

# The International Liquid Mirror Telescope Project - Overview and Scientific Results

Jean Surdej (on behalf of the **ILMT** team)

Université de Liège & VAJRA-ARIES

[jsurdej@uliege.be](mailto:jsurdej@uliege.be)

# The 4 m International Liquid Mirror Telescope: Construction, operation, and science

J. Surdej<sup>1,2,\*</sup> , P. Hickson<sup>3,4</sup>, K. Misra<sup>2</sup> , D. Banerjee<sup>2</sup> , B. Ailawadhi<sup>2,5</sup>, T. Akhunov<sup>6,7</sup> , E. Borra<sup>8</sup>, M. Dubey<sup>2,9</sup> ,  
N. Dukiya<sup>2,9</sup> , S. Filali<sup>1</sup> , J. Hellemeier<sup>10</sup>, M. Kharayat<sup>2</sup>, B. Kumar<sup>11</sup> , H. Kumar<sup>2</sup>, M. Kumar<sup>2</sup>, T. S. Kumar<sup>2</sup>,  
P. Kumari<sup>2</sup>, V. Negi<sup>12</sup> , A. Pospieszalska-Surdej<sup>1</sup>, S. Prabhavu<sup>2</sup>, B. Pradhan<sup>1,13</sup> , K. Pranshu<sup>2,14</sup> , H. Rawat<sup>2</sup>,  
B. K. Reddy<sup>2</sup> , A. Sasidharan Pillai<sup>2,15</sup> , K. Singh<sup>2</sup>, S. Tremblay<sup>3</sup>, S. Turakhia<sup>3</sup>, and S. Vijay<sup>16</sup> 

<sup>1</sup> Institute of Astrophysics and Geophysics, Liège University, Allée du 6 Août 19c, 4000 Liège, Belgium

<sup>2</sup> Aryabhata Research Institute of Observational Sciences, Manora Peak, Nainital, 263001 Uttarakhand, India

<sup>3</sup> Department of Physics and Astronomy, The University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1, Canada

<sup>4</sup> Outer Space Institute, The University of British Columbia, 325-6224 Agricultural Road, Vancouver, BC V6T 1Z1, Canada

<sup>5</sup> Deen Dayal Upadhyay Gorakhpur University, Civil Lines, Gorakhpur 273009, Uttar Pradesh, India

<sup>6</sup> National University of Uzbekistan, Department of Astronomy and Astrophysics, 100174 Tashkent, Uzbekistan

<sup>7</sup> Ulugh Beg Astronomical Institute of the Uzbek Academy of Sciences, Astronomicheskaya 33, 100052 Tashkent, Uzbekistan

<sup>8</sup> Centre for Optics, Photonics and Lasers, Université Laval, 2375 rue de la Terrasse, Québec, Quebec G1V 0A6, Canada

<sup>9</sup> Mahatma Jyotiba Phule Rohilkhand University, Pilibhit Bypass Road, Bareilly 243006, Uttar Pradesh, India

<sup>10</sup> Research School of Astronomy & Astrophysics, Australian National University, Mt Stromlo Observatory, Cotter Road, Weston Creek 2611 ACT, Australia

<sup>11</sup> South-Western Institute for Astronomy Research, Yunnan University, Kunming 650500, Yunnan, P.R. China

<sup>12</sup> Inter-University Centre for Astronomy and Astrophysics (IUCAA), Post Bag 4, Ganeshkhind, Pune 411007, India

<sup>13</sup> Indian Space Research Organization, Bengaluru, Karnataka, India

<sup>14</sup> University of Calcutta, 87/1 College Street, Kolkata 700073, India

<sup>15</sup> Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile

<sup>16</sup> Department of Physics, Ashoka University Rai, Sonapat, Haryana 131029, India

# PyLMT: a transient detection pipeline for the 4-m International Liquid Mirror Telescope

Kumar Pranshu <sup>1,2</sup>★ Kuntal Misra <sup>1</sup> Bhavya Ailawadhi,<sup>1,3</sup> Monalisa Dubey <sup>1,4</sup> Naveen Dukiya,<sup>1,4</sup> Sara Filali,<sup>5</sup> Paul Hickson <sup>6</sup> Brajesh Kumar <sup>7</sup> Vibhore Negi <sup>8</sup> and Jean Surdej<sup>1,5</sup>

<sup>1</sup>*Aryabhata Research Institute of Observational sciences (ARIES), Manora Peak, Nainital 263001, India*

<sup>2</sup>*Department of Applied Optics and Photonics, University of Calcutta, Kolkata 700106, India*

<sup>3</sup>*Department of Physics, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur 273009, India*

<sup>4</sup>*Department of Applied Physics, Mahatma Jyotiba Phule Rohilkhand University, Bareilly 243006, India*

<sup>5</sup>*Institute of Astrophysics and Geophysics, University of Liège, Allée du 6 Août 19c, B-4000 Liège, Belgium*

<sup>6</sup>*Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver BC V6T 1Z1, Canada*

<sup>7</sup>*South-Western Institute for Astronomy Research, Yunnan University, Kunming, 650500 Yunnan, China*

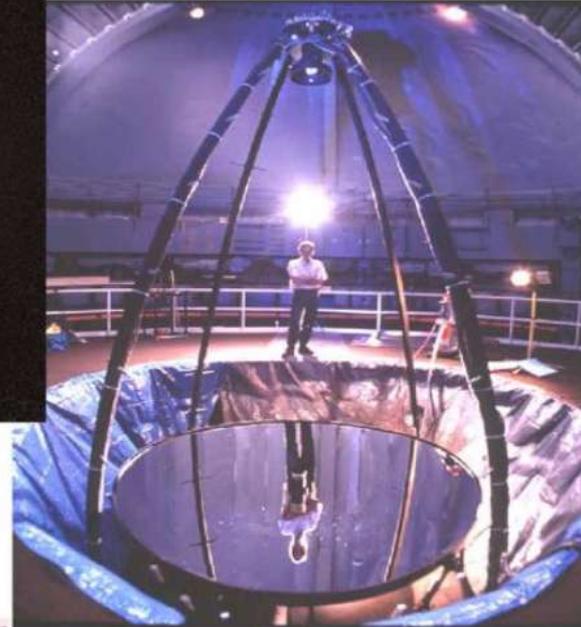
<sup>8</sup>*Inter-University Centre for Astronomy and Astrophysics, Ganeshkhind, Pune 411007, India*

# I. Brief history

- XVIIth century: Isaac Newton
- 1851: Ernesto Capocci
- 1875: Henry Skey, 35 cm mercury mirror
- 1909: Robert Wood, 51 cm prototype
- 1982: Ermanno Borra (air-bearing,  
liquid resin)
- 1994: Borra & Hickson (2.7m LMT)
- NODO: Hickson
- 2003: 6-m LZT, Hickson

# Liquid Mirror Telescopes

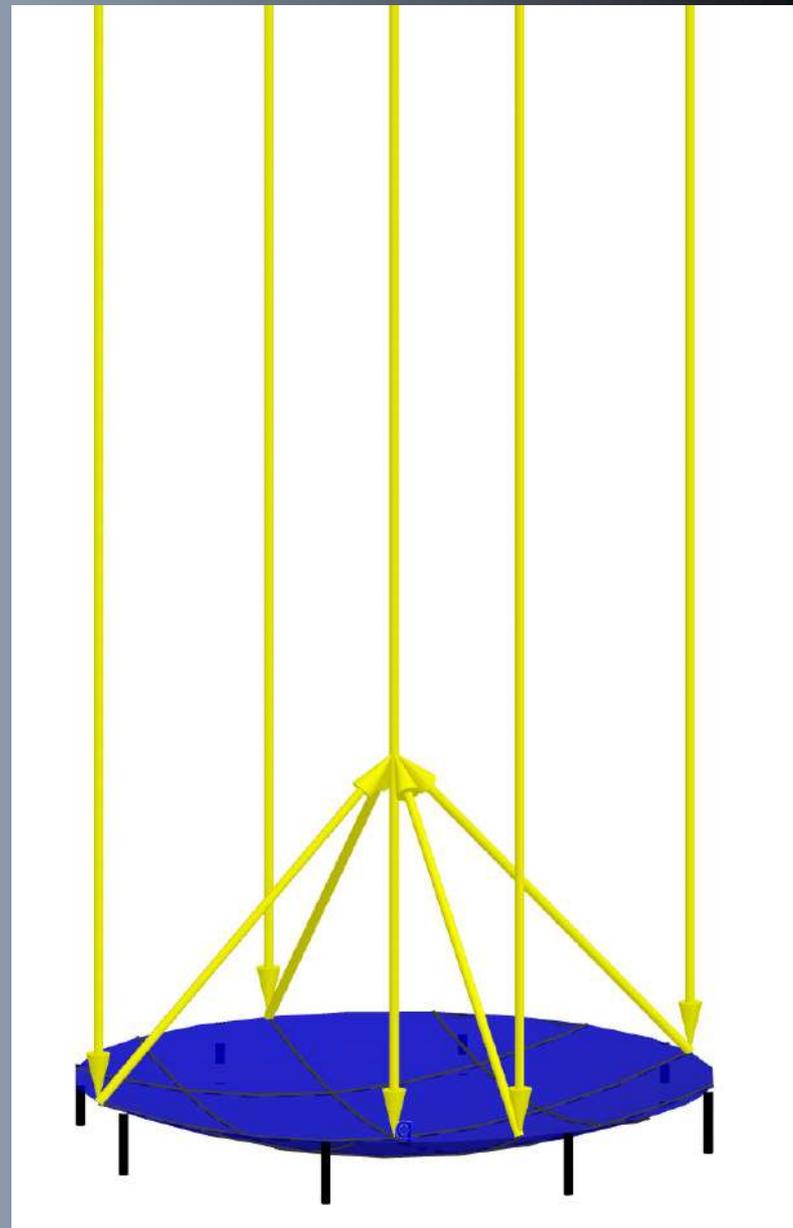
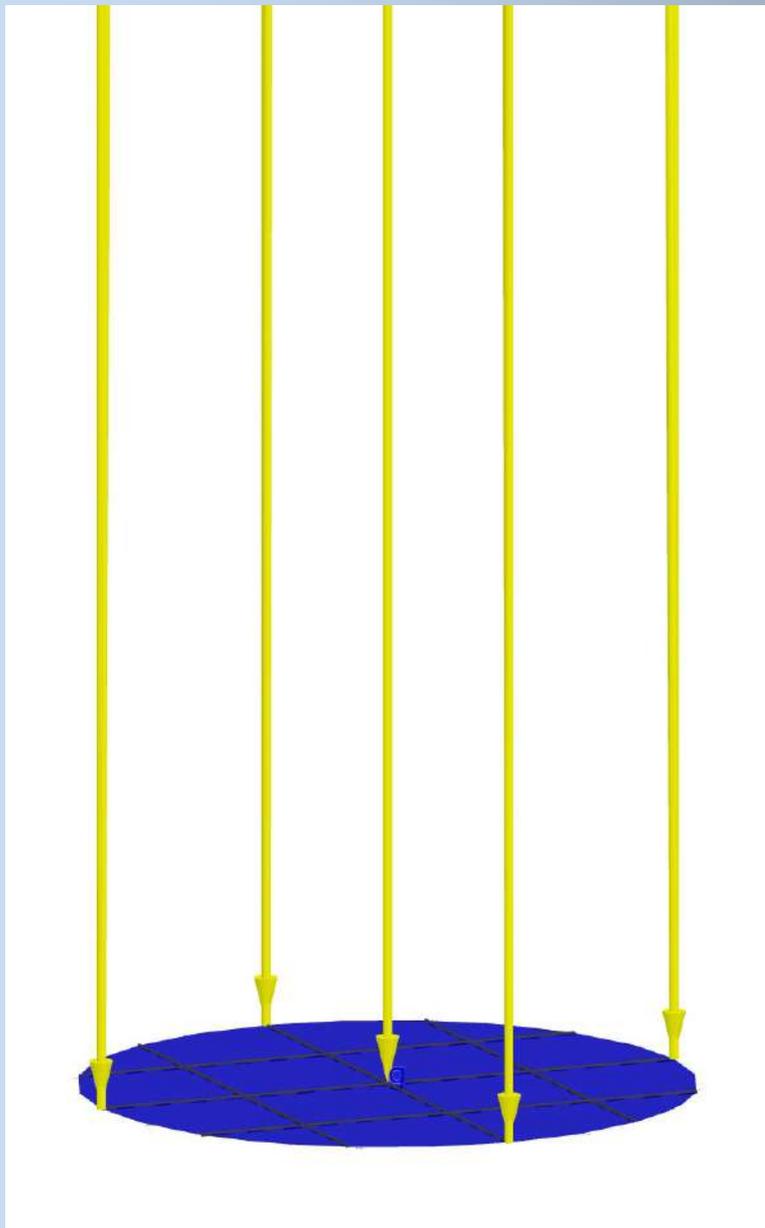
- 2.7m  
UBC/Laval
- 3m NODO
- 3.7m Lab.  
LMT
- 6m UBC LZT



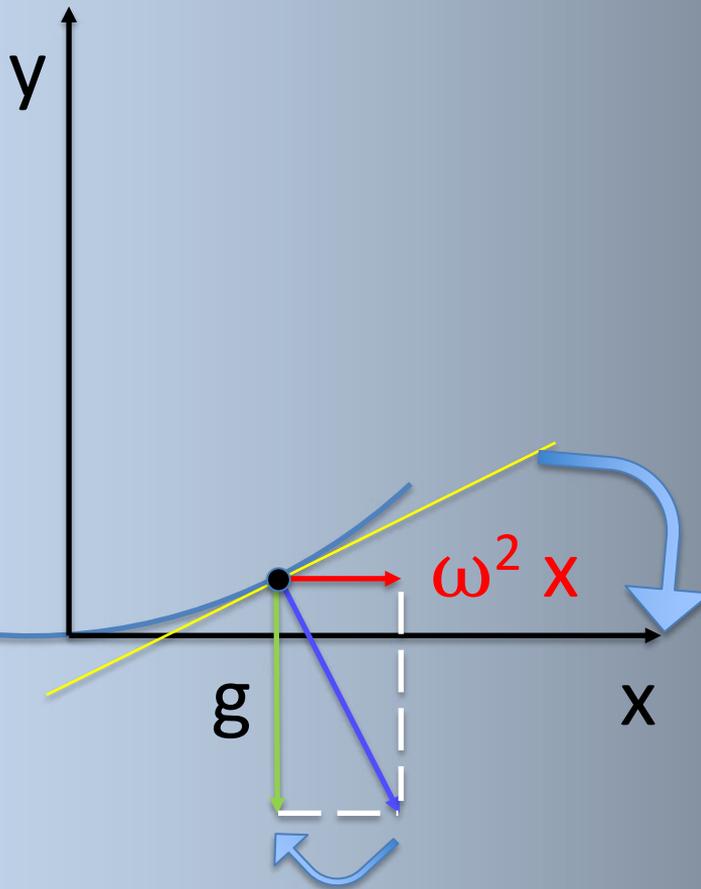
# I. Brief history

- 1996: First contact with Ermanno Borra
- 1997: Marseille conference
- 1997: ILMT
- 2007: Meeting Prof. Ram Sagar





$$y(x) = ?$$



$$\frac{dy}{dx} = \frac{\omega^2 x}{g}$$

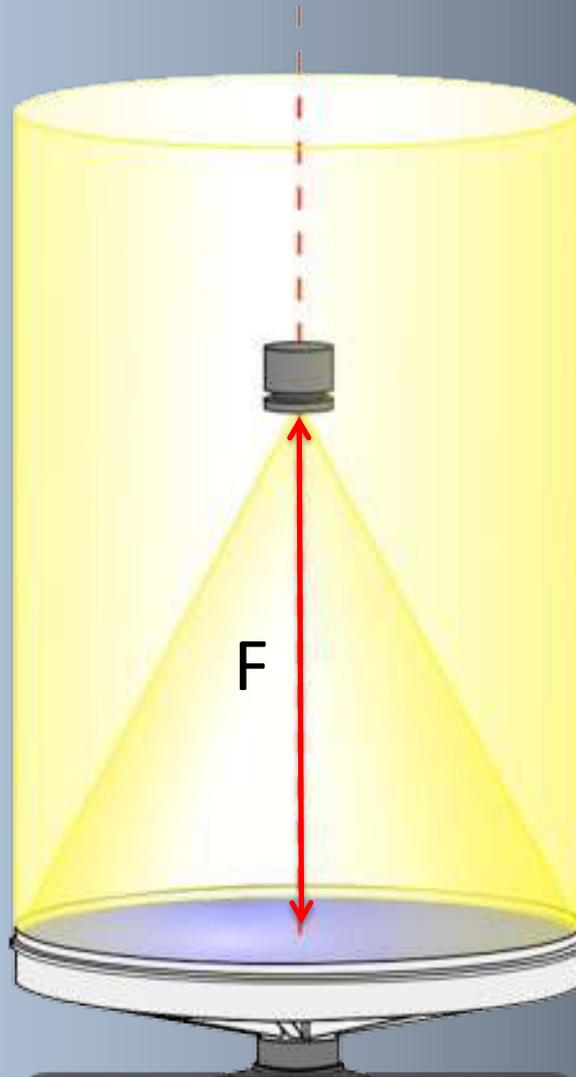
$$y = \frac{\omega^2 x^2}{2g}$$

$$y = \frac{x^2}{4F}$$

$$F = \frac{g}{2\omega^2}$$

# Liquid Mirror

The paraboloid consists of an ideal optical system to focus a beam of // light rays into a single point

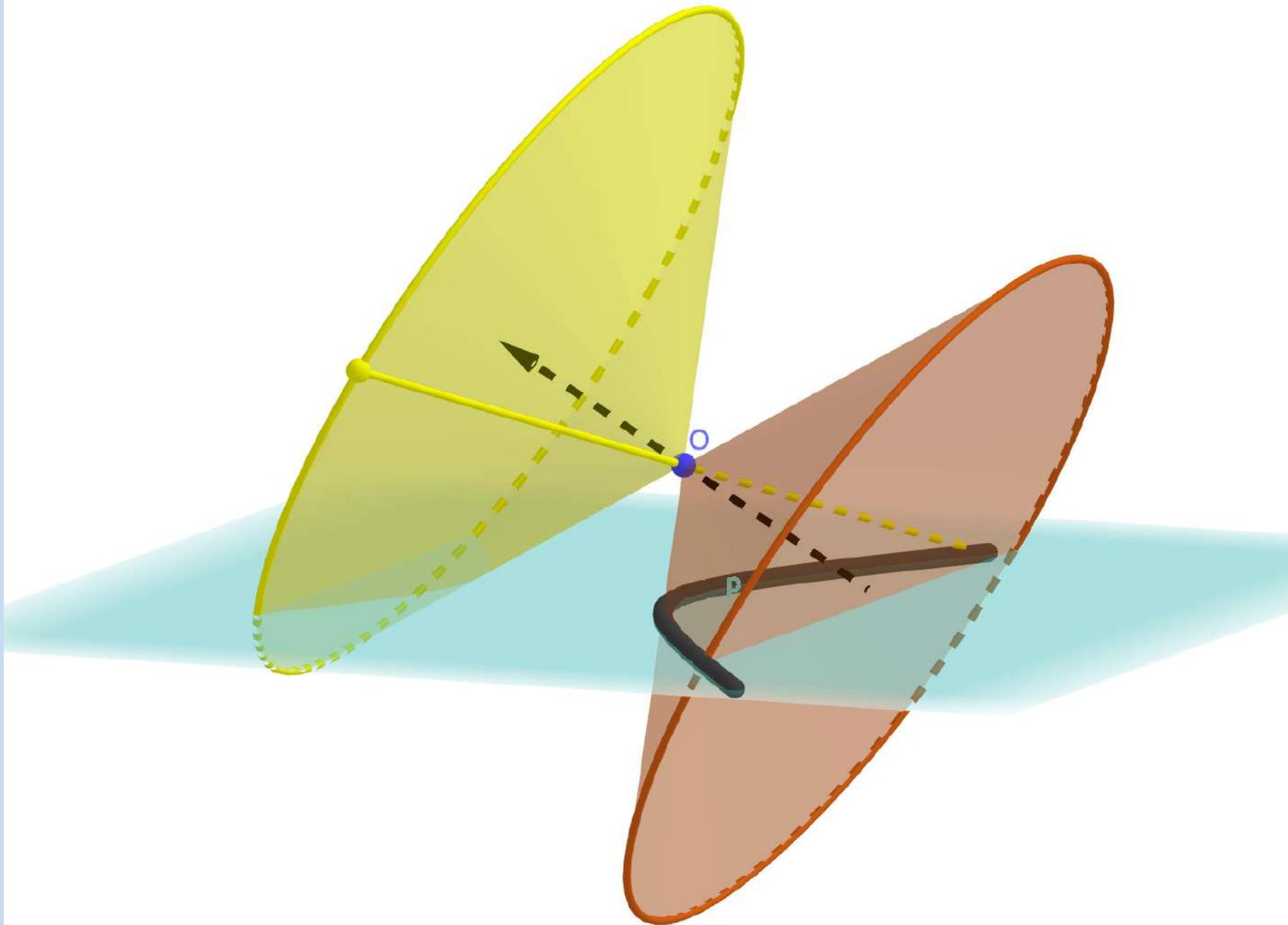


$$F = g / 2\omega^2$$

**Earth rotation ... Sun and star rotation**

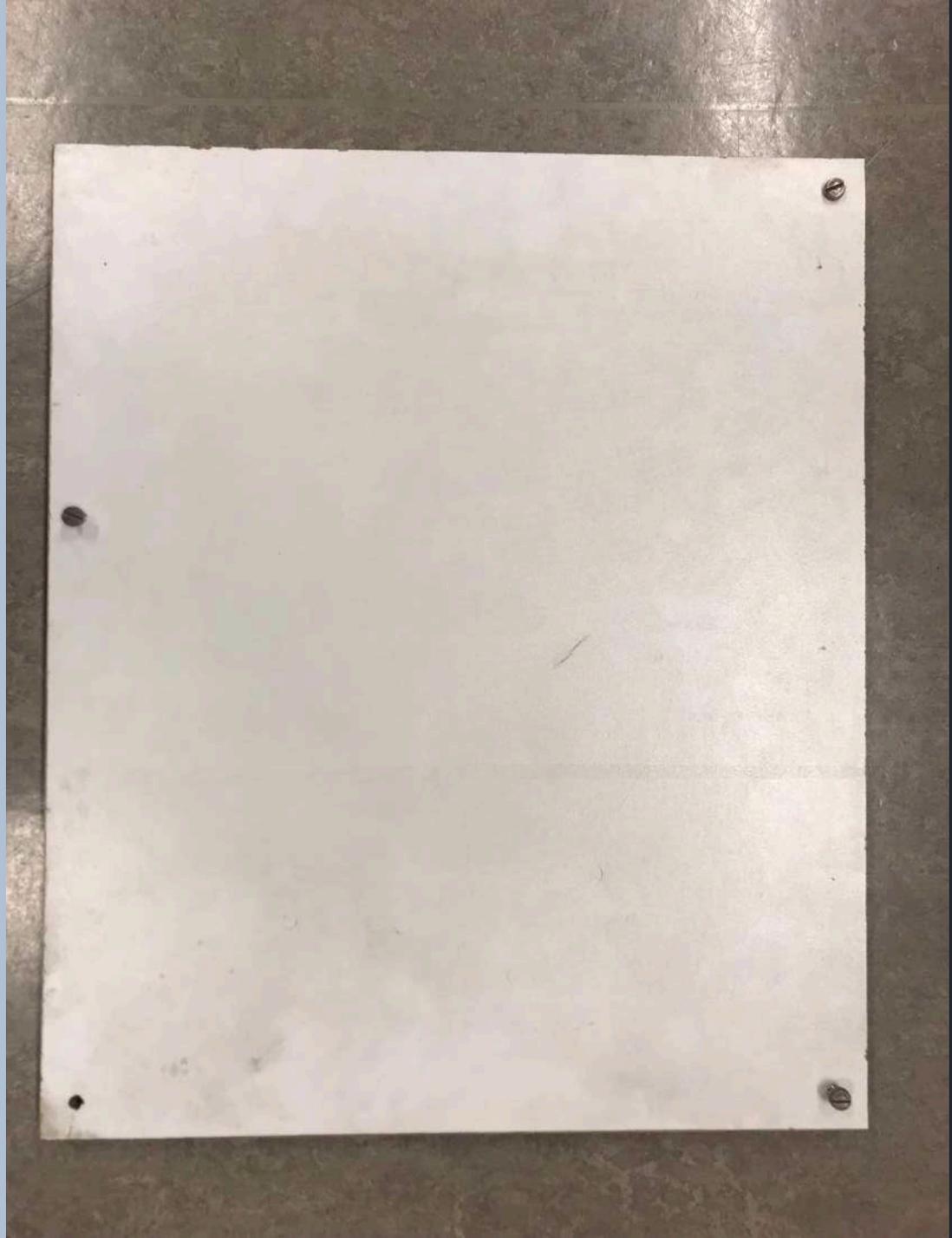
**...**

**and conic trajectories**



- **Liquid Mirror Telescope principles**

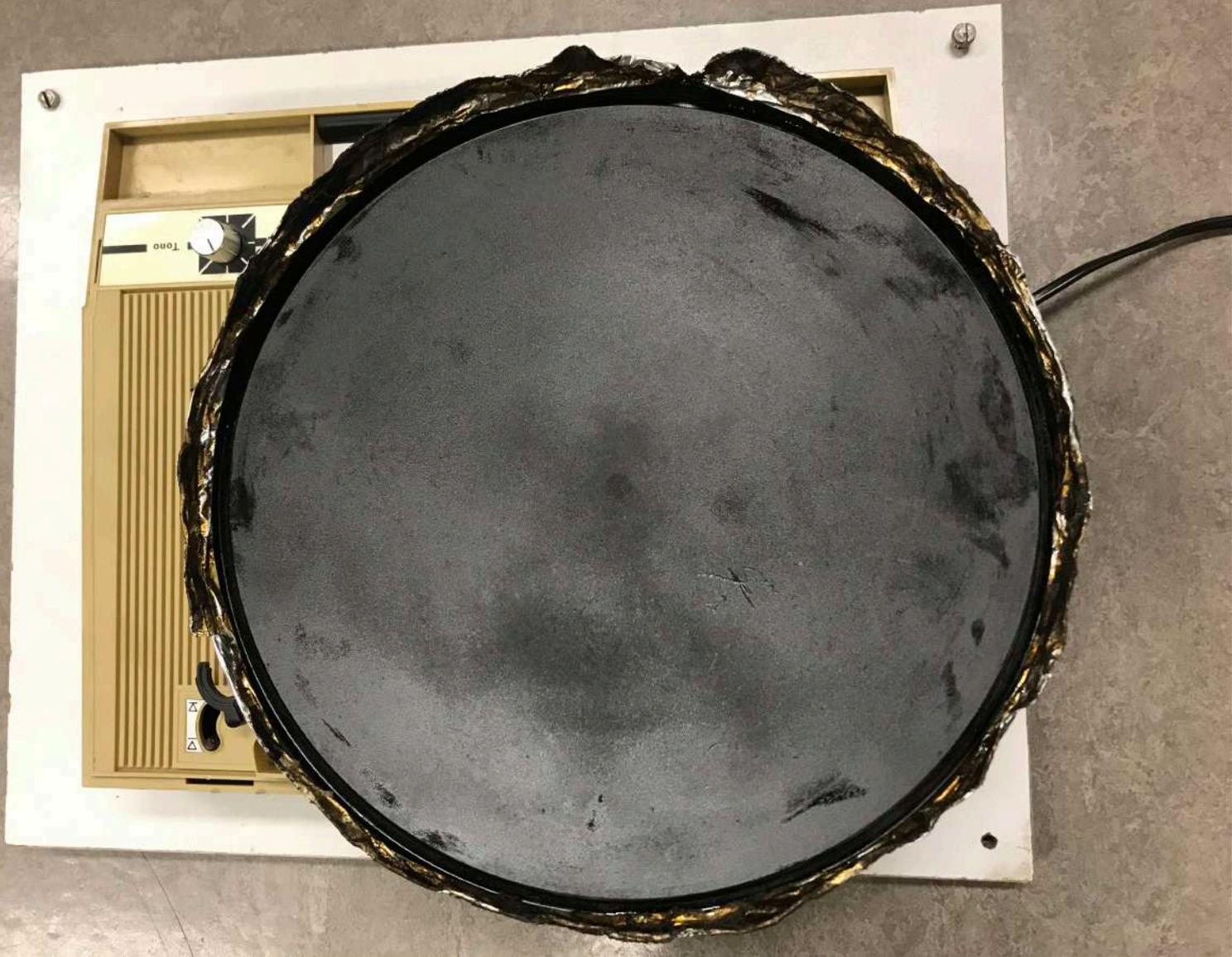
Build at  
home your  
own liquid  
mirror  
telescope ...





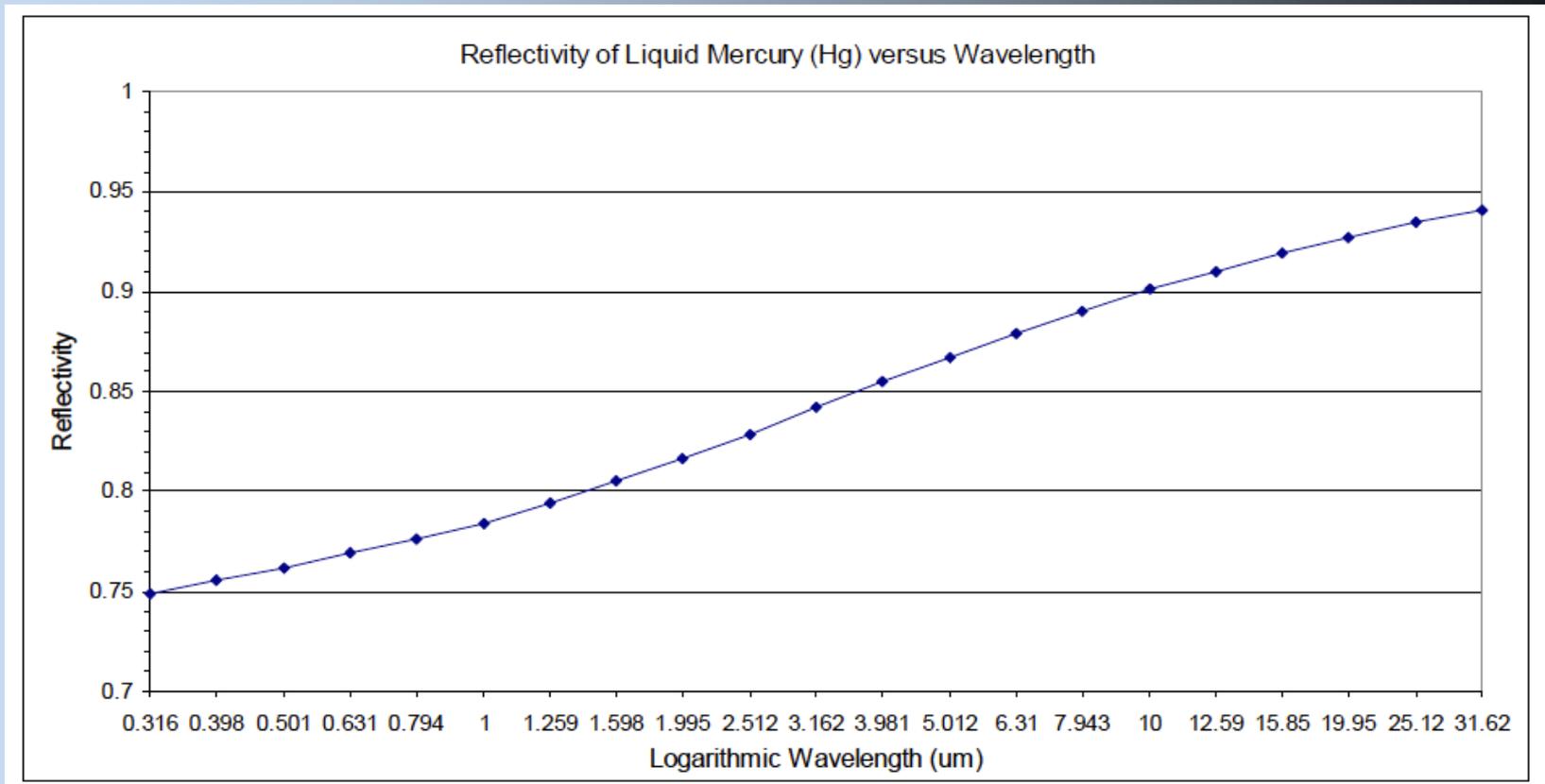






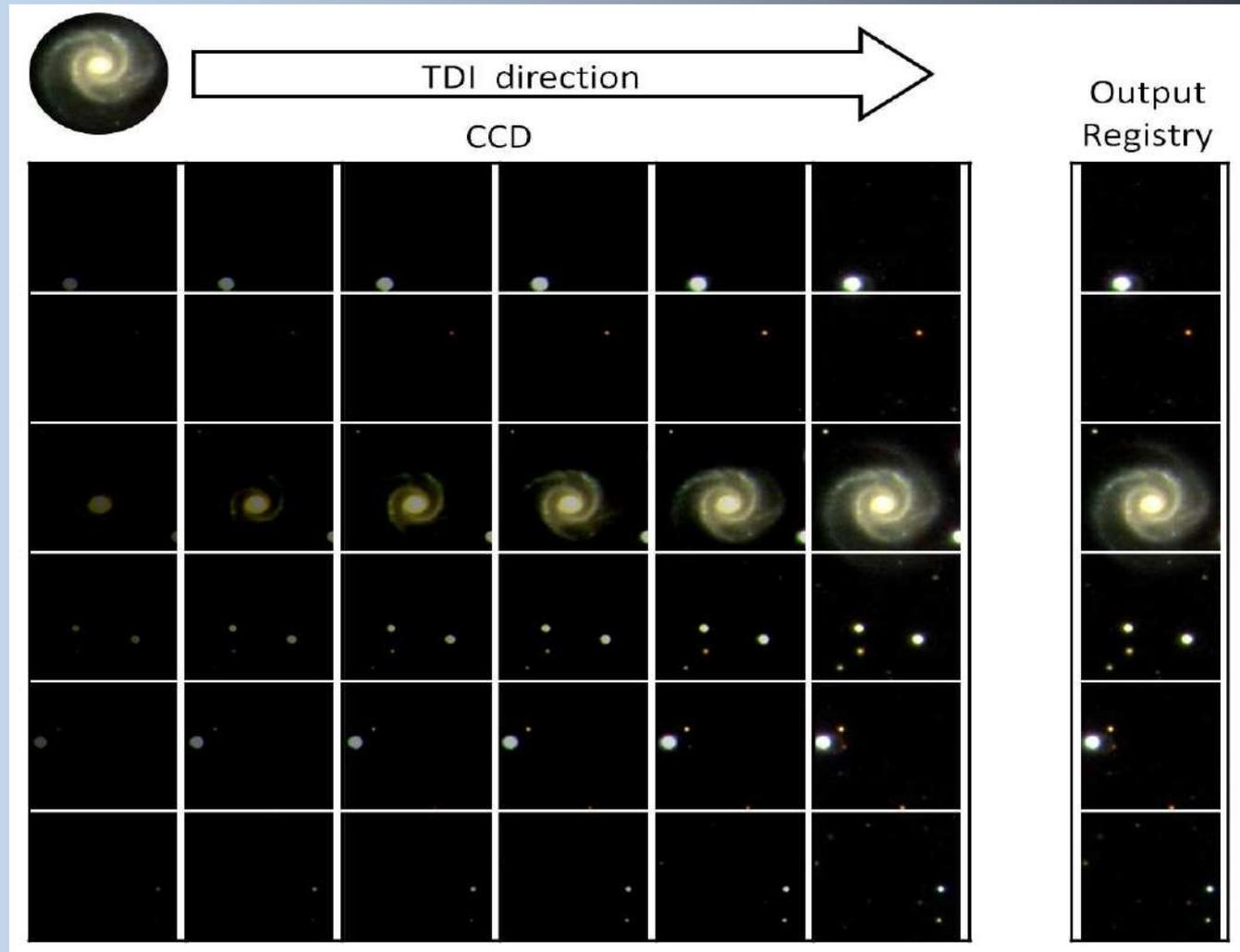


# The Liquid Mirror Telescope principles



# **TDI mode of observation**

# TDI mode (Time Delay Integration)



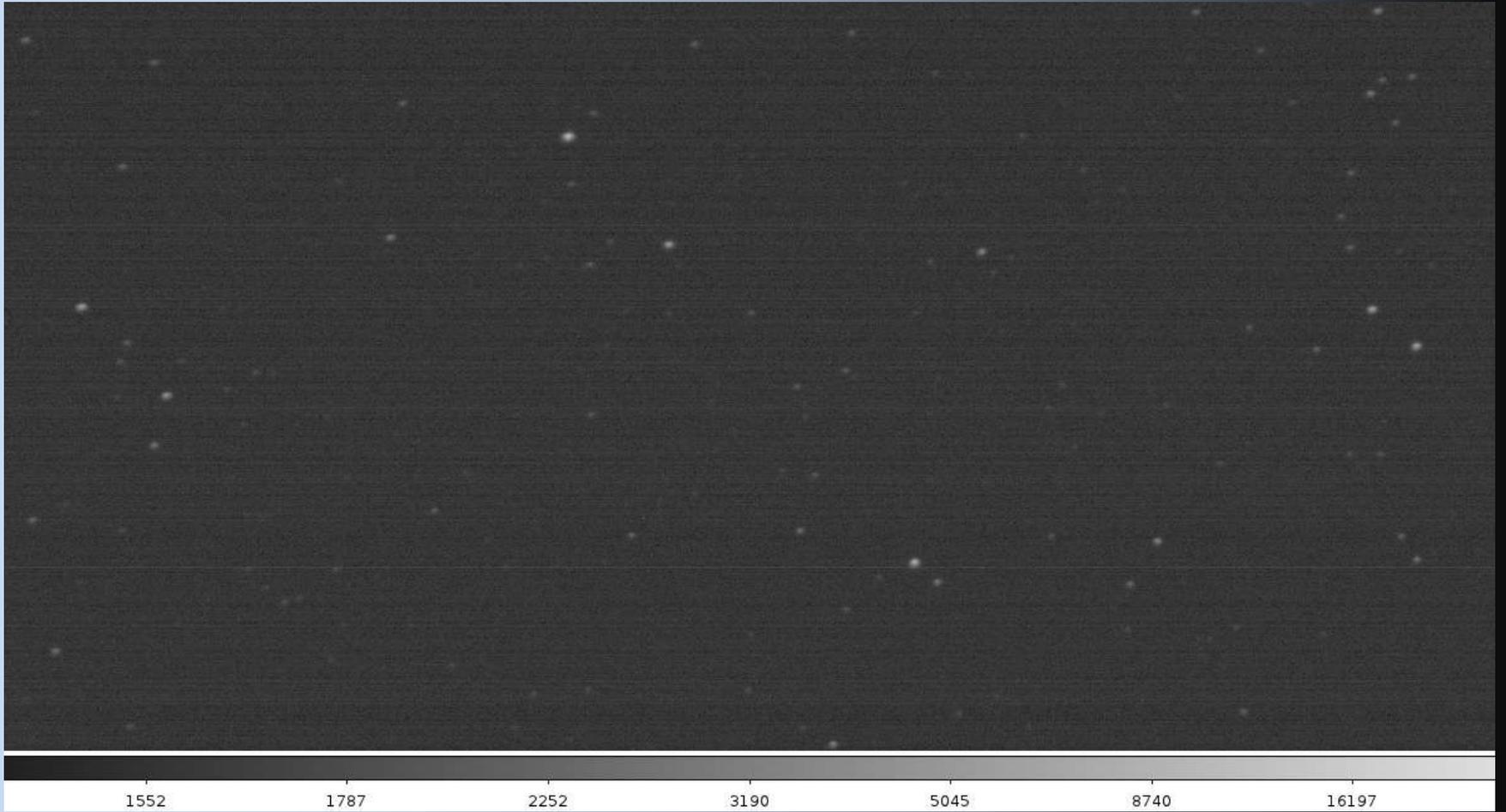
# The TDI mode



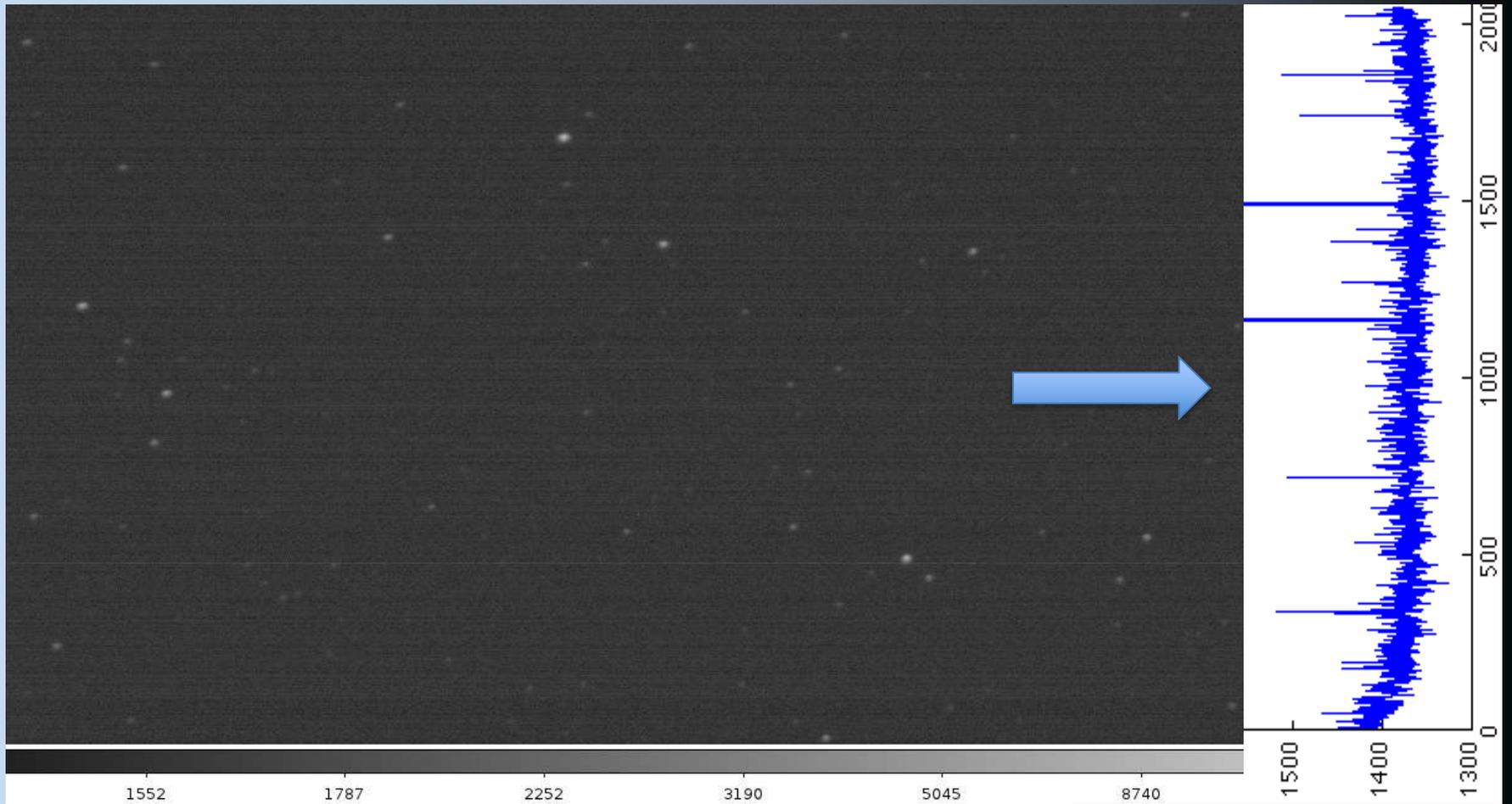
- The exposure time in the TDI mode is limited but the latter one can be increased by co-adding exposures recorded during different nights

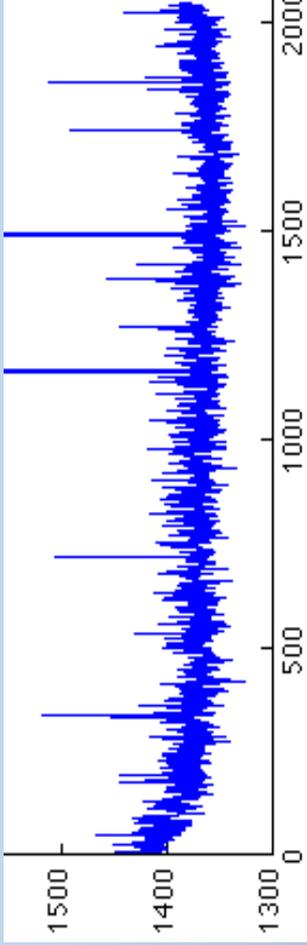
Number of nights	3	6	12	60 (~1 year)	240
$\Delta m$	0.6	1.0	1.35	2.22	2.98

# Raw CCD frame

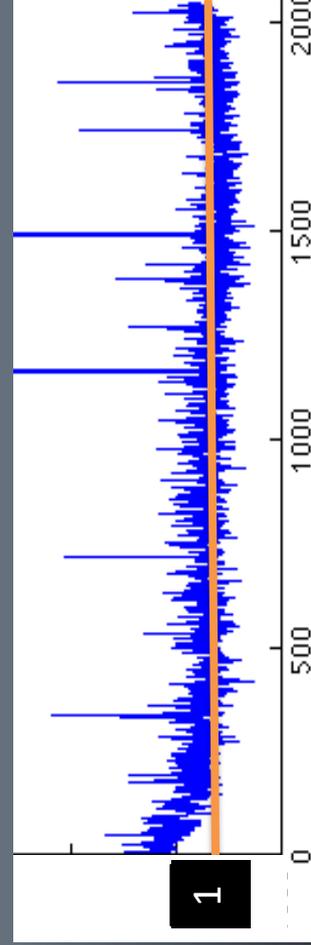


# Construction of a 1 dimension « flat field »

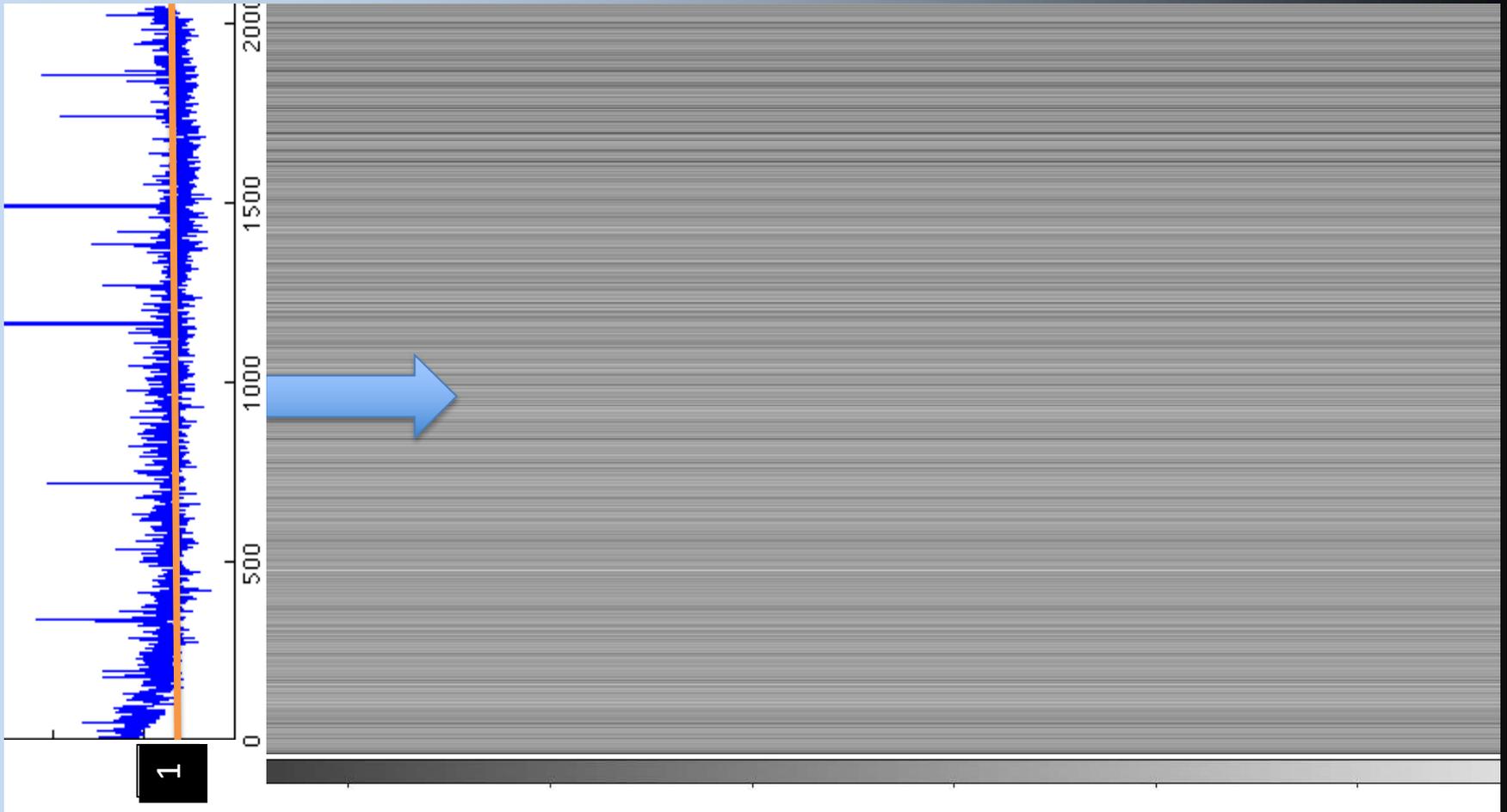




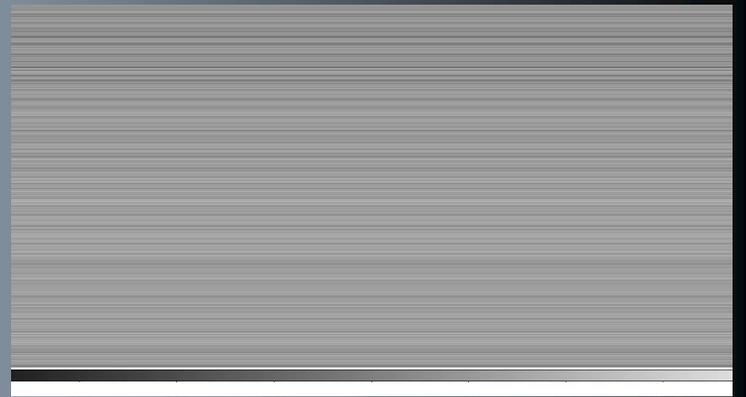
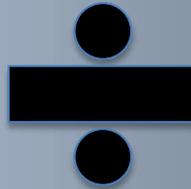
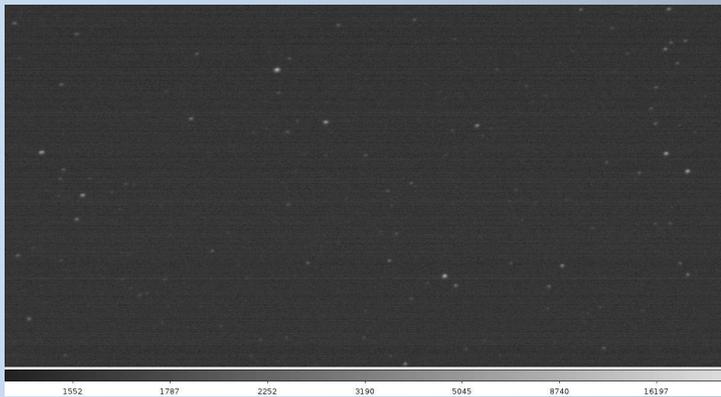
Normalisation



## Construction of a 2 dimension « flat field »



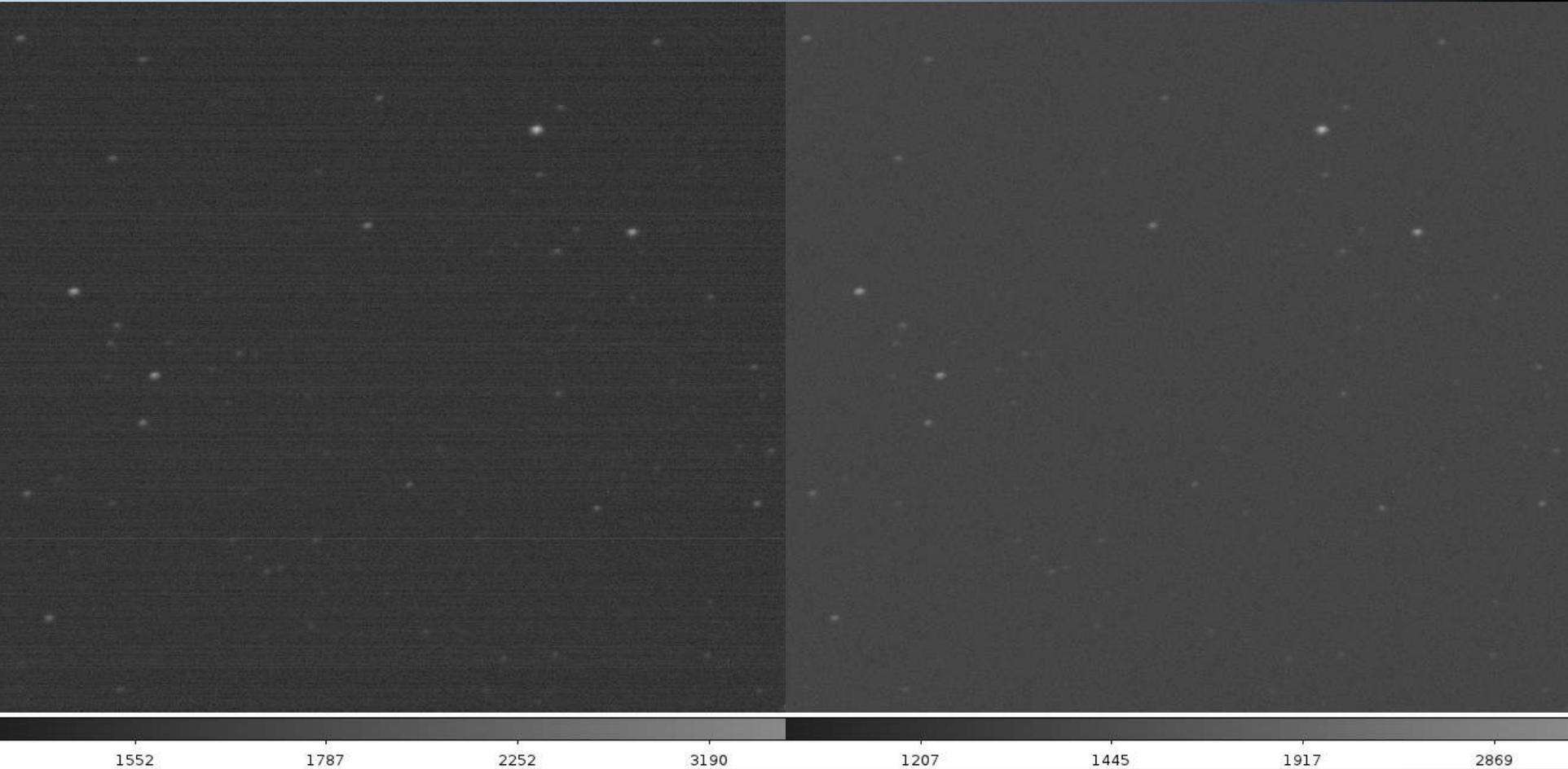
# Pre-processing



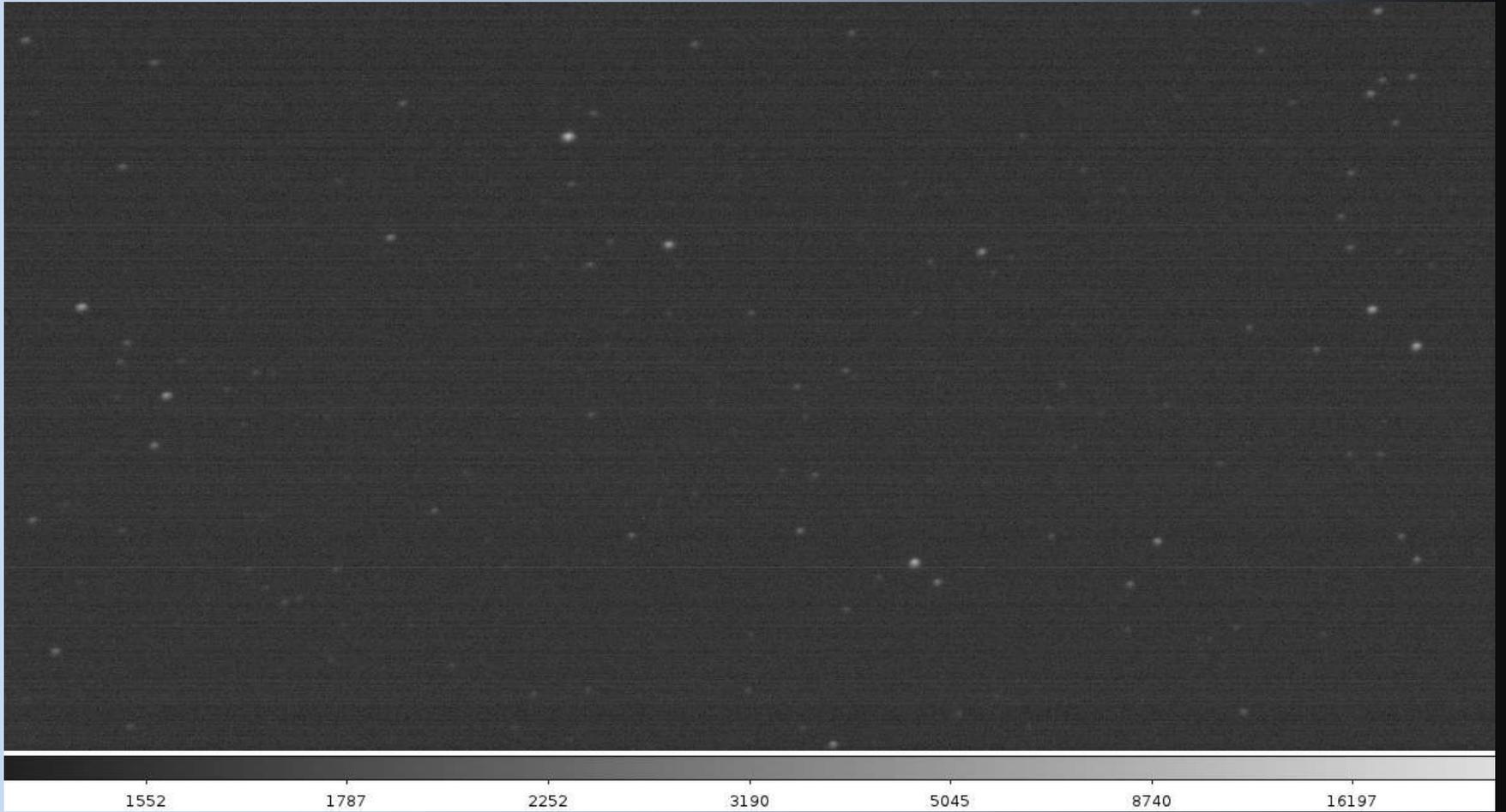
# CCD frame corrected by the « flat field »

Raw CCD frame

After pre-processing

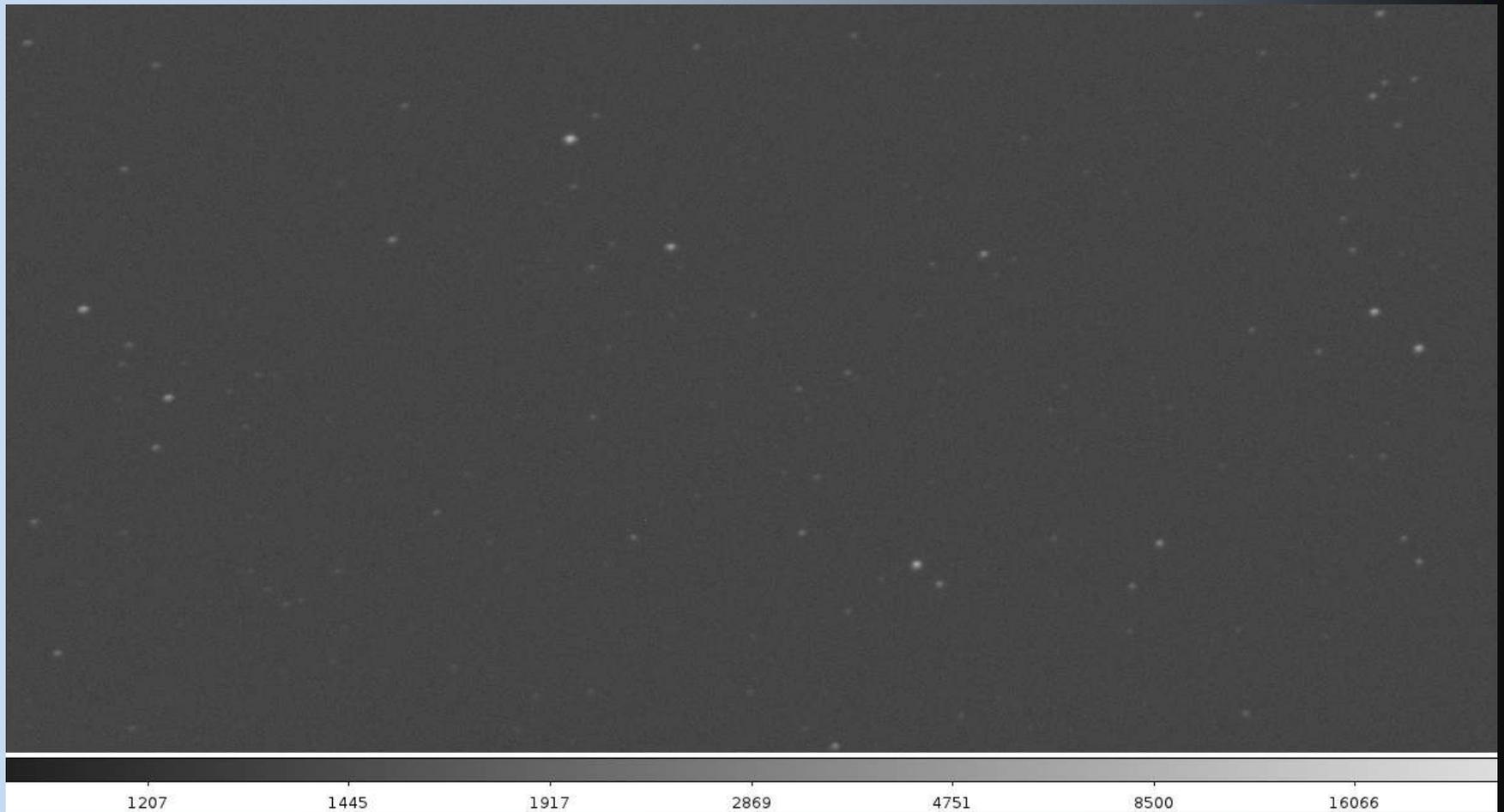


# Raw CCD frame



# CCD frame corrected by the « flat field »

After pre-processing



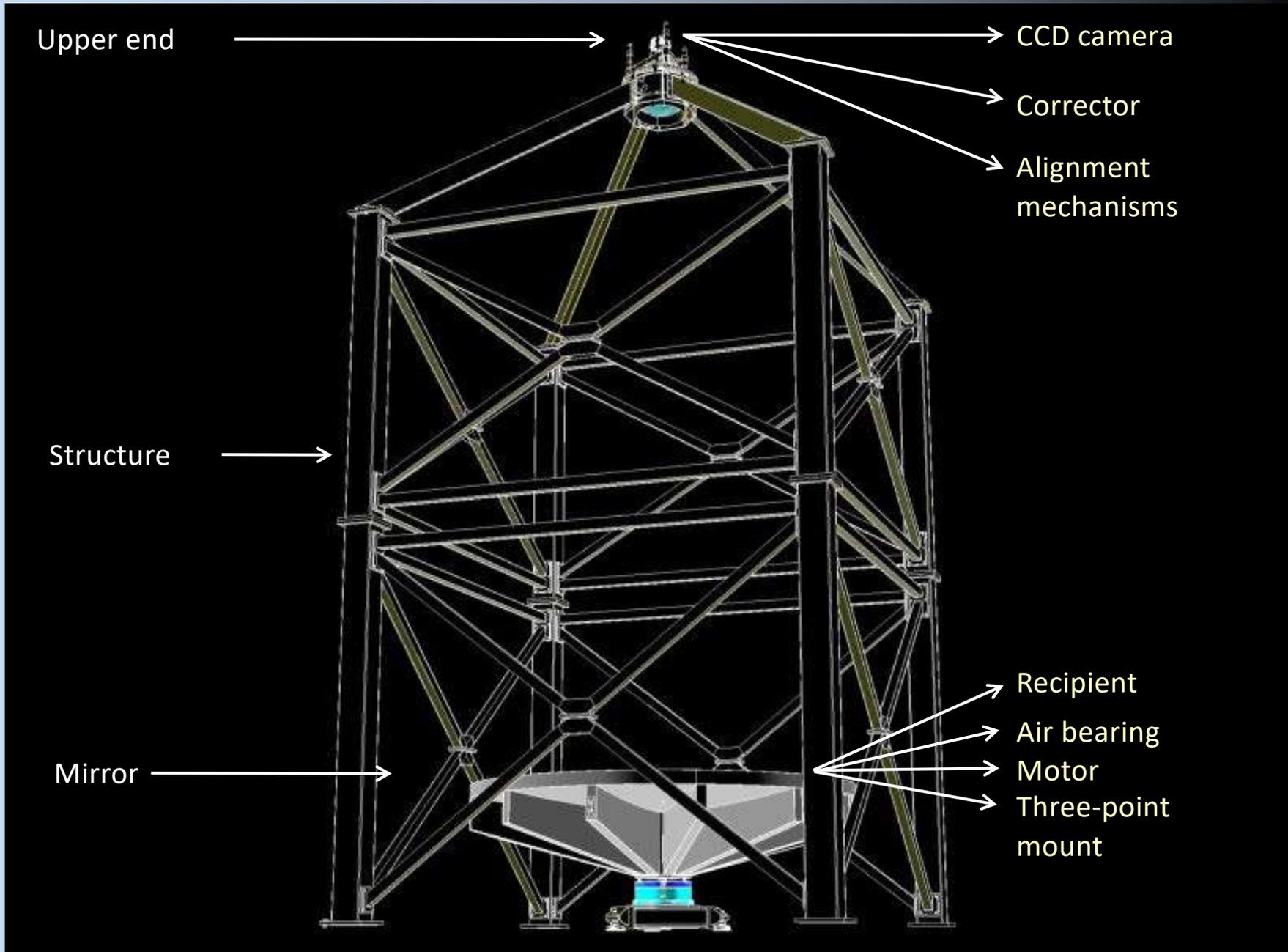
# The International Liquid Mirror Telescope (ILMT)



Prof. S.K. Joshi



Prof. Govind Swarup



# The 4m International Liquid Mirror Telescope



# The International Liquid Mirror Telescope



# Shipping of the ILMT (22 December 2011)



Packing of the mirror with foam, carbon fiber and polyurethane at AMOS, before shipping from Liège to ARIES observatory (Devasthal, India) on the 22nd of December 2011.

Container at AMOS comprising the telescope structure, the air bearing and the TDI corrector, before shipping from Liège to ARIES Observatory (Devasthal, India) on the 22nd of December 2011.





Departure of the container with the telescope structure, the air bearing and the TDI corrector on the 22nd of December 2011.



Departure of the box containing the 4m-mirror on the 22nd of December 2011.



Night shipping of the 4m-telescope and its mirror in India (23rd of March 2012)



Arrival of the truck carrying the 4m-mirror at the site of Devasthal (India)  
(23rd of March 2012)



Crane dropping off the 4m-mirror at the site of Devasthal (India)  
(23rd of March 2012)



Crane dropping off the container with the telescope structure, the air bearing and the TDI corrector at the site of Devasthal (India) (23rd of March 2012)



Transportation of the ILMT primary mirror between the entrance and the summit of the Devasthal Observatory (24 May 2013)



Transportation of the ILMT primary mirror between the entrance and the summit of the Devasthal Observatory (24 May 2013)





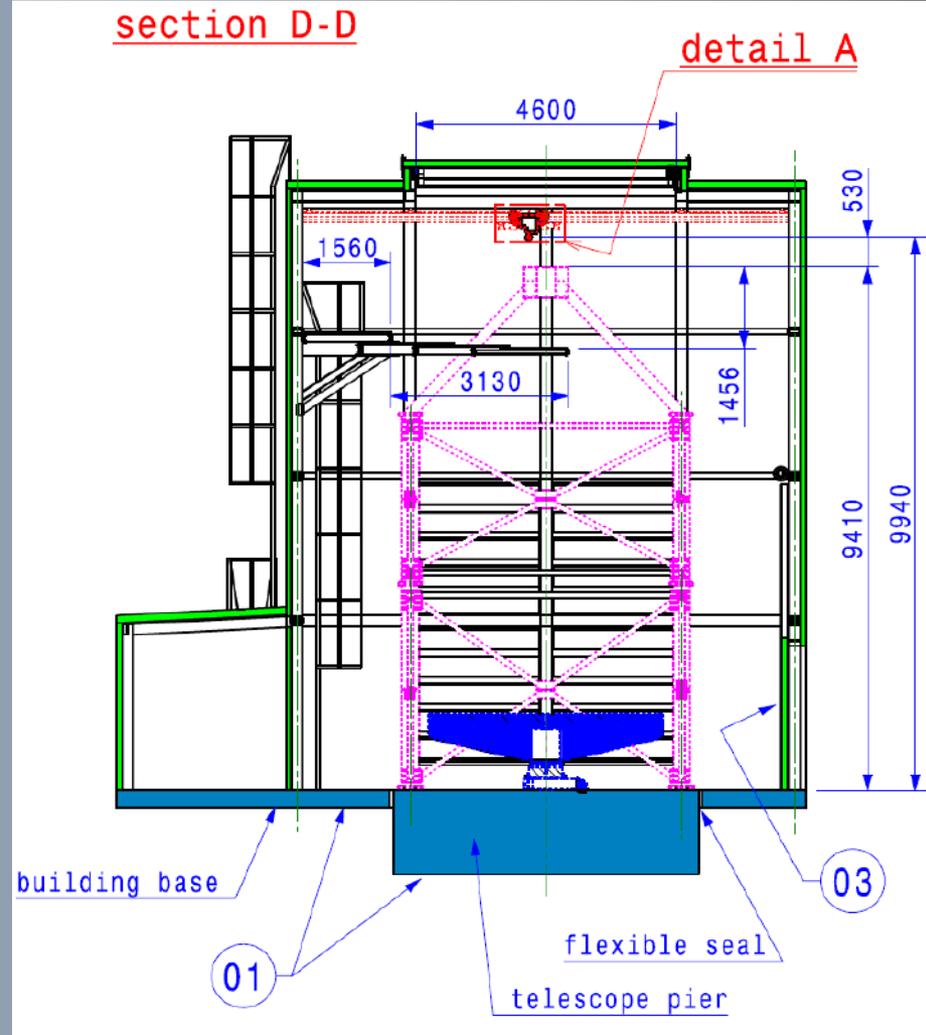
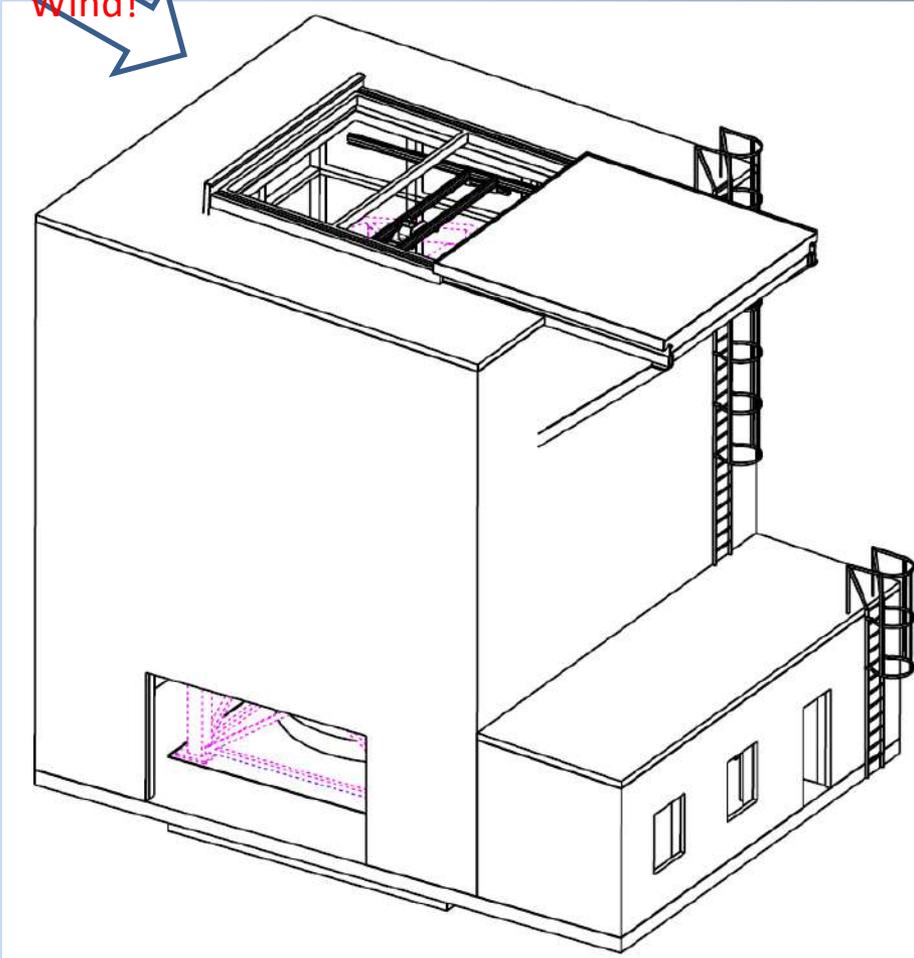
Transportation of the ILMT primary mirror between the entrance and the summit of the Devasthal Observatory (24 May 2013)

# Civil engineering construction of the ILMT dome

# Construction of the ILMT dome

The dome

Wind!





ILMT dome construction on the Devasthal site (7 February 2013)















Members of the Pedvak team finishing the ILMT dome construction



Digging 7 holes, 10 feet deep, to look for good earth grounding (June 2016)









View of the ILMT compressor,  
control and main ILMT buildings





Erection by AMOS of the mechanical structure of the ILMT on 2nd of march 2017



आर्यभट्ट प्रेक्षण विज्ञान शोध संस्थान

**Aryabhata Research Institute of Observational Sciences**

(An Autonomous Institute under DST, Ministry of Science & Technology, Govt. of India)

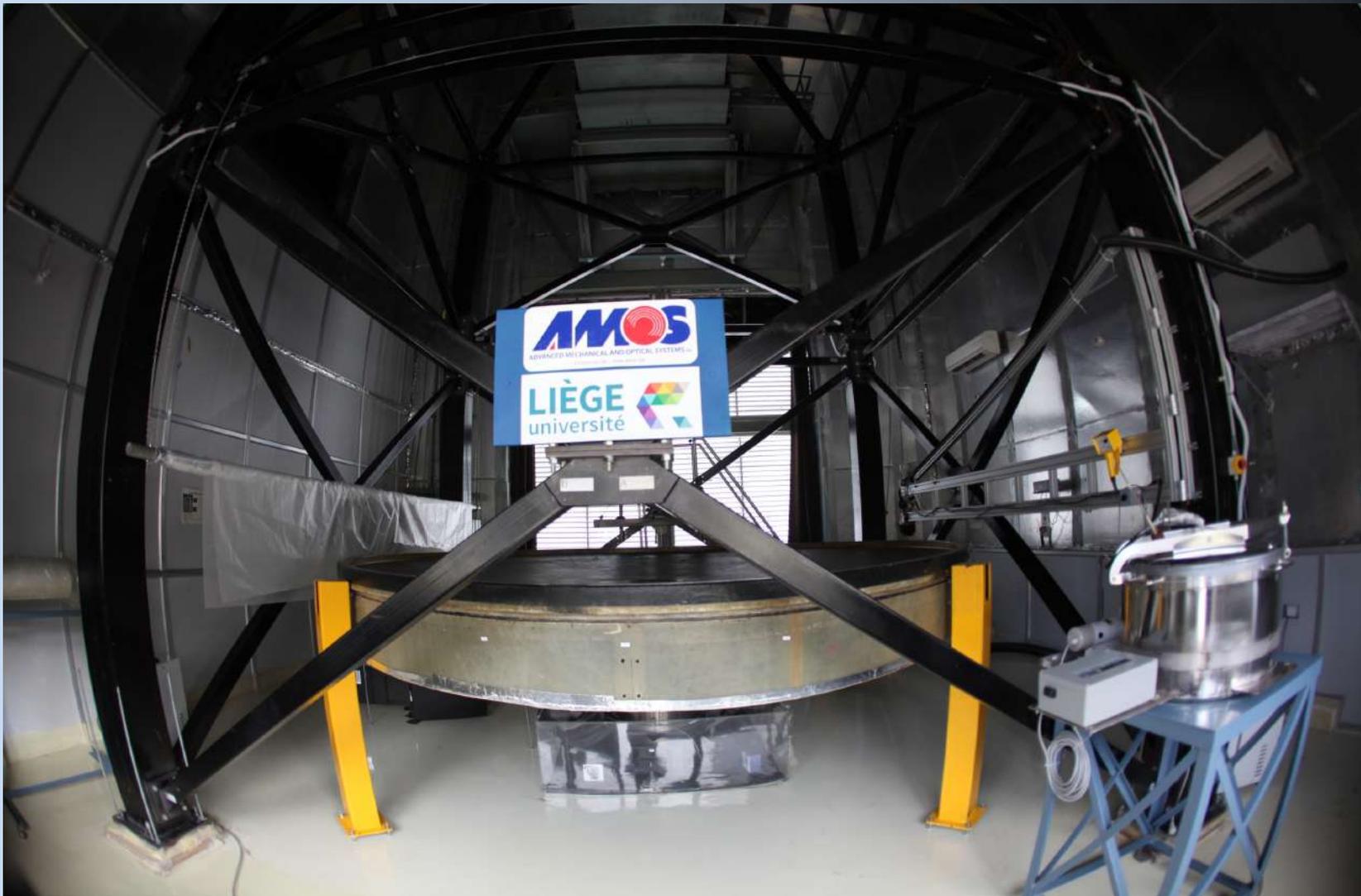
(विज्ञान एवं प्रौद्योगिकी विभाग, विज्ञान एवं प्रौद्योगिकी मंत्रालय, भारत सरकार के अंतर्गत स्वायत्तशासी संस्थान)

**4 मीटर**

**अंतर्राष्ट्रीय तरल दर्पण टेलीस्कोप**

**4 meter**

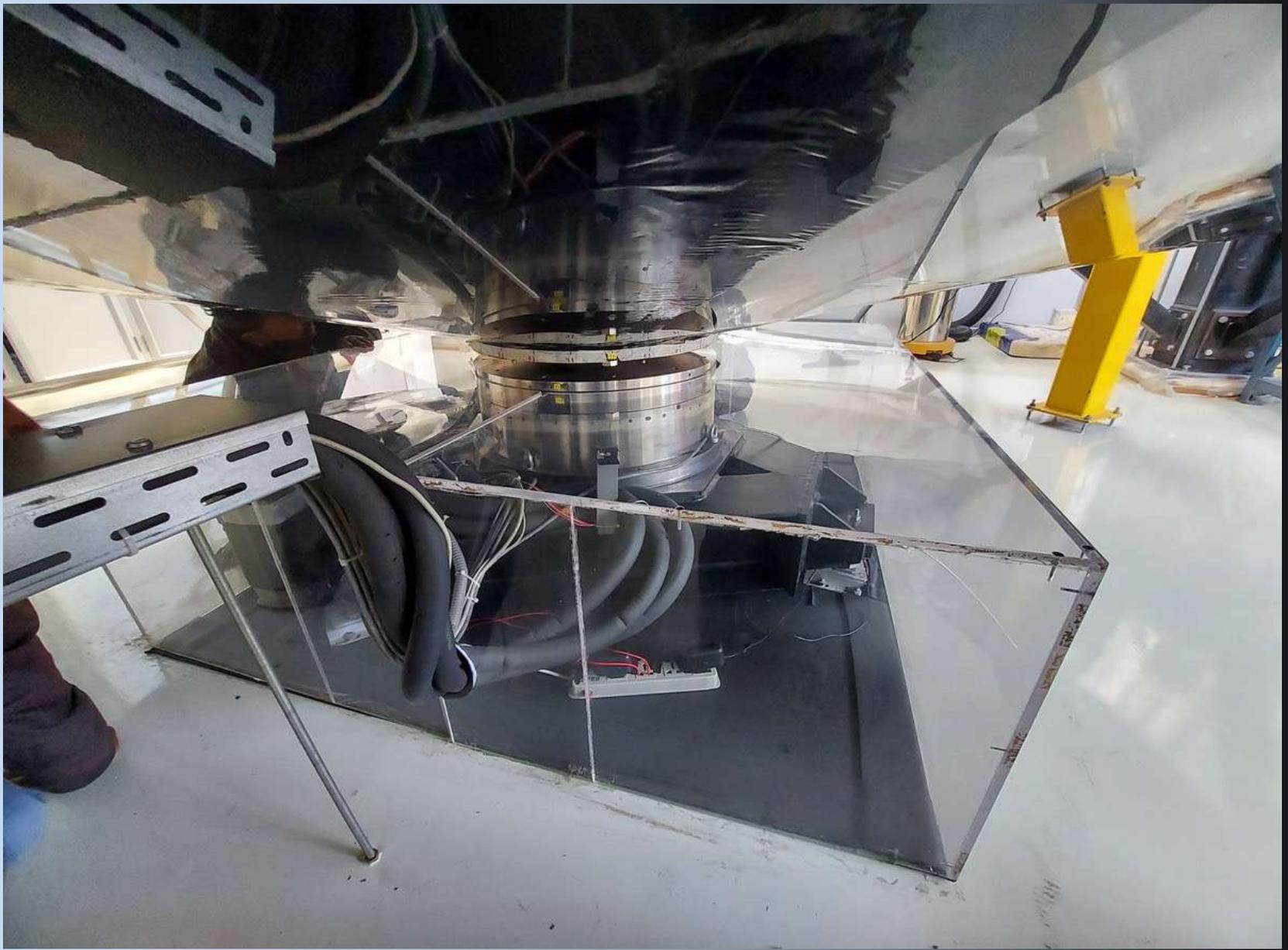
**International Liquid Mirror Telescope**



Fish eye view of the ILMT mirror, the air bearing and four safety yellow pillars to prevent any switchover of the mercury bowl.



Fish eye view of the ILMT from the rear side wall of the main building



Air bearing inside a plexiglas box to maintain a uniform temperature distribution







The two compressors and their associated air tanks

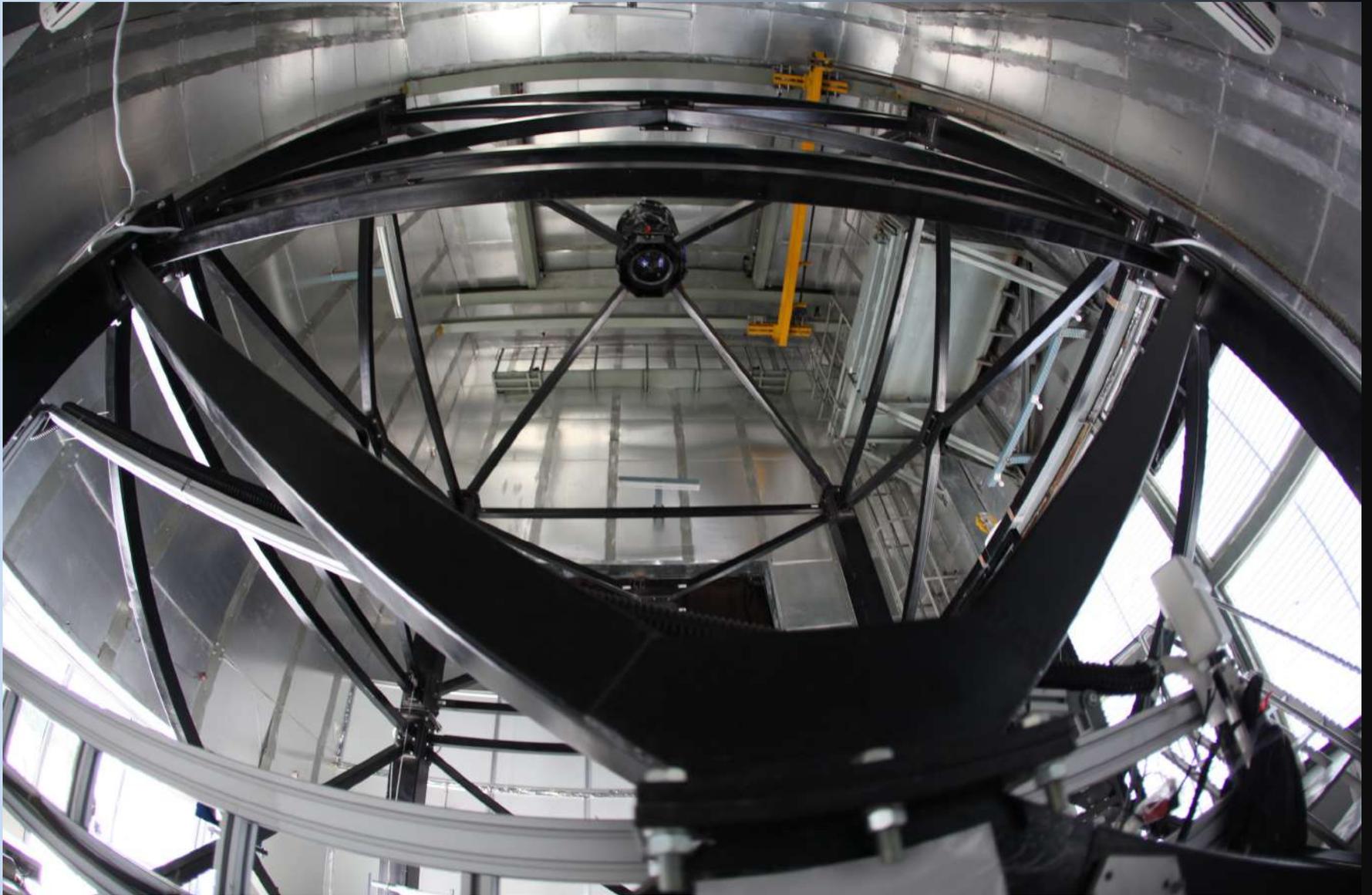




Pneumatic modules located near the 2 air compressors

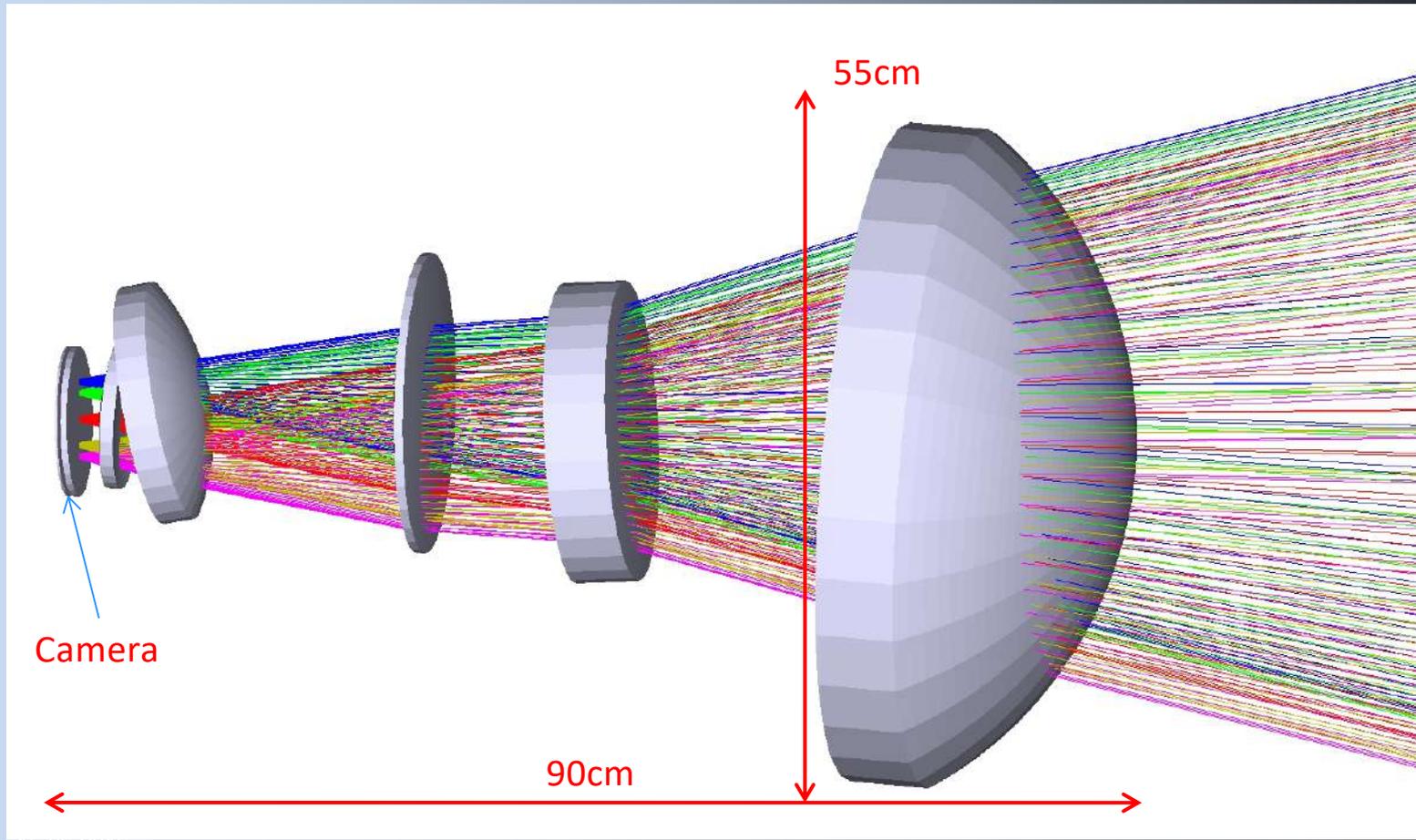


Pneumatic modules located inside the ILMT control room



Fish eye view of the main ILMT structure and of the optical corrector.

# The TDI optical corrector





North-South alignment of the optical corrector





Optical blank used for the L1 lens before polishing



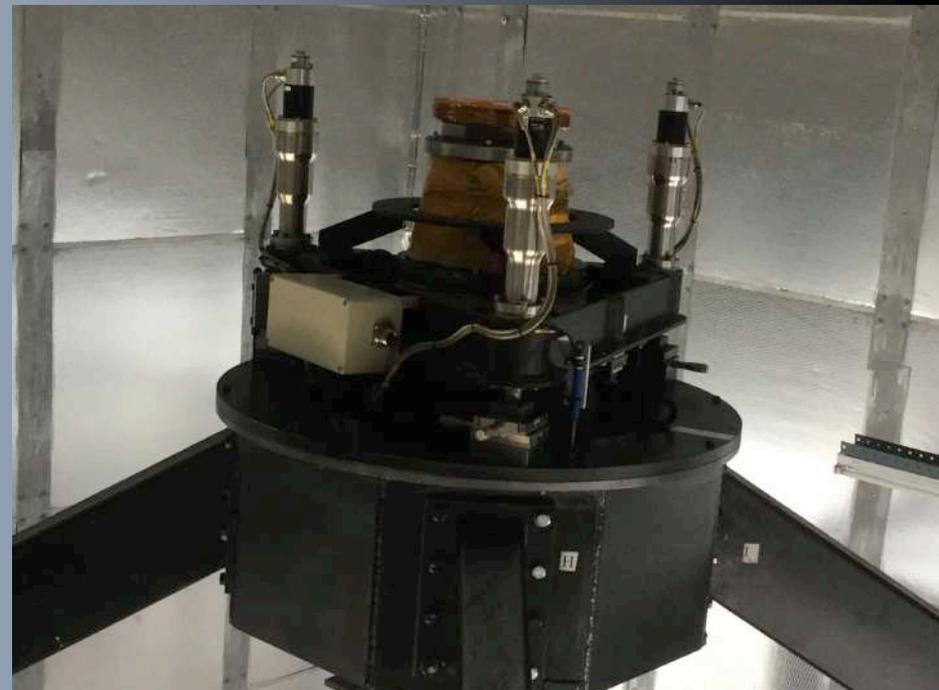


The L1 lens after being polished, inserted inside the cylinder of the ILMT optical corrector



The optical corrector assembled with the focus and tip-tilt adjustment mechanisms

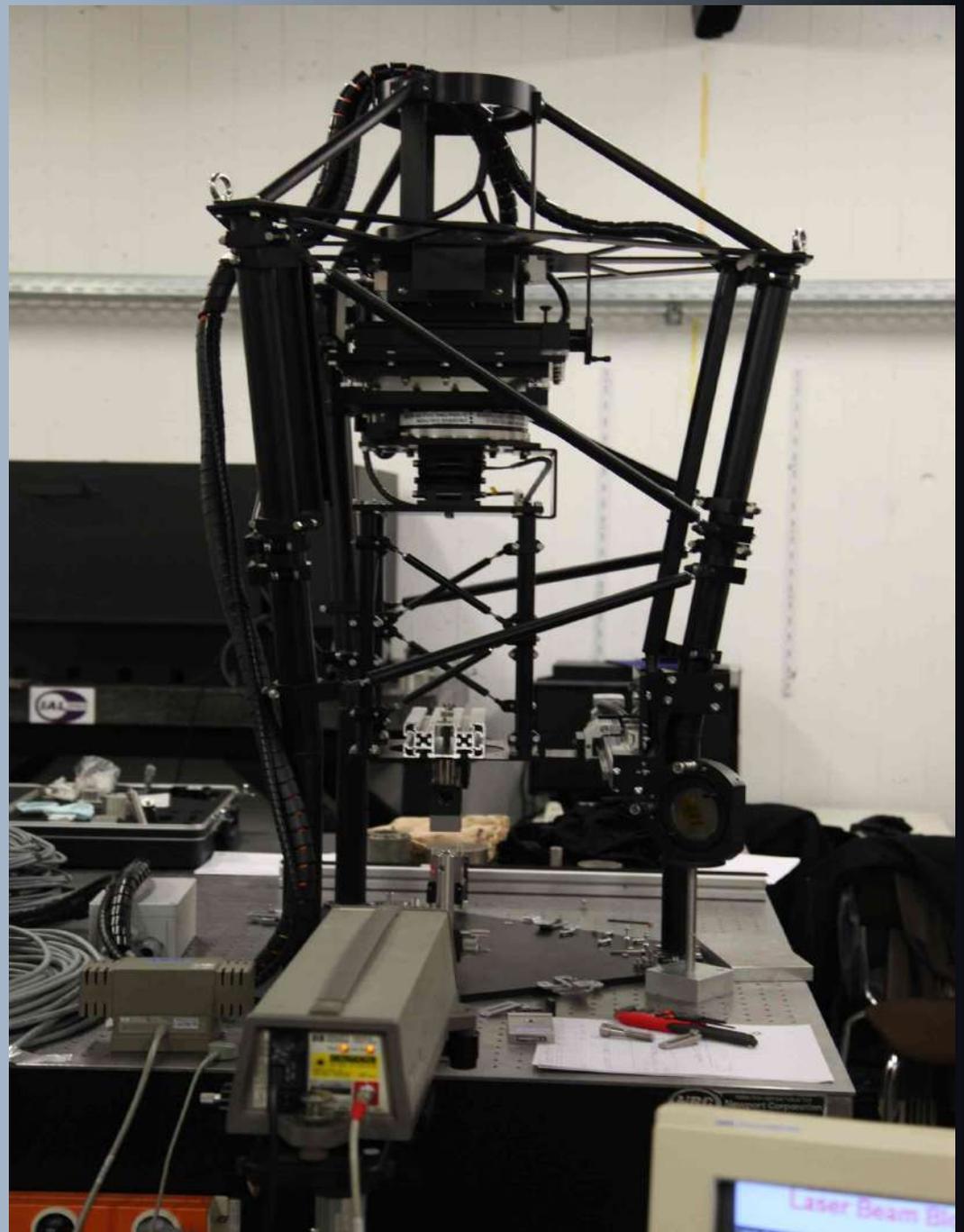
The optical corrector installed on the primary focus support

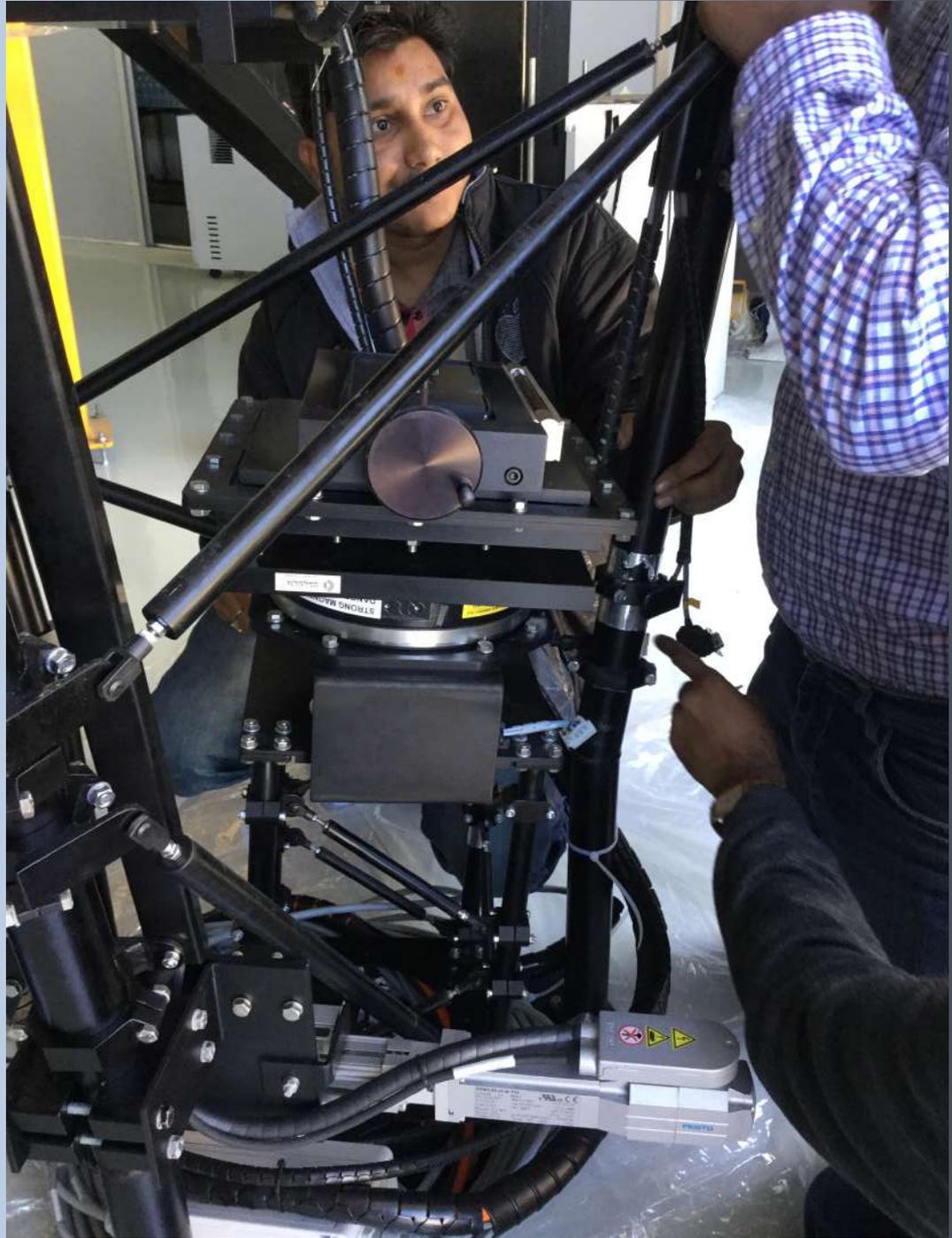




Cleaning of the L1 lens

SOCABELEC Interface under  
test at the Liège Space  
Center (ULiège, 18 November  
2013)



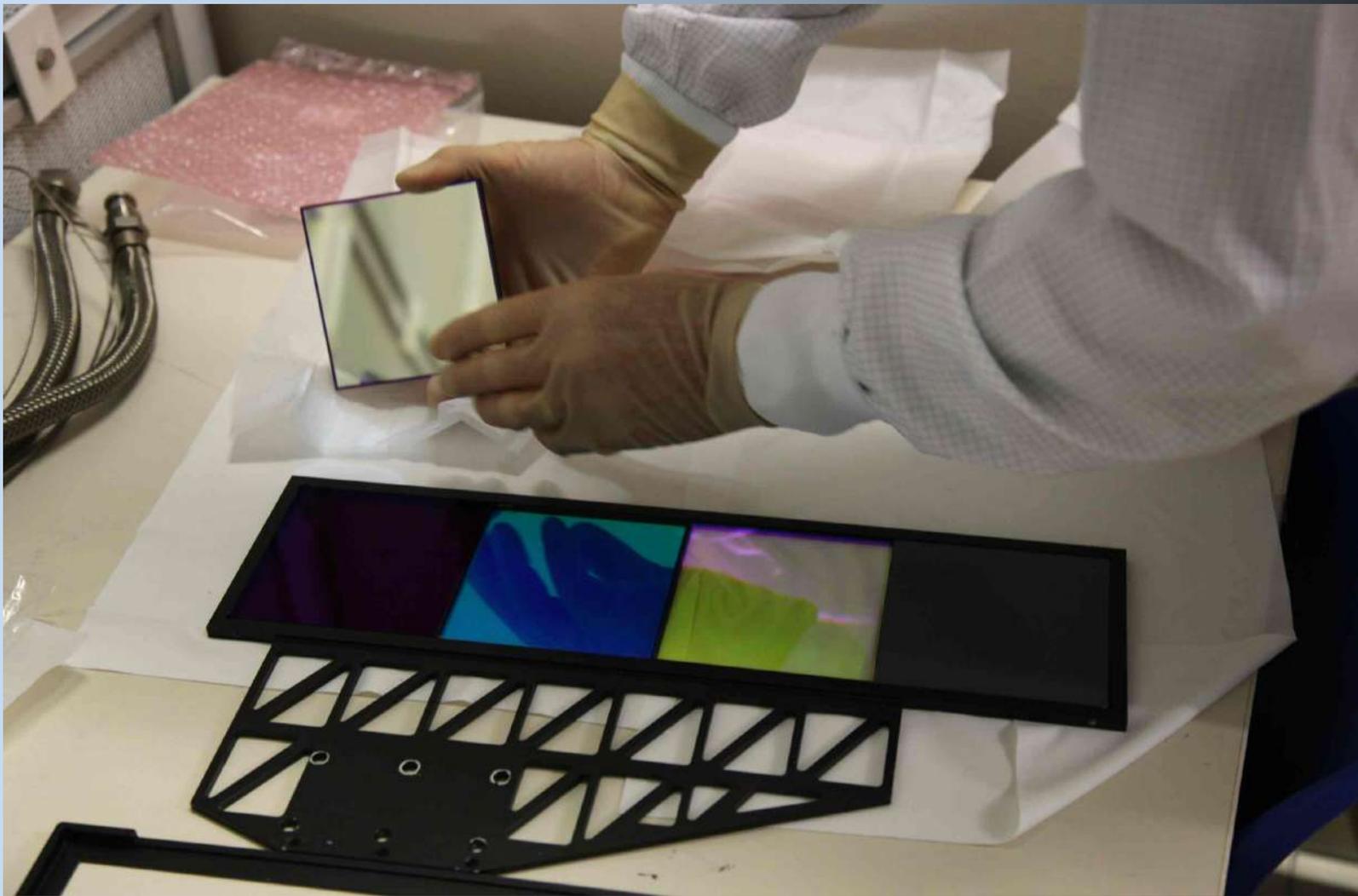




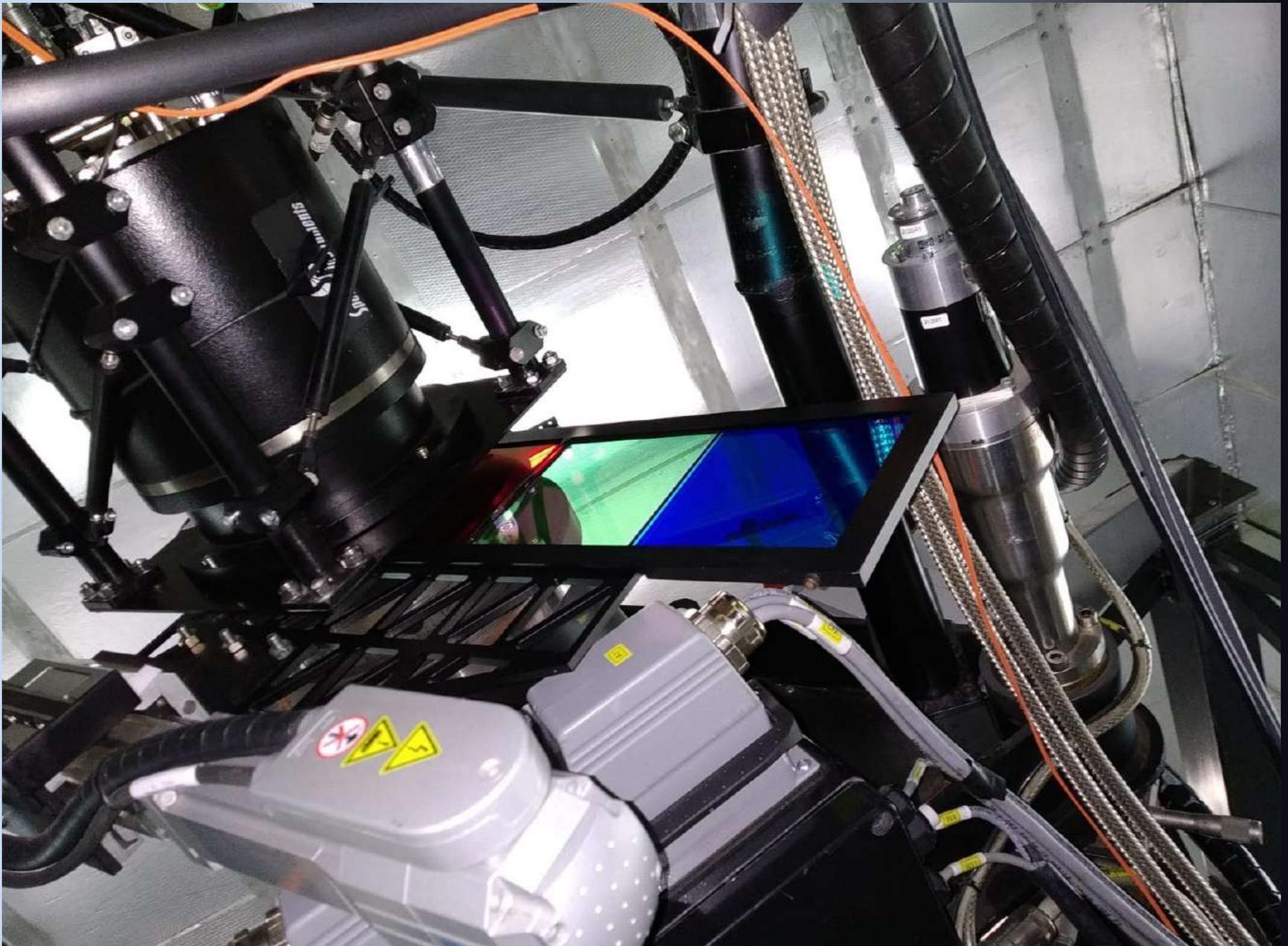
Camera CCD 4Kx4K (Spectral Instruments) with connections for the cooling and an optical fiber for transmitting the data to a computer located in the ILMT control room

DC power supply for the CCD camera and cooling compressor (PT-30 gas)

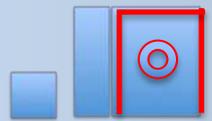




Support of the filter tray (Sloan  $g'$ ,  $r'$ ,  $i'$ ). Tests at the Liège Space Center (ULiège, 18 November 2013)



Installation of the filter tray just under the CCD camera located inside the SOCABELEC interface at the prime focus



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D A

Camera









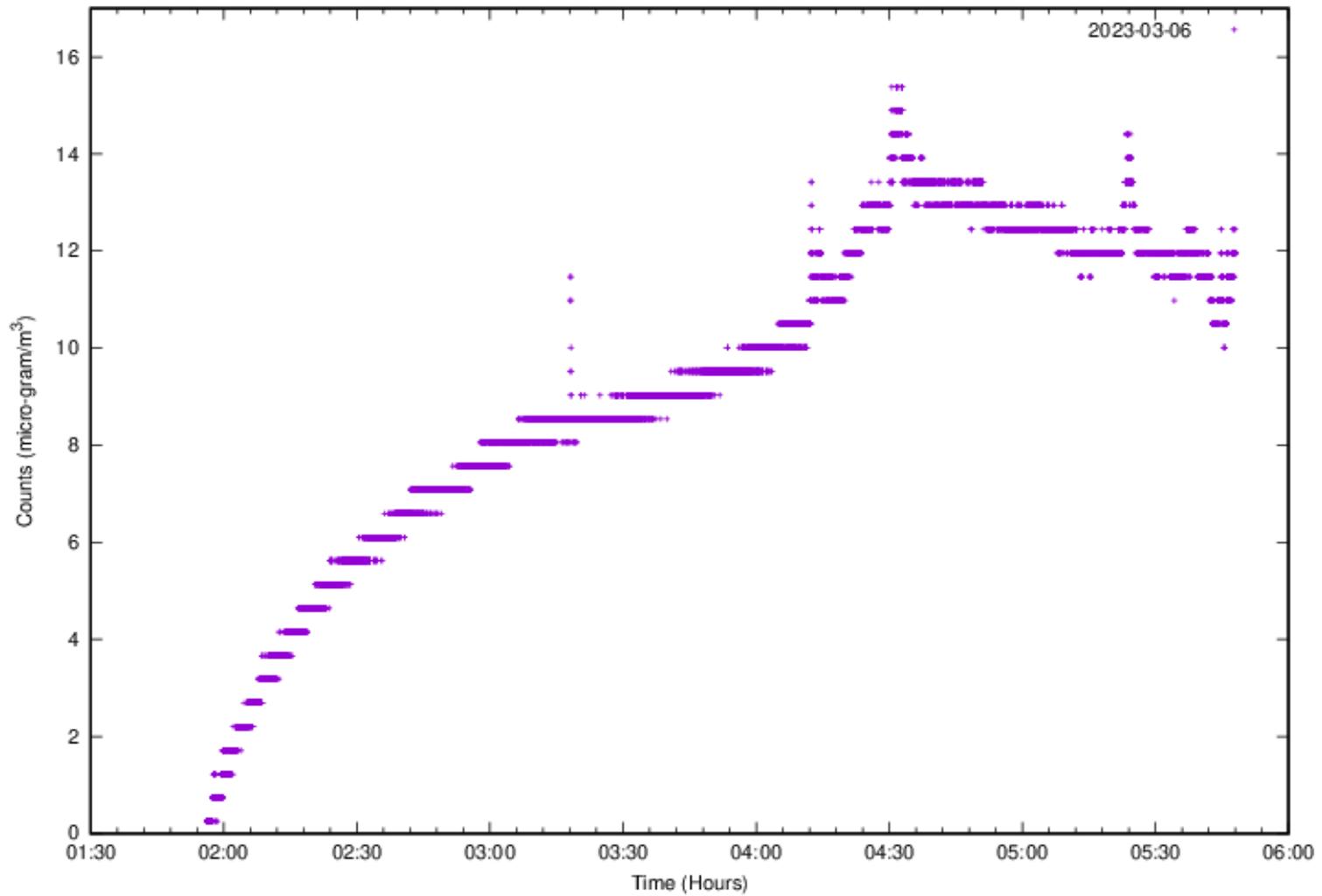
The ILMT mirror filled with mercury and covered with mylar



Aerial top view of the ILMT

# 29 April 2022: Closing the mercury surface and First Light!





Mercury vapor counts plot







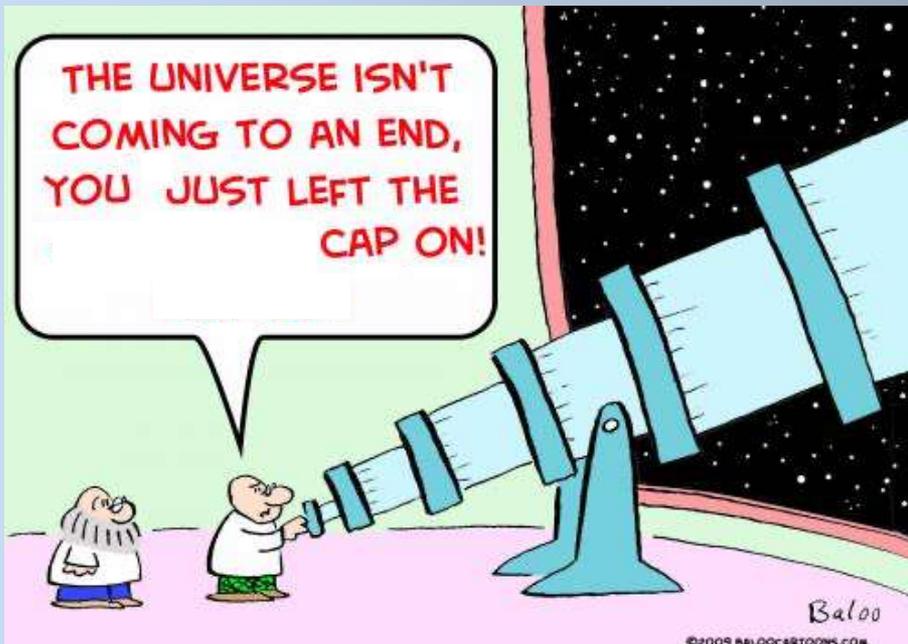
Aerial view of the domes of the 4m ILMT, 3.6m DOT and of the 1.3m DFOT



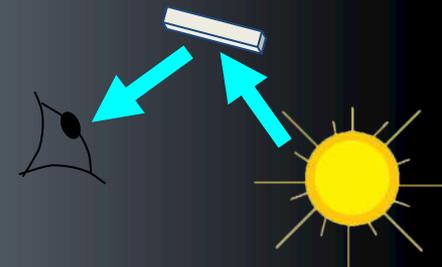
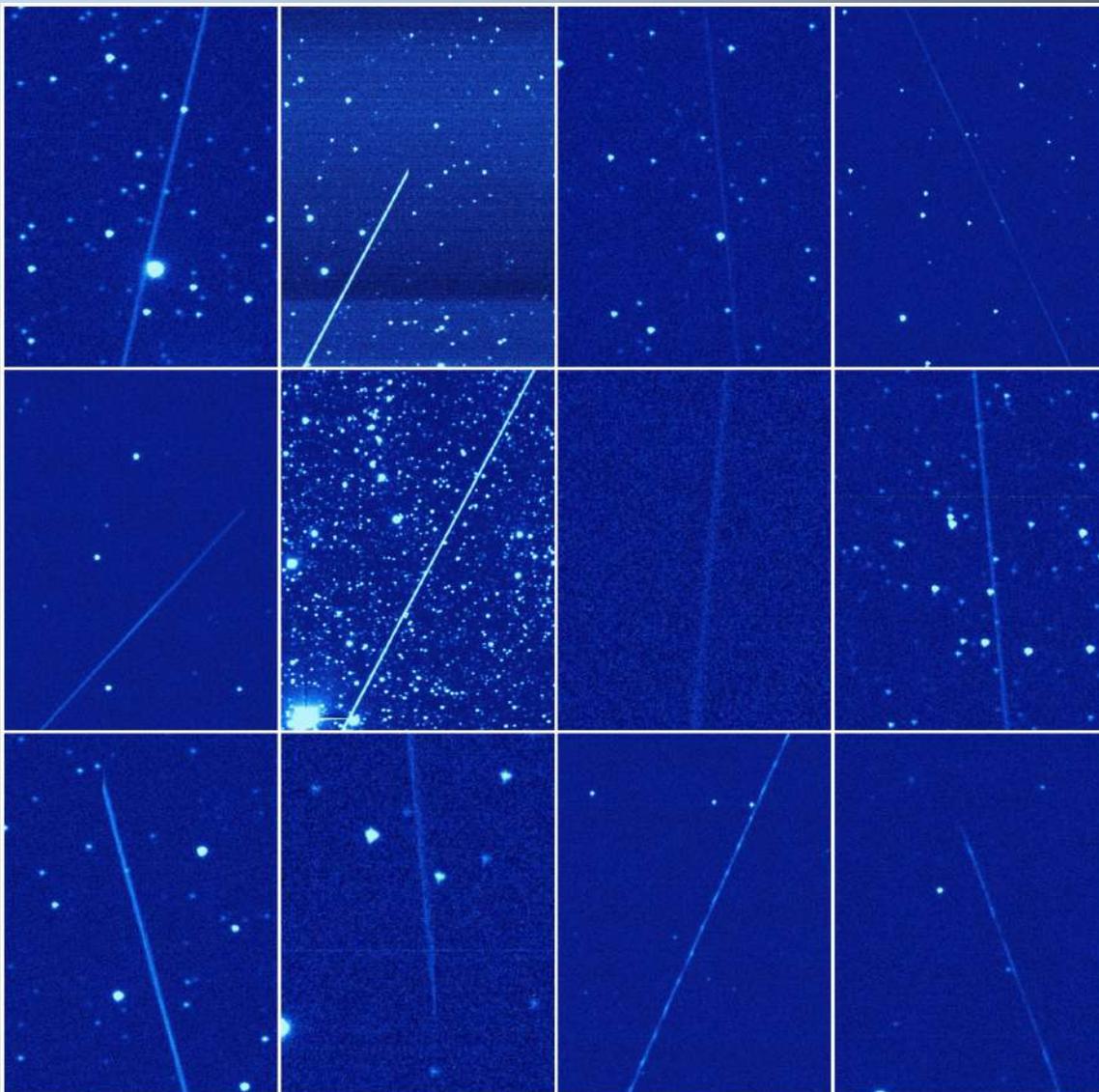
# Science with liquid mirror telescopes

« Without astronomy, man ignores the place he occupies ».

Aristotle



# Detection of space debris



Meridian 3  
(37212)



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reference\_frame\_path:

/home/ilmt/transient\_detection/Reference\_images\_20241026/20241010-0015.fits

Date: 2024-11-02

UT-Start: 15:33:21.526612

RA: 23:47:13.689

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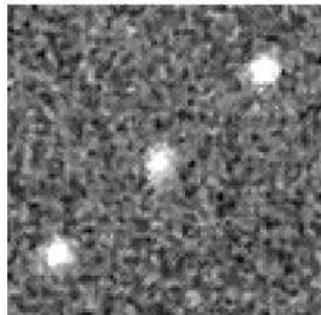
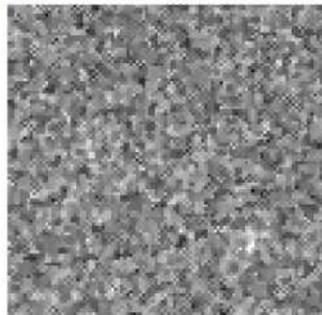
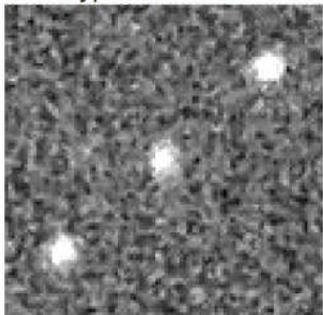
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confidence score: (0.82226, 0.99679536)

x-y coordinates of candidate: (3722, 6309)

wcs coordinates of candidate: ('23h 42m 12.7s', '+29d 4m 26s')

host type: hostless host name: ---



**Spinning satellite  
displaying specular  
reflections?**

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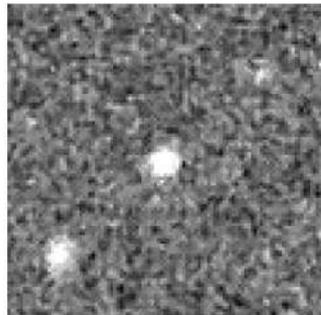
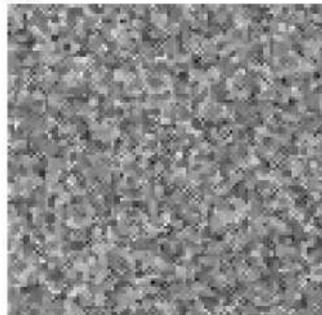
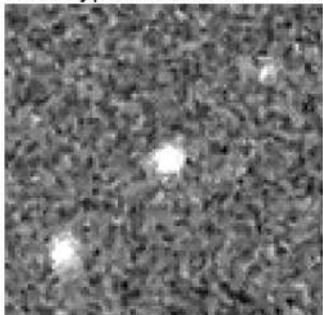
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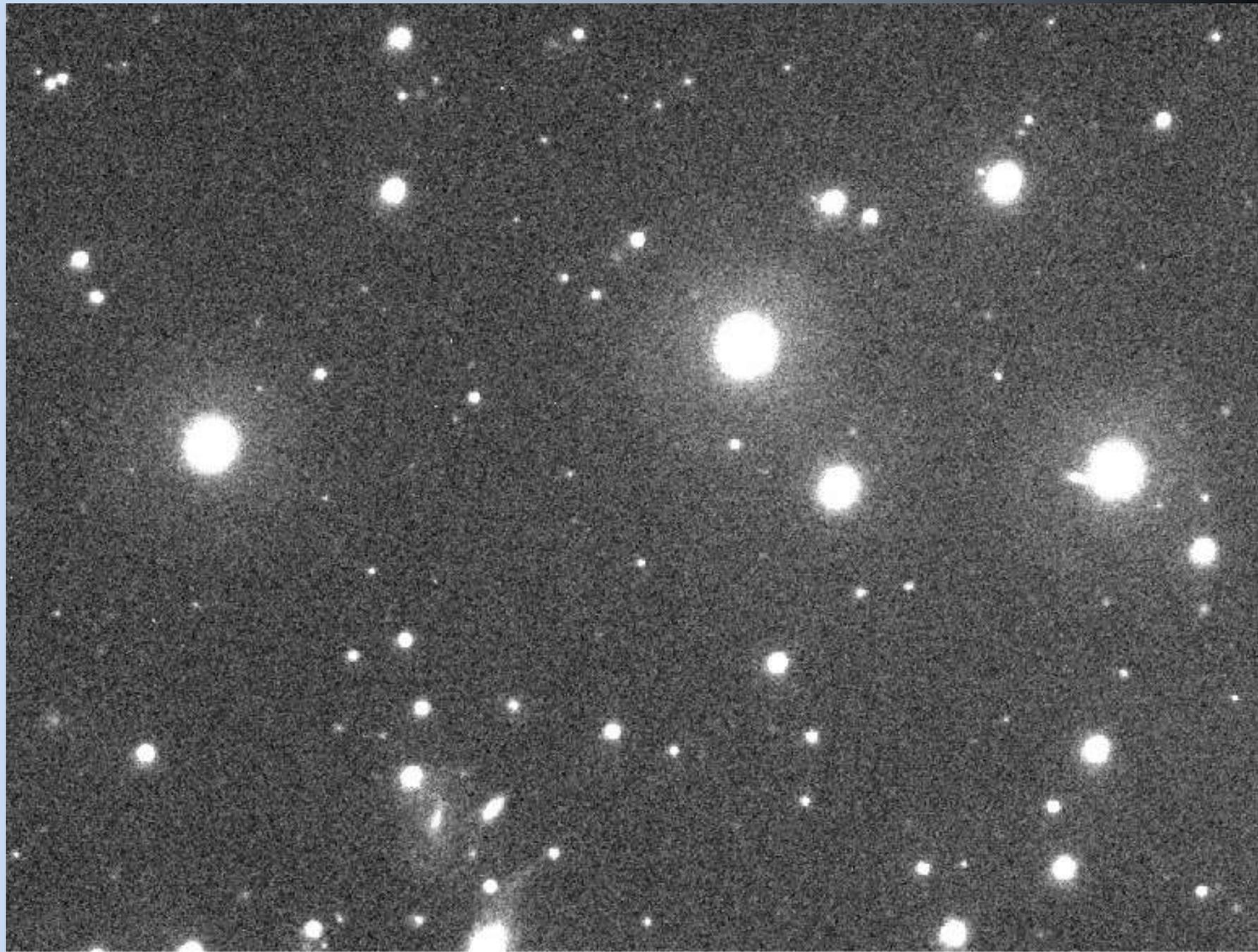
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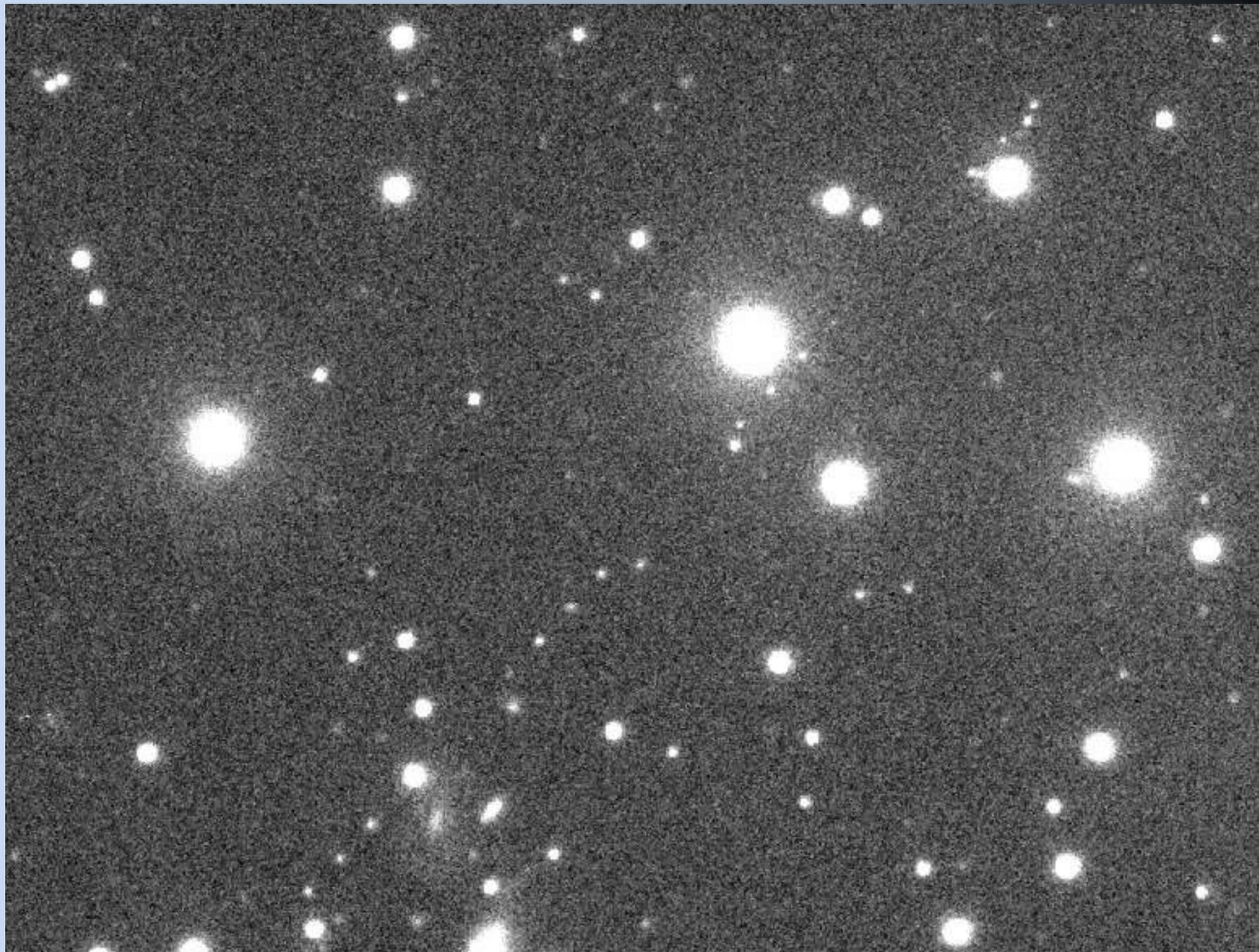
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wcs coordinates of candidate: ('23h 42m 13.4s', '+29d 4m 15s')

host type: hostless host name: ---

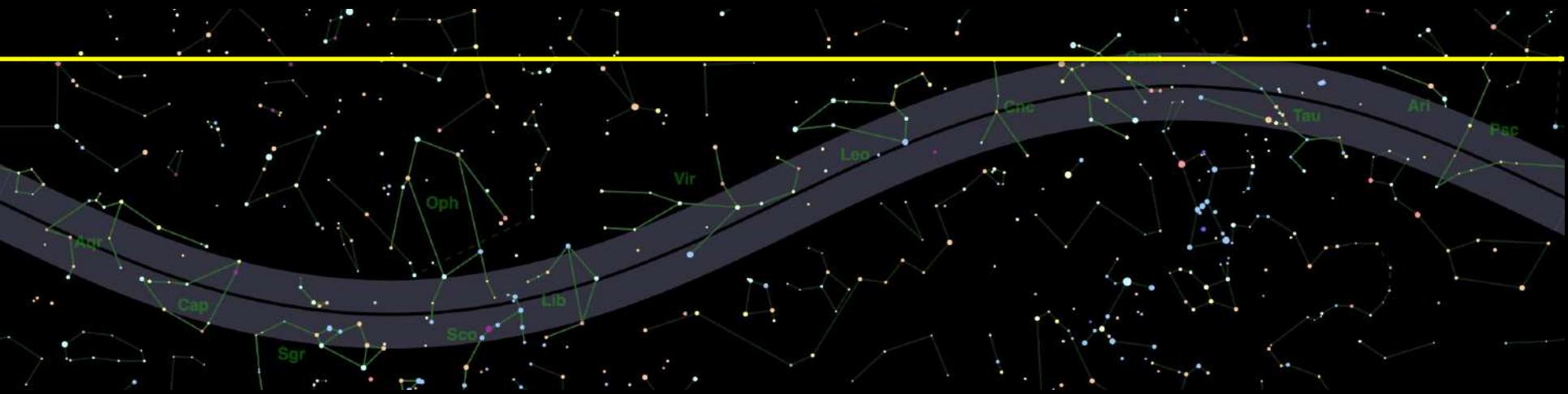






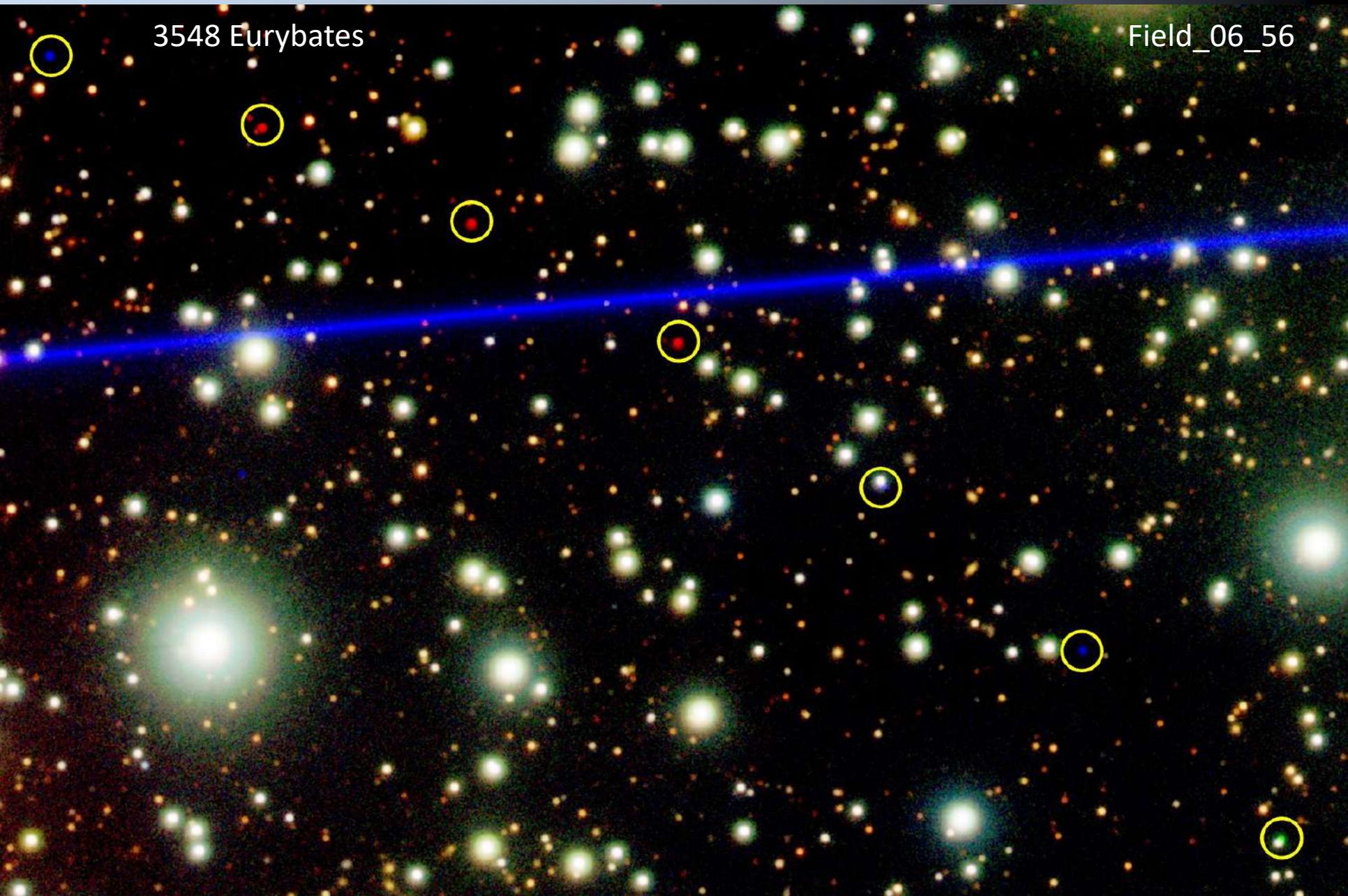


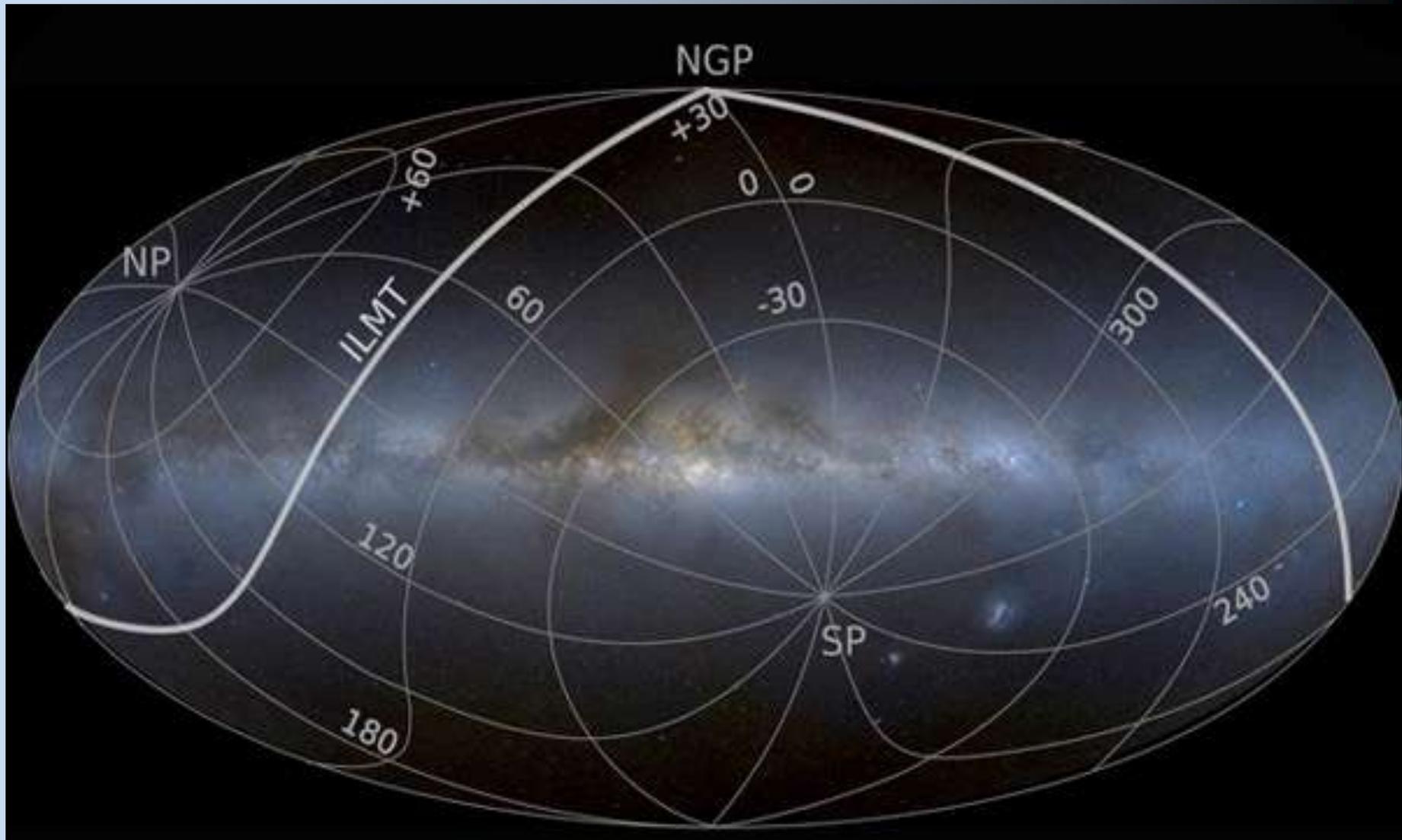
# ILMT



3548 Eurybates

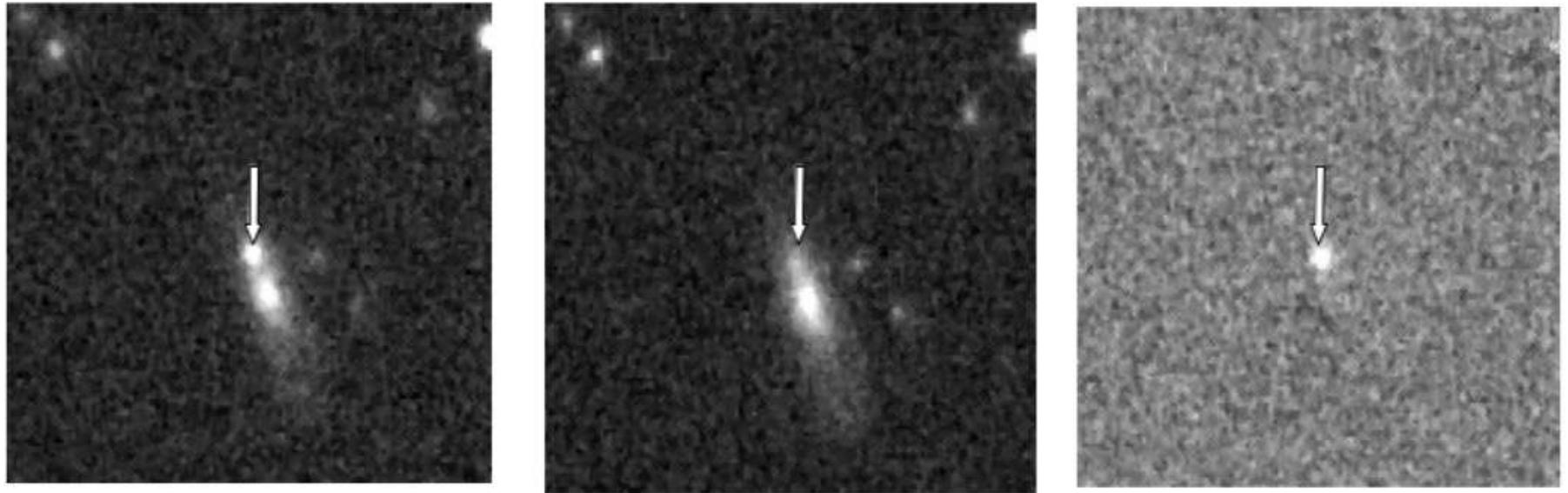
Field\_06\_56





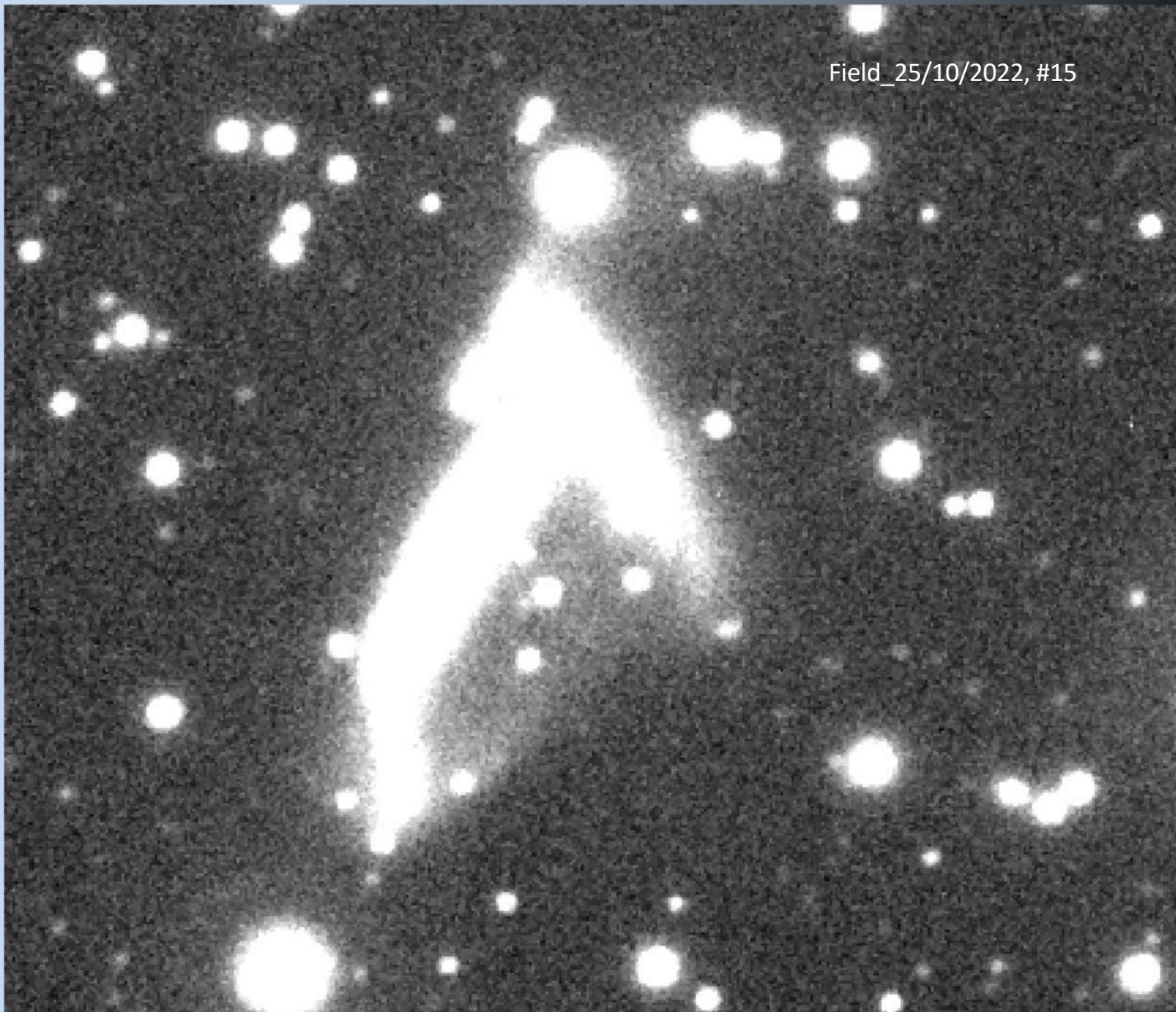


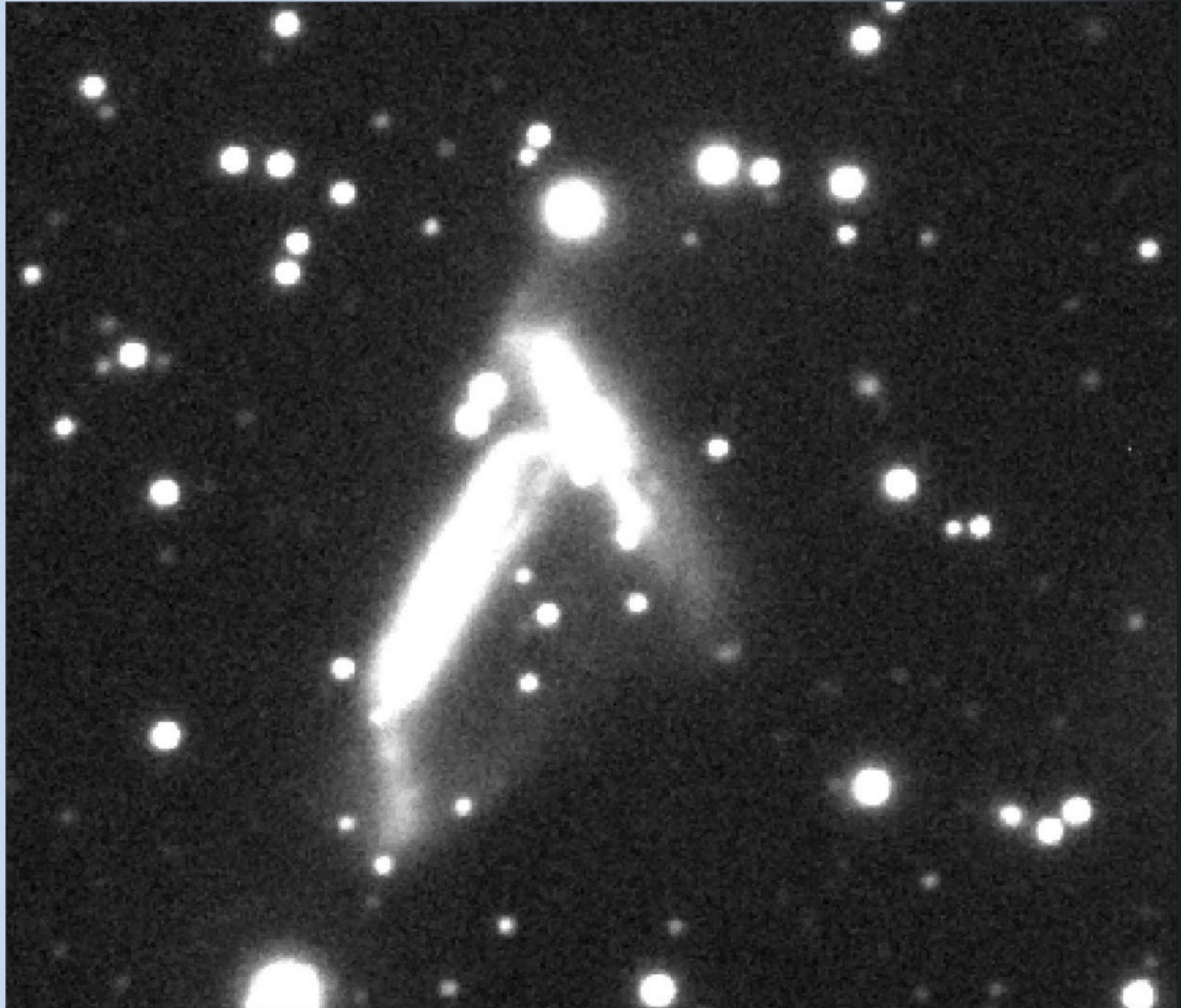
Credit:  
Sarath Prabhavu

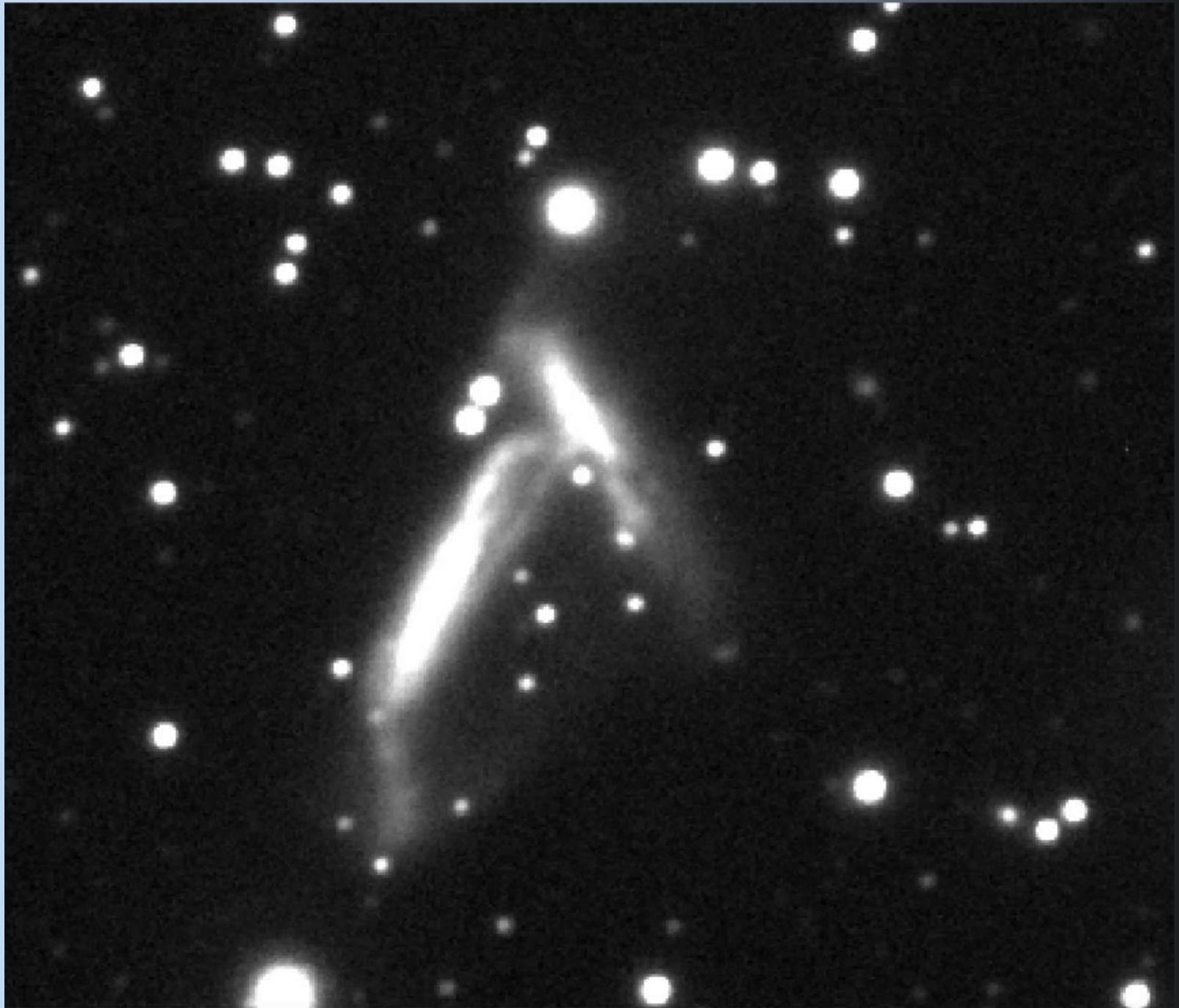


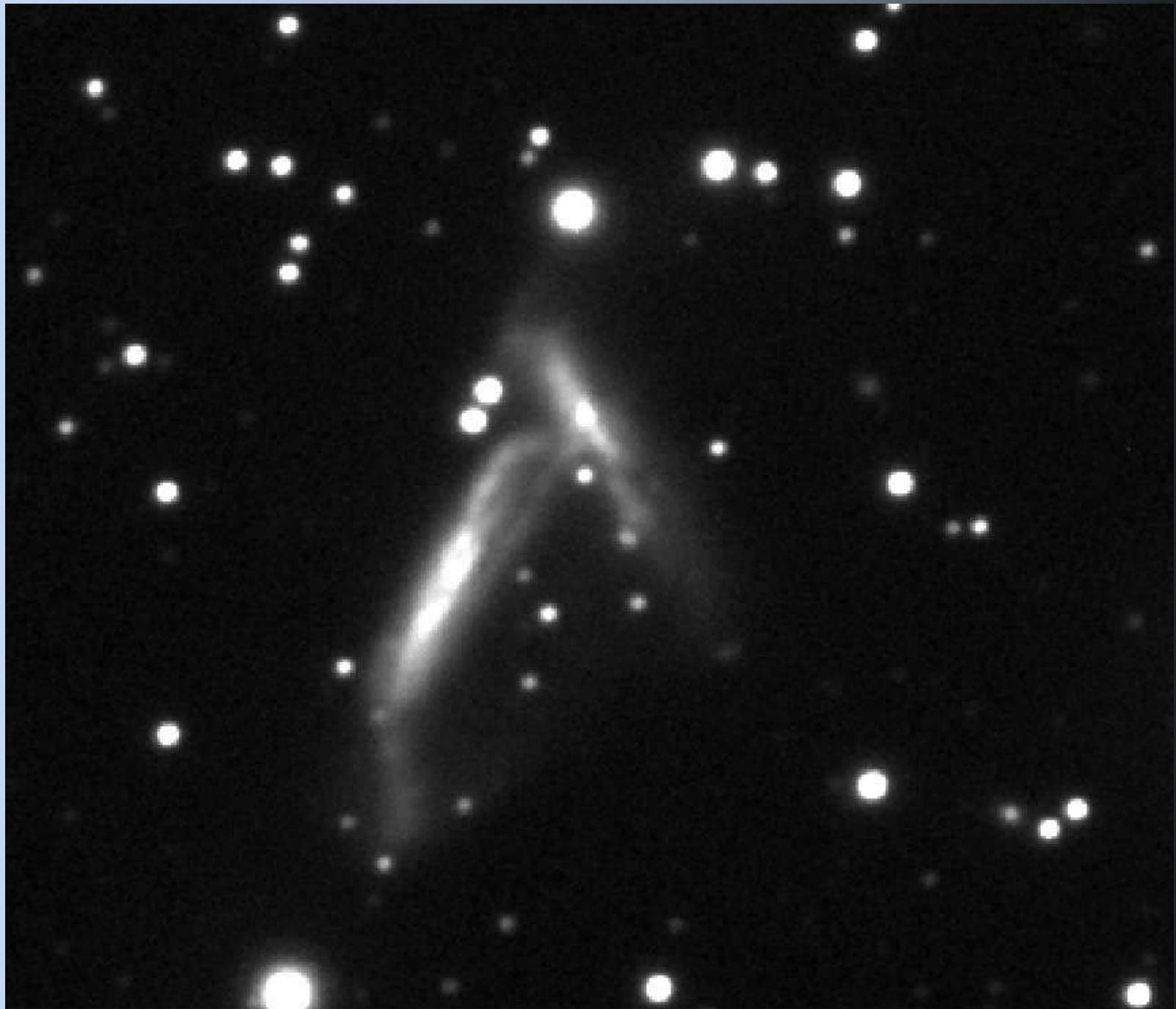
**Fig. 17.** ILMT detection of the supernova 2024cjb in the  $i'$ -band. The left image shows the detection on 16/2/2024, the middle image was recorded on 9/2/2024 and represents the reference image subtracted from the previous one and the right image corresponds to the subtraction between the left and middle images. We see that the host galaxy is very well subtracted. The white arrow indicates the location of SN 2024cjb at  $9^{\text{h}}11^{\text{m}}27.5^{\text{s}} +29^{\circ}29'36''$ . The size of the field is  $1' \times 1'$ . North is up, and east is to the left.

Field\_25/10/2022, #15











Open star cluster NGC6834 in the Milky Way (ILMT, April 2022)



NGC 2371



**Field\_05\_44\_2ndh**



**Field\_05\_08\_1st**



Field\_04\_12\_1sth



Field\_04\_12\_2ndh



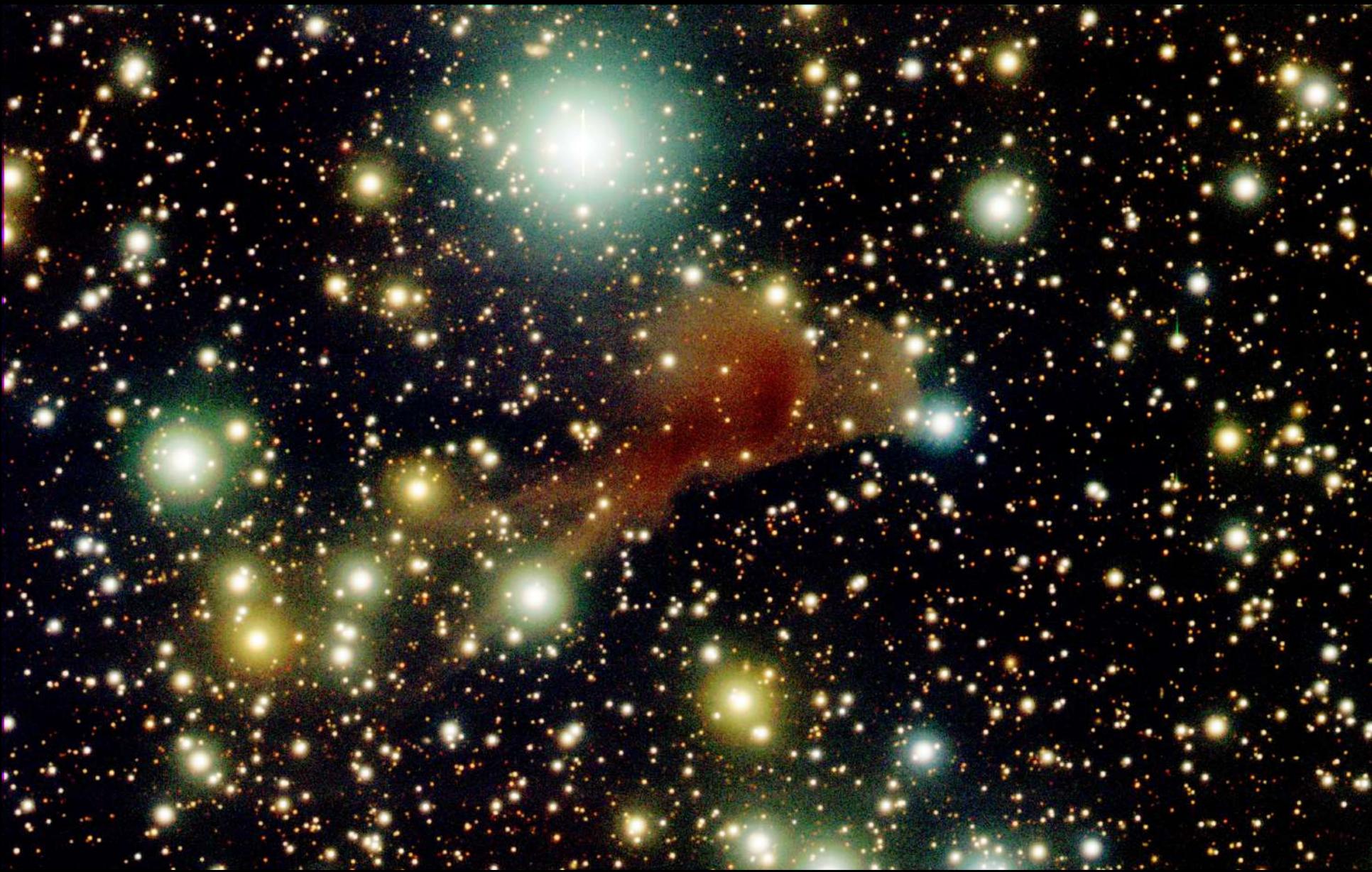
Field\_03\_35\_2ndh



Field\_05\_26\_1sth



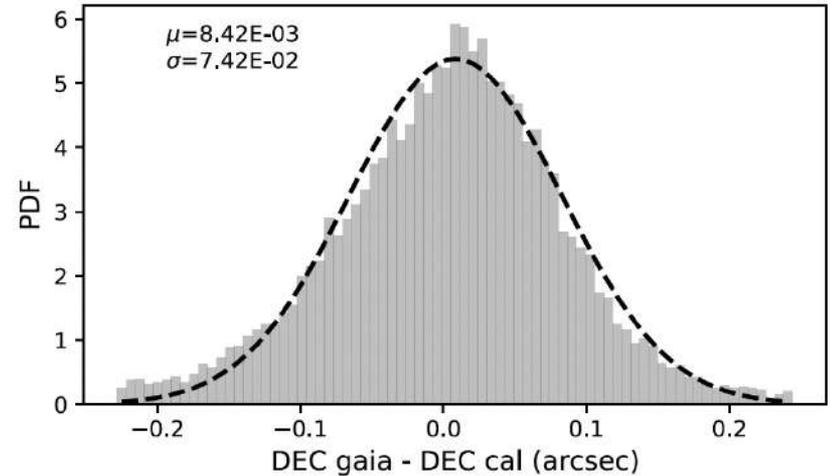
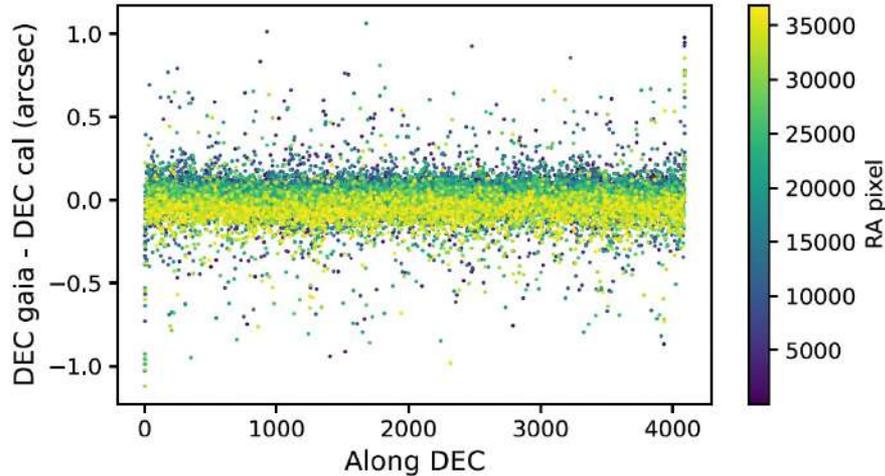
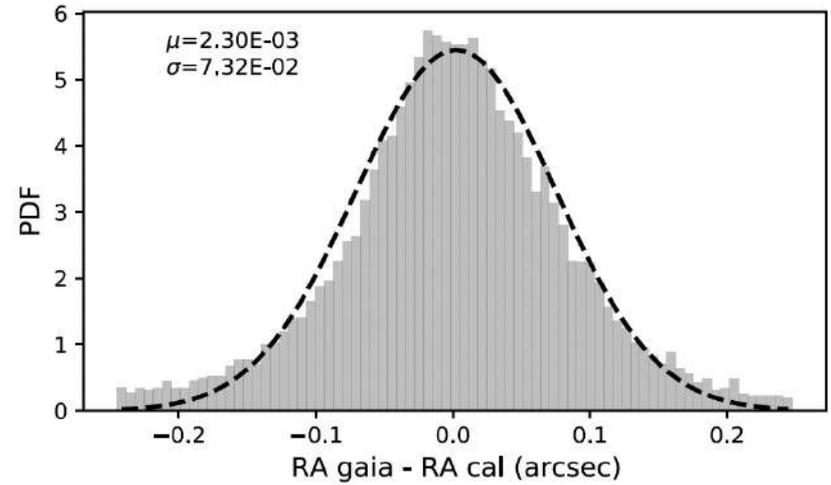
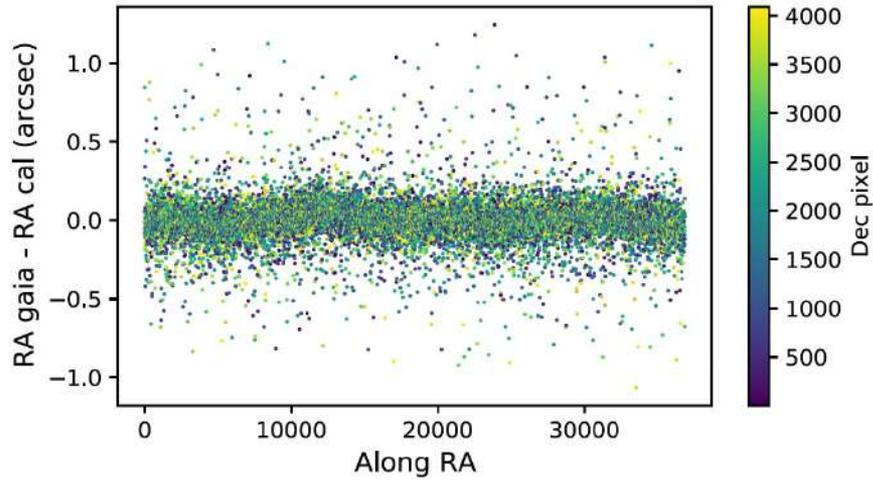
Field\_04\_50



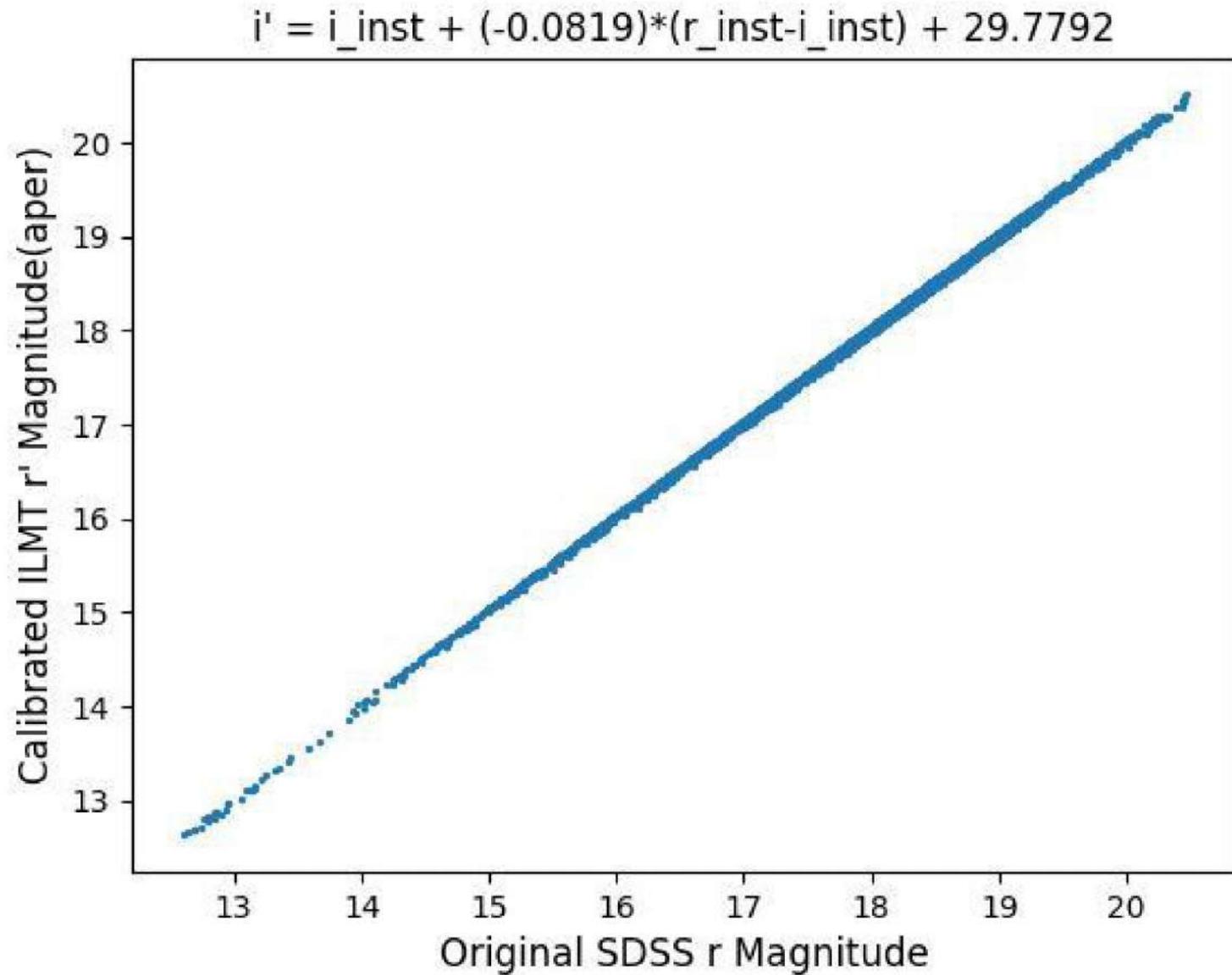
Field\_05\_26\_2ndh\_B



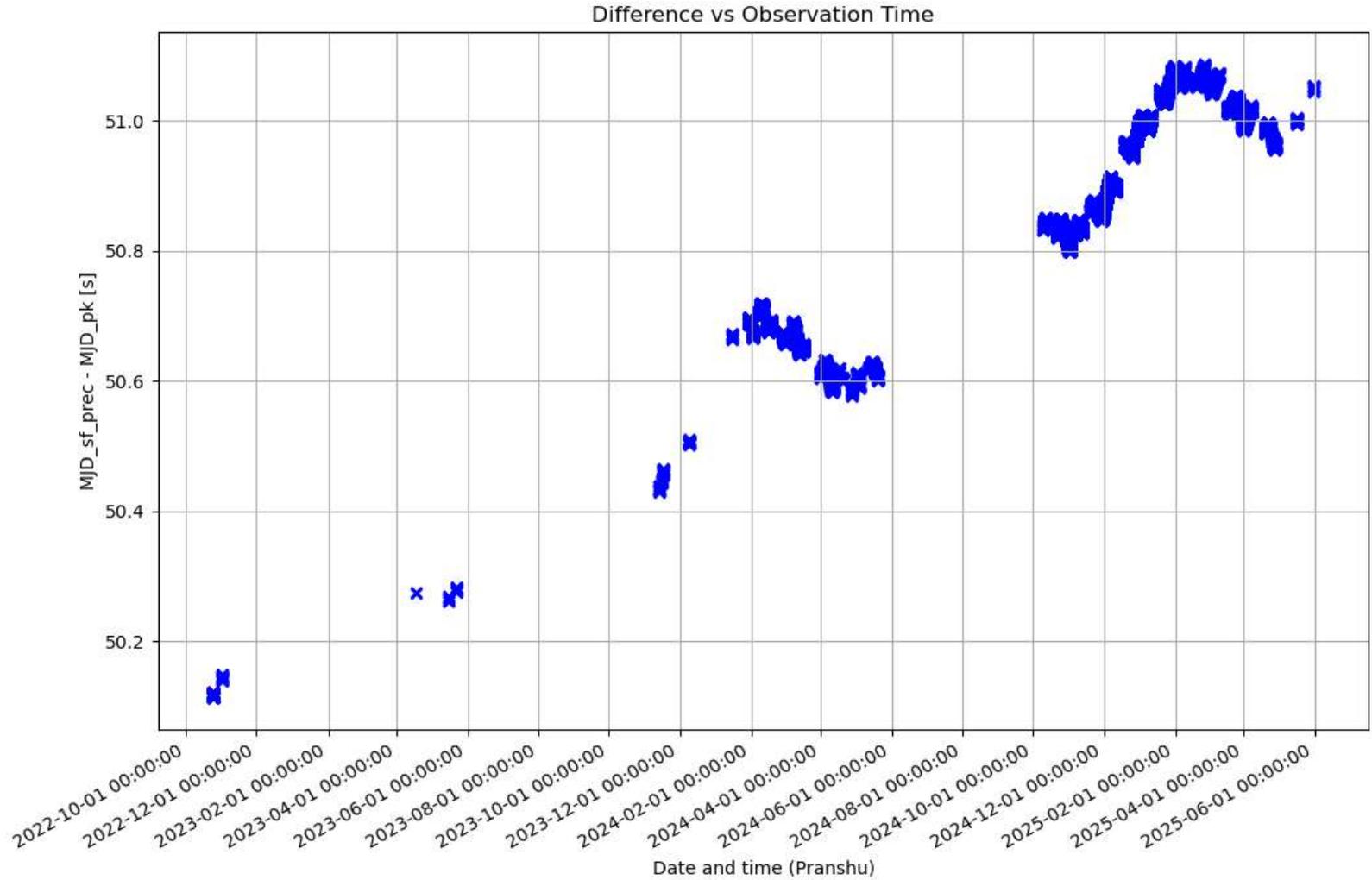
# Astrometry



# Photometry



# Geophysics application?



# XI. Conclusions

- The ILMT is an instrument that is entirely dedicated to a photometric and astrometric variability survey, as well as to hunter astronomical transients + geophysical application
- Its geographical coordinates are  $79^{\circ}41'07.08''$  E,  $29^{\circ}21'41.4''$  N, at an altitude of 2378 m.
- The mirror quality is limited by the diffraction (atmospheric seeing:  $1.2''$ , pixel size= $0.327''$ , FOV= $22.3'$ )
- Plus: continuous zenith observations (best image quality, smallest atmospheric extinction, 1D flat field: higher photometric quality, image subtraction, image addition, ...)
- Relatively cheap
- Several institutes are involved at the international level + free public access to the data
- Cons: non steerable telescope, 102.35 sec. integration, ...
- References : <https://www.ilmt.be>  
<https://aries.res.in/facilities/astronomical-telescopes/ilmt>



***Thanks!***