Multi Application Solar Telescope (MAST)

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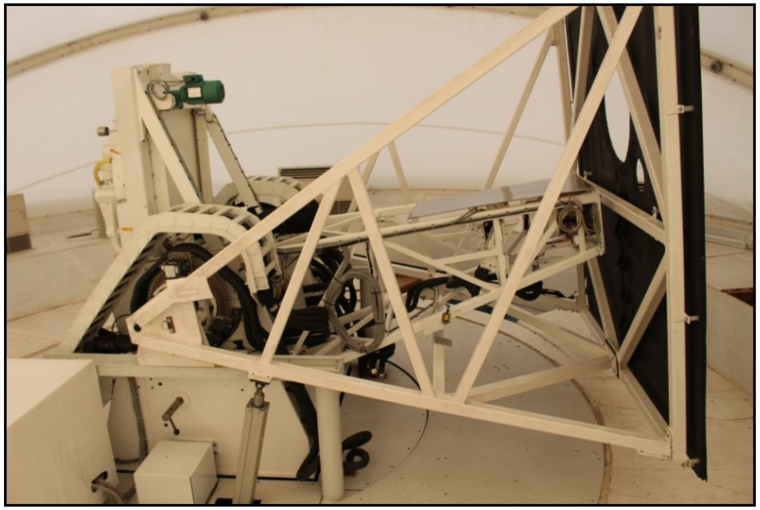
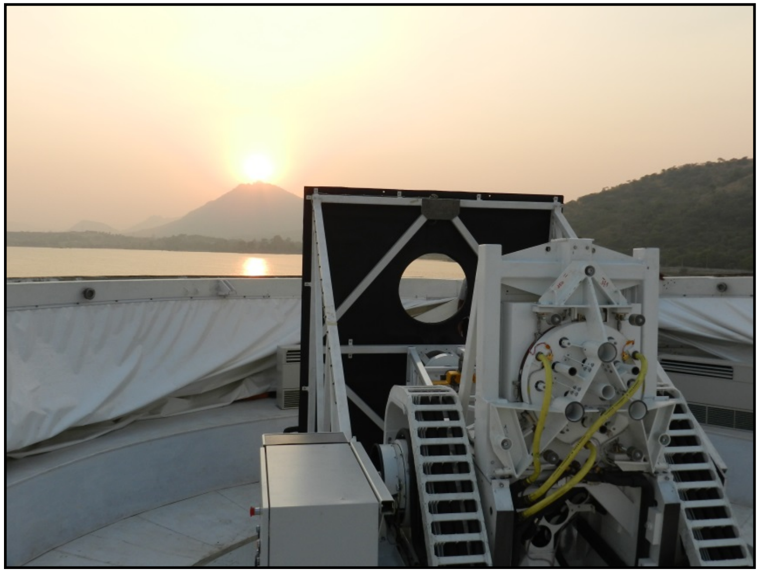
Multi Application Solar Telescope (MAST)

Salient features :

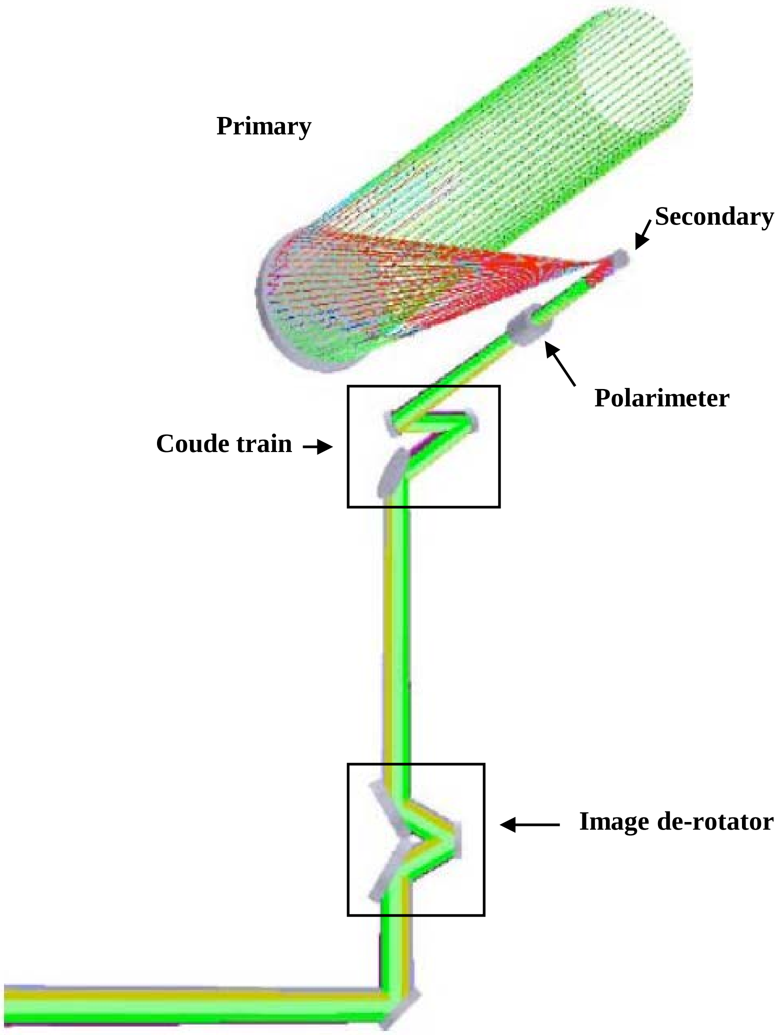
- 50 cm off - axis design for reduced scattered light.
- Zerodur primary, secondary and Coude mirrors with SiC.
- λ/12 wave front error, around 0.25 arc-sec resolution at 600 nm.
- Alt-azimuth mount, image de-rotator for FOV rotation compensation.
- Active thermal control on M1 and all the other mirrors, maintained within ± 1^{o} C to the ambient.
- Collapsible dome, no trapped heat and thus no dome seeing.
- Hexapod mounted secondary mirror for active compensation of aberrations due to thermal flexure.
- Back-end instruments on a stable platform beneath the telescope floor.





MAST Optical design

• Aperture	-	50 cm
• f#	-	4
• Configuration Gregorian	-	Off-axis,
• Mount	-	Alt-azimuth
• Primary mirror	-	Zerodur
• Secondary and		
folding mirrors	-	SiC
• Source Belgium	-	AMOS,



Collimated beam to the observing room

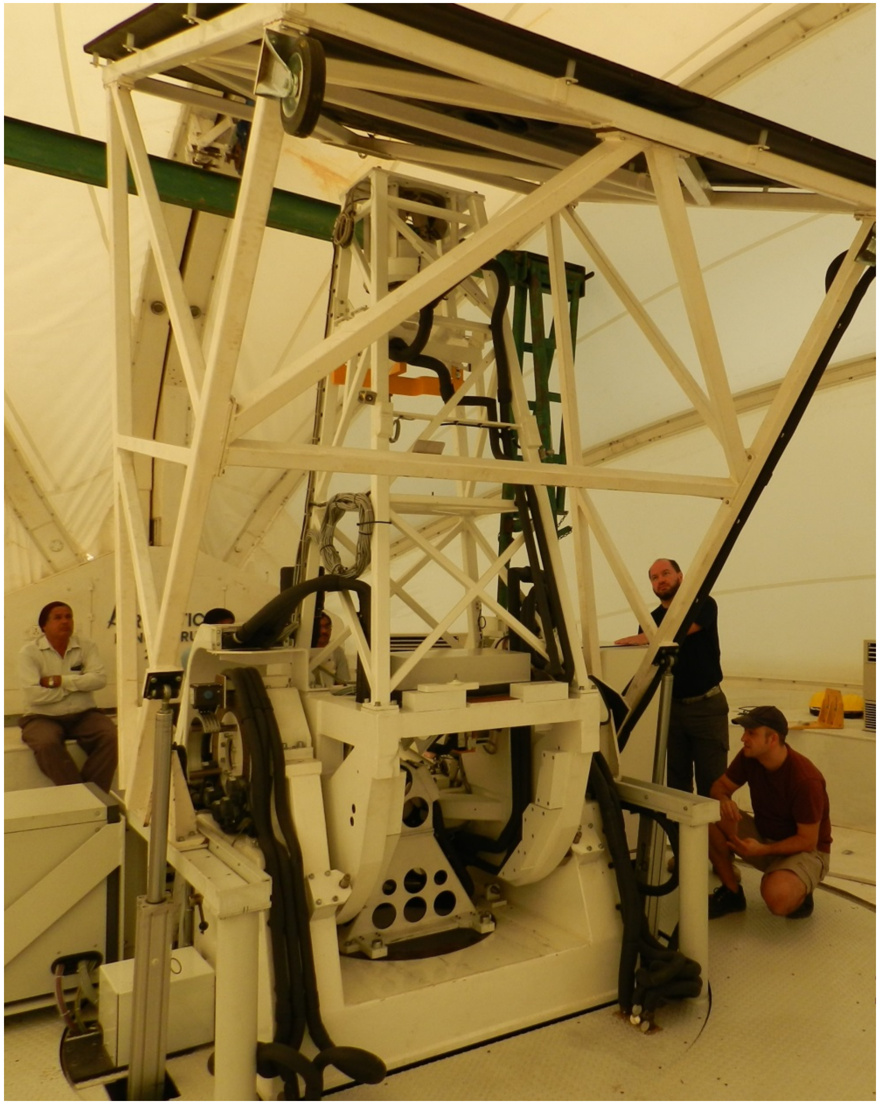
MAST Optical design

Off-axis alt-azimuth mount :

Scattered light	- No scattered light resulting from the secondary supporting structure, better PSF
No central obscuration	- More effective collecting area
	- full pupil plane image is available for AO wave-front sensing
polarimetry package	- polarimtery package can be conveniently placed soon after the secondary mirror
Instrumental polarization	- Resulting from the oblique reflections but can be corrected by calibrating the telescope

MAST Mechanical design

- A stiff central structure connecting the two altitude shafts
- A reinforced strut structure to connect the central structure and M2
- M2 is mounted on a hexapod with correction capabilities for tilt, decentring, and translation
- Support structure for the polarimeter package in the strut



MAST Mechanical design

- Mount : Alt-azimuth
- Differential pointing accuracy : 0.5 arc-sec
- Open loop tracking : 0.25 arc-sec for 10 min
- Closed loop tracking : 0.1 arc-sec for 1 Hr
- M2 mechanism : tip-tilt system

MAST Thermal design

The thermal design of the telescope is aimed at;

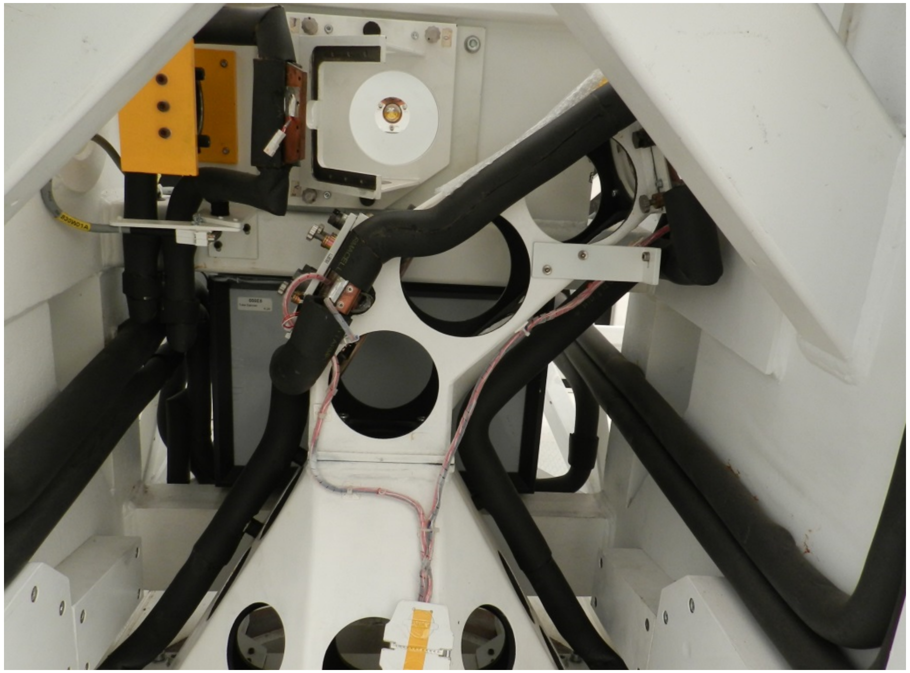
- controlling the solar flux falling on the opto-mechanical components to avoid any differential expansion of the support structures

- controlling the temperature of the equipment so that the difference between the ambient temperature is minimum in order to limit seeing degradation

- This is achieved by heating/cooling of the main telescope elements. Thermal design and control is difficult because of large variations of operating temperature and fast temperature variation

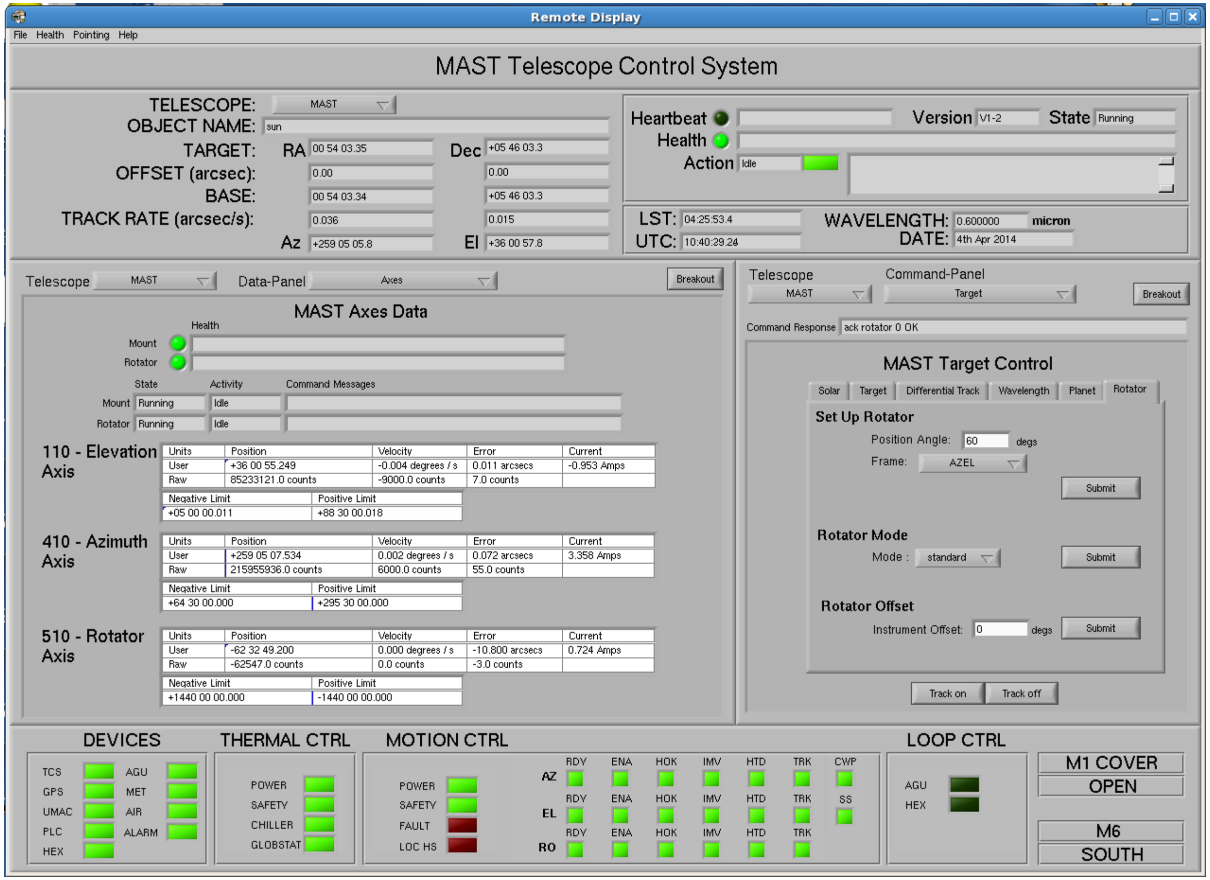
MAST Thermal design

- The tubes and the fork, are shaded from the sun's illumination by an upper sunshield system.
- The M1 mirror is thermally controlled by means of airflows with controlled temperature
- The primary mirror surface is kept at within ±1°C ambient



MAST Telescope Control System (TCS)

GUI of the remote display of TCS



- Telescope Control System (TCS) software is written in LabView.
- PLC control for the thermal and pneumatic systems.
- UMAC controllers for the azimuth, elevation and de-rotator drives.
- The TCS can be accessed and the telescope can be controlled remotely over Ethernet.

MAST transportation & Installation

- The entire telescope mechanical structure transported from AMOS in three pieces, the largest weighing more than 4 tonnes.
- The boxes were transported to the island (around 700m from the shore) on a large pontoon
- Steel structure was erected for lifting the boxes from the lake to the building top

MAST transportation & Installation

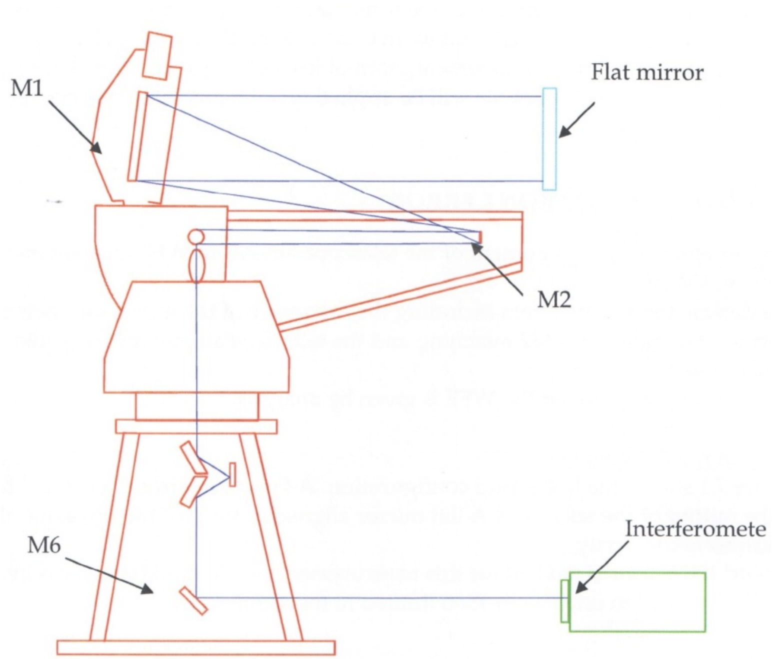
The cable wrap being transported from the shore to the island

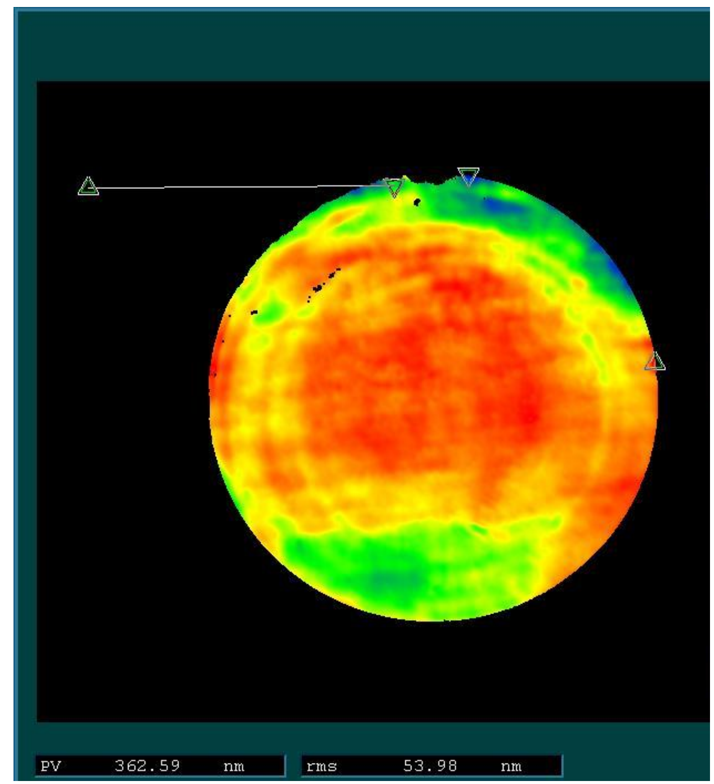
Elevation drive and telescope tube being lifted to the telescope floor

Optical alignment

- Both theodolite and Zygo interferometer are used for the optical alignment.
- Preliminary alignment of all the mirrors with respect to the telescope and optic axes using theodolite.
- A 60 cm flat mounted in front of the telescope and a Zygo interferometer are used for measuring wave-front errors.
- Secondary hexapod parameters were adjusted to minimize the errors in optical alignment of M1 & M2

Rms wavefront vary between $\lambda/12$ - $\lambda/14$





MAST Pointing model

***Atl-azimuth mount, star pointing* :**

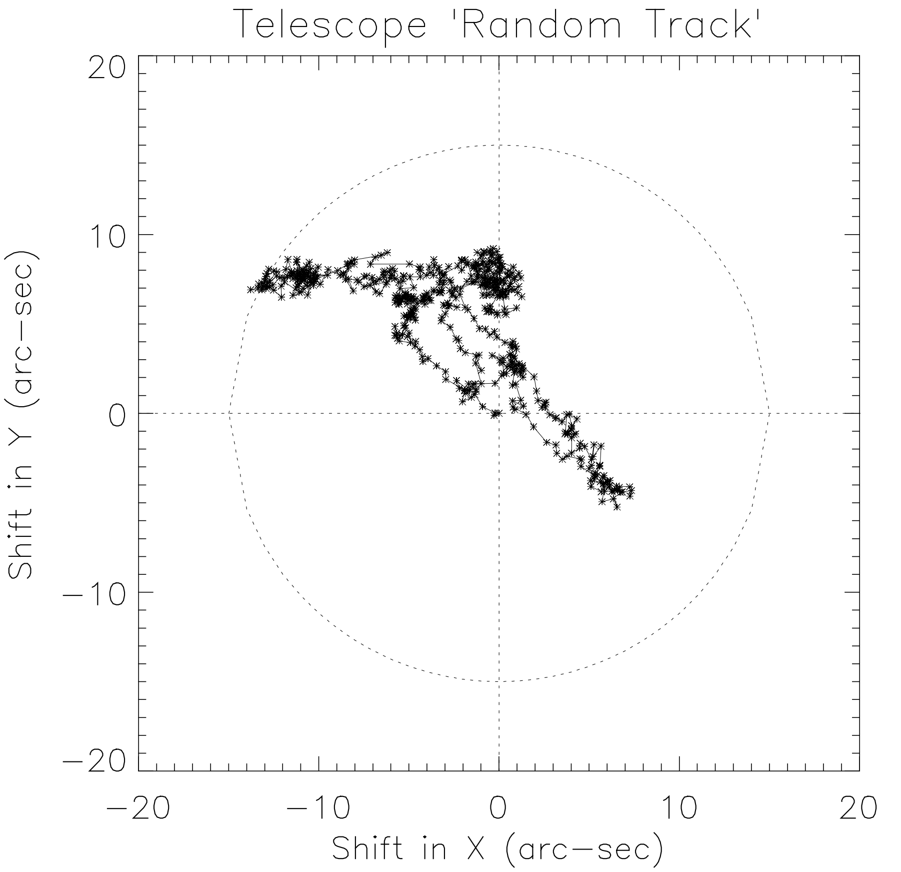
- Night time star pointing tests were conducted for creating tracking model.
- More than 50 stars in different elevations and azimuths were pointed .
- The apparent position of the object in the sky compared with the pointing of the telescope along its two major axes.
- The correlation between the two give levelling errors, non-perpendicularity of the telescope's axes and misalignment of the optical axis to the mechanical axes.
- The data can be fitted with 7 or more parameters to make the model.
- These parameters will be used in tracking of the telescope in solar observations.

IE	-	-34 .0	(elevation offset)
IA	-	801.0	(azimuth offset)
NPAE	-	15.260	(ele-az non orthogonality)
TF	-	24.9	(Tube flexure)

MAST tests

Tracking tests **:**

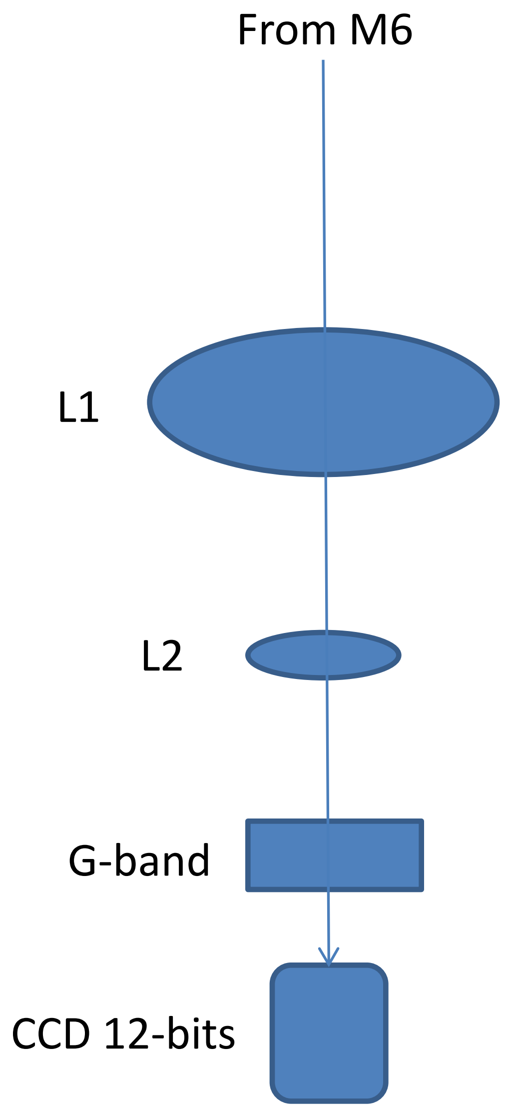
- Tests carried out using G-band observations.
- Sunspots tracked in 10 Hrs of data, in HG co-ordinate frame.
- Shift of the sunspot calculated by registering the mages.
- Maximum shift is with in 15 arc-sec for 10 Hrs, 0.025 arc-sec/min
- Tests will be conducted again after the realignment

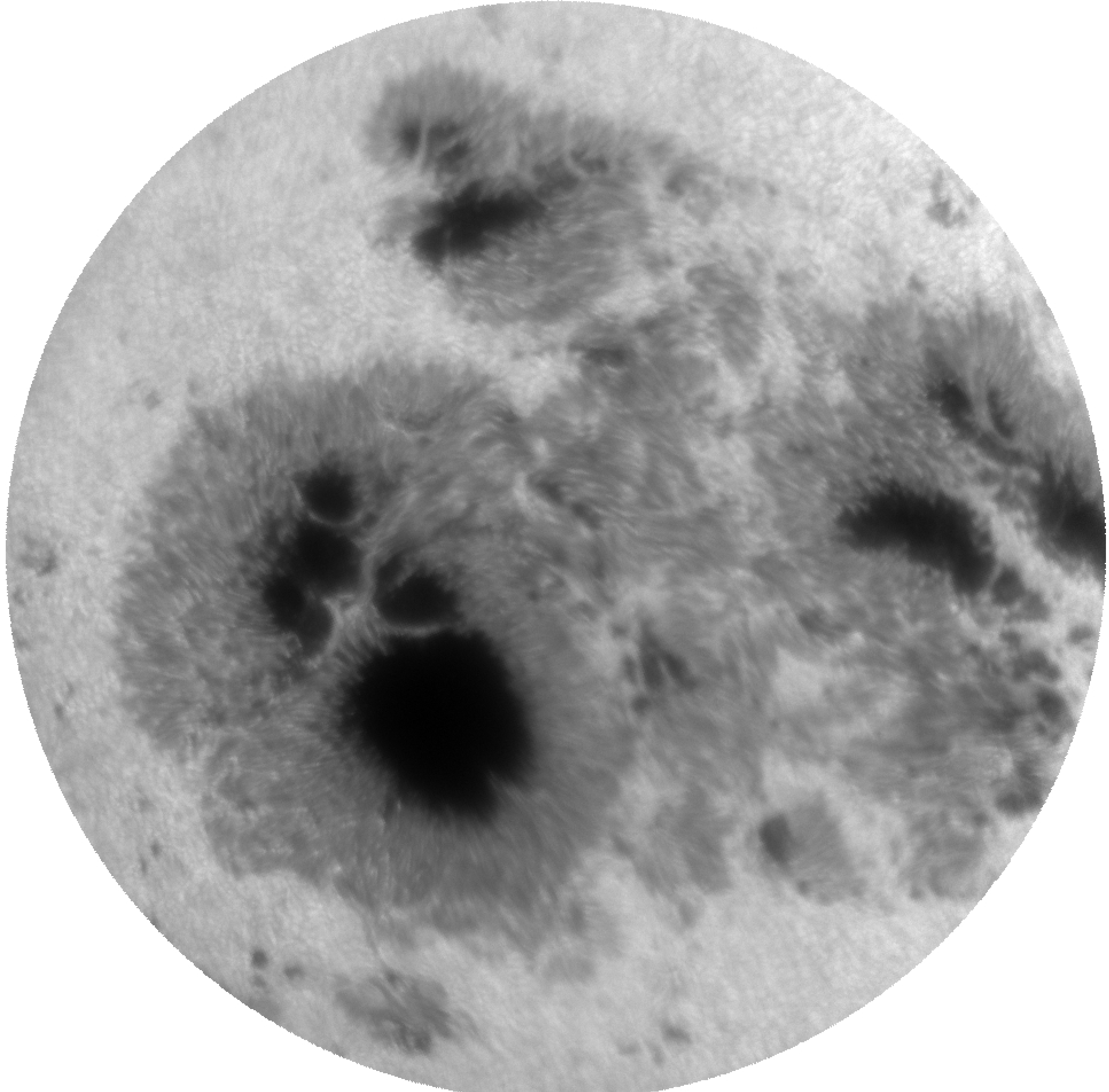


MAST test images

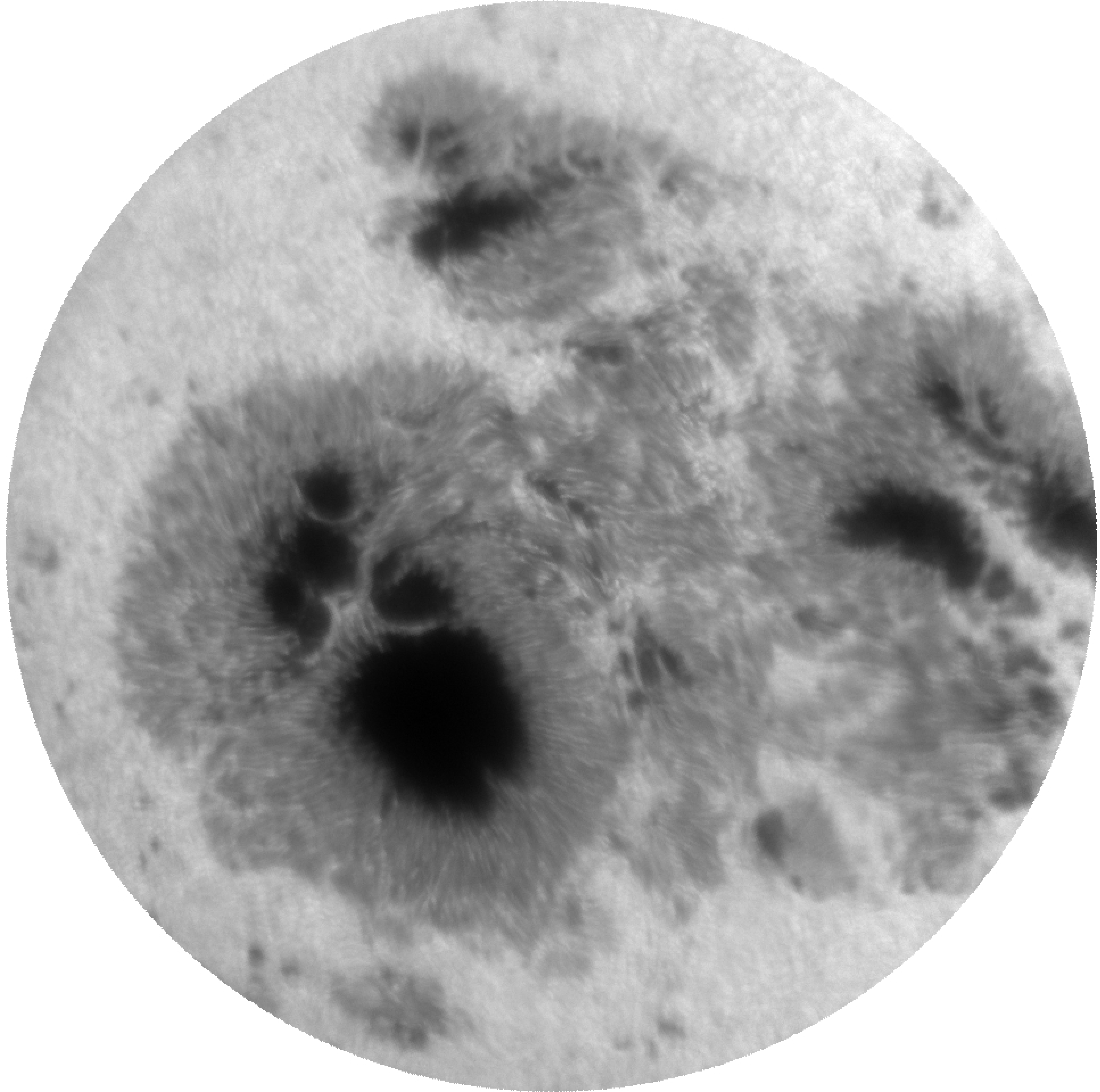
Preliminary test observations set-up :

- Simple set-up using two lenses, g-band 1nm filter and 12-bits CCD camera
- Also obtained images through an old Halle H-alpha filter (500 mÅ) filter
- The image quality could be improved by using a 16-bits CCD which will increase the dynamic range

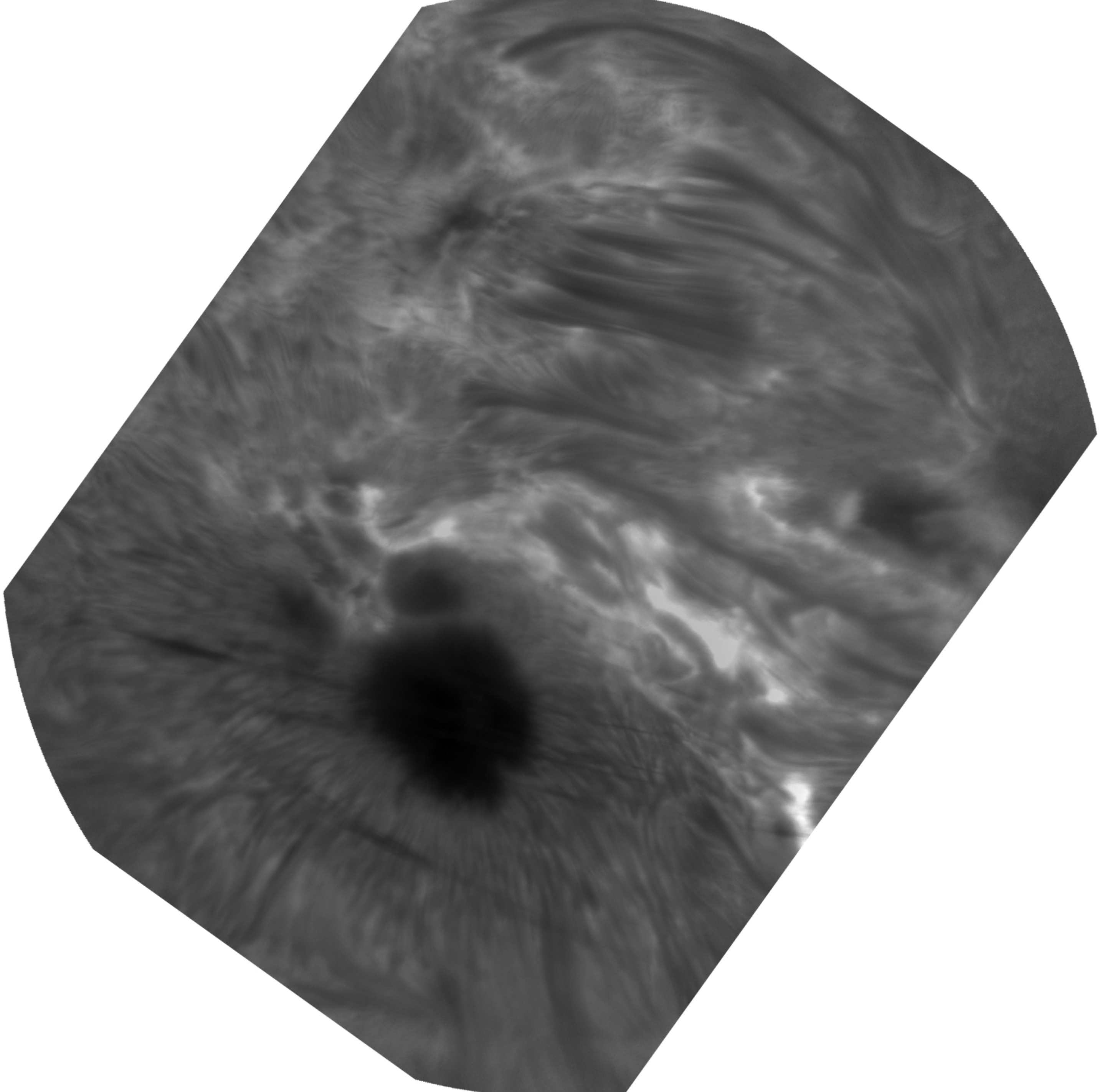




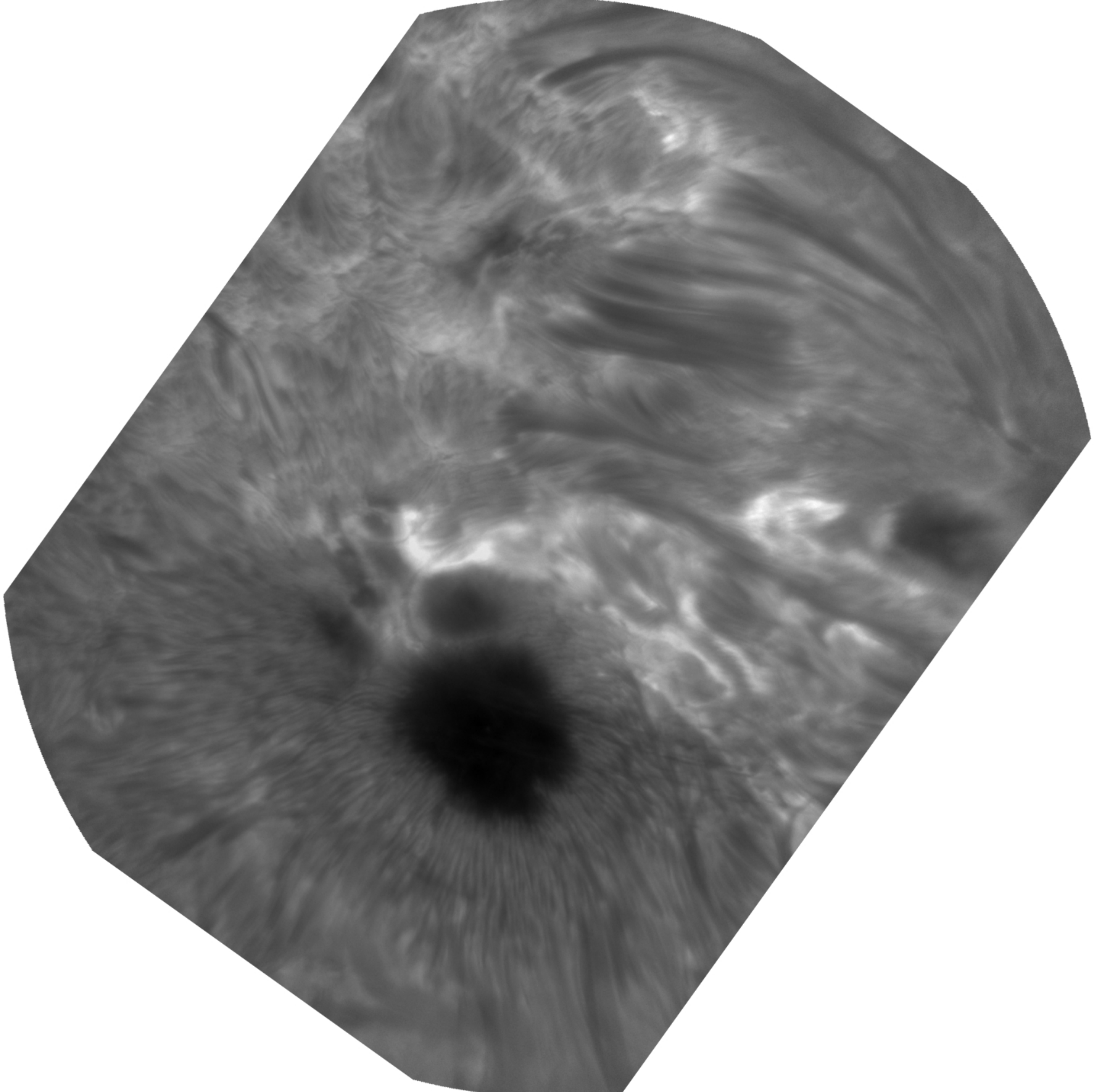
Preliminary test observations:
G-Band
AR 12192
22 OCT 2014
10:51:00 IST
FOV: ~200 arc-sec



Preliminary test observations:
G-Band
AR 12192
22 OCT 2014
10:51:25 IST
FOV: ~200 arc-sec

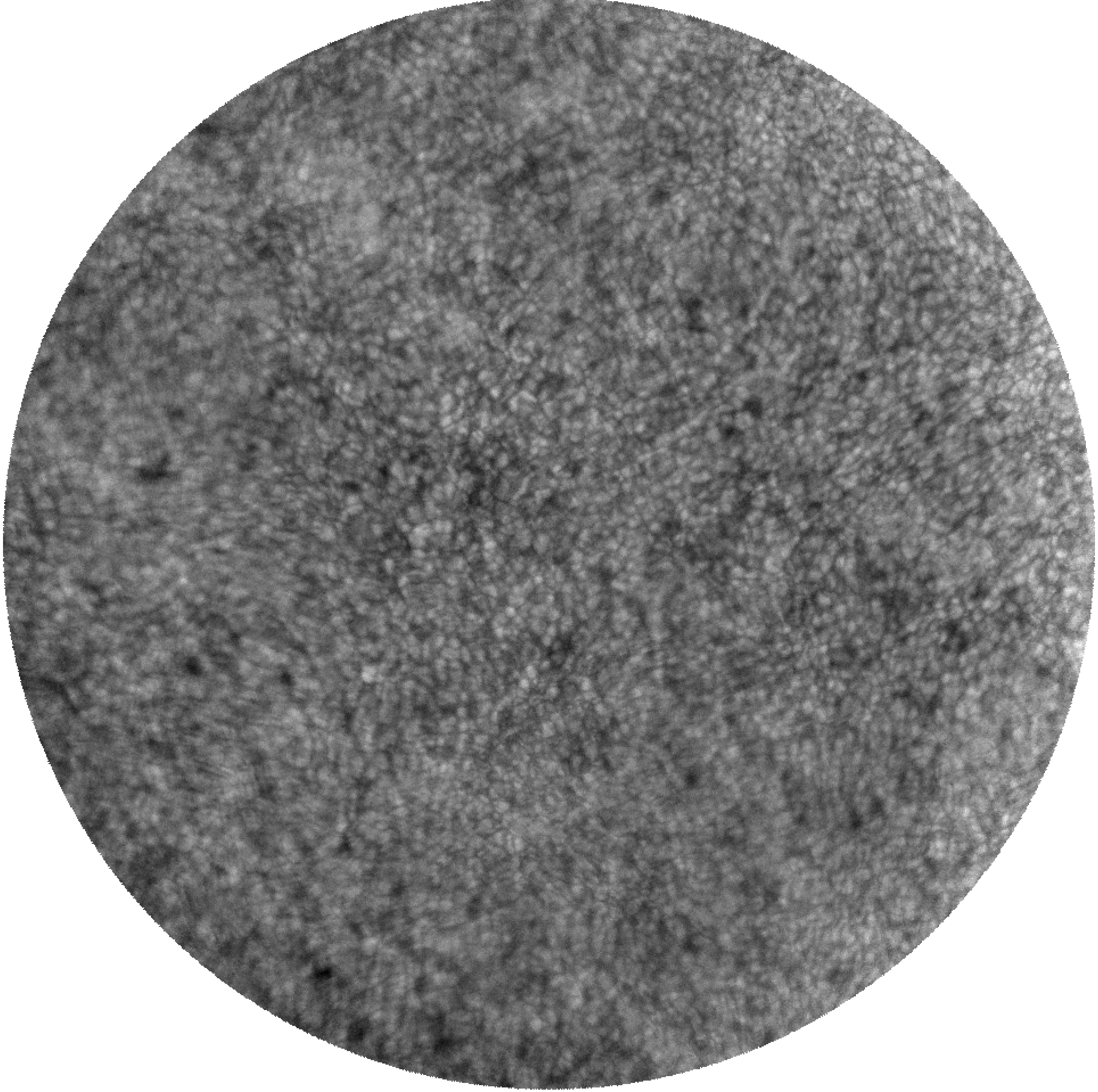


Preliminary test observations:
H-alpha
AR 12192
22 OCT 2014
10:55:00 IST
FOV: ~200 arc-sec



Preliminary test observations:
H-alpha
AR 12192
22 OCT 2014
11:09:00 IST
FOV: ~200 arc-sec

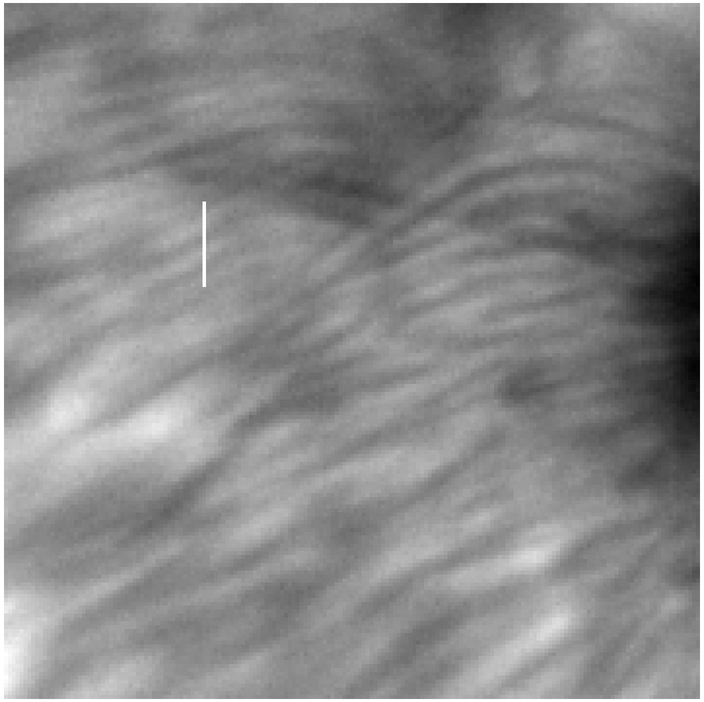
Preliminary test observations:
G-Band
Quiet Sun
22 OCT 2014
10:47:00 IST
FOV: ~200 arc-sec

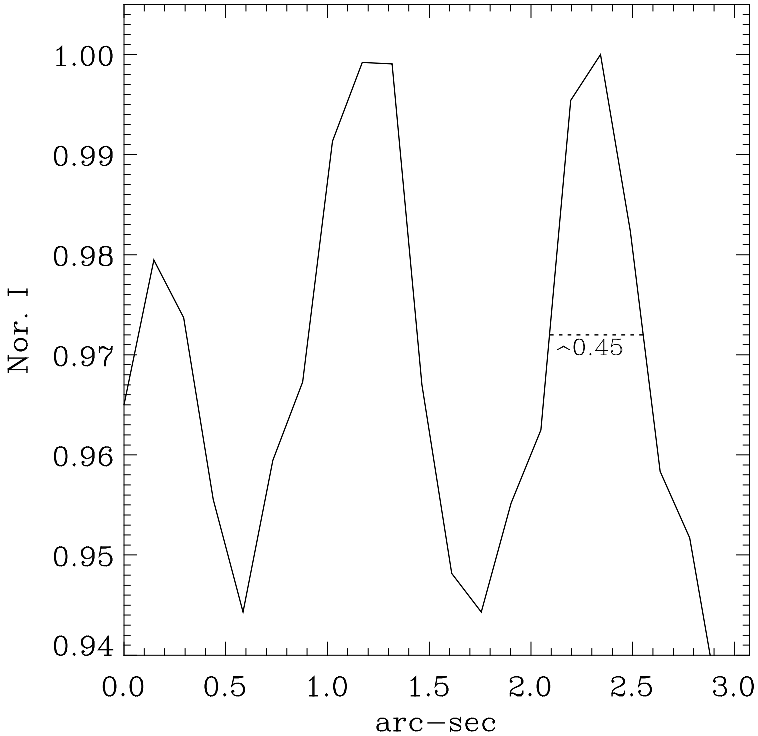


Preliminary test observations:
G-Band
Quiet Sun
22 OCT 2014
10:47:20 IST
FOV: ~200 arc-sec

Spatial resolution:

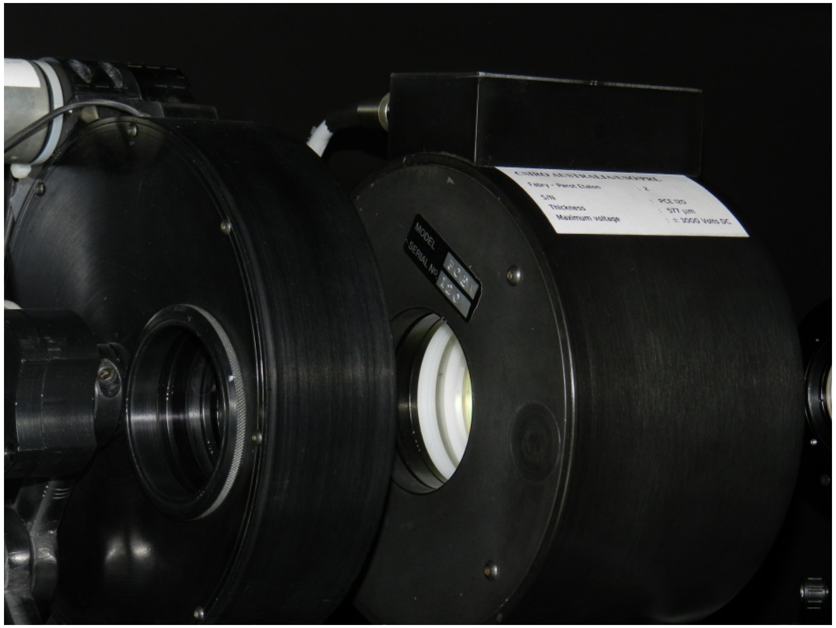
- Cut across the H-alpha structure
- The resolution close to the diffraction limit

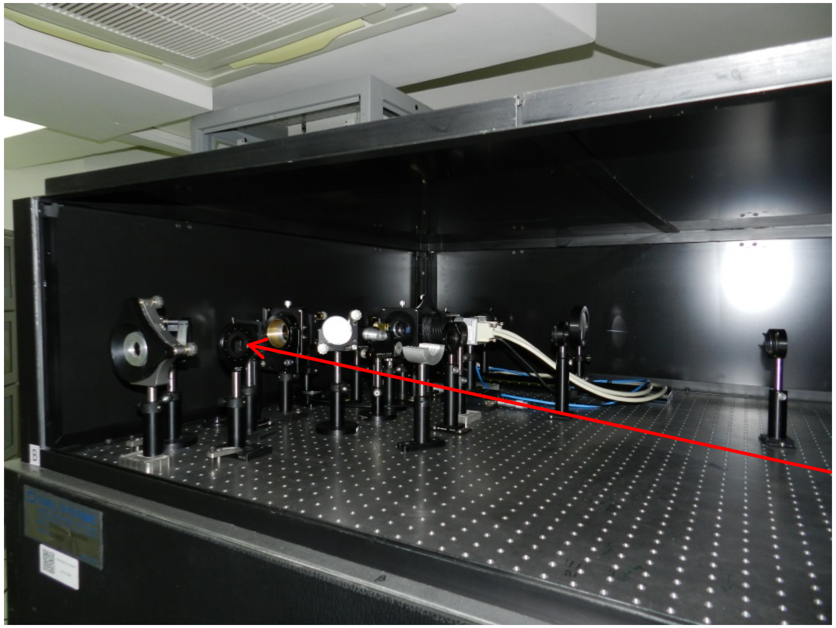




MAST back-end instruments

Adaptive optics, Imager and polarimeter :

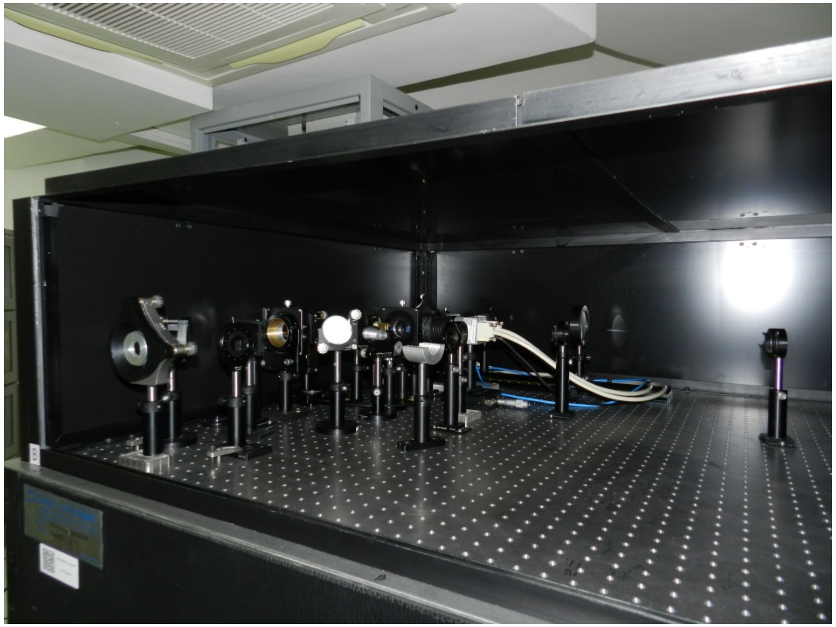




MAST back-end instruments

Adaptive optics:

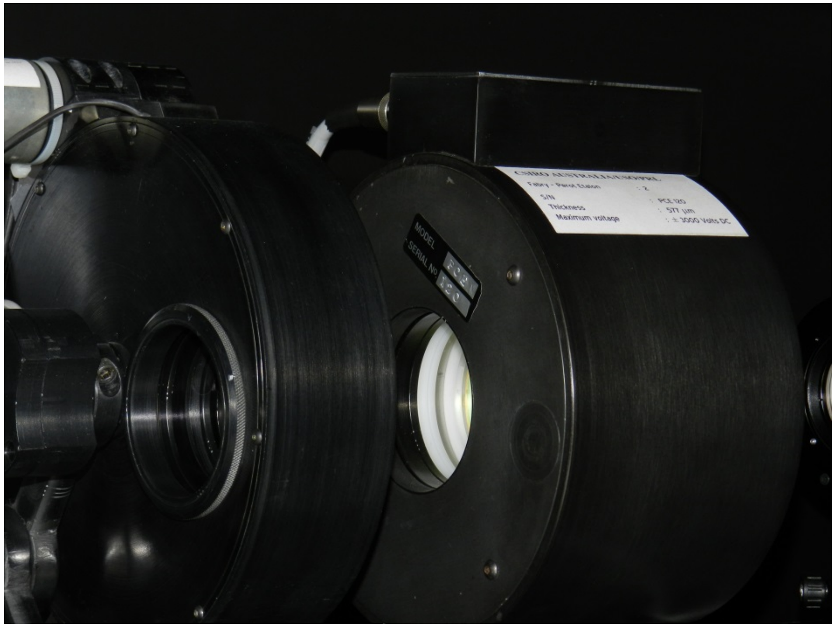
- Deformable membrane mirror for the wave-front correction (MMDM)
- Schack Hartmann (SH) wavefront sensor.
- Tip-tilt mirror for the correction of image wobbling if any
- No. of actuators : 19
- No. lenslets in SH: 19
- Tested with a 15cm Coude telescope, being integrated with MAST

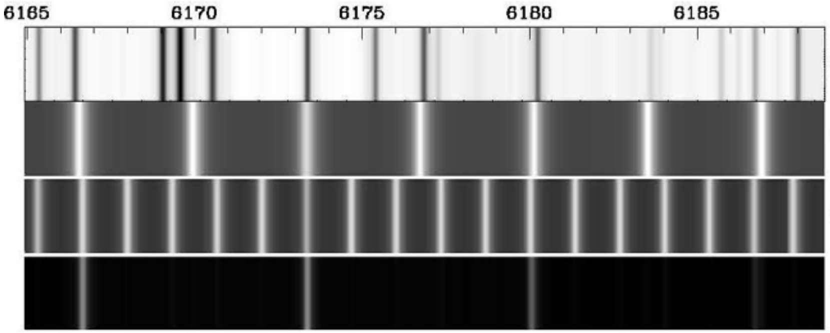


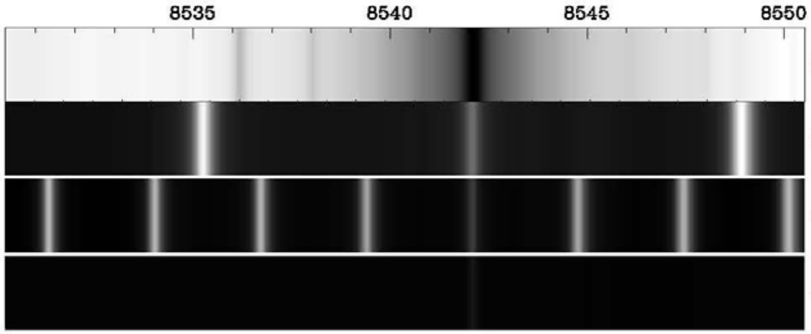
MAST back-end instruments

Narrow band imager:

- Two lithium niobate FP etalons in tandem, resulting pass-band around 60 mÅ.
- Filter wheel with two or more pre-filters.
- Presently two wavelengths at 617.3 nm and 854.2 nm (FeI and CaII) for photospheric and chromospheric observations.
- The filters were tested and tuned with a 15 cm Coude telescope and is being integrated with MAST.



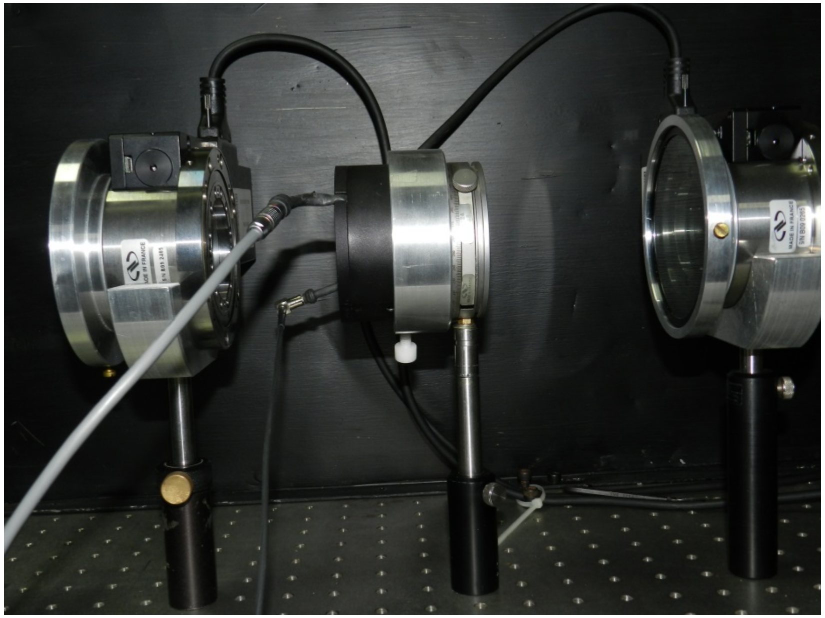




MAST back-end instruments

Polarimeter:

- Two sets of two liquid crystal variable retarders fro 617.3 nm & 854.2 nm, as polarization modulators.
- Linear polarizer as analyser.
- The LCVRs are being characterised for voltage and retardence and will be used with MAST imager for polarimetry.



Multi Application Solar Telescope (MAST)

***Status & future plans*:**

- Installation completed.
- Telescope tested for wave-front accuracy and tracking errors.
- Test observations carried out in G-band and H-alpha.
- Slight modification of secondary support structure is being carried out to reduce the offset due to the seasonal temperature variations, realignment after the modification, final acceptance expected in December, 2014.
- Optical alignment of the back-end instruments, soon after the acceptance.
- Active and adaptive optics in the beginning of 2015.

Thank you!

Thanks to all MAST team members