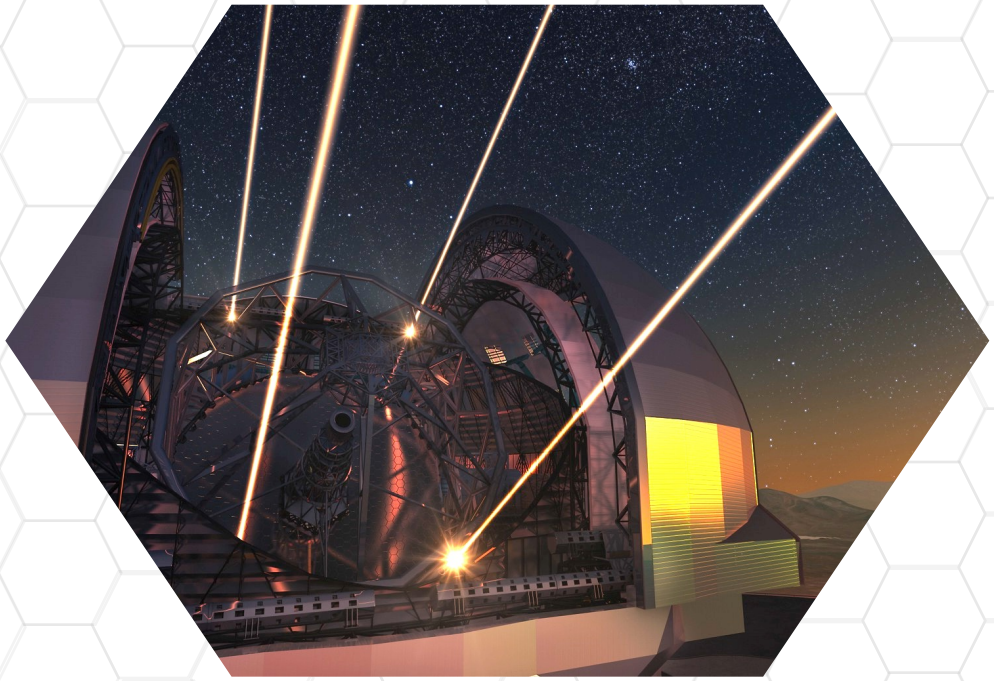
The European Extremely Large Telescope and its instrument suites



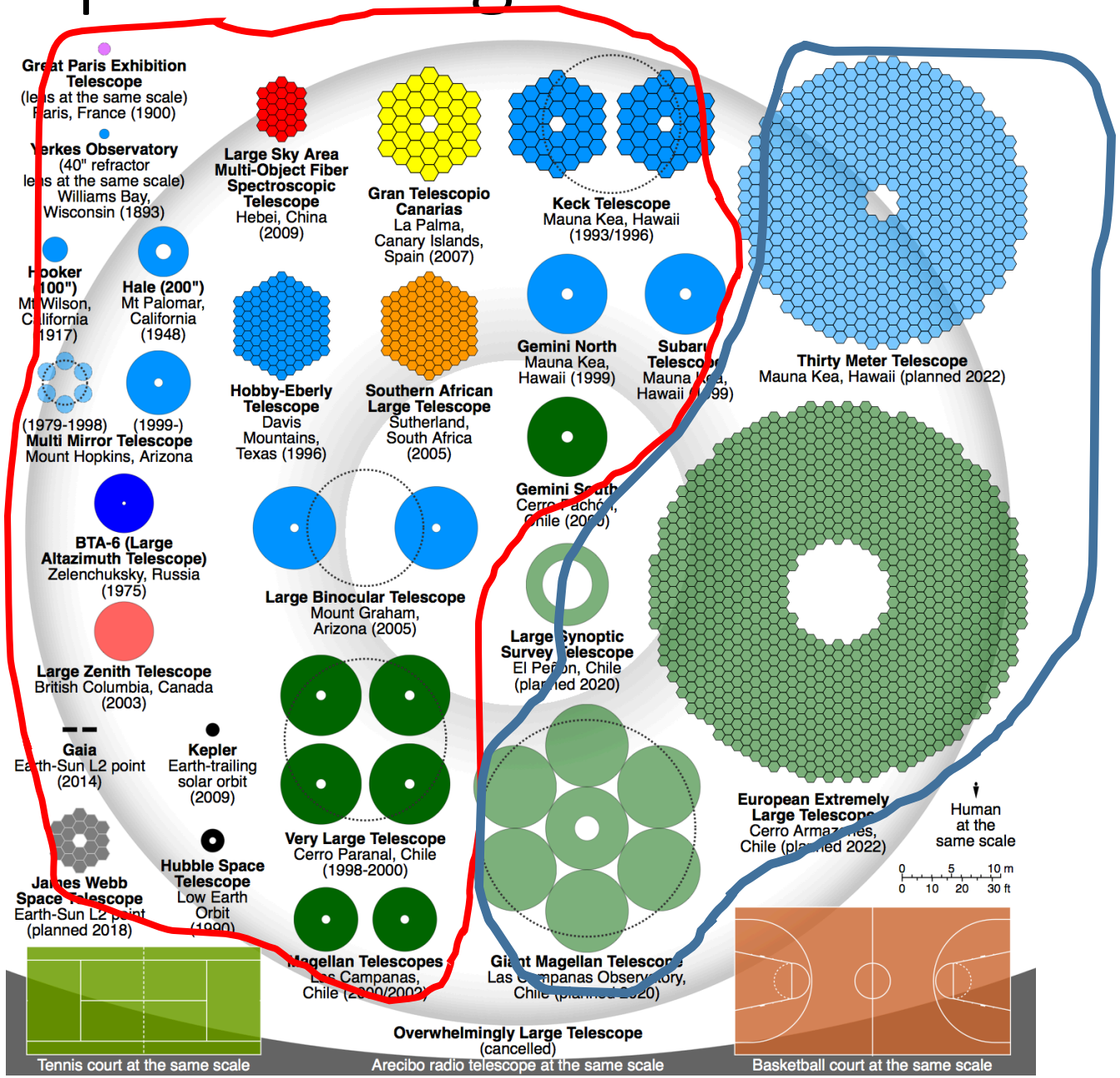
Benoit Neichel

With the help of: Carlos Correia, Jean-François Sauvage, Thierry Fusco, Eric Gendron, David Mouillet

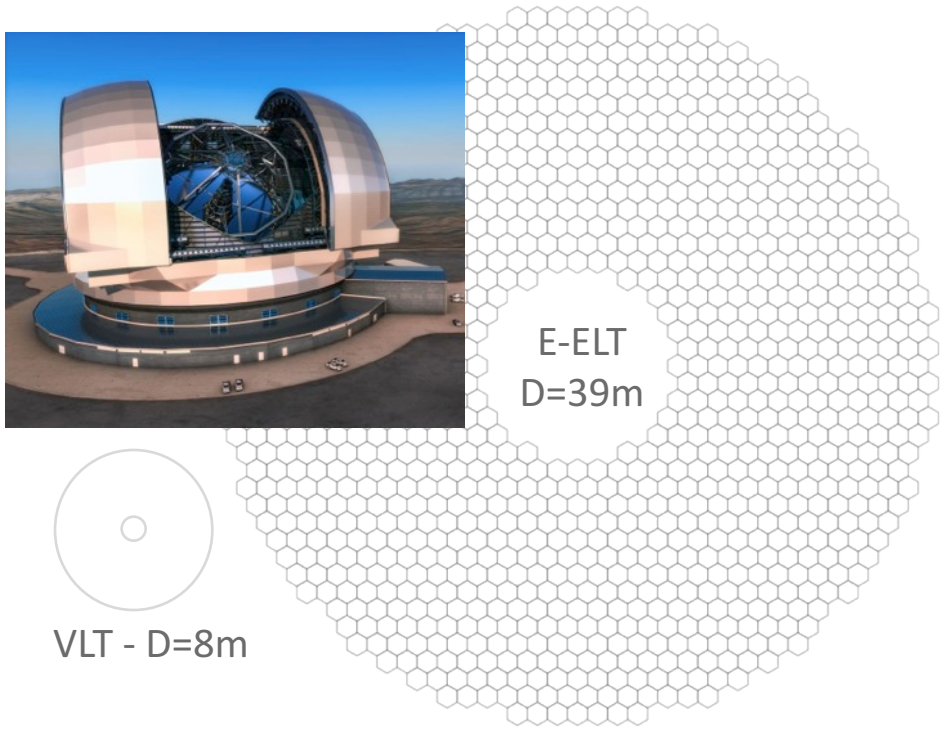
SF2A Juillet 2018

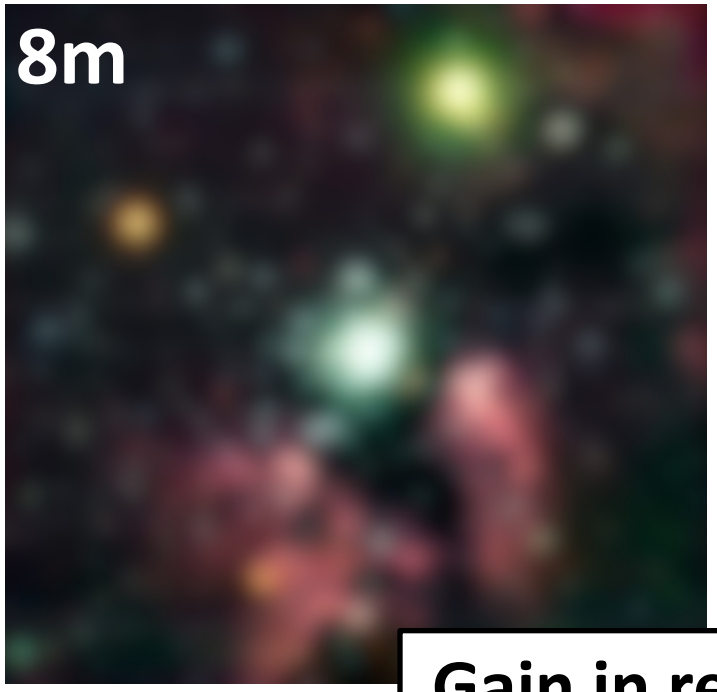
ASHRA
Action Spécifique Haute Résolution Angulaire

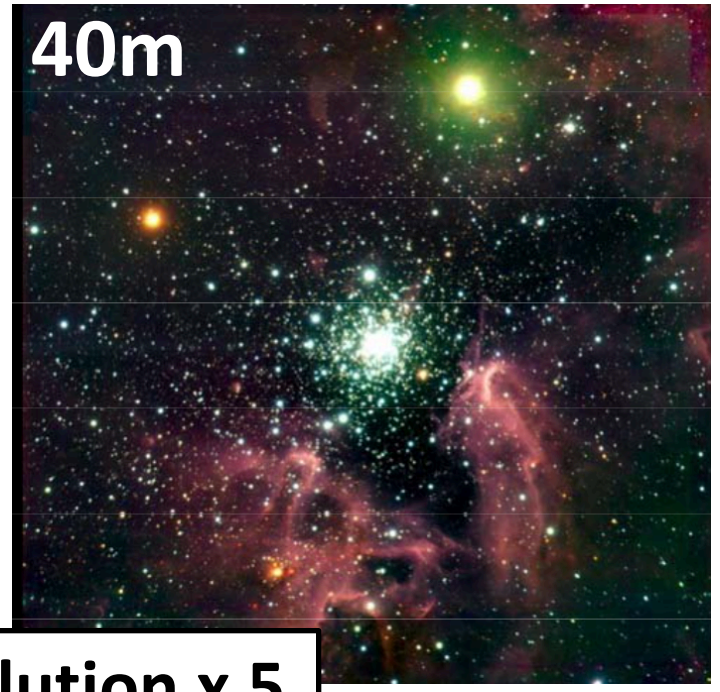
Exponential growth… For collecting power



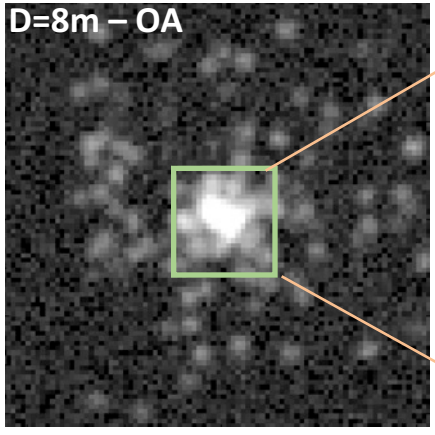
Exponential growth… For angular Resolution

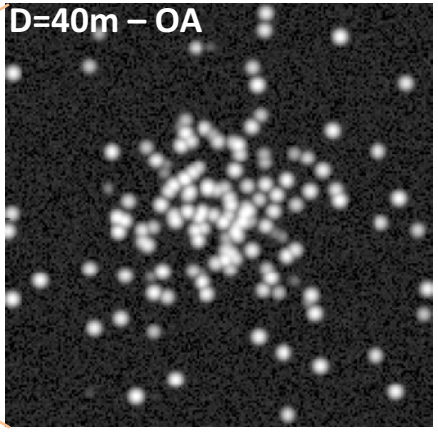






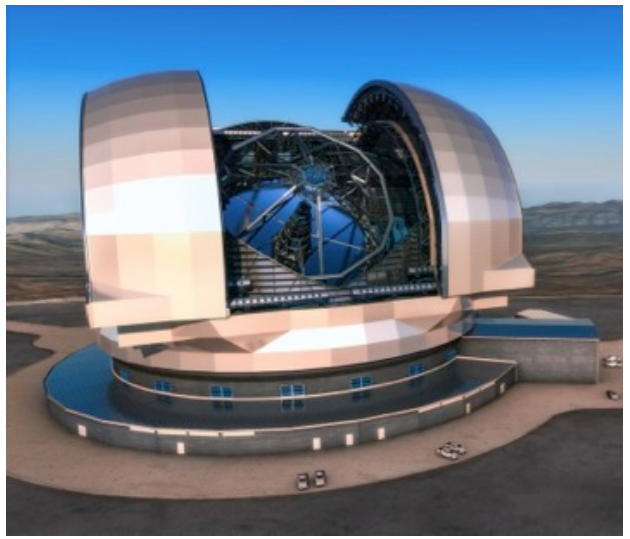
Gain in resolution x 5
Gain in sensibility x 5^4

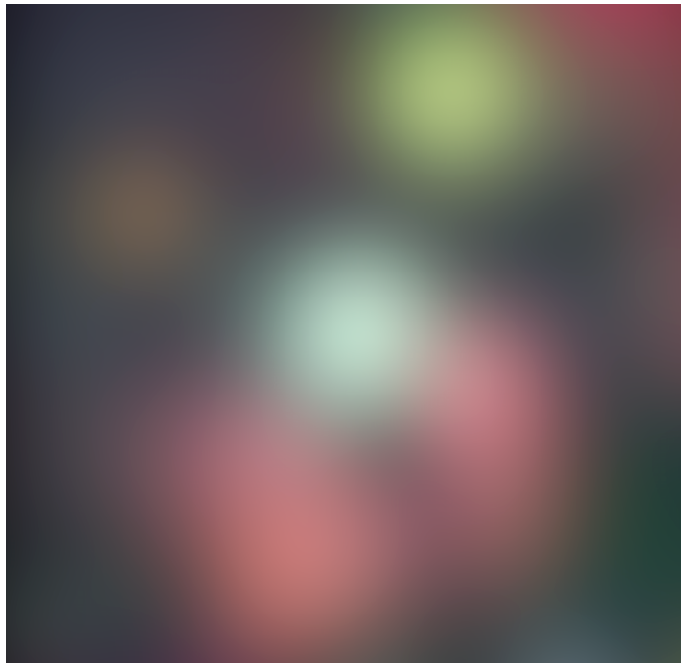




Only true if telescope is working at its diffraction limit

Earth atmosphere + ELT





ESO responsibility

[I-INS/ELT-90]

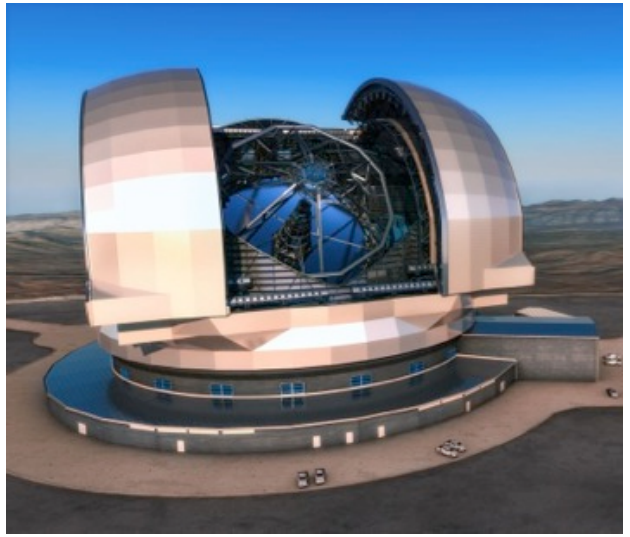
/ / /

The telescope shall deliver seeing-limited performance with natural guide star(s) as follows:

- For the worst 95-percentile seeing conditions the FWHM of a point source generated by an ideal telescope operated in the atmosphere shall not be degraded by more than TBD %

- For the 5-percentile best seeing conditions the FWHM of a point source generated by an ideal telescope operated in the atmosphere shall not be degraded by more than 5% (TBC)

Earth atmosphere + ELT + Instruments



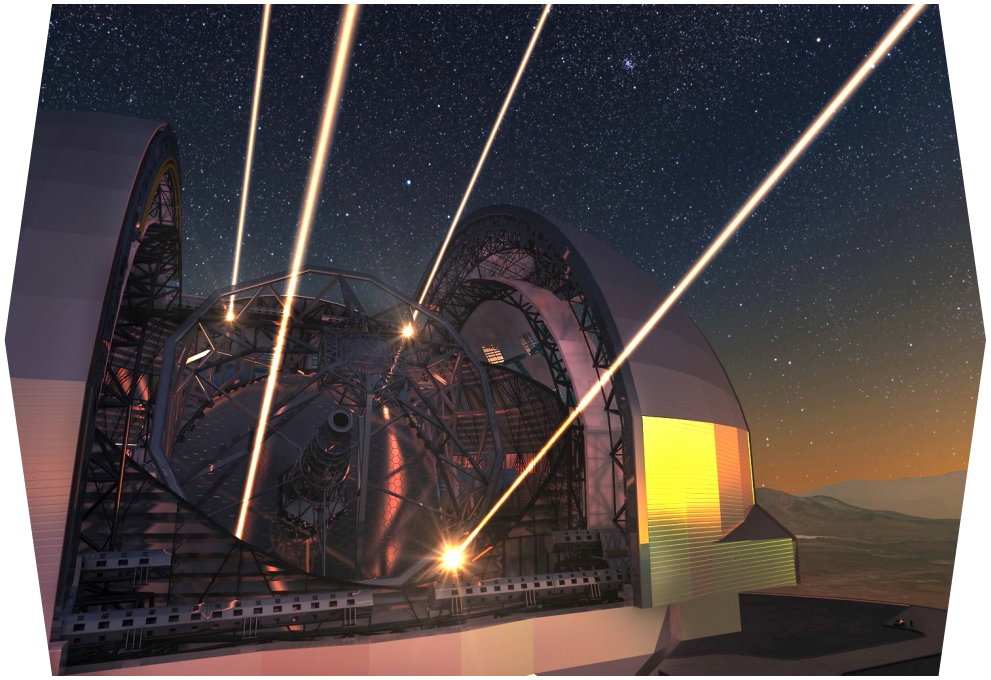
Instruments (community) responsibility

[I-INS/ELT-96] /// Enhancement of the image quality beyond the seeing limited performance specified above shall be achieved via a combination of the telescope, instruments and adaptive optics modules working together.

=> Adaptive Optics

Outline

- The European ELT –
  - How to get a seeing limited telescope
- The ELT instruments –
  - From seeing to diffraction limit
- Putting it all together
- Is it enough for the expected science ?
  - Introduction to the S09 workshop



The telescope

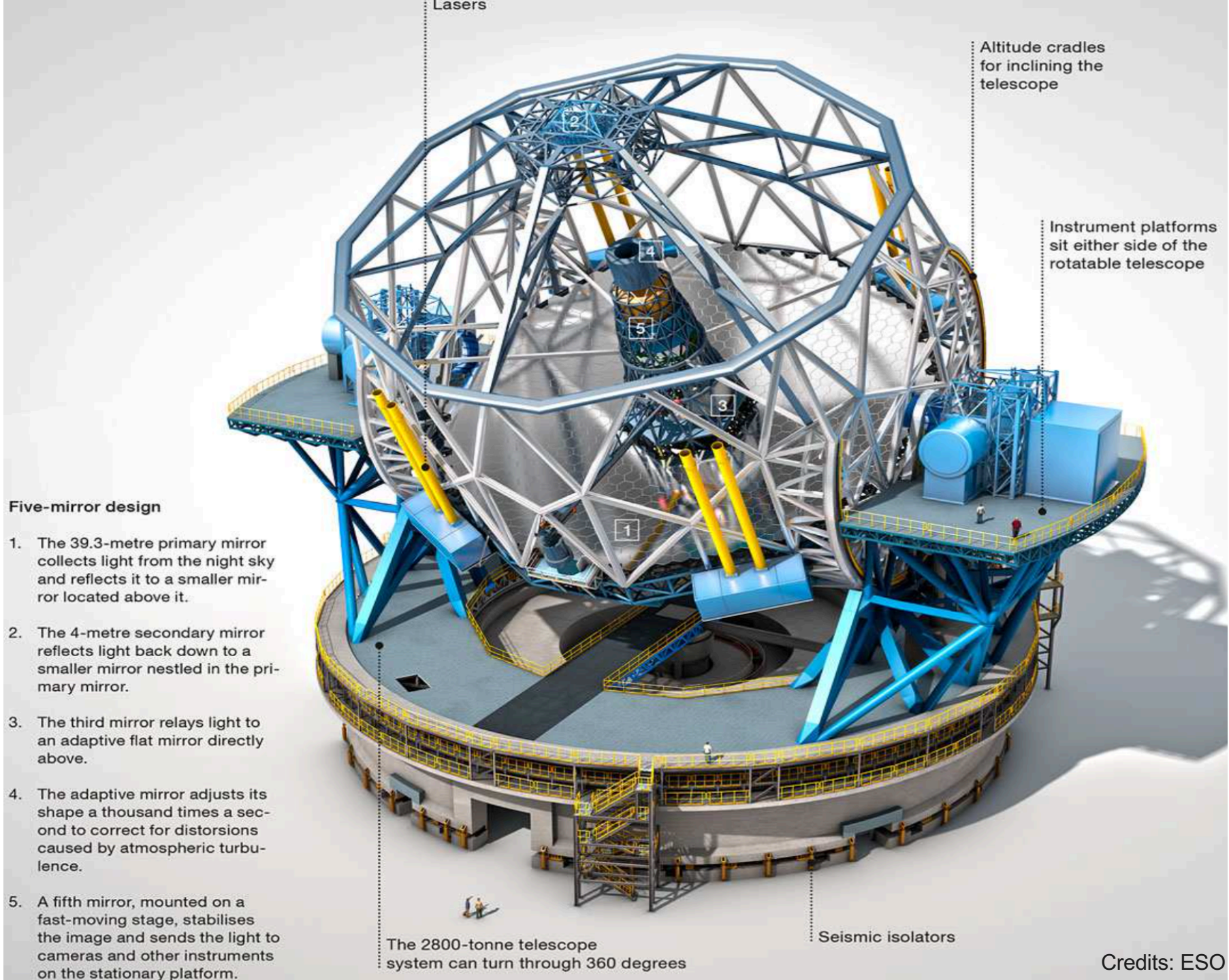
M1 = 39 m (798 hexagonal 1.4 m mirror segments)

M2 = 4m

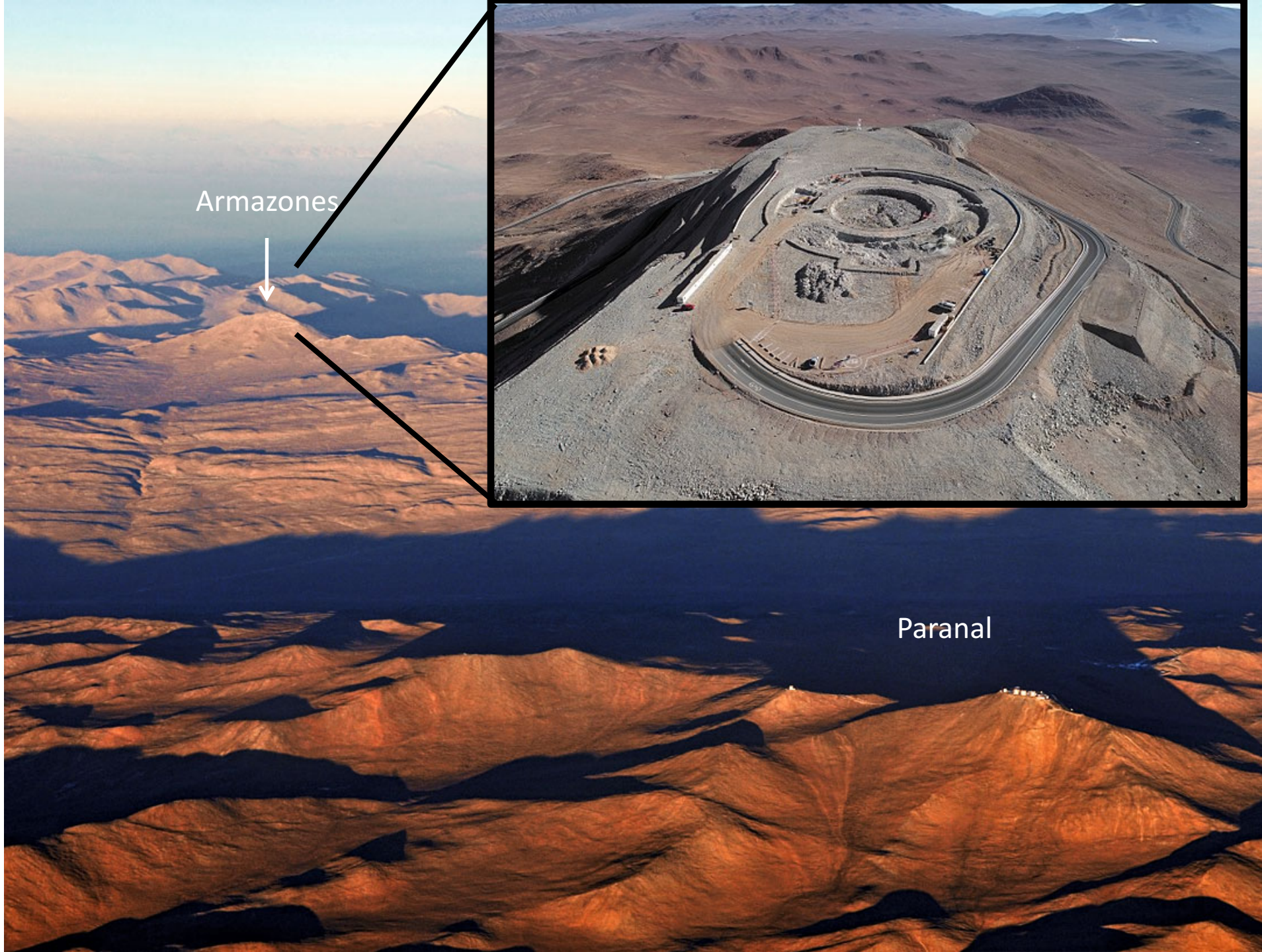
M3 = 3.75m

M4 = 2.40m (deformable mirror) – 5806 actuators

M5 = 2.6m (TT mirror)



The telescope

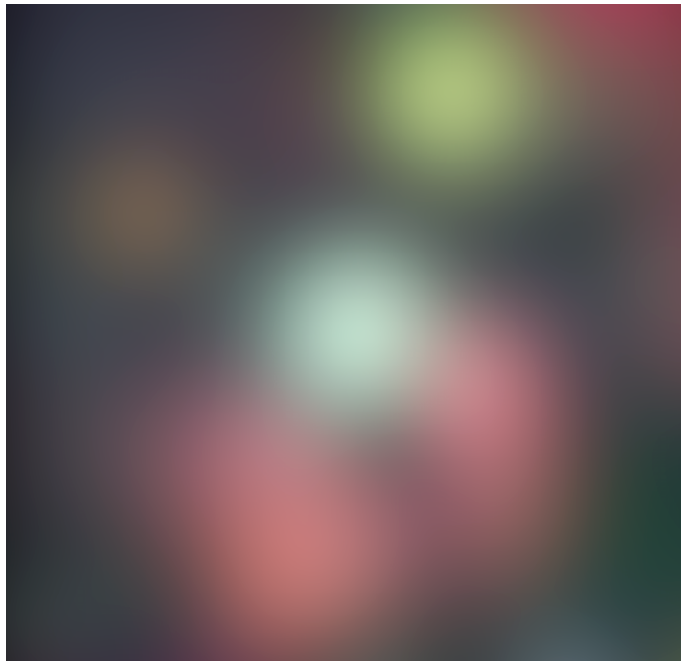


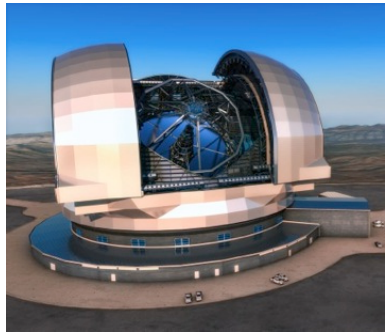
The telescope

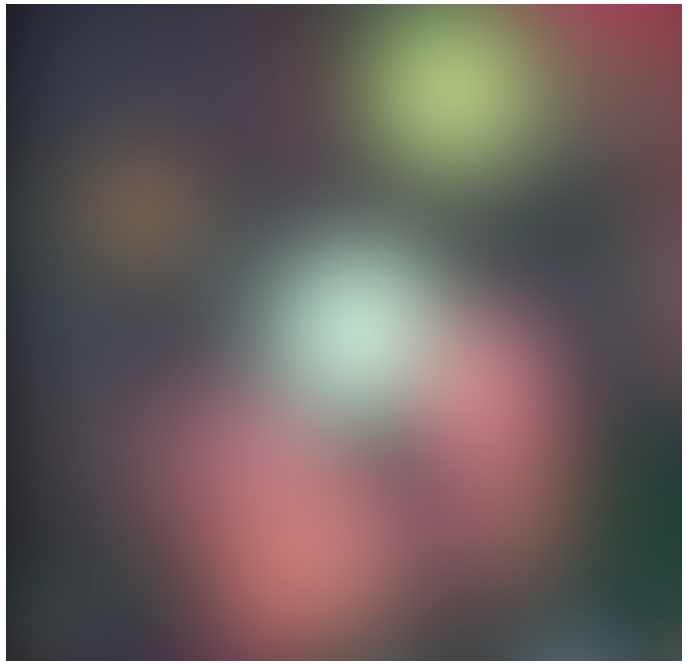
2018 **2024**

What does it take to have a seeing limited telescope ?

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?



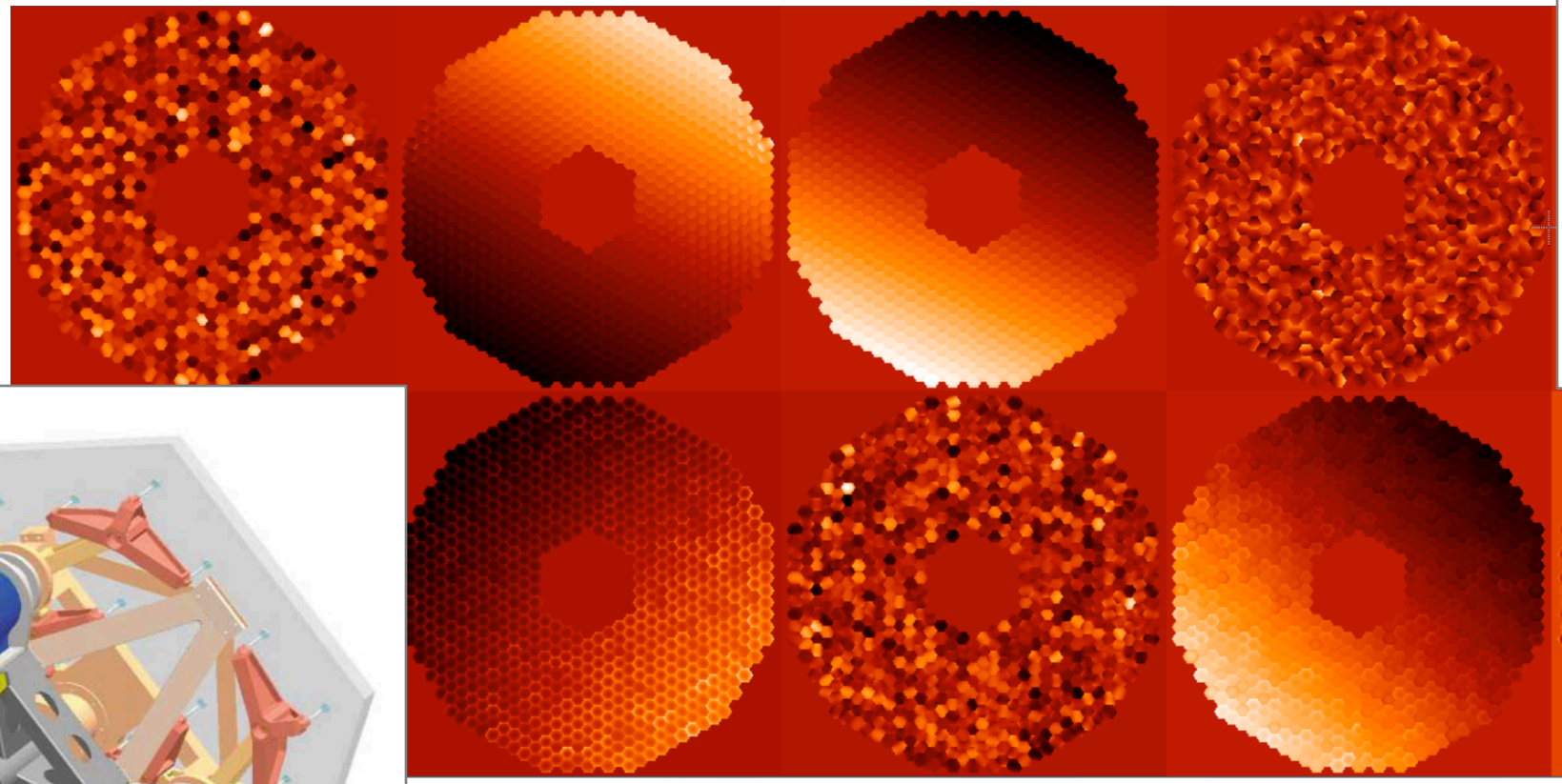


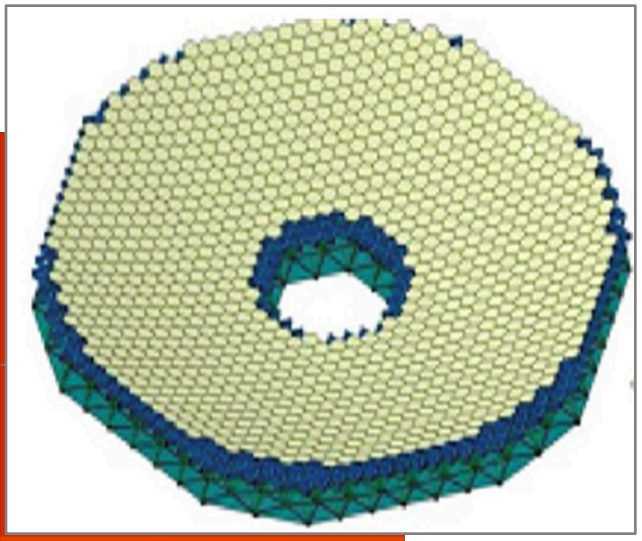


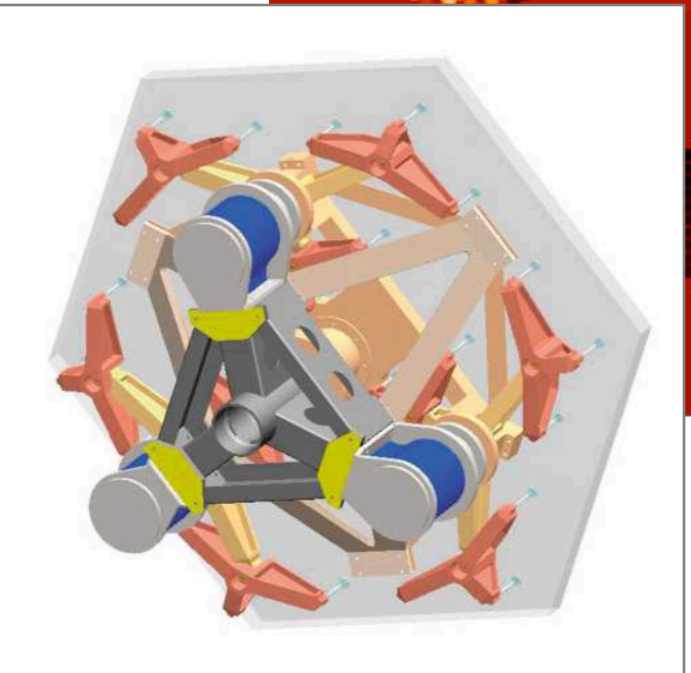
The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

1. Active control and phasing of 798 segments







ELT needs dedicated sensors for phasing

The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

1. **Active control and phasing of 798 segments**
2. **Active control of the 5 telescope mirrors**

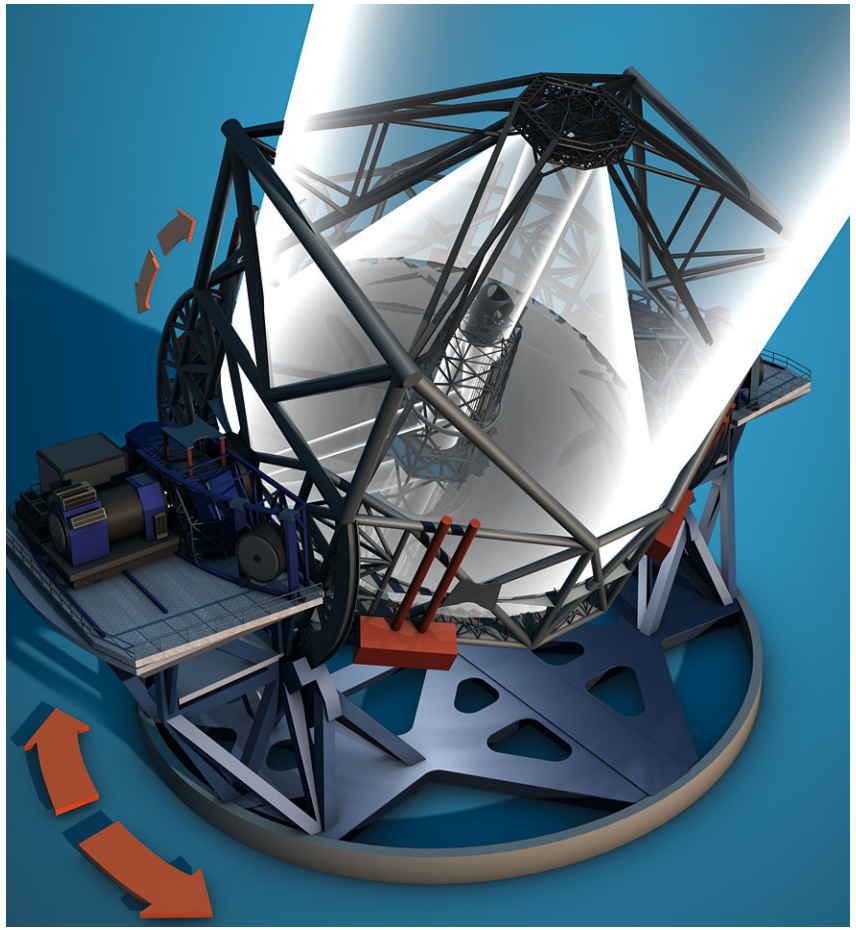
M3, 3.5km

M4, 600m

M2, 300m

M1, 0m

M5, -3.5km



Need multiple (3) sensors working on bright stars

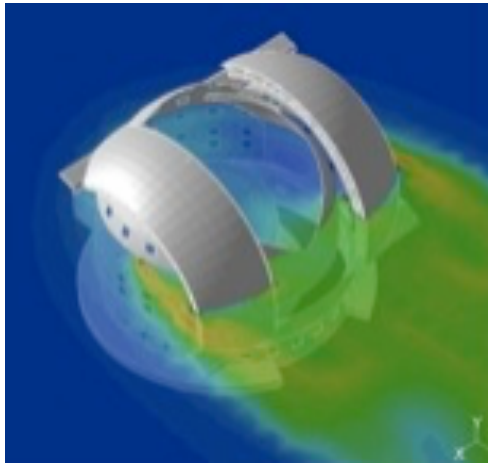
+

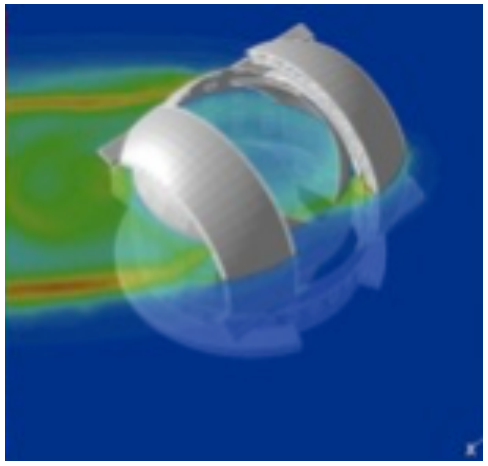
Several degrees of freedom to compensate (M4/M5)

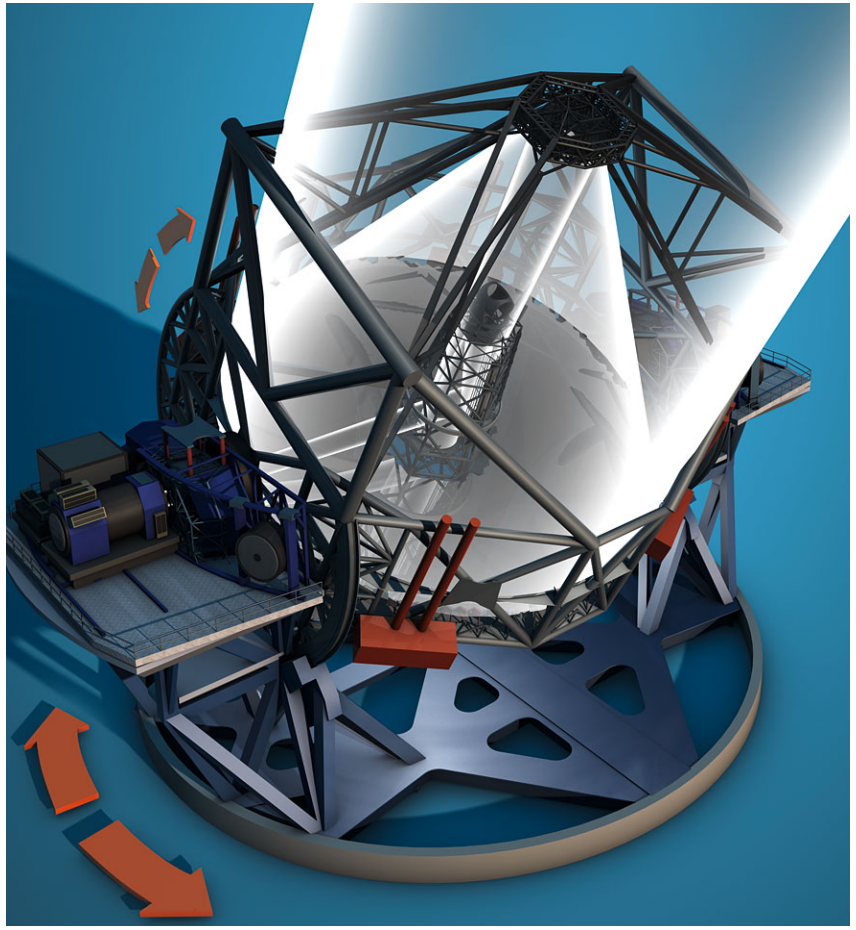
The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

1. **Active control and phasing of 798 segments**
2. **Active control of the 5 telescope mirrors**
3. **Dome seeing**







Need multiple (3) sensors working on bright stars

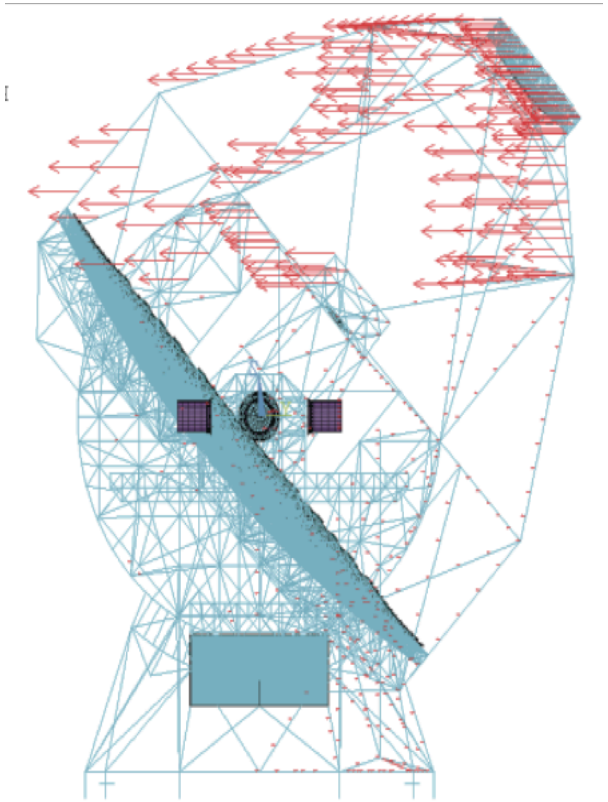
+

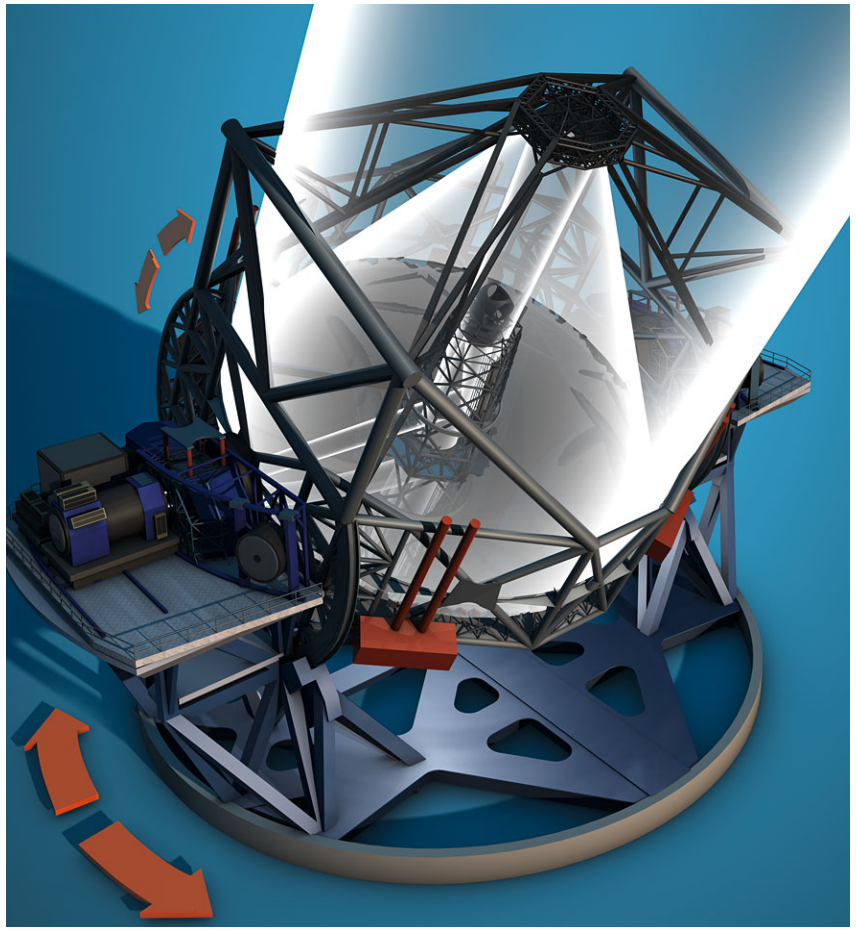
Several degrees of freedom to compensate (M4/M5)

The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

1. **Active control and phasing of 798 segments**
2. **Active control of the 5 telescope mirrors**
3. **Dome seeing**
4. **Wind load**





Need multiple (3) sensors working on bright stars

+

Several degrees of freedom to compensate (M4/M5)

+

Going fast

The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

1. **Active control and phasing of 798 segments**
2. **Active control of the 5 telescope mirrors**
3. **Dome seeing**
4. **Wind load**

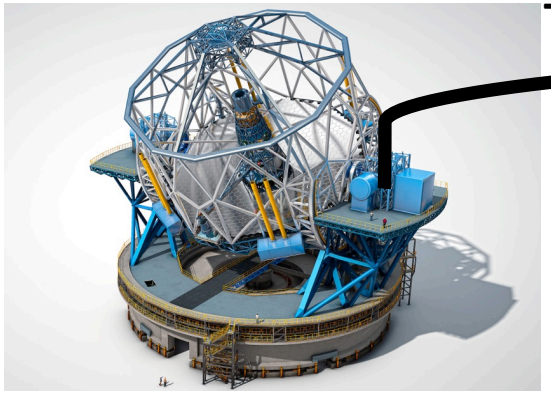
The ELT is too large to operate in conventional seeing-limited mode
Adaptive (pre-focal) correction needed all the time

Need multiple (3) sensors working on bright stars
+
Several degrees of freedom to compensate (M4/M5)
+
Going fast

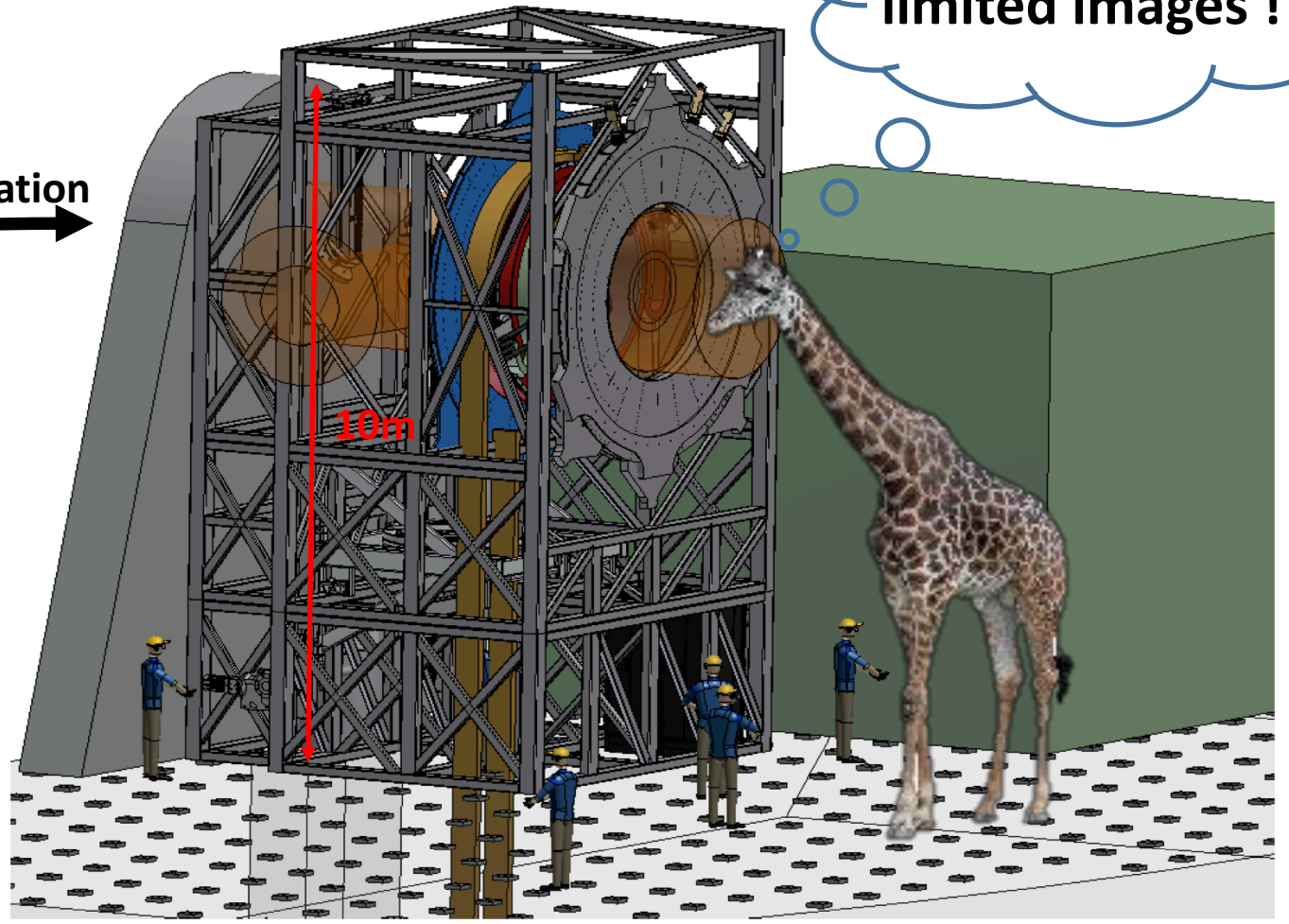
The telescope

Why is it so hard to reach seeing limited images ? What's new compared to the VLT ?

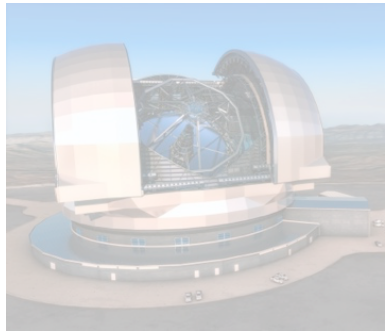
1. **Active control and phasing of 798 segments**
2. **Active control of the 5 telescope mirrors**
3. **Dome seeing**
4. **Wind load**

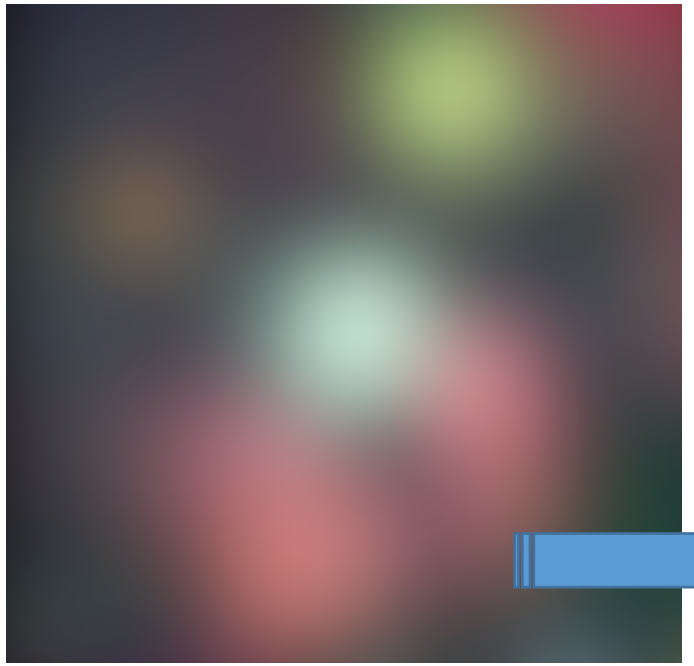


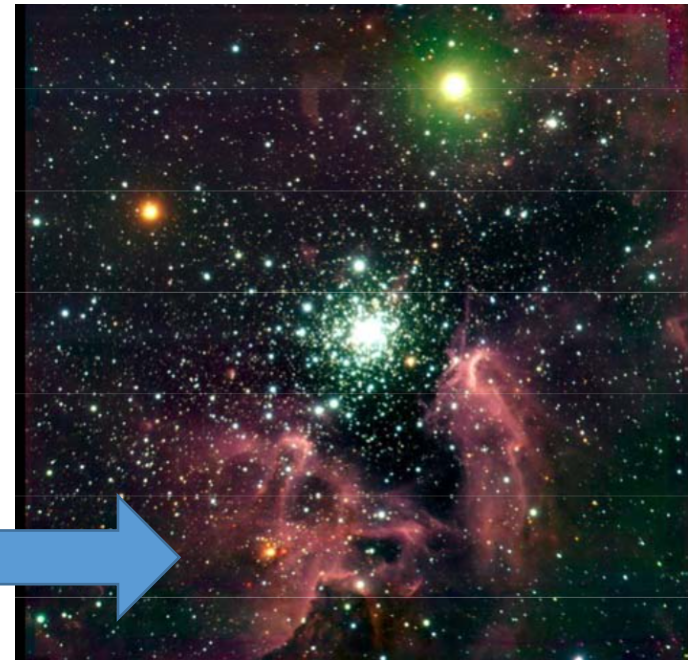
Telescope Pre-Focal Station



What does it take to have a diffraction limited images ?

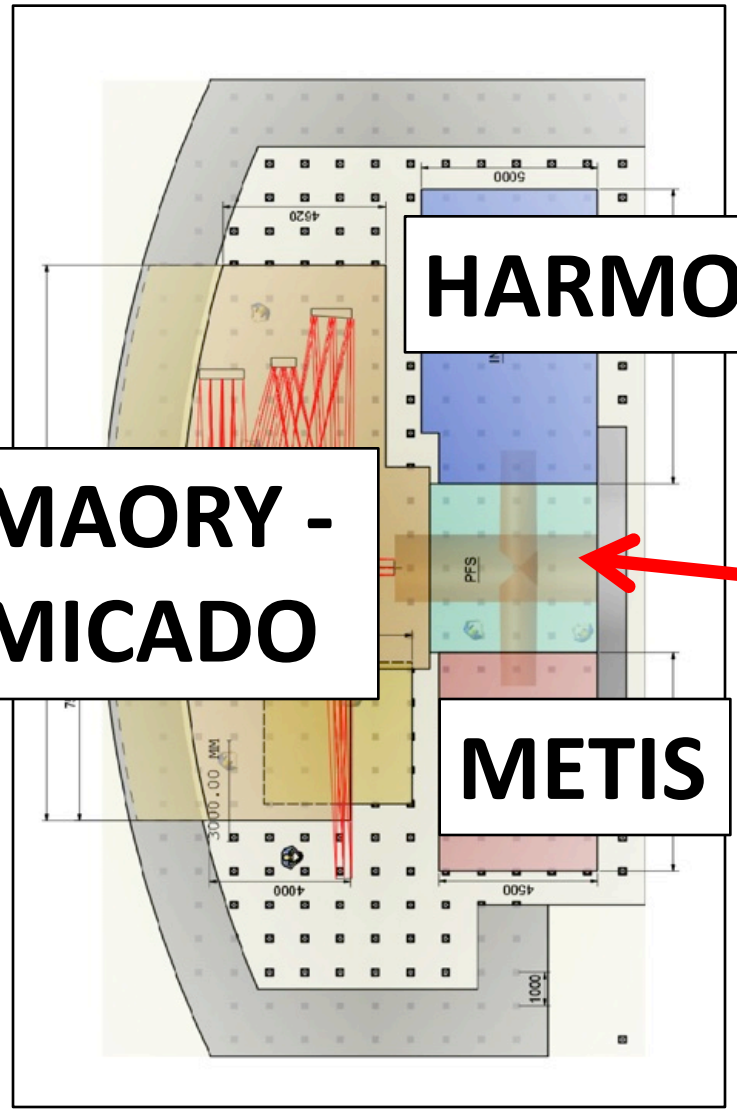


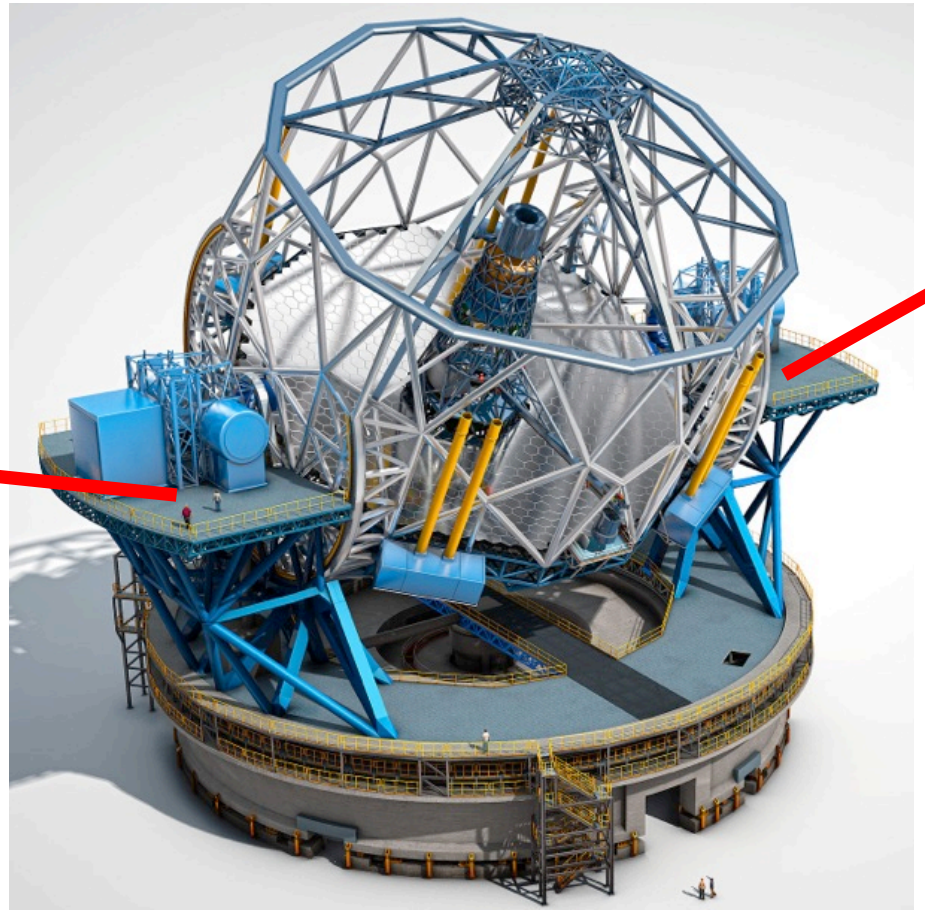




The Instruments, or how to reach the diffraction limit…

First light ELT instrument



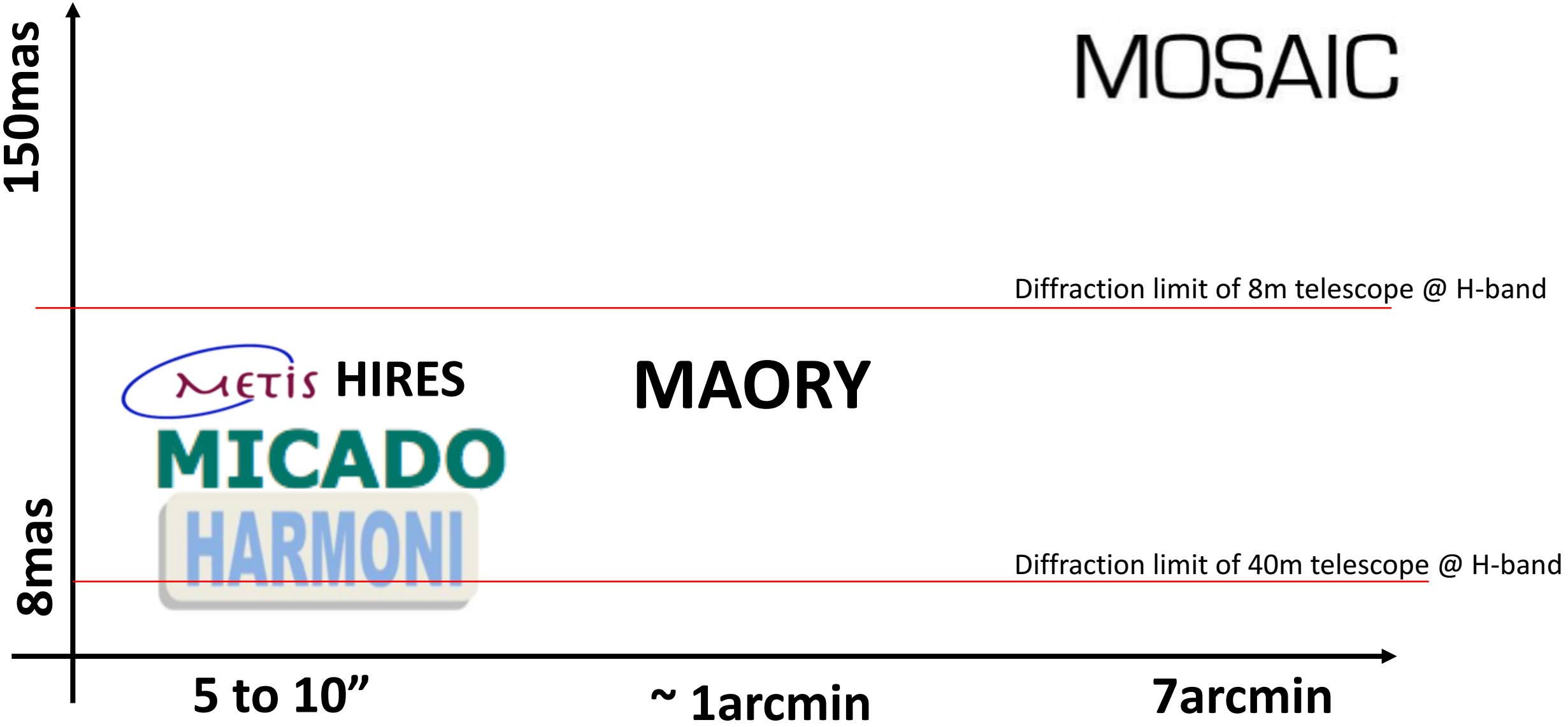


2nd generation

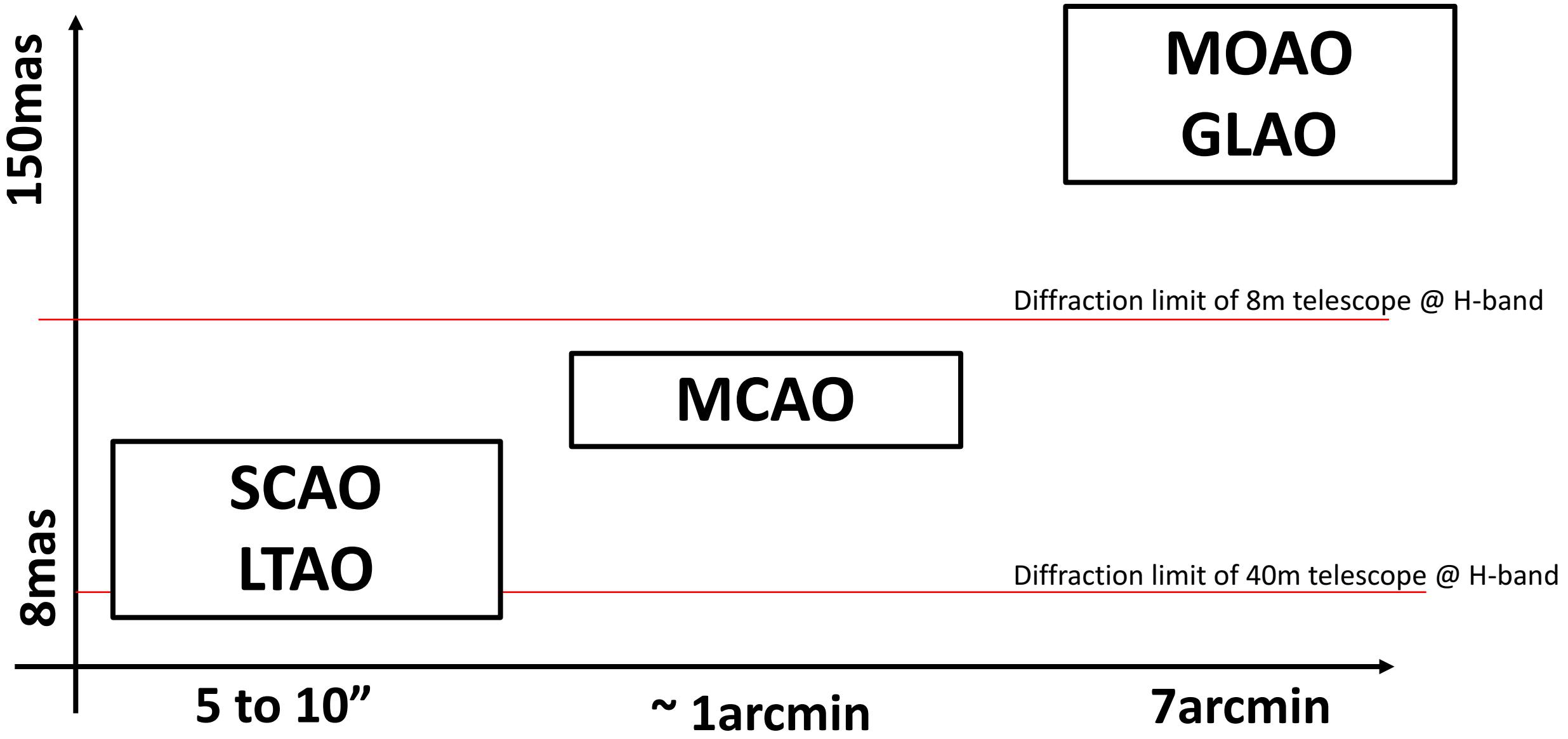
MOSAIC

HIRES

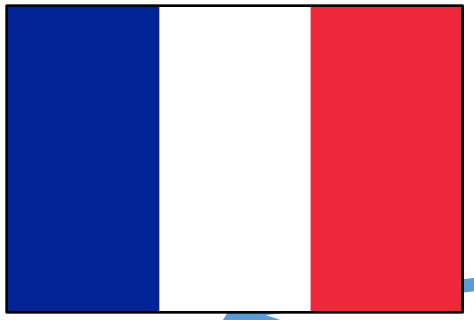
The Instruments, or how to reach the diffraction limit…



The Instruments, or how to reach the diffraction limit…



The Instruments, or how to reach the diffraction limit…



MOSAIC

MAORY

HARMONI

MICADO

METIS HIRES

150mas

8mas

5 to 10”

~ 1arcmin

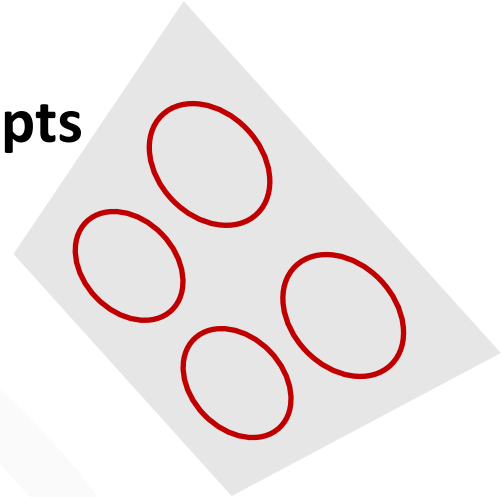
7arcmin

France Adaptive Optics effort
~80FTE / project (320FTE total) !

The Instruments, or how to reach the diffraction limit…

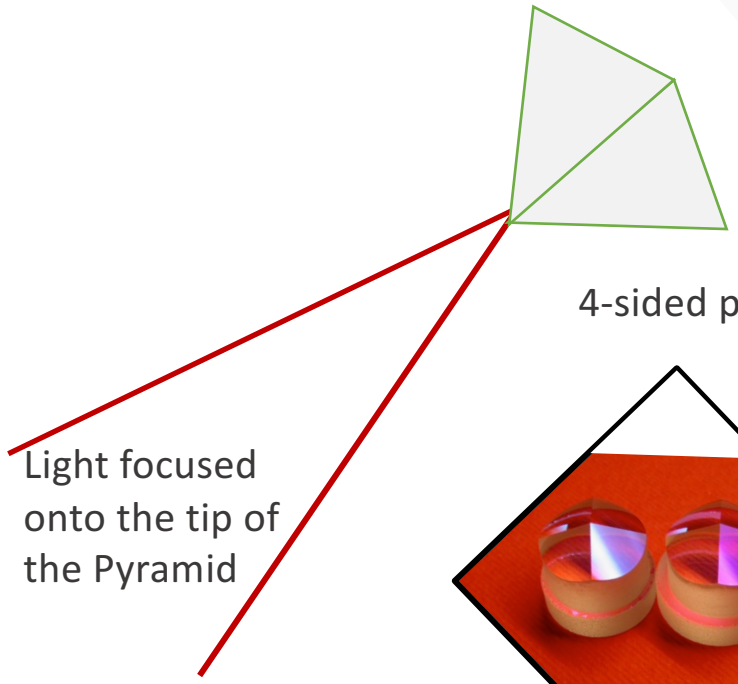
Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

1. New Sensors concepts



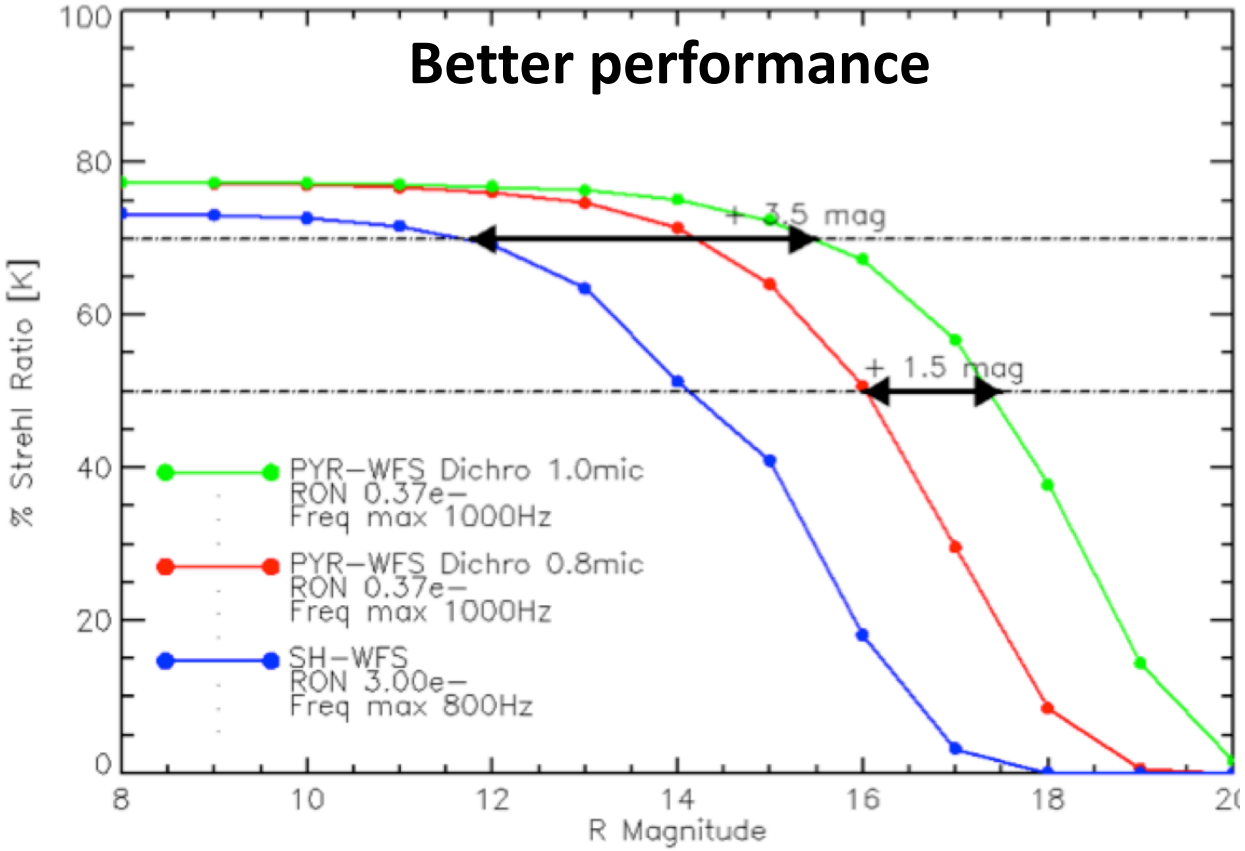
Re-imaging lens

4 images of the pupil projected onto the CCD



4-sided prism

Light focused onto the tip of the Pyramid

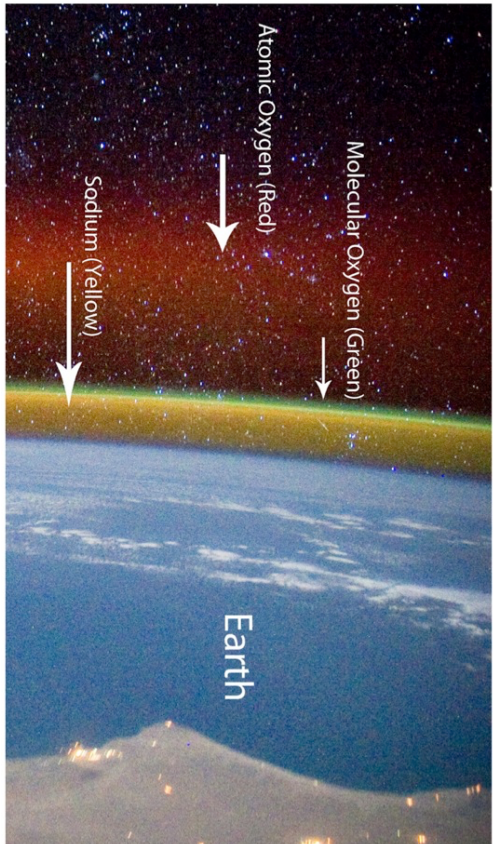


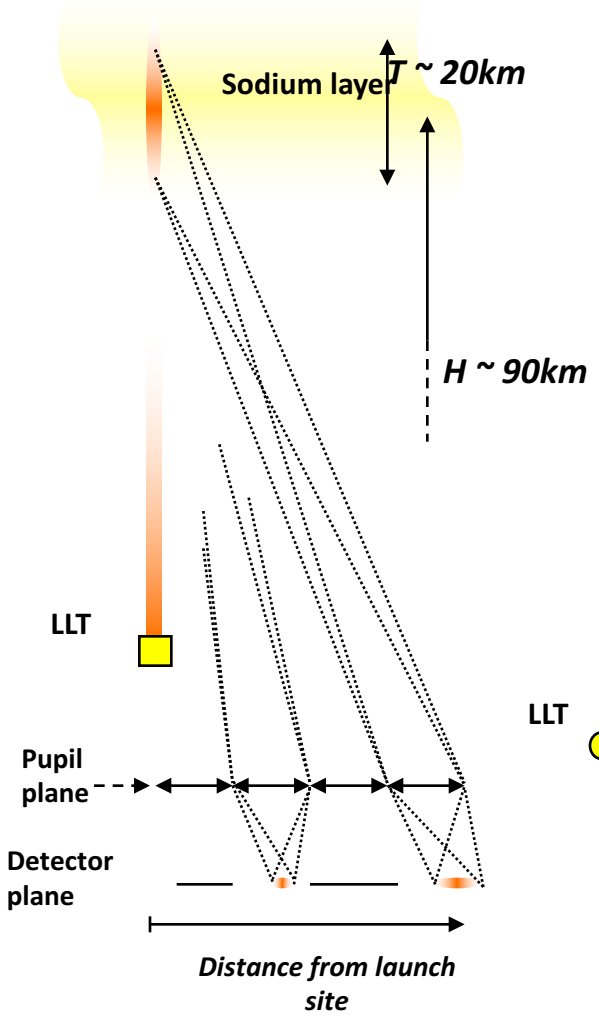
But never used on VLT: lack of experience, and operational feedback.
Several experiments on-going on the French community to cope with that.

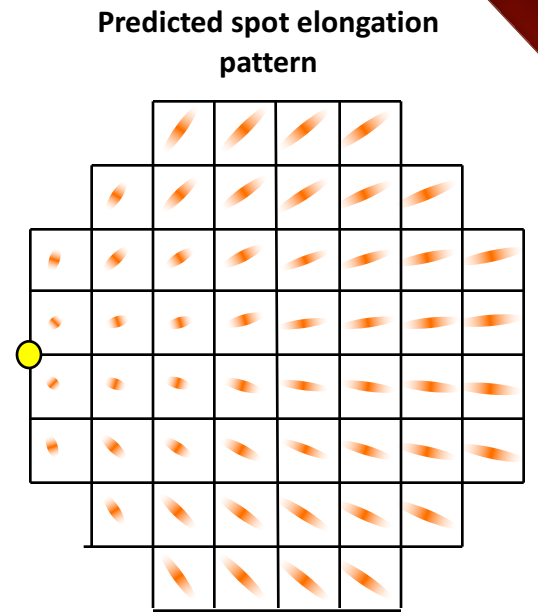
The Instruments, or how to reach the diffraction limit…

Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

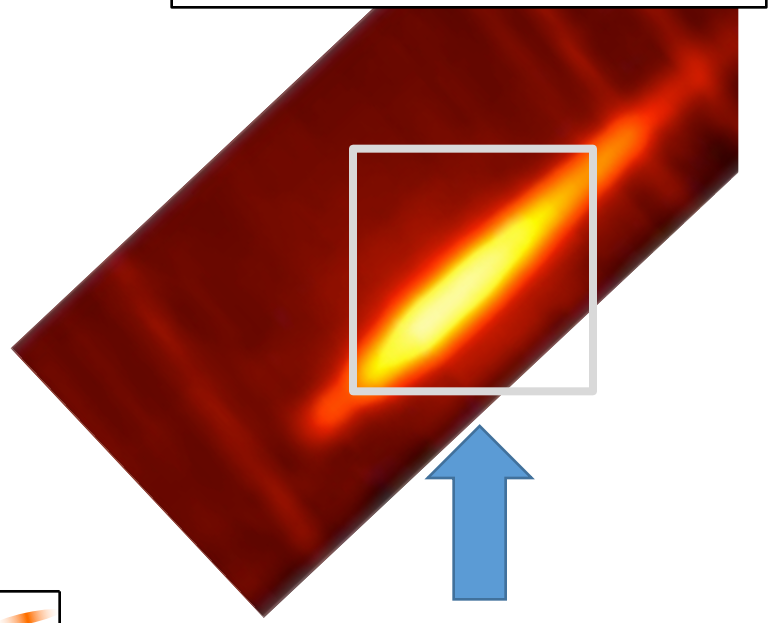
1. **New Sensors concepts**
2. **Lasers on ELTs**







On a ~40m telescope

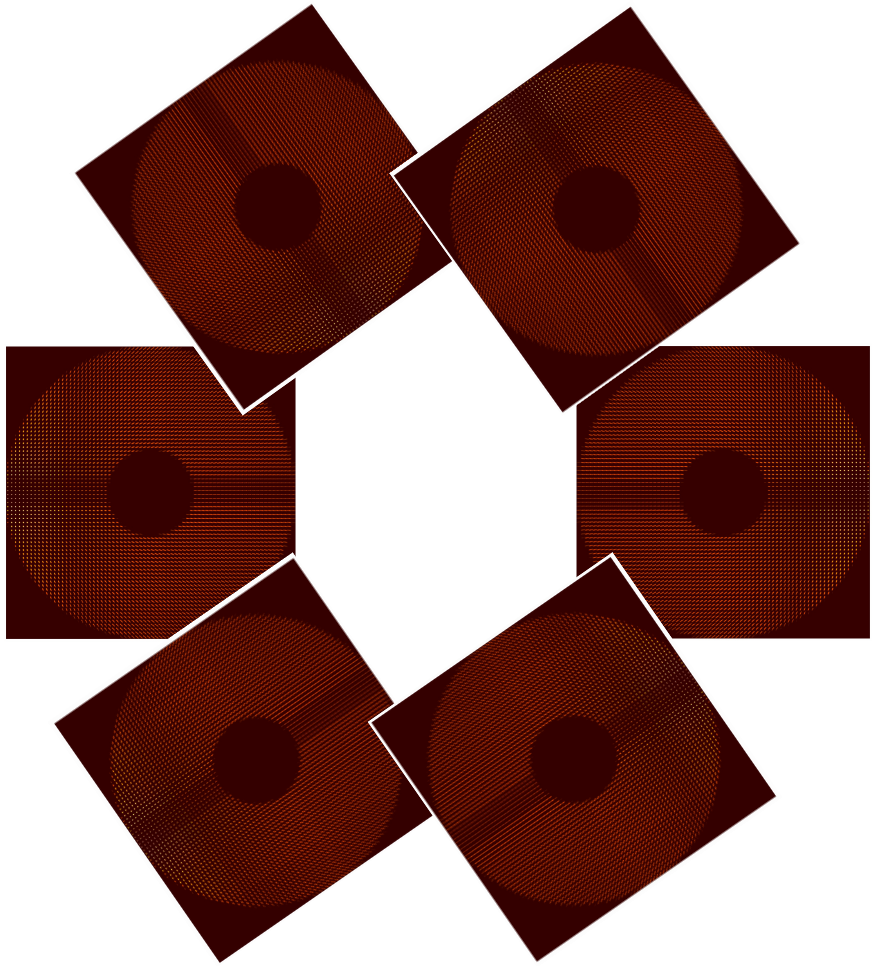


Number of pixels are limited
⇒ Field is truncated
⇒ Strong biases in the measurements
⇒ **Need for new algorithms and/or new WFS concepts**

The Instruments, or how to reach the diffraction limit…

Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

1. **New Sensors concepts**
2. **Lasers on ELTs**
3. **Degrees of Freedom and Real-Time control**



- Number of measurements is ~50000
- Number of actuators is ~5000
- Loop-frequency is ~ 1 kHz

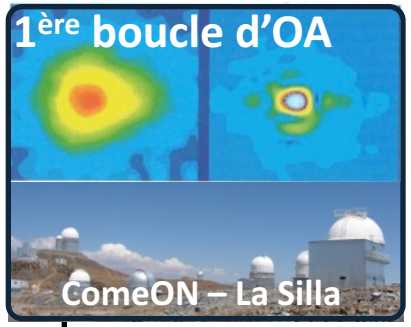
~ Tera Floating-point operations per second

⇒ **But solutions exists (e.g. Green Flash, Microgate, …)**

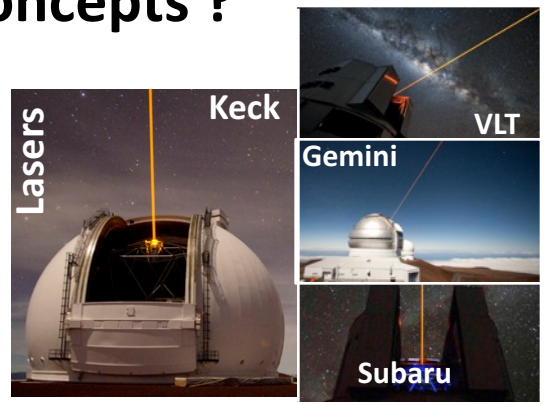
The Instruments, or how to reach the diffraction limit…

Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

1. **New Sensors concepts**
2. **Lasers on ELTs**
3. **Degrees of Freedom and Real-Time control**
4. **Maturity of Concepts ?**

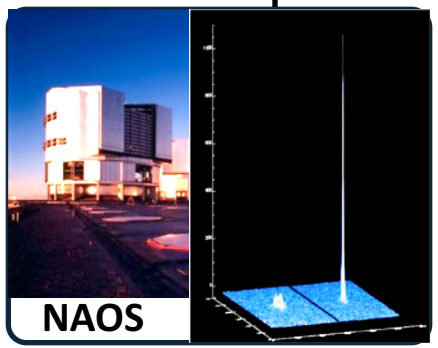


1990



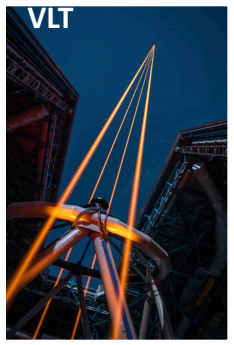
2005

2000



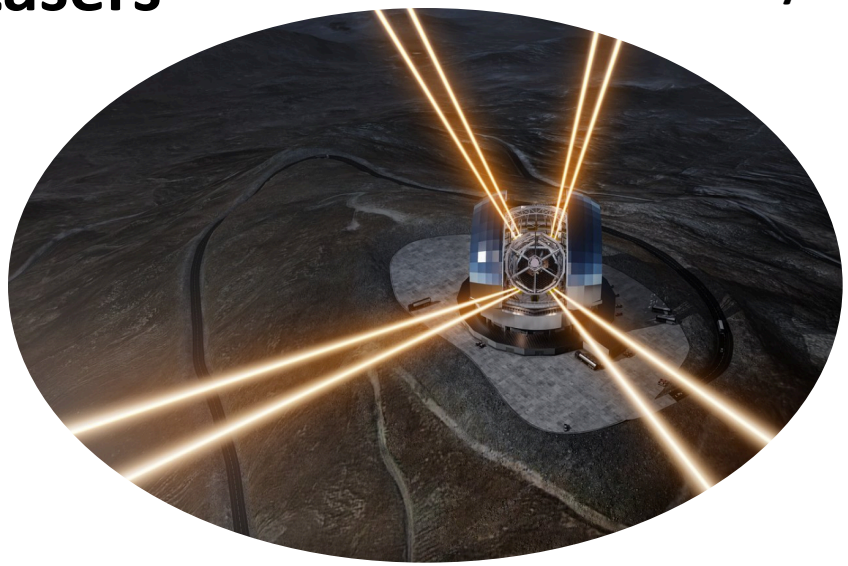
2012

2017



ELT is 100% OA and most of it is with Lasers

Are we ready ?

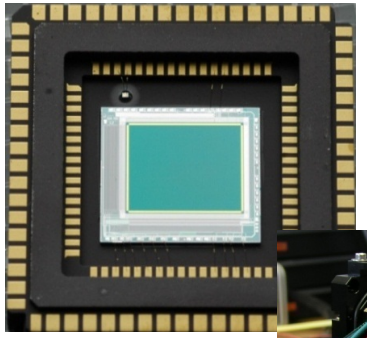


Especially regarding AIT, commissioning, calibrations…

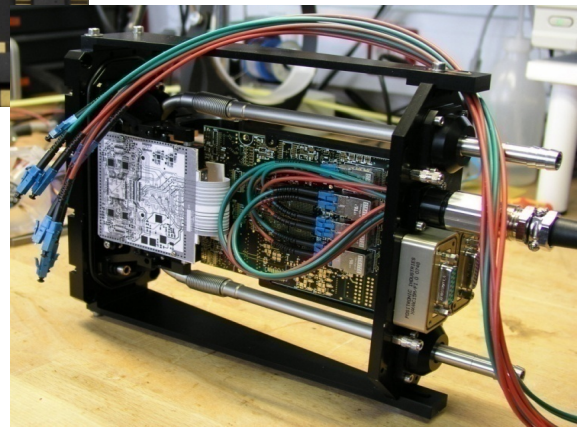
The Instruments, or how to reach the diffraction limit…

Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

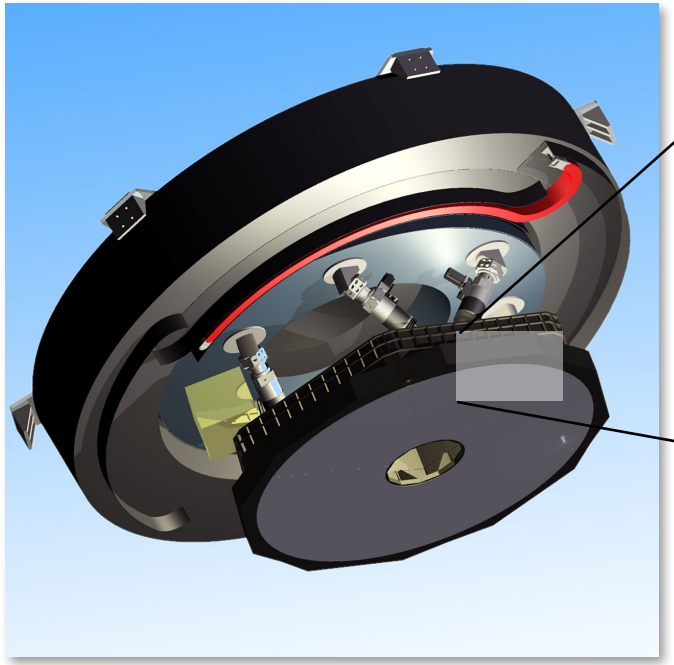
1. **New Sensors concepts**
2. **Lasers on ELTs**
3. **Degrees of Freedom and Real-Time control**
4. **Maturity of Concepts ?**
5. **Maturity of key component ?**



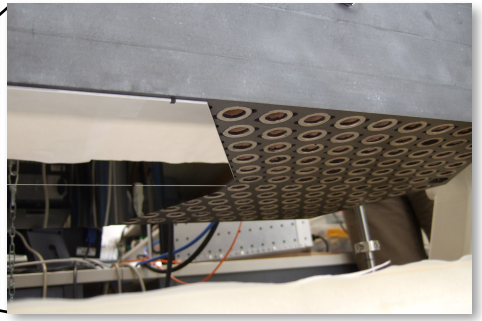
Large array, fast, no-noise WFS detectors



Deformable mirrors



M4: 2.4 m, flat, adaptive
>5000 actuators



The Instruments, or how to reach the diffraction limit…

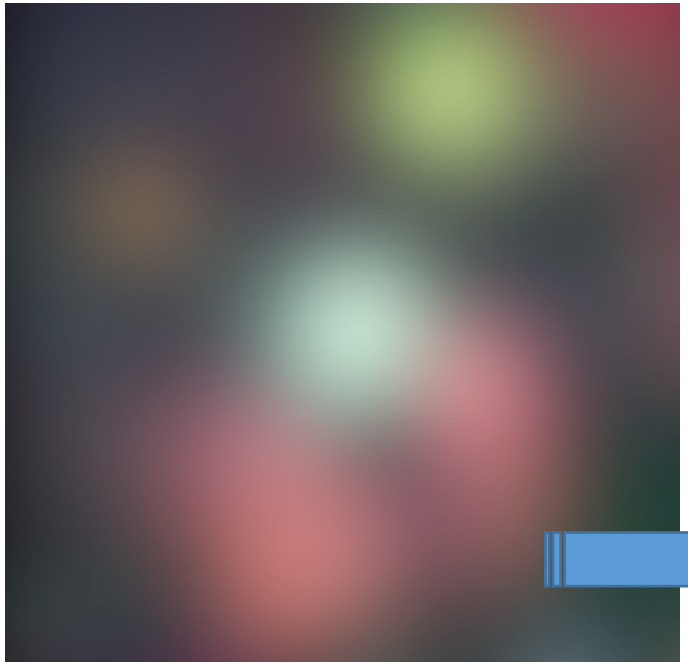
Why is it so hard to reach diffraction limited images ? What's new compared to the VLT ?

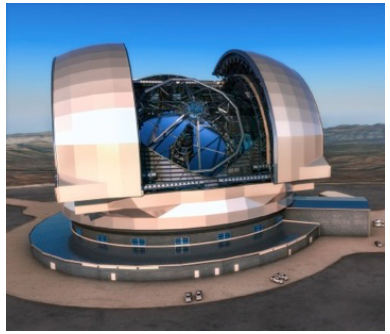
1. **New Sensors concepts**
2. **Lasers on ELTs**
3. **Degrees of Freedom and Real-Time control**
4. **Maturity of Concepts ?**
5. **Maturity of key component ?**

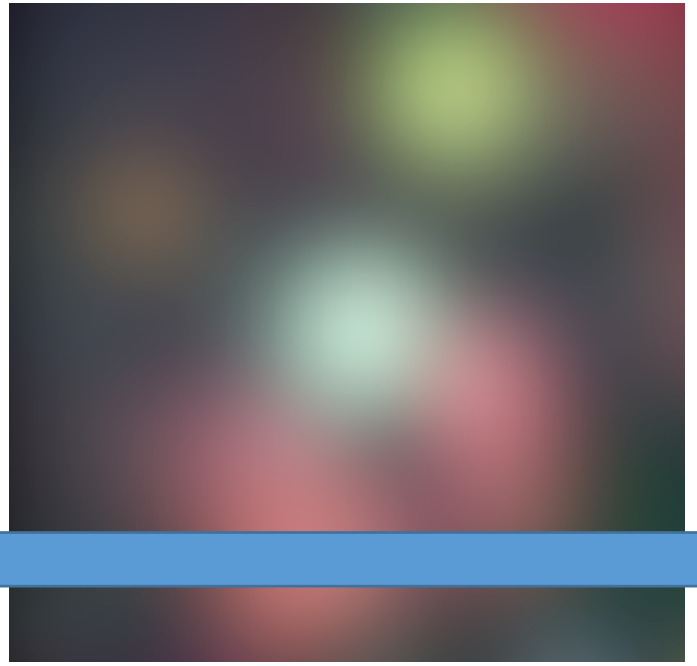
6. **Interfaces between Telescope & Instruments**

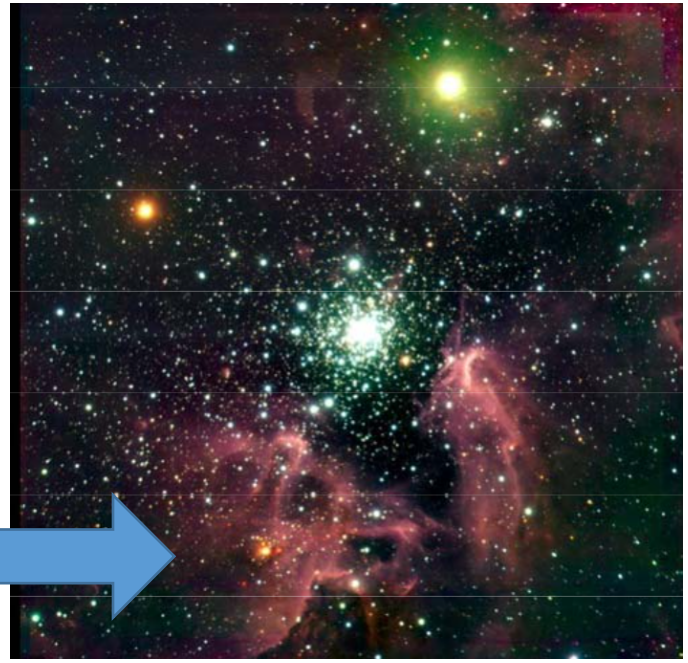
[I-INS/ELT-96] Enhancement of the image quality beyond the seeing limited performance specified above shall be achieved via a combination of the telescope, instruments and adaptive optics modules working together.
/ / /

#3 - Putting all the pieces together





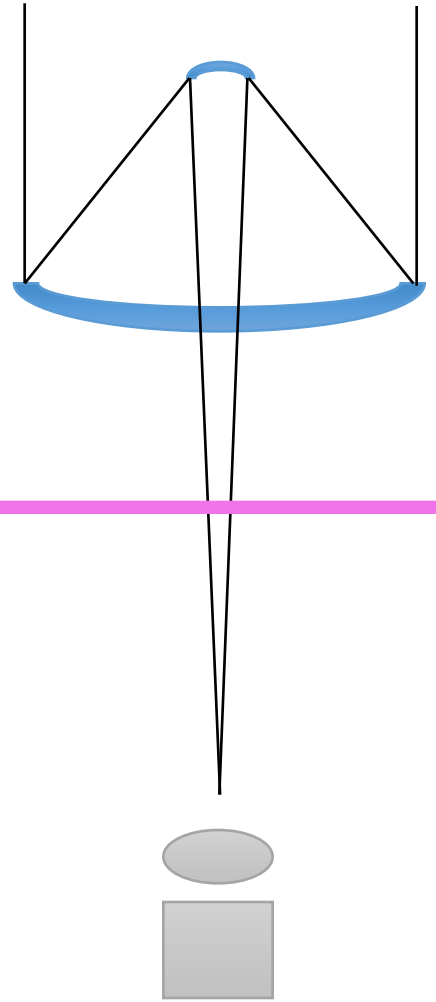




Telescope and instruments interfaces

Telescope

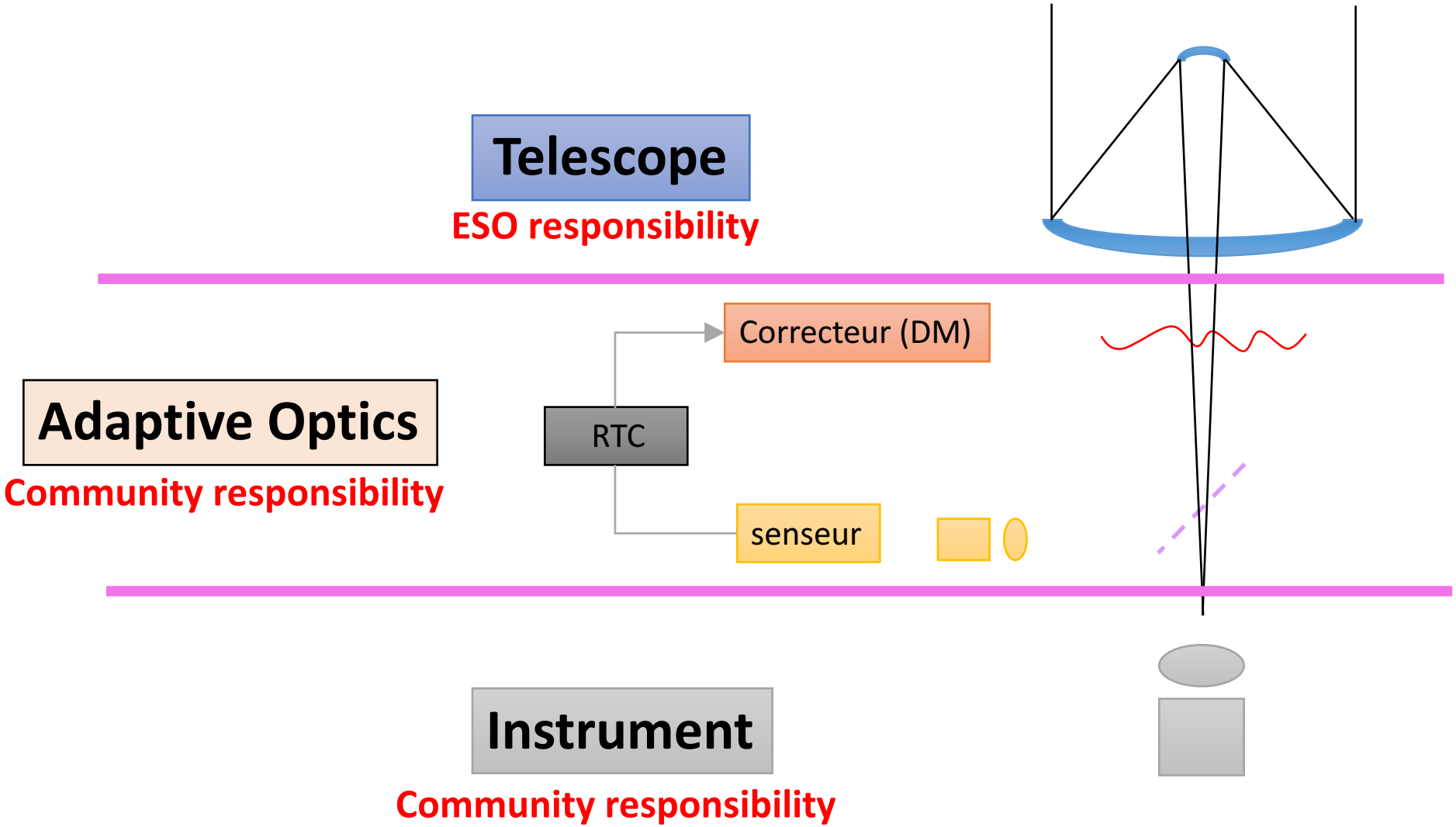
ESO responsibility



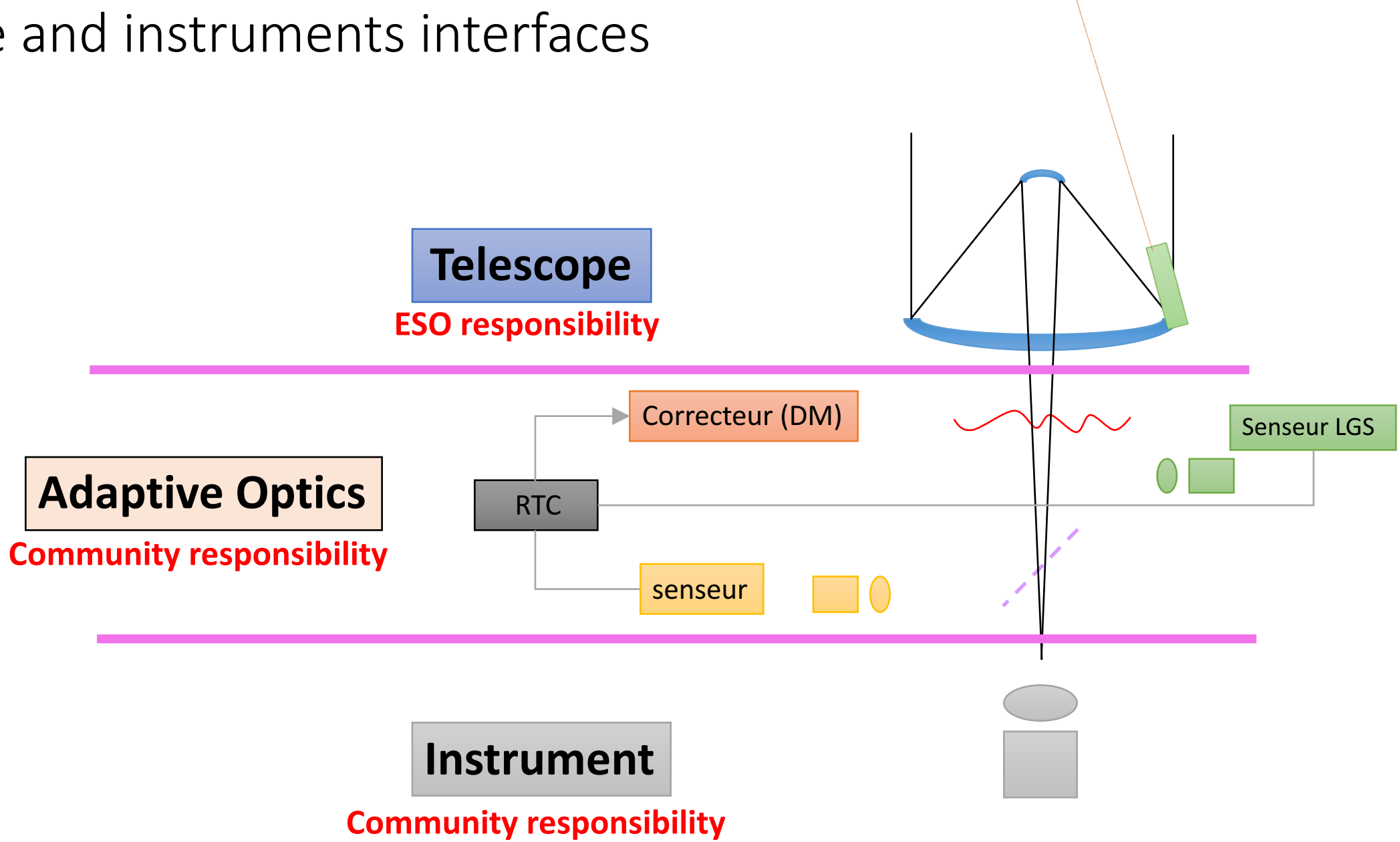
Instrument

Community responsibility

Telescope and instruments interfaces



Telescope and instruments interfaces

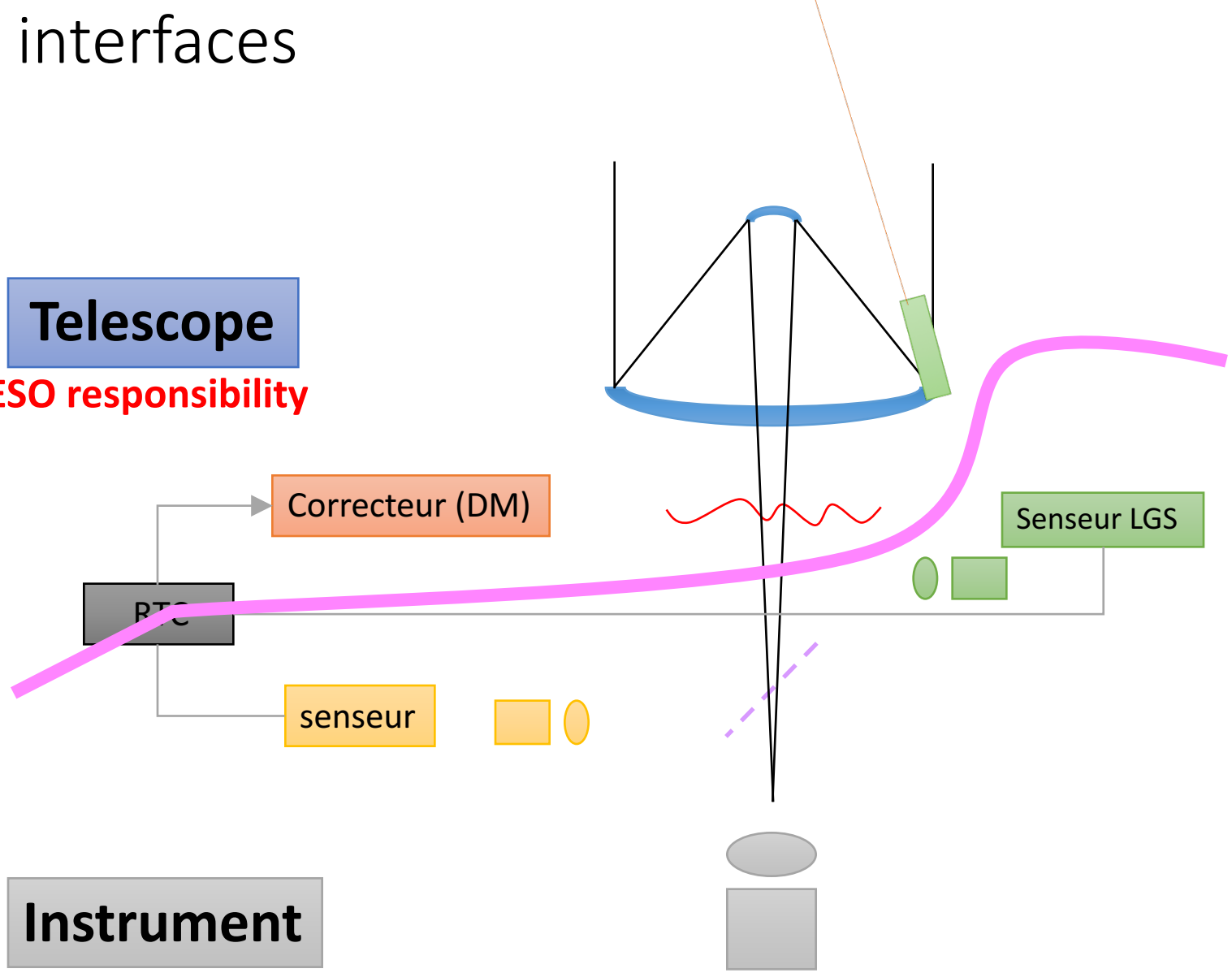


Telescope and instruments interfaces

Both the telescope (via the Pre-Focal Station) and the instruments are controlling M4…

Telescope

ESO responsibility



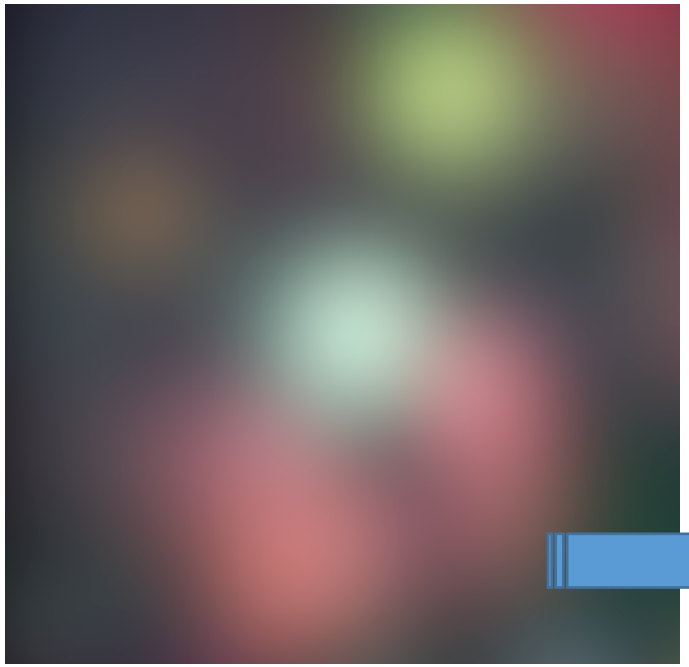
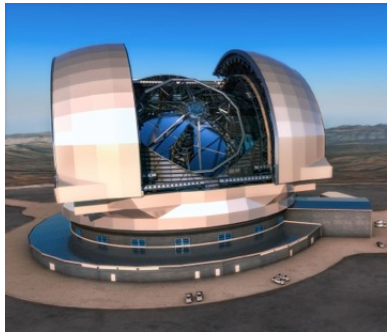
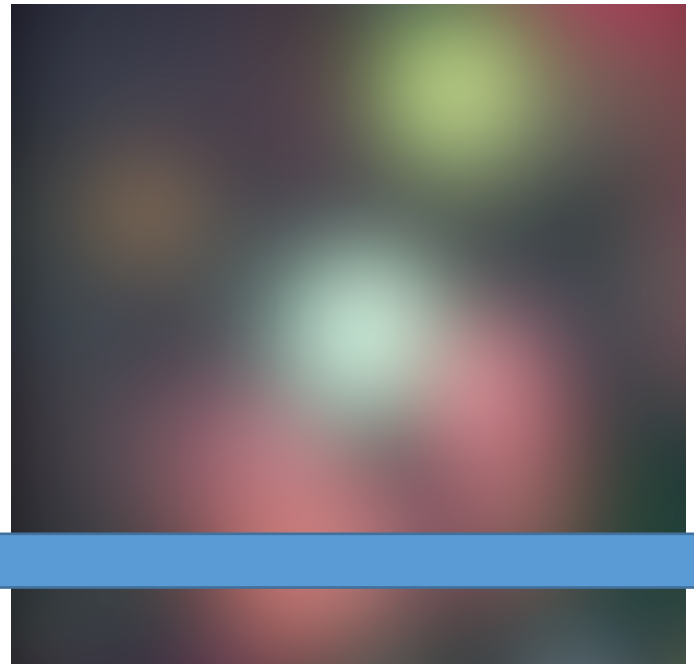
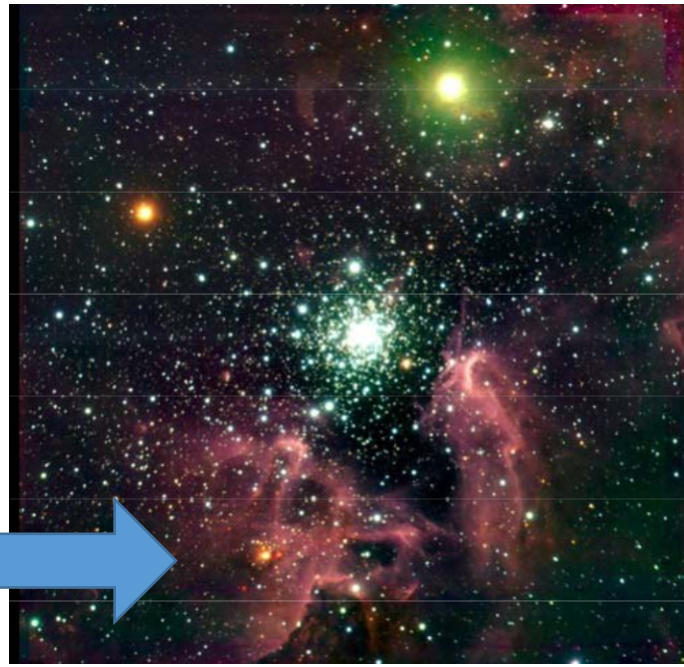
Adaptive Optics

Community responsibility

Instrument

Community responsibility

Requires flexible interfaces between telescope and instrument

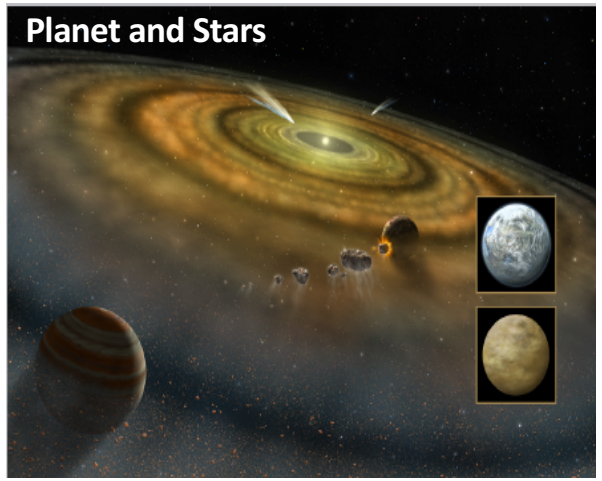





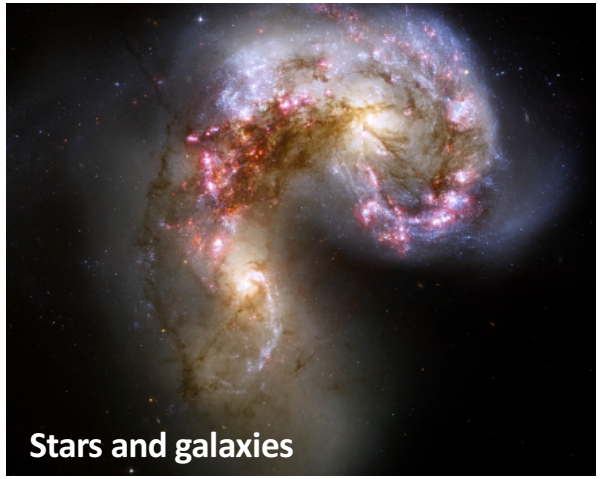
#4. Is this enough to produce the expected science ?

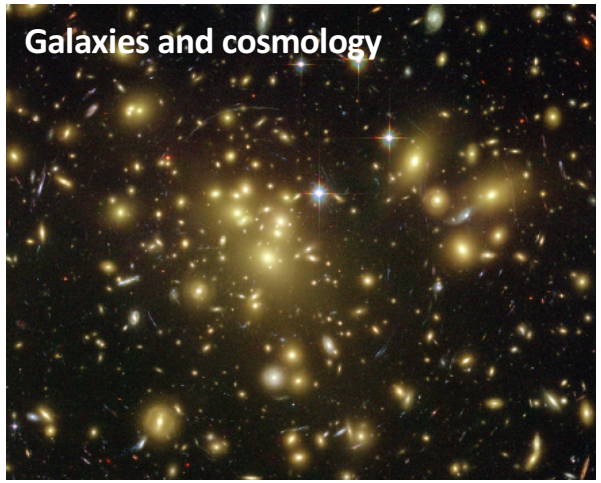
→ Atelier S09 cet aprèm !

Quelles spécifications sont critiques pour quels science cases ?
Les instruments de l'ELT seront-ils en mesure de répondre aux défis ?

Scientific Requirements for a European ELT







i. Anthony Boccaletti, Alexis Carlotti (Exoplanètes / HC)

ii. Frédéric Merlin (Objets du système solaire)

iii. Thibaut Paumard / Guy Perrin (Centre galactique)

iv. Mathieu Puech (formation / évolution des galaxies)

Thank you