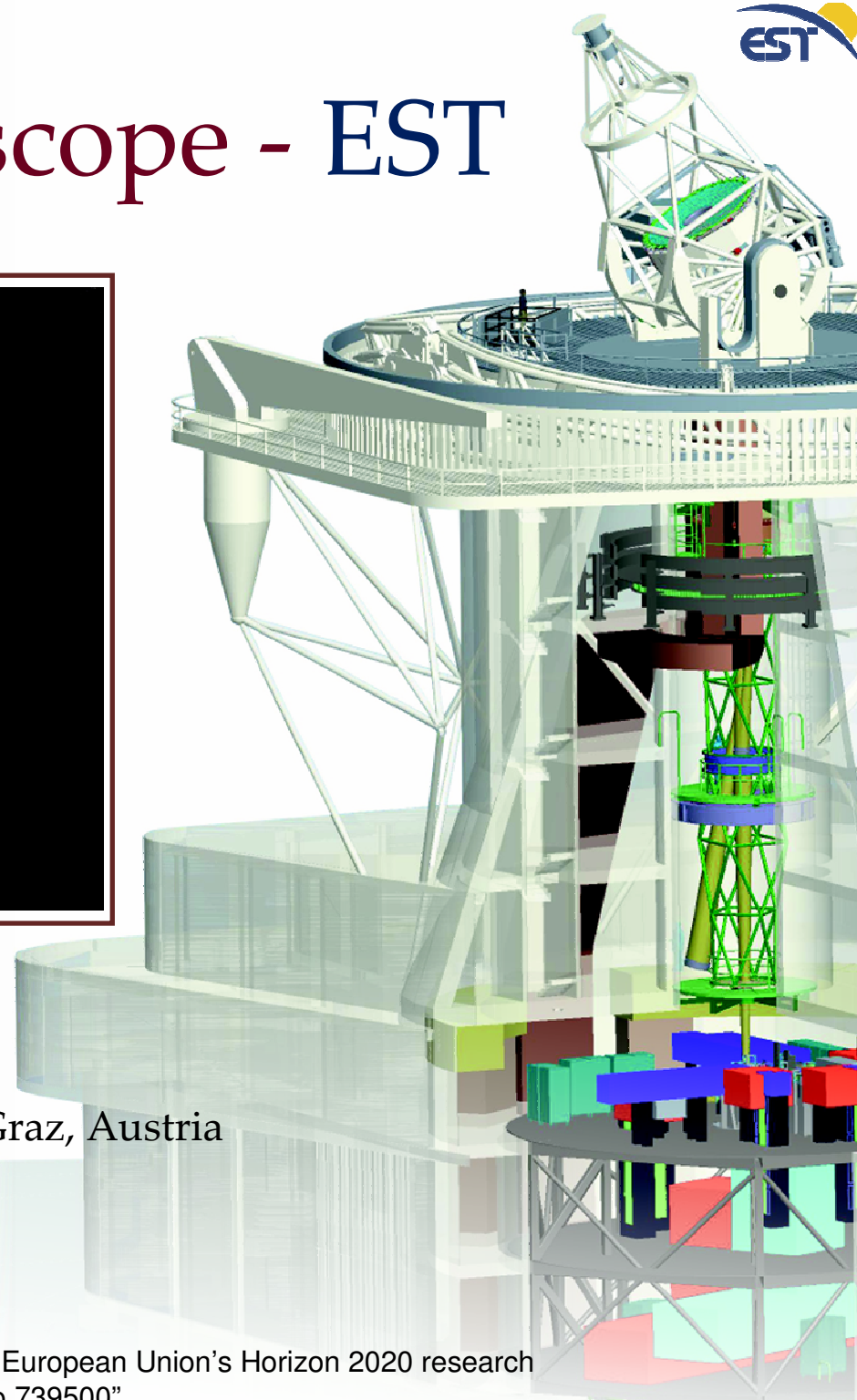


# European Solar Telescope - EST



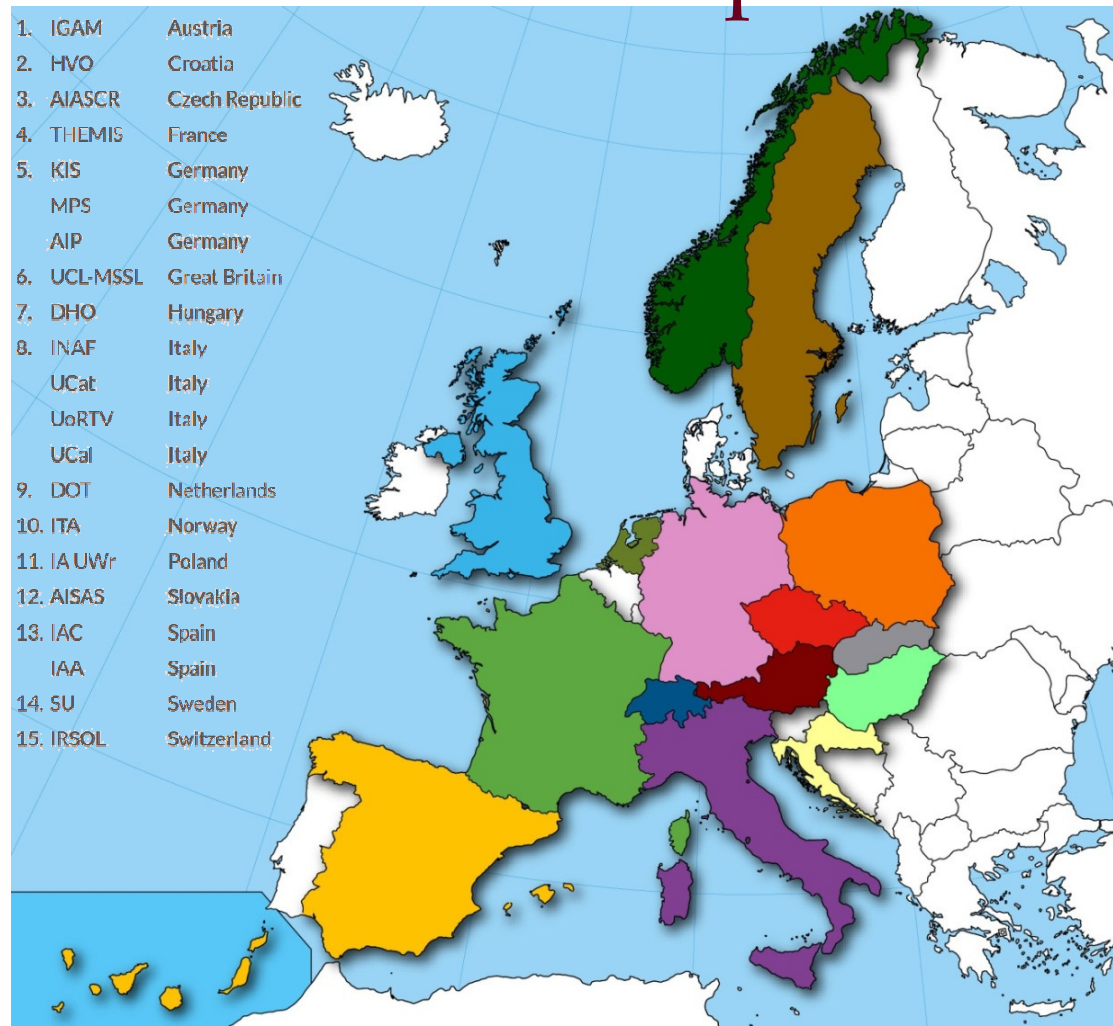
Dominik Utz for the EST team

IGAM/Institute of Physics, Karl-Franzens University Graz, Austria  
Presentation mostly prepared by Peter GÖMÖRY;  
Astronomical Institute, Tatranska Lomnica, Slovakia

# European Association for Solar Telescope

## EAST

- consortium currently uniting 21 institutes from 15 European countries
- founded in 2006
- with a primary goal to develop, construct, and operate EST to ensure the access of European solar physicists to the world-class observing facility
- negotiations with other potential European (Greece, Ireland) and non-European (Japan, Korea, China) partners to join the EST project are in progress
- Stimulate and coordinate also the usage of existing optical solar telescope infrastructure





# Current Directorate of EAST

EAST President



**Mats Carlsson**

Institute for Theoretical Astrophysics,  
University of Oslo

Norway

EAST Vice President

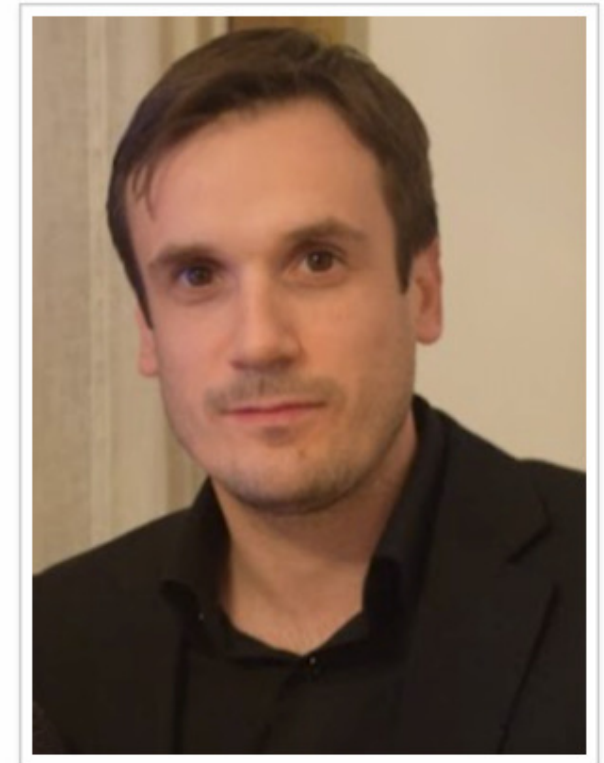


**Prof. Oskar von der Lühe**

Kiepenheuer-Institut für Sonnenphysik,  
Freiburg

Germany

EAST Executive Director



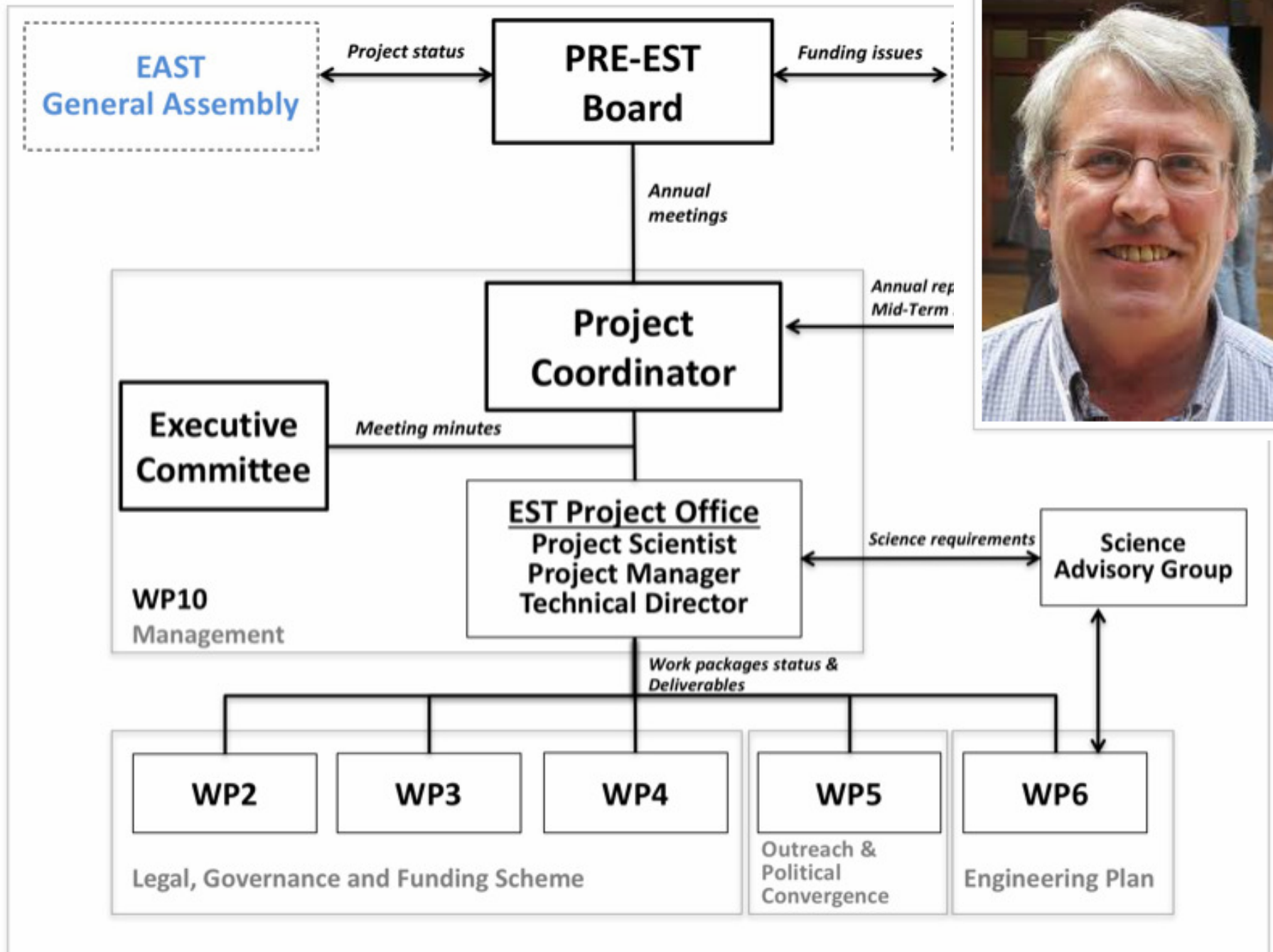
**Marco Stangalini**

Astronomical Observatory of  
Rome-INAF, Rome

Italy

- To provide the EST international consortium and the national agencies with a detailed plan for the implantation of EST
  - Governance
  - Legal structure
  - Financial issues
  - Strategic actions
  - Technical Works leading to final design





# EST: key aspects

- to be built in Canary Islands (Spain): Tenerife or La Palma



**Site testing ongoing ->  
both sites seem equally  
capable to host EST**

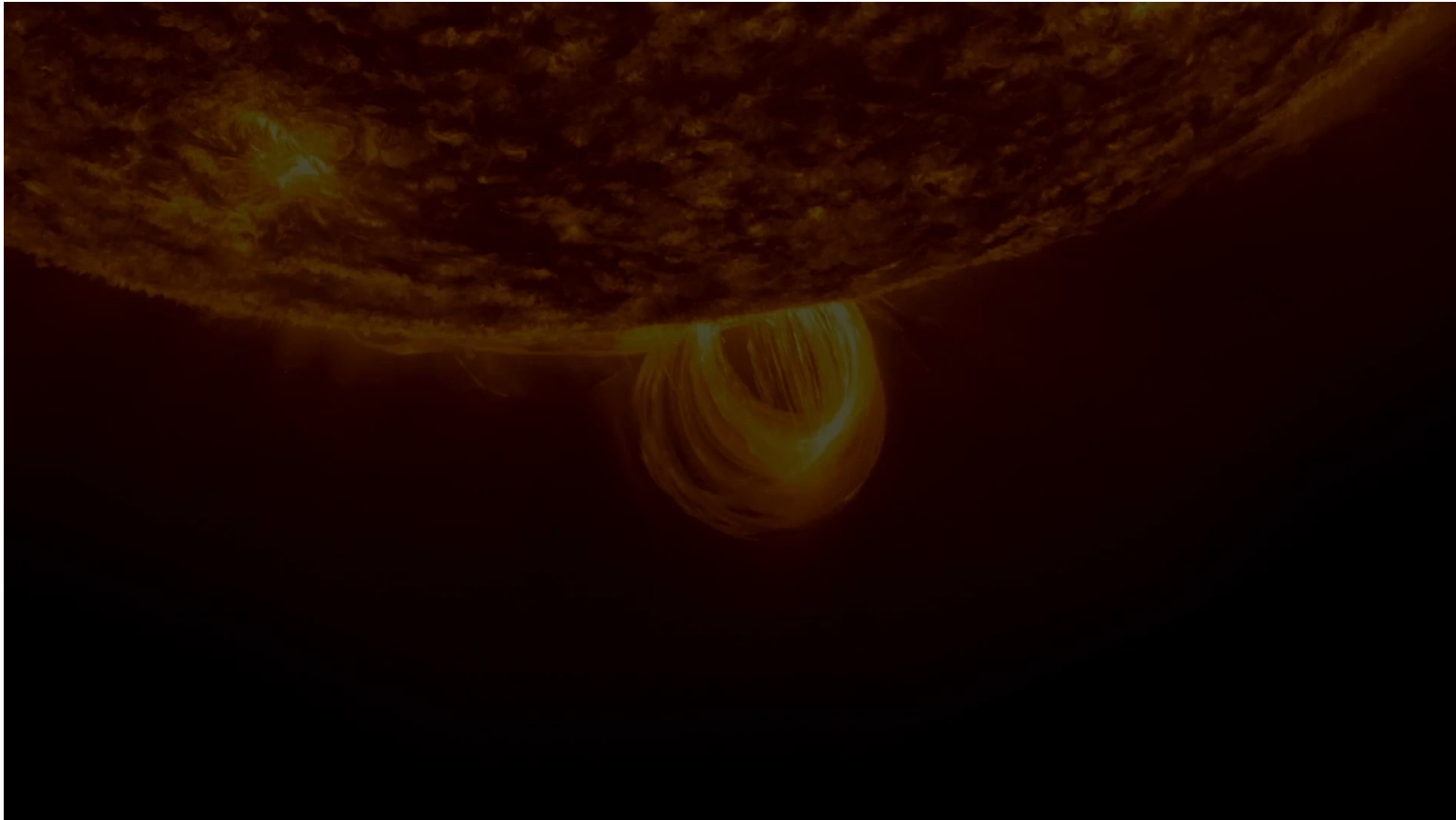
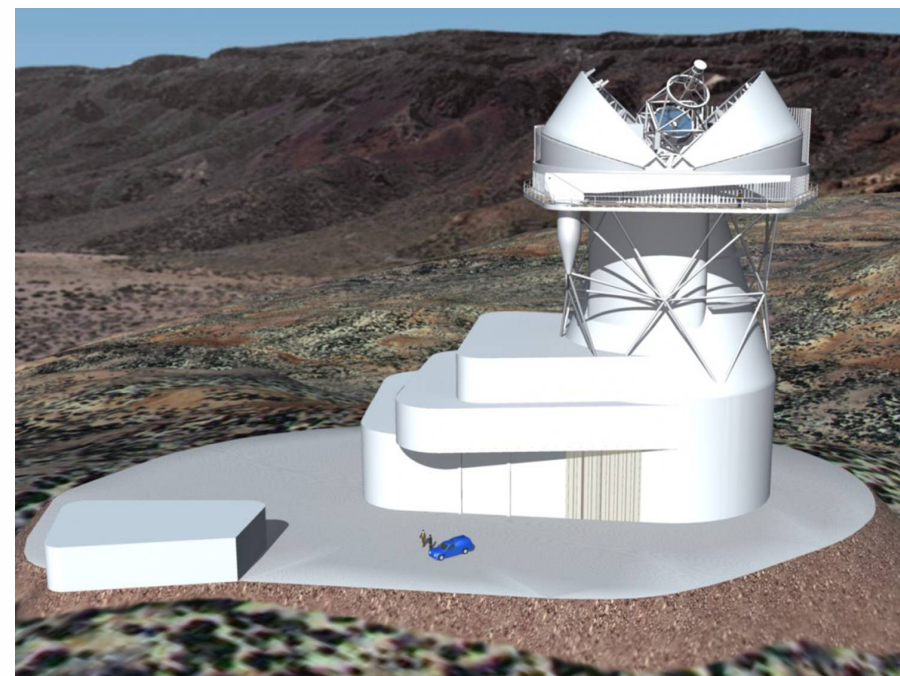


**Observatorios de Canarias**



# EST: key aspects

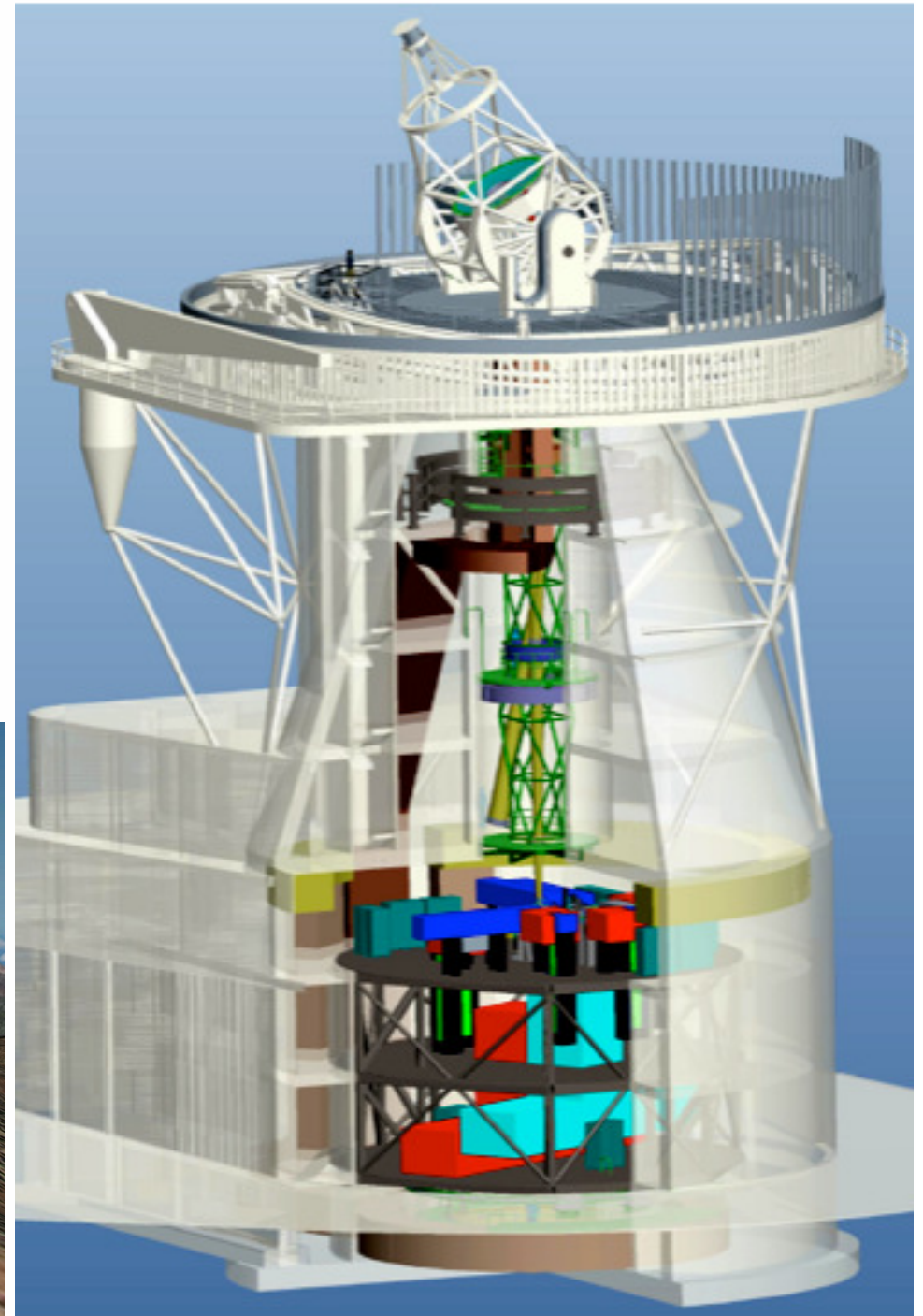
- it will allow us to observe the Sun with superb spatial resolution
- it is optimized to observe the magnetic coupling between the deep photosphere and the upper chromosphere
- it is designed for excellent polarimetric performance





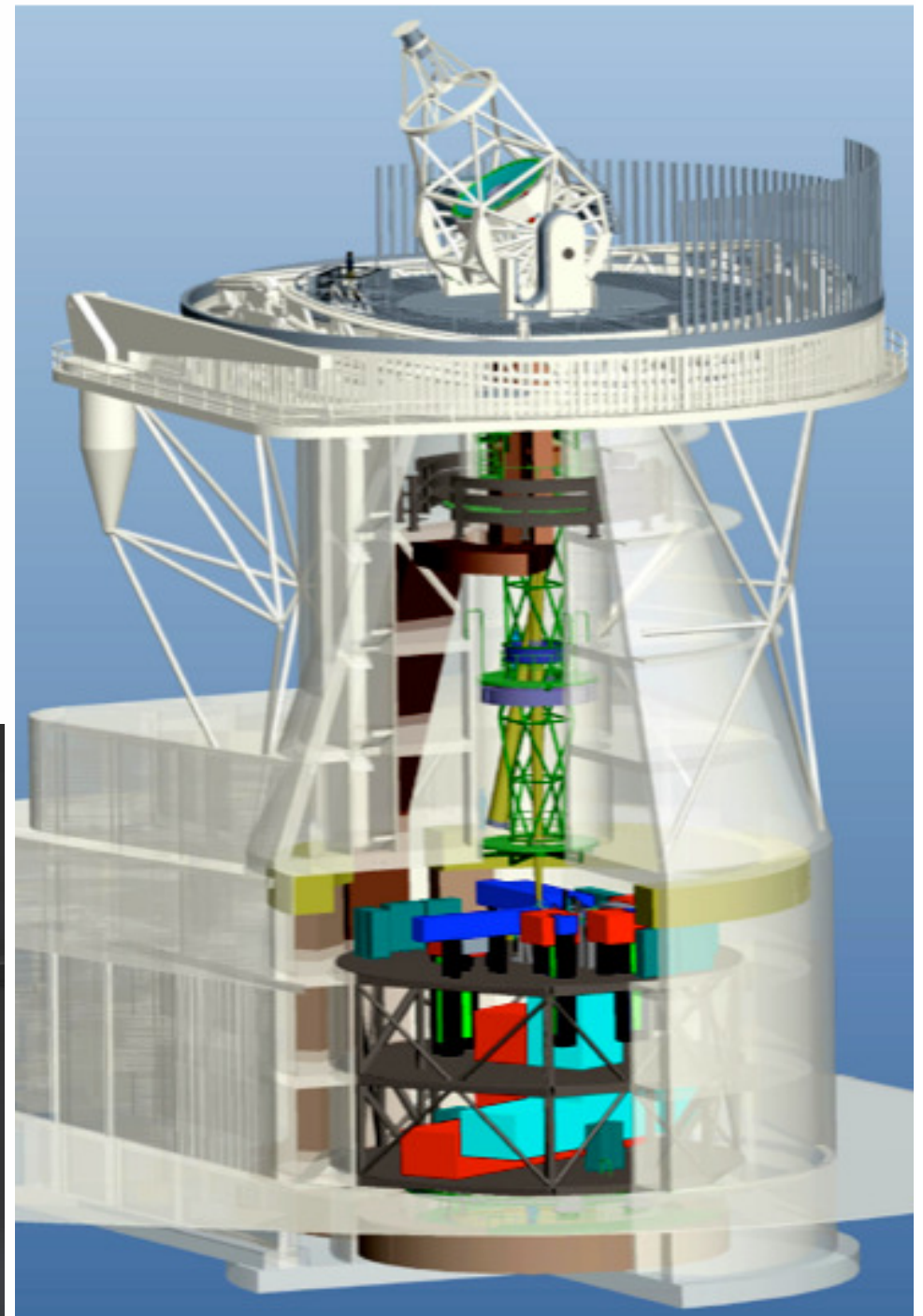
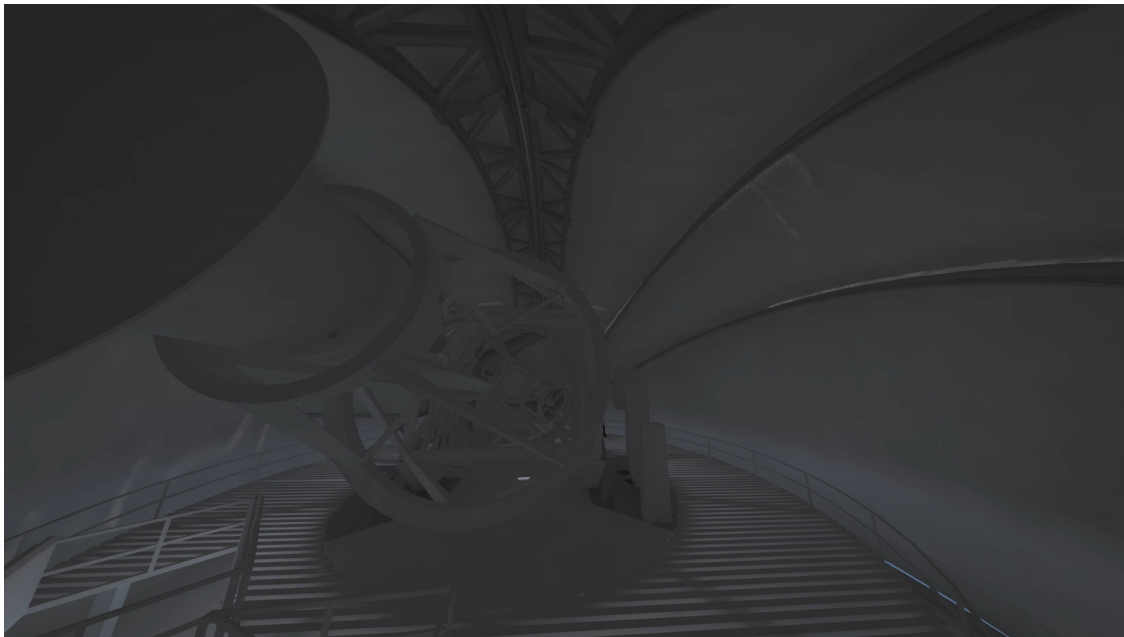
# EST: design baseline

- 4-meter diameter
- on-axis Gregorian configuration
- Alt-Az mount
- simultaneous instruments
  - Broad-band imagers
  - Narrow-band tunable imagers
  - Grating spectrographs
- instruments optimized for the simultaneous observation of the photosphere and chromosphere

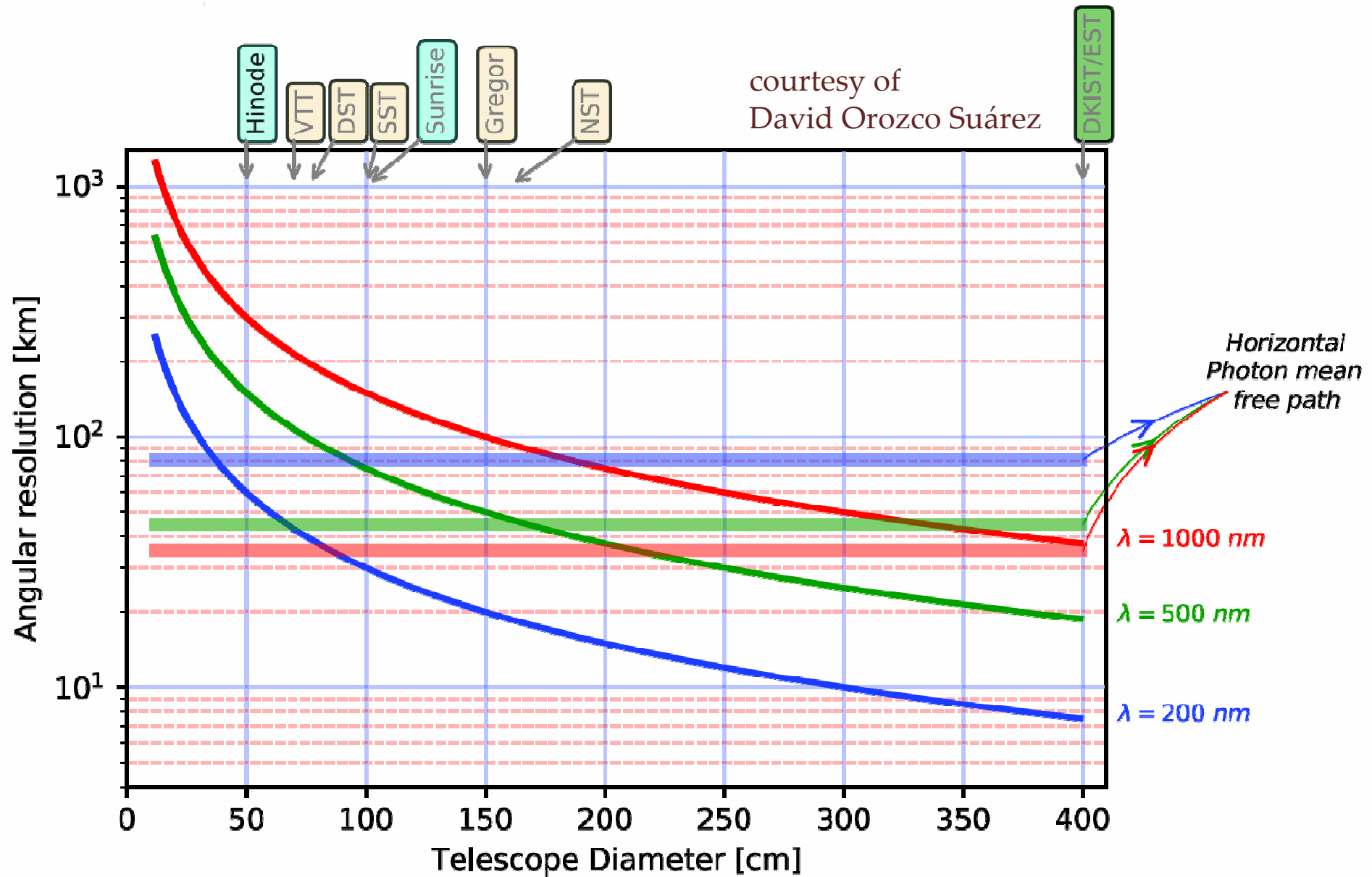


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  - Broad-band imagers
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# EST: resolution issues?



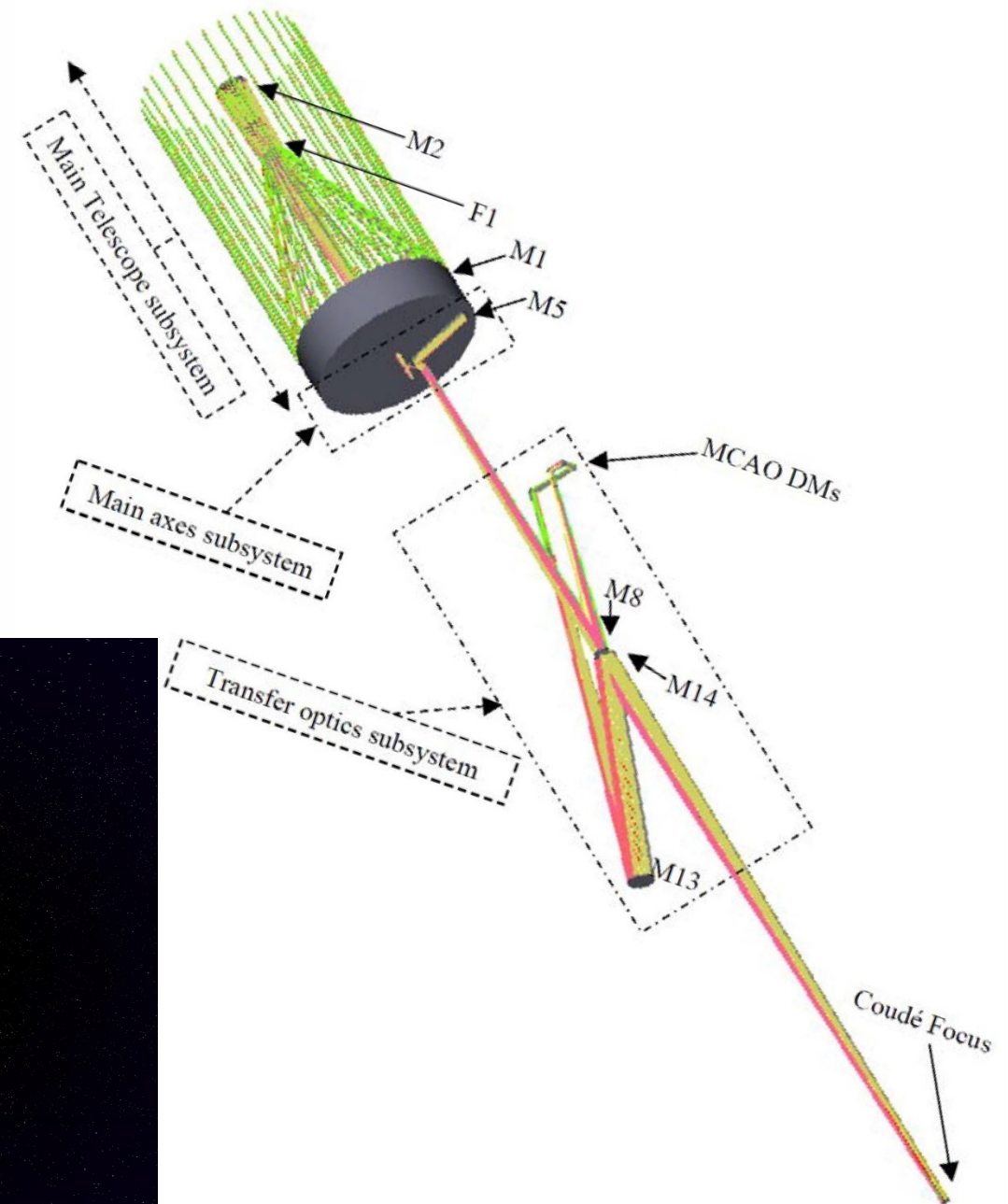
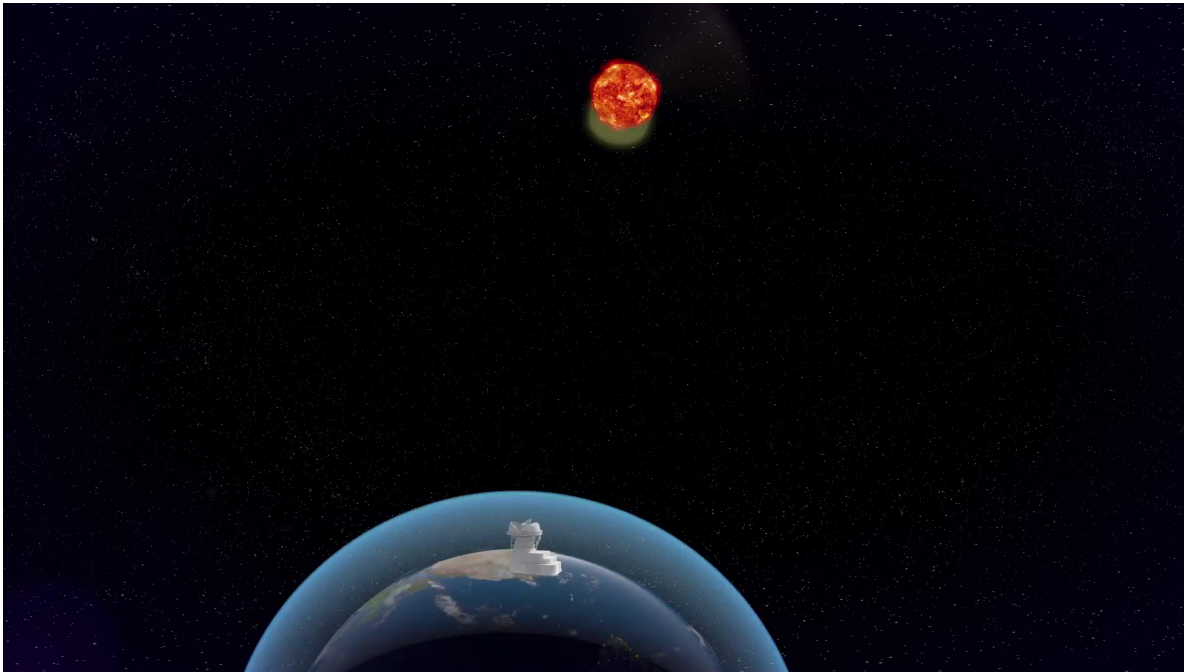
Judge et al. 2014

even in LTE conditions, the source function  
can be influenced by scattering



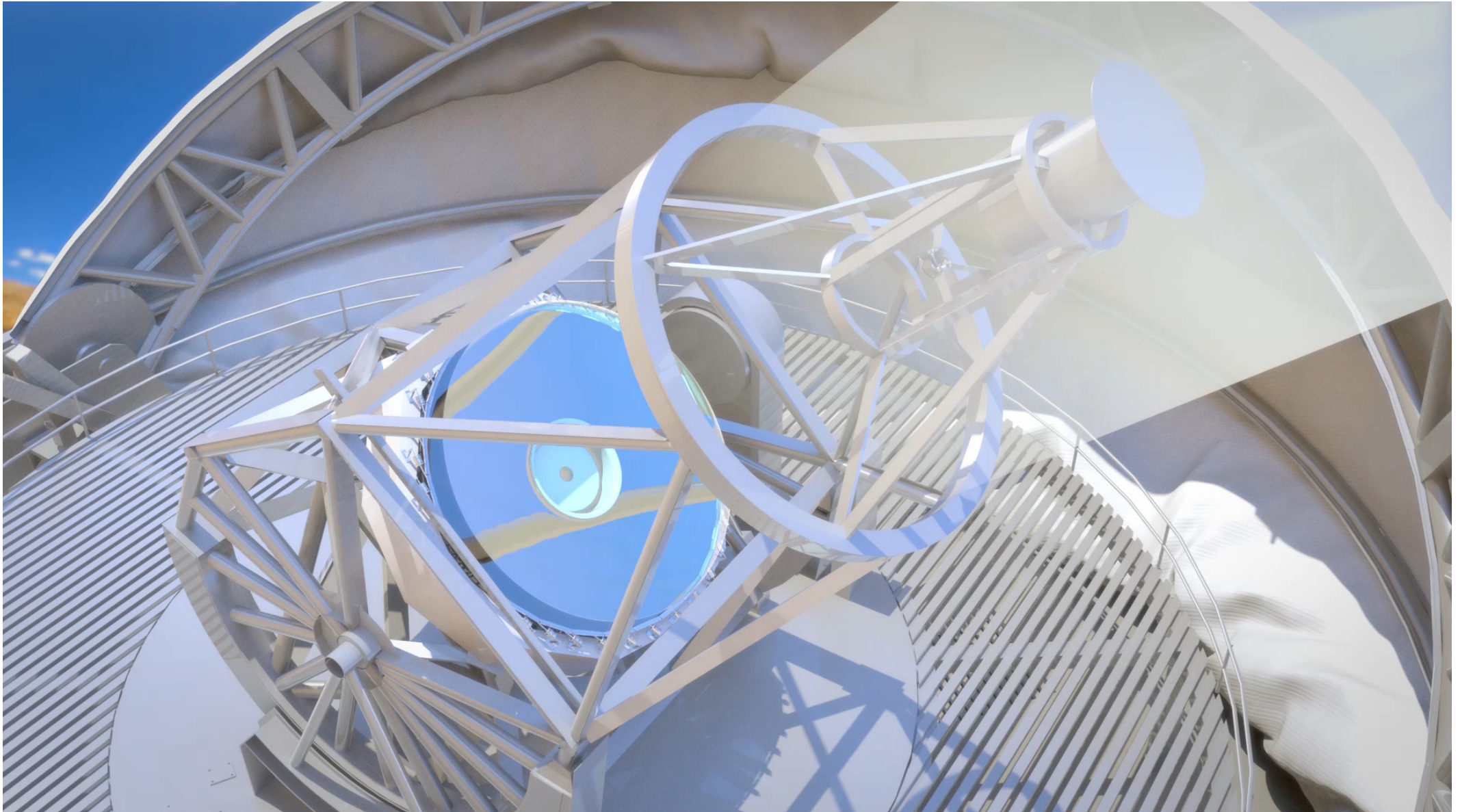
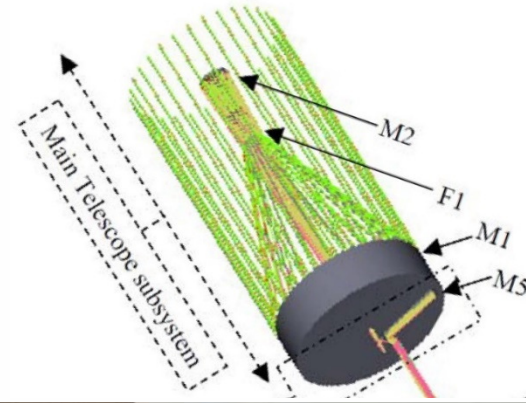
# EST: telescope design

- 14 mirrors to transfer light to the Science Coudé Focus
- rotating transfer optics
- fixed Coudé lab
- AO/MCAO integrated in the optical path
- polarimetrically compensated



# EST: telescope design

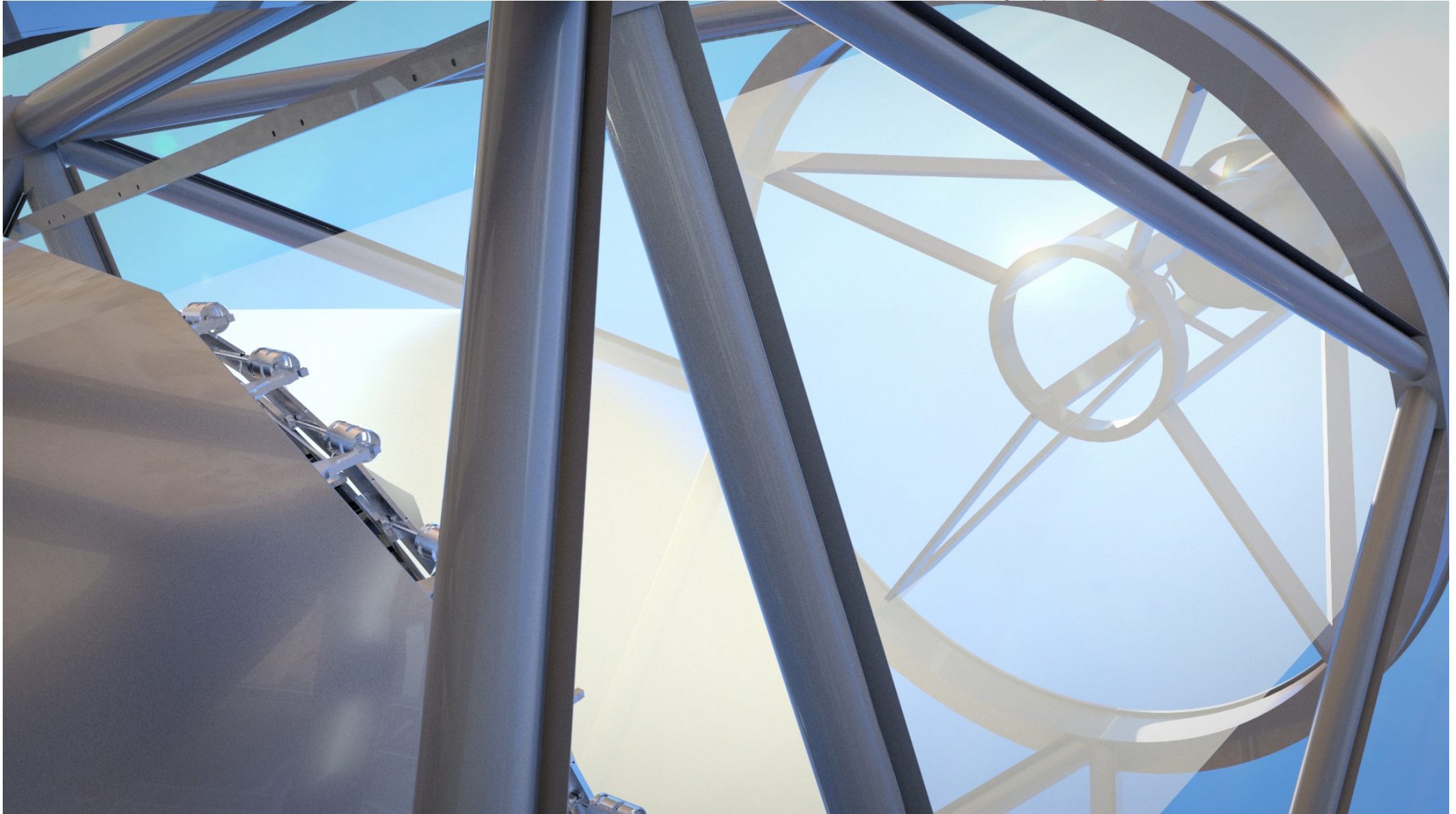
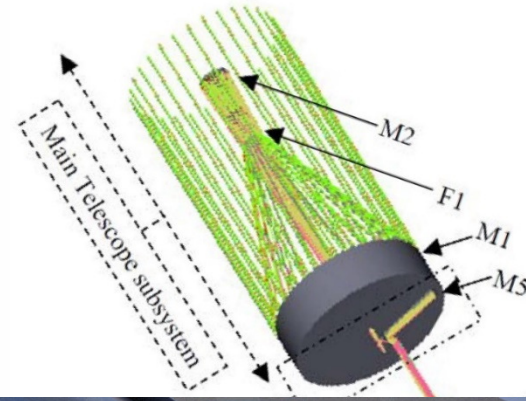
- M1 4.1 m aperture mirror with about 640 hexagonal actuated cells





# EST: telescope design

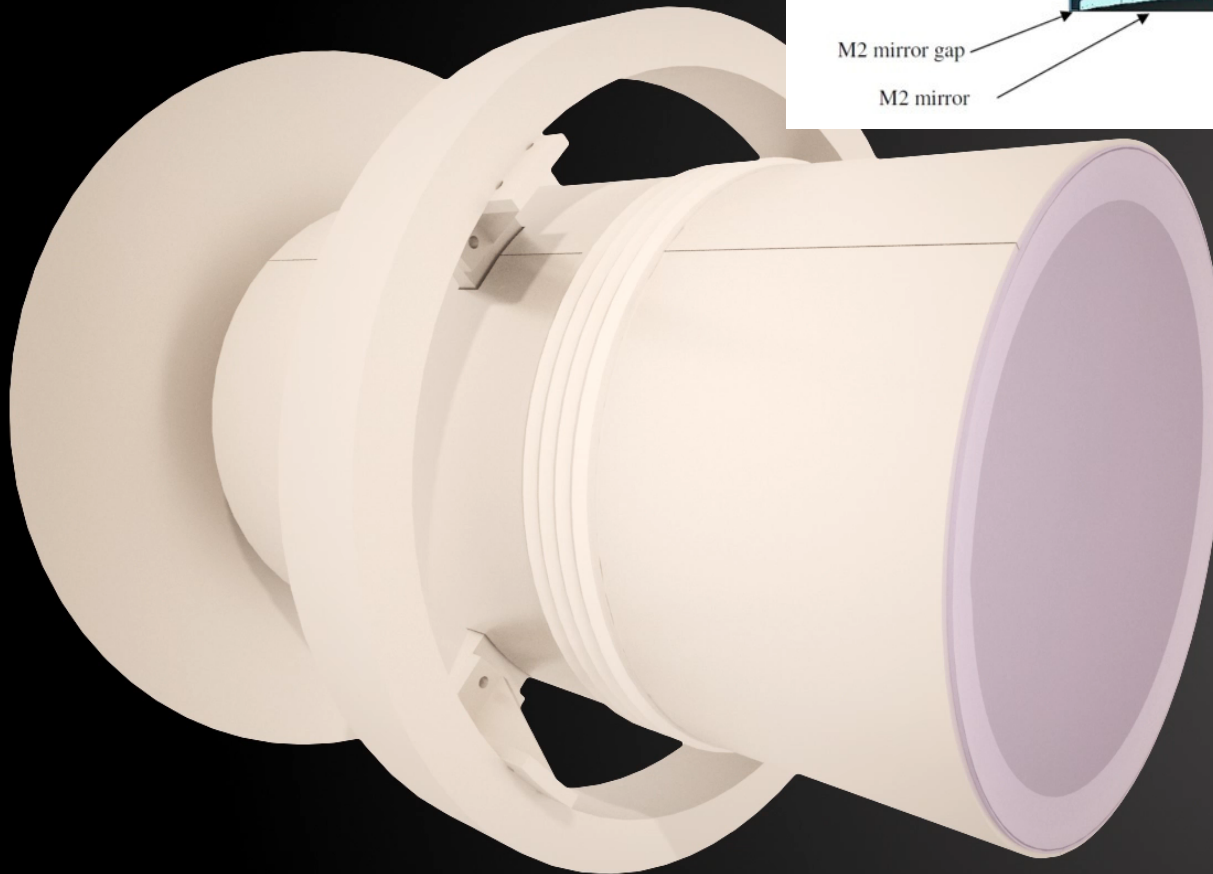
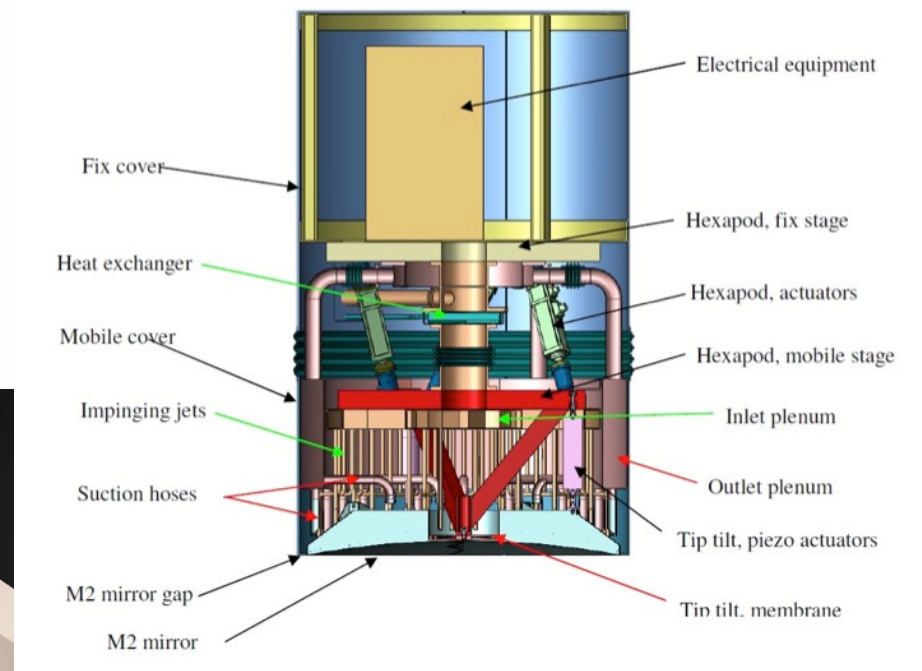
- A powerful heat dump/heat rejection unit needed!





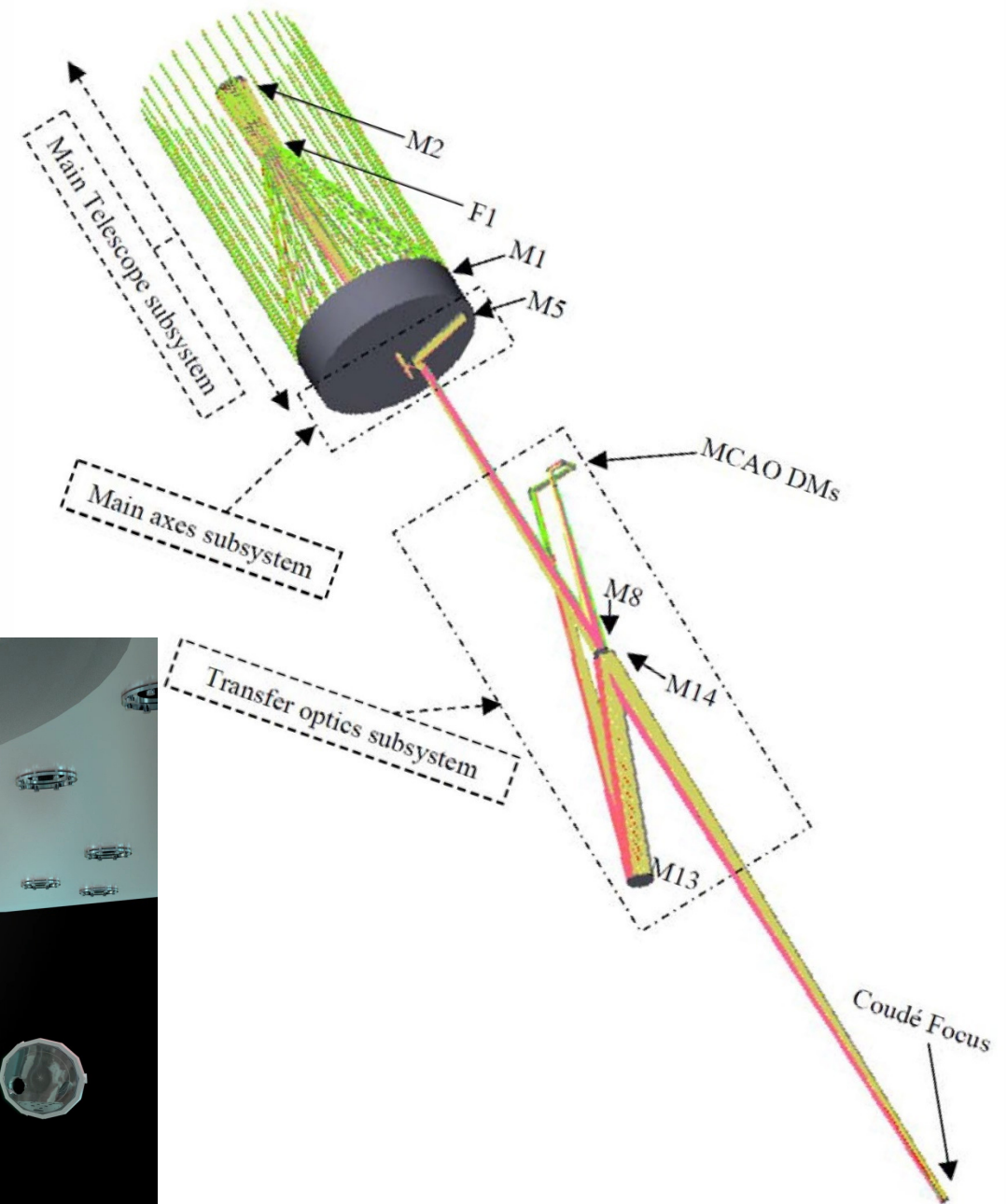
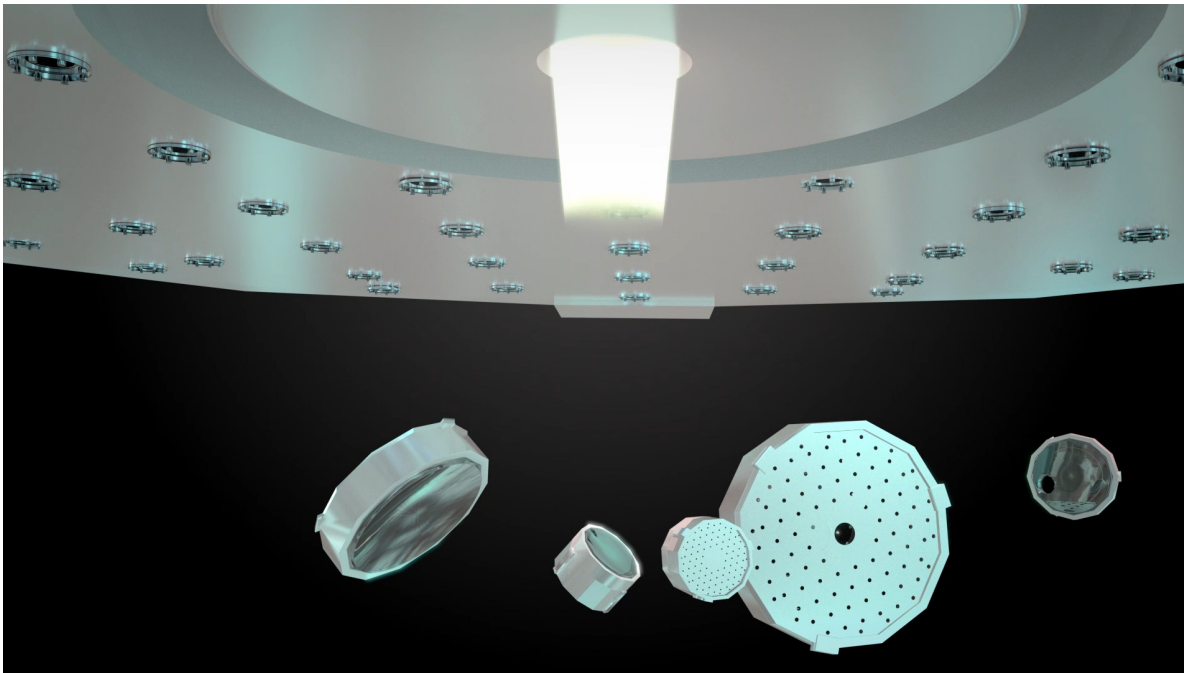
# EST: telescope design

- M2 with tip tilt capabilities on a hexapod for image alignment



# EST: telescope design

- 14 mirrors to transfer light to the Science Coudé Focus
- rotating transfer optics
- fixed Coudé lab
- AO/MCAO integrated in the optical path
- polarimetrically compensated



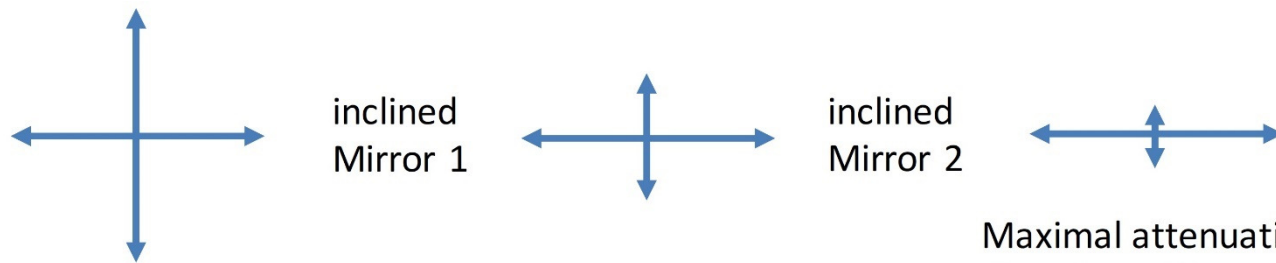
# EST: telescope design

- EST – polarimetrically compensated telescope
- Muller matrix,  $M_{est}$  independent of time (= unity) and independent on wavelength
  - $M(M1) = M(M2) =$  unity matrix, since axially symmetric

$$\begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}_{obs} = \underbrace{\begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ m_{41} & m_{42} & m_{43} & m_{44} \end{pmatrix}}_{\text{Muller}} * \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}_{sun}$$

$$M_{telescope}(t) = M_{M1}(t) * M_{M2}(t) * \dots * M_{Mn}(t)$$

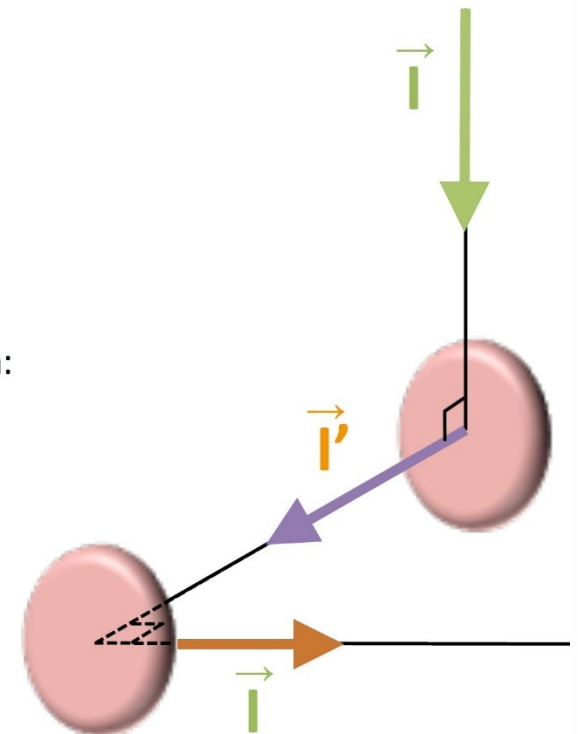
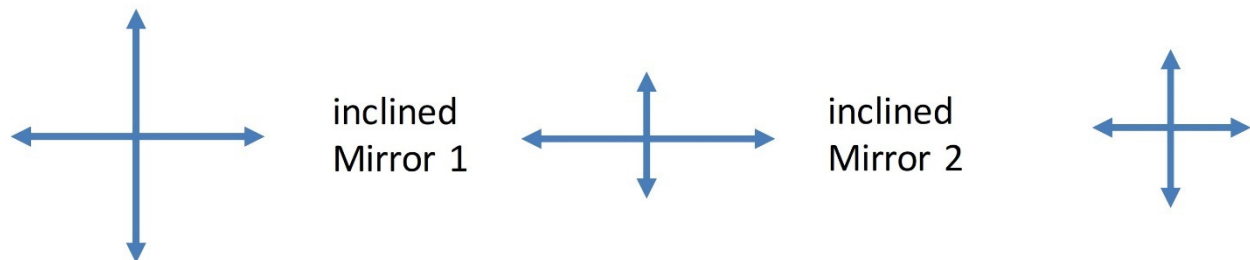
Careless configuration of two subsequent mirrors:



Maximal attenuation of one direction of linear polarisation:

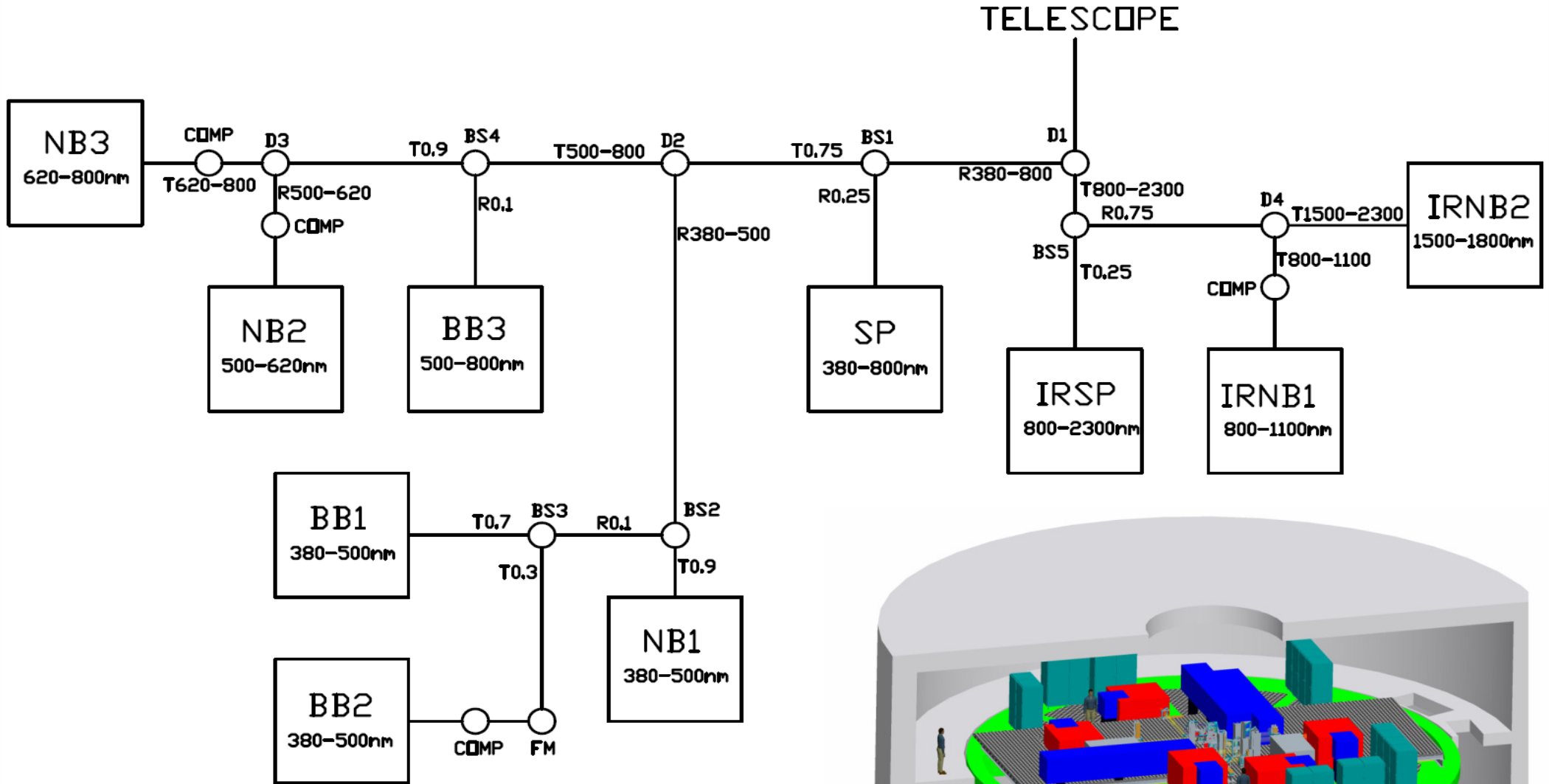
- increase of noise!
- loss of sensitivity!

Compensated design in EST:

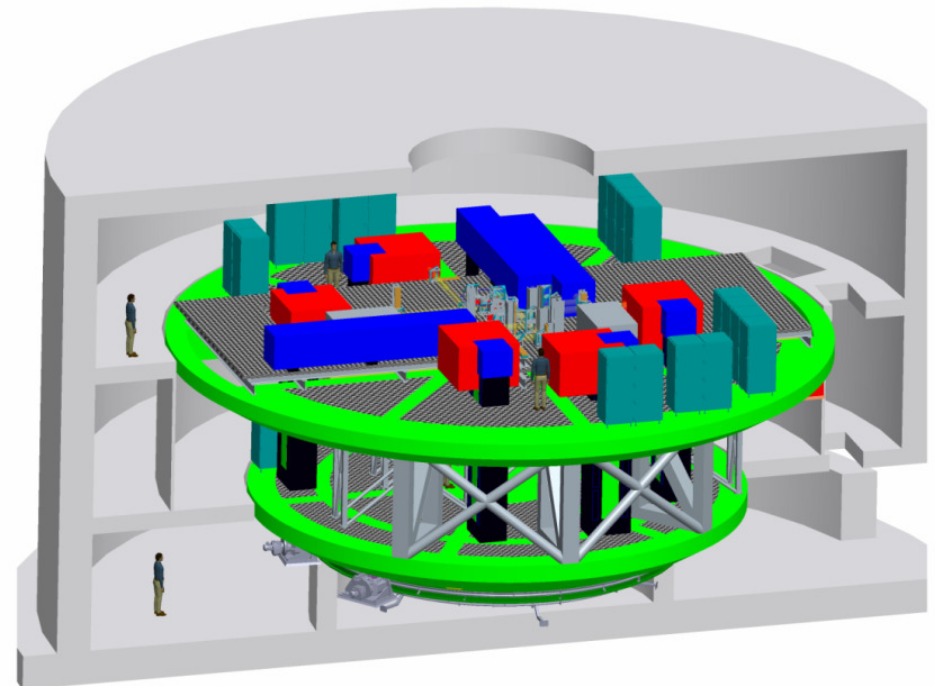




# EST: instruments and light distribution

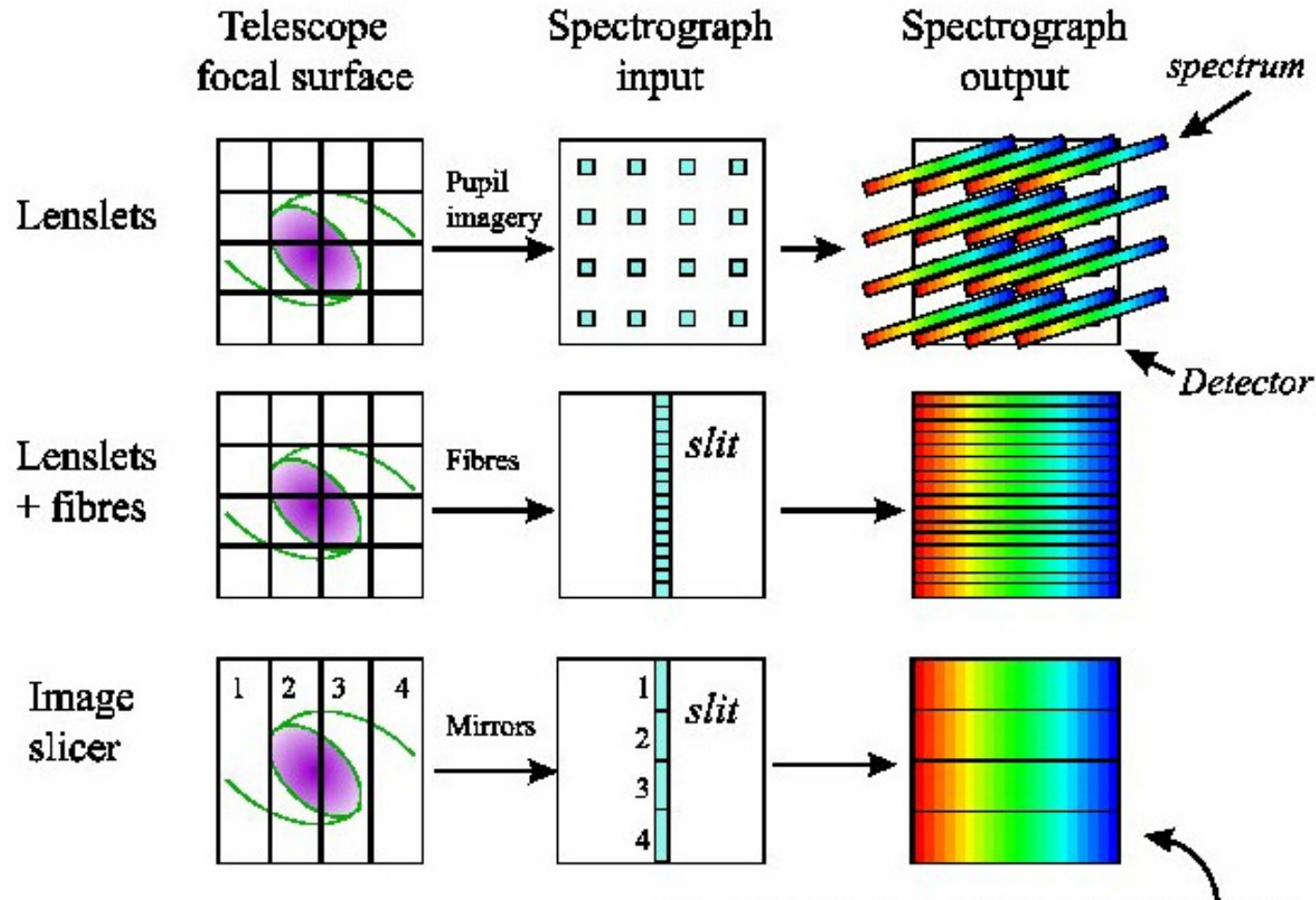


- broad band imagers
- narrow-band tunable imagers
- grating spectropolarimeters



# EST: integral field spectroscopy

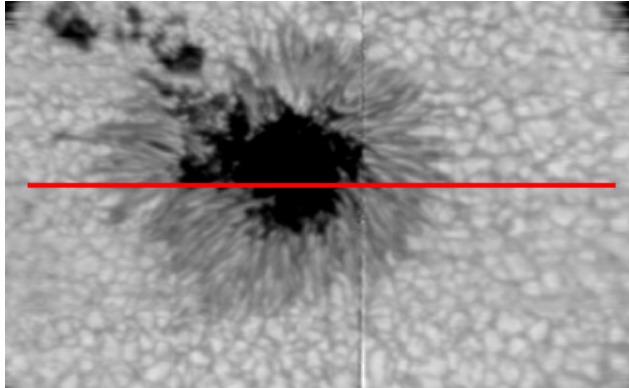
- image slicer (Calcines et al. 2014), IAC
- microlenses (van Noort et al., in prep.), MPS
- fibers (Schad et al., 2014), NSO (for DKIST, DL-NIRSP)



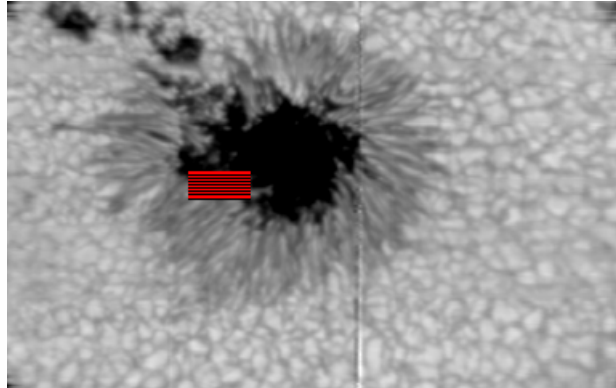
*Only the image slicer retains spatial information within each slice/sample*

# EST: image slicer

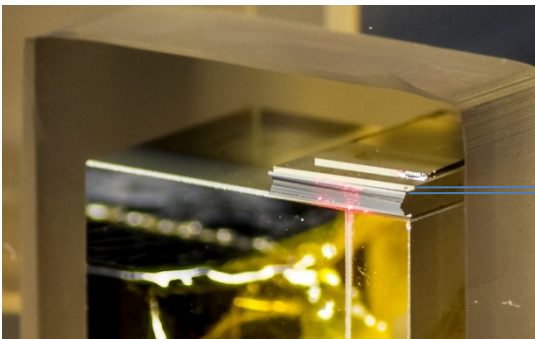
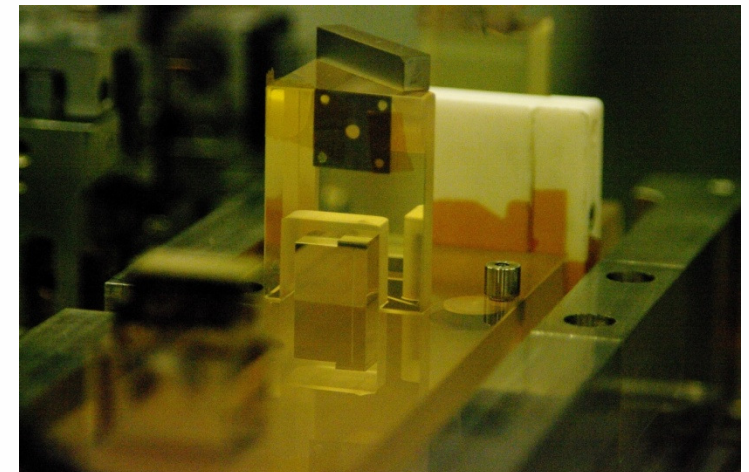
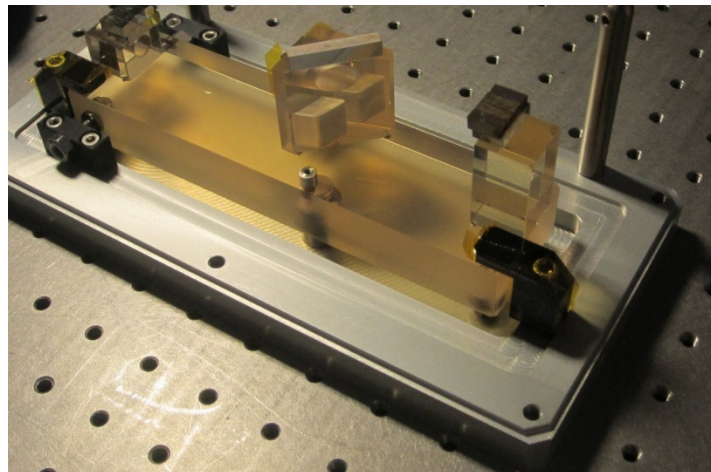
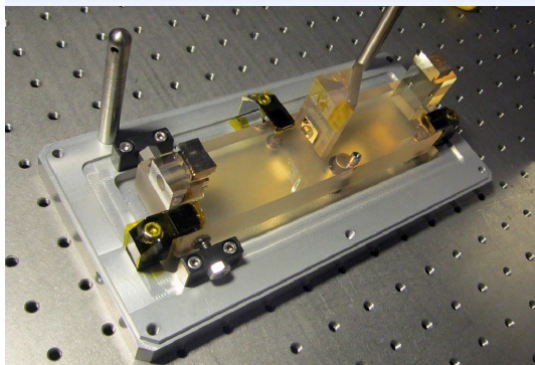
- prototype image slicer developed for GREGOR



64" × 0.27"



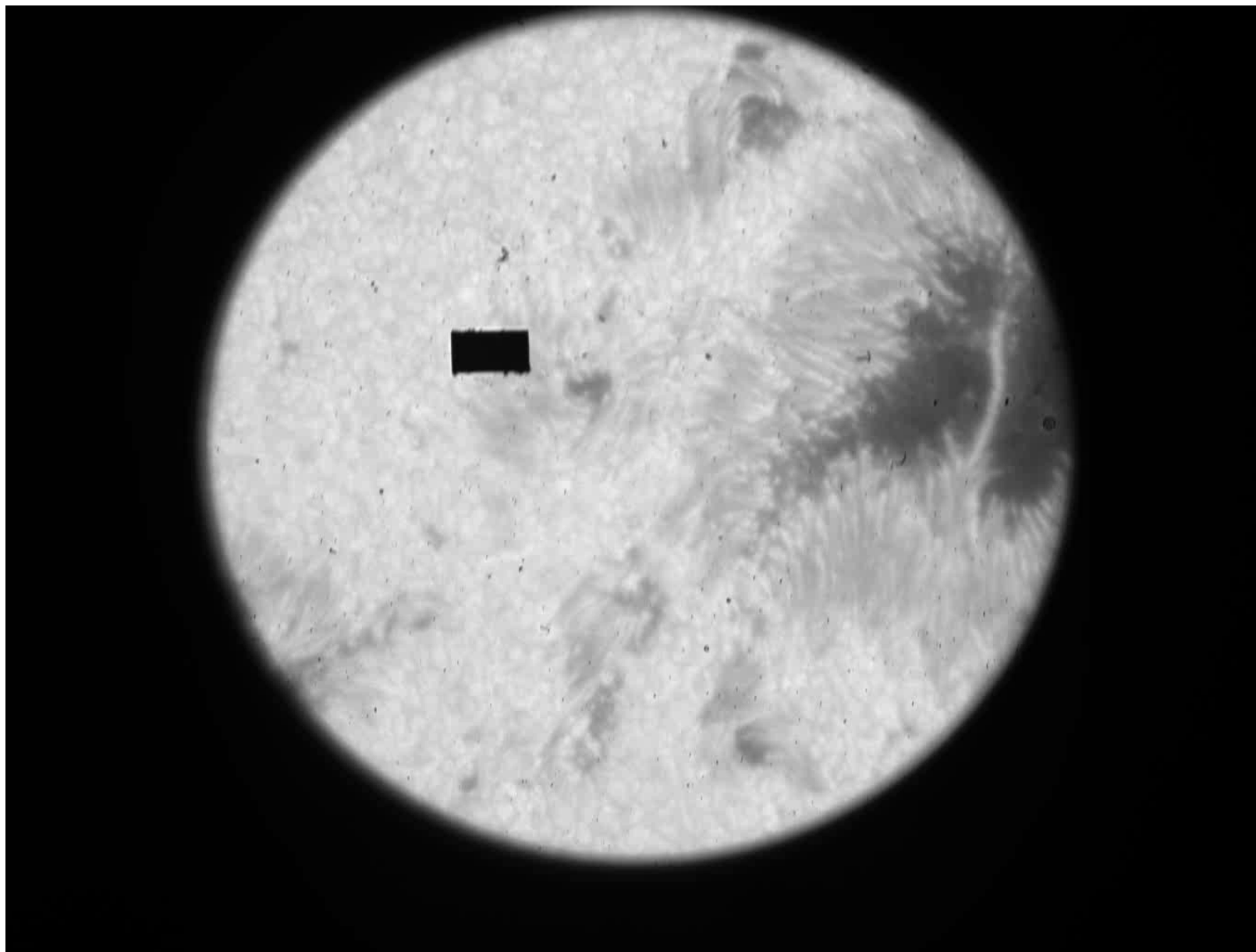
6" × 3"



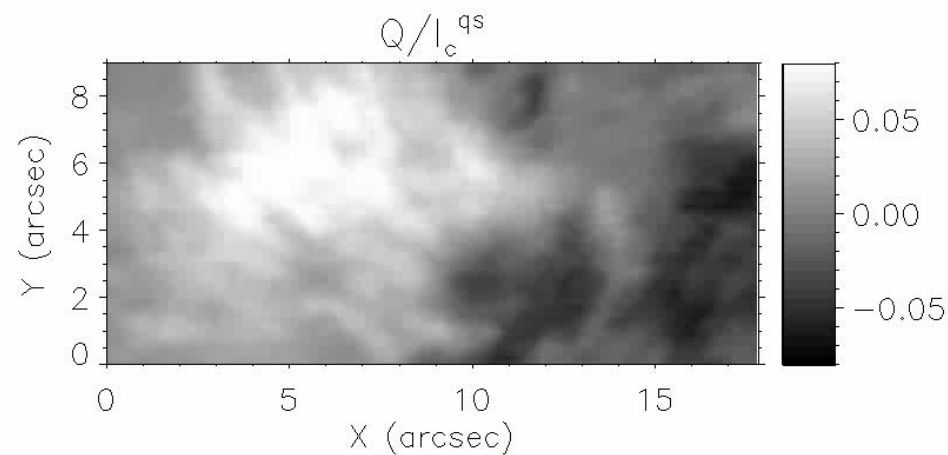
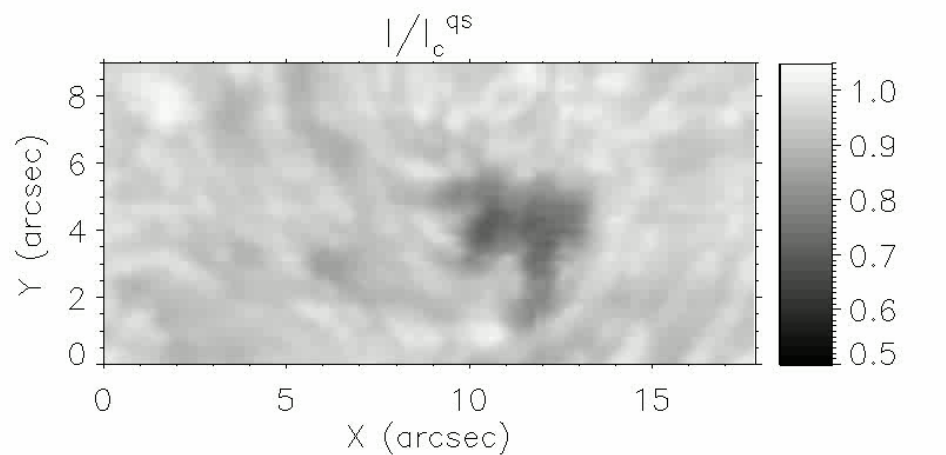
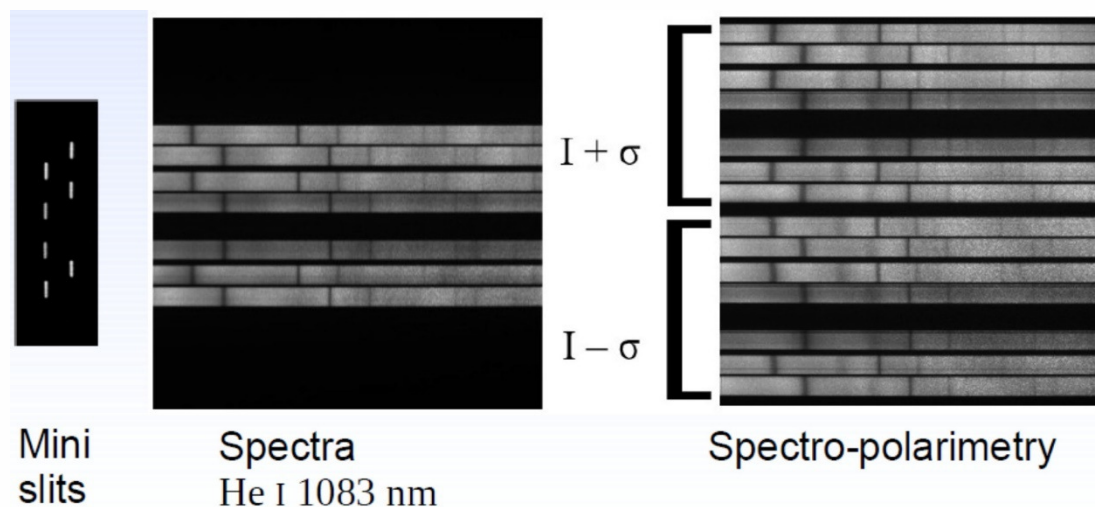
↓  
↑ 100 μm



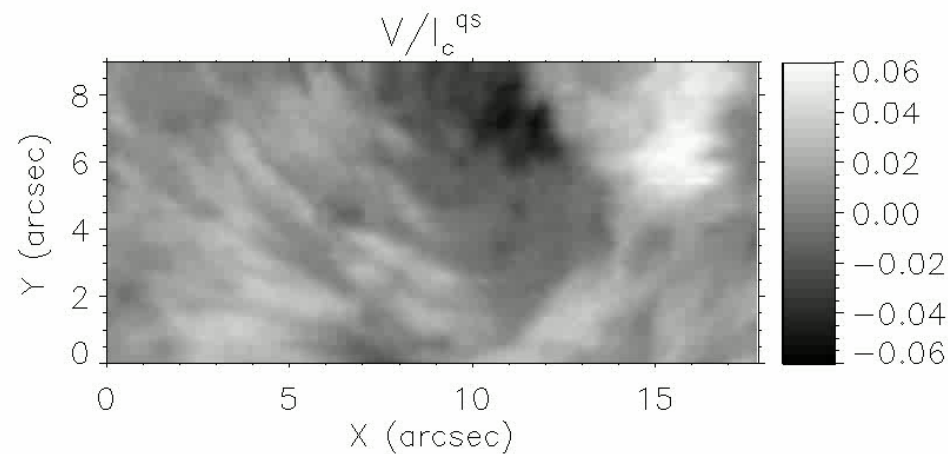
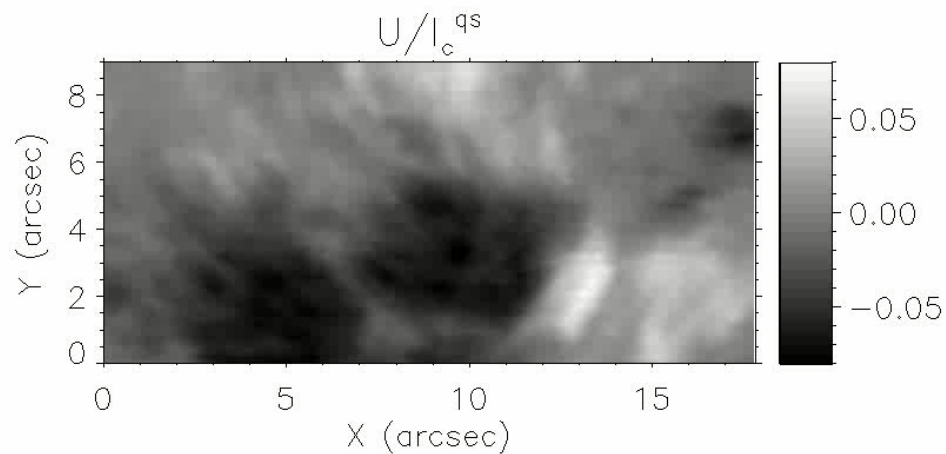
# EST: image slicer



# EST: image slicer

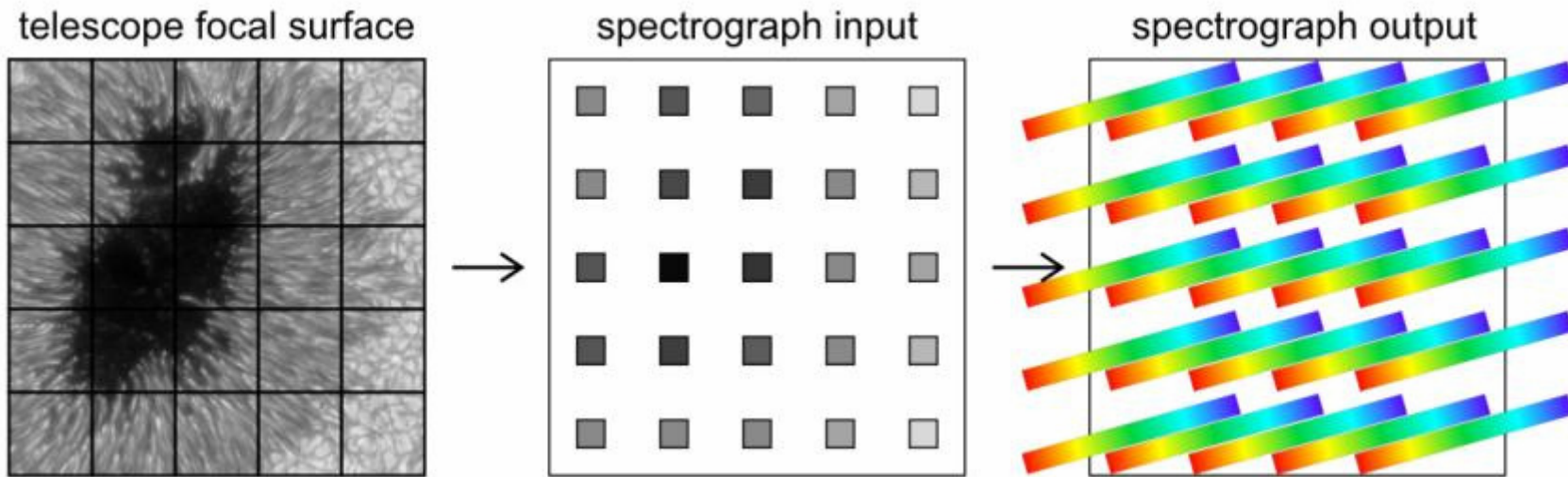


0 s



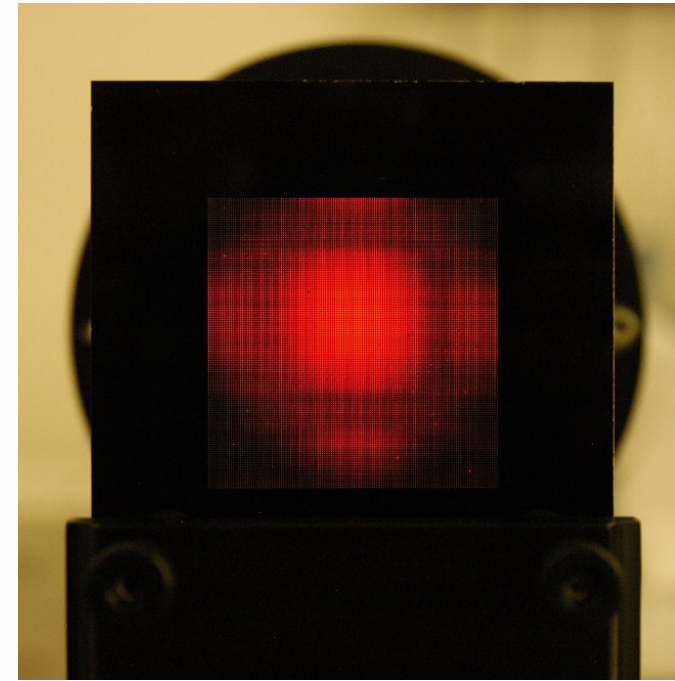
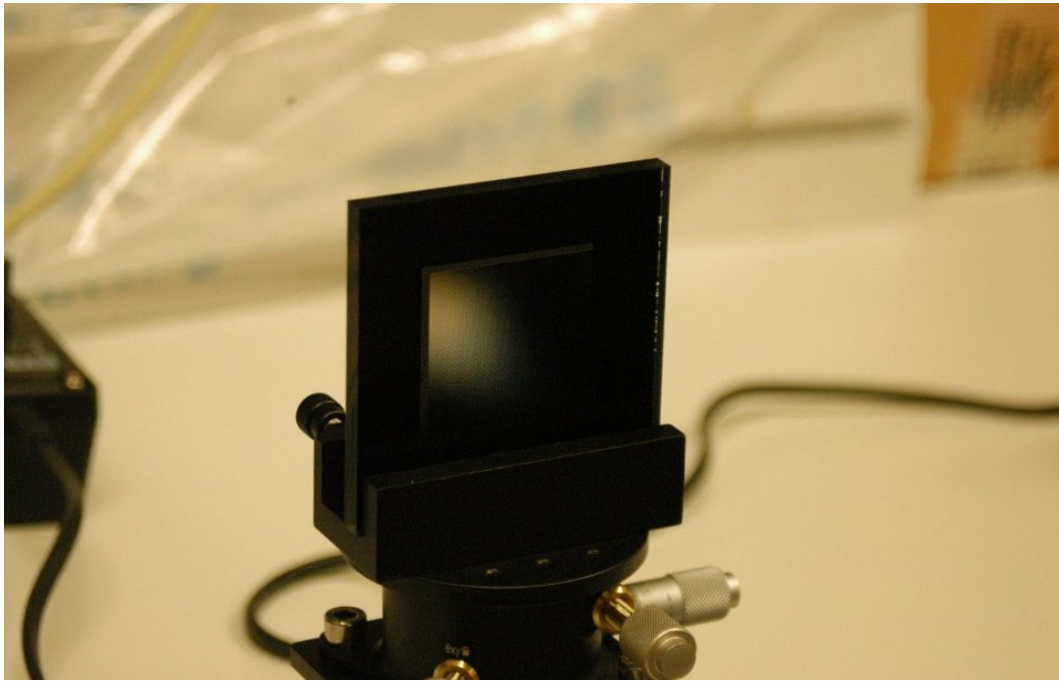


# EST: microlenses

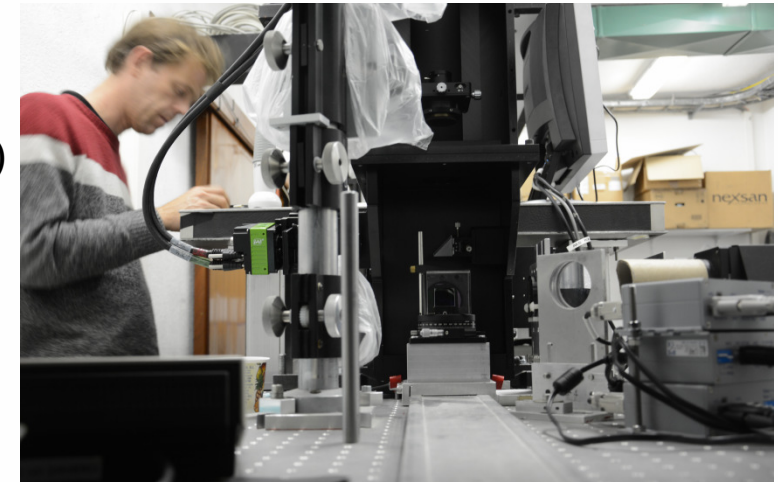


- make space for spectral dimension by “shrinking” pixels
- disperse at a small rotation angle to the pixel grid
- truncate using a narrow prefilter to avoid overlap
- 3D cube recorded in a single exposure
- single microlens array does not work (Suematsu@DST, stray-light issues)
- second microlens array needed to image pupil on grating
- straylight mask on second array
- two sides of single substrate to keep alignment

# EST: microlenses



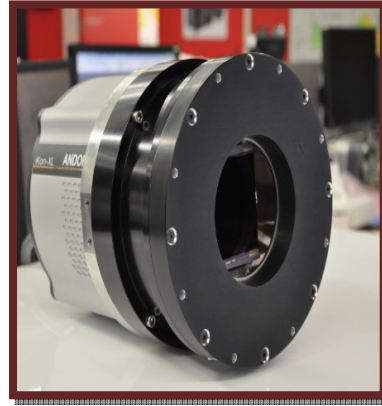
- made by Fraunhofer Inst. for Applied Optics in Jena
- 6.35 mm plate of SiO<sub>2</sub> (maintains alignment very well)
- 128x128 elements (42x42mm)
- front to backside alignment  $\leq 1\mu\text{m}$
- $\square 20$  outliers ( $\square 0.1\%$ )
- tested at TRIPPEL@SST



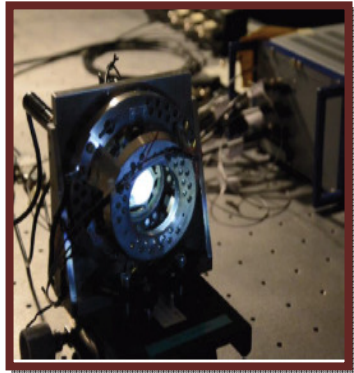


# EST: instrumental developments

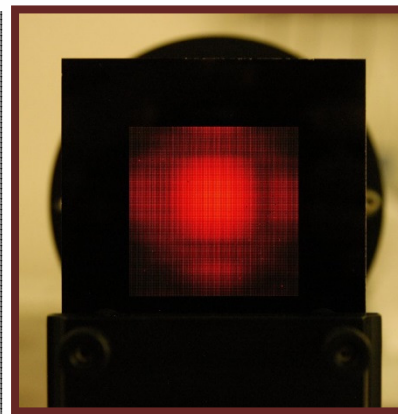
Boosting new generation  
of detectors:  
large format  
high precision  
low noise.



Development of large  
format liquid-crystal  
modulators (LCVR)



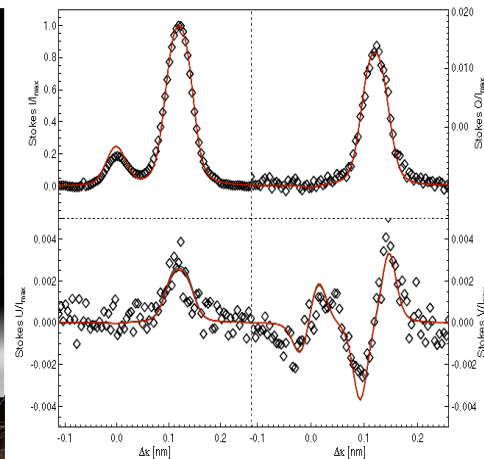
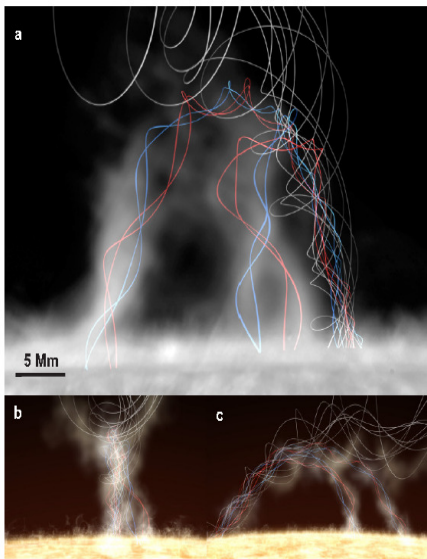
Development of a large **Fabry-Perot prototype** for a high mechanical stability and high quality control of the parallelism of the etalon plates.



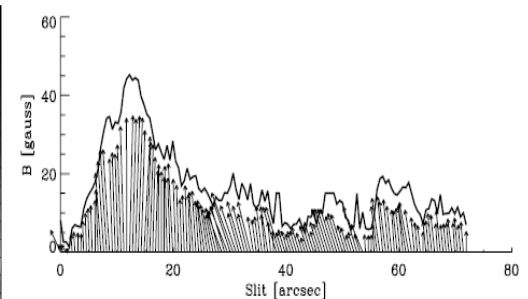
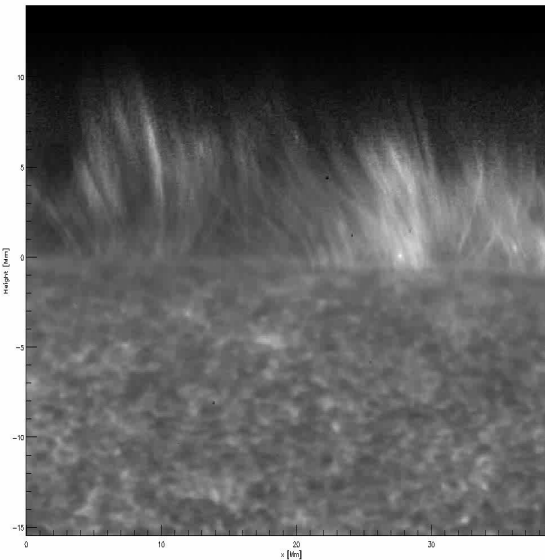
New techniques for **2D solar spectro-polarimetry**:  
image slicers  
microlens arrays

# EST main science questions

- How do magnetic fields emerge into the surface and evolve?
  - How is the energy transported from photosphere to chromosphere?
  - How is the energy released in the upper atmosphere?
  - Why does the Sun have a hot chromosphere?
  - Wave propagation from the photosphere to chromosphere
  - Dynamics of large-scale magnetic structures (sunspots, ARs)
  - Polar magnetic fields
  - Magnetic fields in the chromosphere (spicules, prominences)
  - Energy dissipation in the chromosphere
  - **Main science goal: unveil the magnetic coupling of the solar atmosphere from the deep photosphere up to the upper chromosphere**
- instruments optimized for chromosphere and photosphere



Martínez González et al.  
(2015, 2016)

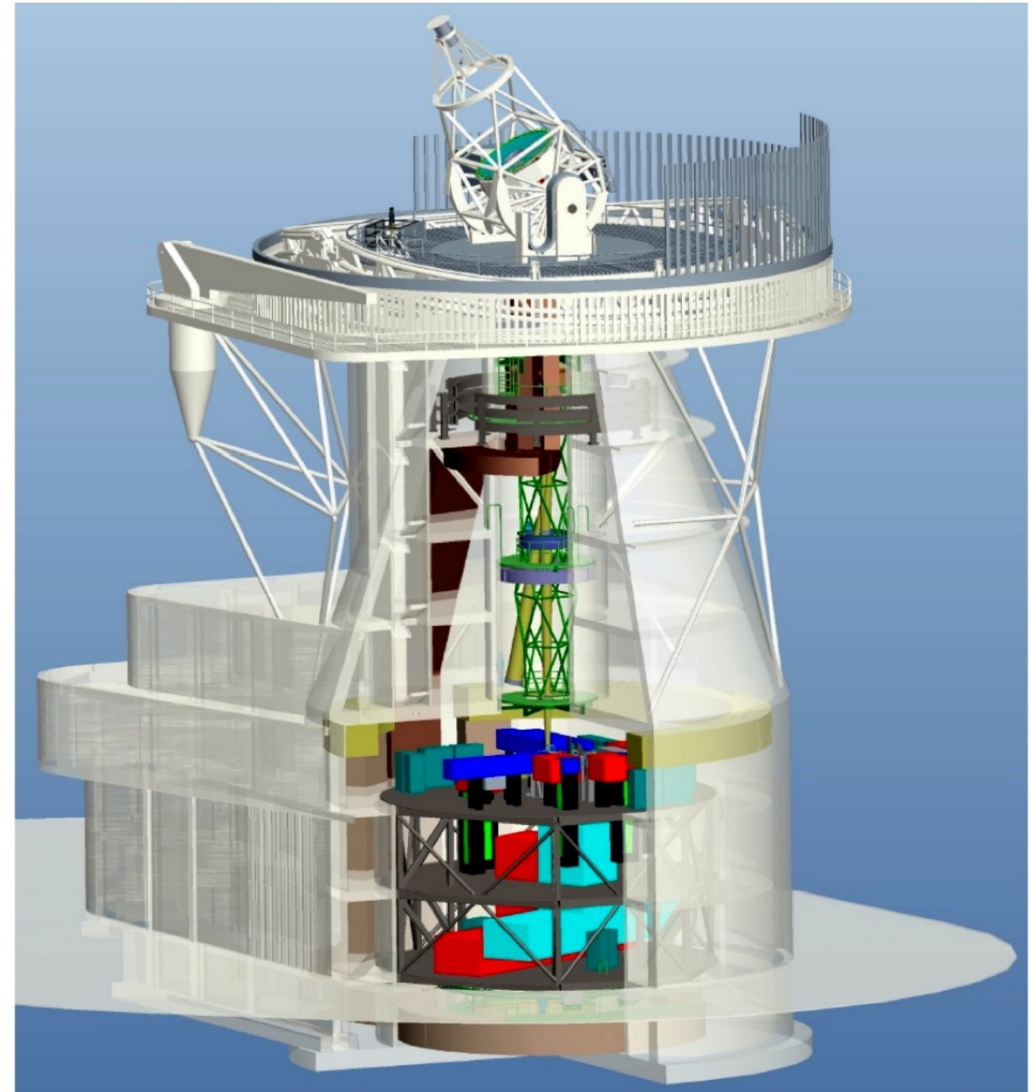
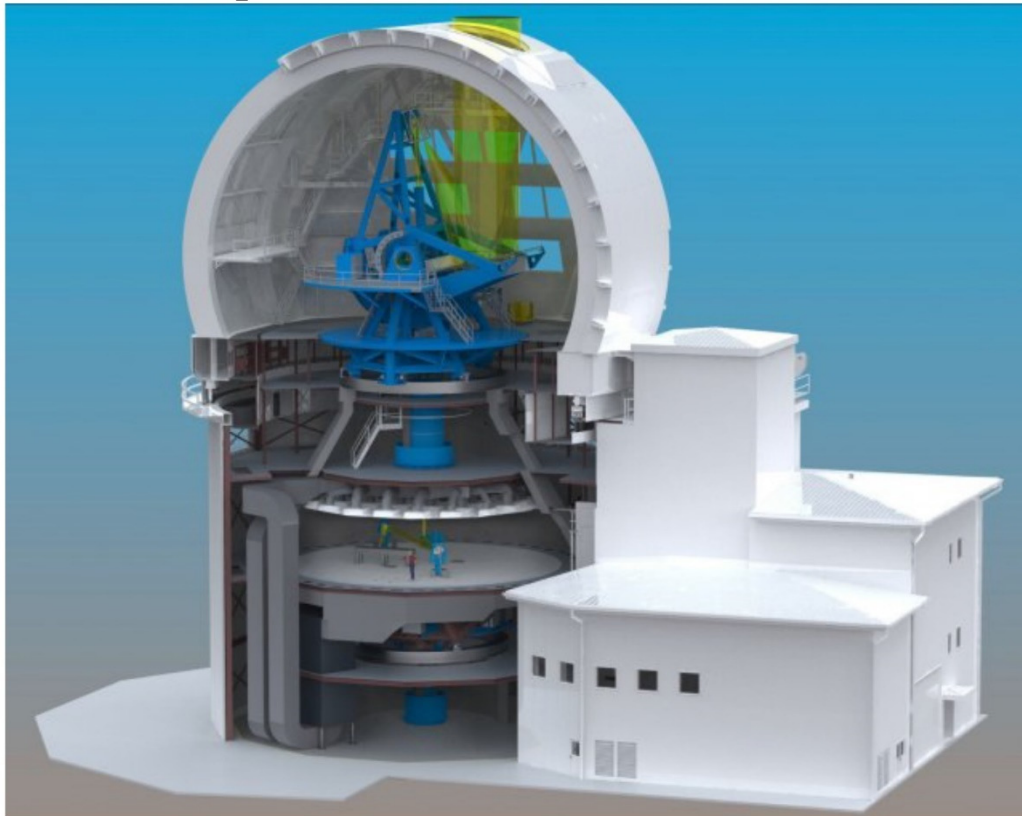


Centeno et al. (2010)



# EST and DKIST

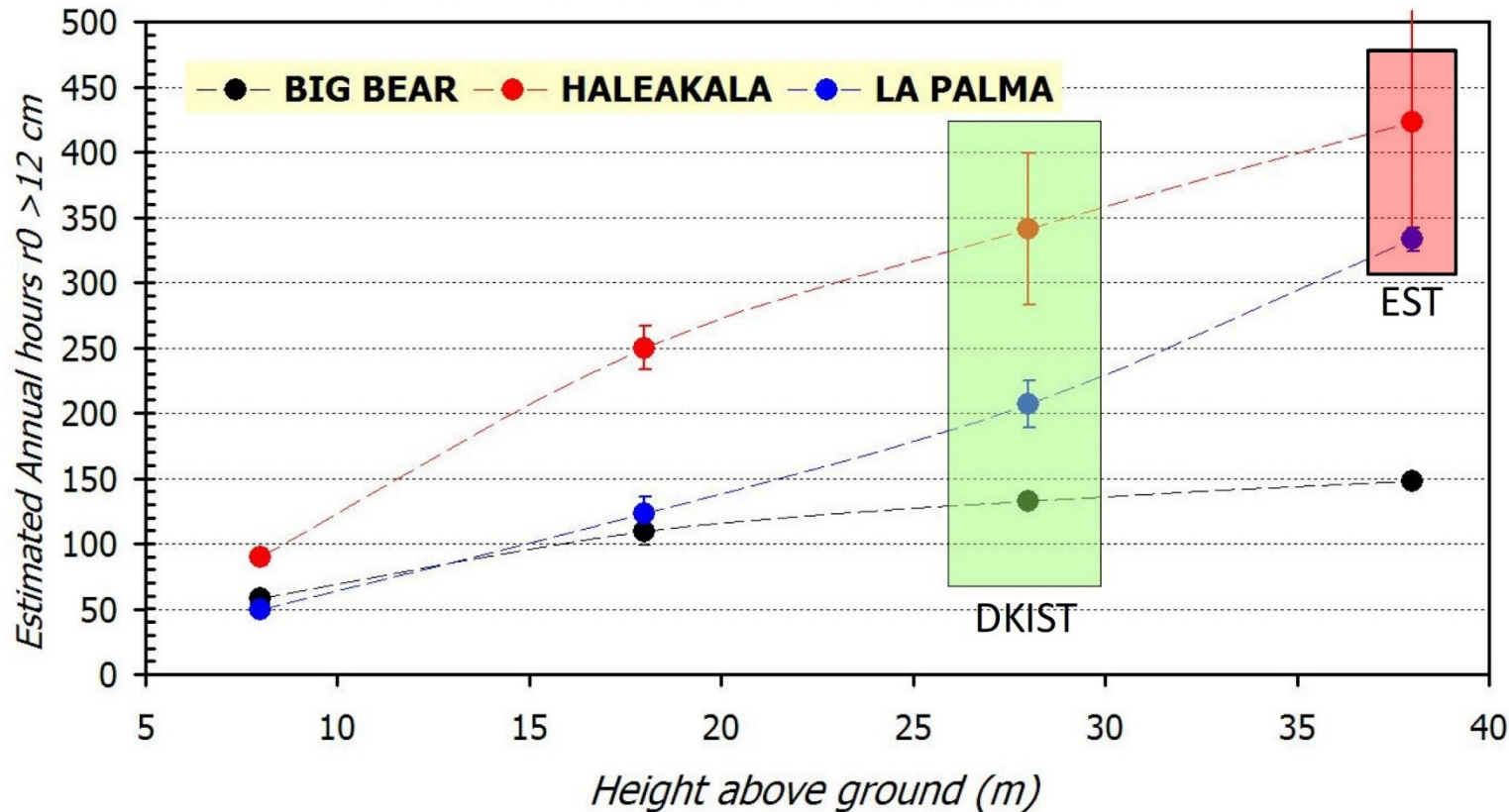
- dome size of 4m off-axis corresponds to 8m on axis
  - EST can be built higher above ground
  - seeing dominated by ground layer, improvement with height
- DKIST Muller matrix is time dependent
  - M1 and M2 are difficult to calibrate and their Muller matrices are time dependent
  - accuracy and sensitivity
    - Muller matrix determines accuracy
    - sensitivity is ability to measure polarisation
    - EST is potentially more accurate than DKIST
  - DKIST polarimetric calibration is much more involved, but in principle possible!



# EST and DKIST

- dome size of 4m off-axis corresponds to 8m on axis
  - EST can be built higher above ground

## Annual hours $r_0 > 12$ . Case #3

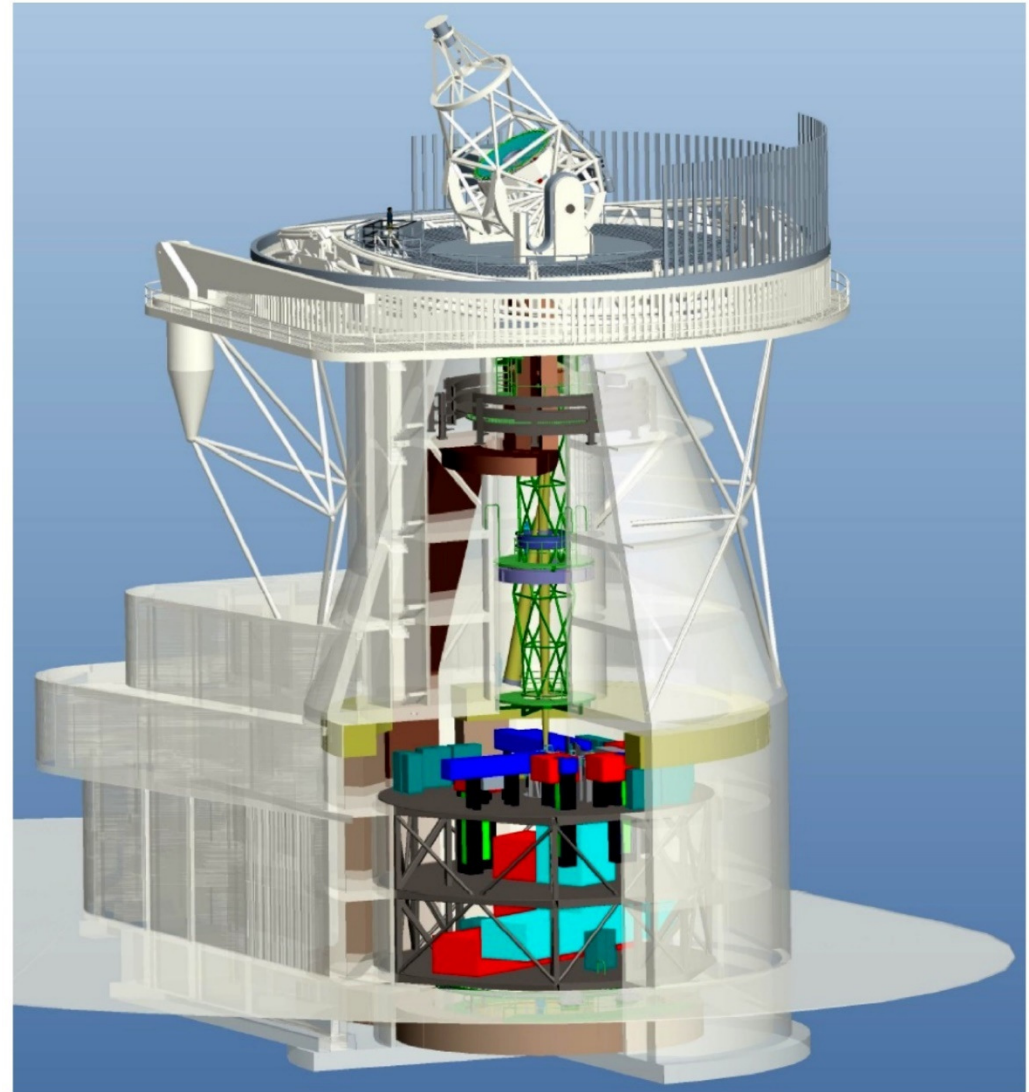
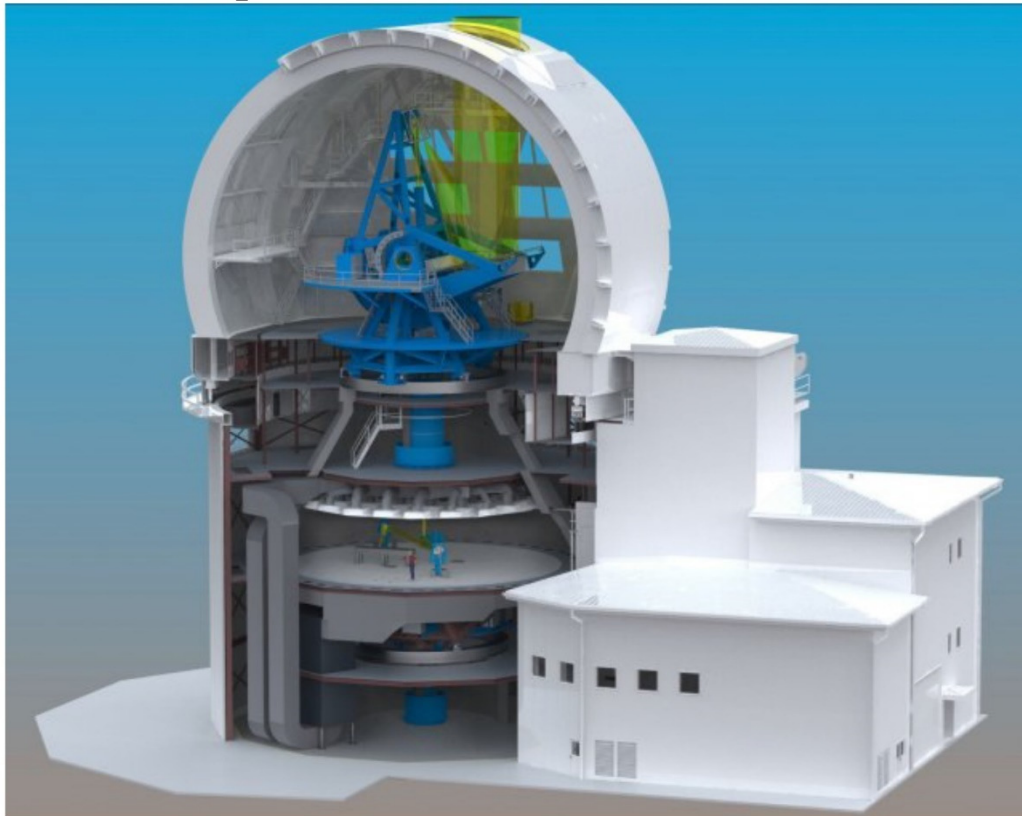


Annual hours with the Fried parameter  $r_0$  being larger than 12cm versus height above ground for Big Bear (black), Haleakala (red), and La Palma (blue). DKIST will be 28m above ground (green box), and EST will be at 38m (red box). (from ATST site survey working group final report)



# EST and DKIST

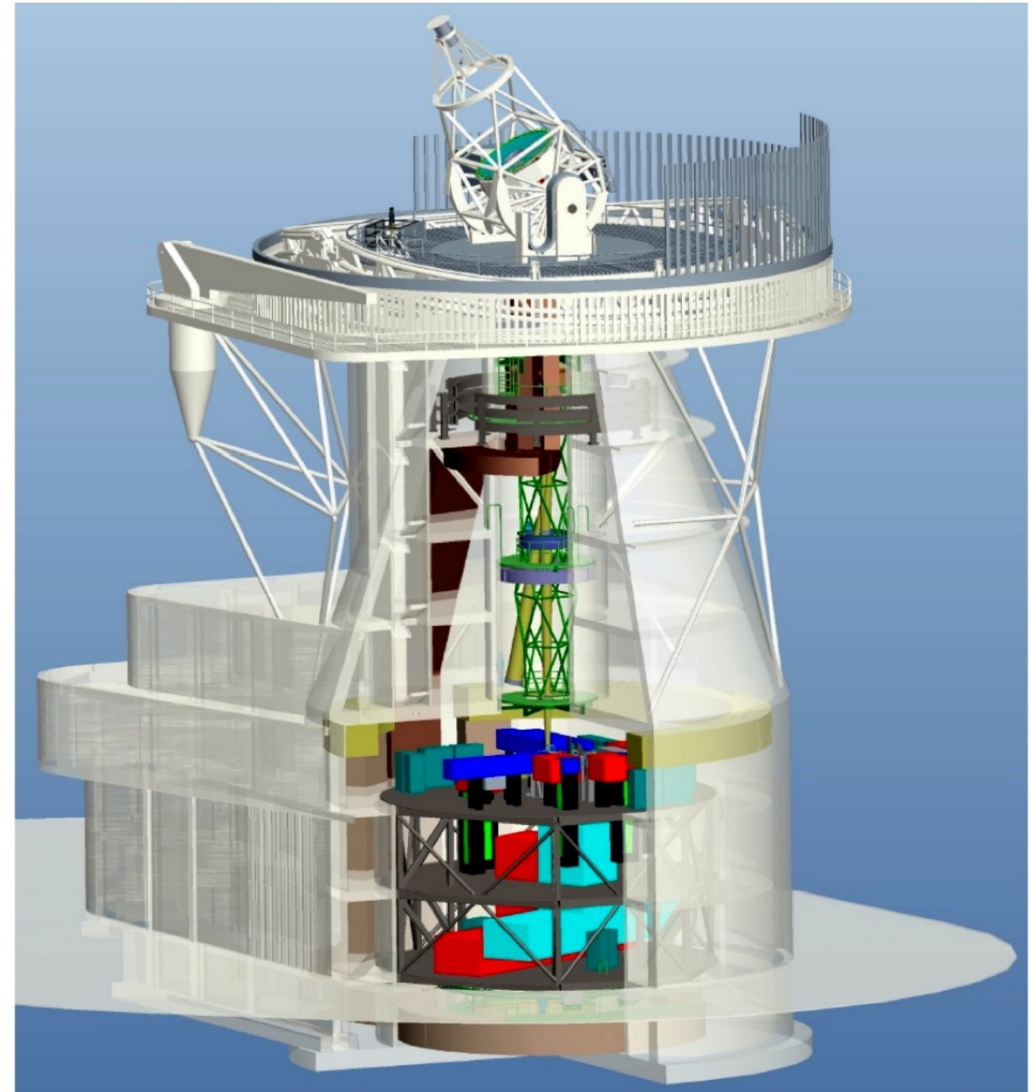
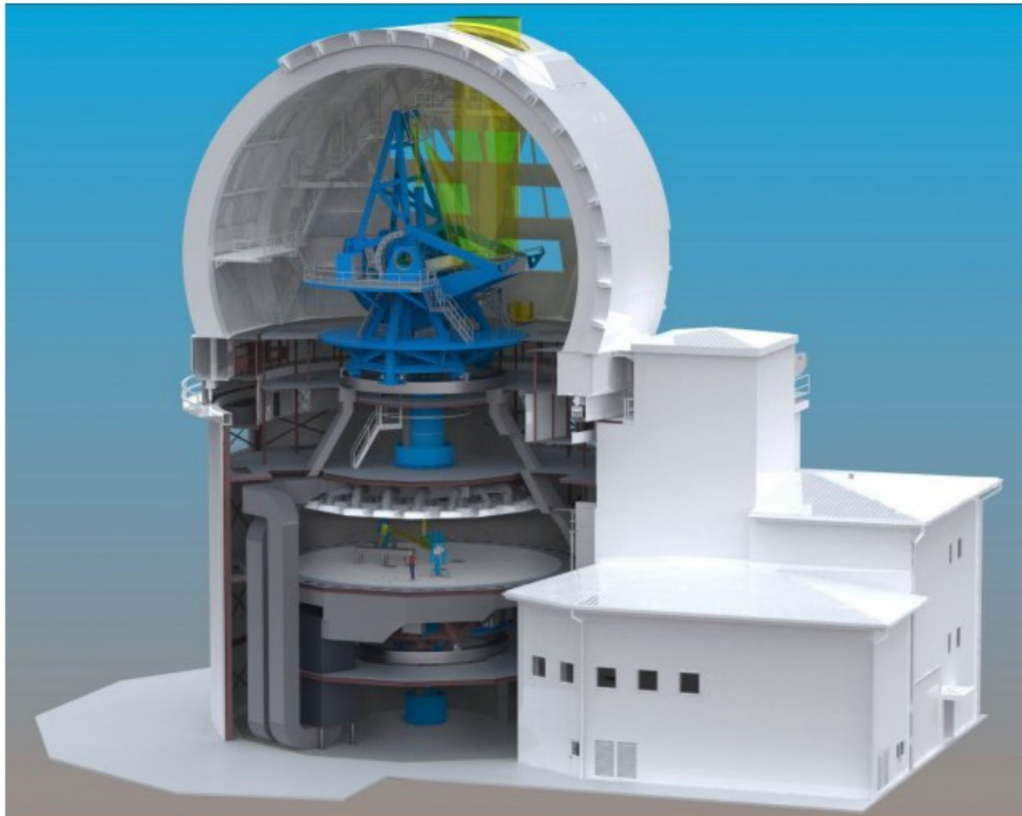
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# EST and DKIST

- Europe has a large young community of solar researchers
- European expertise is crucial for success of DKIST
  - many DKIST experts were educated in Europe
- Europe needs a next generation solar telescope → **the EST**



# EST complementarity with DKIST and Solar Orbiter

Solar Orbiter (ESA/NASA)



- high resolution, long-term studies become a reality  
→ DKIST + EST (weather permitting!)
- imaging/spectroscopy of the TR and corona to constrain energy transport to the outer atmosphere (SO)
- out of ecliptic vantage points to constrain 3D structures; solar wind/energetic particle origin (SO)

DKIST (credit: NSO/AURA/NSF)





# EST - European Solar Telescope

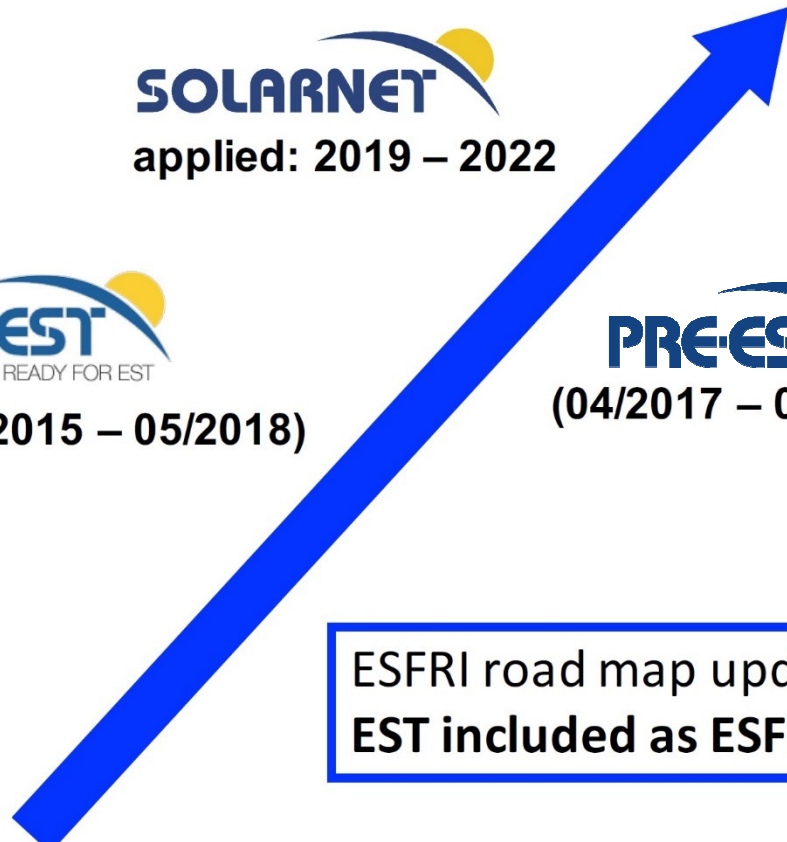


- founded in 2007
- 17 member states



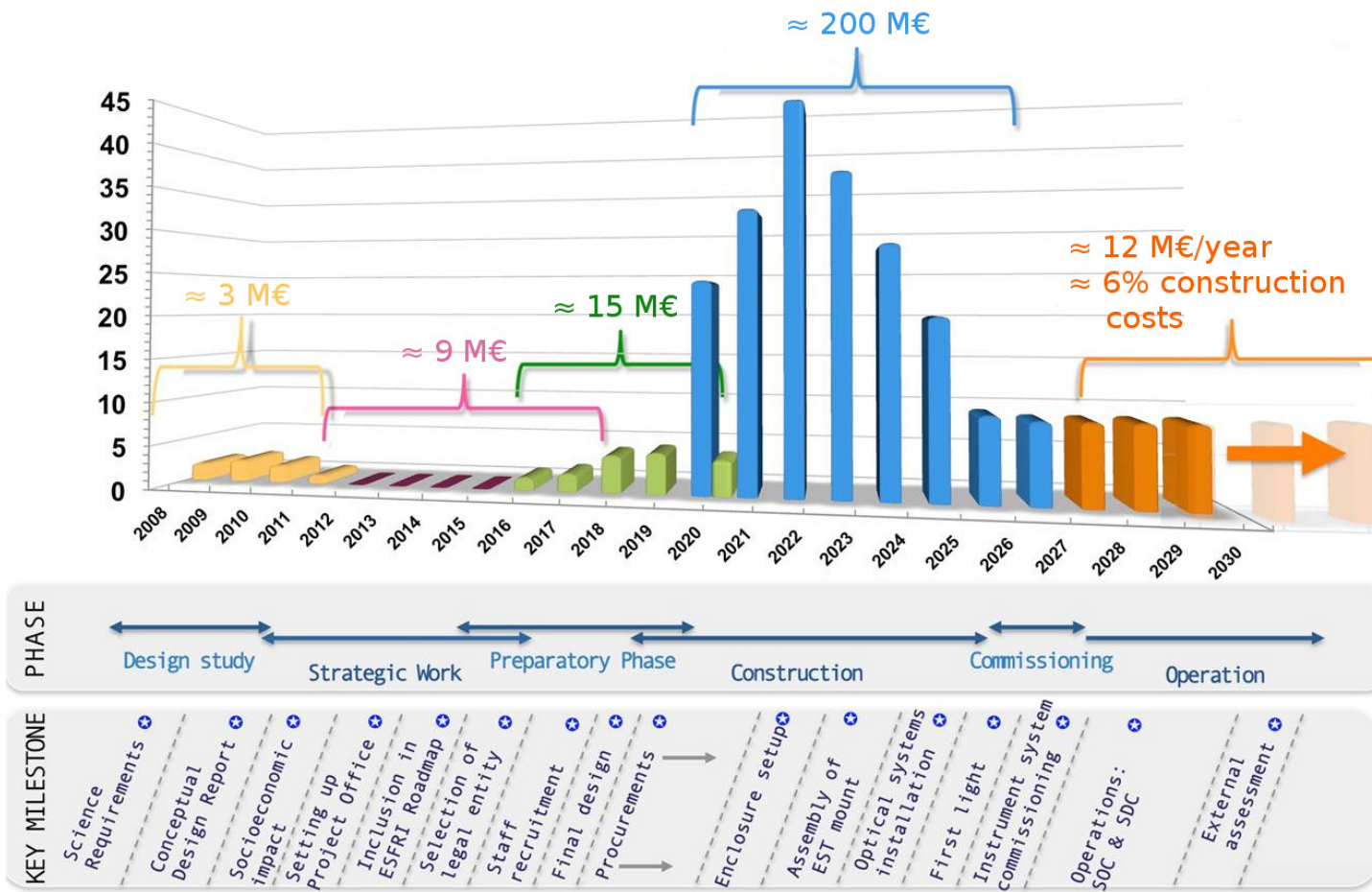
**EST Design Study**  
(2008 - 2011)

ESFRI road map update 2016:  
EST included as ESFRI project





# EST - history and schedule



- EAST coordinated all the projects related to the advancement of the EST
- these projects were co-financed by EU with 16 M€
- addition of EST to the active project list of the ESFRI roadmap 03/2016

- Conceptual design study of EST, EC FP7 project, 02/2008 - 07/2011
- SOLARNET, EC I3 project, 04/2013 - 03/2017
- GREY, EC H2020 project, 06/2015 - 06/2018
- PRE-EST, EC H2020 project, 04/2017 - 03/2021

# EST - community

➤ EAST for more info → follow the EST at social media

- facebook: <https://www.facebook.com/EuropeanSolarTelescope>
- twitter: <https://twitter.com/estsolarnet>
- linkedin: <https://www.linkedin.com/company/european-solar-telescope>

facebook

E-mail alebo telefón  Heslo

[Přihlásit sa](#)

Zabudli ste údaje na prístup k účtu?

**EST**

European Solar Telescope - EST  
@EuropeanSolarTelescope

- Domov
  - Príspevky
  - Recenzie
  - Videá
  - Fotky
  - Informácie
  - Komunita
- [Vytvoriť stránku](#)

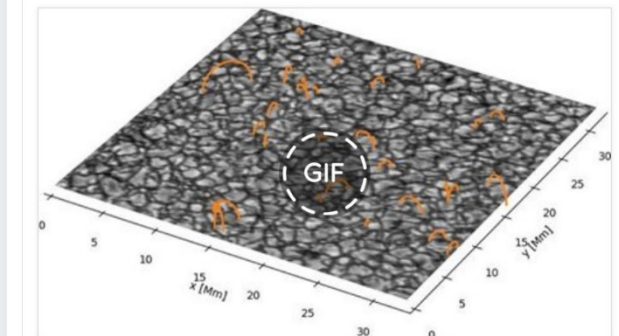
👍 Páči sa mi to   ➡ Zdieľať   ...

### Príspevky

**EST** European Solar Telescope - EST  
Včera o 1:24 · 🌐

Today's 3rd chapter of "The science of EST" is presented by Dr. Marian Martínez González (IAC - Instituto de Astrofísica de Canarias, Spain)

"The smallest dipoles ever observed in a star" ... [Zobraziť viac](#)



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**EST** European Solar Telescope

Research · Tenerife / La Palma, Canary Islands · 31 followers

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About us

The European Solar Telescope (EST), promoted by the The European Association for Solar Telescopes (EAST), is a next generation large-aperture solar telescope. This 4-metre telescope will be optimised for studies of the magnetic coupling between the deep photosphere and upper chromosphere of the Sun. This will require diagnostics of the thermal, dynamic and magnetic properties of the plasma over many scale heights, by using multiple wavelength imaging, spectroscopy and spectropolarimetry. To achieve these goals, the EST will specialise in high spatial and temporal resolution using various instruments simultaneously that can efficiently produce 2D spectral information. EST will be located in Canary Islands (Spain).

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Today's 3rd chapter of "The..."

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Comenzamos el rodaje de "searching for the sun" y donde mejor que en esta la zona el Sol que en los observatorios de las Islas Canarias. Un documental de @estsolarnet con Francisco de @IESCTI, García @ICG-CANARIAS @iaca\_ma

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Thank you for your attention

