Viewing the wonders of Nature – from Camera Obscura to the 4m International Liquid Mirror Telescope (ILMT)

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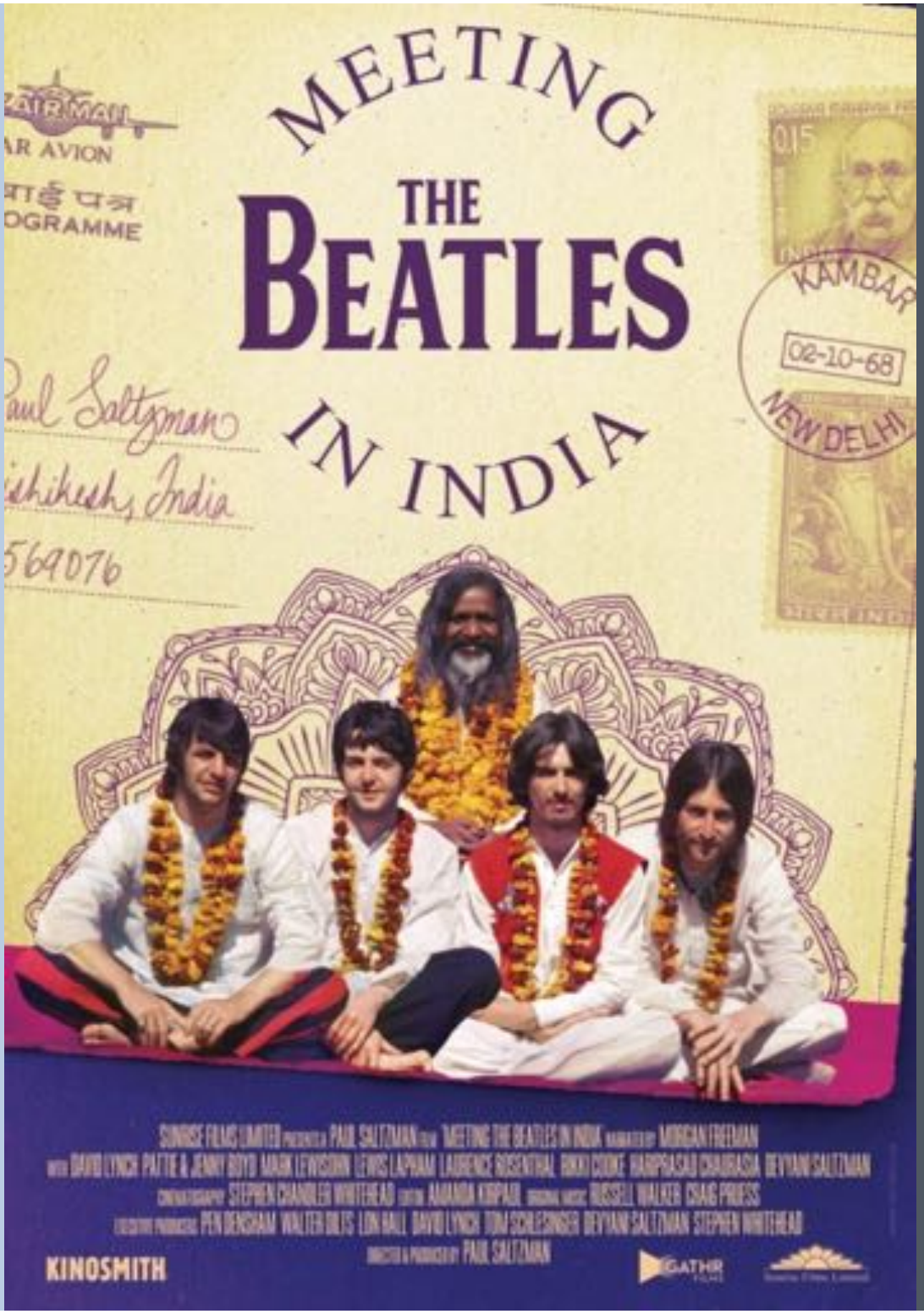
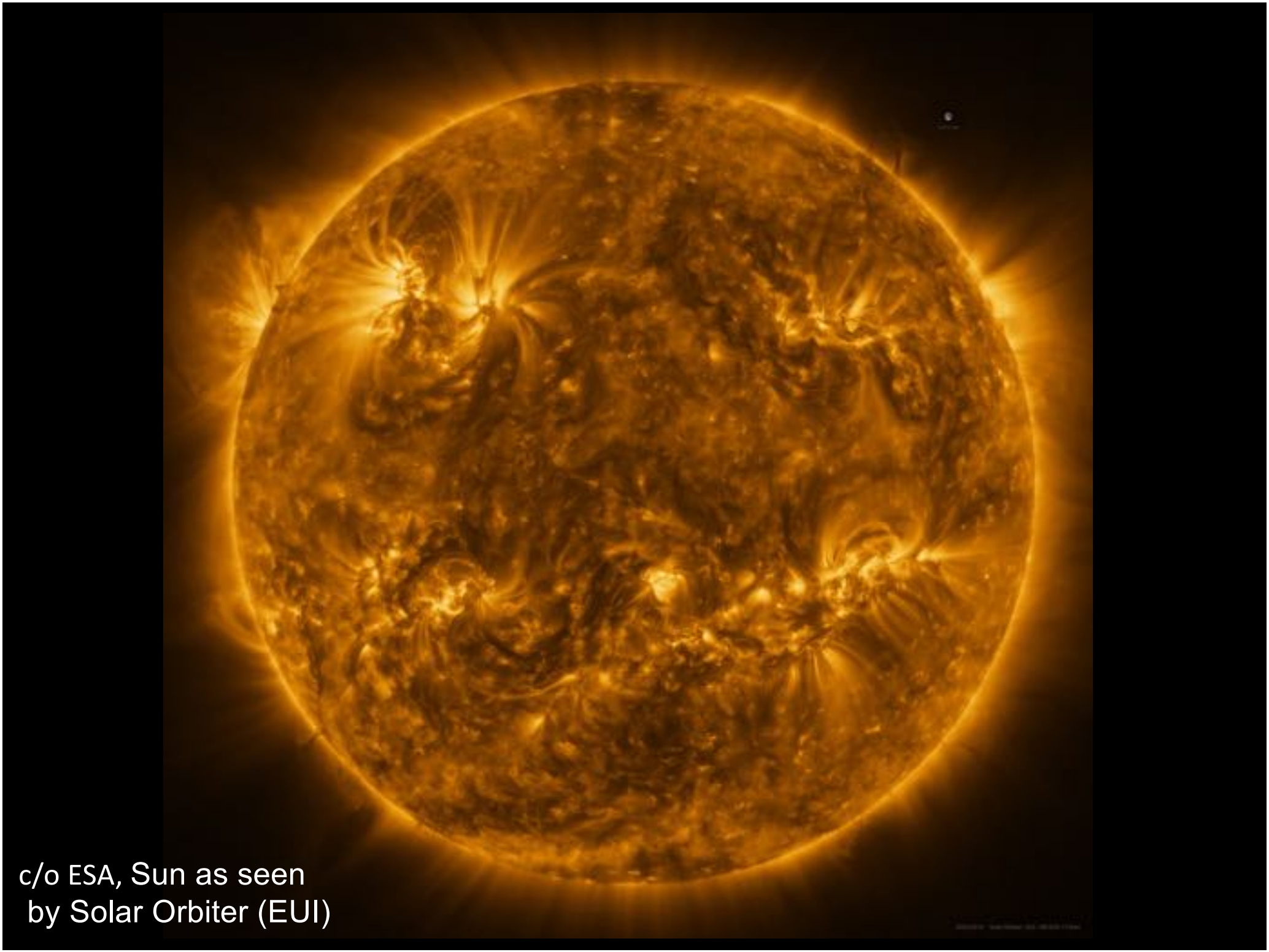
University of Liège (Belgium), University of British Columbia (Canada), ARIES (India)


MEETING
THE
BEATLES
IN INDIA
KAMBAR
02-10-68
NEW DELHI
KINOSMITH


« But the fool on the hill,
Sees the Sun going down.
And the eyes in his head,
See the world spinning around ... »
The Beatles

Layout:

I. Brief history
II. Camera obscura (pinhole camera)
III. Formation of solar disks (convolution)
IV. Basic principles of a telescope
V. Earth rotation … and the Sun
VI. Conic trajectories
VII. Liquid mirror telescope principles
VIII. TDI mode of observation
IX. The 4m International Liquid Mirror Telescope (ILMT)
X. Science with the ILMT
XI. Conclusions
XII. General discussion



c/o ESA, Sun as seen
by Solar Orbiter (EUI)

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

I. Brief history

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Liquid Mirror Telescopes

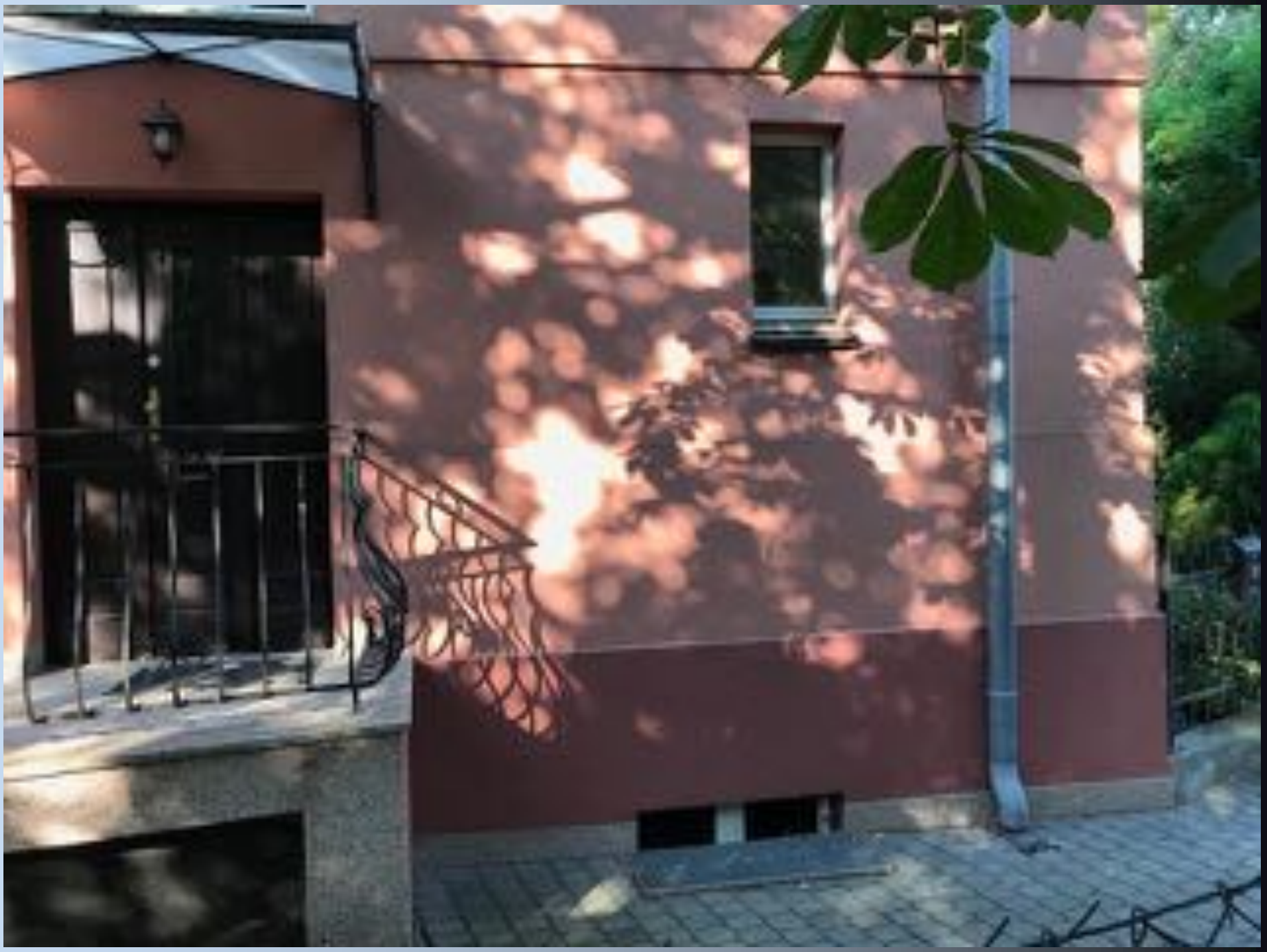
- 2.7m UBC/Laval
- 3m NODO
- 6m UBC LZT
- 3.7m Lab. LMT

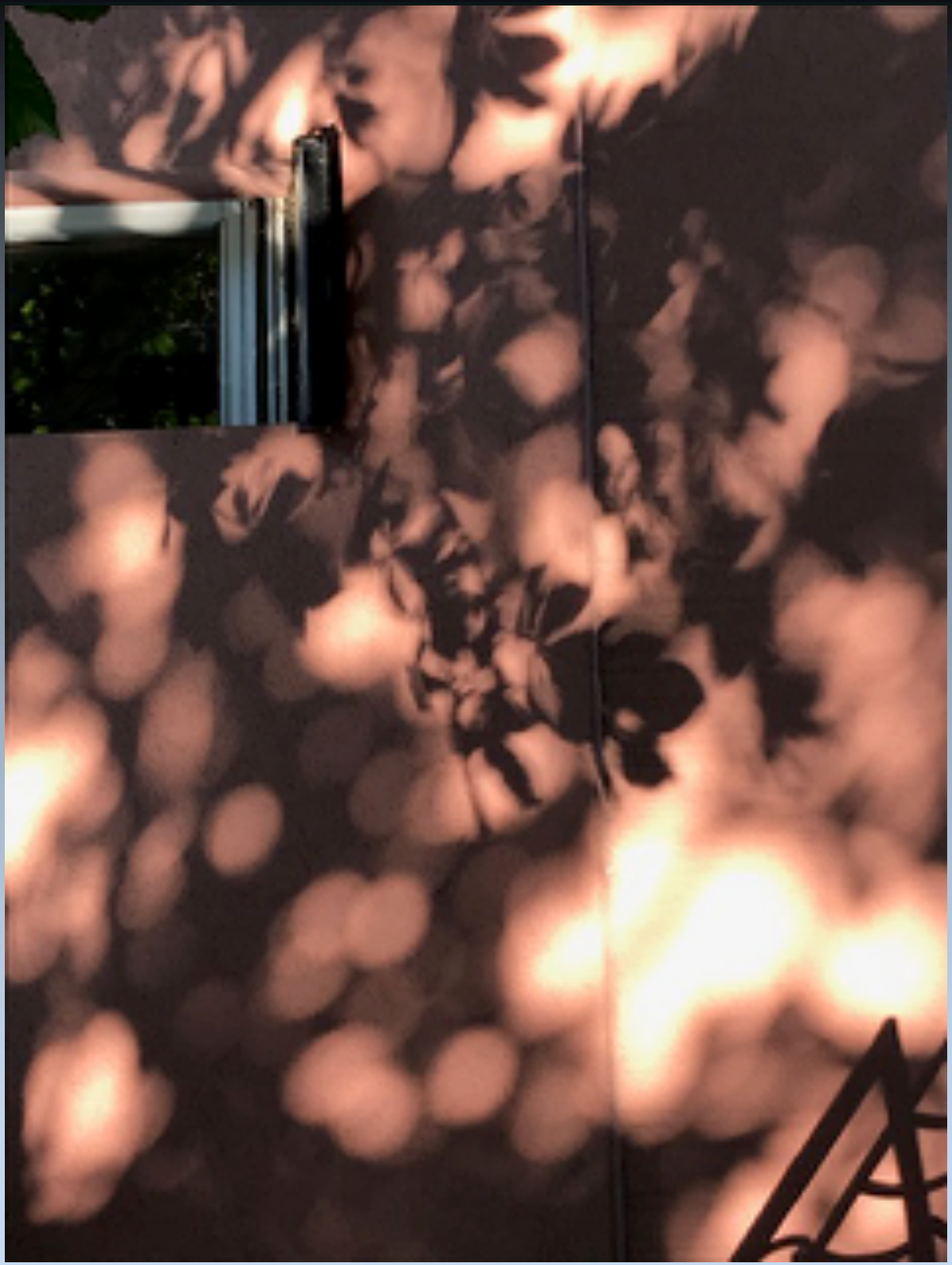
I. Brief history

- 1996: first contact with Ermanno Borra
- 1997: Marseille conference
- 1997: ILMT

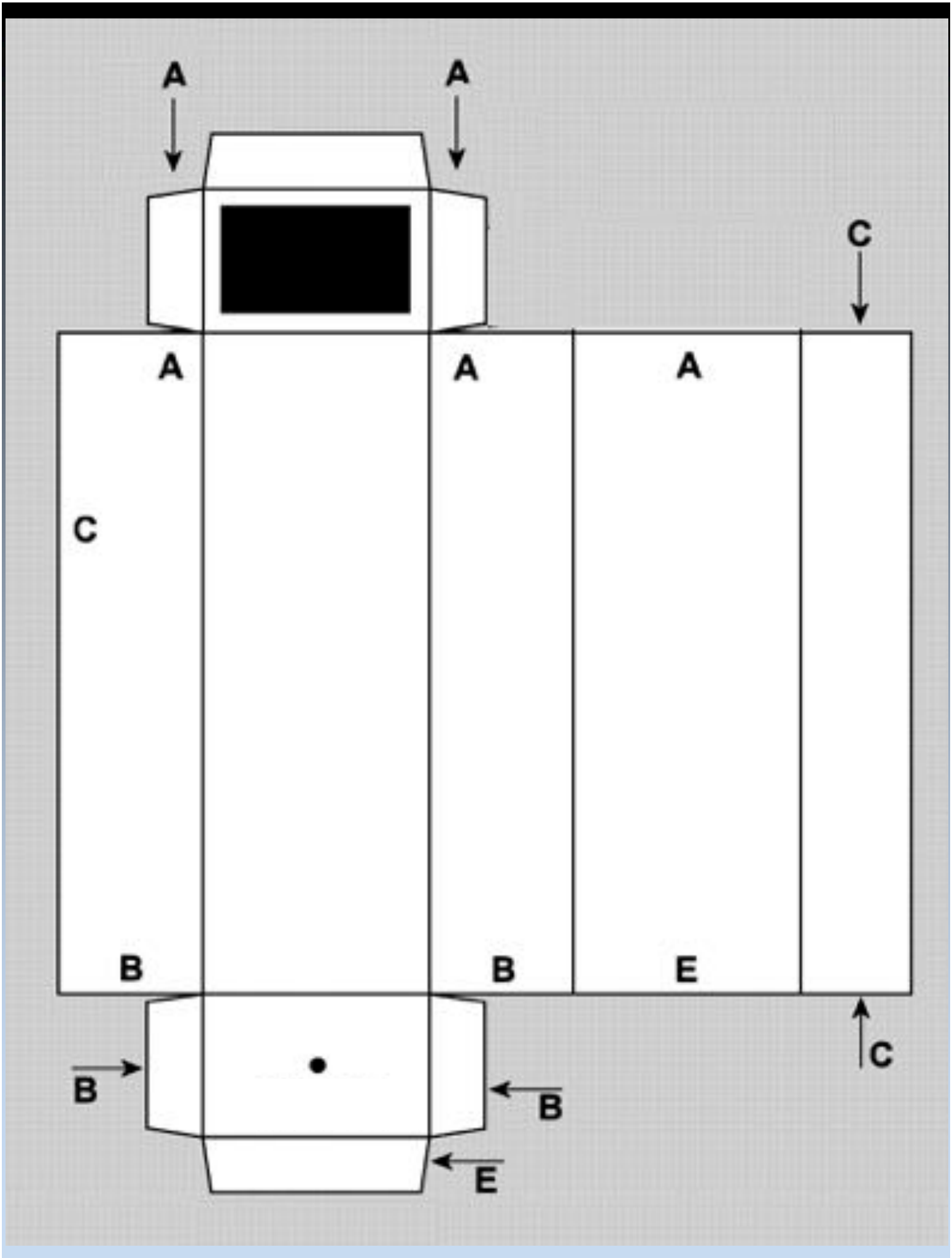
Bal du Moulin de la Gallette, Pierre-Auguste Renoir, 1876


127,4 millions US$





II. Camera obscura (pinhole camera)


A
A
C
A
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A
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E
C
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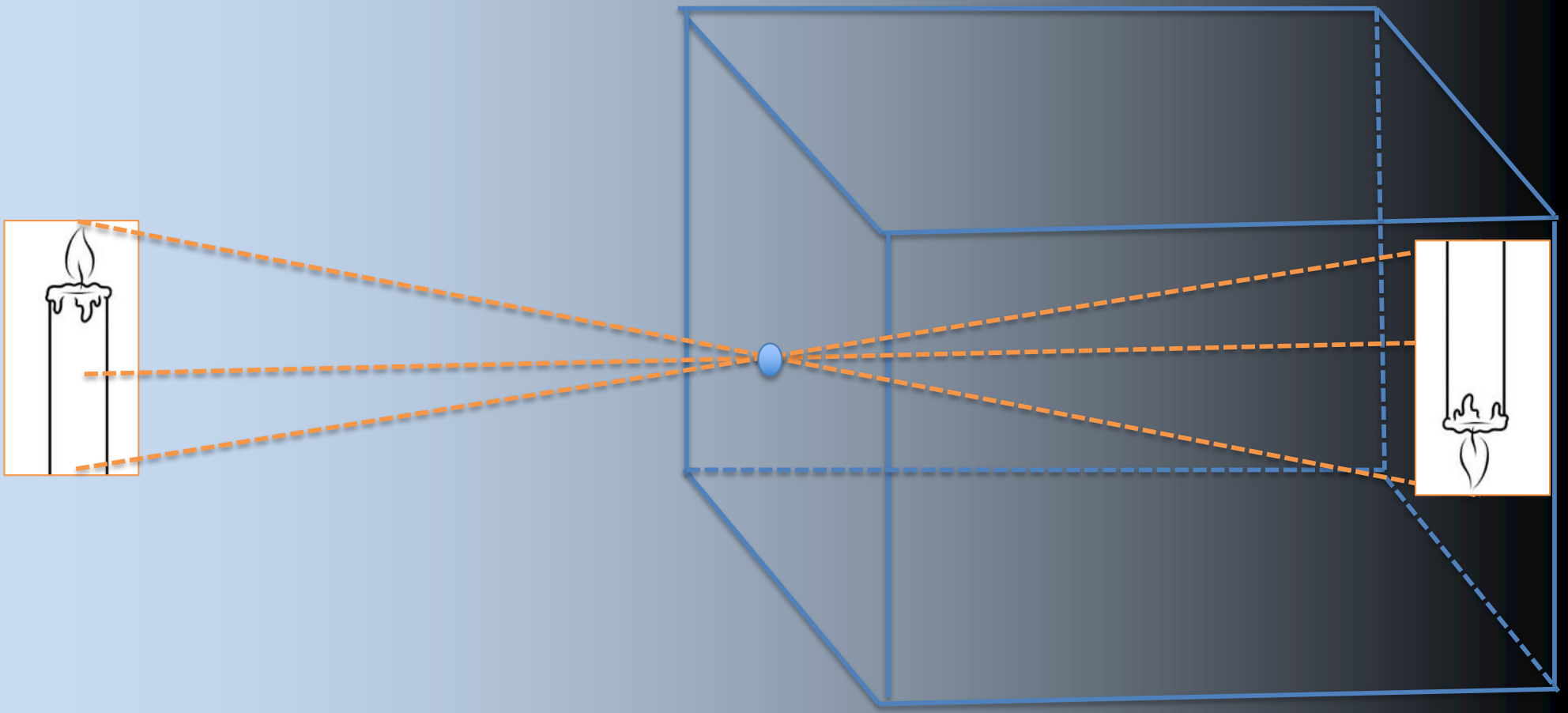
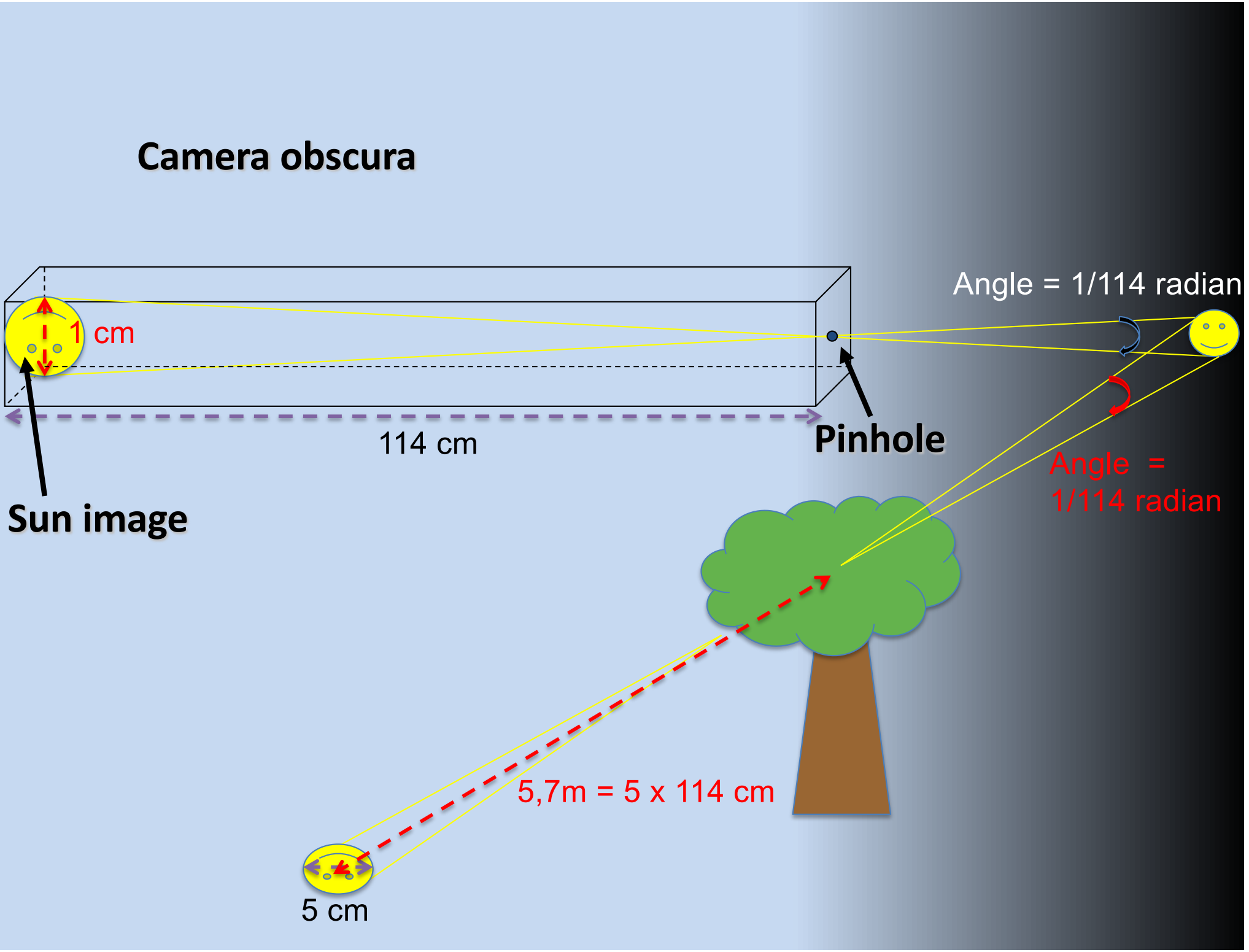
E

Camera obscura

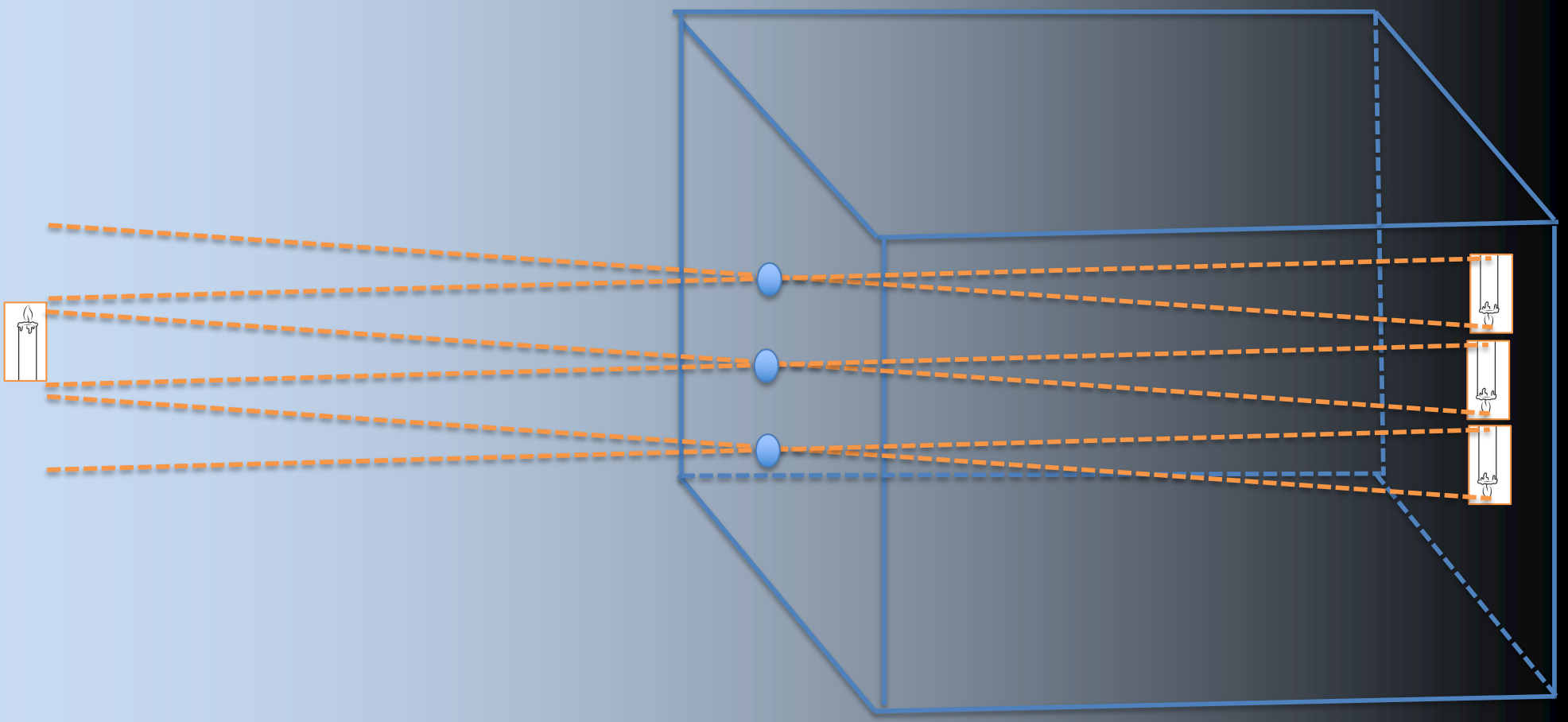


Camera obscura

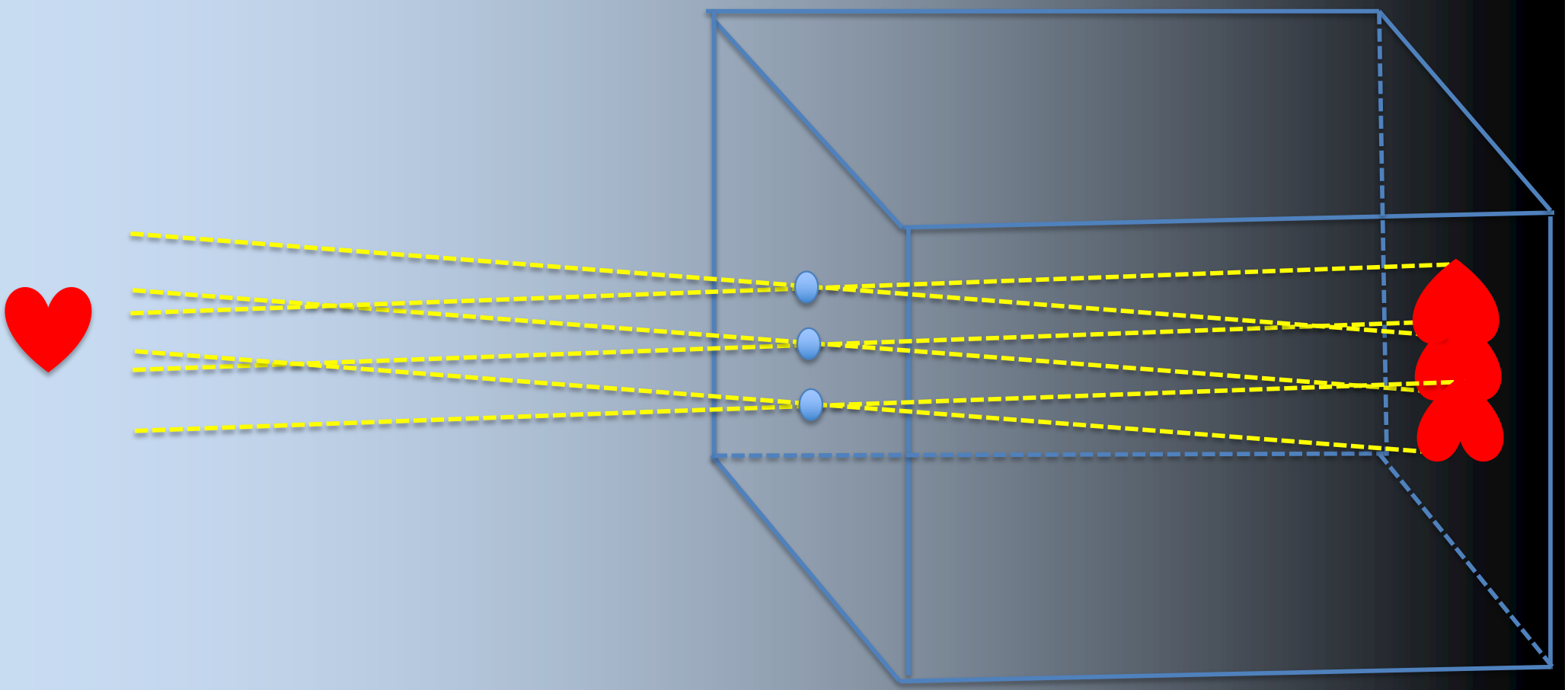


III. Formation of solar disks (convolution)

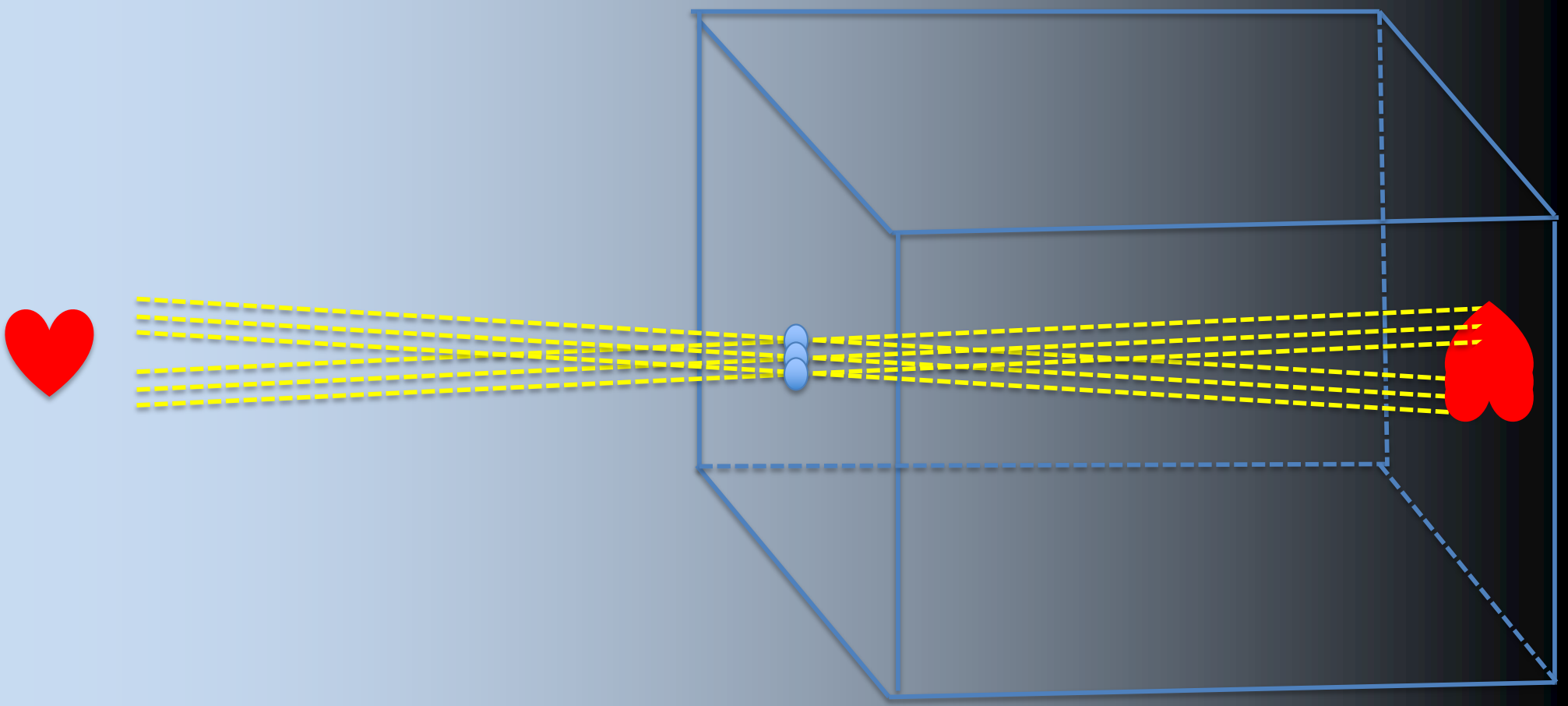
Camera obscura

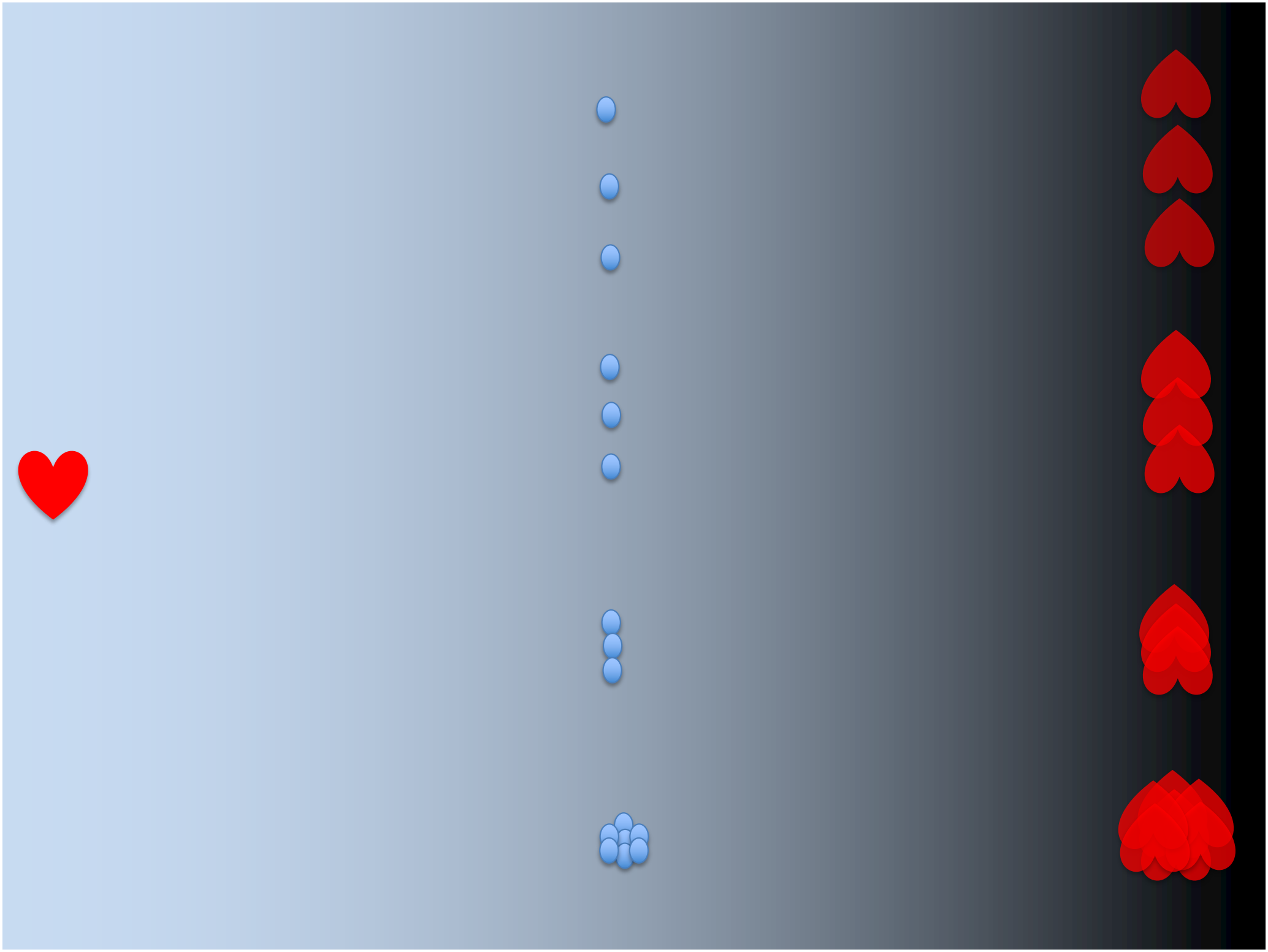


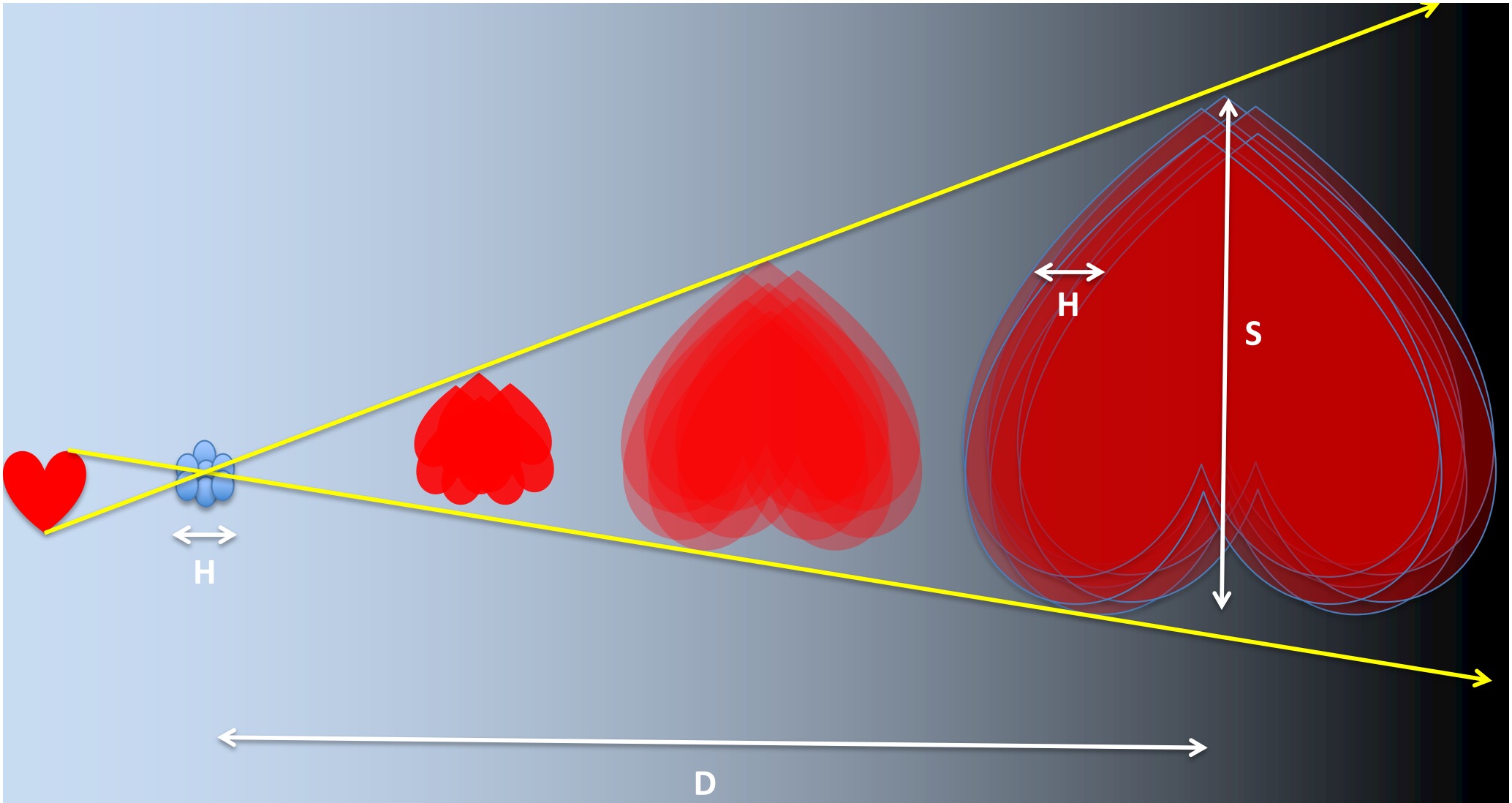
Camera obscura



Camera obscura

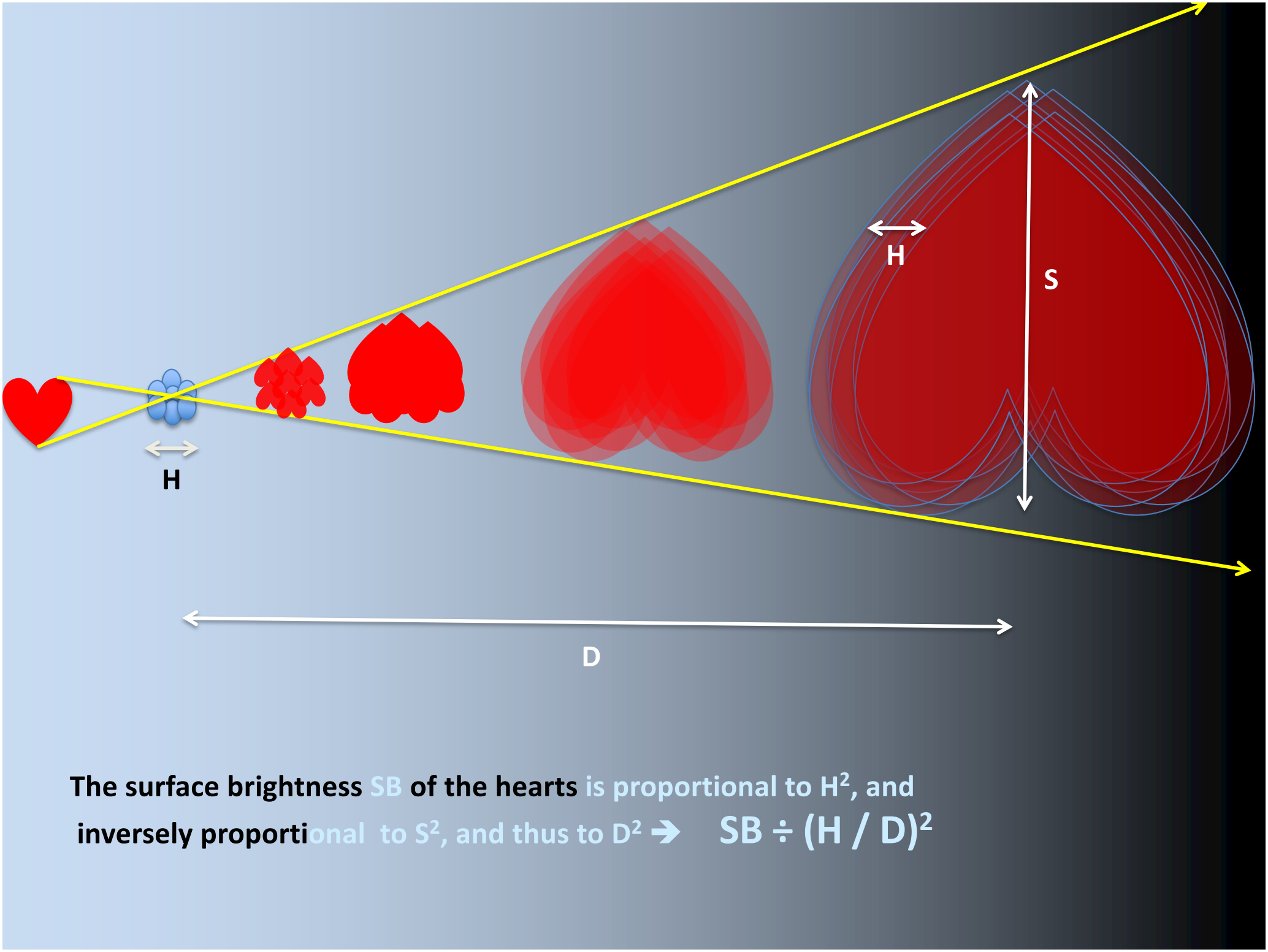




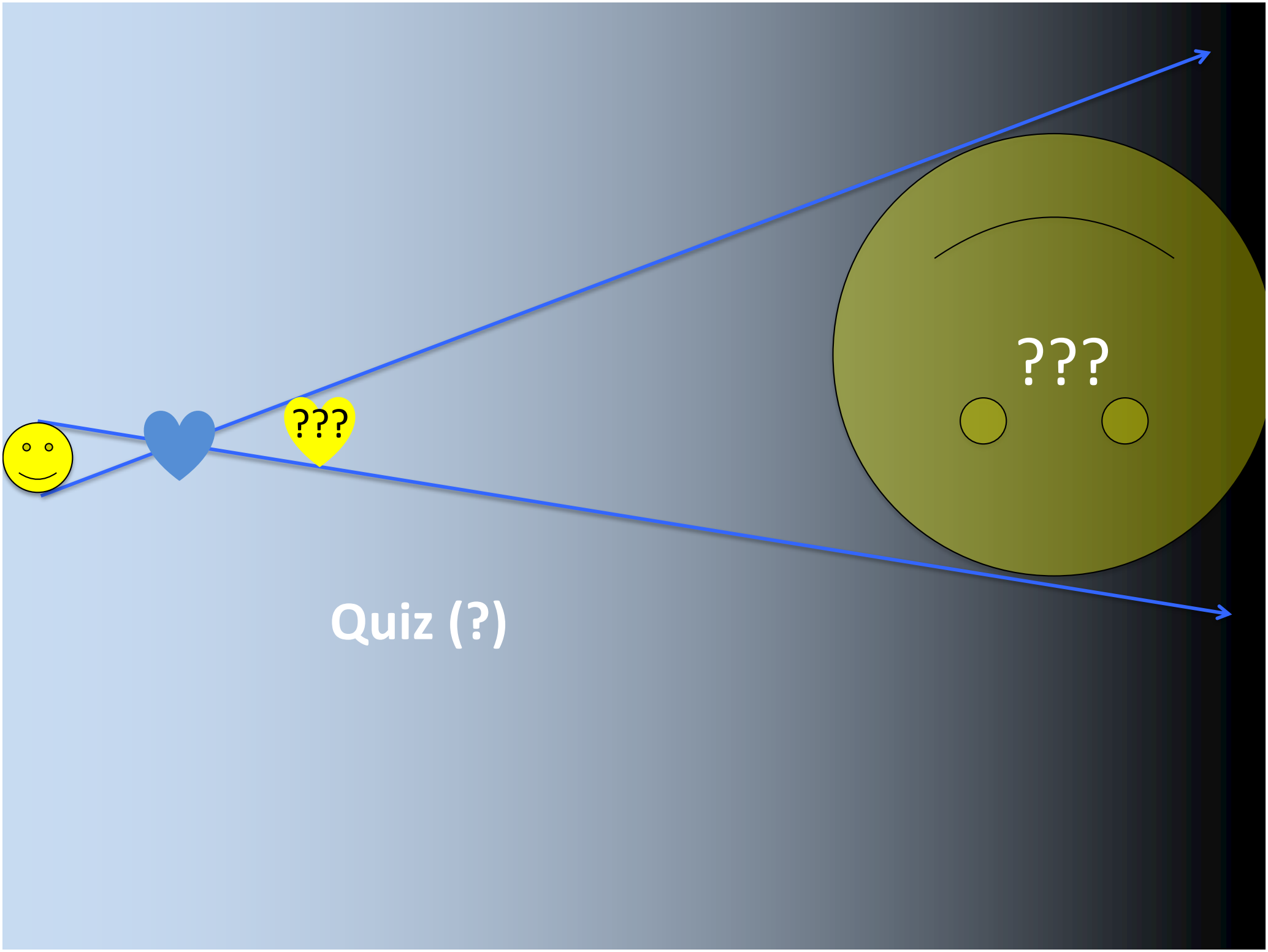


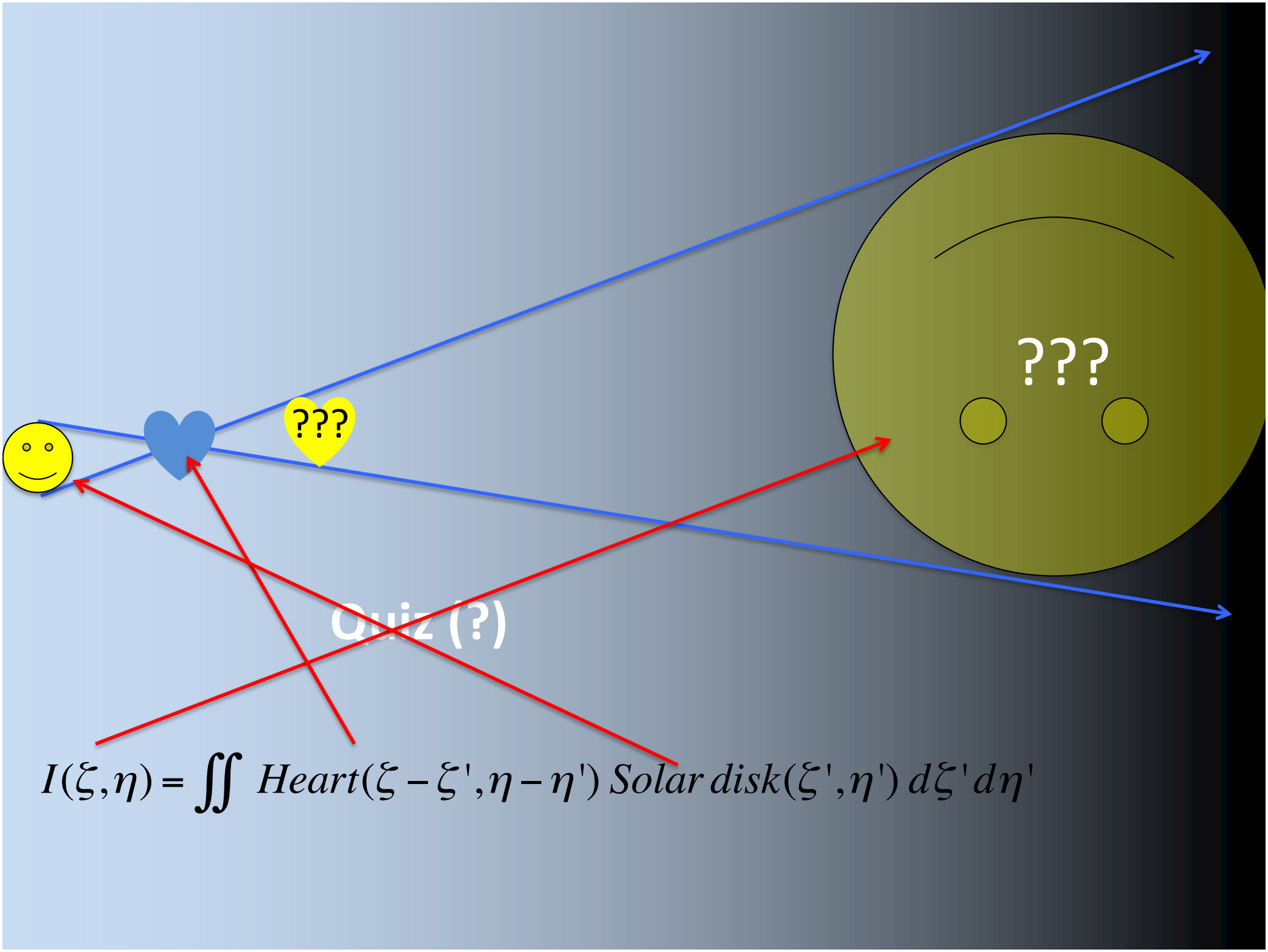
The blur B of the hearts is proportional to H^2, and inversely proportional to S^2, which is itself proportional to D^2 → $B \div (H / D)^2$

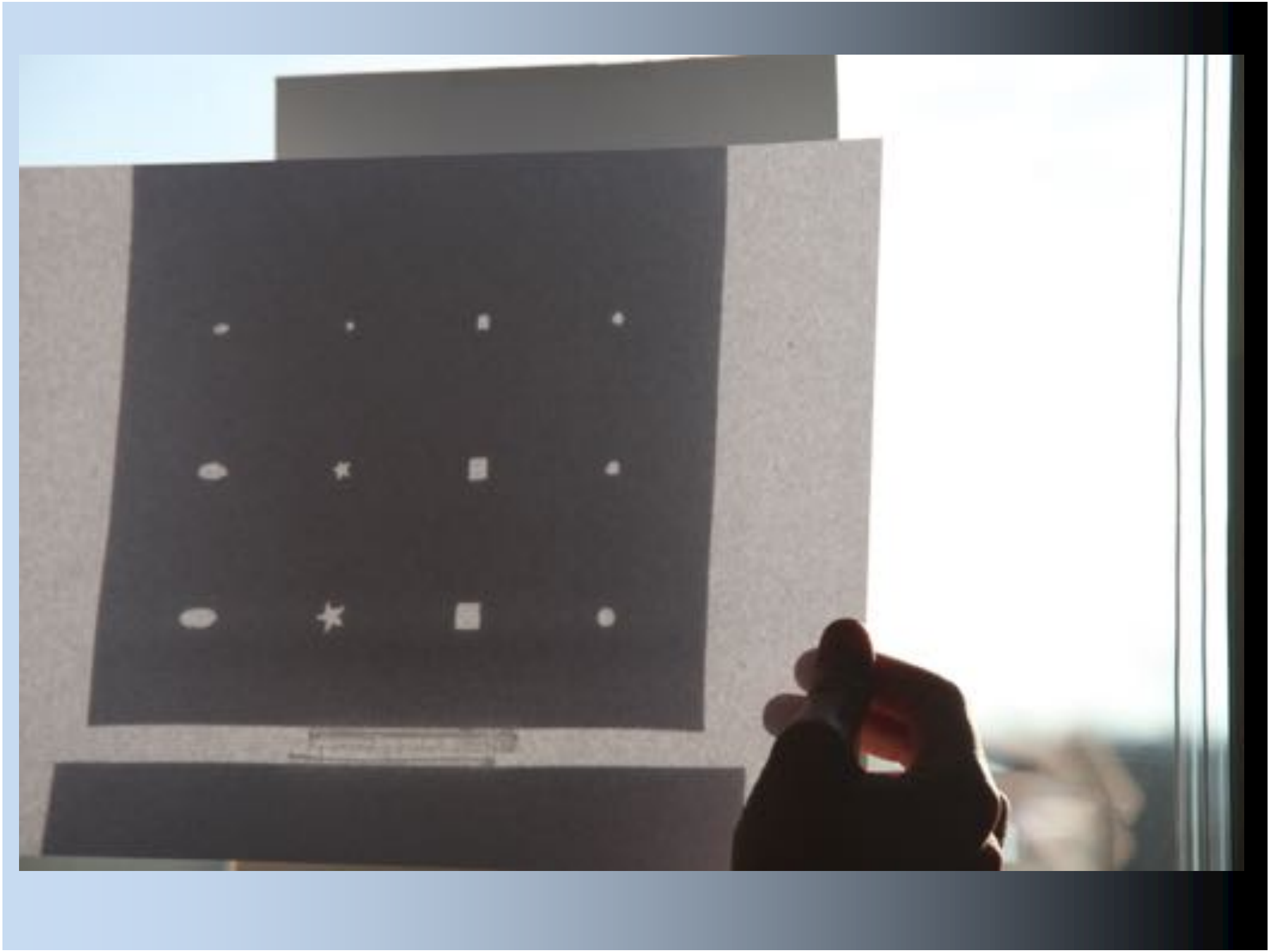
The angular resolution $\Phi = H / D$

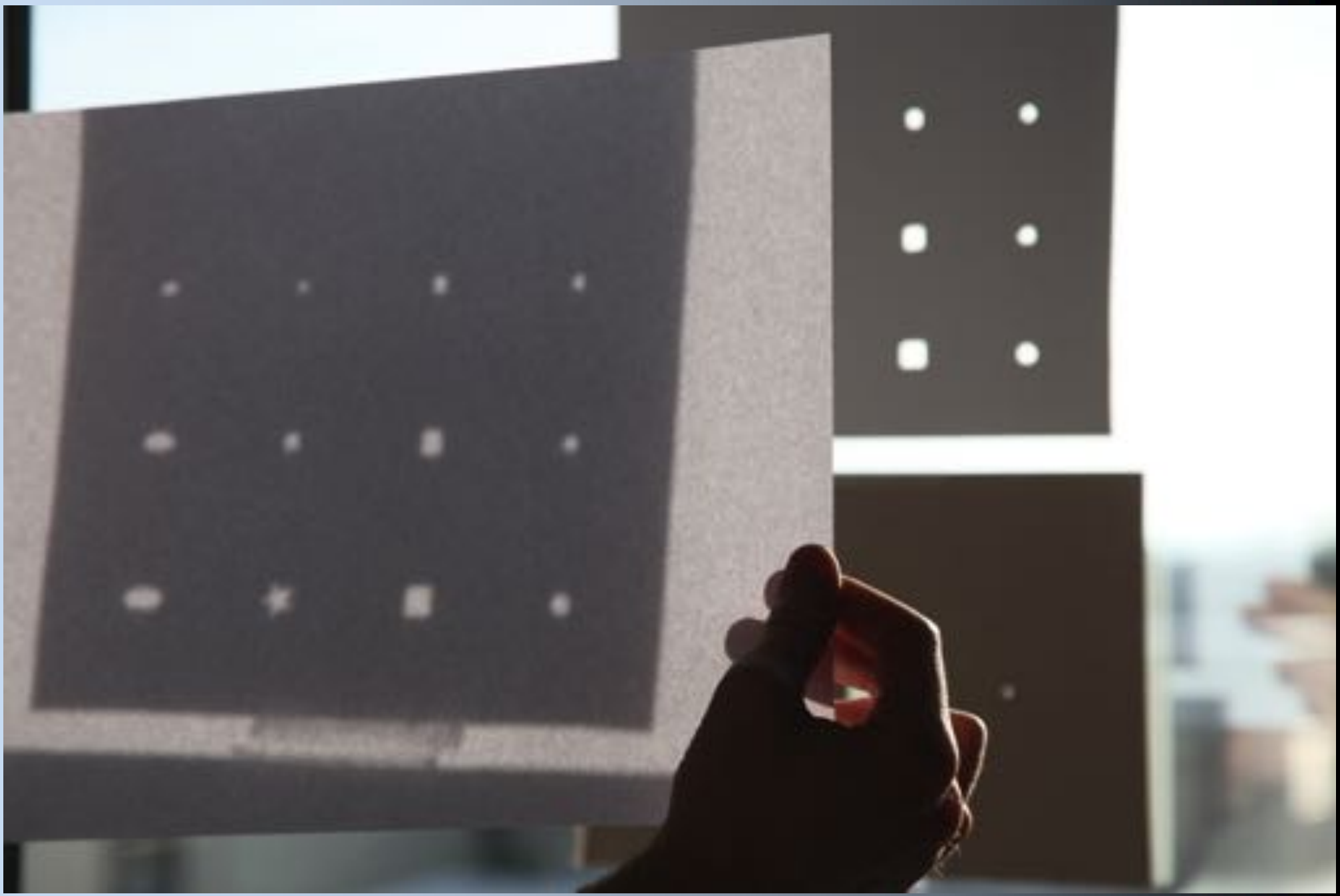


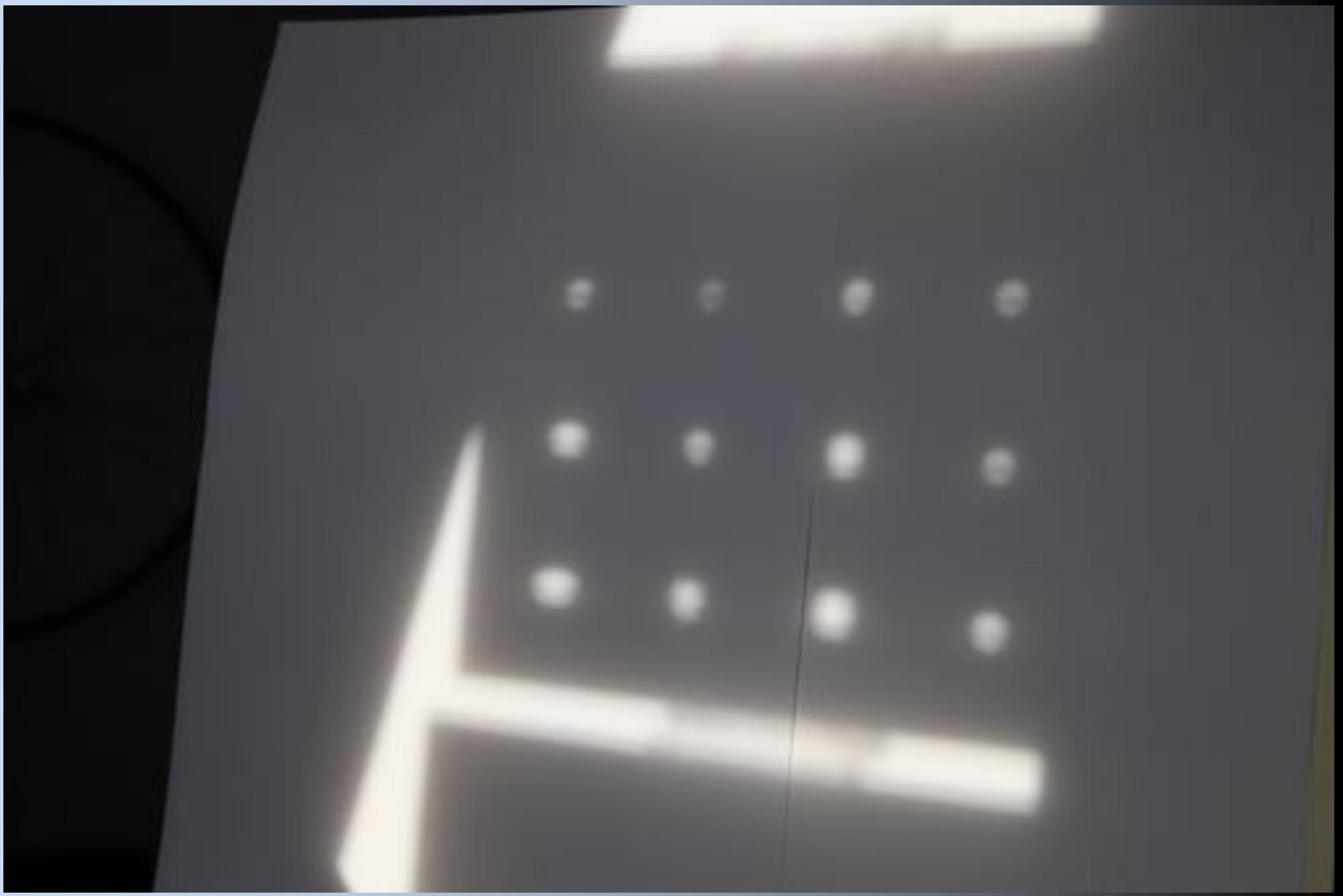
The surface brightness SB of the hearts is proportional to H^2, and inversely proportional to S^2, and thus to D^2 → $SB \div (H / D)^2$

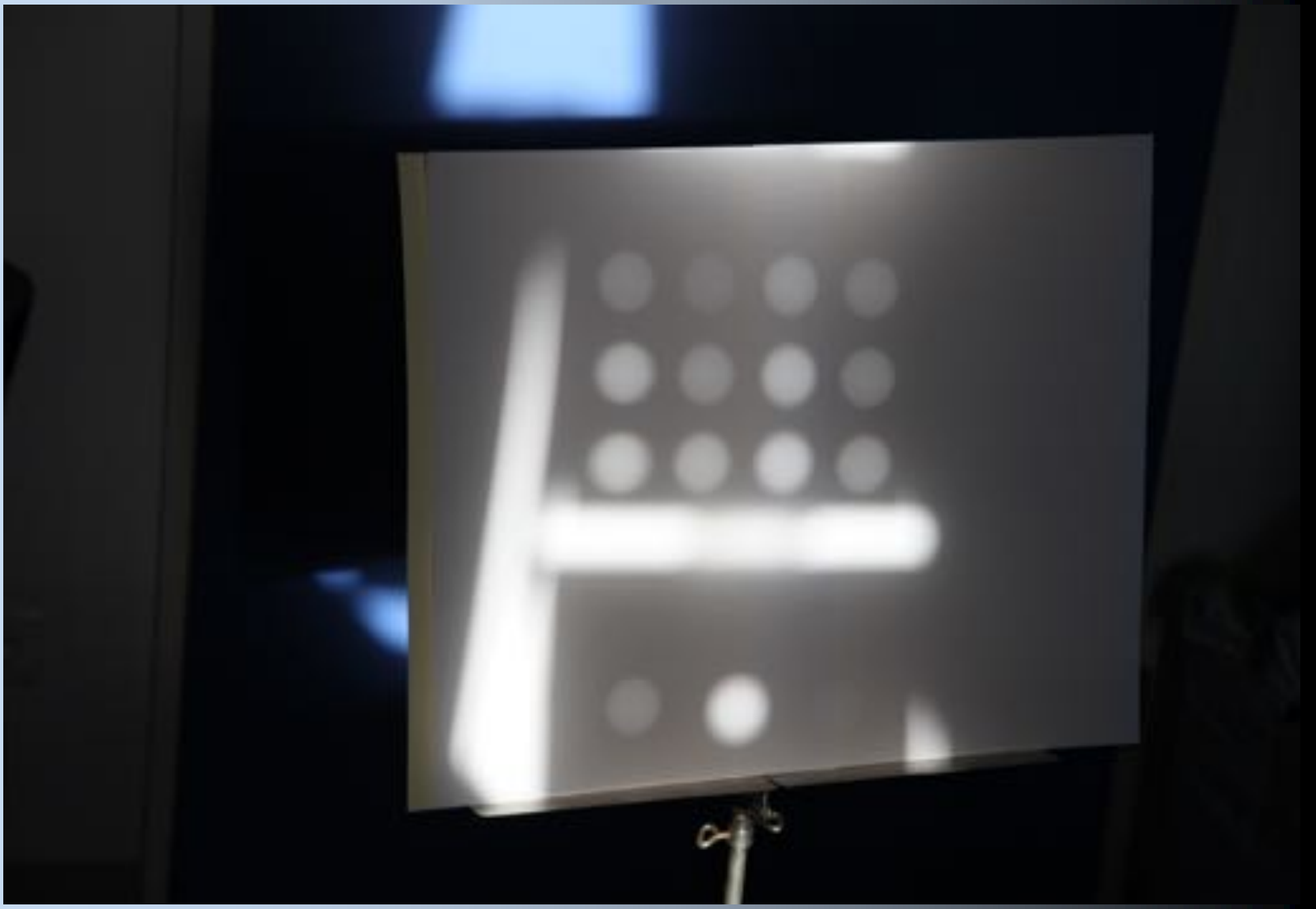

???
???
Quiz (?)

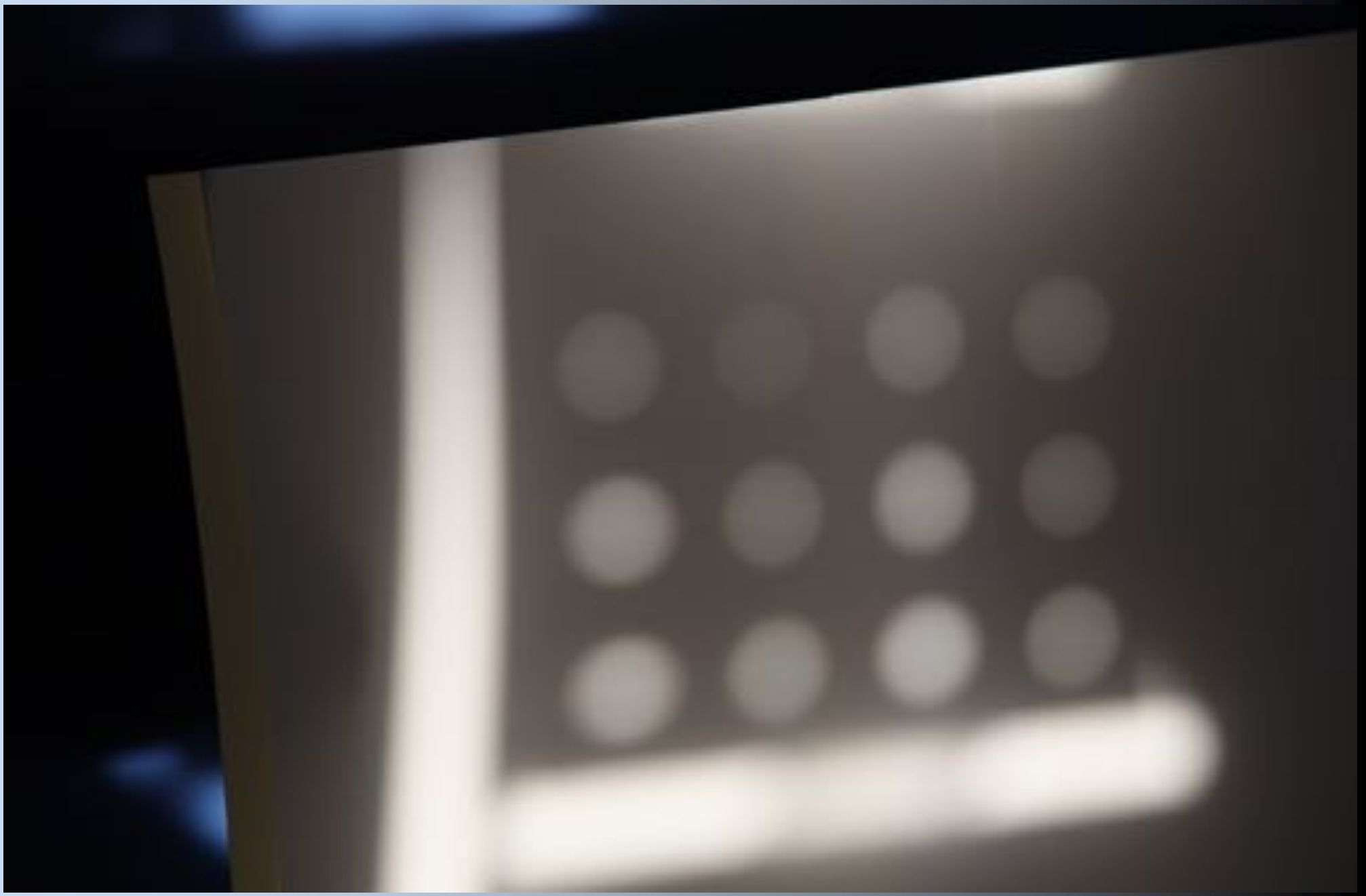

???
???
Quiz (?)
$I(\xi,\eta) = \iint Heart(\xi-\xi',\eta-\eta')\, Solar\, disk(\xi',\eta')\, d\xi'\, d\eta'$



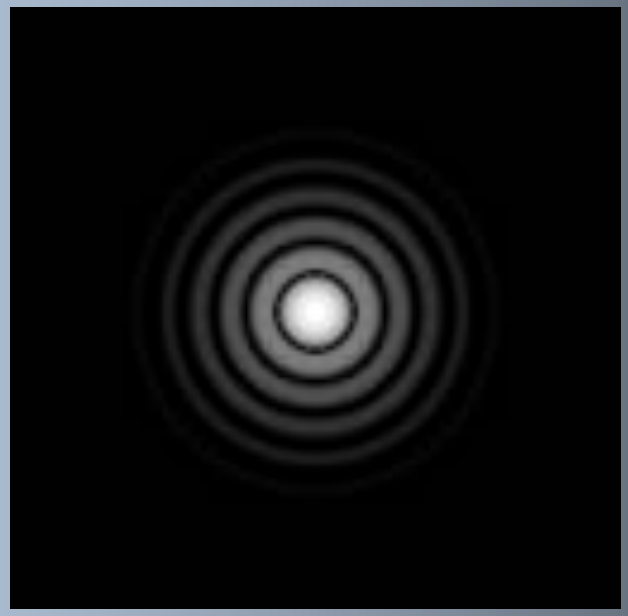




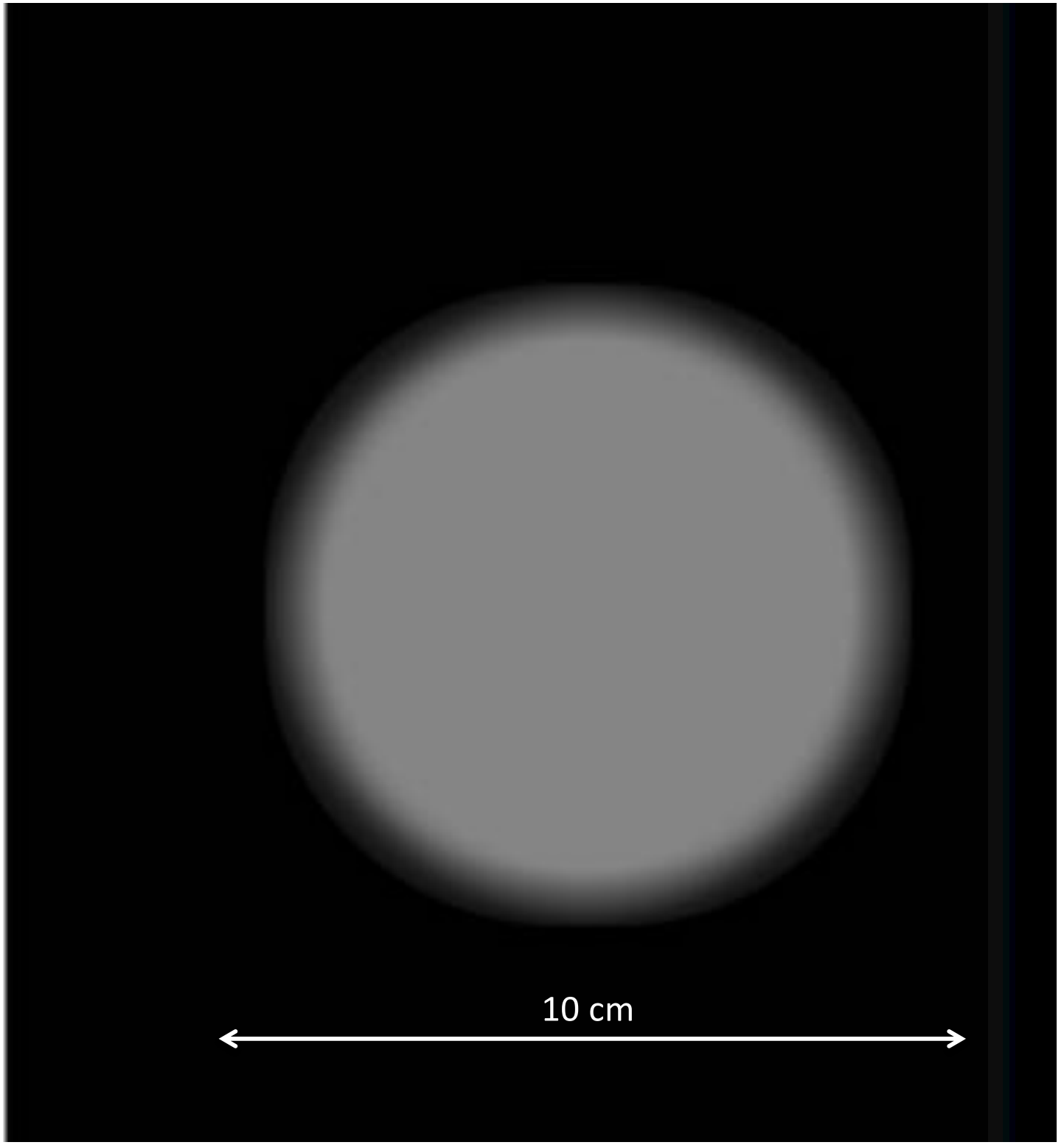


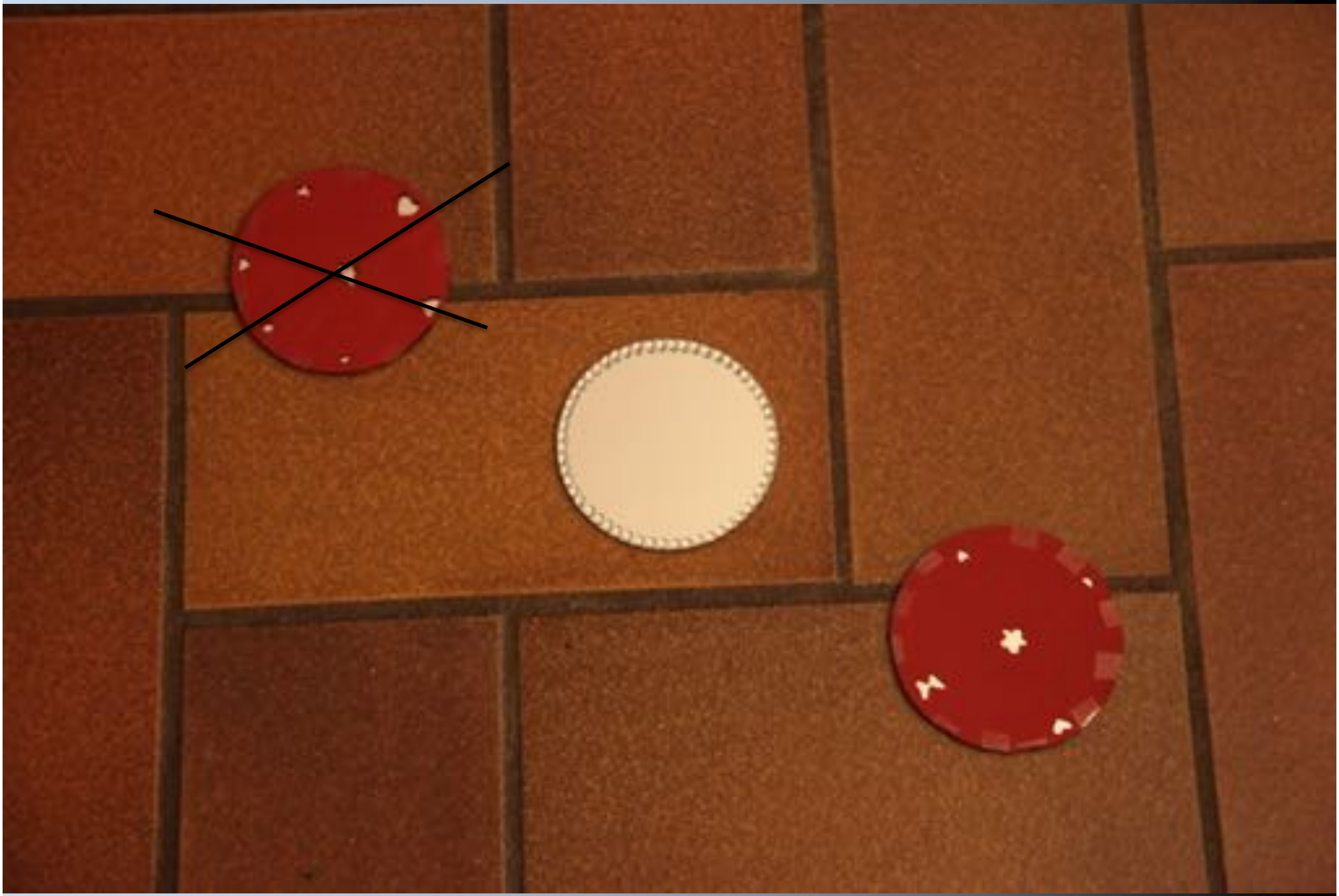


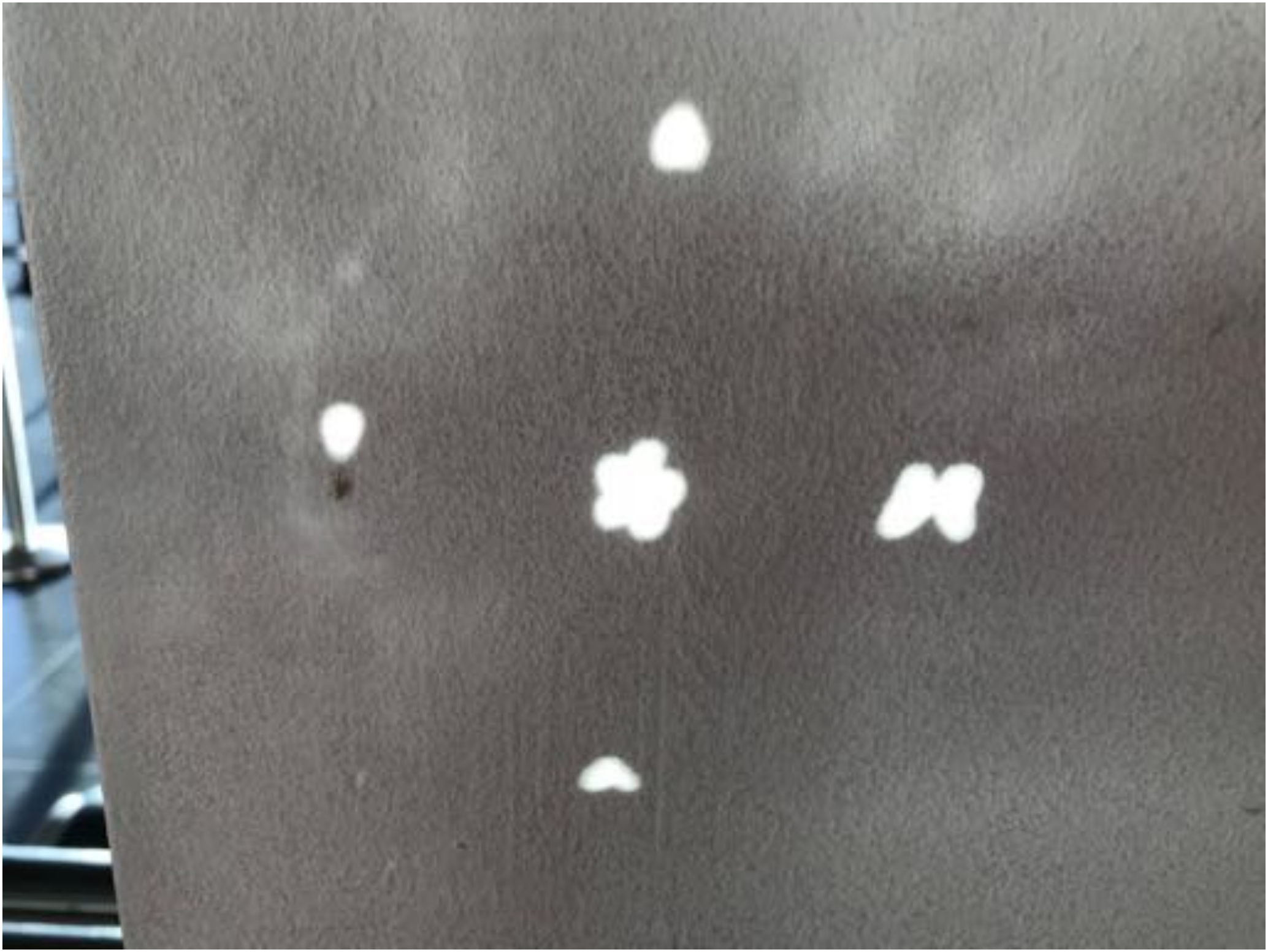
And if the diameter of the pinhole ➔ 0 ?

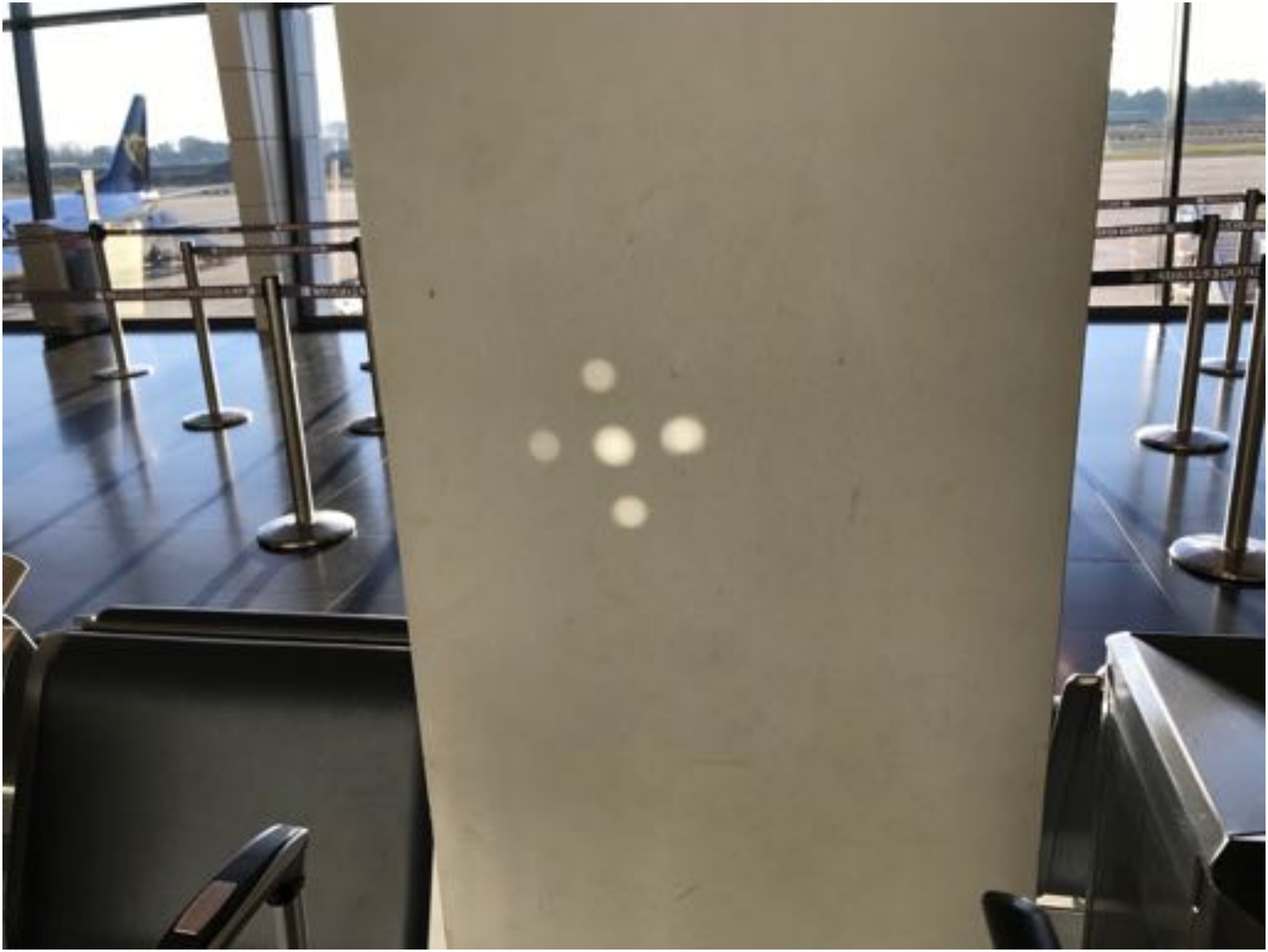


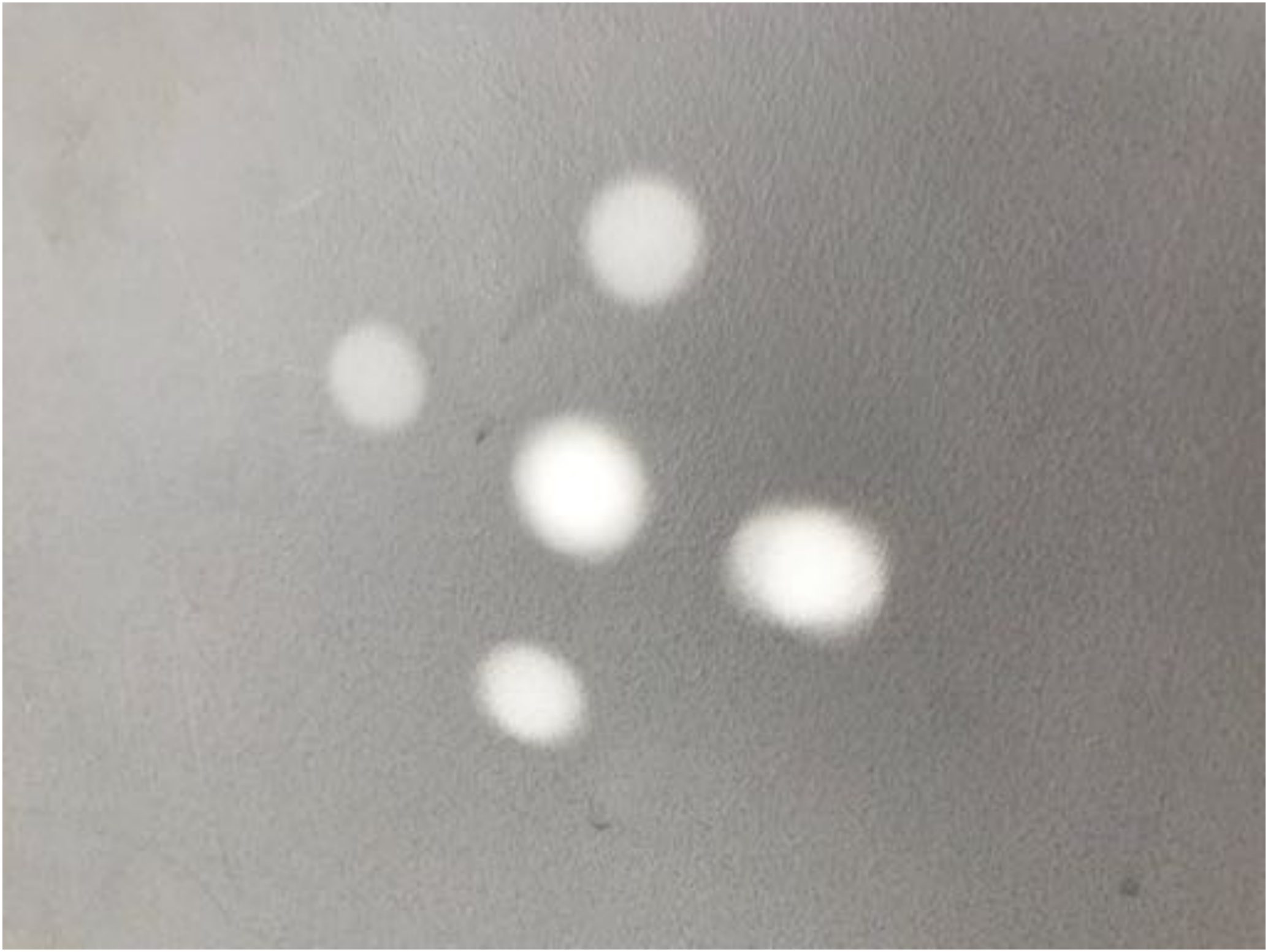
1 cm

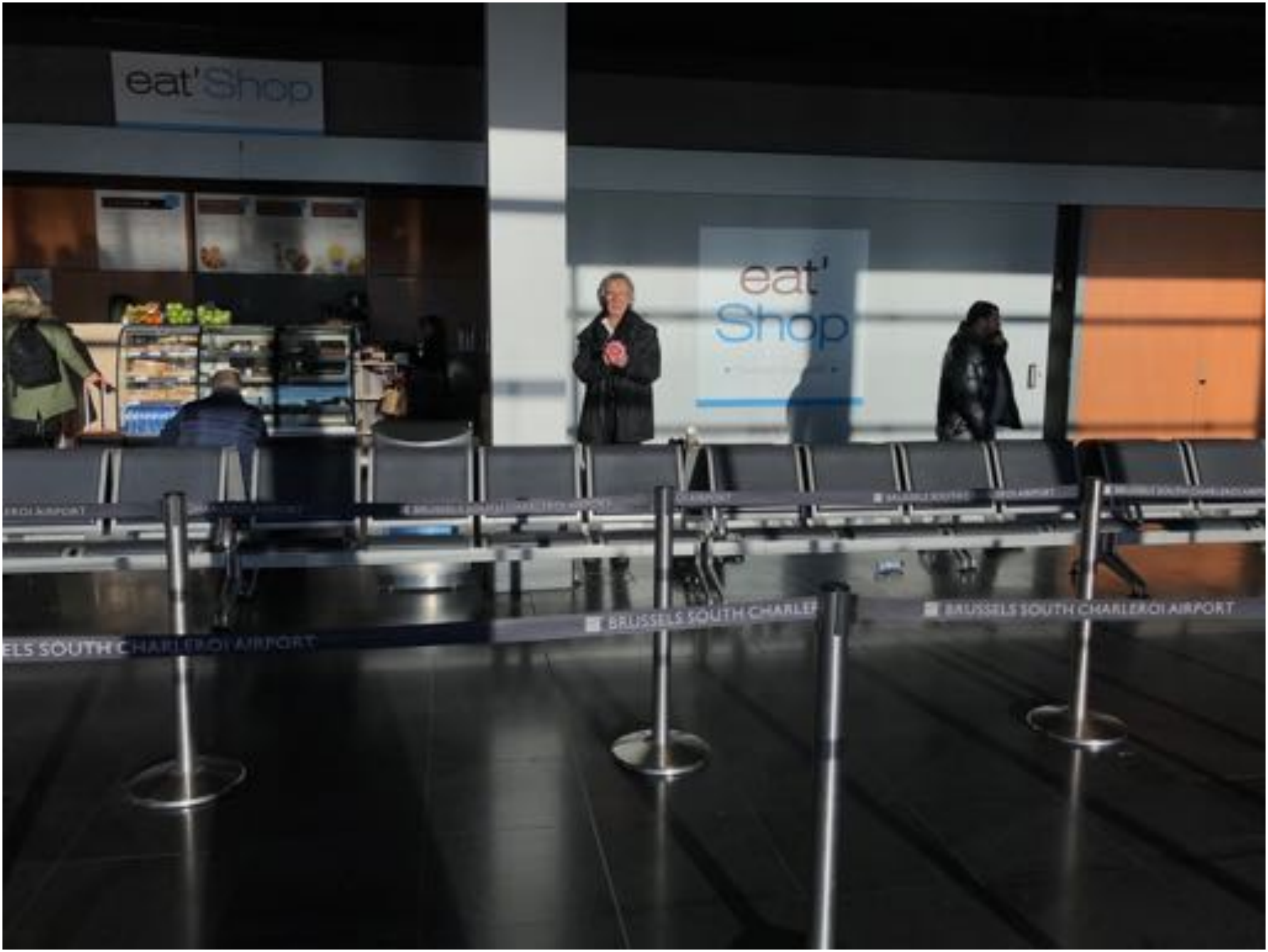






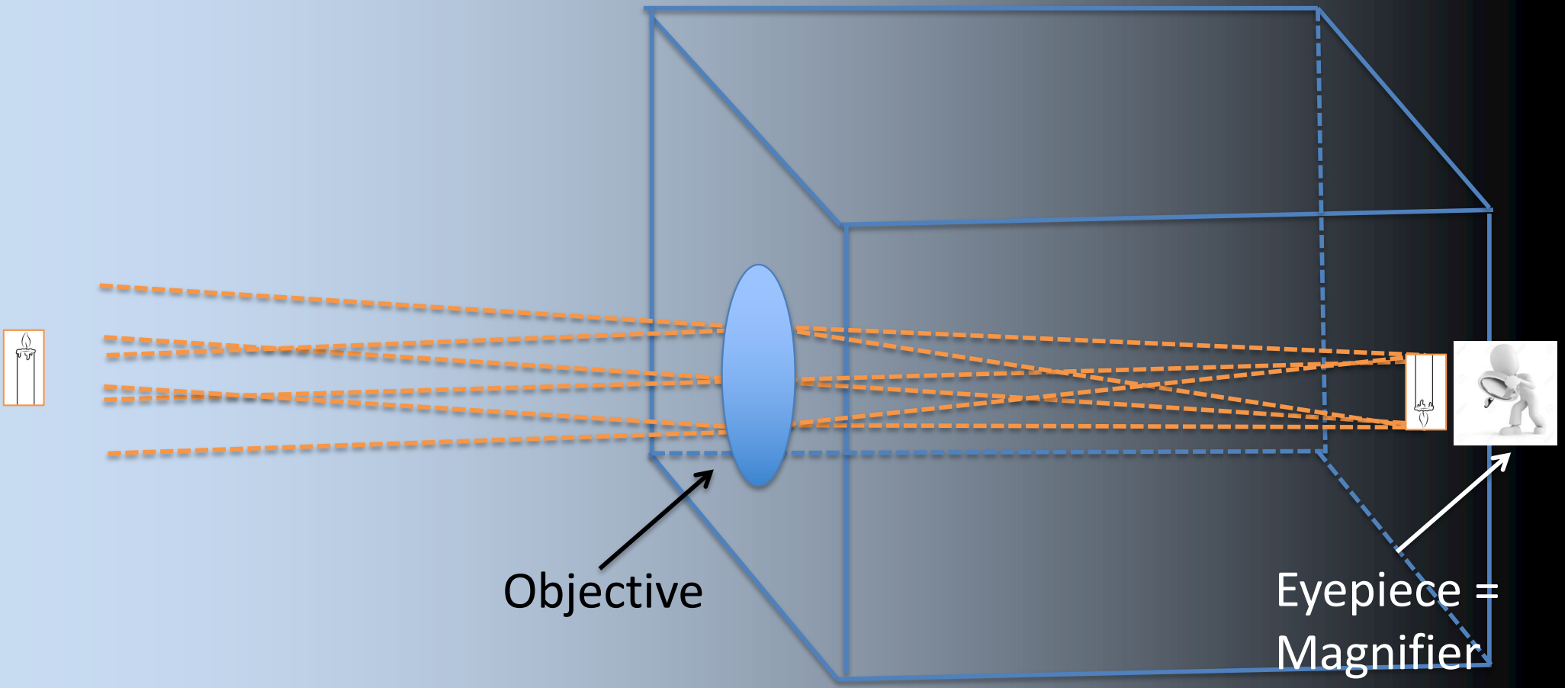


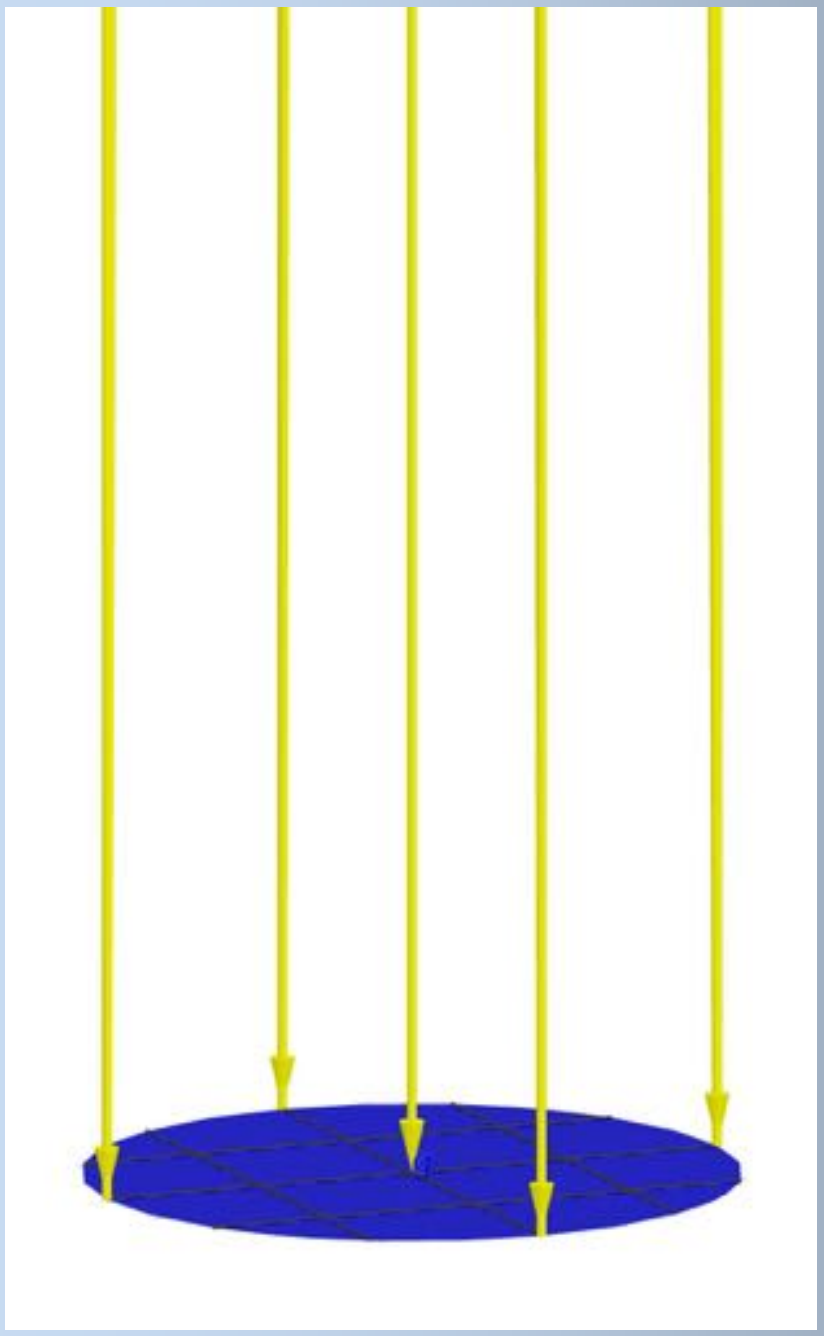


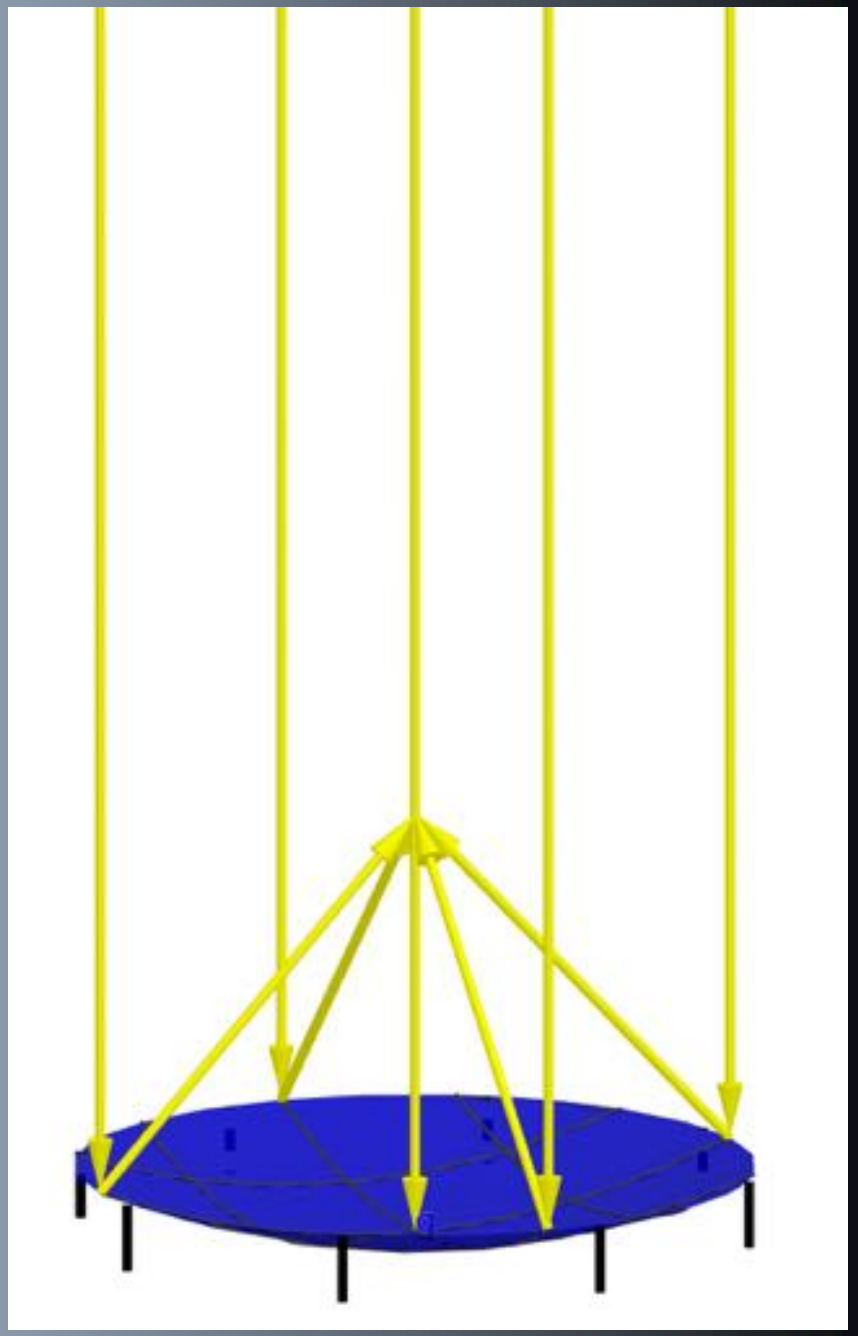

eat' Shop
eat'
Shop
BRUSSELS SOUTH CHARLEROI AIRPORT

- IV. Basic principles of a telescope

Camera obscura

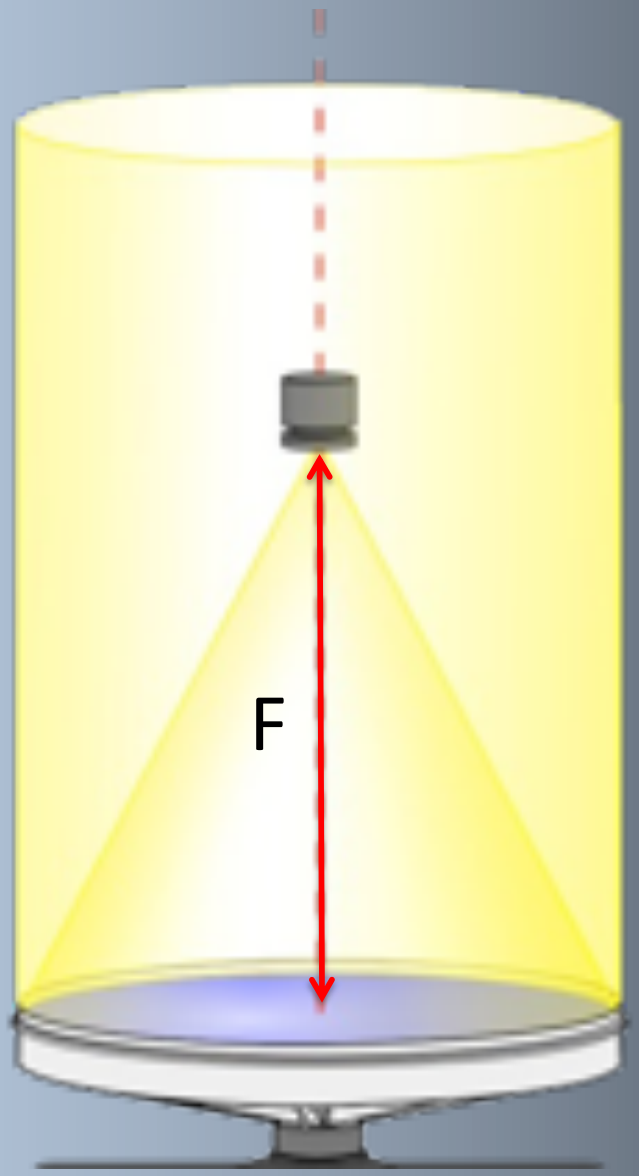




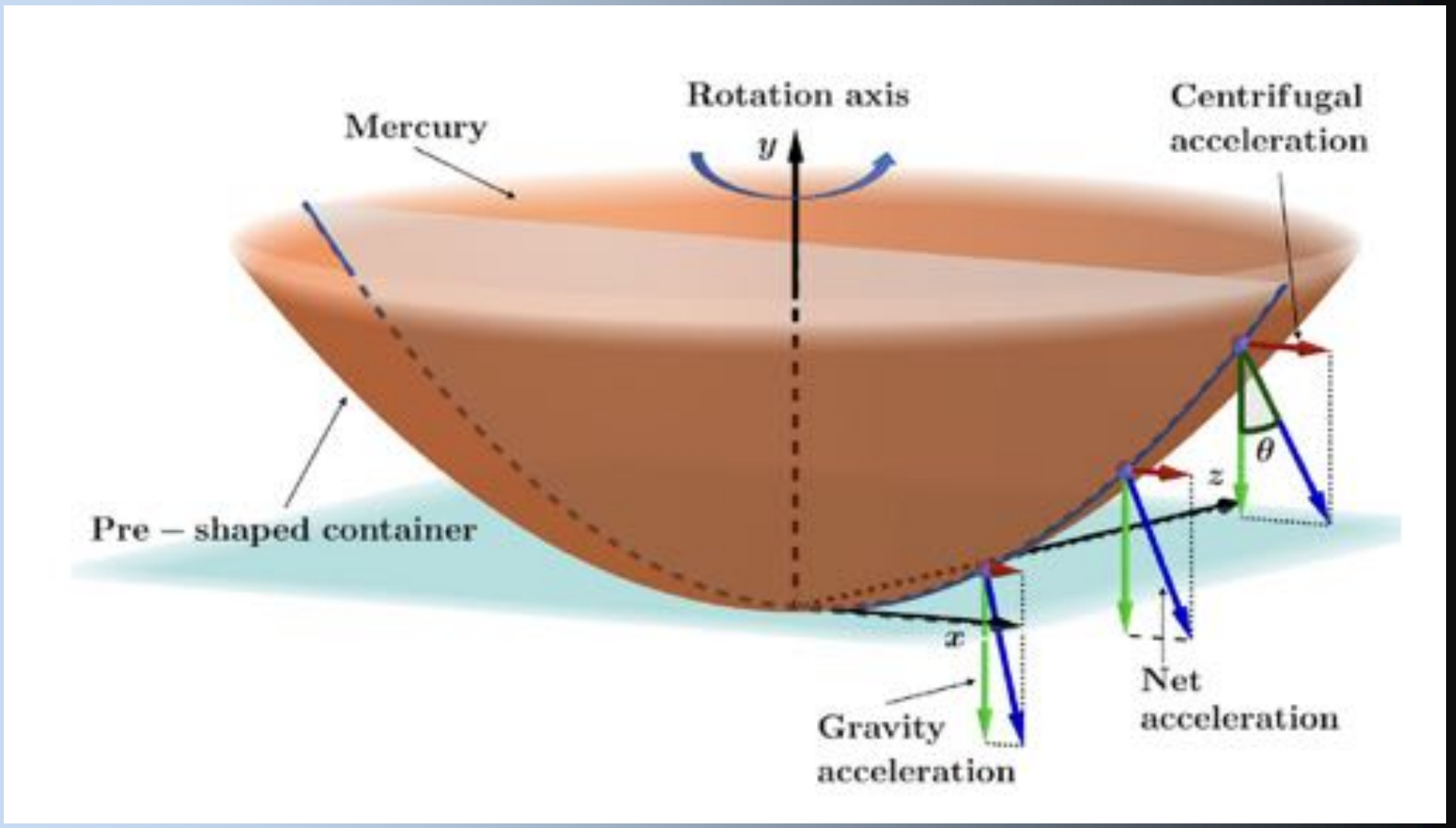


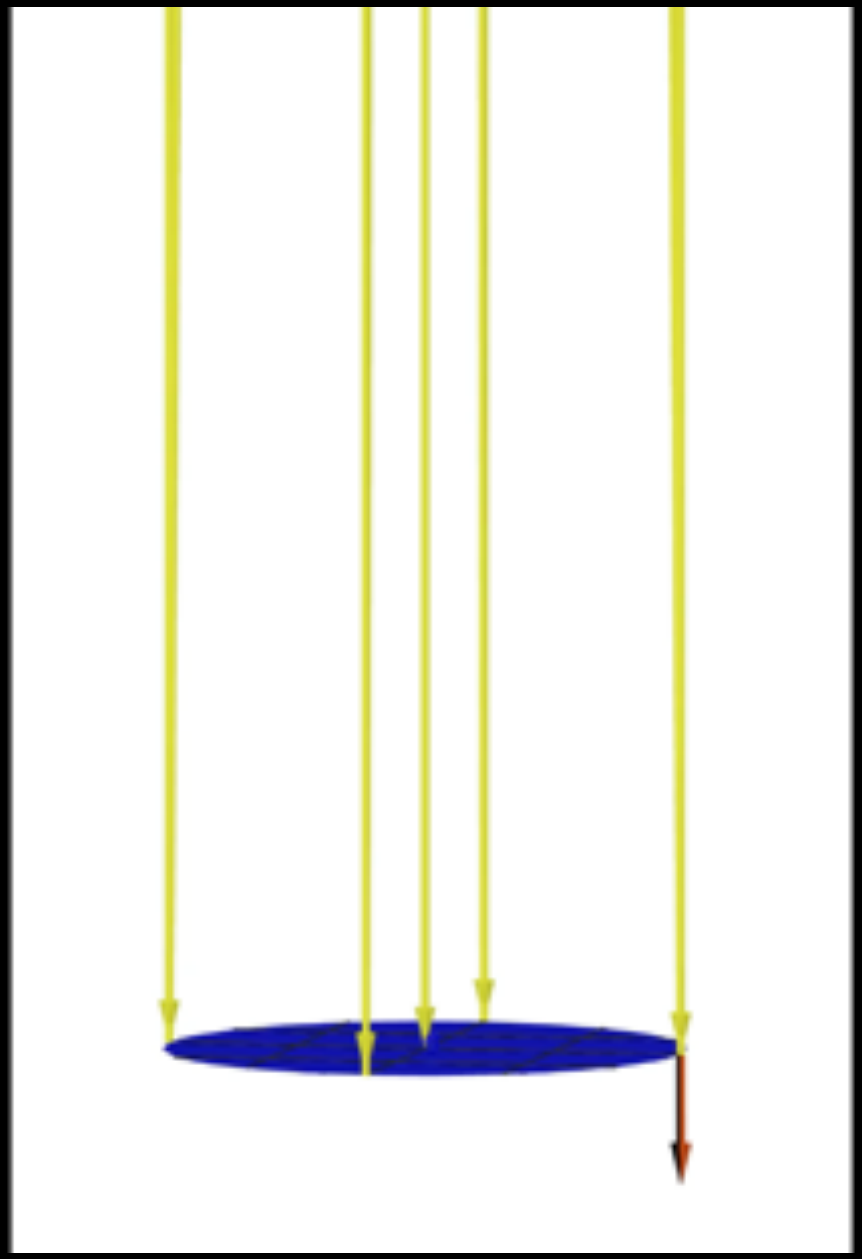
Liquid Mirror

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

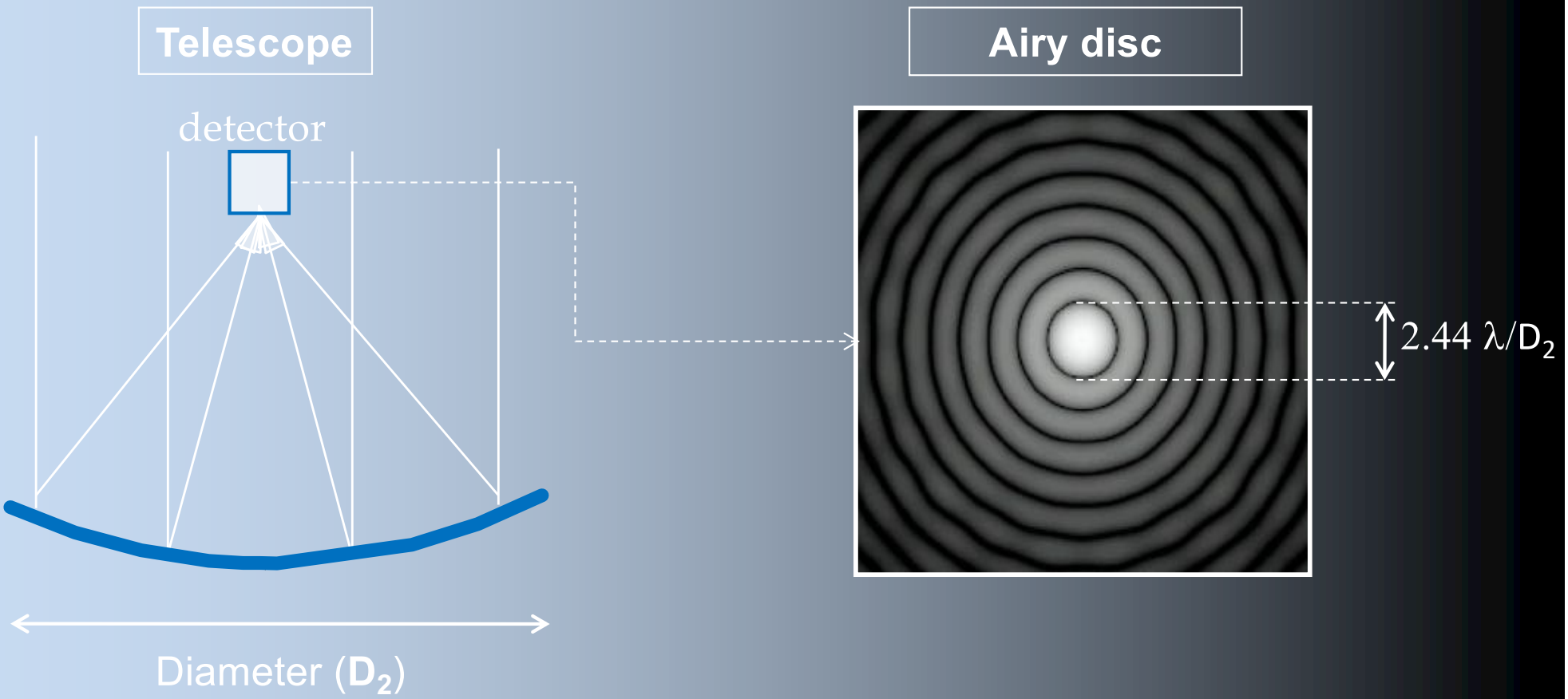


$F = g / 2\omega^2$

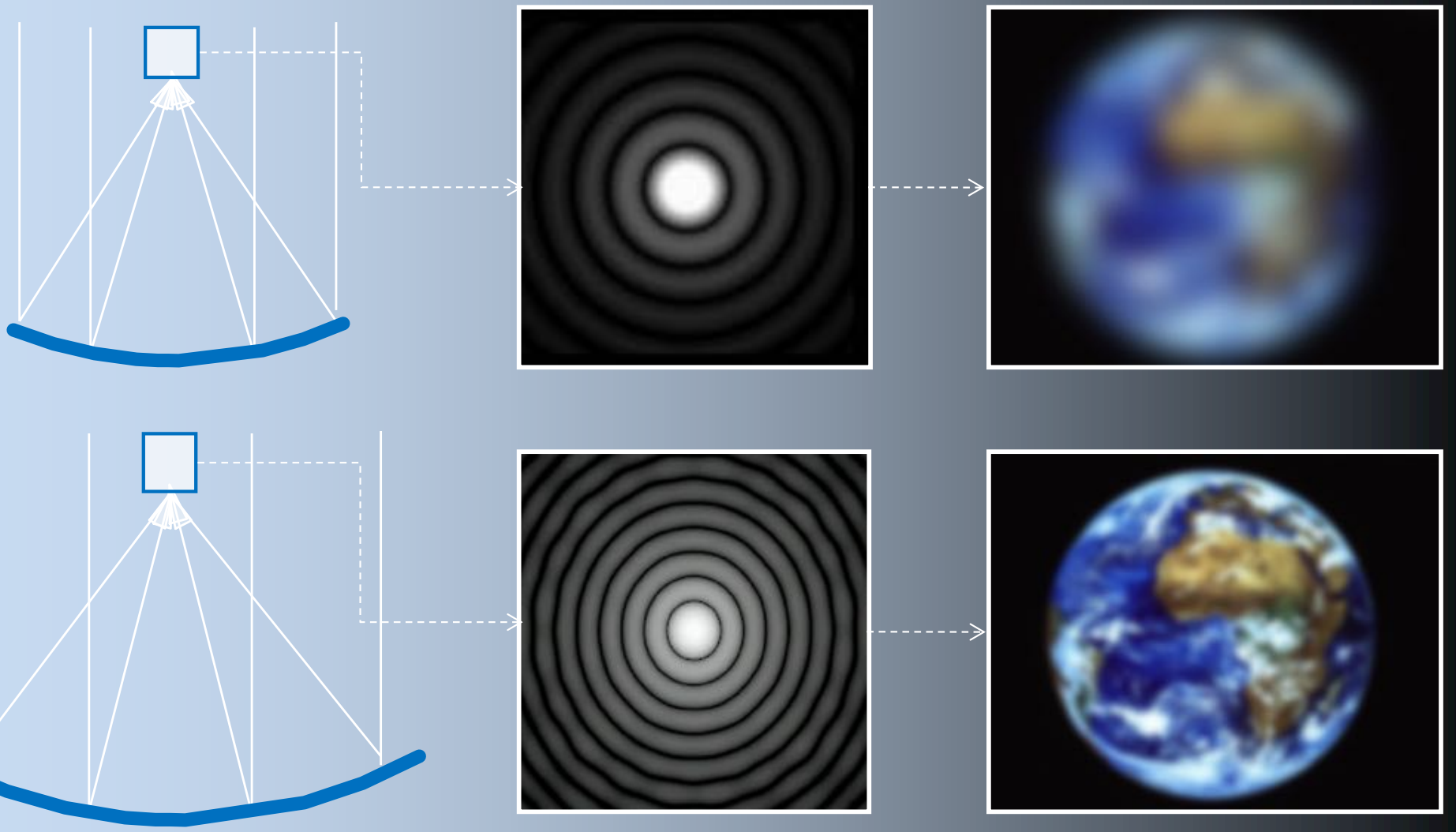

Rotation axis
y
Mercury
Centrifugal
acceleration
θ
z
Pre – shaped container
x
Net
acceleration
Gravity
acceleration



- A stellar image appears as a dot



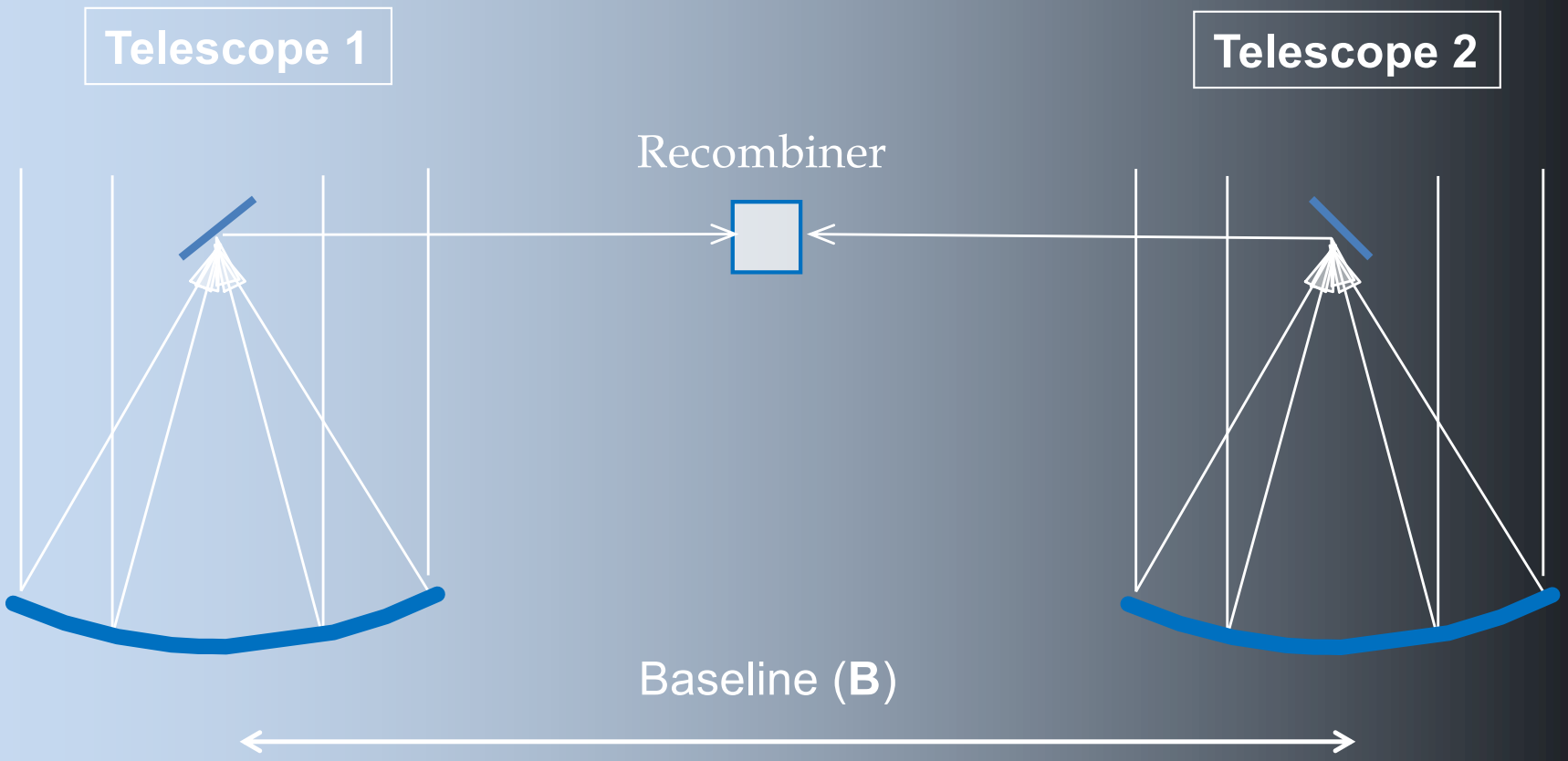
- A stellar image still appears as a dot!

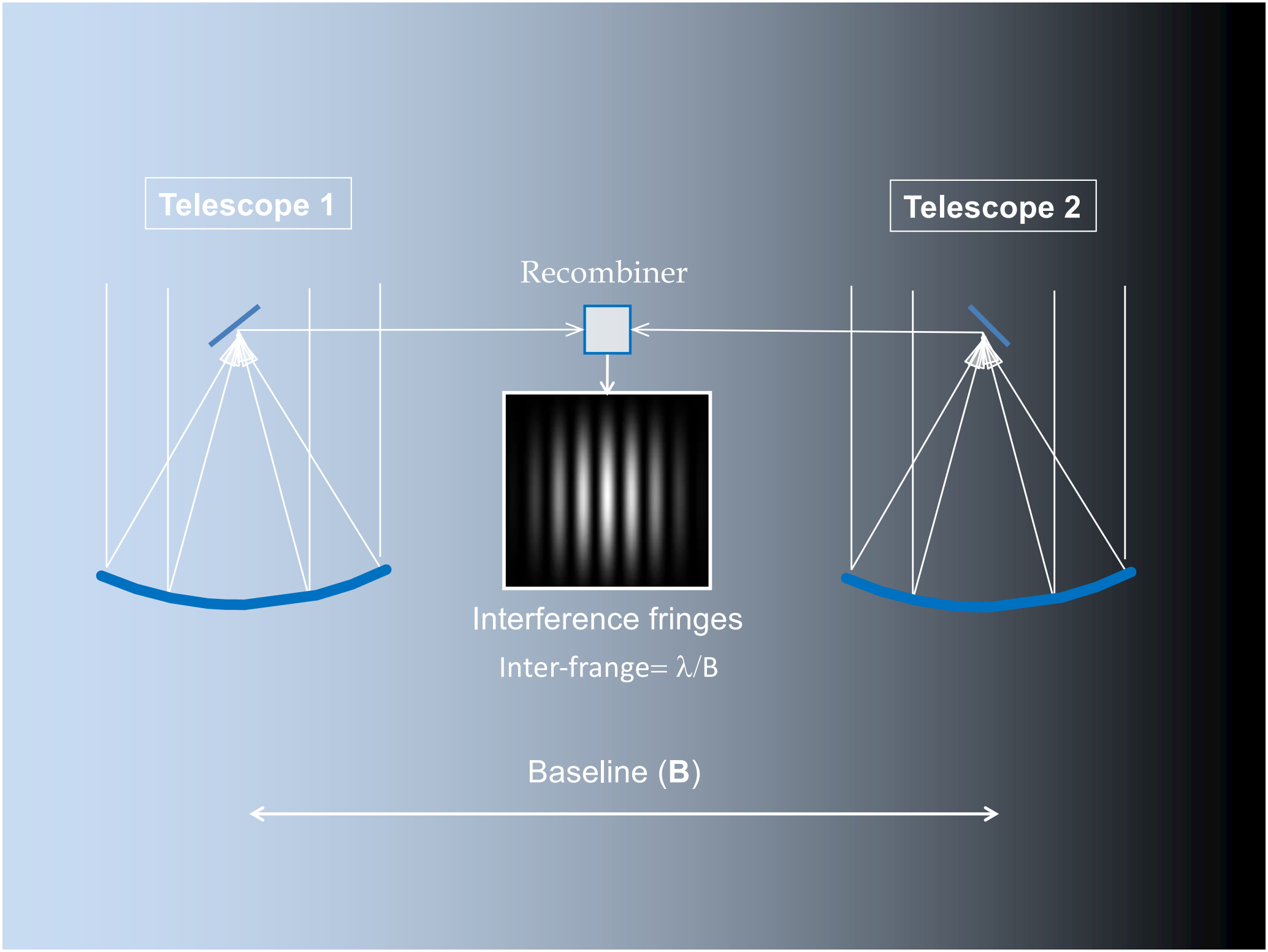


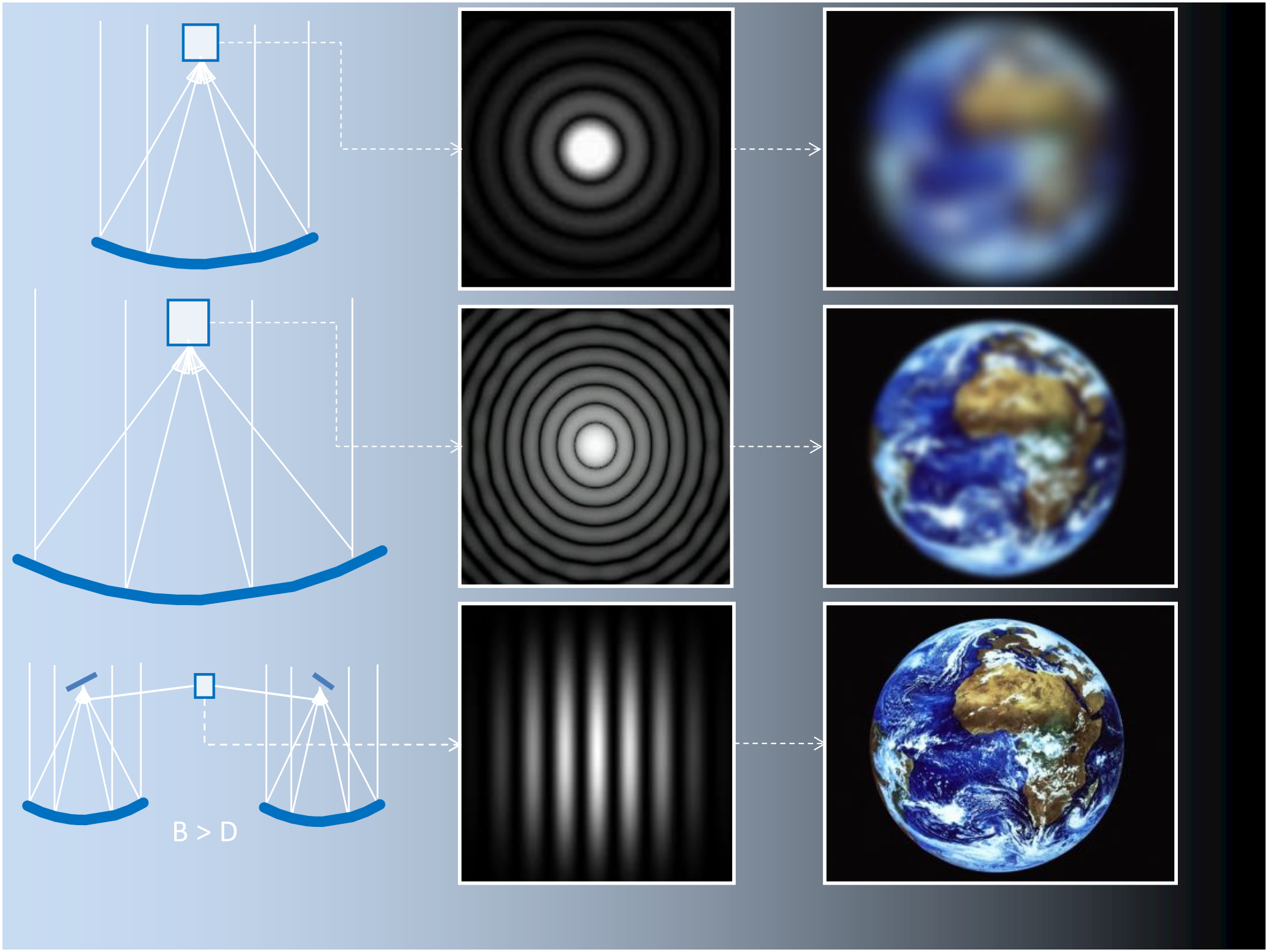
- Justification to construct telescopes ever larger!!!

- H. Fizeau and E. Stephan (1868-1870):

  "In terms of angular resolution, two small apertures separated by a distance B are equivalent to a single large aperture having a diameter equal to B"




Telescope 1
Telescope 2
Recombiner
Interference fringes
Inter-frange= λ/B
Baseline (B)


B > D

V. Earth rotation … Sun and star rotation

Quiz!

Do the stars in the sky always rotate from

- - left to right?
- - right to left?
- - sometimes from left to right and sometimes from right to left?

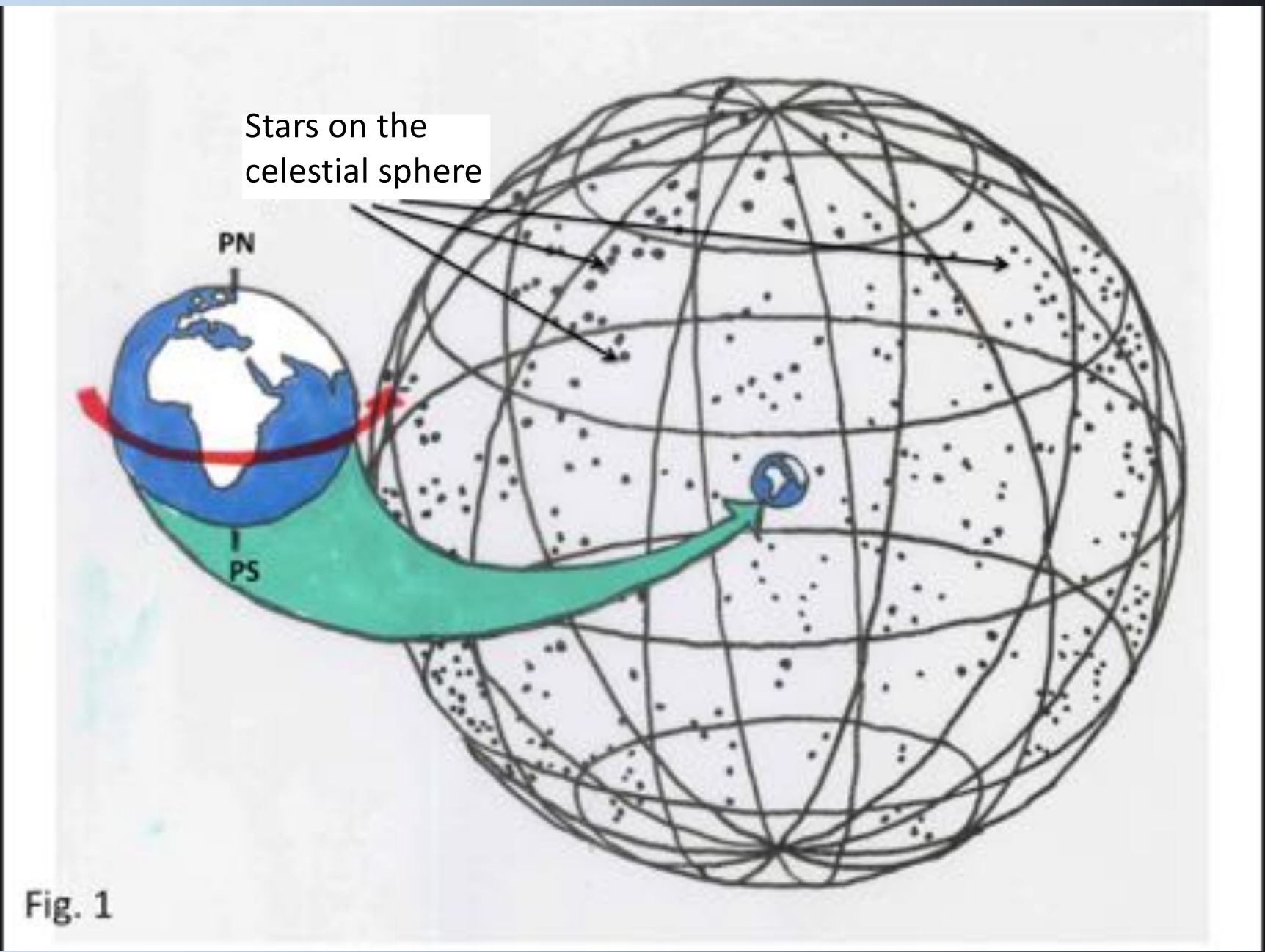


Fig. 1

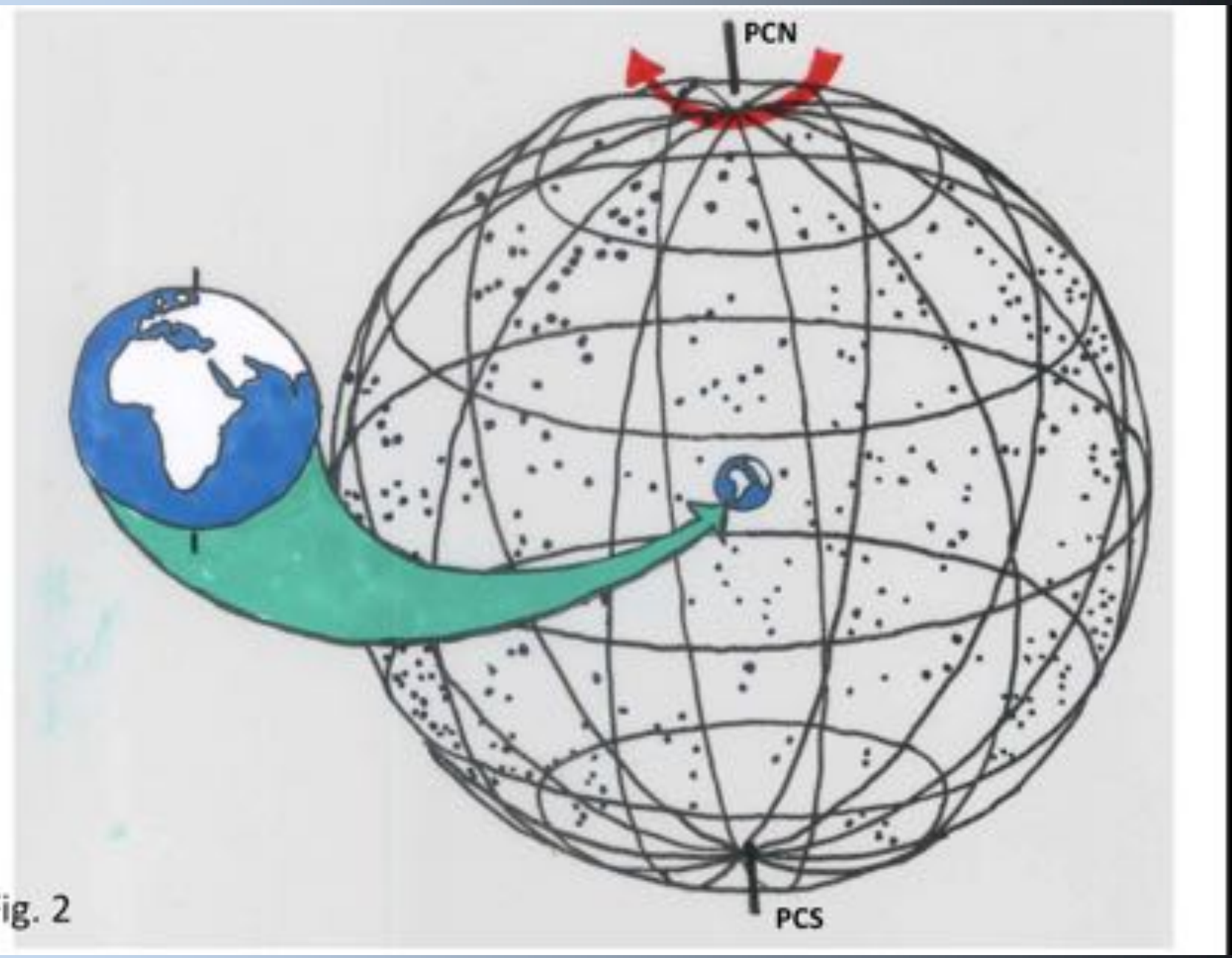
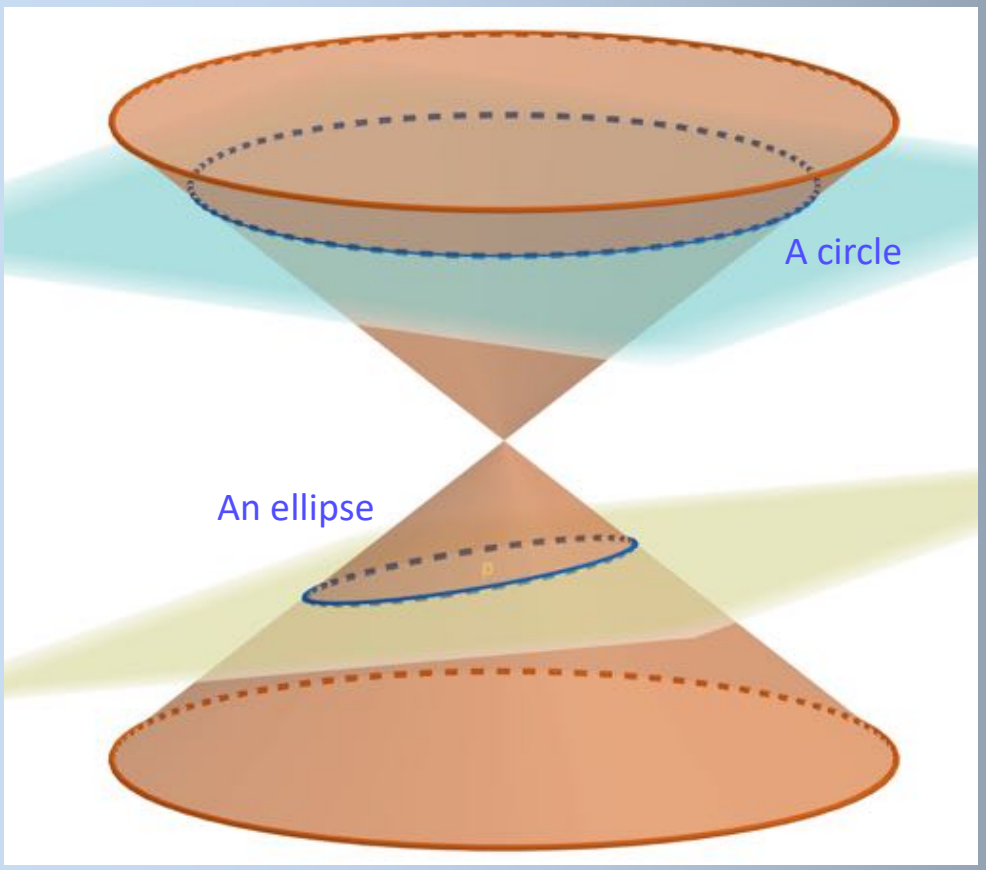
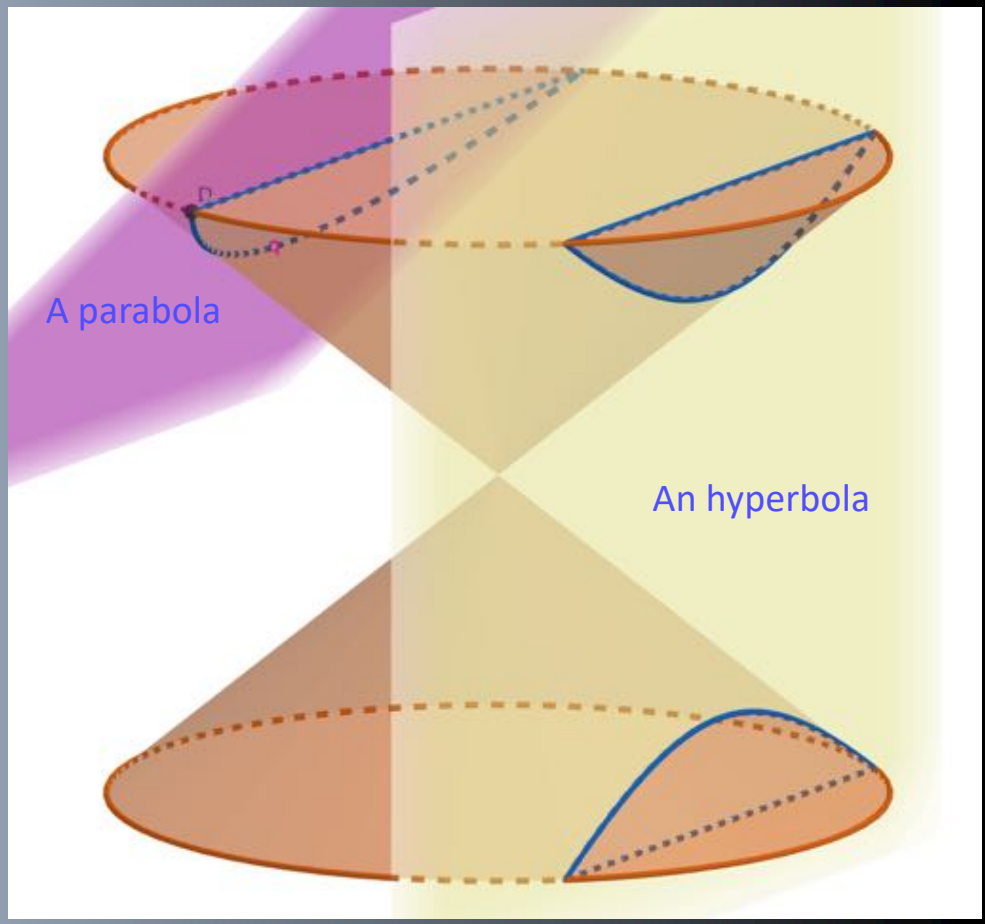
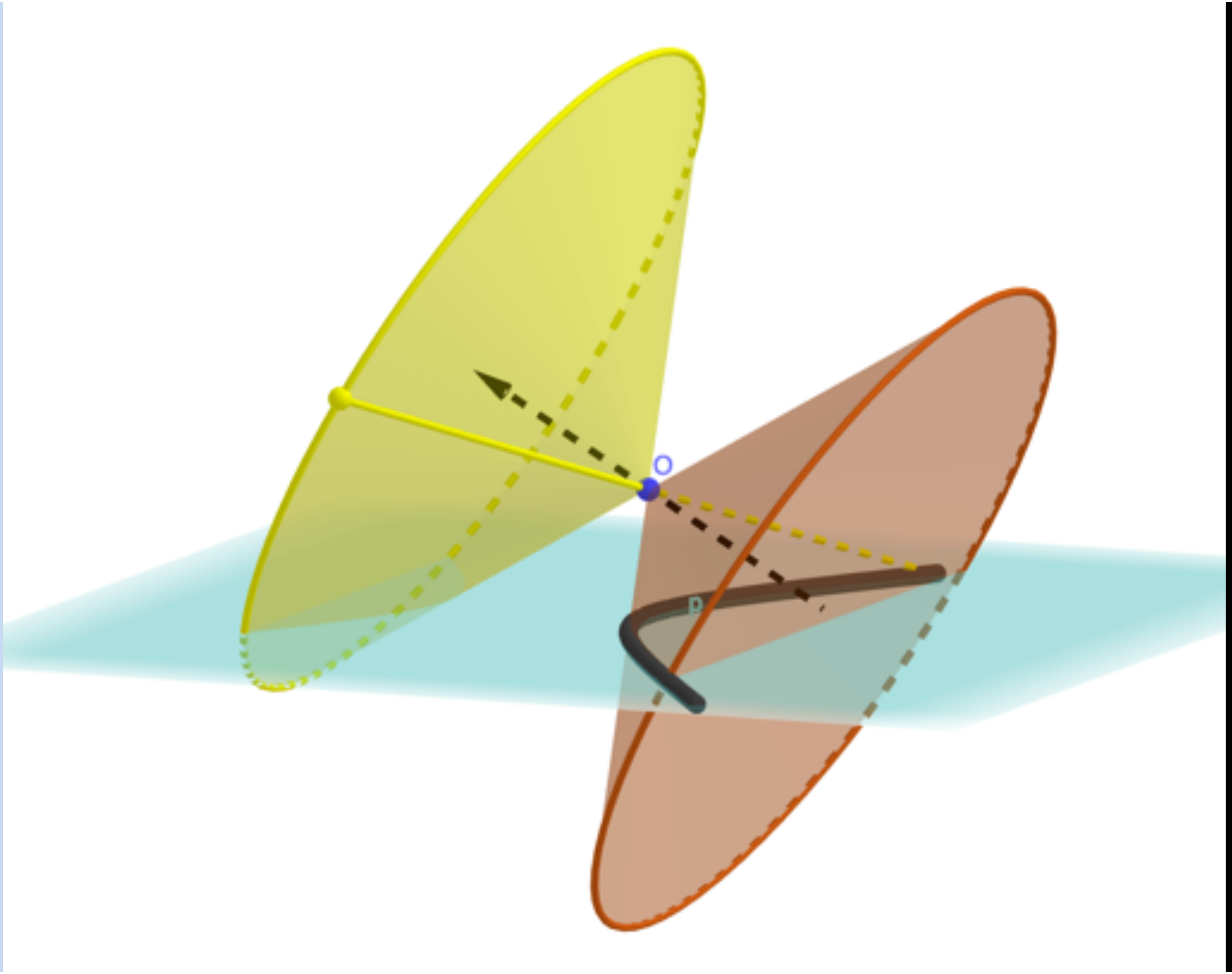


Fig. 2

VI. Conic trajectories


A circle
An ellipse


A parabola
An hyperbola


O
D

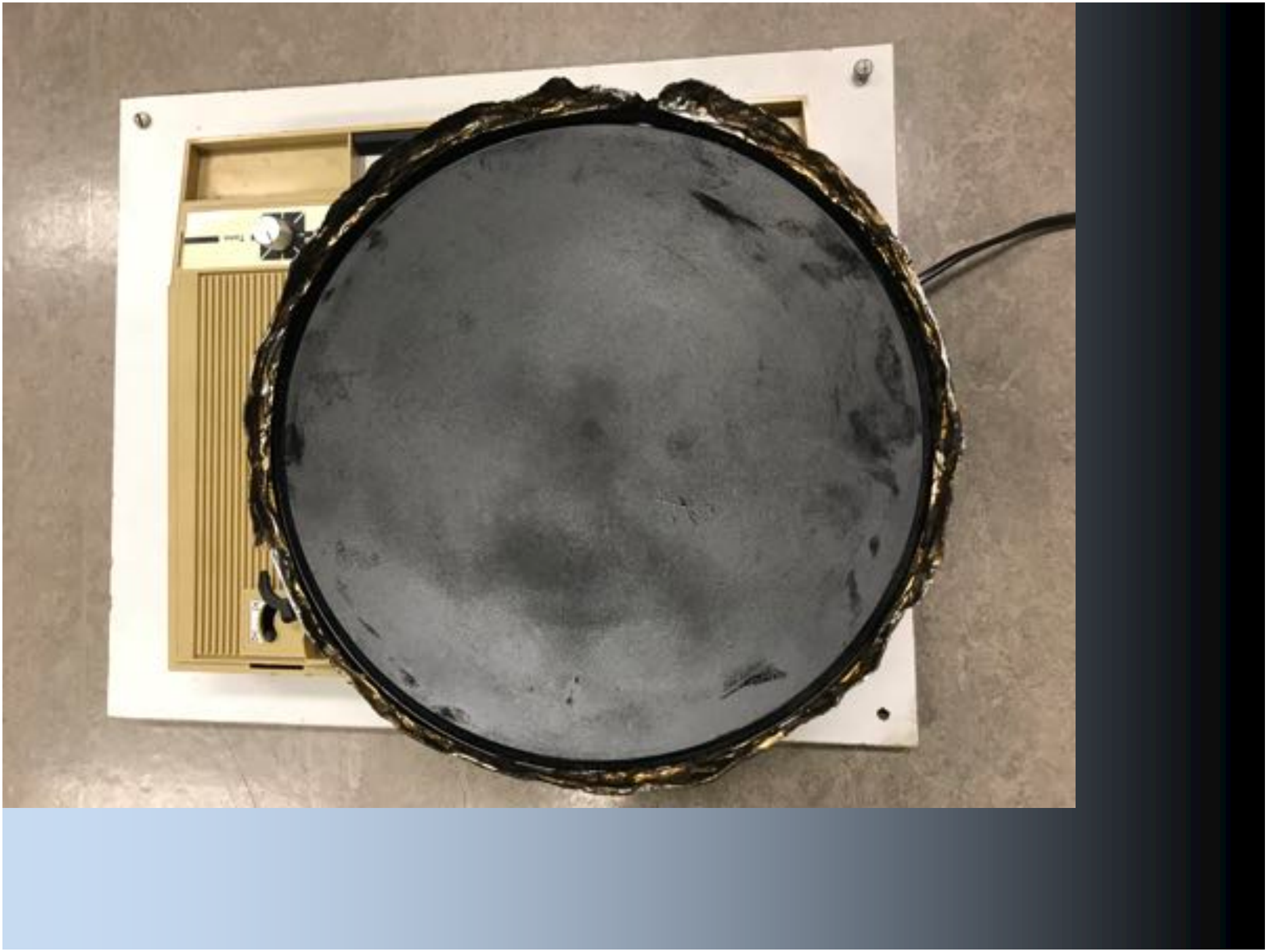
Quiz!

Quiz for You!

- VII. Liquid Mirror Telescope principles

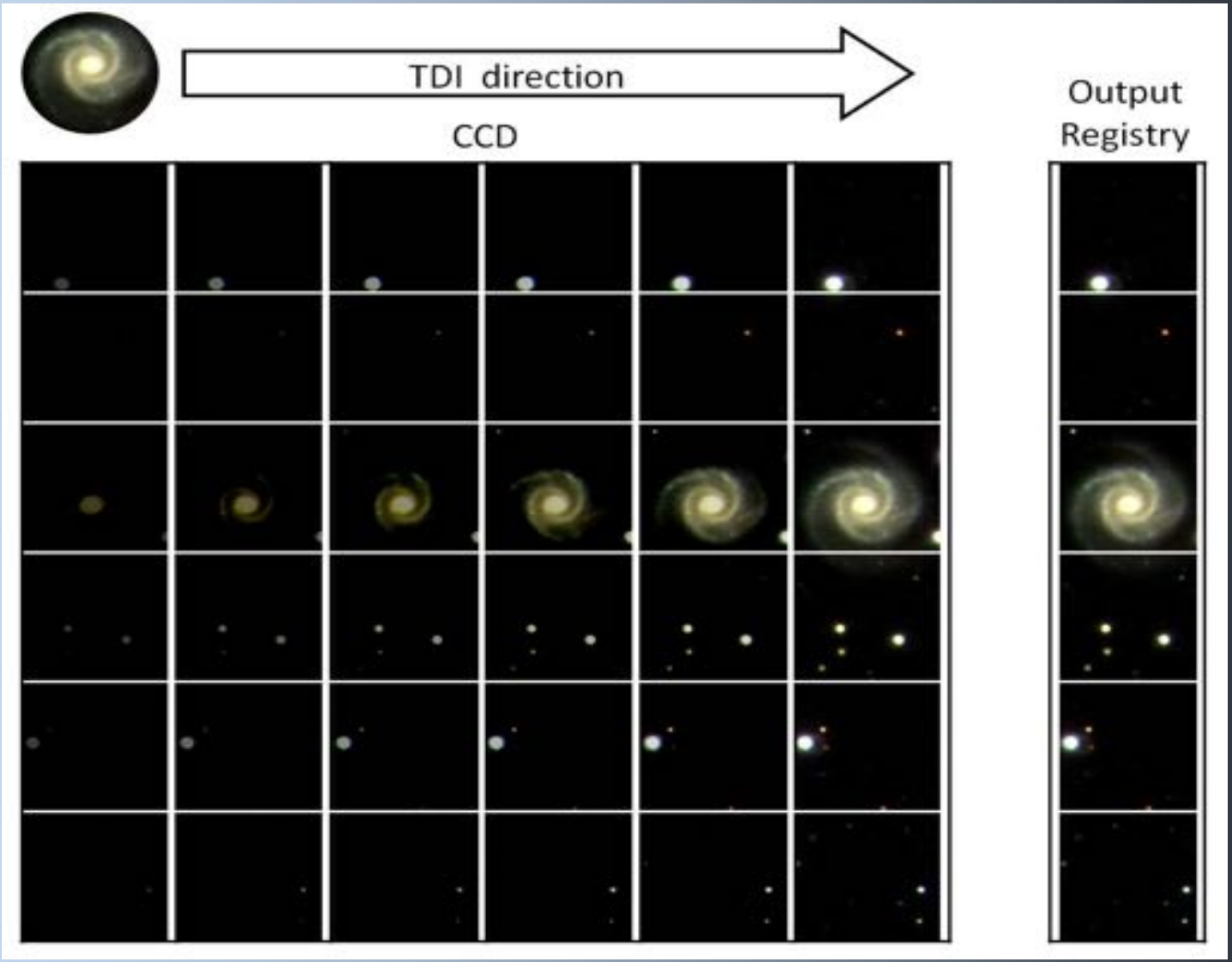
Build at home your own liquid mirror telescope …


Wilson
Volume
Tone

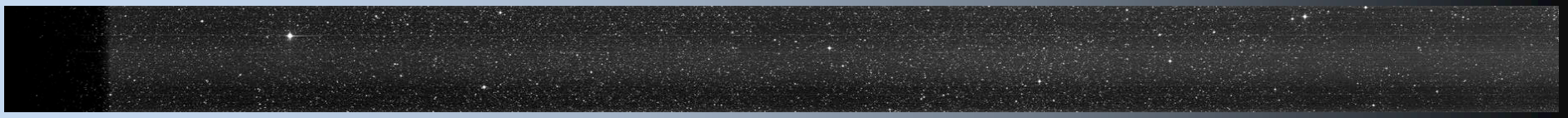


VIII. TDI mode of observation

TDI mode (Time Delay Integration)



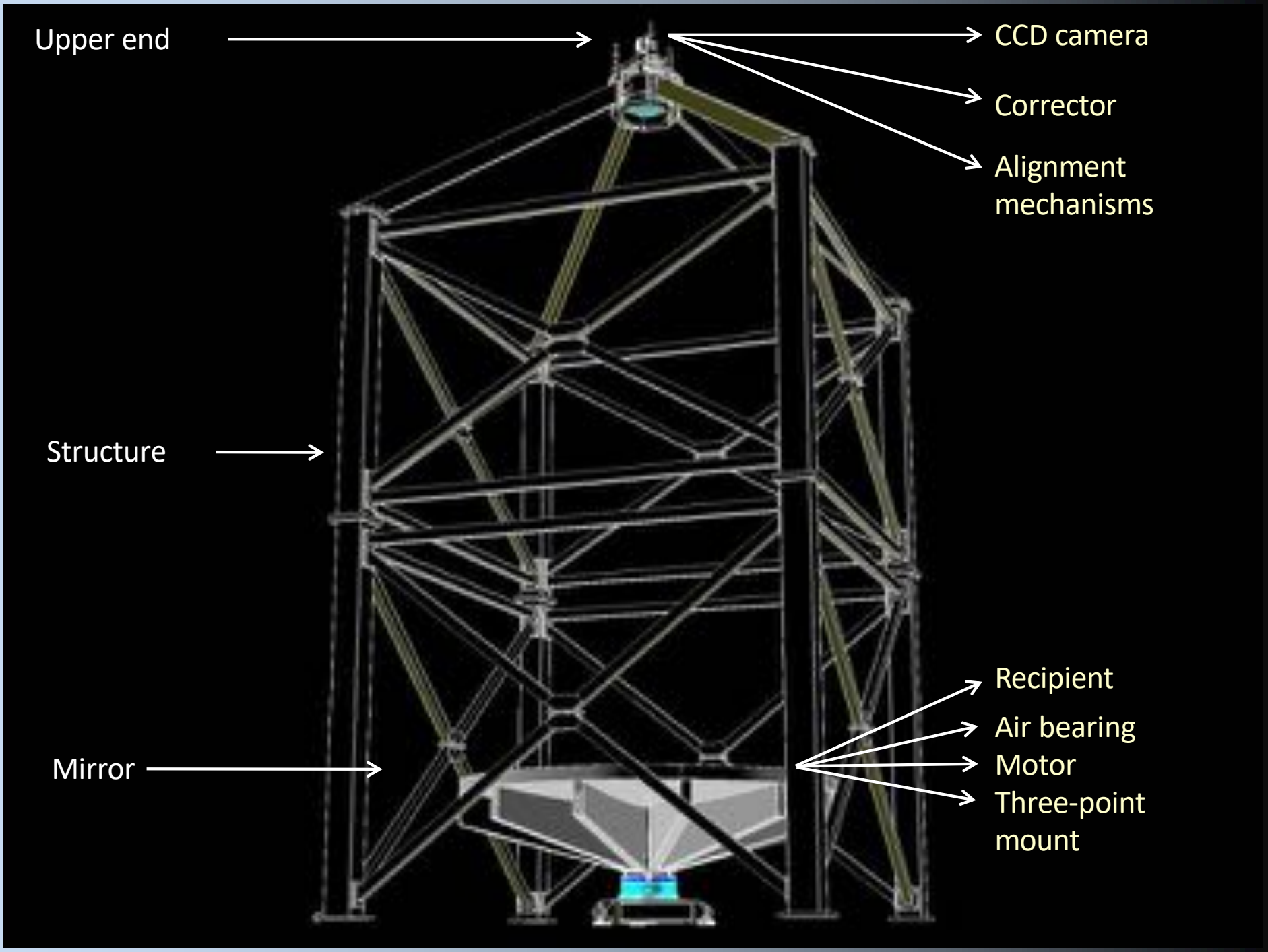
The TDI mode



- 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
Δm	0.6	1.0	1.35	2.22	2.98

IX. The 4m International Liquid Mirror Telescope (ILMT)


Upper end
CCD camera
Corrector
Alignment mechanisms
Structure
Mirror
Recipient
Air bearing
Motor
Three-point mount

January
2007

At the very beginning …

At the very beginning …

At the very beginning …

The 4m 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.

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

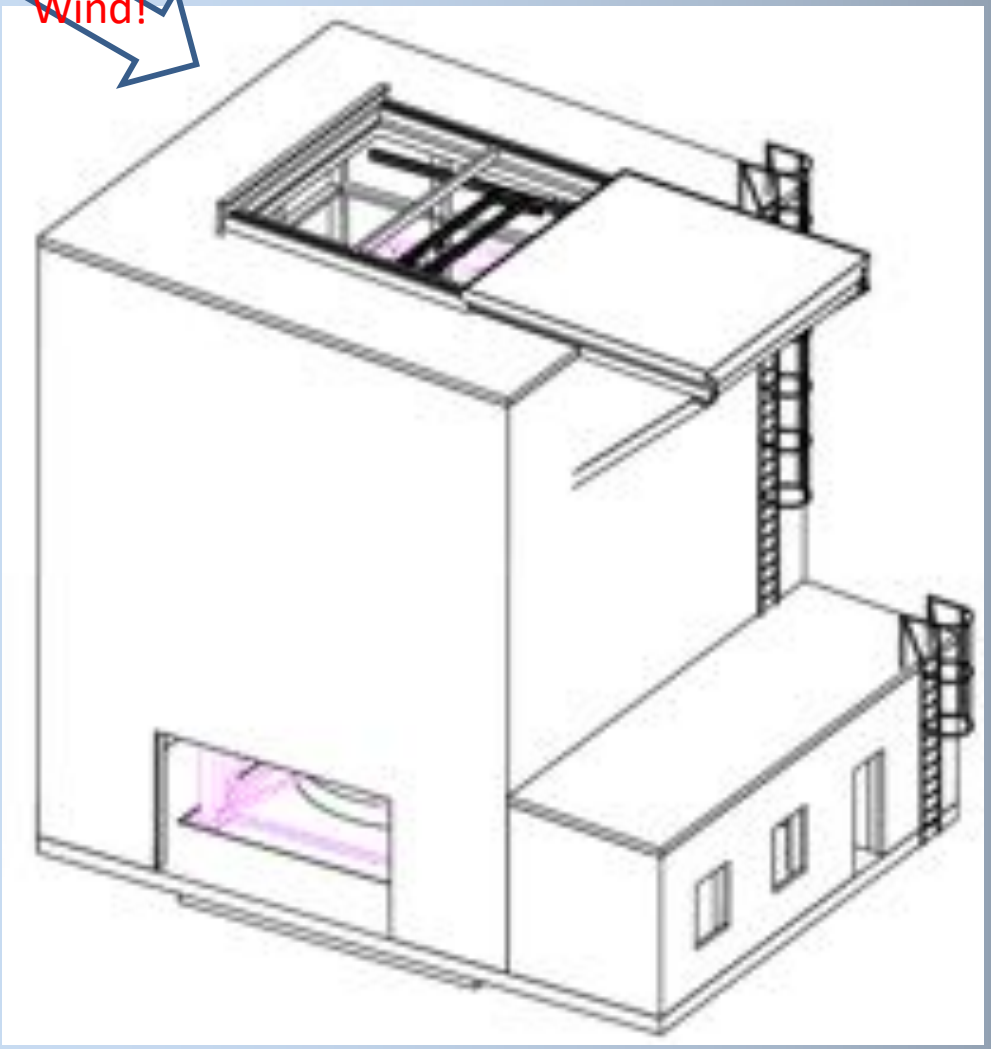
Arrival of the truck carrying the 4m-mirror at the site of Devasthal (India) (23rd of March 2012)

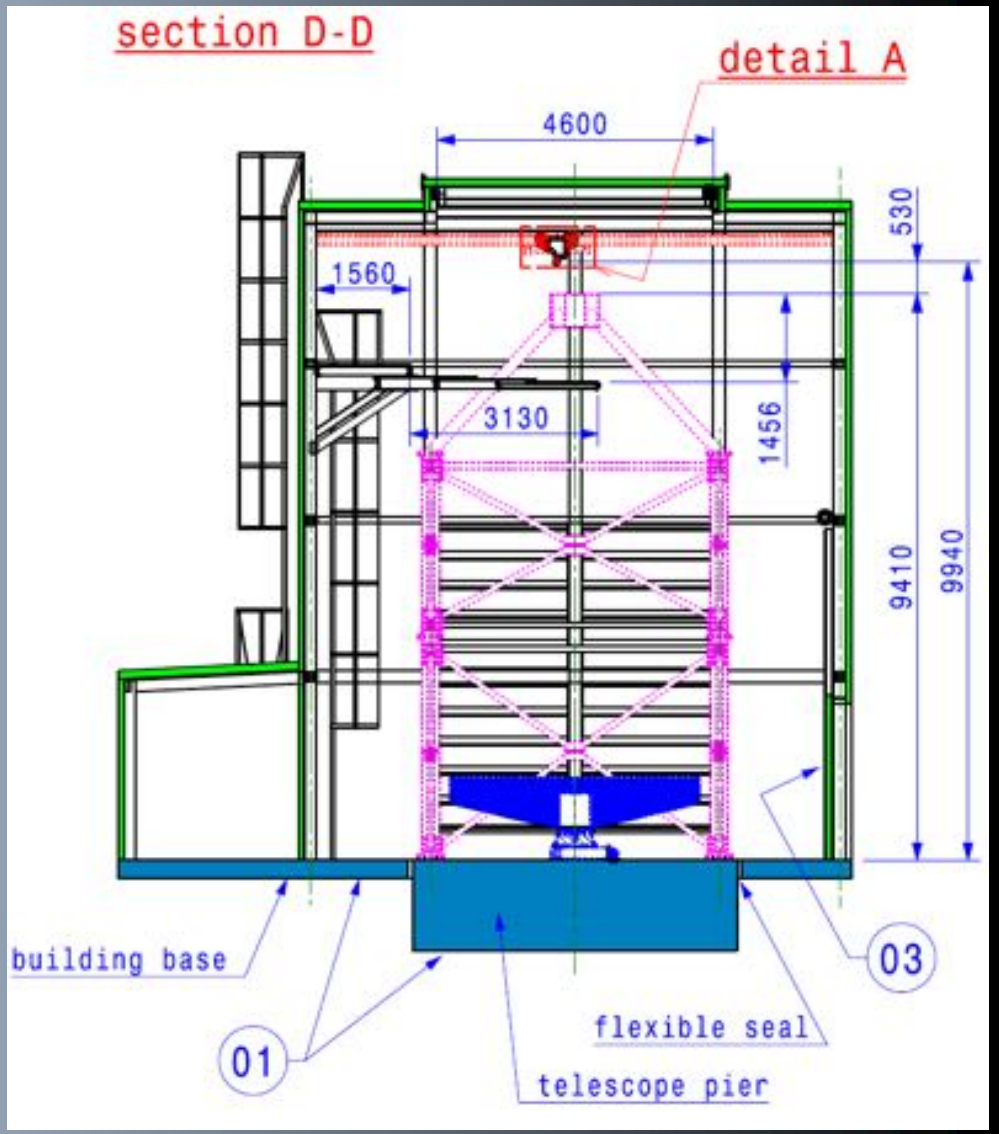
Transportation of the ILMT primary mirror between the entrance and the summit of the Devasthal Observatory (24 May 2013)

Civil engineering construction of the ILMT dome

Construction of the ILMT dome

The dome





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


ACE

Members of the Pedvak team finishing the ILMT dome construction

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

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


aries
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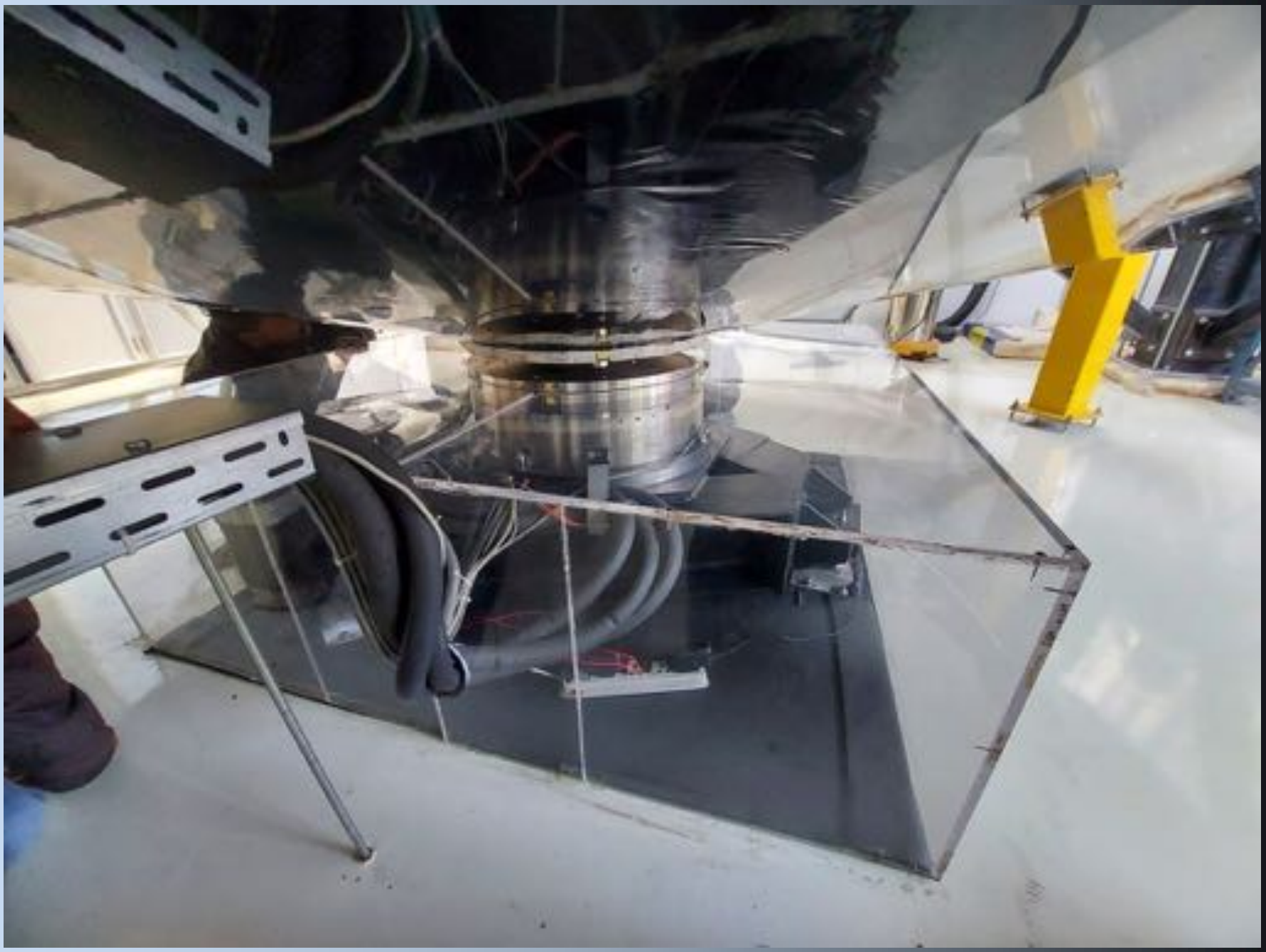
4 मीटर
अंतर्राष्ट्रीय तरल दर्पण टेलीस्कोप
4 meter
International Liquid Mirror Telescope

View of the ILMT compressor, control and main ILMT buildings

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

ILMT UPS, June 2016

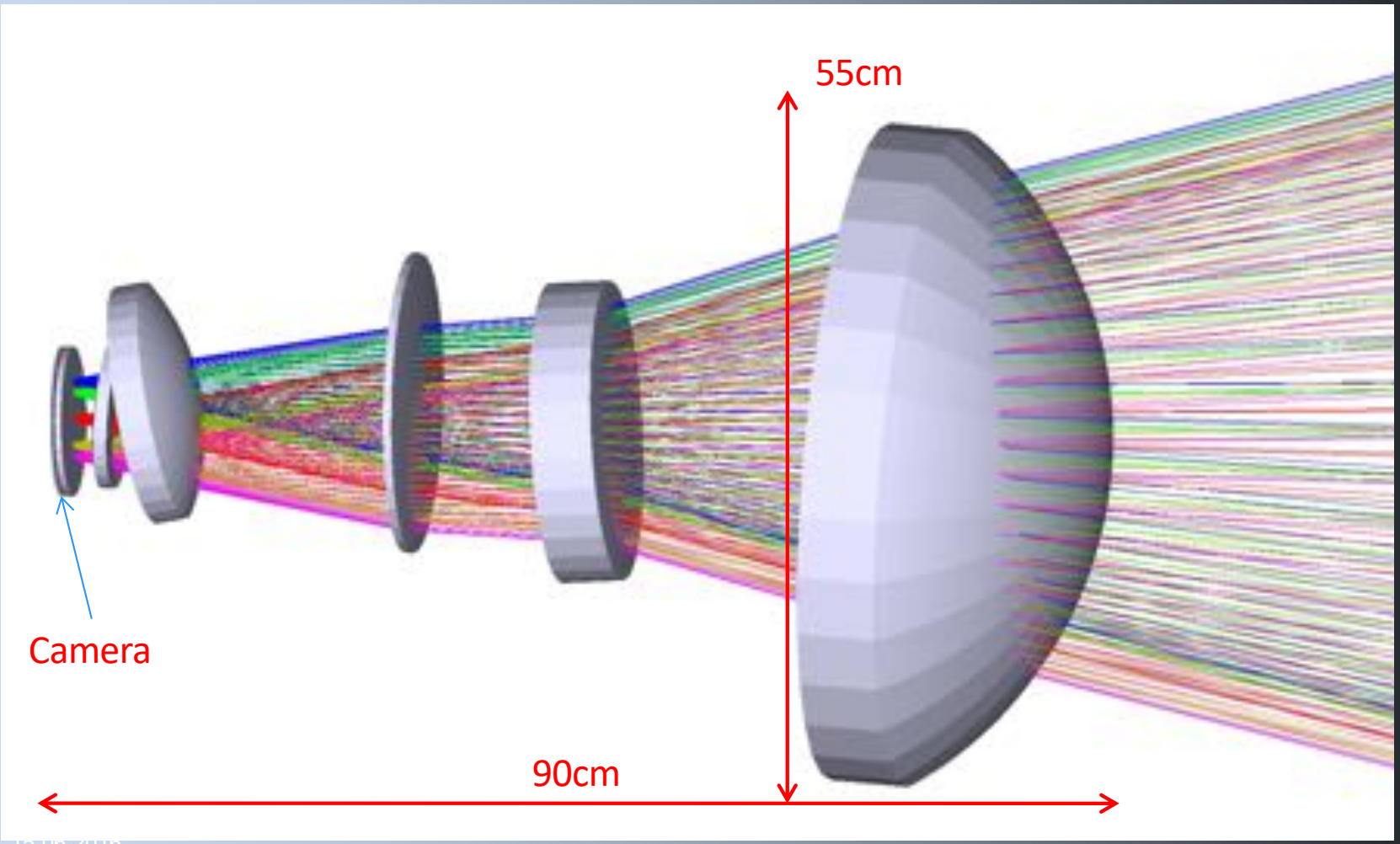
The two compressors and their associated air tanks

Pneumatic modules located near the 2 air compressors

Pneumatic modules located inside the ILMT control room

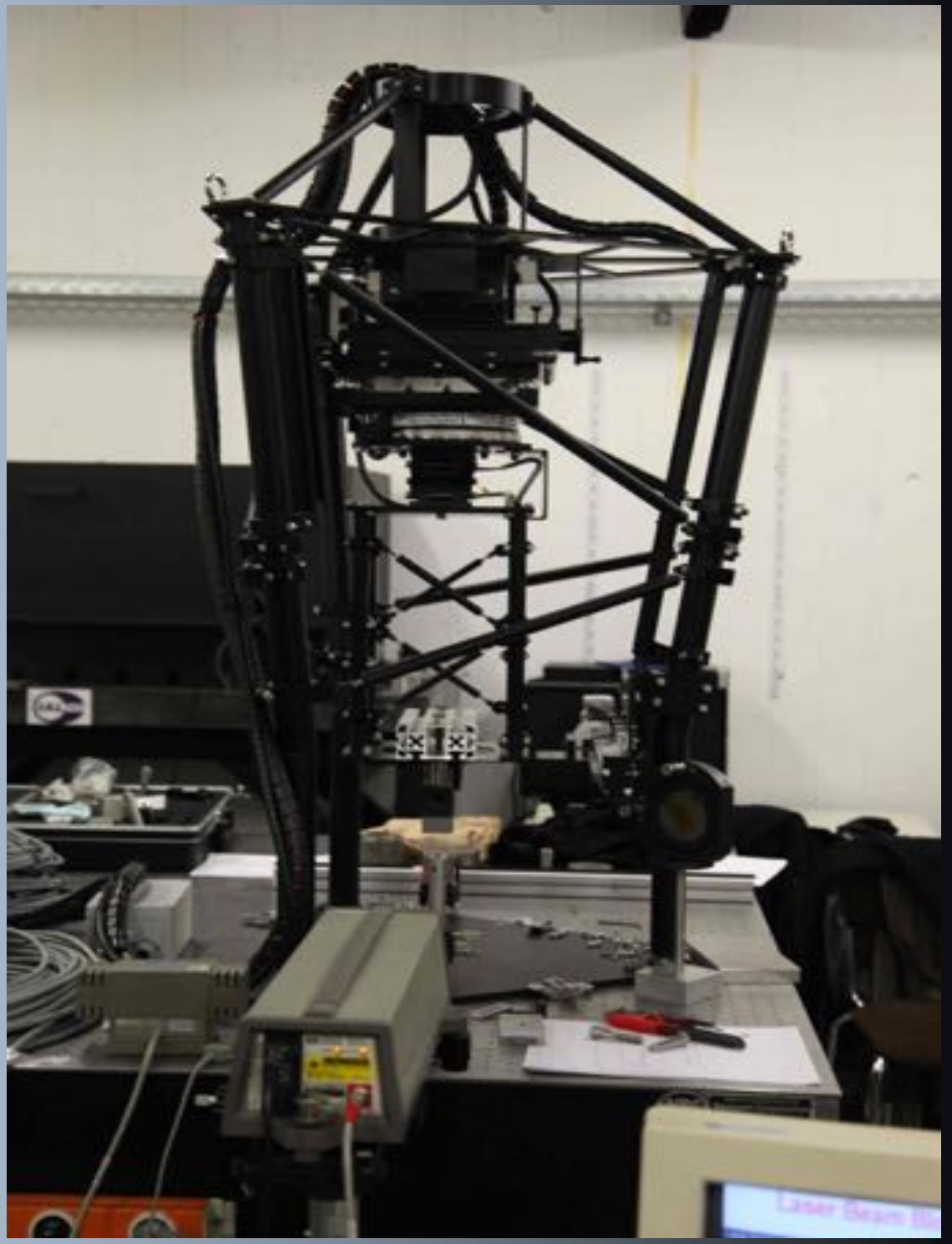
Fish eye view of the main ILMT structure and of the optical corrector.

The TDI optical corrector



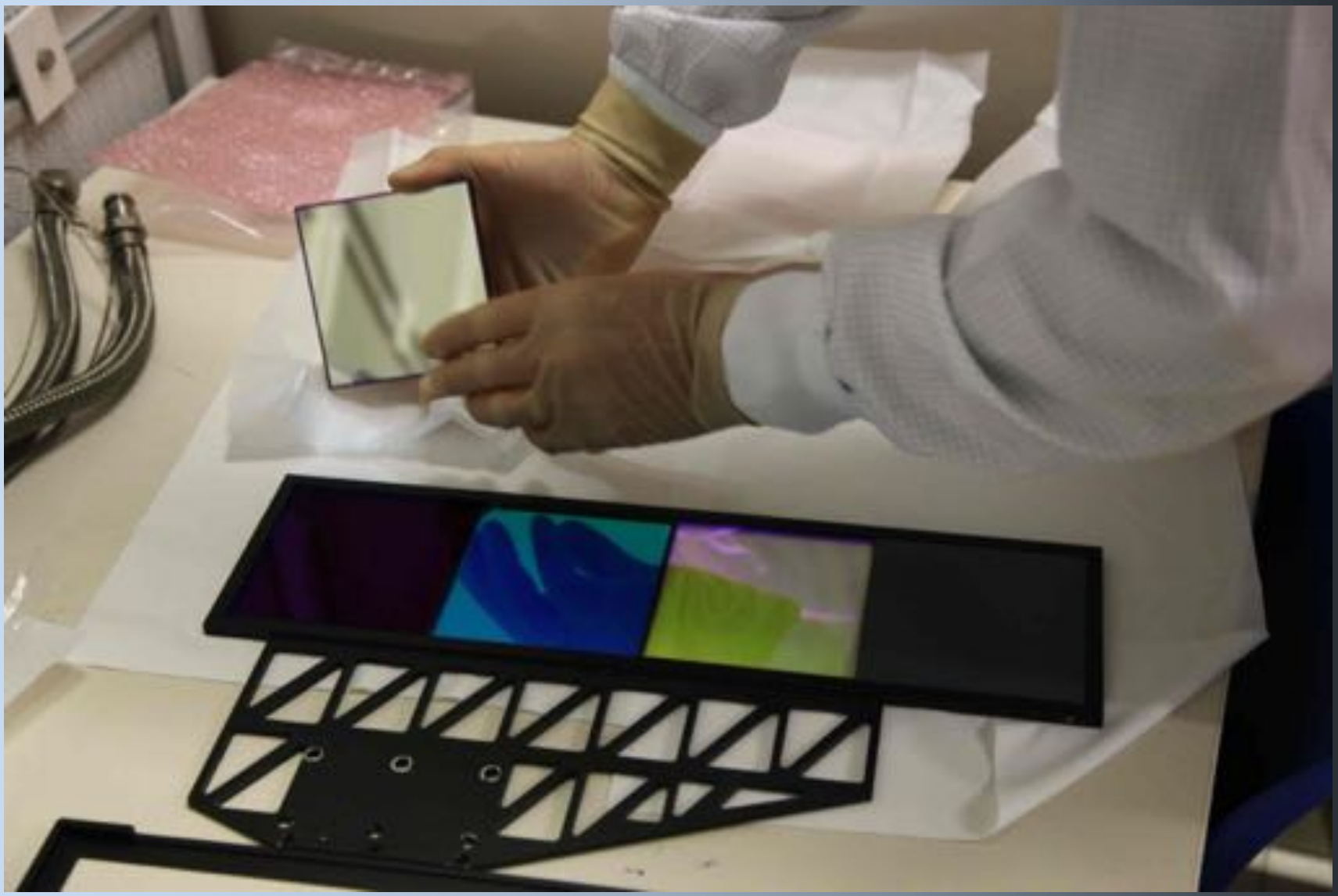
Cleaning of the L1 lens

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

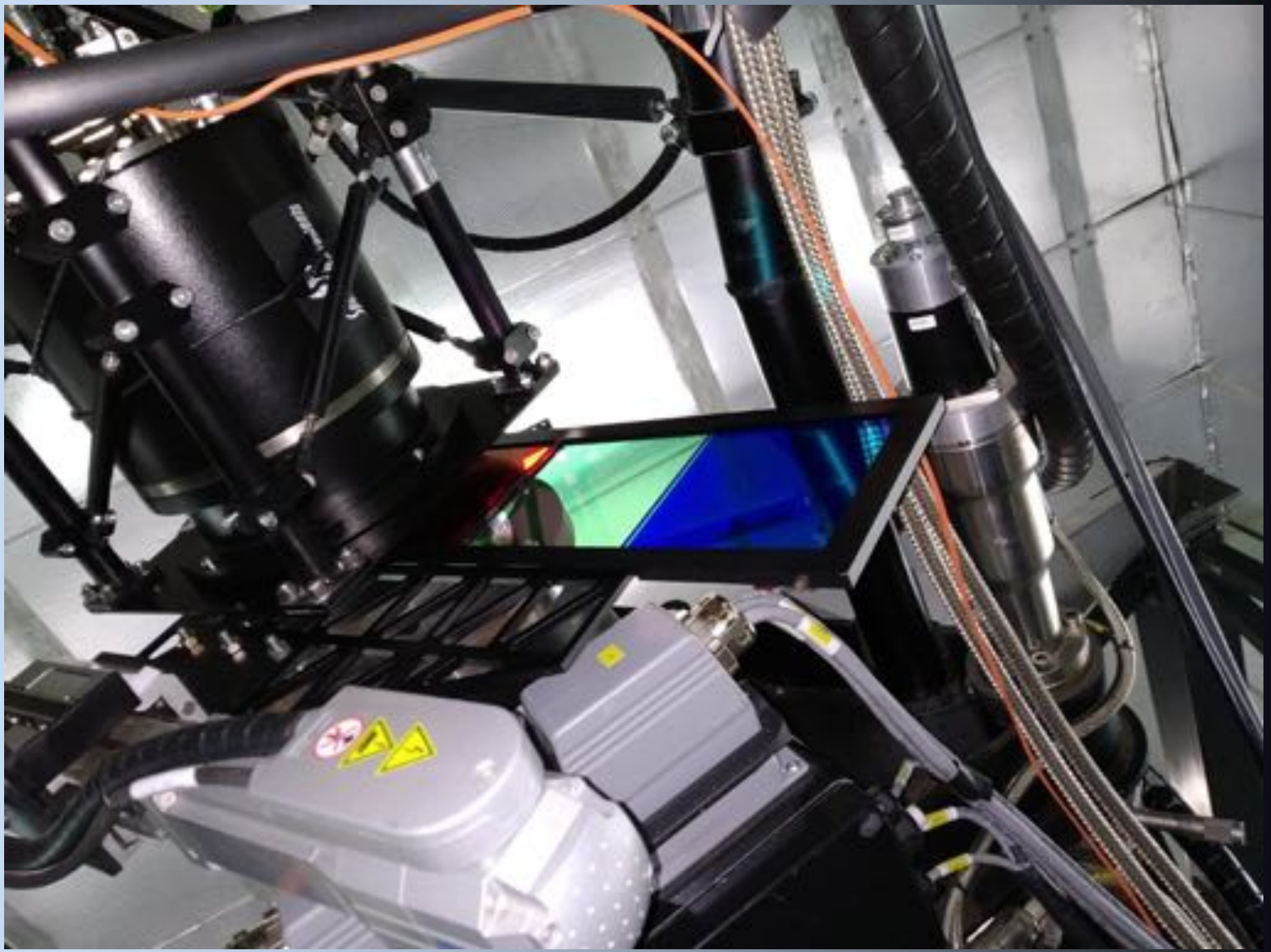


Camera CCD 4Kx4K (Spectral Instruments) with connections for the cooling and an optical fiber for transmitting the data to a computer located in the ILMT control room

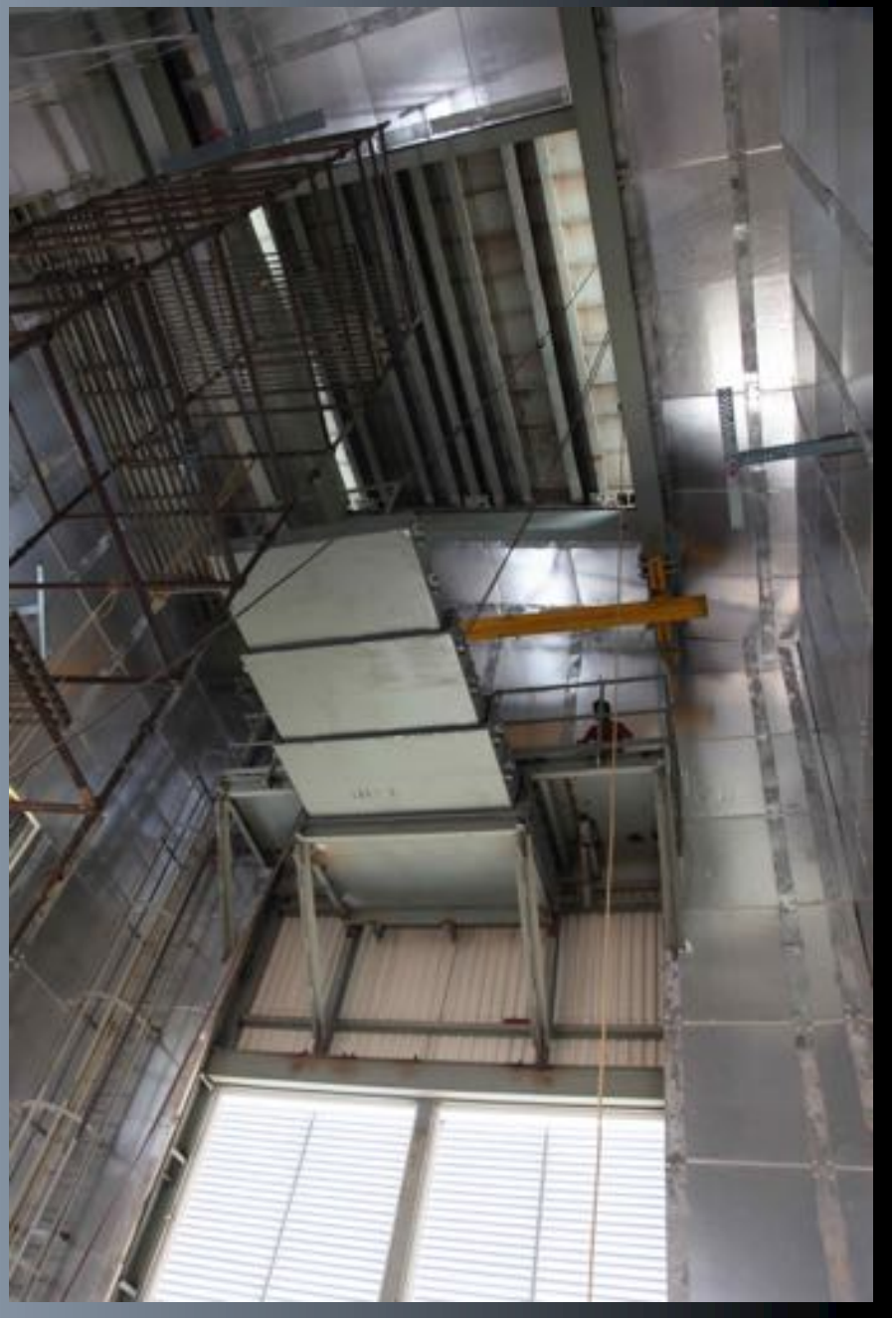
DC power supply for the CCD camera and cooling compressor (PT-30 gas)

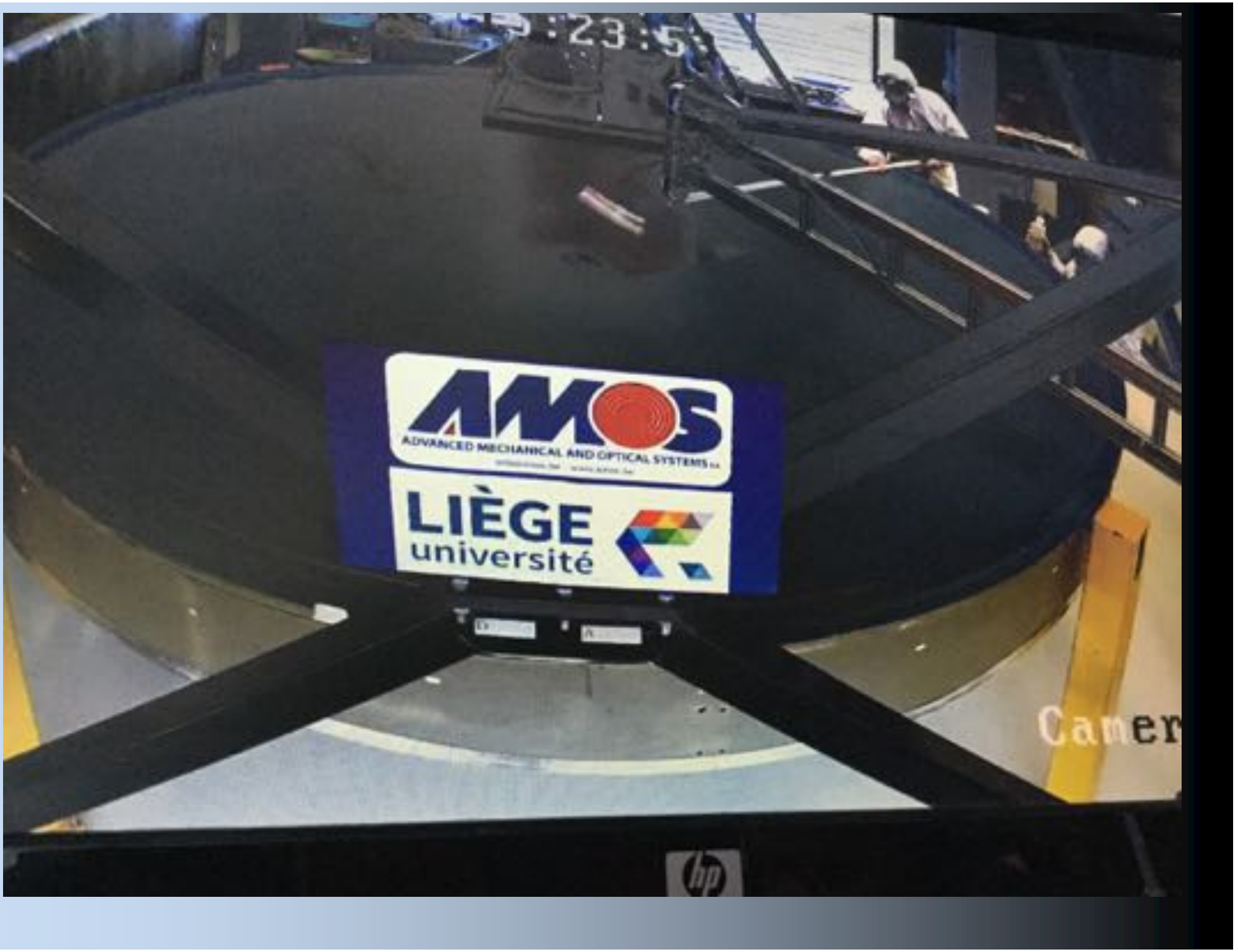


Support of the filter tray (Sloan g', r', i'). Tests at the Liège Space Center (ULiège, 18 November 2013)



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

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LIÈGE
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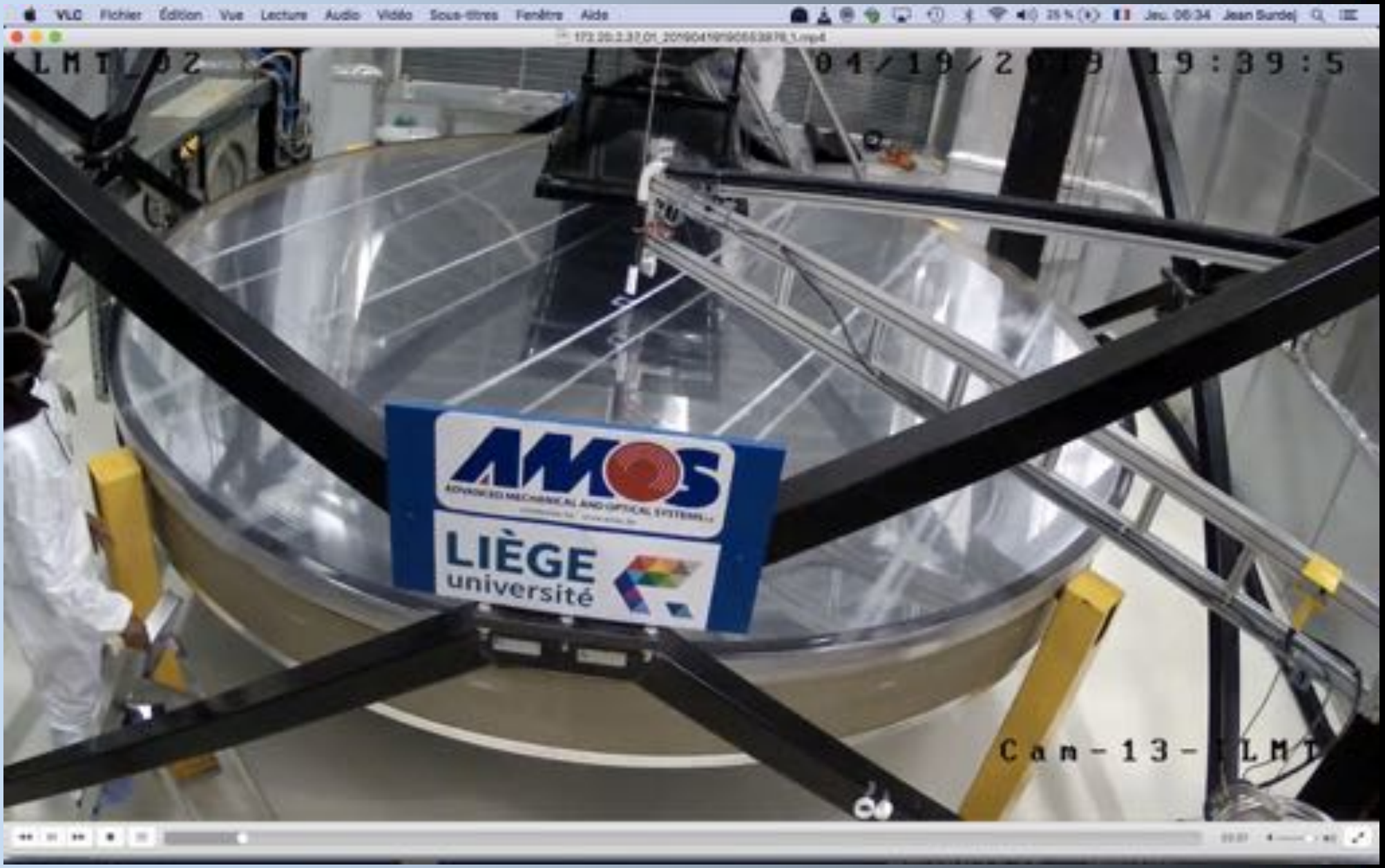
The ILMT mirror filled with mercury and covered with mylar

Aerial top view of the ILMT


VLC Fichier Édition Vue Lecture Audio Vidéo Sous-titres Fenêtre Aide
Jeu. 06:34 Jean Surdej
LMT 02
01/10/2 8 19:39:5
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Can-13-LMT


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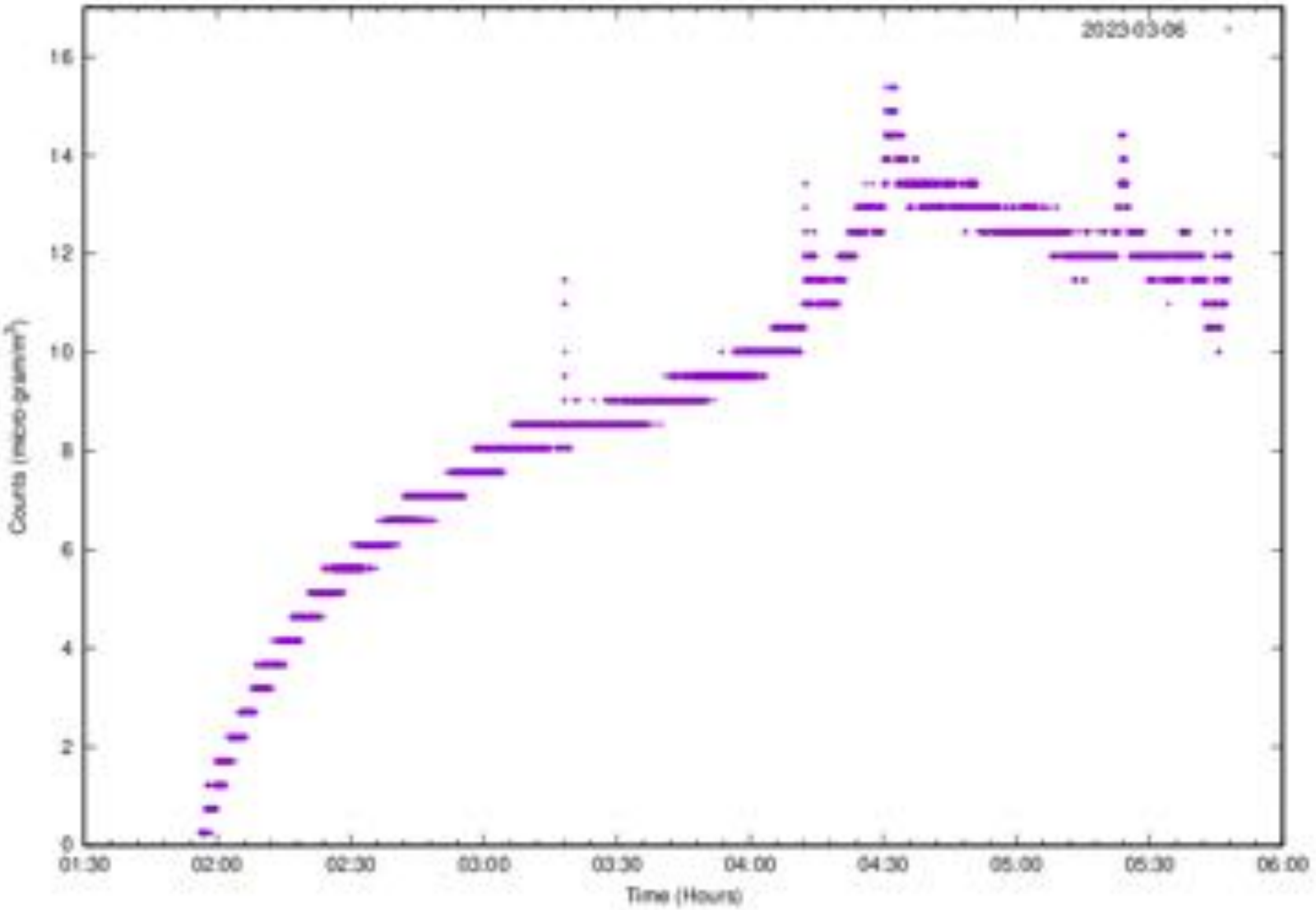
PUSH

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



Mercury vapor counts plot


ILMT2

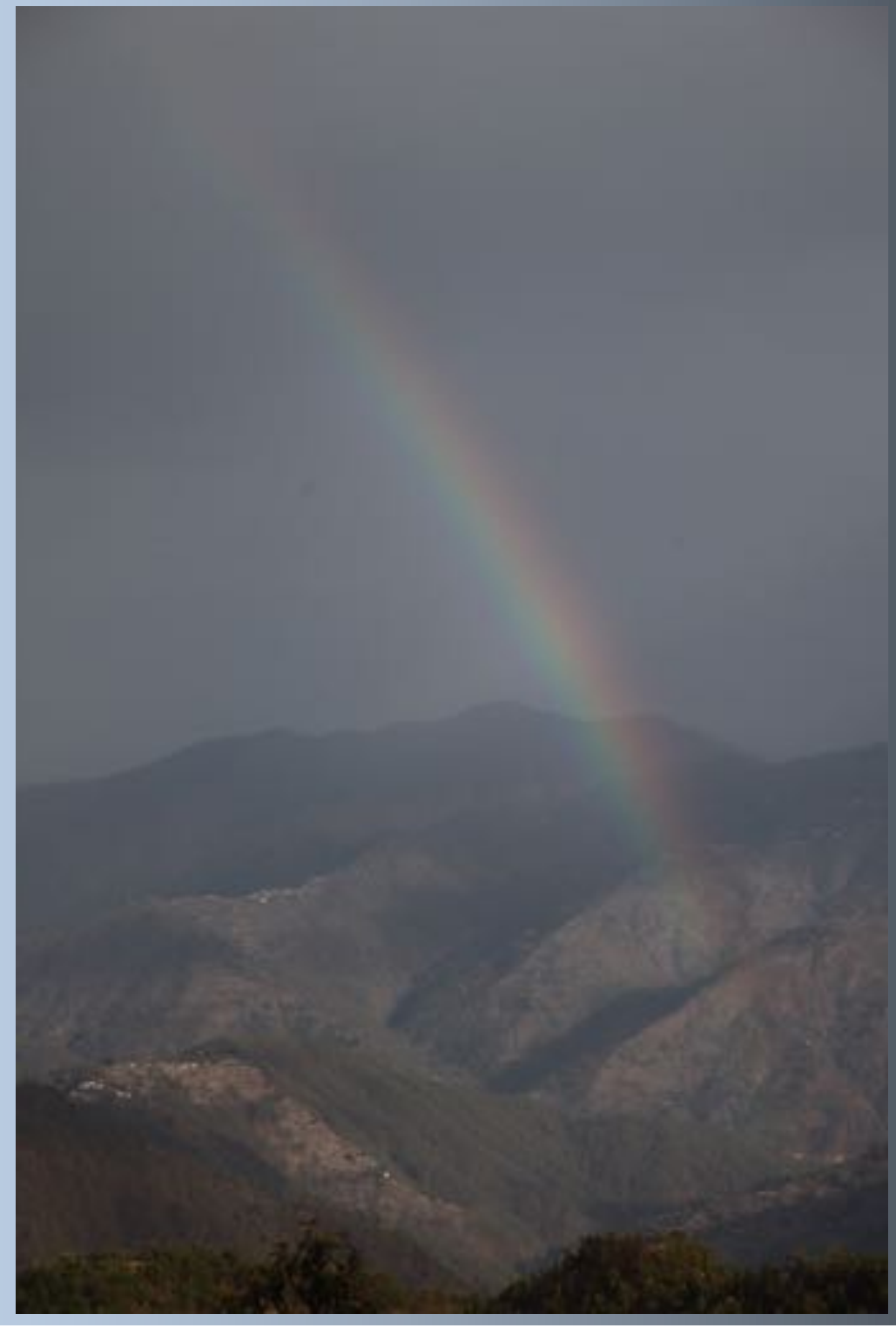

ILMT.


ILMT3


ILMT4

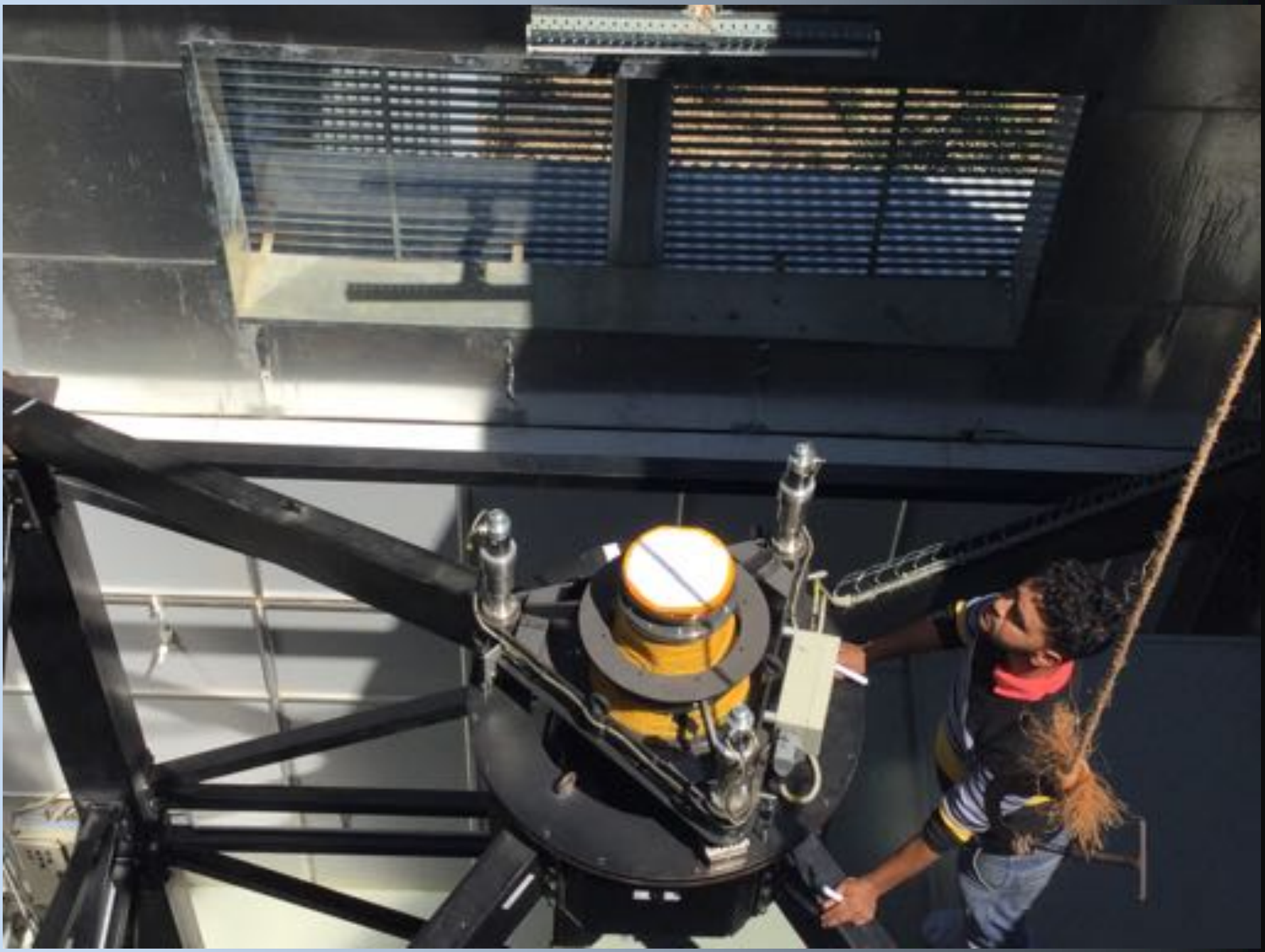

ILMT5

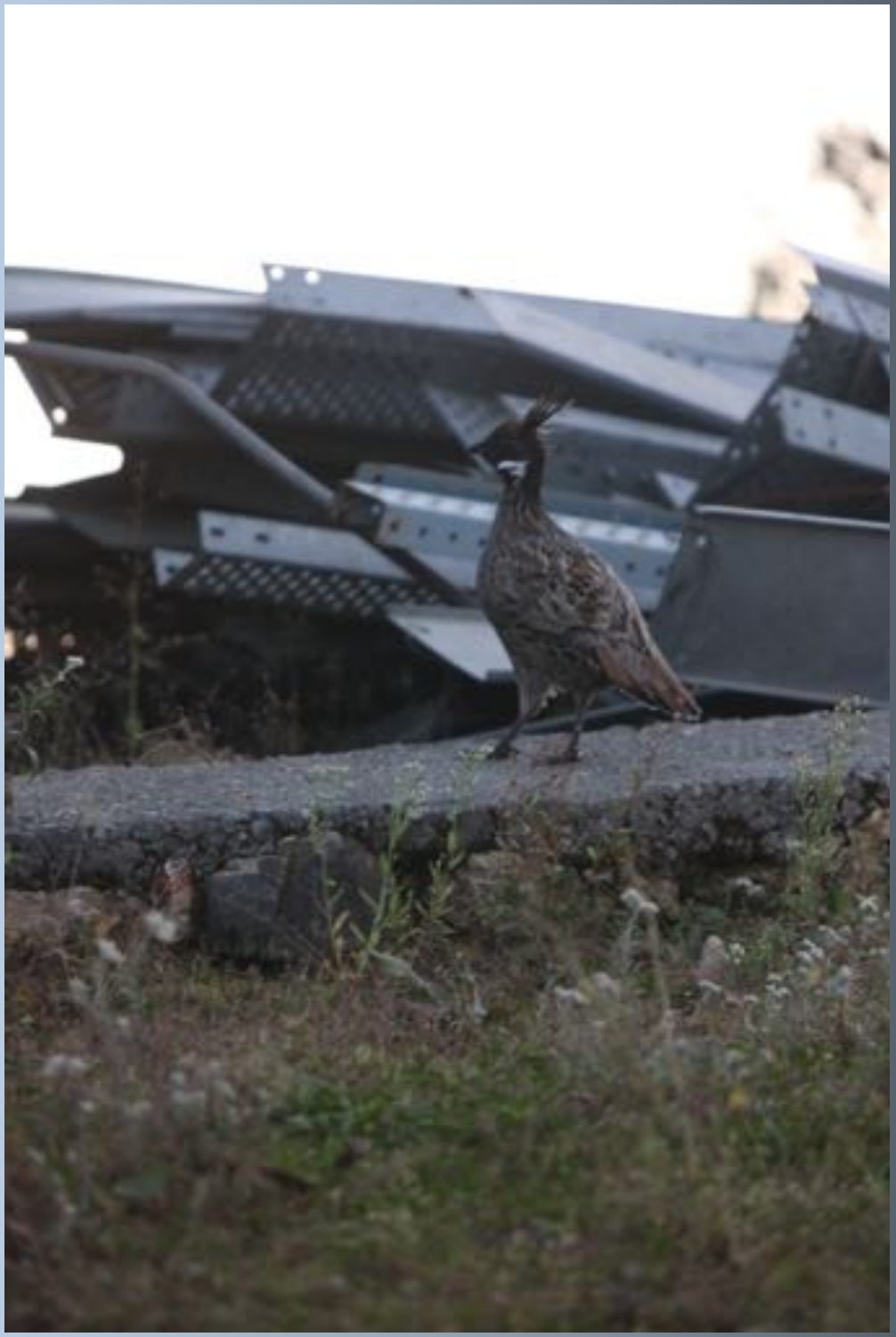
Aerial view of the domes of the 4m ILMT, 3.6m DOT and of the 1.3m DFOT

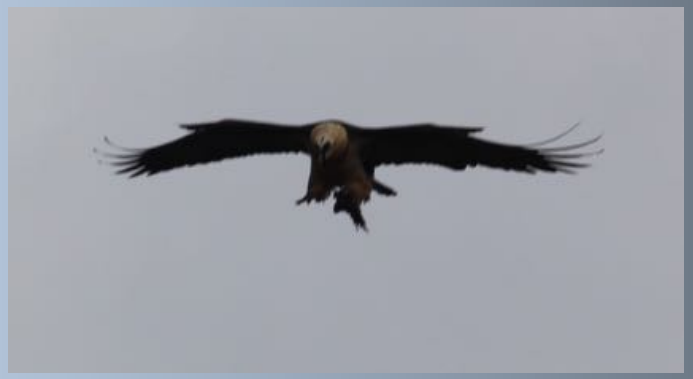


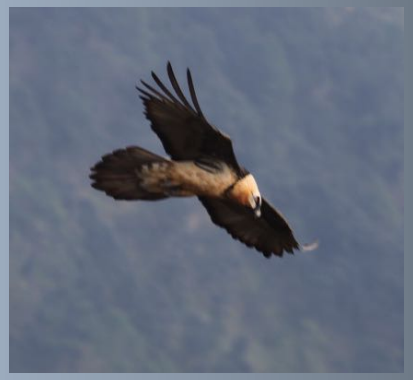

Devasthal (ARIES)
Eastern view from ILMT
28 Avril 2022
(19h57min-21h48min)

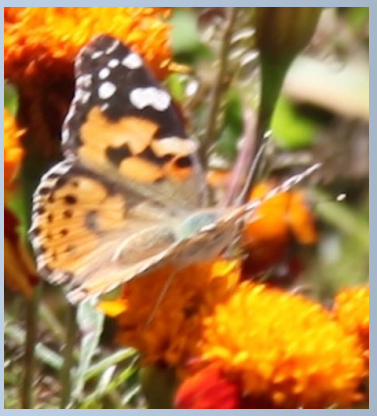
North-South alignment of the optical corrector

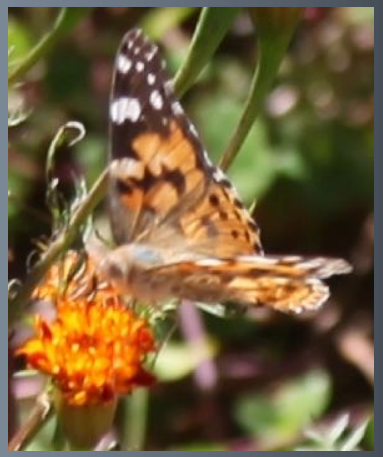
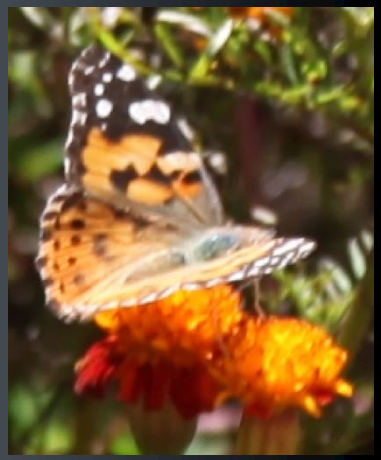


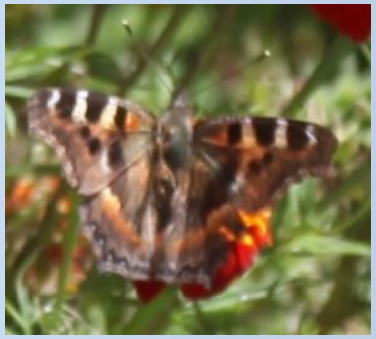
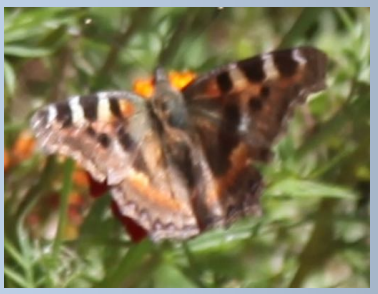
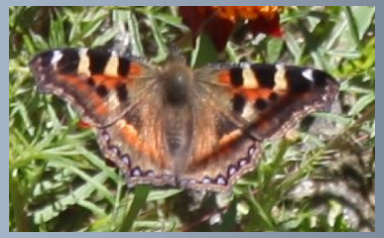


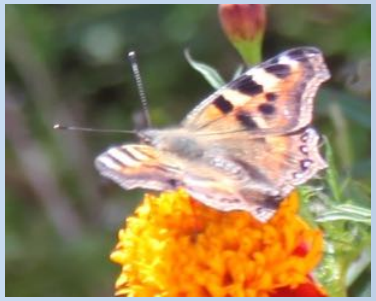
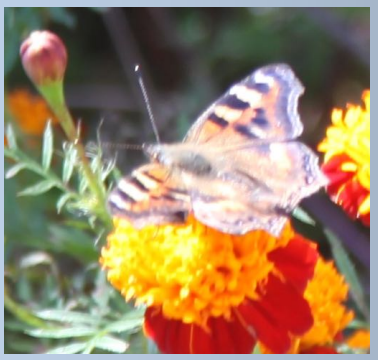
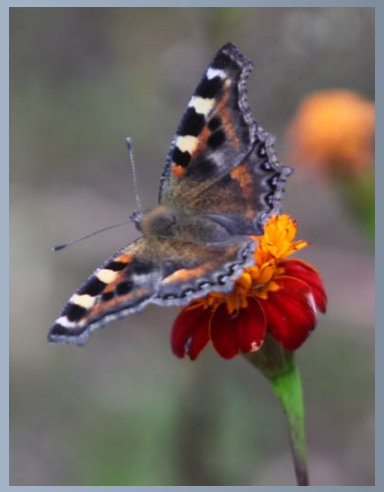
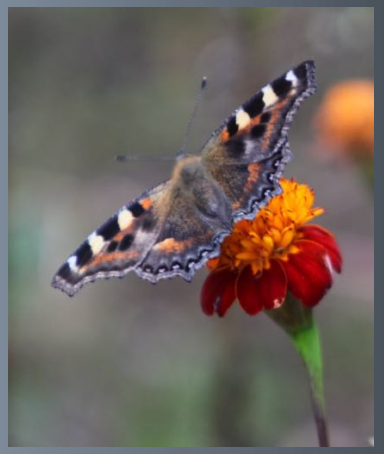
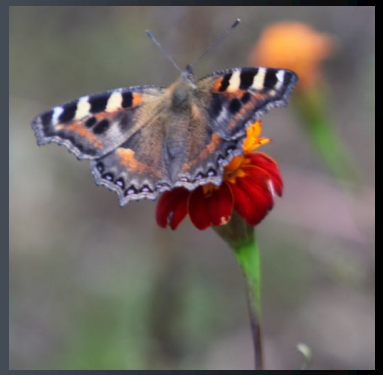
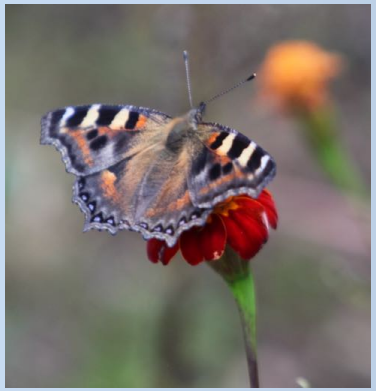




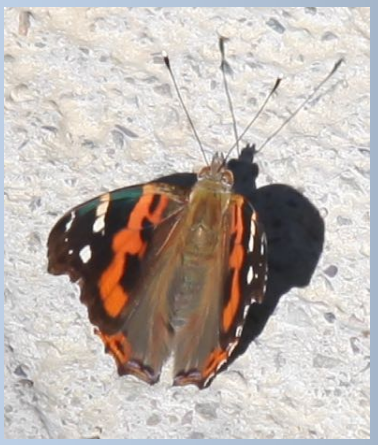
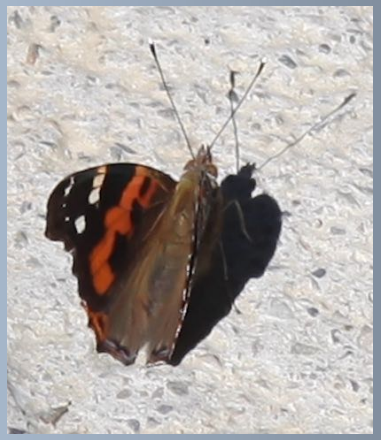



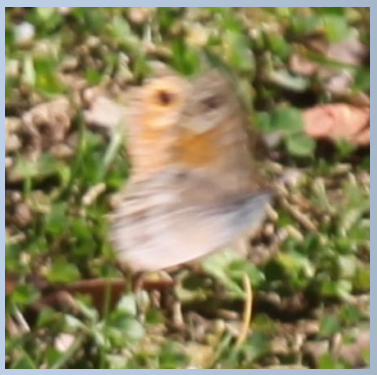



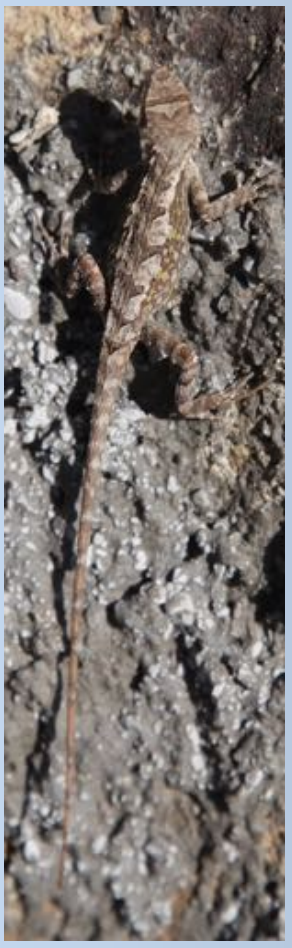








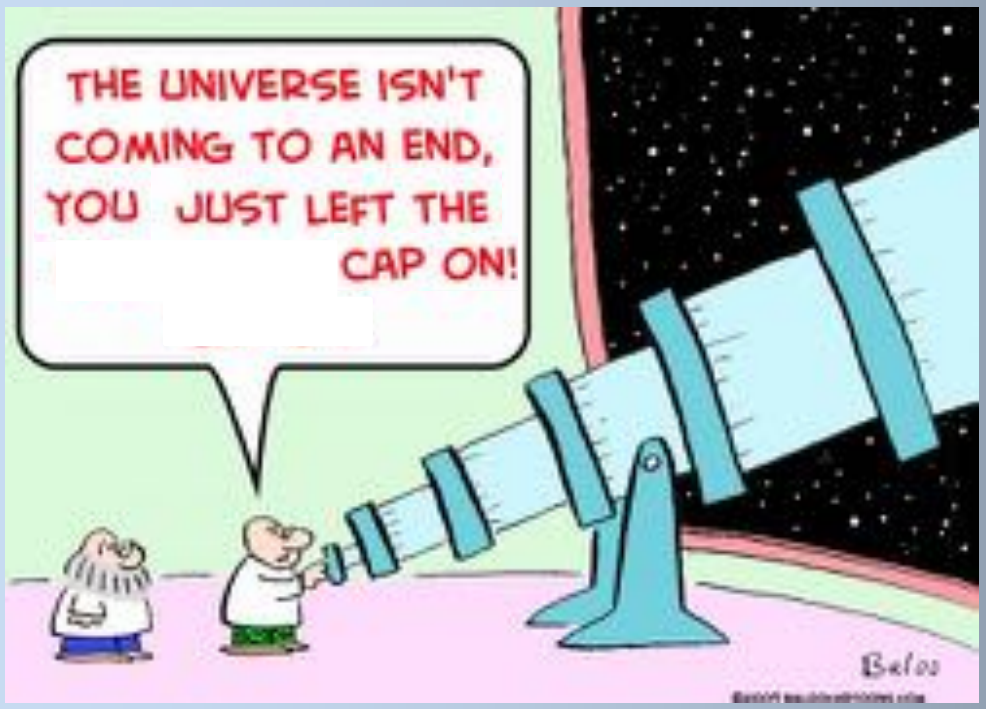


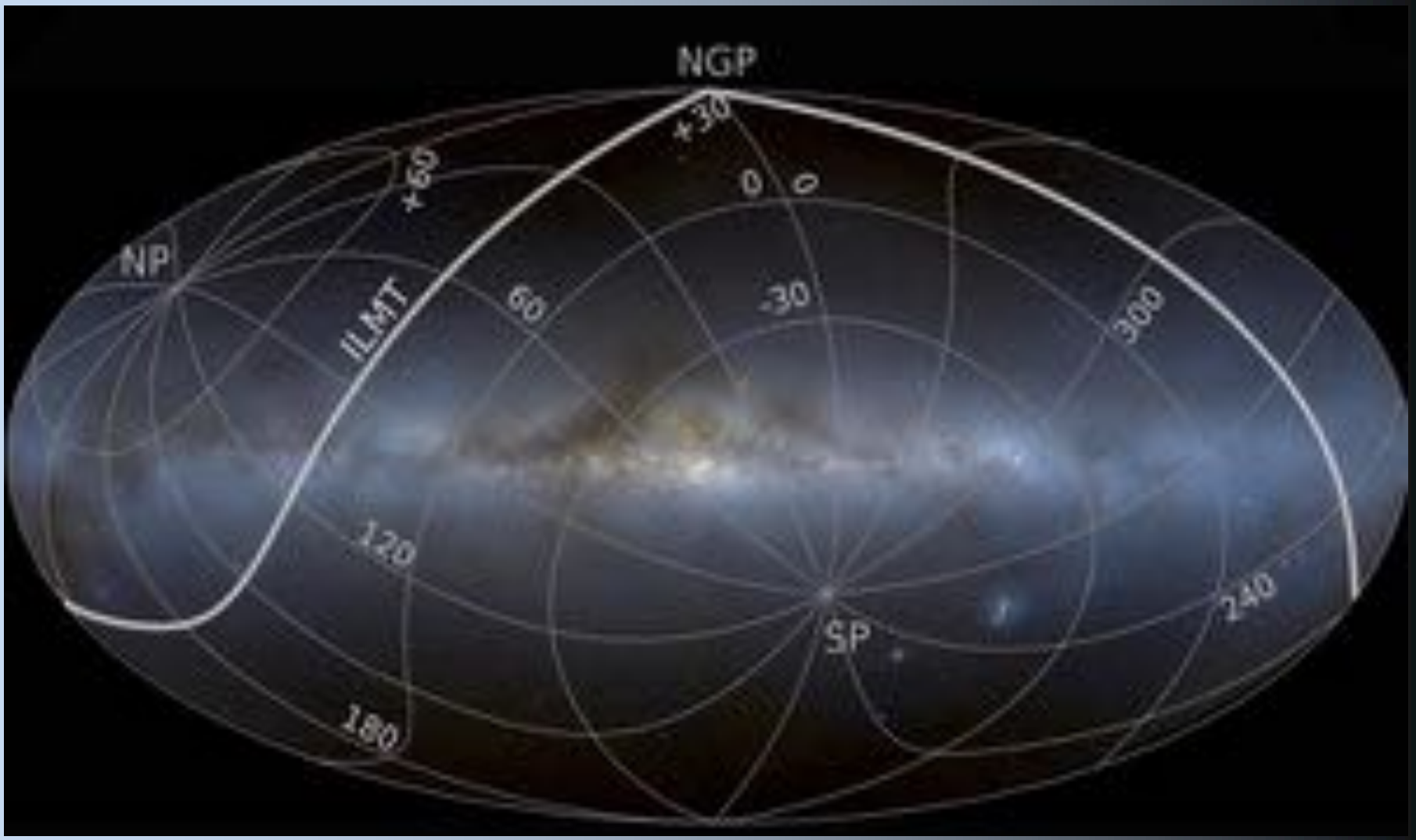
X. Science with the ILMT

Science with liquid mirror telescopes

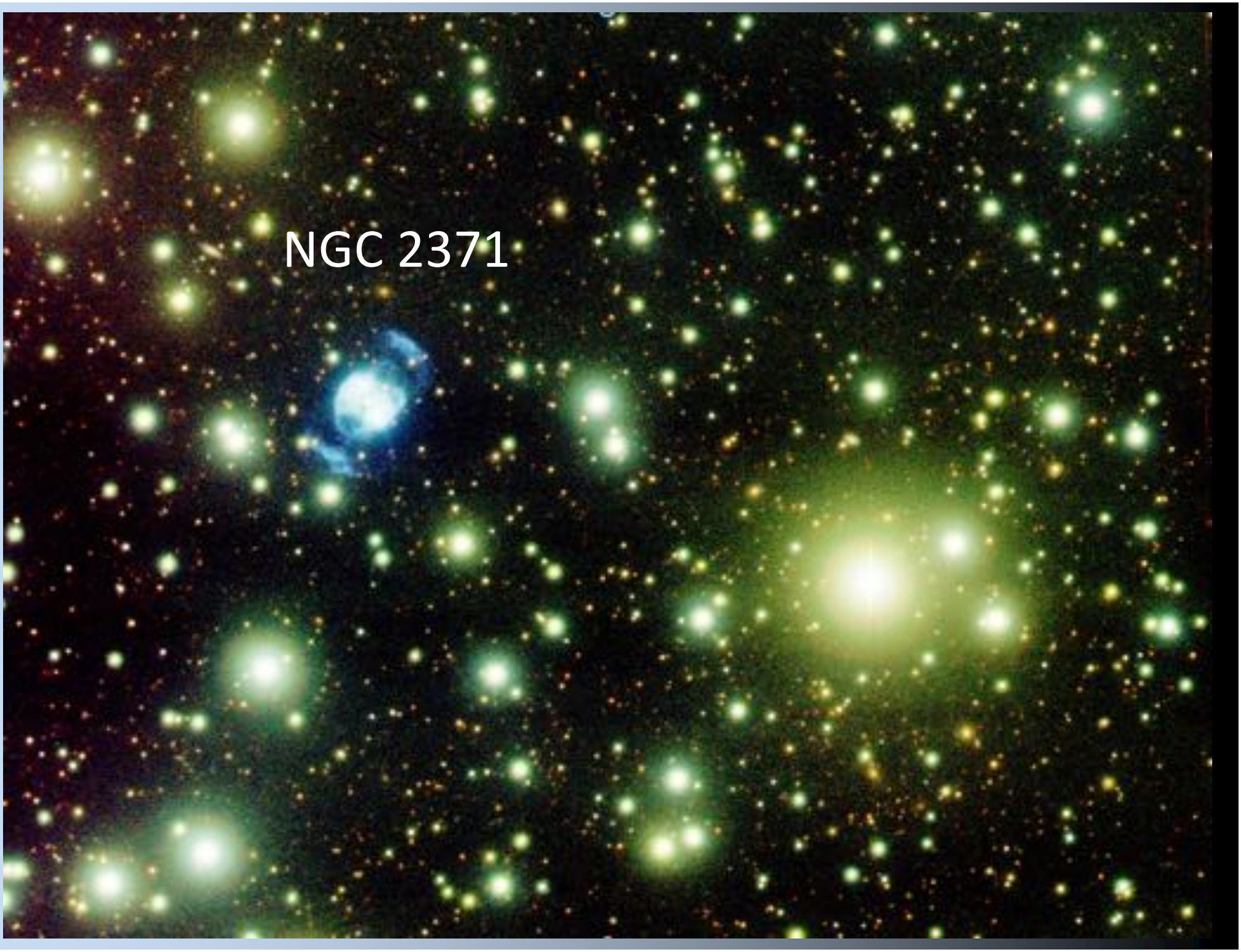
« Without astronomy, man ignores the place he occupies ».

Aristotle

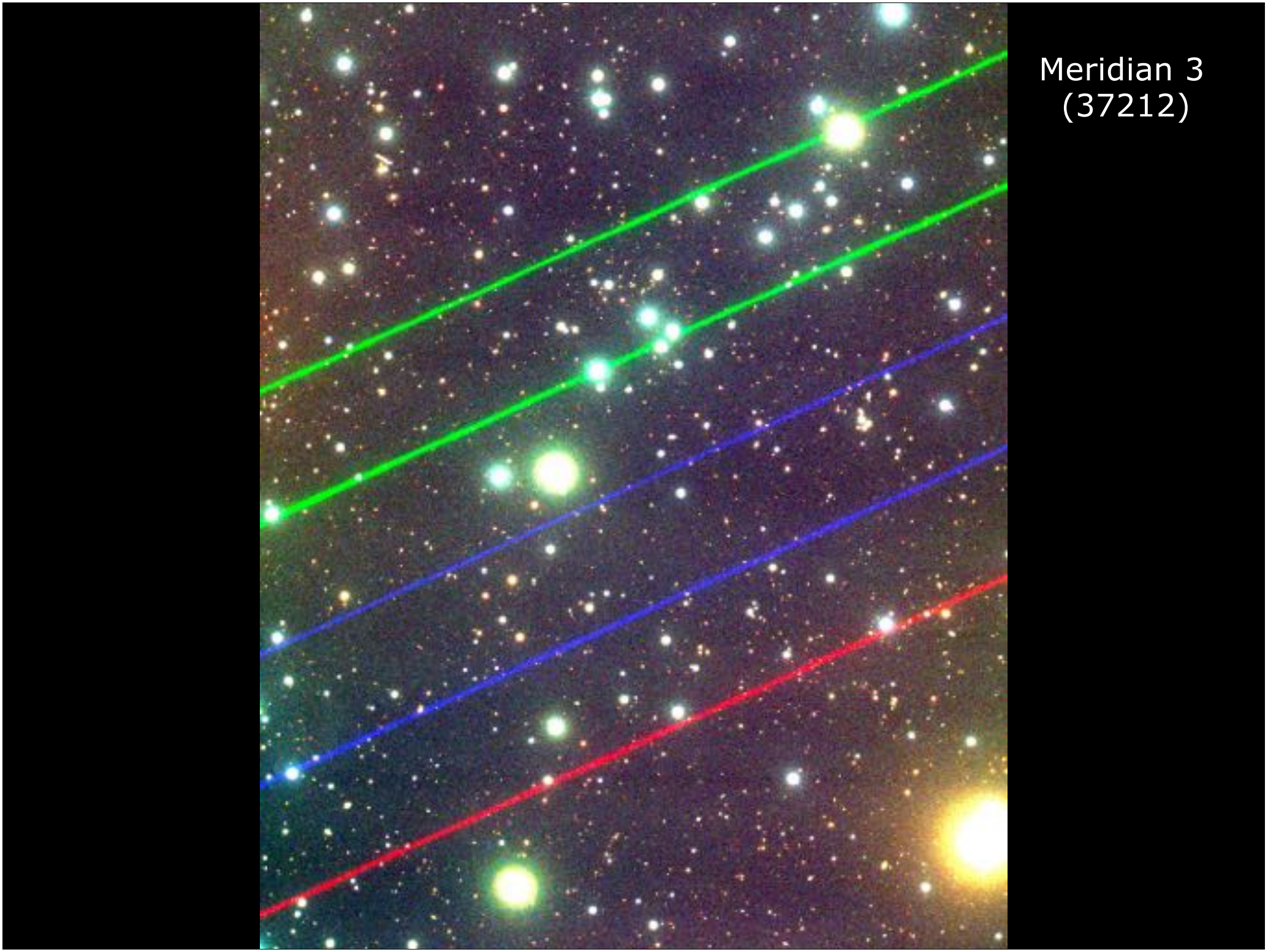



NGP
+30
+60
0
0
NP
ILMT
60
30
300
120
240
SP
180

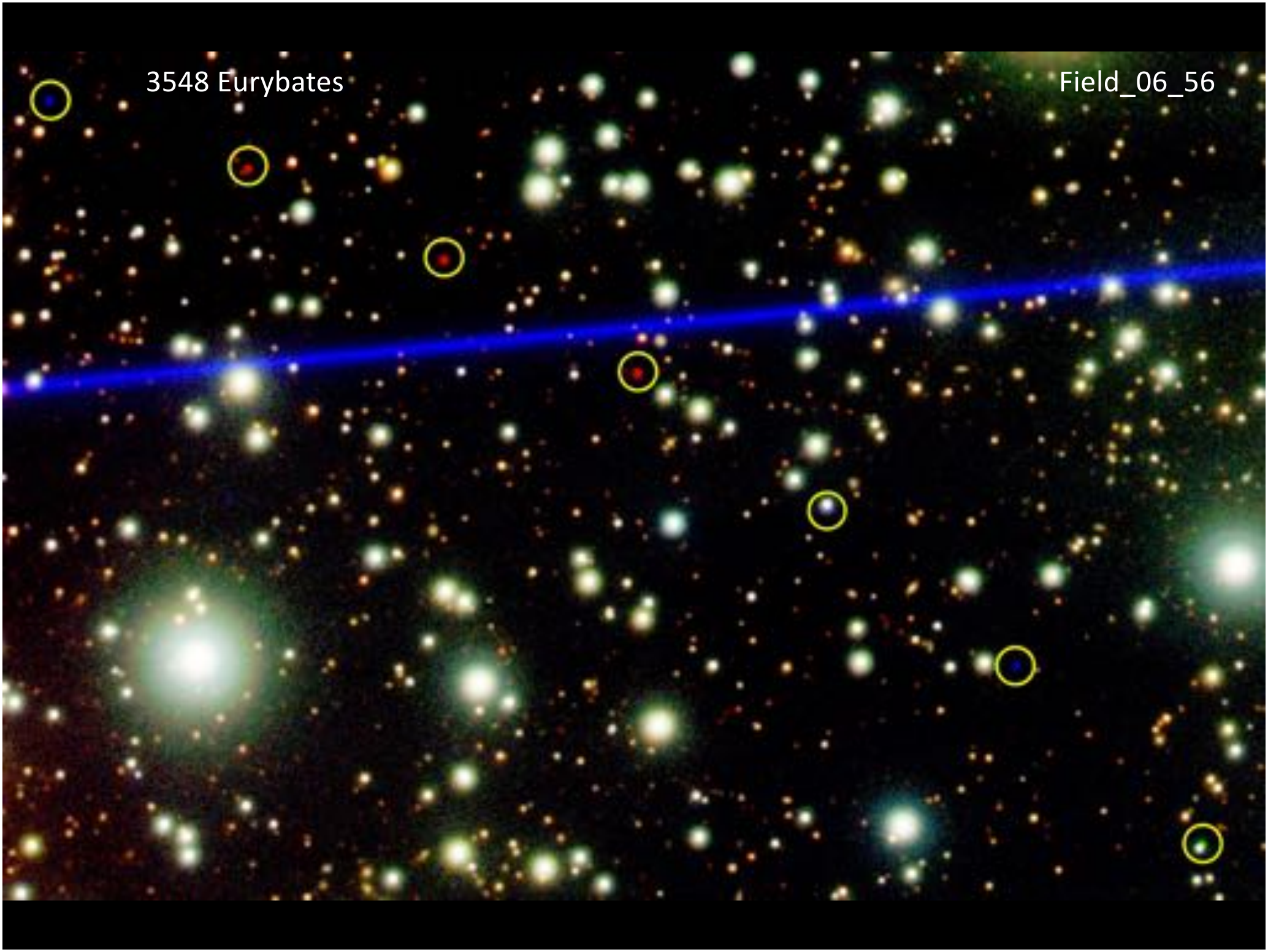
Open star cluster NGC6834 in the Milky Way (ILMT, April 2022)

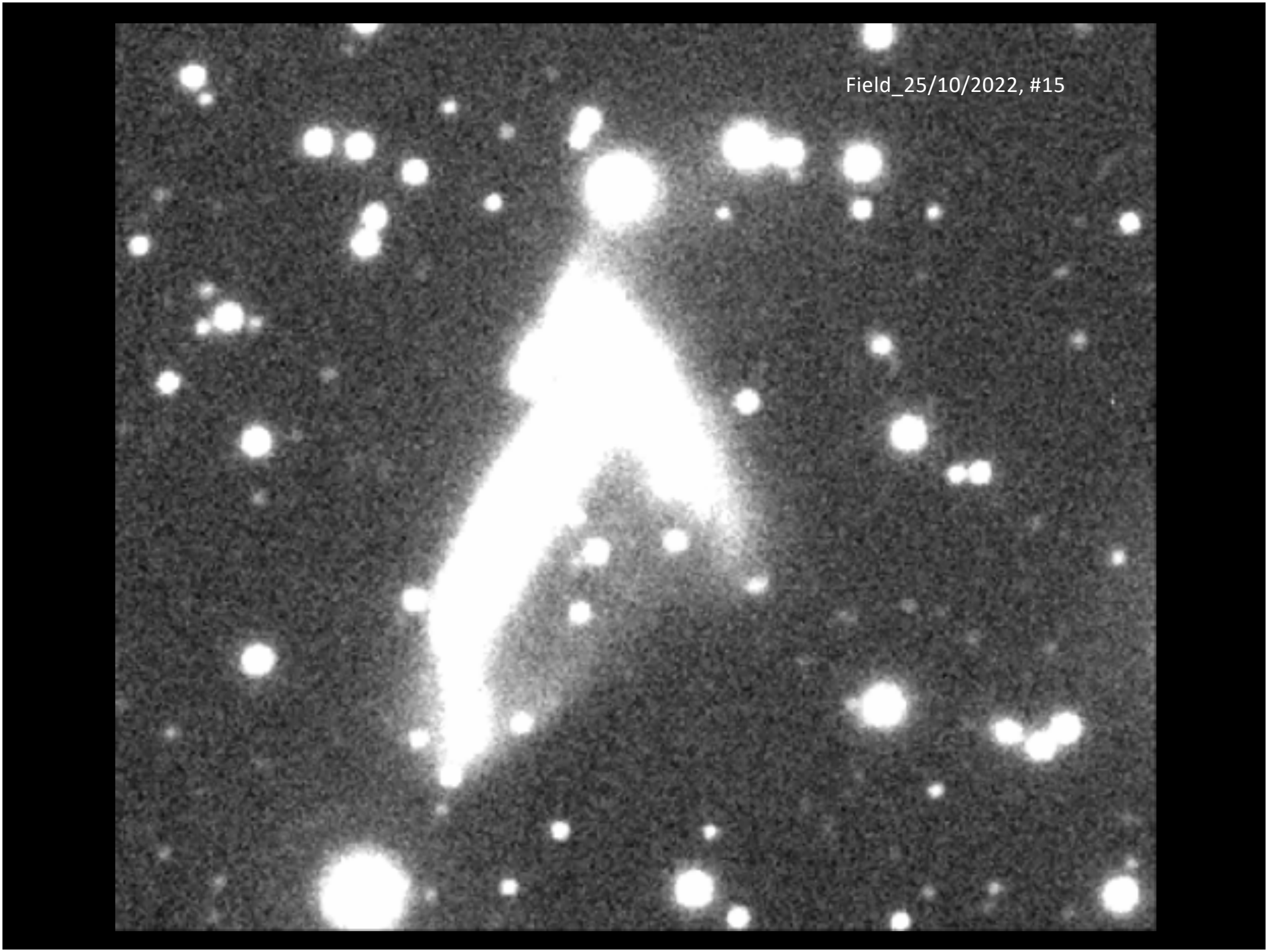

NGC 2371

Field_04_50 B A
D C


Meridian 3
(37212)


Field 23_44_2ndh


3548 Eurybates
Field_06_56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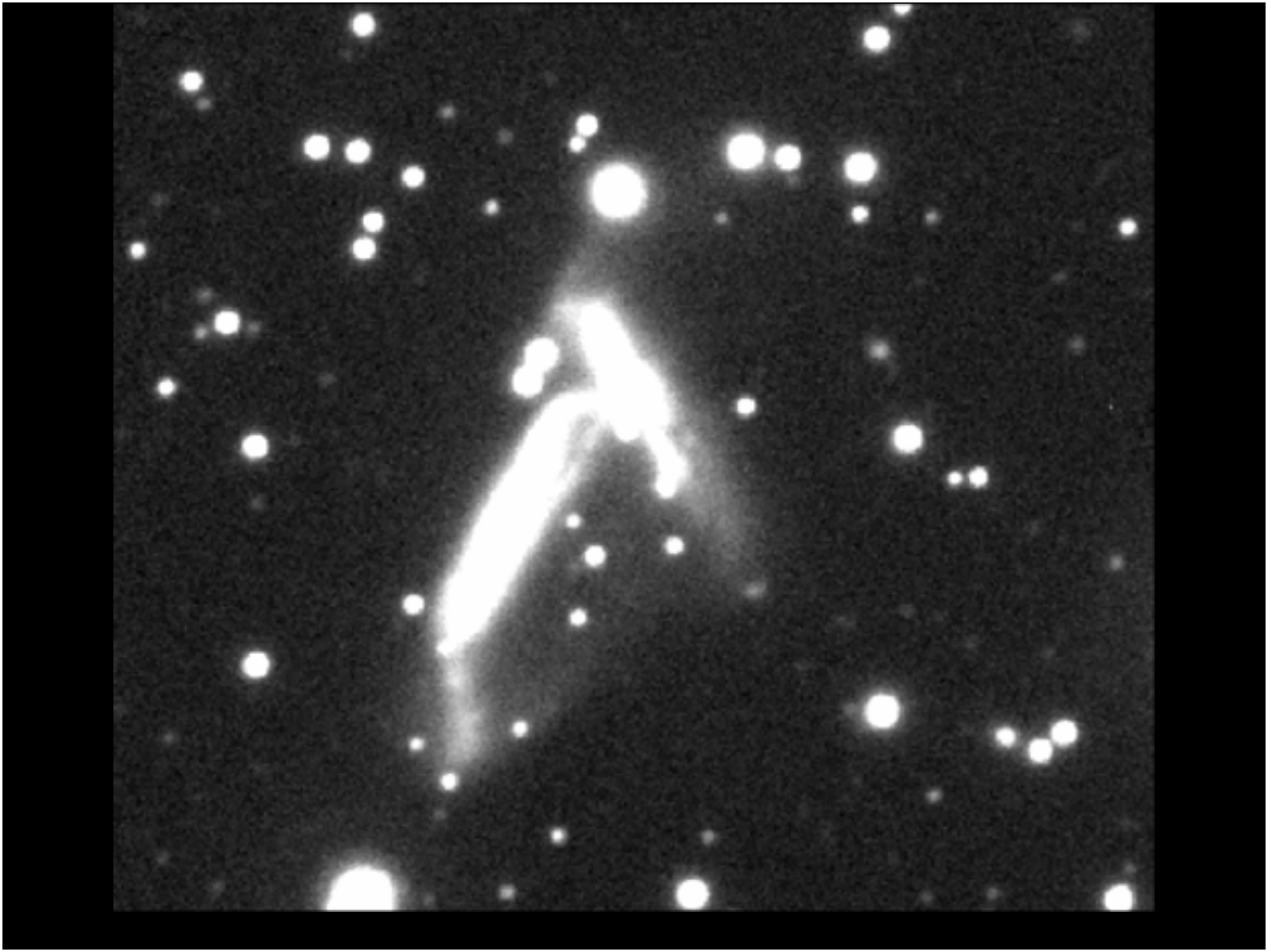

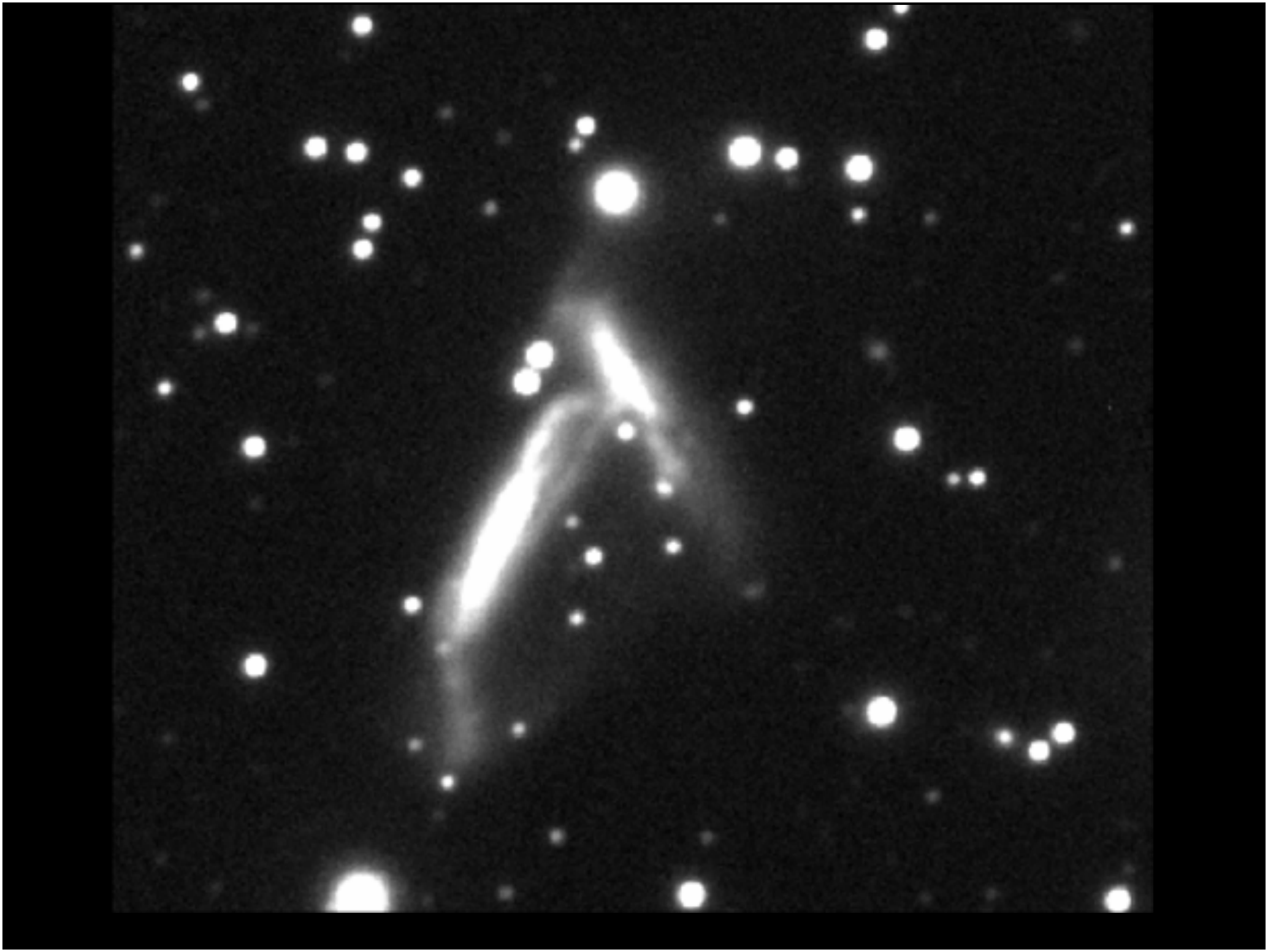

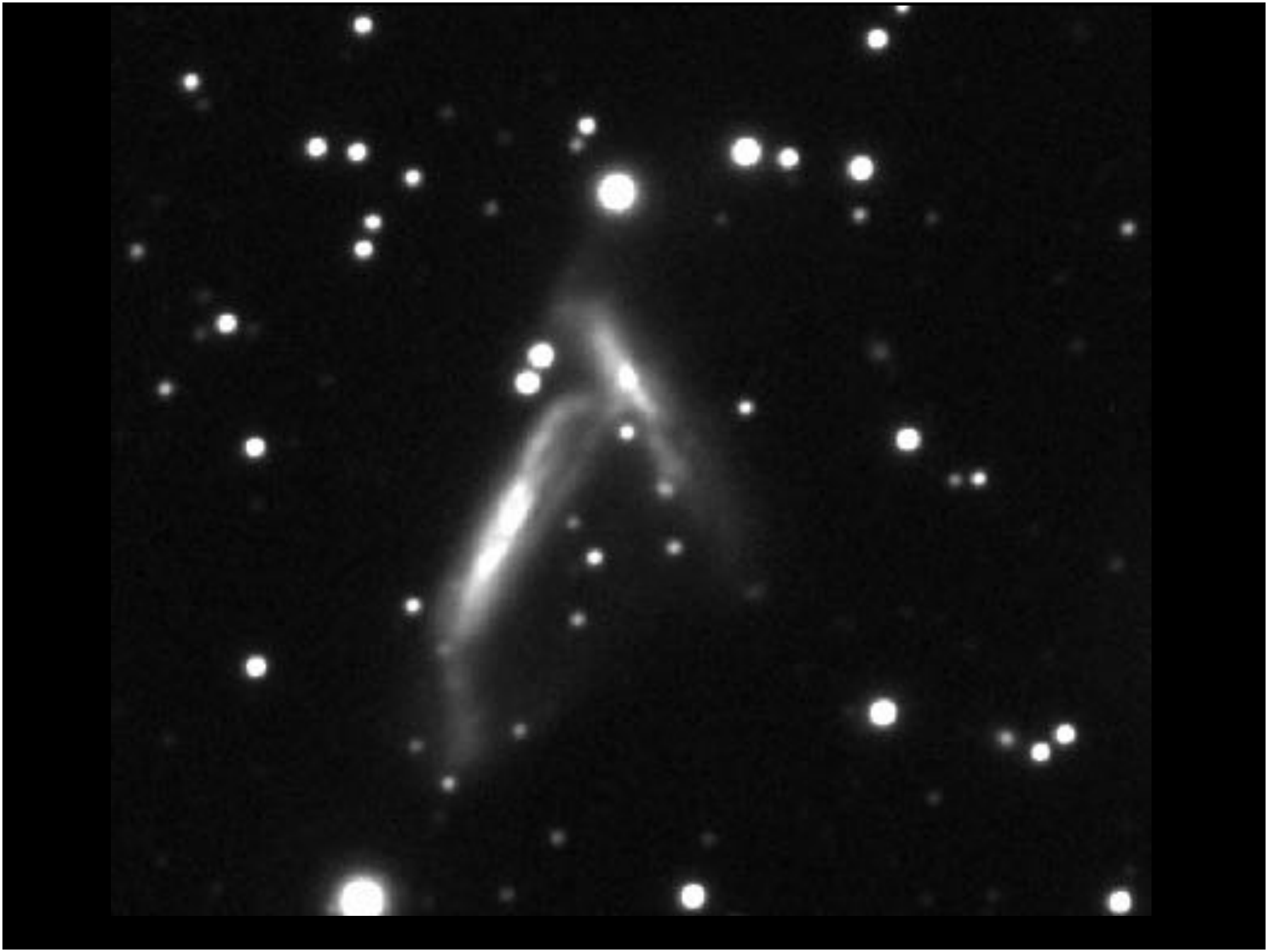

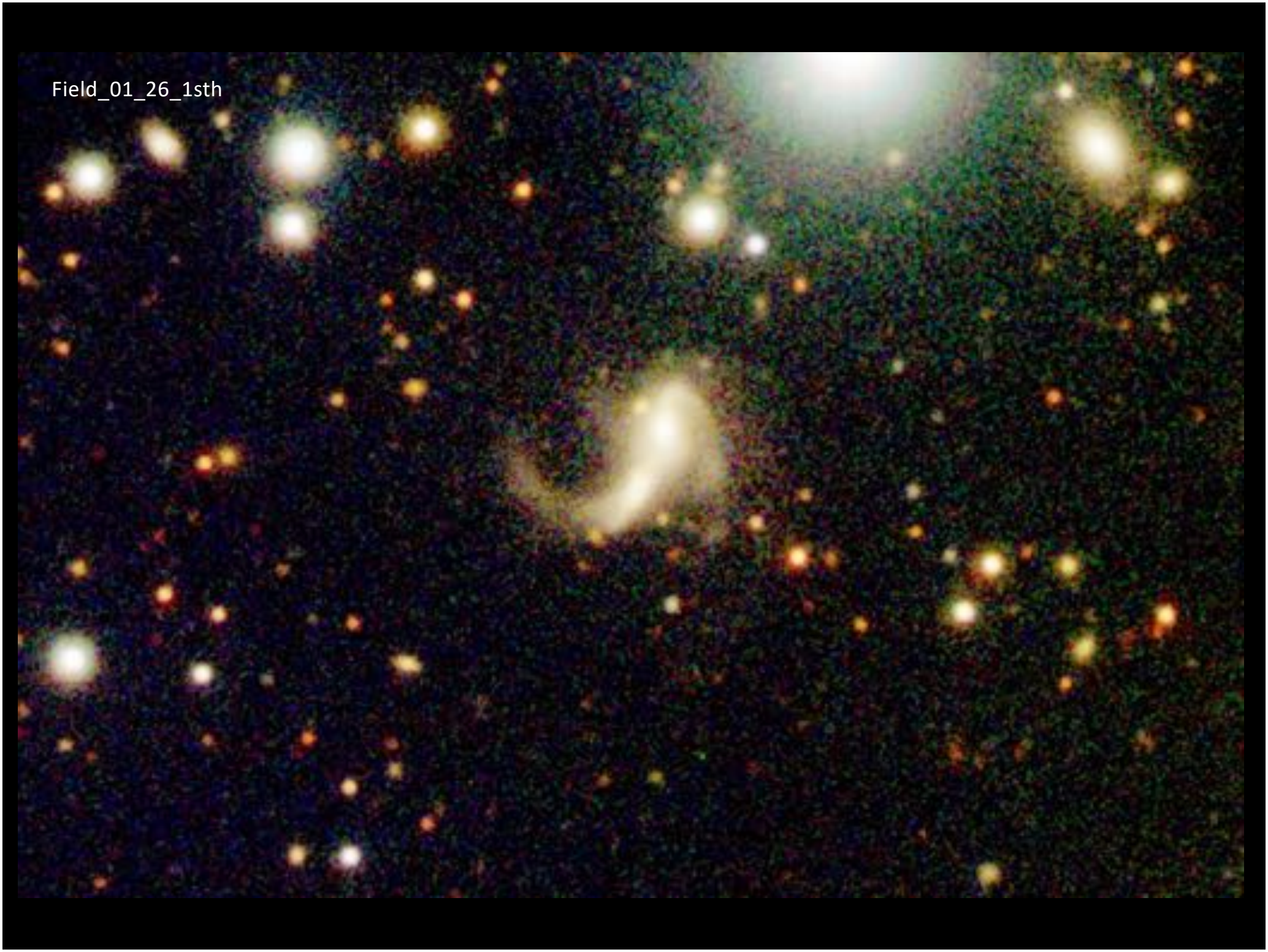
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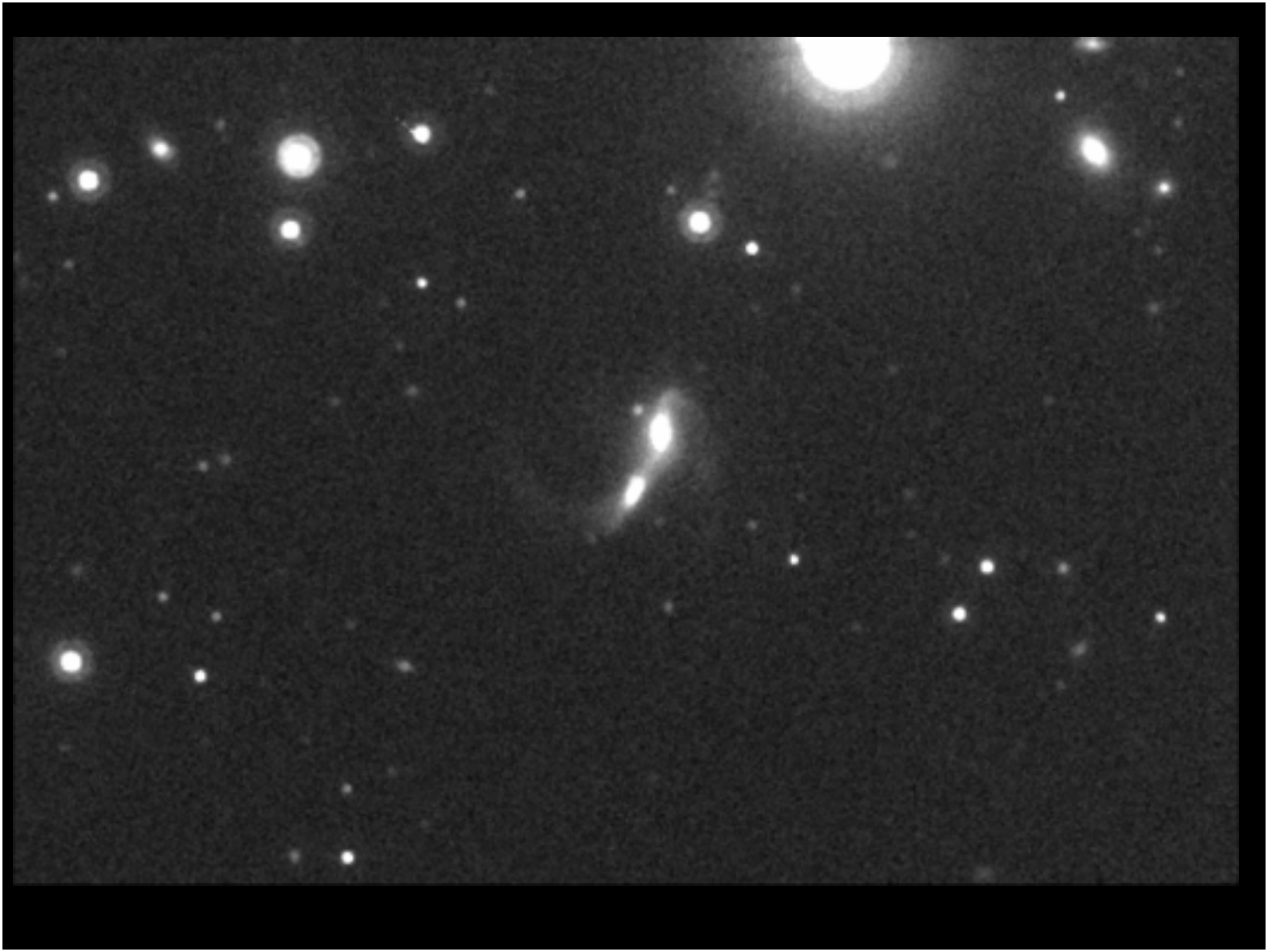
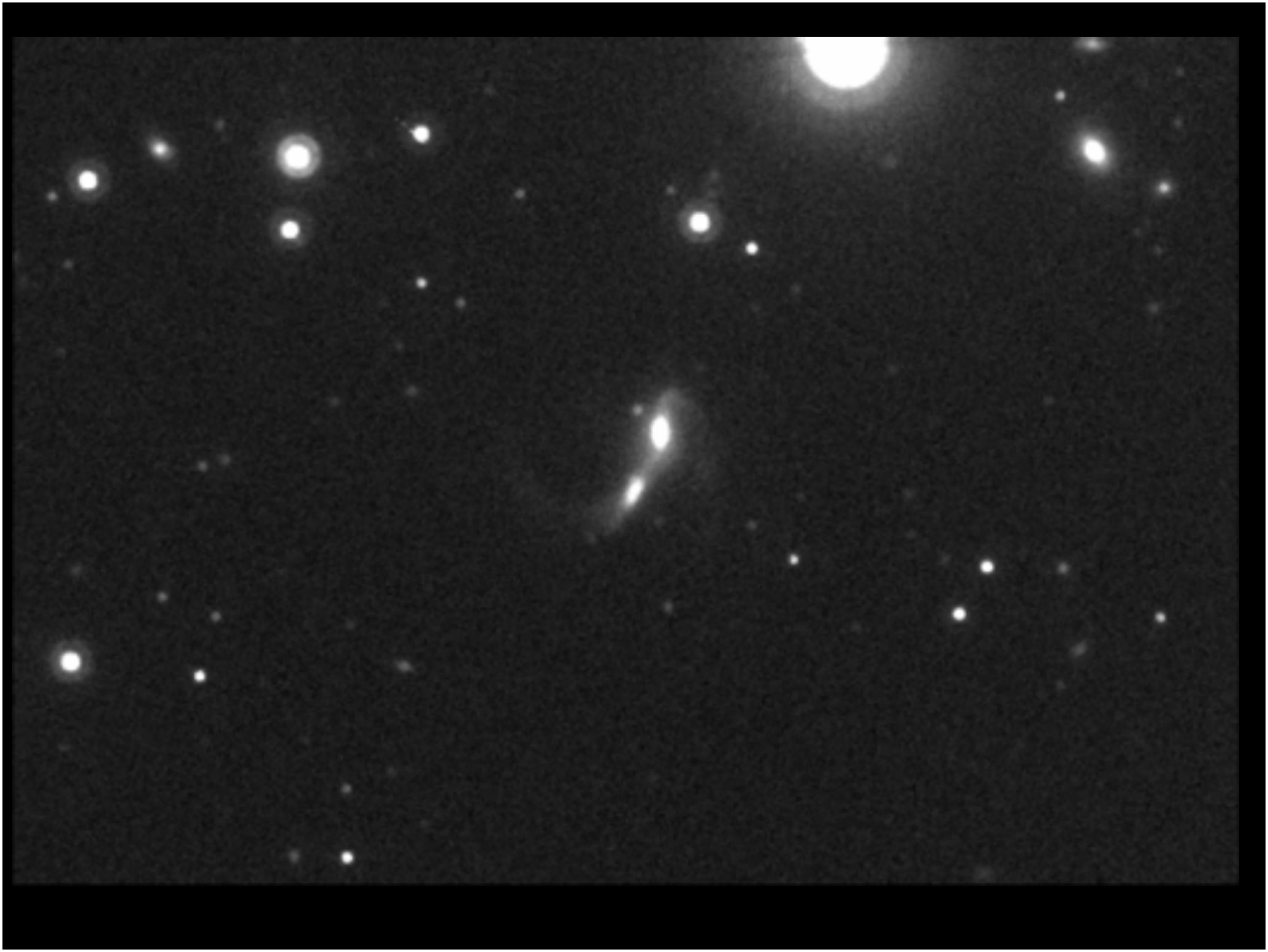
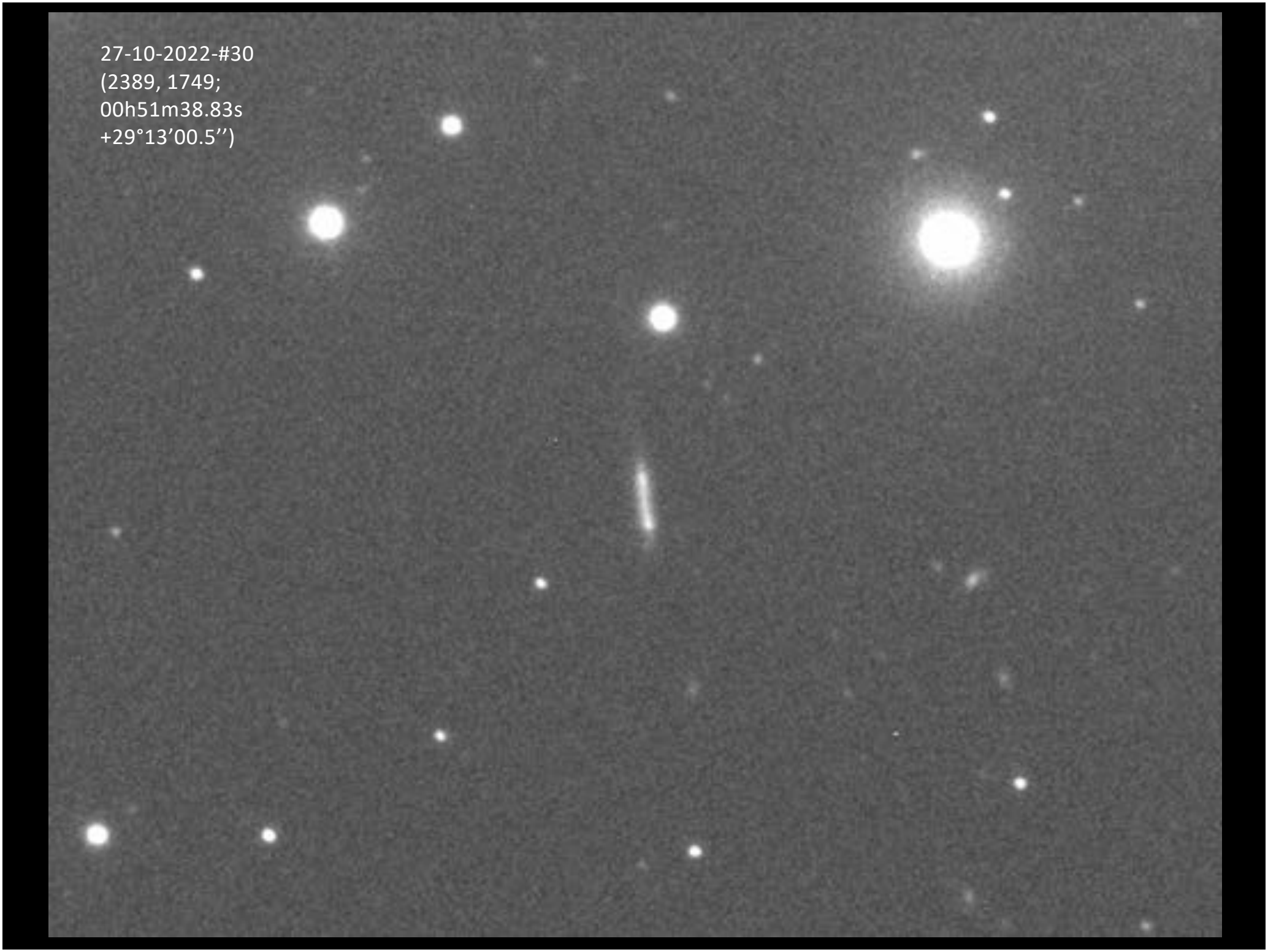
Field_01_26_1sth



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(2389, 1749;
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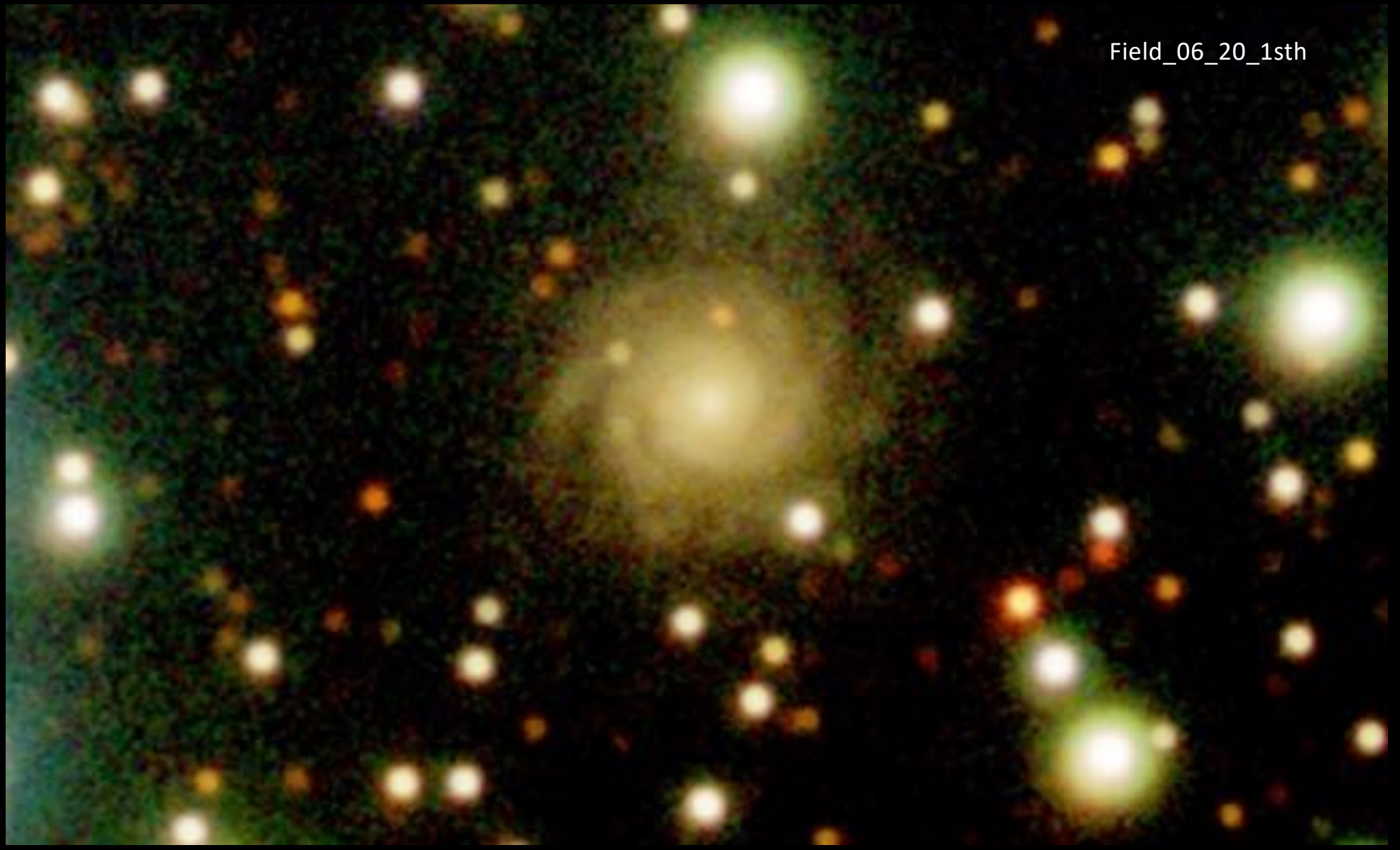
+29°13’00.5’’)


Field_06_20_1sth

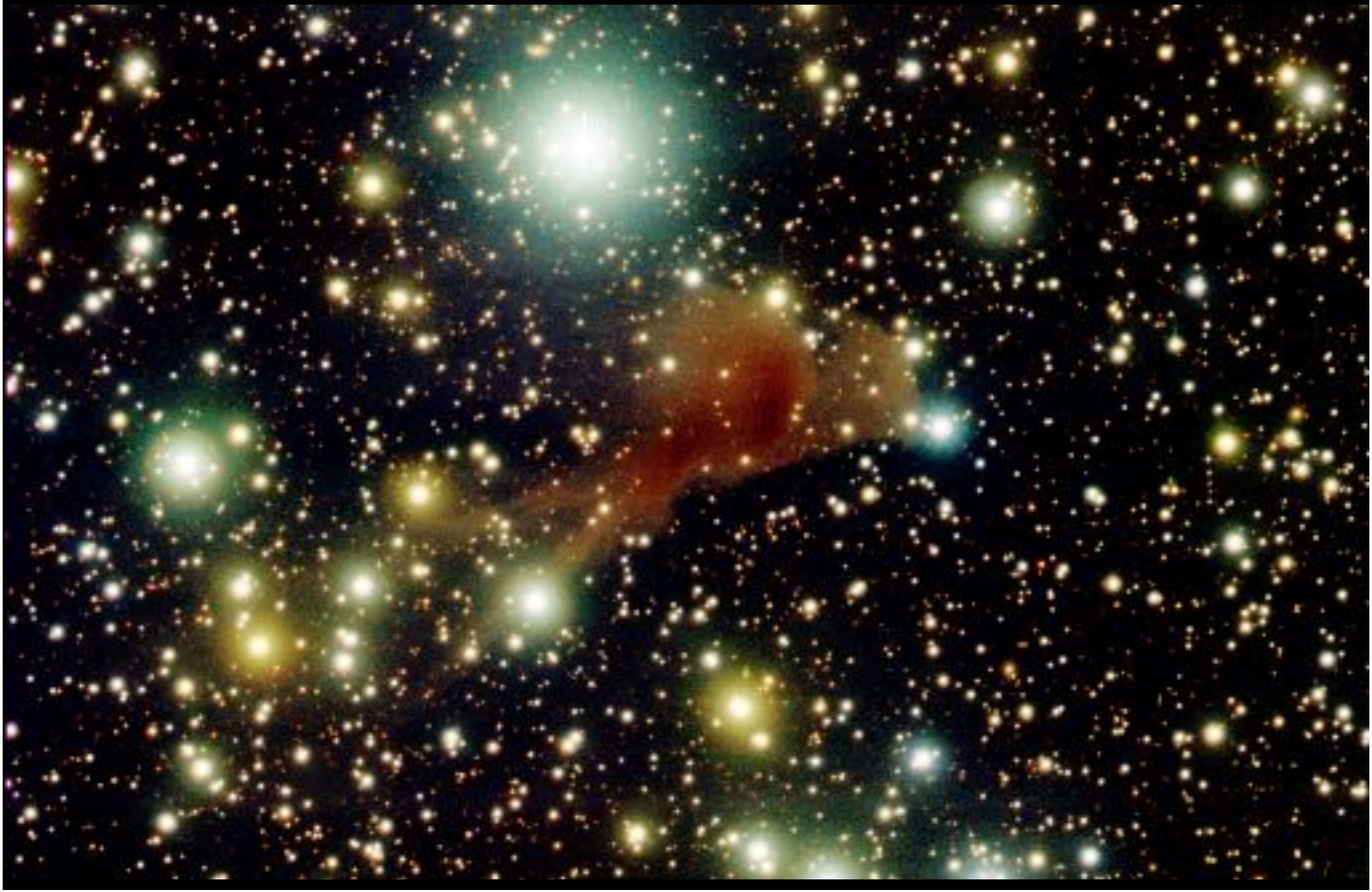

Field_01_26_2ndh


Field_04_12_1sth
Field_04_12_2ndh


Field_03_35_2ndh


Field_05_26_1sth

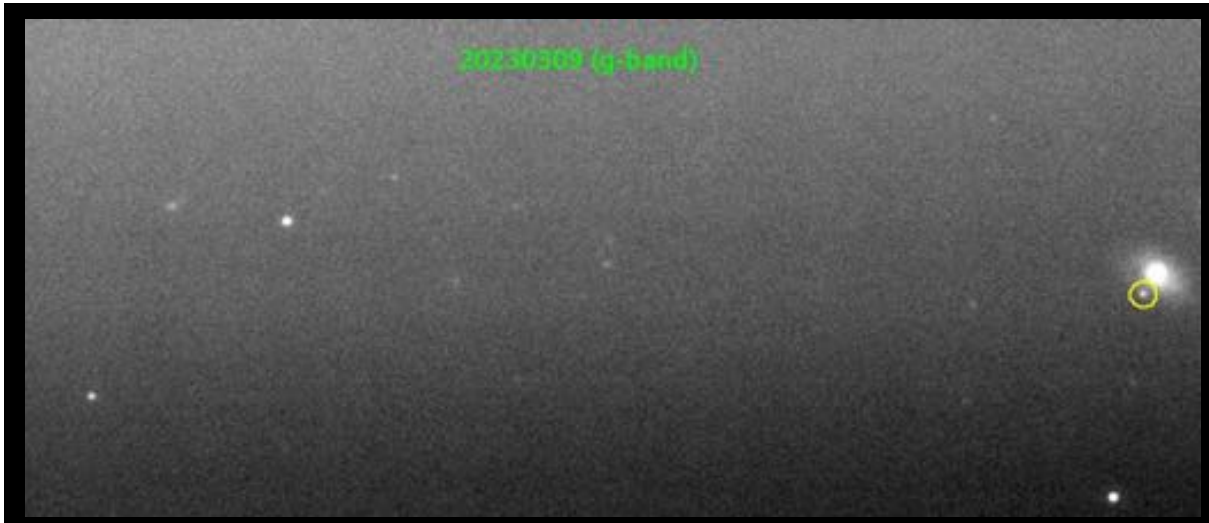
Field_04_50




Field_05_26_2ndh

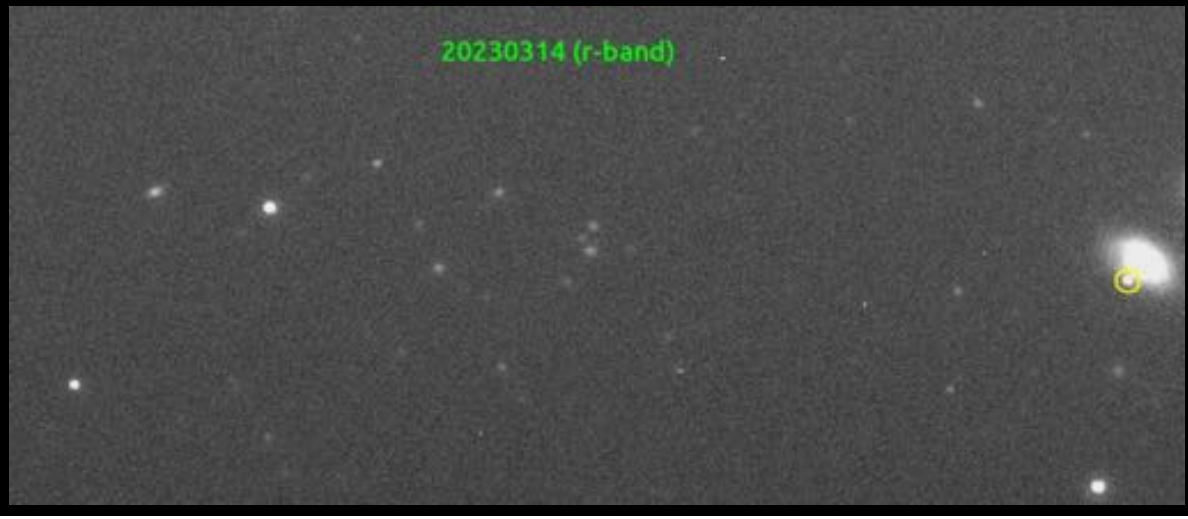

Field_05_26_2ndh_B


Field_05_26_2ndh_B



Supernova 2023af (Type II event)

- Discovery date: 2023-01-02
- RA, Dec: 166.150659, +29.517186
- Host galaxy: MCG+05-26-043
- Distance: 126.3 ± 8.8 Mpc (NED)



XI. Conclusions

- The ILMT is an instrument that may be entirely dedicated to a photometric and astrometric variability survey, as well as to hunter astronomical transients + geophysical application
- In principle, the mirror quality will be limited by the diffraction (atmospheric seeing: 1.2", pixel size=0.3", FOV=22')
- 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
- Cons: non steerable telescope, 102 sec. integration, …
- Need for powerful image subtraction and transient recognition algorithms

References : http://www.ilmt.ulg.ac.be

Rotation of the celestial sphere

Devasthal
2nd December 2019

Stars over Devasthal
(2nd of April 2019)

Free access to the ILMT observations collected during the months of October/November 2022

(see the ILMT poster by Kuntal et al.)

Contact: Jean Surdej (jsurdej@uliege.be)

XII. General discussion


Thanks!