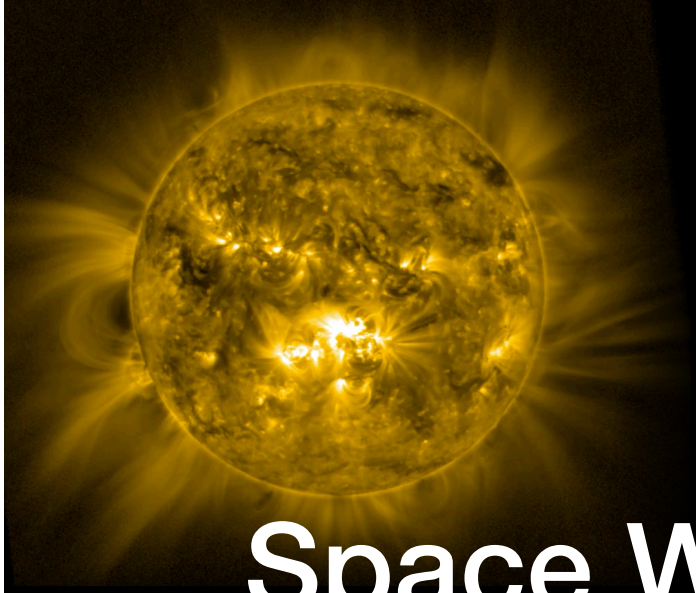
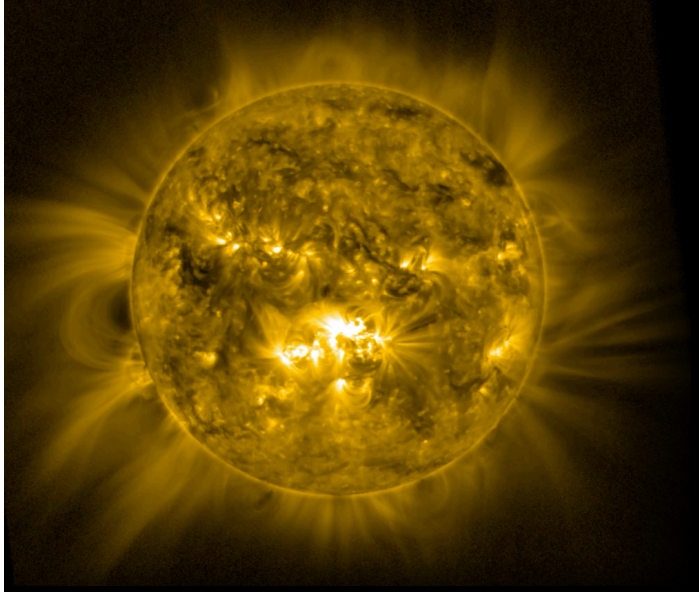


Space Weather: the biggest natural risk in the solar system

D. Berghmans
Royal Observatory of Belgium

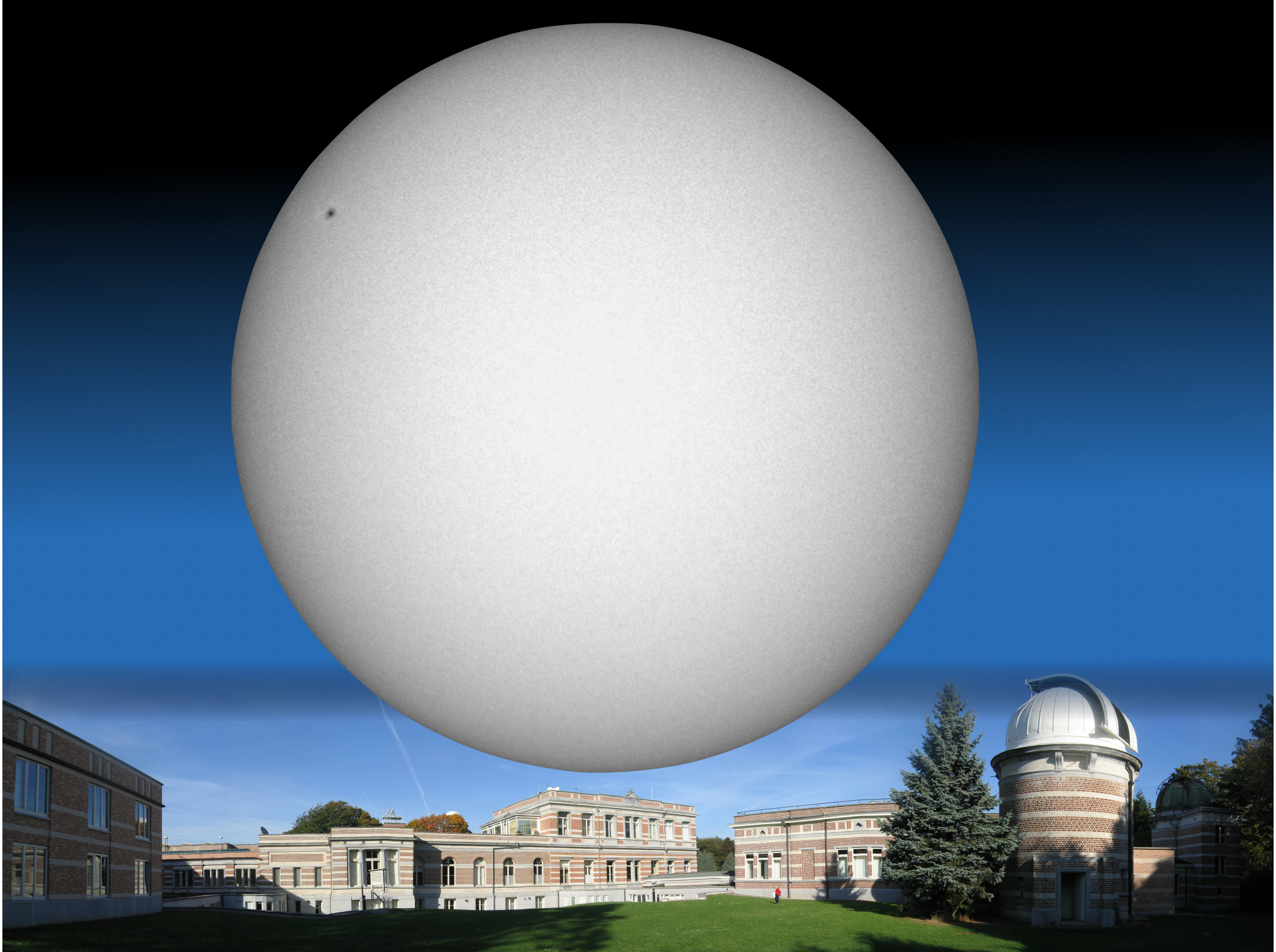


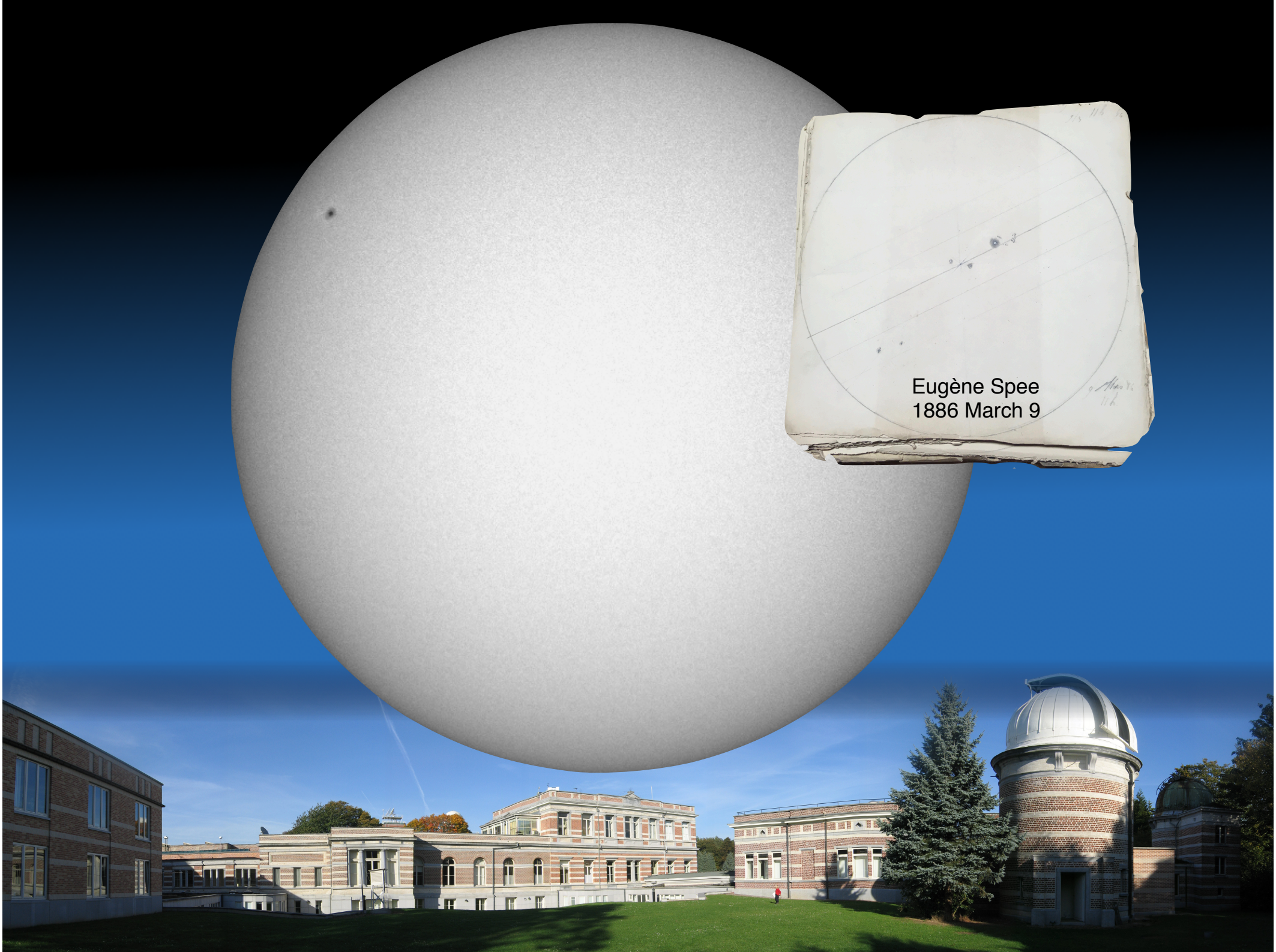
Space Weather

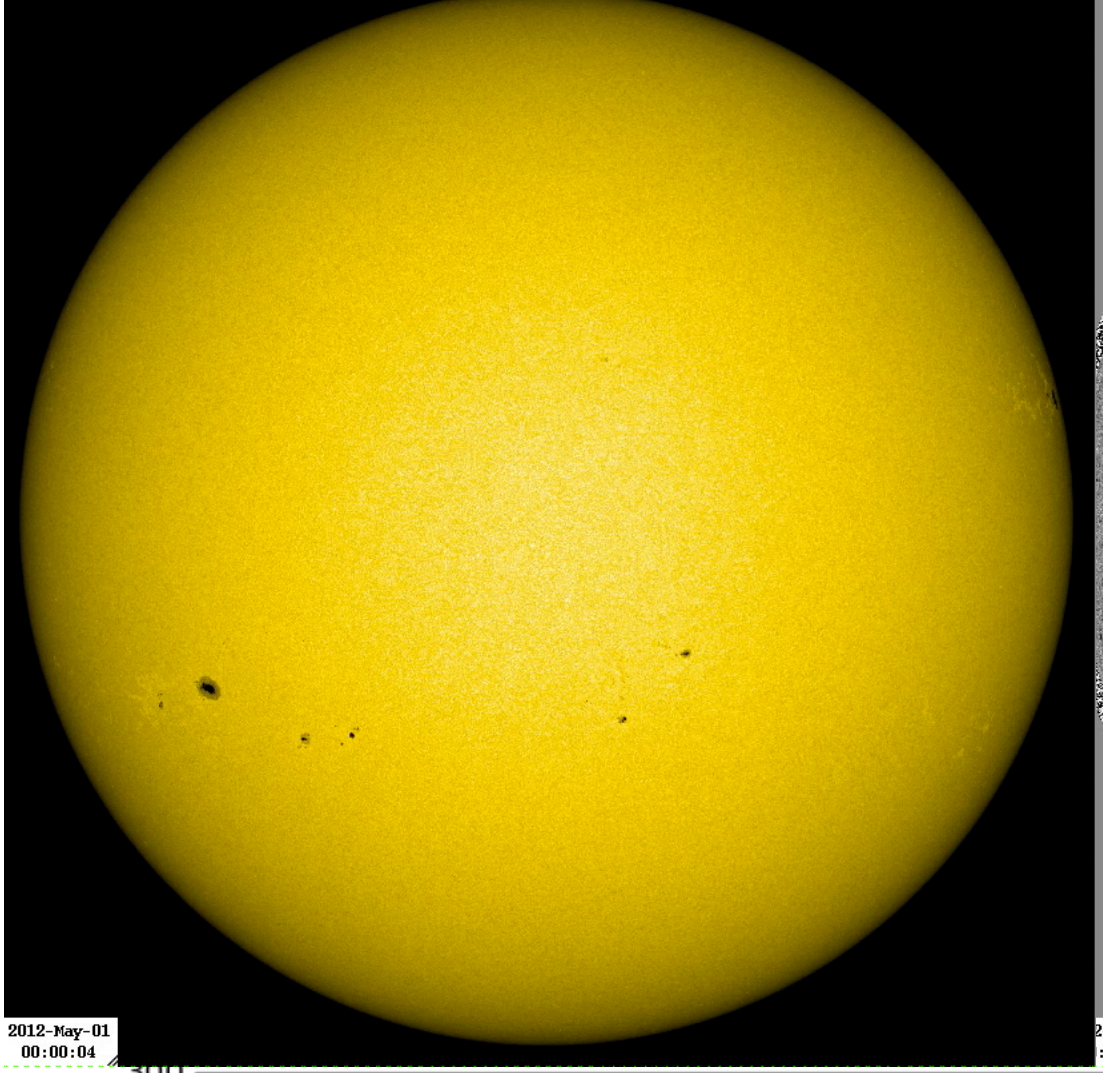
1. What is the cause?
   Solar Physics as the driver of Space Weather

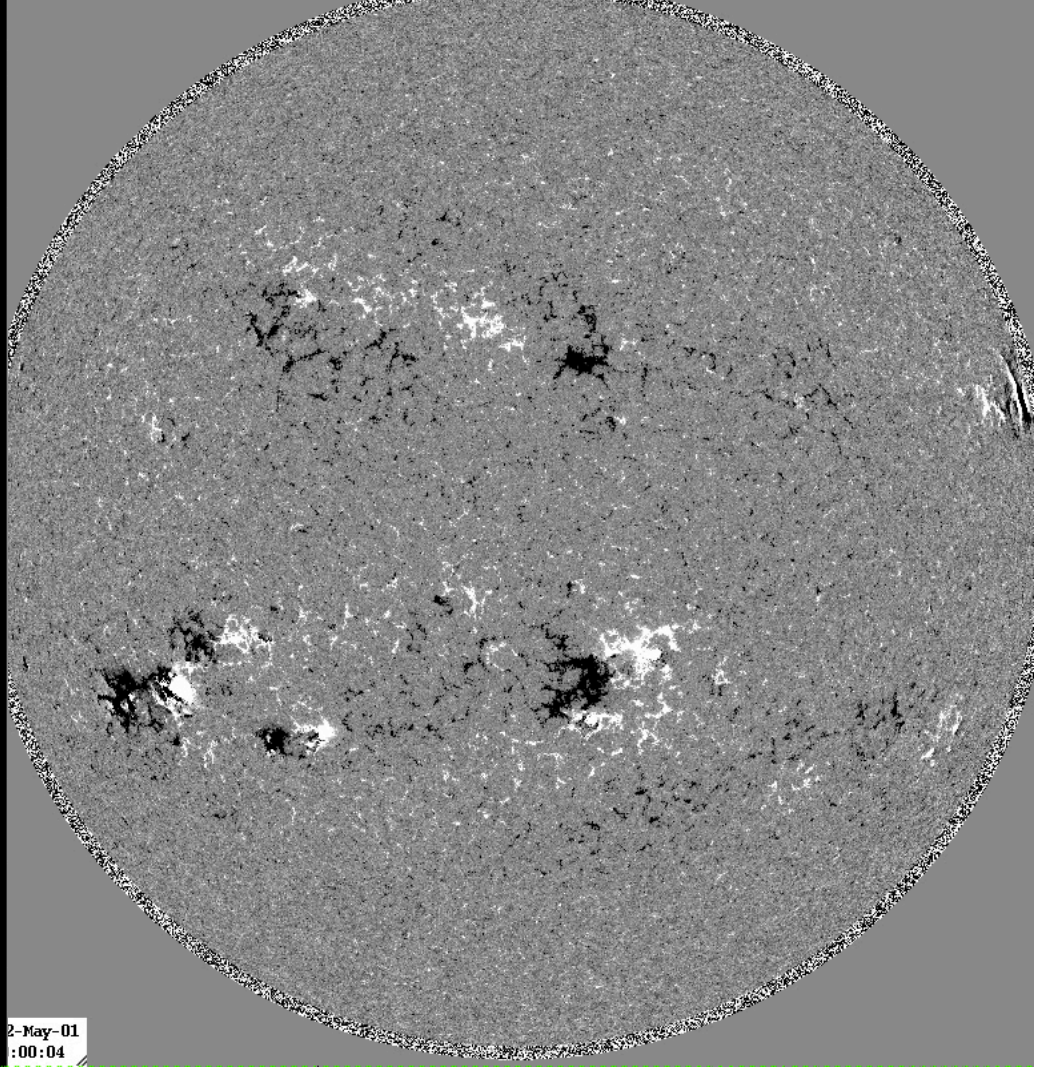
2. What is the effect?
   Impact of Space Weather on the Earth

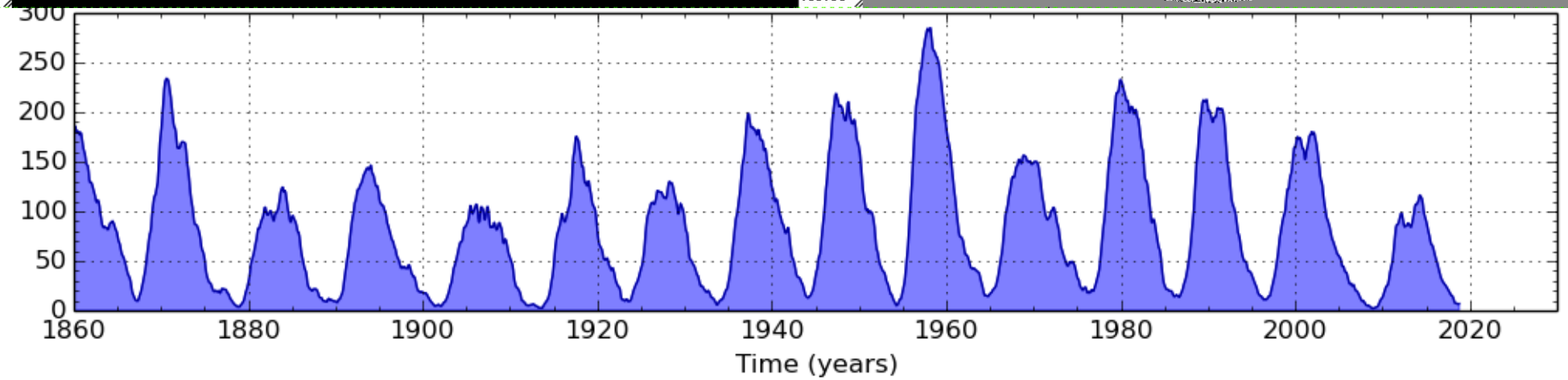
3. What can we do?
   Space Weather Services




Eugène Spee
1886 March 9







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


Earth atmosphere: hydrodynamics

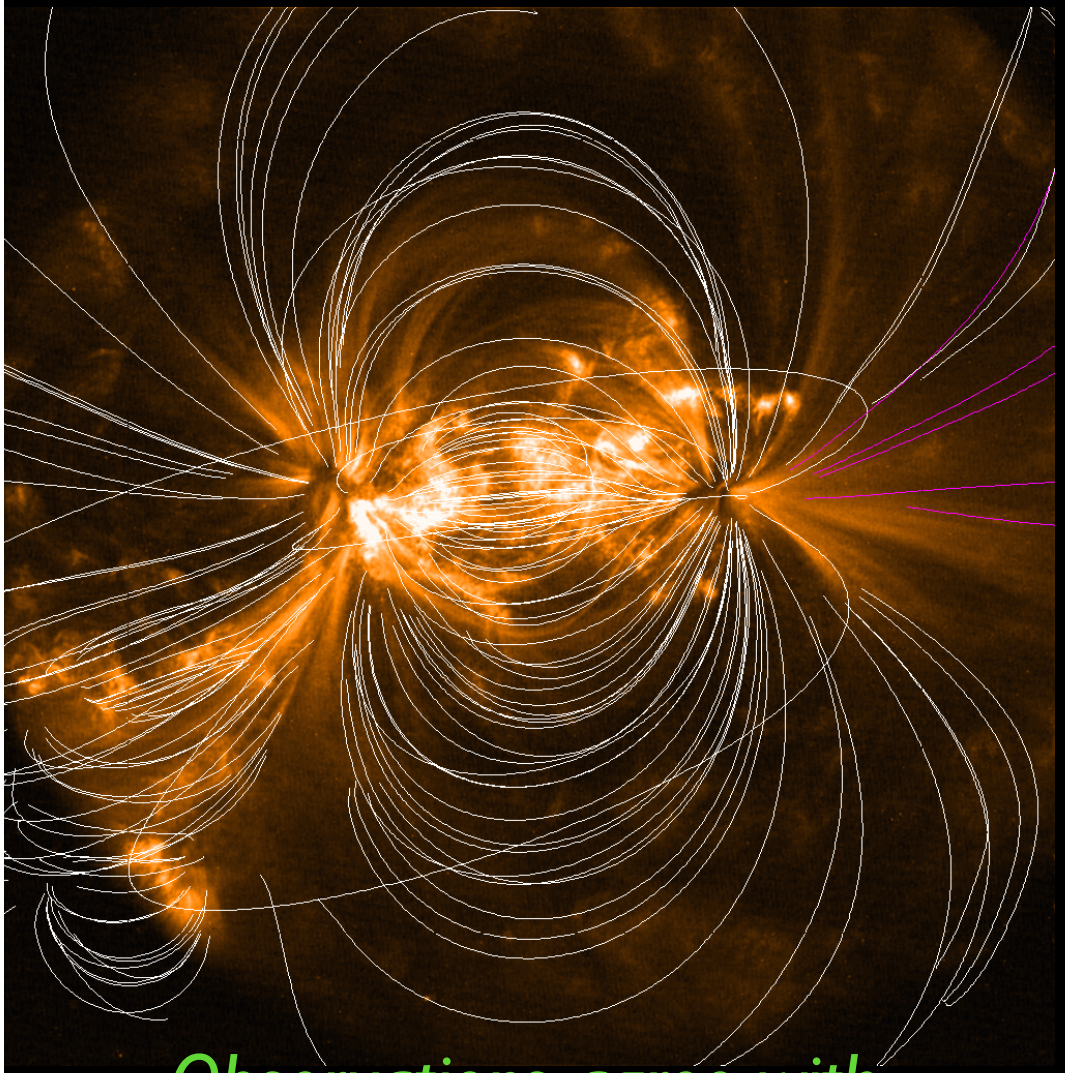
Solar atmosphere: magnetohydrodynamics

Swedish Solar Telescope, H-alpha 2005-10-04

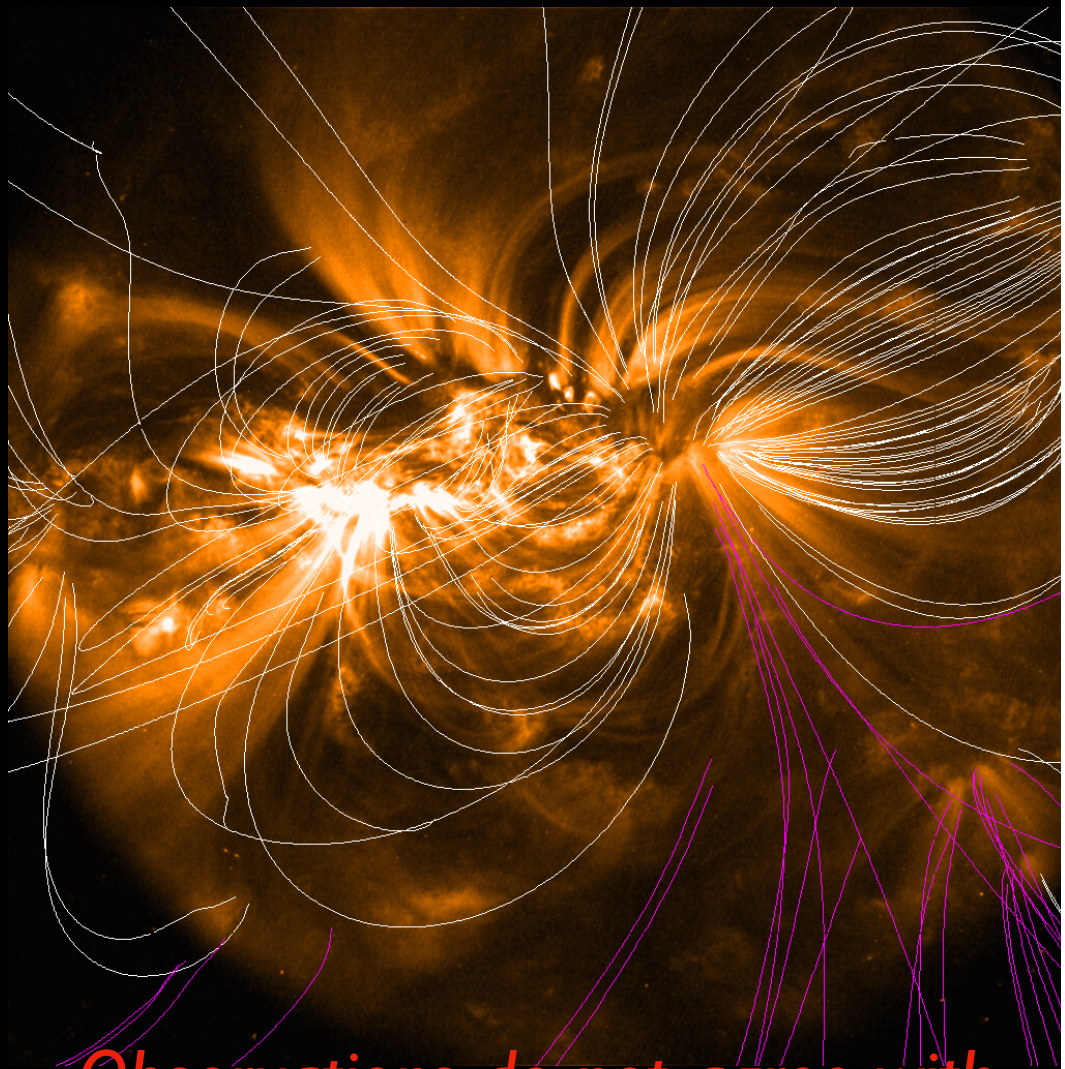
PROBA2

PROBA2/SWAP 174 2011-10-19T18:18:02

The magnetic field can be 'charged' with energy

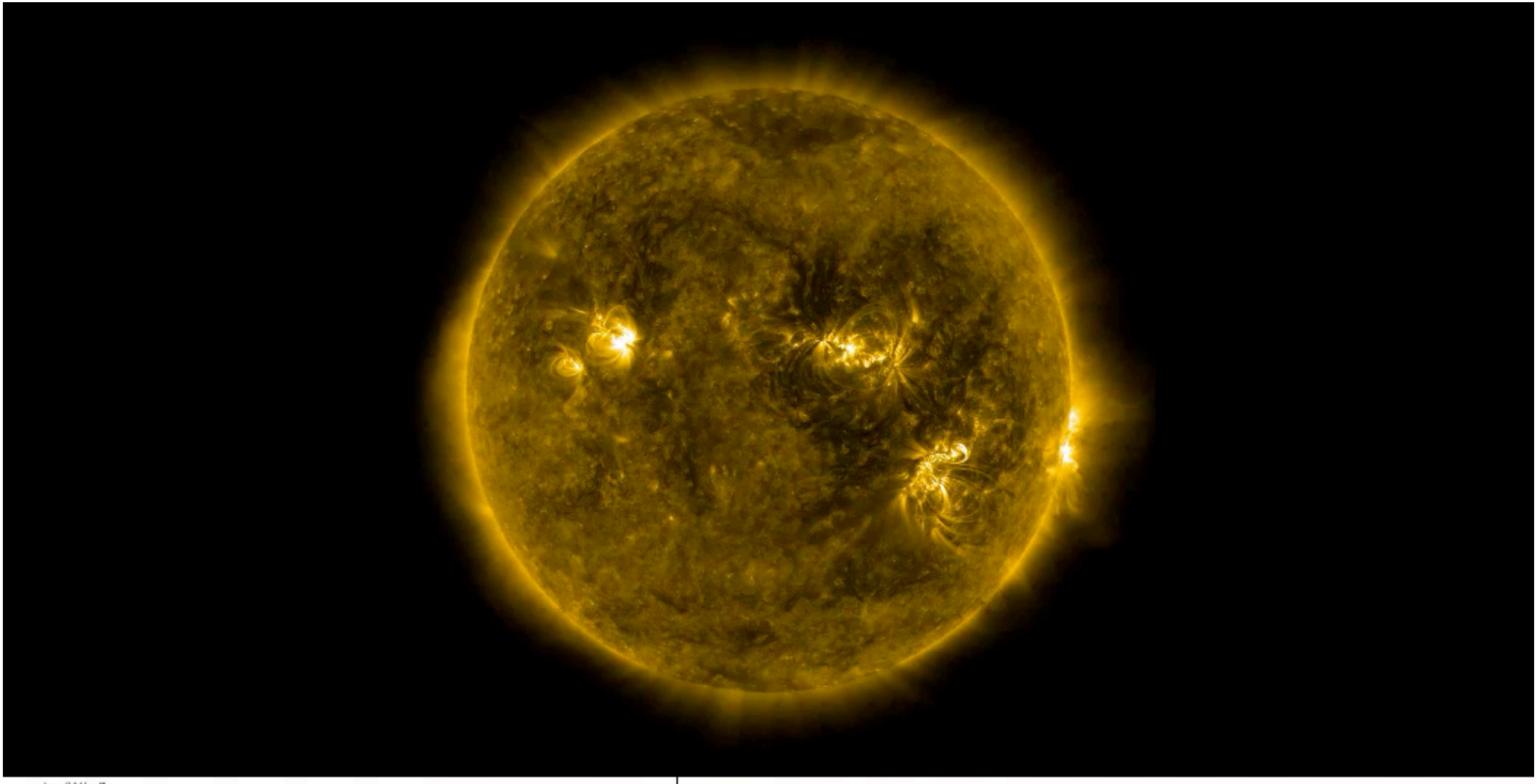


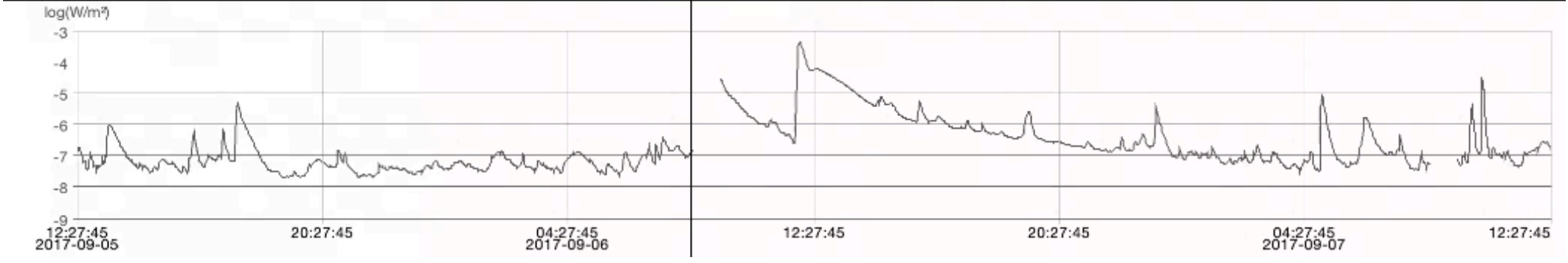
Observations agree with current-free magnetic field



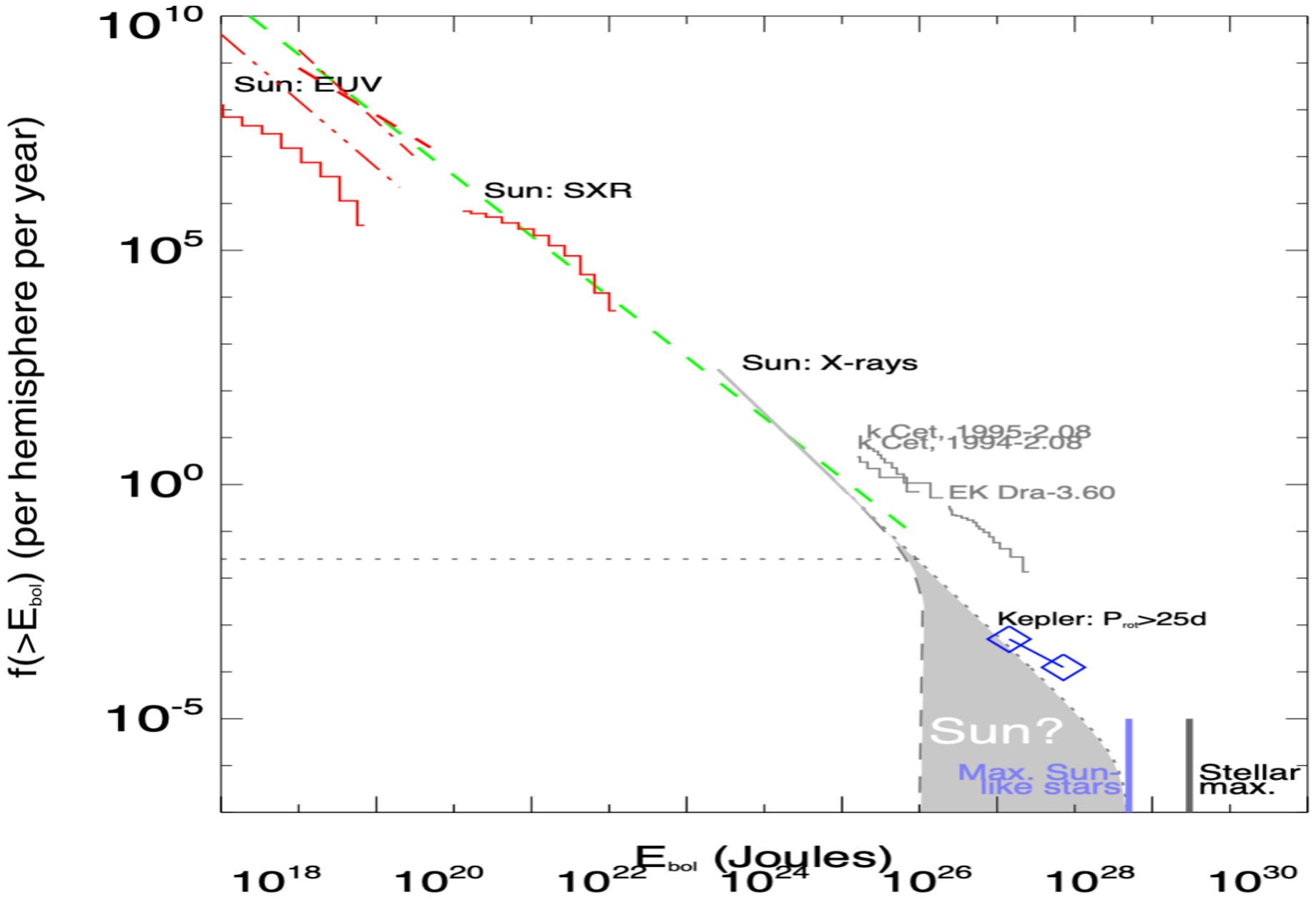
Observations do not agree with current-free magnetic field

2017 Sept 6, 14th biggest solar flare ever recorded (X9.3)





How big can solar flares be?



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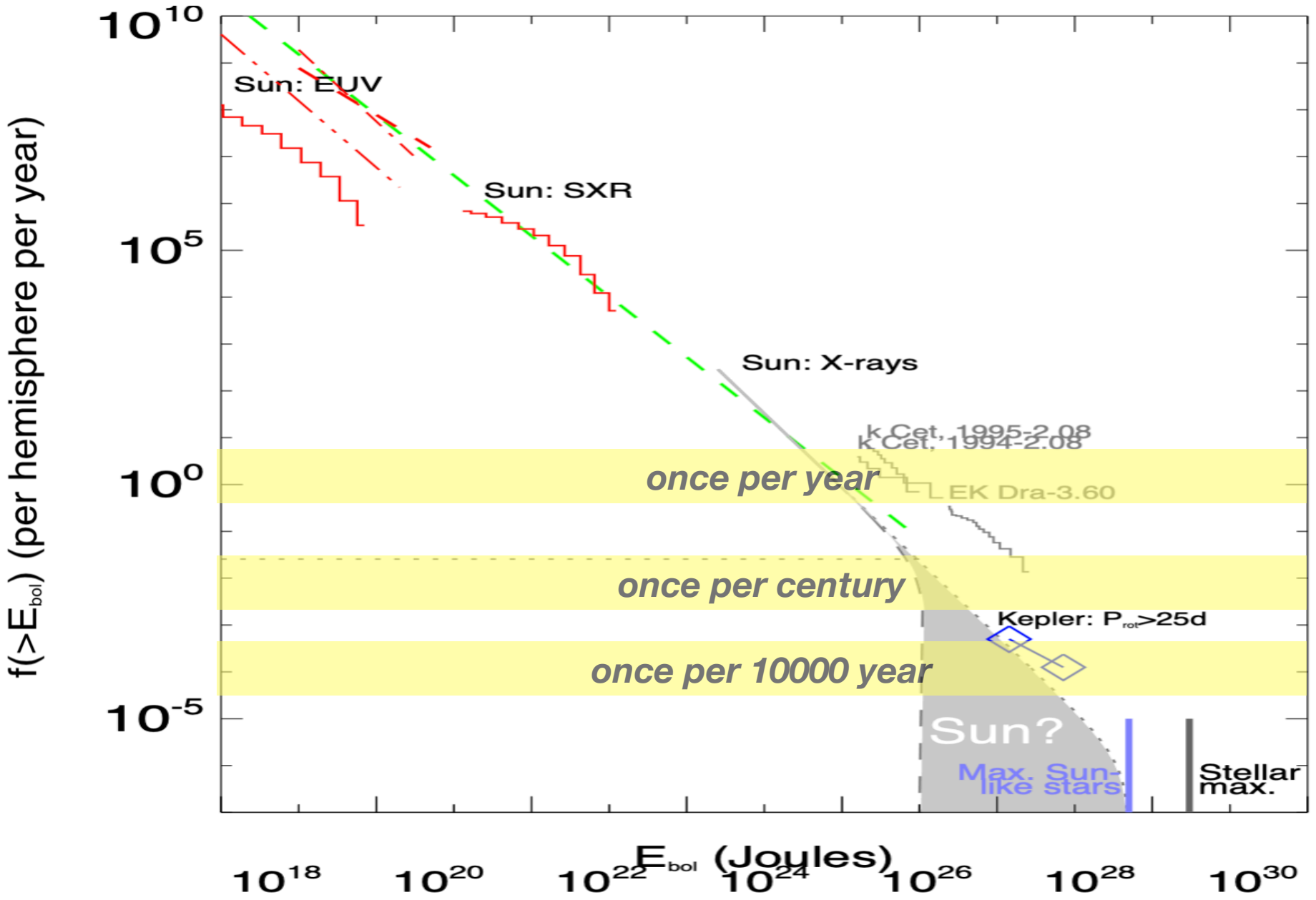
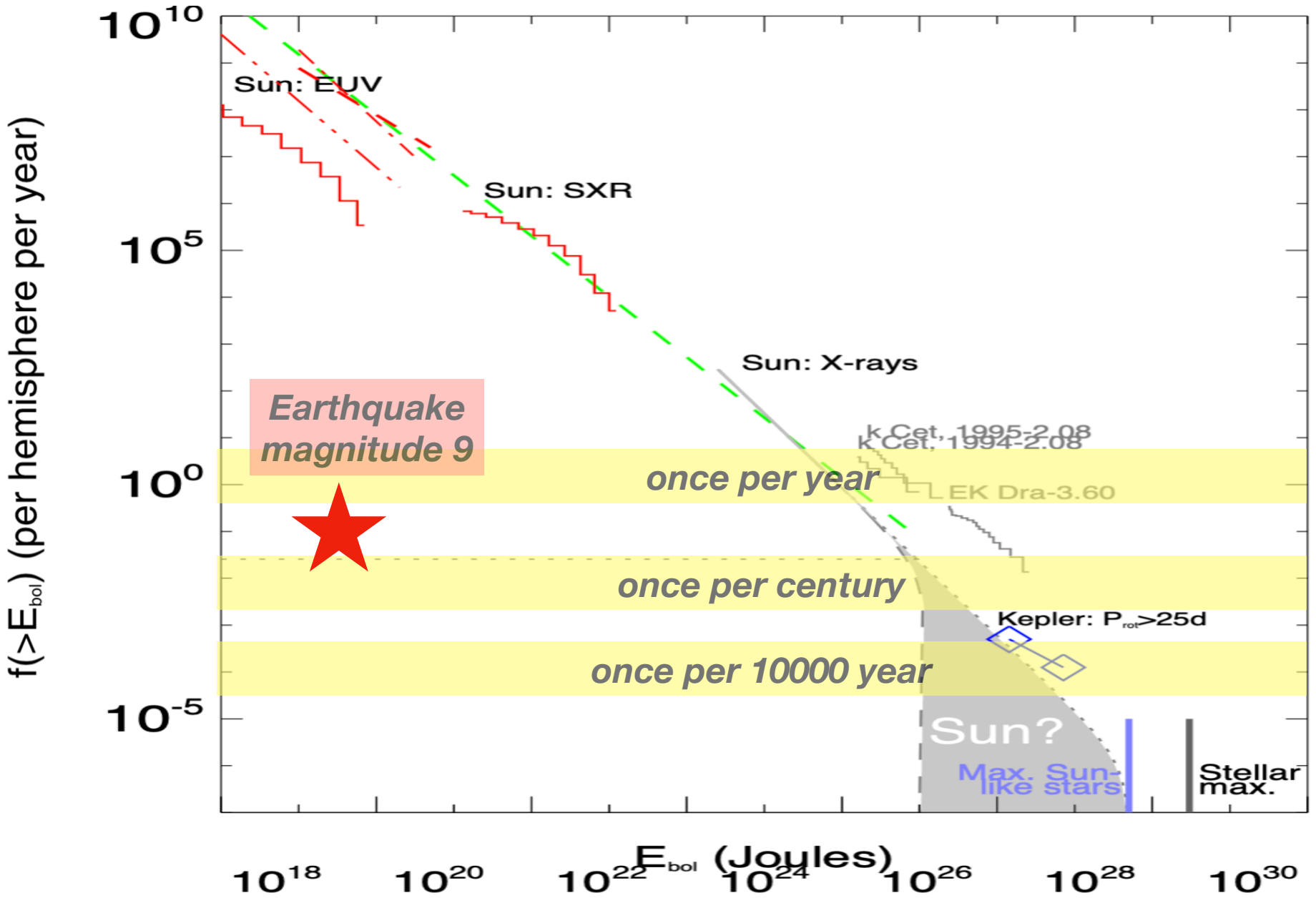
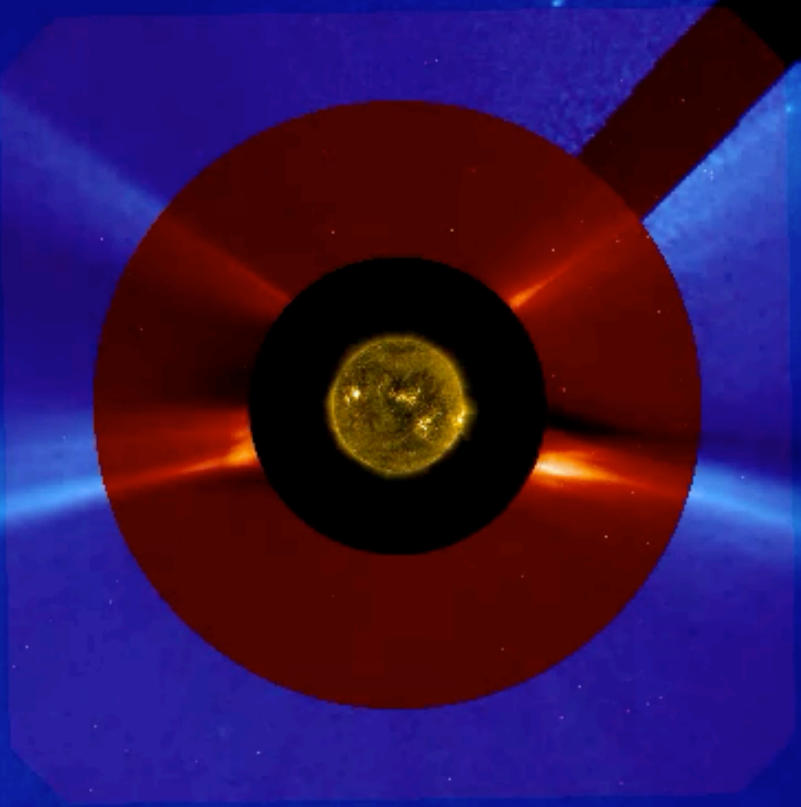


How big can solar flares be?



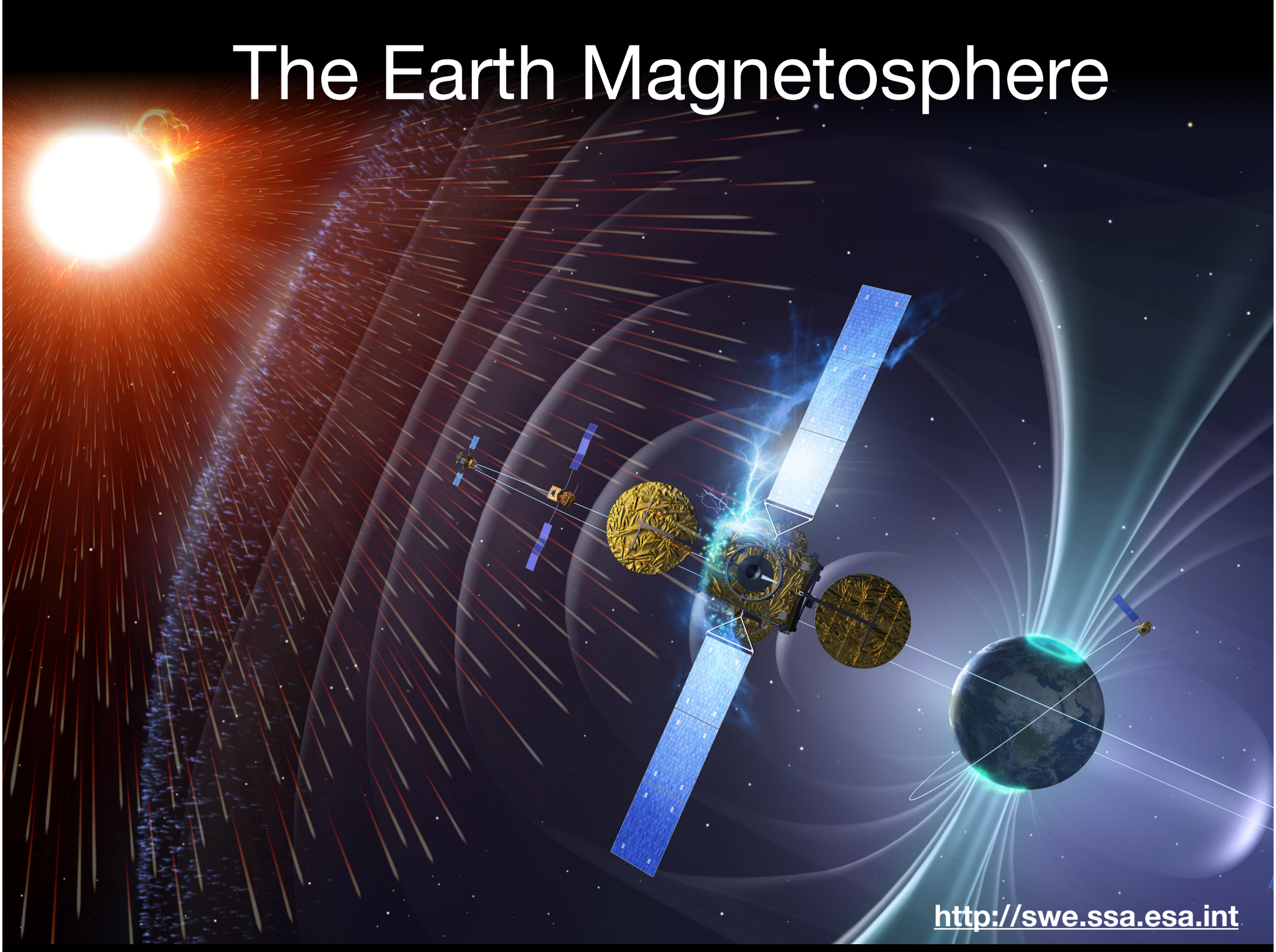
coronal mass ejections



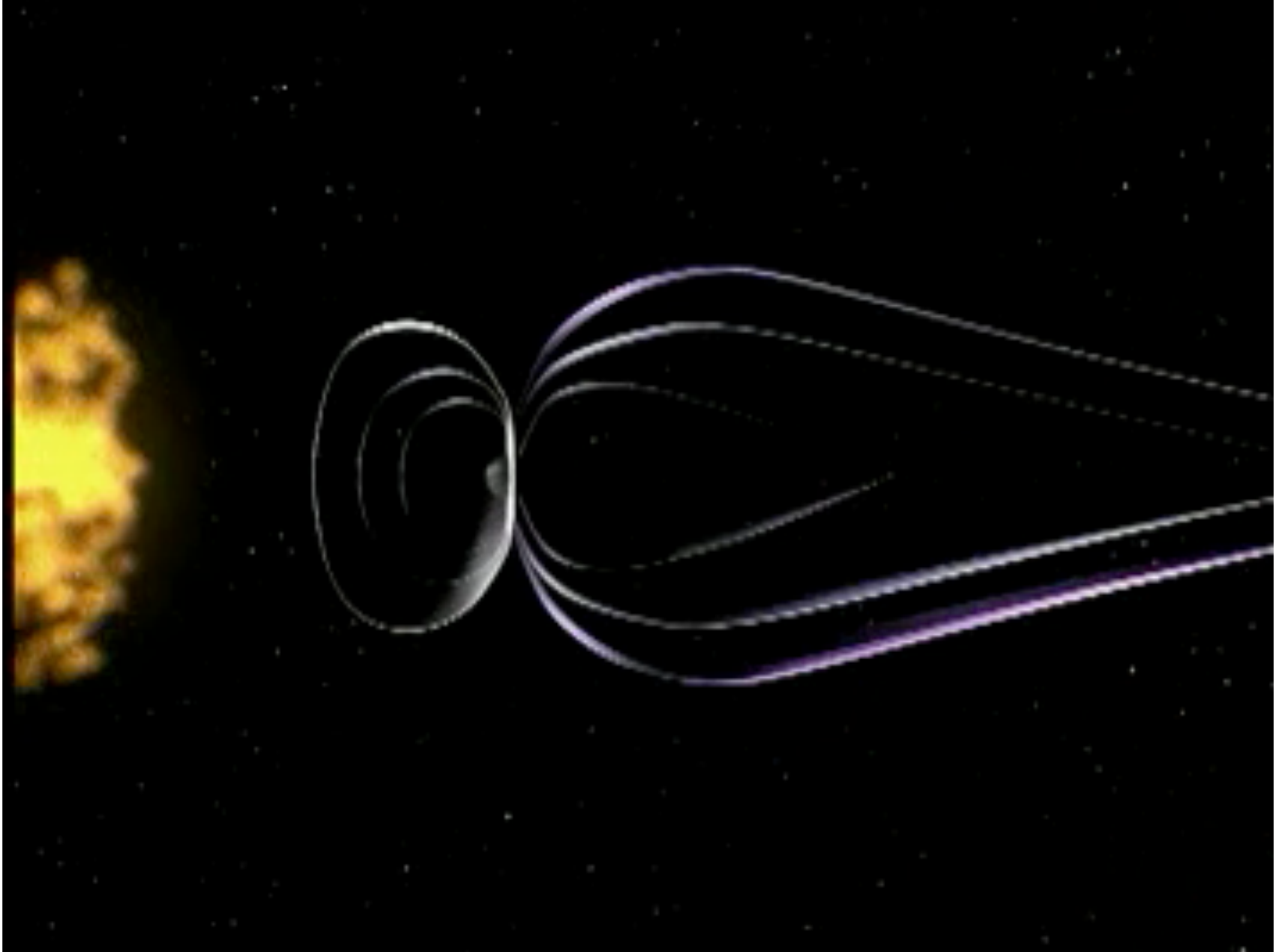
What does it matter to me?

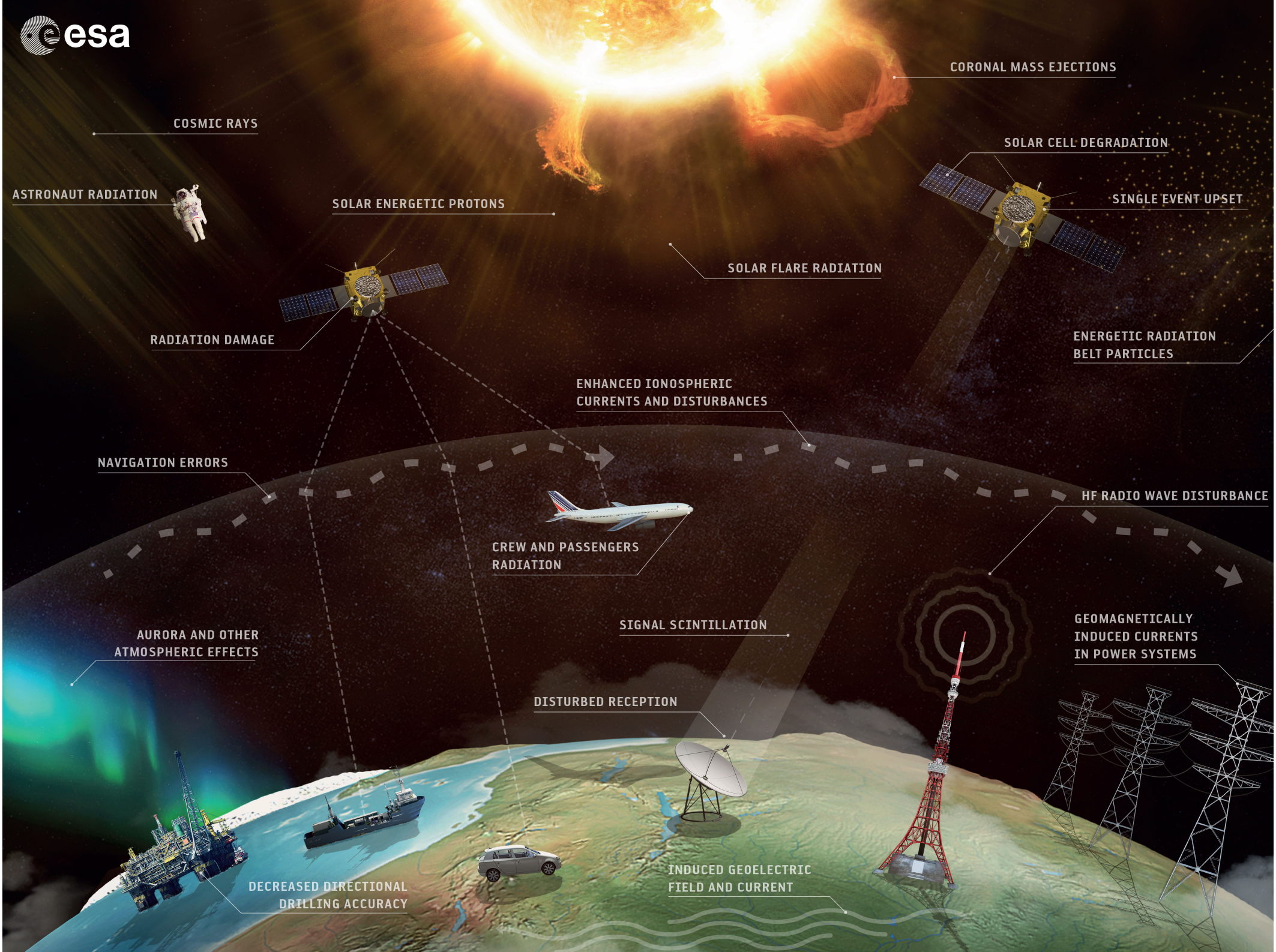
From Fundamental to Applied Research

The Earth Magnetosphere



http://swe.ssa.esa.int

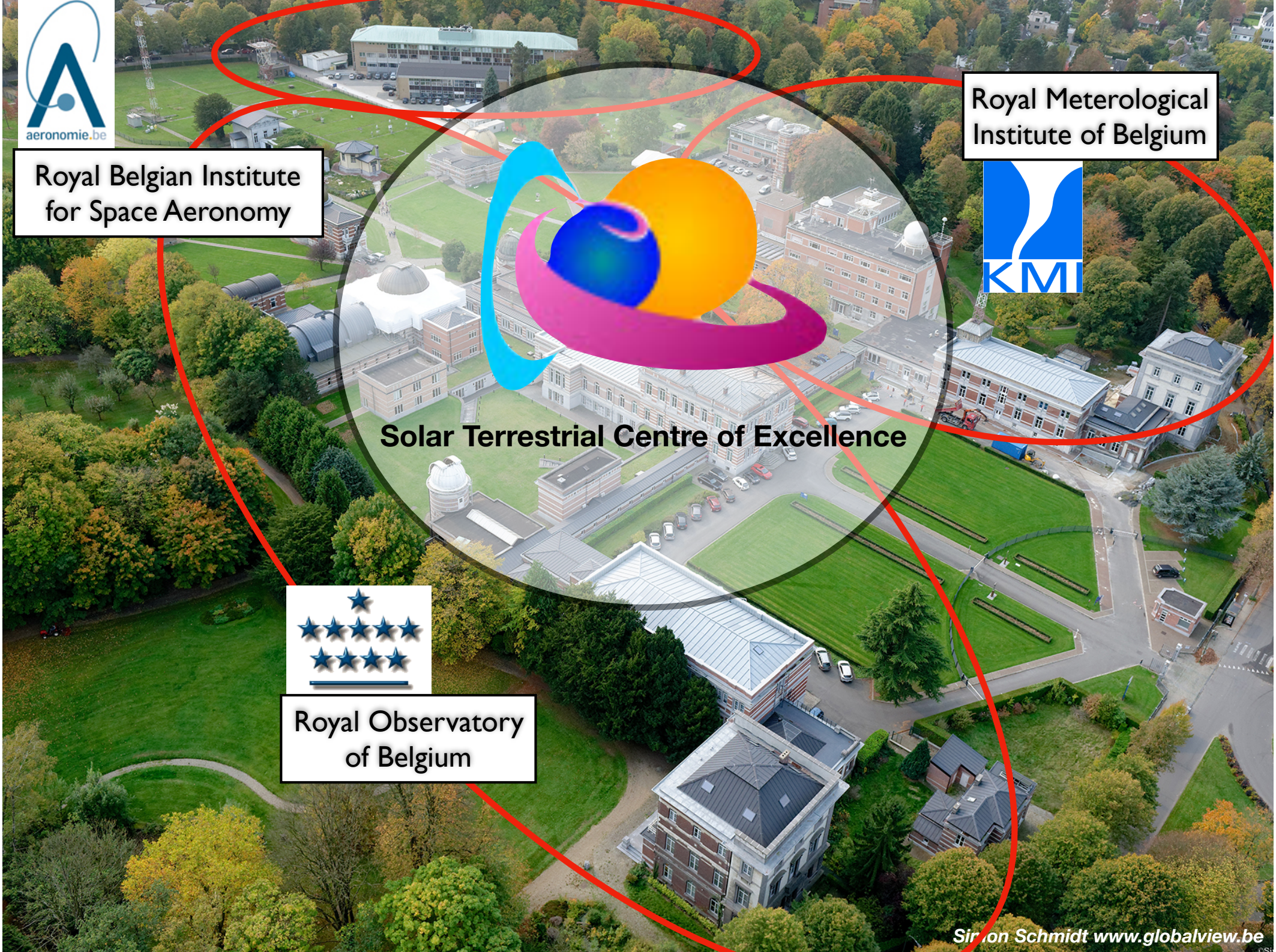



esa
CORONAL MASS EJECTIONS
COSMIC RAYS
SOLAR CELL DEGRADATION
ASTRONAUT RADIATION
SOLAR ENERGETIC PROTONS
SINGLE EVENT UPSET
SOLAR FLARE RADIATION
RADIATION DAMAGE
ENERGETIC RADIATION BELT PARTICLES
ENHANCED IONOSPHERIC CURRENTS AND DISTURBANCES
NAVIGATION ERRORS
HF RADIO WAVE DISTURBANCE
CREW AND PASSENGERS RADIATION
SIGNAL SCINTILLATION
GEOMAGNETICALLY INDUCED CURRENTS IN POWER SYSTEMS
AURORA AND OTHER ATMOSPHERIC EFFECTS
DISTURBED RECEPTION
DECREASED DIRECTIONAL DRILLING ACCURACY
INDUCED GEOELECTRIC FIELD AND CURRENT

What can we do about it?

What can we do about it?

From Applied Research to Space Weather Services

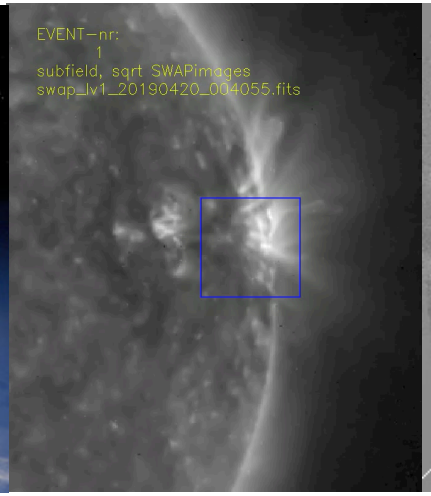

aeronomie.be
Royal Belgian Institute for Space Aeronomy
Royal Meterological Institute of Belgium
KMI
Solar Terrestrial Centre of Excellence
Royal Observatory of Belgium
Simon Schmidt www.globalview.be

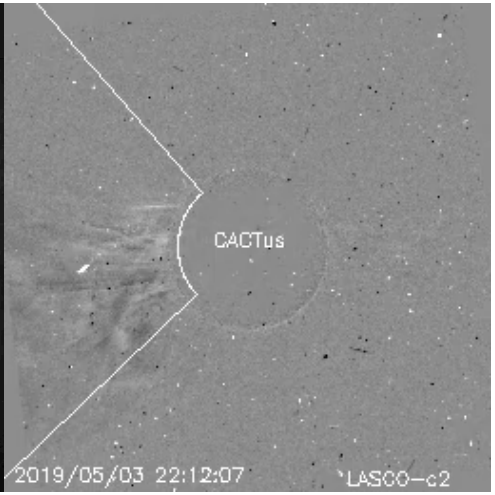
```
:Issued: 2019 May 05 1230 UTC
:Product: documentation at http://www.sidc.be/products/meu
#-----------------------------------------------------------------#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC  #
# (RWC Belgium)                                                   #
#-----------------------------------------------------------------#
SIDC URSIGRAM 90505
SIDC SOLAR BULLETIN 05 May 2019, 1230UT
SIDC FORECAST (valid from 1230UT, 05 May 2019 until 07 May 2019)
SOLAR FLARES  : C-class flares expected, (probability >=50%)
GEOMAGNETISM  : Active conditions expected (A>=20 or K=4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 05 May 2019  10CM FLUX: 068 / AP: 007
PREDICTIONS FOR 06 May 2019  10CM FLUX: 070 / AP: 013
PREDICTIONS FOR 07 May 2019  10CM FLUX: 072 / AP: 011
COMMENT: NOAA AR 2740 is the only visible active region on the solar disc.
It produced a C2.1 flare peaking at 22:43 UT on May 4 and several narrow
(not Earth directed) CMEs. More C-class flares can be expected

No Earth directed CMEs in past 24 h. Solar protons have remained at
background levels over the past 24 hours.

The solar wind speed is at 440 km/s with interplanetary magnetic field
magnitude of 4 nT. Geomagnetic conditions have been mostly unsettled with
an active period detected at Dourbes (k = 4 between 15:00 UT and 17:00 UT
on May 4), due to several hours of negative Bz. The solar wind from an
equatorial negative polarity coronal hole will affect the Earth on May 6-7.
Active conditions can be expected then.

TODAY'S ESTIMATED ISN  : 013, BASED ON 16 STATIONS.
```

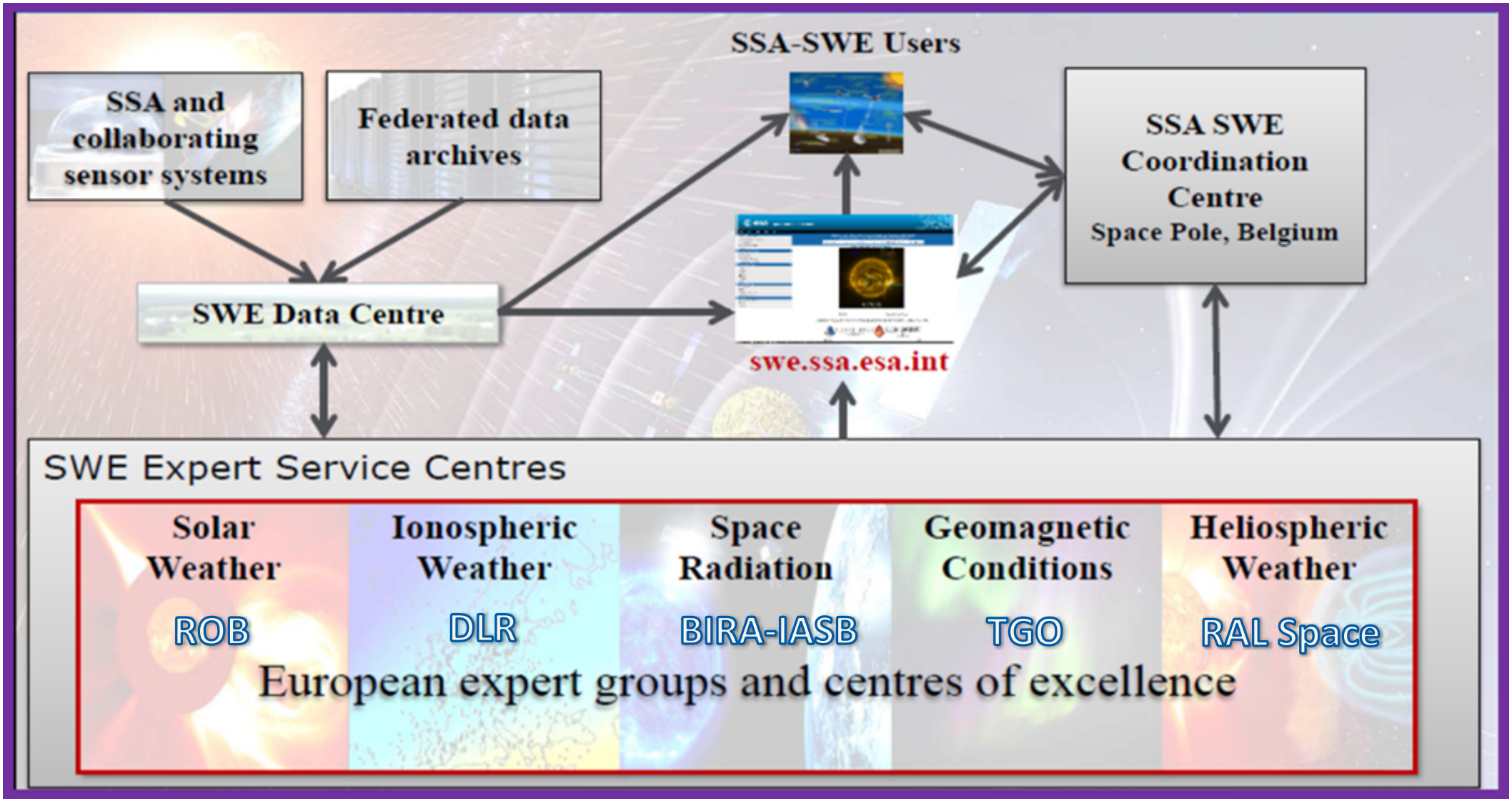
I S E S

International Space Environment Service

- daily space weather forecast
- weekly review of activity






SSA-SWE Users
SSA and collaborating sensor systems
Federated data archives
SSA SWE Coordination Centre
Space Pole, Belgium
SWE Data Centre
swe.ssa.esa.int
SWE Expert Service Centres
Solar Weather
ROB
Ionospheric Weather
DLR
Space Radiation
BIRA-IASB
Geomagnetic Conditions
TGO
Heliospheric Weather
RAL Space
European expert groups and centres of excellence

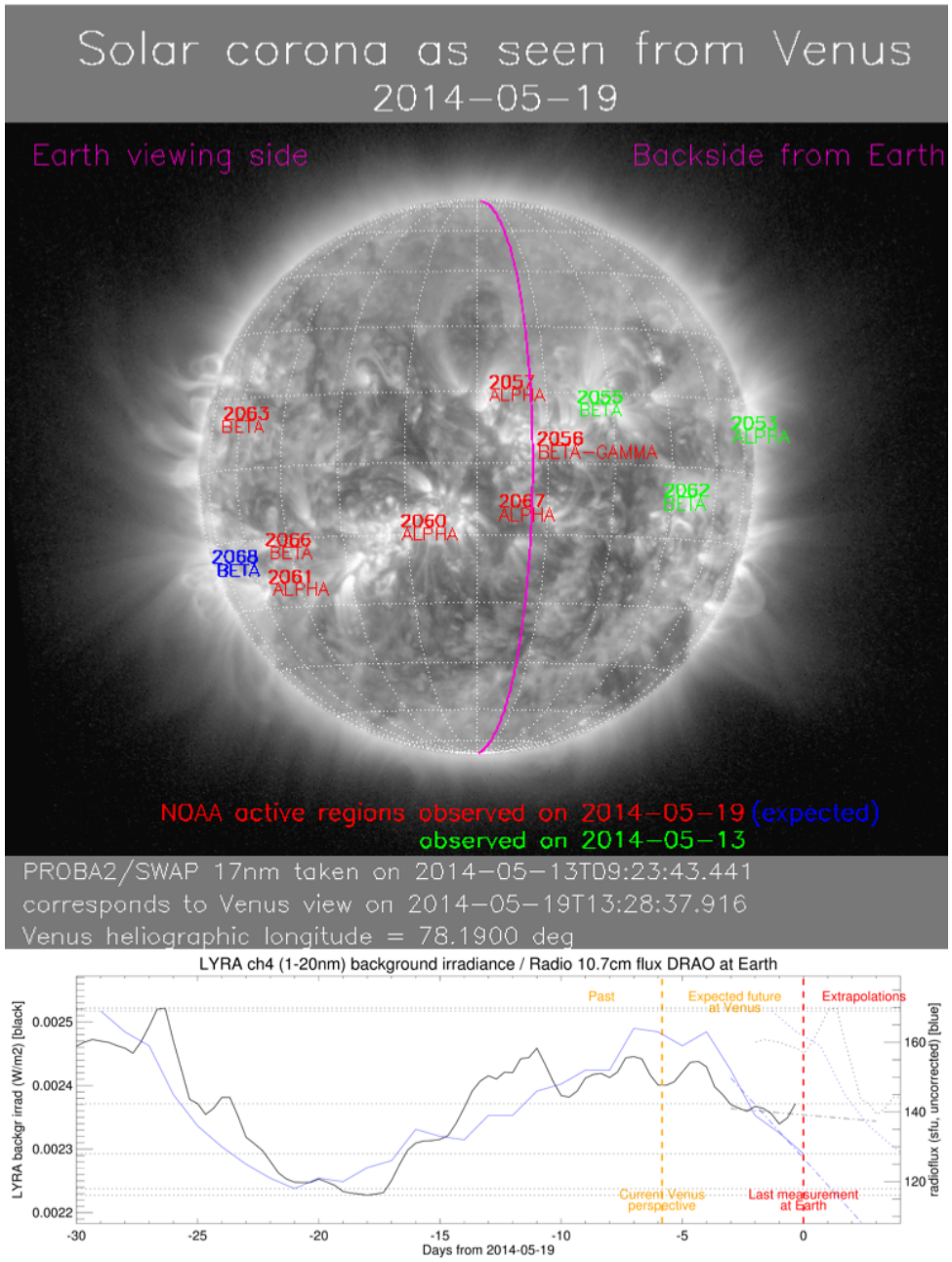

esa
space situational awareness
European Space Agency
ESA
SSA
SWE
NEO
SST
SSA Space Weather Coordination Centre
SSCC
coordination
center

Tailored Space Weather bulletins

venus express

2014 Venus express aerobreaking maneuvre

```
== Space Weather bulletin for Venus Express aerobraking operations ==

Bulletin #1
prepared by SSCC and SIDC forecaster
on May 19, 2014 at 14:10 UTC.

Valid until May 21, 2014 at 14:10 UTC.

=== Past 24 hours (Earth viewpoint) ===
Solar flare activity: no C, M or X flares
10-MEV proton flux:    < 0.2 pfu
F10.7 index:           128 sfu at Earth

=== Next 48 hours (Earth viewpoint) ===
All quiet:        no
Solar flares:     quiet (less than 50 % chance of a C flare)
Solar protons:    quiet

=== Comment ===
There were no C flares nor CMEs during the past 24 hours. In the next 48 hours,
quiet conditions (without C flares) are likely. There is a slight chance for C flares
NOAA active regions 2056 and 2066.
```

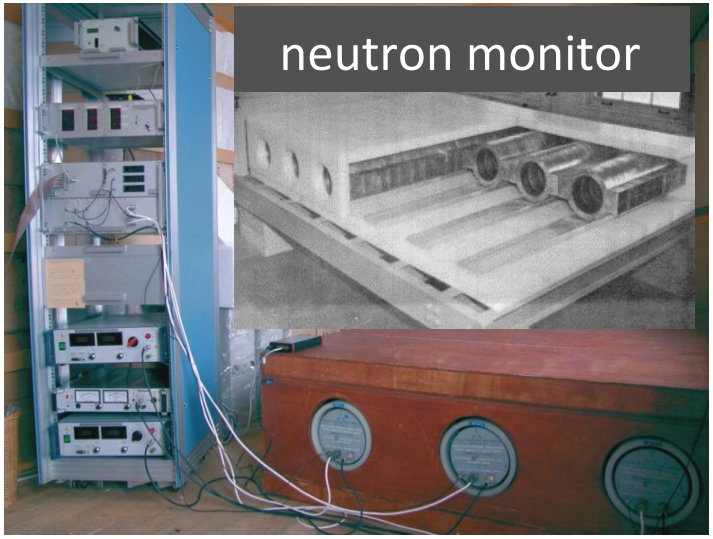


Geofysisch Centrum van het KMI * Centre de Physique du Globe de l'IRM

Ionospheric Observatory

digital sounder

Cosmic Rays Observatory



neutron monitor

Geomagnetic Observatory

magnetic variometer

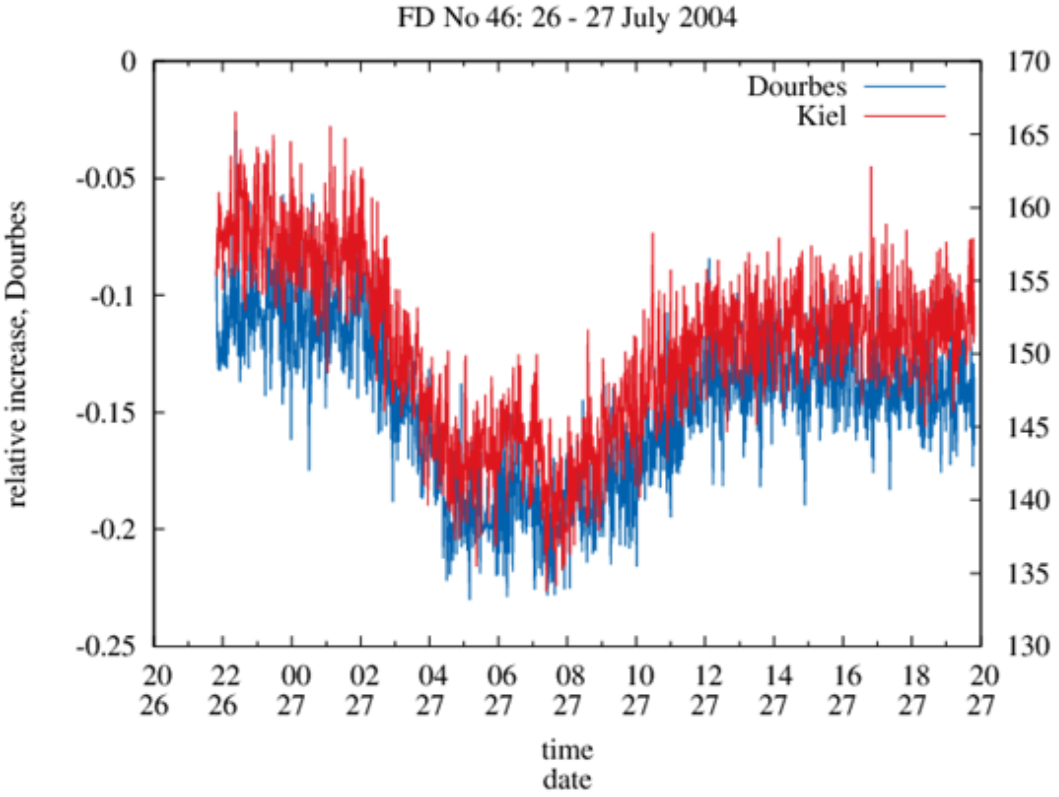
KMI

MagneticValley

Cosmic rays monitoring

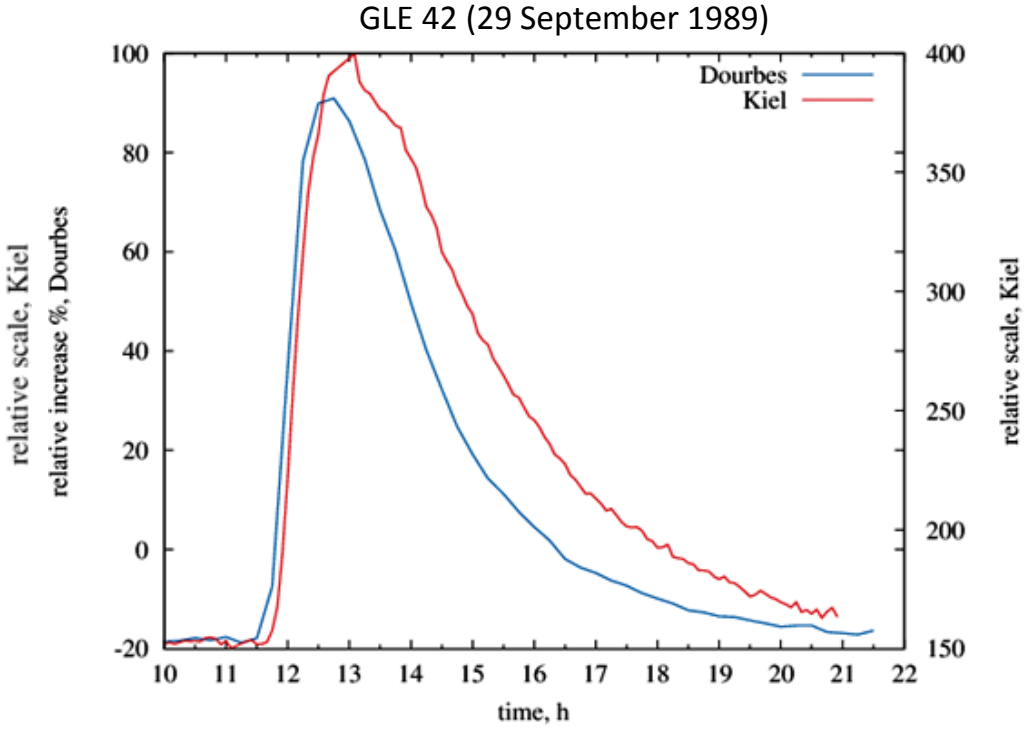
Major events detected by neutron monitors

Forbush Decrease (FD)



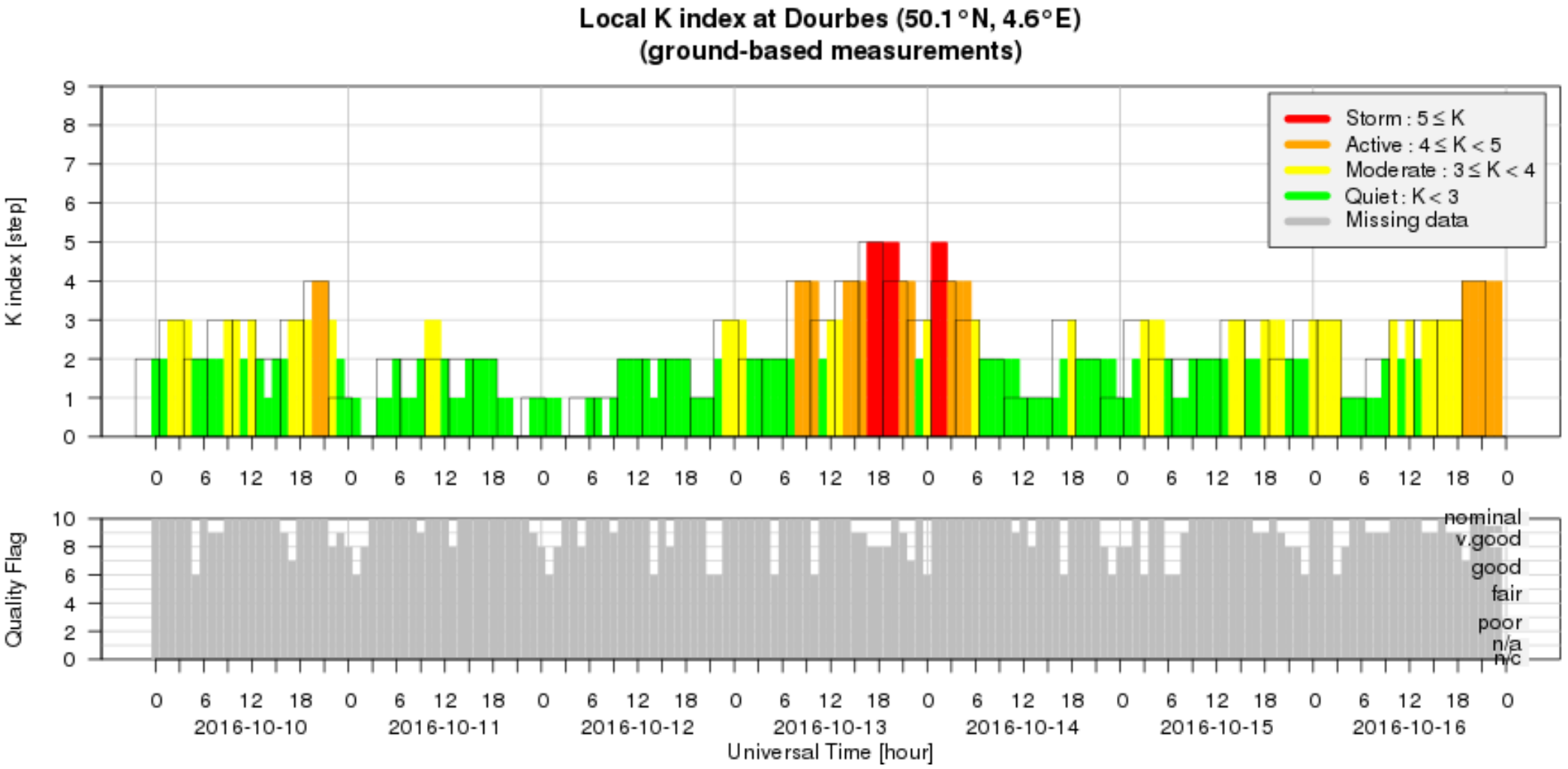
After a Coronal Mass Ejection (CME), the resulting magnetic field suppresses the intensity of the galactic cosmic rays which is seen as a reduced intensity continuing for several days (Forbush Decrease).

Ground Level Enhancement (GLE)



Ground Level Enhancement (GLE) is the transient increase of intensity of the solar cosmic rays, a direct evidence of an interplanetary anomaly that reaches the Earth. Approximately 10-15 times per decade, the Sun emits particles of sufficient energy and intensity to raise radiation levels on Earth's surface.

Local magnetic field monitoring



geomagnetic storm

KMI MagneticValley

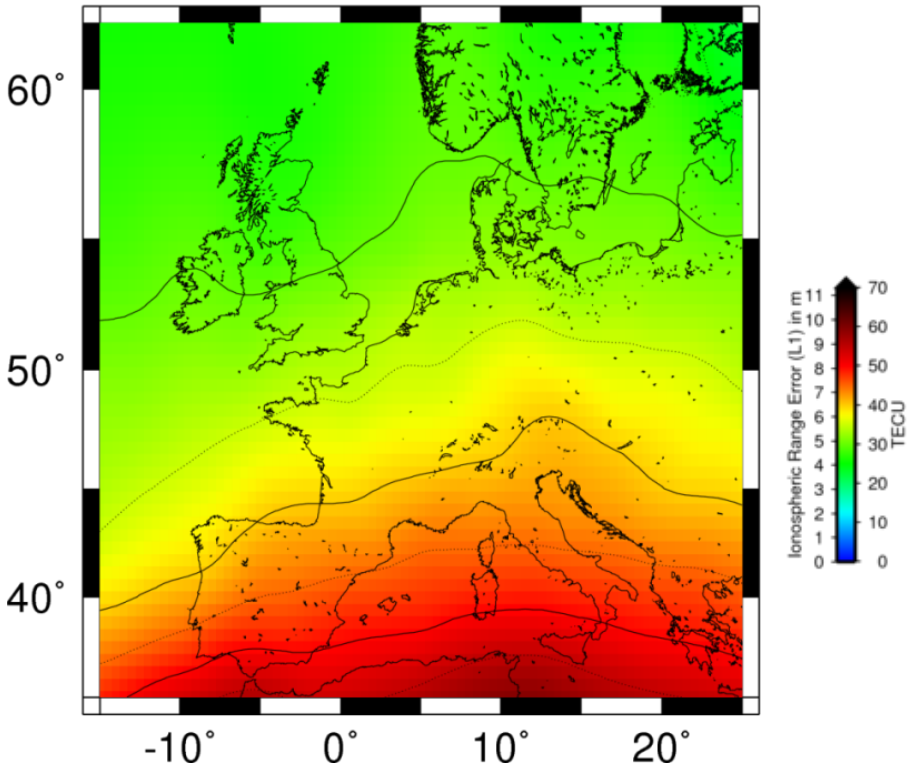
Ionospheric mapping from GNSS

Near real-time ROB-TEC maps since 2012:

- vTEC maps over Europe +Variability
  www.gnss.be
- ASCII files (IONEX format)
  ftp://gnss.oma.be

Sampling rate : 15 min.

Latency : ~3 minutes

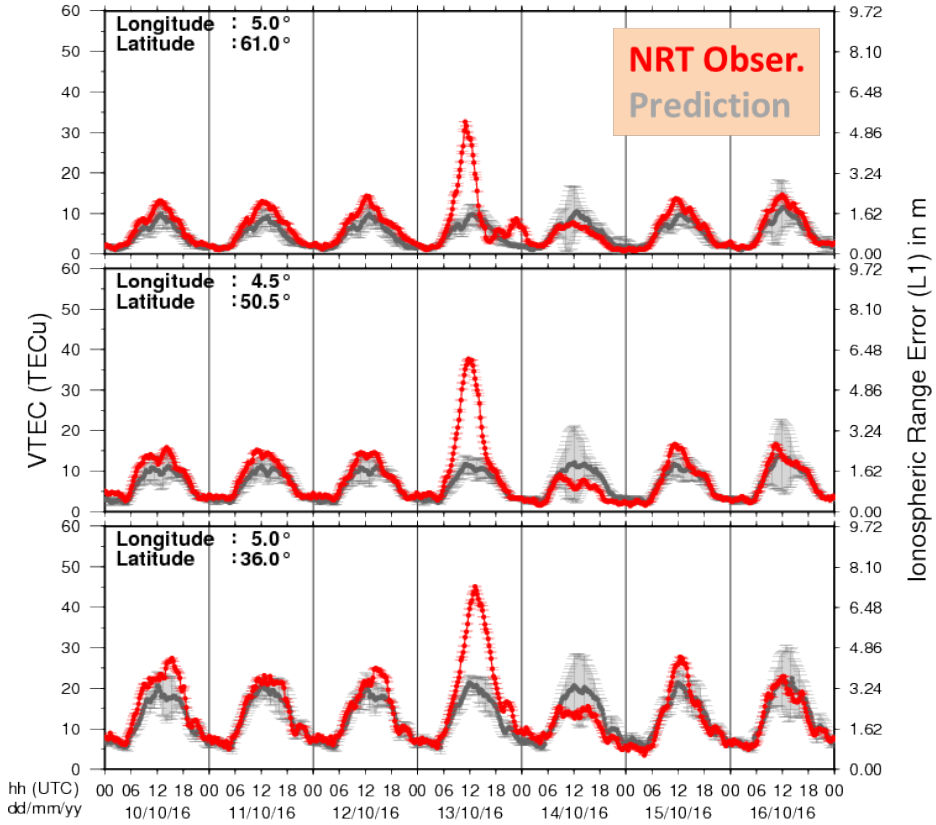


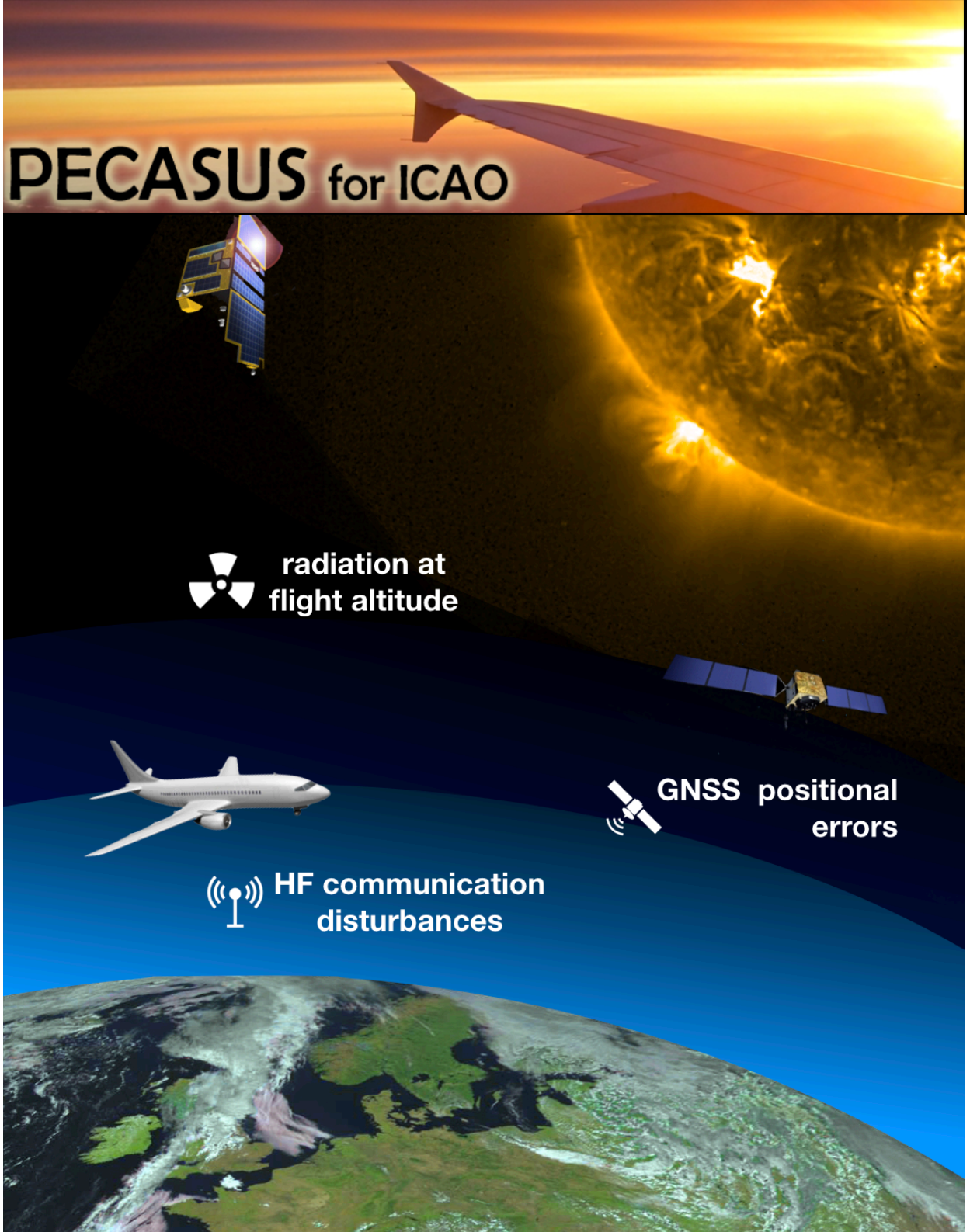
2012–present (43 events)

70% CMEs impact Geom.

20% Geom.

10% Unidentified SWO





ICAO • OACI • ИКАО

国际民航组织 • منظمة الطيران المدني الدولي

International Civil Aviation Organisation

SWX ADVISORY		
DTG:	20170818/020304Z	*time of generation*
SWXC:	PECASUS	*space weather center*
ADVISORY NR:	2017/314	*sequence nr*
SWX EFFECT	HF COM SEV	*impact MOD or SEV*
OBS SWX	20170818/015520Z	*observed time of flare*
	DAYLIGHT SIDE	*affected area*
FCST SWX +6HR:	NO SWX EXP	*forecast*
FCST SWX +12HR:	NO SWX EXP	*forecast*
FCST SWX +18HR:	NO SWX EXP	*forecast*
FCST SWX +24HR:	NO SWX EXP	*forecast*
RMK:	Solar flare occurred. Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.	
NXT ADVISORY:	NO FURTHER ADVISORIES	

Sixteenth European Space Weather Week

18 - 22 November, 2019, Liège, Belgium

Take home message

- Space Weather is very multidisciplinary bringing together Belgian scientists from many disciplines to state of the art research
- Space Weather connects fundamental space research to the needs of a technological society and is therefore strongly growing
- Space Weather is a planet-wide and therefore very international. Oversea networking is essential

Acknowledgements

- A few slides were used from Karel Schrijver's presentation at ESWW11 (2014, Liège)
- Graphs from RMI/Dourbes were used
- The Sunspot Number is a product of the SILSO World data center (http://sidc.be/silso)