

# SPACE WEATHER INTRODUCTORY COURSE



Collaboration of



Solar-Terrestrial Centre of Excellence



Koninklijke luchtmacht



Koninklijk Nederlands  
Meteorologisch Instituut  
*Ministerie van Infrastructuur en Milieu*



# SPACE WEATHER

## Basic Concepts

*Elke D'Huys, Jan Janssens & Petra Vanlommel*



# SPACE WEATHER BRIEFING

## SIDC Space Weather Briefing

See you at our next briefing!

Or visit us at [www.sidc.be](http://www.sidc.be)



Solar Influences  
Data analysis Centre  
[www.sidc.be](http://www.sidc.be)



# SPACE WEATHER BRIEFING

## Summary Report

Solar activity from 2021-04-18 12:00 to 2021-04-25 23:59

Active regions	7 ARs (NOAA AR 2814, 2815, 2816, 2817, 2818, 2819 & 2820)
Flares	# C-class flare: 20 # M-class flare: 1 # X-class flare: 0
Filament eruptions	No big filament eruptions
Coronal Holes	One small equatorial coronal hole (negative polarity)
Proton flux	quiet
Electron flux	the greater than 2MeV electron flux was mostly above the 1000 pfu threshold.

## Solar wind and geomagnetic conditions

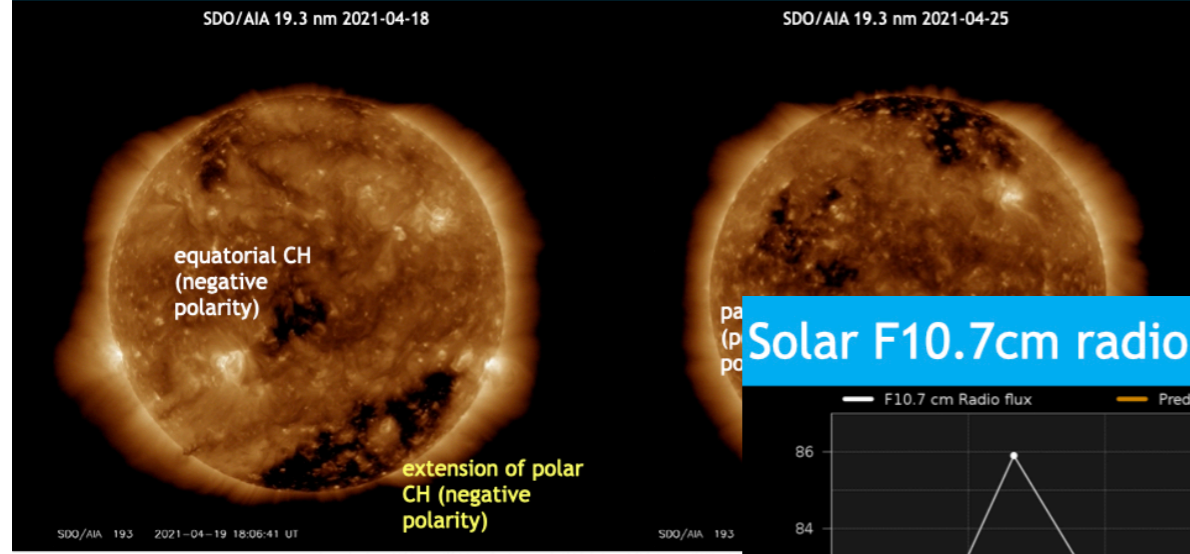
ICME	In situ shock and CME observed on April 24 (22:27 UT)
SW Conditions	B : 0.95 - 11.05 nT // Bz: -10.63 nT to 7.38 nT // Speed: 368.3 - 1153.6km/s
K-indices	max K-index (Dourbes): 5 max Kp-index (NOAA): 5

All Quiet Alert: none

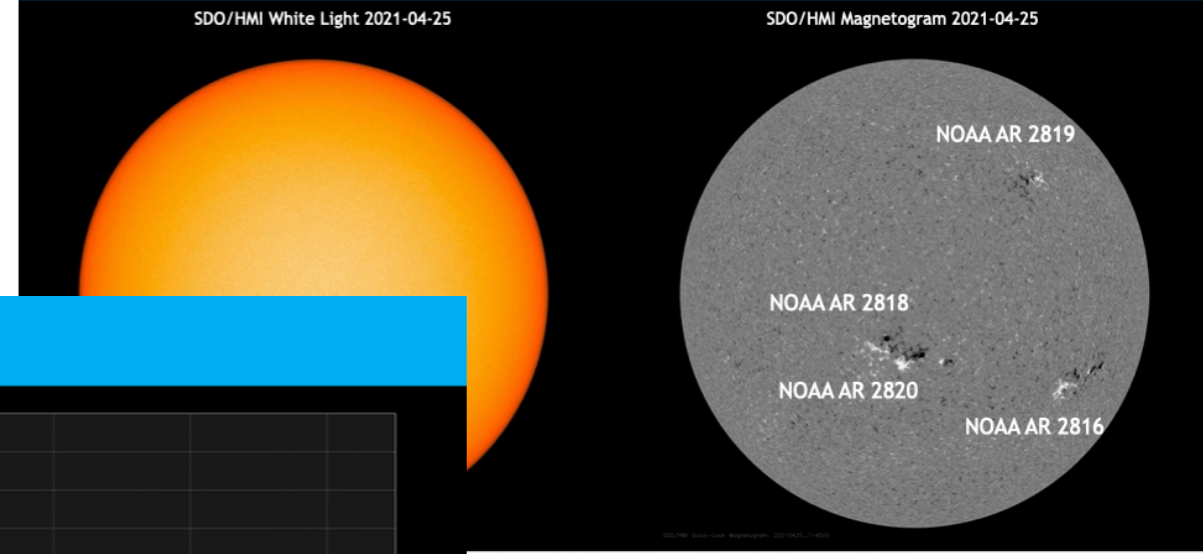


# SPACE WEATHER BRIEFING

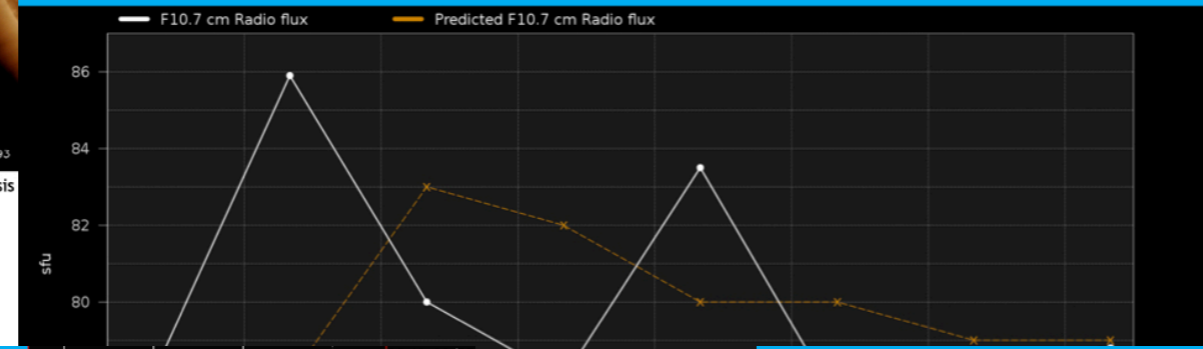
## Coronal holes



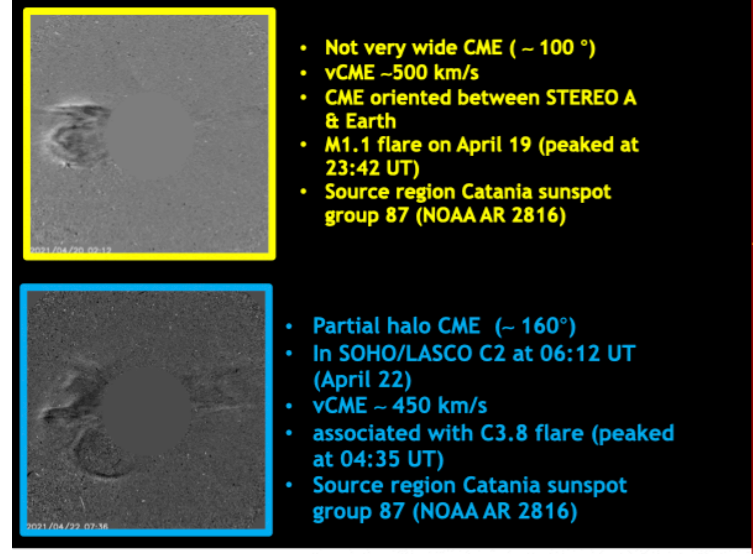
## Solar active regions



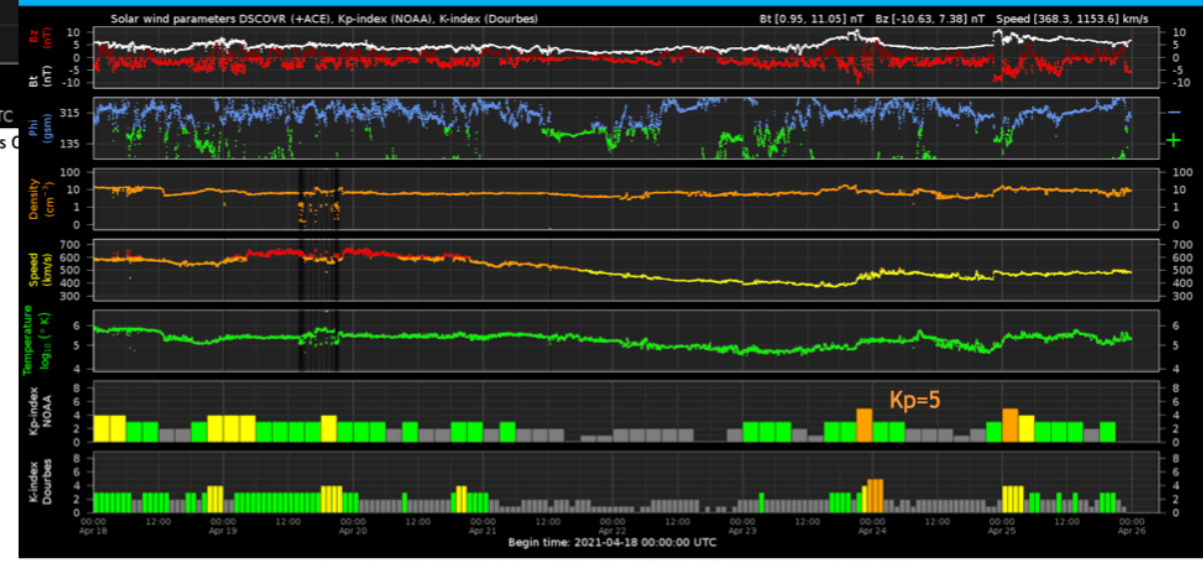
## Solar F10.7cm radio flux



## Coronal Mass Ejections



## Solar wind parameters & geomagnetic activity (K-indices)



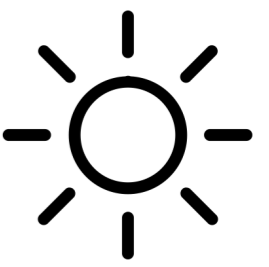
Space Weather Briefing - Solar Influences Data analysis

Space Weather Briefing - Solar Influences Data analysis Centre [www.sidc.be](http://www.sidc.be)

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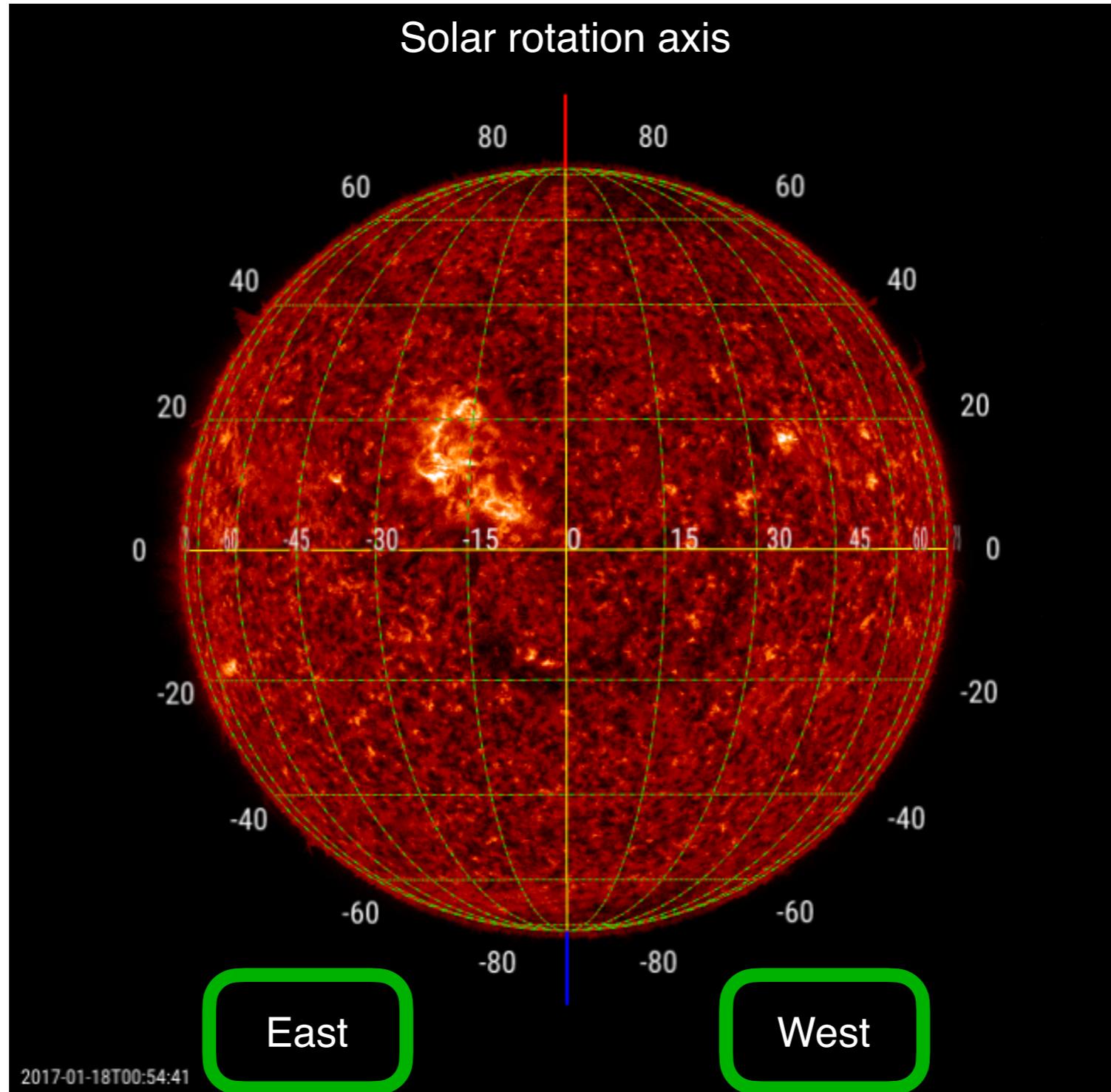




# POSITIONING

Solar North Pole  
Magnetic South Pole  
Positive/Outward

Solar South Pole  
Magnetic North Pole  
Negative/Inward



Northern hemisphere

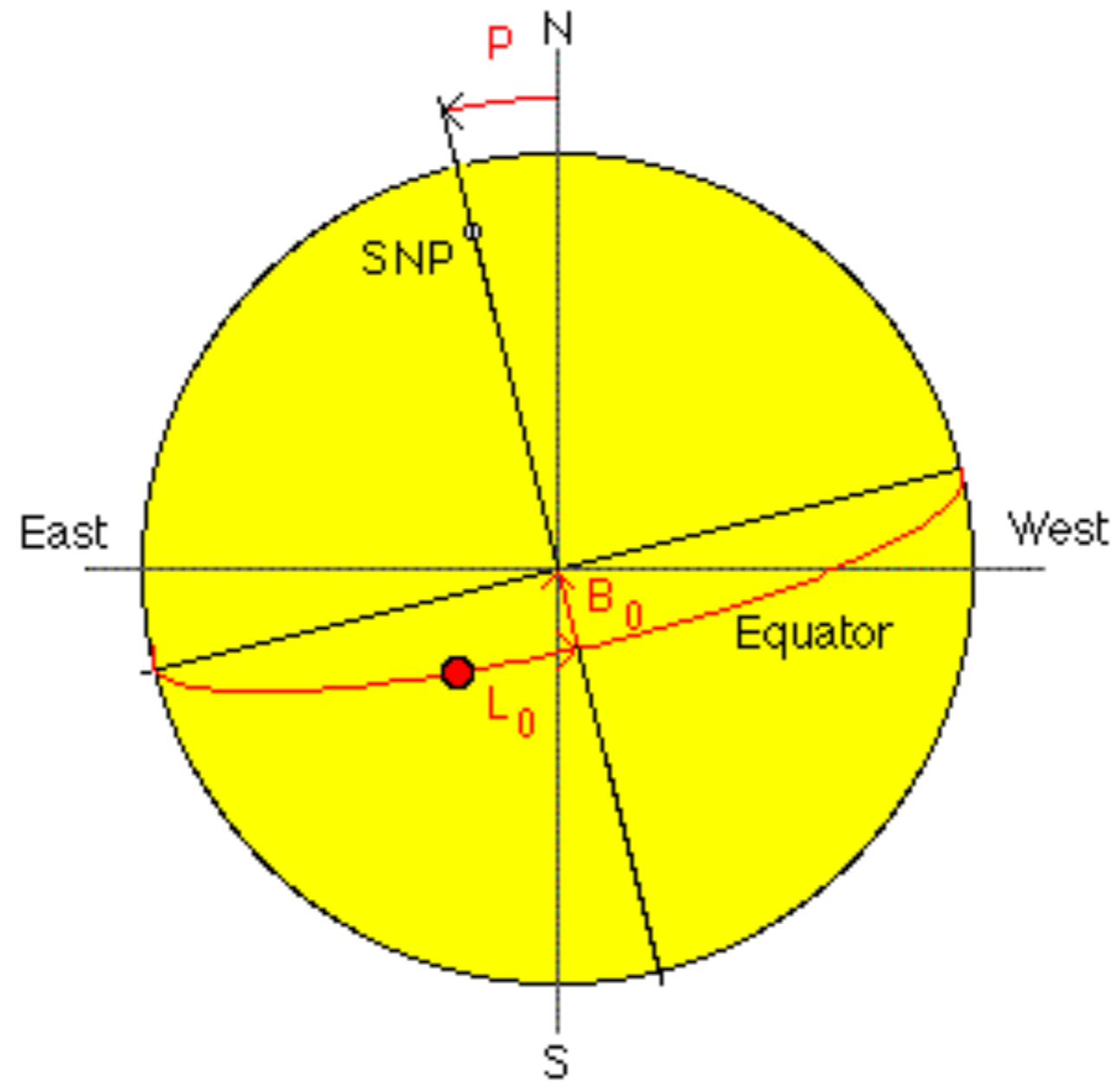
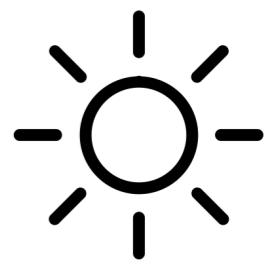
Solar Equator

Southern hemisphere



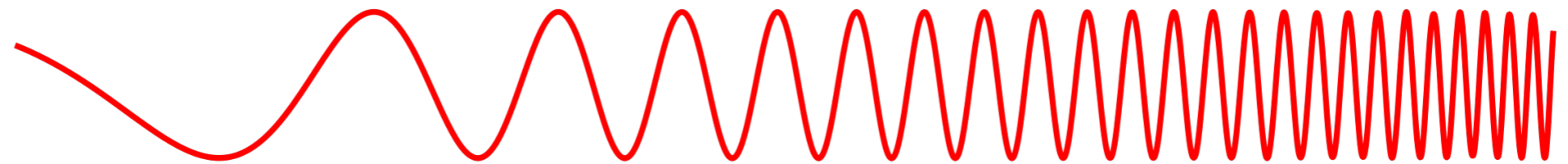
Central meridian

# SOLAR ROTATION

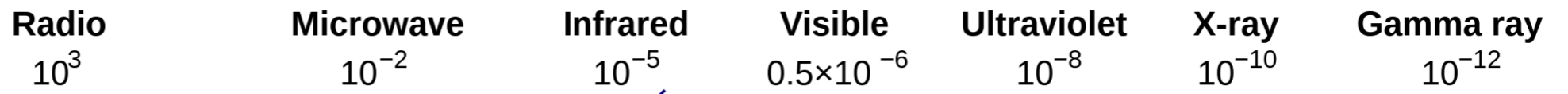


# ELECTROMAGNETIC SPECTRUM

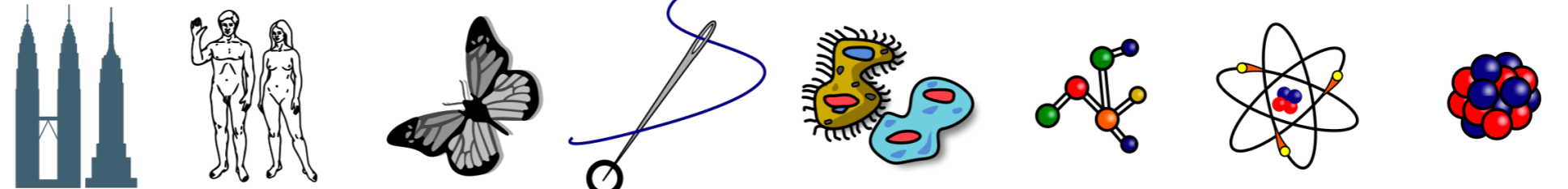
Penetrates Earth's Atmosphere?



Radiation Type  
Wavelength (m)



Approximate Scale  
of Wavelength

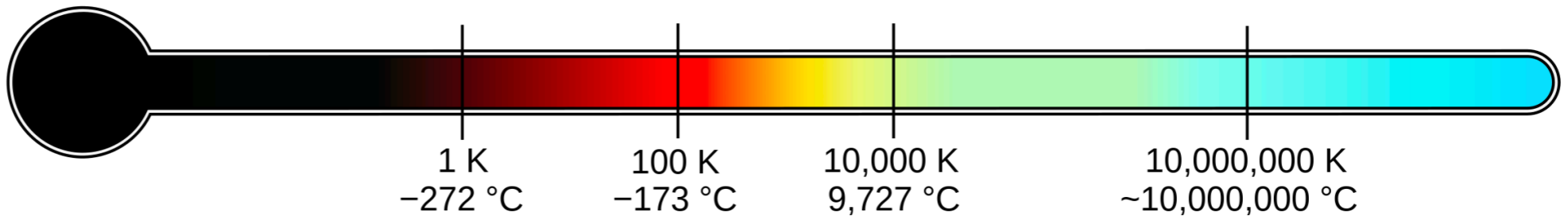


Buildings    Humans    Butterflies    Needle Point    Protozoans    Molecules    Atoms    Atomic Nuclei

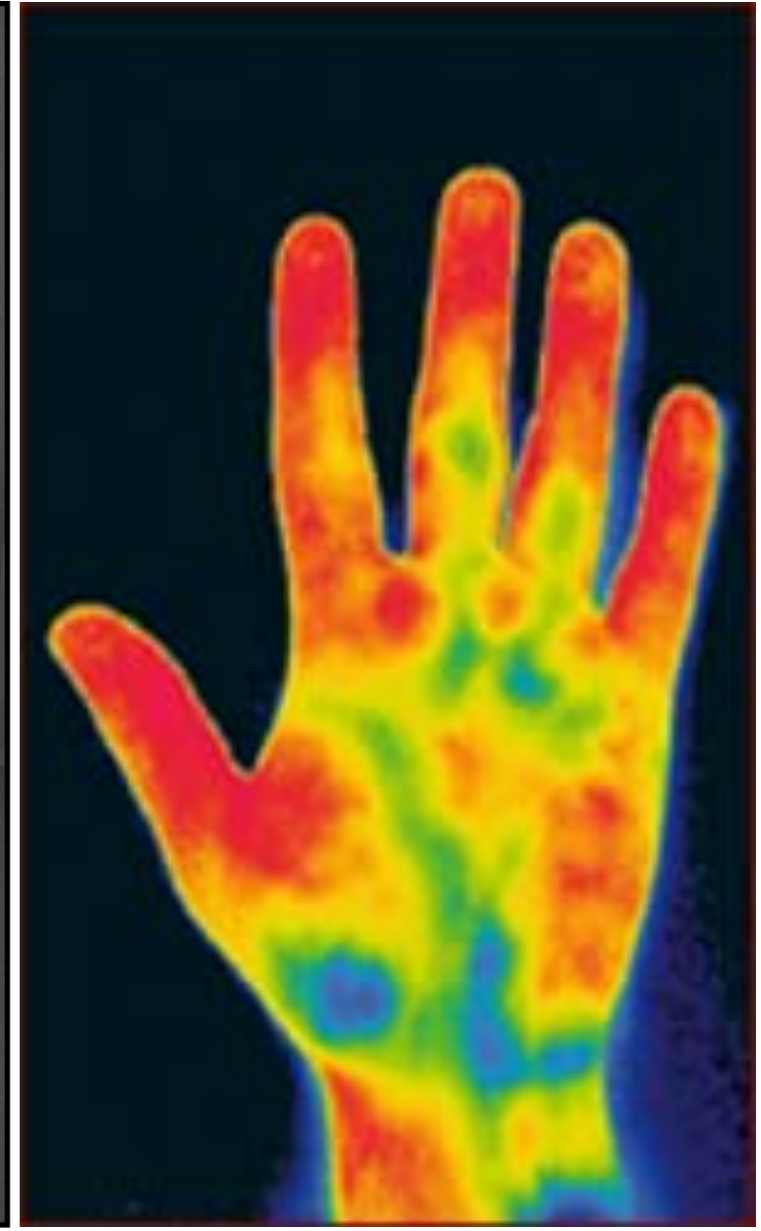
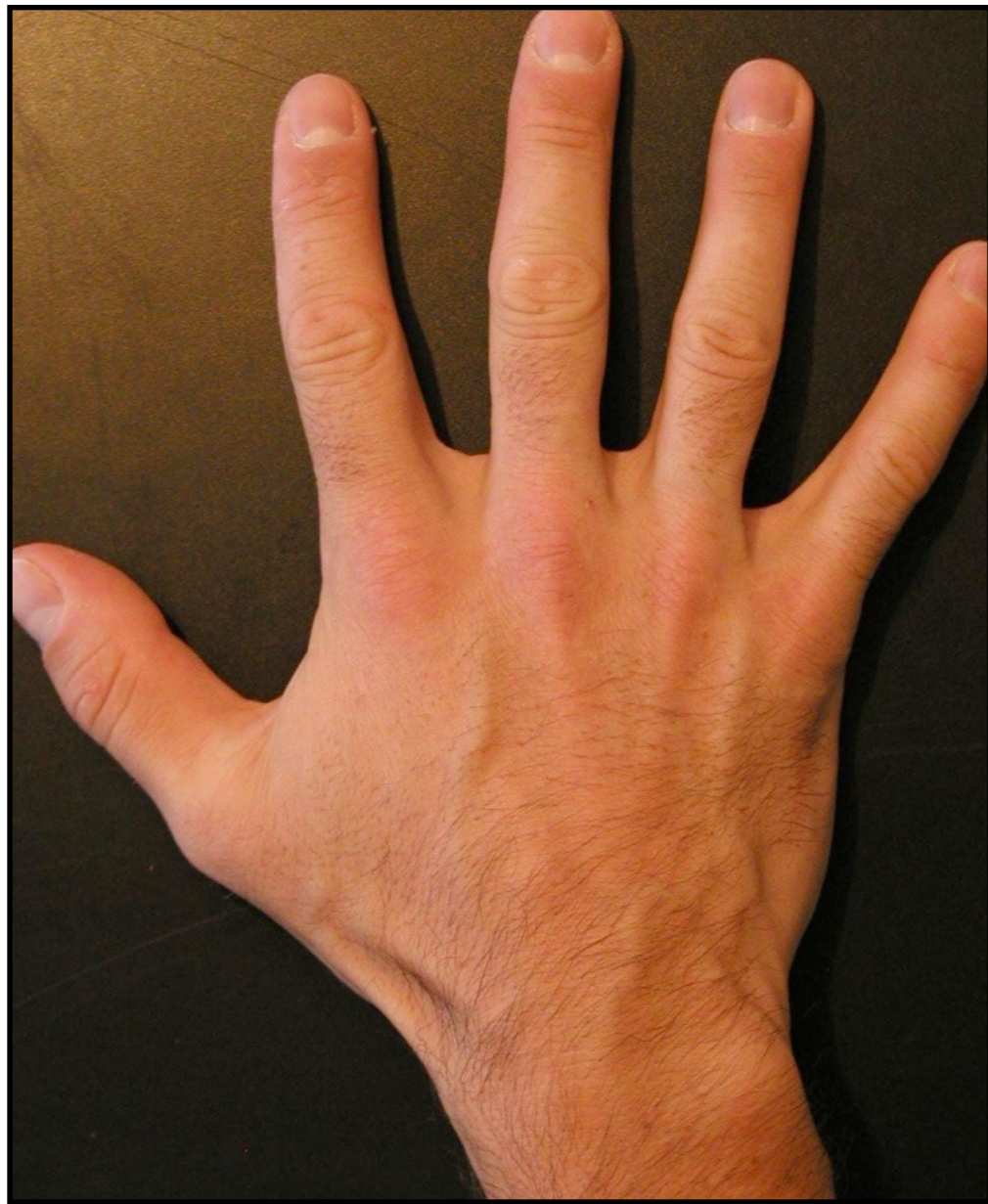
Frequency (Hz)



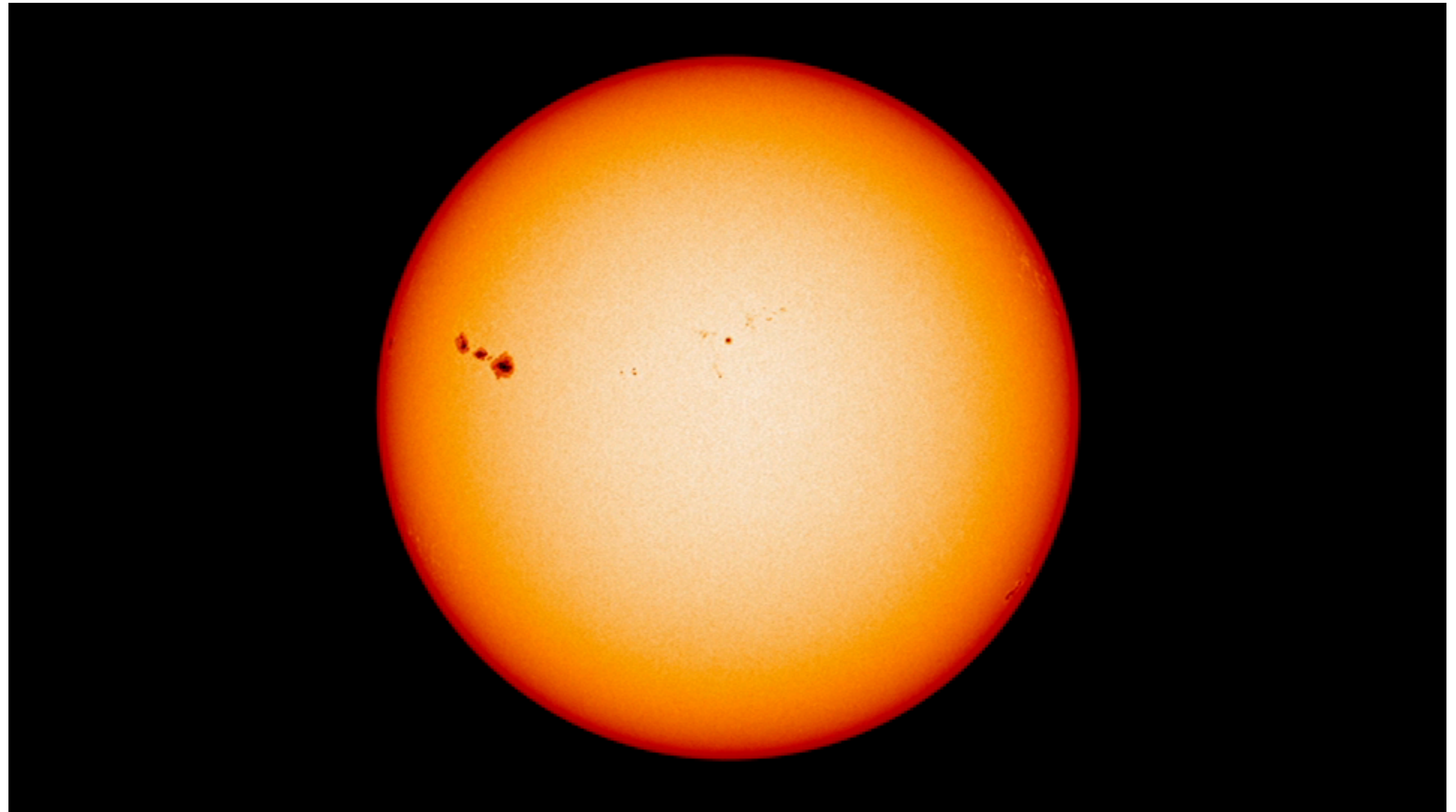
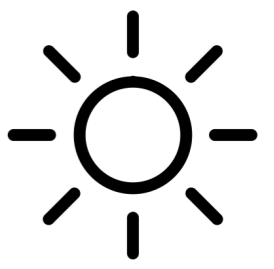
Temperature of objects at which this radiation is the most intense wavelength emitted



# ELECTROMAGNETIC SPECTRUM

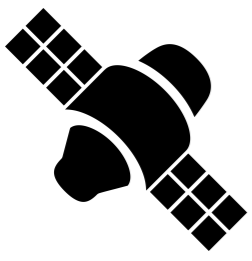


# ELECTROMAGNETIC SPECTRUM

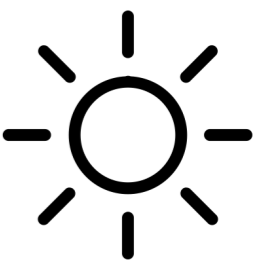


SDO/AIA

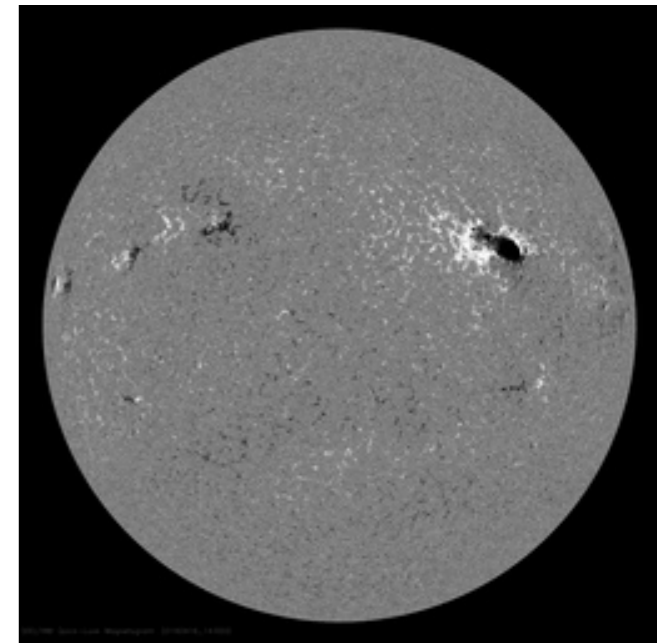
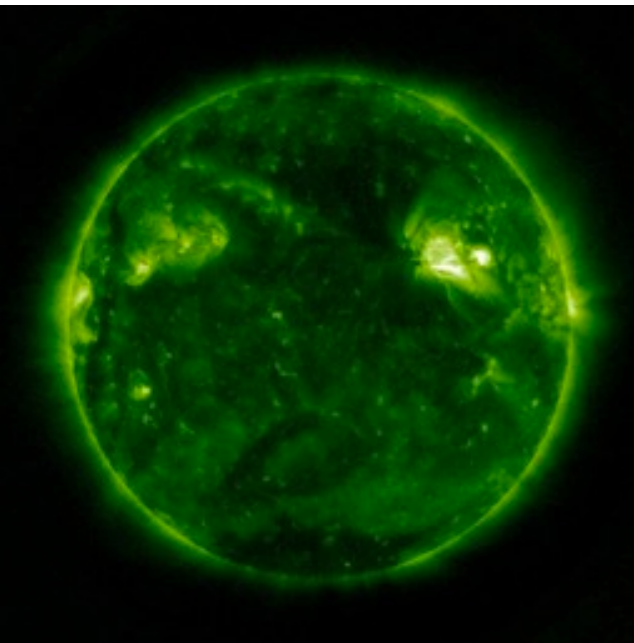
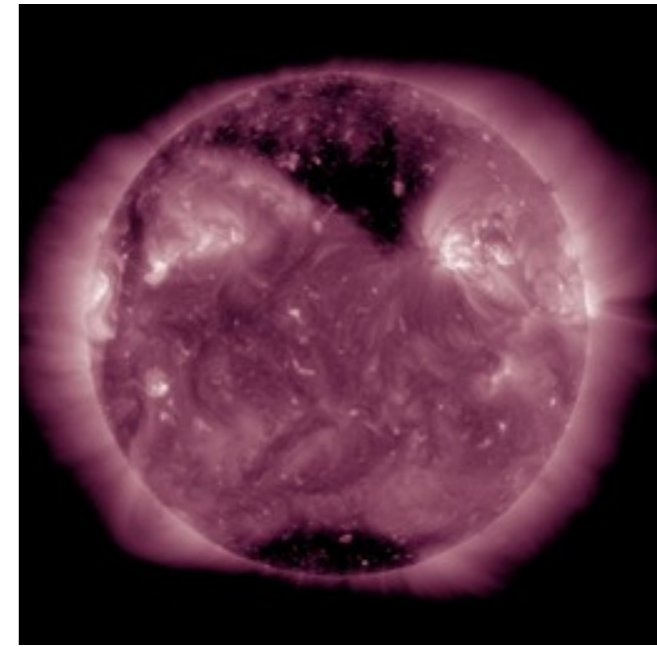
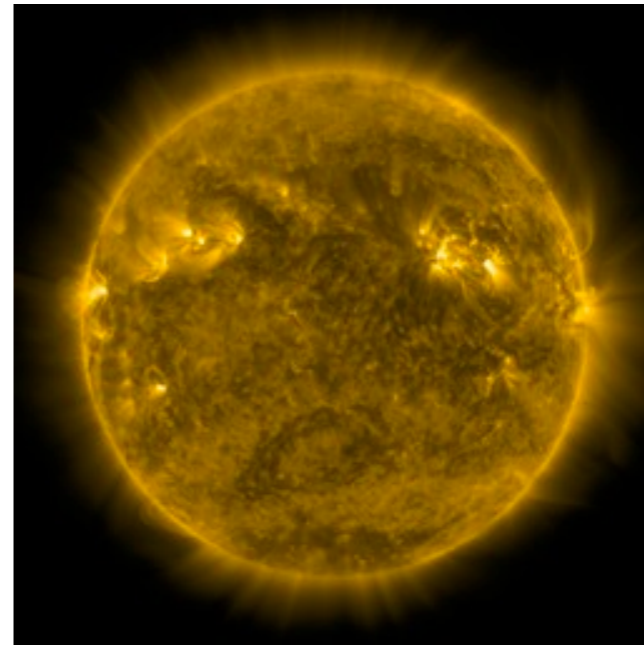
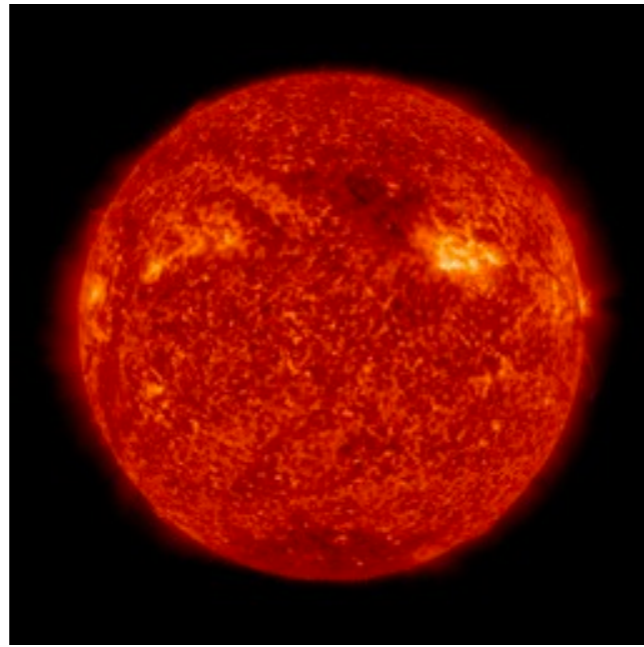
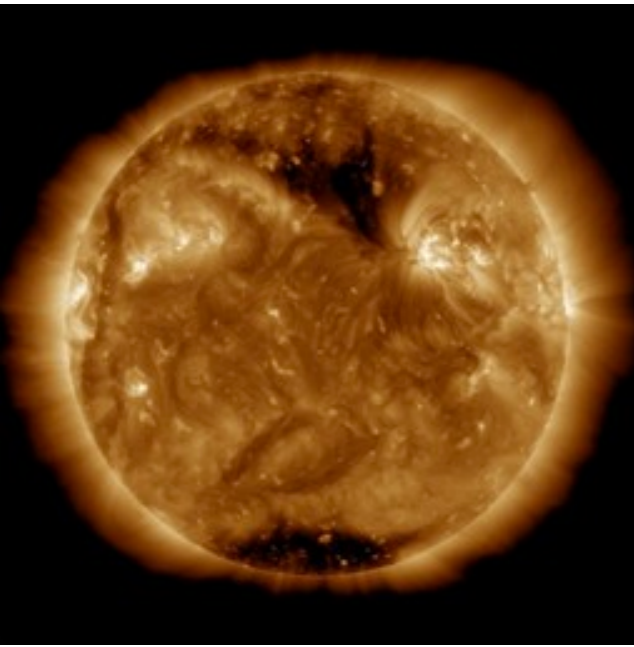


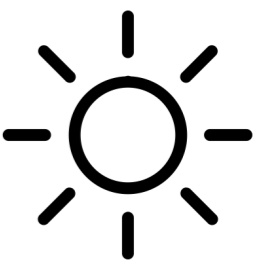


# MANY DIFFERENT FACES

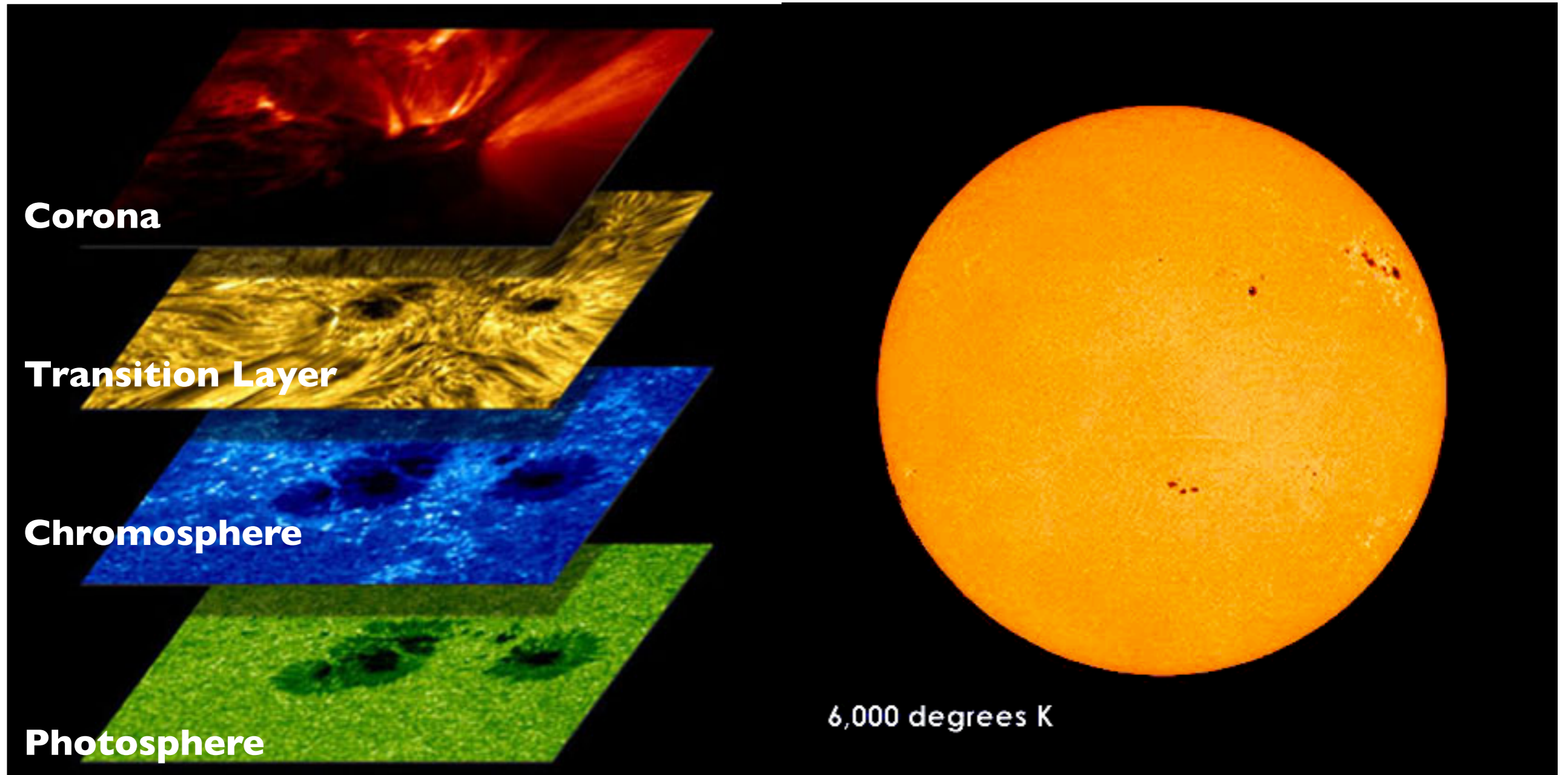


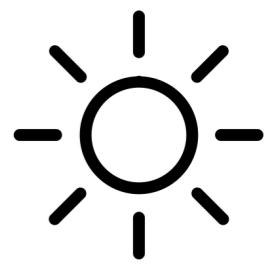
SDO/AIA & HMI



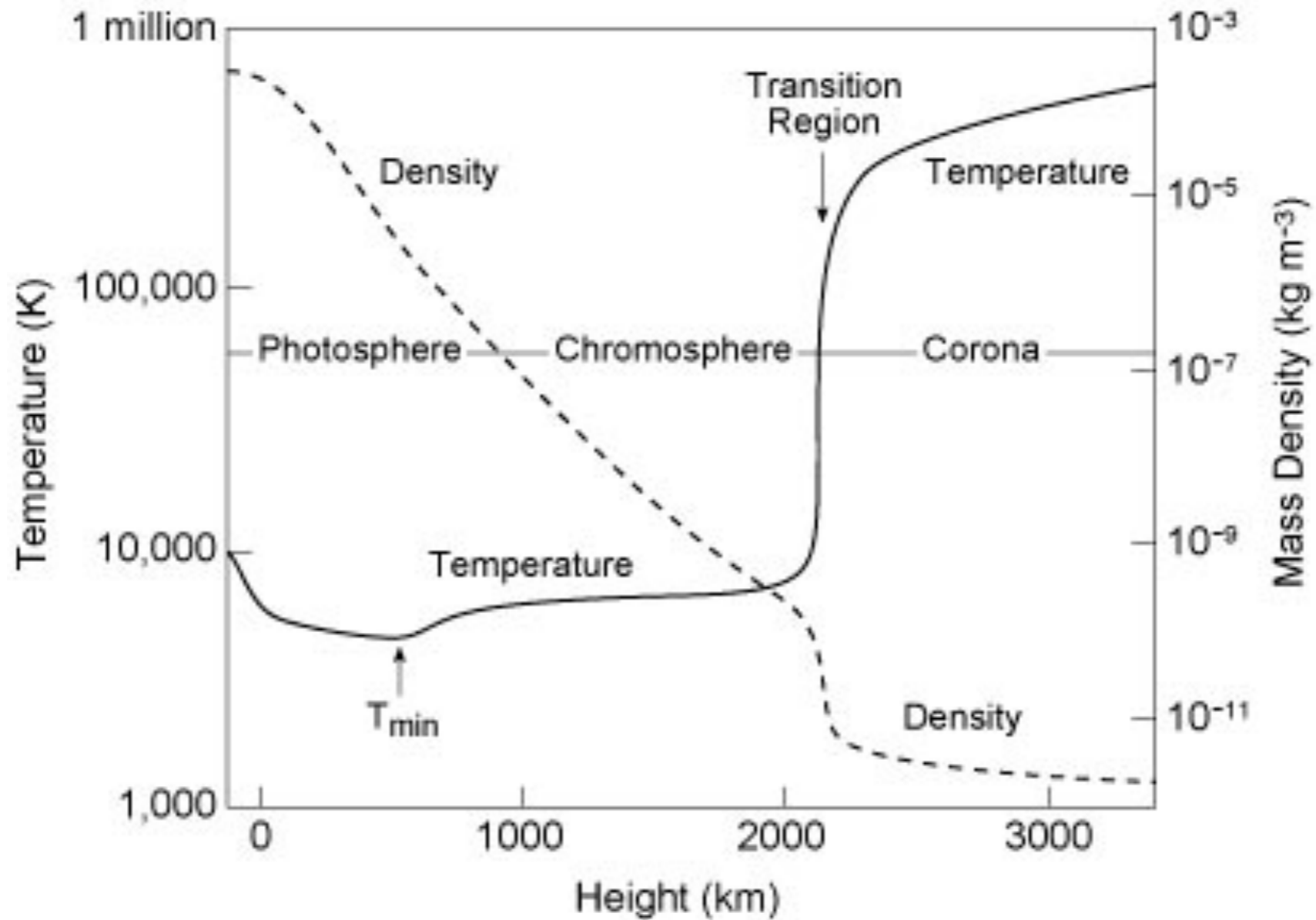


# LAYERS OF THE SUN

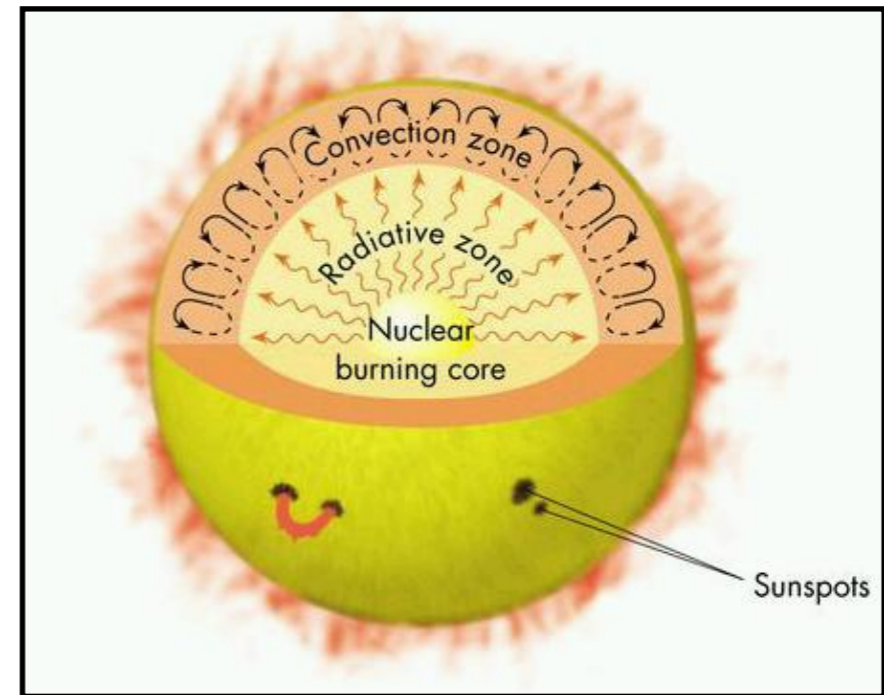
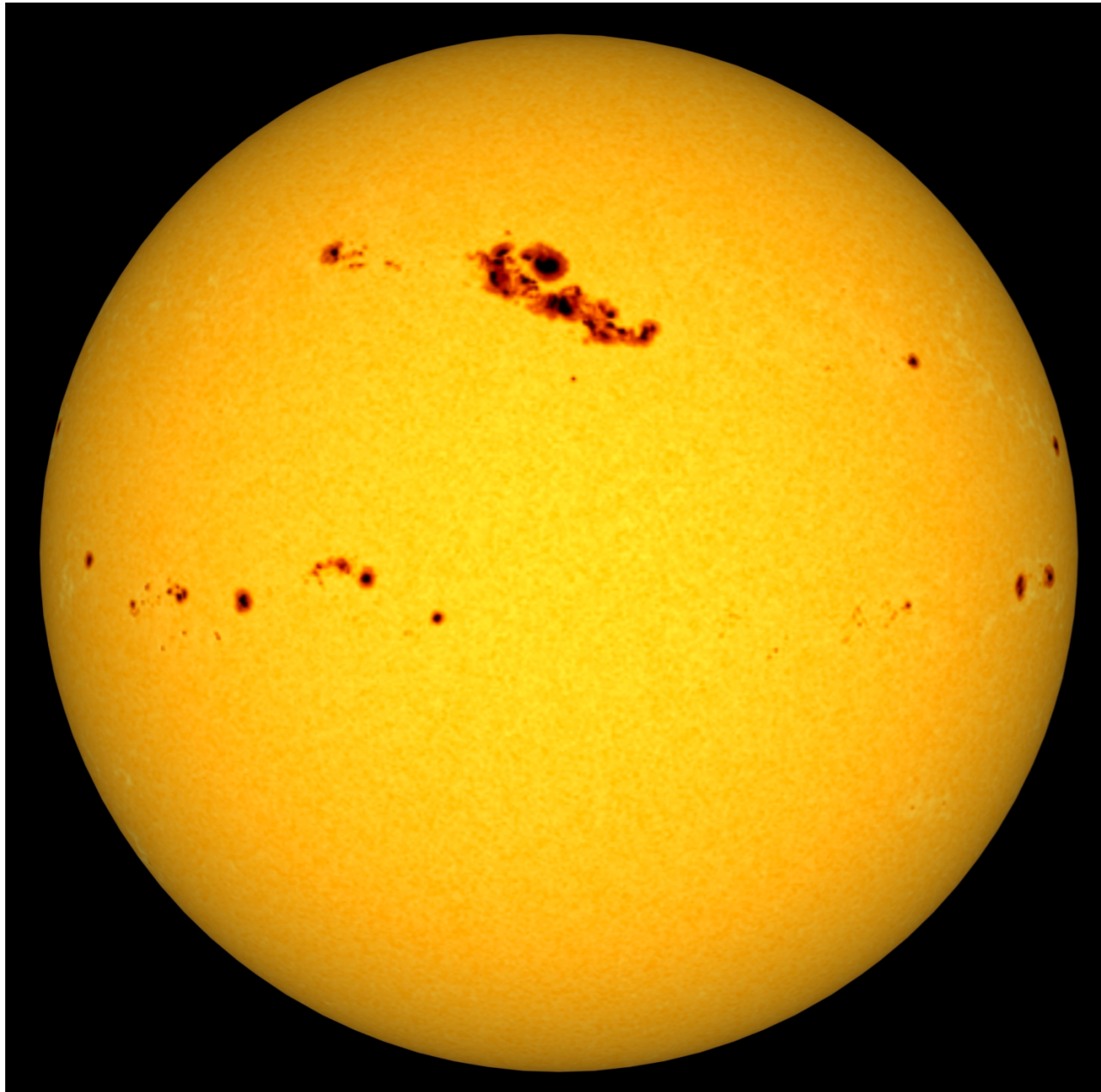
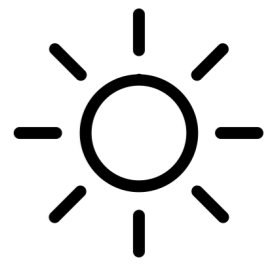


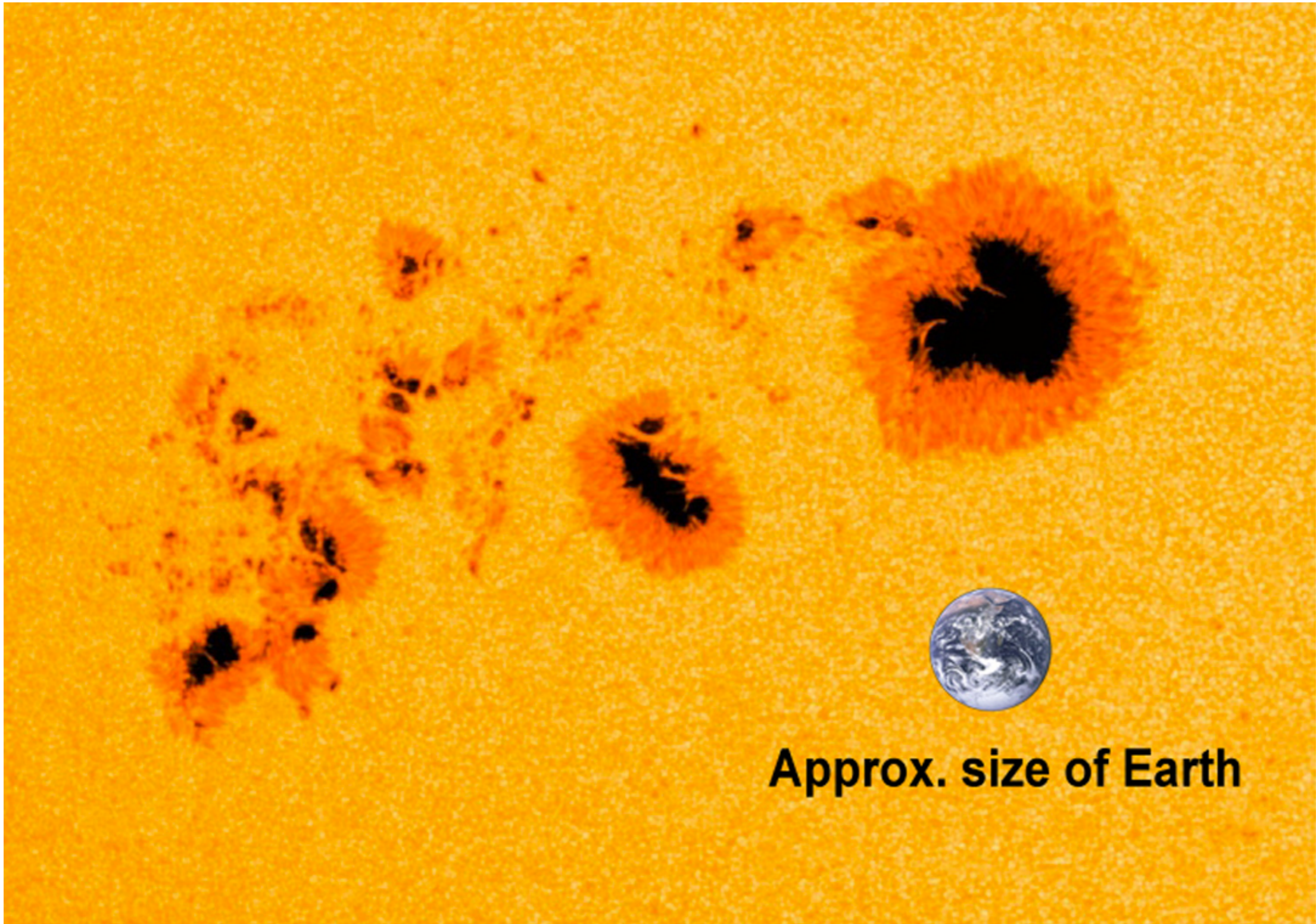
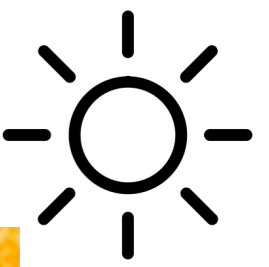


# LAYERS OF THE SUN

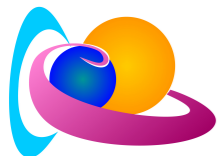


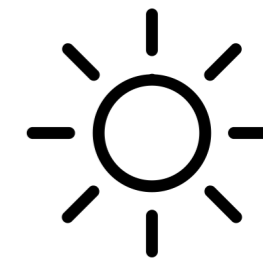
# SUNSPOTS





**Approx. size of Earth**





# DRAWINGS

OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE  
 KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

Rotation N° ..... N° ..... / .....

P : ..... Observateur: J. Vandekerkhove

B<sub>0</sub> : ..... Date: 28/1/2023

L<sub>0</sub> : ..... Heure: 13 H. 55 m (U.T.)

Qualité: 2

W ————— E

Commentaire:  
 .....  
 .....  
 .....

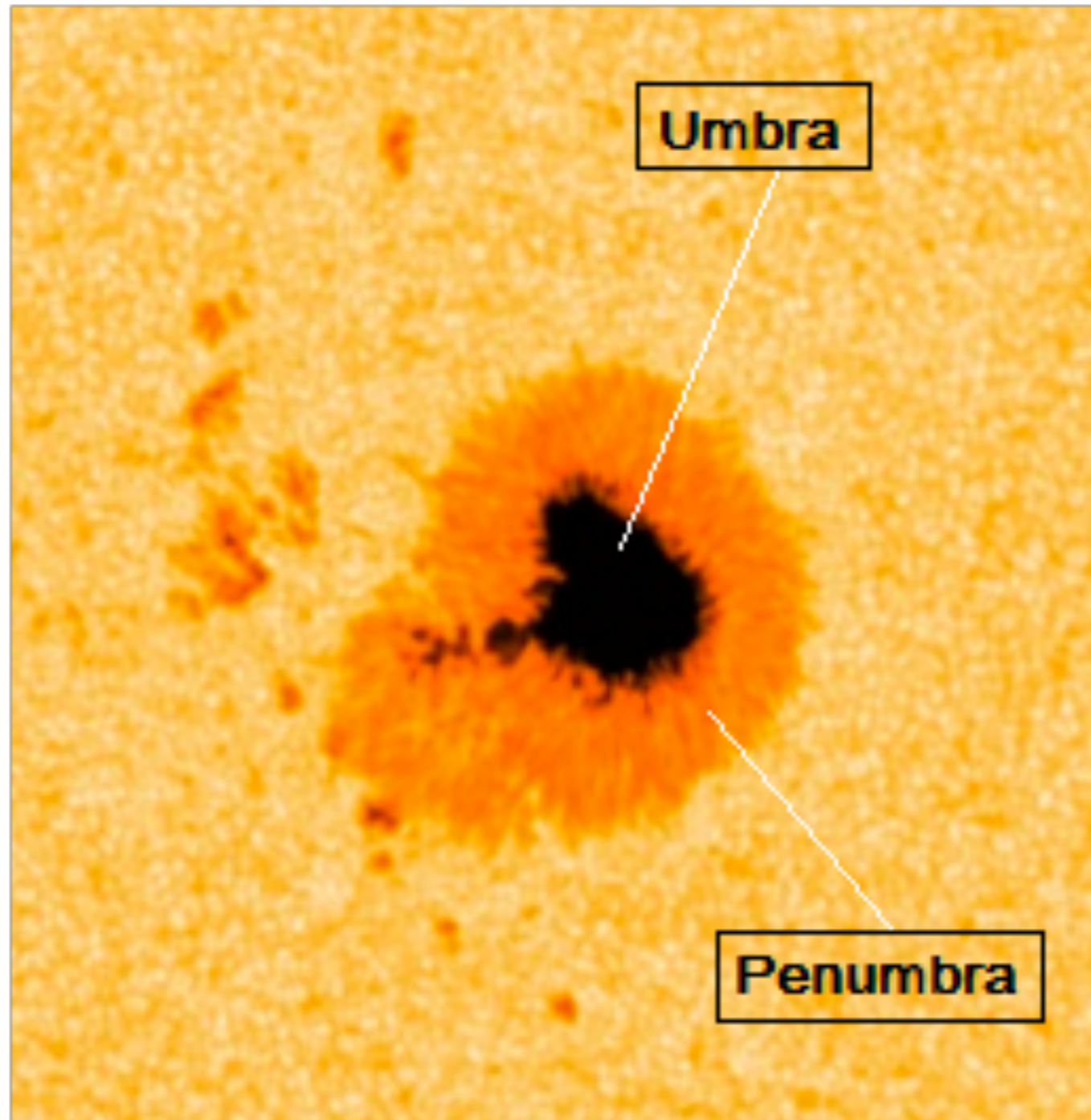
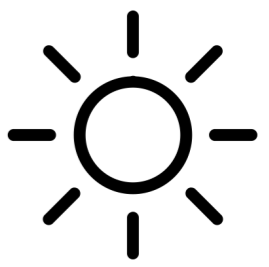
	T	N	S
Nb Groupes	6		
Nb Taches	19		
Nb Wolf	79		

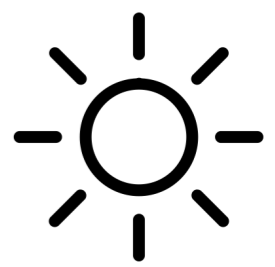
N°	l(mc)	Long	Lat	n	T	A

N°	l(mc)	Long	Lat	n	T	A

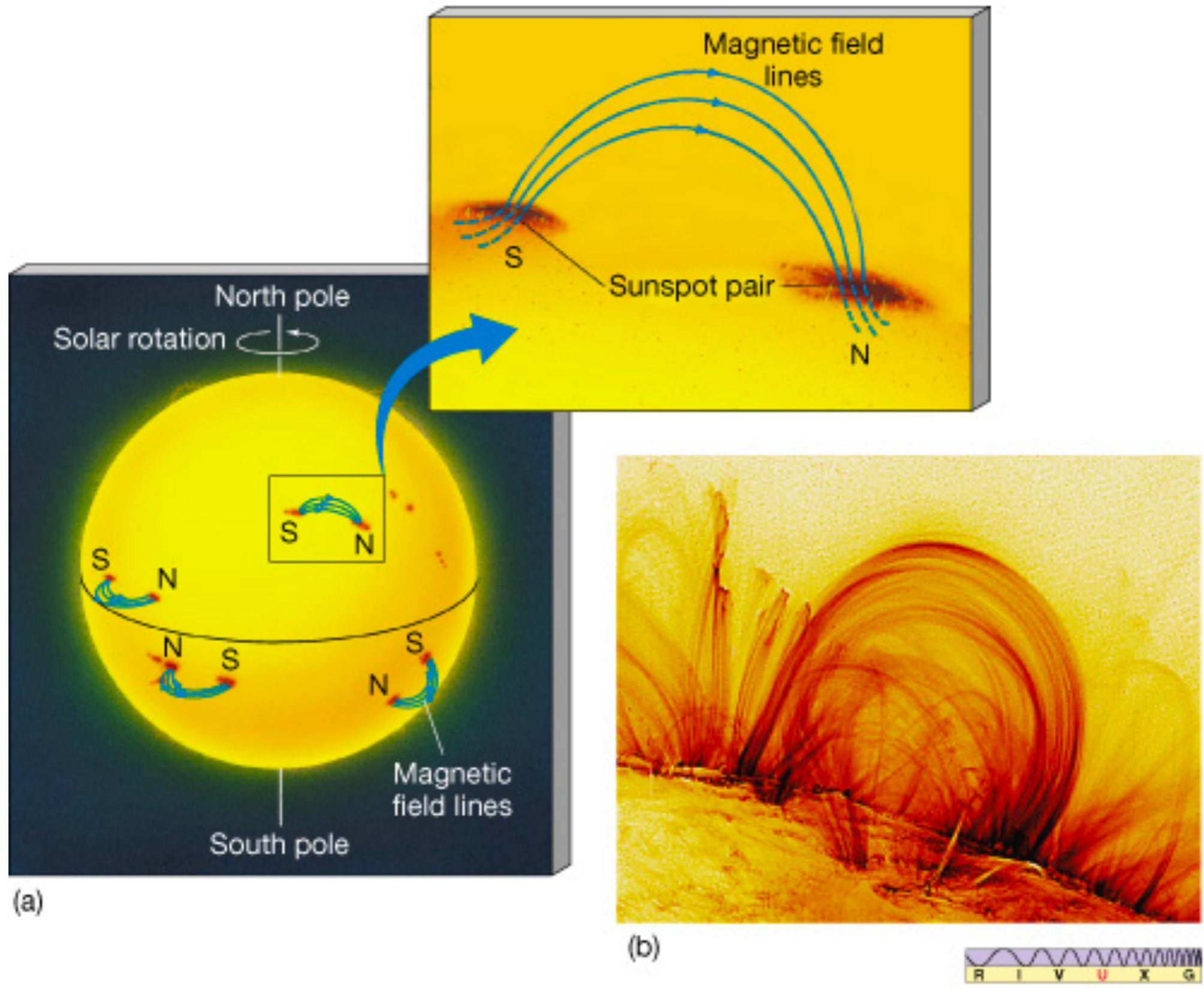


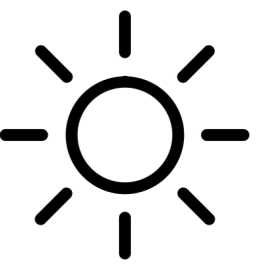
# NOMENCLATURE



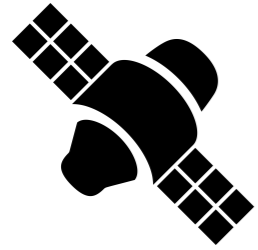


# MAGNETIC FIELD

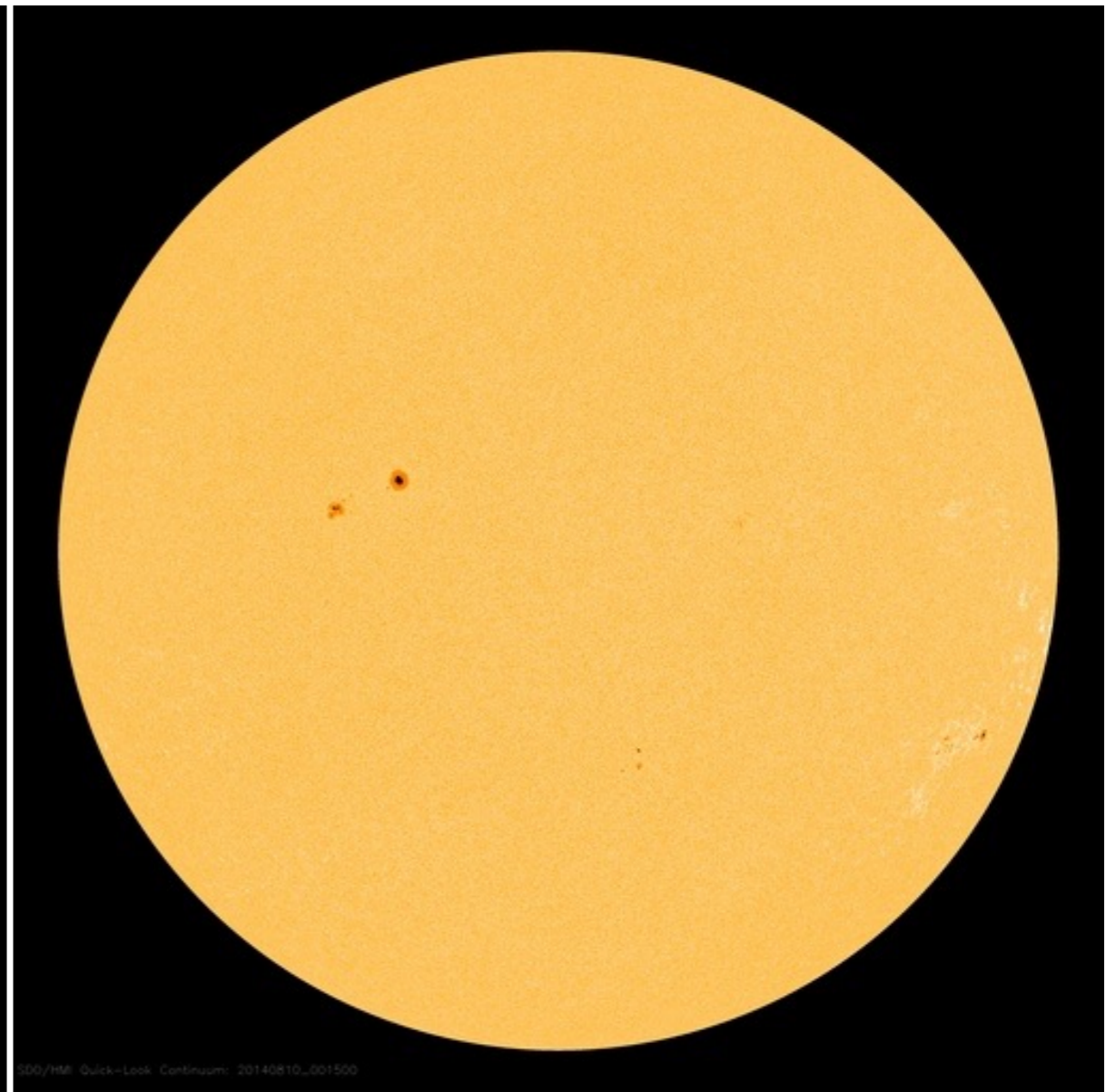
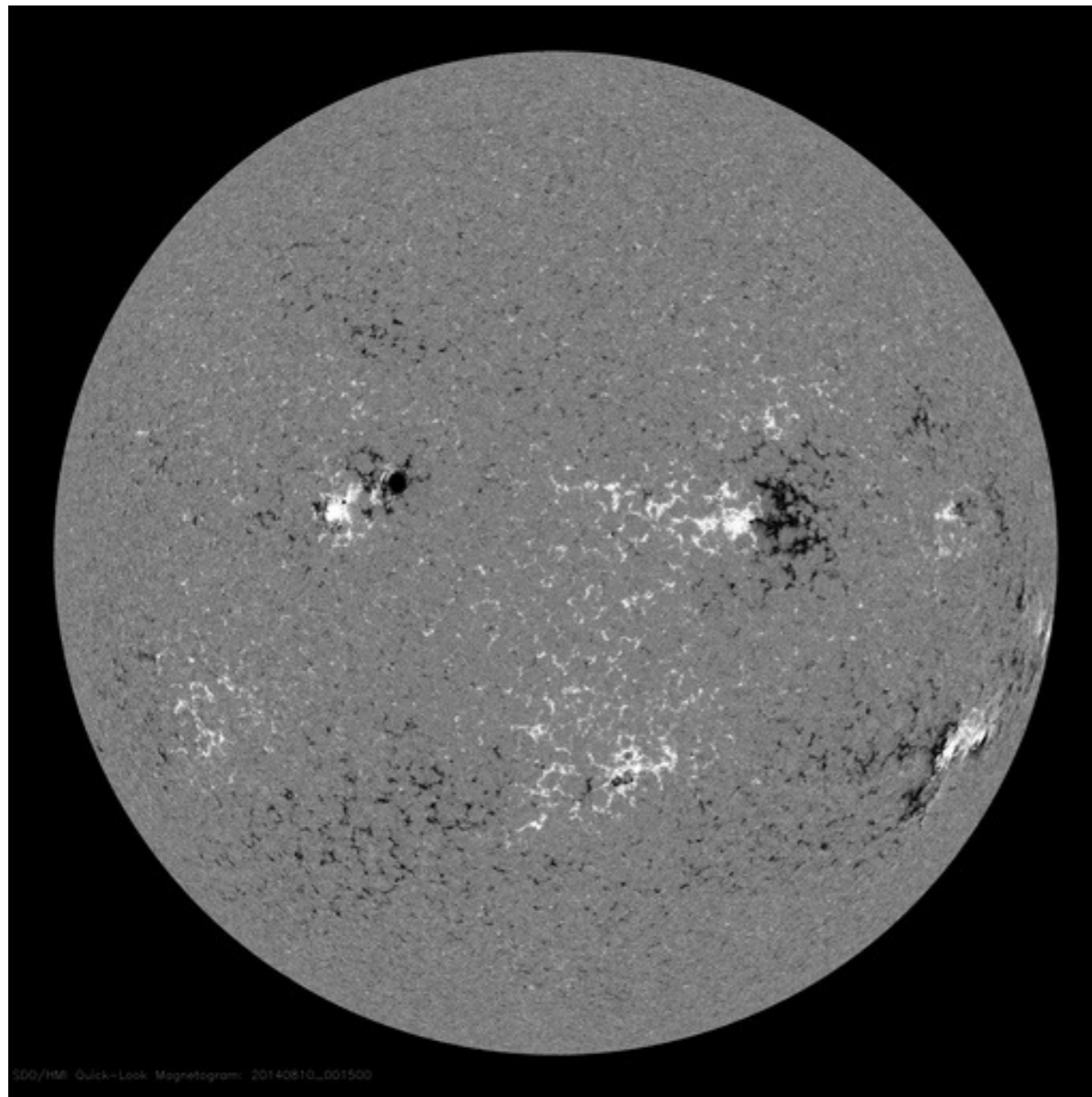




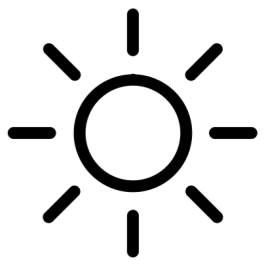
# MAGNETOGRAM



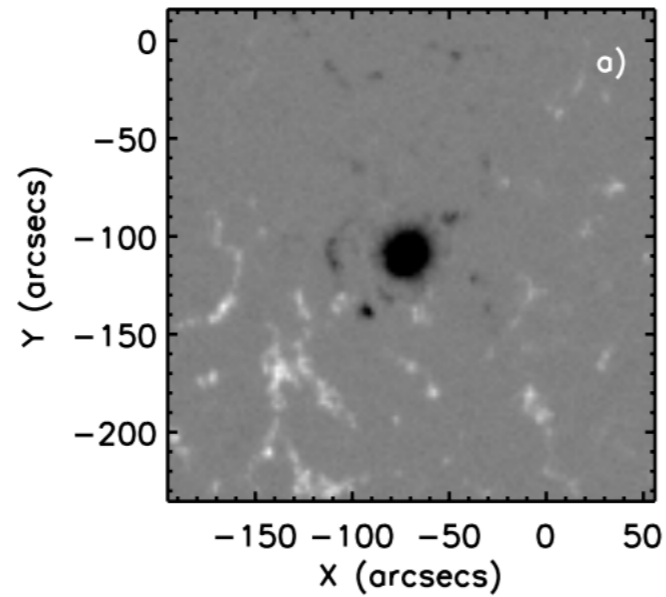
SDO/HMI



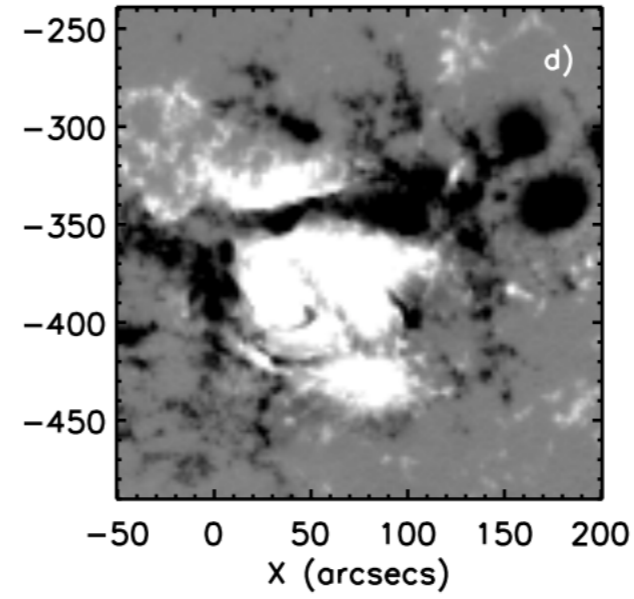
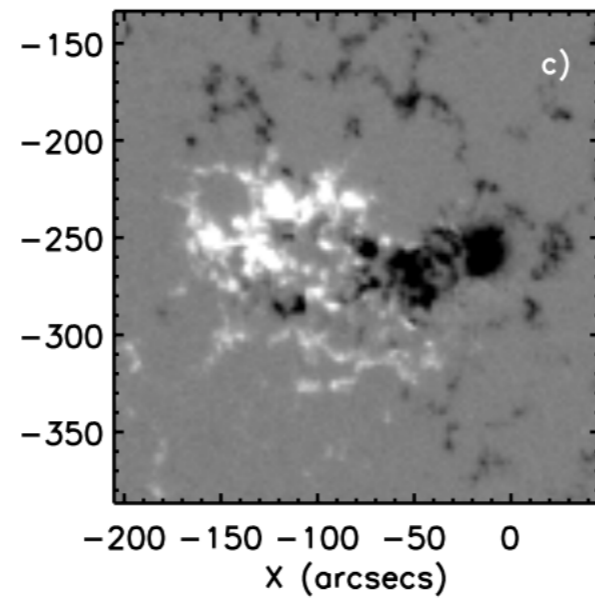
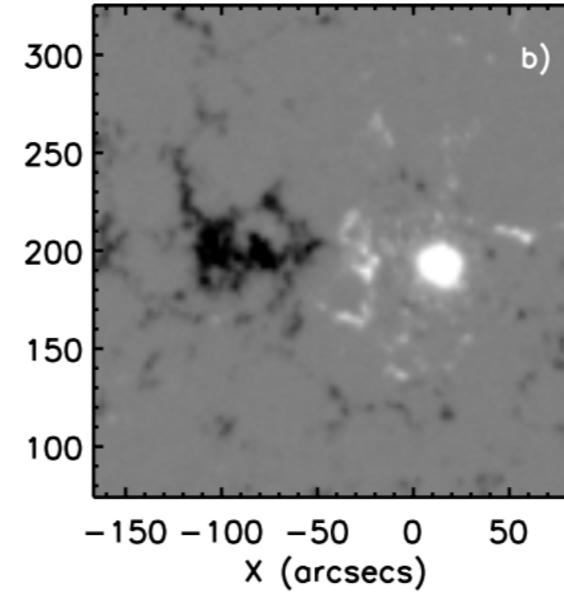
# SUNSPOT COMPLEXITY



$\alpha$



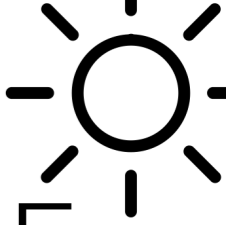
$\beta$



$\beta\gamma$

$\beta\gamma\delta$

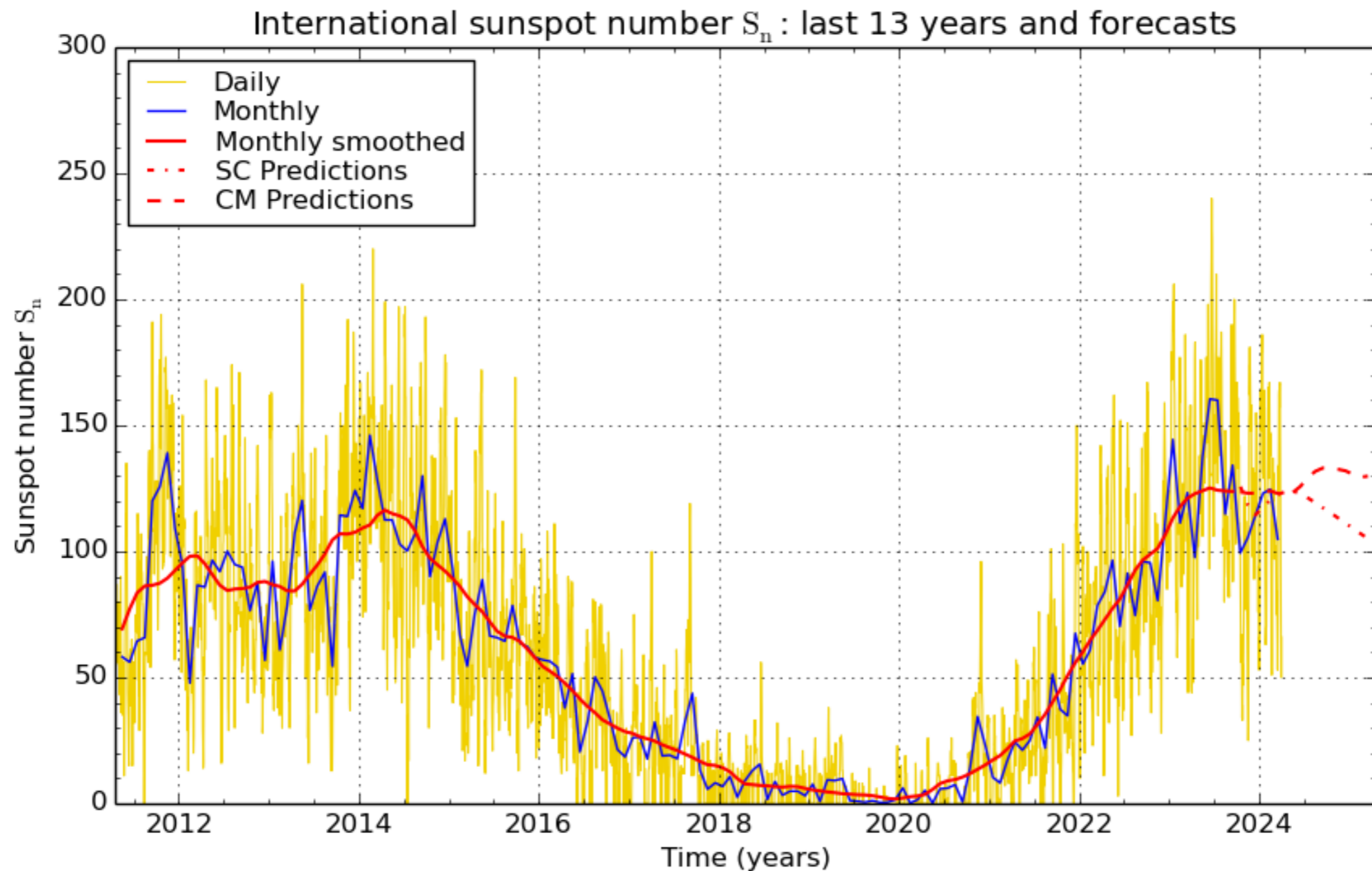




# SUNSPOT NUMBER AND SOLAR CYCLE

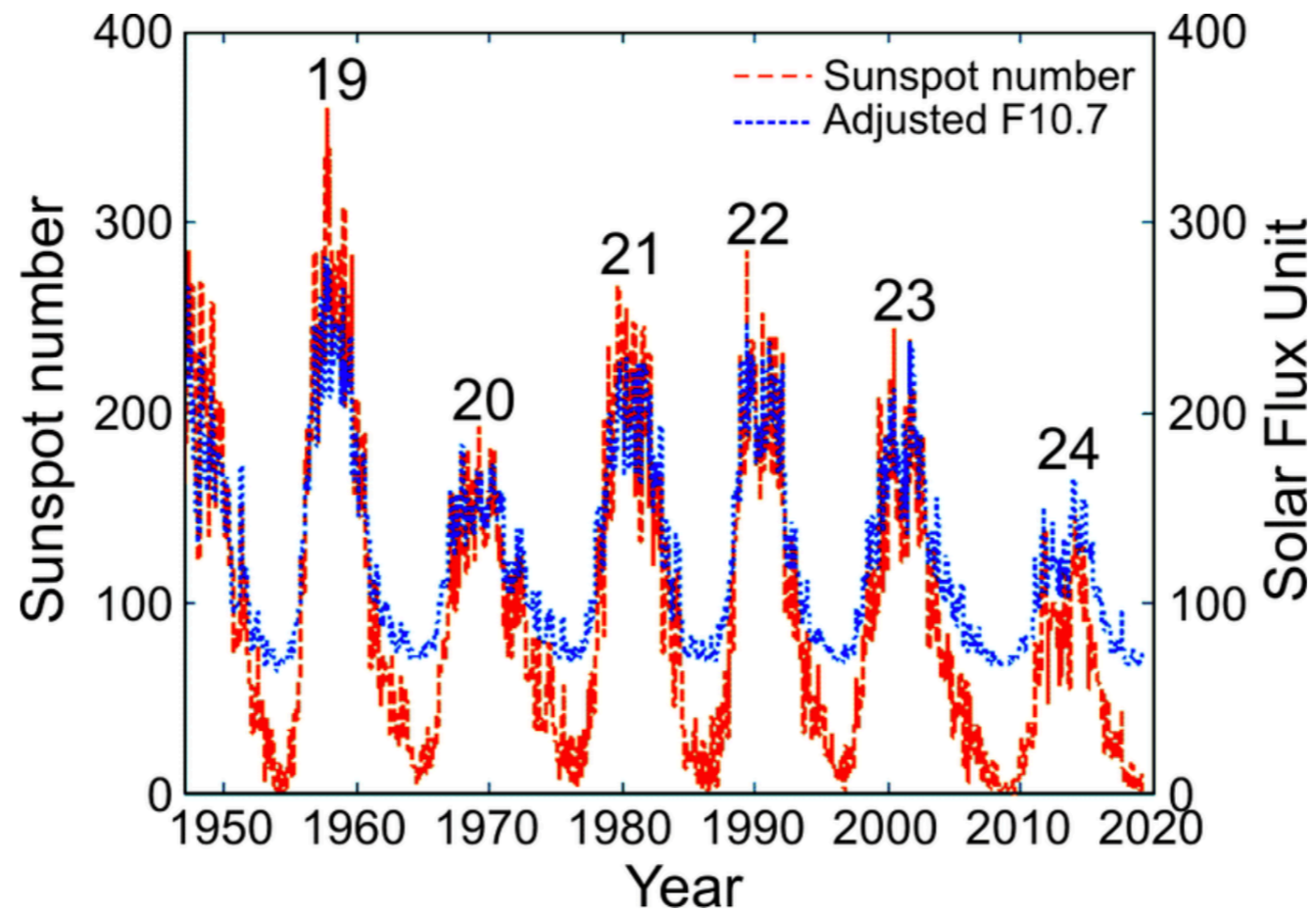
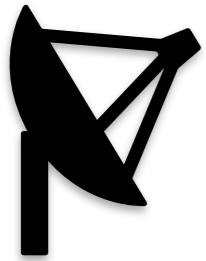


$$R = K (10g + s)$$



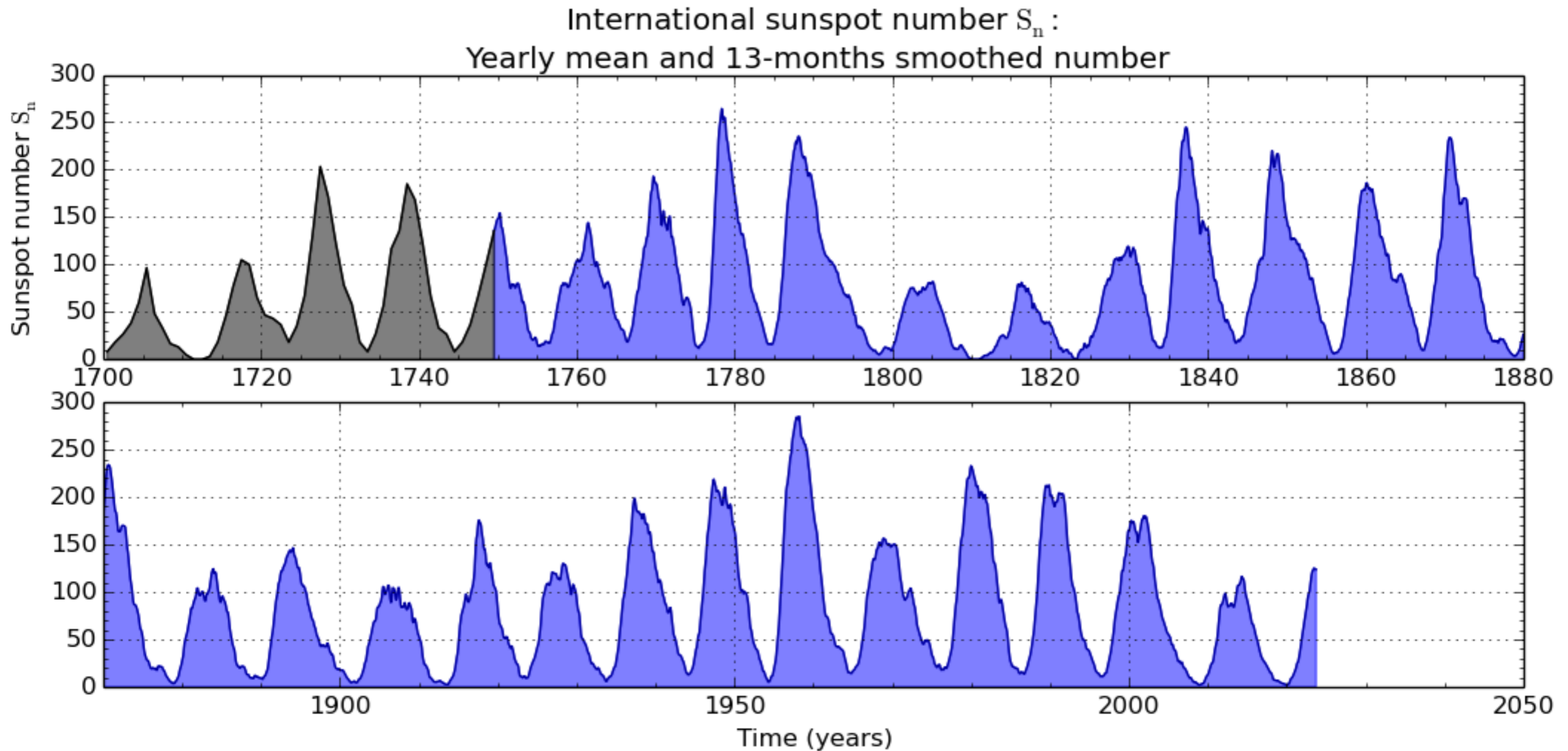
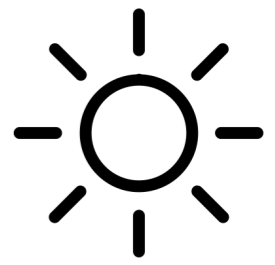
# THE 10.7CM RADIO FLUX

Measured at  
Penticton,  
Canada



The sunspot numbers (red curve) and the 10.7 cm solar flux (F10.7, blue curve) from the middle of the 20th century [69-71]. The F10.7 values are in solar flux units (sfu), 1 sfu is equal to  $10^{-22} \text{ W m}^{-2} \cdot \text{Hz}^{-1}$ . The observed F10.7 is presented on the right axis.

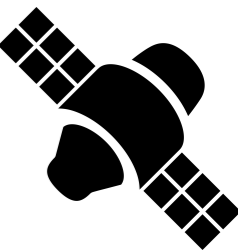
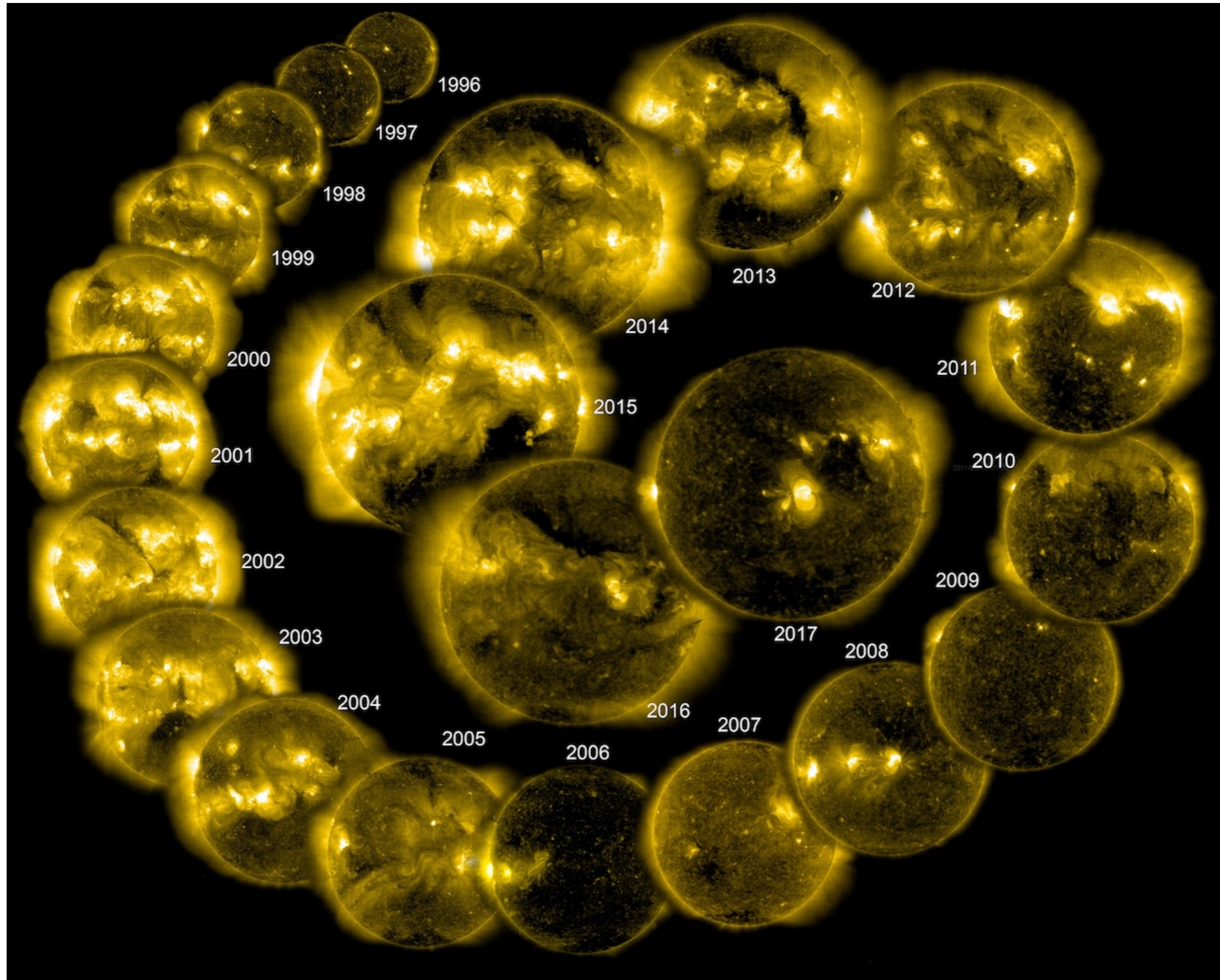
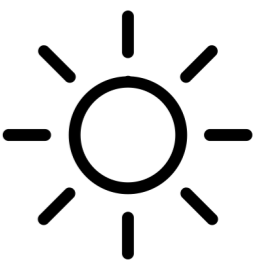
# LONG TERM SOLAR ACTIVITY



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2024 April 1



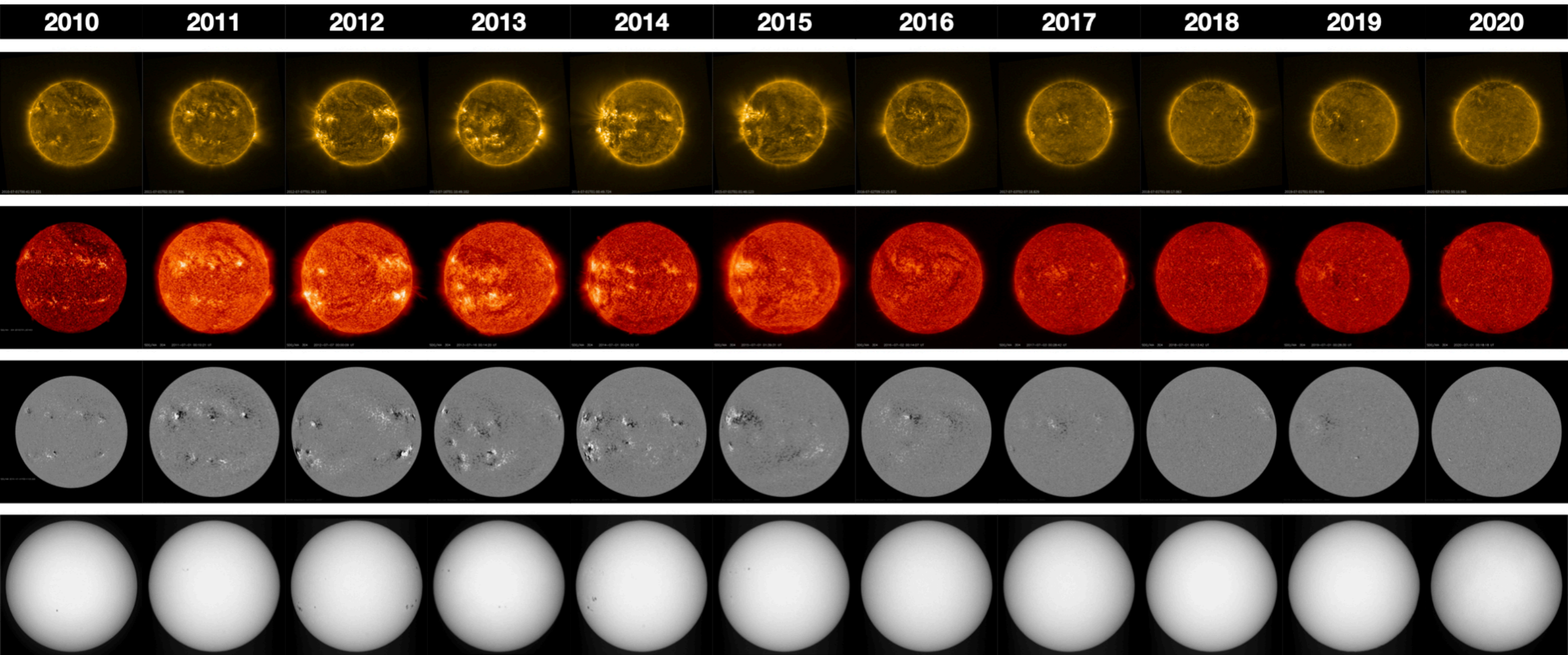
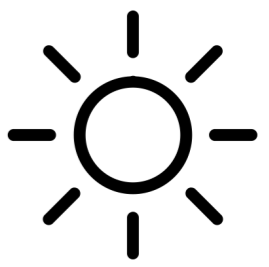
# SOLAR CYCLE



SOHO/EIT



# SOLAR CYCLE



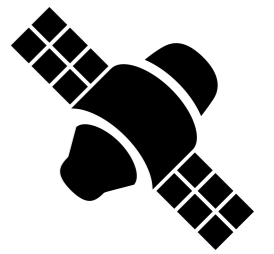
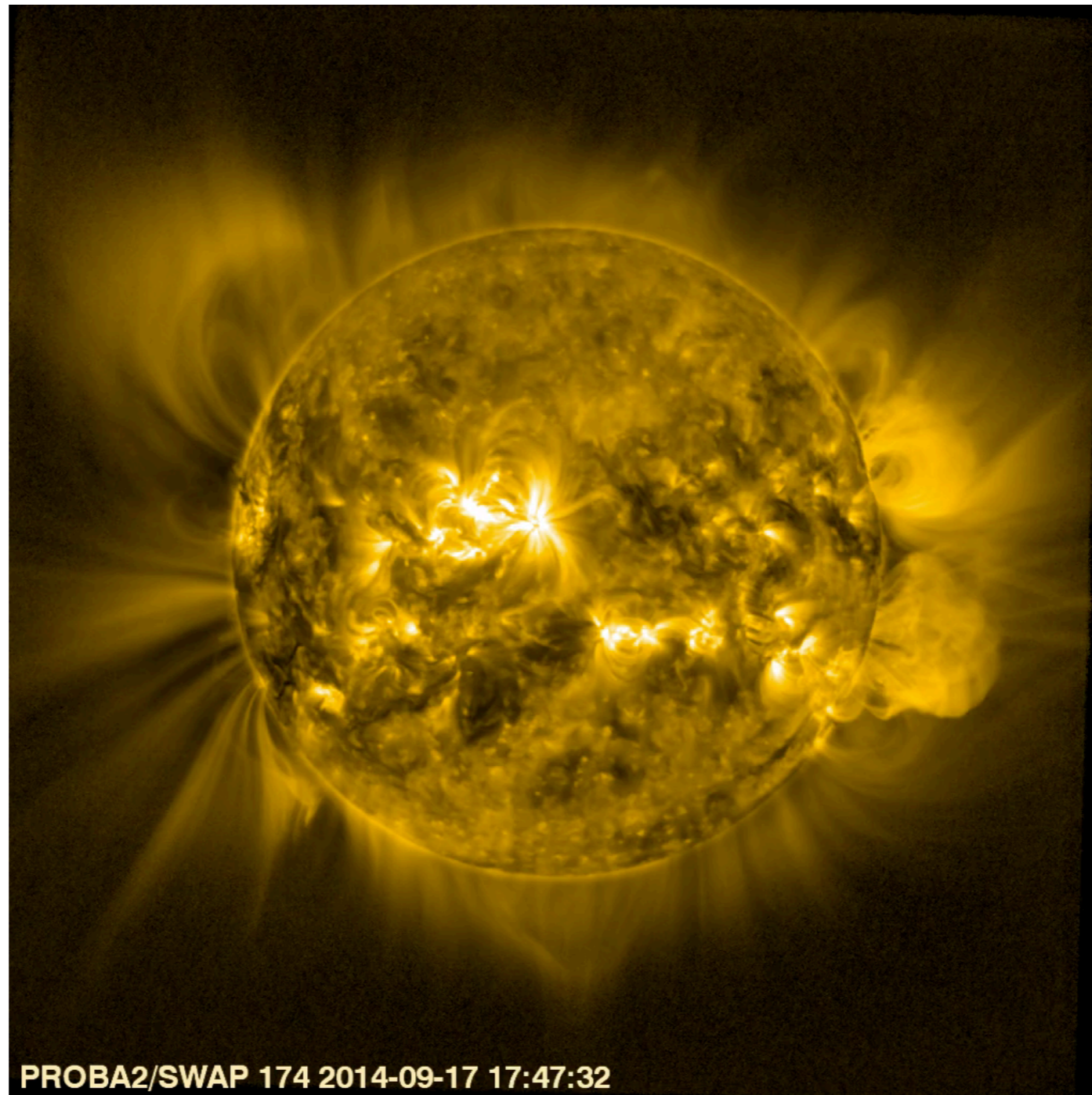
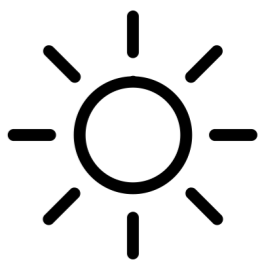
USET



SDO/AIA&HMI  
PROBA2/SWAP



# SOLAR ACTIVITY WITH SWAP

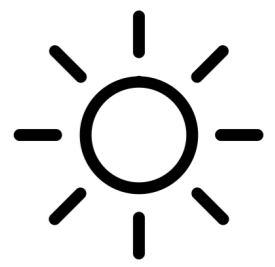


**PROBA2/SWAP**

**PROBA2/SWAP 174 2014-09-17 17:47:32**



# ACTIVE REGION NUMBERING



Showing latest available data on 2016-10-11T08:24:45Z.

[<27d](#) [<7d](#) [<1d](#) [<1h](#)

[Today](#)

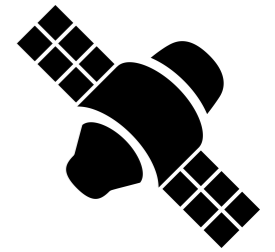
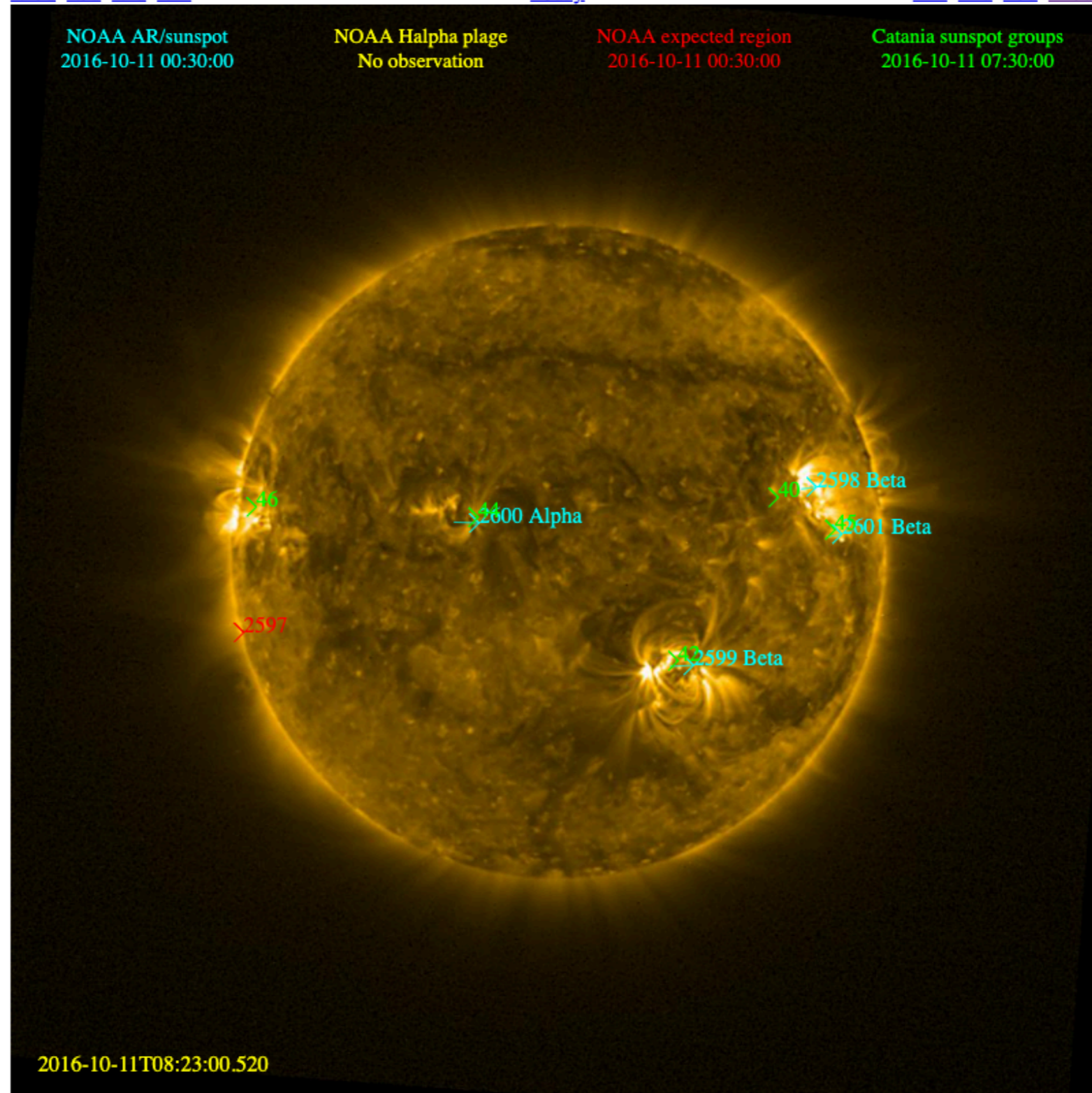
[>1h](#) [>1d](#) [>7d](#) [>27d](#)

NOAA AR/sunspot  
2016-10-11 00:30:00

NOAA Halpha plage  
No observation

NOAA expected region  
2016-10-11 00:30:00

Catania sunspot groups  
2016-10-11 07:30:00



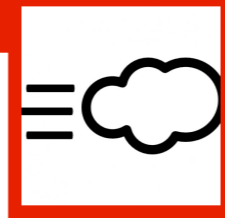
PROBA2/SWAP



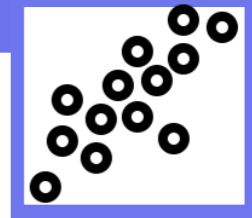
FLARE



CORONAL MASS  
EJECTION  
CORONAL HOLE



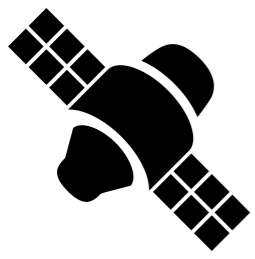
SOLAR  
ENERGETIC  
PARTICLES



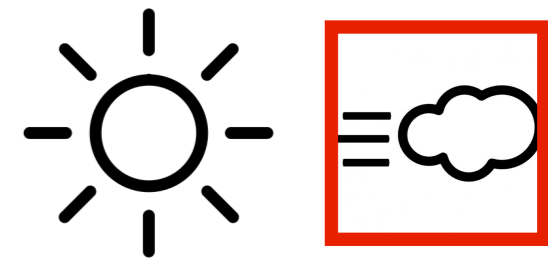
# INGREDIENTS OF SPACE WEATHER

The Sun as a magnetic structure



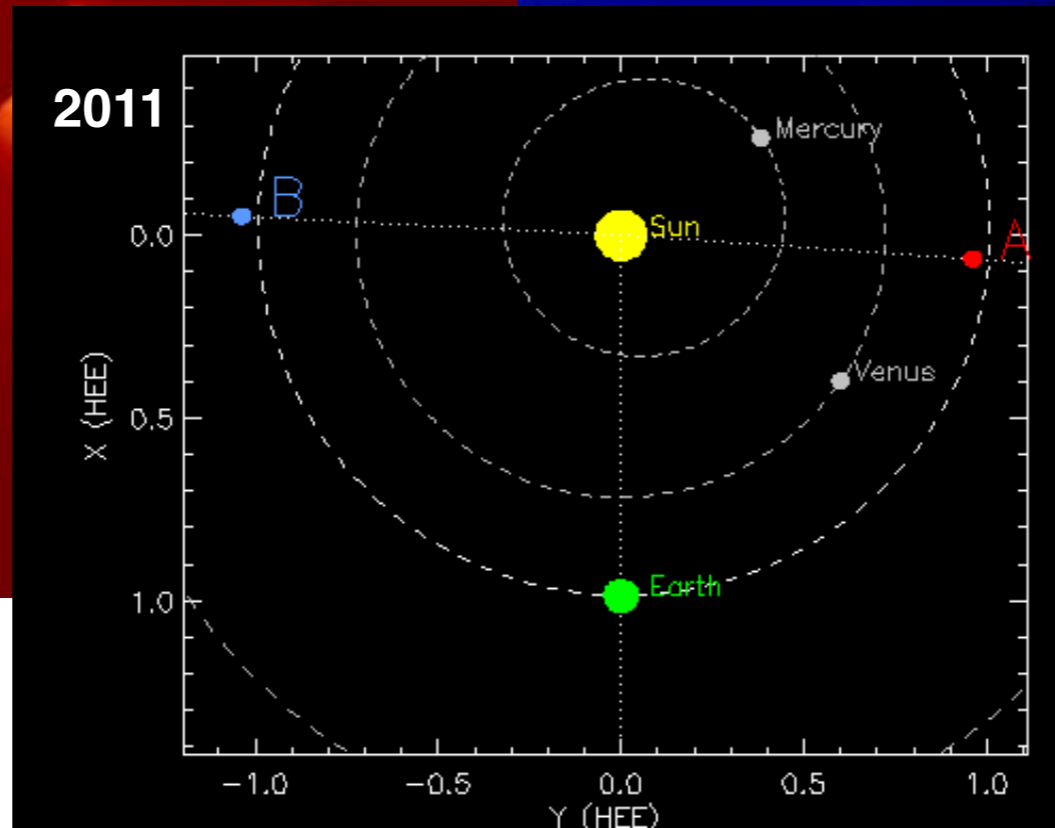
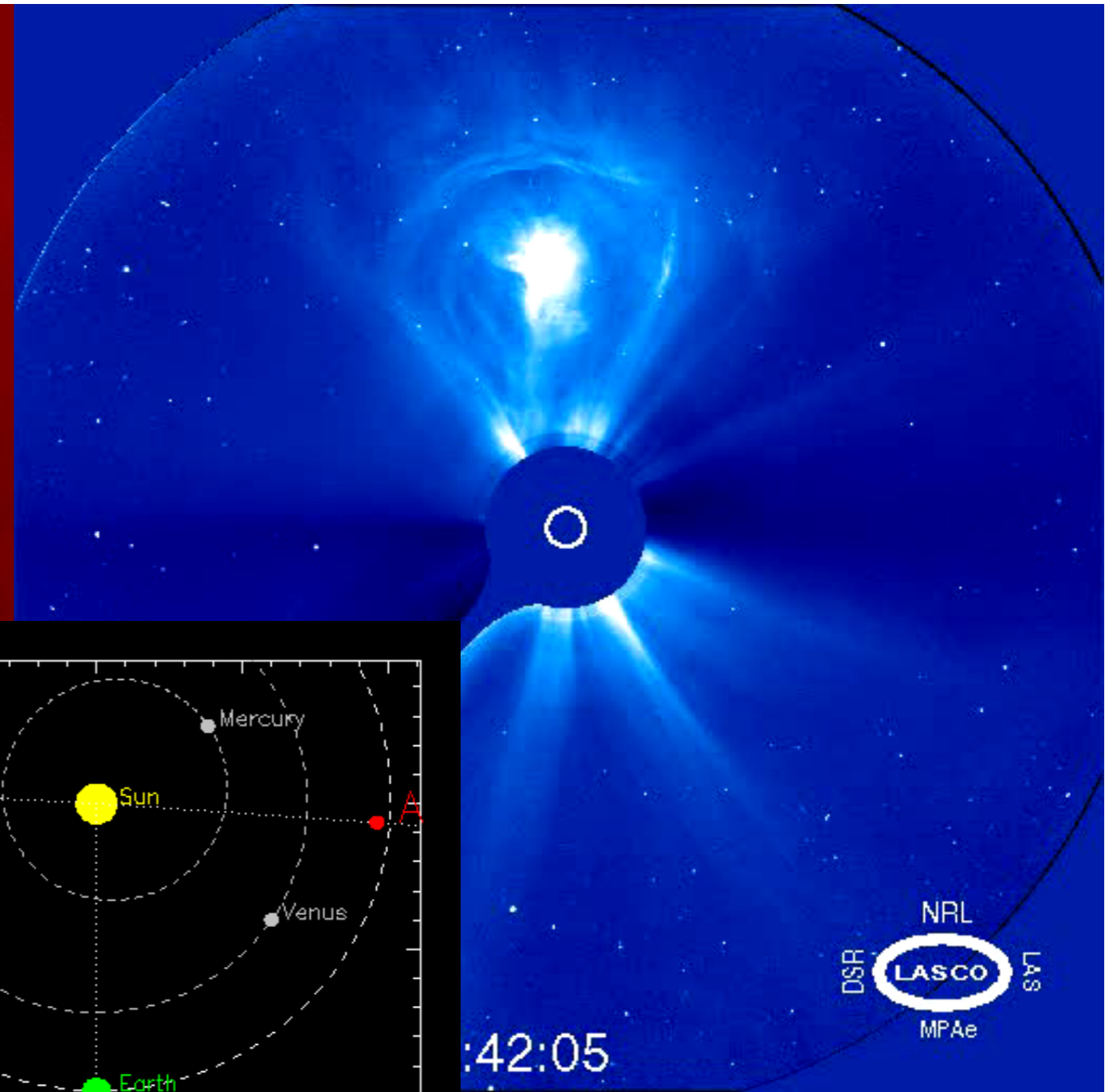
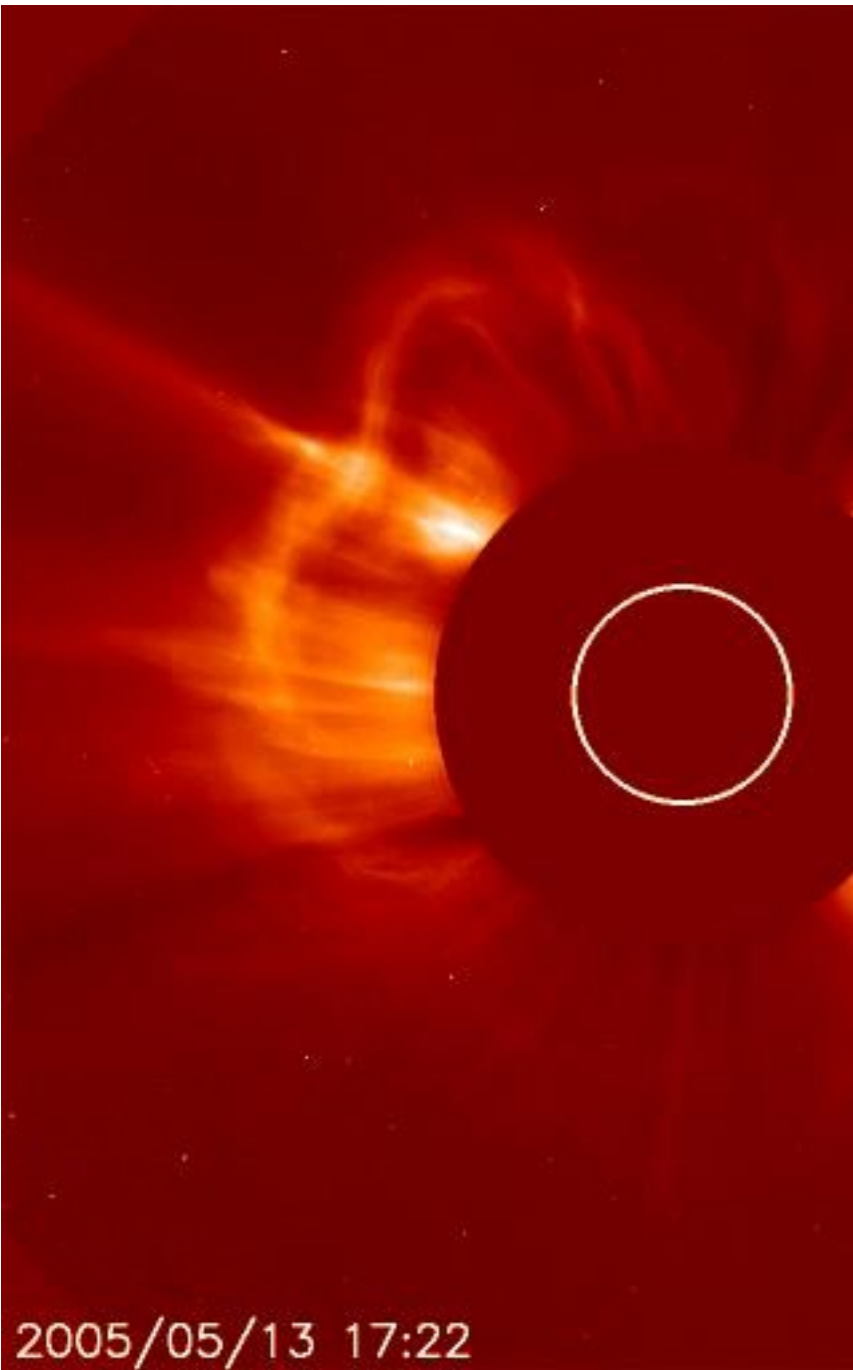


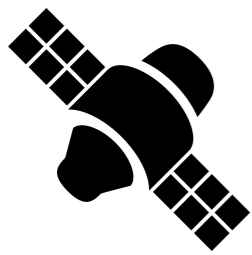
# PLASMA CLOUDS



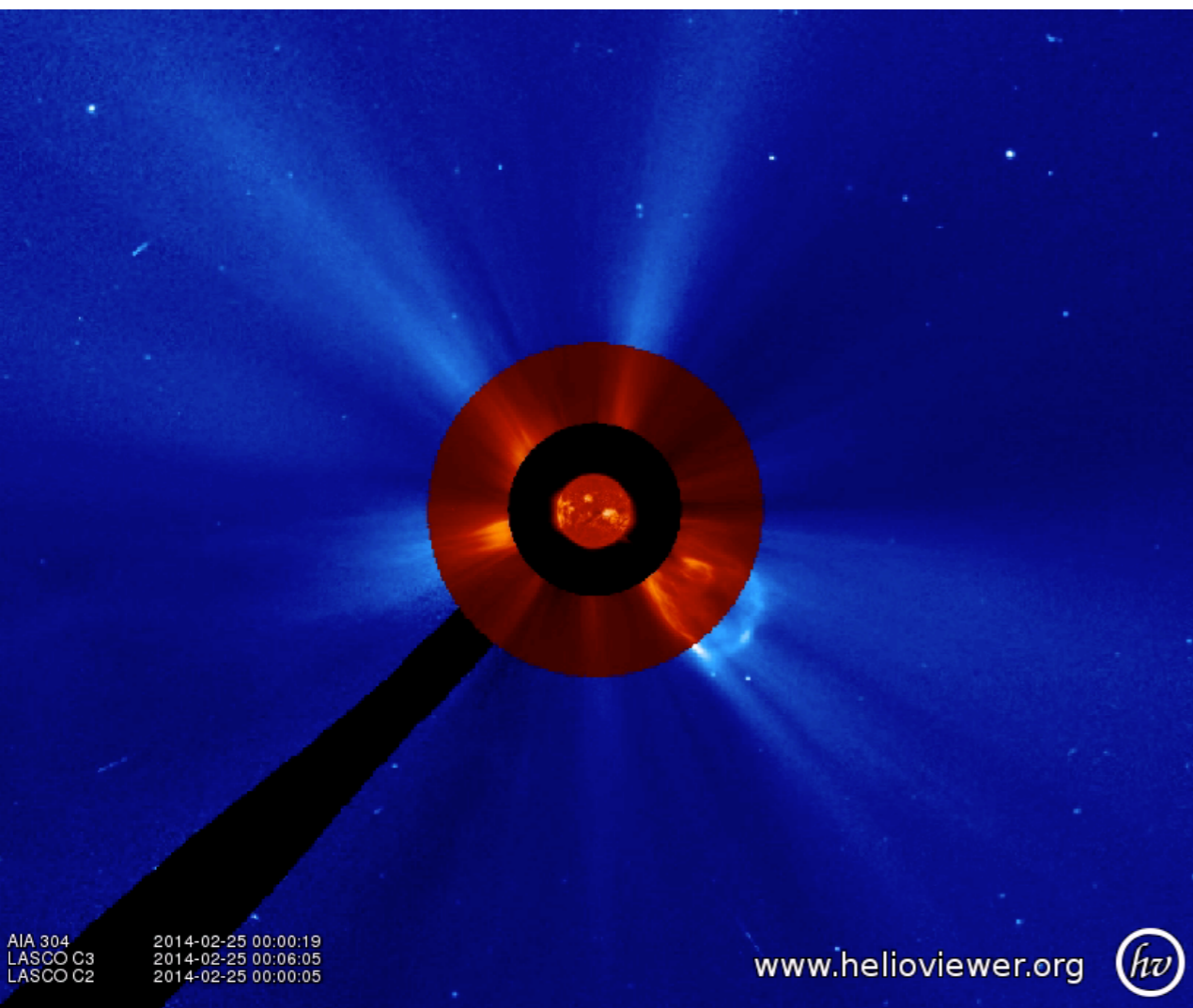
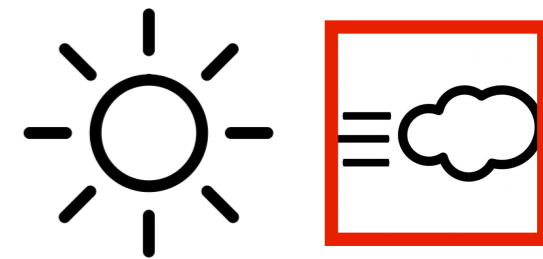
SOHO/LASCO C2

SOHO/LASCO C3



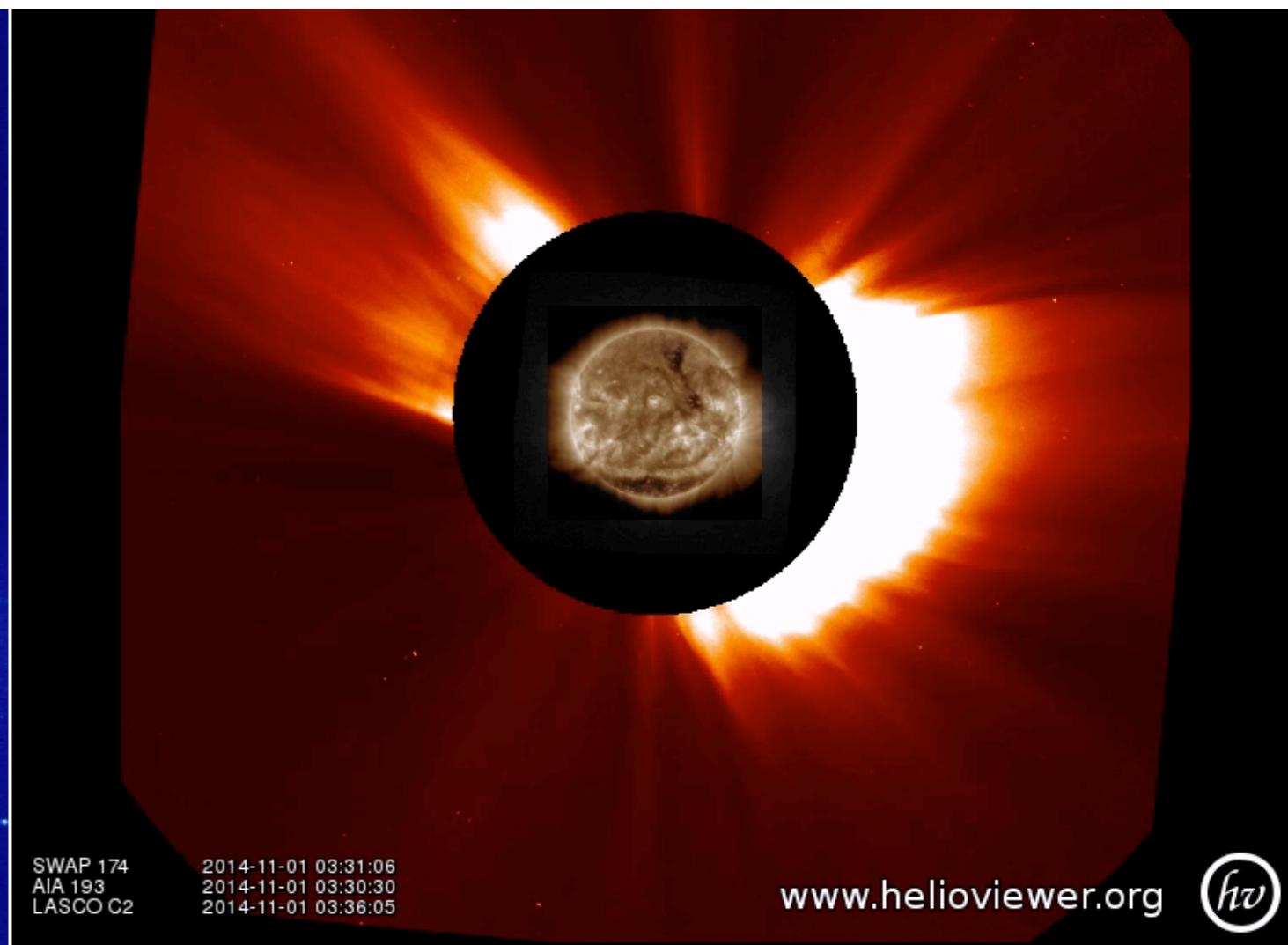


# PLASMA CLOUDS



AIA 304  
LASCO C3  
LASCO C2  
2014-02-25 00:00:19  
2014-02-25 00:06:05  
2014-02-25 00:00:05

www.helioviewer.org



SWAP 174  
AIA 193  
LASCO C2  
2014-11-01 03:31:06  
2014-11-01 03:30:30  
2014-11-01 03:36:05

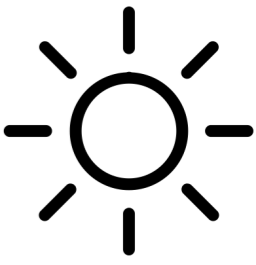
www.helioviewer.org

**SDO/AIA**  
**SOHO/LASCO C2**  
**SOHO/LASCO C3**

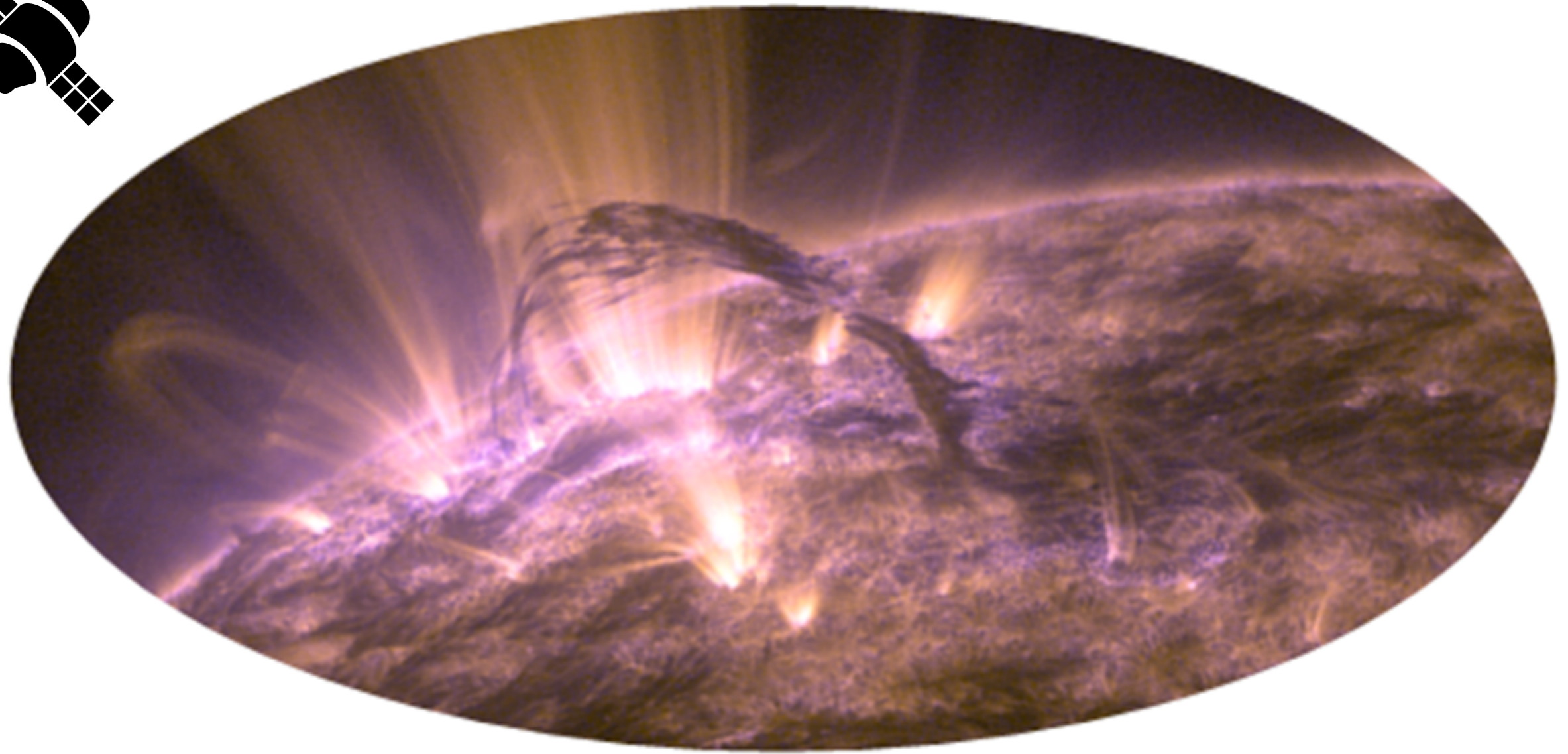
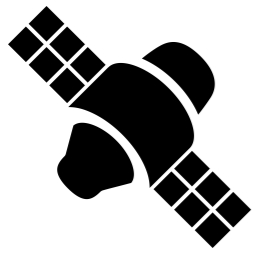
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**PROBA2/SWAP**  
**SOHO/LASCO C2**



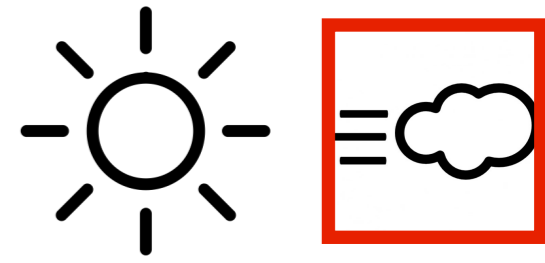
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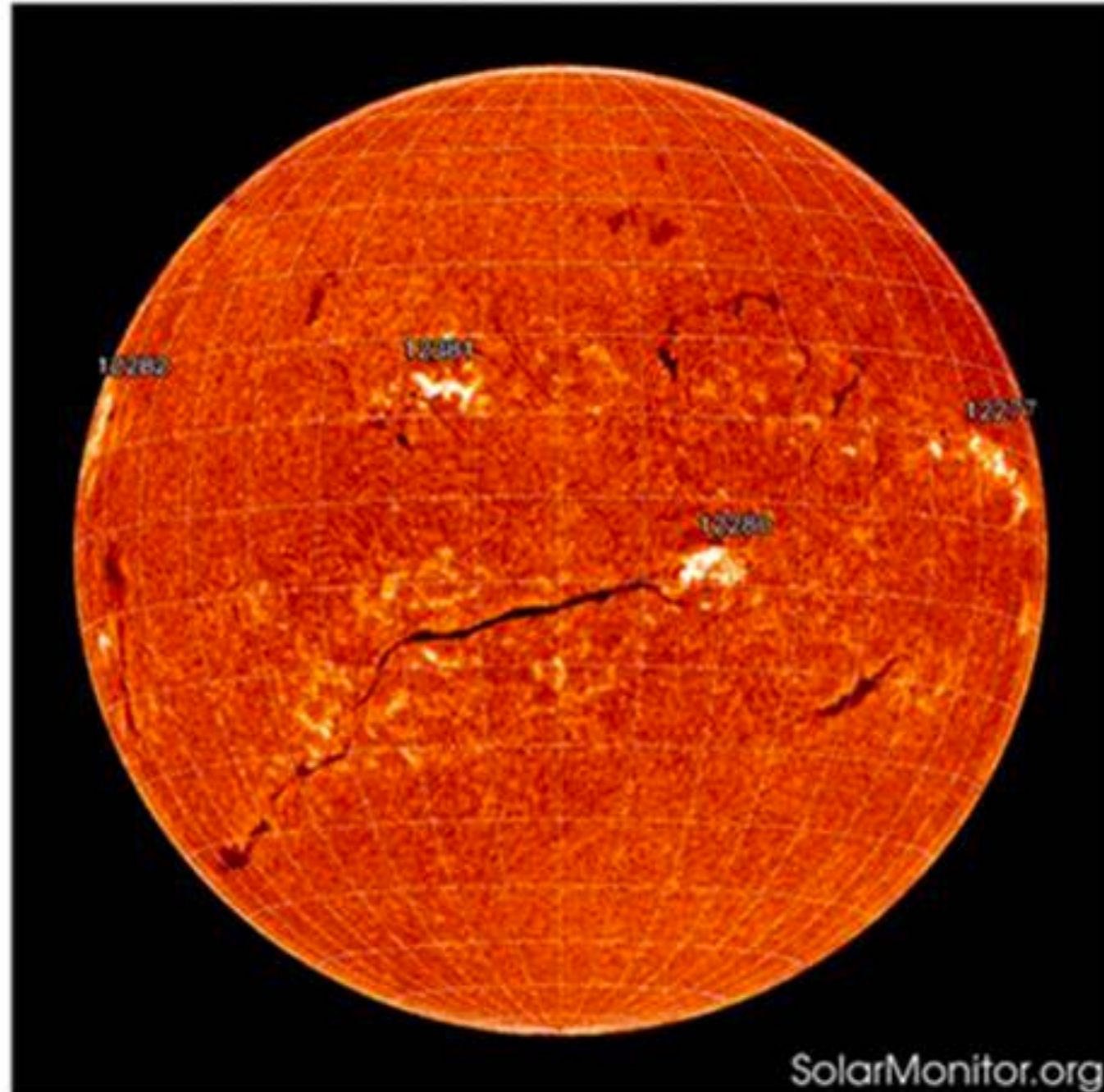
SDO/AIA



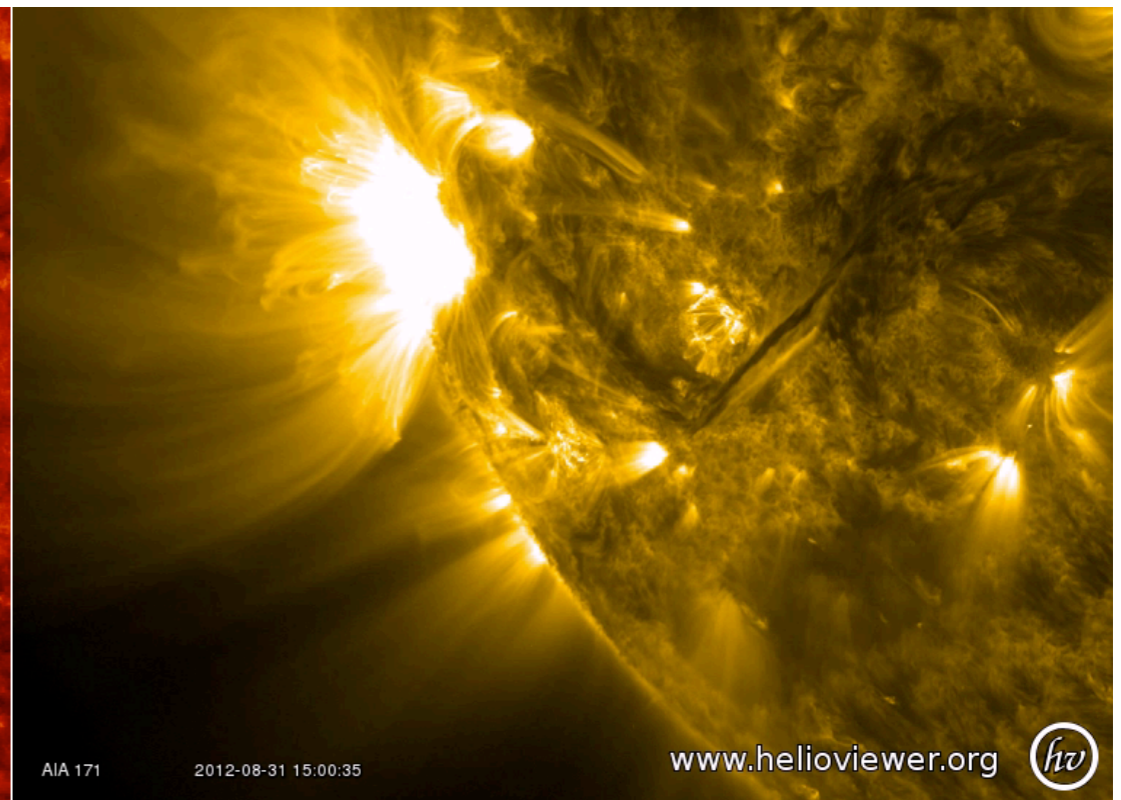
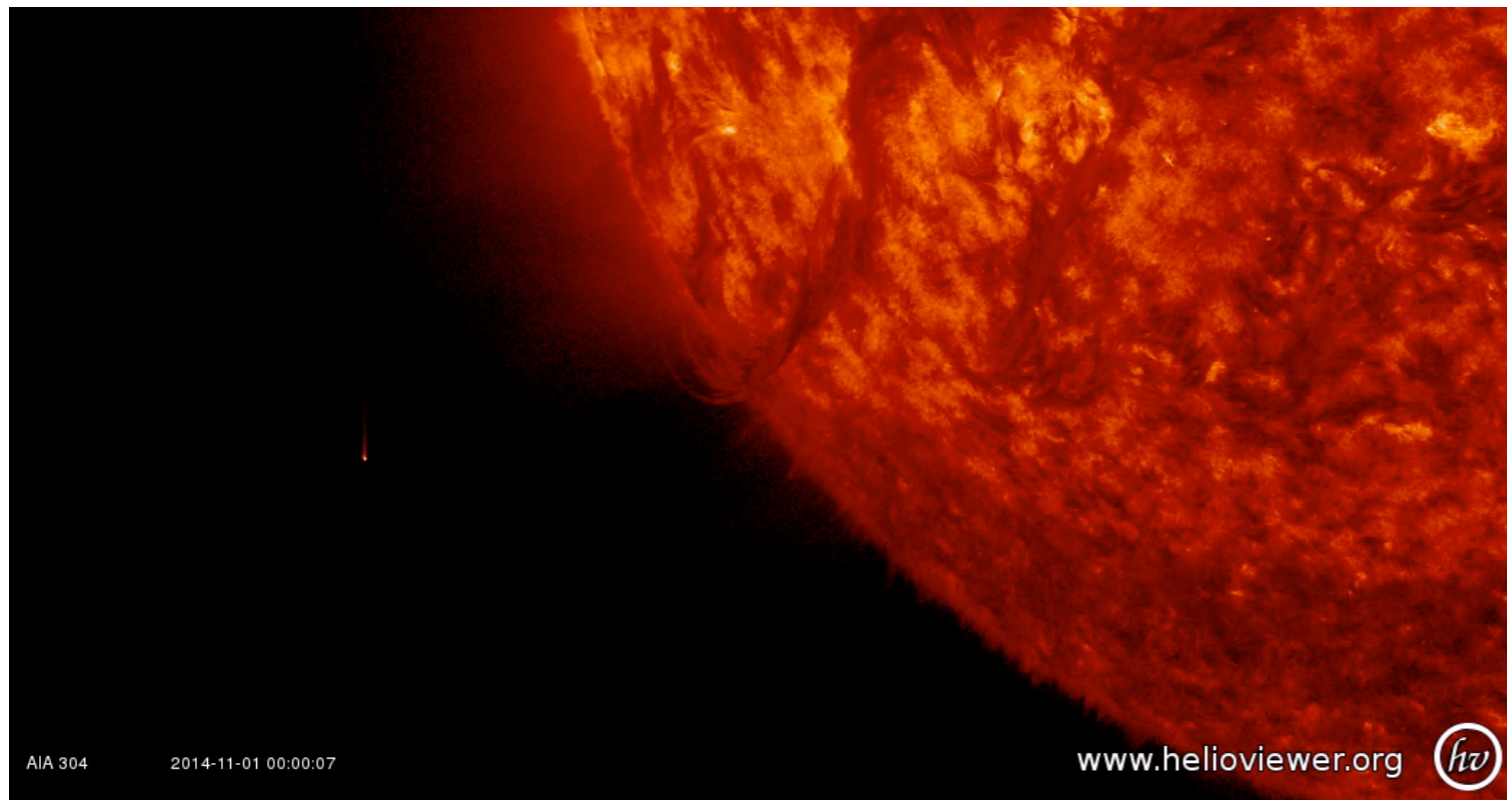
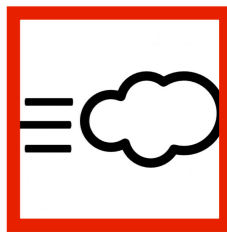
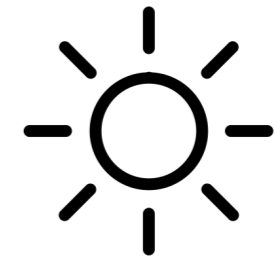
# FILAMENT



Kanzelhoehe H-alpha 8-Feb-2015 12:00:23.000



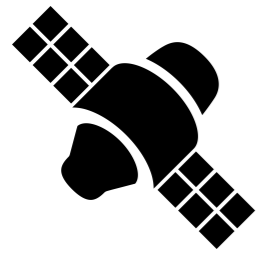
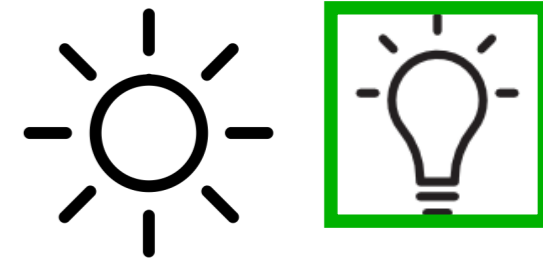
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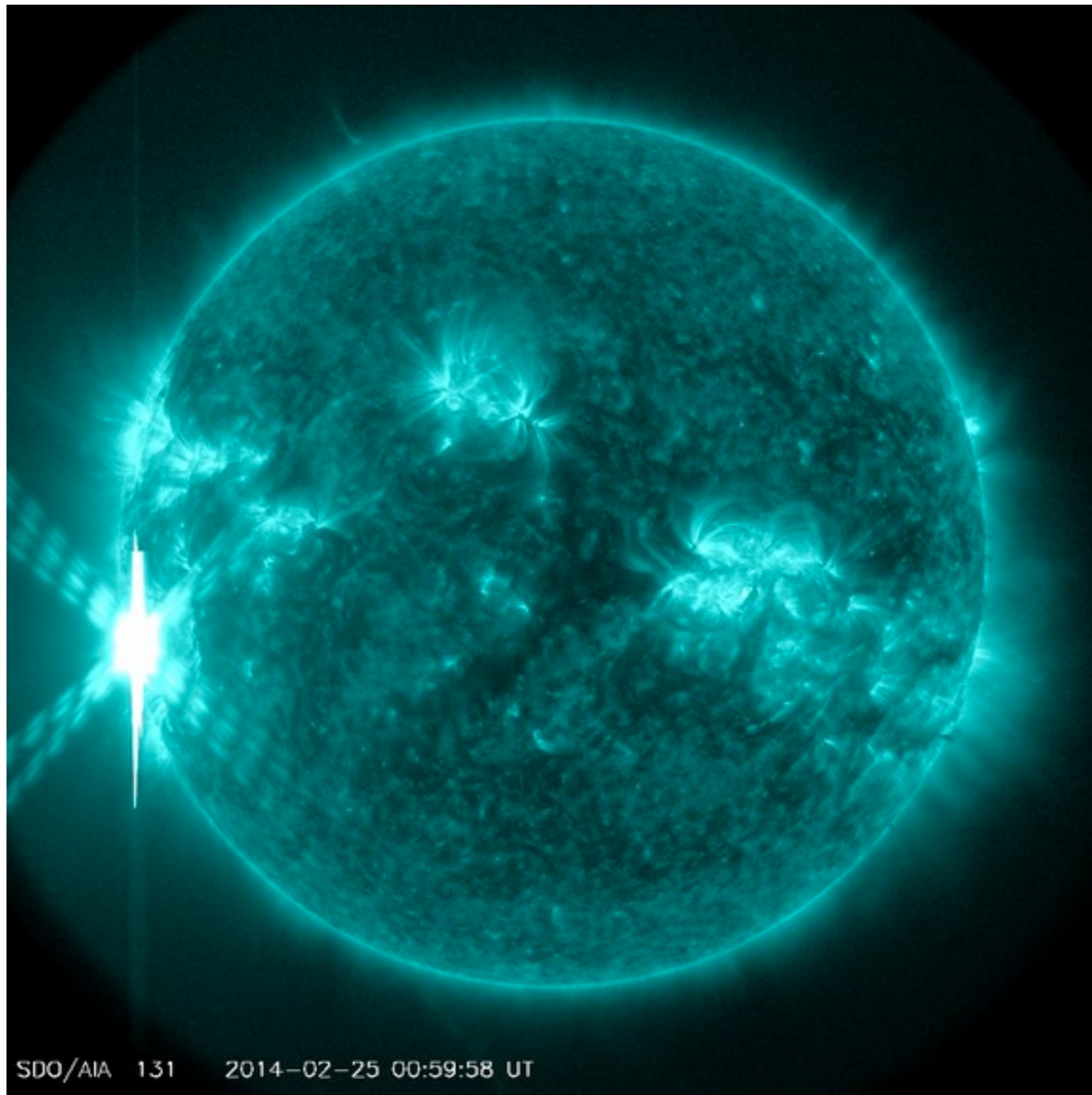
**SDO/AIA**



# FLARES

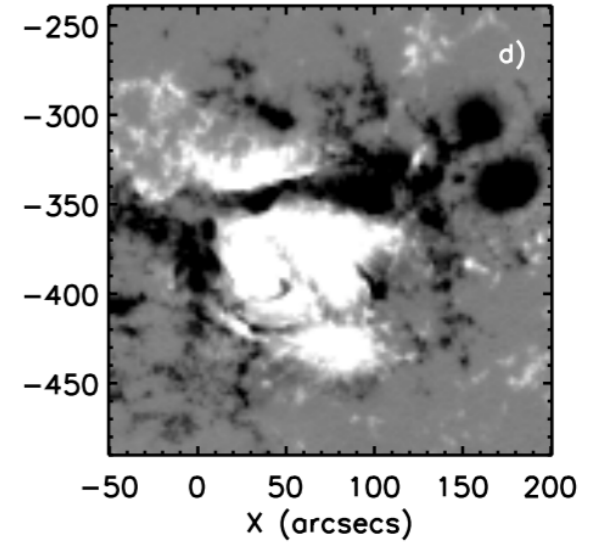
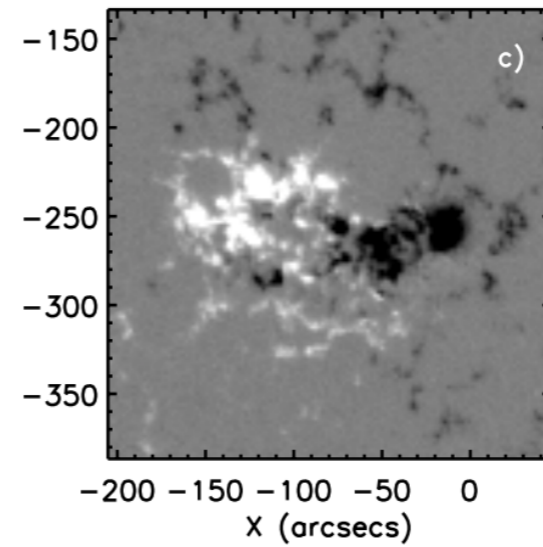
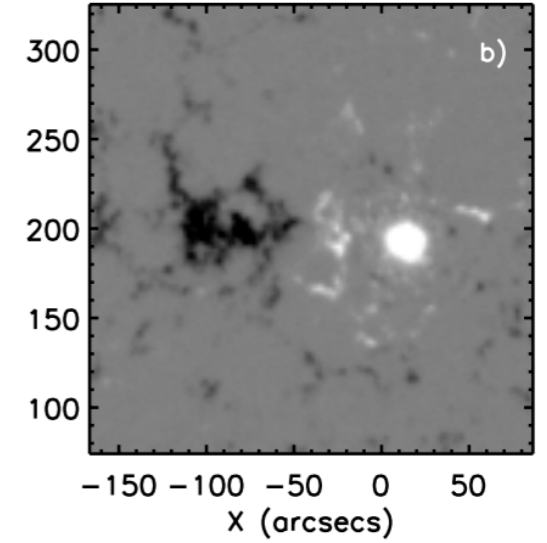
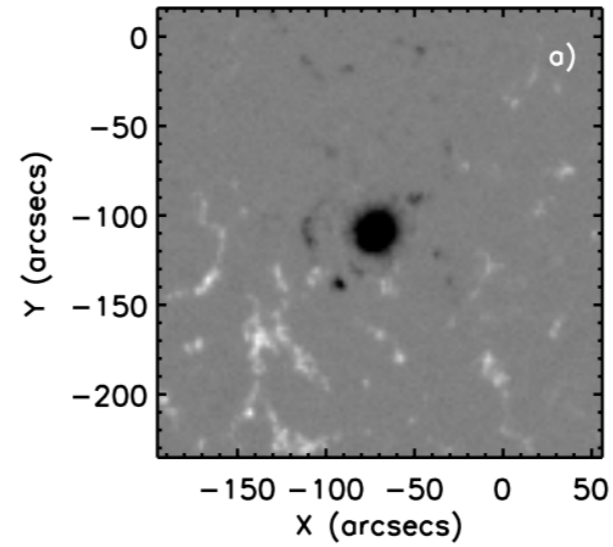


SDO/AIA



$\alpha$

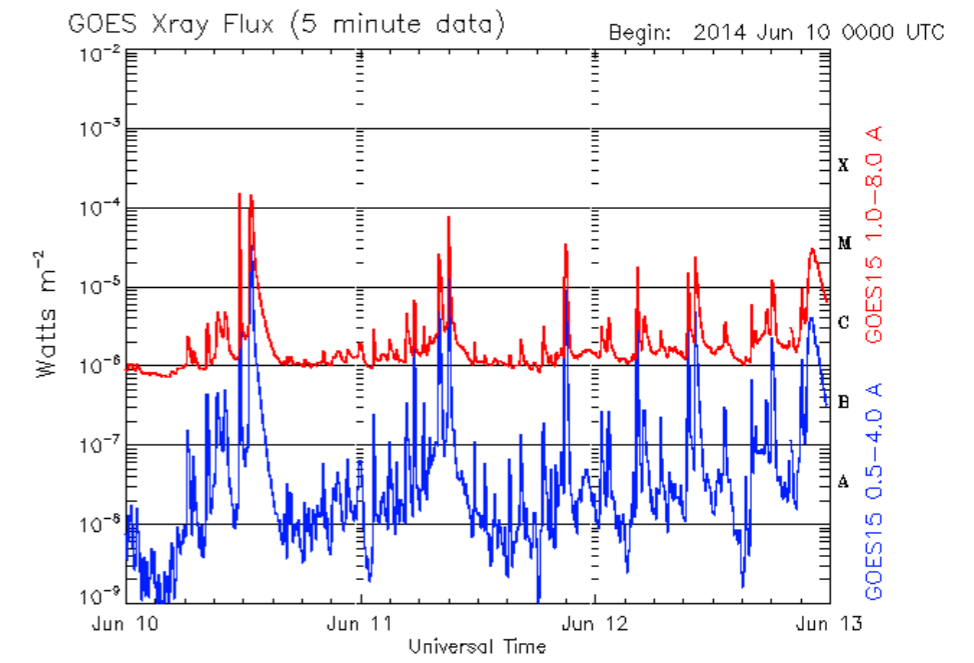
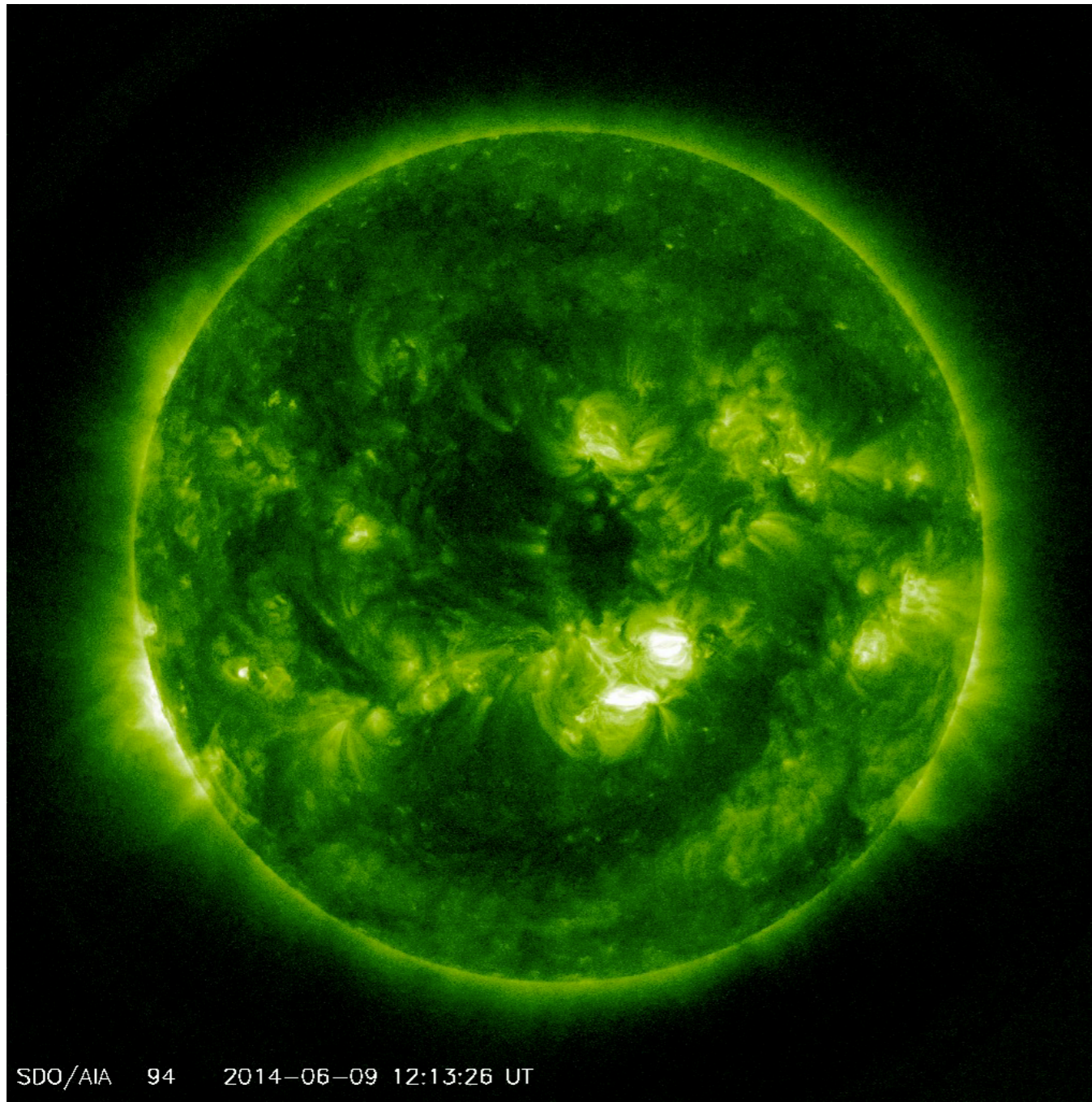
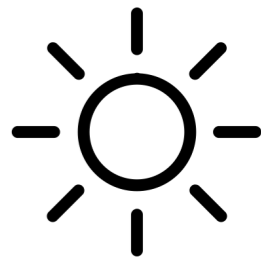
$\beta$



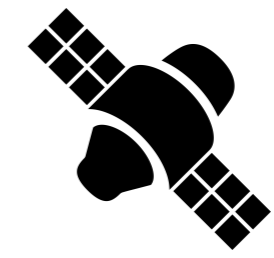
$\beta\gamma$

$\beta\gamma\delta$

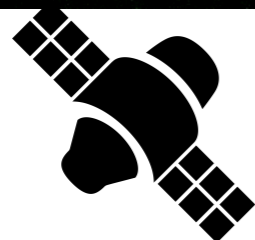
# FLARE OBSERVATION



Updated 2014 Jun 12 23:55:11 UTC NOAA/SWPC Boulder, CO USA



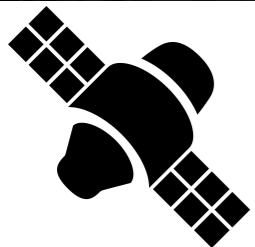
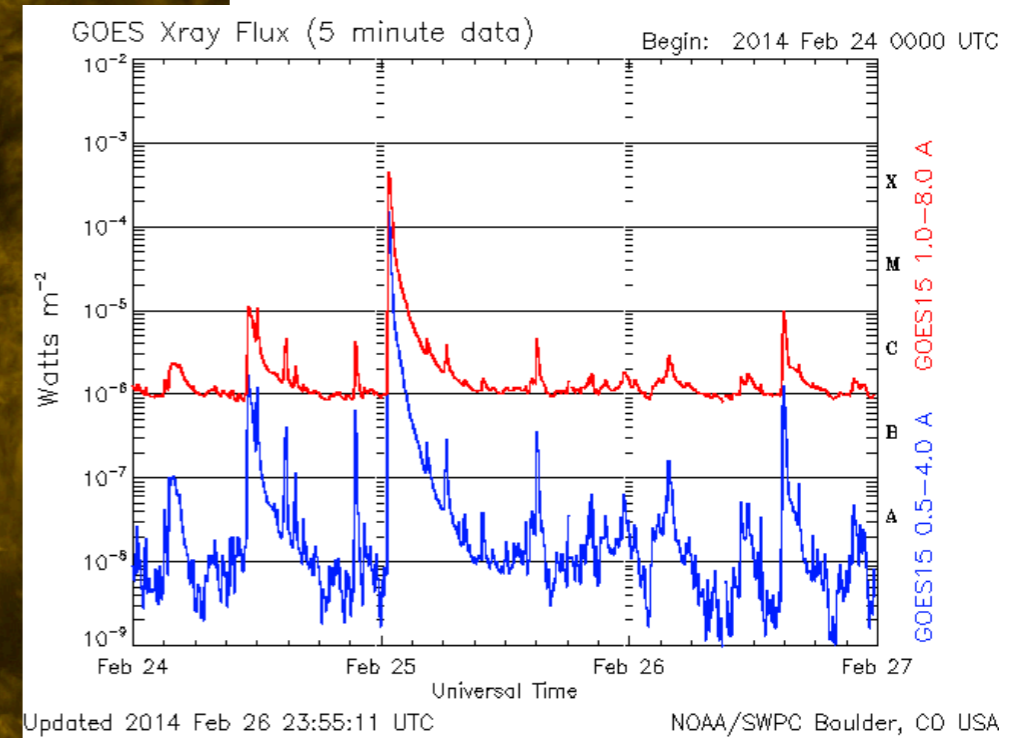
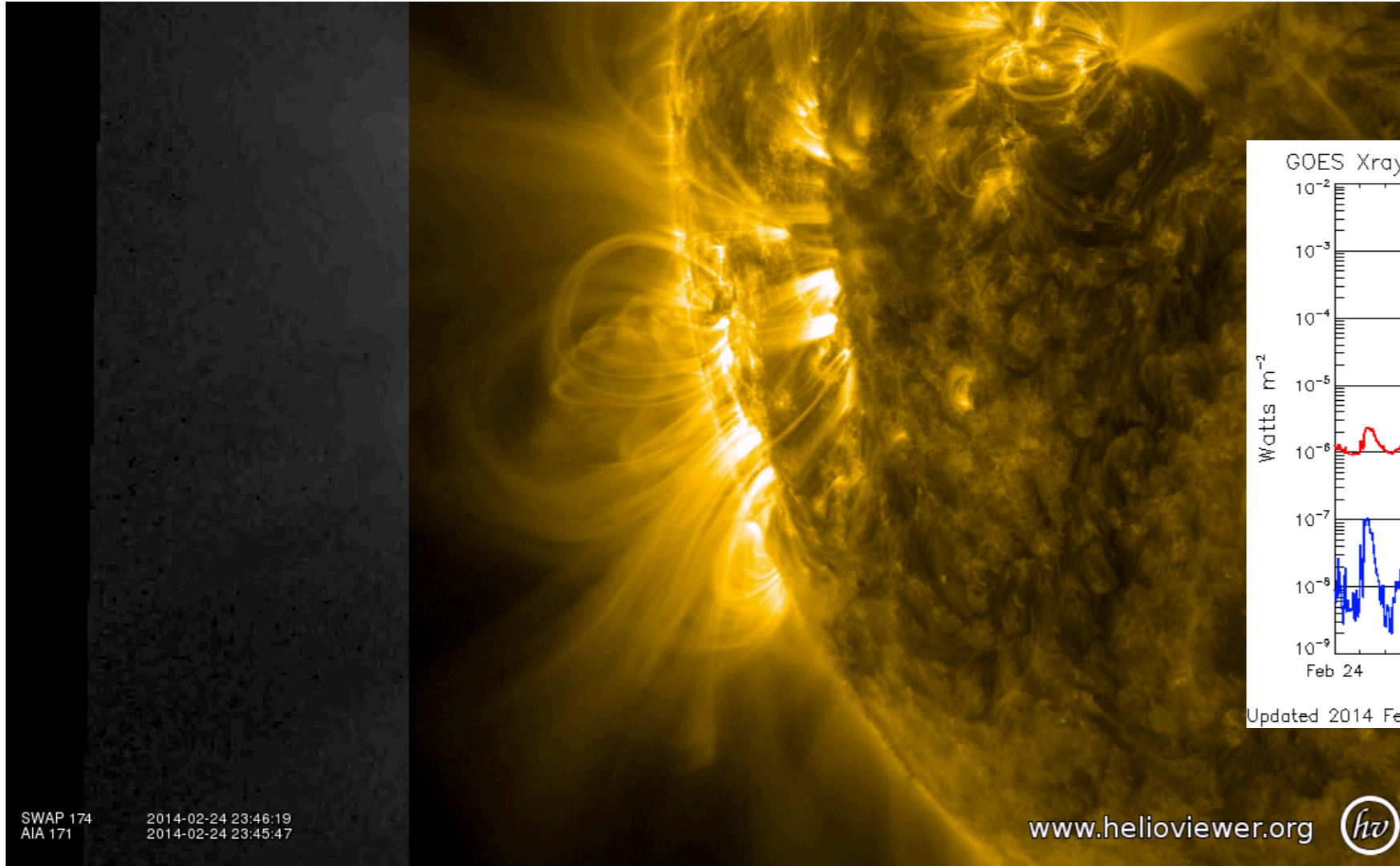
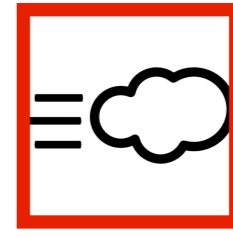
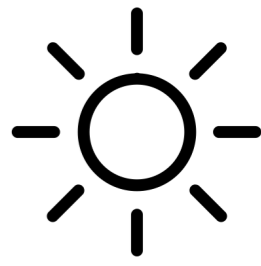
**GOES**



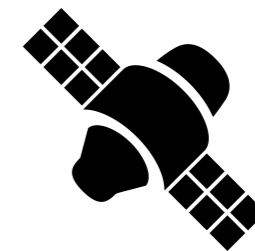
**SDO/AIA**



# FLARE AND PLASMA CLOUD



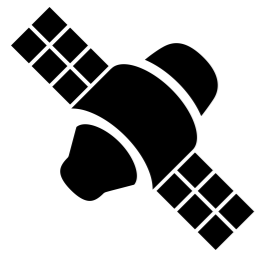
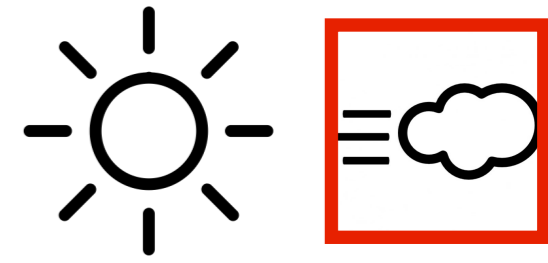
**SDO/AIA**  
**PROBA2/SWAP**



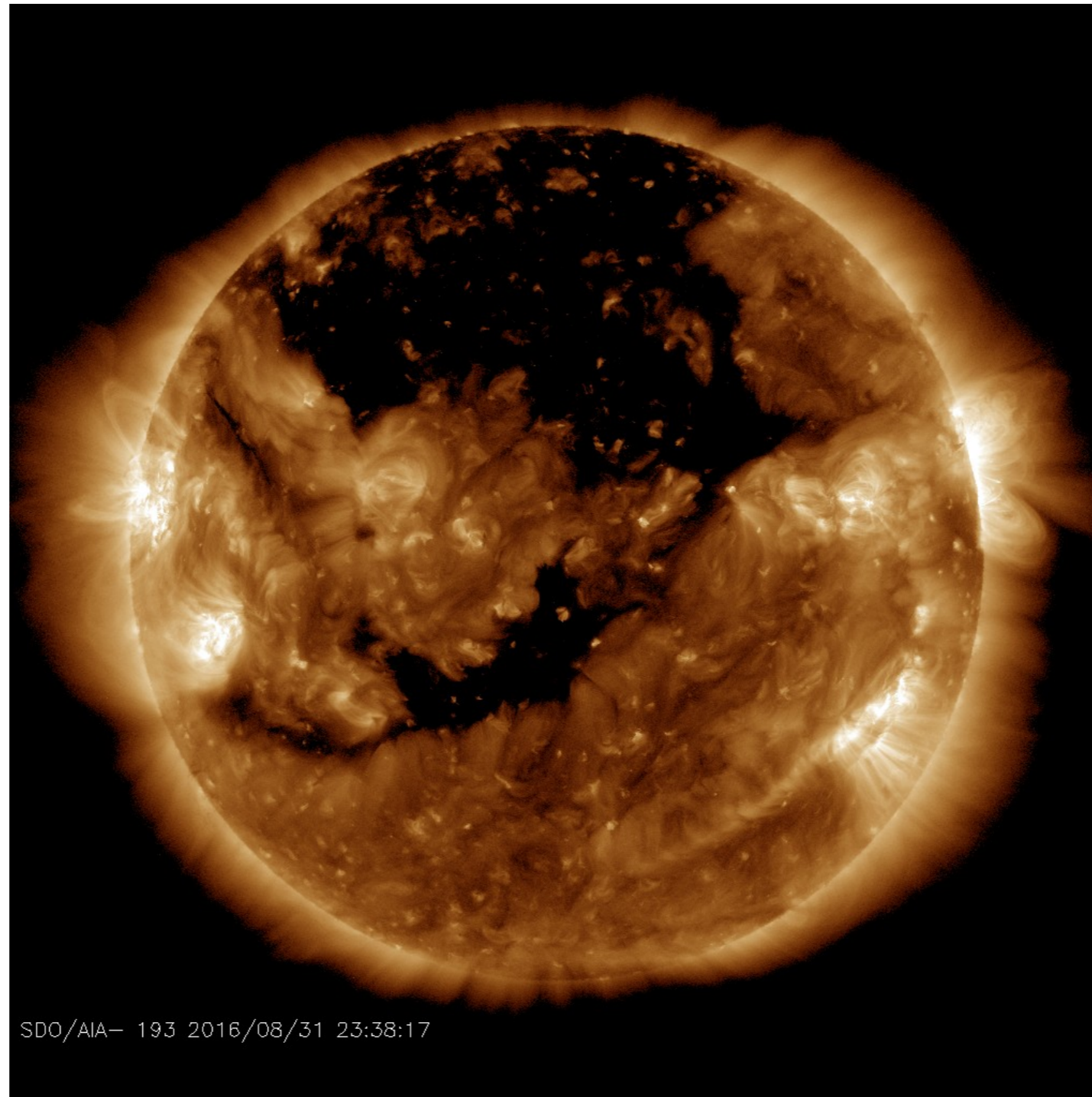
**GOES**



# CORONAL HOLE



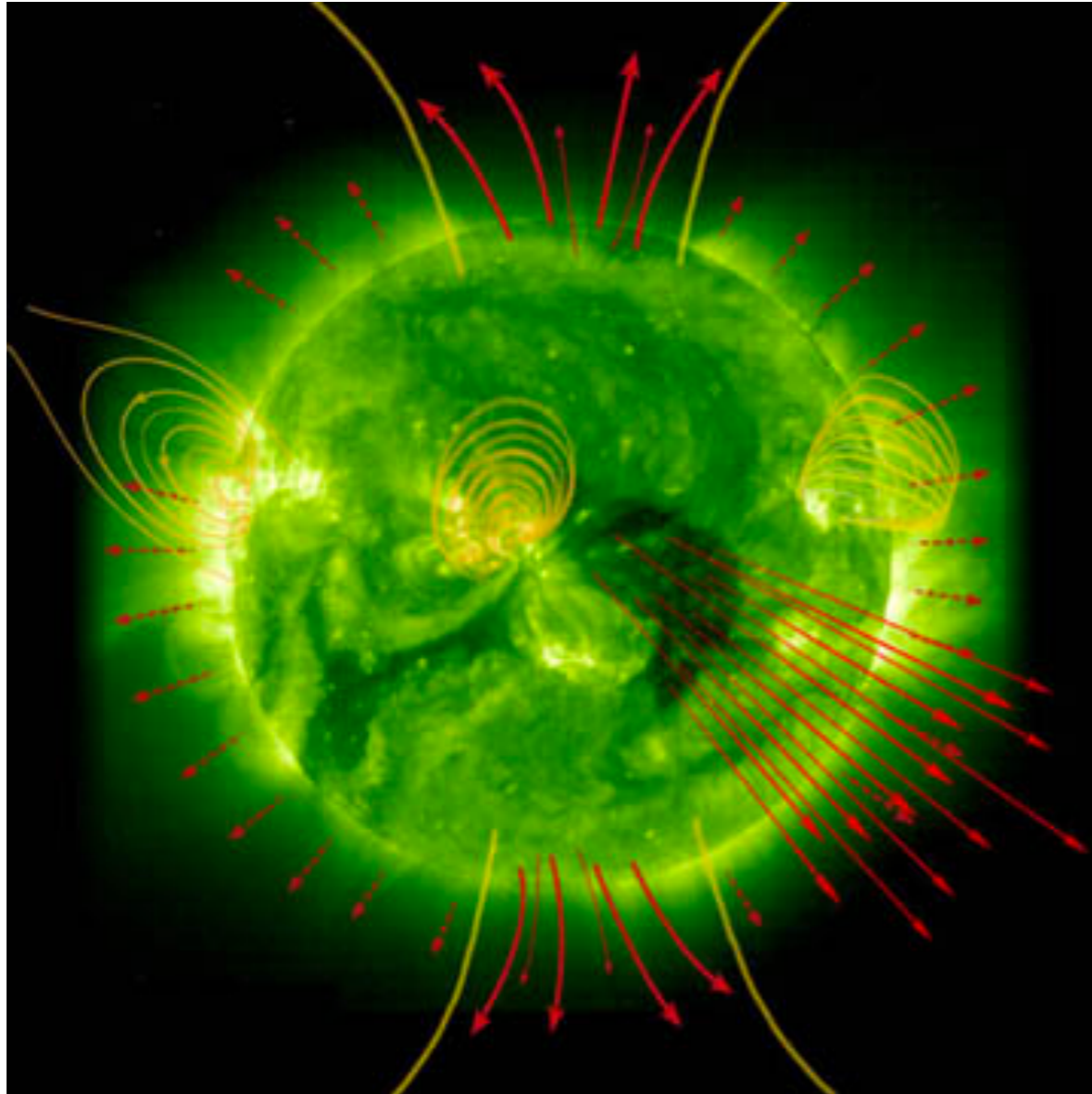
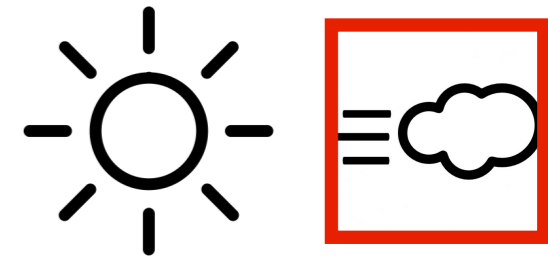
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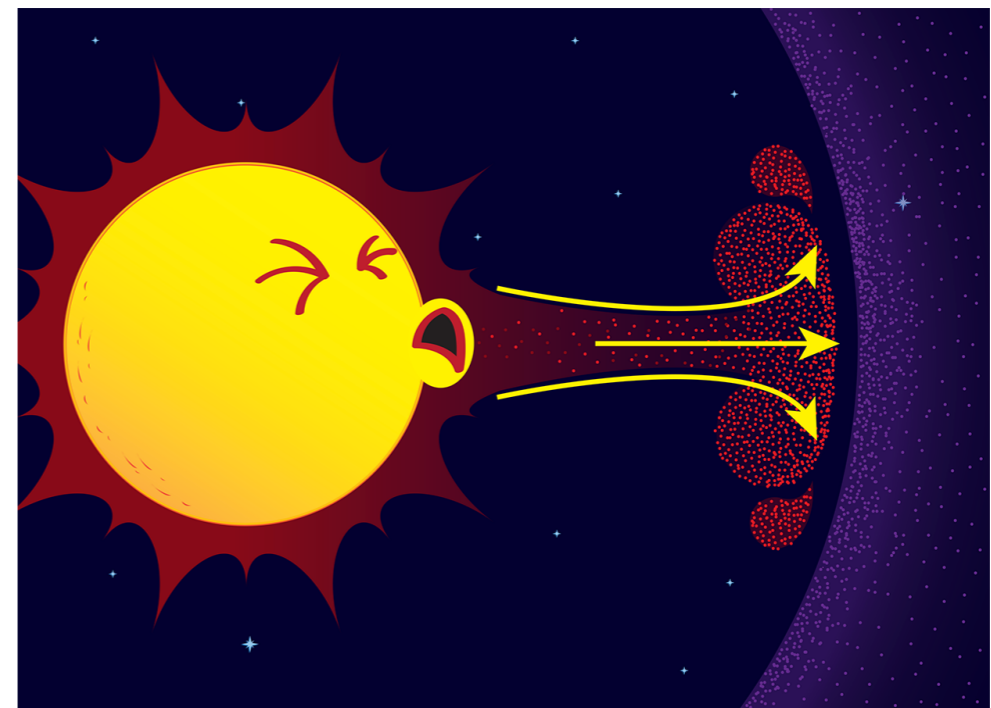
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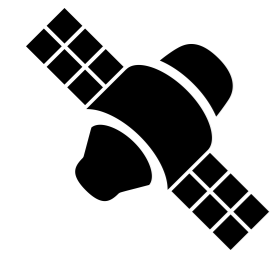


# SOLAR WIND



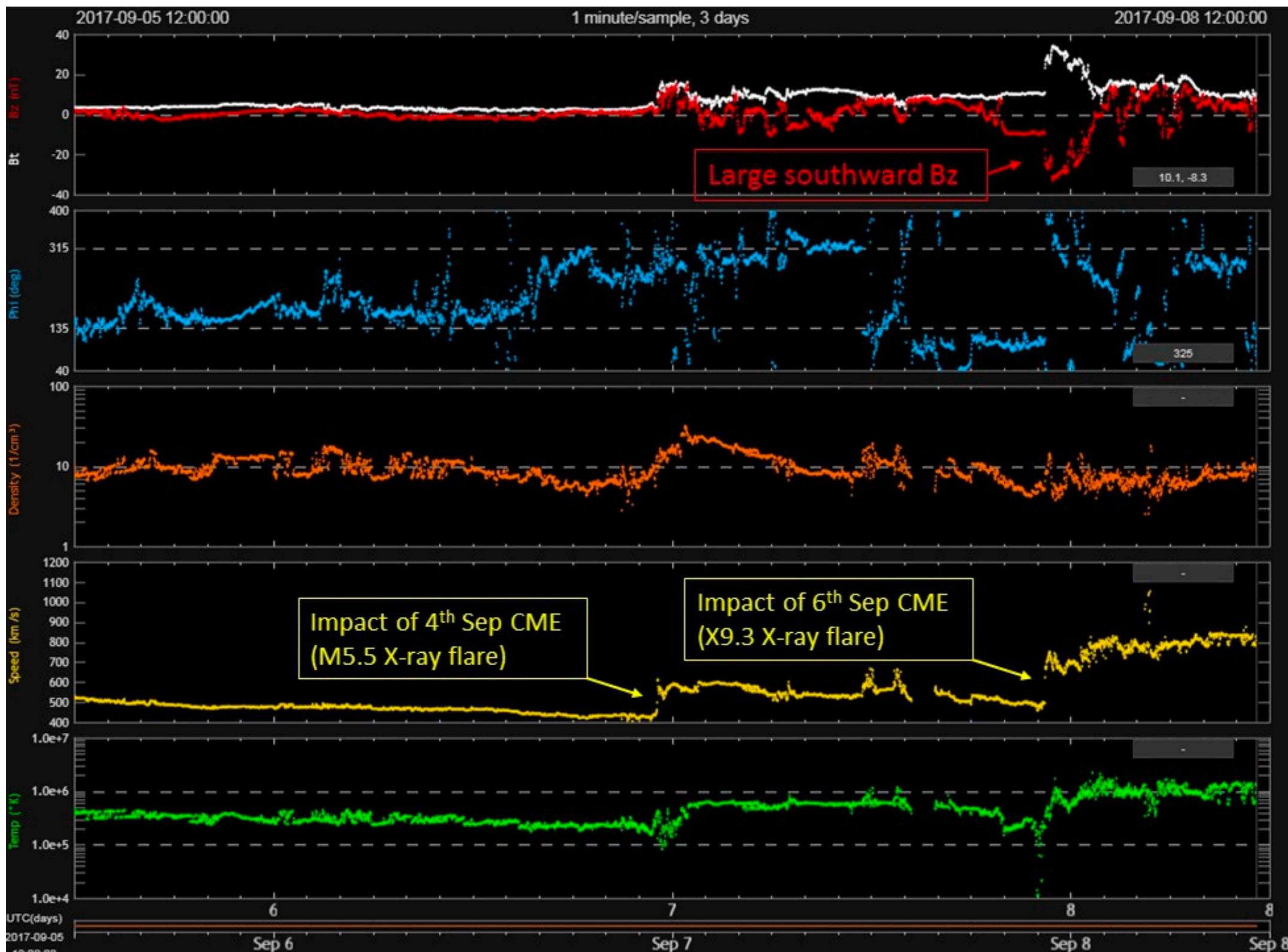
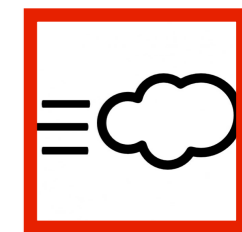
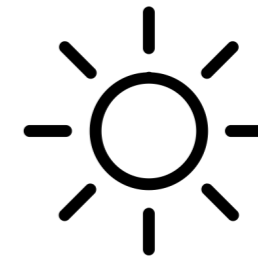
SOHO/EIT

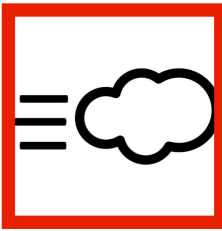




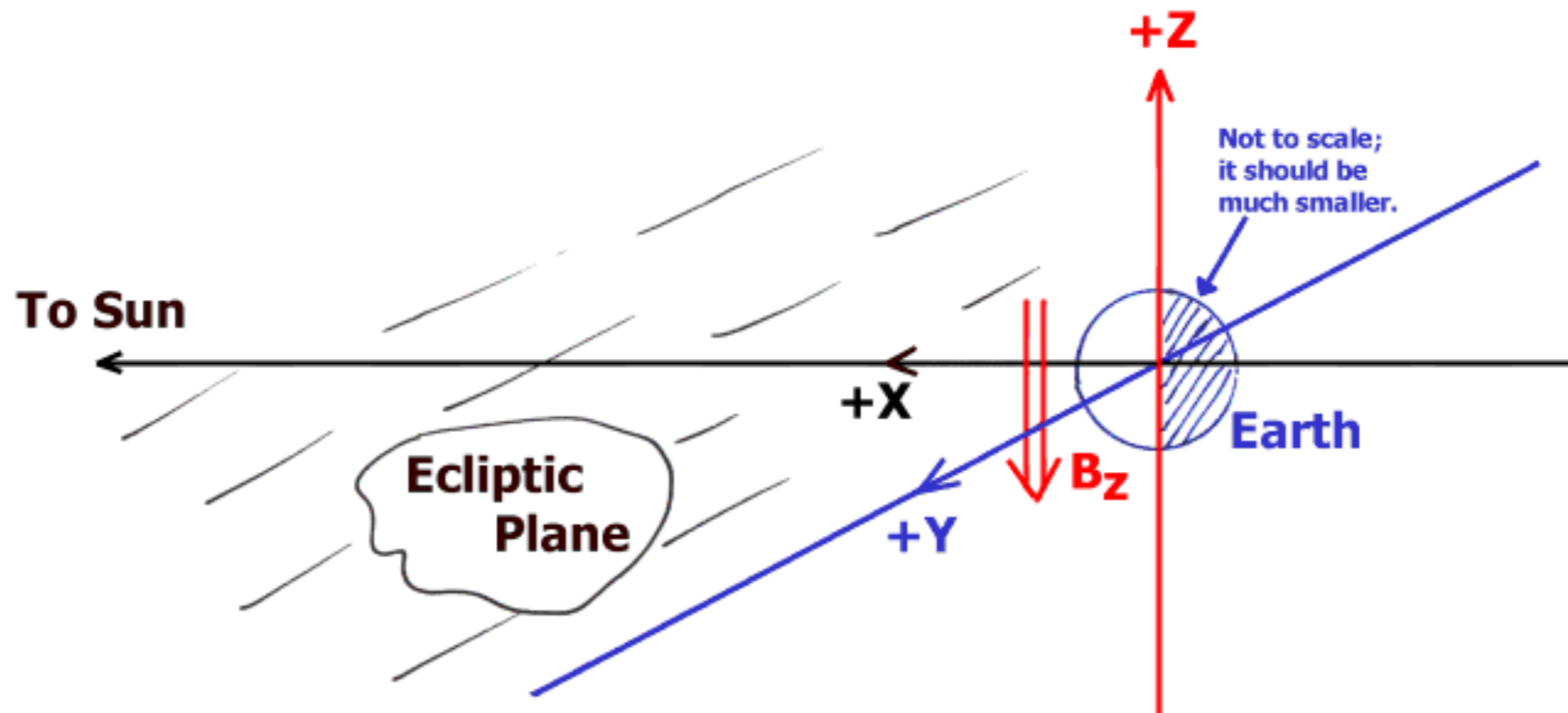
DSCOVR

# SOLAR WIND



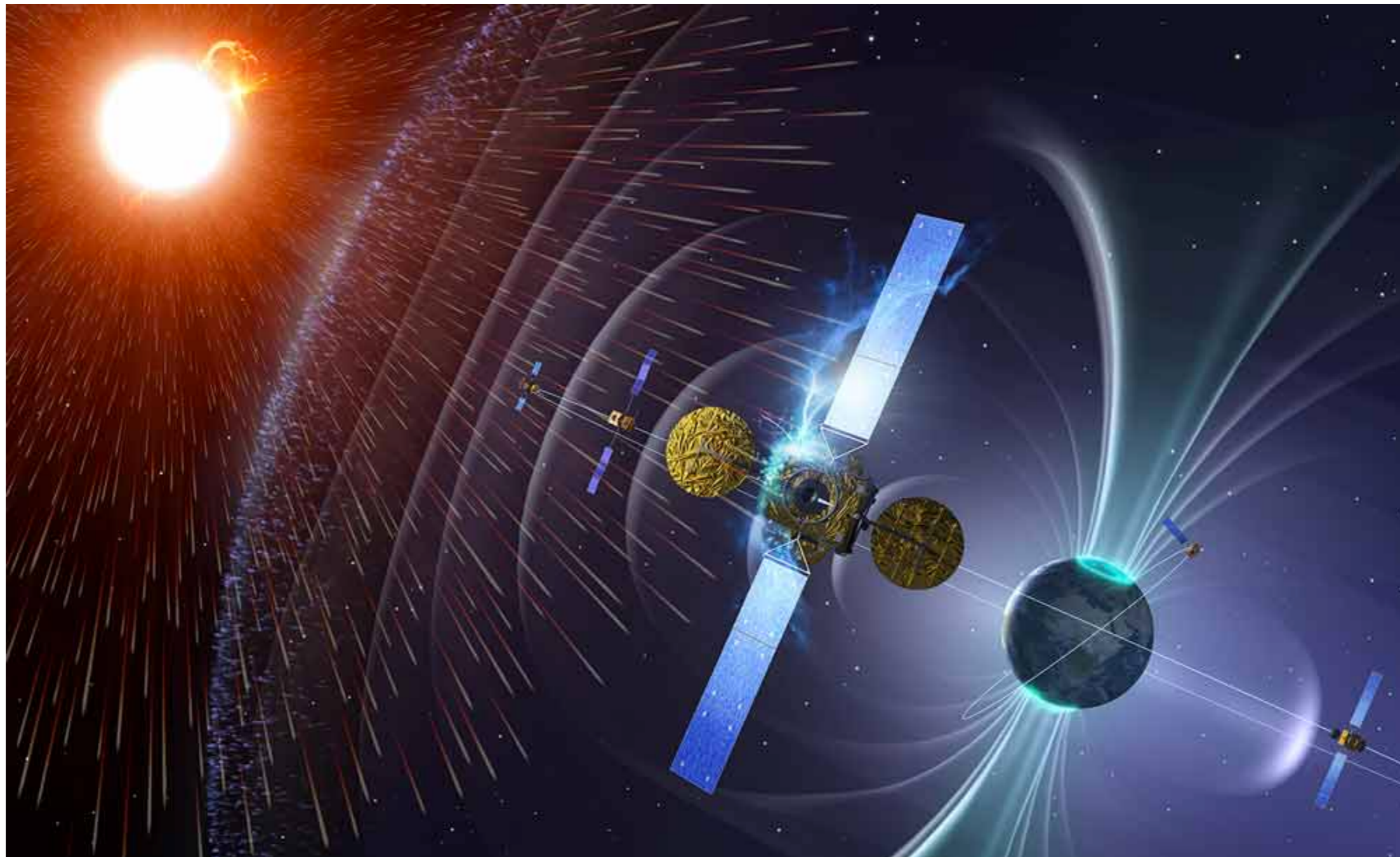
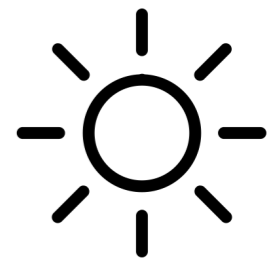
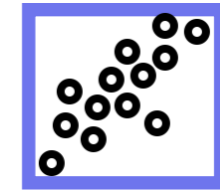


# COORDINATE SYSTEM

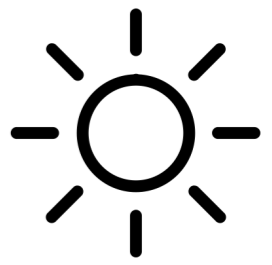
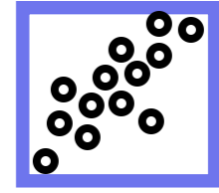
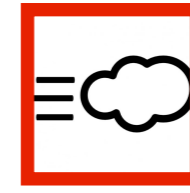


**+Z is perpendicular to the Ecliptic Plane.**

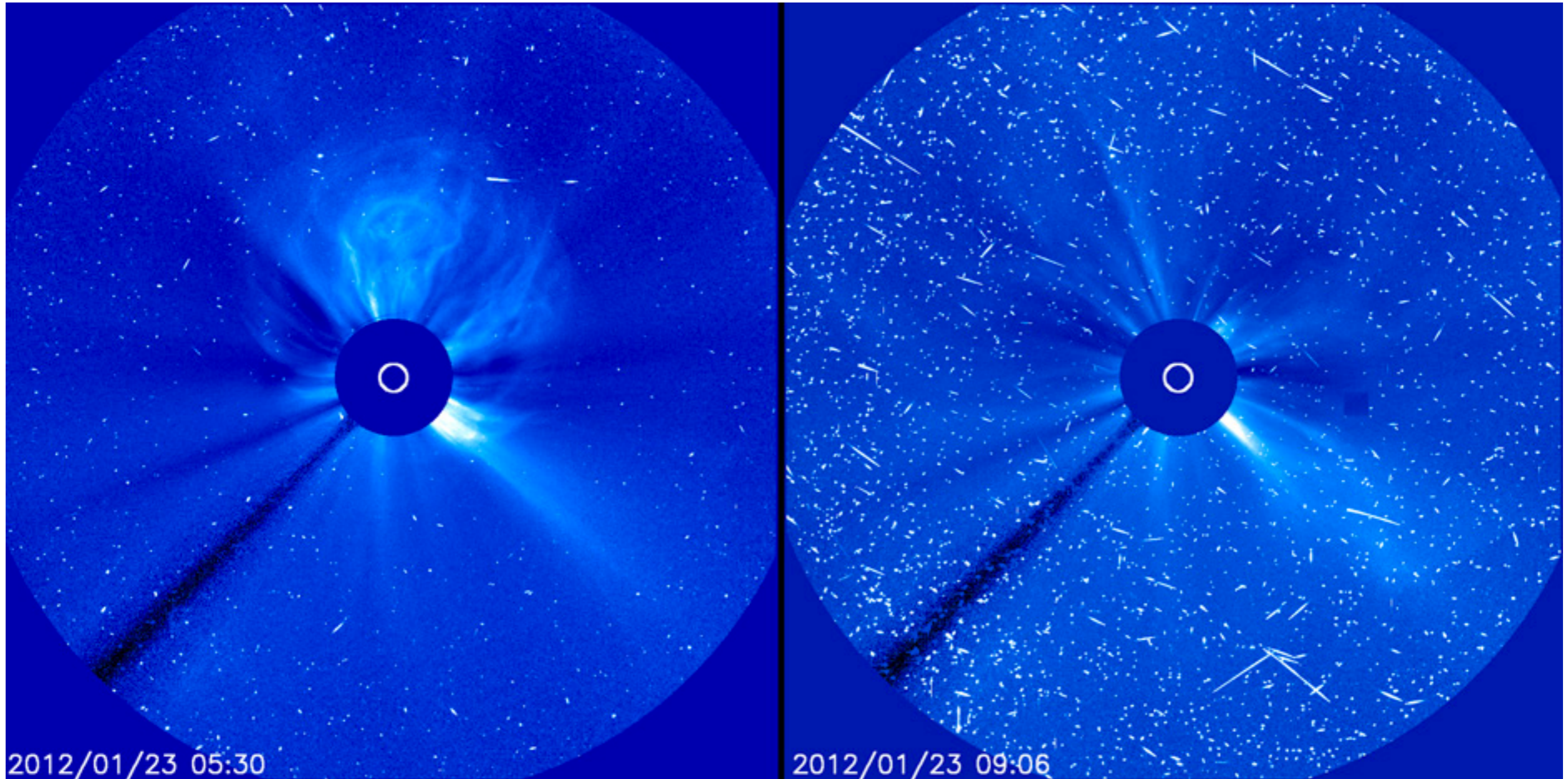
# ENERGETIC PARTICLES

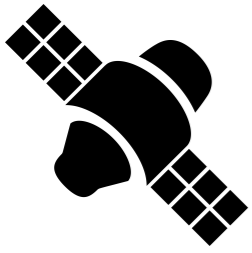


# PARTICLE IMPACT



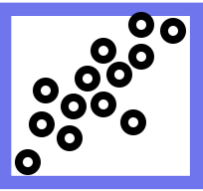
SOHO/LASCO C3



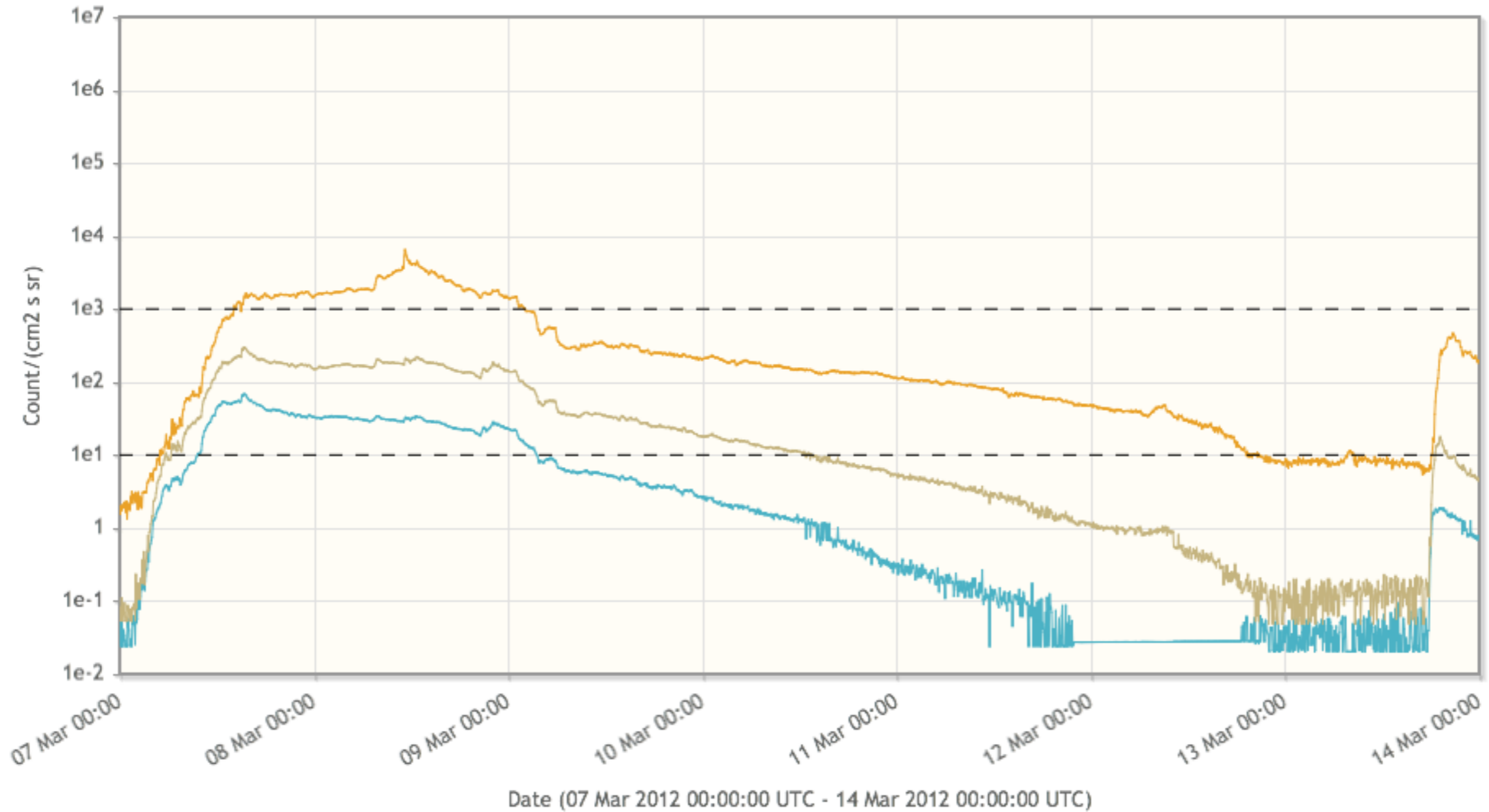


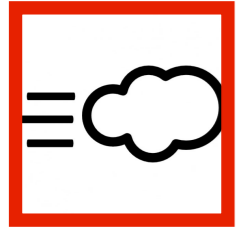
GOES

# MEASURED BY GOES

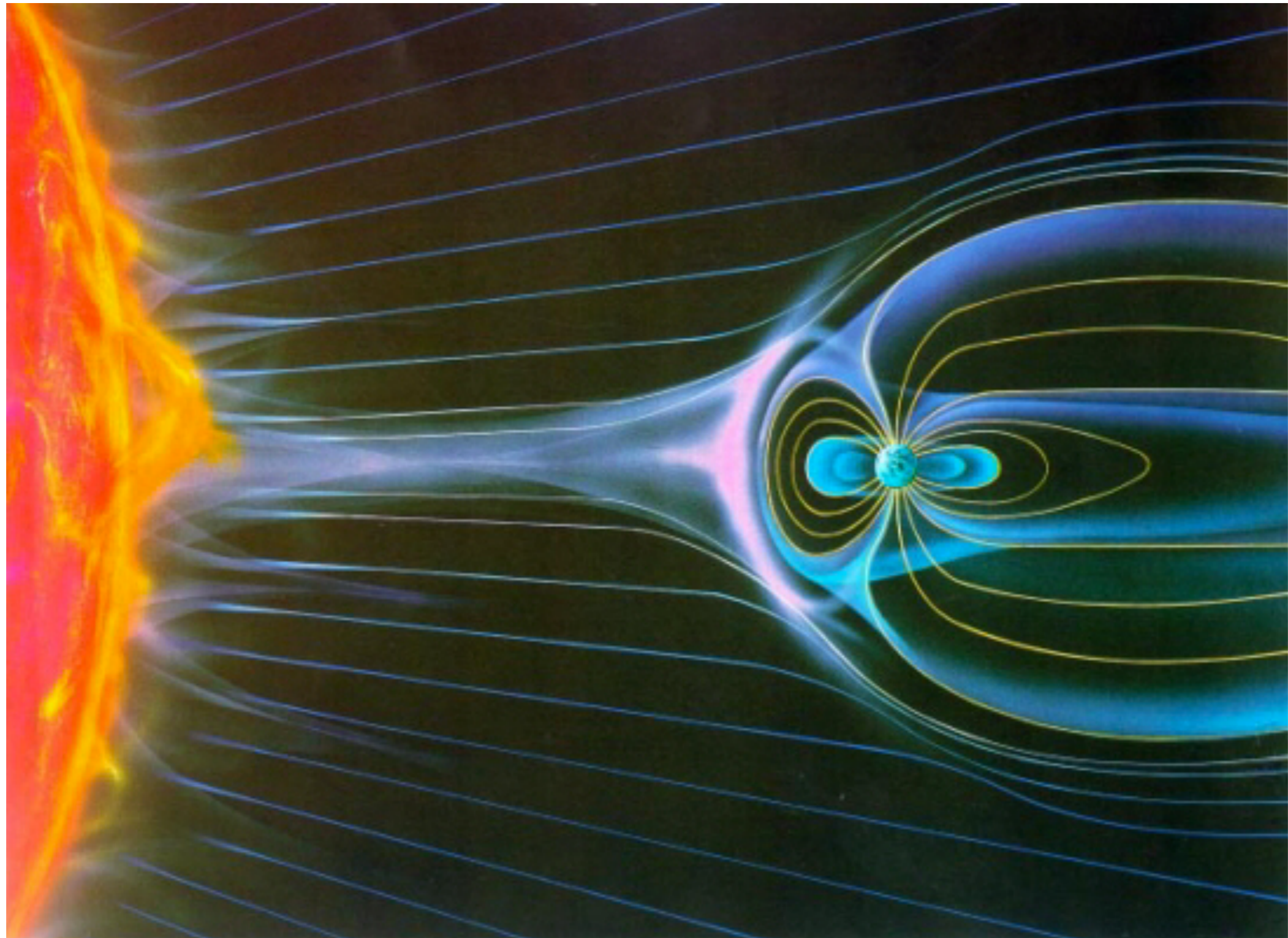
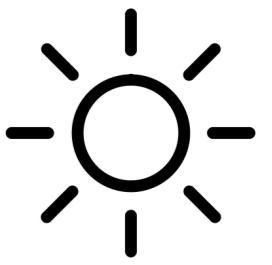


- Protons / Electrons - GOES Particles at > 100 Mev (quicklook) - 2014 data points - (raw - 5 minute data)
- Protons / Electrons - GOES Particles at > 10 Mev (quicklook) - 2014 data points - (raw - 5 minute data)
- Protons / Electrons - GOES Particles at > 50 Mev (quicklook) - 2014 data points - (raw - 5 minute data)

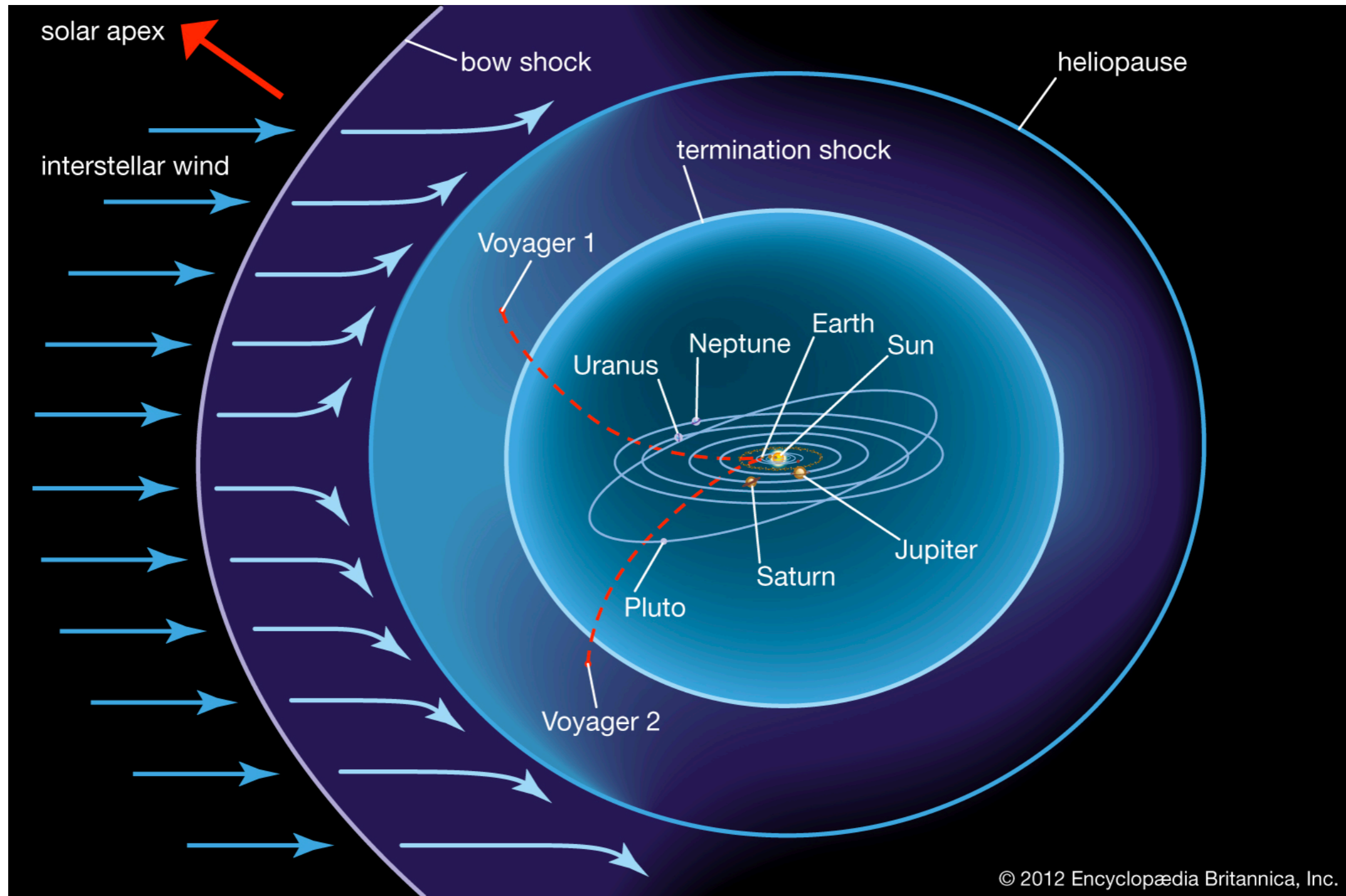
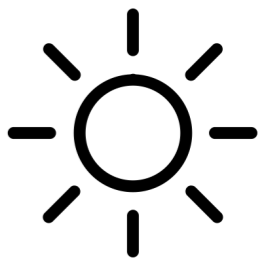
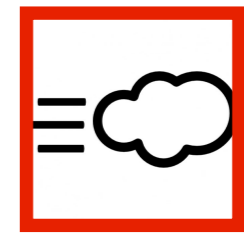


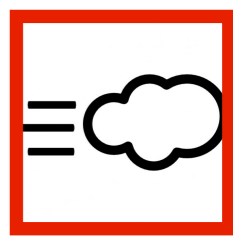
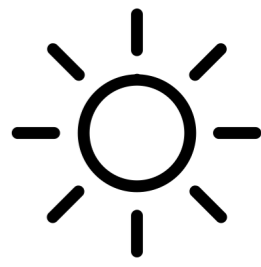


# MAGNETOSPHERE

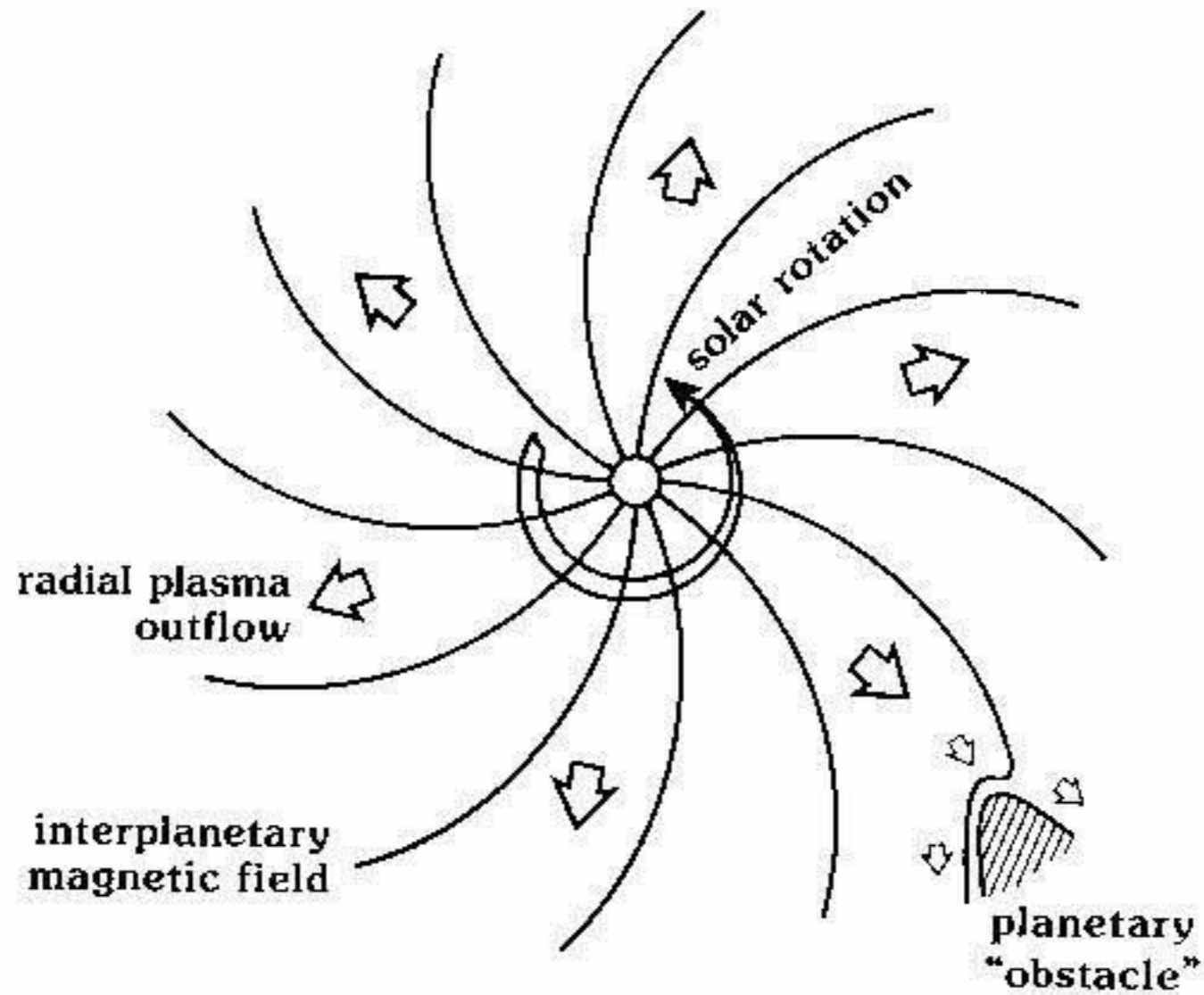


# HELIOSPHERE

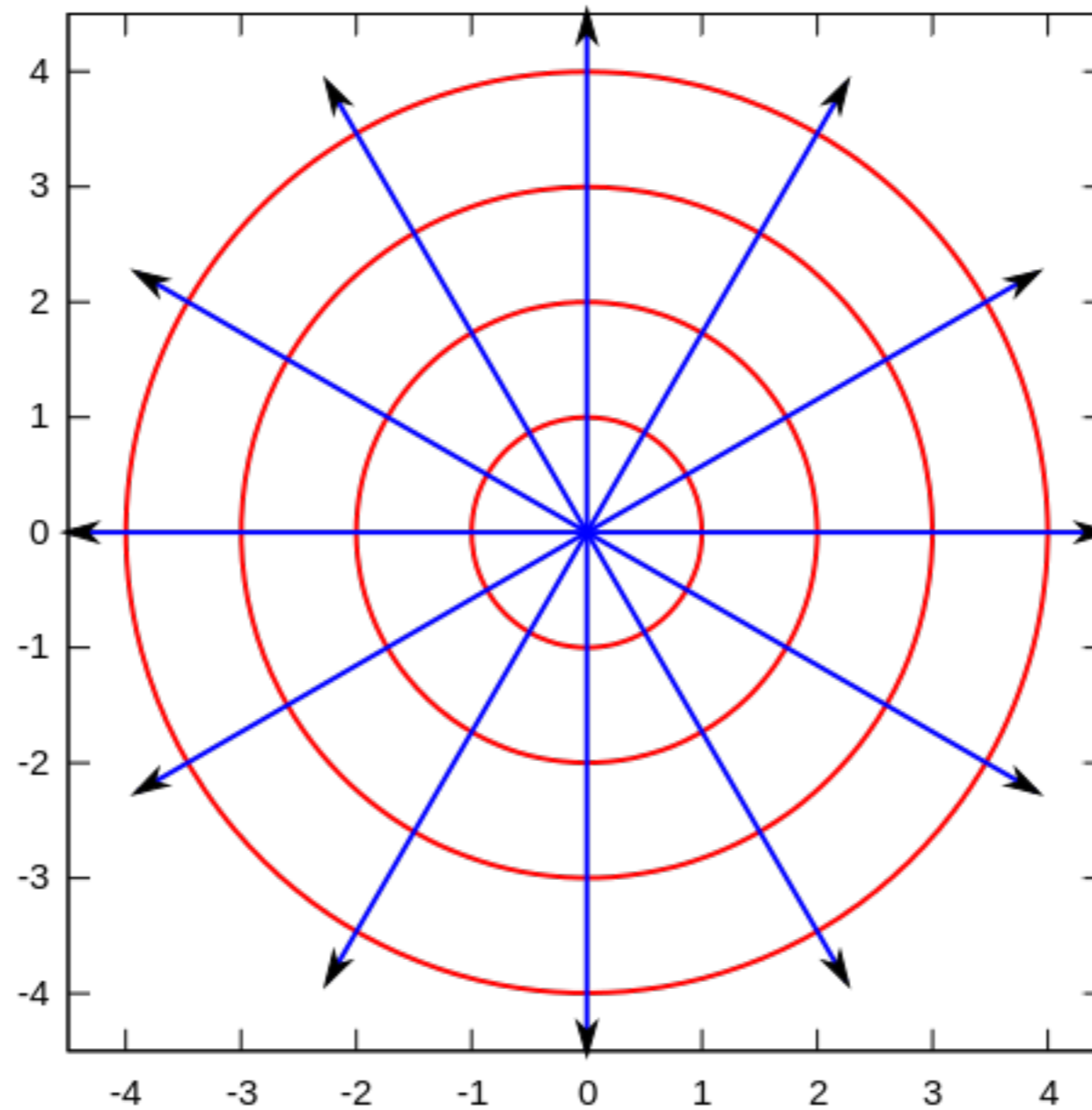
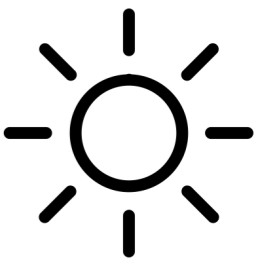
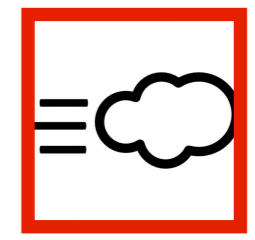


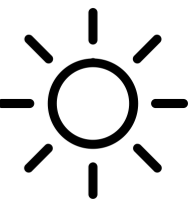
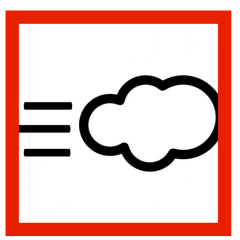


# INTERPLANETARY MAGNETIC FIELD

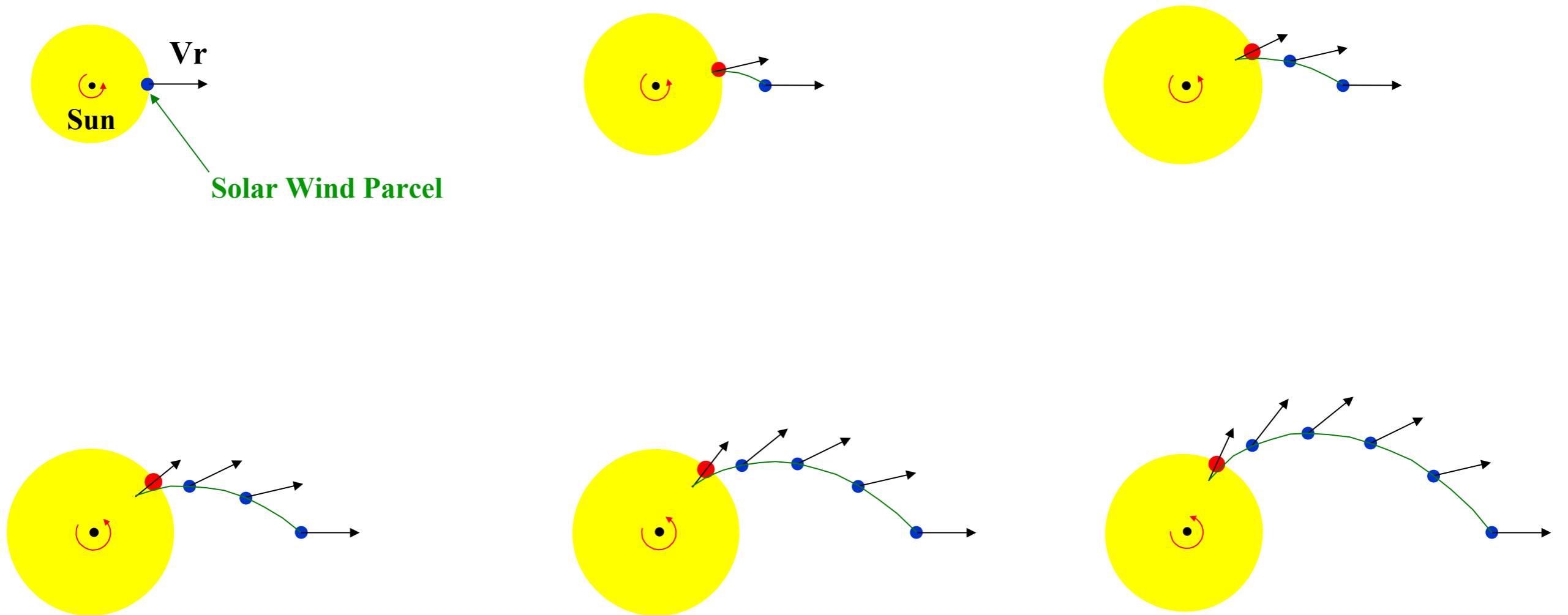


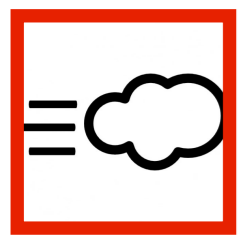
# RADIAL SOLAR WIND



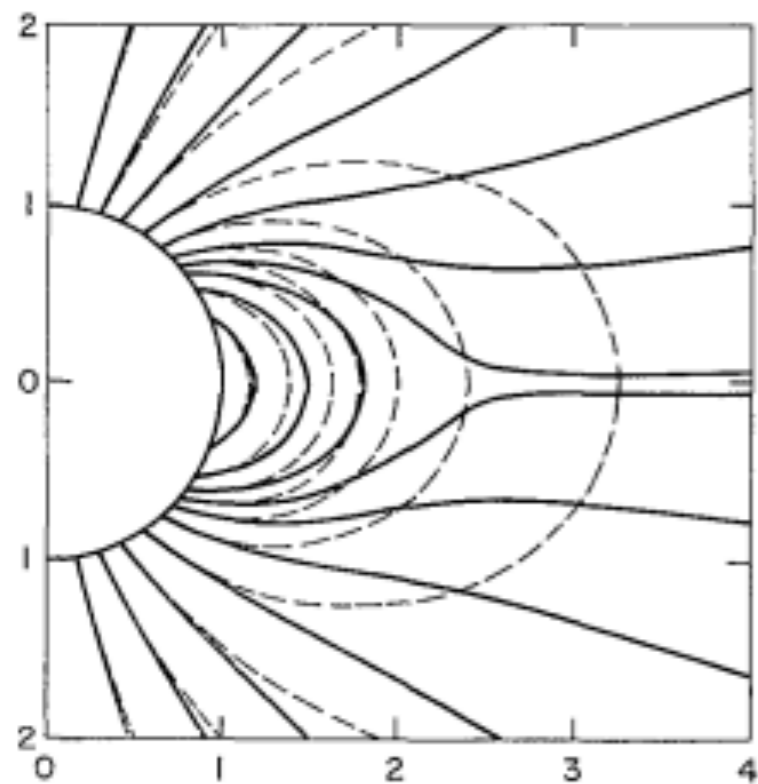
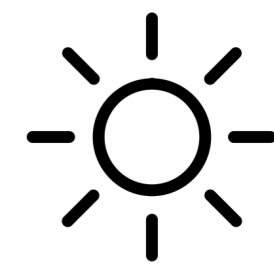


# FORMATION OF THE PARKER SPIRAL

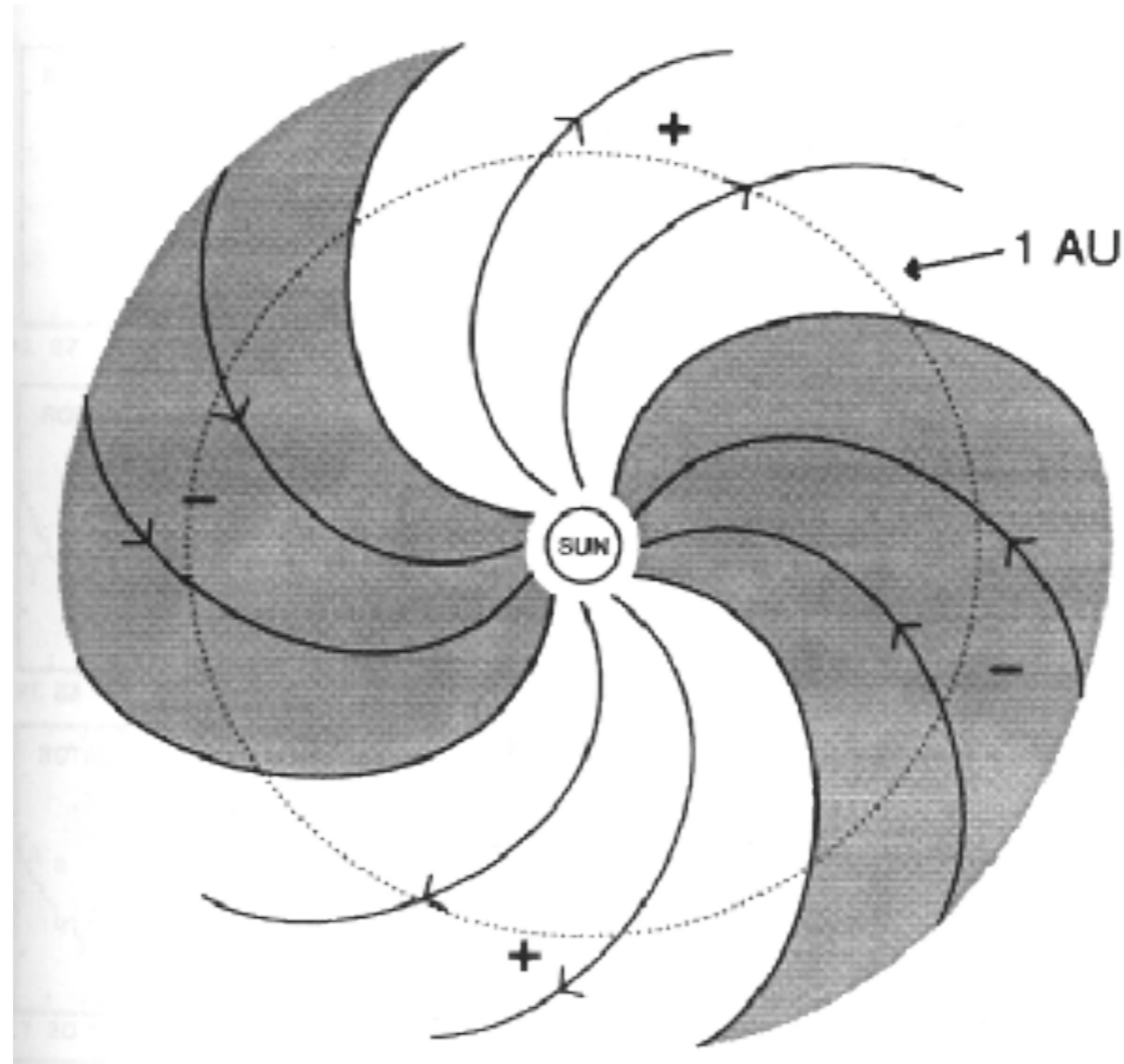


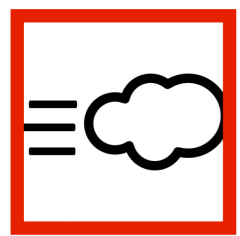


# HELIOSPHERIC CURRENT SHEET

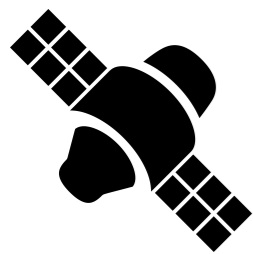
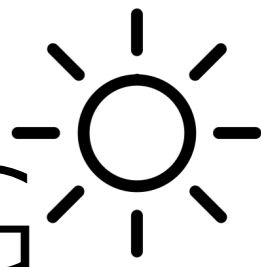


# SECTOR BOUNDARY CROSSING

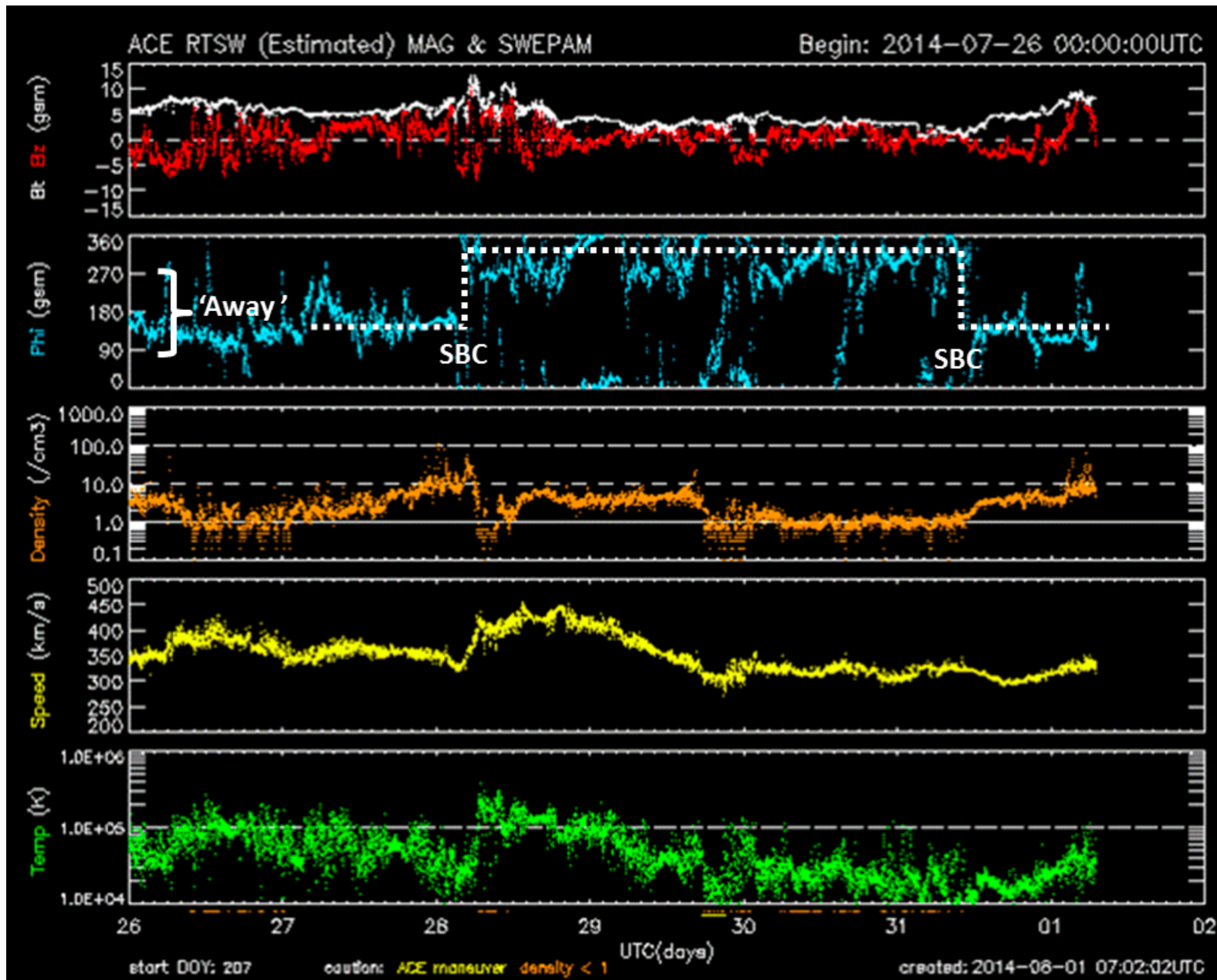


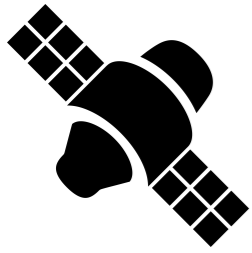


# SECTOR BOUNDARY CROSSING



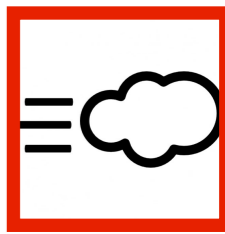
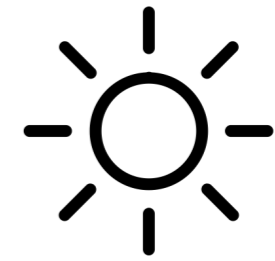
ACE





ULYSSES

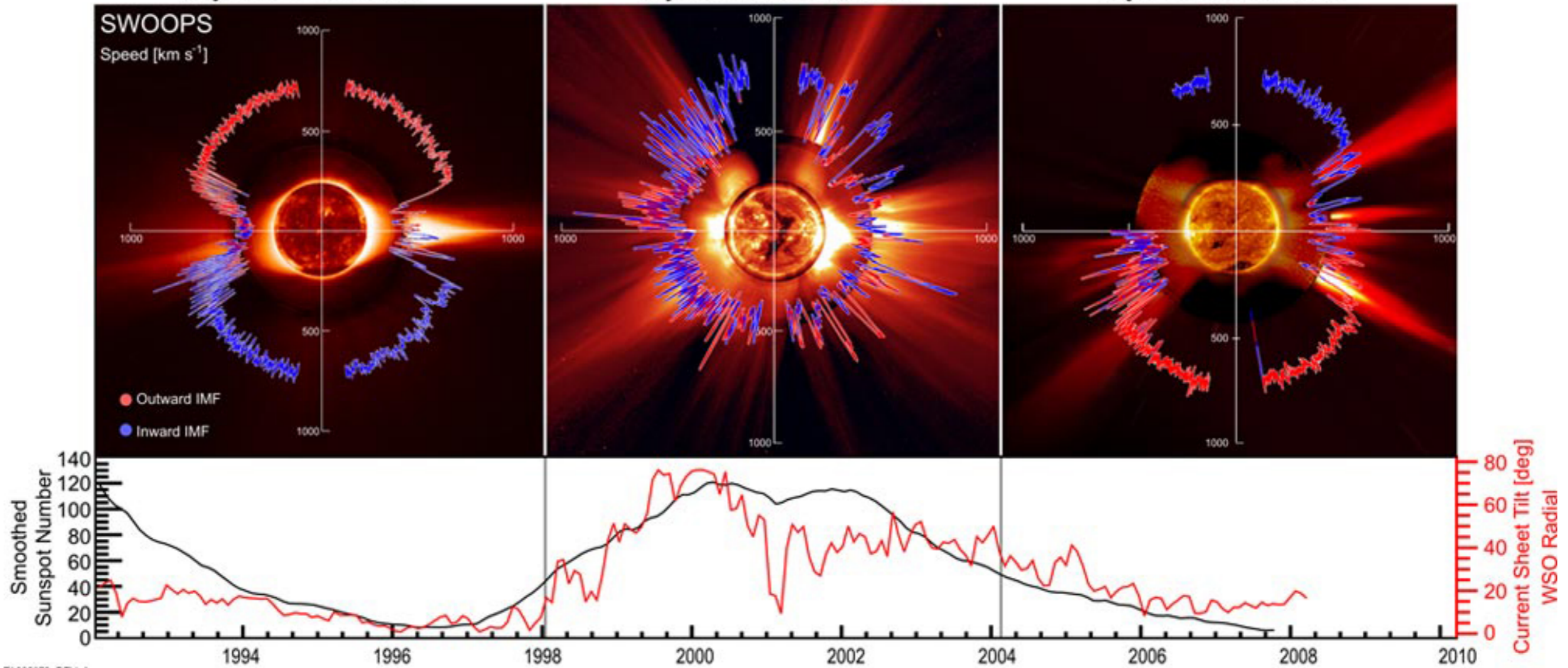
# SOLAR WIND



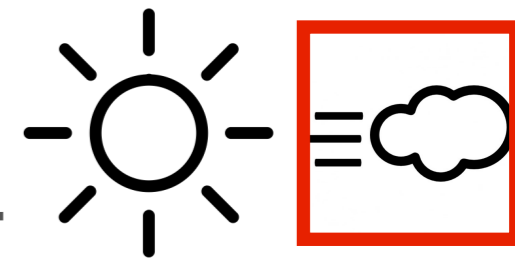
Ulysses First Orbit

Ulysses Second Orbit

Ulysses Third Orbit



# SLOW VERSUS FAST



250-400

km/**s**

400-800

High:  $\sim 10$

Density,  $\text{cm}^{-3}$

Low:  $\sim 3$

Low:  $\sim 10^4\text{K}$ ,  $\sim 1\text{eV}$

Temperature

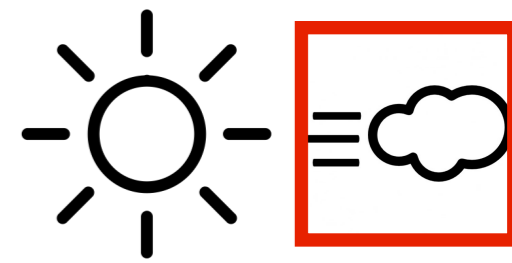
High:  $\sim 10^5\text{K}$ ,  $\sim 10\text{eV}$

Variable

Behaviour

Stationary

# SOLAR WIND VARIATIONS

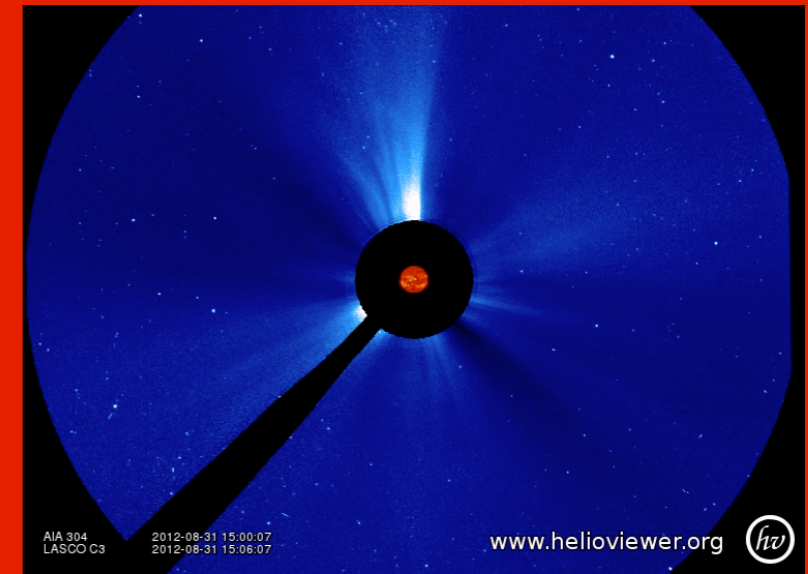
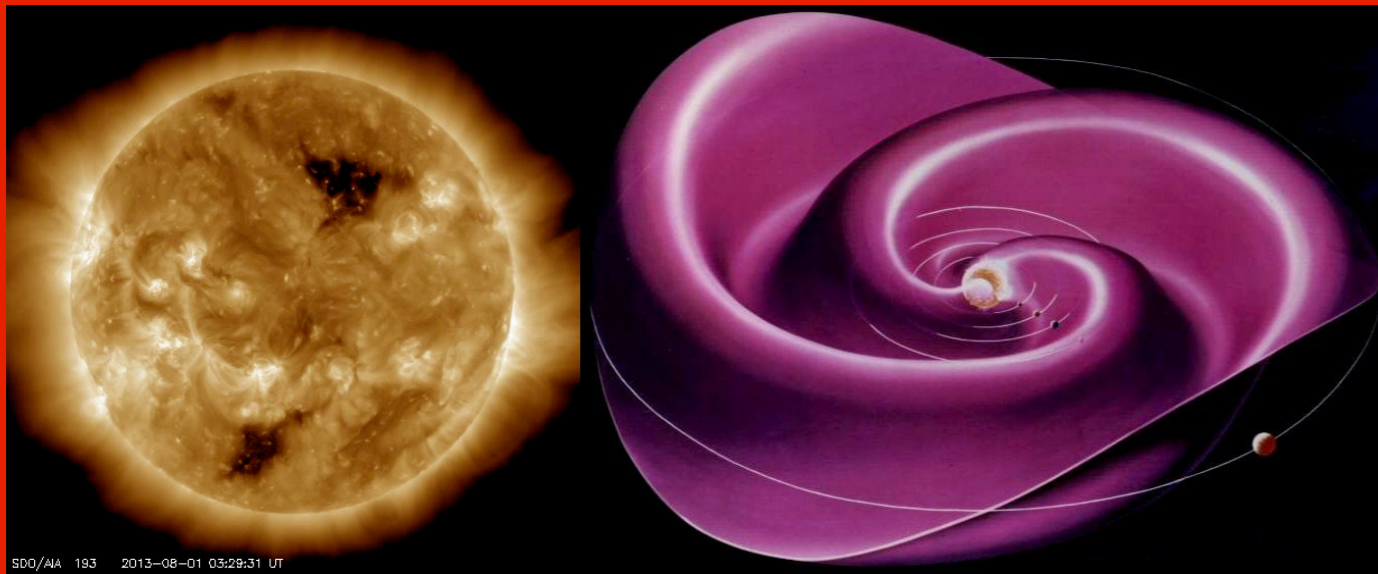


Non-eruptive

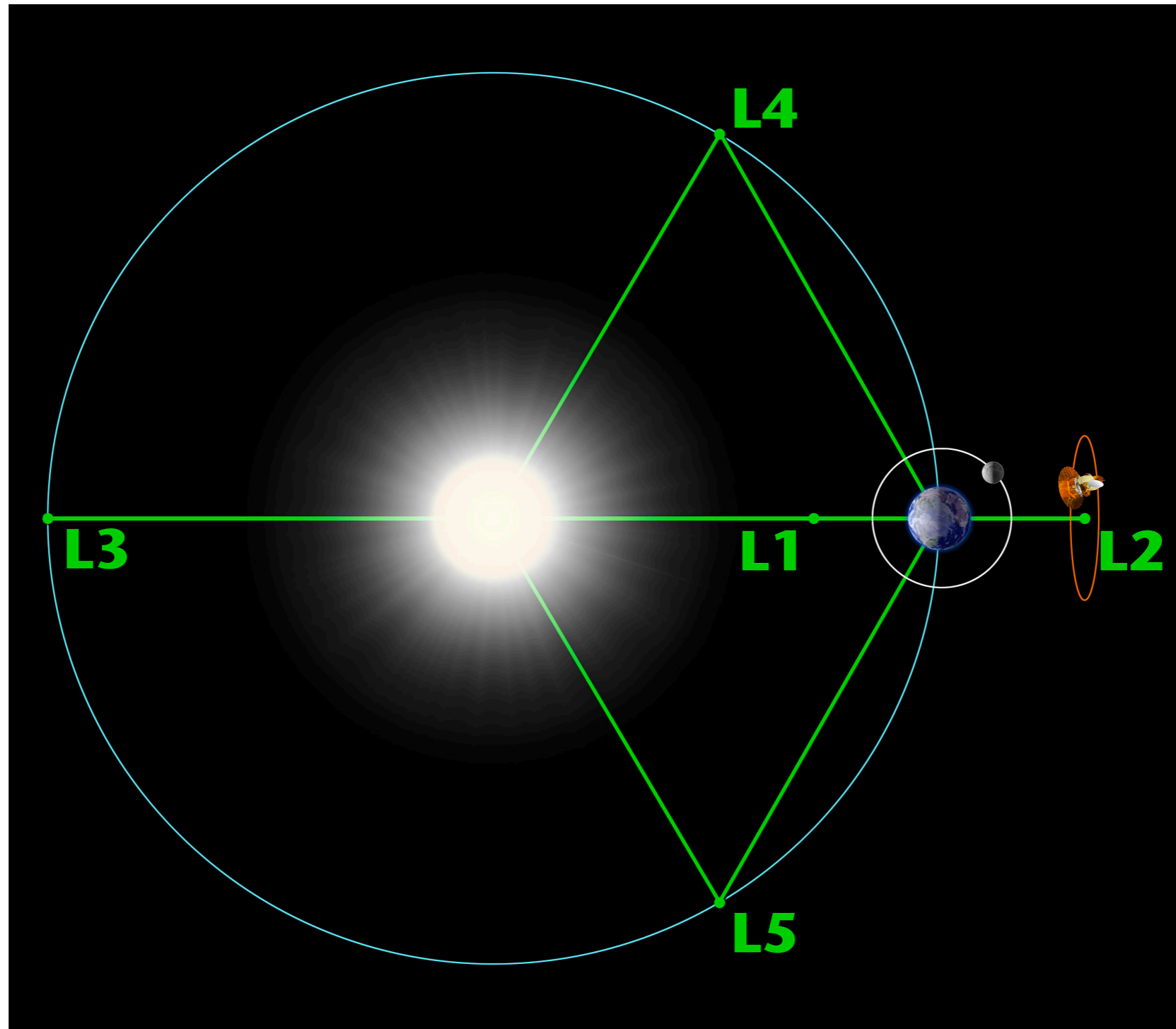
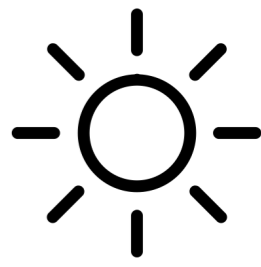
Eruptive

Coronal Hole  
Sector Boundary Crossing

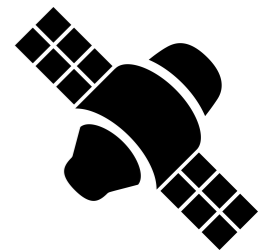
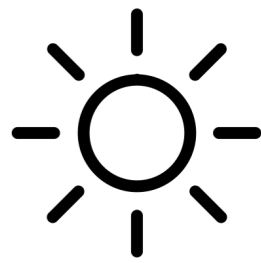
Coronal Mass Ejection



# LAGRANGE POINTS



# SPACECRAFT ORBITING EARTH



PROBA2

→ SWAP - LYRA

SDO

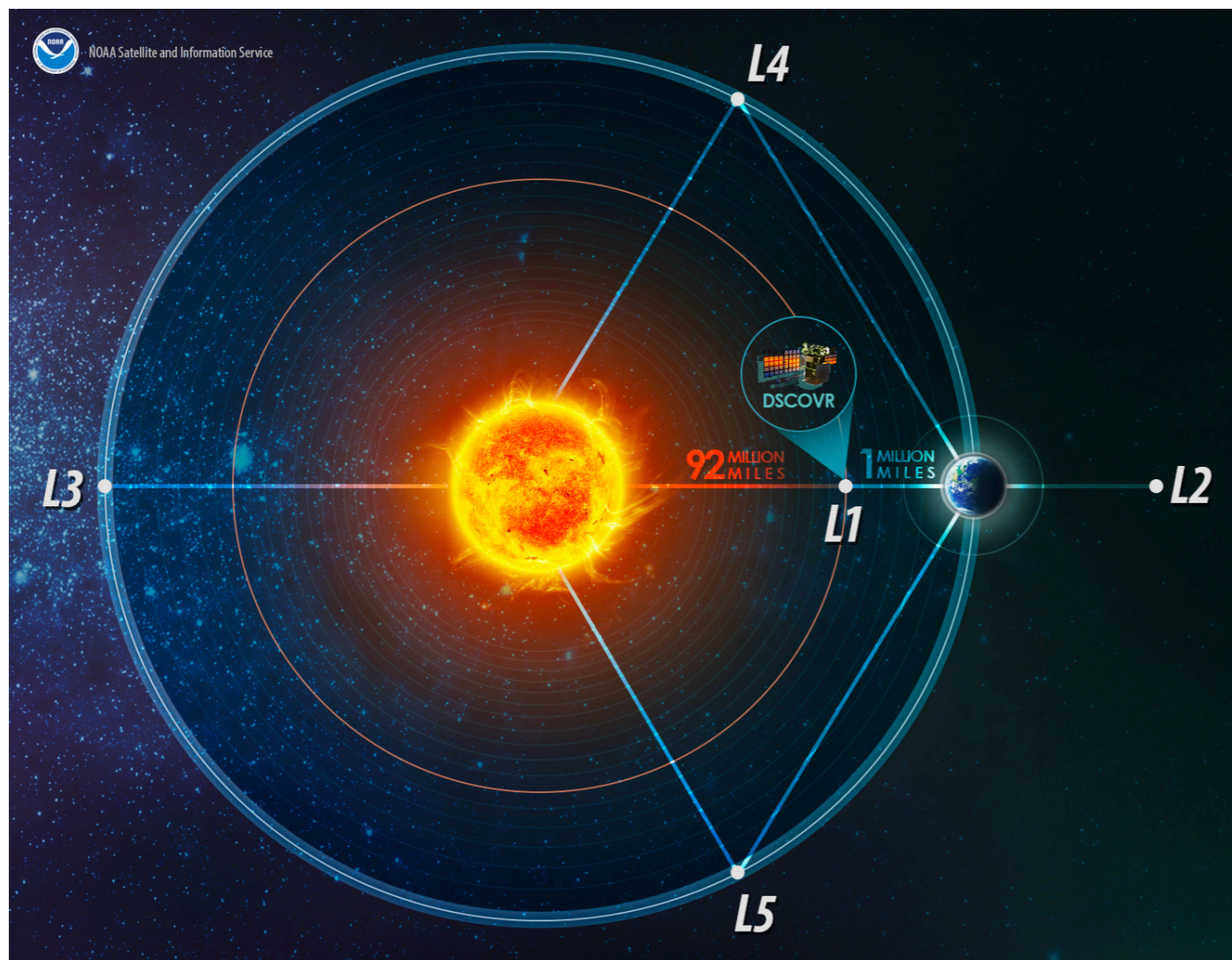
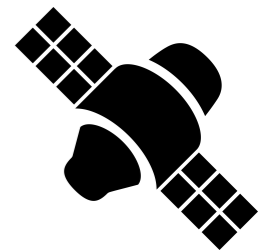
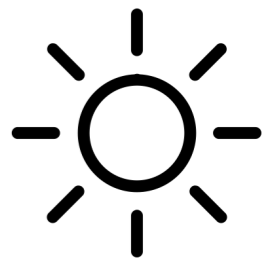
→ AIA - HMI - EVE

GOES

→ SUVI - EXIS - SEISS



# SPACECRAFT ORBITING L1



SOHO

→ EIT - LASCO - MDI

DSCOVR

→ PLASMAG

ACE

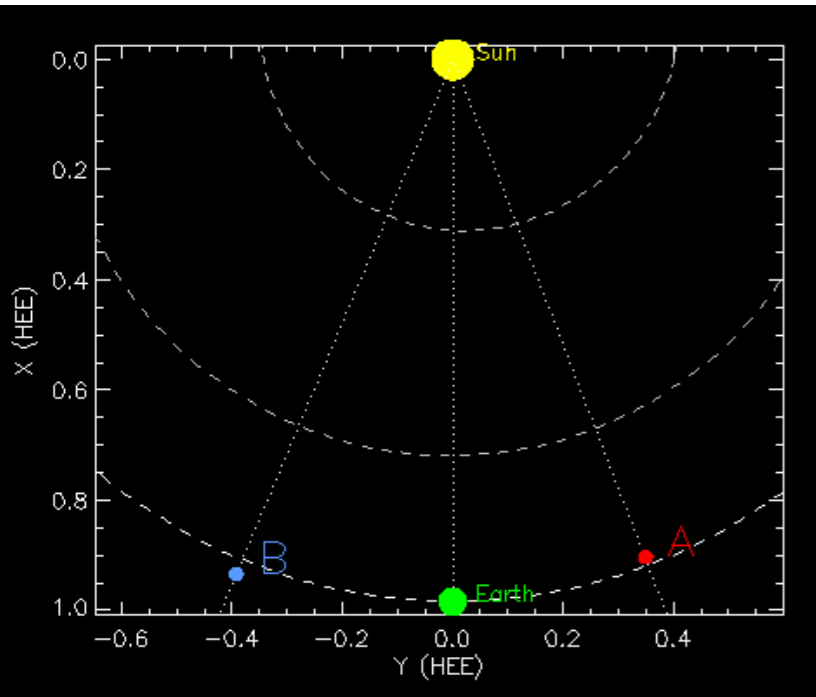
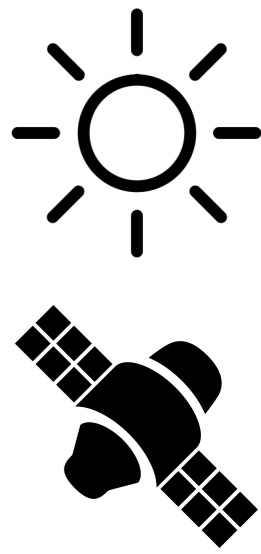
→ SWEPAM - MAG

WIND

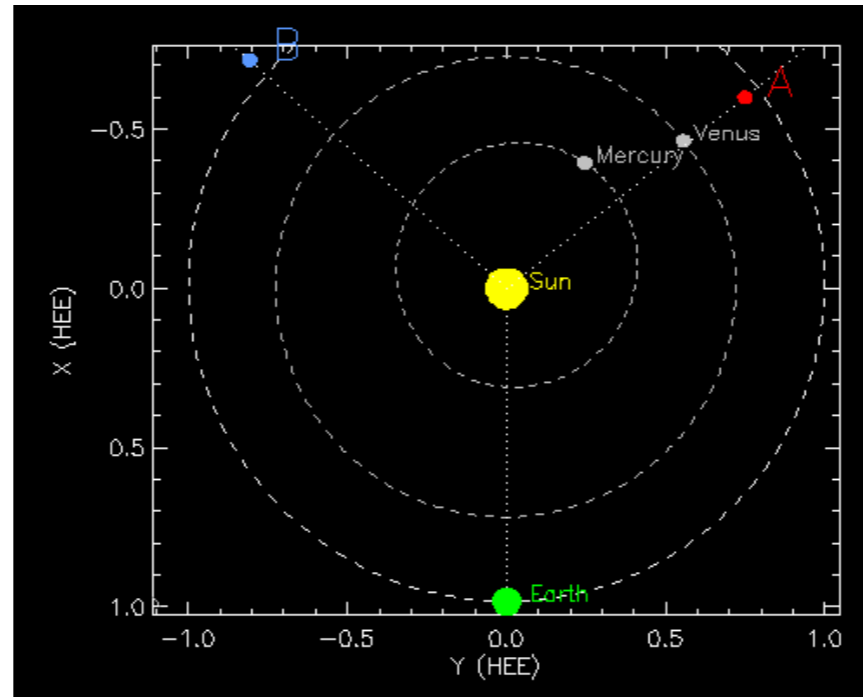
→ MFI - SWE



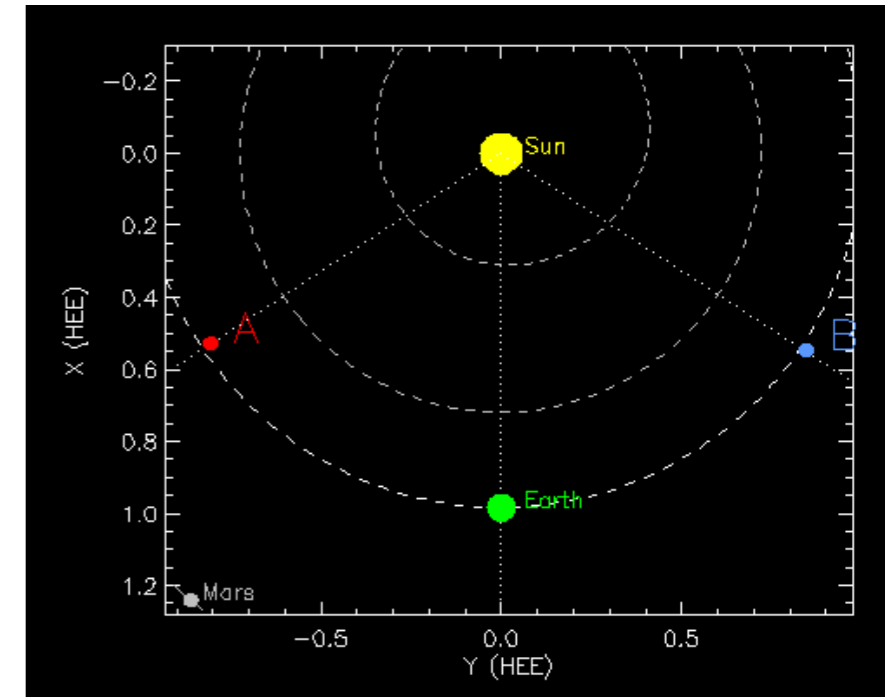
# EXOTIC ORBITS: STEREO



January 1, 2008



January 1, 2013

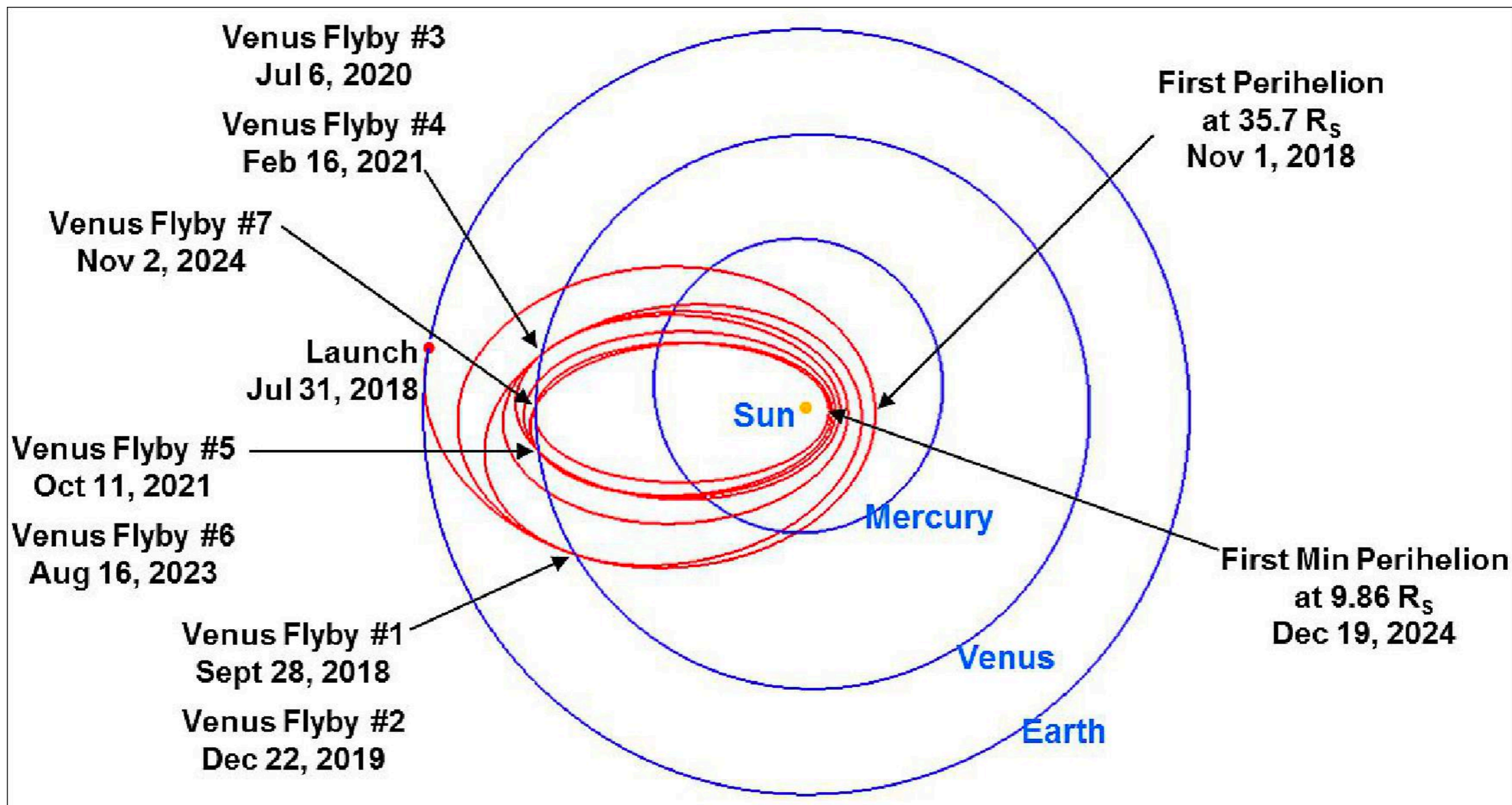
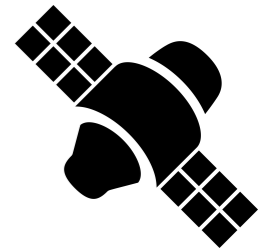
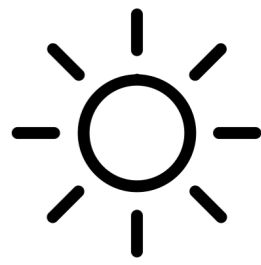


January 1, 2021

SECCHI: EUVI - COR1 - COR2 - HI  
SWAVES - IMPACT PLASTIC



# EXOTIC ORBITS: PSP



# EXOTIC ORBITS: SOLAR ORBITER

