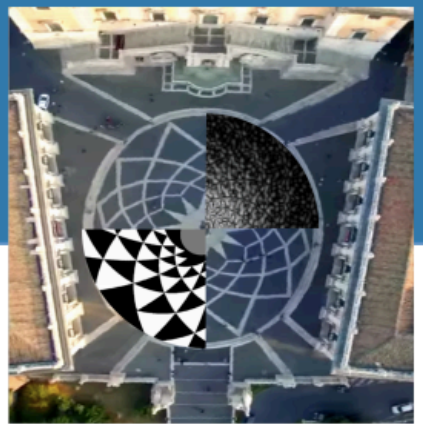
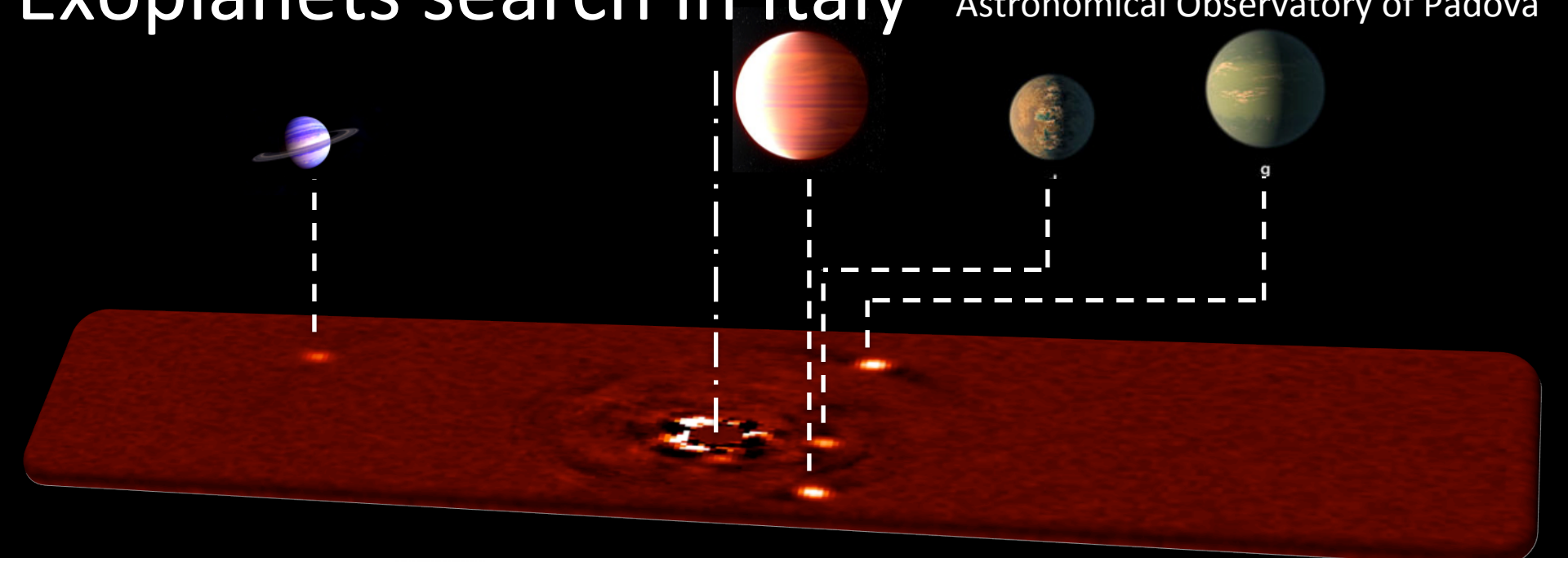


FINDING EARTH TWINS WITHIN 10PC

A conference devoted to developing the Italian involvement in TOLIMAN

Pushing tech developmentes for Exoplanets search in Italy

Roberto Ragazzoni
INAF
Astronomical Observatory of Padova



BREAKTHROUGH INITIATIVES

agenzia spaziale italiana

INAF ISTITUTO NAZIONALE DI ASTROFISICA

FRONTIERA

19-20 | NOV | 18
ASI Headquarters
Via del Politecnico snc, Rome
Sala Cassini


Where I work
(Padova – Italy)
A multiple mirror
(ground based) telescope


Me
Some of the planets
we are looking for


Padova
Rome


Padova
Rome
Ground
Space

Discovery

Characterization

Ground

Space

Discovery

Characterization

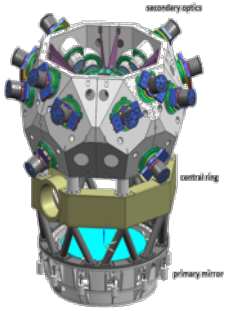
Padova

Rome

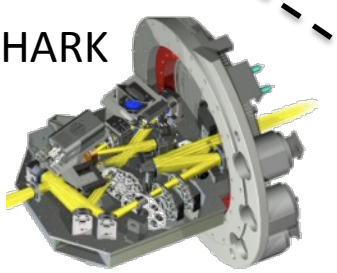
Ground

Space

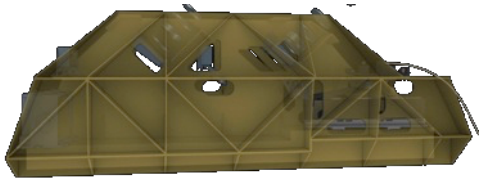
FLY-EYE



AO-SHARK



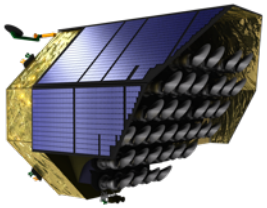
ESPRESSO



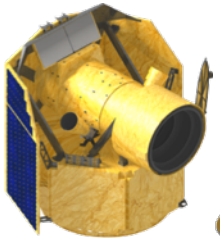
Discovery

Characterization

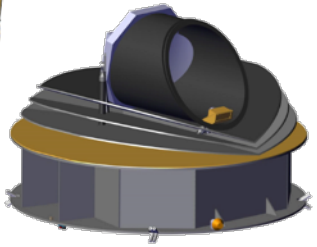
PLATO



CHEOPS



ARIEL

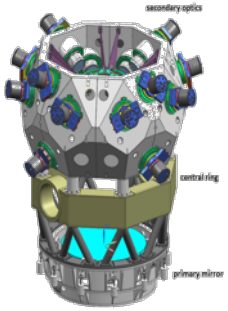


Padova

Ground

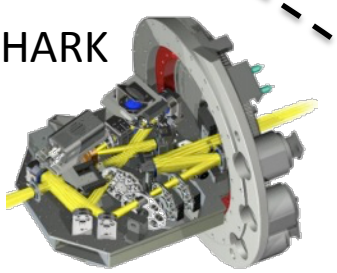
Space

FLY-EYE



Rome

AO-SHARK



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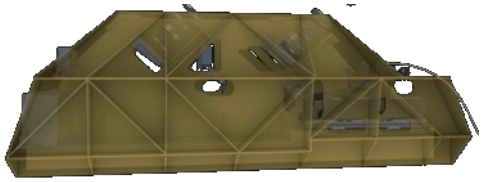
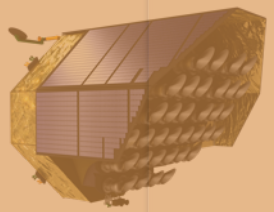


Discovery

Characterization

PLATO



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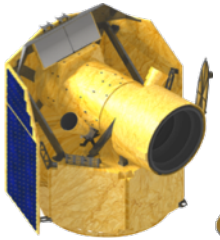

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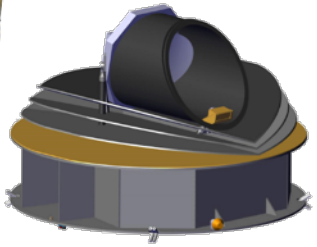


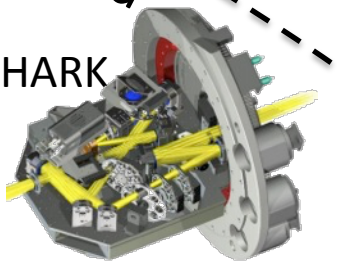
Padova

Ground

Space

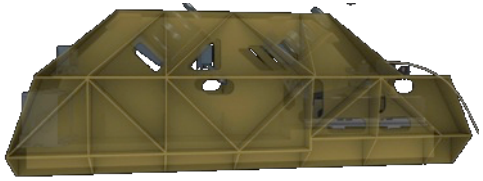
FLY-EYE

AO-SHARK



Rome

ESPRESSO

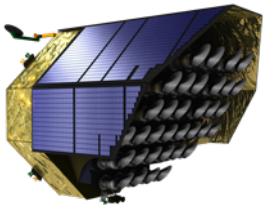


Wide Field

Discovery

Characterization

PLATO



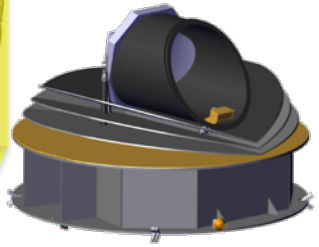
CHEOPS

Photometry

Ground

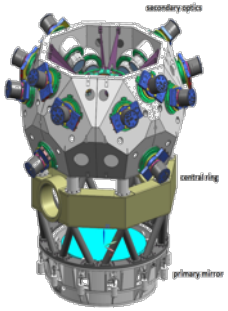
Space

ARIEL



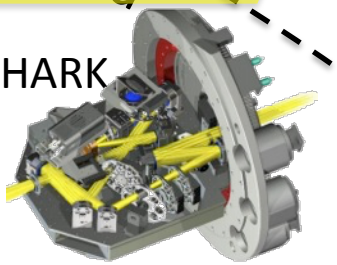
Padova

FLY-EYE



Rome

AO-SHARK



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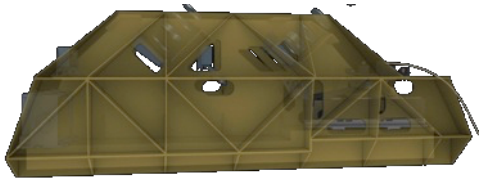
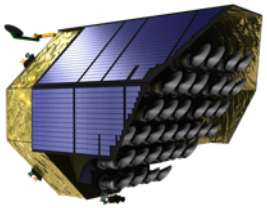


Discovery

Characterization

PLATO



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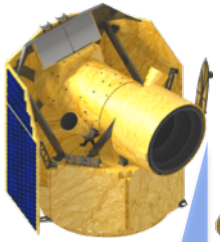

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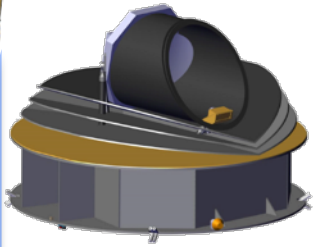
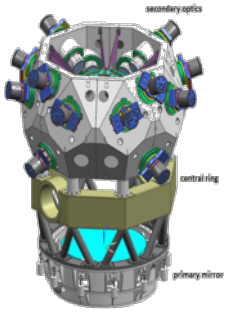


Padova

Ground

Space

FLY-EYE

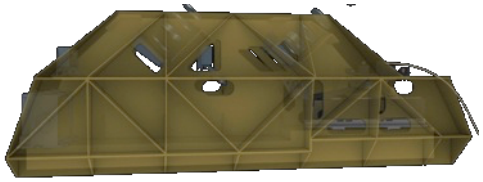


Rome

AO-SHARK

Adaptive Optics

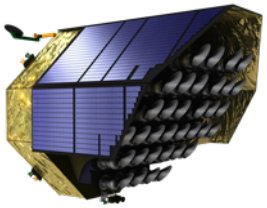
ESPRESSO



Discovery

Characterization

PLATO



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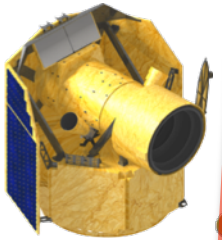

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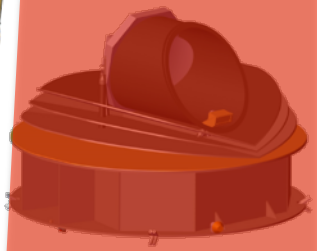
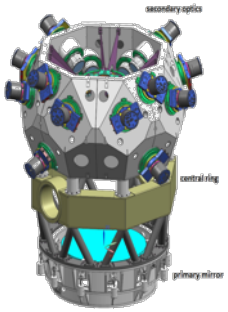


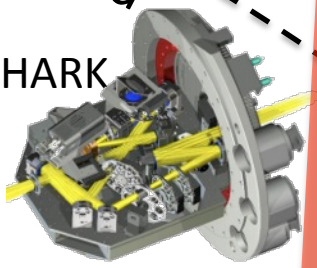
Padova

Ground

FLY-EYE



AO-SHARK



Space

Spectroscopy

Rome

ESPRESSO

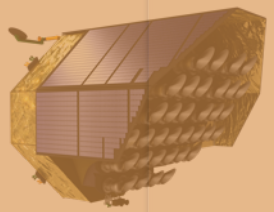
Padova

Rome

Discovery

Characterization

PLATO



FLY-EYE

Wide Field

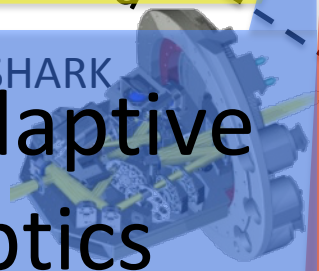
CHEOPS

Photometry

Ground

AO-SHARK

Adaptive Optics



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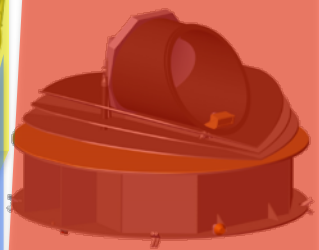
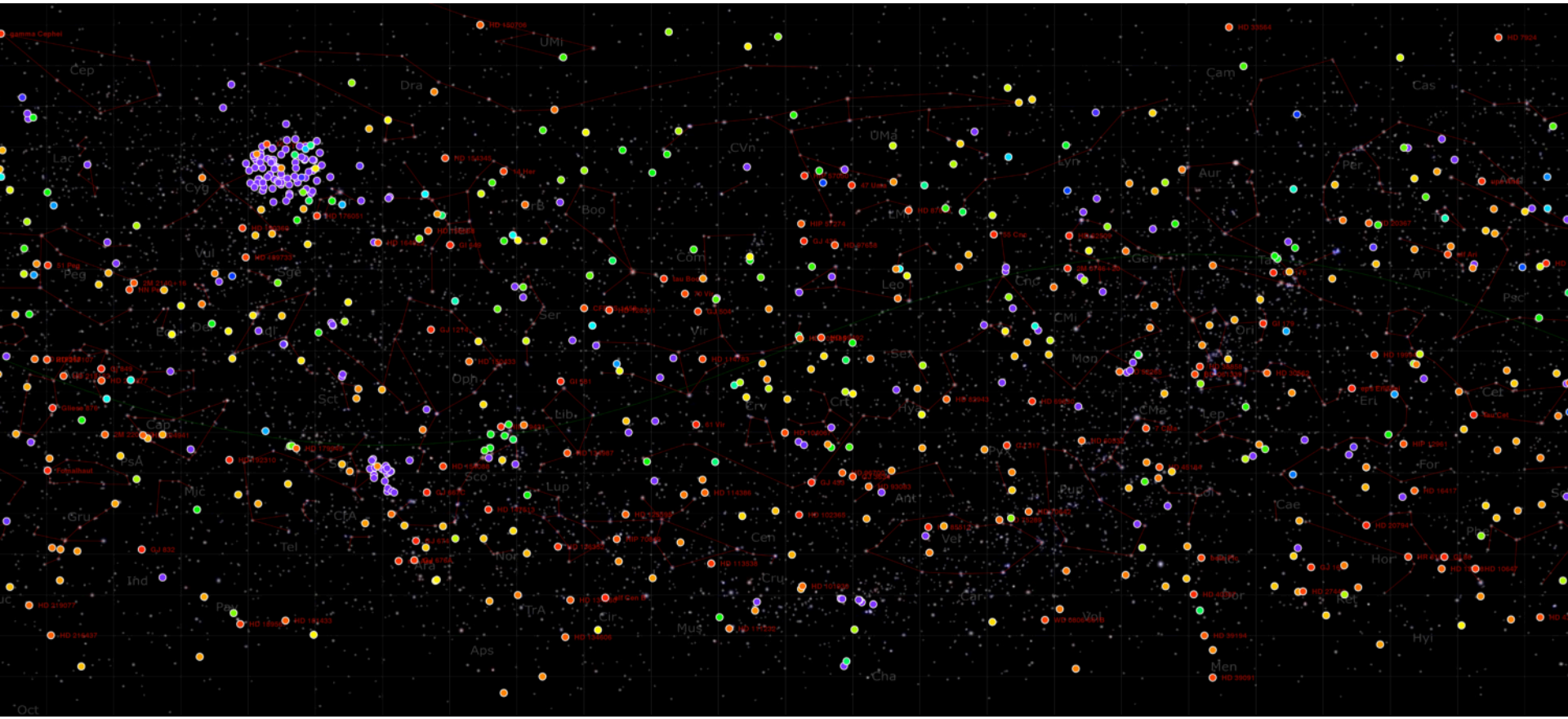


Space

Spectroscopy

ESPRESSO

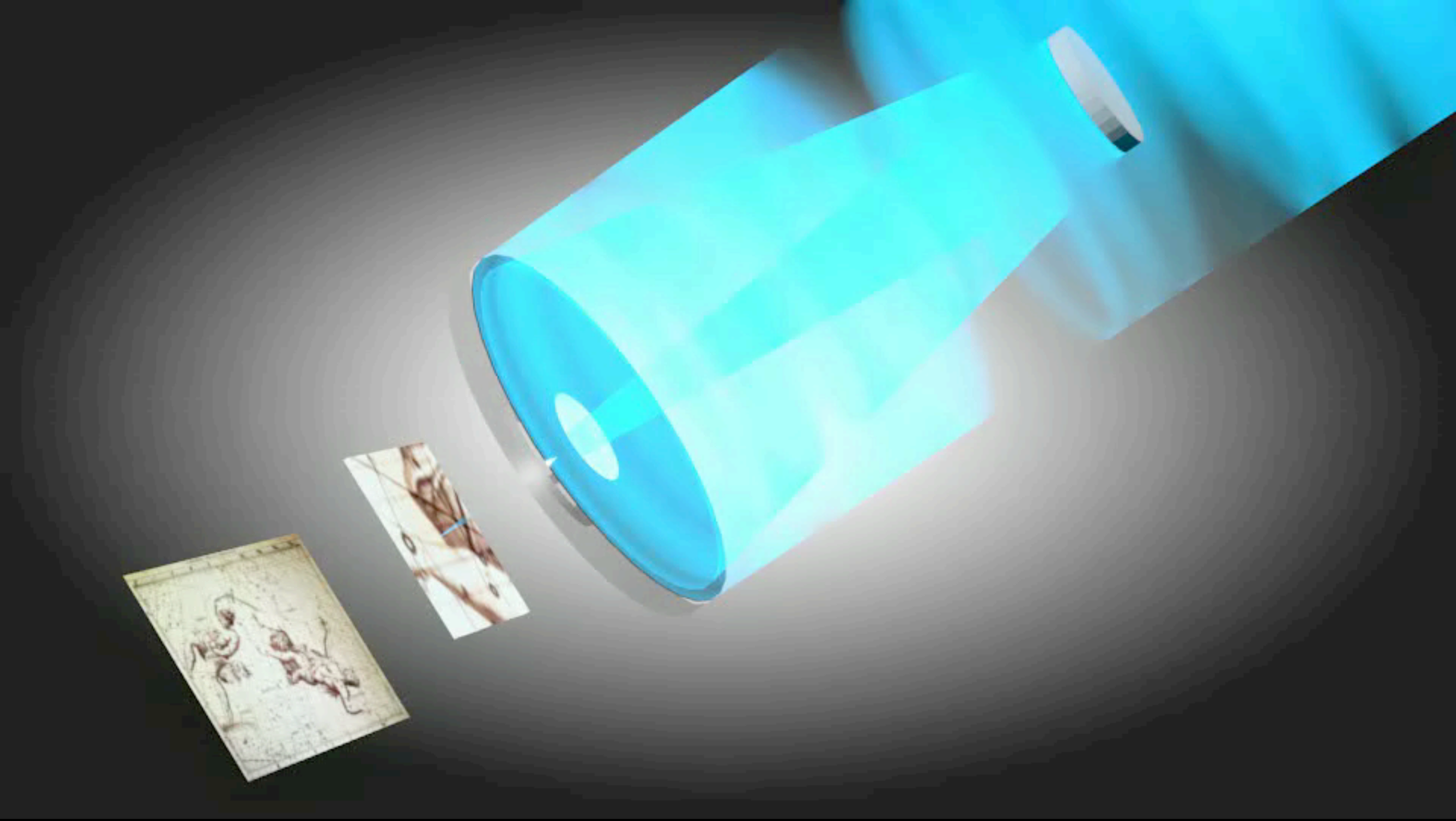
Wide Field



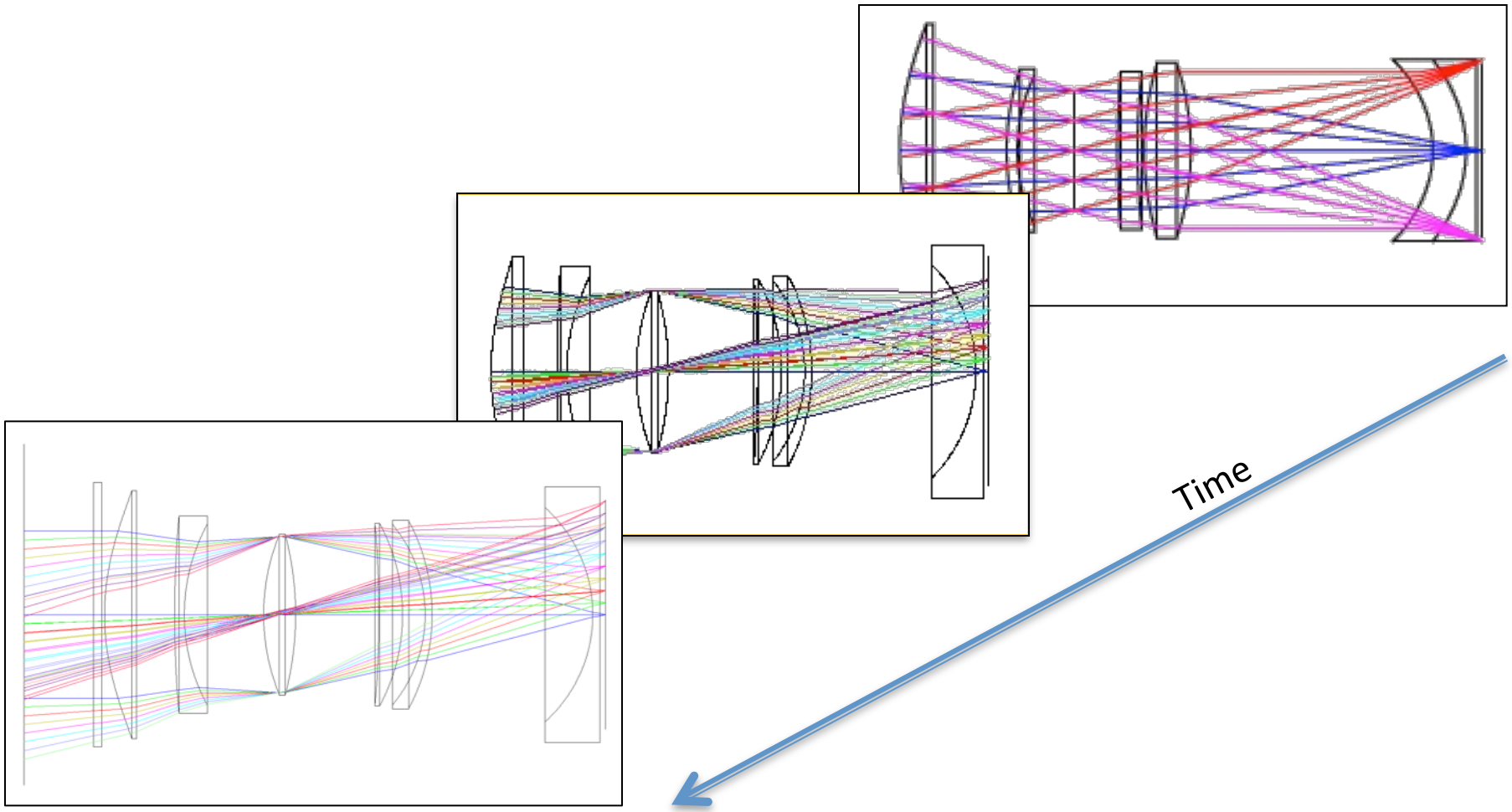
Location of all the stars with known exoplanets

From space…


0

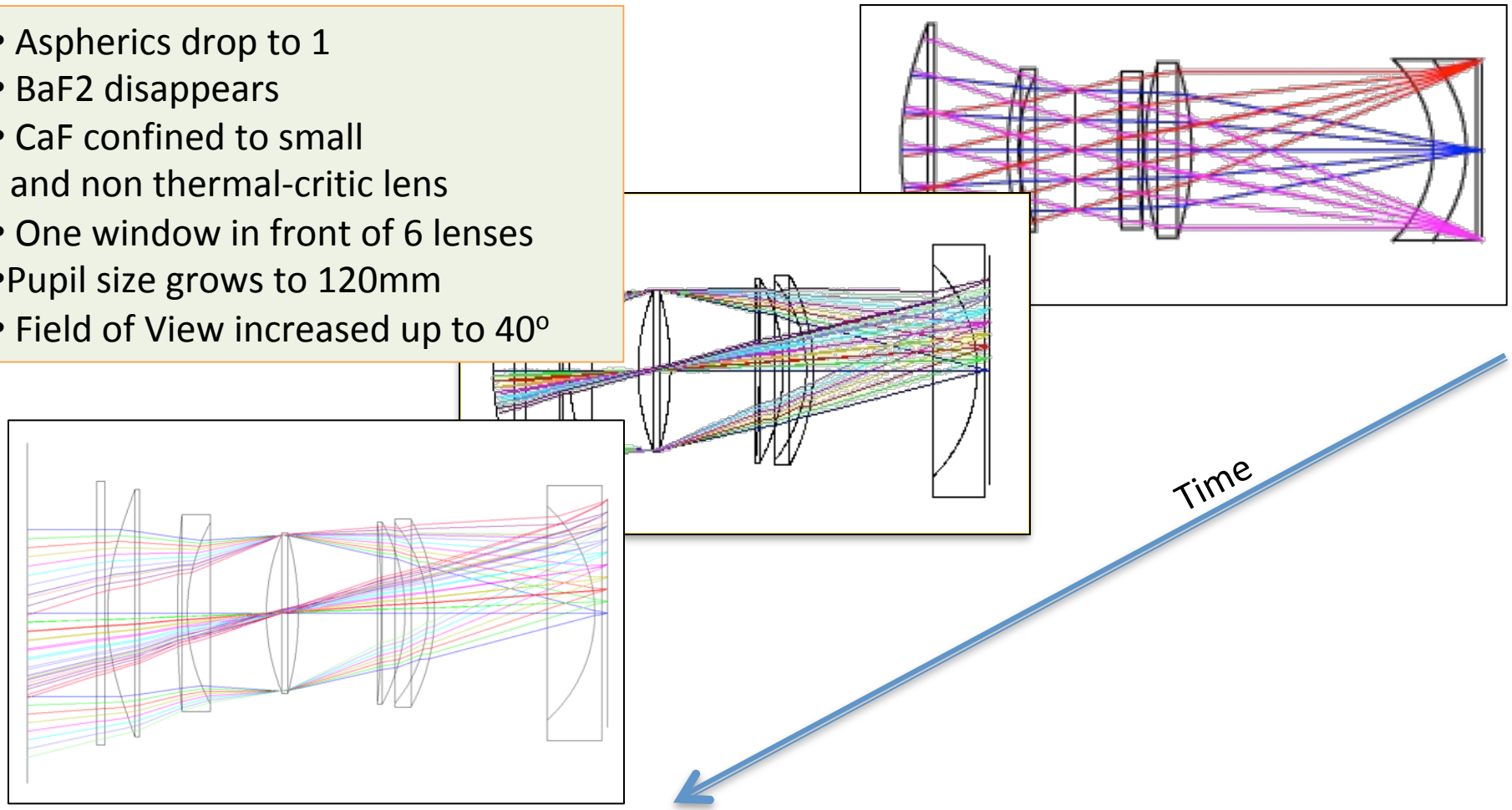


Evolution with time (and meetings)



Evolution with time (and meetings)

- Aspherics drop to 1
- BaF2 disappears
- CaF confined to small and non thermal-critic lens
- One window in front of 6 lenses
- Pupil size grows to 120mm
- Field of View increased up to 40º



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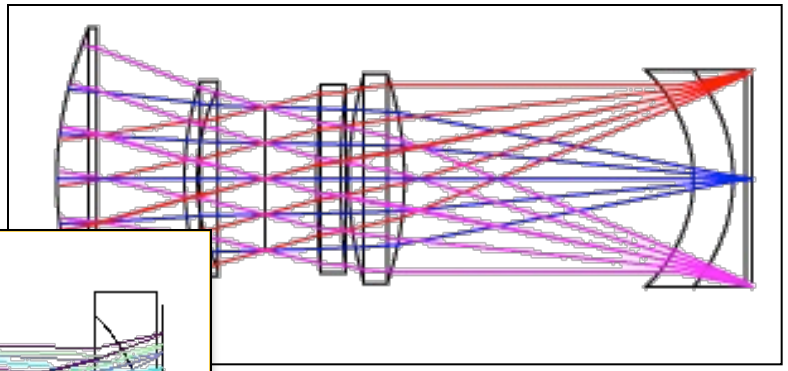
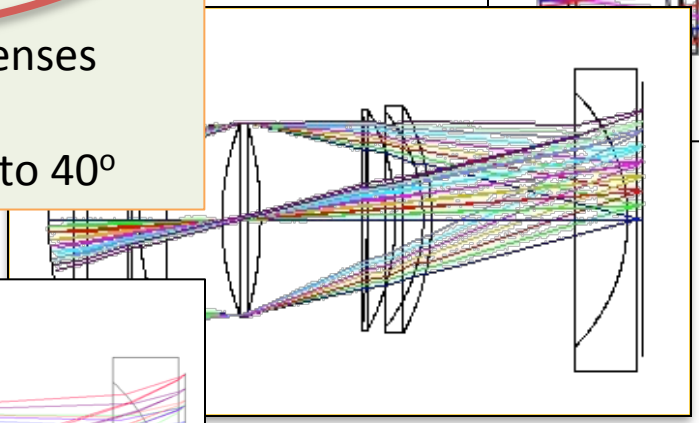
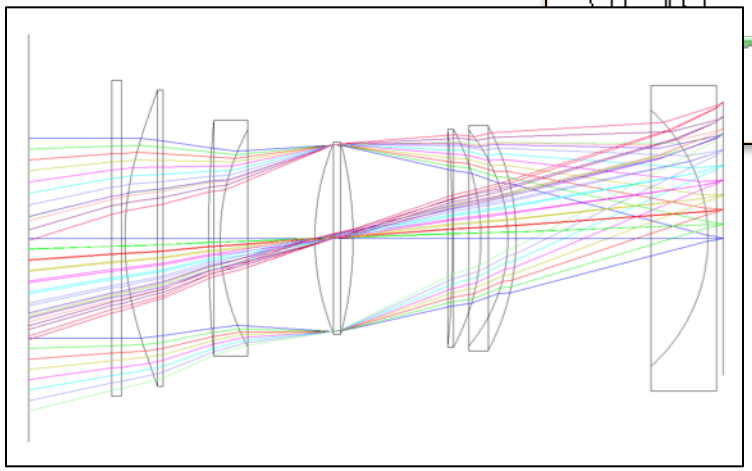
Easier to do







Time

Evolution with time (and meetings)

- Aspherics drop to 1
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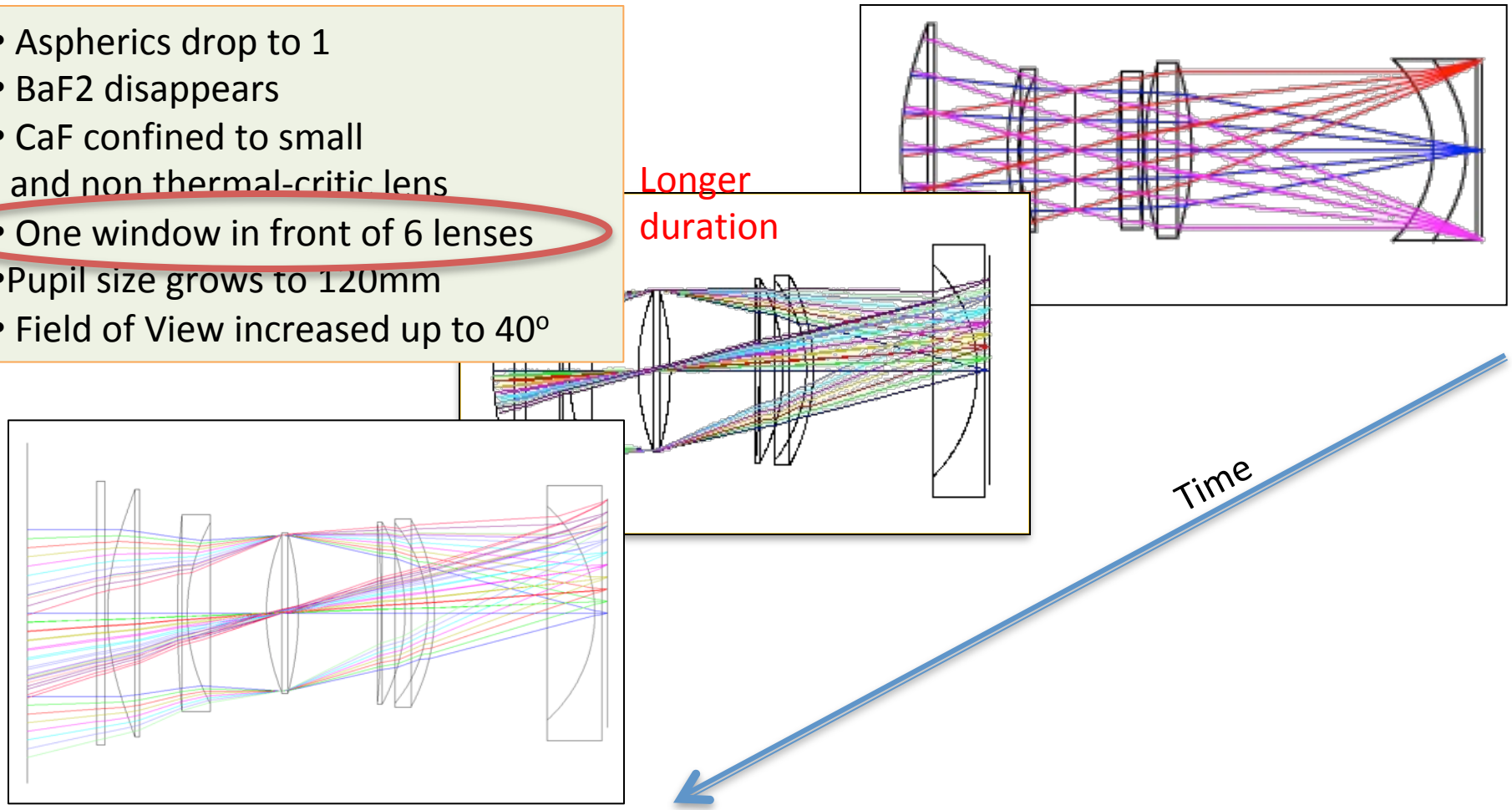

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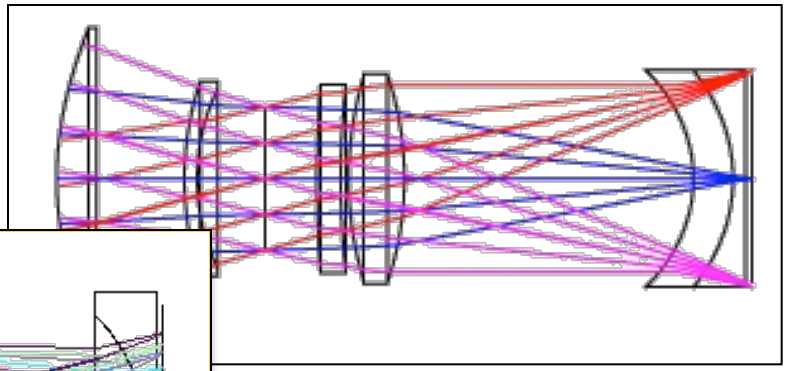
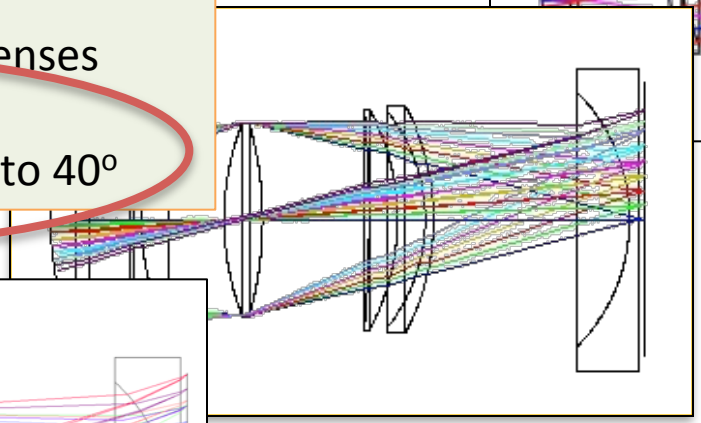
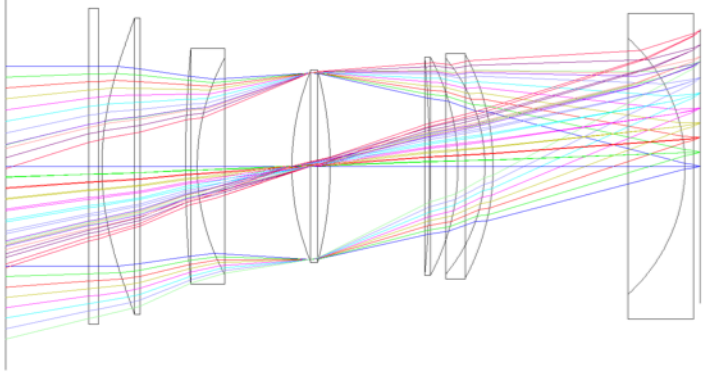
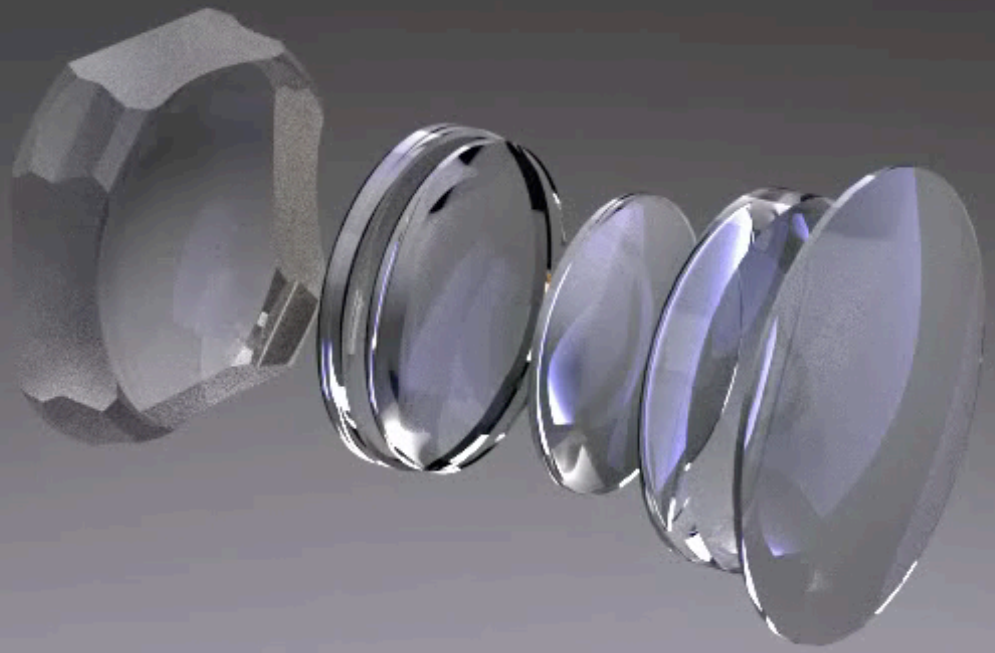




Even better science!!!



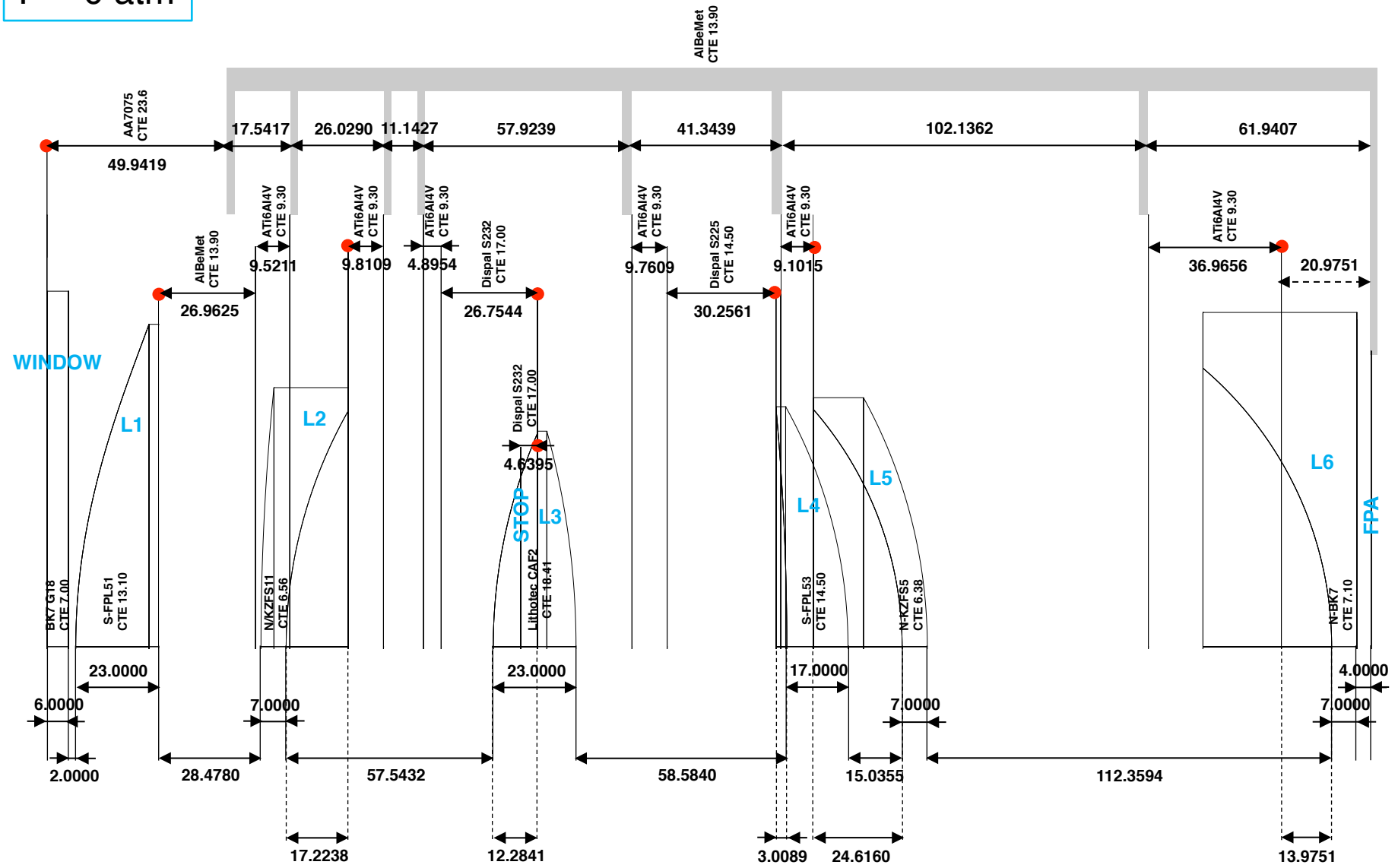
Time



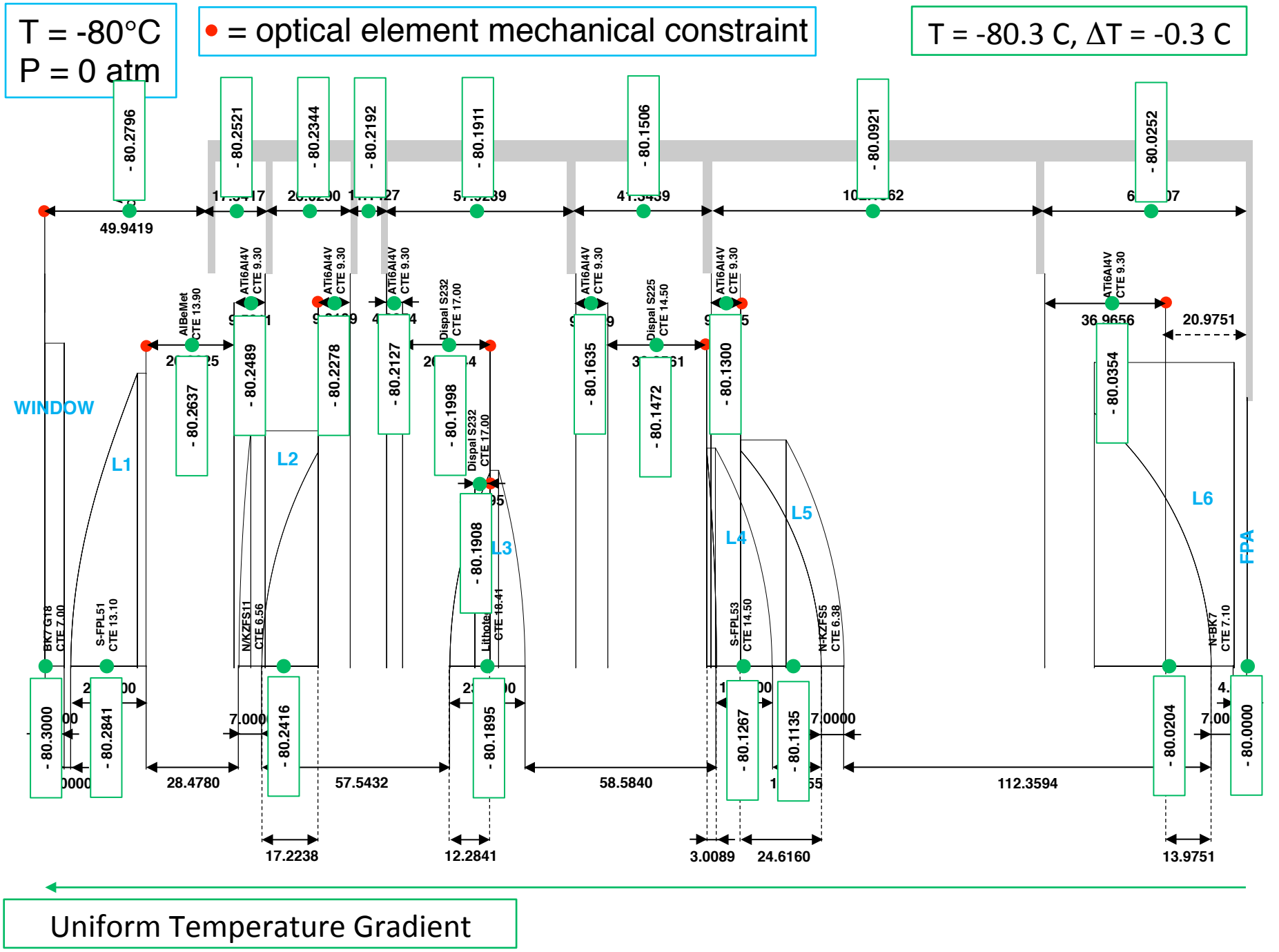
T = -80°C
P = 0 atm

• = optical element mechanical constraint

T = -80.0 C, ΔT = 0 C



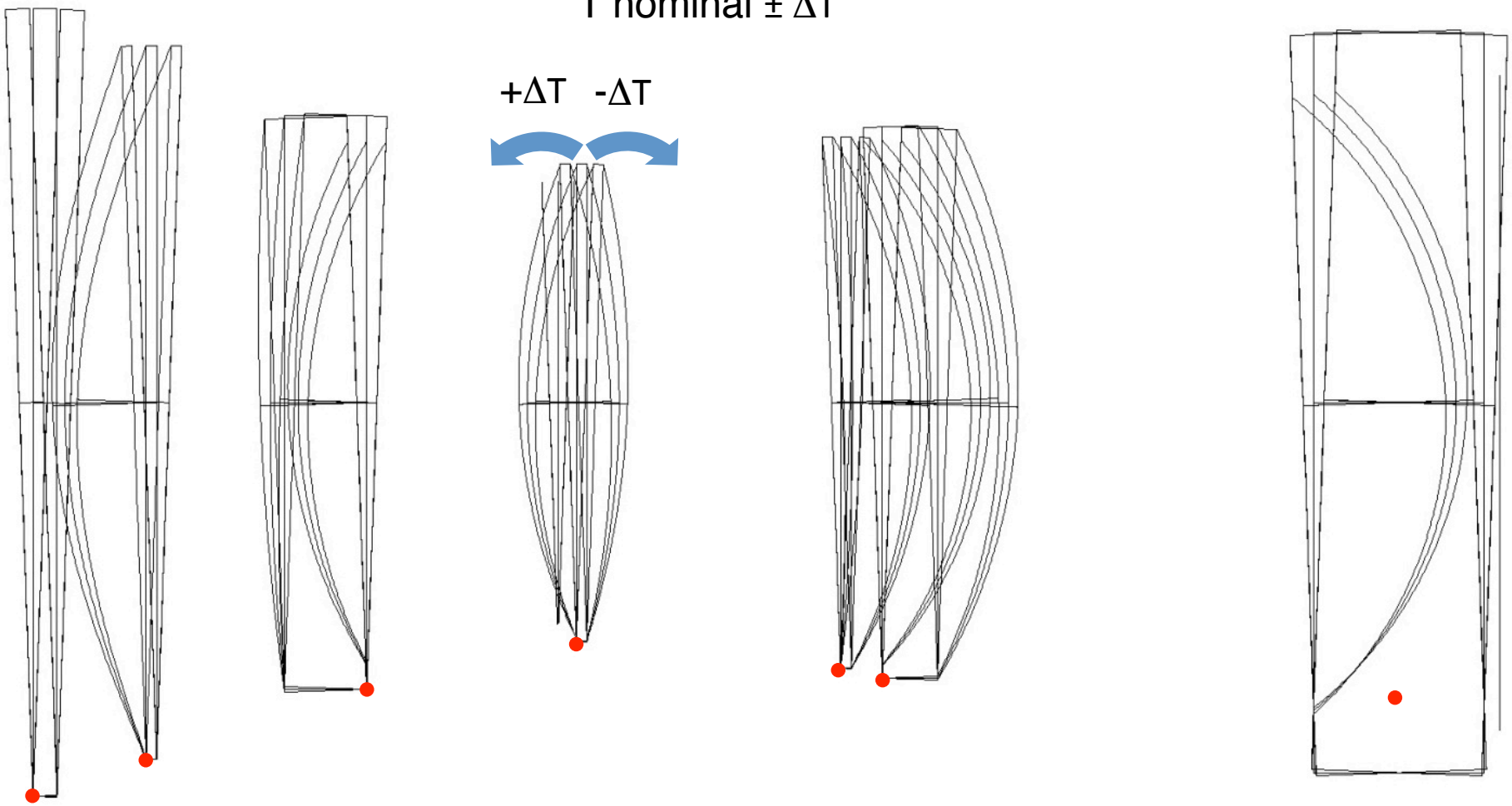
Length units are mm
CTE units are ppm


T = -80°C
P = 0 atm
• = optical element mechanical constraint
T = -80.3 C, ΔT = -0.3 C
- 80.2796
- 80.2521
- 80.2344
- 80.2192
- 80.1911
- 80.1506
- 80.0921
- 80.0252
49.9419
AlBeMet CTE 13.90
ATi6Al4V CTE 9.30
Dispal S232 CTE 17.00
Dispal S225 CTE 14.50
- 80.2637
- 80.2489
- 80.2278
- 80.2127
- 80.1998
- 80.1908
- 80.1635
- 80.1472
- 80.1300
- 80.0354
36.9656
20.9751
WINDOW
L1
L2
L3
L4
L5
L6
FPA
BK7 G18 CTE 7.00
S-FPL51 CTE 13.10
N-KZFS11 CTE 6.56
Lithotec CTE 18.41
S-FPL53 CTE 14.50
N-KZFS5 CTE 6.38
N-BK7 CTE 7.10
- 80.3000
- 80.2841
- 80.2416
- 80.1895
- 80.1267
- 80.1135
- 80.0204
- 80.0000
7.000
7.0000
7.00
28.4780
57.5432
58.5840
112.3594
17.2238
12.2841
3.0089
24.6160
13.9751
Uniform Temperature Gradient

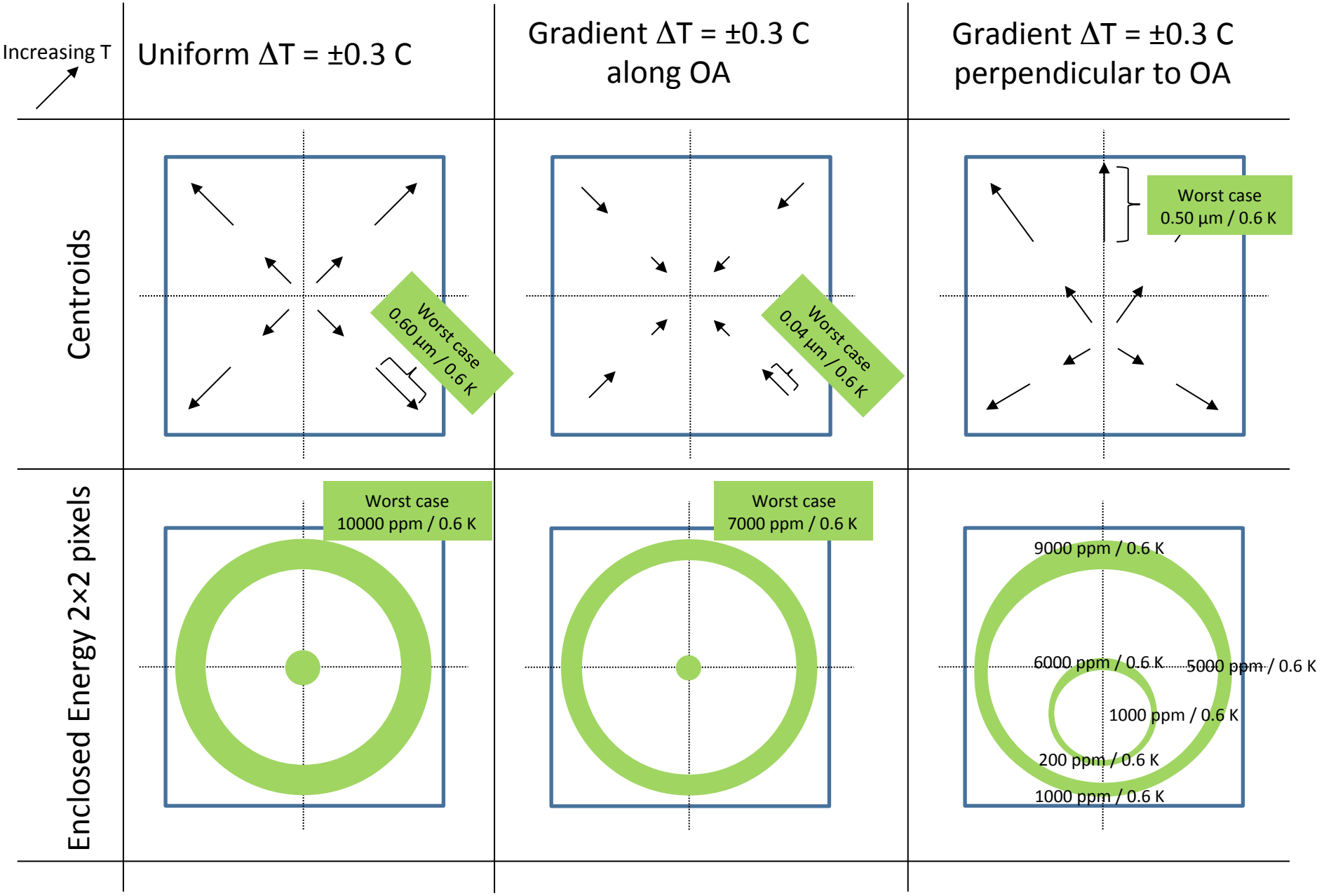
• = optical element mechanical constraint

T nominal ± ΔT

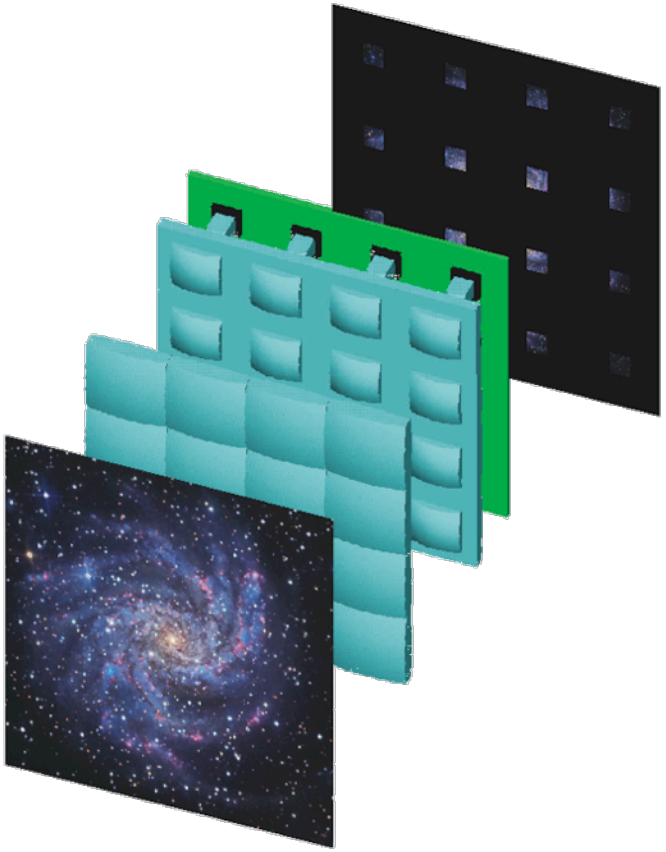
+ΔT -ΔT

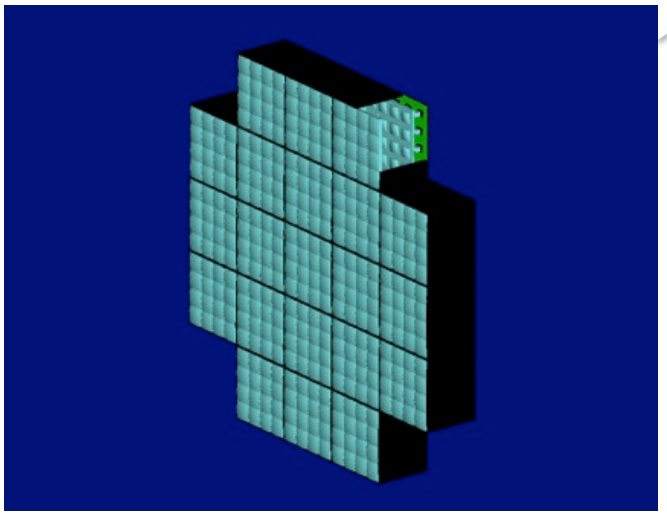


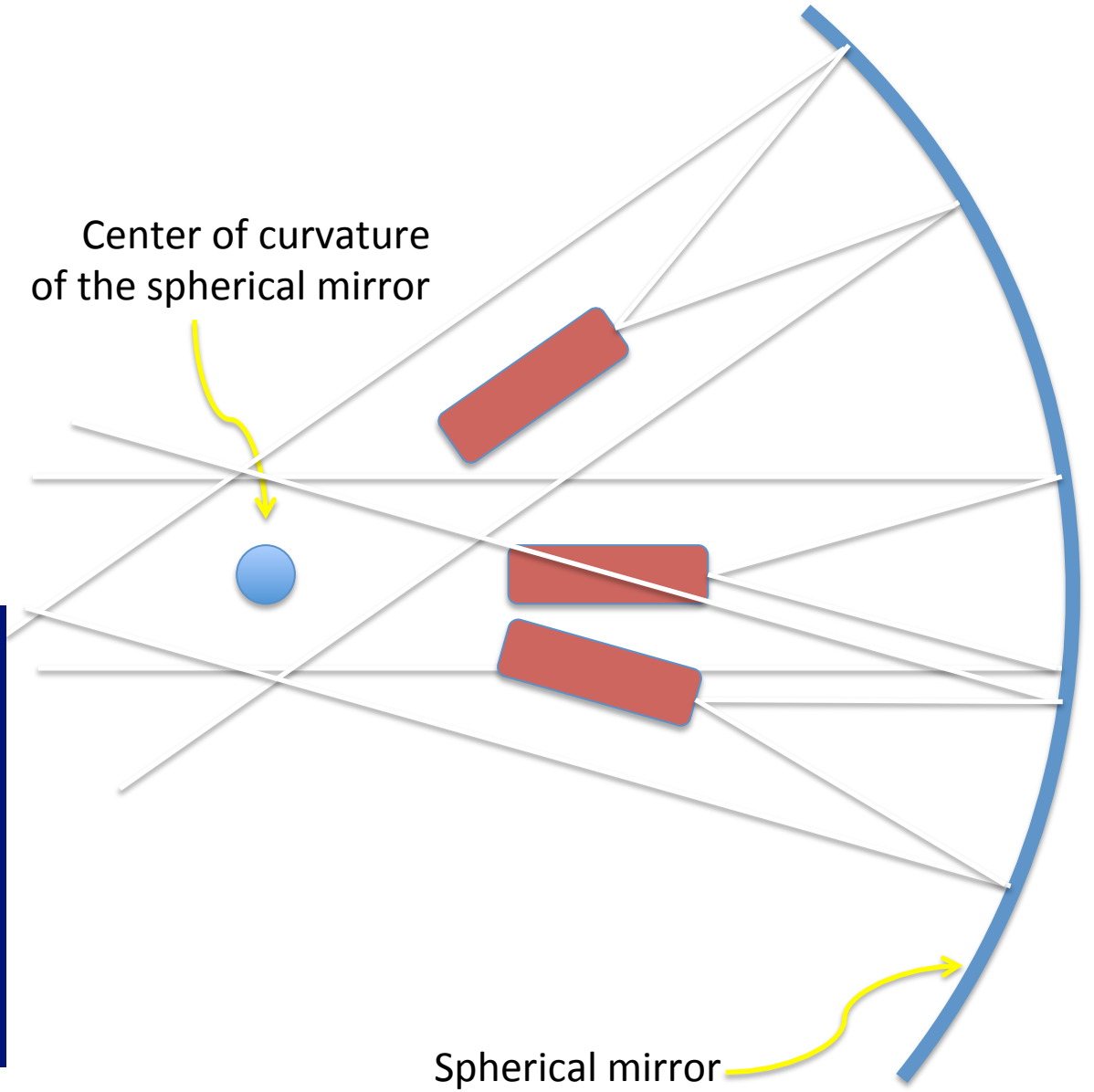
T nominal


Increasing T
Uniform ΔT = ±0.3 C
Gradient ΔT = ±0.3 C along OA
Gradient ΔT = ±0.3 C perpendicular to OA
Centroids
Worst case 0.60 µm / 0.6 K
Worst case 0.04 µm / 0.6 K
Worst case 0.50 µm / 0.6 K
Enclosed Energy 2×2 pixels
Worst case 10000 ppm / 0.6 K
Worst case 7000 ppm / 0.6 K
9000 ppm / 0.6 K
6000 ppm / 0.6 K
5000 ppm / 0.6 K
1000 ppm / 0.6 K
200 ppm / 0.6 K
1000 ppm / 0.6 K

From ground…






Center of curvature
of the spherical mirror
Spherical mirror

Fly-Eye

(54) **TELESCOPE, COMPRISING A SPHERICAL PRIMARY MIRROR, WITH WIDE FIELD OF VIEW AND HIGH OPTICAL RESOLUTION**

(71) Applicant: **CGS SPA COMPAGNIA GENERALE PER LO SPAZIO**, Milano (IT)

(72) Inventors: **Marco Chiarini**, Faenza (IT); **Lorenzo Cibin**, Trecate (IT); **Roberto Ragazzoni**, Roma (IT)

(21) Appl. No.: **14/431,315**

(22) PCT Filed: **Sep. 19, 2013**

(86) PCT No.: **PCT/EP2013/069417**
§ 371 (c)(1),
(2) Date: **Mar. 26, 2015**

(30) **Foreign Application Priority Data**

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Aug. 29, 2013 (IT) CS2013A000022

Publication Classification

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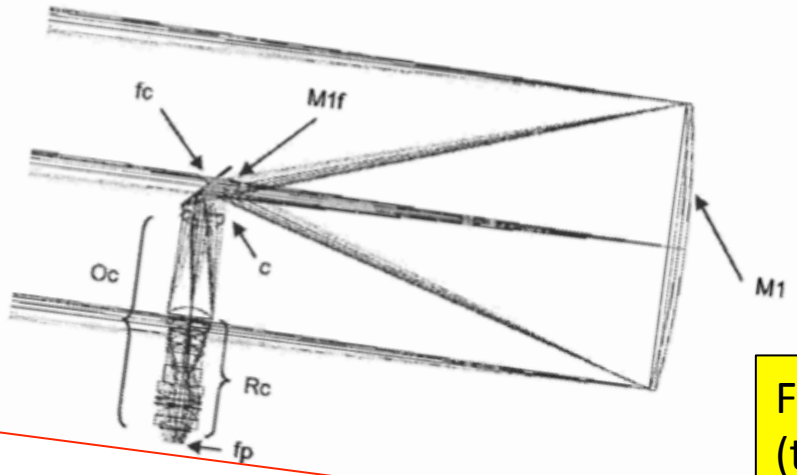
G02B 17/08 (2006.01)
G02B 23/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 17/08*** (2013.01); ***G02B 23/06*** (2013.01)

(57) **ABSTRACT**

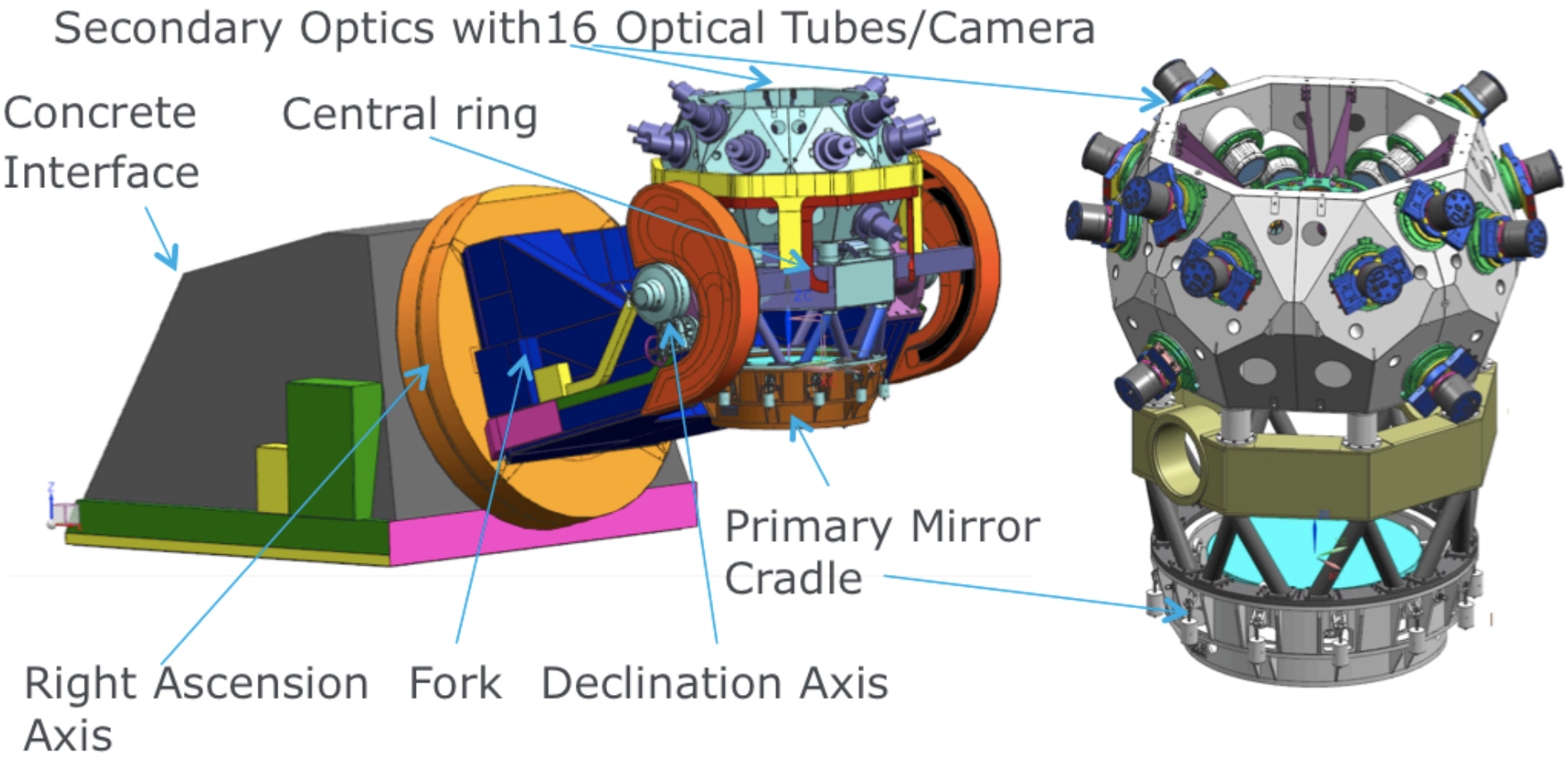
Telescope with wide Field of View, high optical resolution and continuity of the field of view comprising a spherical primary mirror, wherein a) said telescope is equipped with a system of repartitioning of the Field of View, b) that said system of repartitioning of the Field of View is placed in proximity of the focus of the primary mirror, and is constituted by a secondary mirror composed by n planar reflective surfaces, c) said n planar reflective surfaces are contiguous one to the other and form a continuous multifaceted prismatic reflector, in such a way as to obtain the continuity of the field of view over the whole field, d) said n planar reflective surfaces are followed by a corresponding number of optical cameras that form n portions of immage in n distinct focal planes, e) a collecting and recording element is positioned on each n-th focal plane



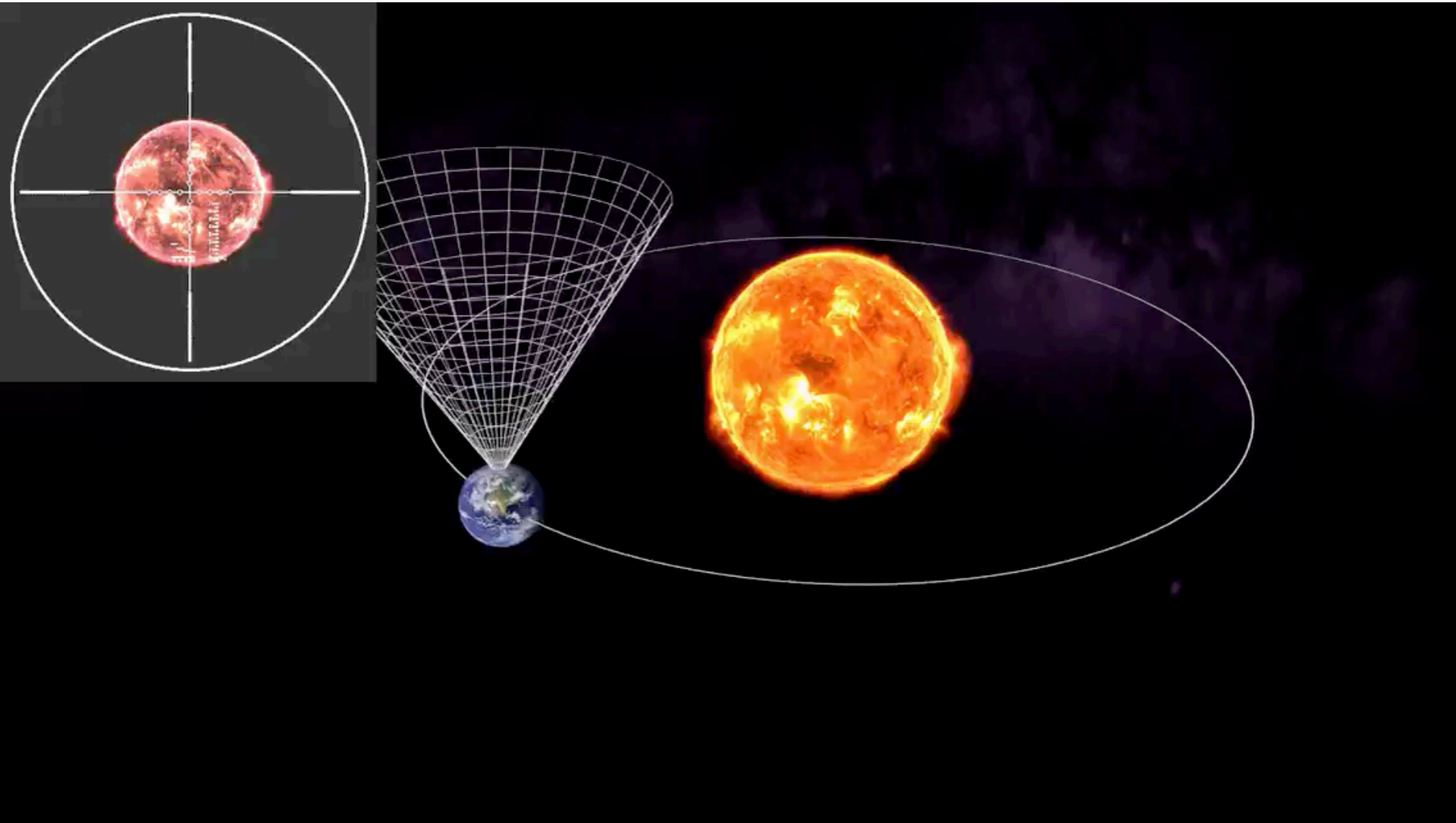
From the Patent to (two) prototype(s)

Fly-Eye

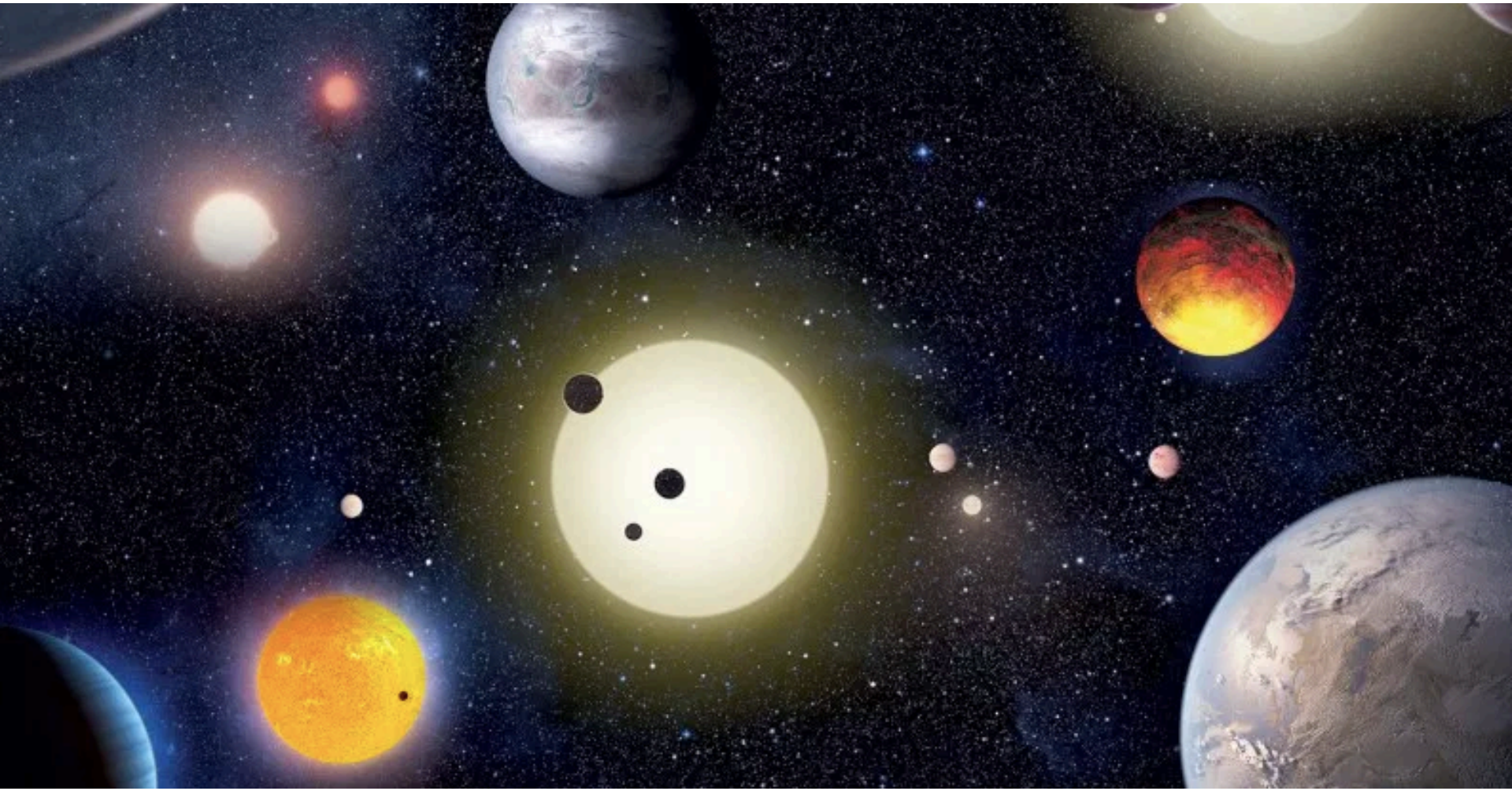
Fly-Eye


Secondary Optics with16 Optical Tubes/Camera
Concrete Interface
Central ring
Primary Mirror Cradle
Right Ascension Axis
Fork
Declination Axis

Us & them…

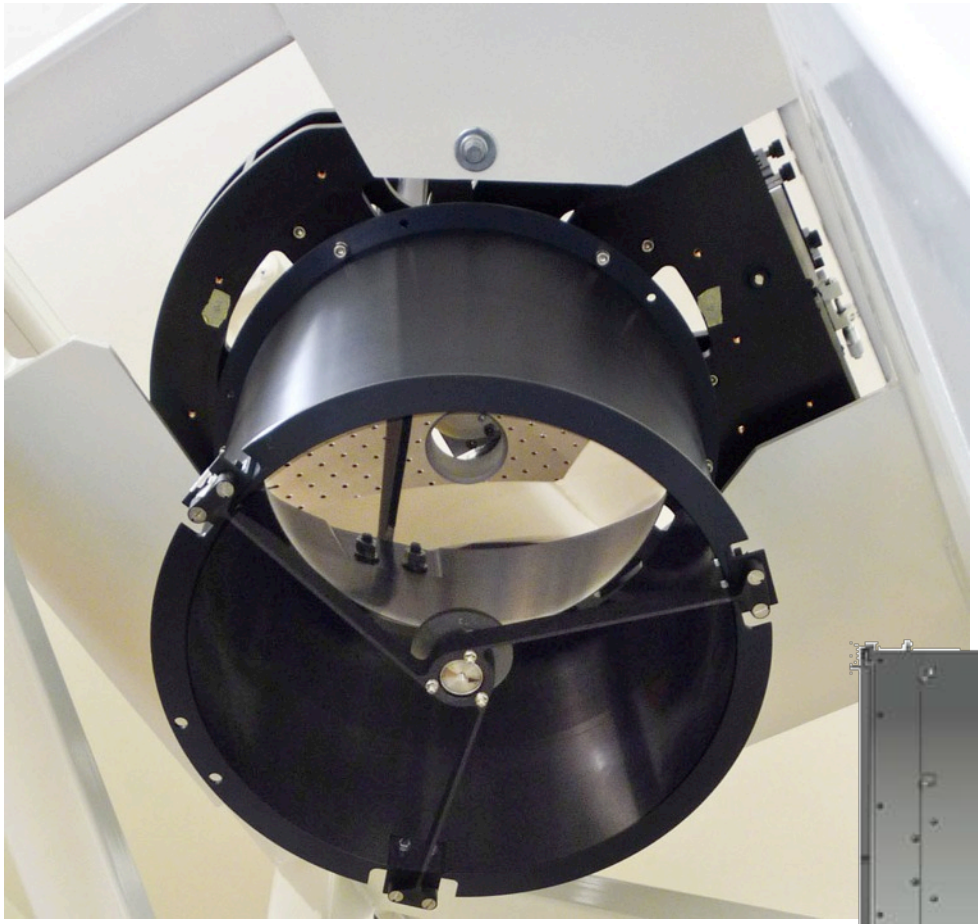


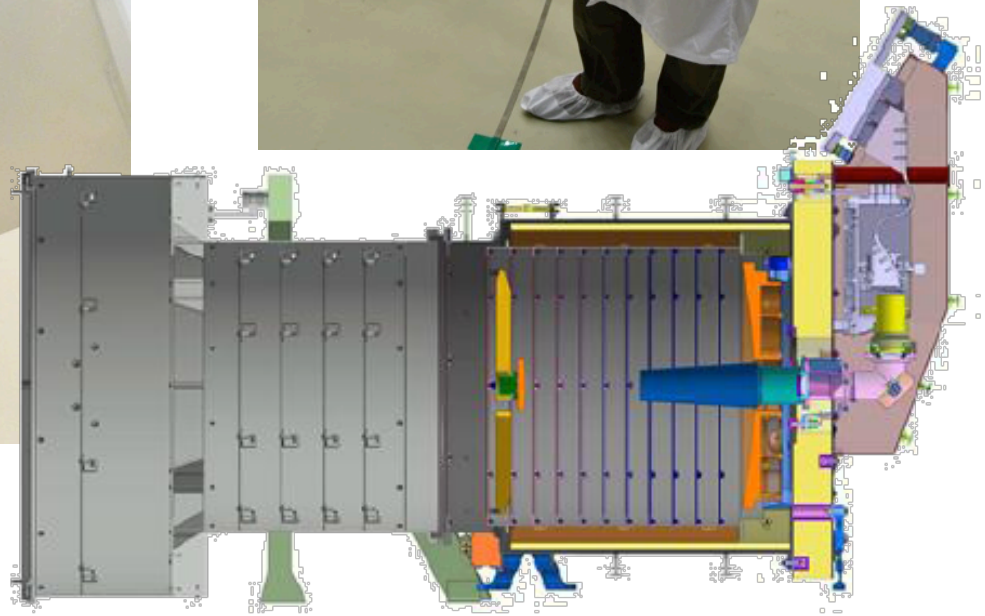
Photometry



Exoplanets discovered by transits

CHEOPS

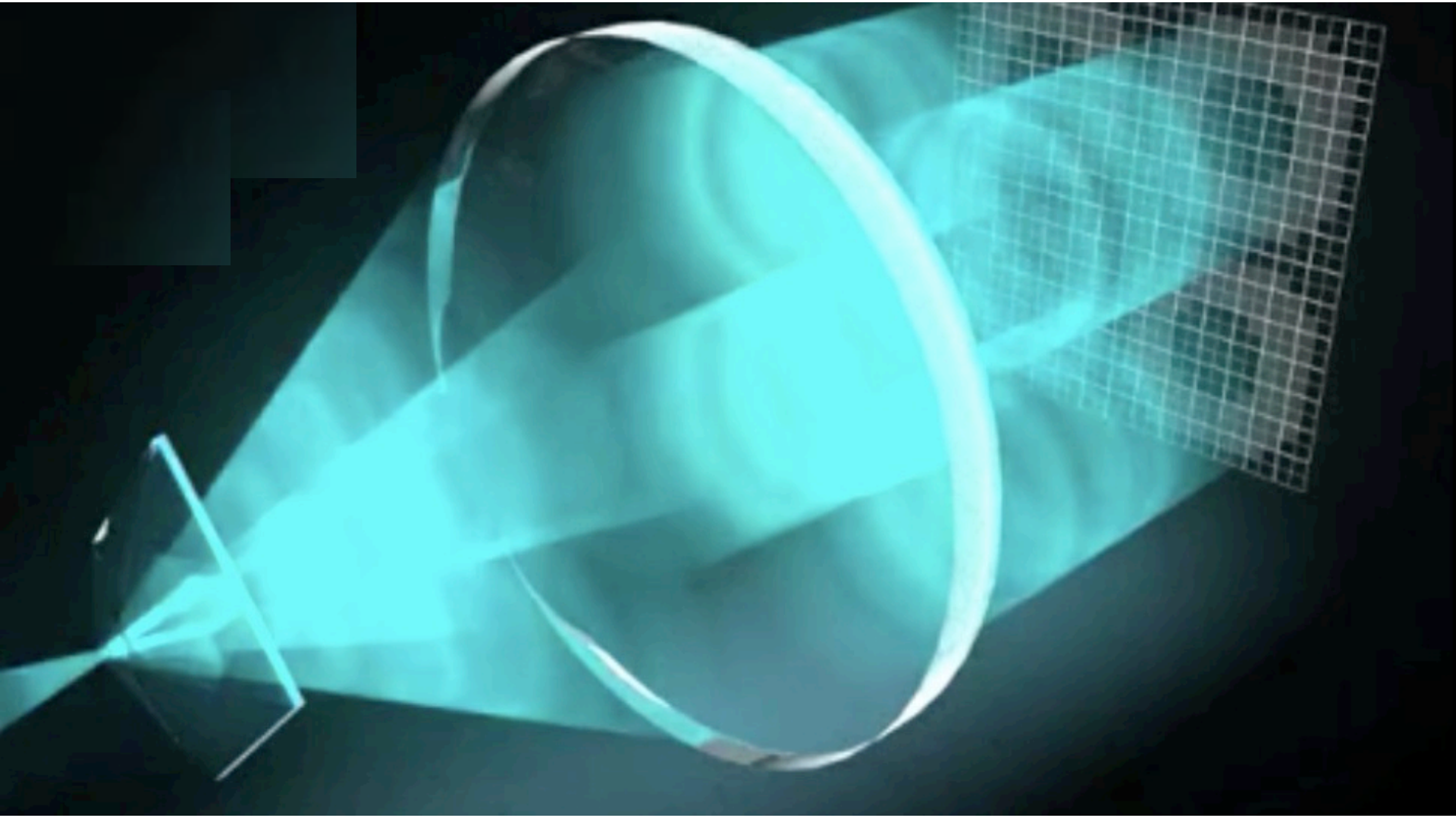




Holographic diffuser

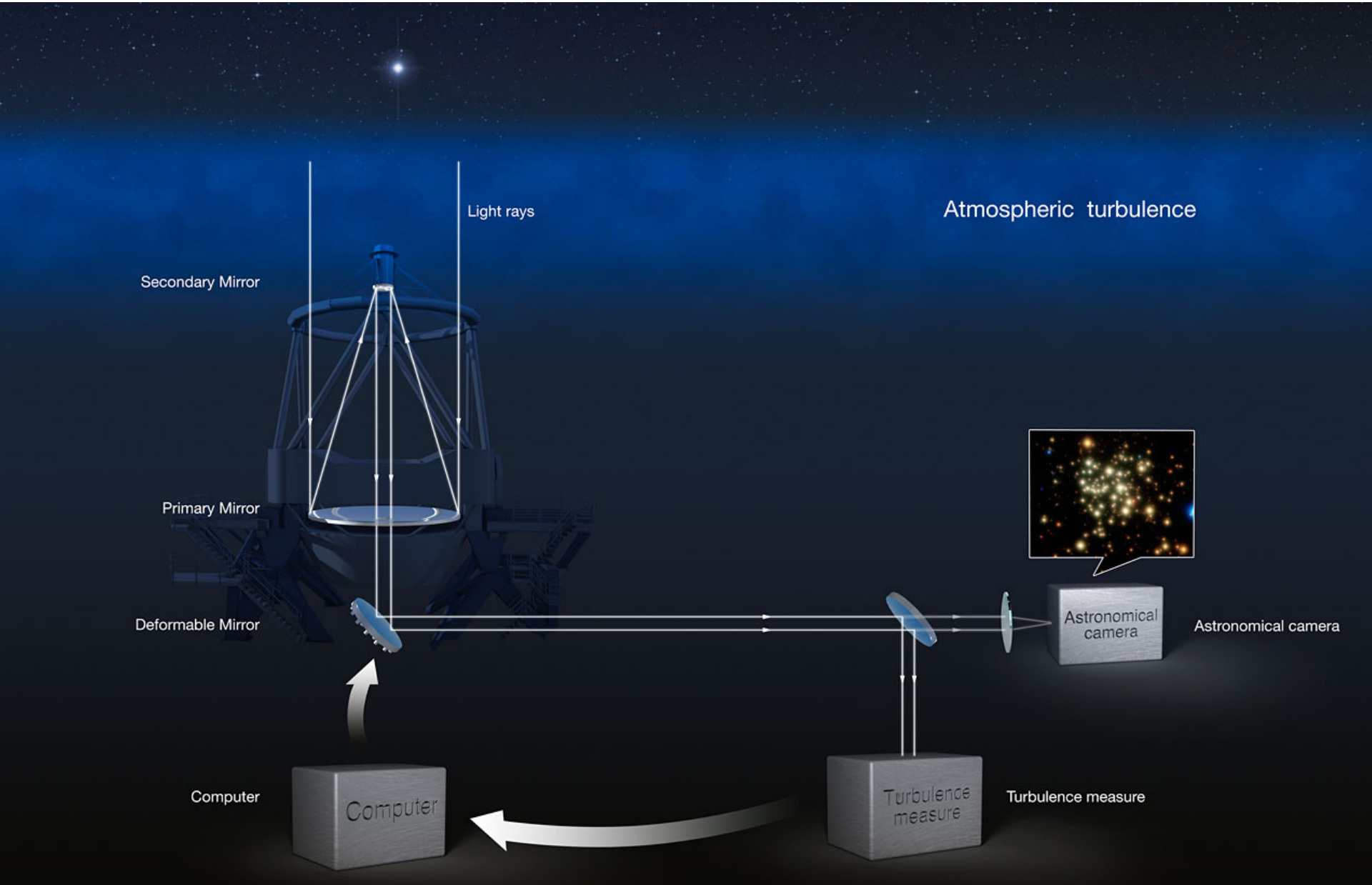
- Tested in the lab as an option for CHEOPS
- Discarded because not enough TRL to fly
- Under implementation for Asiago test
- Spreading of light allow for:
  - Non saturation
  - More robust to pixel to pixel variations
- For bright stars we are studying a concept where only the central (bright) source is diffused and the others are used as reference

Adaptive Optics

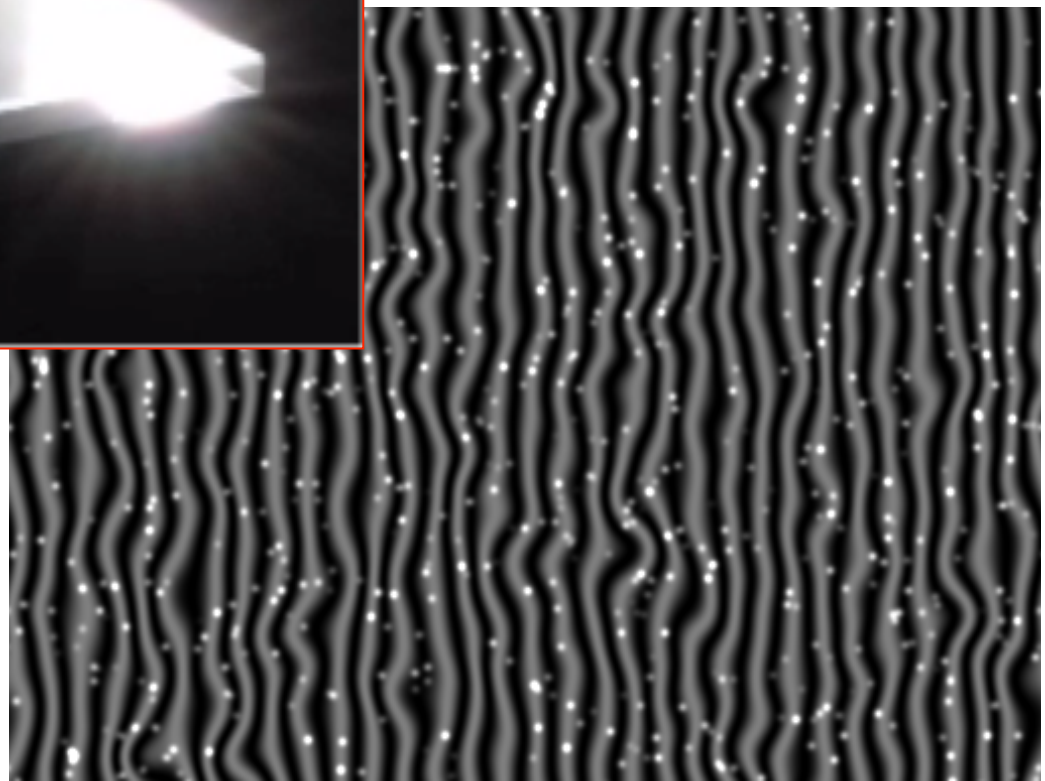


A pyramid wavefront sensor

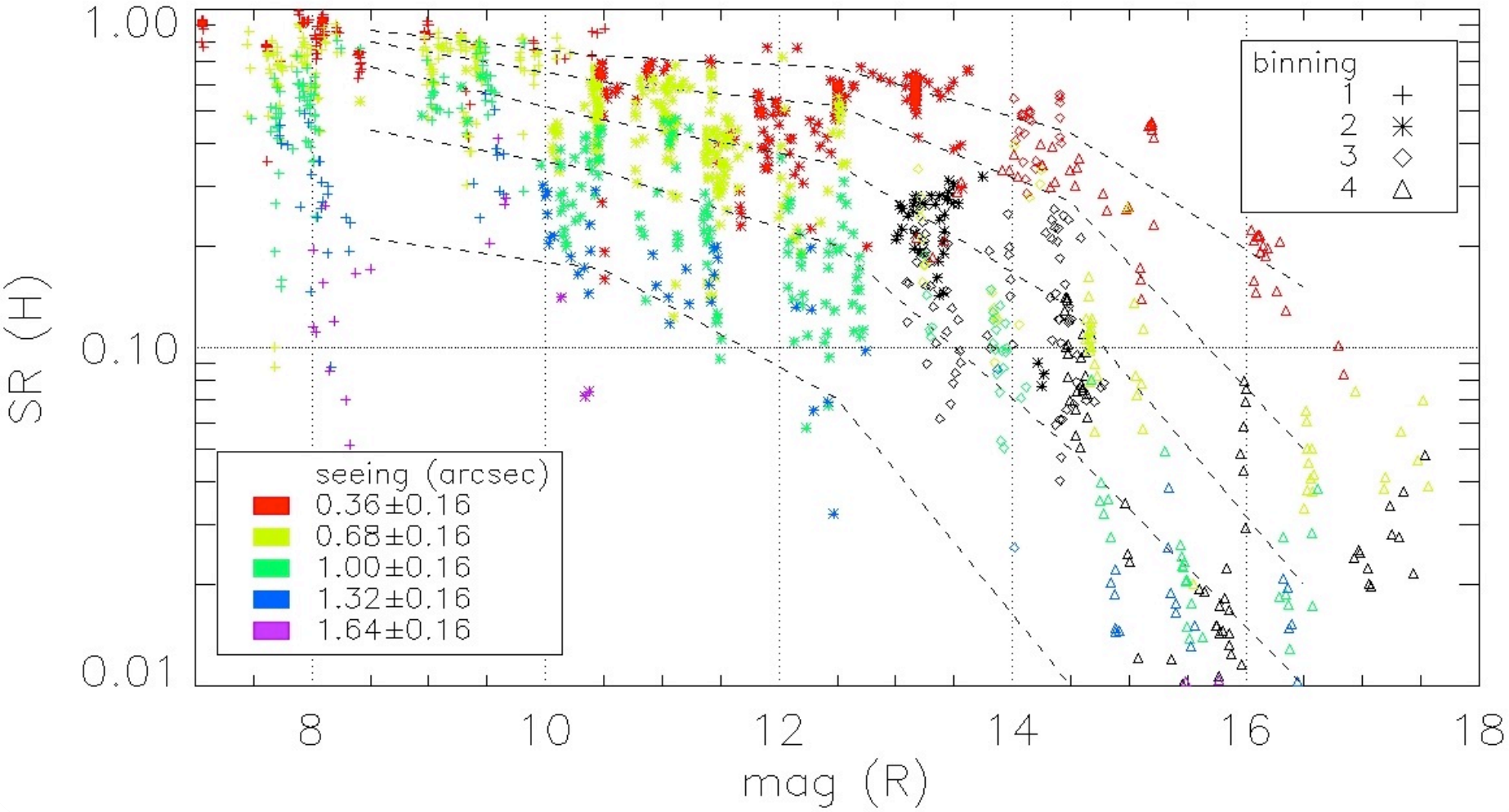
Adaptive Optics



Wavefront Sensing

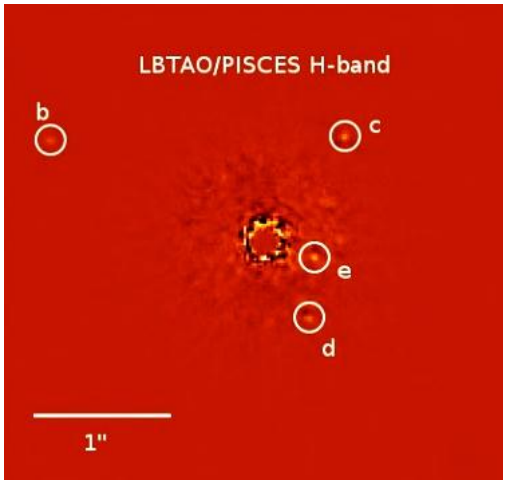


Performances…

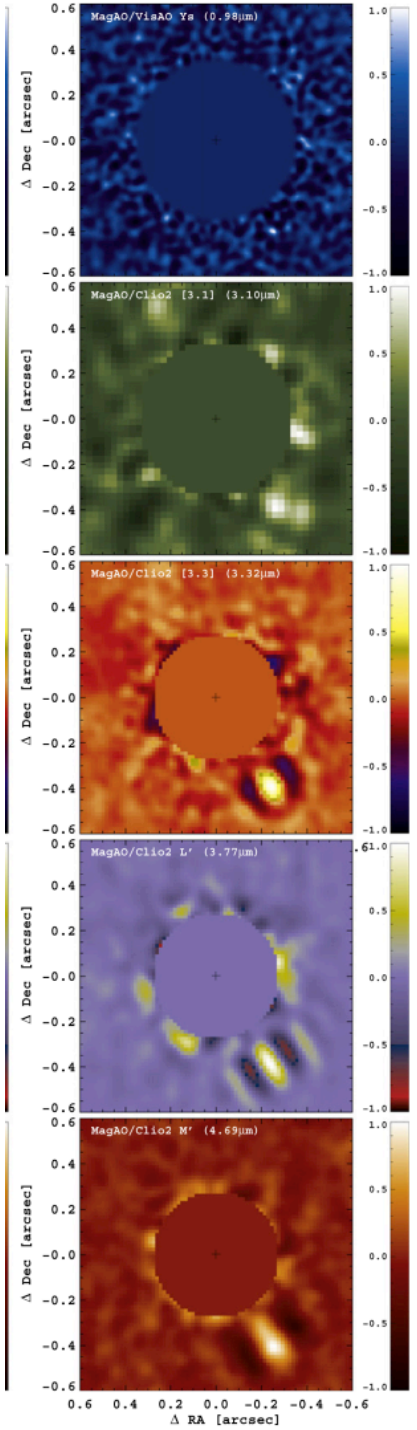


ExoPlanets examples…

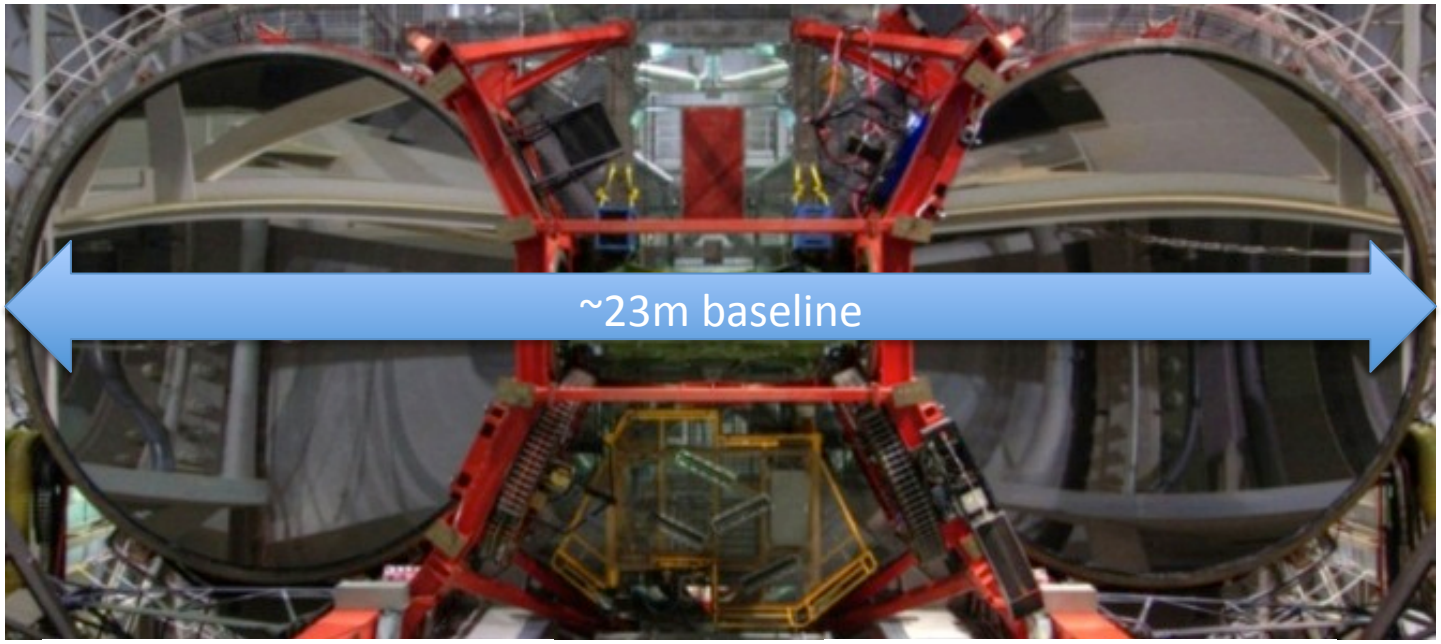
- First detection in H
  of HR8799b,c, d, e

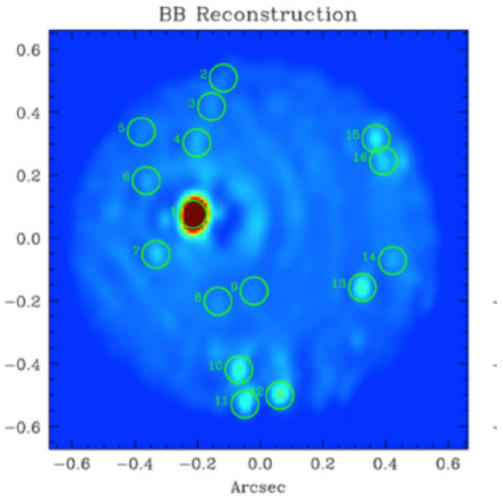


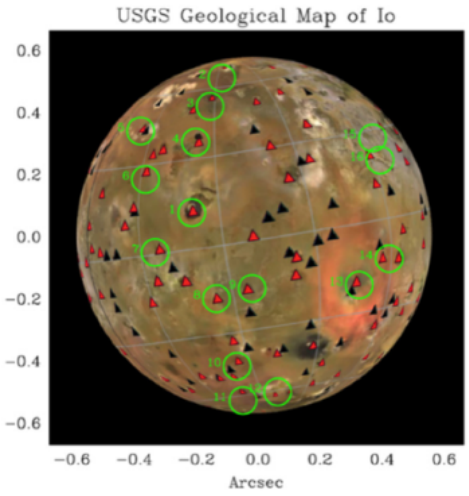
- Imaging in L and M of Beta Pic b



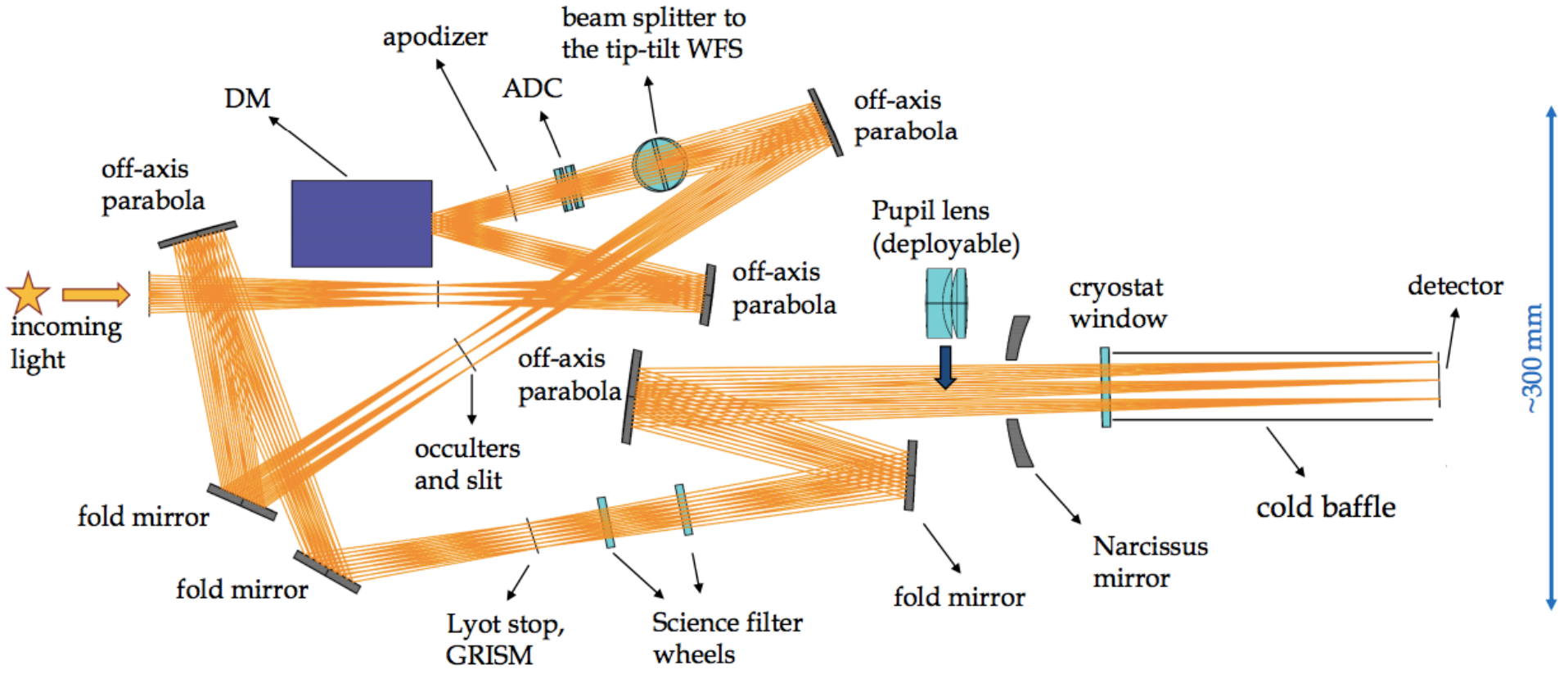
(some) interferometry…



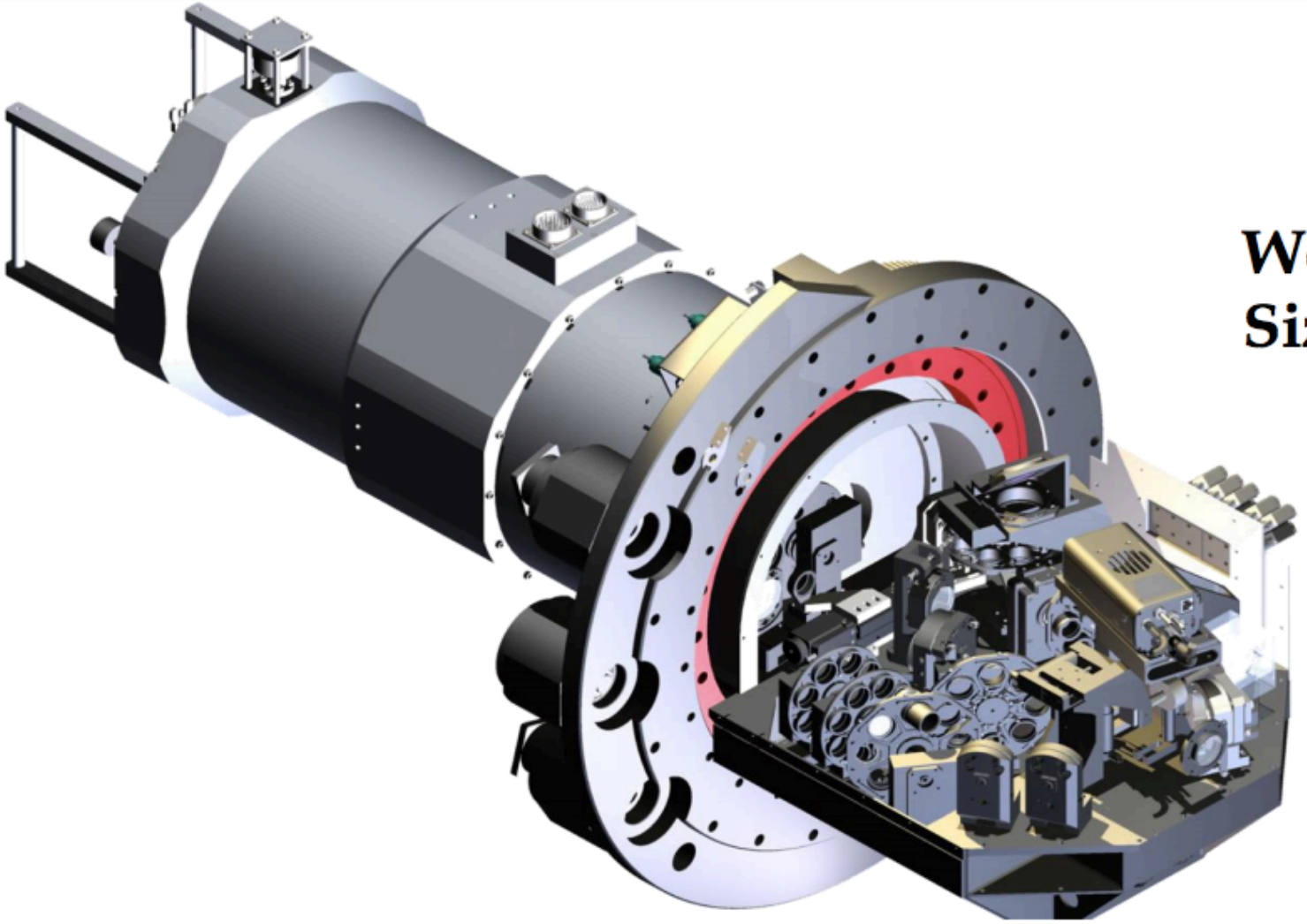




Shark-NIR

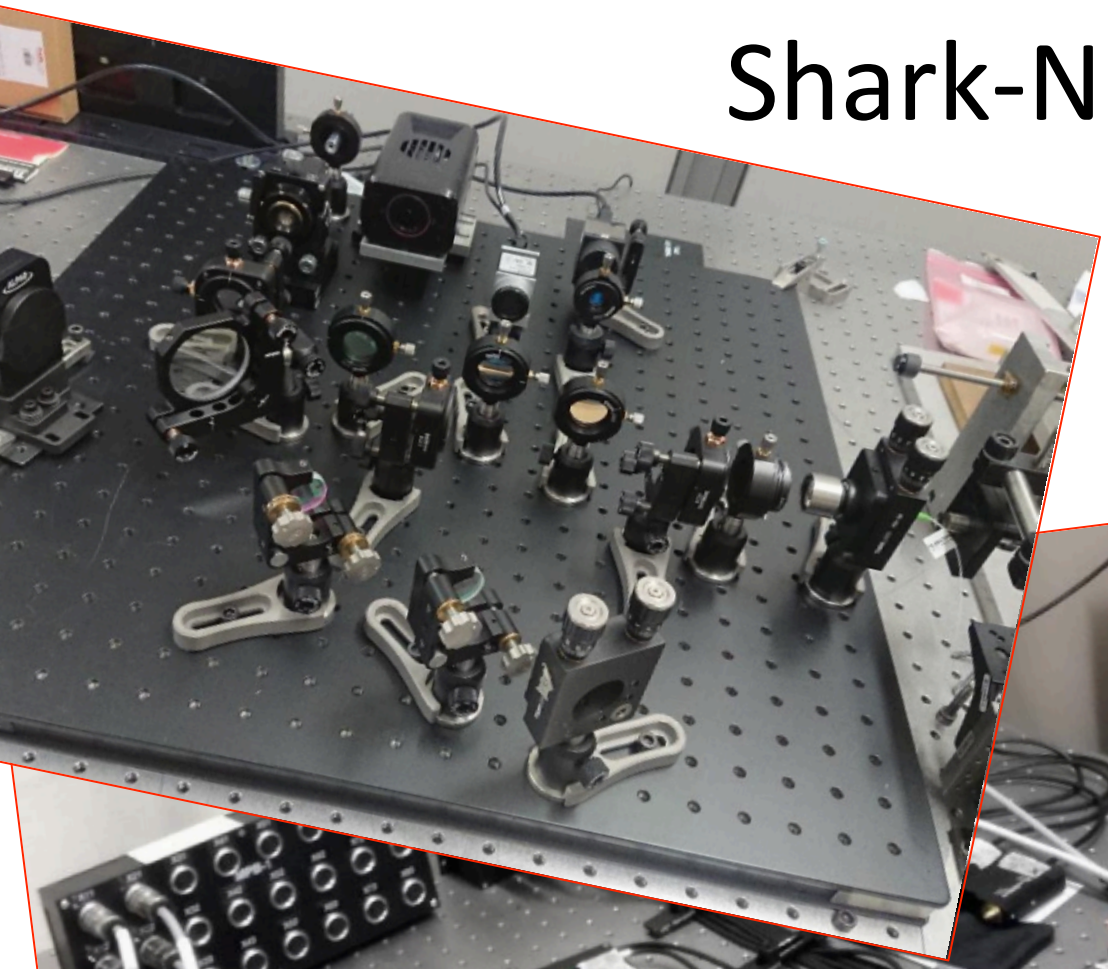

apodizer
beam splitter to
the tip-tilt WFS
DM
ADC
off-axis
parabola
off-axis
parabola
Pupil lens
(deployable)
off-axis
parabola
cryostat
window
detector
incoming
light
off-axis
parabola
occulters
and slit
~300 mm
fold mirror
cold baffle
Narcissus
mirror
fold mirror
Lyot stop,
GRISM
Science filter
wheels
fold mirror

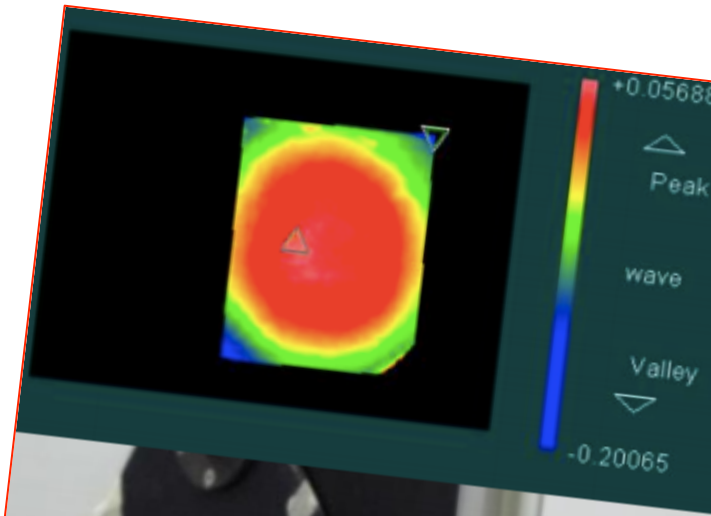
Shark-NIR

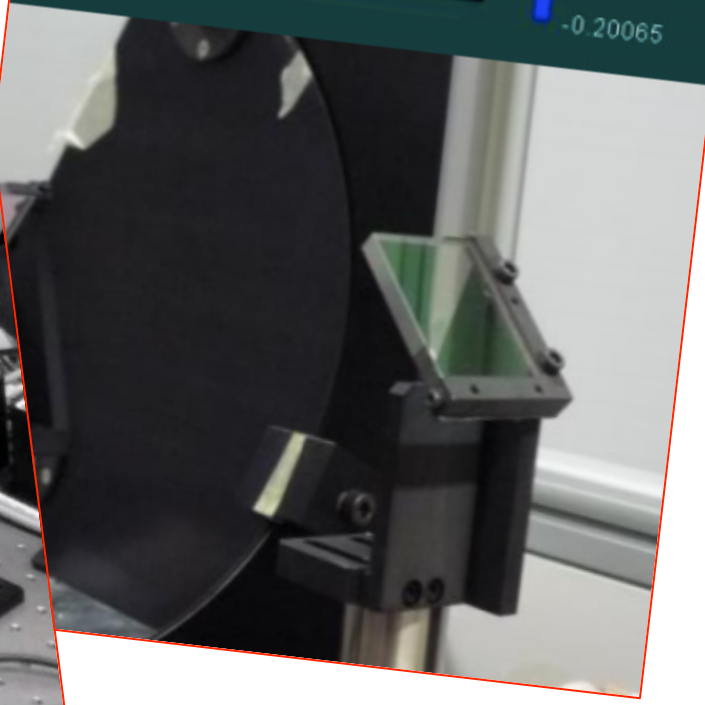


Weight: 350 kg
Size: 1500 x 800
x 800 mm

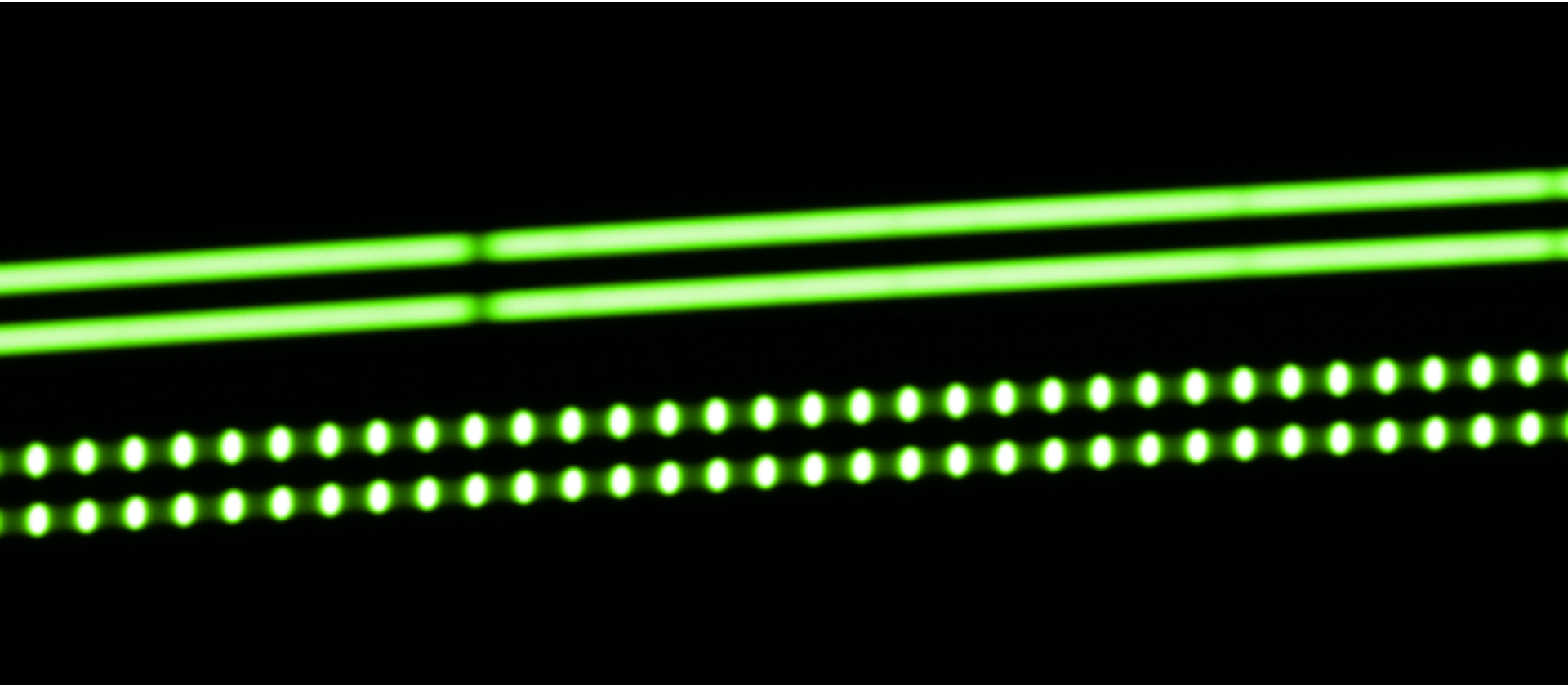
Shark-NIR







Spectroscopy



51 Peg

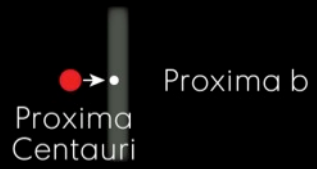
Distanza: 0.05 AU

Vel Rad. 60 m/s

Giove

Distanza 5 AU

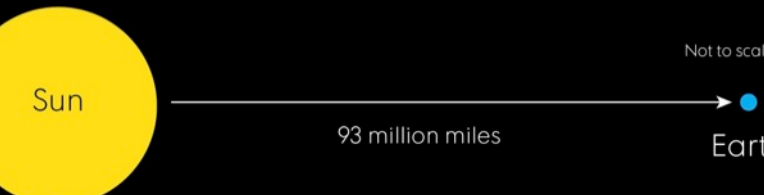
Vel. Rad. 12.7 m/s



Proxima b

Distanza 0.05 AU

Vel. Rad. 1.4 m/s



Terra

Distanza: 1 AU

Vel. Rad. 9 cm/s

Euler+Coralie – La Silla (1998-...)

M. Mayor, S. Udry, D. Queloz
F. Pepe, D. Naef, N.C. Santos

1.2-m Euler Swiss telescope
Simultaneous thorium technique
Precision: ~3 m/s -> Photon-noise limited (-> 3-10 m/s)

> 40 PLANETS

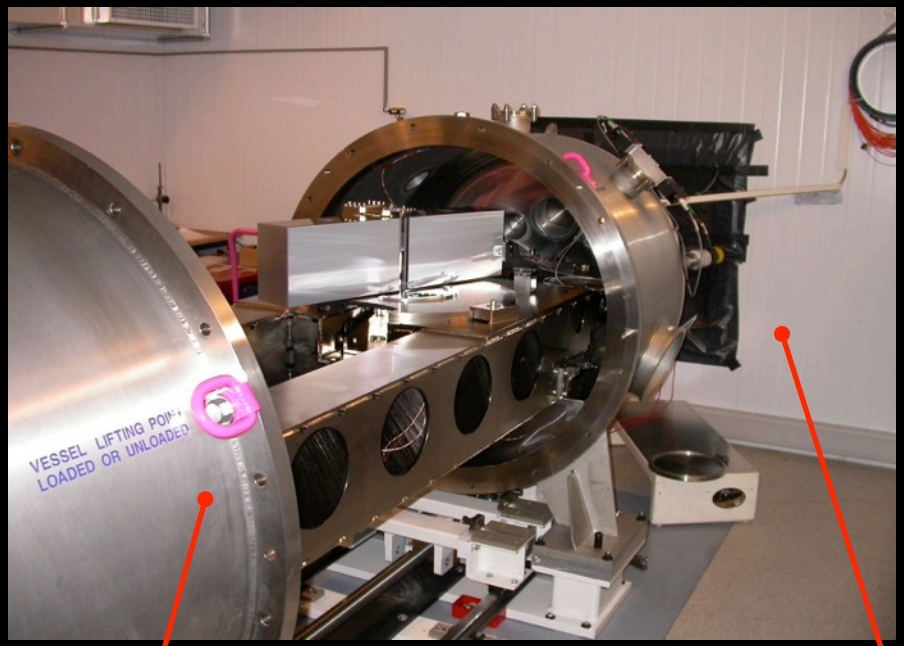
Towards 1 m/s: Stability

ΔRV =1 m/s

Δλ=0.00001 Å

15 nm on CCD

1/1000 pixel



ΔRV =1 m/s

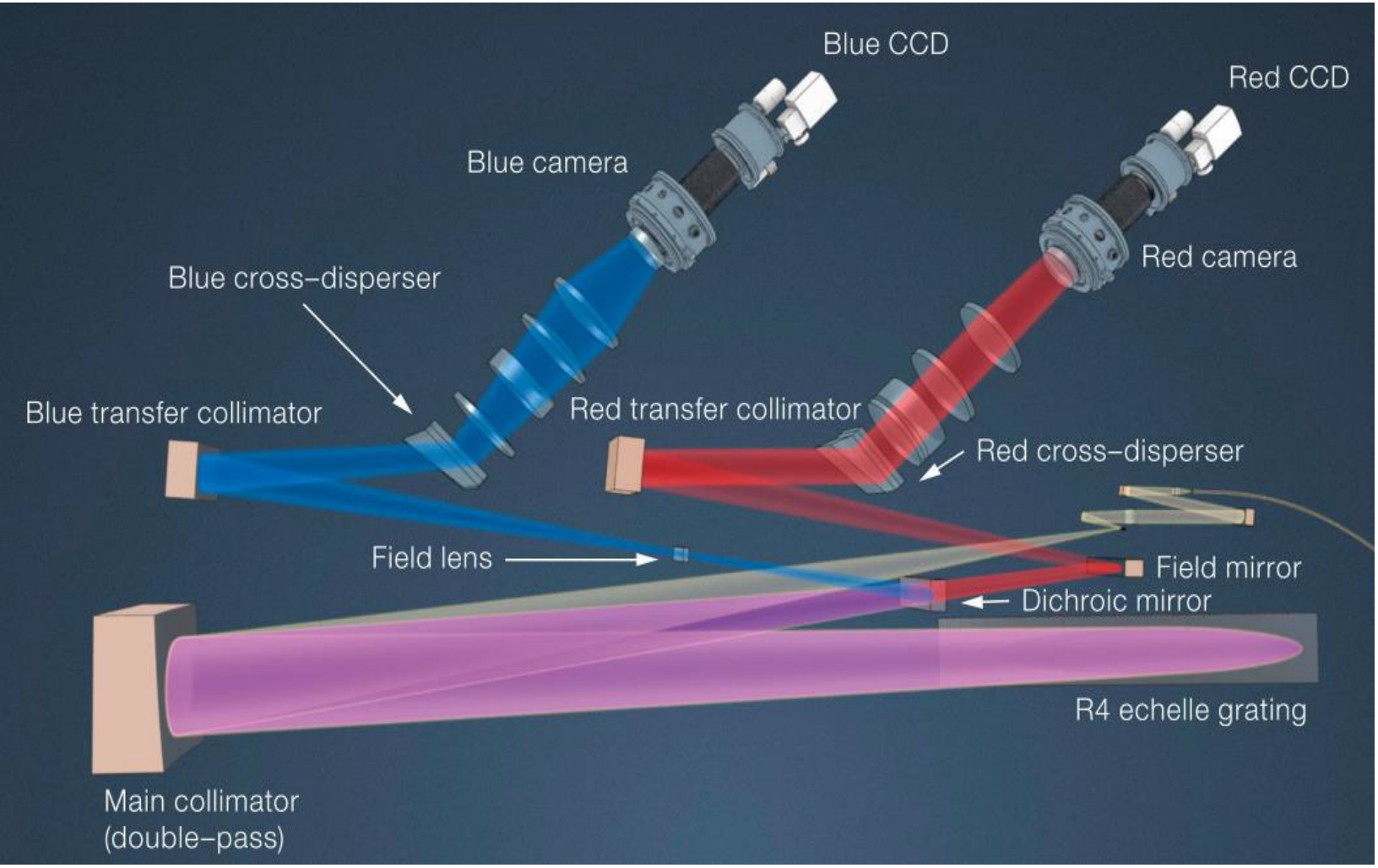
ΔT = 0.01 K

Δp = 0.01 mbar

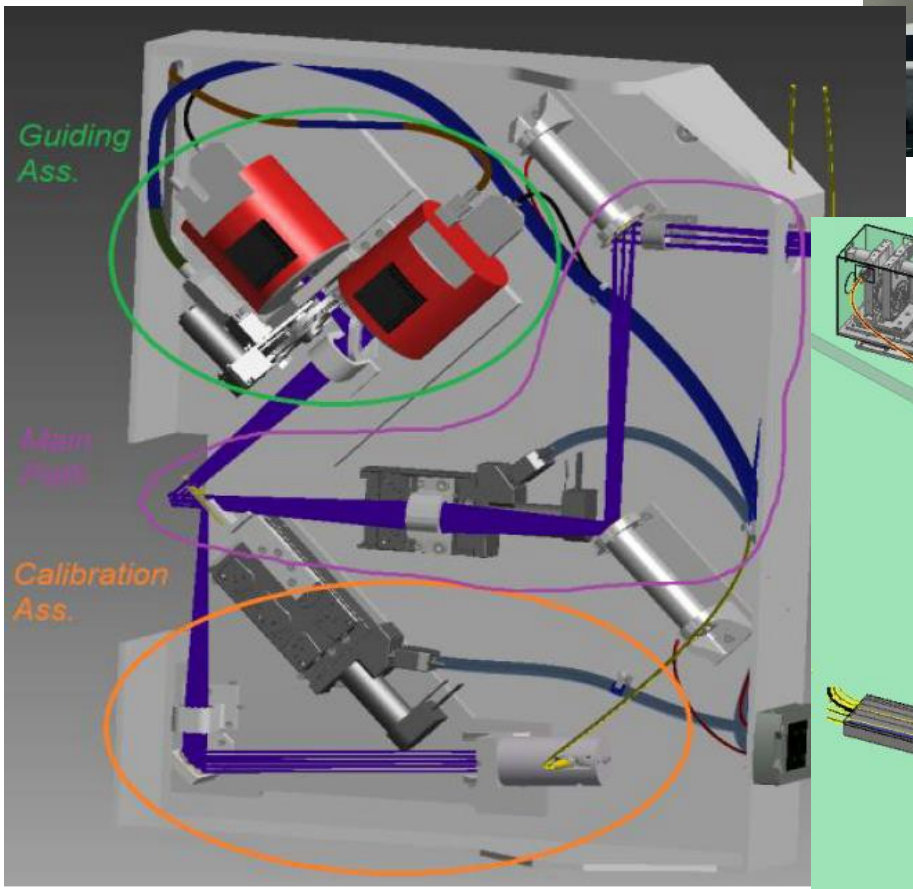
In vaccum

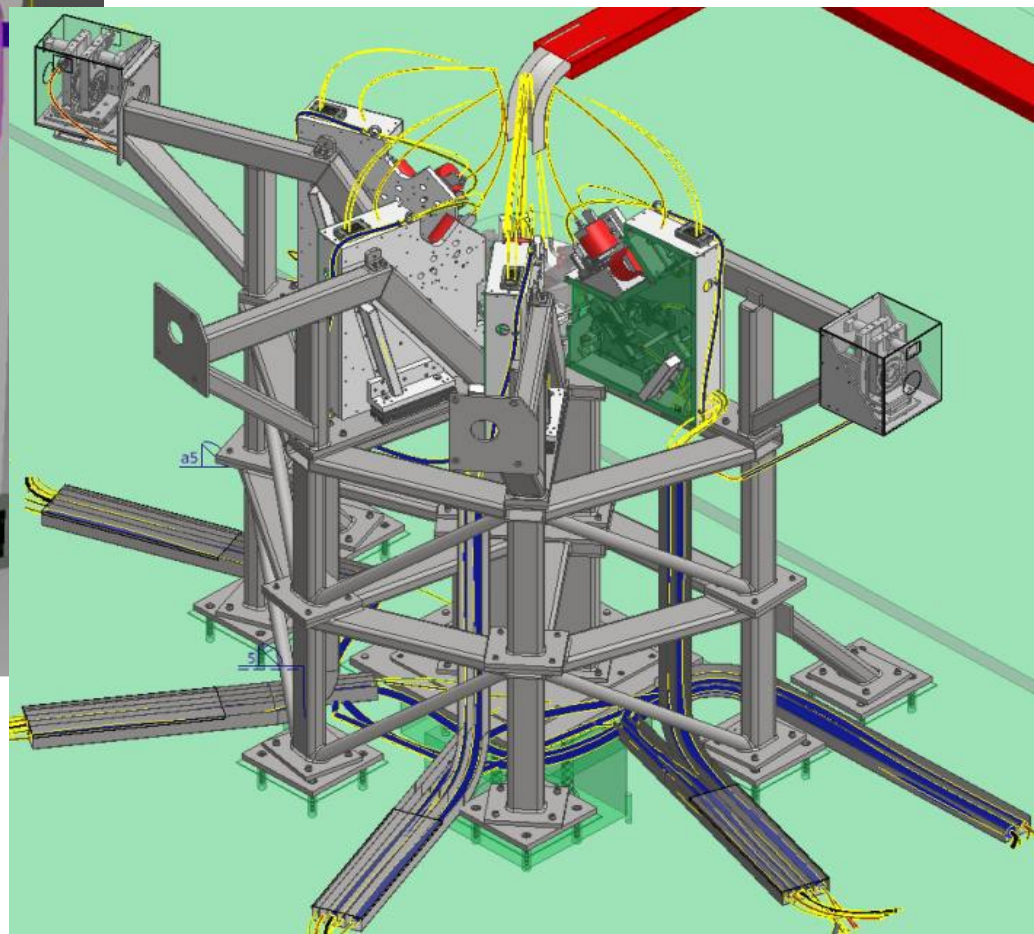
Temperature control

Optical design of the spectrograph…



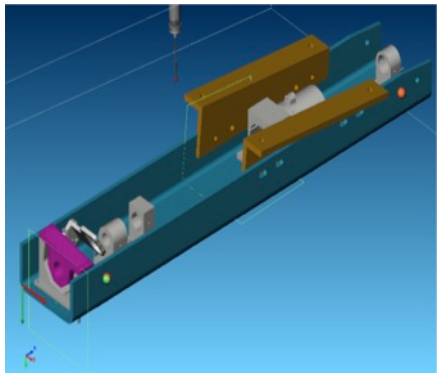
OptoMech project

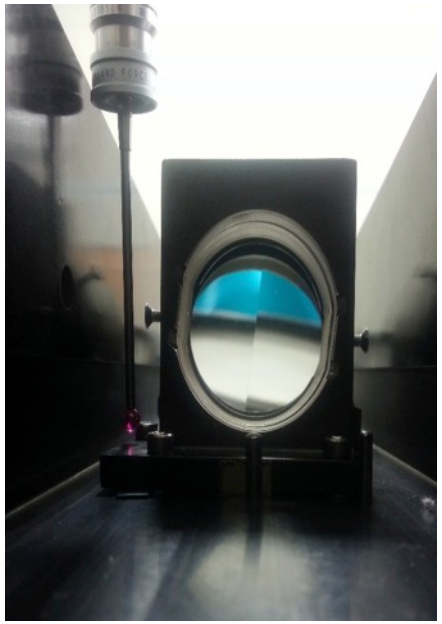


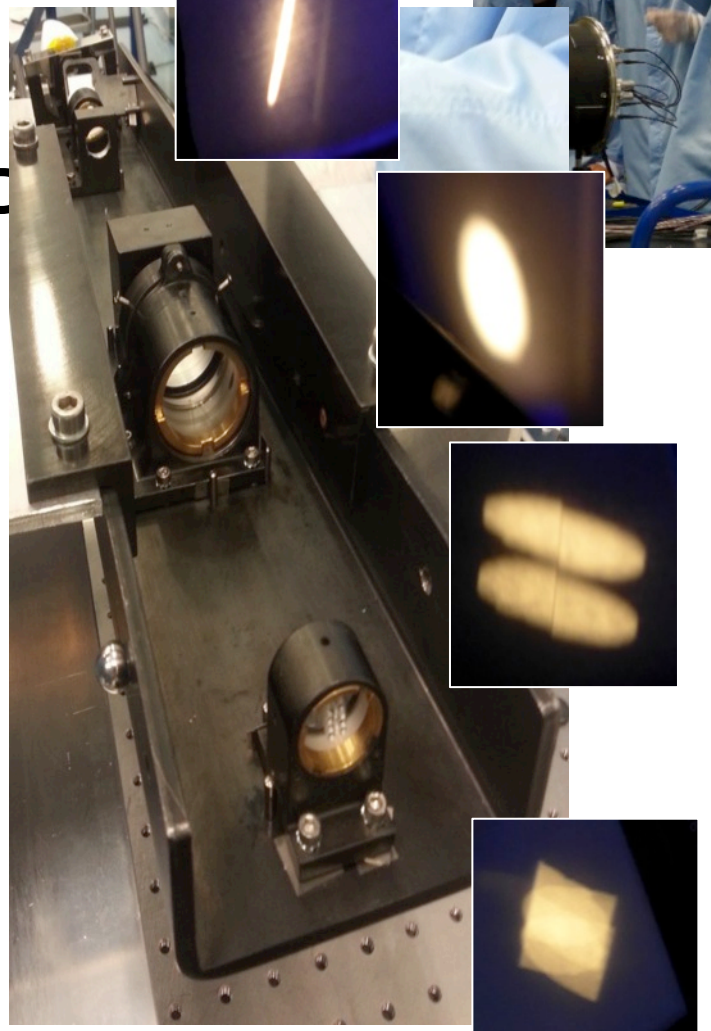


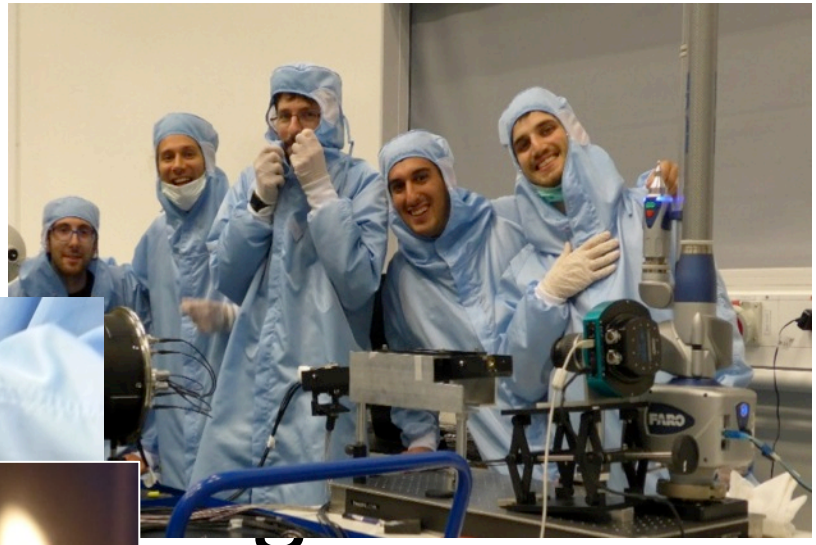
- ~85 optical elements
- ~300 mechanical parts

Integration with CMM

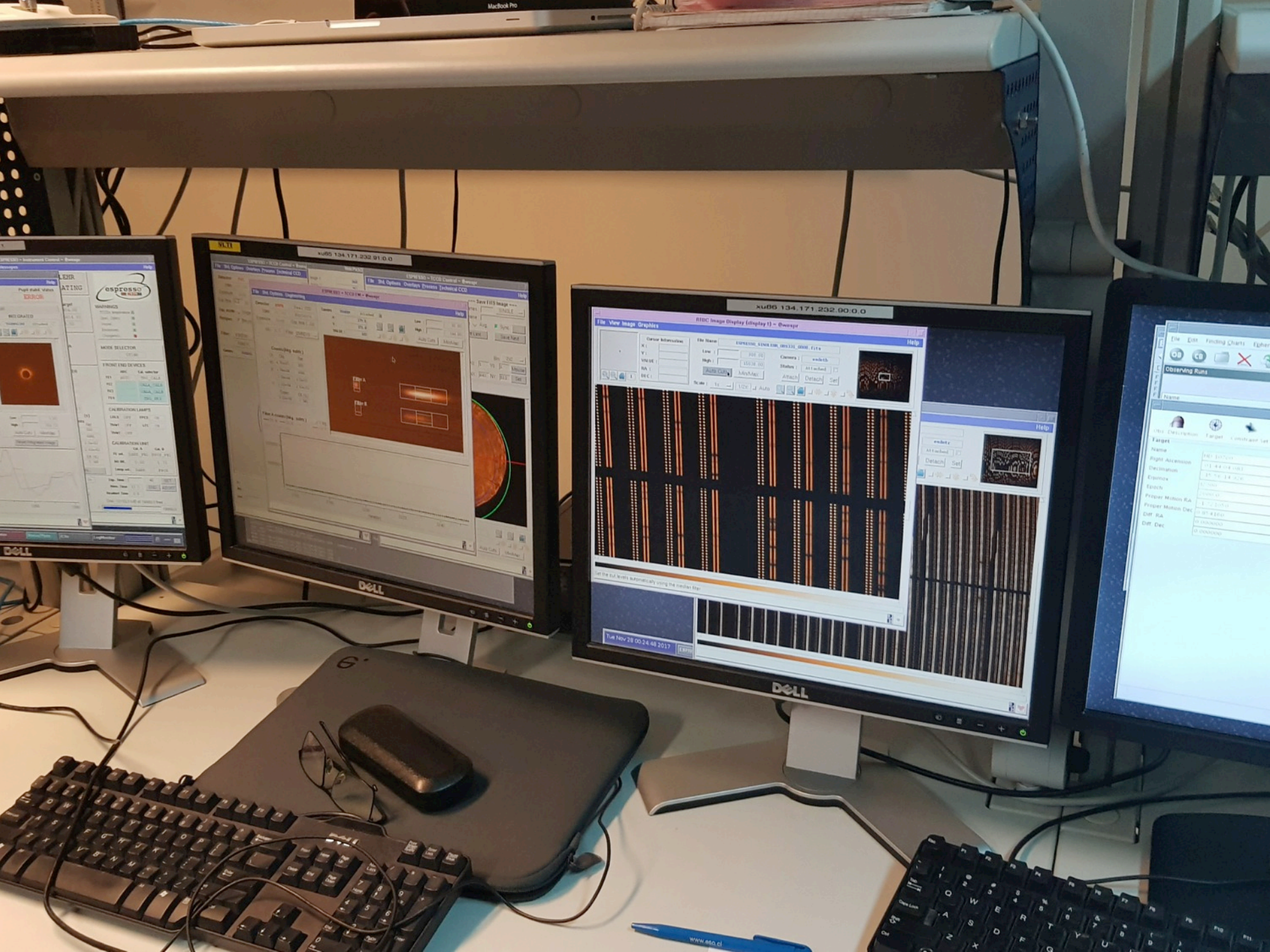




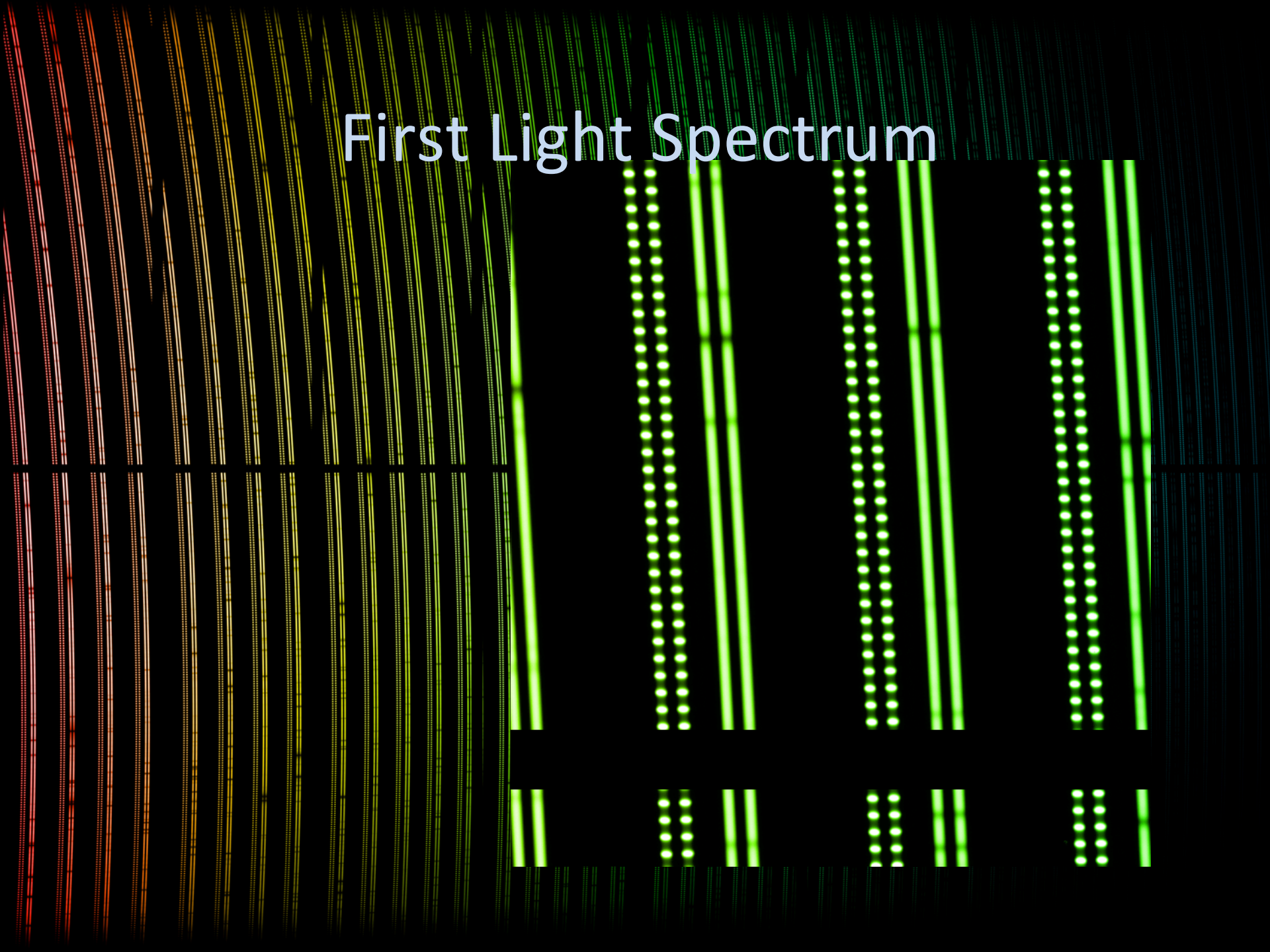





espresso
What else?


MacBook Pro
DELL
DELL
DELL

First Light Spectrum



Wrap-Up….

- Complex optomechanical systems from both ground and space
- Wide (& very wide) innovative optical systems with large number of resolution elements
- Innovative (very) accurate measurements and control of wavefront in Optical & NIR
- Precision spectroscopy
- Interferometry
- Are these bricks to develop a locally monitored high performance imager or interferometer with astrometric capabilities…???