



Een nieuwe bril voor een nieuwe zonnecyclus

Jan Janssens

Solar-Terrestrial Center of Excellence

<http://www.stce.be>

27 december 2019



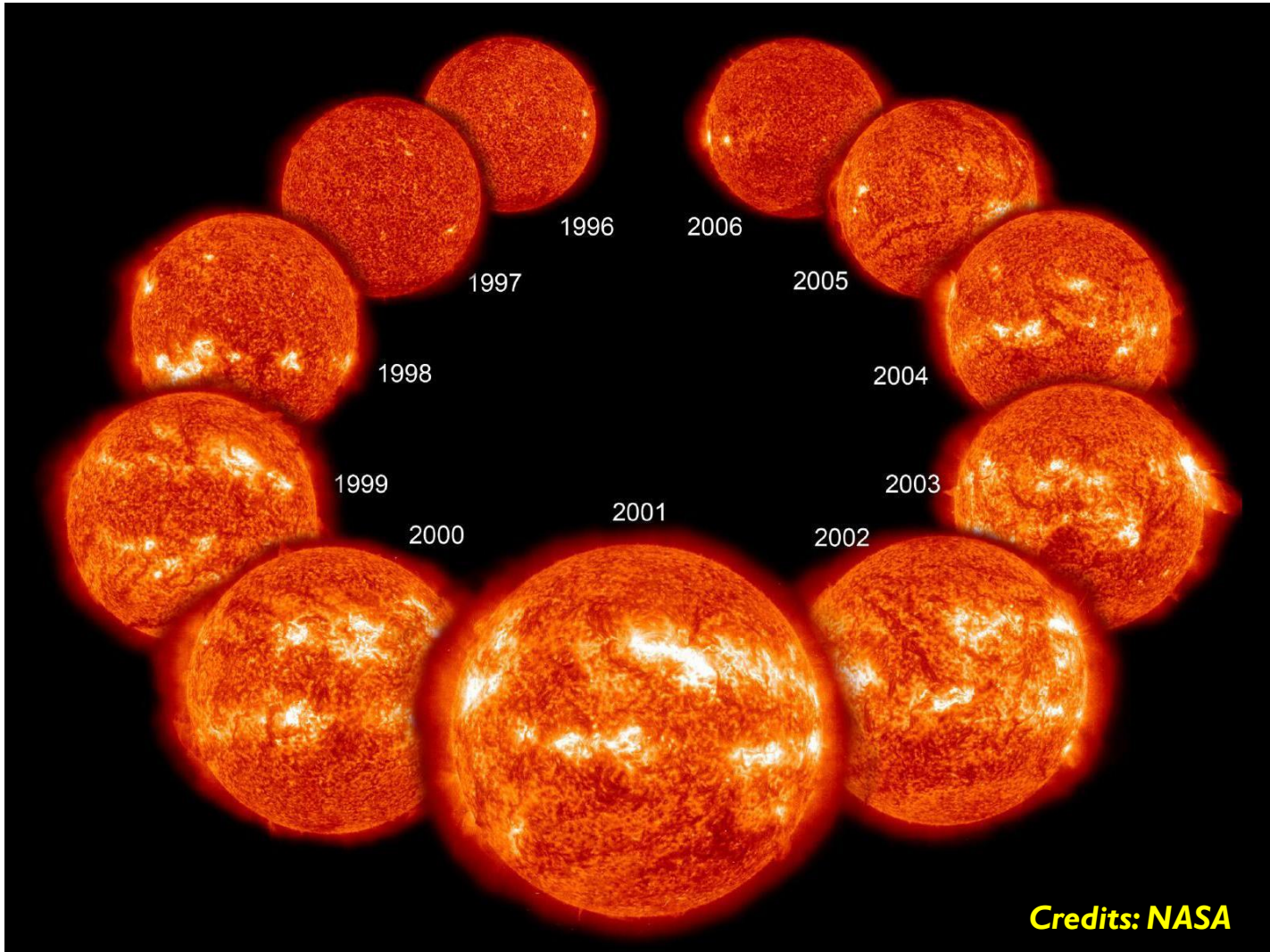


Credits: NASA

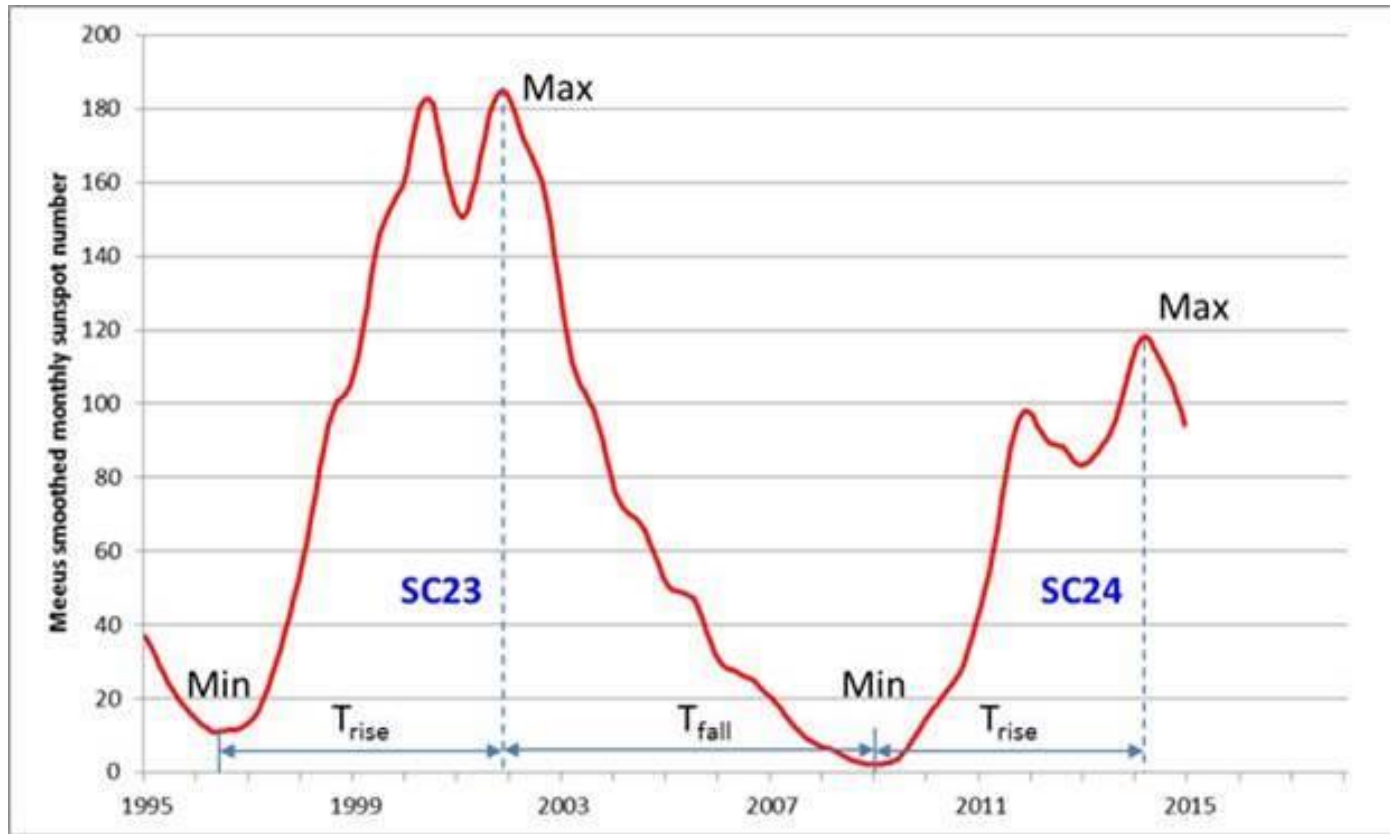
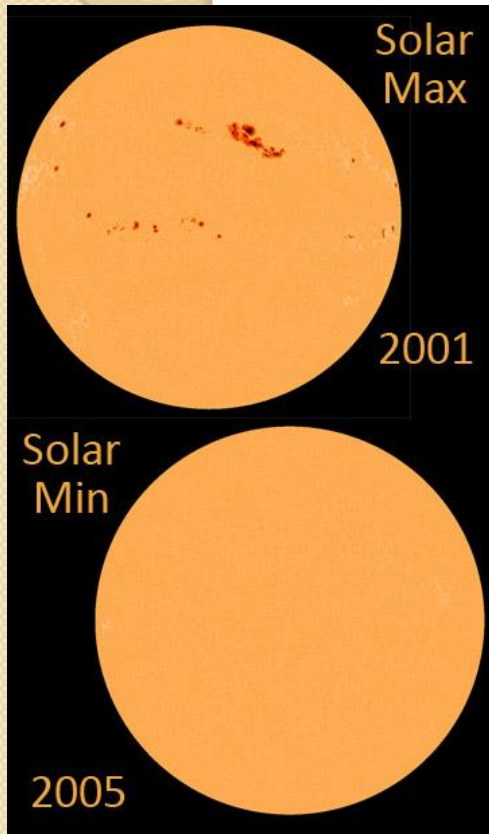
Inhoud

- De zonnecyclus
- Zonneuitbarstingen
- Ruimteweer
 - Oorzaken en gevolgen
 - Historische zonnestormen
- Voorspelling volgende zonnecyclus
- Missies
 - Uit het verleden
 - Naar de toekomst

De zonnecyclus

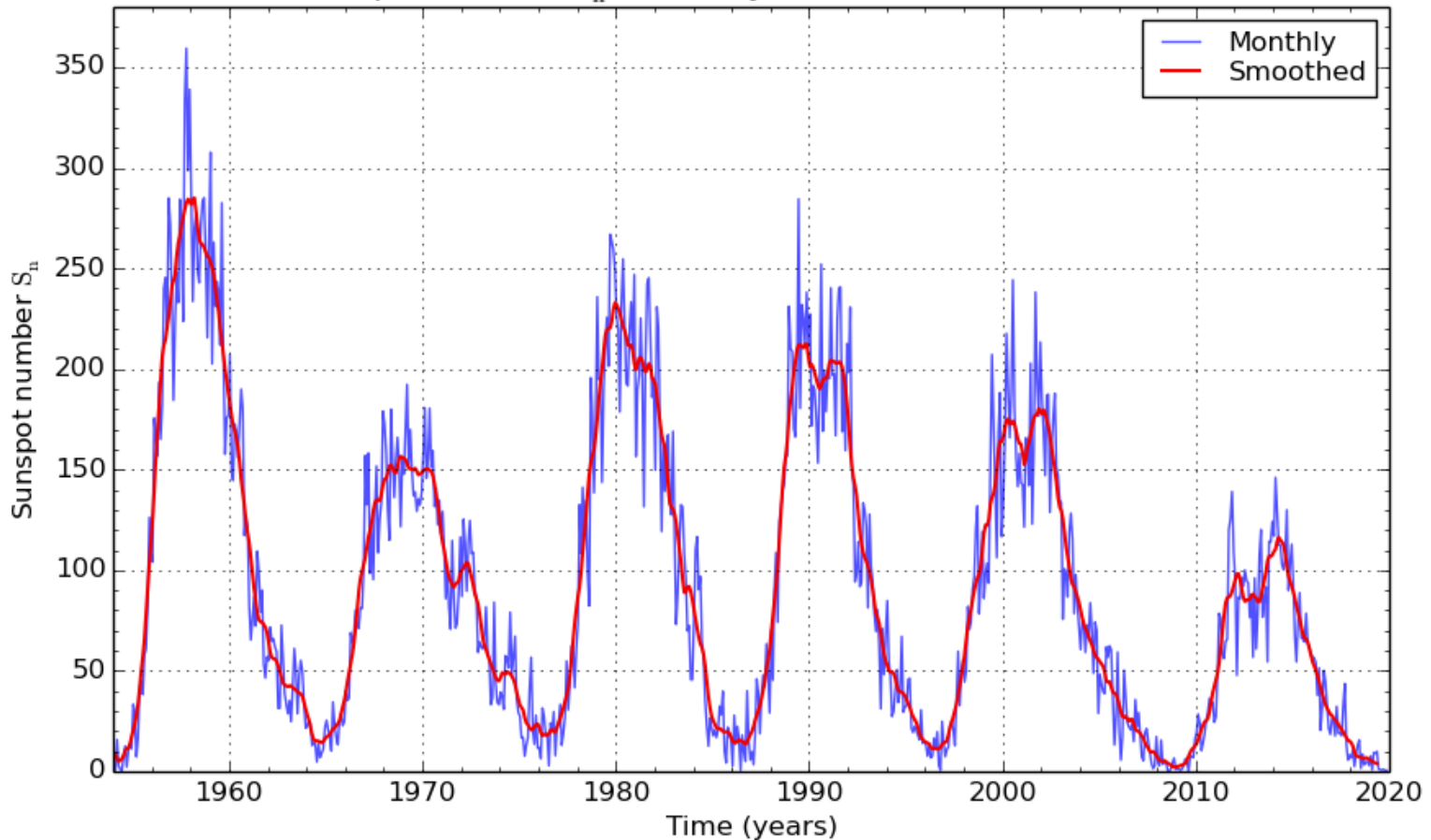


De zonnecyclus



De zonnecyclus

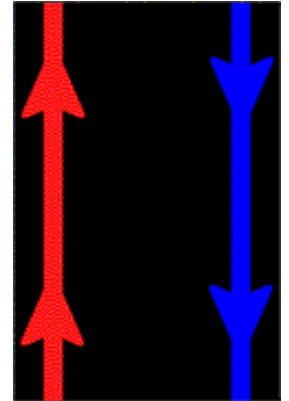
International sunspot number S_n : monthly mean and 13-month smoothed number



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2019 December 1

Zonneitbarstingen

Magnetische Reconnectie

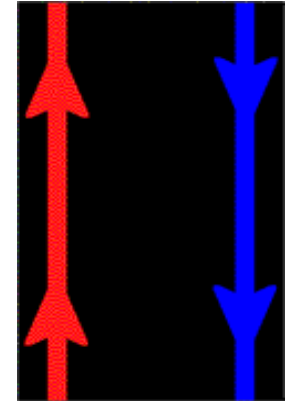


Zonneuitbarstingen

Magnetische Reconnectie

Straling

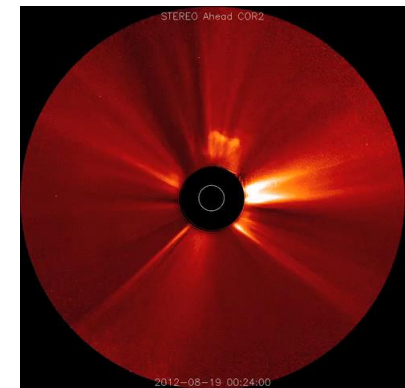
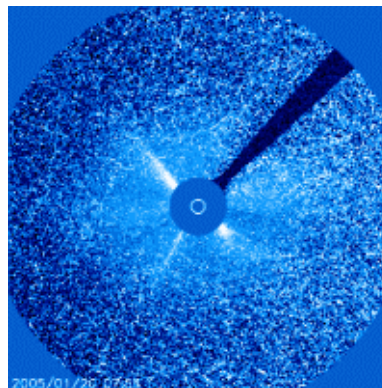
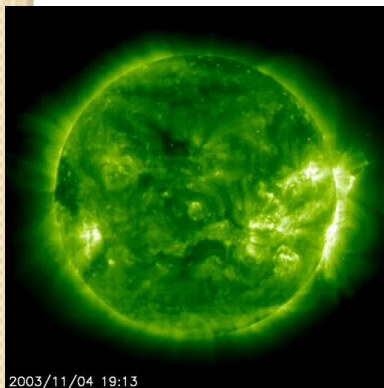
Deeltjes



Zonnevlammen

Protonstormen

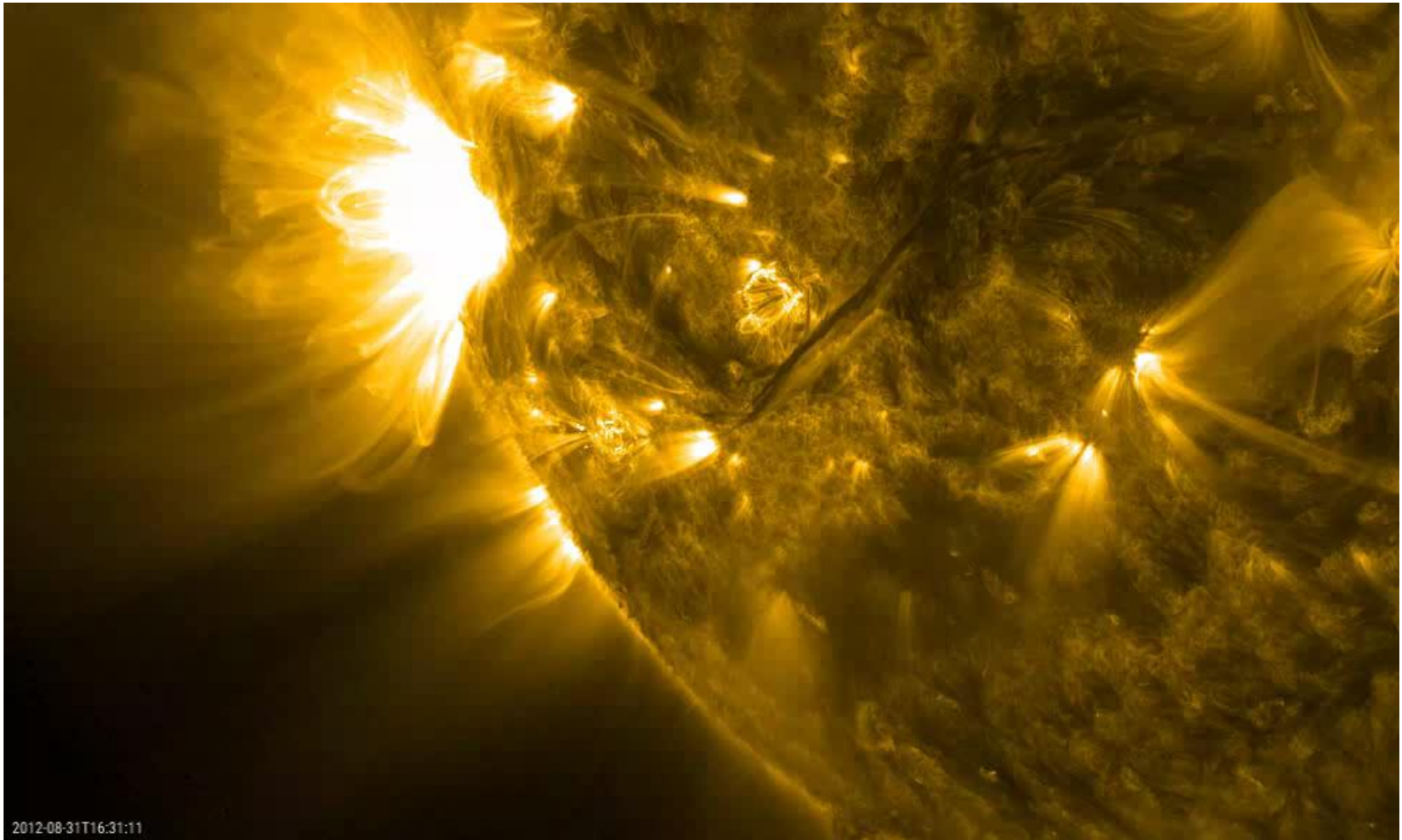
Coronale Massa Ejecties



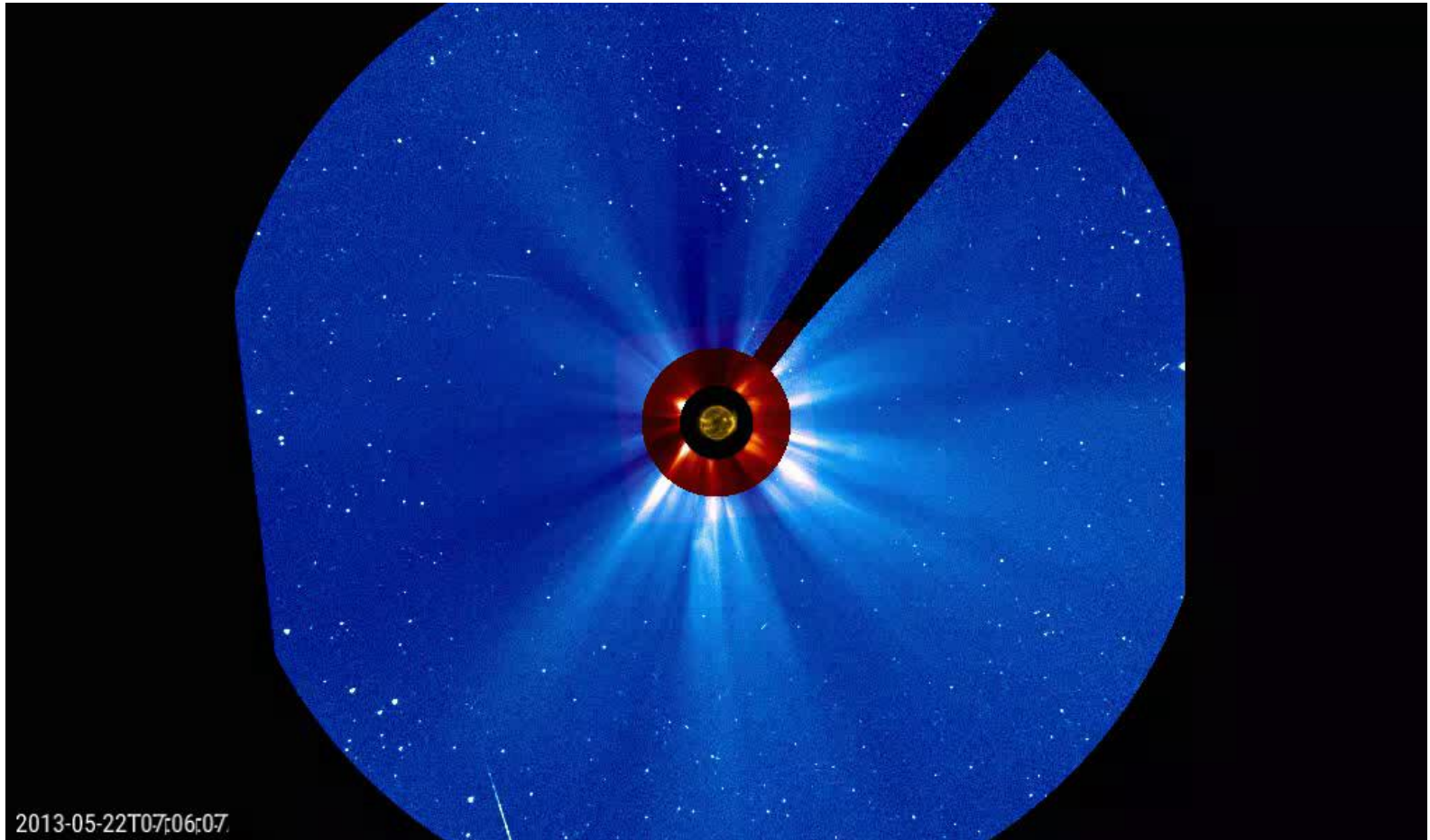
Enkele zonneuitbarstingen tijdens SC24



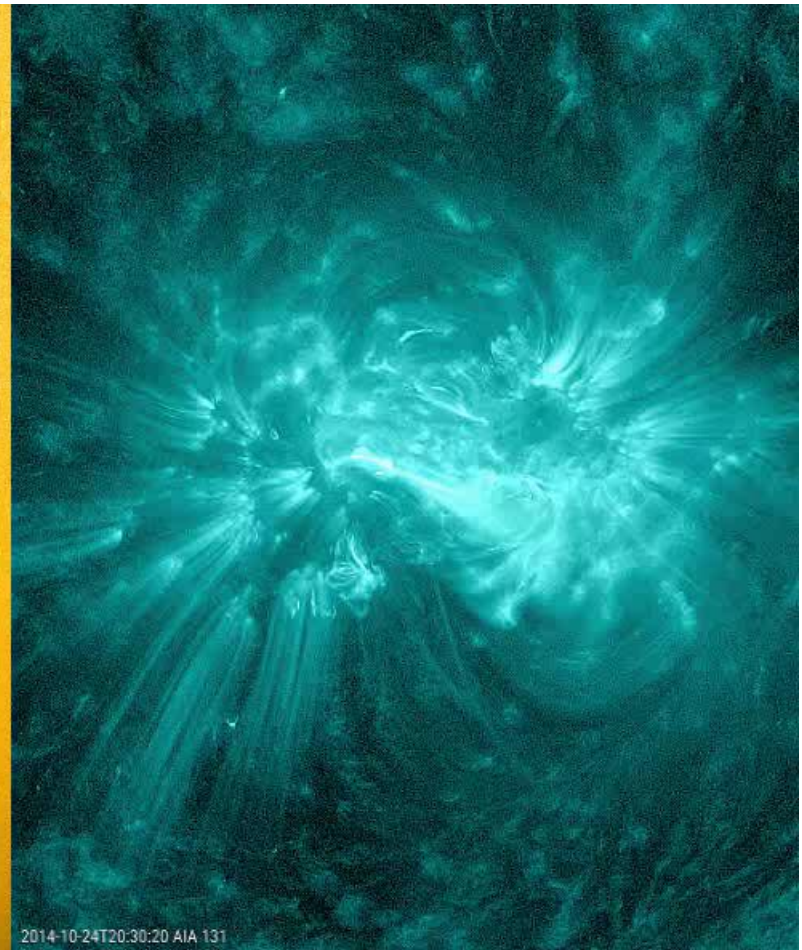
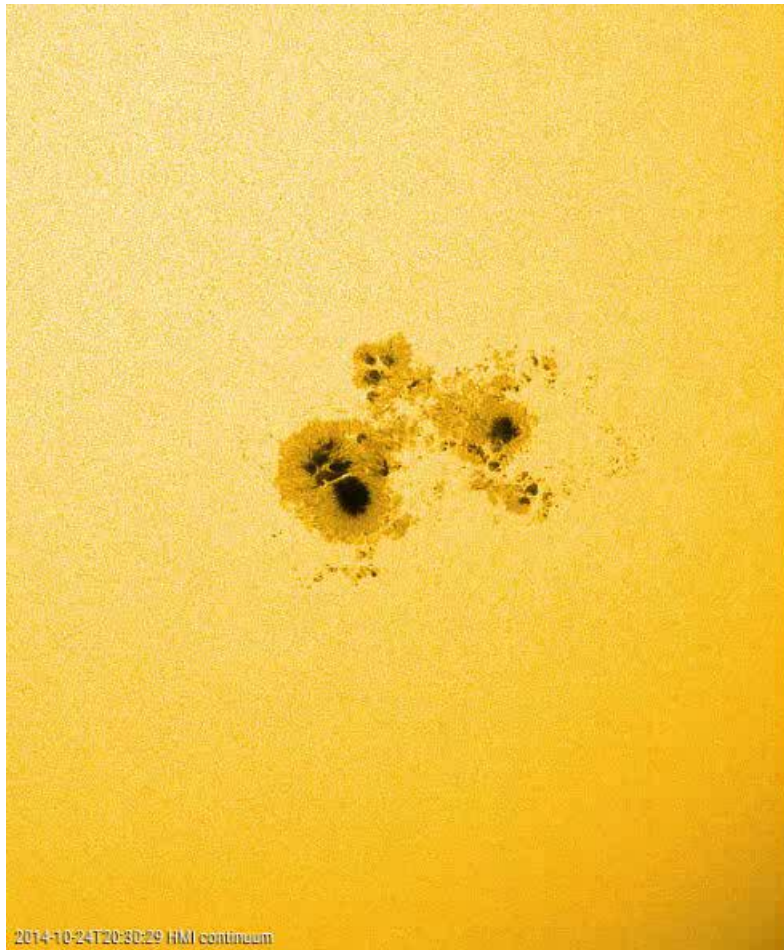
Enkele zonneuitbarstingen tijdens SC24



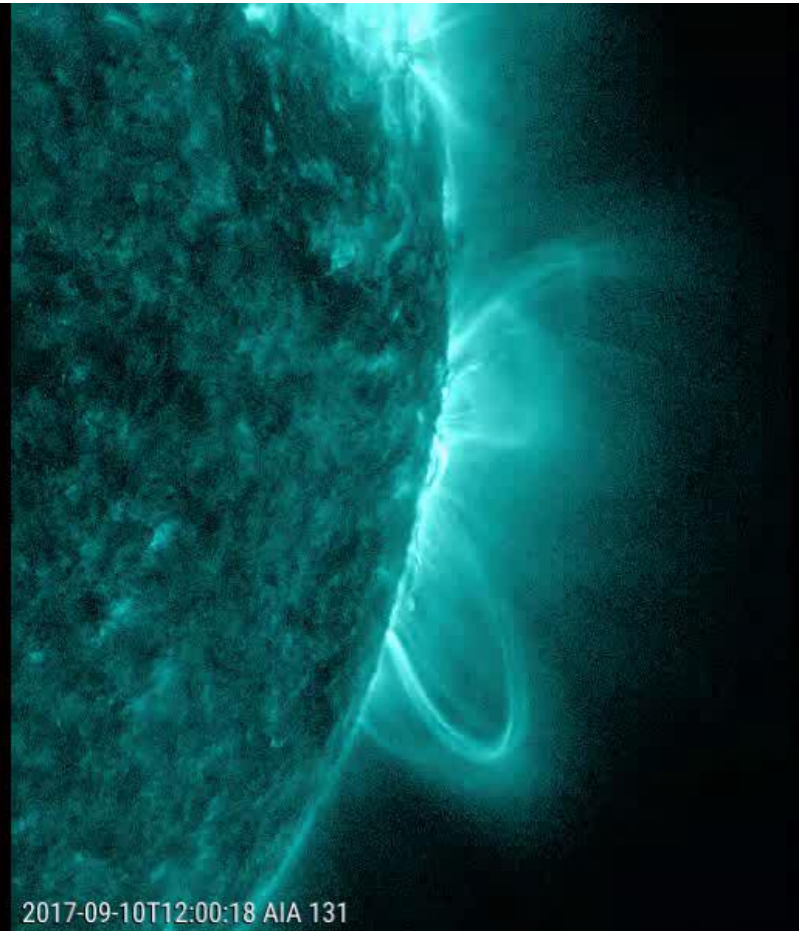
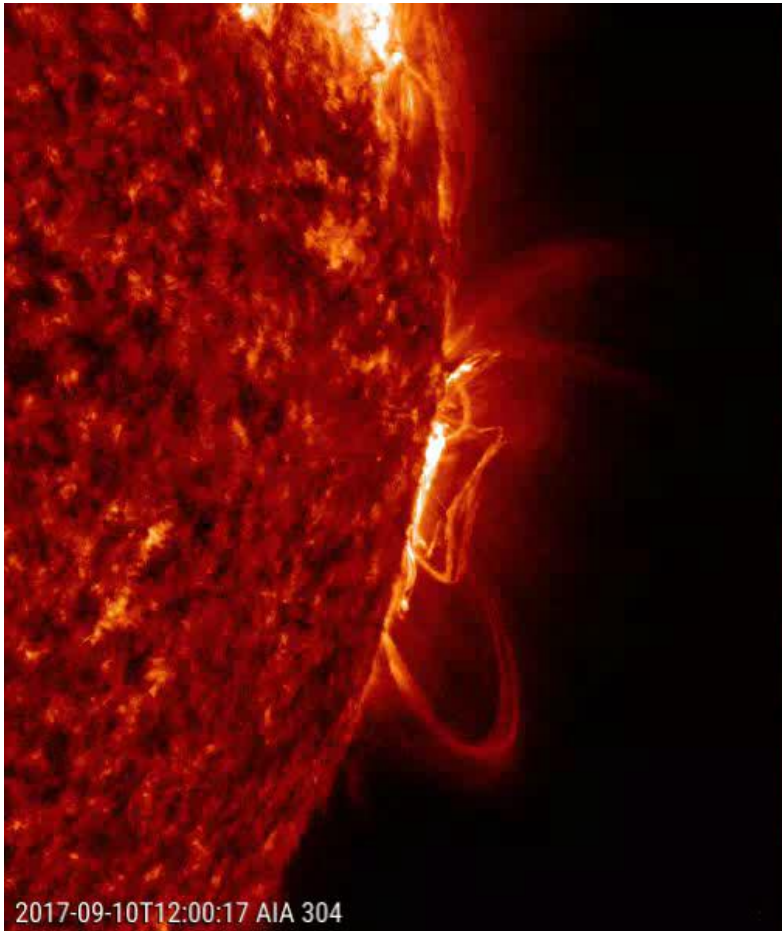
Enkele zonneuitbarstingen tijdens SC24



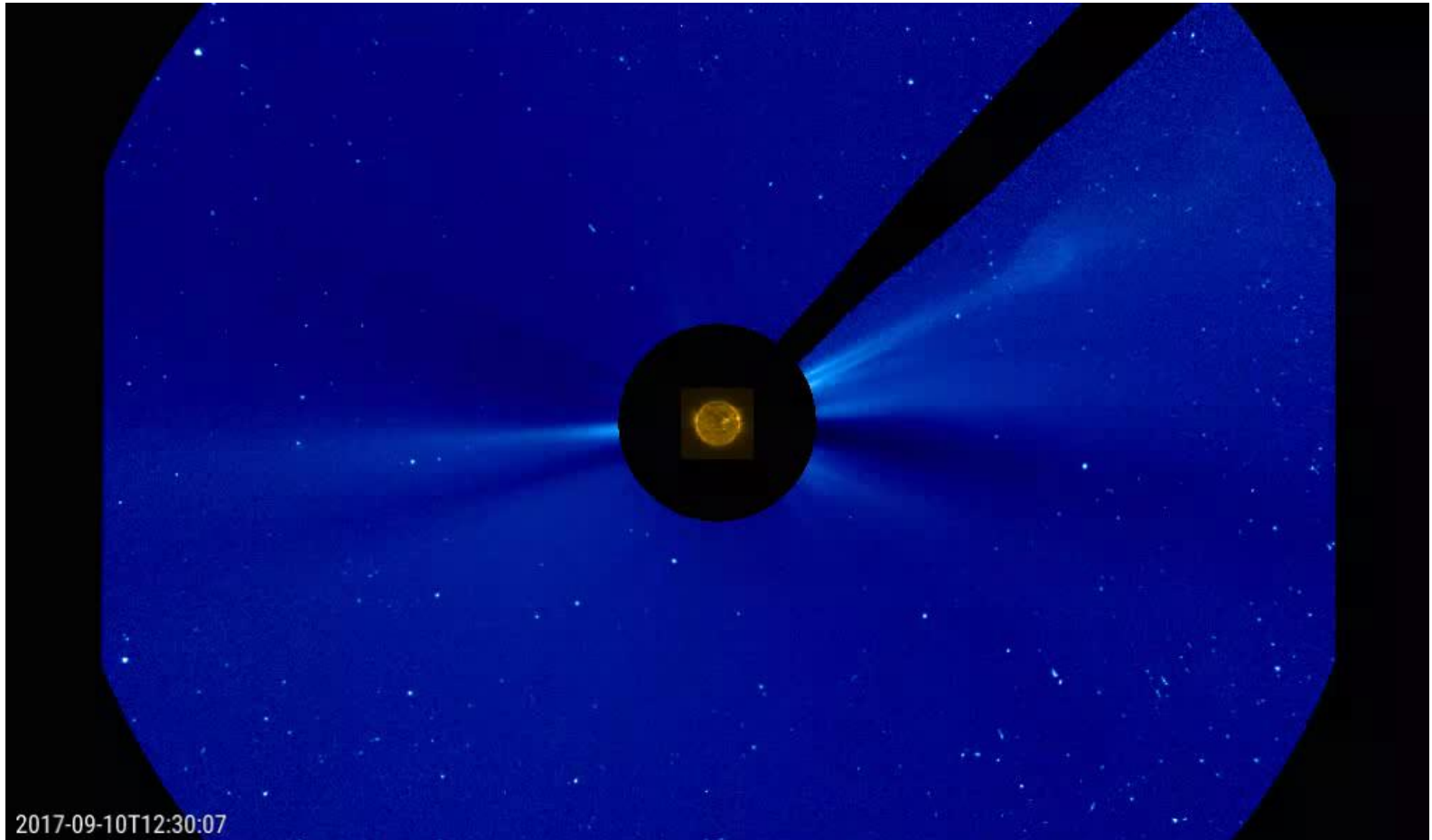
Enkele zonneuitbarstingen tijdens SC24



Enkele zonneuitbarstingen tijdens SC24



Enkele zonneuitbarstingen tijdens SC24

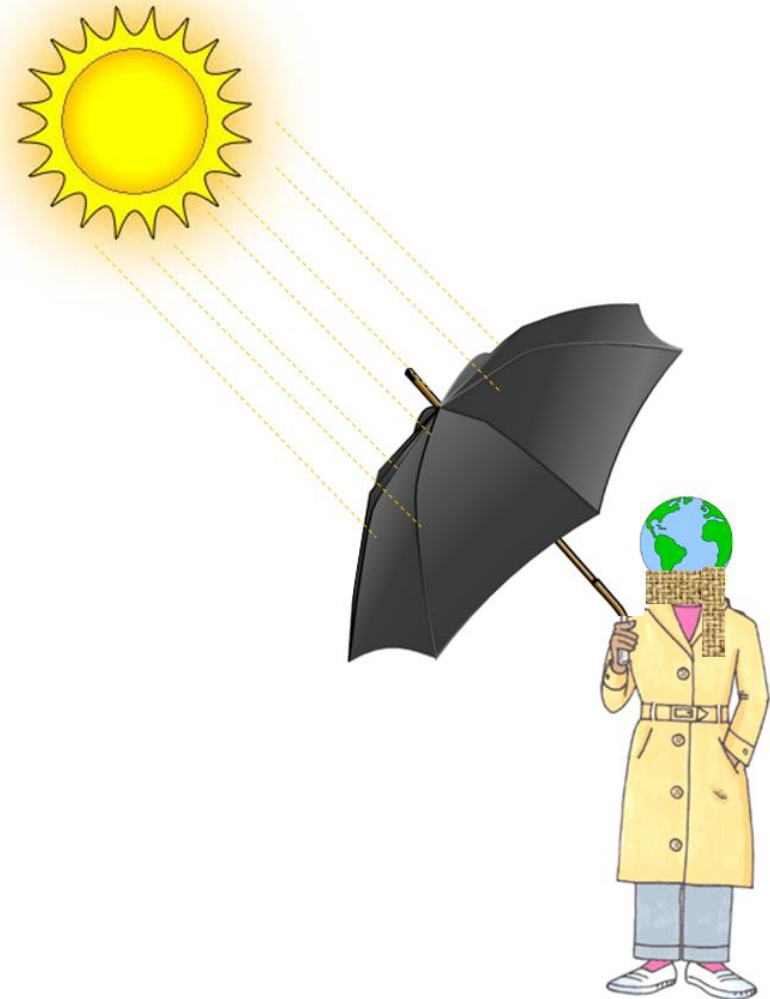


Dracarys!...

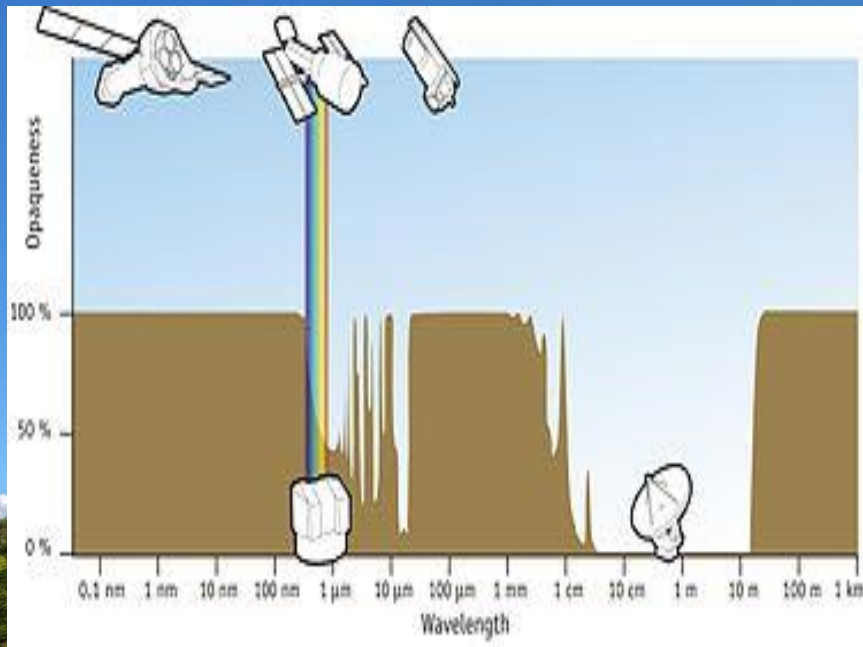


Ruimteweer

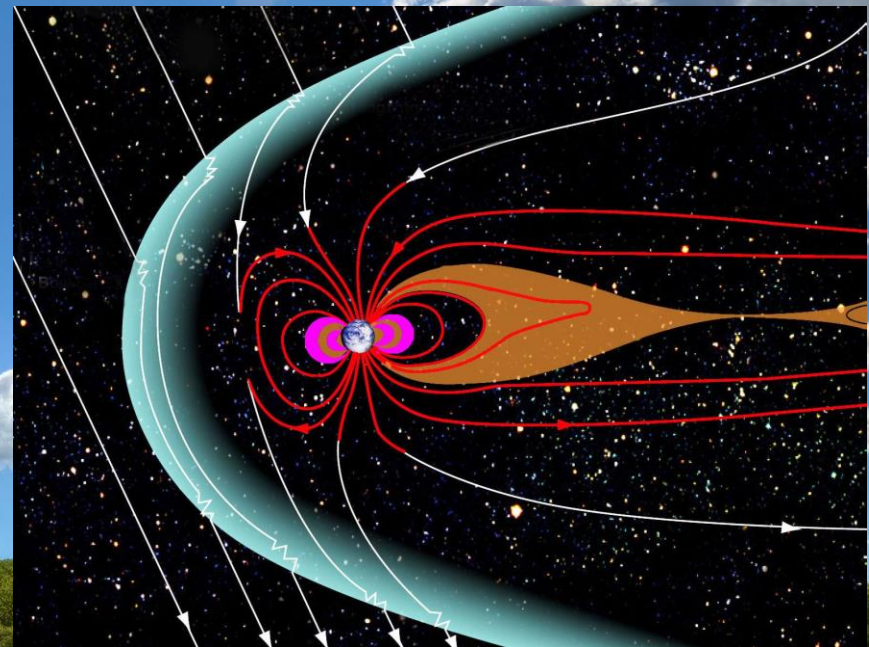
- ...alle omstandigheden op de zon en in de zonnewind, magnetosfeer, ionosfeer en thermosfeer die de prestaties en de betrouwbaarheid van technologische systemen in de ruimte en op grond kunnen beïnvloeden en die een gevaar kunnen betekenen voor het menselijk leven of de gezondheid.



De rustige zon



Elektromagnetische straling

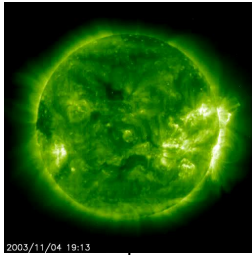


Deeltjes – Zonnewind

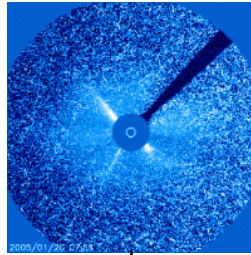
Verstoord ruimteweer

Oorzaak

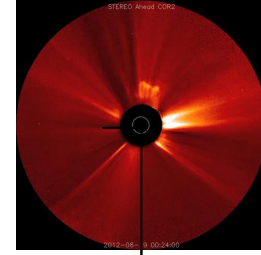
Zonnevlammen



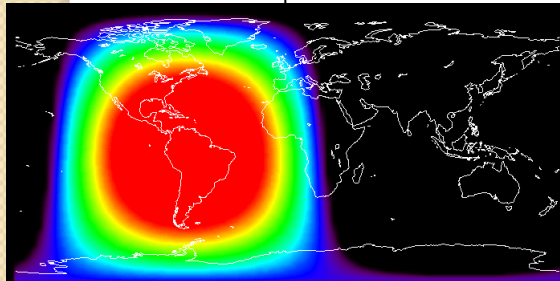
Protonstormen



CMEs

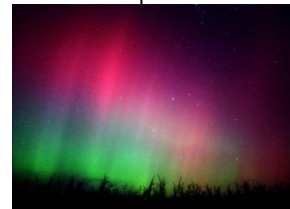
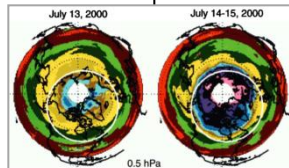


Gevolgen



Strong X-ray flux
 Product Valid At : 2015-03-11 16:22 UTC

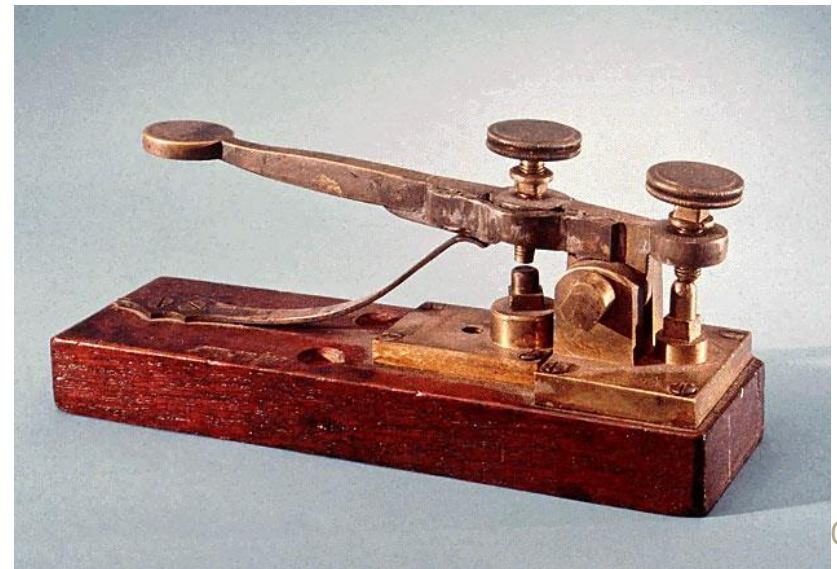
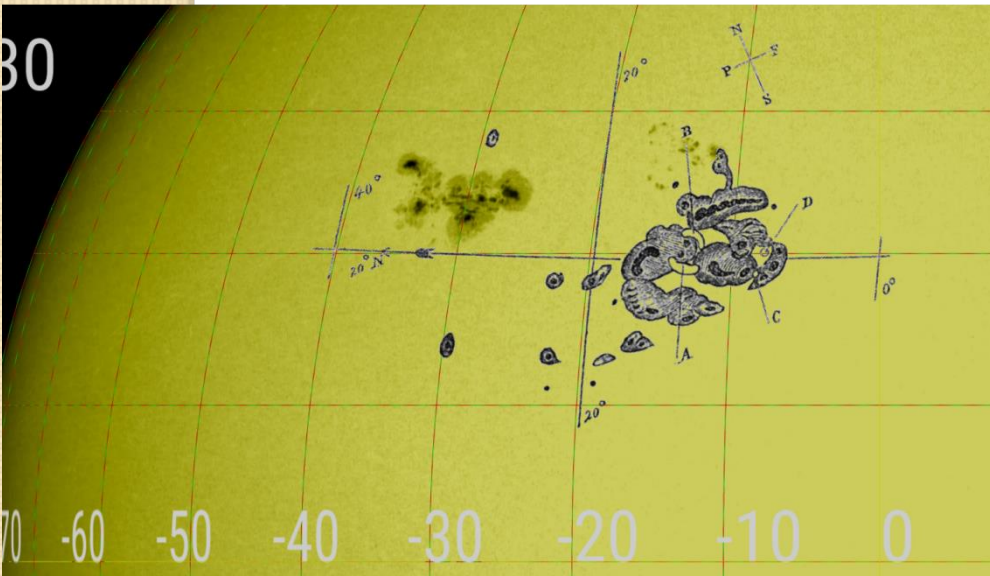
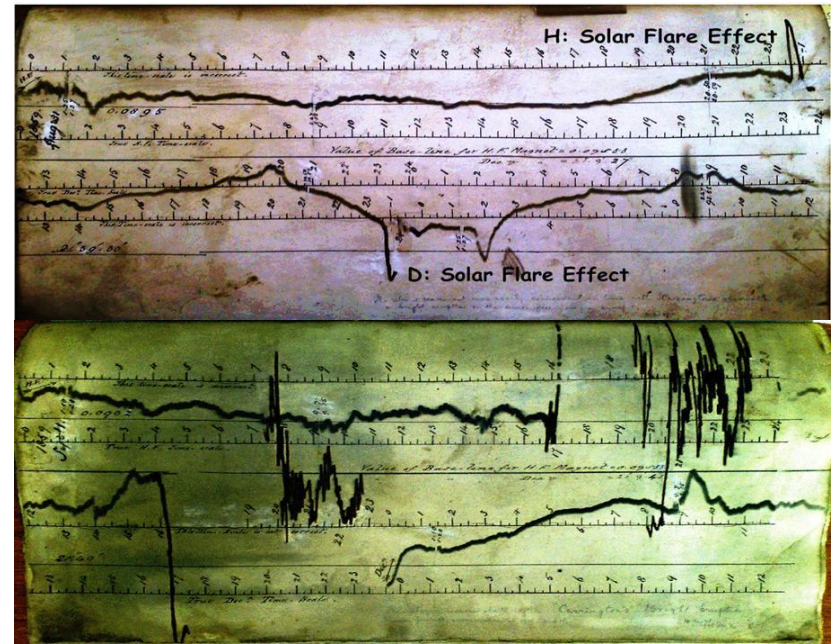
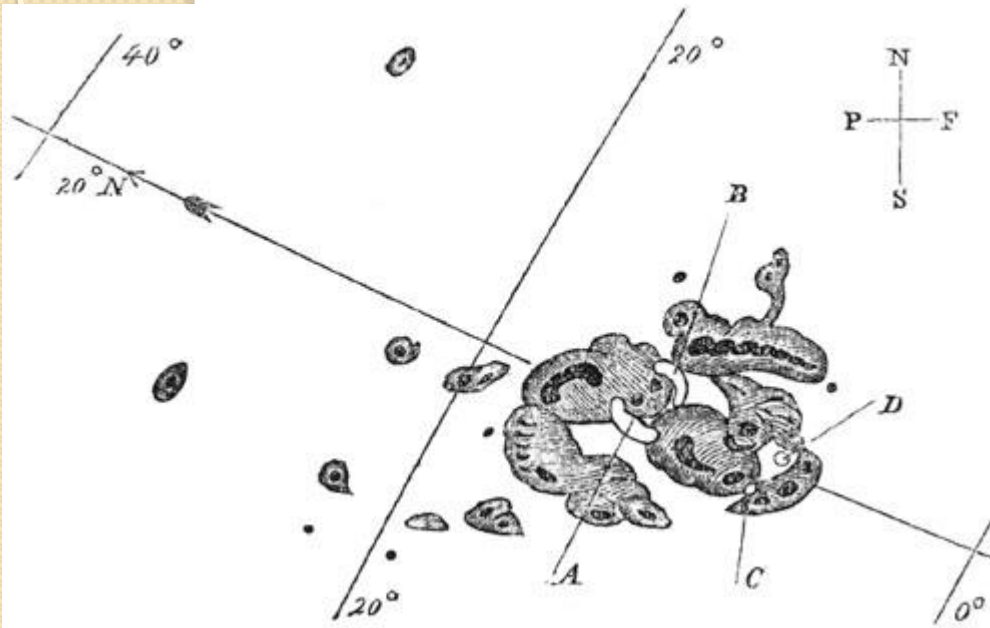
Normal Proton Background
 NOAA/SWPC Boulder, CO USA



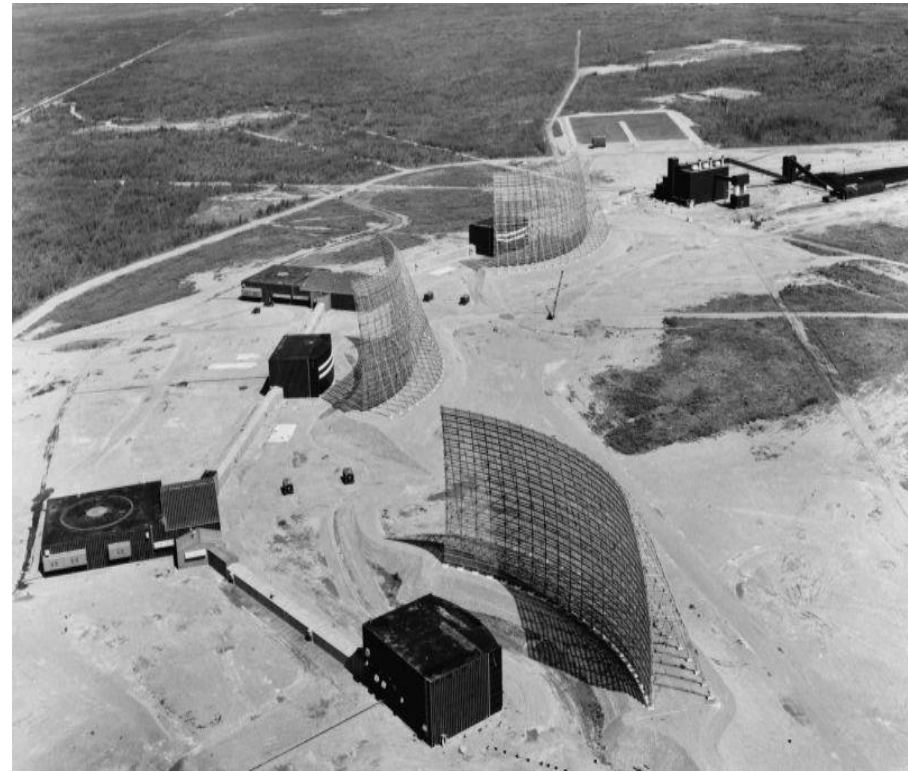
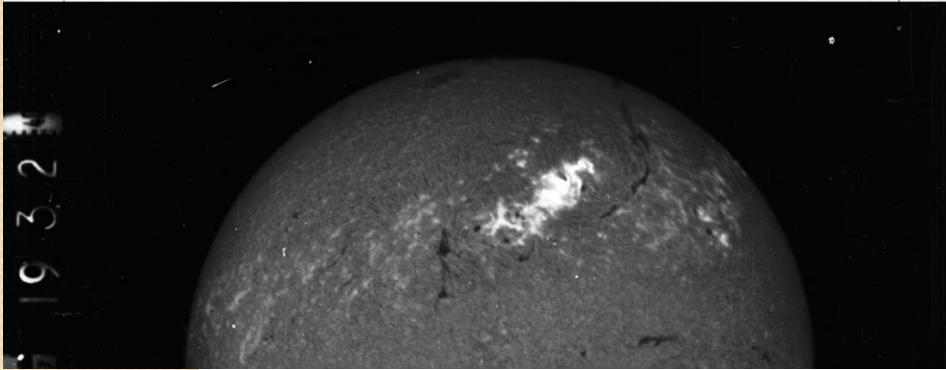
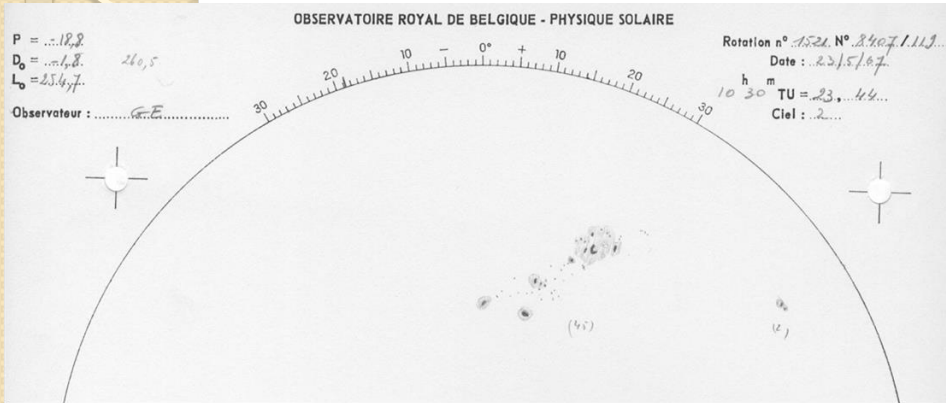
No Donald, you
can NOT build a
wall between the
Earth and a CME!...



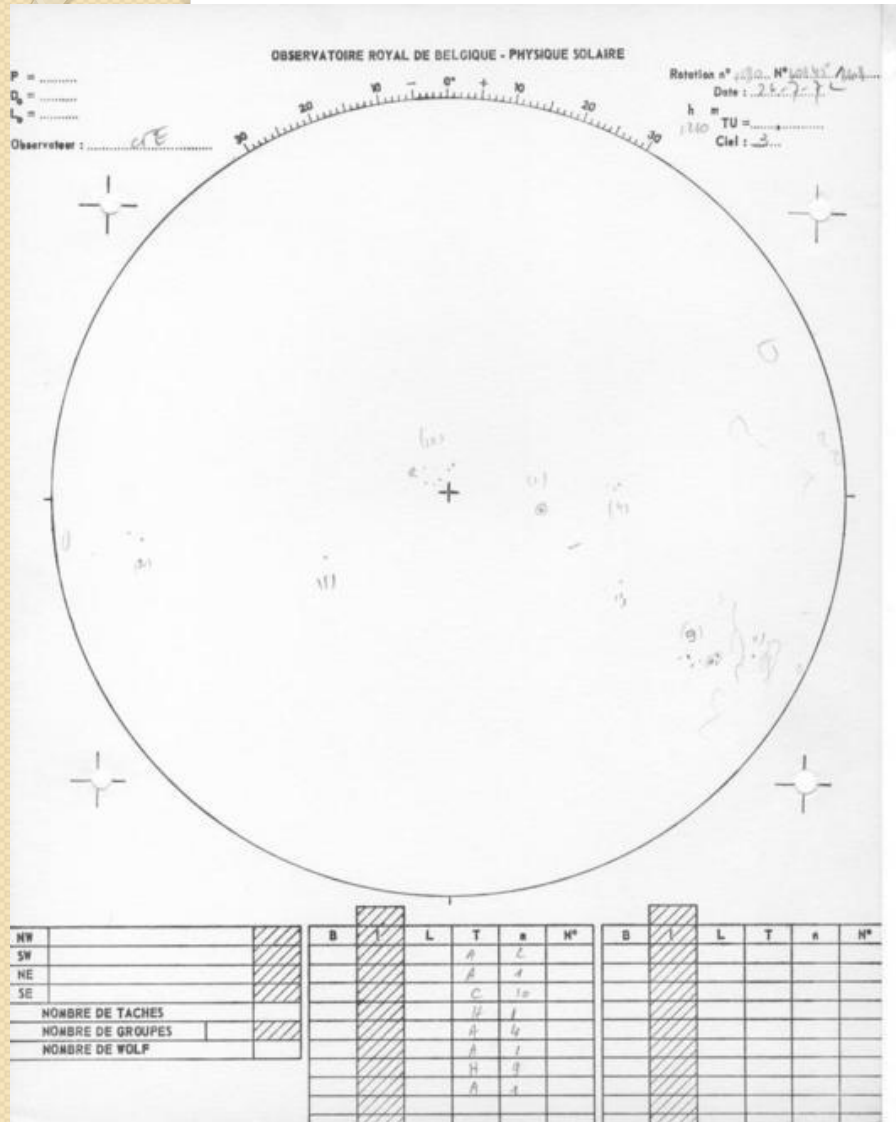
September 1859: Carrington event



23 May 1967 – Cold War event

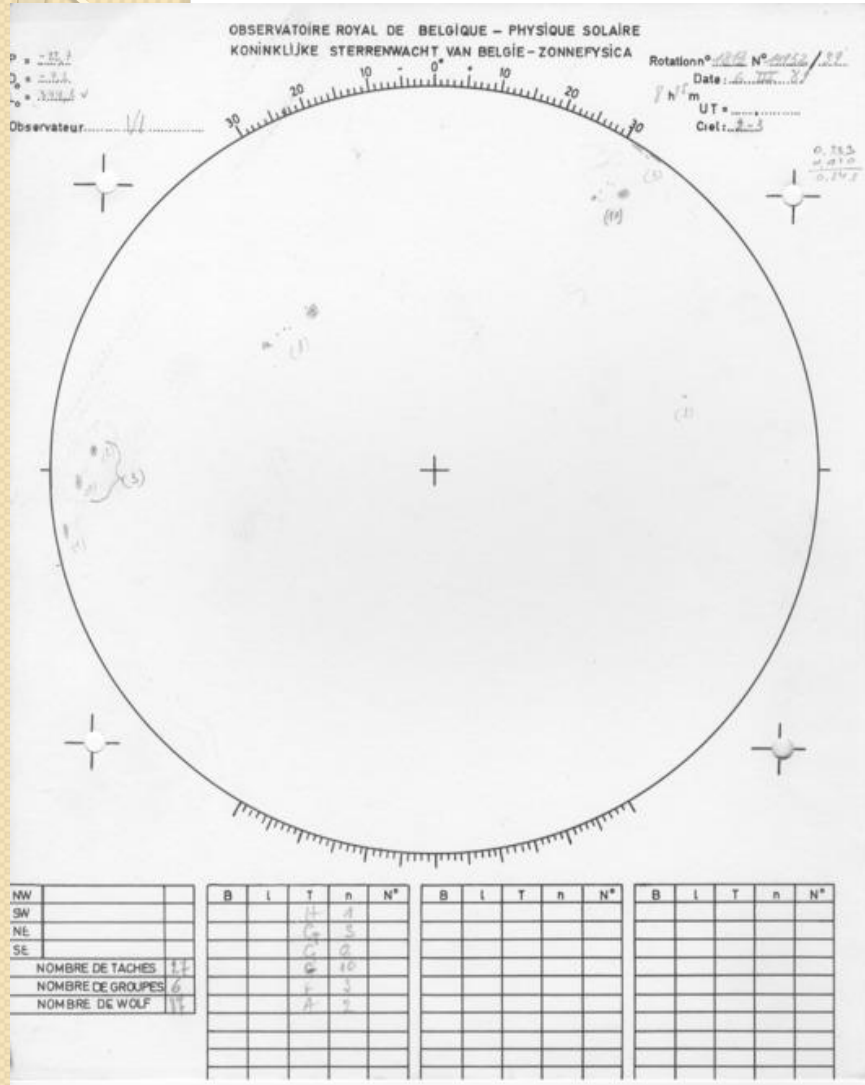


4 August 1972: Apollo event





13 - 14 March 1989: Québec event



Ruimteweer-effecten tijdens SC24

- 24-25 oktober 2011
 - WAAS/EGNOS services onderbroken; bloed-rode aurora
- 24 januari 2012
 - Poolvluchten omgeleid
- 7 maart 2012
 - Poolvluchten omgeleid
- 7 januari 2014
 - Lancering supply rocket ISS vertraagd
- 1 september 2014
 - ST-B verloor sun-lock
- 4 november 2015
 - Zweeds Air Traffic down
- 6-12 september 2017
 - HF comms down tijdens orkaan Irma

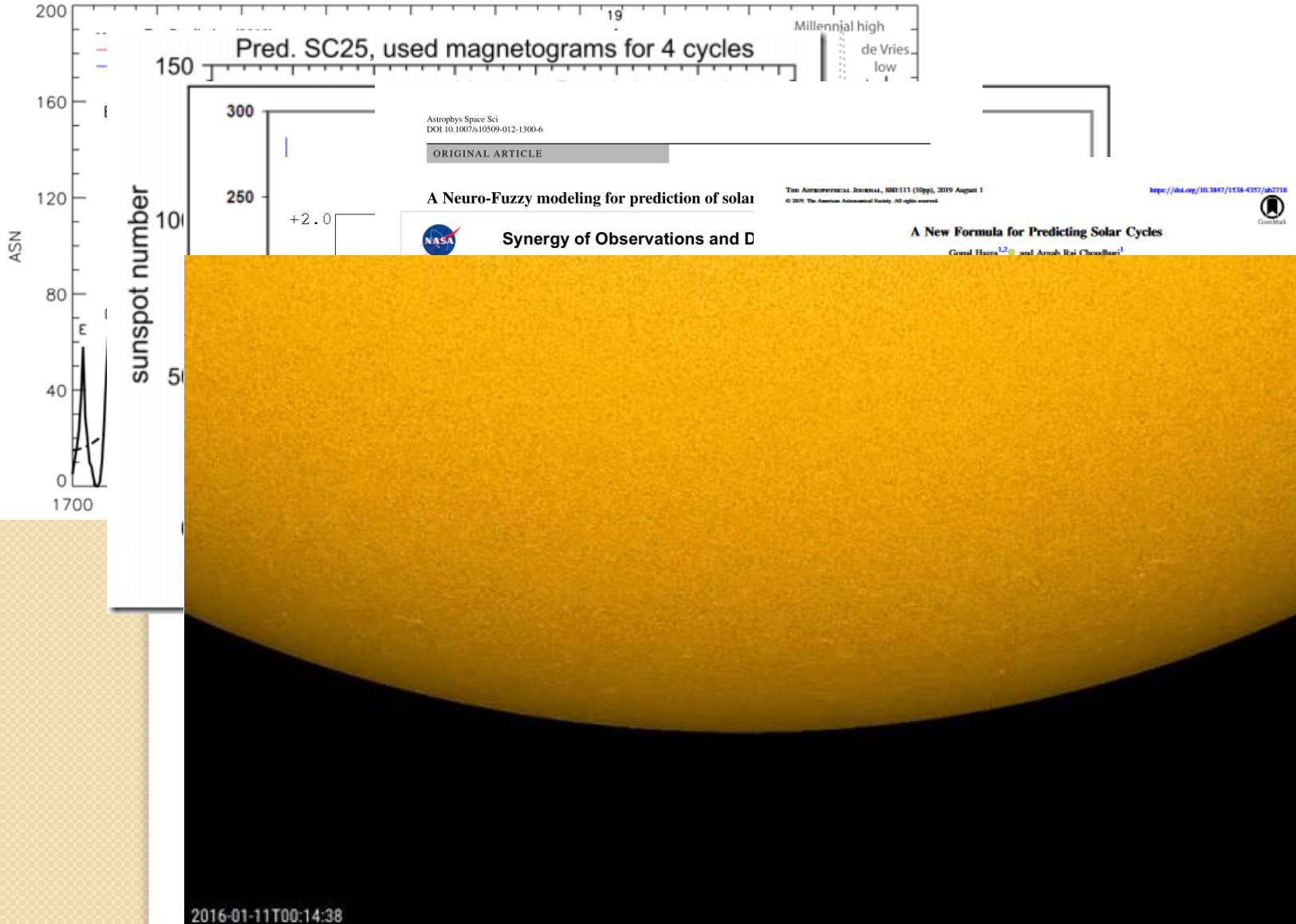


Voorspelling van de volgende zonnecyclus



Verschillende modellen & methoden

Sunspot prediction based on solar activity cycles



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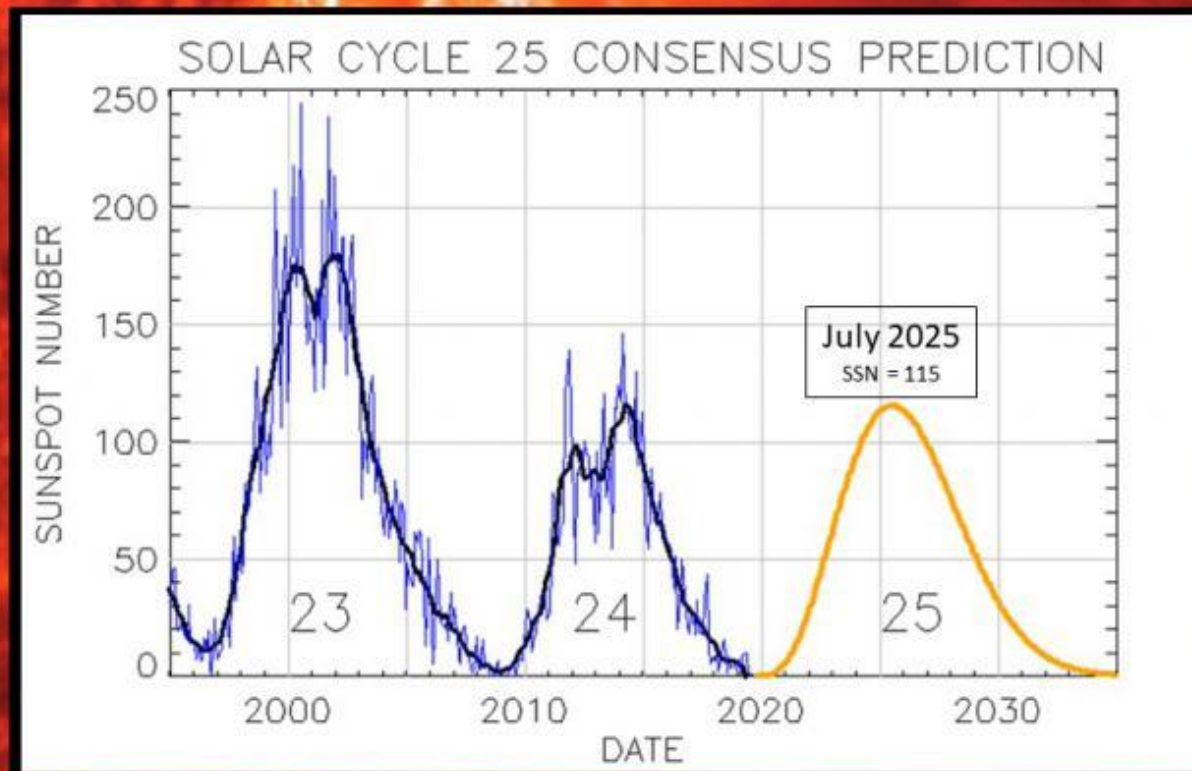
Order! Order!...



SC25 Prediction Panel

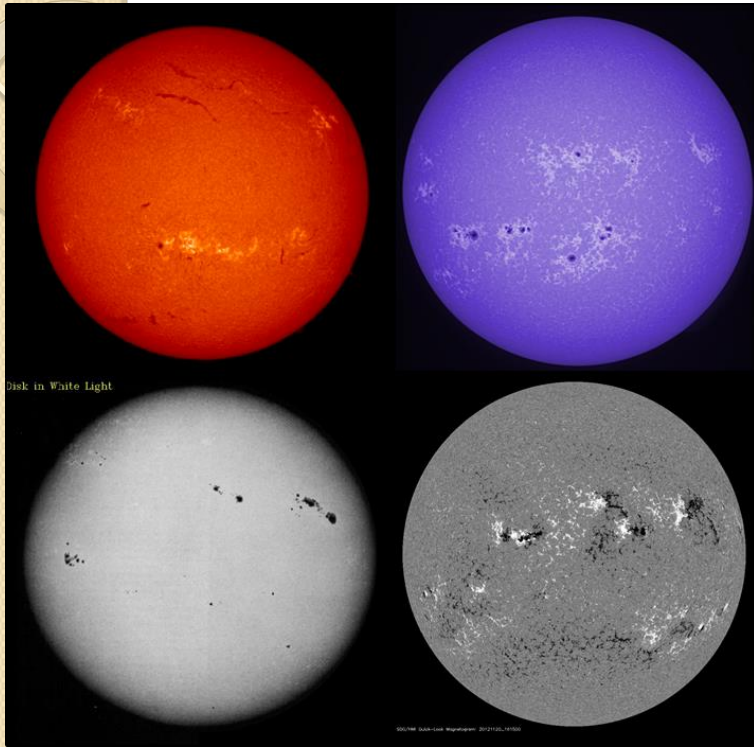
Solar Cycle 25 Forecast Update

- Released December 9th, 2019 -

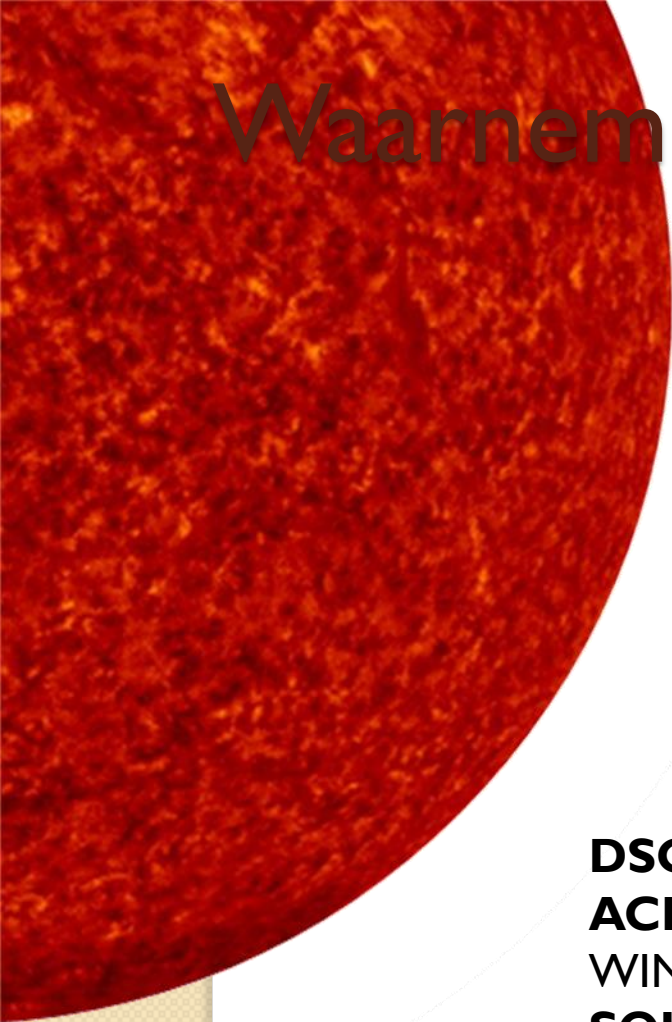


Solar Cycle 25 will have a peak SSN of 115 (± 10) in July 2025
Solar Cycle 24/25 minimum will occur in April, 2020 (± 6 months)

Waarnemingen vanop de grond



Waarnemingen vanuit de ruimte



GOES				
SDO				
INTEGRAL				
PROBA2				
HINODE				
RHESSI				

LI

DSCOVR				
ACE				
WIND				
SOHO				

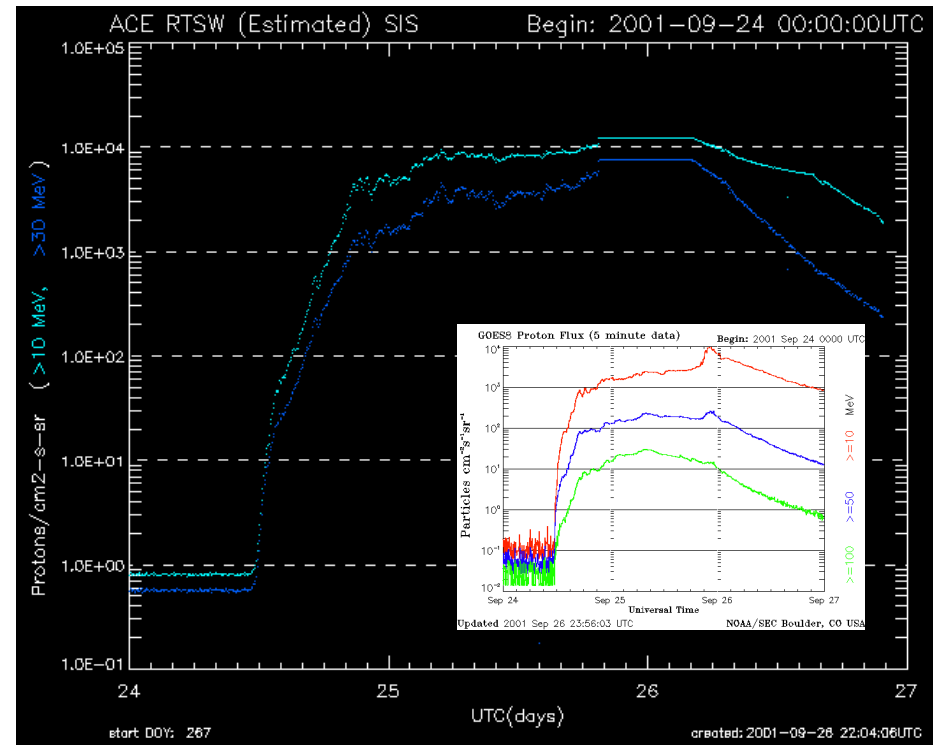
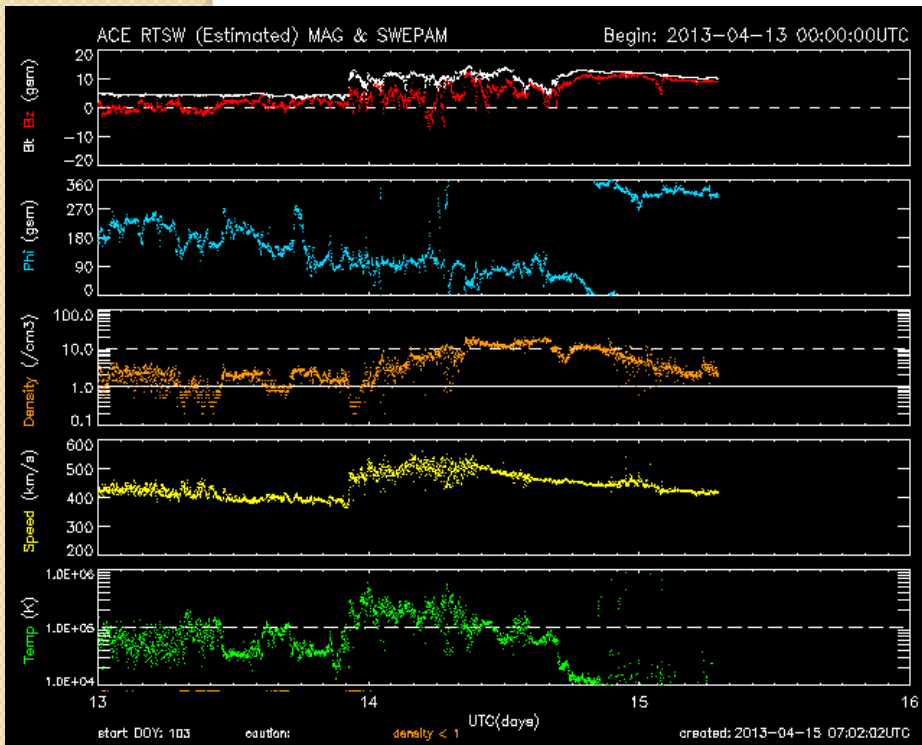


STEREO

- γ /X-ray/EUV
- Coronagraph
- Solar Wind
- Particle flux

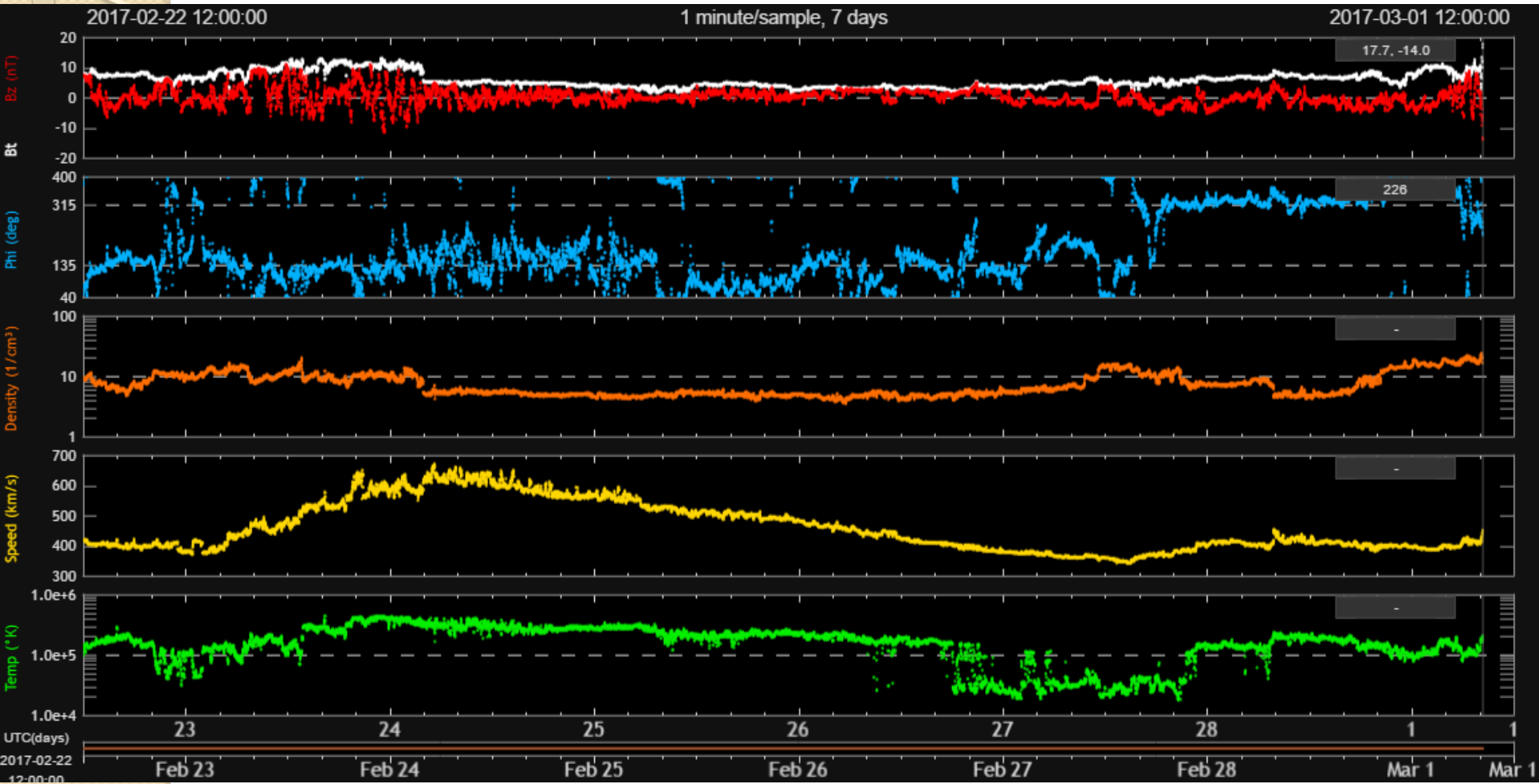
ACE

Advanced Composition Explorer



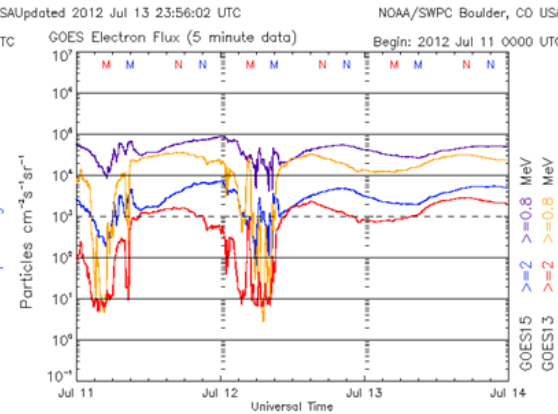
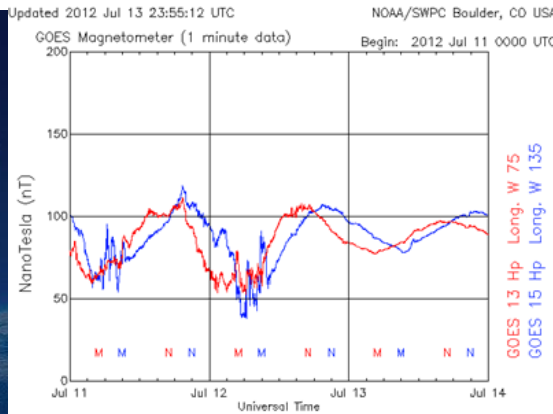
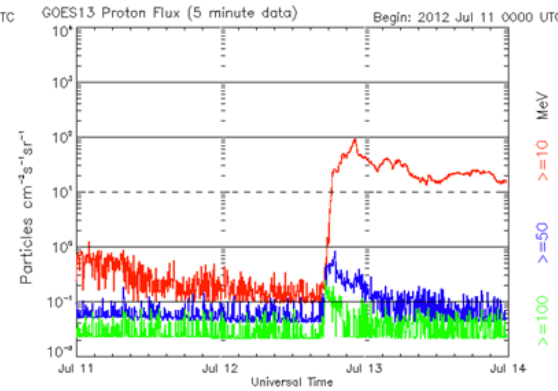
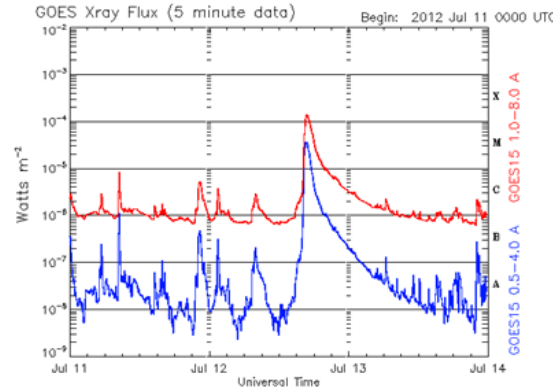
DSCOVER

Deep Space Climate Observatory



GOES

Geostationary Operational Environmental Satellite



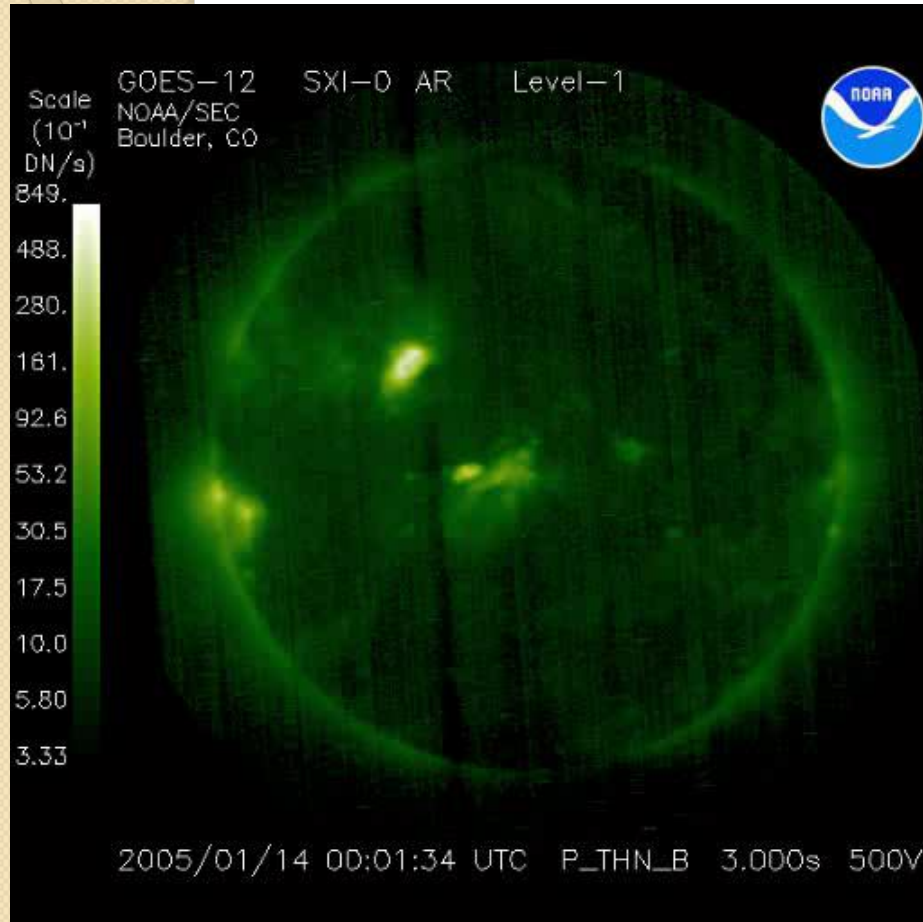
Extreme Ultraviolet and X-Ray Irradiance Sensor (EXIS)

Geostationary Lightning Mapper (GLM)

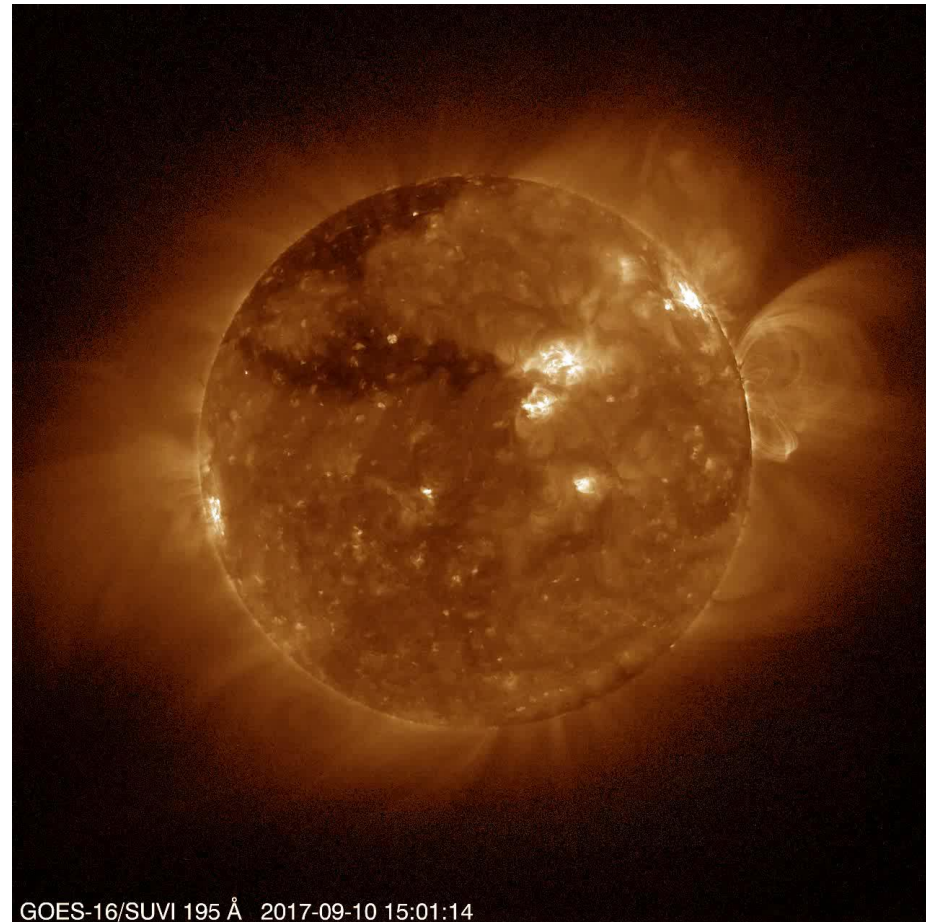
GOES

Geostationary Operational Environmental Satellite

SXI (Solar X-ray Imager)



SUVI (Solar UltraViolet Imager)

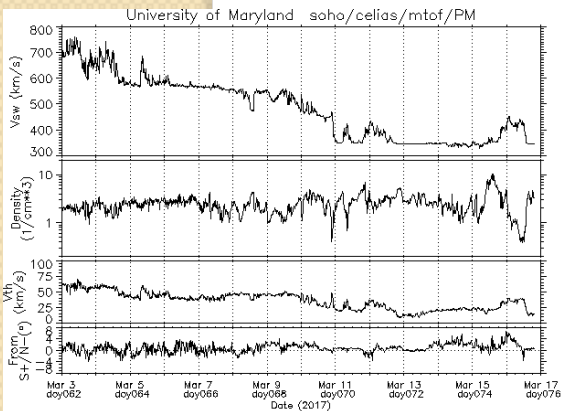
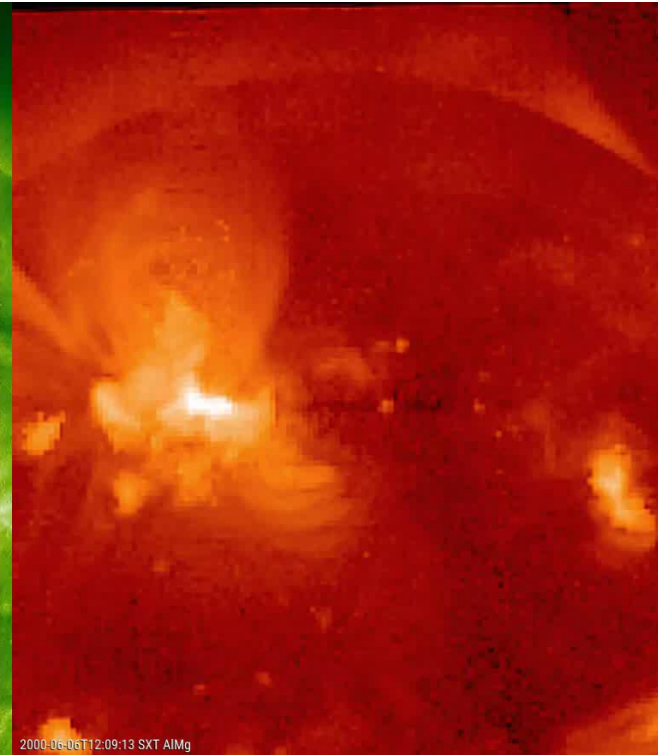
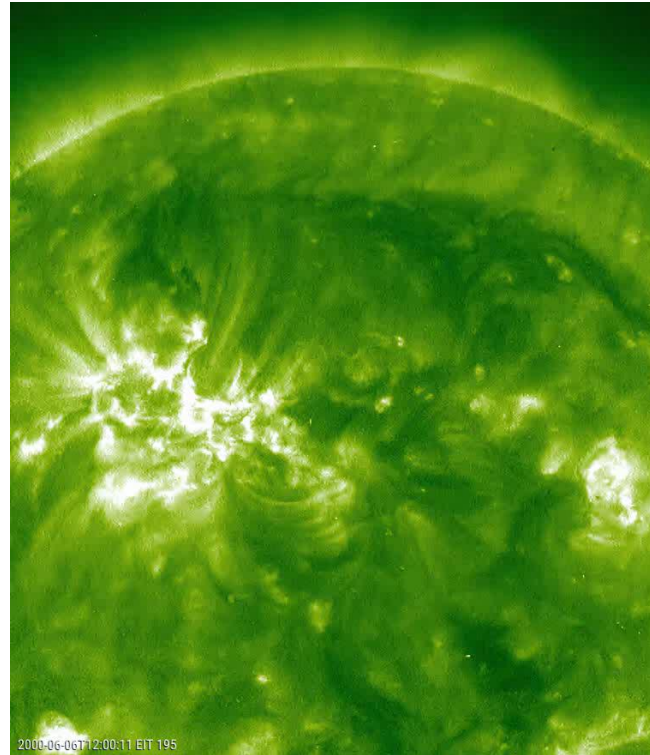
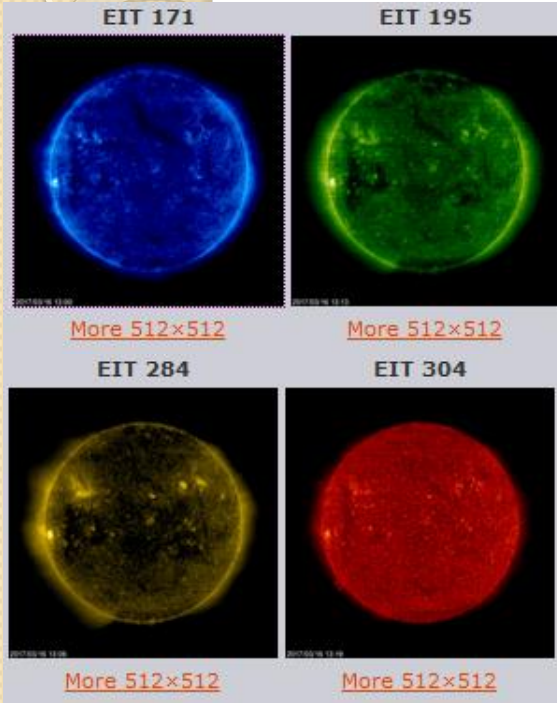


SOHO

Solar and Heliospheric Observatory

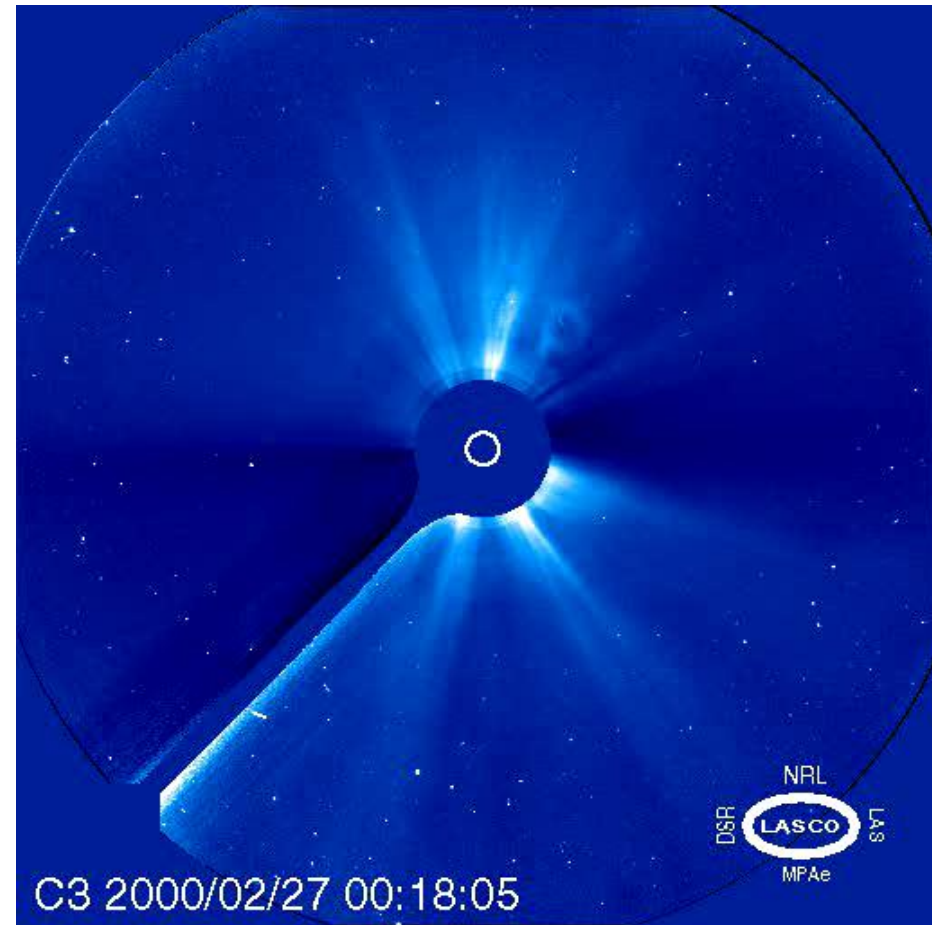
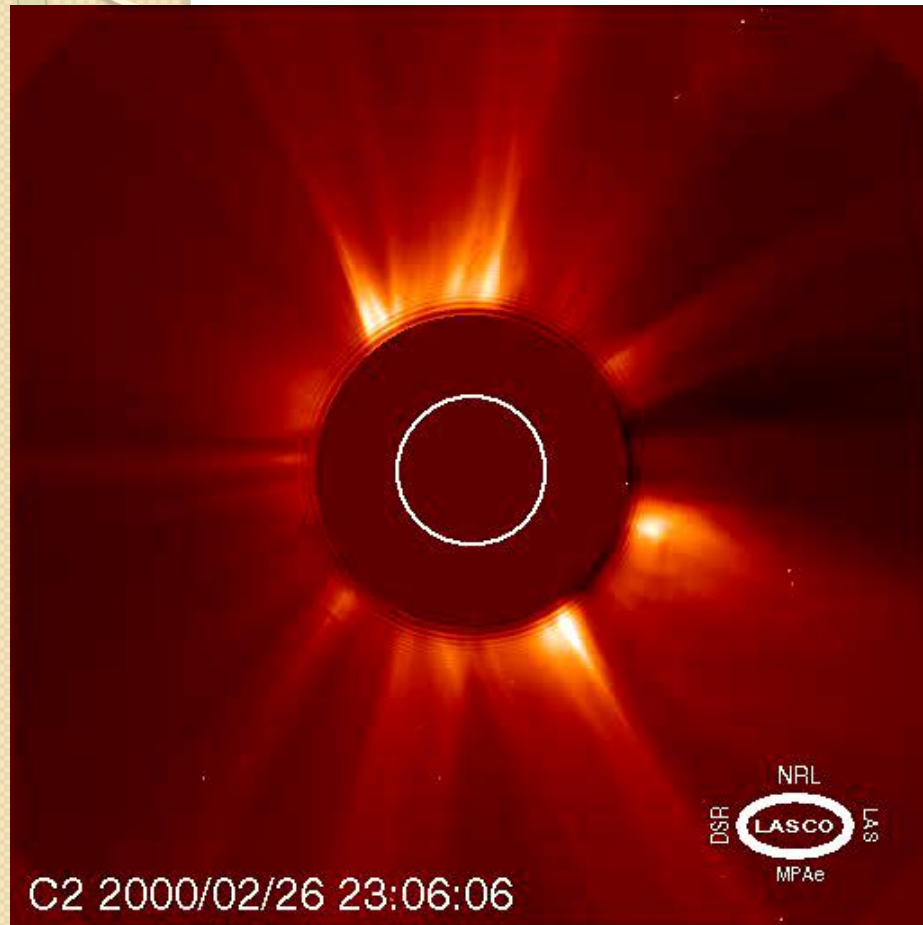
SOHO

YOHKOH



SOHO

Solar and Heliospheric Observatory

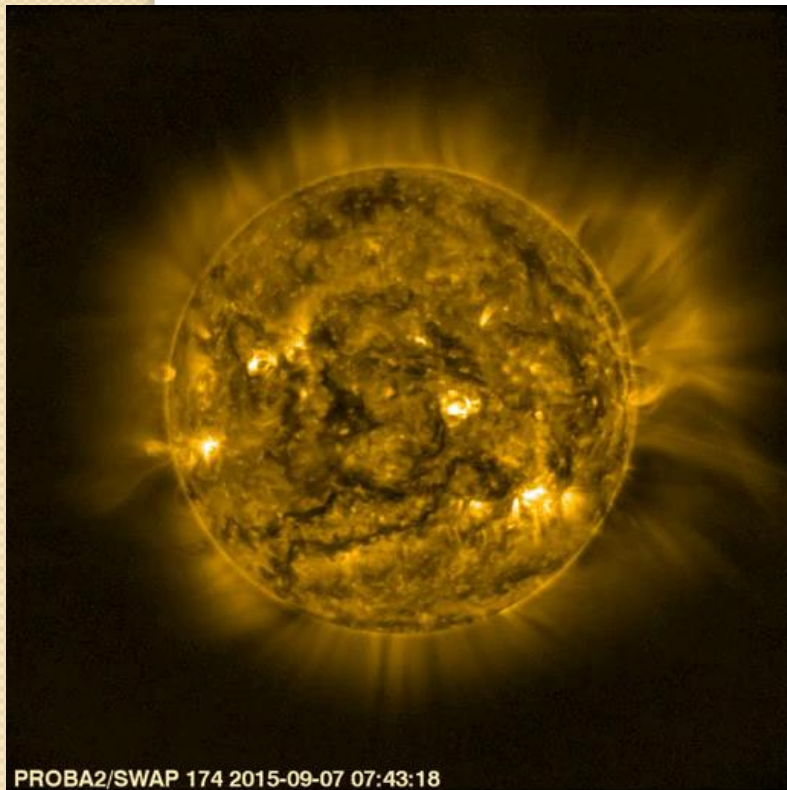


PROBA2

Project for On-Board Autonomy

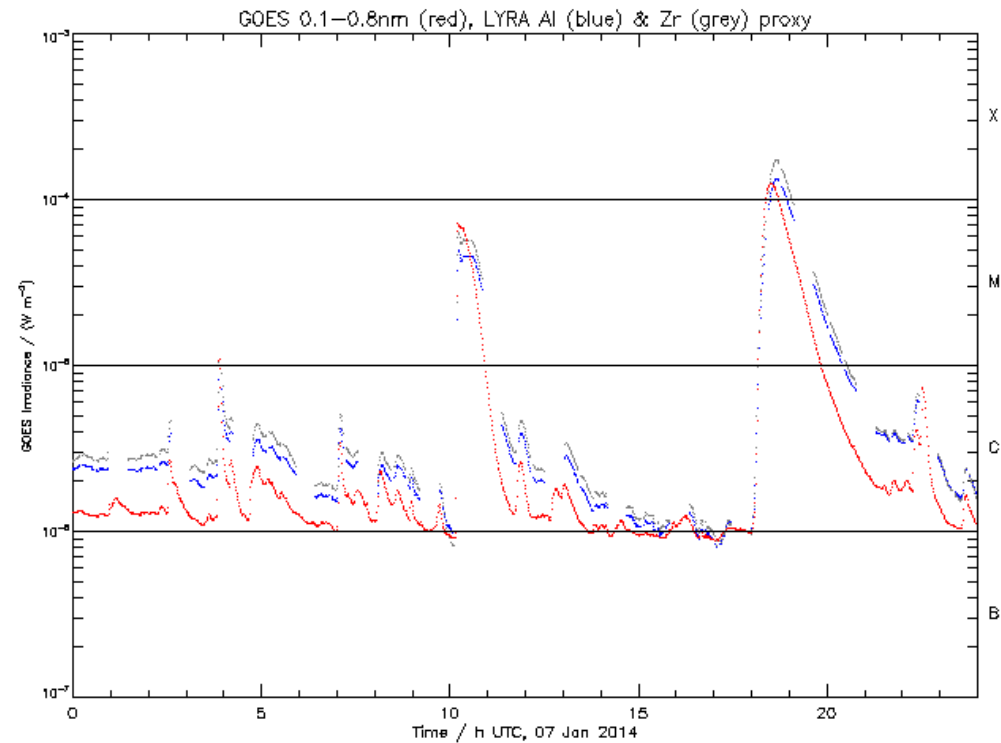
SWAP

Sun Watcher using Active Pixel System detector and Image Processing



LYRA

Large Yield Radiometer



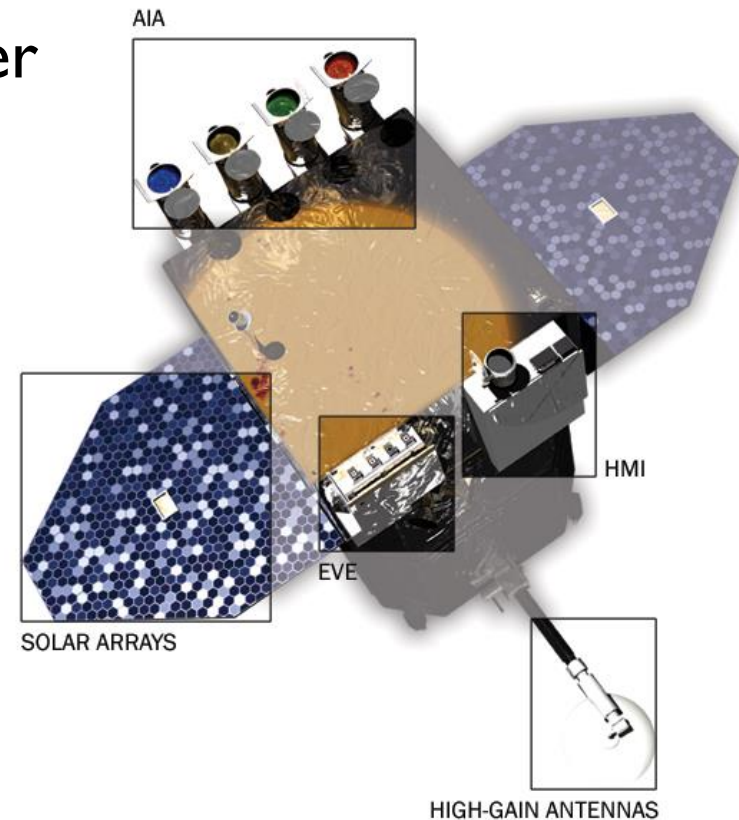
ROB/SIDC, Brussels, Belgium

<https://proba2.sidc.be>

SDO

Solar Dynamics Observatory

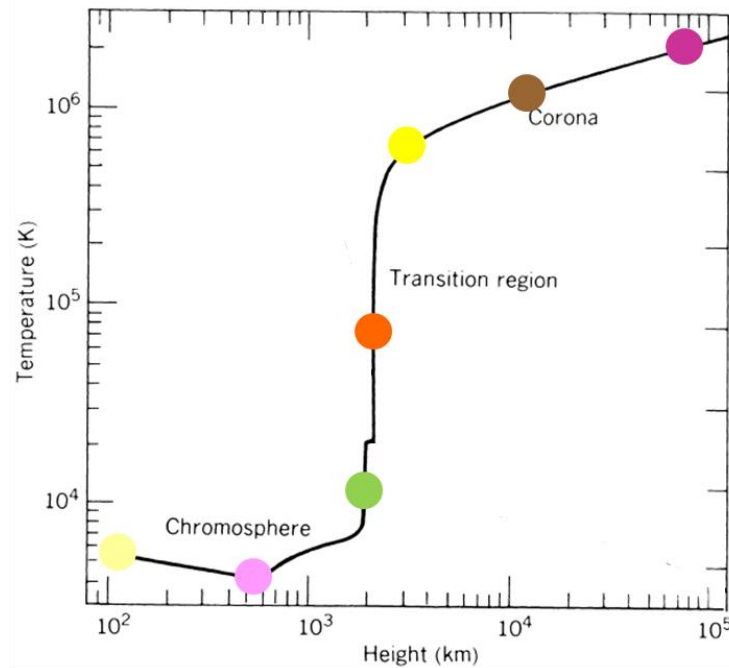
- **HMI**
 - Helioseismic and Magnetic Imager
 - « Wit licht » en Magnetograms
- **AIA**
 - Atmospheric Imaging Assembly
 - EUV beelden met 10 filters
- **EVE**
 - Extreme ultraviolet Variability Experiment
 - Geschaald naar GOES x-ray metingen



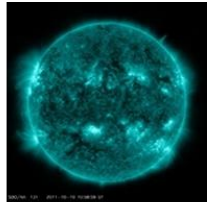
SDO

Solar Dynamics Observatory

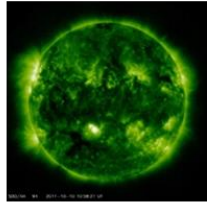
- AIA
 - Sommige filters hebben pieken op verschillende temperaturen
 - AIA 4500 niet langer in gebruik



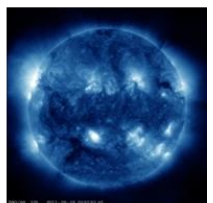
131Å



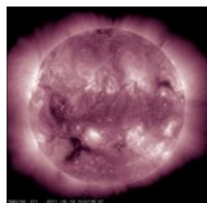
094Å



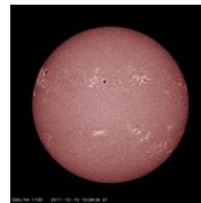
335Å



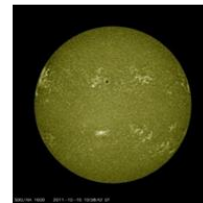
211Å



4500Å



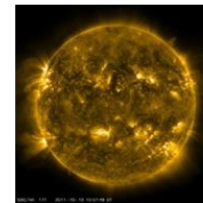
1700Å



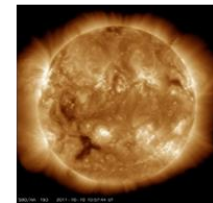
1600Å



304Å



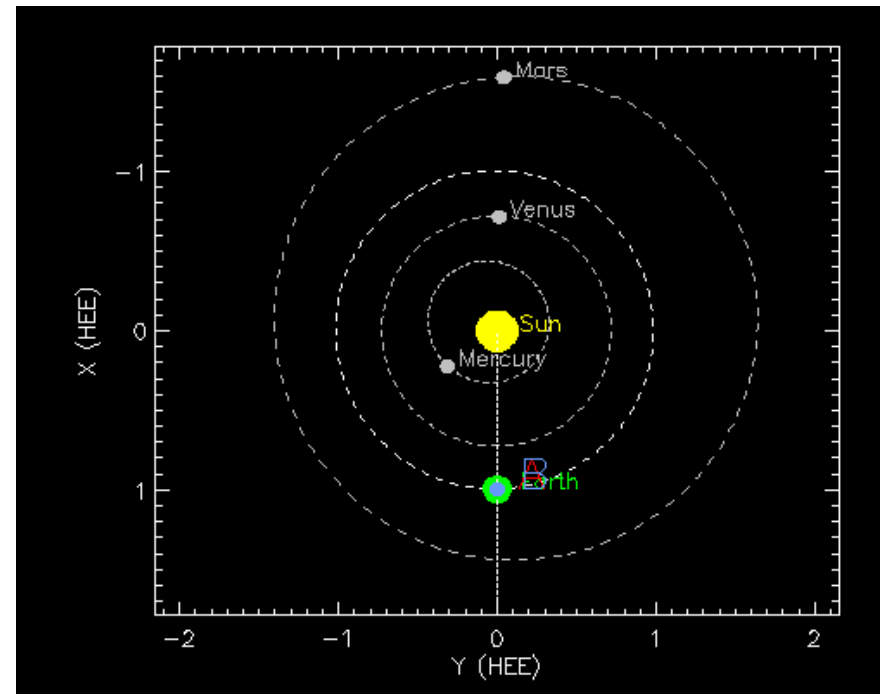
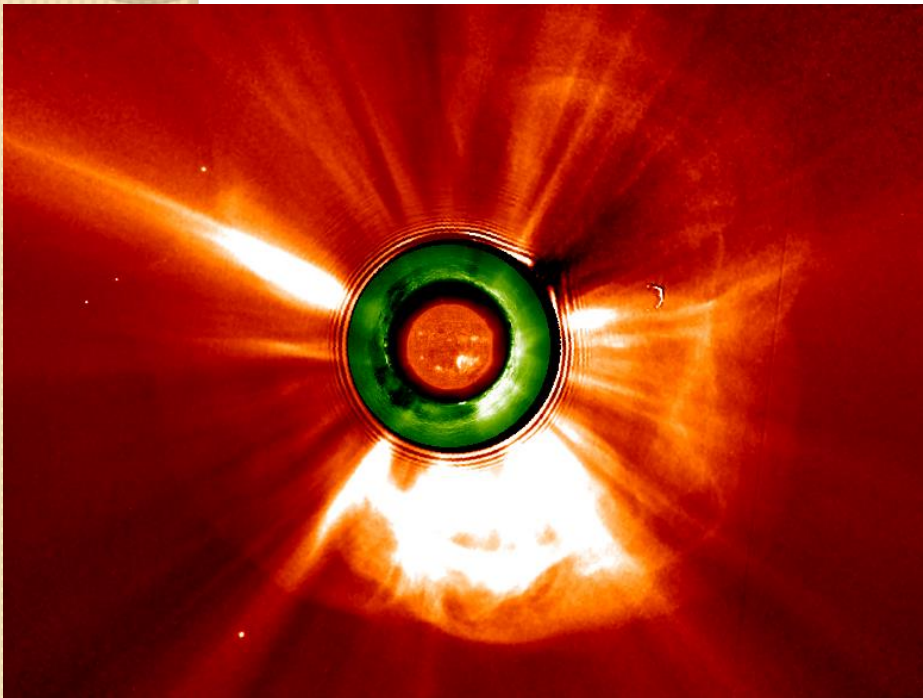
171Å



193Å

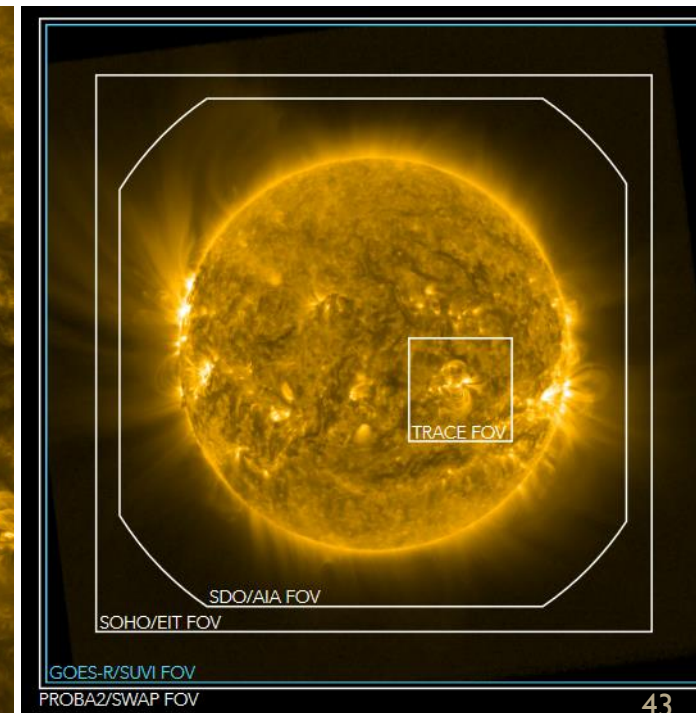
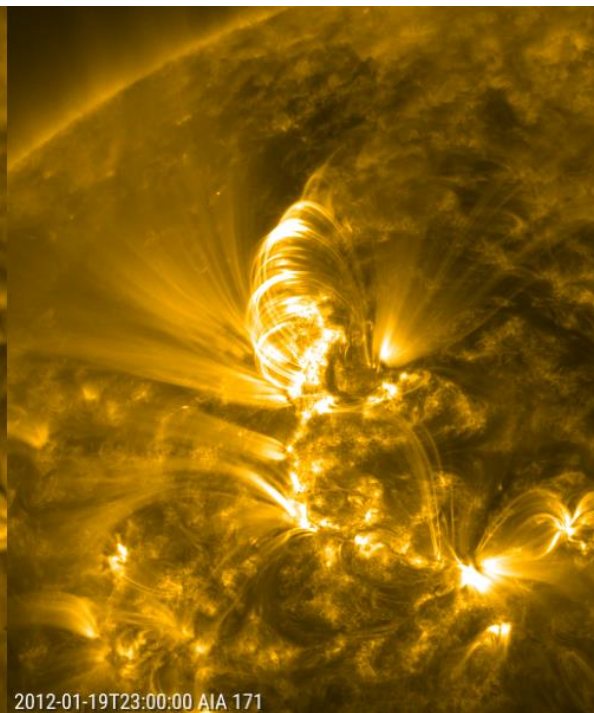
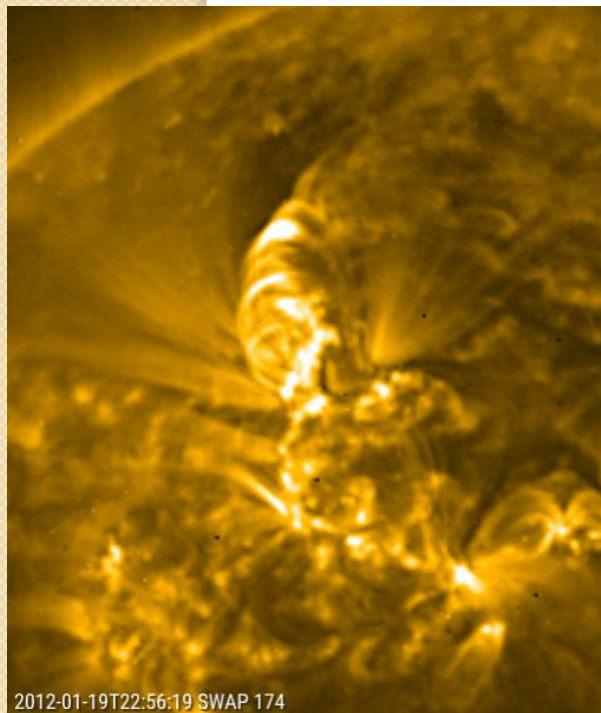
STEREO

Solar-Terrestrial Relations Observatory



Satellieten - Vergelijking

Year	Satellite/Instrument	Resolution (arc seconds/px)	Cadence (seconds/image)	Field of view (arc minutes)	Passbands (#)
1995	SOHO/EIT	2.6	720	45	4
1998	(TRACE)	0.5	10	8.5	8
2006	STEREO/EUVI	1.6	120	54	4
2009	PROBA2/SWAP	3.17	100	54	1
2010	SDO/AIA	0.6	5	41	10
2016	GOES16/SUVI	2.5	10	53	6



Satellites got talent!...

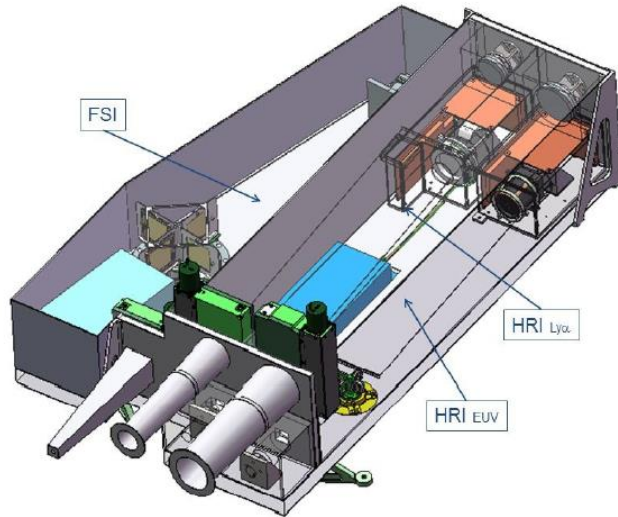


Nieuwe bril I: Solar Orbiter

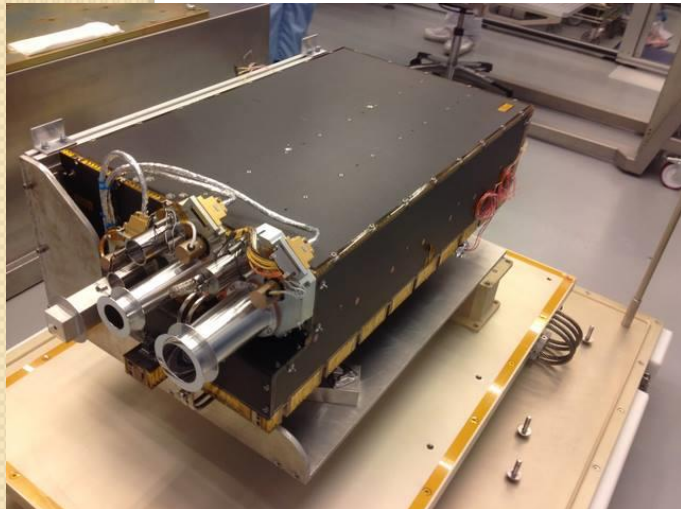


<https://www.youtube.com/watch?v=DkbWvDXo0I4>

Nieuwe bril I: Solar Orbiter



Schühle et al., Proceedings of SPIE 8148, 2011



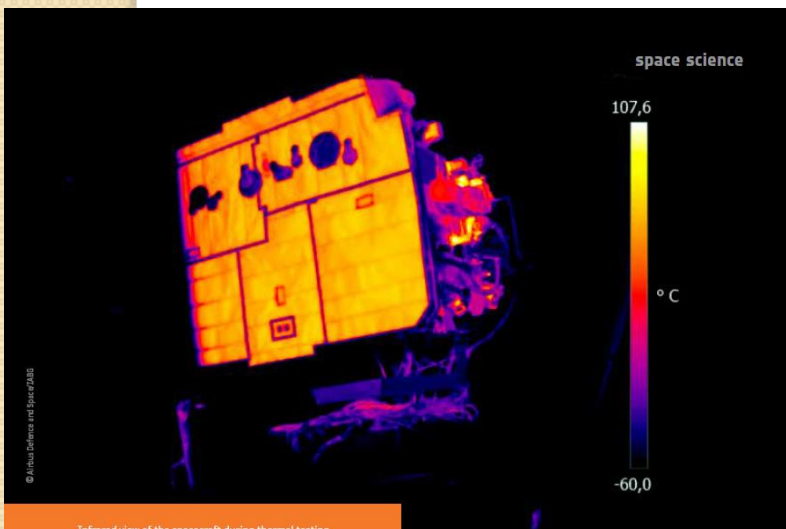
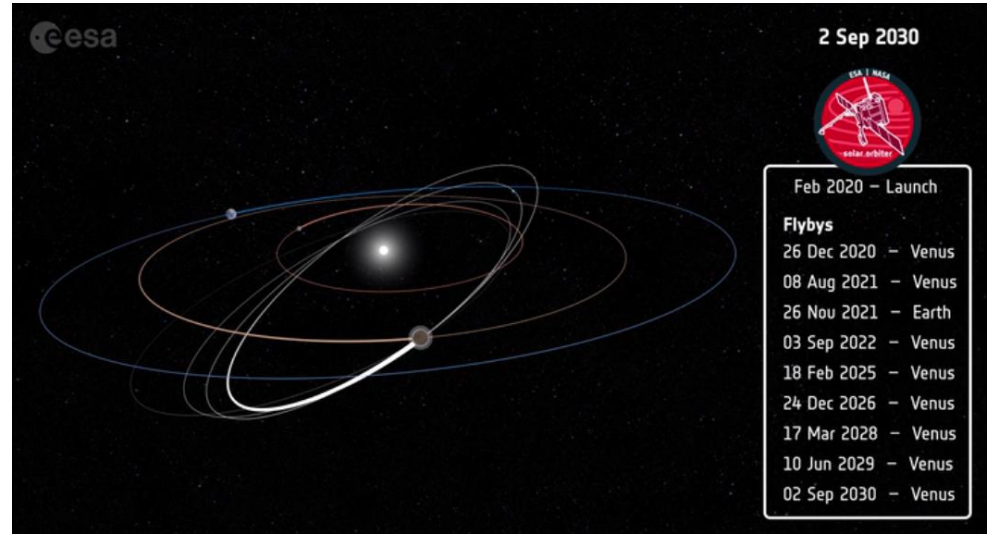
EUI: Extreme Ultraviolet Imager

Channel	Parameter	Values
FSI	Passband	17.4 nm & 30.4 nm
	FOV	3.8 arcdeg
	Resolution (2 px)	9 arcsec
	Cadence	600 s
HRI _{EUV}	Passband	17.4 nm
	FOV	0.28 arcdeg
	Resolution (2 px)	1 arcsec
	Cadence	≥ 1 s
HRI _{Lya}	Passband	121.6 nm
	FOV	0.28 arcdeg
	Resolution (2 px)	1 arcsec
	Cadence	≤ 1 s

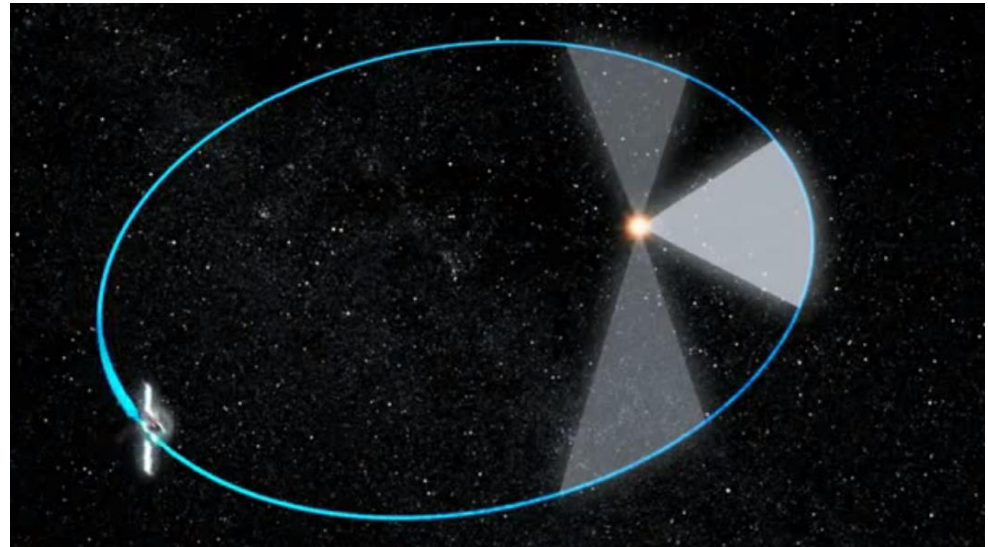
Halain et al., Proceedings of SPIE, July 2012

Nieuwe bril I: Solar Orbiter

Solar Orbiter's 'SolarBlack' heatshield, with covers to protect some of the instruments. Picture taken during a solar array deployment test.



Infrared view of the spacecraft during thermal testing

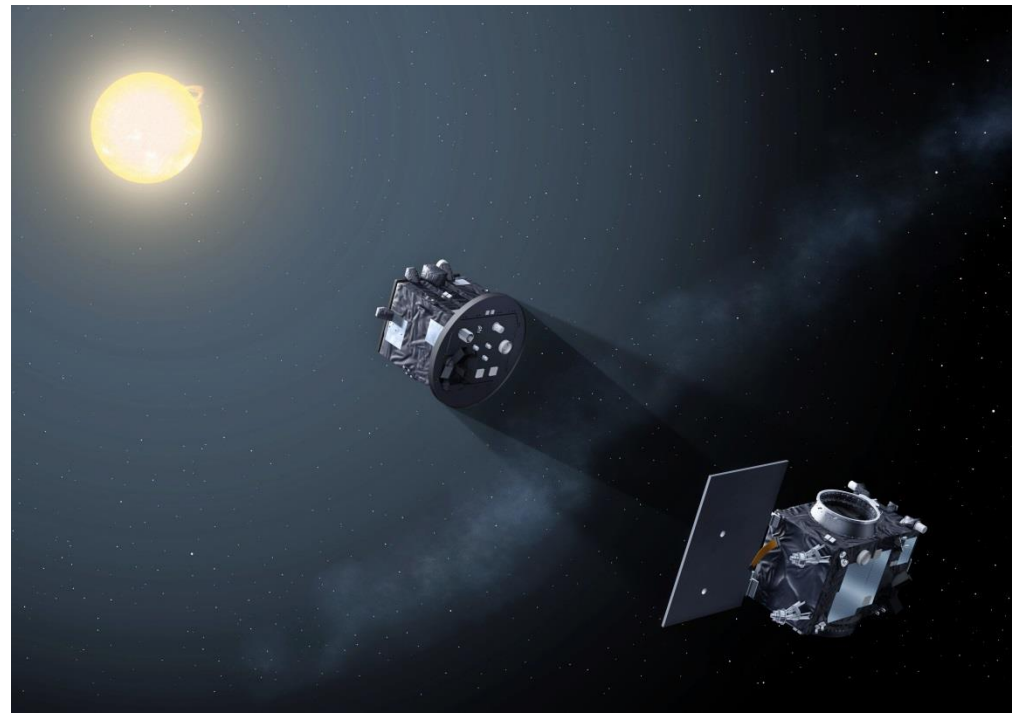


Credits: ESA: Solar Orbiter – Facing the Sun

Nieuwe bril 2: Top Gun in Space

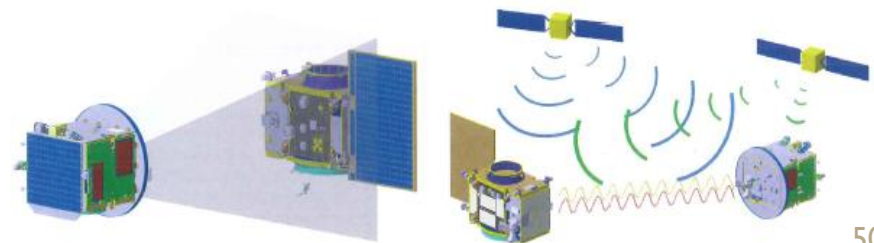
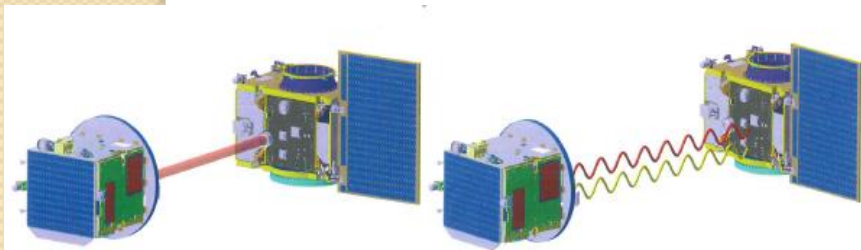


Nieuwe bril 2: PROBA3 / ASIICS



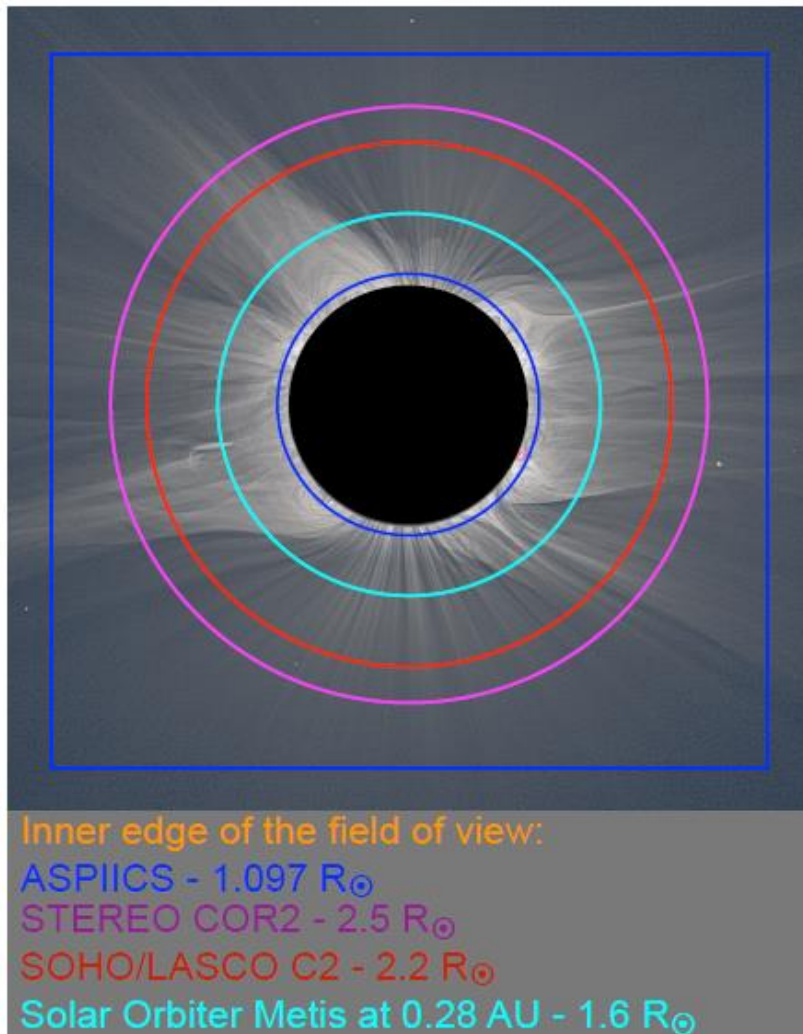
Nieuwe bril 2: PROBA3 / ASPIICS

Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun

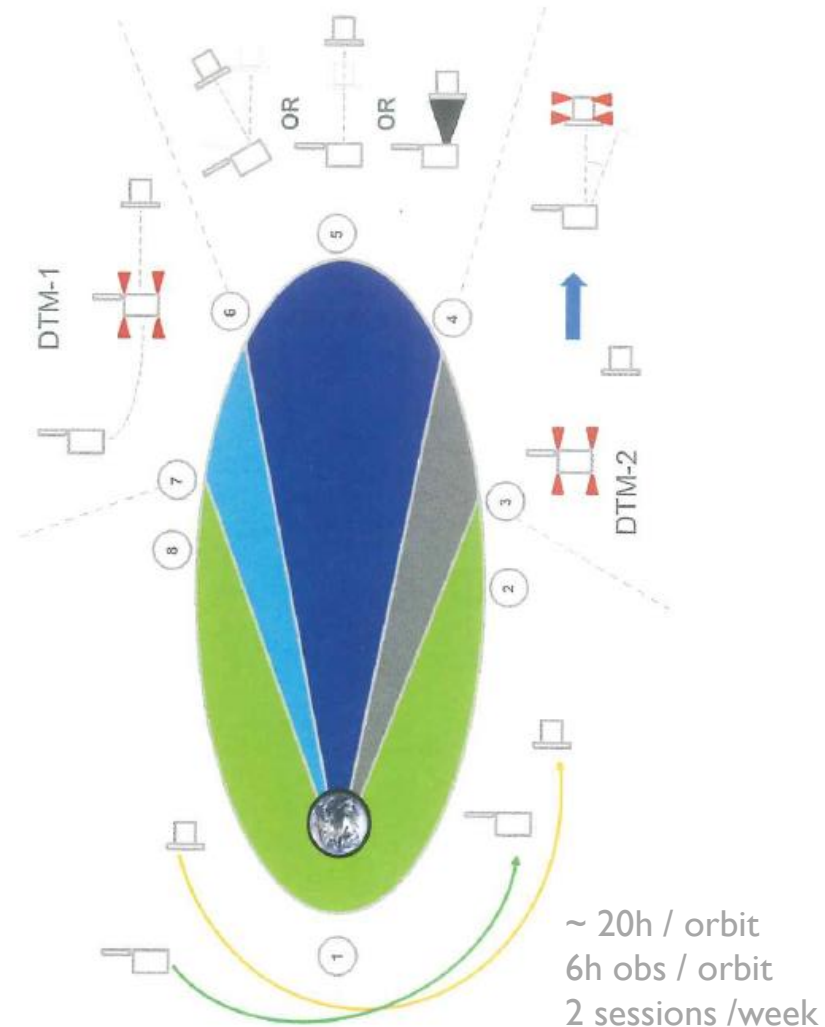


Nieuwe bril 2: PROBA3 / ASPIICS

Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun



Credits: Andrei Zhukov



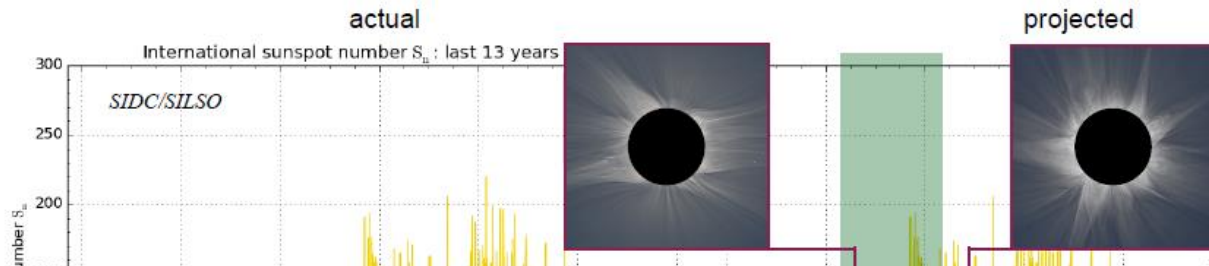
Penin, Galano, Mellab et al., ROOM, 2018

<https://room.eu.com>

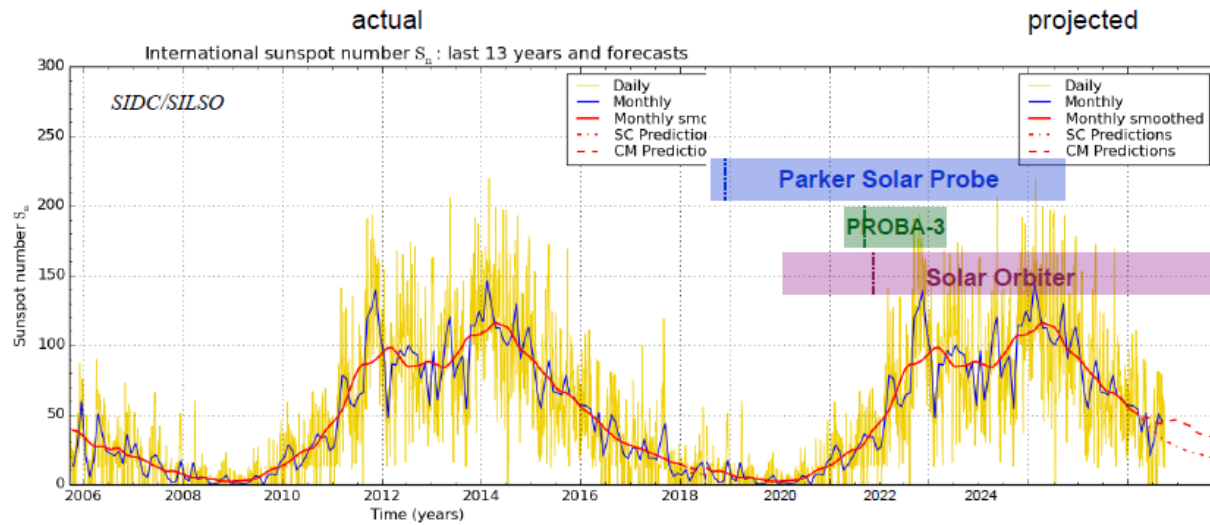
Nieuwe bril 2: PROBA3 / ASIICS

Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun

What will the corona look like?



PROBA-3 in synergy with other missions

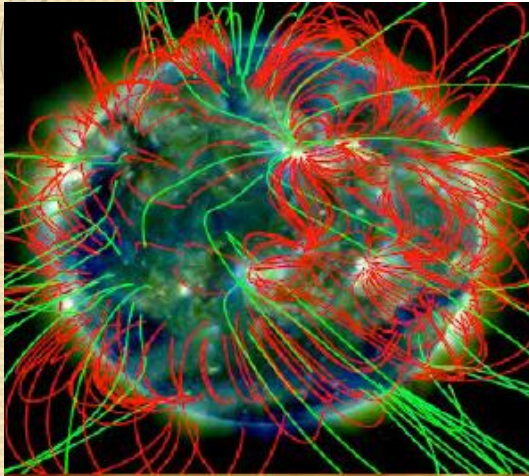


Credits: Andrei Zhukov

Nieuwe bril 3: Lagrange



Nieuwe bril 3: Lagrange



EUV Imager (EUVI)

Single channel 19.5 nm

Photospheric Magnetic Field Imager (PMI)

Vector magnetograph (Zeeman line scanning)

Compact Coronagraph (CCOR)

~3 to 22 solar radii

Heliospheric Imager (HI)

4 to 70 degree

LAGRANGE (L5)

Remote/optical

In-situ

X-ray Flux Monitor (XFM)

Magnetometer (MAG)

Plasma Analyser (PLA)

Medium Energy Particle Spectrometer (MEPS)

Radiation Monitor (RM)

Credits: Stefan Kraft (ESA/Lagrange)

Nieuwe bril 3: Lagrange

Operation 5-10 years

Breaking manoeuvre

Operation during transfer

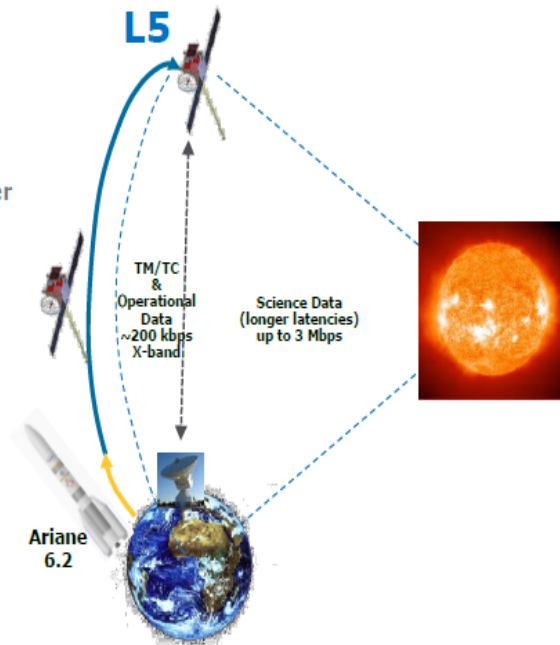
Transfer (14 or 26 m)

Commissioning

S/C (1st month)
In-situ (2nd month)
Optical (4th month)

Launch in 2025

Direct injection



Instrument	Performance (latency/cadence)
Photospheric Magnetic field Imager (PMI)	Range: +/-4 kG Accuracy: 10 G, Zero 0.1G 1.2 arcsec / pixel, (40'/ 30')
EUV Imager (EUVI)	19.5 nm 1.6 arcsec / pixel, (15'/5')
Compact Coronagraph (CCOR)	3 to 22 Solar Radii 1 arcmin / pixel, (15'/5')
Heliospheric Imager (HI)	4° to 70°, 2 arcmin / pixel, (50'/30')
Plasma Analyser (PLA)	±22.5° x 45°, 5° angular 70 eV to 33 keV, (15'/1')
Medium Energy Particle Spectrometer (MEPS)	30 keV/nuc up to 8 MeV/nuc (ions) 30 keV to 0.6 MeV(electrons) 32/16 channels, 2x2 look directions, (15'',1')
Magnetometer (MAG)	Absolute accuracy 1 nT (15'/1')
Radiation Monitor (RM)	2 MeV to 1 GeV (p+, ions), directional 100 keV to 8 MeV (electrons), (15'/1')
X-ray Flux Monitor (XFM)	0.05 to 0.8 nm / 1.55 keV to 25 keV 512 channels, 400 eV @ 6 keV, (15'/1')

Credits: Stefan Kraft (ESA/Lagrange)

Vragen?...

