
EST
EAST
European Association for Solar Telescopes
EST:
A large solar telescope for the XXI century
M. Collados
Instituto de Astrofísica de Canarias
and the EST team
INSTITUTO DE ASTROFISICA DE CANARIAS
IAC

European Solar Telescope

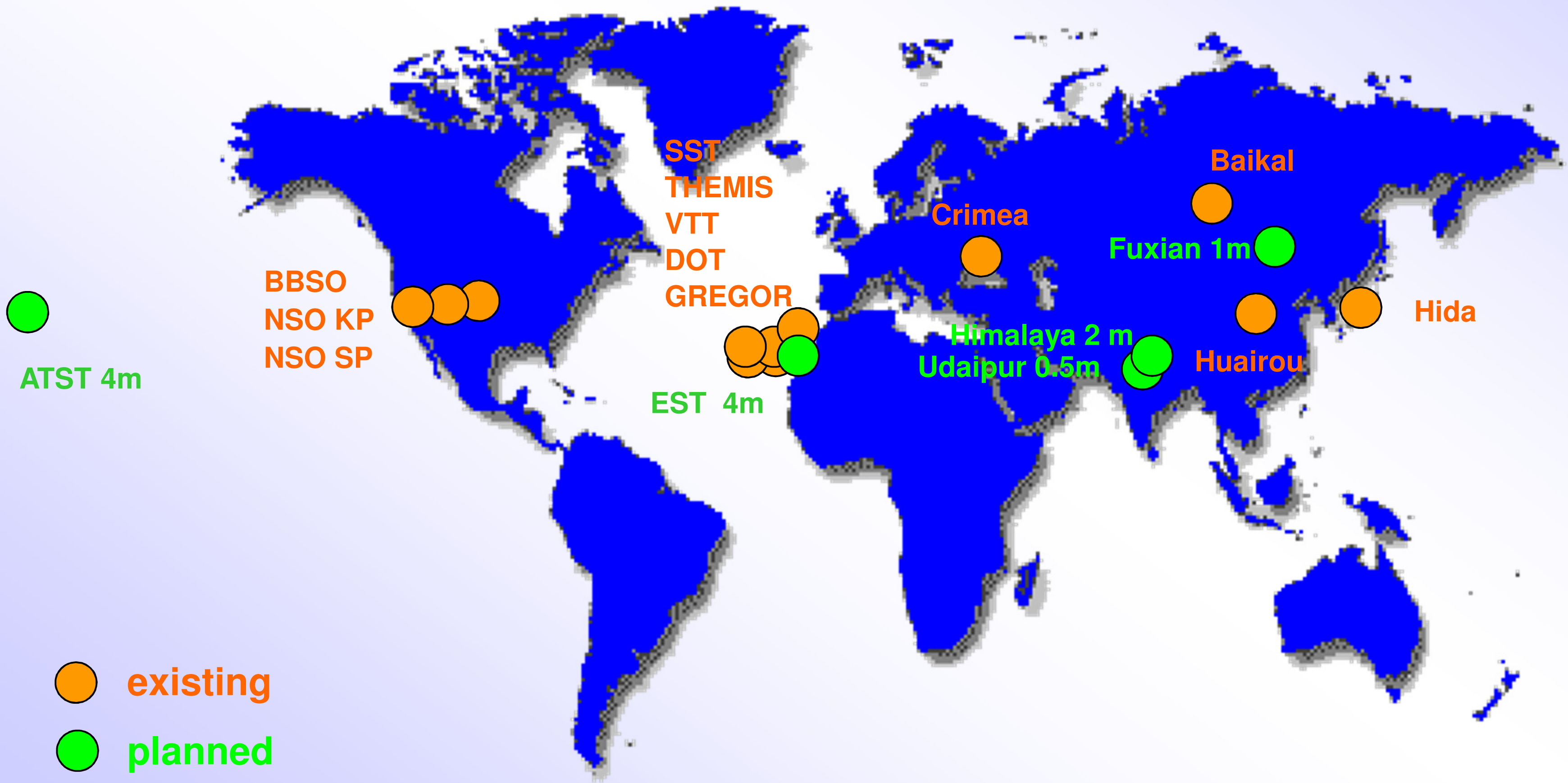
European Association for Solar Telescopes

Large aperture 4-meter telescope to be built in the Canary Islands

AIM:

High-spatial and high-temporal resolution accurate multi-wavelength polarimetry of the photosphere and the chromosphere, both with narrow band filters and 2-D spectrographs

Major Groundbased Solar Observatories



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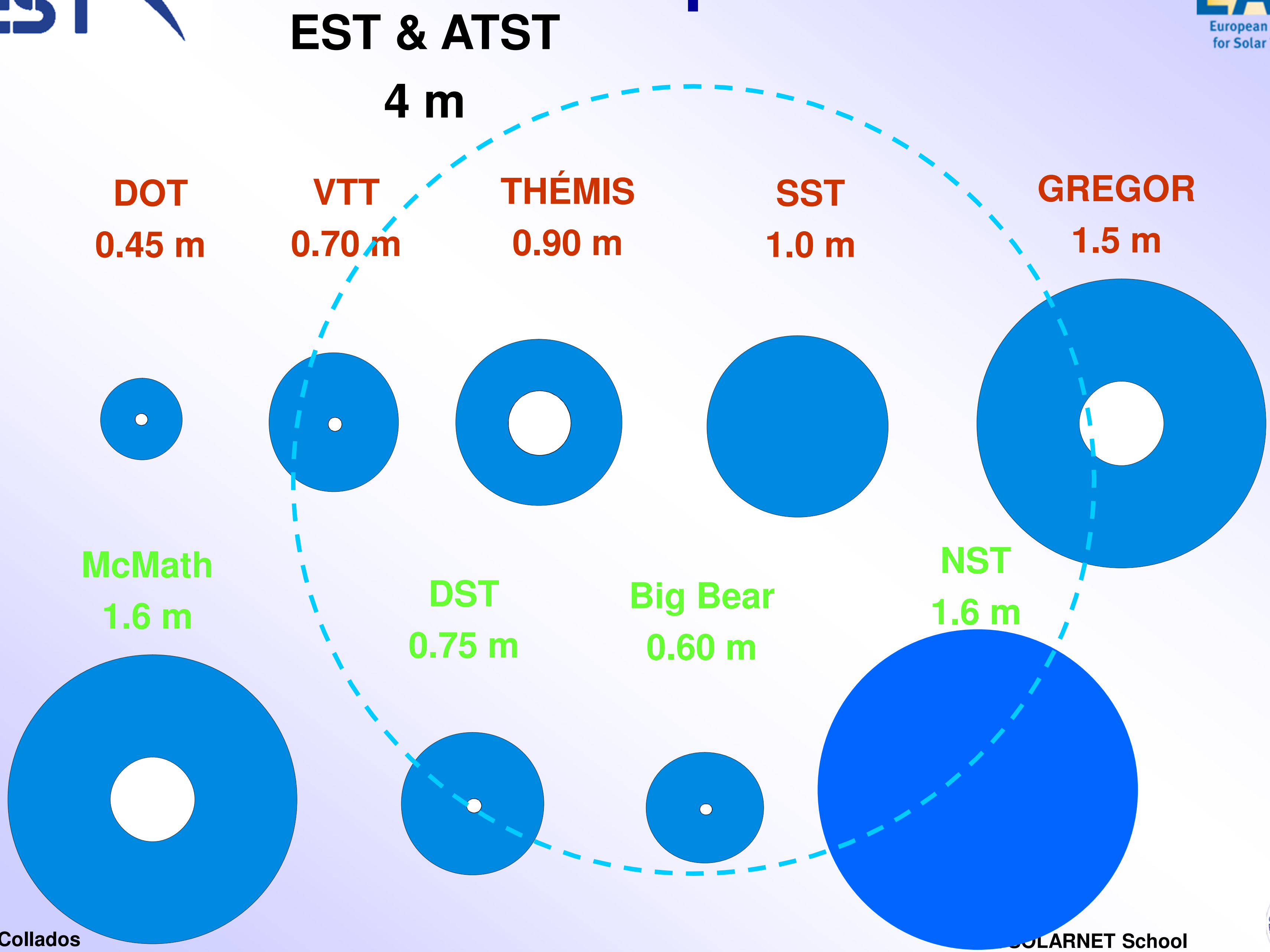
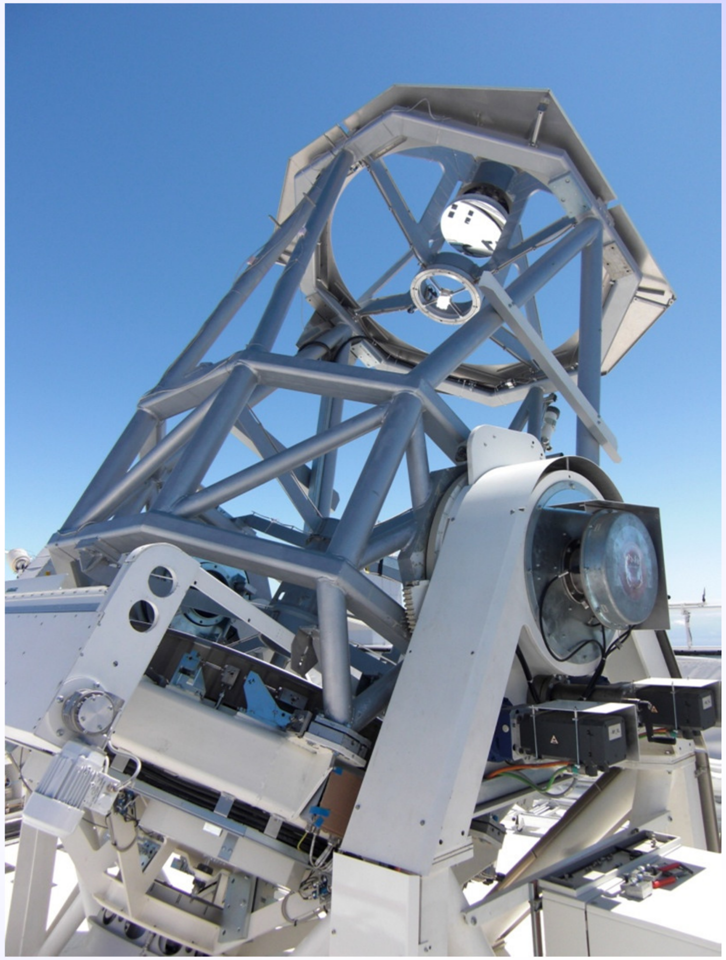
Aperture Sizes



NST 1.6 m

2009

GREGOR 1.5 m



2012

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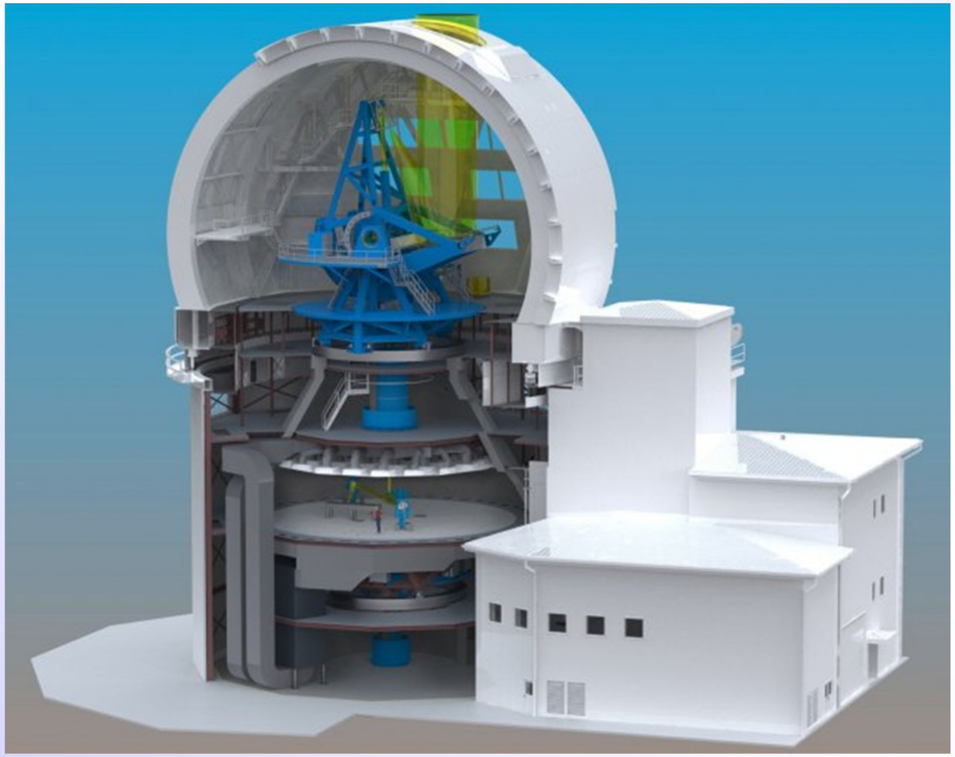
ATST

EST



2017

2020

4- METRE APERTURE

EST LOCATION

OT
Tenerife

ORM
La Palma

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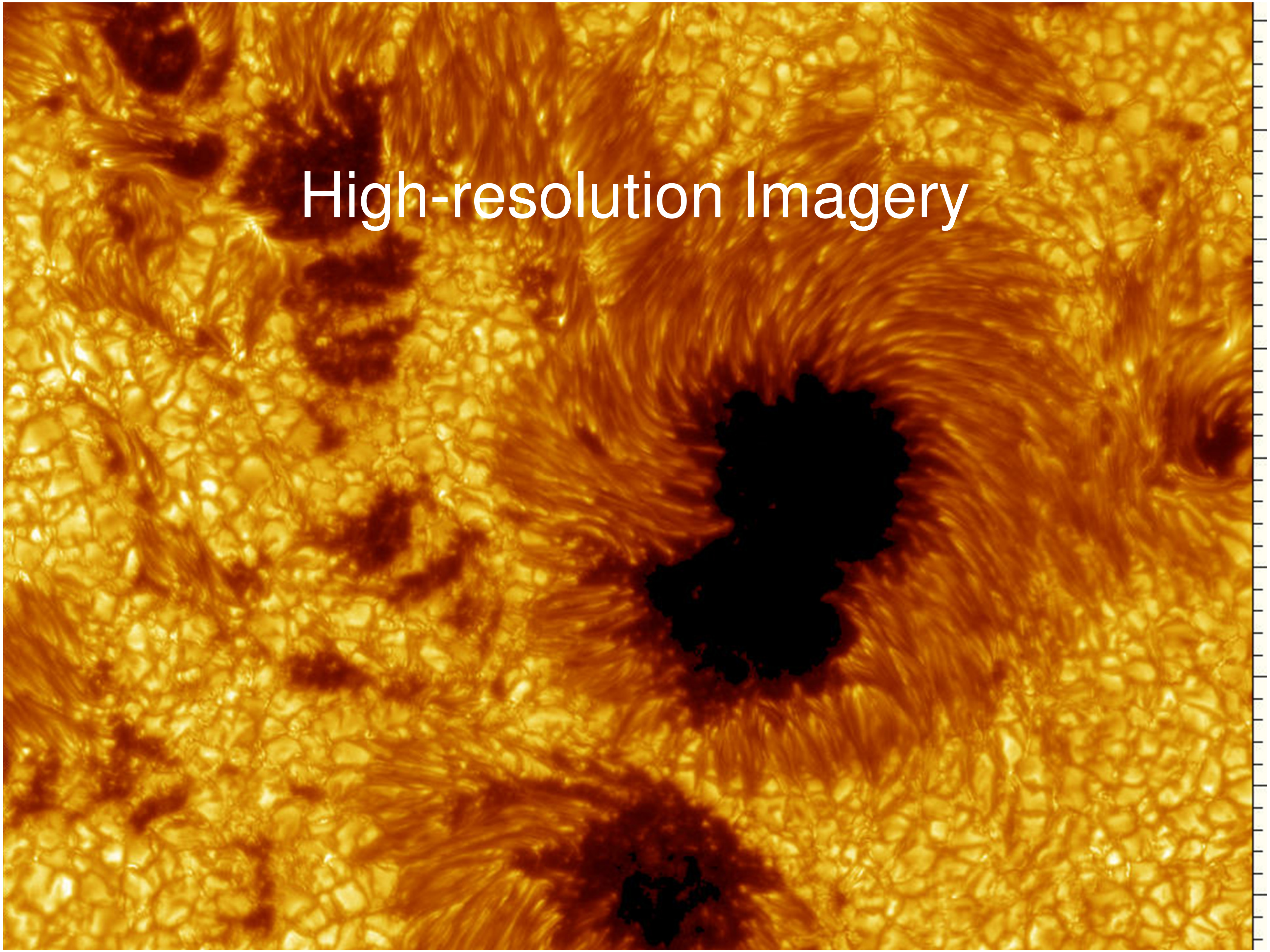
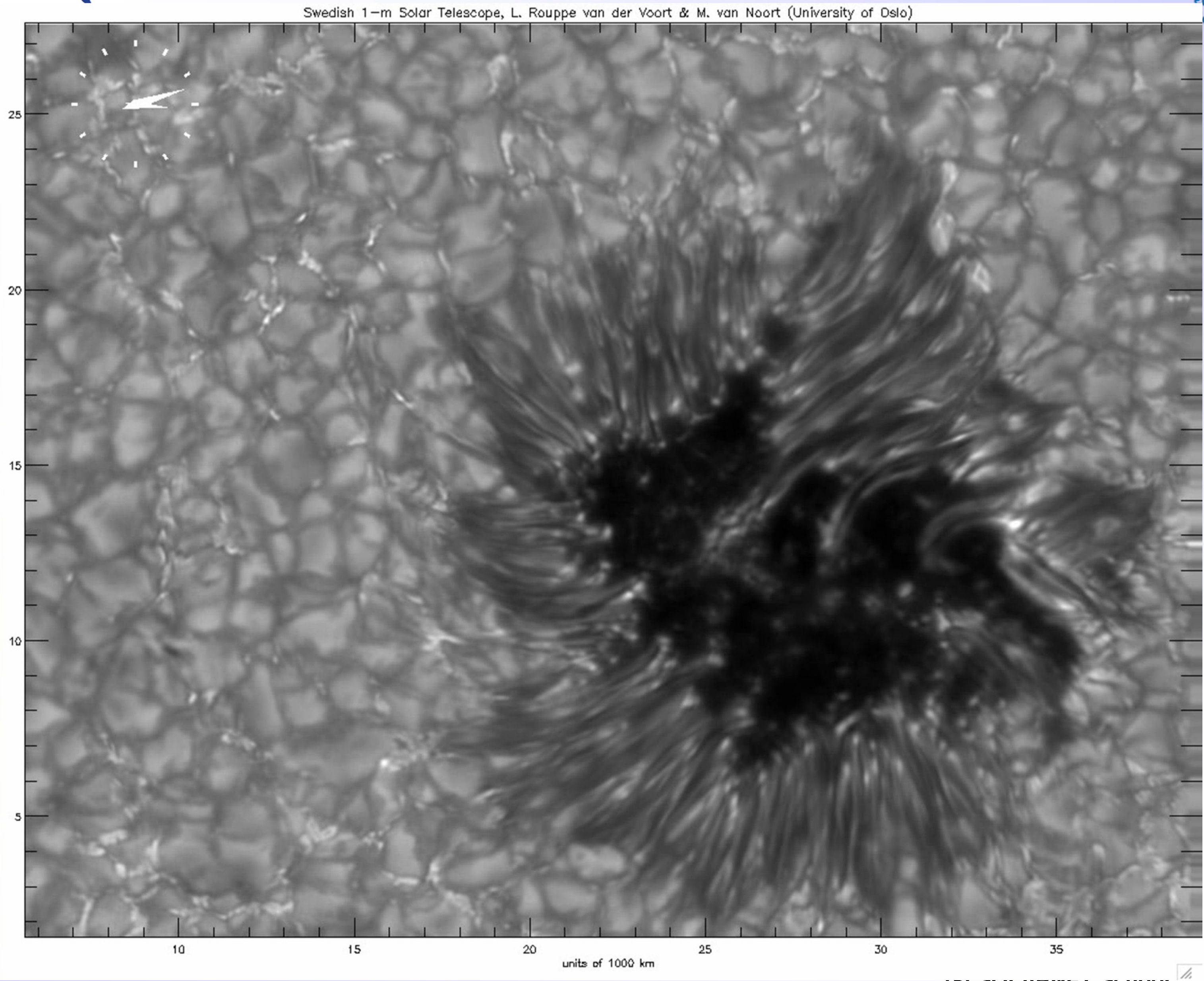
EST is promoted by EAST

(European Association for Solar Telescopes)

● Countries represented in EAST


High-resolution Imagery

Photosphere – temporal evolution



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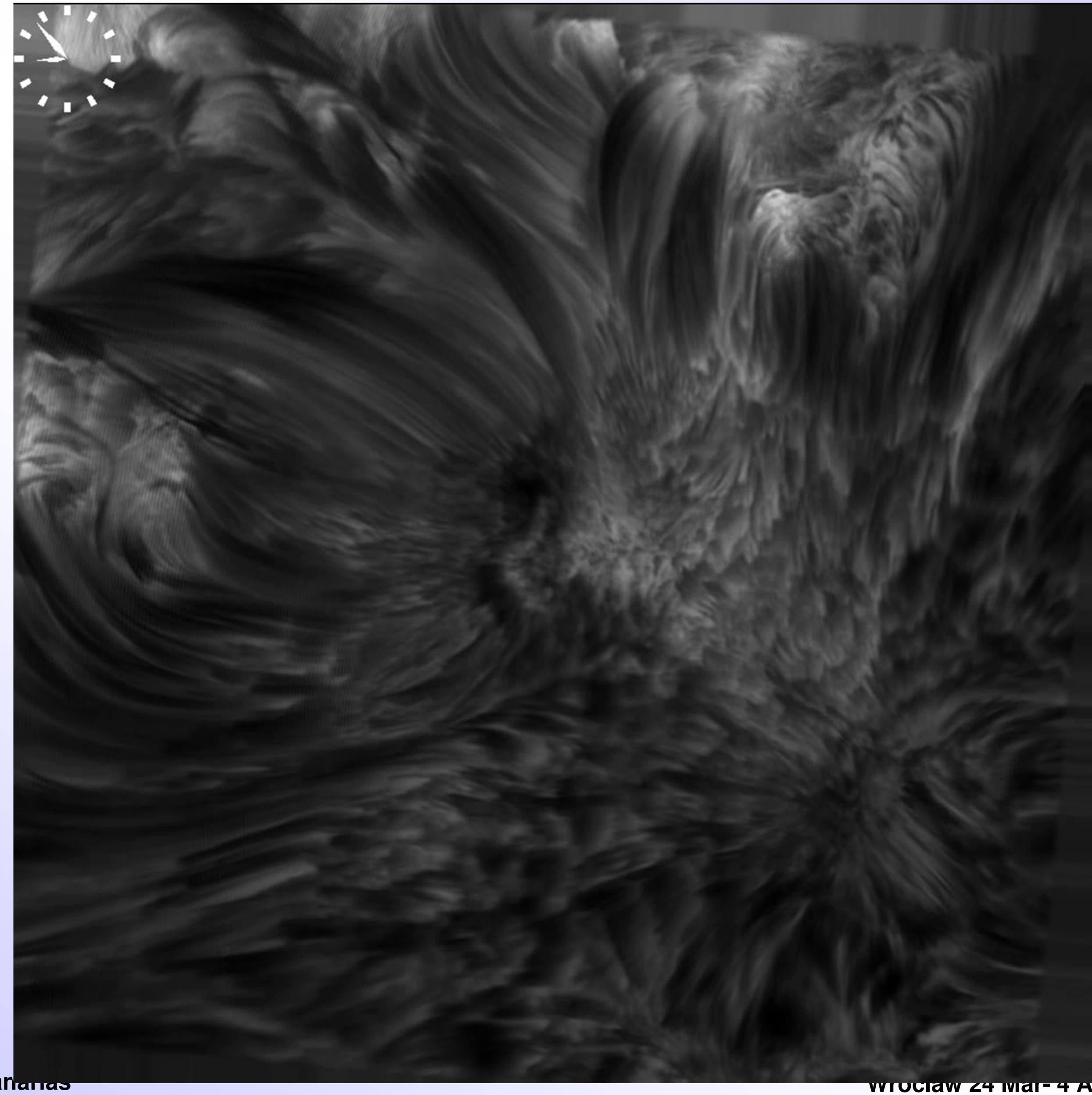
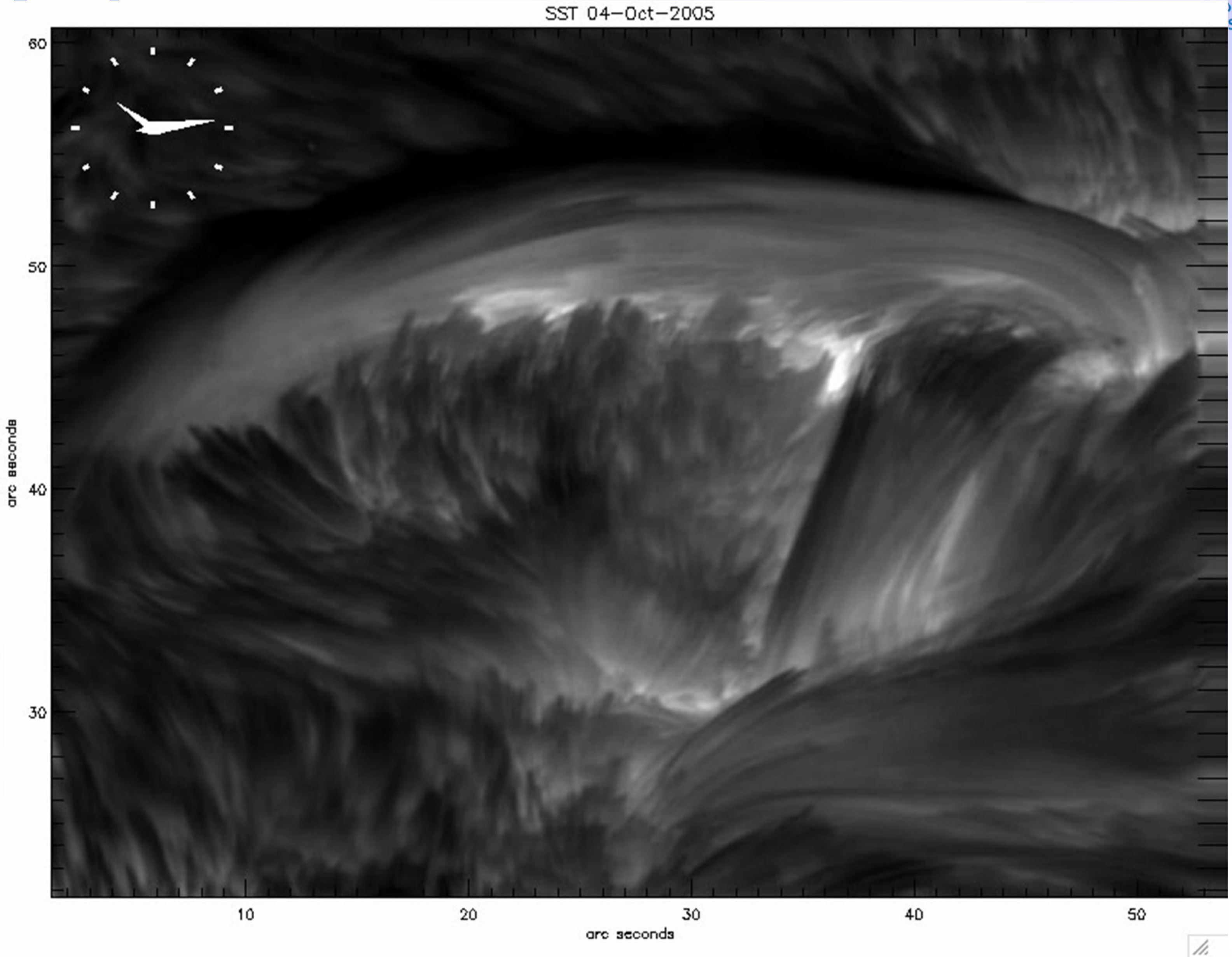
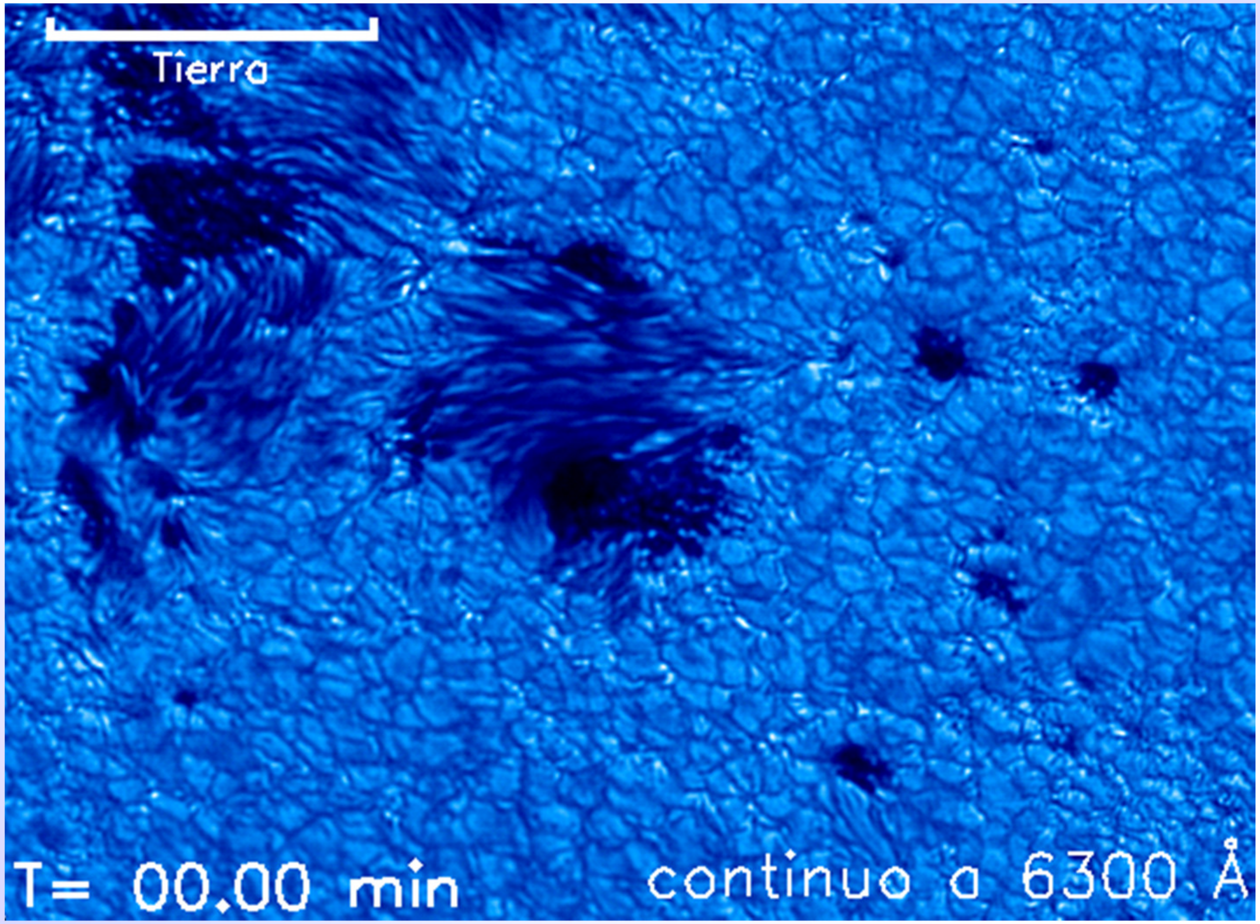
Chromosphere – temporal evolution



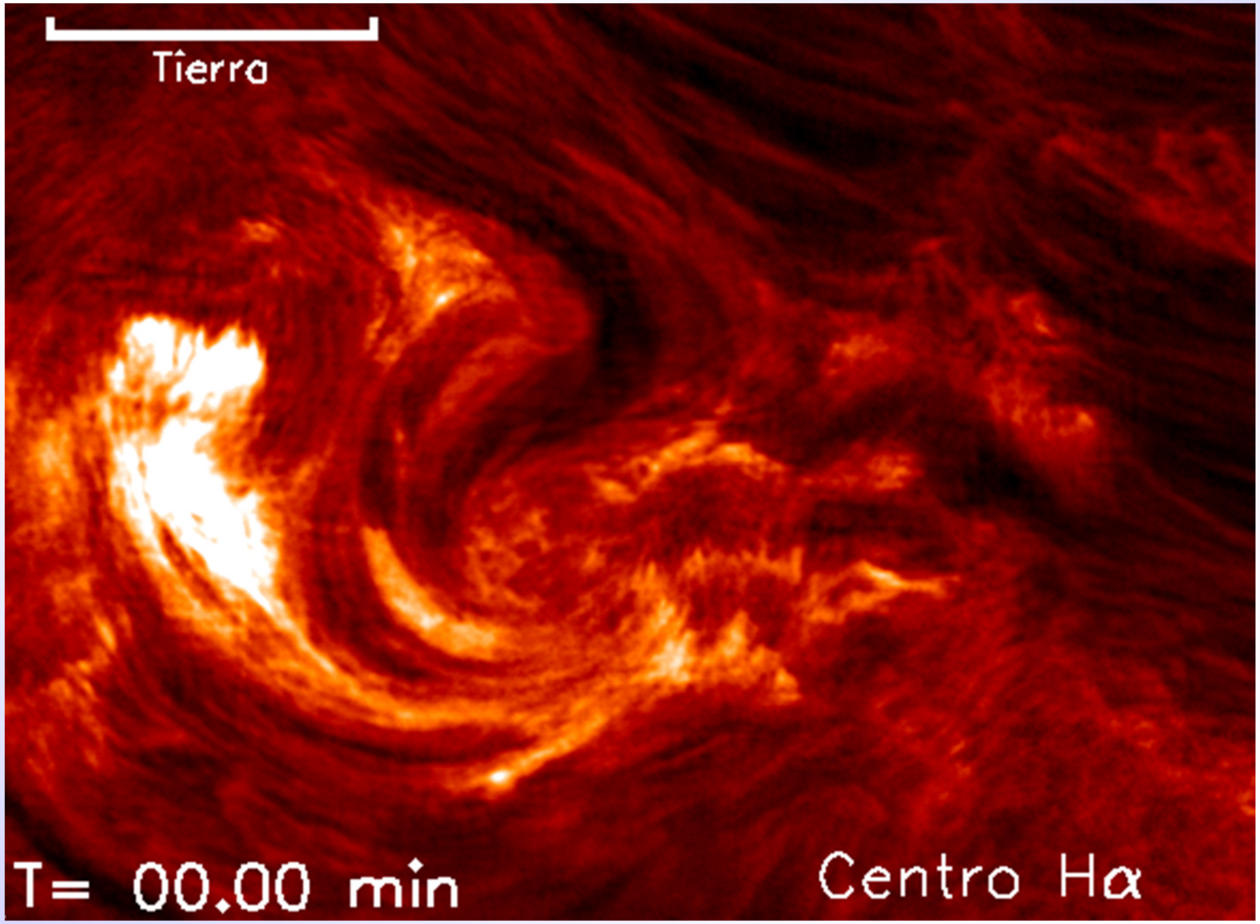
Chromosphere – temporal evolution



Photosphere + Chromosphere temporal evolution



Photosphere + Chromosphere temporal evolution



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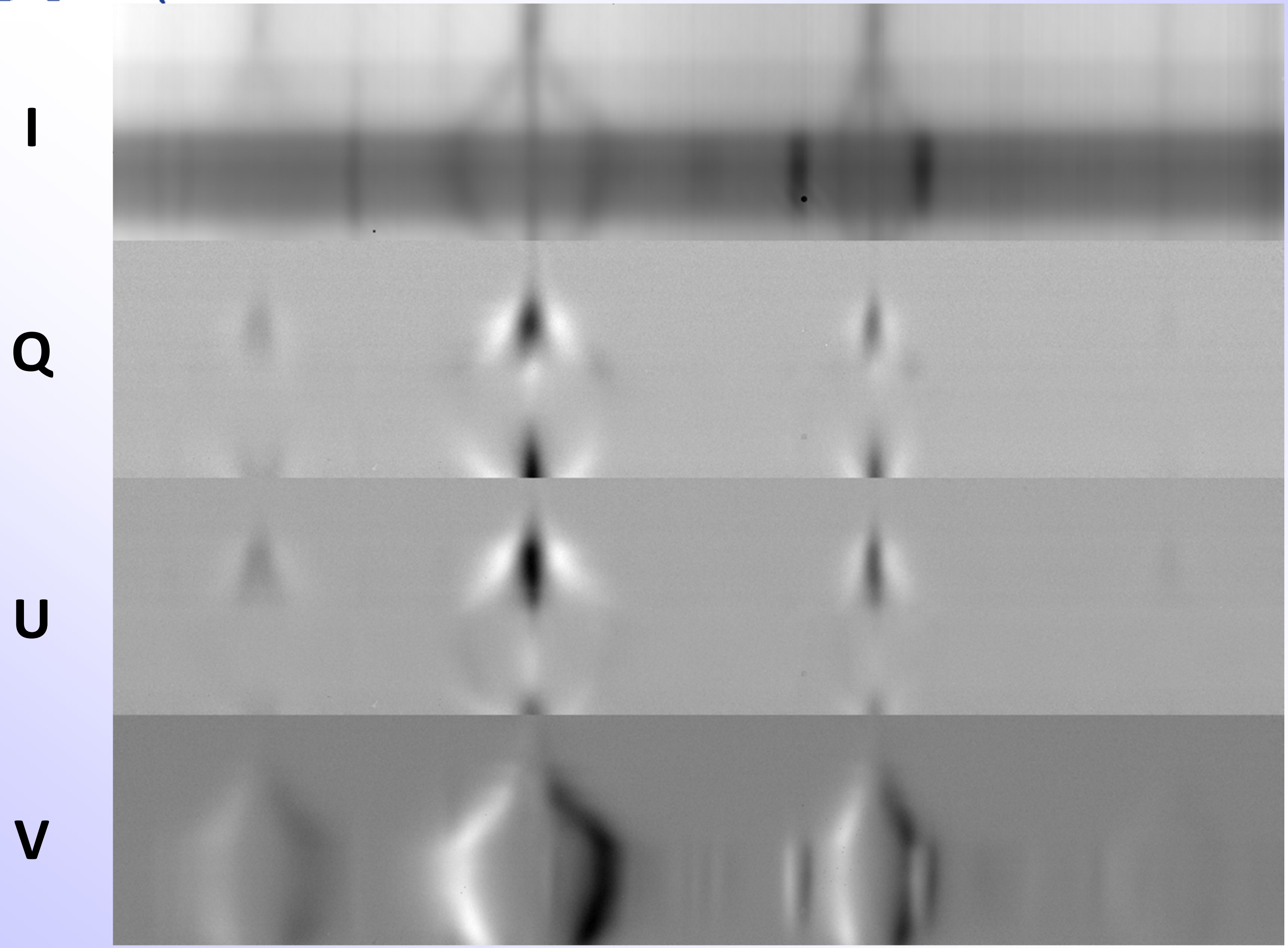
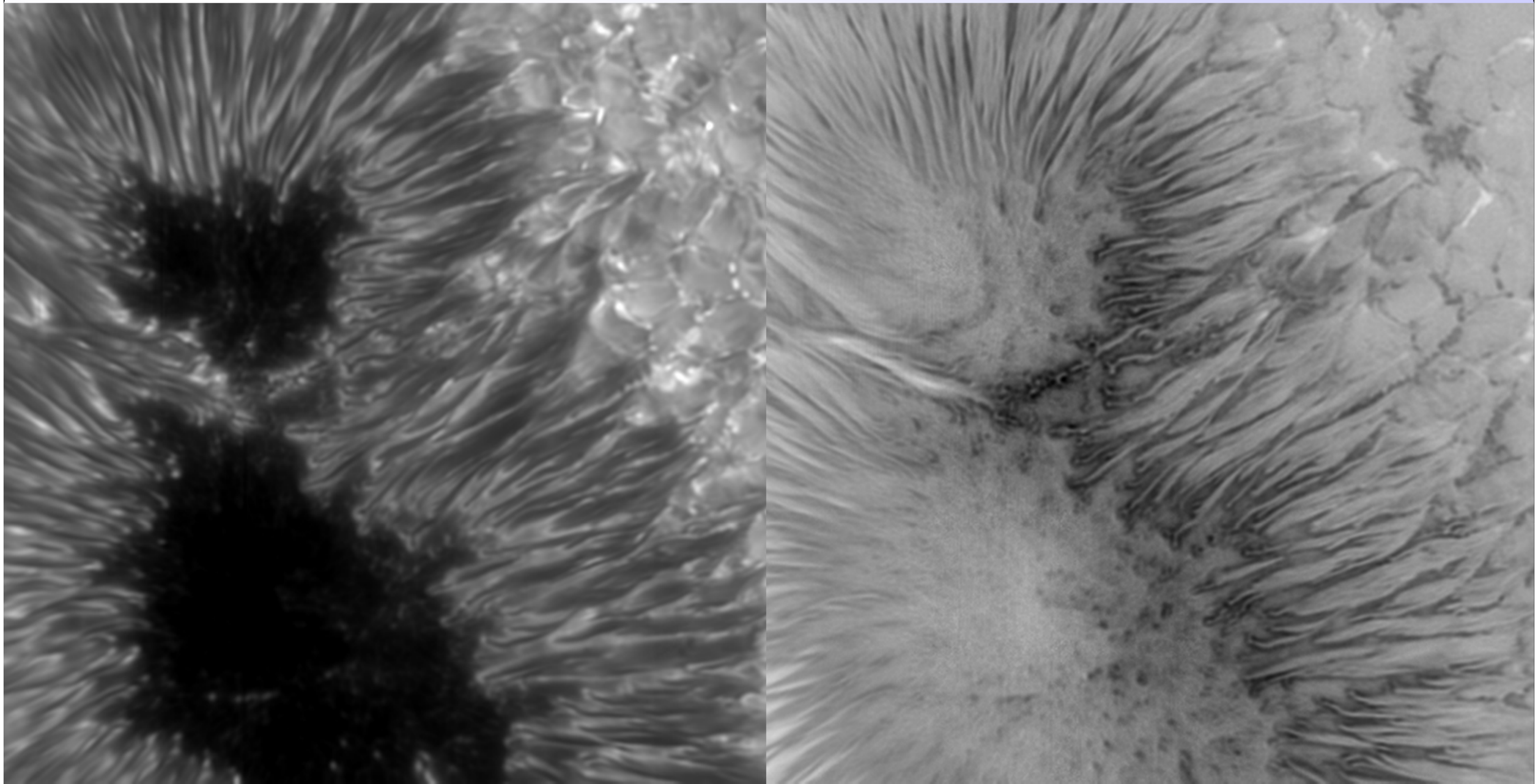
Photosphere - Polarimetry



Photosphere - Polarimetry



I

V

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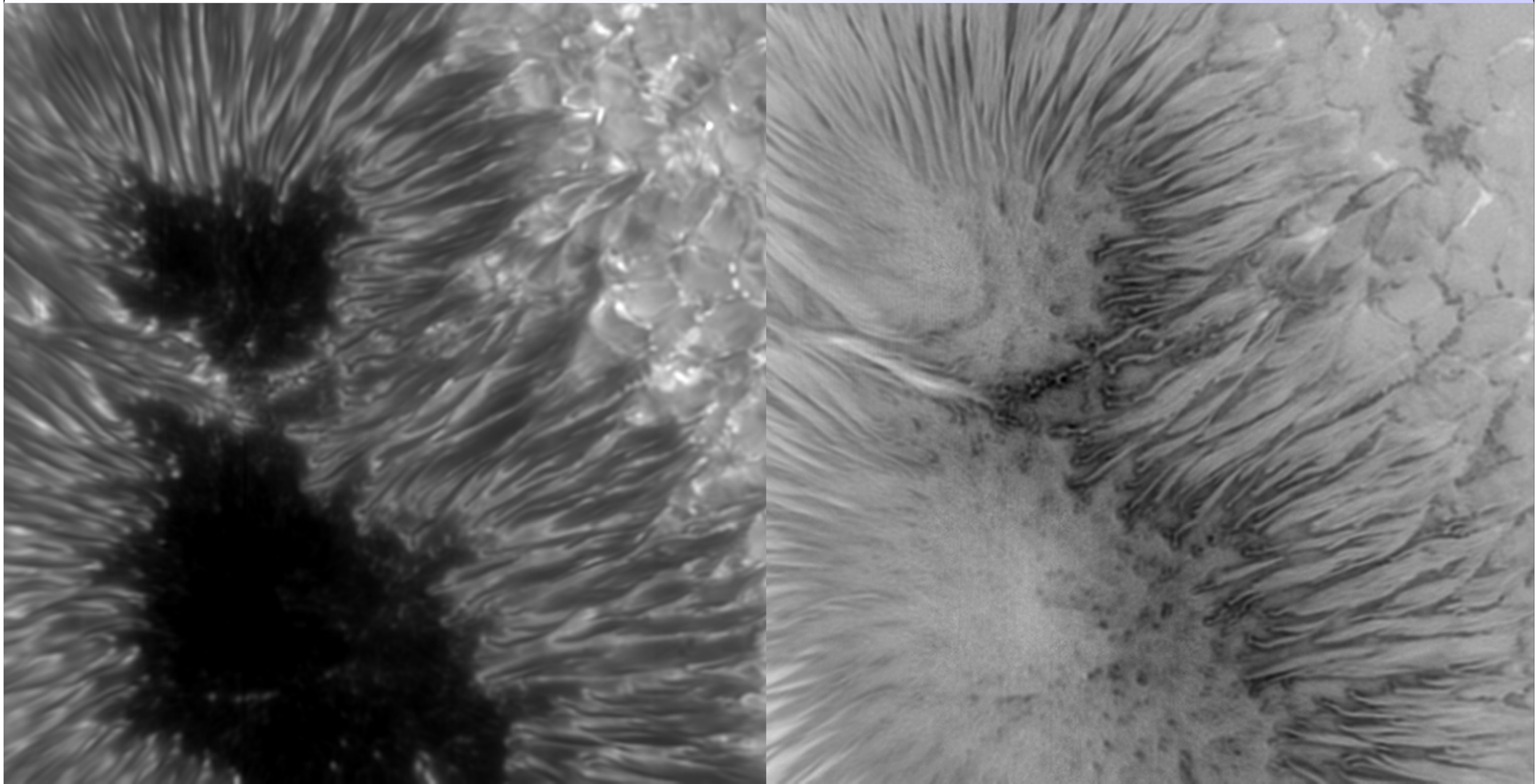
Photosphere - Polarimetry



I Movie 1 V

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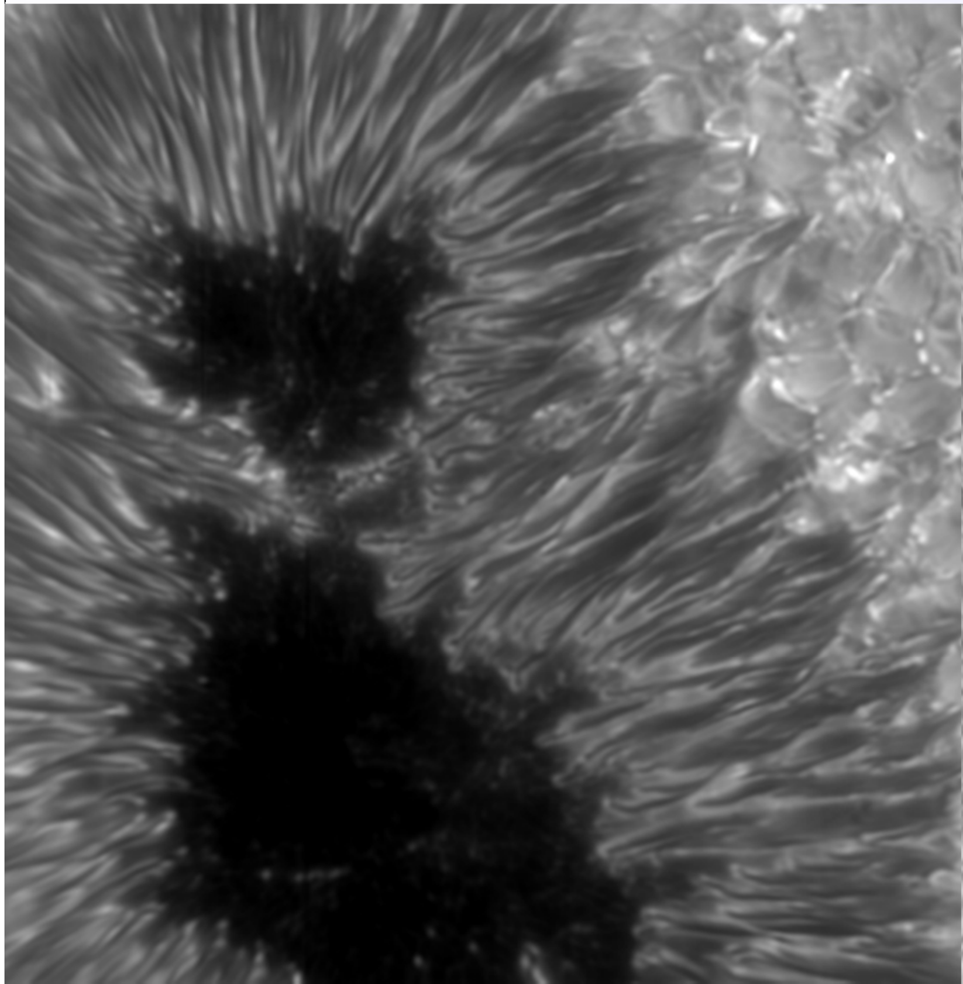
Photosphere - Polarimetry



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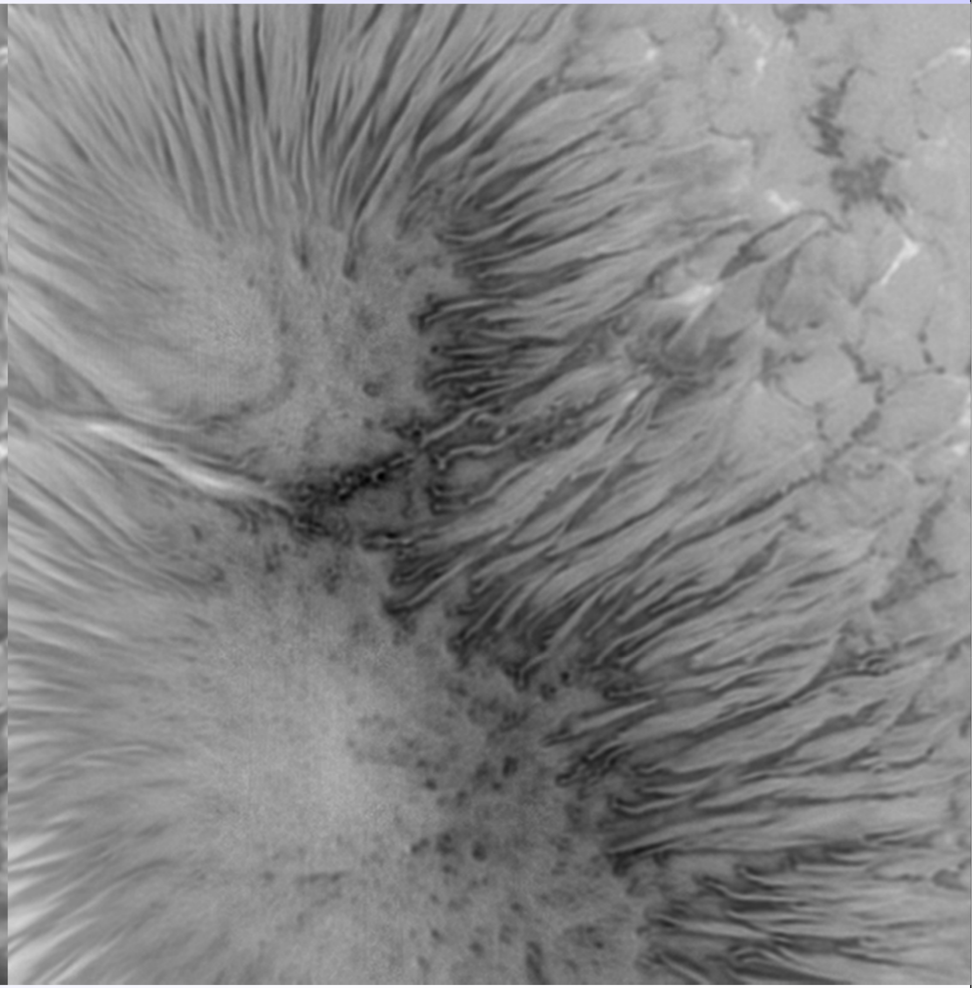

V

Movie 2

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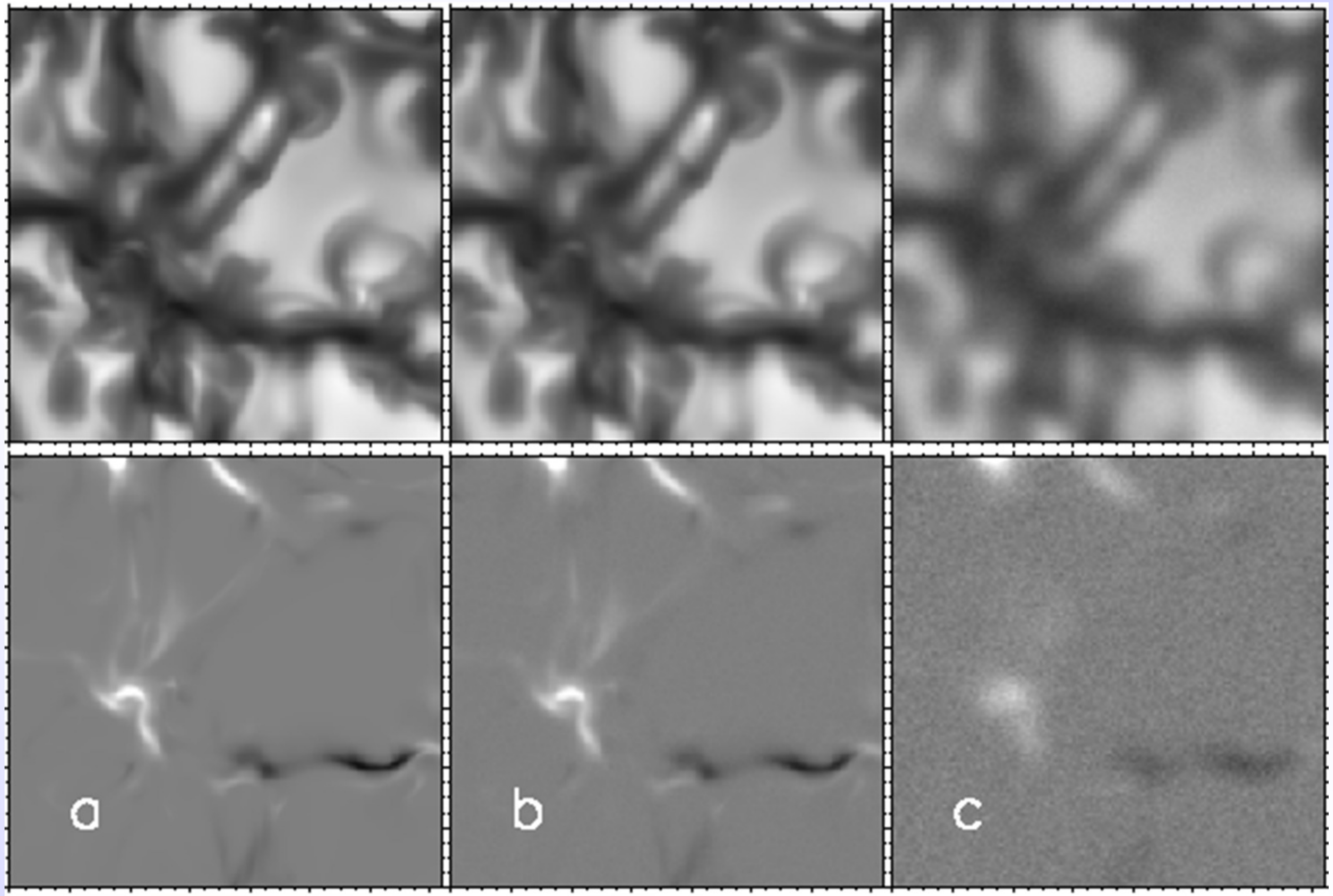
MHD Simulations



Original

4-m Telescope

10^{-3} I_c noise

0.75-m Telescope

Same Int. Time

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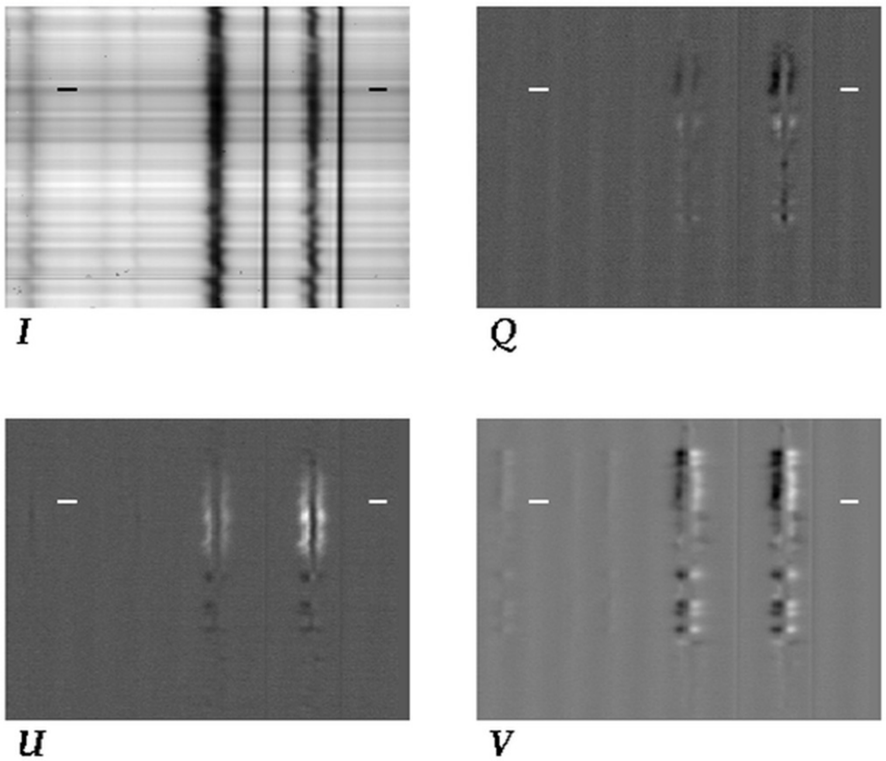
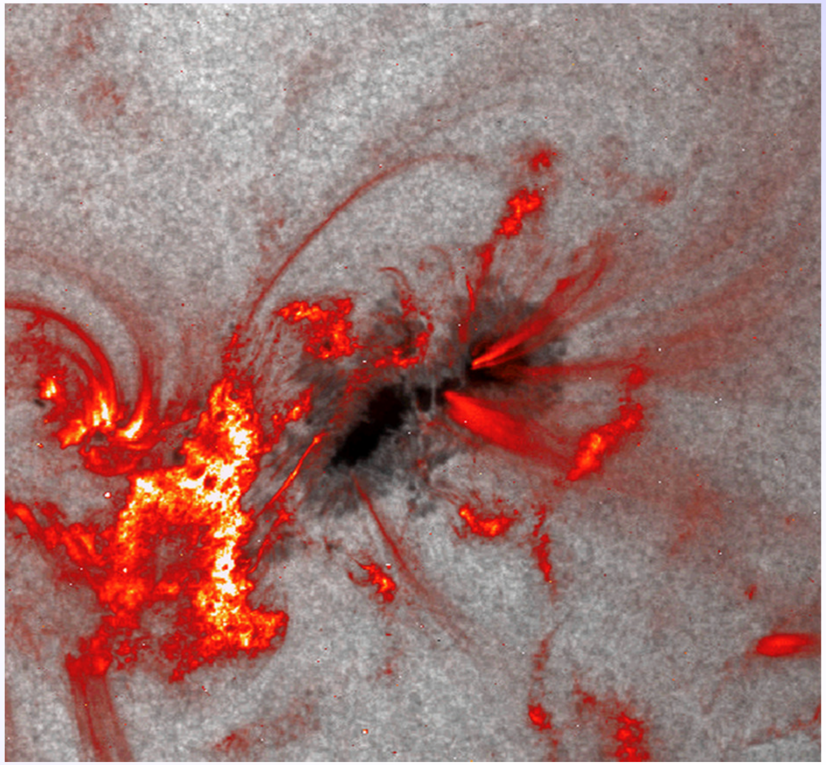
EST:

Magnetic coupling of the solar atmosphere:

from the deep photosphere

up to the upper chromosphere





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Main science questions

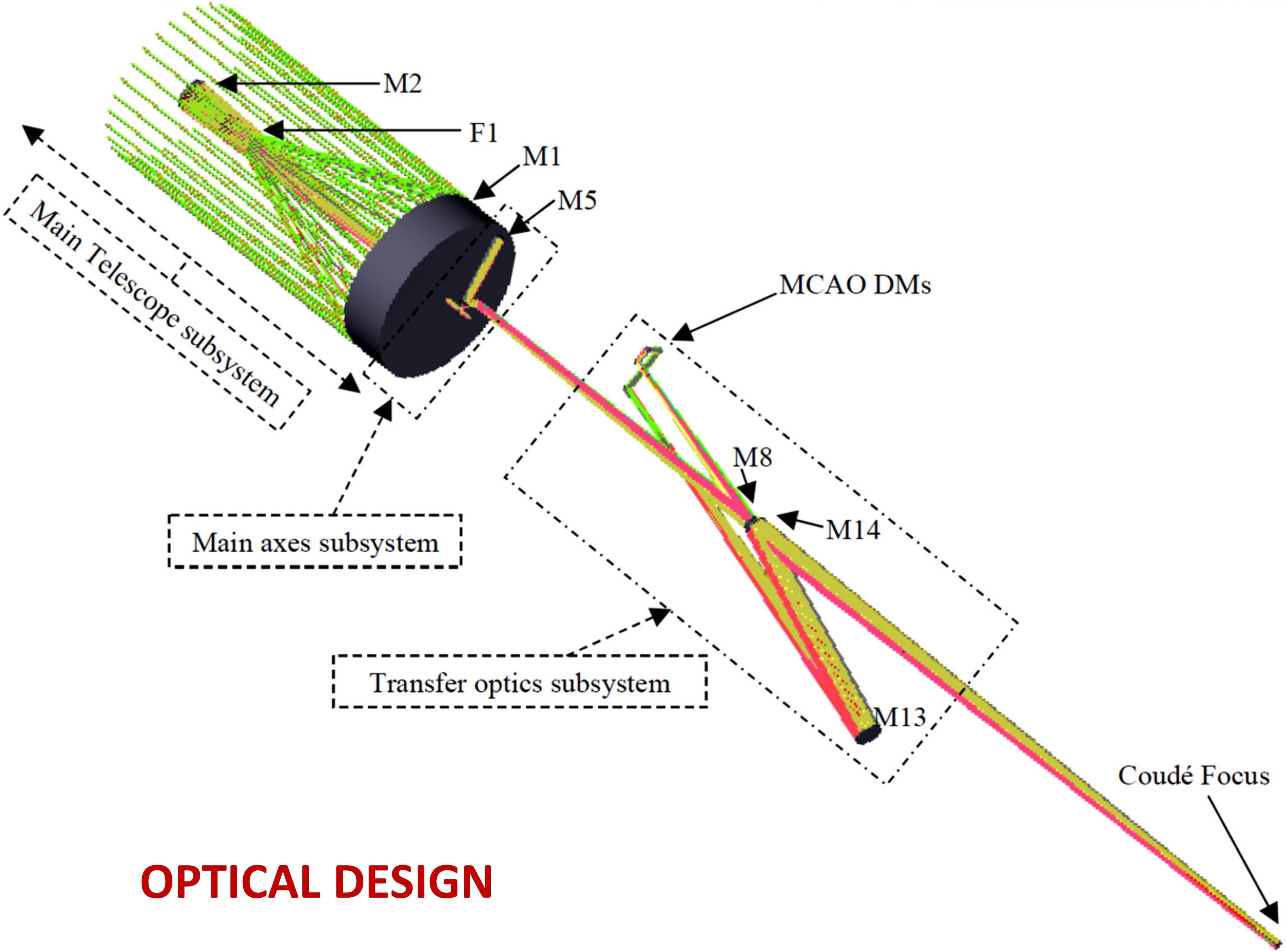
- How does the magnetic field emerge to the surface and evolve?
- How is energy transported from the photosphere to the chromosphere?
- How is the energy released in the upper atmosphere?
- Why does the sun have a hot chromosphere?

Telescope and instrumentation key requirements

- **High angular resolution,** with AO and MCAO for atmospheric distortion correction
- **High precision polarimetric capabilities,** for accurate magnetic field determination
- **Simultaneous observation** of photosphere and chromosphere $\Rightarrow$ multiwavelength, imaging and spectroscopic, capabilities

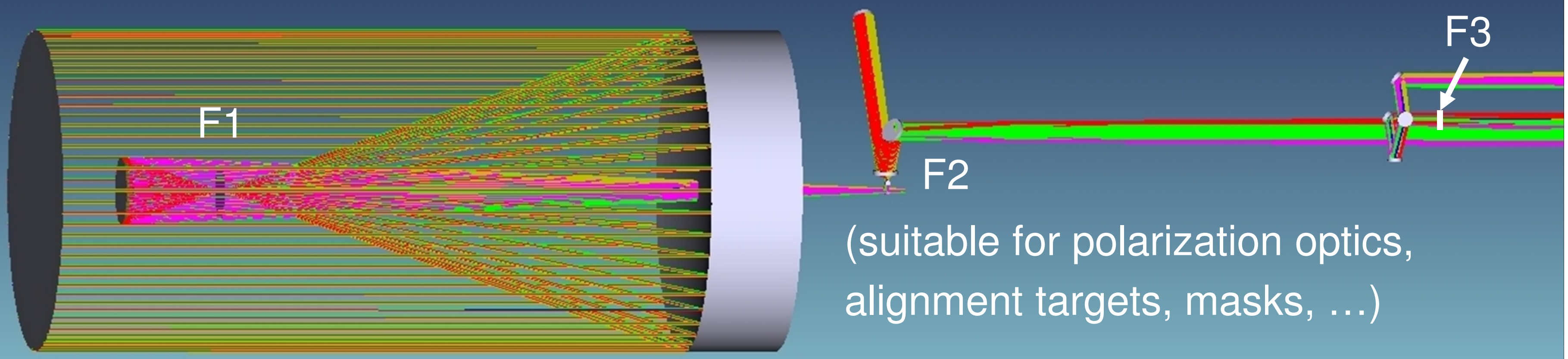
Design baseline

- 4-meter diameter
- On-axis Gregorian configuration
- Alt-Az mount
- Simultaneous instrument stations (each with several wavelength channels)
  - Broad-band imager
  - Narrow-band tunable imager
  - Grating spectrograph
- AO/MCAO integrated in the optical path



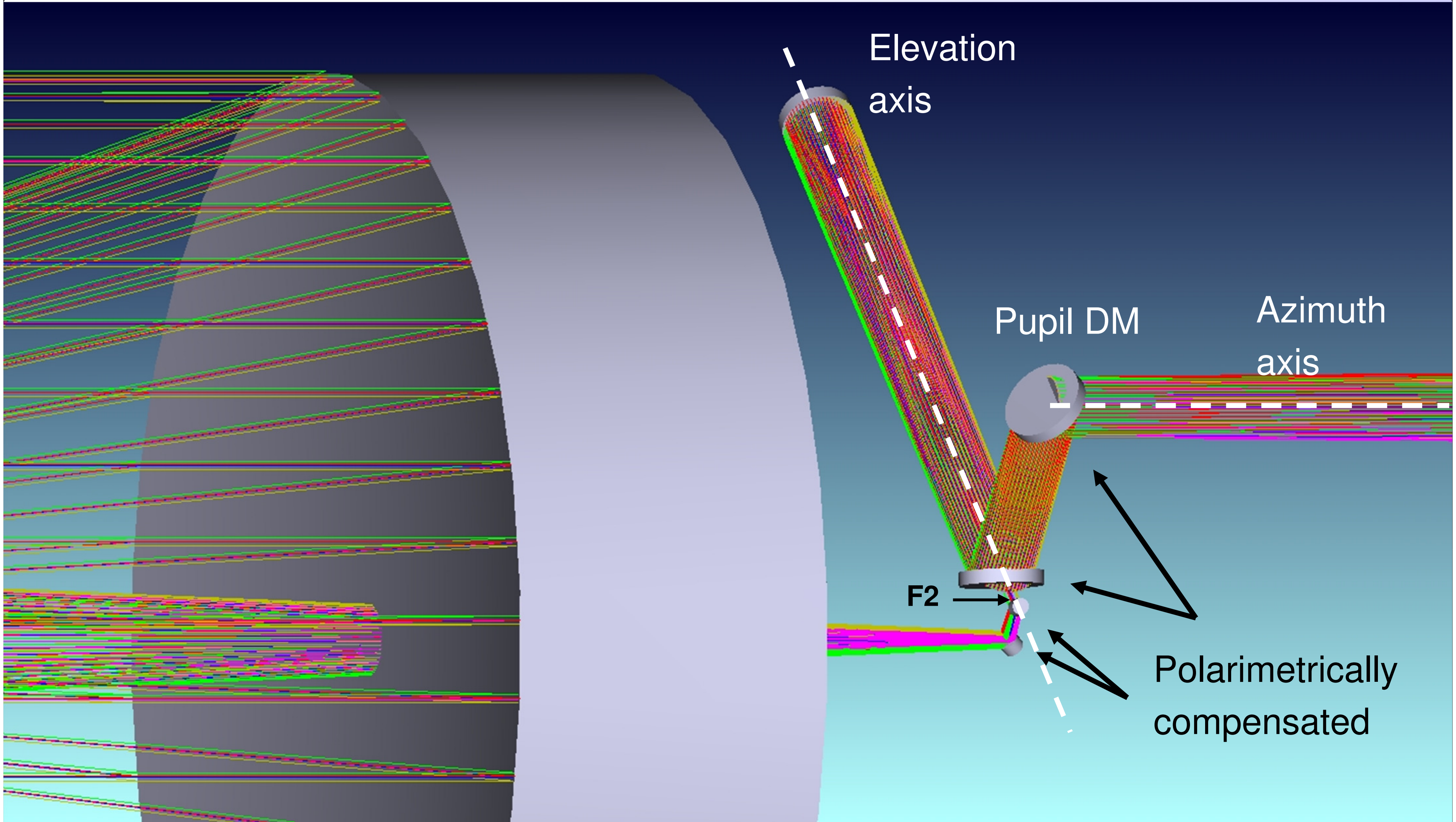
OPTICAL DESIGN

14-MIRROR COMPENSATED DESIGN

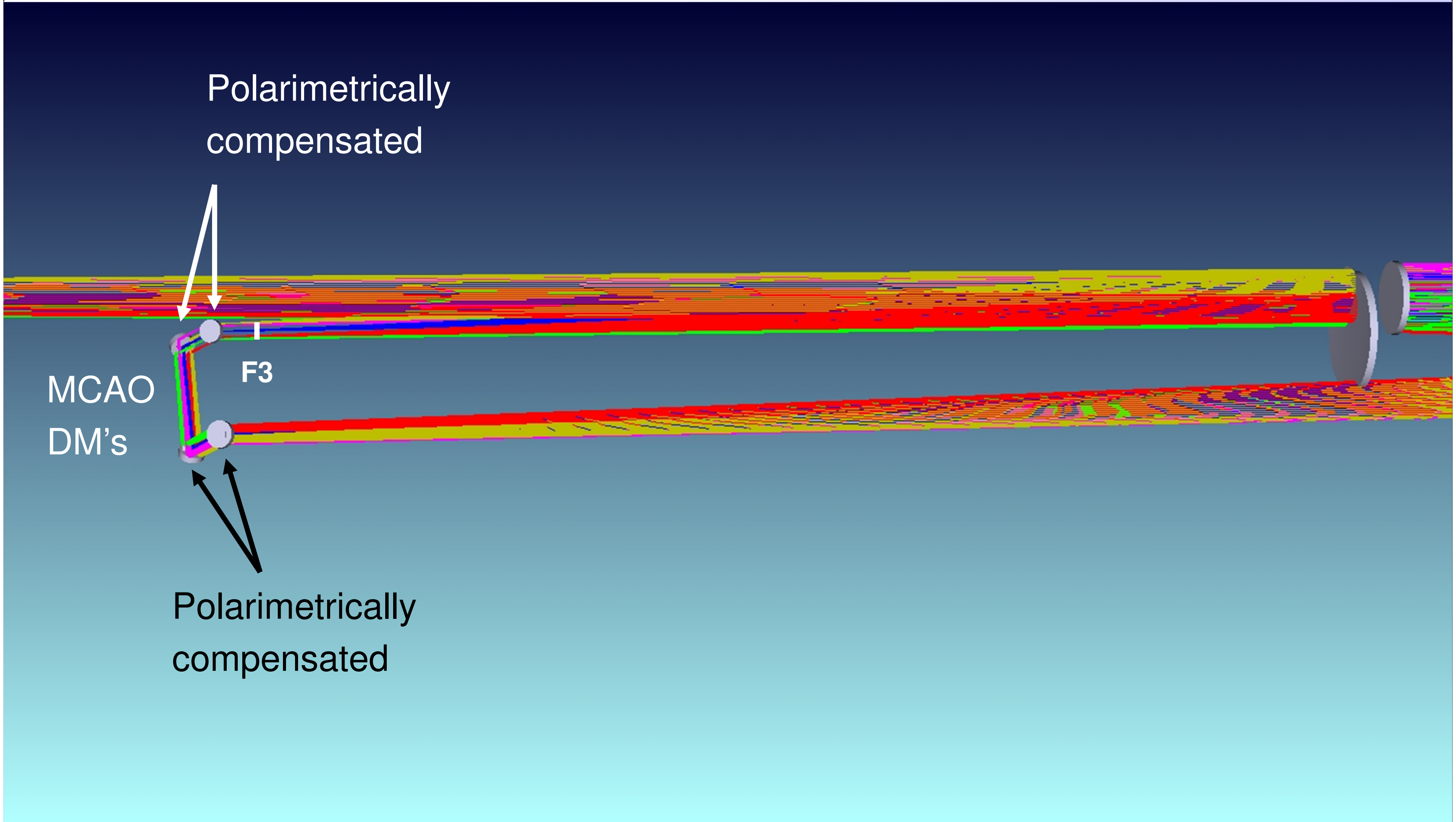


(suitable for polarization optics, alignment targets, masks, …)

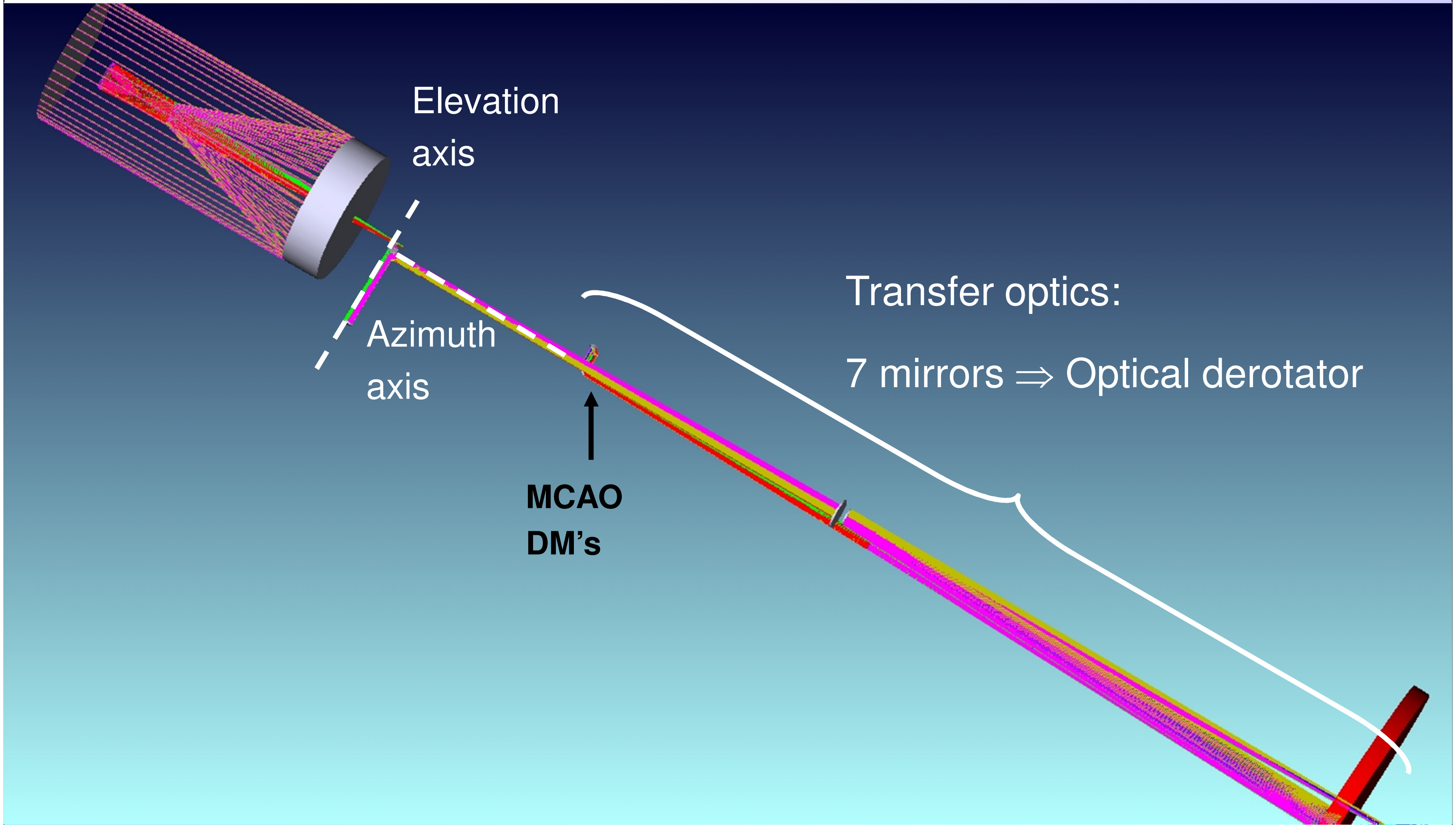
14-MIRROR COMPENSATED DESIGN



14-MIRROR COMPENSATED DESIGN

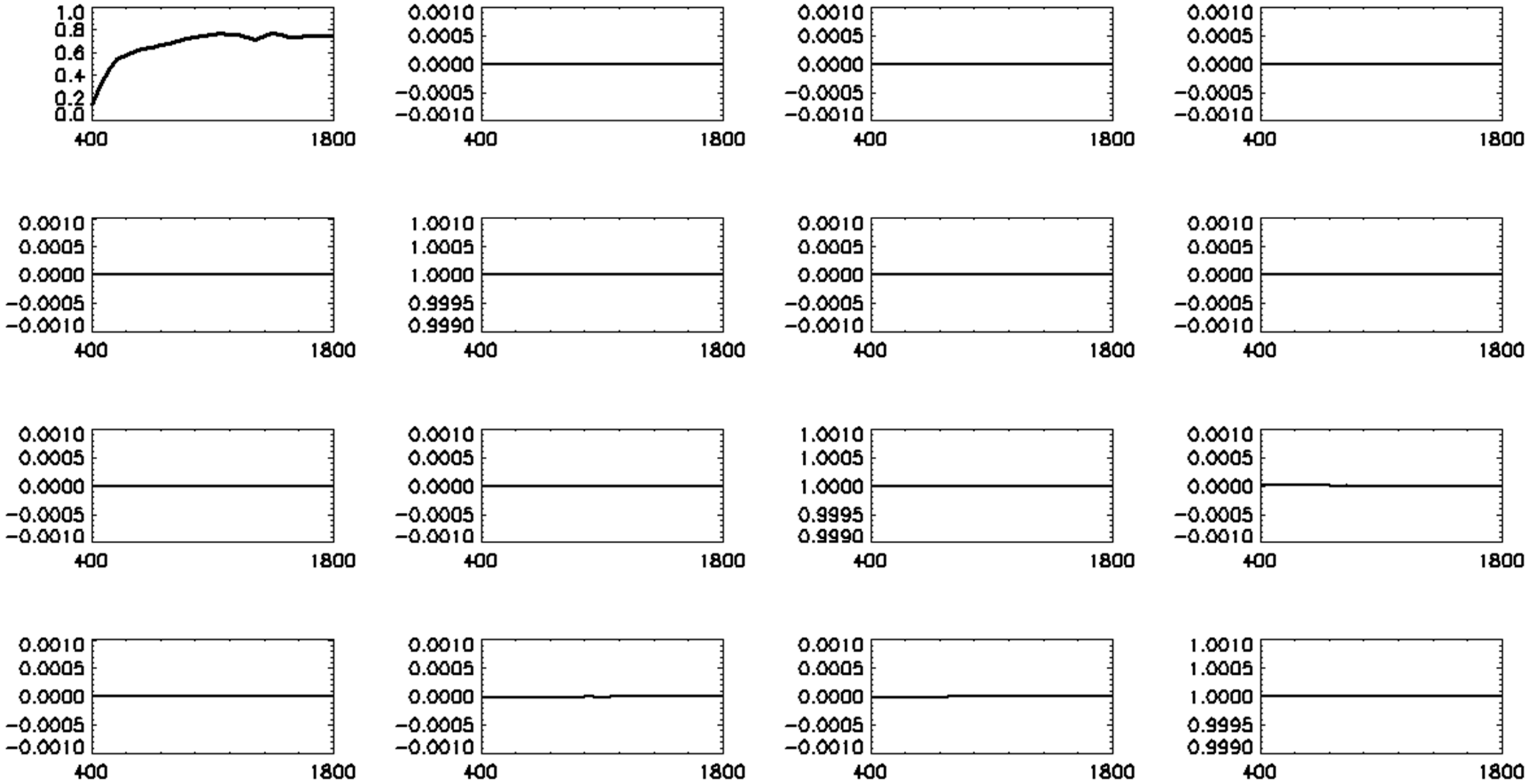


14-MIRROR COMPENSATED DESIGN



MUELLER MATRIX

M1: Aluminium M2 - M14: Silver All λ's and t's



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PROPERTIES

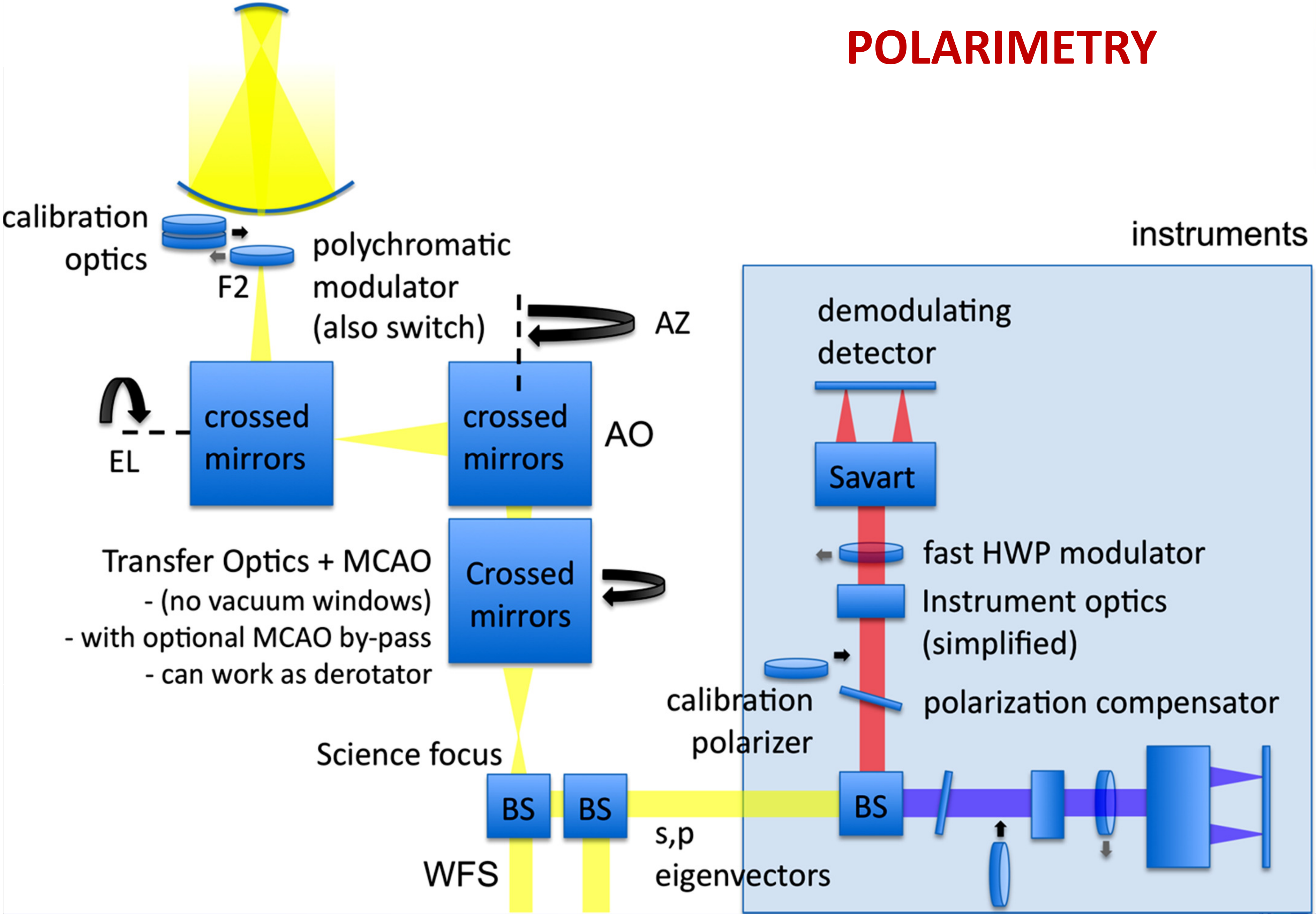
- Telescope Mueller Matrix is Unity for all wavelelegths
  and independent of:
  - Elevation
  - Azimuth

- The transfer optics represents a de-rotator of Mueller matrix Unity (7 mirrors) ⇒ no rotating platform is needed for instruments

- Instruments are fixed ⇒ larger stability

- Polarimeters may be located in any place ⇒ more flexibility

POLARIMETRY



AO/MCAO DMs

- **Ground layer turbulence:**

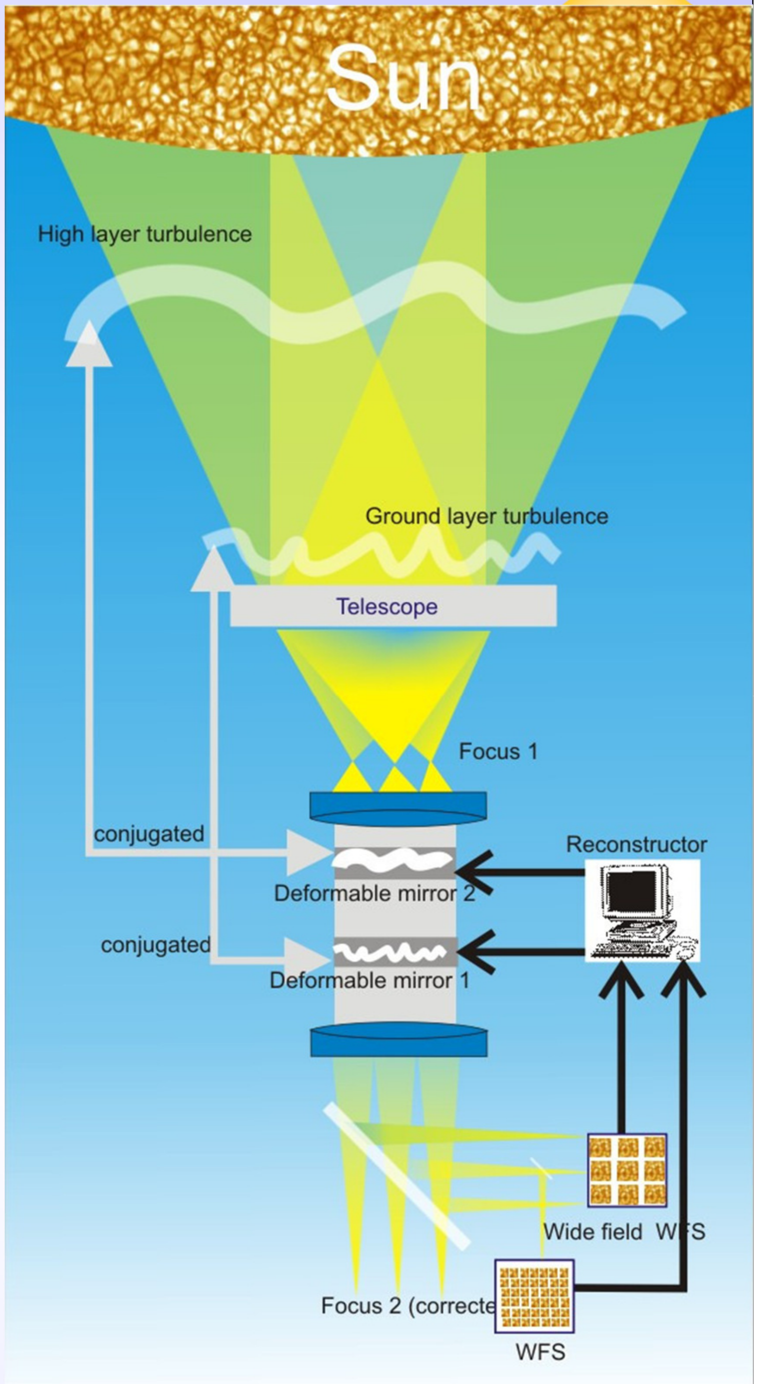
  Same effect on whole FoV

- **High-altitude turbulence:**

  Differential seeing across FoV

- **Distance to high-altitude turbulence**

  varies along the day



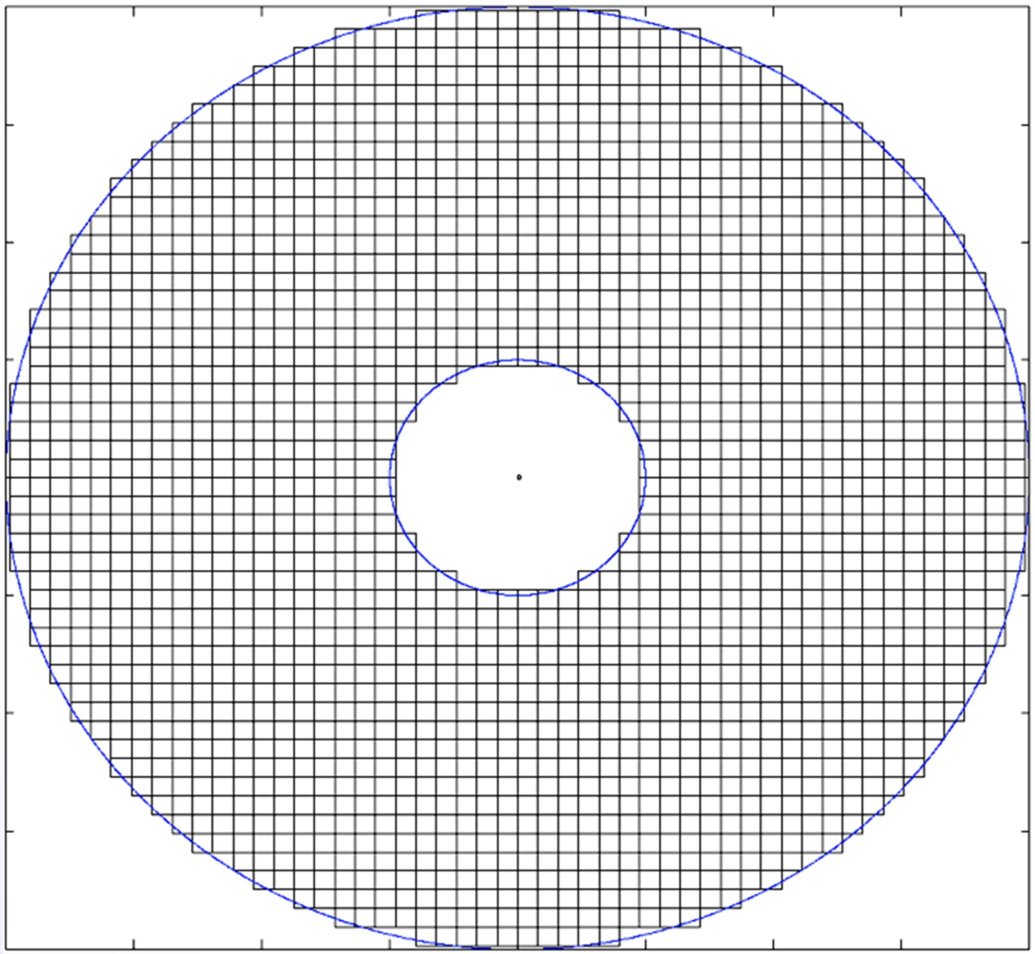
AO/MCAO DMs

AO: Ground layer turbulence correction

Pupil DM

8cm subaperture size

1852 subapertures total



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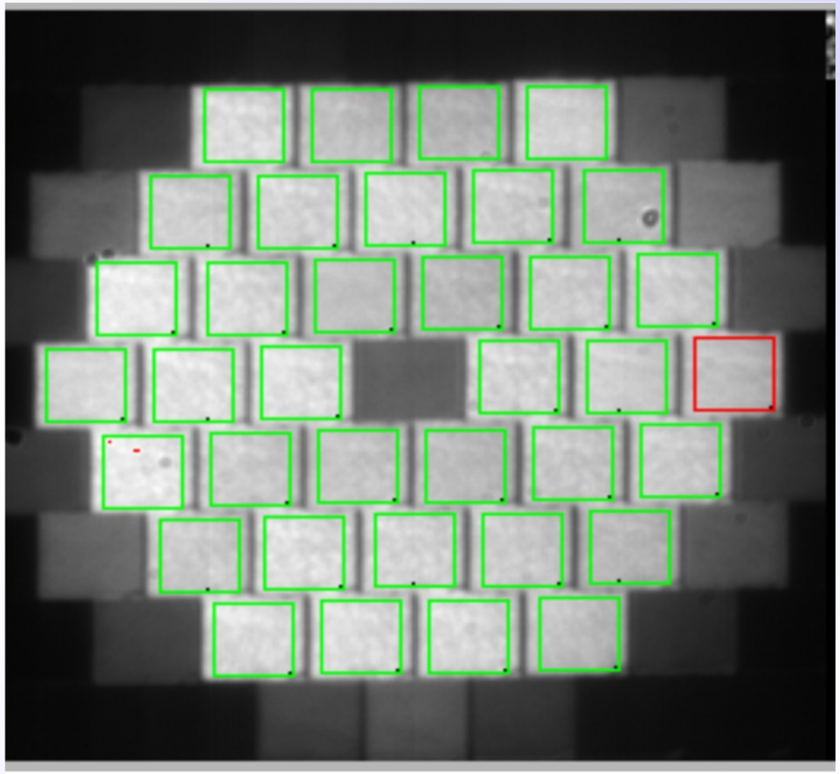
AO/MCAO DMs

AO: Ground layer
turbulence correction

Pupil DM @ VTT/Tenerife

7 cm subaperture size

36 subapertures total



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AO/MCAO DMs

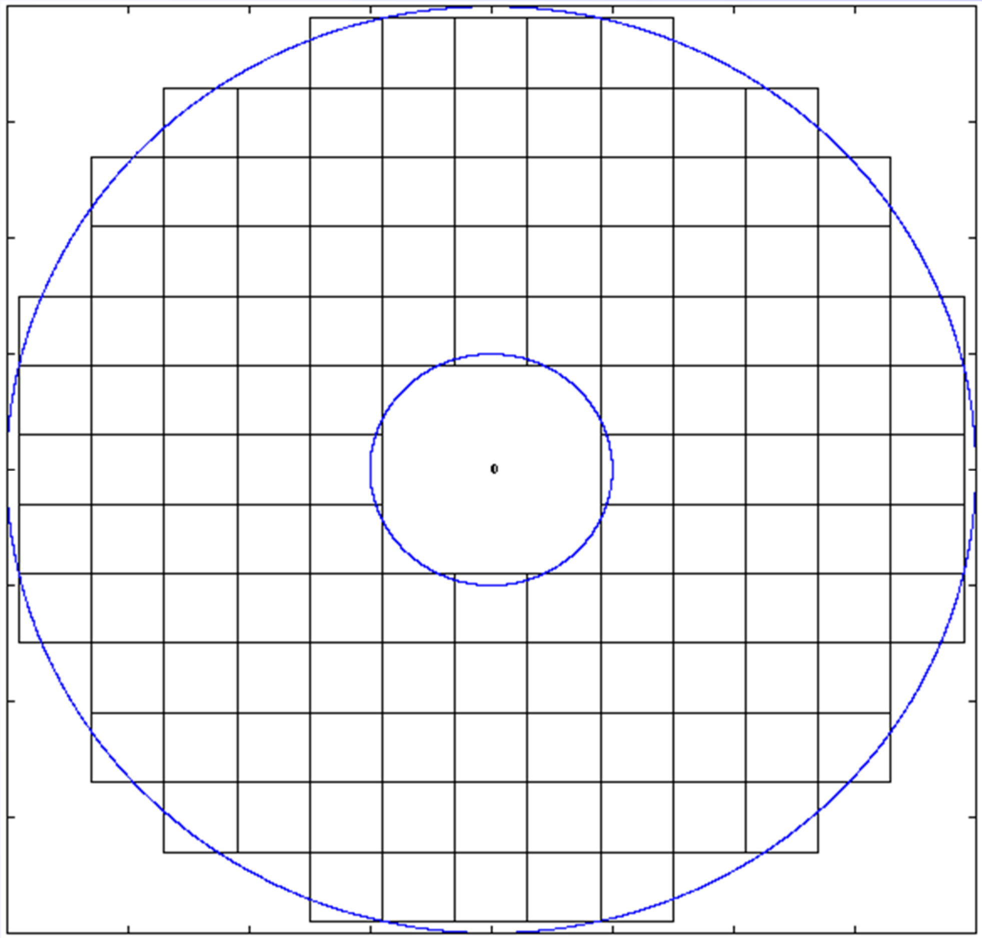
MCAO: High-altitude turbulence correction

Several DMs

30 cm subaperture size

128 subapertures total

FOV: 70”



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AO/MCAO DMs

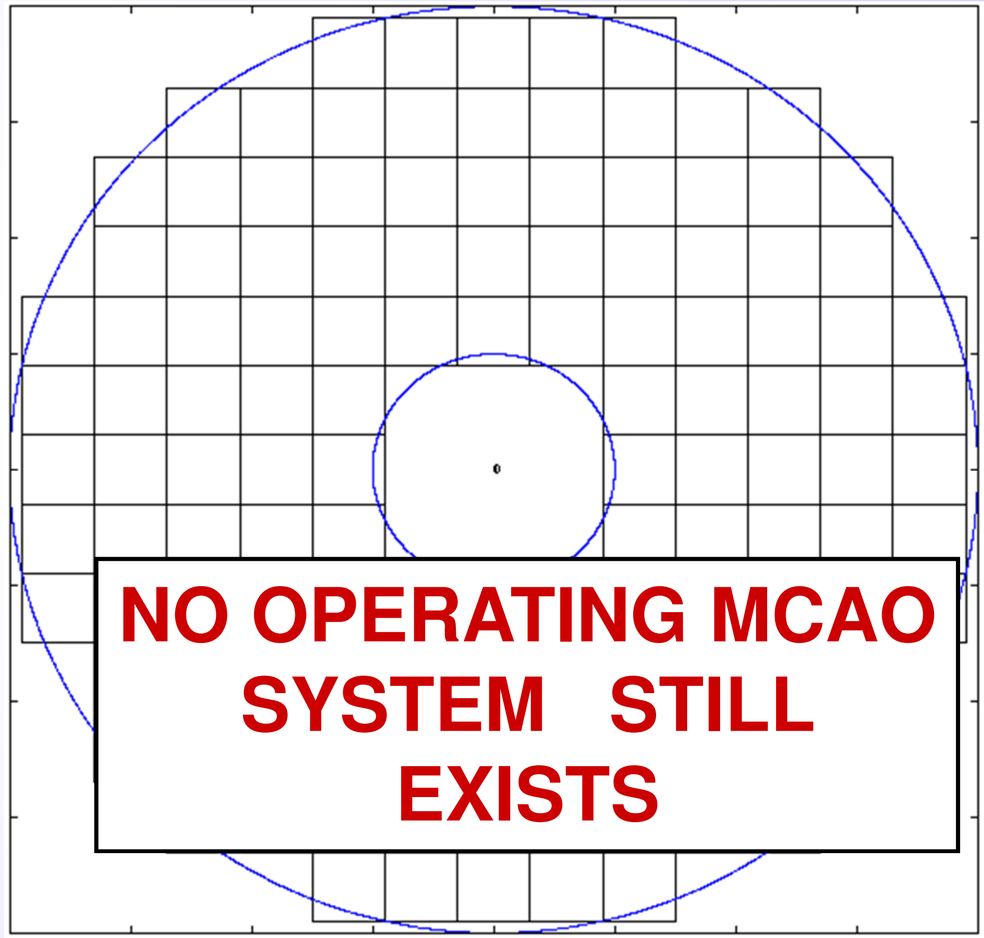
MCAO: High-altitude turbulence correction

Several DMs

30 cm subaperture size

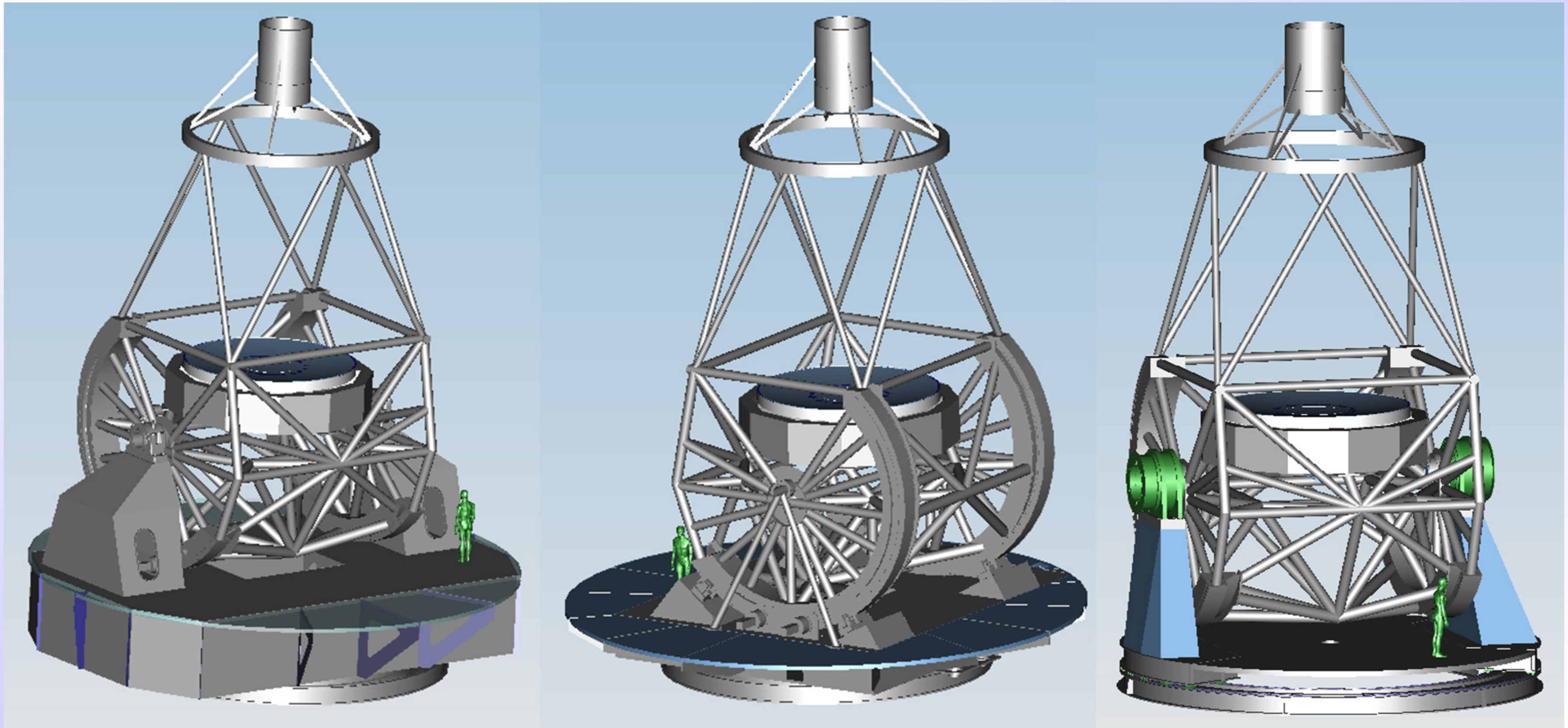
128 subapertures total

FOV: 70”



NO OPERATING MCAO SYSTEM STILL EXISTS

EST STRUCTURE CONCEPTS



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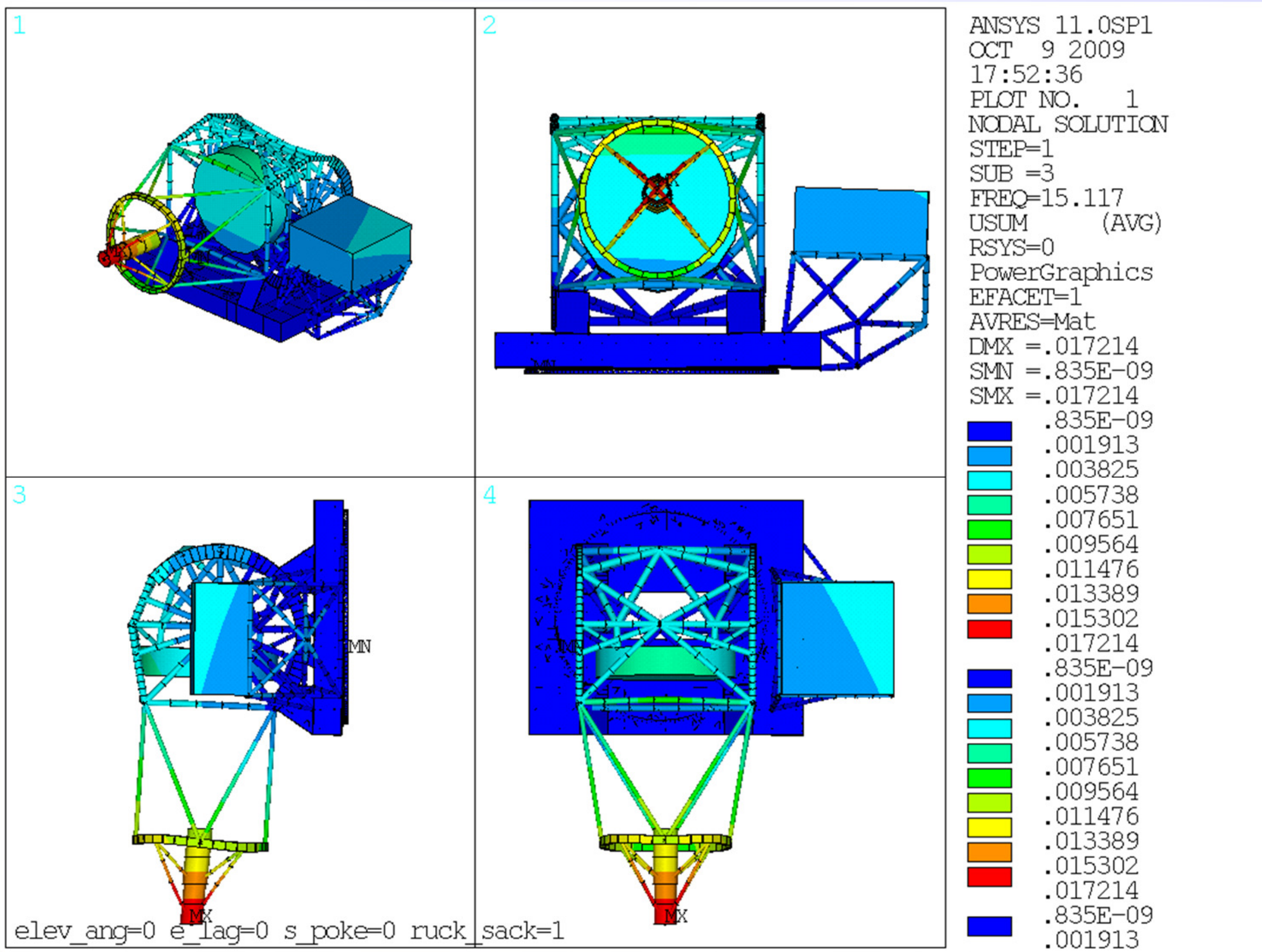
EST FEM ANALYSIS



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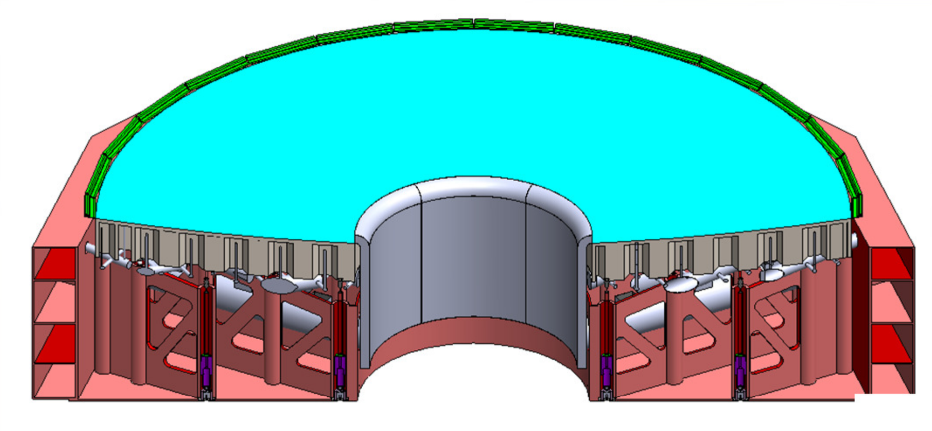
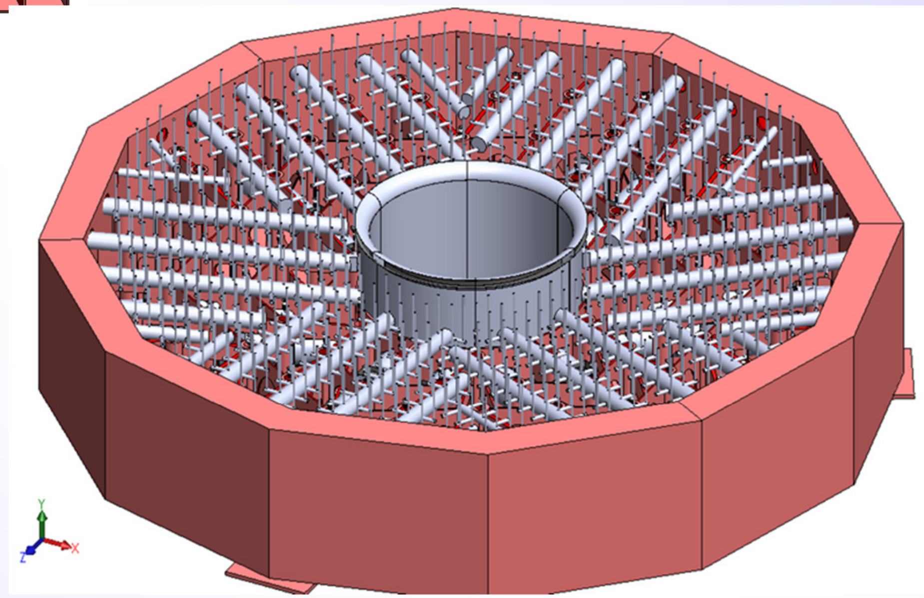
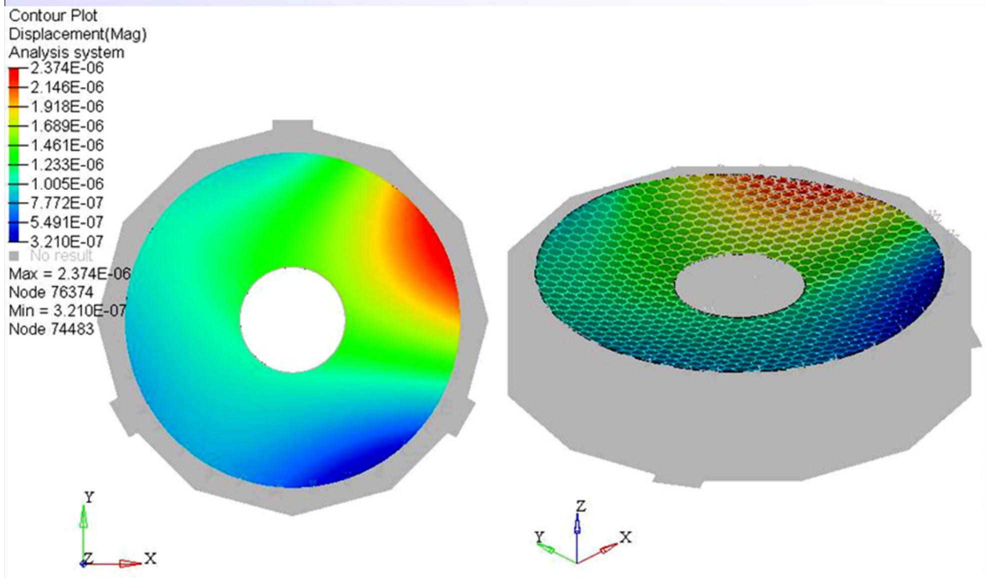
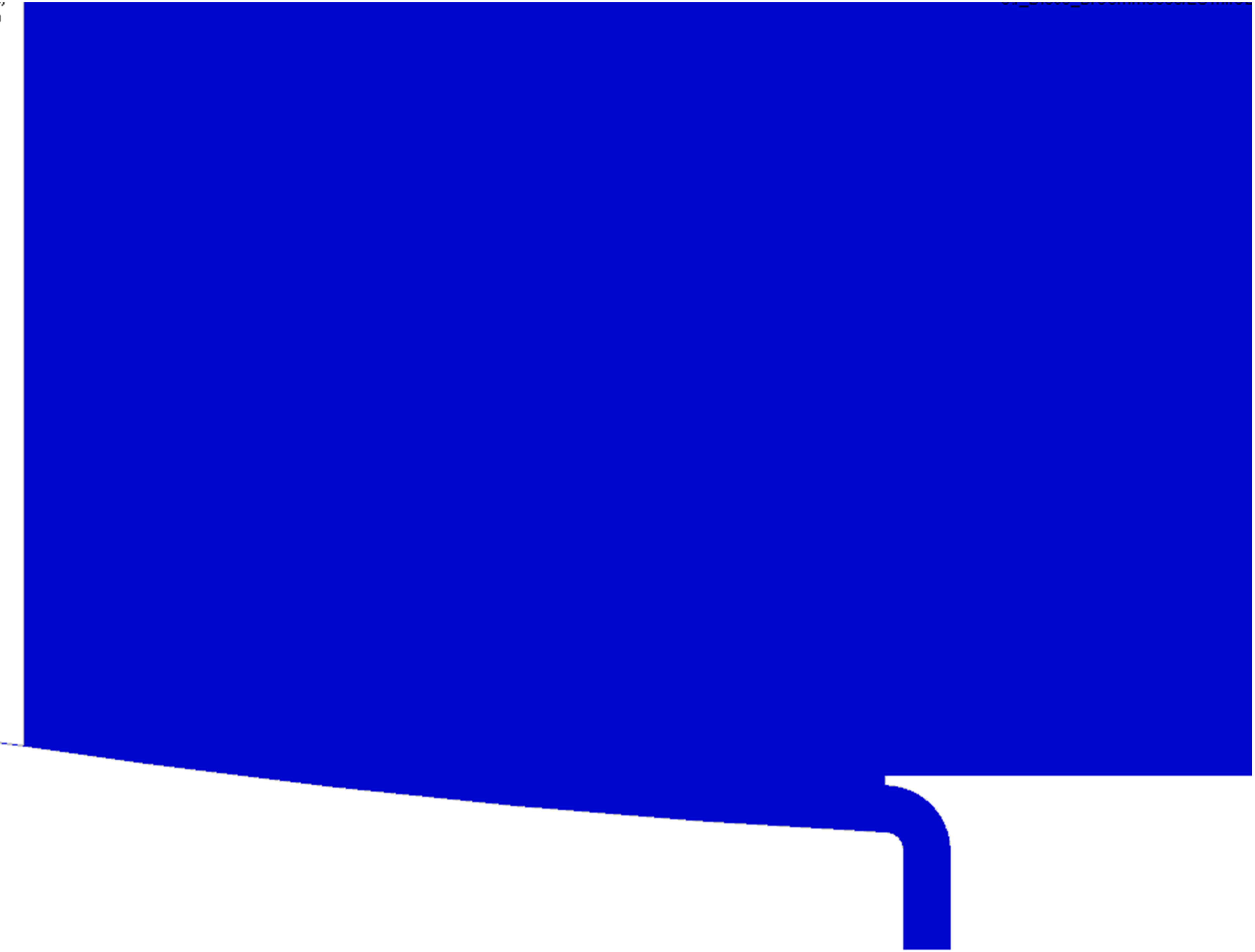
PRIMARY MIRROR



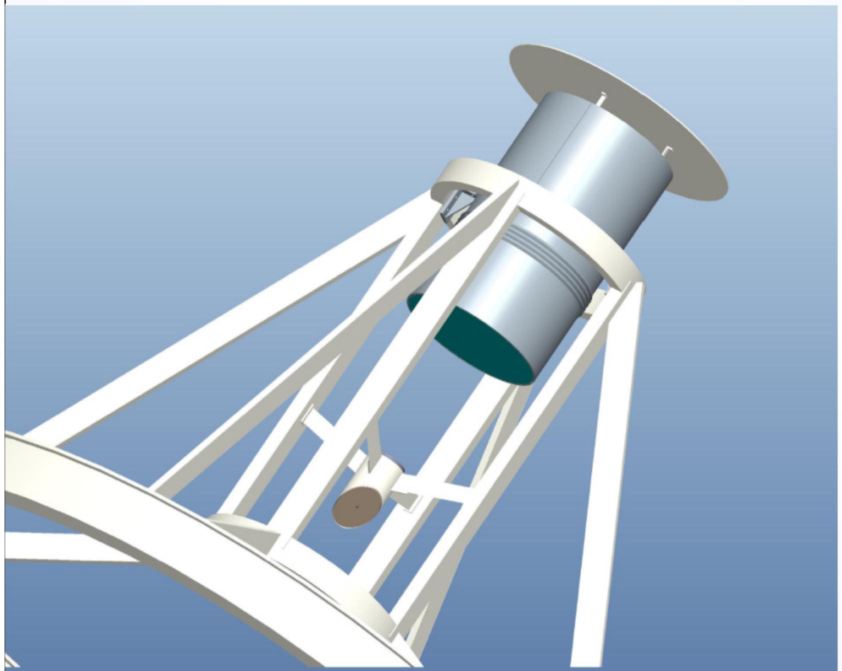


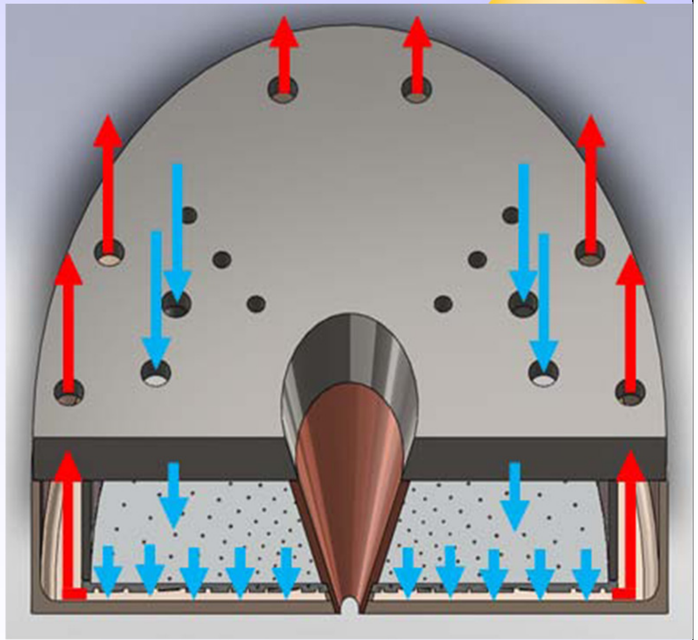


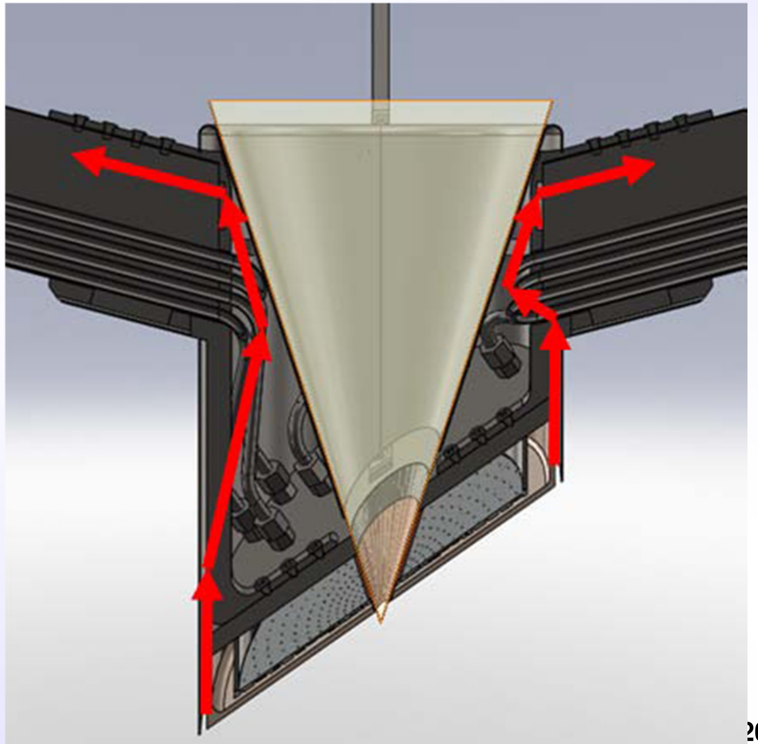
e)



HEAT STOP







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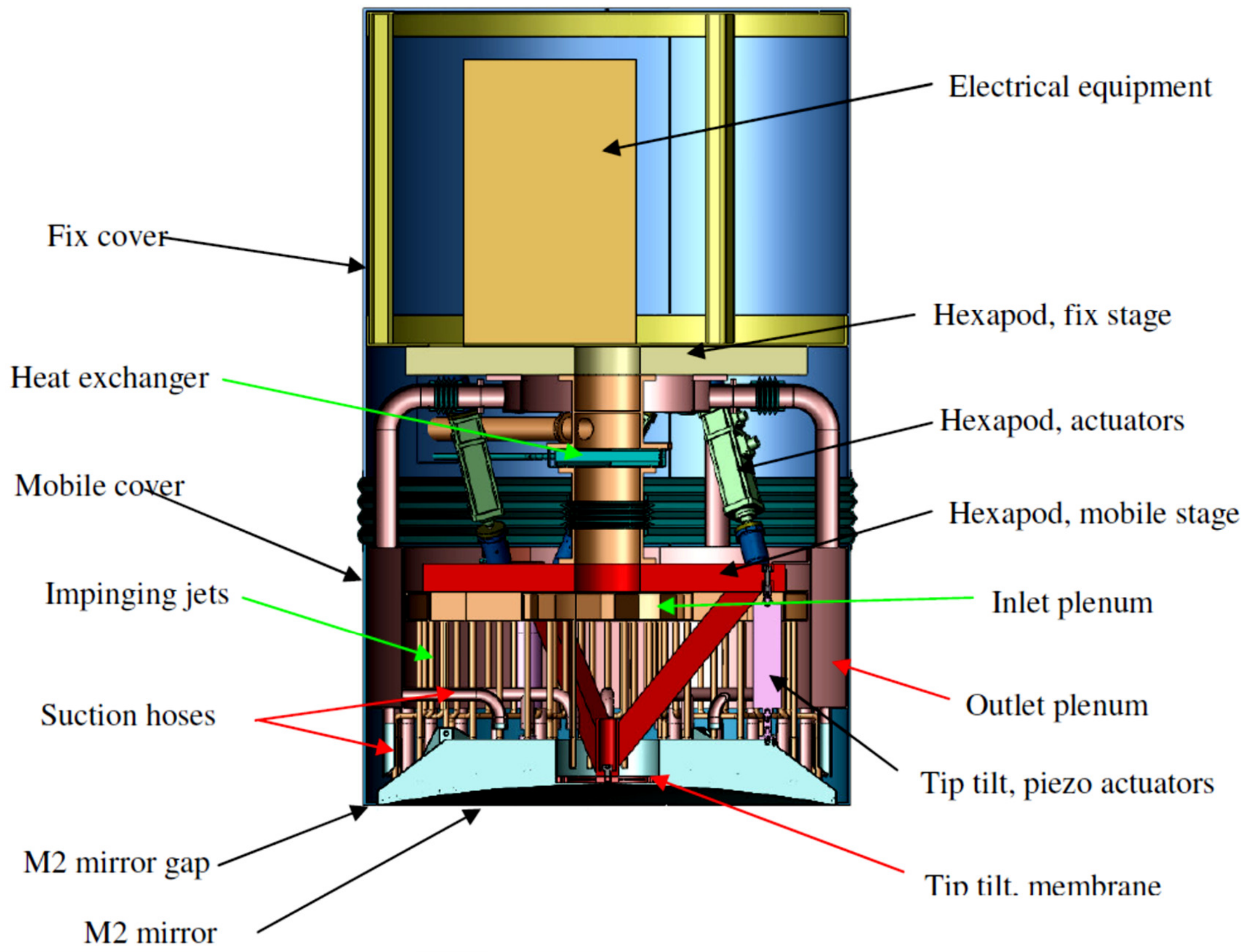
SECONDARY MIRROR



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INSTRUMENTS

- **Instruments:**
  - Broad-band imager
  - Narrow-band tunable filter spectropolarimeter
  - Grating spectropolarimeter

- **Number of instrument channels:**
  - Broad-band imager: 3
  - Visible narrow-band filter (λ<1100 nm): 3
  - NIR narrow-band filter (λ>700 nm): 2
  - Visible spectrograph (λ<1100 nm): > 5 spectral lines
  - NIR spectrograph (λ>700 nm): > 3 spectral lines

BROAD-BAND IMAGER

Blue Arm		Red Arm
Channel 1	Channel 2	Channel 3
Ca II core	Ca II wing	Hα
Ca II continuum	G Band	Ca II IR
	CN band head	Brackett continuum
	Paschen continuum	Hα continuum
	G band continuum	
	Ca II continuum	

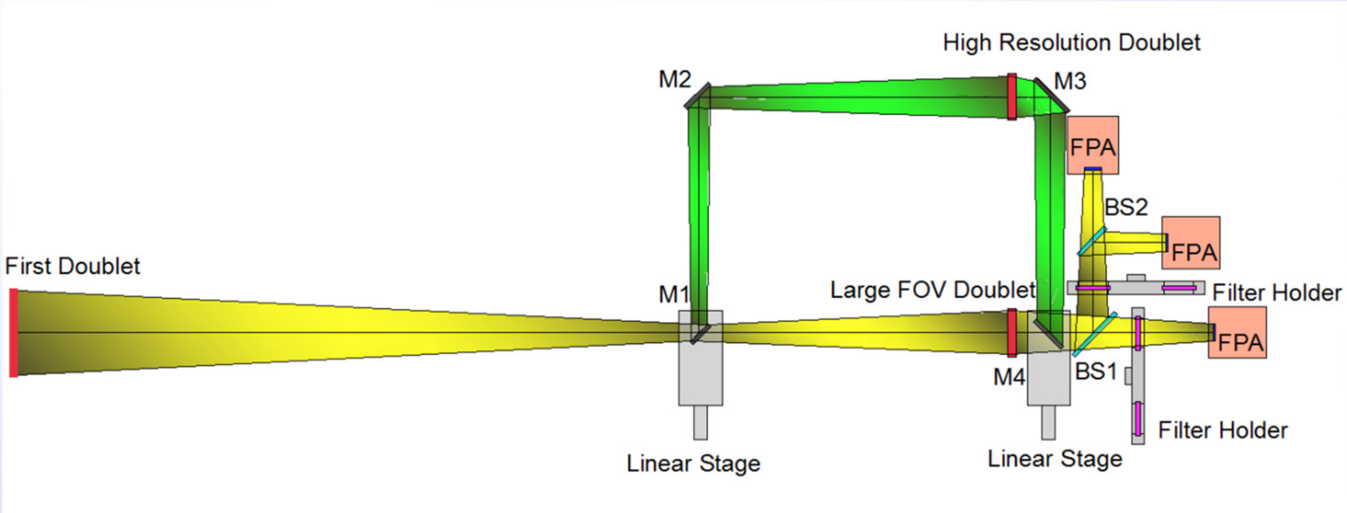
BROAD-BAND IMAGER

Mode 1: HIGH RESOLUTION MODE – SMALL FOV

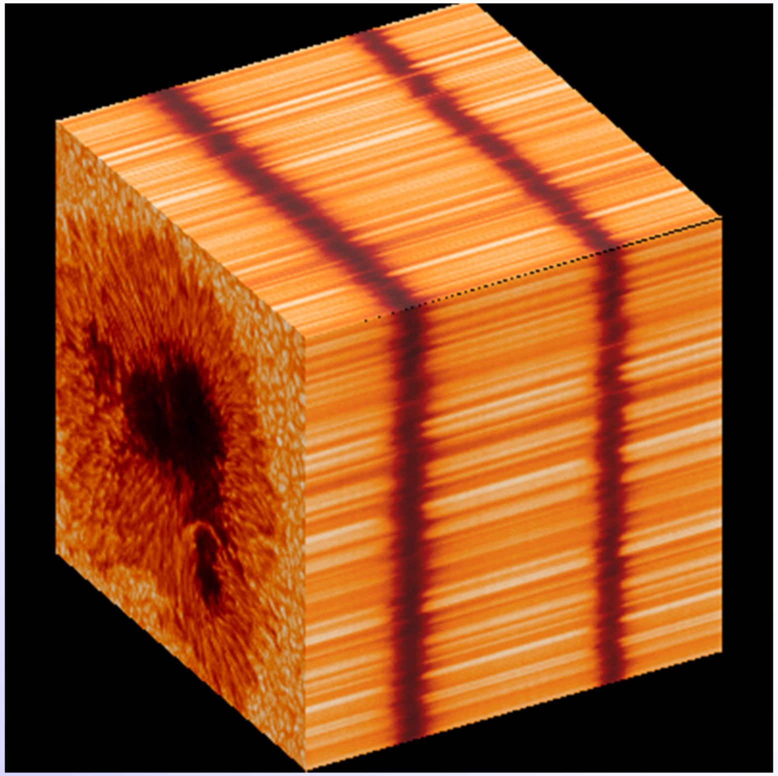
- 0.015 "/px
- FOV: 60" X 60"

Mode 2: LOW RESOLUTION MODE – LARGE FOV

- 0.030 "/px
- FOV: 120" X 120"



SPECTRAL INSTRUMENTS



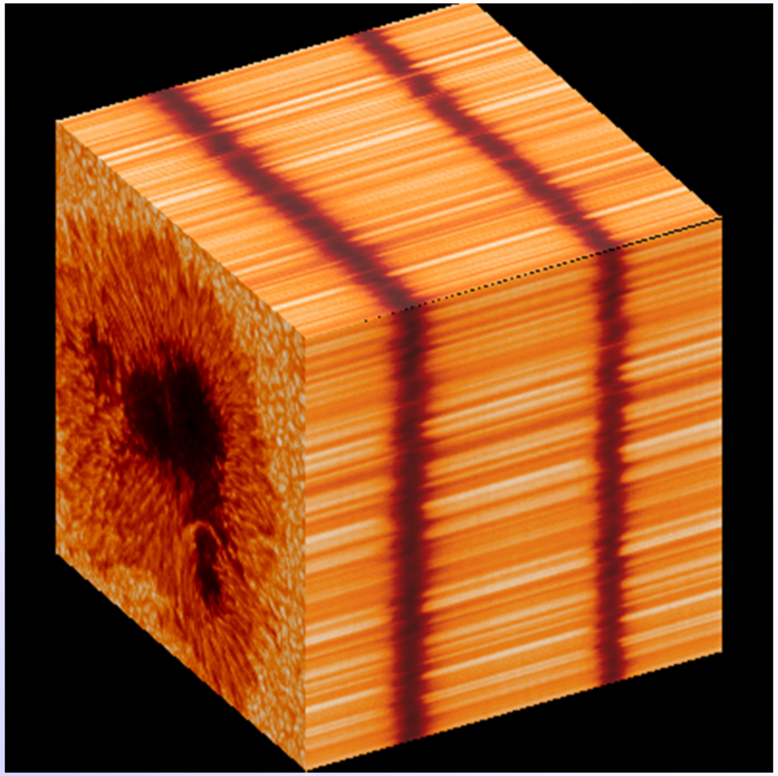
Data cube

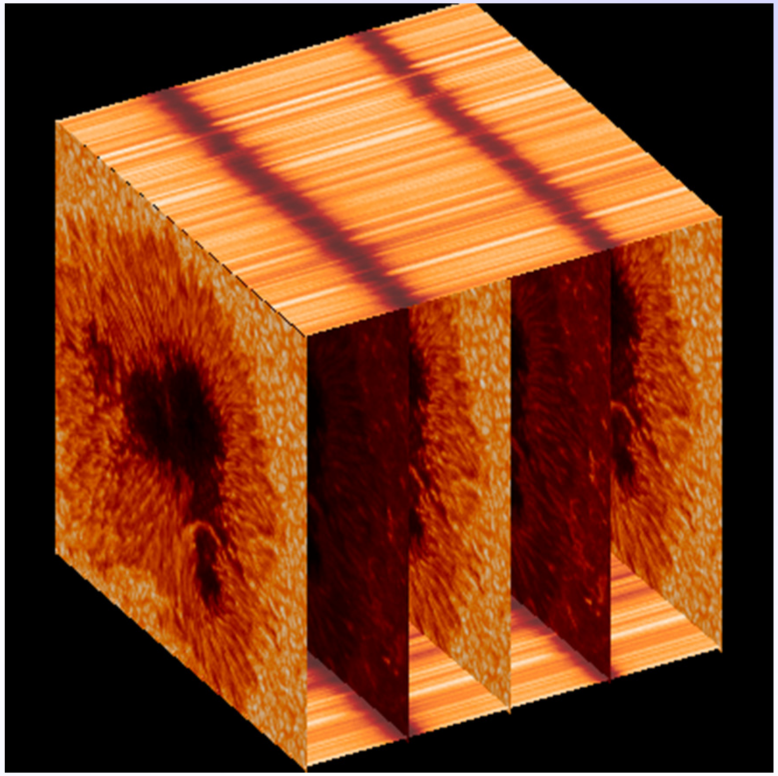
$\vec{I}(x,y,\lambda)$

But

Detectors are only sensitive to 2D images

SPECTRAL INSTRUMENTS





Filtergrams

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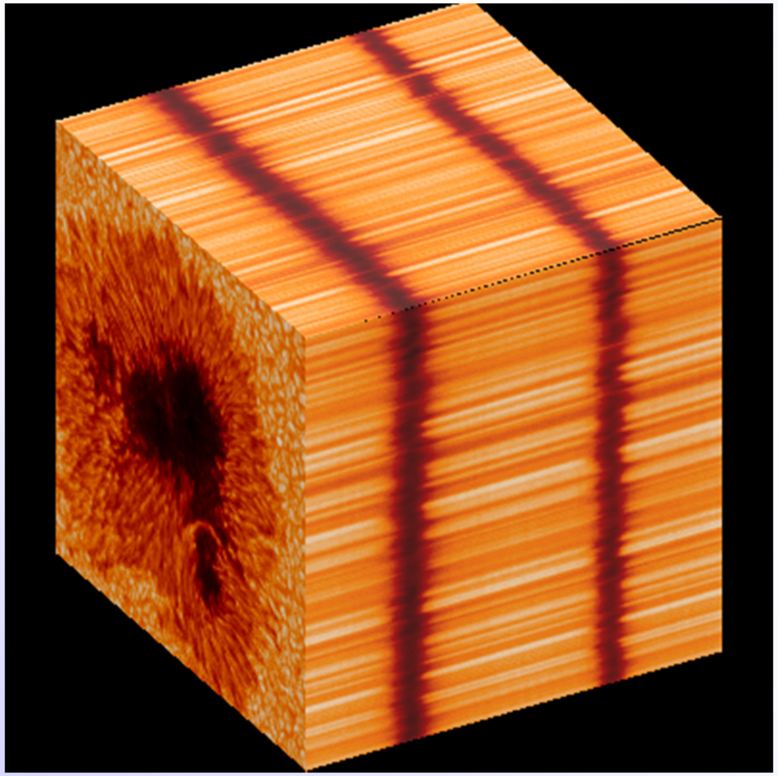
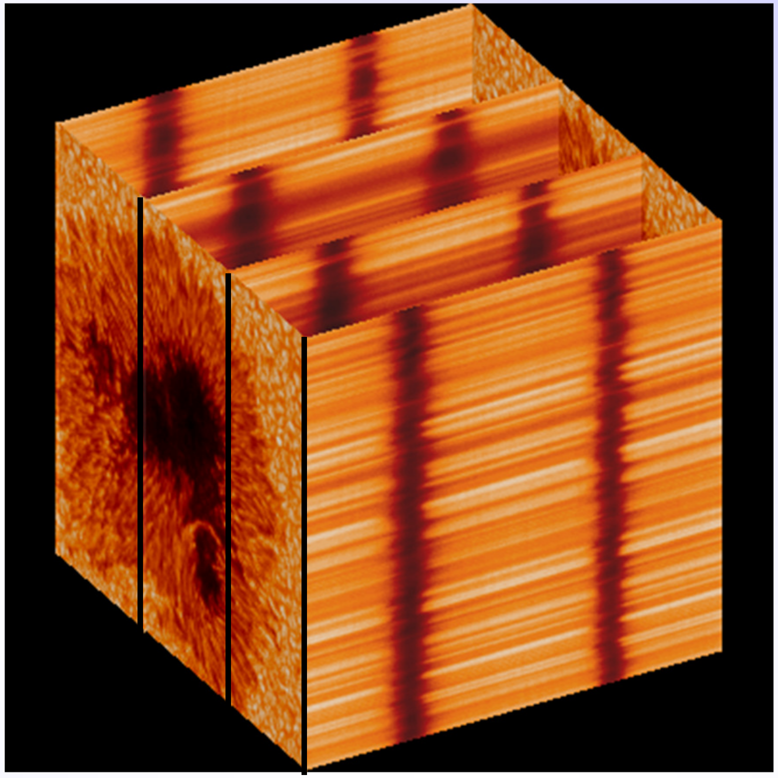
SPECTRAL INSTRUMENTS





Spectral image

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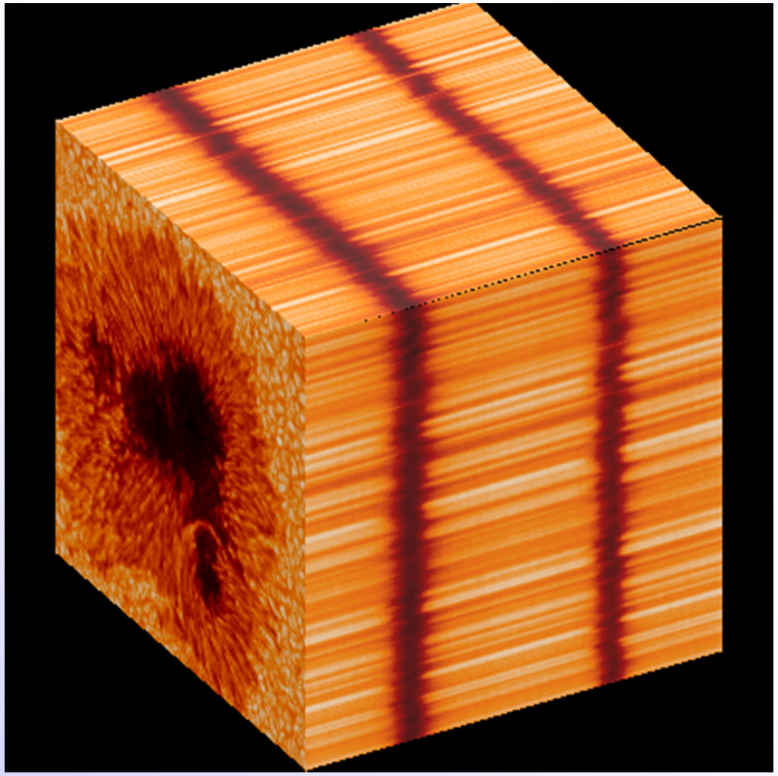
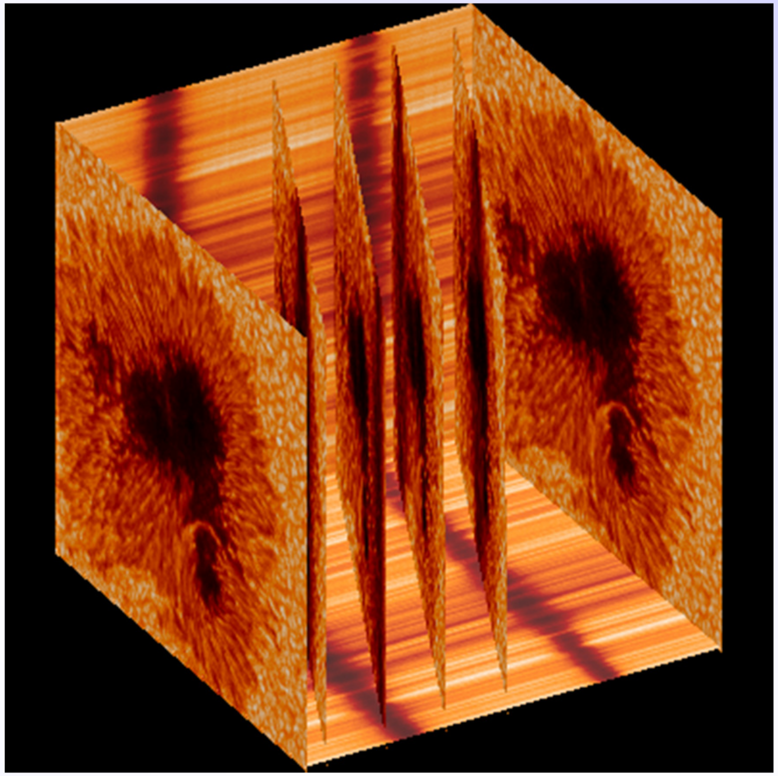
SPECTRAL INSTRUMENTS

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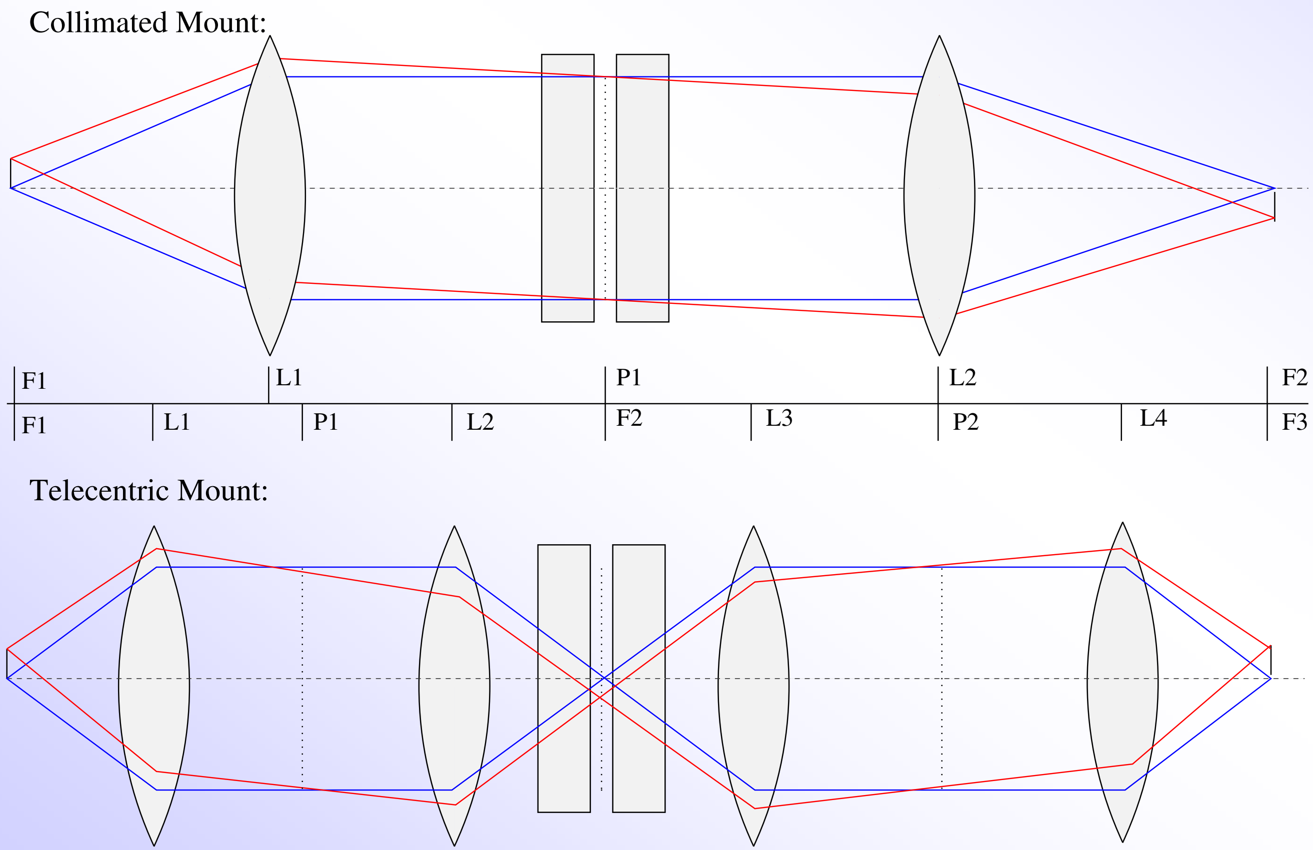
NARROW BAND IMAGING: FABRY-PEROT INTERFEROMETERS



GFPI (double)

IBIS (double)

IMaX

(single, double-pass)

CRISP
(double)

TESOS
(triple)

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NARROW BAND IMAGING: FABRY-PEROT INTERFEROMETERS

Etalon Size:

Telecentric Mount:

Etalon Diameter:

$$\Phi_{ET} = 4.8 \cdot 10^{-6} \cdot FOV \cdot \Phi_T \cdot F\#$$

For F# = 200 and FOV = 60”:

<u>Etalon Diameter: 230 mm</u>

For F# = 150:

<u>Etalon Diameter: 170 mm</u>

Collimated Mount:

Etalon Diameter:

$$\Phi_{ET} = 1.4 \cdot 10^{-6} \cdot \frac{FOV \cdot \Phi_T}{\sqrt{\frac{\Delta\lambda}{\lambda}}}$$

For $\Delta\lambda / \lambda = 5e^{-6}$ and FOV = 60”:

<u>Etalon Diameter: 184 mm</u>

NARROW BAND IMAGING: FABRY-PEROT INTERFEROMETERS

How to fabricate such a big etalon with the required precision?

Weight of 230 mm Etalon: approx. 7 kg !!

How to mount such heavy devices without gravitational bending?

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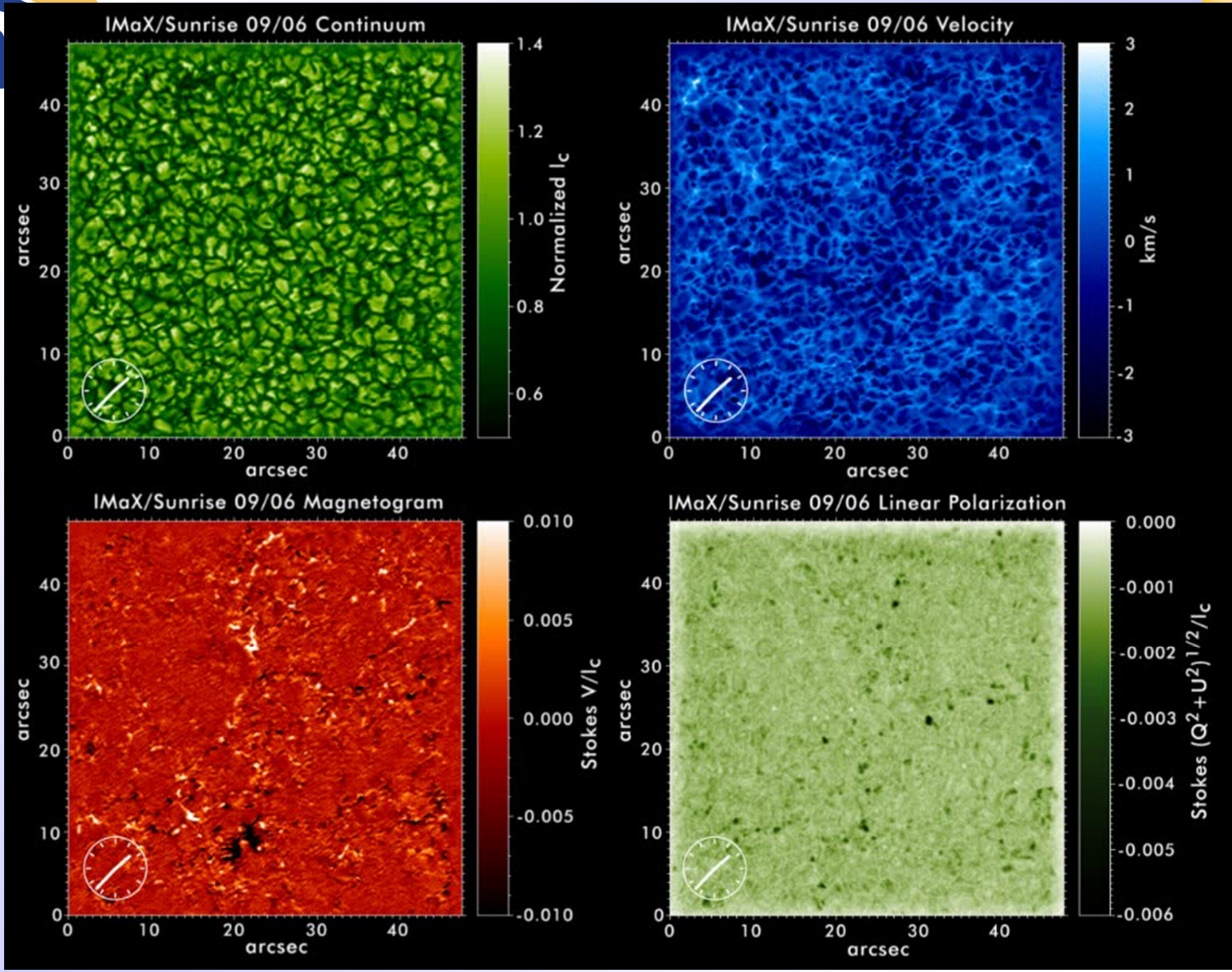

IMAX →120 km resolution

EST →30 km

SPECTROGRAPHS

- Main science programs:

Wavelengths (nm)	Line	Flux tube updated prog 2.1.1/ 2-SRD	Network elements prog 2.2.2.1	Magnetic canopies prog 2.2.1/ 1	Hanle effects prog 2.3.5.2 of SRD	Flares updated prog 2.6.1.2 /3	Planets prog 2.8.1	Sunspots prog 2.4.1.2.5
393,3	CaII K				X	X		
396,8	CaII H				X	X		
397	Hε					X		
410,2	Hδ					X		
422,7	CaI						X	
517,2-518,3	MgIb	X						
525	FeI	X						
557,6	FeI		X					
588,99	NaID2						X	
589,6	NaID1			X			X	
630,2-630,3	FeI	X	X					
656,3	Hα					X		
766,5-769,9	KID						X	
777	OI triplet				X			
849,8	CaII			X				
854,2	CaII	X		X	X	X		
1082,7	SiI	X				X		
1082,9-1083,0	HeI	X						
1526	MnI	X						
1565	FeI	X	X	X				
2222,8-2230	TiI							X

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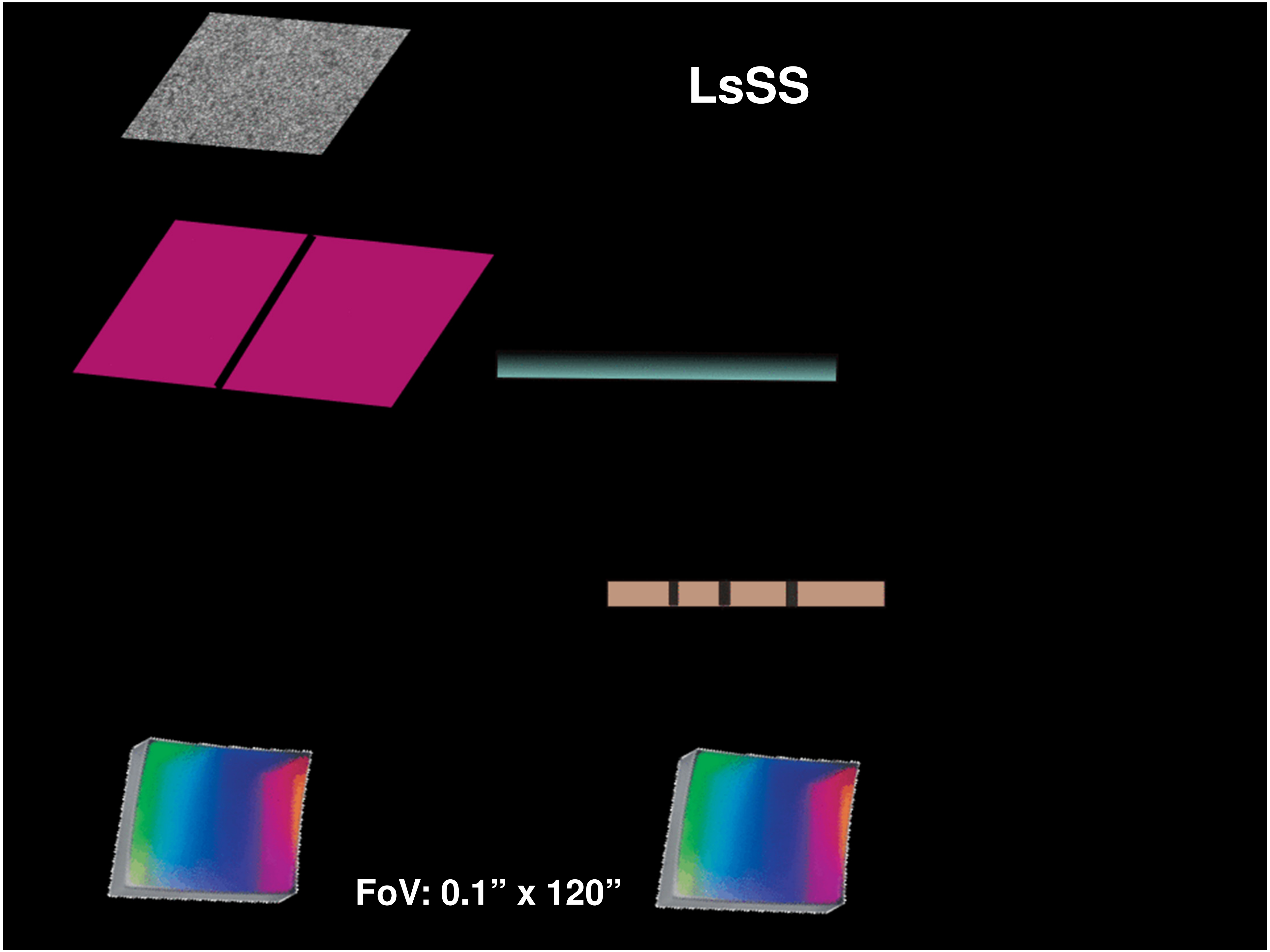
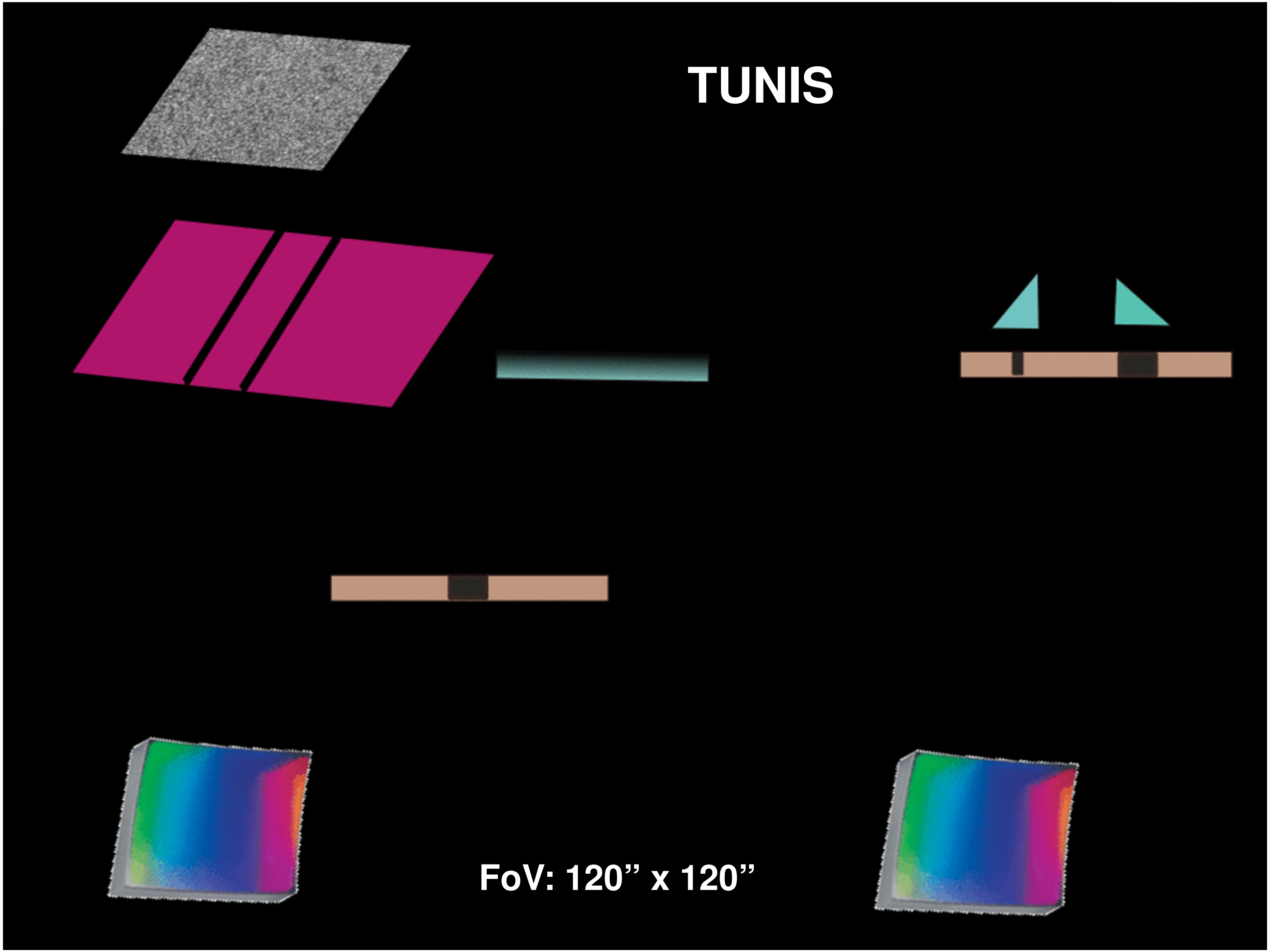
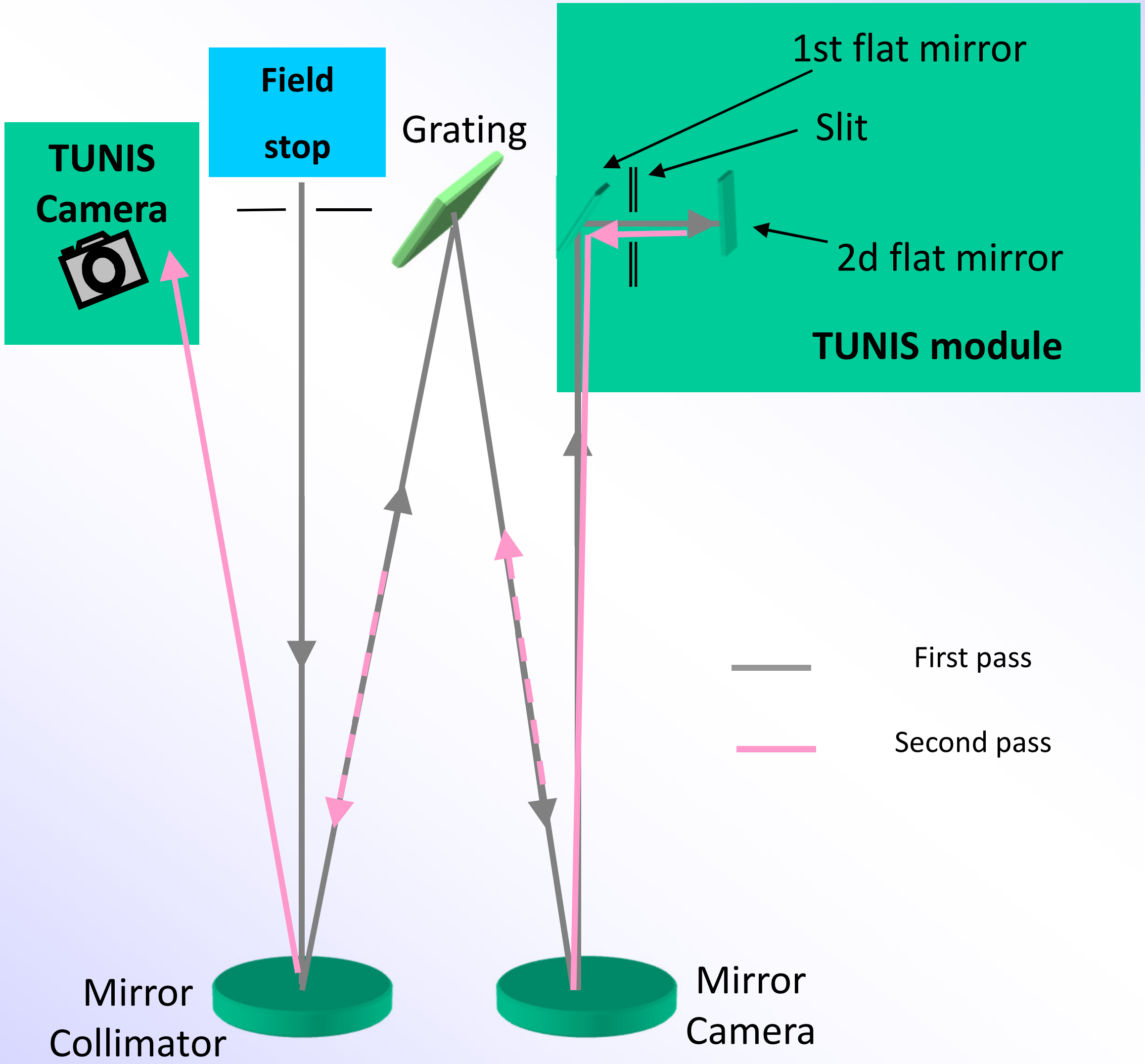
SPECTROGRAPH ALTERNATIVES

- Long-slit Standard Spectrograph (LsSS)
- Tunable Universal Narrowband Imaging Spectrograph (TUNIS)
- Multi-channel Subtractive Double-Pass spectrograph (MSDP)
- Multi-slit multi-wavelength Spectrograph with IFU

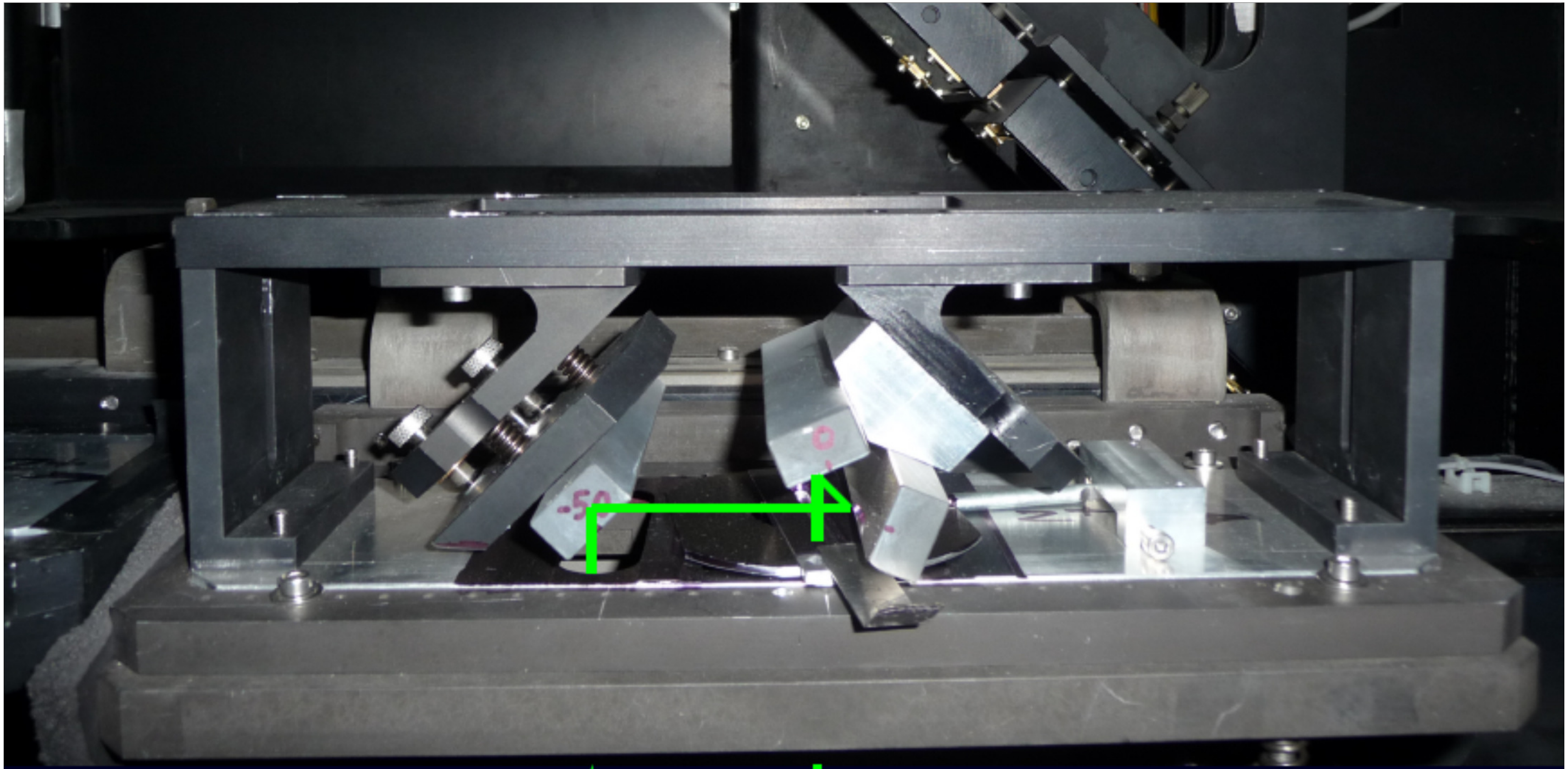

LsSS
FoV: 0.1” x 120”


TUNIS
FoV: 120” x 120”

TUNIS



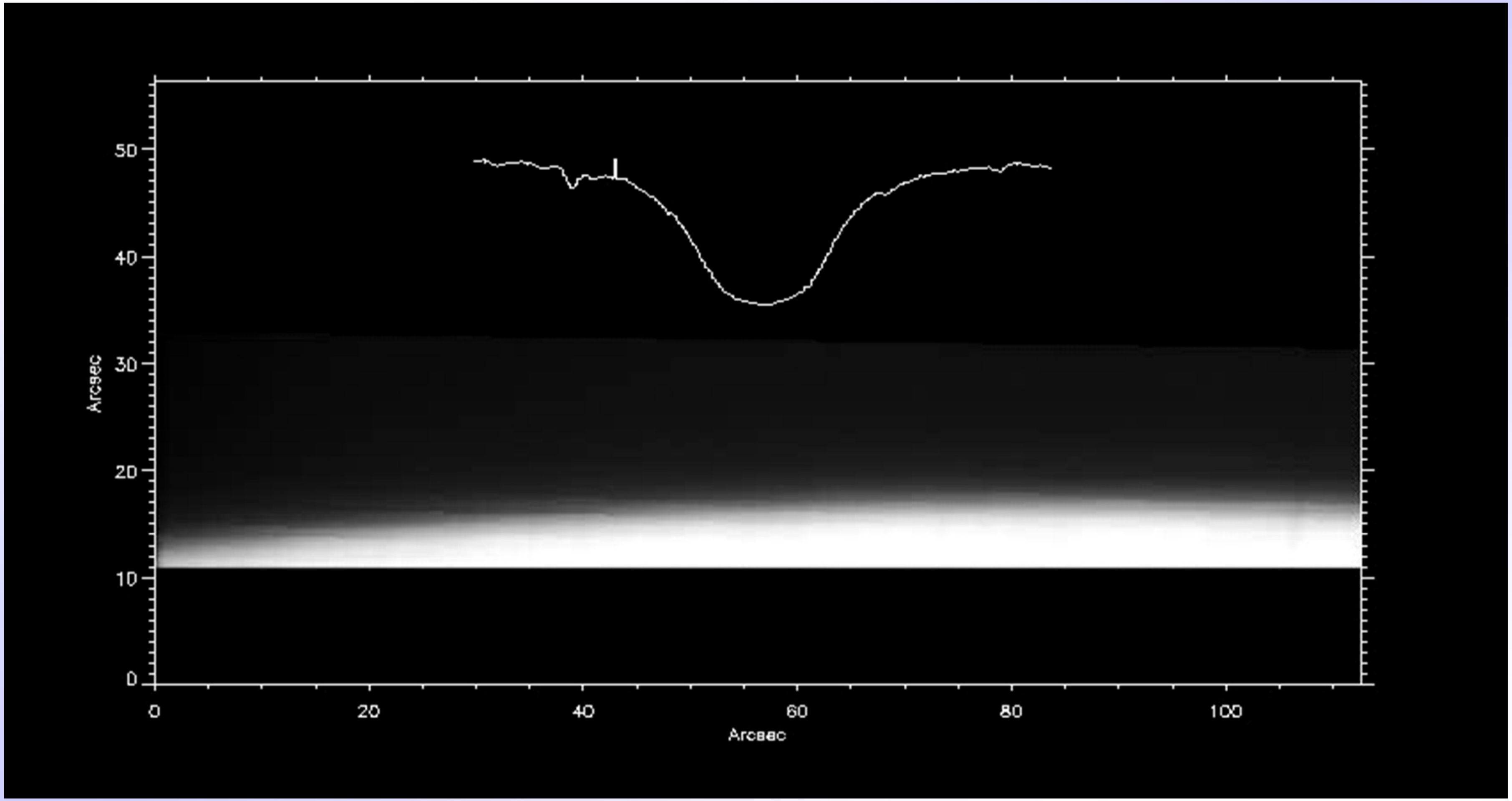
TUNIS Camera
Field stop
Grating
1st flat mirror
Slit
2d flat mirror
TUNIS module
First pass
Second pass
Mirror Collimator
Mirror Camera



TUNIS @ THEMIS

Beam re-injection

TUNIS



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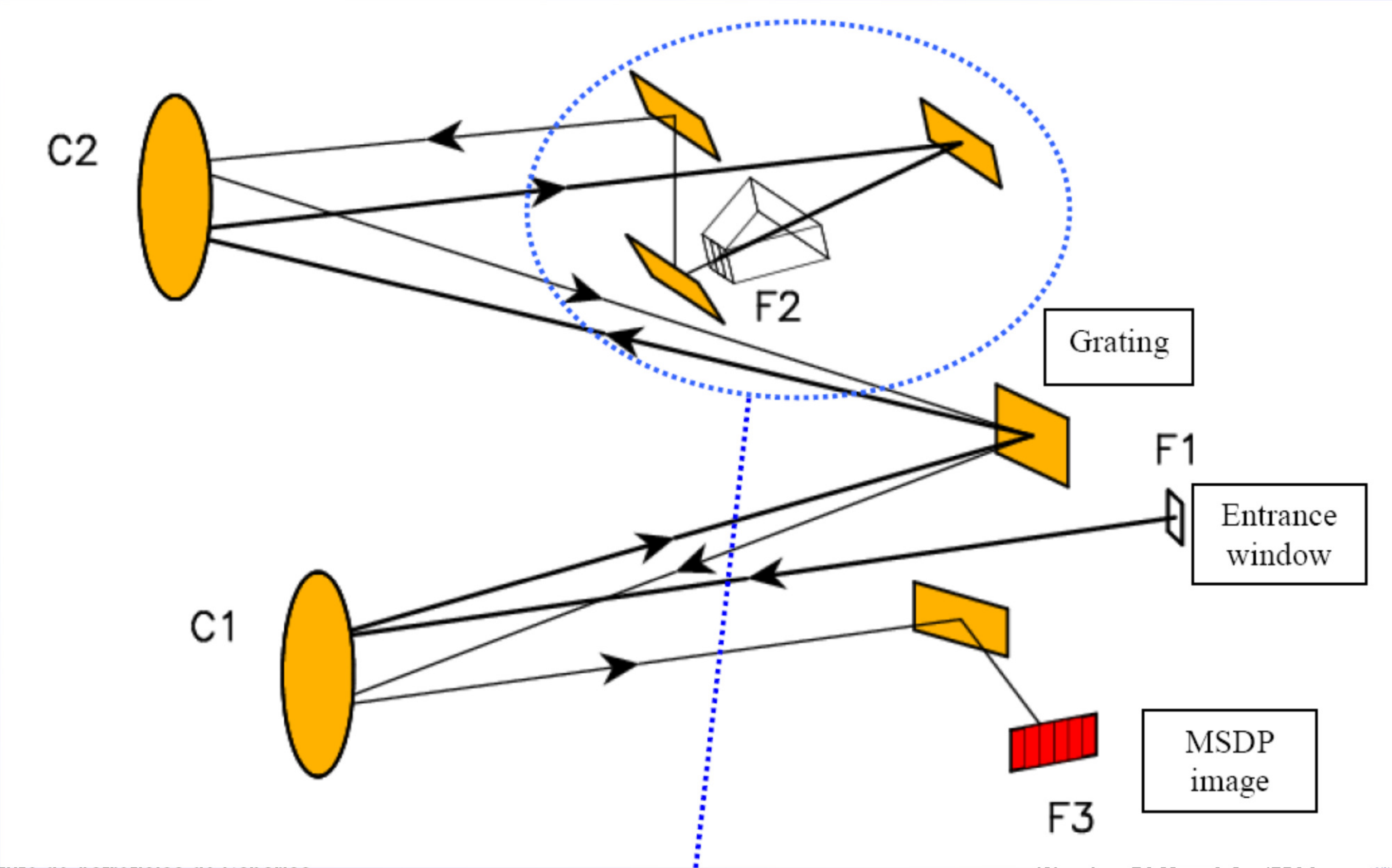
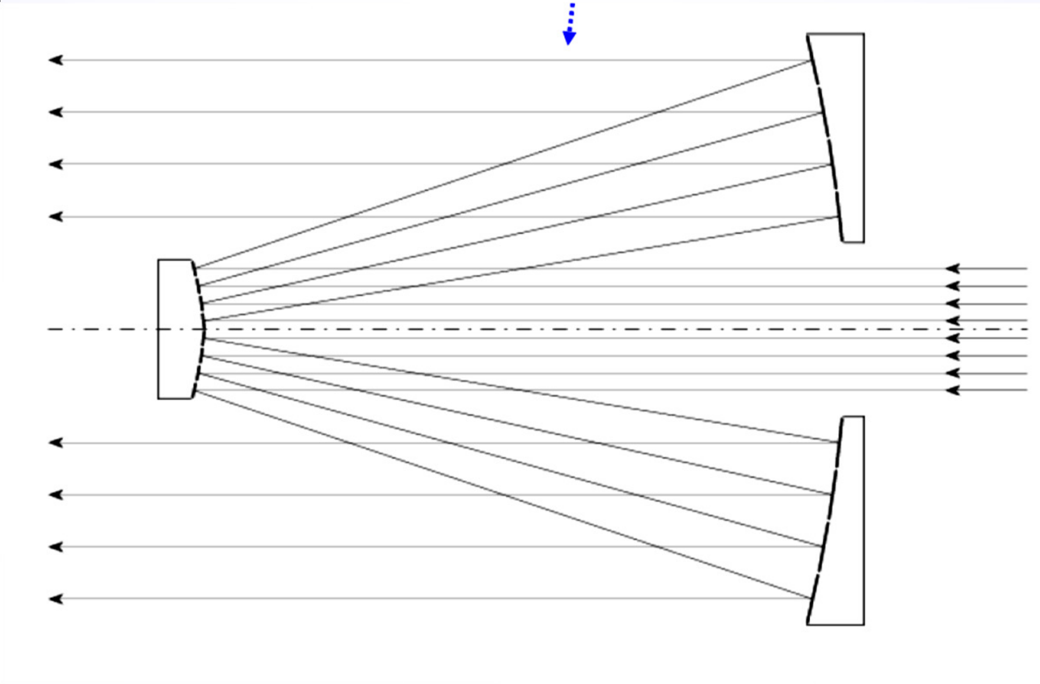
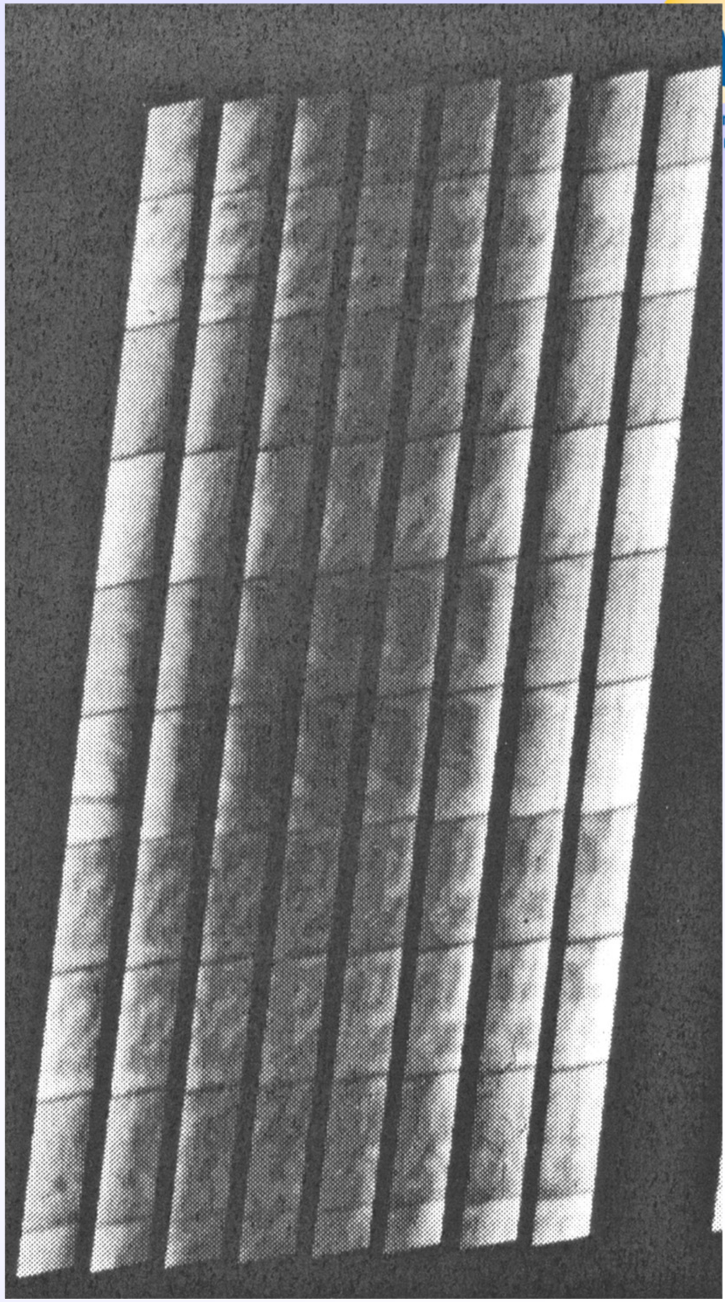
MULTI-CHANNEL SUBSTRACTIVE DOUBLE-PASS SPECTROGRAPH (MSDP)

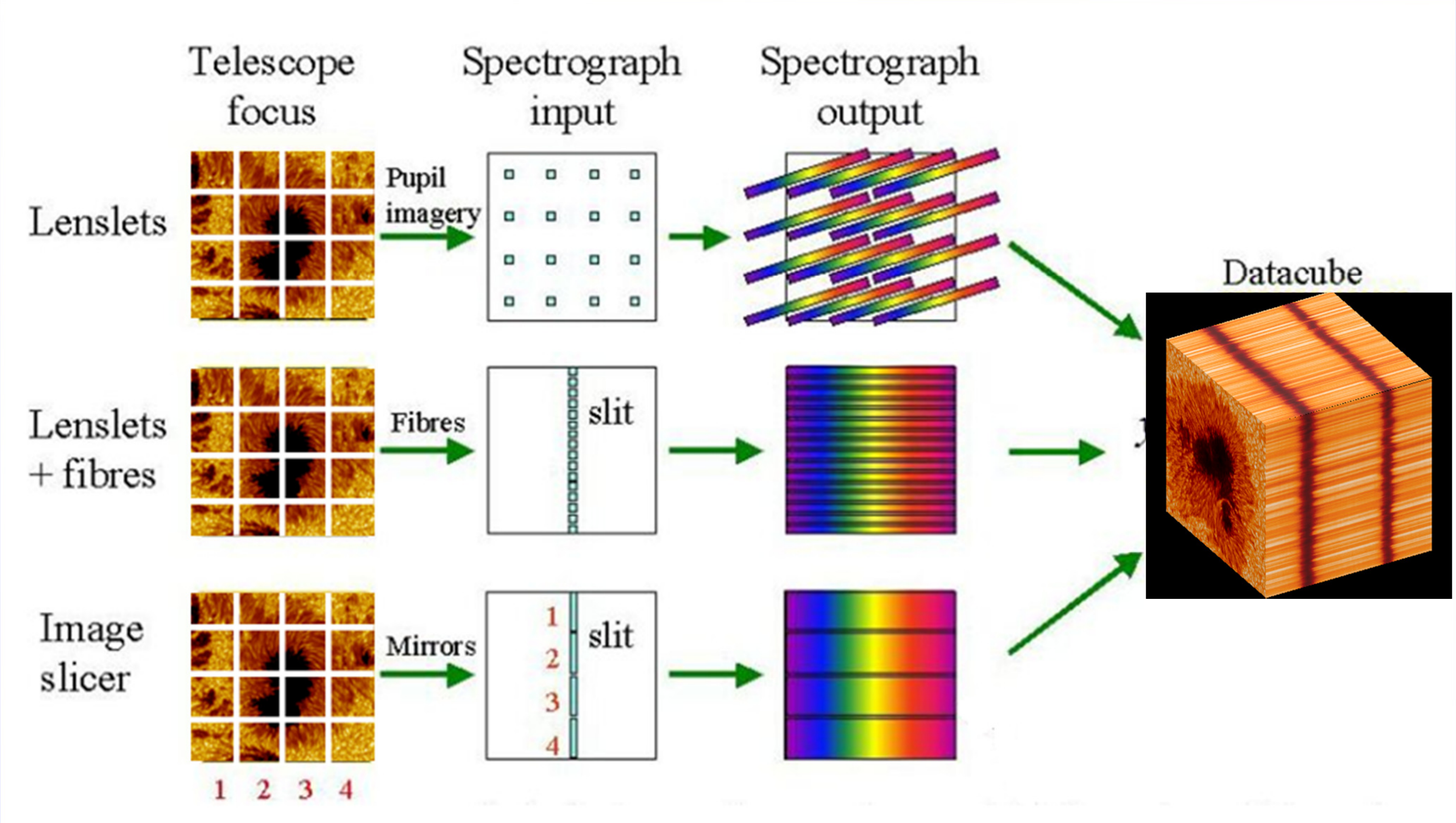






MSDP Slicer concept

INTEGRAL FIELD SPECTROSCOPY



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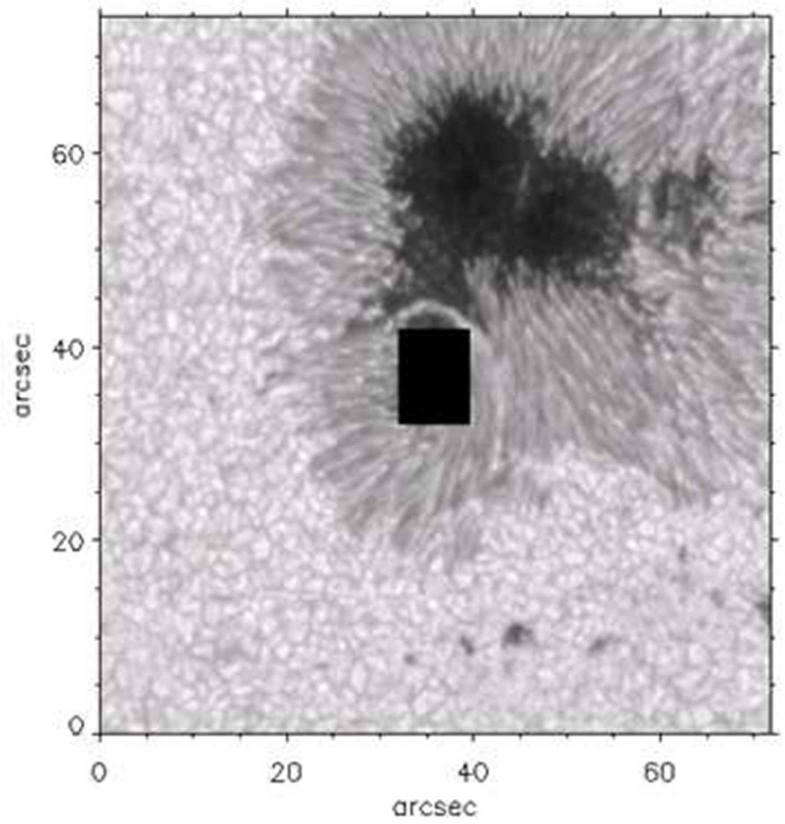
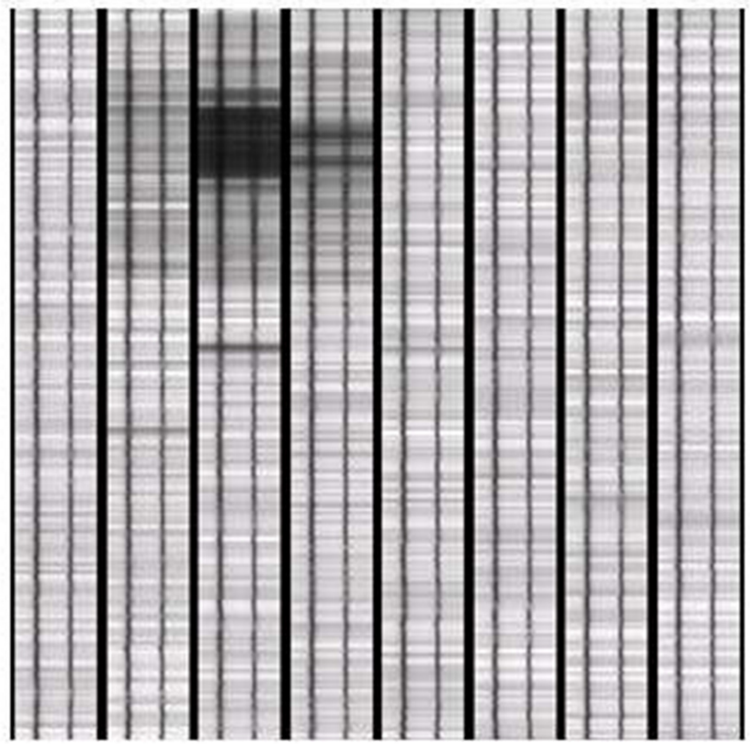
INTEGRAL FIELD SPECTROSCOPY

MAIN IDEA: to observe all points in a 2D FoV and obtain the spectrum from them all simultaneously



SIMULATED EST FOCAL PLANE

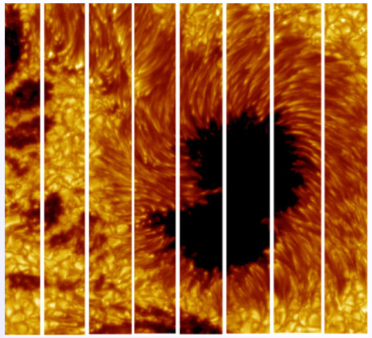


SIMULATED EST DETECTOR

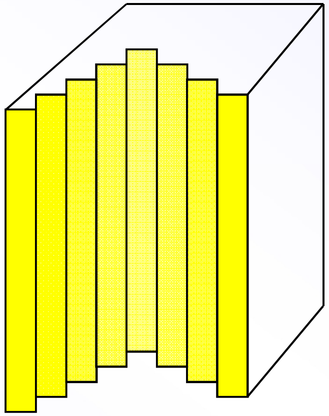
IFU: image-slicer

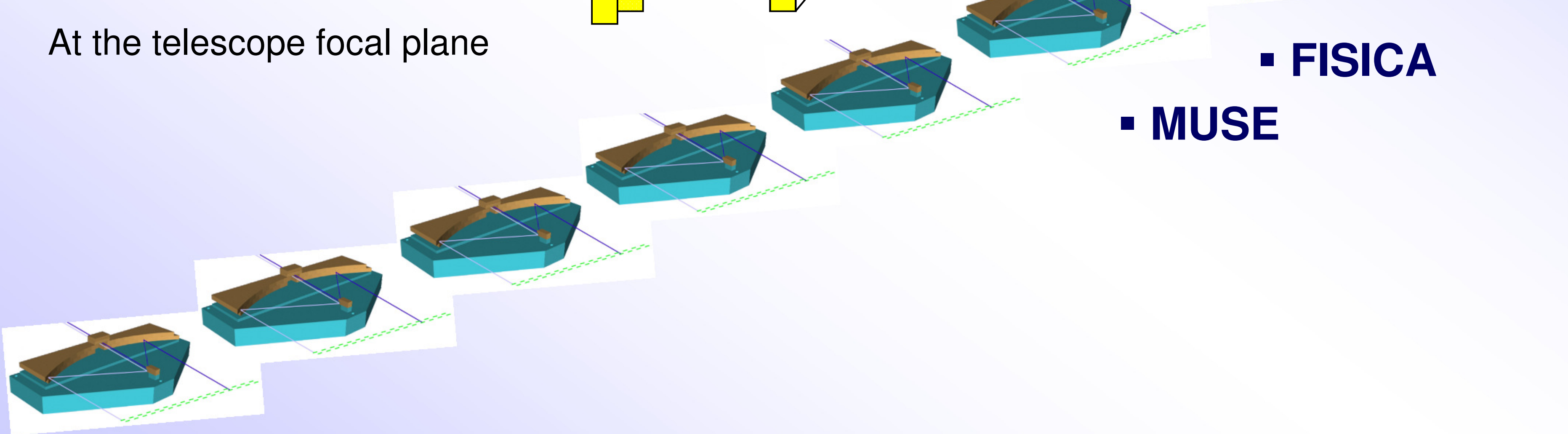
1 Macro-slicer → to divide the FOV into 8 smaller fields

1 image-slicer per slit



At the telescope focal plane





- FISICA
- MUSE

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Instituto de Astrofísica de Canarias

IFU: image-slicer

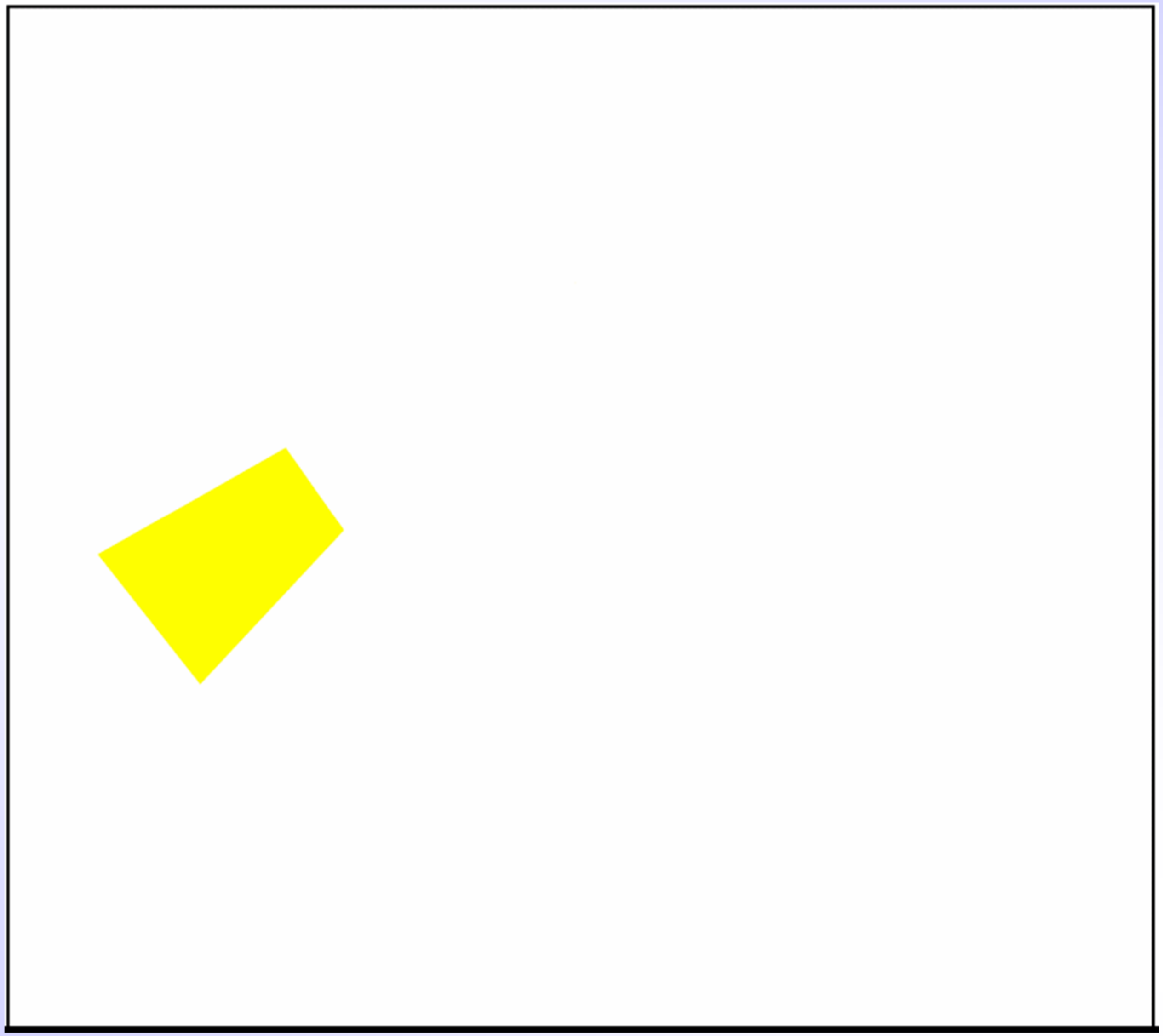
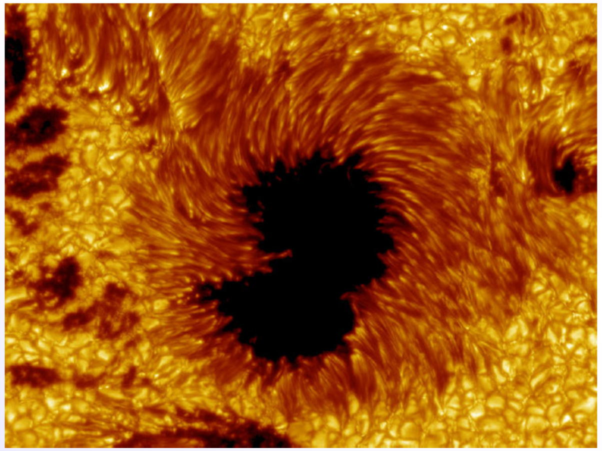
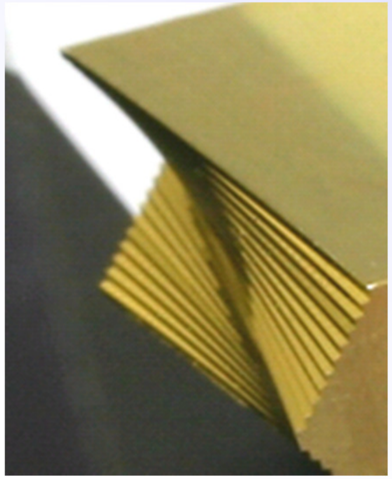
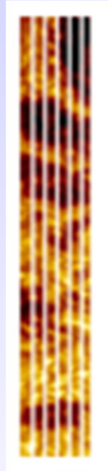


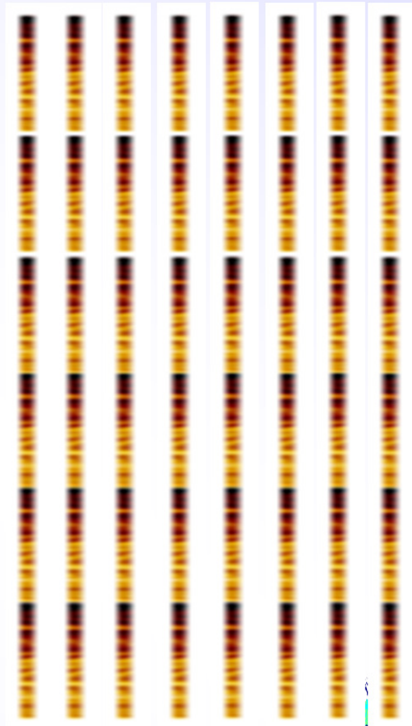
IMAGE-SLICER

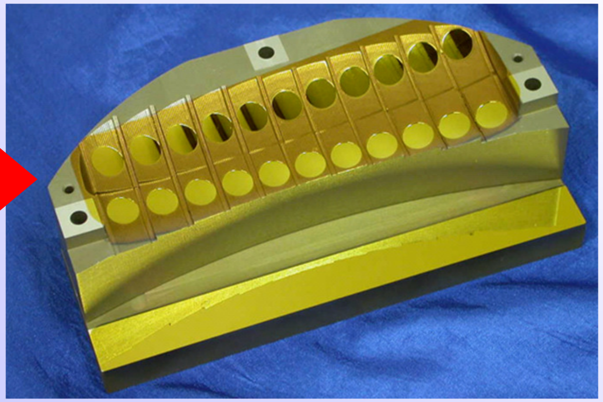


SLICER MIRROR

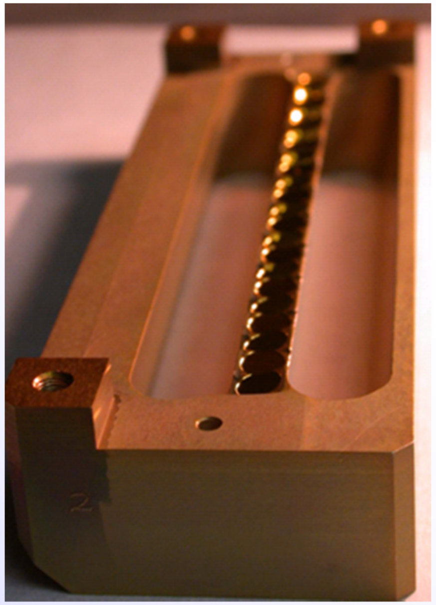








PUPIL MIRROR



FIELD MIRROR

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SUMMARY OF SPECTRAL INSTRUMENTS CONFIGURATIONS

	Fabry-Perot	LsSS	TUNIS	MSDP	IFU
FoV	60” × 60”	120” × 0.1”	120” × 120”	120” × 8” (32” × 30”)	12” × 6”
Scanning	λ	x	λ	x	x-y
Spatial Resolution	high	moderate	high	high	high
Spectral Resolution	moderate	high	moderate	moderate	high

+ TELESCOPE SCANNING FOR LARGER FOV

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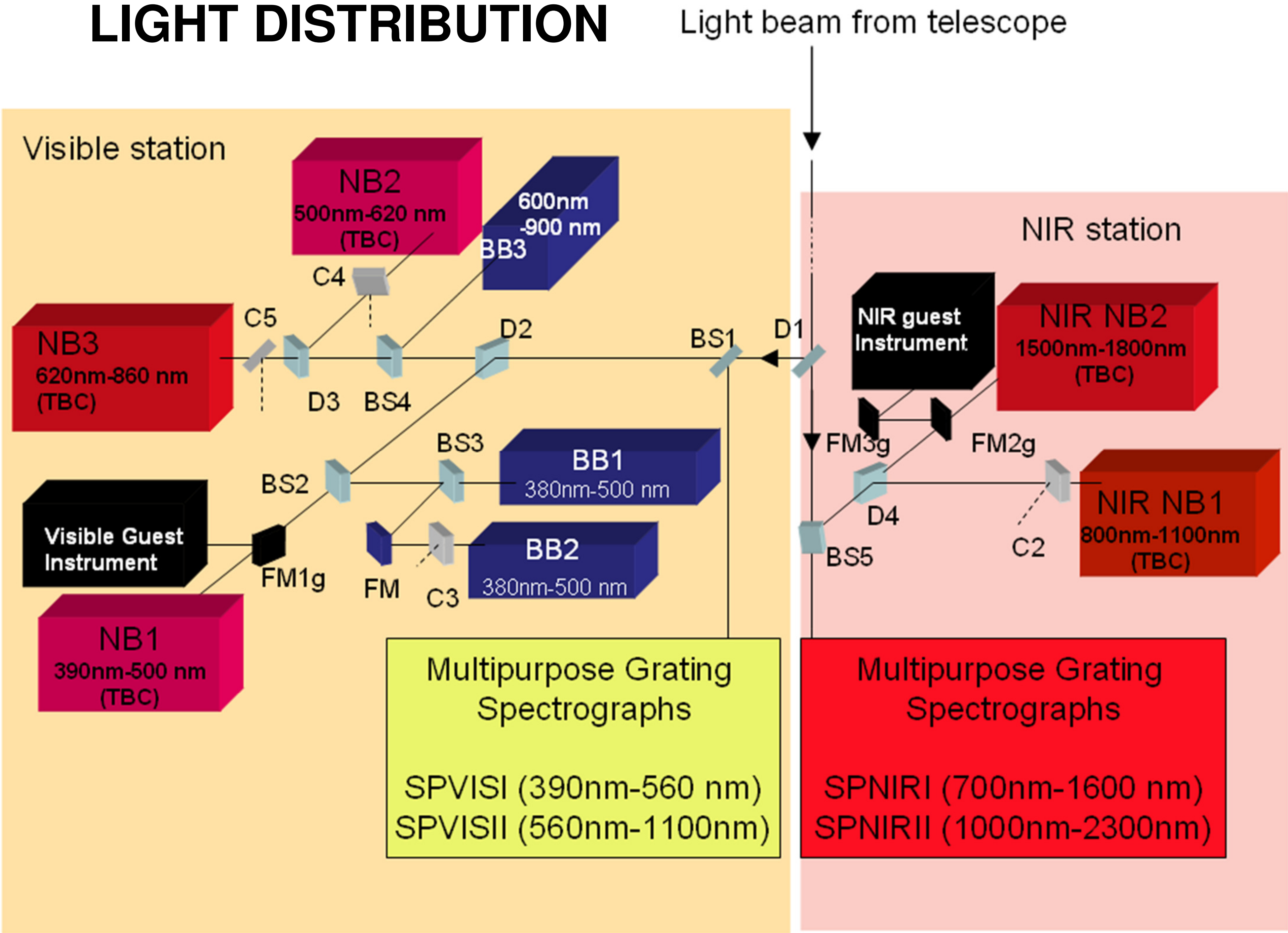
LIGHT DISTRIBUTION



EAST
European Association
for Solar Telescopes