Minutes of the 42^{nd} SOHO SWT Meeting

Institut d'Astrophysique Spatiale, Orsay, France

12 May 2016

Agenda

09:00 Welcome (BF)
09:05 Mission status (BF)
09:45 Instrument status (PIs)
10:30 Coffee break
10:45 Instrument status cont. (PIs)
11:30 Archive status and plans for the SOHO legacy archive (BF, PIs)
12:15 Mission extension and future plans (BF)
12:45 Lunch
14:00 Science highlights and lessons learned (PIs)
17:00 Adjourn

Participants

E. Antonucci (INAF-OATO, UVCS)
T. Appourchaux (IAS, VIRGO)
P. Bochsler (UBe, CELIAS)
P. Boumier (IAS, GOLF)
P. Brekke (NSC)
W. Curdt (MPS, SUMER)
V. Domingo (ESA)
J. Dubau (IAS, SUMER)
B. Fleck (ESA)
A. Fludra (RAL, CDS)
S. Fineschi (INAF-OATO, UVCS)
C. Fröhlich (PMOD, VIRGO)
A. Gabriel (GOLF)
J. Gurman (NASA/GSFC, EIT)
D. Hassler (IAS, SUMER)
B. Heber (CAU, COSTEP)
R. Harrison (RAL, CDS)
R. Howard (NRL, LASCO)
A. Jimenez (IAC, VIRGO)
P. Lamy (LAM, LASCO)
A. Llebaria (LAM, LASCO)
P. Lemaire (IAS, SUMER)
D. Müller (ESA)
S. Parenti (IAS, SUMER)
C. Renaud (GOLF)
M. Romoli (UVCS)
P. Scherrer (Stanford Univ., MDI)
R. Schwenn (MPS, LASCO)
D. Spadaro (INAF-OACT, UVCS)
E. Valtonen (Univ. Turku, ERNE)
J.-C. Vial (IAS, SUMER)
A. Vourlidas (APL, LASCO)
P. Wenzel (ESA)

K. Wilhelm (MPS, SUMER)
R. Wimmer (CAU, CELIAS)

Summary

B. Fleck welcomed the participants and presented the missions status (Annex 1). Scientists from European laboratories and universities who receive funding from national agencies for continued instrument operations should provide information about the level of support to B. Fleck (**Action 42-1**). The PIs presented the status of their instruments in the usual order, including their plans for the SOHO legacy archive (Annex 2). B. Fleck summarized the archive status and future plans (Annex 3). B. Fleck presented the ESA mission extension procedure (Annex 4). The SWT enthusiastically endorsed Alexis Rouillard as presenter of the SOHO mission extension case to the ESA advisory structure on 13-14 October. In the afternoon the PIs presented science highlights from their instruments and lessons learned (Annex 5). E. Antonucci proposed to produce a SOHO monograph, along the lines of the book on Skylab. A comment was made that in order to be available to a community as widely as possible, such a monograph should be available online, if possible also through ADS. B. Fleck will investigate options with ESA and ISSI. F. Auchère proposed to have a Solar Physics Topical Issue on "20 Years of SOHO", with a focus on studies exploiting the exceptional duration of the mission. Possible topics for papers include: long-term variability, comparison of the two cycles, statistical analysis of various types of events, catalogues, etc. There is an action on the PIs to probe interest in their teams for such a topical issue (**Action 42-2**). B. Fleck will contact J. Leibacher if there is sufficient interest. K. Wilhelm circulated a copy of the ESA Bulletin article "Four Years of SOHO Discoveries – Some Highlights" (ESA Bull. 102, May 2000), which was signed by all participants (Annex 6).

Actions

42-1: on European instrument teams that receive funding from national agencies for continued instrument operation: provide information about funding to B. Fleck. Due before 31 May 2016.

43-2: on PIs: probe interest for a topical issue on "20 years of SOHO" in their science teams and provide summary to B. Fleck (due end of June 2016).

Annexes

Annex 1

Mission Status

SOHO Mission Extensions Operations Review

Bernhard Fleck
SOHO Project Scientist & Mission Manager
bfleck@esa.nascom.nasa.gov

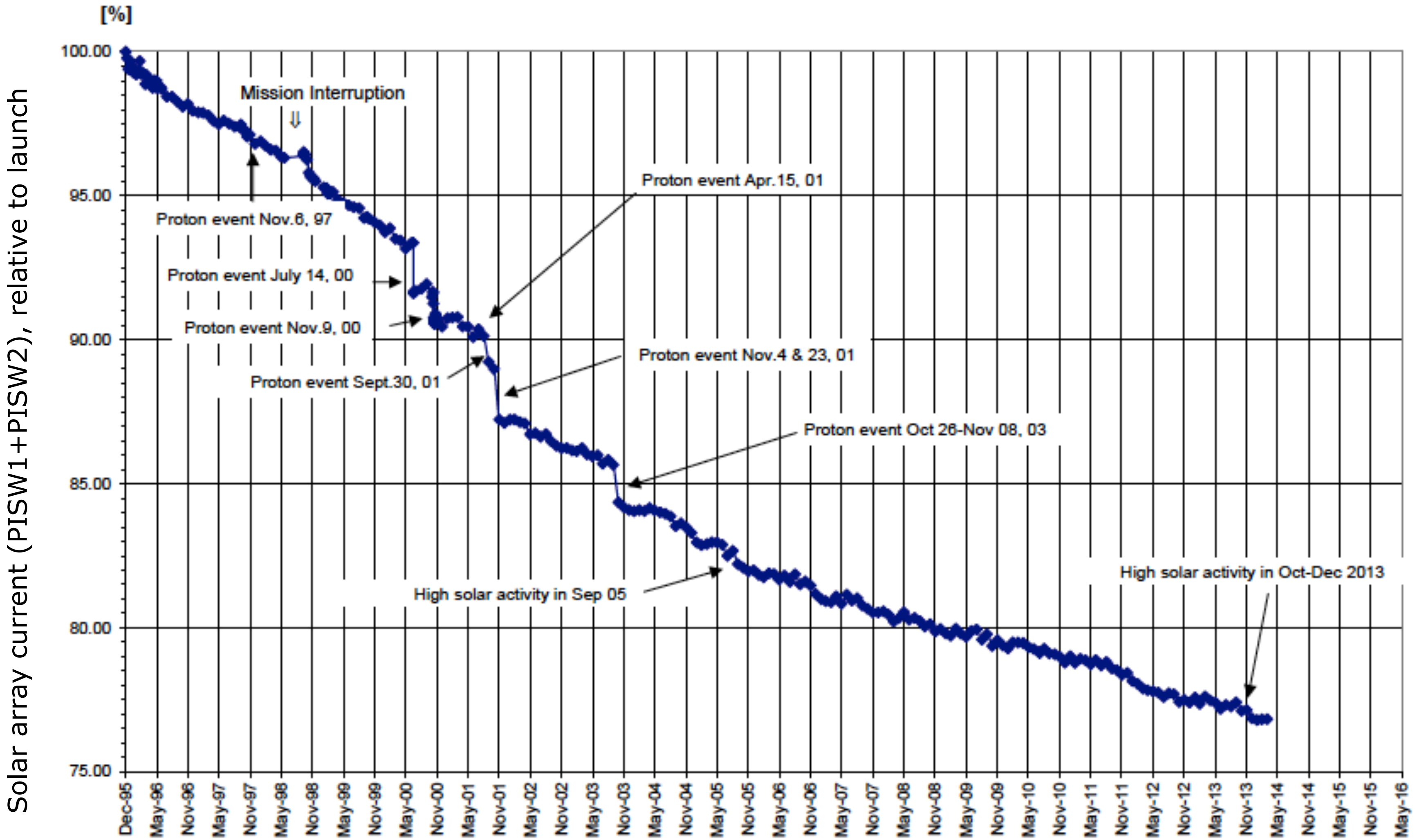
Outline

- Spacecraft status
- Payload status
- Ground system status
- Mission operations changes
- System maintainability and funding
- Disposal Strategy
- Summary

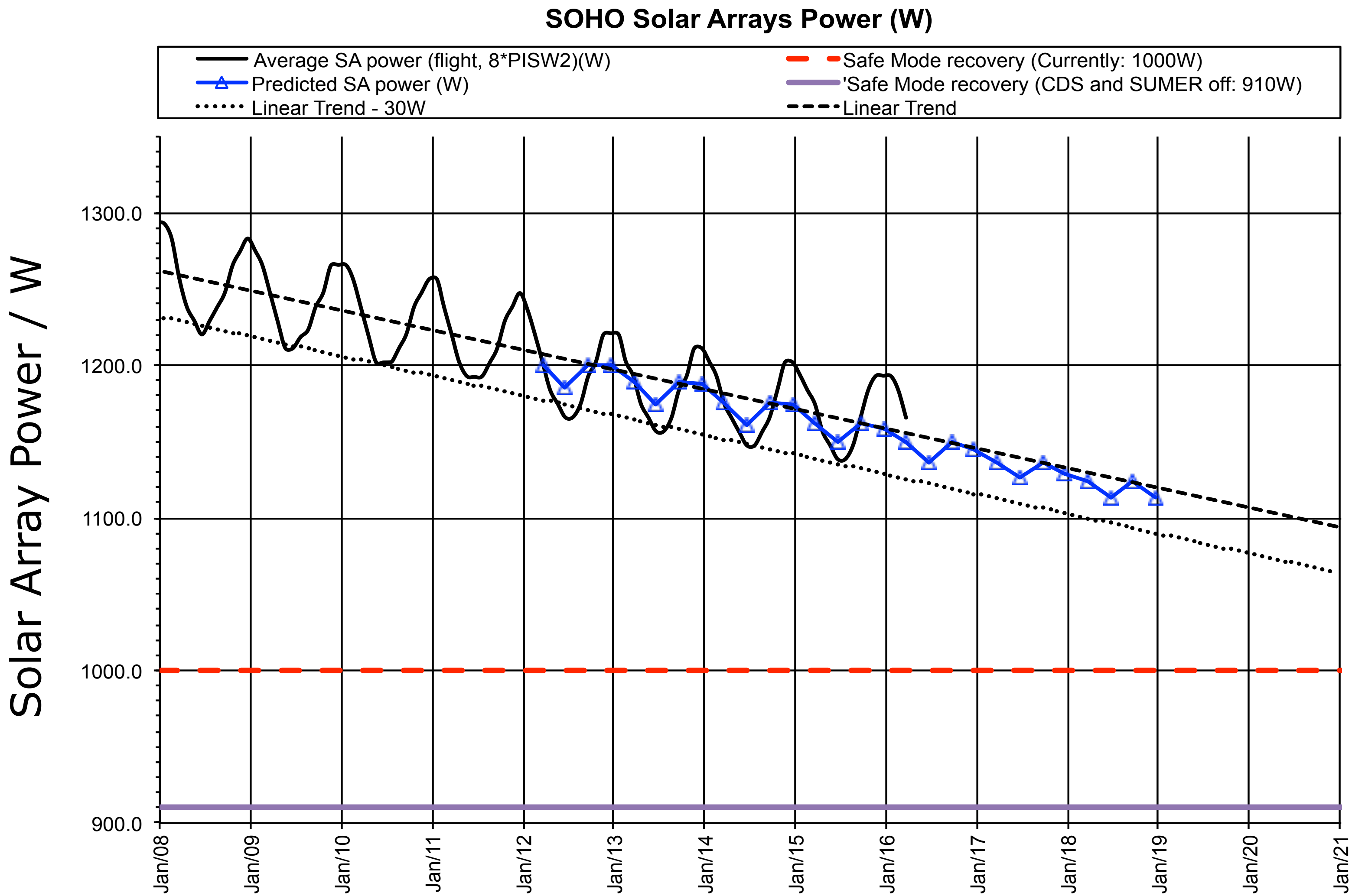
Spacecraft status

- **S/C is healthy and performs entirely within specifications**
  - Hardware Failures (none with impact on science)
    - 1997 April 23: Loss of fast loop of receiver 1 (but still being used in slow sweep mode)
    - 1998 Sep/Dec: Loss of all 3 gyros
    - 2002 March 7: Loss of battery 1 (battery 2 still in trickle charge, but probably low capacity)
    - 2003 May: High gain antenna Z motor stuck (now parked in both axes)
      - causes telemetry "keyholes" every 3 months, but manageable with on-board patch for intermittent recording of selected packets and extra DSN support
    - 2004 April 21: Loss of Fine Sun Pointing Attitude Anomaly Detector (FSPAAD)
    - 2012 May 9: Loss of Coarse Sun Pointing Attitude Anomaly Detector (CSPAAD)
  - Reserves
    - Remaining fuel: 113±3 kg (usage during last 10 years: ~ 6 kg)
    - Solar array degradation after 20.3 years: 23.73% (1.17% / year; budget was 4% / year)
    - > 200 W power reserves
    - Redundant subsystems

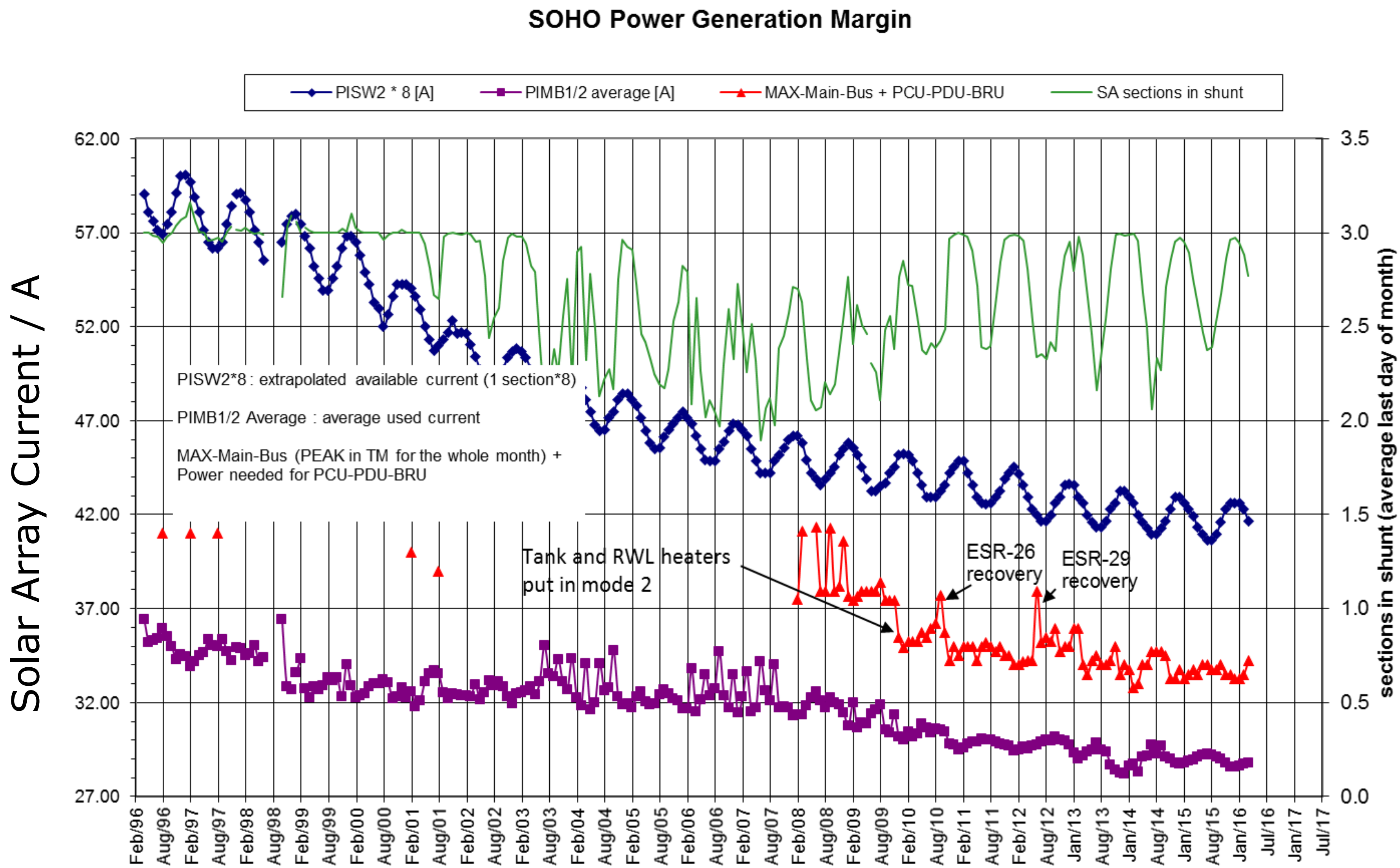
Solar array degradation



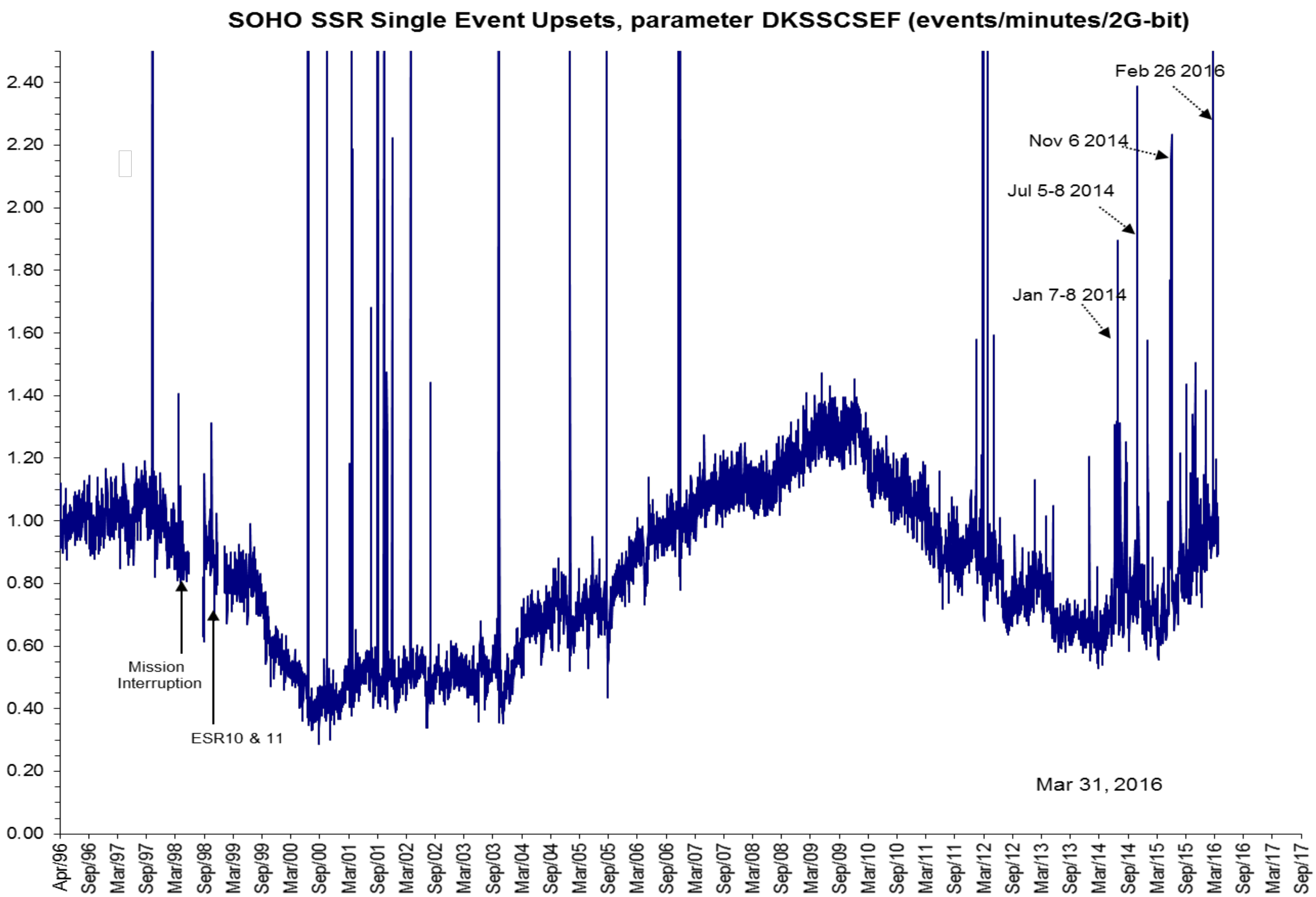
Power reserves



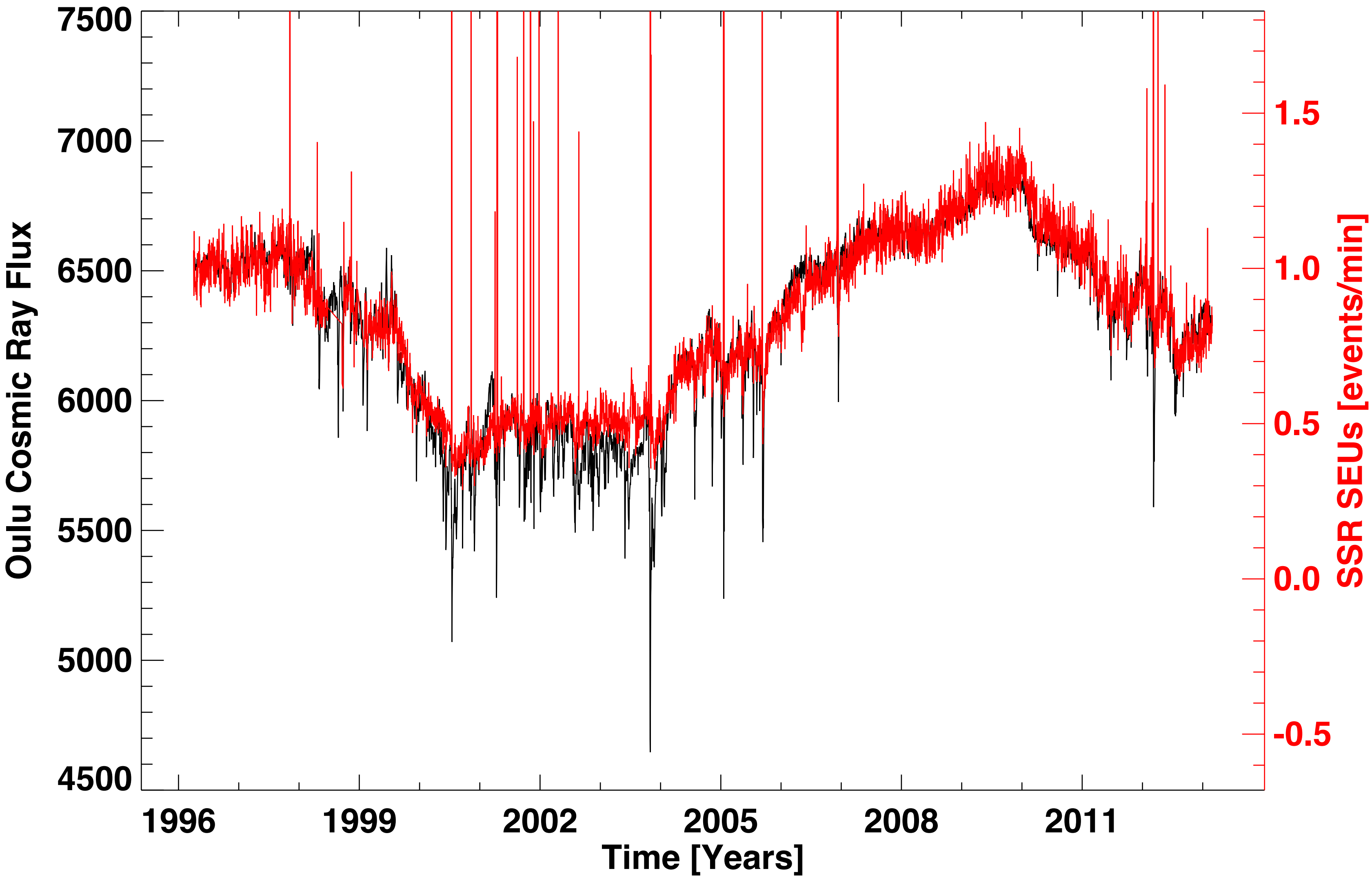
Power generation margin



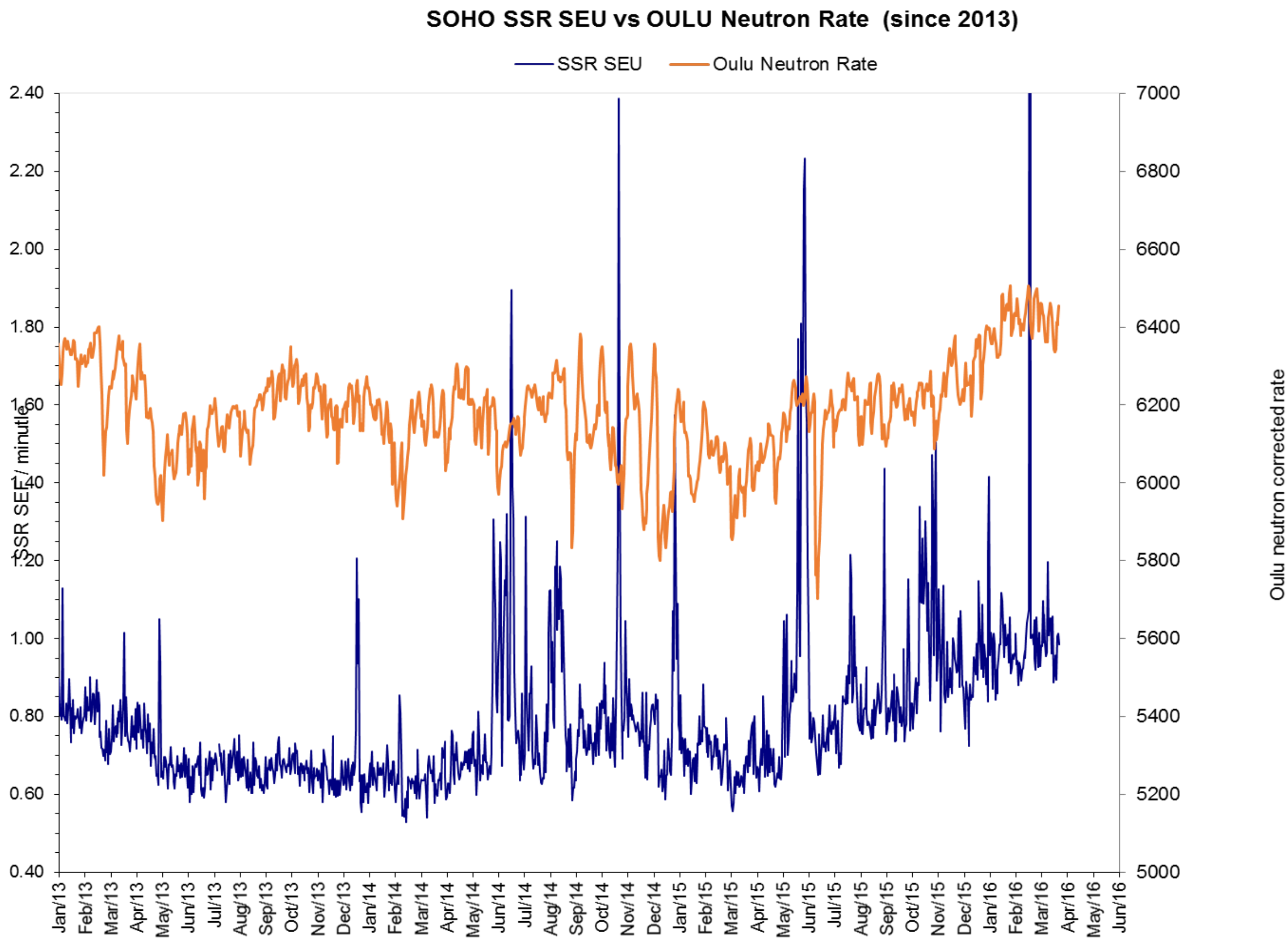
Solid state recorder single event upset rate



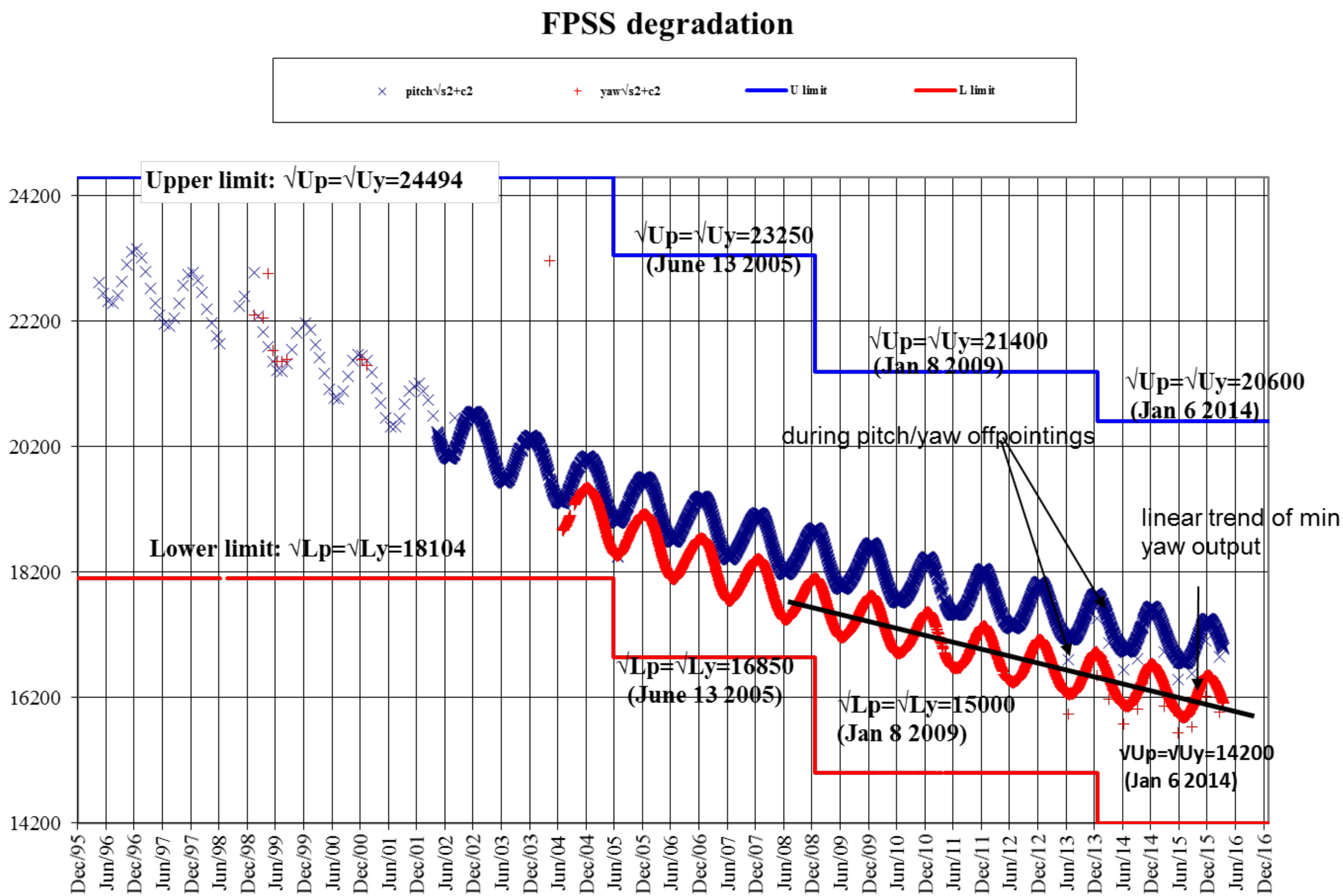
SSR SEU rate vs Oulu Neutron Monitor data



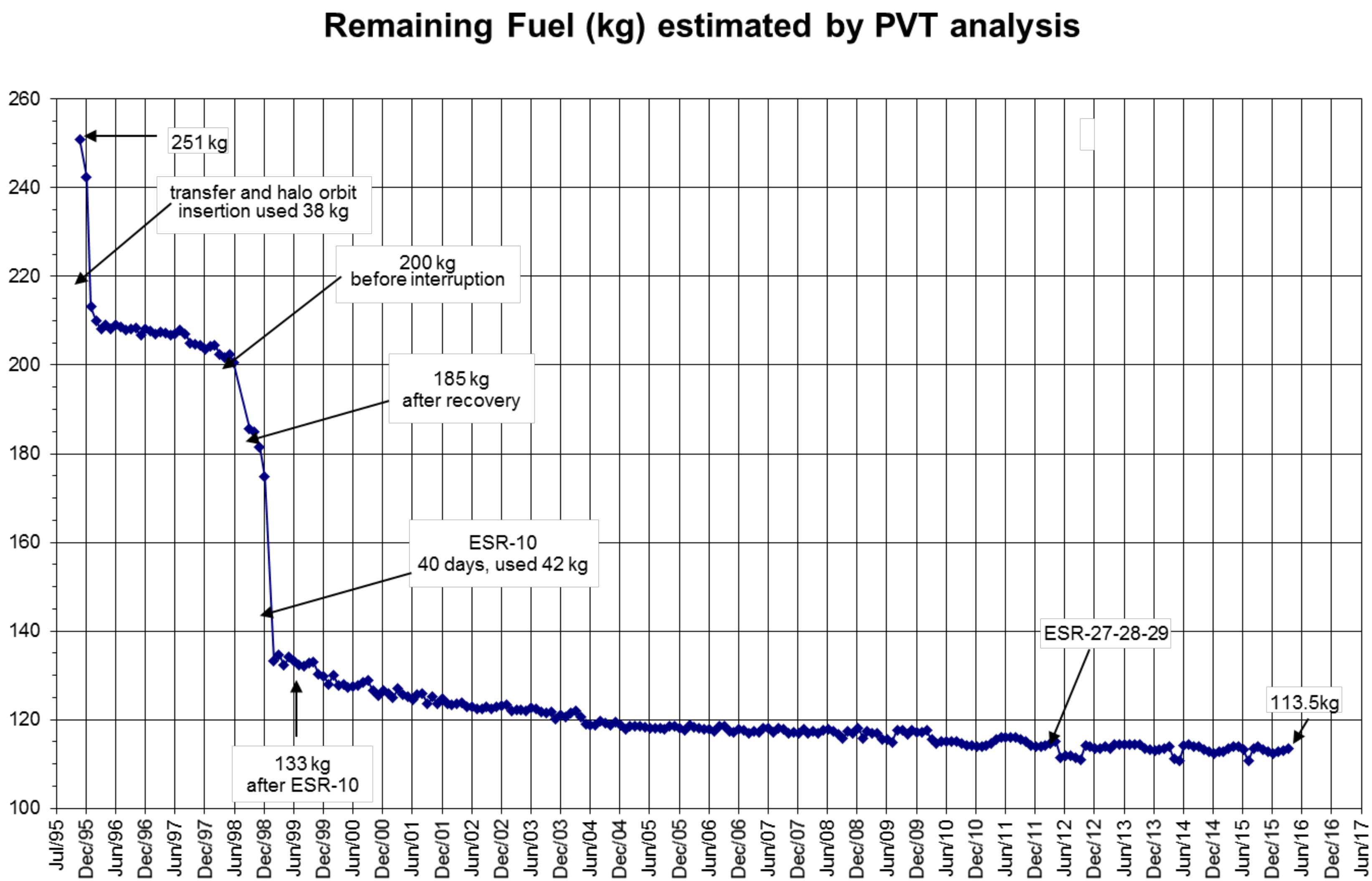
SSR SEU rate vs Oulu Neutron Monitor data



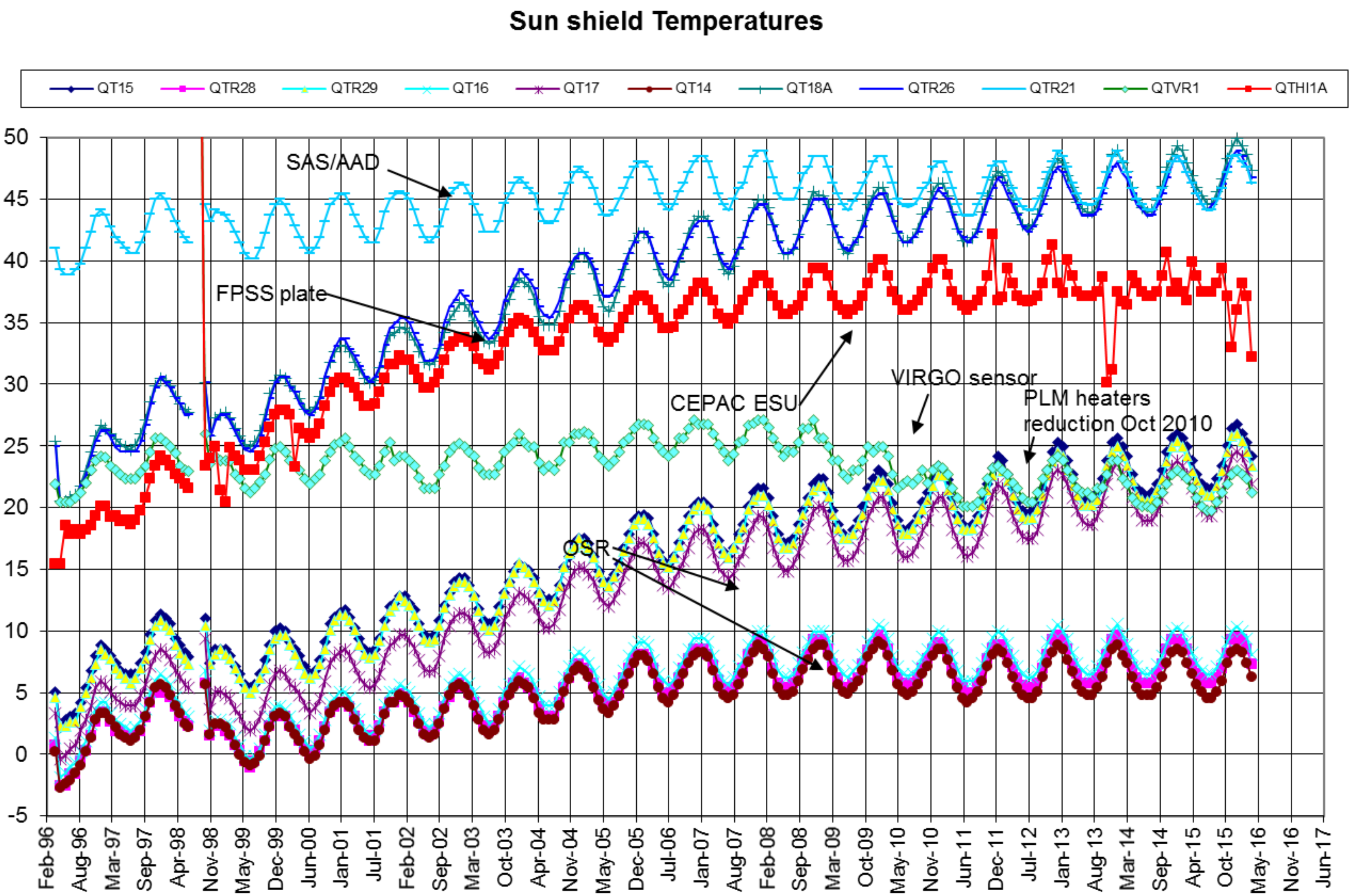
FPSS degradation



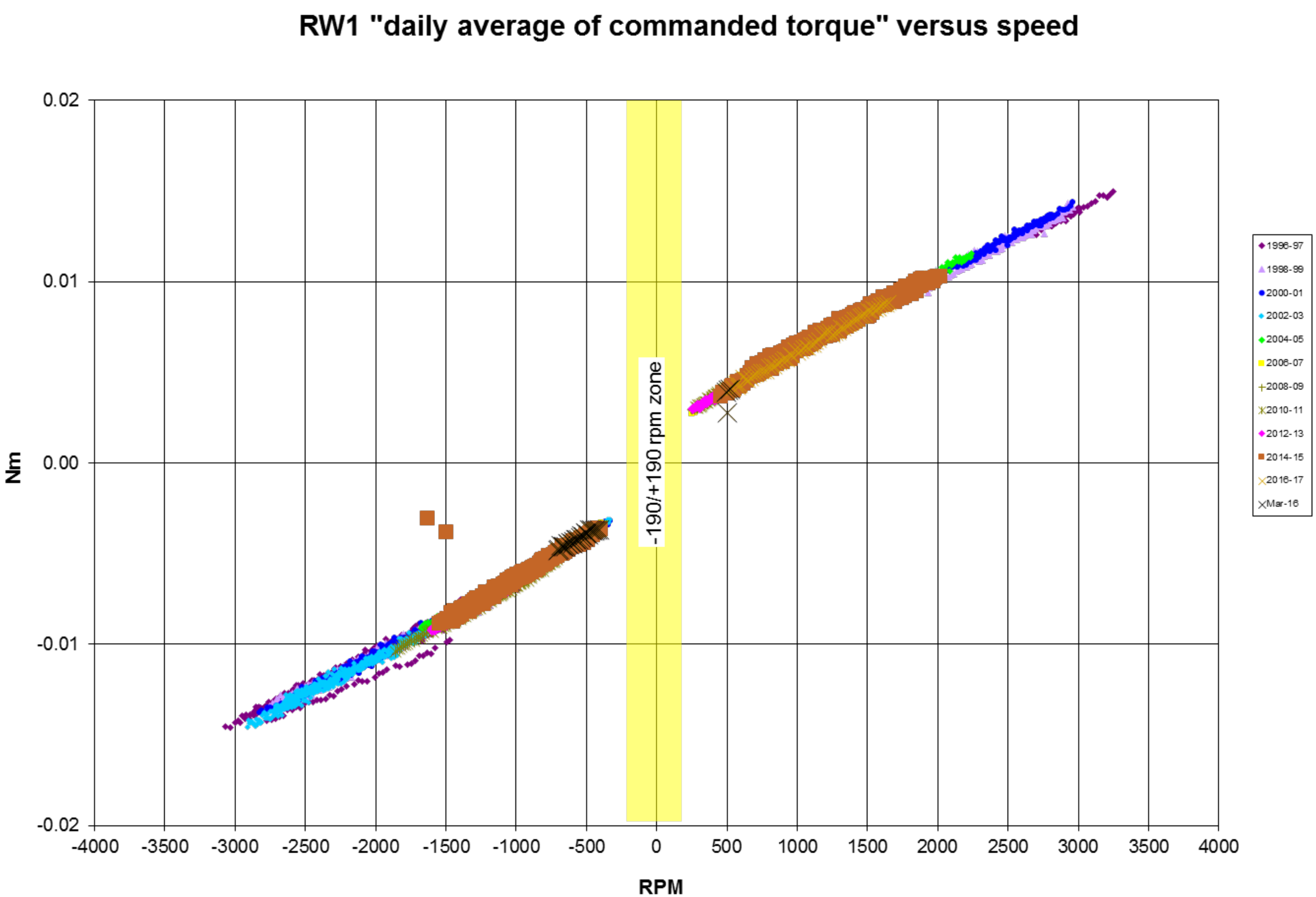
Remaining fuel reserves



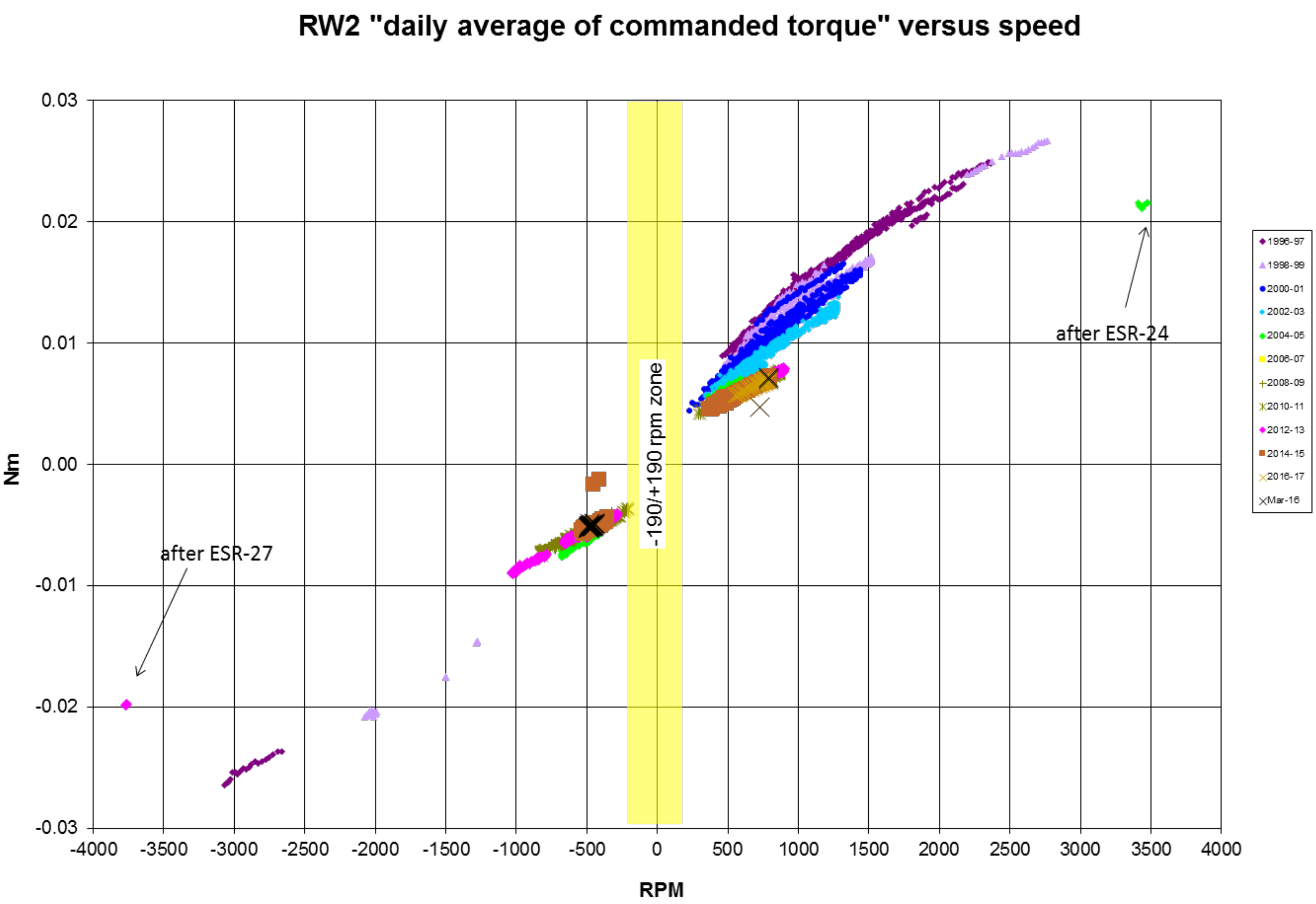
Top panel temperatures



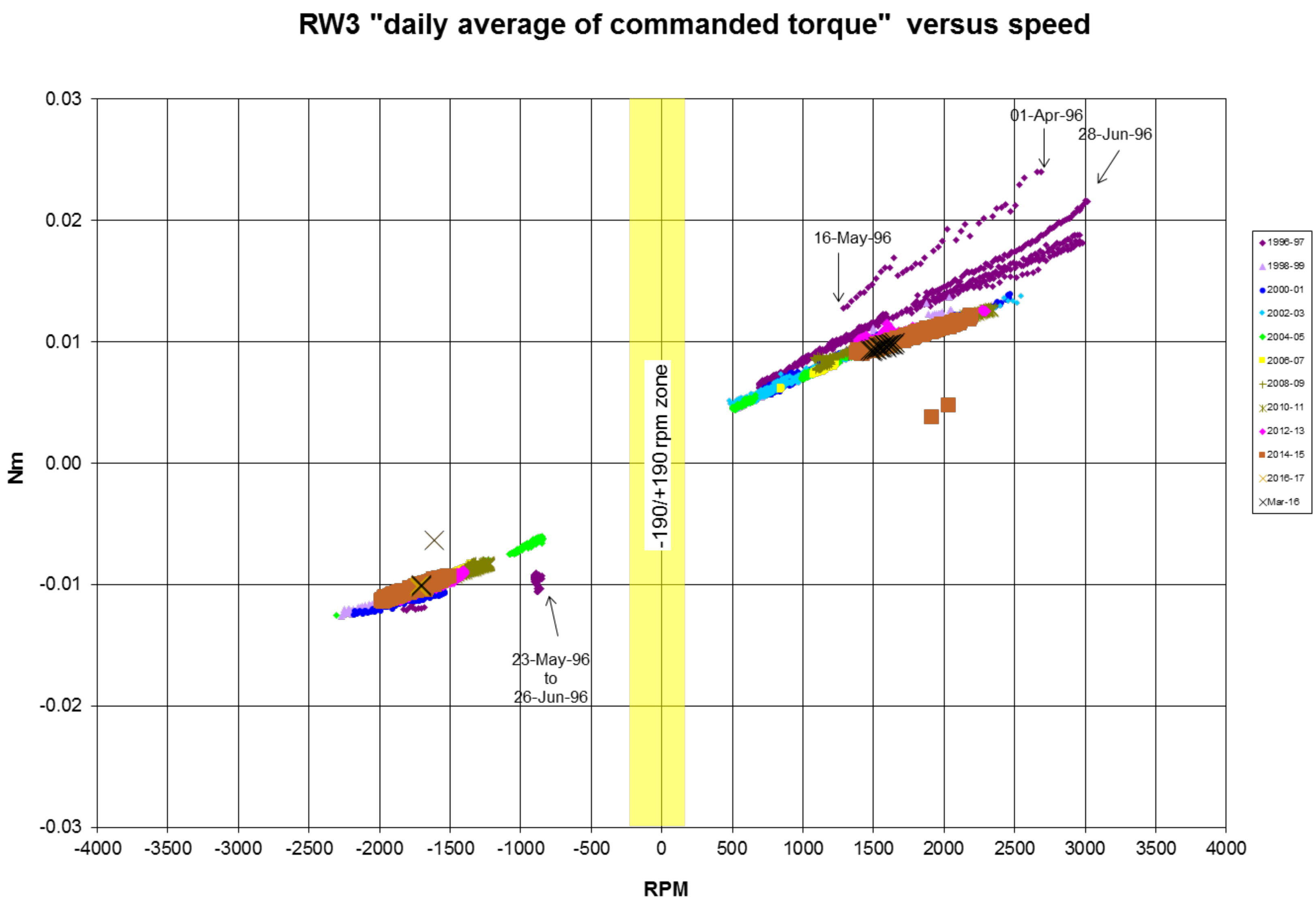
Reaction wheel 1 performance



Reaction wheel 2 performance



Reaction wheel 3 performance



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- Spacecraft Status
- Payload Status
- Ground System Status
- SOC Science & Instrument Support
- Mission Operations Changes
- System Maintainability and Funding
- Cost
- Disposal Strategy
- Summary

Payload status

- Only change since 2014 MEOR: SUMER and CDS hibernated in Aug/Sep 2014
  - GOLF: nominal
  - VIRGO: nominal
  - MDI: stopped taking science data on 11 April 2011 (but restarted for Mercury transit)
  - SUMER: hibernated on 8 August 2014
  - CDS: hibernated on 5 September 2014
  - EIT: nominal (only taking 2 synoptic sets per day)
  - LASCO:
    - C2 & C3 nominal
    - Very stable: decrease in sensitivity < 0.4% per year
    - C1 lost in 1998 (FPI damaged during deep freeze)
  - UVCS: off since 19 January 2013
  - SWAN: nominal
  - CELIAS
    - MTOF, STOF, SEM nominal
    - CTOF impaired since October 1996 (HV power supply hardware failure)
  - COSTEP
    - EPHIN nominal
    - LION impaired since shortly after launch, with increased noise
  - ERNE: nominal (can only operate one of the 2 detectors during hot season)

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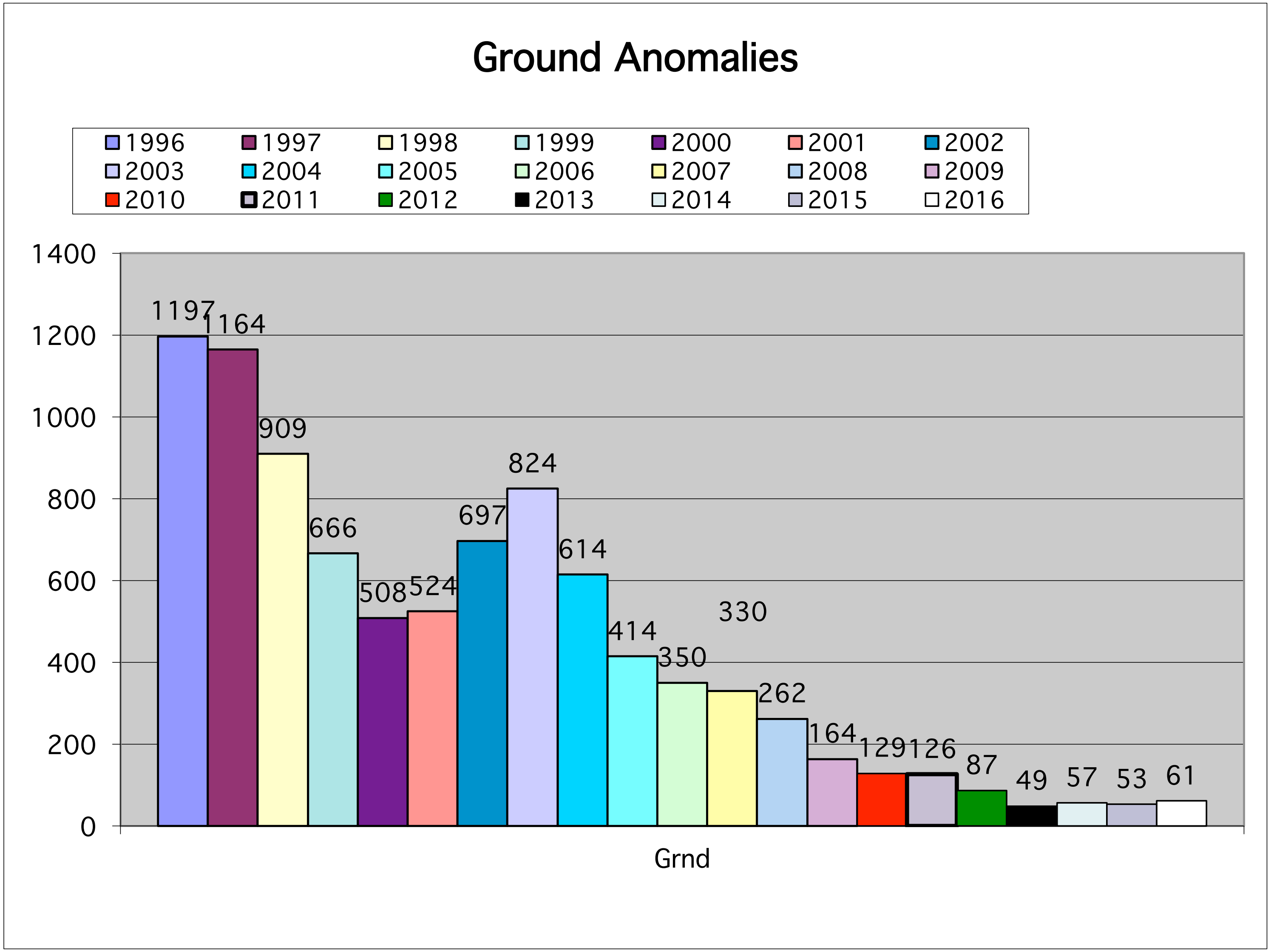
Ground system status

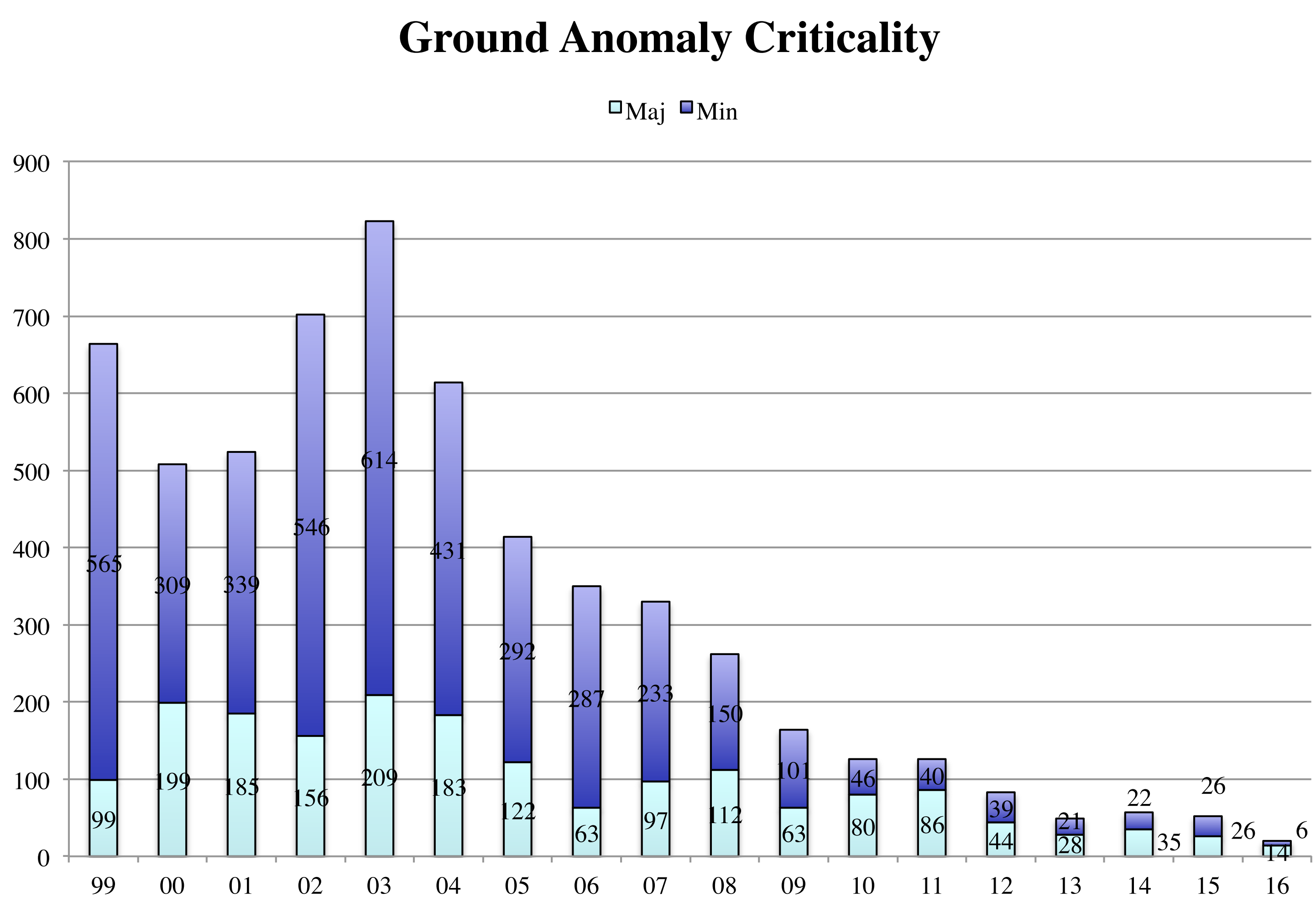
- Under NASA responsibility
- Only change since 2014 MEOR: migration of MOC operational strings to HP Itaniums

Ground anomalies

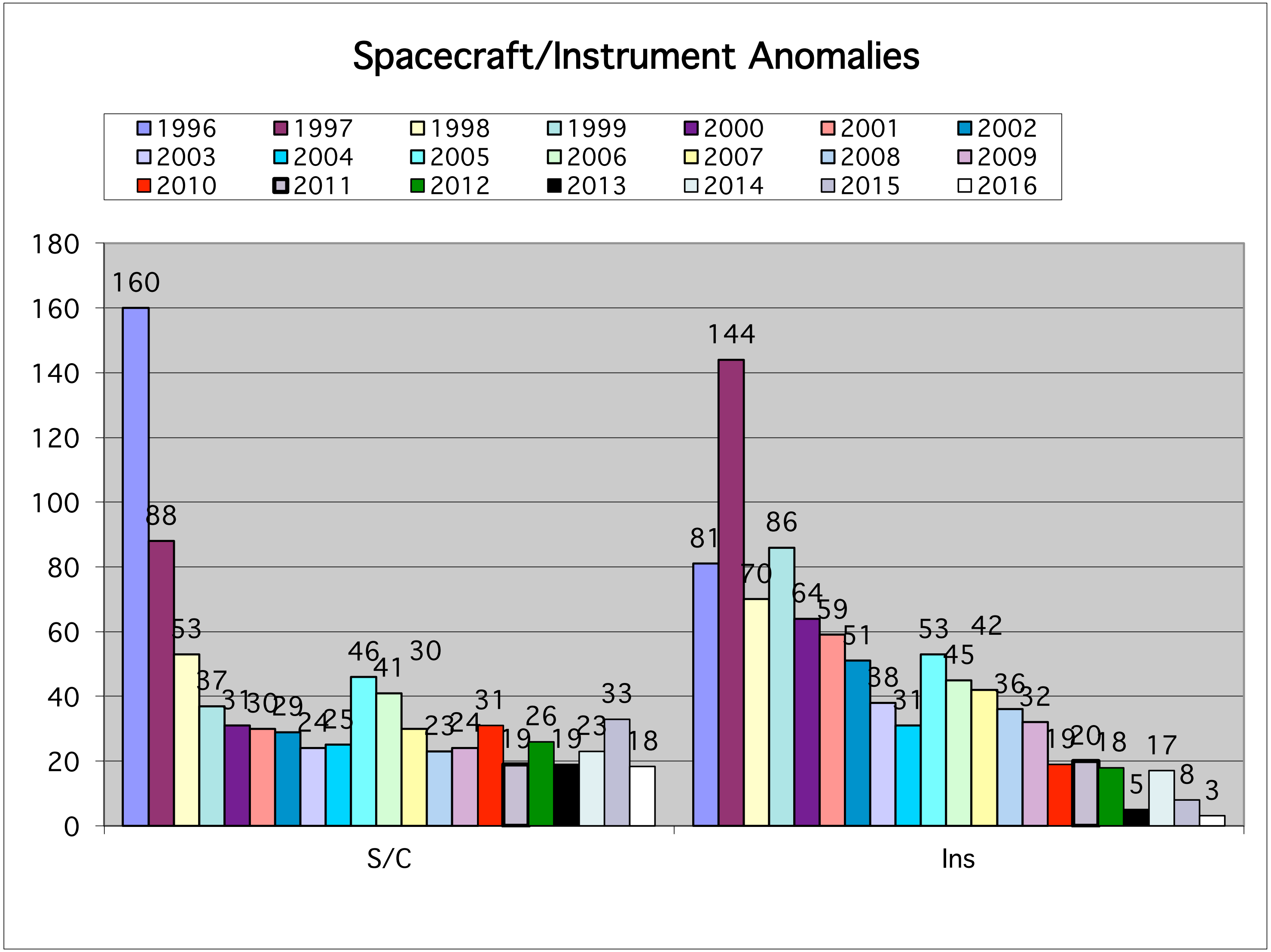


2016 data is projected

Ground anomaly criticality

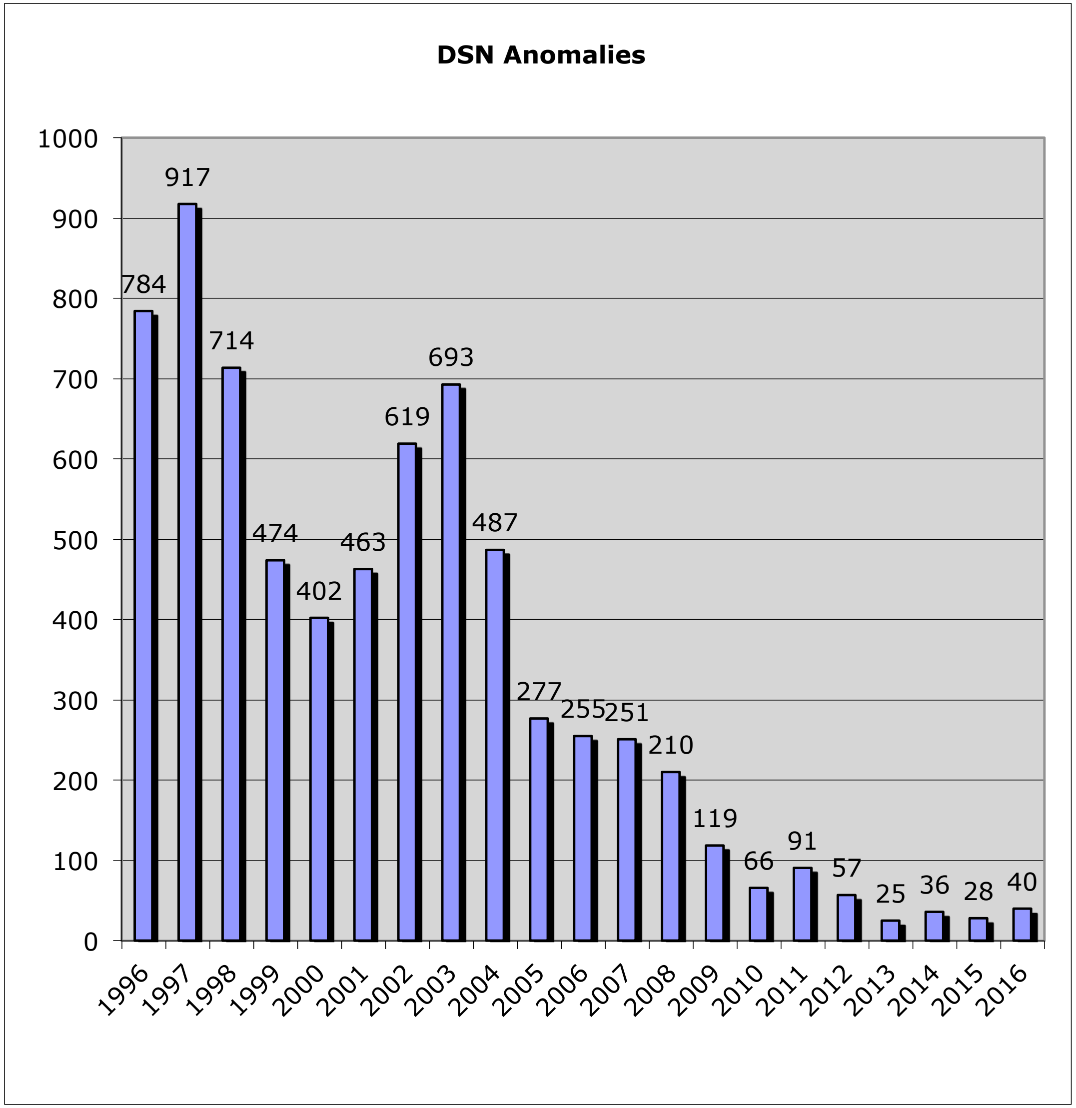


Spacecraft & instrument anomalies



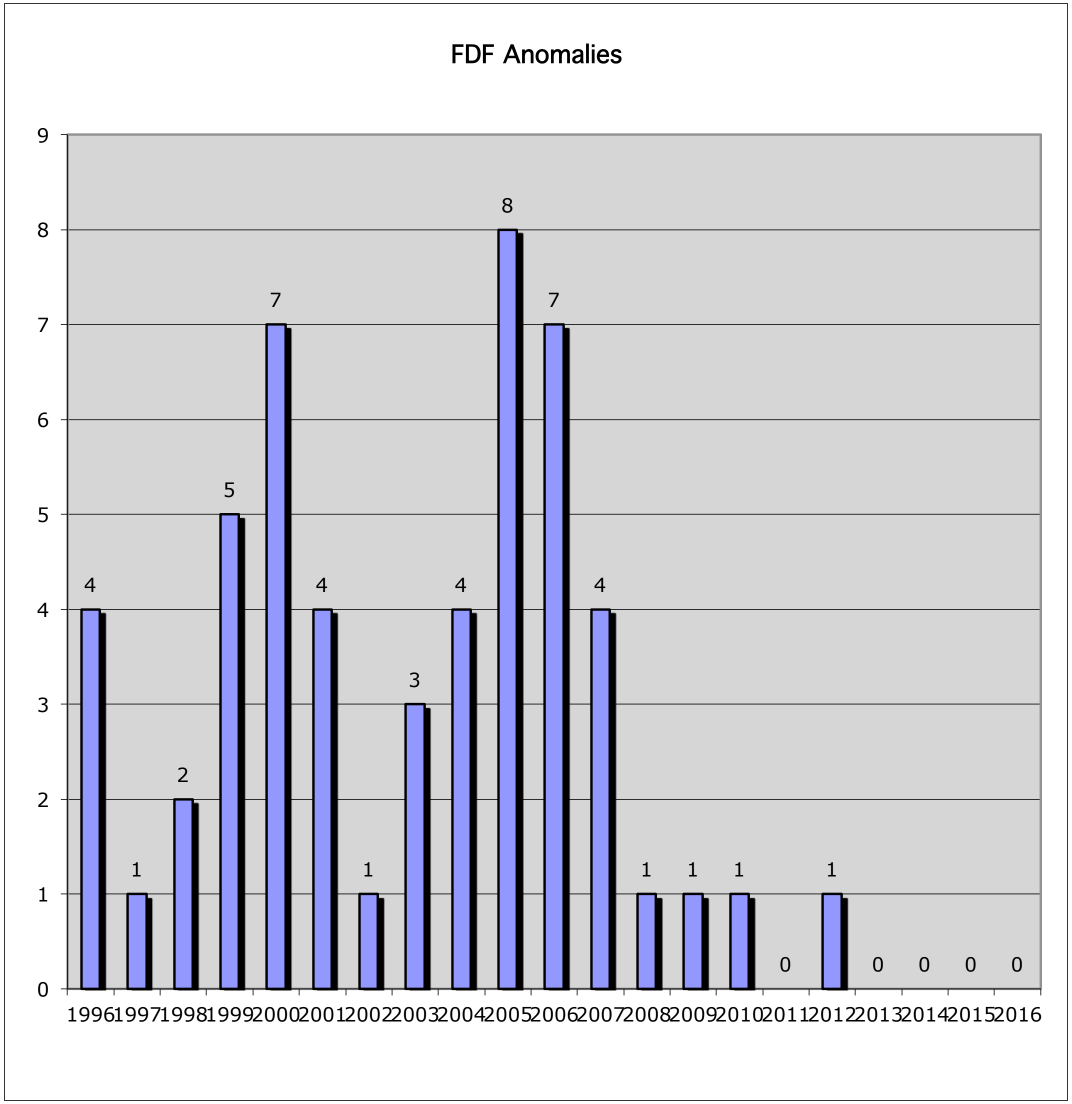
2016 data is projected

DSN anomalies



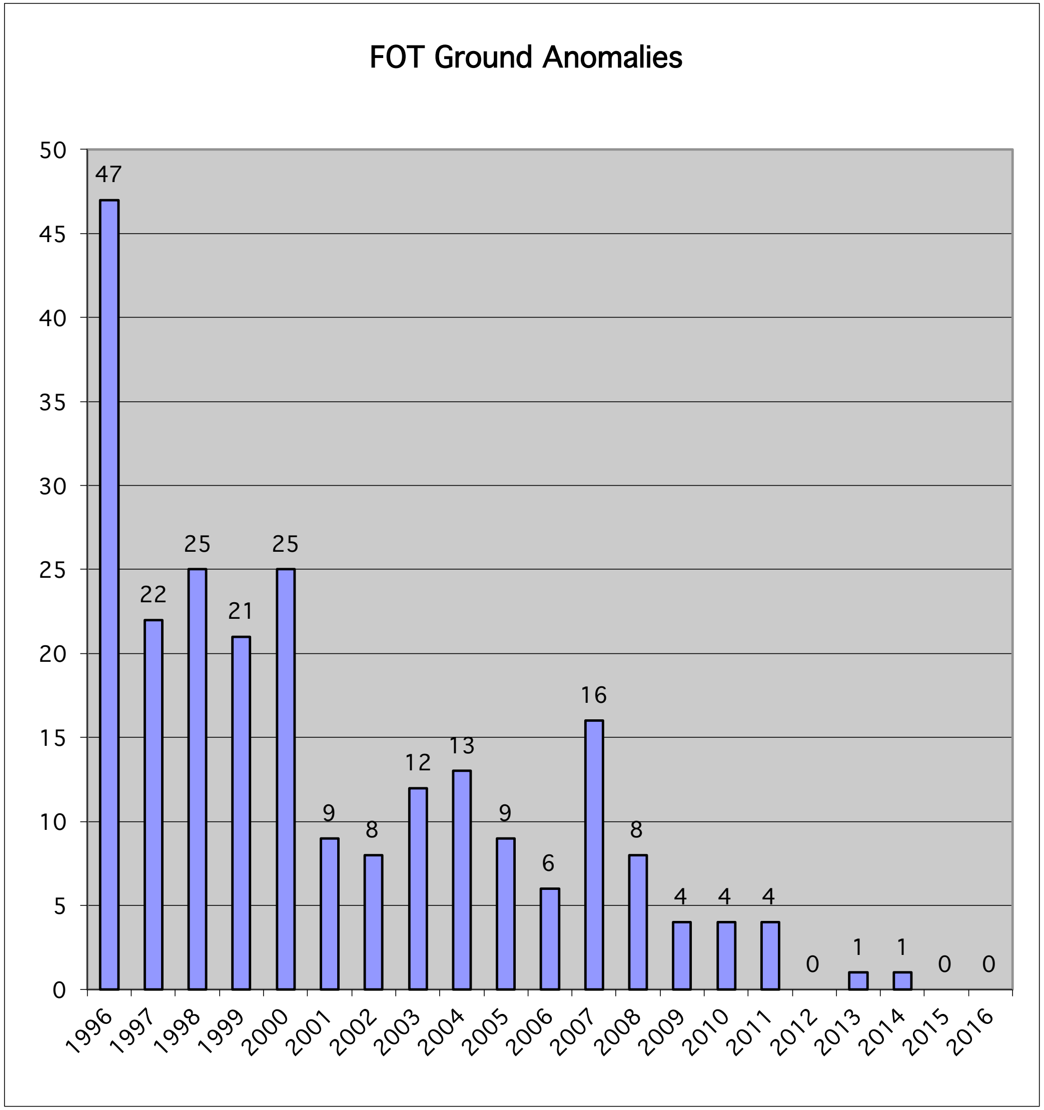
2016 data is projected

FDF anomalies

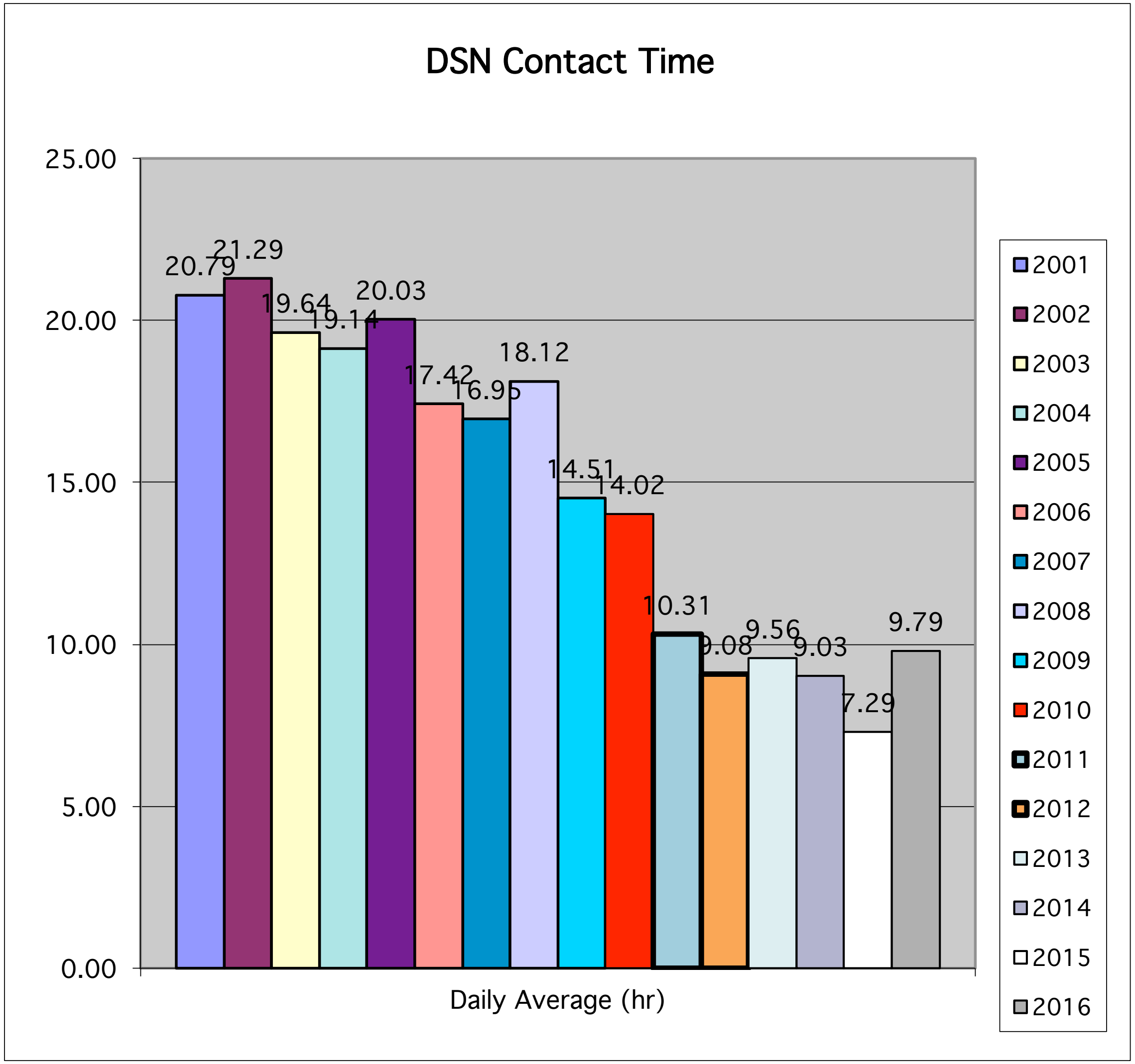


2016 data is projected

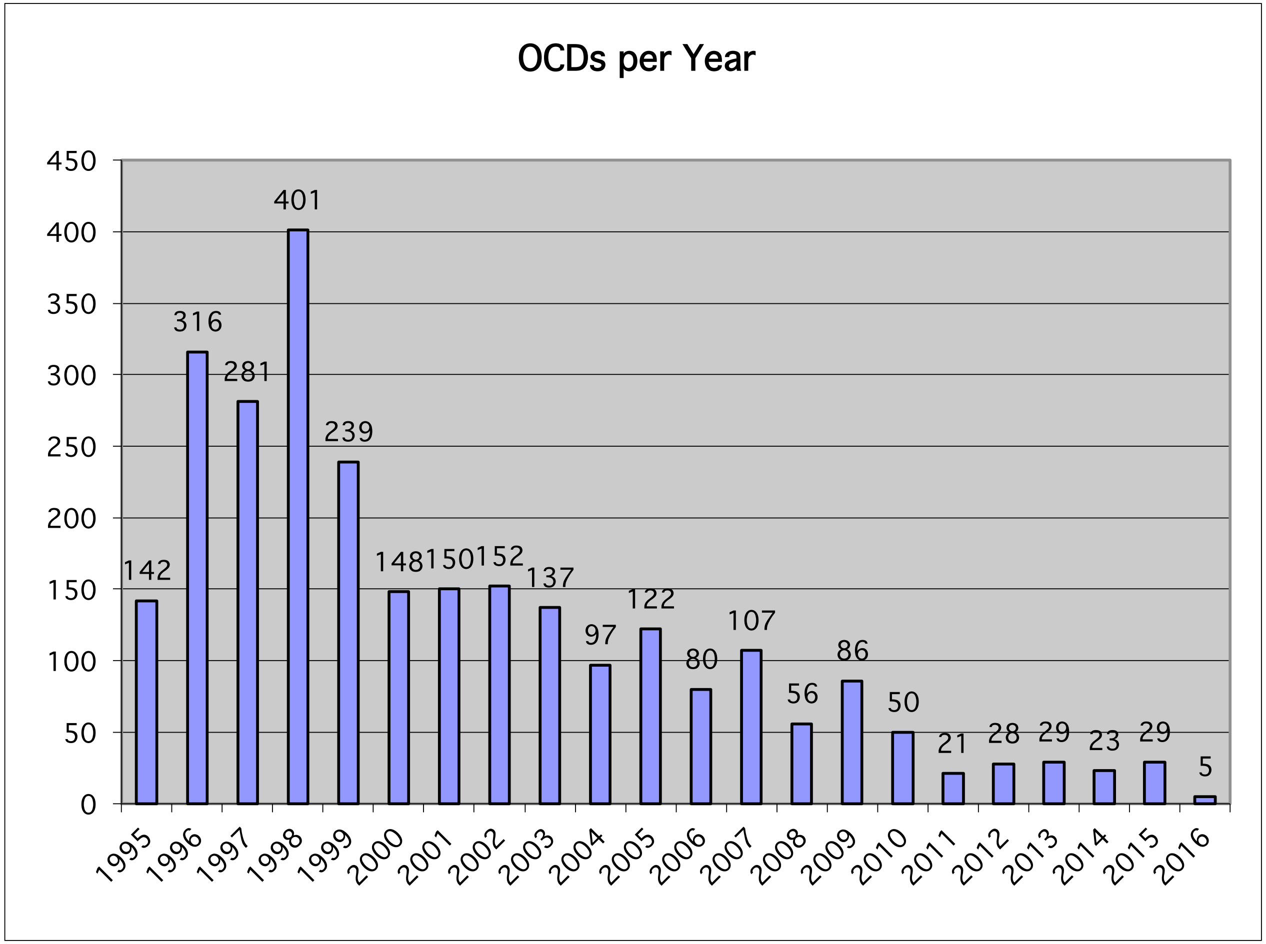
FOT ground anomalies



DSN contact time



Operations Change Directives (OCDs)



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Mission operations changes

- No S/C ops changes since last review and no further modifications planned
- Instrument changes:
  - MDI stopped taking science data on 12 April 2011 (but still on)
  - UVCS operations terminated on 23 January 2013
  - CDS hibernated on 5 September 2014
  - SUMER hibernated on 8 August 2014
  - The other 8 instruments (VIRGO, GOLF, EIT, LASCO, SWAN, CELIAS, COSTEP, ERNE) are expected to continue in current mode

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System maintainability

- Ground system under NASA responsibility
- SOHO is a "mature" mission: maintenance of computing infrastructure challenging
- 2010: upgrade of EOF Core System (used for T&C) to Linux (from AIX)
- 2011: upgrade of ESA SOHO server (used, among other tasks, for ancillary data and real-time image generation) to Linux
- 2012: upgrade of ESA SCOS stations from Sun Sparc 10 running Solaris 2.6 to Linux
- 2012: upgrade of Data Processing System (DPS) to Linux
- 2016: upgrade of operational strings (machines used for S/C operations)
- SOHO Simulator
  - running on Sun Sparc under Solaris 2.6
  - keeping several old Sun Sparc workstations as spare
  - software port to sustainable platform would be quite costly, but now being seriously considered by NASA
    - Reason: potential move of SOHO operations into the virtualized Multi Mission Operations Center (VMMOC)

Funding - NASA

- SOHO does ***not*** have to participate in future NASA Senior Reviews
  - Recognition of critical importance of LASCO observations "to the Nation's space weather architecture" (cf. President's budget requests of previous three years)
  - SOHO considered "infrastructure" that must be maintained
- National Space Weather Action Plan
  - Produced by the National Science and Techology Council
  - Action 5.3.1: DOC, NASA, and NSF will develop a strategy for: (1) the continuous operation of the Solar and Heliospheric Observatory/Large Angle and Spectrometric Coronagraph (SOHO/LASCO) for as long as the satellite continues to deliver quality observations; and (2) prioritizing the reception of LASCO data in anticipation of extreme space-weather events.
  - Interestingly, ESA (the owner of the spacecraft) is not mentioned in this report.
- President's FY17 NASA budget request for SOHO: 2.3 M$ FY17 - FY21

Space Weather Research and Forecasting Act

- On 19 April 2016 members of the US Senate Commerce, Science, and Transportation (CST) committee introduced a bill called the Space Weather Research and Forecasting Act (S.2817)
  - thomas.loc.gov/cgi-bin/bdquery/z?d114:S.2817:
  - "In order to sustain current space-based observational capabilities, the Administrator of the National Aeronautics and Space Administration shall
    - "(1) maintain operations of the Solar and Heliospheric Observatory/ Large Angle and Spectrometric Coronagraph (referred to in this section as 'SOHO/LASCO') for as long as the satellite continues to deliver quality observations; and
    - "(2) prioritize the reception of LASCO data."

Funding of European instruments

- 8 remaining instrument teams expect continued funding at the current level, which is sufficient for
  - safe operation of instruments
  - data validation
  - archiving
- Instrument support mainly by permanent staff, i.e. funded through institutes (labs, universities)
- Funding from national space agencies: 2.45 FTEs annually
  - SWAN: 0.2 FTEs from CNES
  - CELIAS: 1.0 FTE from DLR
  - COSTEP: 1.25 FTEs from DLR

Disposal strategy

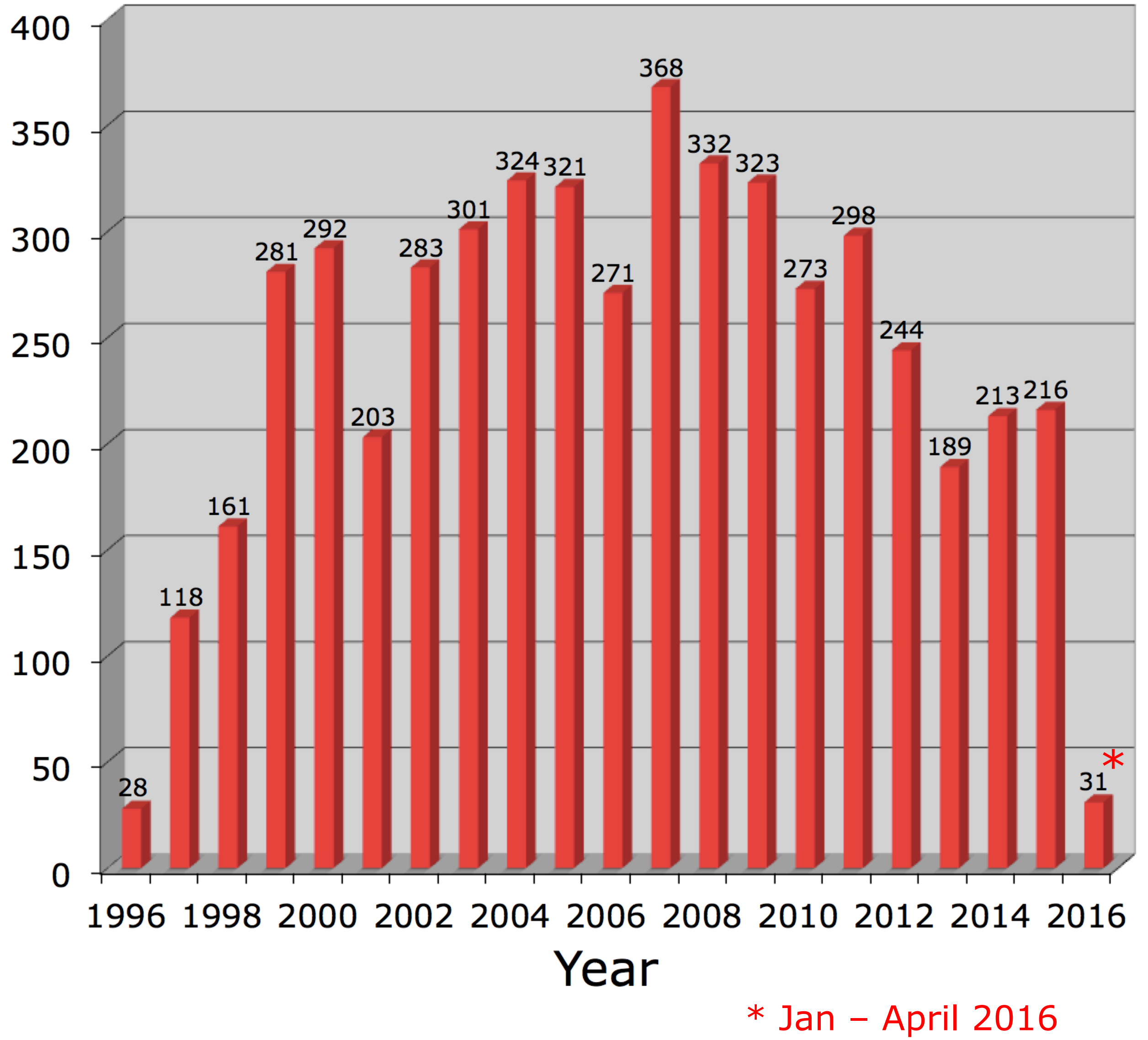
- Craig Roberts (NASA FDF) working on this
  - Also on action for ACE and Wind (also in L1 orbit)
  - Identified elegant solution:
    - Single burn of about 4.2 m/s would kick SOHO out of L1 orbit into a heliocentric orbit of dimensions 0.90796 AU by 0.991478 AU, with a period (targeted by the manuever) of 338.1 days.
    - Needs further analysis (Monte Carlo simulations + regression analysis) but looks promising
- Responsibility?
  - ESA is owner of S/C, but NASA was launch authority
  - According to Thierry Herman (ESA Legal Affairs) both ESA and the US could be held liable by third parties should a damage arise
  - Need a solution that is agreed and signed off by both Agencies

Summary

- Spacecraft and instruments are healthy
- There are no known technical limitations which should prevent SOHO from operating through the end of 2020
- SOHO scientifically still very productive and will continue to make unique and critically important contributions to the "Heliophysics System Observatory"
- The additional cost to ESA is very small and represents excellent value-for-money in return for a significant enhancement of the scientific harvest from the SOHO mission

Publications in refereed literature

- > 5070 papers total
- > 3500 authors
- > 250 theses
  (lost count)
- First authors
  - 40% Europe
  - 40% US
  - 7% China
  - 4% India
  - 3% Russia
  - 6% rest of world
    (Japan, Korea, Brazil, Argentina, Mexico, …)



ADS Publication Statistics

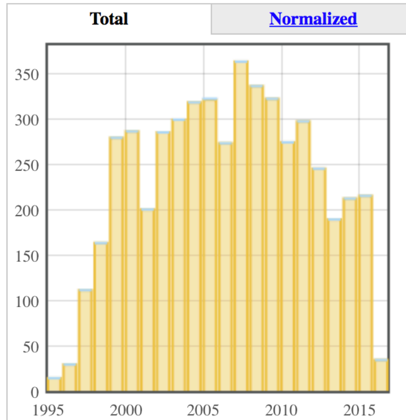
Papers		Total	Refereed
Number of papers	[?]	5,066	5,065
Normalized paper count	[?]	1,792.3	1,792.0
Total reads	[?]	1,485,209	1,485,050
Average reads	[?]	293.2	293.2
Median reads	[?]	234.0	234.0
Total downloads	[?]	735,903	735,831
Average downloads	[?]	145.3	145.3
Median downloads	[?]	113.0	113.0

Citations		Total	Refereed
Number of citing papers	[?]	28,738	28,738
Total citations	[?]	144,272	144,272
Average citations	[?]	28.5	28.5
Median citations	[?]	15.0	15.0
Normalized citations	[?]	45,195.0	45,195.0
Refereed citations	[?]	127,376	127,376
Average refereed citations	[?]	25.1	25.1
Median refereed citations	[?]	13.0	13.0
Normalized refereed citations	[?]	39,924.5	39,924.5

Indices		Total	Refereed
h-index	[?]	135	135
g-index	[?]	201	201
e-index	[?]	119.3	119.3
i10-index	[?]	3,185	3,185
tori index	[?]	996.3	996.3
riq index	[?]	1,434	1,434
m-index	[?]	6.14	6.14

Export to xls

Publications per year



Refereed
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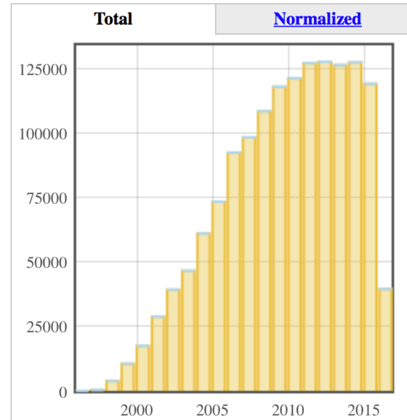
Reads per year



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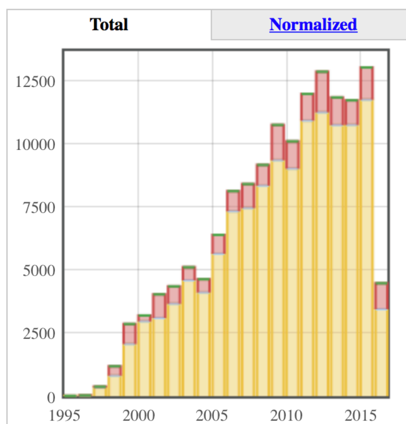
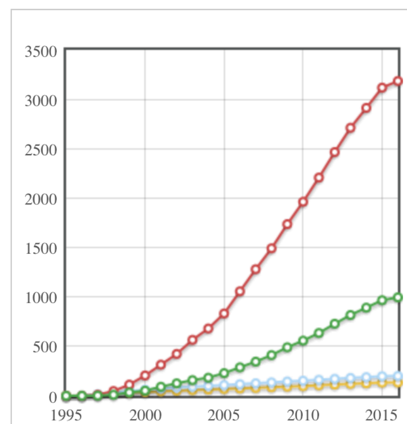
Citations per year



Ref. citations to ref. papers
Ref. citations to non ref. papers
Non ref. citations to ref. papers
Non ref. citations to non ref. papers

Indices



h-index
g-index
i10-index
tori-index

ADS SOHO private libraries

- ADS Classic

http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?library&libname=SOHO&libid=5552588932

- ADS Bumblebee:

https://ui.adsabs.harvard.edu/#/public-libraries/HLx1YisxRhyufHOCBhs_Gg

- Searchable SOHO Bibliography on SOHO Web Site:

http://seal.nascom.nasa.gov/cgi-bin/bib_ui_seal

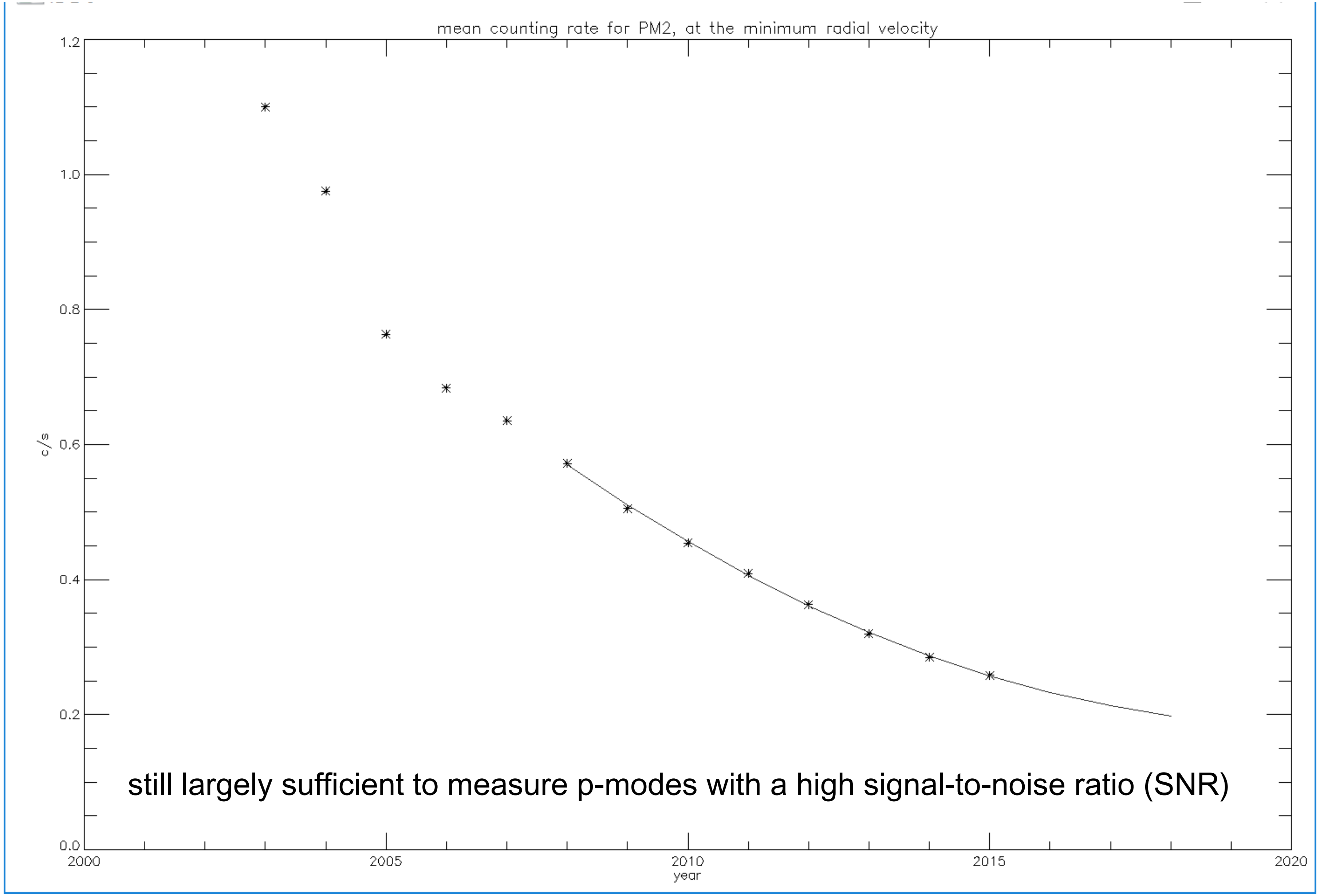
Annex 2

Instrument Status

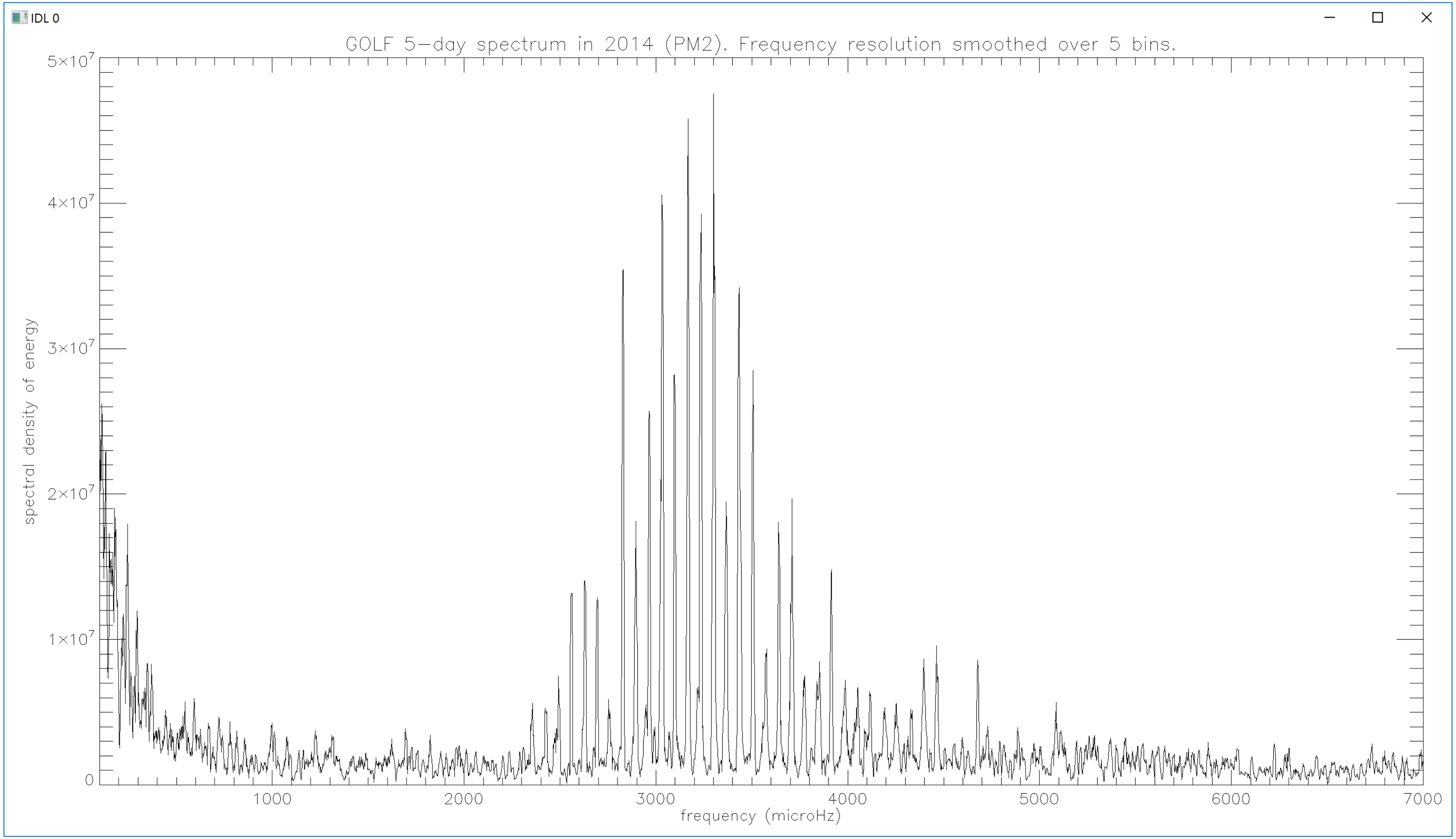
SoHO SWT May 2016
GOLF

Patrick Boumier

Instrument status – counting rates



Instrument status – p-modes SNR



Instrument status – operations

- Anomalies

  - November 2014 23rd: magnetic modulation went OFF. Several % decrease of the counting rates & temperature decrease of 2 to 4 degrees. The log book displays wrong status of parameters (heating, high voltage…). "Switch ON the Magnetic modulation TC" sent to GOLF: back to nominal but the log book. Quick look plots and tables are OK; check in the L1 daily fits file that scientific and housekeeping data are OK. 5 days with non nominal counting rates

  - September 2015 1st: DPU routine crash. OFF&ON procedures: back to nominal; 3 or 4 days lost. Note that the log book went back to nominal.

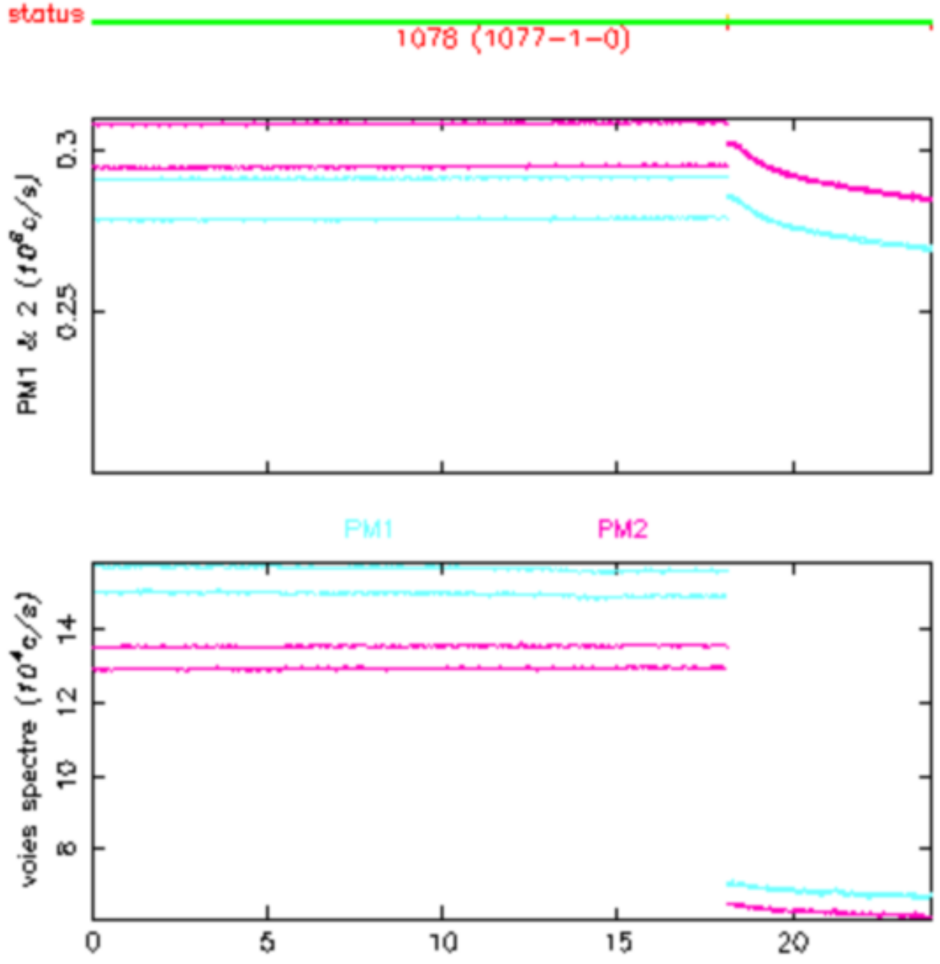
  - February 2016: SOHO warm startup. A new OBT was automatically transmitted to GOLF. 30-second gap in the time series.

- Functionning

  - March 2014: change of PM high voltages (26 V & 42 V for PM1 & 2) : gain 1% of photons.

  - Septembre 2015: update of g_fl_halon_m starting procedure.

G O L F FITSTMql 141123



polariseur . [320000 ... −320000]
quart d'onde : [320000 . −320000]

lobt ligne [1] Di 23 nove 2014 0h 1mn19s 27ms

		Nominal
fine queusot (GTCSFIN)(°):	[171.13 172.33]	[172.25 172.32]
fine filtre (GTFIFIN)(°):	[18.56 19.27]	[19.19 19.26]
cathode PM1 (°):	[26 54 27 41]	[27 35 27 39]
cathode PM2 (°):	[26.01 26.97]	[26.91 26.96]
aimant (°):	[24.84 26.72]	[26.64 26.71]
GTPOELEC (°):	[20.37 20.42]	[20.39 20.42]
GTPOMEC (°):	[20.52 20.55]	[20.54 20.55]
GTSCREEN (°):	[24.40 25.27]	[25.20 25.27]
GTFIRAD (°):	[−3.84 −3.21]	[−3.28 −3.23]
GTFIHOUS (°):	[25.37 26 28]	[26.21 26 26]
GTFIELT (°):	[31.44 32.40]	[32.20 32.37]
GTPM1ELT (°).	[30.40 31.56]	[31.37 31.56]
GTHV1 (°):	[25.34 26.46]	[26.38 26.46]
GTPM2ELT (°)·	[29.99 31 11]	[30.91 31 10]
GTHV2 (°):	[24.08 25.19]	[25.10 25.17]
GTCB (°):	[192.24 193.24]	[193.03 193.24]
GTREARAD (°):	[12.28 13.36]	[13.31 13.36]
GTCLEACK (°)·	[24.74 26 48]	[26.41 26 47]
GTCS (°).	[174.26 175.57]	[175.36 175.57]
GTHSKELT (°):	[28.94 30.17]	[29.99 30.14]
GTDPU (°):	[9.99 10.22]	[10.13 10.20]
GTPSU (°):	[12.66 13.15]	[13.07 13.14]
GTQWELT (°):	[18.99 19.04]	[19.01 19.04]
GTQWMEC (°):	[19.70 19.73]	[19.70 19.73]
Gplus28 (Volt):	[0.53 0.84]	[0.74 0.84]
Gplus5 (Volt):	[5.34 5.36]	[5.34 5.35]
Gmoins5 (Volt):	[−5.30 −5.29]	[−5.30 −5.29]
Gplus15 (Volt):	[15.19 15.23]	[15.19 15.21]
Gmoins15 (Volt):	[−14.87 −14.85]	[−14.87 −14.86]

Archive status and plans for the SOHO legacy archive

- A 16.5-year residual velocity series is available through the official archive.

200 papers published using GOLF data or linked to its analysis.

- 2 web sites: IAS and Saclay. Work in progress to provide all the information (from operational up to calibration hypothesis) required to fully exploit the data.

- Time series, Frequency tables (free of the solar magnetic cycle effect) are provided.

- Higher-level data, such as magnetic proxies are available (FP7-SPACEINN Seismic+ gate: http://www.spaceinn.eu/), Salabert et al. (2016 in prep.).

Future plans

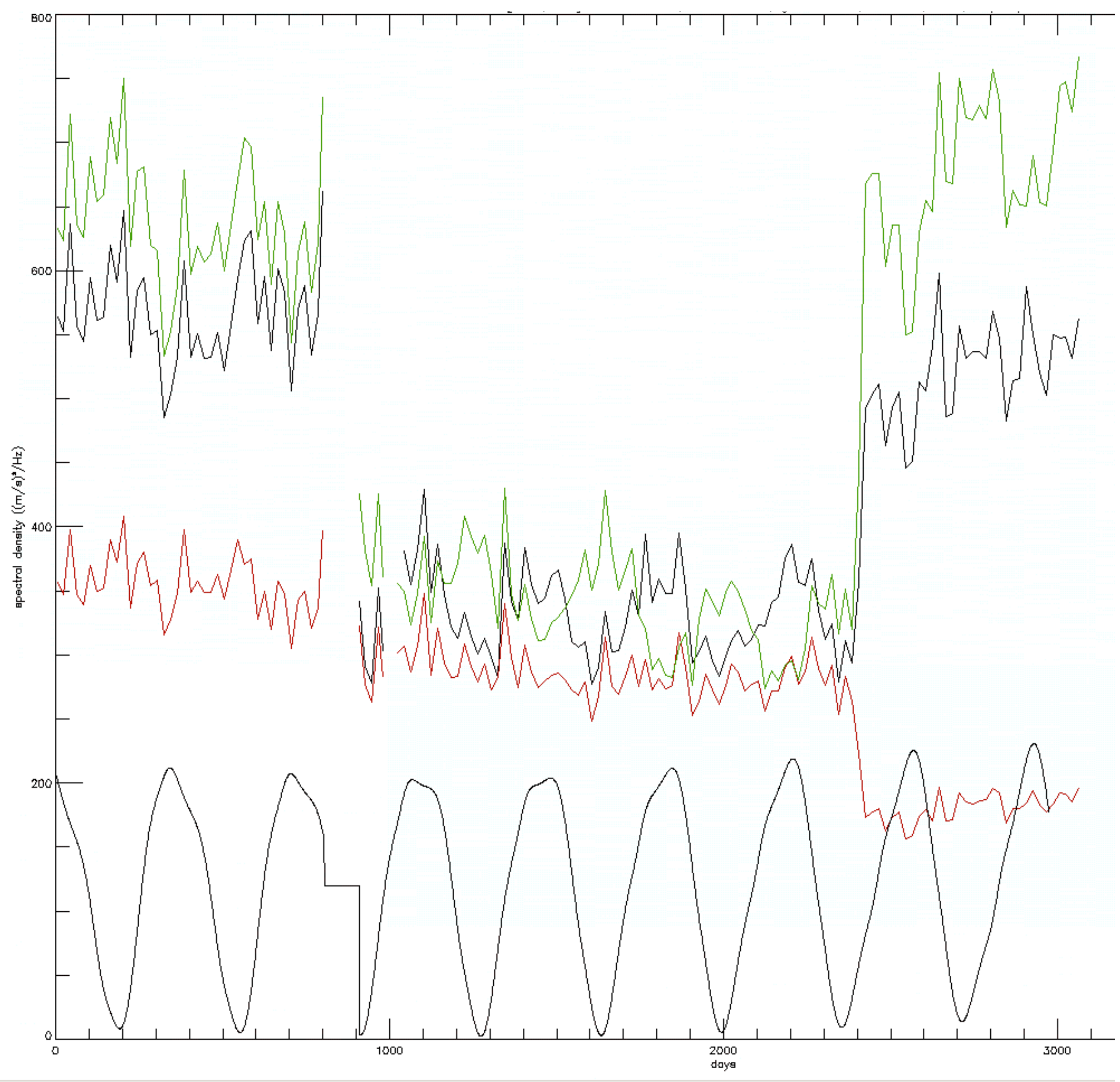
- Velocity calibrations of the 20-y series.

3 different calibrations tried in the past

⇓

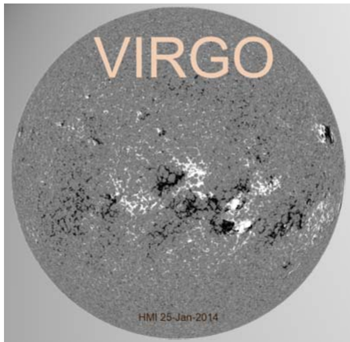
3 different results for the global energy of the 5-mn oscillations ([2.5; 4.5] mHz.

Behavior in opposite way versus the orbital velocity, ie versus the altitude in the solar photosphere.



Future plans

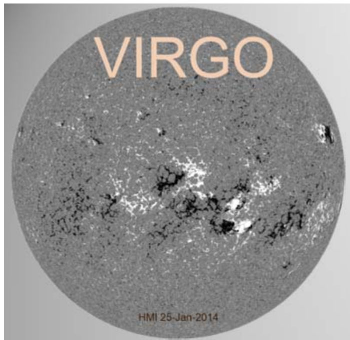
- Long-term legacy.
- P-mode properties along the solar cycle.
- Low frequency analysis (g-modes investigation for individual identification). Modelling. Main challenges: rotation of the solar core: magnitude ??? Axis inclination ??? Inferences on dark matter.
- New solar physics inversion (new opacities; new microscopic diffusion; update from the neutrinos). 3-D modelling with both radiative and convective zones.
- Magnetic proxies – Sun as a magnetic star: peculiar or standard ? – Sun used as a reference for asteroseismic (and giant planet seismology) reference.



20 Years of VIRGO/SOHO

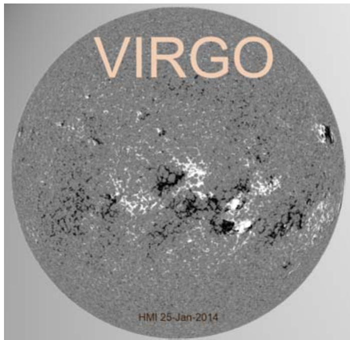
SWT-42 Status Report

Claus Fröhlich
CH 7265 Davos Wolfgang



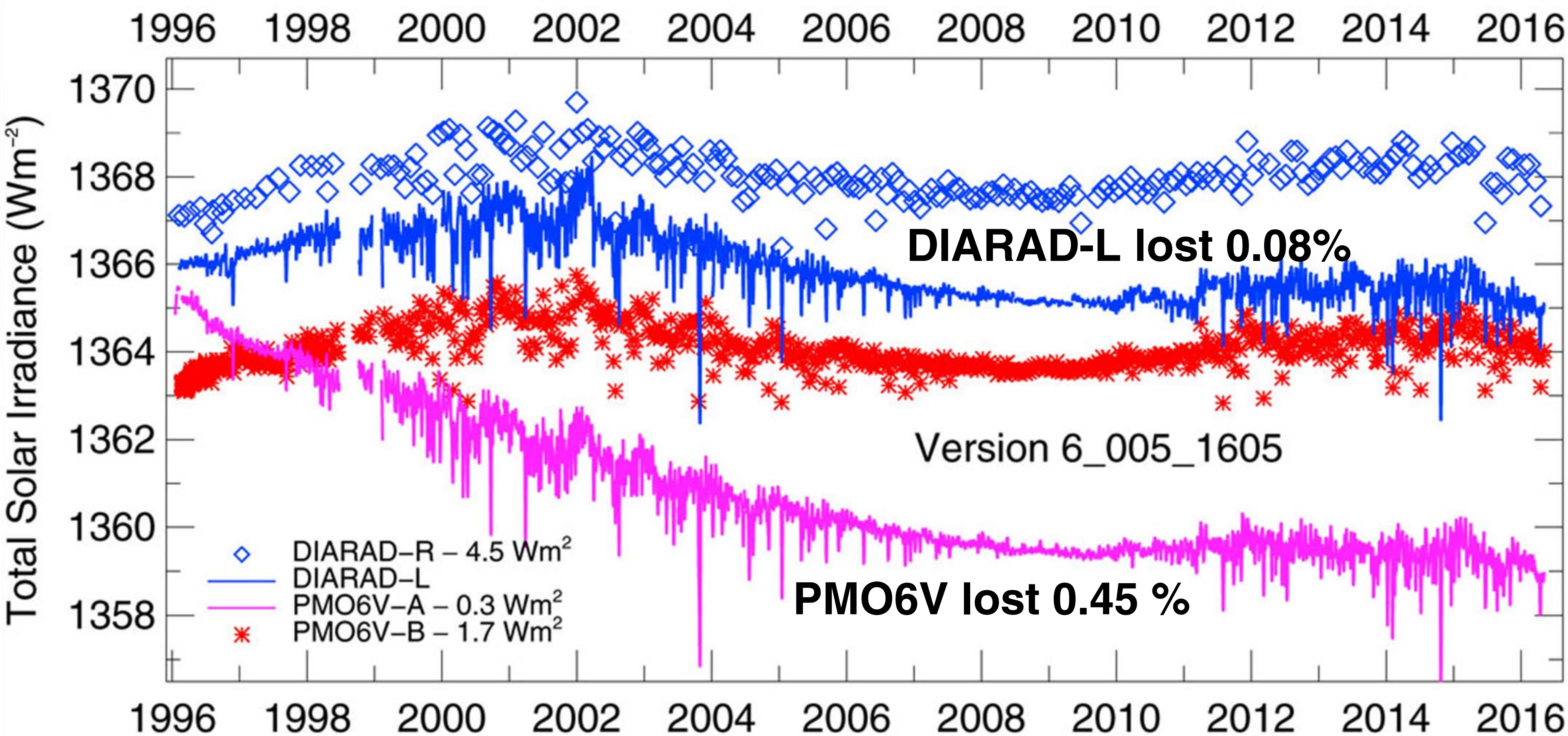
Problems..........

- The first light was very successful, the release mechanism for the covers worked, all covers opened and the instruments provided the first data – a nice Christmas present! Afterwards the covers were closed again to let the instrument degassing
- In mid January measurements with the radiometer started. Soon after the start the shutters of the PMO6V radiometers failed (automatic switch-off). A new procedure was developed using the covers every 8 hours – which still works
- Somewhat later the SPM started measurements
- The start of LOI failed because the cover did not stay open as it bounced always back to closed. The cover was then finally opened by ‘pulling the plug’ in the right moment.
- We had a total of 7 switch-offs due to ECR (including the vacations) and 2 which were due to latch-ups in our power supply (the last one in June 2015)
- From the hourly values we have 96% of the continuous data (4% loss during 20 years). The 1-minute data cover 92%.

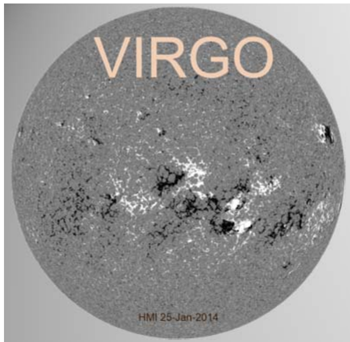


Degradation: How sensitive are we still after 20 years?

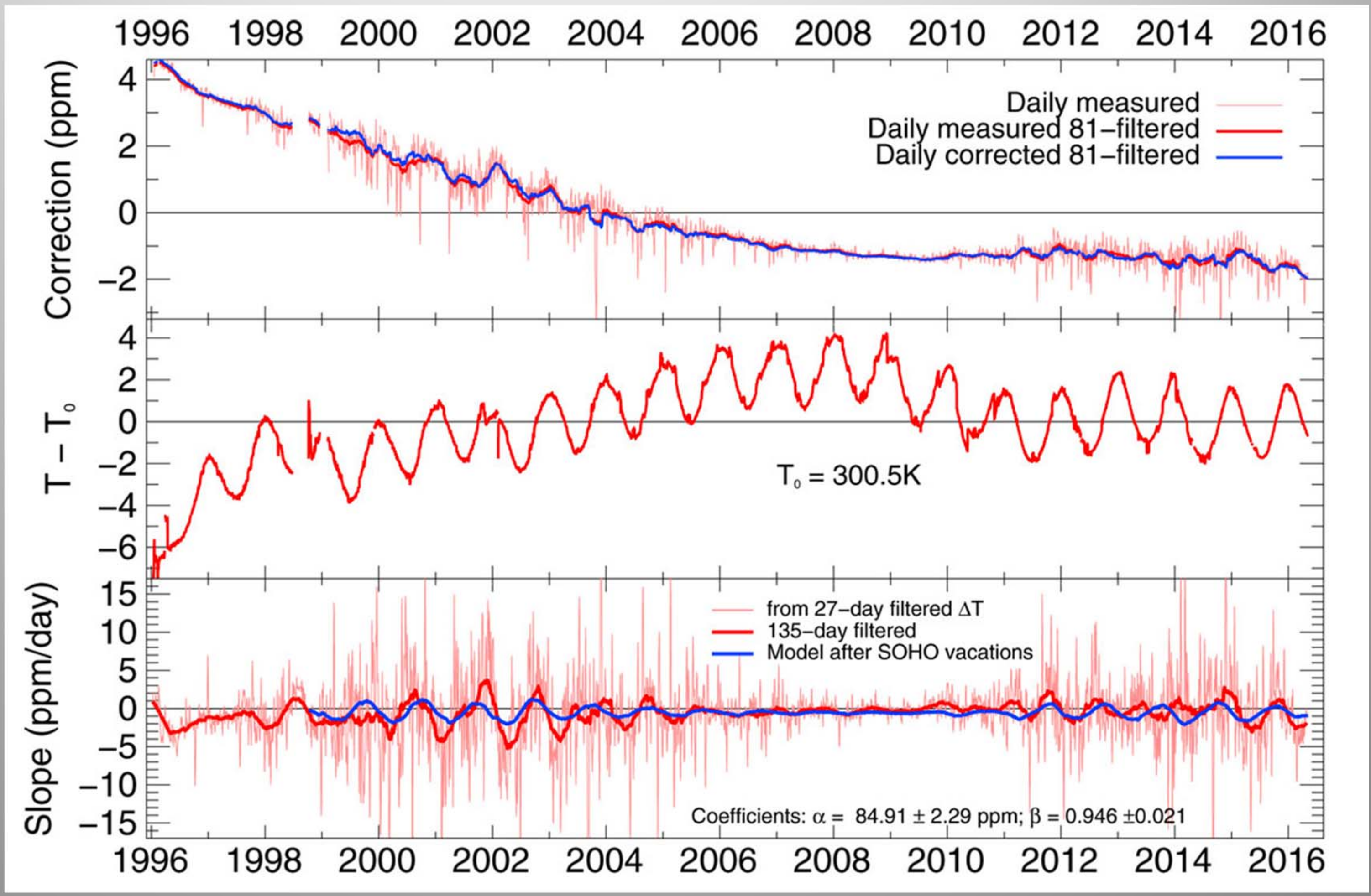
TSI Level 1 data: PMO6V-A and DIARAD-L are operational. PMO6V shows the usual degradation, whereas the one of DIARAD is very small. This could be due to the compensation of the normal degradation of about 1ppm/day and the non-exposure-dependent sensitivity increase of 0.6ppm/day at the beginning of the mission.

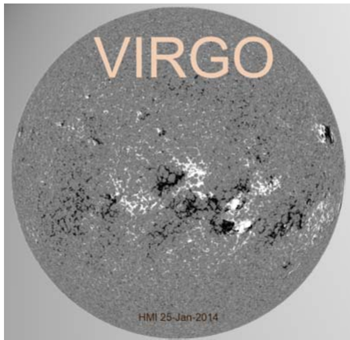


Degradation: How sensitive are we still after 20 years?



Degradation of PMO6V-A is temperature dependent: With the annual variation we can determine this effect in detail as the bottom plot shows (red: measured, blue: model)

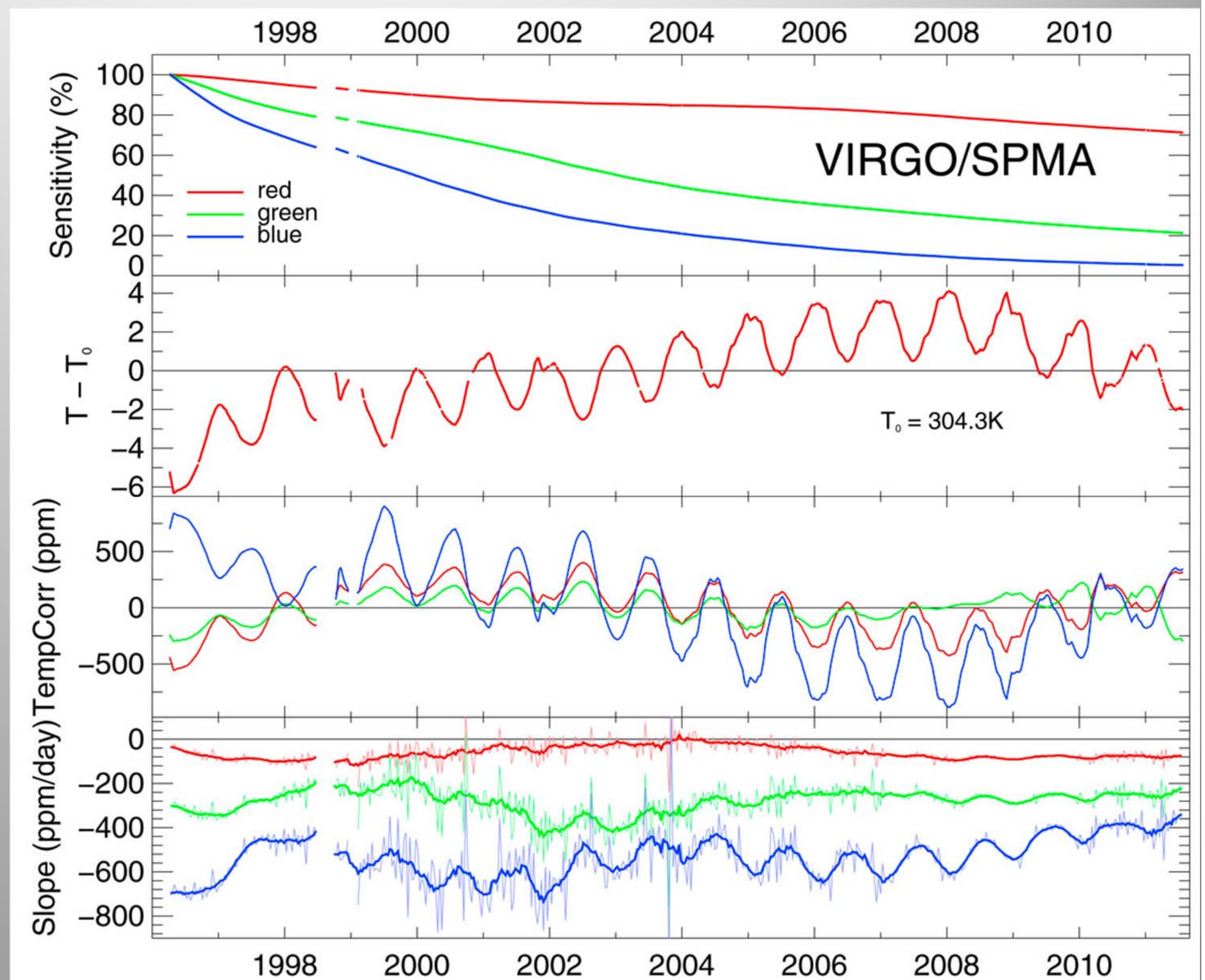




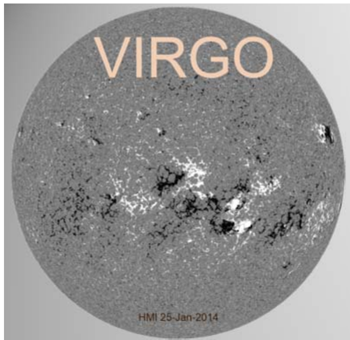
Degradation: How sensitive are we still after 20 years?

Degradation of the SPM is also temperature dependent: With the annual variation we can determine this effect in detail and correct the data accordingly. The bottom panel shows the increasing strength of the modulation from red to blue.

The sensitivity after 20 years is for the red at around 65%, for the green at around 20% and the blue at around 5% which has still a signal-to-noise of more than 30.

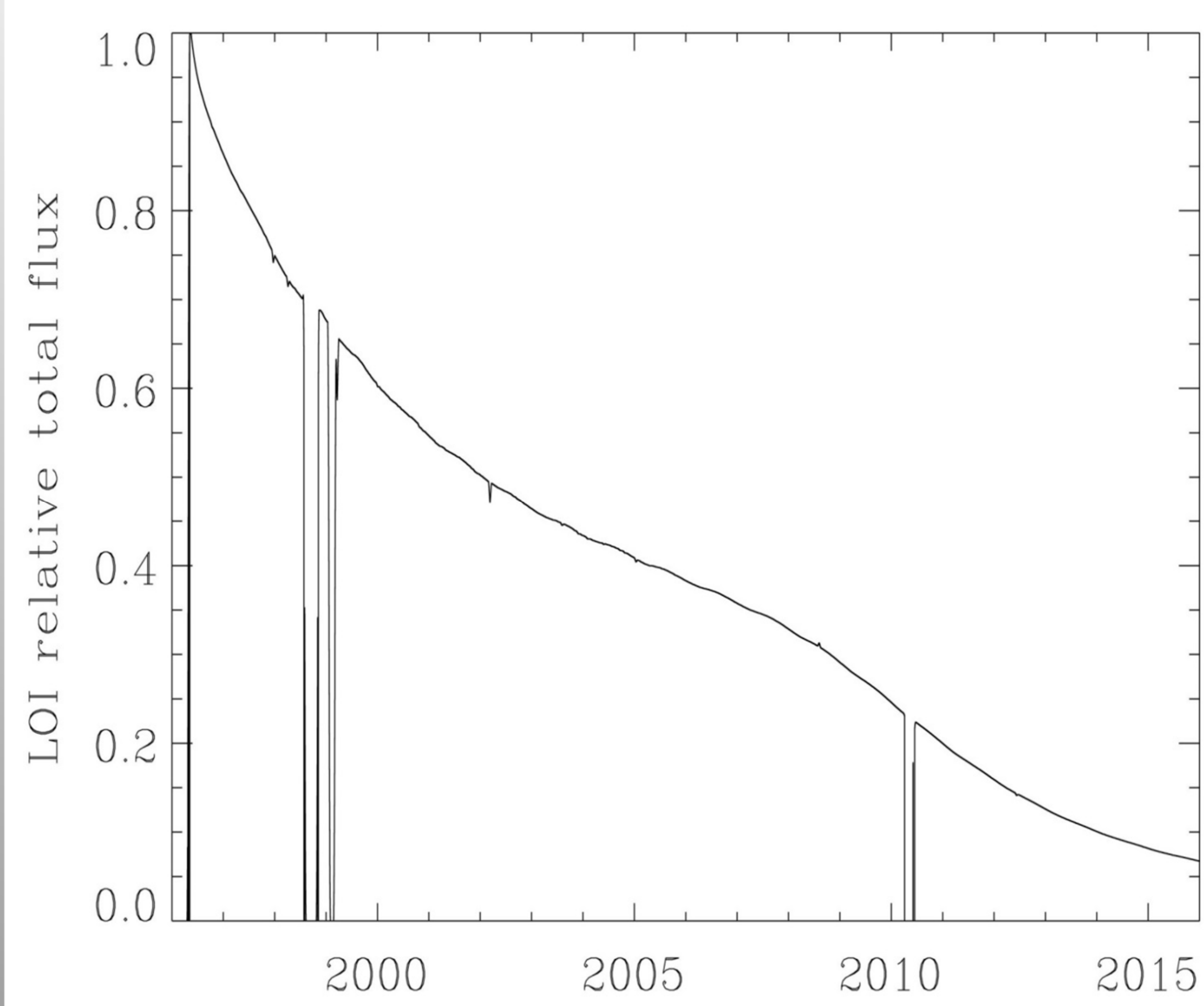


Degradation: How sensitive are we still after 20 years?



Degradation of the LOI follows the same temporal behaviour as the SPM with a steep decrease at the beginning, then a flattening out and restart of a stronger degradation due to the increased dose during the ascending part of cycle 24.

The sensitivity after 20 years is somewhat less than for the green channel with the same filter, but with 7% LOI has still a signal-to-noise of more than 40.



MDI Archive Plans

- All MDI science level data has been migrated into the SDO HMI/AIA JSOC which at present is the MDI “Resident Archive”
- We will at some point migrate the data to the NASA specified Final Archive, when one is specified. The process of migration is simply a JSOC “export” which binds the metadata to the array data and generates meaningful file names.
- If the GSFC SDAC will the MDO and SDO “Final Archive” then it will be a simple process since the SDAC is already a netDRMS site. I.e. it is a remote JSOC site with all of the “export” software and automatic fetching of the data from the JSOC on demand.
- The process will be for the MDI team remotely, or the SDAC personnel to simply request each dataset via the existing JSOC export interface. This can be scripted as many netDRMs and other science data users now do to obtain SDO data.

- There are presently 123 MDI dataseries “published” in the JSOC, that means available at any netDRMS site that chooses to “subscribe” to them.
- In addition to the science-level products we will use the same method to deliver the raw telemetry data and/or the level-0 and level-1 data as desired.
- The code to process data from telemetry to level-0 and then to level-1 then to science level products is all in the BCS software management system and can be migrated to Git if desired. As we expect to do with the JSOC code.
- In addition to the science-level products we will use the same method to deliver the raw telemetry data and/or the level-0 and level-1 data as desired.
- The code to process data from telemetry to level-0 and then to level-1 then to science level products is all in the BCS software management system and can be migrated to Git if desired. As we expect to do with the JSOC code.
- In addition to migrating the MDI data into the JSOC we have built hooks to run the MDI processing code in the JSOC DRMS/SUMS environment.
- This code has been updated and verified in the past few weeks to allow rapid access to MDI images for the Mercury transit.

- The total MDI data volume is about 65.6 TB of which about 33TB will be sent to a permanent archive. At present the JSOC holds about 97% of the total NASA solar data, including the SDO, IRIS, and MDI data. So the MDI final data will be about a 25% increase in SDAC data. We can not begin the migration until NASA has formally decided on the final archive site and arranged capability to absorb the SDO data as well.
- We strongly encourage at least support for the JSOC export capability or for the SDAC to develop equivalent capability for sub-setting in space and time to allow practical use of the data.
- Such a system could be either a subset of the JSOC system or build from scratch. Simple directory trees do not work well for tens of billions of files in presently 10 million gigabytes of storage.

Final MDI Calibration Plans

- While we could deliver the MDI data as is, and will probably do so for most of the data products, we hope to be able to make an improved subset with improved distortion correction and both Doppler and magnetic field calibration for at least the full disk data.

- There are three tasks for this project:
  - Develop better distortion map to correct known image distortions which are in some places in the field more than a pixel shift. The recent Mercury transit will give a “truth line” passing near disk center. This will complement prior HMI cross distortion measurements. This process will also verify the roll angle of MDI wrt SOHO. We believe it to be 0.22 degrees but this was based on cross-calibration with GONG using the 2004 Venus transit and the 2006 and the 2016 Mercury transits. We will try to have a cross-distortion map to allow making MDI images spatially match HMI images for which we have better distortion knowledge.

- The present MDI magnetic field calibration update in 2008 was based in cross calibration with Mt Wilson magnetograms. We know that this has errors in the scale across the field. That is why se still call the data mdi.fd_M_lev182 instead to the intended final mdi.fd_M. Once the MDI->HMI distortion map is ready we can make a MDI->HMI magnetic calibration correction.

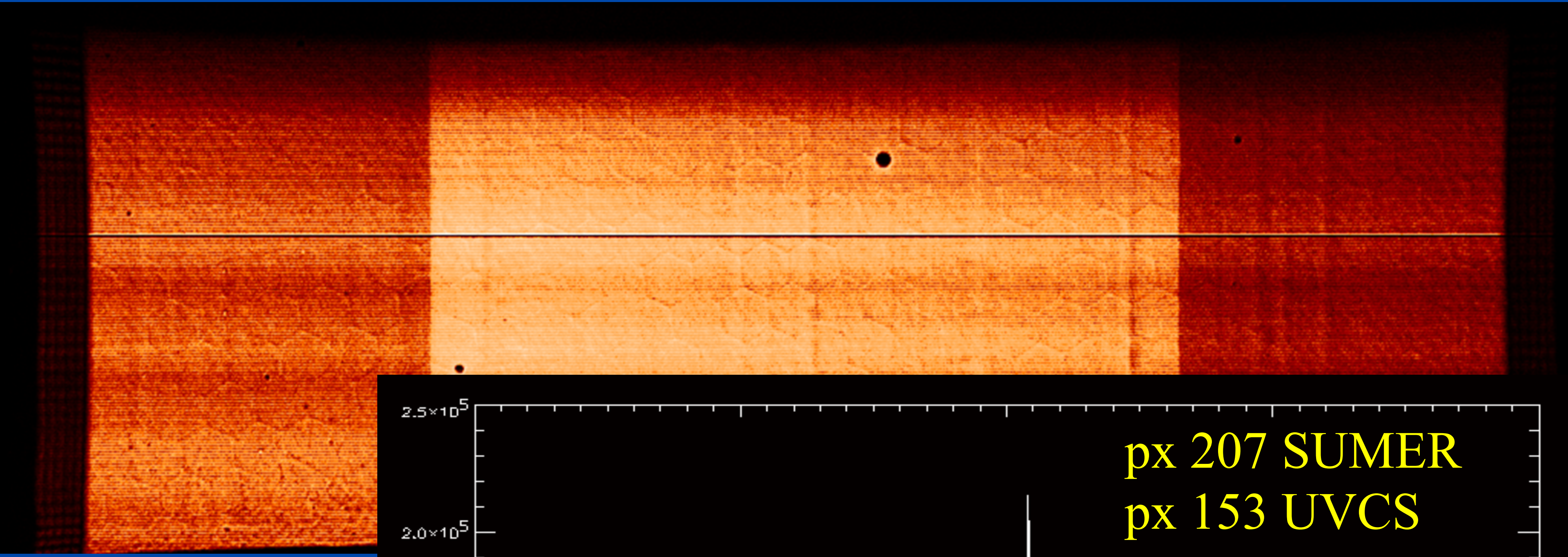
- The present MDI Dopper calibration was intended to be sufficient for helioseismology but we have discovered (as have a few others) that there are differences when SOHO is “upside down”. With our recent work developing better filter profiles for HMI in order to greatly reduce the present 2% Doppler scale error which allows 2% of the orbit velocity to leak into the Doppler data, and hence the magnetograms we believe we can now go back to the regular MDI “detune” calibration sequences and develop a better MDI Doppler calibration as well. This will allow better use of the other half of the data since 2003, and more certain meridional flow measurements over Cycle 23.

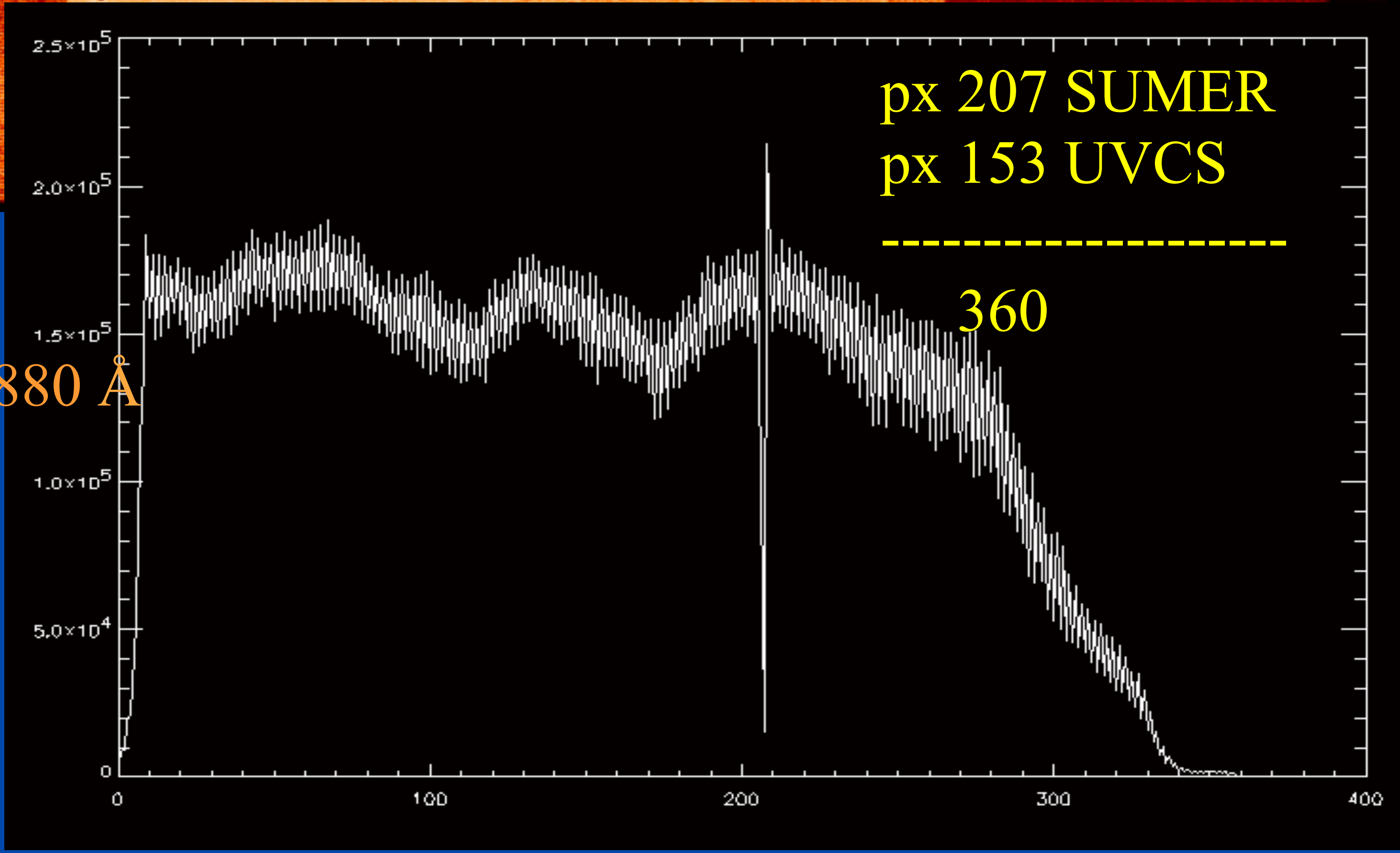
SUMER: Status after 20 years

Werner Curdt on behalf of the SUMER Team

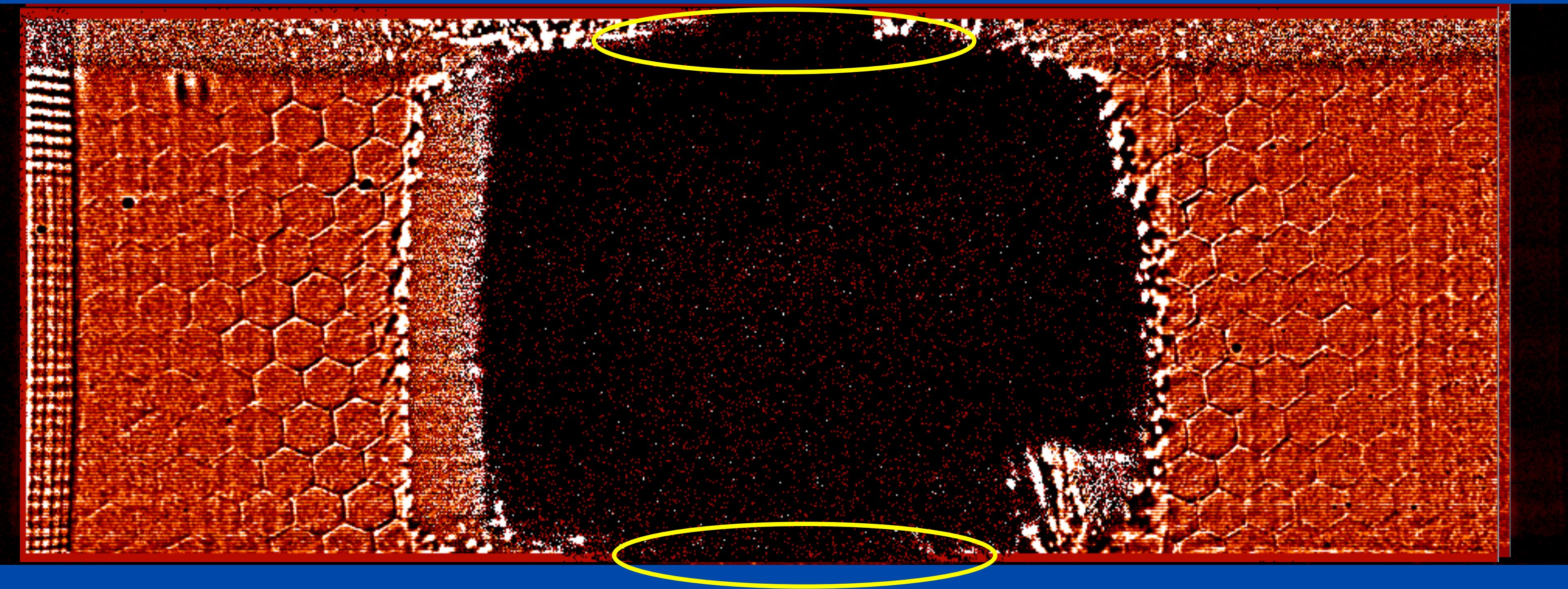
Instrument Status

detector A
detector B
mechanisms
electronics
ground segment

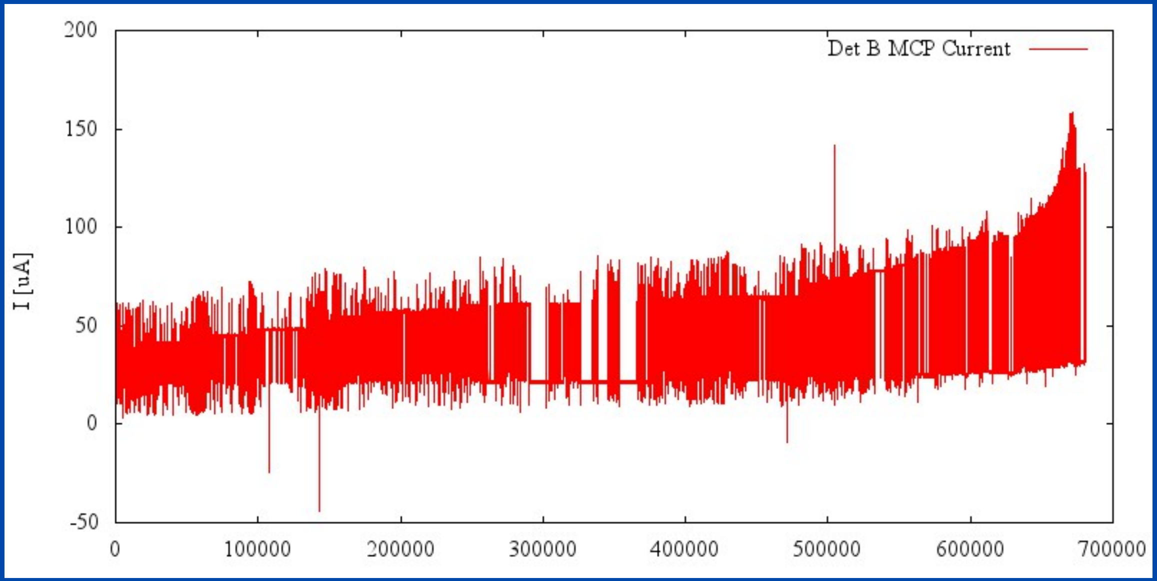




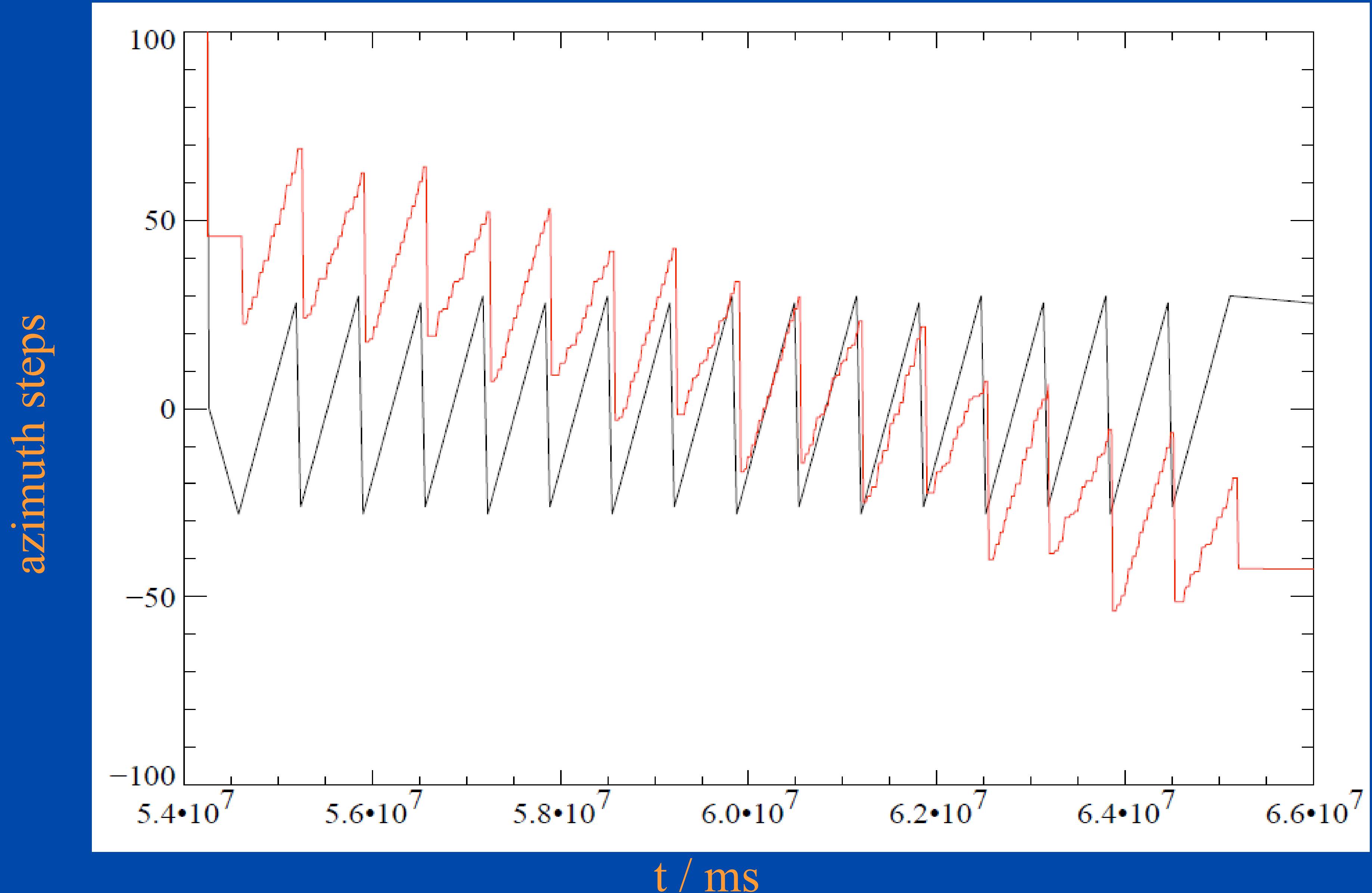
detector A
continuum @ 880 Å
May 24, 2004



detector B
flatfield
June 4, 2009



step loss on Apr 22, 2009



last activities:

comet ISON observation
IRIS co-observation in July 2014
in hibernation since then

ground segment:

computers still in place
archive with level 1 data is in test mode

Status of the SOHO Coronal Diagnostic Spectrometer May 2016

Andrzej Fludra

RAL Space

CDS Status

UKSA funding ended in Sep 2013

CDS operations ended on 5 Sep 2014

CDS placed in Hibernation mode (SNOOZE) with substitution heaters enabled and the doors open (safest option mechanically and thermally)

CDS was still in good health and capable of continuing observations

CDS Status

RAL Space

FOT implemented the CS-11 procedure which includes the range of “safe” temperatures for FOT if they want to carry out spot checks.

Any out-of-range temperatures would trigger an alarm and then switch off CDS.

CDS could resume operations in principle from SNOOZE within a few days notice. Depends on staff availability and all systems still working.

If CDS were to be switched OFF in an emergency then it would take about 2 weeks staff effort to resume operations which is probably not viable.

No further funding, therefore unlikely to operate CDS again.

CDS Data Archiving

The final product will be:

1. Level-0 fits files for entire mission
2. Level-1 calibrated fits files for NIS studies for entire mission

Status:

- The level-1 NIS data files were generated using calibration of Del Zanna et al. (2010).
- There are 315,219 level-0 and 297,482 NIS level-1 files processed and archived currently (1.4 Tb). This is 95% of the total data.
- Processing of the remaining 12,766 fits files is in progress. Approximately 2-3 months work.

EIT

Extreme-ultraviolet Imaging Telescope

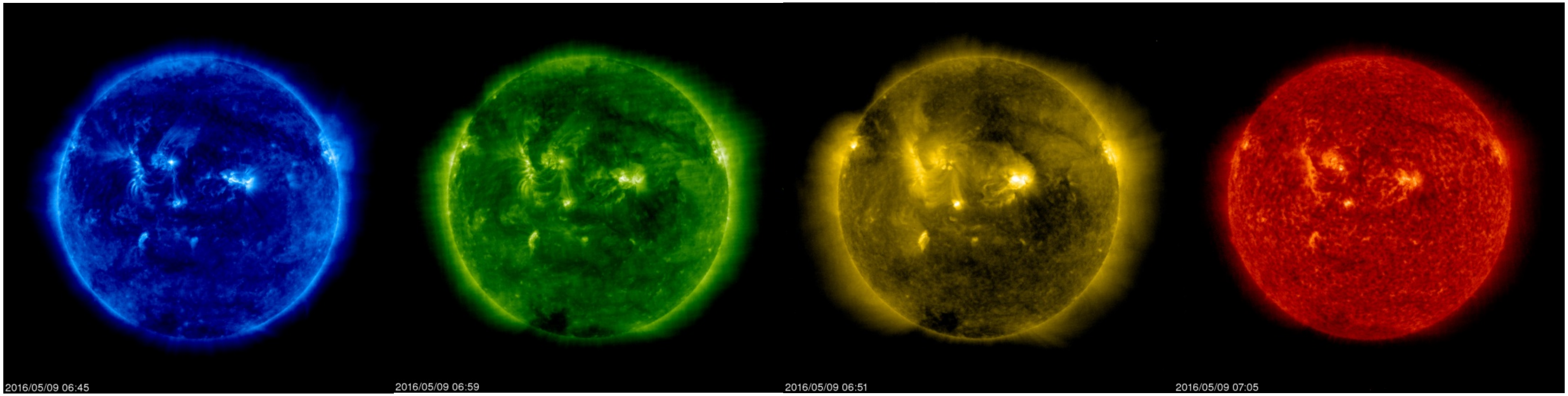
Instrument status report to the SOHO SWT

May 10, 2016, Orsay

Frédéric Auchère & Jean-Pierre Delaboudinière

Instrument status

- EIT is nominal !
- Two synoptic sets (four wavelengths, 1024 × 1024) per day since August 2010
- + special observations (Venus transit 2012, Mercury transit 2016)
- 515 000+ full-field images and counting
- 1291 ADS citations to the EIT instrument paper



Sector wheel hangs

- 23 events since the beginning of the mission (~one per year)

1996/08/30	2000/07/03	2006/01/15	2011/03/14
1997/01/05	2000/08/08	2006/10/18	2011/05/11
1998/05/30	2003/09/04	2006/11/04	2012/08/09
1998/12/11	2003/12/01	2007/01/26	2014/04/03
1999/02/06	2005/01/04	2007/03/19	2015/01/10
1999/07/07		2009/11/09	2015/02/05

- 5 occurrences in January (hottest month), but not statistically significant

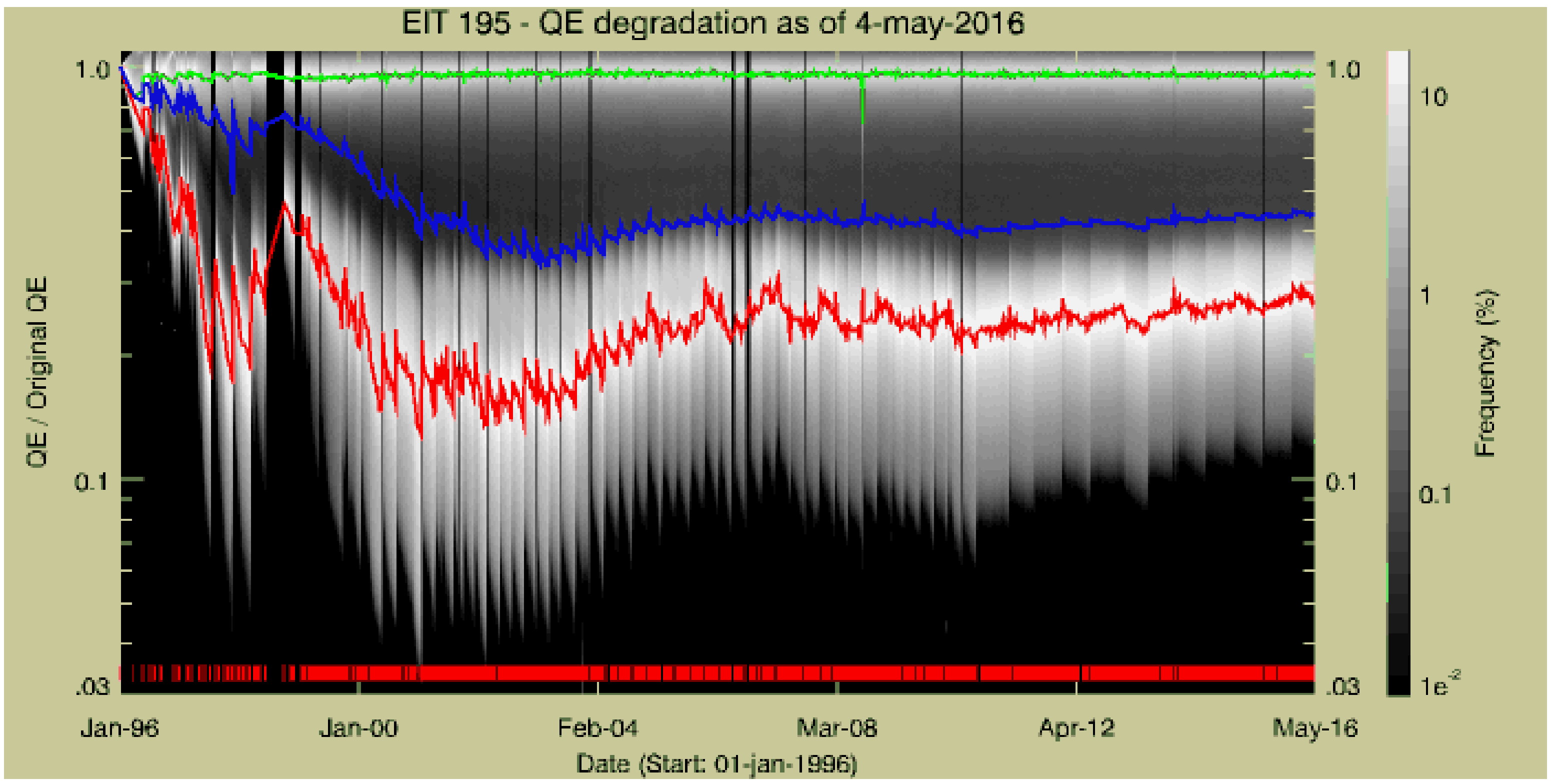
```
*
*
*      *
*** * **  **
***** ******
JFMAMJJASOND
```

- No increase in frequency with time

CCD degradation

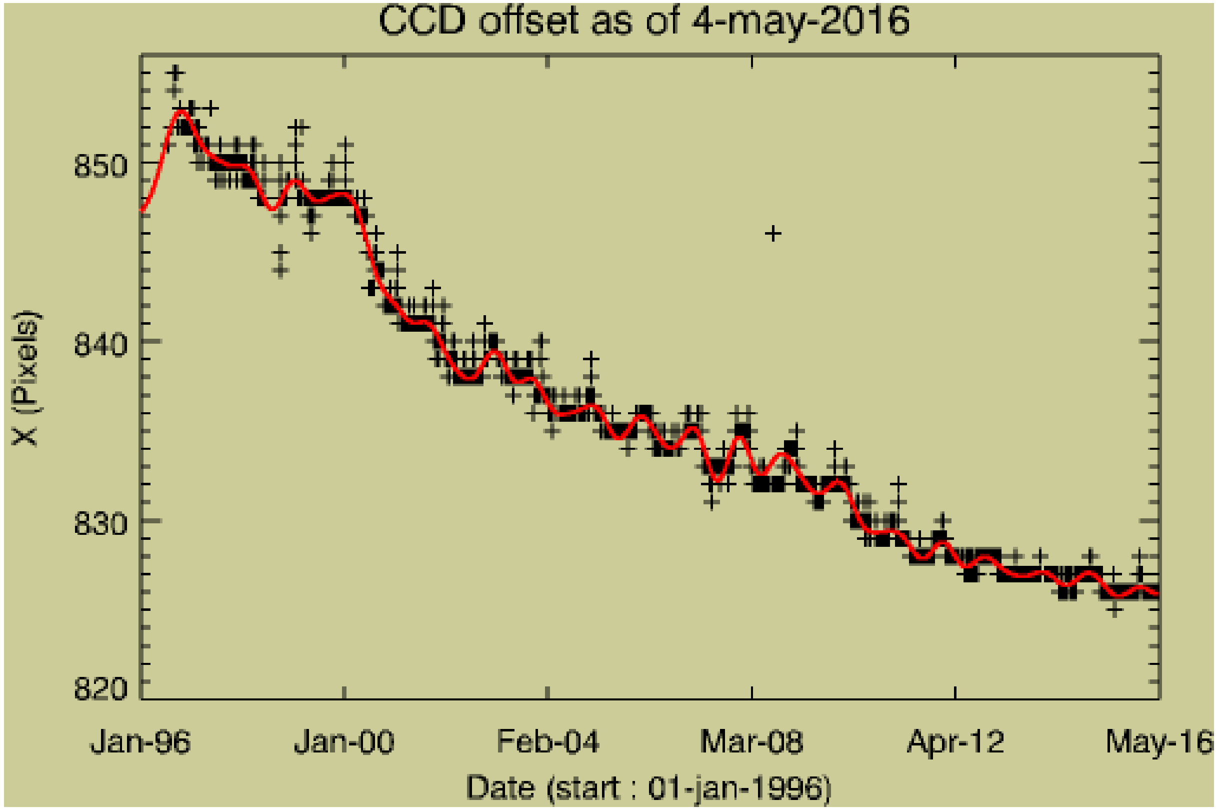
- Several instrument parameters monitored continuously
  `http://umbra.nascom.nasa.gov/eit/eit_guide/`

- Reduced cadence led to a slow recovery after 2010
- Two bake-outs per year since 2010
- Change to one bake-out per year



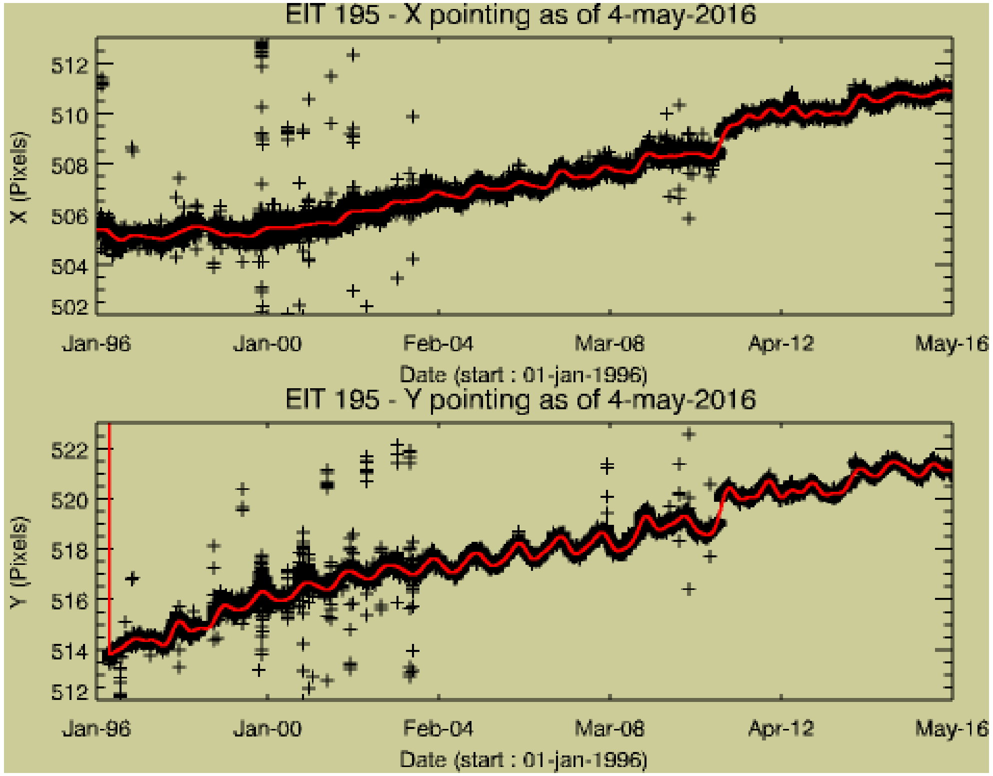
CCD offset

- Continuous slow decrease since the beginning of the mission
- No explanation (ageing of the ADC ?) but monitored

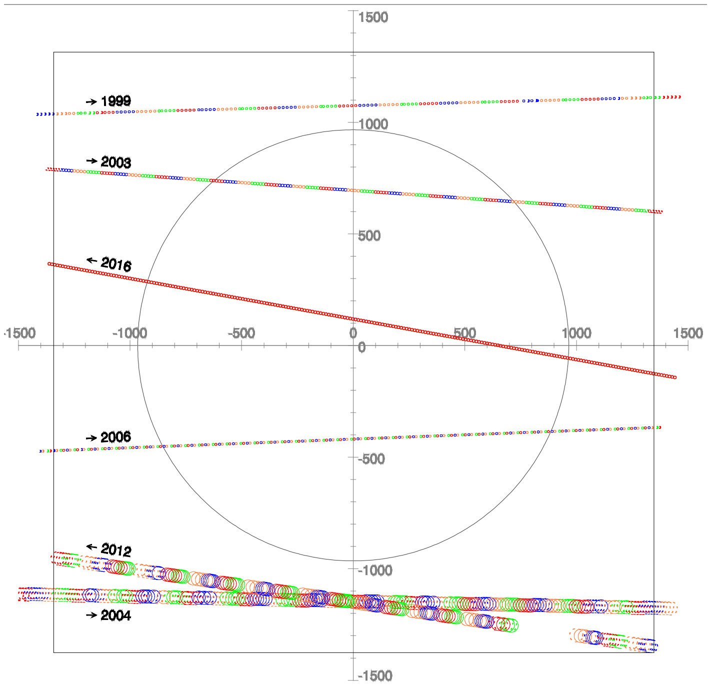


Pointing

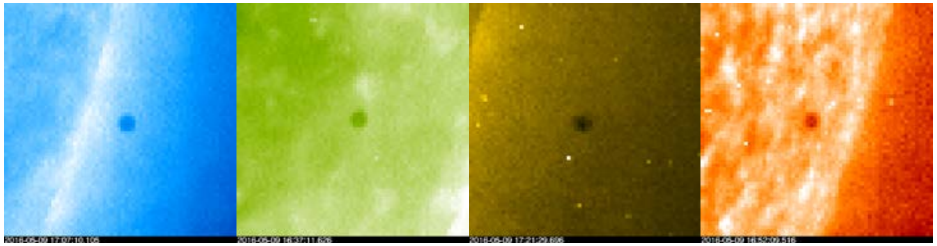
- Continuous slow drift of the pointing (~0.1 pixel RMS accuracy)
  - ~5 pixels in X, ~8 pixels in Y in 20 years
  - one year period oscillation
- Not due to CCD degradation
- Not affected by the regular 180° rolls
- ~1 pixel jump the day of the start of the Bogart mission

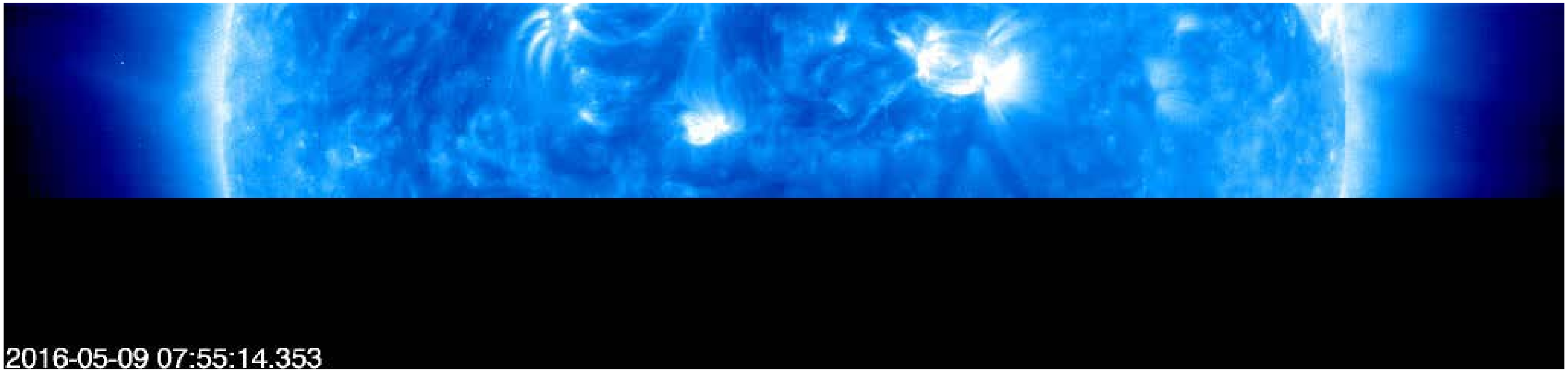


Calibration from planetary transits



- Six planetary transits (so far)
  - Plate scale: 2.627 ± 0.01”/pixel
  - Distortion
  - Instrument roll: ~0.15°
  - Stray-light

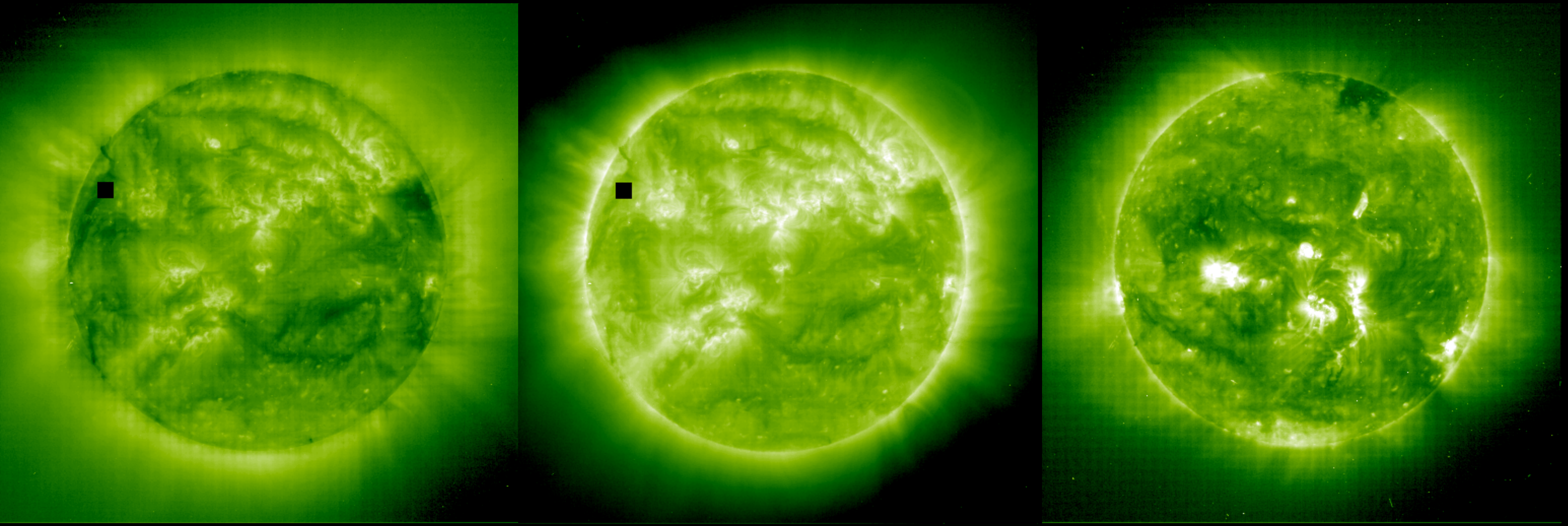




Legacy archive (1/2)

- Several keywords need to be updated in the current Level 0 headers
  - Level 0 means raw data, Level 1 is the output of `eit_prep` (SSW)
  - Pointing & roll for non-nominal attitude periods
  - Nominal instrument roll wrt. S/C: ~0.15°, currently assumed to be 0°
  - Plate scale: 2.627''/pixel, currently 2.629''/pixel
  - Schedule: end of this year ?

- Production of a Level 1 (''prep-ed'') archive
  - Above-mentioned corrections
  - Issues with the calibration after 2010
  - Clean-up of the archive of calibration lamp images (flat fields)
  - Creation of WCS compliant headers
  - Catalogue (or header keyword) of bad images (e.g. mixed LASCOs)
  - Documentation
  - Schedule: 2017 ?



Legacy archive (2/2)

- Existing higher level data products
  - EIT carrington maps
    `http://idoc-solar.ias.u-psud.fr/sitools/client-user/Solar/project-index.html`
  - Daily & monthly movies
    `http://www.ias.u-psud.fr/eit/movies/`
- Other possibilities
  - Calibrated irradiance time-series in the four wavelengths
  - ?

Thanks to

Jean-Pierre Delaboudinière
Elaine Einfalt
Joe Gurman
Scott McIntosh
Jeff Newmark
Amanda Raab
Kevin Schenk
Amanda Shields
Barbara Thompson
Alex Young

for babysitting EIT all those years

Solar Physics Topical Issue

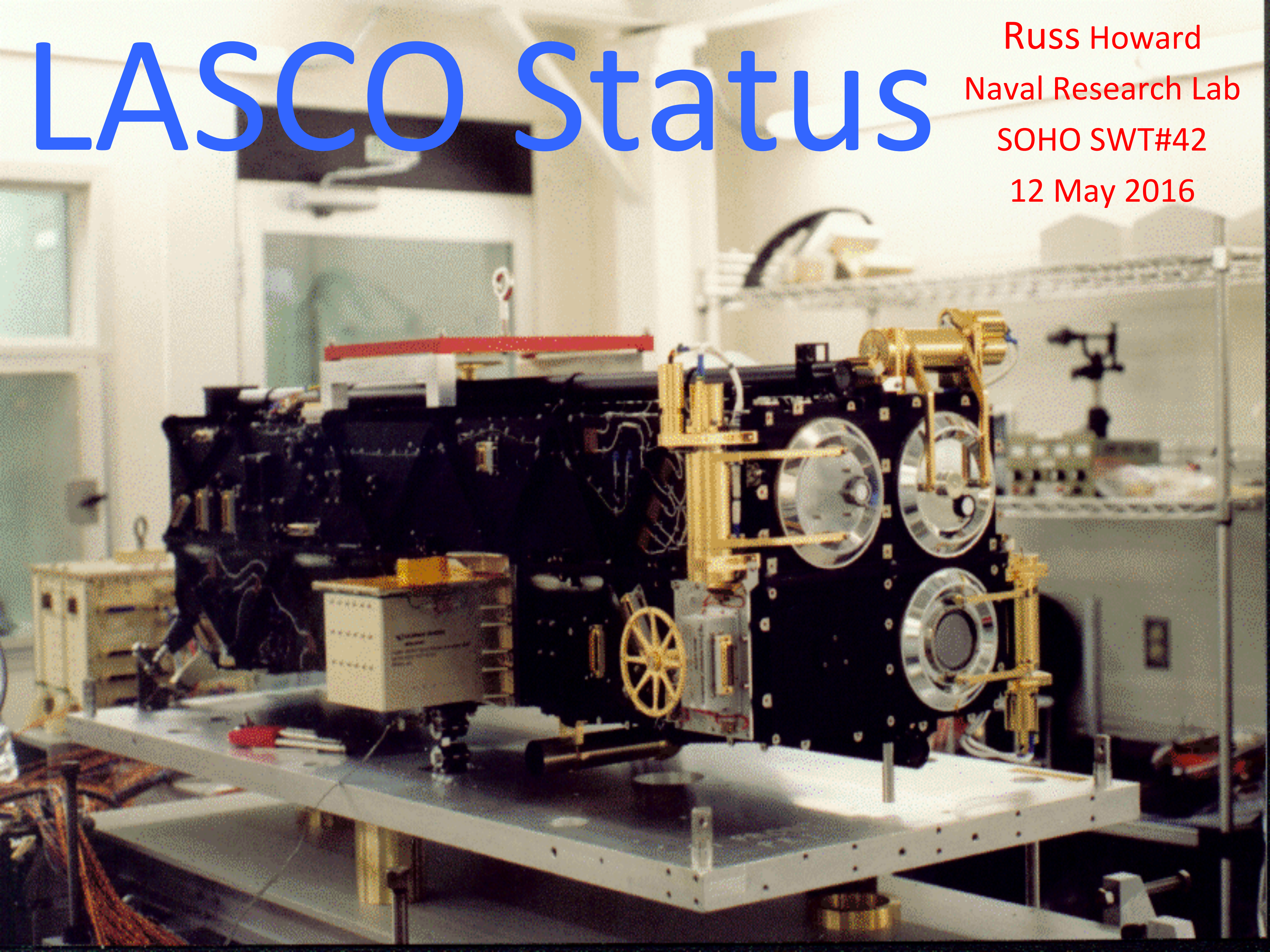
- The SOHO mission
- The first results from SOHO
- 20 years of SOHO ?
  - Focus on studies exploiting the exceptional duration of the mission
    - Long-term variability
    - Comparison of the two cycles
    - Statistical analysis of various types of events
    - Catalogues
    - etc.

LASCO Status

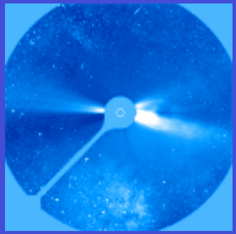
Russ Howard
Naval Research Lab

SOHO SWT#42

12 May 2016

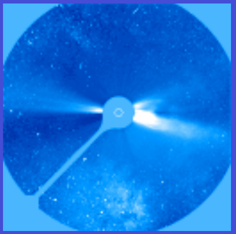


LASCO Status



- At the mispoint in 1998 several subsystems failed due to the extreme cold (~<-80C)
  - C1: Piezoelectric Crystals Controlling Spacing of Fabry-Perot – Catastrophic
  - C3: One of the polarizers failed – Now polarization analyses use the remaining two + clear
  - LEB: the oscillator of the 15 second timer damaged – Now absolute time is generated from the packet time stamp
- C2 and C3 continue to operate extremely well
  - Occasional halts in the program – power cycling resets
  - Well calibrated: Sensitivity degradation ~0.2-0.4%/
- EOF ground system converted to virtual machines

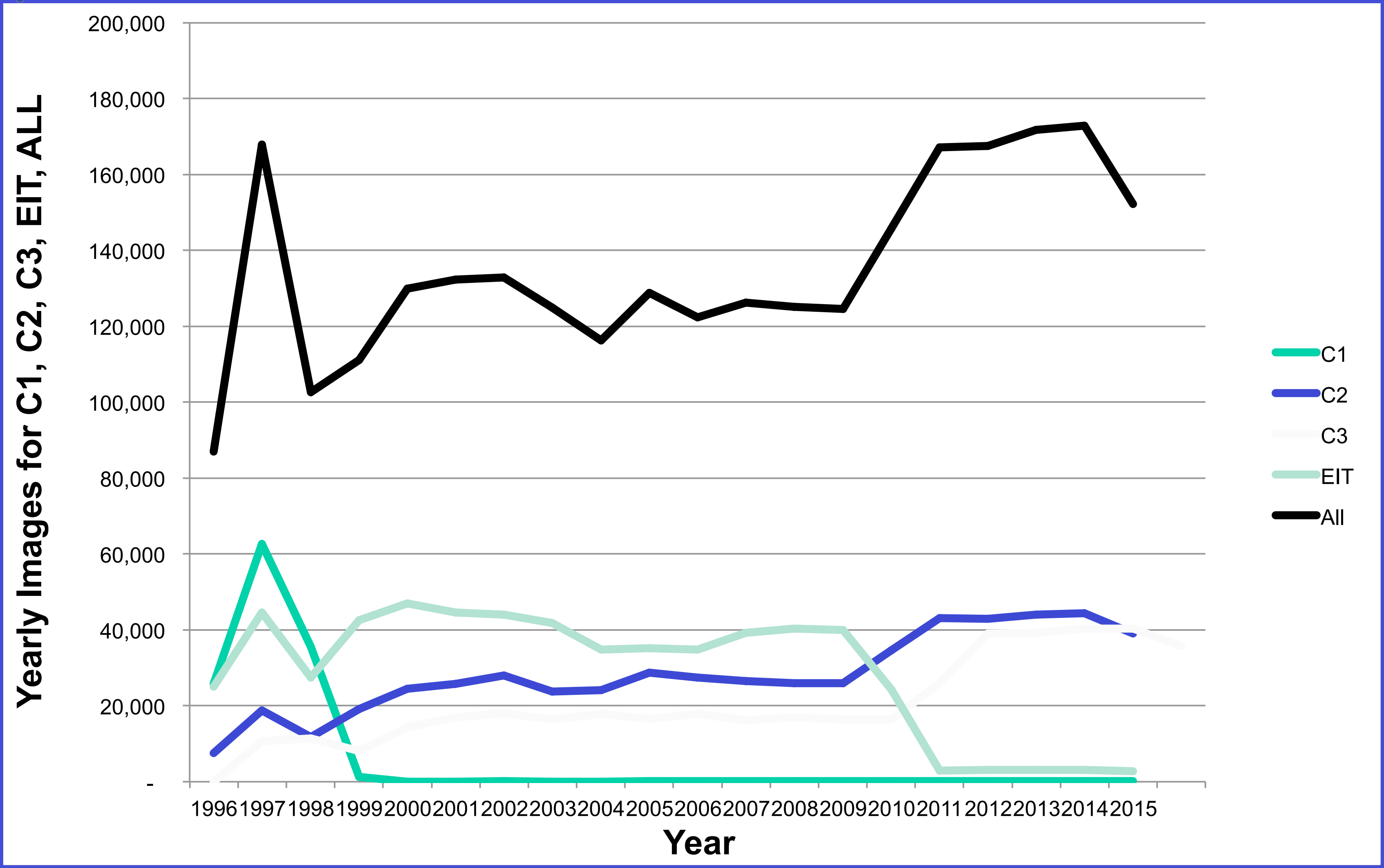
Over a Million Images



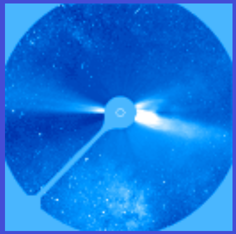
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
C1	25746	62720	35593	1304	16	14	102	5	51	84
C2 Blue	128	309	170	37	230	290	308	322	328	303
C2 Orange	6594	15810	9998	16748	22054	23128	22656	21563	21331	24775
C2 Deep Red	138	310	167	72	65	65	59	85	55	43
C3 Blue	184	317	192	82	252	645	326	825	599	302
C3 Orange	2721	333	189	309	416	729	392	558	567	384
C3 Deep Red	148	321	176	87	95	455	90	494	257	39
C3 IR	170	302	174	83	70	403	71	202	243	39
C3 Clear	6681	8521	6238	12277	14807	14592	14184	14677	13228	15108
					Polarized					
C2 Blue	54	25	23	168	184	180	192	182	136	156
C2 Orange	546	2381	1365	2030	1851	1877	4575	1330	2202	3387
C2 Deep Red	53	36	32	177	200	184	212	184	140	156
C3 Blue	57	21	20	167	184	184	200	188	136	159
C3 Orange	511	1529	967	1333	1020	1098	1033	949	1464	1895
C3 Deep Red	67	29	36	179	200	184	212	184	140	159
C3 IR	9	21	16	13	8	4	0	0	0	3
C3 Clear	99	40	26	20	8	4	3	0	0	0
C1 Total	25746	62720	35593	1304	16	14	102	5	51	84
C2 Total	7513	18871	11755	19232	24584	25724	28002	23666	24192	28820
C3 Total	10590	11413	8014	14383	16876	18114	16311	17889	16498	17929
LASCO Total	43849	93004	55362	34919	41476	43852	44415	41560	40741	46833

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
C1	84	84	101	142	96	113	114	107	116	100	126692
C2 Blue	280	276	285	274	324	170	397	412	403	355	5601
C2 Orange	24061	23391	22960	20664	28885	16258	37732	38764	38978	34386	470736
C2 Deep Red	33	477	42	40	44	29	55	67	52	43	1941
C3 Blue	283	518	292	275	330	235	429	442	407	355	7290
C3 Orange	357	527	383	364	220	98	87	92	52	43	8821
C3 Deep Red	34	197	43	40	44	99	87	91	52	43	2892
C3 IR	34	184	43	40	44	23	47	49	52	43	2316
C3 Clear	13284	14214	14230	13845	24168	15974	37438	38412	38641	34103	364622
						Polarized					
C2 Blue	132	146	172	92	0	229	0	0	3	0	2074
C2 Orange	2822	2060	2315	4645	5226	26094	4470	4584	4694	4101	82555
C2 Deep Red	132	158	180	176	176	242	184	196	208	168	3194
C3 Blue	128	148	175	96	0	231	0	0	0	0	2094
C3 Orange	2145	1164	1292	1604	992	1050	1041	1050	1064	935	24136
C3 Deep Red	132	156	180	168	176	229	135	147	156	126	2995
C3 IR	0	0	0	0	0	30	0	0	0	0	104
C3 Clear	0	0	0	0	0	21248	0	1	5	0	21454
C1 Total	84	84	101	142	96	113	114	107	116	100	126692
C2 Total	27460	26508	25954	25891	34655	43022	42838	44023	44338	39053	566101
C3 Total	16269	16960	16463	16336	25974	38986	39264	40284	40429	35648	434630
LASCO Total	43813	43552	42518	42369	60725	82121	82216	84414	84883	74801	1127423

Yearly Image Totals

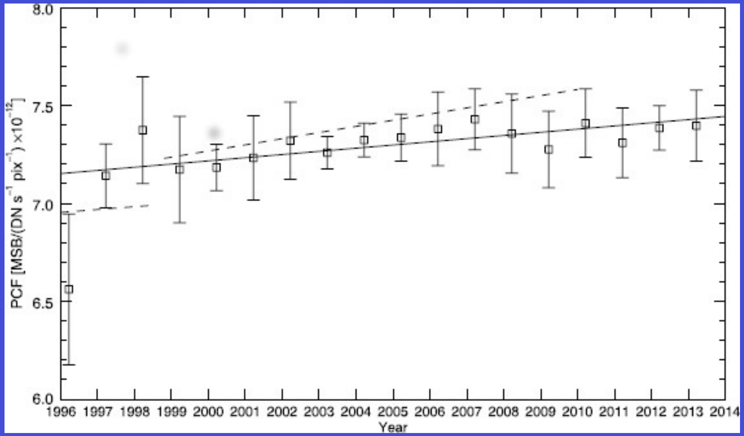


LASCO C2/C3 Calibration

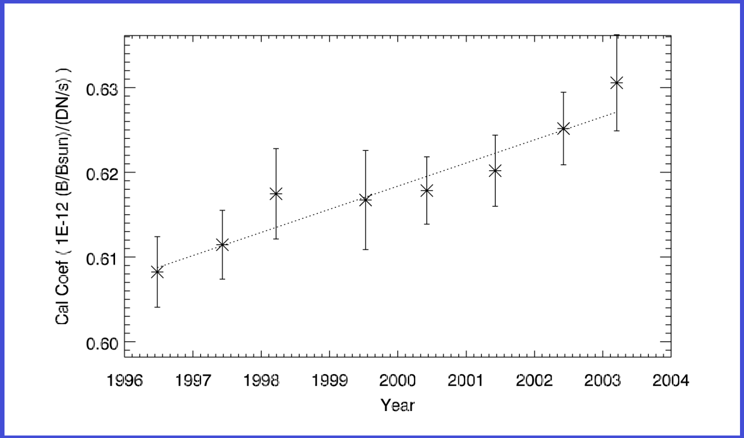


- Star transits enable absolute calibration of the photometric sensitivity -> ~0.5% degradation/year

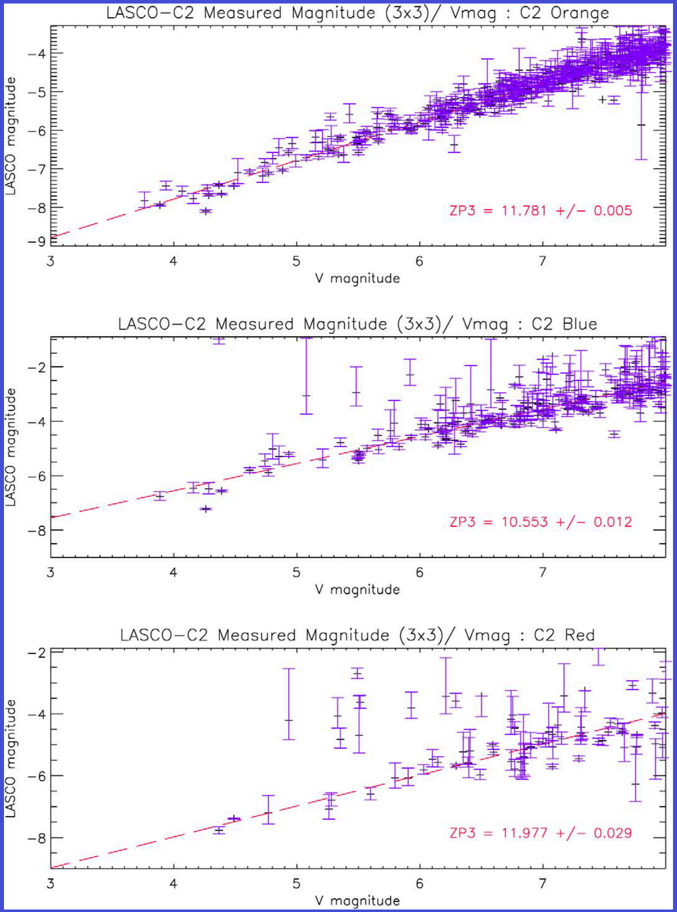
C2



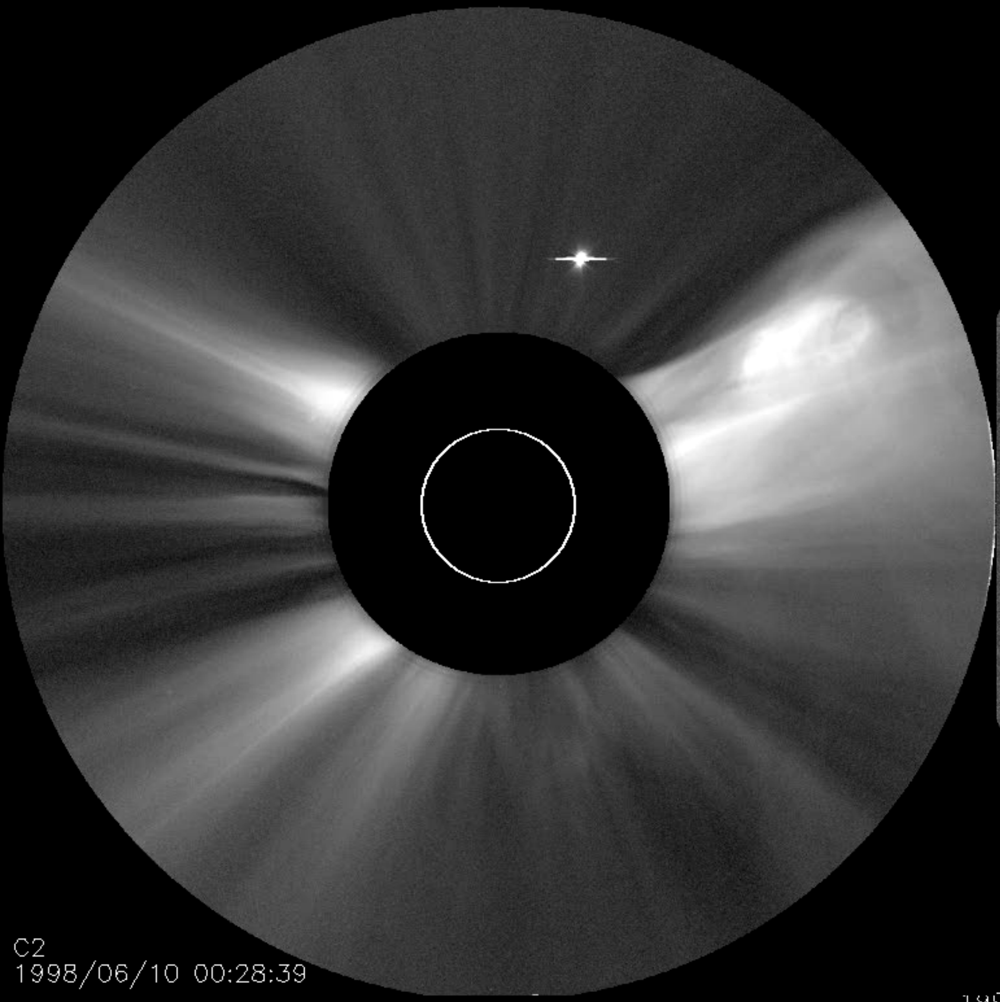
C3

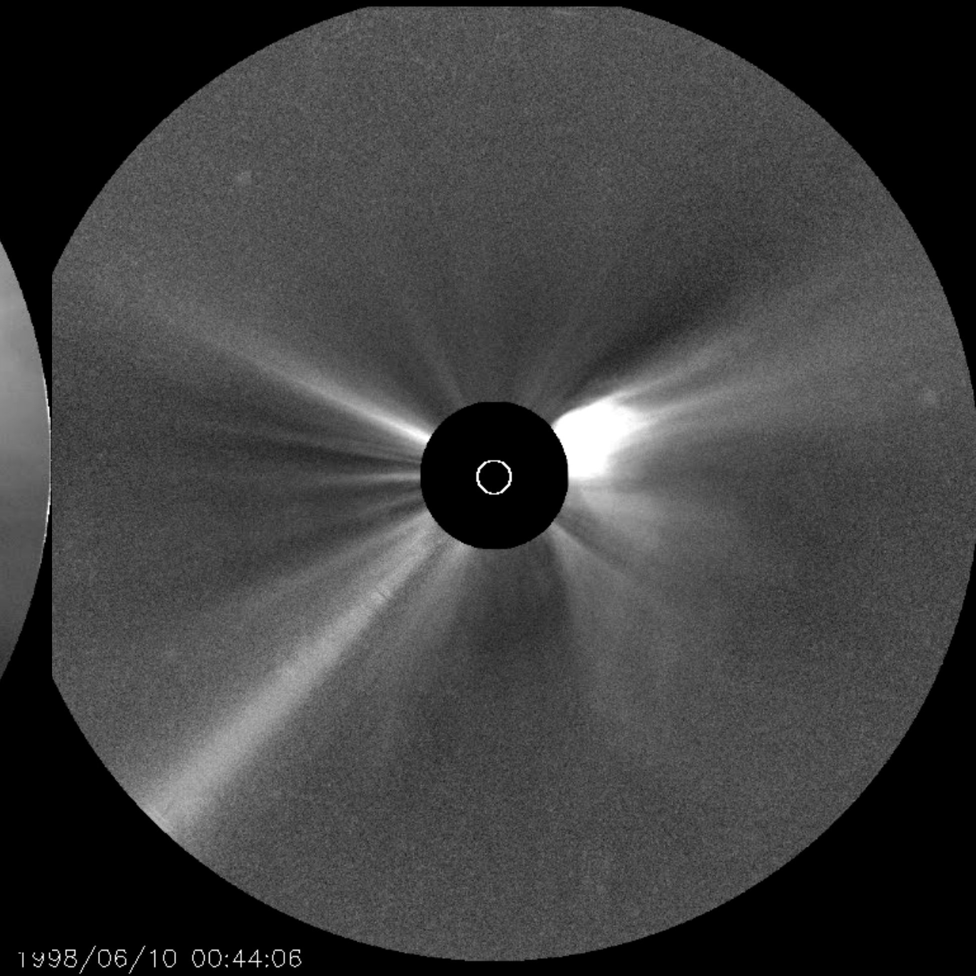


C2

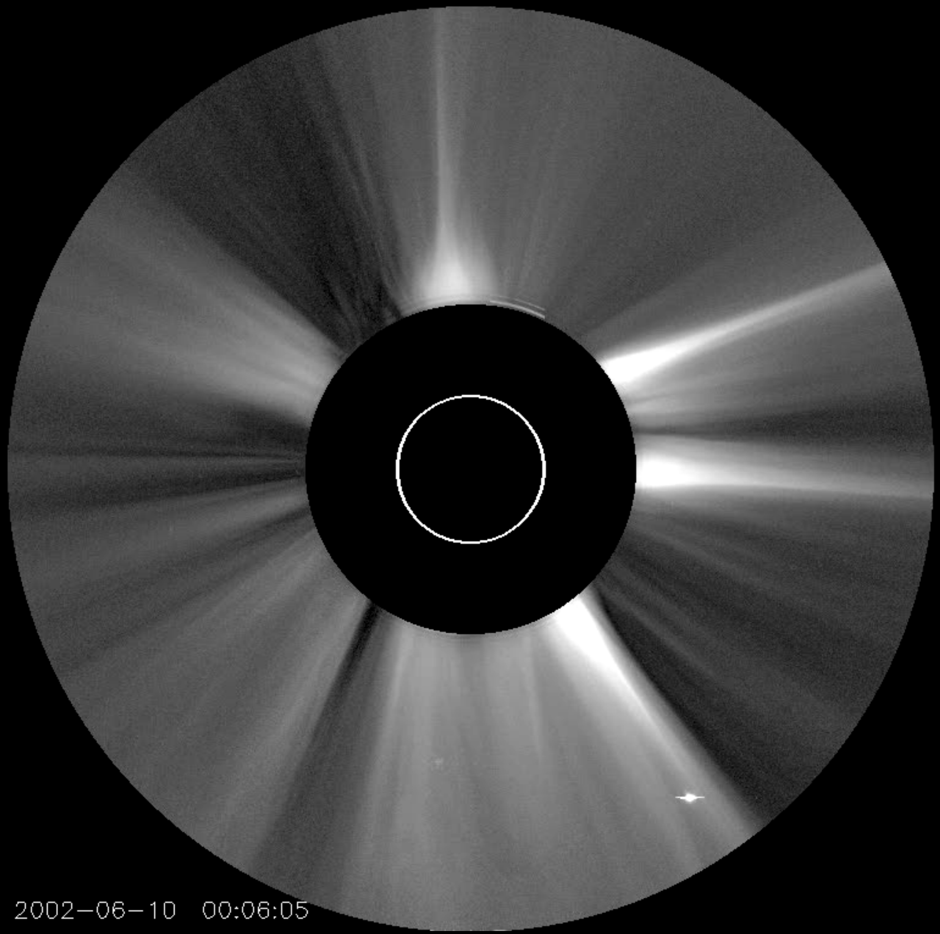


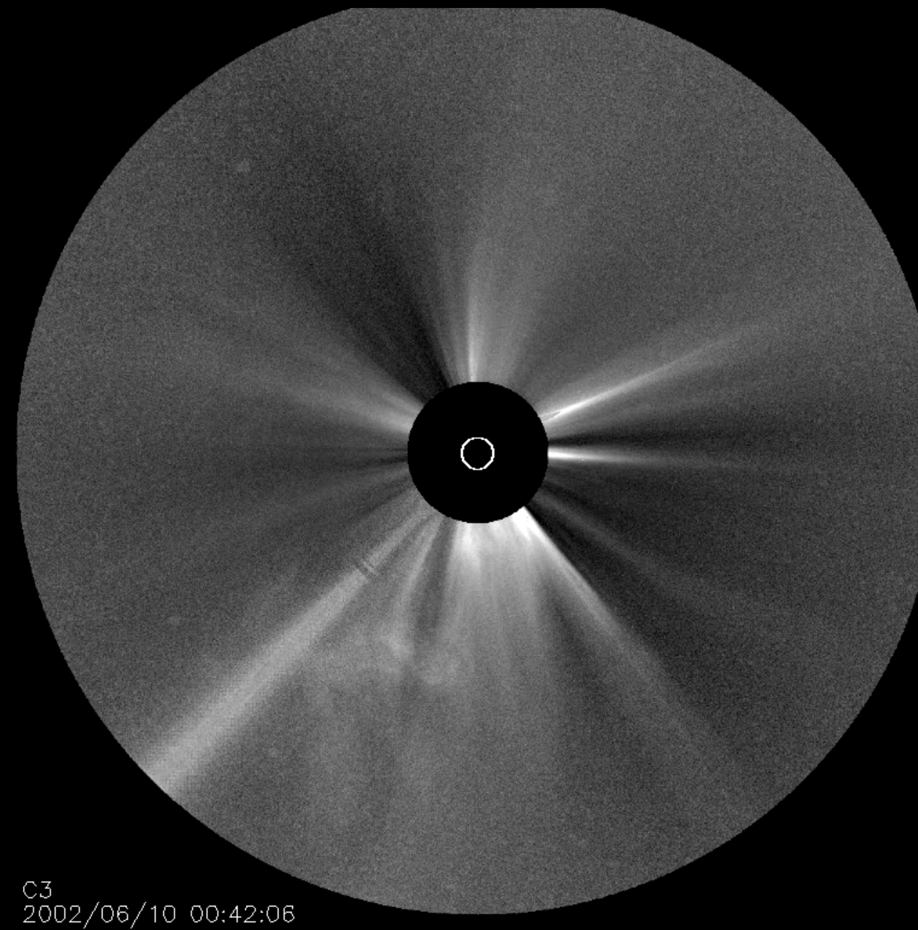
C2 and C3 June 1998



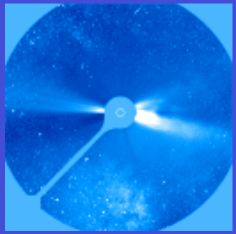


C2 and C3 June 2002



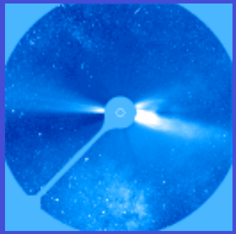


SOHO Archive



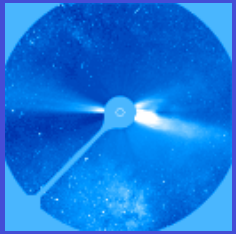
- Delivery of the final, calibrated data for the SOHO legacy (= long-term) archive
  - As the data are still being collected, we are planning to revisit the LASCO calibration
  - We would thus be able to deliver the final calibrated data within a year of the end of the mission
- Higher-level data products? Yes
  - Synoptic/Carrington Intensity maps
  - Electron density distributions
  - Jmaps ?
  - CME mass database
  - Weekly Movies
  - Wavelet Movies of C2

Lessons Learned



- Pay attention to details – contamination, EMC, microvibration, pointing stability, operating procedures, etc
- L1 is an excellent place to observe the sun
- International collaboration has given us a better mission, both in the instrument definition through an open exchange of ideas and cost sharing
- Open data policy has enabled data analyses from scientists around the world, larger than the original international consortium

Final Thoughts



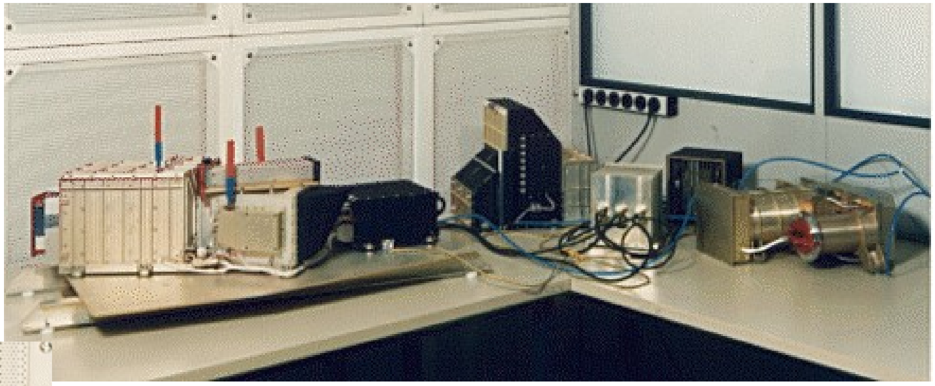
- Thanks to the entire ESA and NASA communities for the concept, implementation and operations of an absolutely fantastic mission

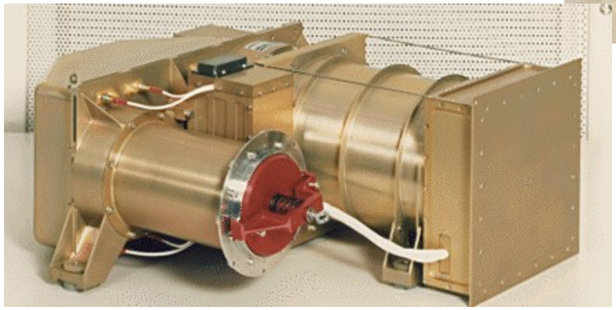
CELIAS

The Charge, Element, and Isotope Analysis System

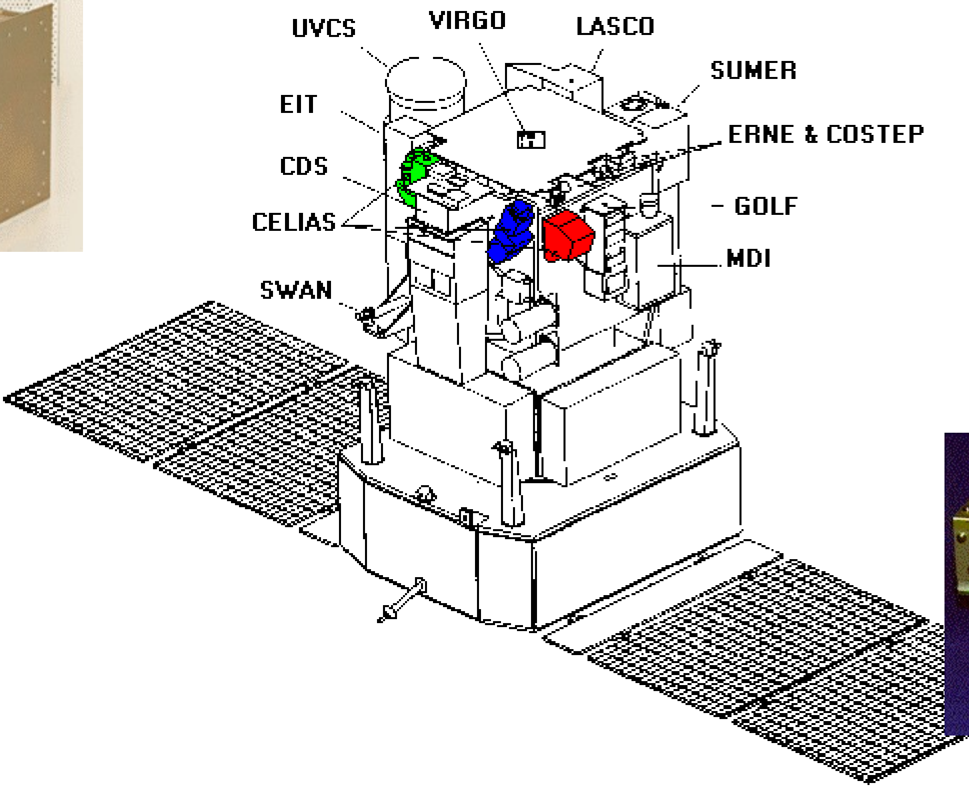
Robert F. Wimmer-Schweingruber for the CELIAS Team

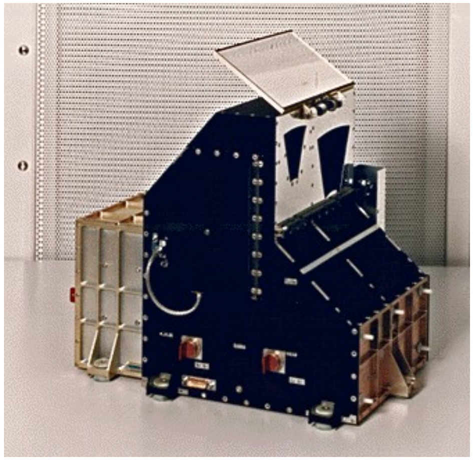
Instrument Status



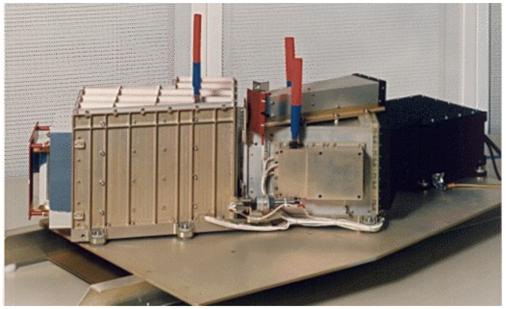


CTOF

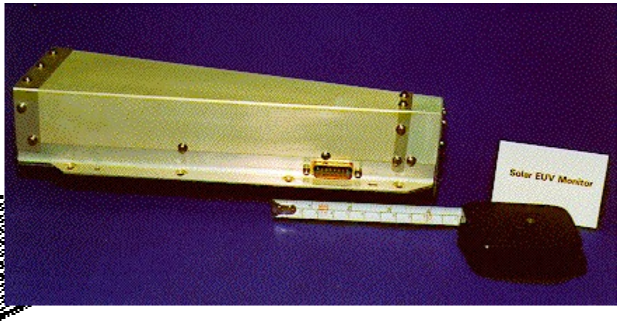




MTOF & PM



STOF & HSTOF



SEM

Instrument Status

CTOF ceased nominal operation on August 8, 1996

MTOF still operating

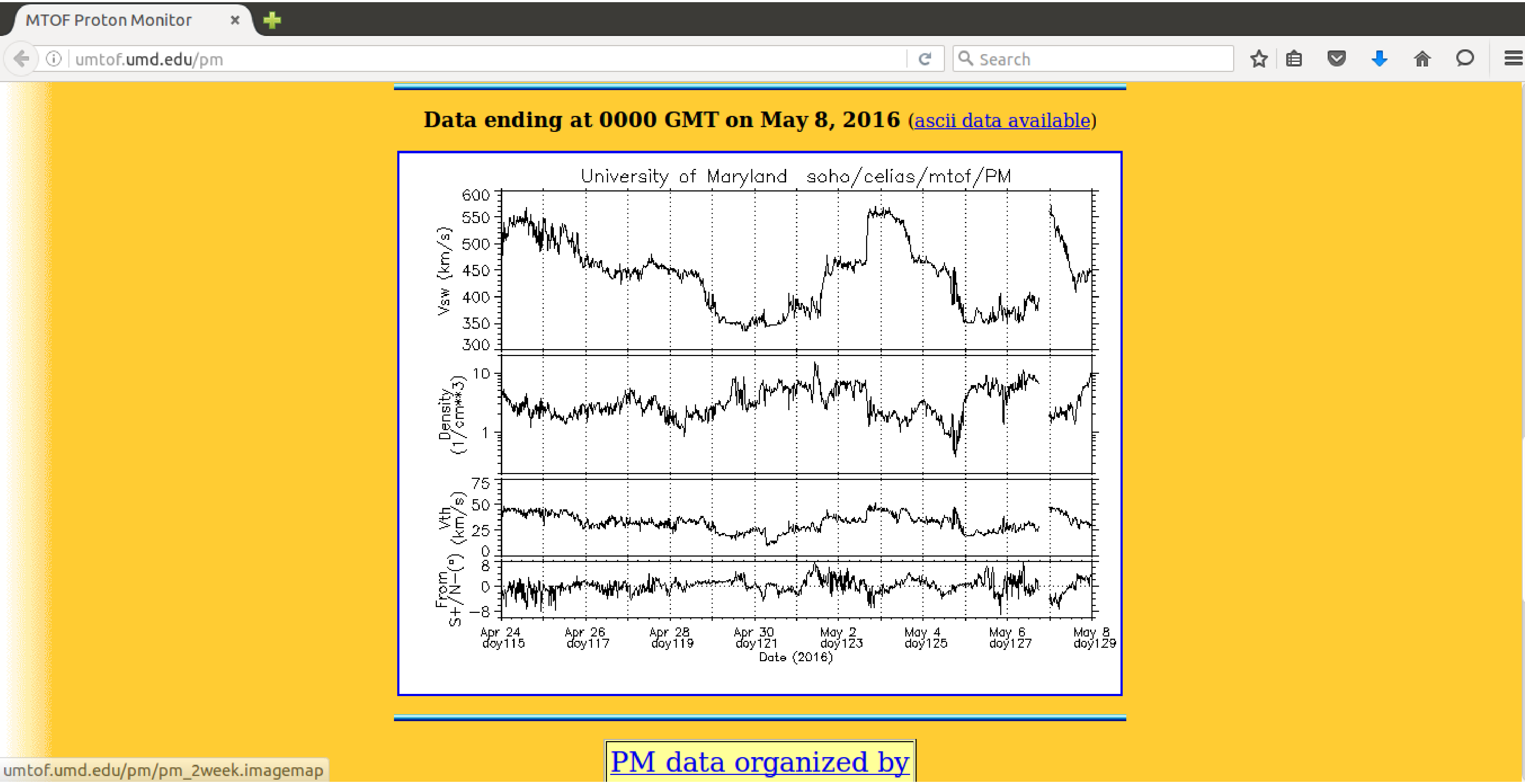
PM still operating

STOF still operating, but with highly degraded efficiency

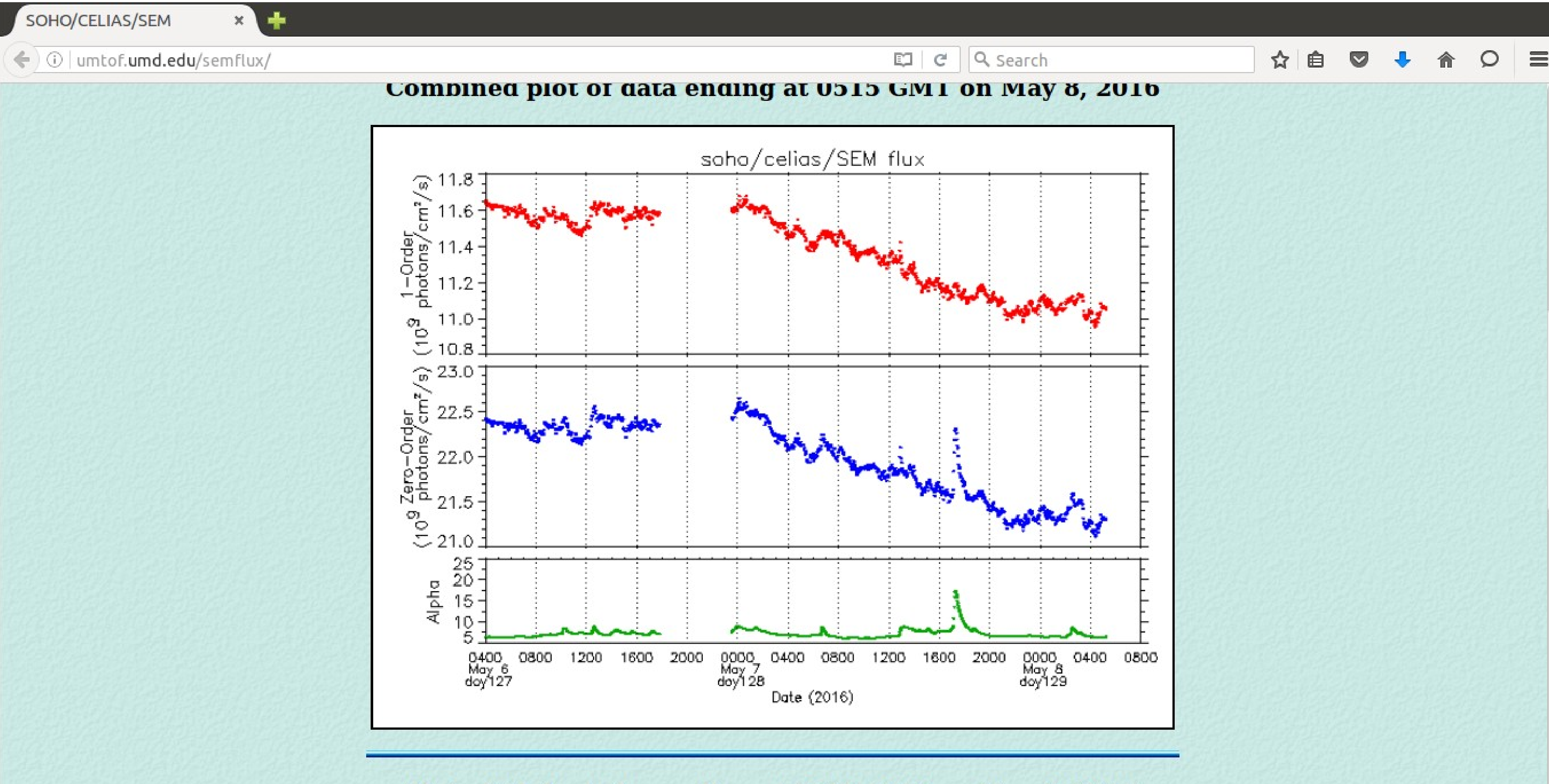
HSTOF still operating, but with highly degraded efficiency

SEM still operating

Proton Monitor (PM)



Solar EUV Monitor (SEM)



CELIAS Issues

People age quicker than SOHO and CELIAS

Institutions change quicker than SOHO and CELIAS

Funding at UMD running out

Need to get all software running at CAU

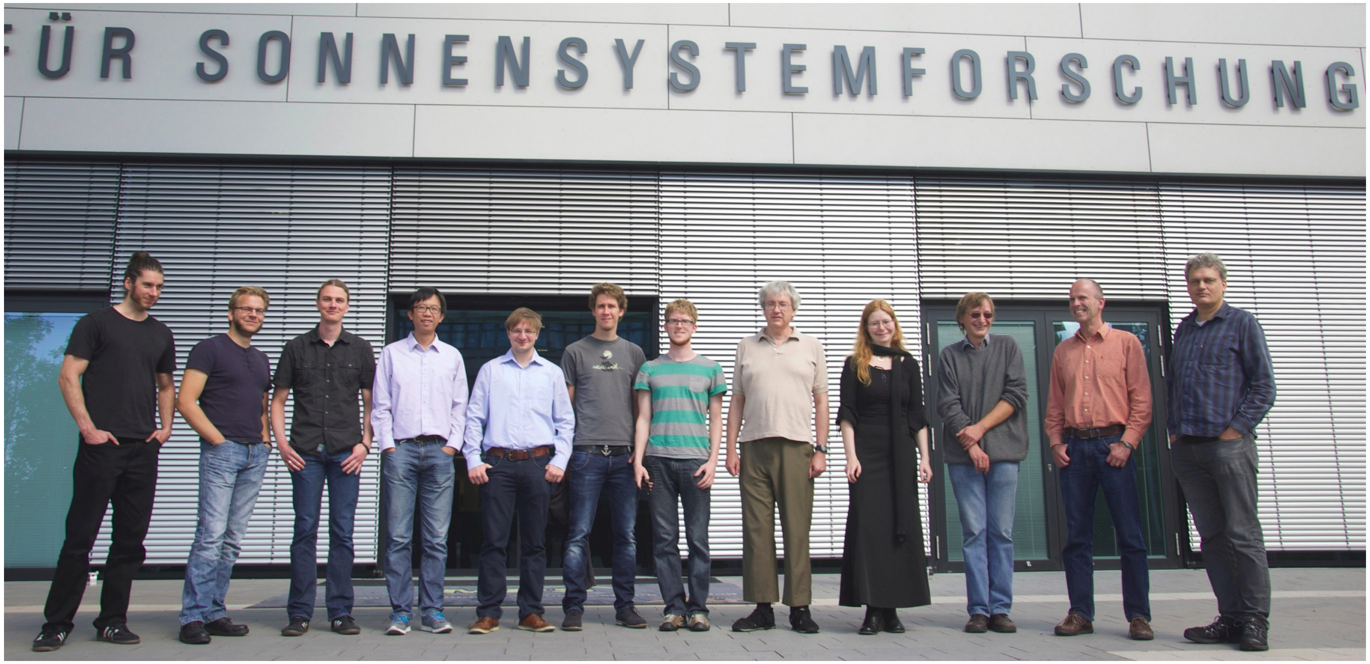
Emergency reactions

CELIAS Summary

CELIAS still operating and producing science data

New team at CAU has taken charge of CELIAS

Still rely heavily on UMD and „old folks“



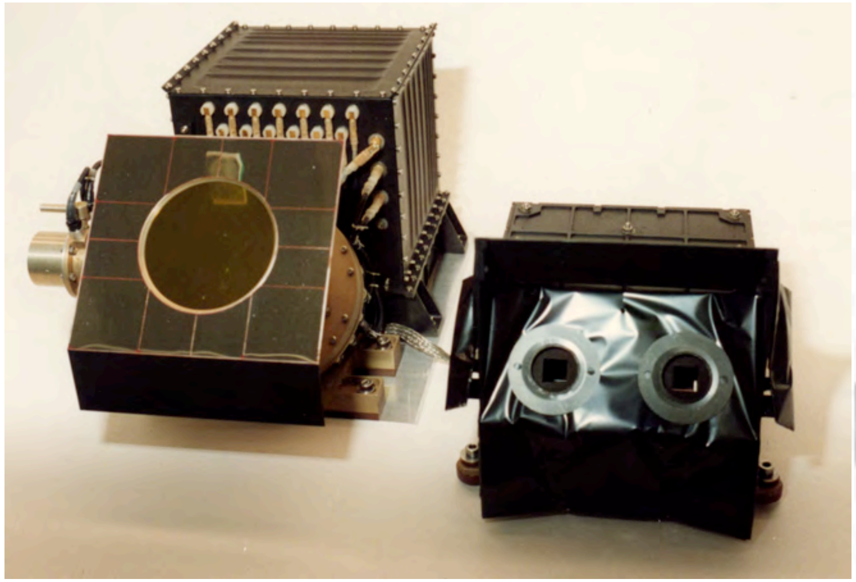
Mathematisch-Naturwissenschaftliche Fakultät

C A U

Christian-Albrechts-Universität zu Kiel

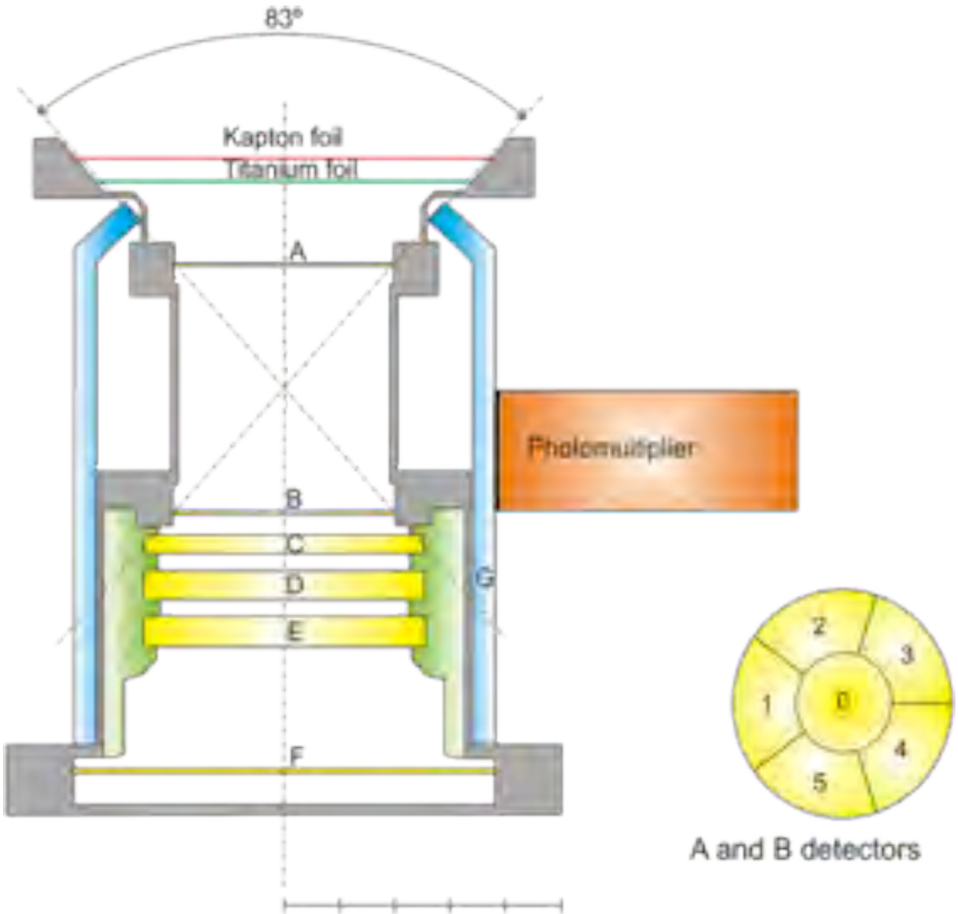
SOHO/COSTEP Instrument status

Bernd Heber, Károly Kecskeméty,
Horst Kunow for the COSTEP team



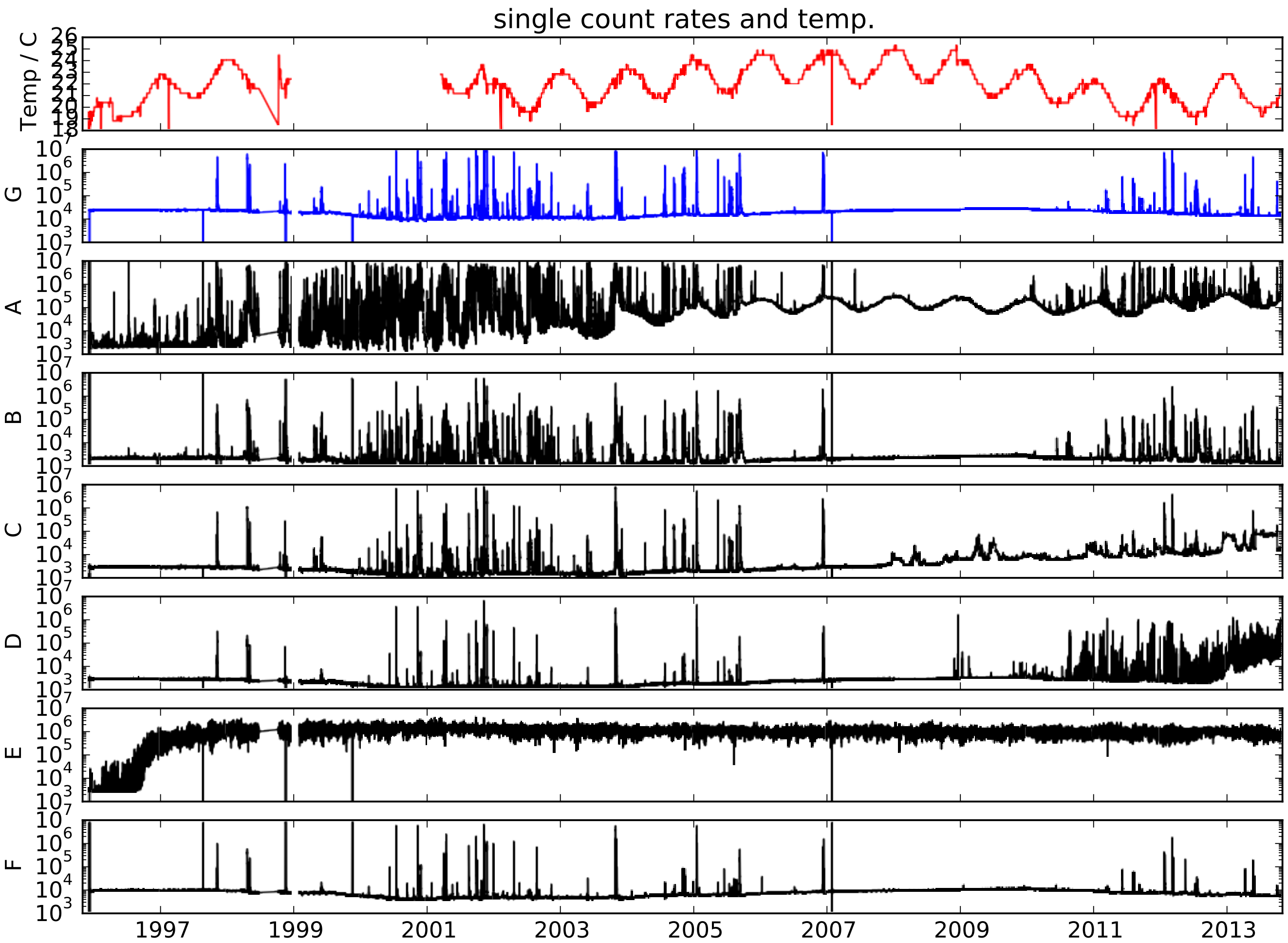
The SOHO COSTEP/EPHIN

- Particle telescope:
- Consisting out of six semiconductor detectors A – F.
- A and B segmented
- Anticoincidence counter G

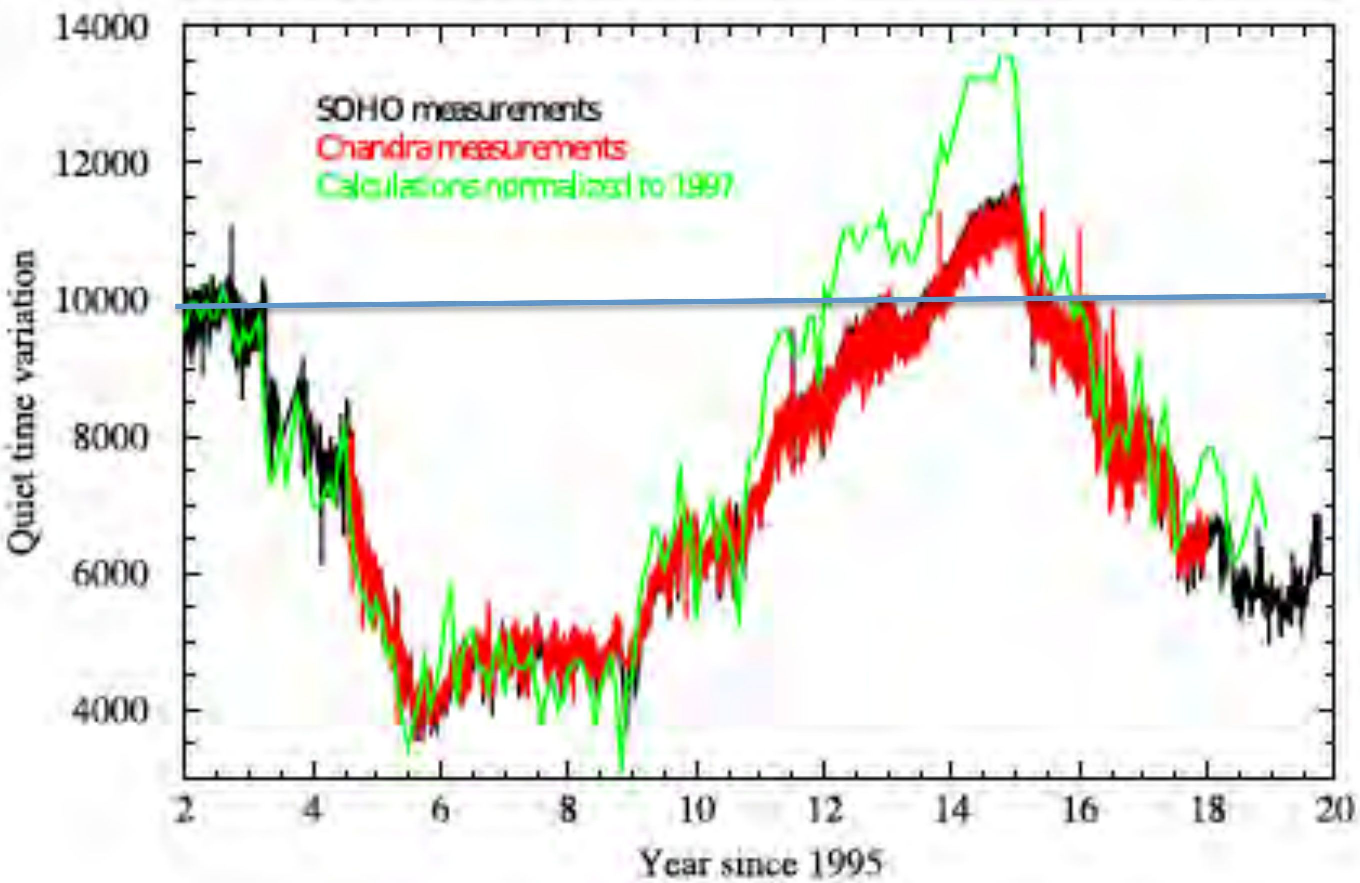


Single count rates (1995-2014)

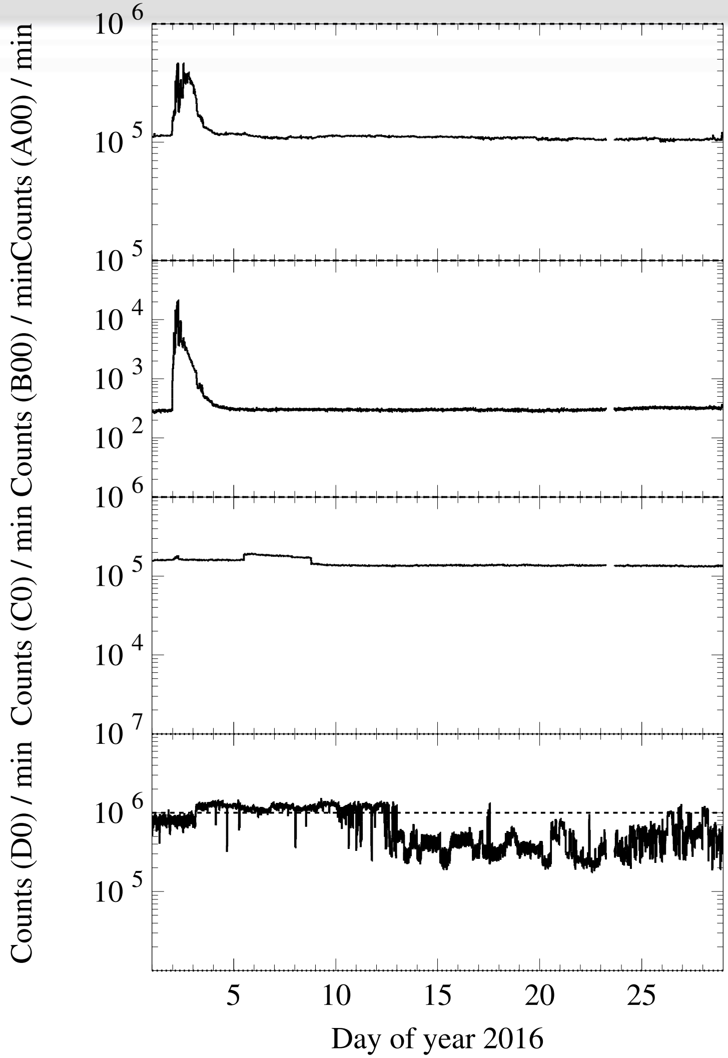
- Very good
- Ok
- Very good
- Ok
- Becomes noisy
- Not working
- Very good

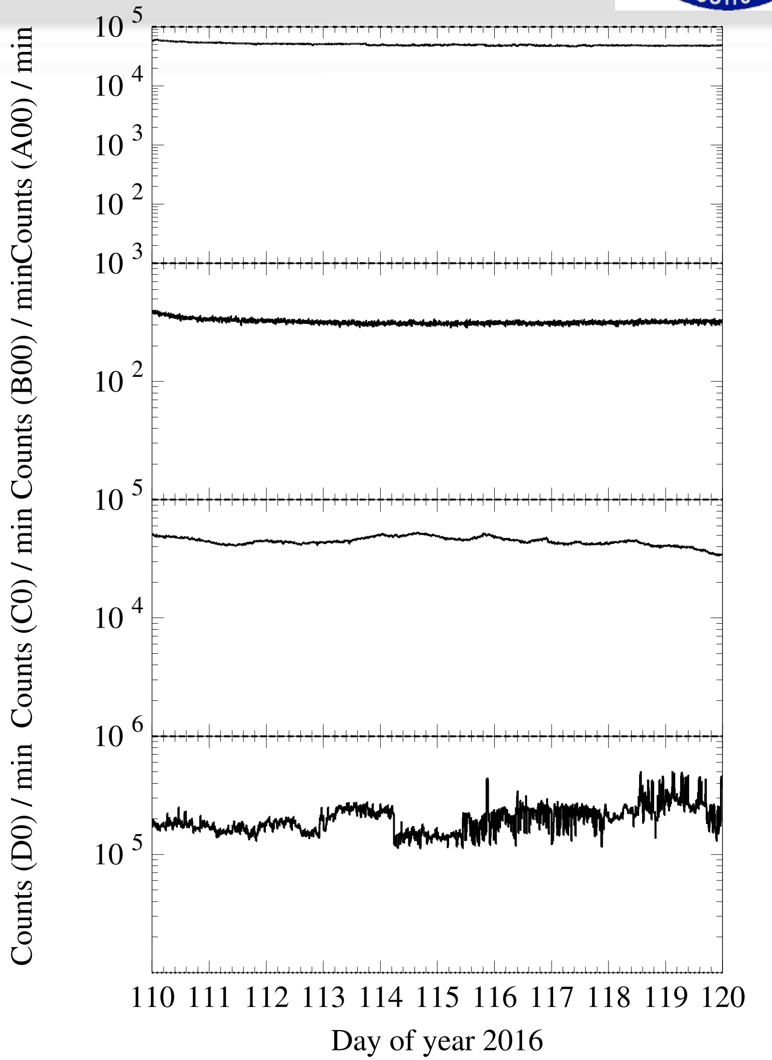


Single count rates detector F



Single count rates (2016)





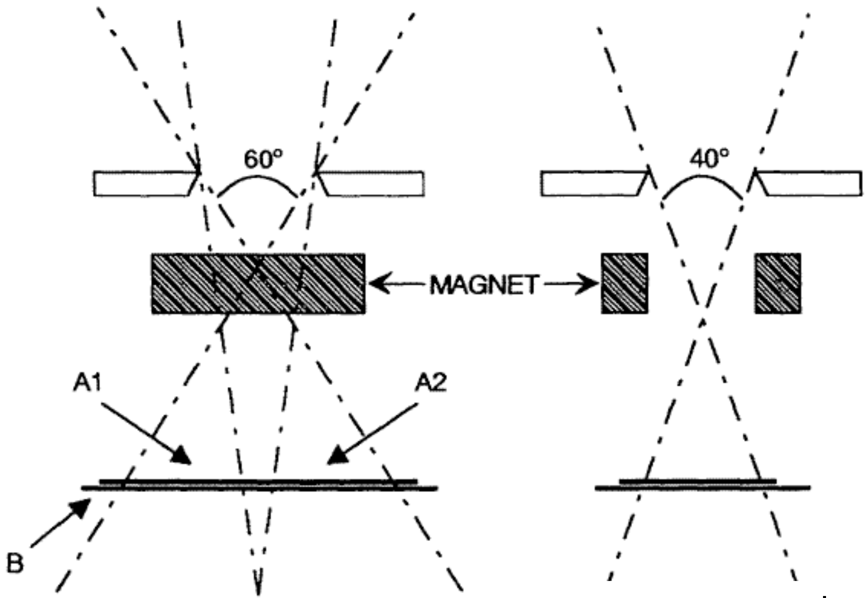
Mathematisch-Naturwissenschaftliche Fakultät

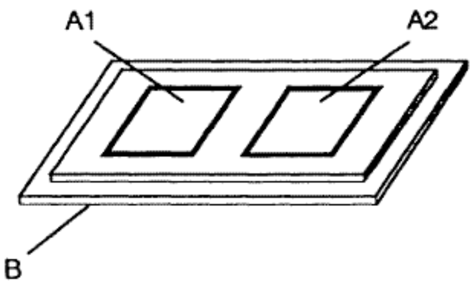
CAU Christian-Albrechts-Universität zu Kiel

Instrument status

- SOHO COSTEP/EPHIN:
  - Loss of detector E by 1997 due to high noise
  - Program patch allowed PHA analysis until 2004 for electrons until now for Helium
  - Since 2009 noise in detector D.
  - Extended period of HV switch
  - Fall 2016: Activate failure mode D for hot periods

The LION telescope

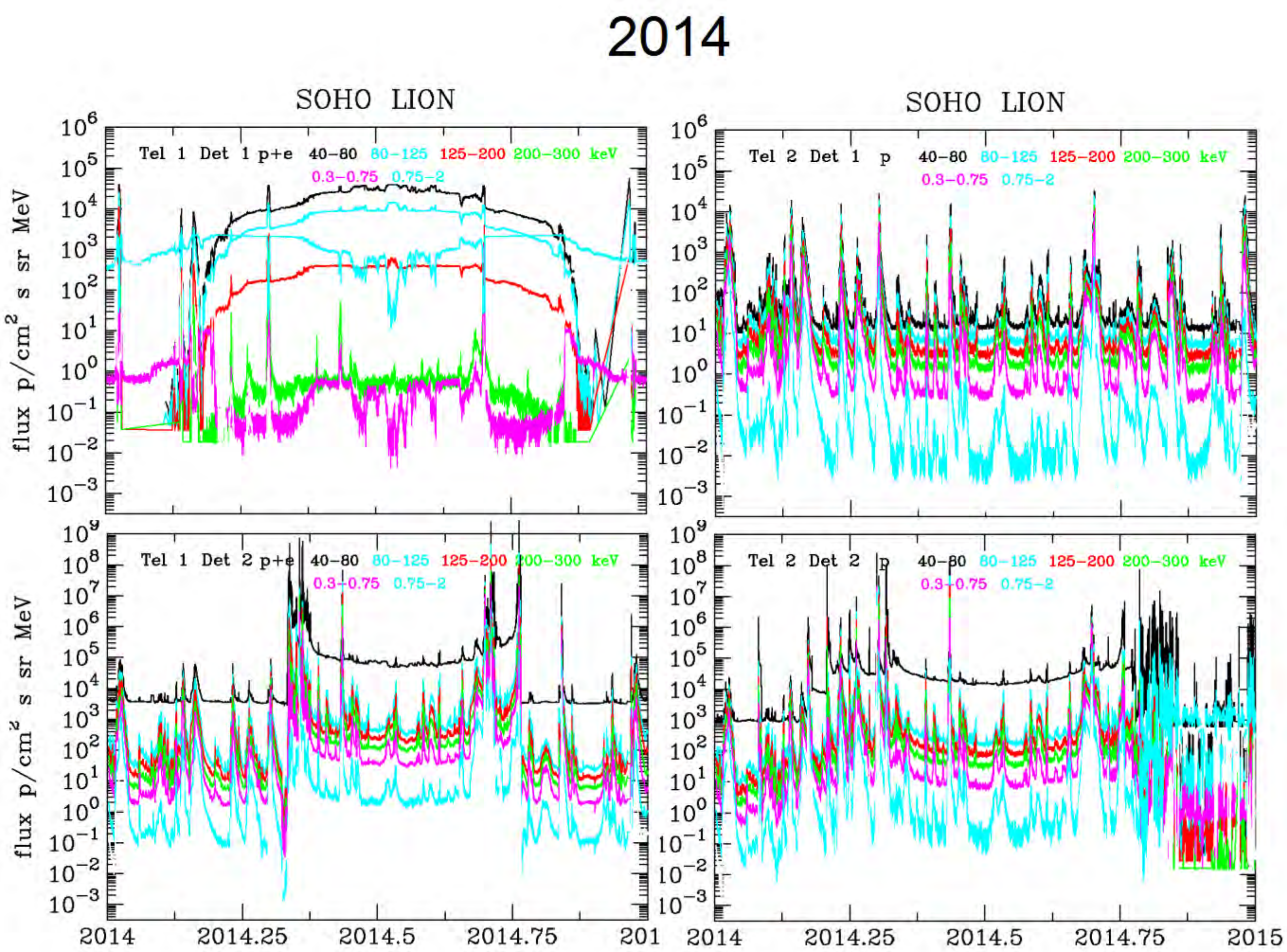




T1D1	Energy Range	T1D2	Energy Range	T2D1	Energy Range	T2D2	Energy Range
P1 + E1	44.5 - 81.9 keV	P1 + E1	44.6 - 81.9 keV	P1	44.4 - 81.9 keV	P1	44.6 - 82.0 keV
P2 + E2	81.9 - 128.1 keV	P2 + E2	81.9 - 127.4 keV	P2	81.9 - 128.1 keV	P2	82.0 - 128.2 keV
P3 + E3	128.1 - 189.1 keV	P3 + E3	127.4 - 193.5 keV	P3	128.1 - 190.1 keV	P3	128.2 - 193.9 keV
P4 + E4	189.1 - 308.9 keV	P4 + E4	193.5 - 305.5 keV	P4	190.1 - 309.1 keV	P4	193.9 - 306.1 keV
P5	308.9 - 755 keV	P5	305.5 - 762 keV	P5	309.1 - 754 keV	P5	306.1 - 762 keV
P6	0.755 - 1.99 MeV	P6	0.762 - 2.02 MeV	P6	0.754 - 1.96 MeV	P6	0.762 - 1.97 MeV
P7	1.99 - 6.04 MeV	P7	2.02 - 6.02 MeV	P7	1.96 - 6.07 MeV	P7	1.97 - 6.01 MeV
H1	6.87 - 26 MeV	H1	6.81 - 26 MeV	H1	6.87 - 26 MeV	H1	6.85 - 26 MeV

Table 2: LION threshold calibration

Measurements 2014

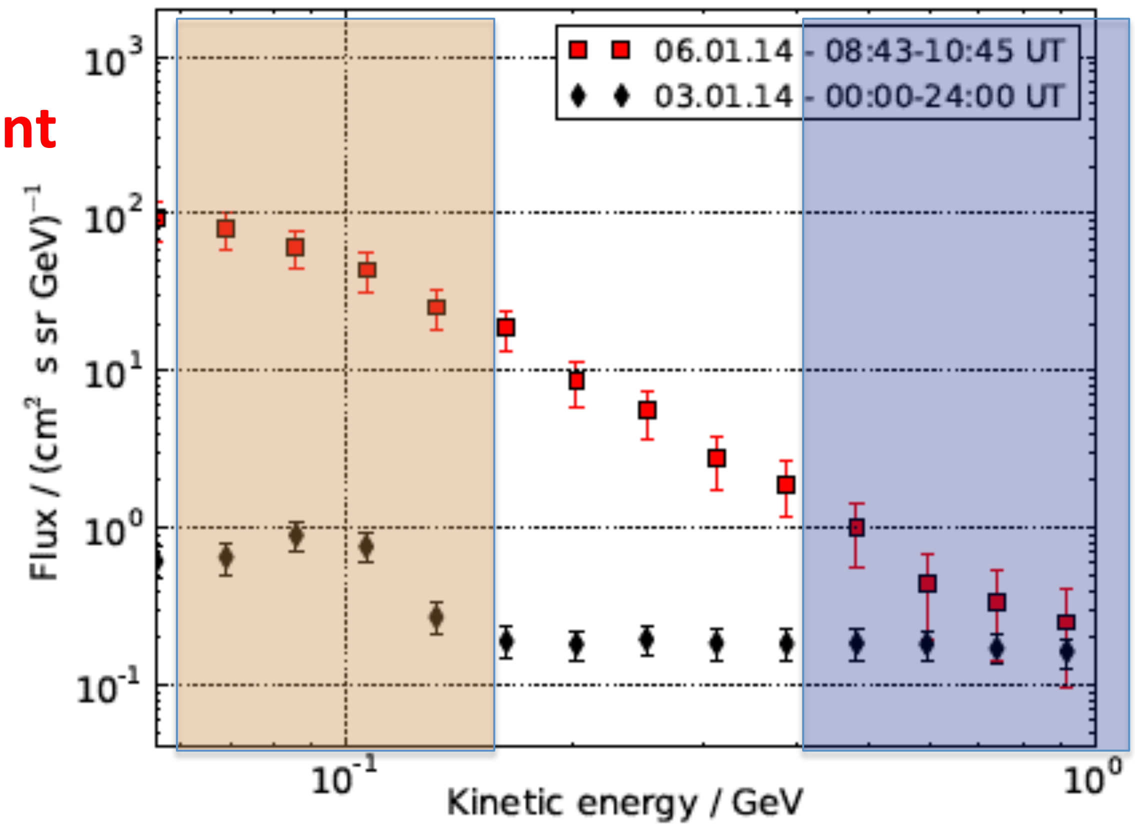


Instrument status

- SOHO COSTEP/LION:
  - Noise in detectors except Tel 2 protons makes data analysis difficult.
  - Periods exists when other LION detectors give scientific valuable data.
- SOHO COSTEP/EPHIN:
  - 2016: Patch in order to analyze penetrating particles with higher statistics

The January 6, 2014 GLE

EPHIN event spectrum



EPHIN background

Instrument status

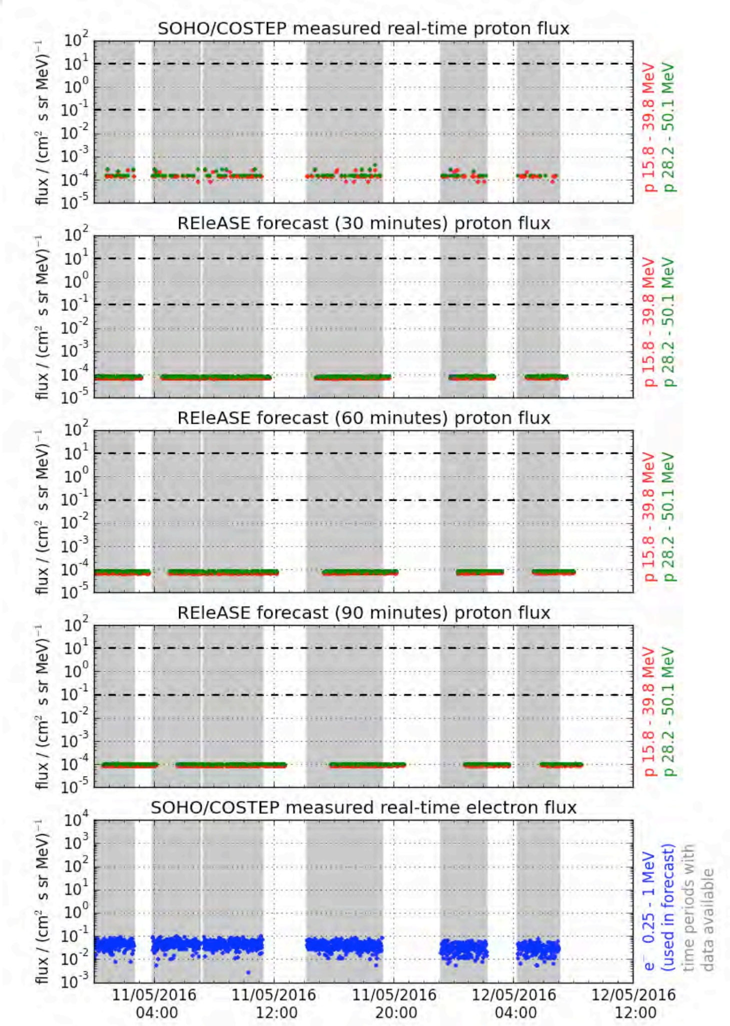
- SOHO COSTEP/EPHIN:
  - Detector B and F no degradation
  - Detector C sporadically unexpected high counts
  - Detector A ok, but correlation with distance due to the efficiency loss of the preceding foils.
- SOHO/LION:
  - Unchanged since the beginning with noisy telescopes

EPHIN today

Measured protons

Predicted protons

Measured electrons



ToDo’s

- High single count rates in E, D, and A lead to high dead time and spurious coincidences.
- Correction for these effects
- Production of cleaned electron, proton, and helium intensities using PHA data (10 minute and hourly averaged data sets).
- Utilize sector structure of A and B in order to infer directionality information

Archiving

- SOHO COSTEP/EPHIN data will be archived including level1 data (count rates, Puls-Height-Information, Housekeeping, about 300 GB)
- SOHO/COSTEP/LION will be archived as Level 2 data (about 20 GB).

ERNE

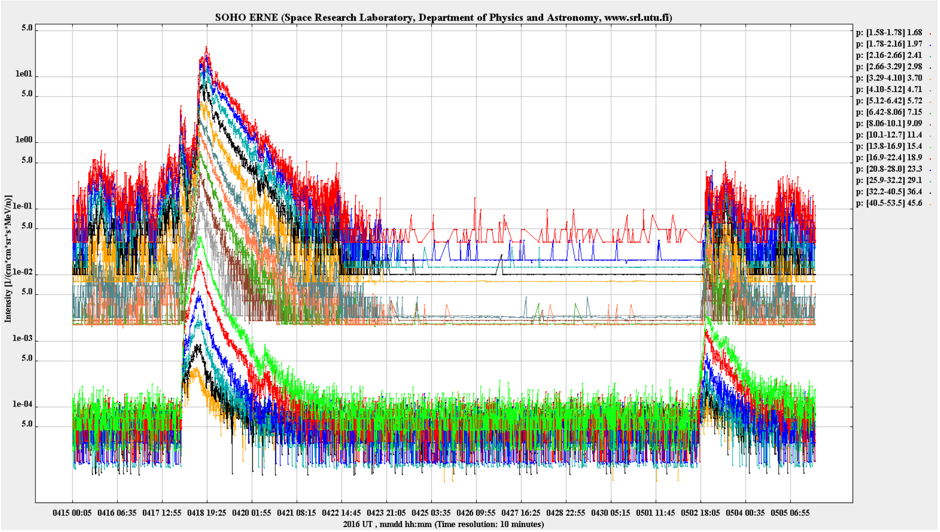
Instrument status
and
data archive status

Eino Valtonen
University of Turku

Turun yliopisto
University of Turku

Overall current instrument performance

- Good quality science data received (more or less) continuously



April 15 – May 5, 2016

- Nominal performance with some corrected failures
  - Fall-back solution in use for one failed critical amplifier channel
  - One spare circuit in use

- Thermal problem prevents operating both sensors simultaneously during SOHO “hot season”
  - First appeared in end November 2011
  - Solved by 1.5 W power reduction by switching off the low energy detector

Experienced failures and anomalies: effects, consequences, and status

- Software errors
  - "ESU data request error": loss of communication with CEPAC common DPU
    - On the average ~1 per month
    - Autonomous recovery
    - Data loss of a few minutes per event
  - "Science software error": continuously sending the same data buffer
    - Every few months
    - Requires running a contingency script by request
    - Onboard detection and alarm message by e-mail
    - Usually loss of 1-2 days of data
- Noisy strip detector S1XH2-E amplifier (one of 16 channels)
  - Failure occurred in November 2000
  - Fixed in July 2001: S1XH2-E disconnected and signal replaced by a proxy based on fixed ratio of signals in lower layers
- Failure of HED nominal detector bias supply
  - Occurred in July 2009
  - Replaced by spare circuit
- Continuously rising temperatures
  - Internal thermal control disabled after two years of flight
  - Rise levelling-off asymptotically
- Hot season thermal problem
  - Sudden rise of temperature
  - Protective action against failure propagation developed by the S/C team
  - ERNE switch-off and configuration to backup mode (only HED on)

Data archive: status

- SOHO data archive routinely (although somewhat irregularly) updated with
  - ERNE status files and some normalization factors (for pulse height data)
  - Proton and helium intensities and corresponding counting rates in 20 energy channels between 1.6 and 130 MeV/n
  - Raw pulse height data
  - Latest data available from the archive: February 5, 2015
- ERNE data also available from U. Turku own data pages at http://www.srl.utu.fi/erne_data/main_english.html
  - Proton and helium intensities with a delay of ~5 days (selectable time resolution and energies)
  - Near-real time 2-hour averages in a few energy channels
  - Archived data by Carrington rotations
- SEP event catalogues based on ERNE observations created in two EU-funded projects
  - SEPServer: http://utu.sepserver.eu/ (high-energy event list)
  - HESPERIA: http://www.hesperia-space.eu/index.php/results/hesperia-event-catalogue (low-energy event list)

Data archive: plans

- The final SOHO archive will include the following updates:

- New complete set of proton and helium intensities
  - Re-calibrated data
- Heavy ion intensities
  - C, N, O, Ne, Mg, Si, (Fe?)
  - 5-min averages, 10 energy channels
- Anisotropy index for selected SEP events
  - Describes the presence (or not) of anisotropy in particle intensities
  - Defined as the difference between the 85th and 15th percentile of intensity as function of time in the 241 directional bins of HED view cone
  - 144 SEP events from 2000 to 2015
- Raw pulse height data also currently provided
  - Are these data of any interest for users?
- The above data planned to be provided by September 2016

Annex 3

Archive Status and Plans for the SOHO Legacy Archive

SOHO legacy archive

- Goal: ensure that complete set of all SOHO observations will be available in the most usable form for future generations of solar scientists
- Need solutions for a long-term ("legacy") archive
  - Expertise in instrument teams slowly but surely disappearing
  - Need to preserve data
    - with best possible calibration
    - without need for special software (e.g. IDL prep routines, calibration tables, …)
    - in a format that can be easily read (ideally even 50 years from now)
- Legacy archive should include
  - Level-0 (uncalibrated) data
  - Level-1 (calibrated) data
  - Higher level data products
  - Ancillary data
  - Software
- Long-term SOHO archive at ESAC as part of a new "Heliophysics Archive" development
  - New "Data and Engineering" Division in the Operations Department at ESAC

SOHO archive status

Available Data as of May 09, 2016

INSTRUMENT	LATEST DATA	UPDATED ON
CDS	2013-05-02	2014-09-15
CELIAS	2016-05-05	2016-05-09
COSTEP	2016-02-17	2016-02-24
EIT	2015-12-18	2016-04-18
ERNE	2015-02-05	2015-04-01
GOLF	2015-10-31	2016-02-26
LASCO	2015-11-19	2016-05-08
MDI	2011-04-11	2012-08-24
SUMER	2014-10-24	2013-11-22
SWAN	2016-01-20	2016-03-30
UVCS	2014-01-15	2013-10-23
VIRGO	2016-02-18	2016-02-26

NOTE: For MDI, 2011-04-11 is the date of the final observation. Instrument no longer observes.
For UVCS, 2013-01-19 is the date of the final observation. Instrument no longer observes.

Higher level data products (1)

- GOLF
  - 3 calibrated line-of-sight velocity series (PM1, PM2, PM1+PM2)
  - GOLF frequency shift tables
  - GOLF radial velocity index (S_{vel})
- VIRGO
  - Calibrated TSI daily, mission long
  - Calibrated TSI hourly, mission long
  - Calibrated SPM blue, green, red series, 60 s cadence, mission long
  - VIRGO photometric index (S_{ph})
  - Others? Calibrated LOI? Calibrated TSI @ full time resolution?
- MDI
  - 6-hour full disk continuum intensity
  - 96-min full disk magnetograms
  - Suggest to add all mags (also high res), frequency tables, … others?

Higher level data products (2)

- SUMER
  - Have to discuss "packaging" of level-2 (calibrated) files
  - Plans for other higher level data products?
- CDS
  - Expected: Level-2 (calibrated) data for NIS
  - What about calibrated data for GIS? (If not now, when? Expertise disappearing rapidly)
  - Plans for other higher level data products?
- EIT
  - Expected: Level-2 (calibrated) data
  - Any others? Bright point list, coronal holes, EIT wave catalogue, ...?
- LASCO
  - Currently only level 0.5 for C1, C2 and C3
  - Level 1 (calibrated) only for subset of C2 and C3 (and not available for many years)
  - Anybody working on calibration of C1?
  - Plans for calibrated, mission long C2 and C3 sets?

Higher level data products (3)

- UVCS
  - Level-2 (calibrated) data delivered to archive
  - Any future developments for UVCS, or closed?
- SWAN
  - Since October 2007 mostly full sky maps (fskyymmdd.fits), with a few exceptions for observations of comet 67P_Churyumov-Gerasimenko
  - Plans for other higher level data products?
- CELIAS
  - SEM calibrated data @ 15 s, 5 min, 10 min res. and daily averages (entire mission)
  - Proton Monitor calibrated data with 30 s and 5 min resolution (entire mission)
  - Plans for other higher level data products?

Higher level data products (4)

- COSTEP
  - Level-2 EPHIN and LION data
  - Plans for other higher level products?
- ERNE
  - Level-2 onboard count rates and pulse height data
  - Heavy ion data (50 min averages for C, N, O, Ne, Mg, and Si in 10 energy channels)
  - Anisotropy index data for selected SEP events
  - Plans for other higher level products?
    - Energetic particle events catalog (ends 2007) ?
    - HED proton events (ends 1999) ?

Annex 4

Mission Extension and Future Plans

ESA mission extension review

- Confirmation for 2017-2018
- New extension for 2019-2020
- MEOR (technical review): **31 May**
- Extension proposal due: **31 July**
- Presentation to ESA advisory structure (SSEWG, SSAC): 13/14 Oct
- New:
  - In the past, the ESA Project Scientists made these presentations. This time, presentations to be made by scientists from community
  - Presenters to be appointed by the SWTs
  - Missions of Opportunity (Hinode, IRIS, Proba-2) and mission operated by partners (SOHO, Hubble) will NOT be ranked, but simple go/no-go decision from SSAC.
  - November SPC meeting: approval for 2017-2018 extensions; 2019-2020 extensions will be proposed, but final decision will be delayed until after the Ministerial, in order to understand the longer-term budget situation that may impact the operations envelope.

Annex 5

Science Highlights and Lessons Learned

SoHO SWT May 2016
GOLF

Patrick Boumier

Highlights

- Seismic solar model in excellent agreement with neutrinos (Turck-Chièze et al 2011):

seismic model : $5.3 \pm 0.6 \ 10^6 \ cm^{-2} \ s^{-1}$

SNO : $5.05 \pm 0.30 \ 10^6 \ cm^{-2} \ s^{-1}$

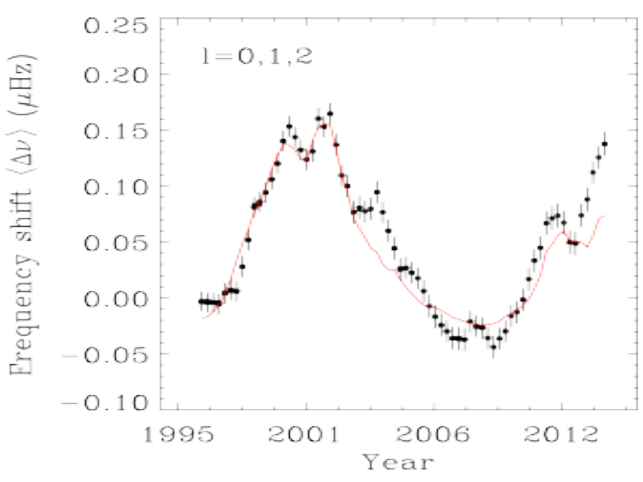
- G-mode dipolar detection (García et al 2007, 2011; TBC by identification of individual modes). In favor of a fast solar core rotation. Fossat 2016 (submitted), estimated g-mode rotationnal splitting not consistent with García et al. Work in // @IAS.

- Constraints on the mass of WIMPS, candidates for dark matter (Turck-Chèze & Lopes 2012):

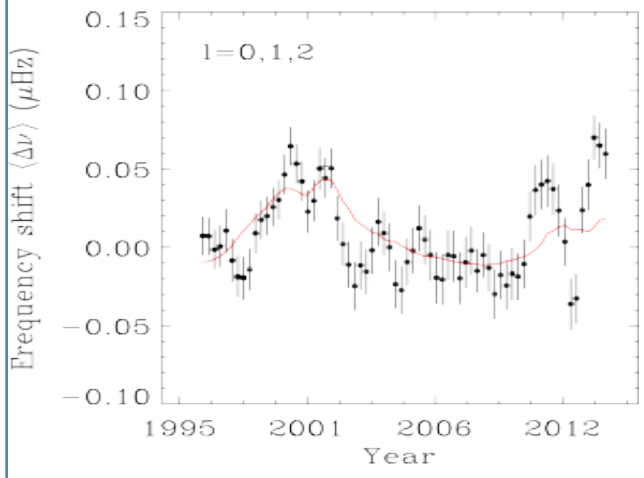
M_WIMPS > 10 GeV

Highlights – Solar activity 1

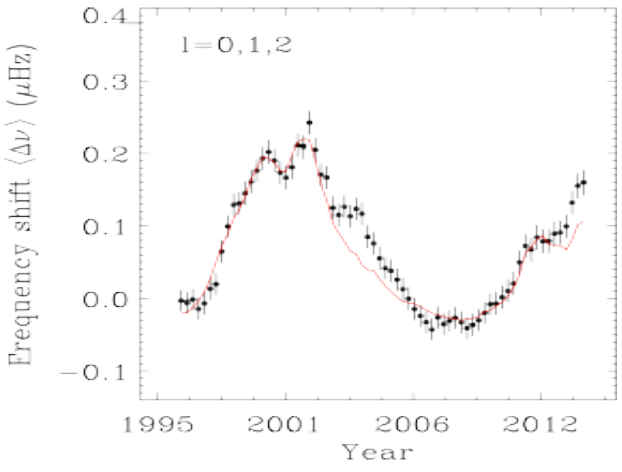
- confirmation of the start of cycle 24, although not visible in surface proxies (Salabert et al 2015).
- biennal oscillation discovery.



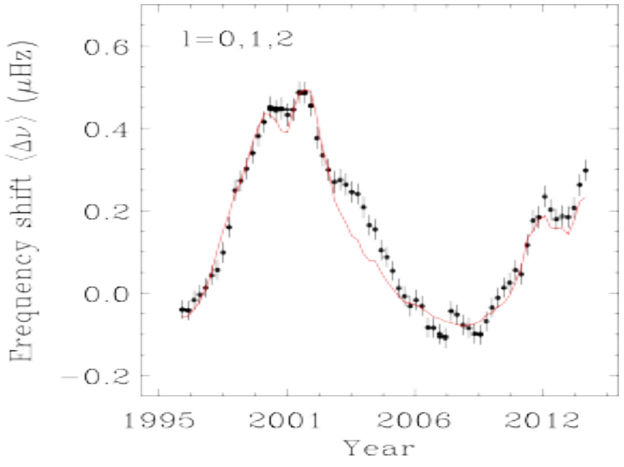
1800 μHz ≤ ν < 3790 μHz



1800 μHz ≤ ν < 2450 μHz



2450 μHz ≤ ν < 3110 μHz



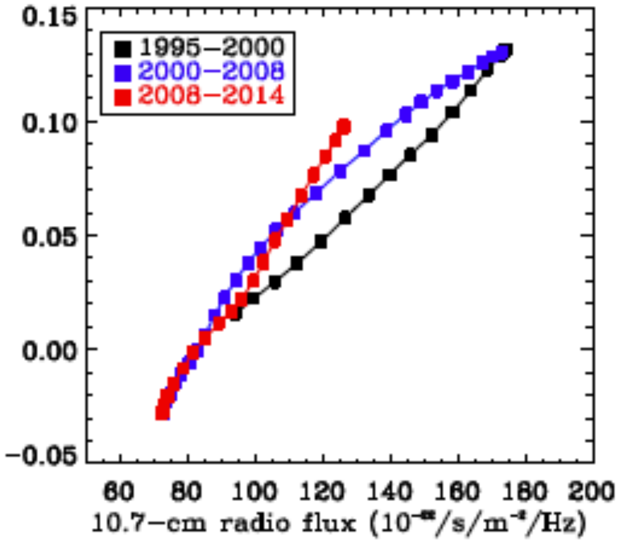
3110 μHz ≤ ν < 3790 μHz

Temporal variations of the frequency shifts in μHz averaged over the modes l = 0, 1, and 2, ($\Delta\nu_{n,l=0,1,2}$), and calculated for four different frequency ranges (black dots). Red solid line: scaled 10.7-cm radio flux.

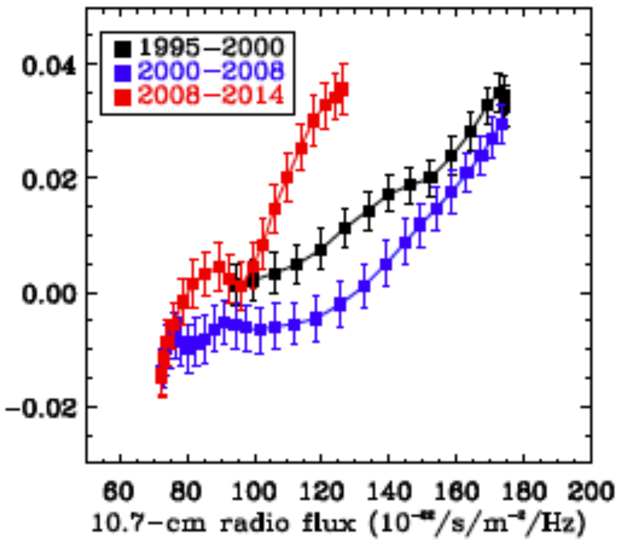
Highlights – Solar activity 2

Location of the magnetic cycle (Salabert et al 2015):

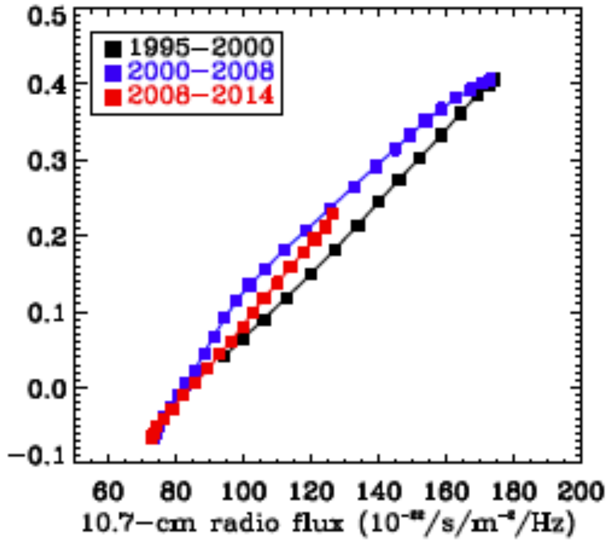
- Low-frequency modes (sensitive to the deeper sub-surface layers below 1400 km) show nearly unchanged frequency shifts between Cycles 23 and 24.
- The modes at higher frequencies (sensitive to upper shallower regions) show frequency shifts 30% smaller during Cycle 24, which is in agreement with the decrease observed in the surface activity between Cycles 23 and 24.



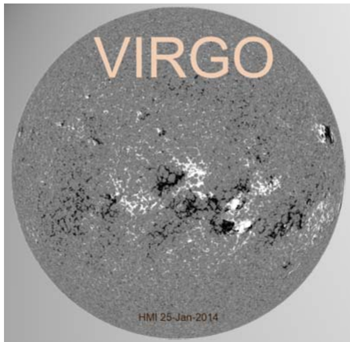
1800 μHz ≤ ν < 3790 μHz



1800 μHz ≤ ν < 2450 μHz



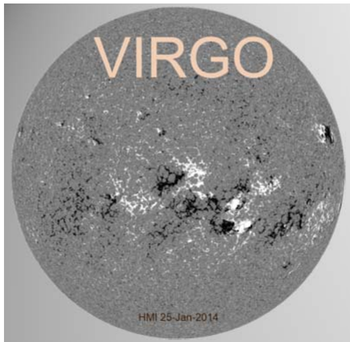
3110 μHz ≤ ν < 3790 μHz



20 Years of VIRGO/SOHO

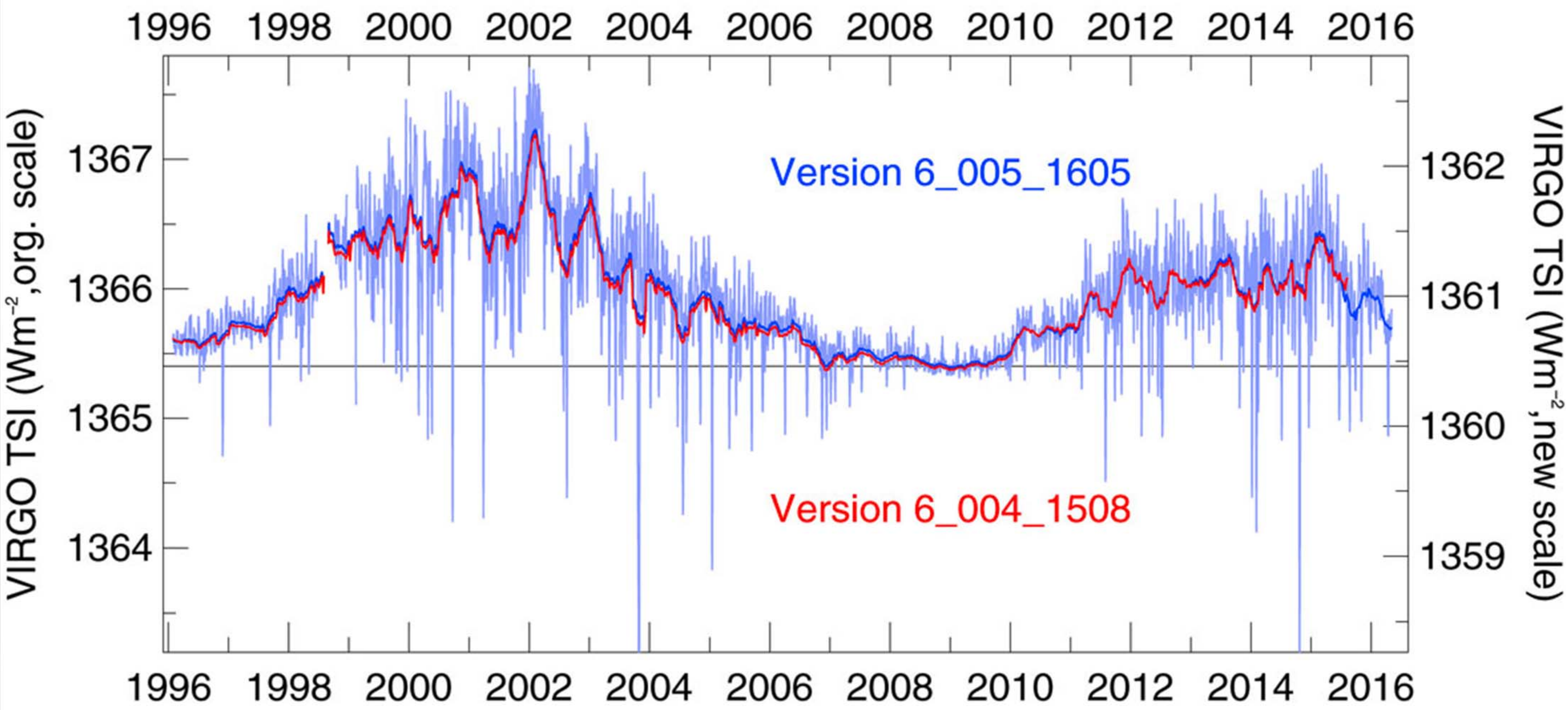
SWT-42 Status Report

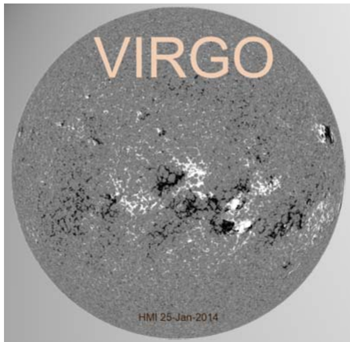
Claus Fröhlich
CH 7265 Davos Wolfgang



Some results

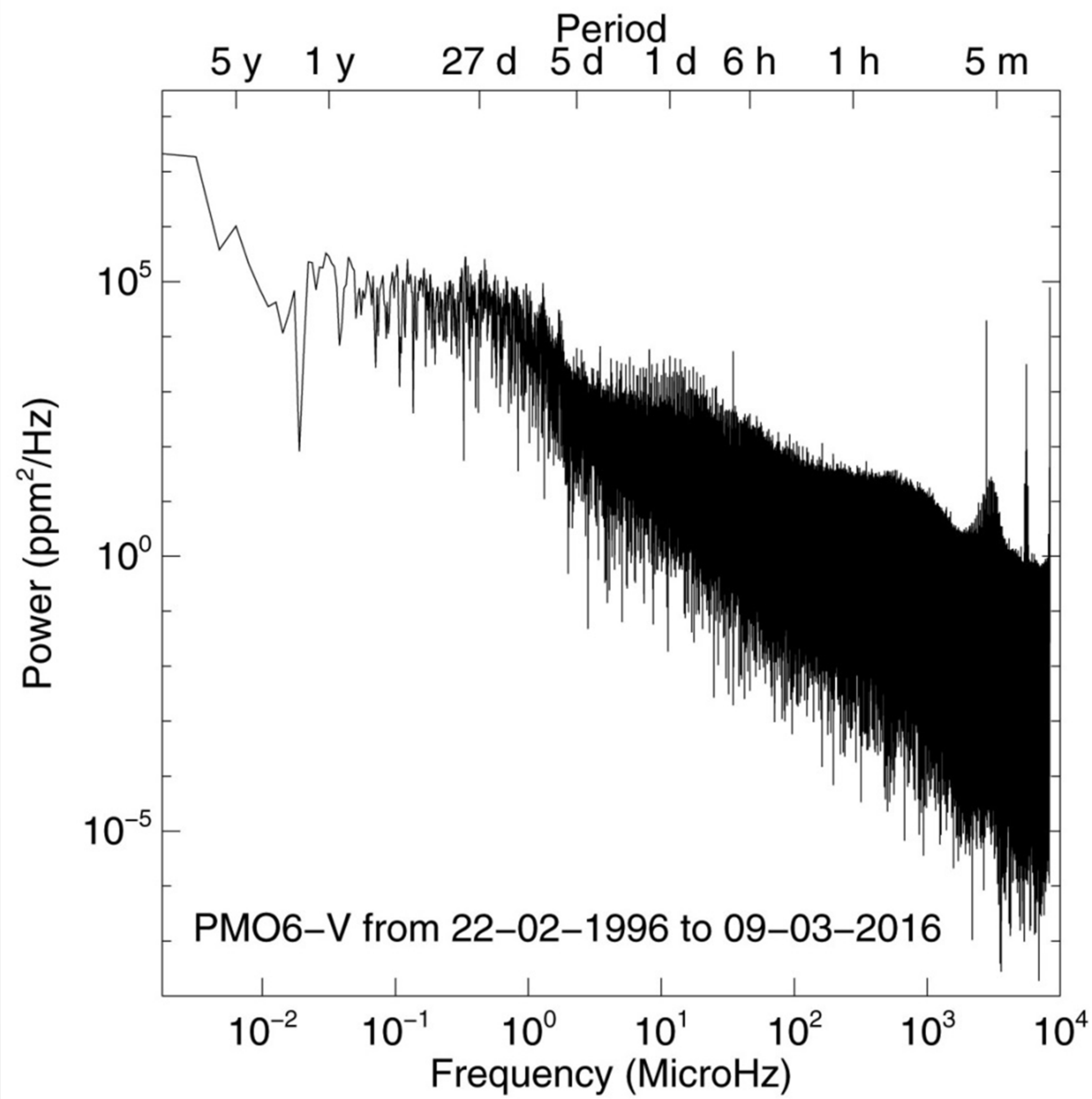
This is the most recent VIRGO TSI record up to May, 5. As we had some problems with the versions after August 2015 the last good is shown for comparison. The new scale is from a re-evaluation of the characterization of PMO6V and DIARAD which has an uncertainty of 0.2% (k=3). The new VIRGO value during the last minimum is fortuitously only 43 ppm below the SORCE/TIM value (average over period 2008/09/20 – 2009/05/05).

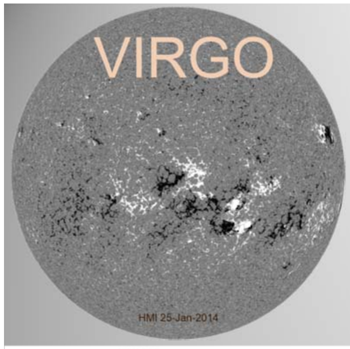




Some results

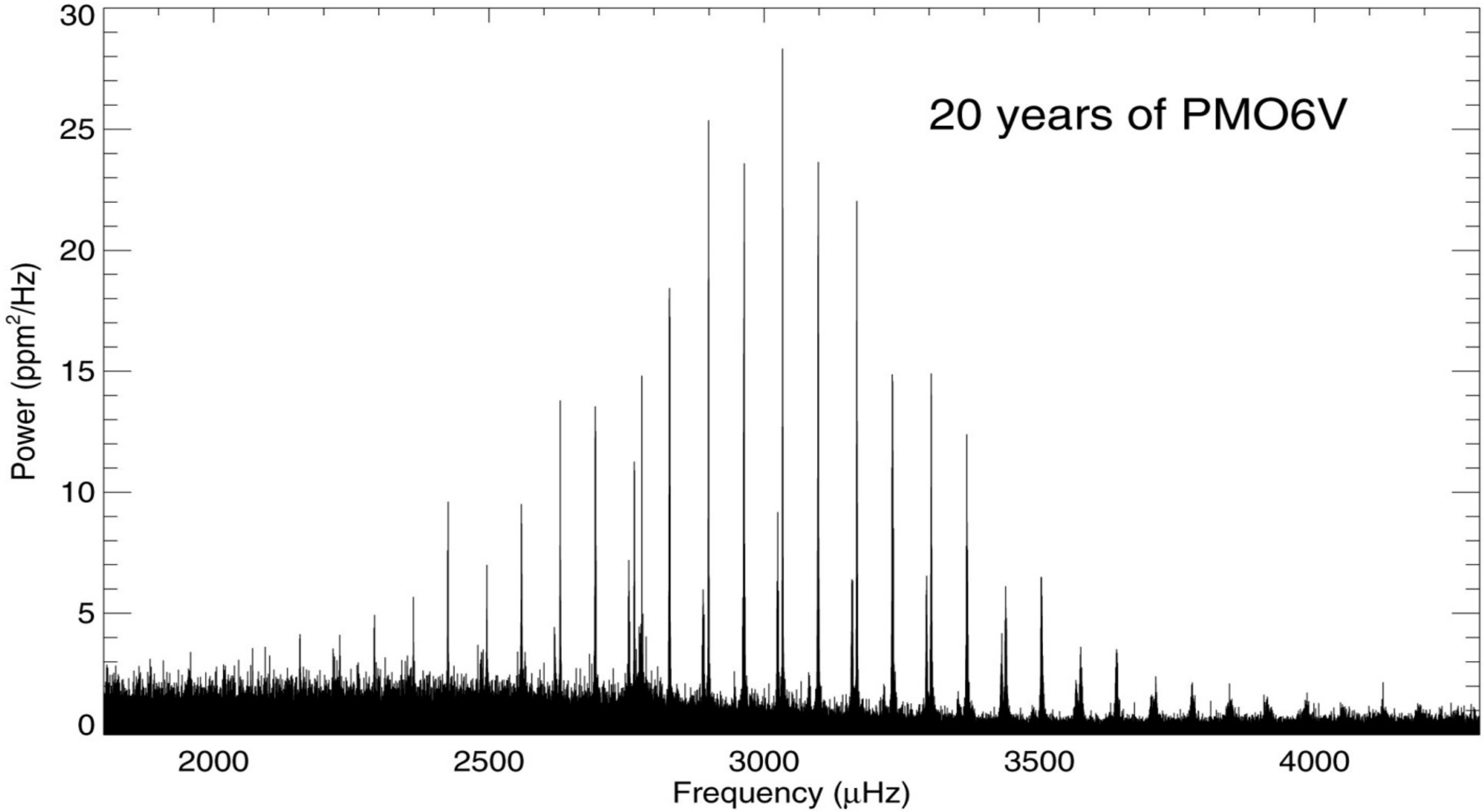
This is the power spectrum of the PMO6V 1-minute data. There are interesting features – some for obvious reasons, others not. The 3-minute peak is due to our basic sampling period as well as the 6-min peak in the middle of the p modes. The peak at around 8 hours is due to the period of the PMO6V closed measurements. The large bump above 1 hour is due super and the normal granulation and the bump around 1 day is unclear, but the one at 27 day activity related

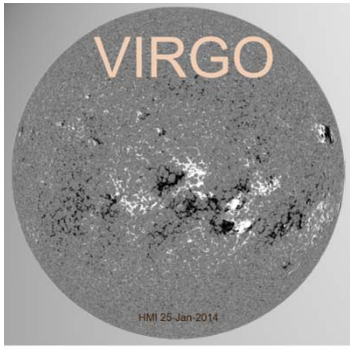




Some results

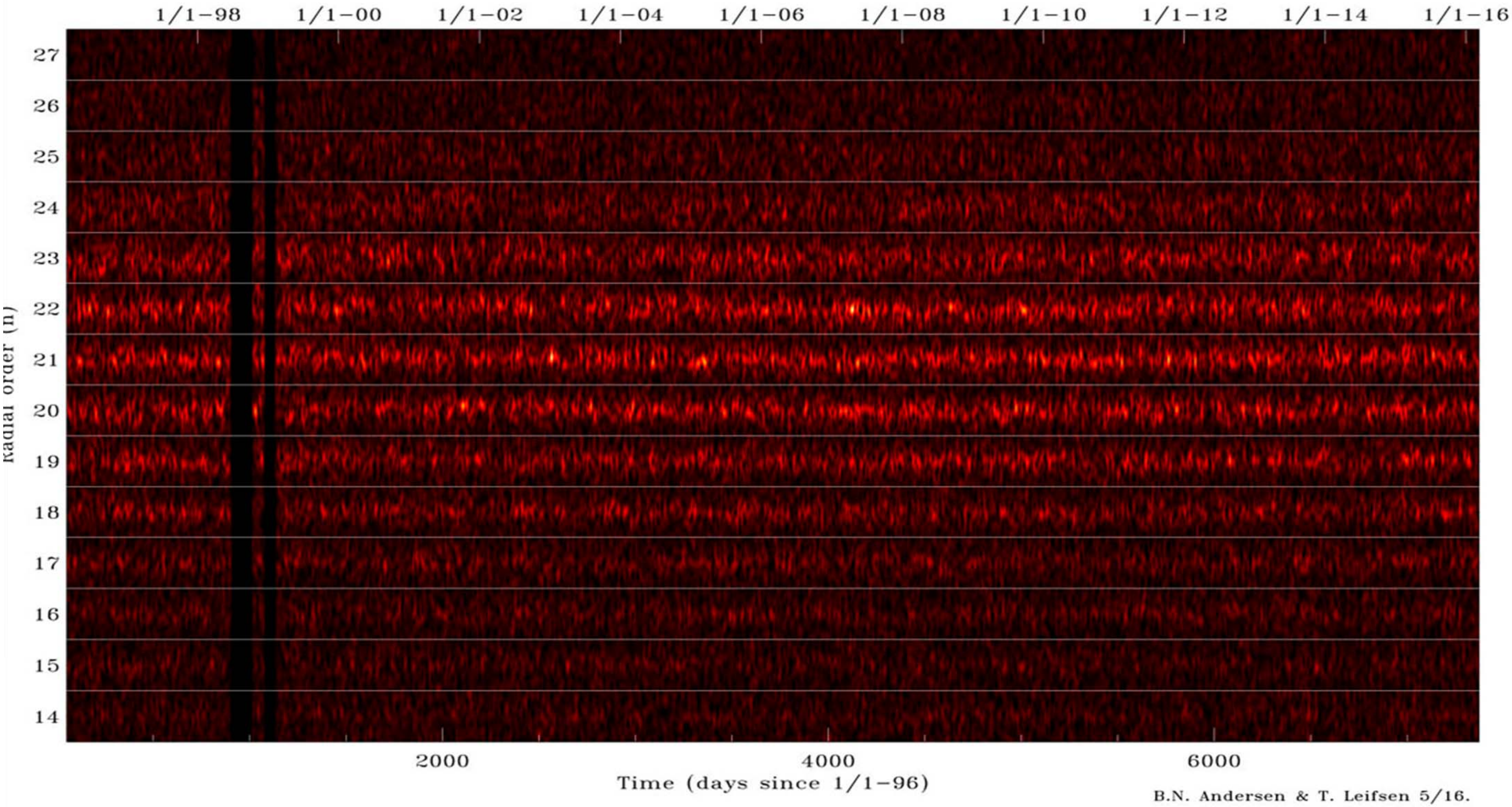
The p-mode spectrum is has more noise than the one of SPM or LOI but still reveal l=0,1 and 2 modes. The lines at 6 minutes (2777.77 Hz) are due to the 3-minute basic VIRGO acquisition period.

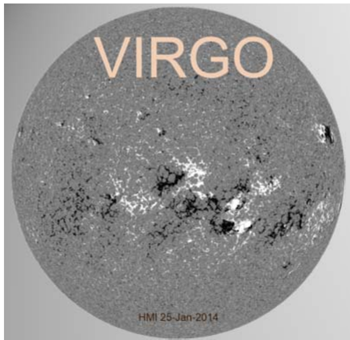




Some results

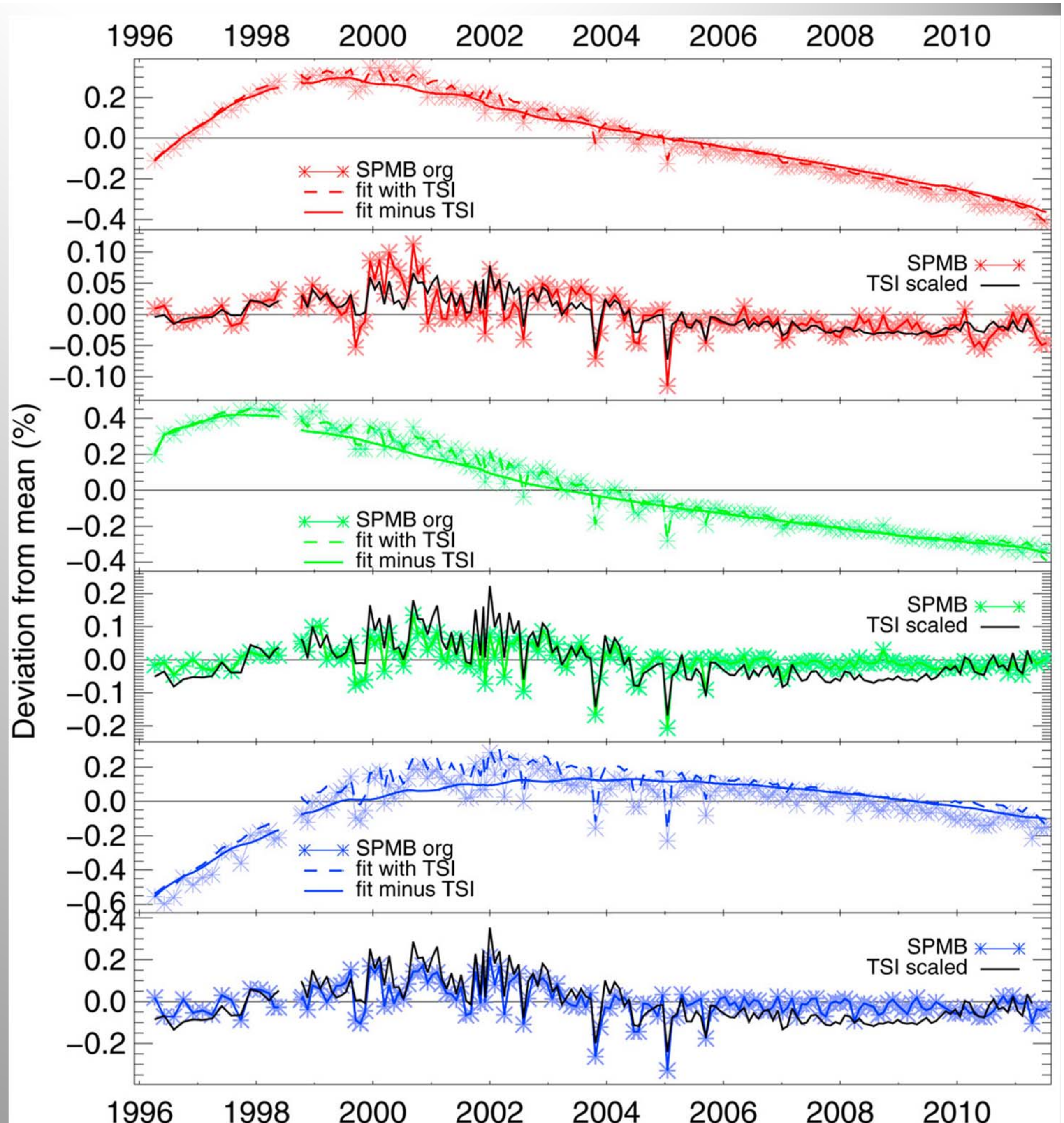
Time evolution of the l=0 modes from the PMO6V spectrum

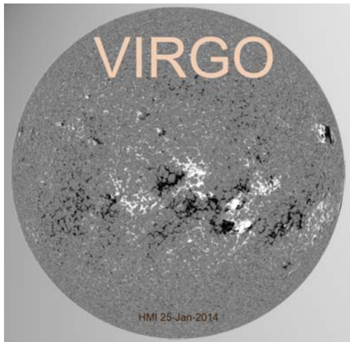




Some results

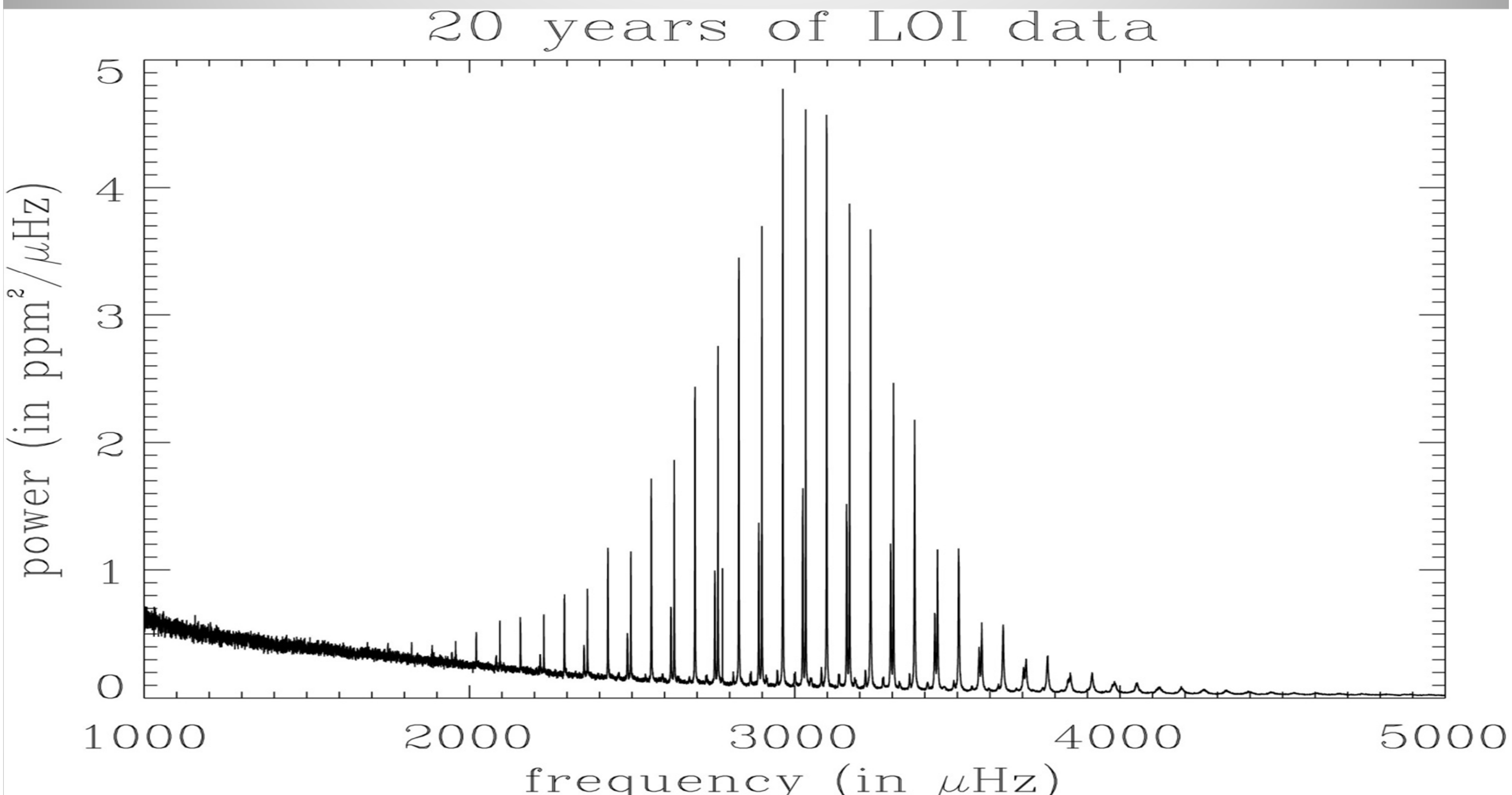
For the SPM-B, the less exposed, the degradation corrections are not so easy with the increase at the beginning and then the start of a kind of exponential decrease. The showed result looks promising, but is still far from really acceptable for the correction of SPM-A, mainly used for helio-seismology. More work is needed.

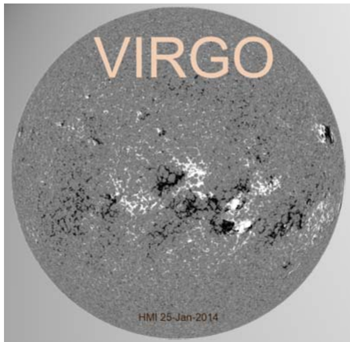




Some results

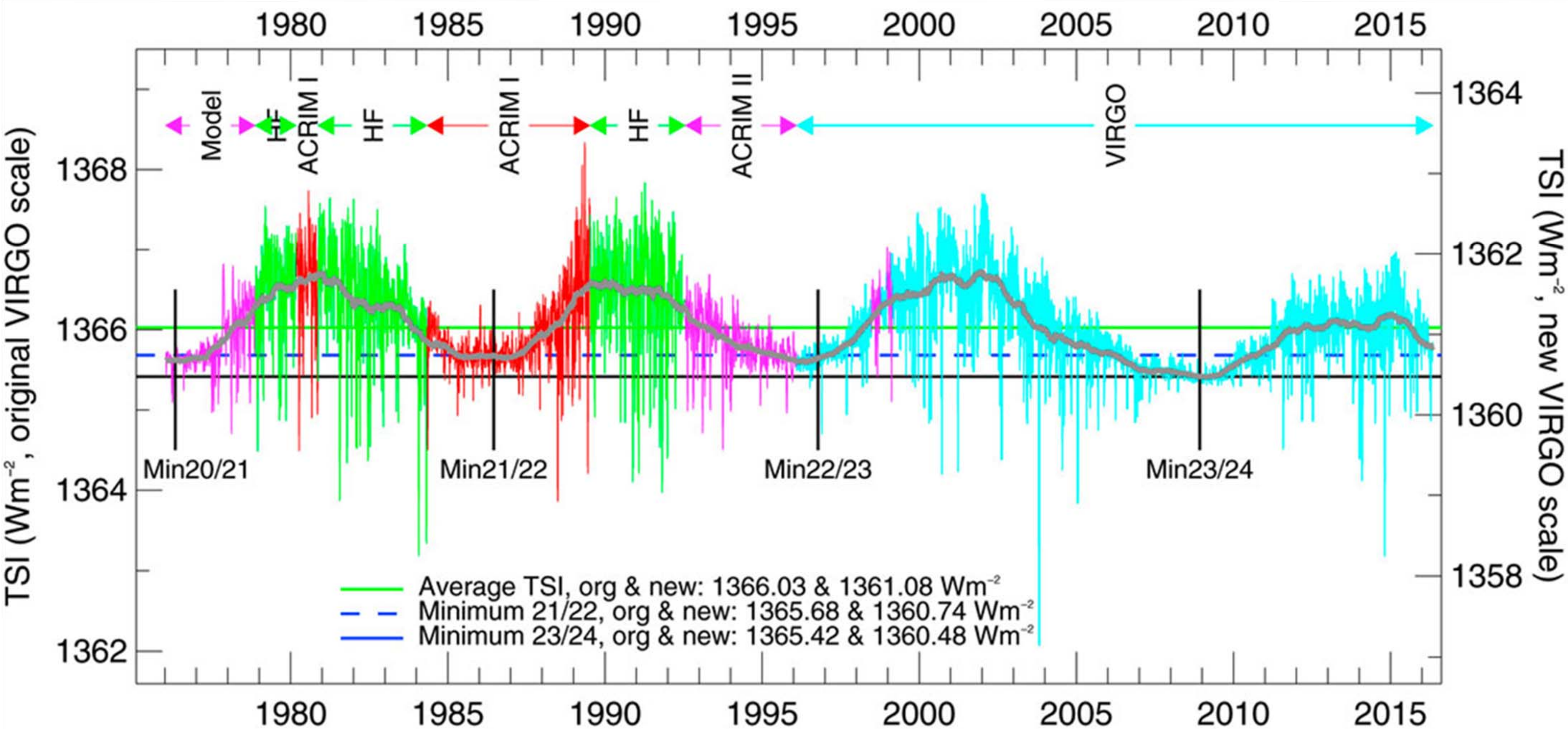
The LOI has a high signal-to-noise ratio and what is seen underneath the modes is solar noise, which is by itself interesting. As in the PMO6V spectrum the 6-minute disturbance is from the 3-minute acquisition period of VIRGO.

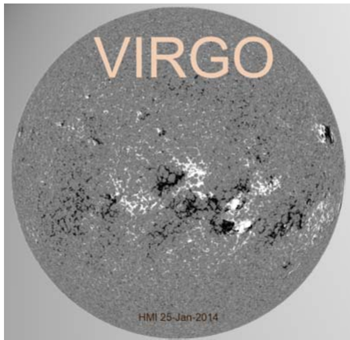




The so-called PMOD composite with half from VIRGO

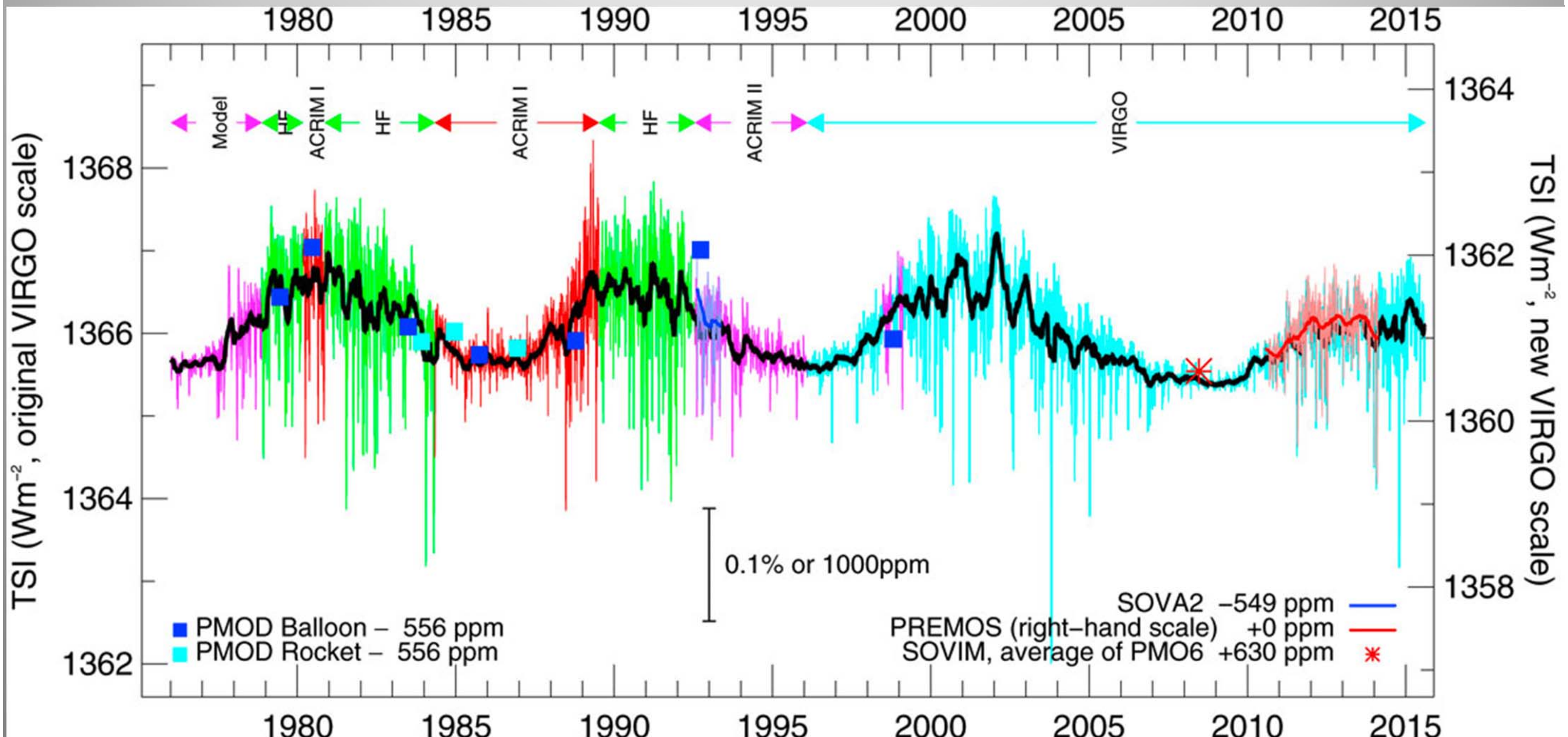
The most interesting result of the whole period is the low minimum in 2008. The only other experiment which covers also 2 minima is ERBS (not shown). That results confirm the difference between the two earlier minima after it is corrected for the early increase (total exposure of 2.7 days during 18.7 years in space)





Comparison of the PMOD/WRC TSI measurements since 1979

All the balloon, rocket and space measurements are well within the stated uncertainty of the PMOD radiometry of 0.17% (k=3). This is an important result of the last 40 years



SOHO-MDI – What Have We Learned?

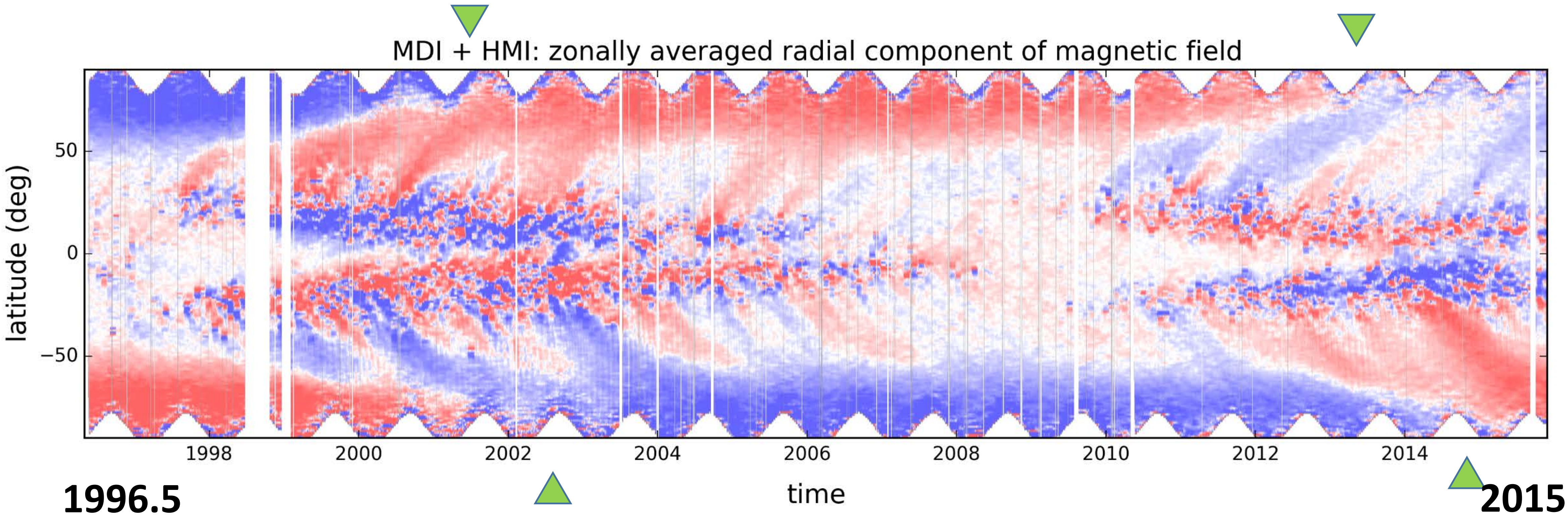
MDI was operated from spring 1995 to spring 2011, and a day in 2016.
In this time there were more than 2980 papers using the data, with 1945 of these in refereed journals.
There have been 1672 citations of the MDI instrument paper.

MDI collected:

- 2.59 million fulldisk magnetograms at a 96m cadence,
- 3.07 million full disk Dopplergrams in XX c. 2-3 month campaigns
- 7.40 million reduced resolution Dopplergrams at a 1m cadence.
- Associated data at 1 minute, 12 minute, 8-hour, cadences.

I will describe some of the findings.

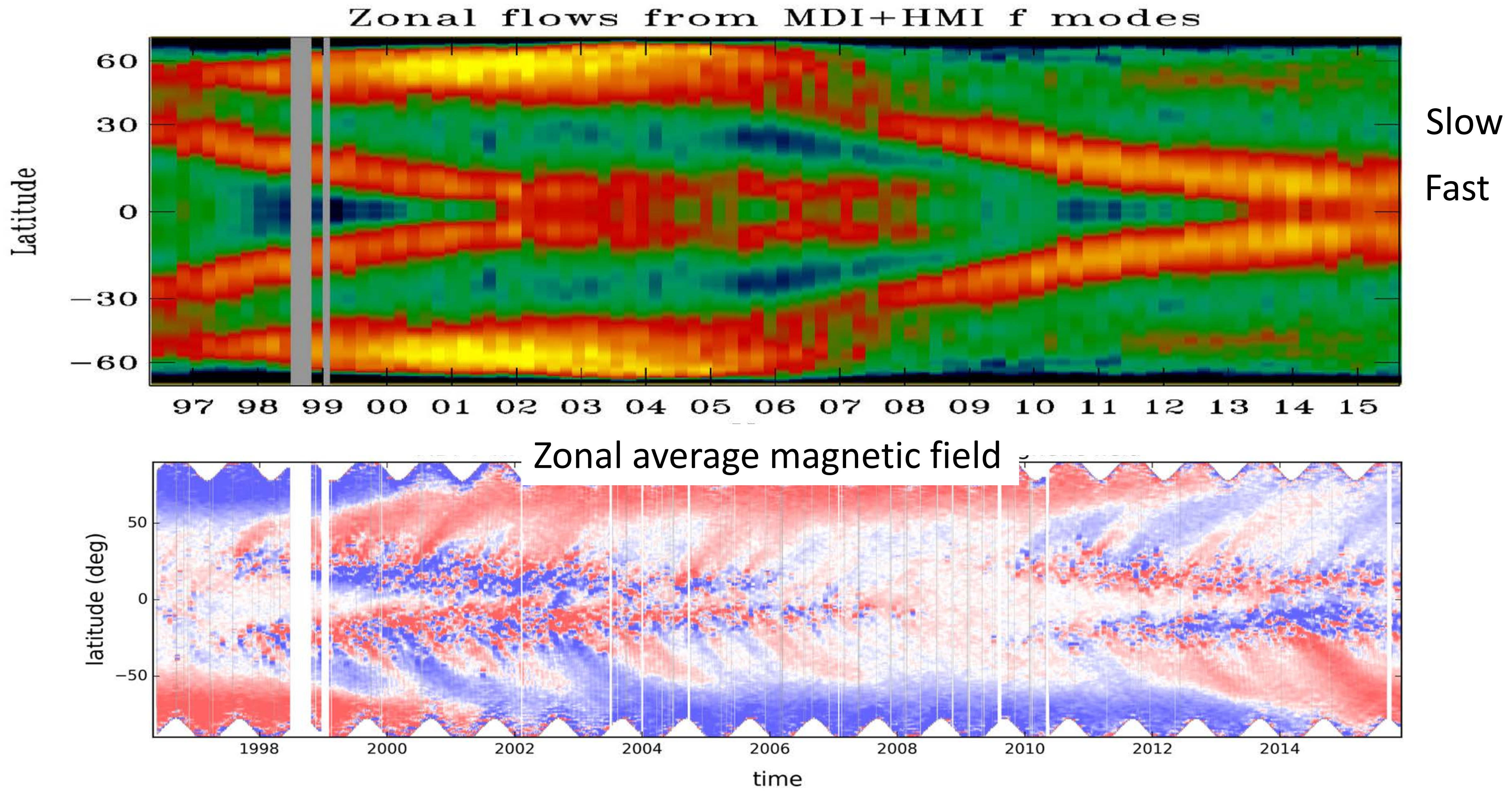
The Sun has Most Structure in Longitude, But Zonal Averages Provide a Useful View of Cycle Progression



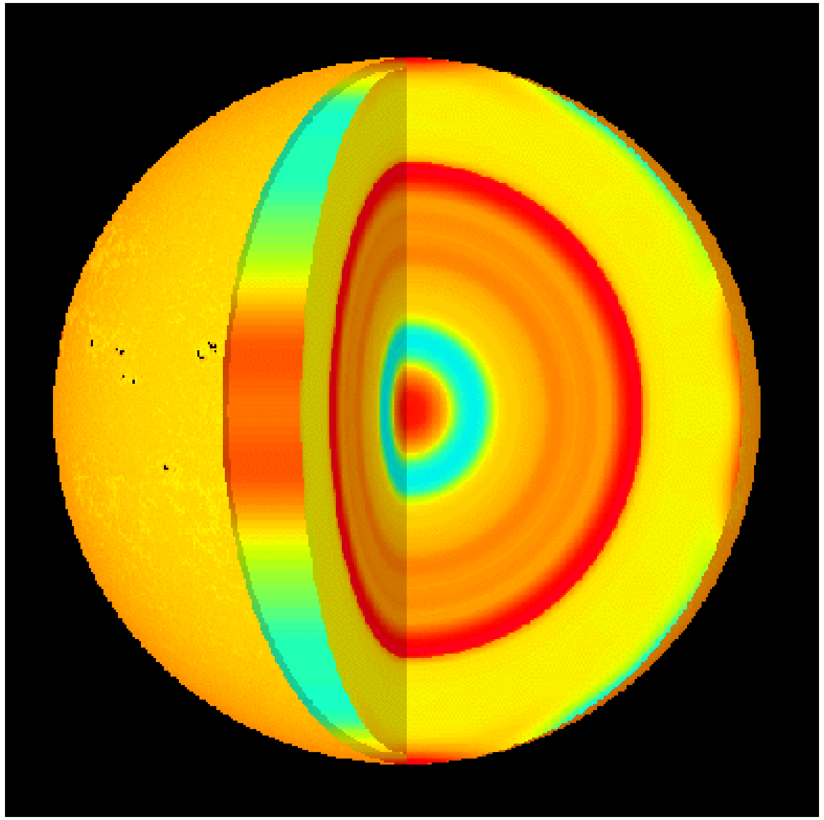
1996.5 **2015.9**

Polar field polarity changes are marked with green triangles
Colors scale from -6 to +6 gauss. HMI scaled up by 20%
HMI starts in May 2010. (HMI analysis: Sun & Bobra, 2015)

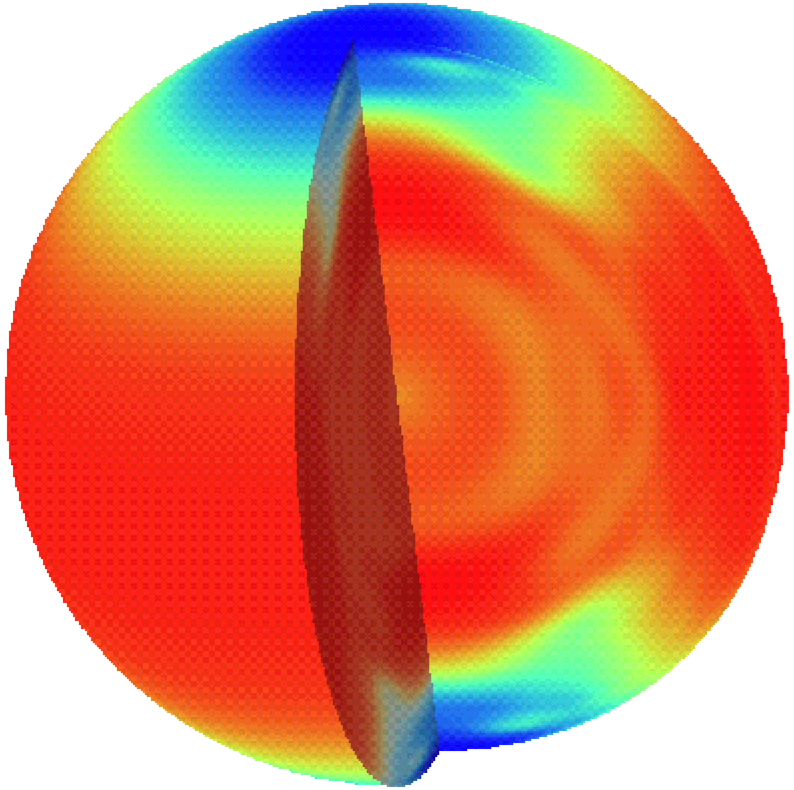
Residual zonal flows after removing smooth constant rotation curve



Global properties of the Sun's interior, e.g. sound speed and rotation can be measured with helioseismology

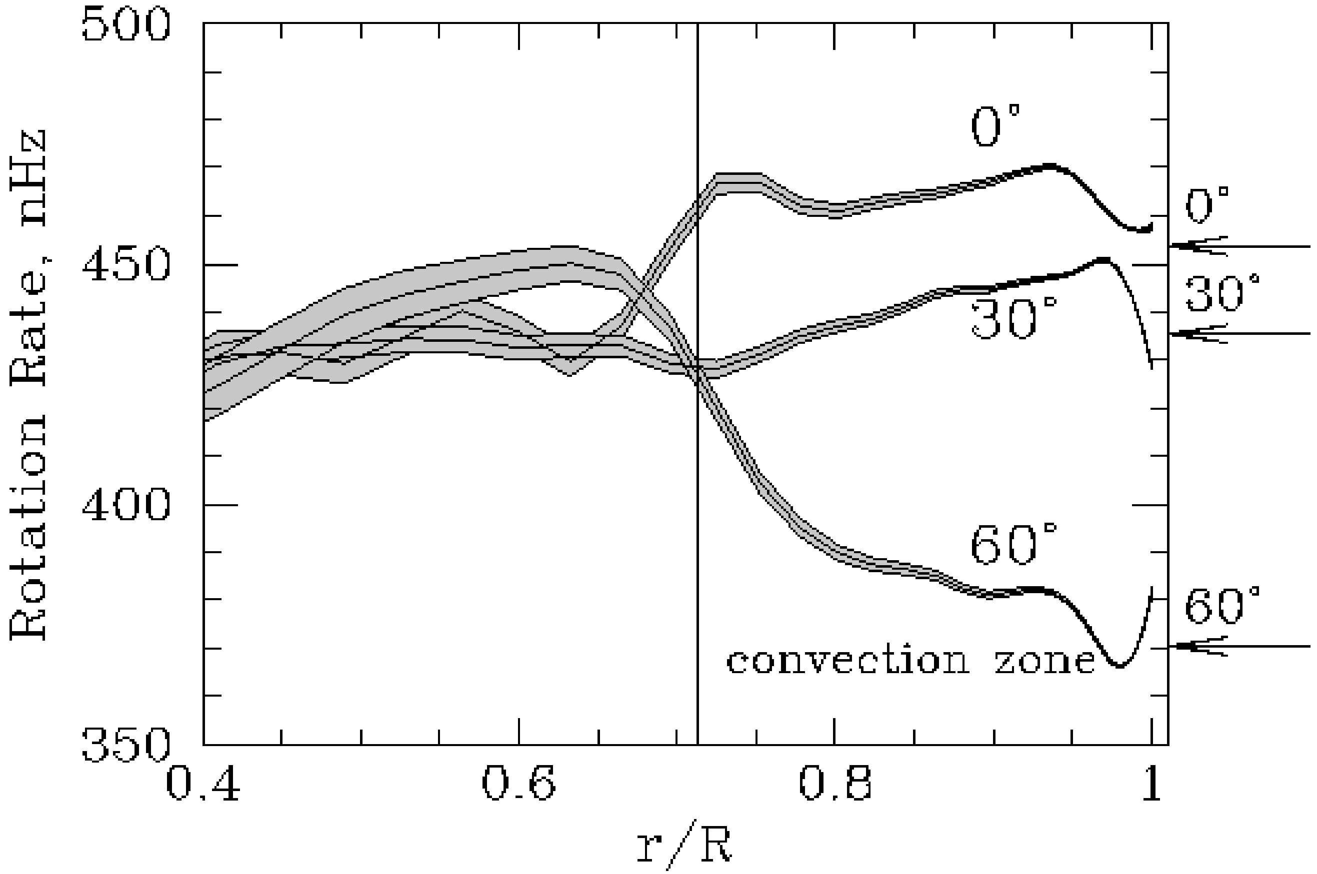


Sound speed difference from standard model of Sun. Red means Sun is "hotter" than expected by 0.2% at that depth.



Rotation rate, red faster, blue slower. Shear layers near bottom of convection zone and near surface.

Inferred Internal Rotation

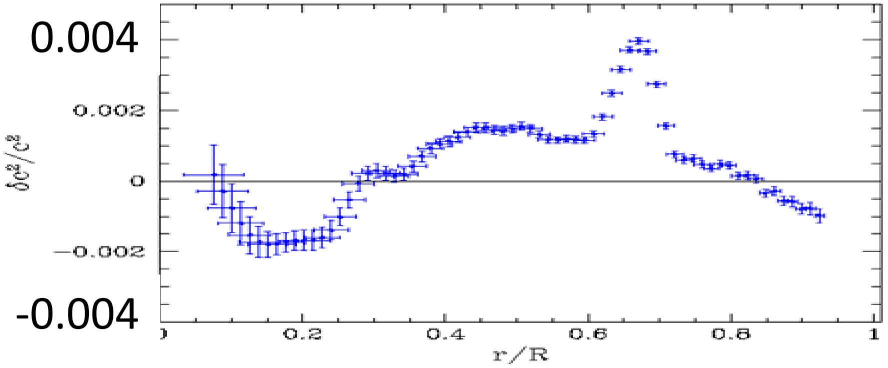


Bottom to top in Sun: The radiative zone rotates as "solid body", tachocline is shear layer that varies with latitude, differential rotation in convection zone, and a surface shear layer

The relative squared sound-speed deviations from Model S as a function of fractional radius

Old

0.004

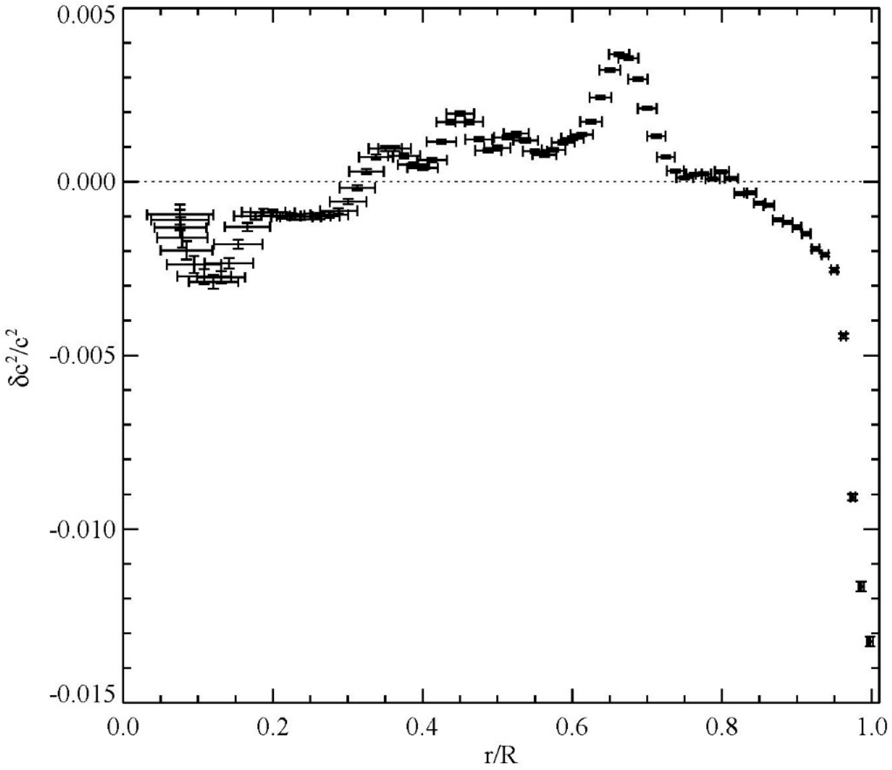


-0.004

0 r/Rsun 1

Decrease of sound speed compared to standard model is in the same region as the near surface shear layer.
Upper 5%.

New

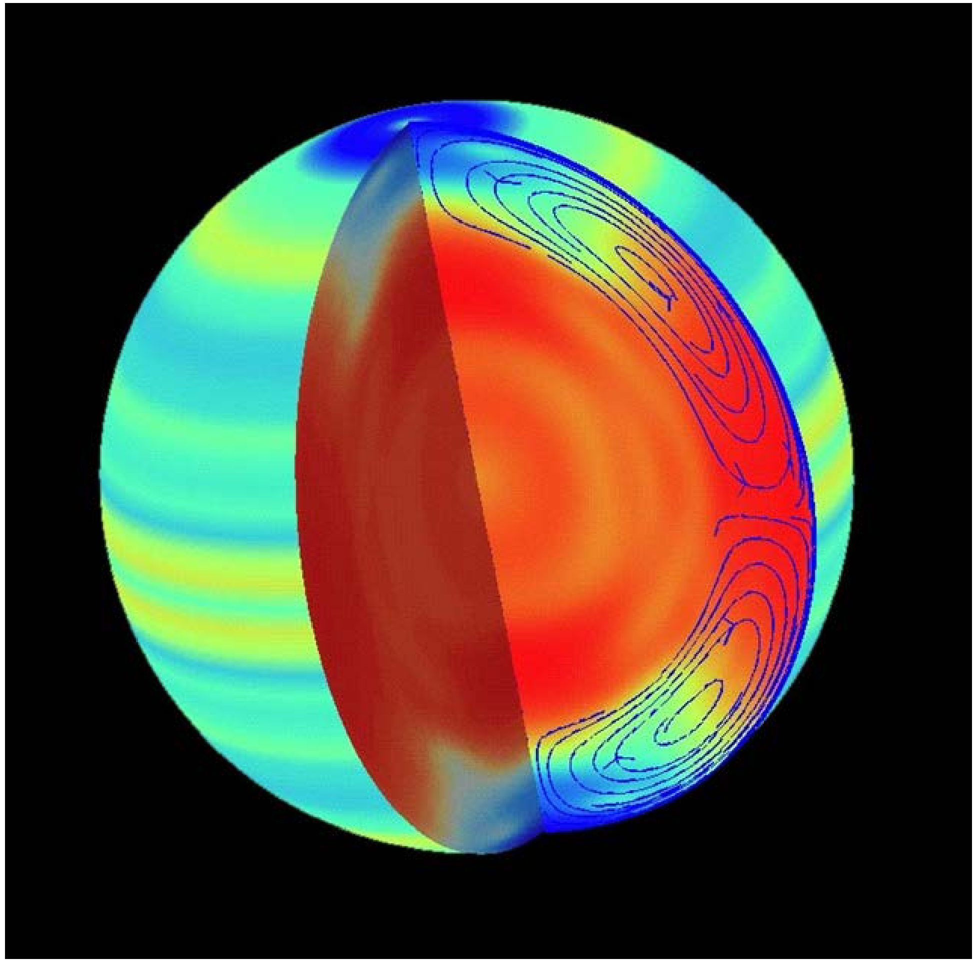


Reiter et al., ApJ 803:92, 2015

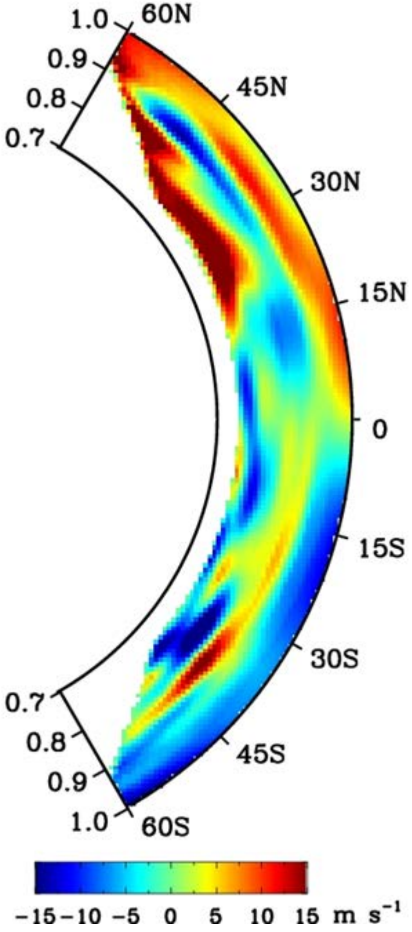
Implications for heat transport near surface, may indicate problems with standard mixing length theory.

MDI observations, Old from “medium-*l* modes” New from “high-*l* ridges”

Topic: Meridional Flow



Old View



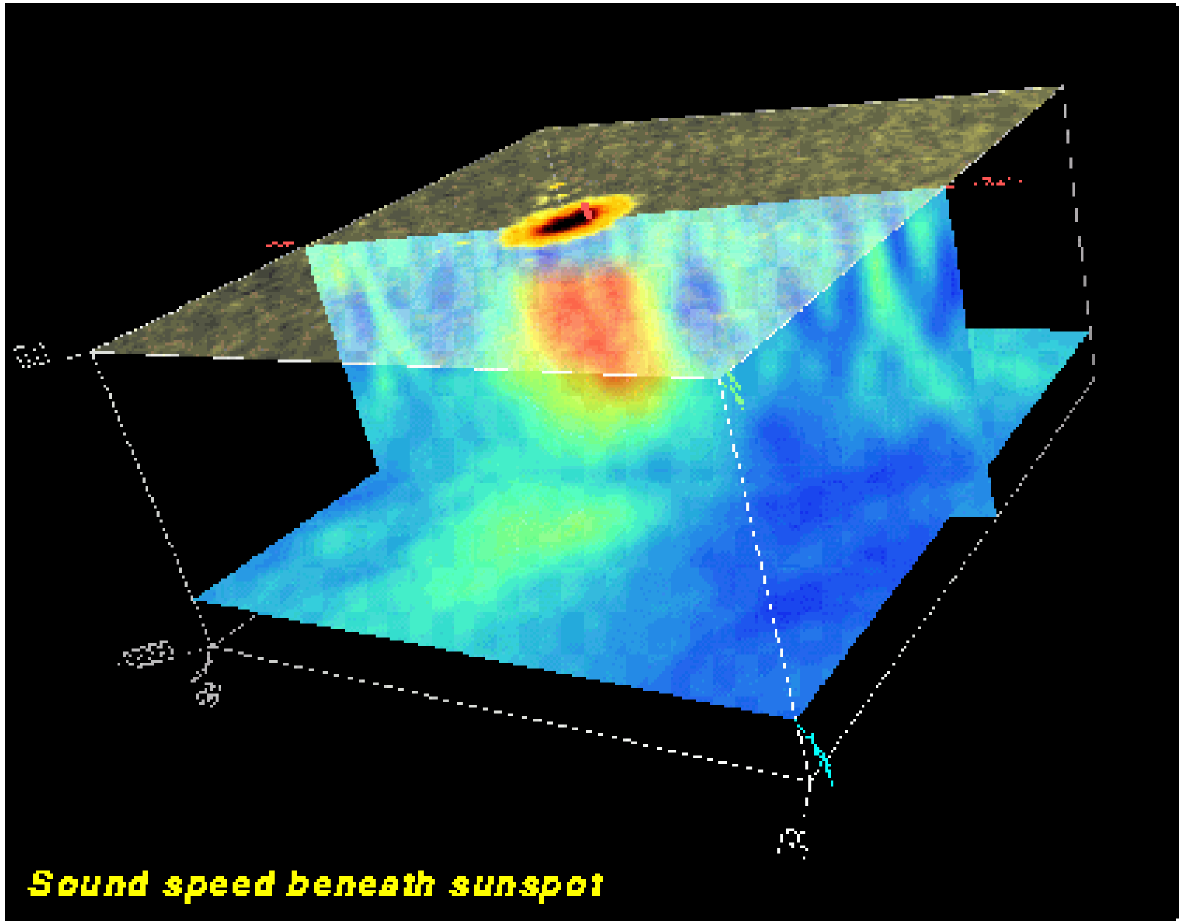
New View

Deep Time-Distance
Needs correction from center-to-limb phase variation.

Junwei Zhao, 2012

Topic: Local Area Helioseismology Example of Problems View of a Sunspot's Internal Structure

Image from two failed proposals: MDI for Triana, and Hale.

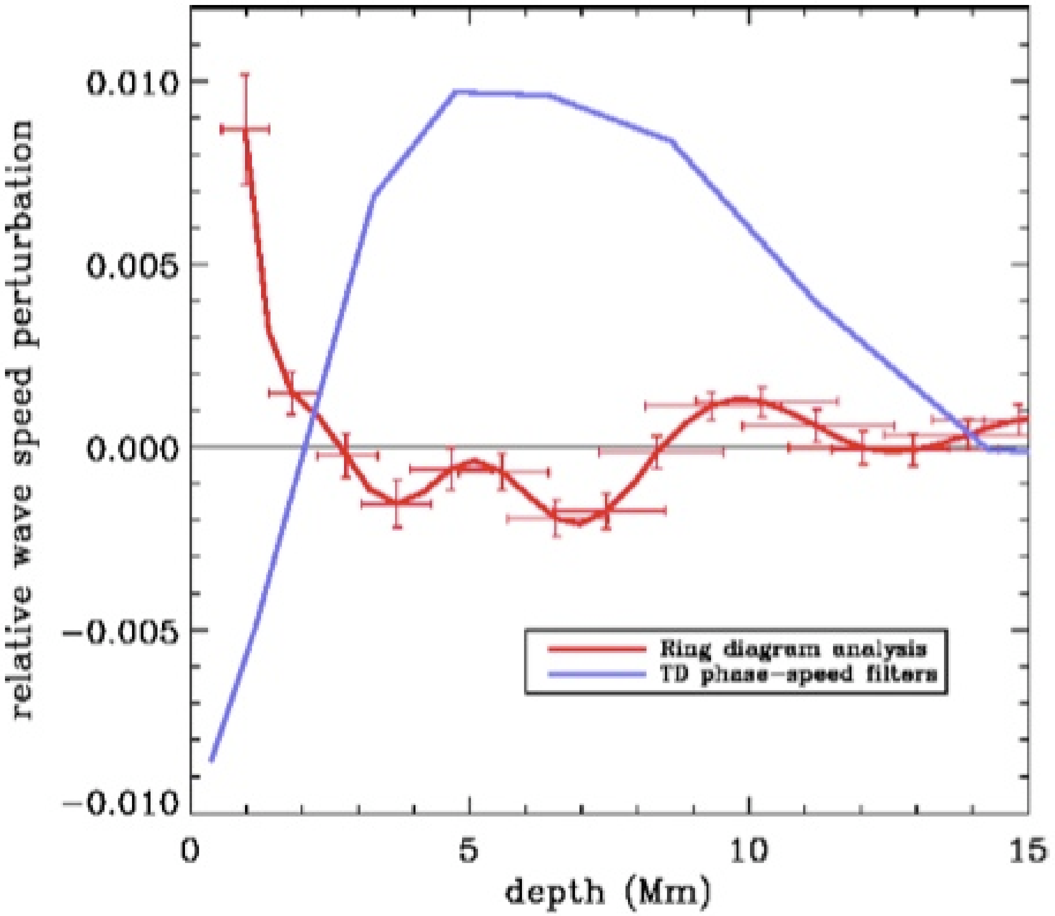


Sunspot data from MDI High Resolution, 18 June 1998

But, we now know this is not completely correct.

Red (fast) part OK, but Blue (cooler) part not OK.

Comparison between different techniques in sunspot



Comparison of two different local helioseismic methods used to infer wave speed perturbations below AR 9787. The red curve shows the averaged ring-diagram results, the solid blue curve shows the time-distance result, after averaging over the same area used for ring-diagram analysis.

We do not know how to do robust inversions where magnetic fields have perturbed the atmospheric structure.

Gizon, L., et al. 2009, Space Science Reviews, 144

“Local” Helioseismology - Successes and Issues*

Quiet Sun - seems to give robust results with all 3 methods giving similar results for near surface features. (Rings, Holography, Time-Distance)

- Farside Holography sees through the Sun to far surface.
- Supergranulation, zonal flows, meridional flows in reasonable agreement.
- Deep meridional flow profile detected. Time-Distance.
- Maybe giant cells. Rings,

Active Sun – So far all measurements made in or near magnetic fields are suspect.

- We need to learn how to do robust inversions in and near magnetic regions.
- Center-limb time-distance bias effect not understood
- Deep detection via time-distance not understood.
- There are research opportunities!!!

* *My opinions*.

Topic: The Future, My Opinion

Science goals not solved and space weather forecast and status requirements will need continued coverage.

SDO is six years old, SOHO is twenty.

SDO was launched when SOHO was ten.

For science and heliospheric coverage we need something like SDO at Earth's vicinity before SDO is old enough to vote.

AND something like STEREO with MDI-like Instrument sent in the "after" direction **each** three or so years at e.g. 30 degrees per year.

L-5 mission would be a good start.

20 Years of SUMER Observations

scientific highlights
lessons learned

Werner Curdt on behalf of the SUMER Team

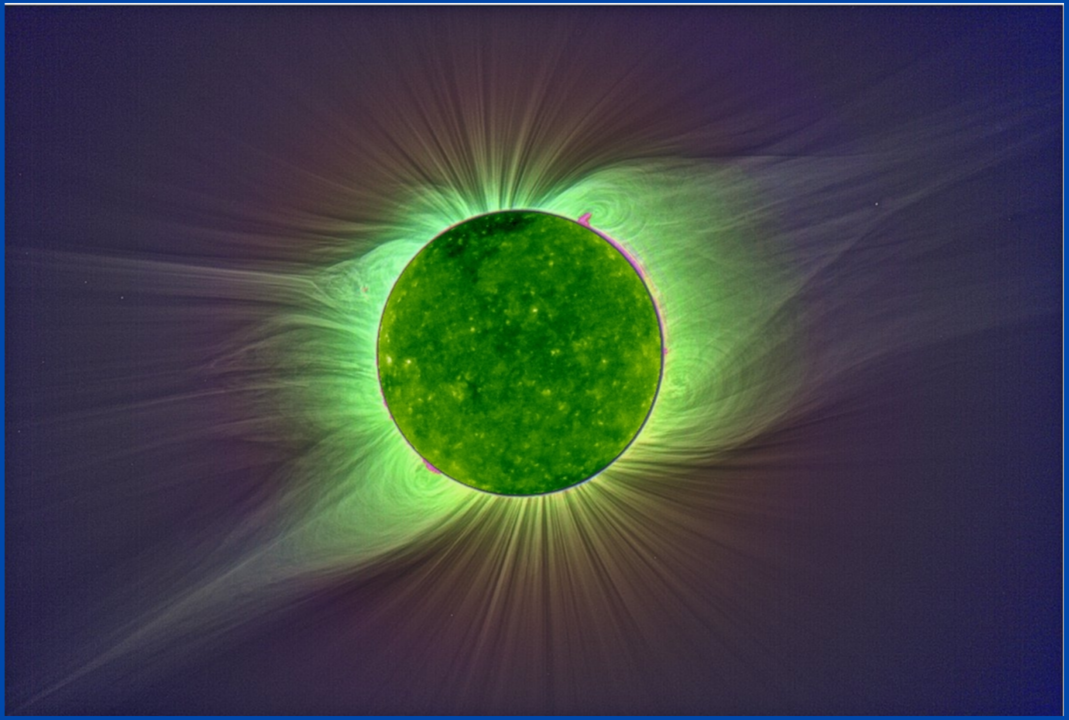
Outline:

- The team
- Selected highlights
- Highlight details
- Lessons learned
- Legacy
- Instrument Status

The team:

Wilhelm
Curdt
Marsch
Schühle
Lemaire
Gabriel
Vial
Grewing
Huber
Jordan
Poland
Thomas
Kühne
Timothy
Hassler
Siegmund

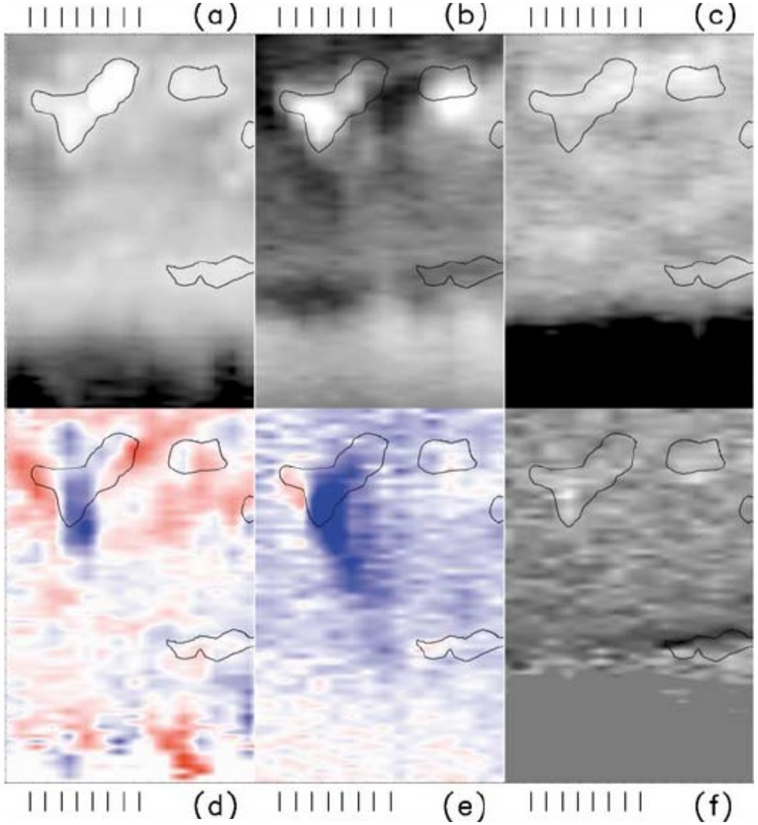
Selected highlights: plumes, interplumes, polar jets



Total eclipse observed on Aug 1, 2008

Pasachoff, Rušin, Druckmüller et al. 2009

Jet and whirling motion in coronal hole

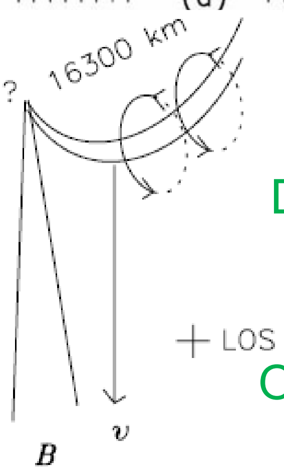


(a, d) C IV
(b, e) NeVIII
(c, f) Si II

Radiances and Doppler shifts

LOS speeds: +/- 30 km/s

Spectra: A to H

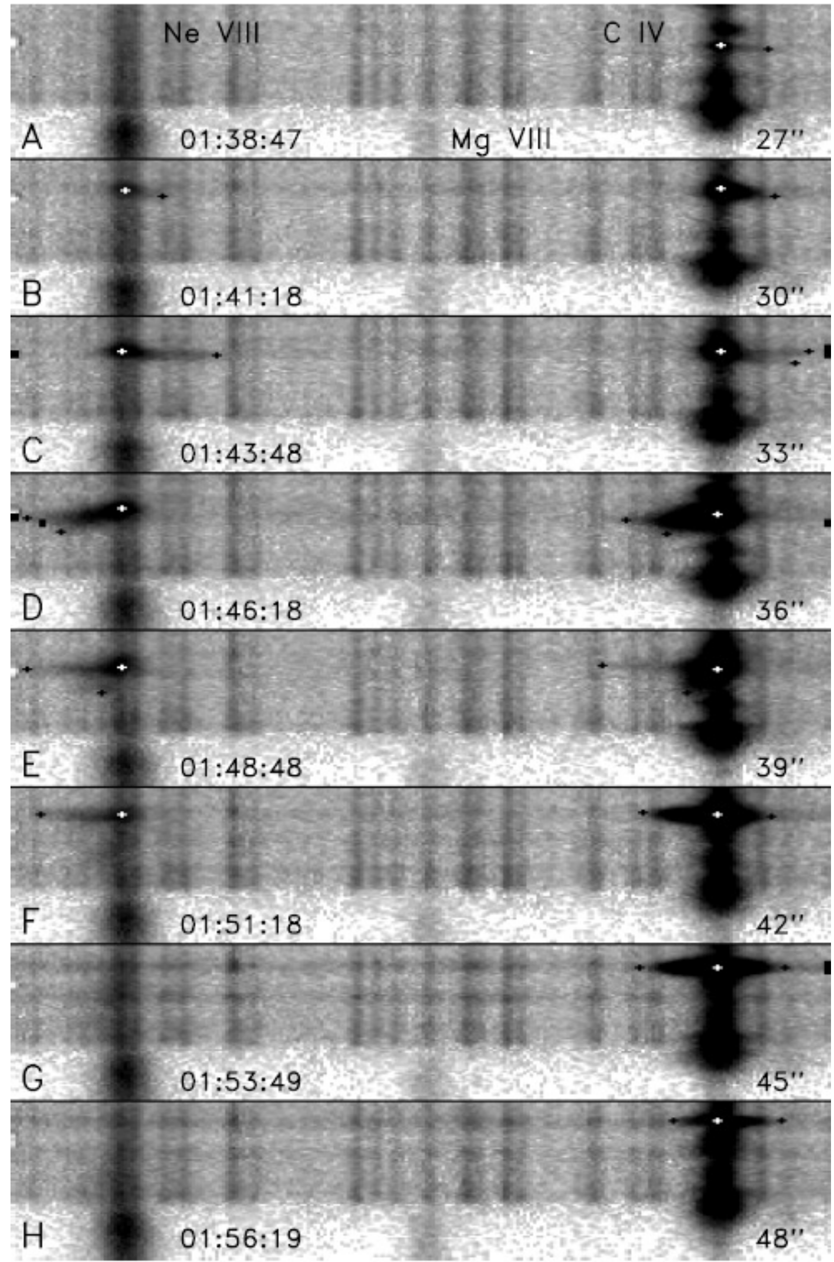


K. Wilhelm, I.E. Dammasch, D.M. Hassler, ApSS, 282,189 (2002)

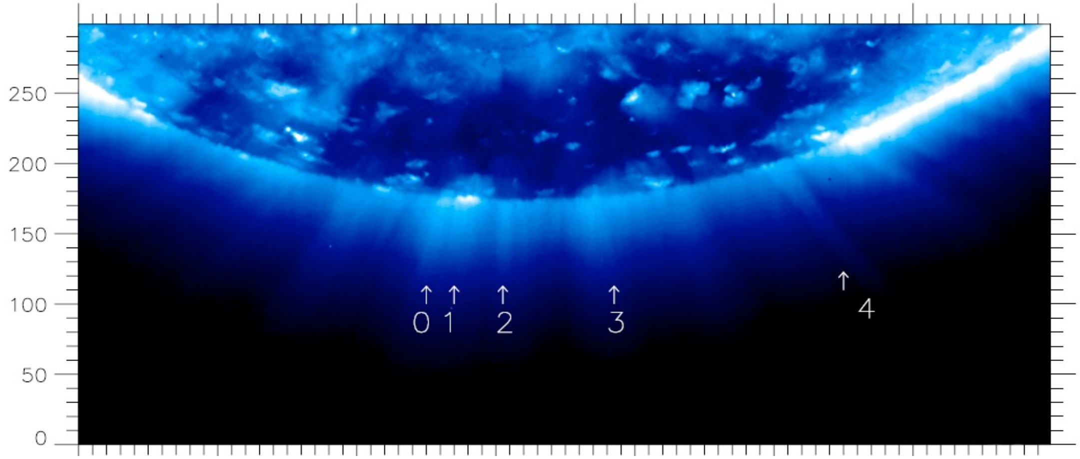
Solar limb

Oblique spectral events (B. Rompolt, Solar Physics, 41, 329, 1975)

77 nm (second order) 154.8 nm

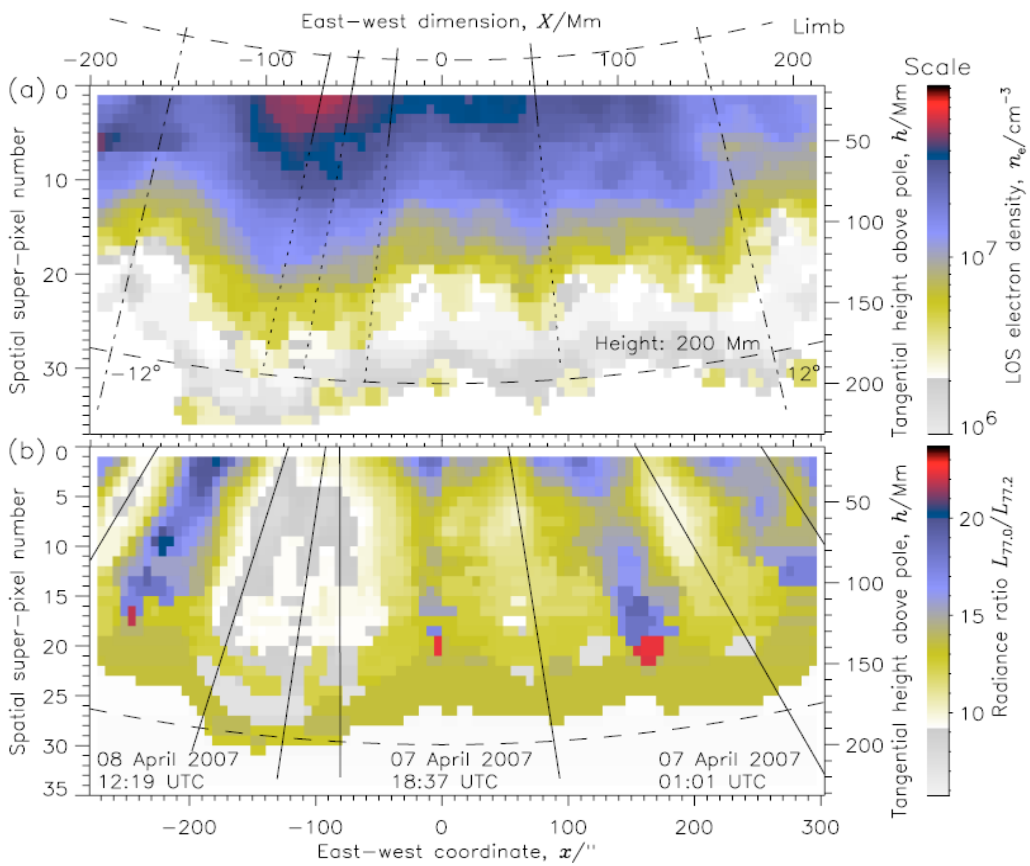


Polar Coronal Plumes and the FIP Effect



Southern coronal hole seen by EUVI/STEREO at 17.1 nm (< 1 MK) (7 April 2007; 22:07 UTC)

Density and abundance diagnostics with SUMER on SOHO:



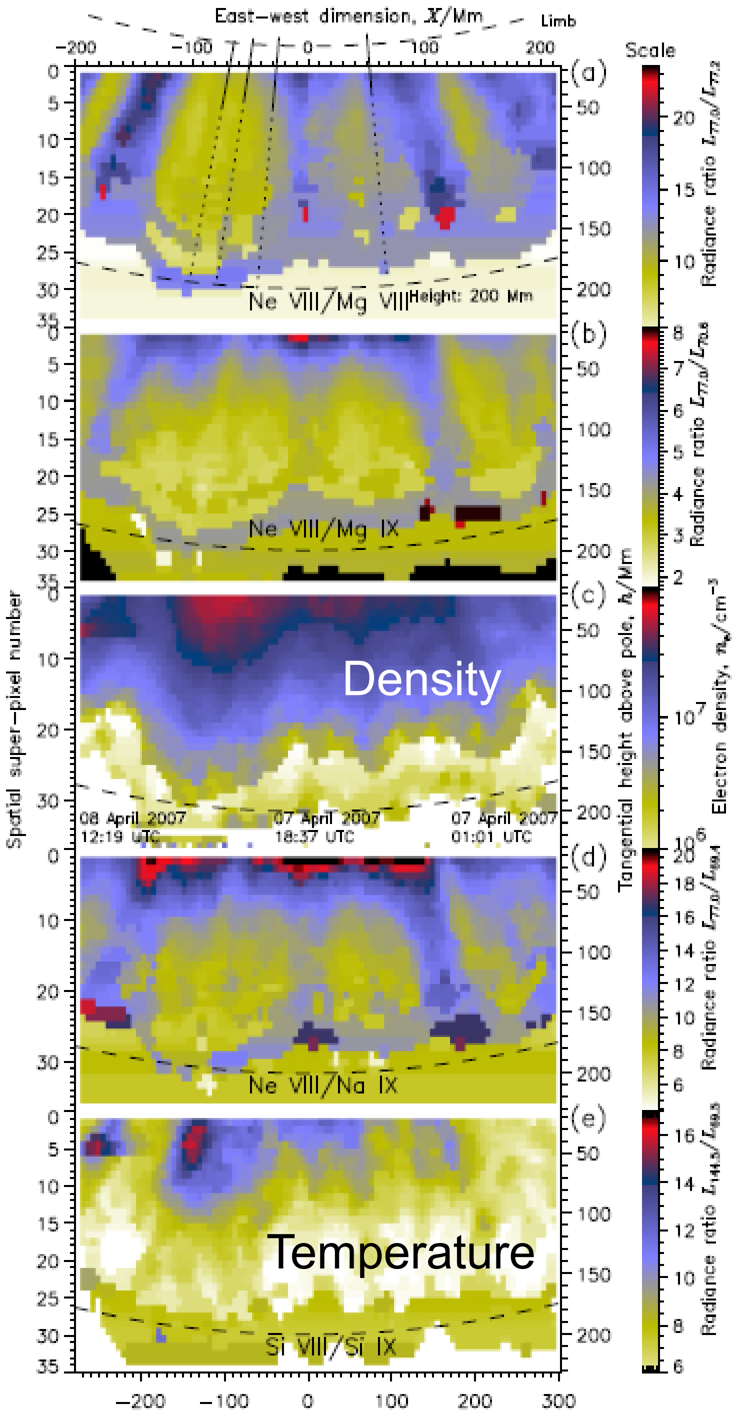
Density from Si VIII line ratio

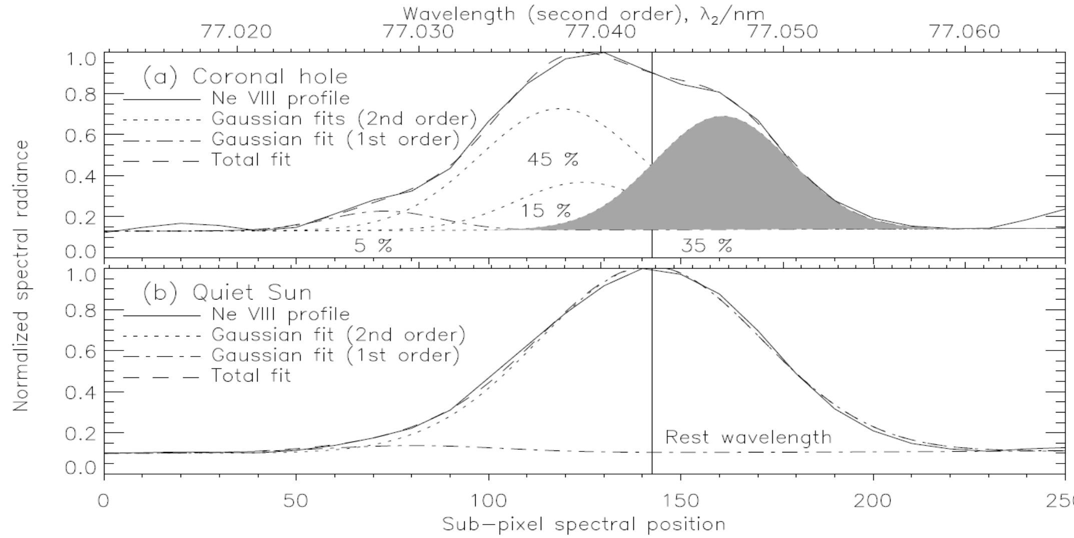
Abundance from Ne/Mg line ratio indicating a strong FIP effect. Low first-ionization potential elements are enhanced over high FIP elements in plumes (details in next viewgraph). FIP values: Na 5.1 eV ; Mg 7.6 eV Si 8.2 eV ; Ne 21.6 eV

W. Curdt, K. Wilhelm, L. Feng, S. Kamio, A&A, 481, 61 (2008)

Solar coronal plumes and the fast solar wind

FIP effect





a Counter-streaming Ne+7 ions in coronal holes:
45 % (blue) 19 km/s; 35 % (red) 15 km/s (LOS)
15 % (blue) 14 km/s (IPR?); 5 % 1st order blend

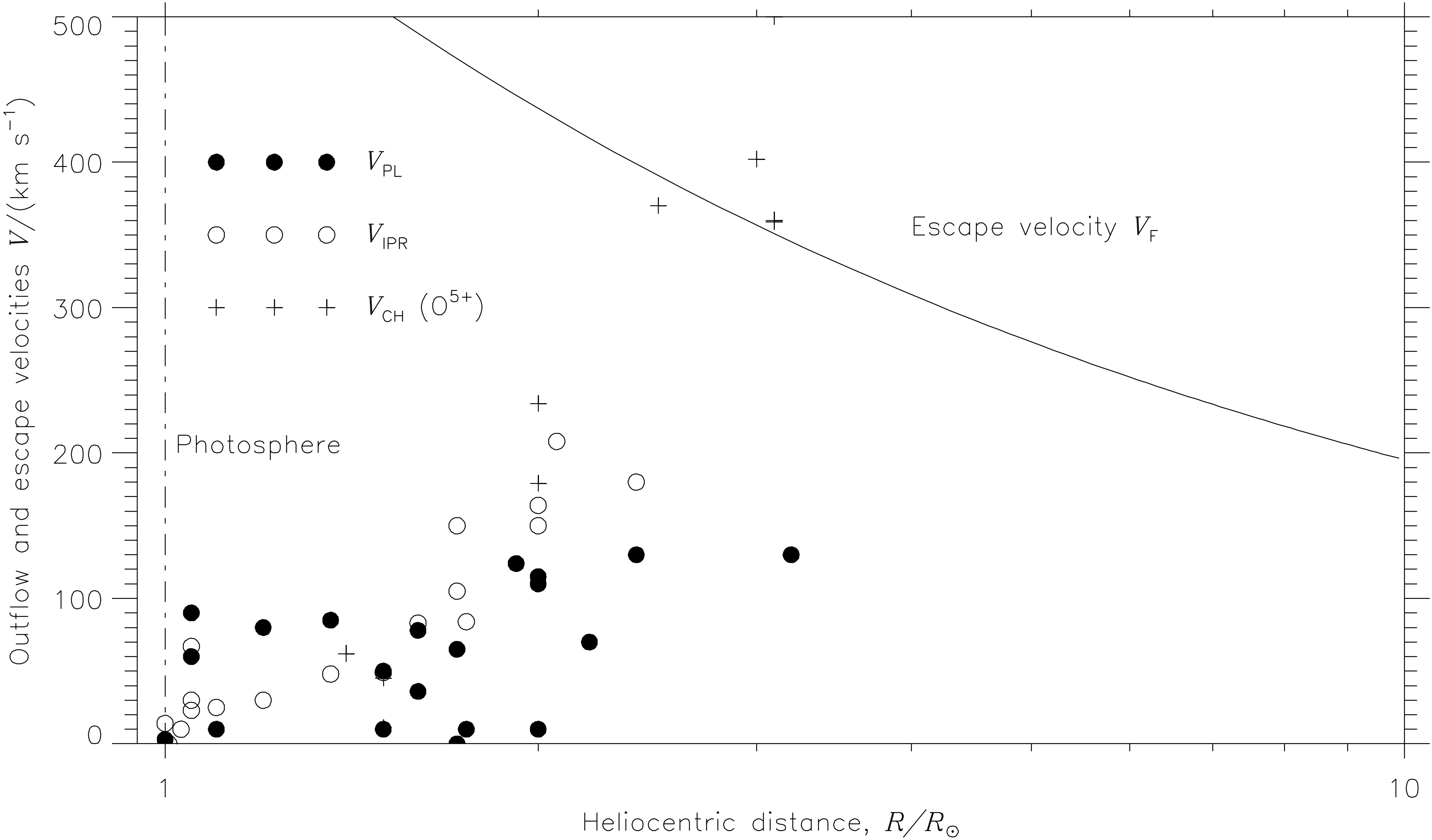
b Gaussian profile of Ne VIII line in quiet-Sun regions

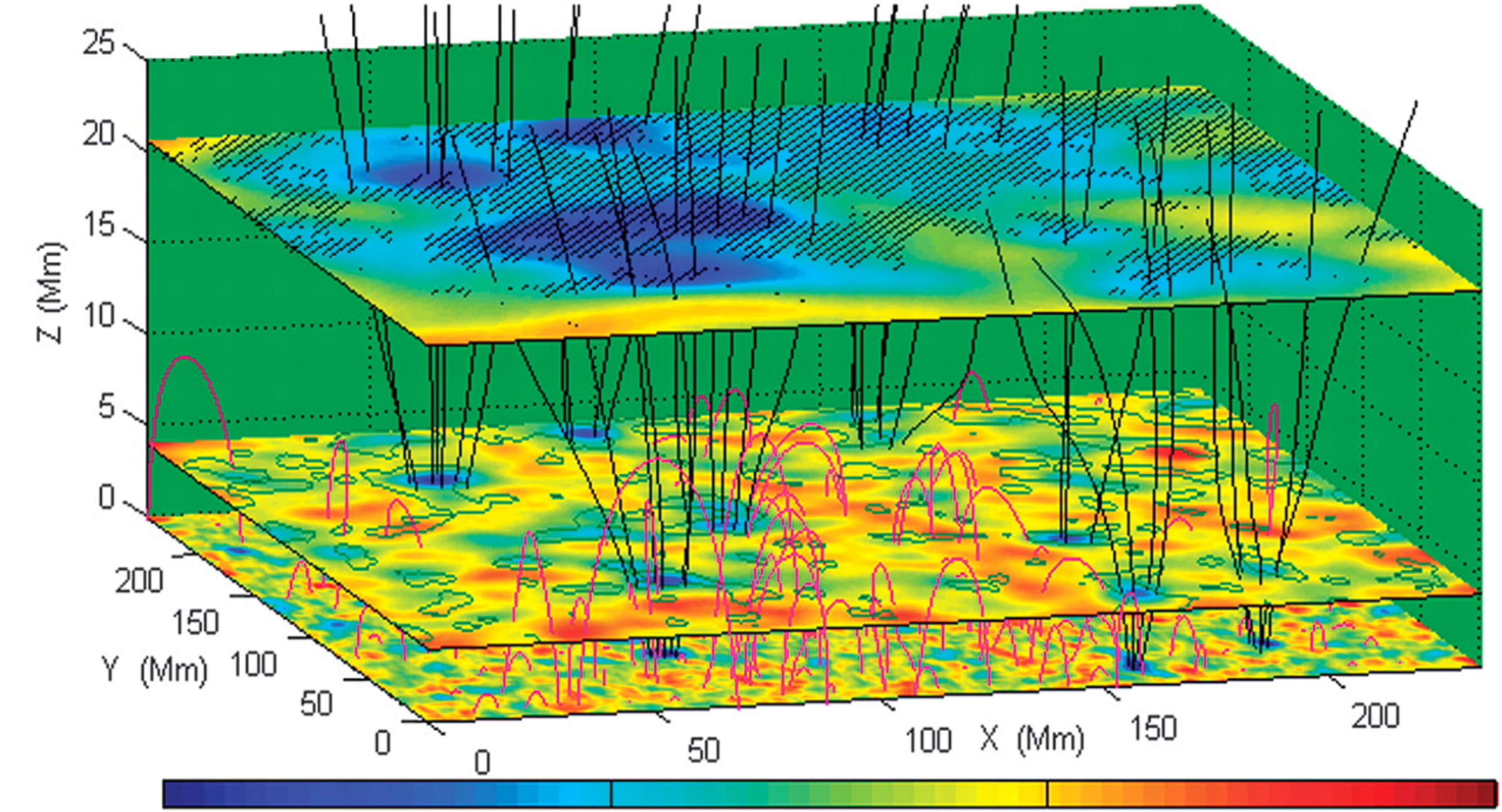
I.E. Dammasch, K. Wilhelm, W. Curdt, D.M. Hassler, A&A, 346, 285 (1999)

B.N. Dwivedi, K. Wilhelm, ApA, 36,185 (2015)

Outflow Speeds in Plumes and Inter-plume Regions

UVCS and SUMER observations as well as model calculations





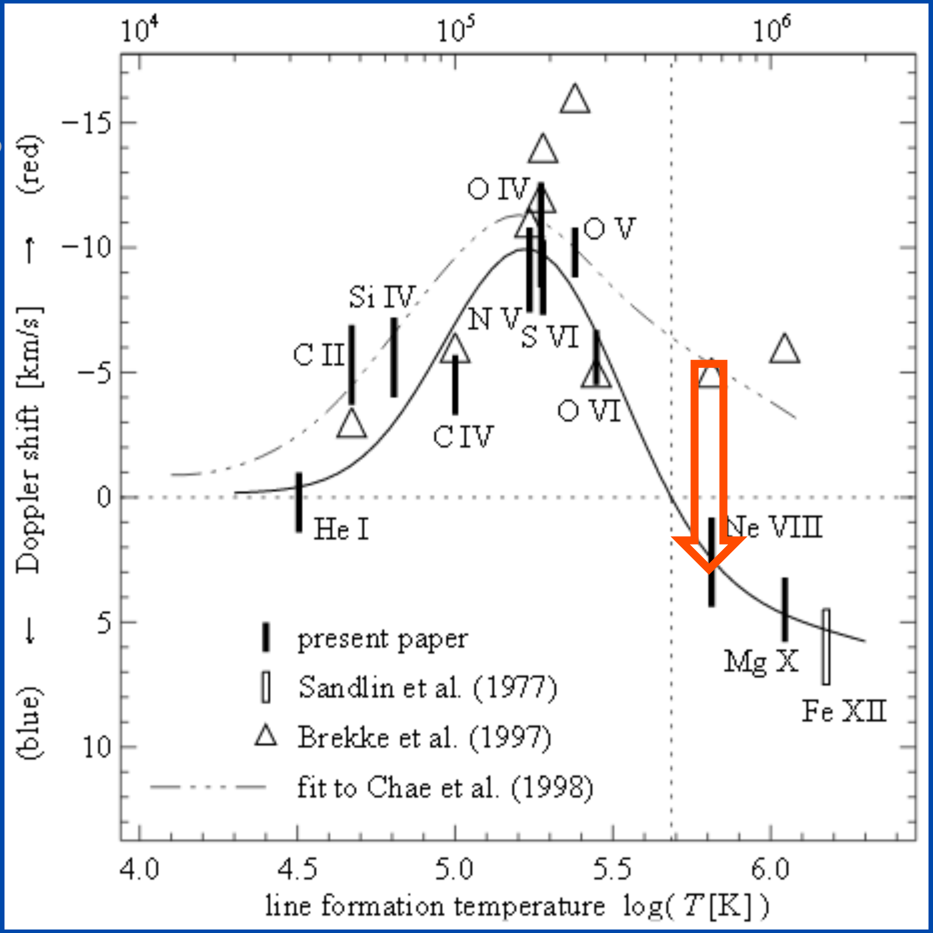
Z=0 Mm 100 G 50 G 0 G -50 G
Z=4.0 Mm 40 G 20 G 0 G -20 G
Z=20.6 Mm 8 G 4 G 0 G -4 G
Contours at 4 Mm indicate the 80% level of Si II radiance;
Shaded regions at 20.6 Mm denote where Ne VIII Doppler shift<-7 km/s.

Tu, Zhou, Marsch, Xia et al. 2005

Selected highlights:

plumes, interplumes, nascent solar wind

rest wavelengths



770.428 Å ± 3 mÅ (1 σ)

Brekke, Hassler, Wilhelm et al. 1997

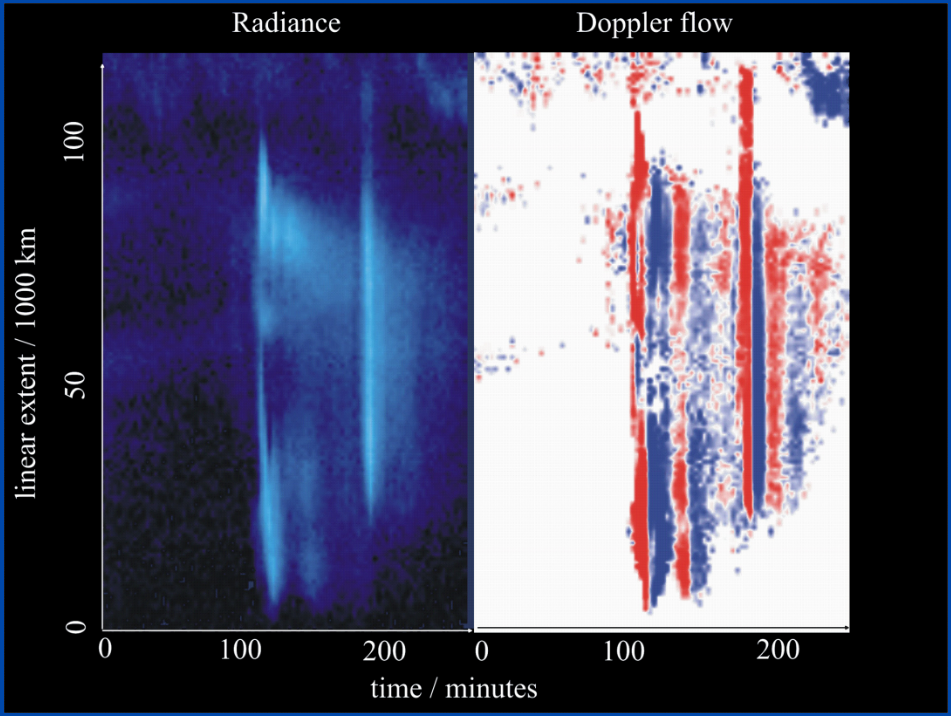
Peter, Judge 1999

Dammasch, Wilhelm, Curdt, Hassler 1999

Wilhelm, Curdt, Dammasch, Hassler 2008

Selected highlights:

plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscillations

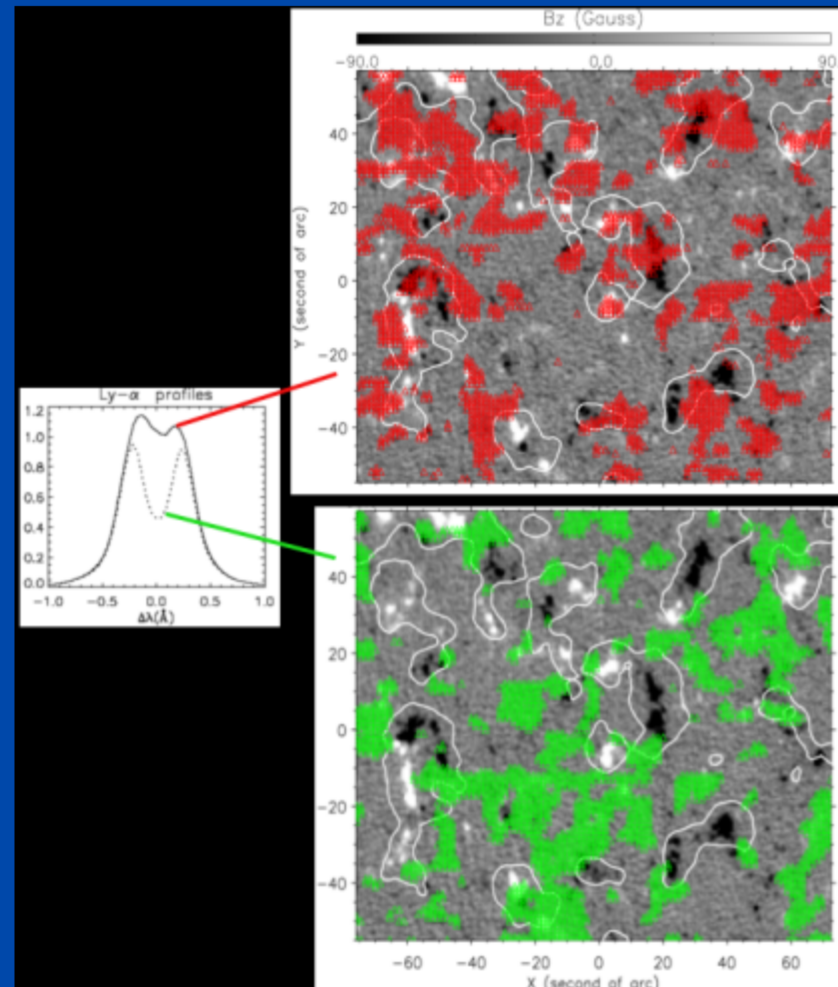


coronal seismology

Kliem, Dammasch, Curdt, Wilhelm 2002
Wang, Solanki, Innes et al. 2003
Curdt, Wang, Dammasch, Solanki 2003

Selected highlights:

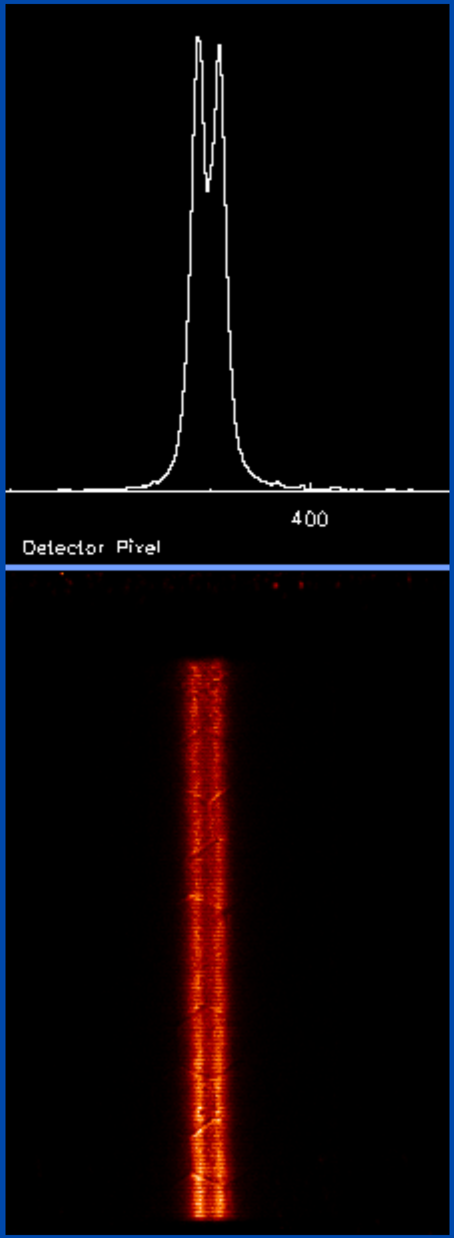
plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscillations
Ly-α profiles



Curdt, Tian, Teriaca et al. 2008
Tian , Curdt, Marsch, Schühle 2009

Selected highlights:

plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscillations
Ly-α profiles
full disk Ly-α / β



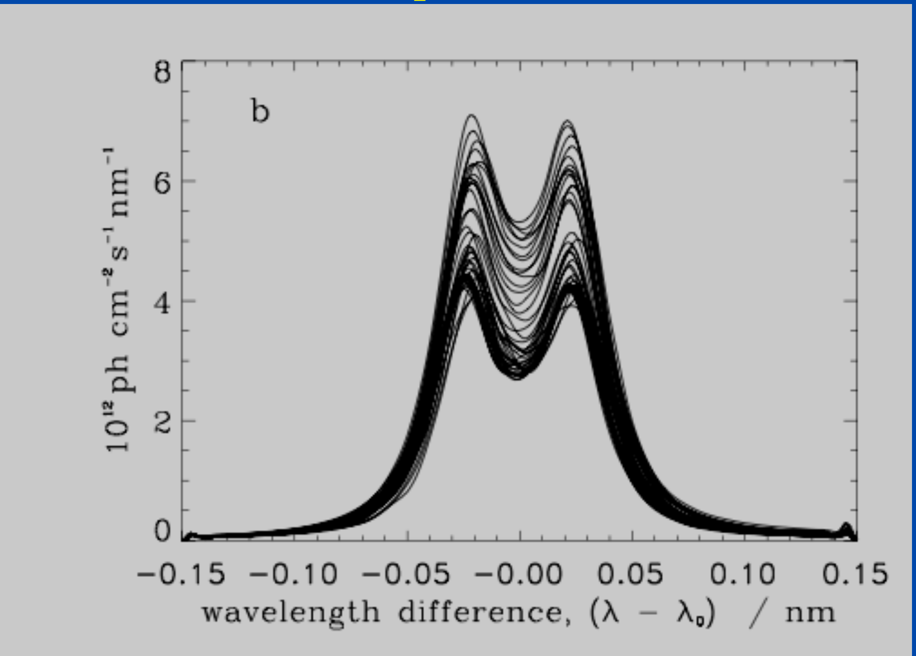
‚Sun as a star' - programme

cycle variation *Lemaire, Emerich, Vial et al. 2002*
flare observation *Lemaire, Gouttebroze, Vial et al. 2003*
catalogue *Lemaire, Vial, Curdt et al. 2015*

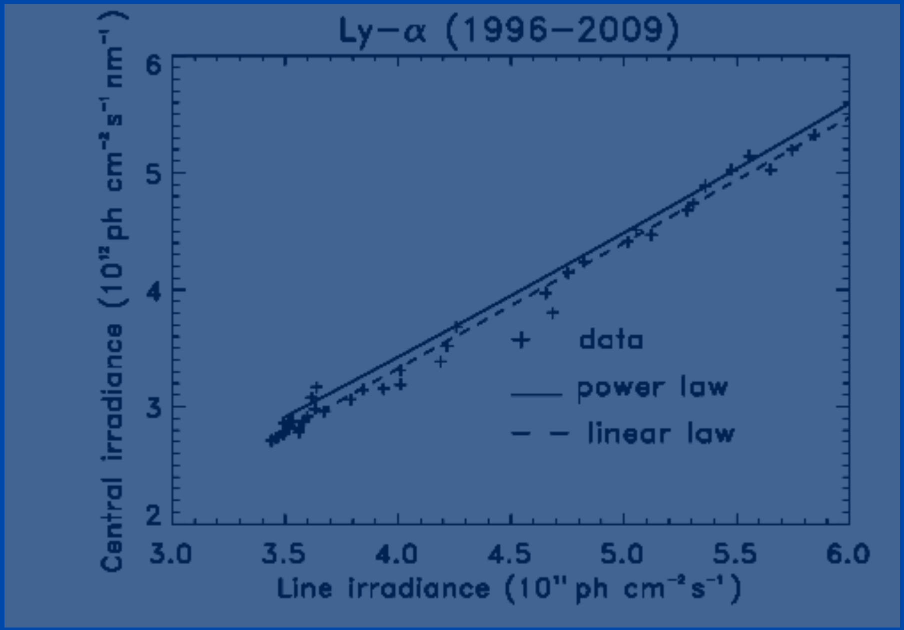
Emerich et al.,Icarus,2005
Lemaire et al. A&A, 2015

Ly-α

Irradiance profiles



Center-to-line relationship



The solar H Ly- line is the main source of resonant excitation of the hydrogen in the planetary and cometary atmospheres and /or exospheres, as well as the heliosphere.

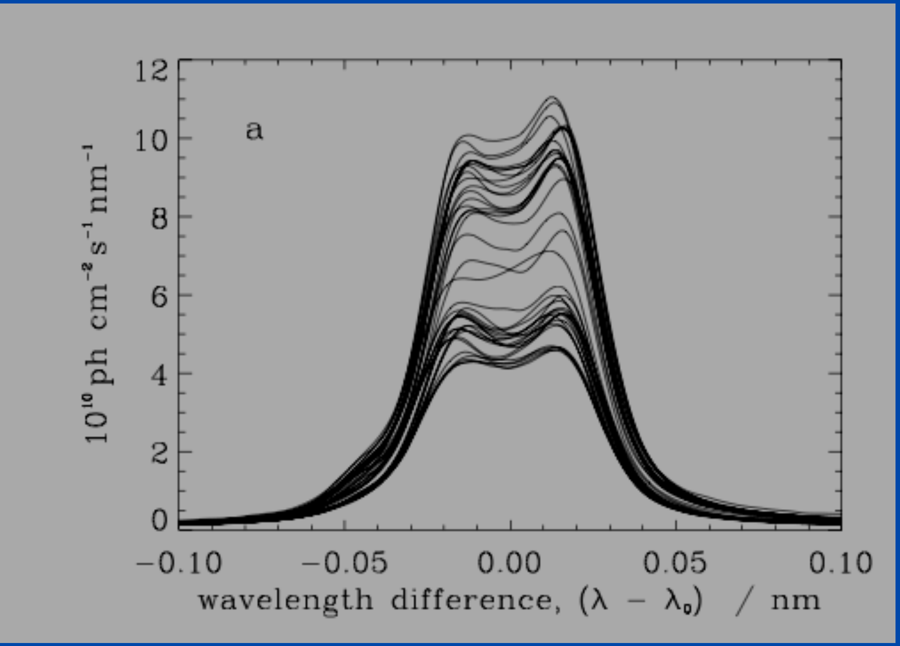
f =- 0.968 (+/-0.070) + 1.074 (+/-0.016) F,

with f=f/(10^{12} cm^{-2} s^{-1} nm^{-1}) where f is the central photon irradiance and with F=F/(10^{11} cm^{-2} s^{-1}) where F is the total photon irradiance.

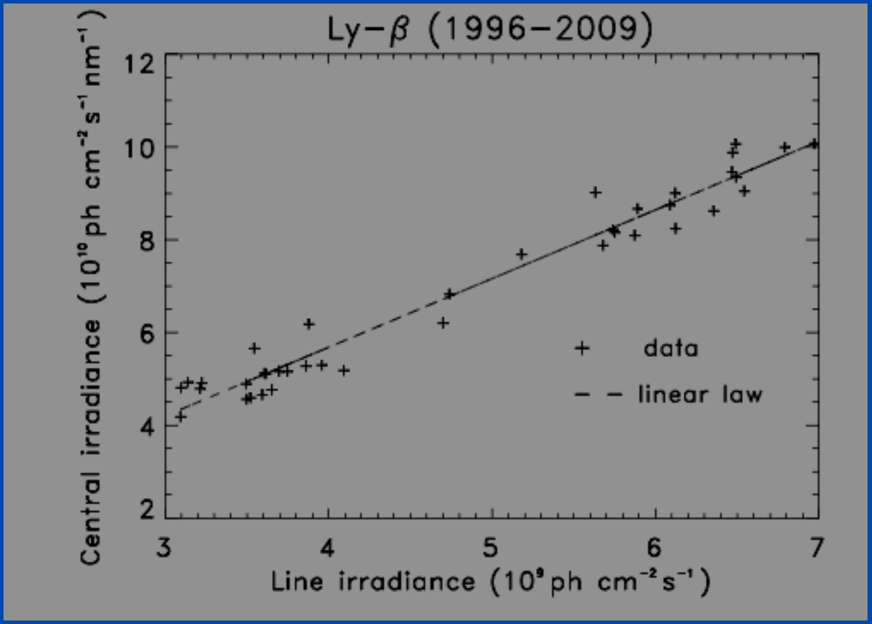
Lemaire et al. A&A, 2015

Ly-ß

Irradiance profiles



Center-to-line relationship



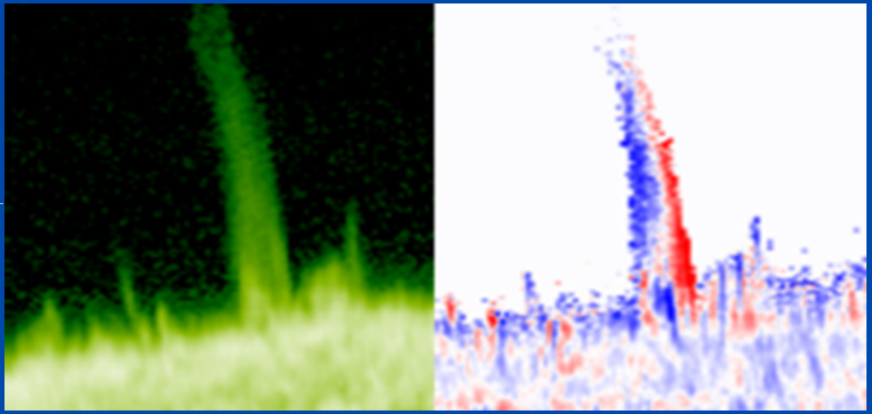
The Ly-ß line (102.572nm) provides complementary constraints on the solar atmospheric models. The line profile is used to determine the fluorescence rate of the O i through the pumping process of O i 102.577 nm line in the solar atmosphere (Haisch et al. 1977) and also in comets (Feldman et al. 1976).

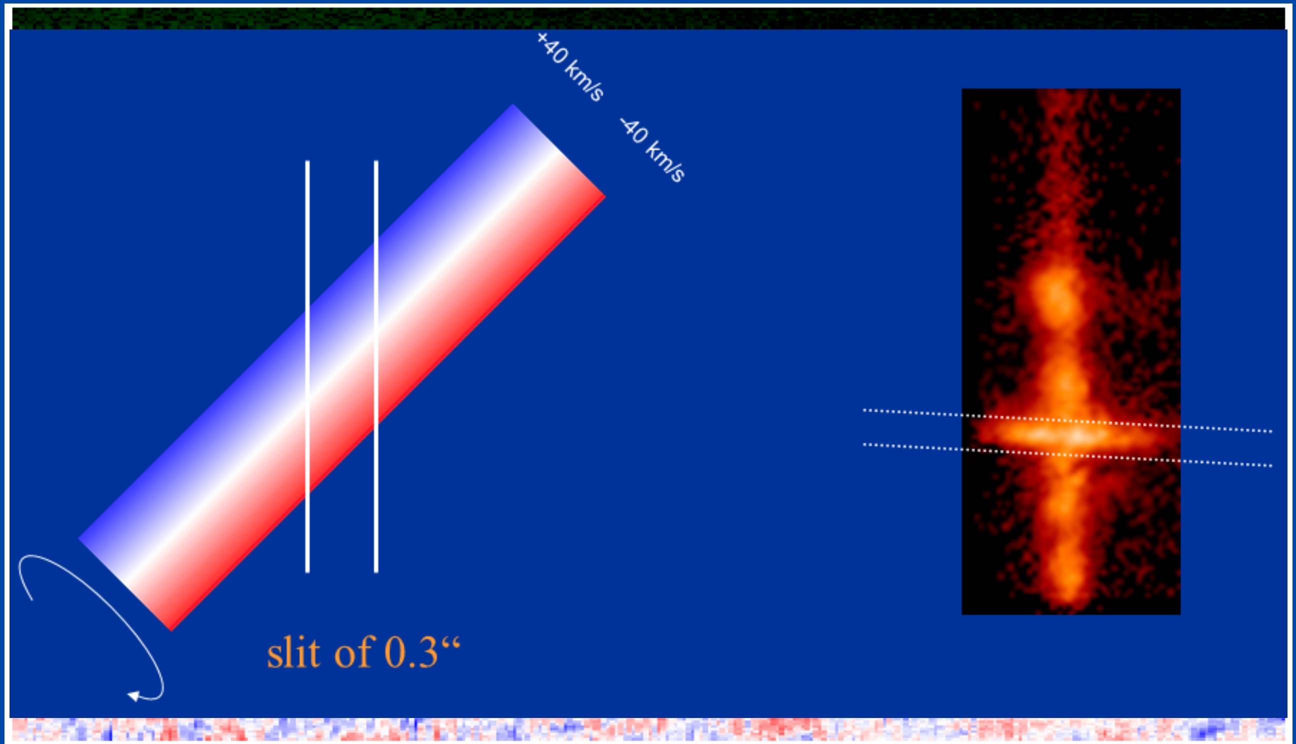
f = 0:248 (0:243) + 1:482 (0:048) F,

with f=f/(10^{10} cm^{-2} s^{-1} nm^{-1}) where f is the central photon irradiance
and F=F/(10^9 cm^{-2} s^{-1}) where F is the total photon irradiance.

Selected highlights:

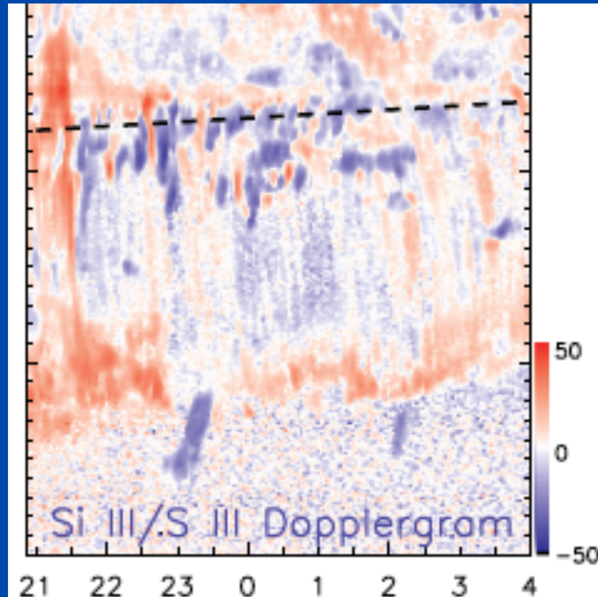
plumes, interplumes, pol
nascent solar wind
rest wavelengths
loop oscillations
Ly-α profiles
full disk Ly-α / β
swirling (macro-)spicules

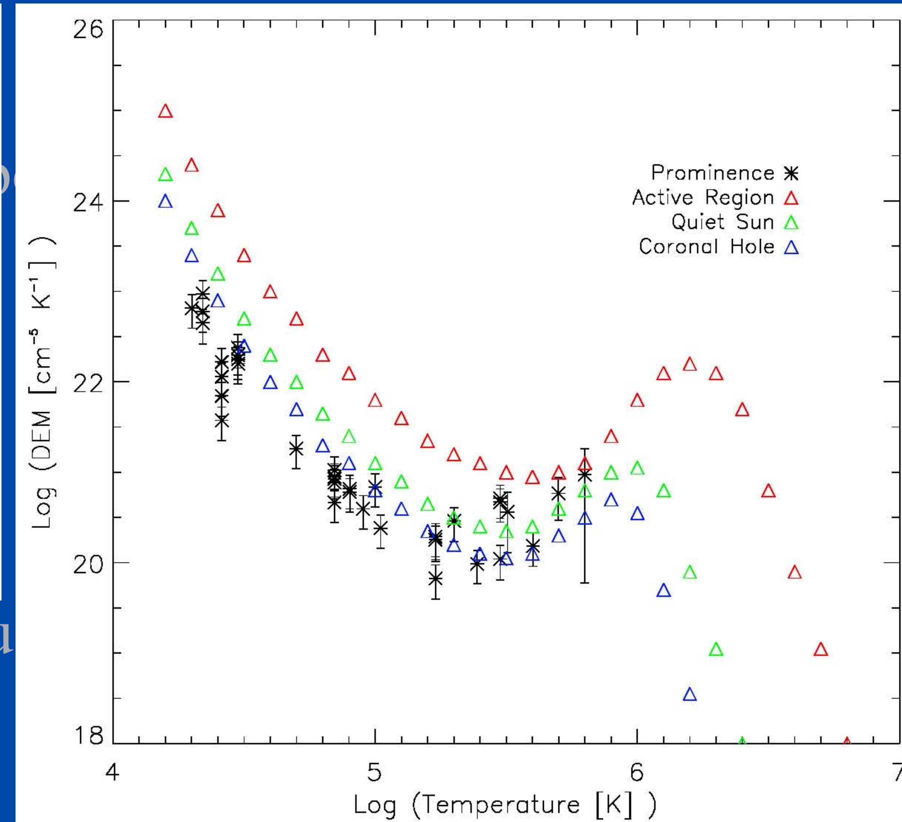




Rompolt 1975
Wilhelm 2000
Curdt & Tian 2011

Selected highlights:





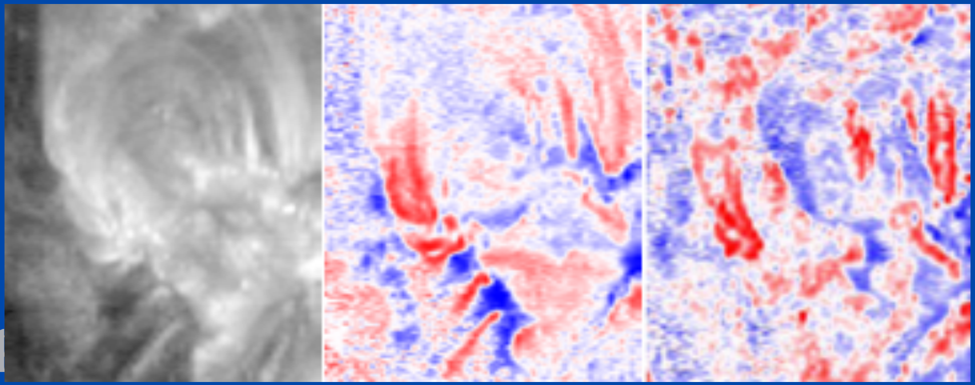
swirling (macro-)spicu

prominences

Doppler oscillations	*Régnier et al. 2001*
DEM analysis	*Cirigliano, Vial, Rovira 2004*
multi-threads modelling	*Gunar et al. 2014*
threads diameter	*Cirigliano, Vial, Rovira 2004*
Ly-α profile	*Vial et al. 2006*

Selected highlights:

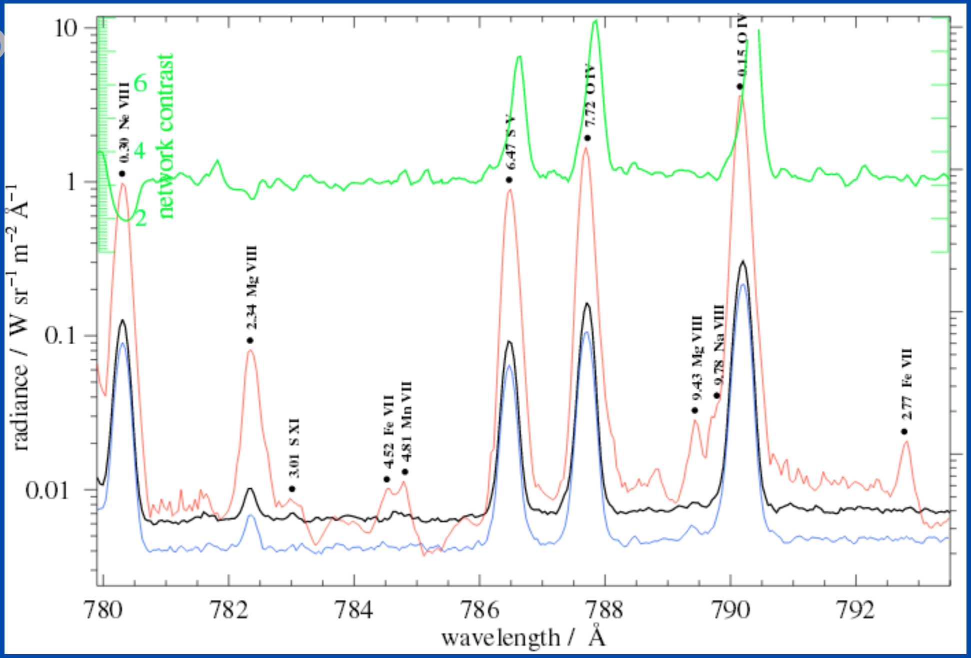
plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscillations
Ly-α profiles
full disk Ly-α / β
swirling (macro-)sp
prominences
coronal convection



Dammasch , Curdt , Dwivedi et al. 2008
Marsch, Tian, Sun et al. 2008
Curdt , Tian, Marsch 2011

Selected highlights:

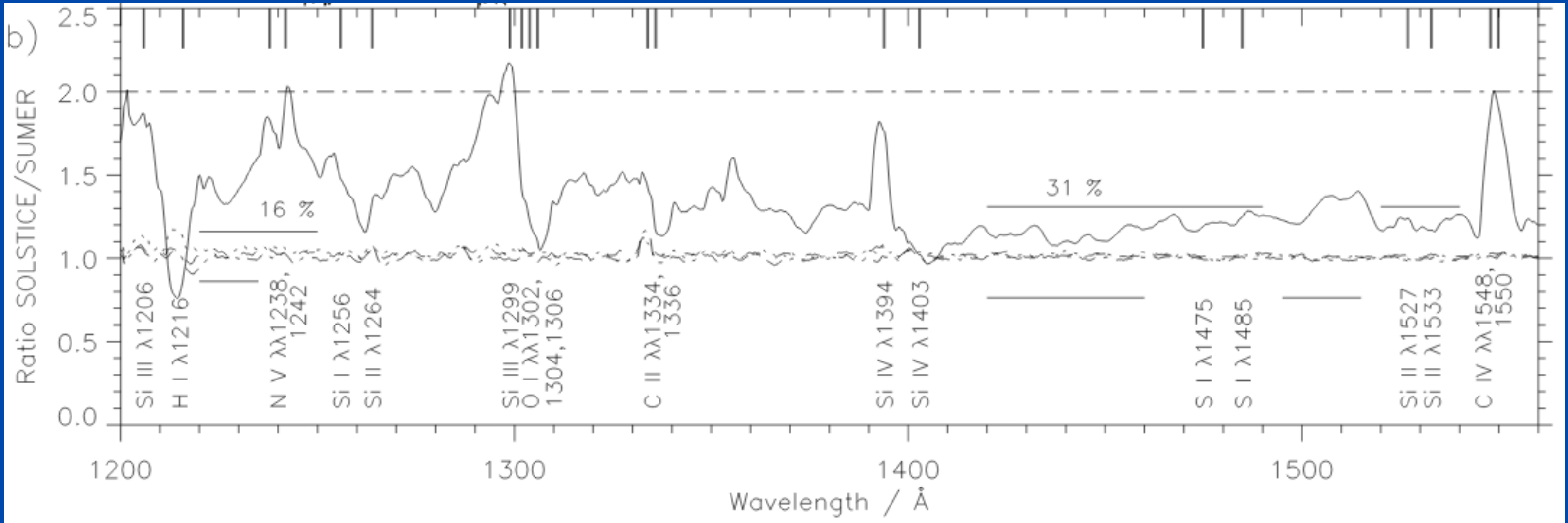
- plumes, interplumes, polar jets
- nascent solar wind
- rest wavelengths
- loop oscillations
- Ly-α profiles
- full disk Ly-α / β
- swirling (macro-)sp
- prominences
- coronal convection
- network contrast



Curdt, Tian, Dwivedi et al. 2008
Wang, McIntosh, Curdt et al. 2013

Selected highlights: plumes, interplumes, polar jets

nascent solar wind



network contrast

radiometric calibration

UARS/SOLSTICE: calibration at NIST

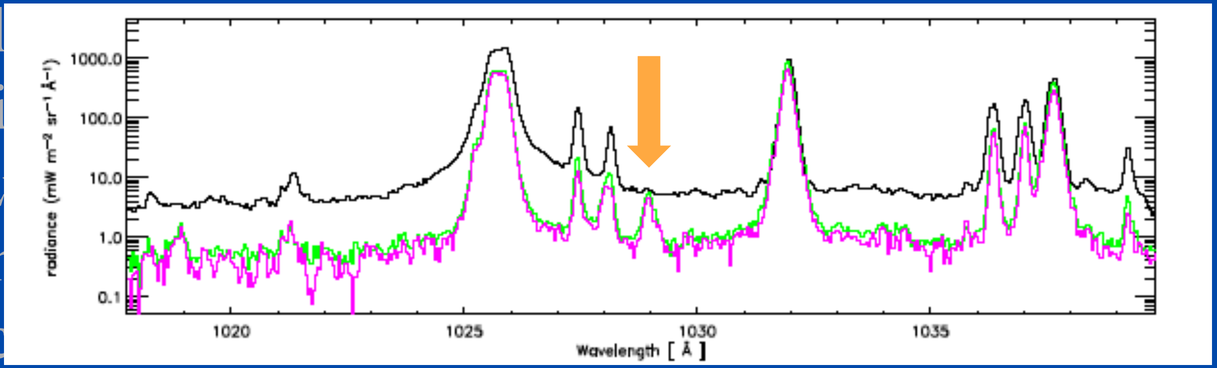
SOHO/SUMER: calibration at PTB

agreement within 10% – 15%

Wilhelm, Woods, Schühle et al. 1999

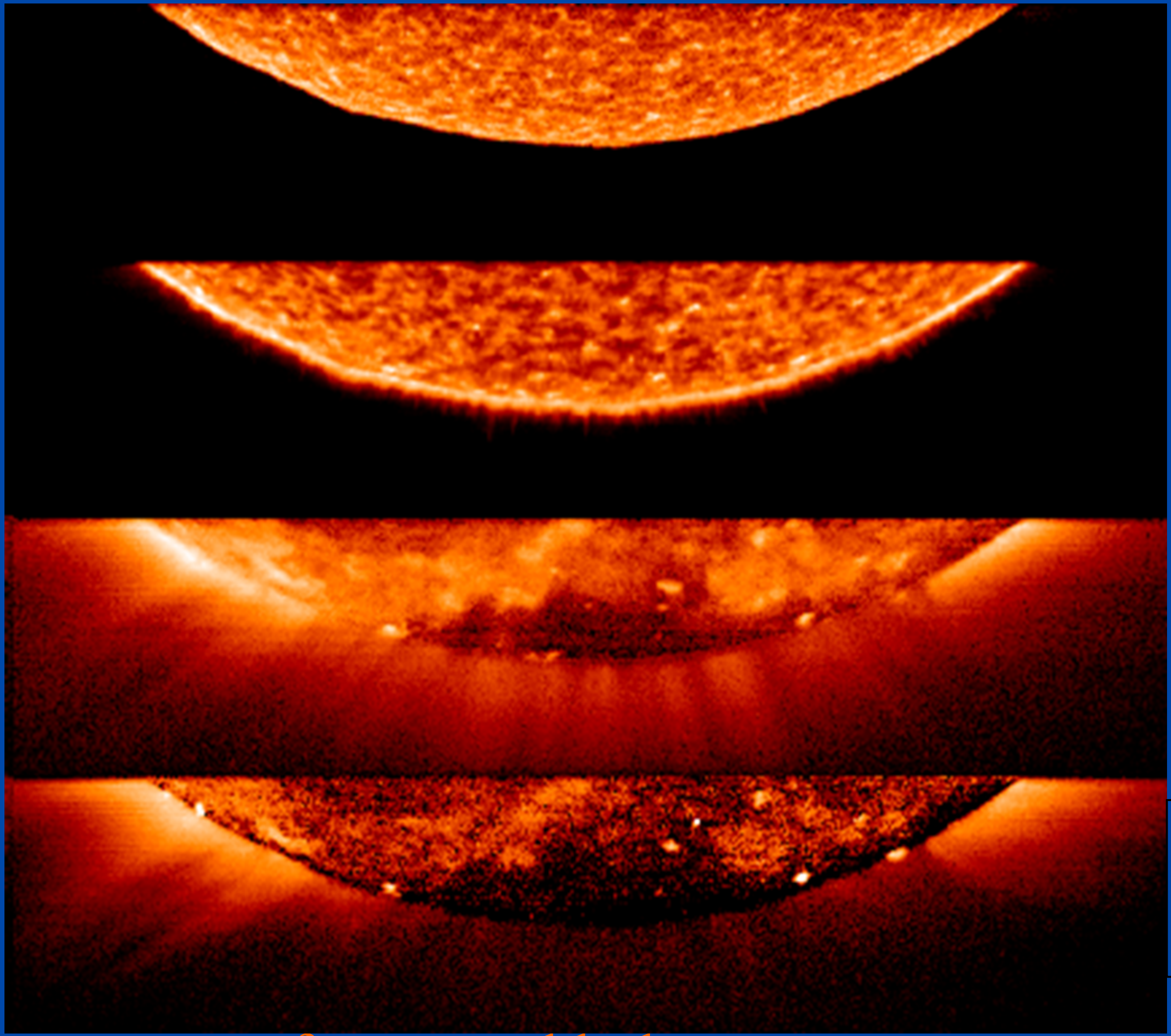
Selected highlights:

plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscill
Ly-α profi
full disk L
swirling (r
prominenc
coronal convection
network contrast
radiometric calibration
atlases



Curdt, Brekke , Feldman et al. 2001
Parenti , Vial, Lemaire 2004, 2005
Feldman, Dammasch, Wilhelm et al. 2003

Selected highlights:



C I 124.9 nm
30 000 K
Network

N V 123.8 nm
190 000 K
(Macro-)spicules

Mg X 60.9 nm
1.1 MK
Polar plumes

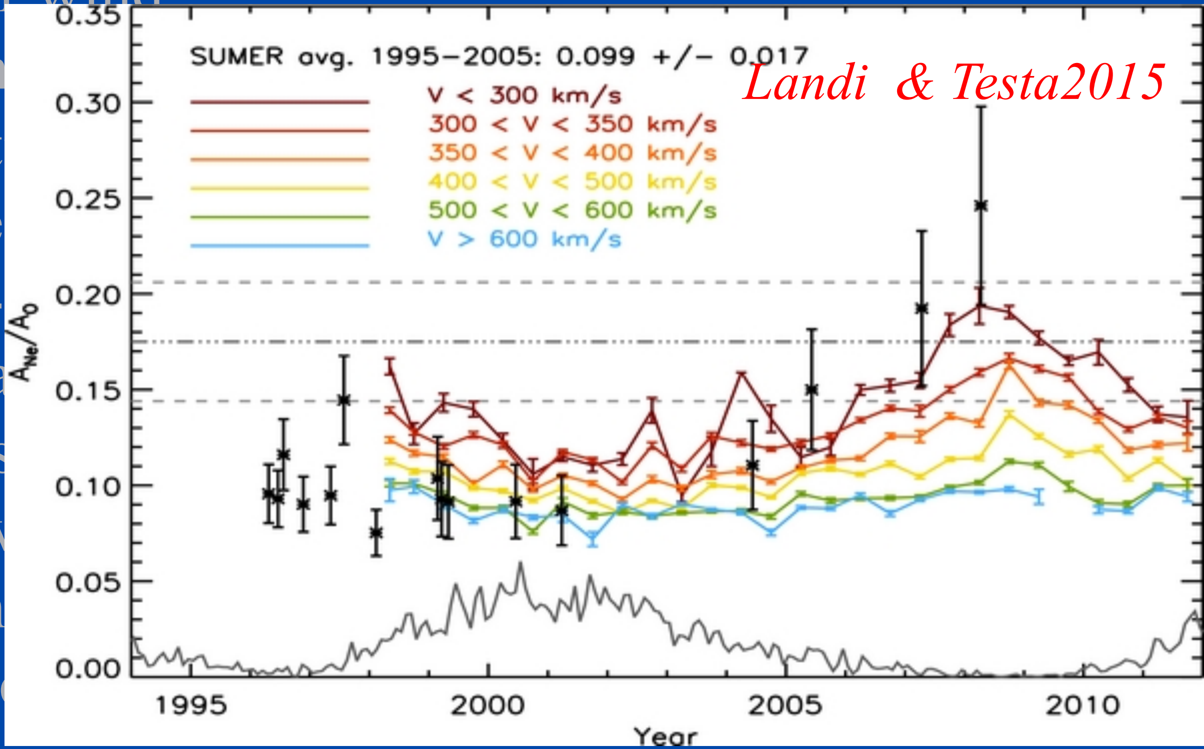
Fe XII 124.2 nm
1.4 MK
Coronal hole

anatomy of a coronal hole

Dammasch 1998

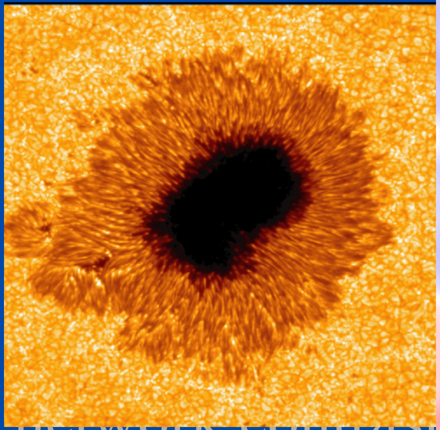
Selected highlights:

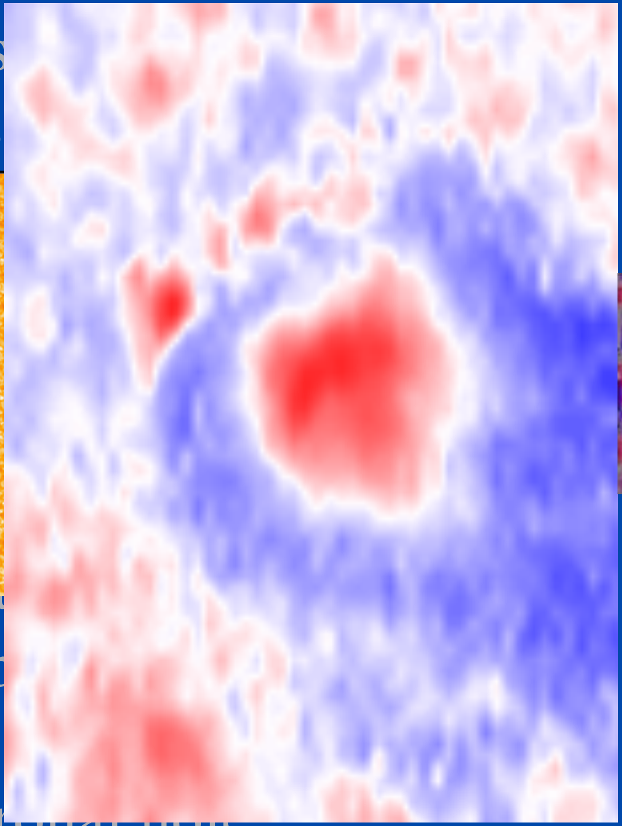
plumes, interplumes, polar jets
nascent solar wind
rest wavelen
loop oscillat
Ly-α profile
full disk Ly-
swirling (ma
prominences
coronal conv
network con
radiometric
atlases
anatomy of a coronal hole
cycle 23 Ne/O ratio, FIP effect

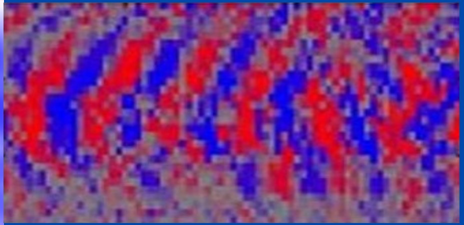


Selected highlights:

plumes, interplumes, polar jets
nascent solar wind
rest wavelengths
loop oscillations







O V 62.9 nm

network contrast
radiometric calib
atlases

Si II 126.0 nm

anatomy of a coronal hole
cycle 23 Ne/O ratio, FIP effect
sunspot oscillation

Brynildsen, Leifsen, Kjeldseth-Moe et al. 1999

Lessons learned: give room for exploration

- unexpected data
- unexpected instrument performance

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‚share‘ your instrument

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spectrometers see different things than imagers do

Lessons learned:

give room for exploration

- unexpected data
- unexpected instrument performance

‚share‘ your instrument

spectrometers see different things than imagers do

ultimate cleanliness is a ‚must‘

Legacy: heritage for next generation spectrometers

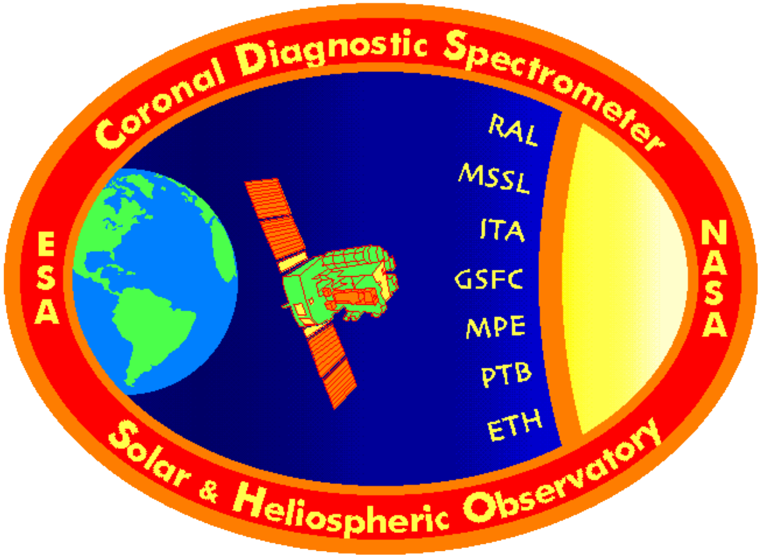
- IRIS
- SPICE

data archive

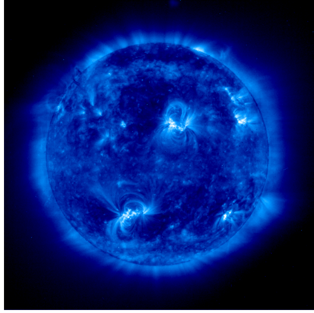
RAL Space

Science Highlights of the SOHO Coronal Diagnostic Spectrometer

Andrzej Fludra
STFC



The CDS Consortium



Rutherford Appleton Laboratory (UK)

Instrument system design, project structure, mechanisms. Leads the instrument operation, data and software management, health and performance monitoring,calibration, observations scheduling and the interfaces to NASA/ESA for mission planning

Mullard Space Science Laboratory (UK)

Detectors, EPS, CDHS. Monitors one of the detector systems, contributions to calibration, software and operations planning.

NASA Goddard Space Flight Center

VDS detector, gratings, ground software, operations, science planning.

MPI Garching Telescope.

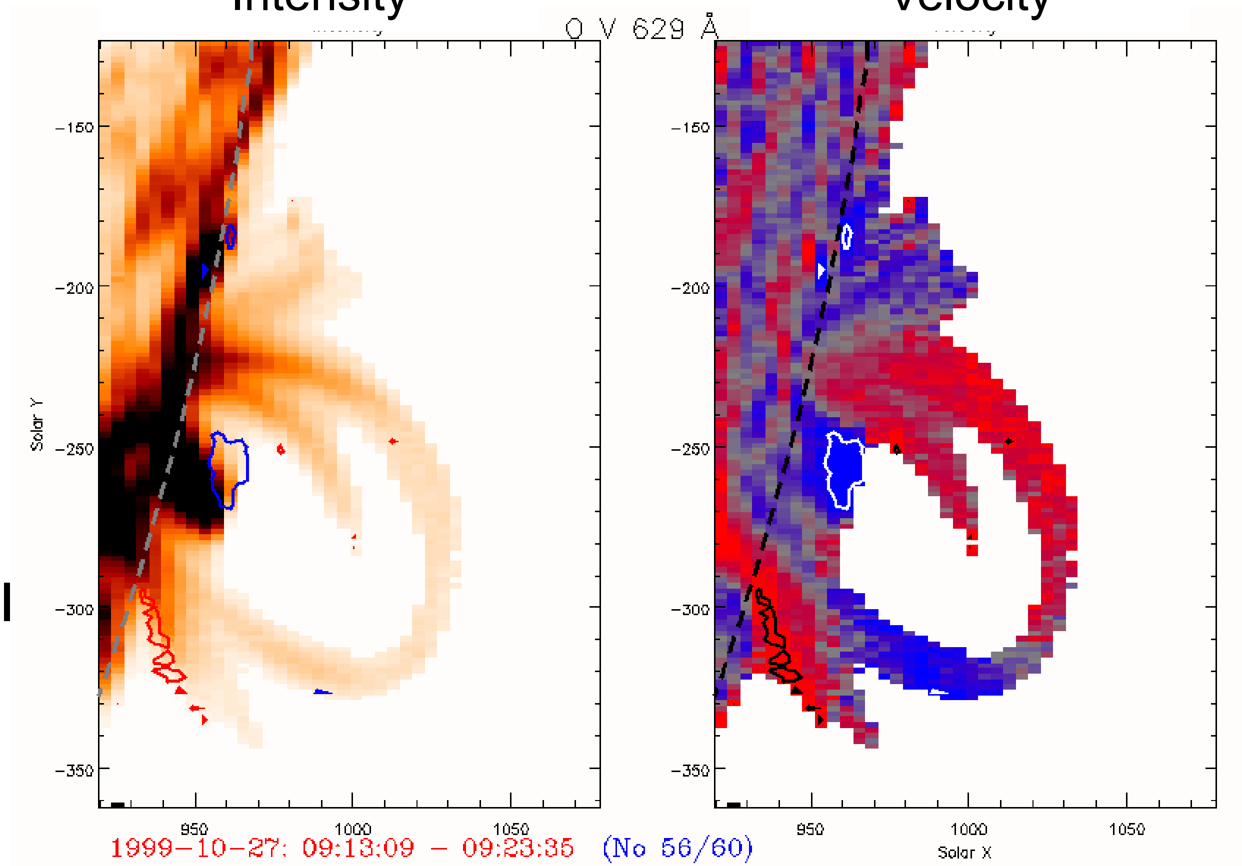
University of Oslo, Norway Ground Support Equipment, Science planning.

PTB (Germany) & ETH (Switzerland) Calibration

Transition Region Dynamics from CDS

- **Transition region extremely dynamic and time variable**
- **Active region loops in TR lines: typical velocities: 50-100 km/s, up to 300 km/s detected**
- **For T>1MK: only small velocities**
- **Implications for modeling:**
  - **Hydrostatic models obsolete**

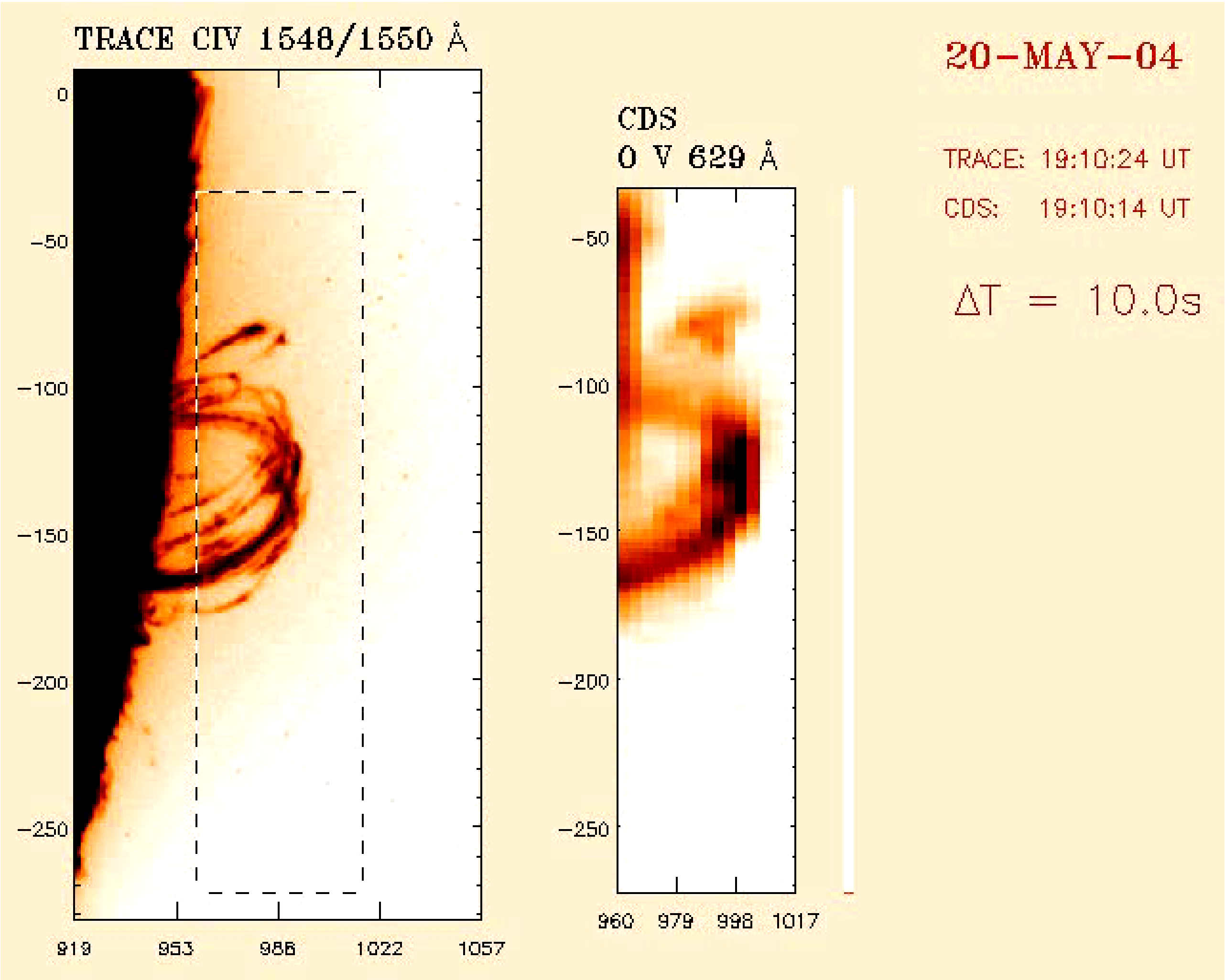
Intensity Velocity

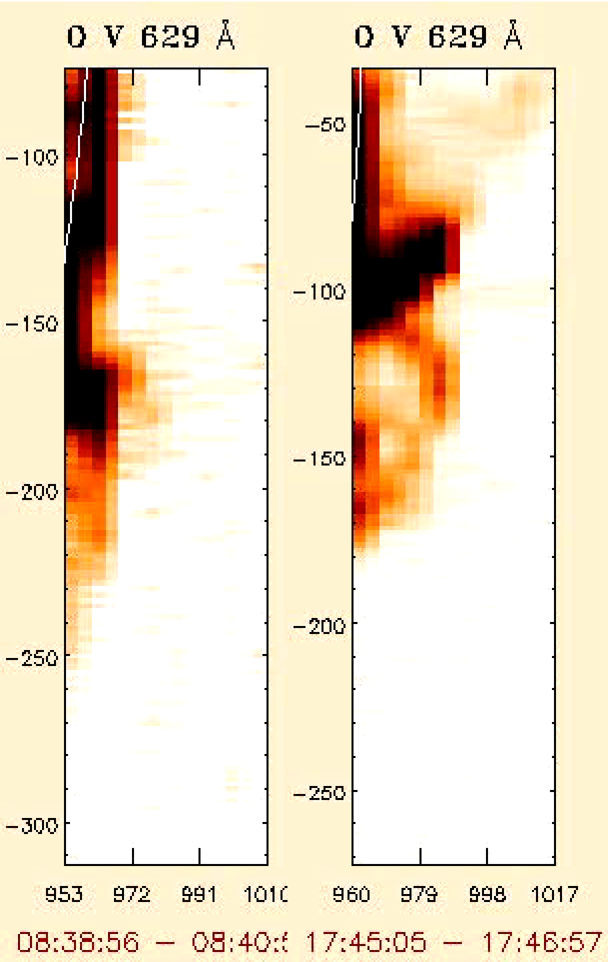


Brekke et al.: 1997, Solar Phys. 175, 511

Kjeldseth-Moe & Brekke: 1998, Solar Phys. 182, 73

Transition Region Loops





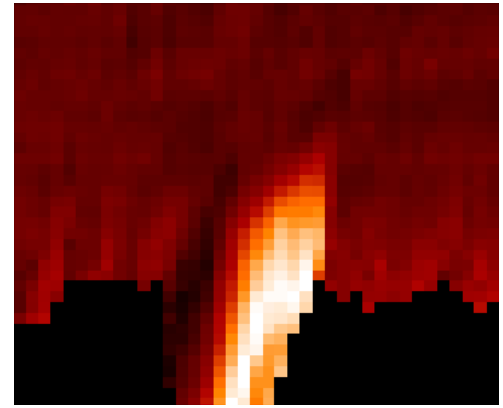
Fredvik et al. 2002

200,000 K plasma = 'cool loops'

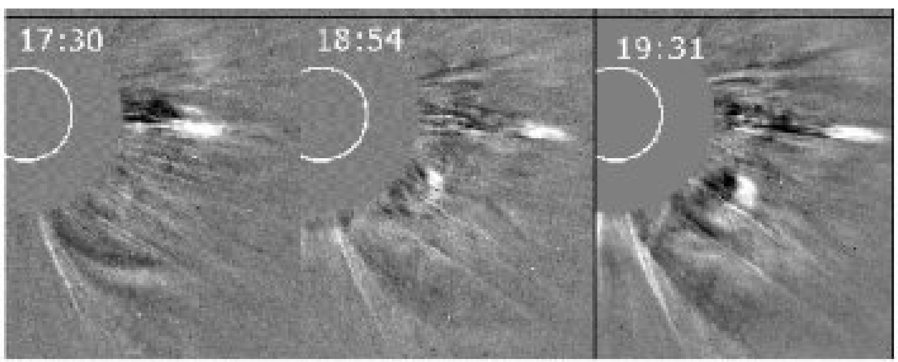
Intensity 'blobs' falling down along magnetic loops – catastrophic cooling.

Rotating jets

- **Rotating macrospicules** - Pike & Mason (1998, Sol. Phys. 182, 333) identified several small events in polar regions showing both redshifts and blueshifts
- Interpreted as cylindrical rotating structures
- Represent a class of macro-spicule

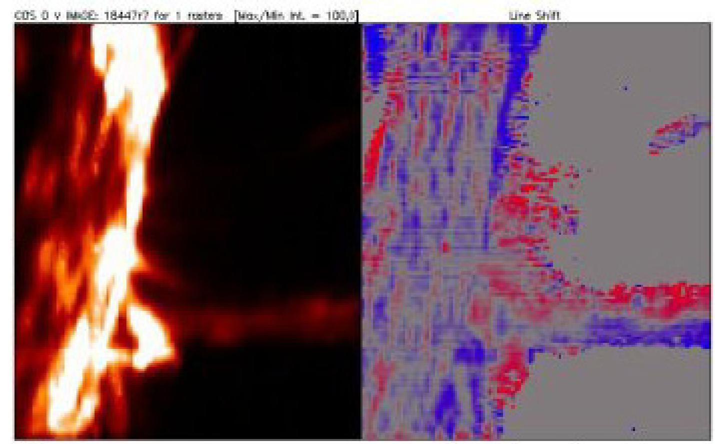


EUV sprays – unique observation of spiralling jets, subsequently detected in the outer corona



LASCO sequence showing jet-like ejection

CDS O V line

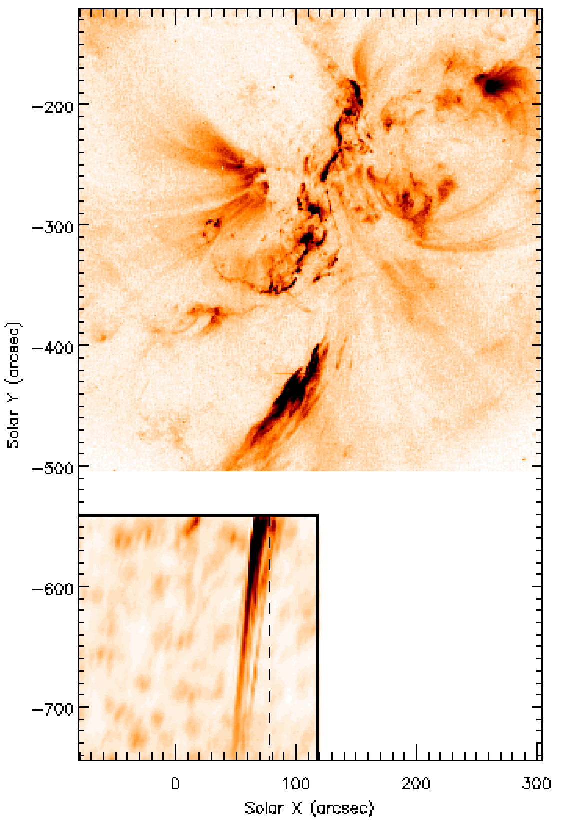


Intensity velocity

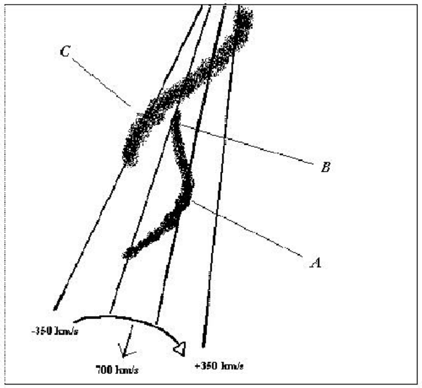
Harrison, Bryans and Bingham, 2001, A&A, 379, 324

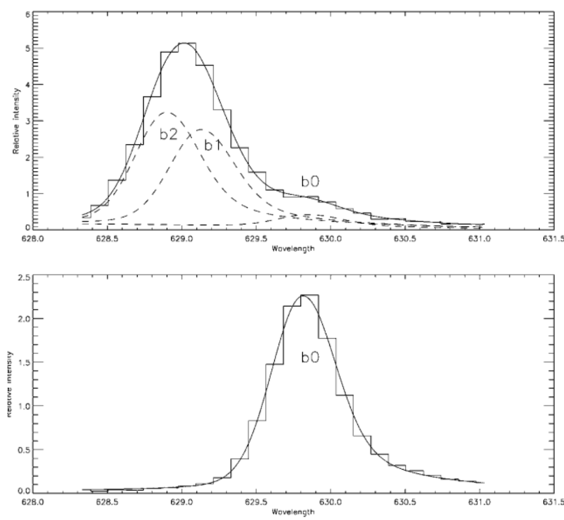
CDS observations of a spray ejecta from an X2 flare

Observations in OV

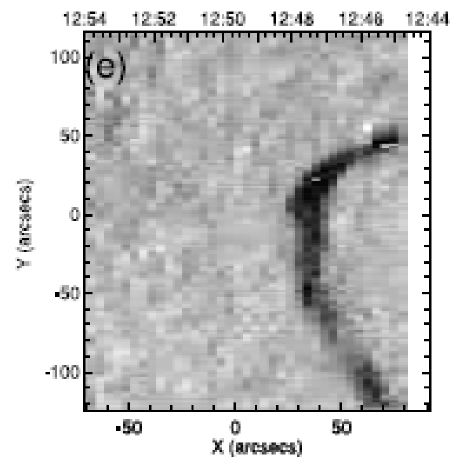


- Outward speed 700km/s
- Rotational vel +/-350km/s





Erupting filament

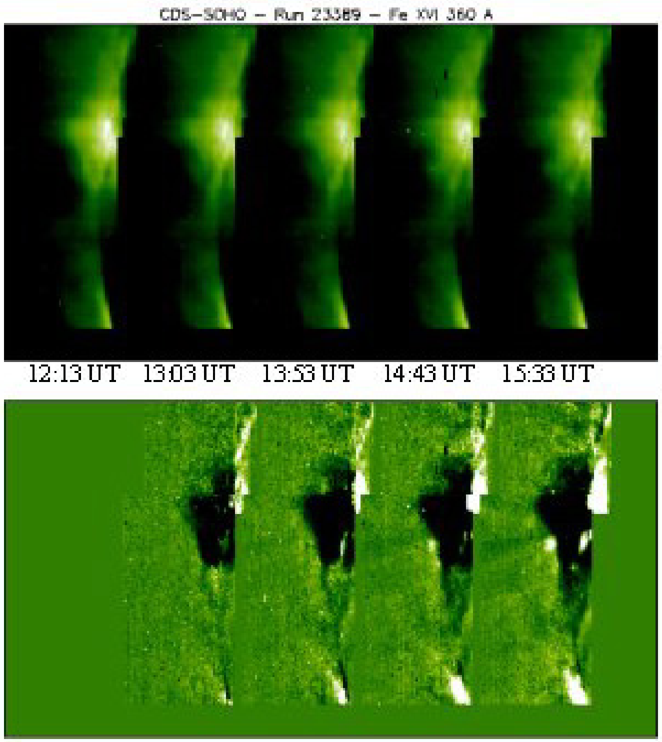


Foley et al. 2002
Pike and Mason, 2002

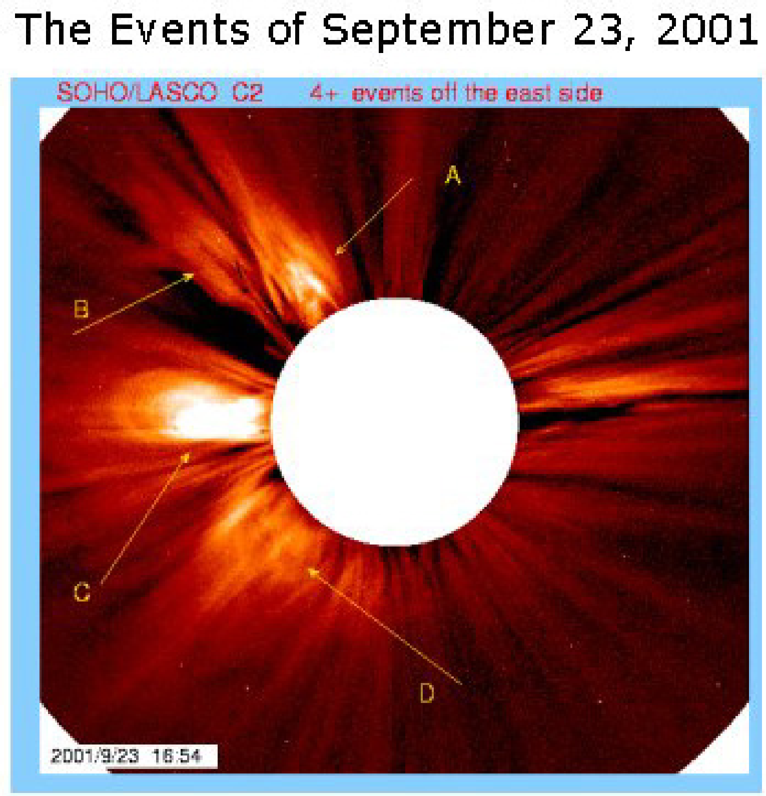
Sterling et al. 2007

CME Onset & Coronal Dimming

Coronal dimming identified in solar EUV spectral data. Associated with CME onset process – spectral analysis showed that dimming was due to mass loss, consistent with overlying CME mass from coronagraph data.

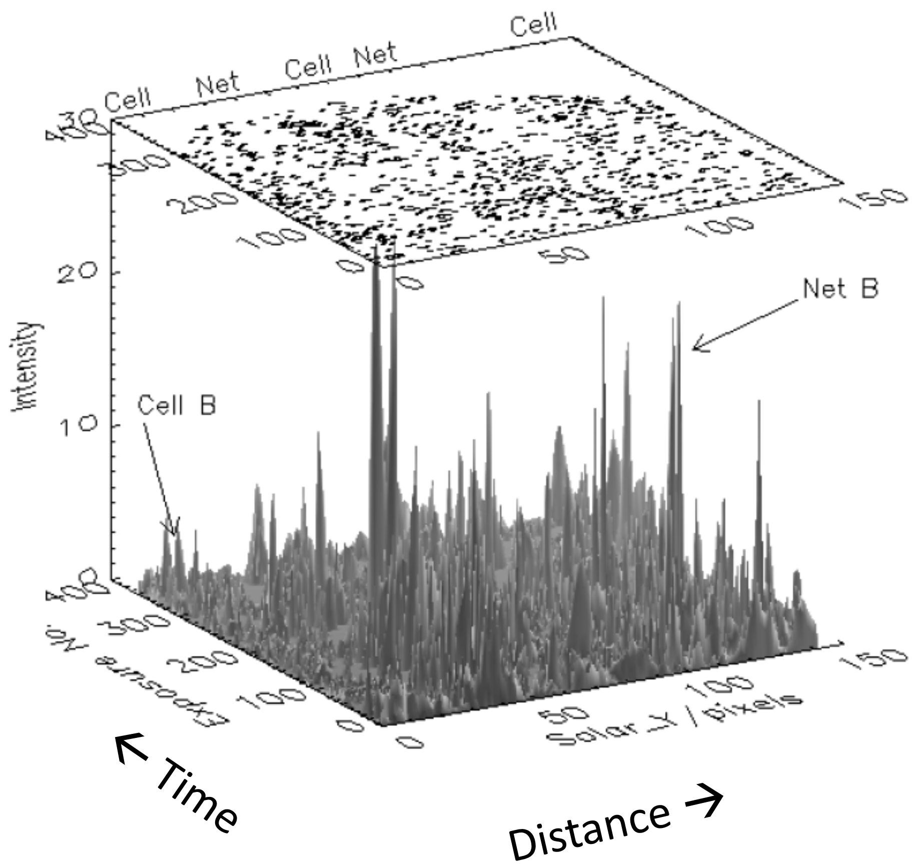


2 million K Fe XVI 360 Å line

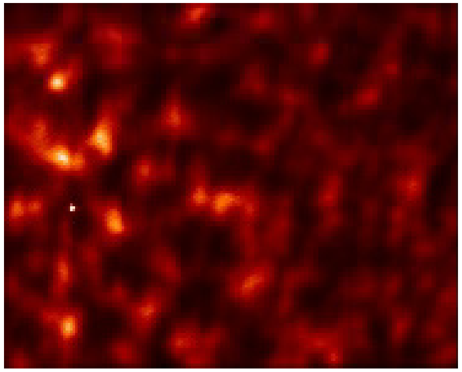


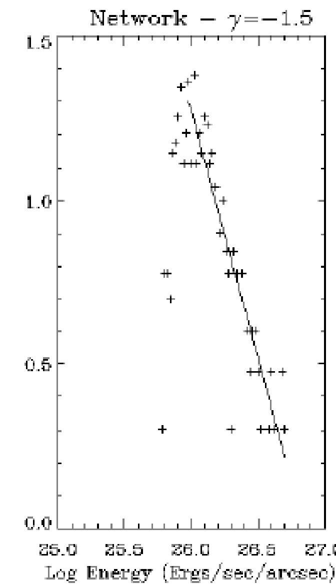
Harrison & Lyons, 2000, Astron. Astrophys. 357, 697; Harrison et al., 2003, Astron. Astrophys. 400, 1071; Bewsher, Harrison & Brown, 2008, Astron. Astrophys. 478, 897, etc…

Quiet Sun Transient Brightenings



CDS NIS in O V 630 A line





← 5 arc min →

Movie duration: 2 hour

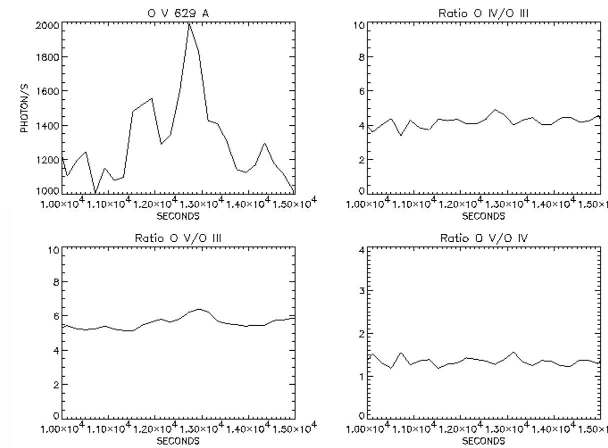
‘Quiet’ Sun areas show thousands of short-lived intensity enhancements

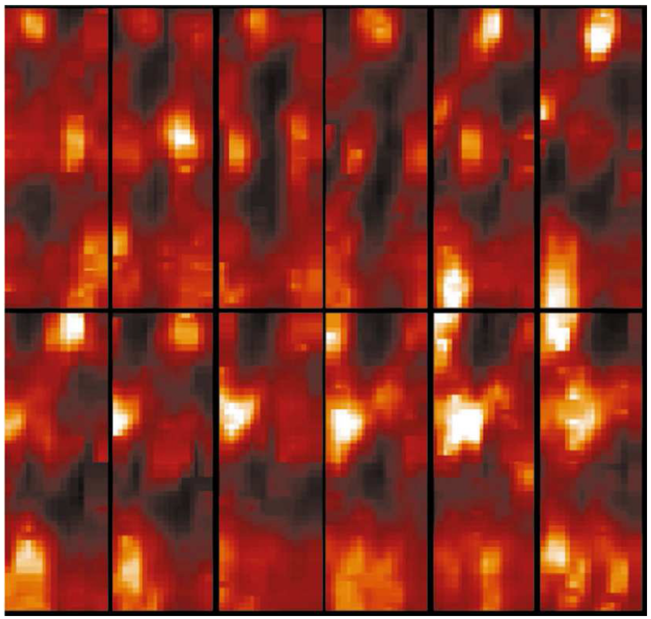
Average duration 1.5 - 2.5 min

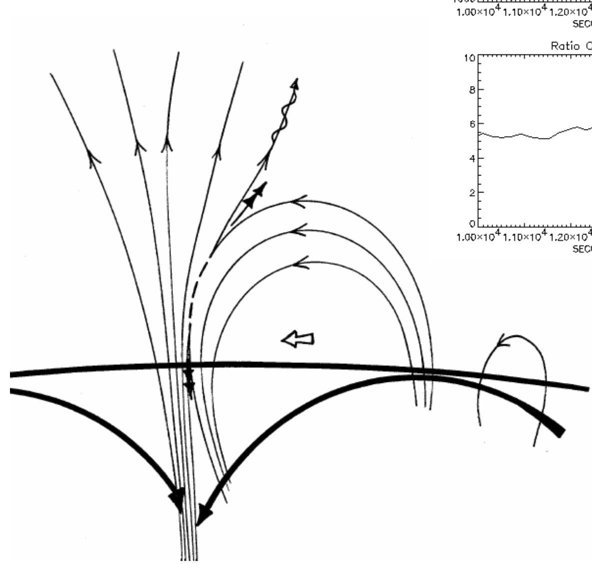
Harra et al. 2000 – derived power law index of energy distribution in the transition region: -1.5 network, -2.7 cell

Blinkers

Identification of EUV flashes known as '***blinkers***' (so named to avoid implication of any process – such as a min-flare). Spectral signatures consistent with density/flow events rather than heating.



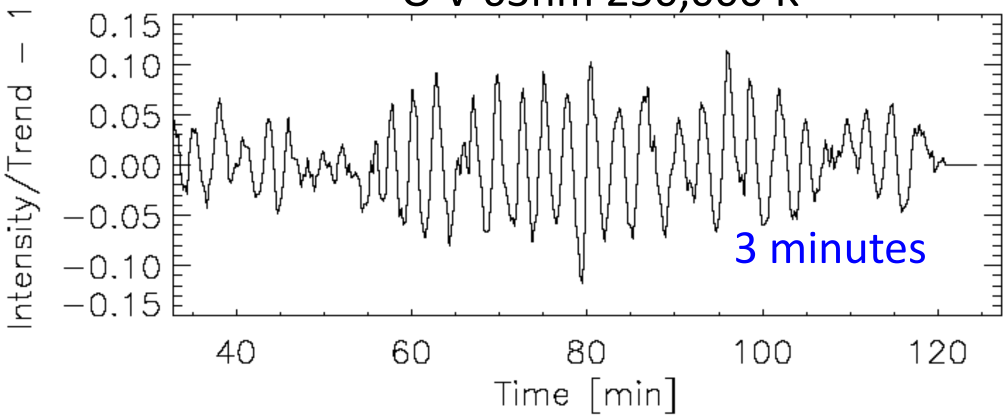


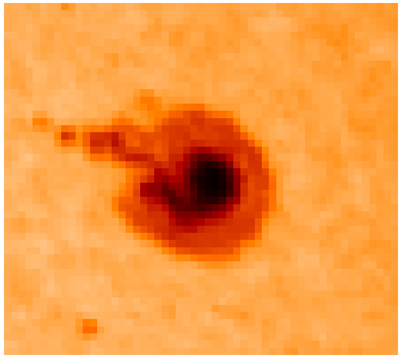


Efforts to 'unify' quiet-Sun transient phenomena (blinkers, explosive events, nanoflares etc..) to assess role in heating and acceleration in quiet Sun.

Harrison, 1997, Solar Phys. 175, 467;
Harrison et al., 1999, Astron. Astrophys. 351, 1115
Harrison et al., 2003, Astron. Astrophys. 409, 755.

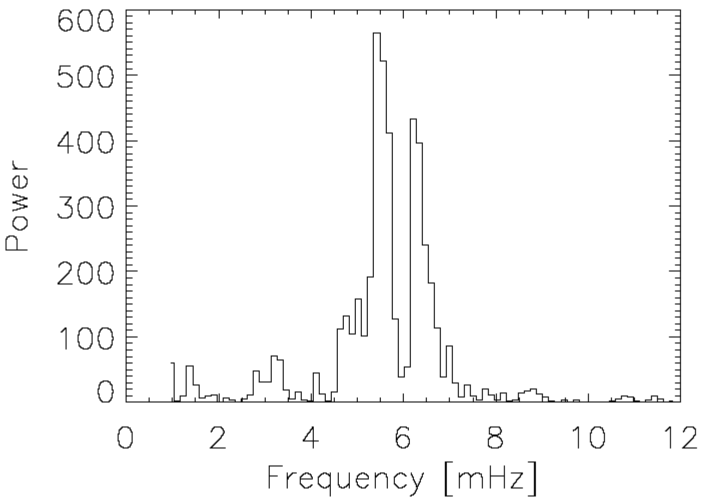
Oscillations and Wave Propagation





Sunspot

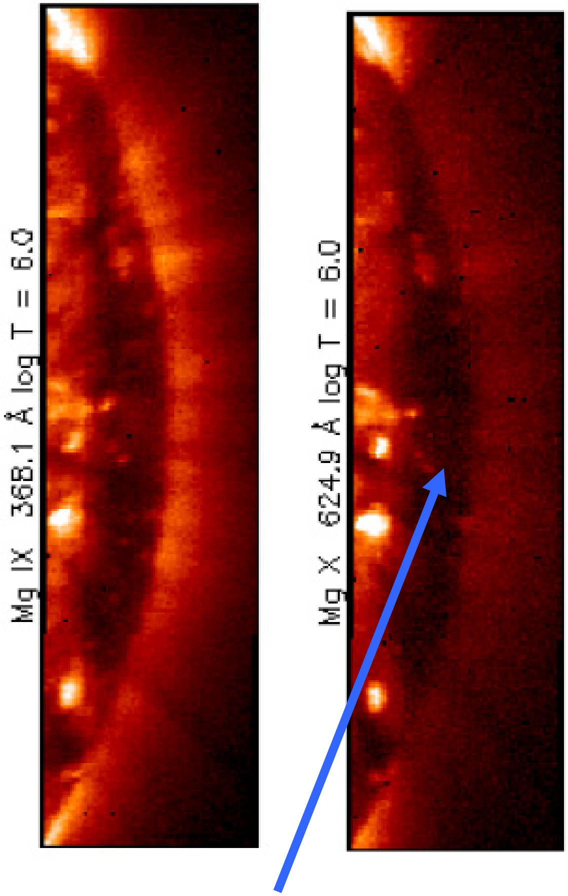
- Oscillations are seen in intensity and velocity time series of chromospheric and TR lines
- Seen in sunspots, active regions, quiet sun and coronal holes. Different periods, from 3 to 12 minutes.
- Magneto-acoustic waves travel outwards from footpoints of magnetic loops to higher altitudes

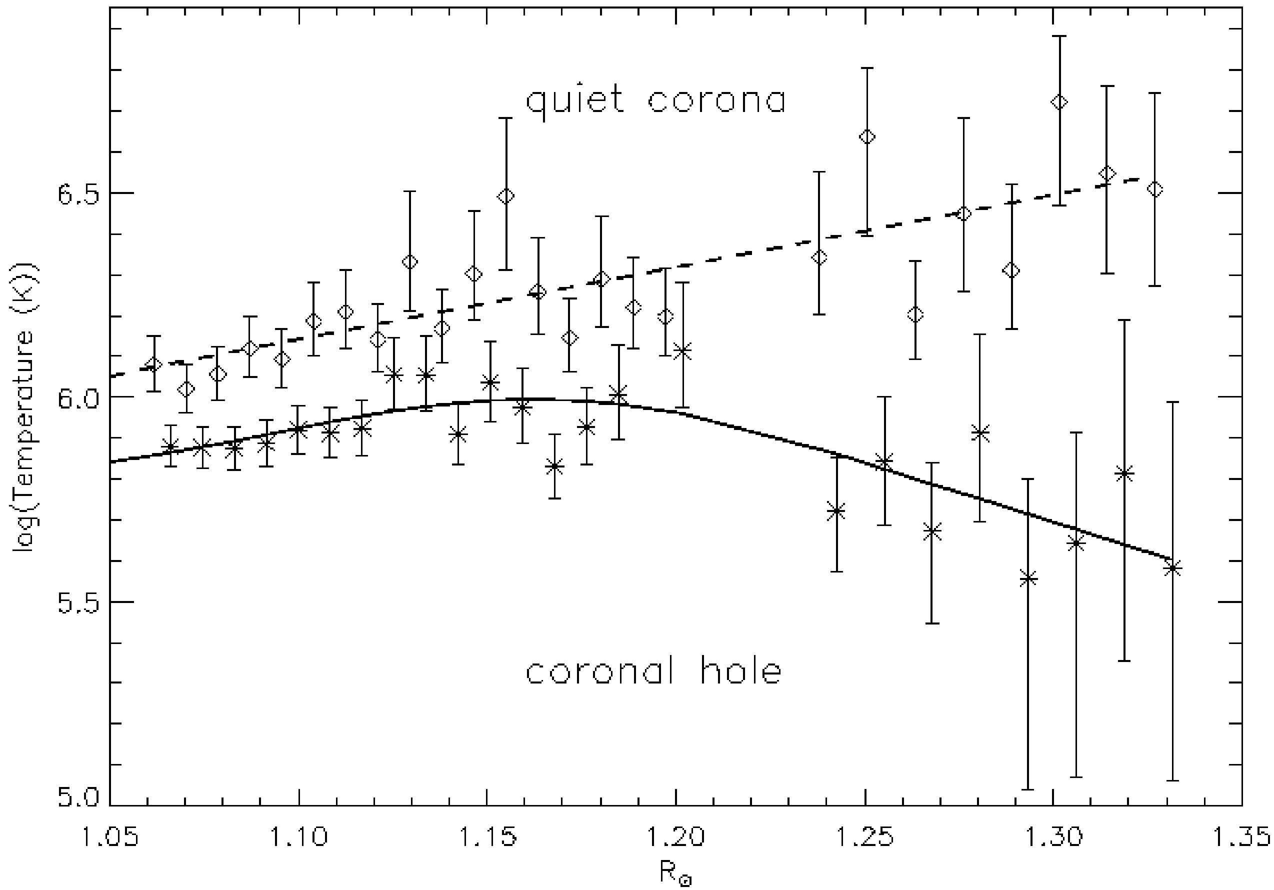


Fourier Power Spectrum

Fludra 1999; 2001
Marsh et al. 2003

Temperature above Polar Coronal Holes





Coronal Hole at North Pole

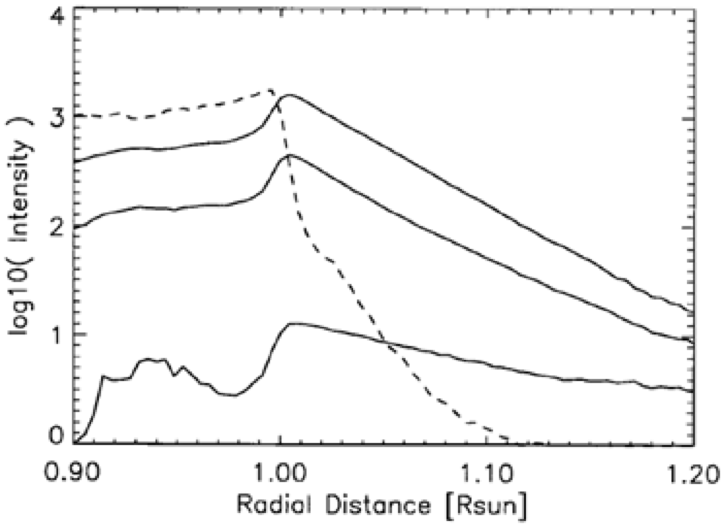
Distance above the limb →

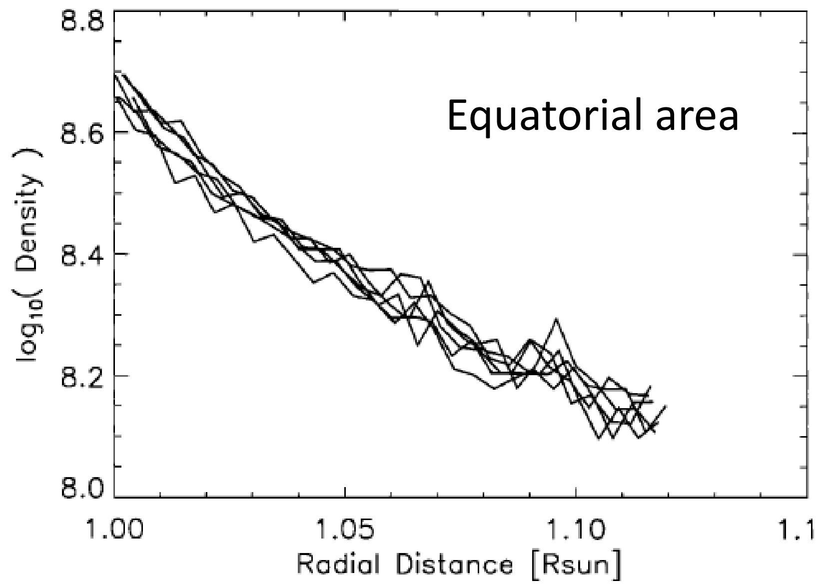
After rolling SOHO by 90 degrees.

CDS/GIS and SUMER

David et al. 1998

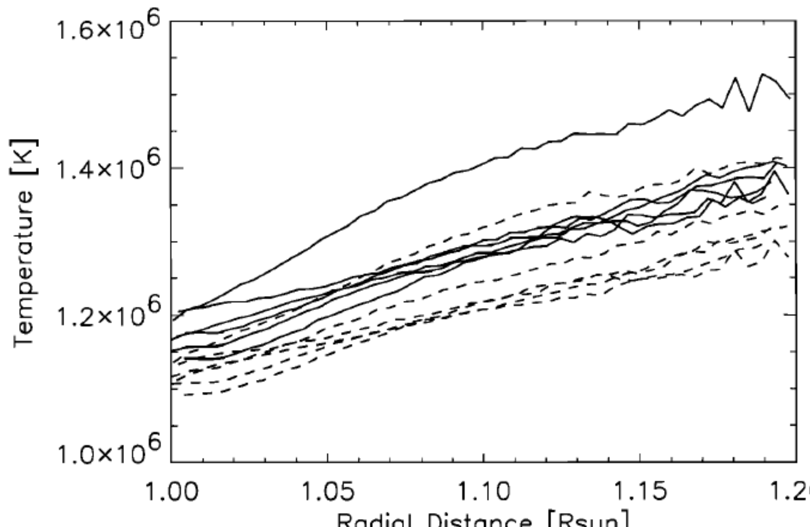
Temperature and Density in the Corona





Comprehensive measurements of **electron temperature and density** with distance above the limb in the **Quiet Sun and coronal holes** during the solar minimum.

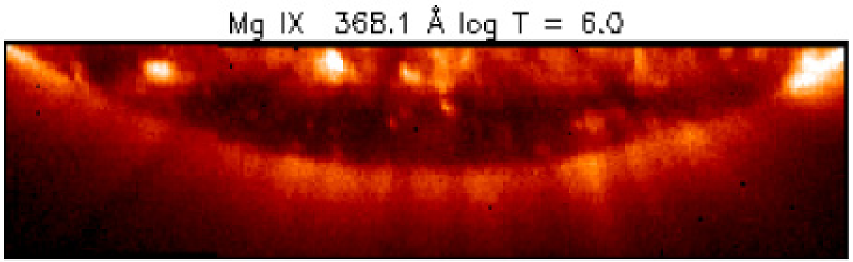
Using Si IX density diagnostics

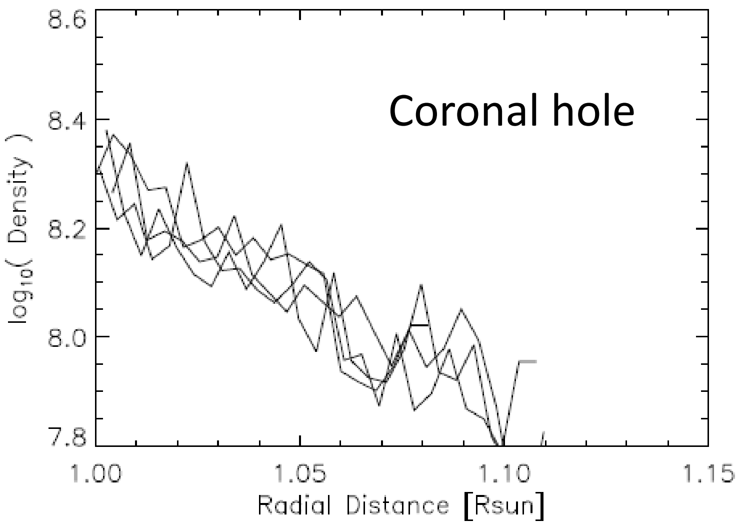


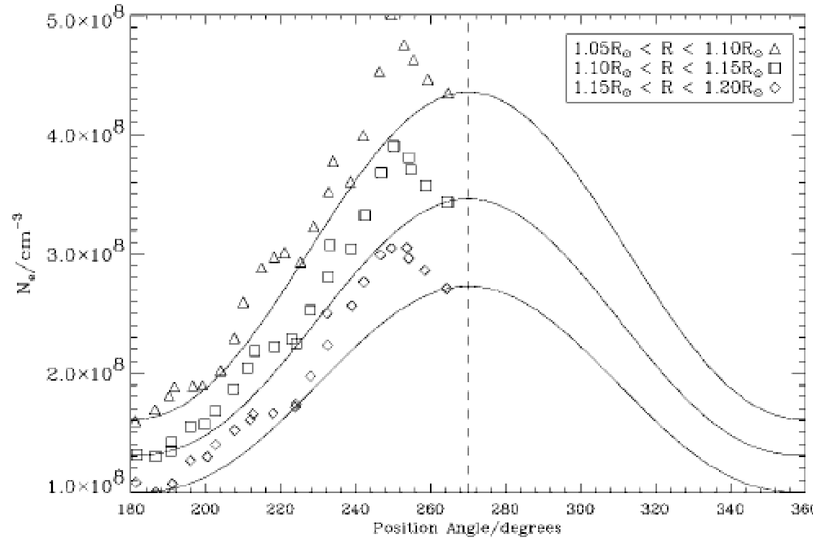
Distance above the limb →

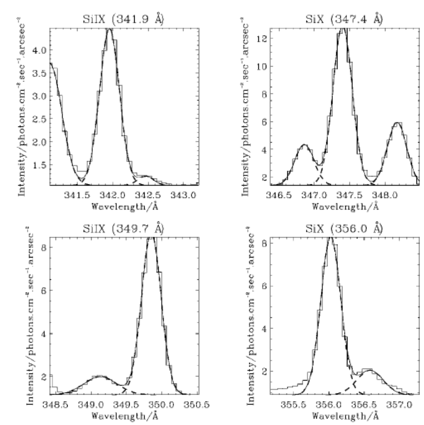
Fludra et al., 1999, JGR

Density above Polar Coronal Holes









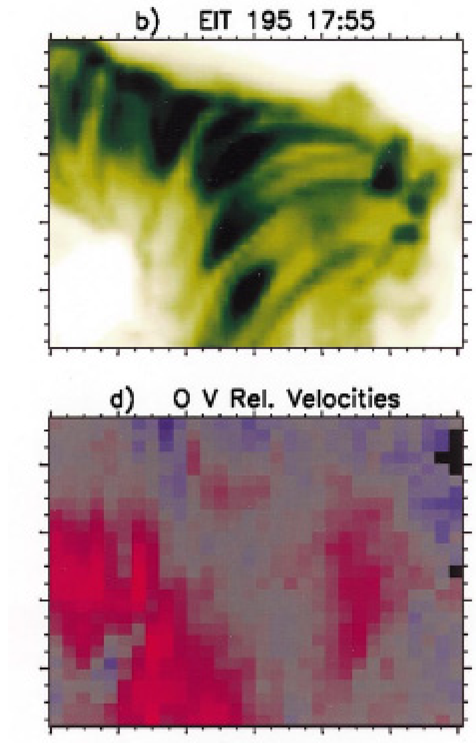
Fludra et al., 1999, JGR

Gallagher et al. 1999

Flares - Chromospheric evaporation in the late gradual phase

The first observation, during the late gradual flare phase, of chromospheric evaporation in transition region and coronal lines occurring above an H-alpha ribbon as it moves away from the magnetic neutral line.

Continuing upflows and downflows provide evidence for ongoing reconnection.



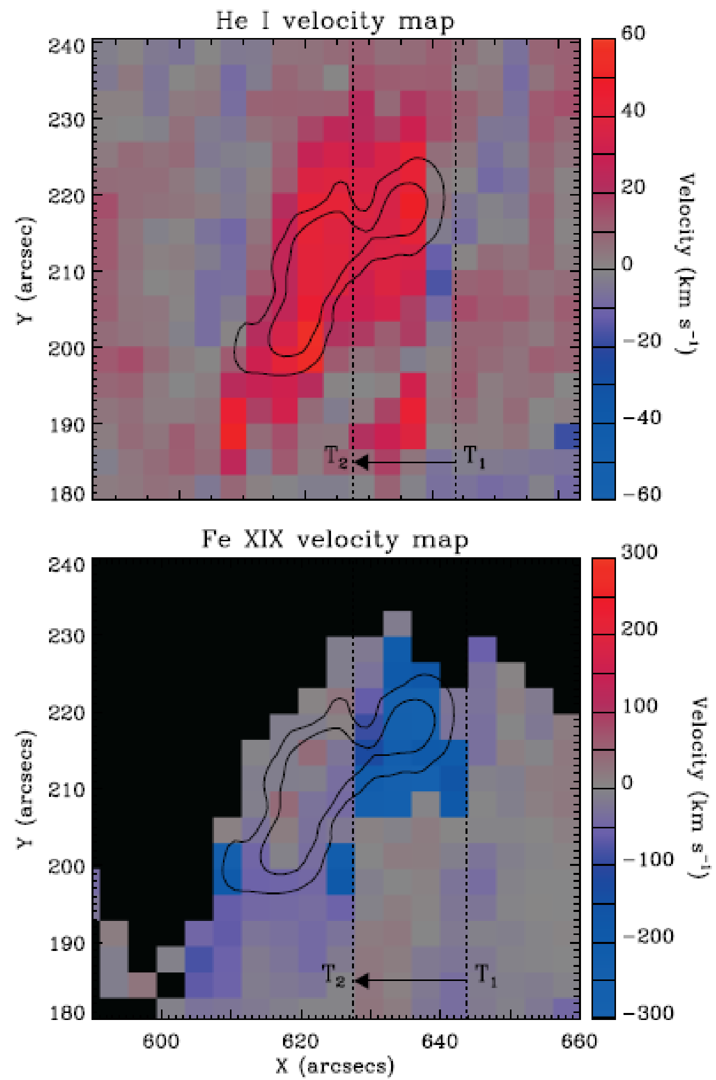
Czaykowska et al. 1999

Explosive Chromospheric Evaporation

Cospatial and cotemporal RHESSI and CDS observations of chromospheric evaporation during the impulsive phase of an M2.2 flare.

High upflow velocities (~230 km s1) were observed in high-temperature Fe xix emission, while much

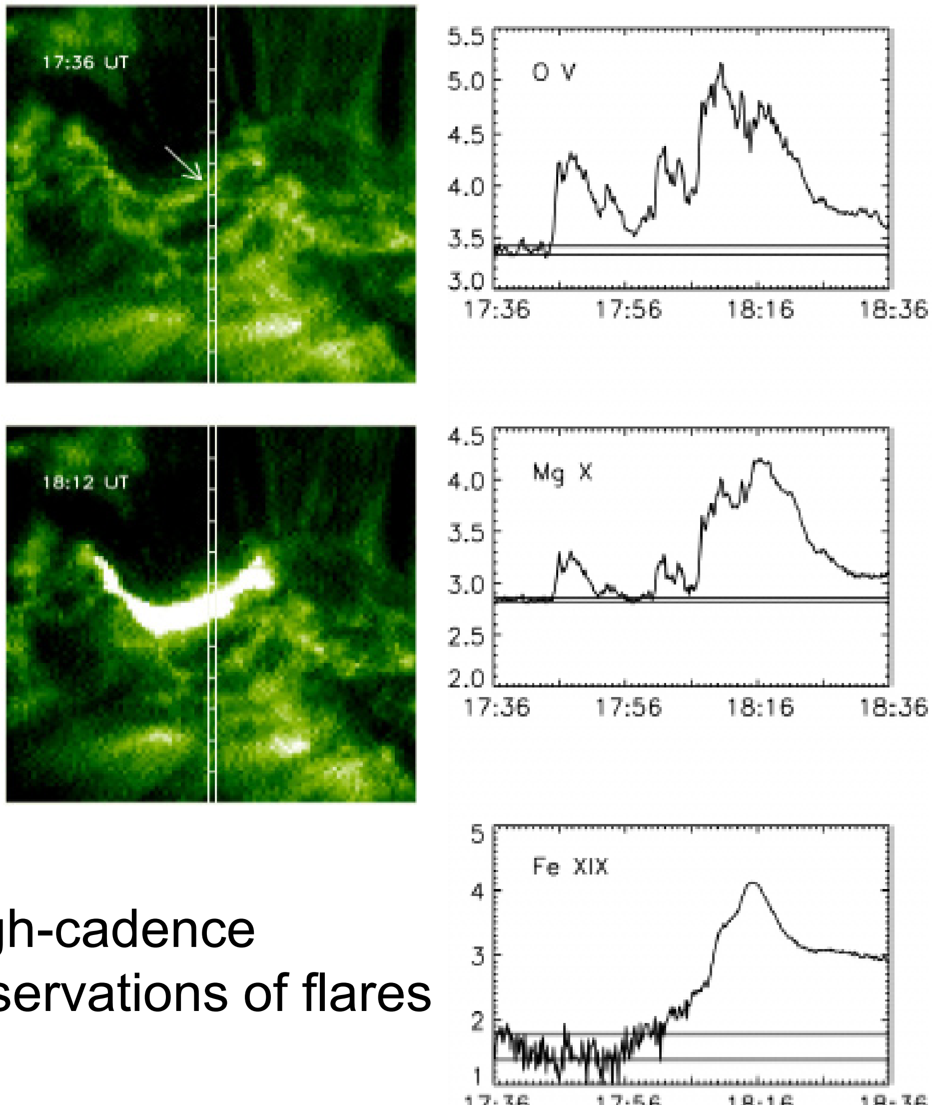
Lower downflow velocities (~40 km s1) were observed in the cooler He I and O V lines.



Velocity maps

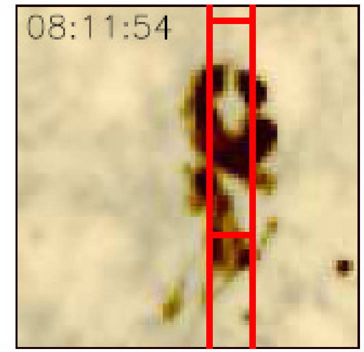
Milligan et al. 2006

High Cadence Flare Studies

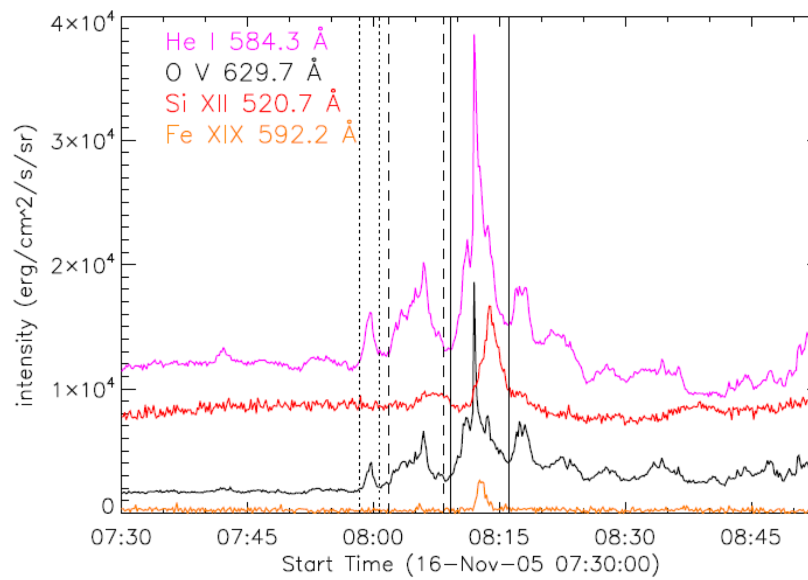


High-cadence observations of flares

Brosius (2004)

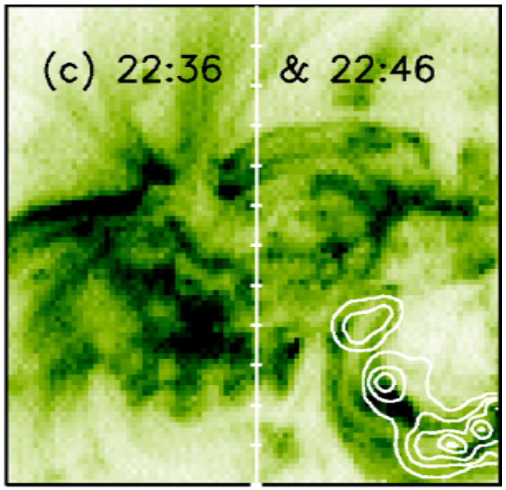


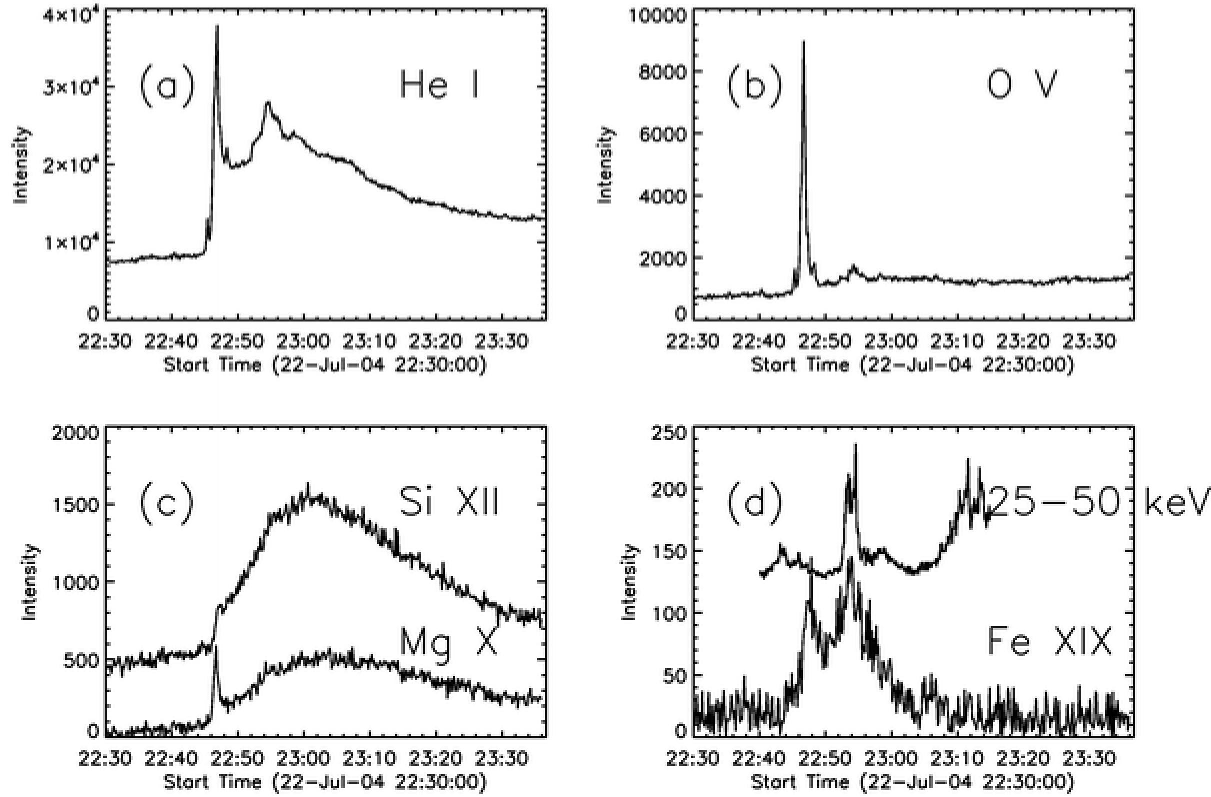
Microflare



Brosius (2009)

High Cadence Flare Studies

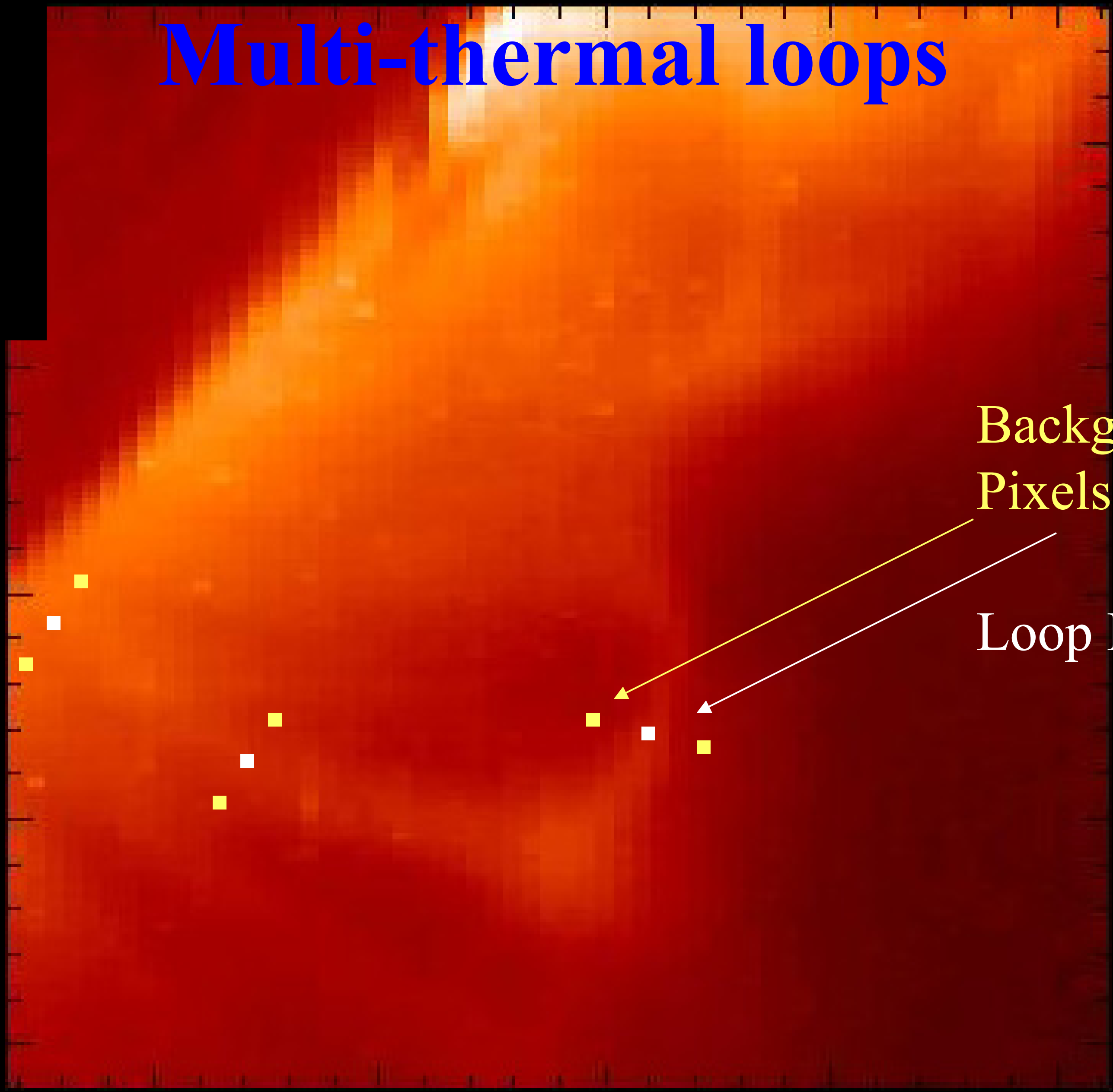




Impulsive flare – Downflows in He I and O V, upflows in coronal lines → explosive chromospheric evaporation (Brosius et al. 2007)

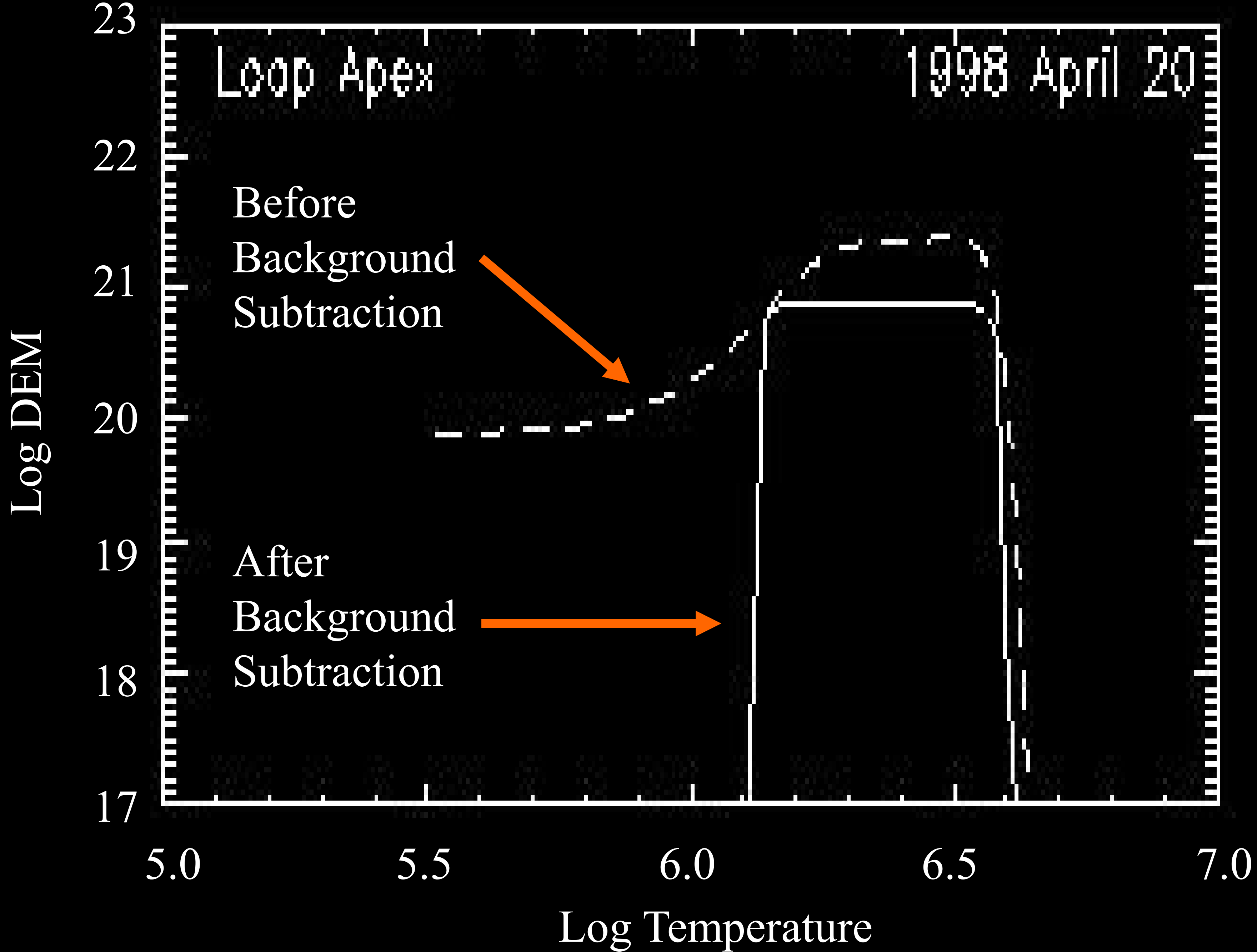
Multi-thermal loops

CDS
Si XII
Log T
= 6.25



Schmelz et al. (2001), ApJ, 556, 896; Schmelz & Martens (2006), ApJL, 636, L49

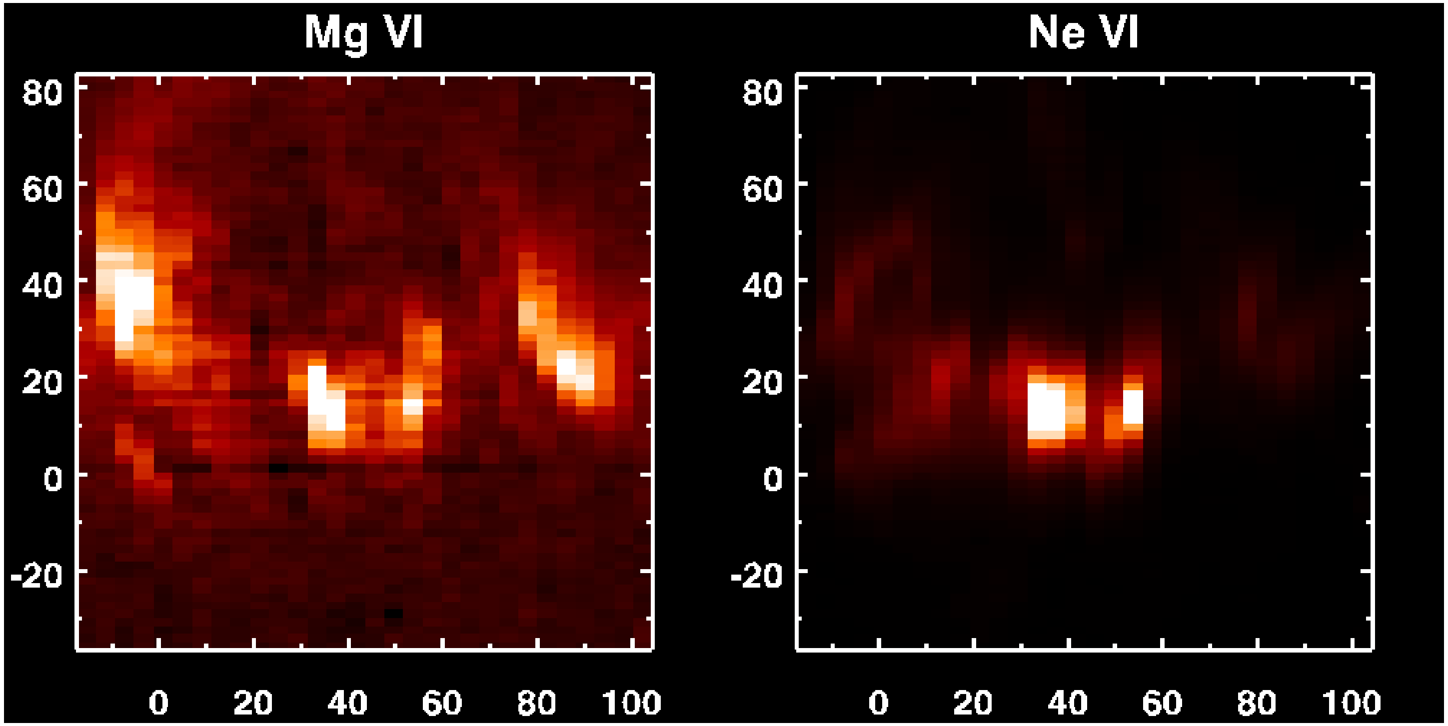
Multi-thermal Loops – Schmelz et al.



Mg/Ne Abundances

Quiet Sun enhancements over photospheric Mg/Ne value:
Network: 1.25 , Cell centres: 1.66.   Young (2005, A&A, 439, 361

Active Region:

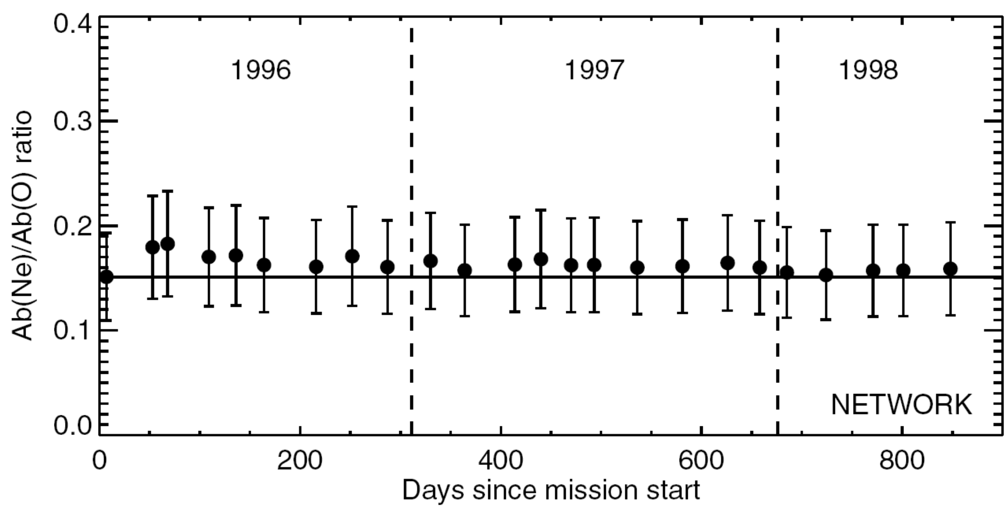


- Central brightenings show photospheric Mg/Ne ratio in area of emerging flux
- Loop footpoints show *factor 10* enhancement in Mg/Ne

Young & Mason (1997, Sol. Phys., 175, 523)

Neon Abundance

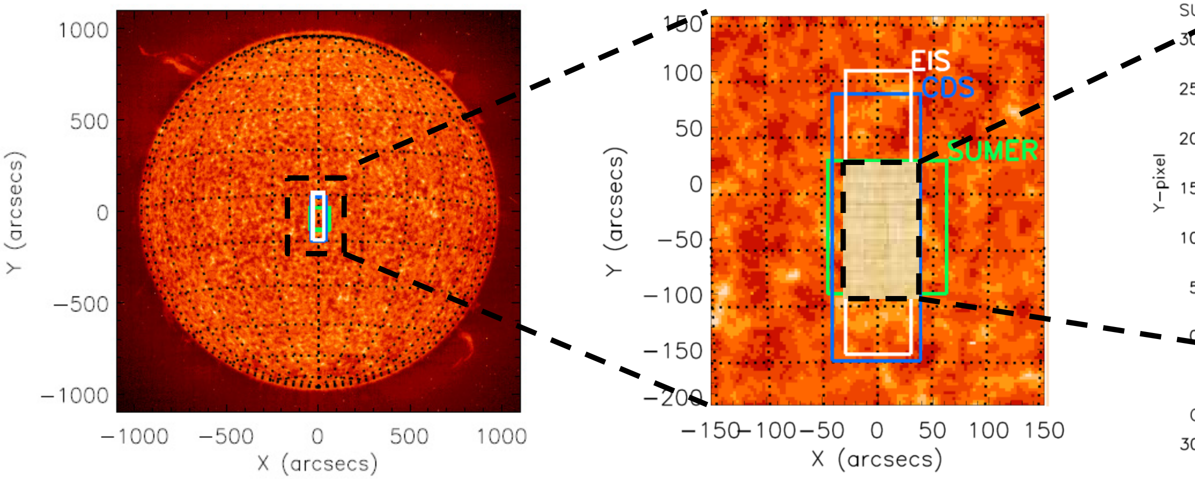
- Solar neon abundance has been determined from solar energetic particles (SEPs): Ne/O abundance ratio = 0.15
- Drake & Testa (2005, Nature) suggested a revised value of 0.52 to *fix the discrepancy for the Standard Solar Model!*
- **The CDS quiet sun data 1996-1998 agrees with the SEP results**!
- The abundance of neon does *not* resolve the theory vs. observations problem for the SSM

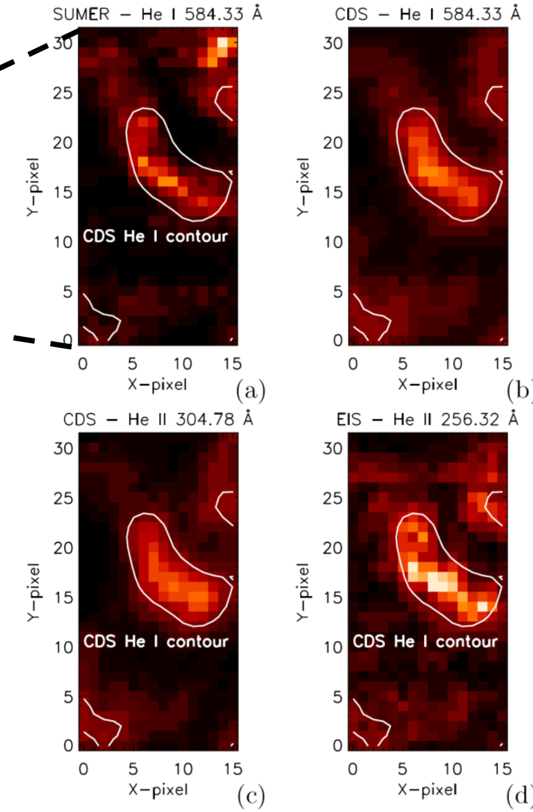


Young (2005, A&A, 444, L45)

Helium Enhancement

Giunta et al. 2015



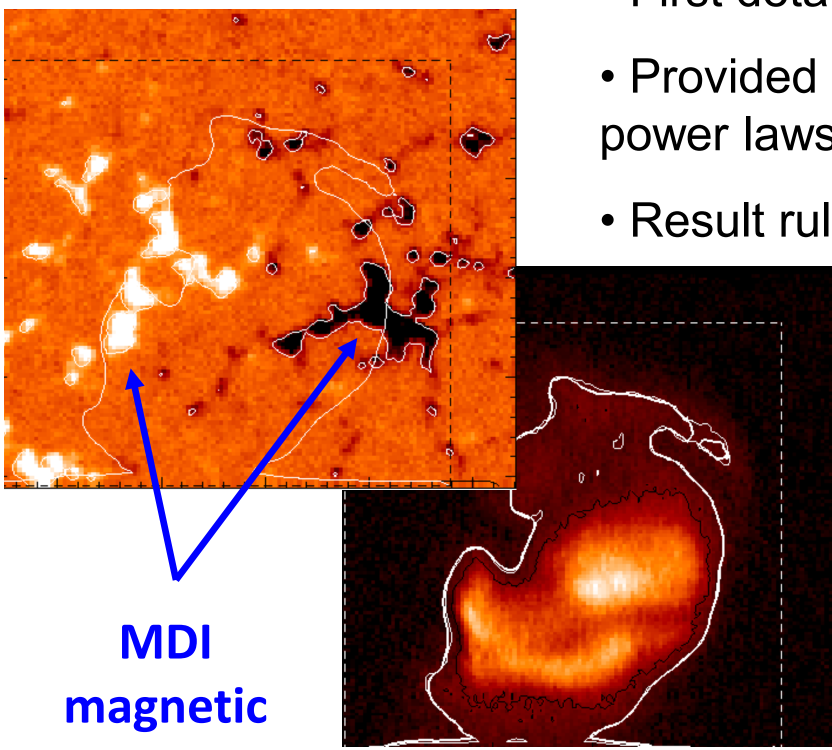


Source	He I	He II
Jordan (1975)	15	5.5
Macpherson & Jordan (1999)	10-14	13-25
Pietarila & Judge (2004)	2-5	2-13
Present work	0.5-2	5-13

- He I resonance lines and the intercombination line do not show a real enhancement.
- He II enhancement (5-13 x) agrees with previous measurements

Coronal Heating in Active Regions

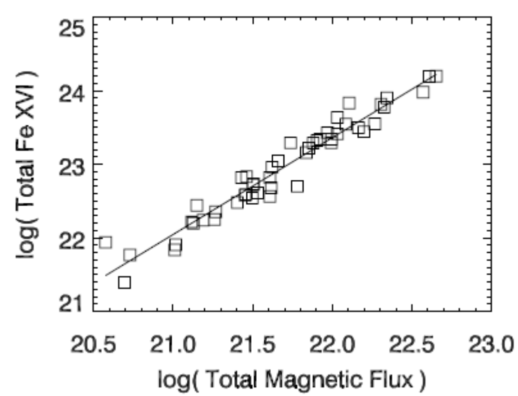
- Established **global relationships** between the **total magnetic flux** and **intensity** for 48 active regions in four EUV lines
- First detailed analysis of global power laws
- Provided correct mathematical interpretation – can the power laws provide constraints on the heating models?
- Result rules out 20 heating models



MDI magnetic field

CDS Fe XVI intensity

Twisting and wrapping of flux tubes in the photosphere, and Ohmic dissipation of currents in the corona? (Parker 1983)



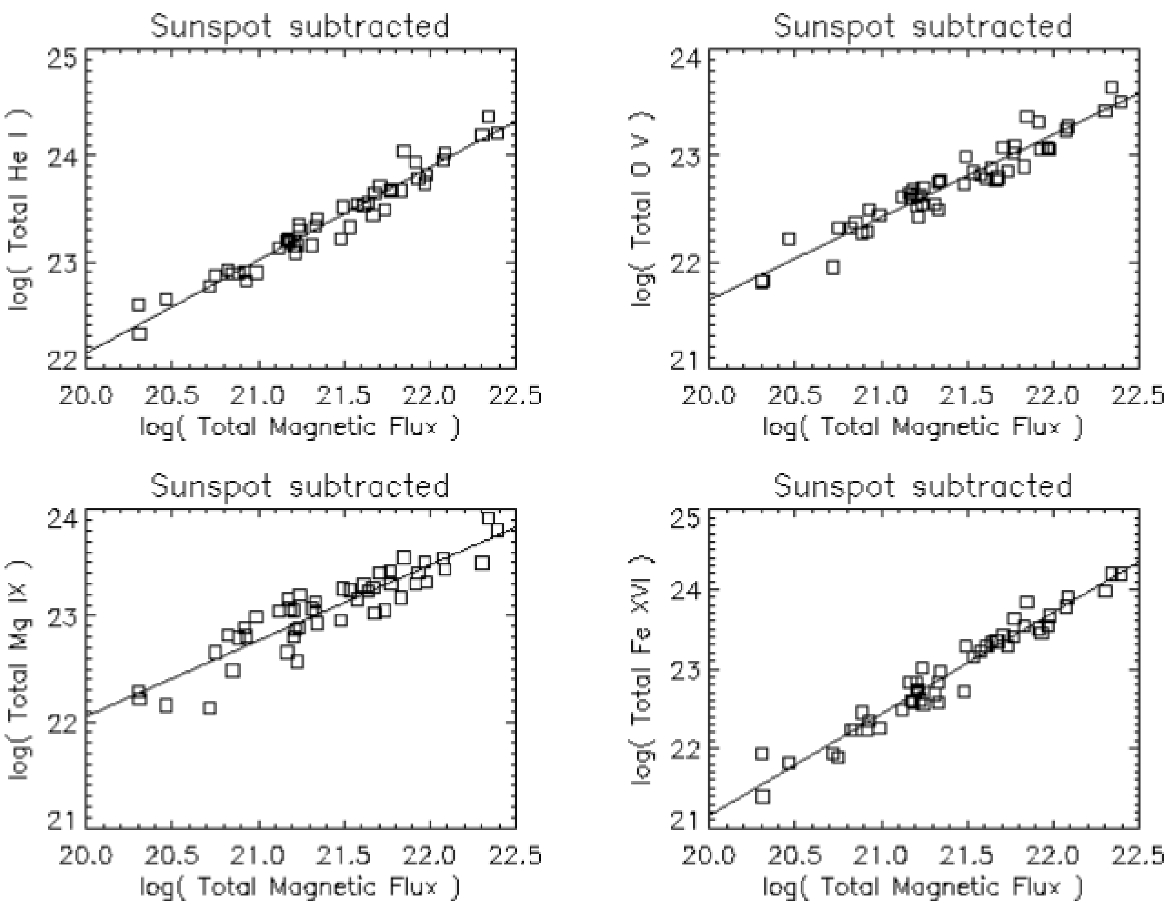
SOHO data

Fludra and Ireland, 2008

Total EUV Line Intensities & Magnetic Flux

CDS global power laws – low scatter, provide constraints on the heating rate

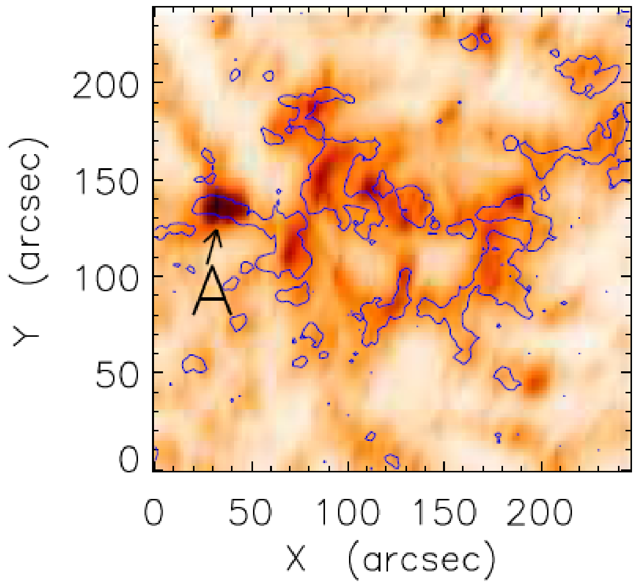
Fludra and Ireland, 2008, A&A

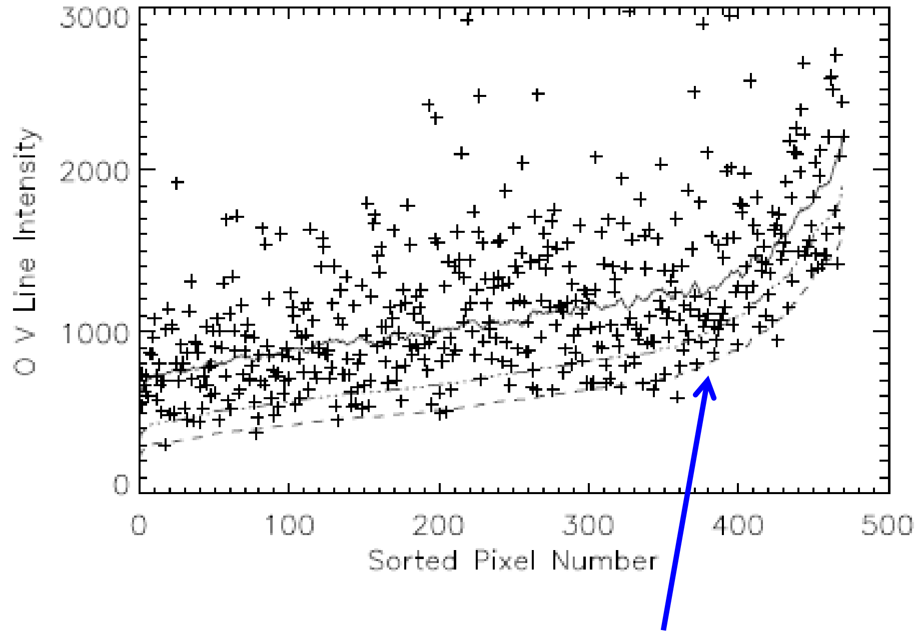


$I_{OV} \sim \Phi^{0.78}$

$I_{Fe} \sim \Phi^{1.27}$

Transition Region Heating





- For the first time, OV line compared to MDI magnetic field using high spatial resolution
- A ubiquitous variable component of heating in the transition region

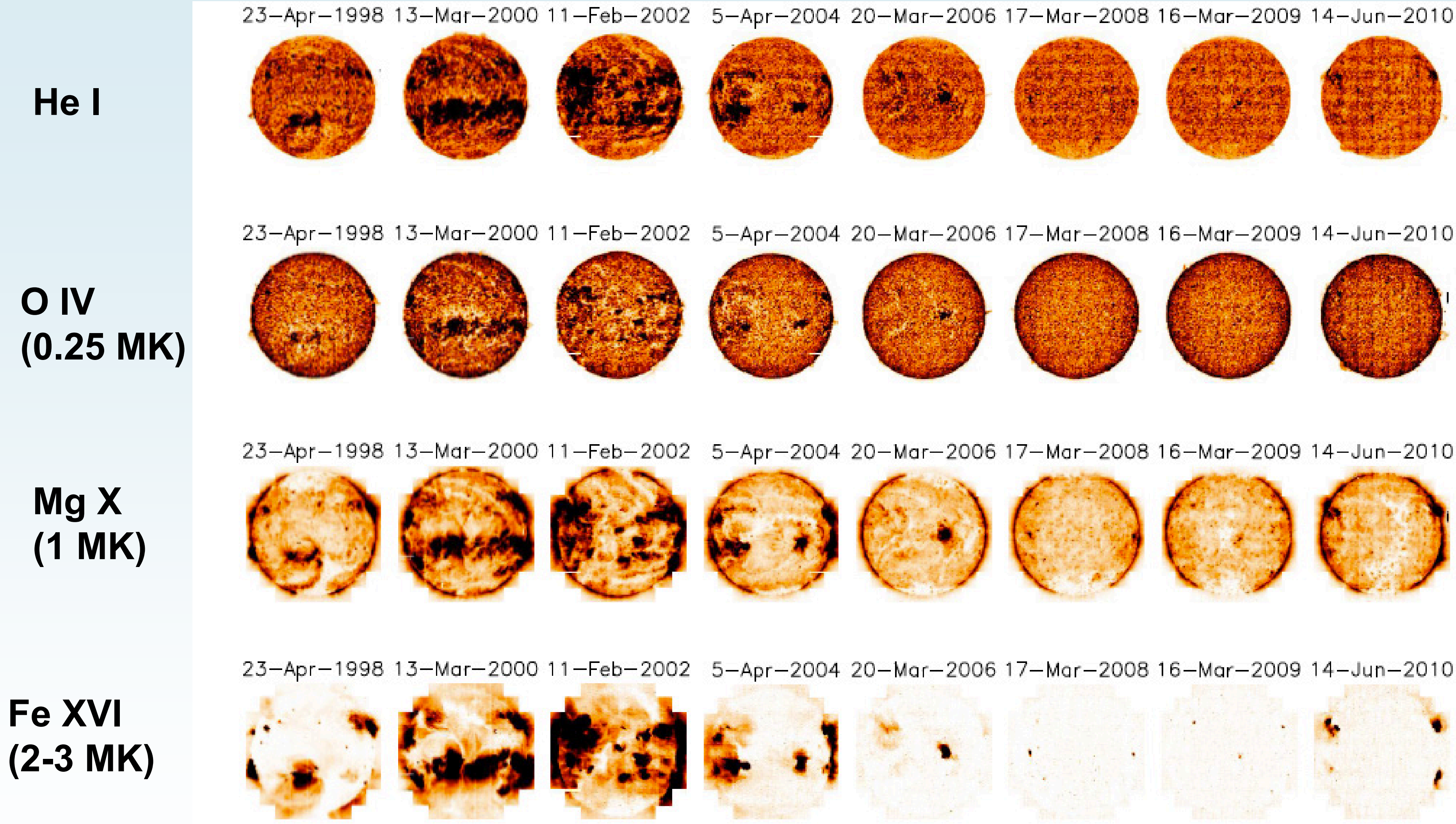
- Discovered <u>basal heating</u> common to all active regions

$$I_{bou}(\phi, L) = 210|\phi|^{0.45} L^{-0.20}$$

$$E_h \propto \phi^{0.5} L^{-1}$$

Fludra and Warren (2010, A&A)

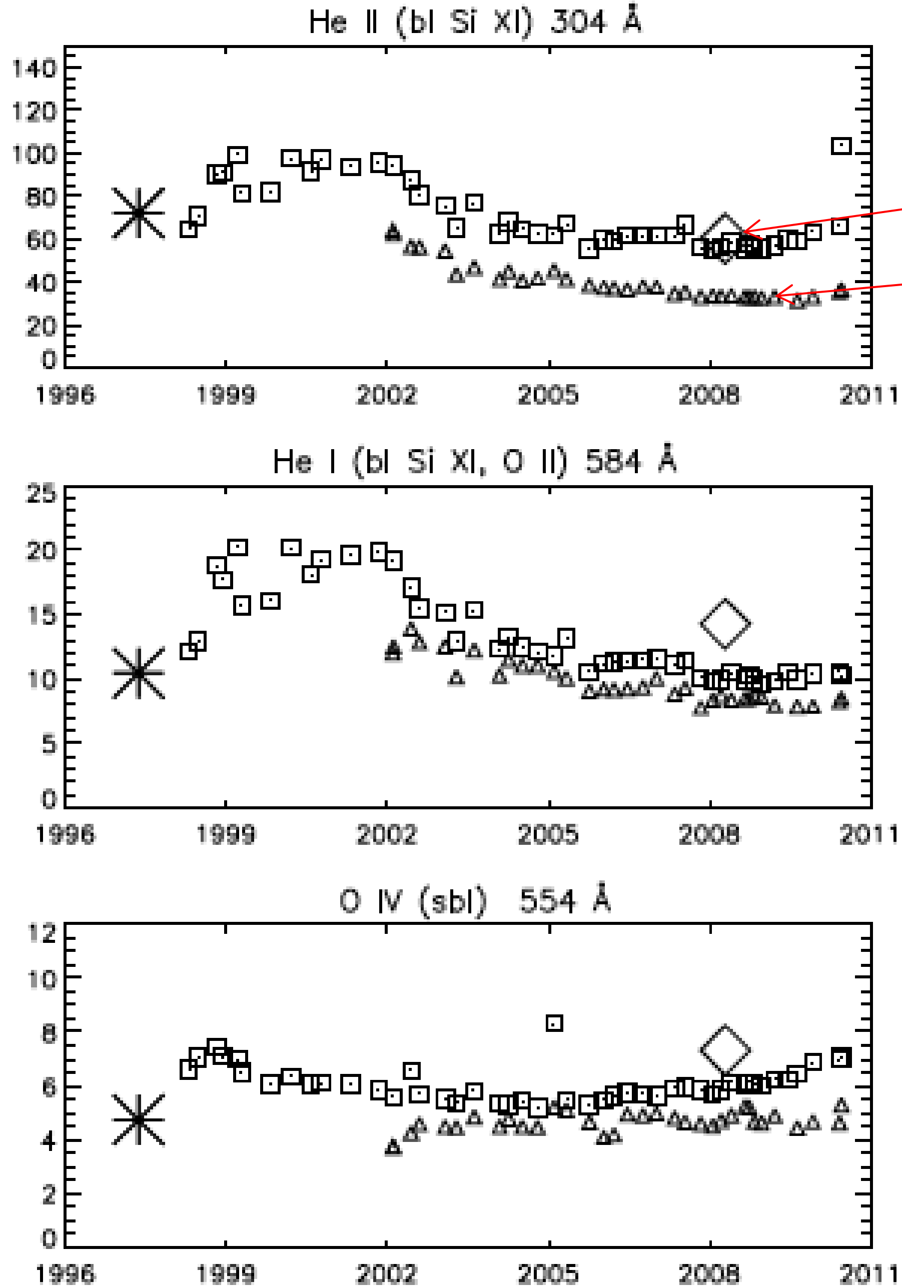
EUV radiances: SOHO CDS NIS USUN



CDS is the only instrument providing radiances in the strong EUV lines

Figure from G. Del Zanna - 2011

SOHO NIS irradiances vs. EVE and TIMED/EGS



Boxes:CDS NIS

SDO/EVE prototype

TIMED/EGS

CDS NIS has provided the first EUV irradiances along a solar cycle.

EUV spectral measurements is the only way to obtain accurate EUV line intensities!

Predictions from 10.7 cm radio flux unsuccessful for TR lines.

Del Zanna et al. (2005,2006, 2009).

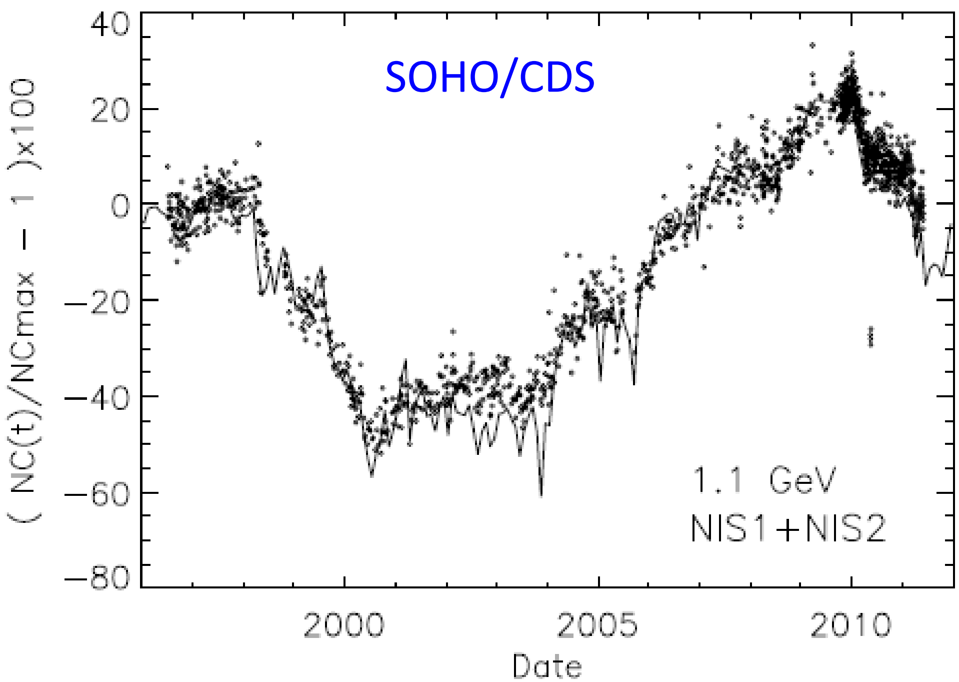
Del Zanna et al. 2010, A&A, 518, A49

Del Zanna & Andretta, 2011, A&A, 528, A139

Modulation of Galactic Cosmic Rays in the Heliosphere

- The only space record of high energy protons in Solar Cycle 23
- An unusually long solar minimum in 2007-2009
- **Record high cosmic ray numbers (20% higher than in 1996)**

- Correlates well with the tilt angle of the HCS
- The number of GCRs depends on the strength and 3D structure of the heliospheric magnetic field.



Fludra 2015, *ApJ*, 799, 31

Lessons Learnt

- The hands-on planning and NRT commanding was key to achieving a lot of good science.
- CDS was designed to be very flexible – allowing scientists to design a wide range of observation sequences
- A regular synoptic programme valuable for maintaining calibration and long-term monitoring of solar conditions.
- The EOF provided link between instruments and the planning of JOPs.
- Visiting science planners from Co-I groups and universities provided invaluable help in operations
- A dedicated facility at RAL enabled many users to learn about the instrument, the data and join in with the planning and operations.
- A working engineering model - useful in training people, for outreach and for the testing of studies.

When we were young…

EIT

Extreme-ultraviolet Imaging Telescope

Science Highlights & lessons learned

May 10, 2016, Orsay

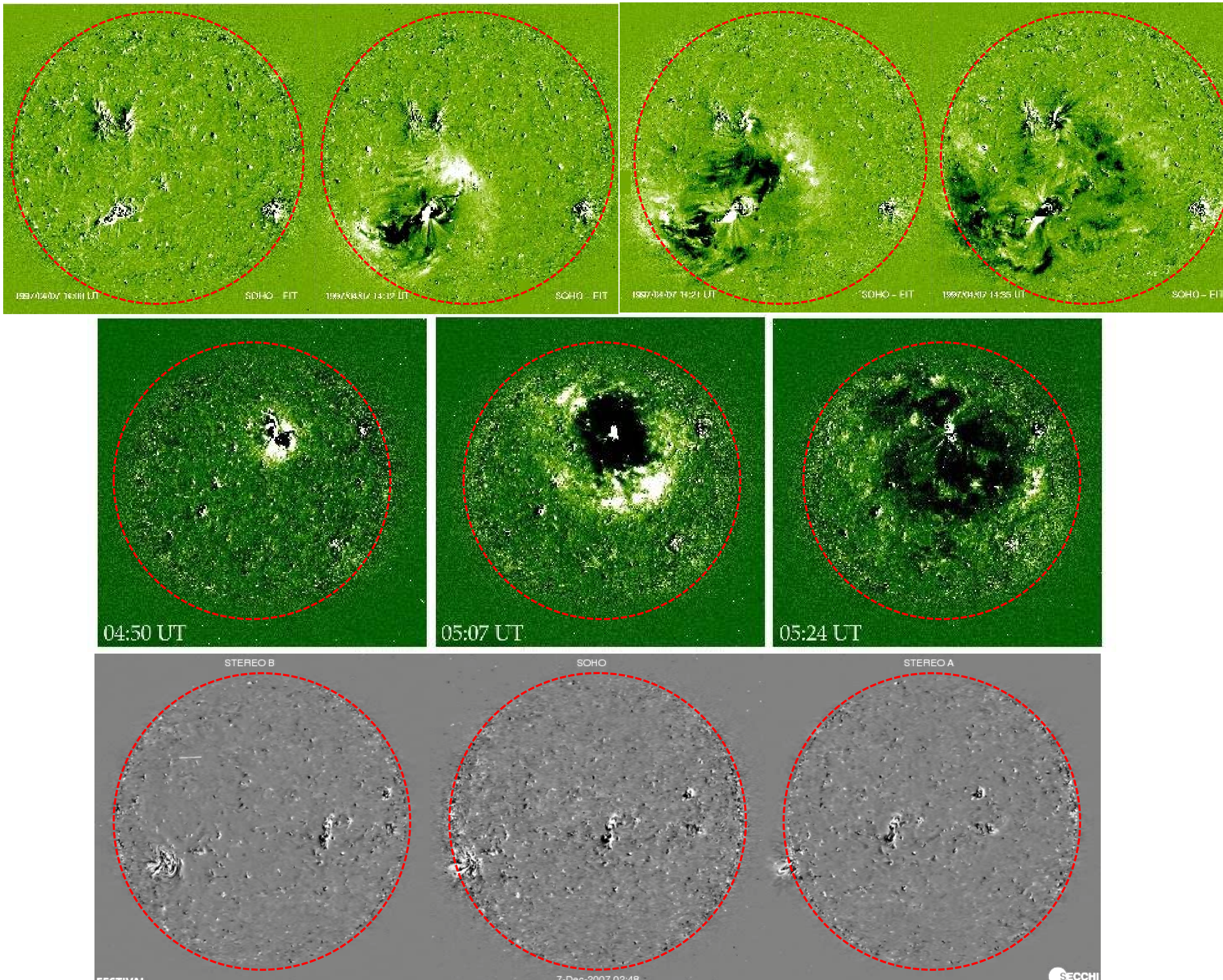
Frédéric Auchère

EIT waves !

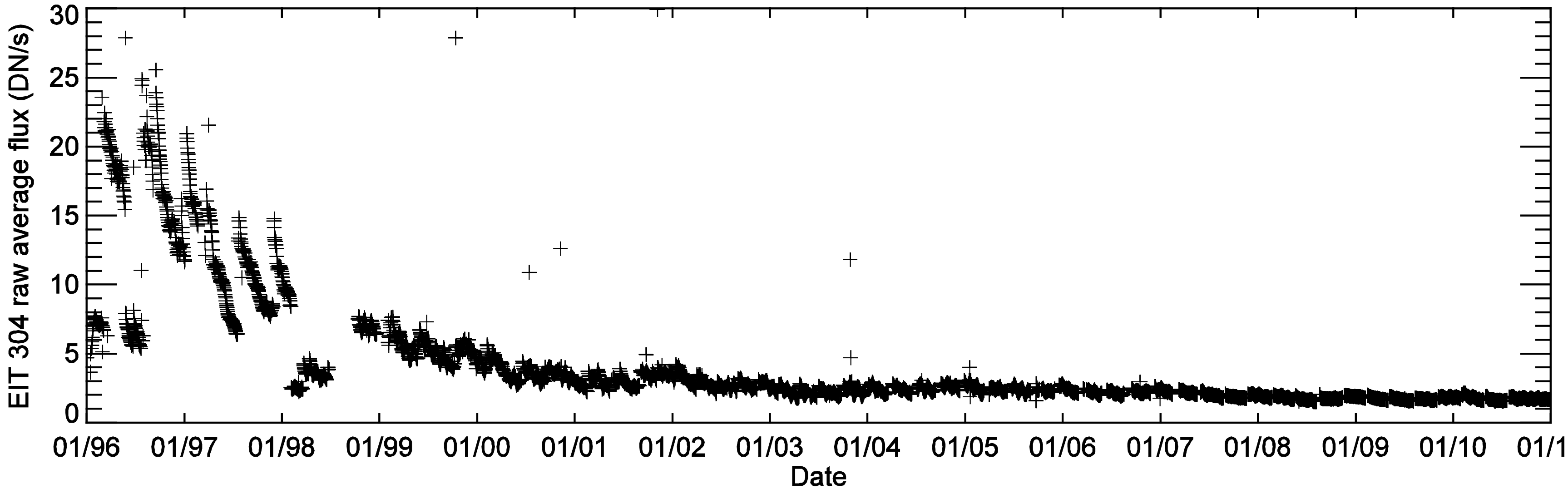
April 7, 1997

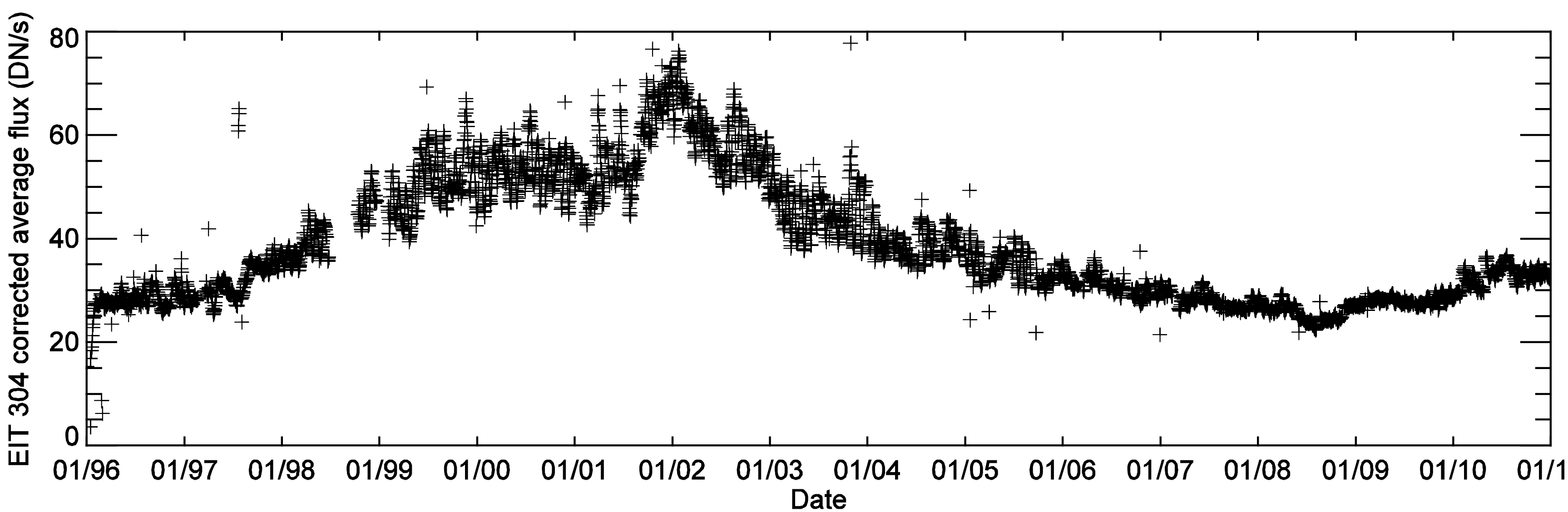
May 12, 1997

December 7, 2007

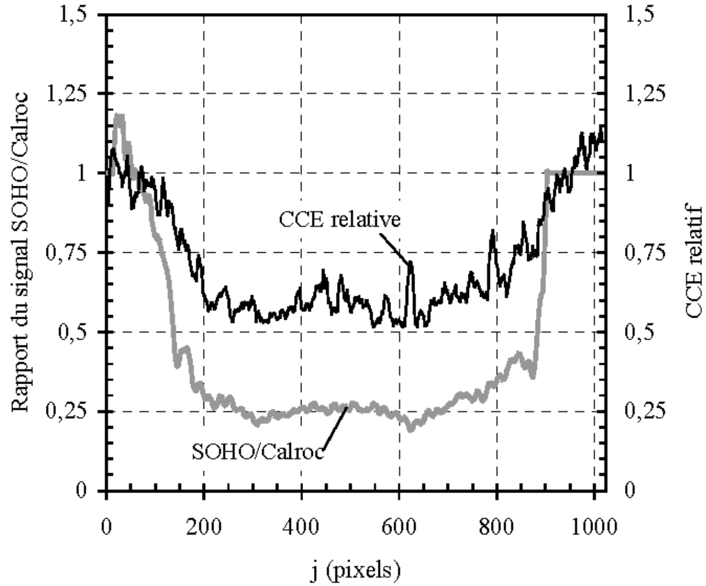


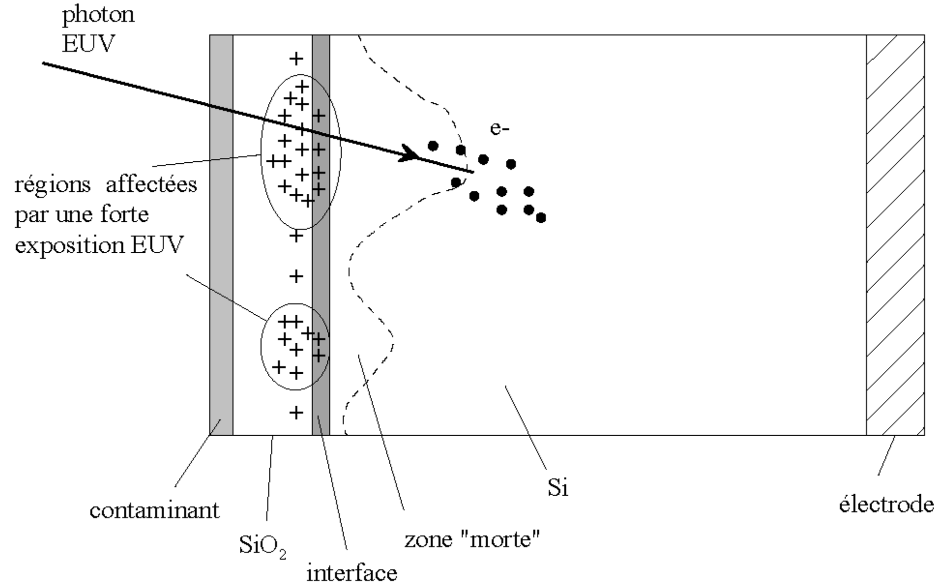
Integrated disk flux @ 30.4 nm before & after correction

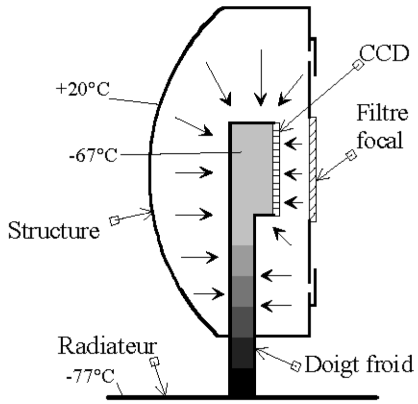




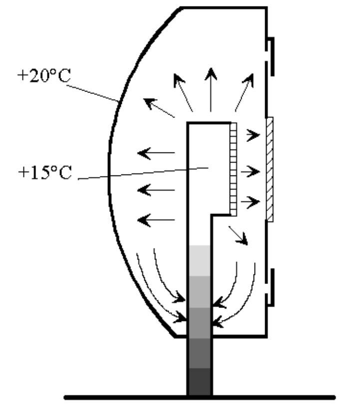
Cause of sensitivity loss: CCE + water







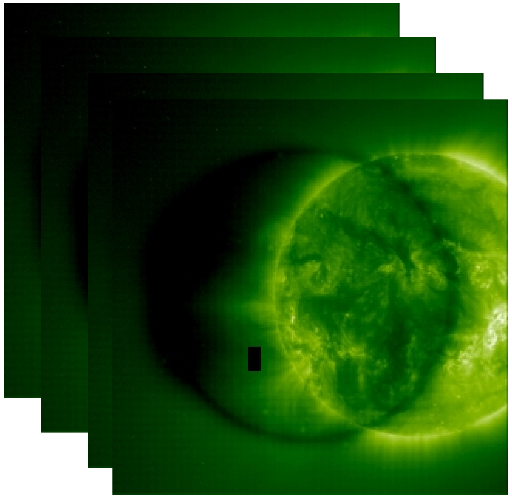
Phases opérationnelles



Phases de réchauffage

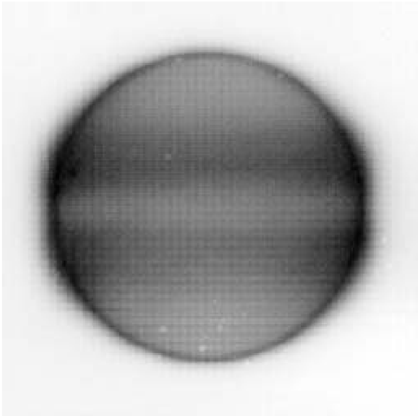
Principle of the in-flight correction

Set of N offset images

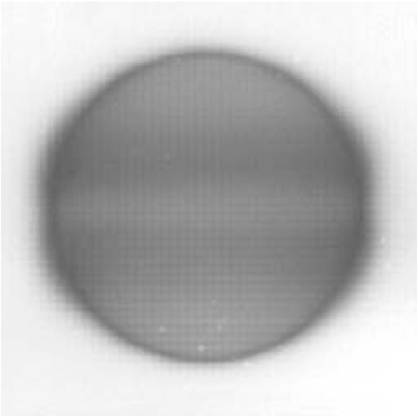


1. Need original 'clean' cal lamp image
2. Need to take cal lamp images regularly
3. Ratio of cal lamp images → WL degradation map
4. Offpoint → EUV degradation map (Kuhn et al.)
5. Correlation → WL to EUV relationship
6. WL degradation → EUV degradation

Kuhn et al. algorithm

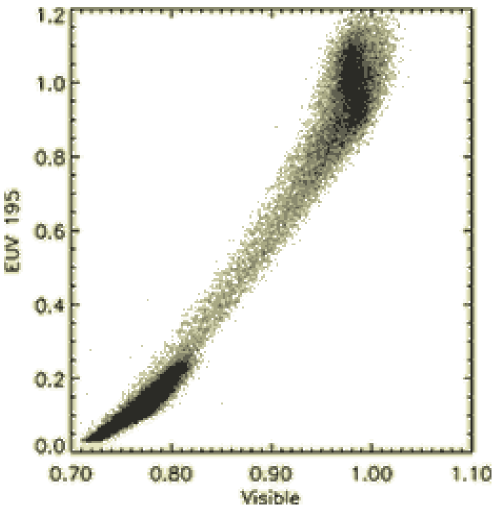


EUV flat field

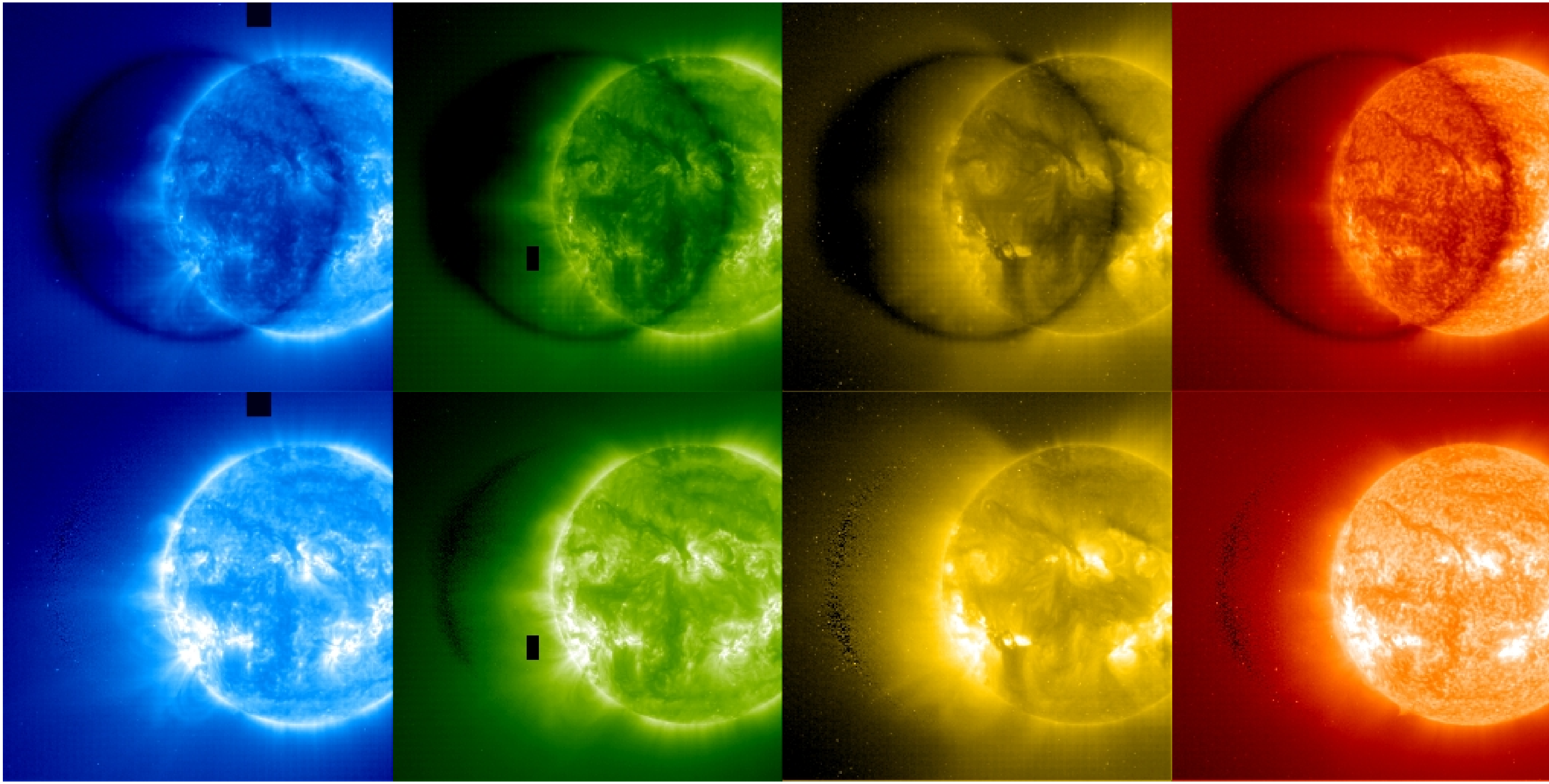


Cal lamp ratio

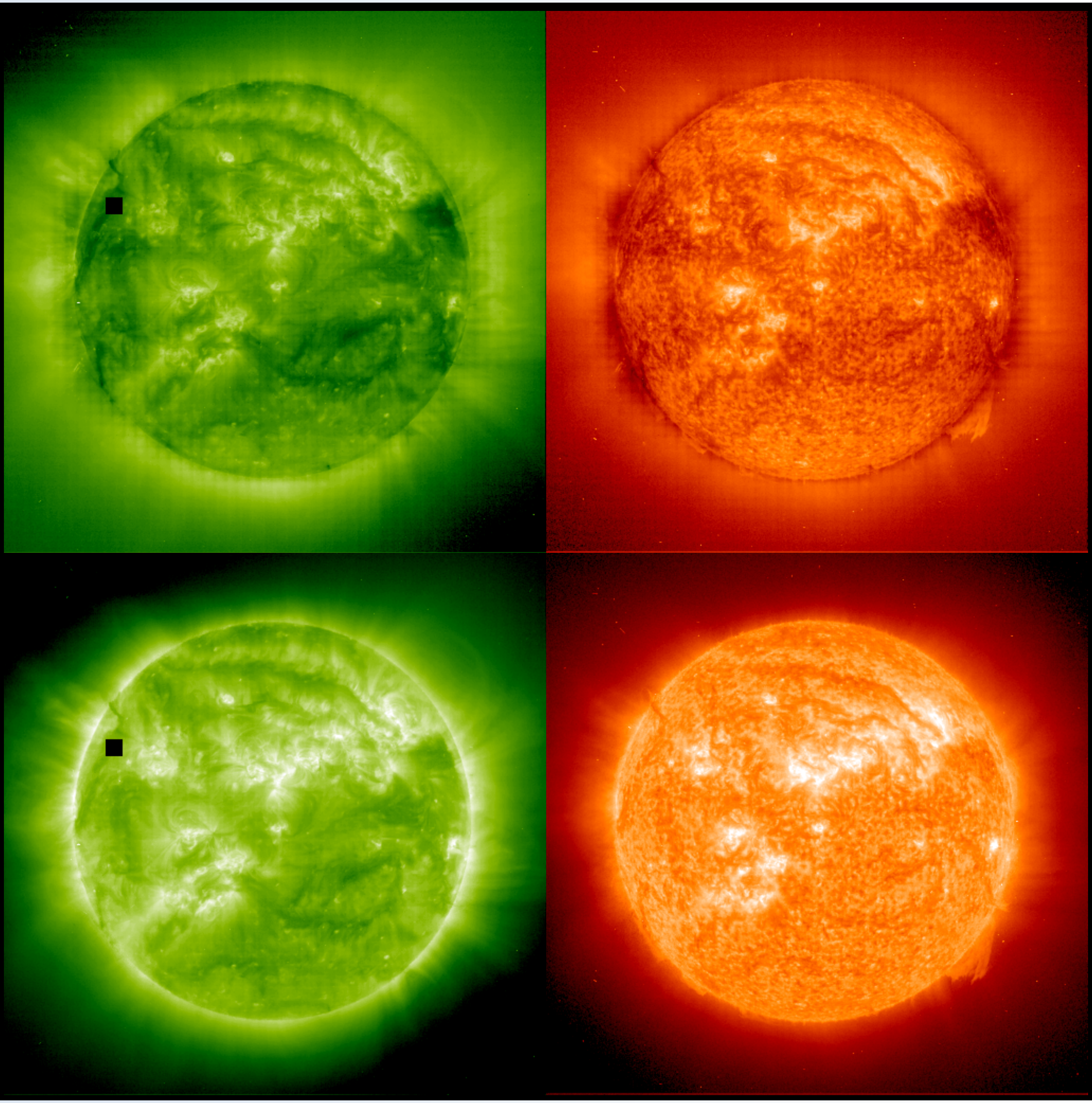
WL to EUV relationship



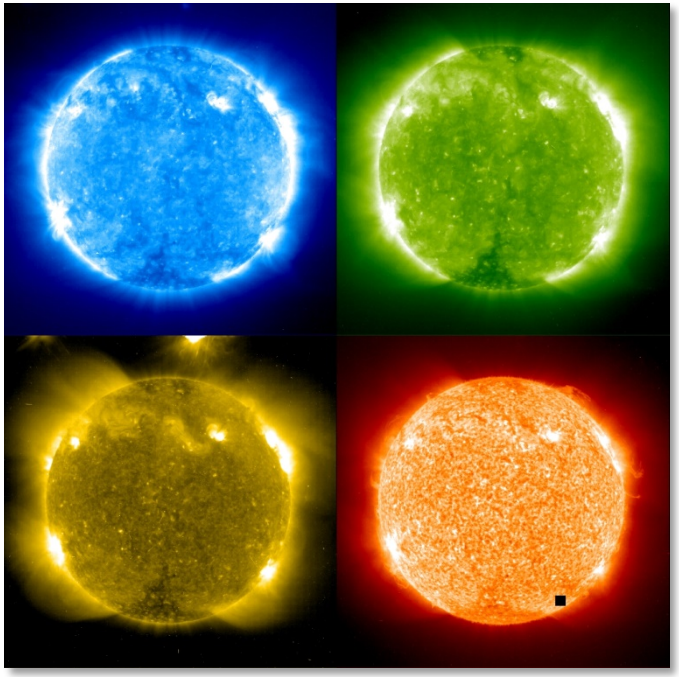
:D (1/2)



:D (2/2)



- Be clean & dry !
- S/C launch decontamination heaters ! (STEREO, SDO, Solar Orbiter …)
- Chose your color tables wisely !

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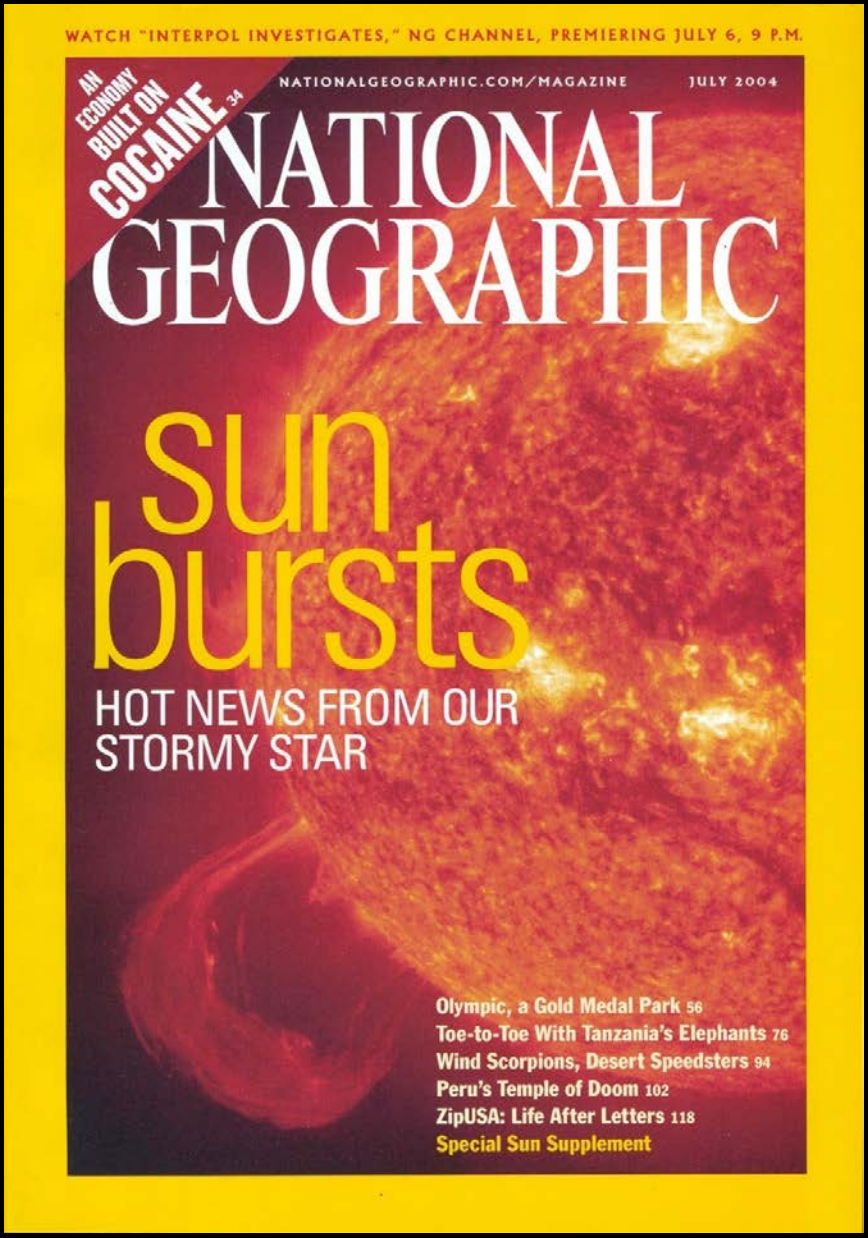
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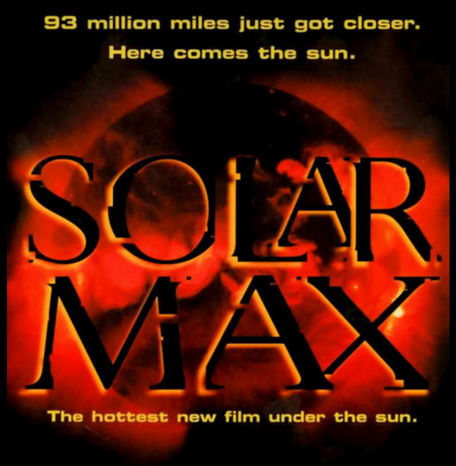
* Or so claim well-funded naysayers who still reject the overwhelming evidence of climate change. Inside the denial machine. By Sharon Begley
NASA image of the Sun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Here comes the sun.
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PAR DANNY BOYLE, LE RÉALISATEUR DE
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SUNSHINE
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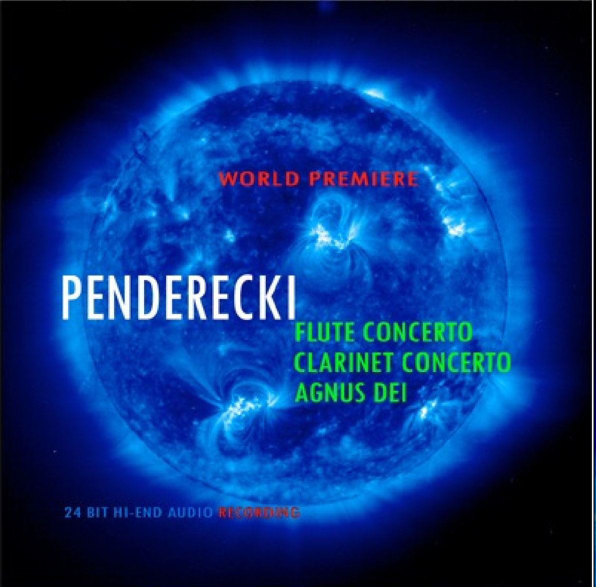
BIENTÔT CE SERA LE NÔTRE.


A MISCHA ROXEMA FILM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PENDERECKI
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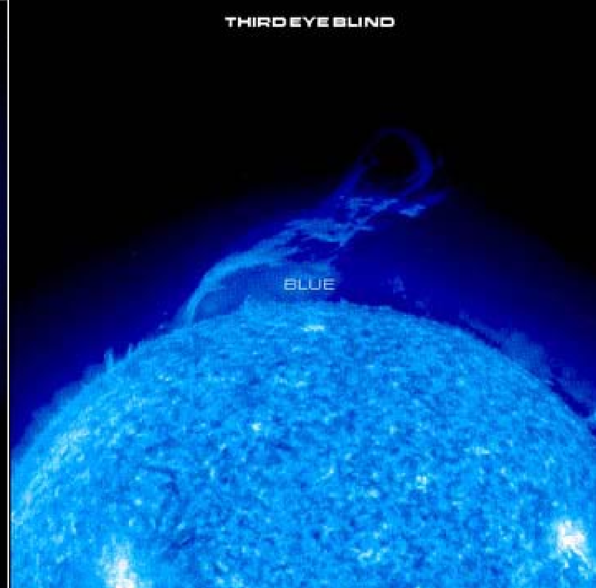
THIRD EYE BLIND
BLUE


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11.11.2016 CLUJ
13.11.2016 BELGRADE
15.11.2016 LJUBLJANA
17.11.2016 VIENNA
18.11.2016 ZURICH
19.11.2016 NUREMBERG
21.11.2016 MUNSTER
22.11.2016 AMSTERDAM
24.11.2016 LYON
25.11.2016 GENEVA
26.11.2016 DIJON
28.11.2016 CLERMONT FER.
29.11.2016 NANTES
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Wednesday, 15 January, 2003, 20:00 GMT

In pictures: Have the aliens landed?

A series of images which it is claimed prove the existence of aliens is going on show at Leicester's National Space Centre.

They are said to have been taken by a Nasa spaceship which is 1,000,000 miles from Earth.

Mike Murray, a UFO enthusiast who is putting on the show warned people not to contact the centre as it has been inundated with interest.

Here BBC News Online reveals why UFO spotters believe aliens have landed.

- Back to main story

Leicester
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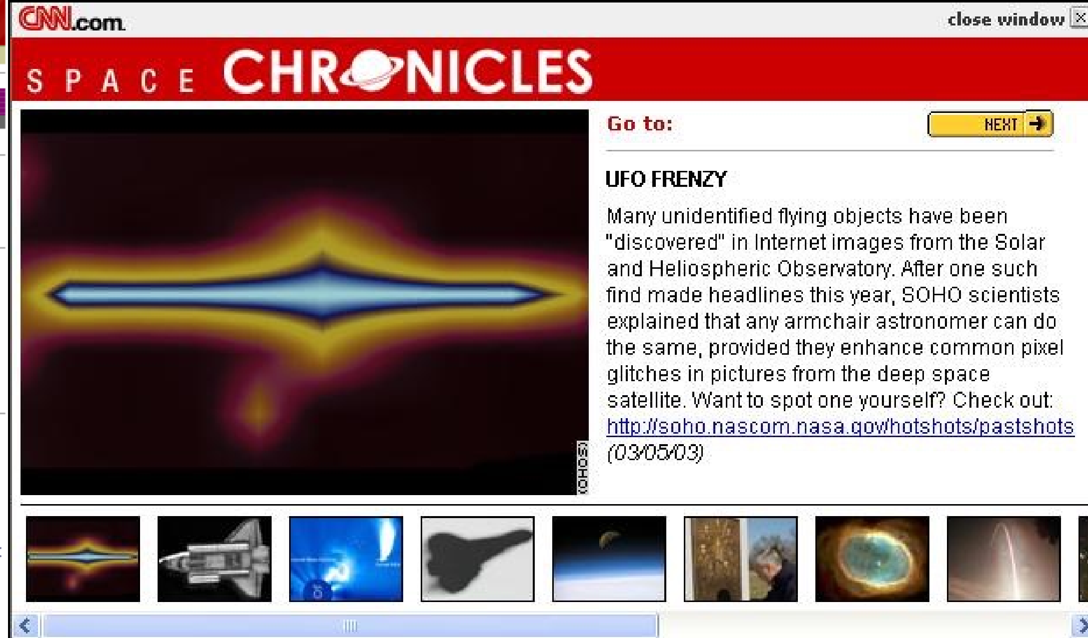

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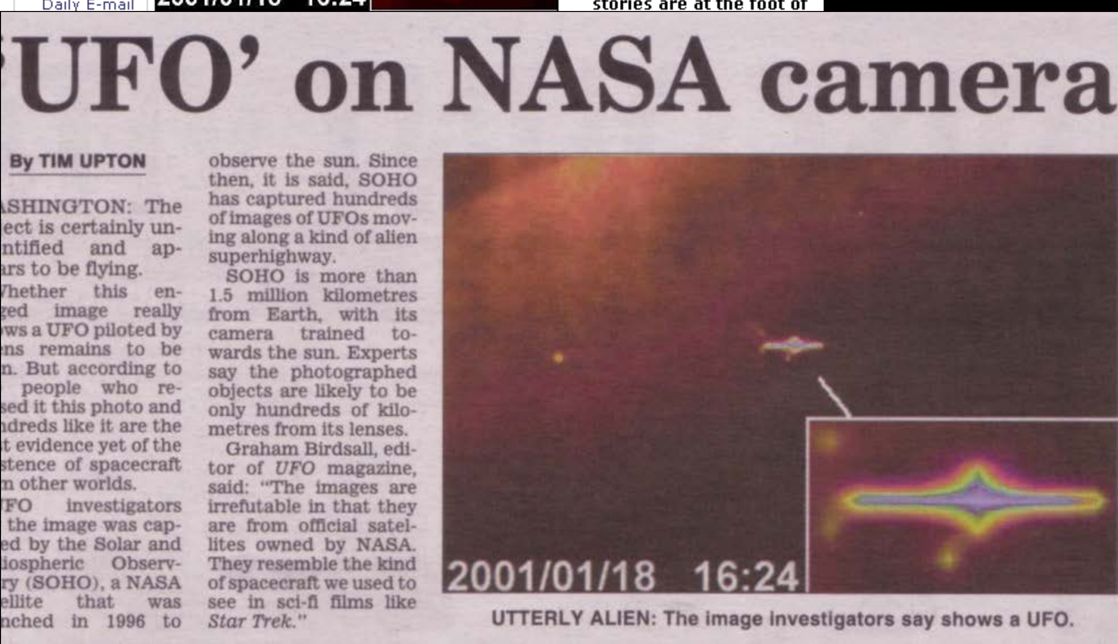
UFO FRENZY

Many unidentified flying objects have been "discovered" in Internet images from the Solar and Heliospheric Observatory. After one such find made headlines this year, SOHO scientists explained that any armchair astronomer can do the same, provided they enhance common pixel glitches in pictures from the deep space satellite. Want to spot one yourself? Check out: http://soho.nascom.nasa.gov/hotshots/pastshots (03/05/03)



'UFO' on NASA camera

By TIM UPTON

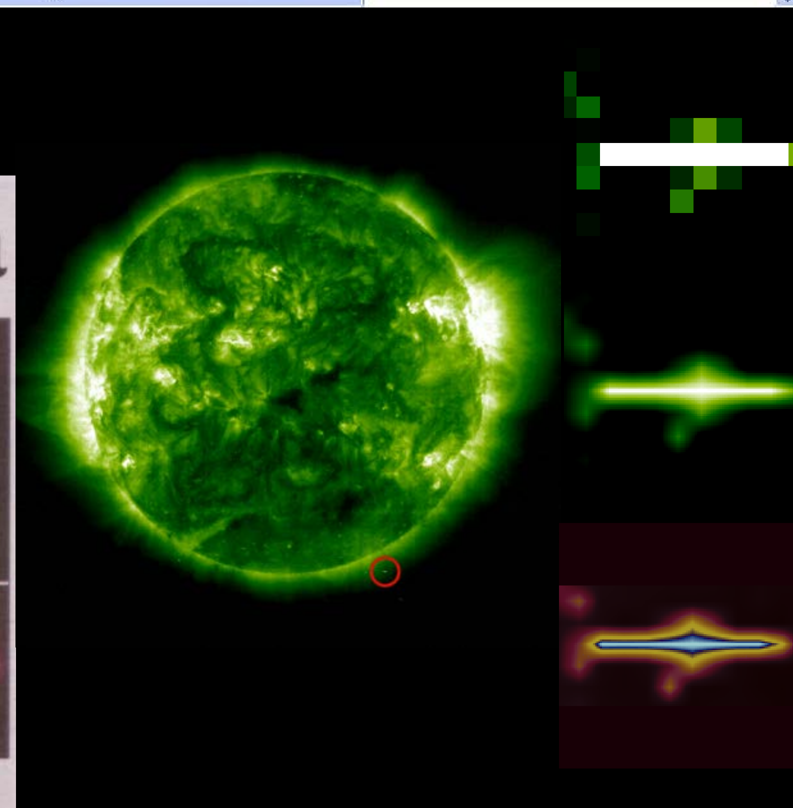
ASHINGTON: The ect is certainly un- ntified and ap- ars to be flying. Whether this en- ged image really ws a UFO piloted by ns remains to be n. But according to people who re- sed it this photo and ndreds like it are the t evidence yet of the stence of spacecraft n other worlds.

FO investigators the image was cap- ed by the Solar and iospheric Observ- ry (SOHO), a NASA ellite that was nched in 1996 to observe the sun. Since then, it is said, SOHO has captured hundreds of images of UFOs moving along a kind of alien superhighway.

SOHO is more than 1.5 million kilometres from Earth, with its camera trained towards the sun. Experts say the photographed objects are likely to be only hundreds of kilometres from its lenses.

Graham Birdsall, editor of *UFO* magazine, said: "The images are irrefutable in that they are from official satellites owned by NASA. They resemble the kind of spacecraft we used to see in sci-fi films like *Star Trek*."

UTTERLY ALIEN: The image investigators say shows a UFO.




PROFILE:
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iPod Nano Skin - Blue Giant - $5.99

ITEM #: IPN-BGIANT
QTY IN CART: 0

SAVE TO WISHLIST | SEND TO A FRIEND | REQUEST SKIN CUSTOMIZATION

more ipod nano skins...

Give your new iPod® Nano a new look in seconds and protect it from abuse at the same time! Forget thick plastic shells - skin it! Check out this ready-to-apply iPod Nano full-color skin with an ultra-high resolution full-color "Blue Giant" design printed on premium grade adhesive-backed vinyl. The skin is then covered with a clear protectant layer for the ultimate in durability. Remember - all of our full-color skins use a patented repositionable/removable/reusable adhesive backing for fast, easy and accurate installation and **goo-free removal**!

This skin kit covers the front and back of the iPod Nano for maximum effect and is 100% compatible with our Screen Armor™ screen protector kits.

Due to differences in monitors, color may vary from photo.

BATTLE ARMOR
SHOP WITH CONFIDENCE...
NO SMUDGING
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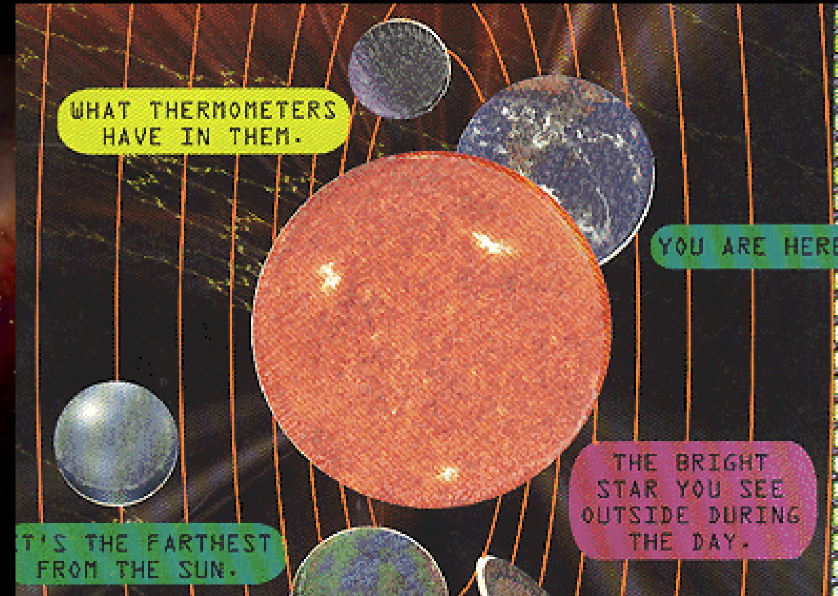
NO BLURRING
WE GUARANTEE IT!

Quantity: 1 **Buy**

12 Piece Master Kit Shown
*Color may be slightly different than photo.

4 Piece Master Kit Shown


POWER RANGERS
SOLAR STRIKE
RANGERS OF SPACE, POWERS OF THE SUN!


WHAT THERMOMETERS HAVE IN THEM.
YOU ARE HERE
THE BRIGHT STAR YOU SEE OUTSIDE DURING THE DAY.
T'S THE FARTHEST FROM THE SUN.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- Mode DNIe™
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- Dynamic contrast (jusqu'à 2000:1)
- Mode MCC (My Color Control)
- Simple tuner (PiP PC/AV)
- Connectiques DVI, Component & PC
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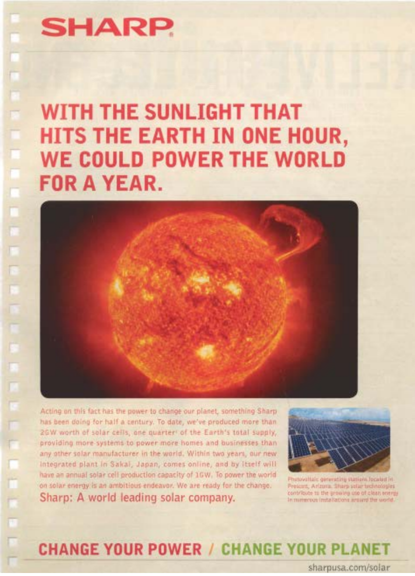
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WITH THE SUNLIGHT THAT HITS THE EARTH IN ONE HOUR, WE COULD POWER THE WORLD FOR A YEAR.
Acting on this fact has the power to change our planet, something Sharp has been doing for half a century. To date, we've produced more than 2GW worth of solar cells, one quarter of the Earth's total supply, providing more systems to power more homes and businesses than any other solar manufacturer in the world. Within two years, our new integrated plant in Sakai, Japan, comes online, and by itself will have an annual solar cell production capacity of 1GW. To power the world on solar energy is an ambitious endeavor. We are ready for the change.
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1050 BRUXELLES

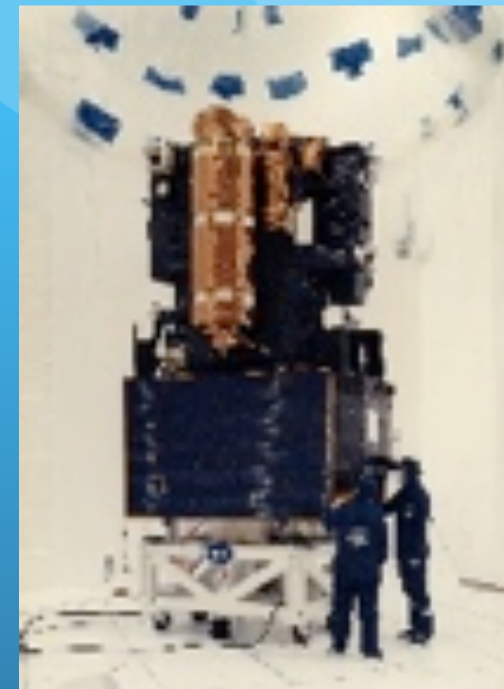
UVCS on SOHO

Science highlights

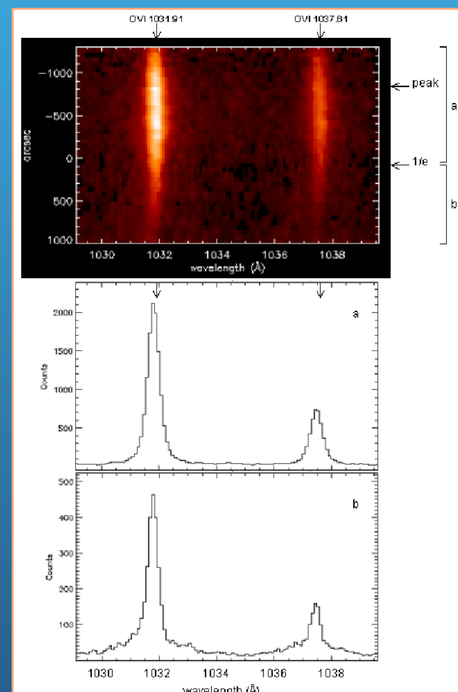
Daniele Spadaro on behalf of the UVCS team

UVCS: UltraViolet Coronagraph Spectrometer

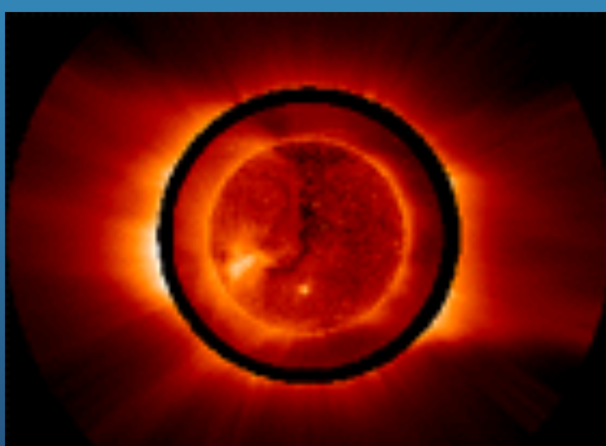
PI: J.L. Kohl, SAO, Cambridge MA, USA
Co-PI: G. Noci, University of Florence, Italy

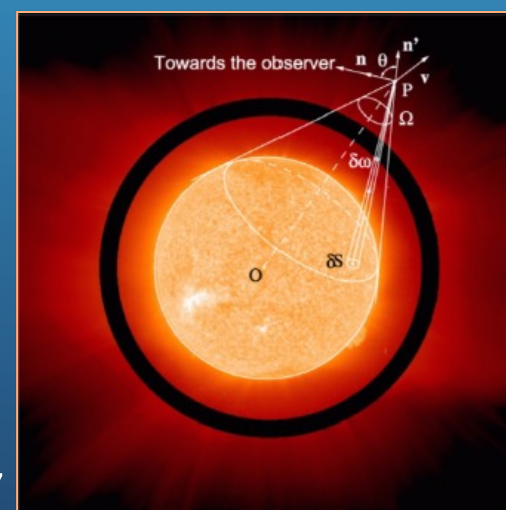


First UV spectroscopic observations of the extended corona :
- solar wind source and acceleration regions
- CME temperature structure and dynamics



- H I Lyα 1216 Å,
- O VI 1032, 1038 Å



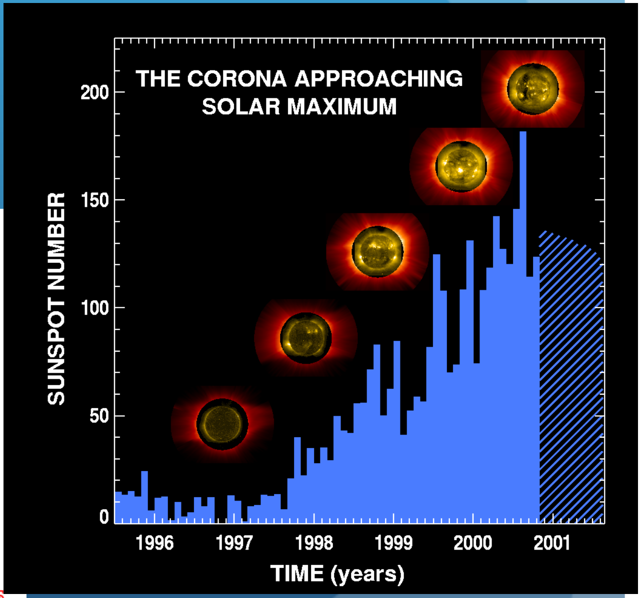


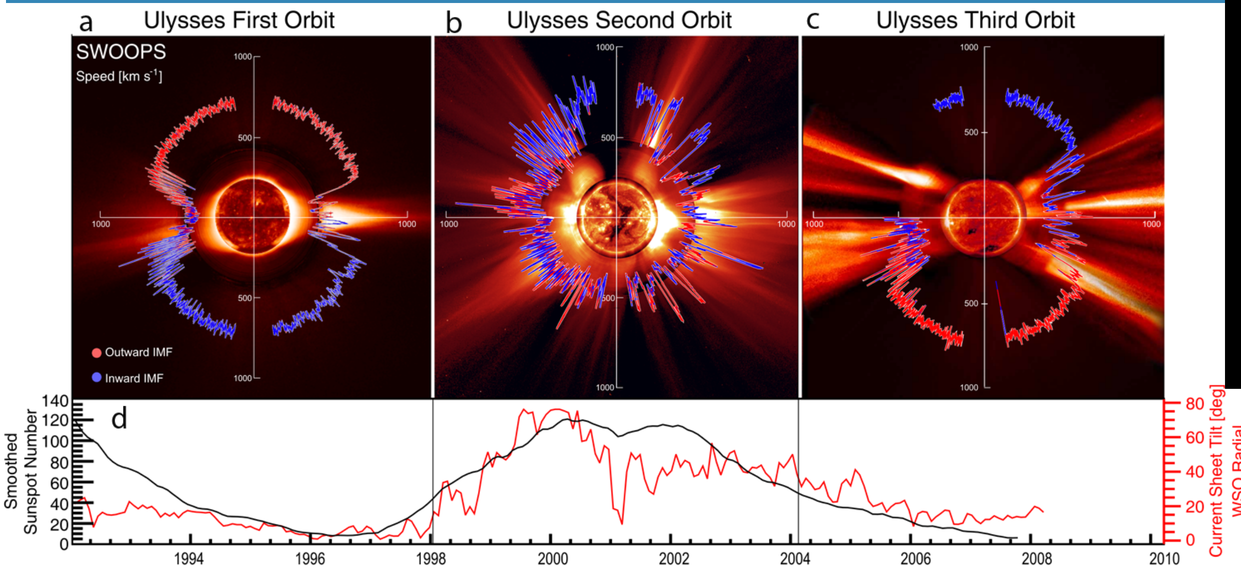
Gabriel 1971, Withbroe et al. 1982, Noci et al. 1987

What did we learn from UVCS?

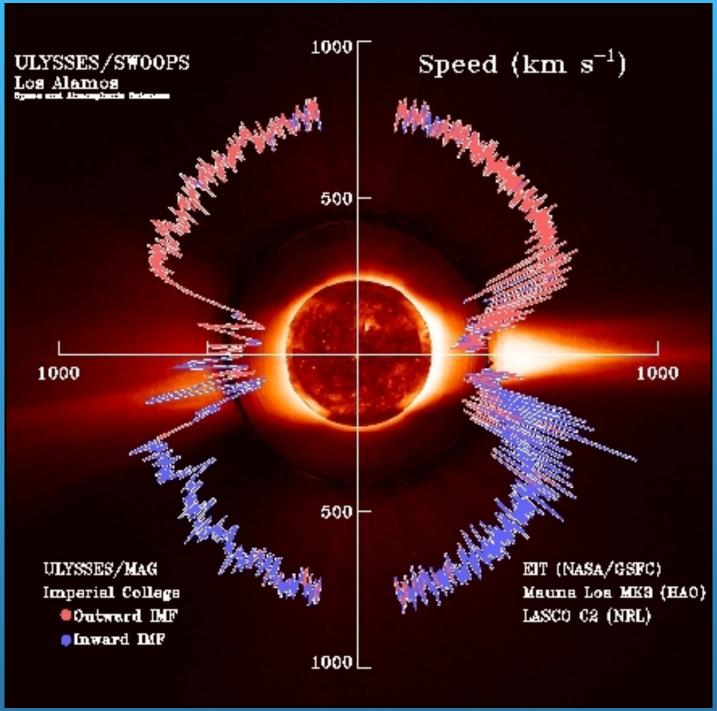
- **Solar wind physical parameters:** expansion velocities, kinetic temperatures, proton and minor ion velocity distributions, chemical composition (minor ions)

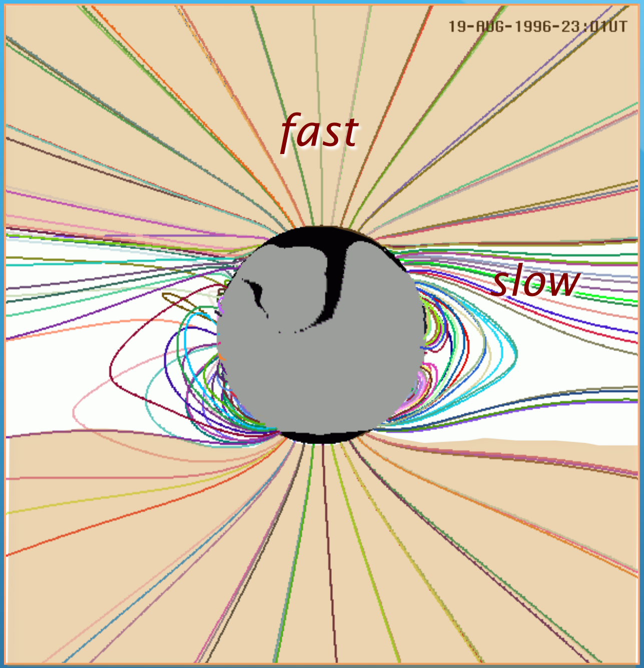
- **More than one activity cycle**





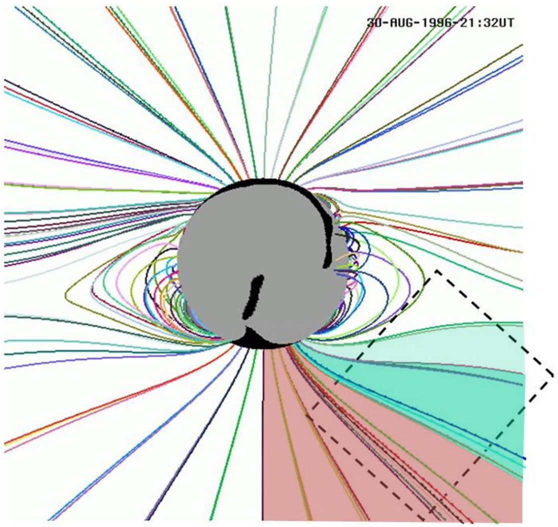
Solar corona expansion during the minimum activity phase

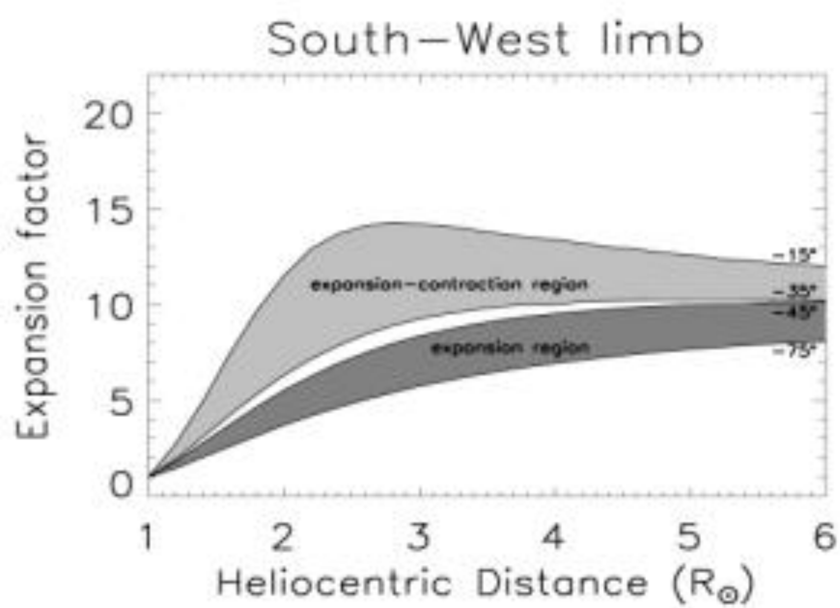


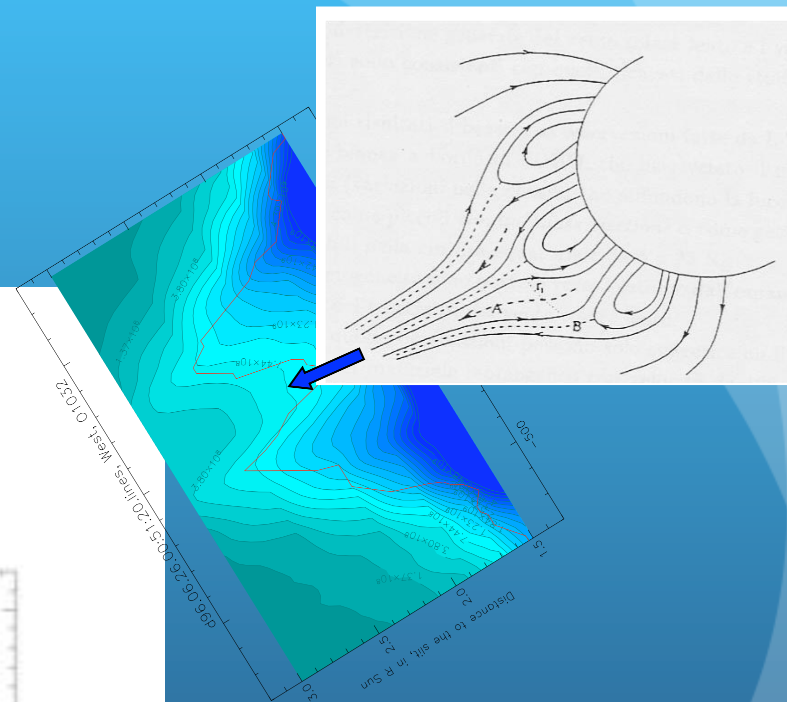


- **Fast solar wind: from polar coronal holes**
- **Slow solar wind: from polar coronal hole boundaries, regions associated with equatorial streamers**

Slow solar wind: where it comes from

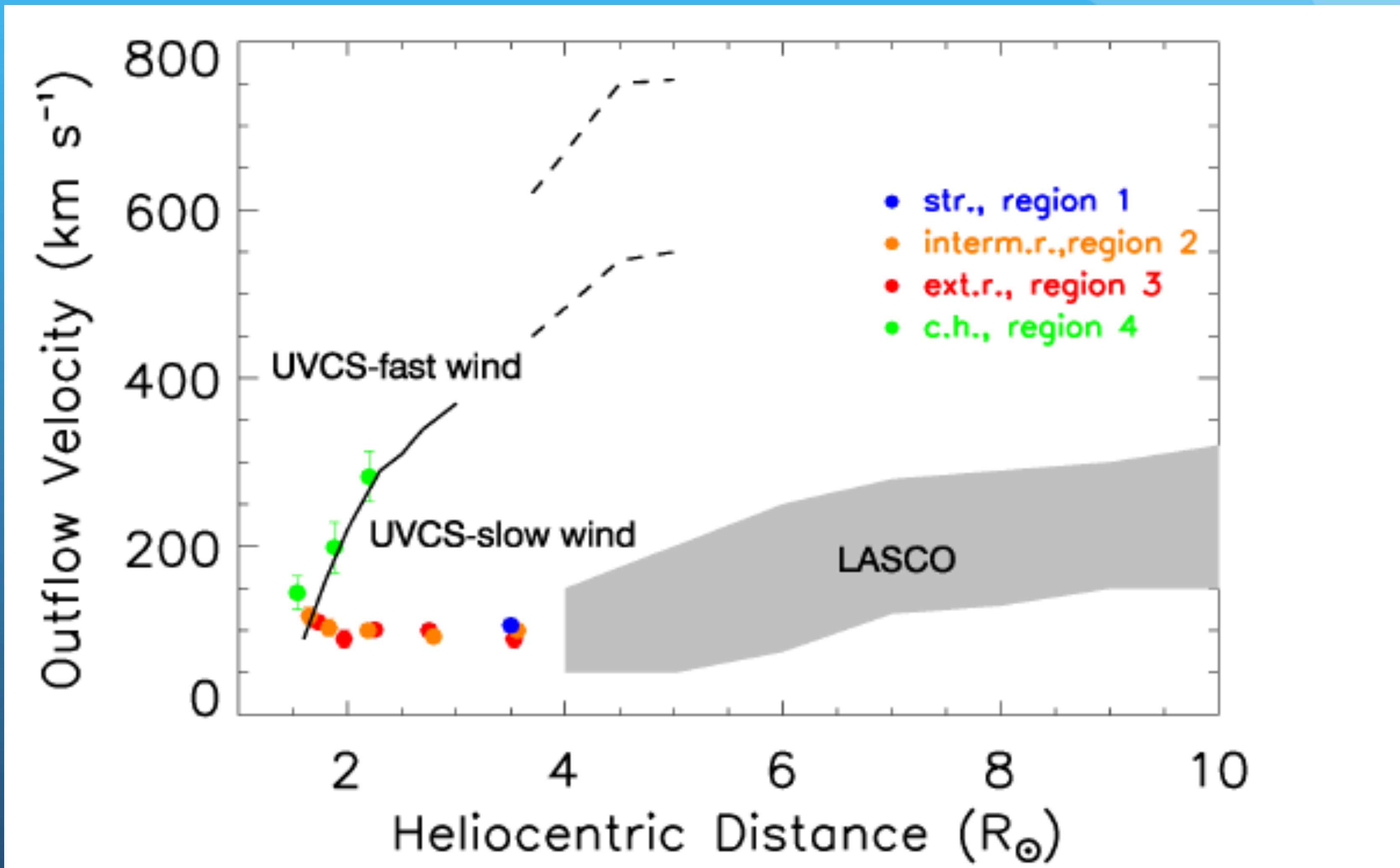






Magnetic topology role

Coronal wind regimes

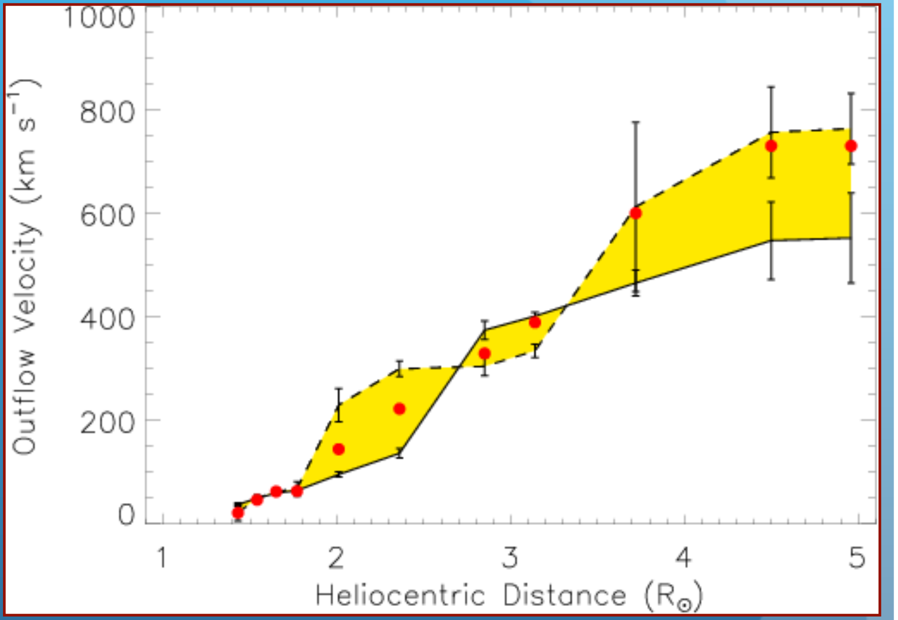


Solar wind from coronal holes

- Expansion velocity

- OVI ion components measured up to 5 $R_\odot$

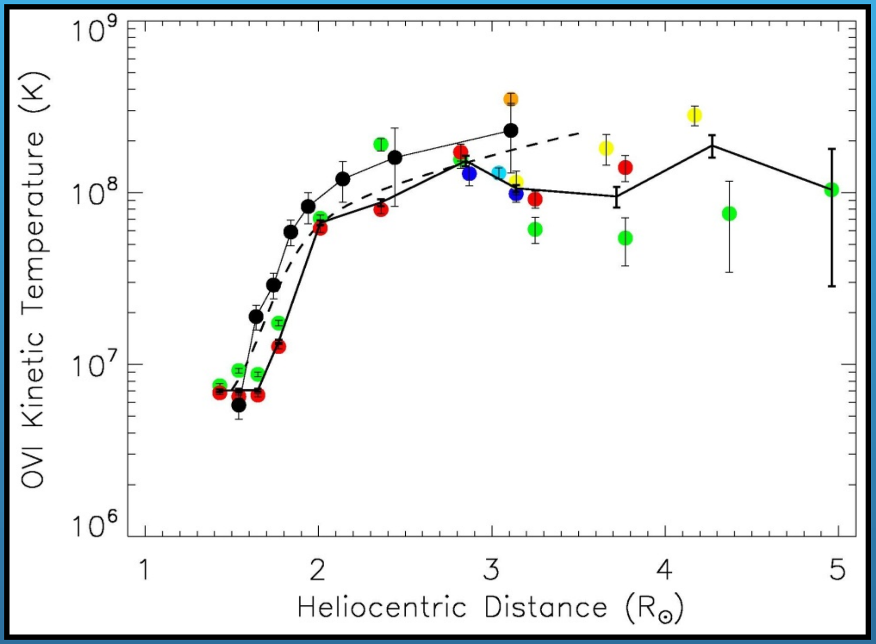
- Proton component measured up to 3.5-4 $R_\odot$

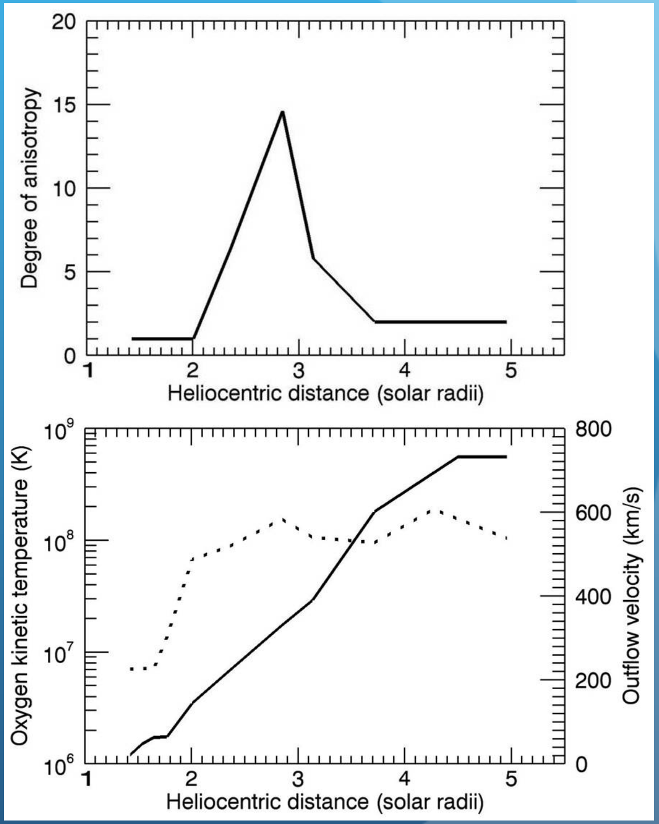


- Beyond 5 $R_\odot$ the O VI component velocity approximates the fast solar wind asymptotic velocity

- **Spectral line broadening**
- **Kinetic temperatures (coronal holes)**
- **O VI ion velocity distribution anisotropies**

  - maximum between 2.0 - 3.7 $R_\odot$ - supersonic regime



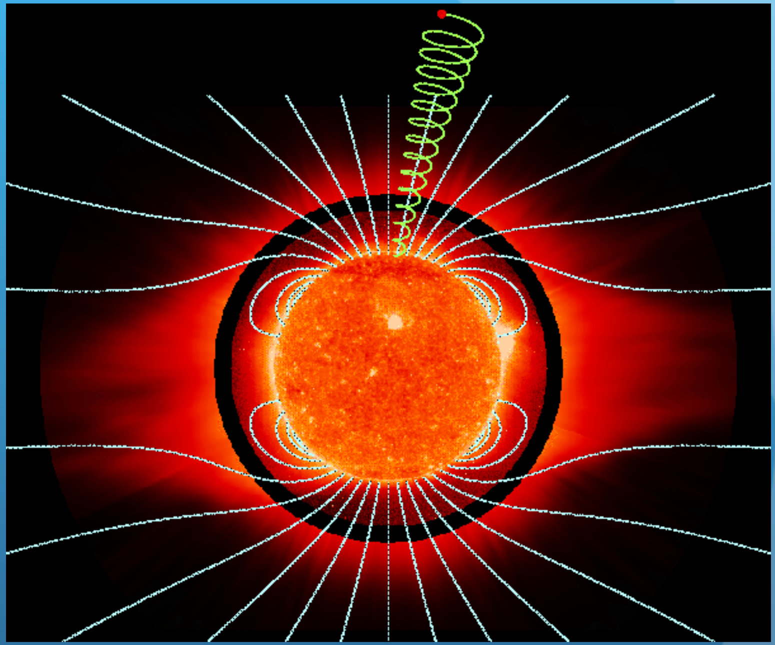


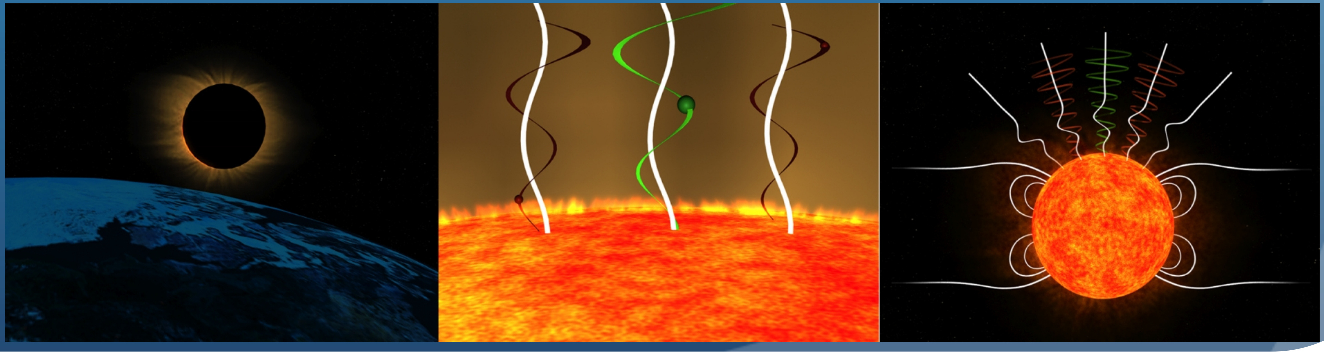
Similar behaviour (significantly lower level)
Inside and along the borders of streamers

Energy deposition in corona by ion-cyclotron resonance:

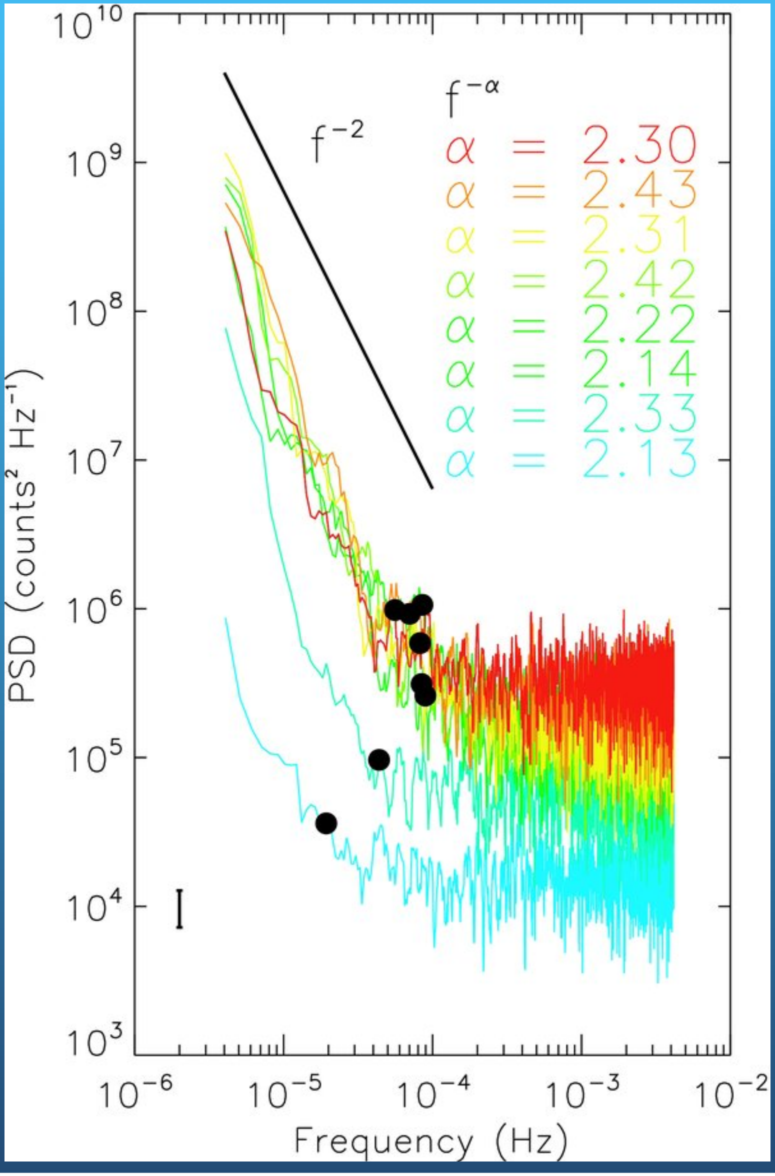
- Dependence on the ion mass-to-charge: Z_i / A_i

$$\Omega_i = q_i B / m_i c = \frac{eZ_i B}{m_p A_i c}$$



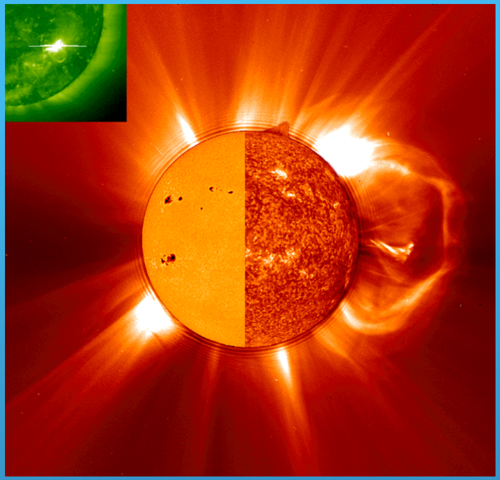


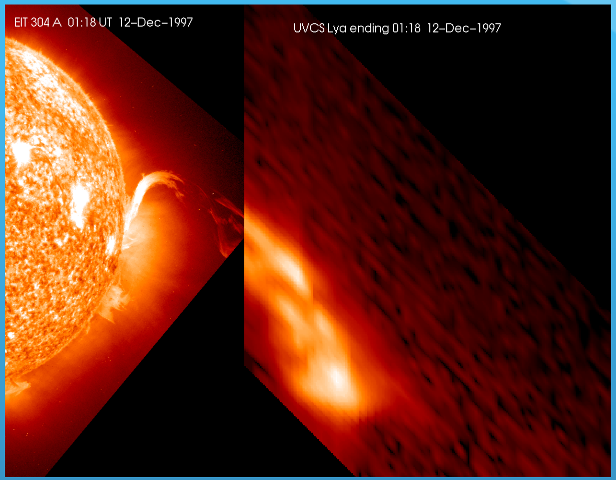
Coronal density fluctuations - H I Ly-α detections

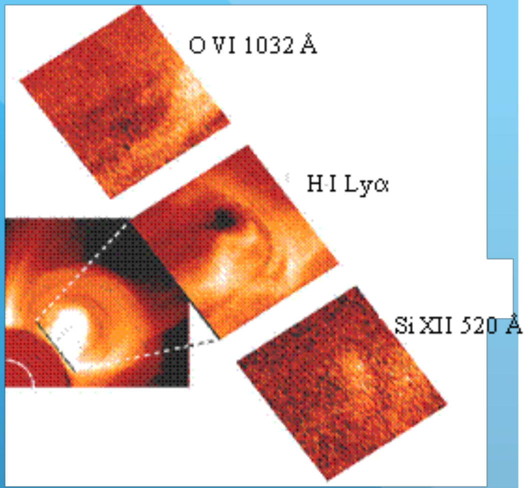


Spectral slope is a characteristic of the solar wind regime

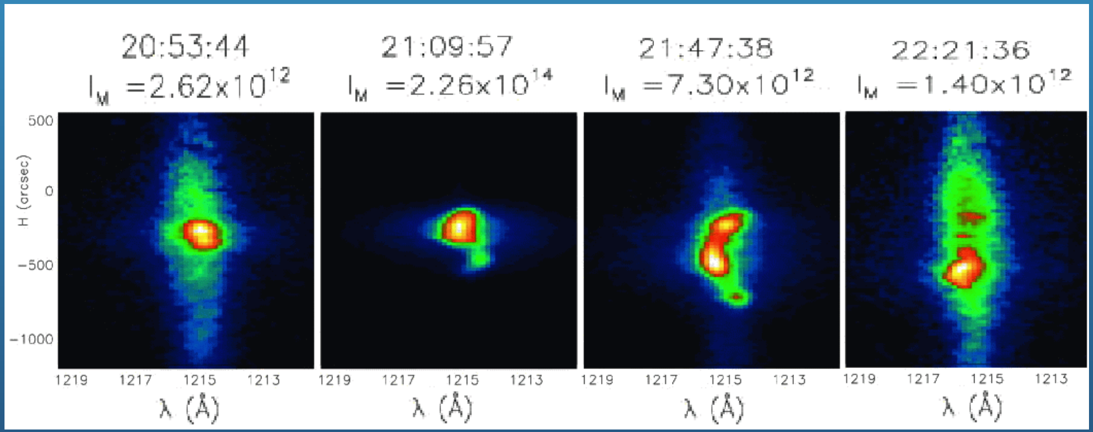
Coronal Mass Ejections (CME) observed by UVCS



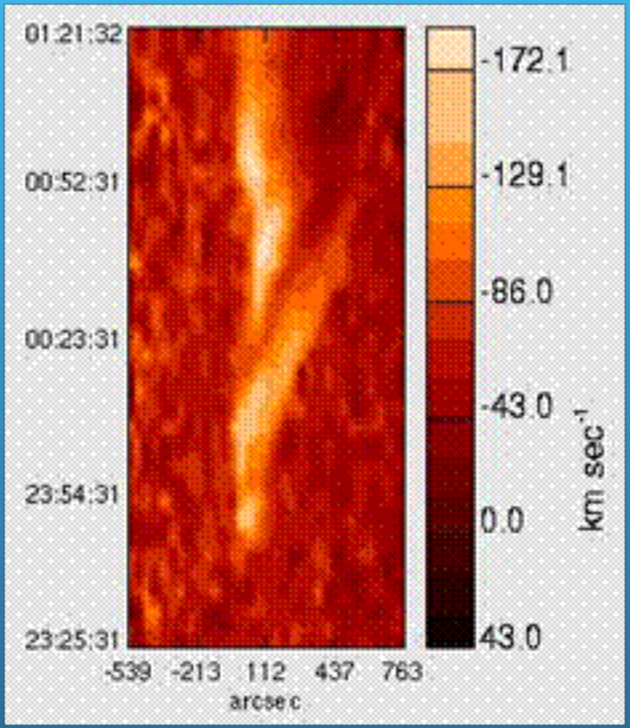


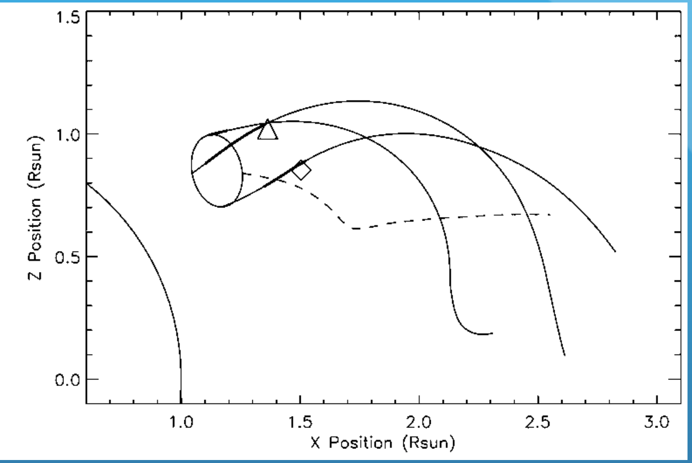


(Ciaravella et al 2003,ApJ,597,1118)



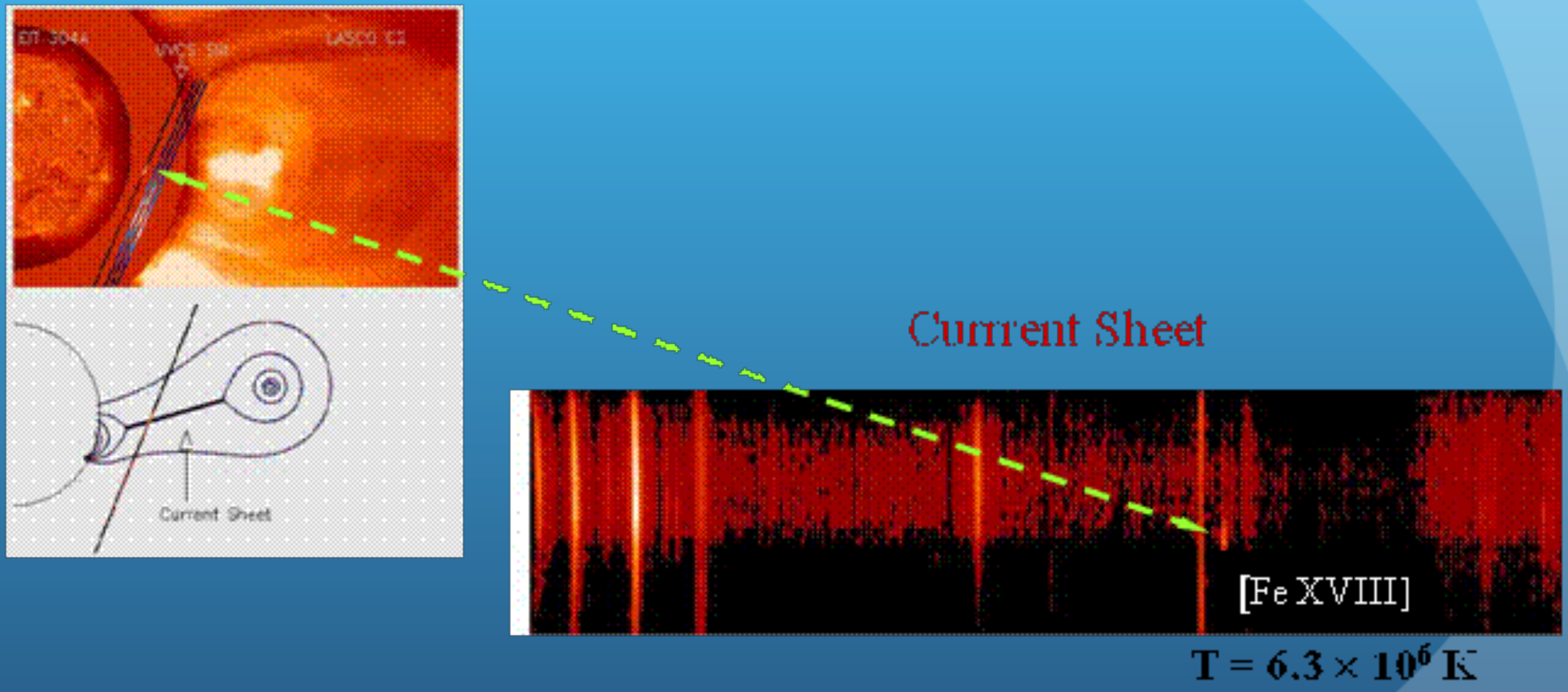
Untwisting magnetic fields in corona



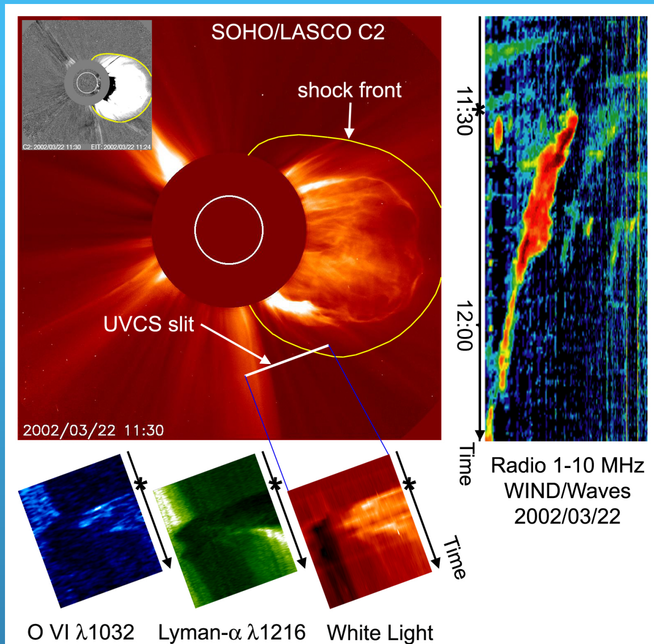


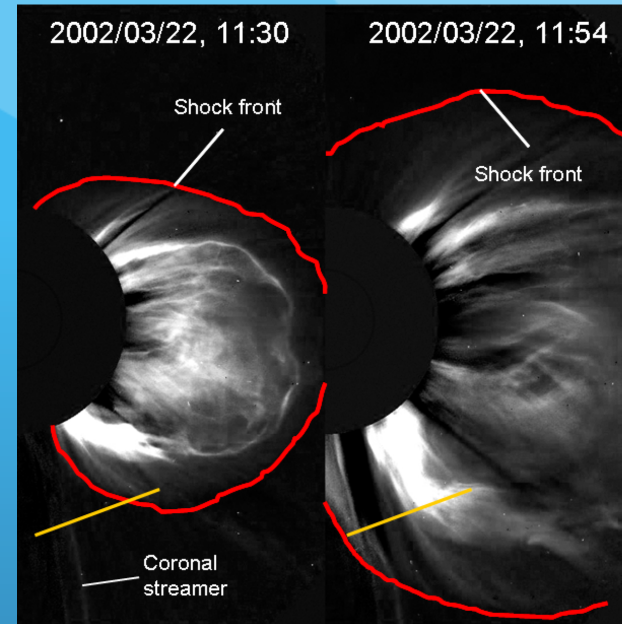
~ 9×10^{-4} rad sec^{-1}

Current sheet high temperature plasma Fe XVIII line (6.3×10^6 K)

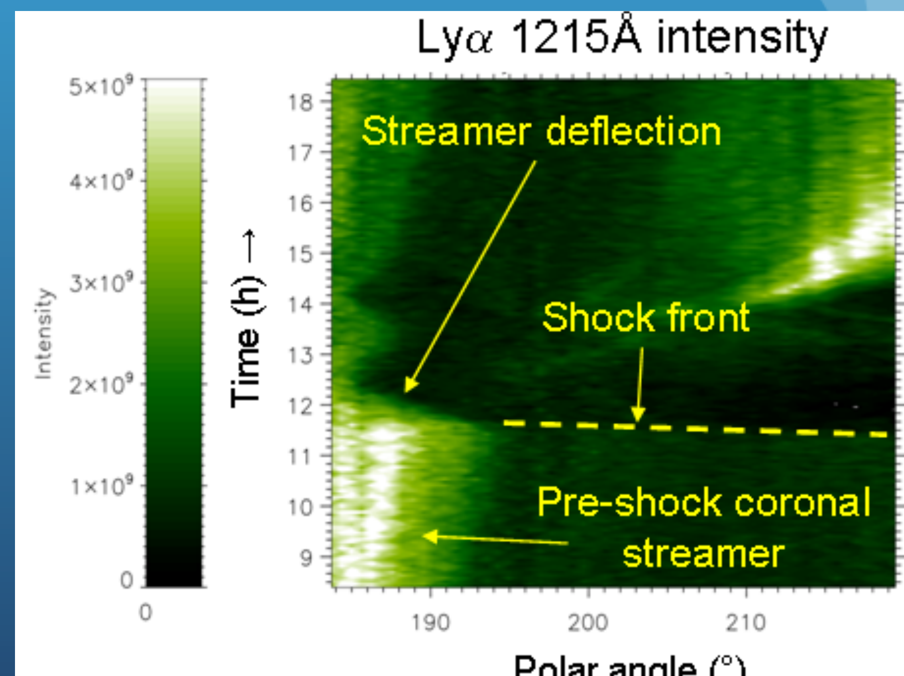


CME-driven shocks

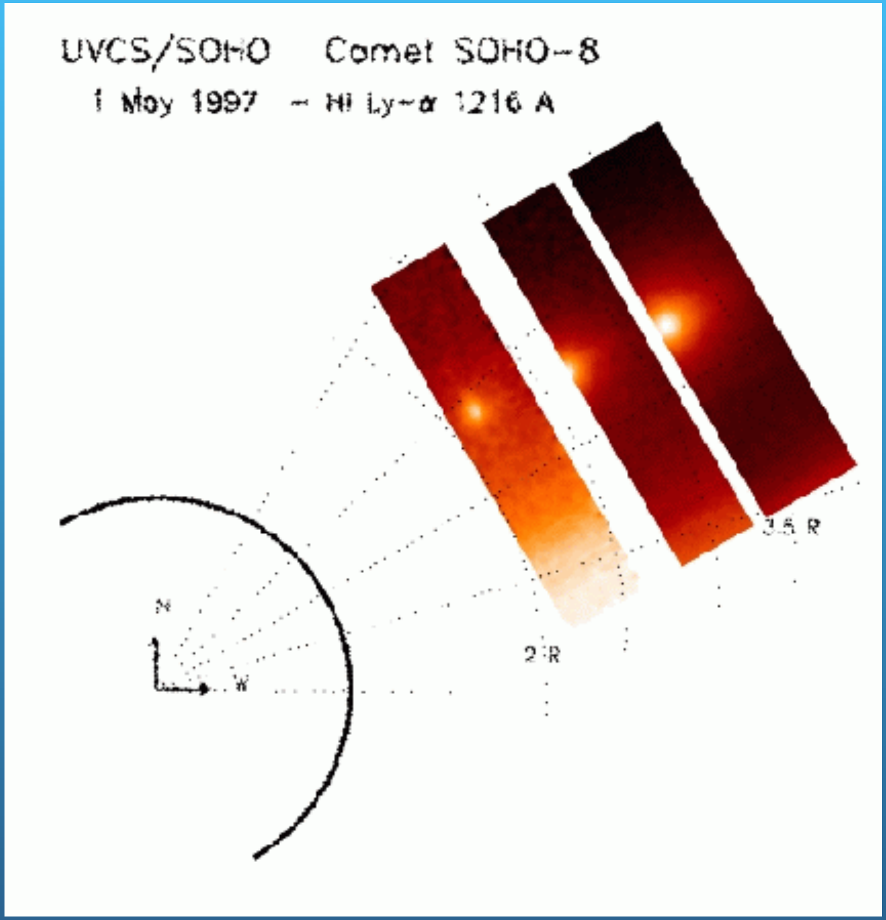


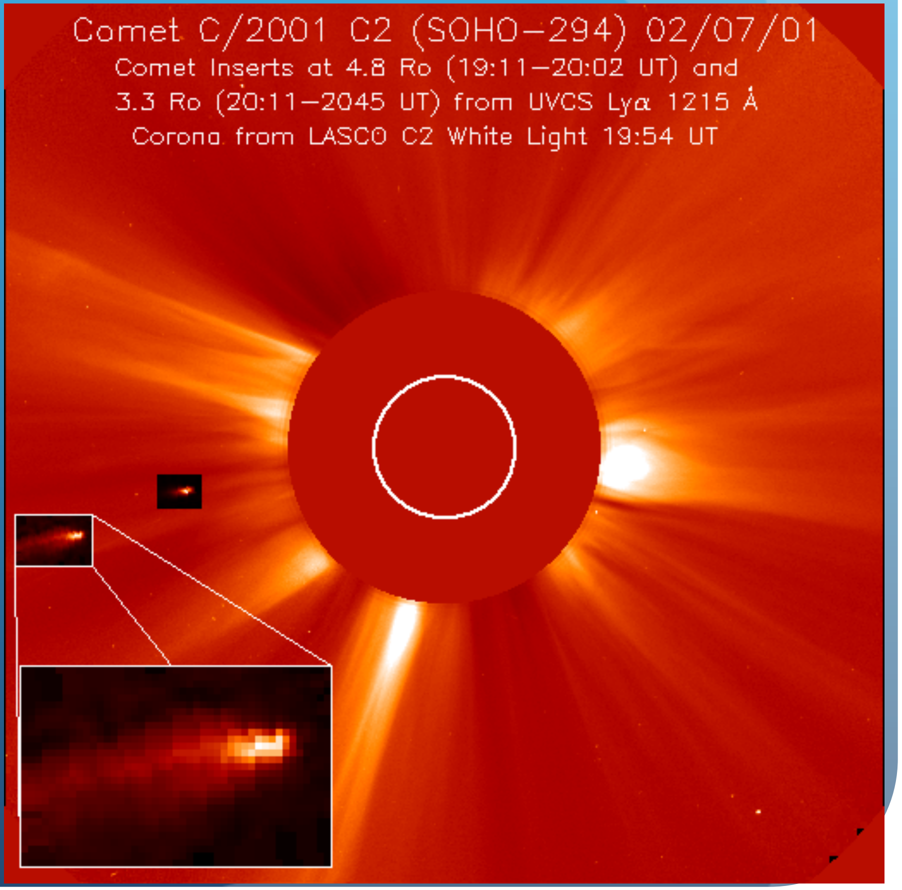


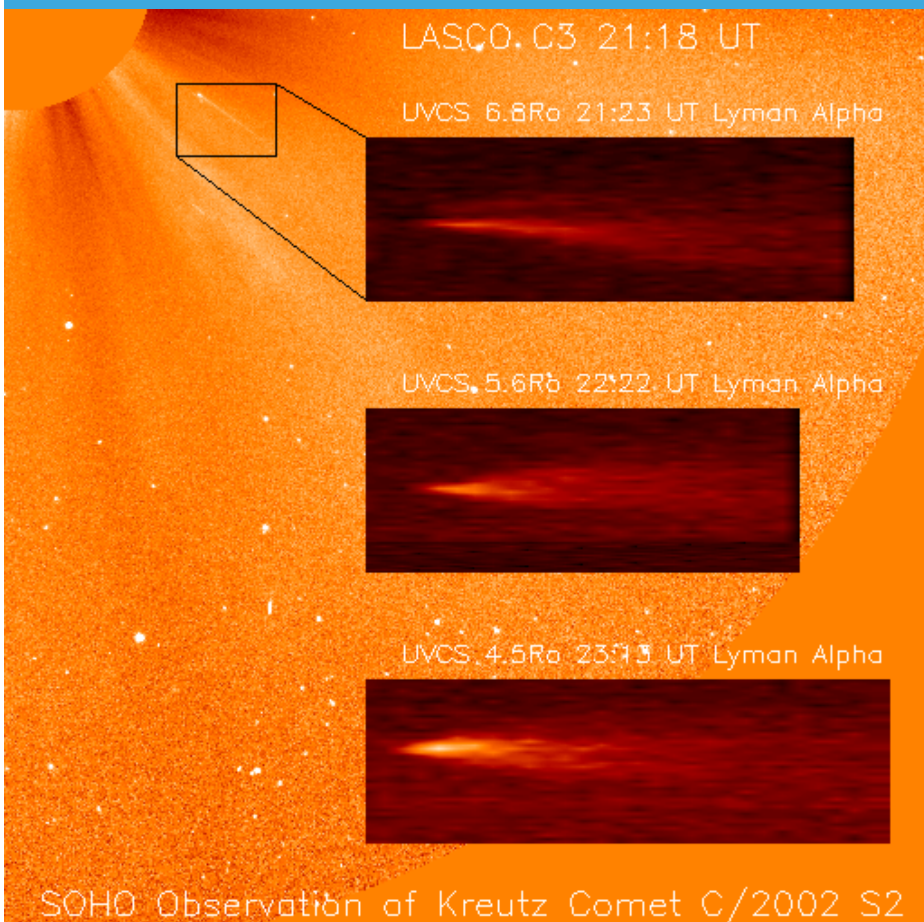
UV line broadening at the shock front

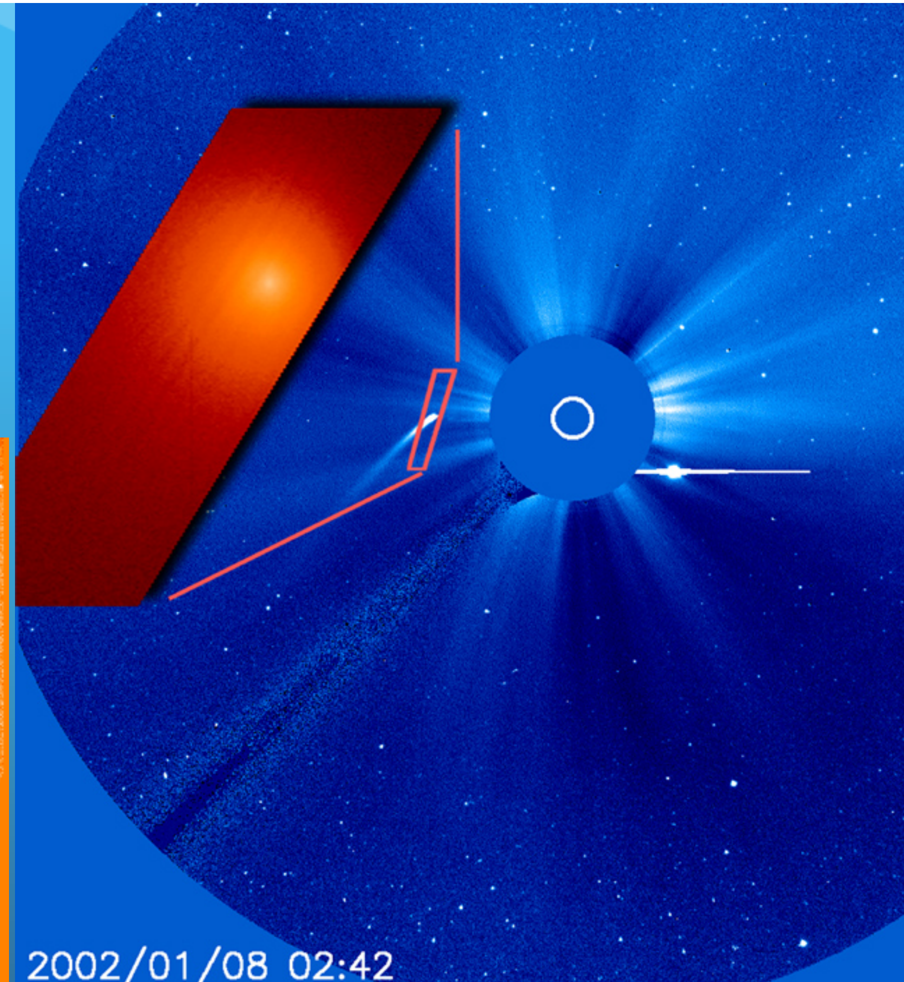


First comet UV observation close to the Sun: H I Ly-α






LASCO C3 21:18 UT
UVCS 6.8Ro 21:23 UT Lyman Alpha
UVCS 5.6Ro 22:22 UT Lyman Alpha
UVCS 4.5Ro 23:13 UT Lyman Alpha
SOHO Observation of Kreutz Comet C/2002 S2


2002/01/08 02:42

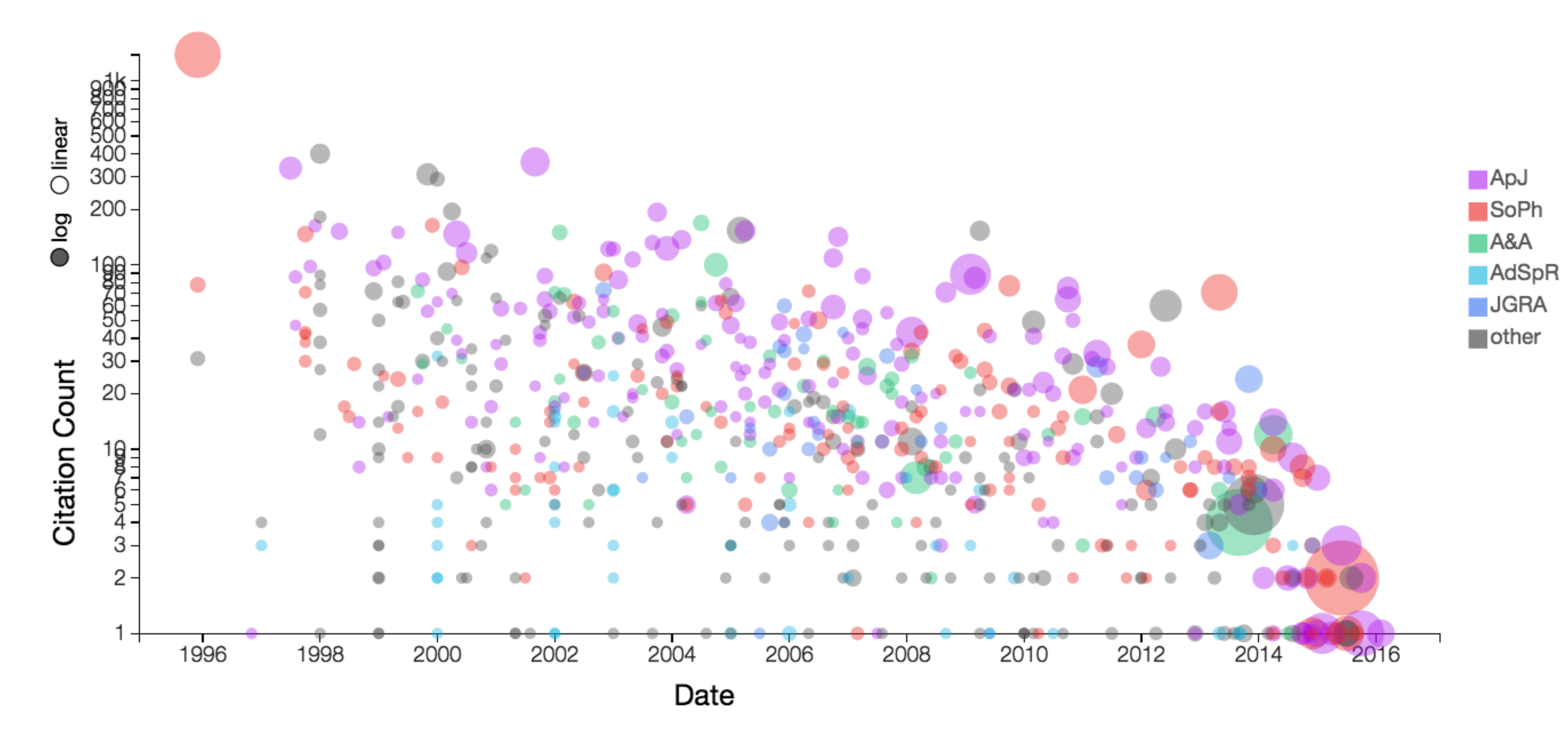
LASCO HIGHLIGHTS AND A LOOK TO THE FUTURE

Angelos Vourlidas (JHU/APL)

Russ Howard (NRL)

LASCO IMPACT (ADS Stats)

- **1382 citations to LASCO instrument paper (Brueckner et al. 1995)**
- **1941 mentions of LASCO in abstracts**

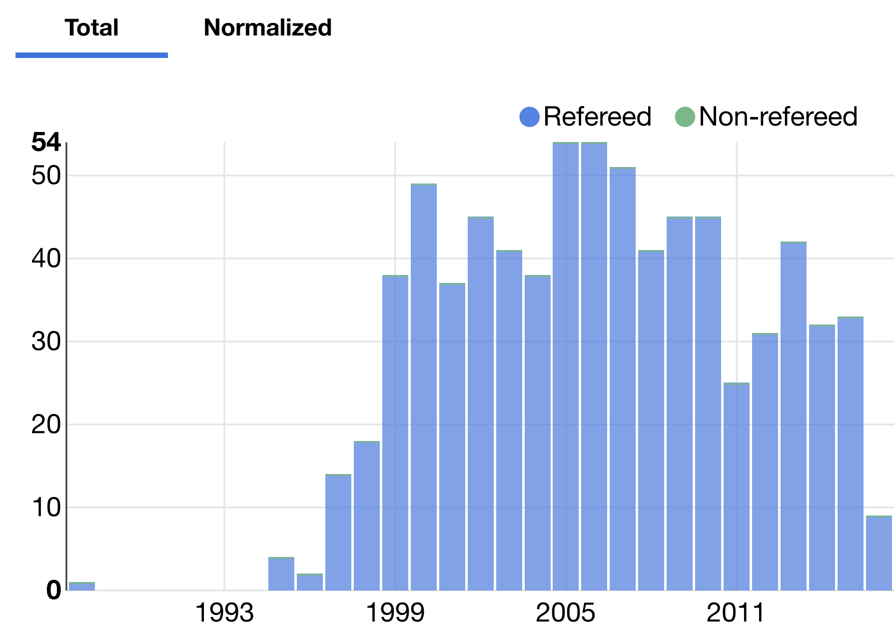


LASCO IMPACT (ADS Stats on 749 peer-reviewed papers)

Research interest on LASCO is undiminished even after 20 years!

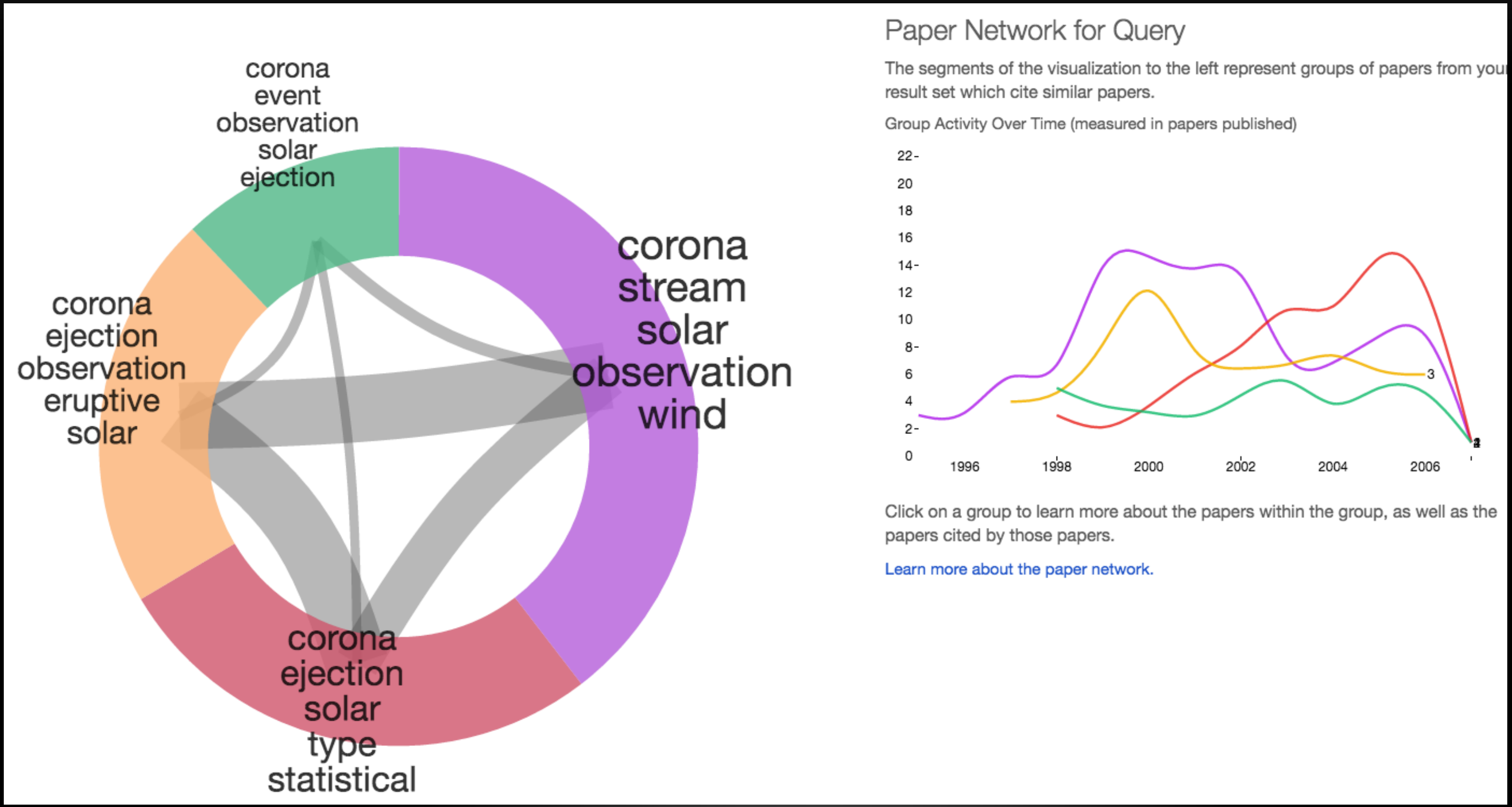
Peer-reviewed papers /year

	Totals	Refereed
Number of papers	749	749
Normalized paper count	260.5	260.5



LASCO IMPACT (ADS Stats on 749 peer-reviewed papers)

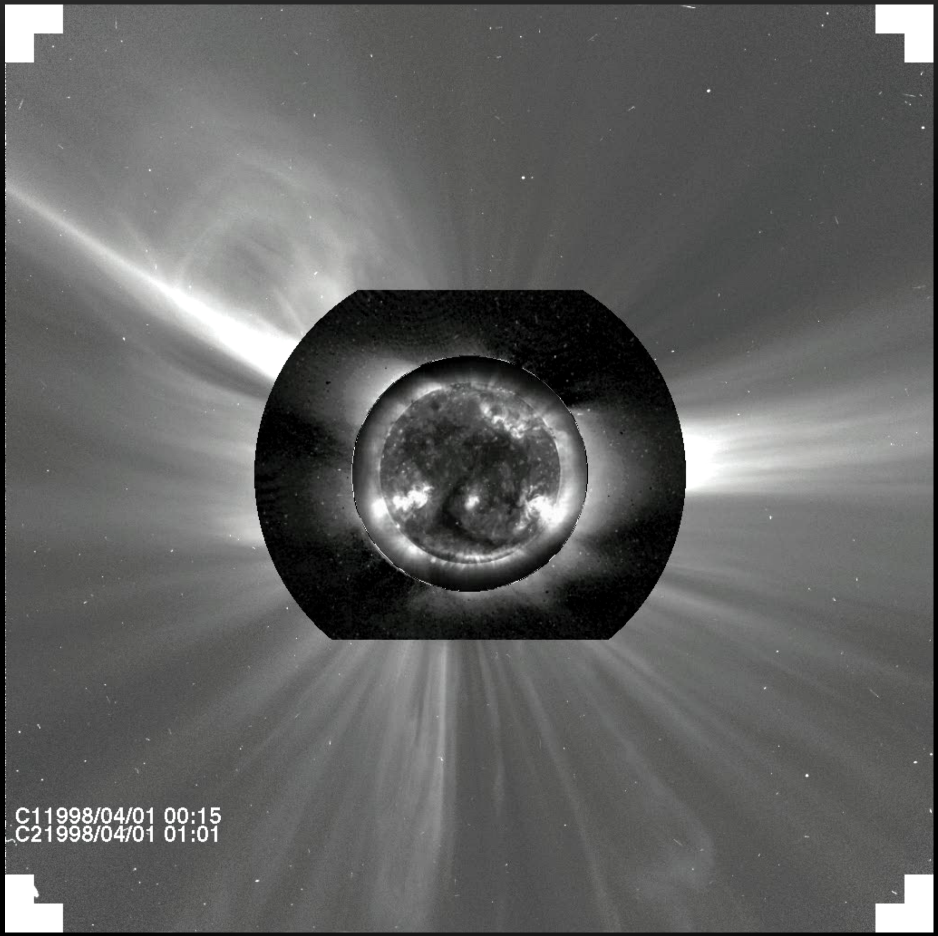
Research trends within LASCO-related papers



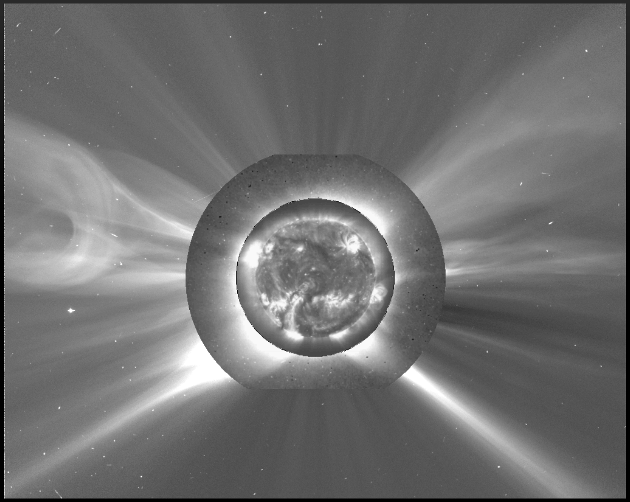
(SOME) SOHO/LASCO CONTRIBUTIONS

- CME Observations and Modeling
  - First complete coverage of the corona (CMES→Sources, CMES→streamers, CMES-→CMEs)
  - CMEs are Flux Ropes
  - Detection and measurement of Shocks.
  - Halos are CMEs.
- Solar Cycle Properties
- Interplanetary Effects of CMEs
- Space Weather
- “Quiescent” Coronal observations and modeling
- Outflows and Inflows

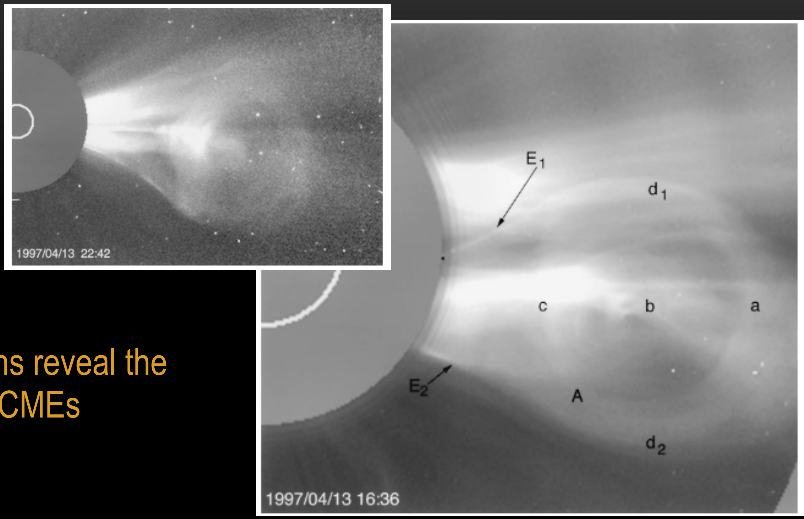
FIRST COMPLETE COVERAGE OF THE CORONA

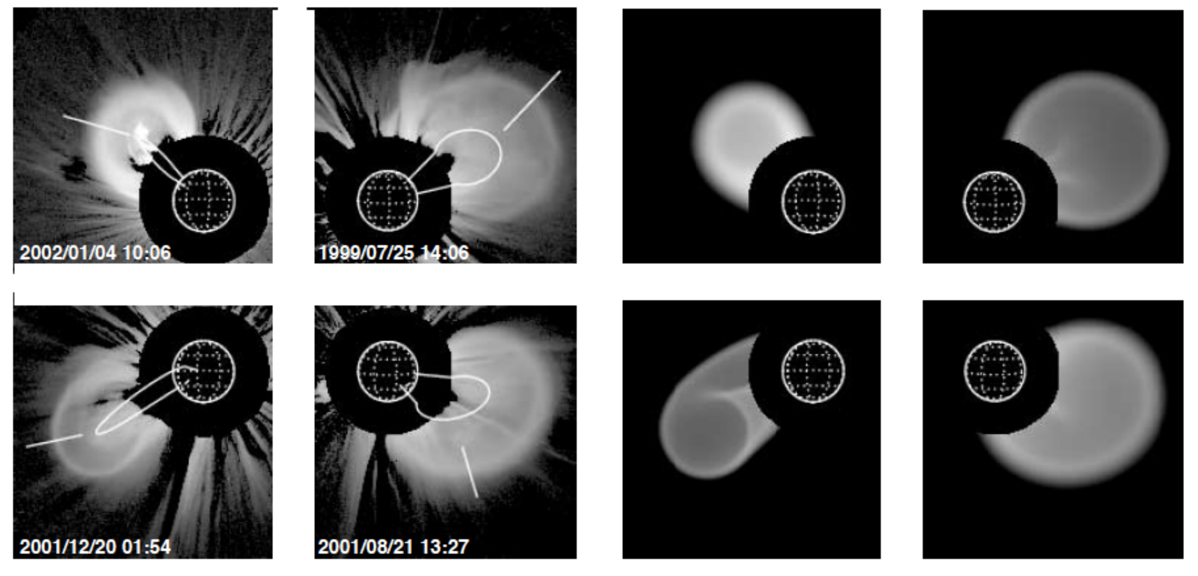


CMES AS FLUX ROPES



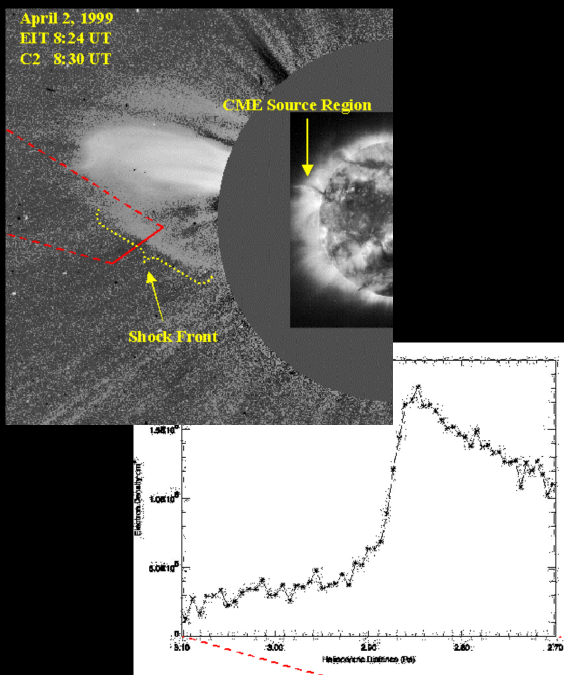
LASCO observations reveal the fine scale of CMEs

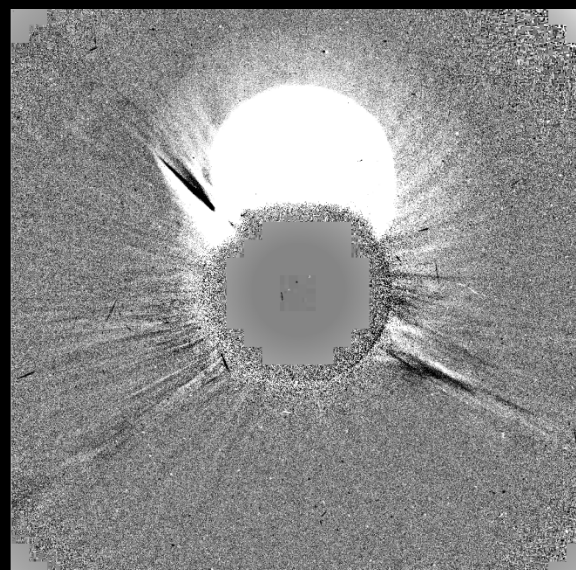


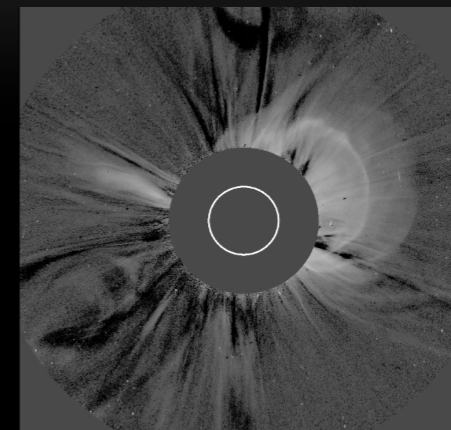


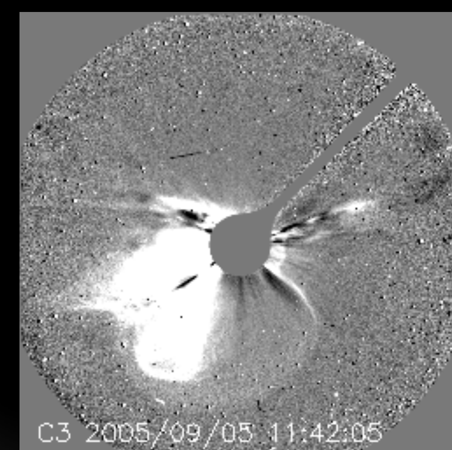
"Croissant" approximation to a Magnetic Flux rope is consistent with observed morphology.

DISCOVERY OF CME-DRIVEN SHOCKS

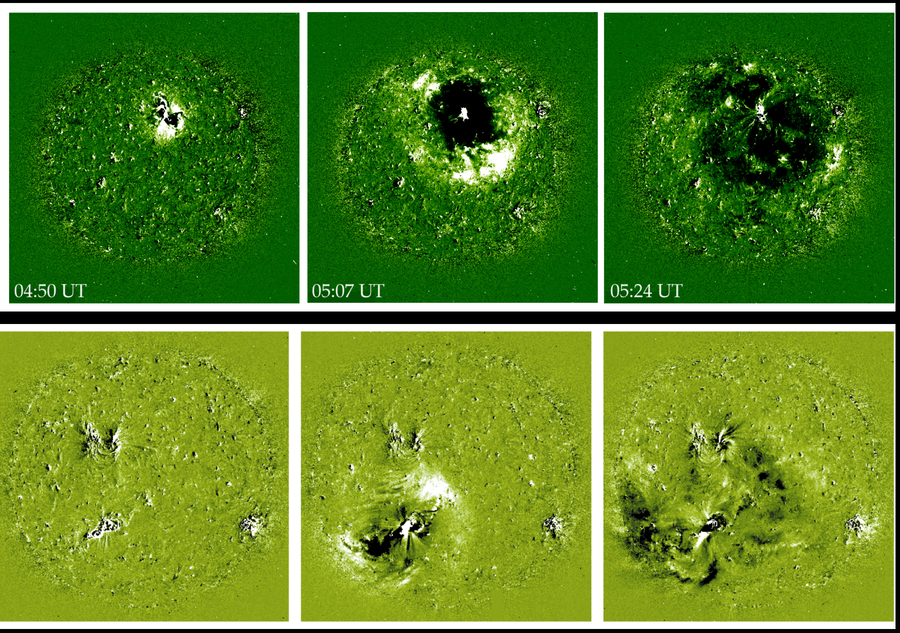


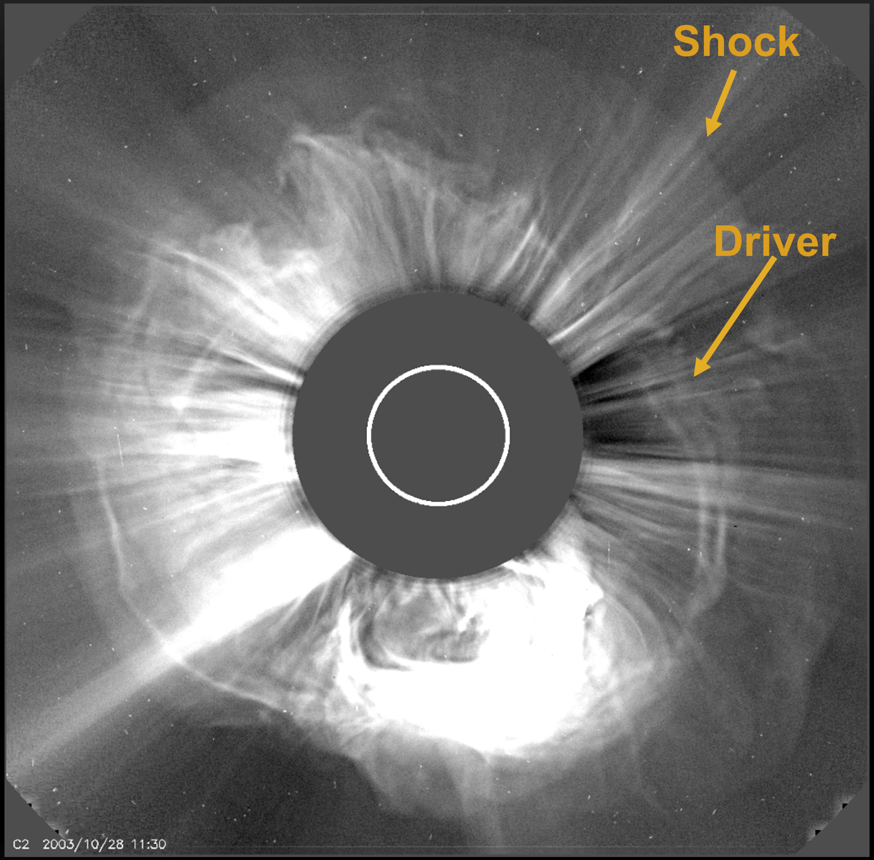




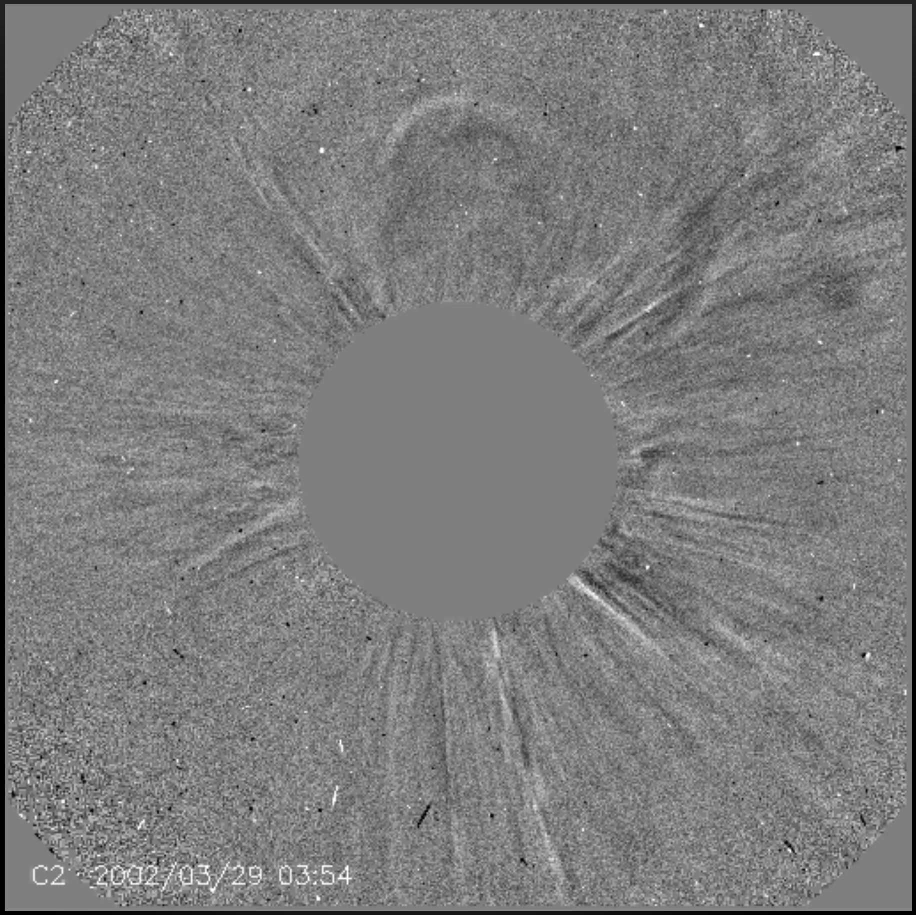


HALO CMES CLARIFIED

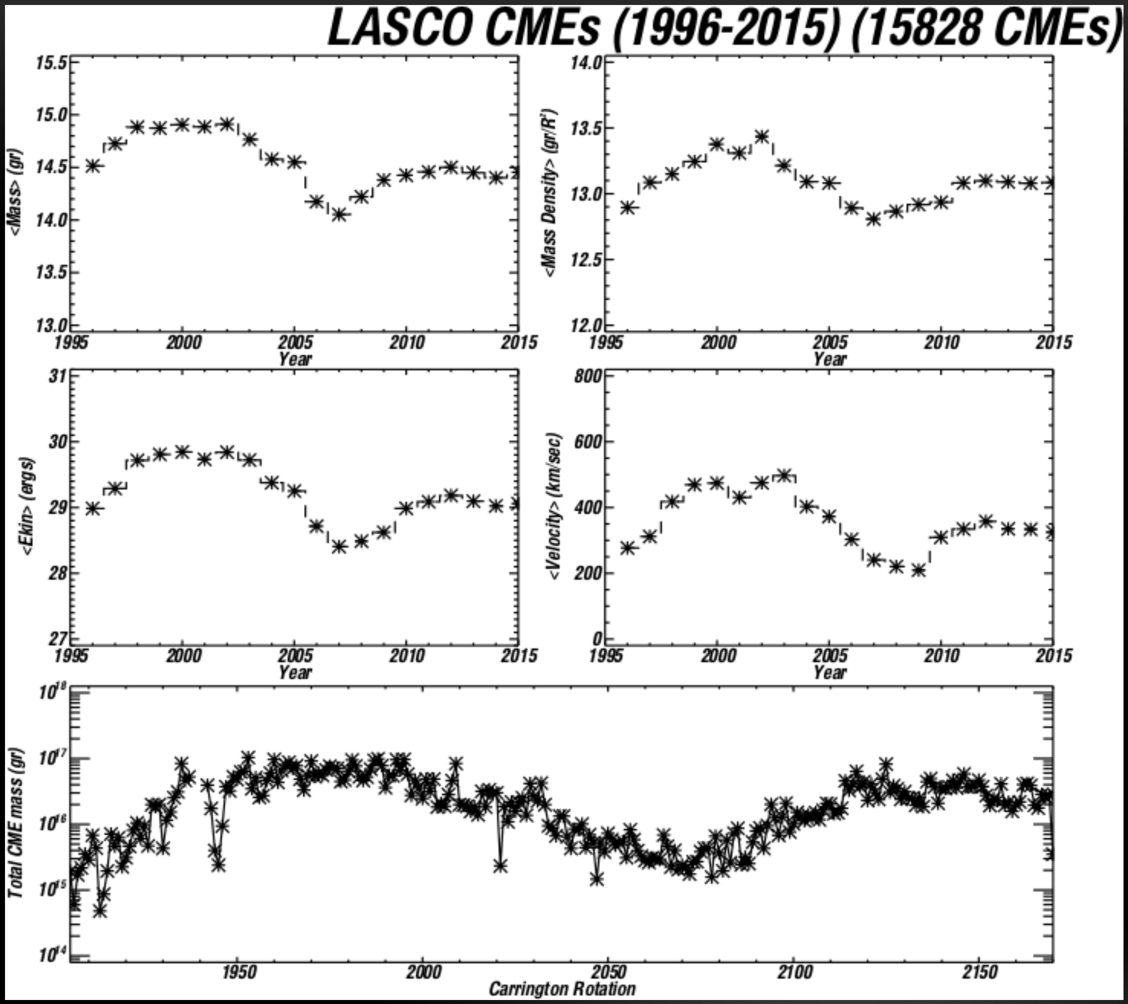




IN-OUT PAIRS



MASS EJECTED IN CMES

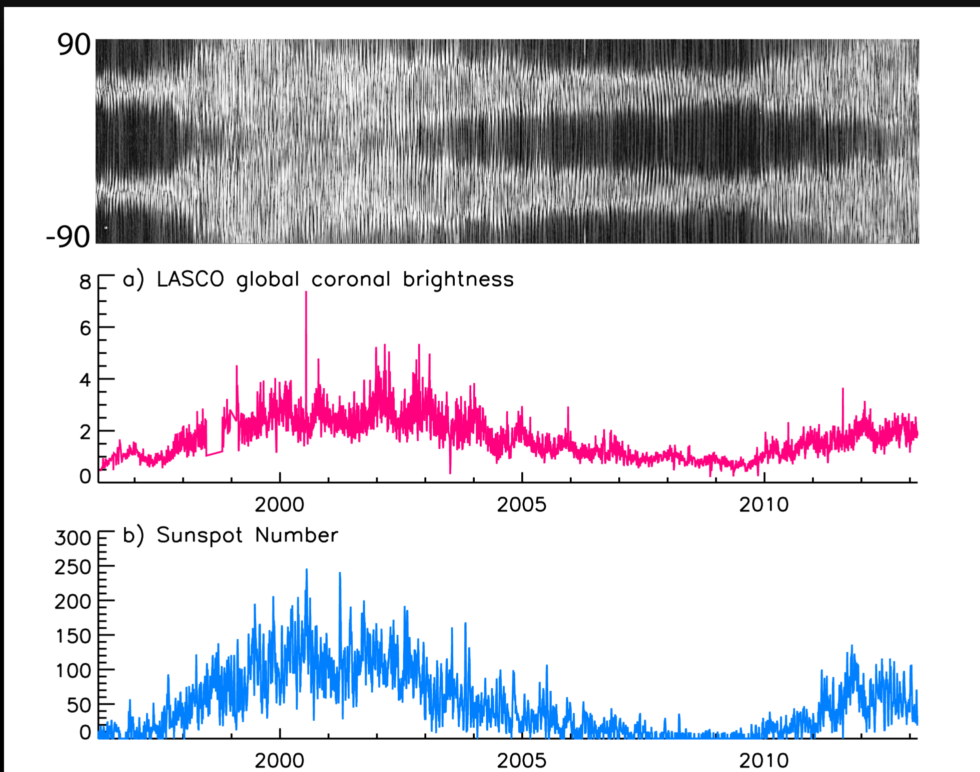


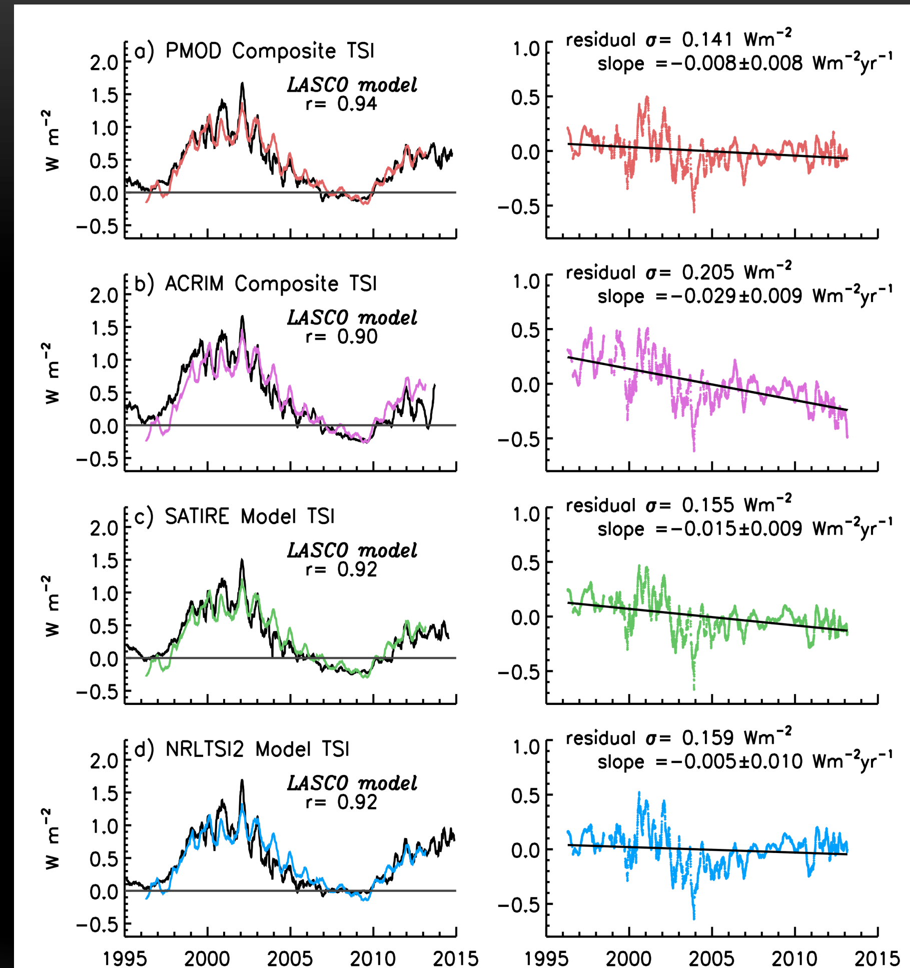
Yearly Mass & Mass Density

Yearly KE & Speed

Mass Ejected Per Rotation

CORONAL BRIGHTNESS & TOTAL SOLAR IRRADIANCE





The high correlation between coronal brightness and Total Solar Irradiance, is revealing long term calibration issues with the TSI.

LESSONS LEARNED

- Pay attention to details – contamination, EMC, microvibration, pointing stability, operating procedures, etc..
- L1 is an excellent place to observe the sun.
- International collaboration has given us a better mission, both in the instrument definition through an open exchange of ideas and cost sharing
- Open data policy has enabled data analyses from scientists around the world

SOME OPEN QUESTIONS (FOR CORONAGRAPHS)

- CME Issues:
  - CME Visibility Function: Are there 'massless' CMEs?
  - How SLOW can a CME be?
  - When the flux rope becomes a plasmoid (CME disconnection from Sun)?
  - How does the CME flux rope evolve in the heliosphere?
  - CME interactions with Solar Wind (structures).
- Solar Wind Issues:
  - What is the fine (temporal, spatial) scale of the corona? (e.g. electron beams, plasma parcels,…)
  - Where is the Alfven point?
  - What is the slow solar wind mass flux?

FUTURE

Heliophysics Research

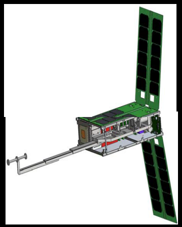
- **Image the corona from the inside-out**: Solar Probe Plus (SPP)
- **Connect to the Surface:** PROBA-3
- **Break the symmetry:** Solar Polar Imager (SPI)

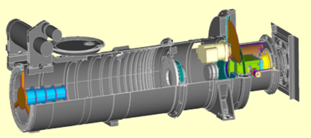
Space Weather Research

- **Understand CME-SW:** L5 Observer
- **Understand Space Weather**: CME-Magnetosphere Interface Imager
- **Predict the (Space) Weather:** L5 + L1 + SPI + L4

FUTURE (INSTRUMENTS)

- **Operational Coronagraphs (high heritage instruments)**
  - Similar to COR2 on STEREO (FOV:~ 2.5 -17 Rs, 30” res, 15-30 min cadence)
  - DSCVR follow-on, L5/L4 missions, …
- **“Practical” Coronagraphs (not flown, LASCO/SECCHI capabilities)**
  - Compact Coronagraphs (CCOR, Mini-COR): 6U Cubesats or higher (~12U)
  - Mostly Space Weather use: DSCVR follow-on, ISS, replacement on-demand
  - Highly constrained missions: SPI, Sentinels
- **Research Coronagraphs**
  - Formation-flying: PROBA-3, (high spatial resolution, corona <1.5 Rs)
  - EUV coronagraph
  - *Magnetosphere/Plasmaphere Coronagraph*





SOHO Project, PIs, NASA/ESA Thank you!

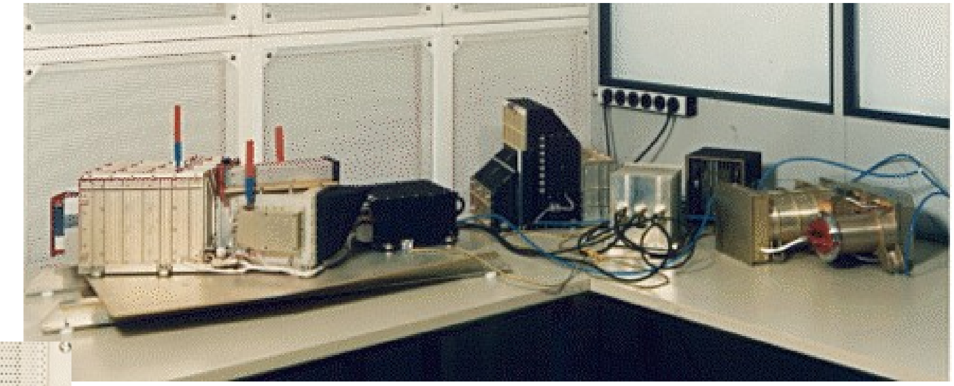
- For giving a whole generation of Solar Physicists
  - An awesome career.
  - Great friends
  - **Amazing mentors.**

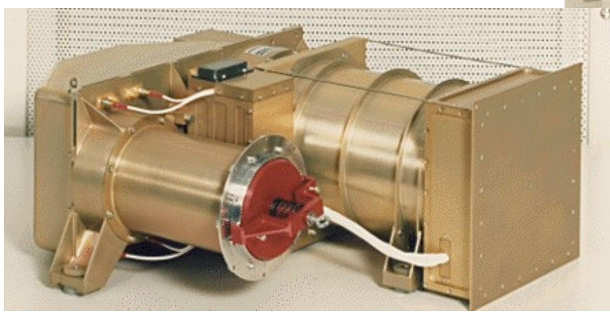
CELIAS

The Charge, Element, and Isotope Analysis System

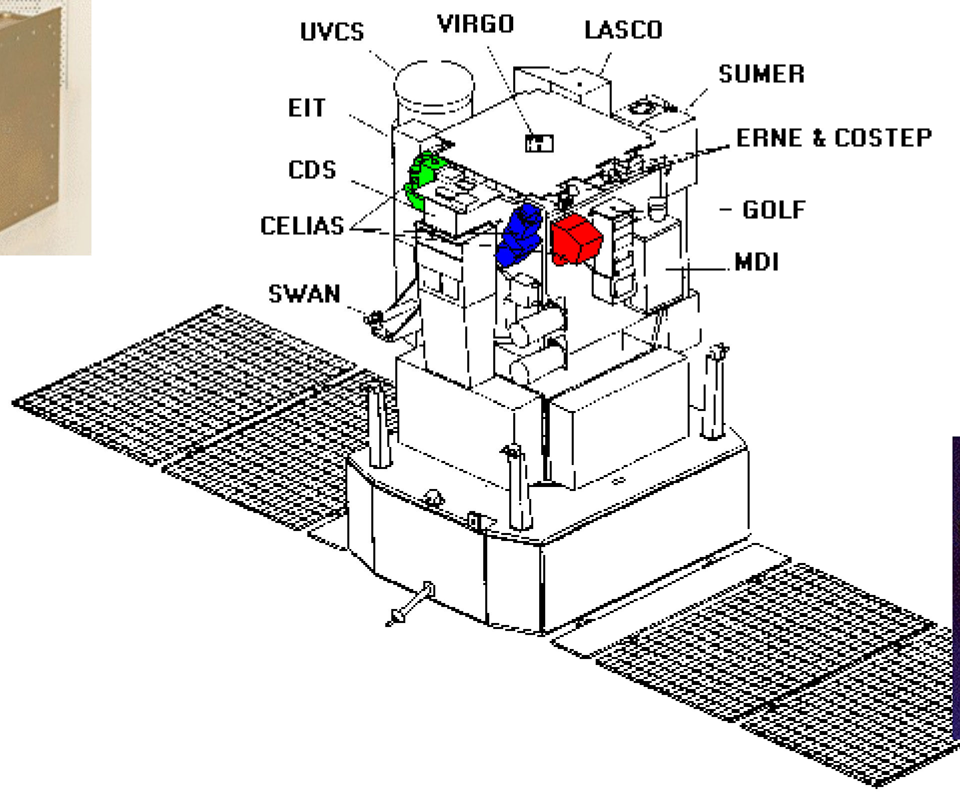
Robert F. Wimmer-Schweingruber for the CELIAS Team

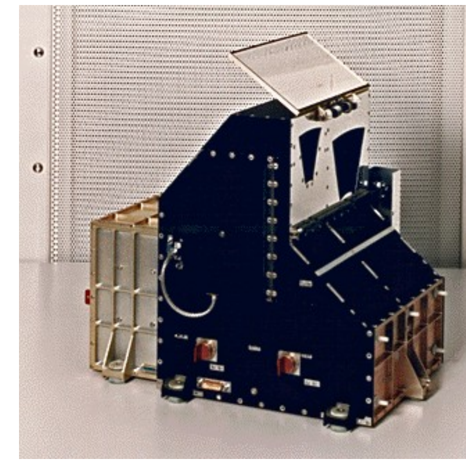
The CELIAS Instrument(s)



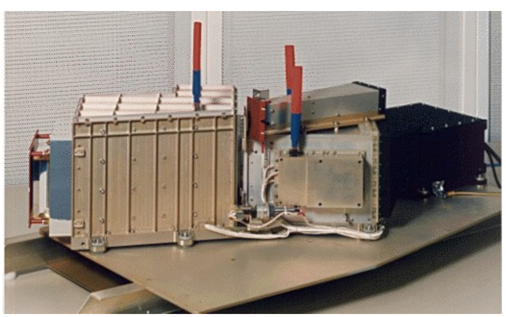


CTOF

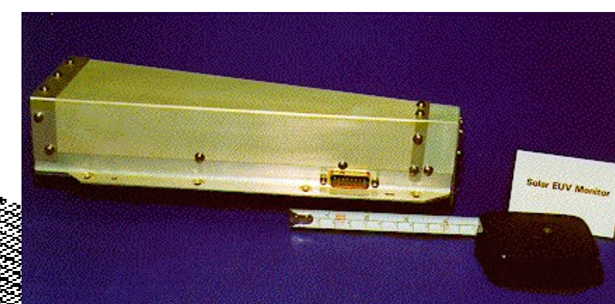




MTOF & PM



STOF & HSTOF



SEM

CELIAS Science Report

- Science Highlights

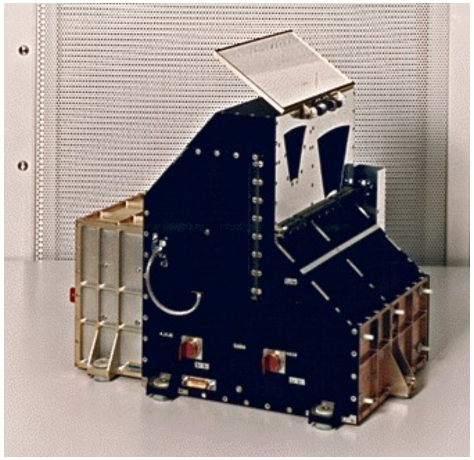
- Lessons learned

- Future outlook: science, team, archiving

  - SOHO legacy archive

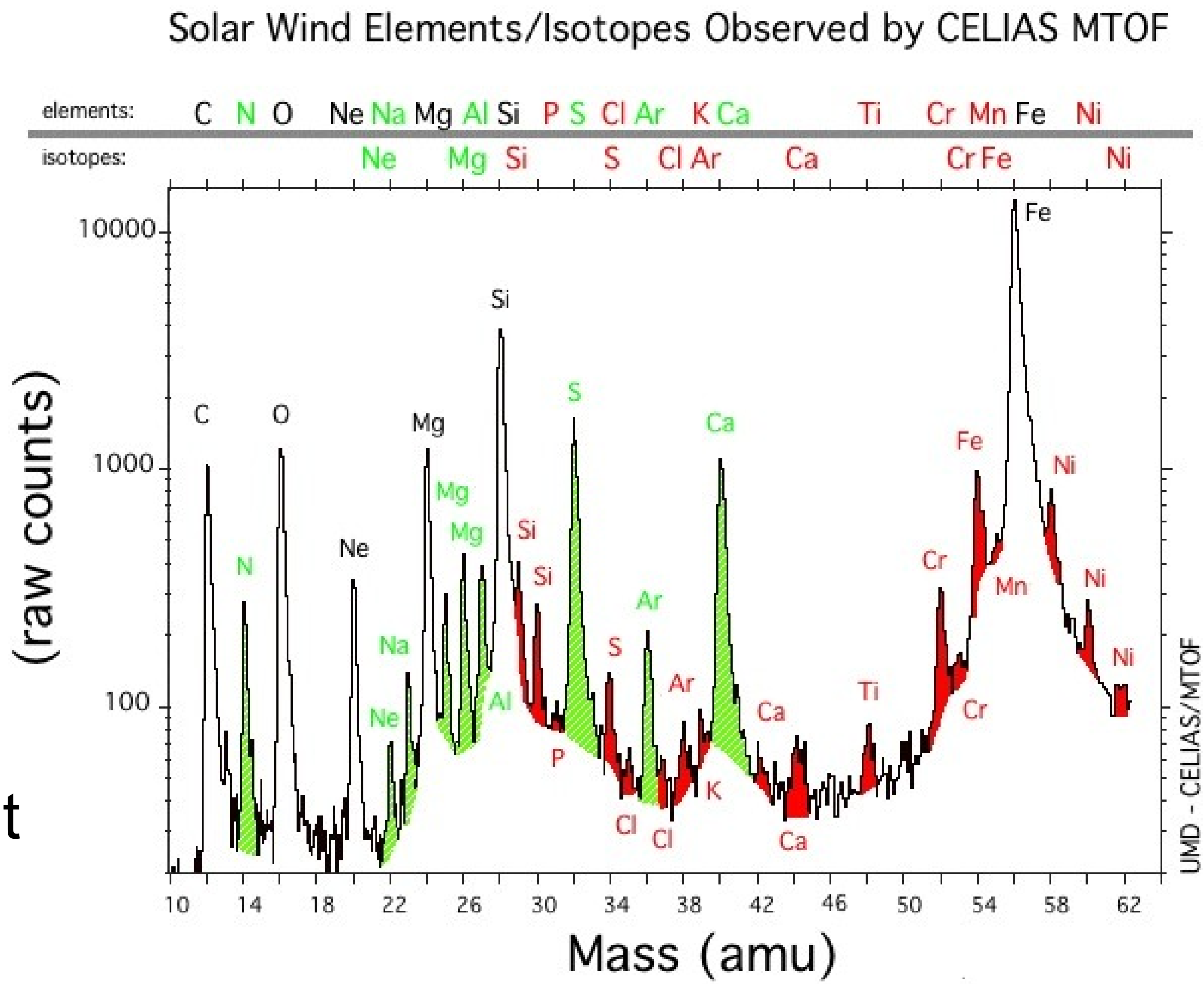
  - Additional higher-level data products?

Solar Wind Composition

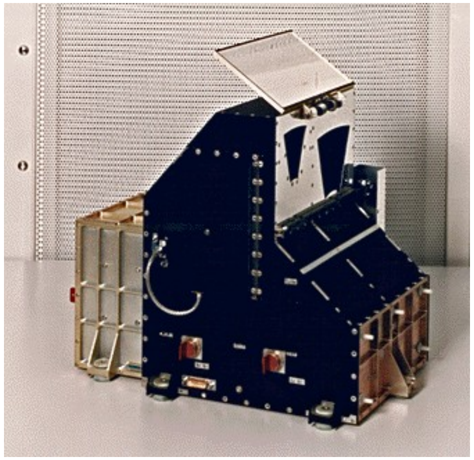


MTOF & PM

Unprecedented mass resolution and geometric factor. High count rates.

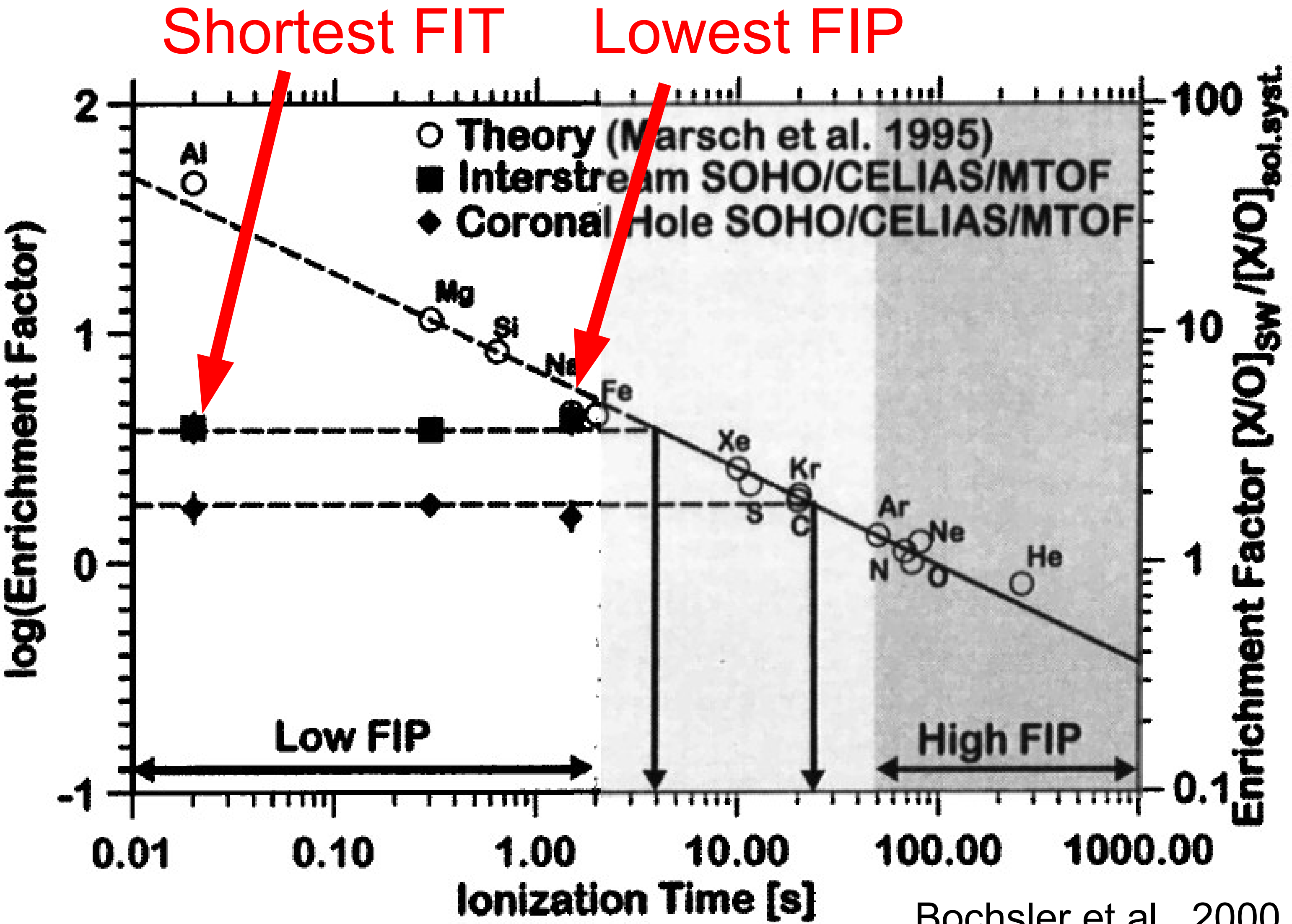


Solar Wind Composition



MTOF & PM

Measurements of Na and Al limit models for FIP effect



Bochsler et al., 2000

Solar Wind Parameters

MTOF Proton Monitor

umtof.umd.edu/pm/

the latest 48 hours of solar wind data

brought to you by the CELIAS/MTOF Proton Monitor on the SOHO Spacecraft

There is a problem with the motor controlling the High Gain Antenna on the SOHO spacecraft. Science data coverage may be less than complete for 1-2 weeks every 90 days (when the spacecraft gets 'flipped'). The next "keyhole" period can be found in this table.

Interplanetary shocks and other interesting events

An energetic particle flare monitor using the PM background rate

An X-ray flare monitor using data from the CELIAS/SEM sensor

Most Recent Shock Candidates:

Date	UT	day of year	F/R	Zone	Confidence Level
11 Mar 2016	1918	71	REV	1	38%
11 Mar 2016	0445	71	fwd	2	68%
6 Mar 2016	1641	66	REV	1	38%

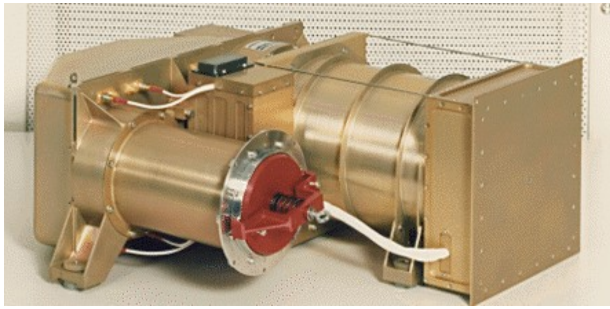
Shock Plots **SHOCKSPOTTER description**

Current time in GMT

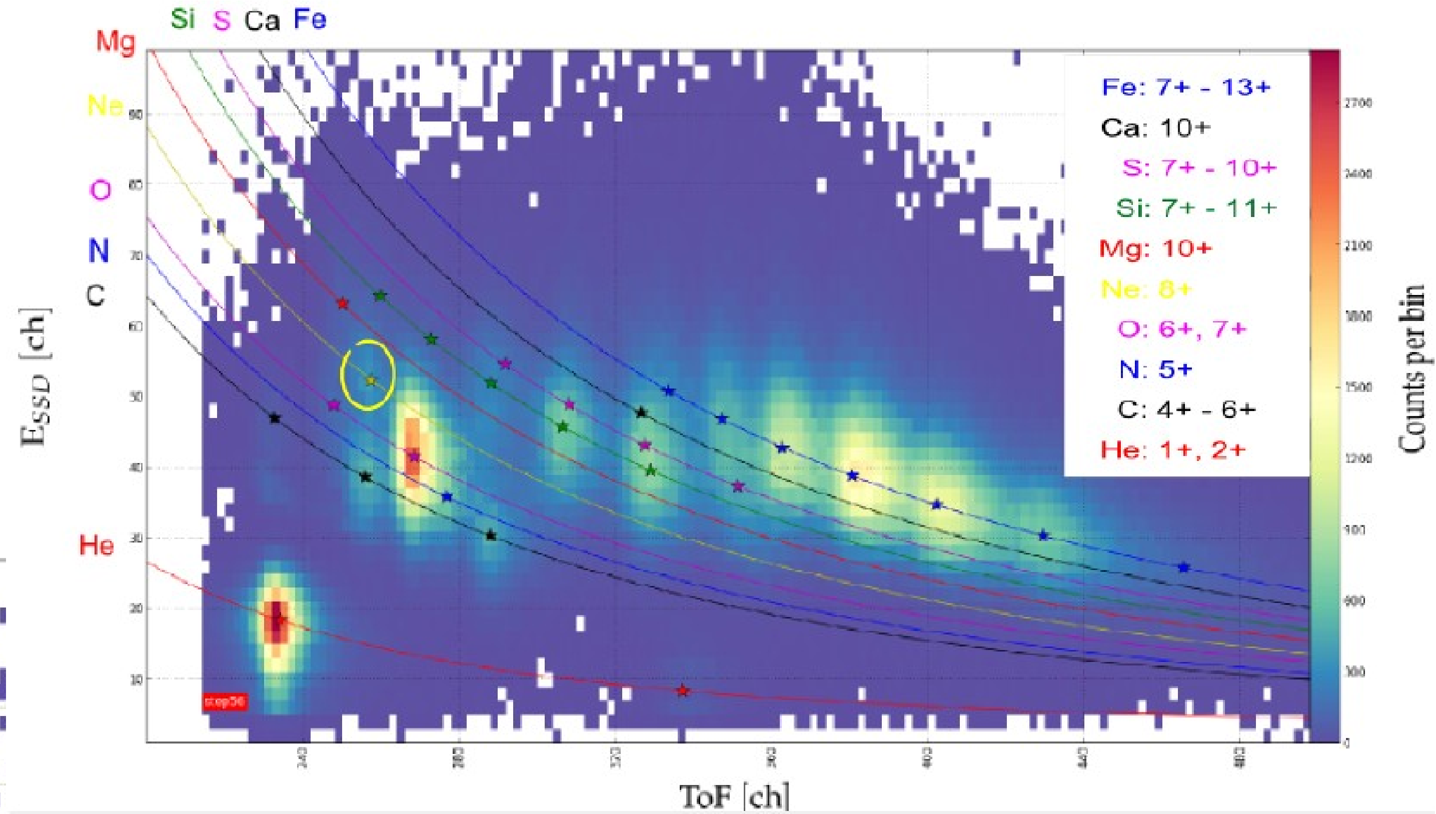
Data ending at 0515 GMT on May 12, 2016 (ascii data available)

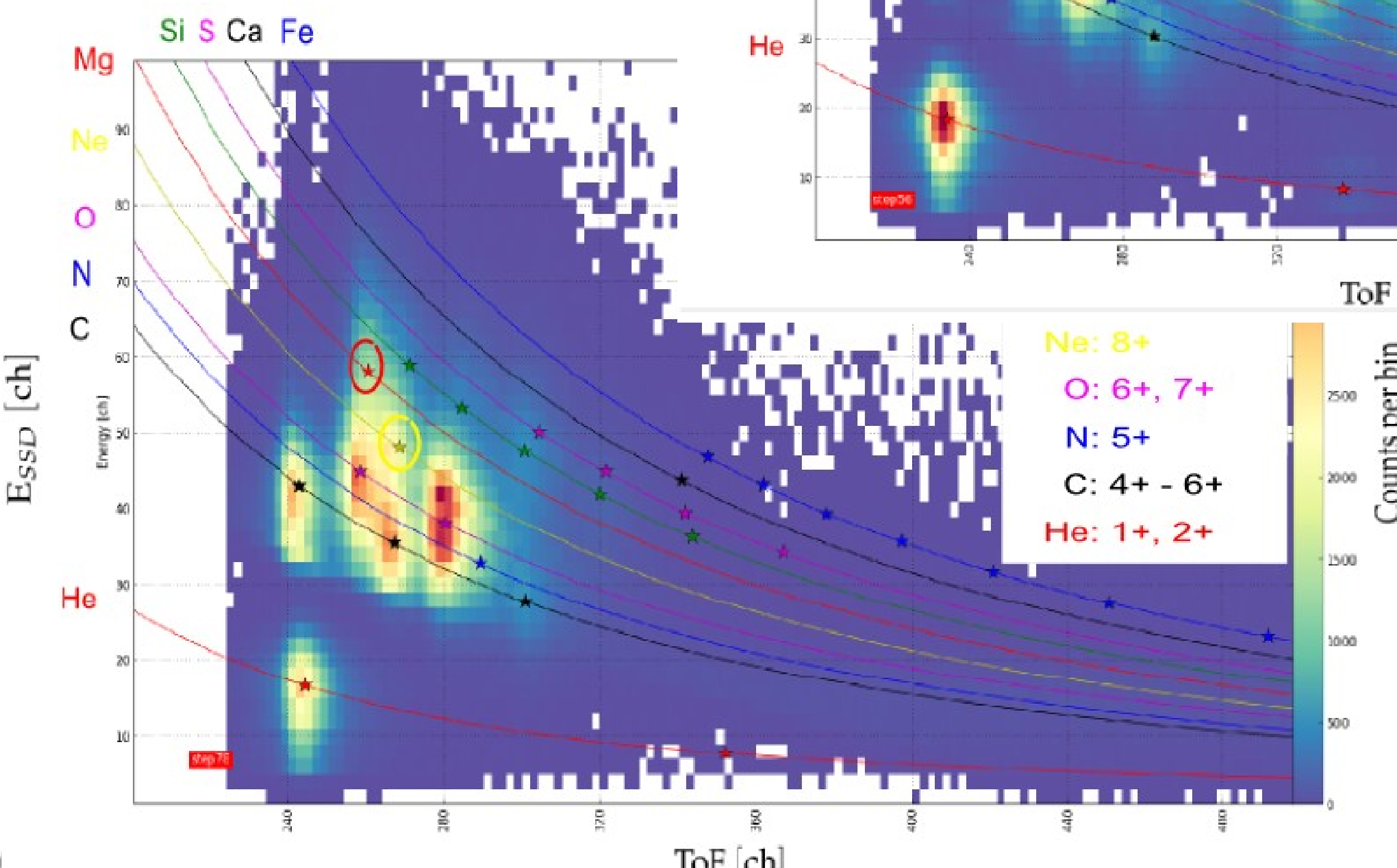
Typically accessed some 10'000 times a day!

Solar Wind Composition



CTOF

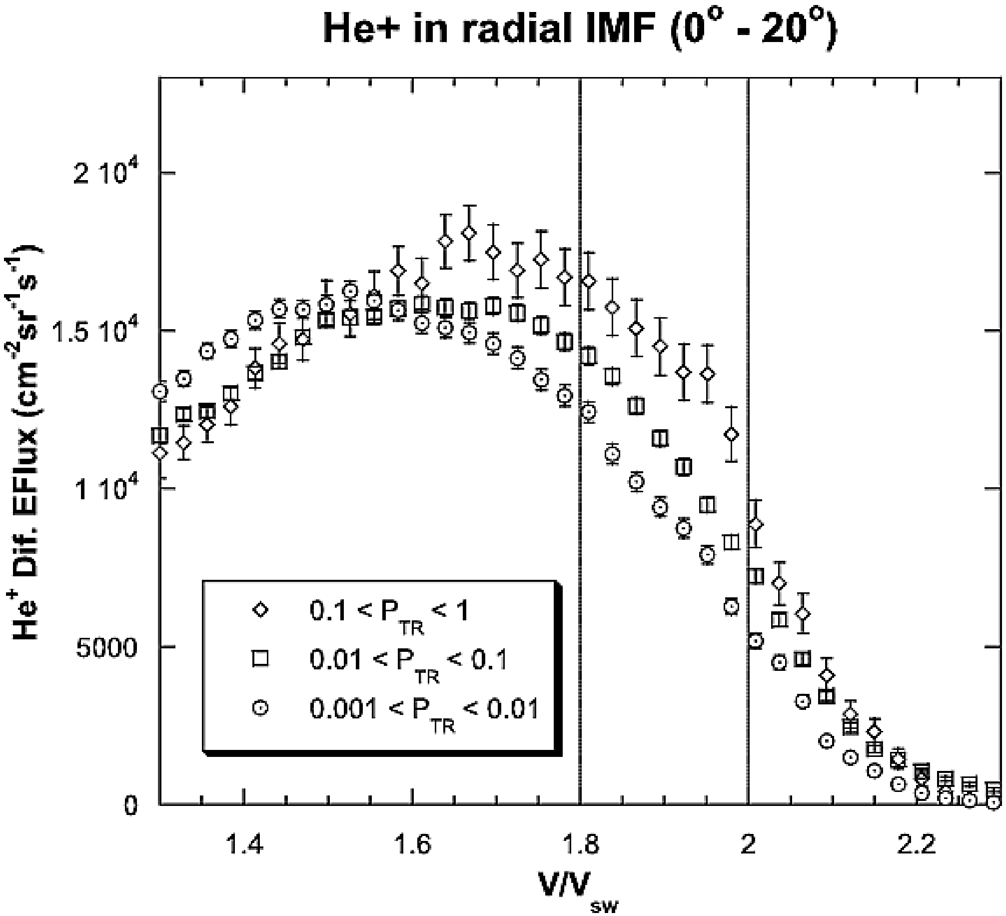


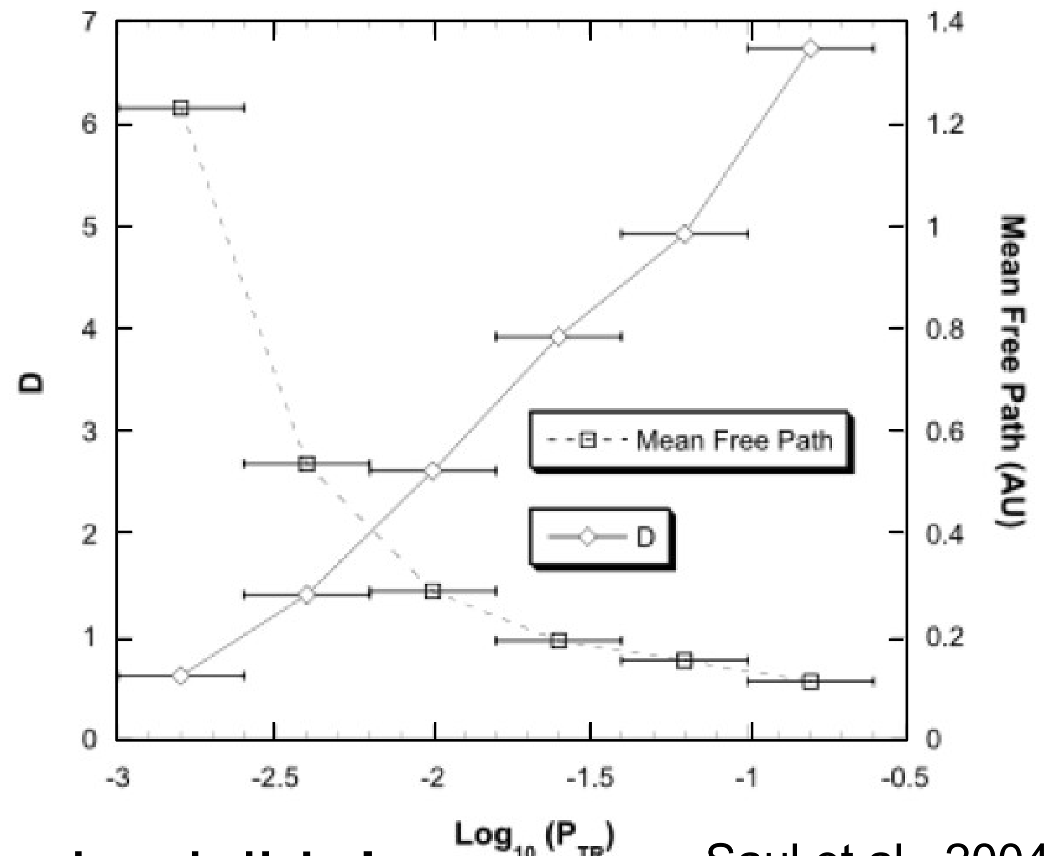


Unprecedented resolution and geometric factor. Very high count rates!

Suprathermal Pickup Ions

CTOF determines the mean free path of ions





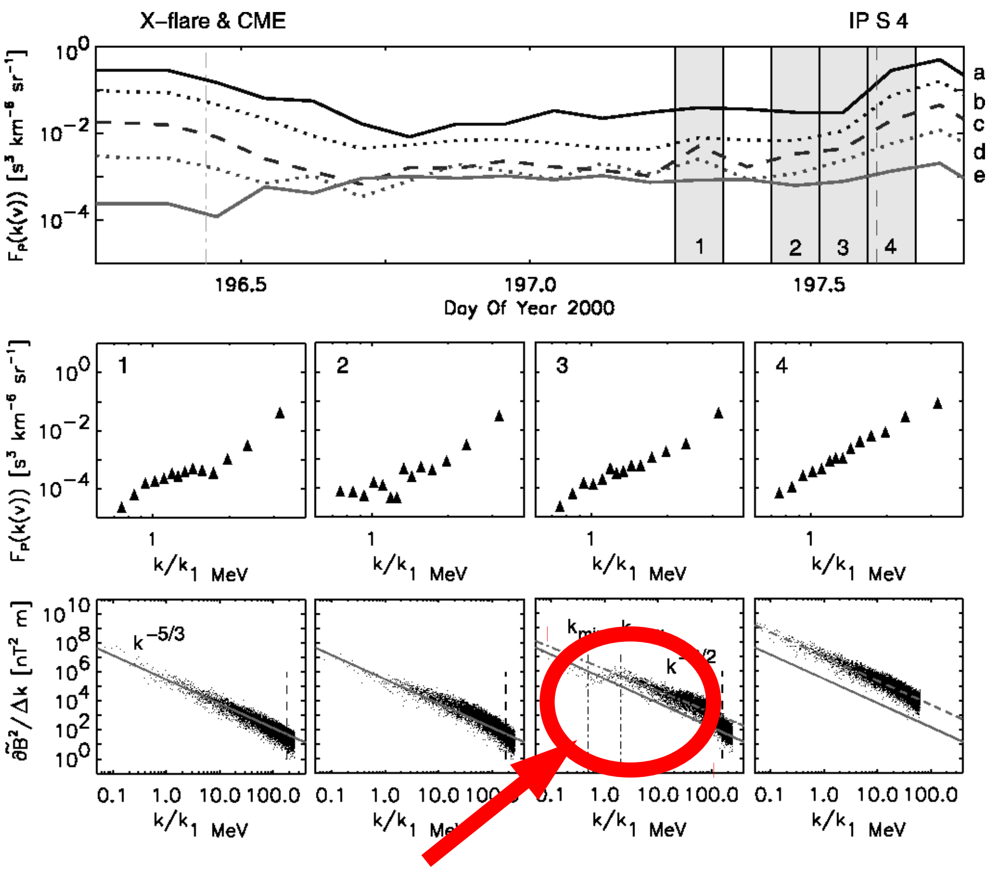
Saul et al., 2004

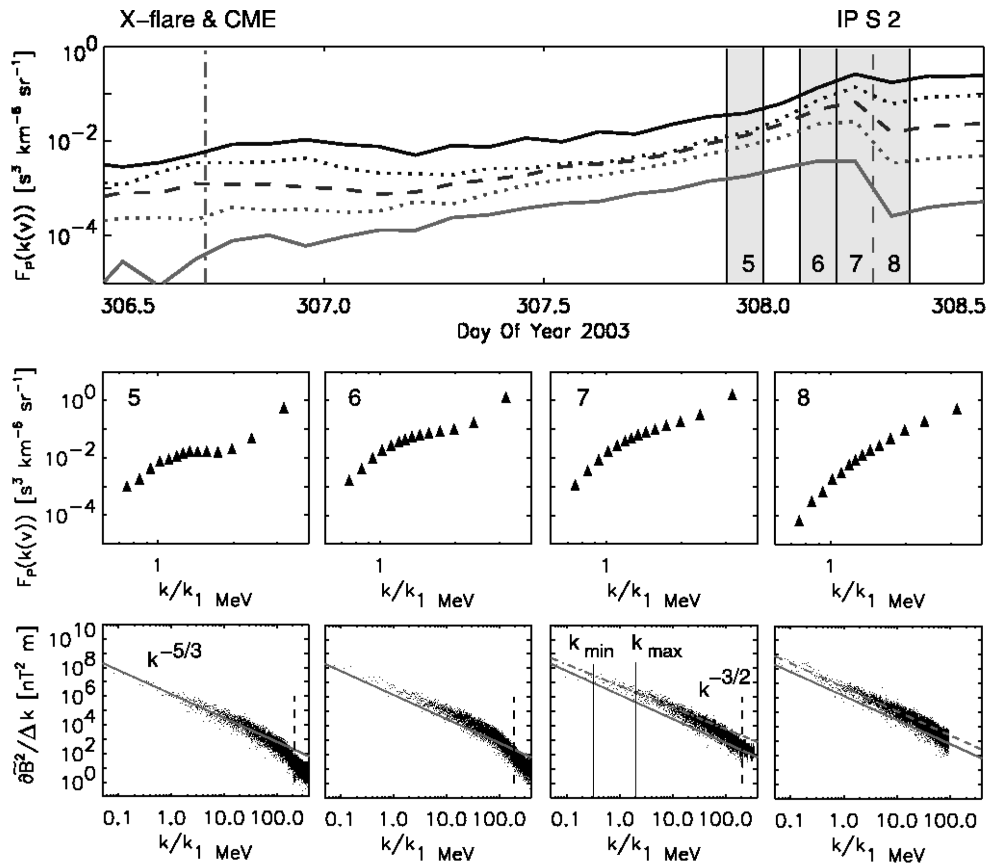
Wave-particle interactions made visible!

Implications for particle transport, PUIs, and IBEX

Suprathermal Particles

STOF discrimnates between different types of turbulent cascades: Kolmogorov vs. Iroshnikov-Kraichnan



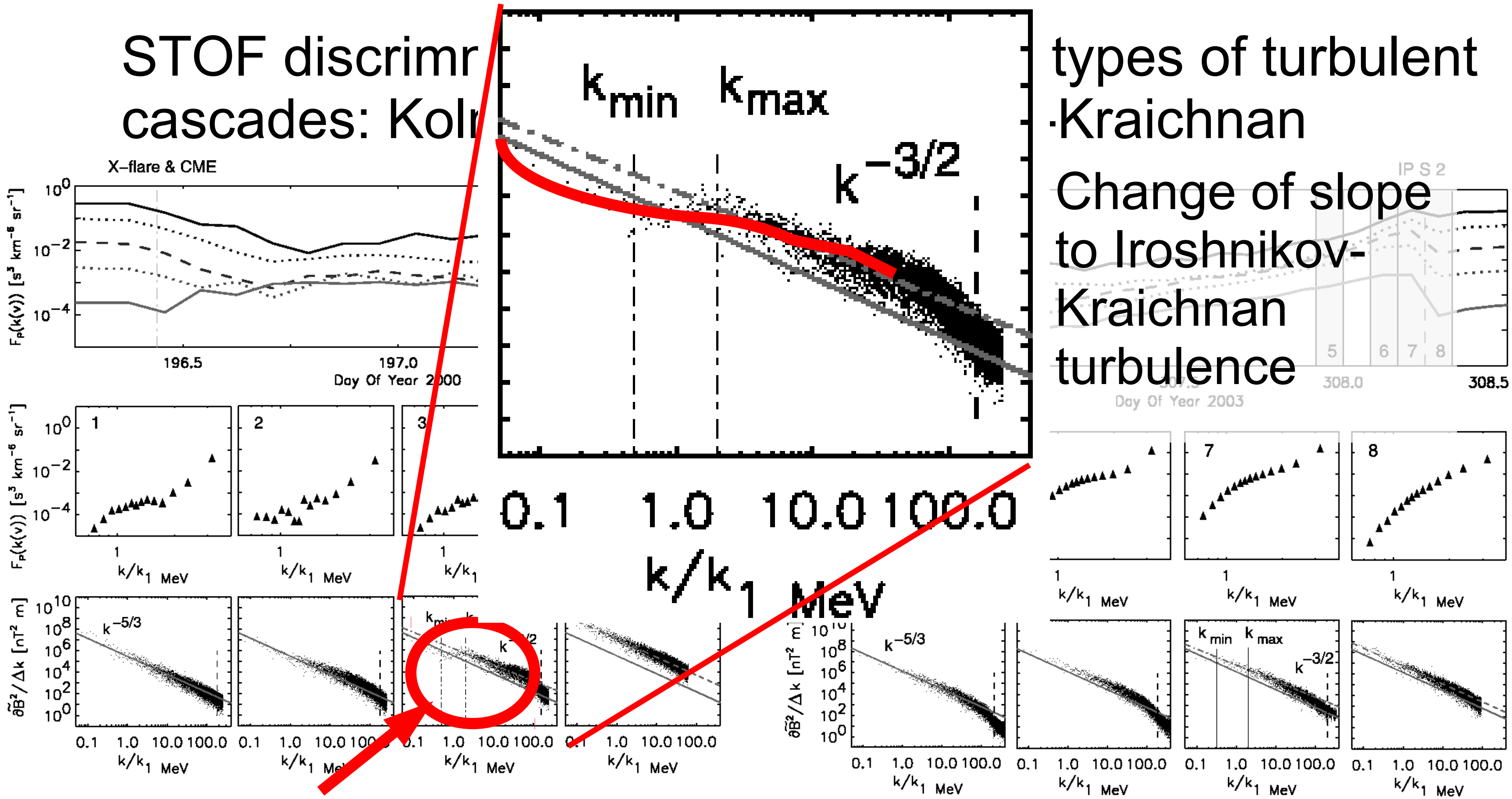


Resonant with 1 MeV protons

Bamert et al., 2008

Suprathermal Particles

STOF discrimr… cascades: Kolr… types of turbulent ·Kraichnan



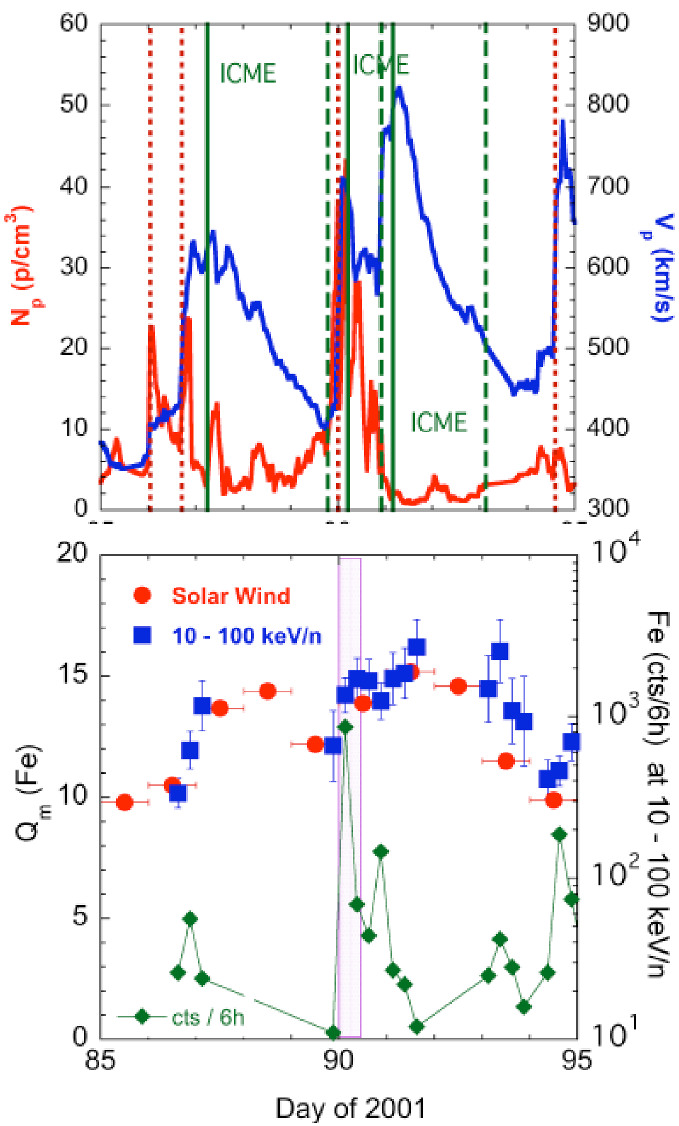
Change of slope to Iroshnikov-Kraichnan turbulence

Resonant with 1 MeV protons

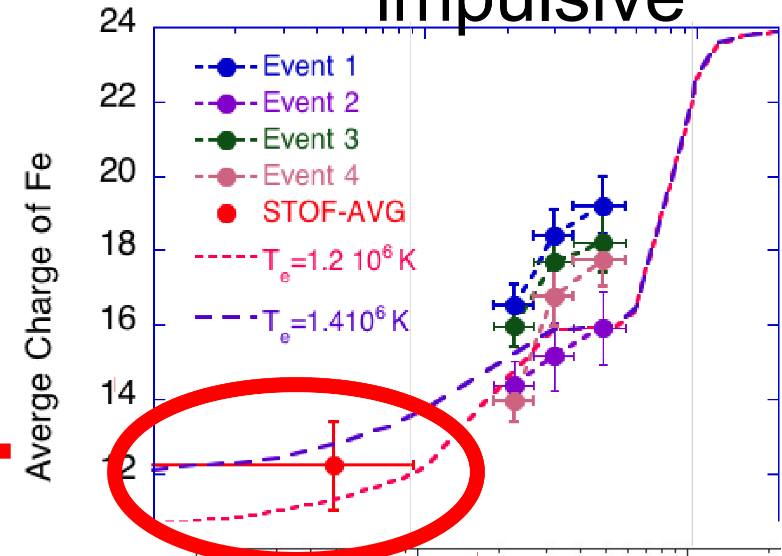
Bamert et al., 2008

Q of Suprathermal Particles

gradual

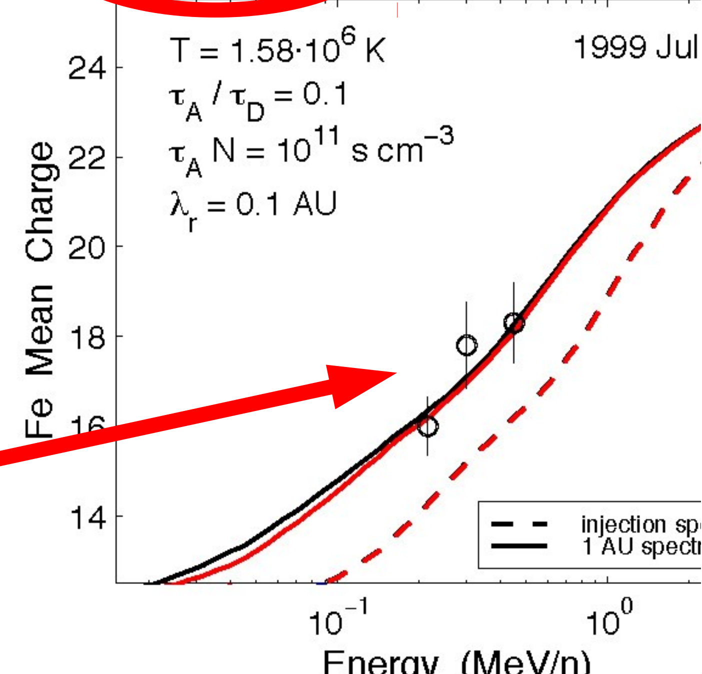


impulsive



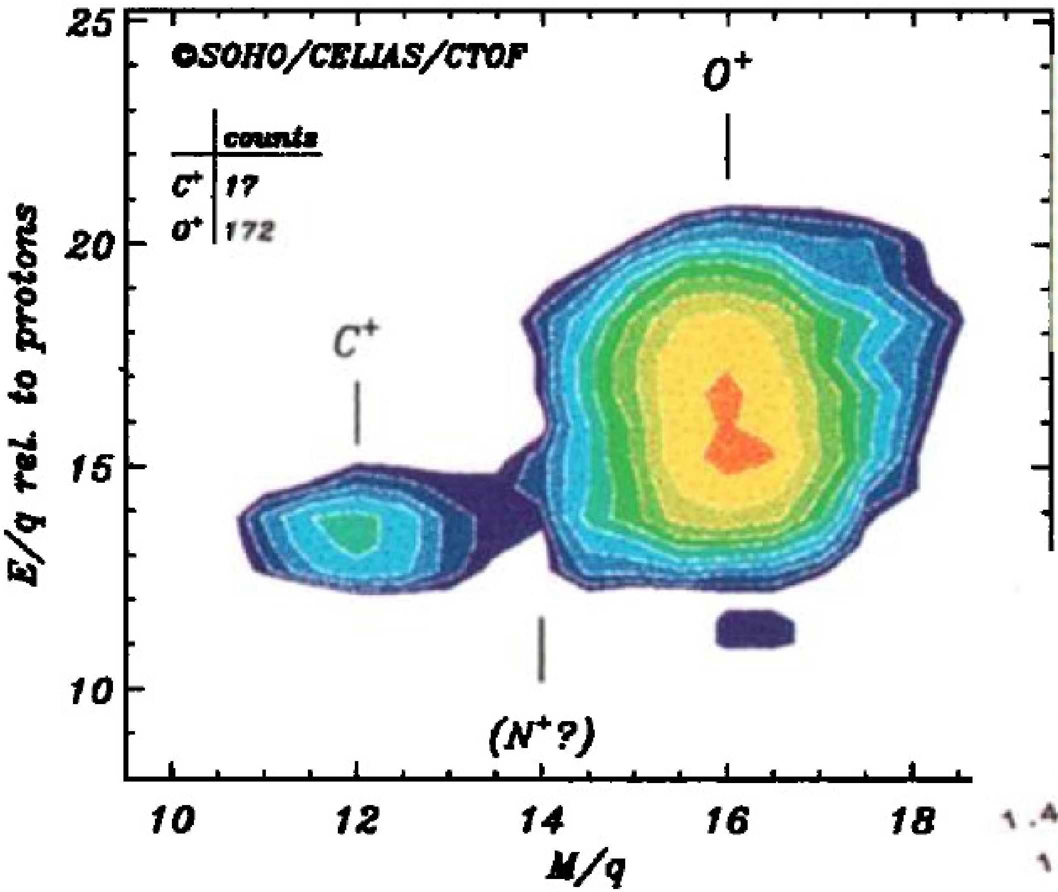
At low energy (E < 100 keV) Q determined by solar wind

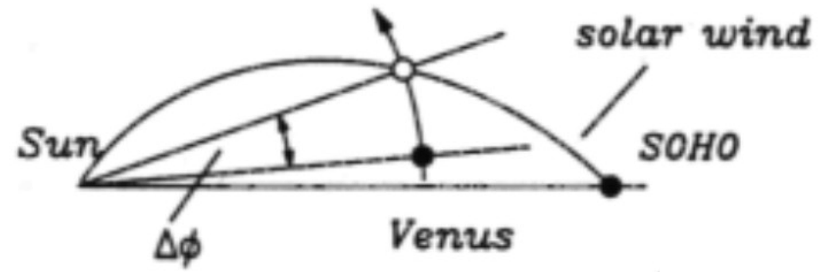
Acceleration and stripping in low corona combined with interplanetary transport.



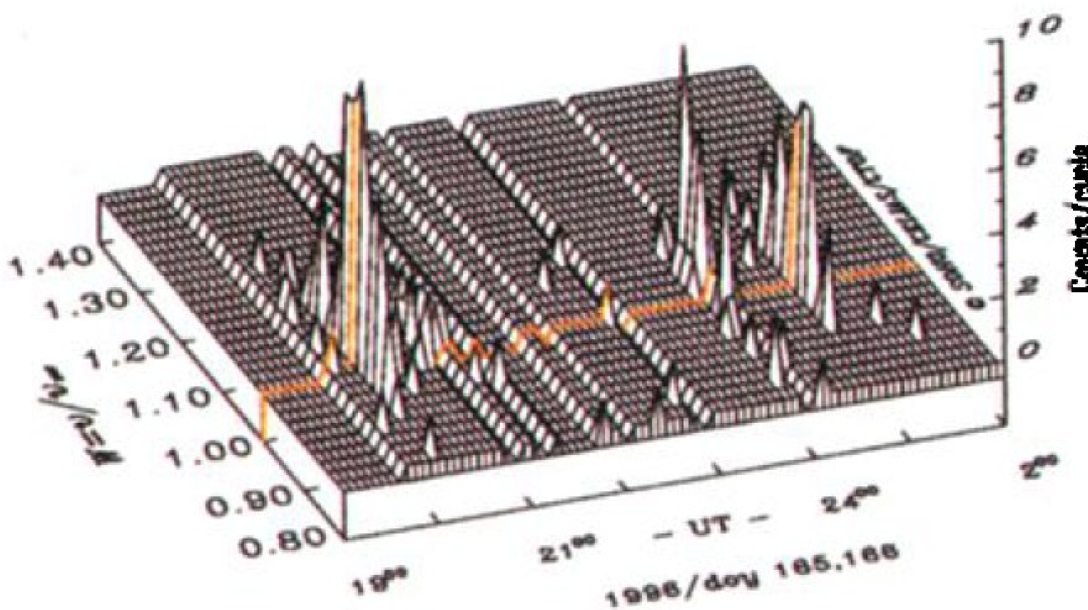
Klecker et al., 2006

Pickup Ions



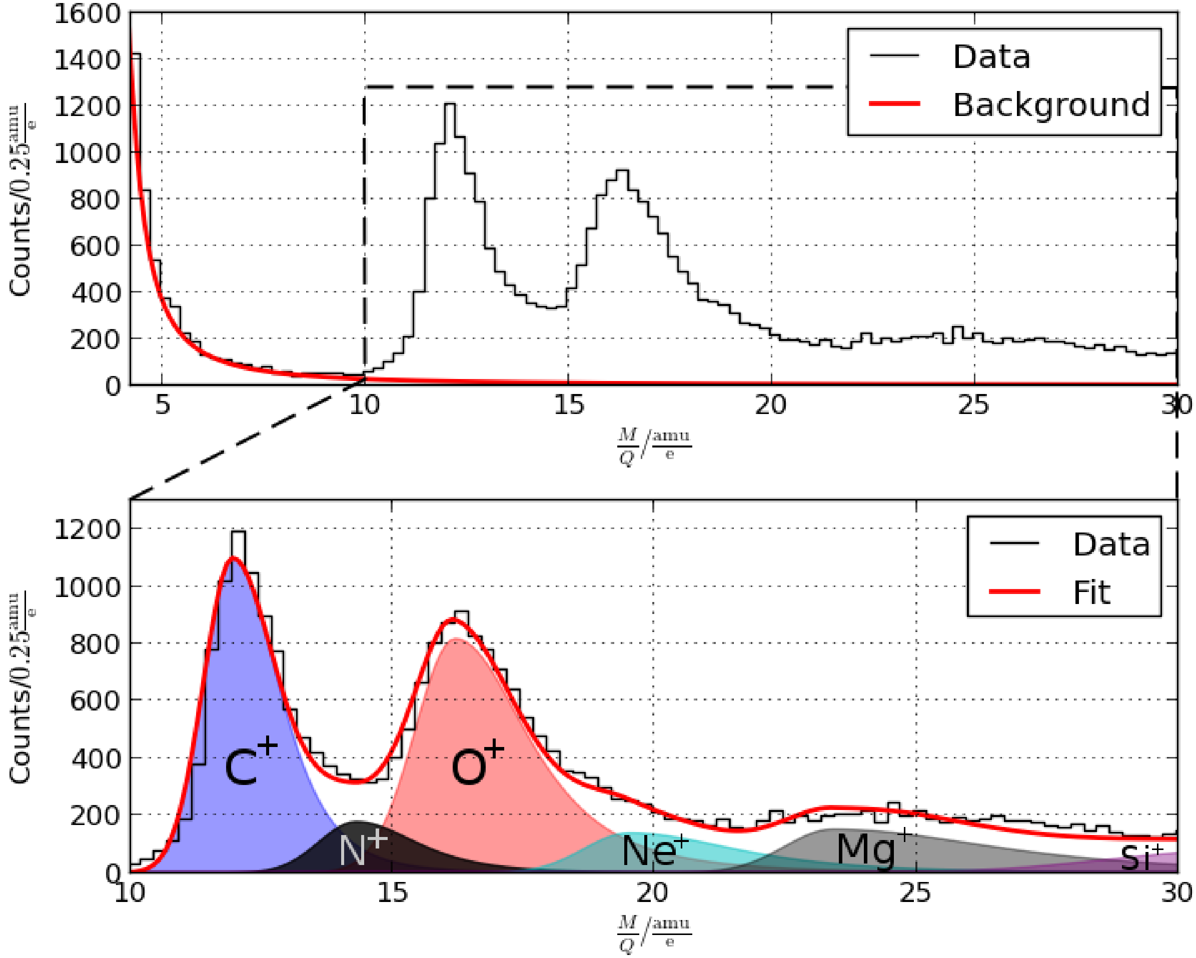


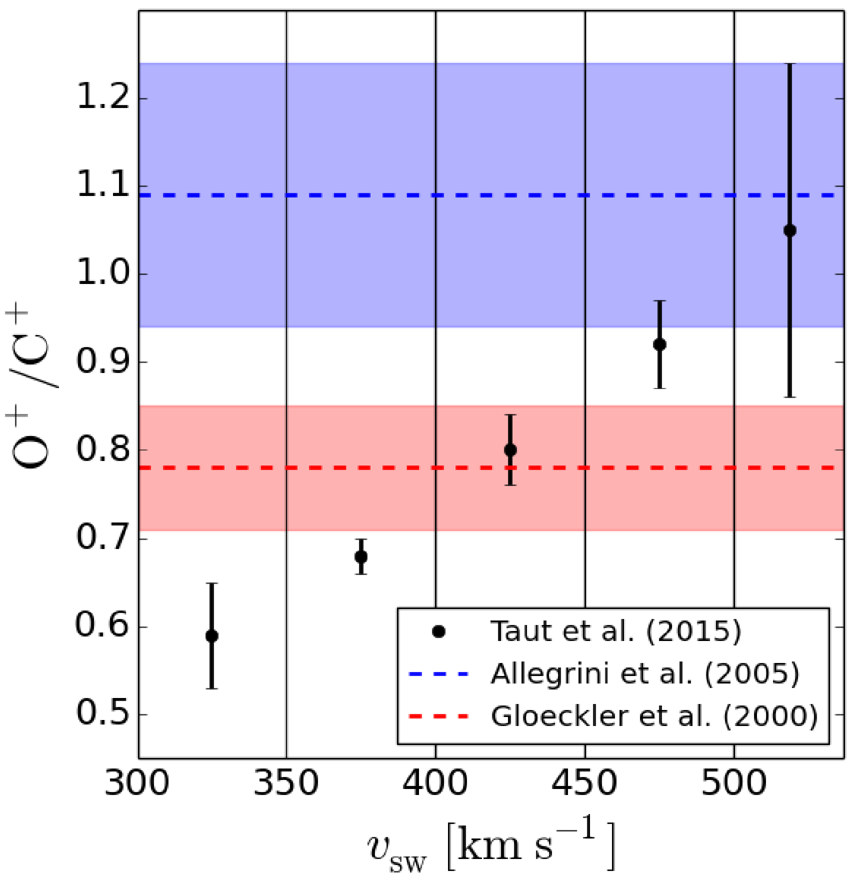
Observation of Venus tail rays by CELIAS/CTOF



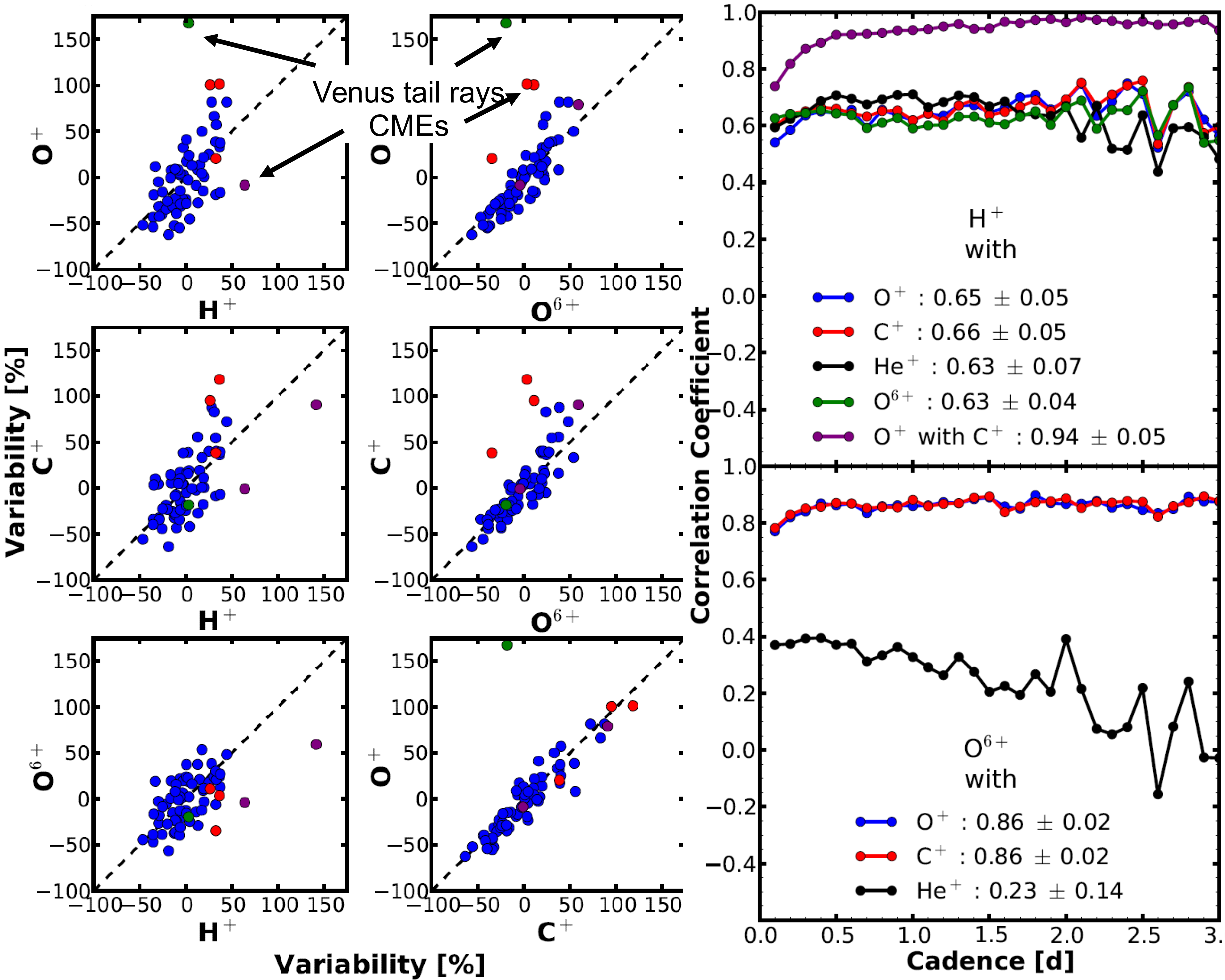
Grünwaldt et al., 1997

Pickup Ions



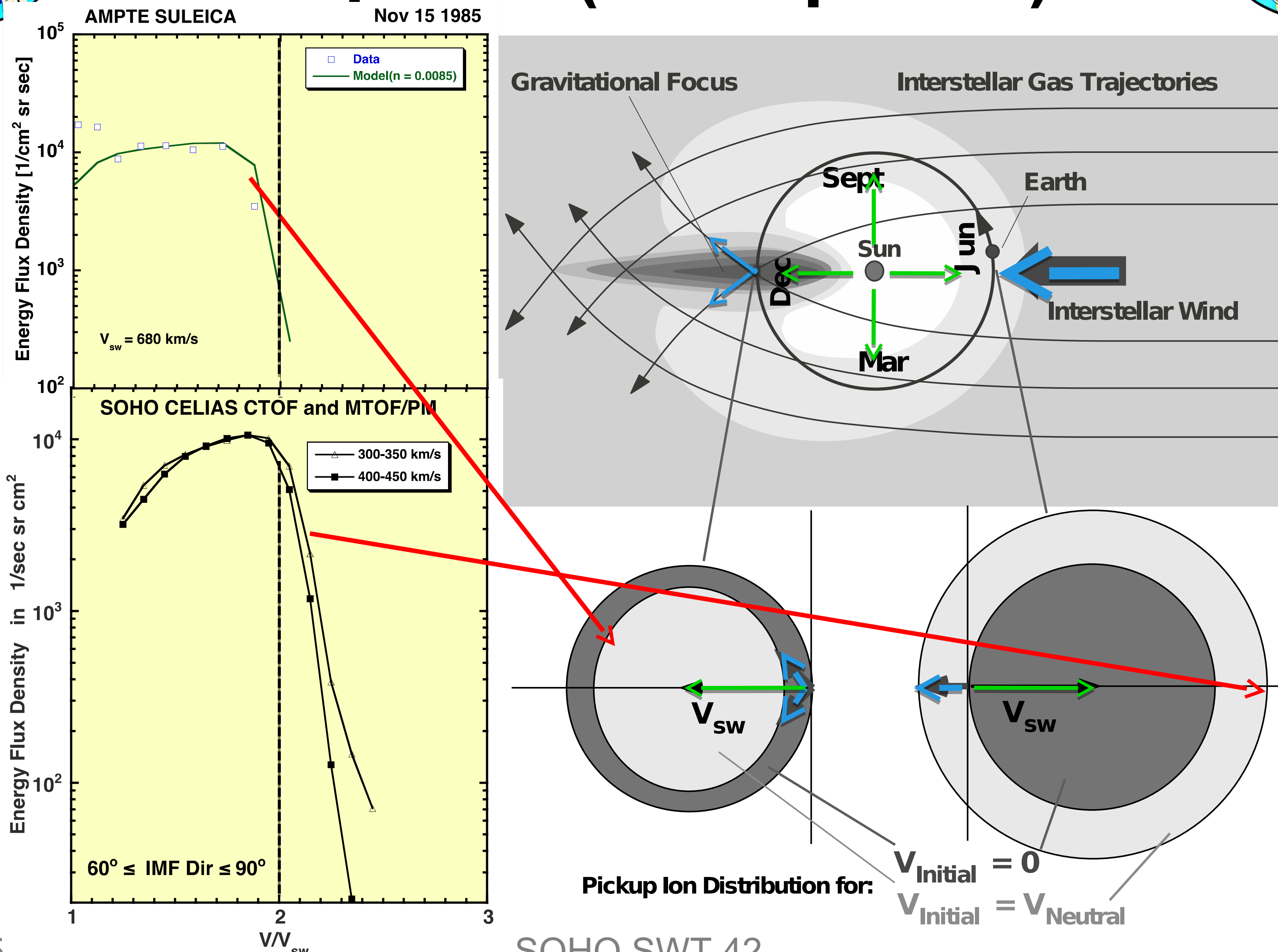


Taut et al., 2015

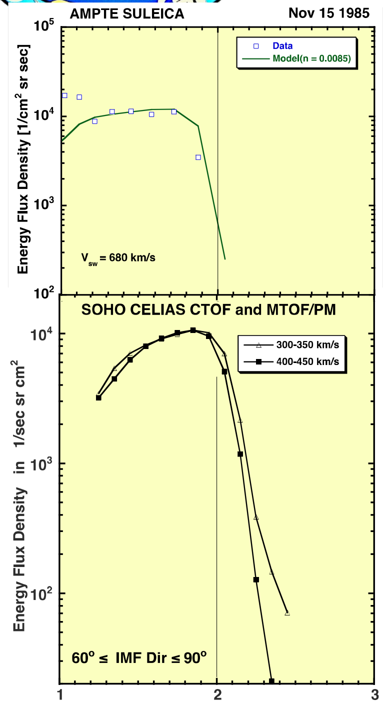


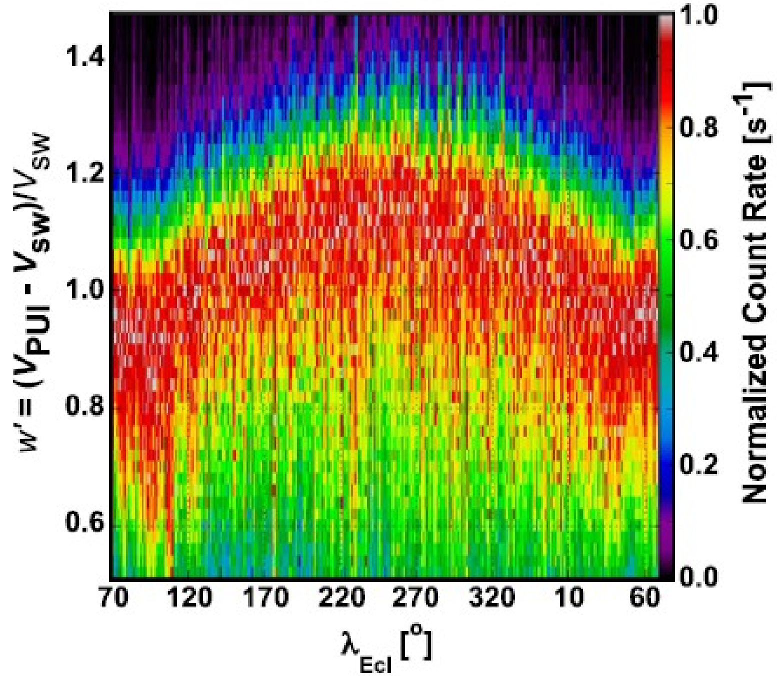
Berger et al., 2015

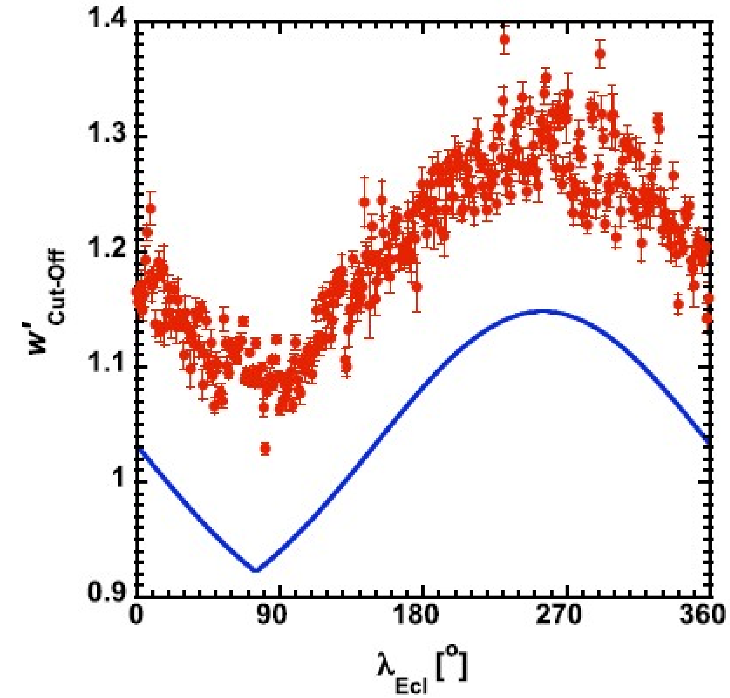
Heliosphere (Pickup Ions)

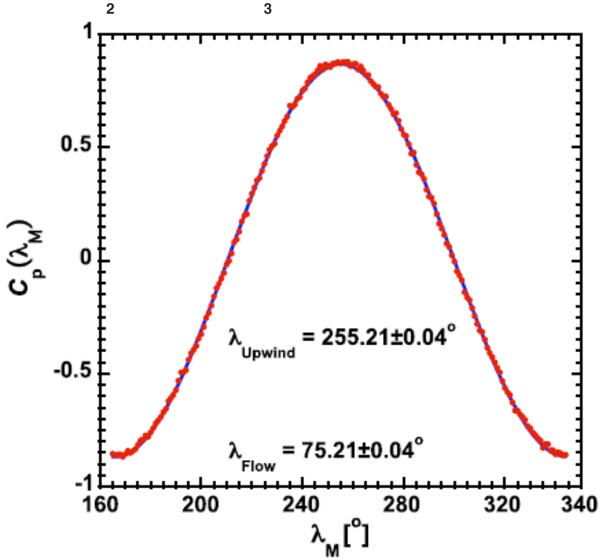


Heliosphere (Pickup Ions)



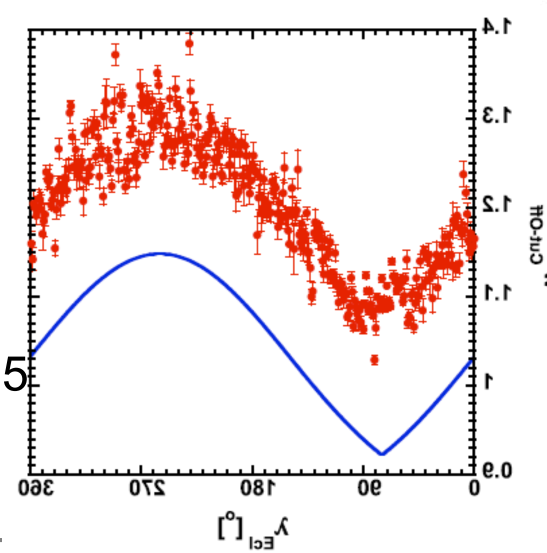






correlate

Möbius et al., 2015



Flip

Suprathermal Particles

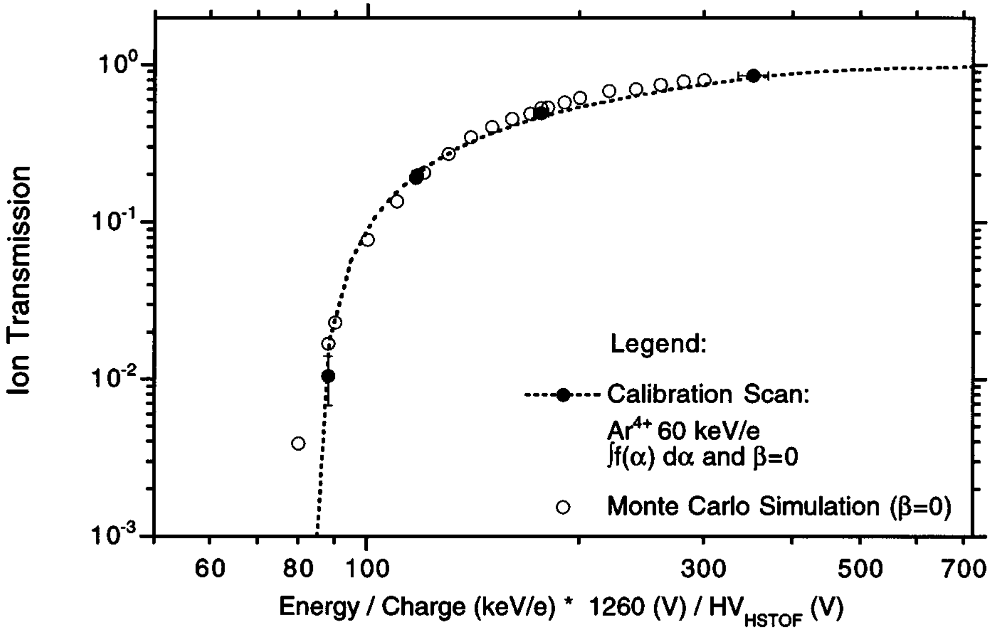


FIG. 2*a*

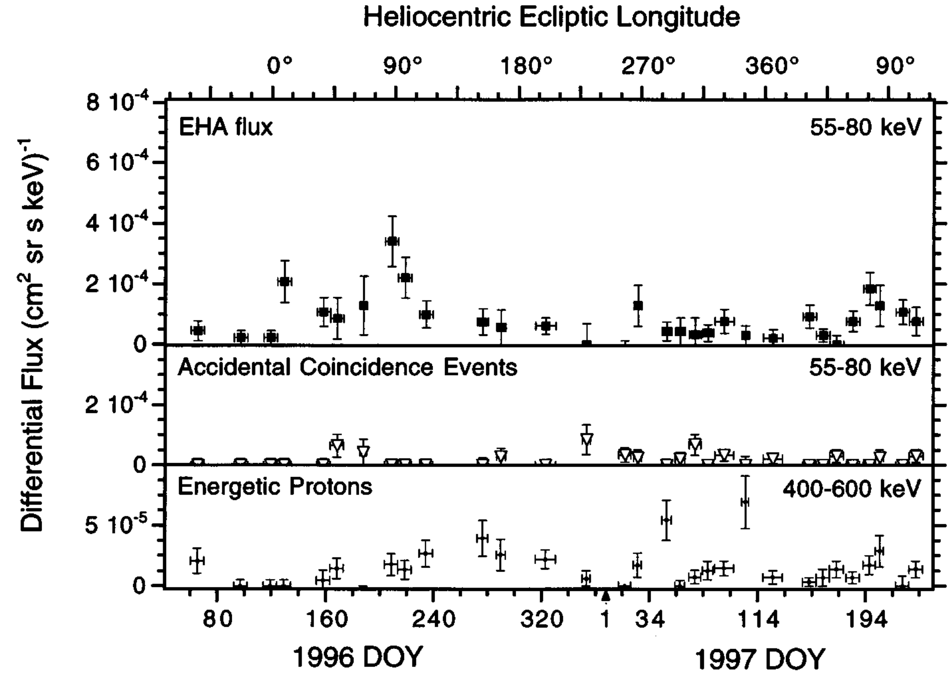
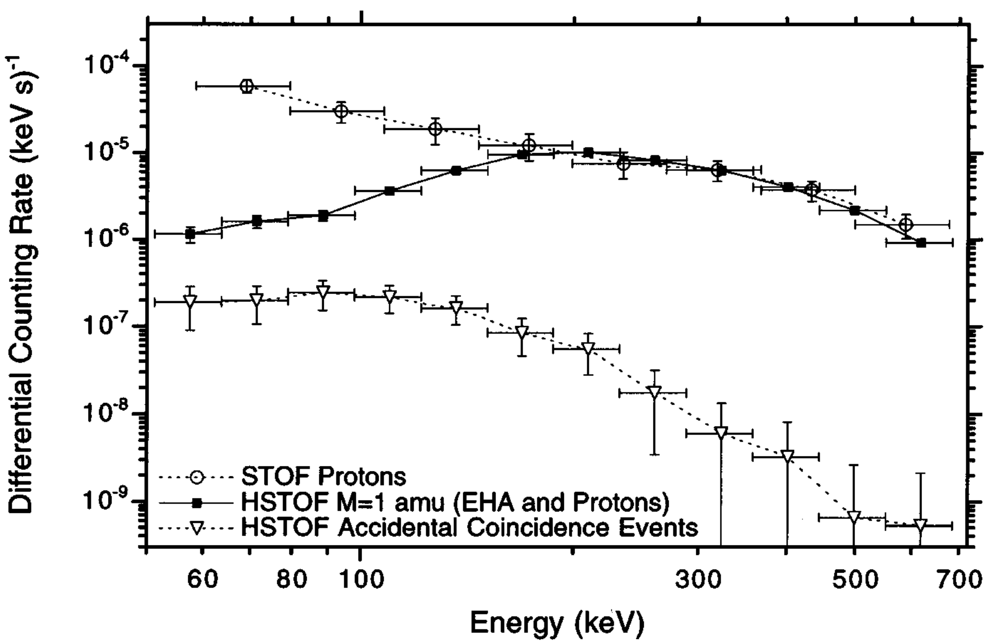
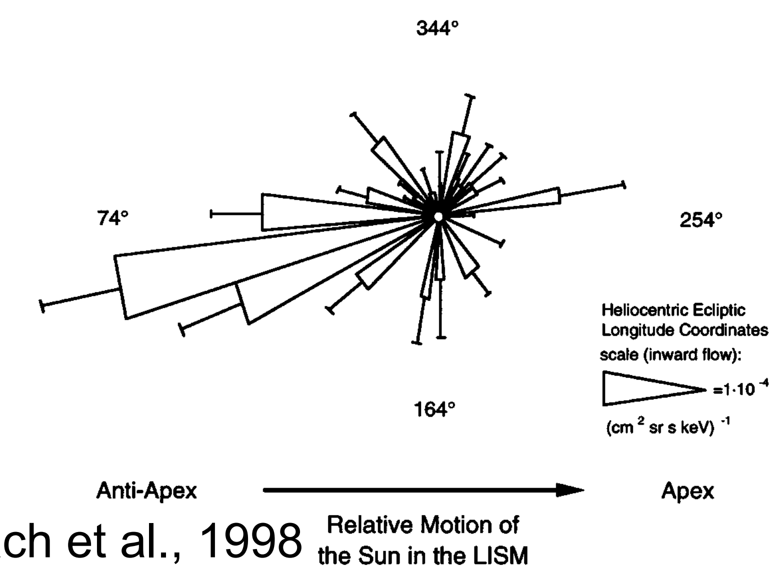


FIG. 6*a*





Hilchenbach et al., 1998

FIG. 6*b*

Future Science

What next?

What is the future of European solar/heliospheric physics?

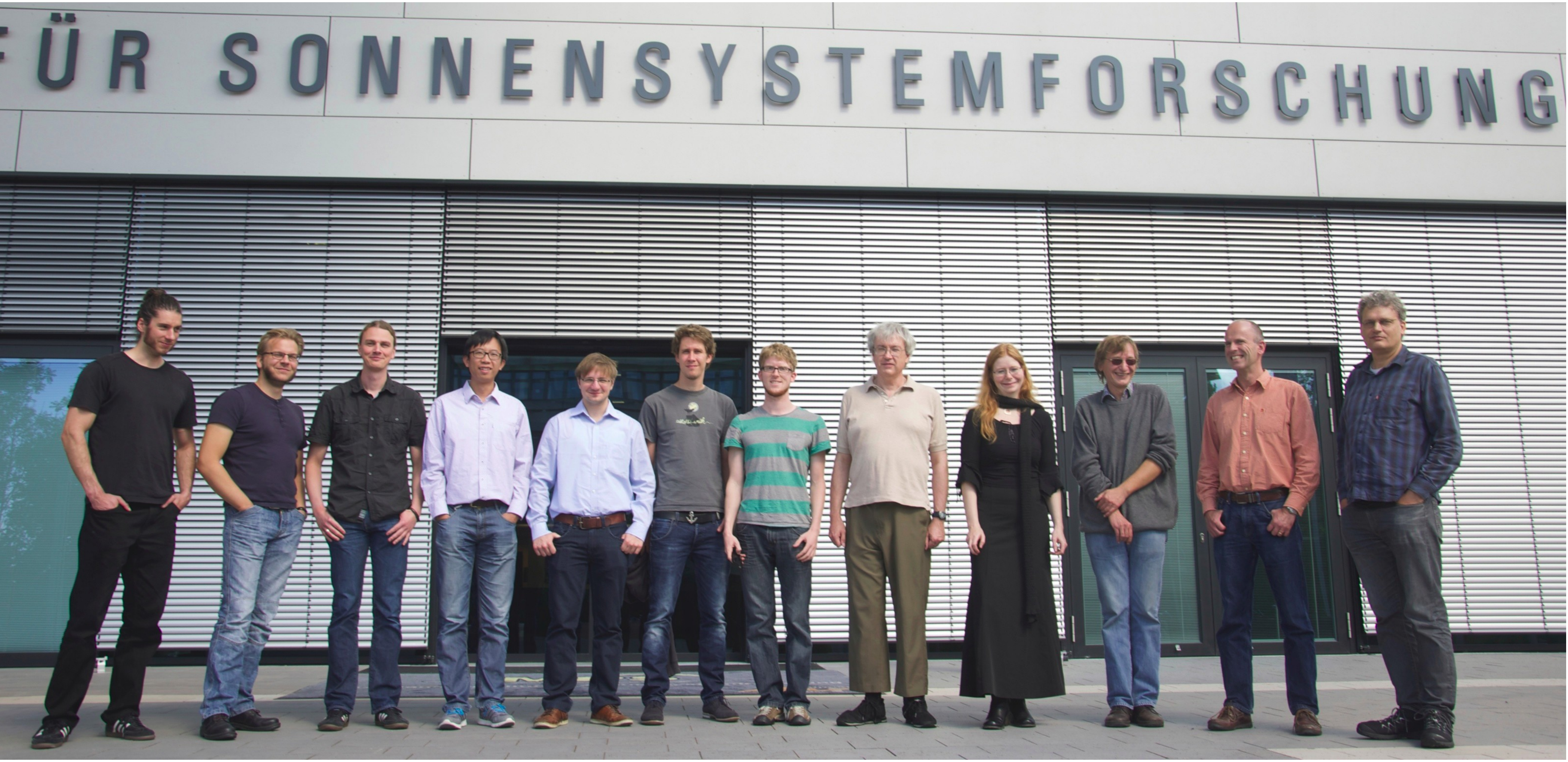
How do we build on SOHO and Solar Orbiter?

The Team in Time

The Team in Time

The Team in Time

The Team in Time



Lessons Learned

PM & SEM exceptionally valuable

CTOF PUI studies, kinetic physics

H/STOF interstellar

MTOF very complicated

SOHO Legacy Archive

Our experience with **Helios** shows that we also need to **archive raw data** (with instructions/descriptions). So apart from raw data, we're investigating the feasibility of the following contributions:

PM: solar wind speed, density, temperature

SEM: EUV flux

CTOF: heavy ion VDFs, charge-state composition

STOF: flux enhancements, selected spectra

MTOF: probably only raw data with instructions

Summary and Conclusions

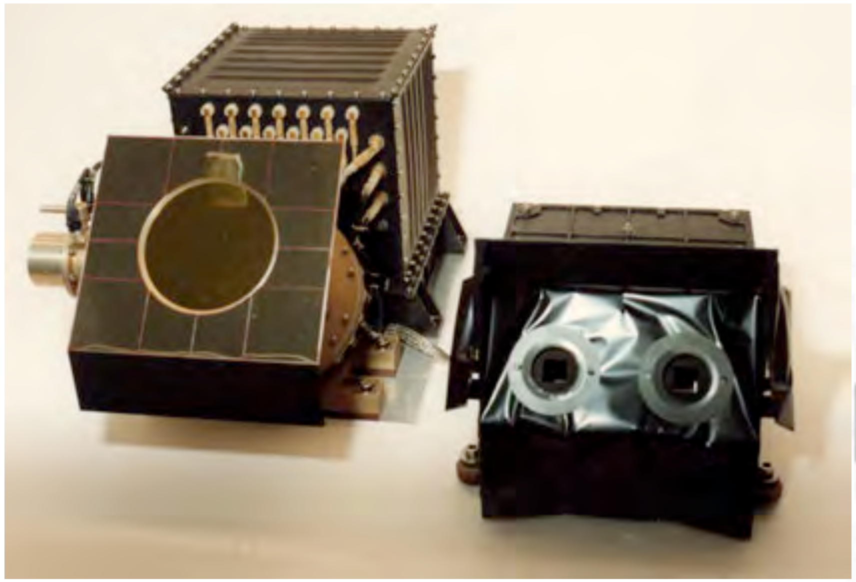
CELIAS has impacted many fields:

- solar (abundances, opacity)
- solar atmosphere (FIP/FIT)
- solar system origin (isotopes)
- inner solar heliosphere (dust, particle transport, Venus)
- kinetic or microphysics of the heliosphere
- outer heliosphere (suprathermal particles, pickup ions)
- interstellar medium (pickup ions)
- heliosperic boundaries (IBEX spectra agree with HSTOF)
- thickness of heliosheath (HSTOF, Voyager, Cassini, IBEX)

Looking forward to another solar cycle of CELIAS science!

Highlights from 20+ years of SOHO/COSTEP/EPHIN

Bernd Heber on behalf of the COSTEP consortium



Outline

- Pre-STEREO period
  - Jovian electrons in the inner heliosphere
  - Upstream electron events (leakage from the Earth magnetosphere)
  - Forecasting solar energetic proton events
- SOHO/STEREO and beyond
  - Wide spread solar energetic particle events
- PAMELA/AMS and beyond

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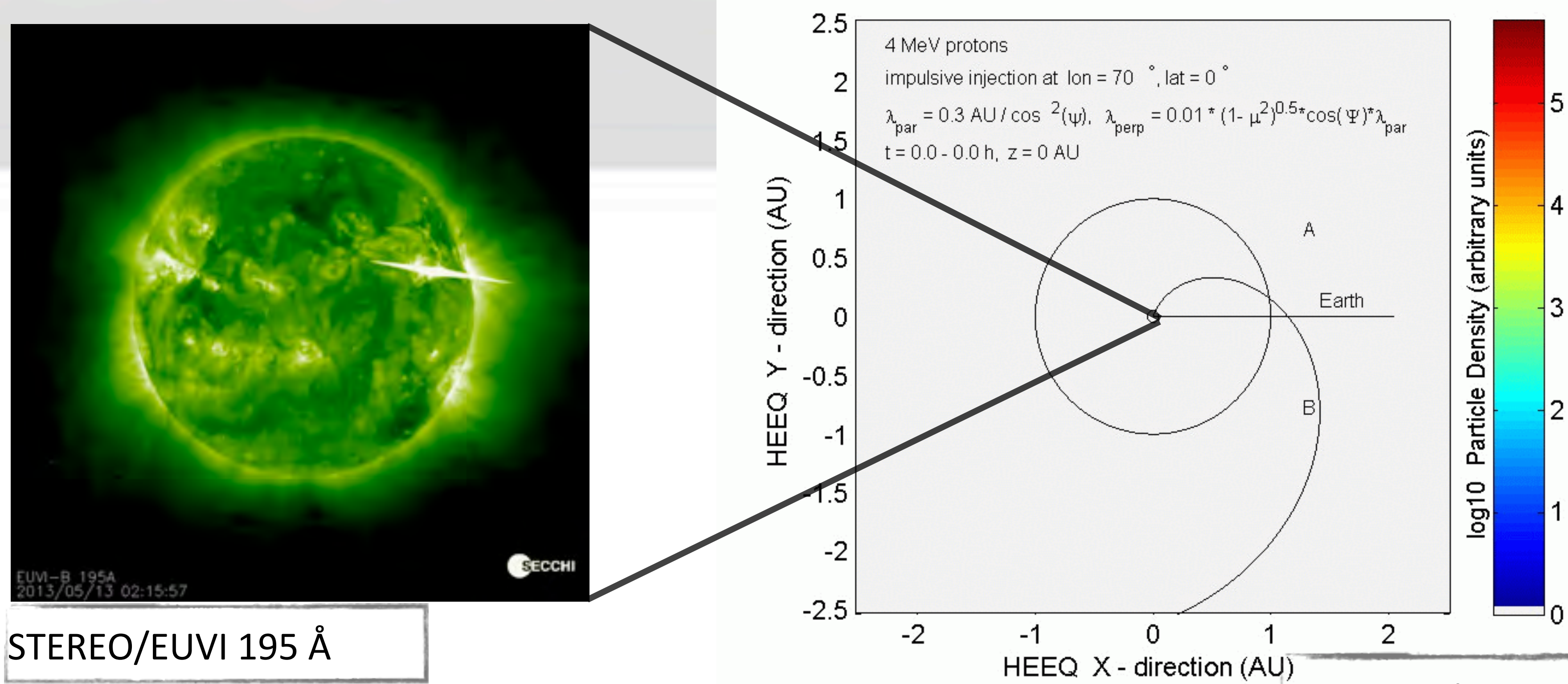


STEREO/EUVI 195 Å

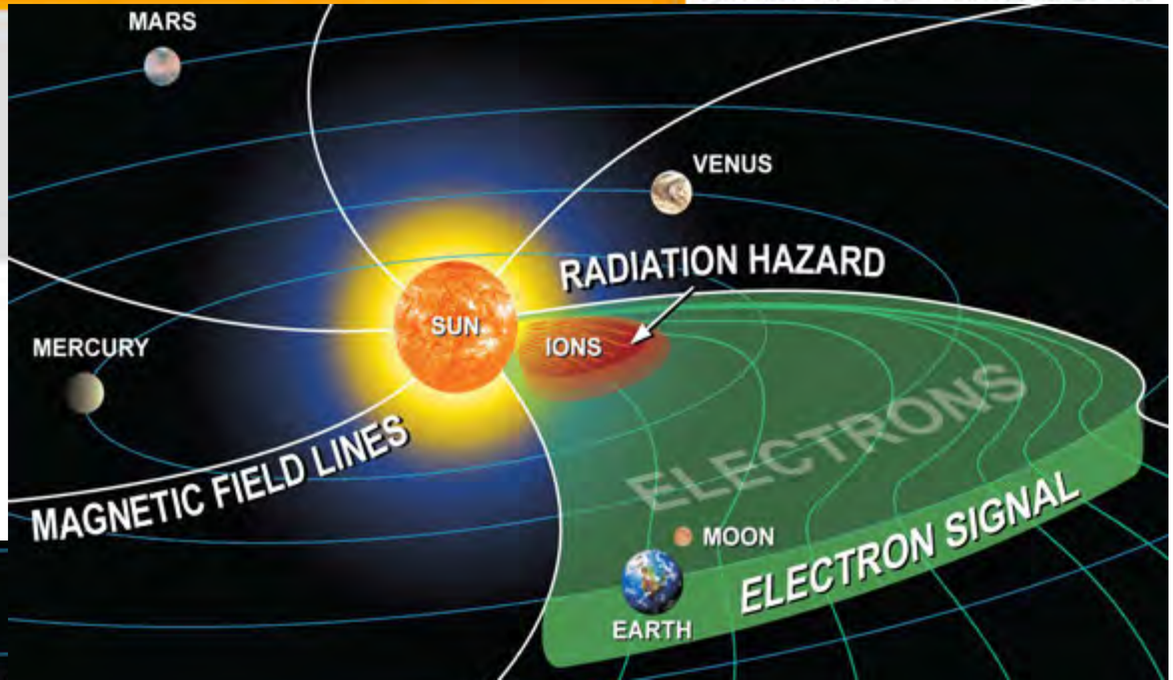
Dröge et al., 2010

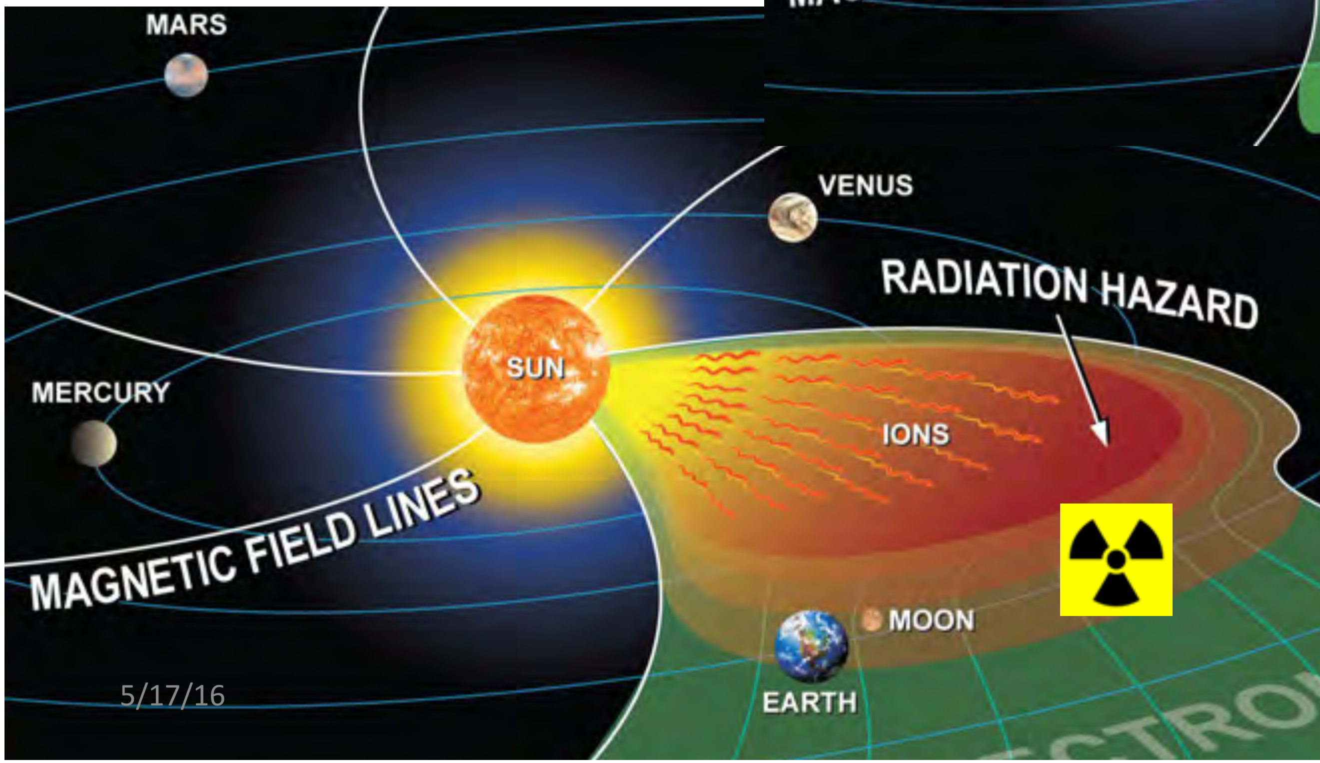
1. What is the source region of the SEPs, where are the particles accelerated and injected?

2. How are the SEPs transported from the source to 1AU?

REleASE — Relativistic Electron Alert System for Exploration

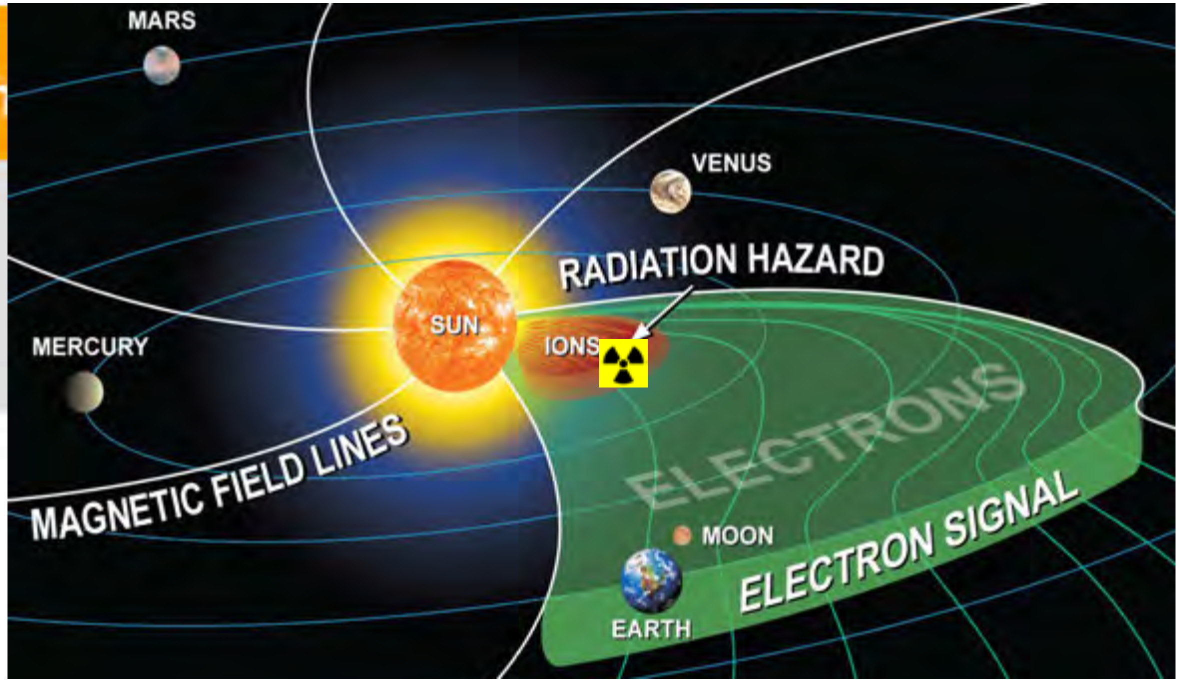
Posner (6 pubs.)

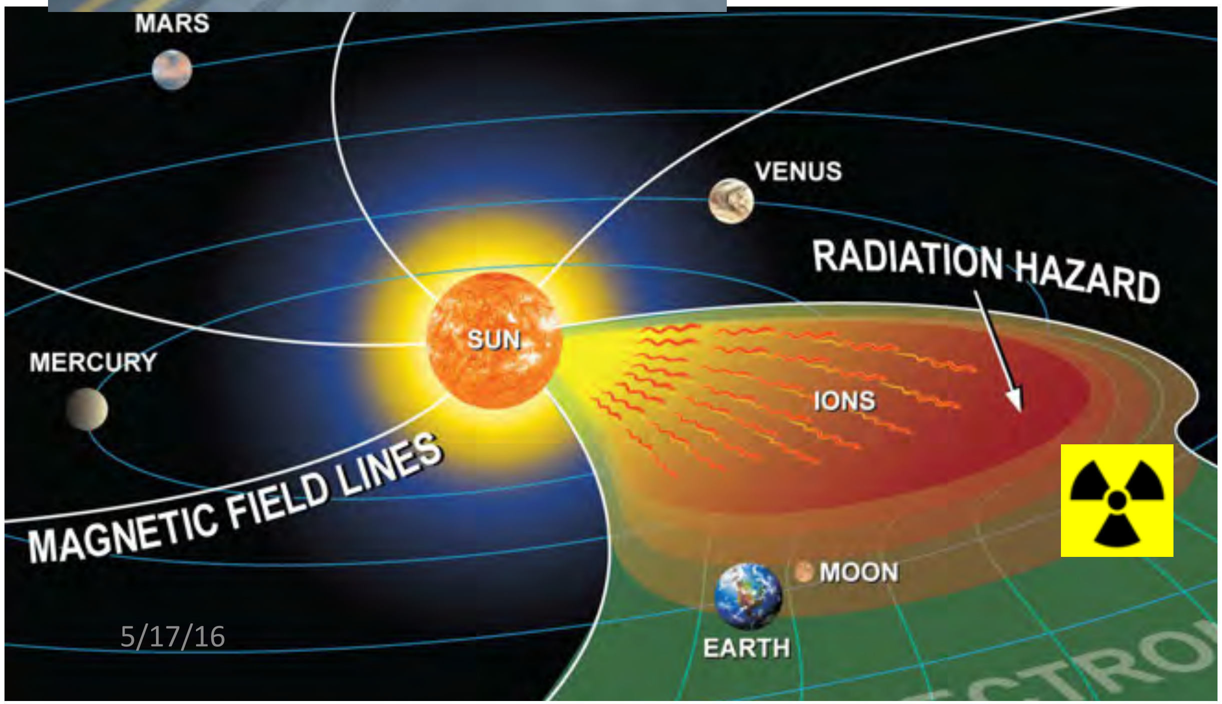




- D ~ 1.2 AU
- v_{el}(1 MeV) = 0.95c
- T_{el} (1 MeV) =10.5min

REleASE
Relativistic Electron Alert System for Exploration





D ~ 1.2 AU

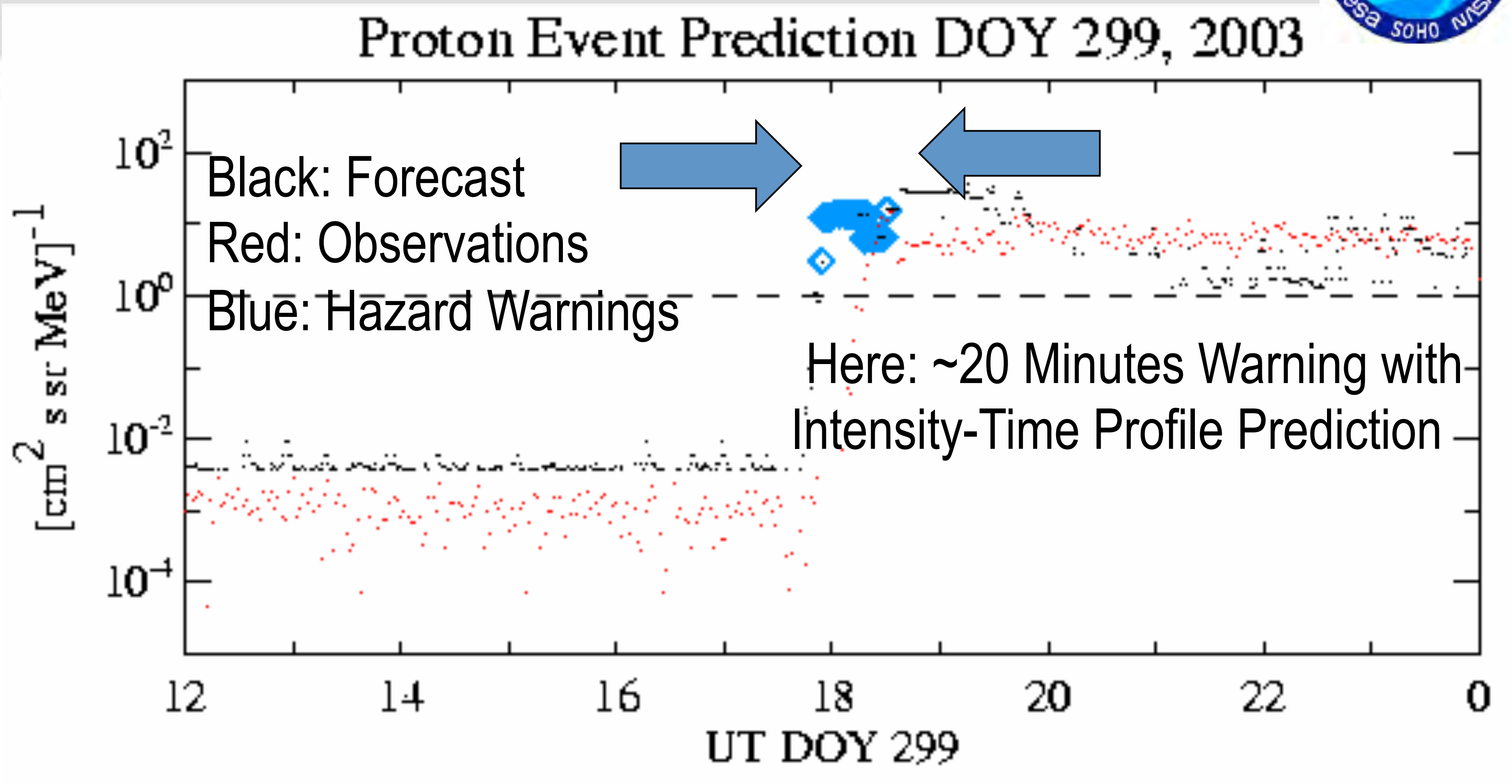
v_{el}(1 MeV) = 0.95c

v_p(30 MeV) = 0.25c

T_{el} (1 MeV) =10.5min

T_p(30 MeV) = 40min

ΔT ~ 30 min



The Oct. 26, 2003 event in detail. The forecast intensity is provided in black, the observations in red. A 20-minute warning allows astronauts on EVAs or inside spacecraft to seek shelter early.

Outline

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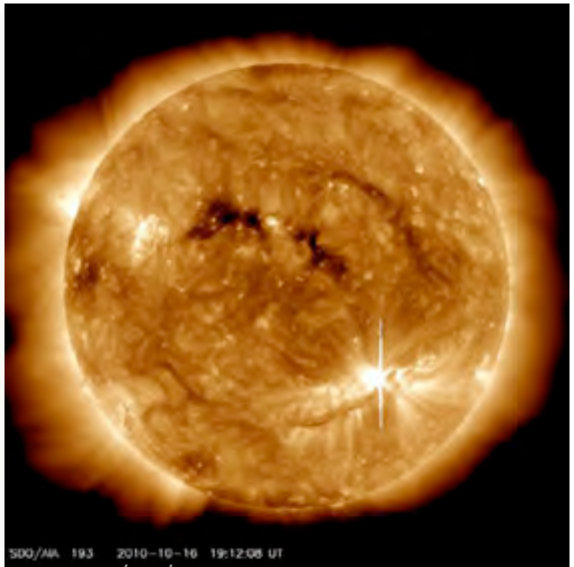
The STEREO Mission – Orbit (above 80 pubs)

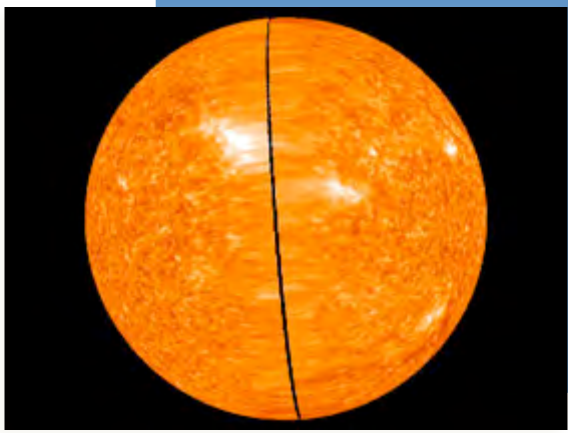
- Progressive longitudinal separations of ~22°/a
- Constant radial distance of ~1 AU

➡ Whole Sun 's surface visible for first time ever!

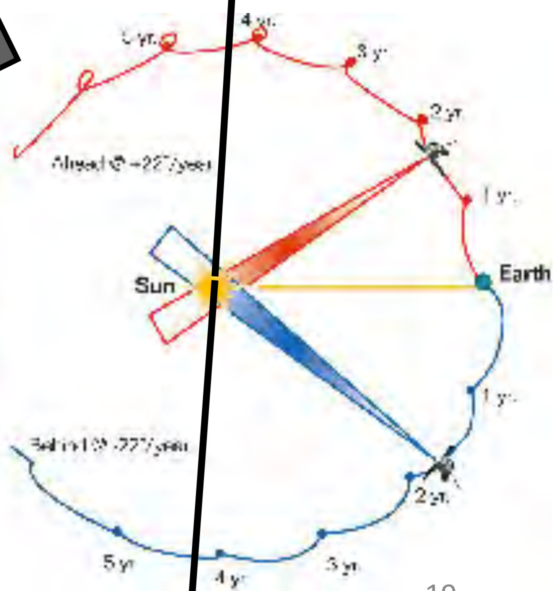
The Sun 's front side
SDO / AIA



The Sun 's **back side**
STEREO / EUVI

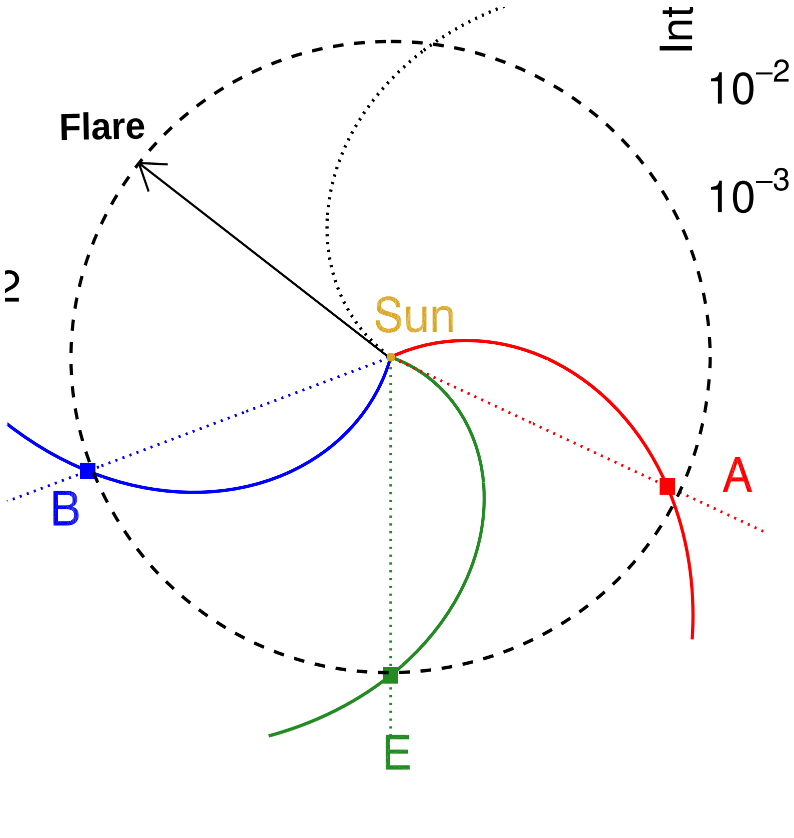


Feb 2011

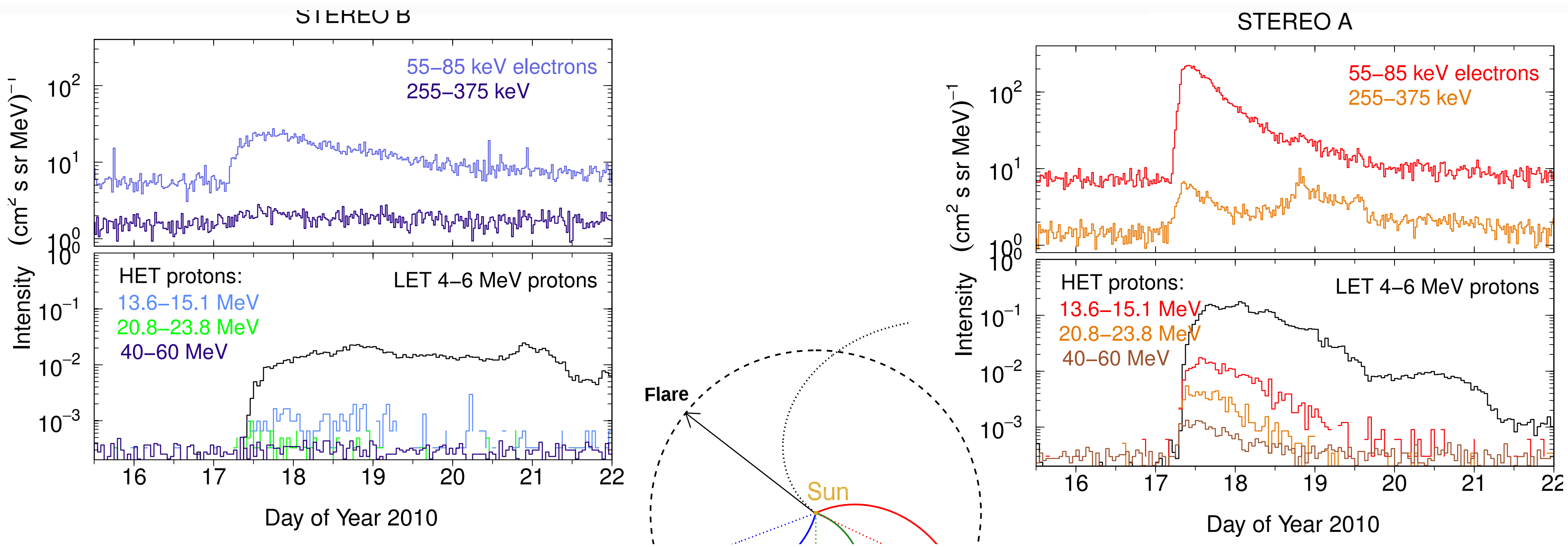


The January 2010 event

On January 17, 2010, a solar energetic particle event was observed by STEREO A and B. The SEP event could attributed to a flare that location is more than 160° away from the Earth footpoint.



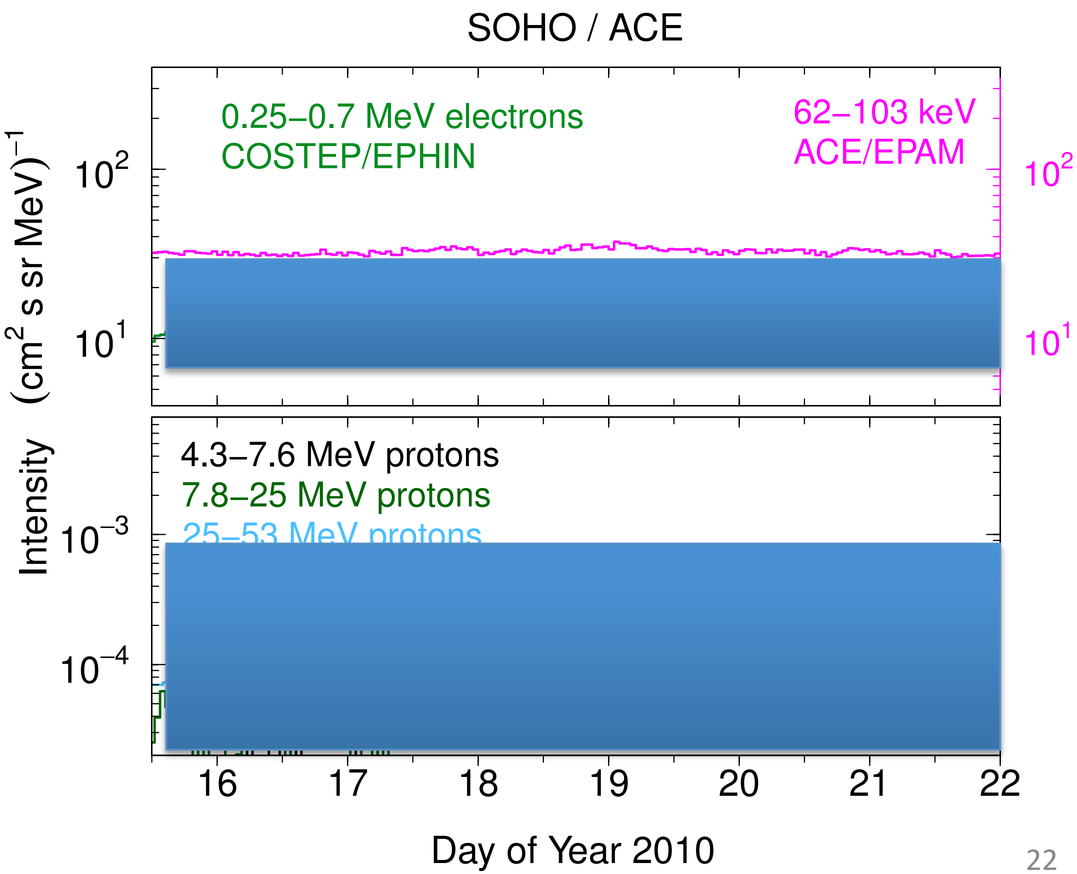
The first wide spread SEP event



In agreement to our understanding a more prompt onset at STA than at STB.

What about Earth?

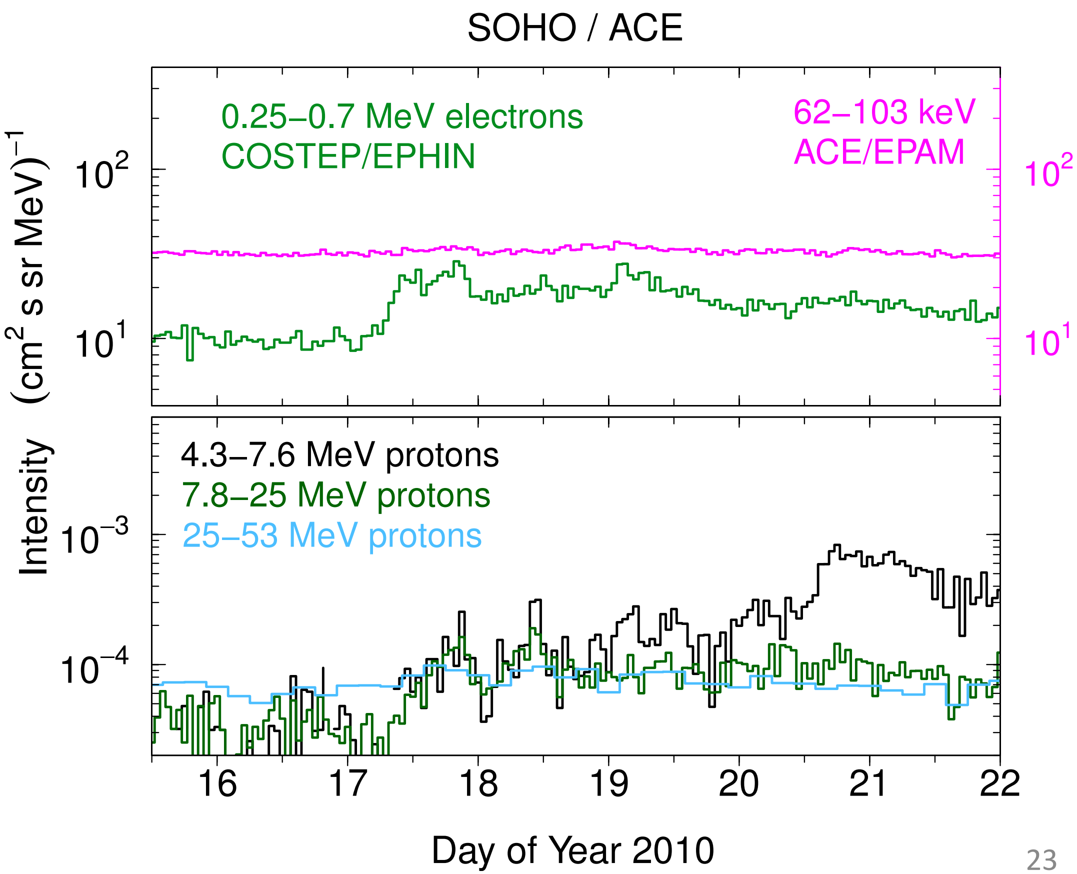
Utilizing ACE/EPAM there are no electrons observed at Earth!



What about Earth?

Utilizing ACE/EPAM there are no electrons observed at Earth!

SOHO: Yes electrons can cover more than 160°! SOHO/EPHIN sensitivity is unique!



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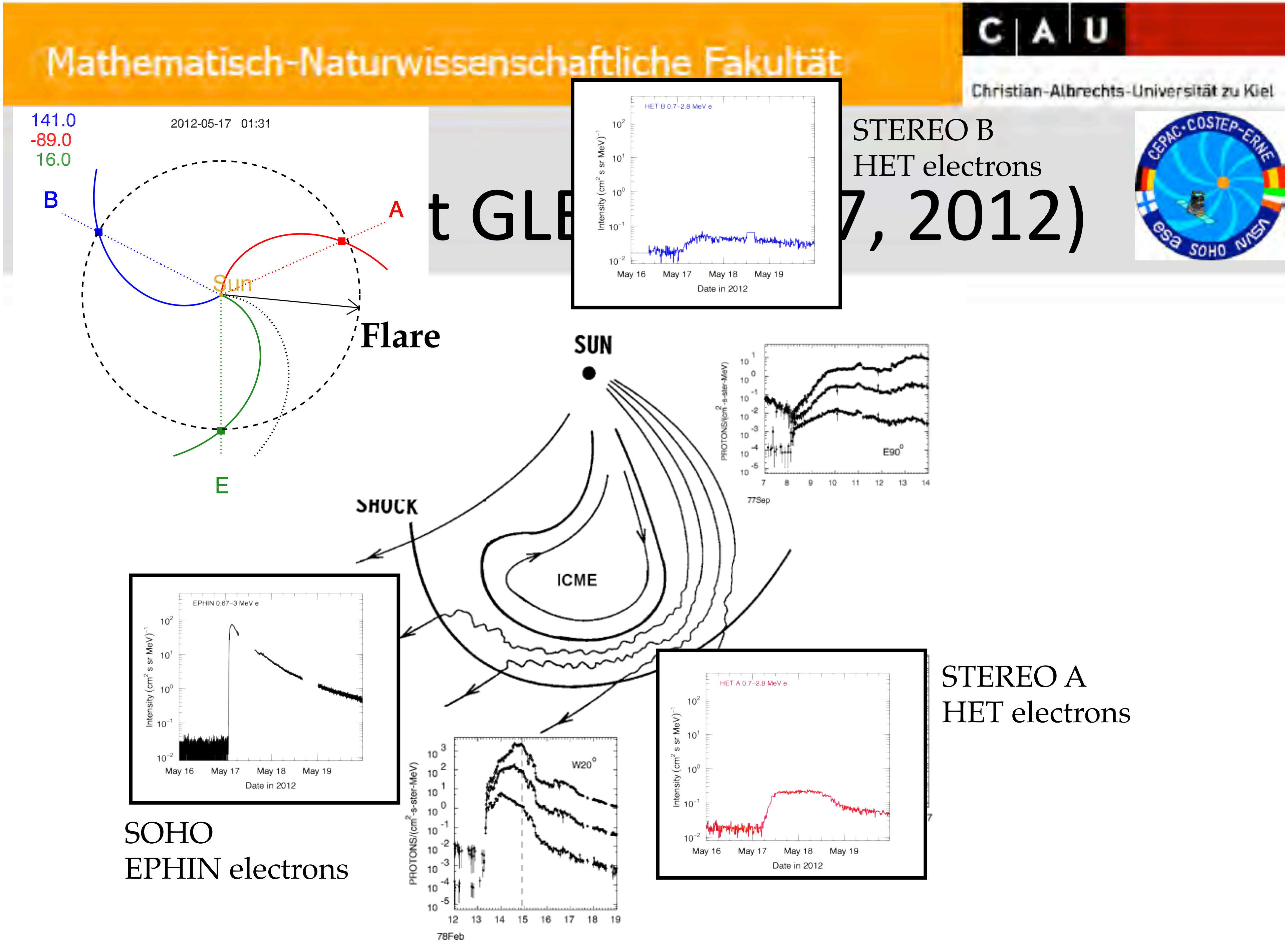
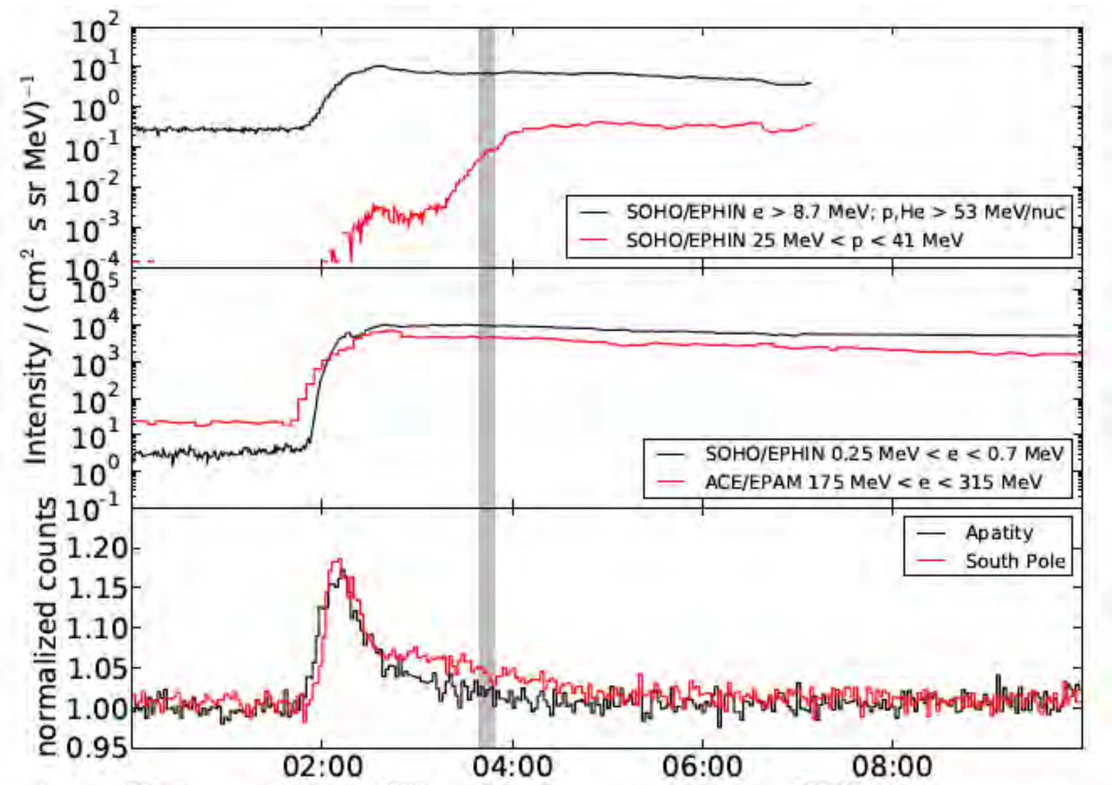
  - – Wide spread solar energetic particle events
- PAMELA/AMS and beyond



Mathematisch-Naturwissenschaftliche Fakultät
Christian-Albrechts-Universität zu Kiel
t GLE
7, 2012)
141.0
-89.0
16.0
2012-05-17 01:31
B
A
Sun
E
Flare
STEREO B
HET electrons
HET B 0.7–2.8 MeV e
Date in 2012
SUN
SHOCK
ICME
E90°
77Sep
W20°
78Feb
SOHO
EPHIN electrons
EPHIN 0.67–3 MeV e
STEREO A
HET electrons
HET A 0.7–2.8 MeV e
May 16
May 17
May 18
May 19

The May 17, 2012 GLE

- Can EPHIN measure the energy spectra of proton that causes the GLE?



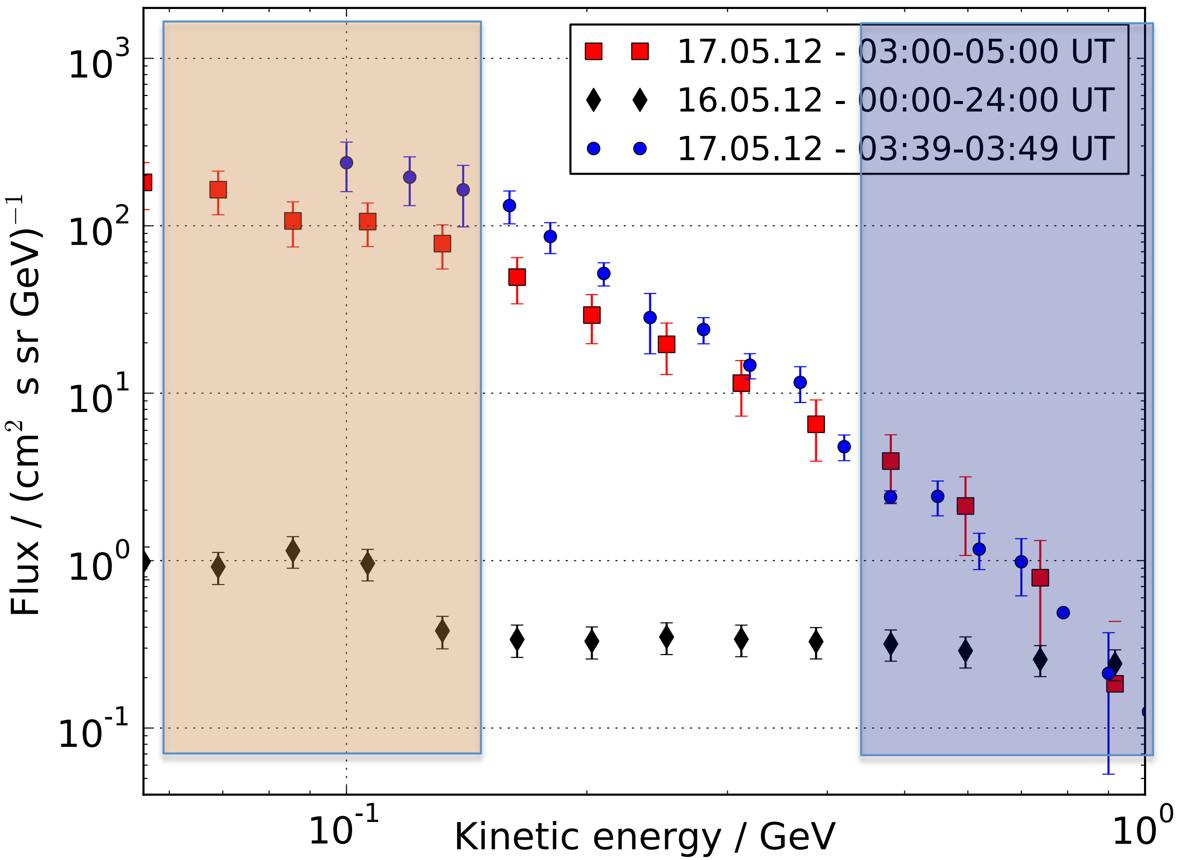
The May 17, 2012 GLE comparison with PAMELA

- Yes it can!. Statistics and energy resolution not as good as for Pamela or AMS

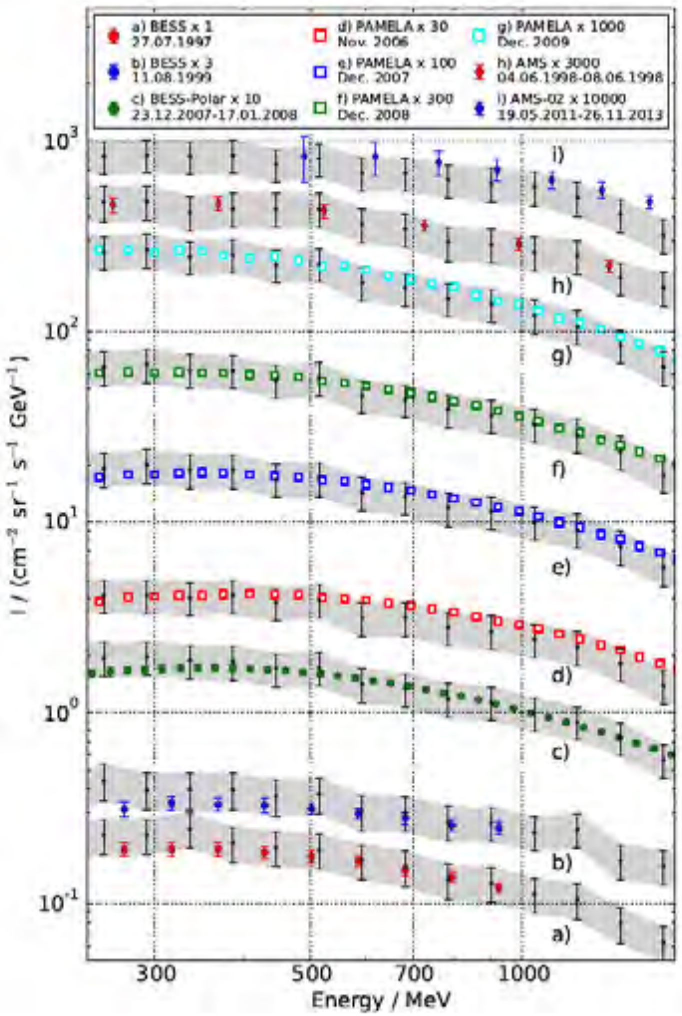
Pamela

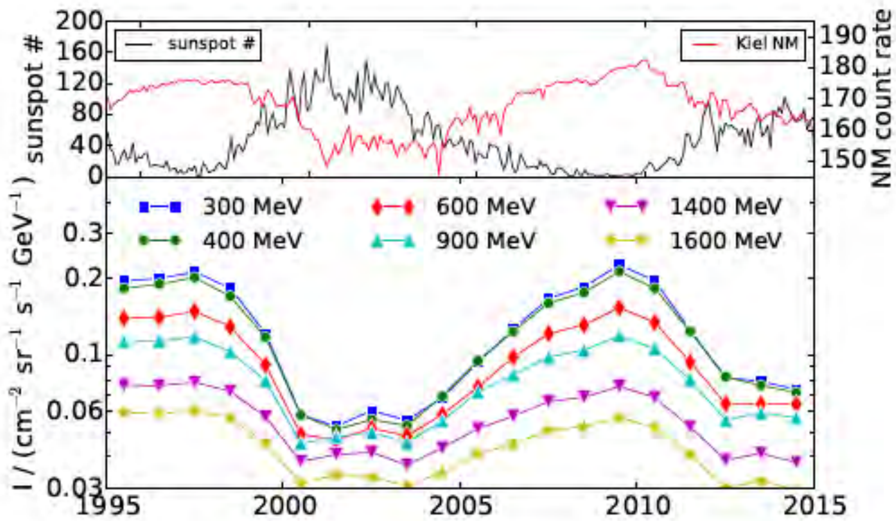
EPHIN

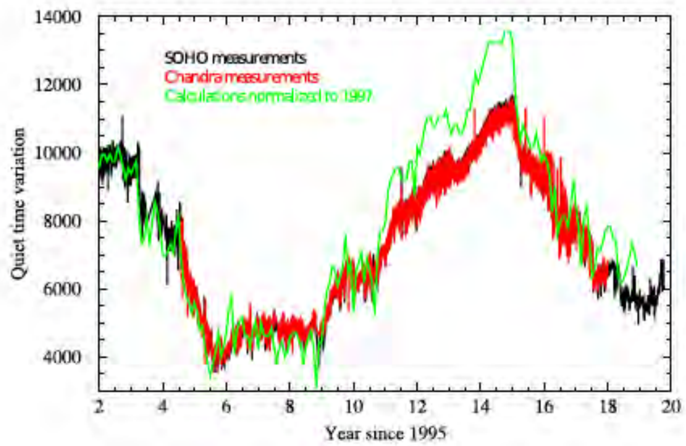
Pre-event spectrum



Solar modulation







Lessons learned

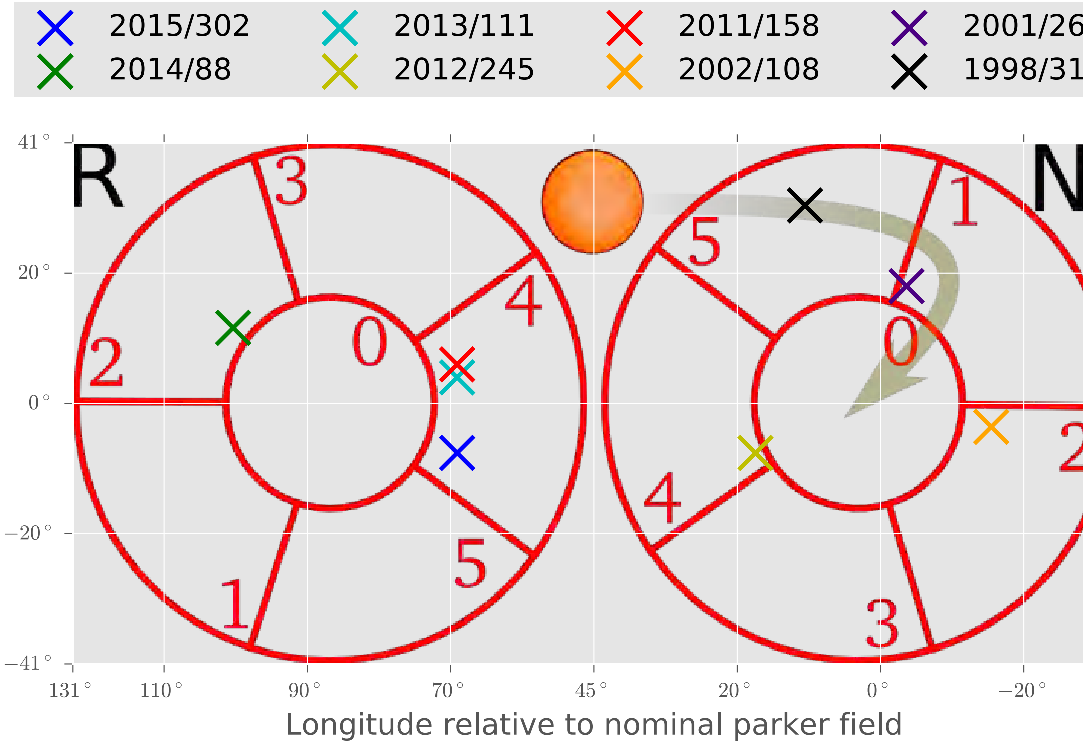
- EPHIN is an important contributor to understand the particle propagation in the inner heliosphere.
- High background reduction makes the instrument superior.
- MeV electrons intensities are an important tool for forecasting ion intensities.
- EPHIN will become an important baseline instrument as IMP8.

Lessons learned

- Missing flexibility of changing onboard data products:
  - Could have GCR spectra on the basis of 10 minute resolution back to 1995.
  - Chance to determine an anisotropy index on the same time resolution.
- Fixed detector threshold without the possibility to increase the threshold.

Lessons learned

- Mounting of the instrument along the nominal Parker spiral?
- Use a detector that gives the particle direction (see Helios E6 :-))
- Pitch angel coverage is important



Advice to the future

- Let scientists develop and employ particle instruments instead of giving it to industry.
- In order to understand acceleration, injection, and propagation build and install well focused instrumentation in and out off the ecliptic. I.e. follow up the philosophy of WIND.

ERNE
Energetic and Relativistic Nuclei and Electron experiment

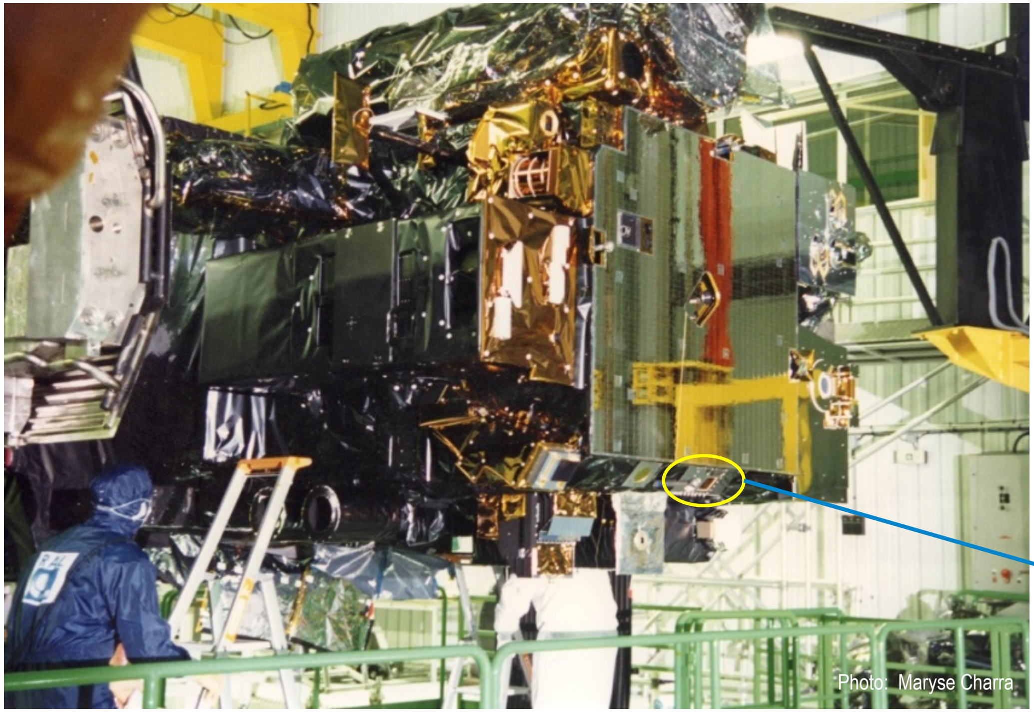
Science Highlights & Lessons Learned

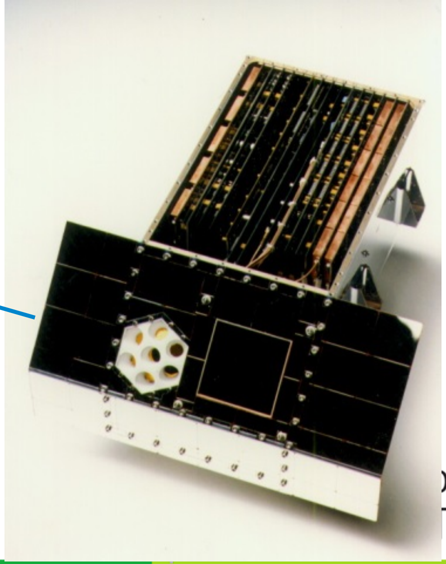
Eino Valtonen
University of Turku

Turun yliopisto
University of Turku

ERNE

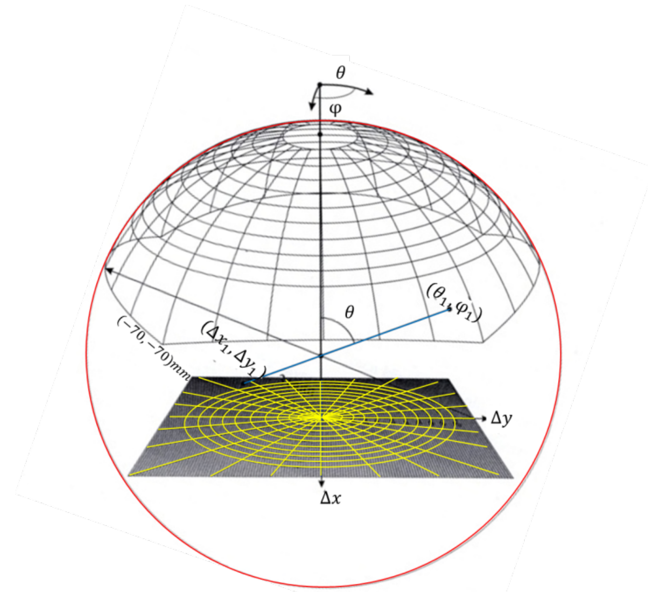
- Solar energetic particle measurements
  - Protons and helium 1.6 – 130 MeV/n
  - All ions C – Fe ~4 MeV/n - ~500 MeV/n
- Isotopes of He, C, O, Ne
- Directional intensities in a 120ºx120º view cone with a few degree precision

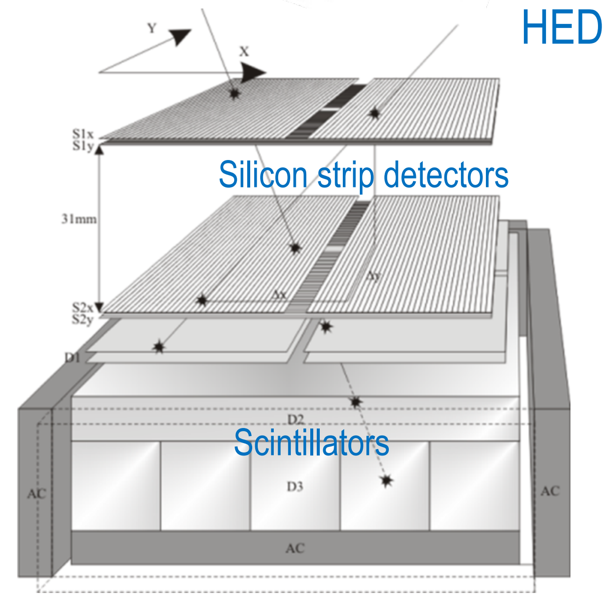


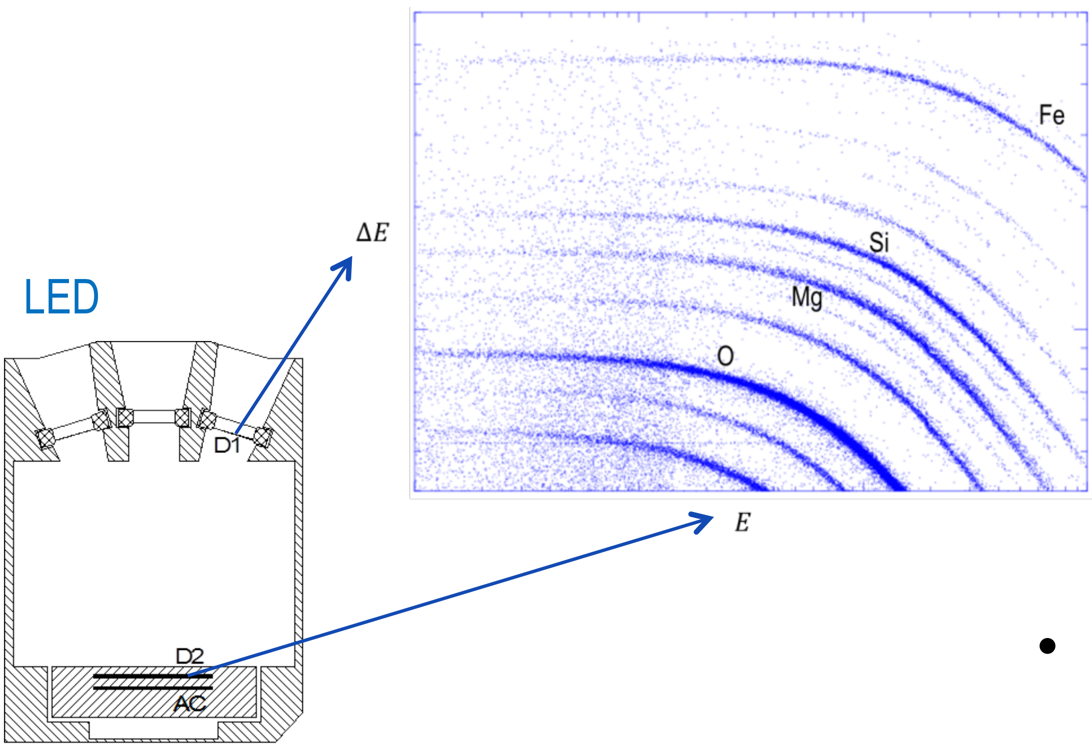


Measurement principles

- Energy measurement with silicon detectors and scintillators
- Particle identification with $\Delta E - E$ – measurements



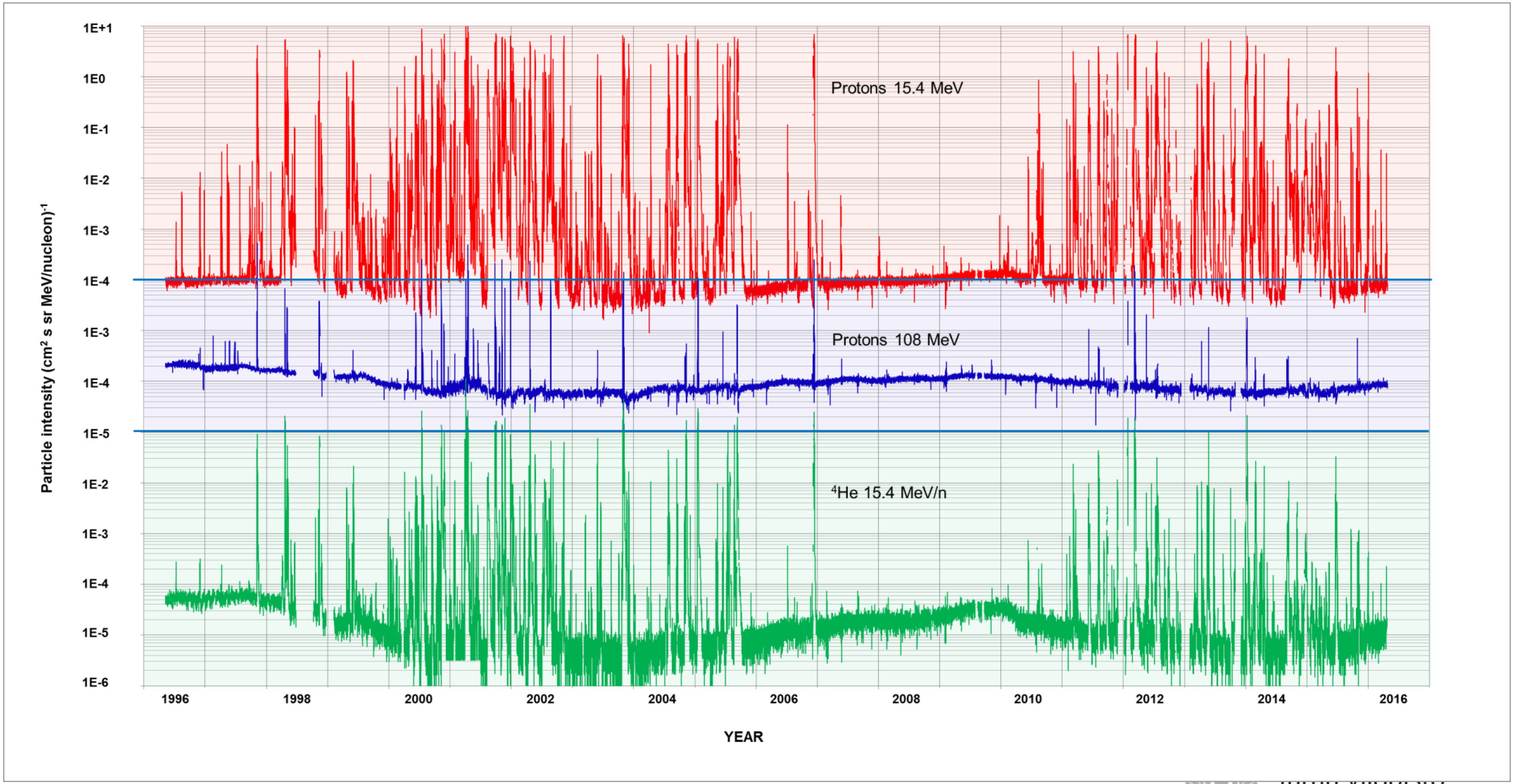




- Directional measurements with silicon strip detectors

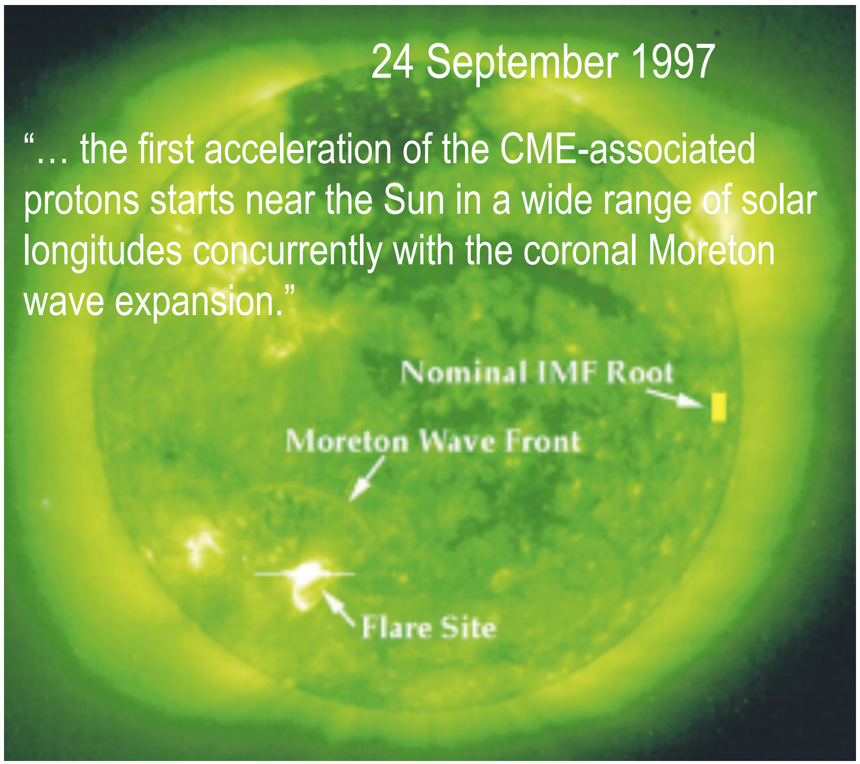
Highlights: Long time series

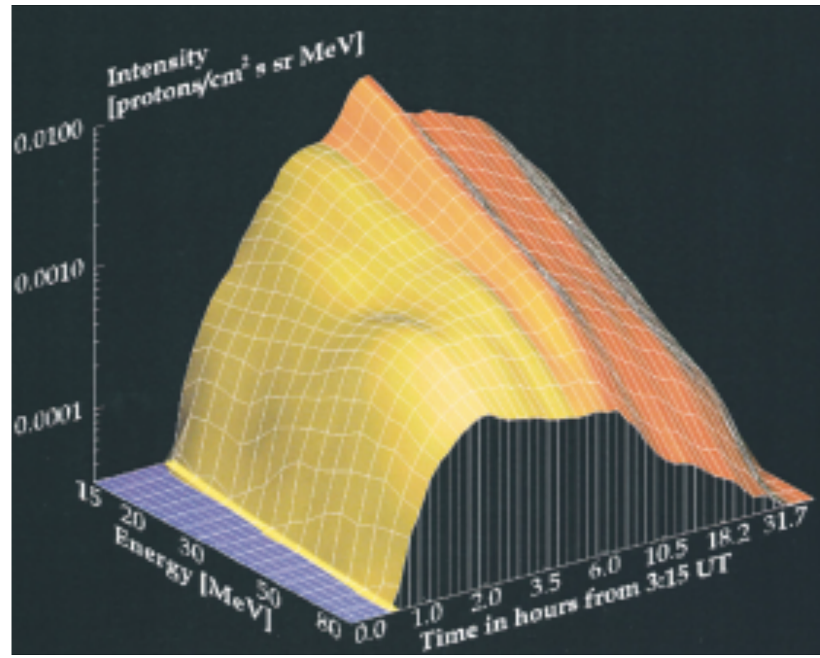
- Particle intensity time series covering two solar cycles



Highlights: Coronal Moreton wave and SEP events

- The role of coronal Moreton/EUV wave in proton injection into IP space
  - Eastern and solar backside events
  - Proton release concurrent with the EUV wave reaching the Earth-connecting IMF foot point region





Initially hard proton spectrum (CME lift-off) with subsequent softening (IP shock)

Torsti, J. et al., ApJ 510, 460, 1999

Torsti, J. et al., JGR 104, 9903, 1999

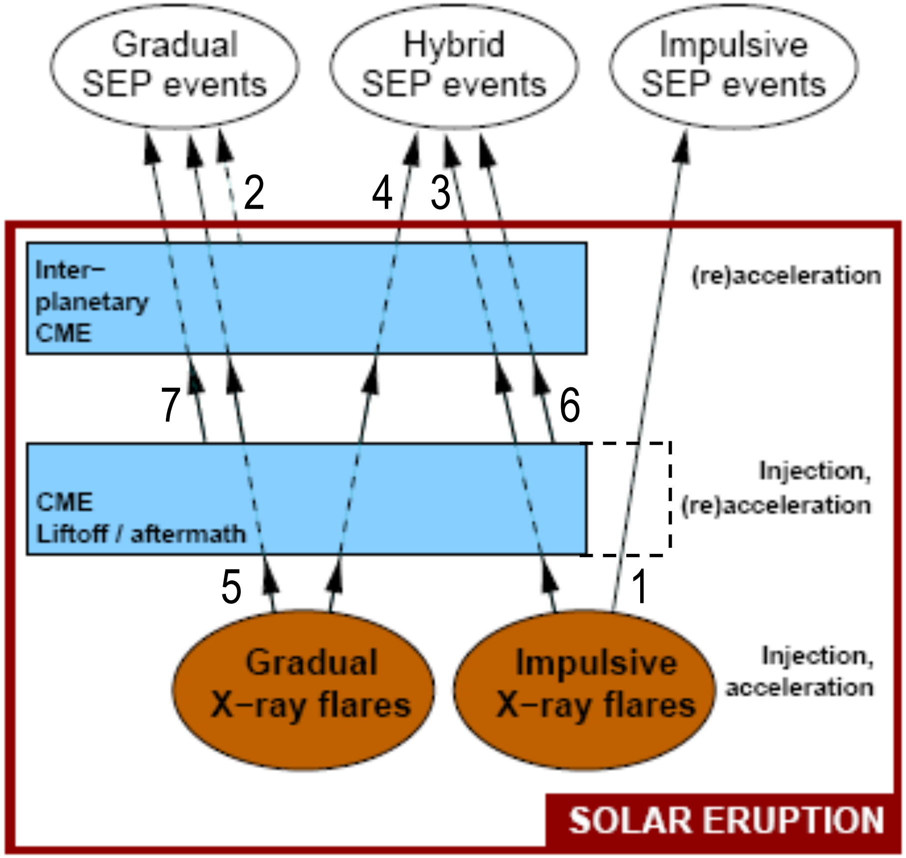
Turun yliopisto
University of Turku

Highlights: SEP production model

- Hybrid model of SEP production to complement the “bi-modal” “gradual-impulsive” paradigm

Acceleration initiated at different coronal sources in concert with CME development and culminates at interplanetary CME

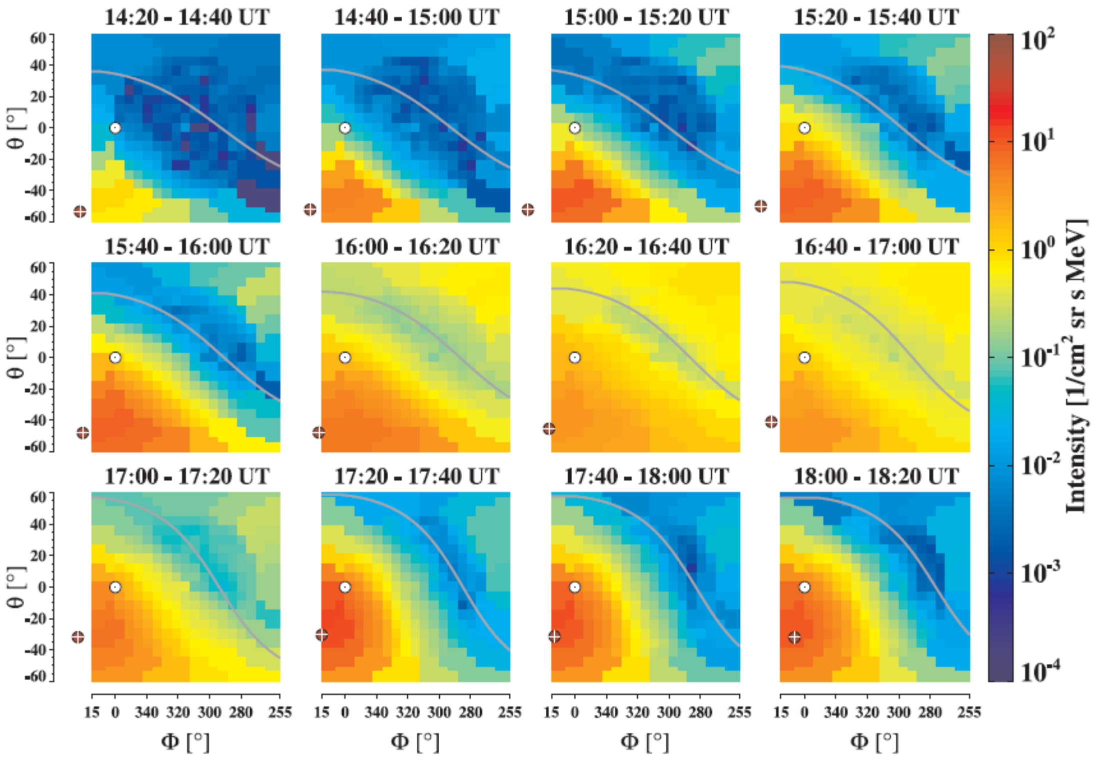
Kocharov, L. & Torsti, J.
Solar Physics 207, 149, 2002



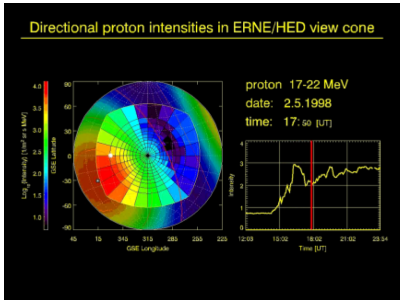
Highlights: Interplanetary highway for SEPs

- Measurement of precise angular distribution of protons injected into and propagating scatter-free inside a magnetic cloud

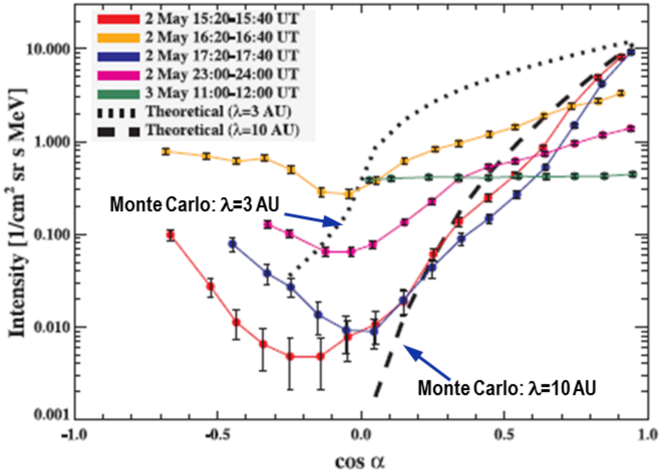
Directional intensity of 17-22 MeV protons 1998 May 2



Torsti, J. et al., ApJ 600, L83, 2004



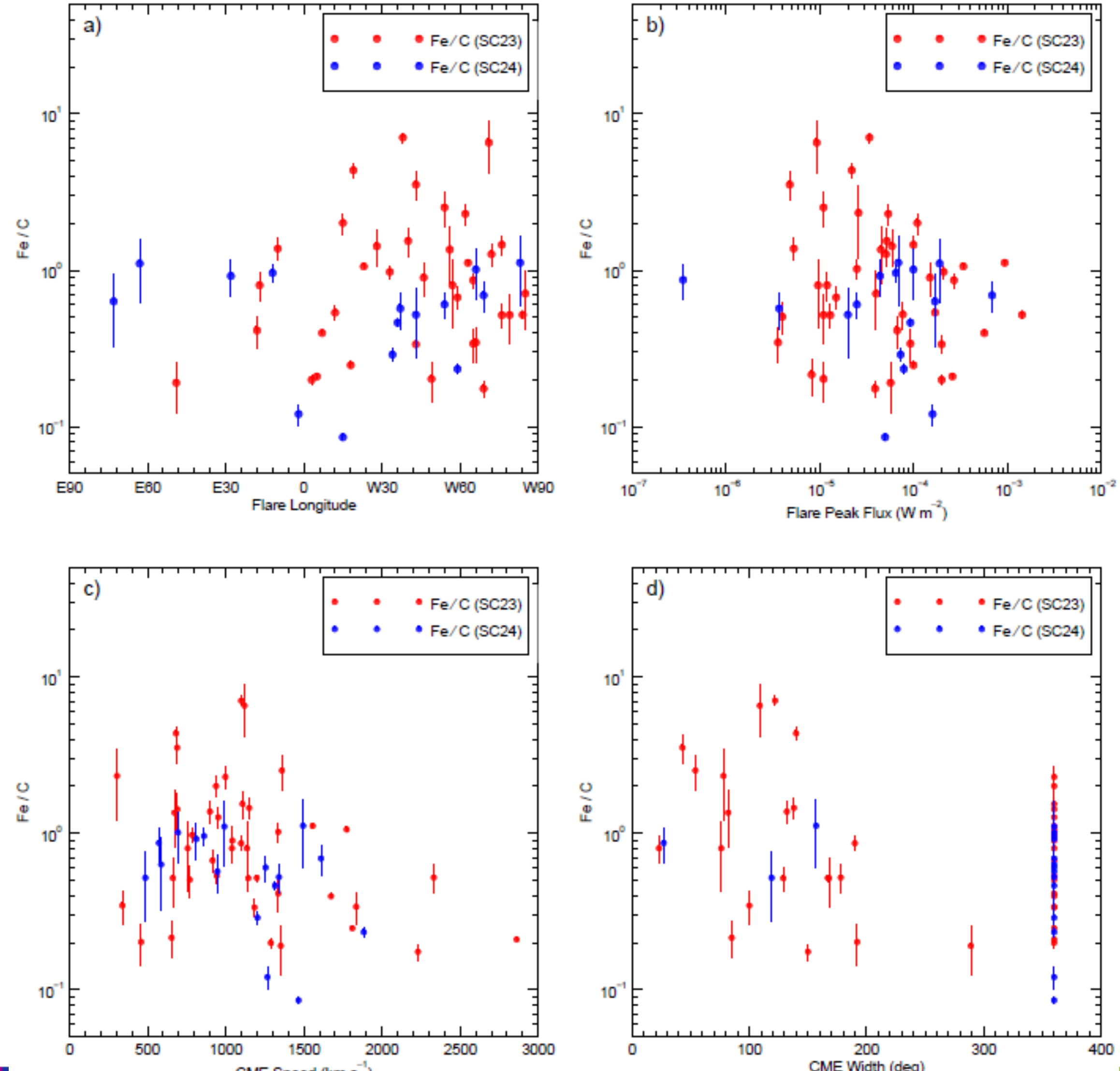
A magnetic cloud can provide an exceptionally fast propagation for SEPs with λ>10 AU



Highlights: SEP heavy ion abundances during two solar cycles

- Comparative study of SEP heavy ion compositions during SC23 & 24

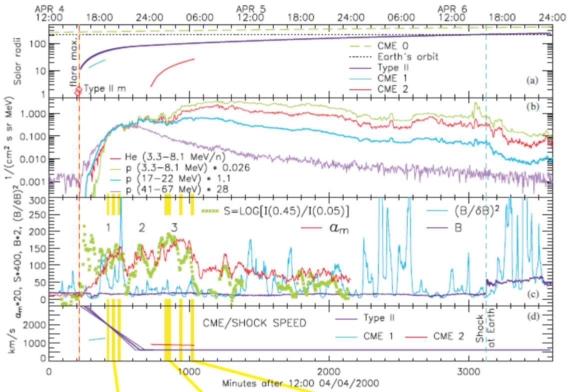
Raukunen, O. et al., A&A 589, A138, 2016



During SC24 events

- Lower overall heavy ion abundances
- Highest Fe/C ratios absent
- Flatter source longitude distribution
- Larger contribution from halo CMEs
  - Weaker solar magnetic field
- Lower acceleration efficiency
  - Reflects the reduced solar activity
- Differences in seed populations

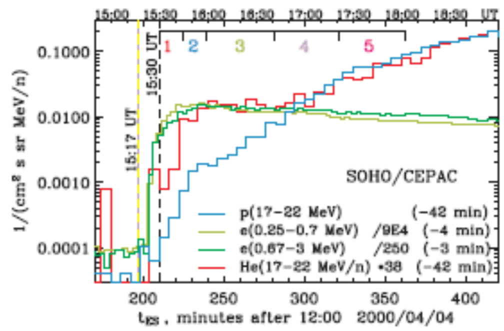
Highlights: SEP analysis in the overall context of solar and heliospheric environments



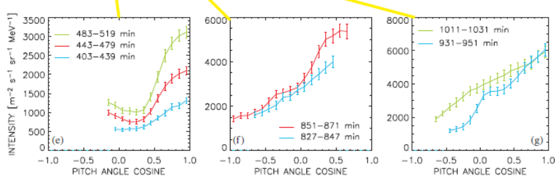
CME properties

Particle intensities

Magnetic field measurements



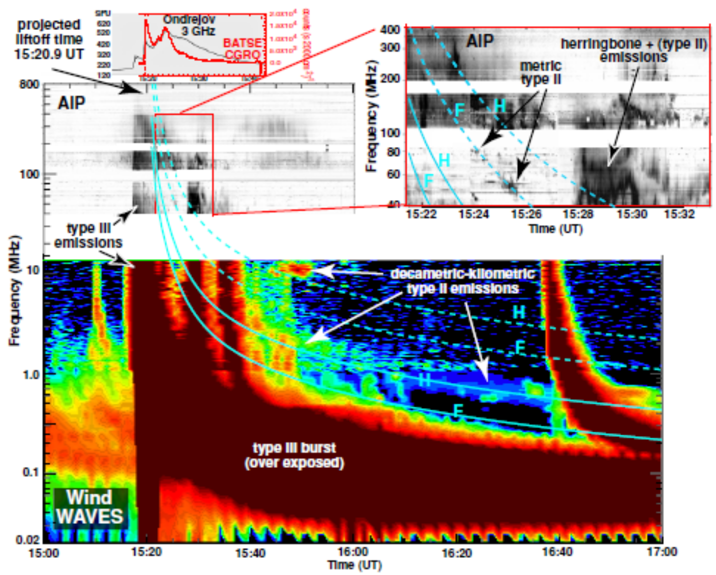
Kocharov, L. et al.
ApJ 700, L51, 2009
ApJ 725, 2262, 2010



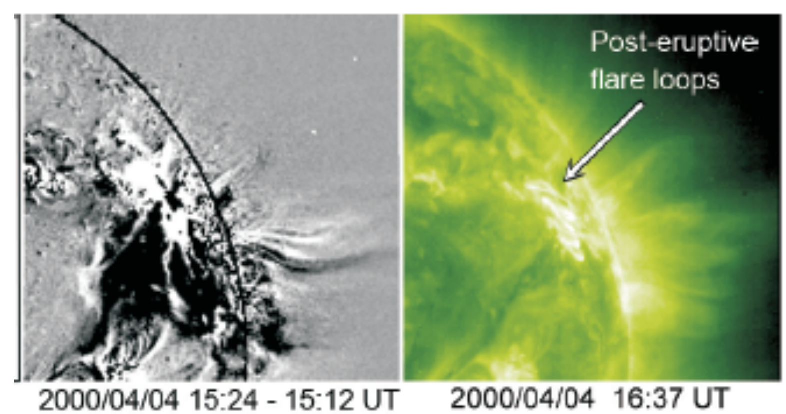
Particle pitch angle distributions

SEP event of April 4, 2000:
Seed particles from various sources and acceleration at coronal and IP shocks

Several different phases of SEP events

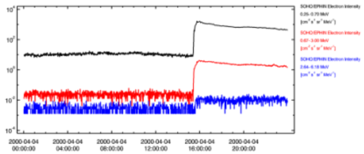


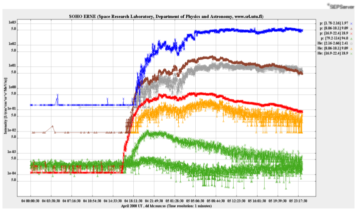
Electromagnetic observation

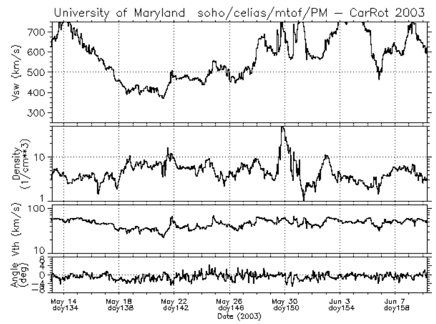


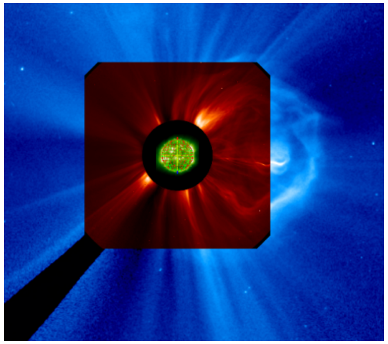
Lessons learned: synergy provided by SOHO is vital for SEP studies

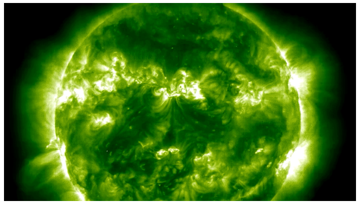
- Essential support for interpreting SEP observations from many SOHO instruments

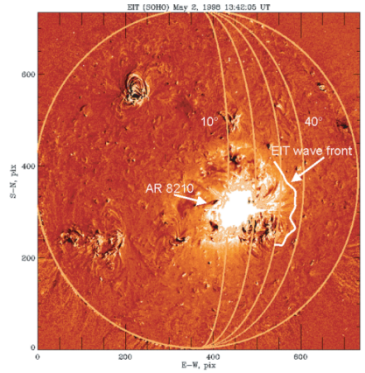


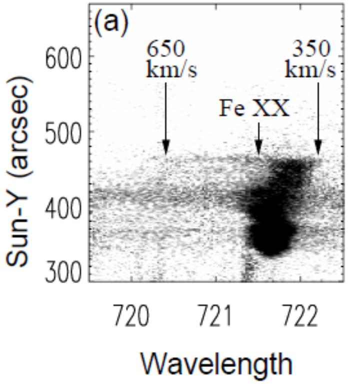




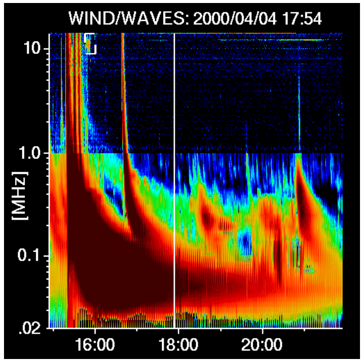


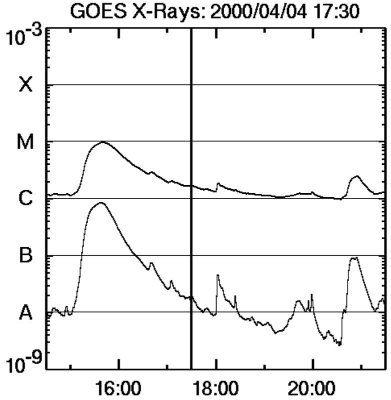


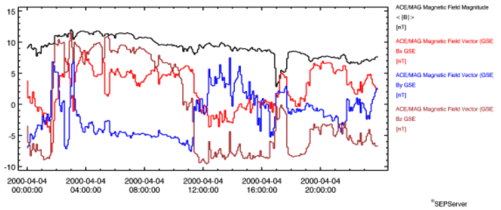


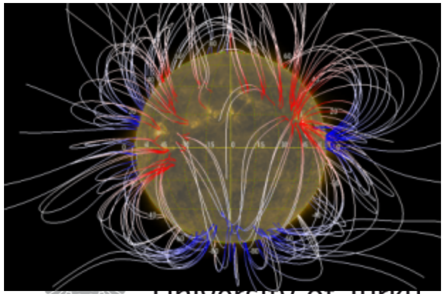


- … and from other observations









Lessons learned:

- Significant advantages of long mission times
  - High event statistics
  - Large amount of individual events with different characteristics
- Continuous SEP observations outside the magnetosphere important
  - Removing magnetospheric effects
  - 24-hour data coverage (more than) desirable
- Precise directional measurements of particle intensities essential
  - To better understand propagation effects
- Interpretation of particle measurements need local magnetic field data
  - Magnetometer an essential part of in-situ instrument package
- Squeezing the science telemetry rate of particle instruments to marginal does not necessarily ideally support the mission goals

Annex 6

Signed Copy of ESA Bulletin 102 Article

“Four Years of SOHO Discoveries – Some Highlights”

Orsay 2016 May 12

esa

Four Years of SOHO Discoveries – Some Highlights

B. Fleck, P. Brekke, S. Haugan & L. Sanchez Duarte
Solar System Division, ESA Space Science Department, NASA/GSFC, Greenbelt, Maryland, USA

V. Domingo
Department of Astronomy and Meteorology, University of Barcelona, Spain

J.B. Gurman & A.I. Poland
Laboratory for Astronomy and Solar Physics, NASA/GSFC, Greenbelt, Maryland, USA

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No. 102, may 2000

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