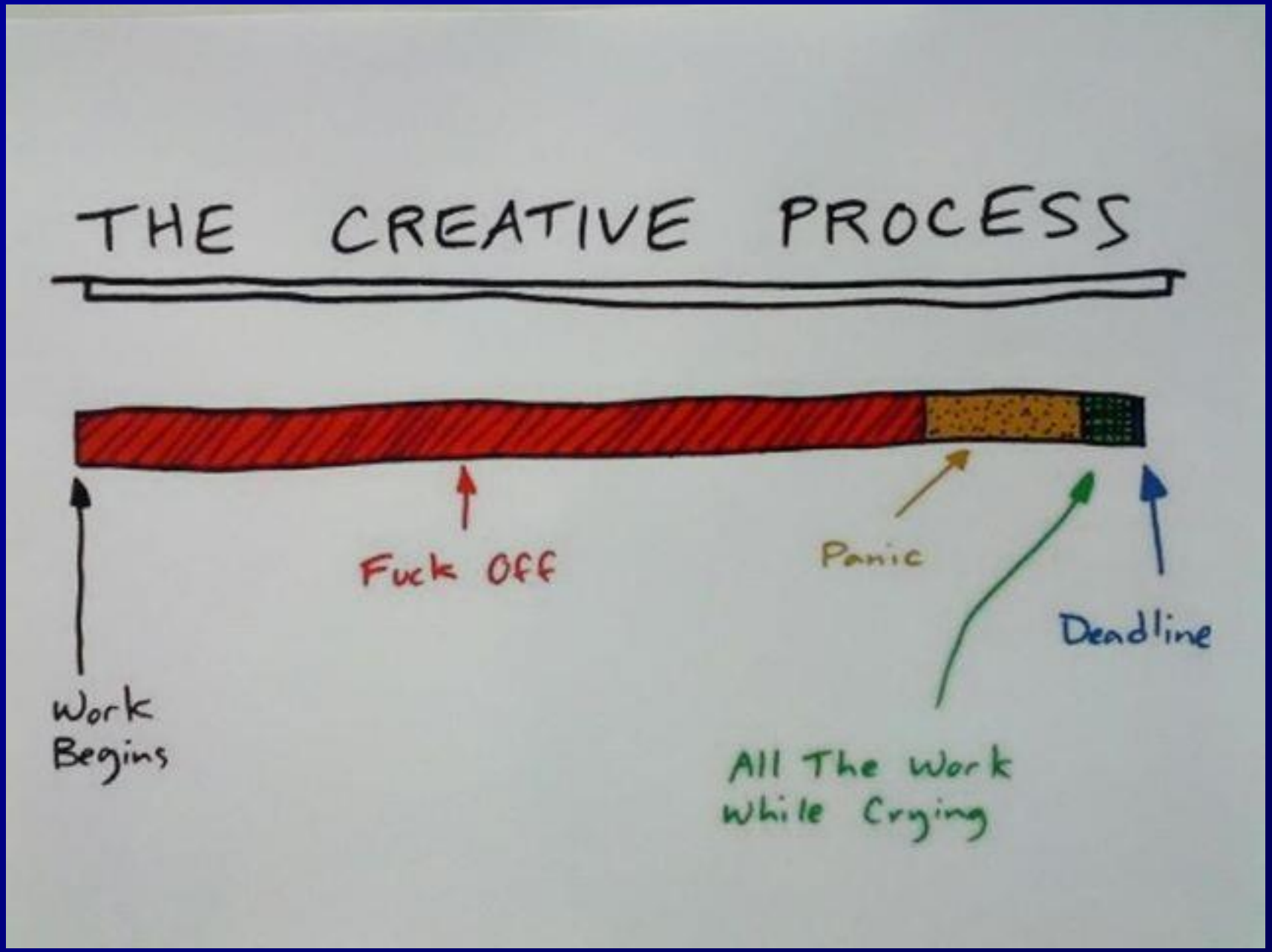
My work at SIDC: how can it benefit your work?

Cis Verbeeck

SIDC seminar
Royal Observatory of Belgium
May 24, 2017


THE CREATIVE PROCESS
Work Begins
Fuck Off
Panic
All The Work While Crying
Deadline

Overview

1. EUI
2. Space weather forecast verification
3. STAFF
4. Solar Demon
5. SPoCA
6. Extra: surprise

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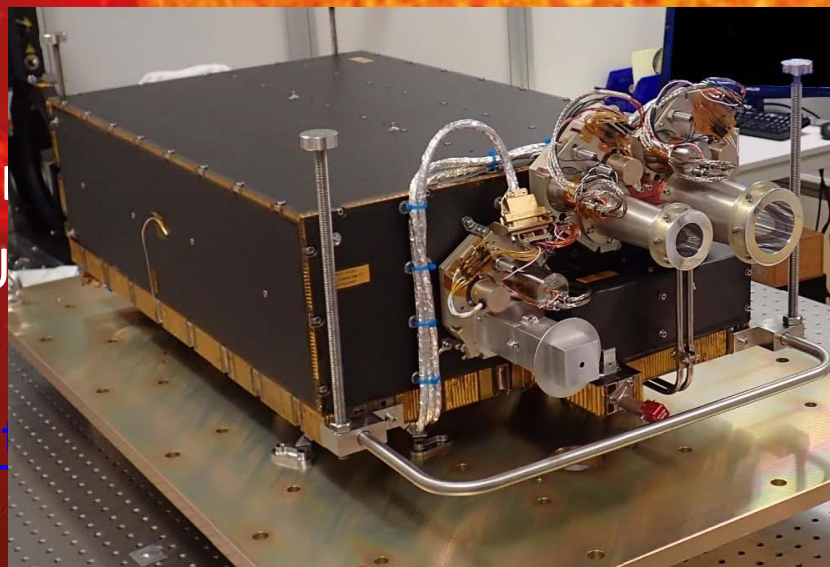
Solar Orbiter / EUI

- Solar Orbiter launch February 2019, to 0.28 AU and 33 degrees above/below solar equator
- EUI built by CSL, D. Berghmans (SIDC) PI after launch
- My tasks:
  - Management of the EUI project at ROB
  - Preparation for EUI-driven science and collaborative science between Solar Orbiter instruments
  - Follow-up of technological EUI work
  - Management of EUI Data Centre @ ROI
- I coordinated the input from all EU *Science Activity Plan*:

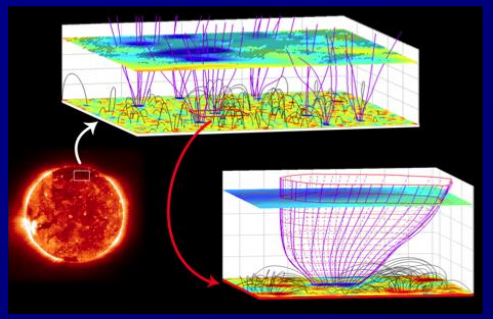
https://issues.cosmos.esa.int/solarorbi related+work



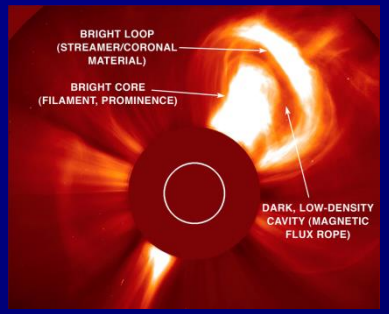
Closer than ever to the Sun…

Four basic science questions

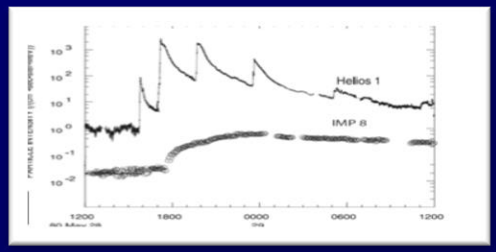
1) How and where do the solar wind plasma and magnetic field originate in the corona?



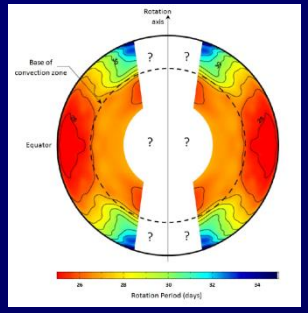
2) How do solar transients drive heliospheric variability?



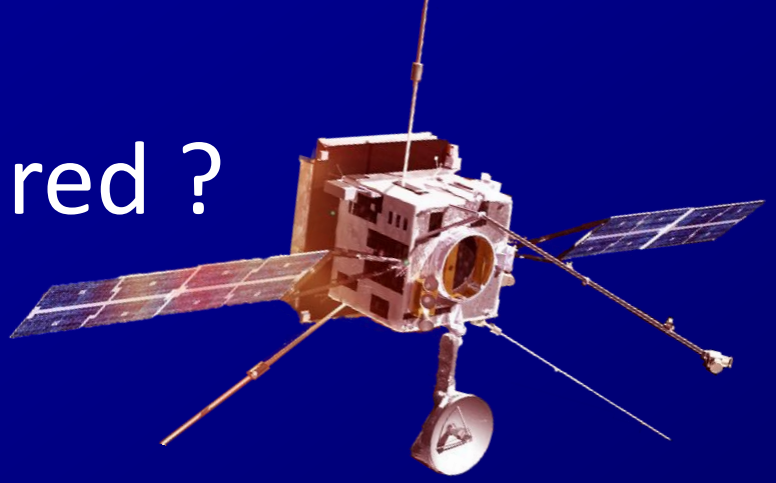
3) How do solar eruptions produce energetic particle radiation?



4) How does the solar dynamo work?



What is required ?

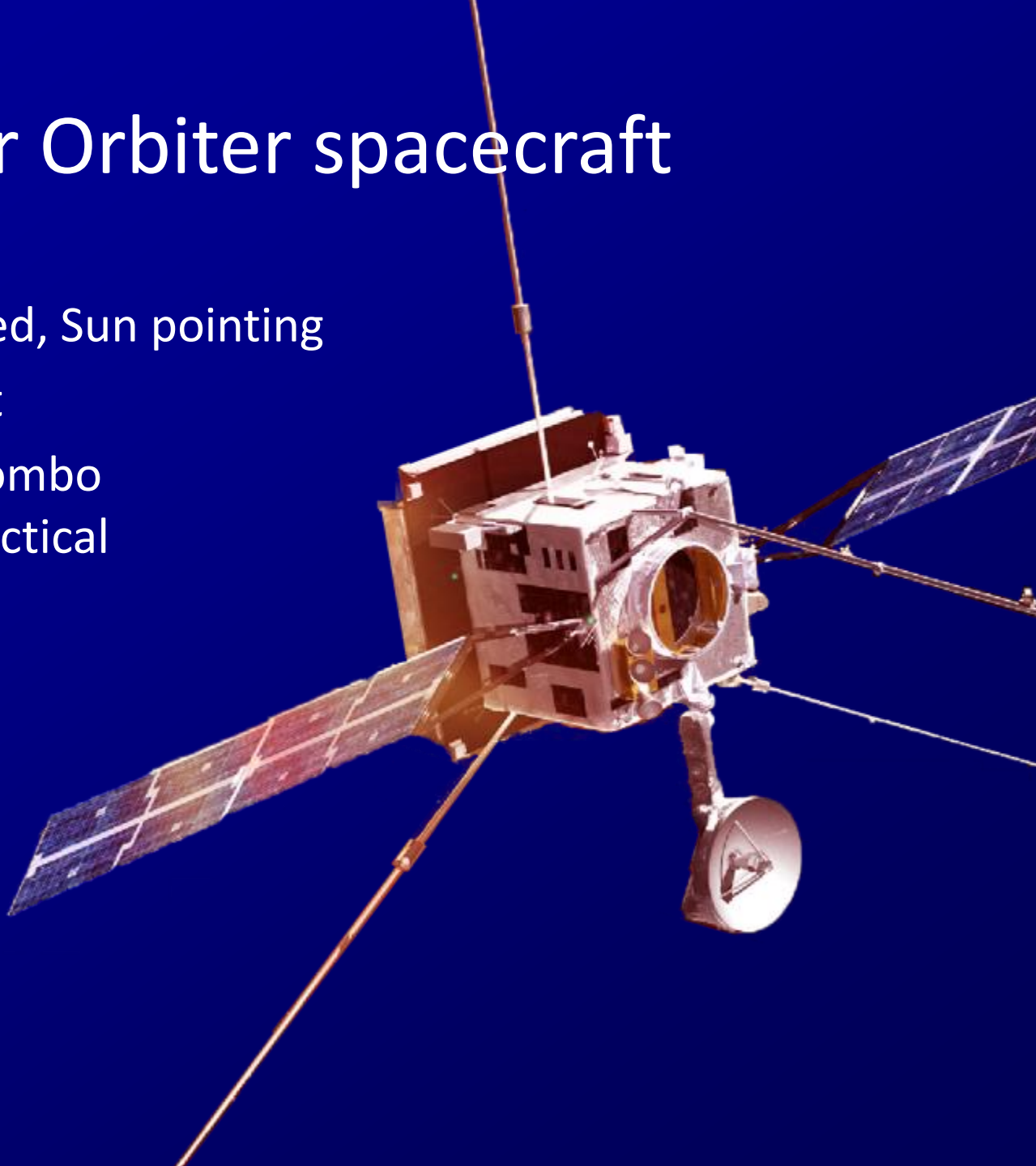


- Close to the Sun
- Out of the ecliptic
- Long duration observations of the same region
- Remote measurements of the Sun and corona
- In situ measurements of fields and particles

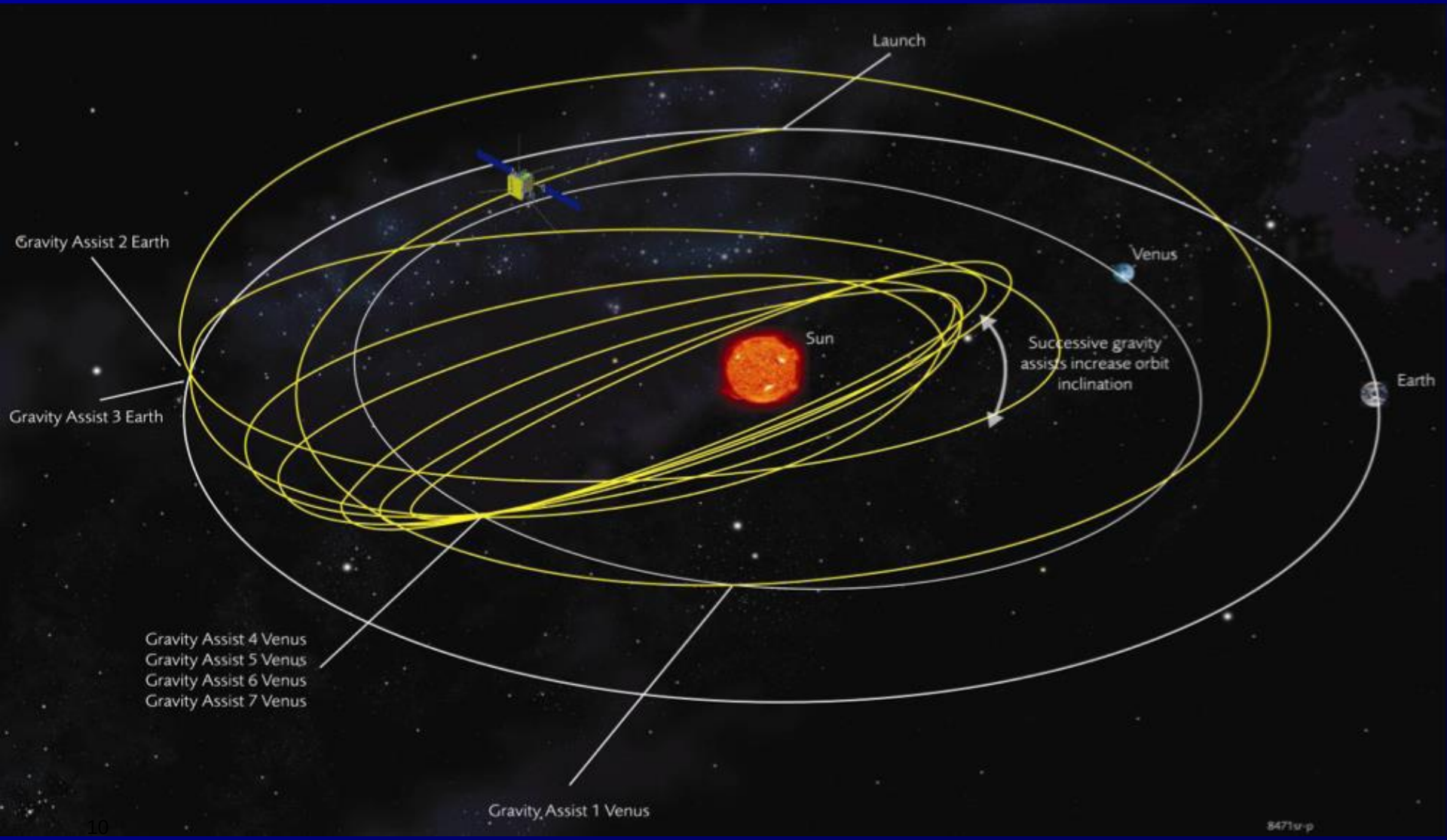
- It is this unique combination provided by Solar Orbiter that makes it possible to address the question of how the Sun creates and controls the heliosphere

Solar Orbiter spacecraft

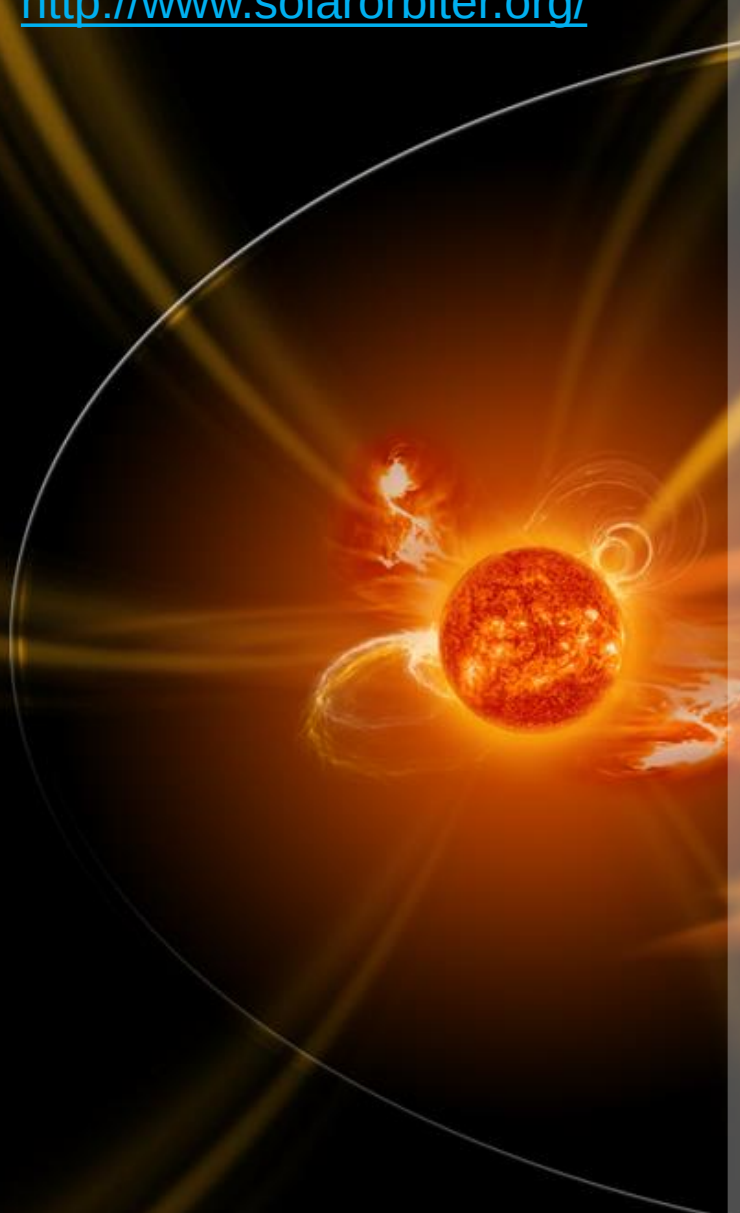
- Three-axis stabilised, Sun pointing
- Heatshield at front
- Re-use of BepiColombo unit designs as practical
- Mass: 1750kg
- Power: 1100W



Solar Orbiter mission profile



http://www.solarorbiter.org/



Solar Orbiter

Carefully optimised payload of ten remote sensing and in situ instruments

Launch: February 2019

Cruise Phase: 3 years

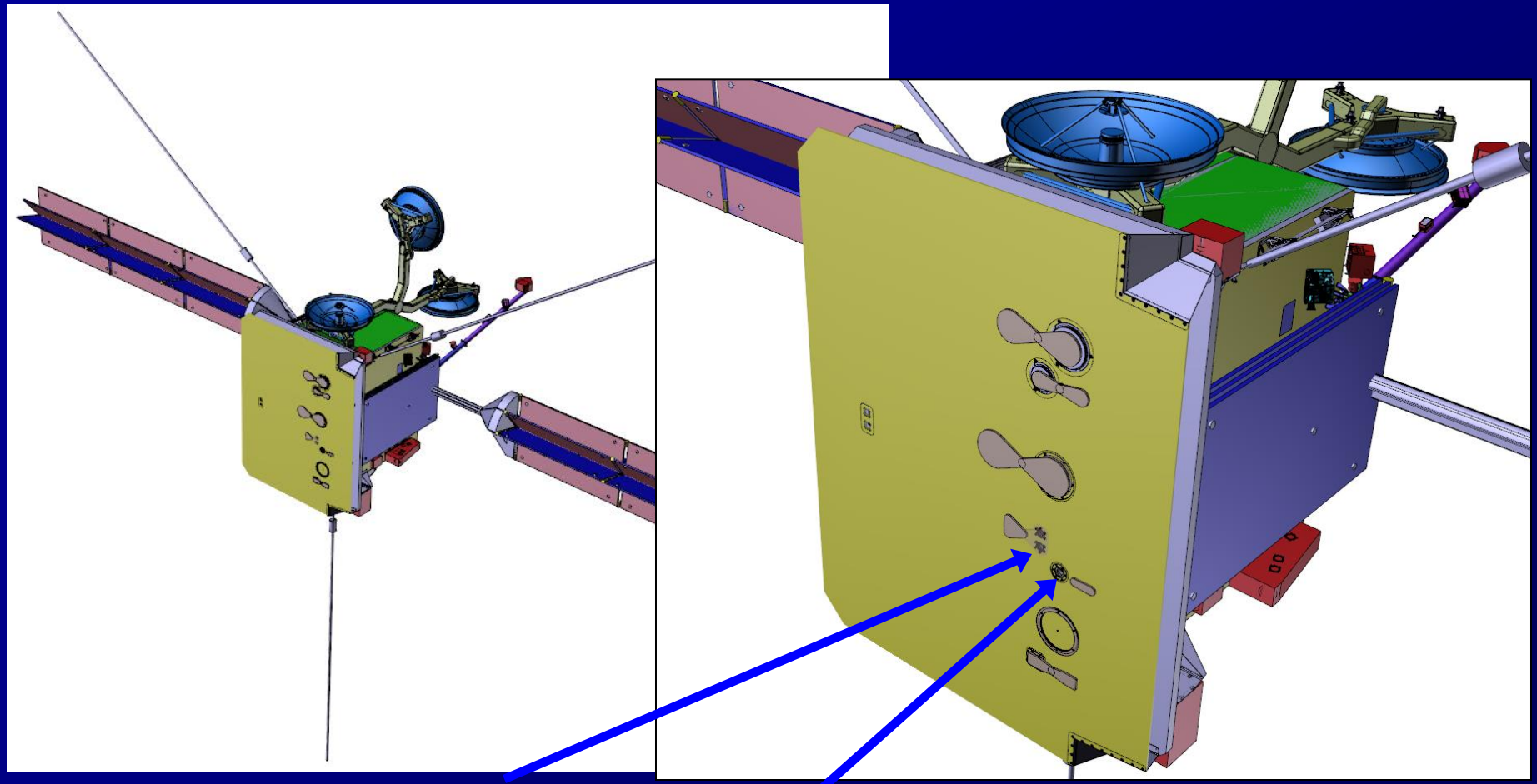
Nominal Mission: 3.5 years

Extended Mission: 2.5 years

Perihelion: 0.28 – 0.3 AU

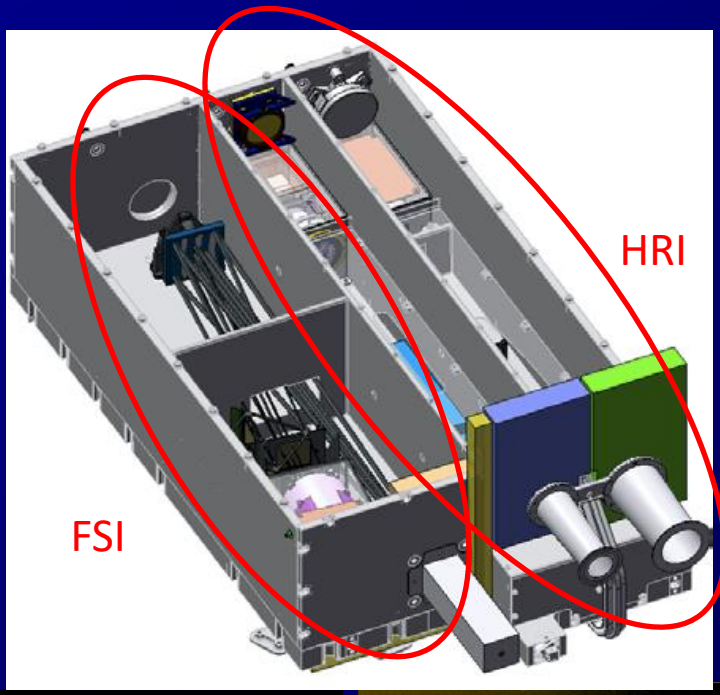
Fast perihelion motion: solar features visible for almost complete rotation

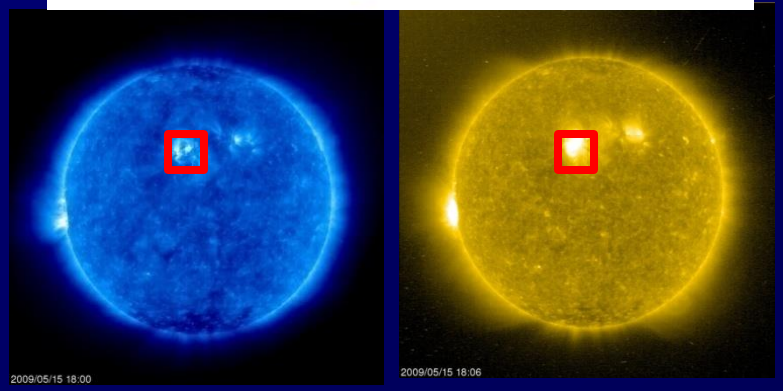
Out of ecliptic: first good view of solar poles


HRI entrance apertures
FSI entrance aperture

EUI (Extreme Ultraviolet Imagers) onboard Solar Orbiter

Channel	Parameter	Values
	Dimensions	
	- Optical bench	- 550x175x785mm
	- Electronic box	- 120x300x250mm
	Mass (incl. margins)	18.20 kg
	Nominal power	28 W
	Telemetry	20 kb/s
FSI dual EUV	Wavebands	174 Å et 304 Å
	Field of View	5.2 arcdeg × 5.2 arcdeg
	Resolution (2 px)	9 arcsec
	Cadence	600 s
HRI	Wavebands	174 Å
	Field of View	1000 arc sec square
	Resolution (2 px)	1 arcsec
	Cadence	2 s
HRI Lyman-α	Wavebands	1216 Å
	Field of View	1000 arcsec square
	Resolution (2 px)	1 arcsec
	Cadence	< 1s





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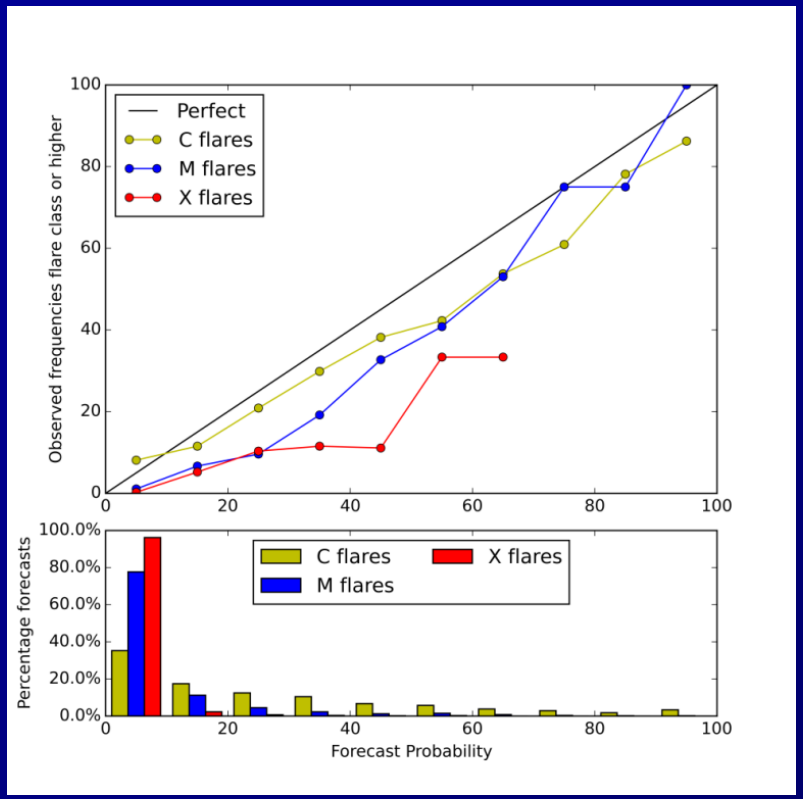
Just a minute—He's watching His favorite comedy.
5-DAY FORECAST
11 65 62 63 68
55 50 48 48 52
uCOMICS.COM
DAN PIRARO
03-18-09

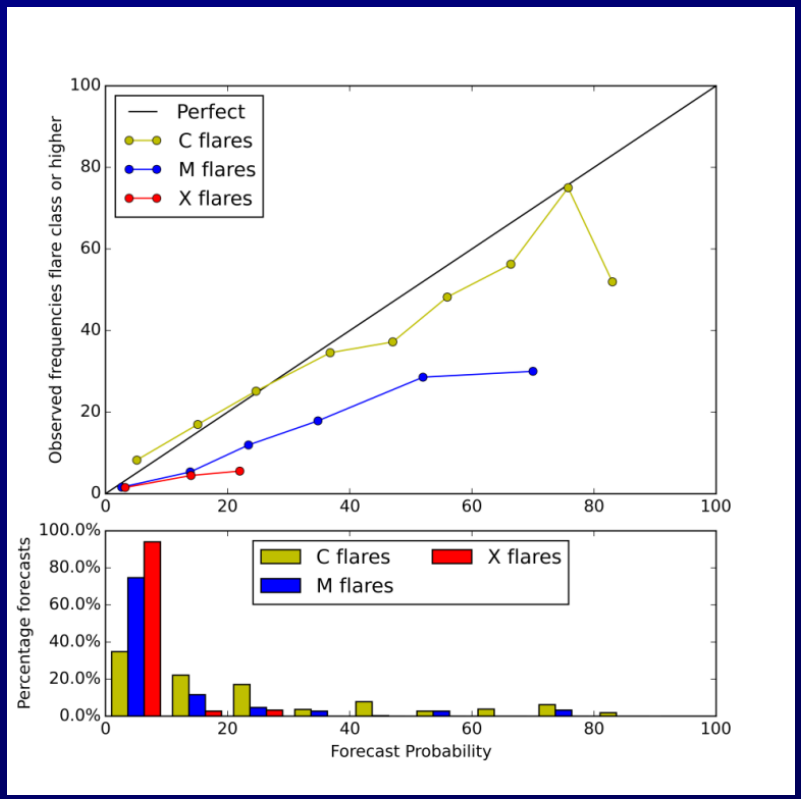
Space weather forecast verification

- I'm an SIDC space weather forecaster since 2011
- Forecast verification: supervision of Andy Devos

http://sidc.be/forecastverification/

A. Devos, C. Verbeeck, E. Robbrecht, J. Space Weather Space Clim. 4 (2014) A29





Reliability diagrams for the probabilistic flare forecast for regions, using human forecast at SIDC (left) and the forecast based on the McIntosh classification (right).

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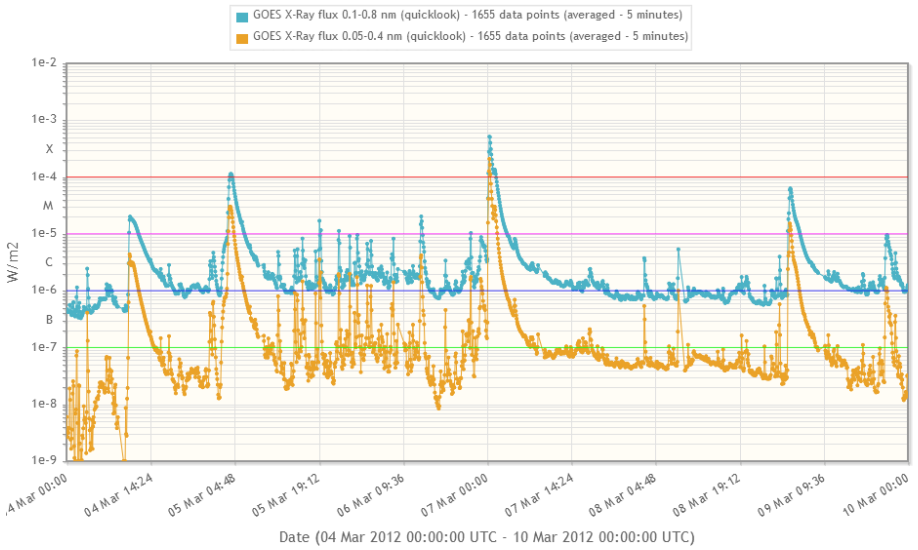
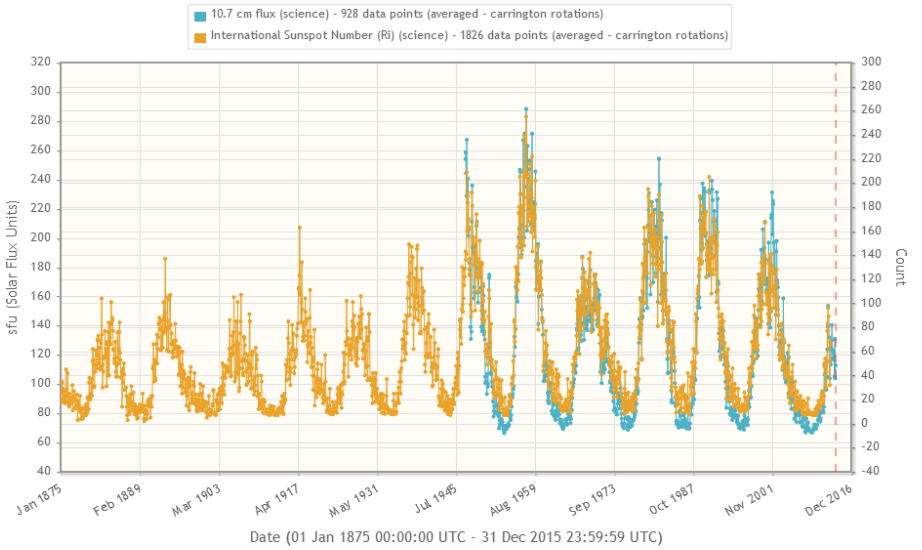
STAFF database and STAFF viewer

- I came up with the STAFF concept and requirements
- Supervision of Vincent Malisse's work on STAFF
- http://www.staff.oma.be
- *Suggestions are welcome!*





STAFF plots of GOES X ray flux in March 2012 (*left*) and F10.7 (1947-2016) and ISN (1875-2016, *right*).

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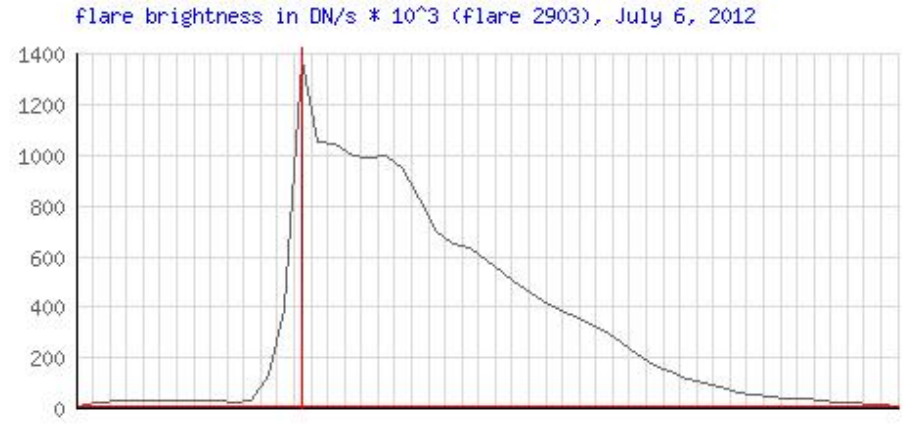
Solar Demon

- *Automatic detection of flares, dimmings, EUV waves*
- Near real time detection (space weather)
- Science catalog of flares and dimmings, EUV wave catalog in preparation
- Supervision of research/development Emil Kraaikamp
- http://www.solardemon.oma.be

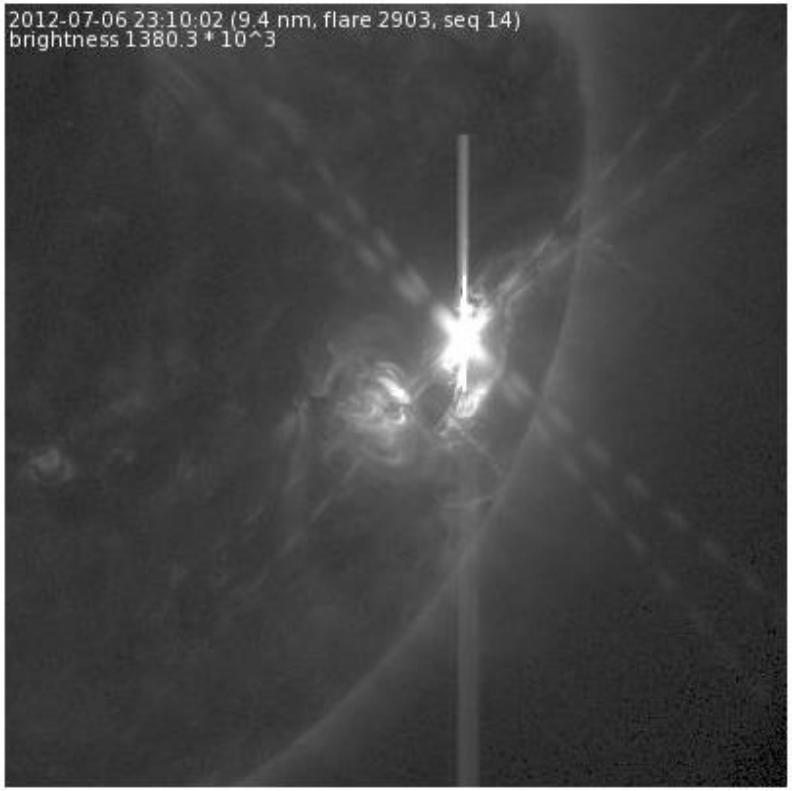
E. Kraaikamp, C. Verbeeck, J. Space Weather Space Clim., 5, A18 (2015)

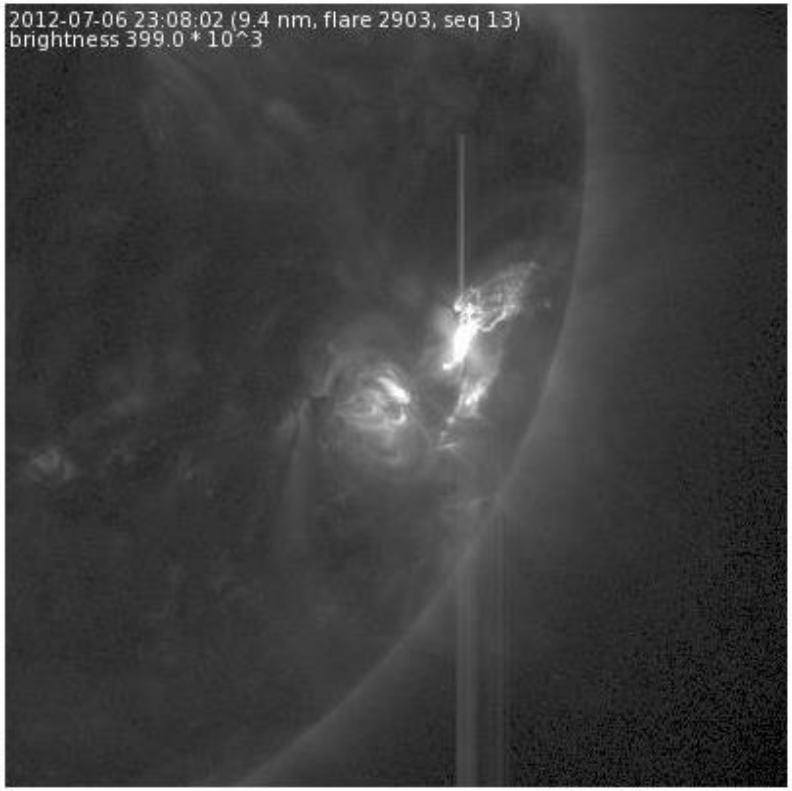


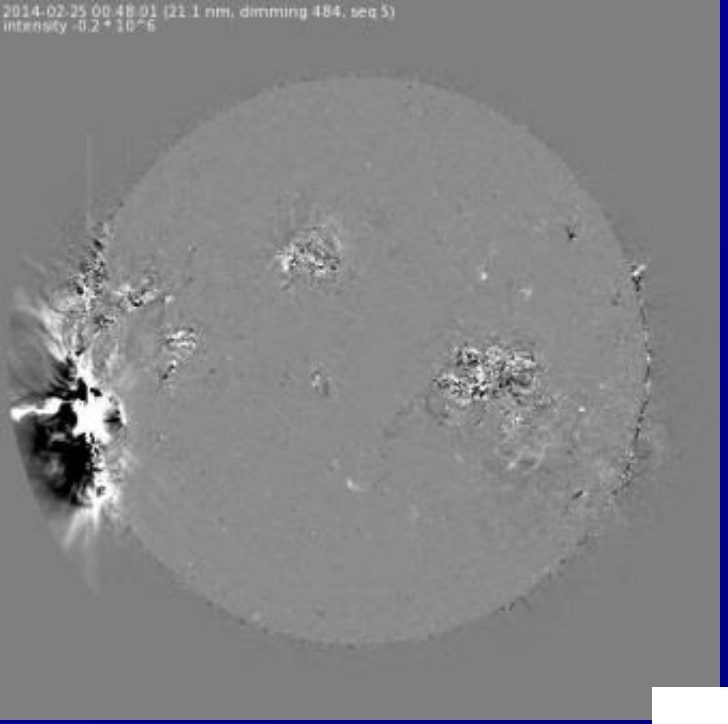
A flare detected by Solar Demon

Time: 23:10 (UTC), brightness: 1380330 DN/s

Animation

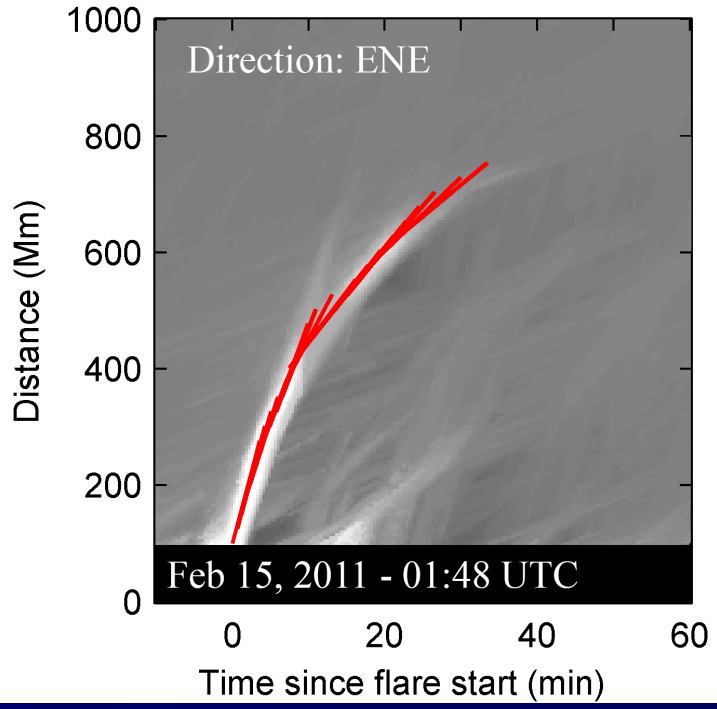






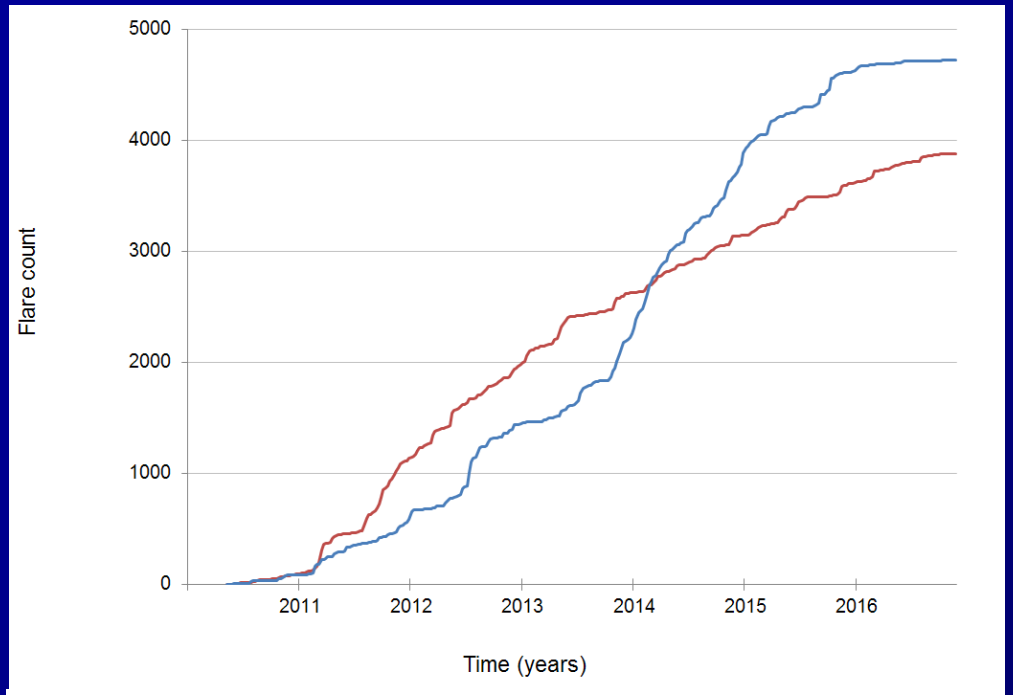
Dimming detected by Solar Demon: 6 minute running difference image showing a fast change in brightness in 211 Å SDO/AIA images (February 25, 2014).

Estimated EUV wave speeds for the ENE direction at different distances for a flaring event on February 15, 2011.



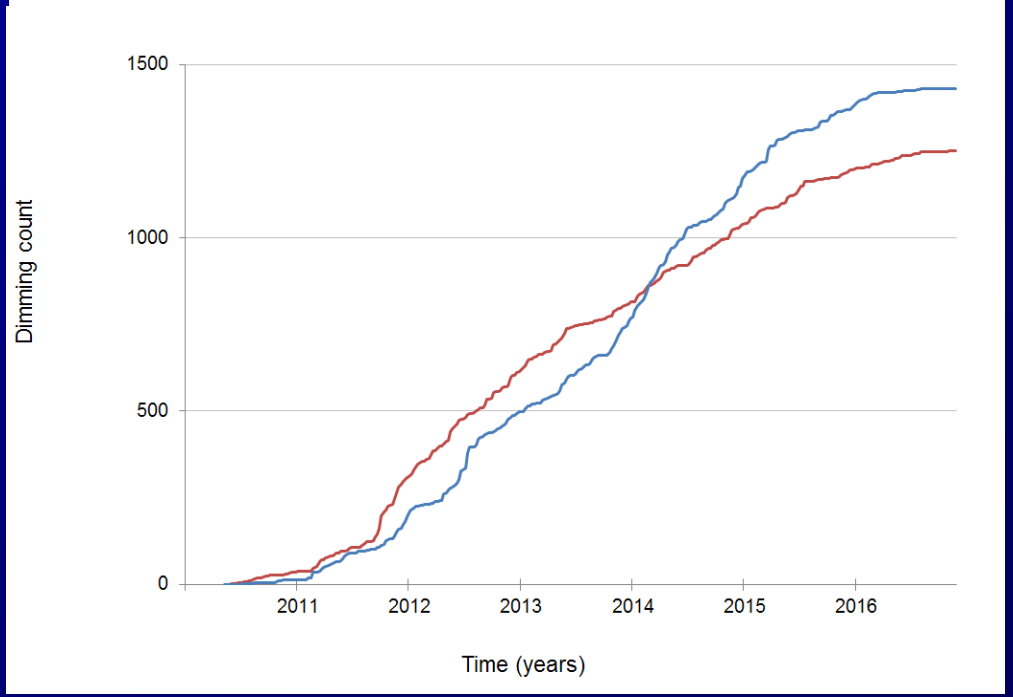
Distance (Mm)	V (km/s)
200	805
250	696
300	551
350	539
400	572
450	391
500	269
550	259
600	256
650	200

Cumulative count of flares detected by Solar Demon in northern and southern hemisphere.



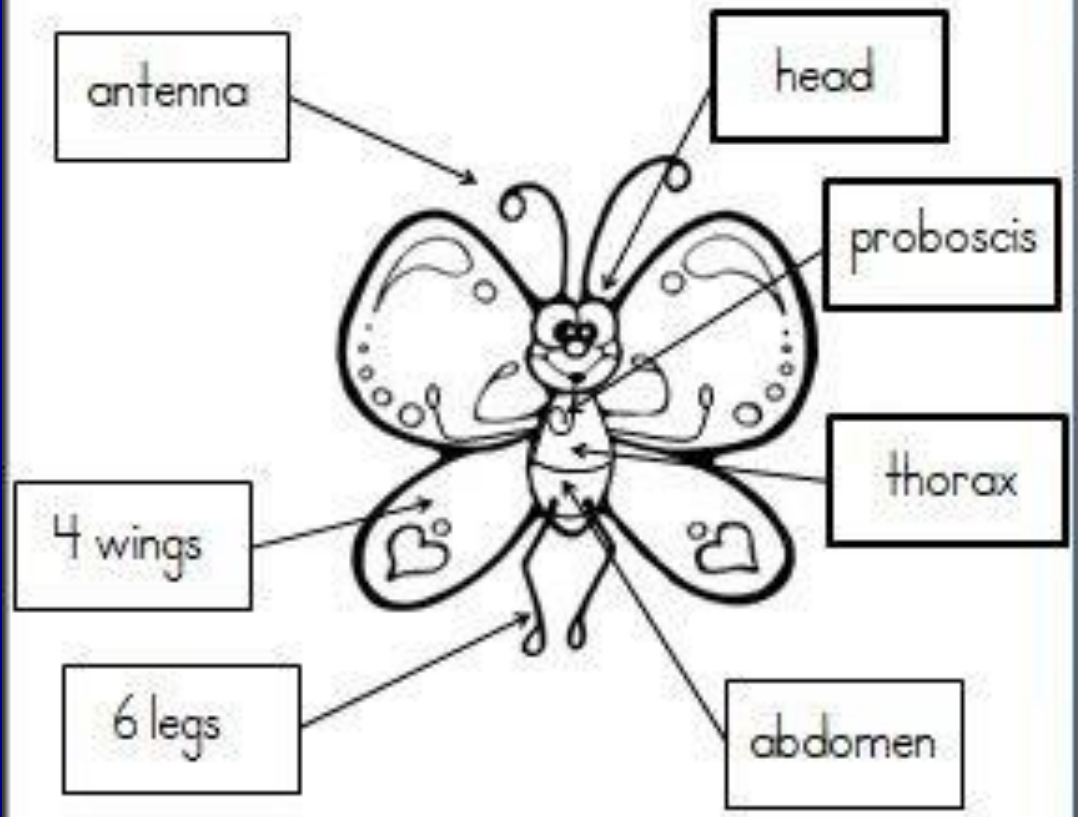
North: red;
South: blue

Cumulative count of dimmings detected by Solar Demon in northern and southern hemisphere.



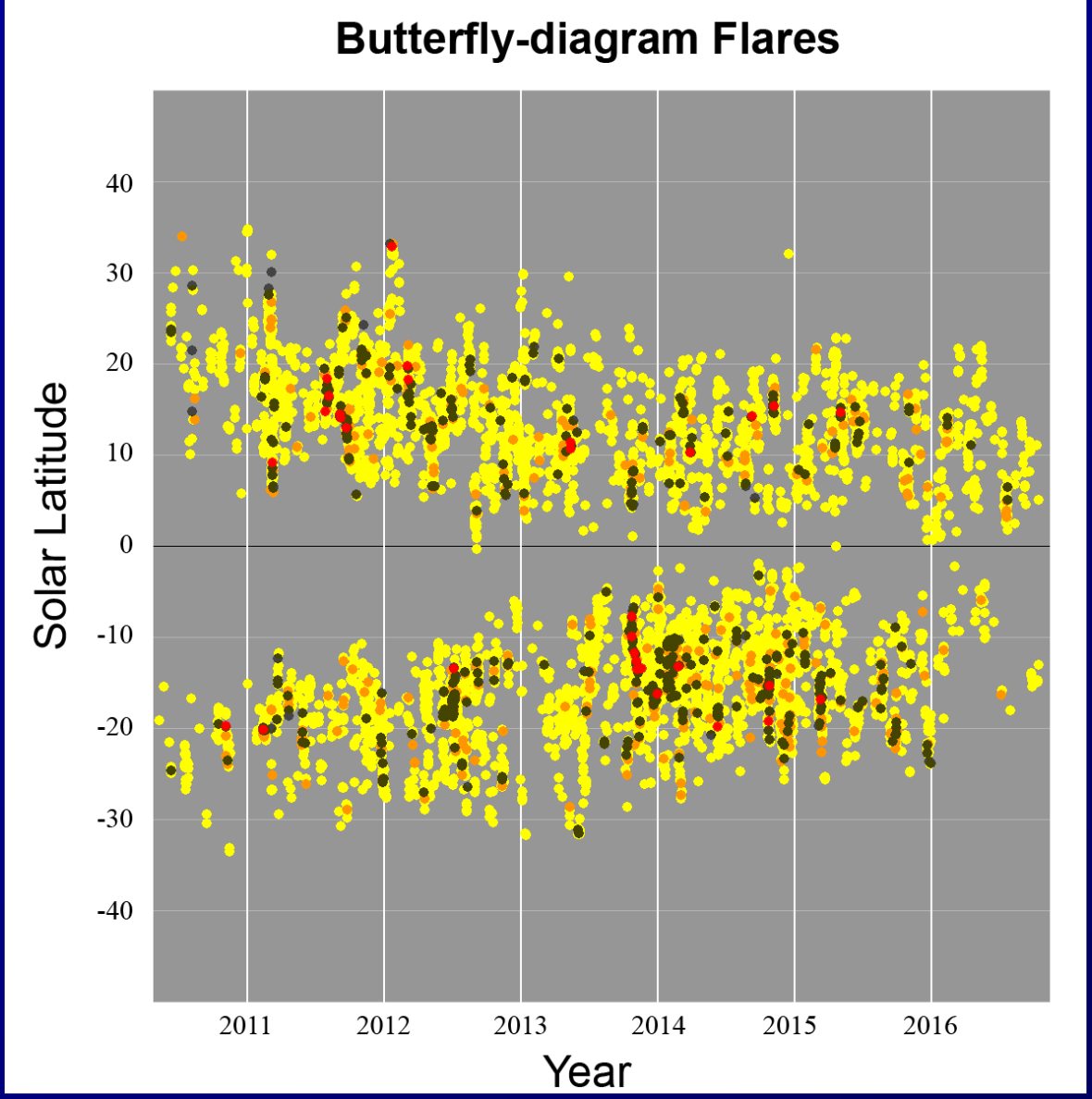
North: red;
South: blue

Butterfly diagram



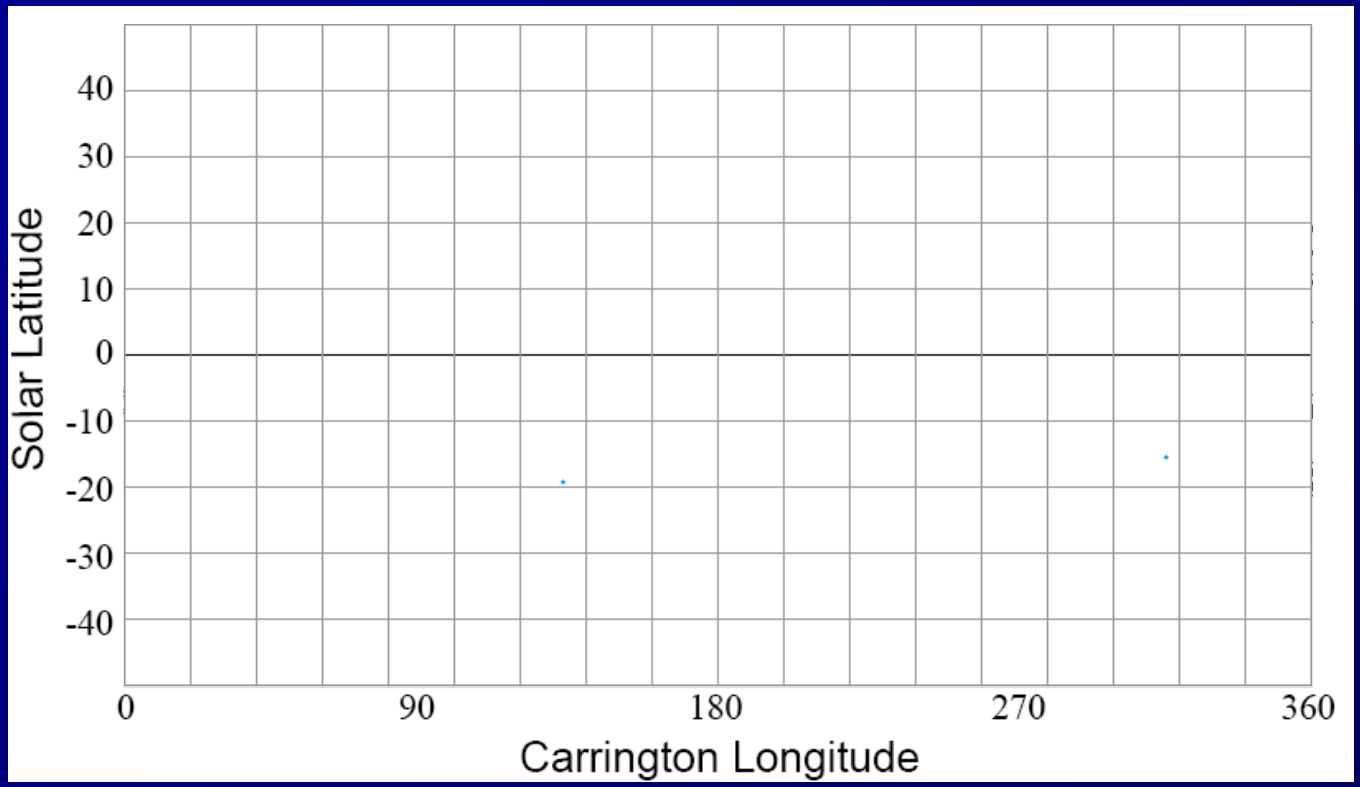
Butterfly Facts

Butterflies are insects.
All insects have 3 body parts (head, thorax, abdomen).
All insects have 6 legs.
A butterfly has 4 wings.
It has 2 antennae on its head.
It sips nectar with a proboscis which is like a straw.

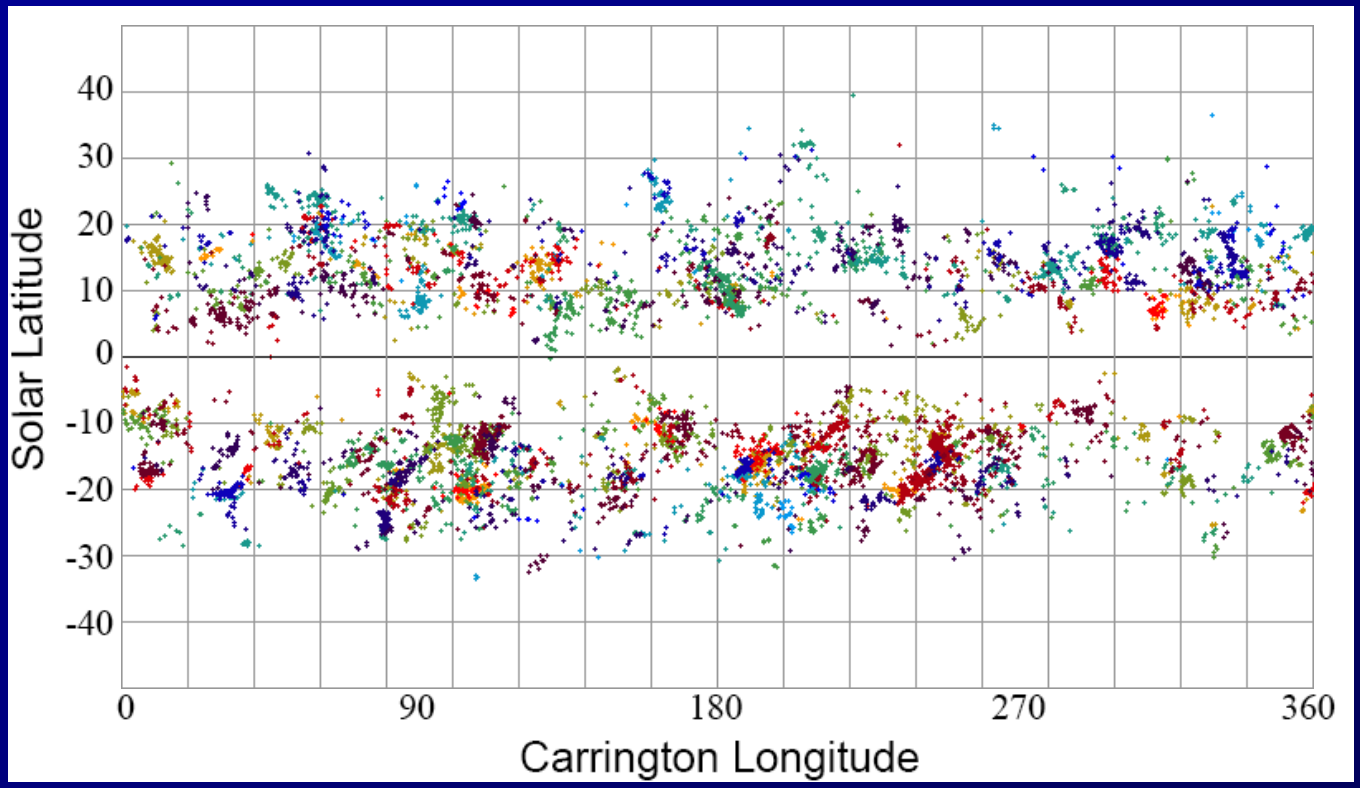


Butterfly diagram displaying the solar latitude of all detected flares from May 2010 to November 2016. Each colored dot represents a flare occurrence detected by Solar Demon.

Flares – Longitudinal Distribution



Flares – Longitudinal Distribution



Solar Demon – ideas for the future

- Statistical study of flares, dimmings and EUV waves: butterfly diagrams, longitudinal distribution, size distributions, periodicities, solar cycle dependence, …
- Multi-channel AIA light curves, energy, and shape of flares
- Early evolution of solar eruptions and conditions of impacted solar atmosphere as probed with EUV waves (*N. Nitta, LMSAL*)
- Relation dimmings/EUV waves/CMEs (*B. Thompson, GSFC*)
- Relation EUV waves/SEP events (*K. Kozarev, SAO; R. Miteva, Bulg. Ac. Sc.*)
- Relation different types of ICMEs and their coronal origins using EUV imaging spectroscopy (*V. Slemzin, Rus. Ac. Sc.*)
- Comparison to other detection algorithms (*L. Krista, U. Colorado*)

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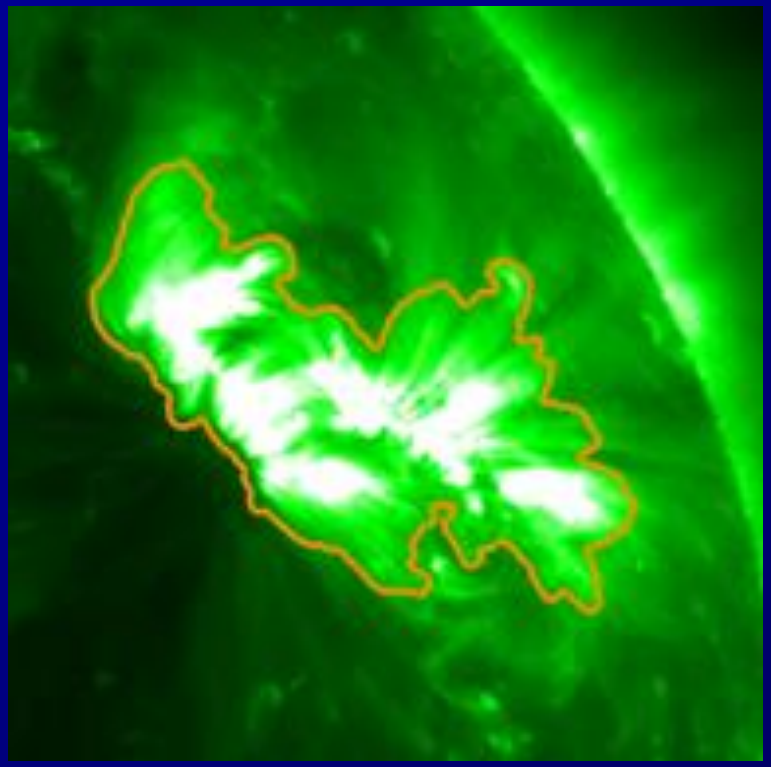
SPoCA

- SPoCA: SIDC software for extraction, characterization, and tracking of Active Regions/Coronal Holes in EUV images
- Lead: Véronique Delouille, development: Benjamin Mampaey
- SPoCA is intended to enable large scale science studies of AR/QS/CH properties, such as:
  - In-depth study of a particular AR/CH region over its lifetime
  - Statistical study of individual AR/CH regions over solar cycle time scales (e.g., butterfly diagram)
  - Total AR/QS/CH statistics over solar cycle time scales
- Automated detection scheme: needed in view of amount of images to be analyzed
- Fixed algorithm: ensures coherent and reproducible results
- http://sdoatsidc.oma.be/web/sdoatsidc/SoftwareSPoCA/

Active Region and Coronal Hole statistics

- Several parameters are calculated:
  - for every AR/CH region: position, size, pixel intensity statistics
  - for the entire AR/QS/CH classes: size, pixel intensity statistics
- This allows statistical surveys of AR/QS/CH properties:
  - Throughout the solar cycle
  - Within the lifetime of a specific region of interest



Region Statistics

Barycenter :	(3121,2622)
NumberPixels :	175353
MinIntensity :	322 DN/s
MaxIntensity :	9696 DN/s
Mean :	1834.809 DN/s
Standard Deviation :	1286.050
Skewness :	0.005
Kurtosis :	-3.000
TotalIntensity :	3.217 e+8 DN/s
Area Raw :	33680.616 Mm^2
Area At Disk Center :	55882.873 Mm^2

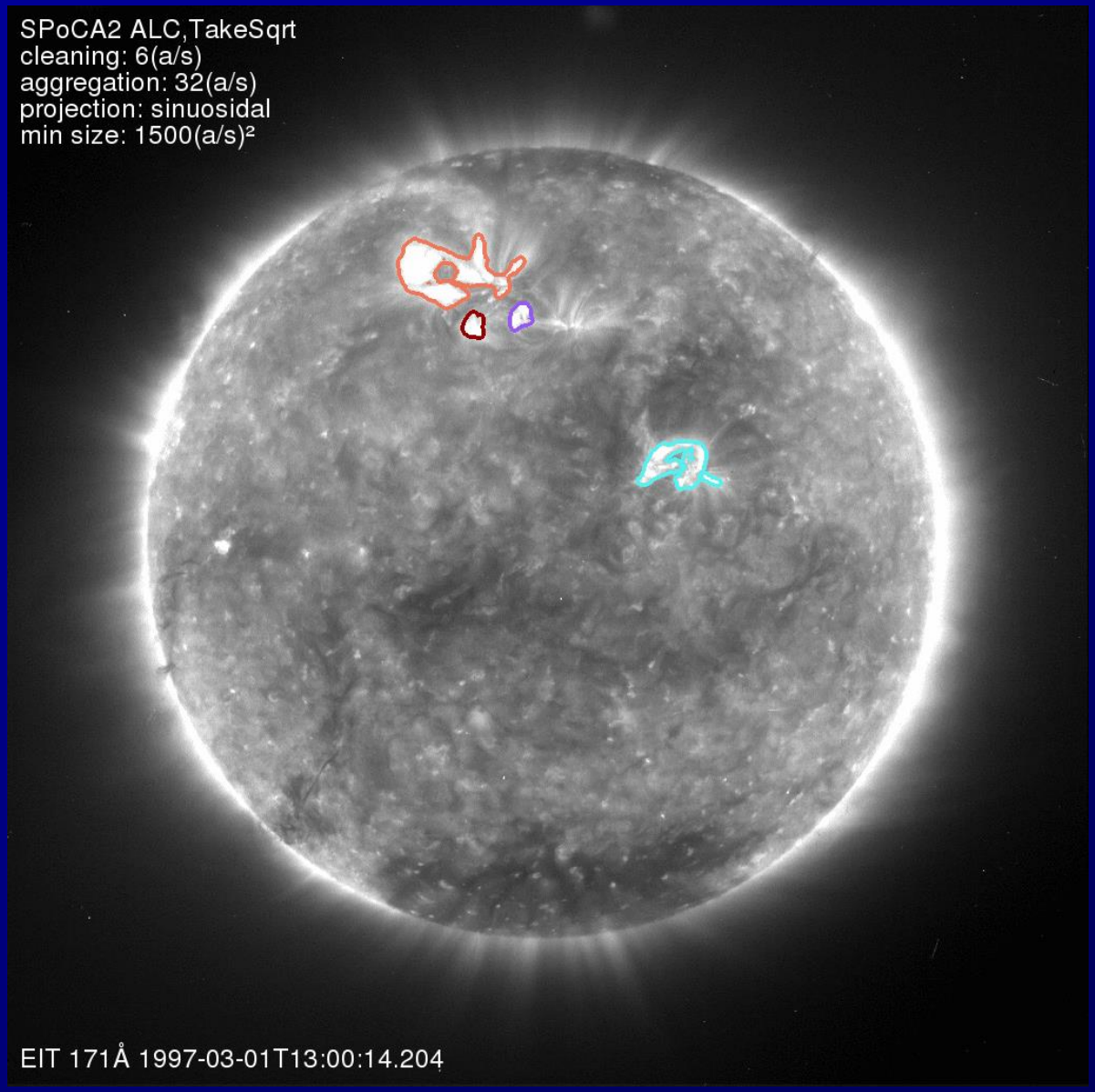
SPoCA analysis AR/QS/CH EIT 1997-2011

Dataset:
- 1k x 1k EIT image pairs (171 & 195 Å)
- Time range: March 1997-August 2011
- Cadence: 6 hours

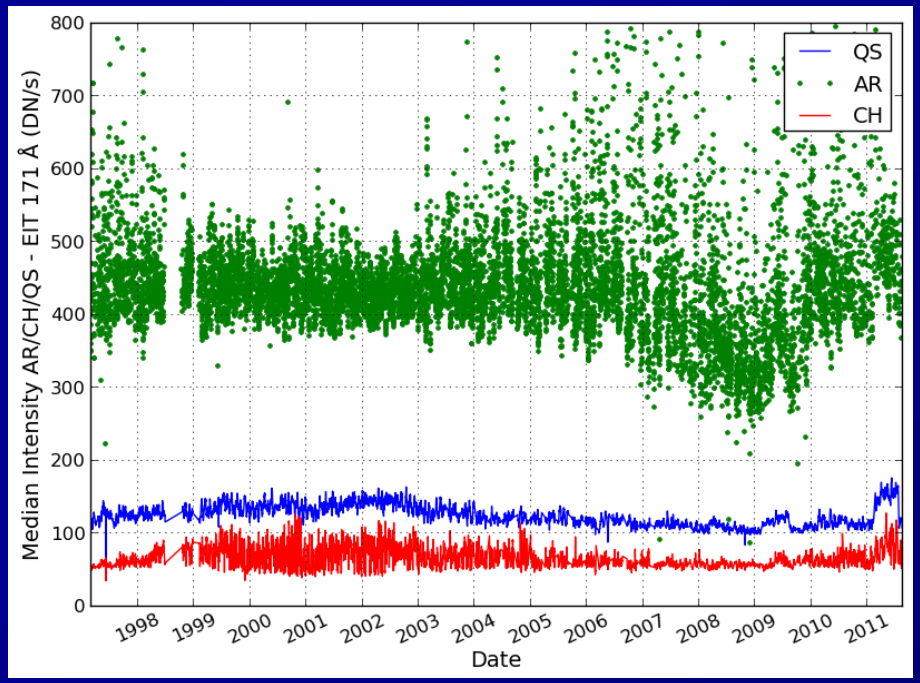
C. Verbeeck, V. Delouille, B. Mampaey, R. De Visscher, A&A 561, A29 (2014)

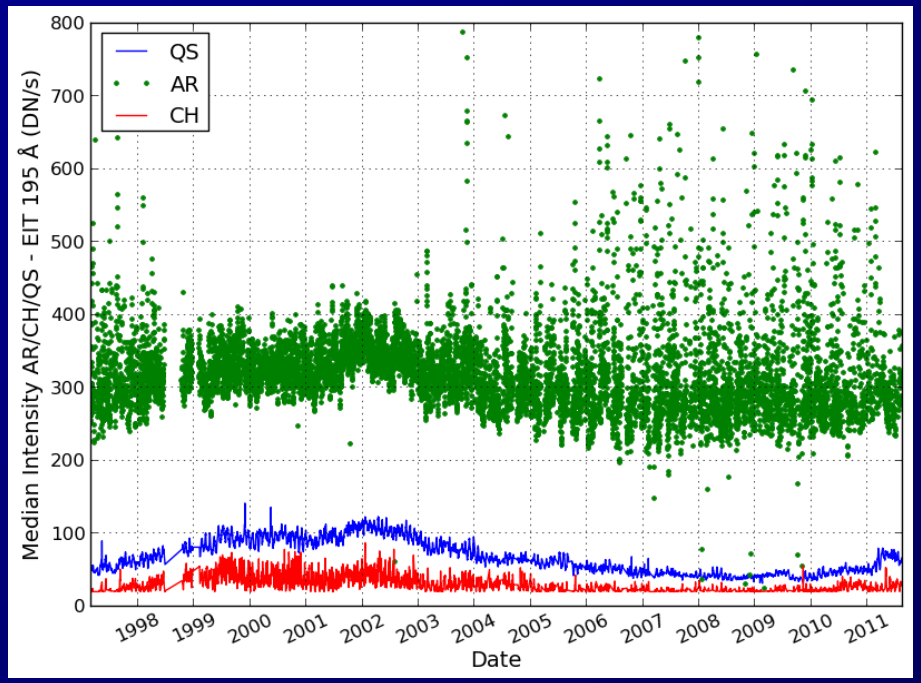
SPoCA AR/QS/CH segmentation:
- Input: square root; 4 classes: CH = {1}, QS={2,3}, AR = {4}
- Initial SPoCA run on subset: 1 image pair per month (112 pairs)
- Problem: AR not well detected during solar min: too little AR pixels
- Solution: Perform fixed attribution on whole dataset using average center and eta values from solar max (42 pairs)
- Results:
  - Segmentations in monthly subset were satisfactory
  - 1997-2011 segmentation criteria are fixed, not image-dependent
  - AR/QS/CH timelines (9 540 points): median I, total I, filling factor

EIT AR movie 1997-2011



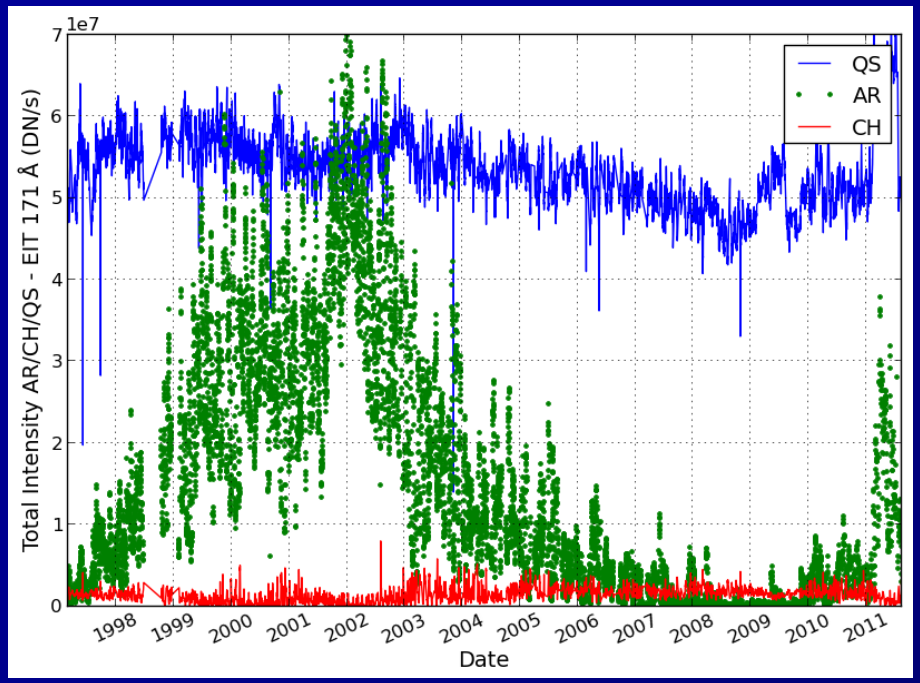
Median intensity EIT 1997-2011

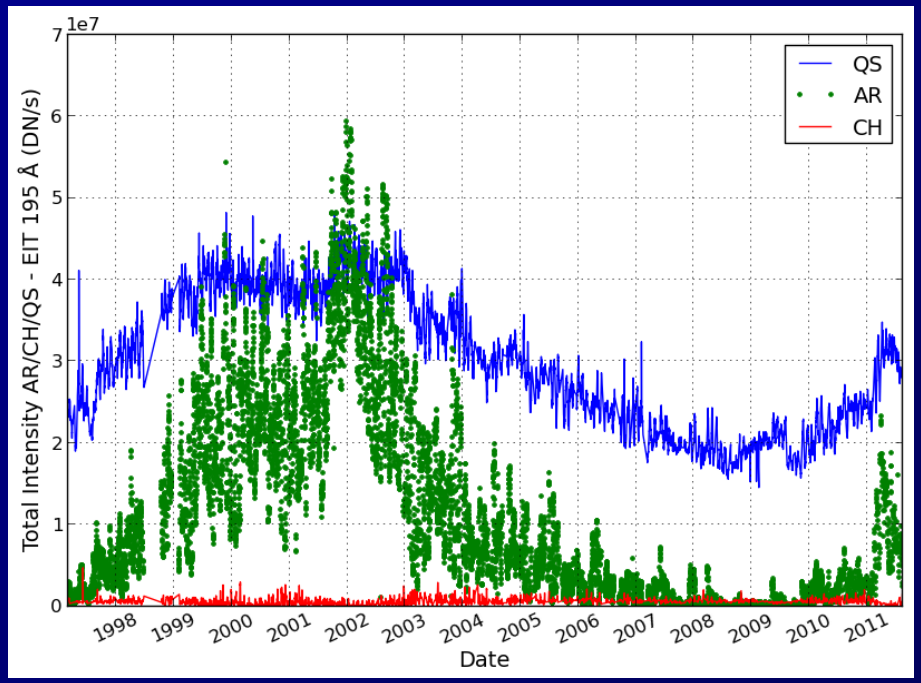




- Slight variation of median intensity AR/QS in sync with solar cycle
  - QS variation is probably due to overlying AR canopies
- Median intensity varies substantially more for AR than for QS & CH

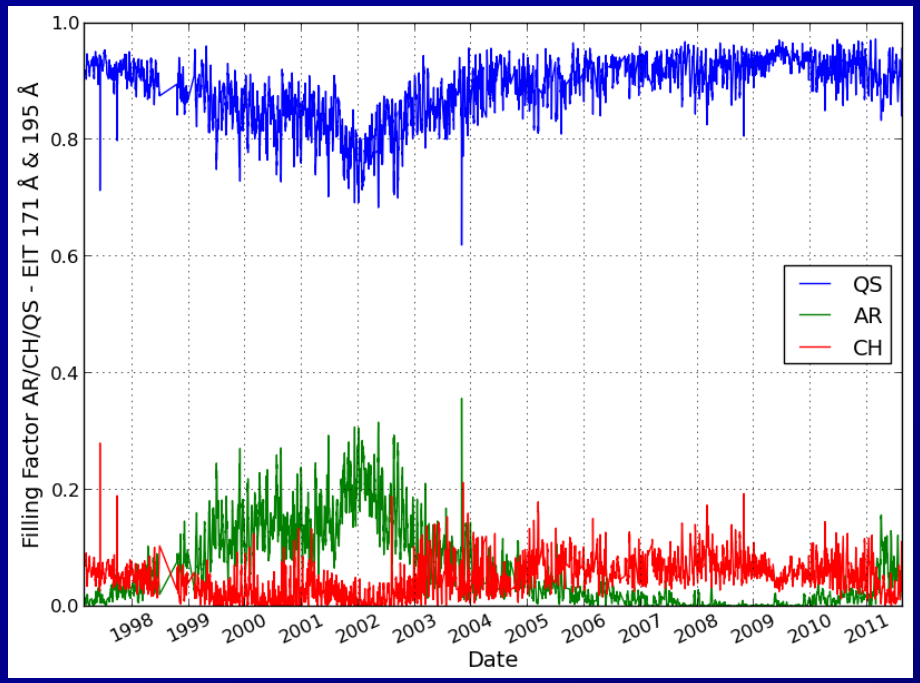
Total intensity EIT 1997-2011

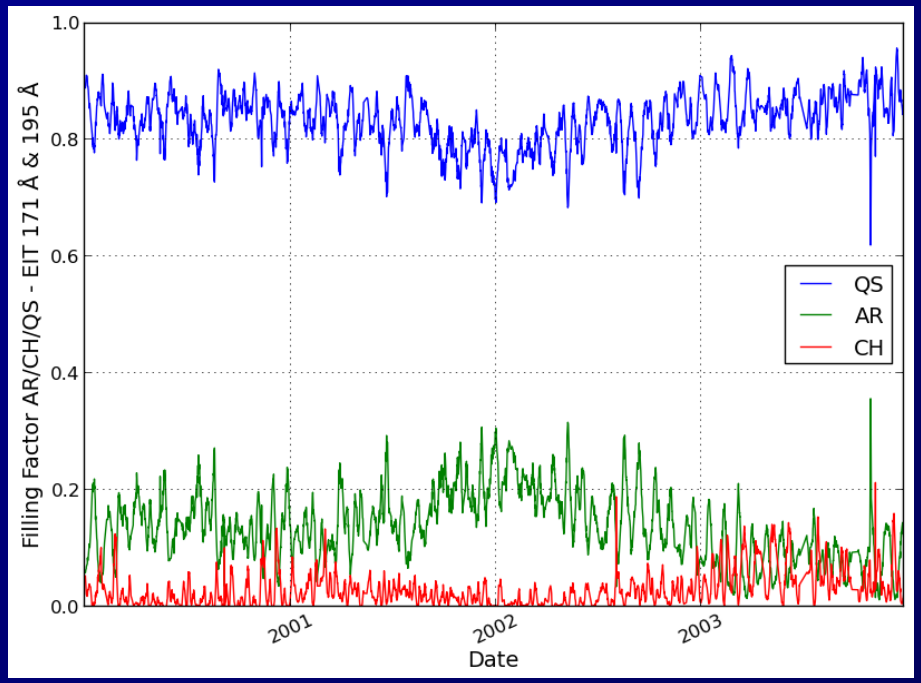




- Total intensity AR in sync with solar cycle, incl. double max 2000 & 2002
- Total intensity QS slightly in sync with solar cycle
- Total intensity CH in anti-phase with solar cycle

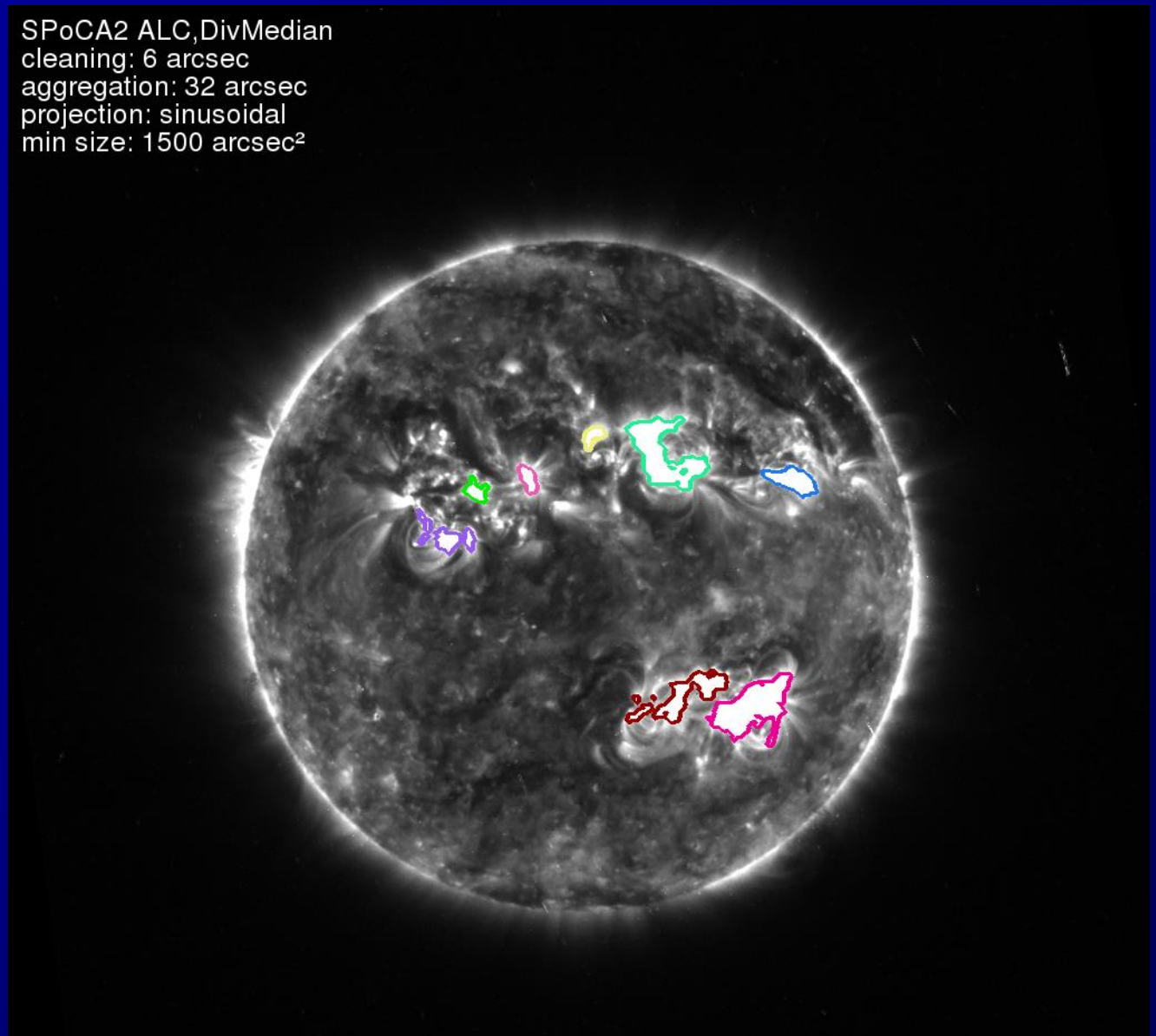
Filling factor EIT 1997-2011



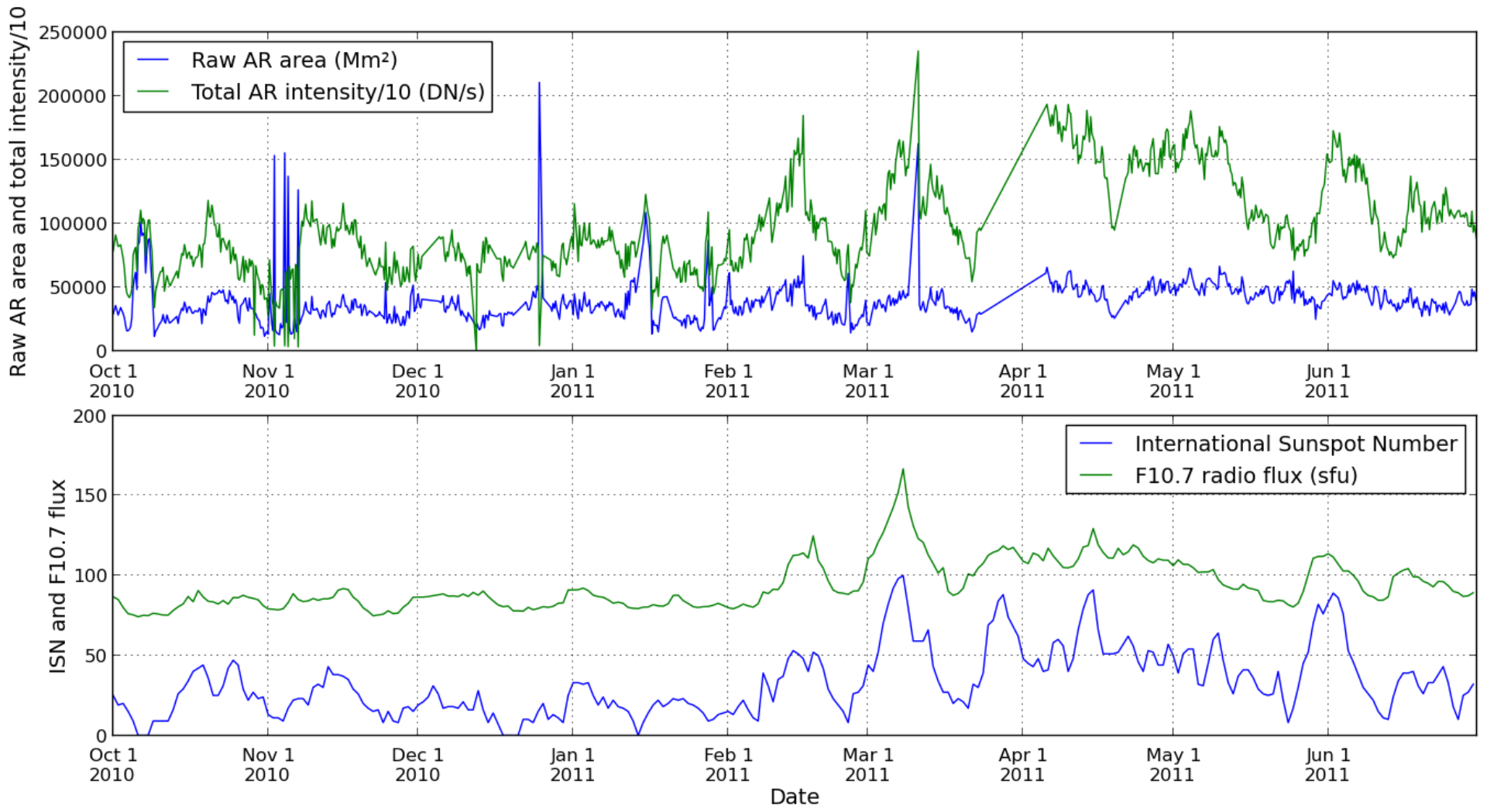


- Filling factor (FF) = relative area AR/QS/CH on solar disk
- FF AR in sync with solar cycle, incl. faint double max 2000 & 2002
- FF QS & CH in anti-phase with solar cycle
- Zooming in on FF clearly reveals the 27-day period of solar rotation

AR detection on SWAP

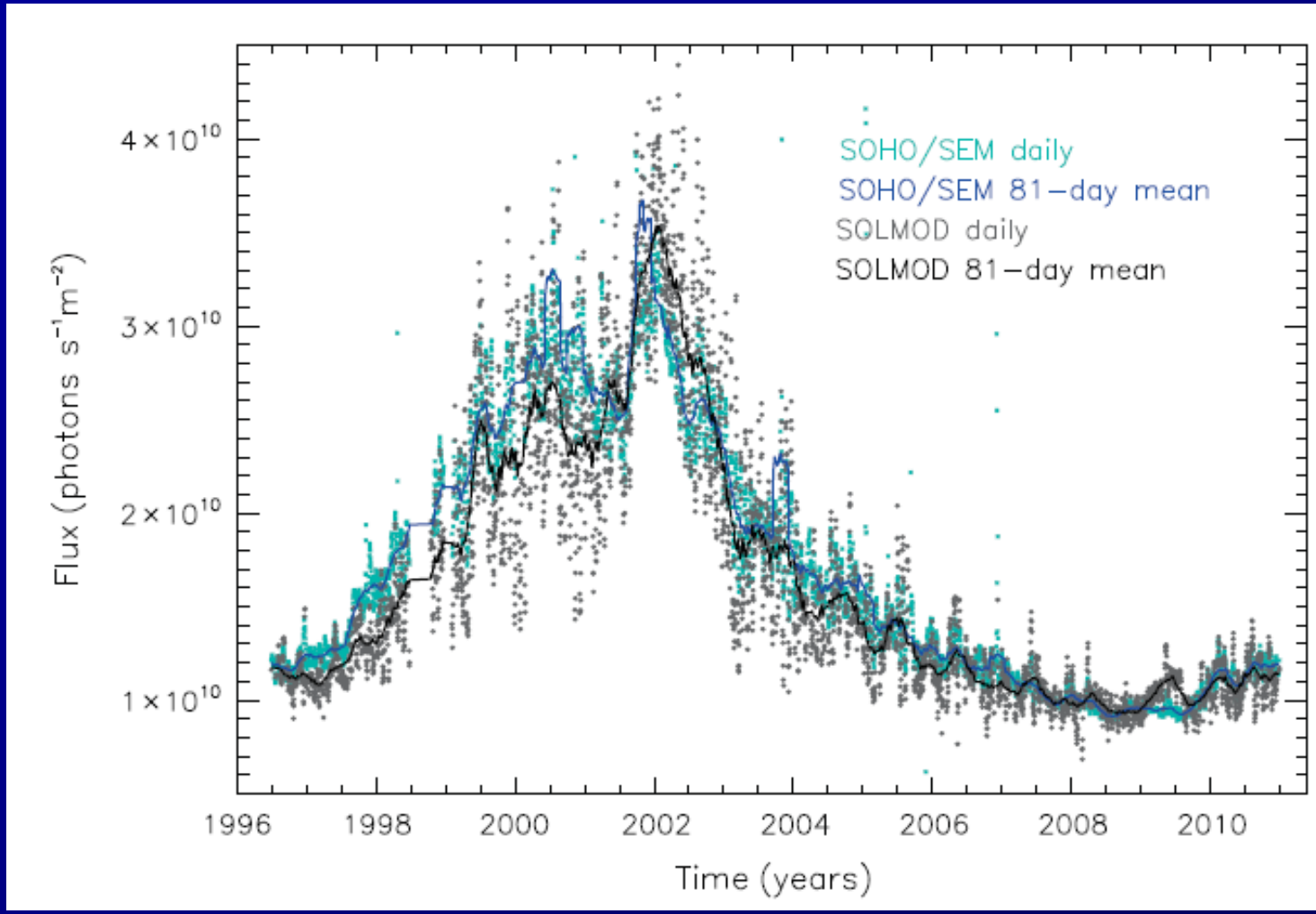


Total intensity & FF SWAP 2010-2011



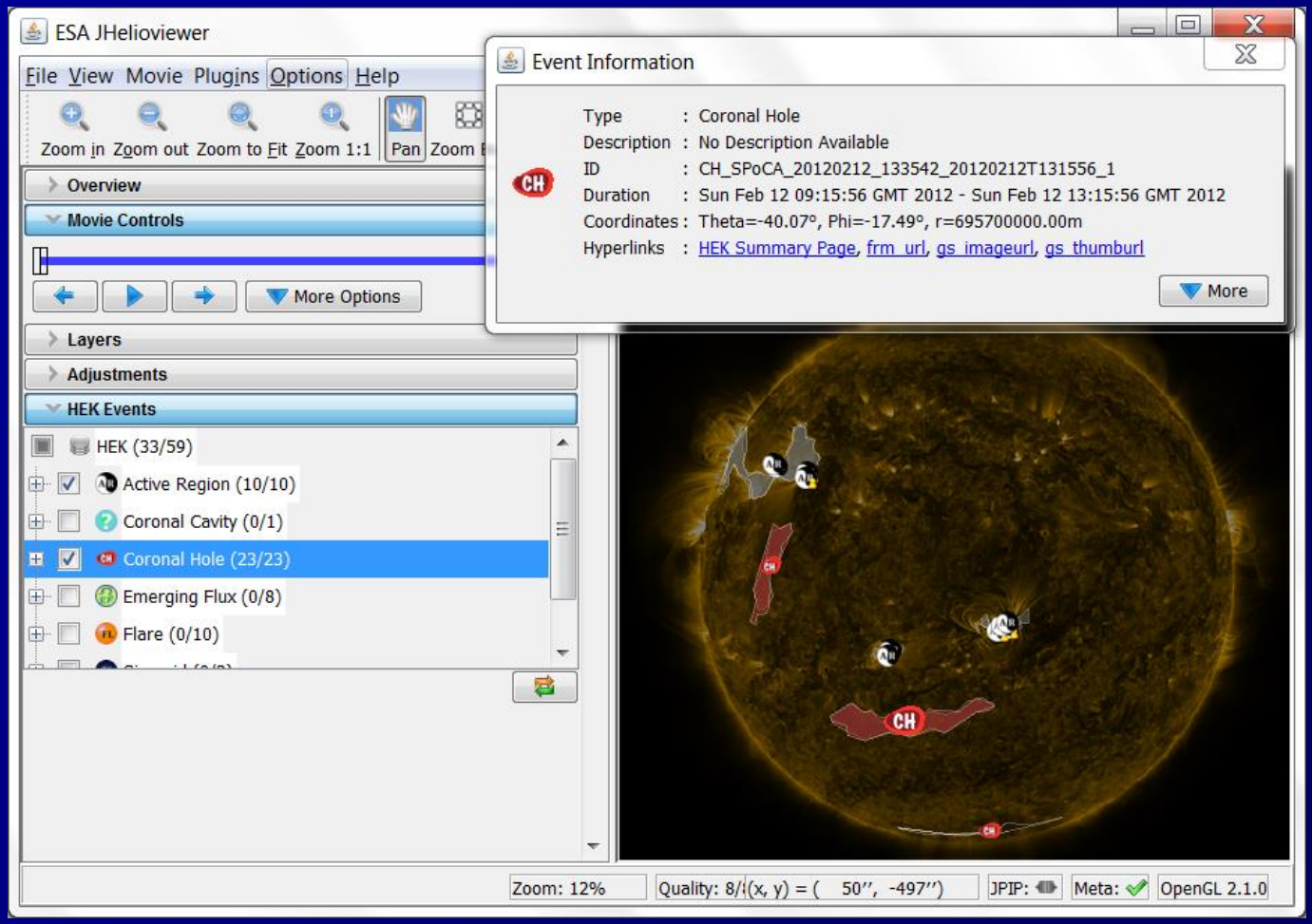
Visually obvious correlation of AR area & especially AR total I with International Sunspot Number & F10.7

M. Haberreiter, V. Delouille, B. Mampaey, C. Verbeeck, G. Del Zanna, S. Wieman, J. Space Weather Space Clim. 4 (2014) A30



Comparison of SOLMOD reconstruction (gray) to SOHO/SEM (light blue) irradiance data. The 81-day mean is also given for the reconstruction (black line) and the SOHO/SEM data (dark blue line). The reconstruction is based on SPoCA AR/QS/CH filling factors.

SPoCA AR & CH in HEK and JHelioviewer



AIA 171 Å image Feb 12, 2012 @ 9:15:56 UT together with AR & CH location and chain code info recorded in the HEK.

An Event Information window pops up when clicking on an event or feature.

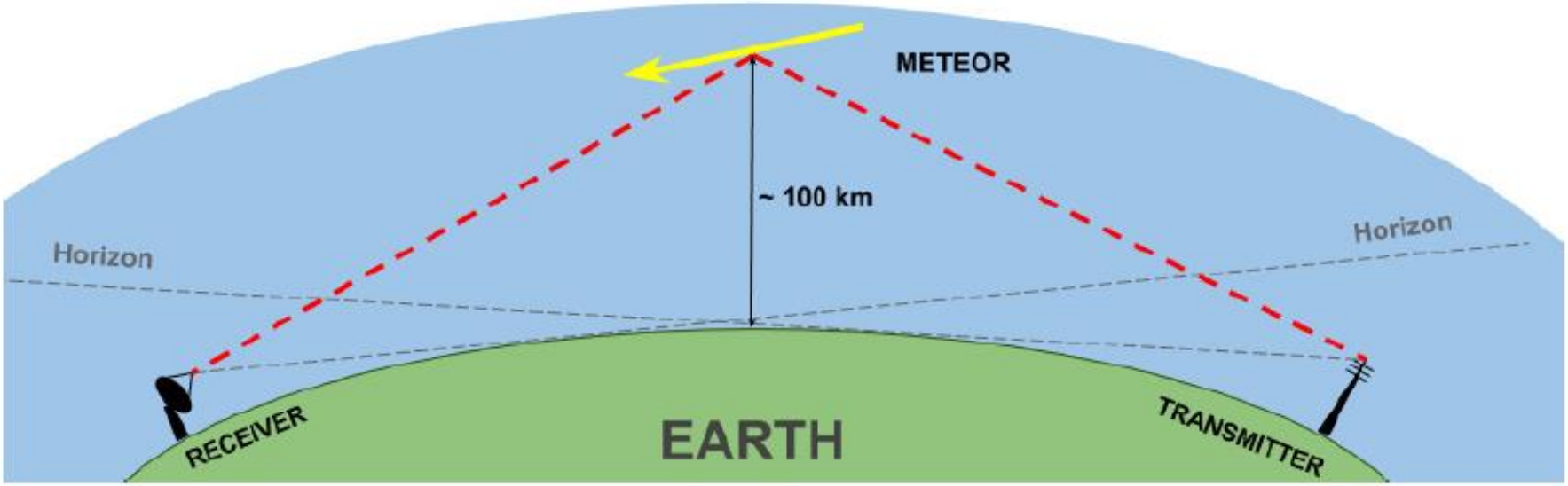
SPoCA – ideas for the future

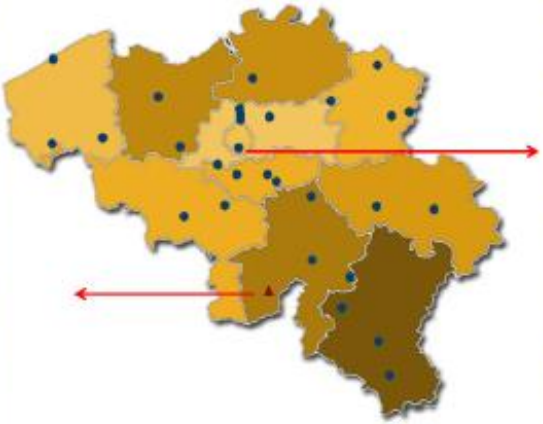
- Statistical study of AR/CH/QS properties: butterfly diagrams, longitudinal distribution, size distributions, periodicities, solar cycle dependence, …
- Study of individual AR/CH over their lifetime, including far side observations (also for the C-flaring, M-flaring, X-flaring regions)
- Reconstruction of solar irradiance from semi-empirical solar atmosphere models combined with region areas: AIA and EUI data (*M. Haberreiter, PMOD*)
- Validation of ADAPT Coronal Hole maps (*N. Arge & M. Kirk; GSFC*)
- Space weather applications: SPoCA's near real time position and size of CH can aid velocity estimation of CH high speed streams in the solar wind

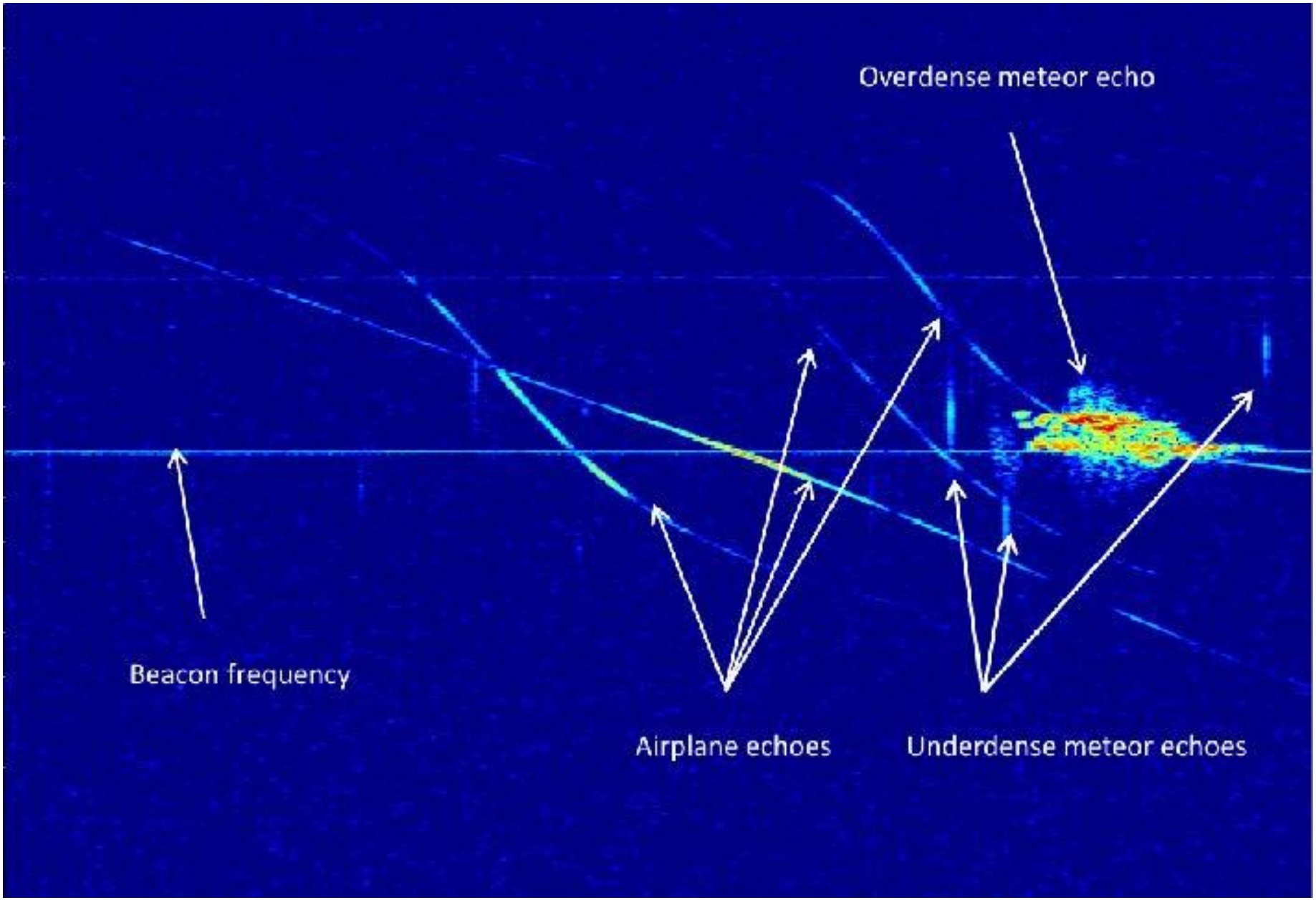
Overview

1. EUI
2. Space weather forecast verification
3. STAFF
4. Solar Demon
5. SPoCA
6. Extra: meteor research

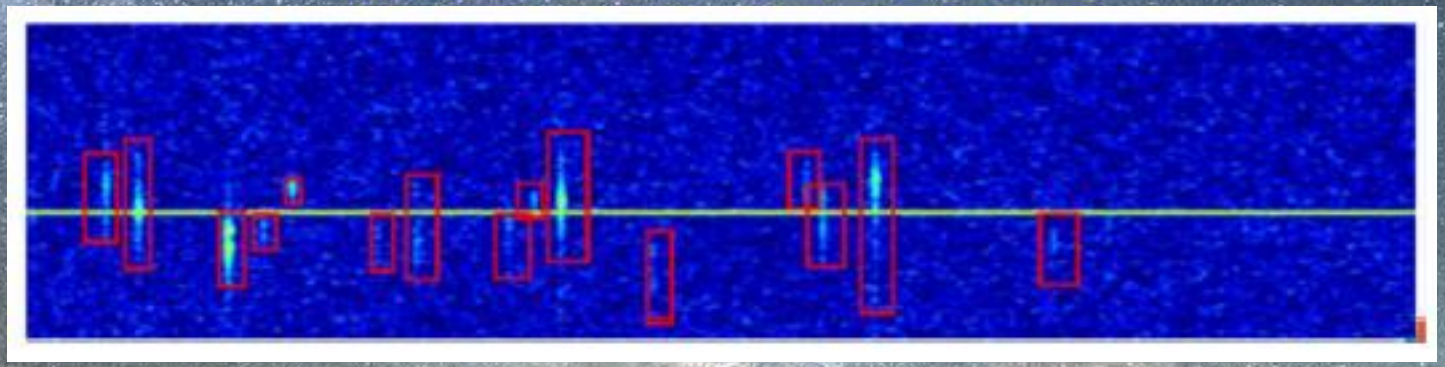
The BRAMS network






Overdense meteor echo
Beacon frequency
Airplane echoes
Underdense meteor echoes

The Radio Meteor Zoo : a world-wide effort to hunt for BRAMS radio meteor echoes



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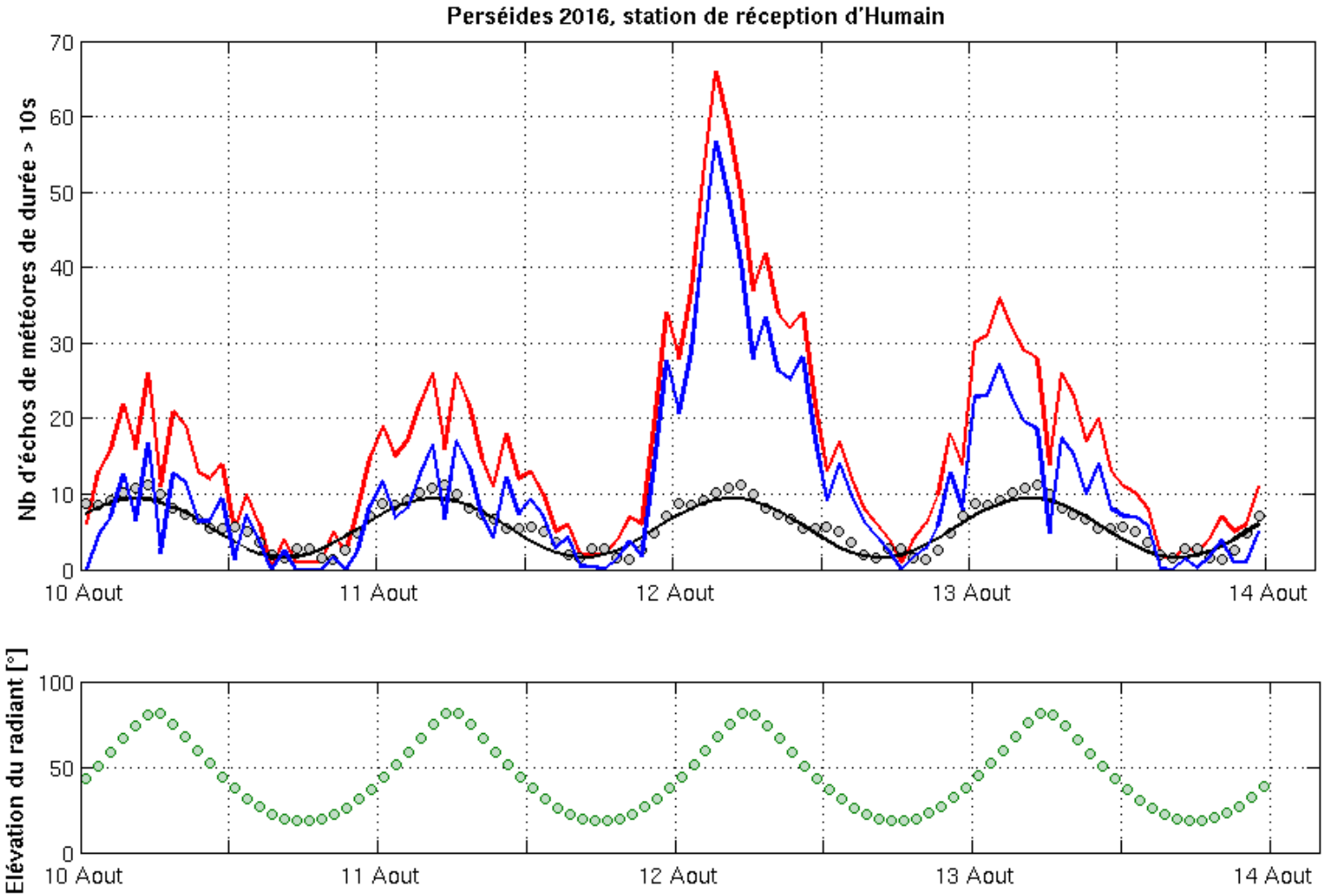
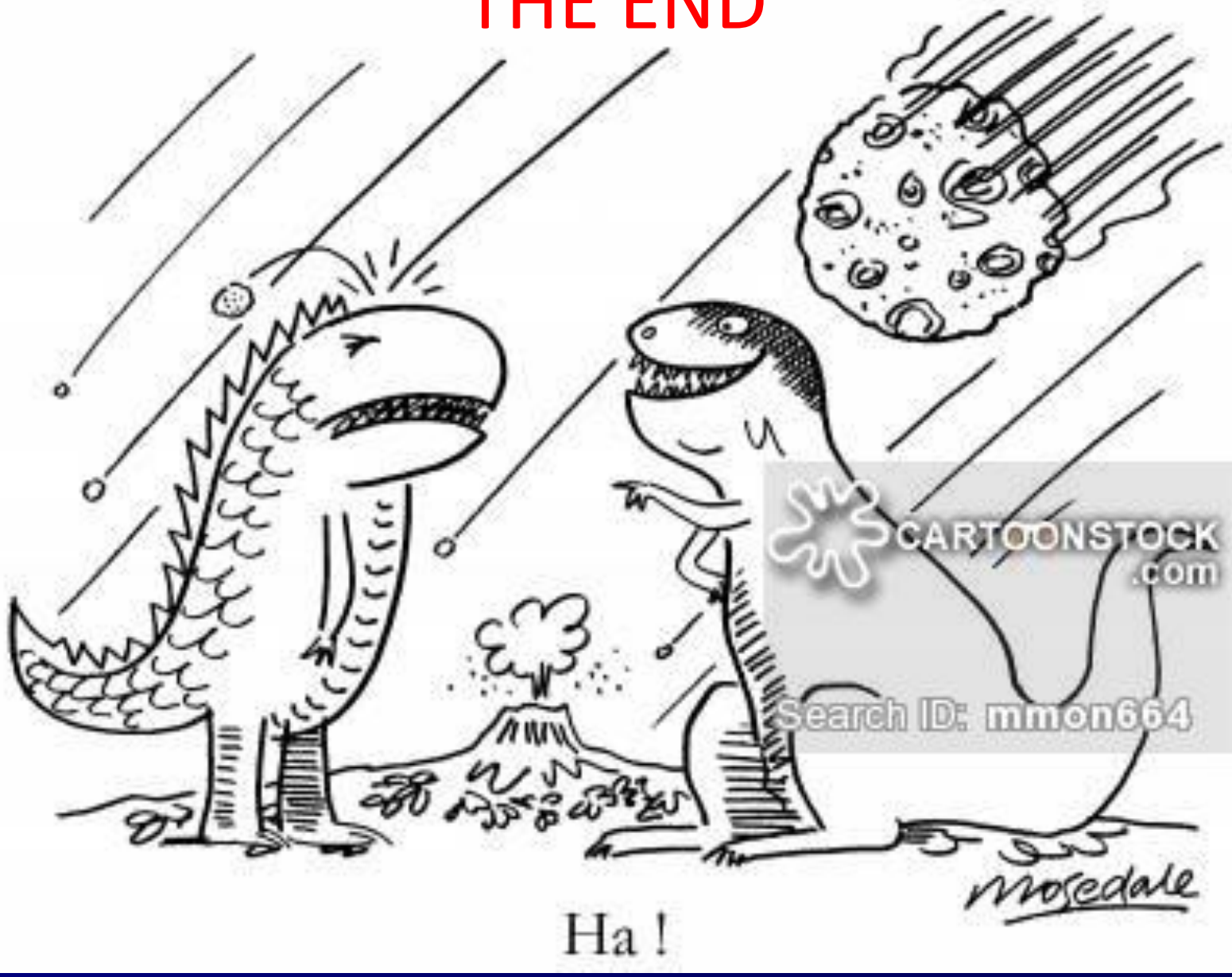
C. Verbeeck[2], A. Martinez Picar[2], E. Gamby[1]

[1] BIRA-IASB

[2] KSB-ORB


Perséides 2016, station de réception d'Humain
Nb d'échos de météores de durée > 10s
70
60
50
40
30
20
10
0
10 Aout
11 Aout
12 Aout
13 Aout
14 Aout
Elévation du radiant [°]
100
50
0
10 Aout
11 Aout
12 Aout
13 Aout
14 Aout

THE END

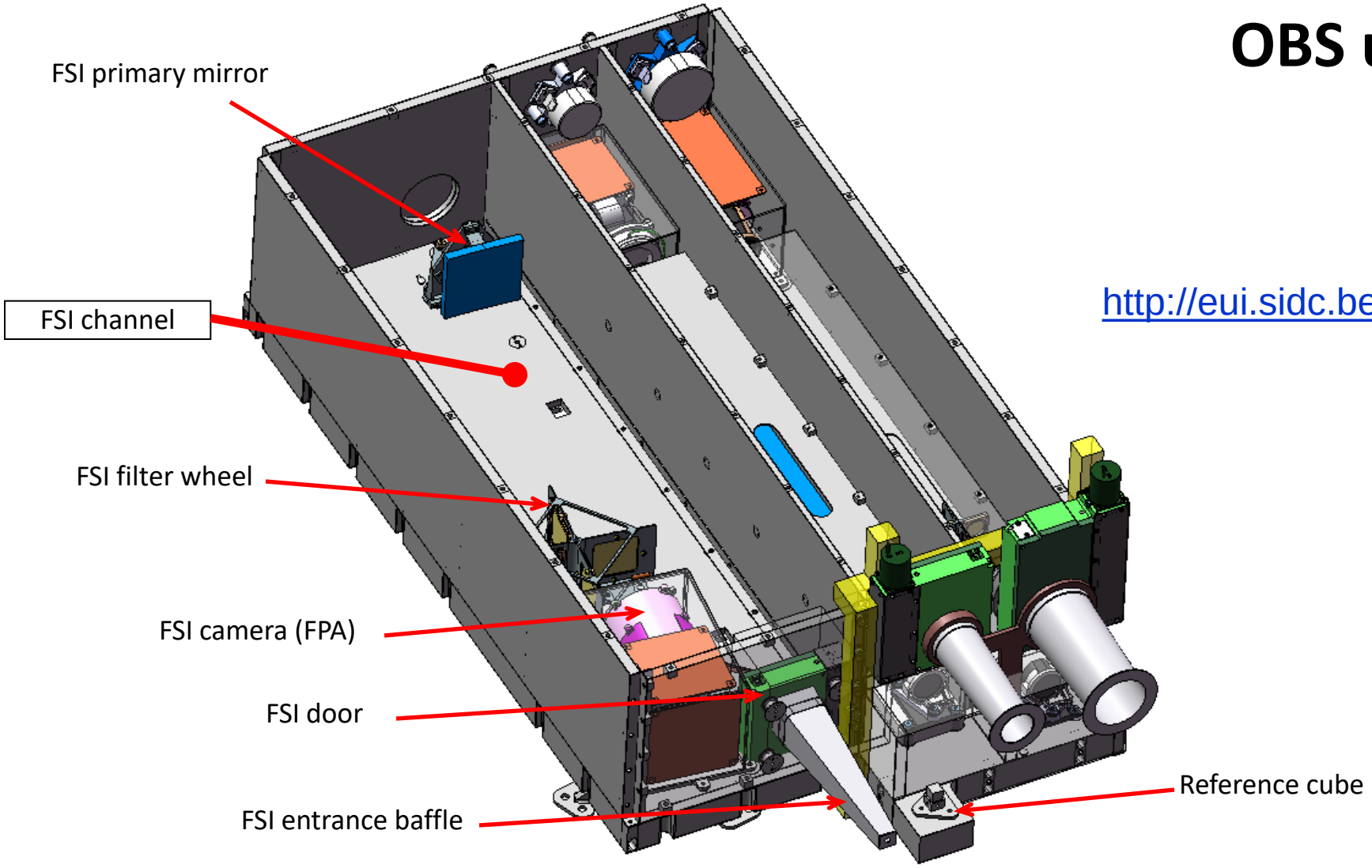


Extra slides

In situ instruments			
SWA	Solar wind analyser	Chris Owen, UK	Sampling protons, electrons and heavy ions in the solar wind
EPD	Energetic particle detector	Javier Rodriguez-Pacheco, Spain	Measuring timing and distribution functions of accelerated energetic particles
MAG	Magnetometer	Tim Horbury, UK	High-precision measurements of the heliospheric magnetic field
RPW	Radio and plasma wave analyser	Milan Maksimovic, France	Studying local electromagnetic and electrostatic waves and solar radio bursts
Remote sensing instruments			
PHI	Polarimetric and heliospheric imager	Sami Solanki, Germany	Full-disc and high-resolution visible light imaging of the Sun
EUI	Extreme ultraviolet imager	Pierre Rochus, Belgium	Studying fine-scale processes and large-scale eruptions
STIX	Spectrometer/telescope for imaging X-rays	Arnold Benz, Switzerland	Studying hot plasmas and accelerated electrons
METIS	Multi-element telescope for imaging and spectroscopy	Ester Antonucci, Italy	High-resolution UV and extreme UV coronagraphy
SoloHI	Solar Orbiter heliospheric imager	Russ Howard, US	Observing light scattered by the solar wind over a wide field of view
SPICE	Spectral imaging of the coronal environment	Facility instrument, ESA provided	Spectroscopy on the solar disc and corona

EUI: Extreme Ultraviolet Imagers

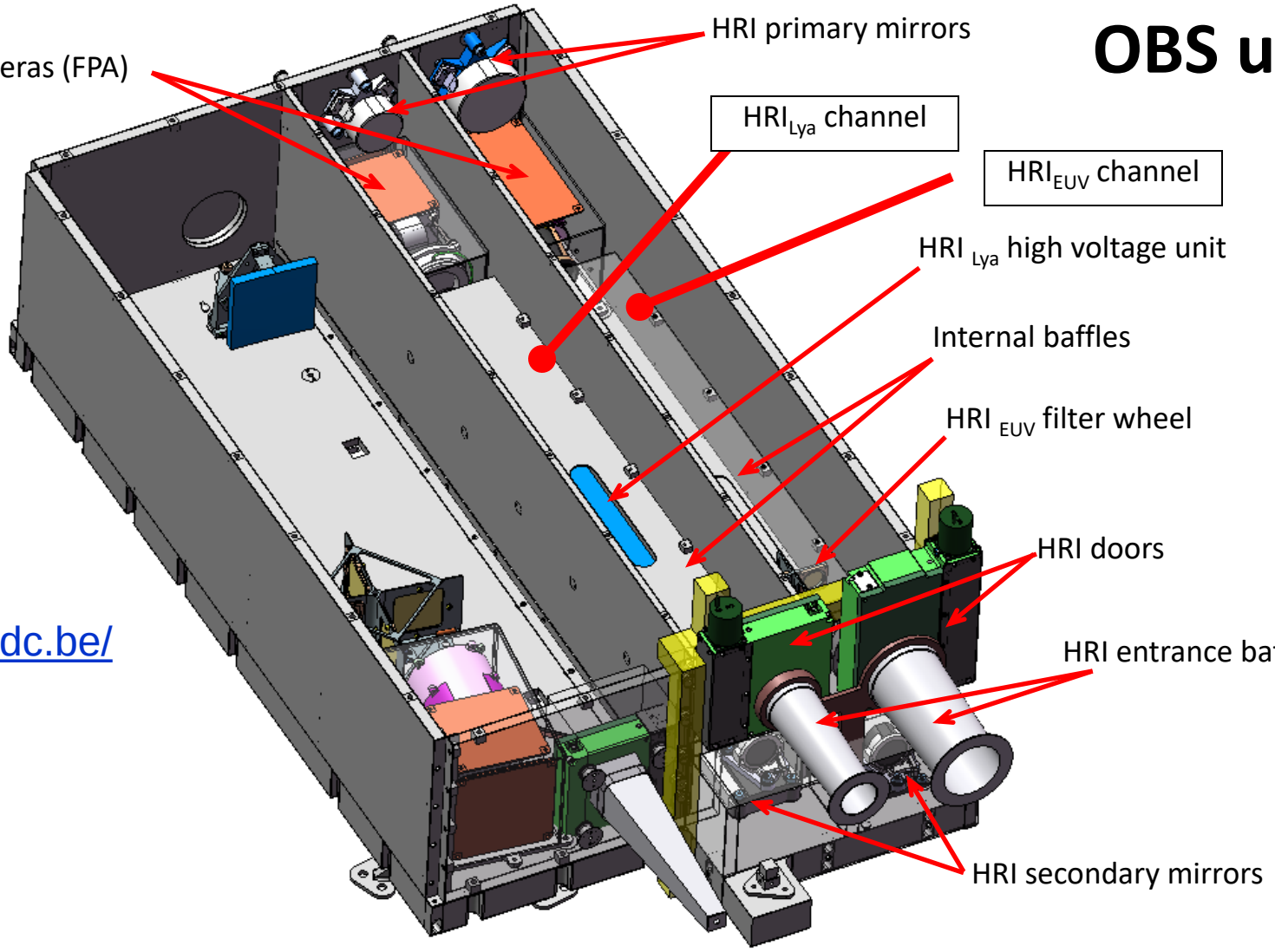
OBS unit



http://eui.sidc.be/

EUI: Extreme Ultraviolet Imagers

OBS unit



http://eui.sidc.be/

EIT CH movie 1997-2011