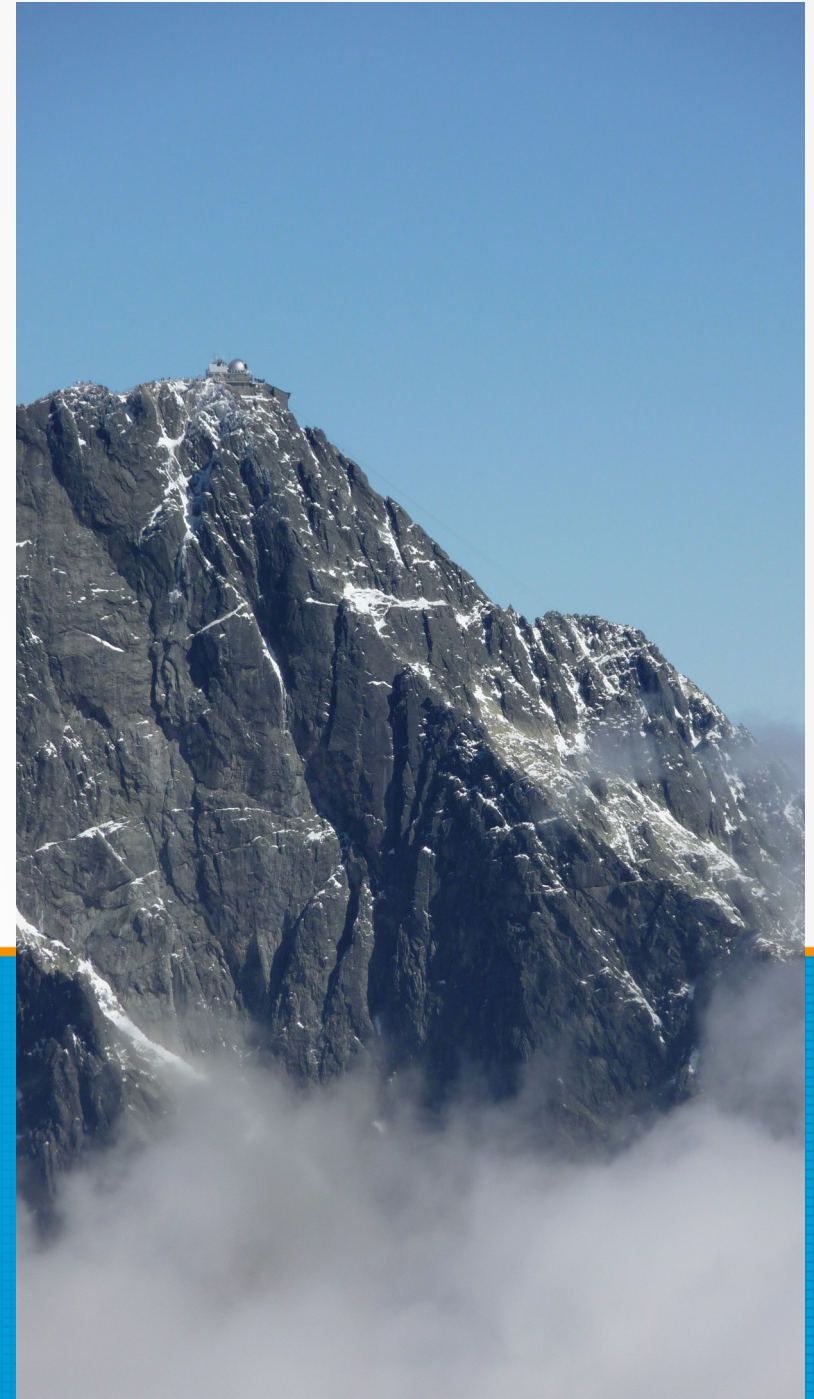


# LSO summer internship program: pointing to the Sun

Ján Rybák  
Lomnický Štít Observatory (LSO)  
AI SAS, Tatranská Lomnica, Slovakia



2024



# Content:

- Two main topics:
  - Pointing the telescope with a post-focus instrument to the Sun in the course of the day
  - Observing conditions and the image quality

# Pointing to the Sun:

- Sun is a star but its position...
- Sun motion across the sky:
  - Theory: hour angle, declination
  - Practice: terrestrial atmosphere + telescope position

# Telescope position and orientation:

- Terrestrial atmosphere:
  - Scattering
  - Differential refraction
  - Definitely not a still snapshot image...
- Mechanics:
  - Mount: northern axis, equatorial plane, hour angle and declination axes, fixing coronagraph~mount, motor drives
  - Coronagraph mechanical structure: bending

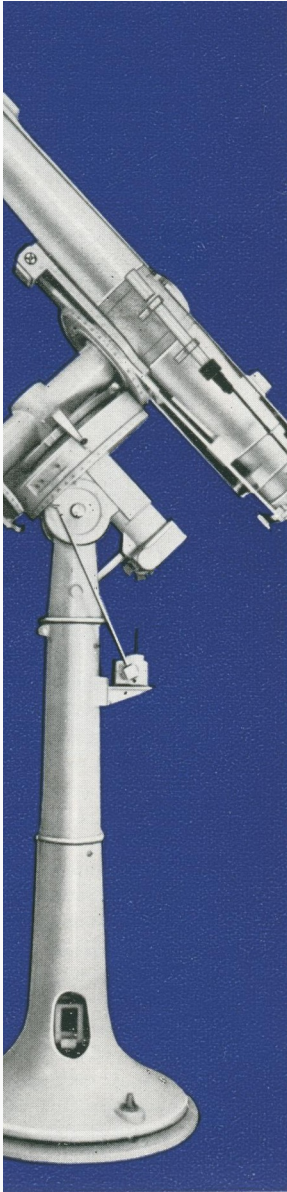
# Pointing to the Sun:

- Very long time ago - 1962-1990:
  - Visual adjustment of the coronagraph pointing to the disk center checking the image around the artificial moon edge (inside coronagraph, in the final focal plane, in the post-focus final image)
  - Hour drive of a nominal speed (15 degrees/hour)
  - Manual corrections for declination changes and/or imperfections of the hour drive
  - Definitely not good for some measurements



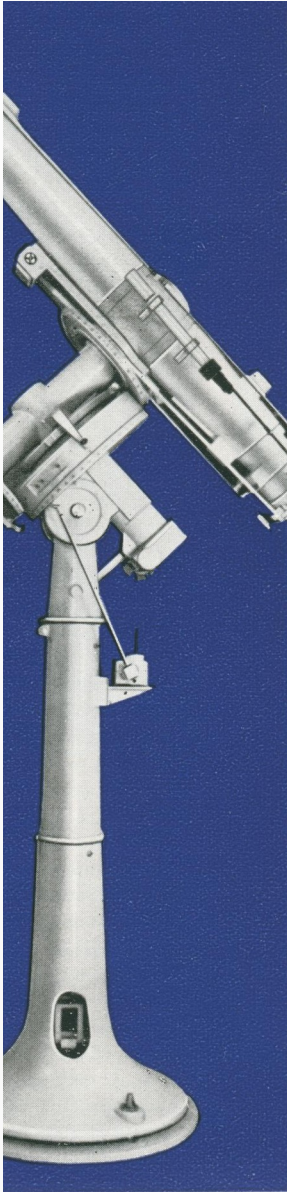
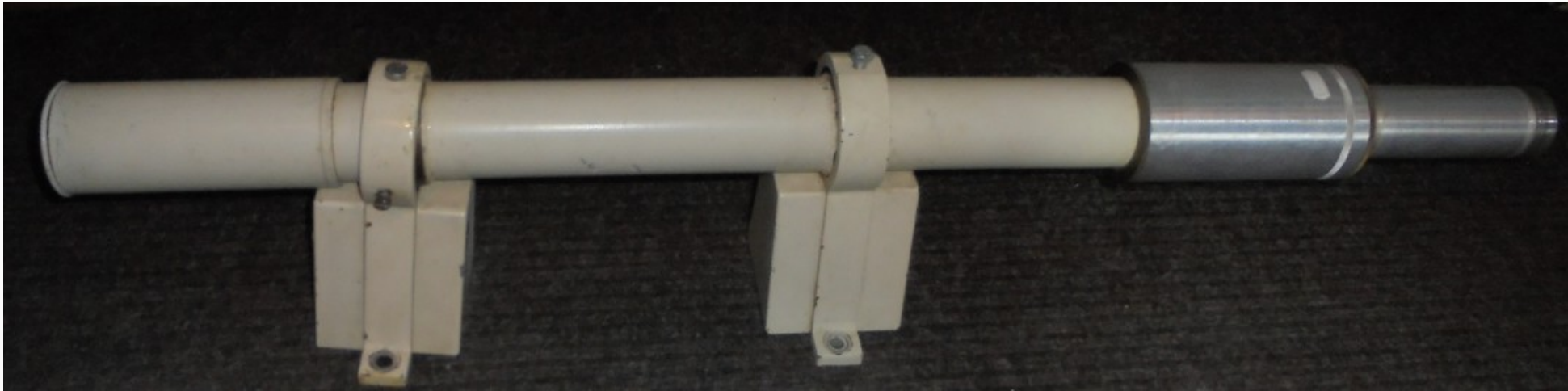
# Pointing to the Sun:

- Very long time ago - 1990-2010:
  - A separate telescope for guiding (originally produced by ZEISS)
  - A quantitative measurement of the solar disk image position and operation of the driving motors using an analogue electrical system: 4 diodes at the limb/sky transition in the a/d orientation



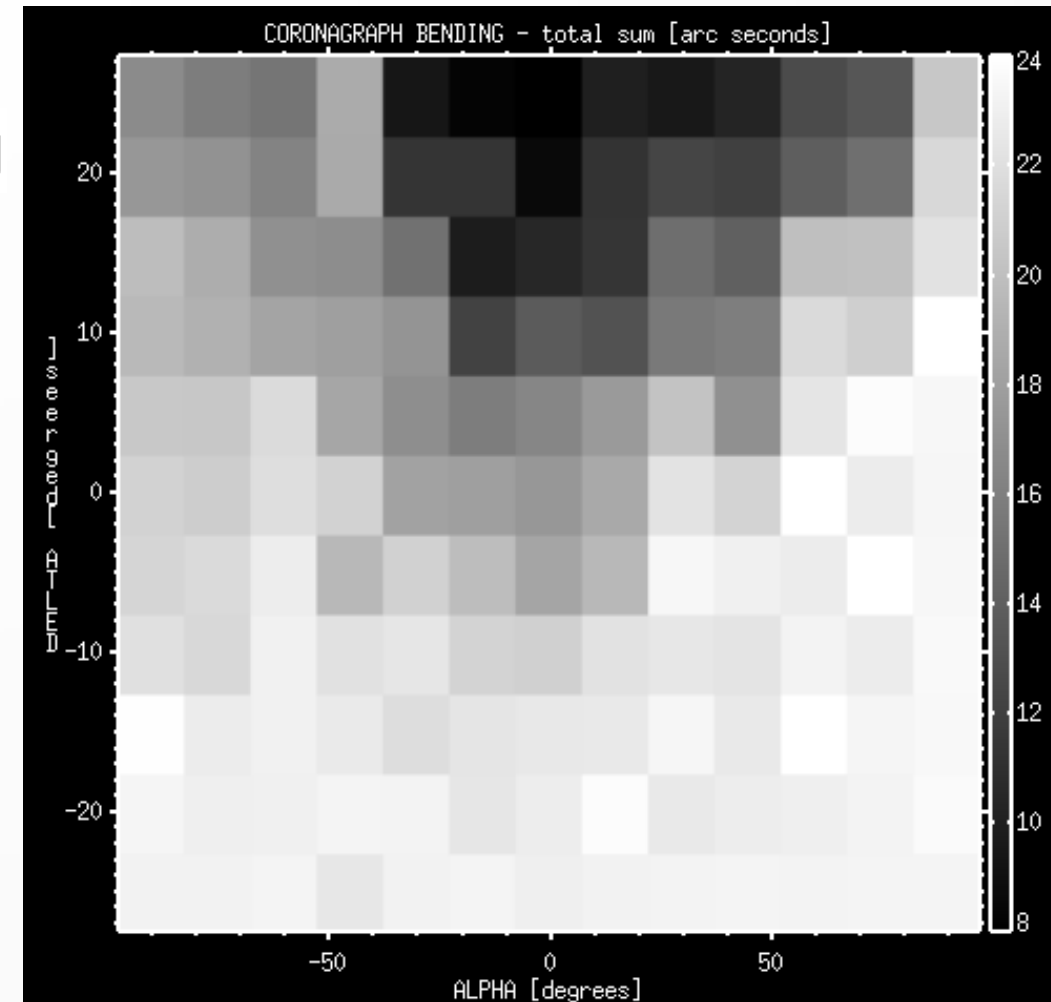
# Pointing to the Sun:

- Very long time ago - 1990-2010:



# Pointing to the Sun:

- Very long time ago - 1990-2010:
  - still problems with fine pointing better than 5" in a hour...
- Mechanical problem?
- Checking: laser near lens + camera near moon
- Result: relative changes of the coronagraph optical axis
  - relative changes in 1 hours
  - reference:  $\alpha=0$ ,  $\delta=49$



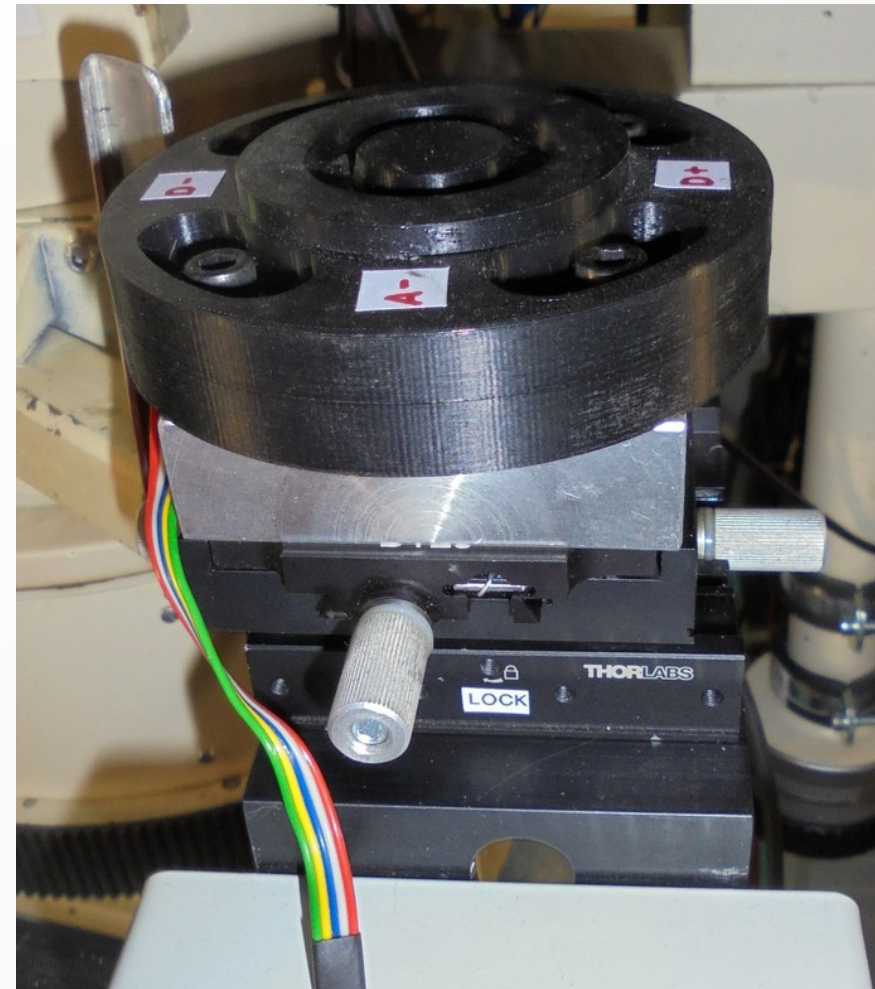
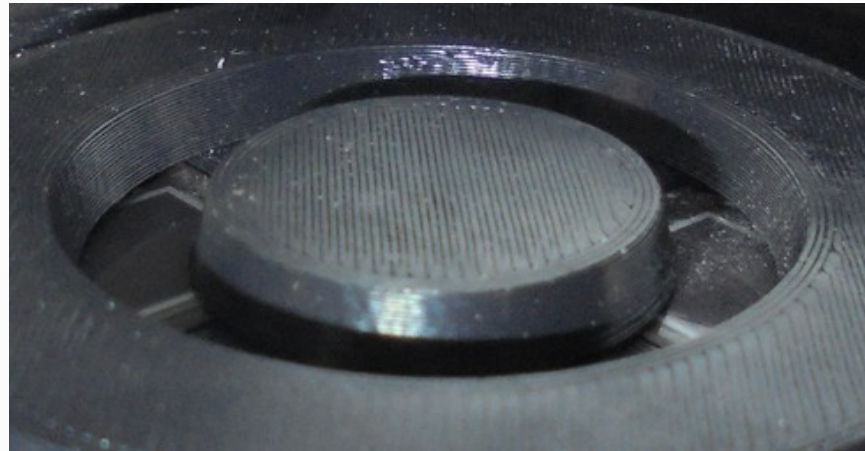
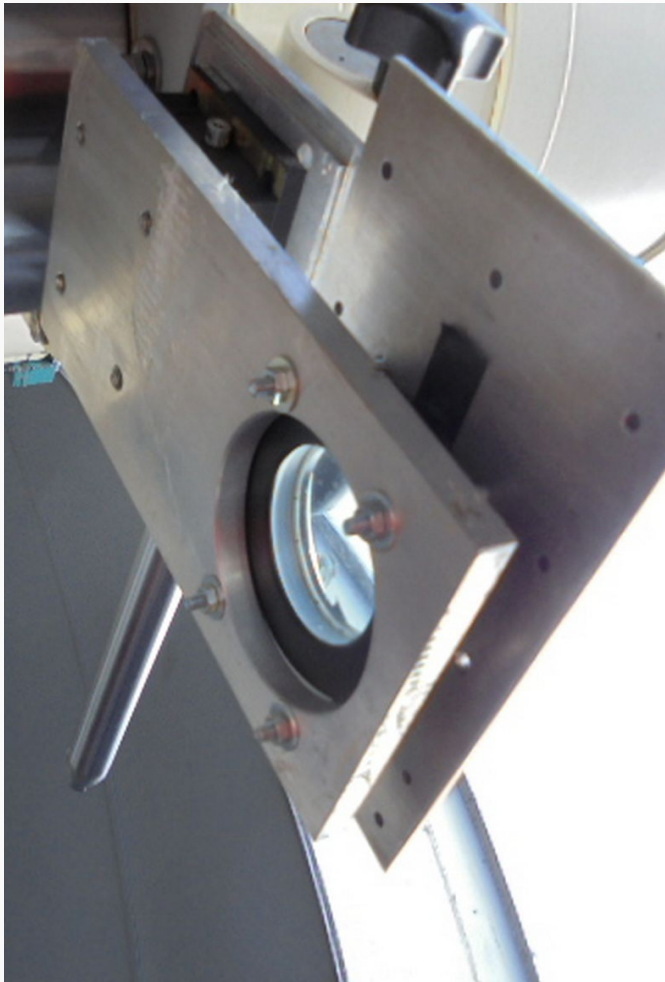


# Pointing to the Sun:

- Idea: the same external pointing idea with a significant update (2011):
  - the lens fixed tightly to the coronagraph objective lens
  - diodes fixed tightly to the artificial moon
  - lens diodes mechanically separated
- Development of installations at the right coronagraph:
  - 50/3000 mm BK7 lens + Shott Kg3 thermal insulation glass filter
  - different types of diodes
  - LabVIEW code for diode data acquisition, calculations, operation of drivers, auto-balance option, residual motions, automatic fine eclipse adjustment, clouds detection, closed loop operation of a/d drives

# Pointing to the Sun:

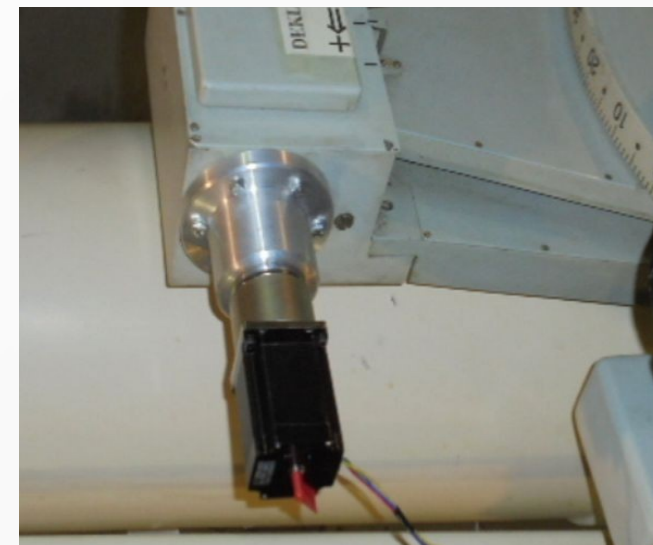
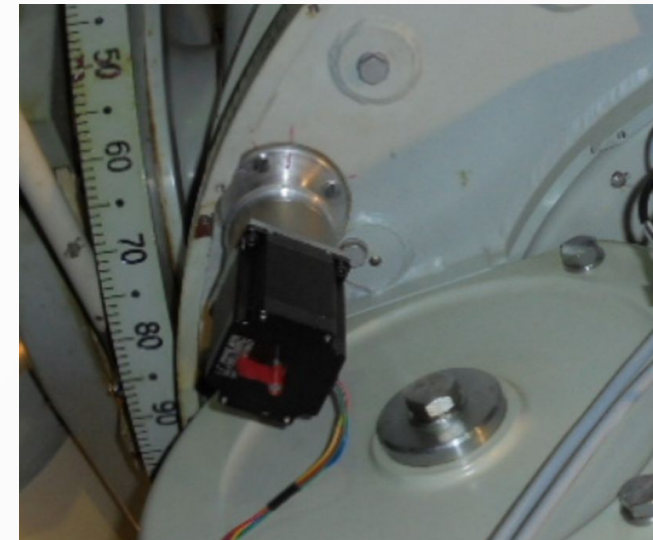
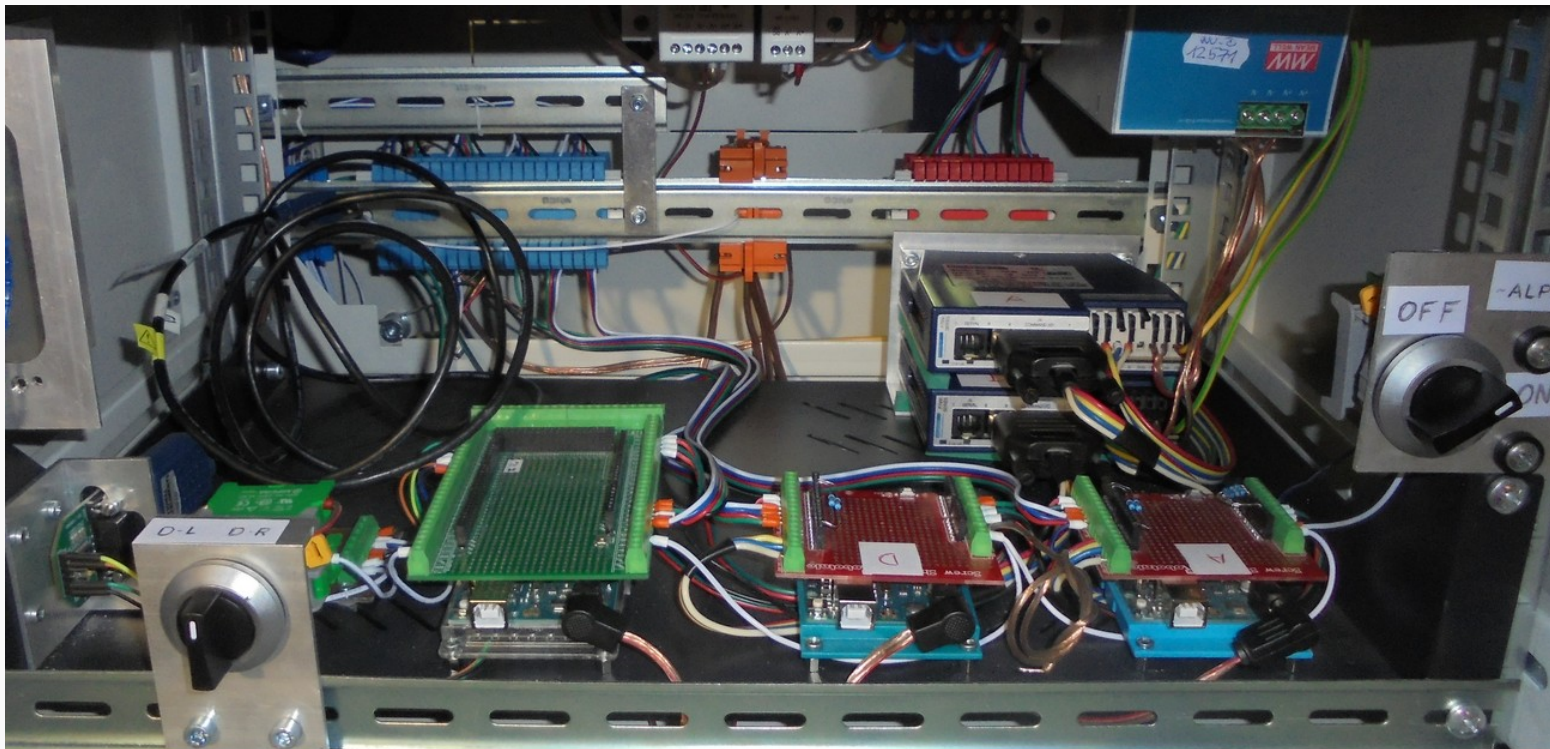
- Current installation @ the right coronagraph





# Pointing to the Sun:

- Current installation @ the right coronagraph



# Pointing to the Sun:

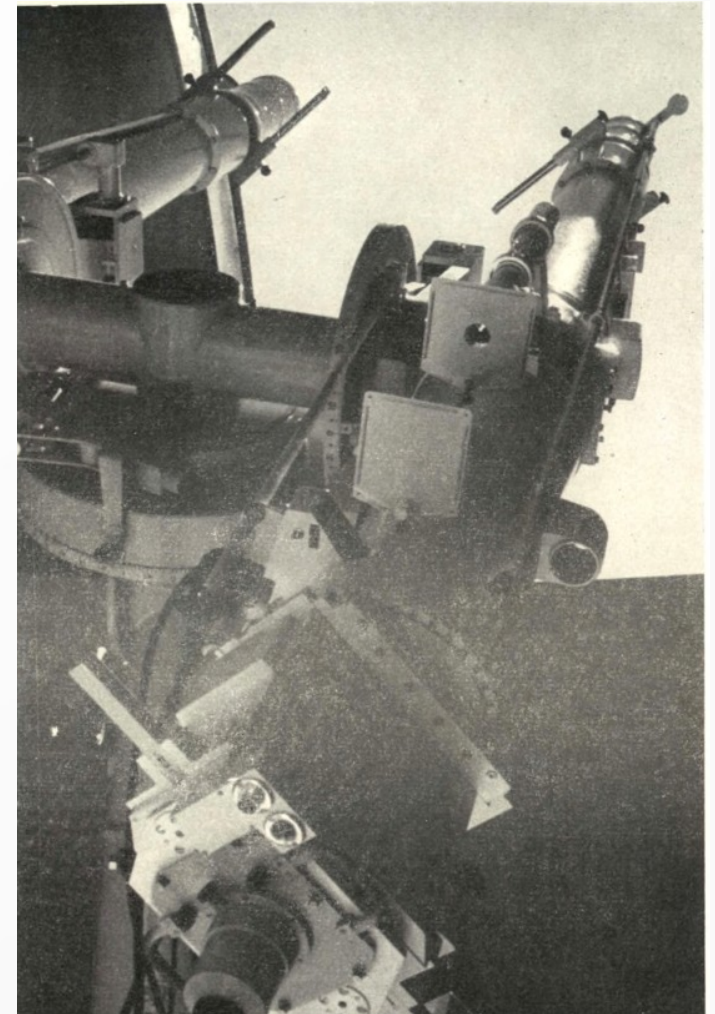
- Current installation @ the right coronagraph





# Pointing to the Sun:

- 1 coronagraph → 2 coronagraphs at the same mount: 1970-1971

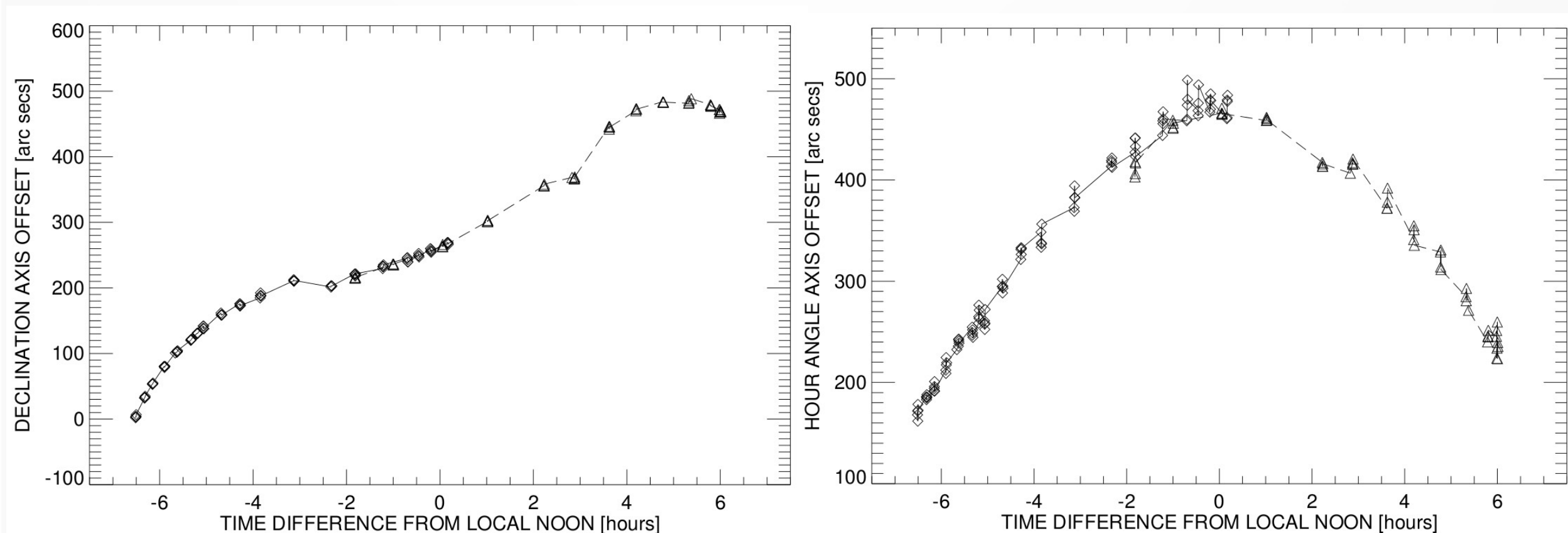


# Pointing to the Sun:

- 1 coronagraph → 2 coronagraphs at the same mount: 1970-1971
- Co-alignment:
  - Obvious in declination
  - Impossible in hour angle
- Result:
  - no simultaneous eclipse measurements with both coronagraphs
  - Two different post-focus instruments at coronagraphs → only sequential eclipse measurements possible

# Pointing to the Sun:

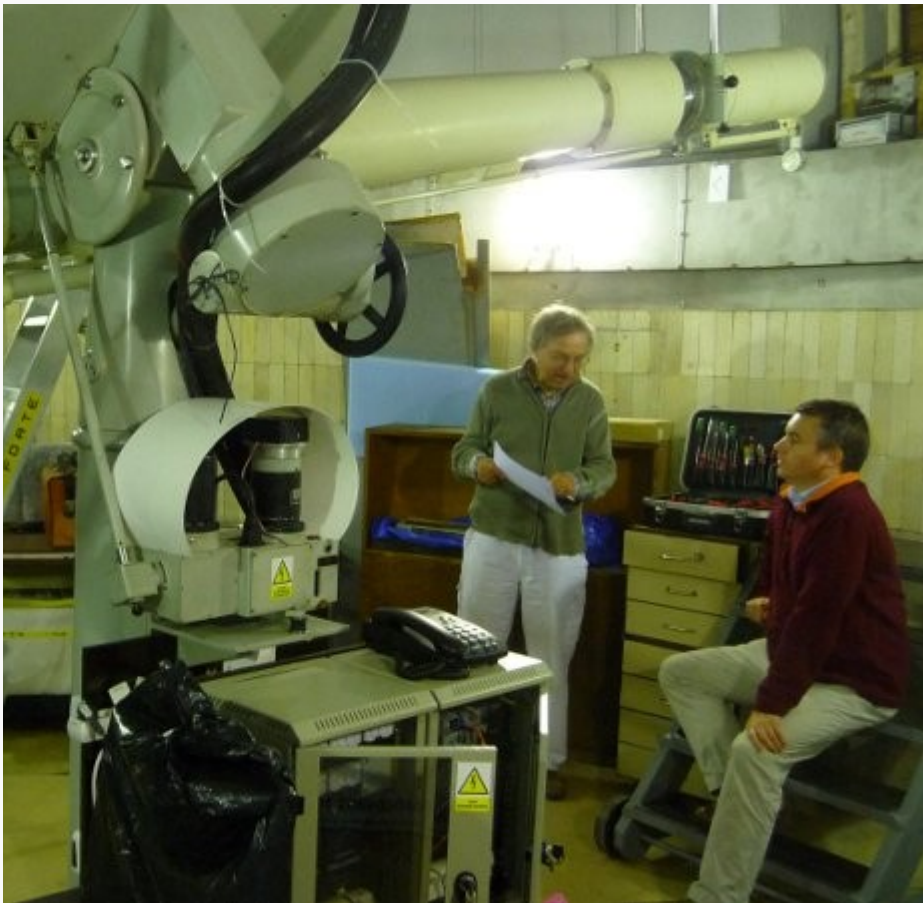
- 1 coronagraph → 2 coronagraphs at the same mount: 2012 – measurements of the residual misalignment between coronagraphs during a summer day (start: declination difference set to 0, pointing of the right coronagraph + free motion of the left coronagraph) → differences to 500''!





# Pointing to the Sun:

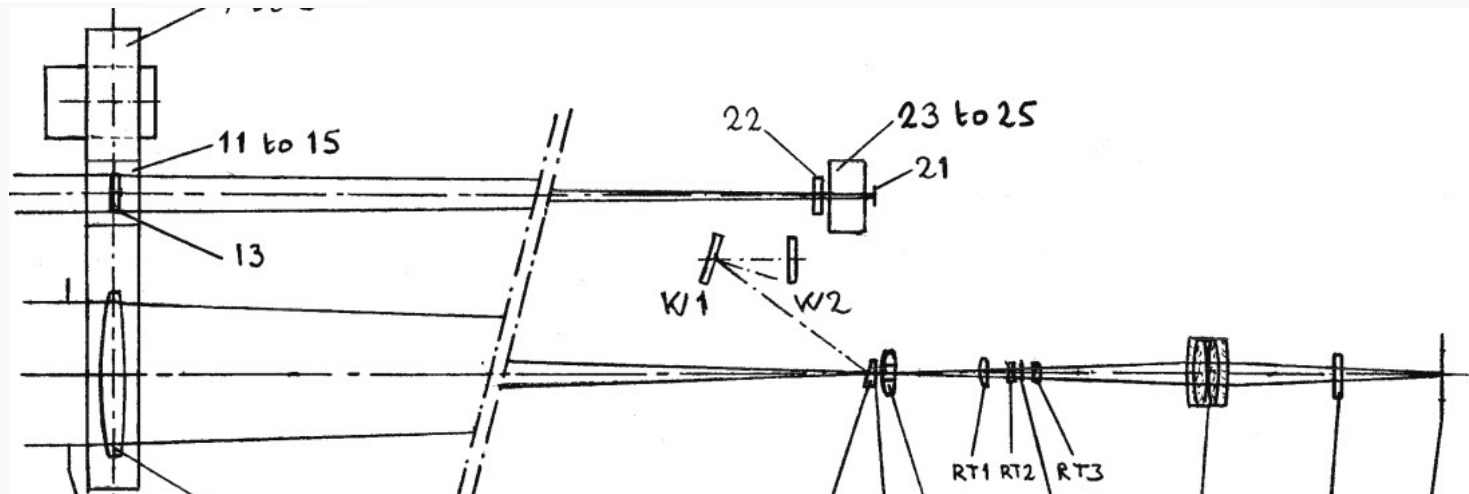
- 1 coronagraph → 2 coronagraphs at the same mount: invitation of the HANKOM company (Netherlands) → idea how to solve the problem → order of the instrument → final installation + testing: 09/2013





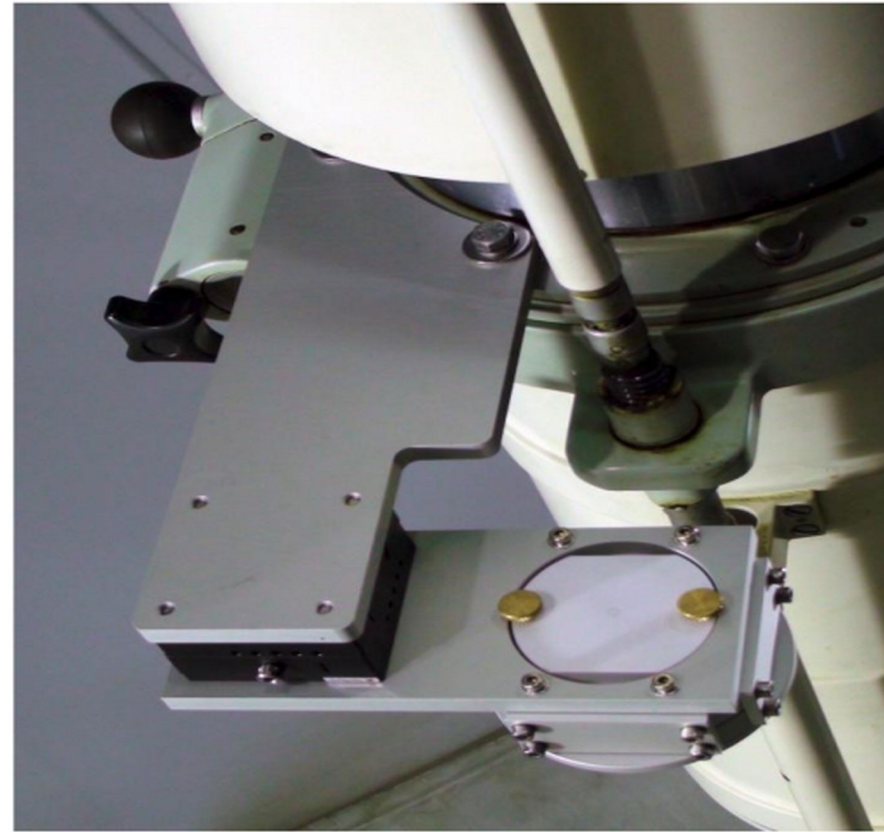
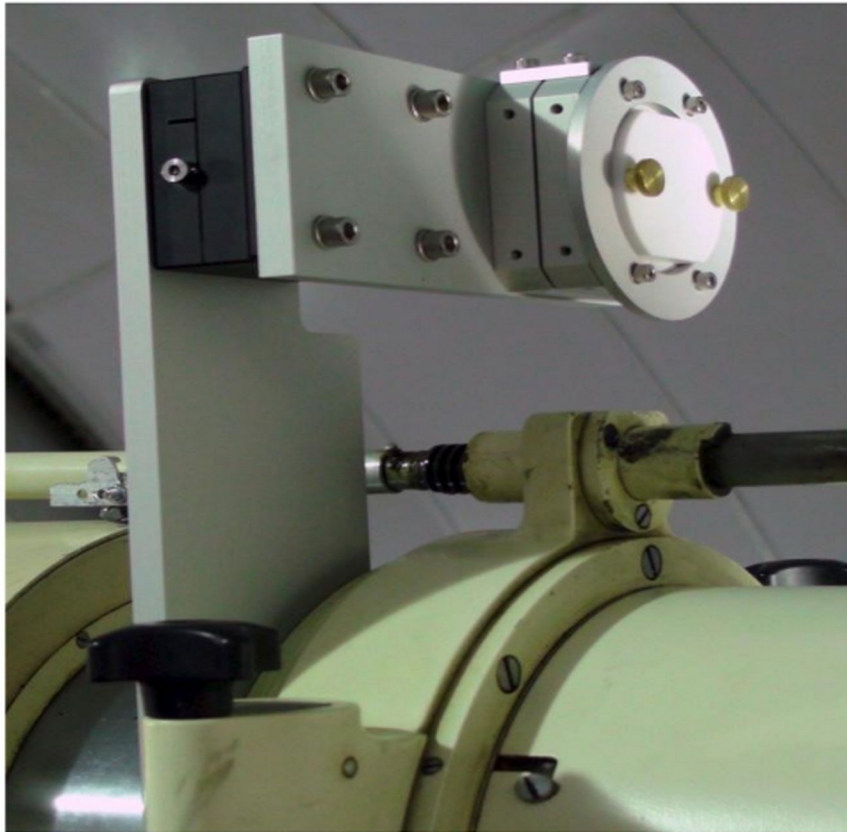
# Pointing to the Sun:

- 1 coronagraph → 2 coronagraphs at the same mount:
- HANKOM idea how to solve the problem:
  - doubling the originally developed pointing system at the right coronagraph
  - mechanical corrections of the front part of coronagraphs mutually to reach the eclipse at both coronagraphs (near the objective lenses)
  - The critical point: small fast stepper drives + small gear mechanisms of high reduction ratio



# Pointing to the Sun:

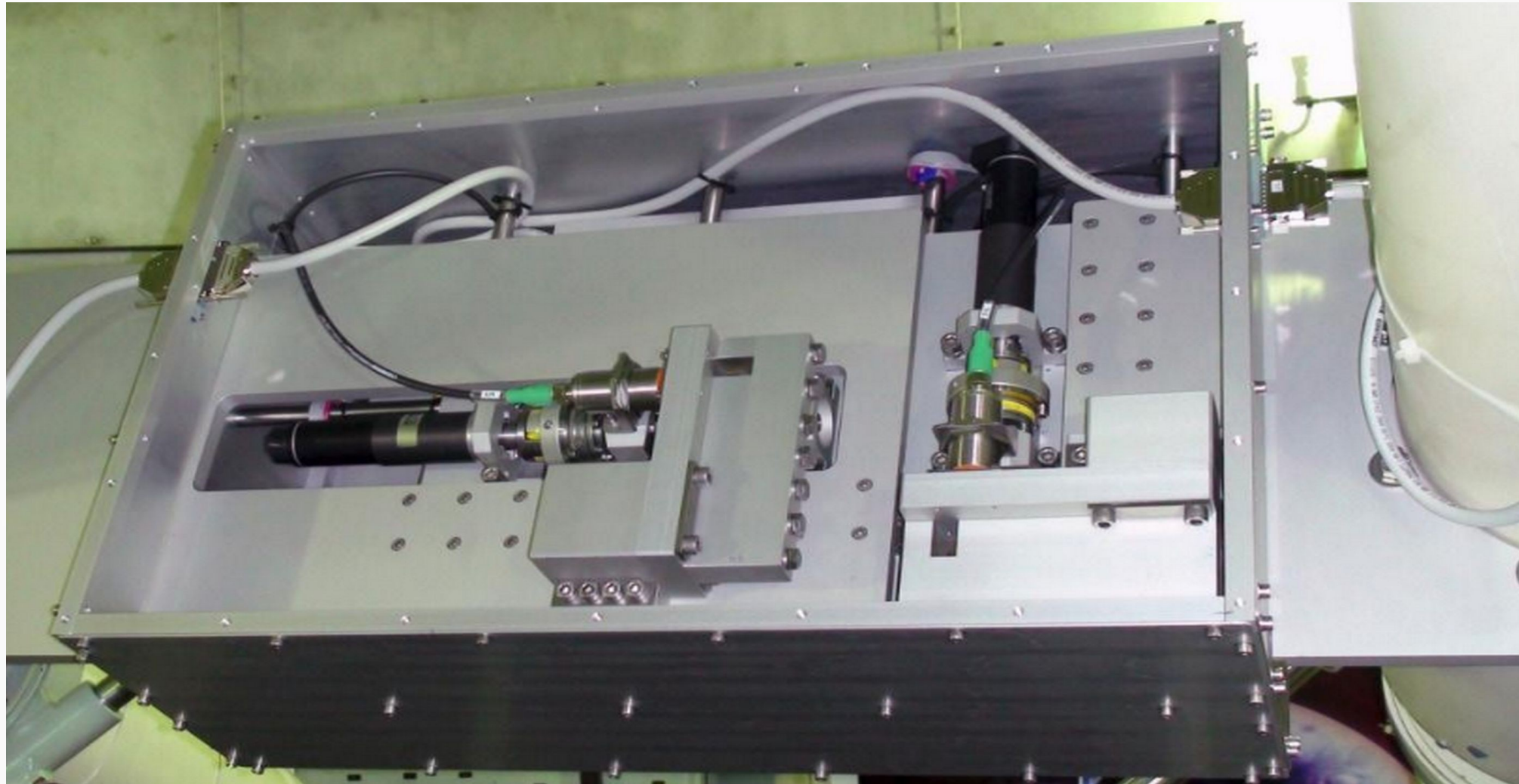
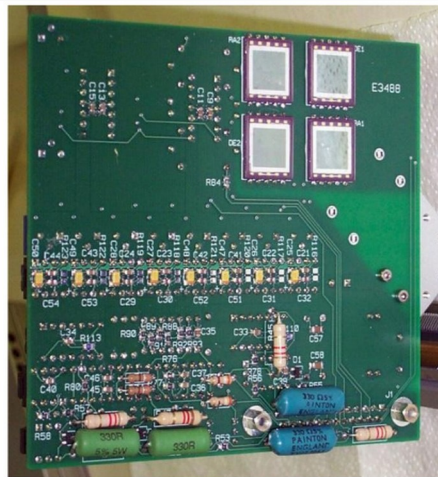
- 1 coronagraph → 2 coronagraphs at the same mount: HANKOM





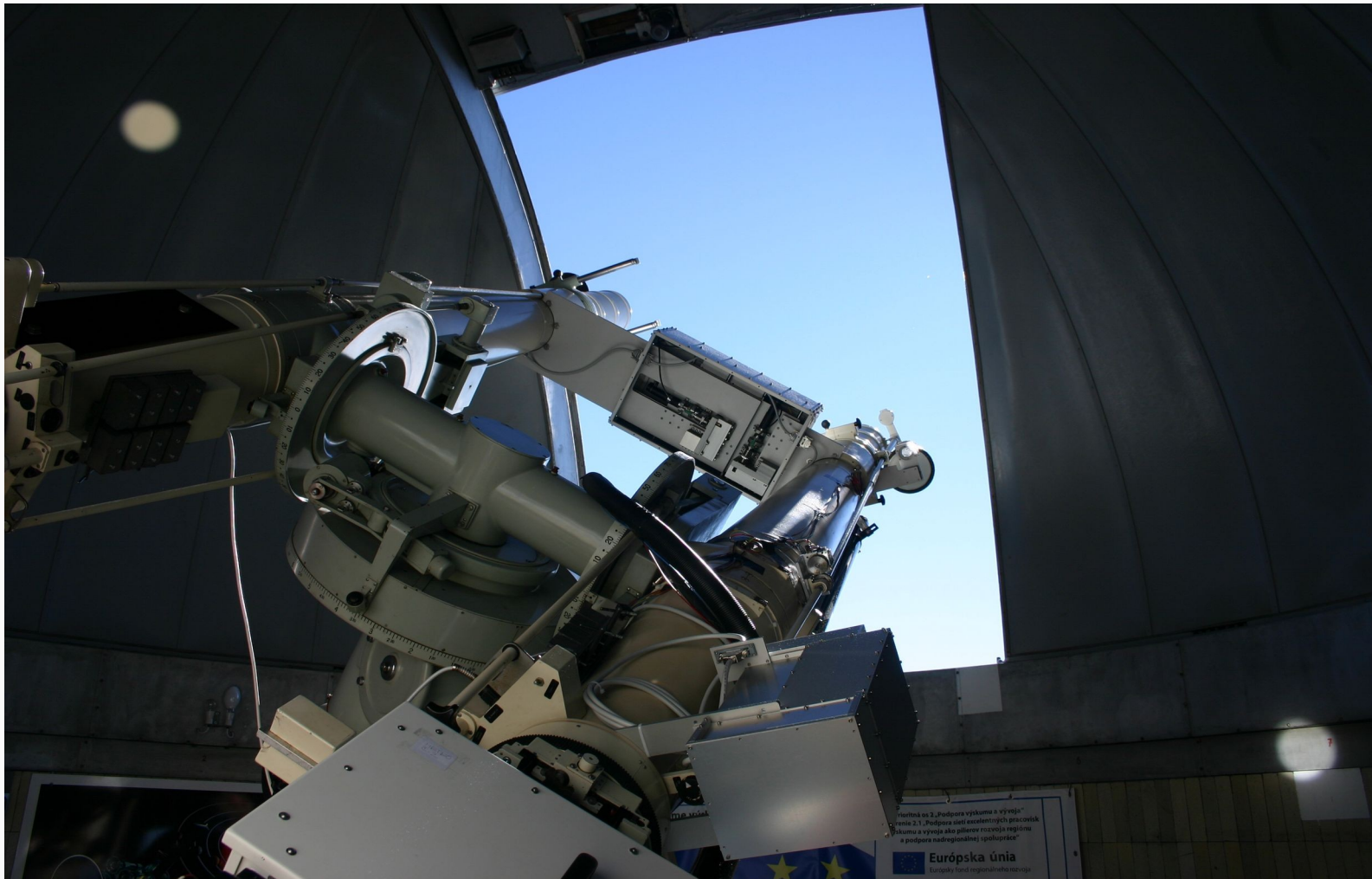
# Pointing to the Sun:

- 1 coronagraph → 2 coronagraphs at the same mount: HANKOM



# Pointing to the Sun:

- 1 coronagraph → 2 coronagraphs at the same mount: HANKOM → after 43 year two eclipses in the LSO dome (06/09/2013)





# Observing conditions and image quality:

- Image the Sun = snapshot of a live image (of an animal alive...), when:
  - the ground-based instrument
  - without online adaptive optics in action
  - without post-facto image processing
- Reason: the terrestrial atmosphere
- Solutions/corrections:
  - Space-born instrument
  - Adaptive optics
  - Post-facto corrections
- LSO situation and possible improvements

# Observing conditions and image quality:

- Terrestrial atmosphere effects:
  - Differential refraction
  - Scattering
  - Blurring
  - General term in astronomy: seeing

# Observing conditions and image quality:

- the LSO location:
  - Height – inversion layer height
  - Surrounding: ground, plants, snow
  - Location: the High Tatras range, wind direction, air circulation
  - Weather
  - problems:
    - water vapor, dust, pollen, insects, snowflakes, fog, clouds
    - global/local warming

# Observing conditions and image quality:

- the LSO statistics:

- 2023:  
~20%

	počet dní	podiel dní / celý rok <sup>1</sup>	podiel dní / prevádzka <sup>2</sup>
Reálne pozorovania	32	8.7 %	11.4 %
Pokusy o pozorovania	19	5.2 %	6.8 %
Testovania pozorovacích prístrojov	6	1.6 %	2.1 %
Pripravenosť observatória na pozorovanie	252	69.0 %	90.0 %
Prevádzka	280	76.7 %	100.0 %
Mimo prevádzky	86	23.6 %	

- 1963-2009:  
~20%/~33%

	1991-2009	1963 – 2009
total number of days	6940	17167
without observations [%]	65.7	65.1
observations of prominences [%]	33.9	34.0
observations of the emission corona [%]	22.3	20.0
coronal conditions (0.0-0.5)hod [%]	0.1	0.1
coronal conditions <0.5-1.0)hod [%]	2.8	1.8
coronal conditions <1.0-2.0)hod [%]	5.3	4.5
coronal conditions <1.0-2.0)hod [%]	14.0	13.7



# Observing conditions and image quality:

- Possible improvements (dreams):
  - Obvious: height - 5000 m asl ?
  - More prospective: location
    - high air pressure all the time, inversion layer below: Canary Islands, Hawaii, Chile, (China/India?), Antarctica
    - stratospheric balloon
    - Orbit
    - Moon
    - Lagrangian point L1 (like SOHO, ACE)