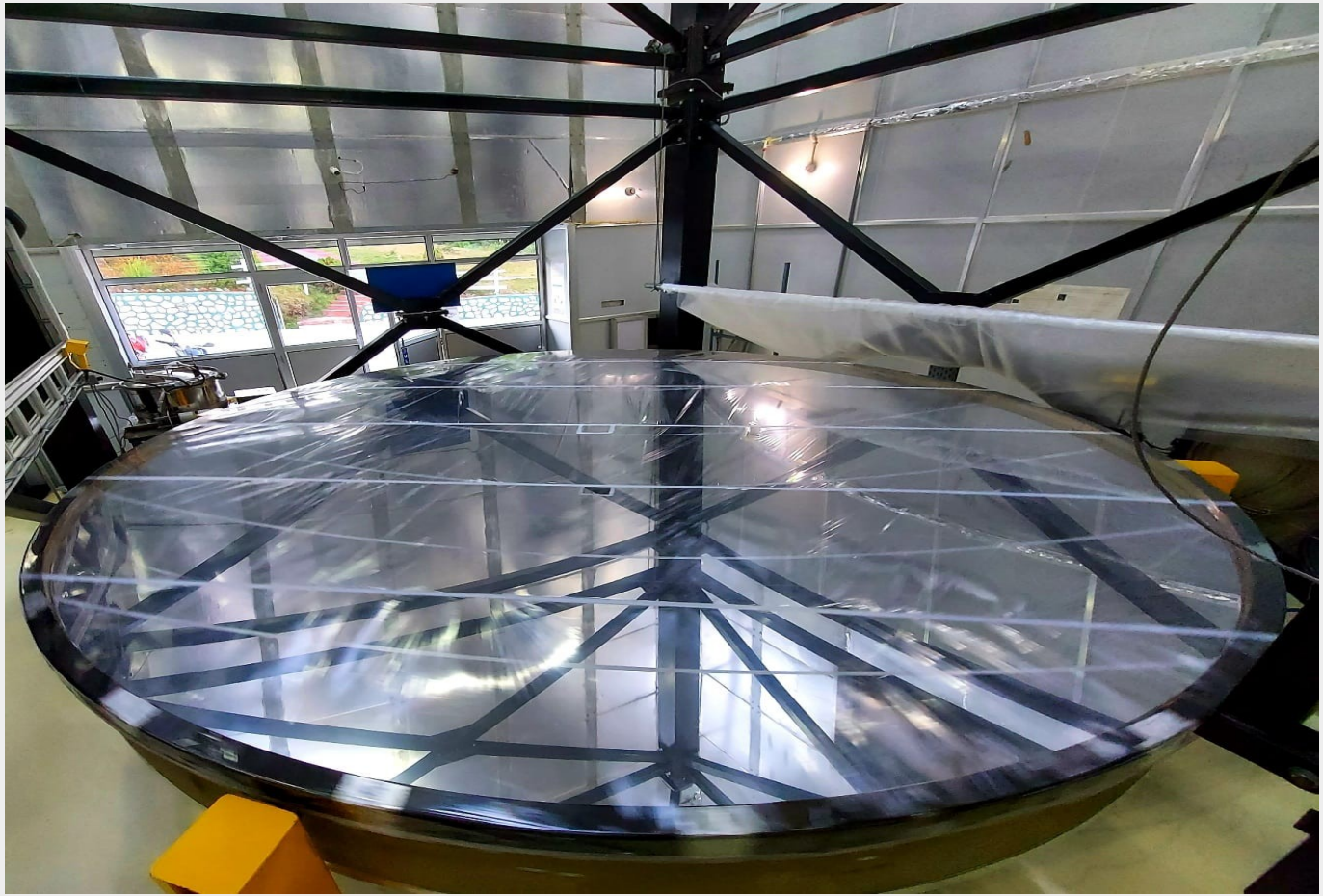
4m International Liquid Mirror Telescope (ILMT)

Brajesh Kumar

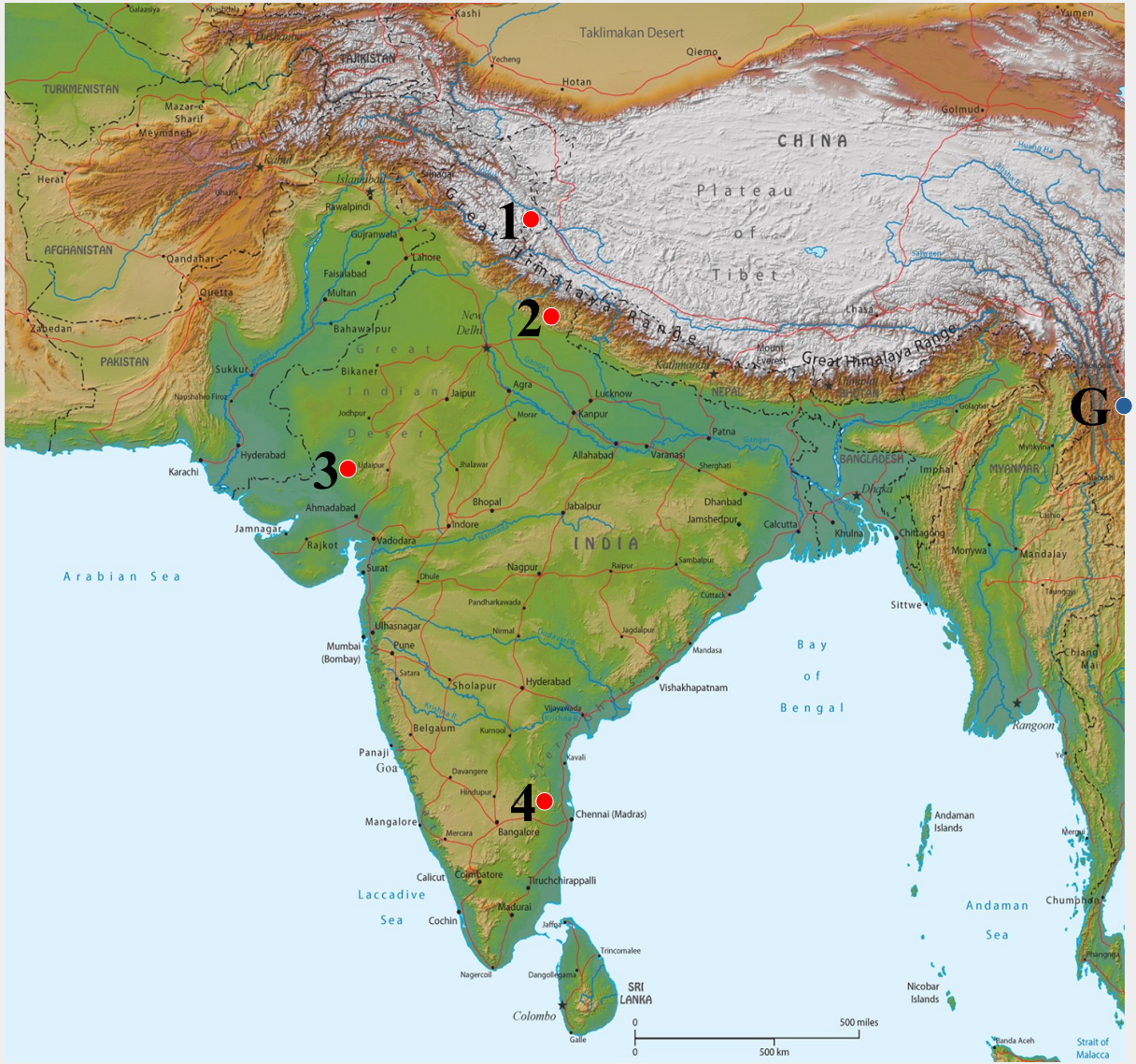
Astro-ph: 2311.05615, 2311.05618

(Journal club 06/12/2023)



Major optical observing facilities in India

1. Indian Astronomical Observatory
2. Devasthal Observatory
3. Mount Abu Observatory
4. Vainu Bappu Observatory



Devasthal Observatory, Nainital, India

(Abode of God)

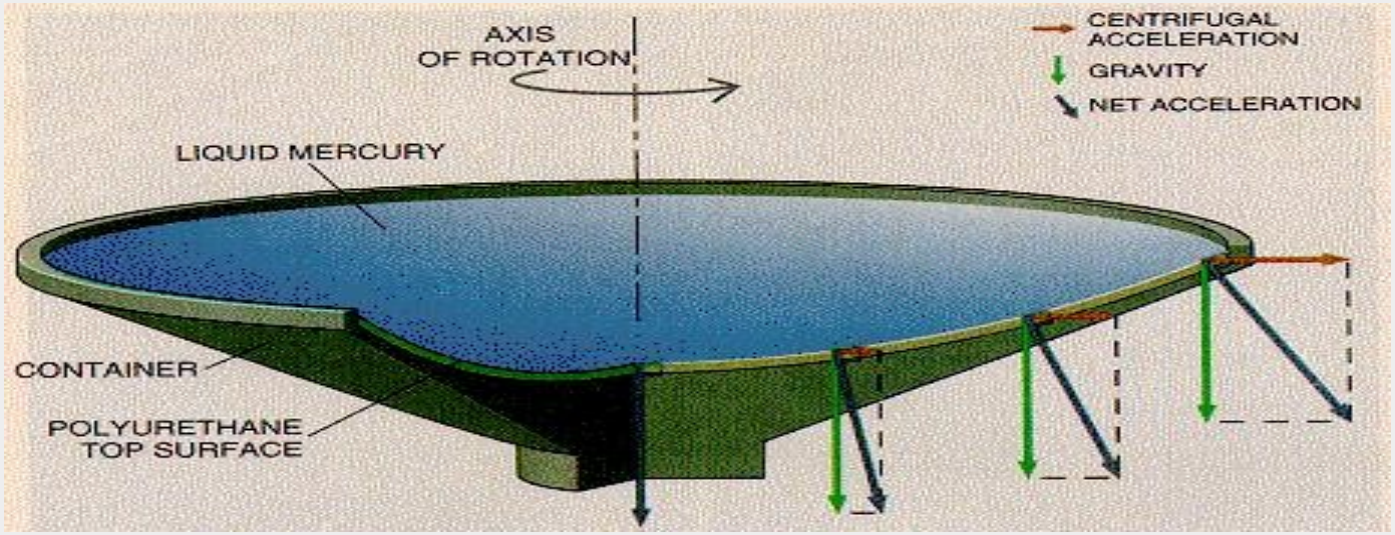
(Long: 79.68° E, Lat: 29.36° N, Alt: 2420m)

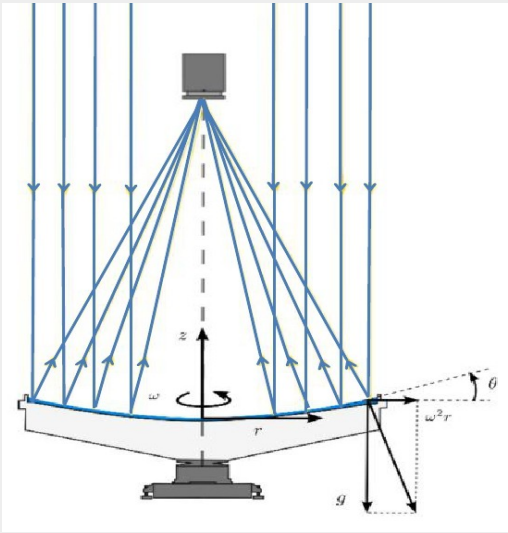
Interesting visitors to the site!

Liquid Mirror (LM)

- **Reflecting paraboloid : Ideal surface to focus a beam of parallel light rays.**
- **Gravitational force + centrifugal acceleration → parabolic surface.**
- **The liquid automatically compensates for thermal and mechanical deformation of the substrate.**

$$F = g/2\omega^2$$





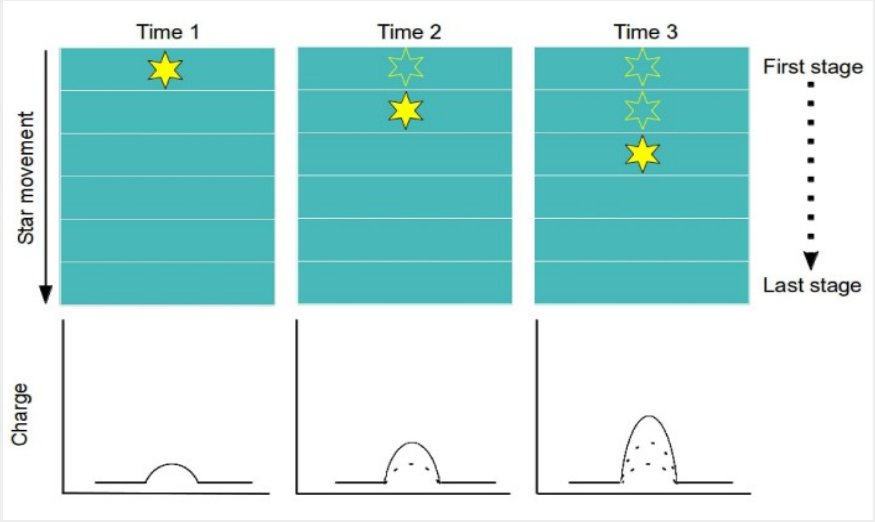
Imaging with LMTs

Time-delay integration (TDI):
Stellar objects move continuously across the CCD due to Earth's rotation.

Charge being generated by photons is shifted electronically along the CCD columns, equal to the local sidereal rate of the observatory.

The data is read continuously whole the night (long image strip is obtained).

Here, **integration time** is the time taken for an image to cross the whole CCD. Although the integration time is limited in case of LMTs but SNR can be increased by co-adding different night images.



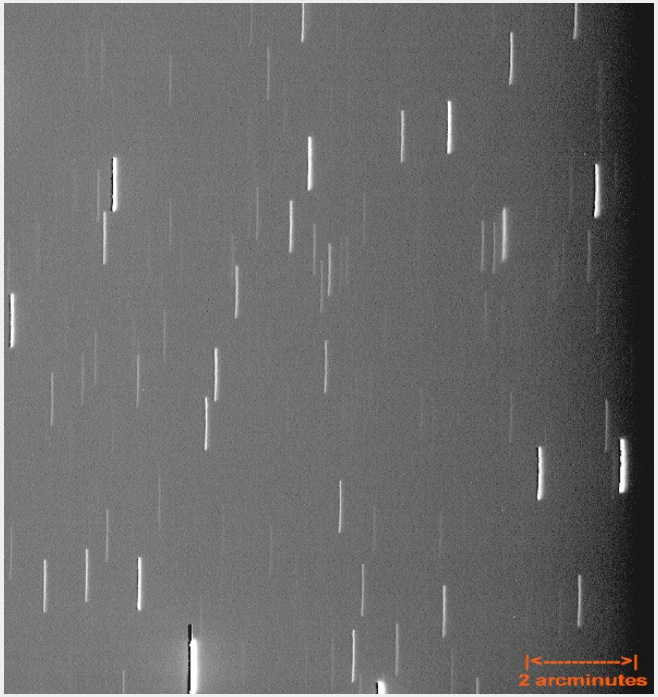
Need of an optical corrector

TDI images are degraded by two effects:

Star-trail curvature: Due to fixed pointing of the telescope, the stars move in the focal plane along slightly curved trajectories.

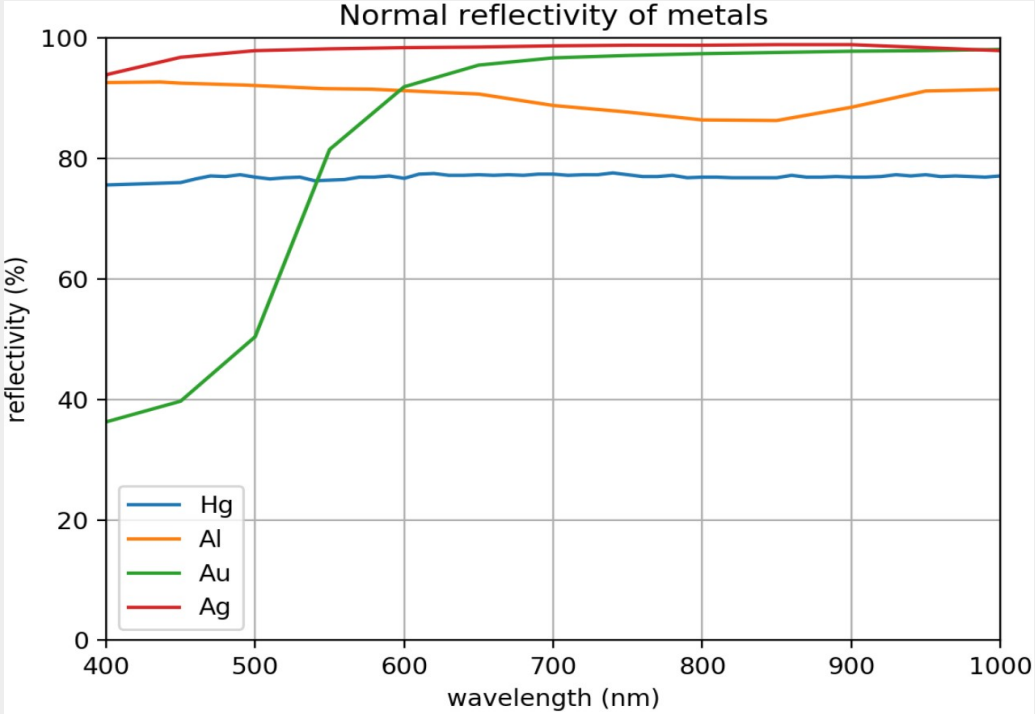
Differential drift rates: In the northern hemisphere, star images on the north side of the field move more slowly than those on the south side.

Therefore, a curvature-compensating optical corrector is used. Decentered and tilted lenses assembly of the corrector remove star trail curvature and drift-rate variations.



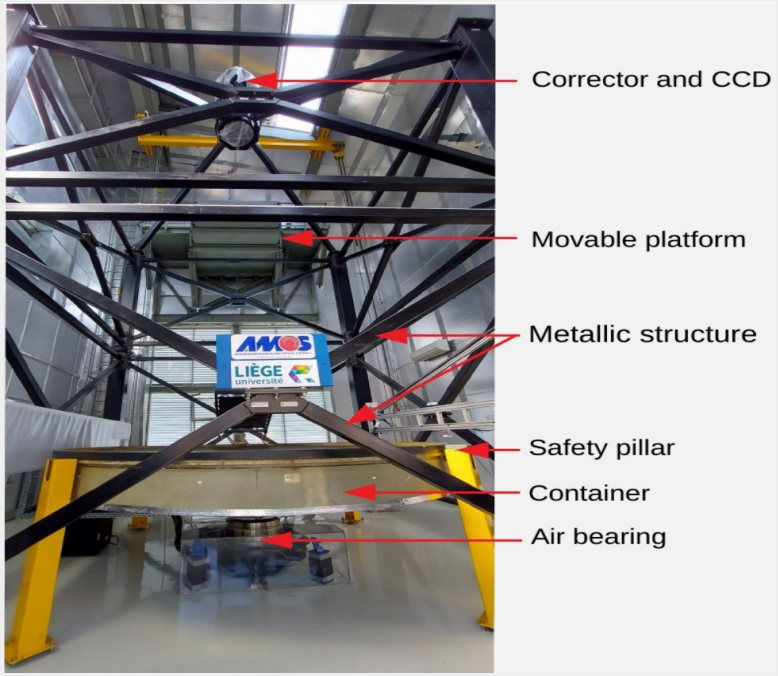
TDI curvature

Usually, mercury is used to make a liquid mirror as its reflectivity is ~75%.
Liquid at room temperature.



(Ref: Optical properties of metals, AIP handbook)

4m International Liquid Mirror Telescope



- **Joint project between India, Belgium, Canada, Poland**
- **and Uzbekistan.**
- **AMOS (advanced mechanical and optical systems), Belgium has fabricated the ILMT.**

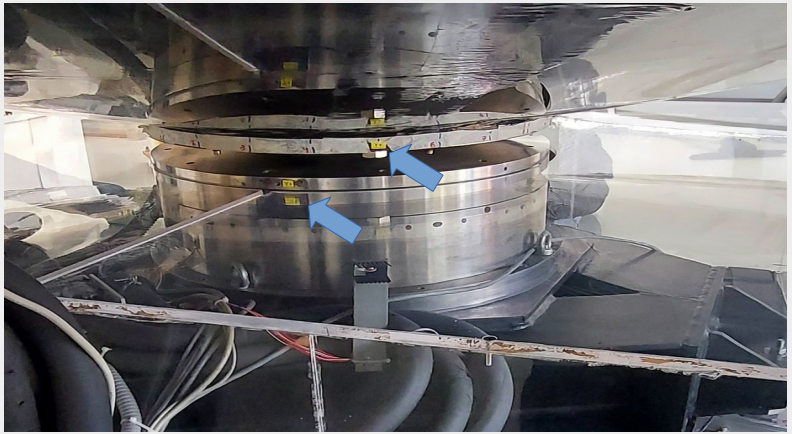
Diameter	**4m**
Focal length	**8m (f/2)**
Rotation period	**8.04 sec**
CCD camera	**4096 x 4096 pixels**
Pixel size	**0.33”/pixel**
Filters	**SDSS (g, r, i)**
FoV	**22’ x 22’**
TDI time	**102 sec**

Pneumatic modules

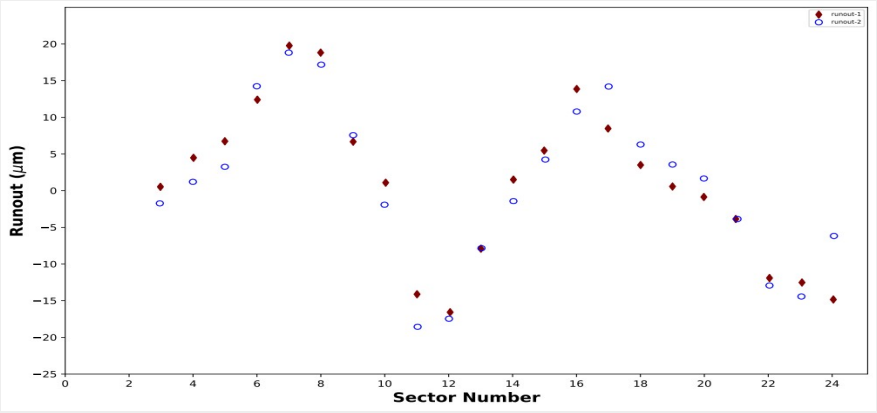
ILMT observing preparations

Alignment of air bearing
Vertical runout check
Mirror leveling
Mylar installation
Mirror formation

Air bearing alignment

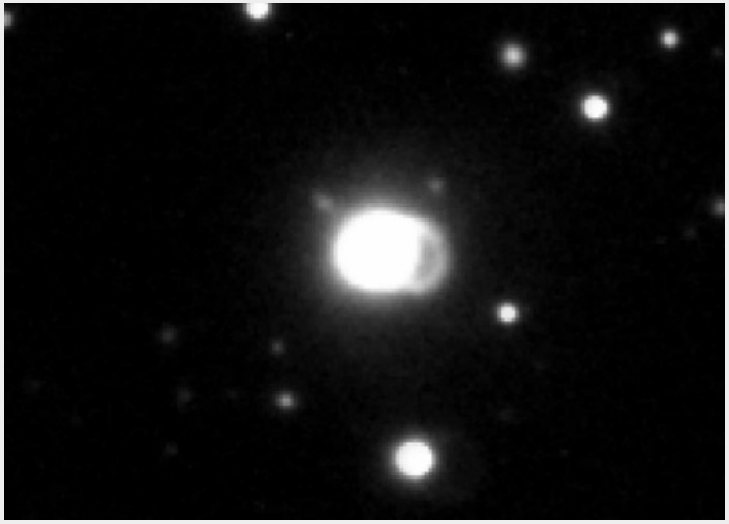


Vertical runout check

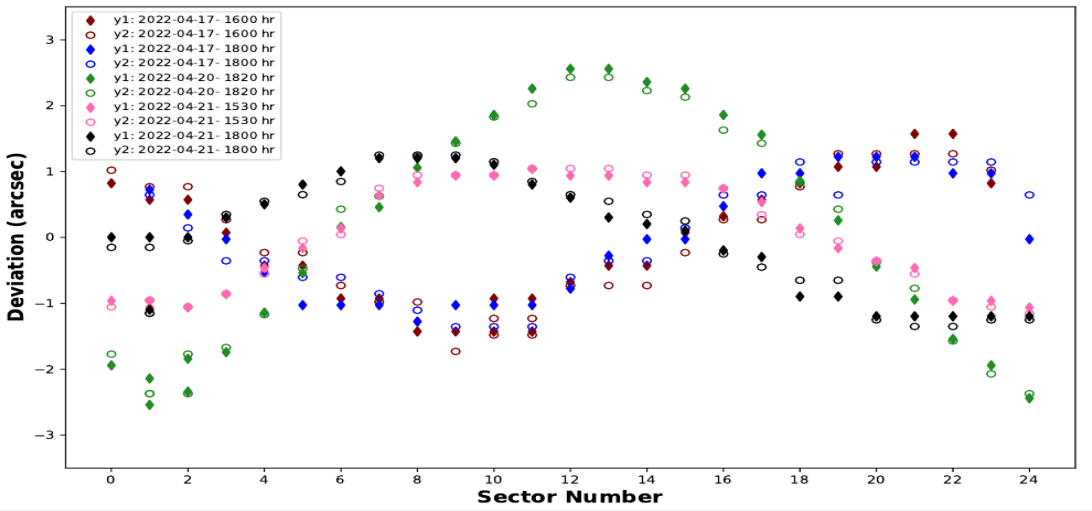


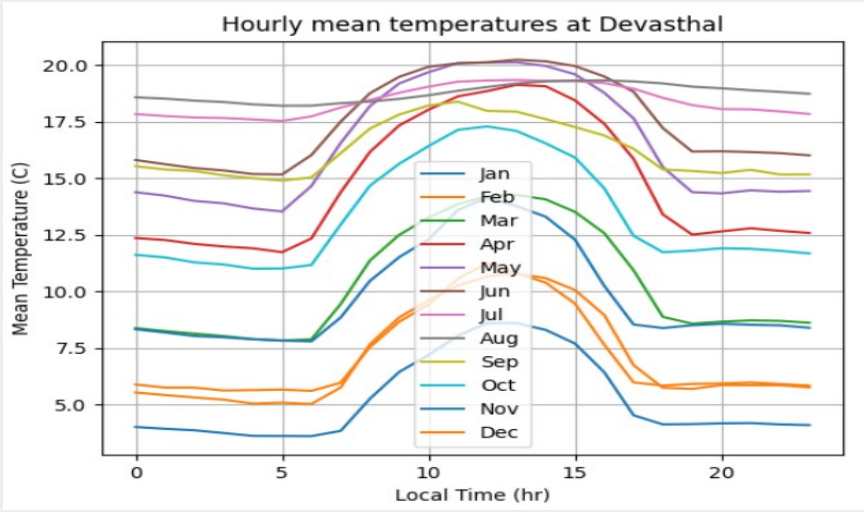
Mirror leveling

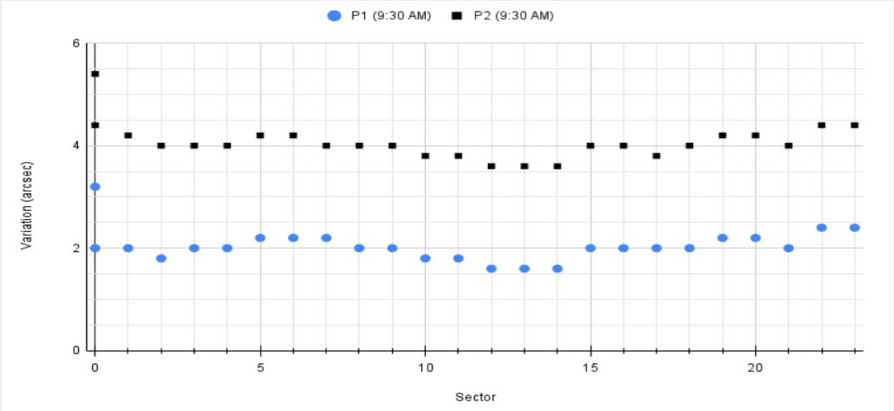
- **The mirror rotation axis must be vertical (~arcsec) otherwise, it produces a "diamond-ring" feature in the images (standing wave that is induced in the rotating liquid).**
- **The ILMT air bearing can be leveled with help of three-point mounting system (stations A, B and C).**



Mirror leveling (temperature variation effect)



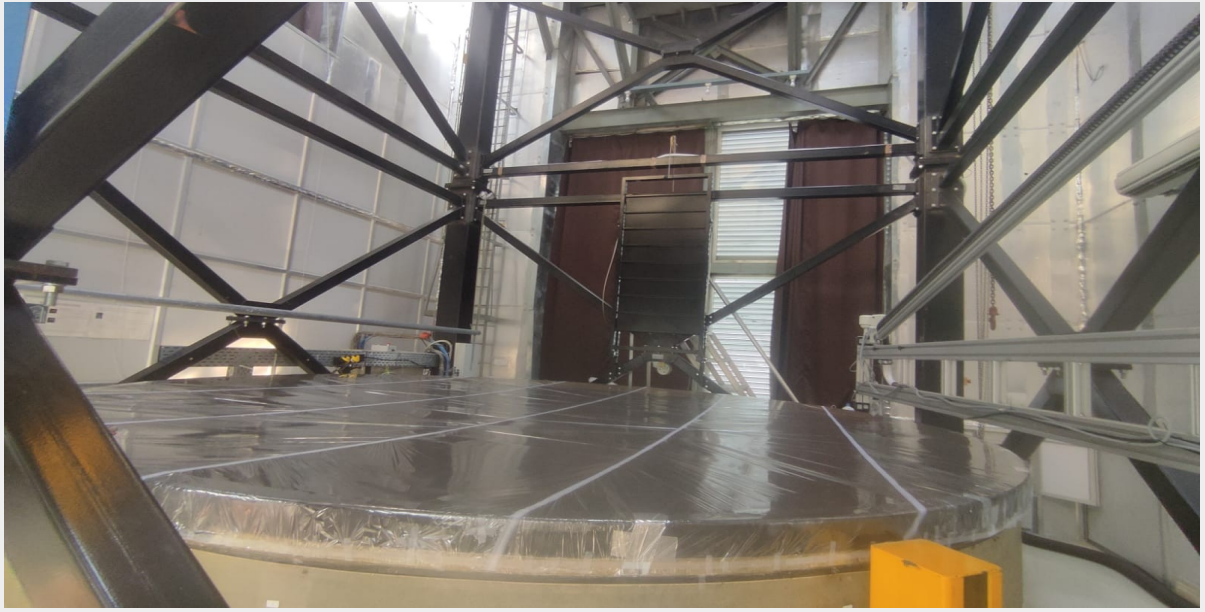




Mylar installation

- **A co-moving transparent mylar sheet covered over the rotating bowl can suppress the friction between the air and the mercury. It improves the image quality. The mylar sheet also protects from spreading the harmful mercury vapor.**

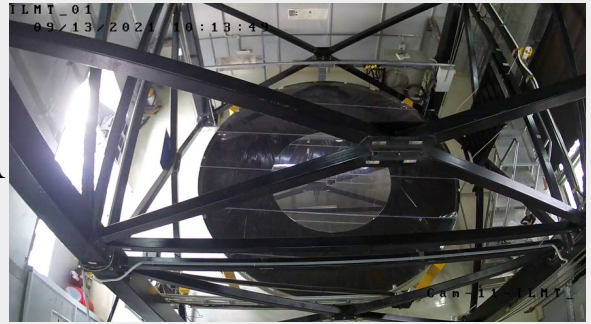
- **1.4 um DuPont type ‘C’ mylar film is used in ILMT.**



Mirror formation

- **50 liters of mercury is transferred into the bowl with the help of mercury pumping system.**
- **The mercury-filled bowl is rotated with hand push button switch. The bowl is accelerated/decelerated to fill up the holes created during the spread of mercury towards the outer edges and finally, the mirror is formed.**

A



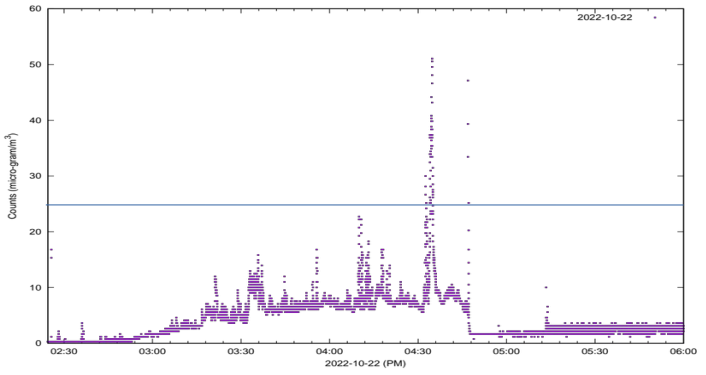
B

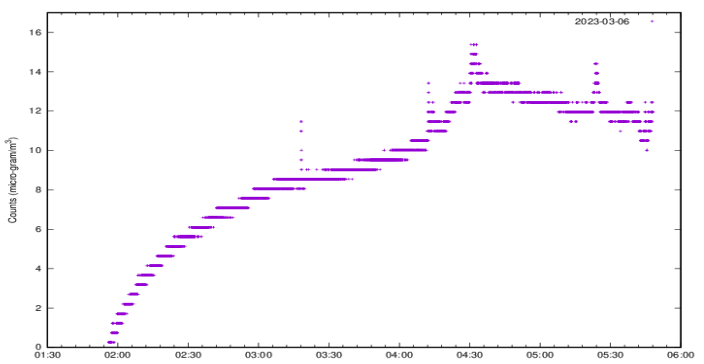
C

D

Mercury safety considerations

- **Mercury vapors are highly toxic.**
- **Safety equipment are used while mercury handling.**
- **Mercury vapors are monitored with mercury vapor monitors (exposure limit is 25 ug/m^3).**
- **After ~8 hrs, mercury oxide layer is formed which suppresses the evaporation.**

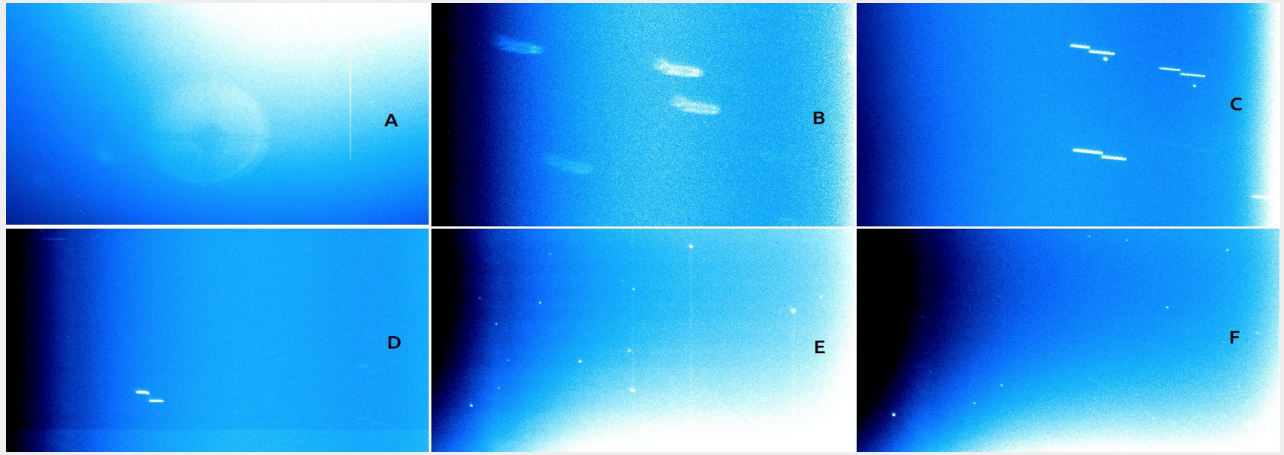




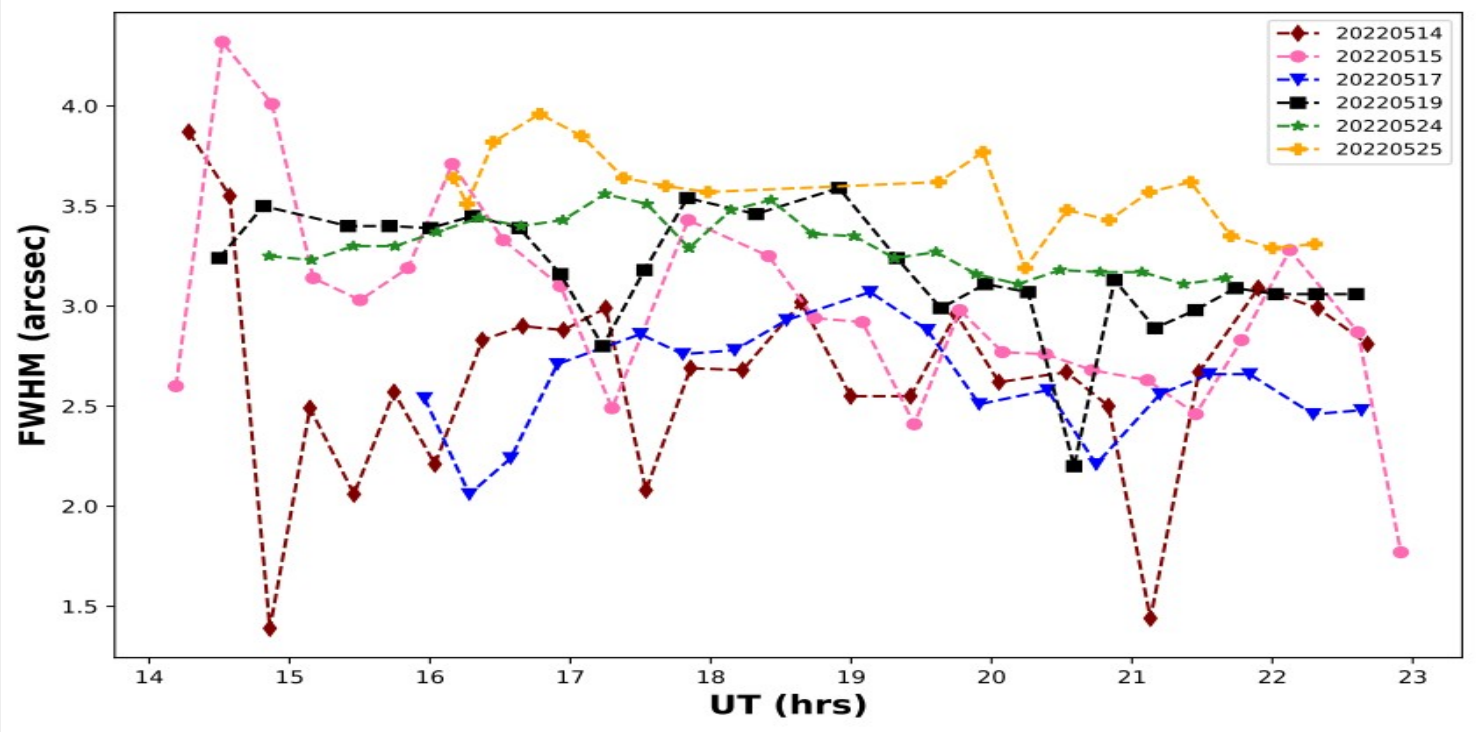
ILMT first light

ILMT first light was achieved on 29th April 2022.

Images were obtained after proper alignment of CCD columns along the E-W direction, setting optimal TDI scan rate and focus on different nights.



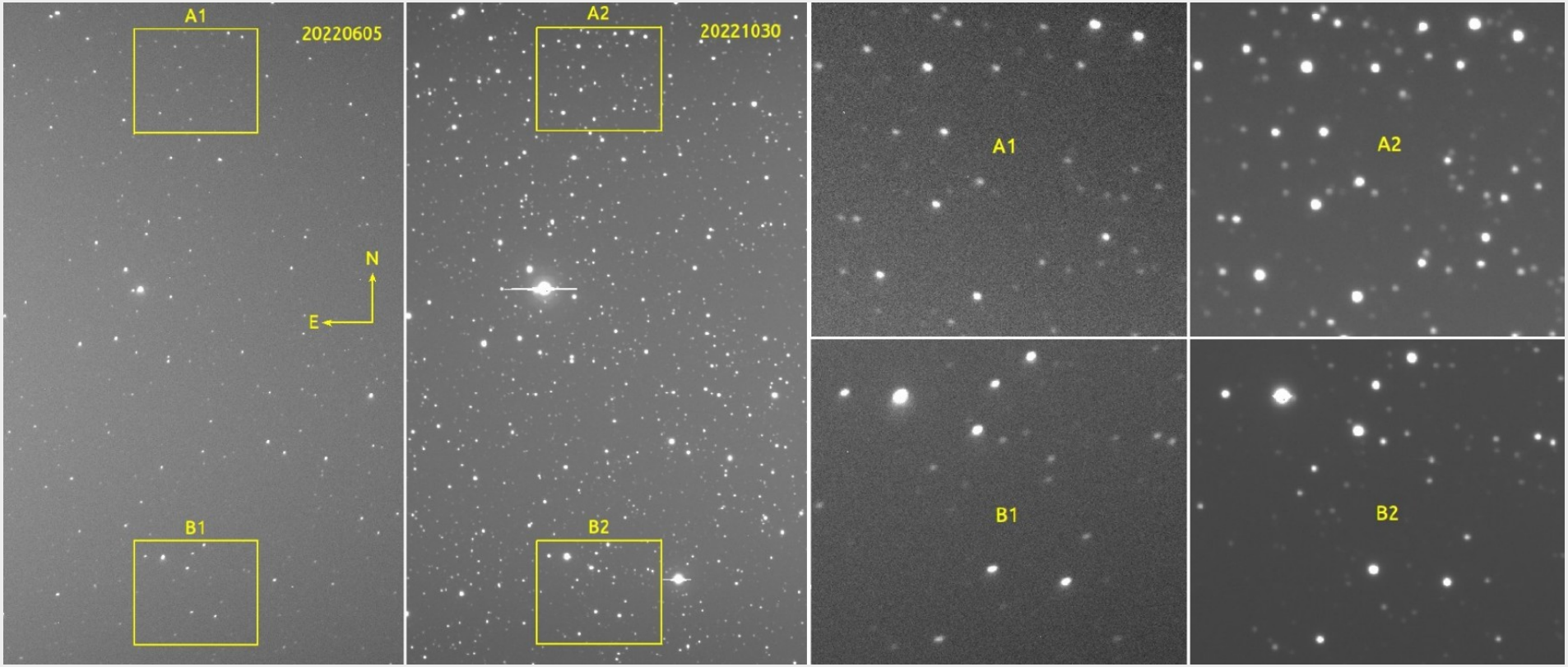
- **The ILMT first light image quality was poor. The limiting magnitudes were 21.9, 21.7 and 21.5 in g, r and i bands, respectively.**



FWHM variation

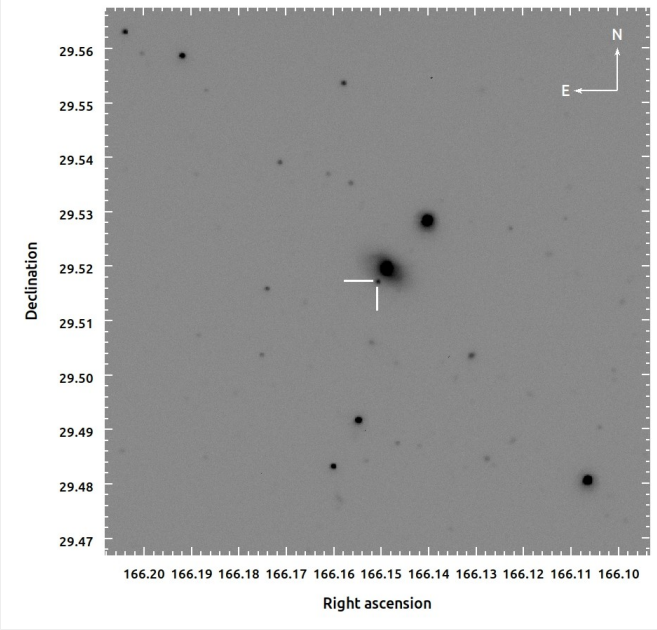
Optical corrector orientation issue

TDI distortion in the images (wrongly oriented corrector) which was corrected later and it resulted better image quality.



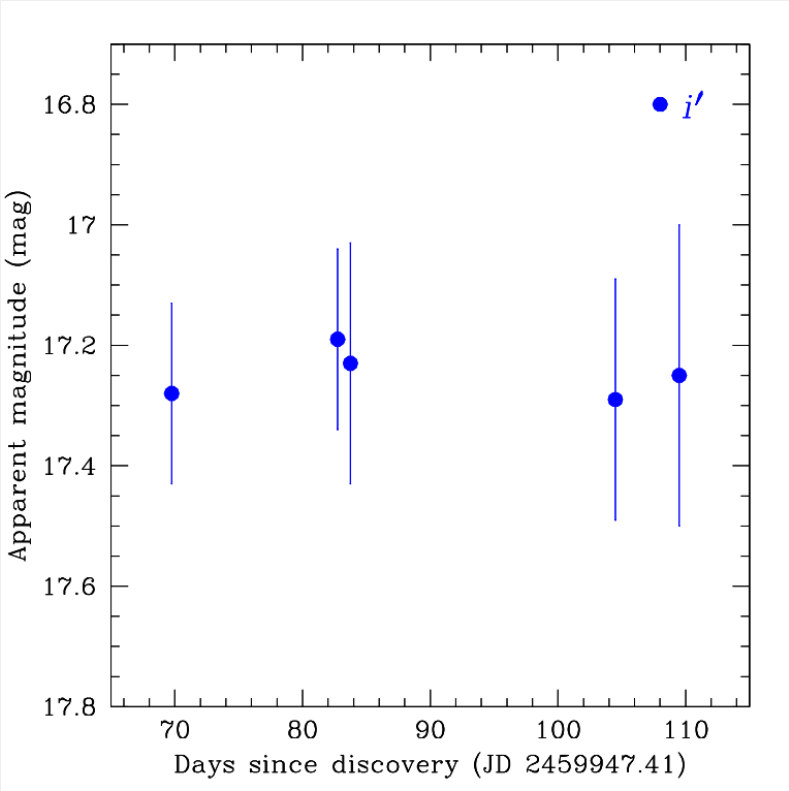
SN 2023af in ILMT FoV

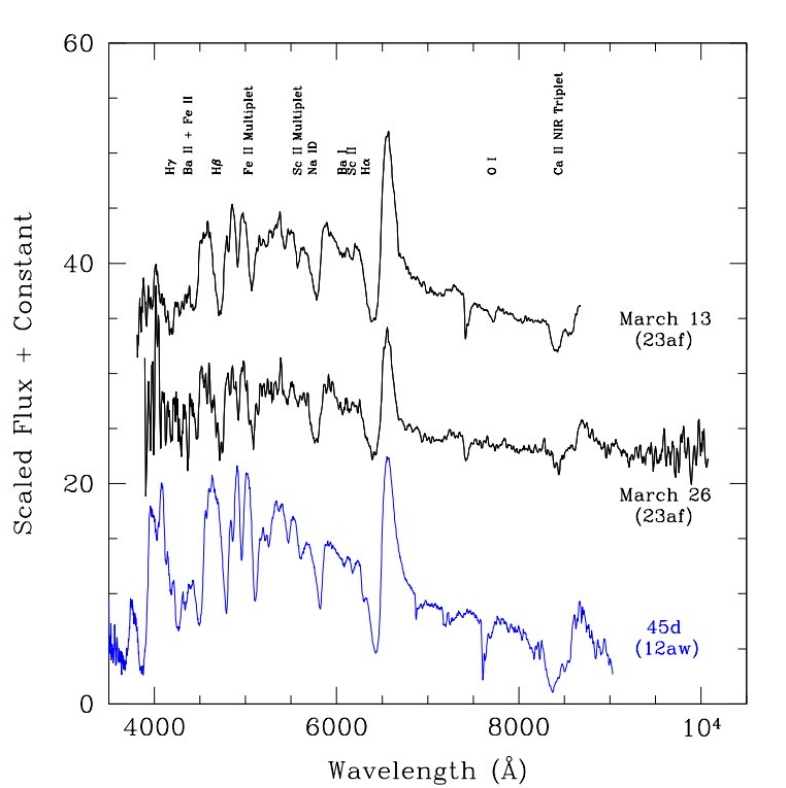
- **SN 2023af was discovered on 2023 Jan 02 by Zhang et al. (Xinjiang Astronomical Observatory).**
- **Classified as young Type II SN on 2023 Jan 06 by Li et al. using YFOSC mounted at 2.4m Lijiang Telescope.**
- **We searched TNS data base and cross-examined the ILMT images acquired in March 2023 (commissioning cycle 3).**
- **The SN was identified in the ILMT image (g-band) taken on 09 March.**
- **Later, it was followed up with ILMT (5 epochs imaging) and 3.6m DOT (2 epoch imaging and spectra).**



SN 2023af location in ILMT i'-band image.

SN 2023af light curve and spectra





ILMT supernova detection rate

- **ILMT FoV 22'x22'**
- **ILMT sky coverage at Devasthal: ~47 deg^2**
- **Average observable sky: 8 hours**
- **Photometric nights: 160**
- **It is possible to detect hundreds of SNe with ILMT each year.**

Table 2. SN detection rates with the ILMT. 1_N, 3_N, and 6_N indicate the number of SNe for the limiting magnitudes of single, and co-added images of three and six nights, respectively. Total number of SNe (Columns 6, 7, and 8) are the redshift-integrated events in a year (only 160 photometric nights of the site and an average 8 h of observing time each night have been accounted for).

SN type	Filter	SNe (deg^{-2} yr^{-1})			Total SNe in a year		
		1_N	3_N	6_N	1_N	3_N	6_N
Ia	g'	63	89	115	1299	1835	2371
	r'	155	274	426	3196	5649	8783
	i'	28	71	174	577	1464	3588
CC	g'	50	97	177	1031	2000	3649
	r'	20	43	87	412	887	1794
	i'	3	8	19	62	165	392

(Kumar+ 2018b, MNRAS)

Summary

- **The 4m ILMT facility is operational at Devasthal Observatory, India. It is a zenithal telescope which performs Time Delay Integration mode observations of 22'x22' strip of sky in g, r and i bands.**
- **After achieving successful first light on 29th April 2022, the ILMT is presently in commissioning phase.**
- **ILMT is already producing good photometric data.**
- **SN 2023af was the first supernova that has been identified in the ILMT FoV and its follow-up strategy with other facilities (1.3m DFOT and 3.6m DOT) was checked. It is possible to discover transient events including hundreds of supernovae with the ILMT.**