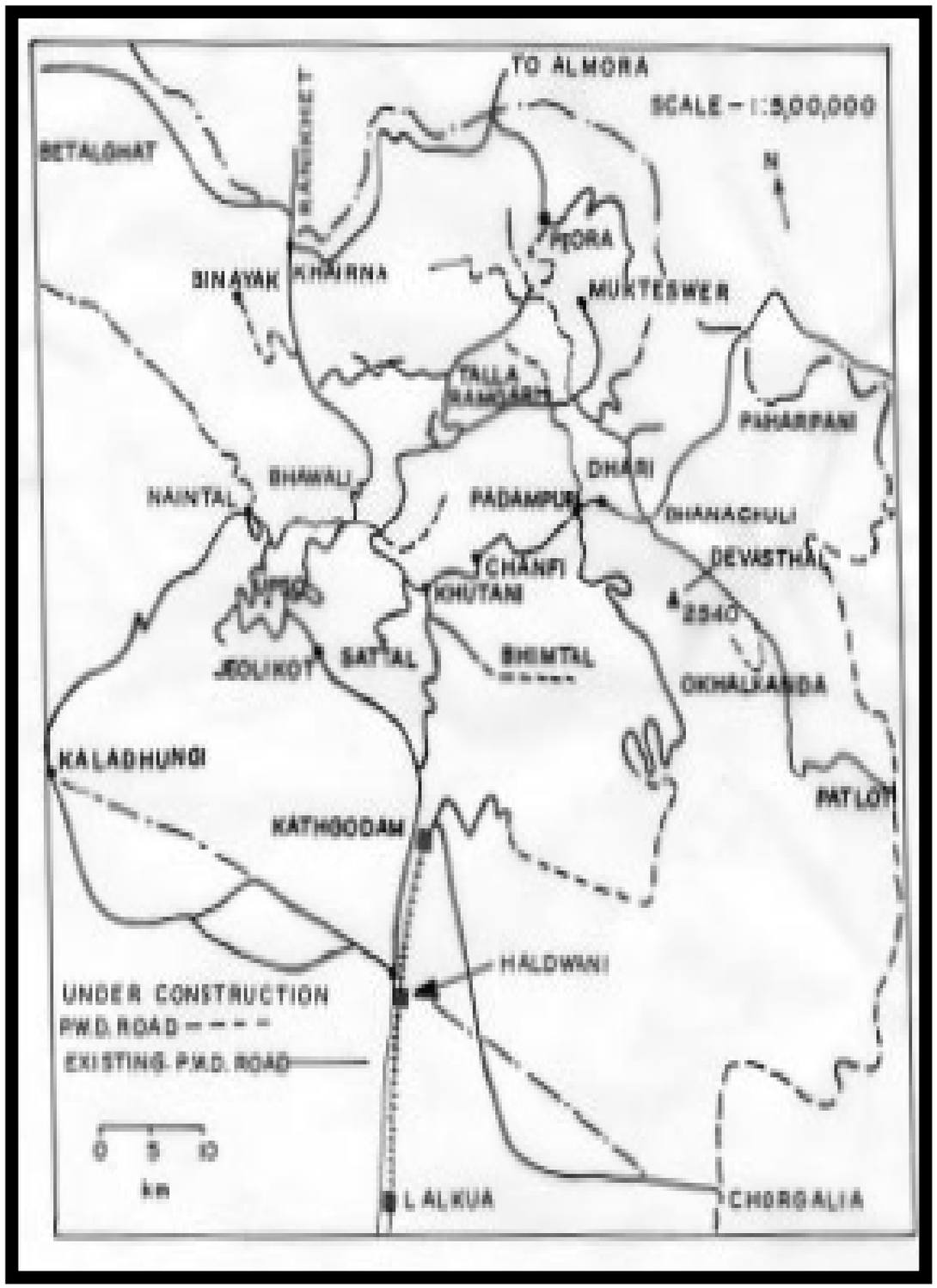
3.6m Devatshal Optical Telescope – Current status and forthcoming instruments

Yogesh C. Joshi

(On behalf of 3.6m DOT Project Team and Instruments PIs)

Survey to select potential astronomical site in the Himalaya Region (1980 to 2000)



Out of half a dozen sites, Devasthal was identified as potential astronomical site

Characterization of Devasthal site

Location : 79d 41m E; 29d 23m N
Altitude : 2424 +/- 4 m

Seeing : 1.1 arcsec (median); best 0.6 arcsec
Wind : < 3m/s for 75% of time (6 m/s max)

Base-camp

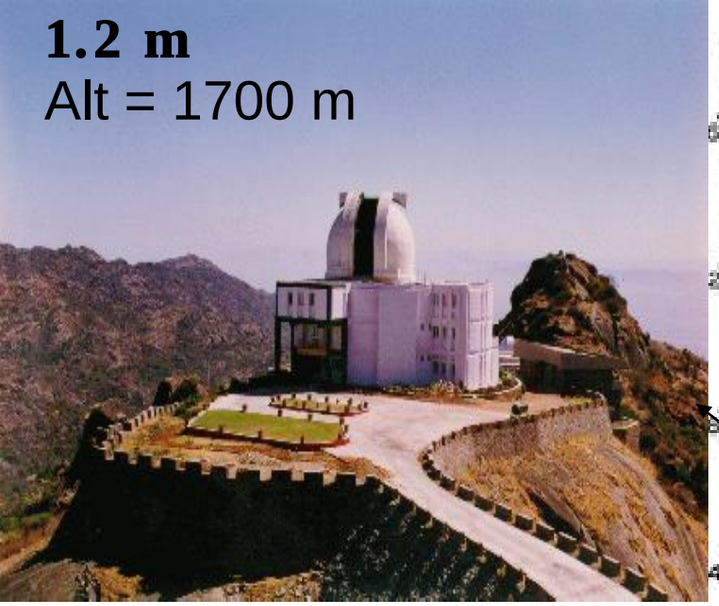
Air Temp. : -4.5 to 21.5 deg C
Rain : 2m/yr; 2ft of snowfall during Jan-Feb

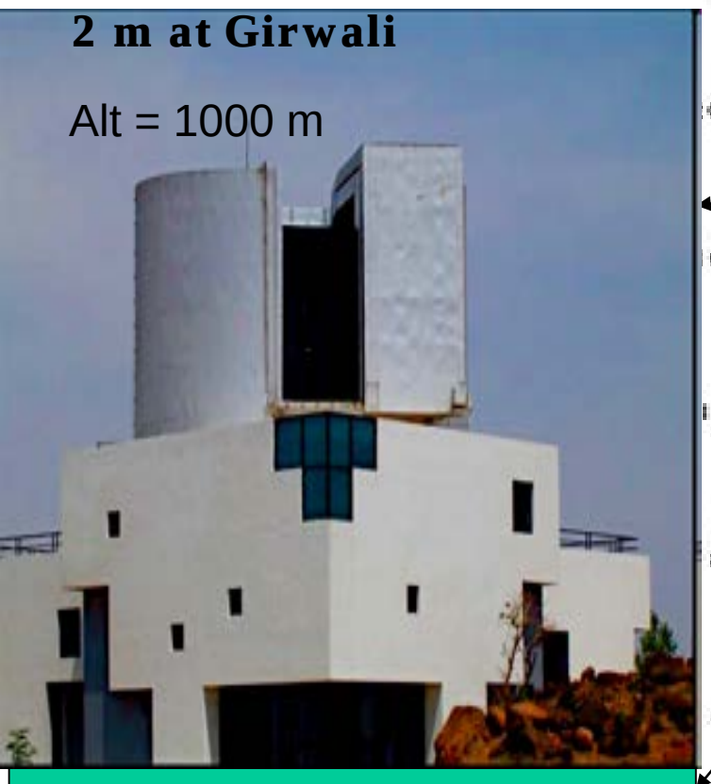
Variation of temp during night : 2 deg C
Clear nights : 210 per year (photometric and spectroscopic)

Extinction (best) : 0.40 mag in U and 0.12 in V

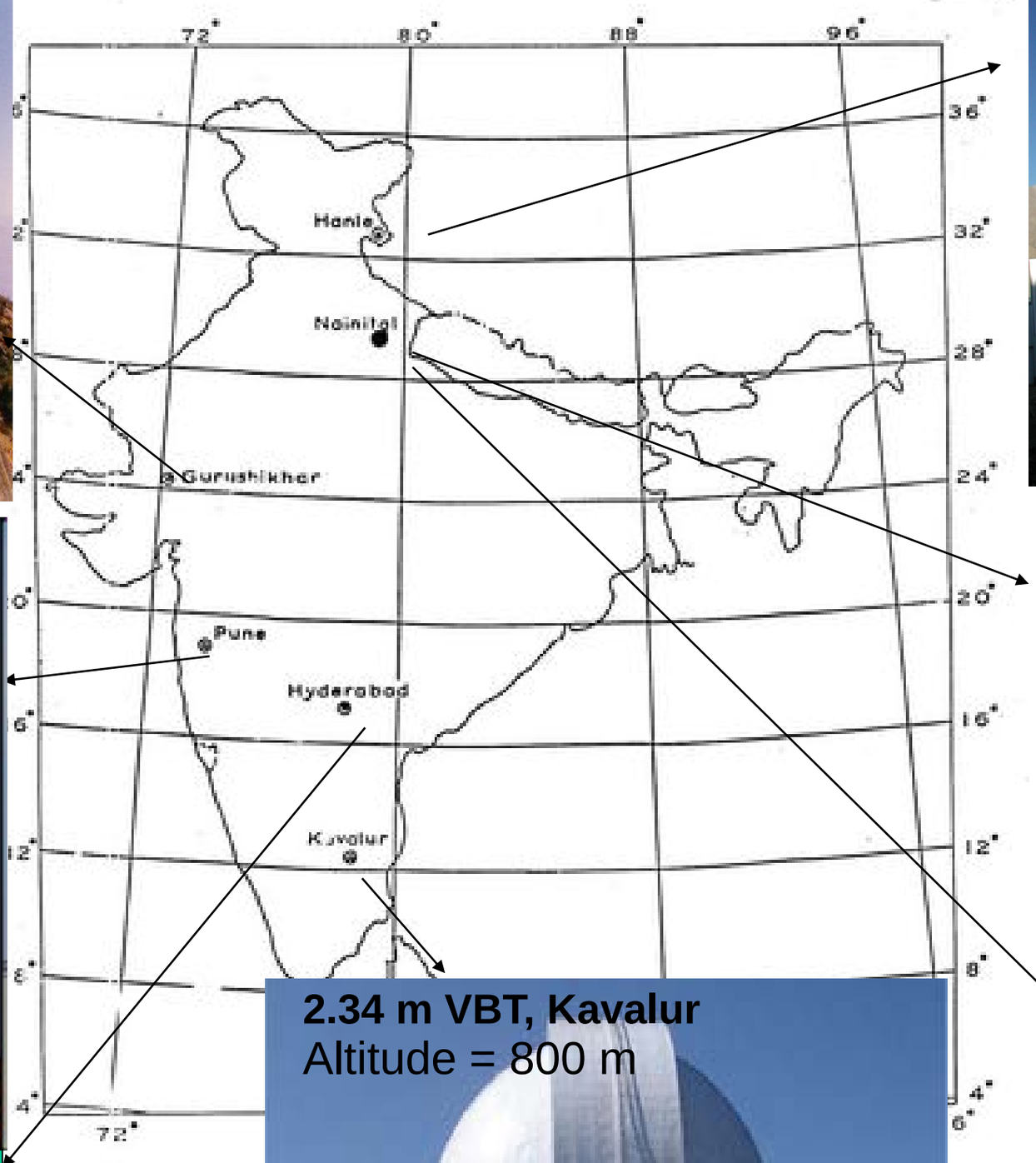
Hill-top

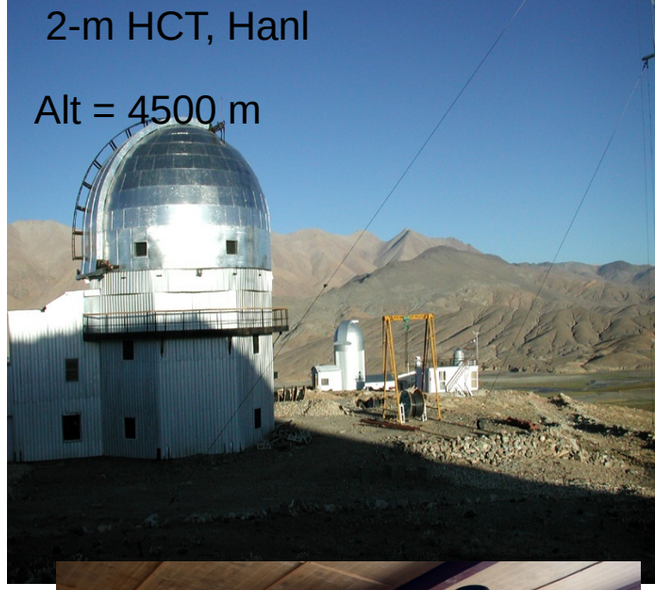
Site characteristics are at par with the world's good sites

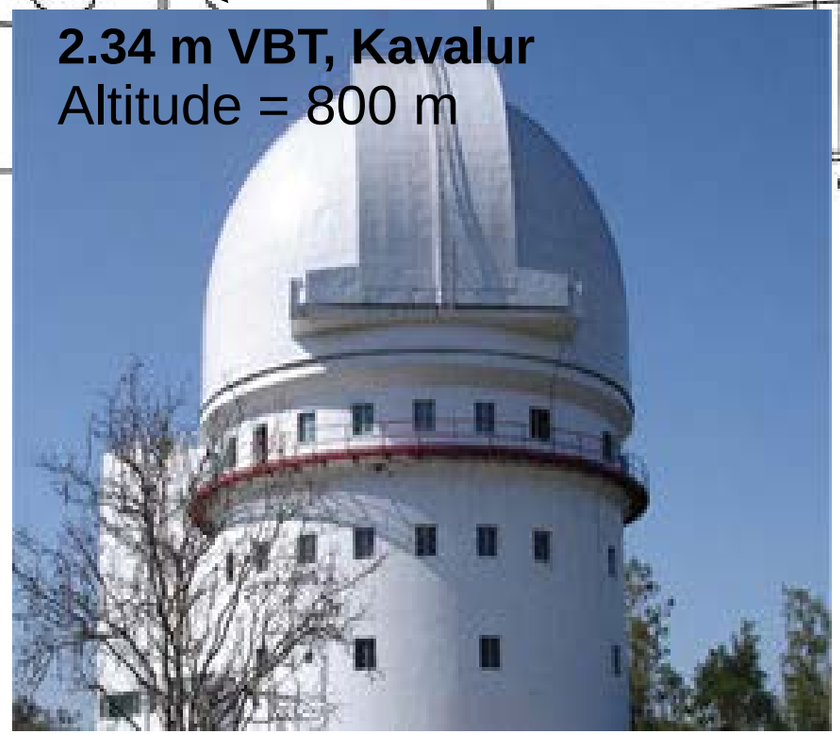


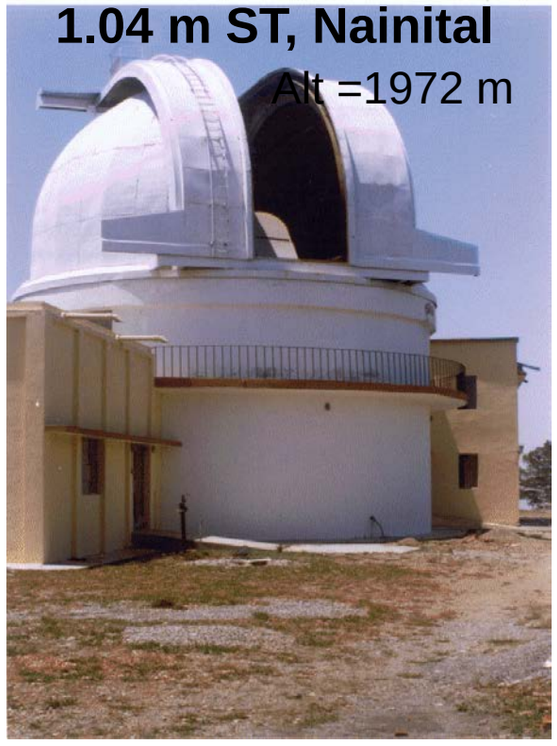


1.2 m
Japal Rangapur
Alt = 700 km









Motivation for 3.6m Devasthal Optical Telescope (DOT)

- Direct access to Indian astronomers for a 4-m class optical telescope with high resolution spectral and seeing-limited imaging capabilities at visible and near-infrared bands.

- Follow-up optical studies of sources identified in the radio region by Indian telescopes like GMRT and UV/X-ray instruments on ASTROSAT.

- Over 12 hours longitudinal gap over globe between the locations of 4-m class optical facilities – Indian site crucial for time-critical and multi-site astronomical observations.

- Synergy with the existing 2-m class optical observing facilities.

- Participation towards projects like LAMOST, TMT, etc

- Building up of technological know-how needs within the country for astronomy.

The 3.6m DOT Project Time-line

Telescope : March 2007 – March 2013

Telescope building : June 2014

AIV of telescope at Devasthal : Oct 2014 – March 2015

Al-Coating plant : Feb 2015

Dome Control software : March 2015

First light and acceptance tests : Dec 2015

Telescope Inauguration : Mar 2016

Available for scientific use : March 2017

Jan 2014

Feb 2014

Mar 2014

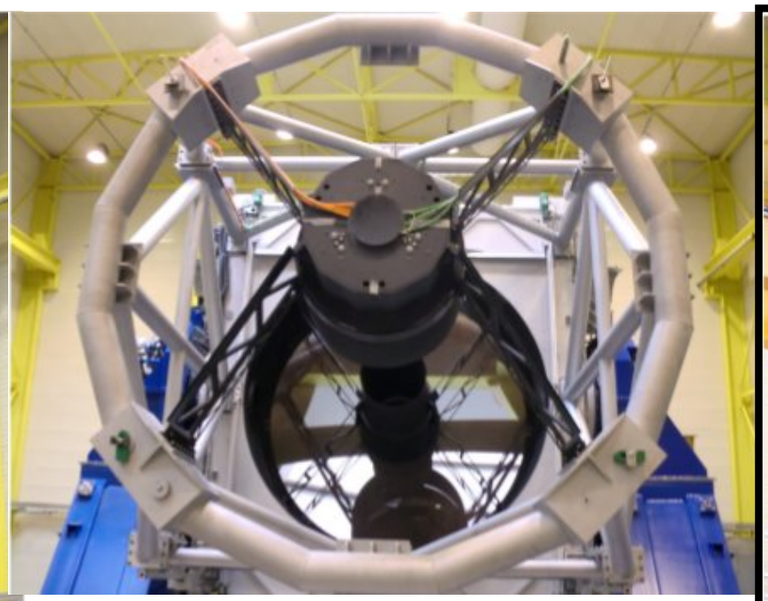
Apr 2014

May 2014

Jun 2014

Present

The 3.6-m DOT



Height : 13 m

Width : 7 m

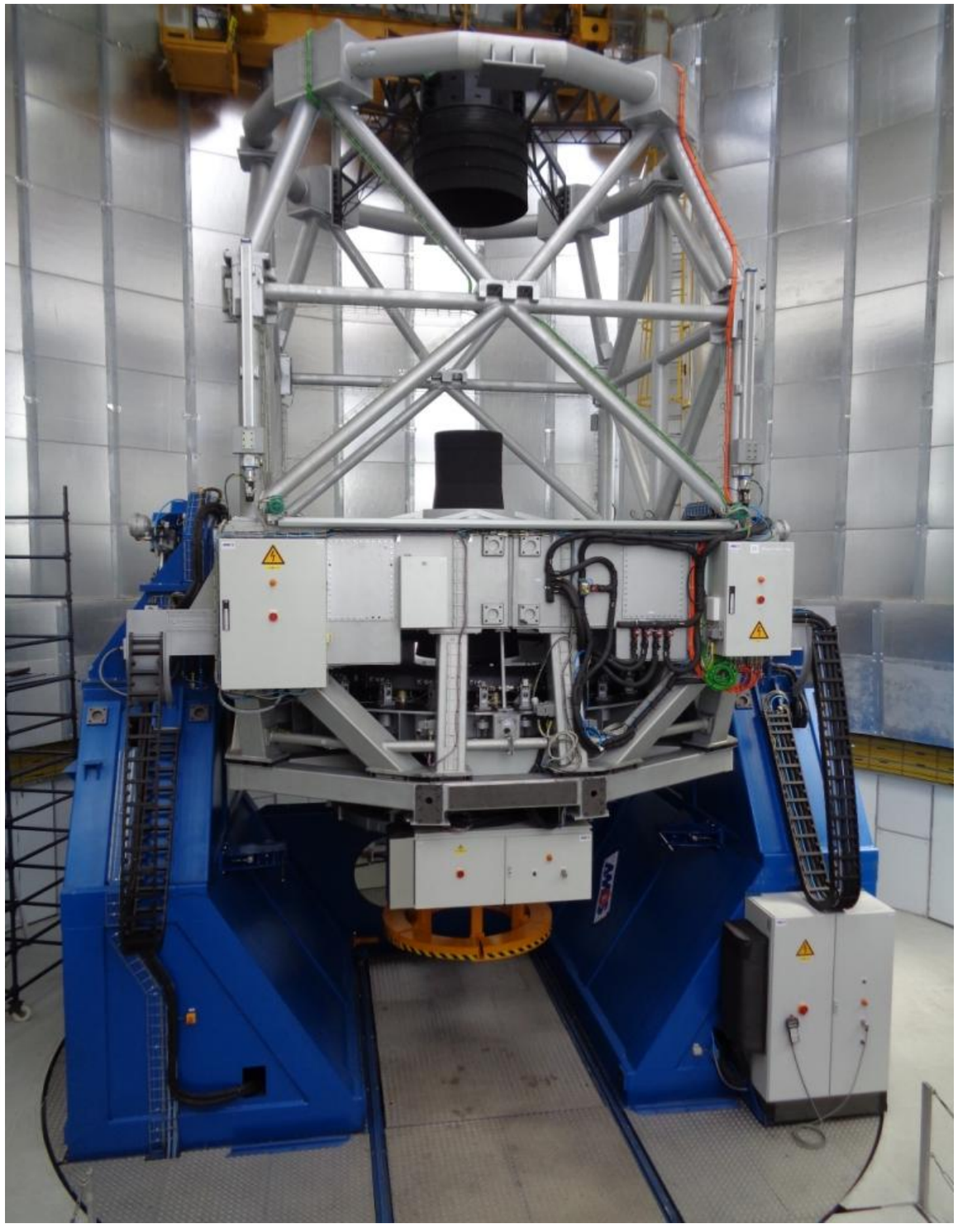
Weight : 150 ton

Telescope Time: Belgium – 7%, ARIES – 33%, Indian Astronomical Community – 60%

Assembly and integration of telescope at Devasthal

- Mechanical, electrical and optical Parts integrated

- Refurbishment and repair activities were also done

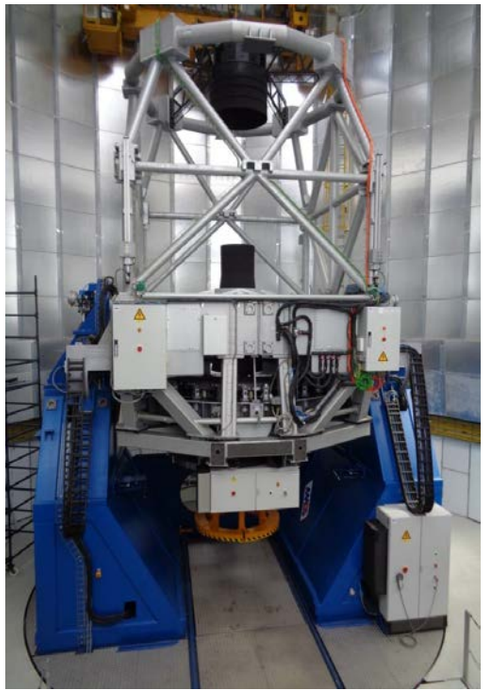


Installation of Aluminium coating plant
M1 Mirror coated successfully at Devasthal

Design consultancy : M/s PPS, Pune
Construction : M/s HHV, Bangalore

Reflectivity : 86%
Uniformity : 2 nm

KEY COMPONENTS



M1 Mirror blank from Germany
Mirrors are figured and polished by LZOS, Russia;

M1 Mirror coated by India

Telescope is manufactured and assembled by AMOS, Belgium

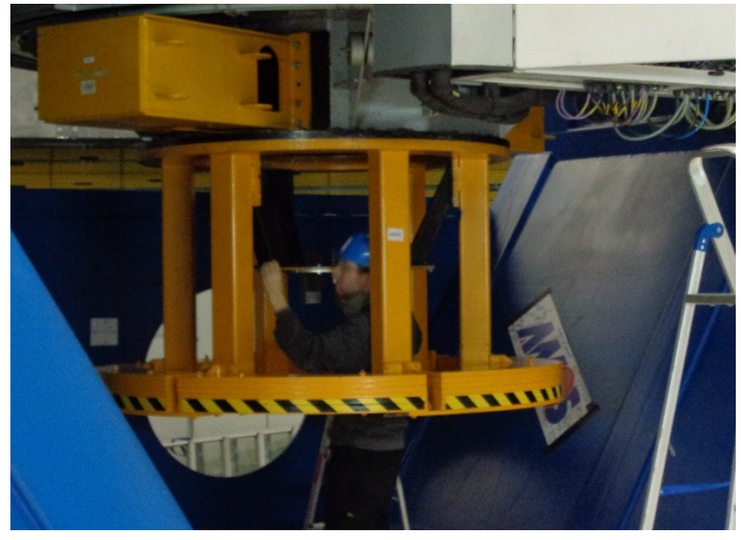
Telescope

Al-Coating

Enclosure

Observatory Control

Indigenous Resources



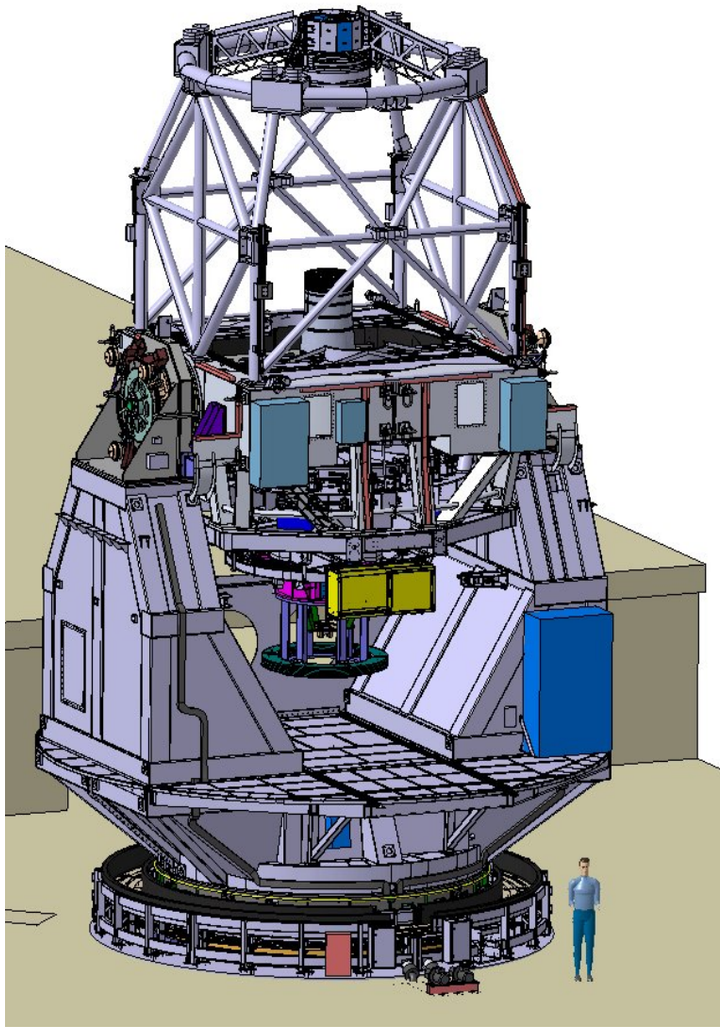
Instruments

The Telescope: Basic Configuration

- 80% encircled energy diameter in less than 0.45 arcsec
  (Not more than 10% degradation of 0.7 arcsec seeing)

- Compact (alt-azimuth) and seeing-limited (Active optics) Telescope

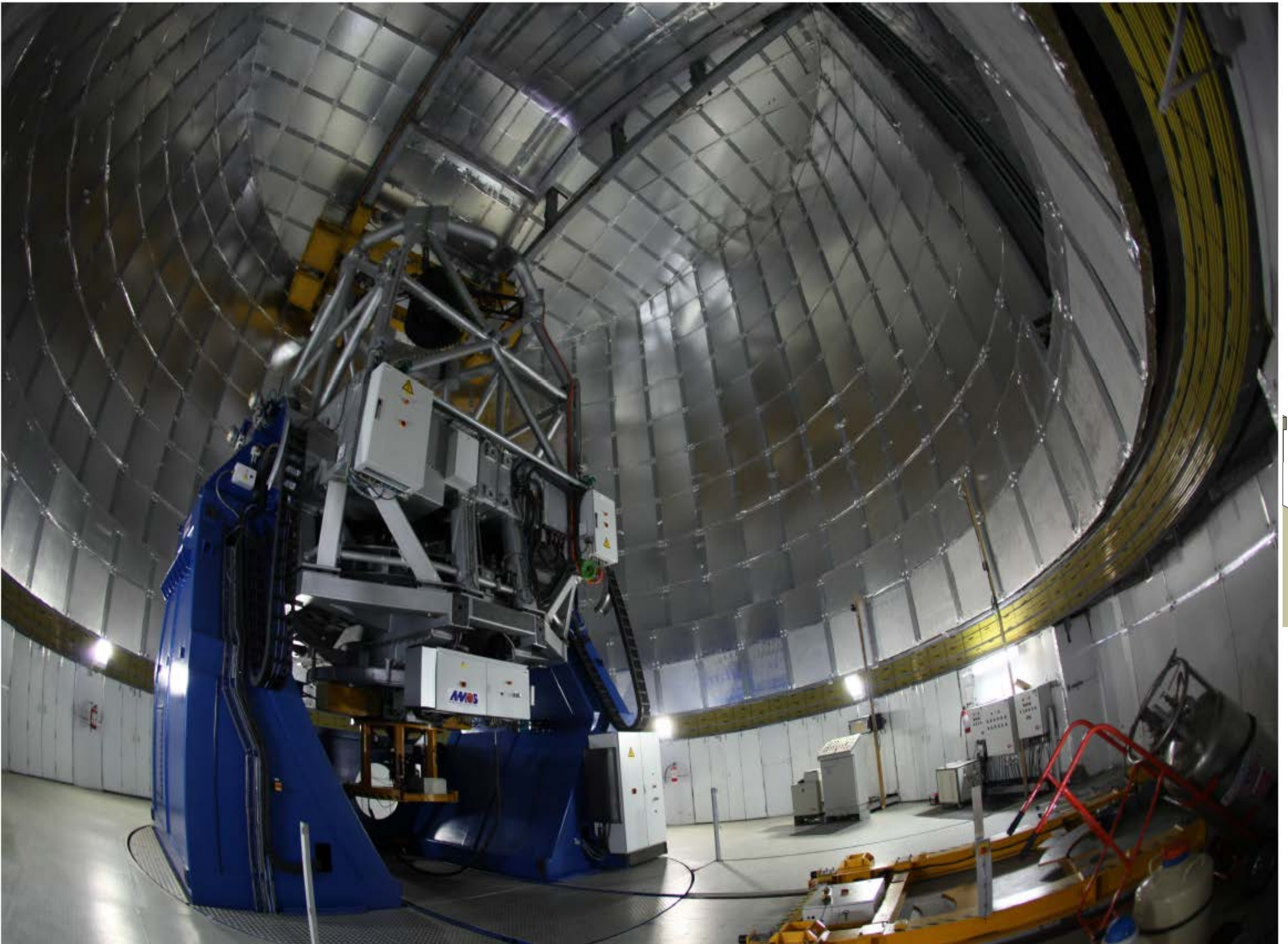
- Science field of view : half degree



- Pointing accuracy : < 2 arcsec RMS

- Tracking accuracy :
  < 0.1 arcsec rms in 1 min (without guider)
  < 0.1 arcsec rms in 1 hr (with guider)

- Image quality :
  E80 < 0.45 arcsec


AMOS

The telescope optics

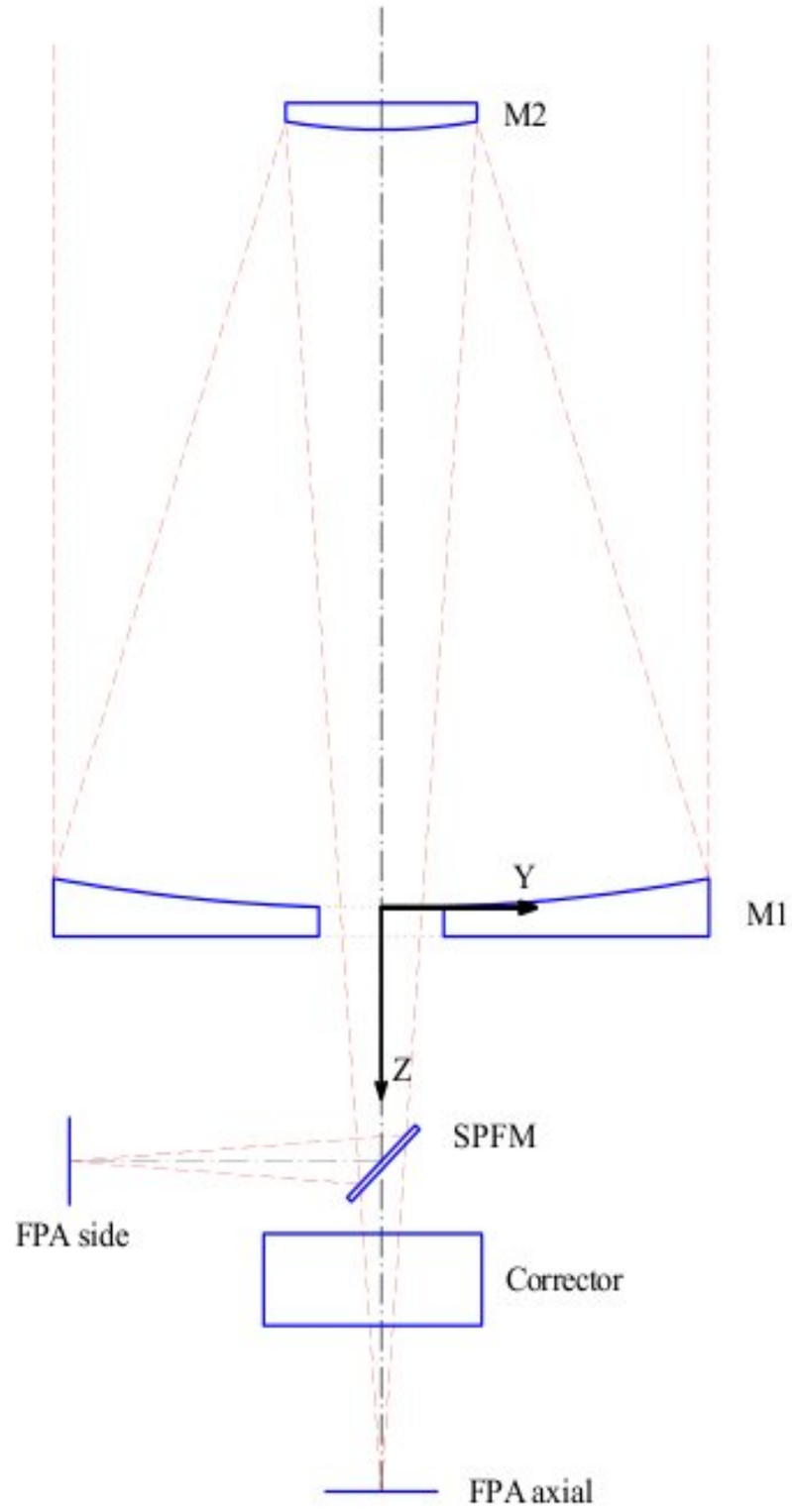
- F/9, Ritchey-Chretien

- 2 side ports, 1 axial port
  FoV : 10 arcmin on side ports
  : 30 arcmin on axial port

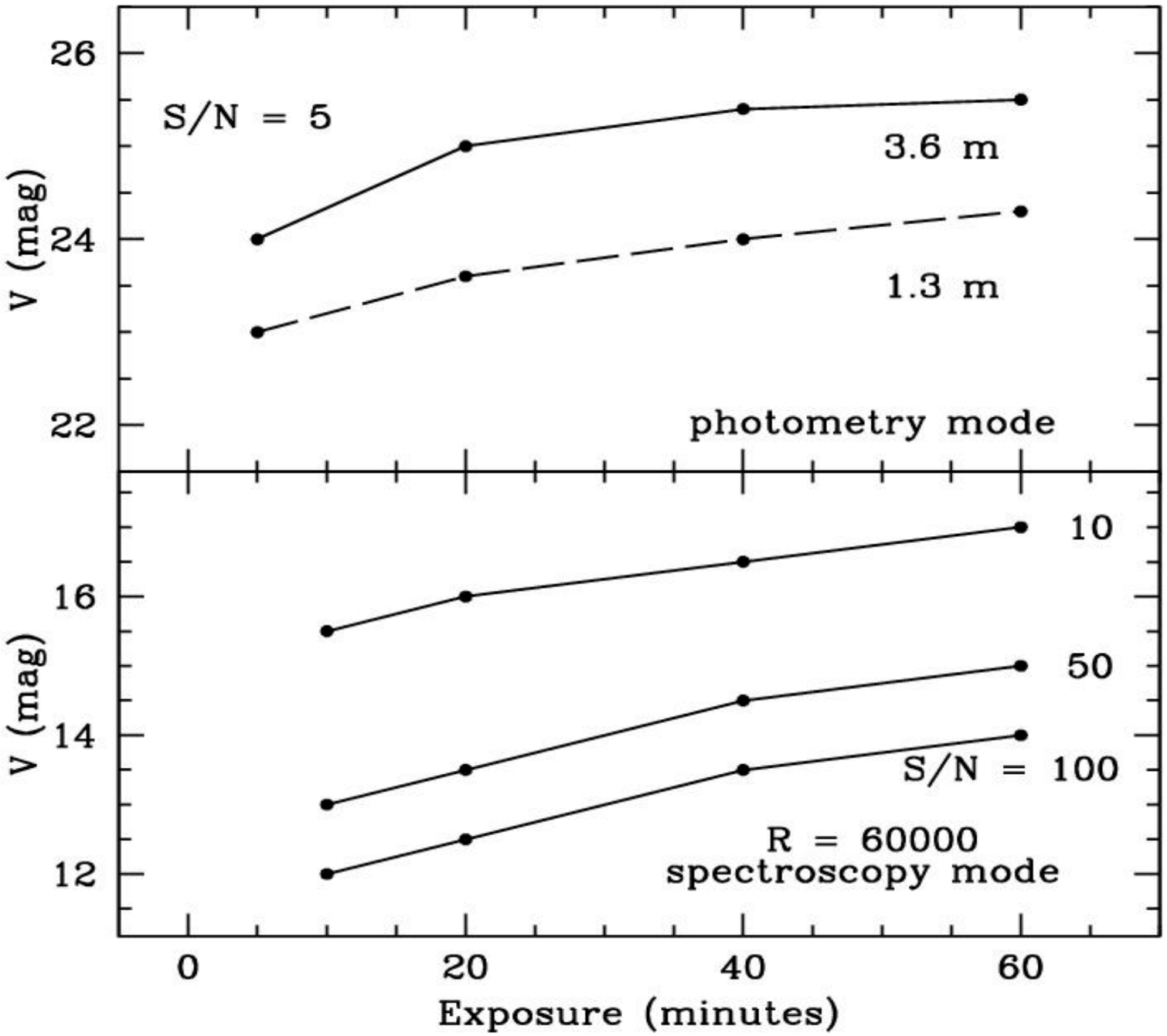
- 350 – 5000 nm

- M1 : 3.6m optical dia, F/2,
  RMS WFE < 40 nm
  M2 : 0.95m optical dia,
  RMS WFE < 30 nm

- Plate scale : 0.06 arcsec / 10 micron



Sensitivity of the 3.6m DOT



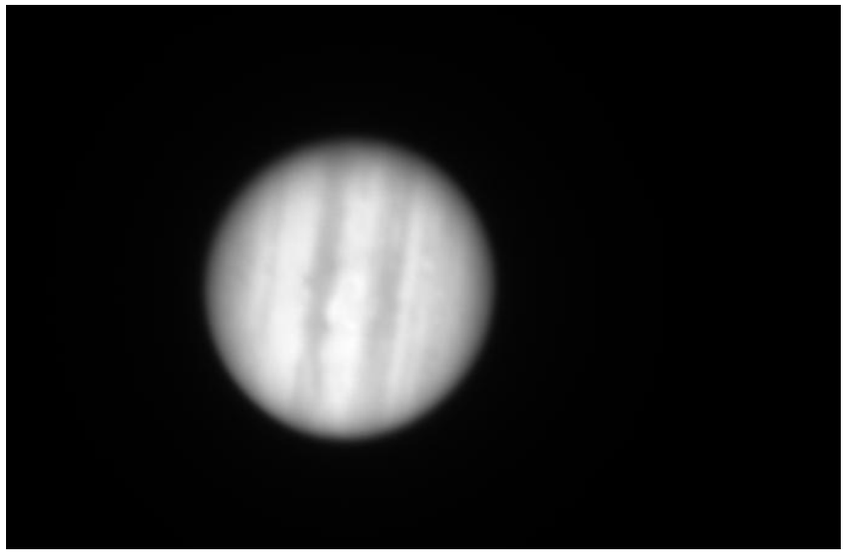
Seeing ::

1 arcsec FWHM

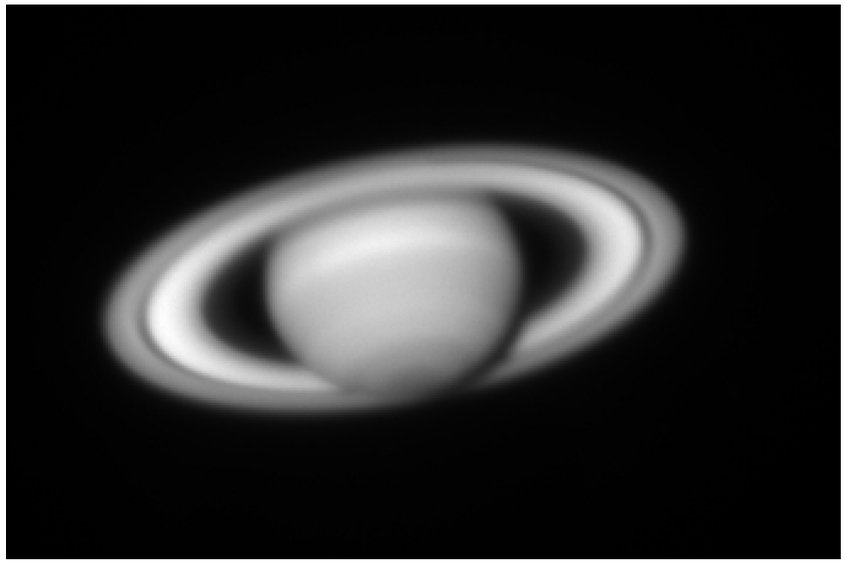
Extinction::

0.13 mag/airmass

On-sky Performance verification



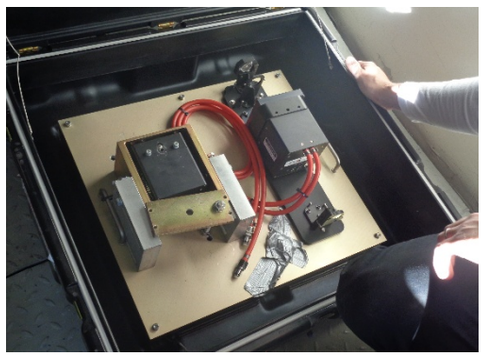
First Light :
22 March 2015



Instruments to test the performance of telescope

1 – AGU (Guider) Camera – Tracking/pointing

Microline ML 402ME
768x512, 9 micron px
Water cooled
60 x40 sq arcsec (TBC)
SNR of 30; 13 V-mag star in 2s



2 – Test Camera – tracking/pointing/IQ

Microline ML 402ME
768x512, 9 micron px
Air cooled
44x33 sq arcsec

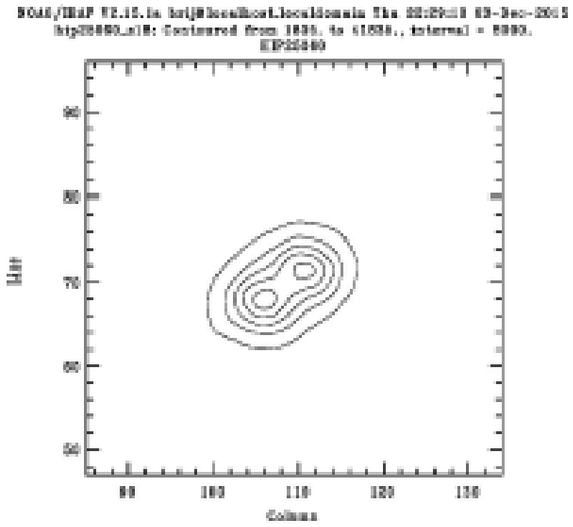
3 – AGU WFS - IQ /WFE

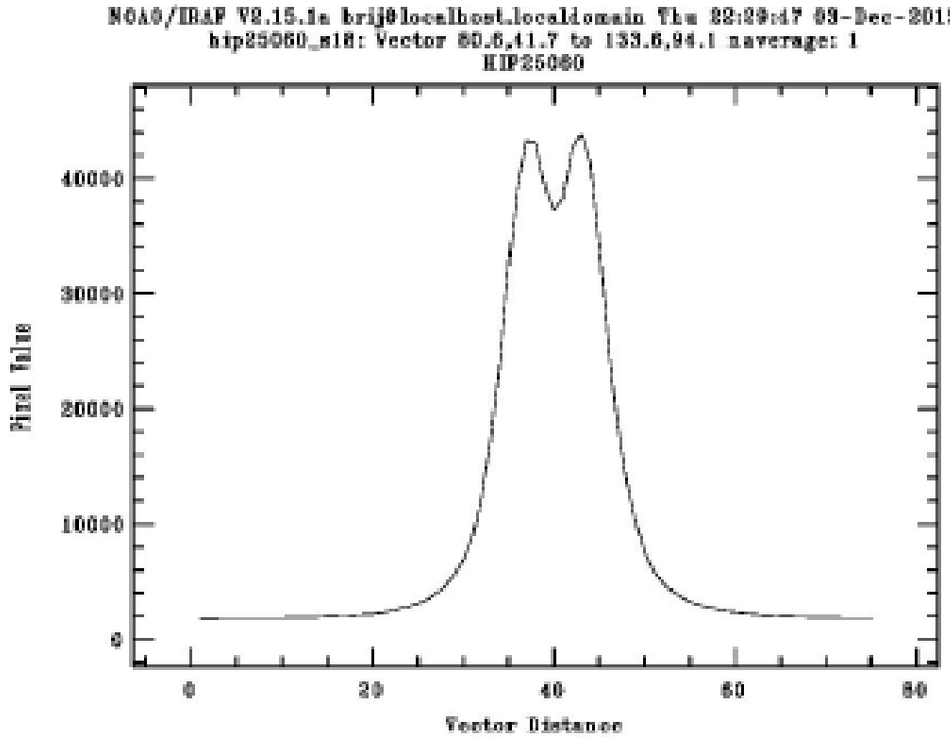
Microline ML4710-1-MB
1024x1024, 13 micron px
Pupil 12 mm
11x11 lenslet array

4 – Test WFS – IQ /WFE

Microline ML4710-1-MB
1024x1024, 13 micron px
Pupil 12 mm
33x33 lenslet array

HIP 25060 – double star
(with known separation ~ 0.37 arcsec)





First generation Instruments

CCD Optical Imager – axial port
(PI: S. B. Pandey)

- **4Kx4K, 15 micron CCD**
- **LN2 Cooled system**
- **Design and fabrication of filter automation done in-house**

FoV : 6.5 x 6.5 arcmin

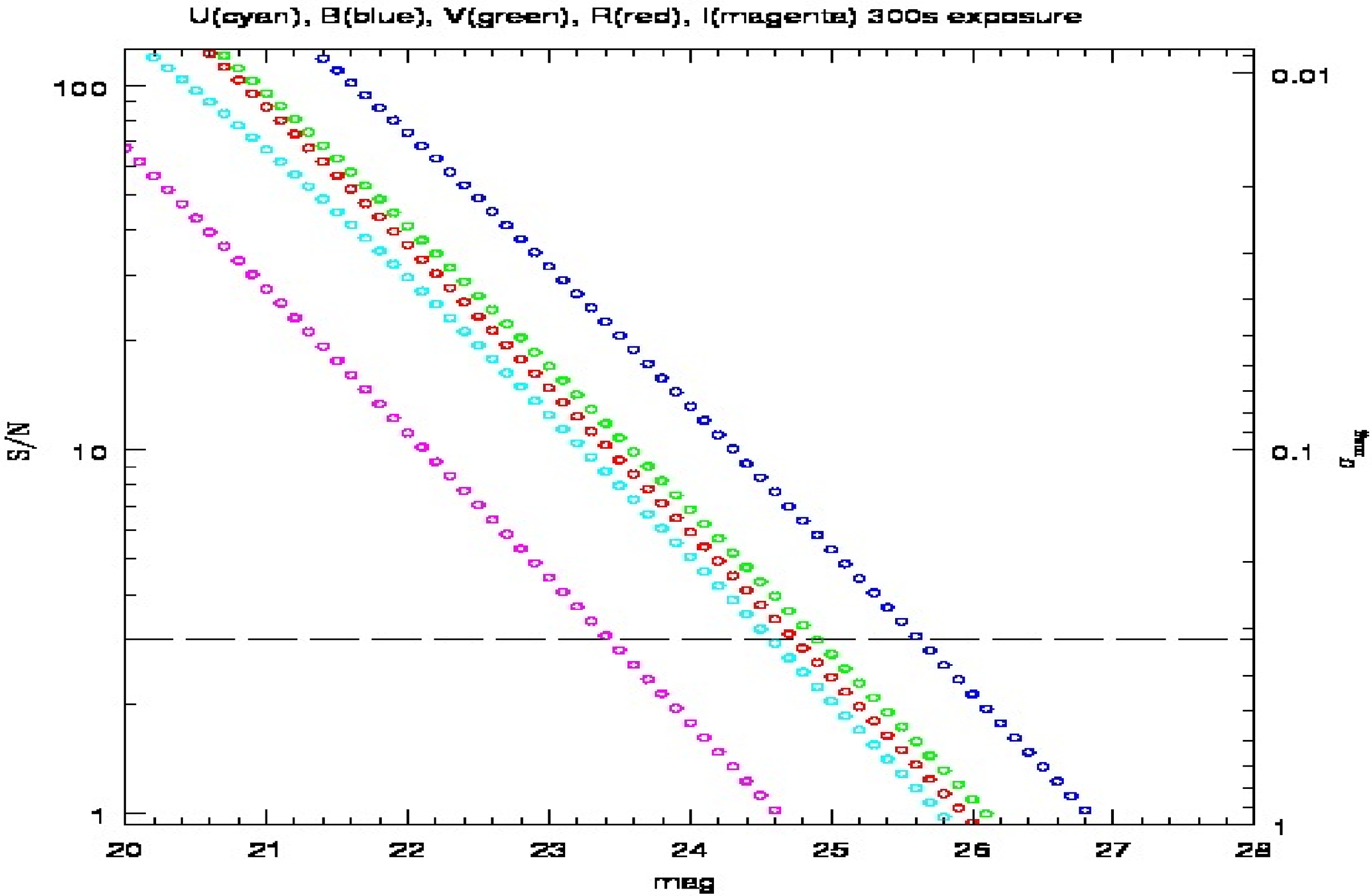
Filters : 10; Bessel UBVRI and SDSS ugriz

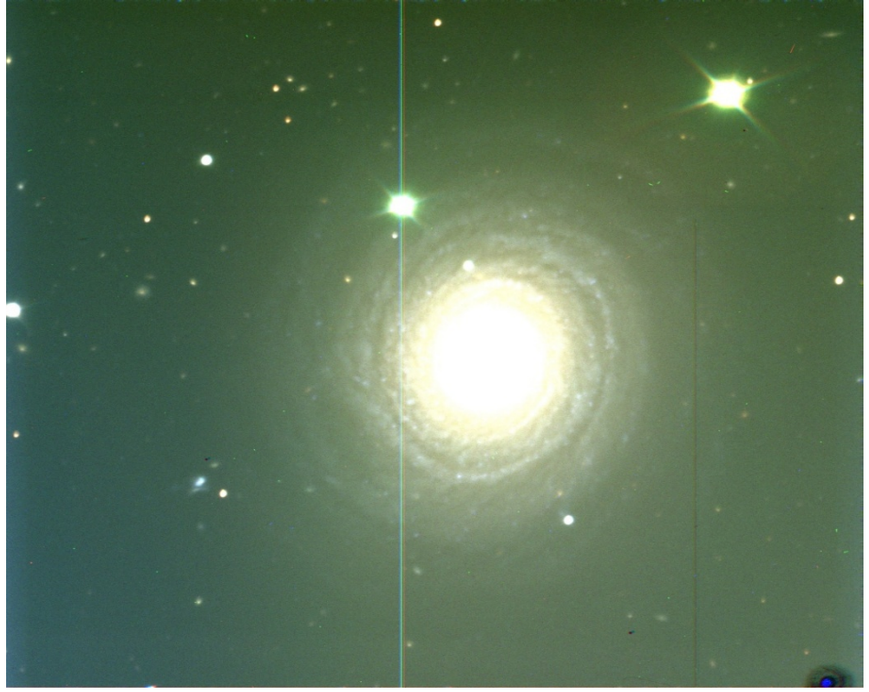
Scientific goals

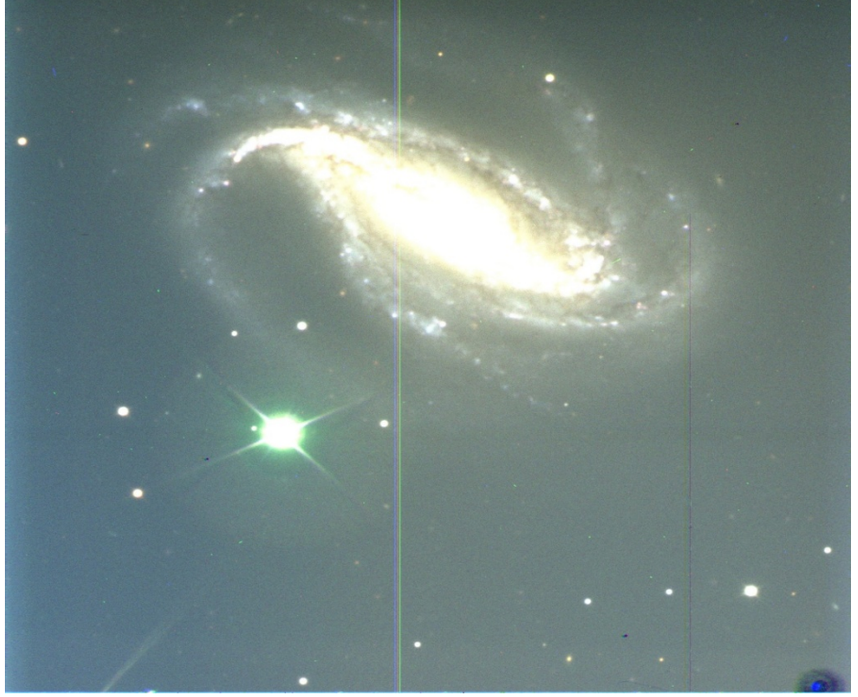
- ❑ **Variable stars and asteroseismology**
- ❑ **EUV-bright and soft X-ray sources**
- ❑ **Study of GRB afterglows and Supernovae**
- ❑ **Optical variability of AGNs**
- ❑ **Galaxy photometry**
- ❑ **Star clusters**
- ❑ **PMS stars in young clusters**
- ❑ **Interacting binary systems**
- ❑ **Other scientific goals (optical follow-up of GMRT, ASTROSAT and ILMT sources)**

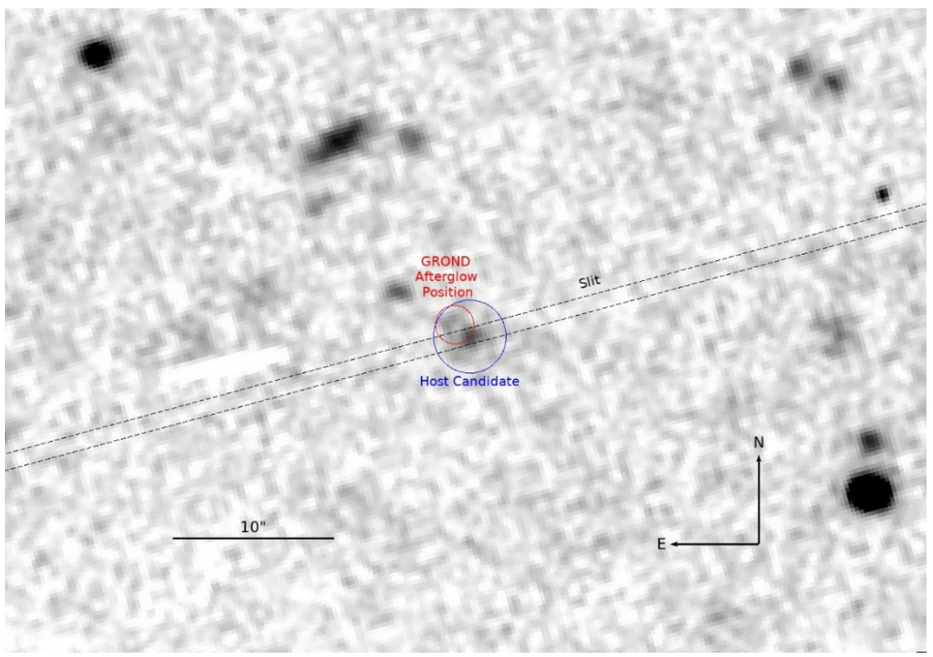
Name of CCD parameters	Values	Comments
Read out Speeds/Noise	100 KHz, 500 KHz, 1 MHz/2-3 e, 4-5 e, and 7-8 e respectively	GUI selectable
Gain	1,3,5,10 e/ADUs	GUI selectable
Binning	2x2,3x3 and 4x4	GUI selectable as per seeing and other requirements for better S/N
CCD chip	4096X4096 pixels, 15 micron each pixel	16-bit LN2 cooled blue-enhanced CCD by STA-USA, one could choose over-scan area for better noise information with each frame

Sensitivity of CCD Imager with 3.6m telescope for 300s exposure









GTC 10.4m r-band finding chart of SGRB 170428A

SGRB 170428A (z@0.45), R-band, 300 sec, ~ 10.5 hours post-burst: R ~ 21.9+-0.15

(astrometry gives RA ~ 22:00:18.5, Dec ~ +26:54:56.4, embedded host?)

First short-duration GRB detected by the 3.6m DOT

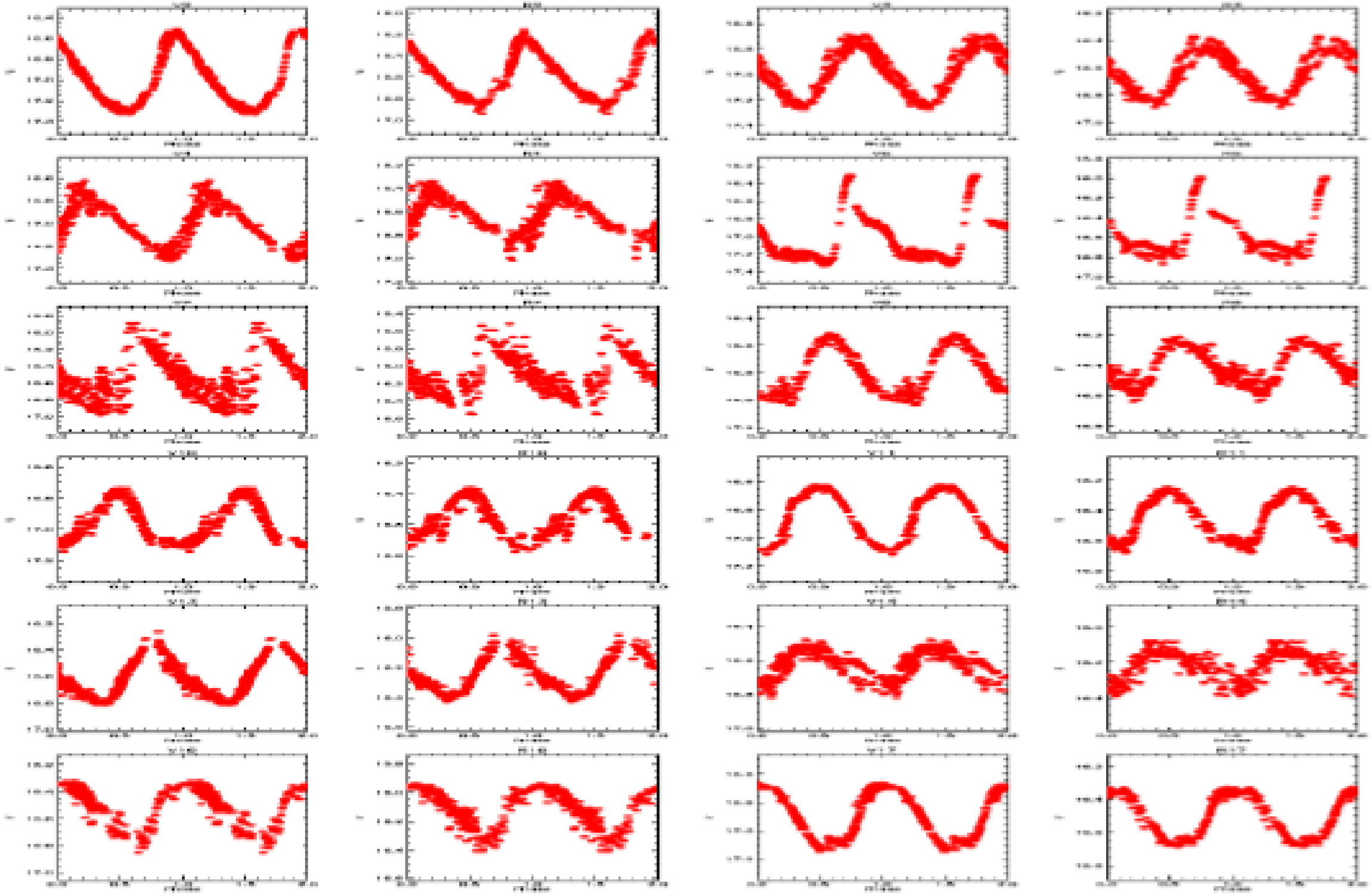
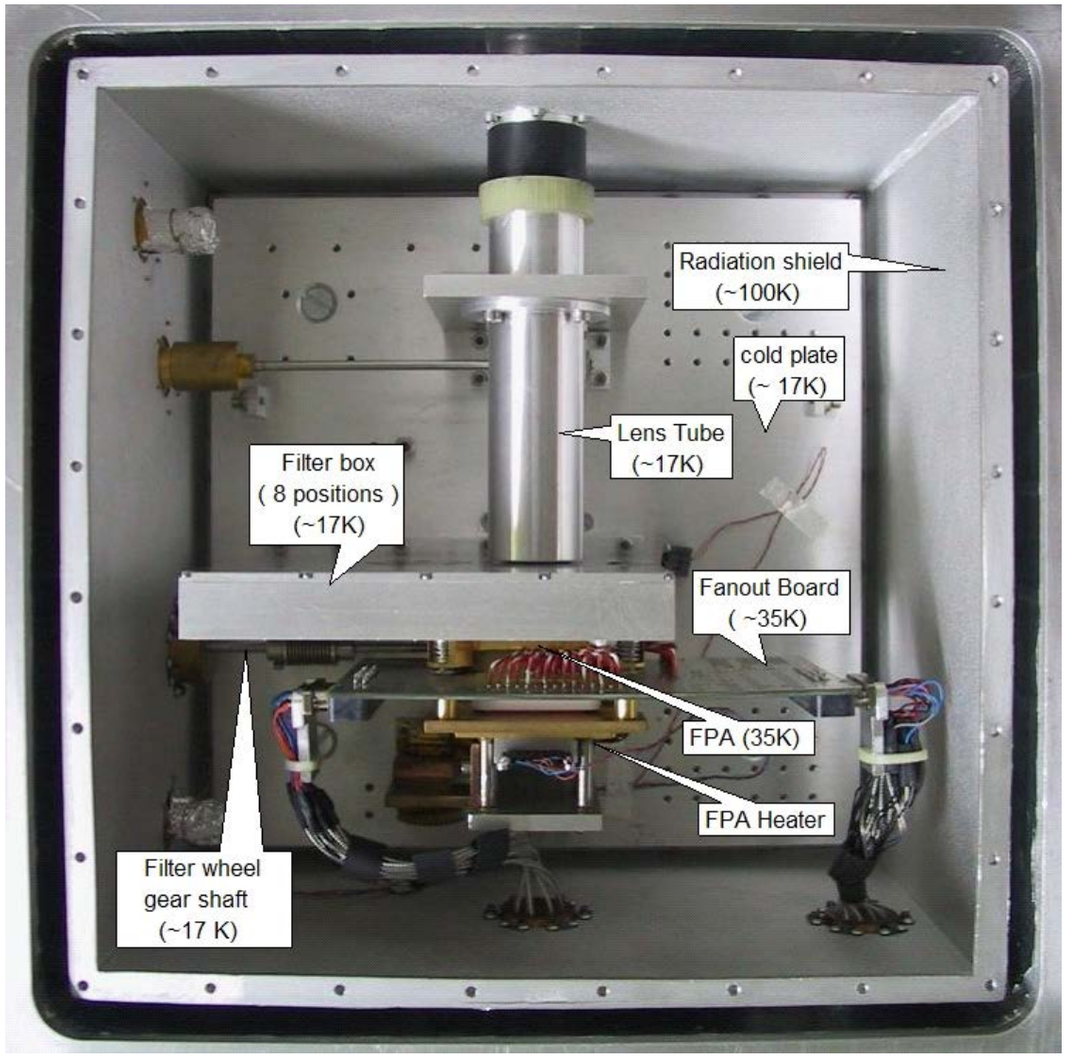
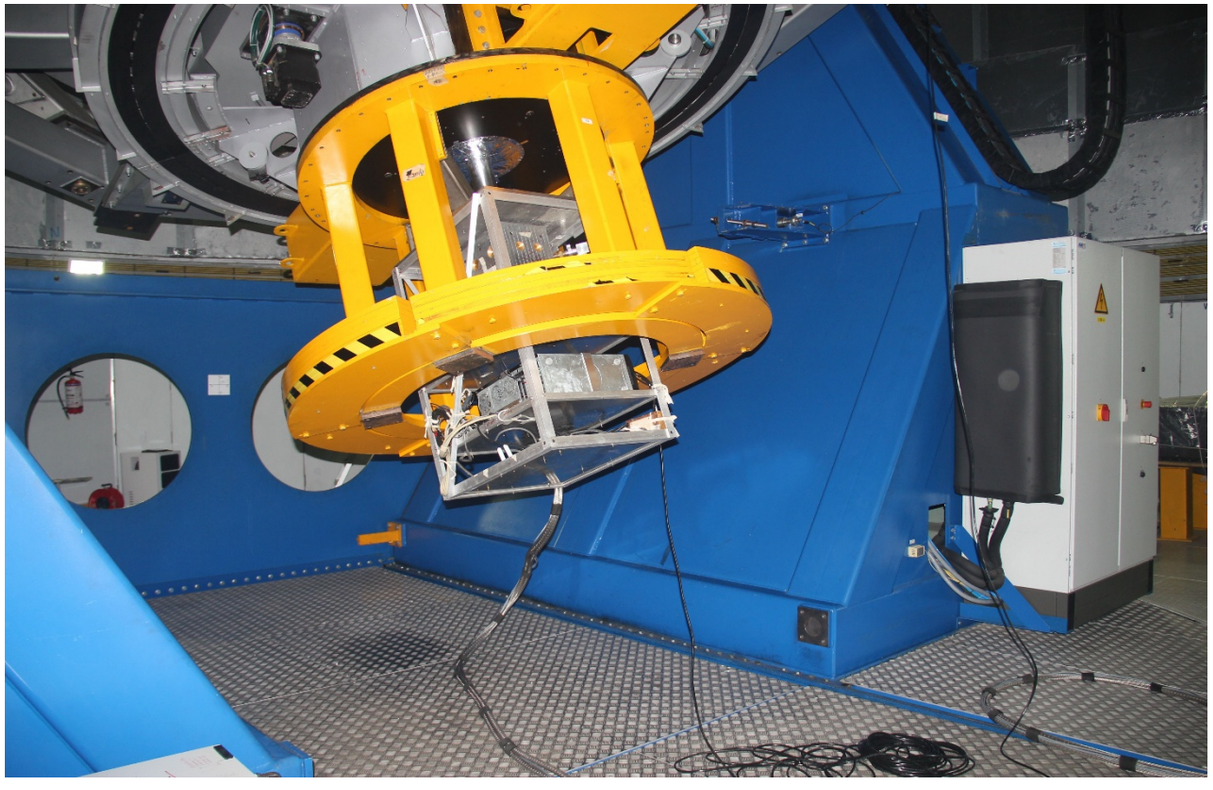


Figure 6: Examples of lightcurves of several variable stars as observed in the field of the Globular cluster field NGC 4147. The lightcurves have a range of periodicities and brightness as expected in case of such older clusters. The data and calibration results presented in this report will be published soon.

TIRCAM2 (TIFR Near Infrared Imaging Camera – II) - Axial port



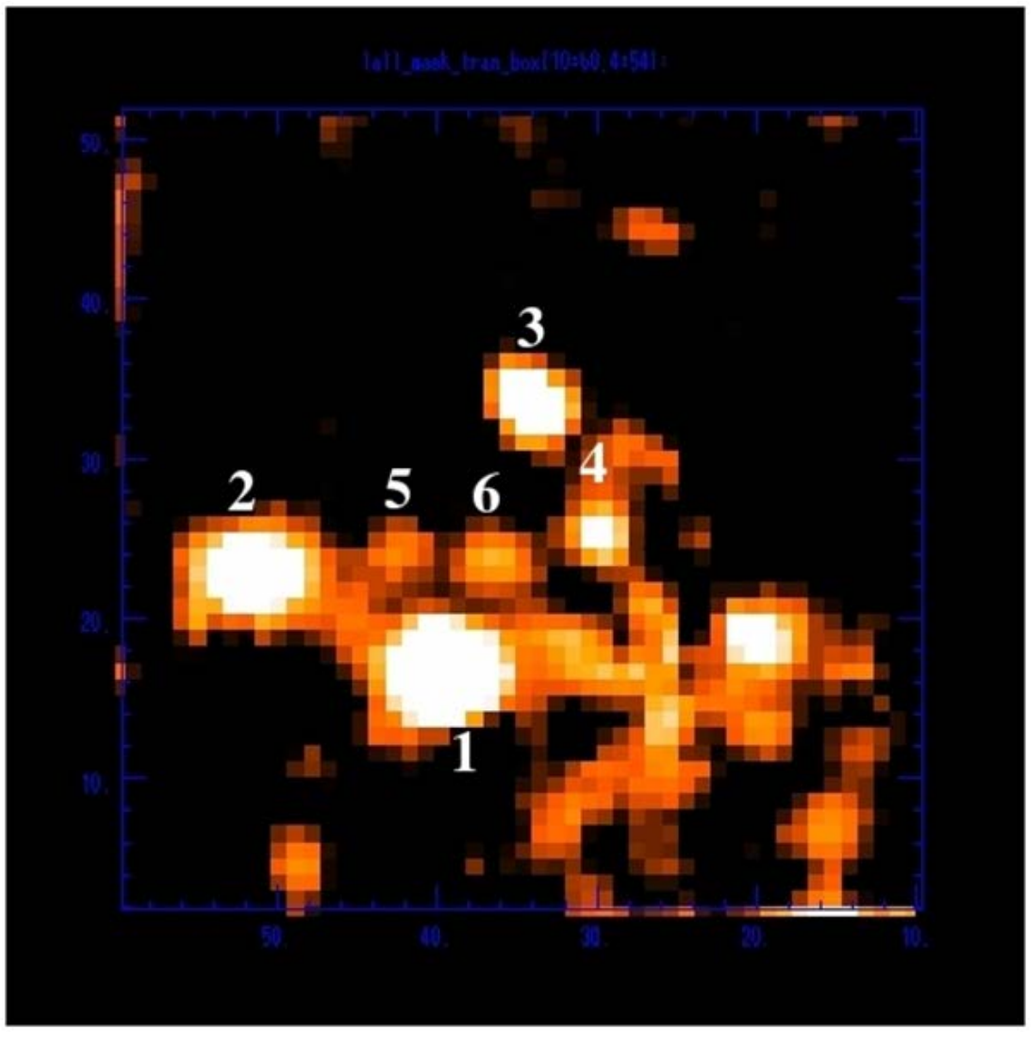


FoV (DOT) ~ 86.5 x 86.5 arcsec^2
Pixel Scale ~ 0.169 arcsec/pixel

TIRCAM2: Available filters

Filter	λcen (μm)	Δλ (μm)
J	1.20	0.36
H	1.60	0.30
Br-Gamma	2.16	0.03
K	2.19	0.40
Kcont	2.17	0.03
PAH	3.27	0.06
nbL	3.59	0.07

(TIFR Near Infrared Imaging Camera-II)



L' band image of Trapezium (3.9 μm)

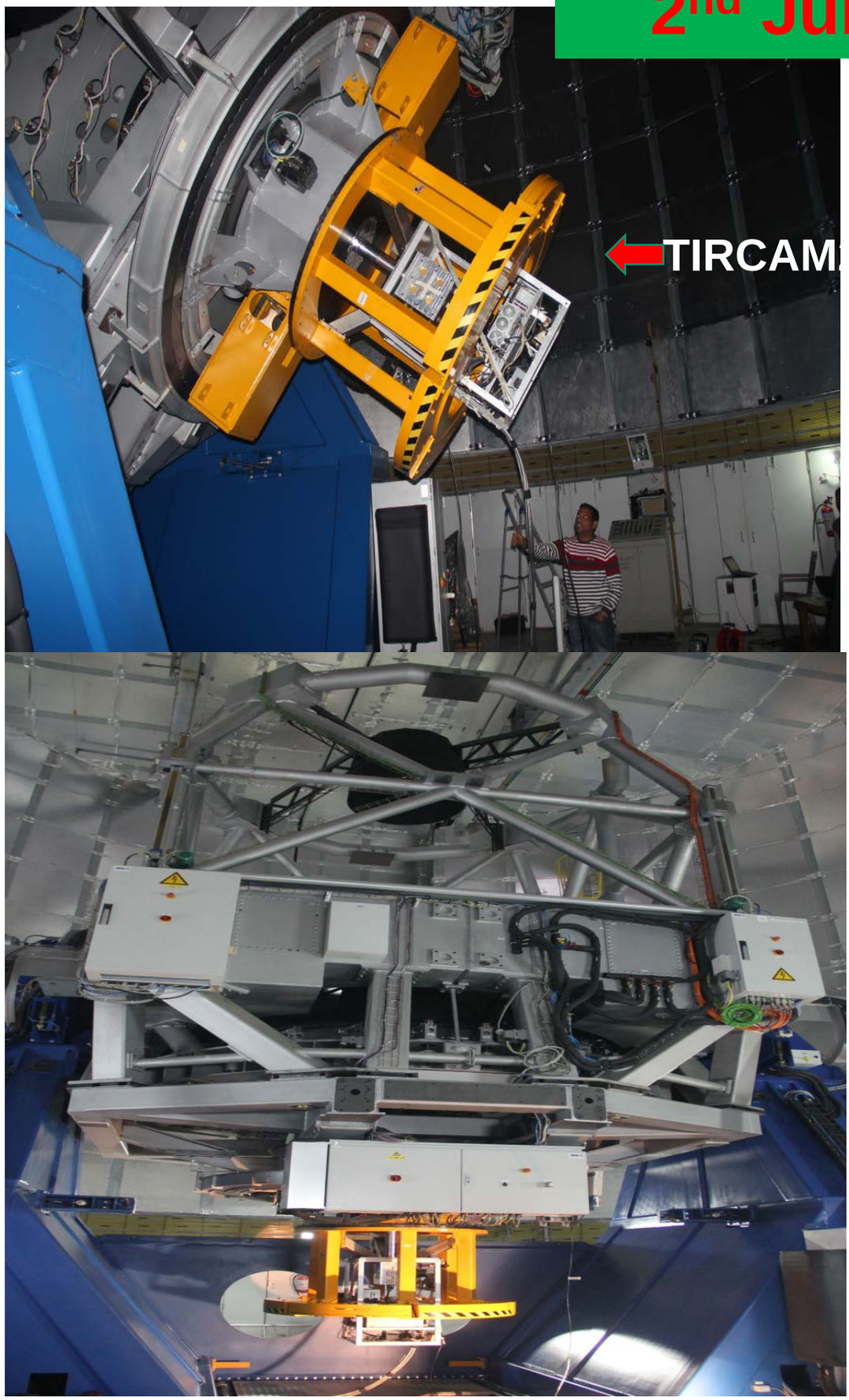
TIRCAM2@ DOT (achieved Sensitivity):

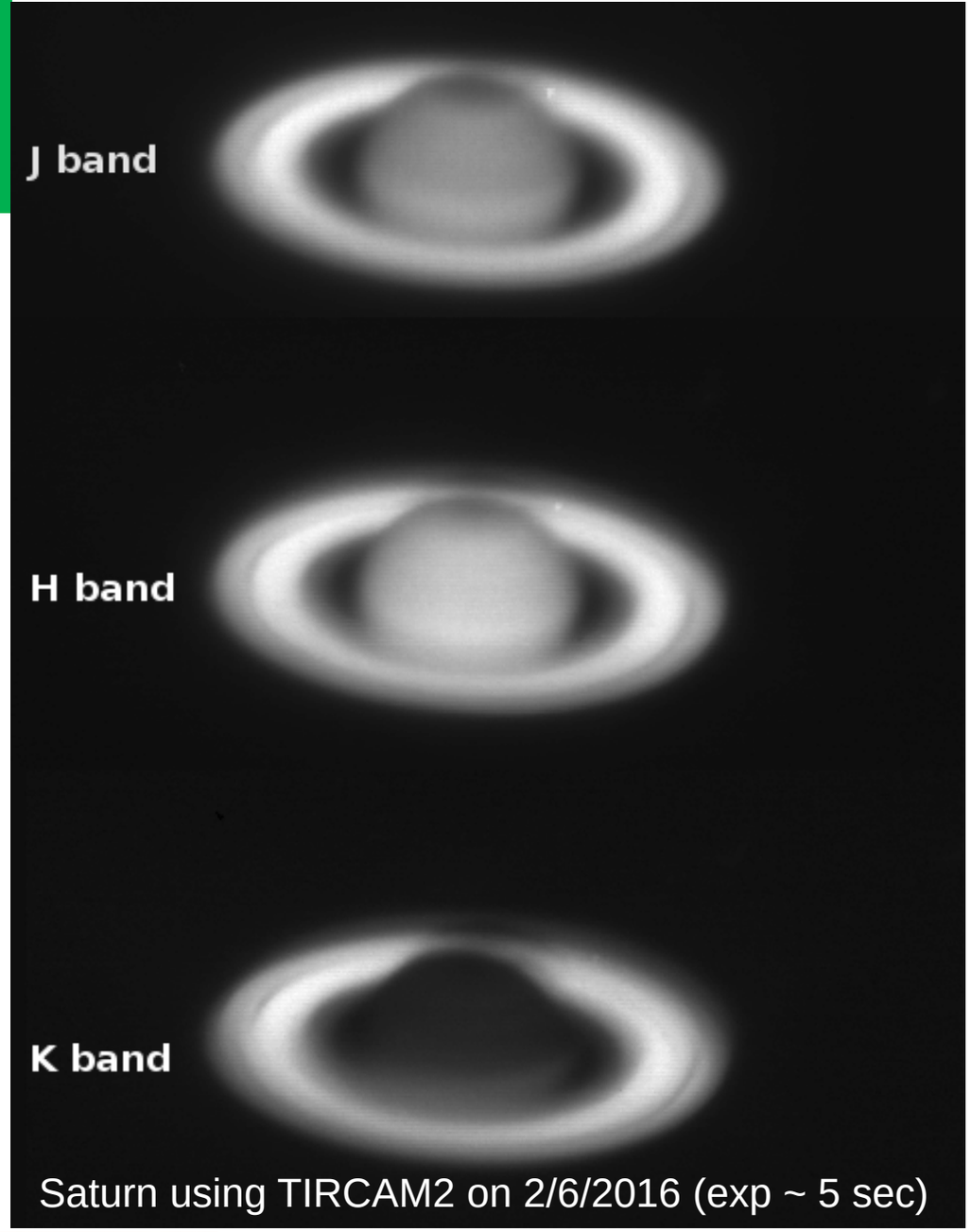
19 mag in J (S/N ~ 10; 550s)

18 mag in K (S/N ~10; 1000s)

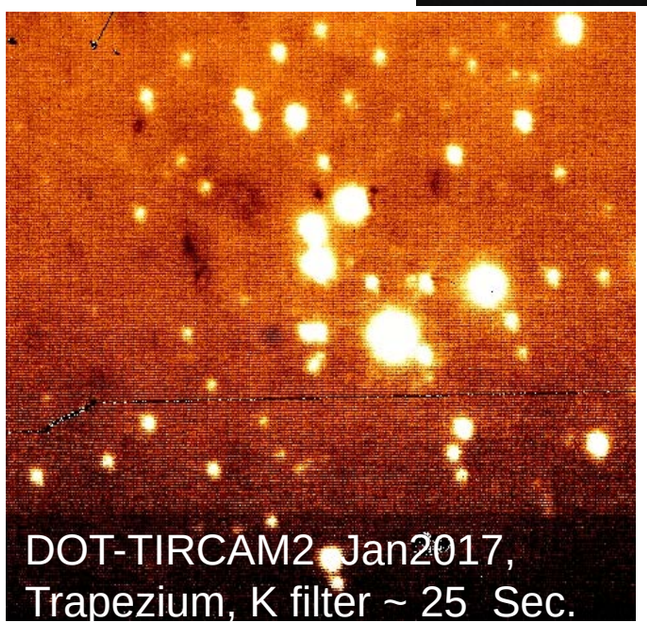
8.2 mag in nbL band (detection limit; 20s) in a typical seeing condition at DOT.

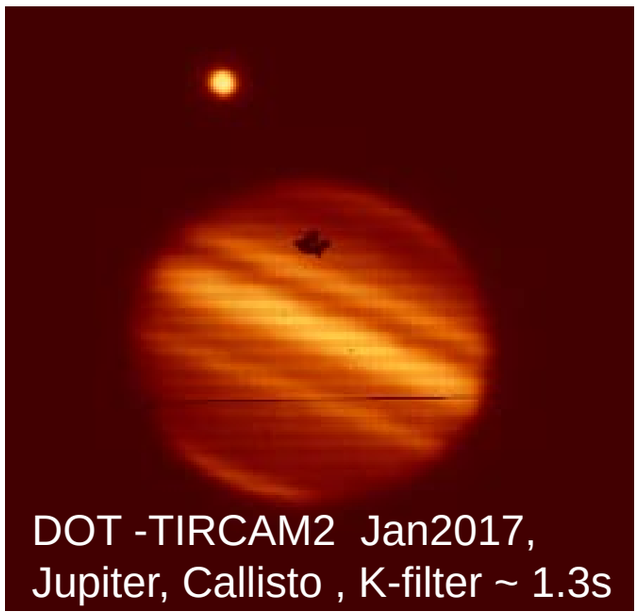
First Light on DOT
2nd June 2016



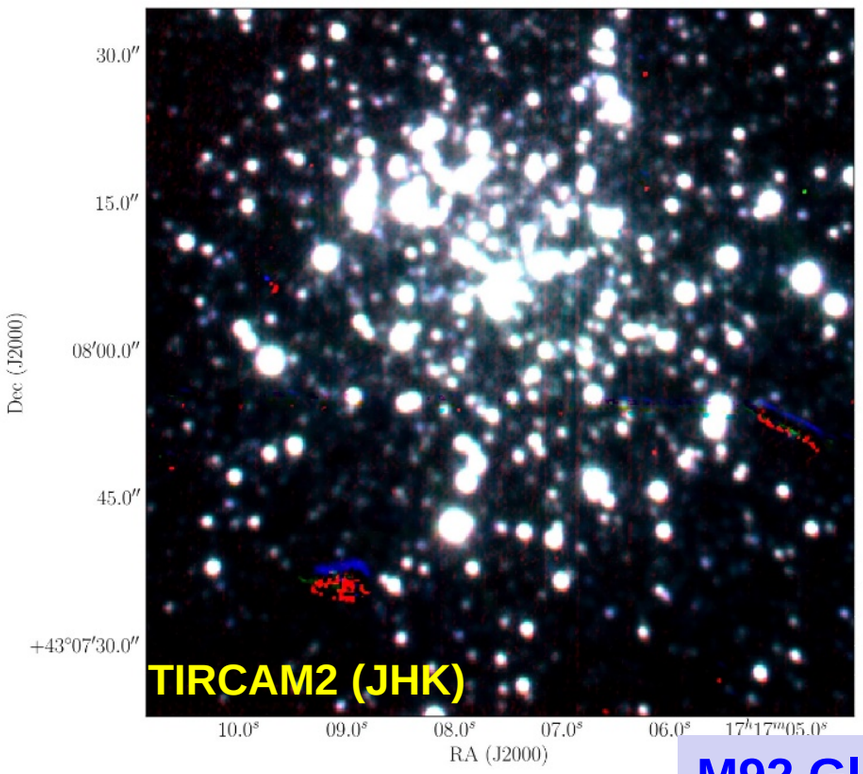


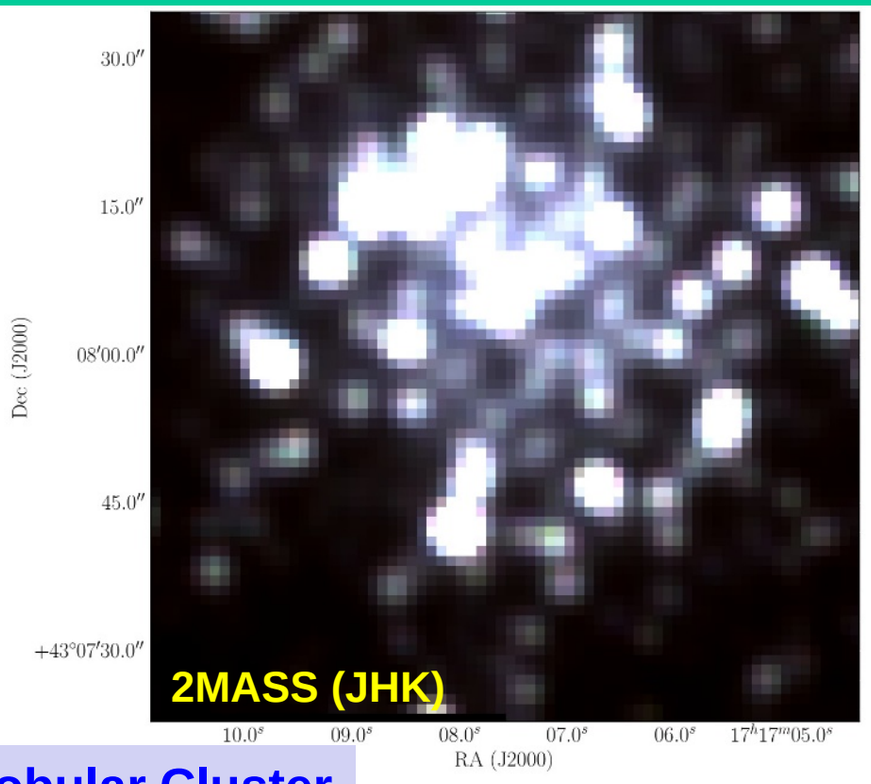
Saturn using TIRCAM2 on 2/6/2016 (exp ~ 5 sec)


DOT-TIRCAM2 Jan2017,
Trapezium, K filter ~ 25 Sec.

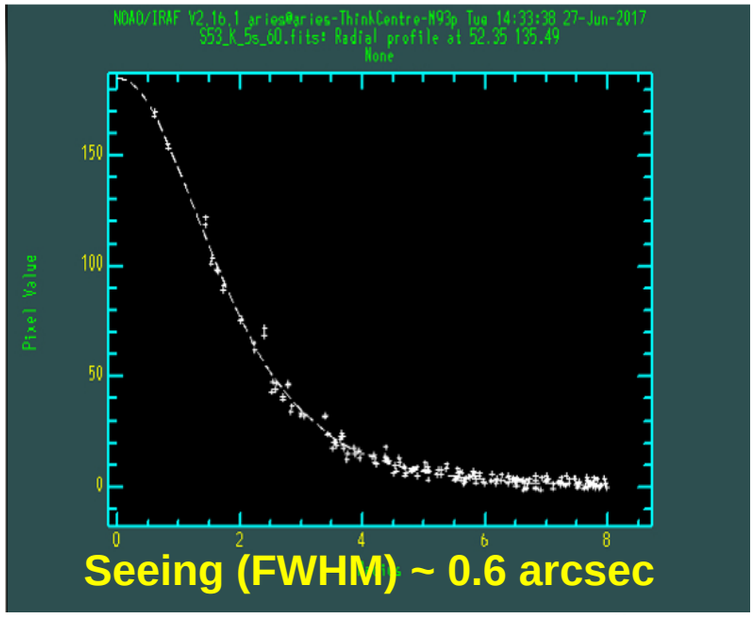

DOT -TIRCAM2 Jan2017,
Jupiter, Callisto , K-filter ~ 1.3s

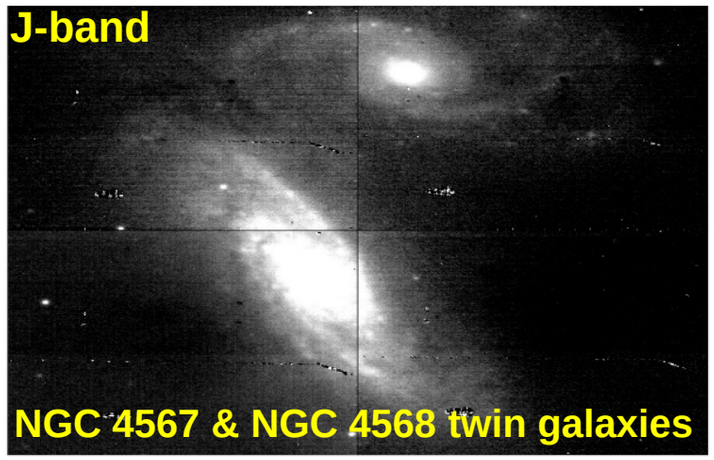
TIRCAM2@DOT : Cycle 2017A - Early Science Results (May 2017)

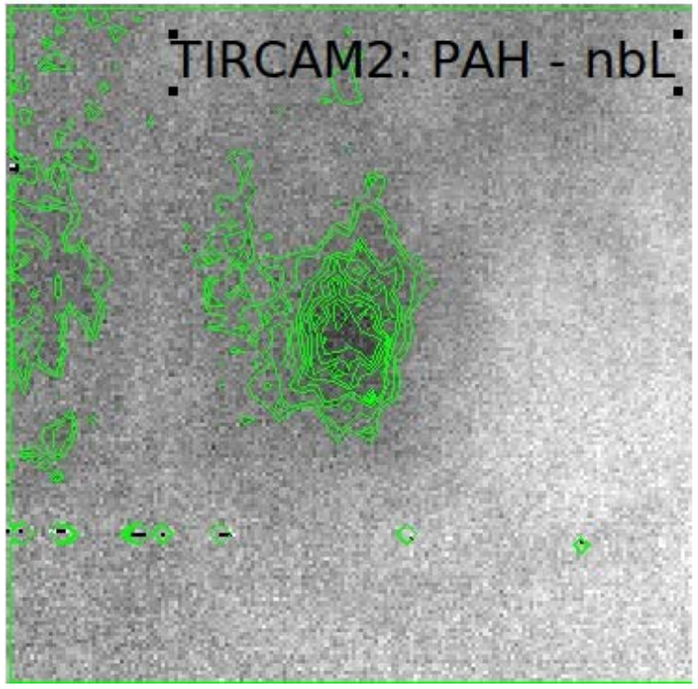


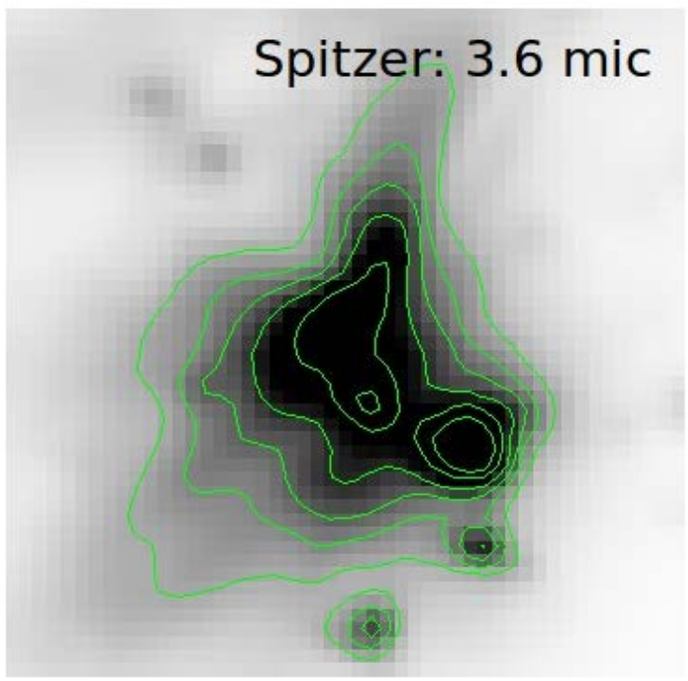


M92 Globular Cluster

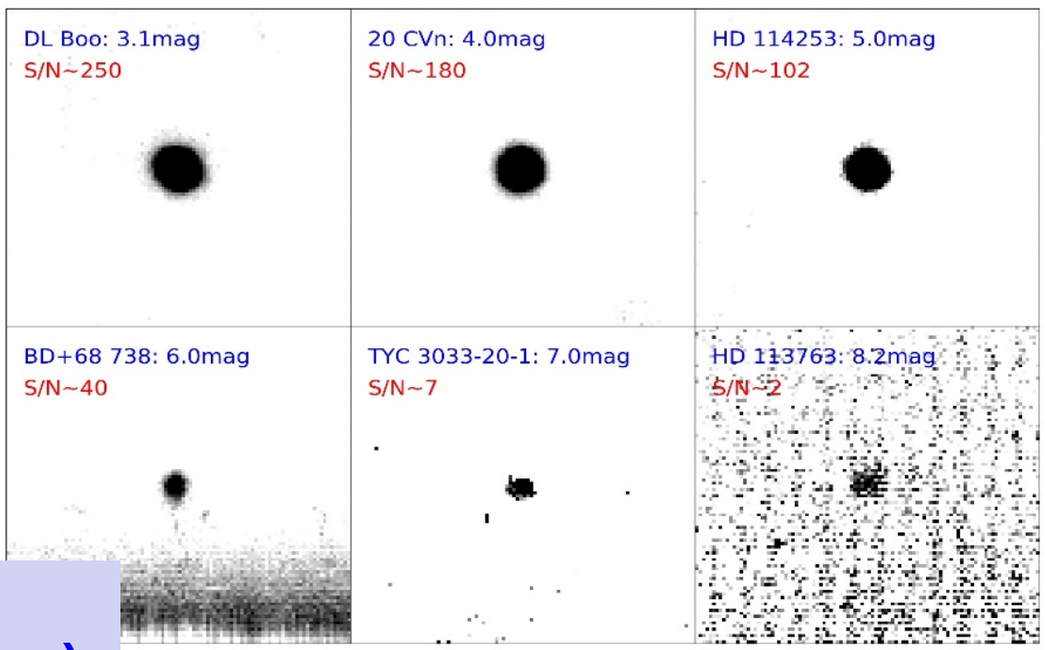








Sh 2-61 SF region



Mosaic of nbL band (3.59 μm) images(Detection nbL ~ 8.2 mag)

Second generation Instruments

Faint object spectrograph and Camera – axial port (PI: Amitesh Omar)

FOSC is a versatile instrument, which enables one to do spectroscopy, imaging, and also polarimetric observations of faint celestial objects.

Wavelength range : 350-900 nm

Imaging mode :
- FOV : 14 x 14 arcmin
- Broad and narrow band filters
- 0.2 arcsec pixel resolution, 4k CCD chip

Long-slit spectroscopy mode :
- Resolution : 250-2000
- Normal and VPH gratings

FOSC for the 3.6 meter Devasthal Optical Telescope (DOT) is designed, developed and assembled by ARIES with inputs from various organizations like ISRO, IUCAA, IIA, and several industries.

Expected Science capabilities

FOSC should enable

•Narrow-band (Hα, Hβ) and broad-band photometry

•Photometry down to R=25 mag objects

•Low resolution (R~800) slit spectroscopy down to 20 mag

•Fast (millisecond) multi-color (prism dispersed) photometry using EM CCD camera

•Field of view ~ 14 arcmin on 4kx4k (62 mm) CCD

•Sampling ~ 0.2 arcsec / pixel.

- First engineering light was obtained in May, 2016 using a small CCD camera.
- Full engineering tests and science verification observations using DOT are scheduled during Nov 04 -11, 2017.
- Thereafter, regular or shared-risk observing mode science observations will be advertised.

IMAGE4.FIT_0

(pixels)

2500

2000

1500

1000

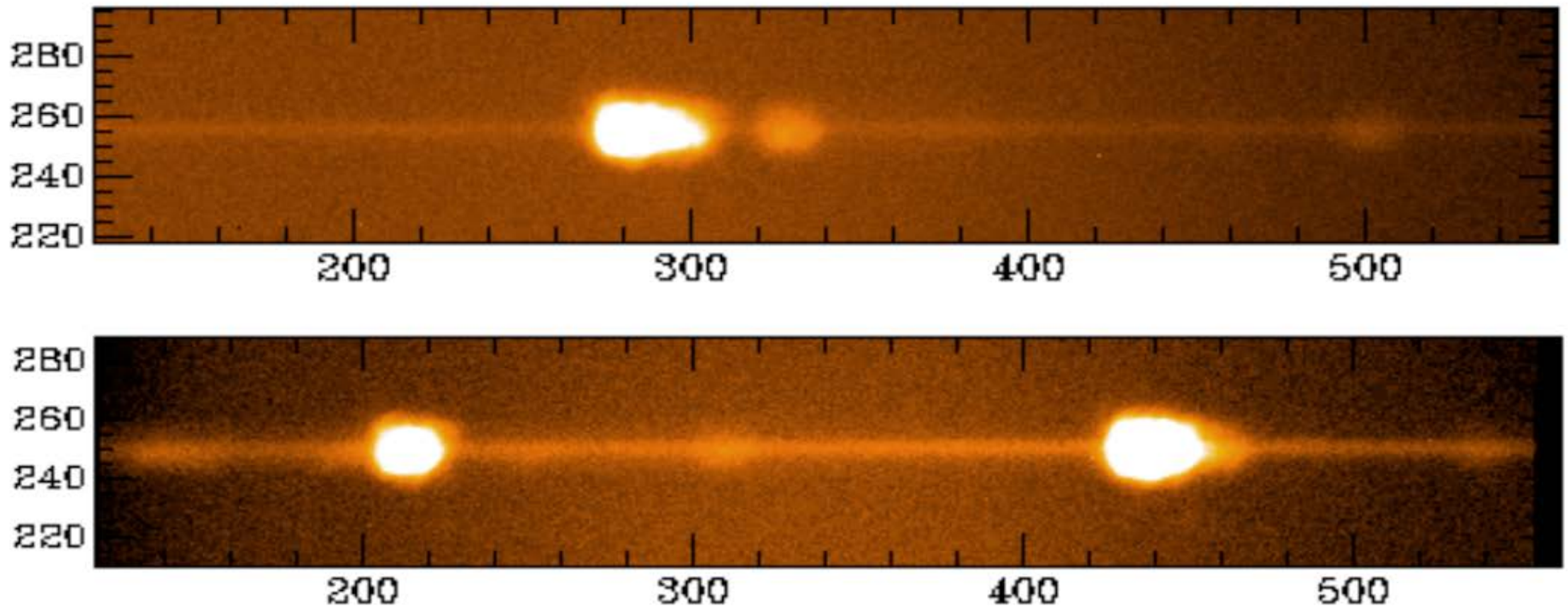
500

1000

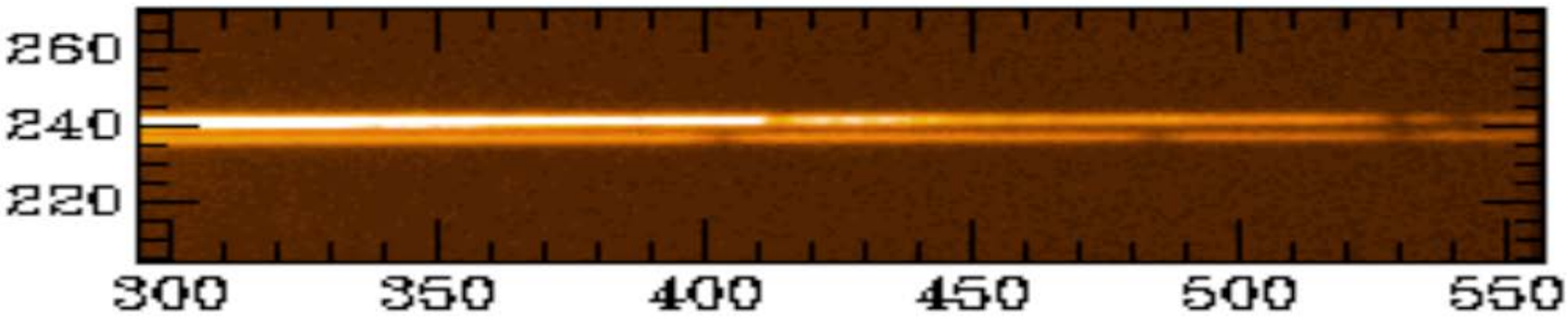
2000

3000

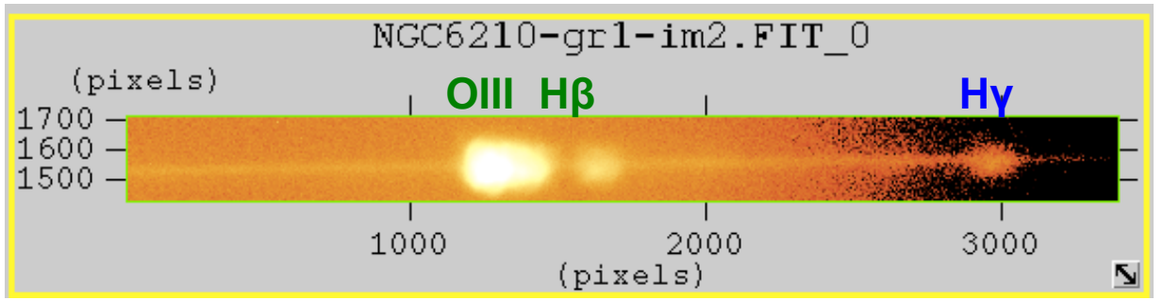
(pixels)

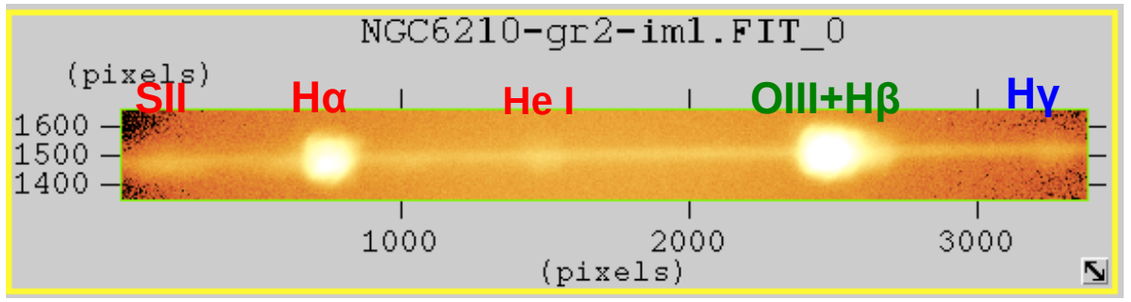


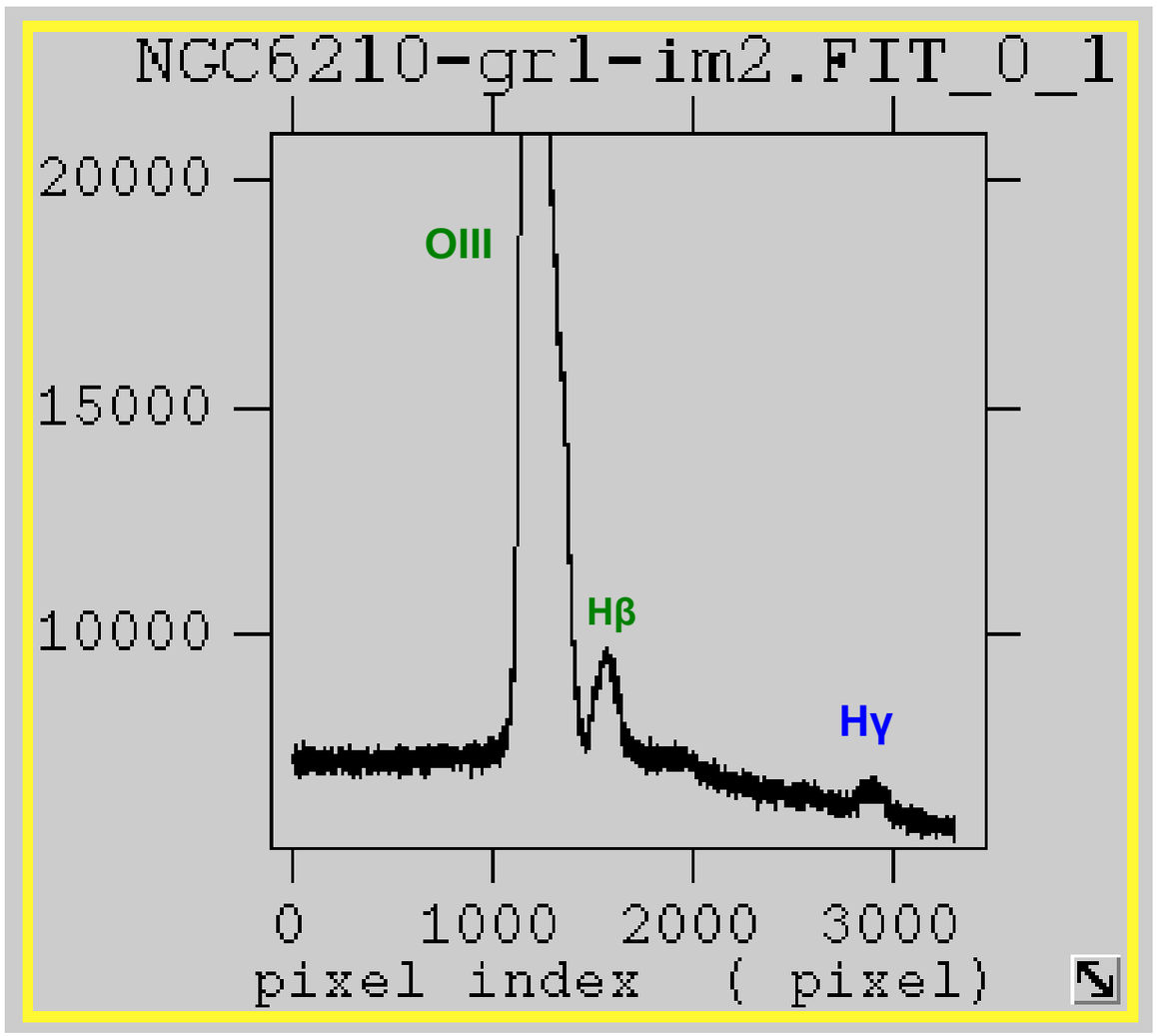
[The slit-less spectrum of the planetary nebulae NGC 6210 obtained with grism-1 (300 gr/mm, top) and grism-2 (420 gr/mm, bottom). The emission lines are detected, typical of planetary nebulae.]

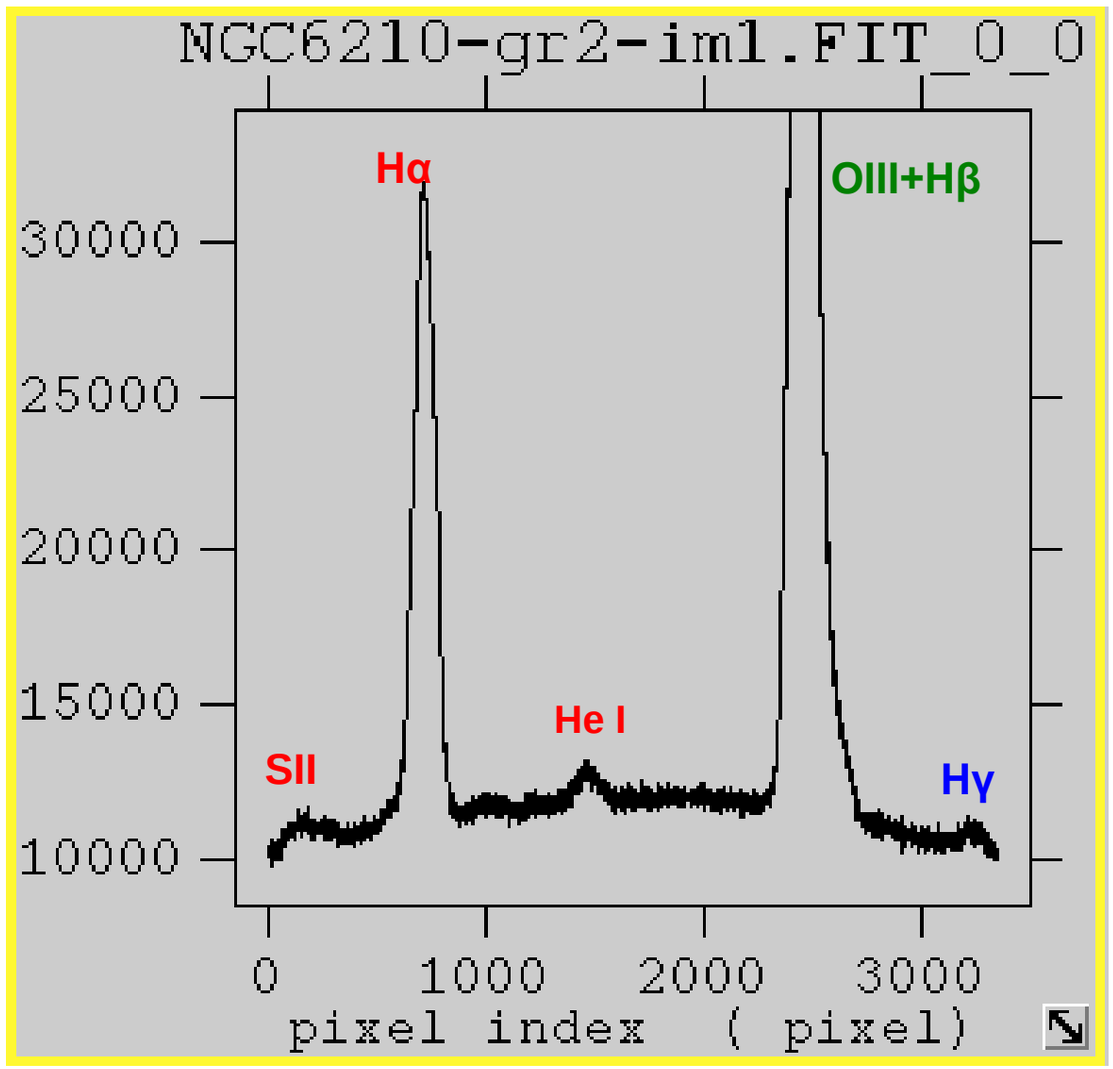


[Spectrum of the binary star Izar. The upper spectrum is of K-type and the lower spectrum is of A-type companion star. The Balmer absorption lines in the A-star and Ca H+K lines in the K-star are prominently visible.]


NGC6210-gr1-im2.FIT_0
(pixels)
OIII
Hβ
Hγ
1700
1600
1500
1000
2000
3000
(pixels)


NGC6210-gr2-im1.FIT_0
(pixels)
SII
Hα
He I
OIII+Hβ
Hγ
1600
1500
1400
1000
2000
3000
(pixels)

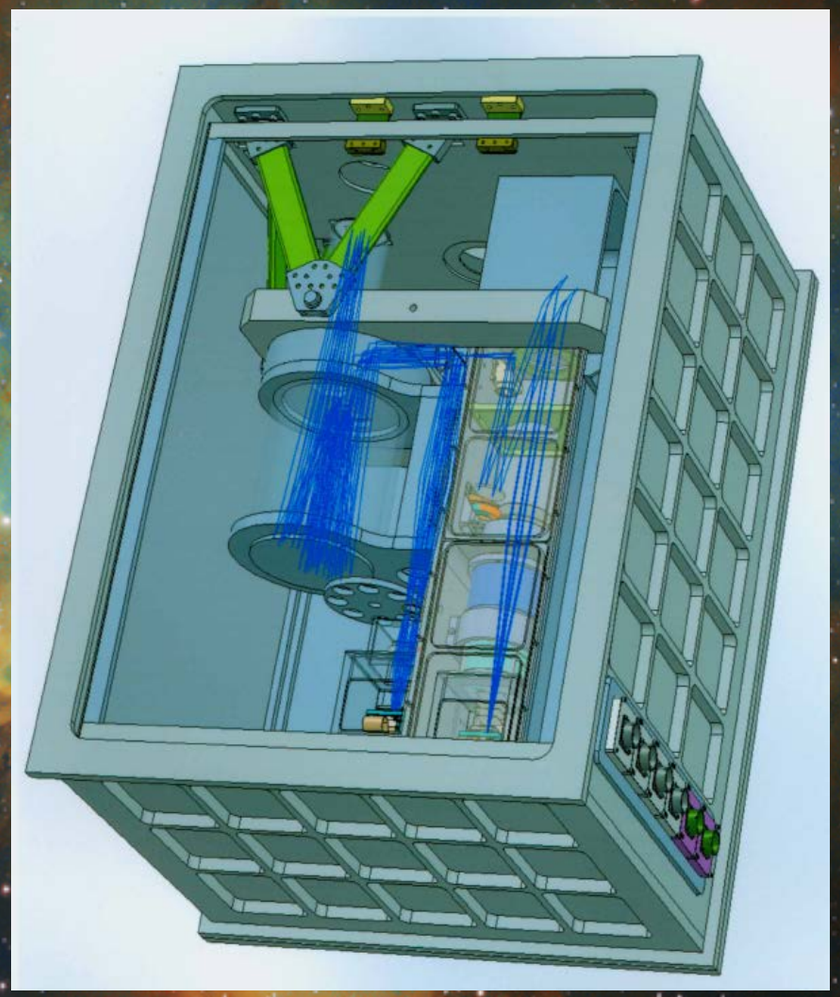

NGC6210-gr1-im2.FIT_0_1
20000
15000
10000
OIII
Hβ
Hγ
0
1000
2000
3000
pixel index (pixel)


NGC6210-gr2-im1.FIT_0_0
Hα
OIII+Hβ
30000
25000
20000
15000
10000
SII
He I
Hγ
0
1000
2000
3000
pixel index (pixel)

TANSPEC

(TIFR – ARIES NEAR INFRARED SPECTROMETER)

PI: D. K. Ojha (TIFR)



On the behalf of TANSPEC Team

Science Drivers for TANSPEC

NIR spectrographs are extremely sensitive to low temperature stellar photospheres (T·2500 K) and objects surrounded by warm dust envelopes or embedded in dust/molecular clouds. It is therefore particularly suited to study:

1. Low mass stars (red and brown dwarfs)

2. Confirmation of metal poor sub-dwarfs

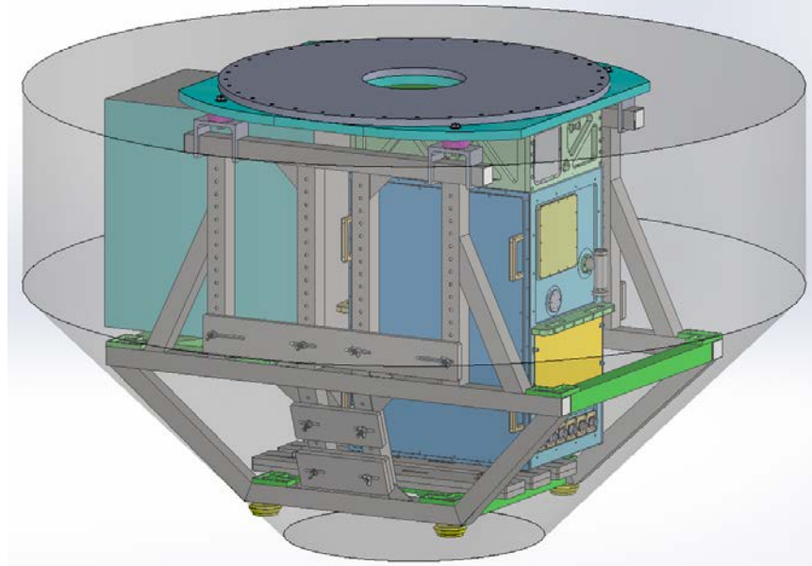
3. Evolved giant, super-giant and asymptotic giant branch stars

4. Galactic structure

5. Star formation

6. The Optical -Near Infrared spectral library

Characteristics of TANSPEC



Wavelength range : 600-2500 nm

Imaging : 60 x 60 arcsec

Long-slit spectroscopy mode :
- resolution : 200 and 2000
- cross-dispersed/prism

Limiting Magnitude(K -Band):
14.5 in 10 min exp
16 mag in 1 hr exp

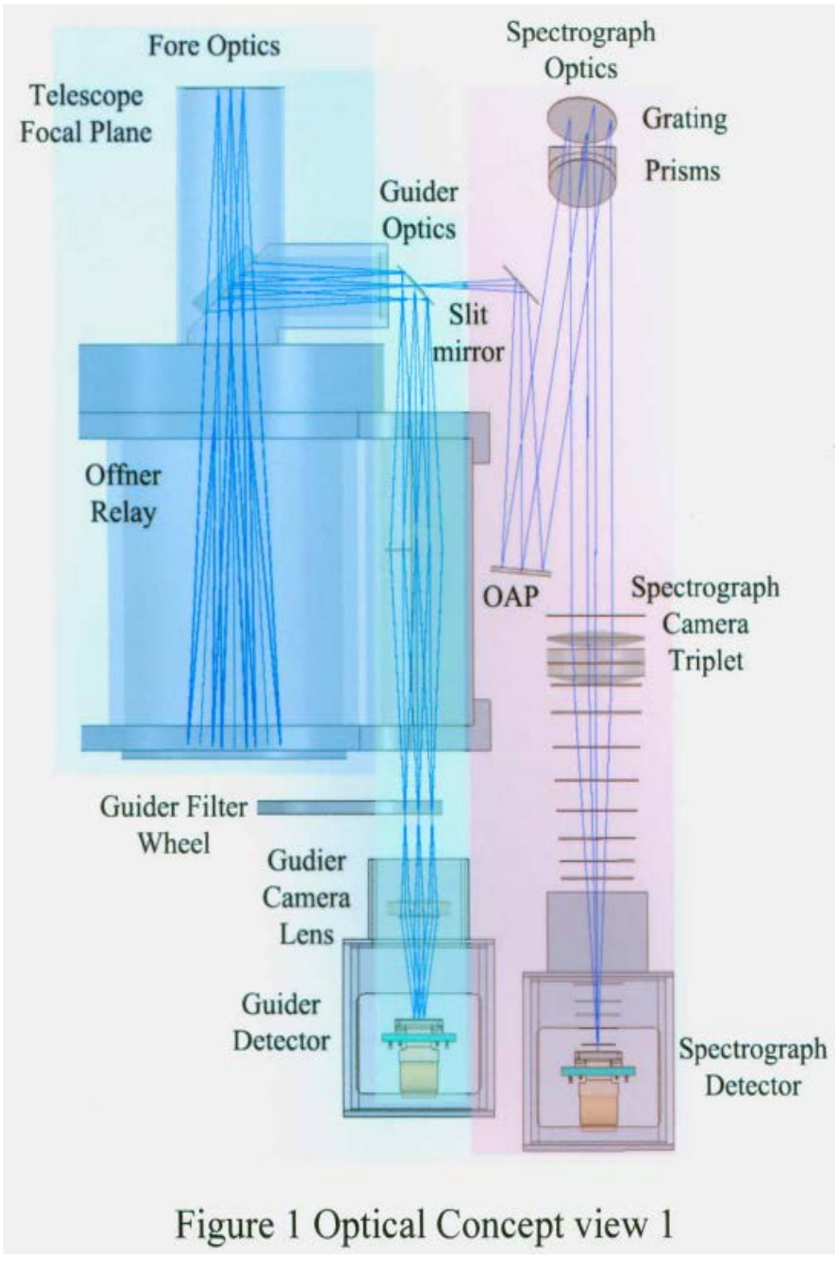


Figure 1 Optical Concept view 1

TANSPEC on 3.6 m DOT

Wavelength Coverage = 0.6- 2.5 micron

Medium resolution (R ~ 2750) cross-dispersed (XD) mode (20'' slit length, 0.5'' width)

Low resolution (R ~ 100-350) prism mode (60 '' slit length)

Slit viewer/guider/imager 60x60 arc-second field; JHK and narrow band filters

HgCdTe Hawaii-1/2 (H2/H1RG) arrays

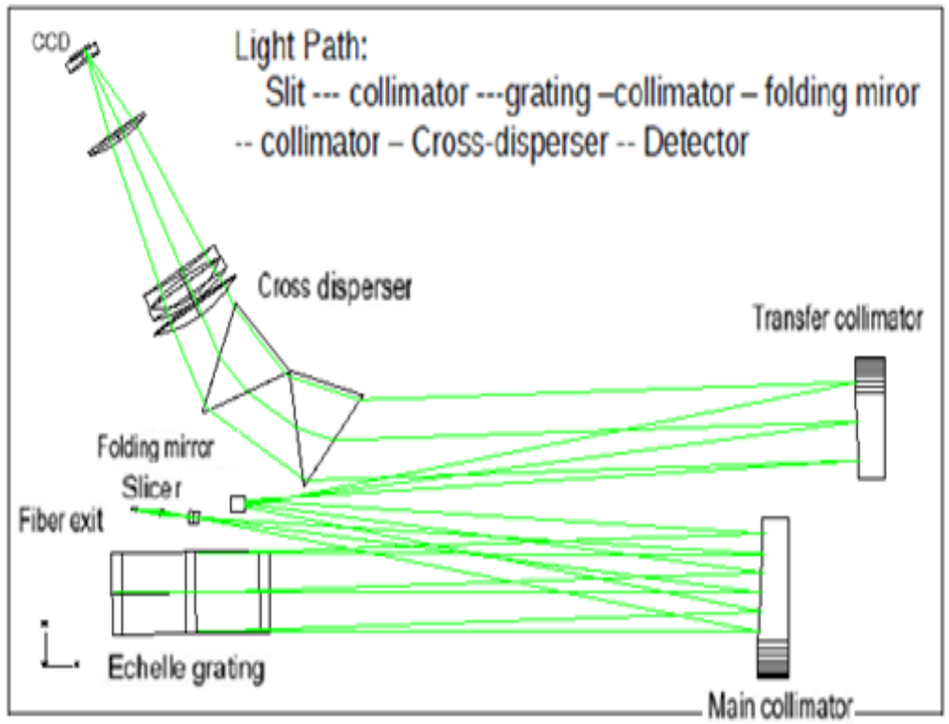
Throughput (including telescope): ~33% at 2.2 micron

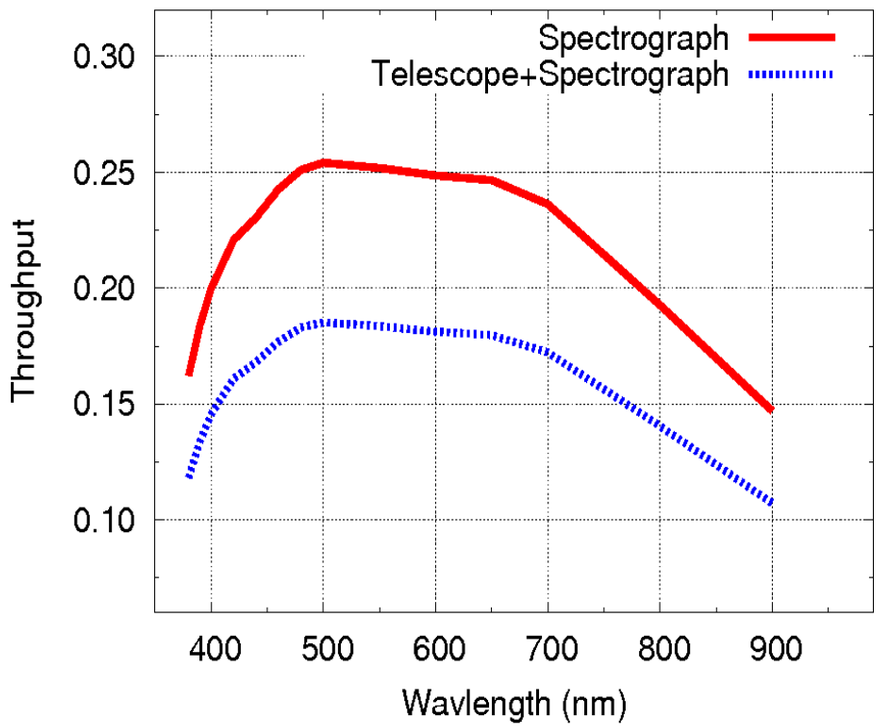
Limiting Magnitude(K Band)
Kmag = 13.5 in 1 Hr exp
for S/N > 100

1. median resolution XD mode: 1 hour exposure, 1 arcsec seeing, at 2.25 micron, 100 S/N , Jmag = 13.5
2. Low resolution: 1 hour exposure, 1 arcsec seeing, at 2.25 micron, 100 S/N, Jmag = 15
3. Estimated slit viewer/IR guider sensitivity (1x1 arcmin square FoV) 1 arcsec seeing, at 2.25 micron Jmag= 17.2 (10 sigma 1 min exp) and Jmag = 18.4 mag (10 sigma, 10 min exp)

High resolution Optical spectrograph – axial port

- Fiber fed: Two fibers mode, one to observe spectrum and other to either sky background or reference source.
- 20k and 80k resolution
- Wavelength coverage ~ 350 – 900 nm
- RV stability ~ 2 m/s stability
- Spectral throughput of ~ 15-20%





Technical Specification

Parameters/Interface Units	Specs	Remarks
Spectral Coverage	380-900 One go and through multiple channel	
Spectral Resolution	Low Resolution mode: 20000 High Resolution mode: 80000	
RV Stability	2 m/s	
Throughput :with telescope and detector :Spectrograph alone	 15-20 % ~40%	
Atmospheric Dispersion Corrector (ADC)	Required	Corrects lateral chromatism
Exposure-meter	Required	
Guiding Unit	Required	For keeping object in the FOV of fiber
Simultaneous Object and sky spectra	Required	
Simultaneous Object and Calibration	Required	Calibration purpose
Interface between telescope and Spectrograph	Required	
Vacuum tank	Required	10^{-5} torr
Temperature Controlled	Required	Better than 0.05 ^{0}C RMS ~0.005 ^{0}C
Possible Spectrograph housing	Under the telescope Pier	Diameter of pier: 5.0 m **Width of Entry Gate: 0.75 m** **Height of Entry Gate: 1.86 m**
Distance from Telescope focal plane to a possible location of Spectrograph	~11.0 m	
Software:	Interface to the Telescope Control System, Quick-look data viewer, other control software, etc.	
Detector	CCD	

4-m International Large Mirror Telescope (ILMT)

Helping partner: ARIES, Leige University and AMOS

THE DEVASTHAL OBSERVATORY

Thank You