The Lomnicky Peak Observatory (LSO) - a status report and coronal polarimetry prospects

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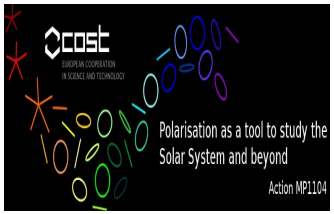

"The magnetic solar corona as revealed by polarimetry" workshop
Toulouse, November 4-6 2014

Presentation content

- LSO history
- LSO Zeiss coronagraphs
- LSO past science
- What's next, LSO?
- LSO instrumentation
- LSO infrastructure
- LSO “details“
- LSO future plans

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LSO history

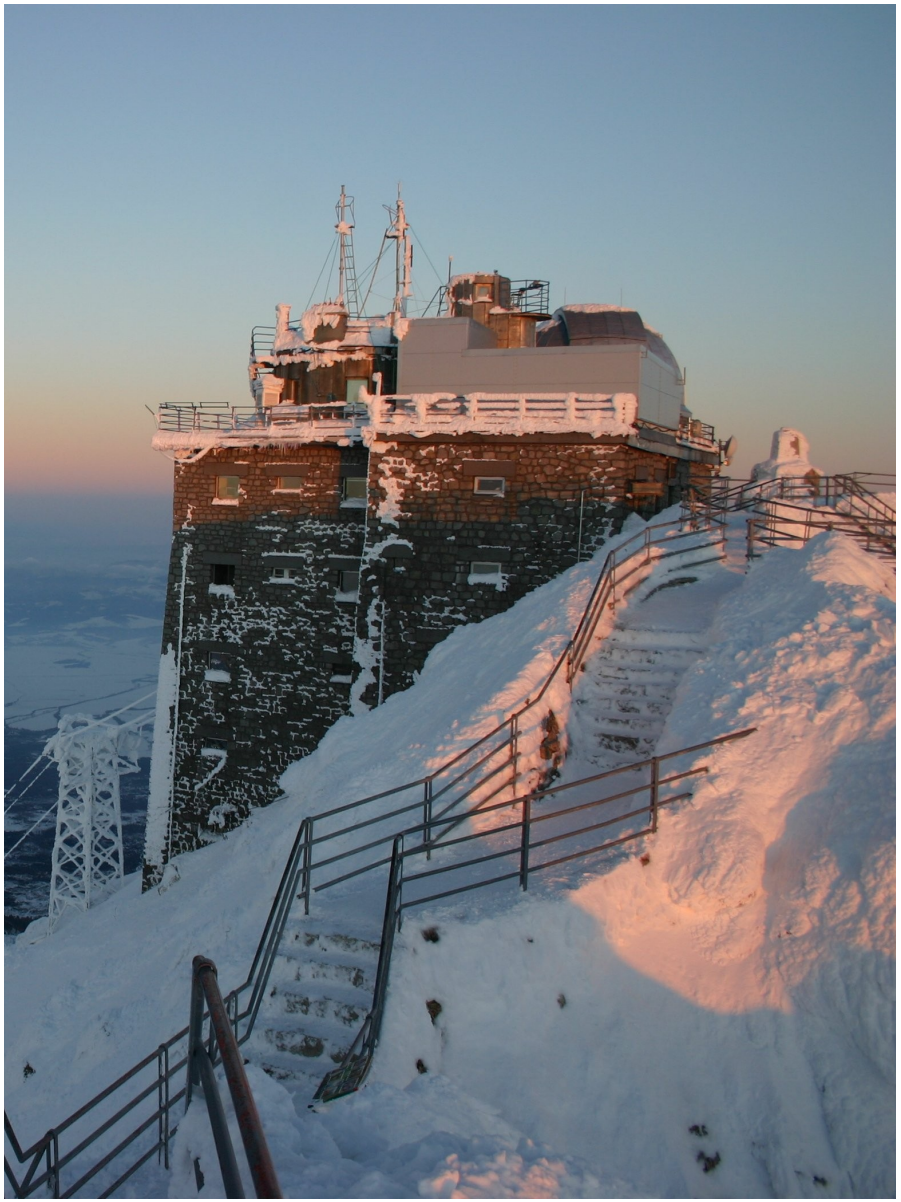
LSO history

- Motivations: to perform measurements which can not be realized at lower altitudes (2633 m a.s.l.), politics of the „cold” war and IGY 1957

- 1957-1962 – building
- 1962 - first coronagraph
- 1970 - second coronagraph

- 1962 - H alpha prominences
- 1965 - coronal emission lines
- 1991 - photoelectric data recording
- 2008 - CCD data recording

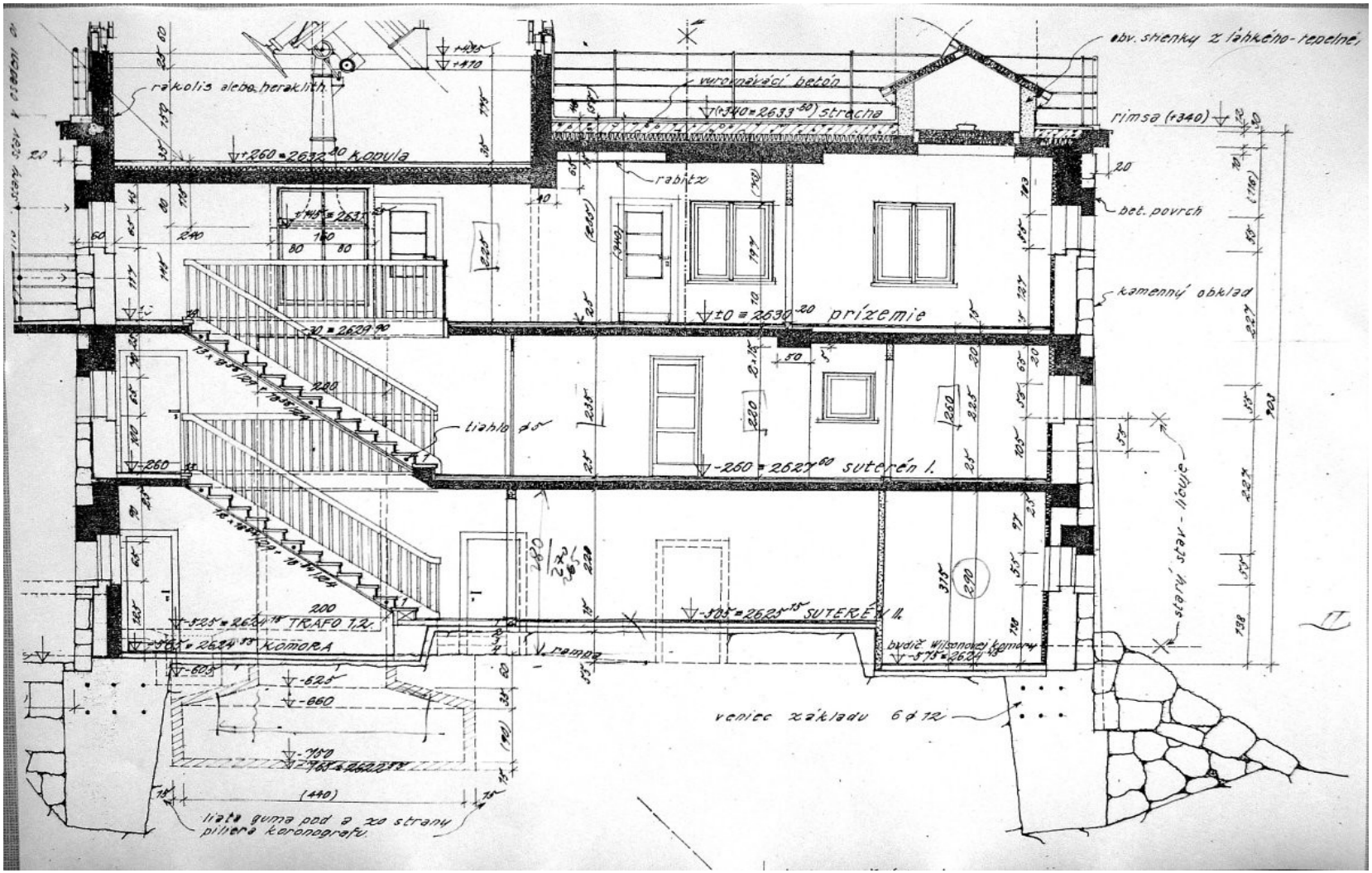
- Nowadays: the LSO is one of few ground-based high-altitude observatories performing regular coronagraphic observations of the Sun



Winter 2013/2014

LSO history

- Building, dome and mount



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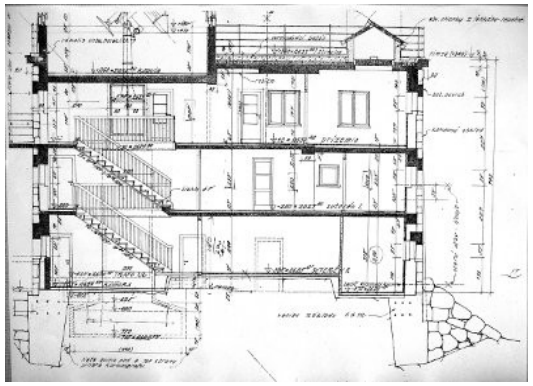
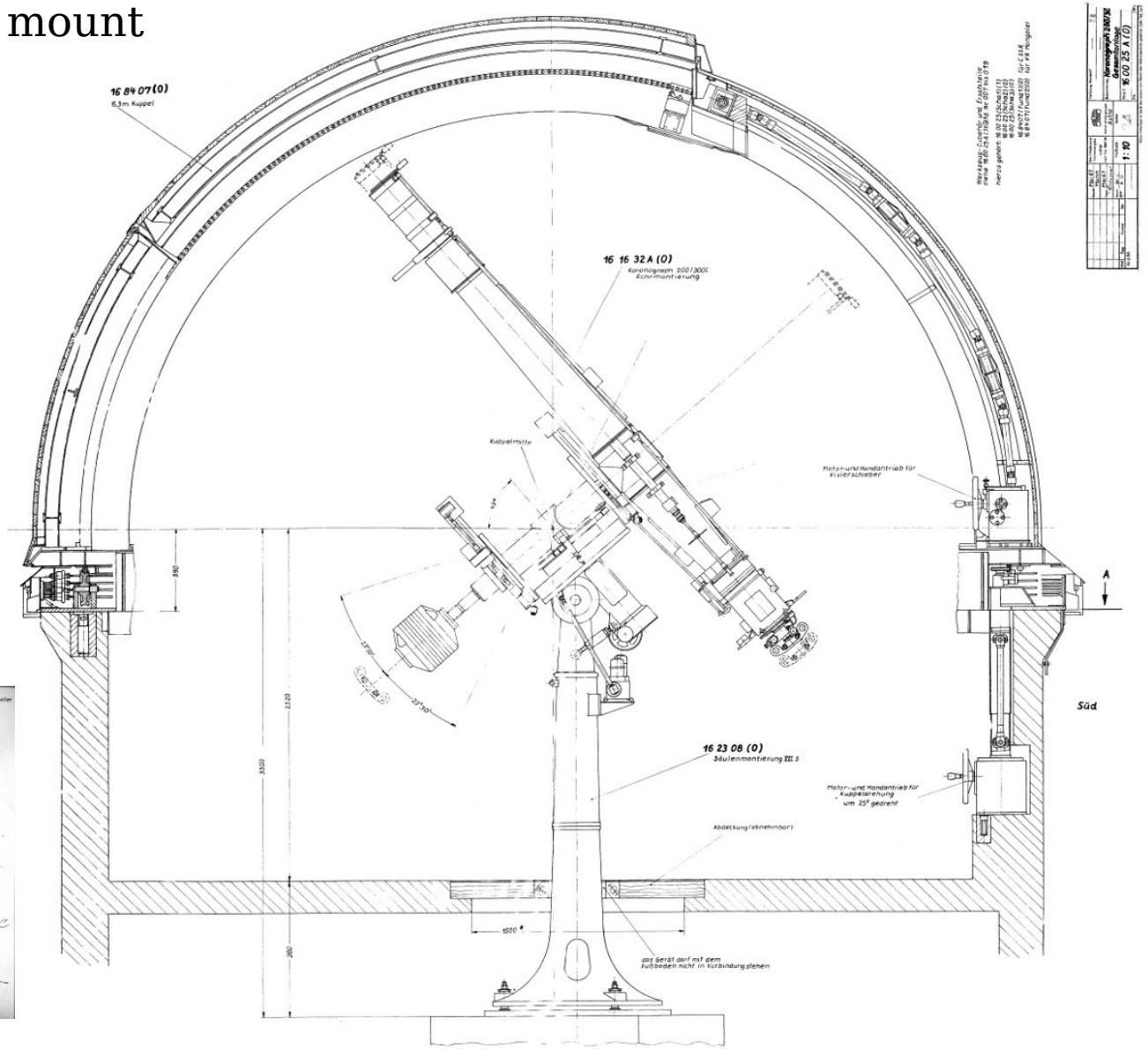


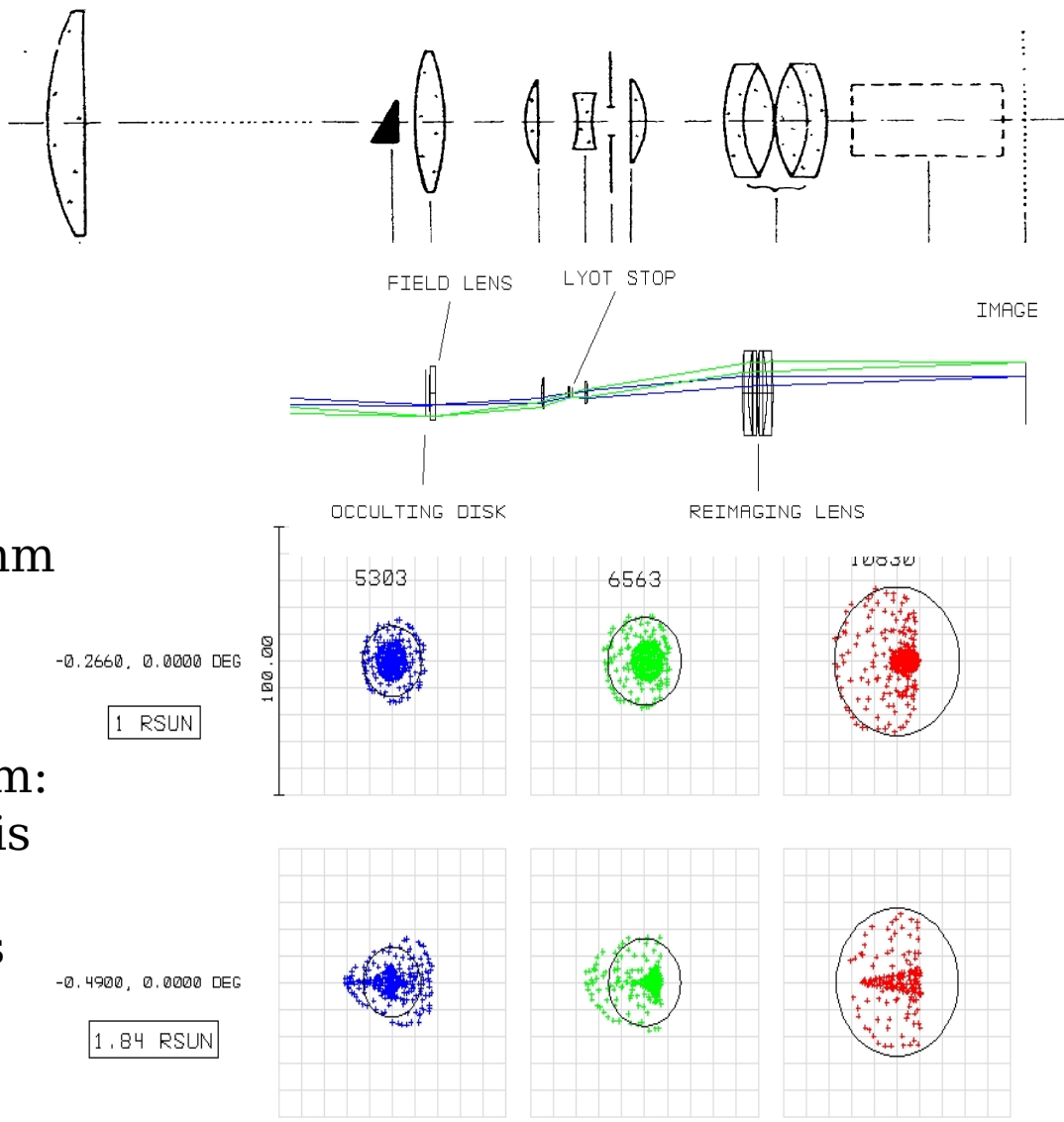


LSO Zeiss coronagraphs

LSO Zeiss coronagraphs

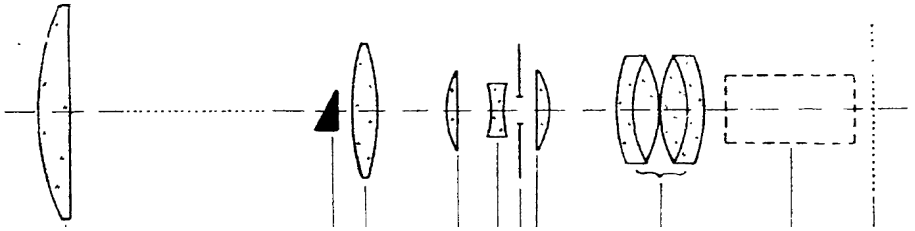
- Carl Zeiss Jena (former Eastern Germany)
- Lyot type coronagraph
- a primary objective 200/3000
- an artificial moon
- a single field lens
- 3 small single corrective lenses
- a Lyot stop
- achromatic reimaging lenses
- diffraction limited: 530 - 1100 nm
- theor. spatial resolution: 0.7”@530nm - 1.4”@1083nm
- a post-focus instrument platform:
  - rotation around the optical axis
  - an offset to the optical axis
  - focusing along the optical axis
- only as individual instruments

*Lexa, J., 1963, BAC **14**, 107*



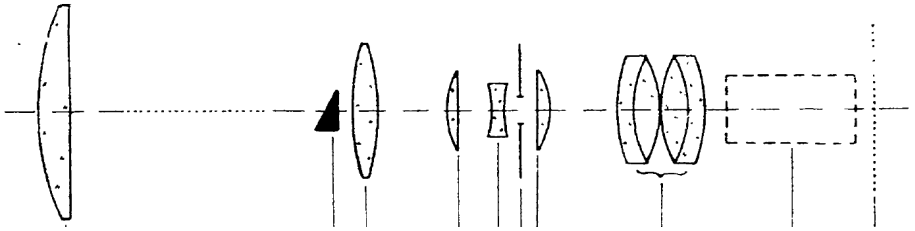
LSO Zeiss coronagraphs

- Front part of the coronagraph: a scrollable lid and the objective lens assembly



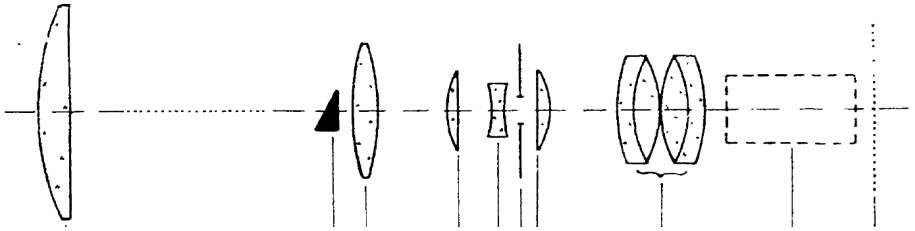
LSO Zeiss coronagraphs

- Central and rear part of the coronagraph: the artificial moon assembly, the rear part interface, handles for actions



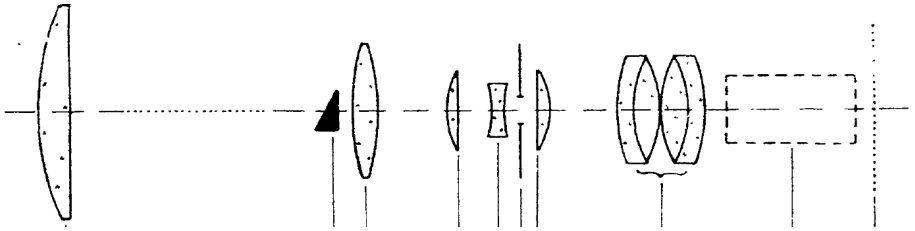
LSO Zeiss coronagraphs

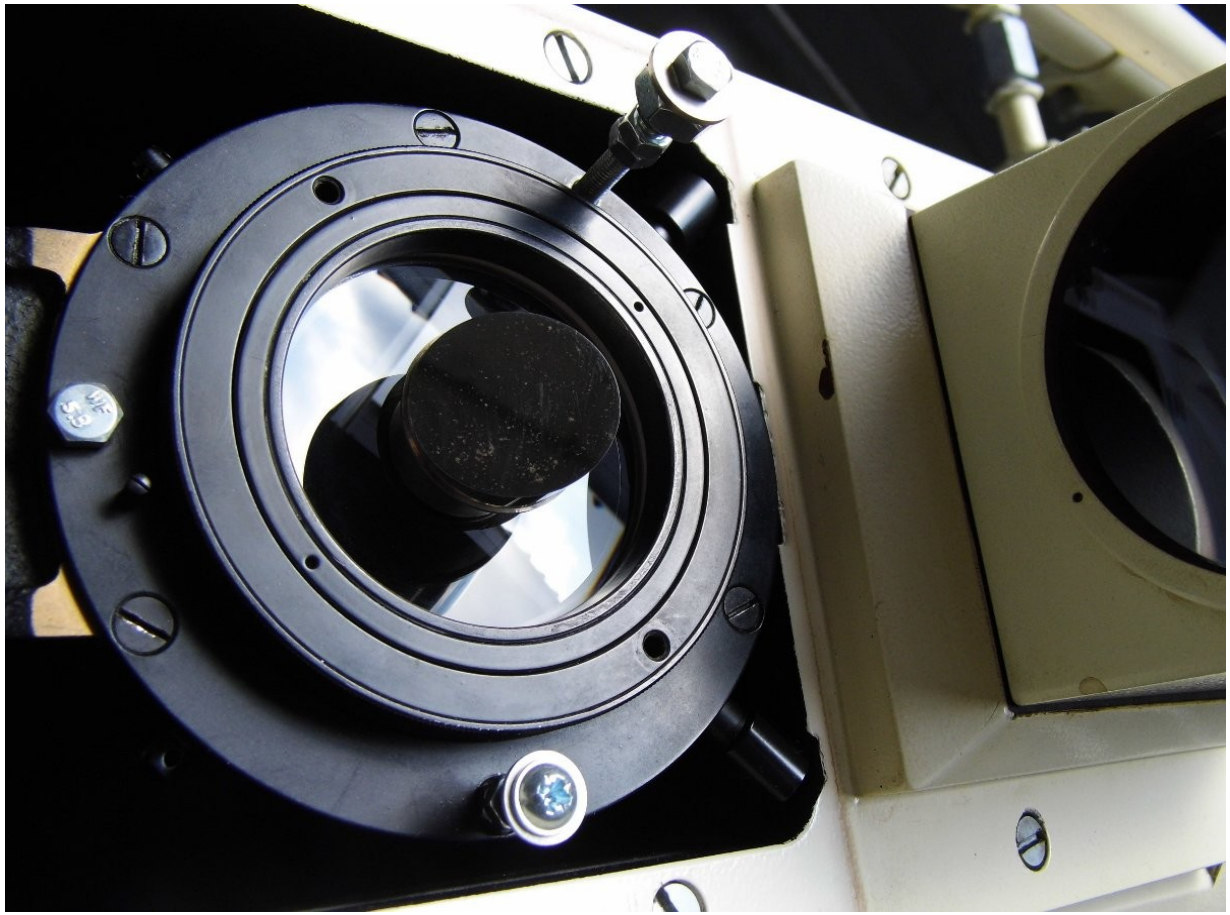
- The objective lens:
  ZEISS 200/3000, BK7,
  D=224 mm, aperture 196mm,
  R_1=1.710 m, R_2=17.000 m



LSO Zeiss coronagraphs

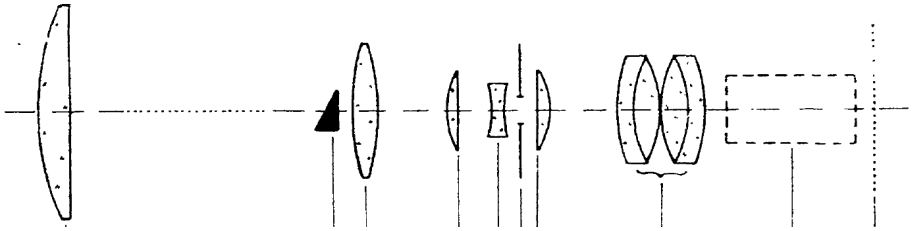
- The artificial moon and the field lens assembly

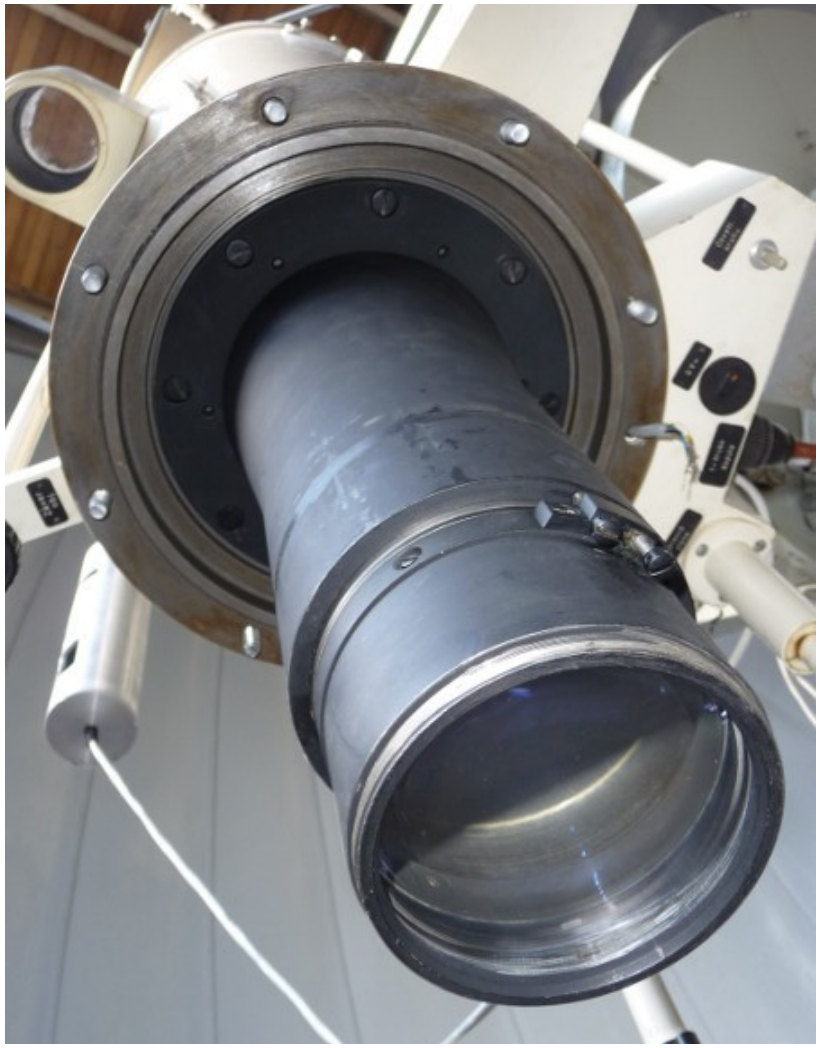




LSO Zeiss coronagraphs

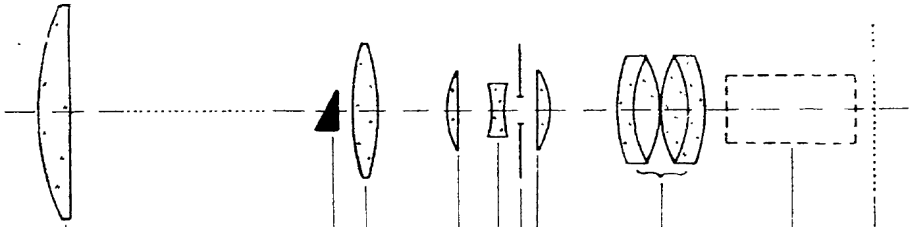
- Re-imaging lenses: D=100mm, BK7

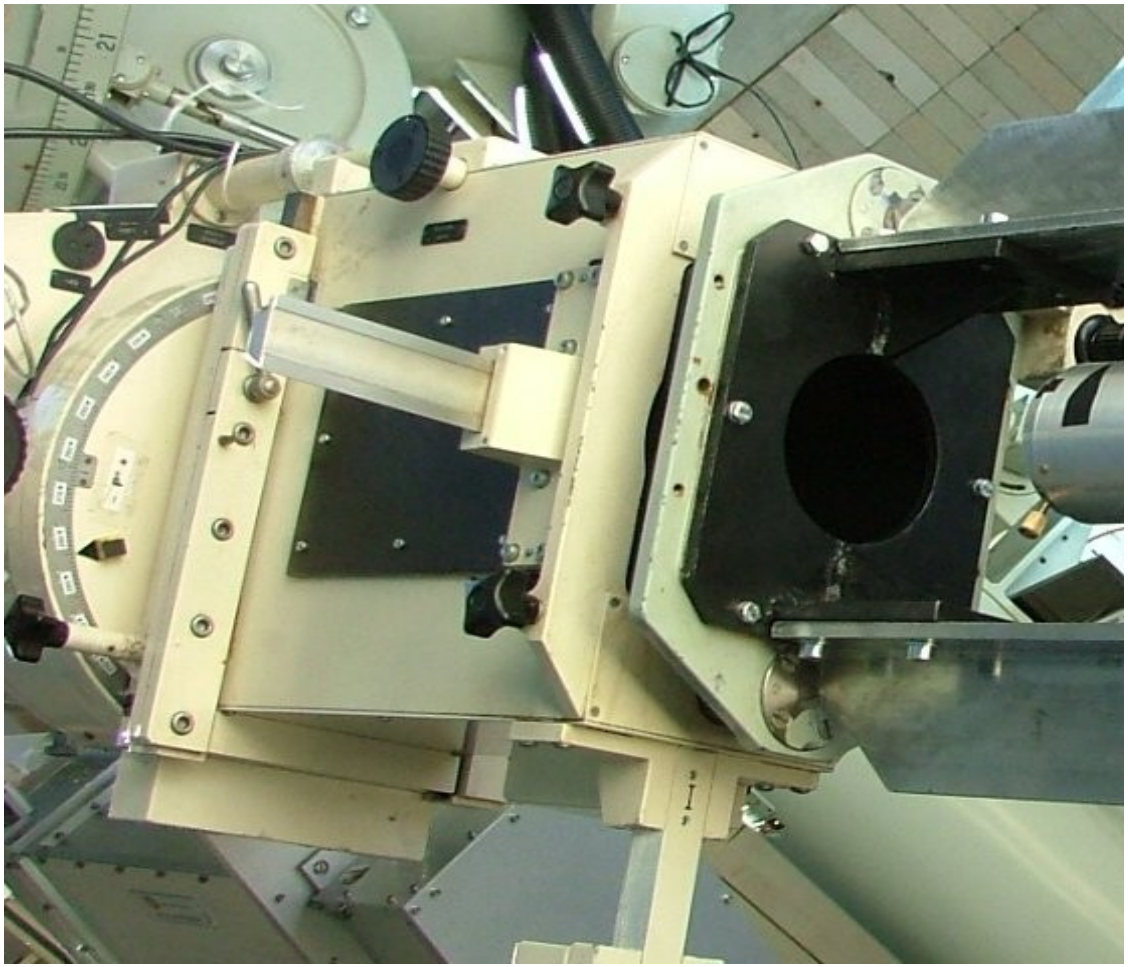




LSO Zeiss coronagraphs

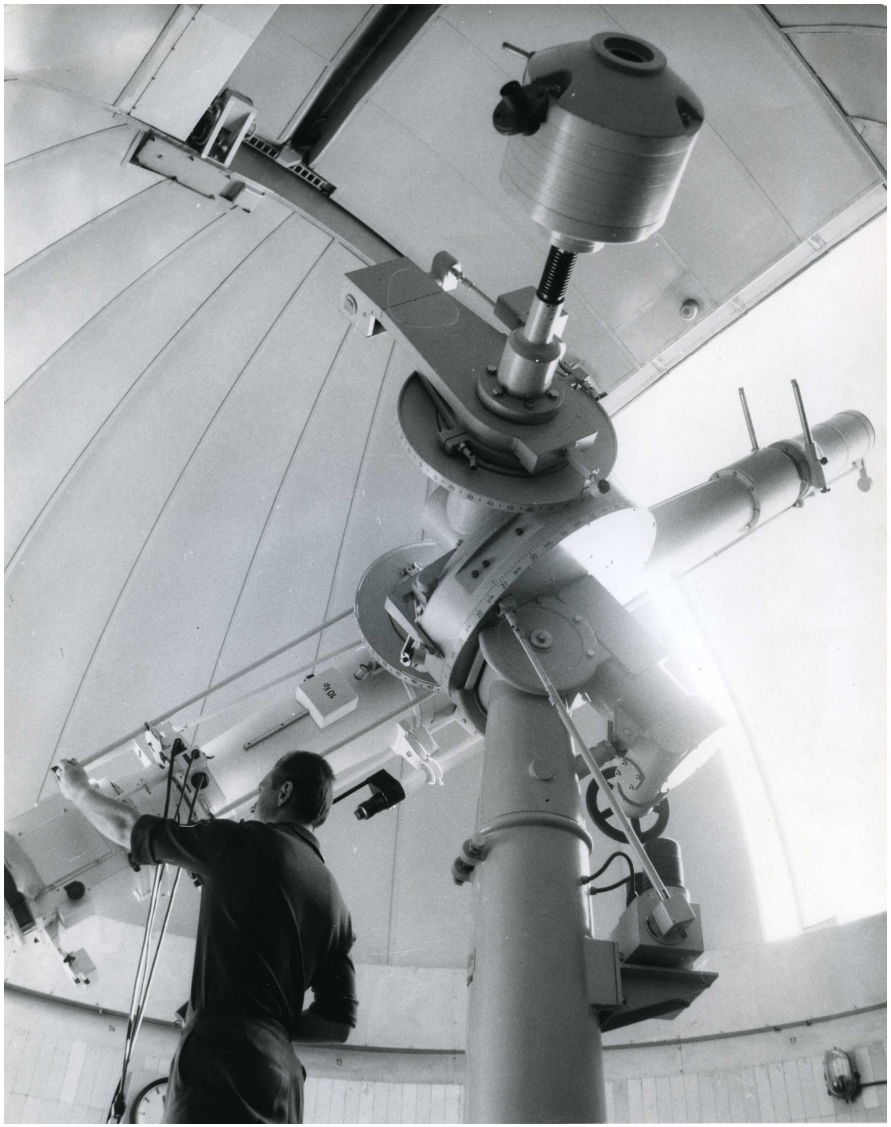
- Rear part interface for the post-focus instrument rotation, offset, and focusing





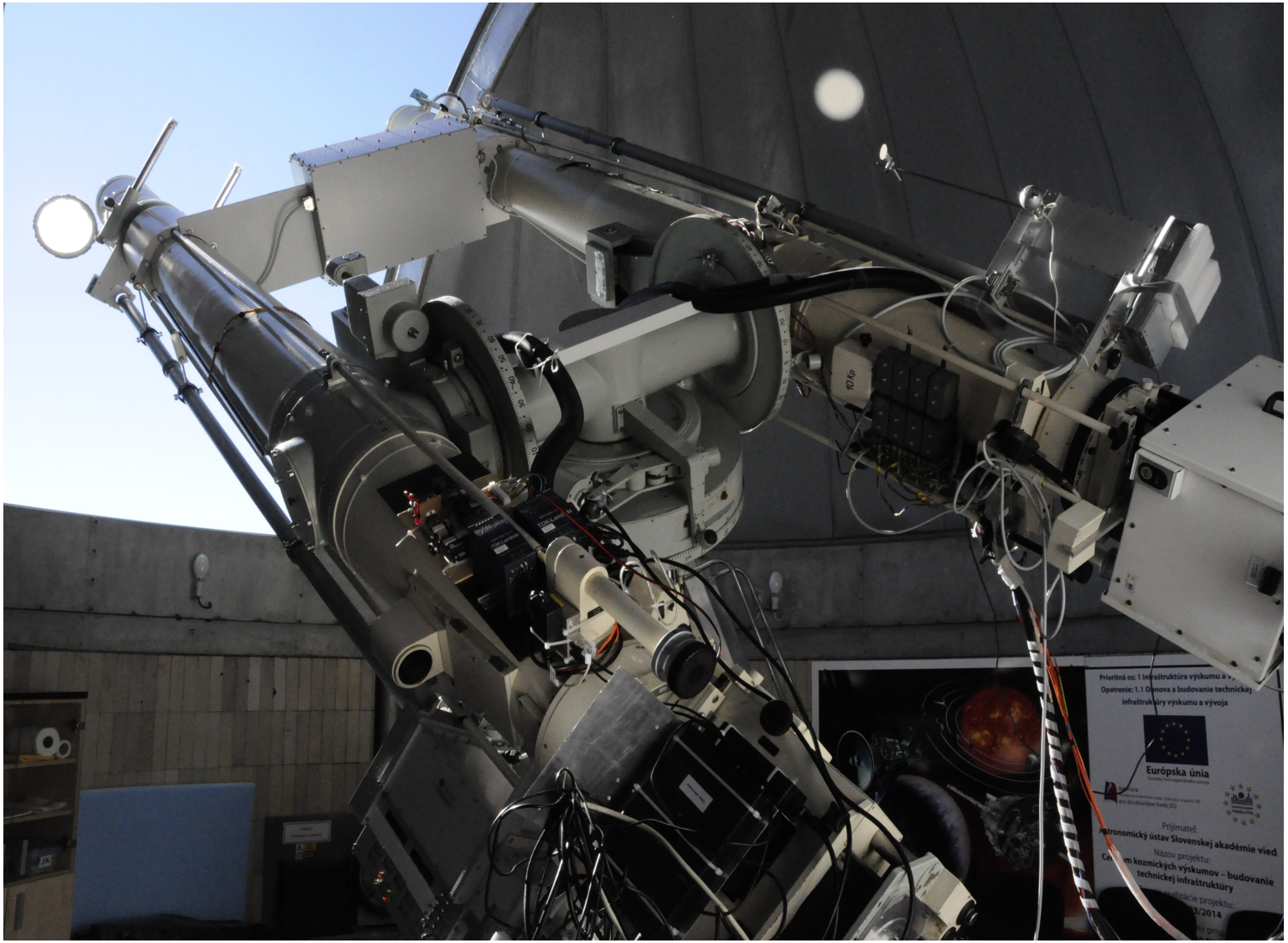
LSO Zeiss coronagraphs

- Past (~1967)



LSO Zeiss coronagraphs

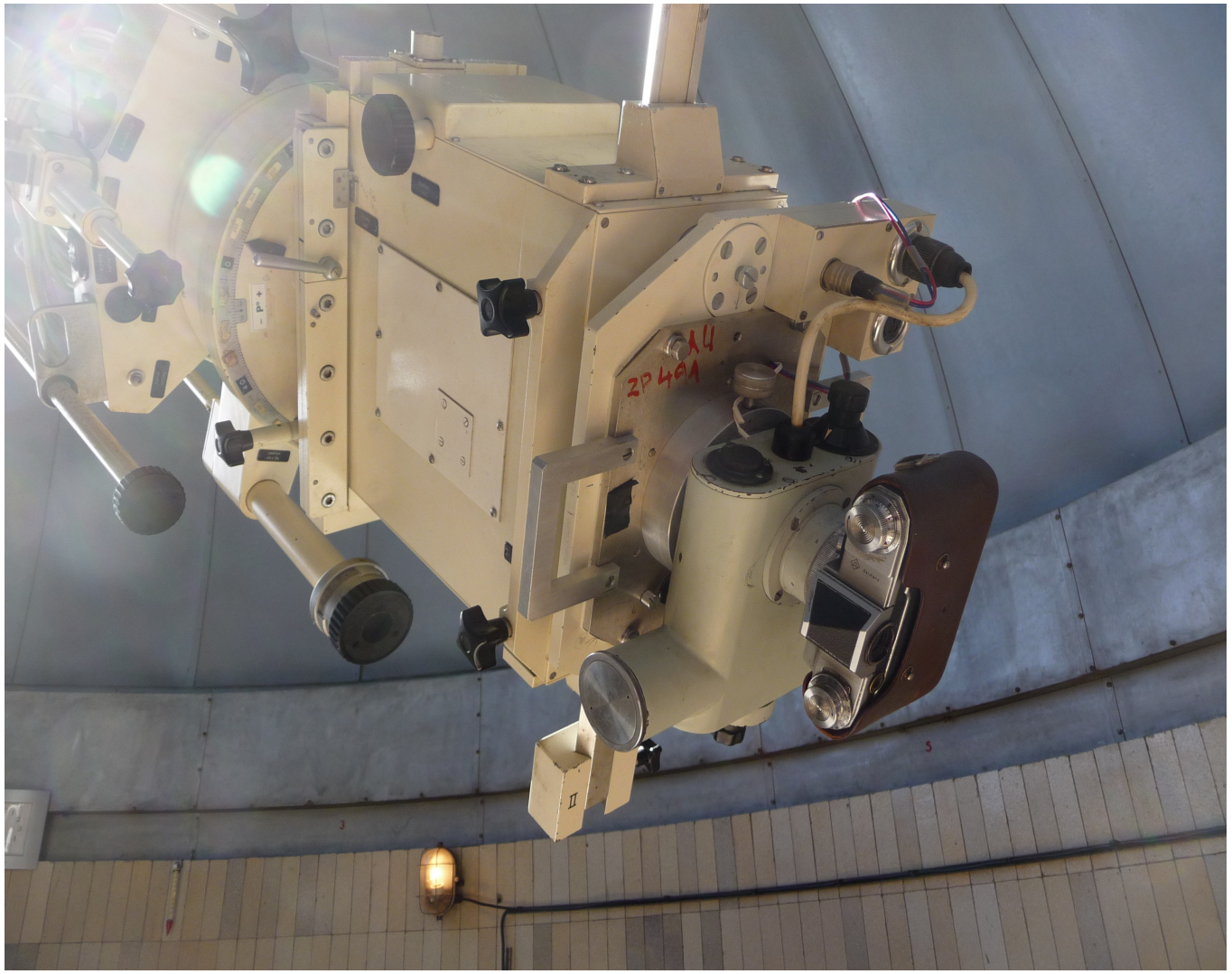
- Nowadays (~9/2014)



LSO past science

LSO past science

- patrol observations of the H alpha prominences → long-term data set of the H alpha prominence catalogue



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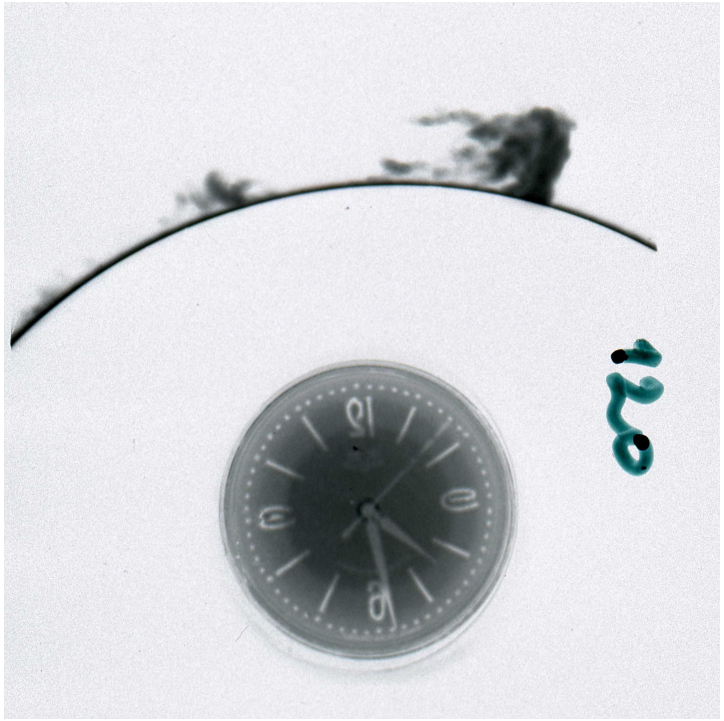

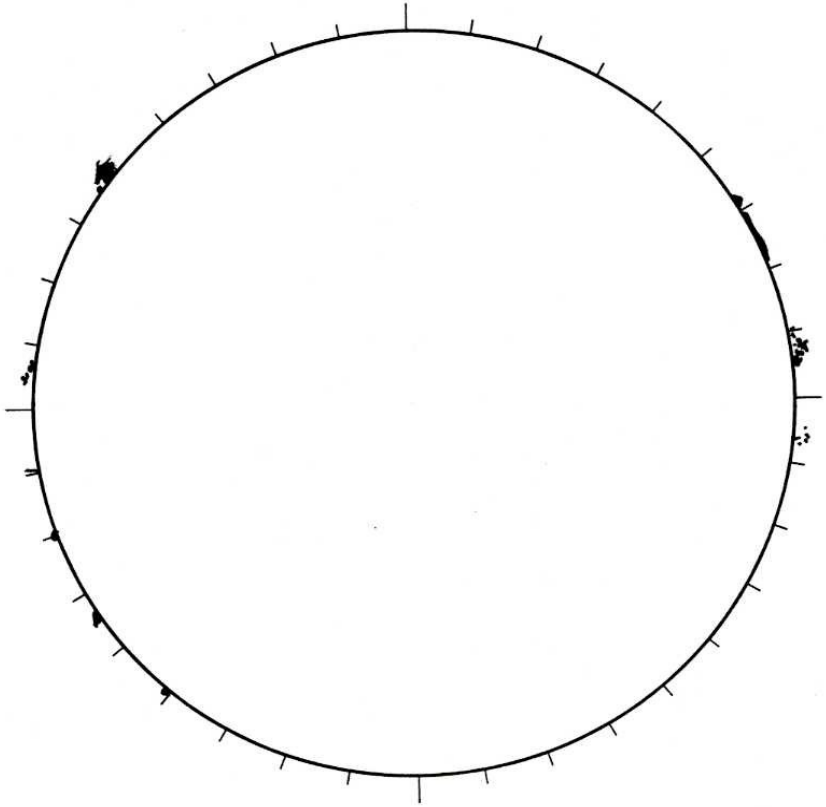

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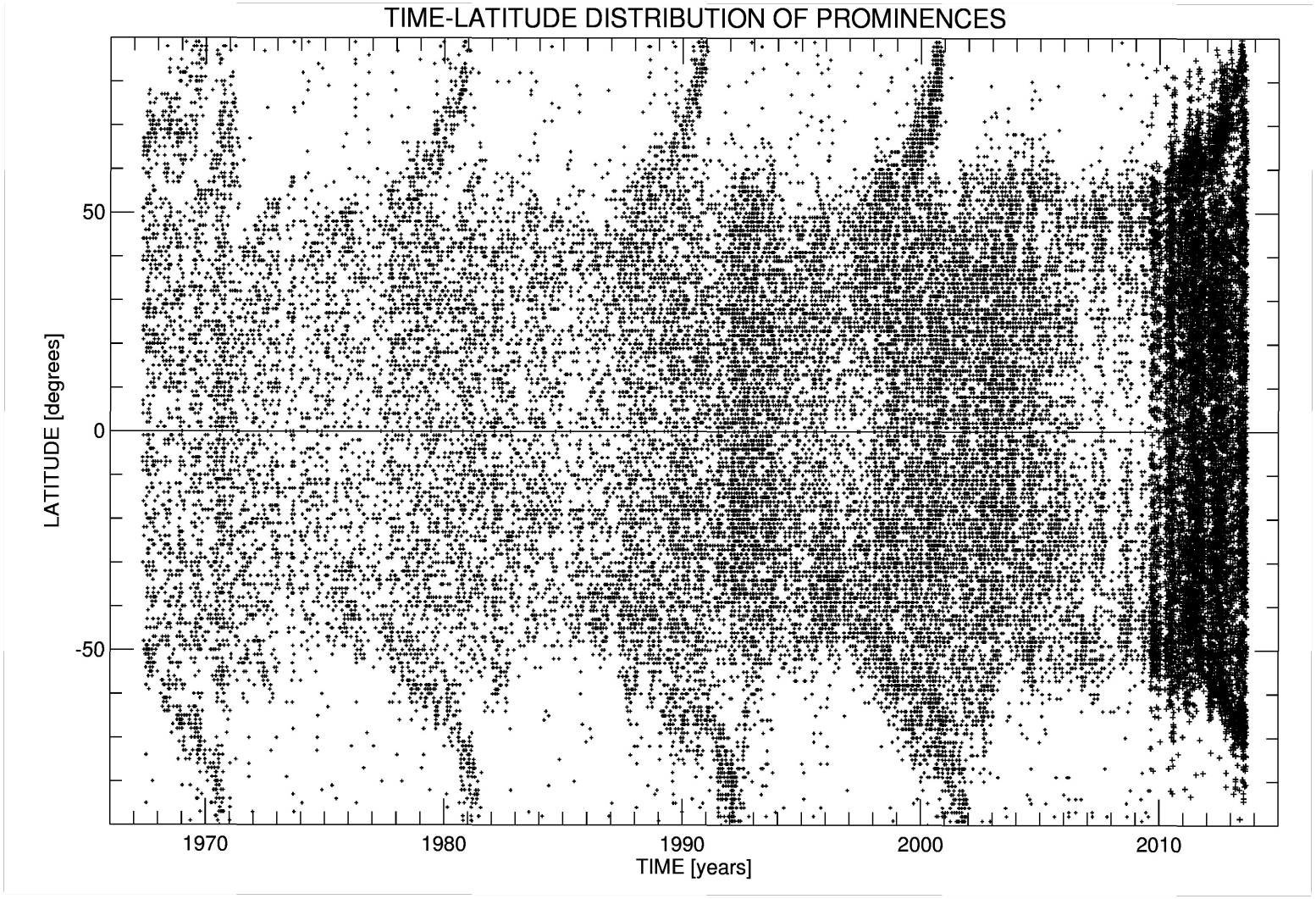
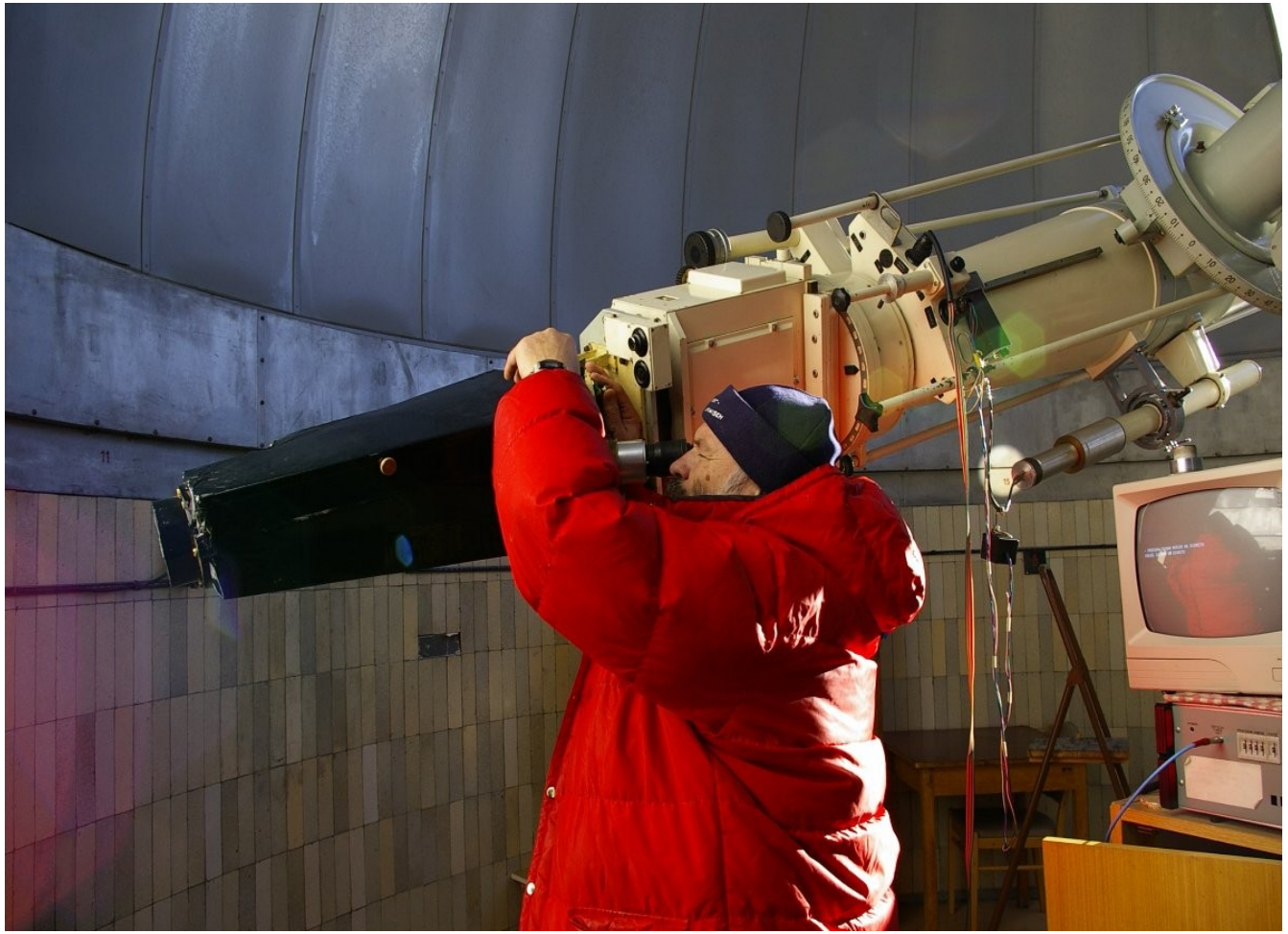


LSO past science

- patrol observations of the coronal emission lines intensities → long-term data set of the “Homogenous green line intensity catalogue” / the green line coronal index



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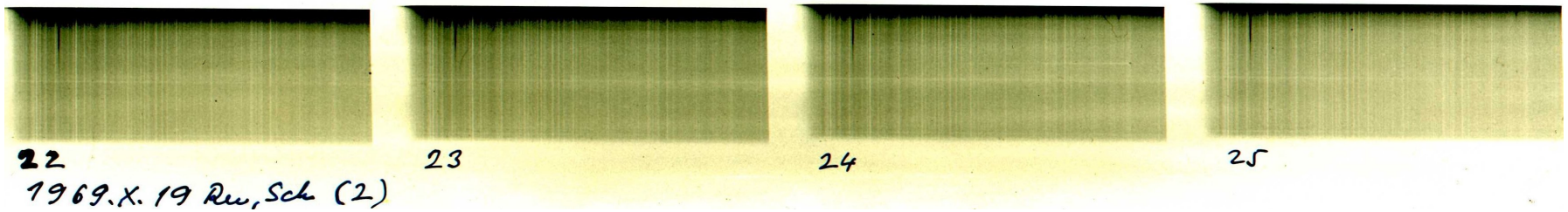

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- Julius Sykora, former AISAS staff person memories (2008):
  - Bagnéeres de Bigorre, 1967, workshop on “Normalization of the coronal measurements“
  - all stations: Pic du Midi, Arosa, Climax, Wendelstein, Kanzelhöhe, Norikura, Sacramento Peak, Kislovodsk, Alma Ata, Lomnický štít
  - selected as a volunteer (27-years old) to homogenize the green line data from all stations taken by different methods

- AISAS since 1970: 2 independent attempts to reach this goal

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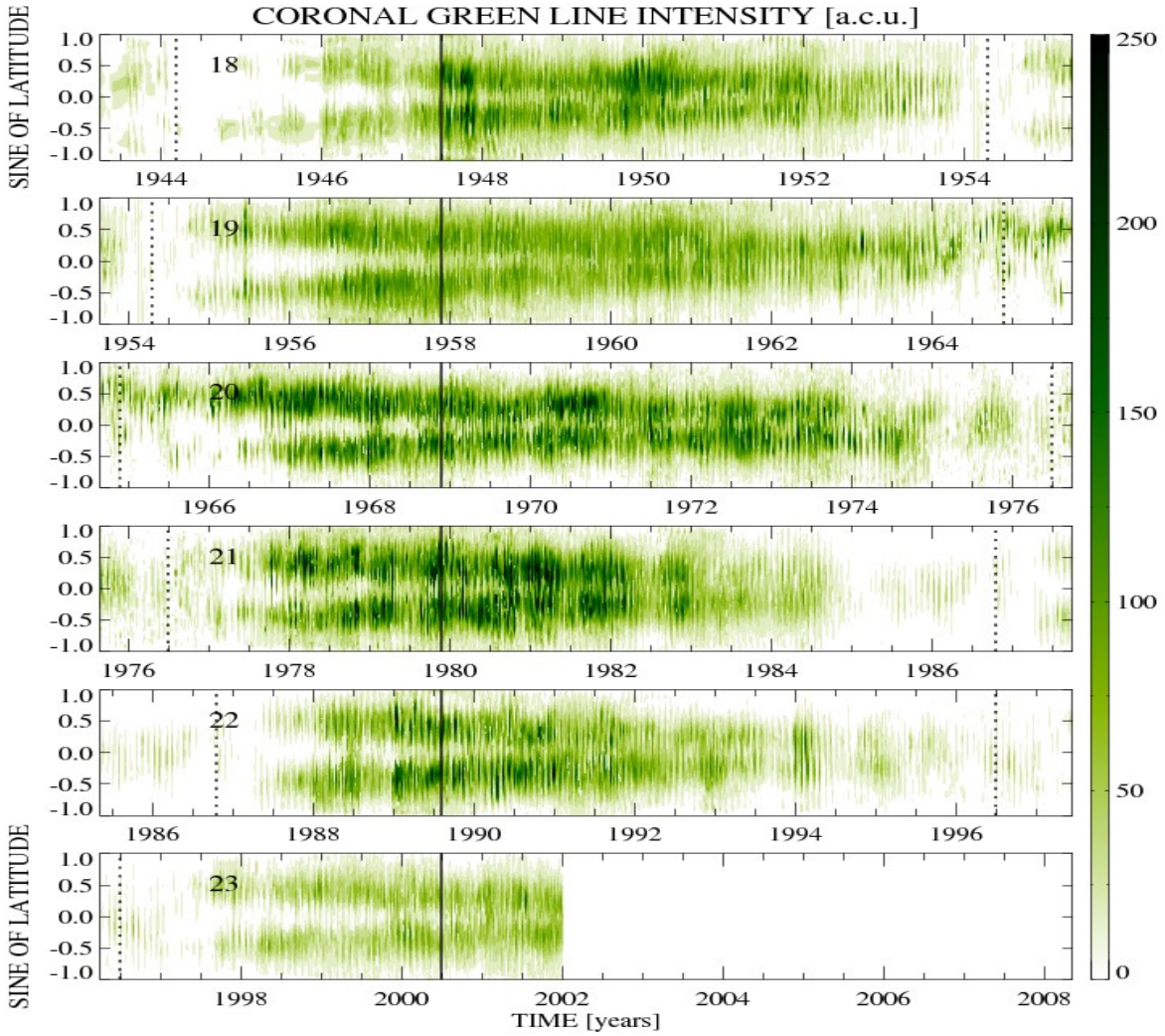

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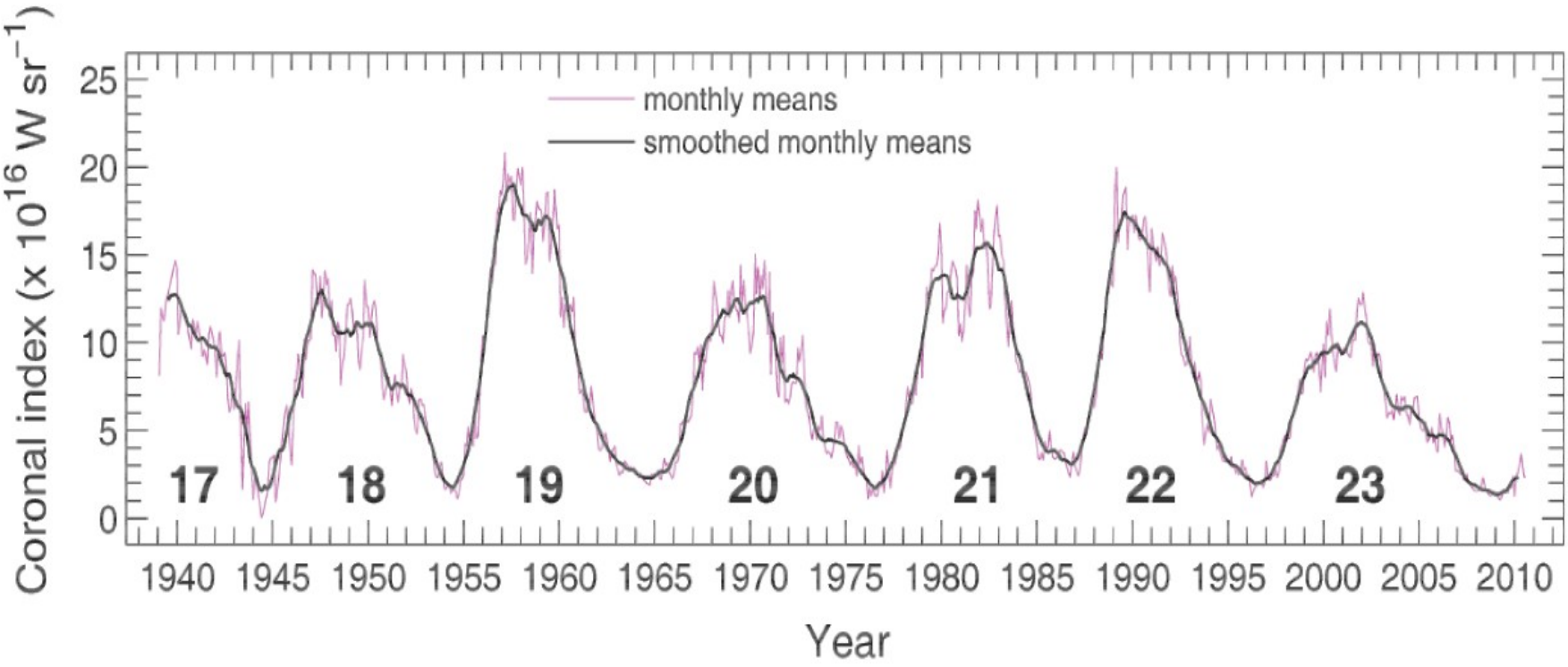
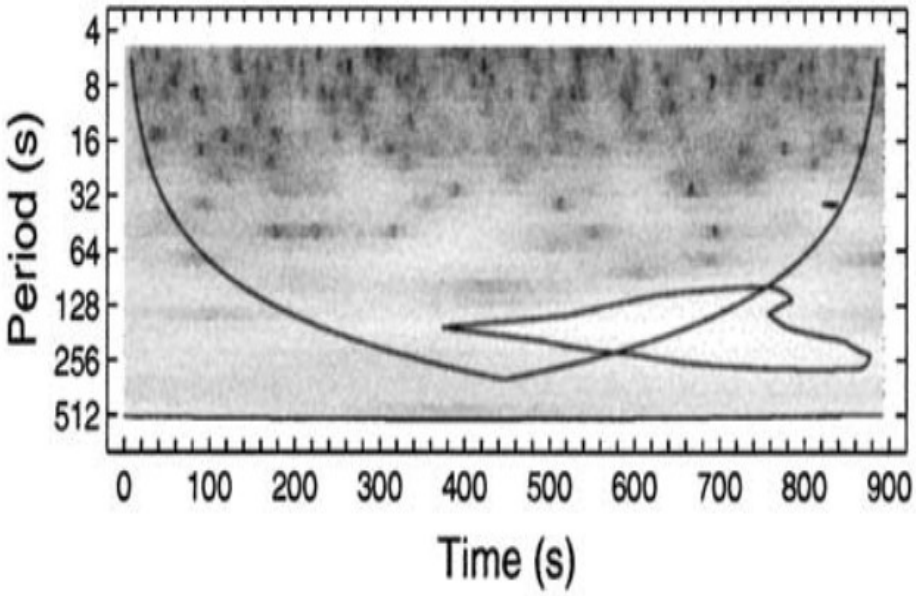
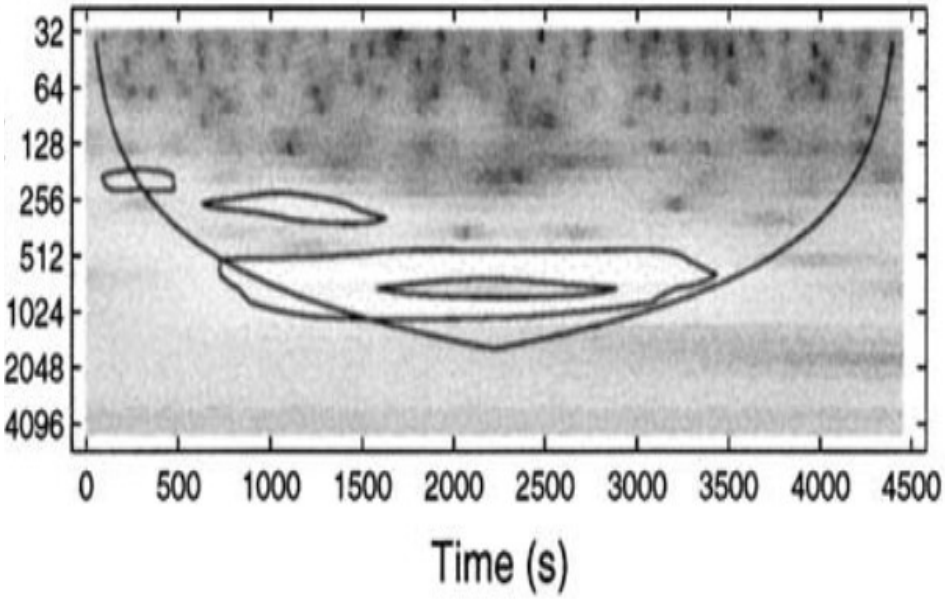


*Rybanský, M., 1975, BAC **26,** 367*
*Minarovjech, M., 2011, CAOSP **41**, 137*

LSO past science

- Special measurements → 5-min oscillations in the solar green line





Minarovjech et al., 2003, Solar Phys ***213****, 269*

What's next, LSO ?

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- Recent decades (1960 – ~2005):
  - prominences and solar corona ground-based coronagraphs: a decline but also progress at the same time
  - eclipses: limited in many ways, e.g. too short ...
  - space-born instruments: UV, X-rays, great progress...
  - optics/photoelectronics/computers

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- Review of plans of institutes and space agencies:
  - Pic-du-Midi, Norikura, SacPeak, ATST, Maona Loa, Haleakala,...
  - satellites in operation and Solar Orbiter, Solar-C, Proba-3, Aditya-1,...
  - space: imagers (UV, X-ray), spectrometers (UV)
  - spectro-polarimeters: ASPIICS/Proba-3, SUVIT/Solar-C, METIS/SO
  - ground: spectro-polarimeters: only CoMP@Maona Loa (COSMO ?)

What's next, LSO ?

- What's next? A simple but quite difficult question...
- When all our limitations of different types are taken into account:

2D spectro-polarimetry using
VIS and near IR emission lines:

coronagraphic measurements of
prominences and corona

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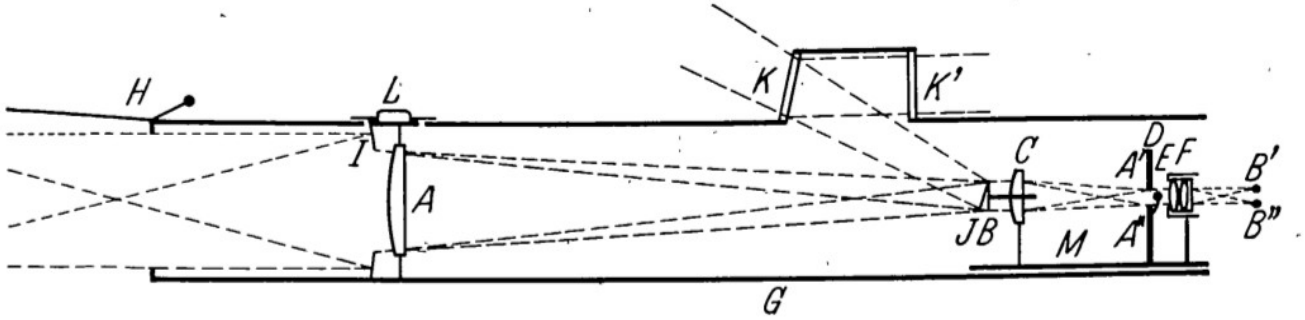
- But a budget needed is above all means...
- Miracle of the EU structural funds for science in less-developed regions of Slovakia

What's next, LSO ?

- A short historical note: the LSO is a tribute to B. Lyot...



*Lyot, B., Zeitschrift für Astrophysik **5**, 73 (1932)*

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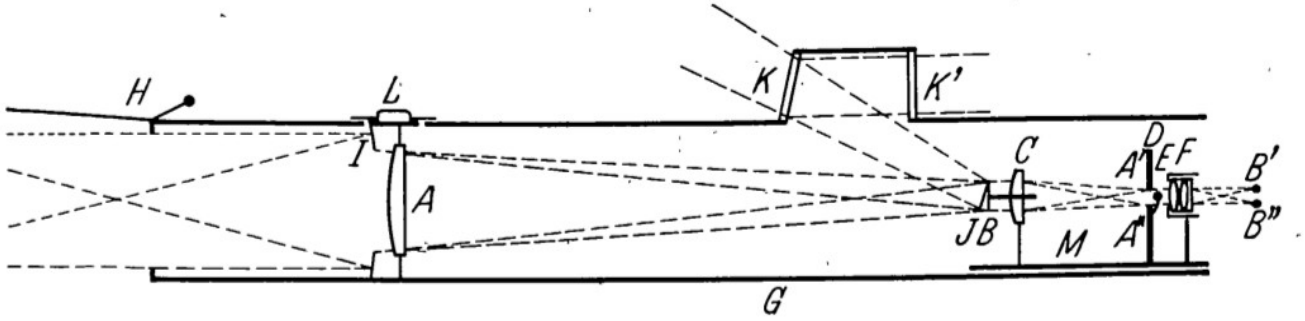

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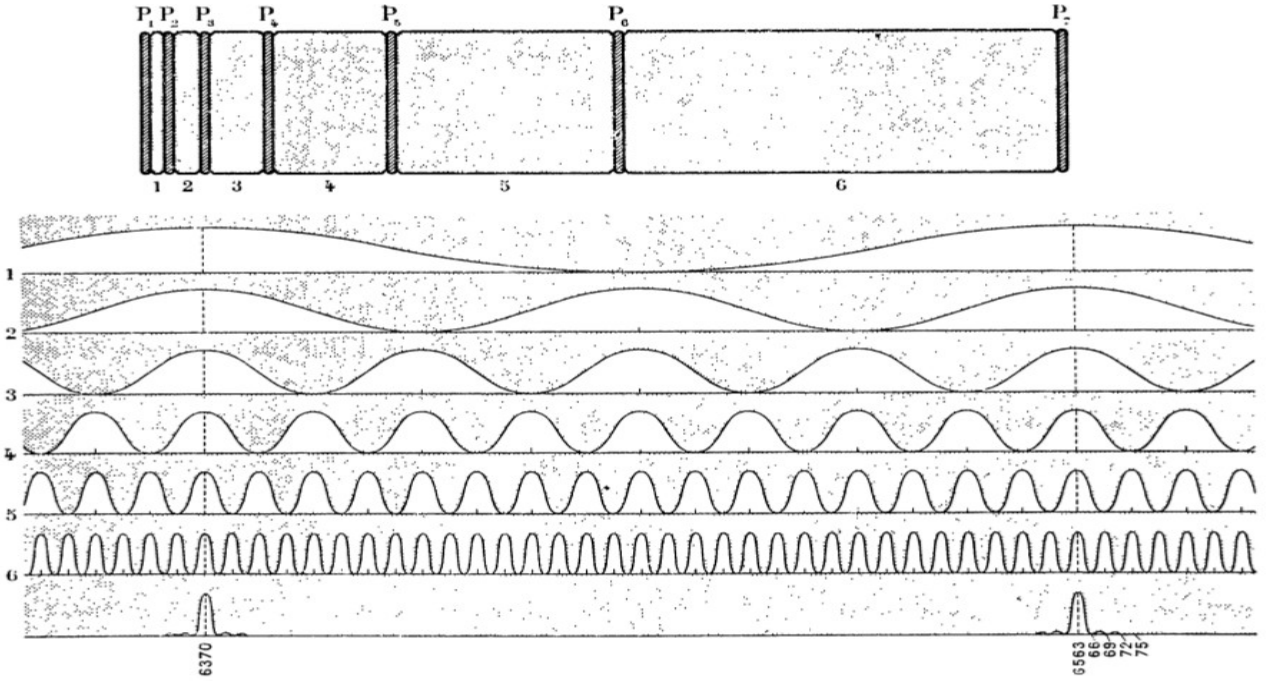

*Lyot, B., Annales d'Astrophysique, **7**, 31 (1944)*

LSO instrumentation

LSO instrumentation

CoMP-S with PDSS
pointer R
CorMag
pointer H
SCD
H alpha full disk+aureola

LSO instrumentation

CoMP-S with PDSS
pointer R
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LSO: CoMP-S

- **The Coronal Multi-channel Polarimeter for Slovakia – CoMP-S**

- **Main feature:** wavelength range **500 – 1100 nm** allowing spectropolarimetric measurements of several VIS + near-IR emission chromospheric and coronal emission lines (CoMP only 1070-1090nm)

- **Other specifications:** not a full-disk FoV, simultaneous imaging of a 2D area, sequential data acquisition in wavelength and polarization, a refocusing needed when the spectral line is changed

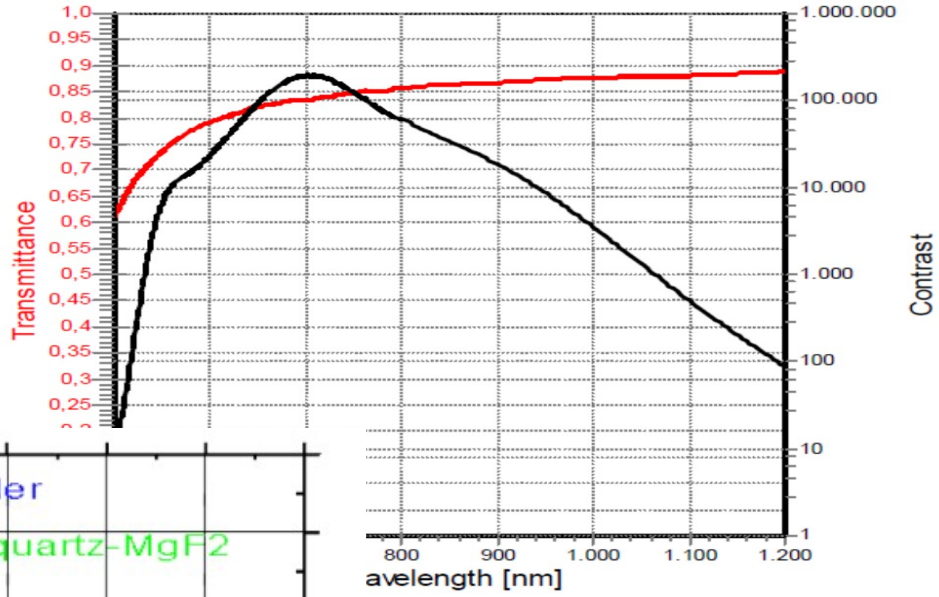
Producer: HAO/NCAR, Boulder (USA), team led by S. Tomczyk and S. Sewell

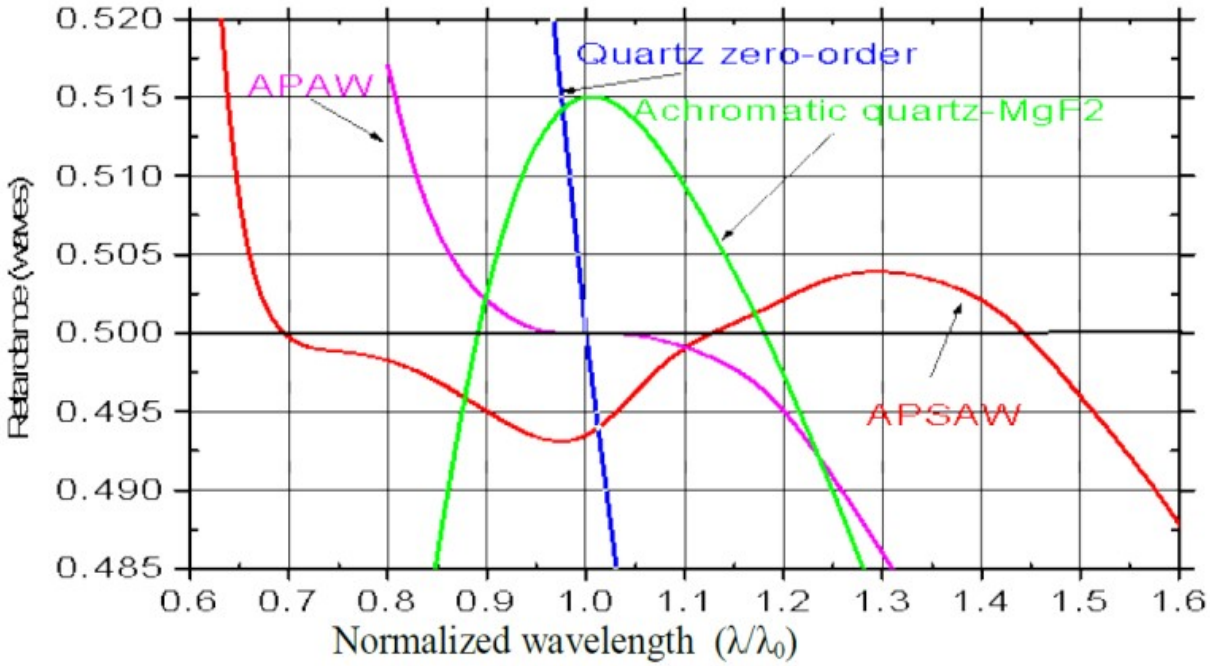
LSO: CoMP-S

- How this can be achieved? Advances in broadband polarizers and super-achromatic waveplates optics...

  - polarizer material:
    VIS700BC4 by CODIXX
    more than ~70% transmission

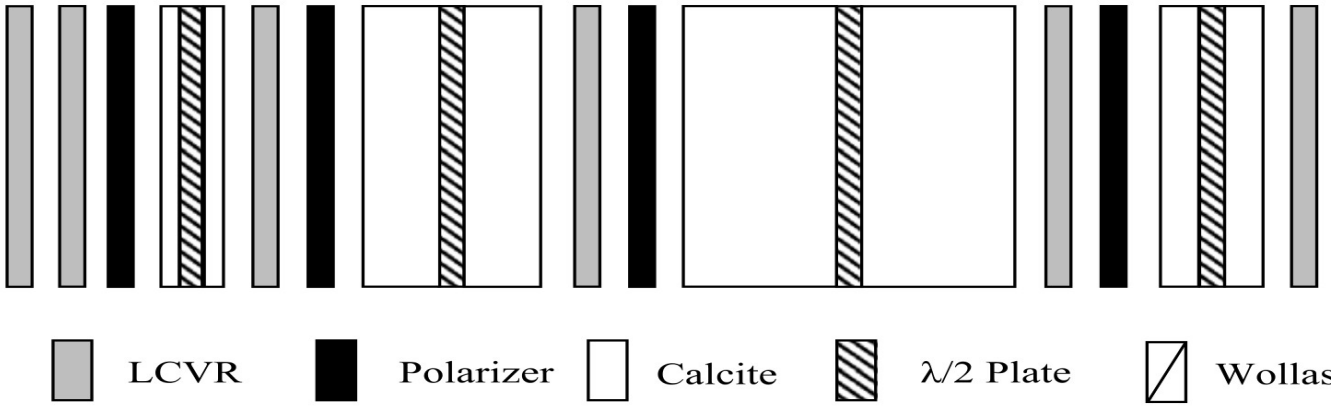
  - super-achromatic λ/2 plates:
    APSAW by ASTROPRIBOR
    range: 0.7- 1.5 $\lambda_{nominal}$

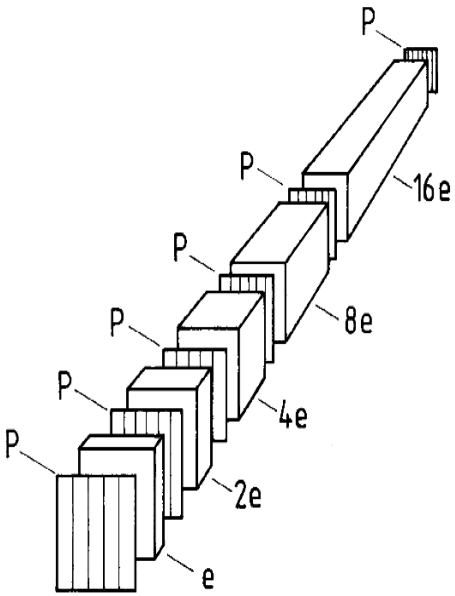


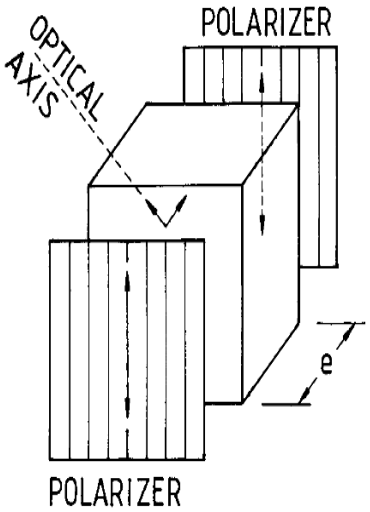


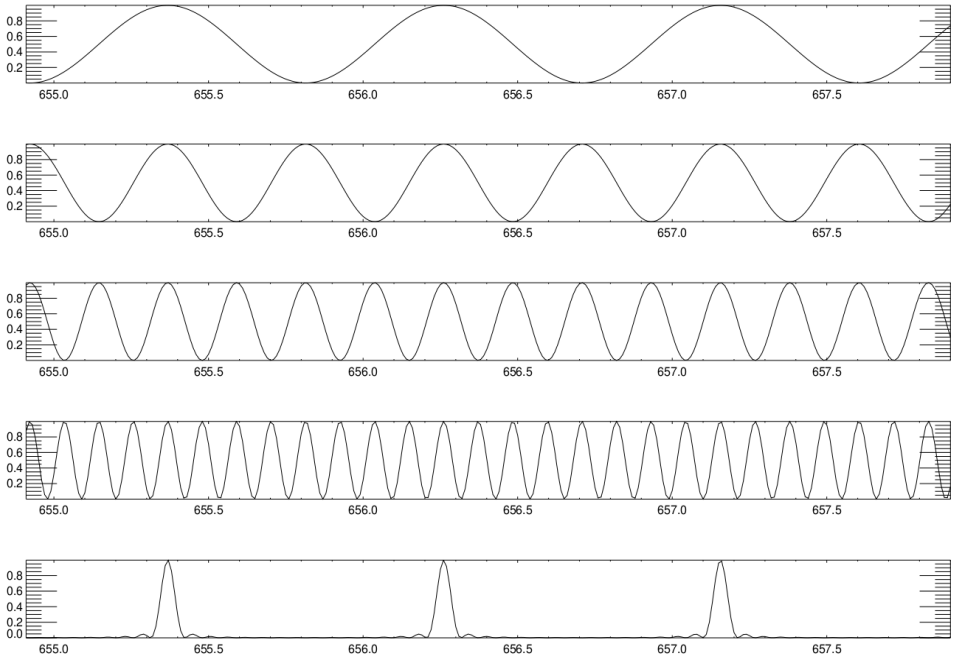
LSO: CoMP-S

- How this can be achieved?



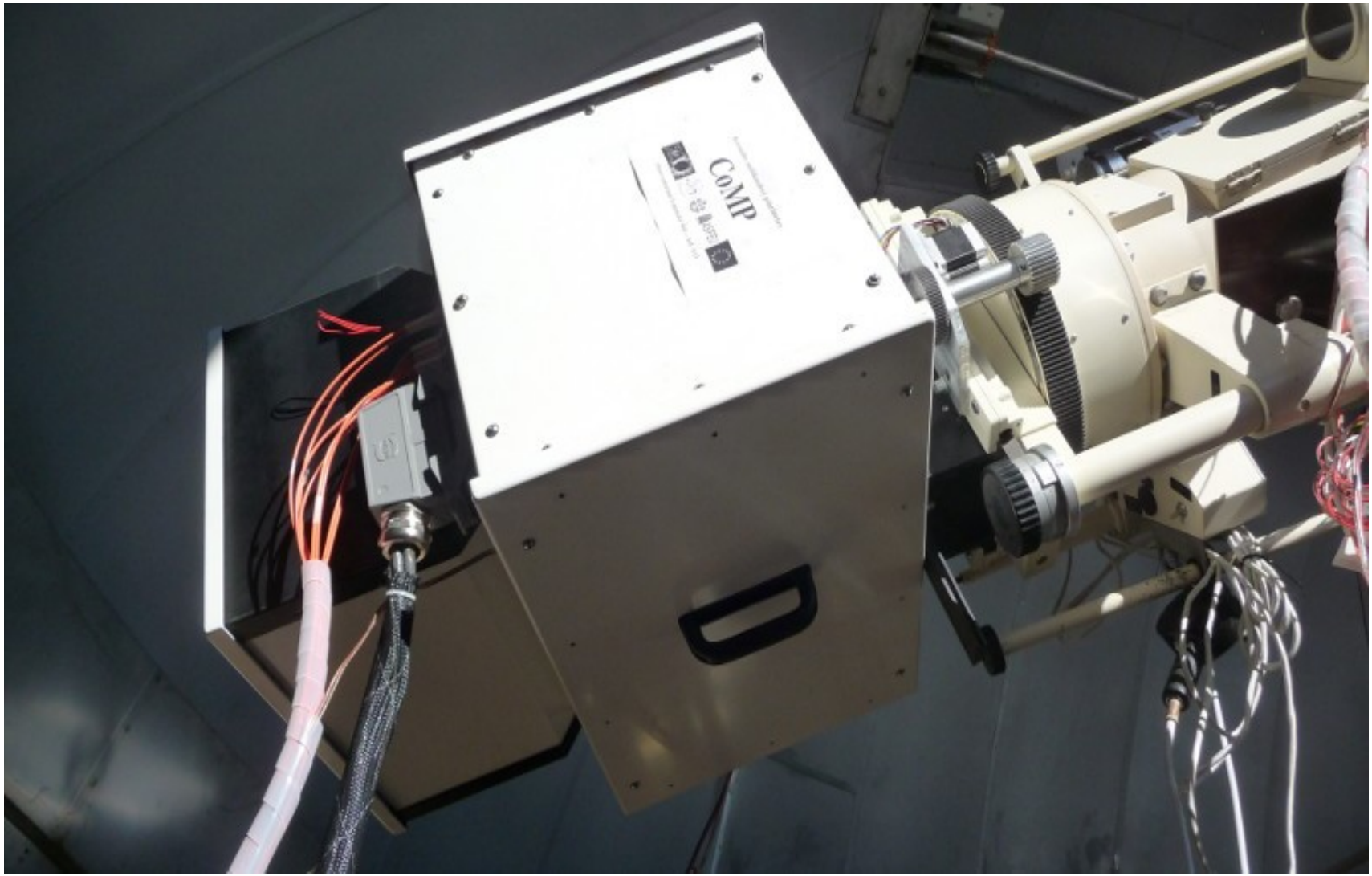






LSO: CoMP-S

Main modules: mechanical interface, filter module, camera module, …



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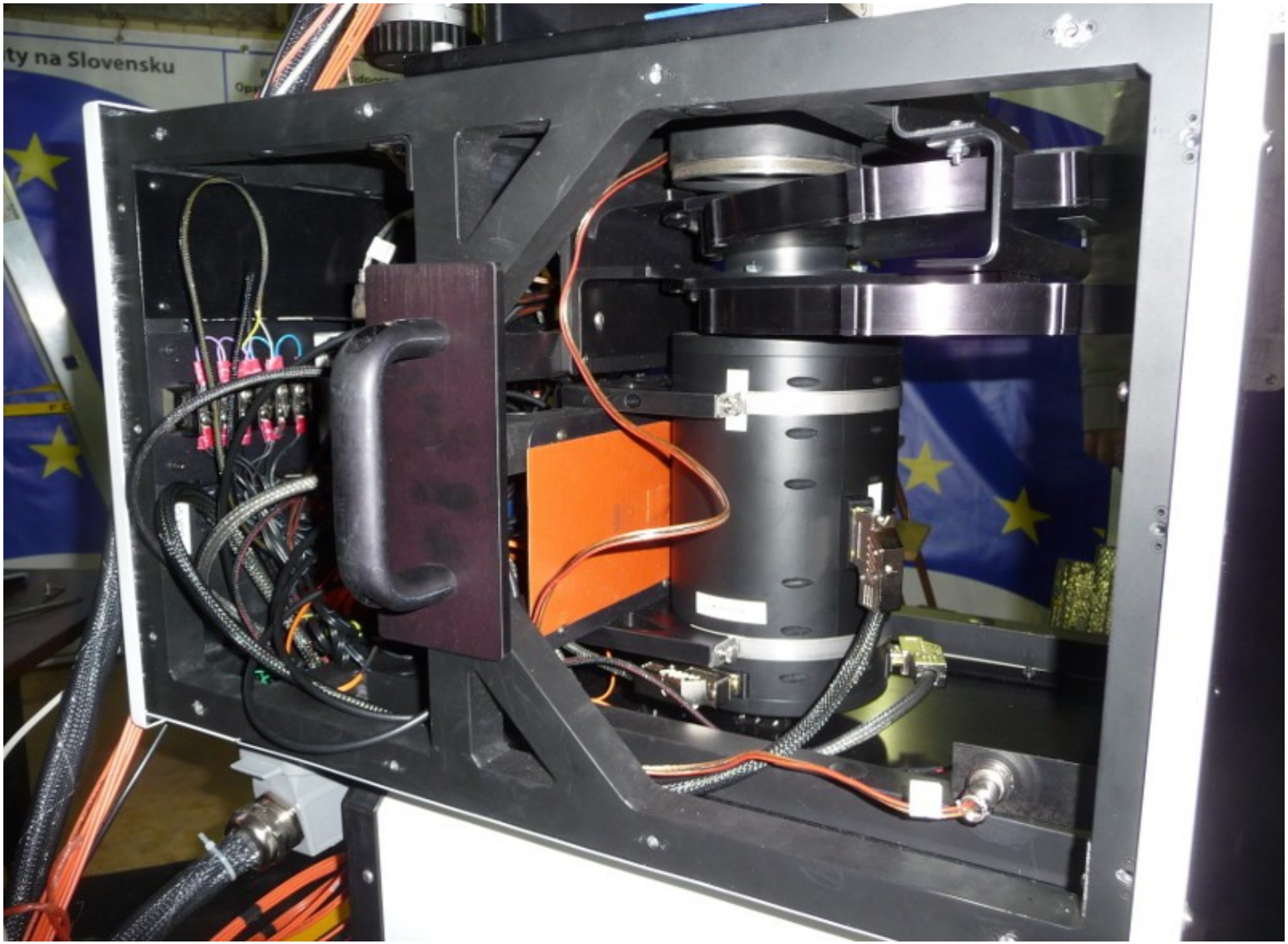
Main modules: filter module

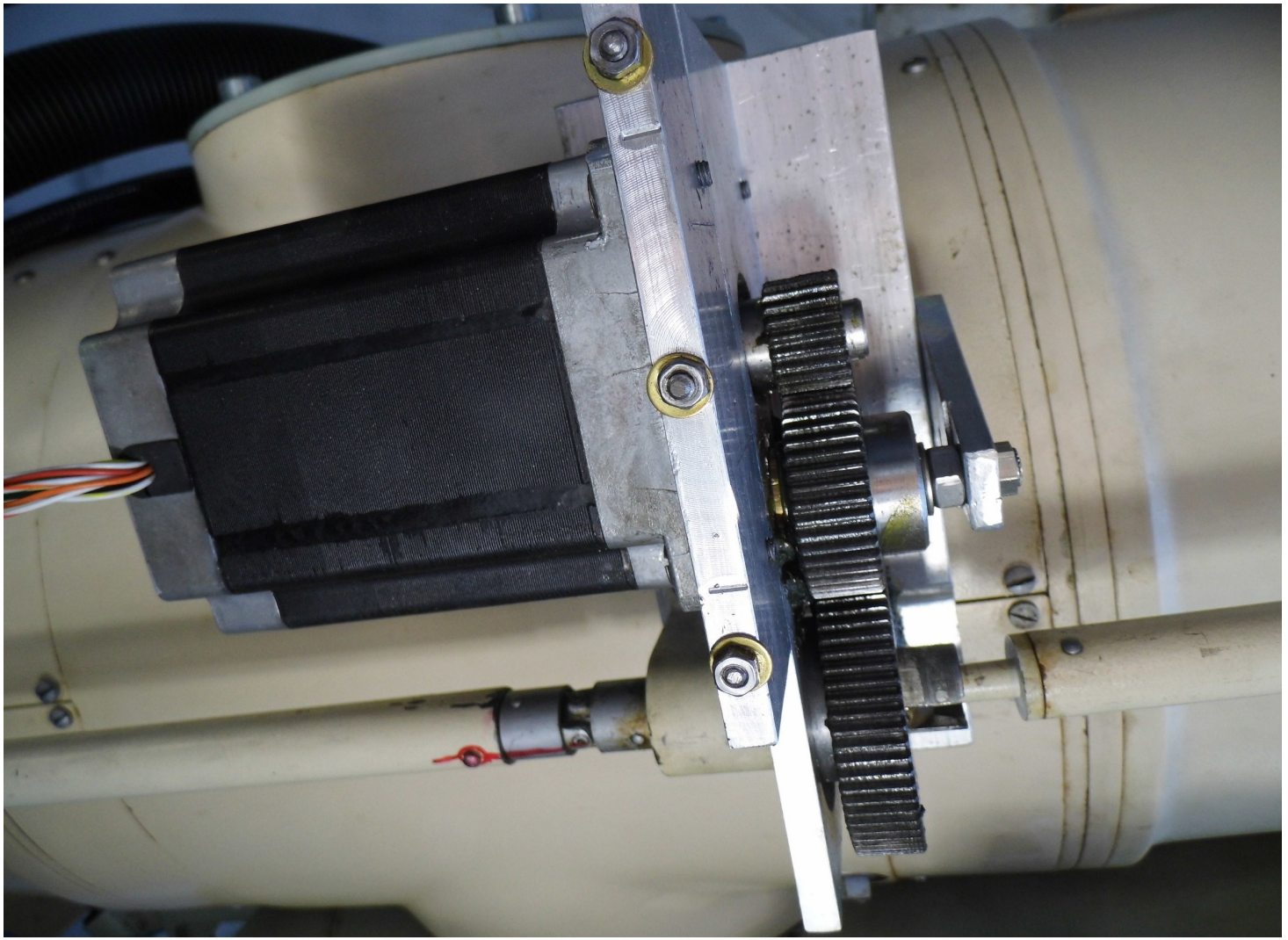


LSO: CoMP-S

Main modules: camera module

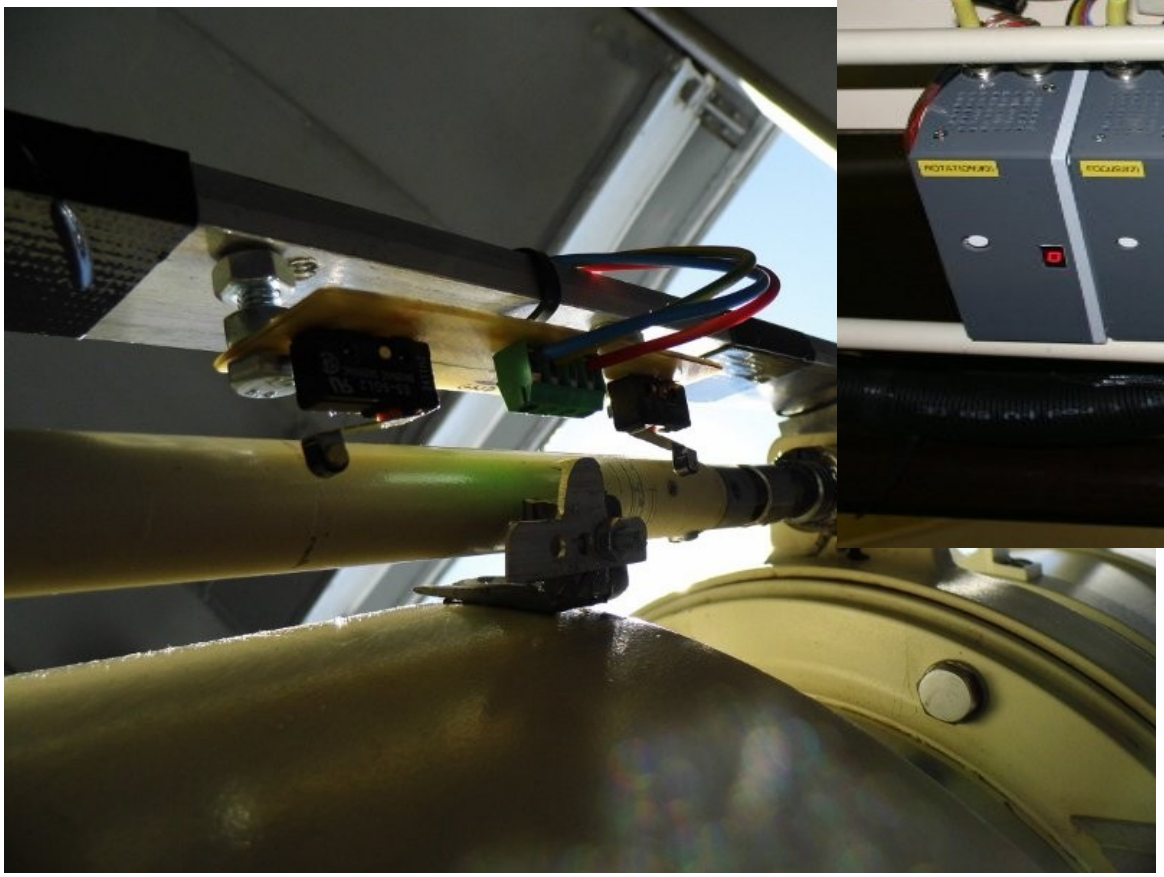
LSO: CoMP-S

Focusing the objective lens: stepper motor Powerpac SM32-5008S



LSO: CoMP-S

Motor electronics for computer operation of the rotation, diffuser, and focusing including end switches



LSO: CoMP-S

CoMP-S instrument briefly:

- installed in March 2011
- regular observations since May 2013

- 4 stage wide-field tunable Lyot filter, FLC polarimeter
- strategy: 2 orthogonal pol. states in shifted bandpasses simultaneously
- selected emission lines:
  corona: Fe XIV 530.3nm, Ca XV 569.5nm, Fe X 637.5nm,
  Fe XI 789.2nm, *Fe XIII 1074.7nm, 1079.8nm*
  prominences: He I 587.6nm, H I 656.3nm, Ca II 854.2nm,
  He I 1083.0nm

- deliverables: 2D I (A,v,w), *2D full Stokes I, Q, U, V*

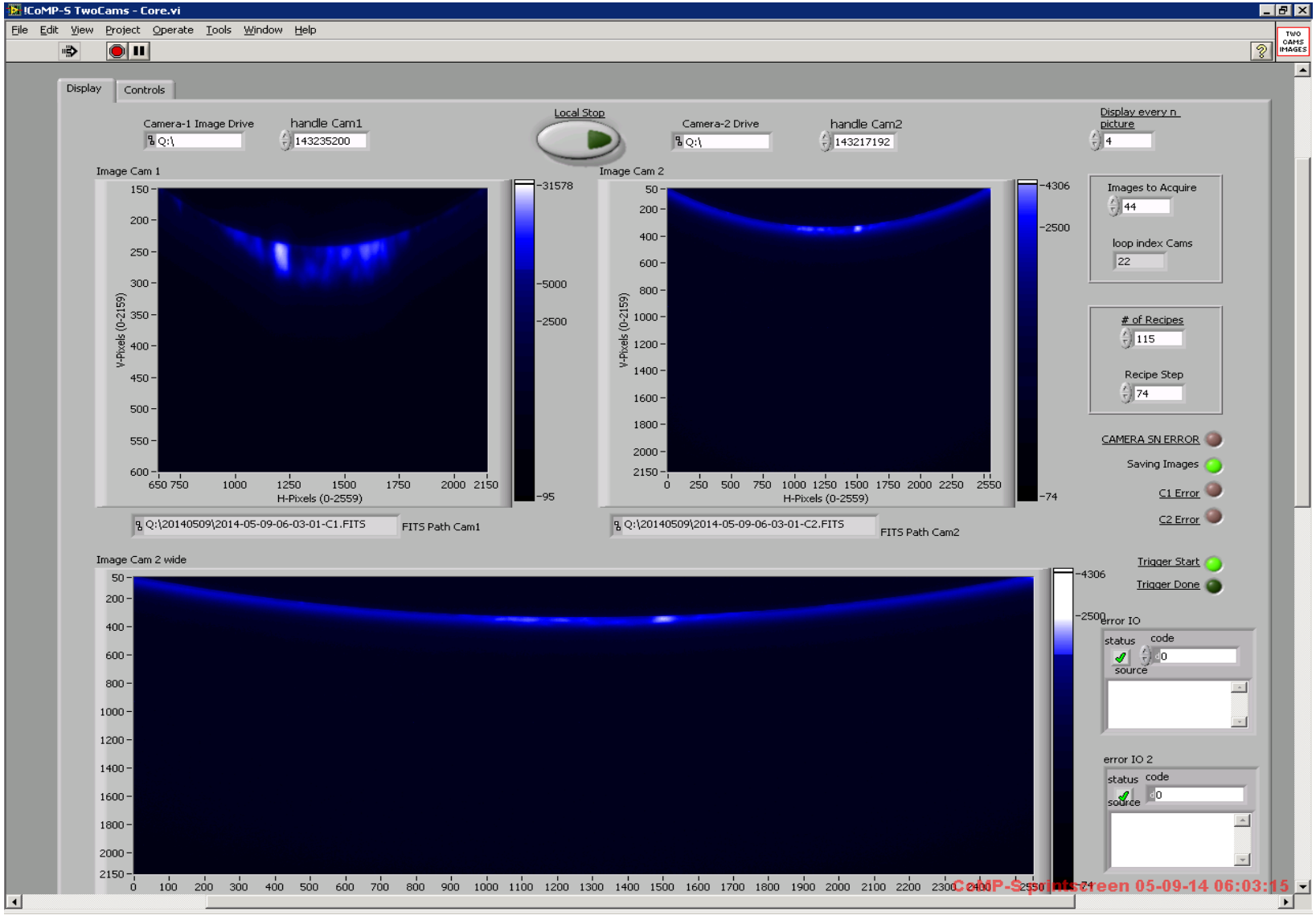
- FoV: ~860” x 680”, diffraction limited (0.33”/pixel @ 656.3nm)

- FWHM: 0.028 - 0.13 nm (530 – 1083nm)

- typical exposure times: ~100 ms – prominence lines
  ~1 s – coronal lines
- wavelength tuning time : ~0.2 s
- polarization change time: ~30 ms

LSO: CoMP-S

Example of the Labview control program GUI – 9/5/2014:



LSO: CoMP-S

Hα quiescent prominence – Oct 20, 2012, 07:09 UT:

- HOP 186 „Mass loading of quiescent prominences from multi-wavelength observations“
- Hα line profile: 11 wavelength settings, only Stokes I parameter presented
- Exposure time: 50 ms, total scan time: 20.75 s, wavelength steps: core: 0.1 Å, wings: 0.2 Å
- post-facto 4 x 4 pixel binning to final sampling: 1.3 arcsec/px
- Gaussian fitting of 11 samples of the H alpha profiles: **amplitude**

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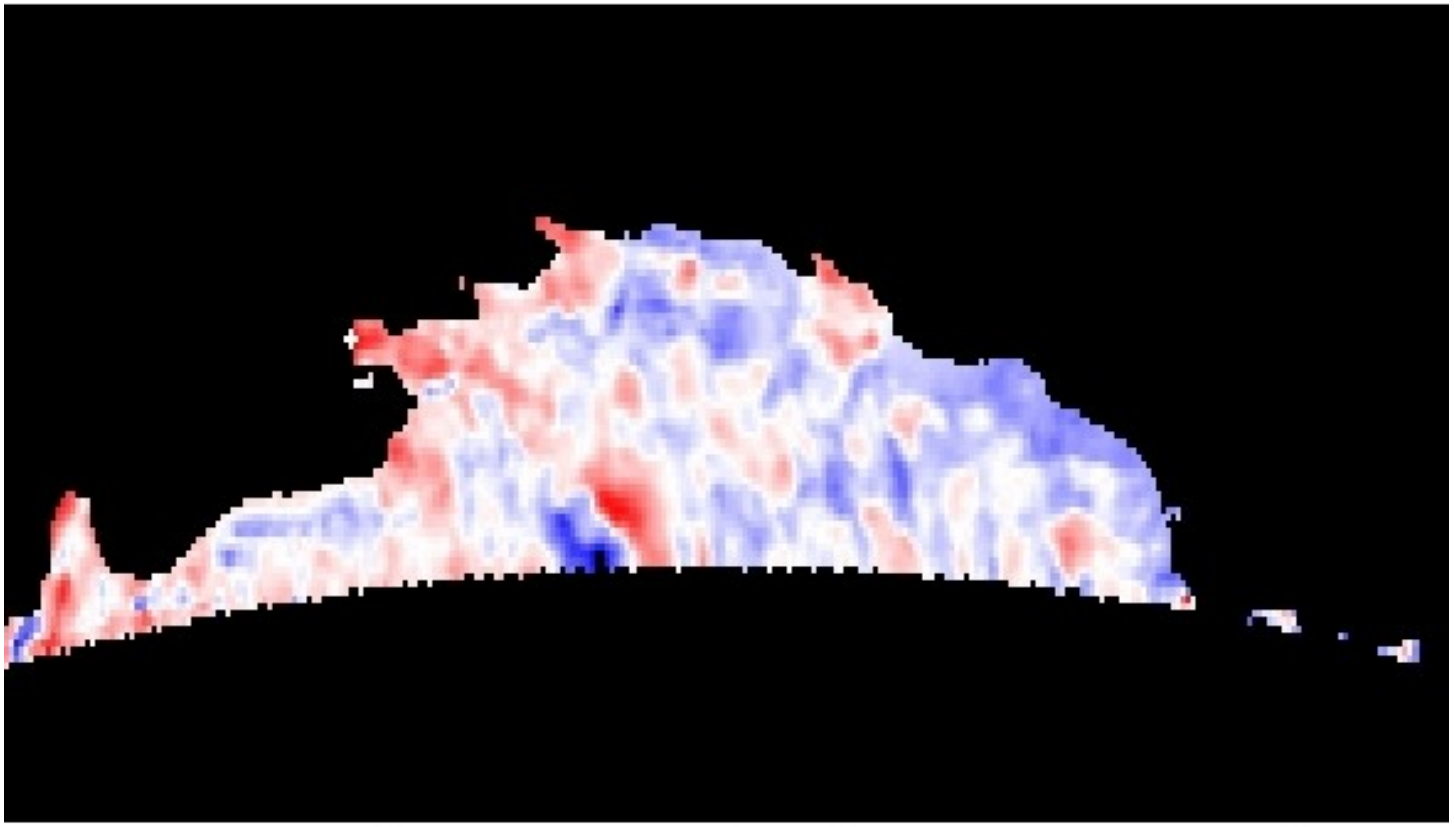
- Gaussian fitting of 11 samples of the H alpha profiles: **dopplershifts [+/-12 km/s]**



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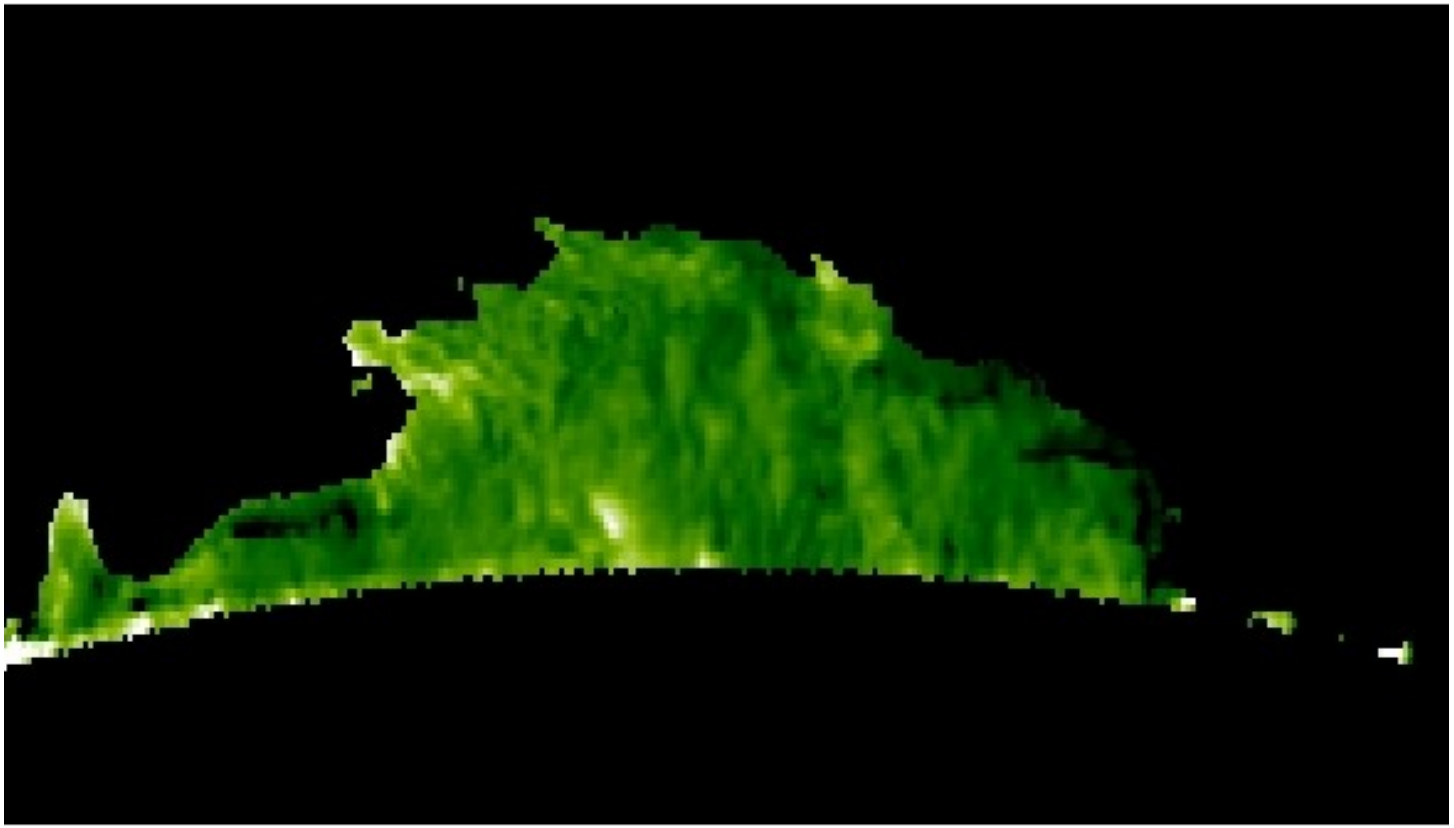
- Gaussian fitting of 11 samples of the H alpha profiles: **Gaussian width [0.020-0.045 nm]**



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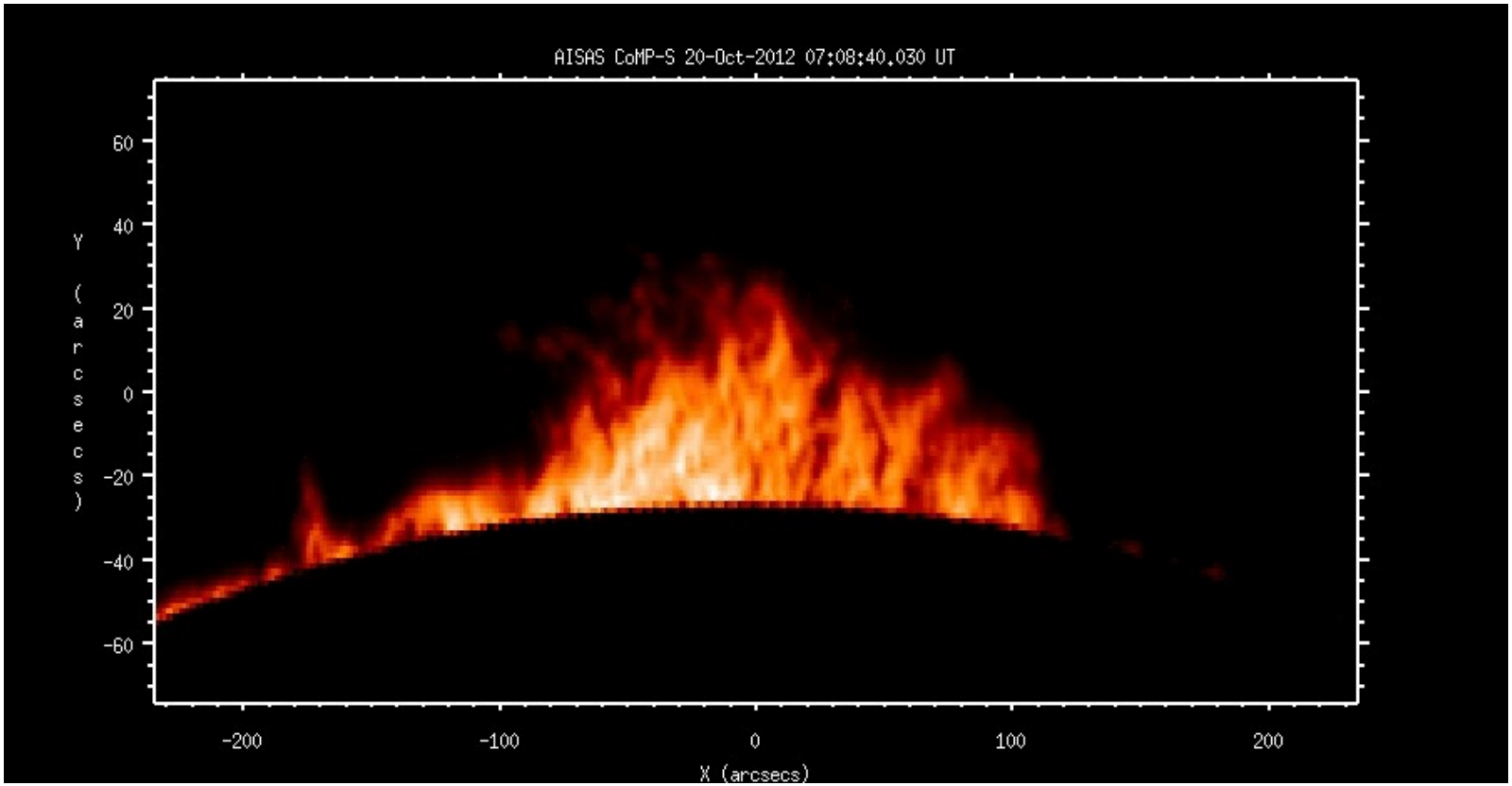
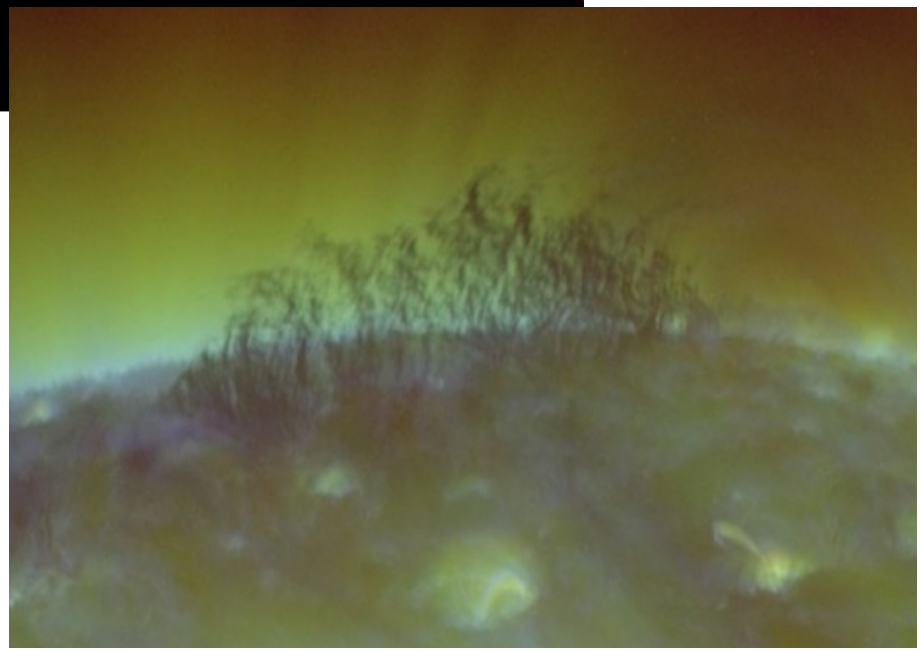
- post-facto 4 x 4 pixel binning to final sampling: 1.3 arcsec/px
- Gaussian fitting: **amplitude ~ dopplershift ~ width**



LSO: CoMP-S

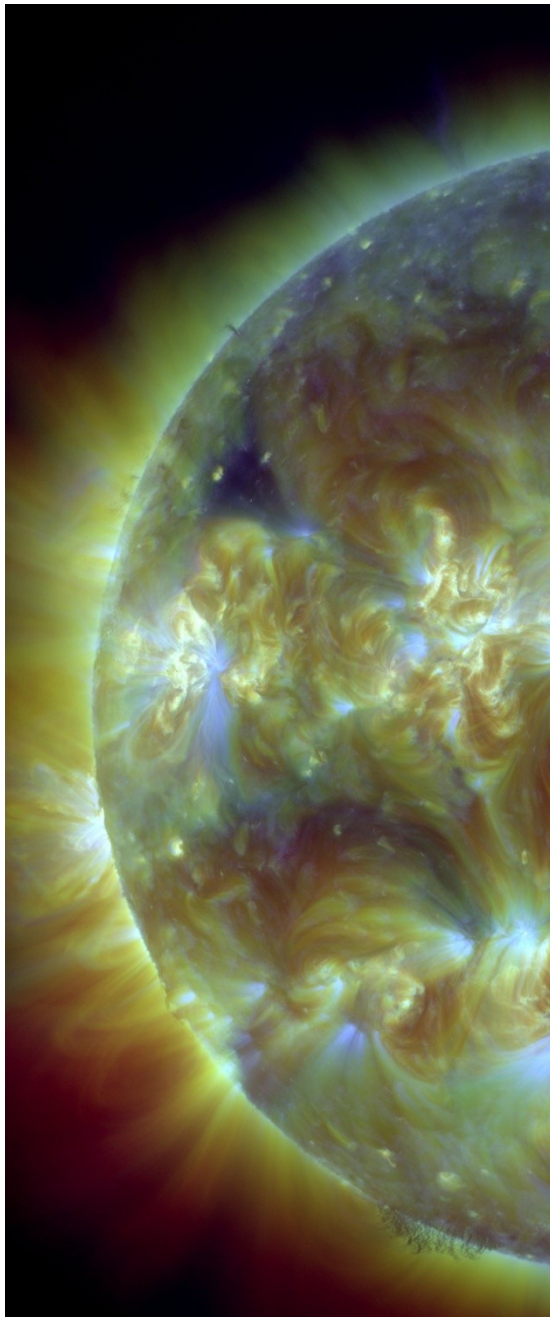
Hα quiescent prominence – Oct 20, 2012:

CoMP-S: 07:09 UT,
H I 656.3 nm



Help of J. Koza

AIA/SDO: 07:11 UT,
21.1+19.3+17.1nm



LSO: CoMP-S

Actual CoMP-S instrument status:

- several problems already solved in cooperation of HAO+AISAS:
  - electrical grounding
  - temperature stabilization (heating and also cooling)
  - simplification of data acquisition
  - replacement of the PCO edge sCMOS cameras
  - reliability of the external diffuser in/out, rotation, focusing actions

- regular observations

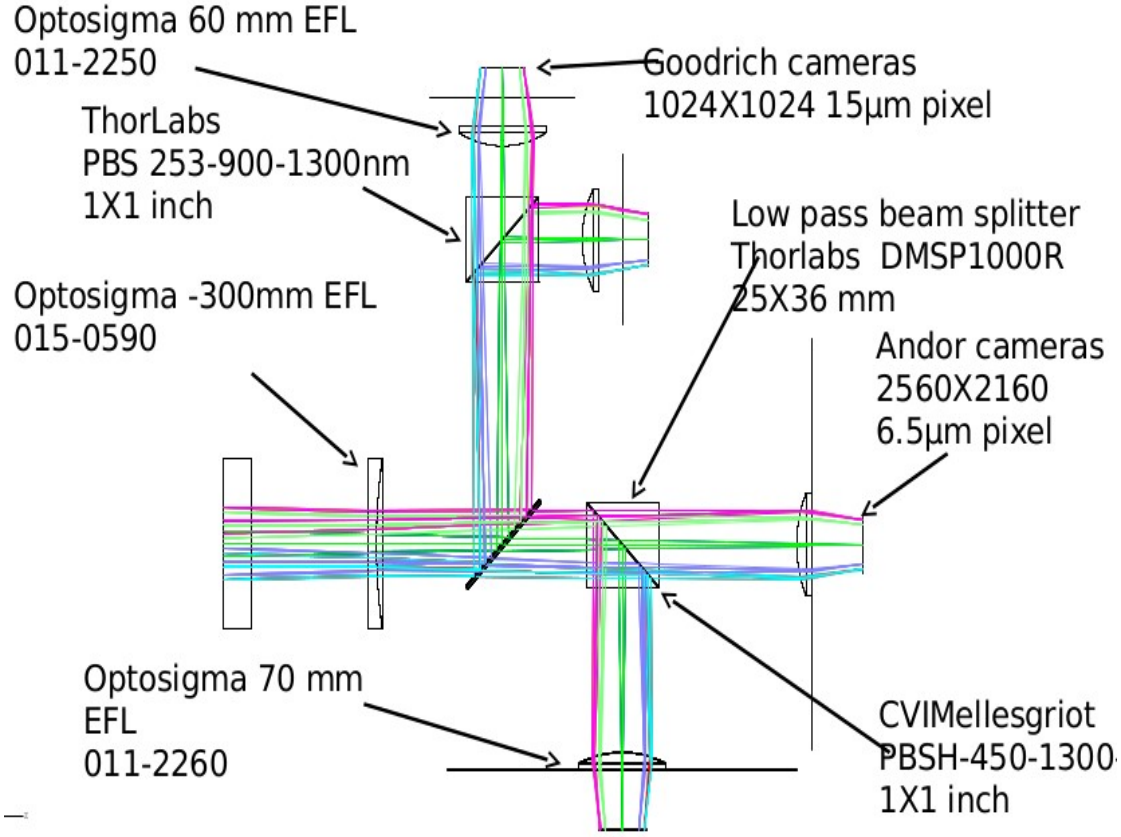
- still some problems of different types unsolved so far:
  - mechanical stability of the camera module
  - PCO edge sCOMS cameras + LabVIEW operation reliability
  - problems with the polarizing cube beam splitter for 530 nm

- an upgrade of the CoMP-S instrument:
  - requirement to add IR detectors to the camera module
  - technical solution of the faced problems mentioned above

LSO: CoMP-S + PDSS

The Post-focus Detectors for Solar Spectrometer – PDSS: an upgrade of the original CoMP-S camera module

Main feature: new detectors for VIS + near-IR spectral ranges: VIS - ANDOR Neo, near IR – Goodrich GJ 1280, better mechanics for stability, focusing, a new computer, a little more optics and electronics



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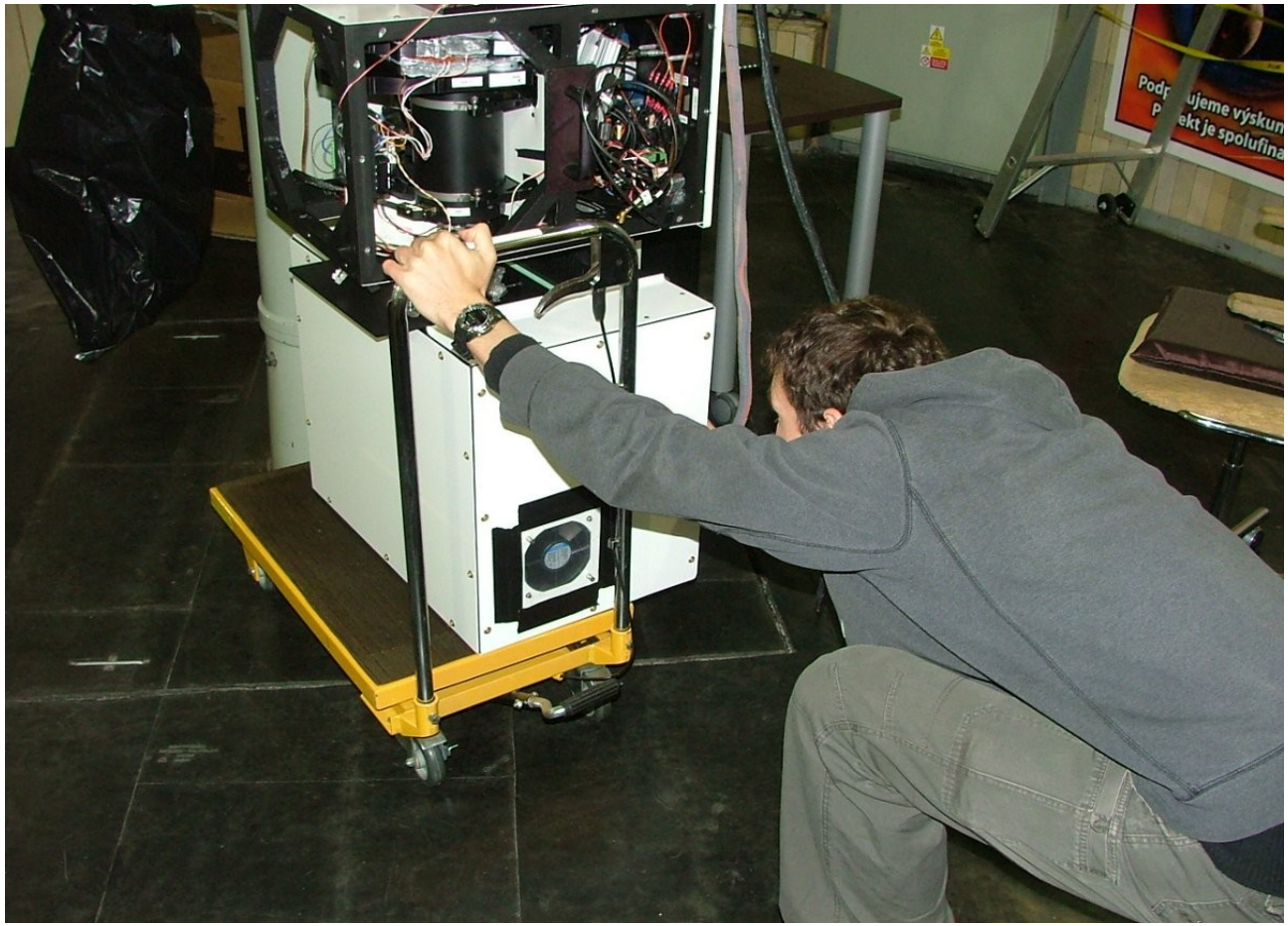
The PDSS actual status: the instrument has been delivered to AISAS, the first mechanical and electrical tests have started recently



Matúš Kozák moving the PDSS under the CoMP-S for the first time (13/05/2014)

LSO: CoMP-S + PDSS

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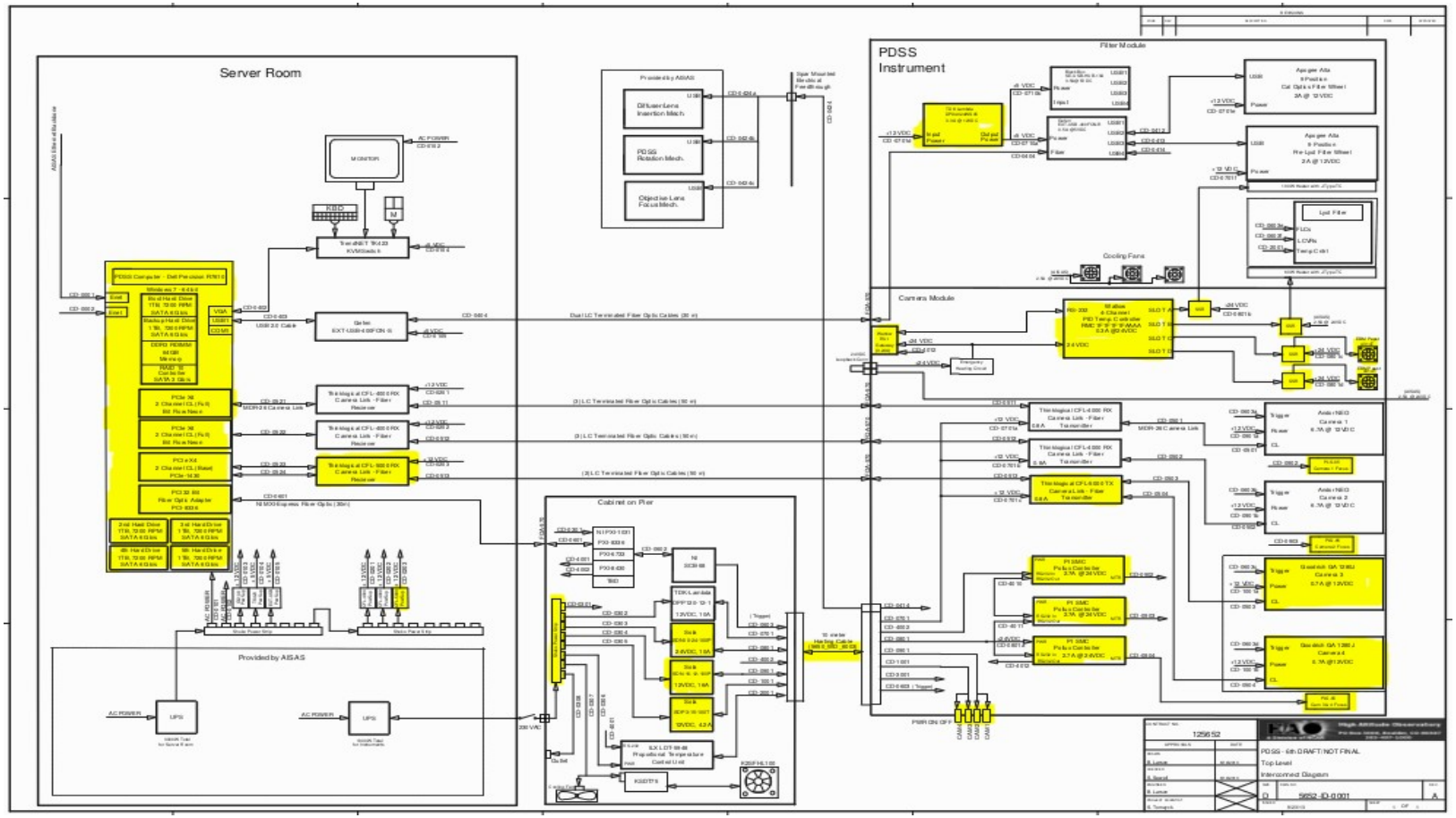
LSO: CoMP-S + PDSS

The PDSS actual status: the instrument has been delivered to AISAS, the first mechanical and electrical tests have started recently, expected incorporation to the CoMP-S instrument – January 2015



A general interconnect diagram of the CoMP-S + PDSS (yellow)

LSO instrumentation

CoMP-S with PDSS
pointer R
CorMag
pointer H
SCD
H alpha full disk+aureola

LSO: pointer R

Photoelectric digital pointing telescope:

- “uhrgang” is not enough due to changing declination of the Sun
- a residual bending of the coronagraph tube (45“ at 45°, up to 8“/hour
- simple idea helping to solve this problem

LSO: pointer R

Photoelectric digital pointing telescope: a 50/300 single lens attached to the coronagraph objective lens only

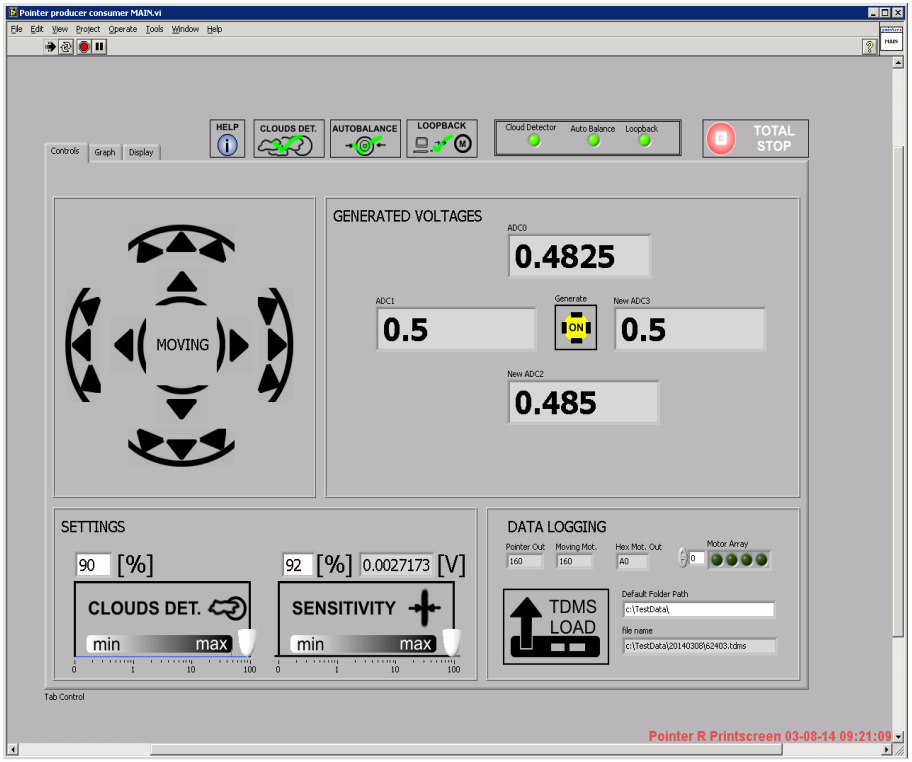
LSO: pointer R

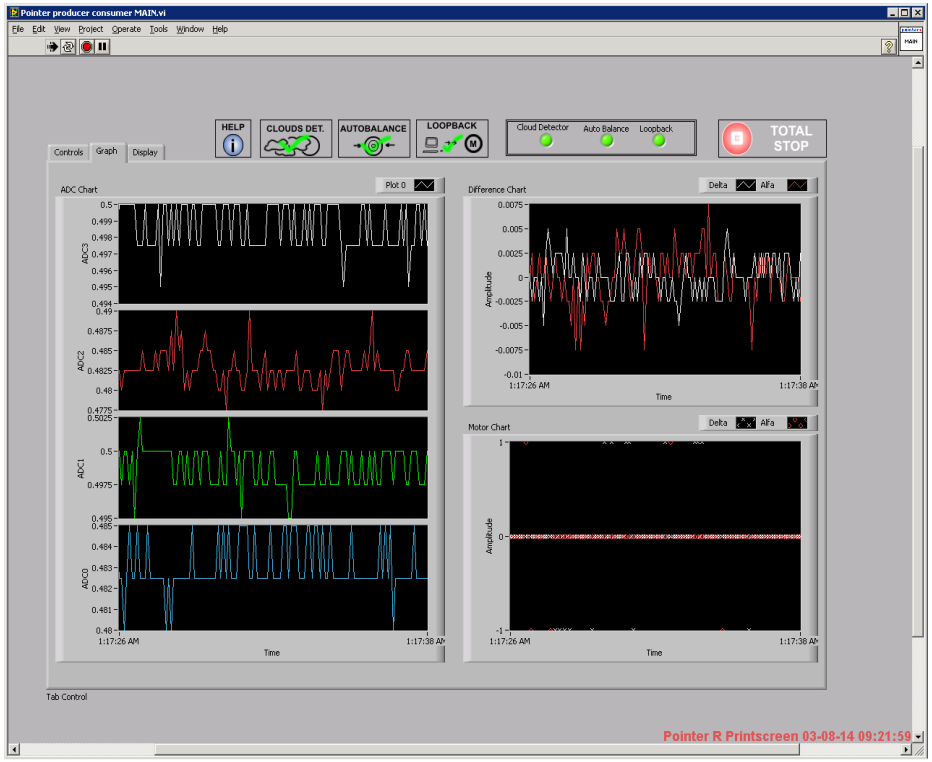
Photoelectric digital pointing telescope: 4 photodiodes attached to the artificial moon assembly only

LSO: pointer R

Photoelectric digital pointing telescope:

- AISAS: work of Matúš Kozák - electronics + LabVIEW code
- 2.3” pointing precision
- detector of clouds
- correction for a starting off-pointing
- logging





LSO: pointer R

Photoelectric digital pointing telescope: 4 photodiode voltages

LSO: pointer R

Photoelectric digital pointing telescope: photodiode voltage differences

LSO instrumentation

CoMP-S with PDSS
pointer R
CorMag
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LSO: CorMag

The Coronal Magnetometer (Cormag) at LSO since September 2014

- team of prof. S. Fineschi (Osservatorio Astronomico di Torino)
- originally part of ASPIICS - a solar coronagraph to be flown on PROBA 3
- a liquid crystal Lyot tunable-filter and polarimeter (LCTP)
- nematic liquid crystal variable retarders (LCVRs)
- a four stage Lyot filter with all four stages wide-fielded
- bandpass FWHM 0.15 nm, FSR 2.7 nm (at 530.3 nm)
- tunable in 0.01 nm steps

*Fineschi et al., Proc. of SPIE **8148,** 814808-1, 2011*

LSO: CorMag

The Coronal Magnetometer (Cormag) at LSO since September 2014

- tests/modifications/observations performed at LSO
- instrument hosted at the left coronagraph
- excellent plans in our minds: green-green, green-H alpha,...
- more detail information in the lecture of G. Capobiano later

LSO instrumentation

CoMP-S with PDSS
pointer R
CorMag
pointer H
SCD
H alpha full disk+aureola

LSO: pointer H

Pointer of the company HANKOM (pointer H)

Why another device is needed?

Reasons:

1/ two coronagraphs are offset now for hundreds of arc seconds
2/ individual tube is bending during the day (max. change of 8“/h)
3/ general offsets in declination and hour angle are variable

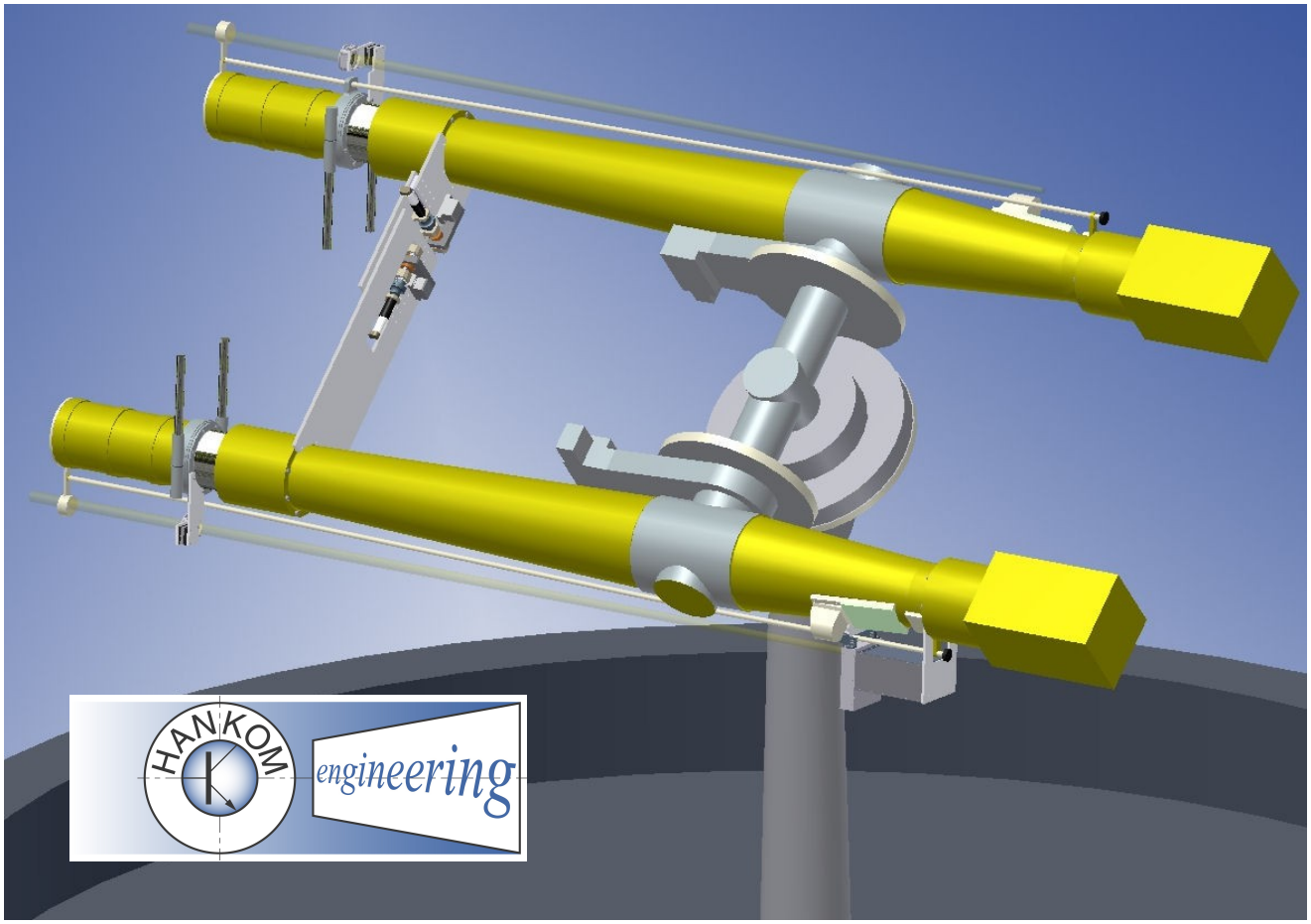
LSO: pointer H

How to correct these mechanical problems?

LSO: pointer H

How to correct these mechanical problems?

Objective lens shift with an on-line correction of the tube directions by pulling/pushing their hour angle distance and variating their declination difference. Easy to write but a little harder to do! HANKOM company...



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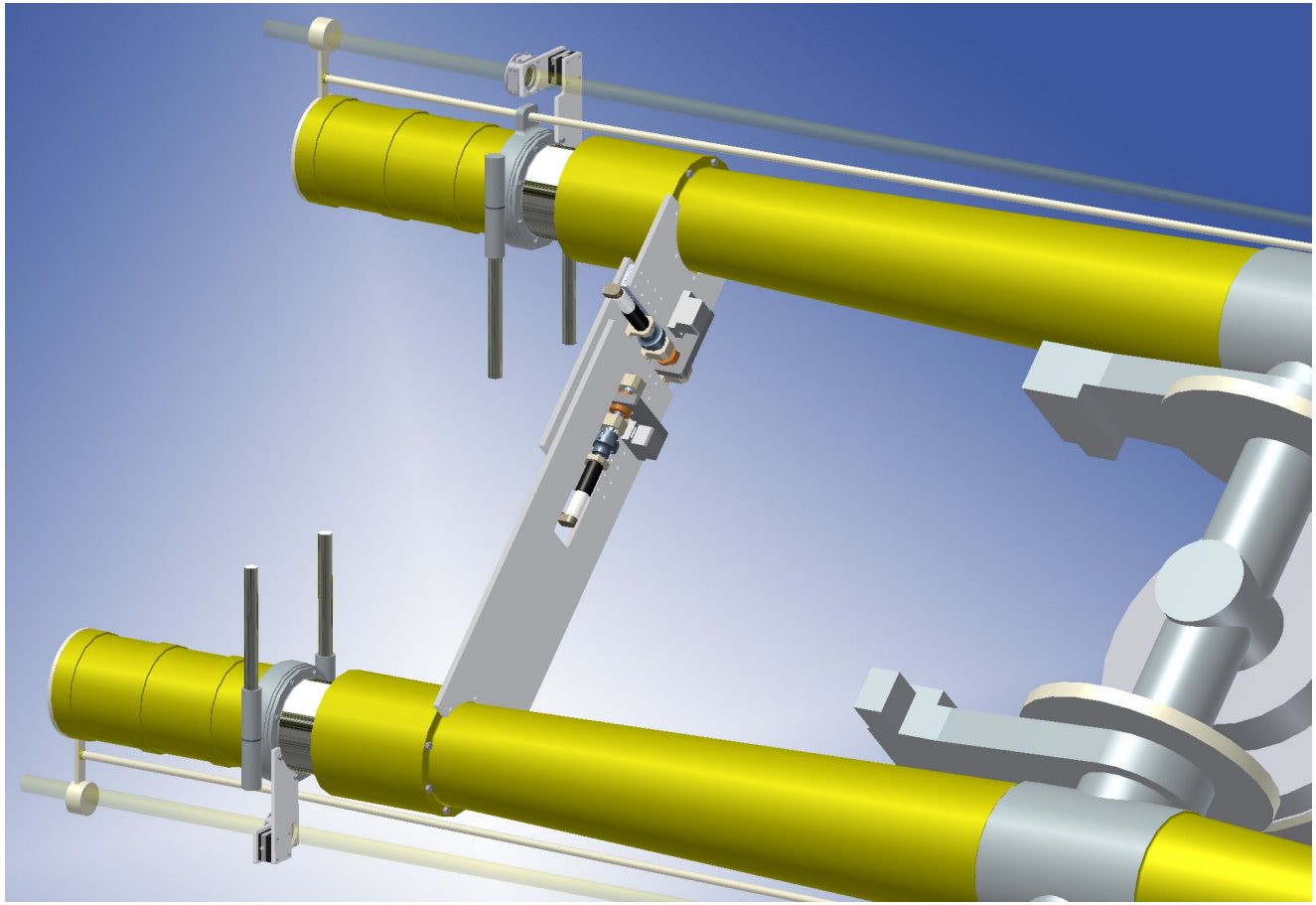

An alignment unit - sketch

LSO: pointer H

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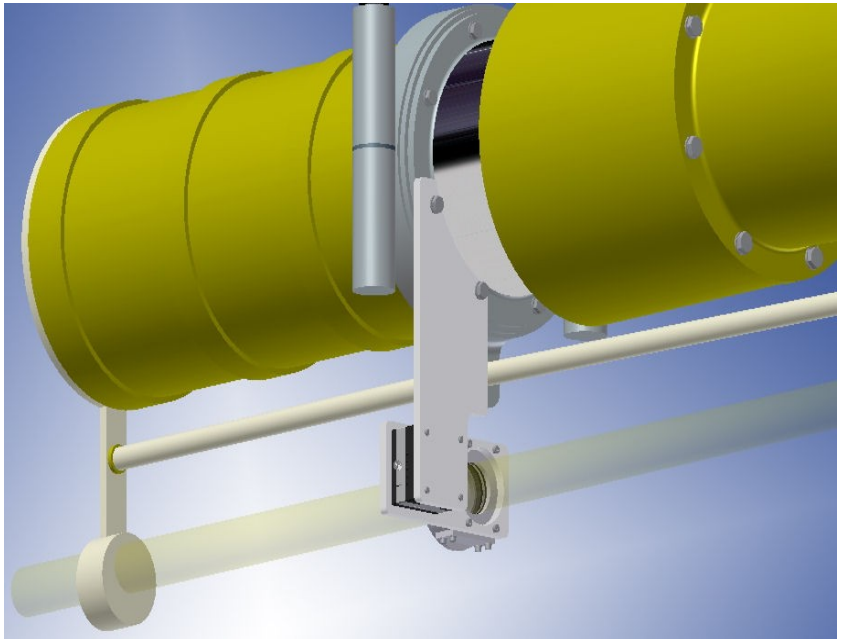
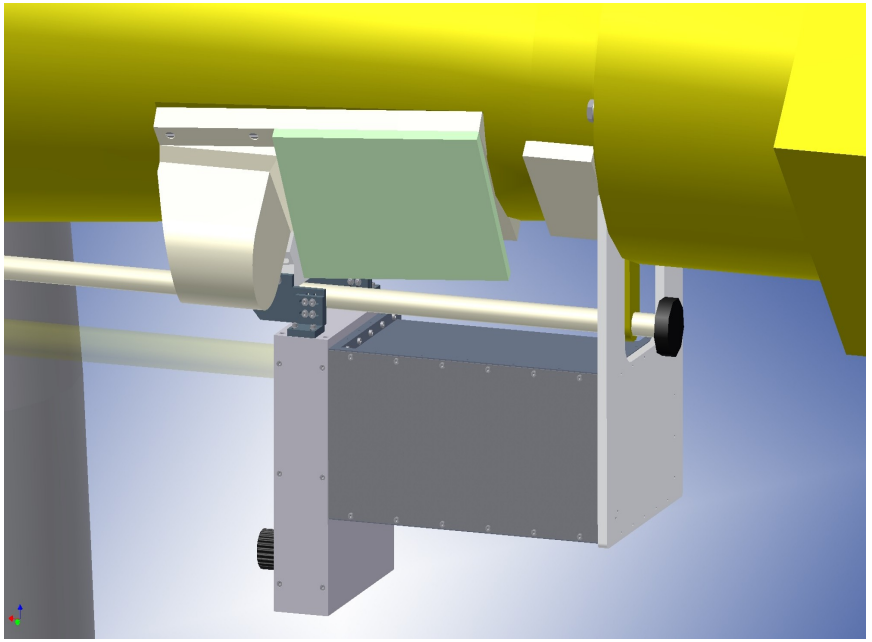


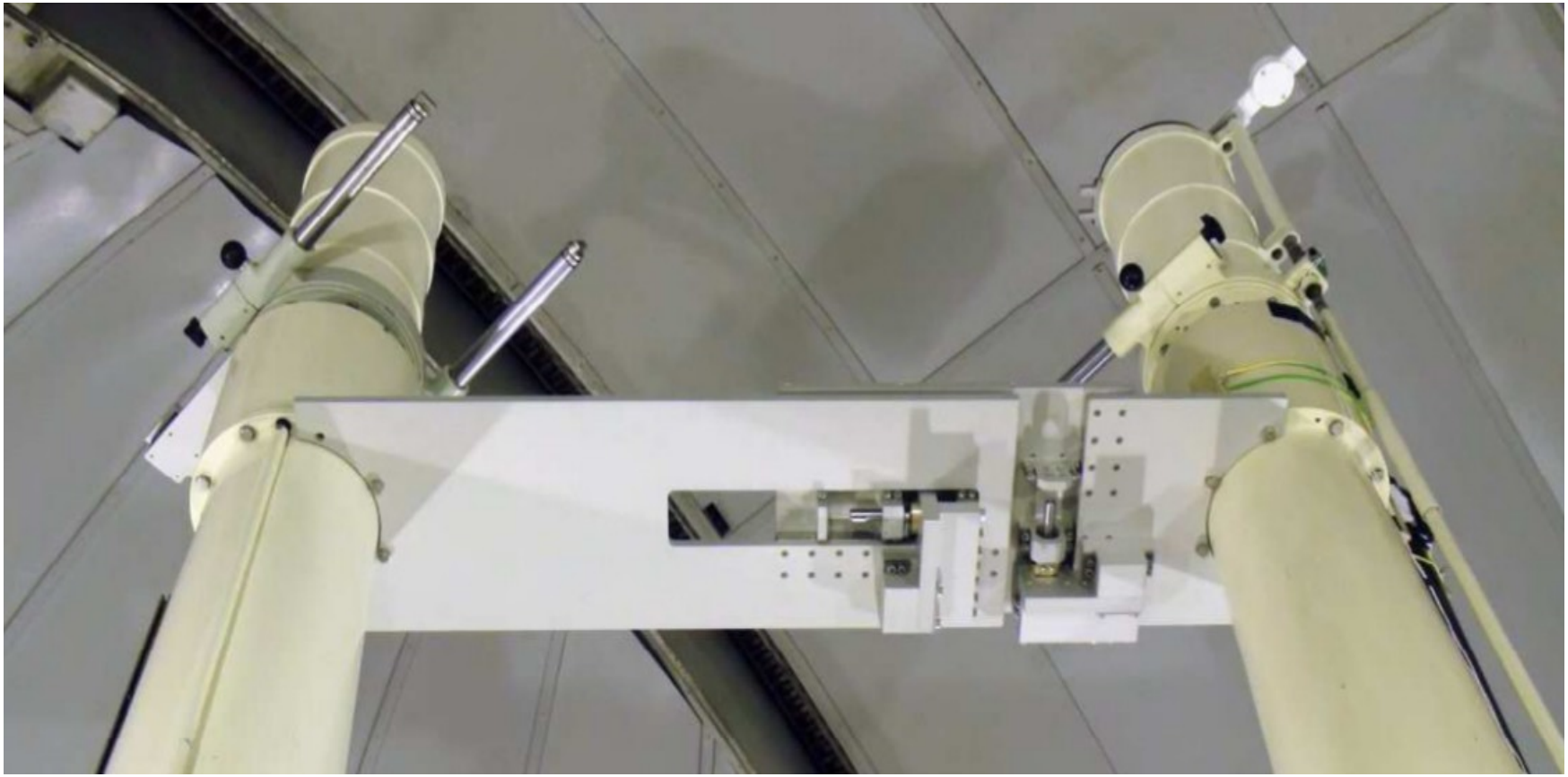
A lens unit - sketch



A detector unit - sketch

LSO: pointer H

Realization: HANKOM company

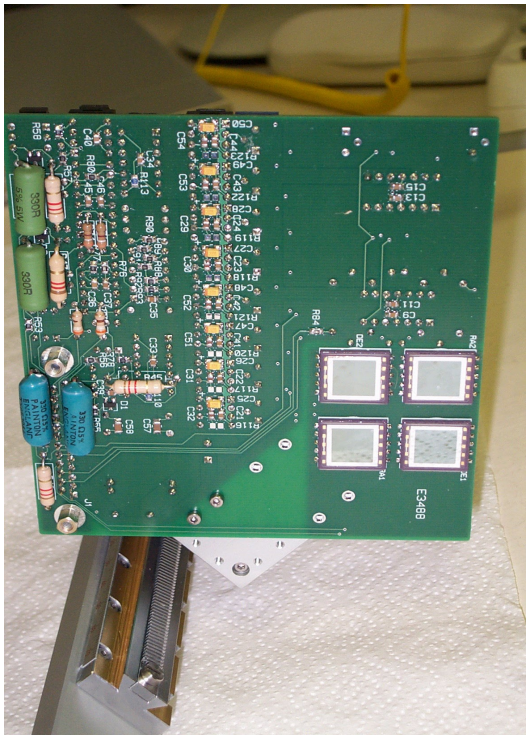


The alignment - reality

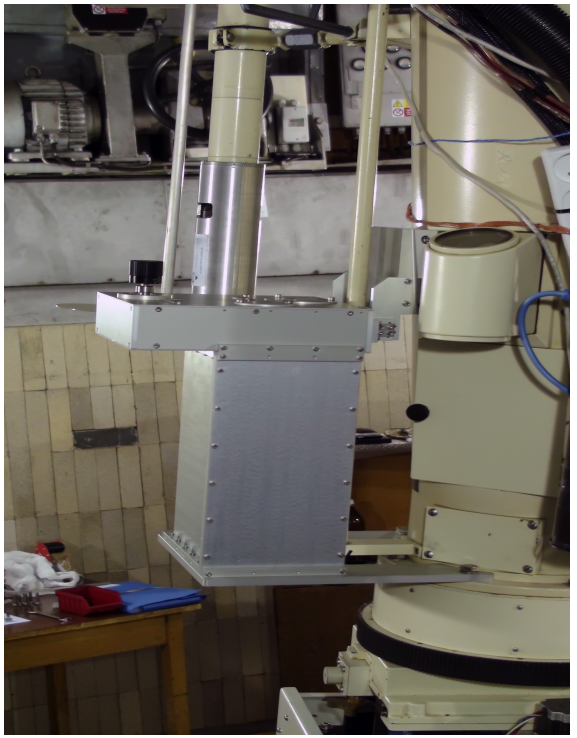
LSO: pointer H

Realization: HANKOM company

The lens unit - reality



Electronics - reality



The detector unit - reality

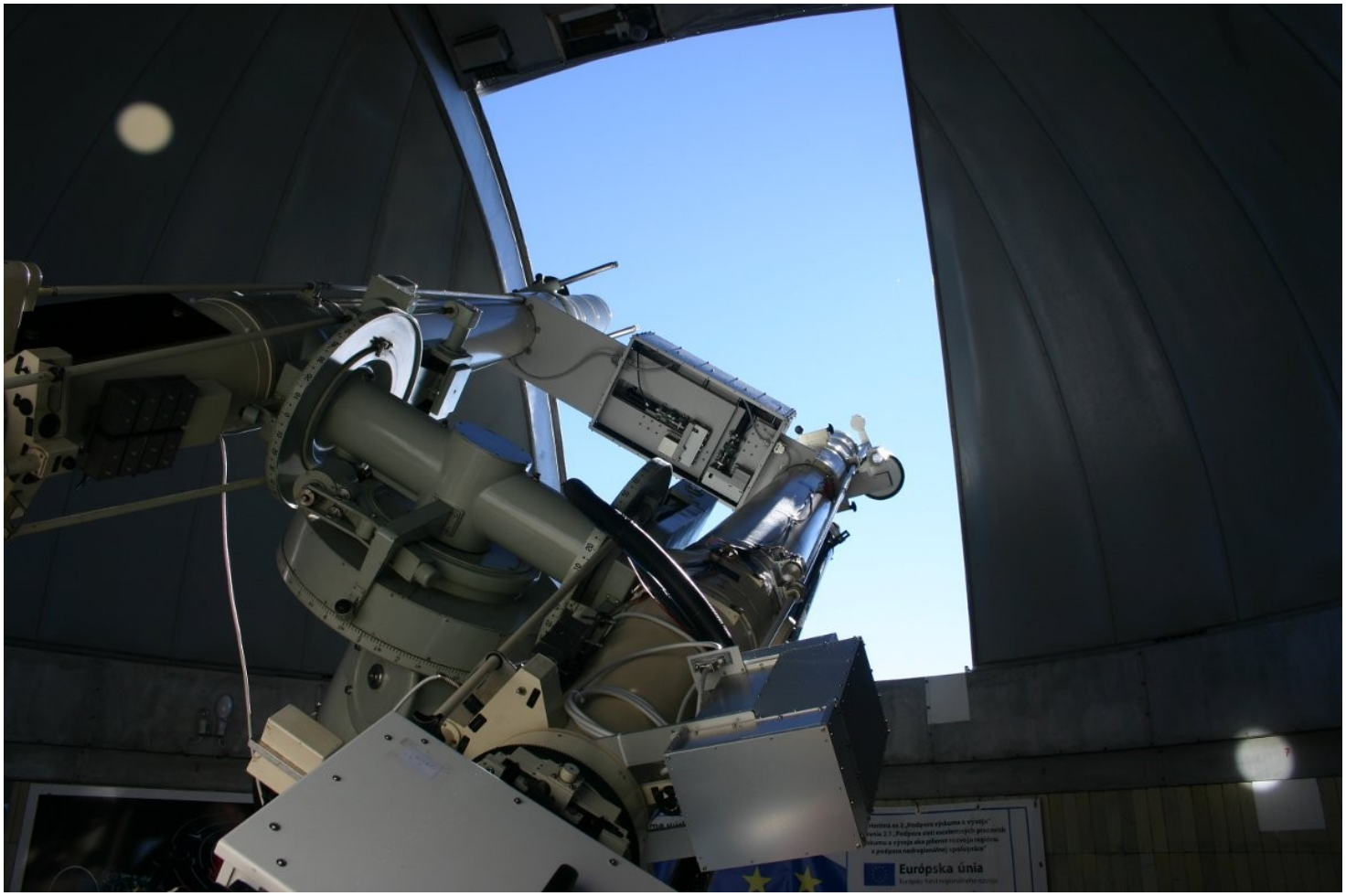
LSO: pointer H

Small celebration: two Zeiss coronagraphs pointed properly to the solar disk center for **simultaneous** coronagraphic scientific measurements for the first time on **21/05/2014** (for an hour in frame of the coordinated observing campaign with Hinode/EIS+XRT+SOT + IRIS)

LSO: pointer H

Small celebration: two Zeiss coronagraphs pointed properly to the solar disk center for **simultaneous** coronagraphic scientific measurements:

24-26/09/1970 → 21/05/2014



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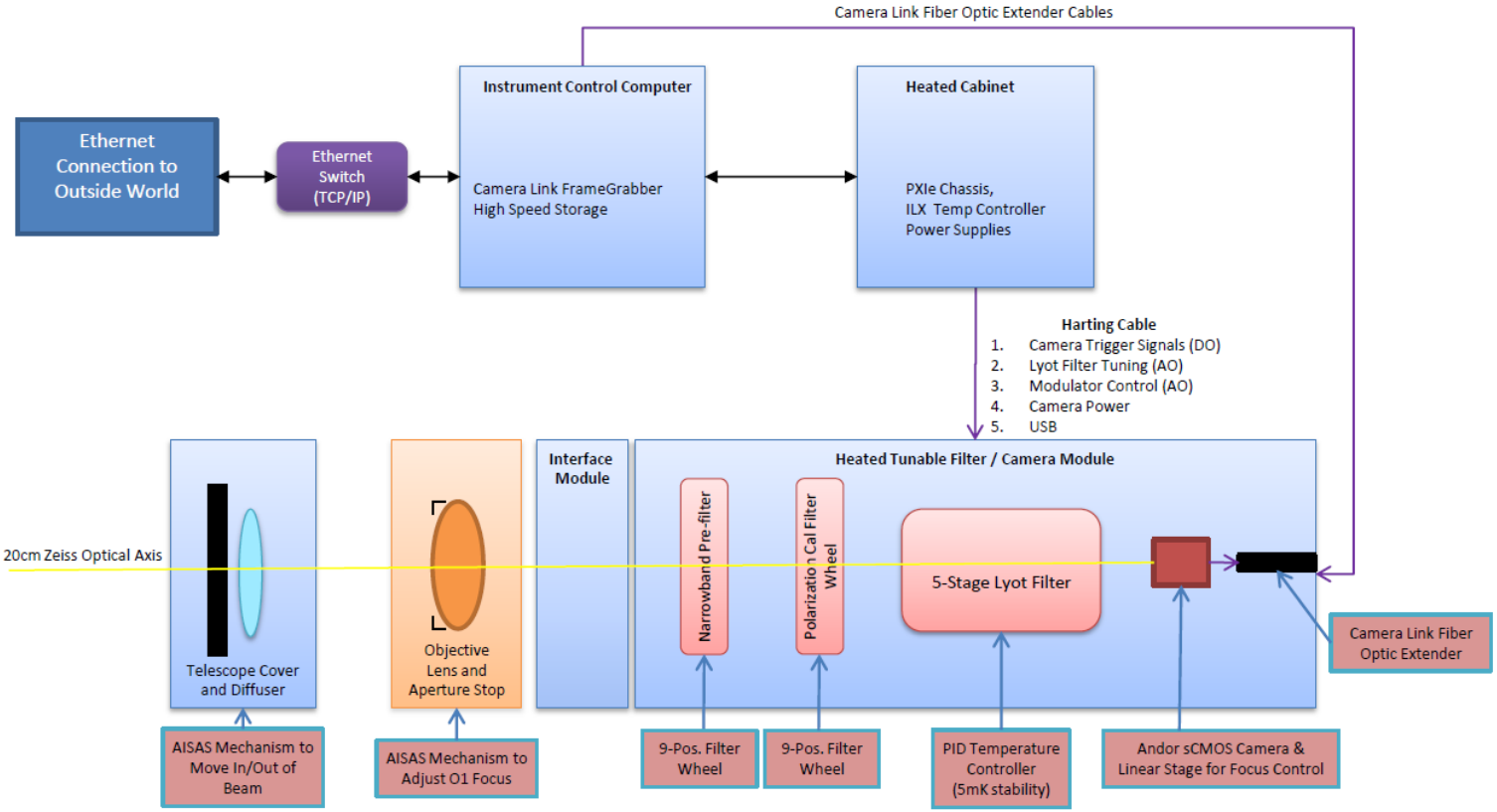
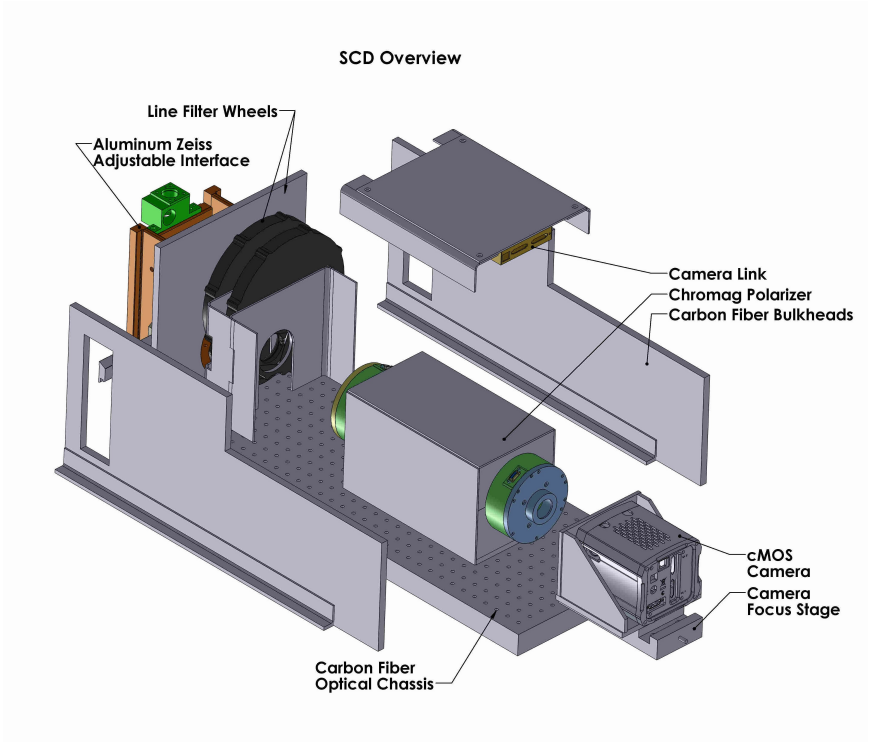
LSO: Solar Chromospheric Detector (SCD)

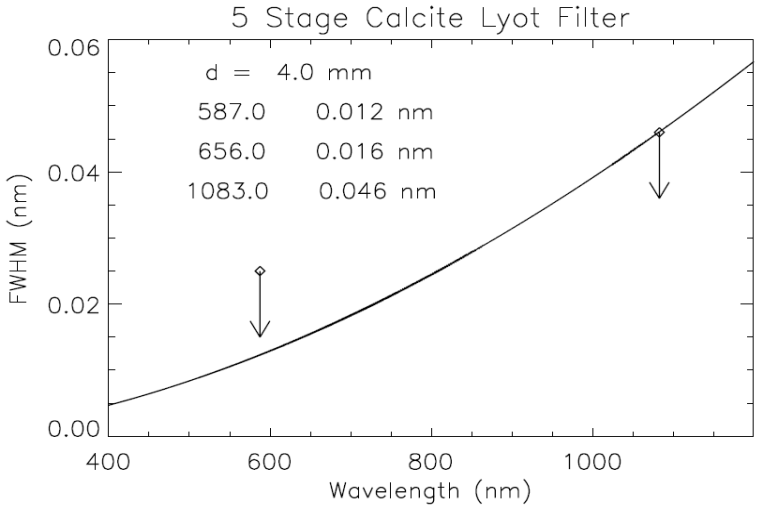
- a contract with HAO/NCAR – “CHROMAG for Slovakia“
- 5-stage Lyot filter + polarimeter
- wavelength range: 500-1100 nm
- chromospheric lines: He I 587.6 nm, Na I 589.6 nm, H I 656.3 nm,
  CaII IR triplet and HeI 1083.0 nm
  photospheric lines: Fe I 557.6 nm, Fe I 630.25 nm
- Andor sCMOS NEO camera: 2560 x 2160 pixels of 6.5 micron size

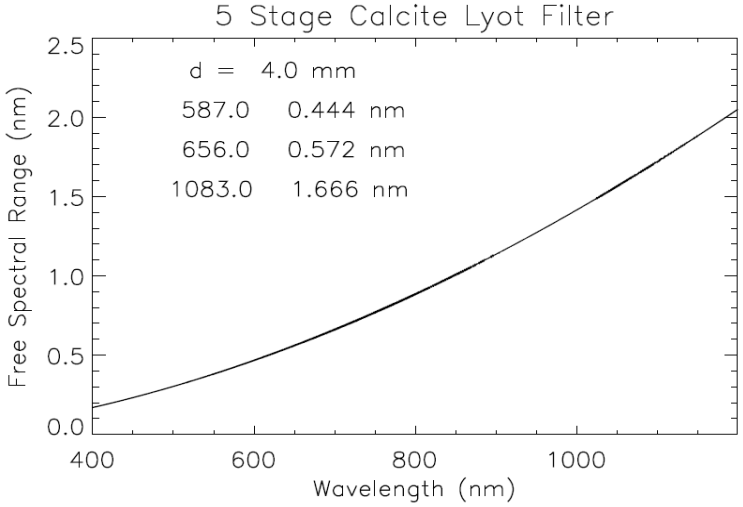


LSO: Solar Chromospheric Detector (SCD)

- a contract with HAO/NCAR – “CHROMAG for Slovakia“
- 5-stage Lyot filter + polarimeter
- FWHM: 0.012nm@587nm →
  0.046nm@1083nm







LSO coronal polarimetry prospects

Instrumentation & Observations

LSO coronal polarimetry prospects

A summary of current situation:

- 2 ZEISS coronagraphs
- 2 post-focus spectropolarimeters: CoMP-S and CorMag
- co-pointing system

LSO coronal polarimetry prospects

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- installation of the PDSS – upgrade of the CoMP-S
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- installation of the SCD instrument
- optimization of the hour drive/pointing system

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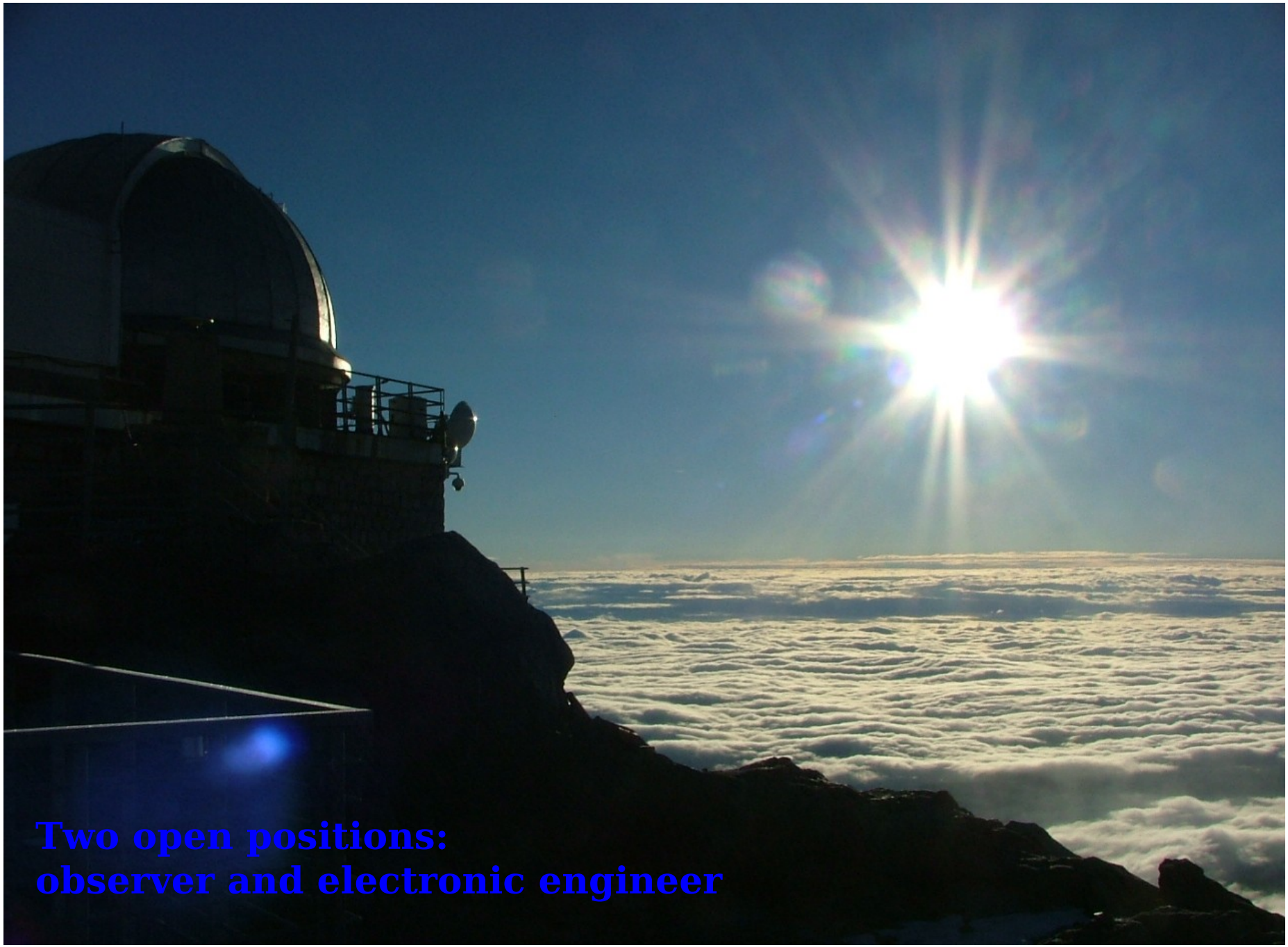
More results later...


Two open positions:
observer and electronic engineer


On behalf of the LSO team:
thank you for your attention