Dual instrument for flare and CME onset observations

Double Solar Coronagraph with Solar Chromospheric Detector and Coronal Multi-channel Polarimeter at Lomnický štít Observatory

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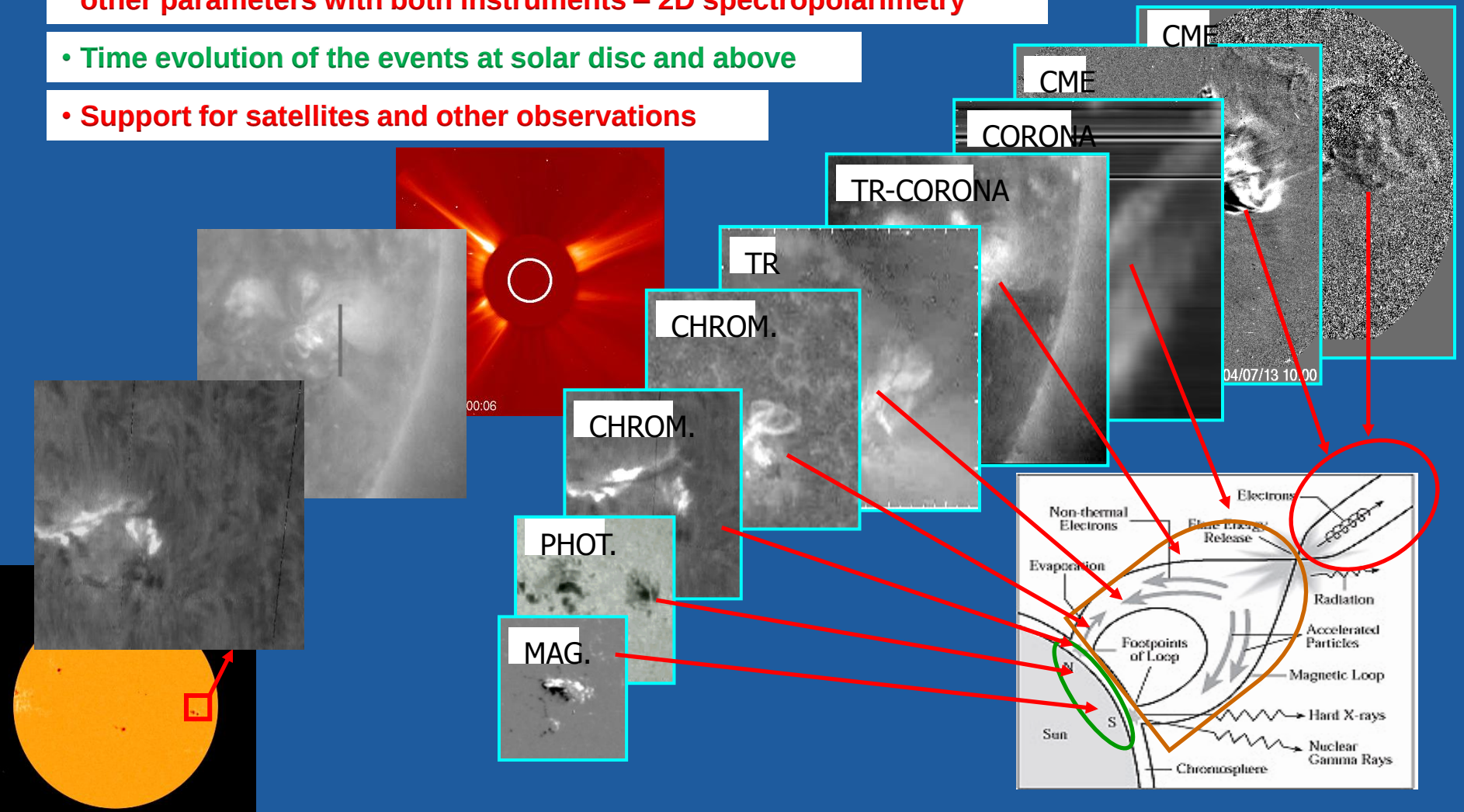
IAUS 320 - Solar and Stellar Flares and Their Effects on Planets, August 10-14, 2015, Honolulu, Hawaii, USA

Presentation outline:

- Scientific background
- Observatory and Double Solar Coronagraph
- Postfocus instrument: Coronal Multi-channel Polarimeter
- Postfocus instrument: Solar Chromospheric Detector
- An example and near future plans

Scientific background

- Observations of onset and development of active events in the solar chromosphere and corona
- Measutement of plasma parameters of flares, CMEs and eruptive prominences
- Simultaneous measurements of velocity and full magnetic fields and other parameters with both instruments – 2D spectropolarimetry
- Time evolution of the events at solar disc and above
- Support for satellites and other observations



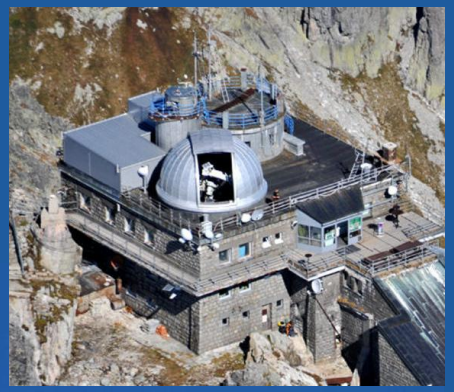
Observatory and Double Solar Coronagraph

Lomnický štít Observatory

- 2633 m above see level
- High Tatras mountain in the North Slovakia
- One of a few sites still performing routine ground-based coronal observations
- Astroclimate:

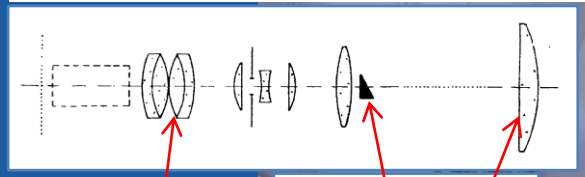
  120 days/year, sunshine, observations of prominences

  70 days/year, observations of emission corona



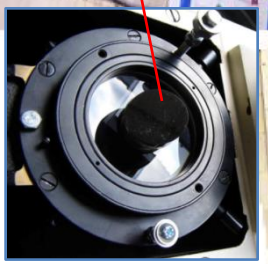
Observatory and Double Solar Coronagraph

Zeiss Double Solar Coronagraph



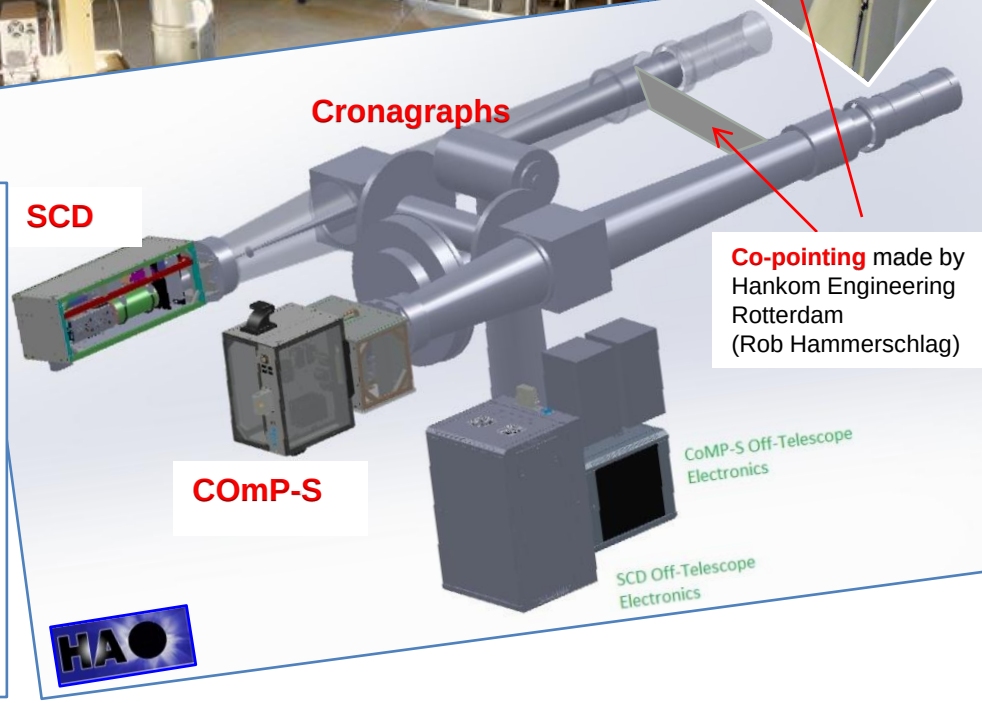
imaging 100-mm objective

20 cm single-lens objective, f = 3000 mm



Lyot diaphragm in the field lens

Cronagraphs



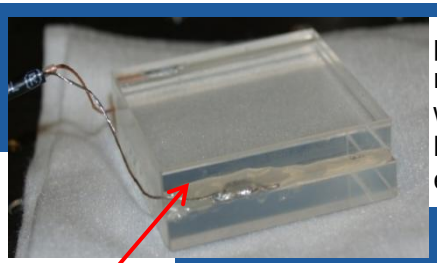
Co-pointing made by Hankom Engineering Rotterdam (Rob Hammerschlag)

- two Zeiss 200/3000 coronagraphs installed in 1961 and 1970
- optical twins, co-pointing precision of 2 arcsec
- diameter of the solar image in the focal plane: 4 cm
- field-of-view: 1.02 - 1.84 of the solar radius
- diffraction limited from 530 nm to 1100 nm
- focusing by moving the objective lens along the optical axis ~80mm

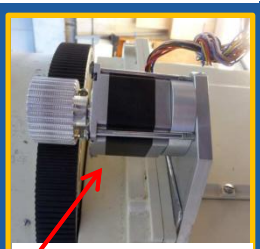
Postfocus instrument
Coronal Multi-channel Polarimeter CoMP-S (new visible + infrared)

Main features of CoMP-S

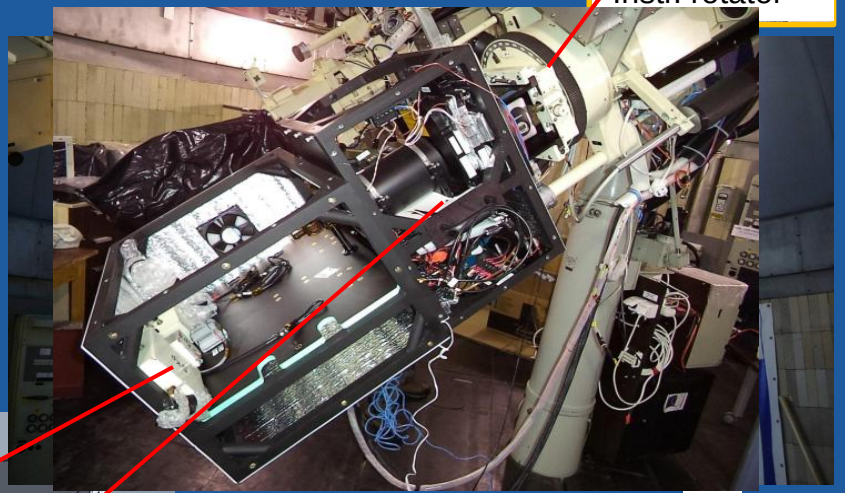
- operating spectral range: 500 – 1100 nm
- field of view: 14 arcmin × 11 arcmin
- 4-stage tunable Lyot filter with polarimeter (two ferro-liquid crystal polarizers)
- sequential measurement of several VIS and near-IR lines
- deliverables: 2D full Stokes I, Q, U, V
- actual observational output: the linear combinations of
  $I \pm Q$ $I \pm U$ $I \pm V$
- then, e.g., Stokes I reconstructed from the sums



polychromatic modulators FLCs, wide wavelength range, high polarimetric efficiency

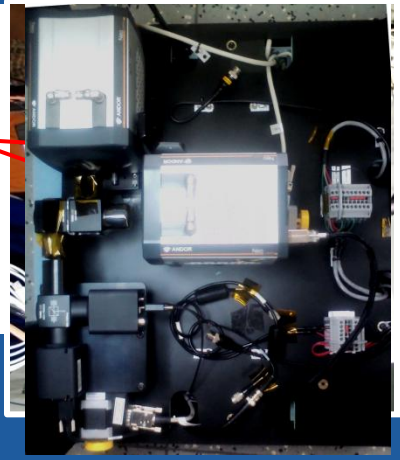


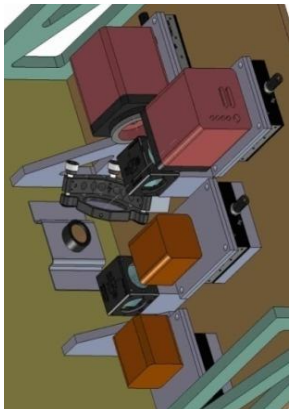
Instr. rotator



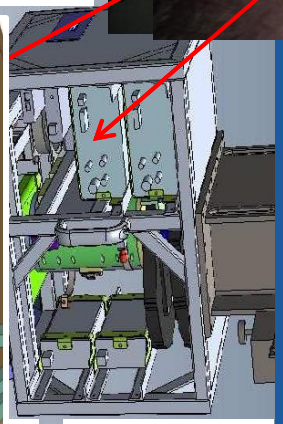
Starting concept VIS cameras only

Two PCO edge CMOS cameras

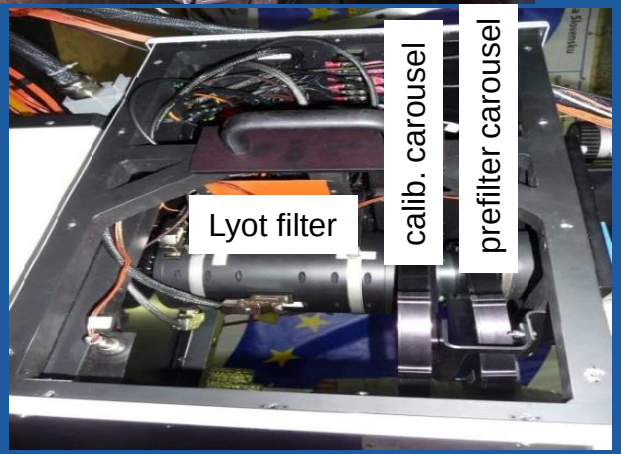




camera module



filter module



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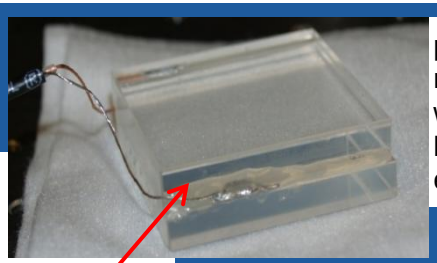

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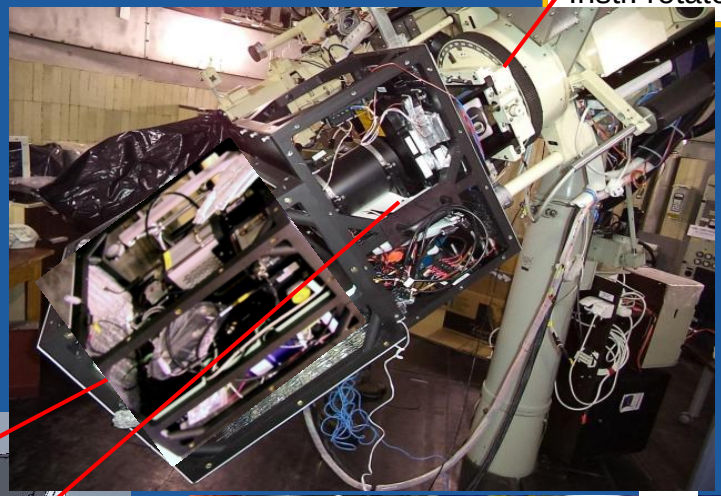
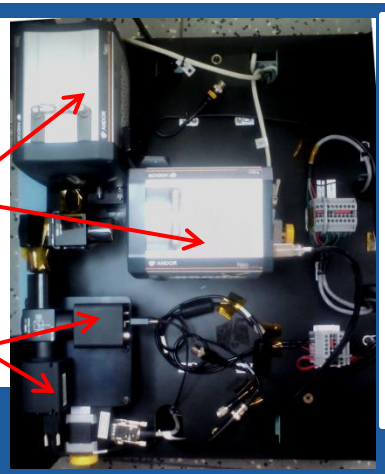
Instr. rotator



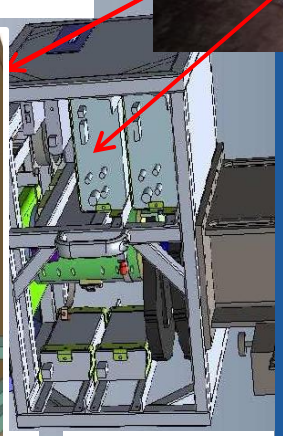
New concept VIS + IR cameras

VIS- Andor Neo sCMOS

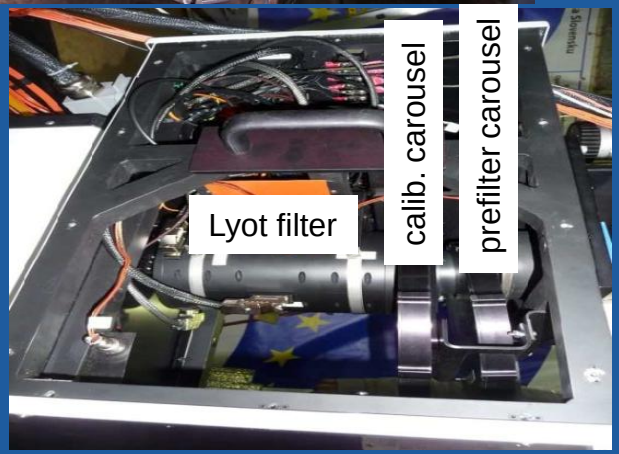
IR- Goodrich GA1280J



camera module

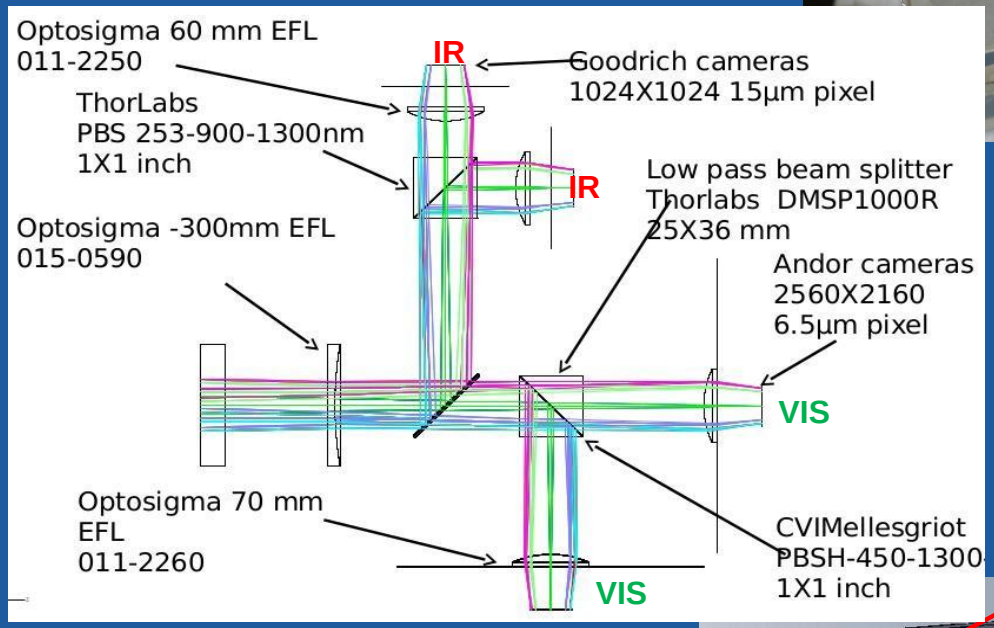


filter module



Postfocus instrument
Coronal Multi-channel Polarimeter CoMP-S (new visible + infrared)

Camera modul scheme



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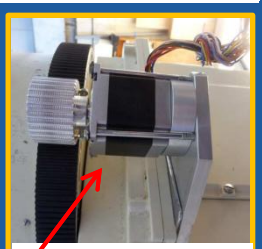
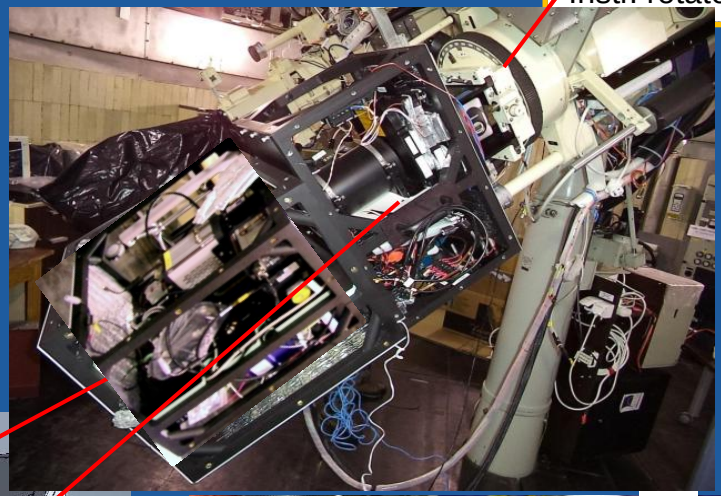


Instr. rotator



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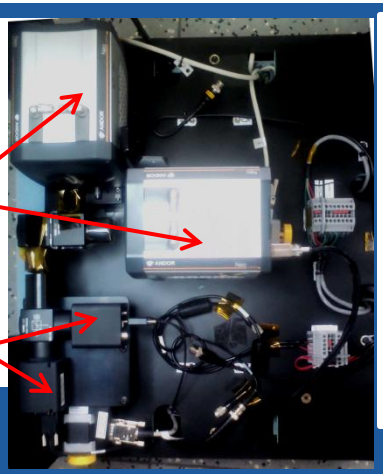
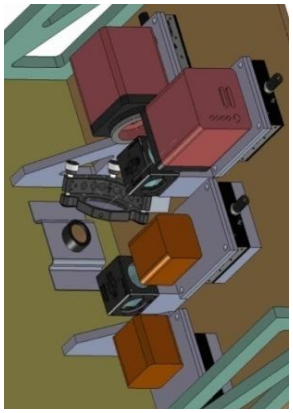
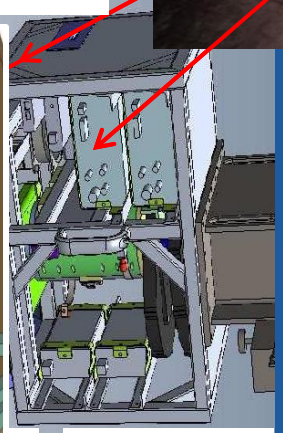
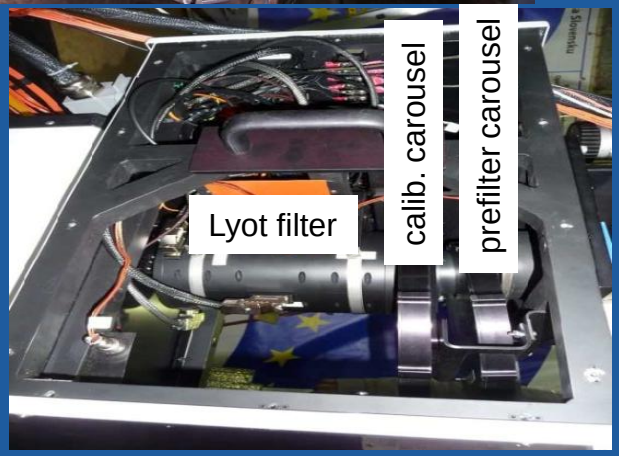




camera module



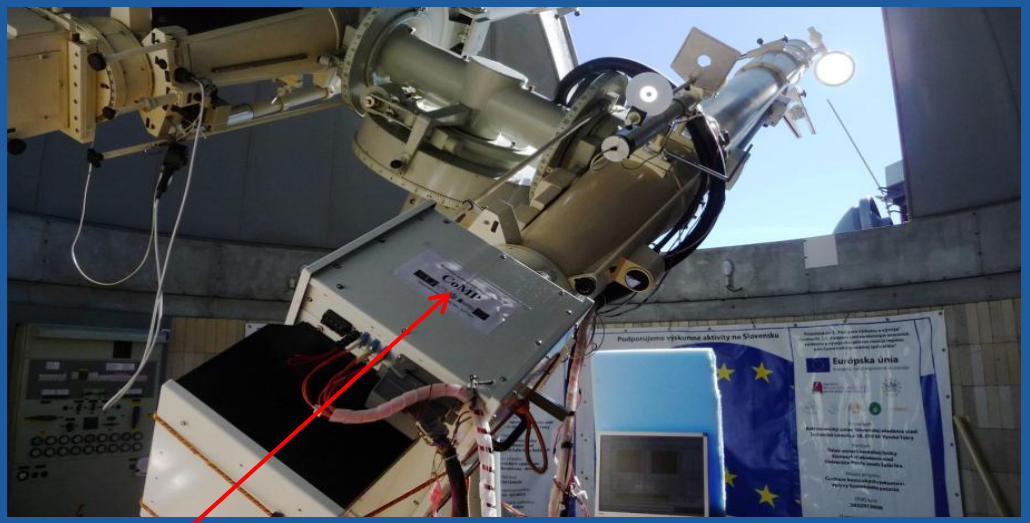
filter module



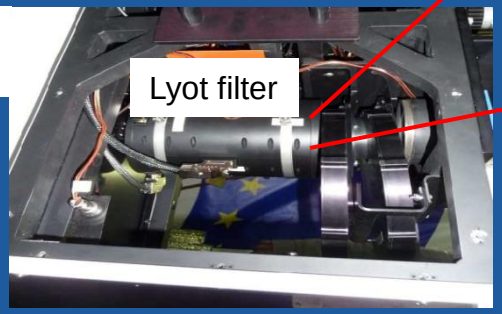
Postfocus instrument
Coronal Multi-channel Polarimeter CoMP-S (new visible + infrared)

Selected emission lines
given by prefilters available in the prefilter carrousel

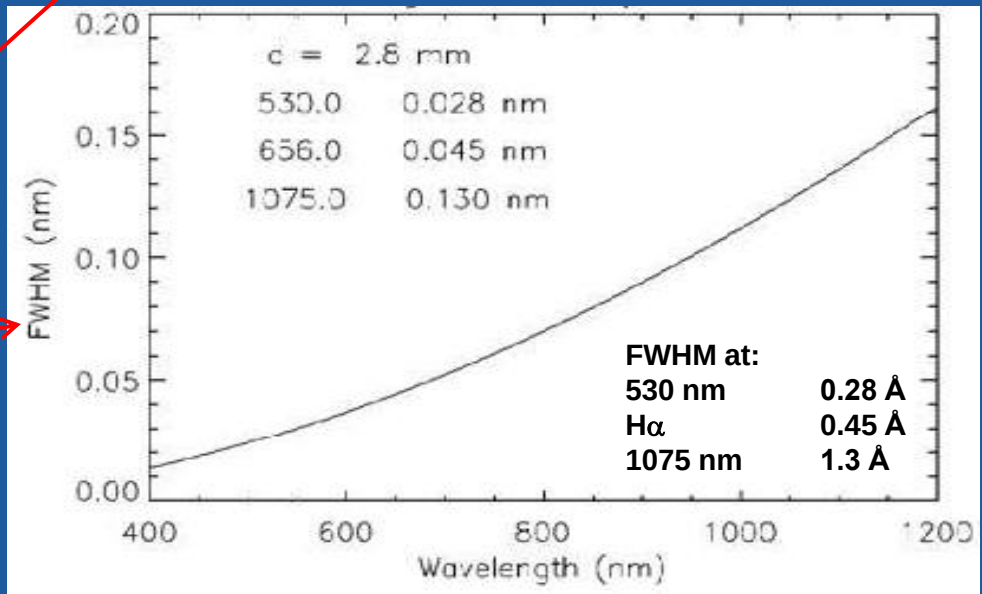
prominences	**He I 587.6 nm D_3**
	Hα 656.3 nm
	Ca II 854.2 nm
	He I 1083.0 nm
corona	**Fe XIV 530.3 nm**
	Ca XV 569.5 nm
	Fe X 637.5 nm
	Fe XI 789.2 nm
	Fe XIII 1074.7 nm
	Fe XIII 1079.8 nm



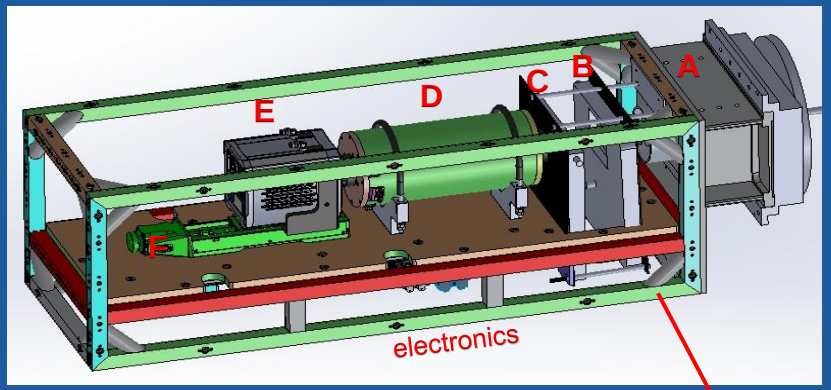
filter module



FWHM of the Lyot filter



Postfocus instrument (based on CoMP-S concept)
Solar Chromospheric Detector (ON and OFF coronagraph version)

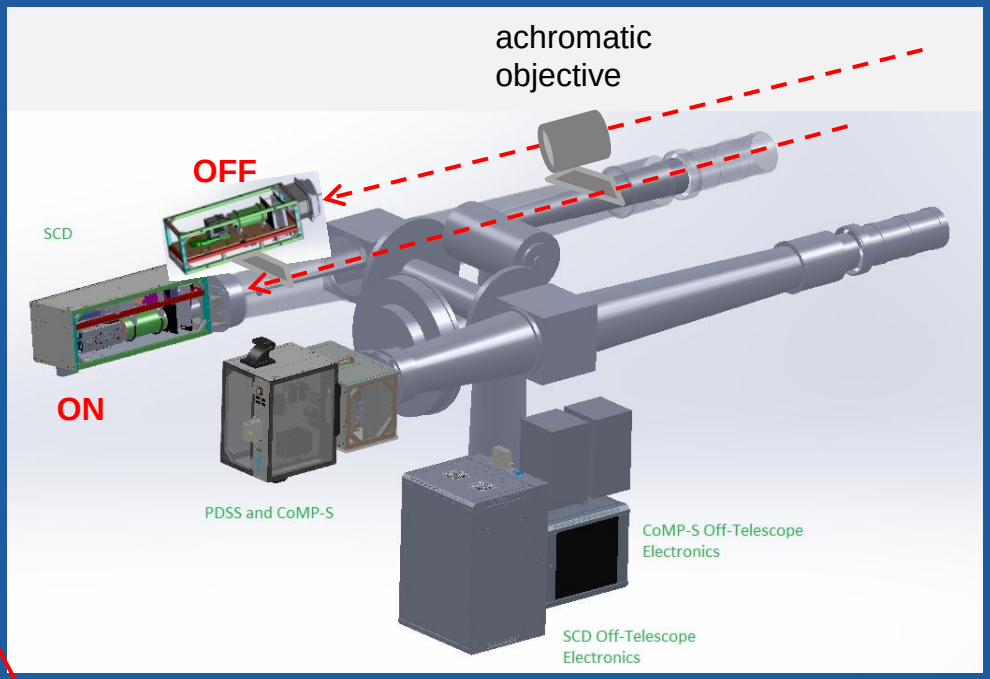


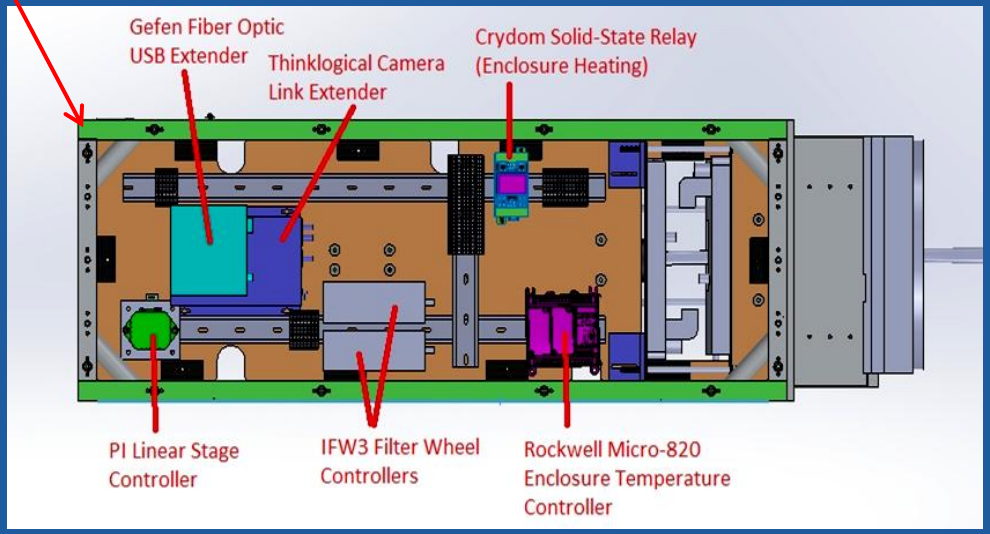
SCD components and parameters

A: mechanical interface,
B: carousel prefilter: **lines selection in 500-1100 nm**, **chromospheric:** He I 587.6 nm, Na I 589.6 nm, H I 656.3 nm, Ca II 849.8 nm, Ca II 854.2 nm, Ca II 866.2, He I 1083.0 nm
photospheric Fe I 557.6 nm, Fe I 630.15 nm, Fe I 630.25 nm
C: calibration carousel
D: 5-stage tunable Lyot filter with polarimeter (two ferro-liquid crystal polarizers) FWHM from **0,012 (550 nm)** to **0,046 nm (1100 nm).**
E: Camera: **Andor Neo sCMOS**
F: pointing device for camera

Electronics – bottom
Dimensions height, length, width: 30x110x40 cm

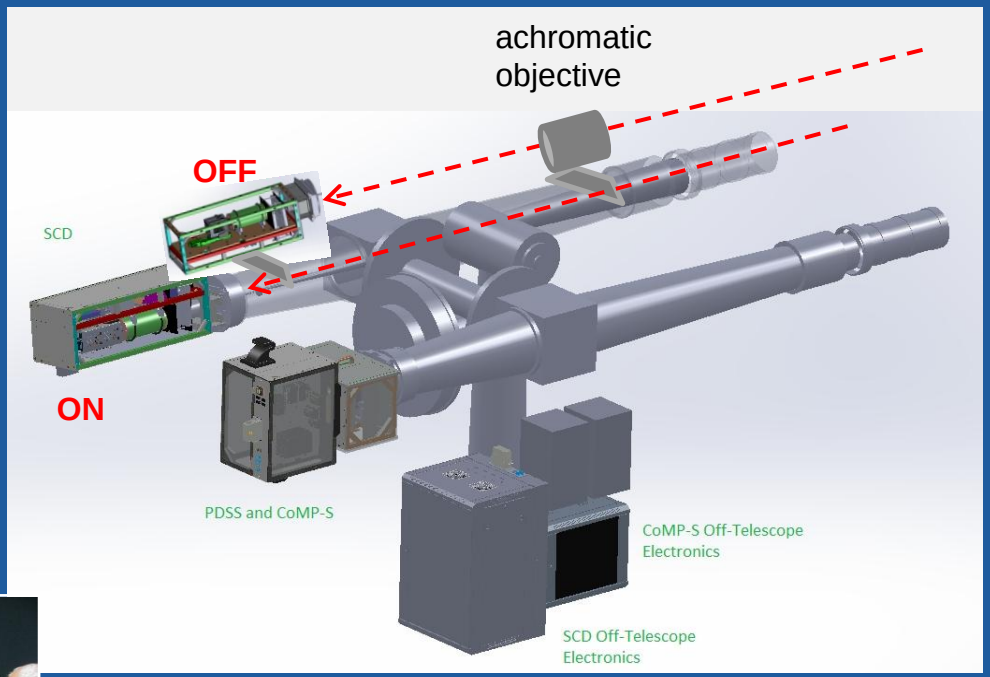
The same for „Coronagraph OFF“ version with achromatic objective.

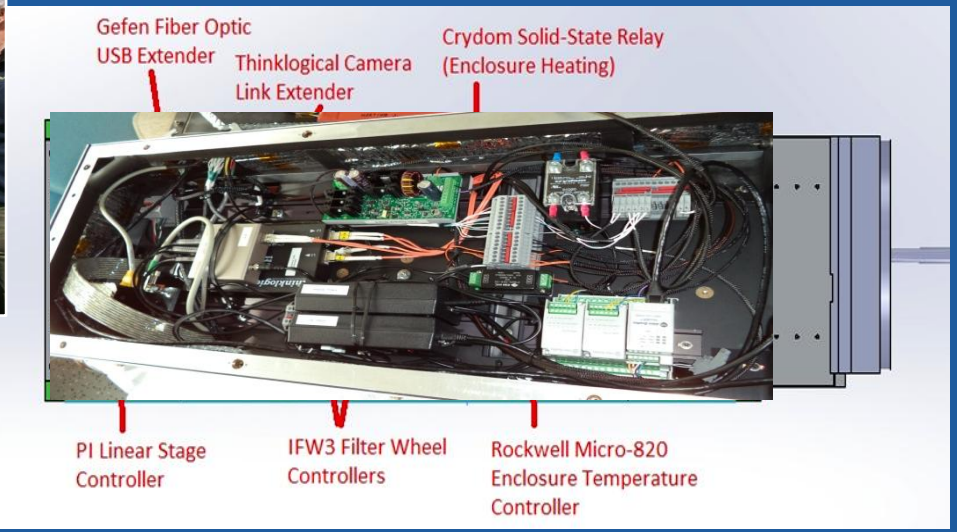




Postfocus instrument (based on CoMP-S concept)
Solar Chromospheric Detector (ON and OFF coronagraph version)

SCD is going to be assembled in September at Lomnický štít Observatory by colleagues from High Altitude Observatory



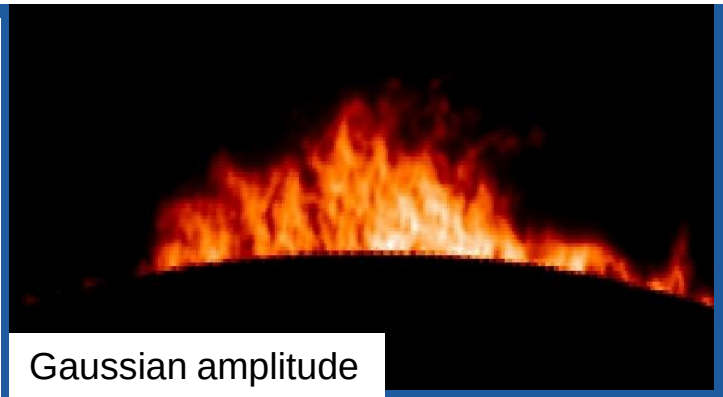


An example and near future plans

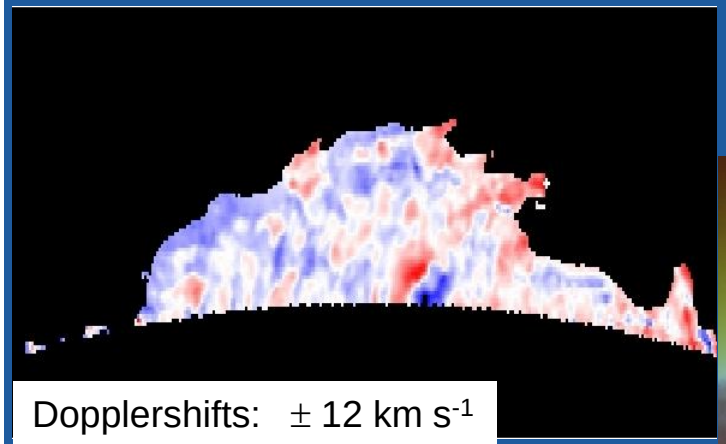
Data taken during HOP 186 „Mass loading of quiescent prominences from multi-wavelength observations“

- a quiescent prominence on 20 October 2012

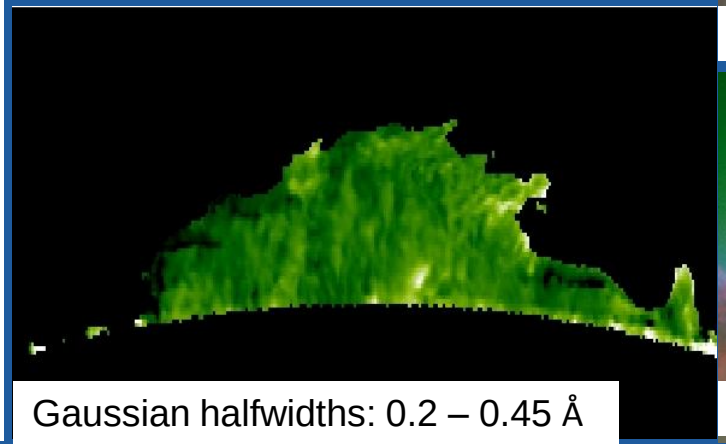
  at 07:09 UT
- Hα profile scanned in 11 wavelength settings, only Stokes I
- total scan time: 20.75 s
- wavelength steps core: ± 0.1 Å, wings: ± 0.2 Å
- FWHM of filter: 0.45 Å
- post-facto 4 × 4 pixel binning, final sampling: 1.3 arcsec/px
- Gaussian fitting of 11 samples of Hα profiles
- derived parameters:
  - Gaussian amplitude A
  - Dopplershift of λ_C
  - Gaussian halfwidth w



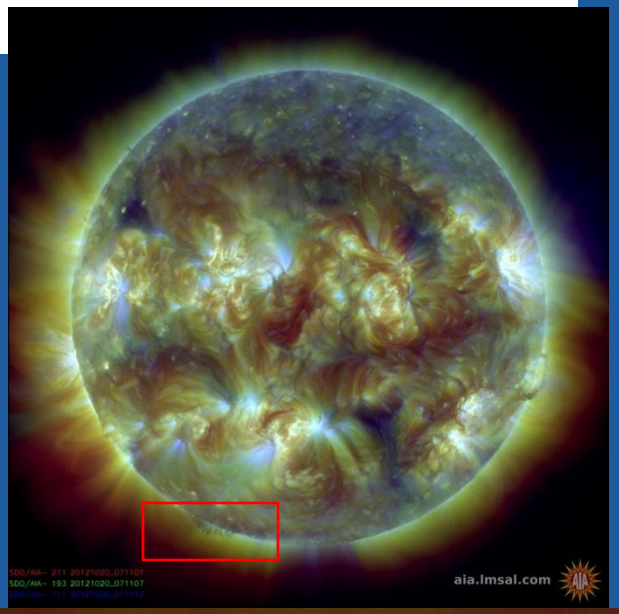
Gaussian amplitude

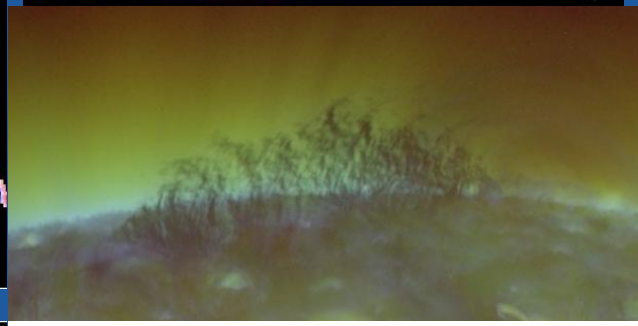


Dopplershifts: ± 12 km s^{-1}

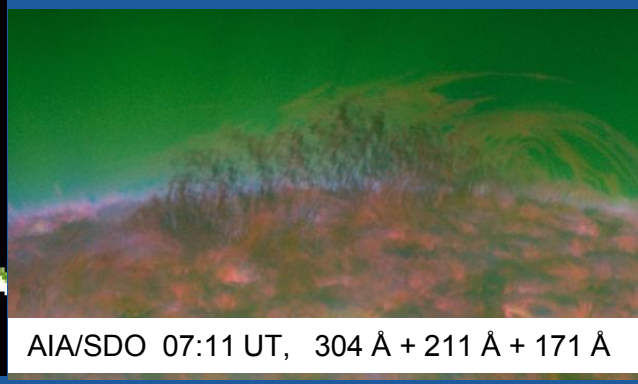


Gaussian halfwidths: 0.2 – 0.45 Å





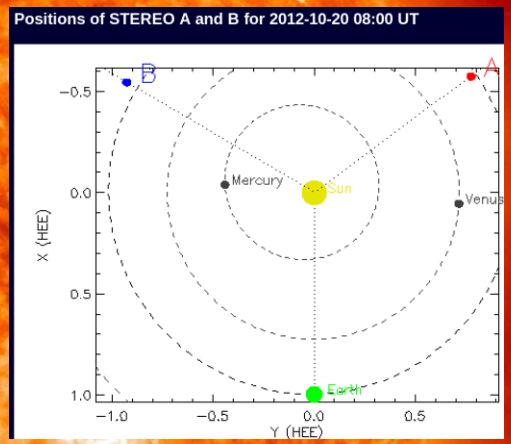
AIA/SDO 07:11 UT, 211 Å + 193 Å + 171 Å



AIA/SDO 07:11 UT, 304 Å + 211 Å + 171 Å

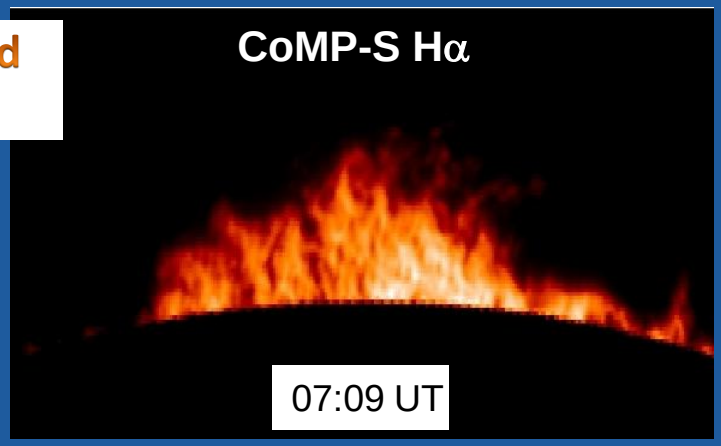
Example of observation and synergy with satellites

STEREO Behind EUVI 304 Å

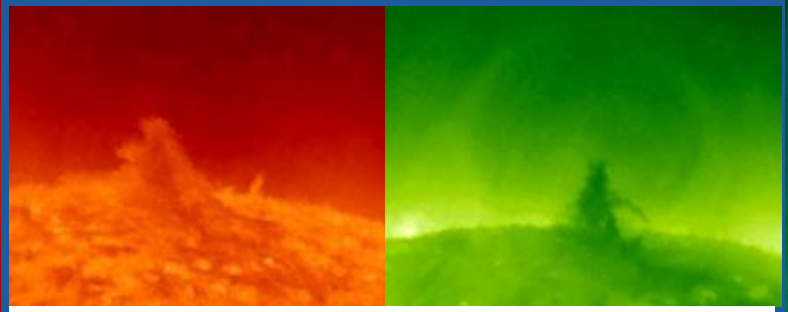


07:07 UT

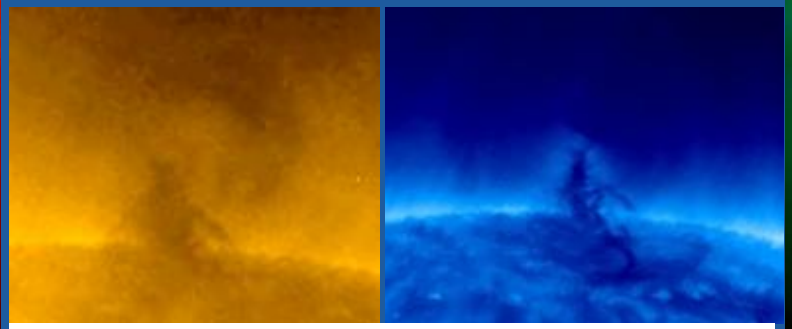
CoMP-S Hα



07:09 UT

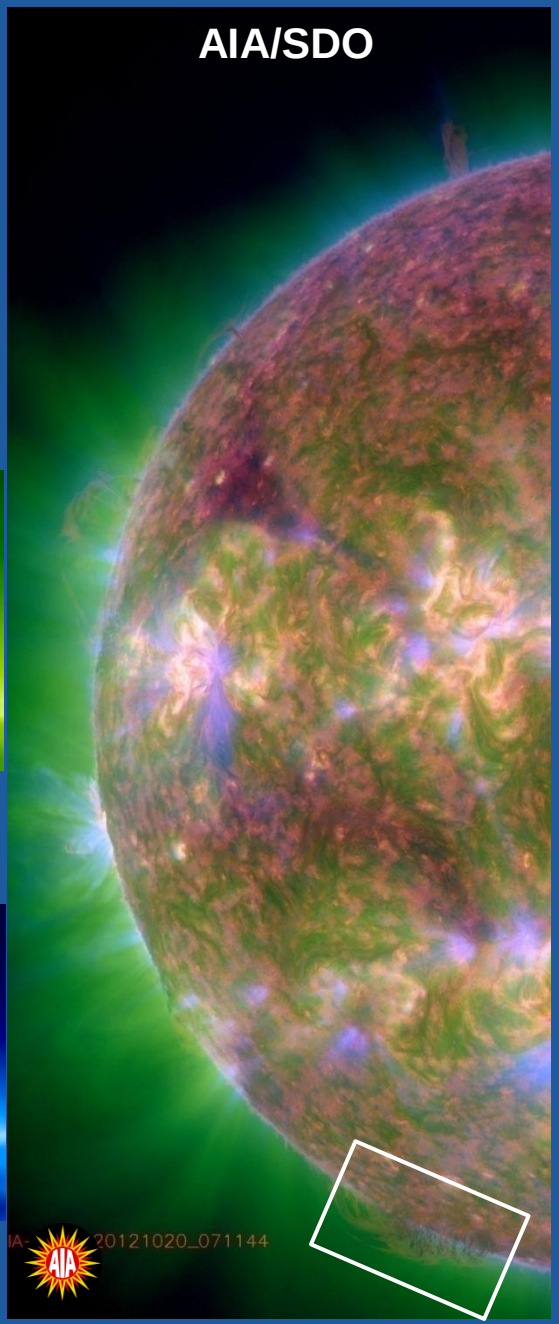


304 Å, 07:07 UT 195 Å, 07:06 UT



284 Å, 06:17 UT 171 Å, 06:14 UT

AIA/SDO



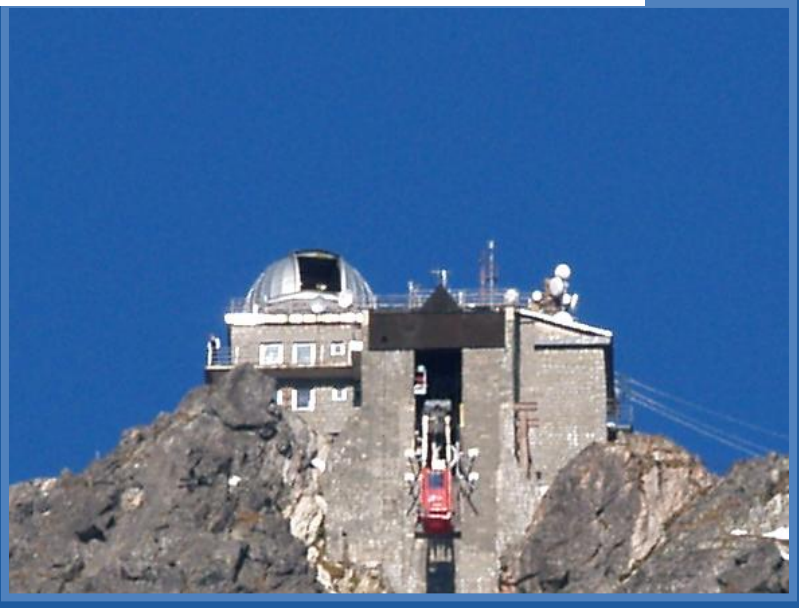
07:11 UT, 304 Å + 211 Å + 171 Å

An example and near future plans

Observations and cooperation

High Altitude Observatory, National Center for Atmospheric Research, Boulder, USA

Lomnicky Peak
Longitude: 20.22° E
Latitude: 49.20° N
Altitude: 2632

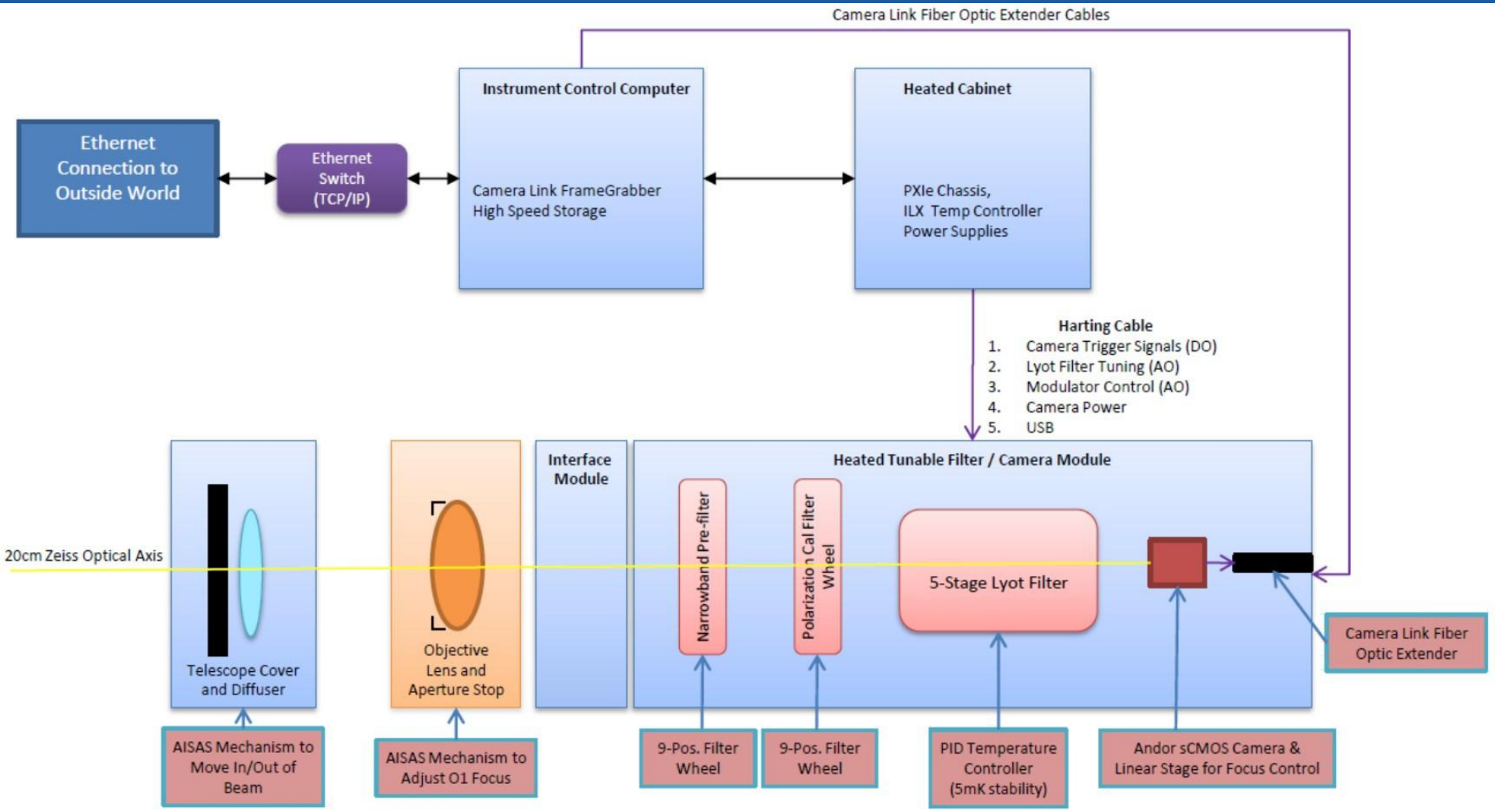


Mauna Loa
Longitude: 155.58° W
Latitude: 19.54° N
Altitude: 3414

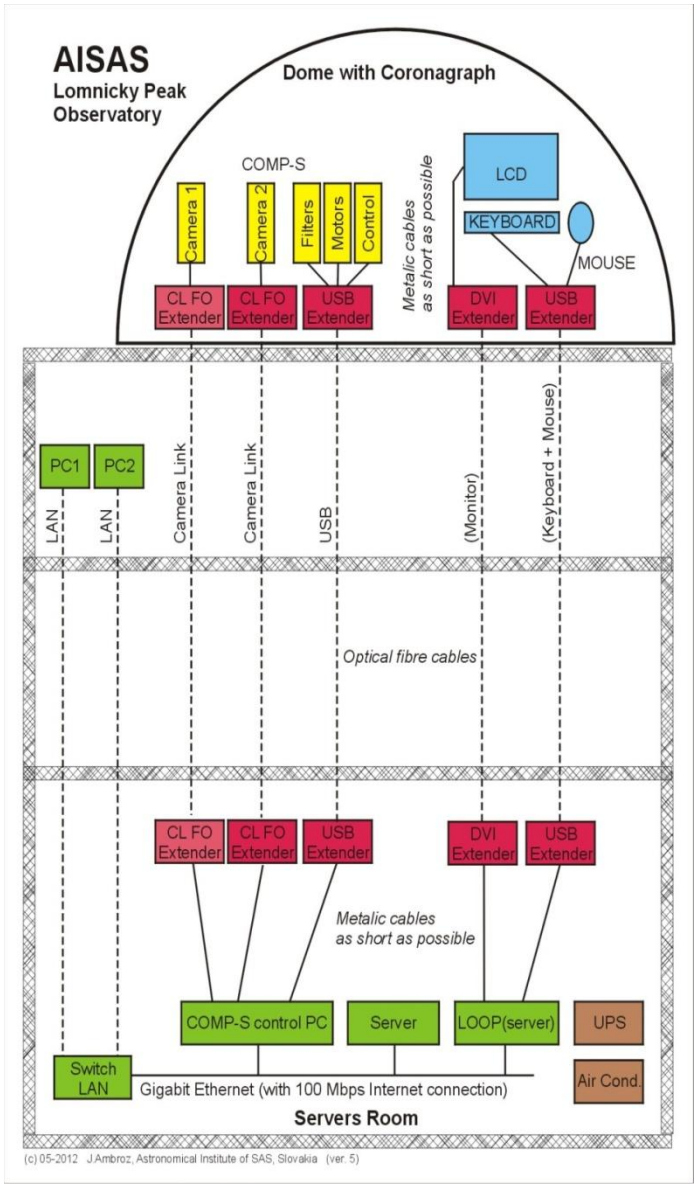
Longitude Difference is 175.80° which offers the possibility of coordinated observing


Thank you

SCD scheme (ON coronagraph case)



Postfocus instrument
Coronal Multi-channel Polarimeter



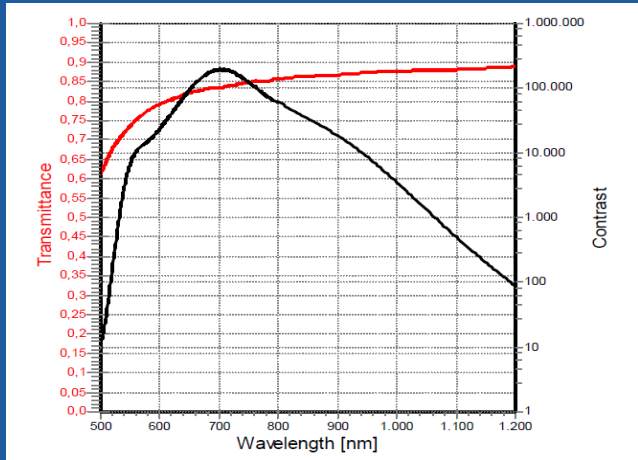
24 TB RAID Storage System,
800 MB/s sustained

2) New instrument for Lomnický peak: CoMP-S

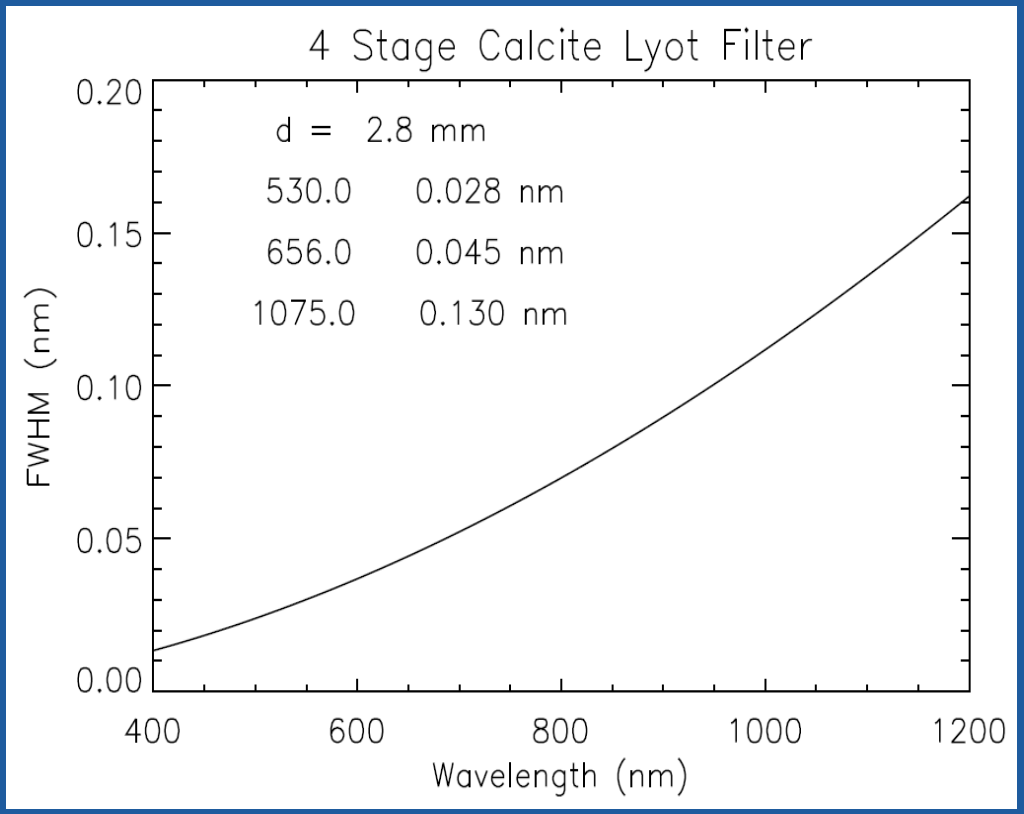
c) technical parameters

CoMP-S Tunable Filter

Advances in broadband polarizers and super-achromatic waveplates offer the possibility for the CoMP-S Lyot filter to operate over a much wider wavelength range than CoMP



Codixx



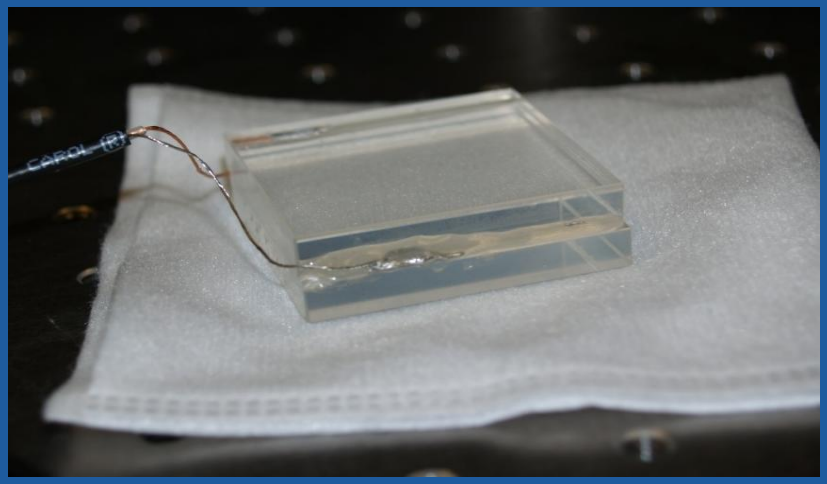
2) New instrument for Lomnický peak: CoMP-S

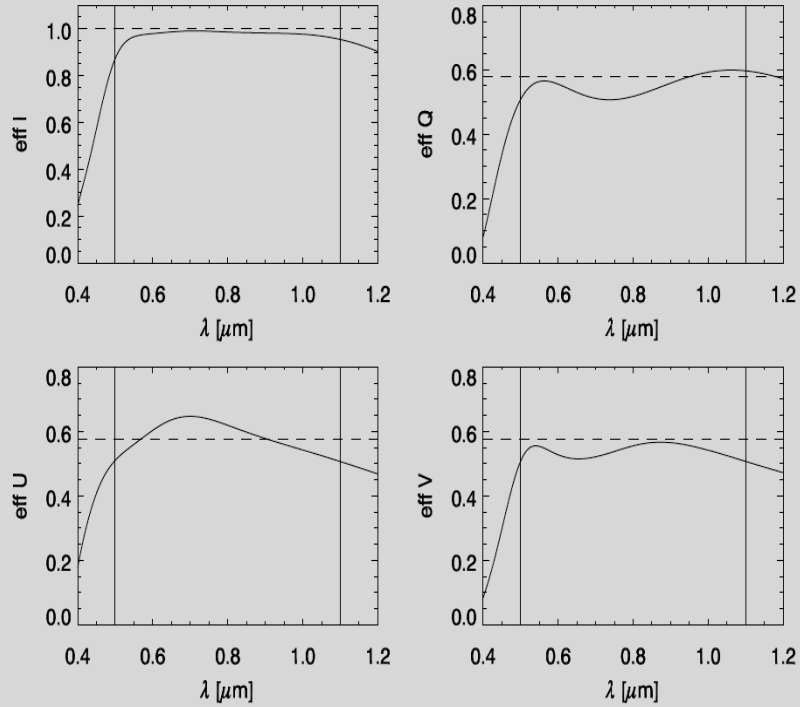
c) technical parameters

CoMP-S Polarimeter

1. polarization modulator: scheme from HAO Prominence Magnetometer (ProMag): 2 ferroelectric liquid crystals (FLC), fixed retarder followed by a linear polarizer (analyzer)

2. Recent polychromatic modulators based on FLCs can operate over a wide wavelength range with high polarimetric efficiency





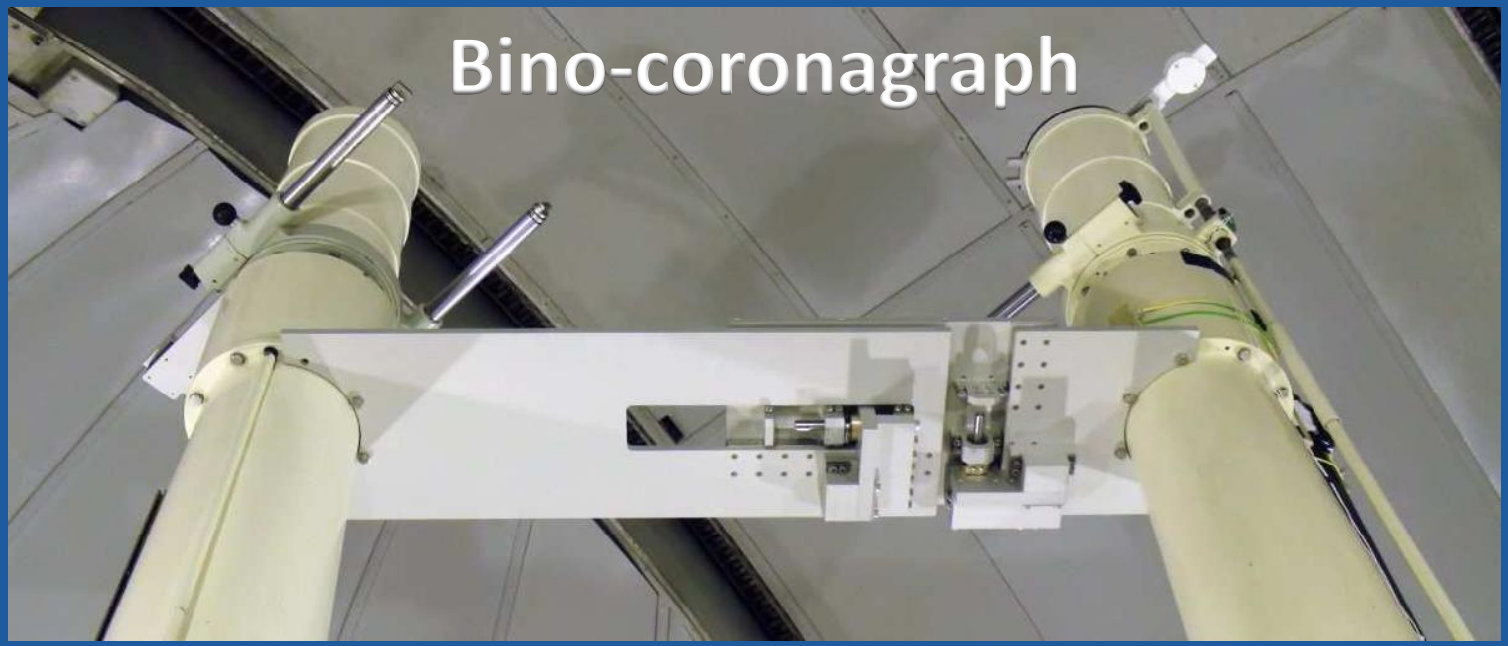
Theoretical efficiency of the Stokes polarimeter for the CoMP-S

Emission Line Choice

Judge et al. (NCAR Tech Note 446, 2001) showed that FeXIII 1074.7 has the best expected S/N for Stokes V based on line intensity and background levels

Ion	λ μm	Log I erg cm^{-2} s^{-1} sr^{-1}	Figure of merit (max s/n (V))	Max V/I	Log T_e
Fe XIII	1.0746	1.35	23.8	5.6-4	6.22
Si IX	3.9346	-0.17	23.4	1.5-3	6.04
Si X	1.4300	0.73	11.4	4.5-4	6.13
Mg VIII	3.027	-0.36	7.2	5.6-4	5.92
Fe XIII	1.0797	0.72	6.9	2.3-4	6.22
Fe XIV	0.5303	1.36	5.8	1.5-4	6.30
Fe XI	0.7891	0.96	5.8	1.8-4	6.10
Fe X	0.6374	1.12	5.2	1.5-4	6.03
S IX	1.252	-0.07	1.7	7.2-5	6.0
Si VII	2.481	-0.71	1.1	7.0-5	5.8

Prospects and possibilities



- to exploit joint potential of twin coronagraphs on the common mount
- on-going work on co-pointing of the coronagraphs, an aim: 2-arcsec co-pointing precision (Rob Hammerschlag, Hankom Engineering Rotterdam)
- possibility of parallel observations in the future
- right coronagraph: CoMP-S, left coronagraph:

  - small diffraction grating spectrograph
  - tests of new instruments, please contact: J. Rybak - rybak@astro.sk
  - at disposal for hosting instruments for temporary joint observations (since October 2013: CorMag spectropolarimeter for the green coronal line developed in Osservatorio Astronomico di Turin, INAF, by prof. Silvano Fineschi)

shape of the camera modul

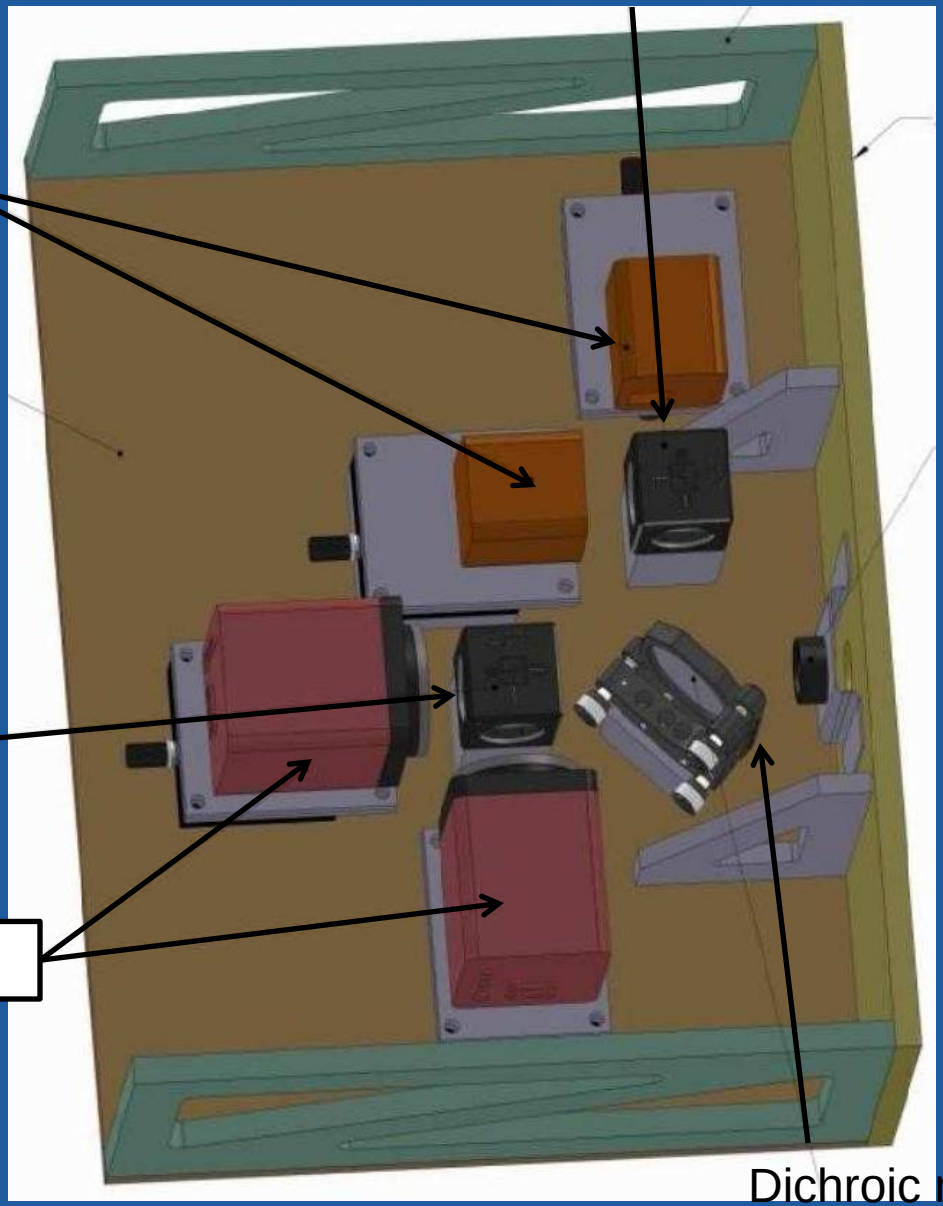
IR beamsplitter

IR cameras (line + background)

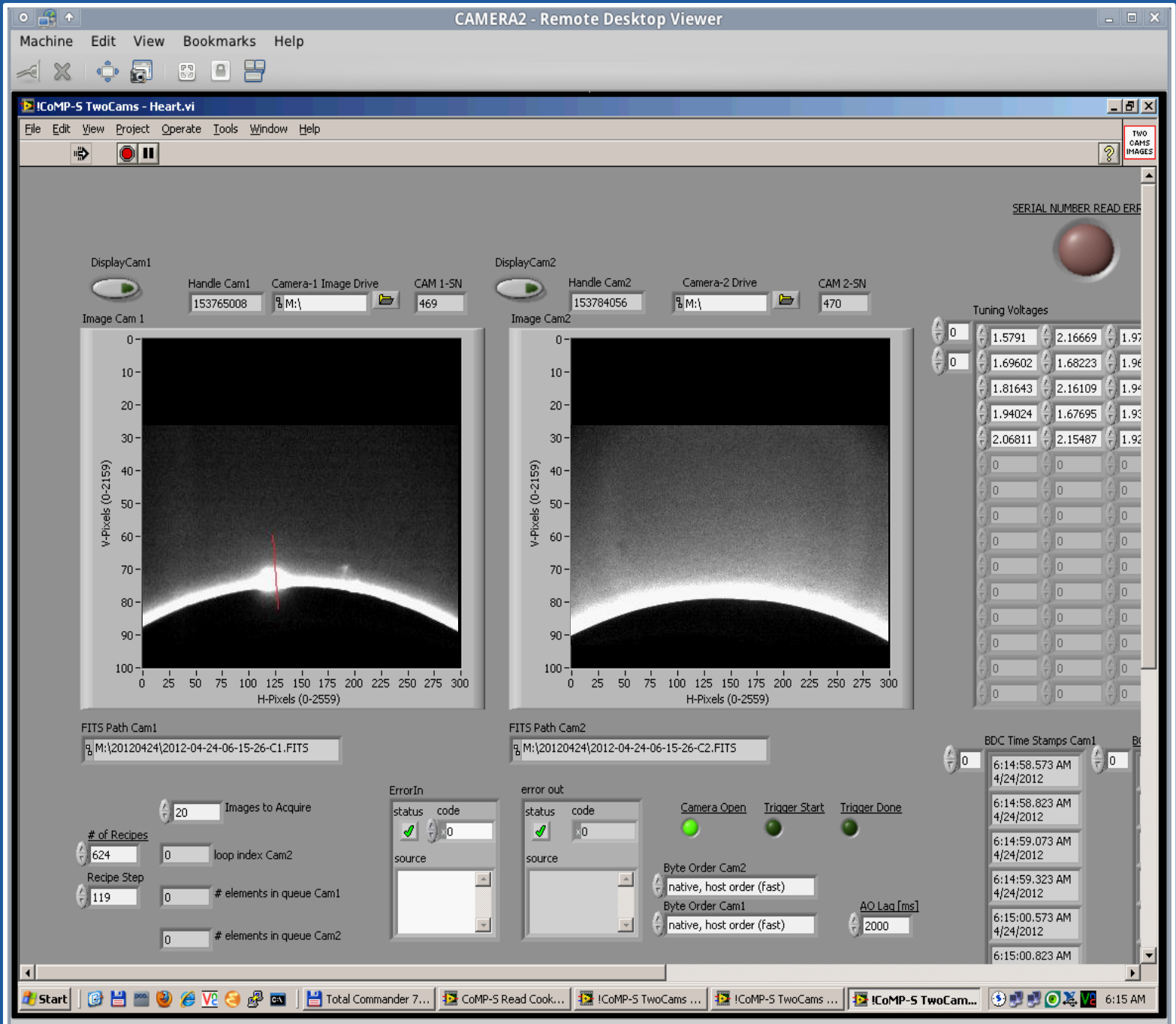
The background cameras are for strictly simultaneous acquisition of the scattered light in the Earth atmosphere.

VIS beamsplitter

VIS cameras (line + background)



Dichroic mirror


CAMERA2 - Remote Desktop Viewer
Machine Edit View Bookmarks Help
!CoMP-S TwoCams - Heart.vi
File Edit View Project Operate Tools Window Help
TWO CAMS IMAGES
SERIAL NUMBER READ ERR
DisplayCam1
Handle Cam1
153765008
Camera-1 Image Drive
M:\
CAM 1-SN
469
DisplayCam2
Handle Cam2
153784056
Camera-2 Drive
M:\
CAM 2-SN
470
Image Cam 1
Image Cam2
V-Pixels (0-2159)
H-Pixels (0-2559)
Tuning Voltages
1.5791
2.16669
1.69602
1.68223
1.81643
2.16109
1.94024
1.67695
2.06811
2.15487
FITS Path Cam1
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FITS Path Cam2
M:\20120424\2012-04-24-06-15-26-C2.FITS
BDC Time Stamps Cam1
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6:14:59.323 AM 4/24/2012
6:15:00.573 AM 4/24/2012
6:15:00.823 AM
Images to Acquire
20
# of Recipes
624
Recipe Step
119
loop index Cam2
elements in queue Cam1
elements in queue Cam2
ErrorIn
status
code
source
error out
Camera Open
Trigger Start
Trigger Done
Byte Order Cam2
native, host order (fast)
Byte Order Cam1
native, host order (fast)
AO Lag [ms]
2000
Start
Total Commander 7...
CoMP-S Read Cook...
!CoMP-S TwoCams ...
!CoMP-S TwoCams ...
!CoMP-S TwoCam...
6:15 AM