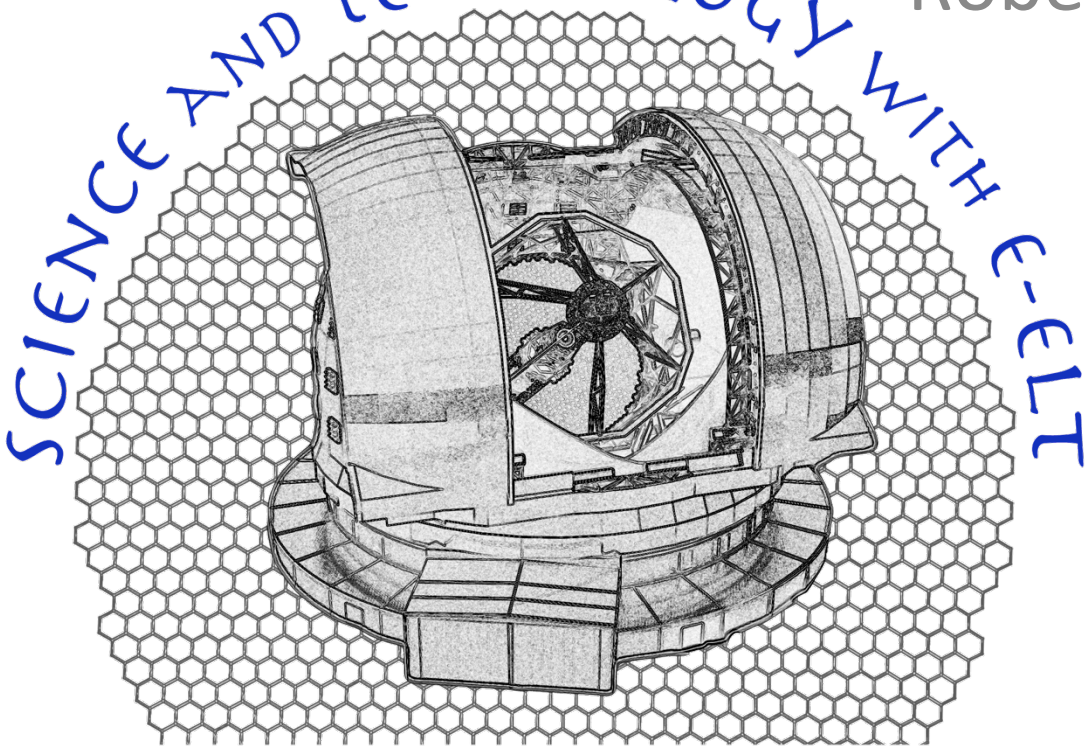
Mult Conjugated Adaptive Optics
The (heretic) dark side

Roberto Ragazzoni



INTERNATIONAL PHD SCHOOL "F. LUCCHIN"
XIV CYCLE - II COURSE
ERICE, SICILY
8-20 OCTOBER 2015

LABORATORIO NAZIONALE
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STEEL
ROBERTO RAGAZZONI

Mult Conjugated Adaptive Optics
The (heretic) dark side

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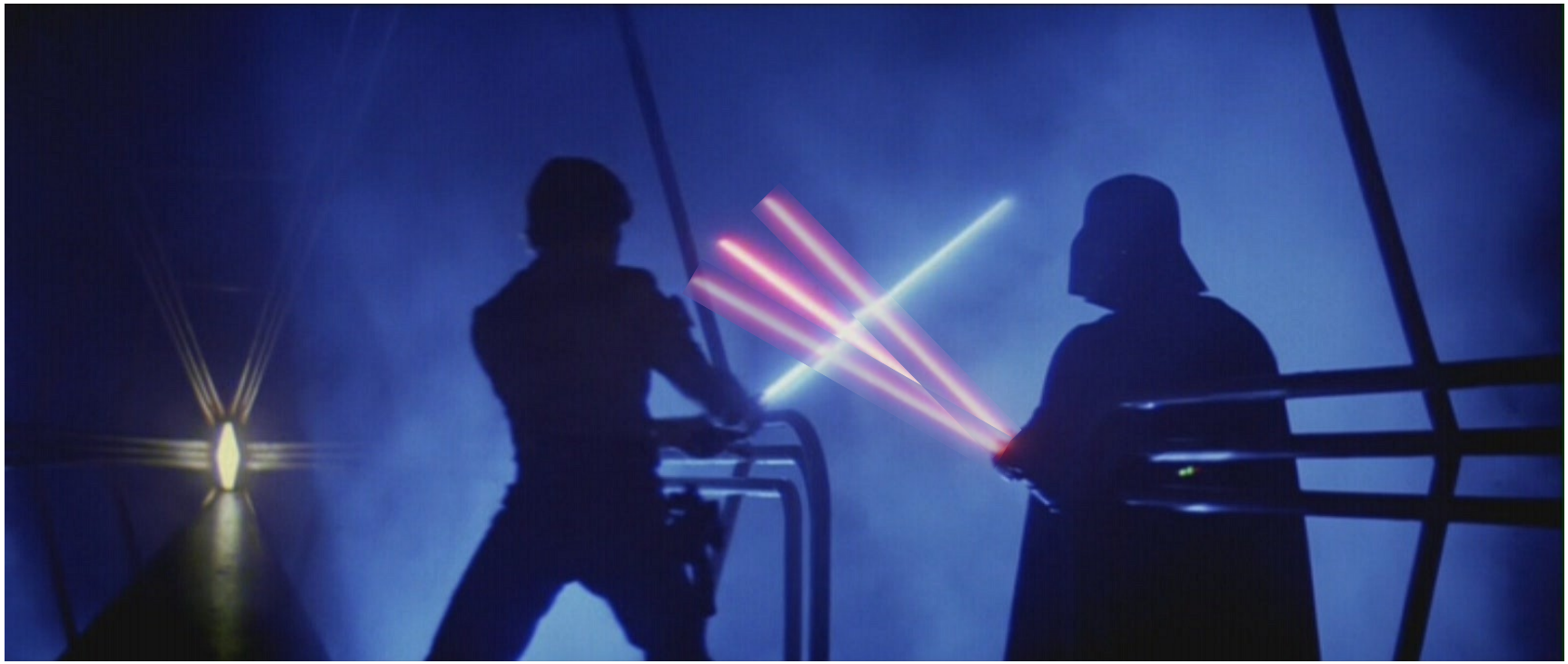

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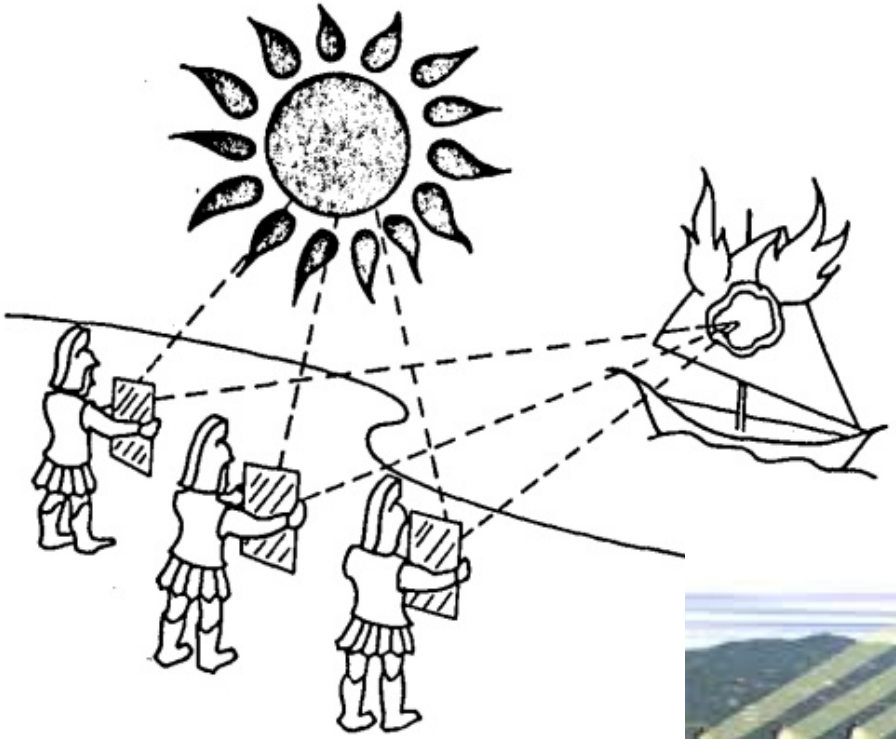
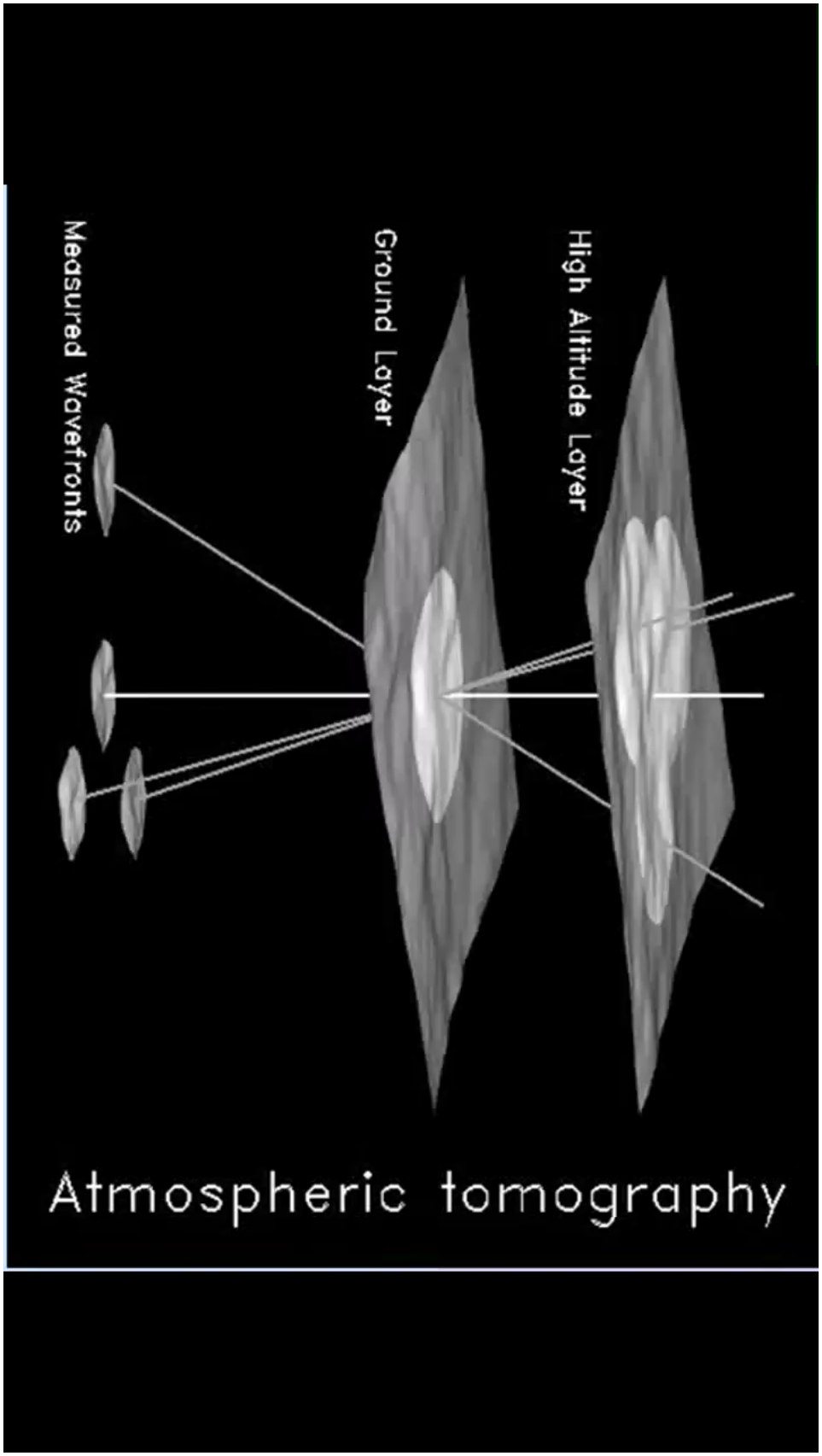
The (very) early days

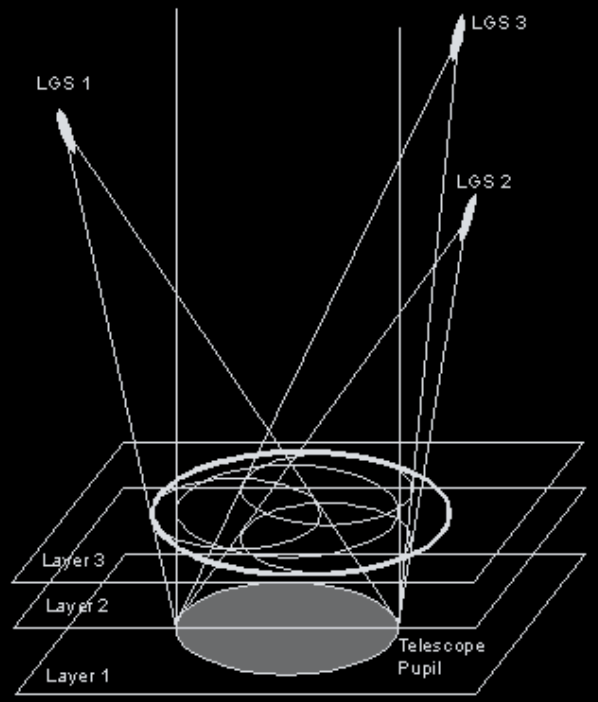



Measured Wavefronts
Ground Layer
High Altitude Layer
Atmospheric tomography

The early days

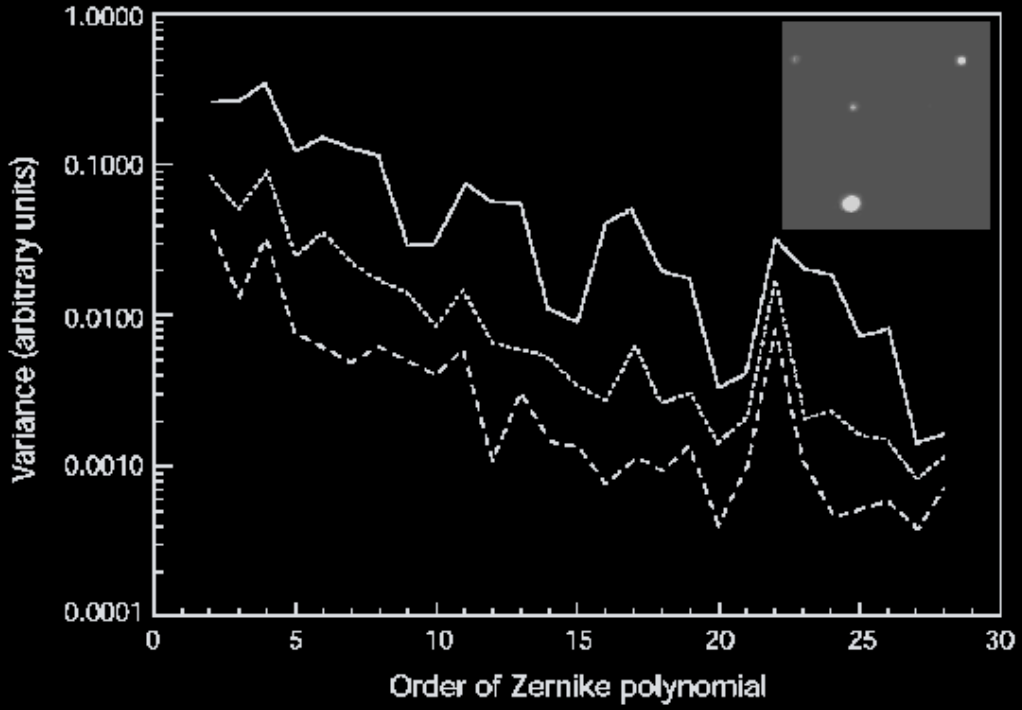
Modal tomography: from mathematics to open loop experiment

Modal formulation allow to easier determination of WF from off-axis measurements



A&A 342, L53 (1999)

Open-loop experiment with the 3.5m TNG on a Y-shaped four stars asterism succesful.
Solid line: Central star variance
Dotted line: average of neighborouds stars
Dashed line: Modal tomographyc result



Nature 403, 54 (2000)

The early days

Modal tomography: from mathematics to open loop experiment

Modal formulation allow to easier determination

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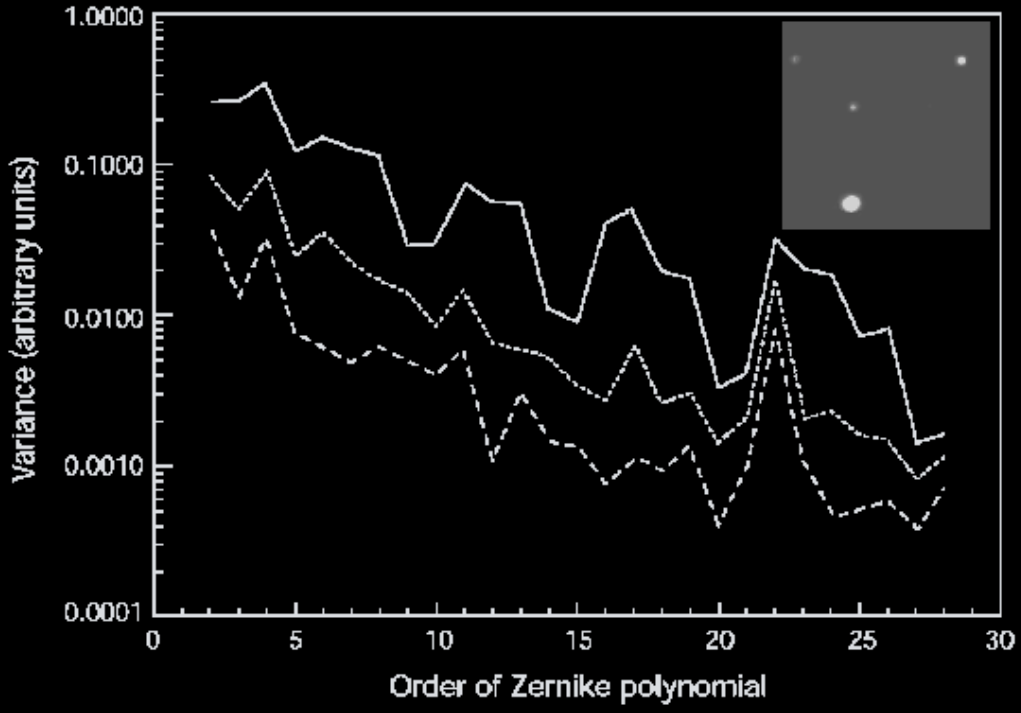

Nature 403, 54 (2000)

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An information approach

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An information approach

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A mirror

An information approach

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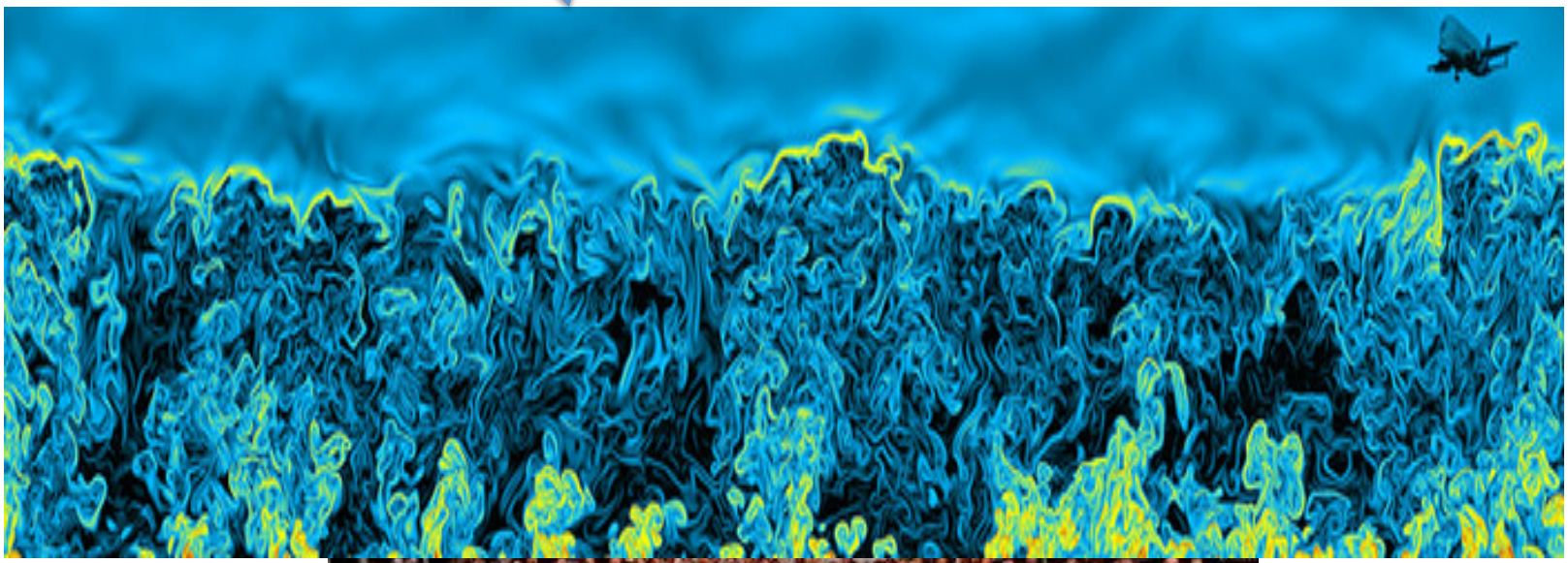
A pupil

An information approach

A (turbulent) atmosphere



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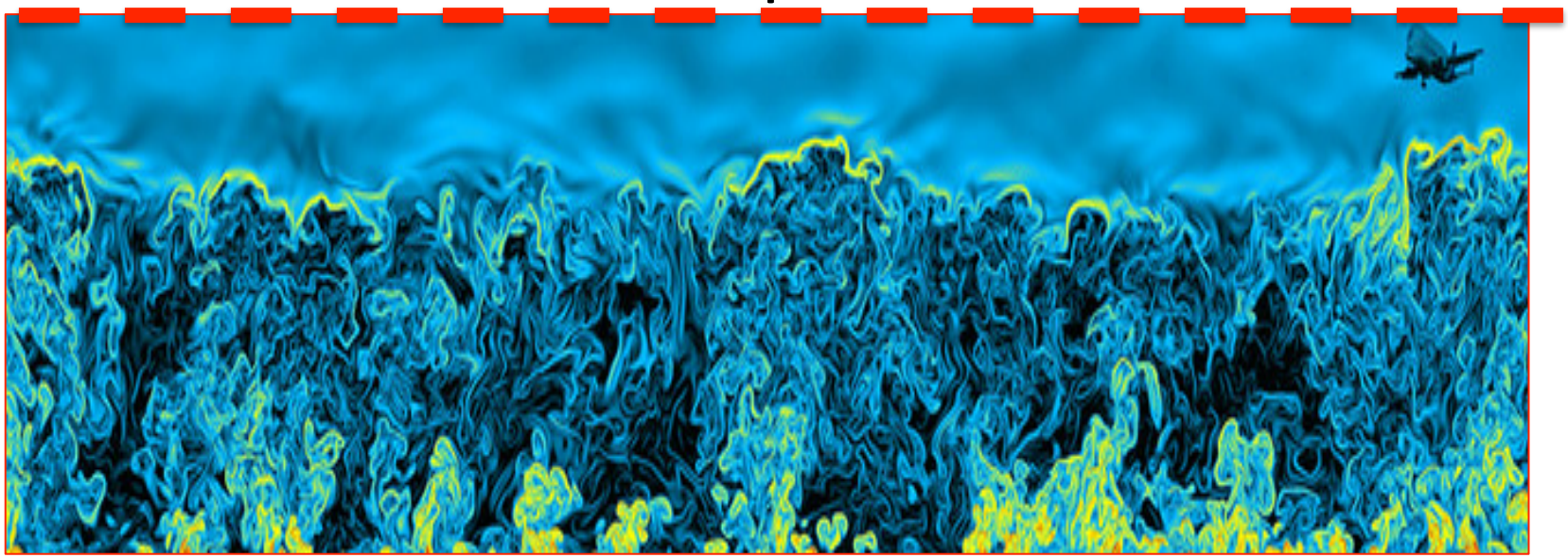
At least up to here…



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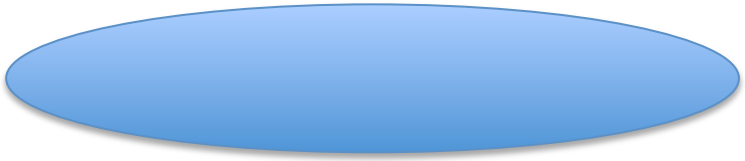

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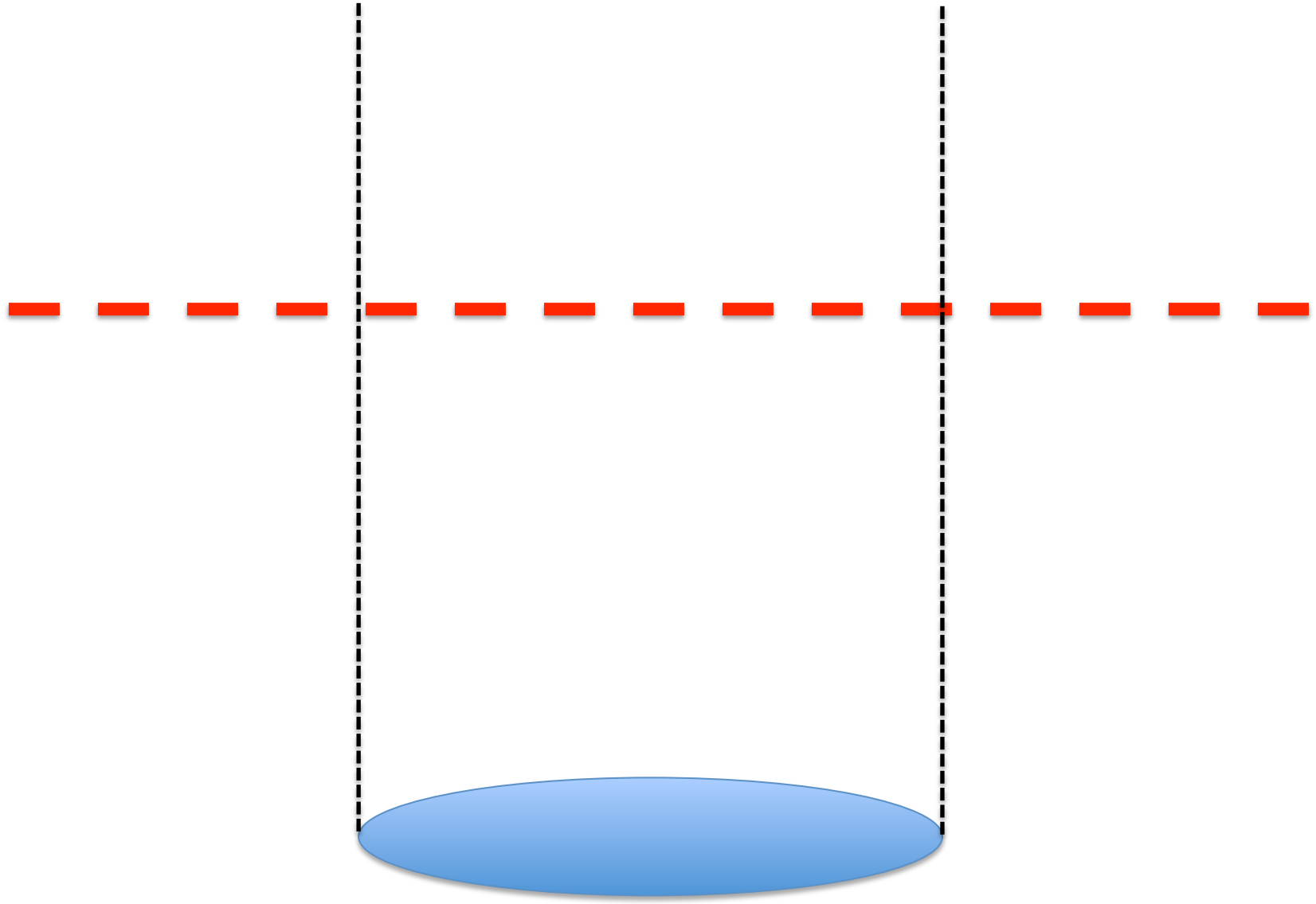

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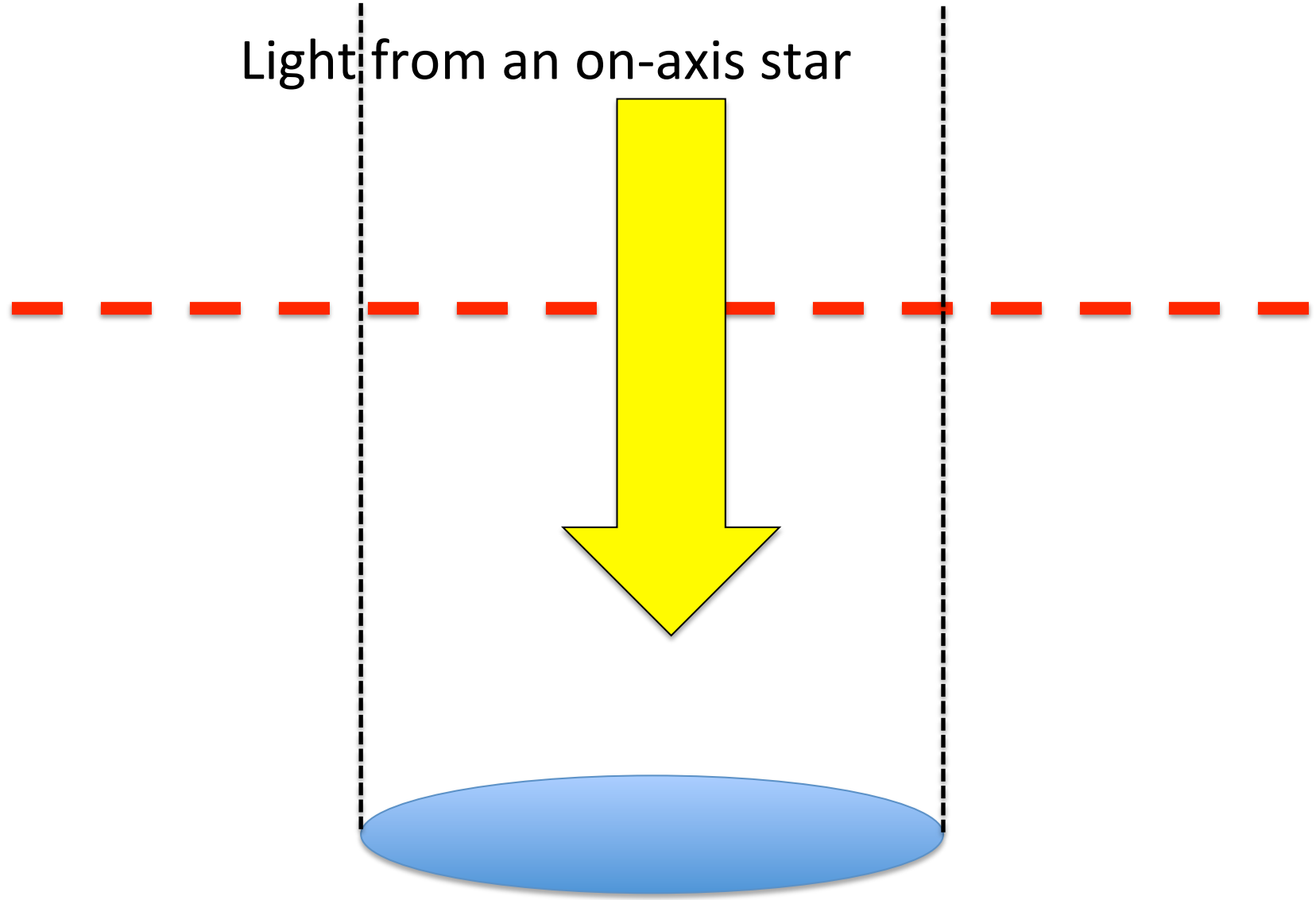

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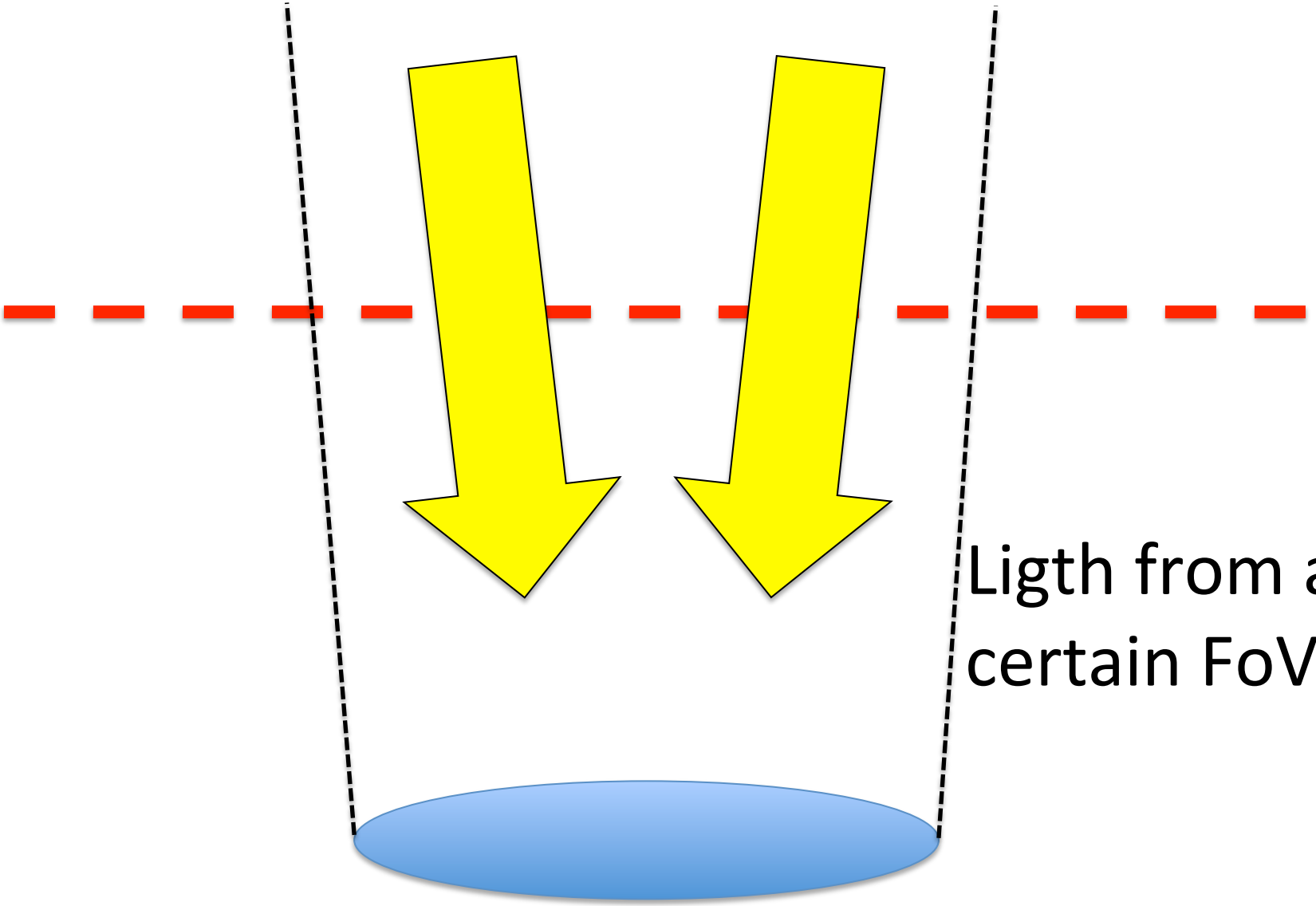
An information approach



Ligth from a certain FoV

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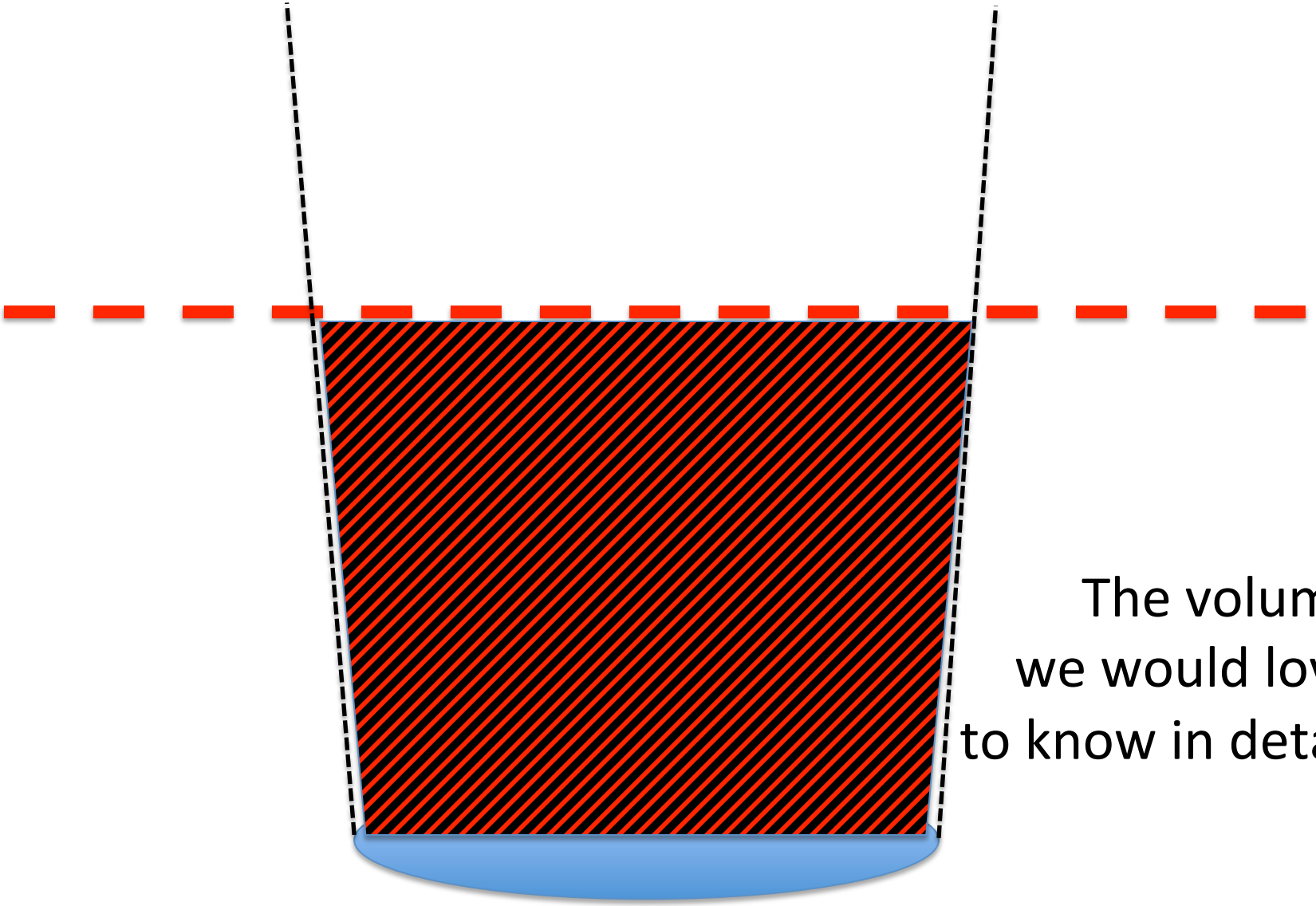
An information approach



The volume
we would love
to know in detail

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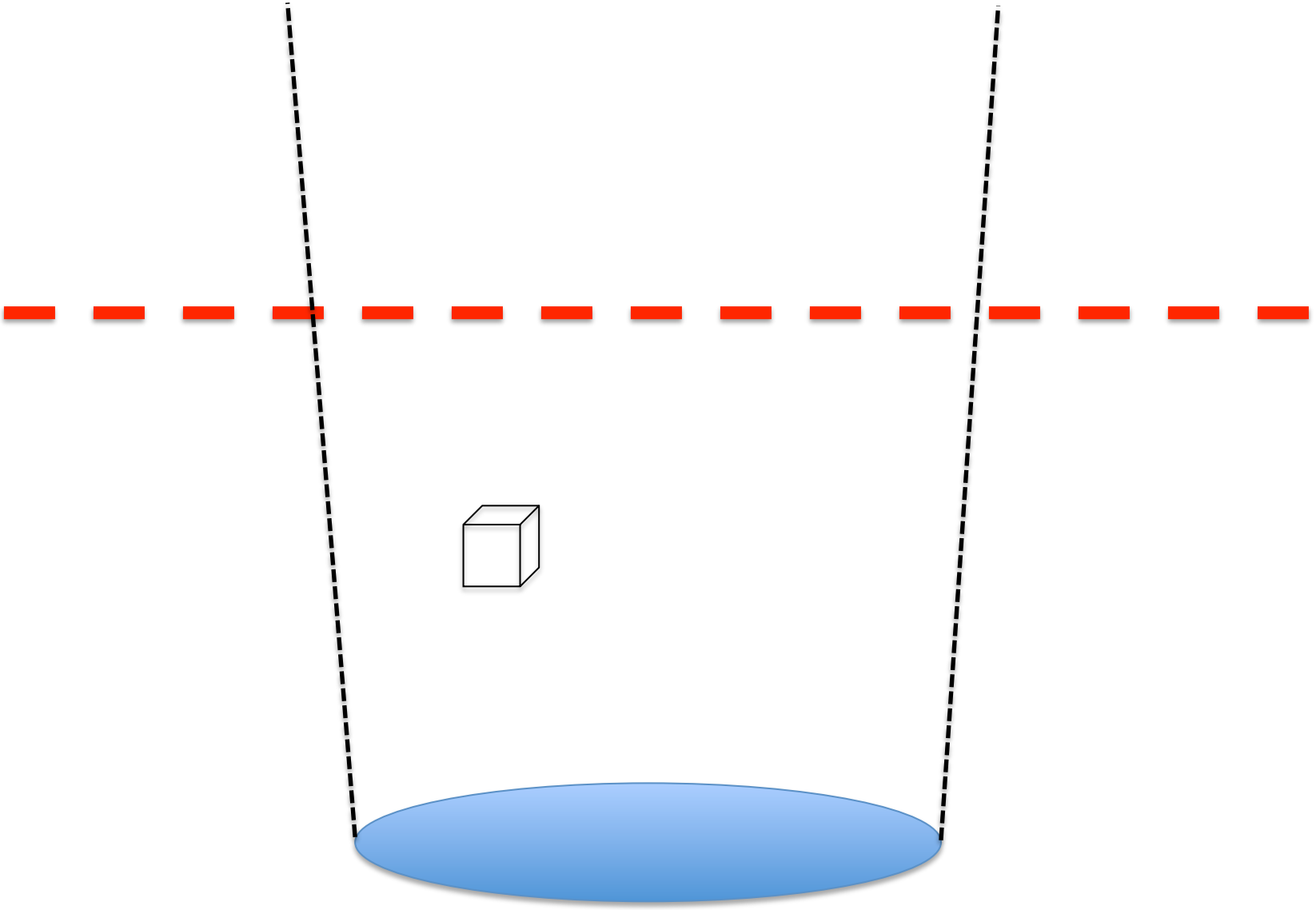
An information approach



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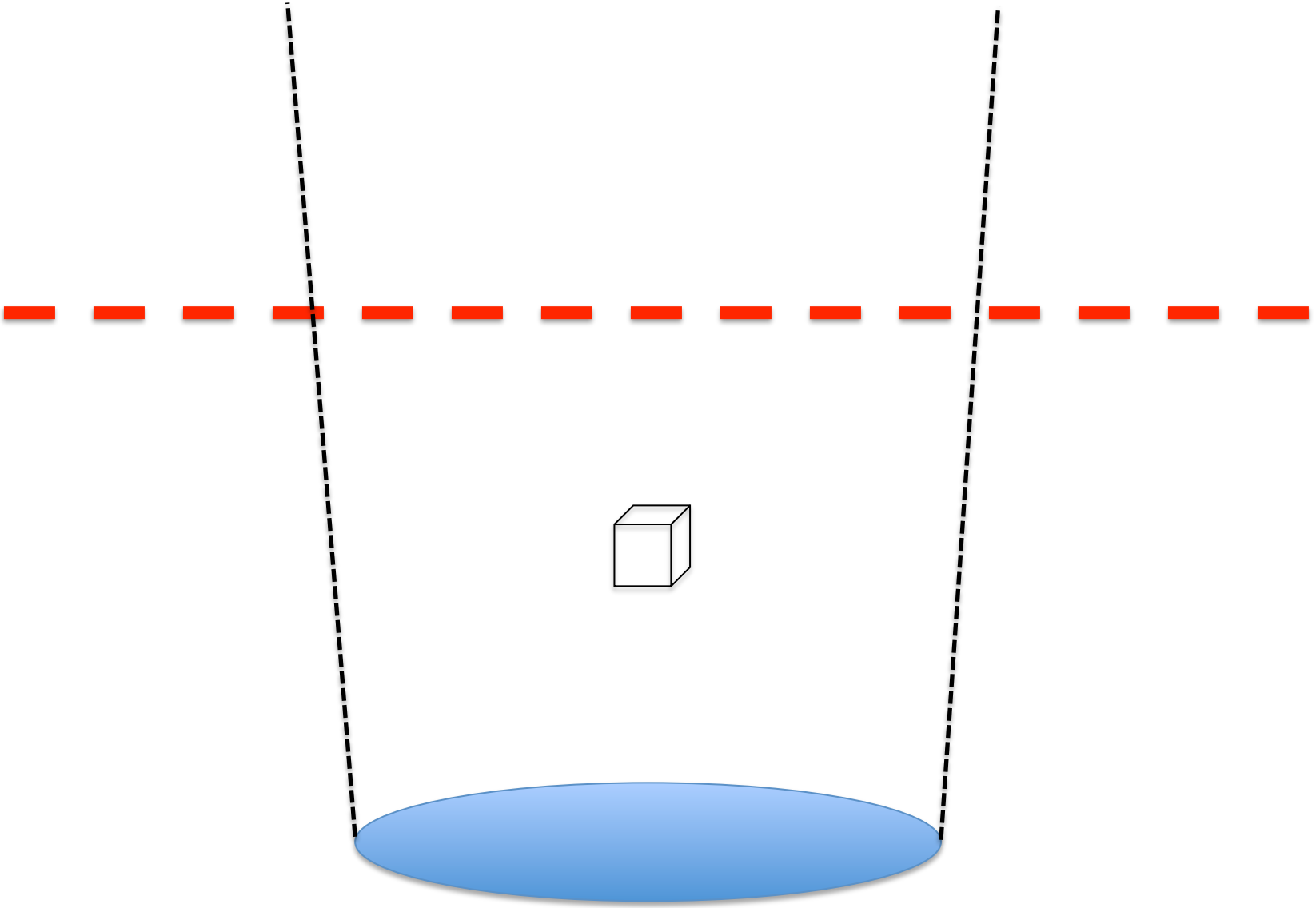

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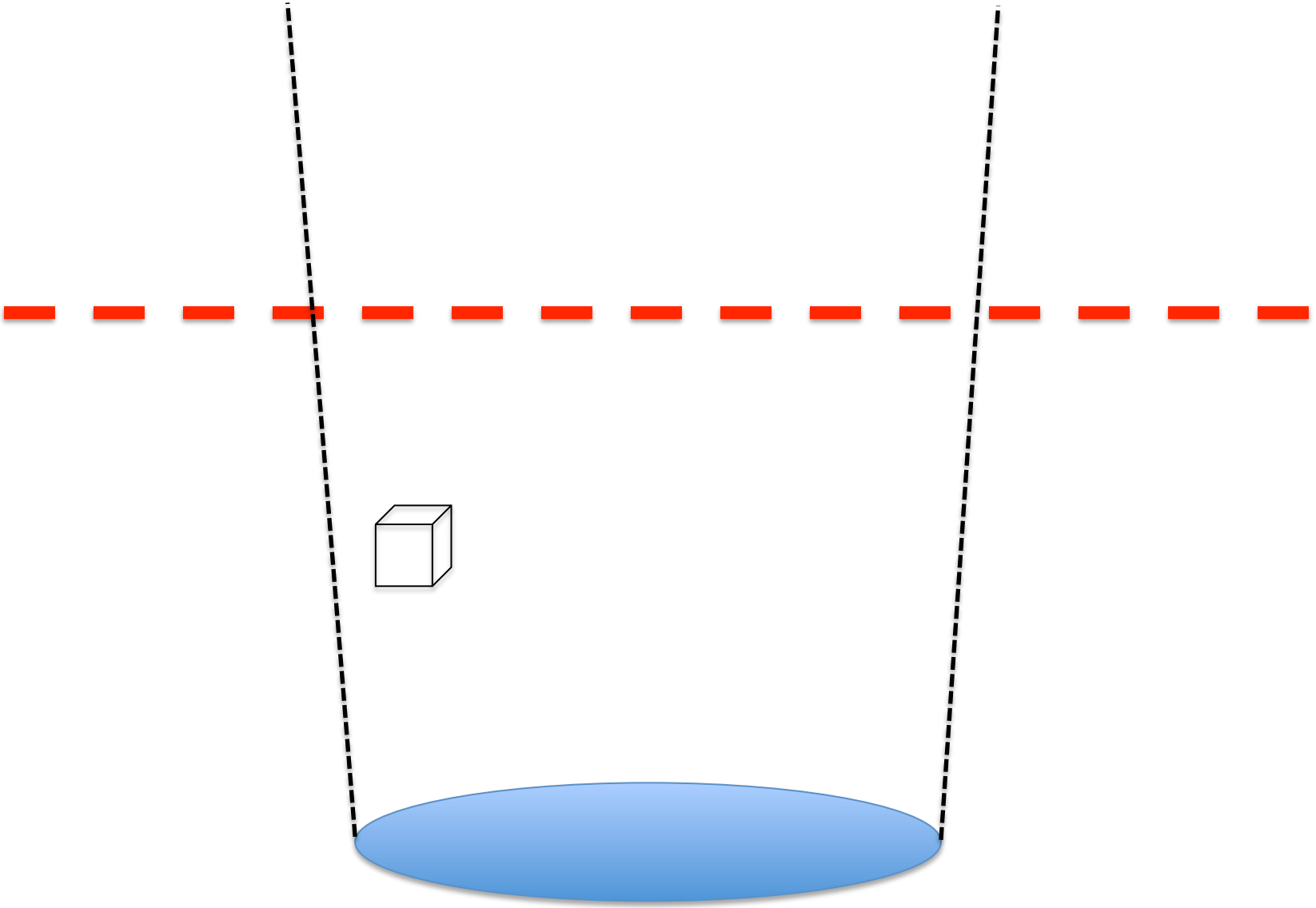

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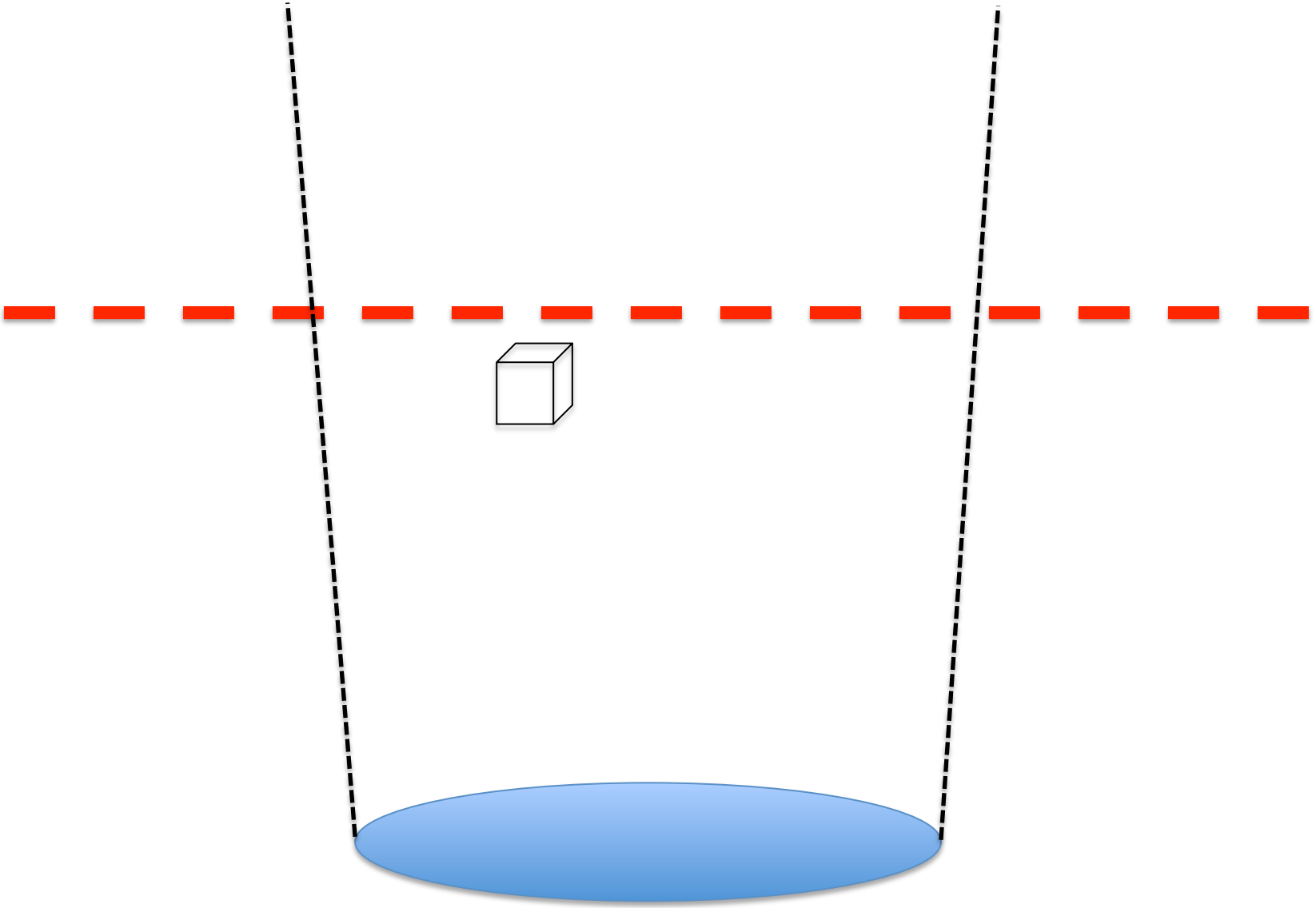

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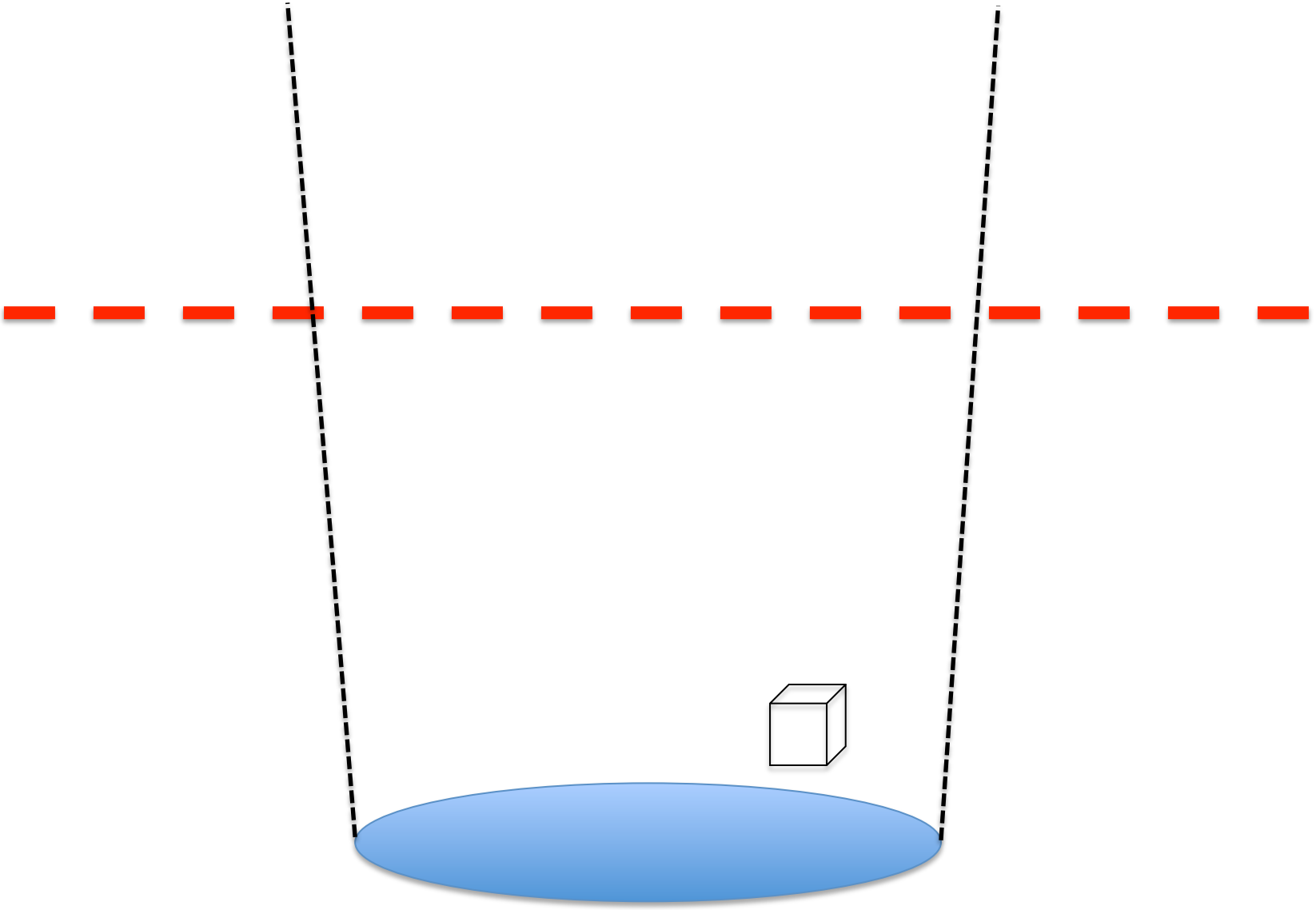

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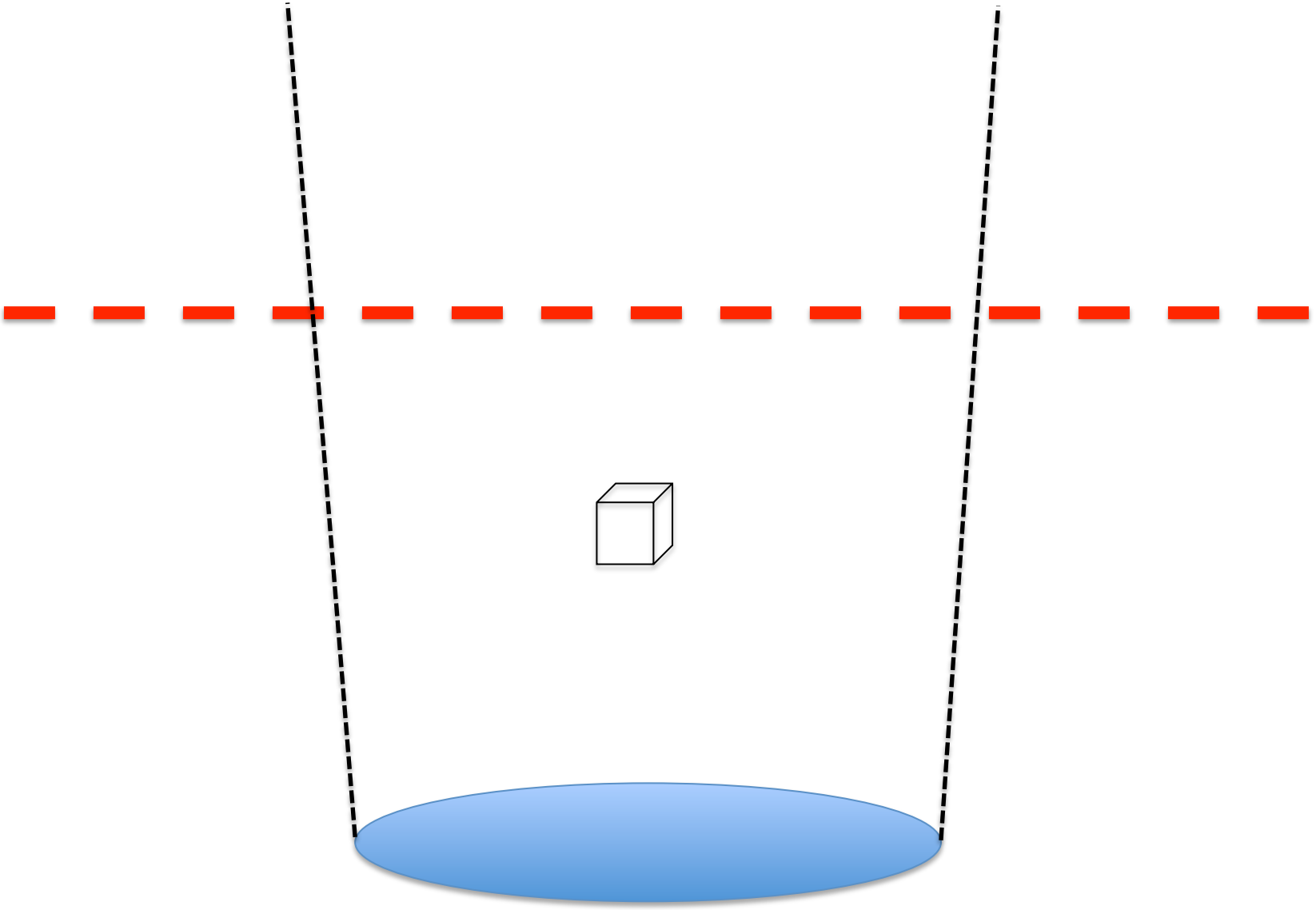

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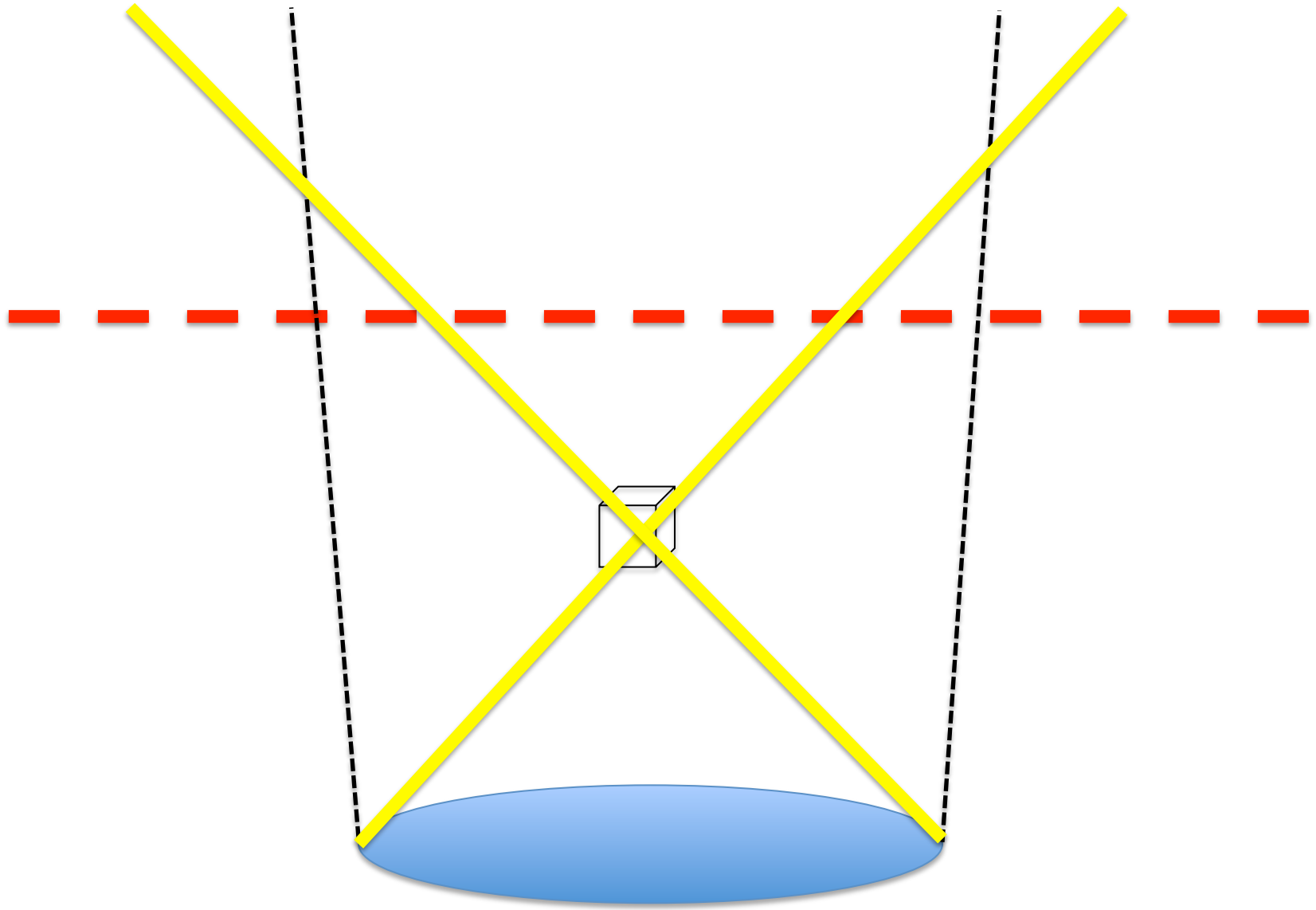

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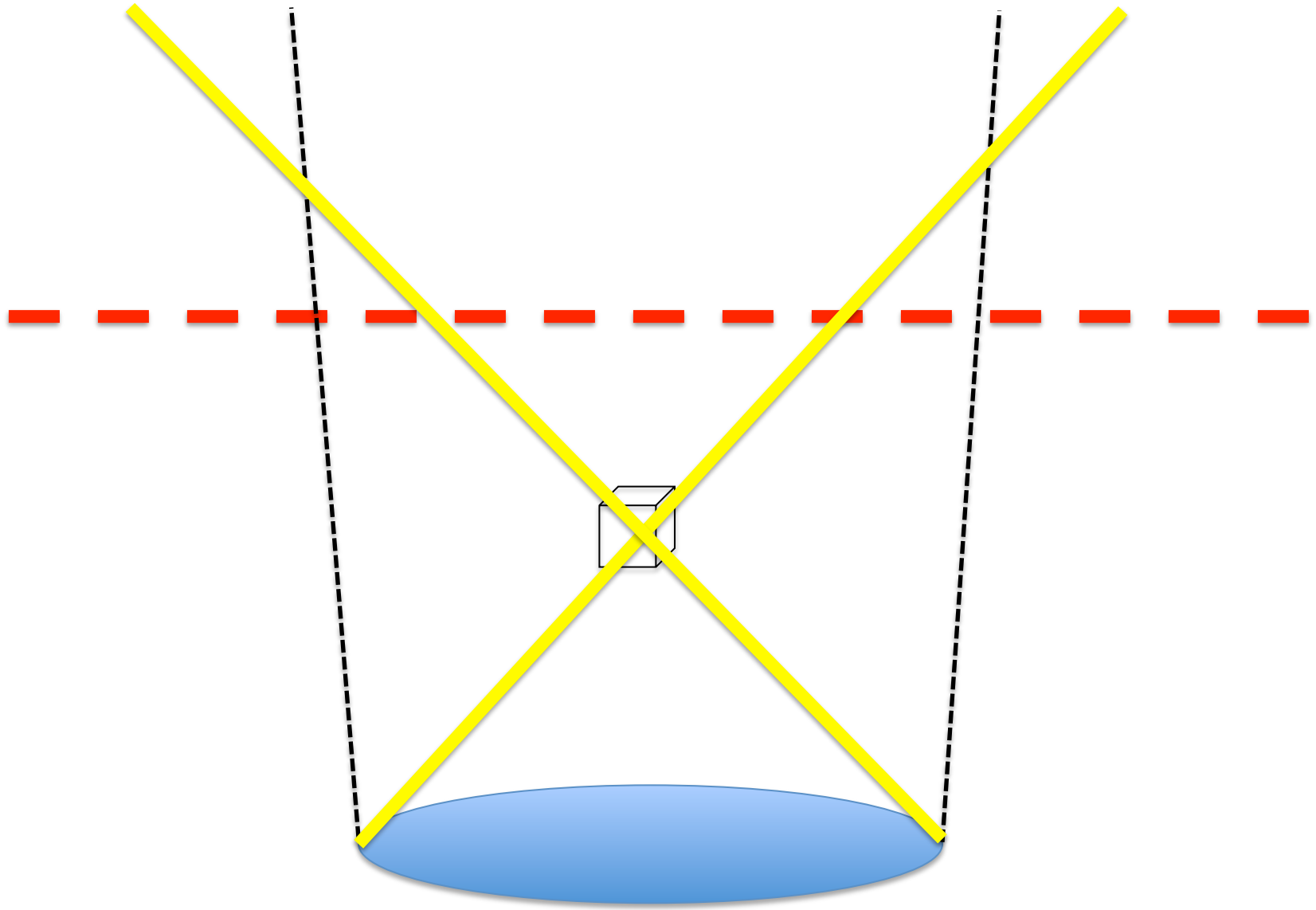

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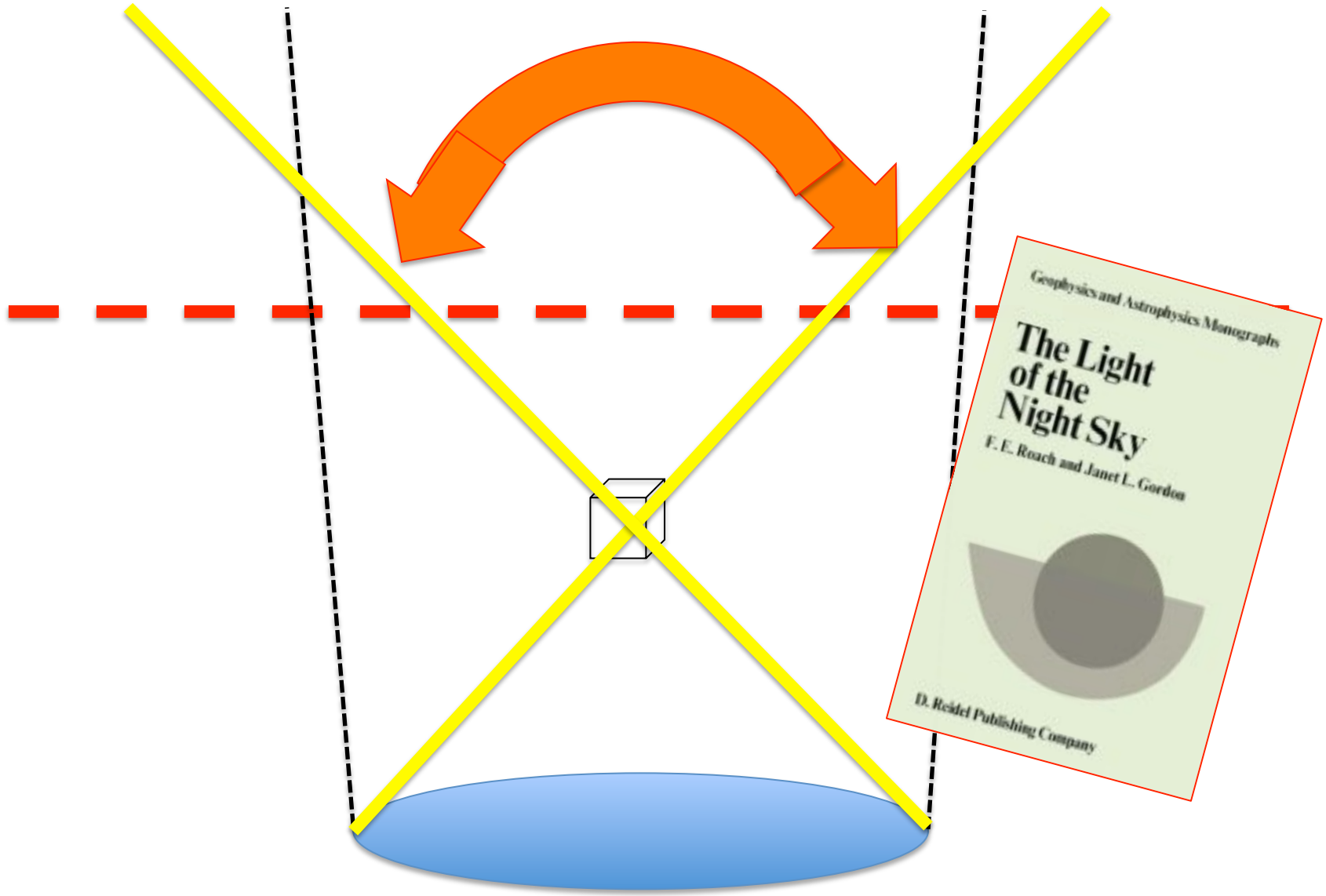

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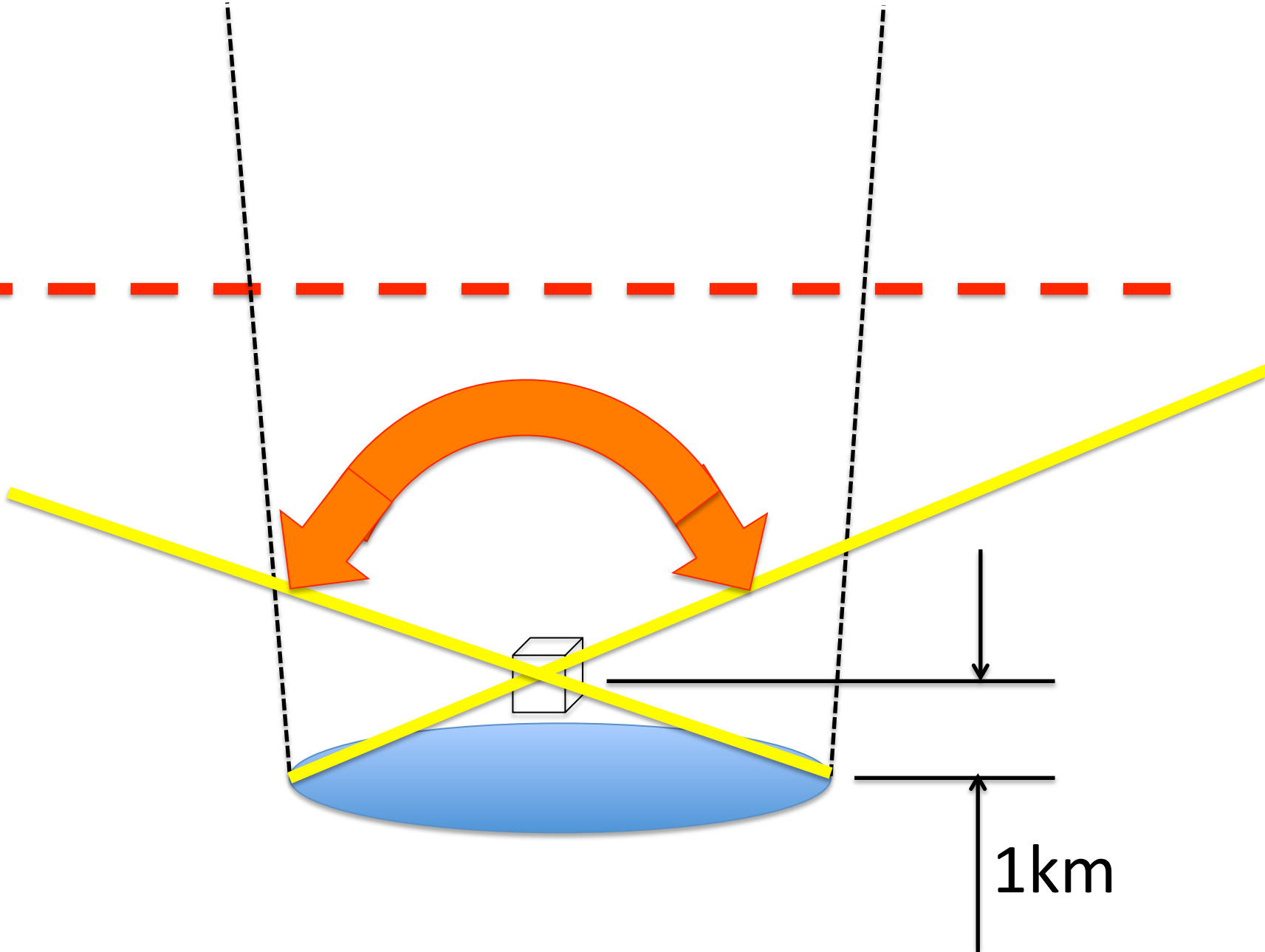

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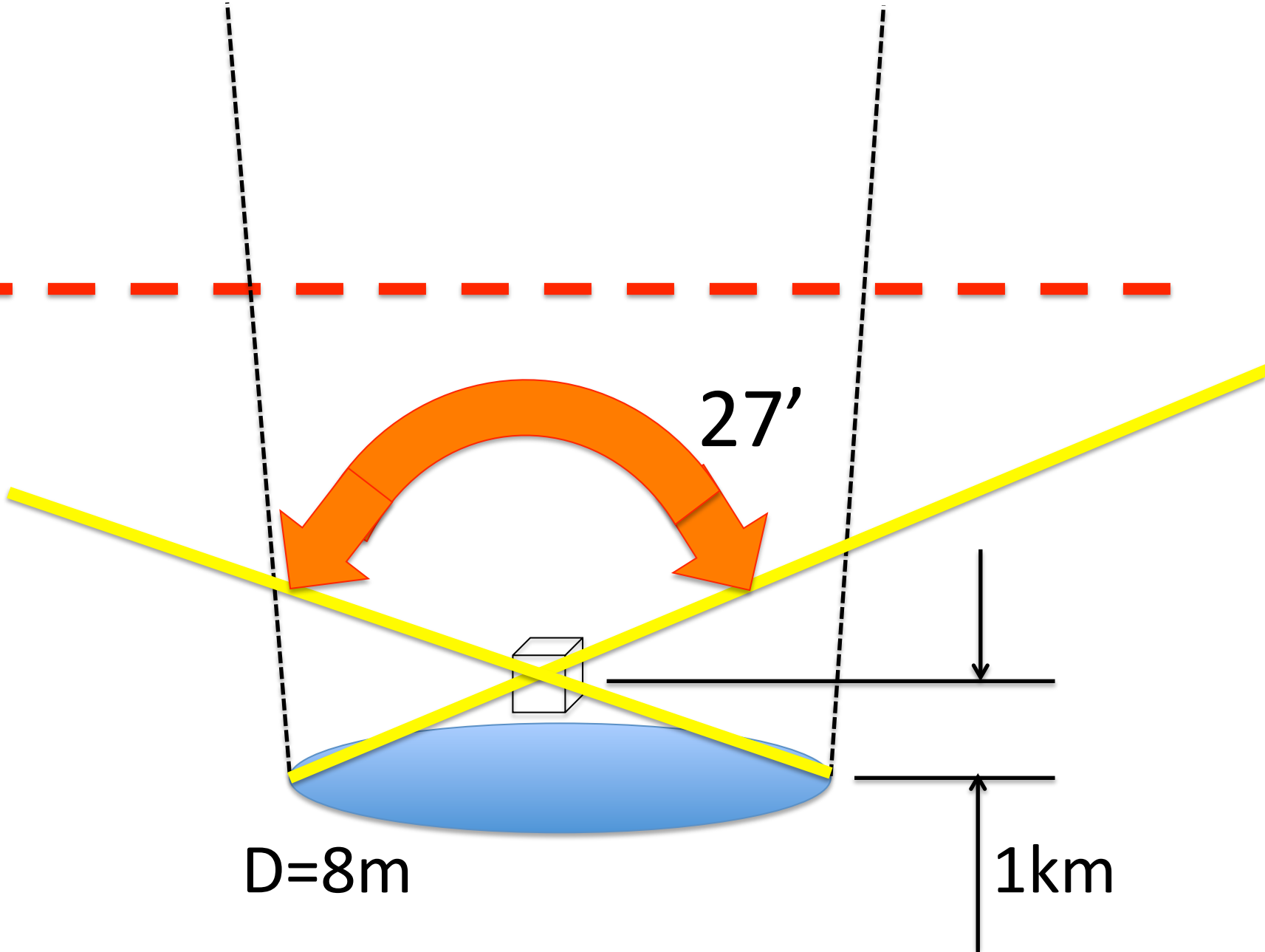

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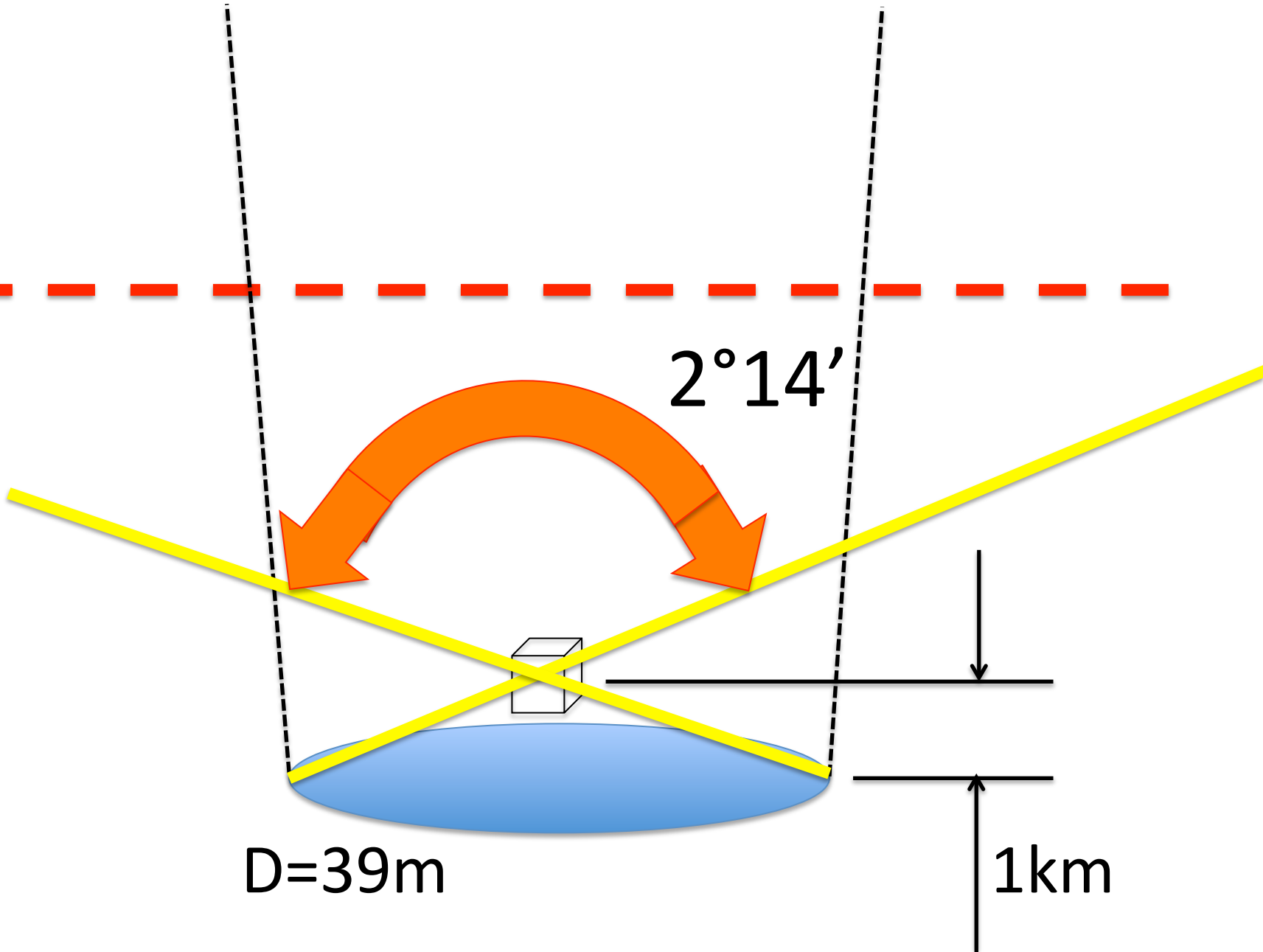

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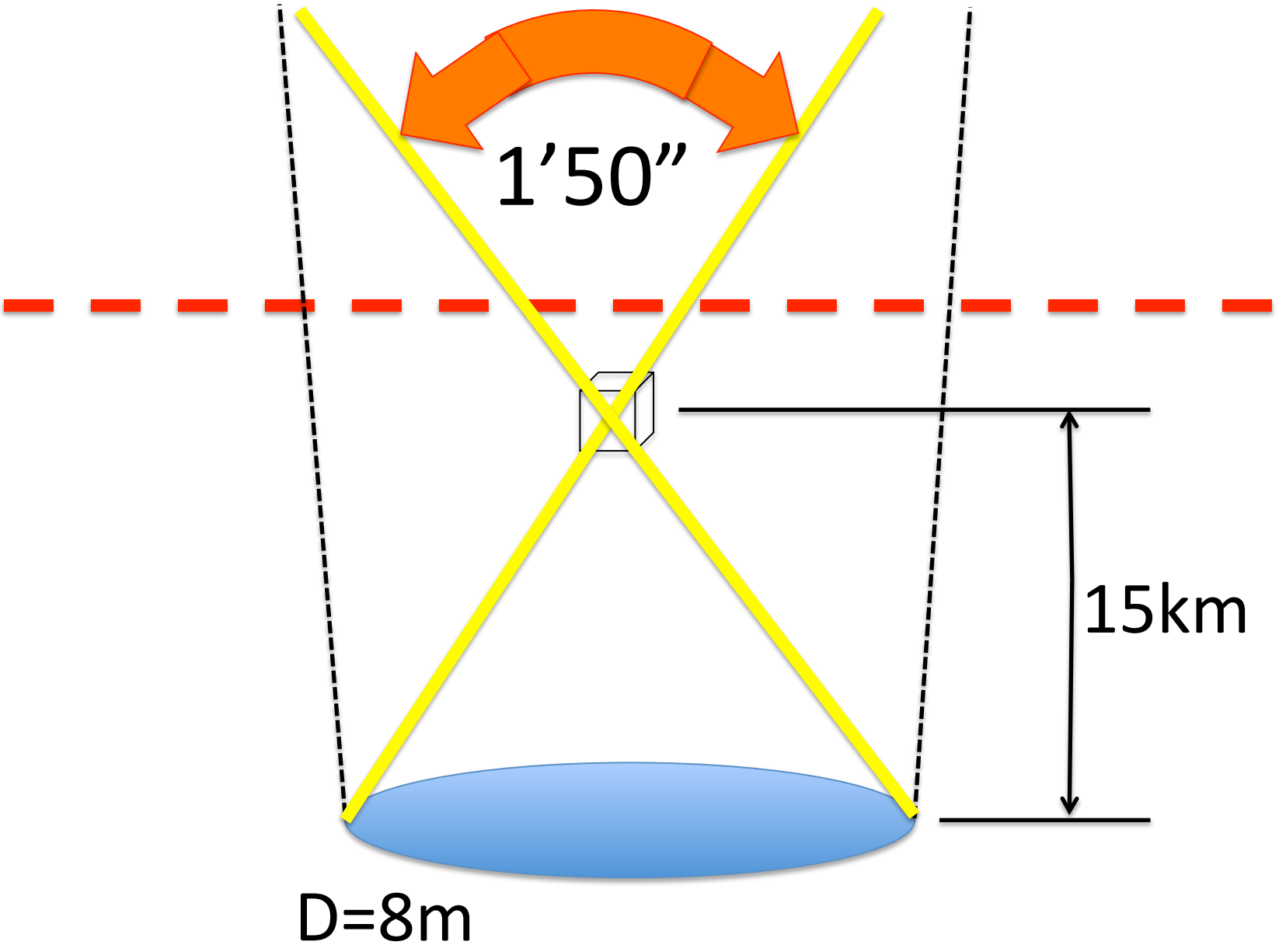

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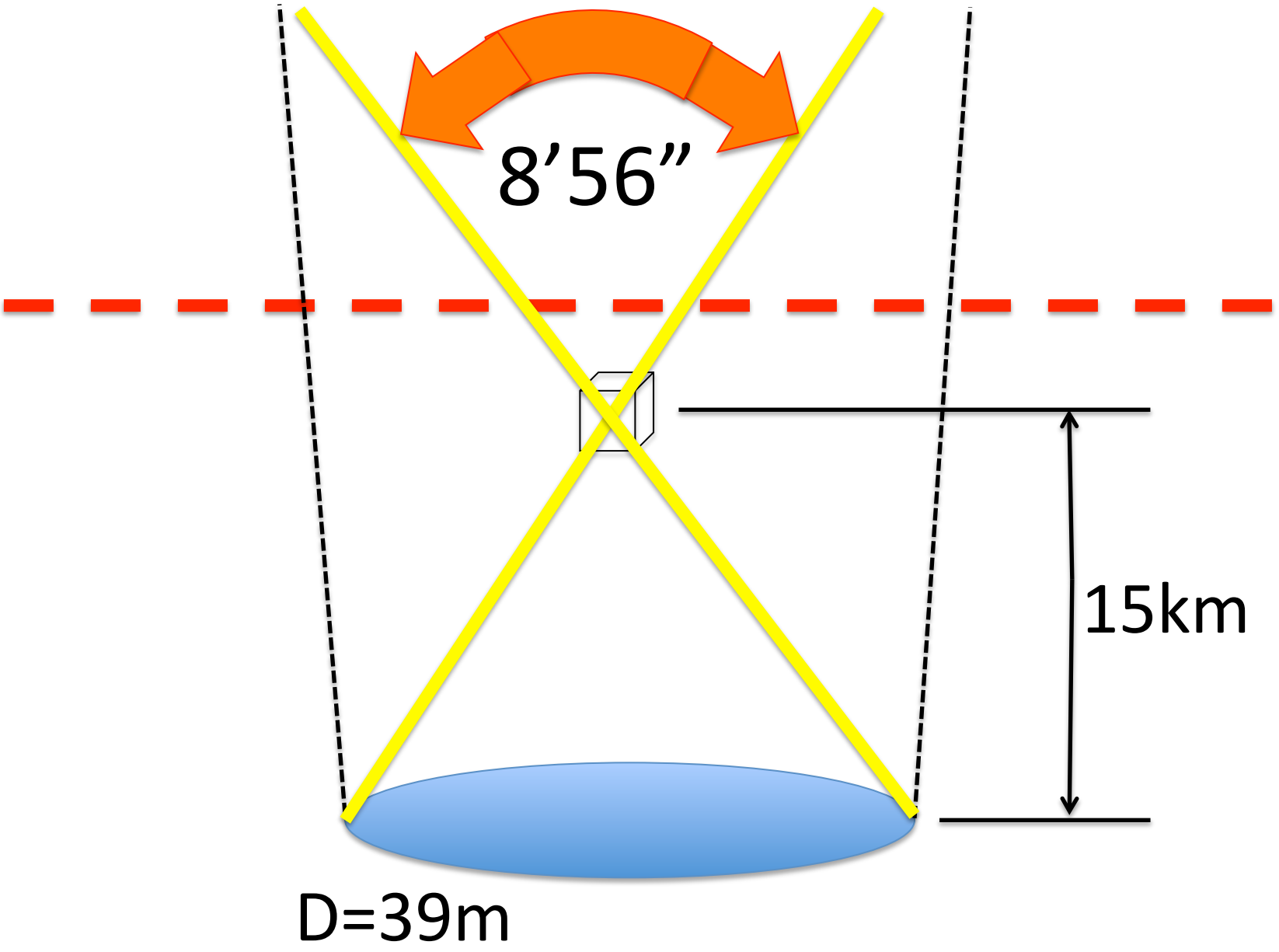

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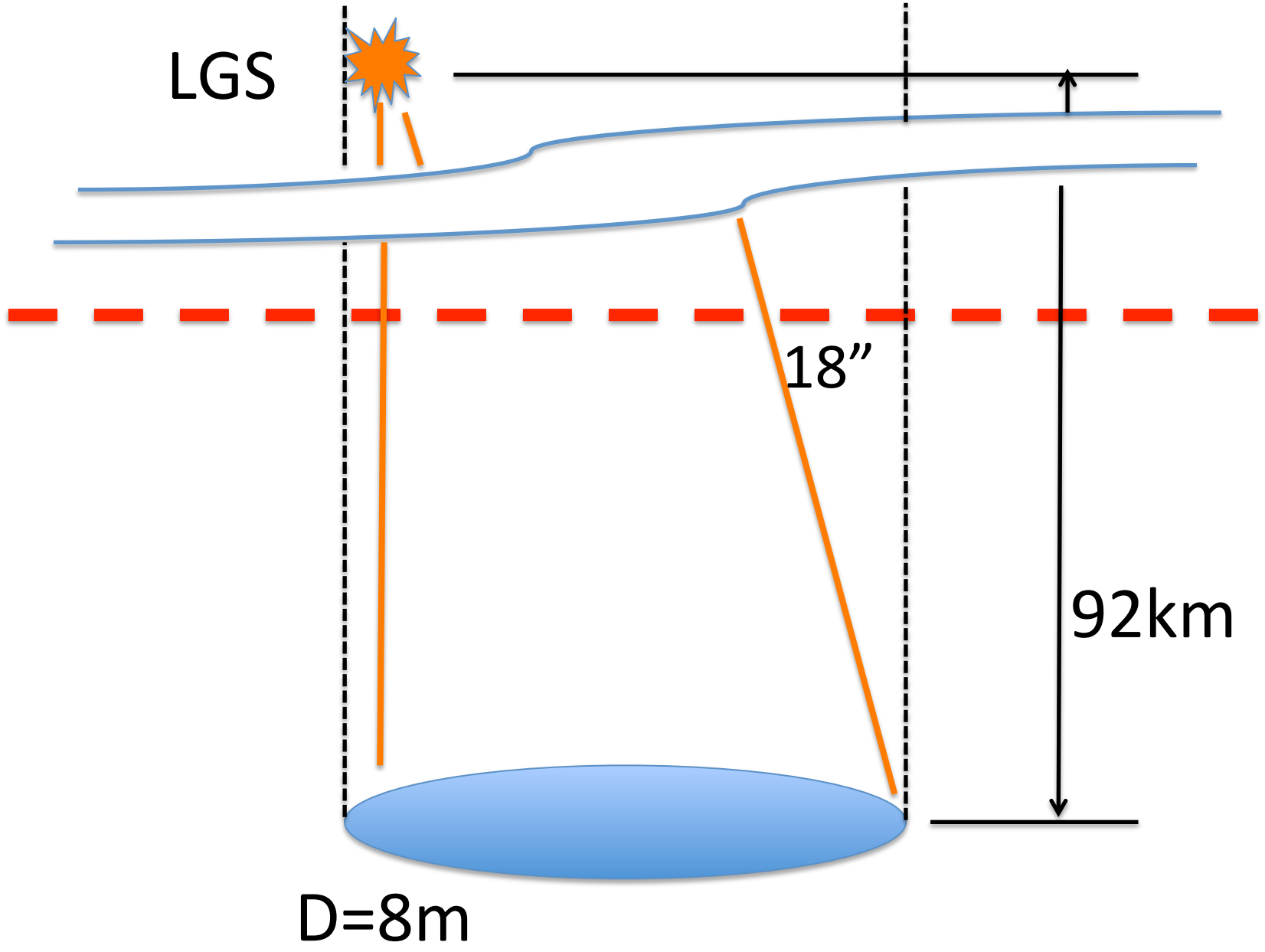

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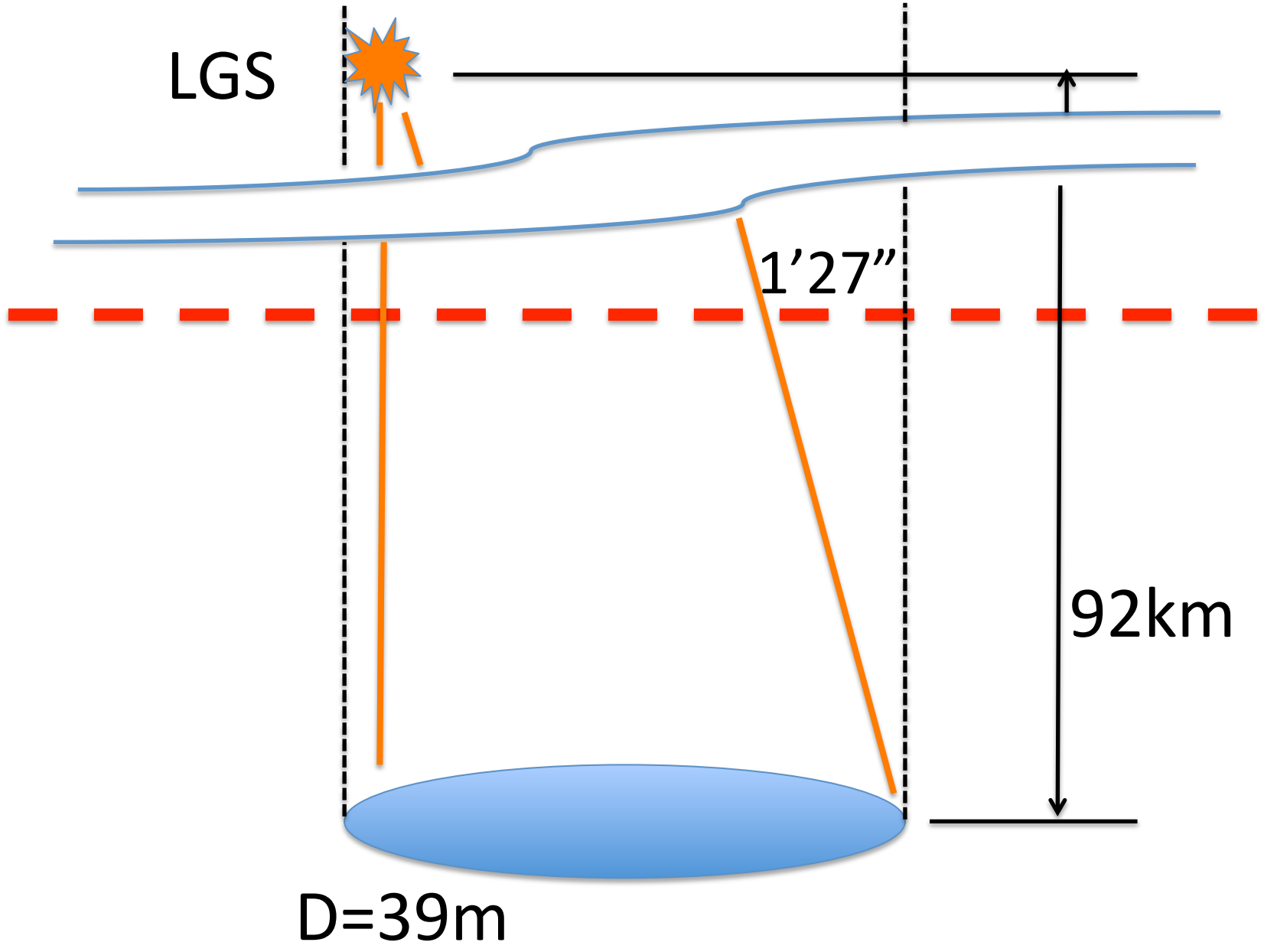

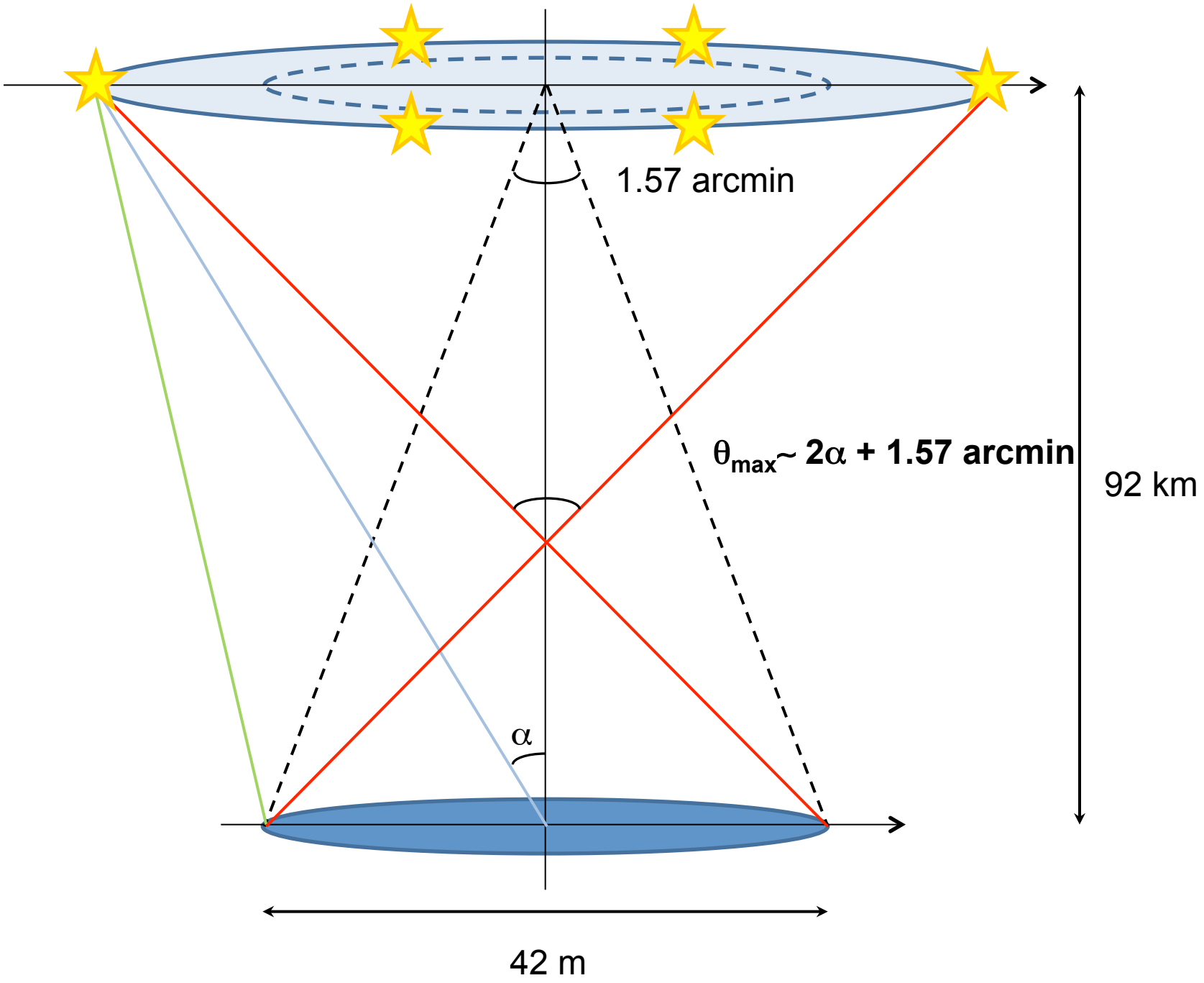

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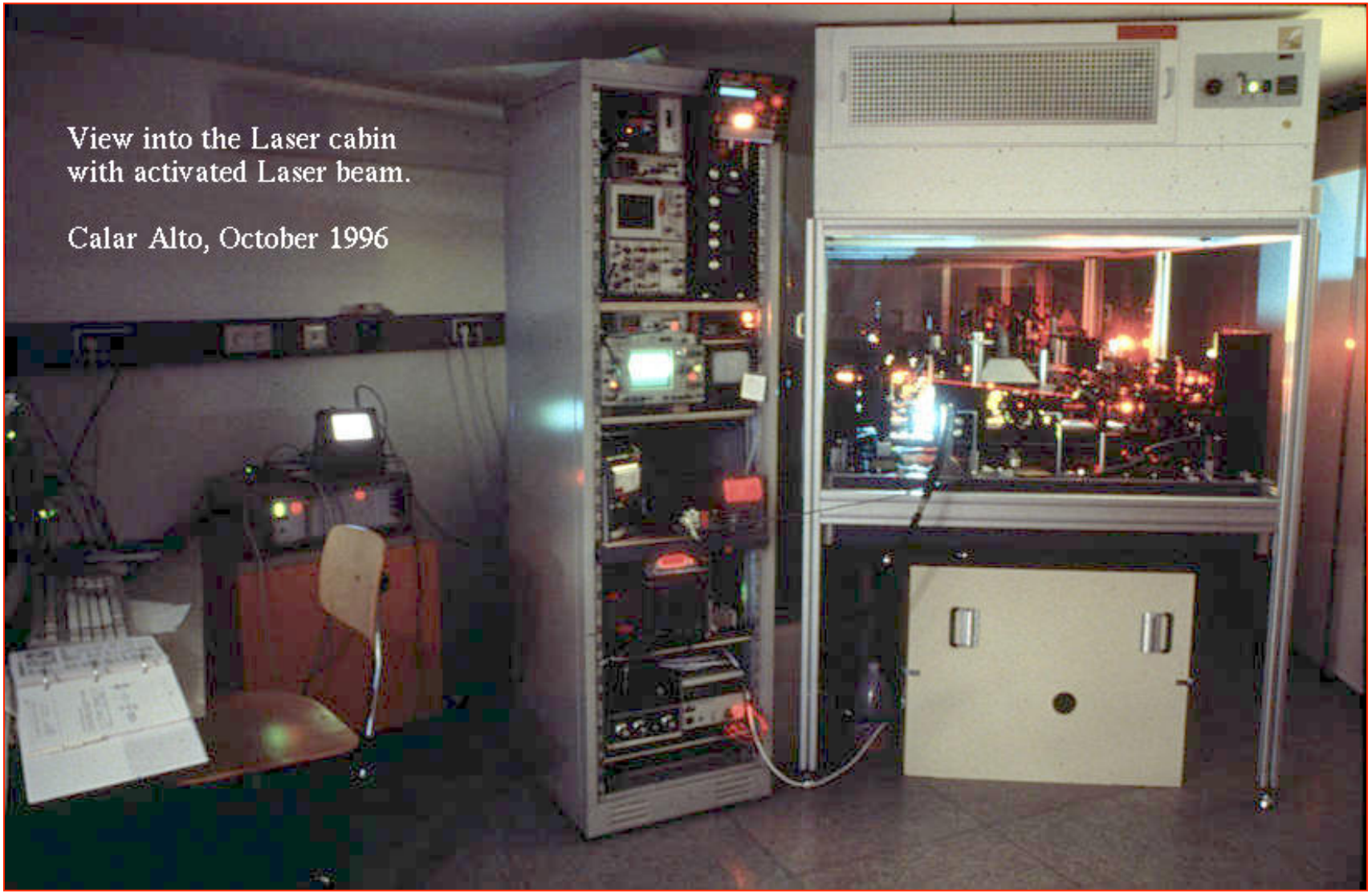
A dye laser…


View into the Laser cabin
with activated Laser beam.
Calar Alto, October 1996

A dye laser…


View into the Laser cabin
with activated Laser beam.
Calar Alto, October 1996

A dye laser…

Yes, the previous/current Laser exhibits some trouble in power/quality/reliability but the next one is great!

Let's try to summarize…

- The usable FoV to compensate ground layer can be huge…
- The usable FoV to compensate highest altitude layer can be significant large for larger telescopes
- LGSs will employ nevertheless a certain relatively large angle of the rays involved
- Why not to push for going natural…???

ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES
APRIL I 1999,
Astron. Astrophys. Suppl. Ser. **136**, 205–209 (1999)

No Laser Guide Stars for adaptive optics in giant telescopes?

R. Ragazzoni

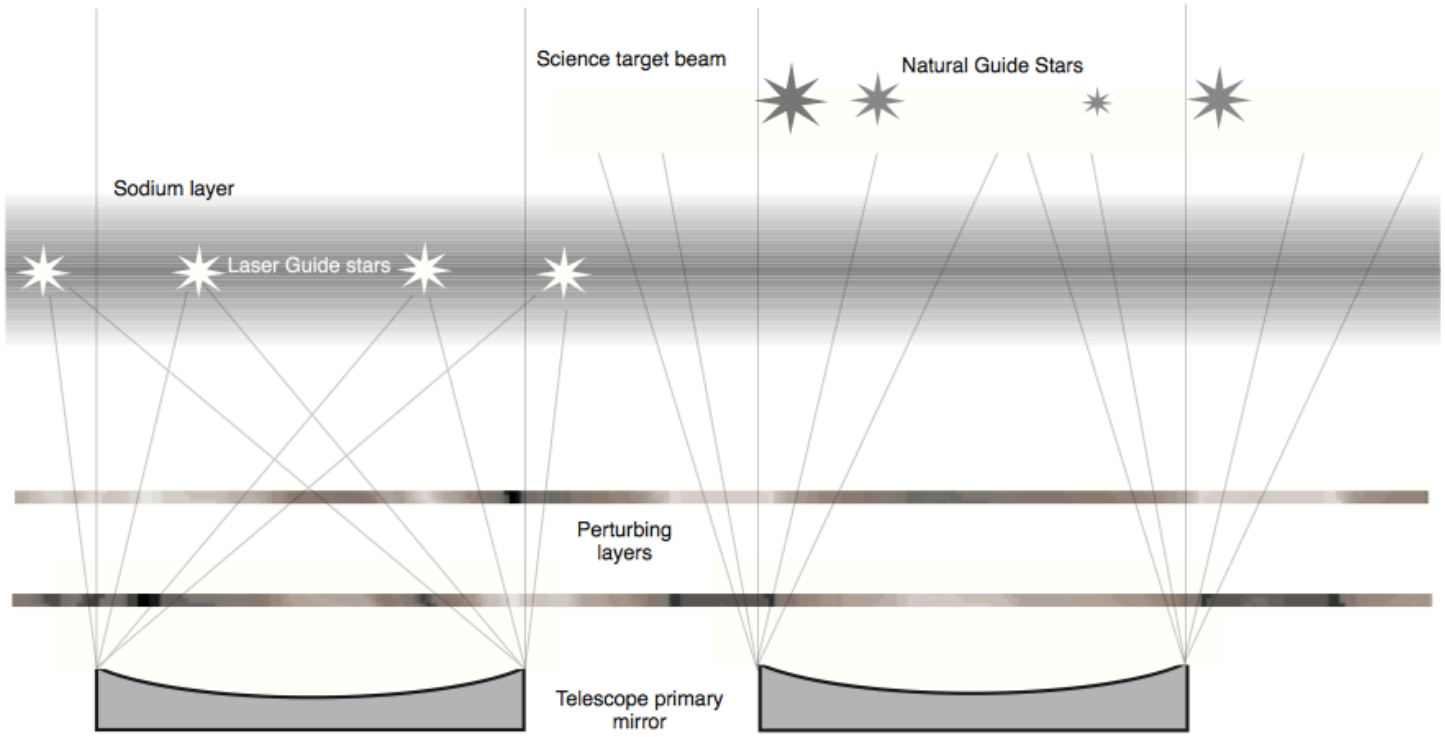
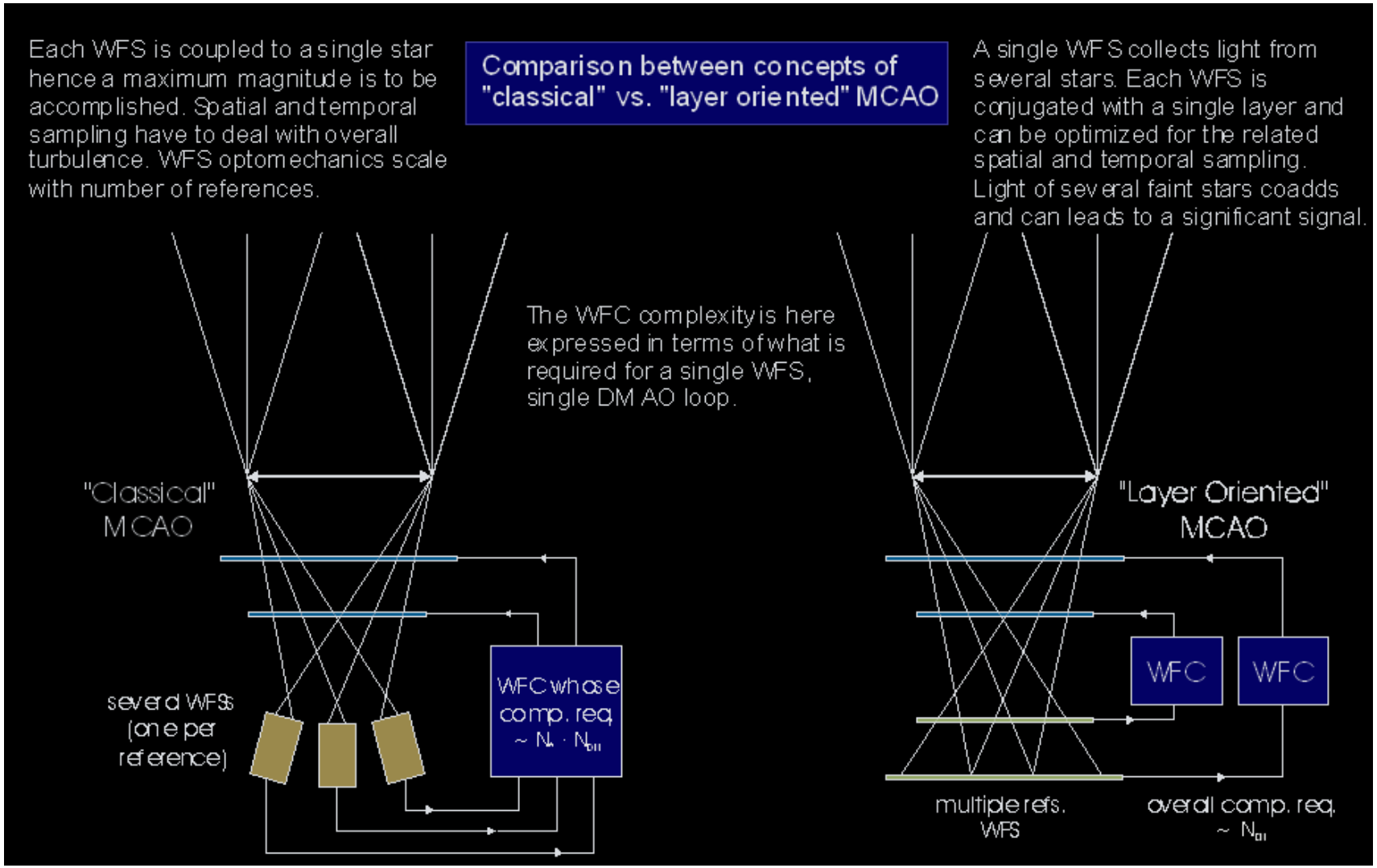


Fig. 1. In this schematic representation the LGS–based tomographic technique (left) is illustrated in a sectional view. In this case LGSs can be fired at some precise locations on the sky and some conical beams *explore* the various perturbing layers. Tilt is to be retrieved in some other way. On the right side the NGS–based case is briefly sketched: the stars have different brightness and are unevenly located on the sky. On the other hand the beams are cylindrical and tip–tilt is retained

The layer oriented



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ETTORE MAJORANA FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE

TO PAY A PERMANENT TRIBUTE TO GALILEO GALILEI, FOUNDER OF MODERN SCIENCE AND TO ENRICO FERMI, "THE ITALIAN NAVIGATOR", FATHER OF THE WEAK FORCES

STEEL

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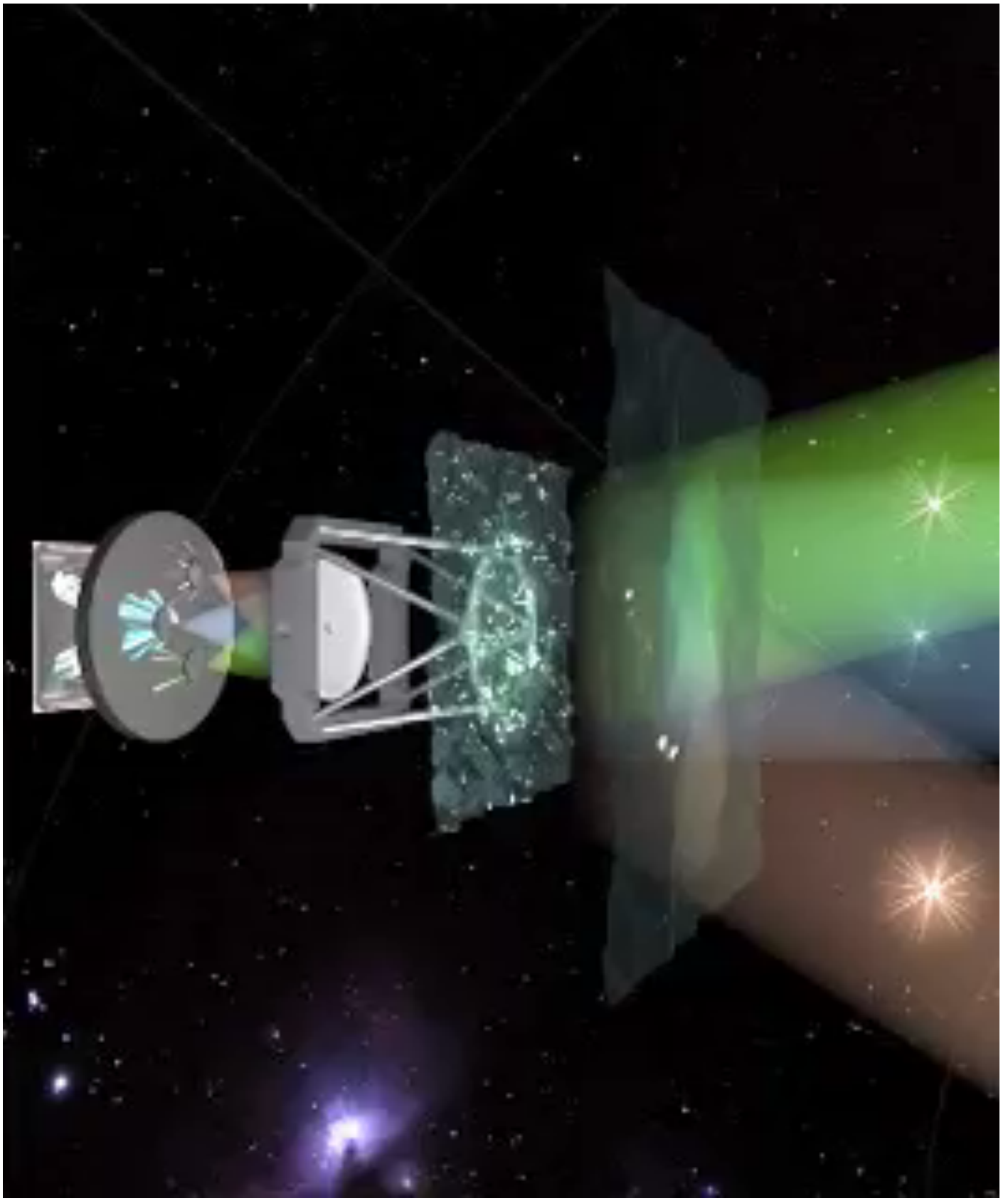
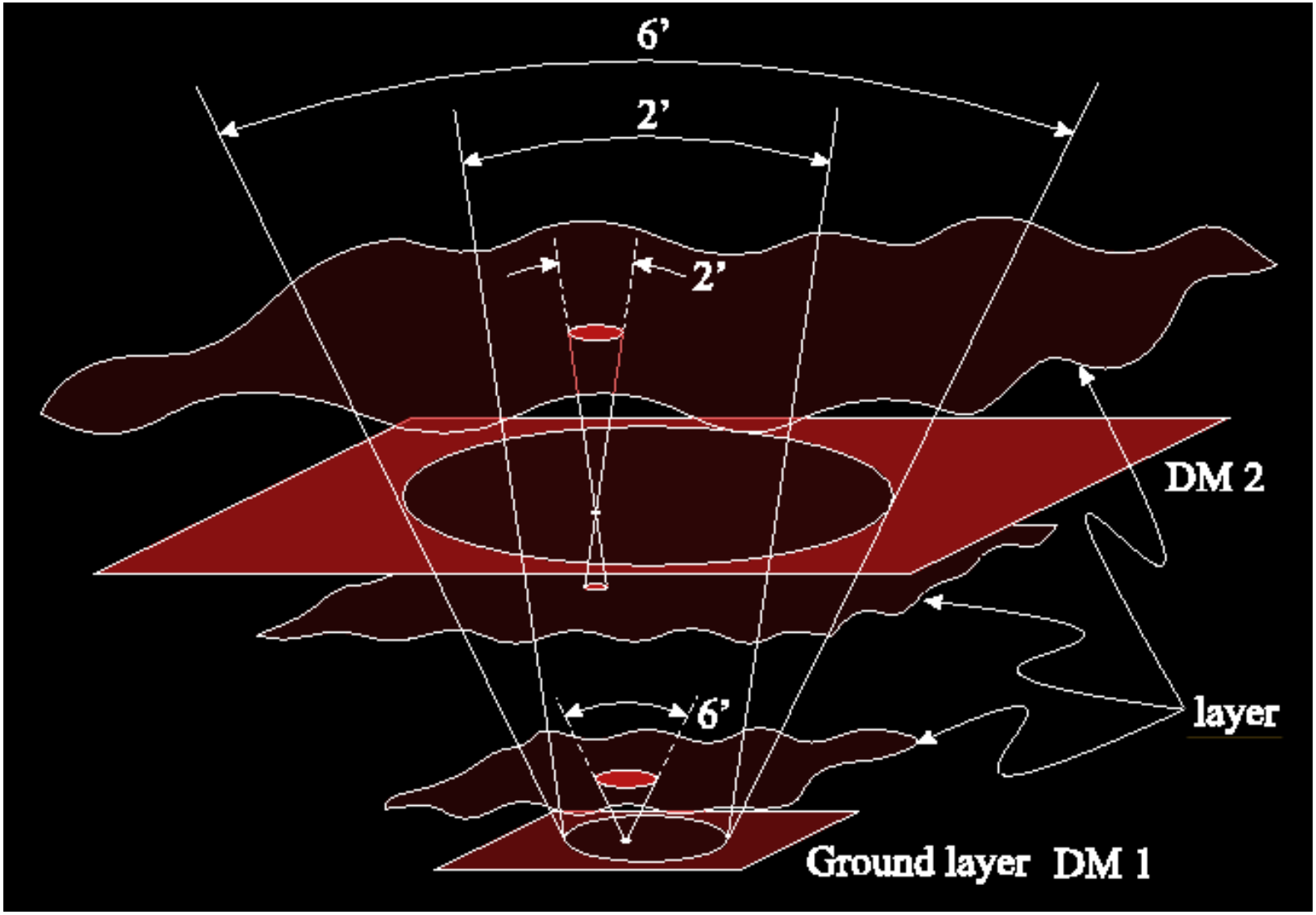
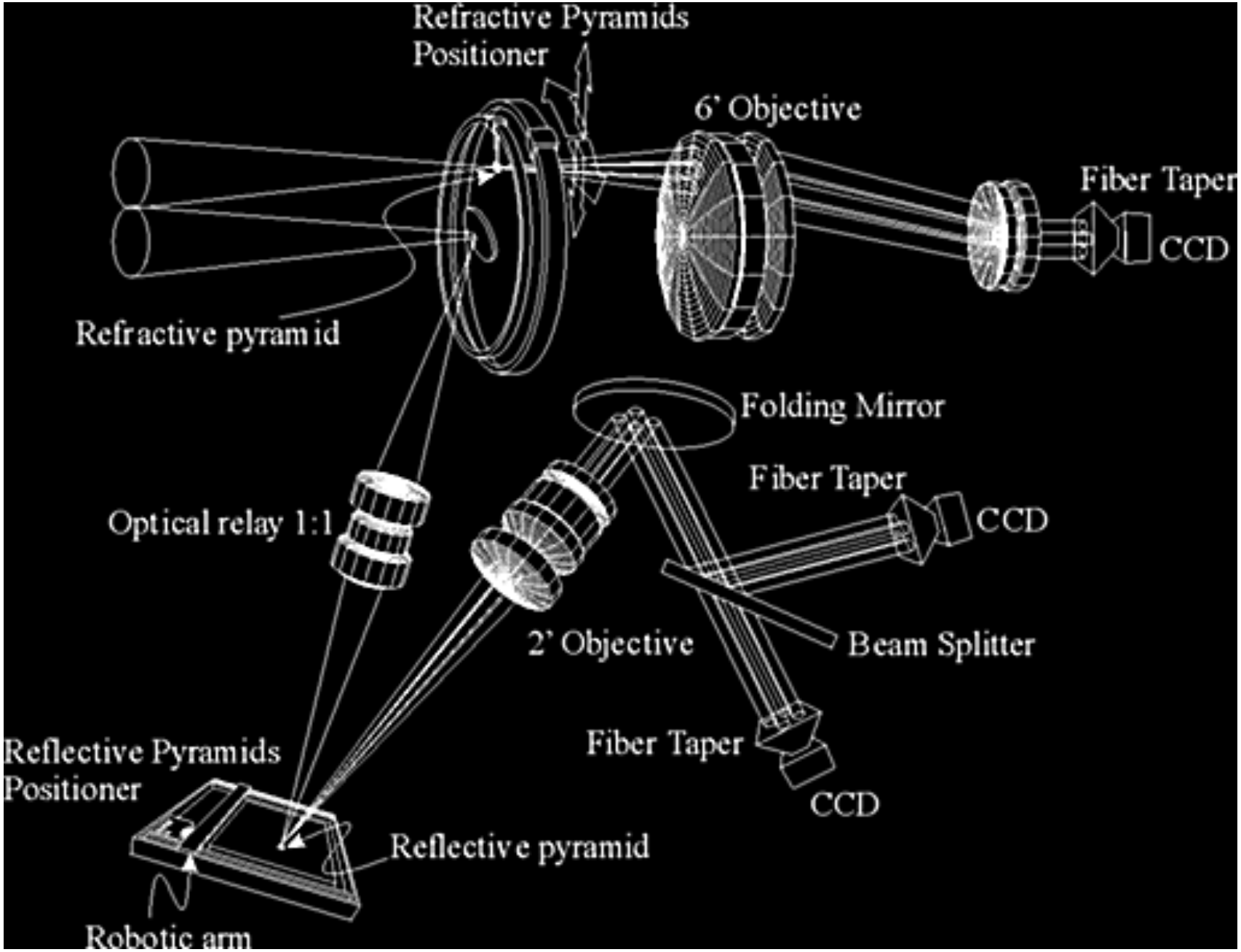


LO Multiple FoV concept





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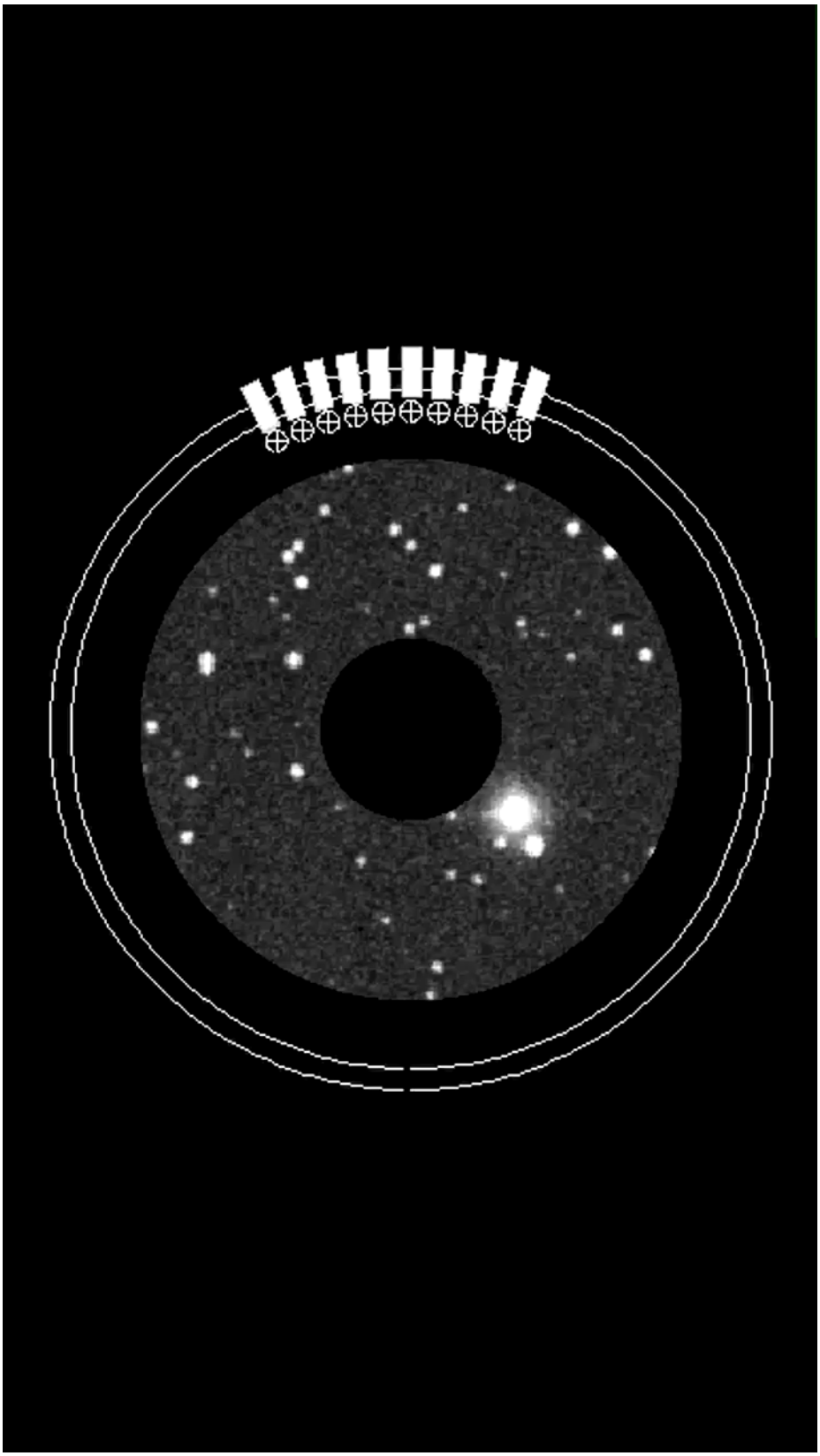

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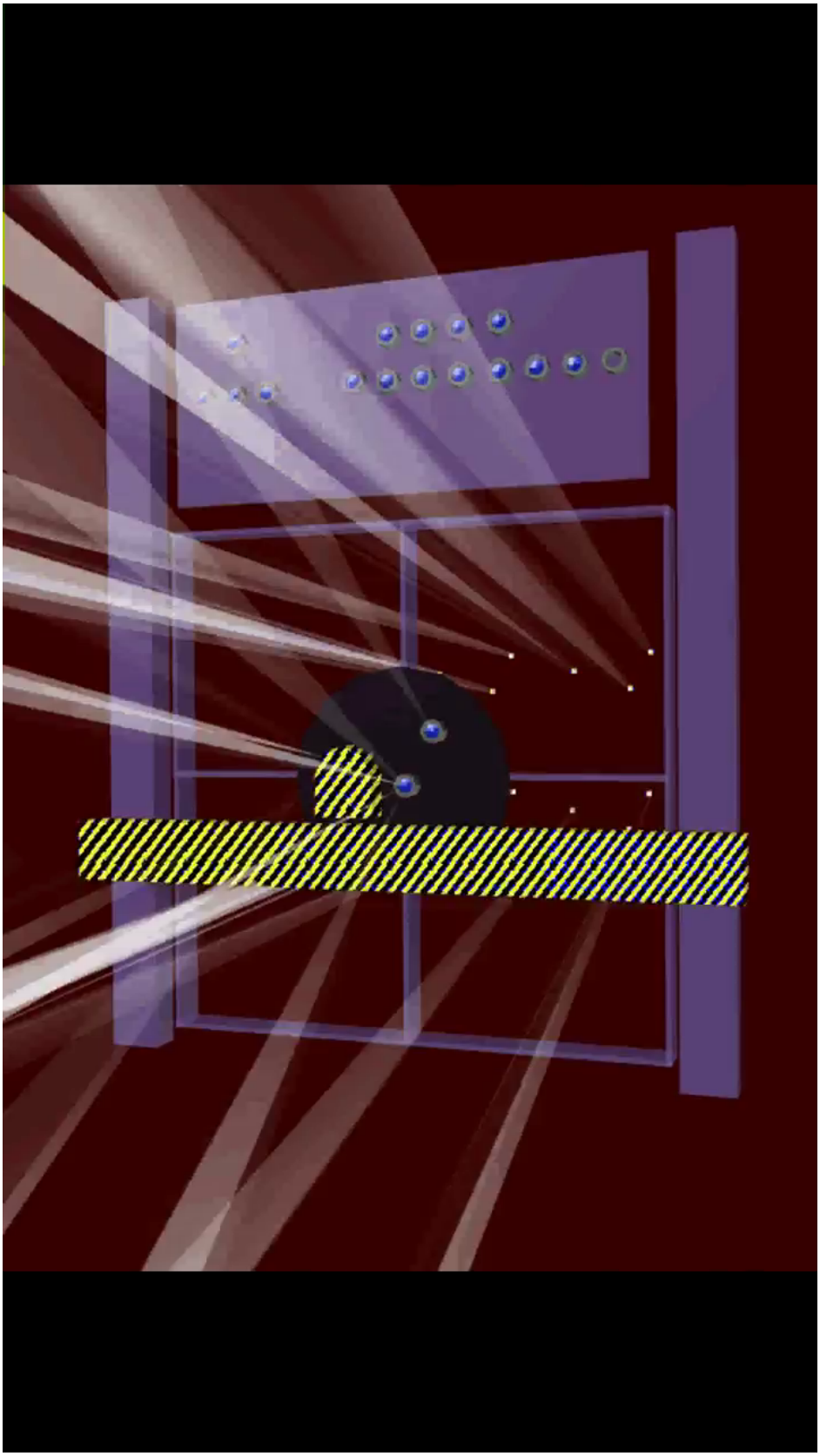


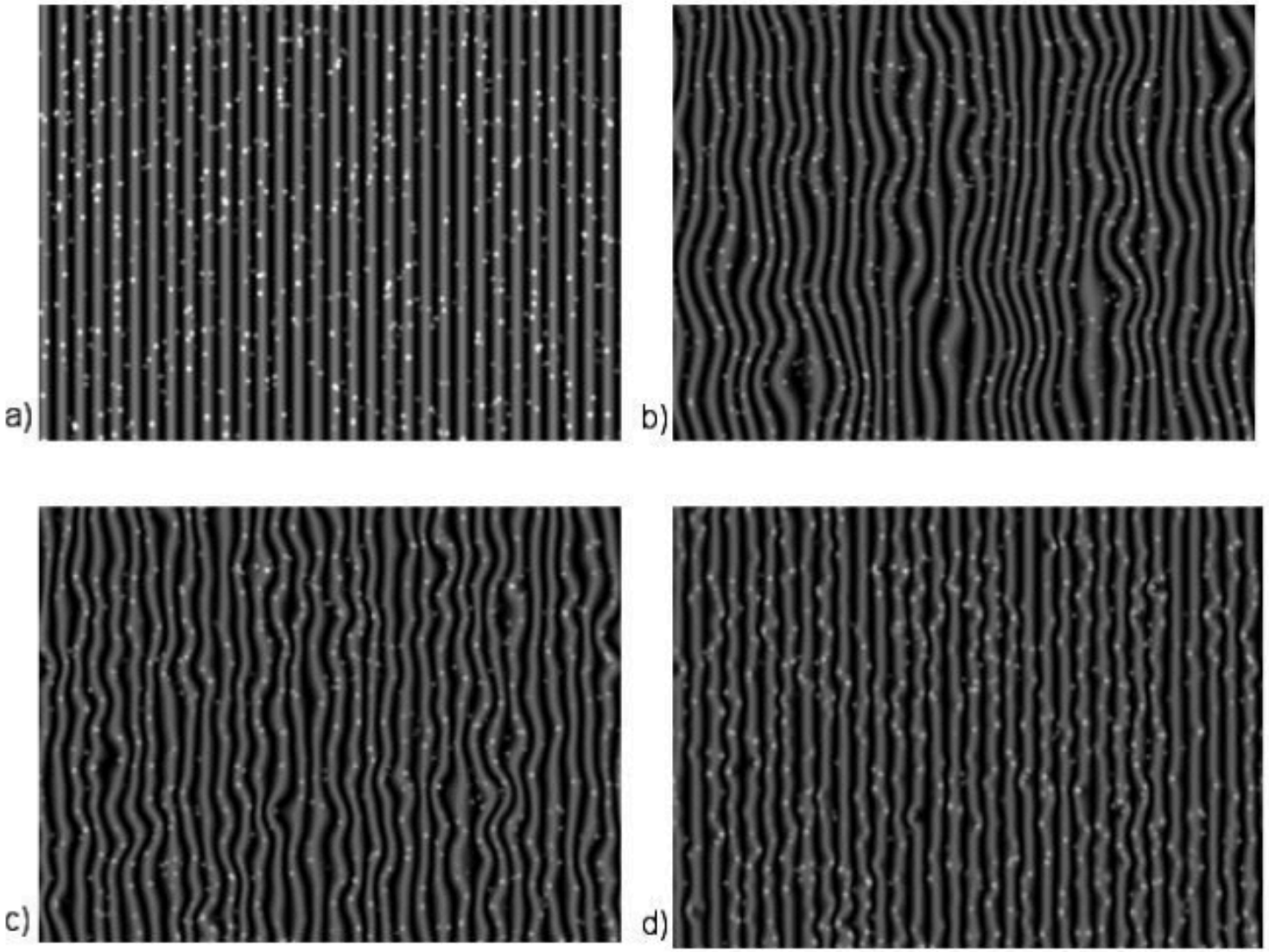
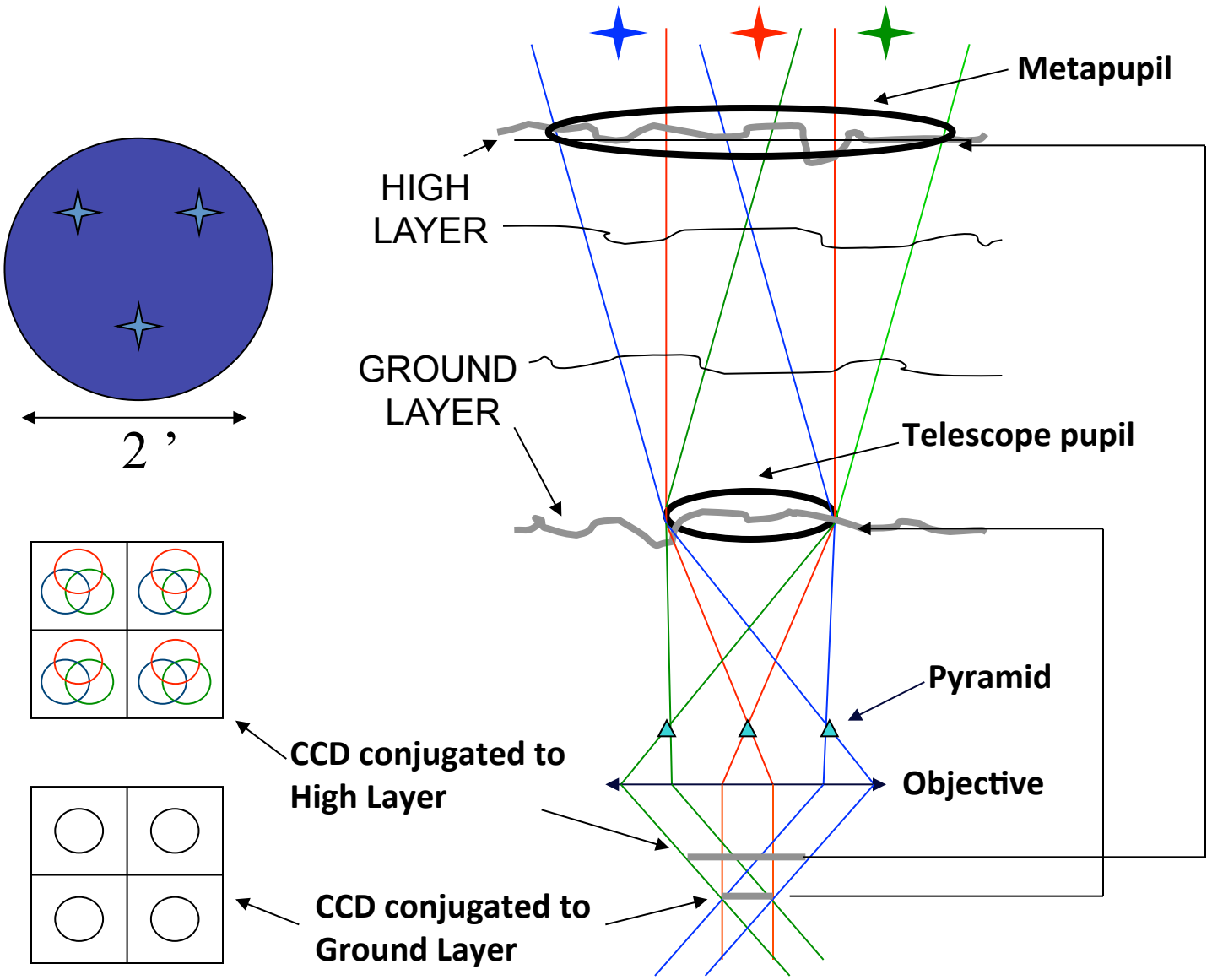


Fig. 4. A star-field is shown superimposed on a sinusoidal pattern described in the text for whole star-field wavefront sensing. In a) the pattern is straight. The signal strength is small but does not depends upon the position of the stars inside the pattern. From b) to d) an increasing tuning of the distortion will makes the signal stronger and stronger, but requiring more and more precise alignment with the star-field.

WFS conjugated to High Layer



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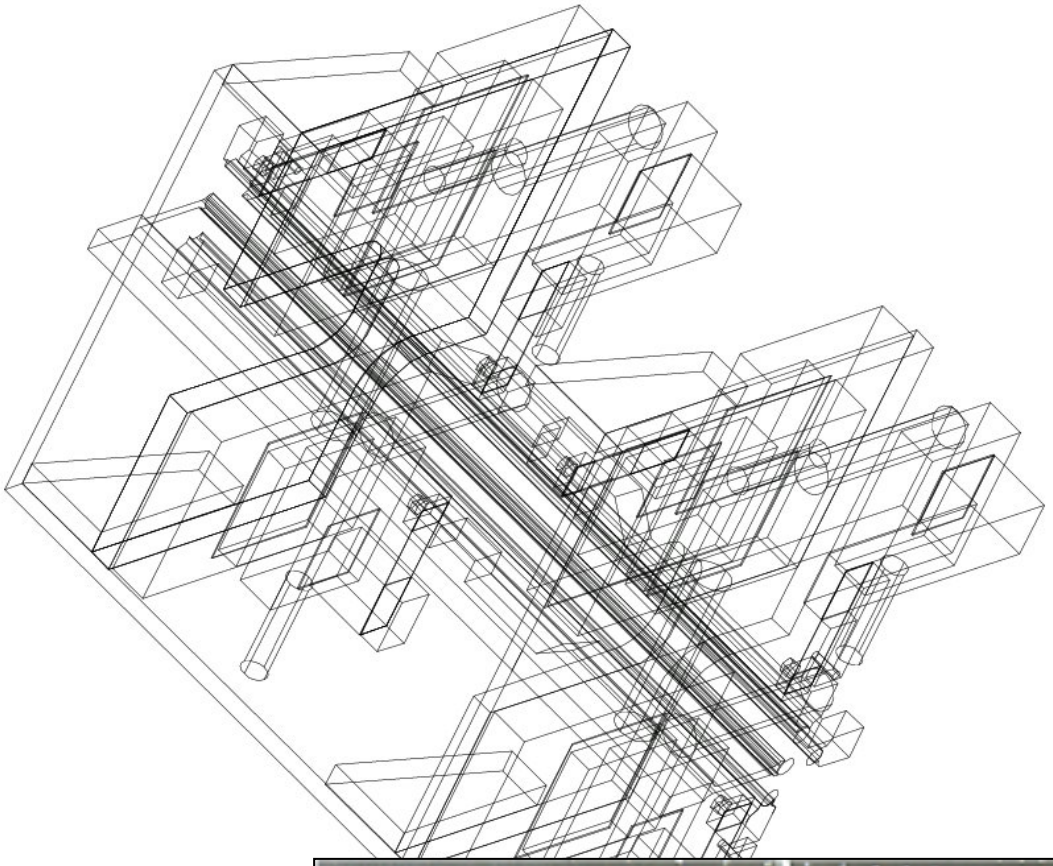

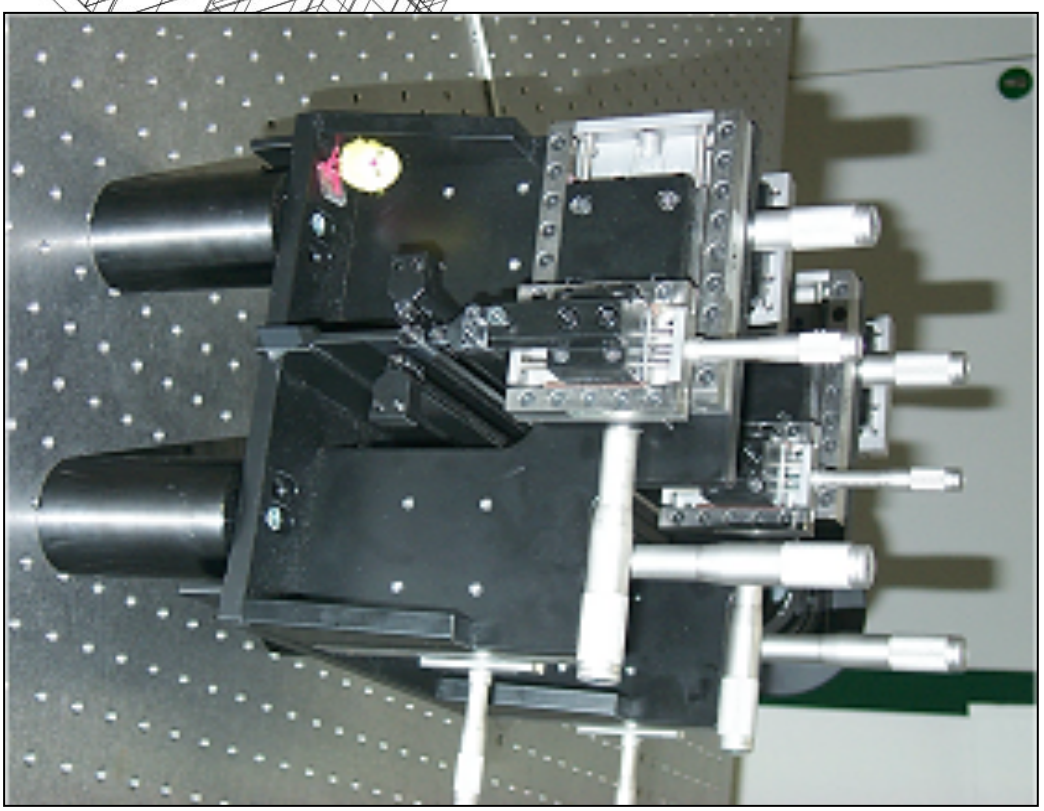

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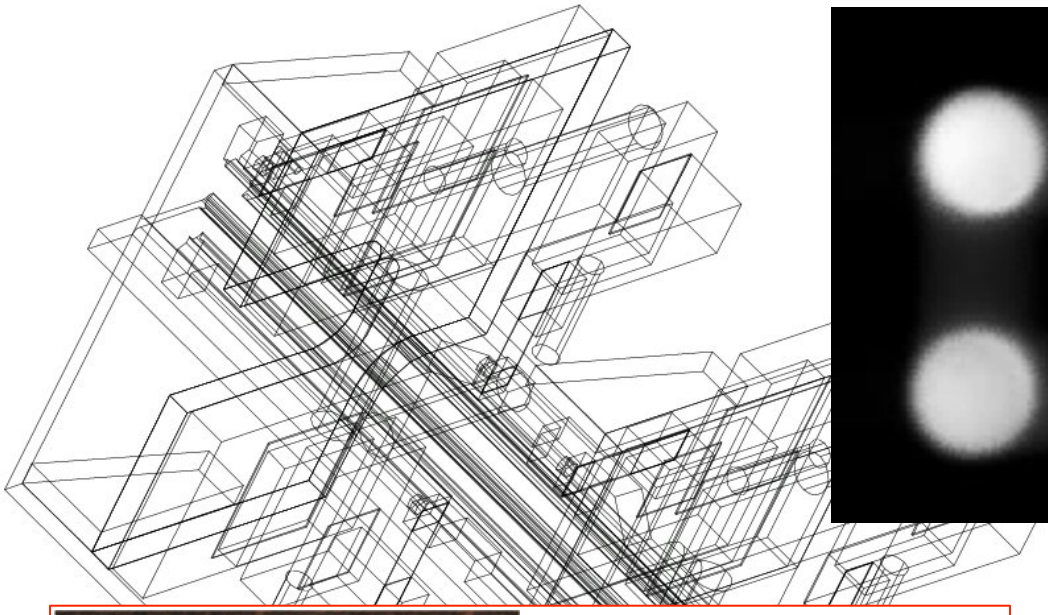
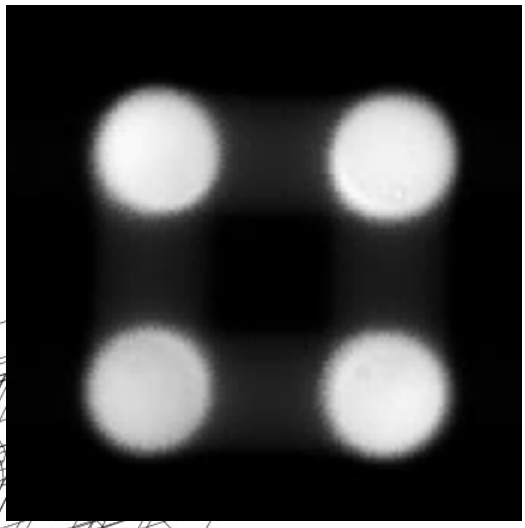
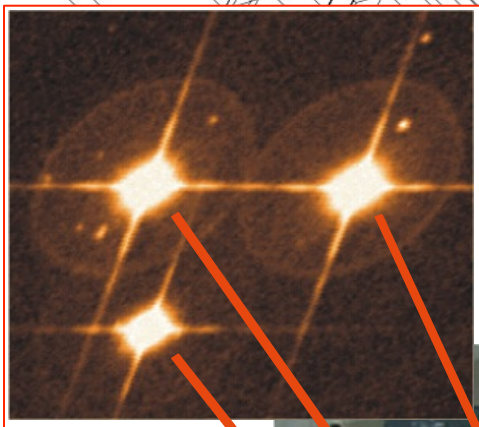
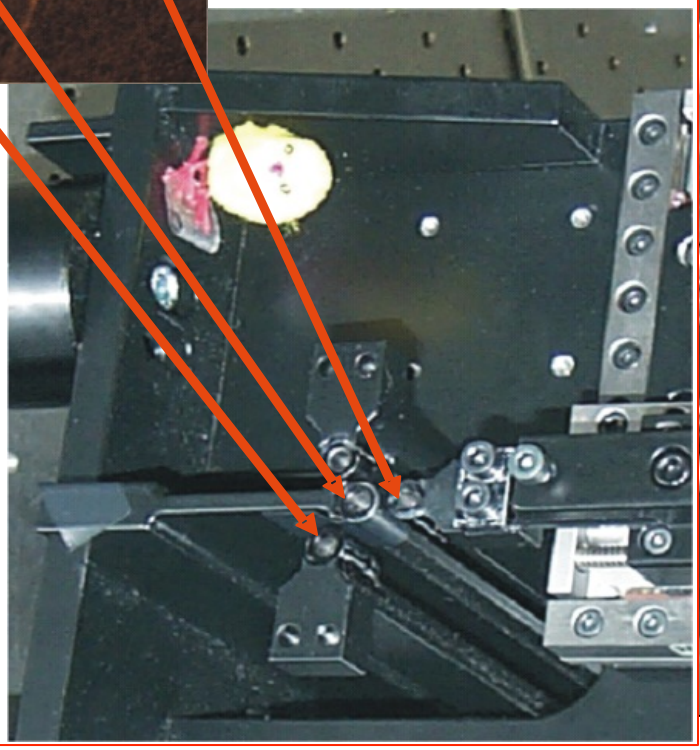
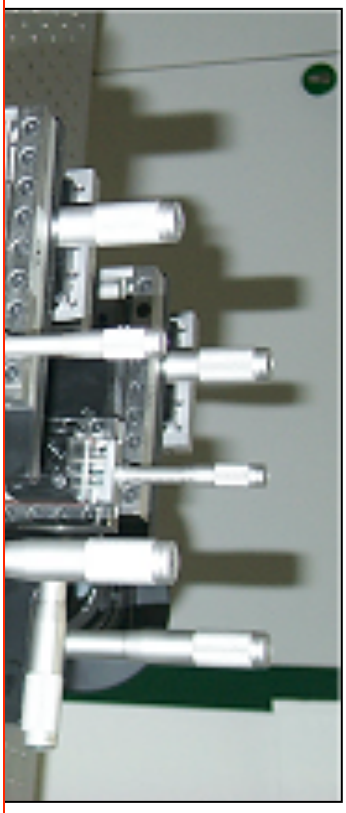






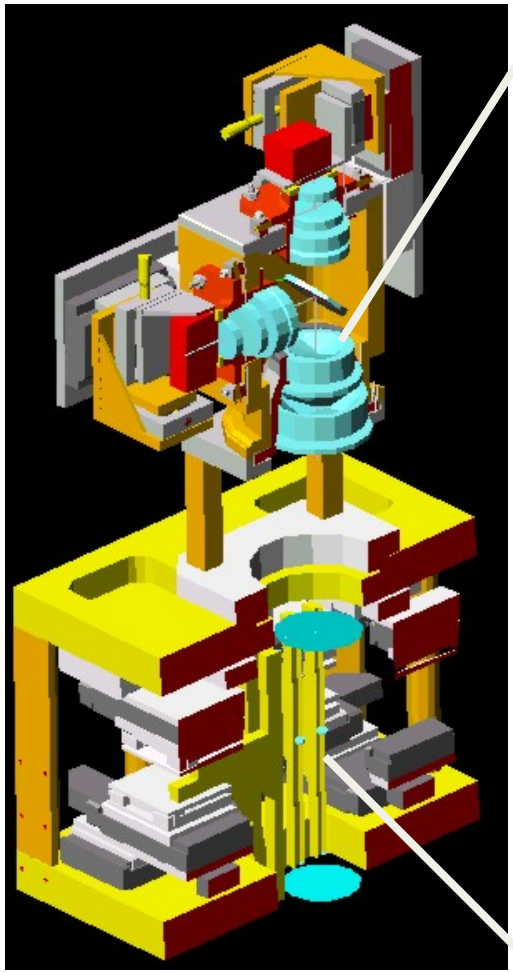


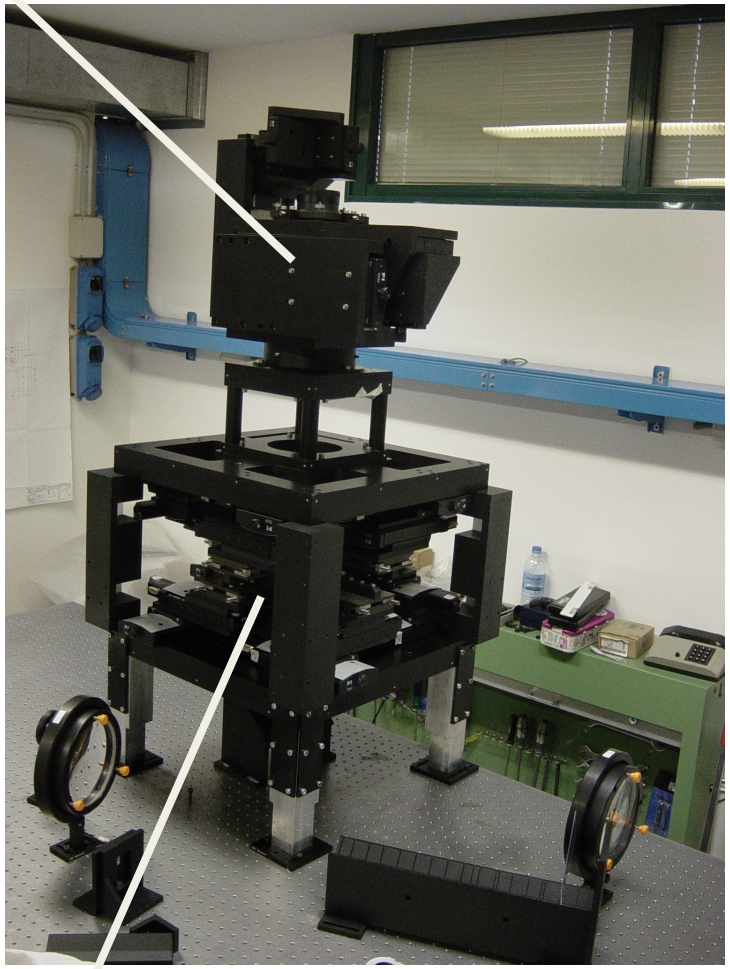


From drawings…

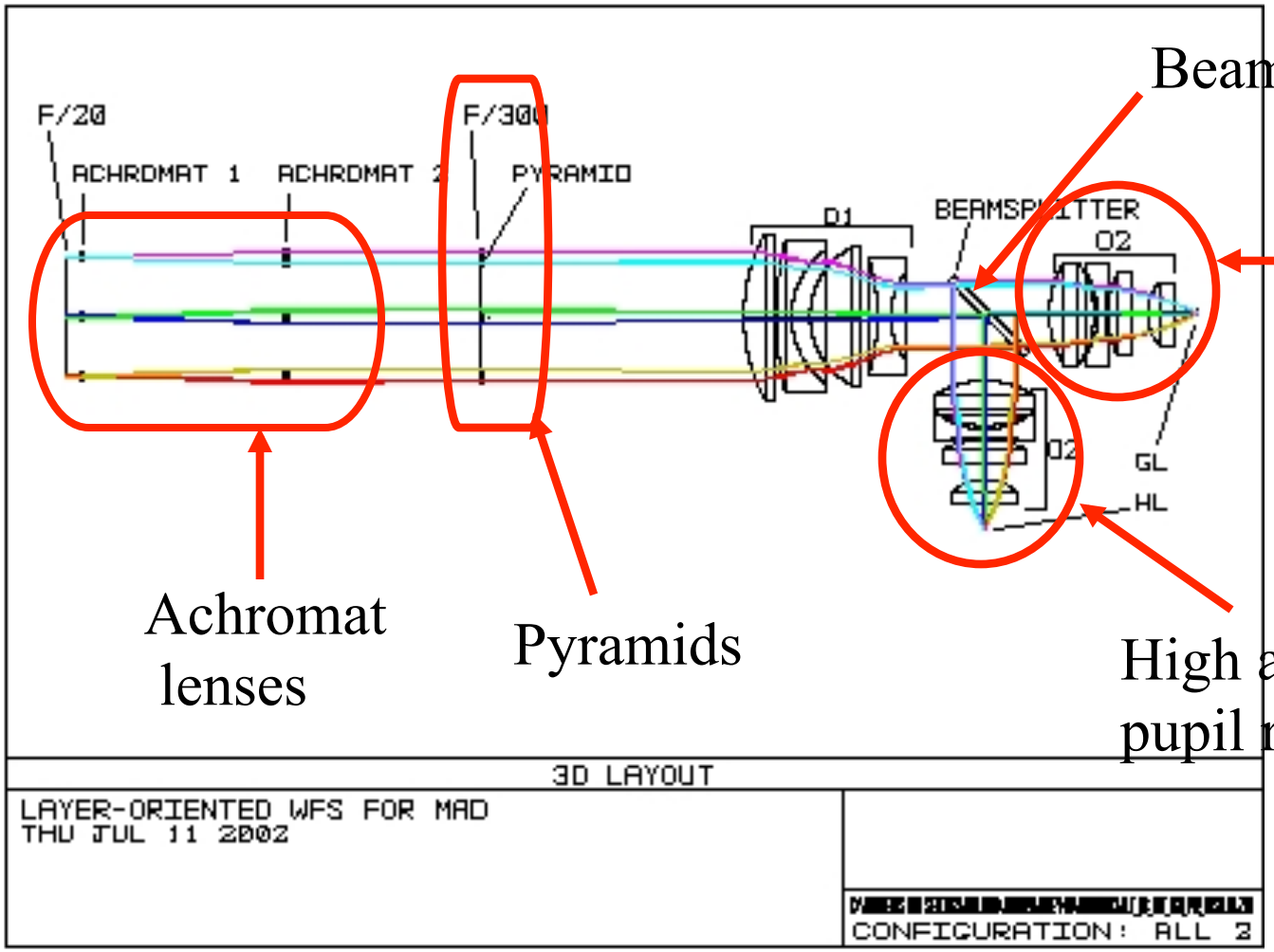
Pupil objectives

…to metal!





Stars enlargers



Beam splitter

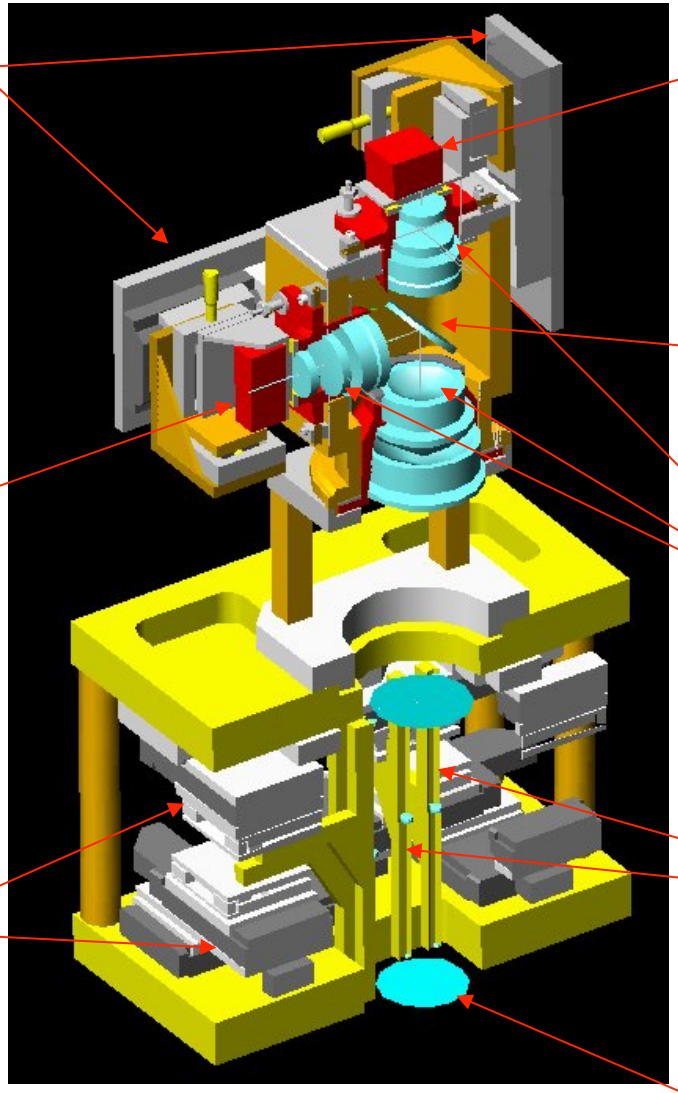
Ground pupil re-imager

Achromat lenses

Pyramids

High altitude pupil re-imager

Mechanical Design



Focusing mechanisms

CCD conjugated to the ground layer

Beam splitter

CCD conjugated to the high altitude layer

Pupil re-imaging optics

XY stages for Stars positioners

Star enlargers

Entrance focal plane

6 nights/7 science papers

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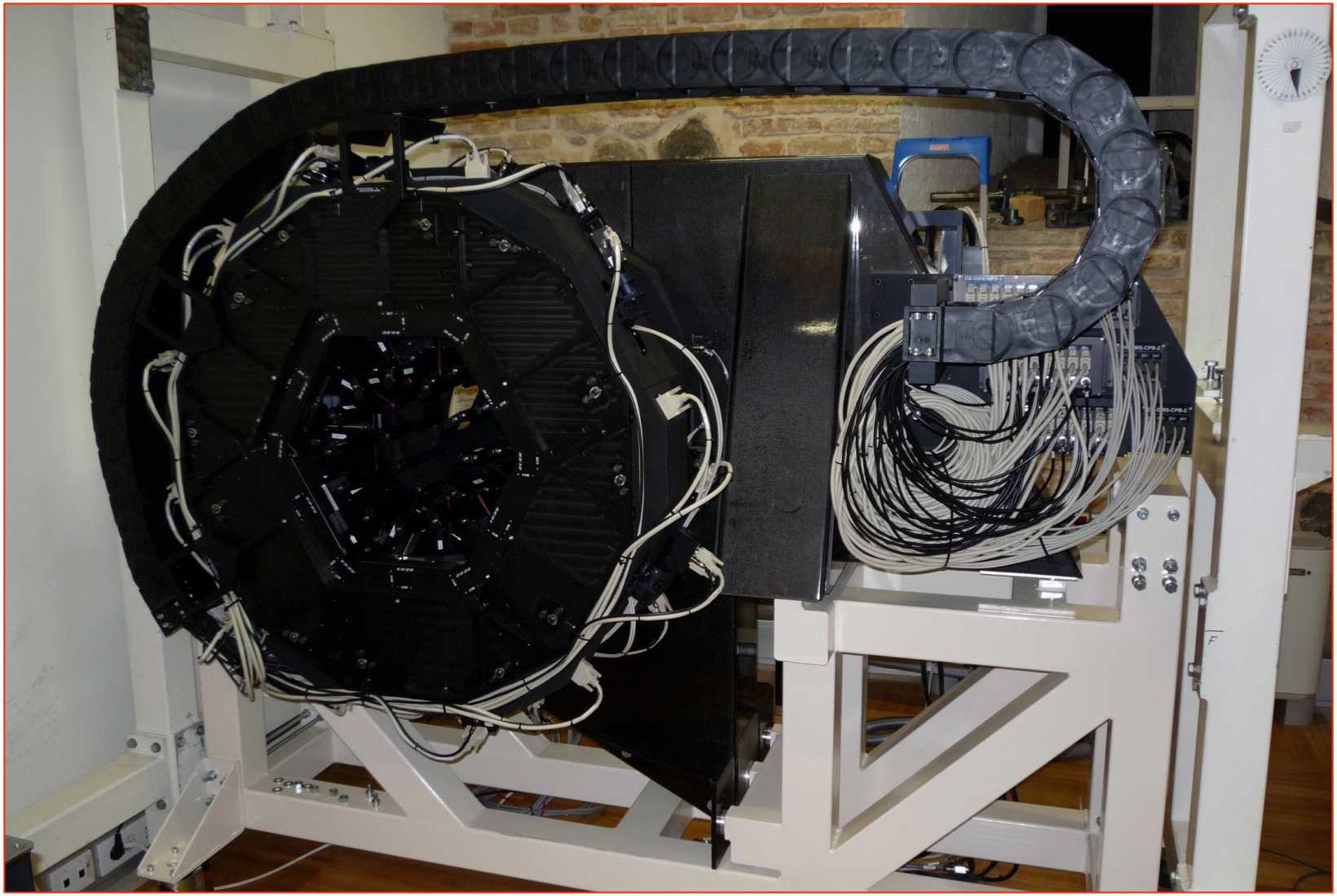
6 arcmin 12 NGS



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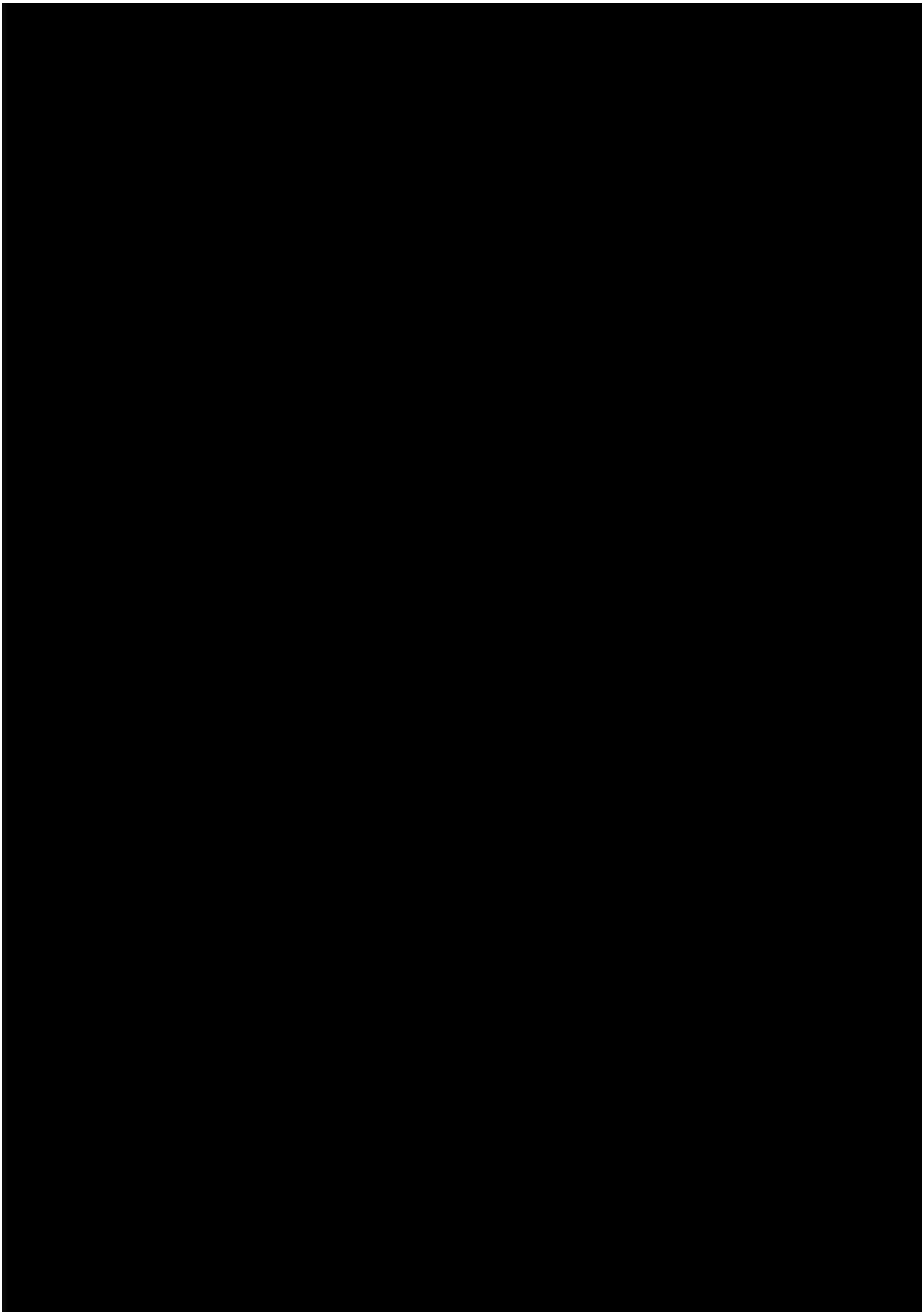

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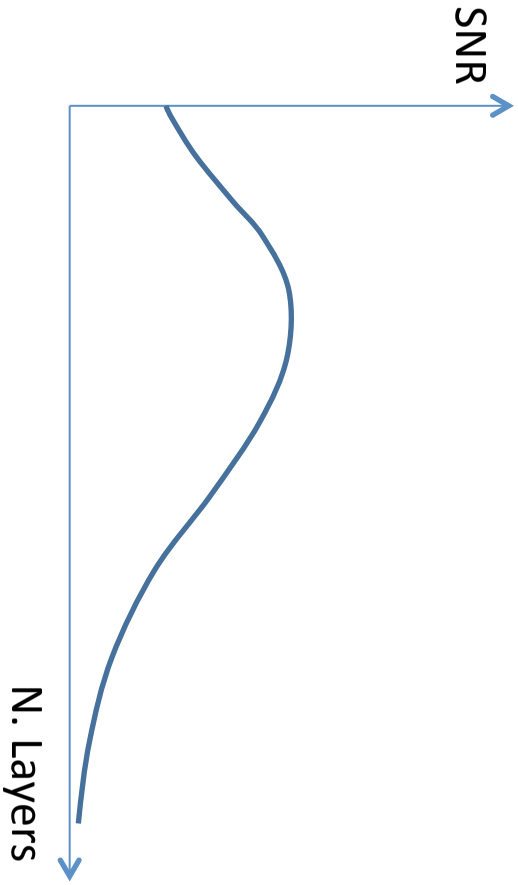
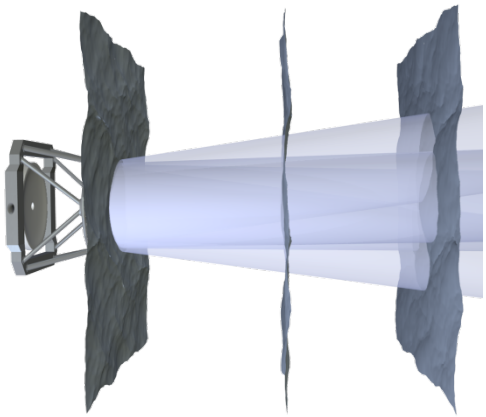
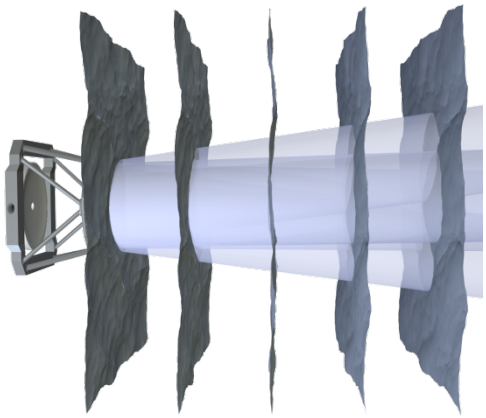
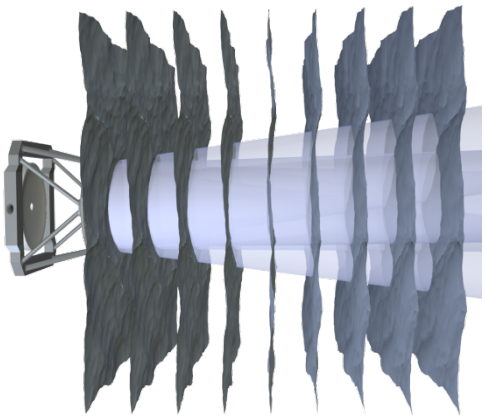
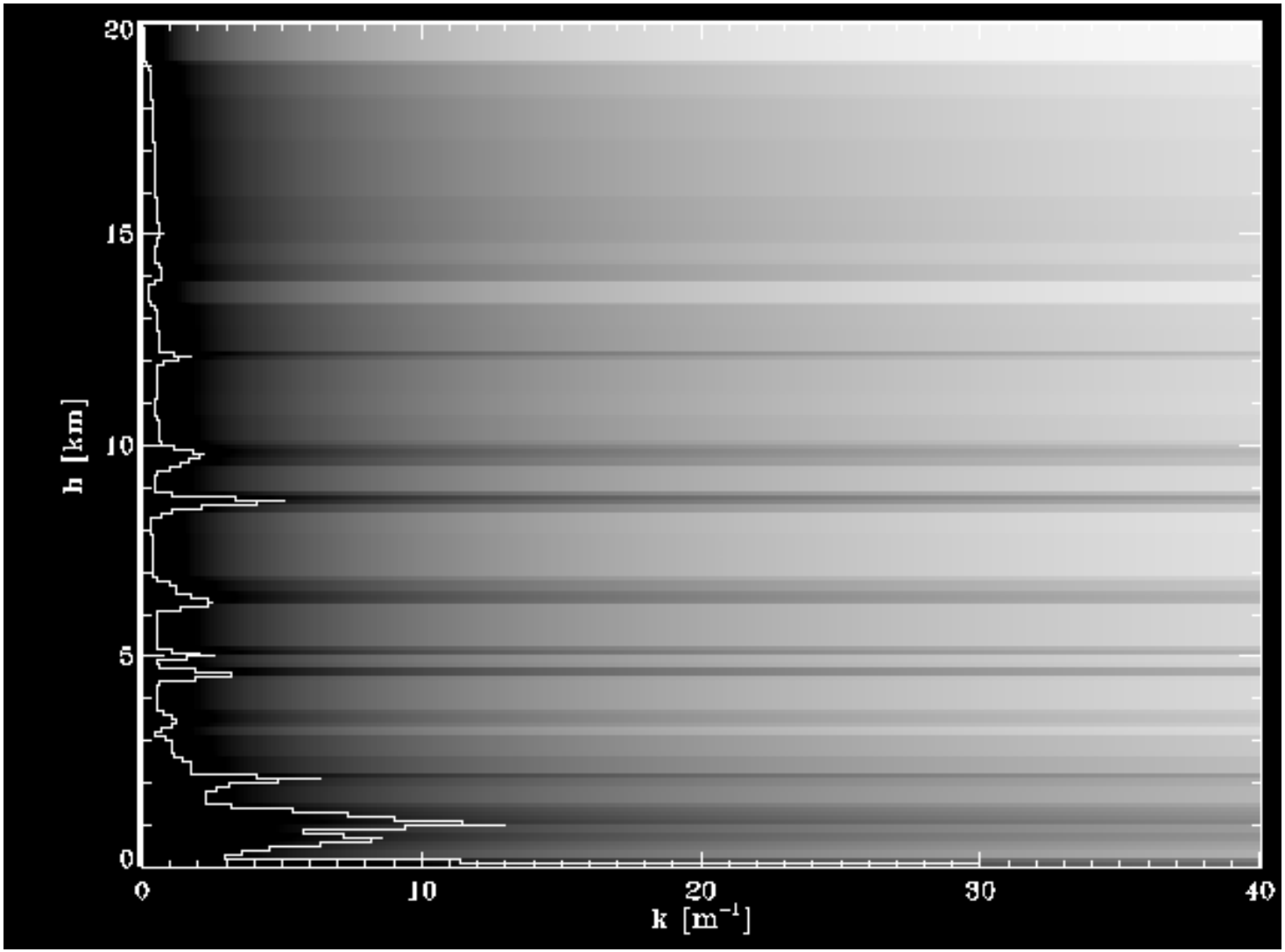








A 2D plot of turbulence



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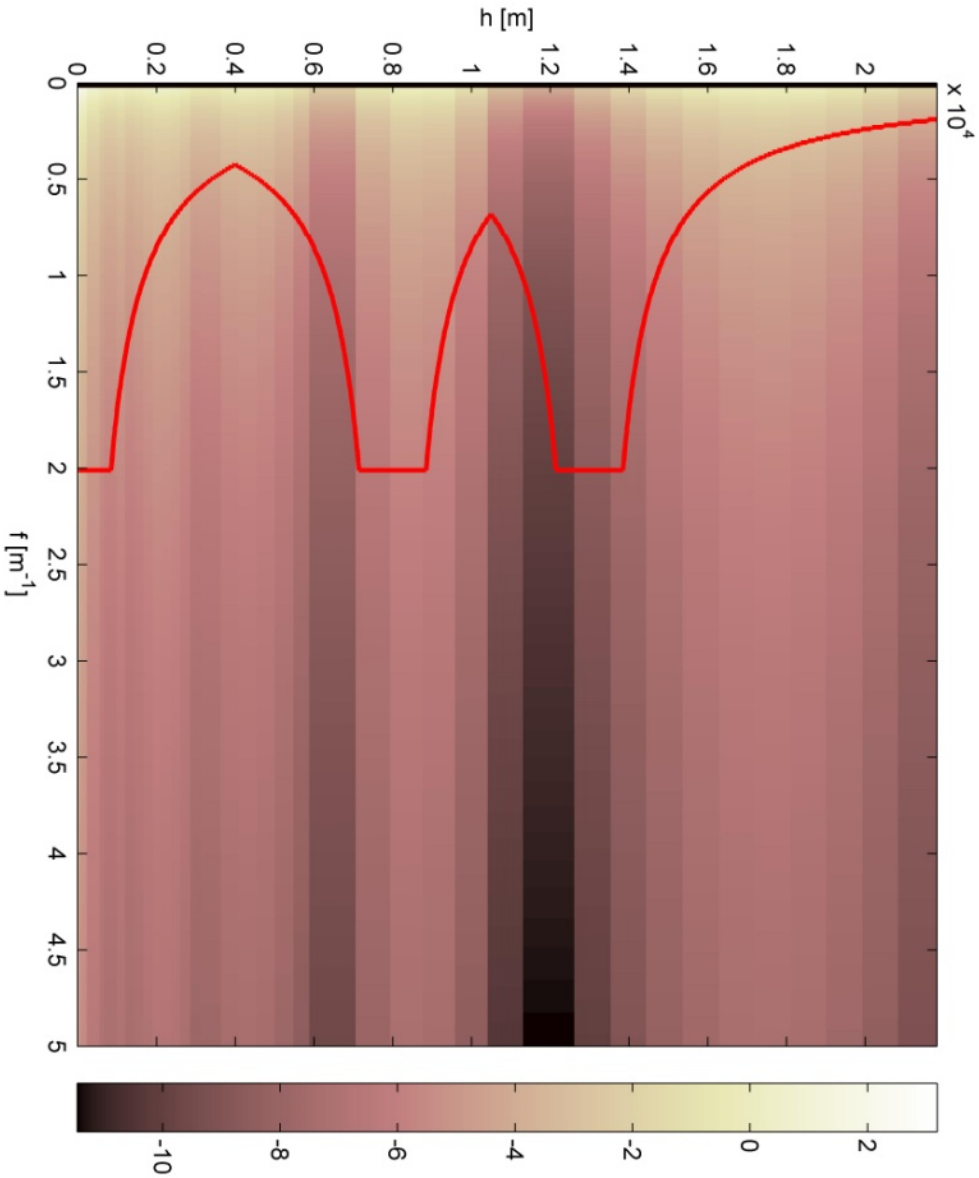
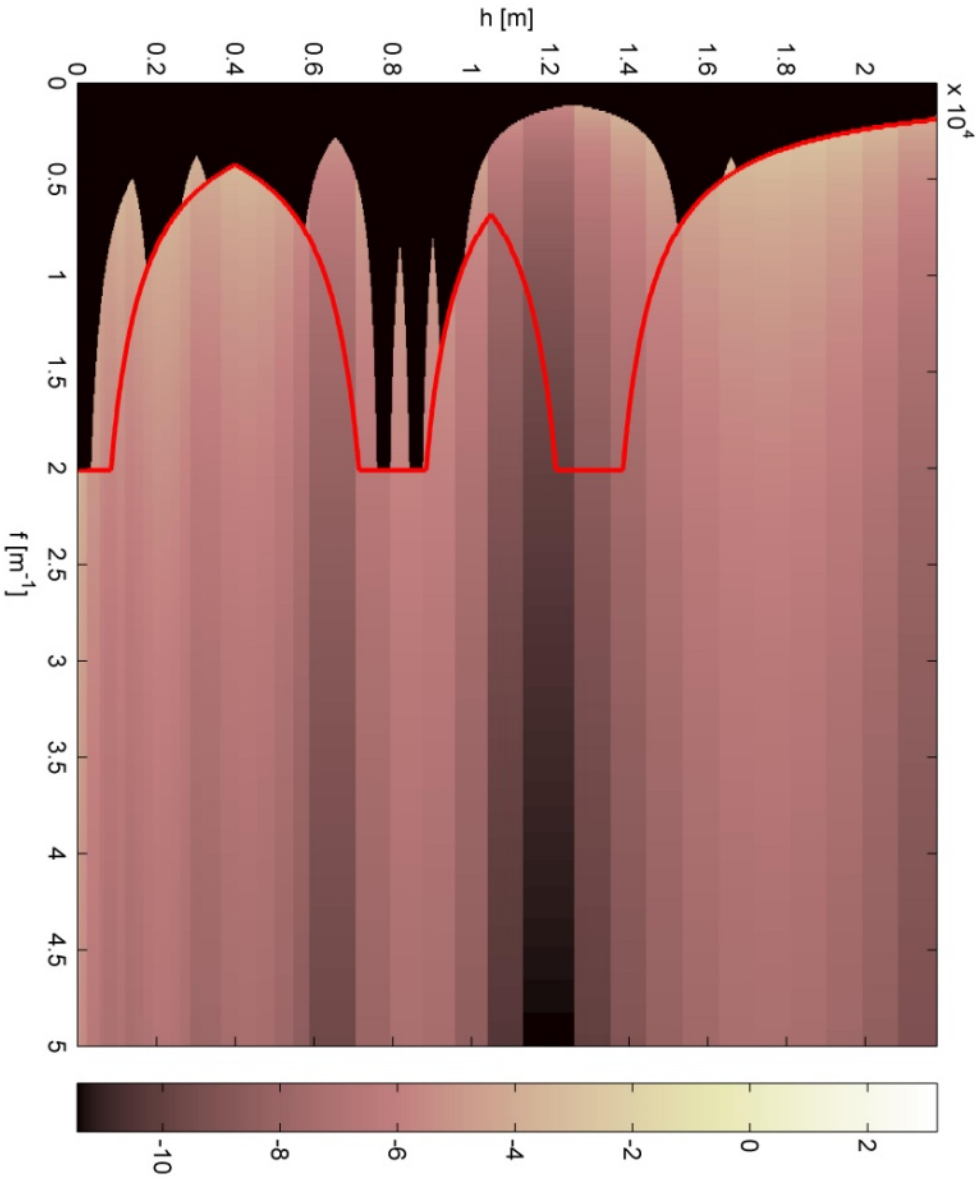
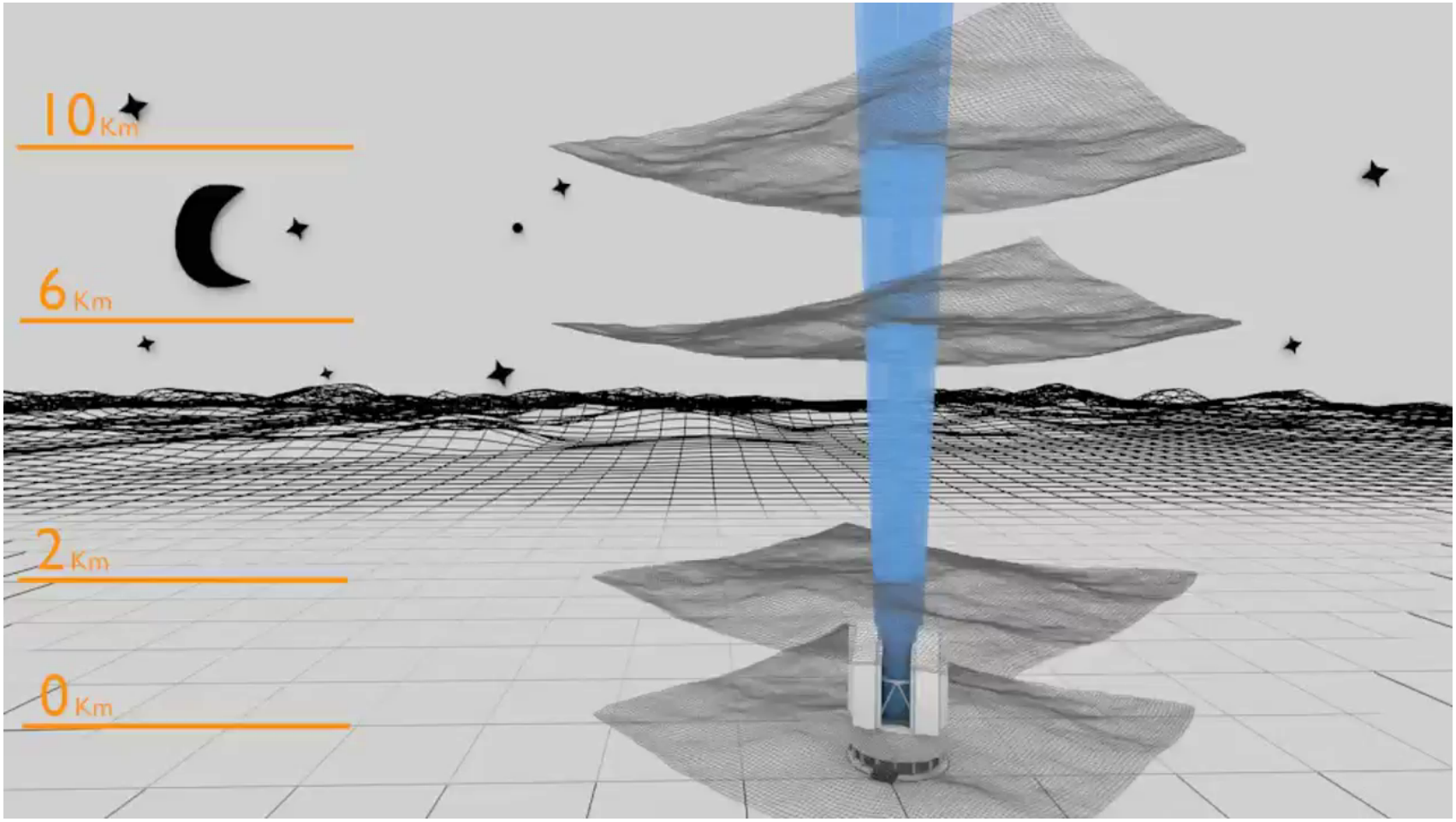

h [m]
x 10^4
f [m^-1]


h [m]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
x 10^4
f [m^-1]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
-10
-8
-6
-4
-2
0
2

Wider Field of View



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Beyond…

Just 4 things…

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Beyond…

1. Are we at the ultimate sensitivity in WFS…???

- *Remember heading to the vis means even less photons per subap per int. time (even with LGSs)…*

Beyond…

1. Are we at the ultimate sensitivity in WFS…???

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Do we even need actual photons…??

LGSs are so different from NGSs that still very few has been done (remember the z-invariant?)

Beyond…

1. Are we at the ultimate sensitivity in WFS…???

- *Remember heading to the vis means even less photons per subap per int. time (even with LGSs)…*

2. Can we take advantage of the S≈1 era…???

- *A number of techniques and sensing approaches discarded because of the "low Strehl"…*

Beyond…

1. Are we at the ultimate sensitivity in WFS…???
- *Remember heading to the vis means even less photons per subap per int. time (even with LGSs)…*
2. Can we take advantage of the S≈1 era…???
- *A number of techniques and sensing approaches discarded because of the "low Strehl"…*

Let's try to be smart, or even Smartt…

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Beyond…

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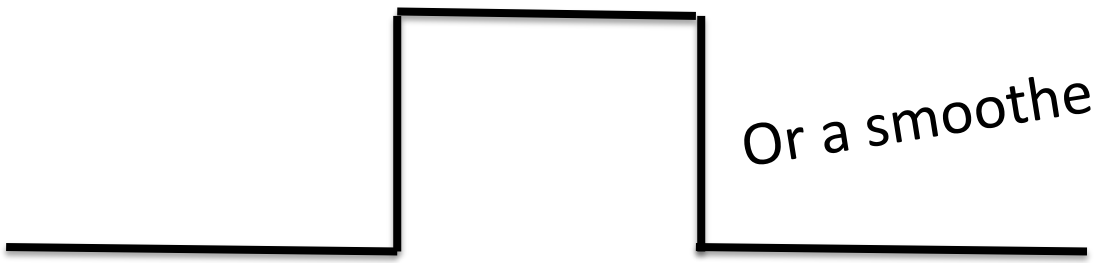
- *Remember heading to the vis means even less photons per subap per int. time (even with LGSs)…*
2. Can we take advantage of the S≈1 era…???
- *A number of techniques and sensing approaches discarded because of the "low Strehl"…*
3. I want a WFS that makes hat larger than λ/D…!!!
- *Spectroscopist would love that…!!! – Engineering partial AO*



Or a smoother, easy to handle PSF…

Beyond…

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4. I want a refractive wavefront corrector…!!!
- Designing new instruments and retrofitting existing ones so easy that this would made a new era

Beyond…

1. Are we at the ultimate sensitivity in WFS…???
   - *Remember heading to the vis means even less photons per subap per int. time (even with LGSs)*
2. C…
   - …*ded*
3. …akes flat larger than λ/D…!!!
   - *Spectroscopist would love that…!!! – Engineering partial AO*
4. I want a refractive wavefront corrector…!!!
   - Designing new instruments and retrofitting existing ones so easy that this would made a new era

Even voice coil acts. technology, that is now baseline even for ESO was just a Piero's (et al.) dream a decade ago

Beyond…

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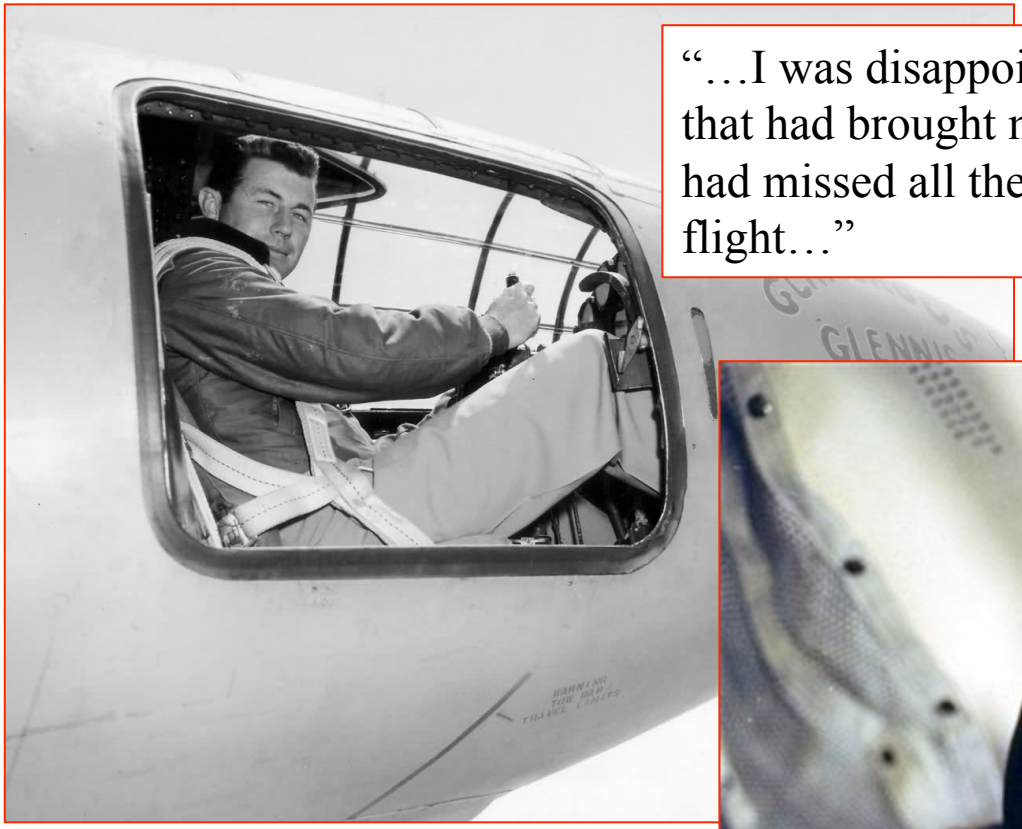
Otctober 1947 (Neil is 17 years old)



Chuck Yeager

"…I was disappointed by the wrinkle in history that had brought me along one generation late. I had missed all the great times and adventures in flight…"

Neil Armstrong July 1969

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Thanks for your patience