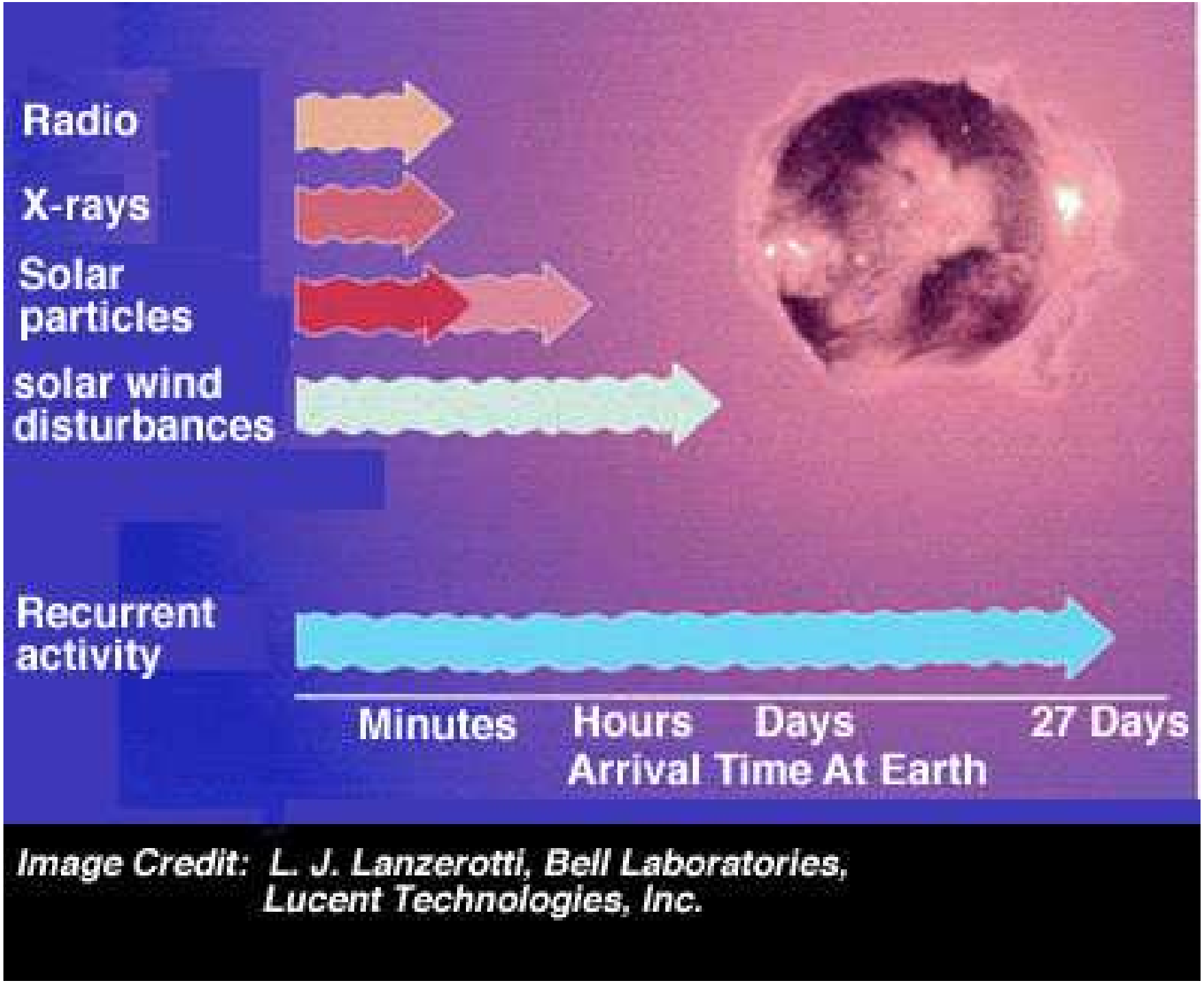
→拋射出的質量為10^{14}至10^{17} grams。

→日冕物質拋射的速度範圍從20 km/s至3200 km/s。

→當日冕物質拋射在太陽風中傳播時，快速的日冕物質拋射會產生激震波。

typical coronal temperature 10^6 K
→ sound speed:10^2 km/s

http://en.wikipedia.org/wiki/Coronal_mass_ejection



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

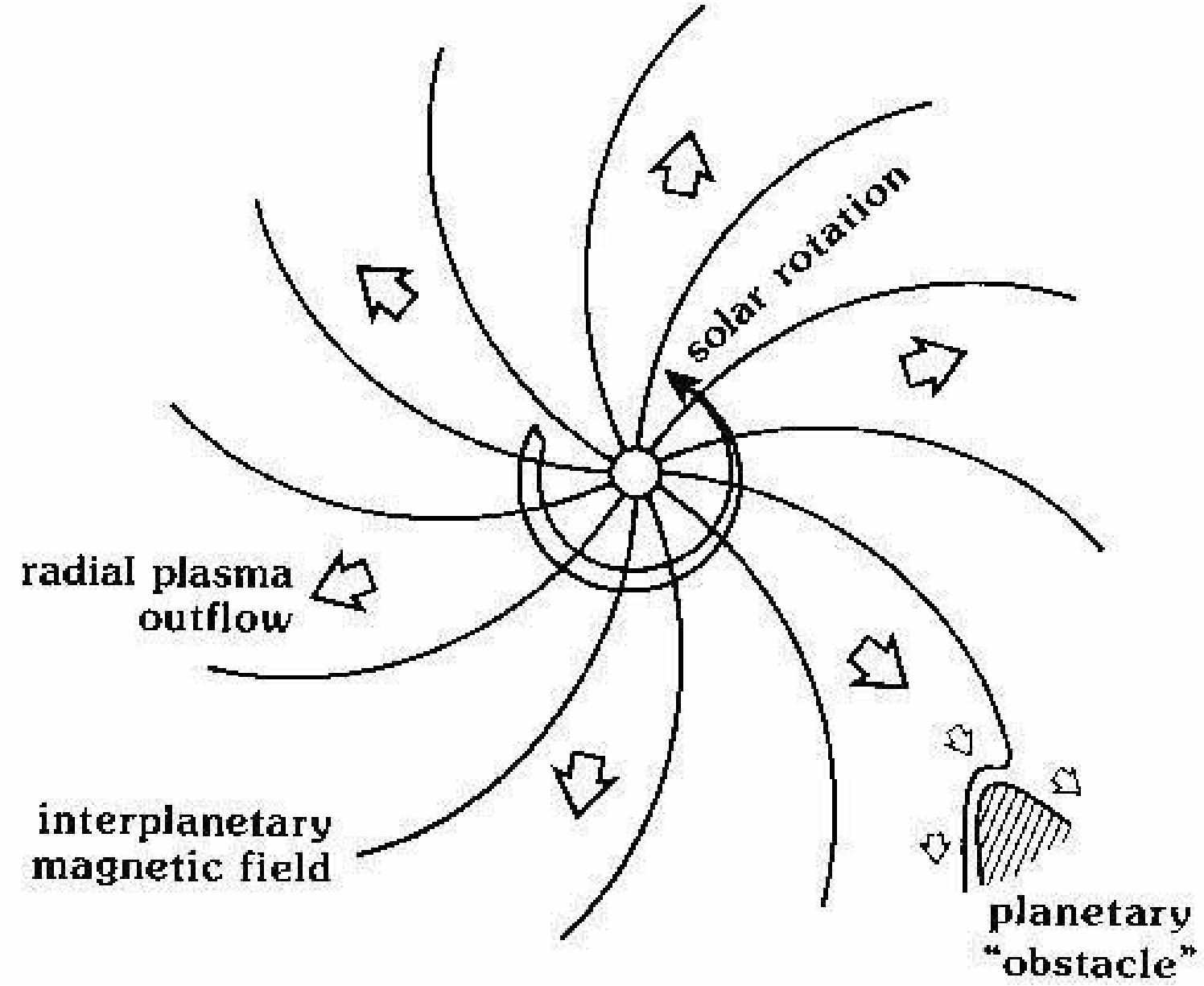
太陽風

太陽風是一種由太陽表面吹出來的電漿流，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，其在1 AU的平均速率約為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)。

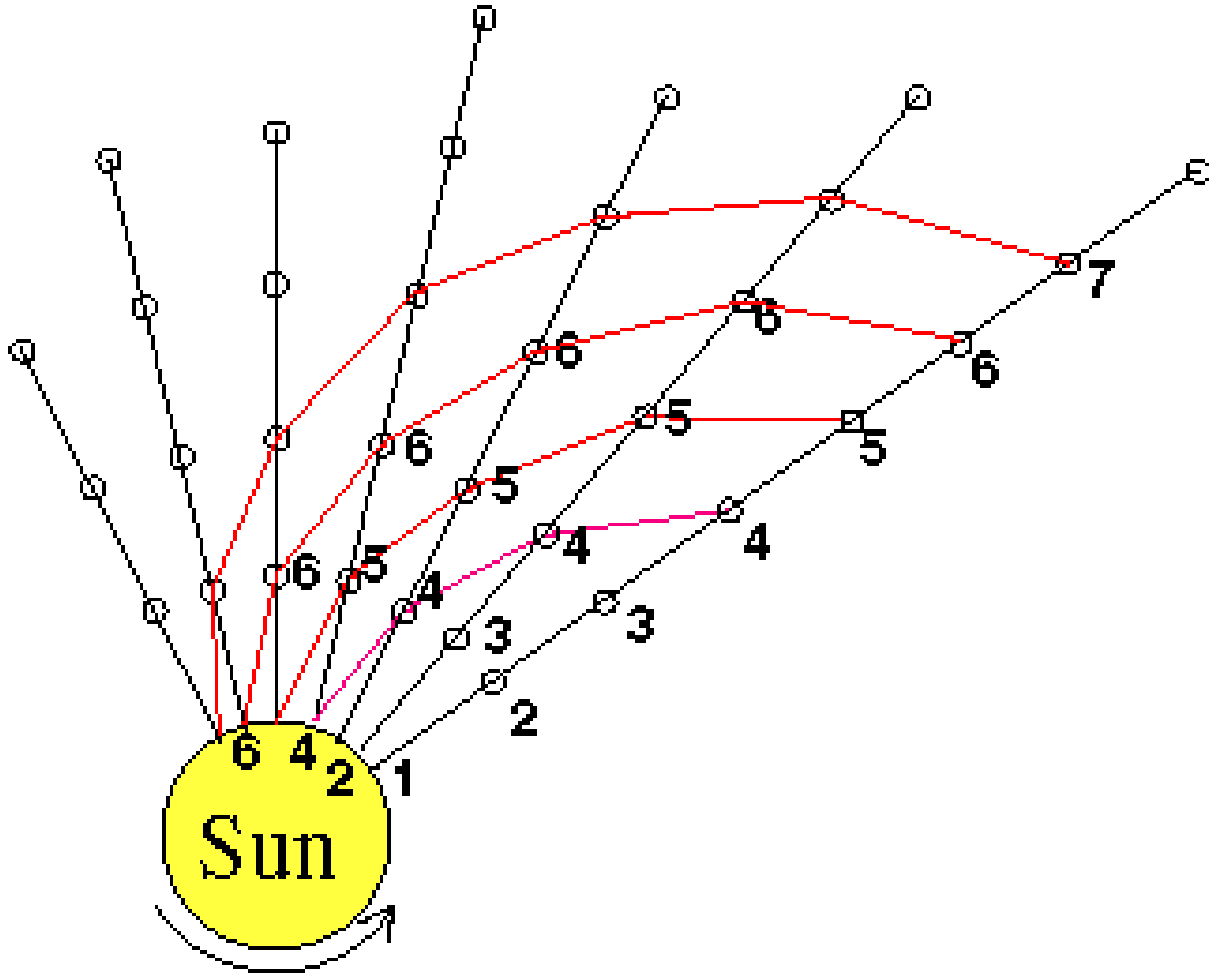
SOLAR WIND



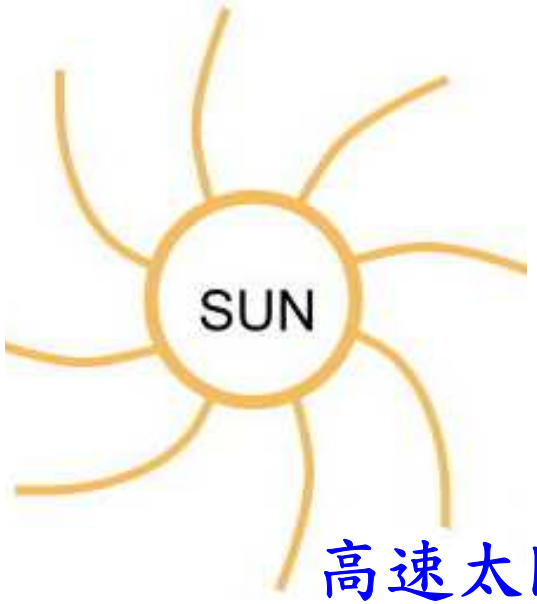
http://pwg.gsfc.nasa.gov/istp/outreach/images/Gusts/windsprl.jpg

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