

# SPACE WEATHER INTRODUCTORY COURSE



Collaboration of



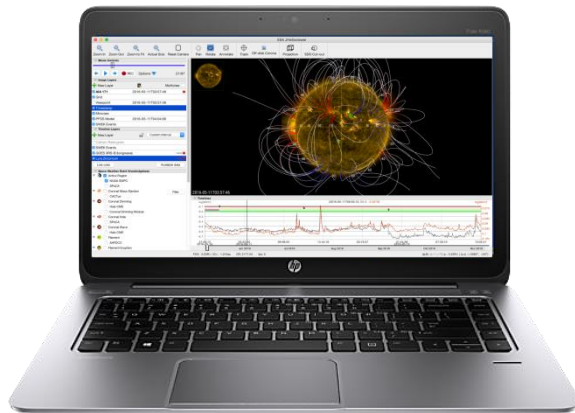
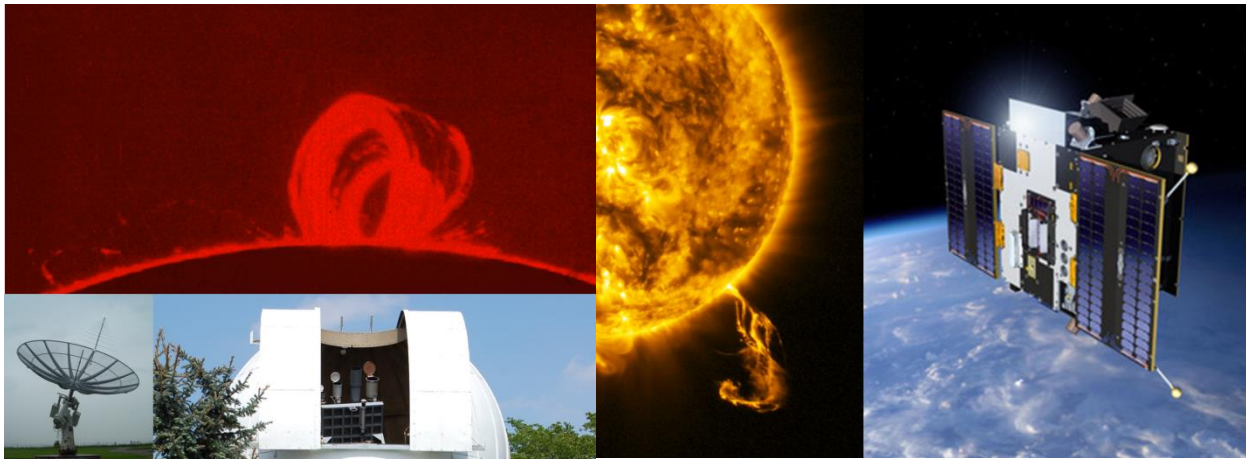
**Solar-Terrestrial Centre of Excellence**



**Koninklijke luchtmacht**



**Koninklijk Nederlands  
Meteorologisch Instituut**  
*Ministerie van Infrastructuur en Milieu*



## Sensors & measurements

Jan Janssens, Dr Christophe Marqué

# Contents



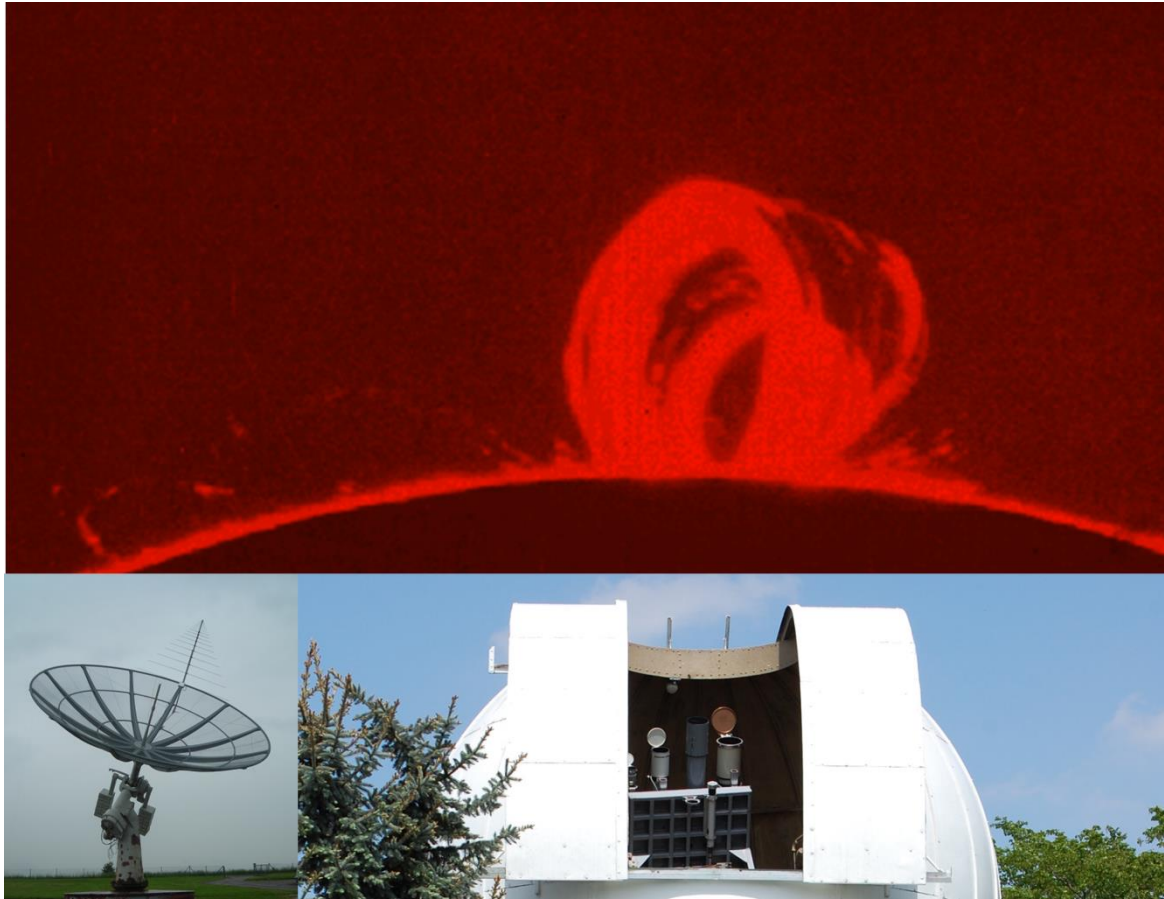
- **Groundbased sensors**

- Visible light
- Radio domain
  - Humain
- Magnetosphere-Ionosphere
- Geomagnetism
- Neutron monitors
  - Dourbes

- **Spacebased sensors**

- GOES
- SDO
- PROBA2
- SOHO
- ACE
- DSCOVR
- STEREO





## Groundbased sensors

Jan Janssens, Dr Christophe Marqué



# Visible light

- GONG Network
  - White Light (WL)
  - H-alpha ( $H\alpha$ )
  - Magnetogram
- SILSO
  - Sunspot number (Sn)
  - USET
    - WL,  $H\alpha$ , CaIK
    - 250 obs. days / year
- Catania
- NOAA / SOON

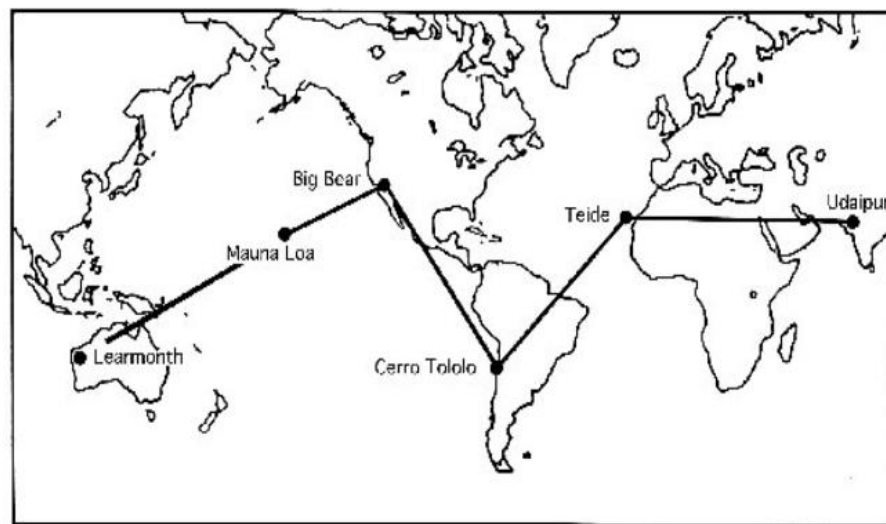
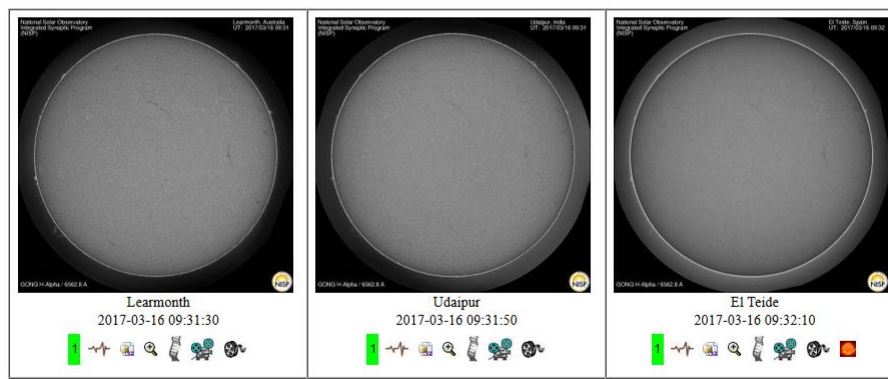
Global Oscillation Network Group

H Alpha Network Monitor



Views: [Main](#) [All](#) [Movies](#) [Archive](#) [Dashboard](#) [History](#)


Main View





# Visible light

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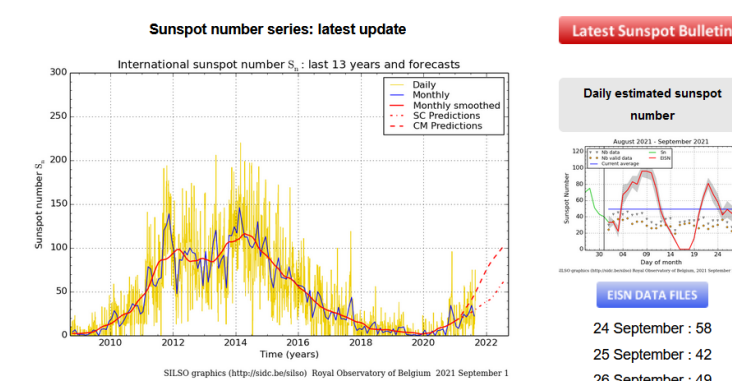
Sunspot Index and Long-term Solar Observations

**Menu**

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- Analyses
- FAQ & News
- Observers
- Contact
- Legal notices

Home Data Products Analyses FAQ & NEWS Observers Contact

World Data Center for the production, preservation and dissemination of the international sunspot number



★★★★★



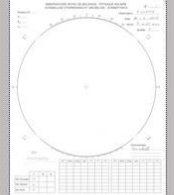
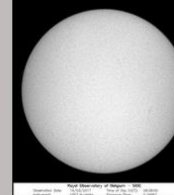
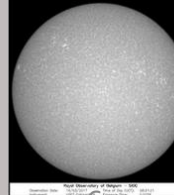
USET - The Uccle Solar Equatorial Table 

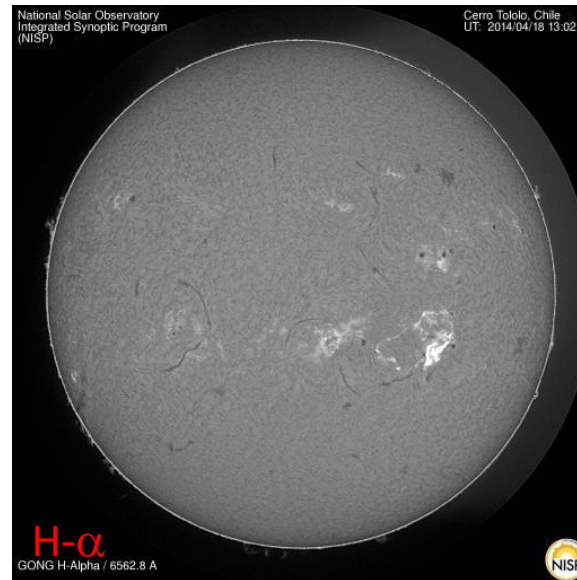
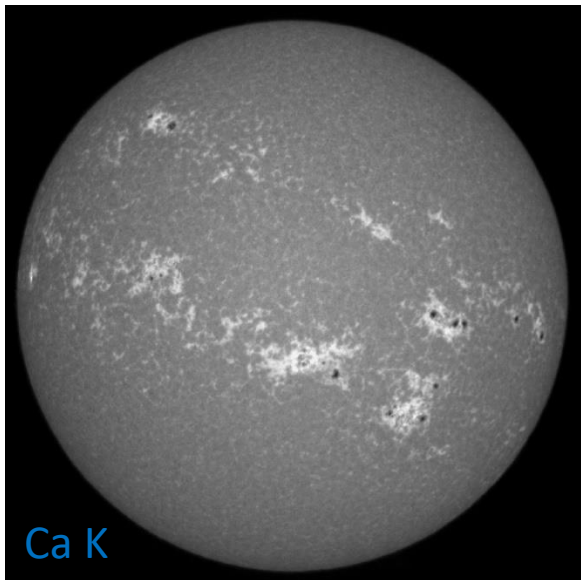
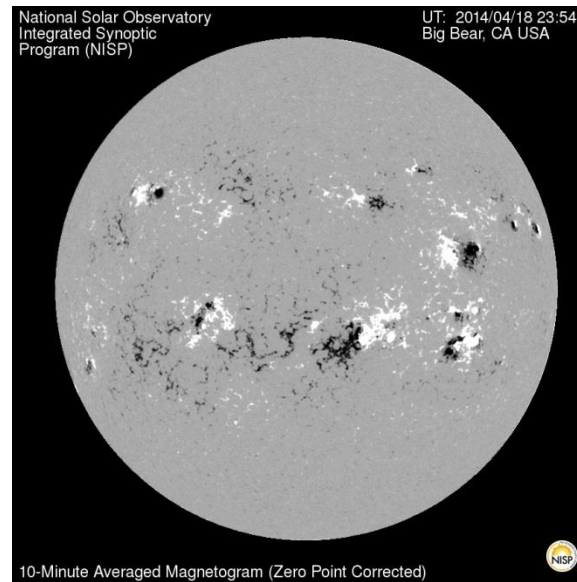
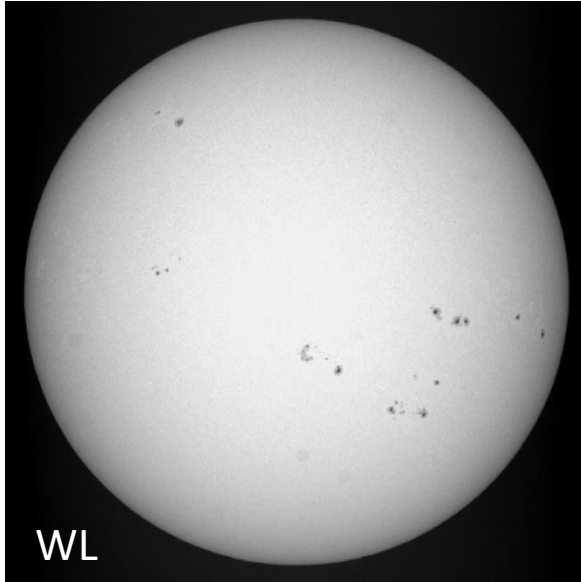
Image Gallery Movies Technical Data

Latest images

White-light	Latest Drawing	H-alpha	Ca-IIK
			
16/03/2017 - 08h32	16/03/2017 - 08h25	16/03/2017 - 08h38	16/03/2017 - 08h31



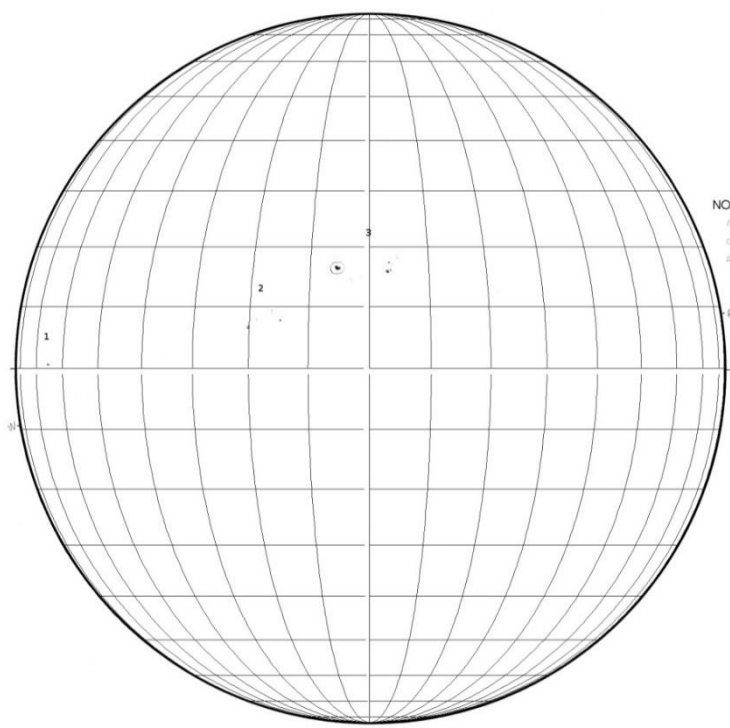
# Ground views from the Sun





# Visible light

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  - White Light (WL)
  - H-alpha ( $H\alpha$ )
  - Magnetogram
- SILSO
  - Sunspot number ( $S_n$ )
  - USET
    - WL,  $H\alpha$ , CaIIK
    - 250 obs. days / year
- Catania
- NOAA / SOON



INAF - CATANIA OSSERVATORIO ASTROFISICO

SUNSPOT OBSERVATIONS (U.T.)

year	month	day	hour	min	P	Bo	Lo
2017	JAN	24	09	20	-8.64	-8.40	180.00

Obs. P. COSTA S 2 Q 2 R 52

NOAA	g	cat	s	p	Z	lat	long	A(mm)
7830	1	A8	00	02	A	66.0	66.0	000.50
7831	2	80	01	06	C	16.0	16.0	002.50
7832	3	81	02	12	D	12.0	12.0	018.00
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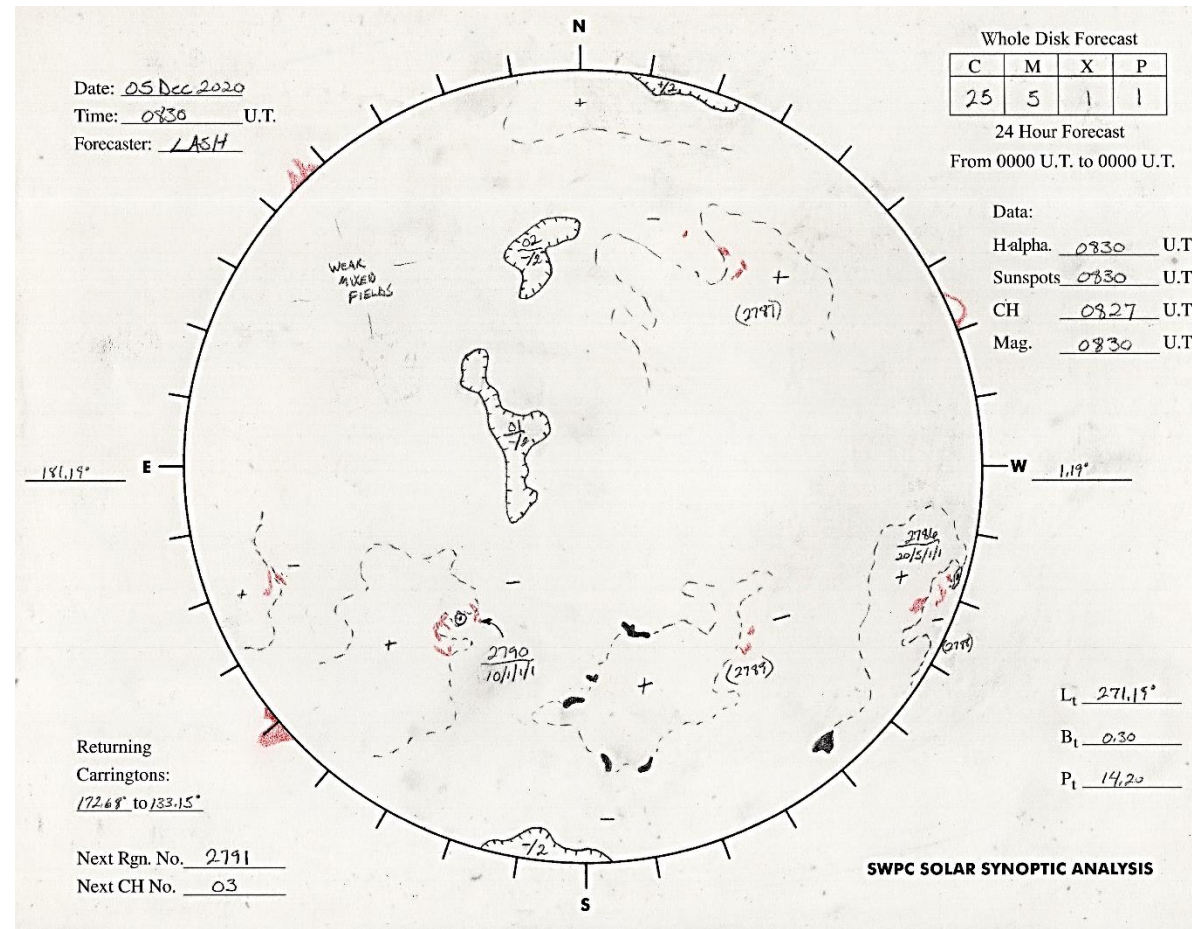
Catania info ( Last update: 2017-Jan-24 )						NOAA info ( Last update: 2017-Jan-24 )					Probabilities for			
Number	area	nspots	Zurich	Longitude	Latitude	Number	Macintosh	Mag. type	Longitude	Latitude	C flare	M flare	X flare	Proton
78	1	2	A	66.0	7.0	2626	Hsx	Alpha	63.0	8.0	--	--	--	--
80	3	7	C	16.0	6.0	2627	Dai	Beta	12.0	6.0	--	--	--	--
81	19	14	D	-2.0	12.0	2628	Dso	Beta	-7.0	12.0	--	--	--	--





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    - 250 obs. days/yr
- Catania
- NOAA / SOON
  - National Oceanic and Atmospheric Administration
  - Solar Observing Optical Network



:Issued: 2014 Apr 17 1325 UTC

:Product: documentation at <http://www.sidc.be/products/tot>

#-----#

# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #

#-----#

SIDC URSIGRAM 40417

SIDC SOLAR BULLETIN 17 Apr 2014, 1304UT

SIDC FORECAST (valid from 1230UT, 17 Apr 2014 until 19 Apr 2014)

SOLAR FLARES : Active (M-class flares expected, probability >=50%)

GEOMAGNETISM : Quiet (A<20 and K<4)

SOLAR PROTONS : Quiet

PREDICTIONS FOR 17 Apr 2014 10CM FLUX: 180 / AP: 013

PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007

PREDICTIONS FOR 19 Apr 2014 10CM FLUX: 188 / AP: 005

COMMENT: Eleven sunspot groups were reported by NOAA today. NOAA ARs 2035, 2036, and 2037 (Catania numbers 24, 25, and 26 respectively) maintain the beta-gamma configuration of the photospheric magnetic field. The strongest flare of the past 24 hours was the M1.0 flare peaking at 19:59 UT yesterday in the NOAA AR 2035 (Catania number 24). The flare was associated with an EIT wave and a weak coronal dimming, but the associated CME was narrow and is not expected to arrive at the Earth.

We expect further flaring activity on the C-level, especially in the NOAA ARs 2035 and 2037 (Catania numbers 24 and 26 respectively) as well as in the NOAA AR 2042 (no Catania number yet) that yesterday appeared from behind the east solar limb, with a good chance for an M-class event.

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We expect quiet to unsettled (K index up to 3) geomagnetic conditions, with active geomagnetic conditions (K = 4) possible, but unlikely.

TODAY'S ESTIMATED ISN : 145, BASED ON 17 STATIONS.

99999

SOLAR INDICES FOR 16 Apr 2014  
WOLF NUMBER CATANIA : ///

10CM SOLAR FLUX : 184

AK CHAMBON LA FORET : 012

AK WINGST : 004

ESTIMATED AP : 004

ESTIMATED ISN : 139, BASED ON 29 STATIONS.

NOTICEABLE EVENTS SUMMARY

DAY	BEGIN	MAX	END	LOC	XRAY	OP	10CM	Catania/NOAA	RADIO_BURST_TYPES
16	1954	1959	2004	S14E09	M1.0	1N		24/2035	II/2
END									



*Finding your way  
in the  
URSIgram*

## Catania & NOAA regions

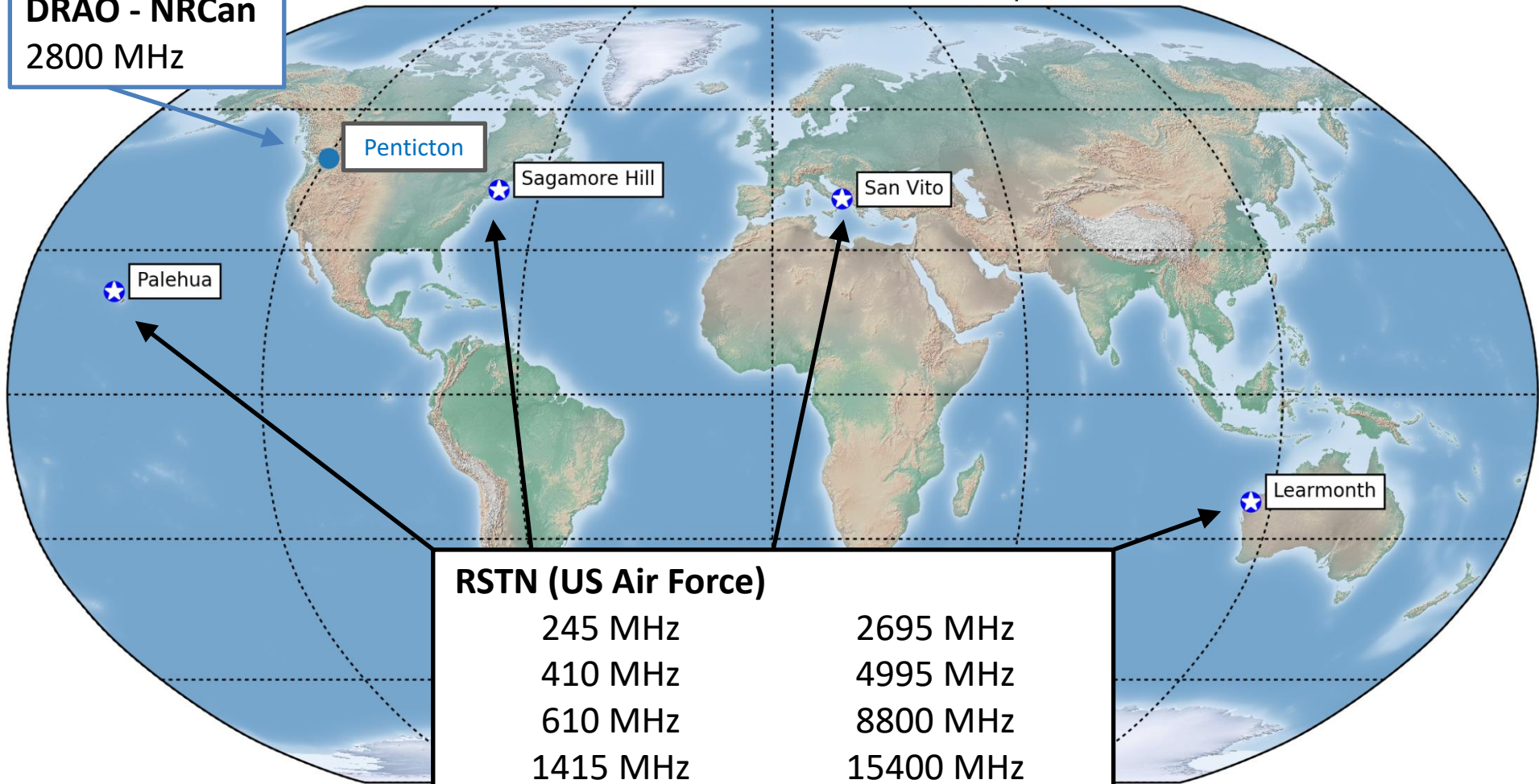
## Sunspot numbers



# Radio observations

Solar radio observations from NOAA reports

**DRAO - NRCan**  
2800 MHz



**RSTN (US Air Force)**

245 MHz	2695 MHz
410 MHz	4995 MHz
610 MHz	8800 MHz
1415 MHz	15400 MHz

Dynamic spectra 25 – 180 MHz





# Radio burst magnitudes

## Typ. Quiet Sun values [SFU]

Frequency	Solar min.	Solar max. (Z=200)
245 MHz	10	15
410 MHz	25	35
610 MHz	30	45
1415 MHz	50	100
2695 MHz	70	200
2800 MHz	70	200
4995 MHz	100	200
8800 MHz	220	290
15400 MHz	580	650

1 sfu = 1 solar flux unit =  $10^{-22} \text{ W}\cdot\text{m}^{-2}\cdot\text{Hz}^{-1}$

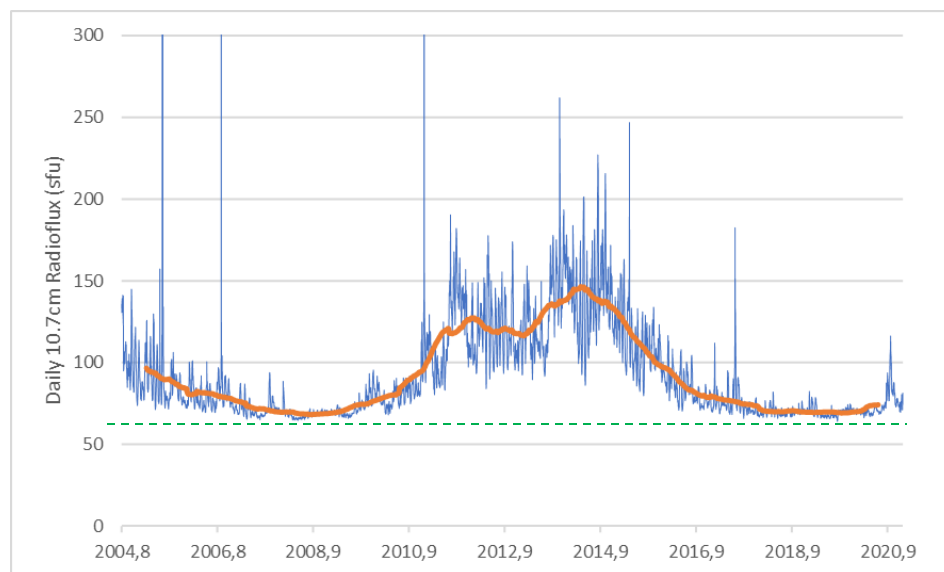




# Penticton



- Flux measurement at 2800 MHz (10.7 cm), 100 MHz bandwidth
- 3 times per day
- “official” value for the day is the one of 20:00 UT (local noon)
- Accuracy:
  - < 100 sfu: 1 sfu
  - > 100 sfu: 1% of flux
- Uncorrected for solar flares
- R-, S-, Q-component



:Issued: 2014 Apr 17 1325 UTC

:Product: documentation at <http://www.sidc.be/products/tot>

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10CM SOLAR FLUX : 184

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ESTIMATED AP : 004

ESTIMATED ISN : 139, BASED ON 29 STATIONS.

NOTICEABLE EVENTS SUMMARY

DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO\_BURST\_TYPES

16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2

END



**10.7cm Radio flux**



# Humain: Solar instruments

- 6-m dish
- Automated operations, Sun tracking ~7h30 – 16h00 UT
- VHF antenna (piggy back)
- UHF antenna at focus

- VHF antenna (45 – 450 MHz)
  - Callisto receiver
  - ARCAS receiver
- UHF antenna (275 – 1495 MHz)
  - HSRS receiver

Data available in near realtime  
<http://sidc.be/humain>

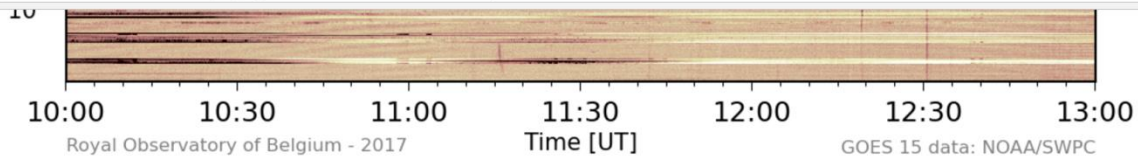


- VHF: Very High Frequency (30-300 MHz)
- UHF: Ultra High Frequency (300-3000 MHz)
- Callisto: Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory
- ARCAS: Augmented Resolution Callisto Spectrometer
- HSRS: Humain Solar Radio Spectrograph

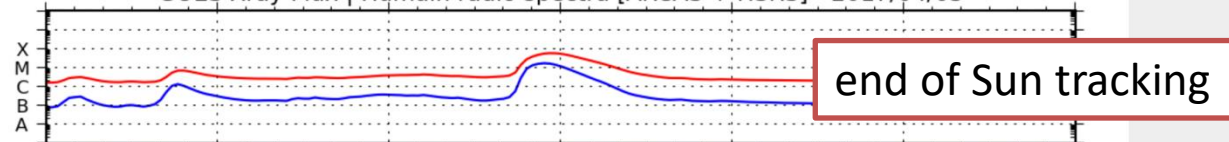




- [Home](#)
- [Instruments](#)
- [Events](#)
- [Team](#)



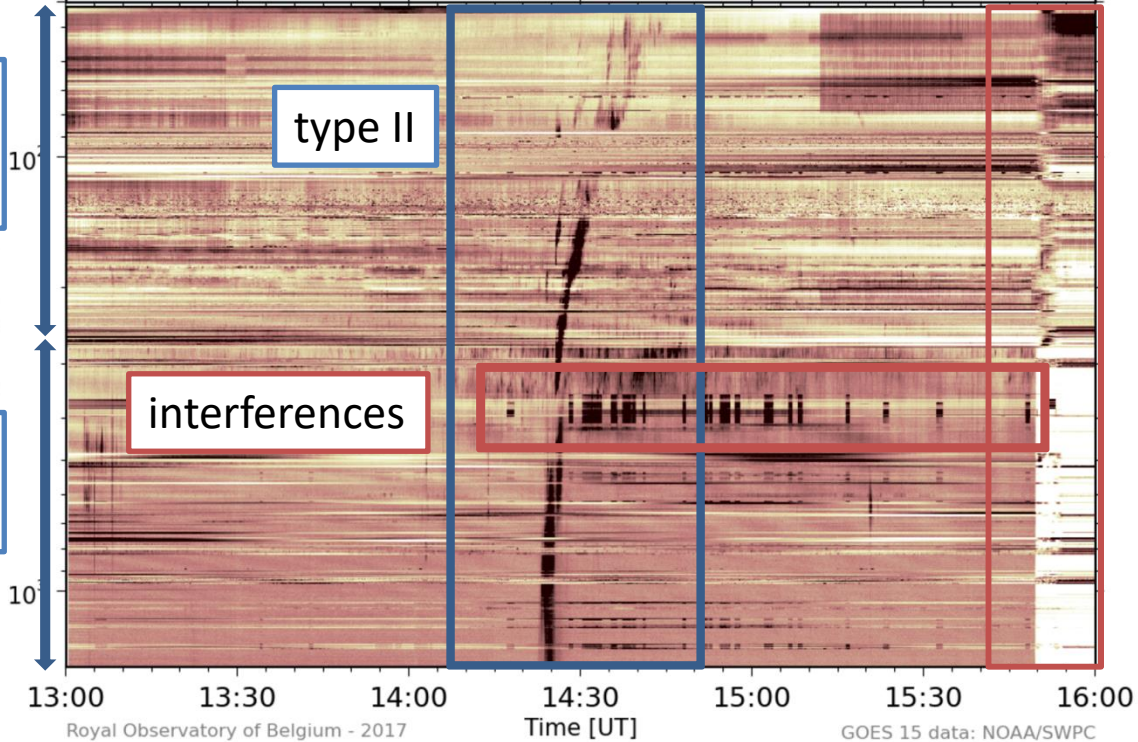
GOES Xray Flux | Humain radio spectra [ARCAS + HSRS] - 2017/04/03



ARCAS

HSRS

frequency [MHz]



**Sun observations in Humain**  
 April 26, 2017

**Solar ephemeris**  
 sunrise: 04:22:13 UT  
 sunset: 18:51:04 UT  
 transit: 11:36:39 UT

**Current observations**  
 Observation status: **ON**  
 ARCAS & HSRS  
[Last hours](#)  
[Spectral overview](#)

Callisto  
[Last spectrum](#)  
[Bursts of the day](#)

**Technical parameters**  
[Monitoring](#)



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END



*Radio bursts*



# Magnetosphere - Ionosphere

## Magnetosphere

- Magnetometers
- Neutron monitors
- ...

⇒ Magnetosphere

⇒ SWx effects



## Ionosphere

- Ionospheric sounders
- Riometers
- ...

⇒ SWx effects – Aviation

⇒ Ionosphere

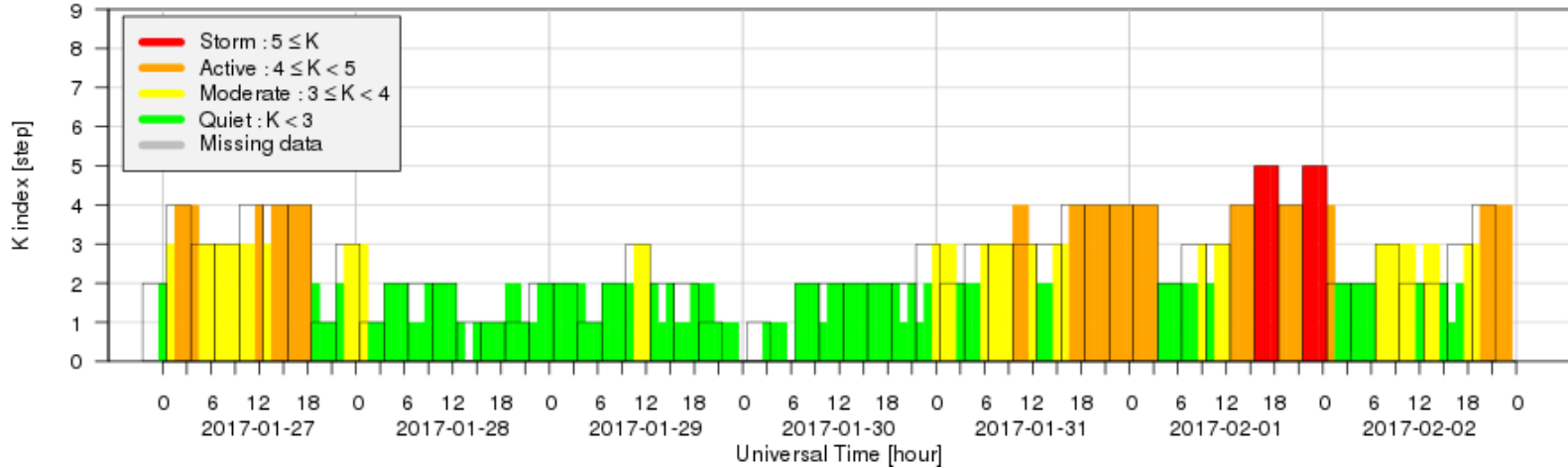




# Dourbes



K-type index of local magnetic activity, Dourbes (50.1°N, 4.6°E)  
(copyright RMI)



**NMDB**  
neutron monitor database

HOME STATIONS | COSMIC RAYS NOW! | DATA AND PRODUCTS | TECHNICAL DOCS | NMDB BROCHURES | PUBLIC OUTREACH | NEWS

**BOOK NAVIGATION**

- NMDB Stations
- Data and Products
- NMDB Documentation
- Public Outreach
- Work Packages and Project Groups
- Meetings and Events
- NMDB news
- Contact Us
- Impressum

**NAVIGATION**

- NMDB site materials

**USER LOGIN**

Username: \*  
Password: \*

**NMDB: REAL-TIME DATABASE FOR HIGH RESOLUTION NEUTRON MONITOR MEASUREMENTS**  
Posted May 21, 2009 - 3:13pm by Adlar Stragrov

**DATA & PRODUCTS**

**COSMIC RAYS NOW!**

**PUBLIC OUTREACH**

**WHO WE ARE**

**TRAINING**



**RMI**  
Ionosphere & Space Weather Services

**Dourbes**  
Belgium

**LDI**  
LOWELL TECHNOLOGIES INTERNATIONAL

**DIGISONDE 4D**  
PORTABLE SOUNDER

Ionograms | Skymaps | Drift Velocities | Directograms

2017-May-11 -130 14:50 UT | 2017-May-11 -130 14:49 UT | 2017-May-11 -130 | 2017-May-11 -130

900 | 600 | 400 | 200 | 0 | -200 | -400 | -600

5 | 10 | 15

0 3 6 9 12 15 18 21 24

0 3 6 9 12 15 18 21 24

0 3 6 9 12 15 18 21 24

0 3 6 9 12 15 18 21 24

Latest | History | Latest | History | Latest | History | Latest | History

SAC Long-term Archive

**SYSTEM CONTROL**

- DCART Screen Output
- Dispatcher Screen Output
- Latest System Status (RTT)

Contact

**STORAGE STATUS**

HD [Progress Bar] Thu May 11 06:10:26 2017

CP/DVD No backup to removable media Thu Mar 27 04:52:28 2014

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# Contents



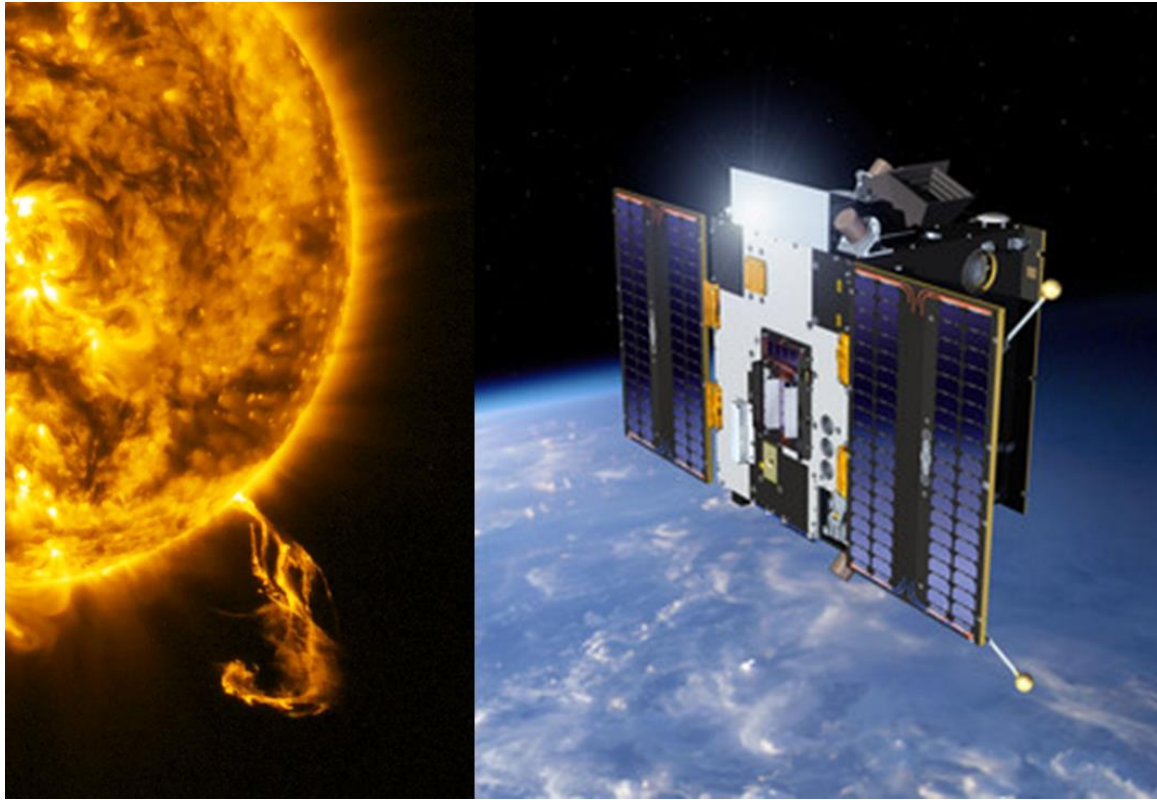
- **Groundbased sensors**

- Visible light
- Radio domain
  - Humain
- Magnetosphere-Ionosphere
- Geomagnetism
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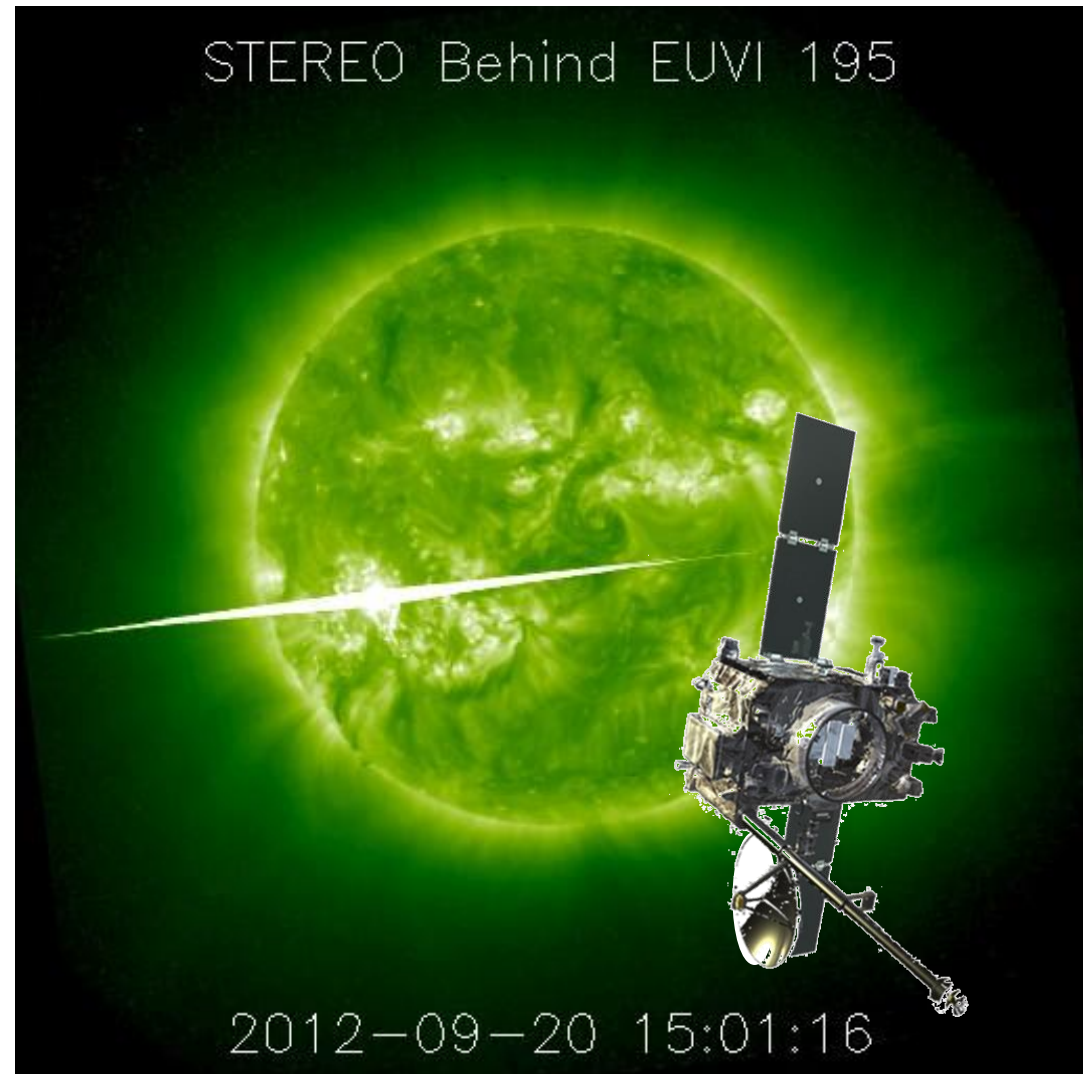
## Spacebased sensors

Jan Janssens



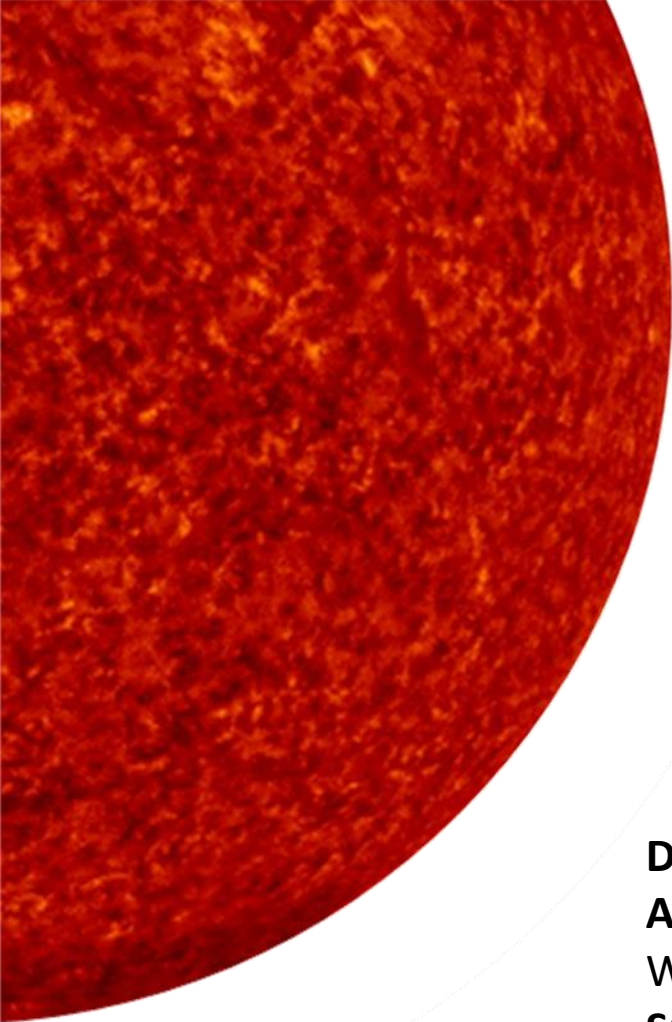
# Why do we need SWx satellites?

- EUV and X-ray (solar atmosphere)
  - Flares & Coronal holes
- Coronagraphs
- Solar wind (in-situ)
- Solar farside
  - 20 September 2012
  - 23 July 2012
  - ...
- Radio
  - Triangulation
  - Low frequencies
- Science
- White light (24hrs)
- ...





# Satellites



GOES  
SDO



INTEGRAL

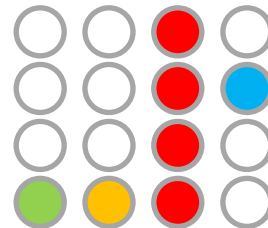


PROBA2  
Hinode



### L1

DSCOVR  
ACE  
WIND  
SOHO



STEREO



- $\gamma$ /X-ray/EUV
- Coronagraph
- Solar Wind
- Particle flux





# GOES

Geostationary Operational Environmental Satellite



- X-ray flux
  - X-ray Sensor (XRS)



- Proton flux

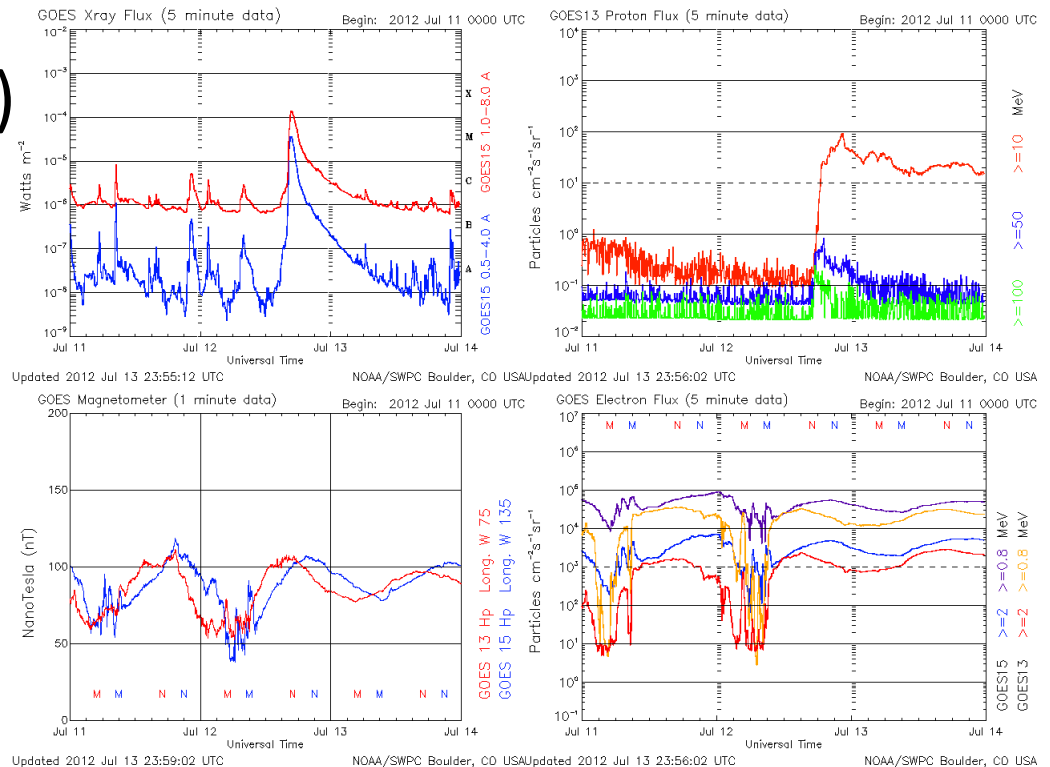


- Magnetic field



- Electron flux

- Imagery







# GOES

Geostationary Operational Environmental Satellite

- X-ray flux
- Proton flux
- Magnetic field
- Electron flux

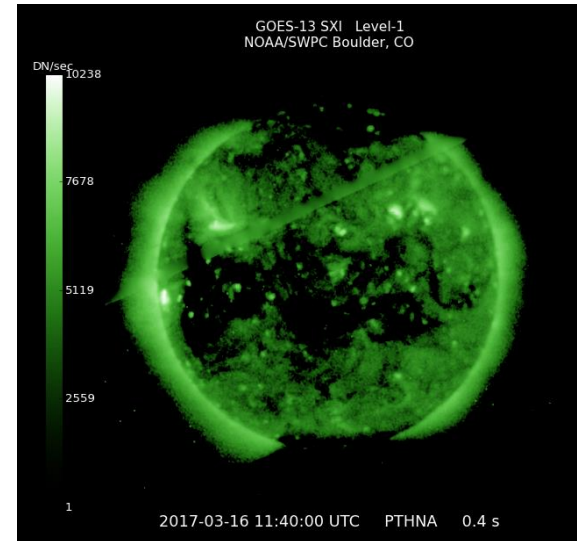
- Imagery

- GOES-12-15

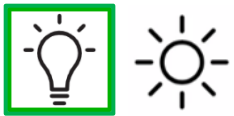
- X-ray: SXI
      - Solar X-ray Imager
      - Discontinued

- GOES-16-17

- EUV: SUVI
      - Solar Ultraviolet Imager
      - Operational



GOES SOLAR ULTRAVIOLET IMAGER (SUVI)

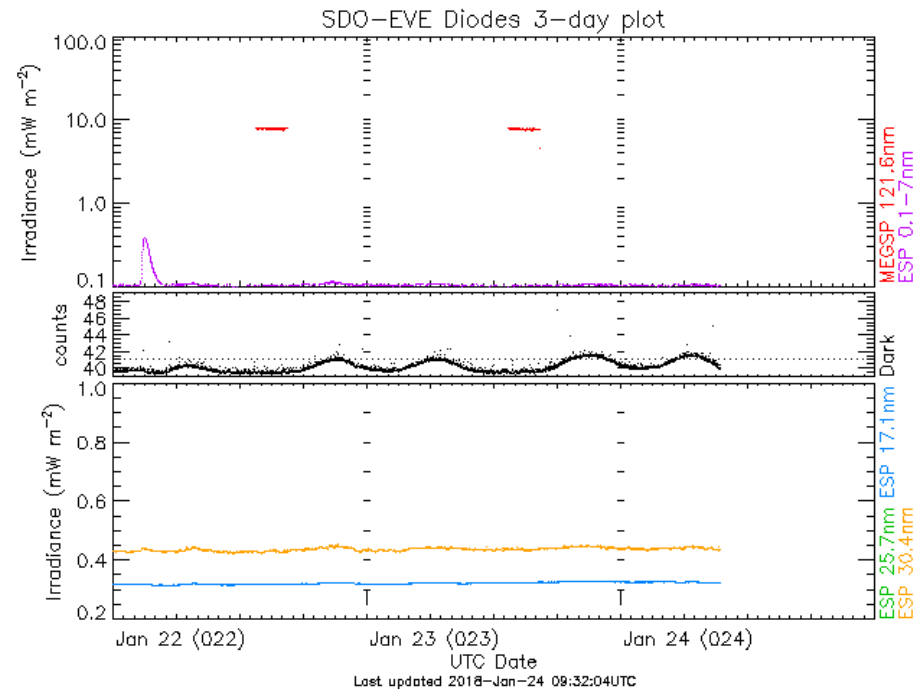
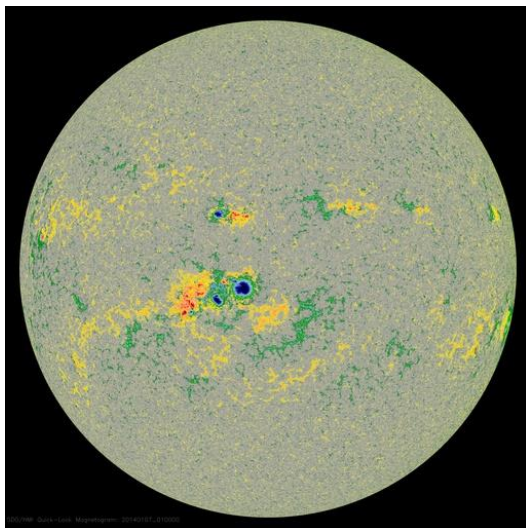
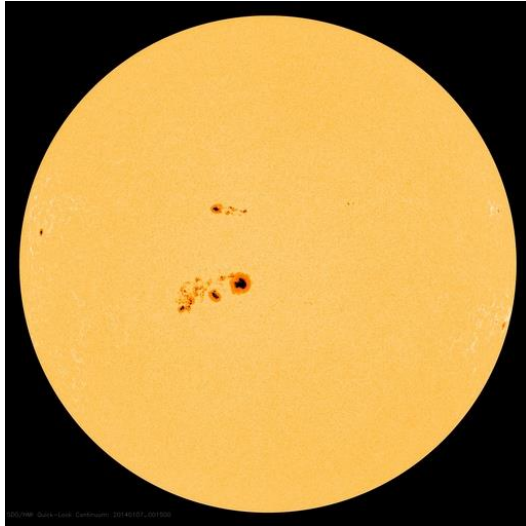


# SDO

Solar Dynamics Observatory

## < HMI

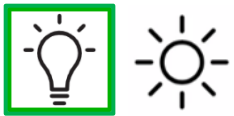
- Helioseismic and Magnetic Imager
- « White light » and Magnetograms



## EVE ^

- Extreme ultraviolet Variability Experiment
- Scaled to GOES x-ray measurements

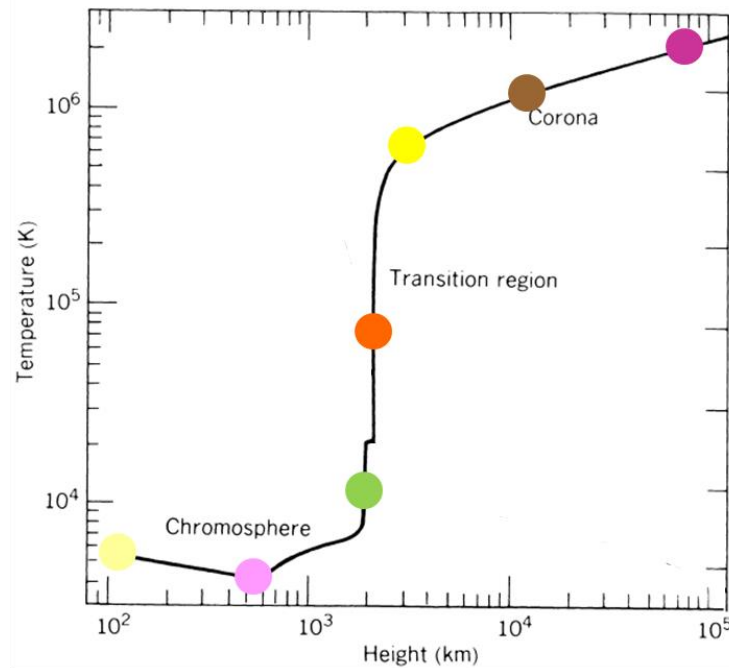




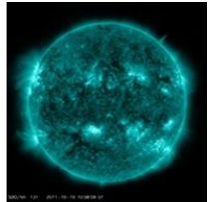
# SDO

## Solar Dynamics Observatory

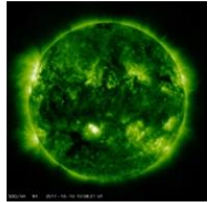
- AIA
  - Atmospheric Imaging Assembly
  - EUV imagery in 9 filters
  - Some filters peak at multiple temperatures
  - AIA 4500 no longer in use



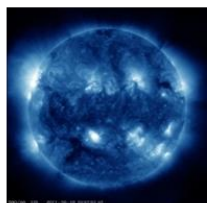
131Å



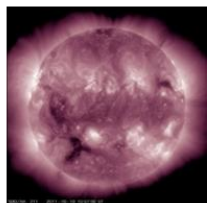
094Å



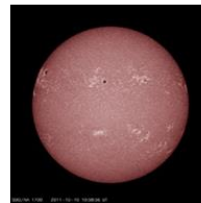
335Å



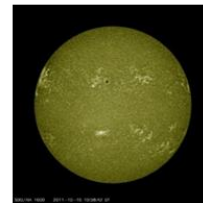
211Å



4500Å



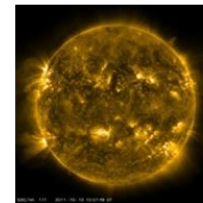
1700Å



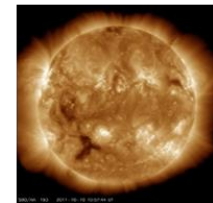
1600Å



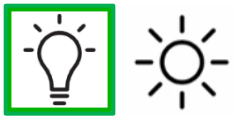
304Å



171Å



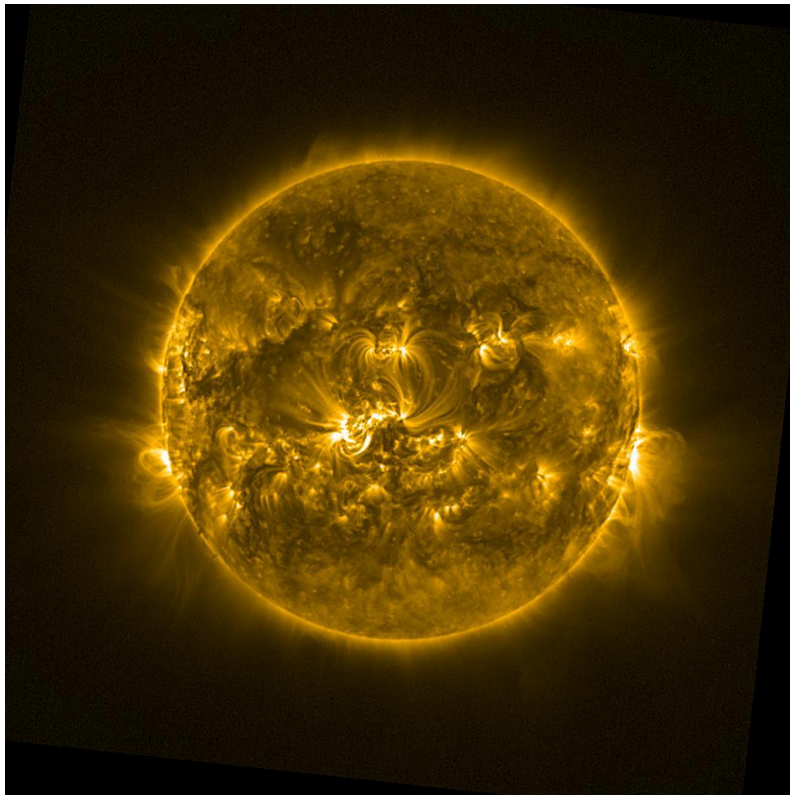
193Å



# PROBA2

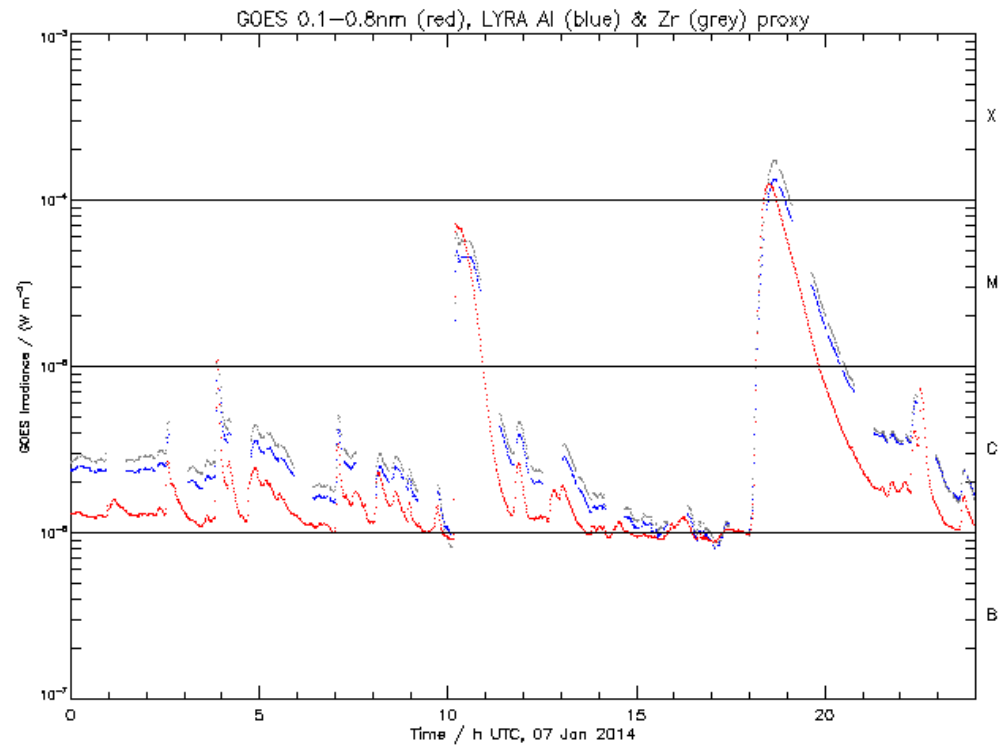
Project for OnBoard Autonomy

## SWAP



Sun Watcher using APS detector and image Processing

## LYRA



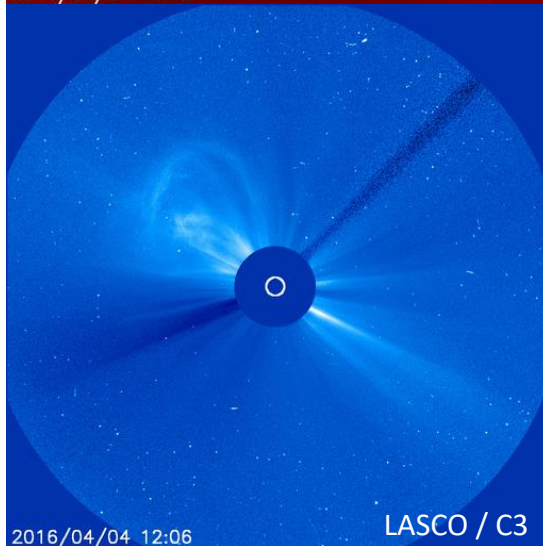
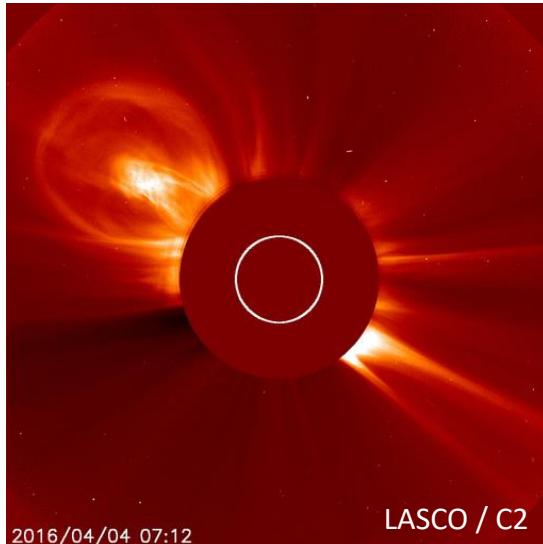
ROB/SIDC, Brussels, Belgium

Large Yield Radiometer

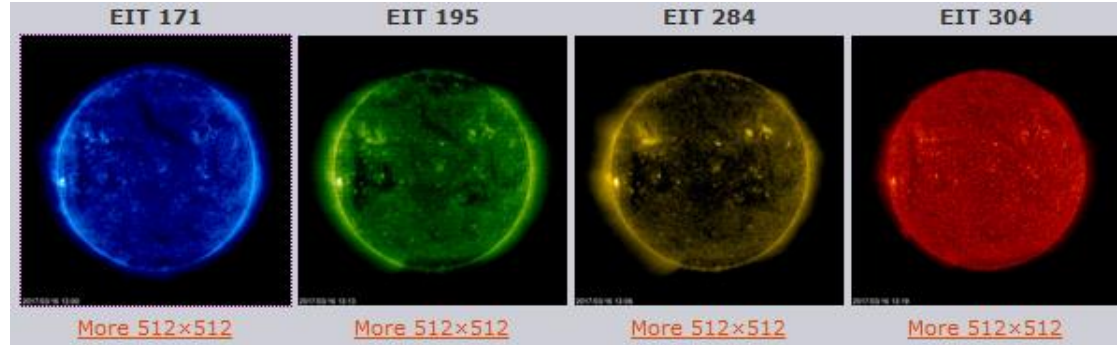


# SOHO

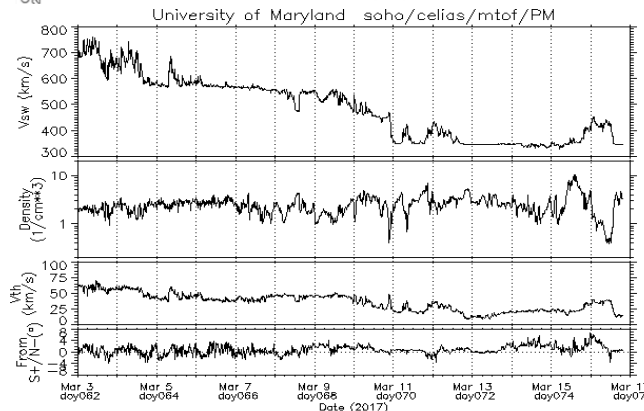
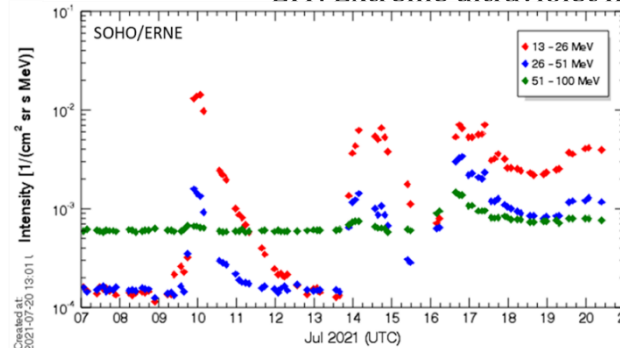
Solar & Heliospheric Observatory



LASCO: Large Angle Spectrometric Coronagraph



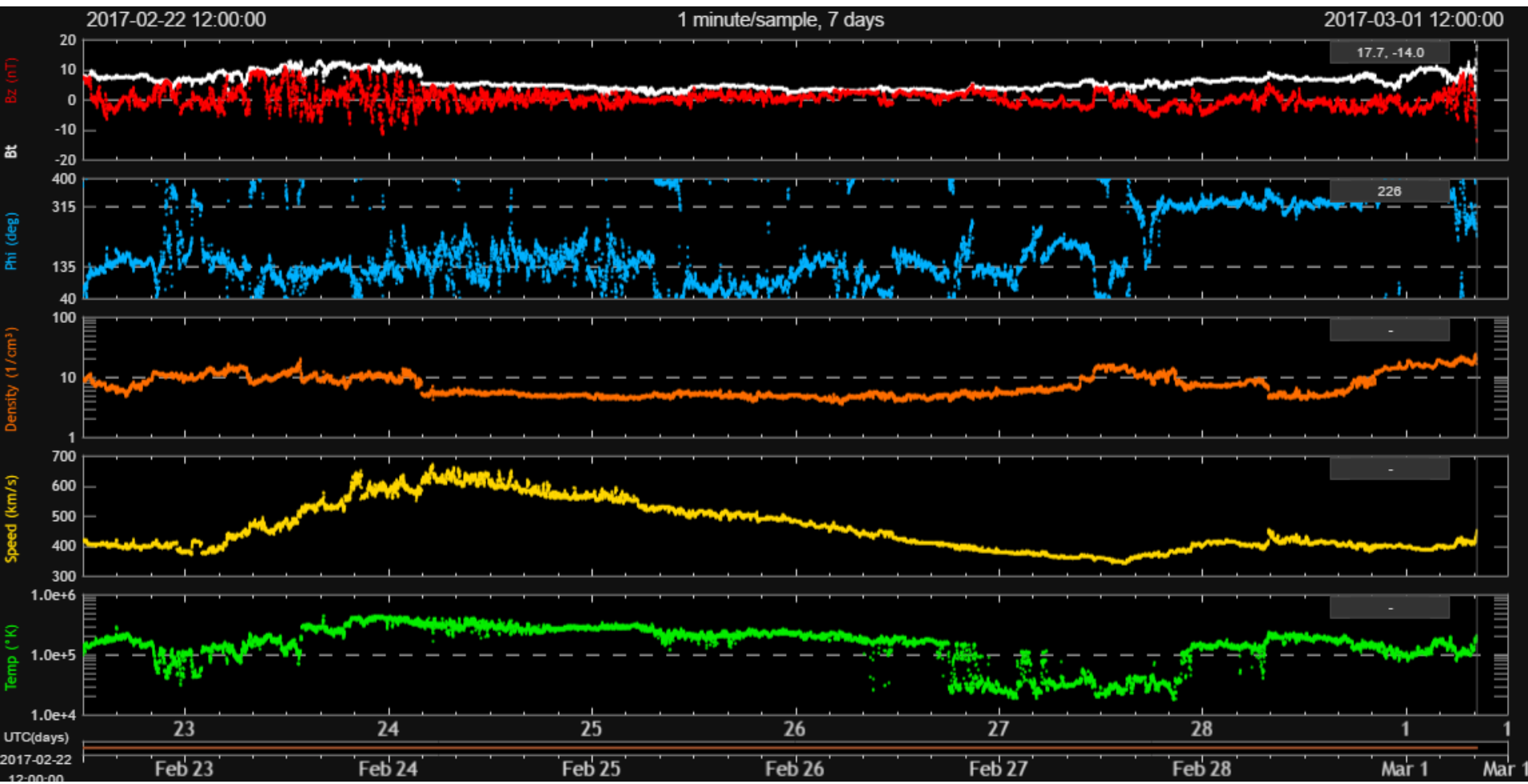
EIT: Extreme ultraviolet Imaging Telescope





# DSCOVER

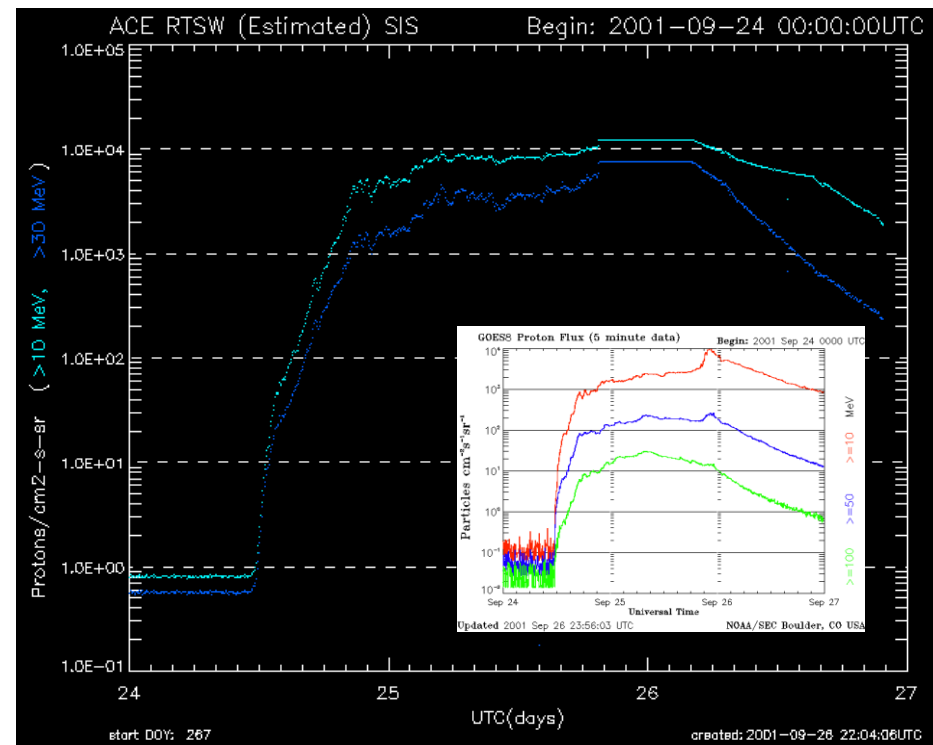
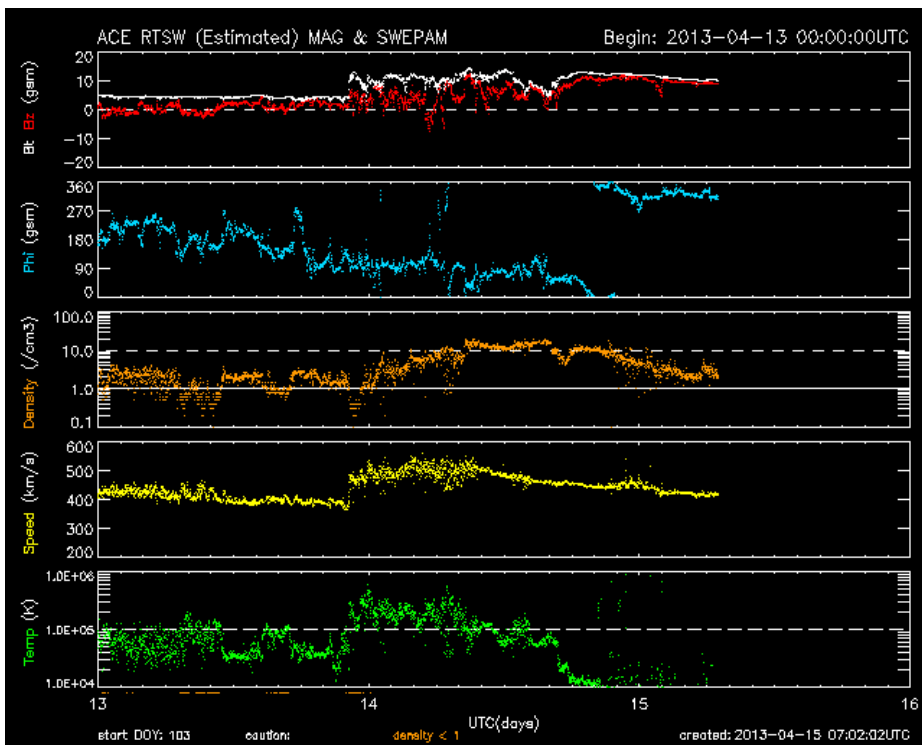
Deep Space Climate Observatory





# ACE

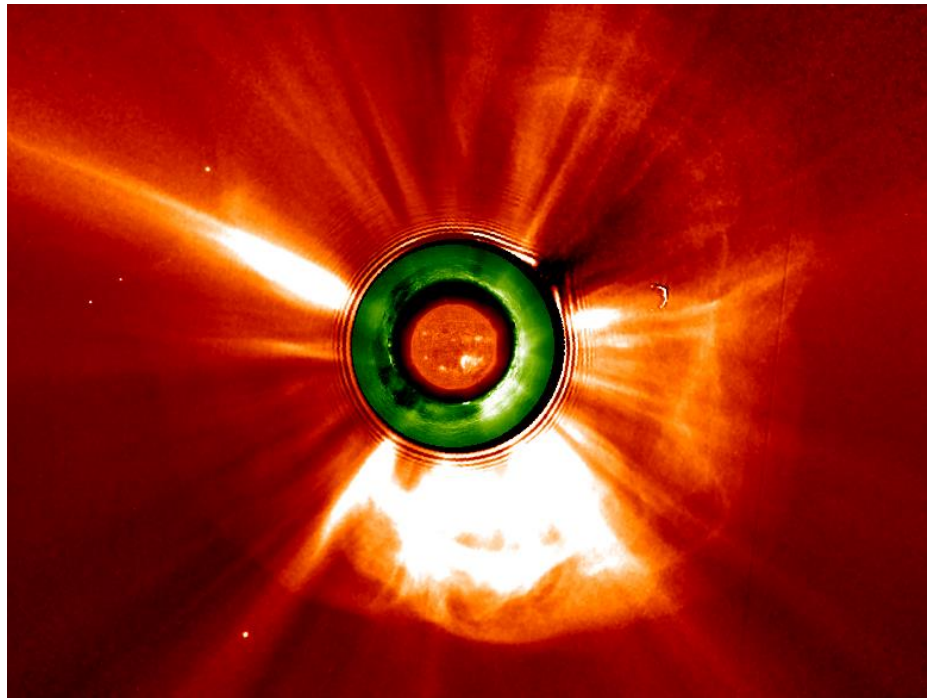
## Advanced Composition Explorer





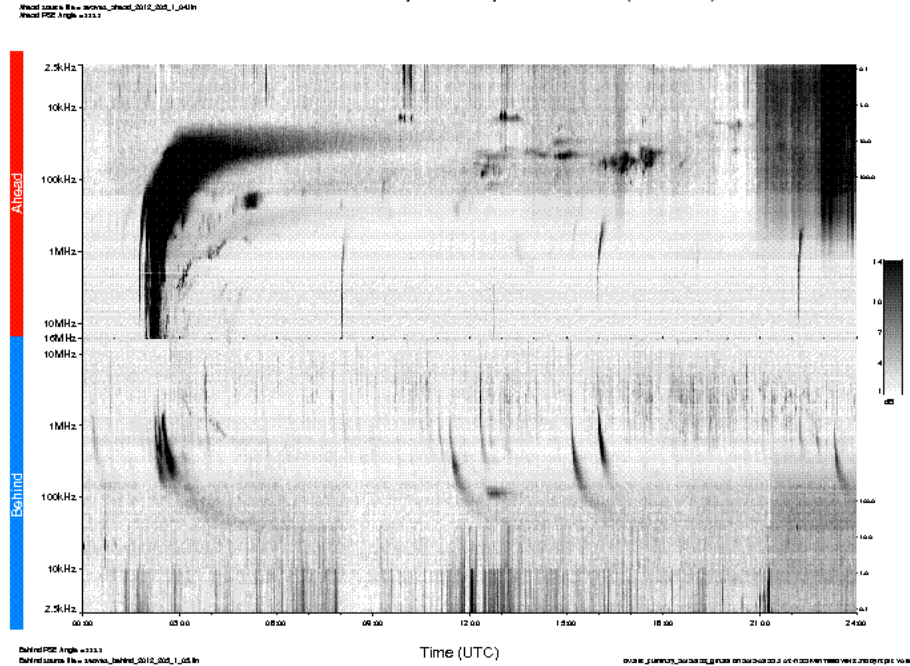
# STEREO

## Solar-Terrestrial Relations Observatory



EUVI: Solar EUV imager  
COR: Coronagraphs  
HI: Heliospheric Imagers

STEREO/WAVES Daily Summary - 23-Jul-2012 (DOY 205)



WAVES: radio observations

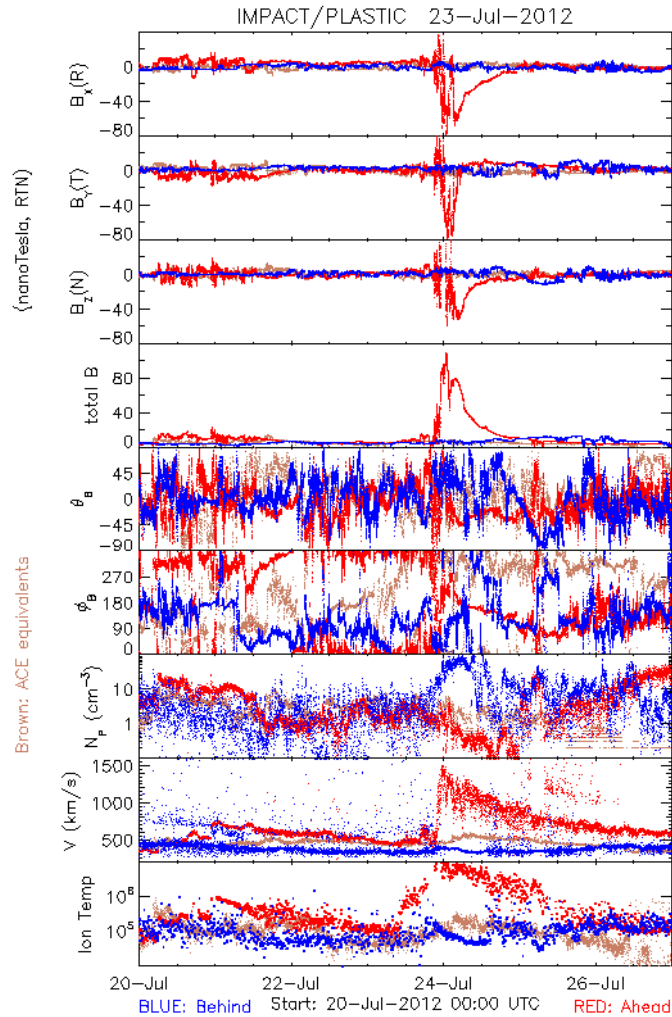




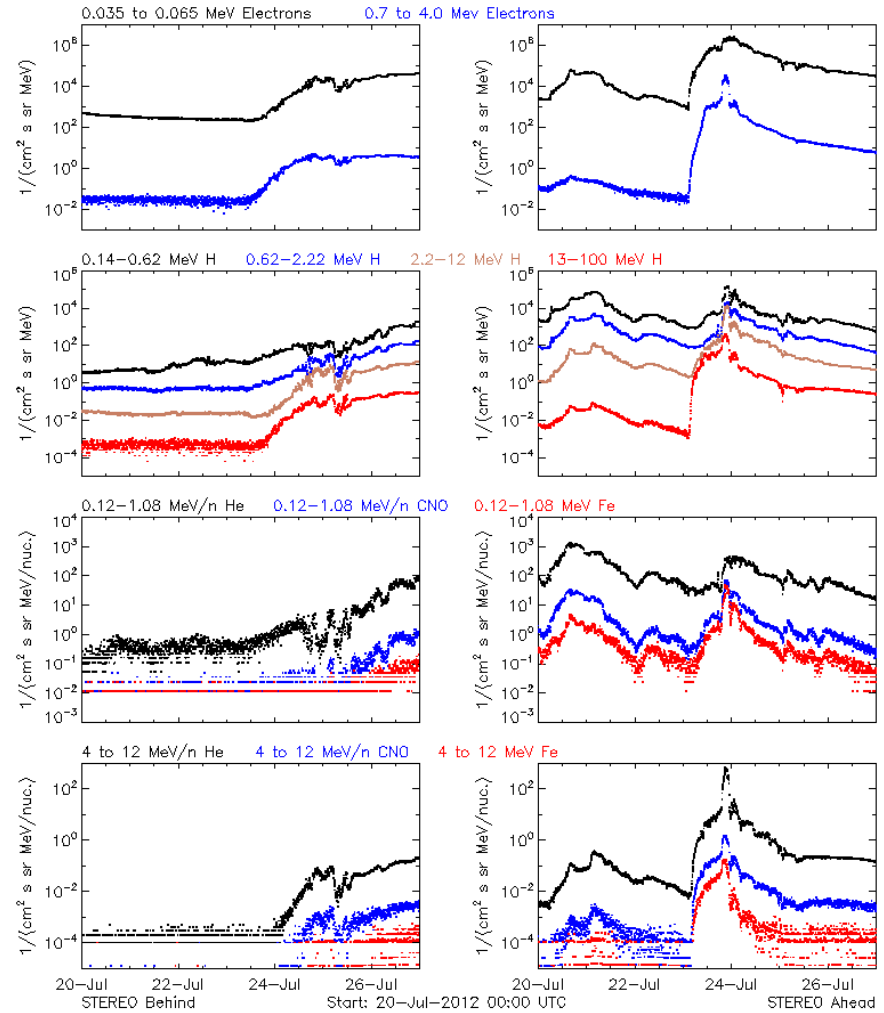


# STEREO

## Solar-Terrestrial Relations Observatory



Brown: ACE equivalents



PLASTIC: Solar wind data

IMPACT: Solar energetic particles



:Issued: 2014 Apr 17 1325 UTC

:Product: documentation at <http://www.sidc.be/products/tot>

#-----#

# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #

#-----#

SIDC URSIGRAM 40417

SIDC SOLAR BULLETIN 17 Apr 2014, 1304UT

SIDC FORECAST (valid from 1230UT, 17 Apr 2014 until 19 Apr 2014)

SOLAR FLARES : Active (M-class flares expected, probability >=50%)

GEOMAGNETISM : Quiet (A<20 and K<4)

SOLAR PROTONS : Quiet

PREDICTIONS FOR 17 Apr 2014 10CM FLUX: 180 / AP: 013

PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007

PREDICTIONS FOR 19 Apr 2014 10CM FLUX: 188 / AP: 005

COMMENT: Eleven sunspot groups were reported by NOAA today. NOAA ARs 2035,2036, and 2037 (Catania numbers 24, 25, and 26 respectively) maintain the beta-gamma configuration of the photospheric magnetic field. The strongest flare of the past 24 hours was the M1.0 flare peaking at 19:59 UT yesterday in the NOAA AR 2035 (Catania number 24). The flare was associated with an EIT wave and a weak coronal dimming, but the associated CME was narrow and is not expected to arrive at the Earth.

We expect further flaring activity on the C-level, especially in the NOAA ARs 2035 and 2037 (Catania numbers 24 and 26 respectively) as well as in the NOAA AR 2042 (no Catania number yet) that yesterday appeared from behind the east solar limb, with a good chance for an M-class event.

Since yesterday evening the Earth is situated inside a solar wind structure with an elevated interplanetary magnetic field magnitude (occasionally up to 10 nT). It may be a weak ICME or the compression region on the flank of an ICME that missed the Earth. The solar origin of this structure is not clear. The north-south magnetic field component Bz was not strong, so no significant geomagnetic disturbance resulted (K index stayed below 4). Currently the solar wind speed is around 380 km/s and the IMF magnitude is around 8 nT.

We expect quiet to unsettled (K index up to 3) geomagnetic conditions, with active geomagnetic conditions (K = 4) possible, but unlikely.

TODAY'S ESTIMATED ISN : 145, BASED ON 17 STATIONS.

99999

SOLAR INDICES FOR 16 Apr 2014

WOLF NUMBER CATANIA : ///

10CM SOLAR FLUX : 184

AK CHAMBON LA FORET : 012

AK WINGST : 004

ESTIMATED AP : 004

ESTIMATED ISN : 139, BASED ON 29 STATIONS.

NOTICEABLE EVENTS SUMMARY

DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO\_BURST\_TYPES

16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2

END



*Satellites and instruments*

# Tools

- Various
  - Soteria
  - Solar Demon
  - CACTus
  - Drag model
  - JHV (SWHV)
  - STAFF
  - COR2 J-plots
  - COMESEP
  - EUHFORIA
    - WSA-ENLIL (SWPC)



**CACTUS 2.5.0**

A software package for 'Computer Aided CME Tracking'

## CMEs detected by Cactus

```

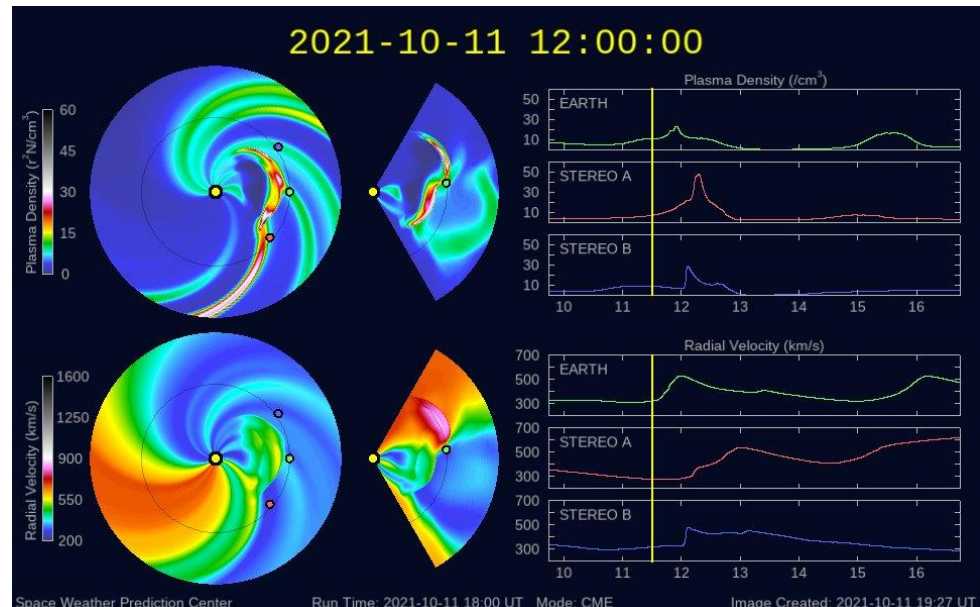
:Issued: Wed Oct 27 16:31:12 2021
:Product: CACTus catalogue (http://sidc.be/cactus)
-----
# Instrument: LASCO Detector: c2 # Instrument: LASCO Detector: c3
# Threshold : 0.30 | Factor : 2 | Minimal CME width: 5

first c2: 2021/10/21 00:00:07.942 23864539.fts
last c2: 2021/10/27 15:05:48.794 23865296.fts
first c3: 2021/10/21 00:06:07.438 33701775.fts
last c3: 2021/10/27 14:42:07.411 33702459.fts
-----
Output: Detected cmemap with the following characteristics:

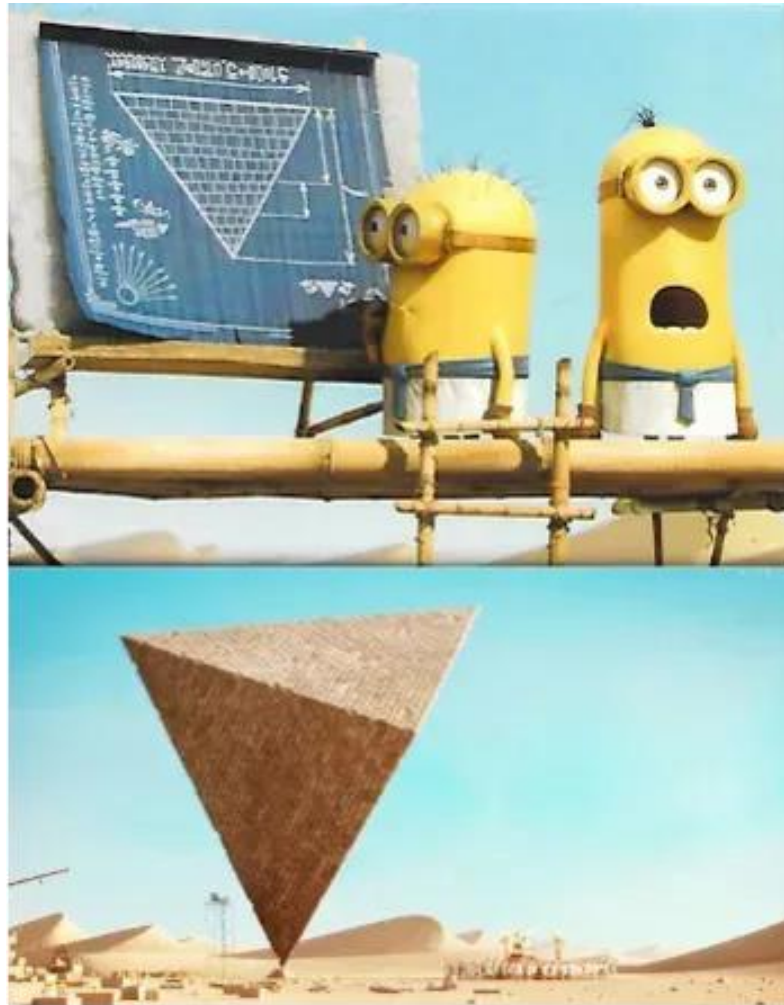
CME: CME number
Flow: Flow number. Flows are suspicious detections, their color in the detectionmap is dark blue
t0: onset time, earliest indication of liftoff
dt0: duration of liftoff (hours)
pa: principal angle, counterclockwise from North (degrees)
da: angular width (degrees)
v: median velocity (km/s)
dv: variation (1 sigma) of velocity over the width of the CME
minv: lowest velocity detected within the CME
maxv: highest velocity detected within the CME
halo?: 11 if da>90, 111 if da>150, 1V if da>270, indicating potential halo/partial halo CME
    
```

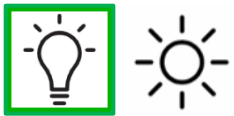
```

# CME | t0 | dt0 | pa | da | v | dv | minv | maxv | halo?
0023|2021/10/27 04:16| 01 | 044 | 096 | 0530 | 0031 | 0421 | 0632|
0024|2021/10/27 04:00| 06 | 096 | 074 | 0222 | 0039 | 0147 | 0322|
0023|2021/10/26 23:12| 01 | 075 | 016 | 0346 | 0083 | 0294 | 0480|
0022|2021/10/26 20:24| 01 | 081 | 024 | 0276 | 0097 | 0171 | 0428|
0021|2021/10/26 20:12| 01 | 130 | 014 | 0162 | 0097 | 0188 | 0171|
0020|2021/10/26 20:00| 02 | 129 | 060 | 0179 | 0039 | 0129 | 0260|
    
```



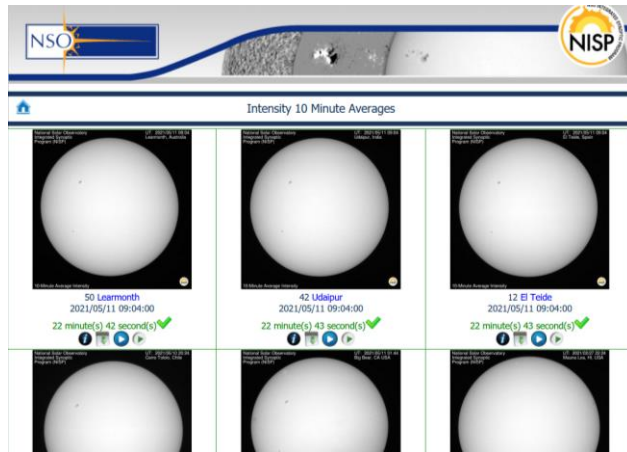
# Reversed engineering



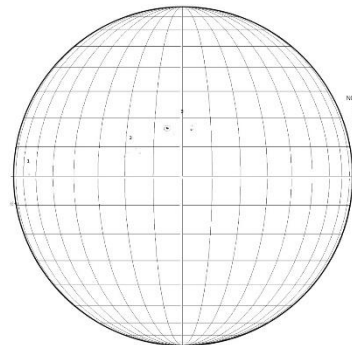
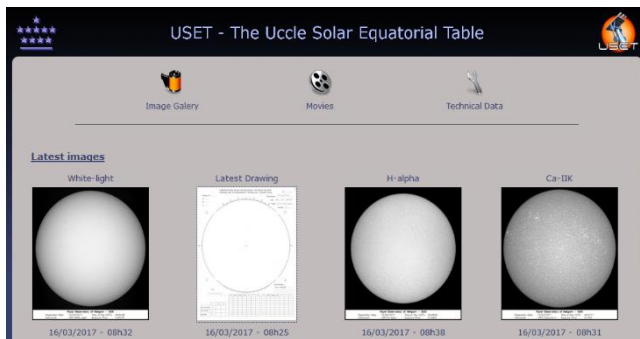
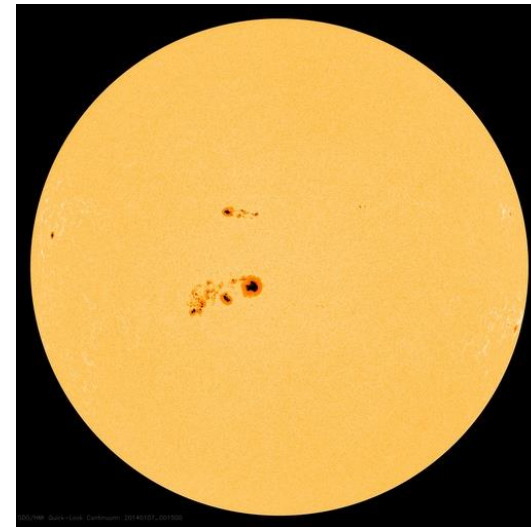


# White light solar imagery

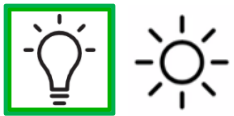
## Ground-based



## Space-based



GONG: Global Oscillation Network Group  
USET: Uccle Solar Equatorial Table  
Catania Astrophysical Observatory  
SDO: Solar Dynamics Observatory  
HMI: Helioseismic and Magnetic Imager



# Sunspot number

Ground-based



Space-based



Sunspot Index and Long-term Solar Observations

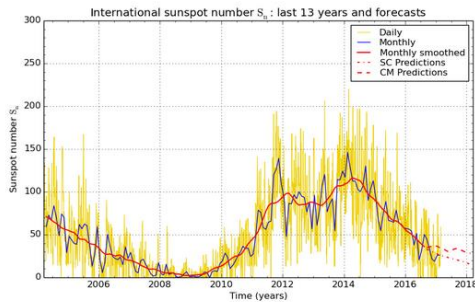
## Menu

- Home
- Data
- Products
- Analyses
- FAQ & News
- Observers
- Contact

Home Data Products Analyses FAQ & NEWS Observers Contact

World Data Center for the production, preservation and dissemination of the international sunspot number

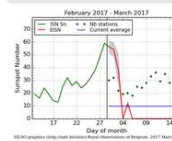
### Sunspot number series: latest update



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium: 2017 March 1

### Latest Sunspot Bulletin

#### Daily estimated sunspot number



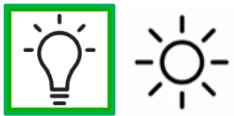
SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium: 2017 March 14

#### ESN DATA FILES

12 March : 0  
 13 March : 0  
 14 March : 0

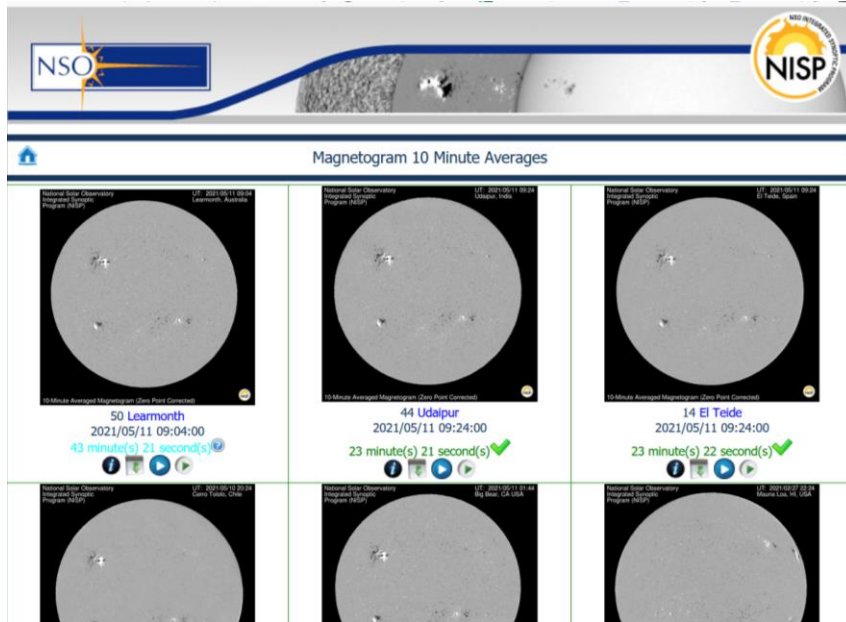
SILSO: Sunspot Index and Long-term Solar Observations



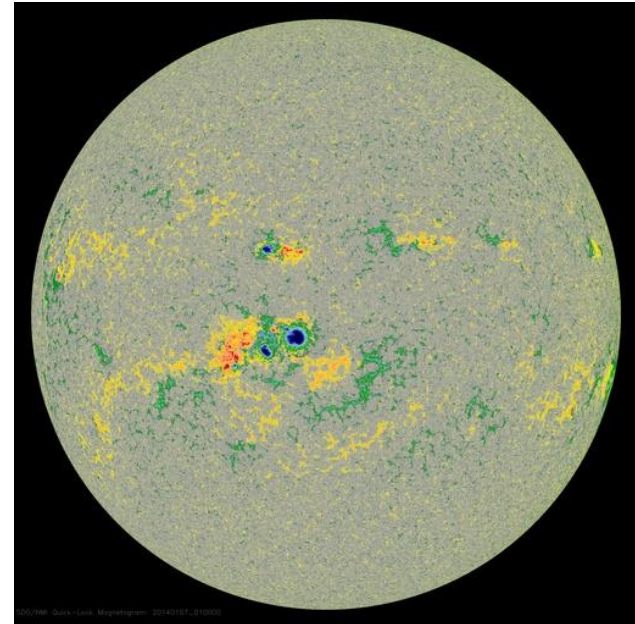


# Solar magnetograms

Ground-based 



Space-based 



GONG: Global Oscillation Network Group  
 SDO: Solar Dynamics Observatory  
 HMI: Helioseismic and Magnetic Imager



# H-alpha solar images

Ground-based 

Space-based 

NSO NISP GONG H-Alpha data

 488 Learmonth 2021/05/11 09:02:30 39 minute(s) 51 second(s) ✗	 442 Udaipur 2021/05/11 09:40:50 1 minute(s) 31 second(s) ✓	 142 El Teide 2021/05/11 09:40:10 2 minute(s) 11 second(s) ✓

USET - The Uccle Solar Equatorial Table

Image Gallery Movies Technical Data

Latest images

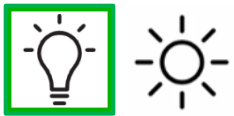
 White-light 16/03/2017 - 08h32	 Latest Drawing 16/03/2017 - 08h25	 H-alpha 16/03/2017 - 08h08	 Ca-11k 16/03/2017 - 08h31
---------------------------------------	--	-----------------------------------	----------------------------------



GONG: Global Oscillation Network Group  
USET: Uccle Solar Equatorial Table  
Kanzelhöhe Observatory







# Solar radio flux

## Ground-based



## Space-based



```

:Product: Solar Radio Data          7day_rad.txt
:Issued: 0602 UTC 10 May 2021
#
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center
# Please send comments and suggestions to SWPC.Website@noaa.gov
# Units: 10-22 W/m2/Hz
# Missing Data: -1
#
# Daily local noon solar radio flux values - Updated once an hour
#
Freq  Learmonth  San Vito  Sag Hill  Penticton  Penticton  Palehua  Penticton
MHz   0500 UTC  1200 UTC  1700 UTC  1700 UTC  2000 UTC  2300 UTC  2300 UTC

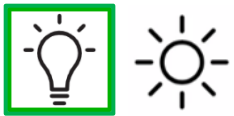
2021 May 4
245   15      16      11      -1      -1      -1      -1
410   26      29      27      -1      -1      -1      -1
610   -1      -1      38      -1      -1      -1      -1
1415  55      50      56      -1      -1      53      -1
2695  75      -1      76      -1      -1      74      -1
2800  -1      -1      -1      71      70      -1      70
4995  112     107     120     -1      -1      112     -1
8800  231     217     231     -1      -1      219     -1
15400 489     554     478     -1      -1      526     -1

2021 May 5
245   14      15      12      -1      -1      -1      -1
410   27      29      26      -1      -1      -1      -1
610   40      -1      38      -1      -1      -1      -1
1415  55      51      55      -1      -1      52      -1
2695  79      -1      75      -1      -1      73      -1
2800  -1      -1      -1      69      70      -1      -1
4995  109     102     119     -1      -1      114     -1
8800  226     215     226     -1      -1      219     -1
15400 480     560     473     -1      -1      518     -1

```

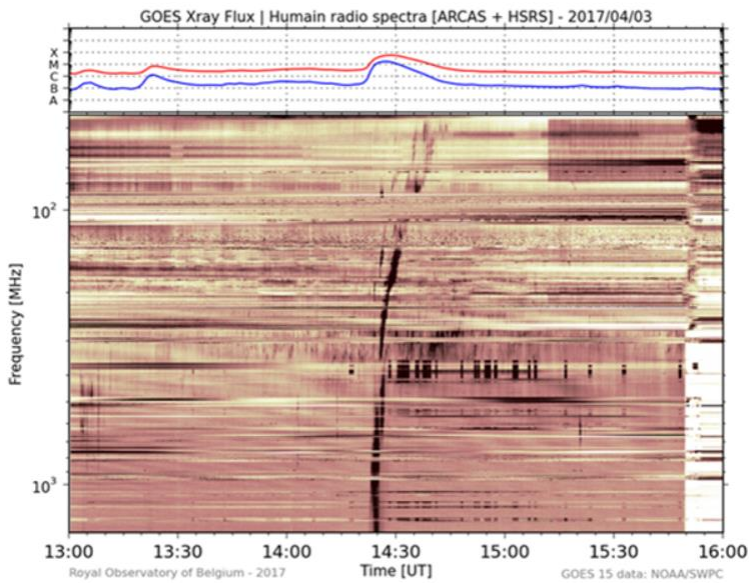
DRAO: Dominion Radio Astrophysical Observatory  
 NRCan: Natural Resources Canada  
 RSTN: Radio Solar Telescope Network



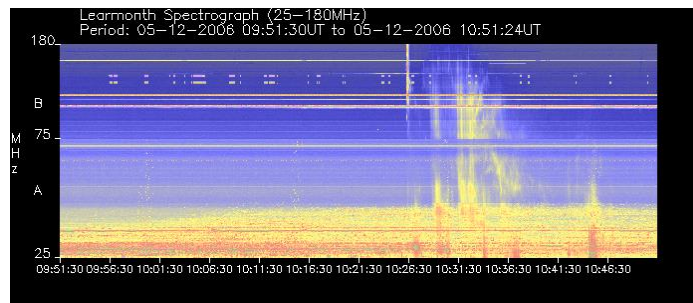
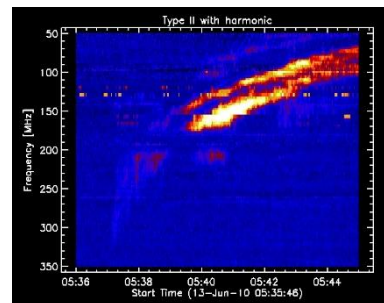
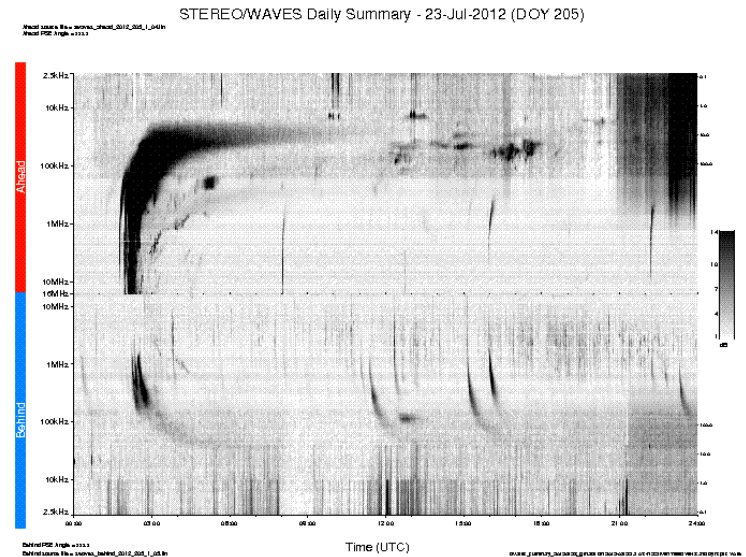


# Solar radio spectra

## Ground-based



## Space-based



Human Radioastronomy Station  
 eCallisto  
 Learmonth  
 STEREO: Solar-TERrestrial Relations Observatory

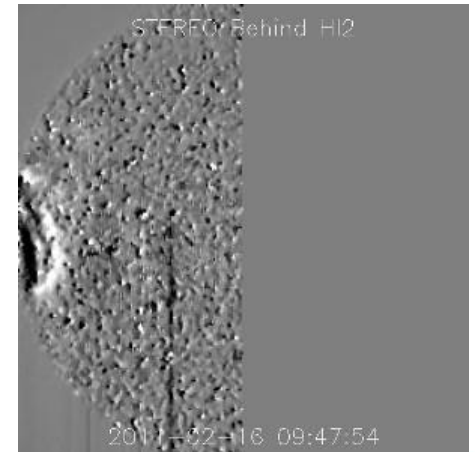
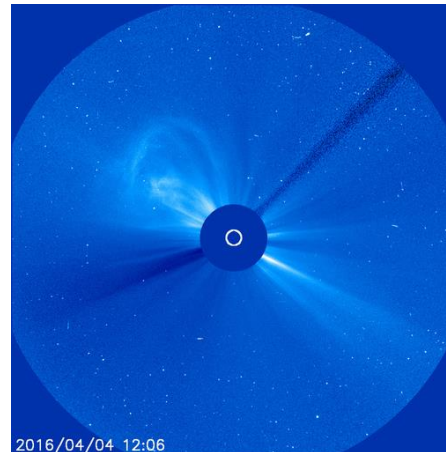
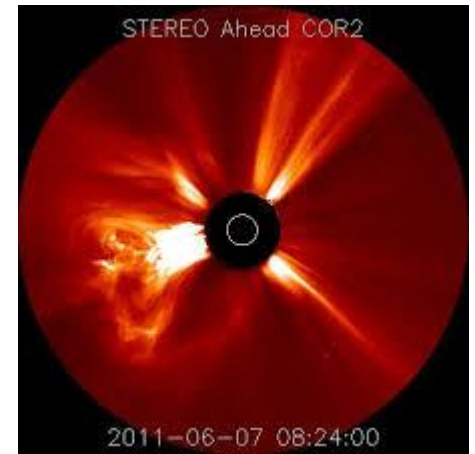
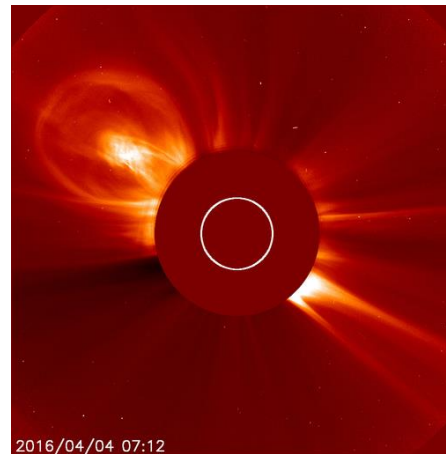




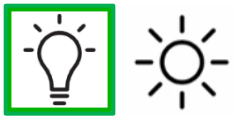
# Solar coronagraphic imagery

Ground-based 

Space-based 



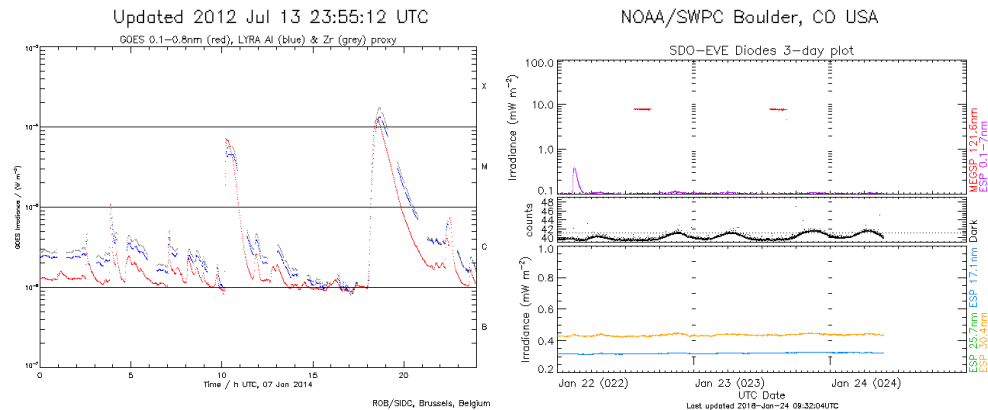
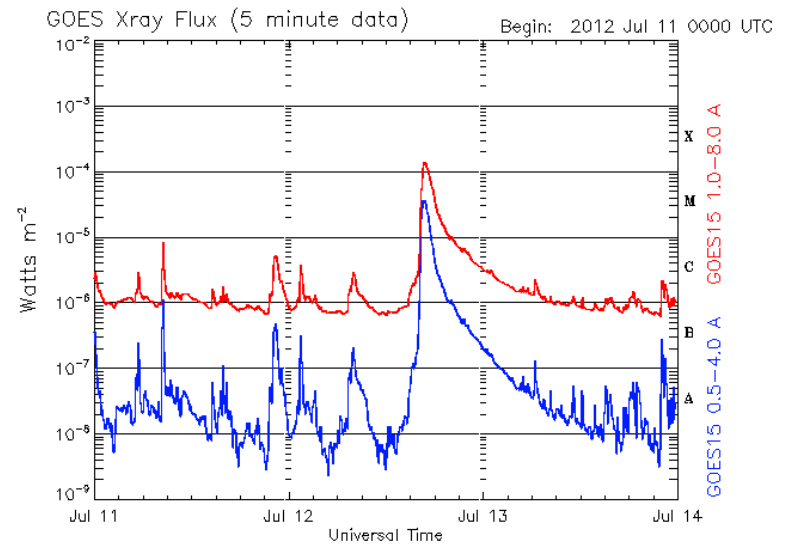
SOHO: SOlar & Heliospheric Observatory  
LASCO: Large Angle Spectrometric Coronagraph  
STEREO: Solar-TERrestrial RELations Observatory  
COR: Coronagraph  
HI: Heliospheric Imager



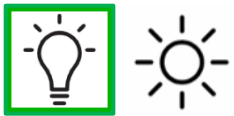
# Solar X-ray flux and proxies

Ground-based 

Space-based 



- GOES: Geostationary Operational Environmental Satellite
- XRS: X-Ray Sensor
- SDO: Solar Dynamics Observatory
- EVE: Extreme ultraviolet Variability Experiment
- PROBA2: PRoject for OnBoard Autonomy
- LYRA: Large Yield RAdiometer

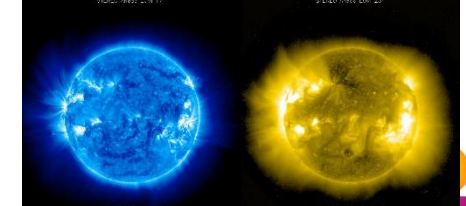
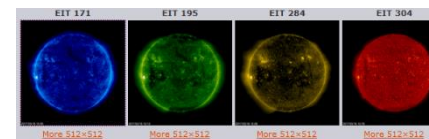
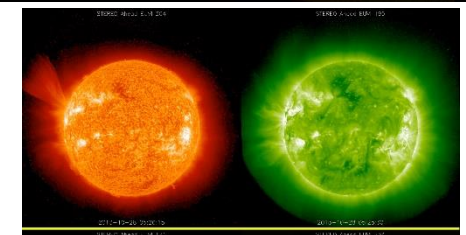
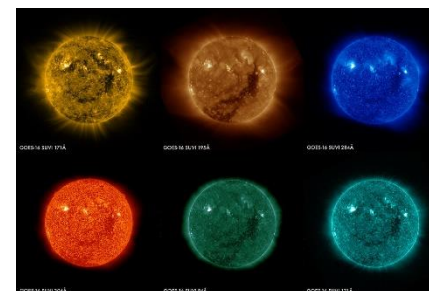
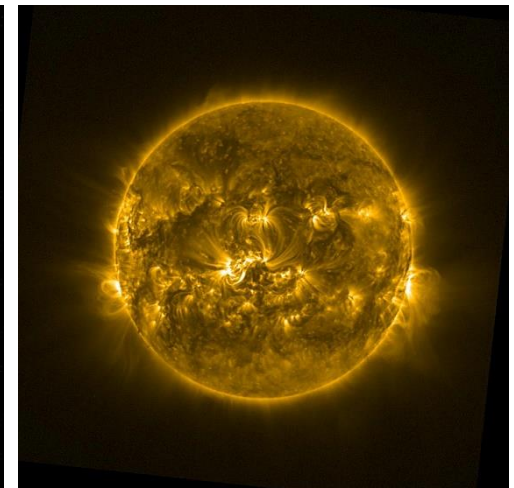
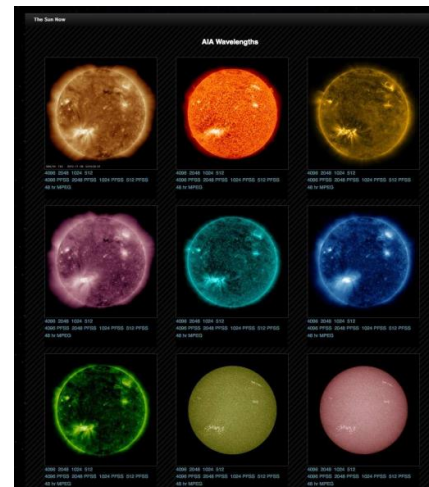


# Solar EUV imagery

Ground-based 

Space-based 

- GOES: Geostationary Operational Environmental Satellite
- SUVI: Solar Ultraviolet Imager
- SDO: Solar Dynamics Observatory
- AIA: Atmospheric Imaging Assembly
- PROBA2: Project for OnBoard Autonomy
- SWAP: Sun Watcher using APS detector and image Processing
- SOHO: Solar & Heliospheric Observatory
- EIT: Extreme ultraviolet Imaging Telescope
- STEREO: Solar-TERrestrial Relations Observatory
- EUVI: Extreme UltraViolet Imager

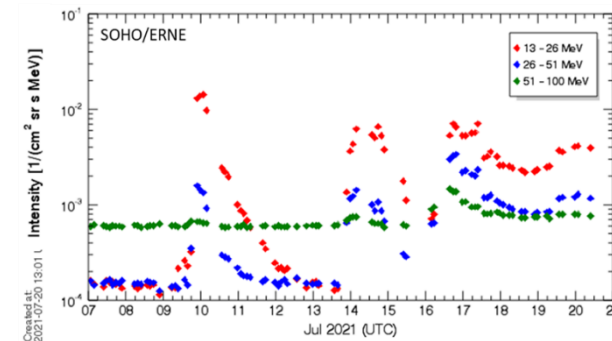
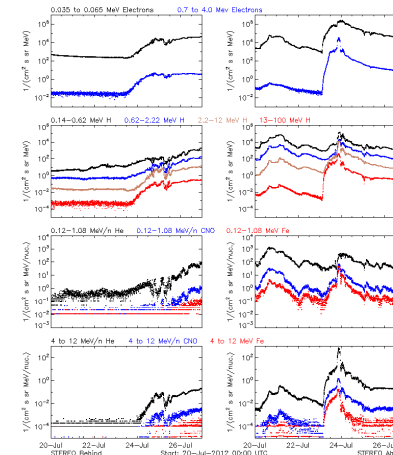
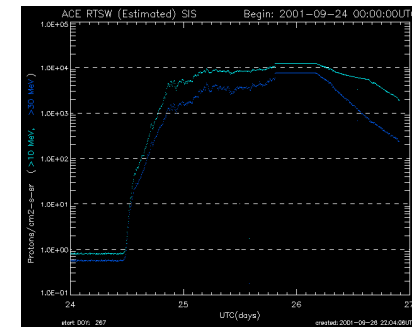
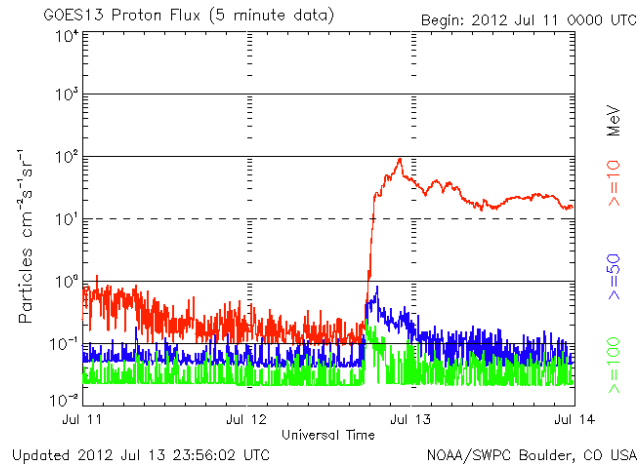




# Solar proton flux

Ground-based 

Space-based 



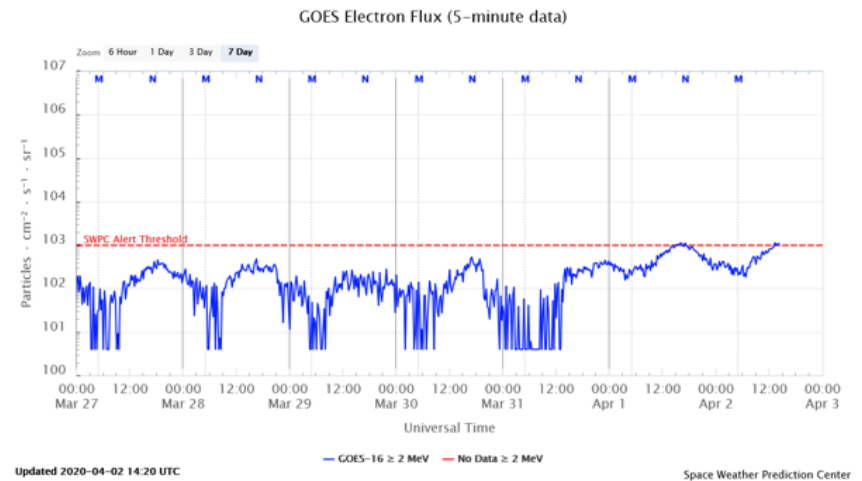
GOES: Geostationary Operational Environmental Satellite  
 ACE: Advanced Composition Explorer  
 STEREO: Solar-TERrestrial Relations Observatory  
 SOHO: Solar and Heliospheric Observatory



# $\geq 2$ MeV electron flux

Ground-based 

Space-based 



GOES: Geostationary Operational Environmental Satellite

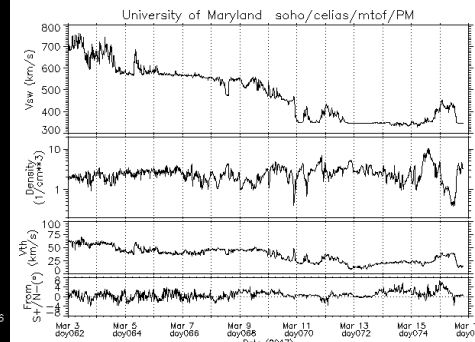
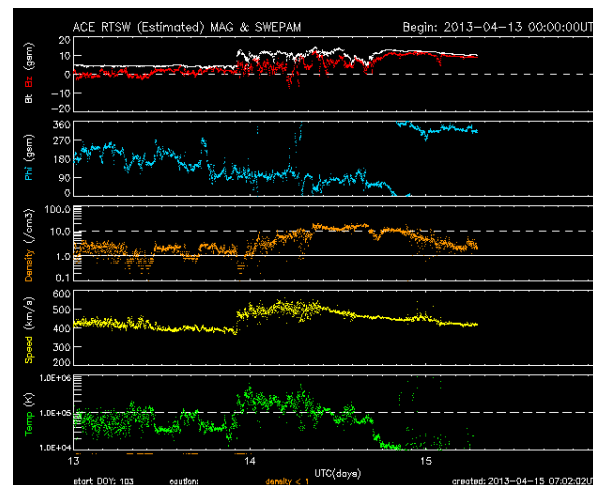
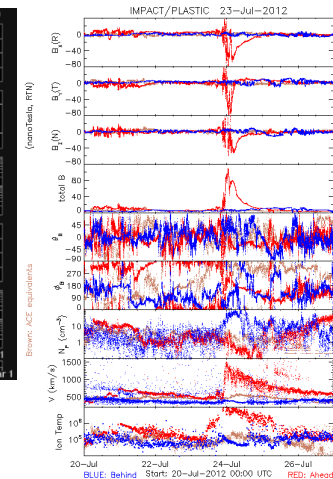
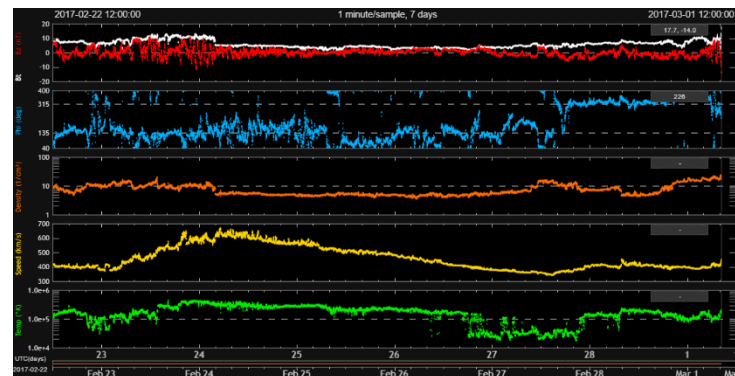




# Solar wind

Ground-based 

Space-based 



SOHO: Solar & Heliospheric Observatory  
 DSCOVR: Deep Space Climate Observatory  
 ACE: Advanced Composition Explorer  
 STEREO: Solar-TERrestrial Relations Observatory





# Exercises



*Identify the ground-based stations, satellites, sensors, tools,... in the following URSIgrams (Comment)*

# URSIgram 1

```
:Issued: 2020 Feb 27 1230 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
#-----#
SIDC URSIGRAM 00227
SIDC SOLAR BULLETIN 27 Feb 2020, 1230UT
SIDC FORECAST (valid from 1230UT, 27 Feb 2020 until 29 Feb 2020)
SOLAR FLARES : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 27 Feb 2020 10CM FLUX: 071 / AP: 010
PREDICTIONS FOR 28 Feb 2020 10CM FLUX: 071 / AP: 006
PREDICTIONS FOR 29 Feb 2020 10CM FLUX: 071 / AP: 004
COMMENT: Solar activity was at very low levels. The Sun is still spotless, but this may change
as two small active regions at resp. latitudes S10 and N25 are about to rotate over the east limb
as seen in SDO/AIA and STEREO-A/EUVI imagery. No earth-directed coronal mass ejections (CMEs) have
been observed in available coronagraphic imagery. The greater than 10 MeV proton flux was at
nominal values. Some small and patchy equatorial coronal holes (CHs) are present on the solar disk.

Solar activity is expected to remain at very low levels.

Solar wind conditions were at background levels. Solar wind speed varied steadily between 330 and
370 km/s (ACE). Bz undulated between -5 and +5 nT. The direction of the interplanetary magnetic
field (phi angle) was variable. Geomagnetic conditions were at quiet levels, with an unsettled
episode (09-12UT) recorded at Dourbes.

Geomagnetic activity is expected to remain mostly at quiet levels, with an isolated unsettled
interval remaining possible.
```



# URSIgram 2

```
:Issued: 2018 Oct 13 1230 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
#-----#
```

```
SIDC URSIGRAM 81013
SIDC SOLAR BULLETIN 13 Oct 2018, 1230UT
SIDC FORECAST (valid from 1230UT, 13 Oct 2018 until 15 Oct 2018)
SOLAR FLARES : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM : Minor storm expected (A>=30 or K=5)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 13 Oct 2018 10CM FLUX: 072 / AP: 006
PREDICTIONS FOR 14 Oct 2018 10CM FLUX: 072 / AP: 029
PREDICTIONS FOR 15 Oct 2018 10CM FLUX: 072 / AP: 021
```

COMMENT: Beta region NOAA AR 2724 near the East limb has produced a B2.1 flare peaking at 01:50UT on October 12, associated with a Type II radio burst observed at Learmonth, and a B7.1 flare peaking at 14:08 UT, associated with a Type II radio burst registered in Humain. The chance for a C flare in the next 24 hours is estimated at 35%.

No Earth-directed Coronal Mass Ejections (CMEs) were observed in available coronagraphic imagery.

The greater than 10 MeV proton flux was at nominal levels in the past 24 hours, and is expected to stay at nominal levels in the next 24 hours.

Solar wind speed near Earth as registered by DSCOVR decreased from about 400 to 340 km/s about in the past 24 hours. The Interplanetary Magnetic Field (IMF) was predominantly directed away from the Sun and its magnitude varied between about 1 and 8 nT. Bz was never below -5 nT. A high speed stream from a negative polarity equatorial coronal hole is expected to arrive at Earth near the start of October 14, enhancing the solar wind conditions.

Quiet geomagnetic conditions (K Dourbes between 1 and 2; NOAA Kp between 1 and 3) were registered in the past 24 hours. Quiet to unsettled levels (K Dourbes < 4) are expected on October 13. Active geomagnetic levels (K Dourbes = 4) are possible on October 14 and 15 due to the expected arrival of a high speed stream from a negative polarity equatorial coronal hole, with a chance for minor storm (K Dourbes = 5) intervals.



# URSIgram 3

```
:Issued: 2017 May 24 1310 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
#-----#
```

```
SIDC URSIGRAM 70524
SIDC SOLAR BULLETIN 24 May 2017, 1310UT
SIDC FORECAST (valid from 1230UT, 24 May 2017 until 26 May 2017)
SOLAR FLARES : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM : Active conditions expected (A>=20 or K=4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 24 May 2017 10CM FLUX: 076 / AP: 004
PREDICTIONS FOR 25 May 2017 10CM FLUX: 075 / AP: 007
PREDICTIONS FOR 26 May 2017 10CM FLUX: 076 / AP: 013
```

COMMENT: Over the past 24 hours solar activity has been very low. There has been one B4.4 flare peaking at 14:21 UT on 23-May-2017, coming from NOAA Active Region (AR) 2660 (McIntosh class:Bxo; Mag.Type:Beta). There are three more decaying NOAA AR on the visible side of the solar disk. Solar activity is expected to remain low over the next 24 hours with a probability of C-class flares.

A slow partial halo CME, with projected speed of about 192 km/s and angular width of about 122 degrees, was detected at 05:24 UT by CACTUS on 23-May-2017. The PROBA2/SWAP images analysis indicates strong dimming near solar disk centre as the source of the CME. WSA-ENLIL model predicts the arrival of CME at Earth around noon on 26-May-2017.

The total electron flux for electrons with energies above 2 MeV reached high levels. The total proton flux for protons with energies above 10 MeV remained at background level. The greater than 2 MeV electron flux is expected to reach high levels today and tomorrow (25-May-2017) in response to elevated solar wind speeds.

The solar wind speed decreased from about 520 km/s to values around 470 km/s during last 24 hours. The total interplanetary magnetic field (IMF) strength, as recorded by the DSCOVR satellite, was around 4 nT. Bz fluctuated between -3 and +3 nT being mostly negative. Geomagnetic conditions were ranged K Dourbes between 1 and 3; NOAA Kp between 1 and 2. The geomagnetic field is expected to be quiet today and tomorrow. Unsettled to active conditions are expected, with a minor storm possibility after noon 26-May-2017 due to the arrival of the 23-May-2017 CME.



# URSIgram 4

```
:Issued: 2017 Oct 21 1236 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
#-----#
```

SIDC URSIGRAM 71021

SIDC SOLAR BULLETIN 21 Oct 2017, 1236UT

SIDC FORECAST (valid from 1230UT, 21 Oct 2017 until 23 Oct 2017)

SOLAR FLARES : C-class flares expected, (probability >=50%)

GEOMAGNETISM : Active conditions expected (A>=20 or K=4)

SOLAR PROTONS : Quiet

PREDICTIONS FOR 21 Oct 2017 10CM FLUX: 077 / AP: 017

PREDICTIONS FOR 22 Oct 2017 10CM FLUX: 077 / AP: 007

PREDICTIONS FOR 23 Oct 2017 10CM FLUX: 077 / AP: 007

COMMENT: From the East limb, returning NOAA region 2682 produced a long duration M1.1 flare peaking at 23:28 UT on October 20. An associated dimming was detected by Solar Demon, and an associated Type II radio burst was observed by Palehua at 23:35 UT with a corresponding speed of 344 km/s. SOHO LASCO C2 and C3 and STEREO COR2 A have observed an associated bright CME, first seen in LASCO C2 at 00:00 UT on October 21, from the northeast to the southeast. Analysis of COR2 A jplots revealed a plane of sky speed of about 385 km/s, yielding a full speed of 770 km/s. Due to the position of the source, this CME will not be geoeffective. C flares are likely in the next 24 hours (70% probability), with a chance for an M flare (30% probability).

No Earth-directed Coronal Mass Ejections (CMEs) were observed in available coronagraphic imagery.

The greater than 10 MeV proton flux was at nominal levels.

A small, fast forward shock in the solar wind occurred at 5:16 UT on October 21. Solar wind speed registered by DSCOVR jumped from about 340 to 365 km/s, while the magnitude of the Interplanetary Magnetic Field (IMF) jumped from about 4 to 6 nT. Current solar wind speed is about 360 km/s and current IMF magnitude is about 8.5 nT. The IMF was directed away from the Sun until it started pointing towards the Sun around 7:40 UT on October 21. Quiet to unsettled conditions (K Dourbes between 1 and 3; NOAA Kp between 1 and 2) were registered in the past 24 hours. There is a chance for active geomagnetic levels (K Dourbes = 4) on October 21. Quiet to unsettled geomagnetic levels (K Dourbes < 4) are expected on October 22 and 23.



# Summary

- Both ground- and space-based data and imagery are used in SWx
  - Depends on the SWx user community and the purpose
  - Tools
- Multiple stations are a must
  - Back-up, cross-check & continuous monitoring
  - Reversed engineering

