Current status and prospects of the Lomnicky Peak Observatory (LSO) and its instrumentation

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14/05/2013, Astronomický ústav AV ČR, Ondřejov, Česká republika

Presentation content:

- LSO past
- ZEISS coronagraphs
- What's next
- CoMP as motivation for the ComP-S@LSO
- LSO CoMP-S and infrastructure done lists
- CoMP-S@LSO - experience, changes, status, plans
- LSO future steps

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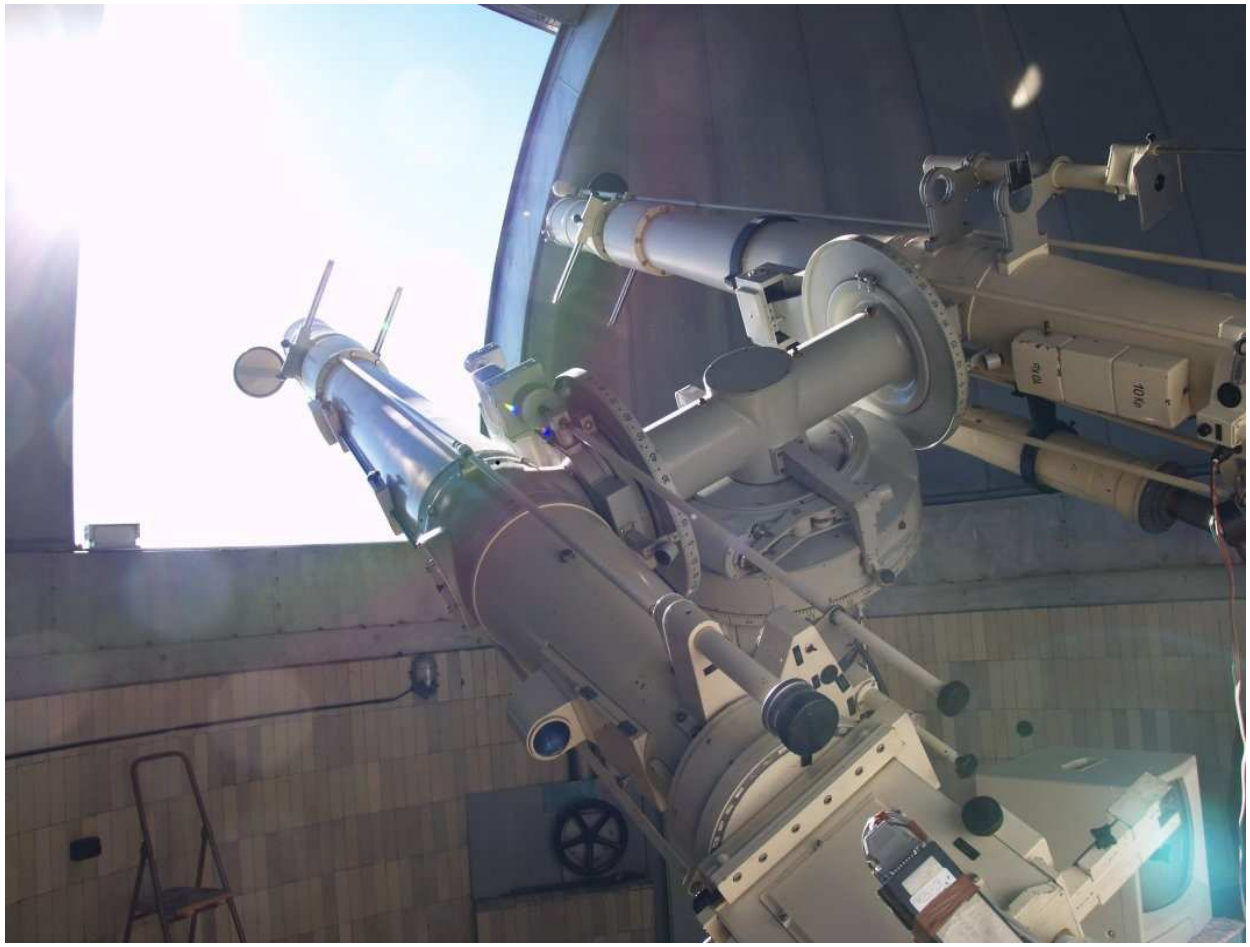

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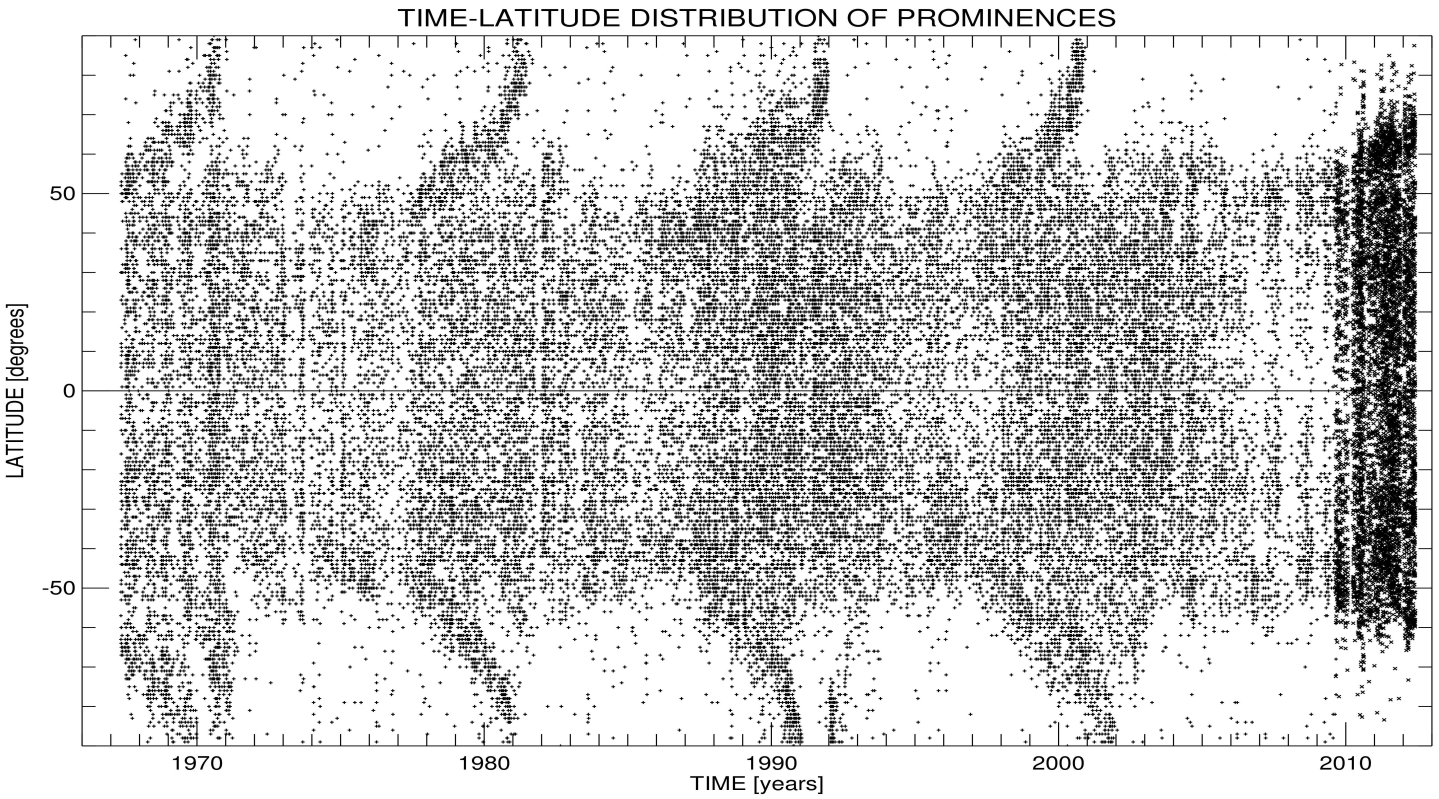

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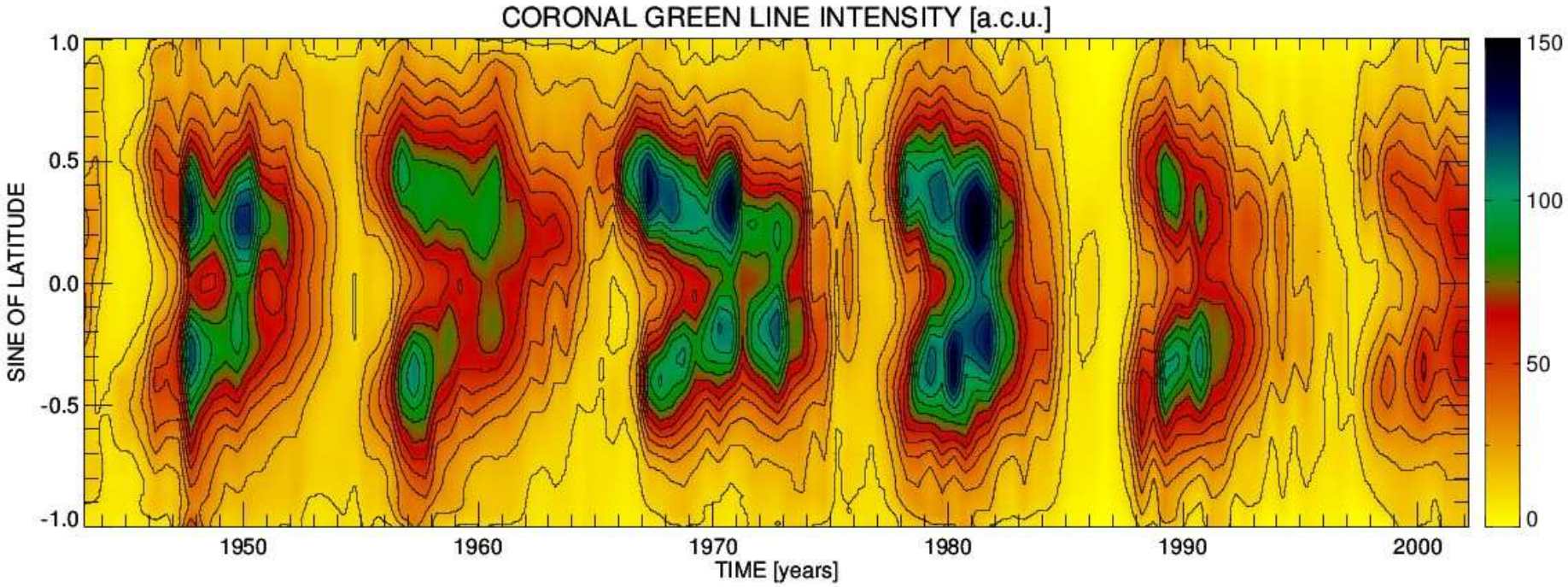

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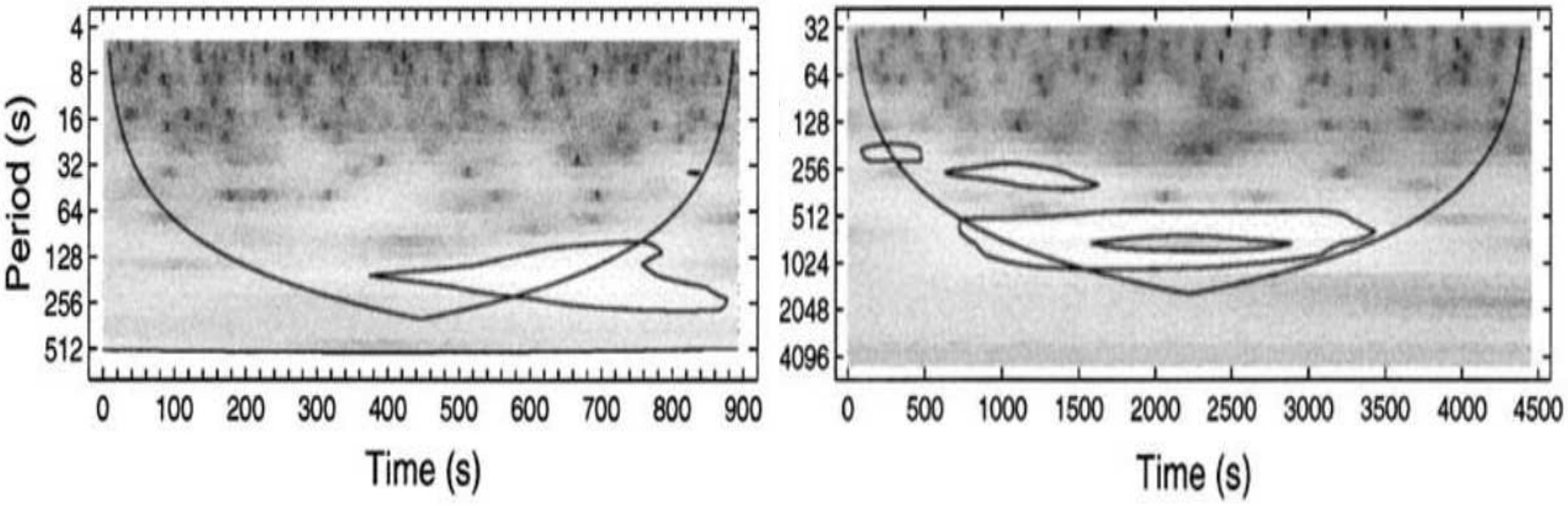
- 5-min oscillations in the solar green line



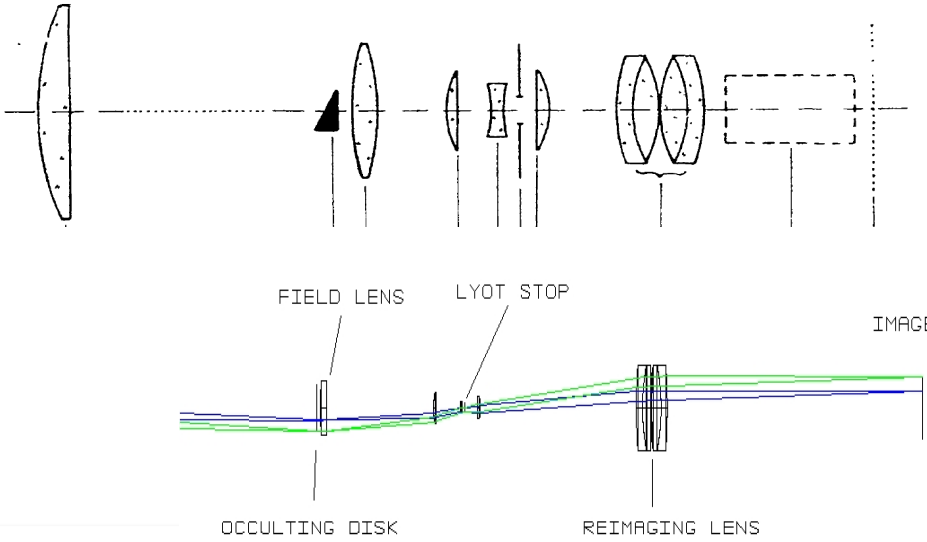
Minarovjech et al., 2003, Solar Phys ***213****, 269*

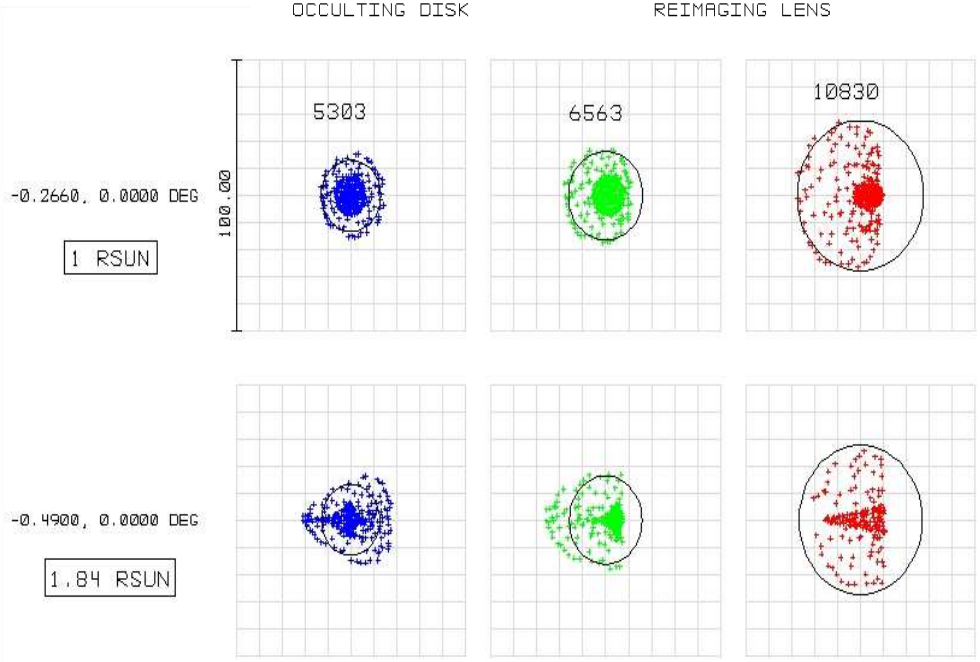
Zeiss coronagraphs

LSO: Zeiss coronagraphs

- D=196mm, f=~3m, D_{Sun}=4cm
- diffraction limited from 530 nm to 1083 nm
- spatial resolution: 0.7”@530nm, 0.8”@656nm, 1.4”@1083nm
- post-focus instrument: rotation, shift, focusing
- photoelectric pointing
- only as individual instruments

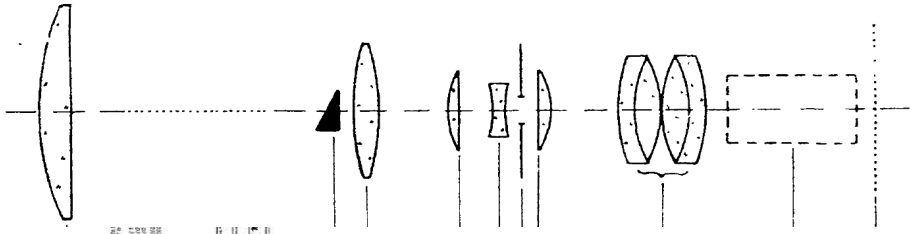
*Lexa, J., 1963, BAC **14**, 107*

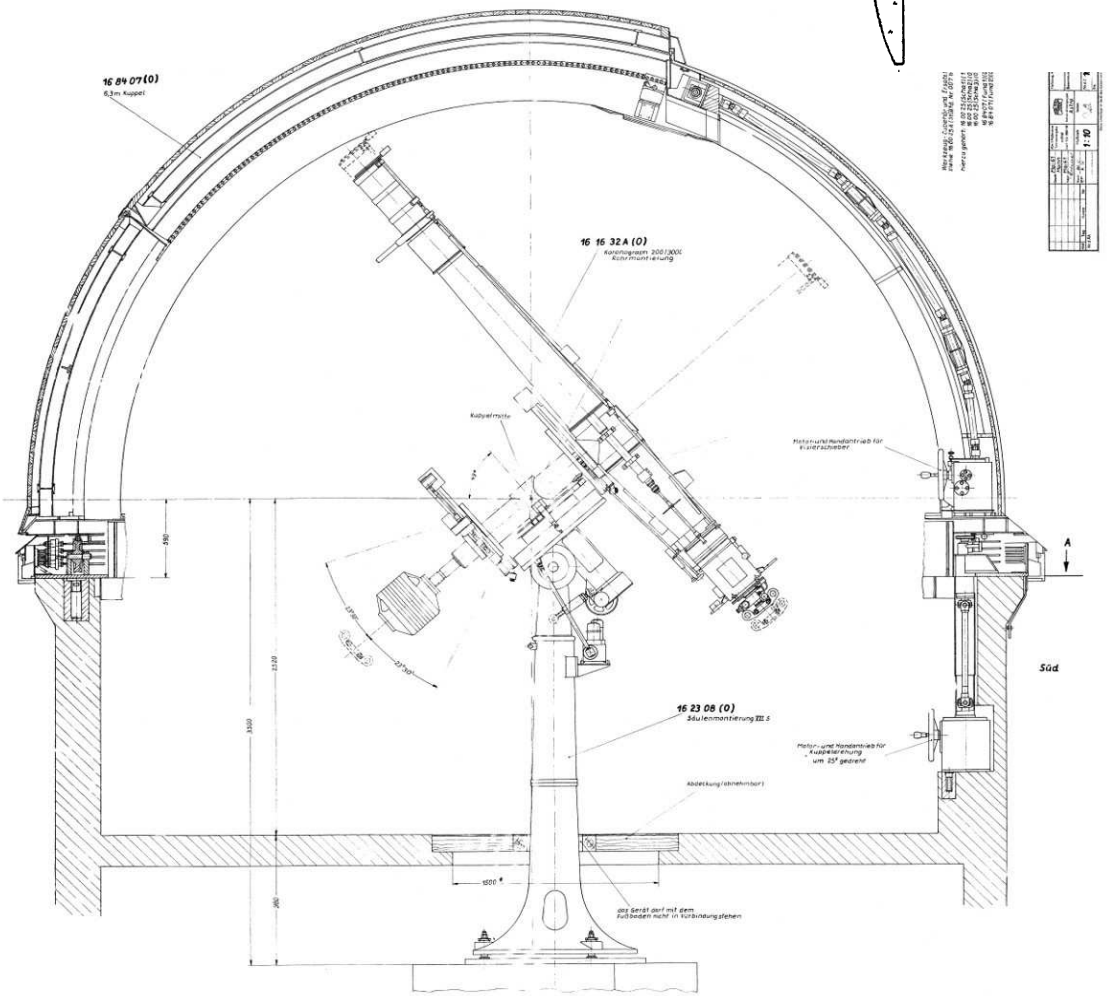




LSO: Zeiss coronagraphs

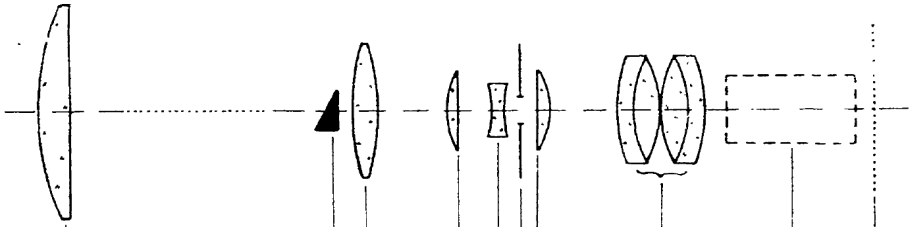
- Dome and mount





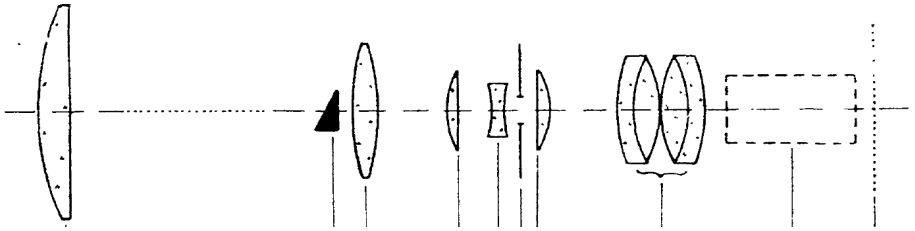
LSO: Zeiss coronagraphs

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



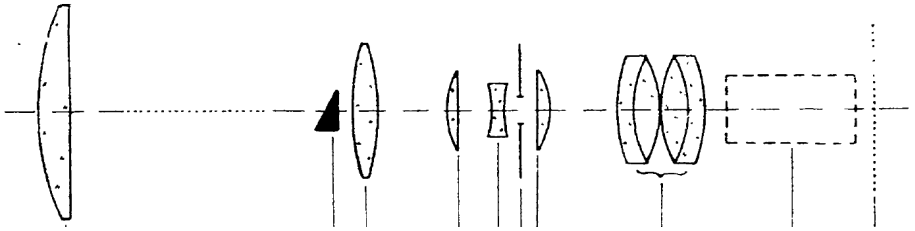
LSO: Zeiss coronagraphs

- Rear part of the coronagraph: artificial moon assembly, interface for rotation, shift, and focusing of the post-focus instrument



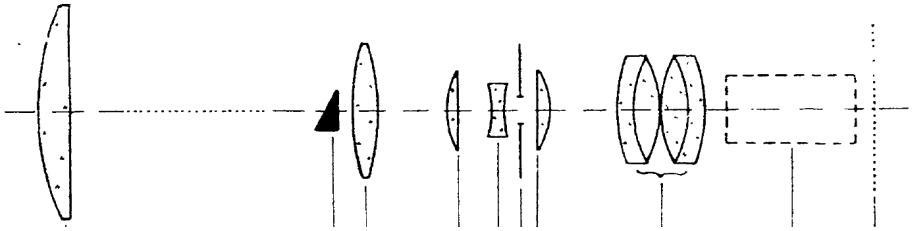
LSO: Zeiss coronagraphs

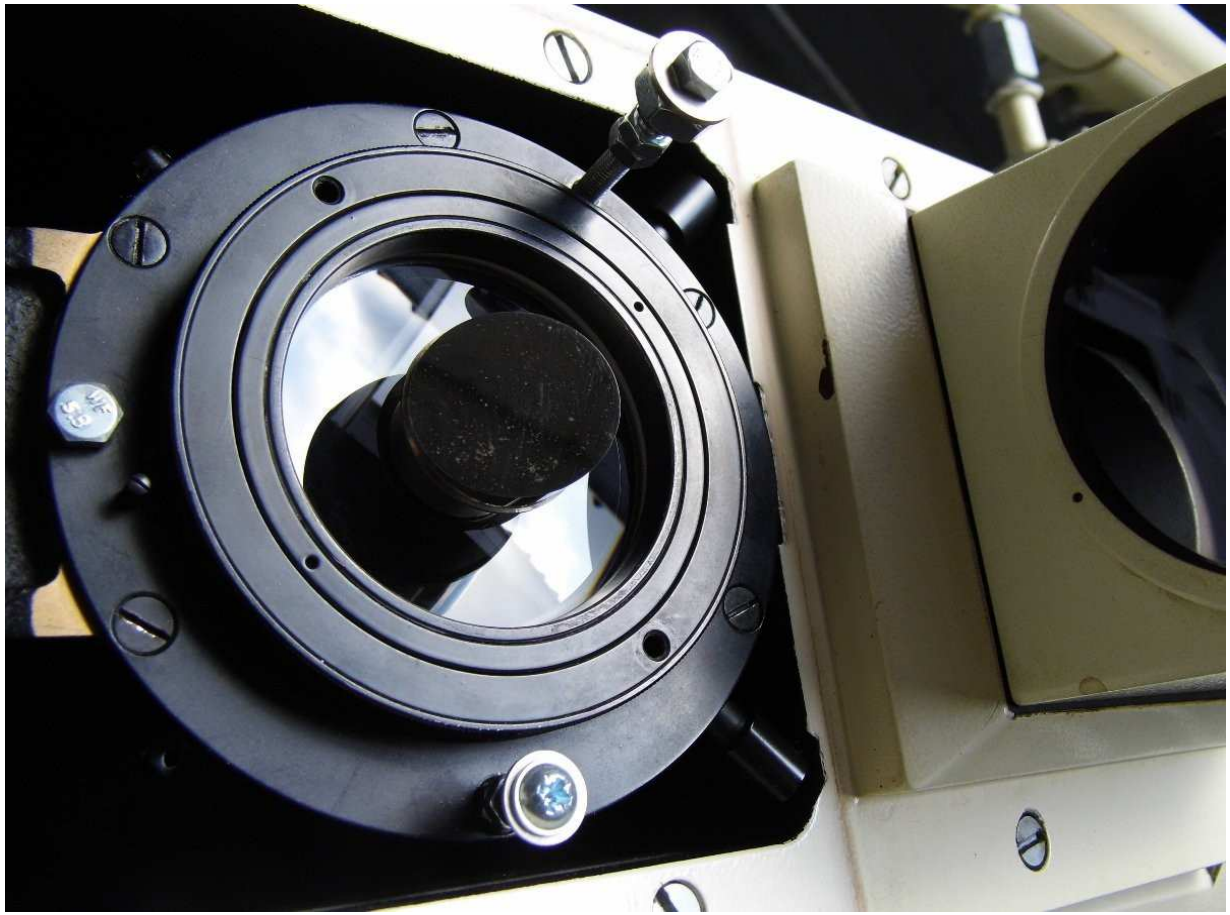
- Objective lens: ZEISS 200/3000
  R_1=1.710 m, R_2=17.000 m, BK7



LSO: Zeiss coronagraphs

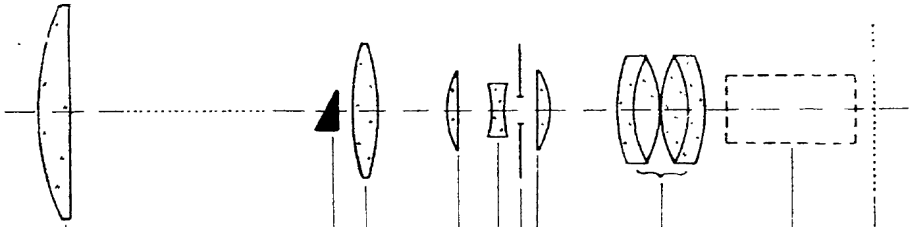
- Artificial moon and field lens

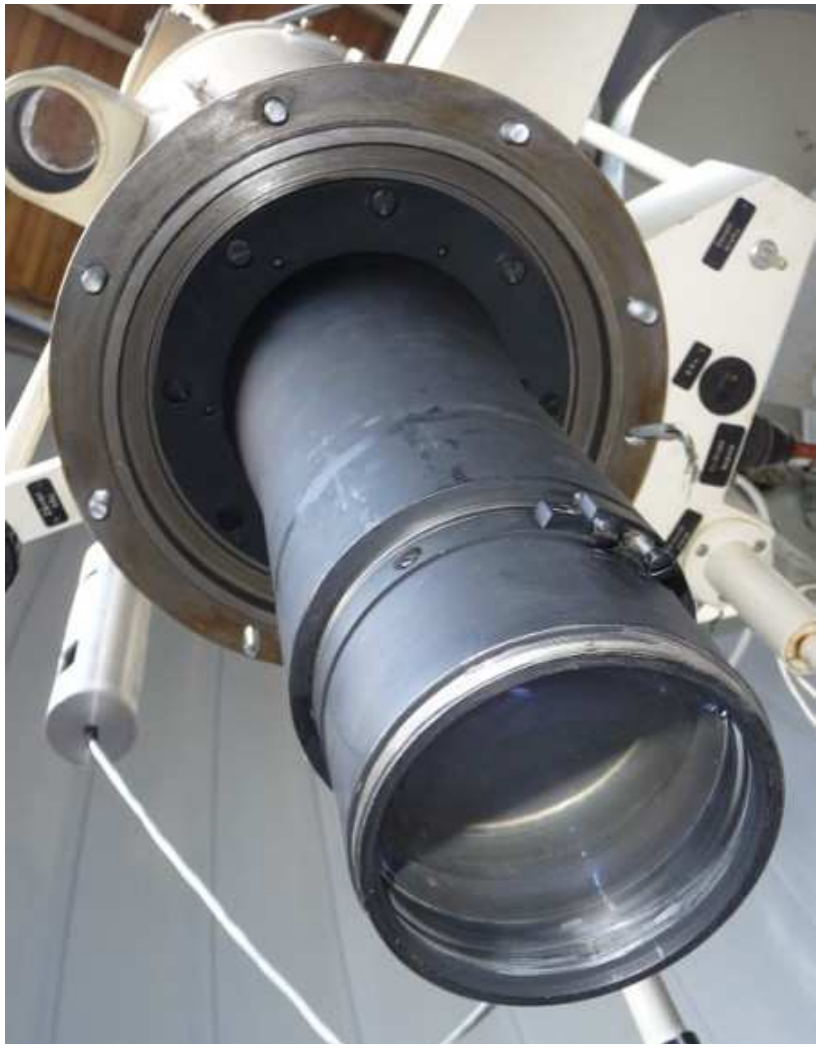




LSO: Zeiss coronagraphs

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





What's next?

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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...
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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 ?)

LSO: What's next?

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

  2D spectropolarimeter for VIS and near IR emission lines of prominences and corona

- But a budget needed is above all means...

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- **A miracle!**

  Miracle in this case: an opportunity for a miracle and its realization by a tremendous work of few colleagues **completely** engaged in administration of such applications and consequent realization of the projects following all details of the EU/SK rules for the EU structural funds project

  (BTW, a crude estimate for AISAS is 4 miracles per a century)

LSO: What's next?

- Structural funds of the EU for support of science in Slovakia: successful applications in calls of 2008, 2009, and 2012:

  - Centre of Space Research: Space Weather Influences (*ckv.astro.sk)*
  - Centre of Space Research: Technical Infrastructure (*ckv3.astro.sk/ckv/etapa3/)*

- The first application based on a post-focus instrument for the Lomnicky Peak Observatory devoted to **2D spectropolarimetry of VIS and near-IR emission lines of prominences and corona**
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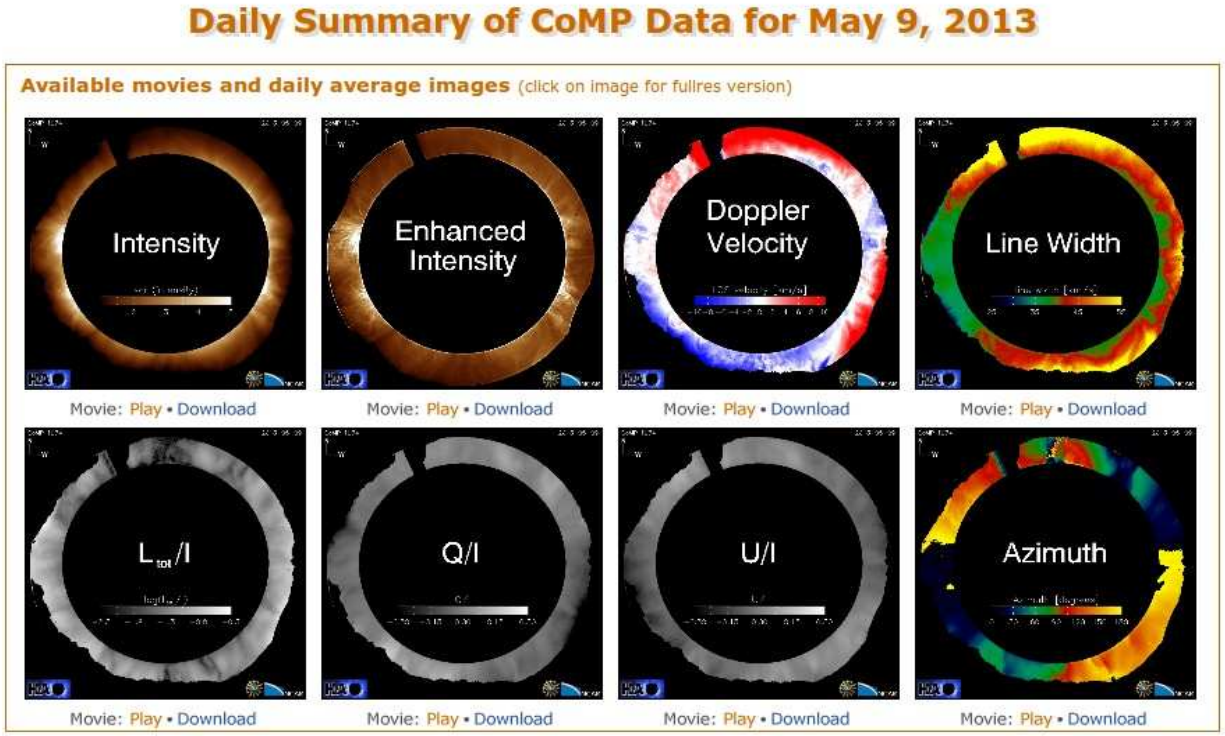
LSO: an example in mind

- **The Coronal Multi-channel Polarimeter (CoMP)** instrument
  - full FOV in the low corona (~1.03 to 1.5 R), 4.5“/px
  - intensity and the linear and circular polarization - Stokes I,Q,U,V
  - coronal forbidden lines of Fe XIII at 1074.7 nm and 1079.8 nm, prominence line He I 10830 nm, filter passband width 0.14nm
  - Maona Loa Observatory – HAO/NCAR, Boulder, USA
  - web page: *http://mlso.hao.ucar.edu/mlso_data_COMP_2013.html*



Tomczyk et al., 2008, Solar Physics ***247****, 411*

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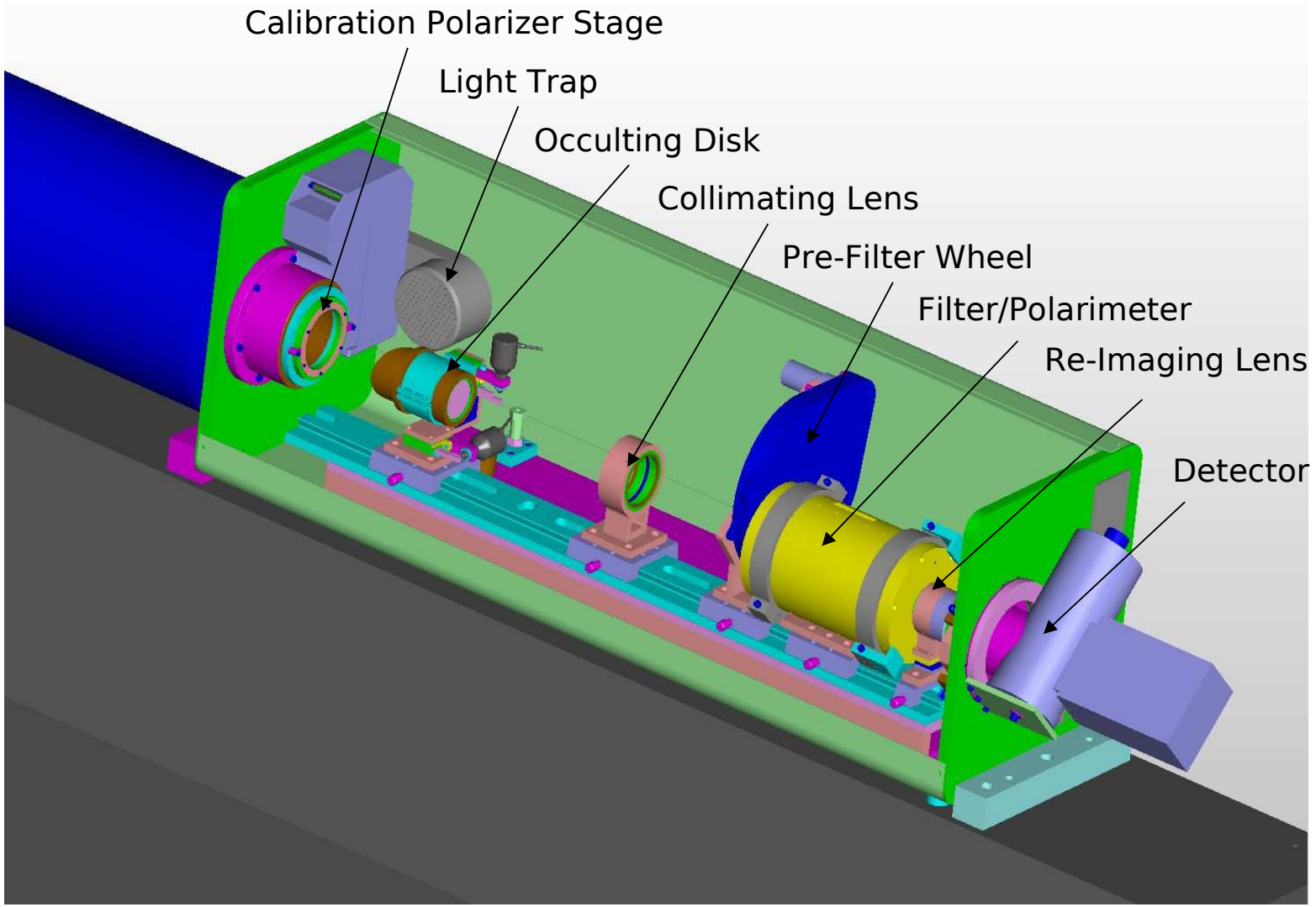

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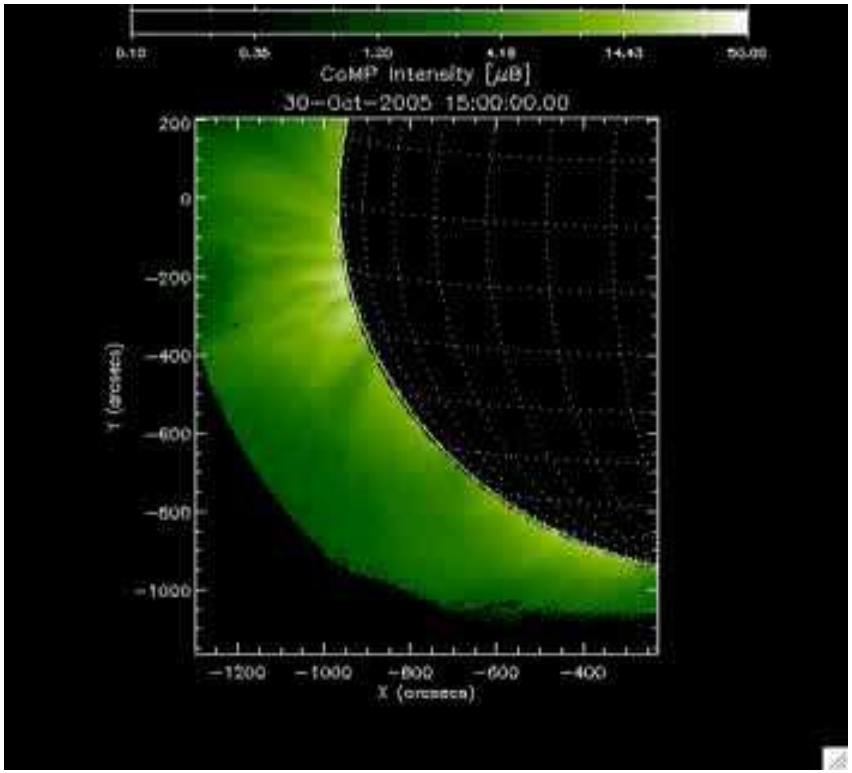
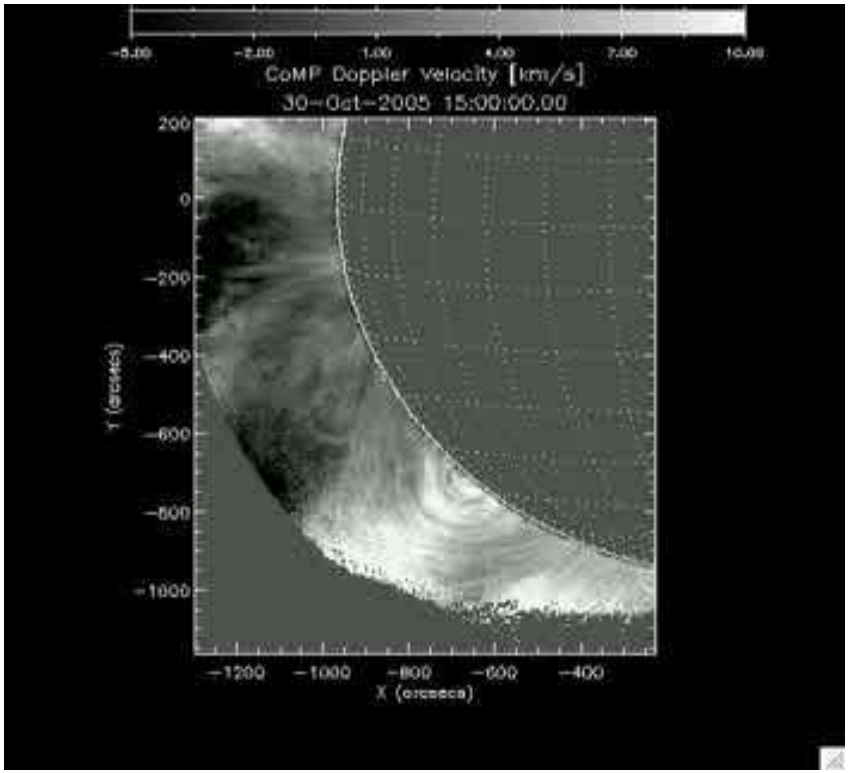




*Tomczyk et al., 2007, Science **317**, 1192*

LSO: CoMP-S (for Slovakia)

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

- **The CoMP-S will NOT be a duplicate of the CoMP instrument**

- **Main reasons:**

  - new technologies : optics, electronic cameras, computers
  - the ZEISS coronagraph final focal plane of the re-imaging part is without a chromatic aberration
  - technological knowledge already gathered with the CoMP
  - budget available

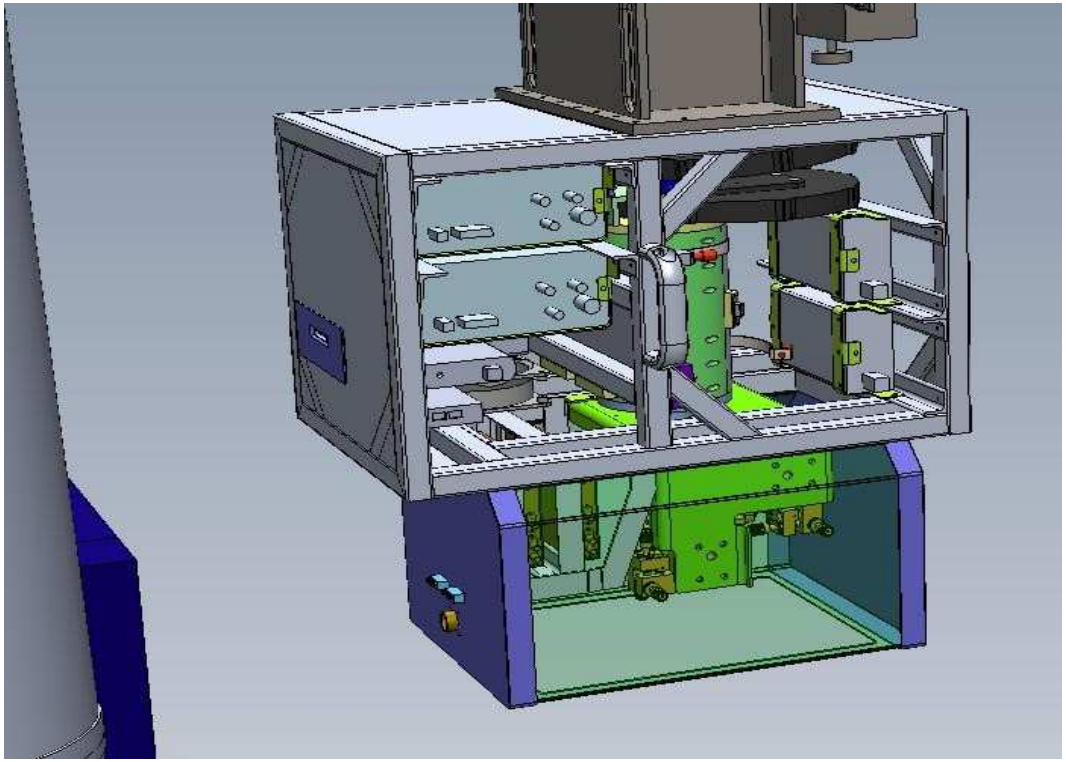
- **Main new features:**

  - wavelength range: **500 – 1100 nm** (CoMP only 1070-1090nm) allowing sequential measurements of several VIS + near-IR emission chromospheric and coronal emission lines
  - not a full-disk FoV

LSO: CoMP-S

- **Main parts:**

  - mechanical interface: connection of the CoMP-S to the coronagraph
  - filter module: a Lyot filter with polarimeter, 2 filer wheels with narrow-band pre-filters and polarization/calibration optics
  - camera module: beam division optics, 2 cameras
  - box with electronics (attached to the mount)
  - computers and data storage (in server room)
  - cabling for all….

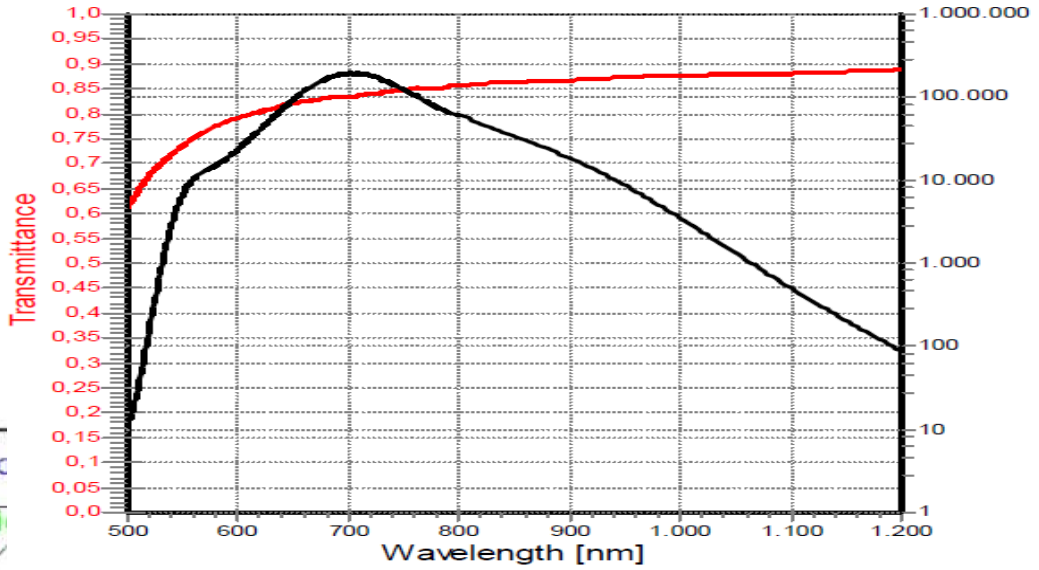


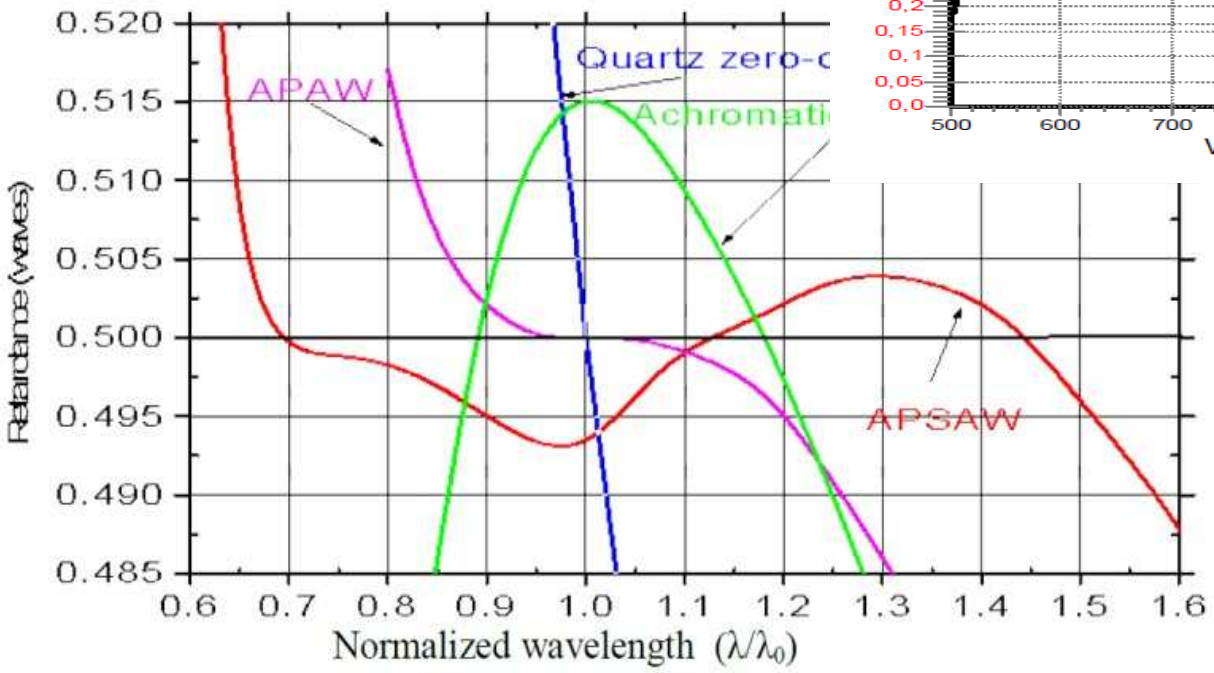
LSO: CoMP-S filter

- 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 $\lambda_{nominal}$

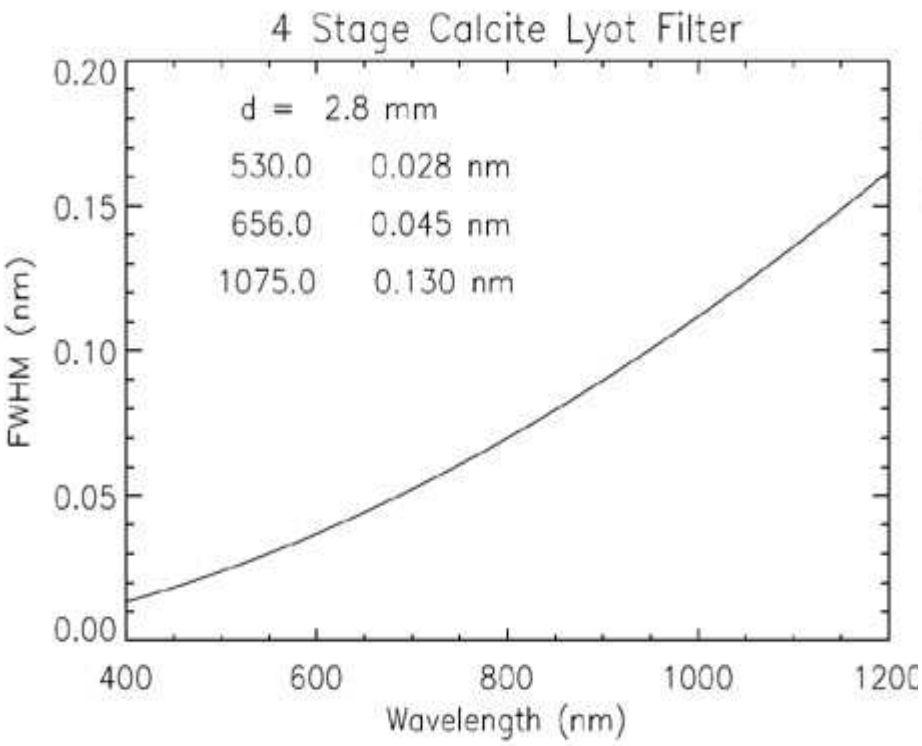


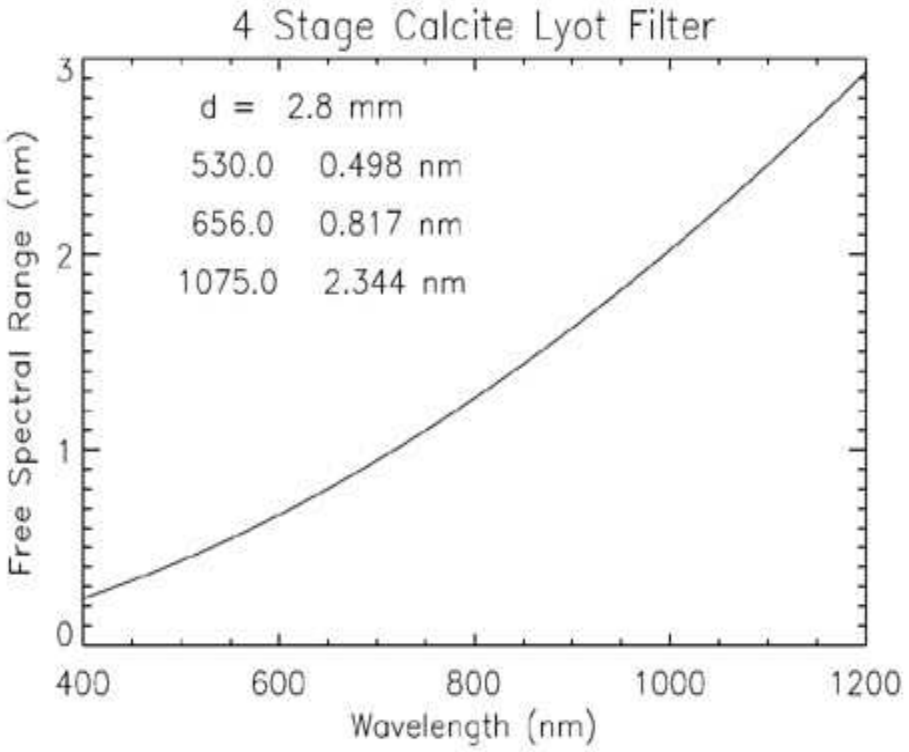


LSO: CoMP-S filter

- Lyot filter – 4 stages:

  - width of the spectral profile (FWHM)
  - free spectral range (FSR)



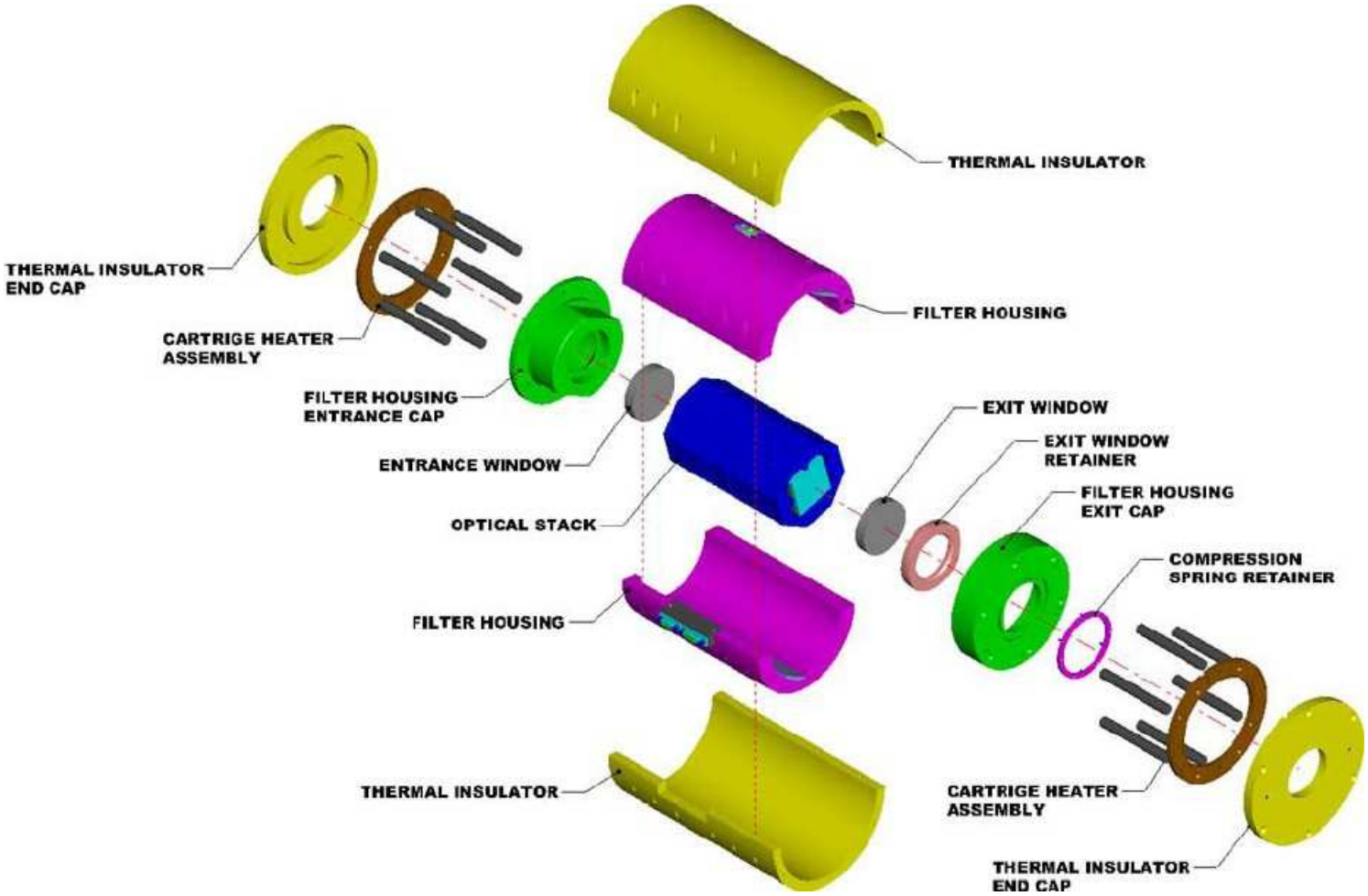


FWHM FSR

of the proposed Lyot filter for the CoMP-S instrument

LSO: CoMP-S filter

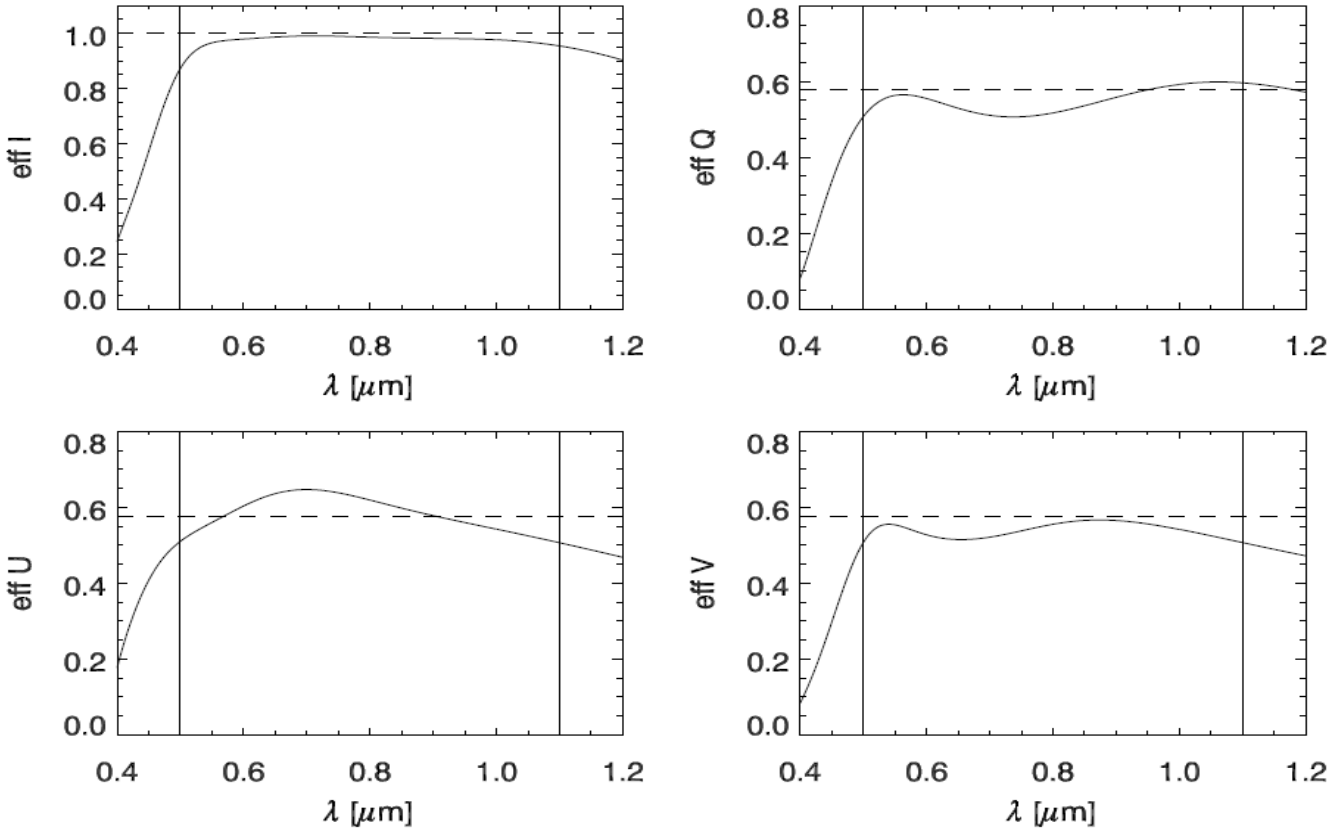
- 4-stage Lyot filter, diameter: 30mm for an unvignetted FoV
- temperature stabilization



Exploded view of the CoMP filter/polarimeter

LSO: CoMP-S polarimeter

- polarization modulator : scheme from HAO Prominence Magnetometer (ProMag): 2 ferroelectric lyquid crystals (FLC): fixed retarder followed by a linear polarizer (analyzer)

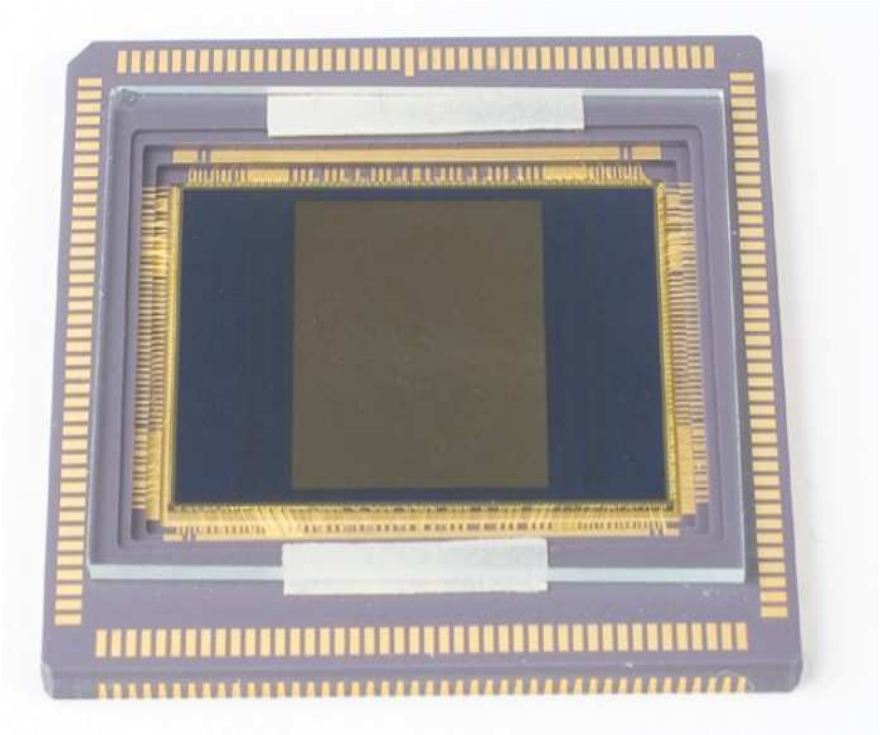


Theoretical efficiency of the Stokes polarimeter for the CoMP-S

LSO: CoMP-S detectors

- VIS: PCO scientific CMOS detector : 60% QE (500nm), 6.5µm pixels, 30 fps, 2560 x 2160 pxs, 2 e^- read noise, full 14bit resolution, T= $+5^0$ Celsius (FoV 860”x 680”) - technical specification 2013

  More details later...



LSO: CoMP-S expected parameters

- 4 stage wide-field tunable Lyot filter, FLC polarimeter

- strategy: 2 orthogonal polarization states in the 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 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)

- expected exposure times: ~100ms – prominence lines
  ~2s – coronal lines

LSO: CoMP-S AISAS duties

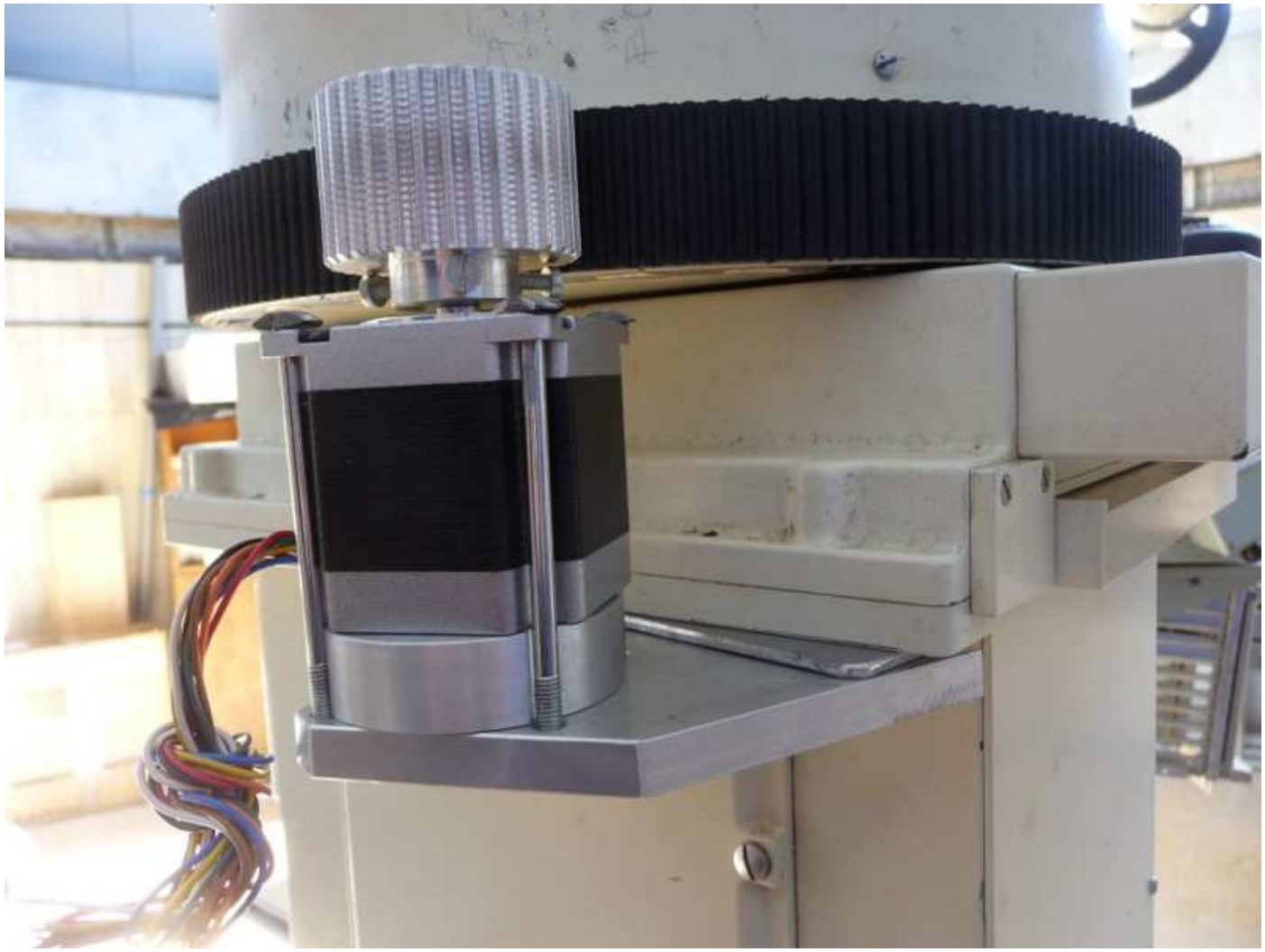
- motorizing 3 actions: objective lens focusing,
  rotation of the whole CoMP-S in position angle,
  movement of the calibrating diffuser
- power distribution in the dome/building and on the coronagraph
- operation computer console in dome and offices
- computing power for the data reduction
- data storage
- secure power supply for 24V air heating in the filter module
- and many other things as well...

The CoMP-S done list

Actions needed to host such instrument at the LSO

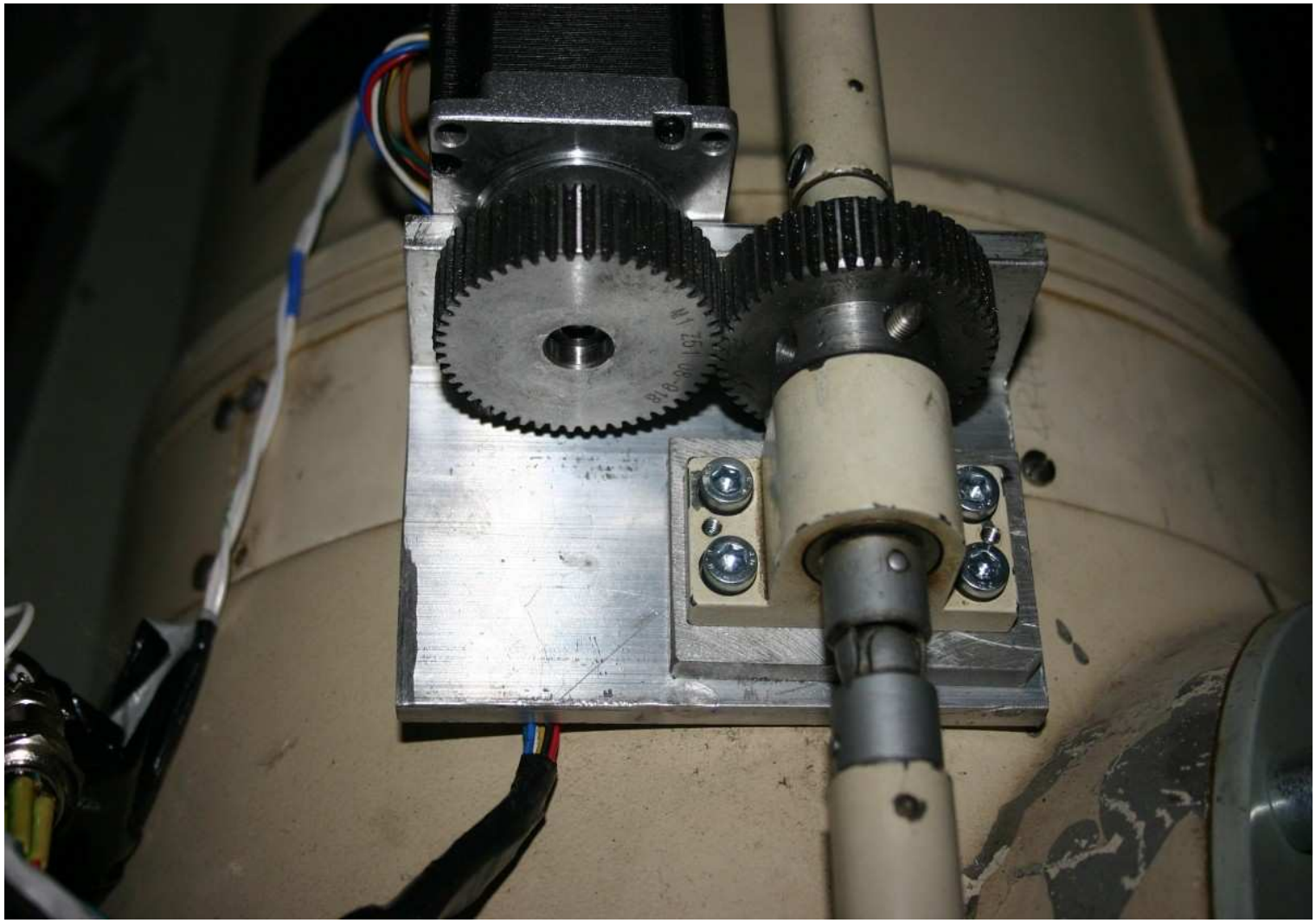
LSO: CoMP-S done list

- motor for rotation of the instrument: stepper motor Microcon SX23-1012



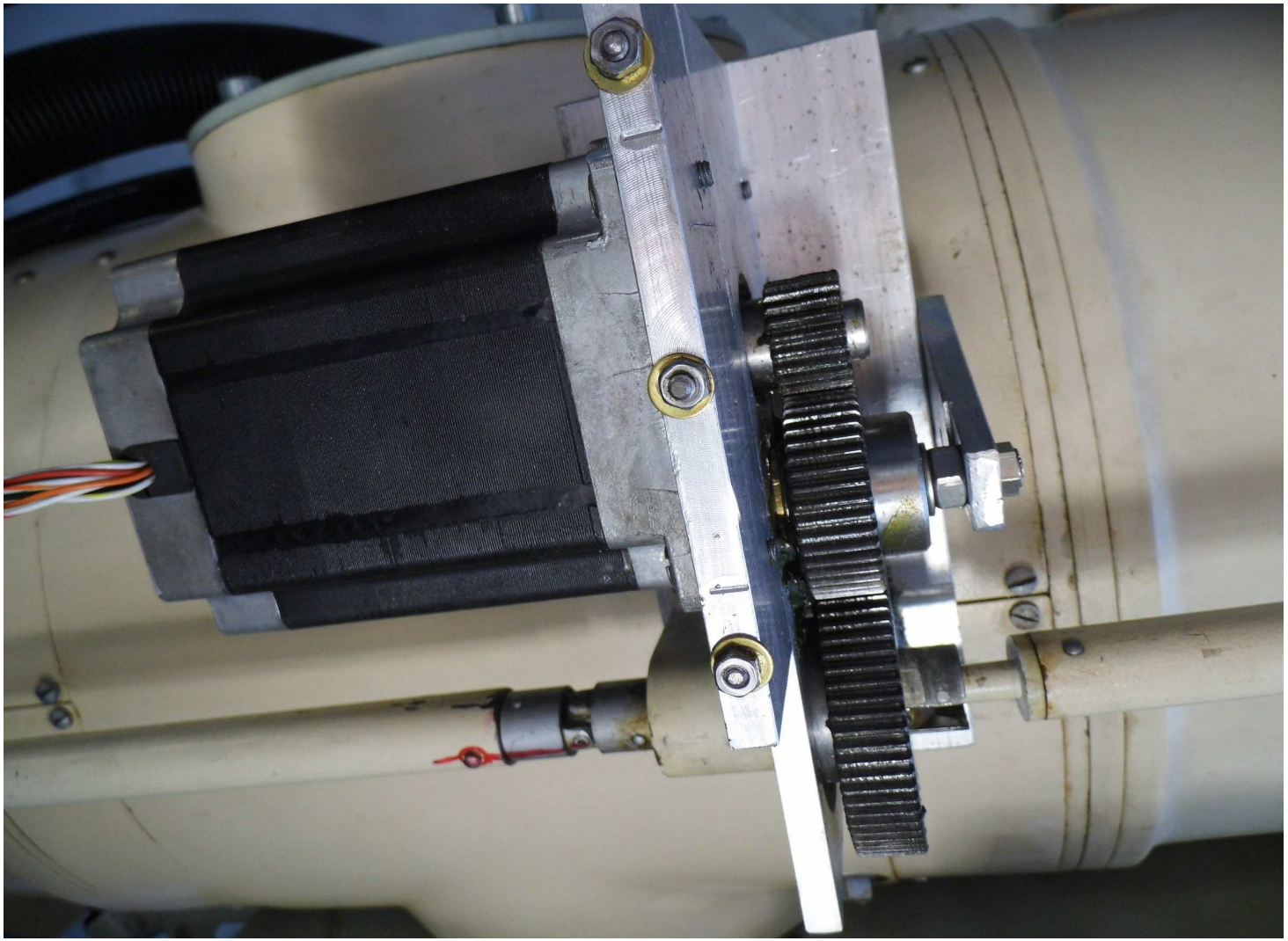
LSO: CoMP-S done list

- motor for the scrollable lid diffuser: stepper motor Microcon SX23-1012



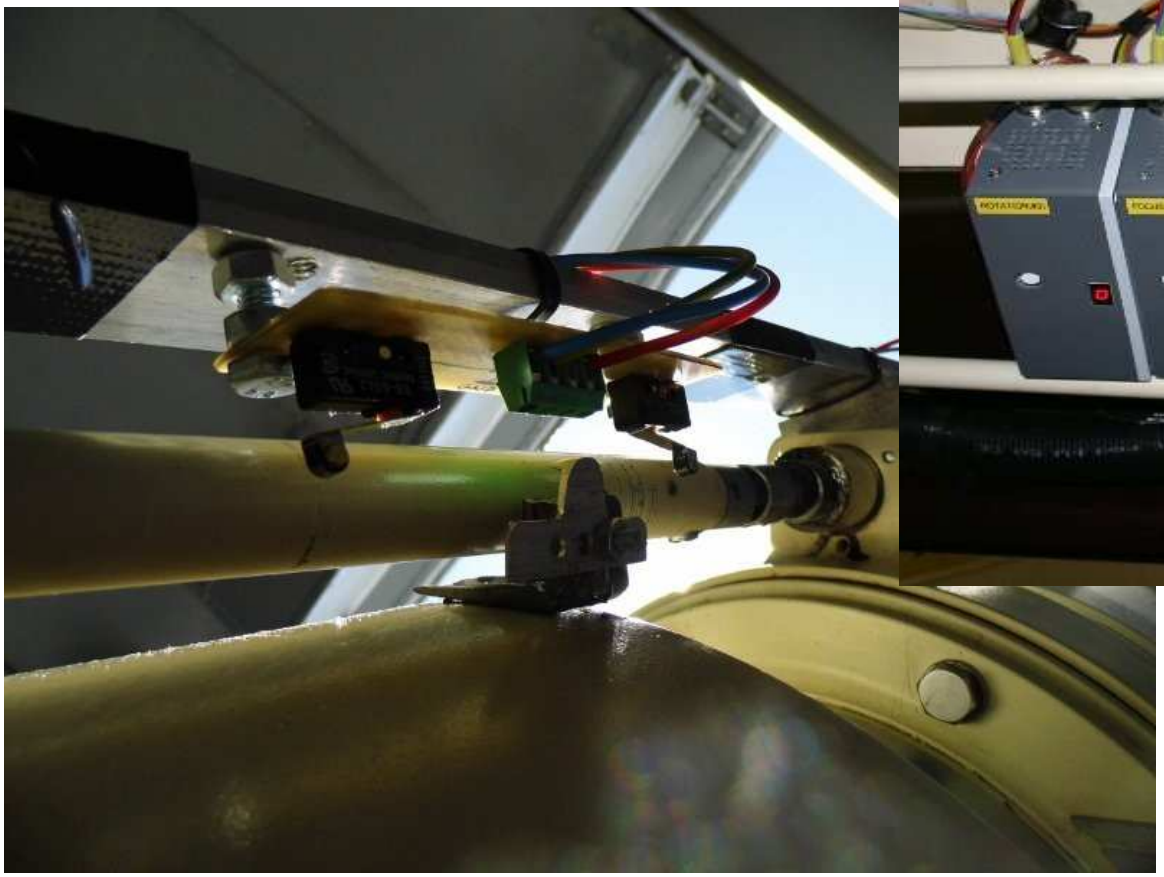
LSO: CoMP-S done list

- motor for focusing of objective lens: stepper motor Powerpac SM32-5008S



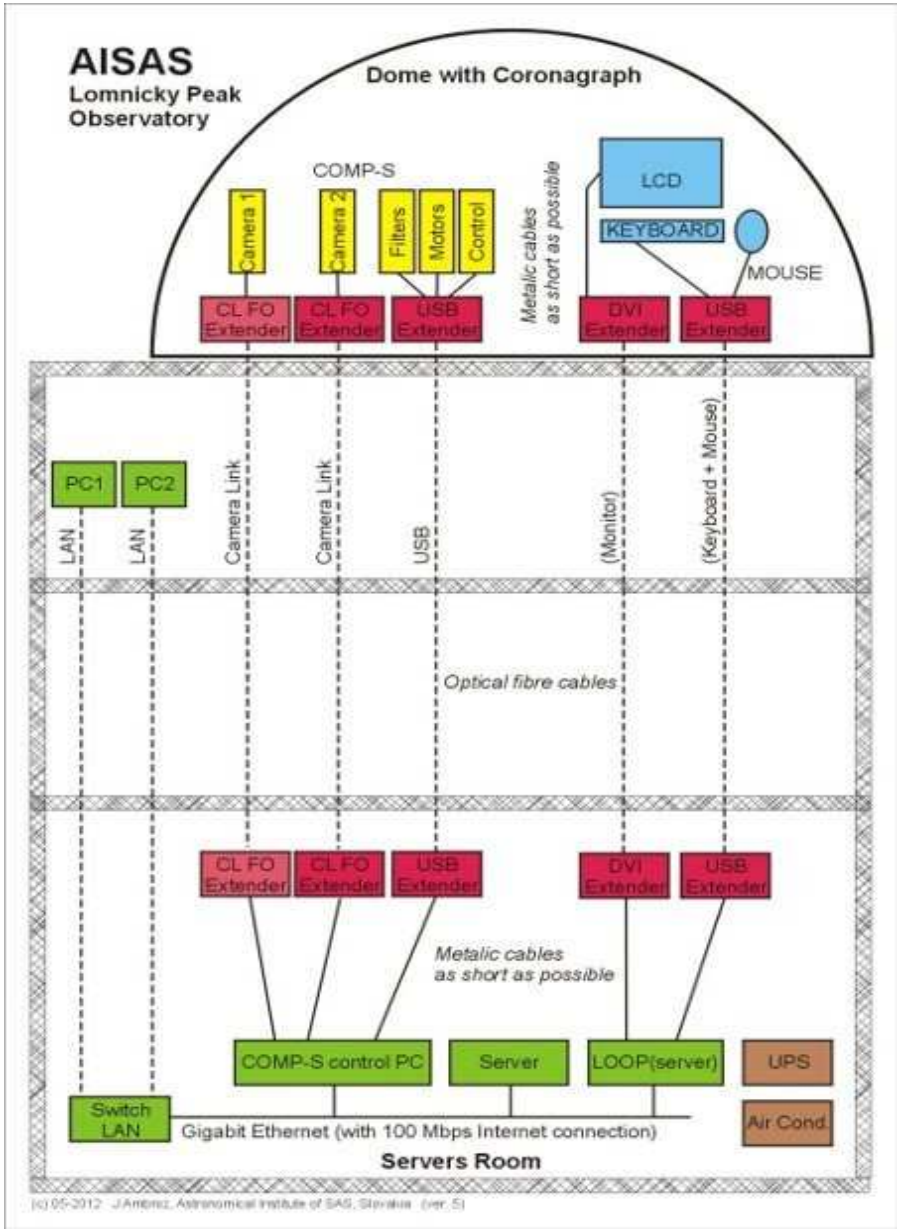
LSO: CoMP-S done list

- electronics for motor actions for operation from LabVIEW codes including two types of end switches



LSO: CoMP-S done list

- cabling in the building:
  - power supplies
  - signal cables via FO
  - KVM and USB extension via FO
  - data cables via FO
  - two electric grounds
  - galvanic insulation



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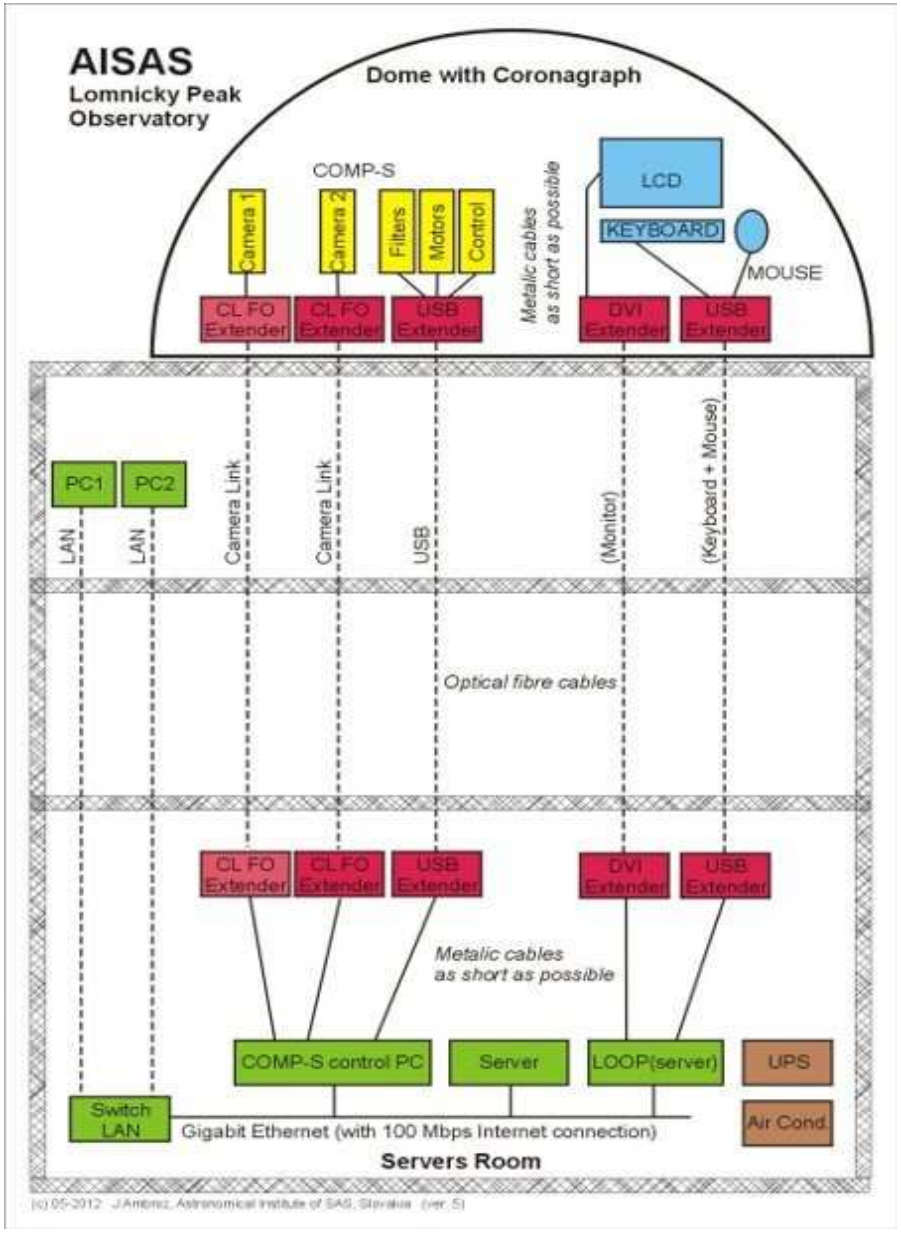
  - quite expensive toys and no telescope present at all !



LSO: CoMP-S done list

- cabling: ....

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- server room: 2x2m, double floor, dual cooling system, 19“ rack, ….

LSO: CoMP-S done list

- photoelectric digital pointing telescope:

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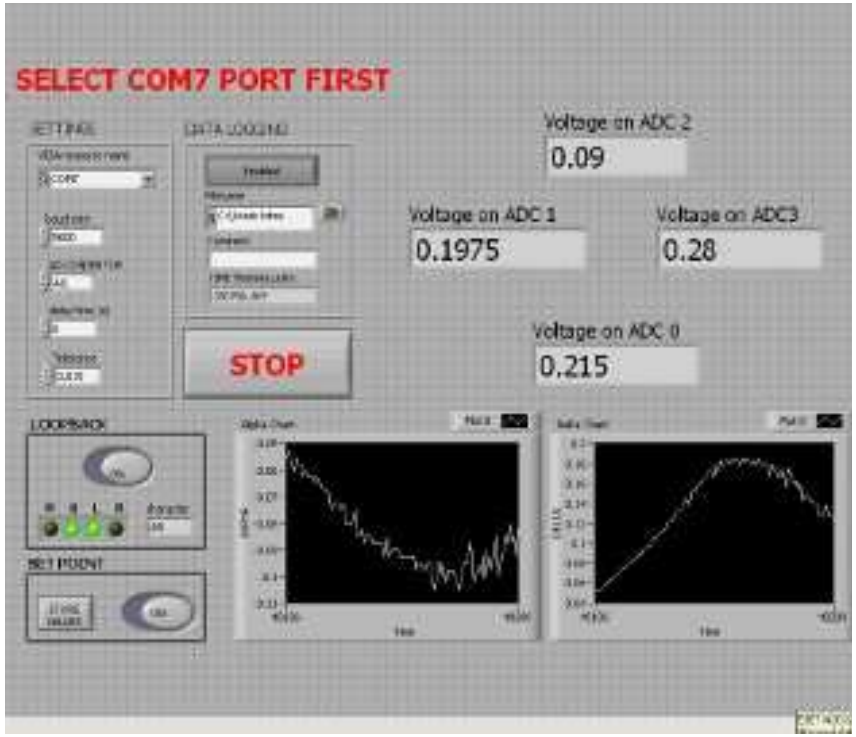

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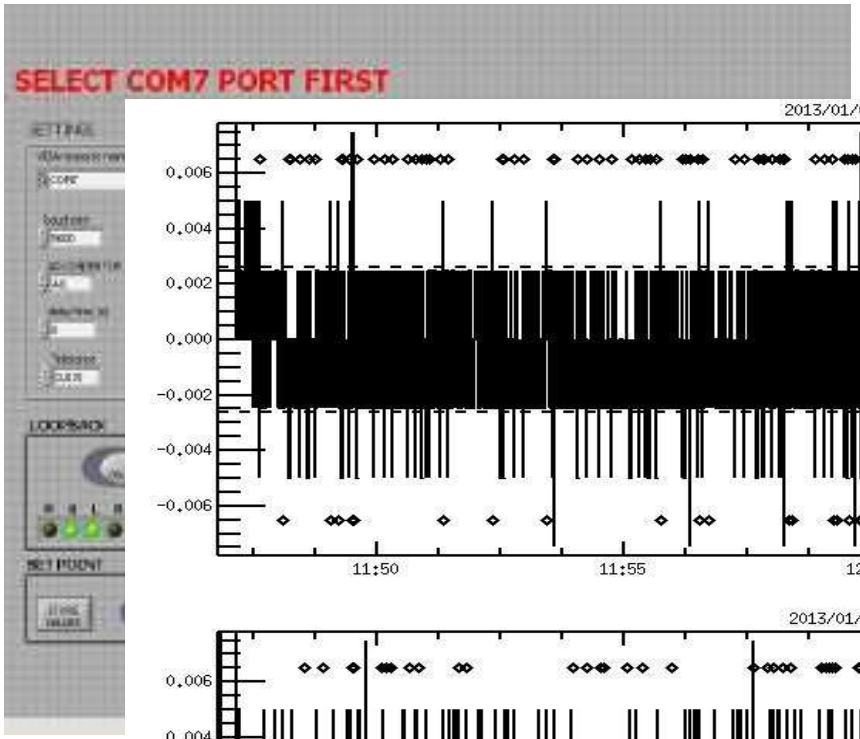
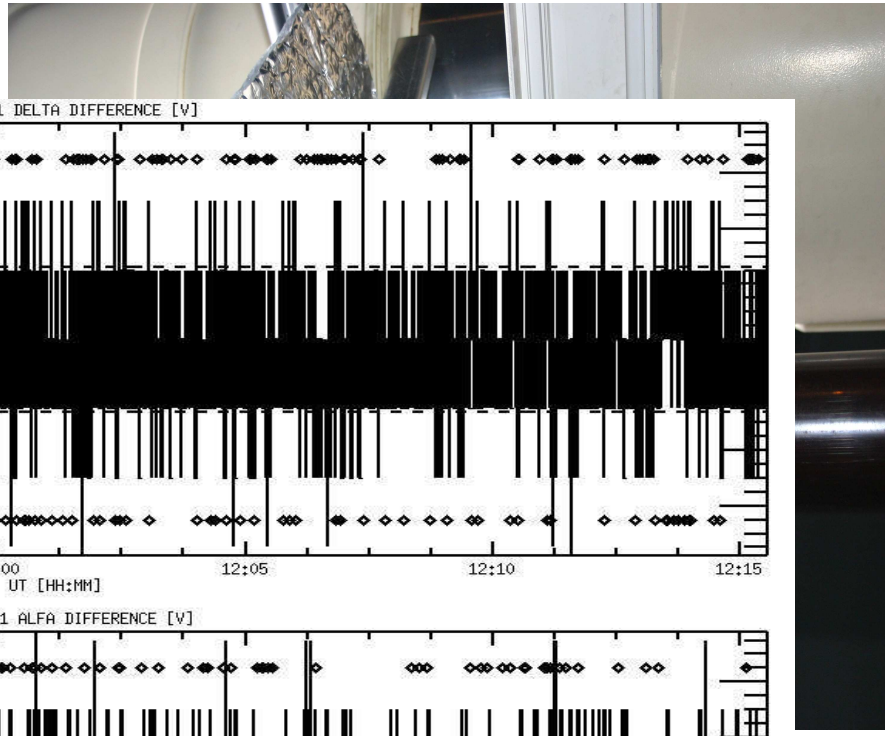
- photoelectric digital pointing telescope:





LSO infrastructure done list

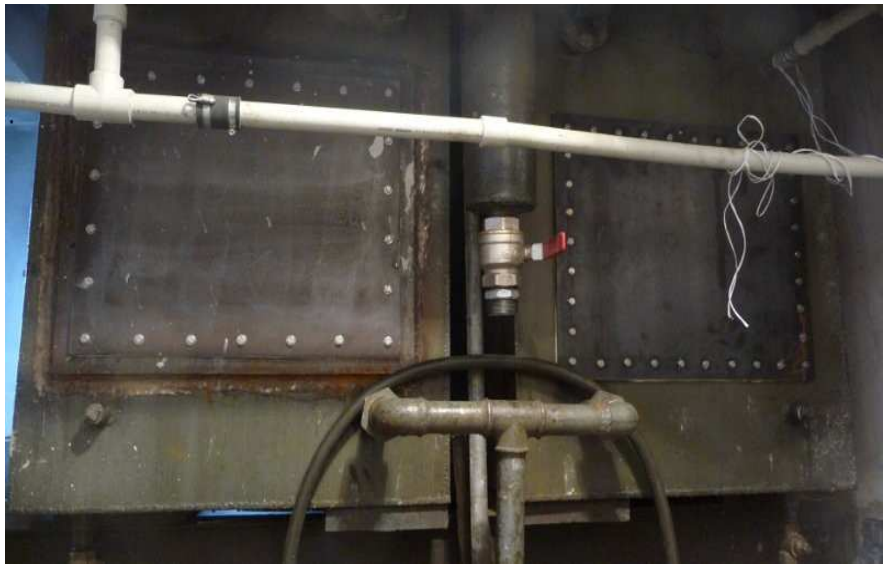
Actions far away and at the same time so close to solar astrophysics at the LSO

LSO: infrastructure done list

- potable water: 300 l tank, regular cleaning, two stage Fe/Mg/C filters, (~5m^3 delivered from Skalnaté Pleso cable car building by the cable car yearly) – **your coffee and tea!**

LSO: infrastructure done list

- water for other purposes: 4 tanks, 11.4 m^3, cleaning after 50 years...
- summer: roof water
- winter: delivered from Skalnaté Pleso cable car building by the cable car (~20 m^3 yearly)



LSO: infrastructure done list

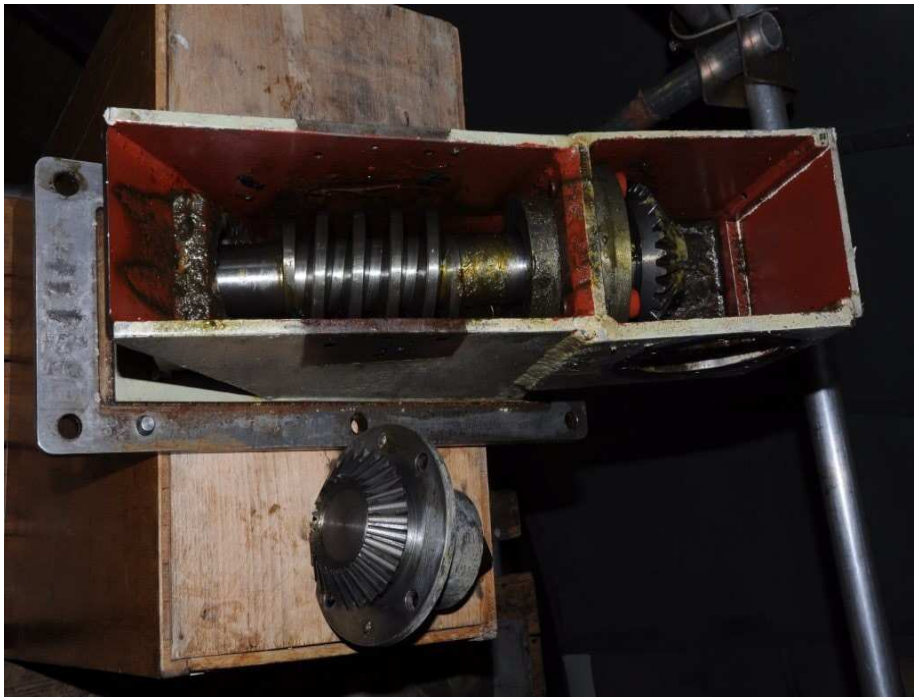
- dome slit motion (and stop):
  vertical motion, an unbalanced weight
  of 1.5 ton, an electromechanical brake,

LSO: infrastructure done list

- dome slit motion (and stop):
  vertical motion, an unbalanced weight of 1.5 ton, an electromechanical brake, electro-mechanical end switches

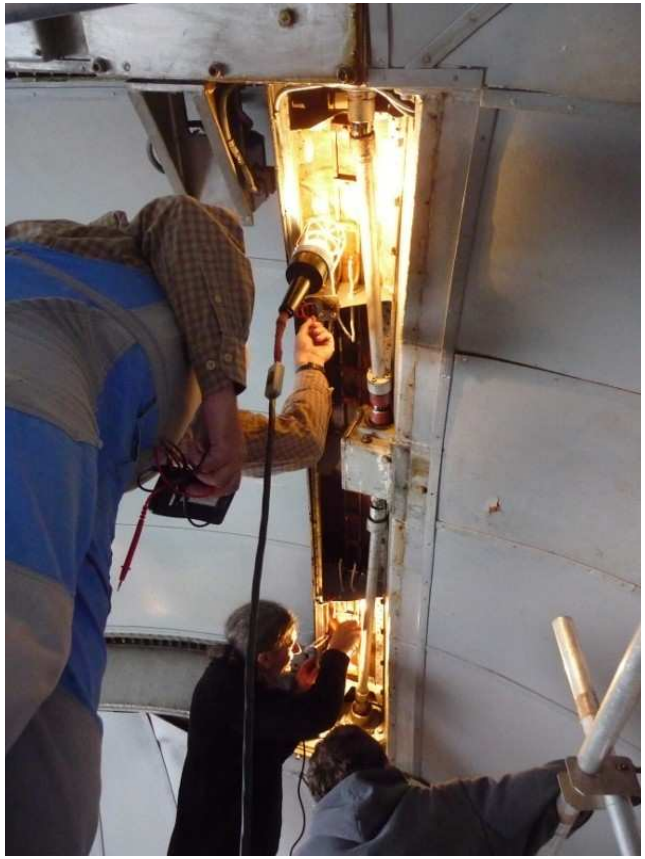
LSO: infrastructure done list

- dome slit motion (and stop):
  vertical motion, an unbalanced weight of 1.5 ton, an electromechanical brake, electro-mechanical end switches and gearboxes - **to open and also close the dome slit safely!**



LSO: infrastructure done list

- heating of the moving interfacing parts of the dome/slit/wall: 27 heaters, 17.5 kW of power input
- own aluminum scaffolding



LSO: infrastructure done list

- two-part dome slit: motorized disconnection/reconnection mechnism repaired

LSO: infrastructure done list

- dome outer roof (copper plates) “problems” due to too narrow clearance between the moving slit and the roof plates – interruption of observations for almost 4 months

LSO: infrastructure done list

- dome outer roof (copper plates) “problems” due to too narrow clearance between the moving slit and the roof plates – interruption of observations for almost 4 months - **a lot of luck!**

LSO with the CoMP-S

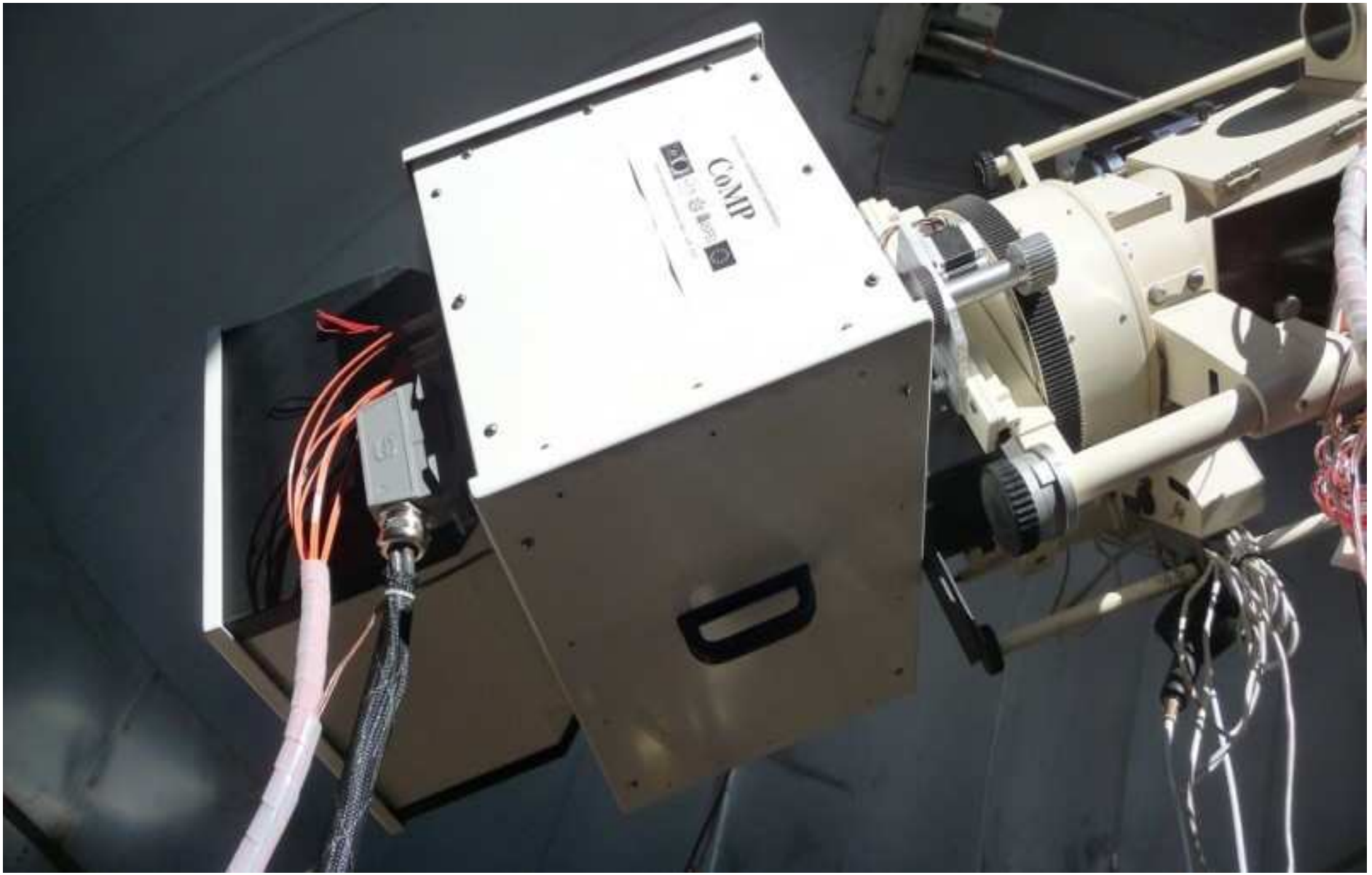
Work done at the LSO

LSO: CoMP-S

- a high moment at the LSO : the CoMP-S instrument is being attached to the coronagraph for the first time – 31/03/2011 (Filter and camera modules)

LSO: CoMP-S

- Main modules: mechanical interface, filter module, camera module, ...



LSO: CoMP-S

- Main modules: filter module

LSO: CoMP-S

- Main modules: camera module

LSO: CoMP-S

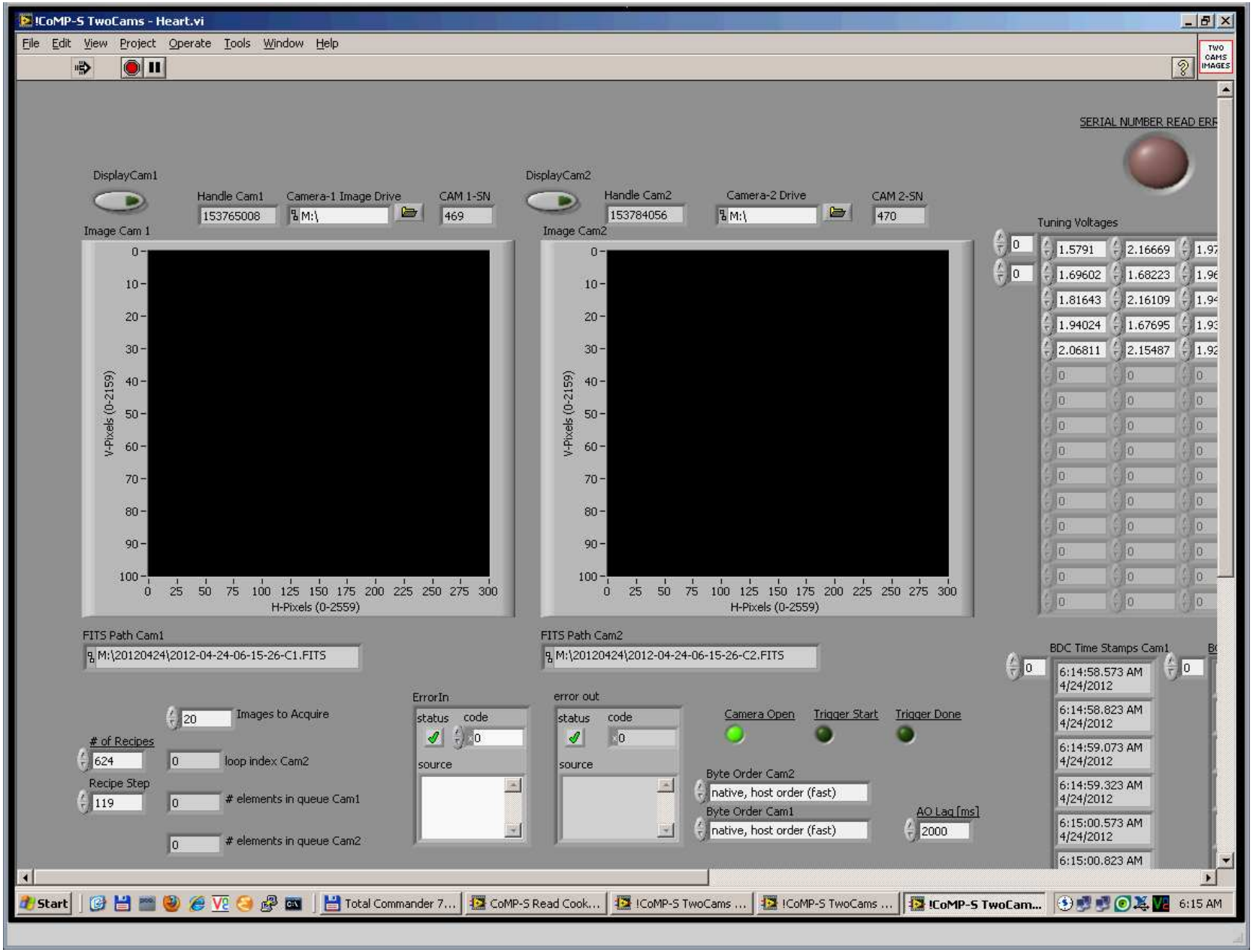
- Main modules: 19” cabinet attached to the mount

LSO: CoMP-S

- Main modules: computers and data arrays in the server room

LSO: CoMP-S

- Main modules: programs written in LabVIEW



LSO: CoMP-S

- Operating conditions:

- Lyot filter: +35.000 degrees (polarizing optics)
    - internal heating and regulation within the filter body
    - ILX electronics
- filter and camera modules: +23º Celsius (pre-filter bandpass):
    - heating system with regulation – 24 VDC
    - cameras and electronics as heaters as well
    - duplicated power lines and supplies
- 19“ inch cabinet: +10º - +40º Celsius (ILX electronics):
    - heating system with regulation – 230 VAC
    - cooling system with regulation – 230 VAC
    - electronics as heaters as well

- Security procedures (thunderstorms, lightnings, power failure):

- disconnection and unplugging (except heating of the air inside the filter and camera modules)
- duplicated power supplies
- diesel generator
- batteries
- human heat for the Lyot filter...

LSO: CoMP-S

- Operating the instrument:

- List of operated devices:
  - the cup with diffuser – in/out
  - focus position of the objective lens: ~0.1mm
  - revolution in position angles along the limb: ~0.2°
  - the filter wheel with 9 pre-filters
  - the filter wheel with calibration optics: dark, clear, I±V, I±Q, I±U, and a lens for imaging of the objective lens
  - the Lyot filter tuning: 4 analog voltages for tuning the Nematic Liquid Crystal Variable Retarders (LCVR) including voltage decrease in ~7m cables
  - 2 FLC polarizers - ±5 VDC
  - trigger signal - +5 VDC
  - PCO cameras: initialization, data readout

- Programs:

- LabVIEW – several VIs and libraries
- ASCII cookbooks and recepies:

```
exposure-0100ms.rcp
comment-logfile-exposure-0100.rcp
comment-datatype-obse.rcp
comment-logfile-run_obse_start.rcp
obse_854_pos11_rep001.rcp
obse_854_pos11_rep001.rcp
```

```
0        1        854.11
0        1        854.13
0        1        854.15
0        1        854.17
0        1        854.19
0        1        854.20
0        1        854.21
0        1        854.23
0        1        854.25
0        1        854.27
0        1        854.29
```

LSO: CoMP-S

- Observations:

- A typical observing procedure:
  - DARK
  - FLAT
  - OBSE
  - CALI – polarimetric calibration
  - ABSO – calibration to energetic units
  - OREX – exchange of the extra/ordinary beams
  - TARG – coalignment of the FoV on two detectors

- Peculiarities:
  - 2 detectors for one FoV...
  - 3 flat-field sources (basically): field lens dust, vignetting and interference fringes from optics and filter, detector pixel+readout effects

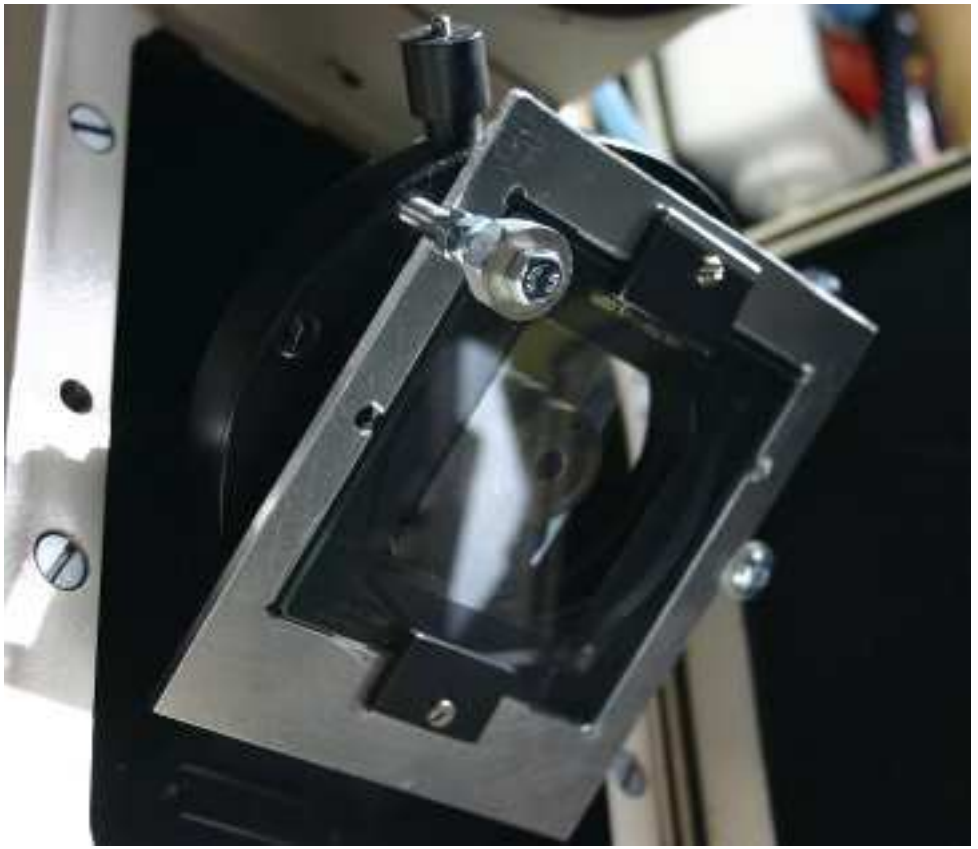
- Data format:

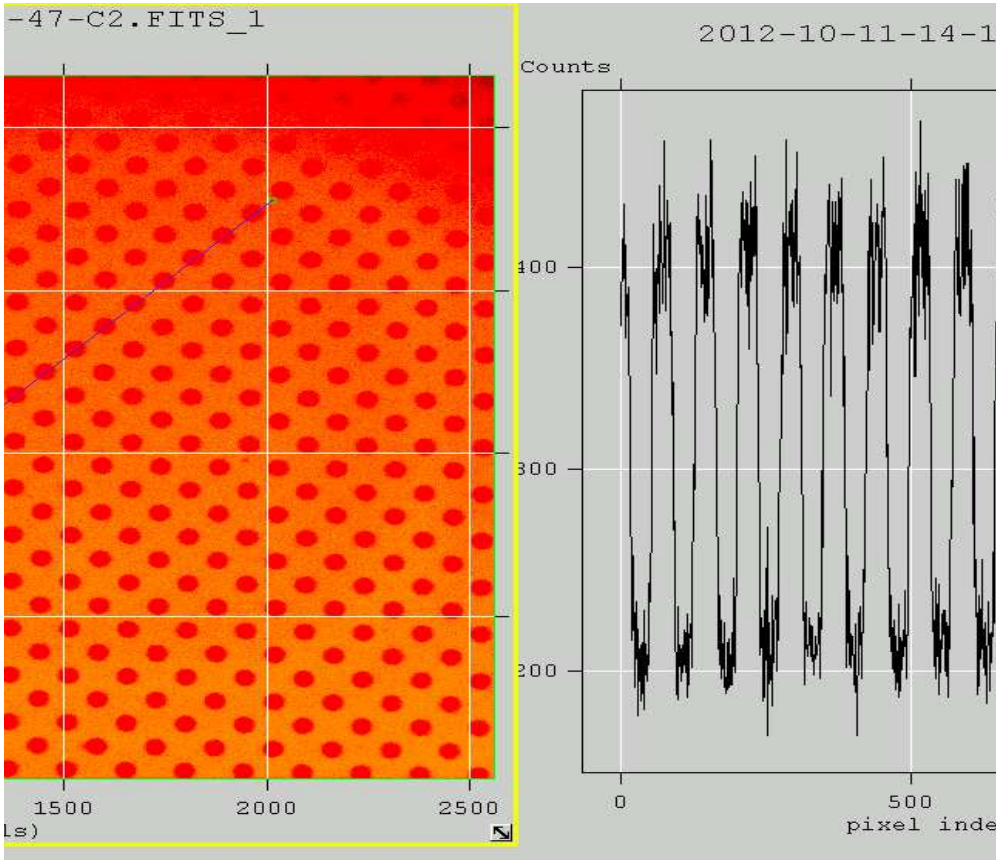
  - FITS format
  - major header: basic common information
  - binary extensions: header with particular information and 2D 16bit image
  - 1 data acquisition recipe – 1 FITS file – (1 scan of a line)

LSO: CoMP-S

- TARG procedure:

- A glass plate with a grid of chromium dots:
  - artificial moon out
  - dots at surface of the glass plate into the focal plane
  - the whole free coronagraph FoV is covered

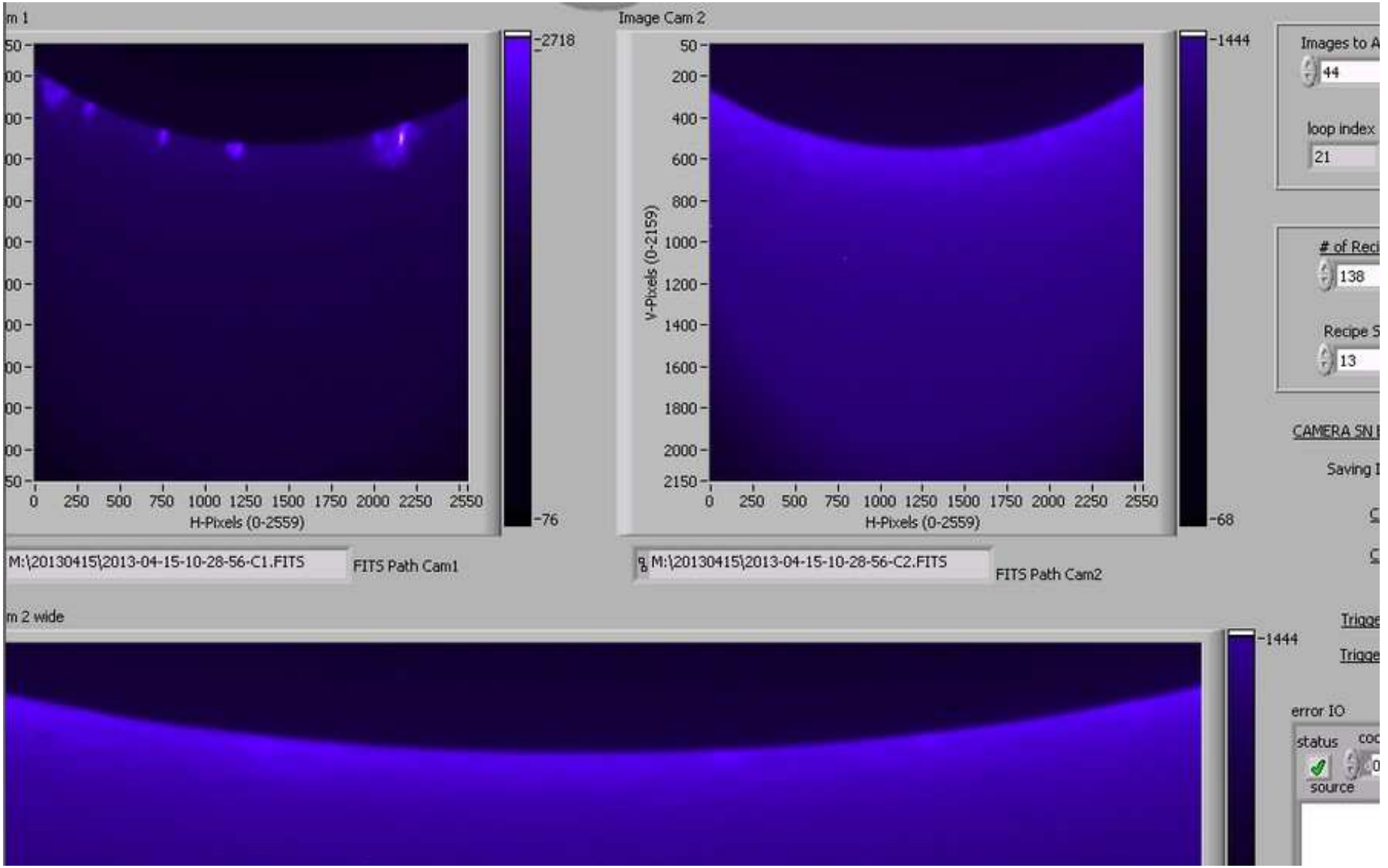




LSO: CoMP-S

- Measurements:

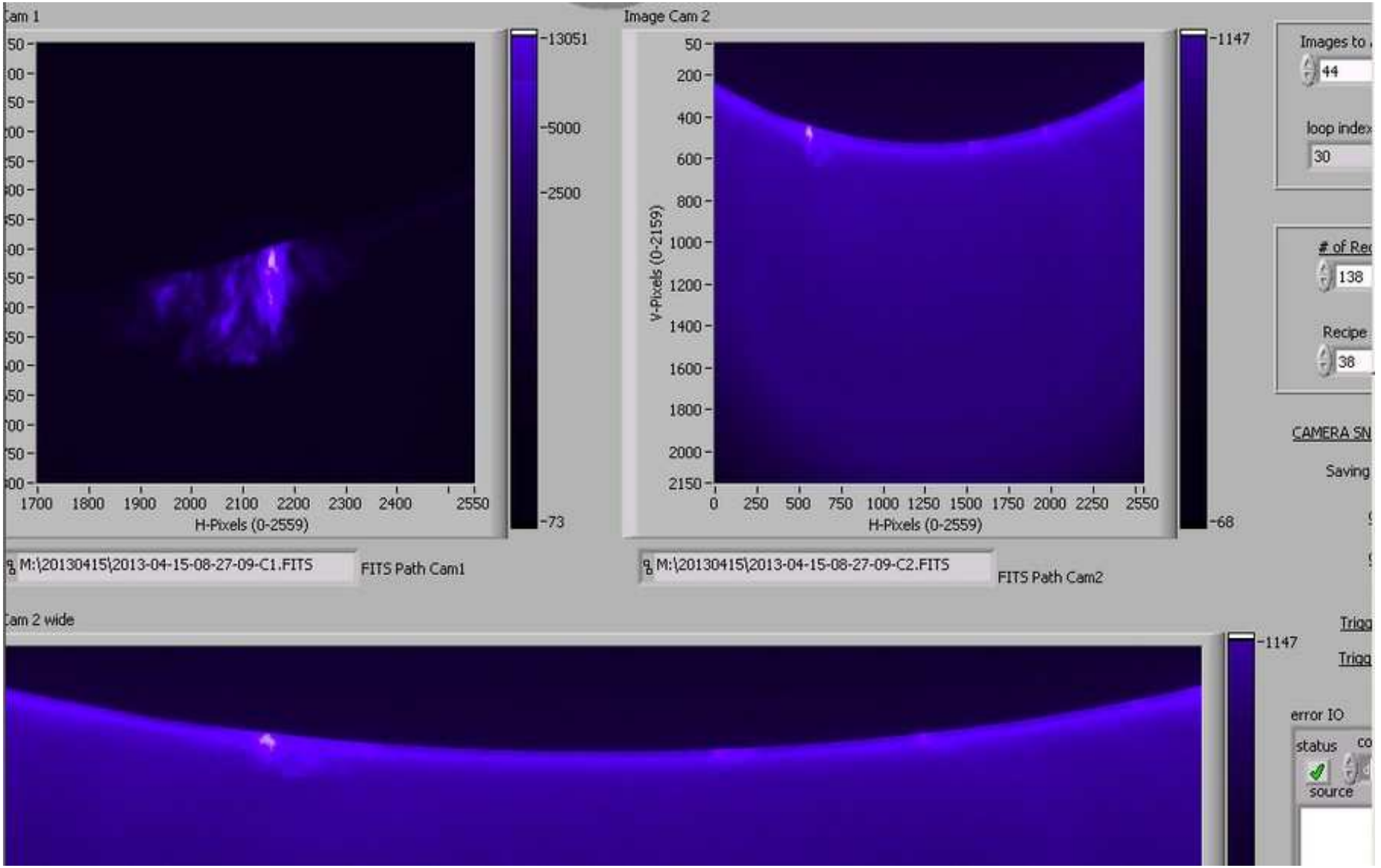
- Ca II 854 nm: t_exp=100 ms



LSO: CoMP-S

- Measurements:

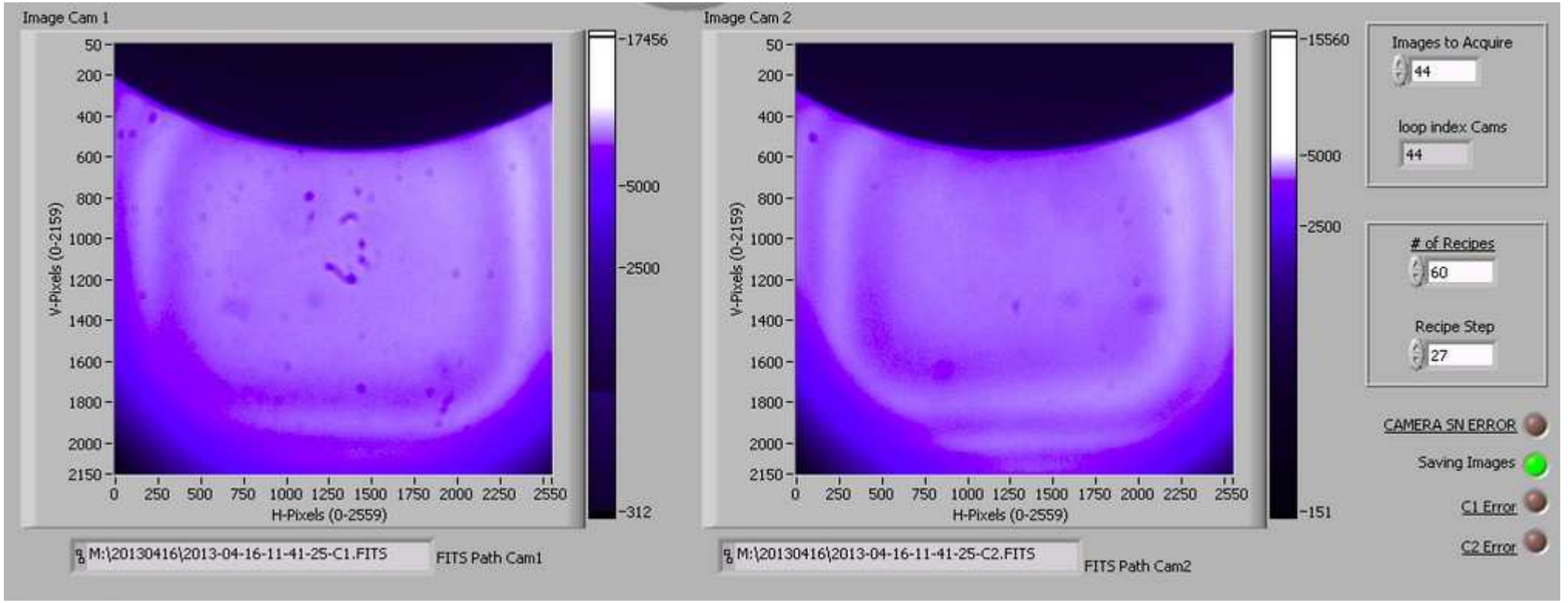
- H I 656 nm: t_exp=50 ms



LSO: CoMP-S

- Flats:

- H I 656 nm: t_exp=50 ms
- field lens dust, vignetting and interference fringes from optics and filter, and detector pixel+readout effects
- different flats for each wavelength tuned across a line profile



- Calibrations? There are still no conclusive results to be presented ...

LSO: CoMP-S

- Why is it still not finished ?

- more than two years: 1/4/2011 – today …
- commissioning phase with a lot of tests/changes/improvements due to needed reshape of the instruments from lab to dome conditions and other reasons

LSO: CoMP-S

- Why is it still not finished ?

- more than two years: 1/4/2011 – today …
- commissioning phase with a lot of tests/changes/improvements due to needed reshape of the instruments from lab to dome conditions and other reasons:
  - new mechanical interface
  - installation of an additional heating and passive insulation
  - investigation of the data acquisition failures leading to:
    - CAMs_in_PCs: 2 in 2 → 2 in 1
    - FO cable connections cleaning
    - RAID-0 → RAID-6 data array architecture
    - replacement of the used HDDs (1/3 of them with problems)
    - reliability of the 3 external motorized actions
    - **camera problems never-ending story:**
      - „inaccurate and misleading“ technical information from vendor - PCO/Andor/Fairchild sCMOS large and fast sensor development
      - PCO producer selling as the first one: seems mostly for just “qualitative” large-scale imaging only
      - very preliminary cameras with low SNs provided by PCO with a (fulfilled) promise to replace them after a year or so
      - step-by-step improvements of LabVIEW VI, library, and firmware
      - rolling shutter only with much later introduction of global shutter
      - sensor operating temperature: only one – **+5º ! Hot pixels…**

LSO: CoMP-S

- Why is it still not finished ?

- tiny but important details overlooked …
  - 2 separated electrical grounds: 1/ building and dome, 2/ instrument itself
  - August 2013 – failure of both cameras at the same time – an internal fuse blown (repaired in October)
  - March 2014 – grounds are connected at two places: holders of the FO extenders for data transfer inside the filter module and connection of the Harting cable to the filter module

LSO with the CoMP-S

Work at the todo list of the LSO

LSO: CoMP-S

- Observe! Regular operation has started since 1/5/2013 with 2+3 observers

- Finish the data reduction pipeline

- Analyze all technical parameters – polarimetric calibration

- Improve the instrument as much as possible:

- addition of a cooling system to the camera module
- change of heating of the 19” cabinet
- an alarm for detection of inappropriate filter module conditions
- “inversion” of the operation procedures
- new data storage
- completely free operation of the polarimeter
- optimization of the data handling

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- optimization of the data handling

- Use other miracles better!

LSO: CoMP-S

- Miracle: addition of the near IR cameras into the CoMP-S camera module

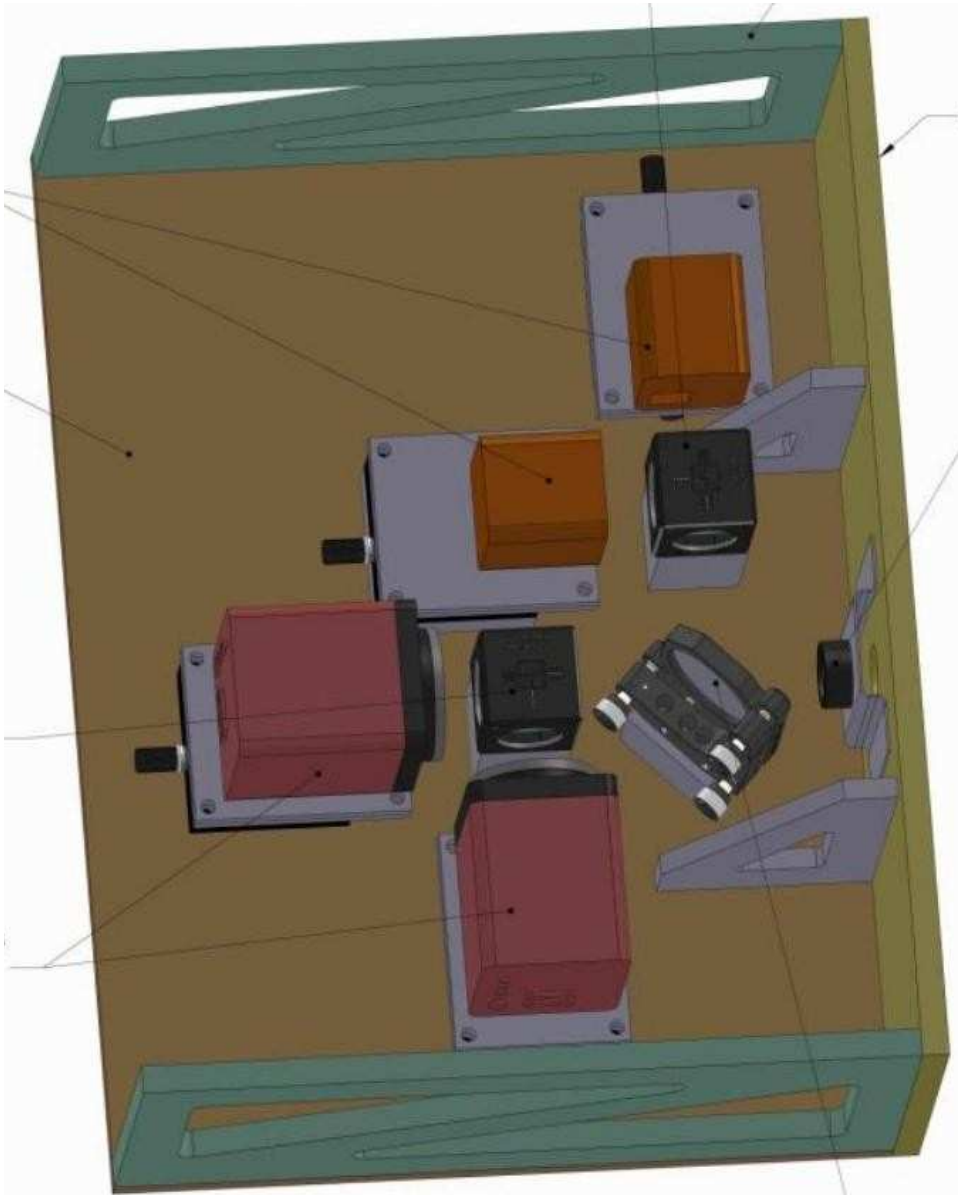
- Content of the contract no 2.:

- 2 near-IR Goodrich GA1280J cameras
- a negative lens system
- a dichroic beam splitter
- 2 polarizing splitting cubes
- 4 positioning devices
- adoption of new VIS cameras
- another basic concept for mechanics
- very much closer technical cooperation and supervision with/of the HAO/NCAR
- work on technical details has started

- Content of the contract no 3.:

- 2 ANDOR NEO cameras with the same sensor but better vacuum, cooling, and operation than the present PCO ones
- 2 RAID-5 data storages (~40TB)
- new ZEISS objective and field lenses

A real change to exploit knowledge gained...



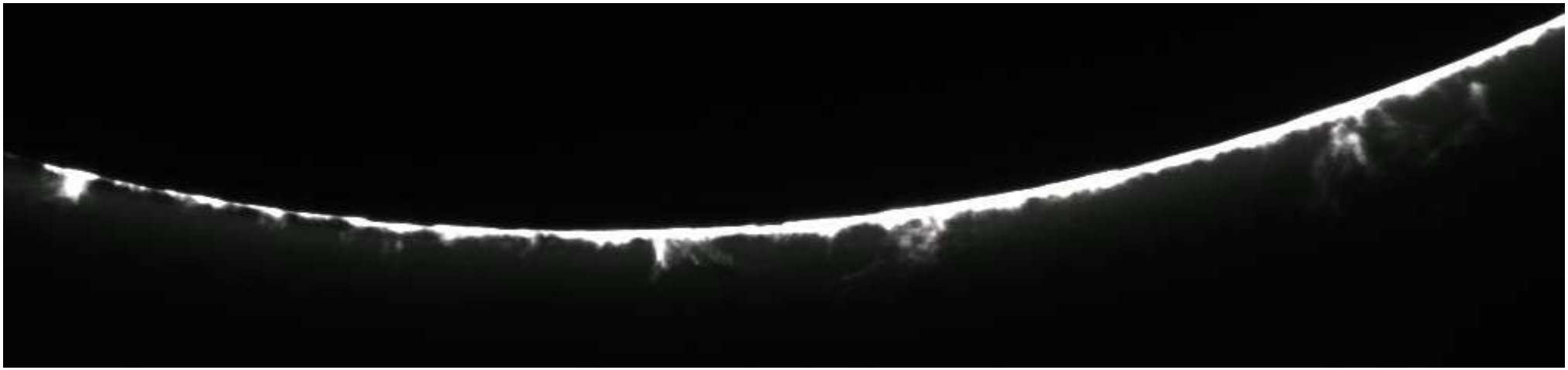
LSO: CoMP-S

- Instrument ready for more observing programs

- Basic performance parameters (at the moment):

- 6 chromospheric and coronal VIS lines
- line change time: 5 – 114 s
- filter tuning time: 230 ms
- fixed 4 polarization states sequence
- polarization change time: 30 ms
- t_exp: 854 nm ~100 ms, 656 nm ~50 ms
- typically 9 wavelength points per line profile

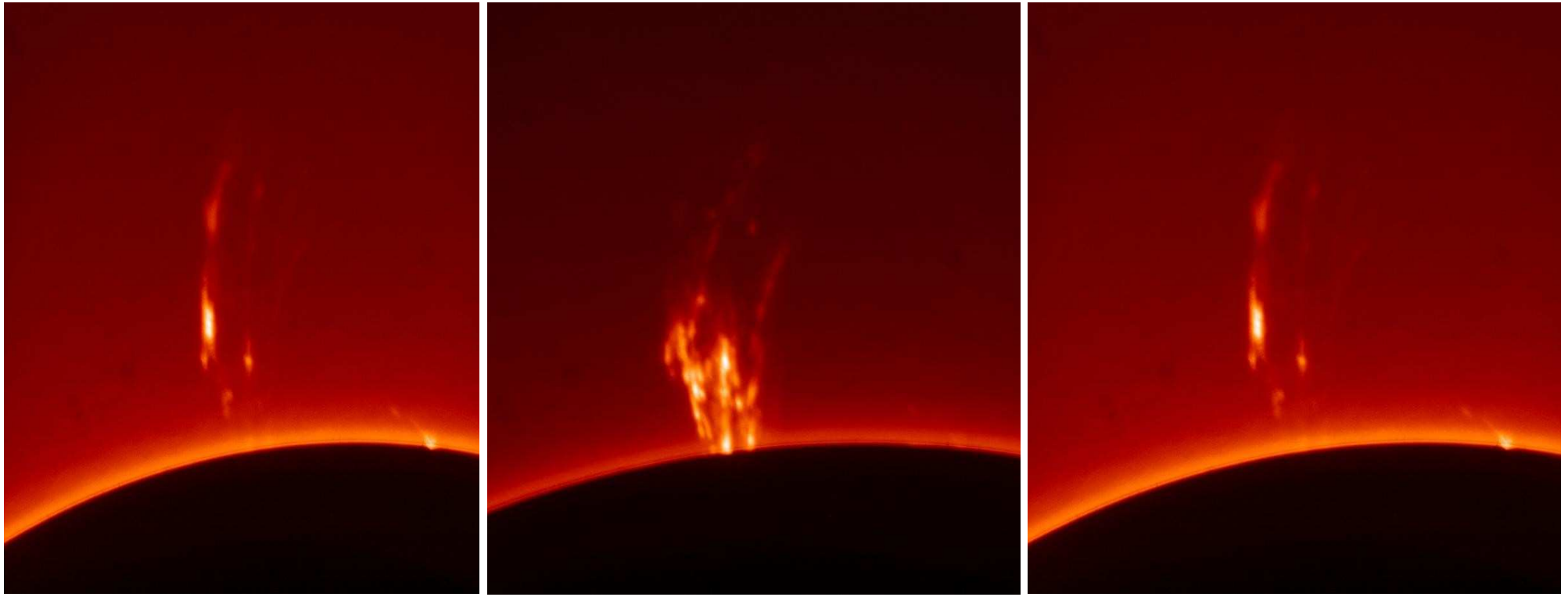
- Astro-climate of the LSO: statistics of almost 50 years - ~120 observing days, ~70 „coronal“ days, ~50 long “coronal” days, typical air high-pressure periods (e.g. October, January,...)



LSO: CoMP-S

- Instrument ready for more observing programs

- Prominences/chromosphere & Stokes I → corona & full Stokes



-0.1 nm | 656.28 nm | +0.1 nm

26/04/2012 H alpha (AR 11459, PA=250°)

Comp-S@LSO Web page: *http://www.astro.sk/LSO/COMP-S/*

LSO: CoMP-S

- presentation on behalf of the LSO/CoMP-S team:

- Aleš Kučera – head, administration

LSO: CoMP-S

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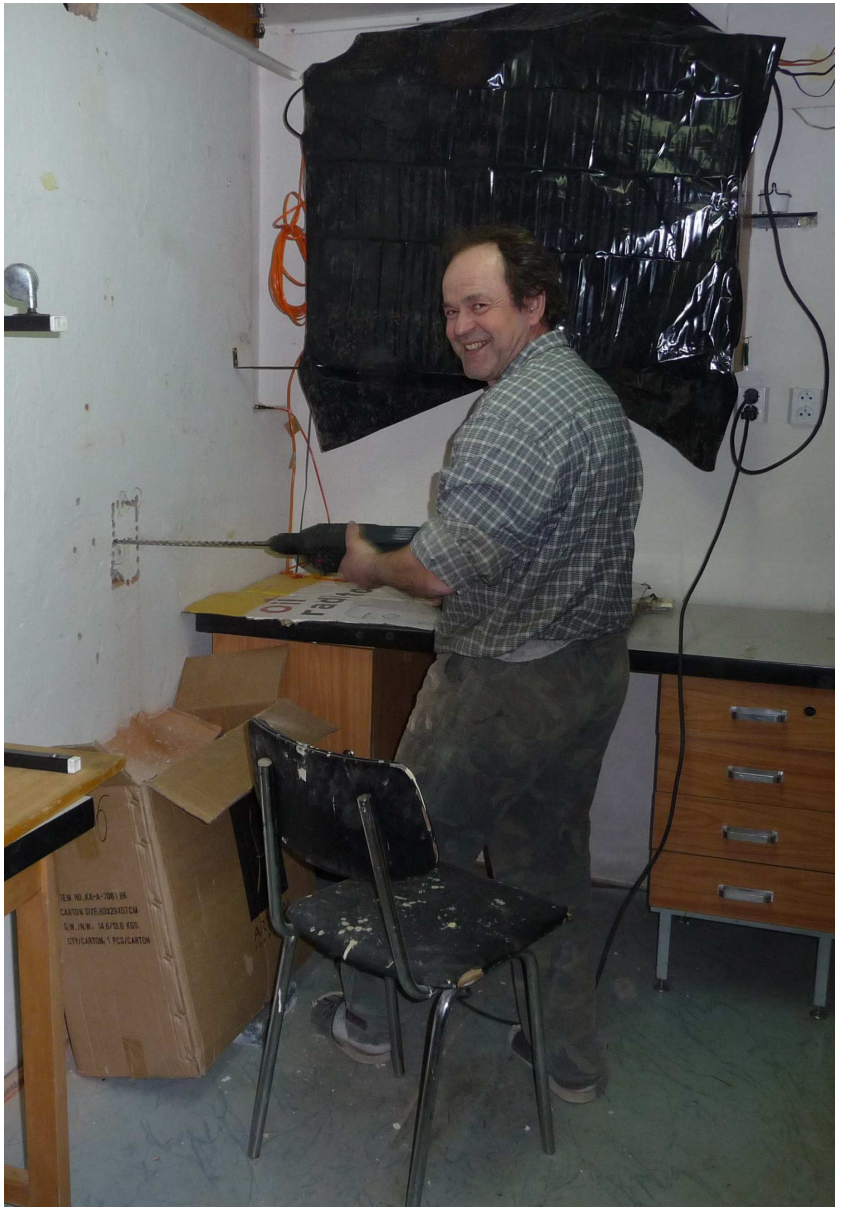

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- Peter Gömöry

- František Budzák – workshop/supply

- Richard Komžík – system administrator
- Ján Klein - workshop

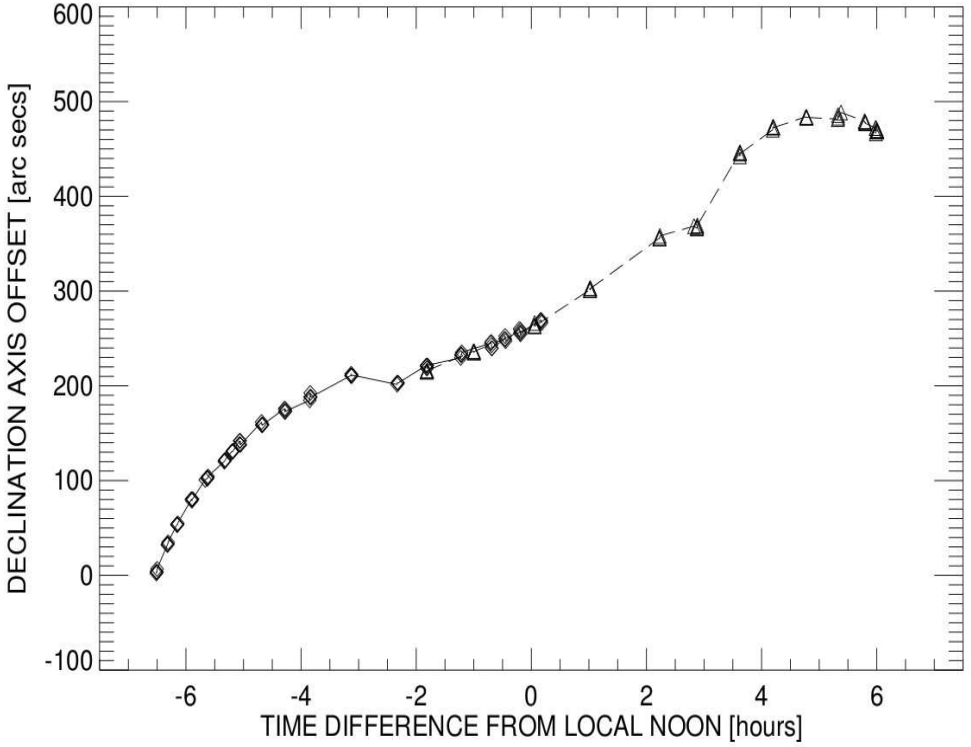

Thank you for your attention

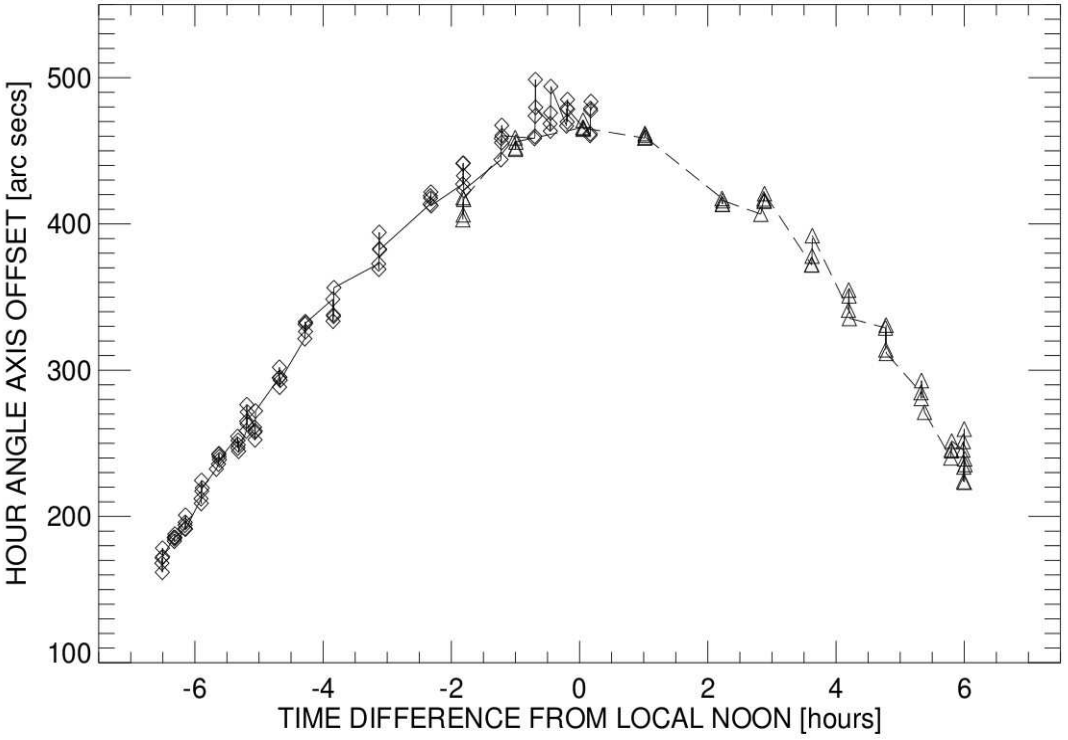
LSO: pointing system

- a contract with HANKOM company for study and realization of the coronagraph pointing system – both tubes coaligned on-line with 2” precision

- **Why? A two-fold answer:** 1/ individual tube is bending during the day (maximum of 8“/hour change for midday of summer days), 2/ two coronagraphs are offset now for more than 400“

- **How?** Objective lens shift, an on-line correction of the tube directions by pulling-pushing their hour angle distance and variating their declination difference





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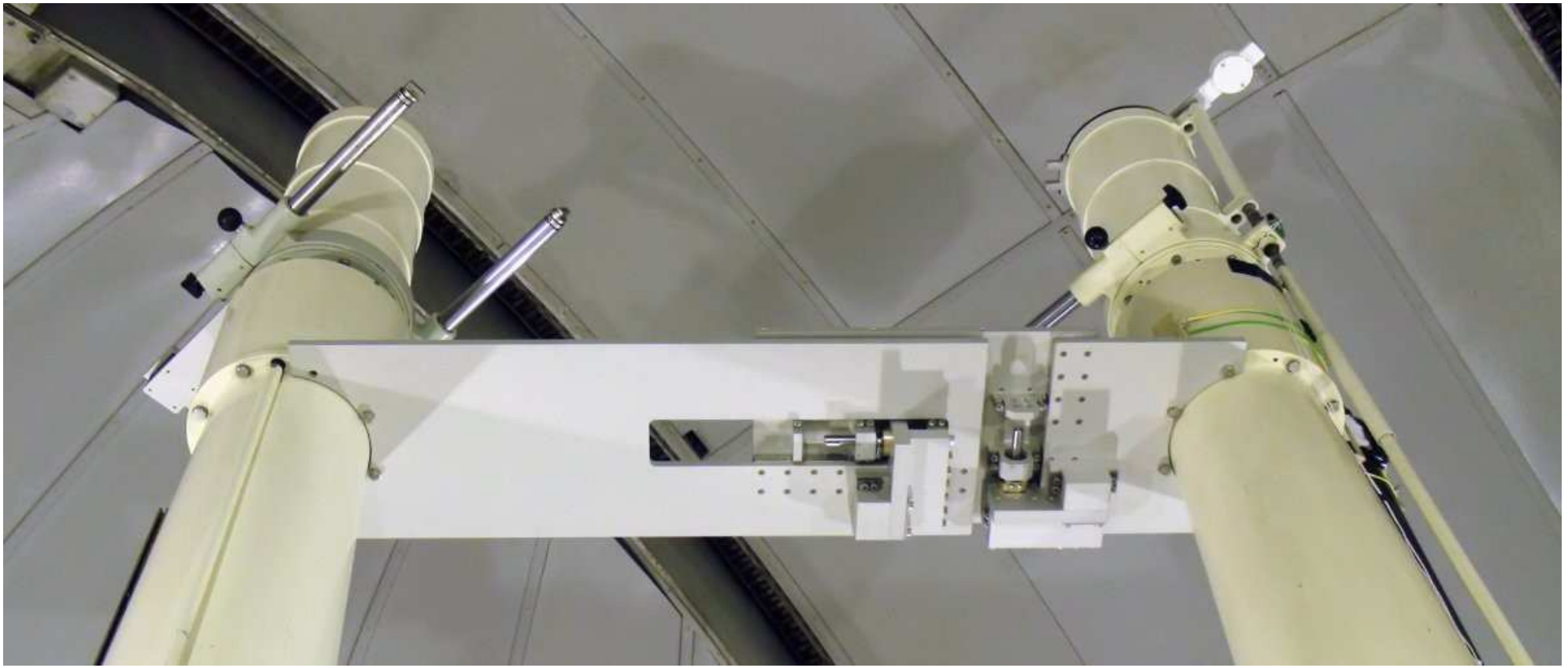
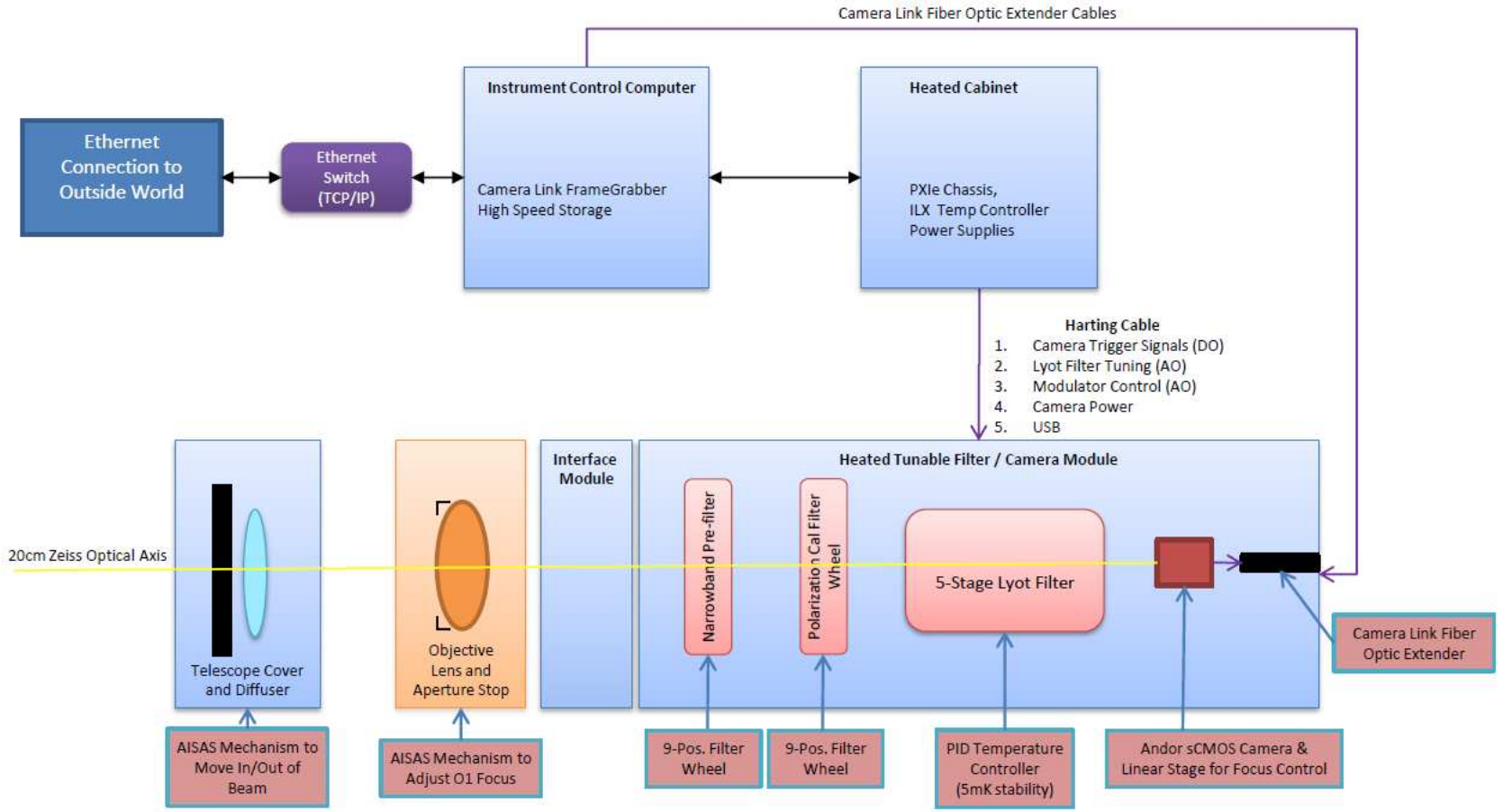


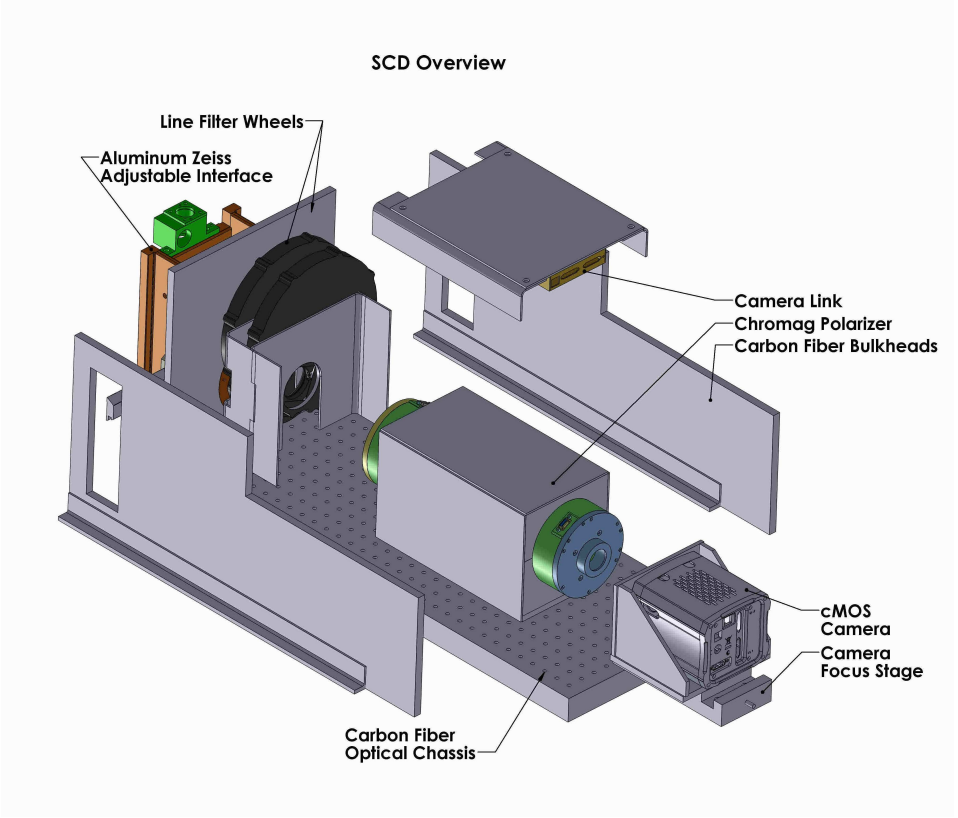
LSO: Solar Chromospheric Detector (SCD)

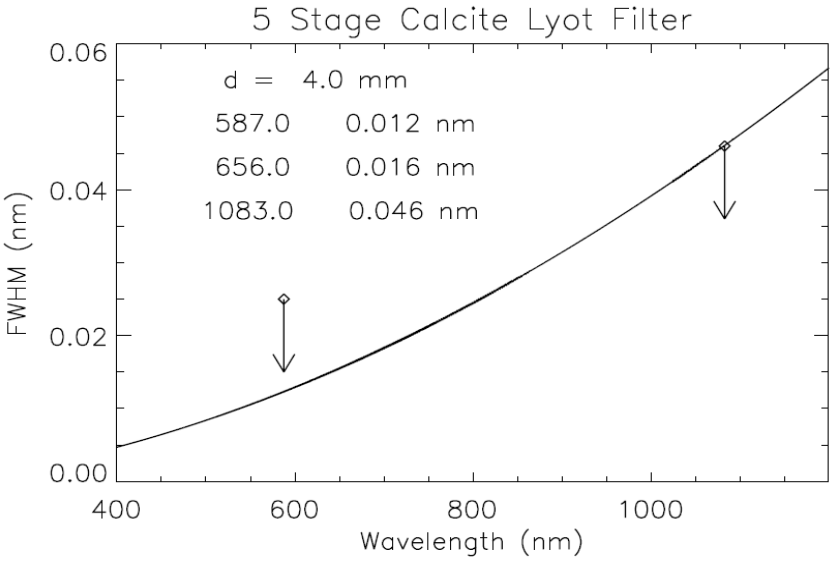
- a contract with HAO/NCAR – “CHROMAG for Slovakia“
- 5-stage Lyot filter + polarimeter
- wavelength range: 500-1100 nm
- chromospheric lines: He I 587.6 nm, Na I 589.2 and 589.6 nm, HI 656.3 nm, CaII 854.2 nm and HeI 1083.0 nm
  photospheric lines: Fe I 617.3 nm, Fe I 630.15 and 630.25 nm, continuum
- Andor sCMOS NEO camera: 2560 x 2160 pixels of 6.5 micron size

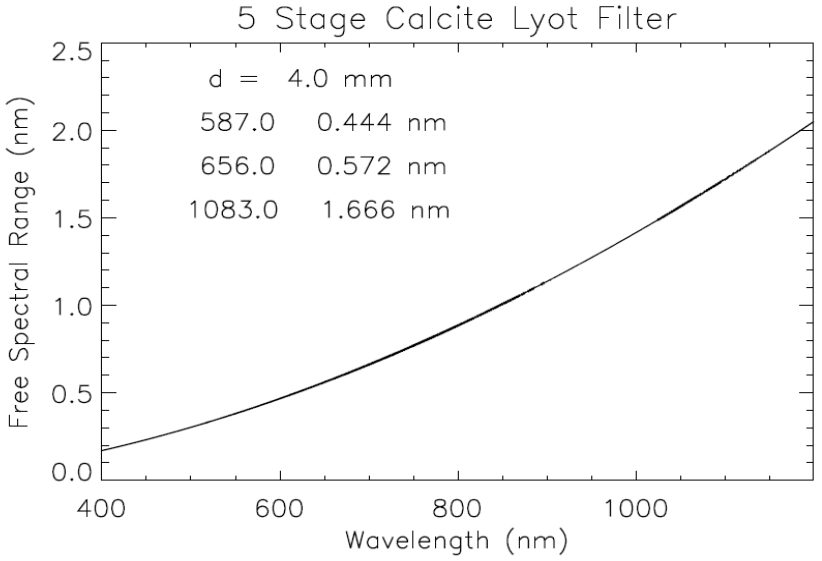


LSO: Solar Chromospheric Detector (SCD)

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







LSO: work for future

- dome improvements: → THEMIS-line
- dome cleaning from snow – fast, safe, manual

- motions of coronagraphs from a PC keyboard
- automatic eclipse/non-eclipse positioning of coronagraphs

- automatic revolution of the dome

- TARG and ABSO measurements without personal actions in dome

- CorMag@LSO
- broad-band H alpha full disk prominence/CME patrol

- TiO_2 painting of dome