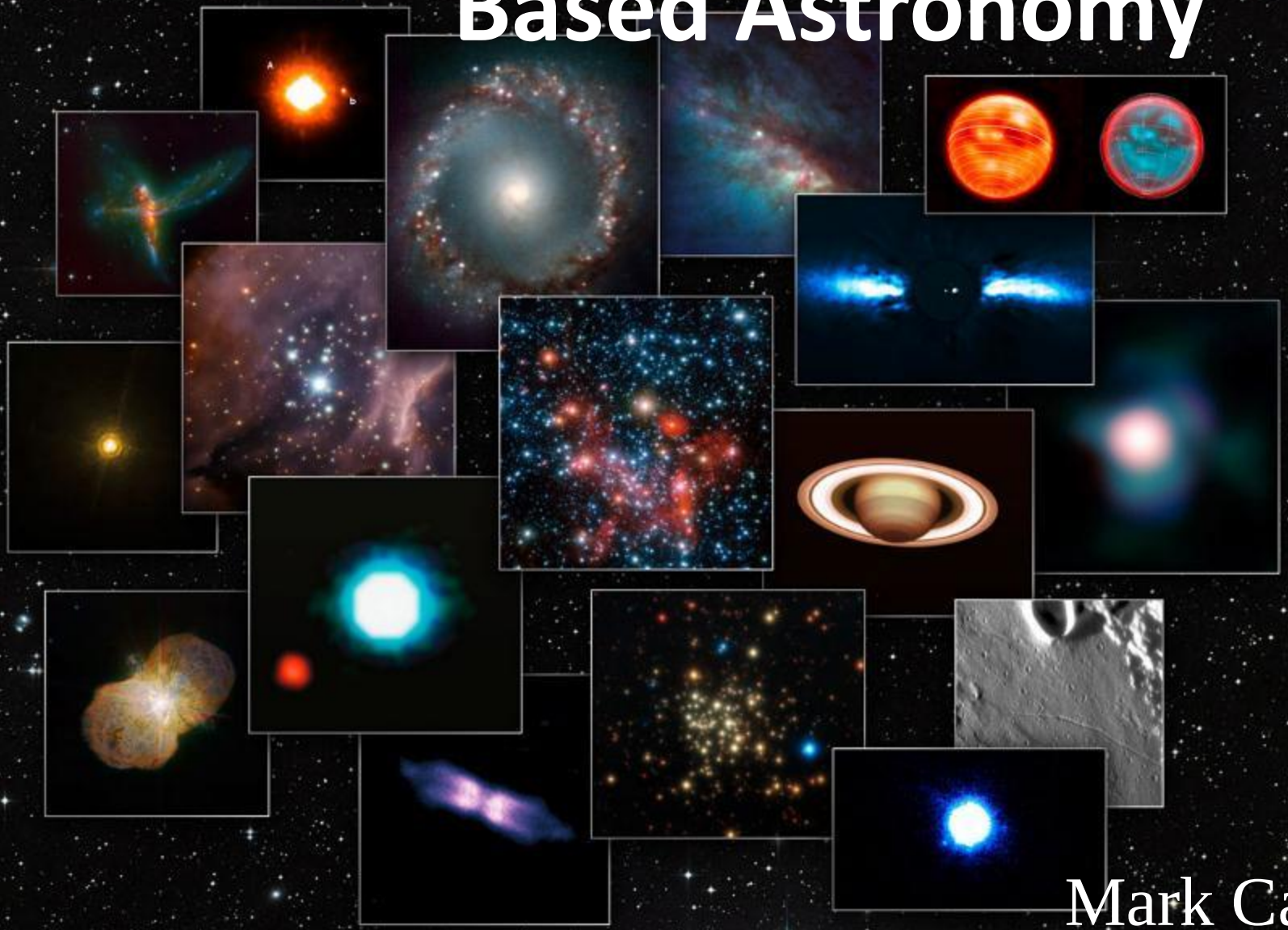
ESO Programmes in Ground-Based Astronomy



Mark Casali

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Summary of Programmes

1. Optical / IR astronomy facilities and instruments
   - Towards the diffraction limit
2. mm interferometry with ALMA
3. metrics of success
4. European Extremely Large Telescope (E-ELT)

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1. Optical / IR facilities and instruments

La Silla, ESOs first observatory

Cerro Paranal
Very Large Telescope (VLT)

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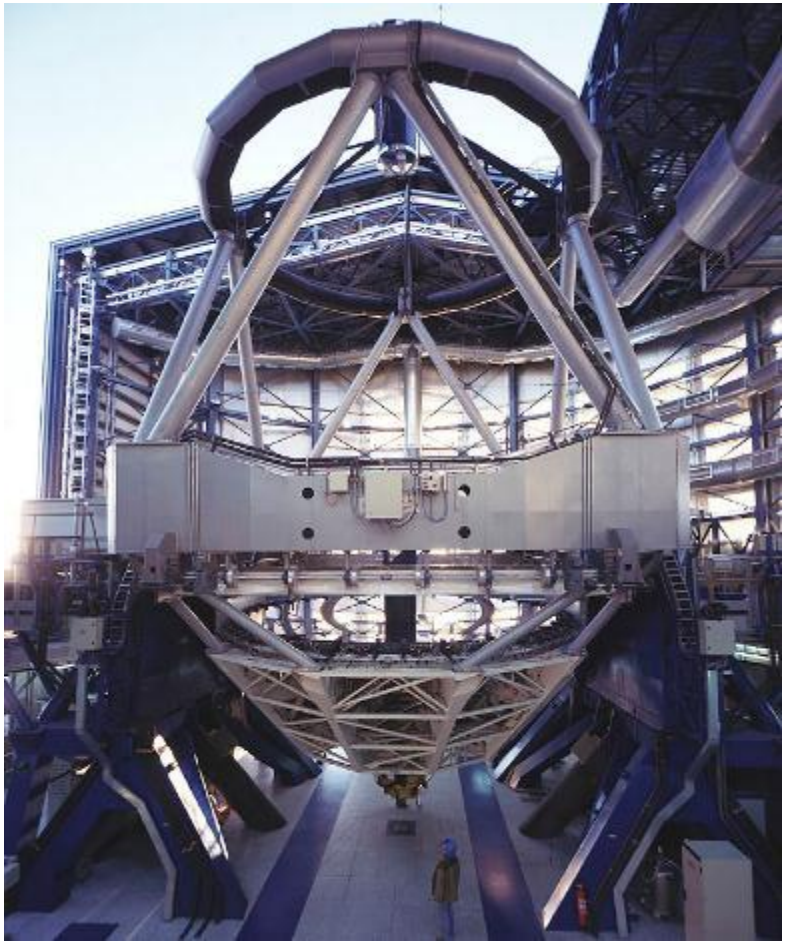
VLT : 4 x 8.2m telescopes

- The 8.2 m diameter primary mirrors weigh 23 tonnes and are only 175 mm thick
- Active optics preserves image quality under gravity/temperature changes
- UV – visible - near IR - 28 microns



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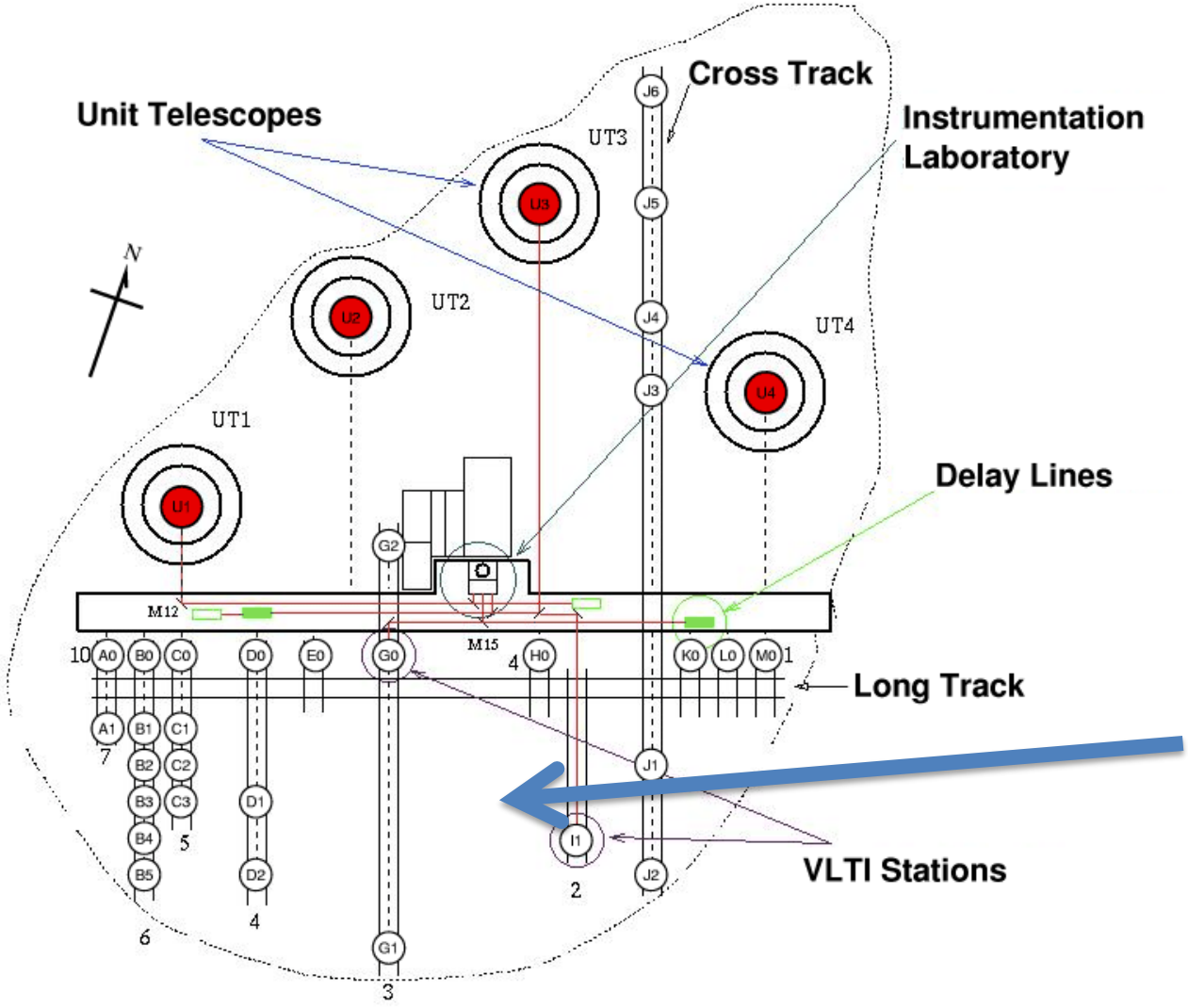
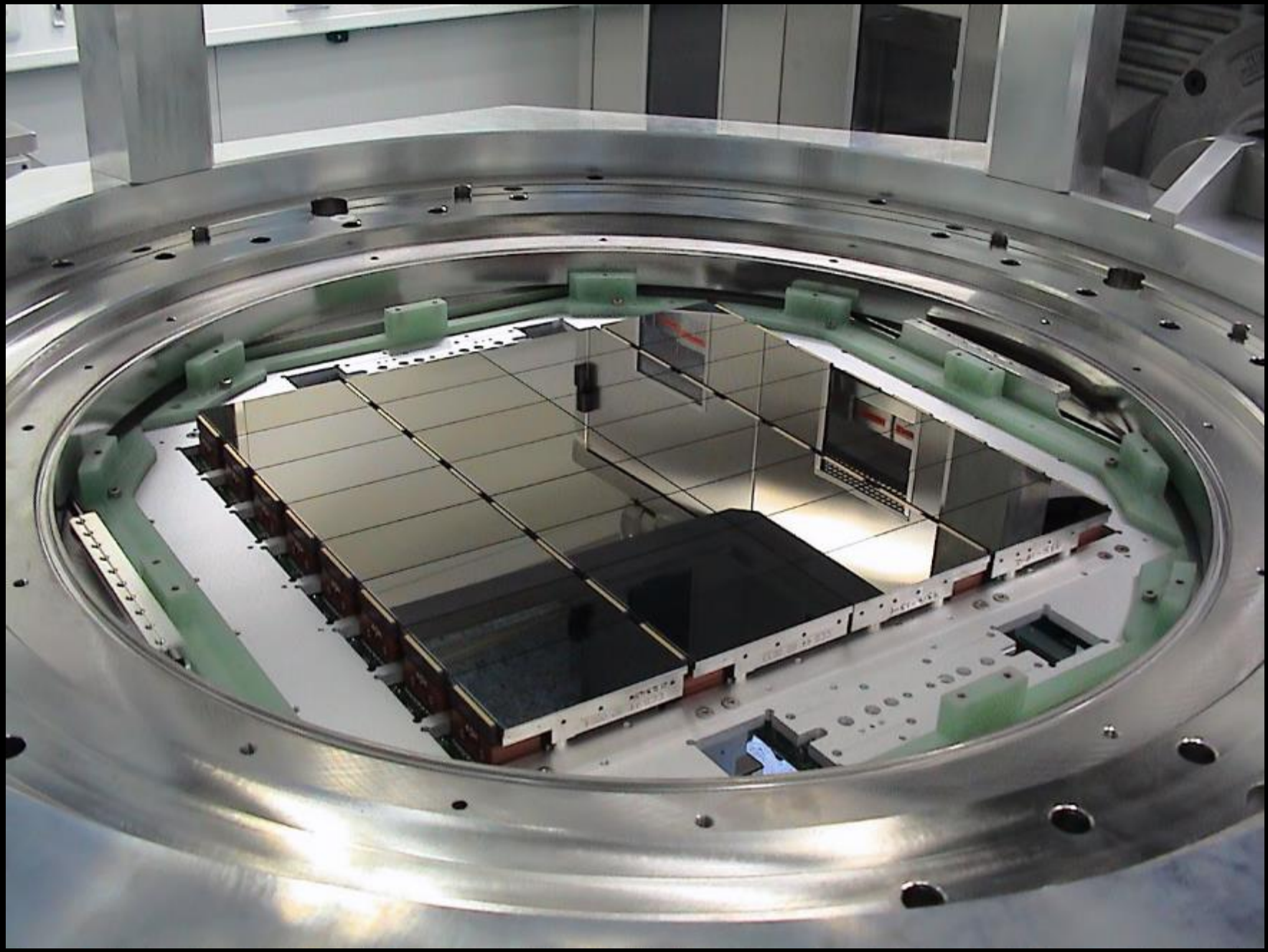
VLT interferometry



Four 1.8 m movable Auxiliary Telescopes for interferometry



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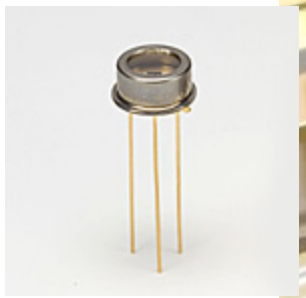
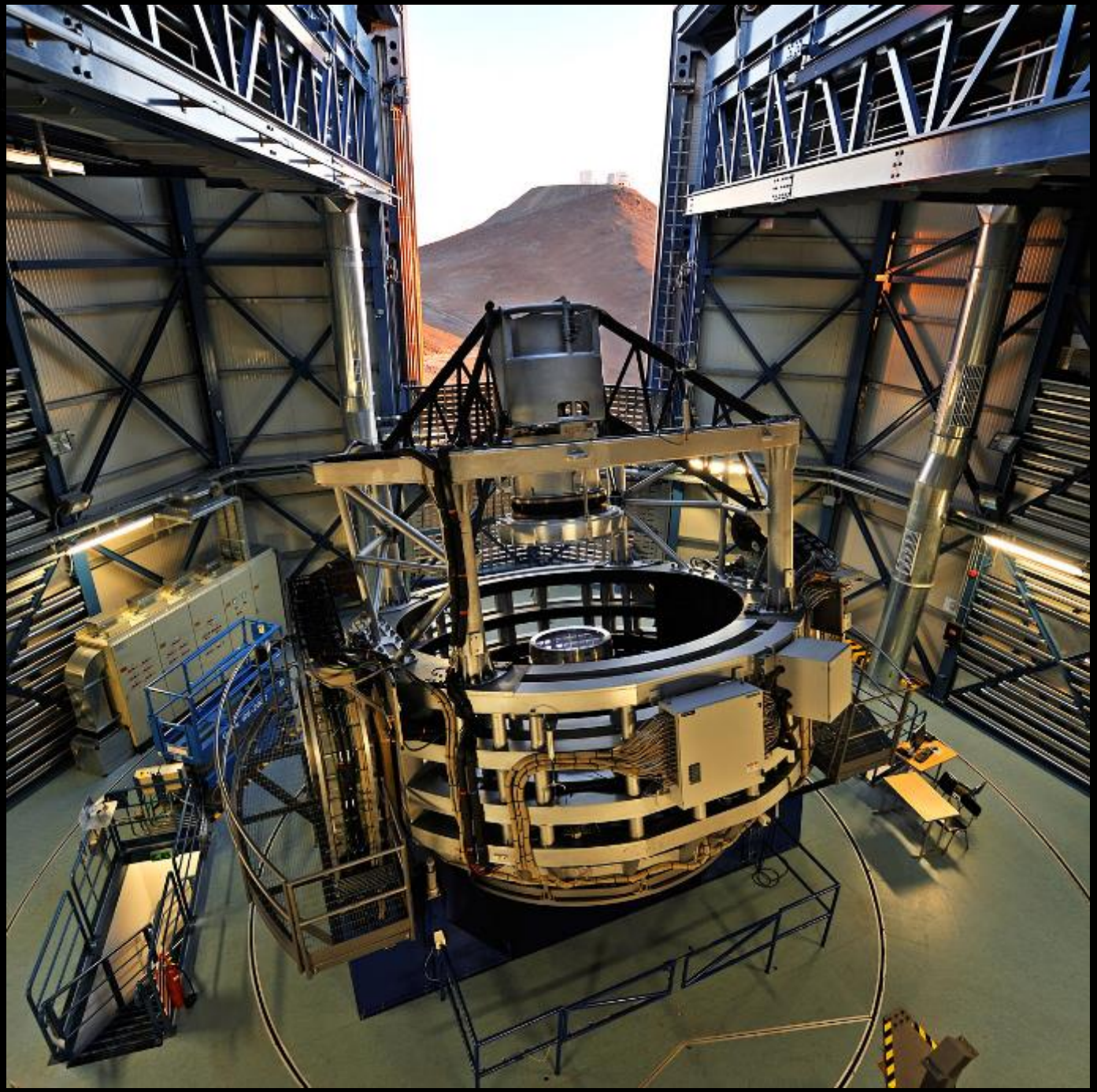
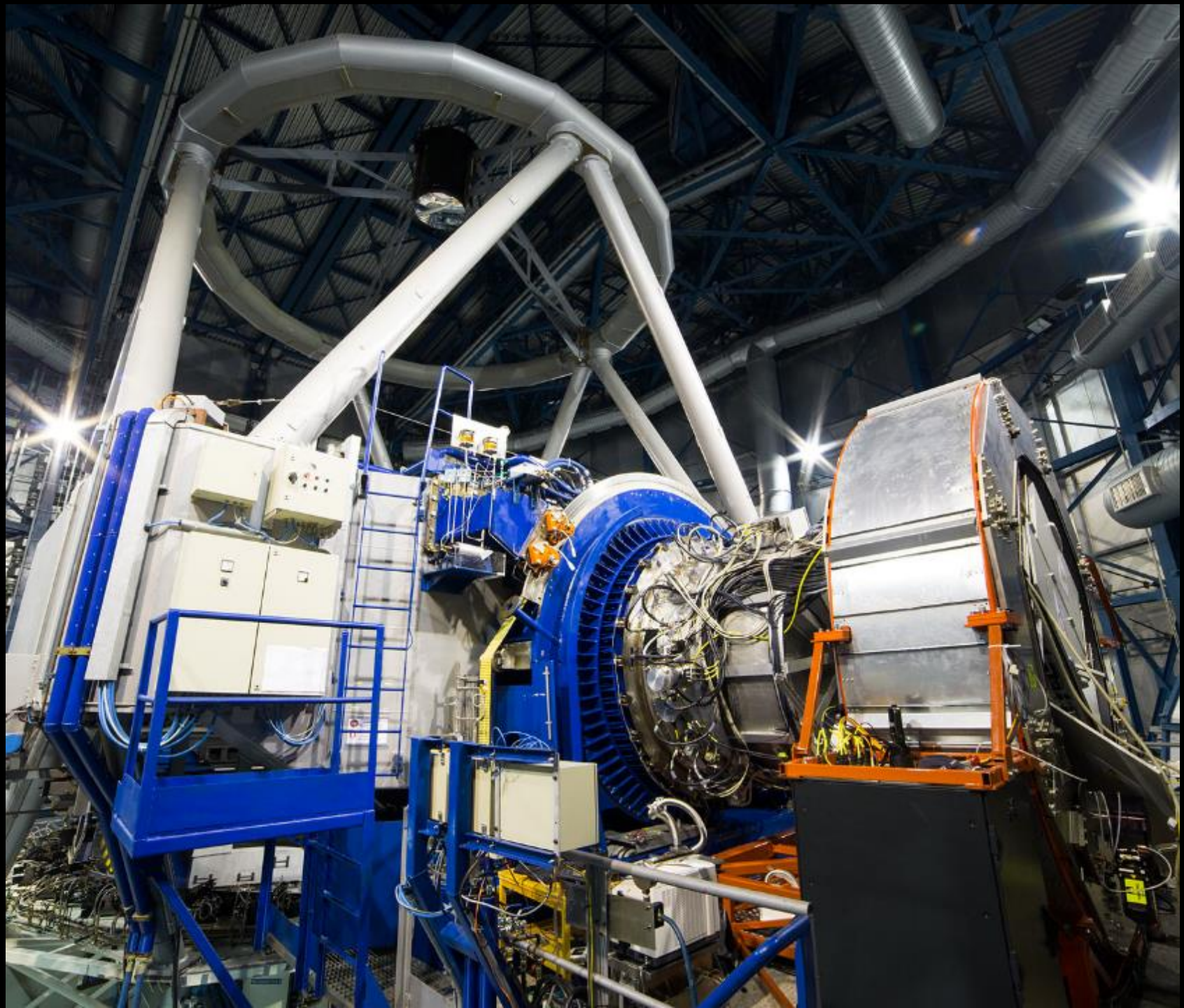
Giant VISTA IR focal plane
16 x 2k x 2k HgCdTe



1986

2008 VIRCAM





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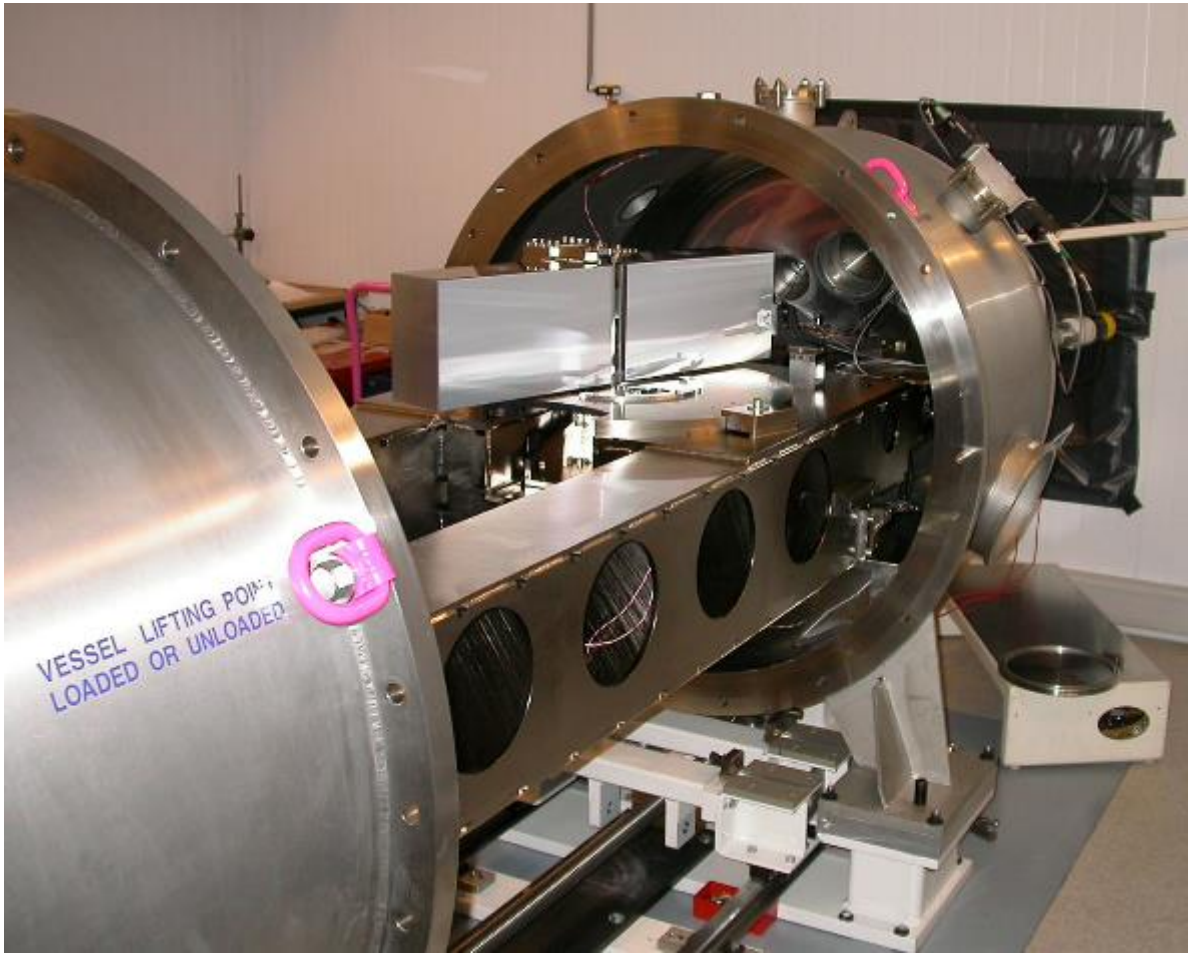
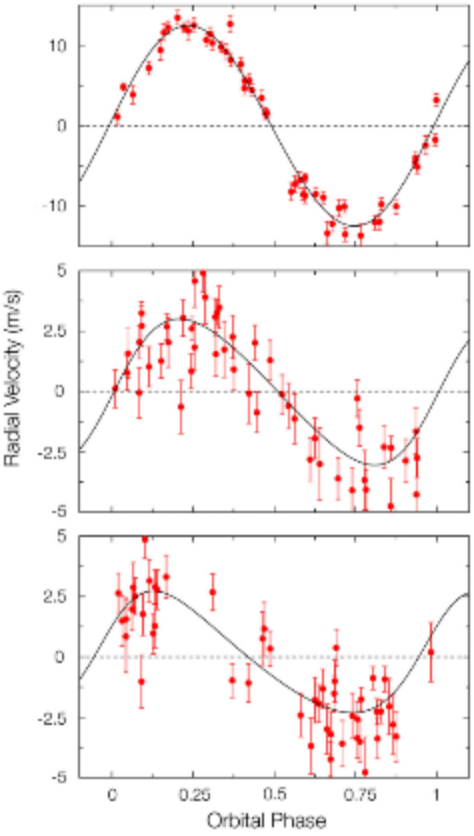
High stability - HARPS





<1 m/s stability

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Partnership with Community

- Most instruments built by *consortia of institutes*
  - Large amount of technical expertise built up in Europe over last 20 years
  - ESO pays hardware (1/3-1/2 of total cost)
  - Consortia provide effort; compensated in Guaranteed Time
  - Consortia constitute a very powerful support network

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Achieving diffraction limit – a final technical frontier

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Astronomers hate the atmosphere

- Absorption at different wavelengths
  - We're stuck with it
- Turbulence (fasten your seatbelts) causes wavefront distortions with ms timescales
  - We can try to correct it

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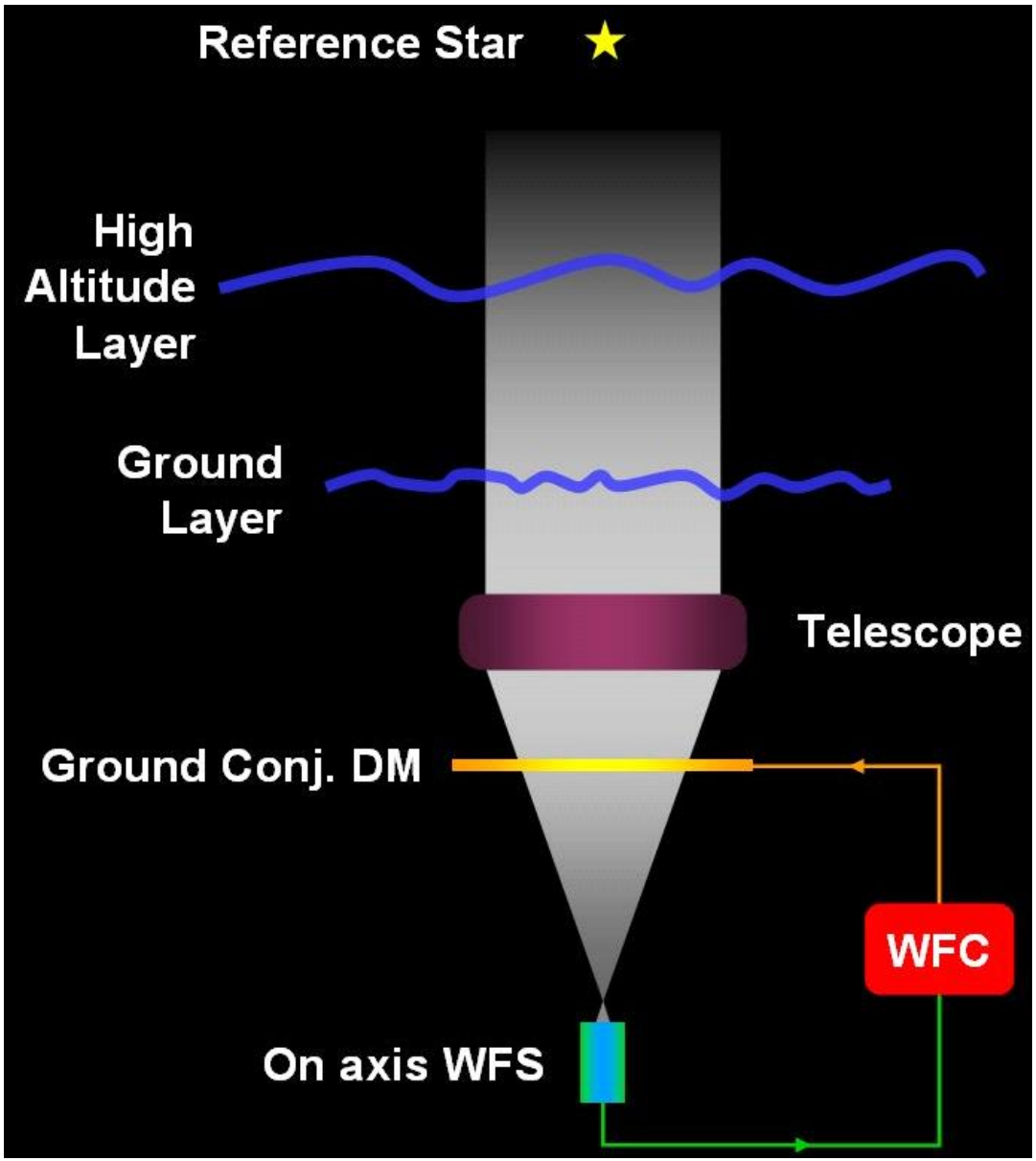
At the diffraction limit



Development of Piezo DM technology

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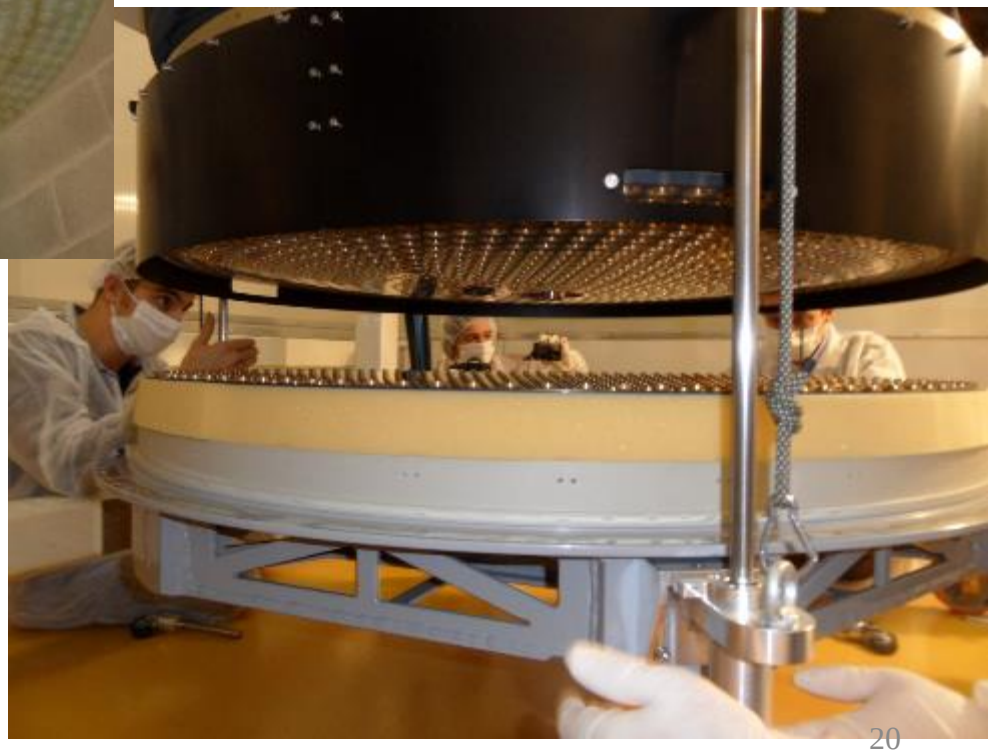
Voice Coil DMs



- **Ø 1.1m convex**
- **1170 actuators**
- **29 mm actuator pitch**
- **1 ms response**
- **Stroke 50 / 1.5 μm**

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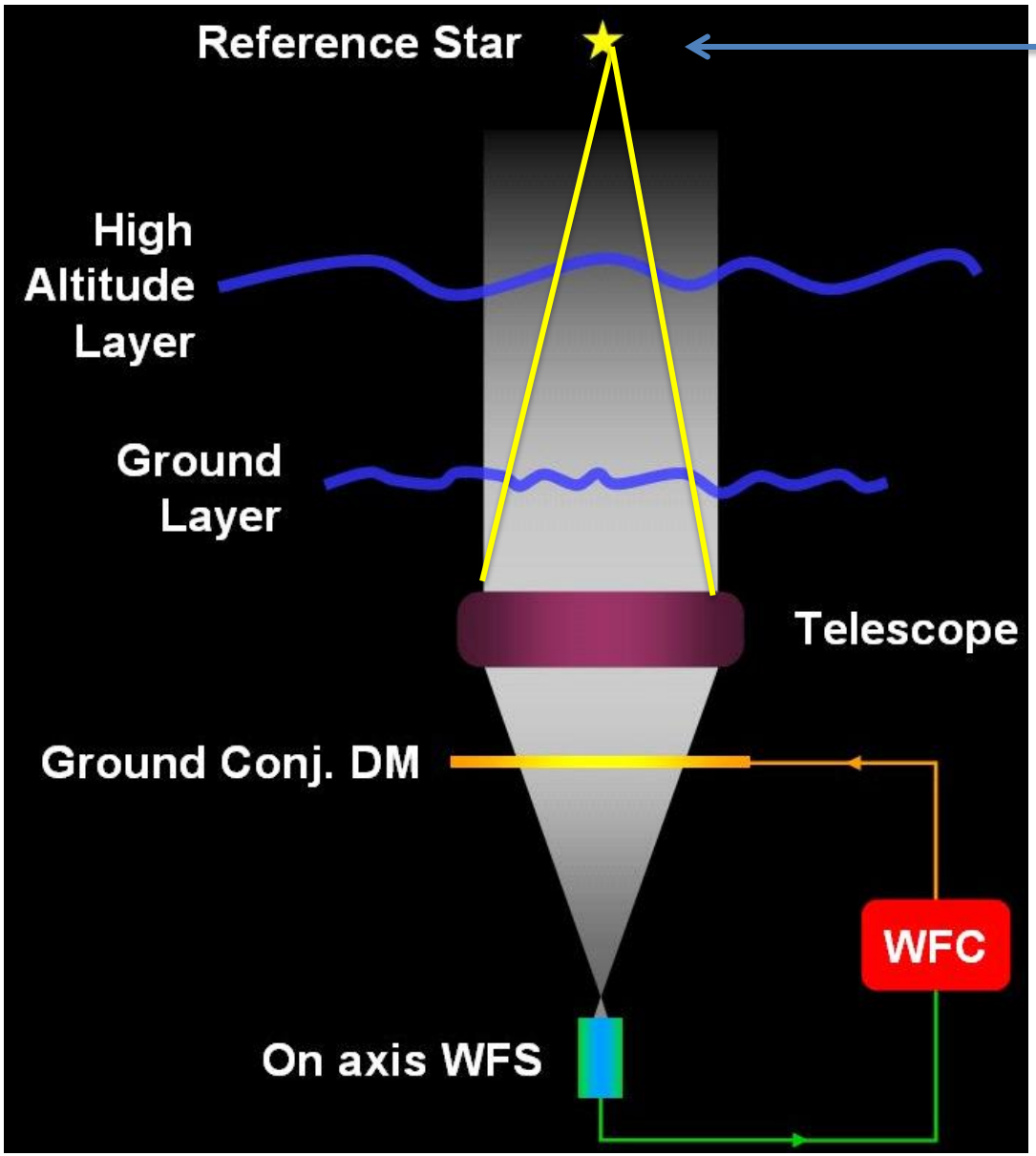
Laser Reference Star



Na layer

589nm

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Adaptive optics flavours

- on-axis AO with NGS
- on-axis AO with single laser
- ground layer correction with NGSs/Lasers
- multiple lasers for LTAO
- multi-conjugate correction with multiple lasers
  - high density of actuators for extreme correction
  - adaptive telescopes (VLT and ELT)

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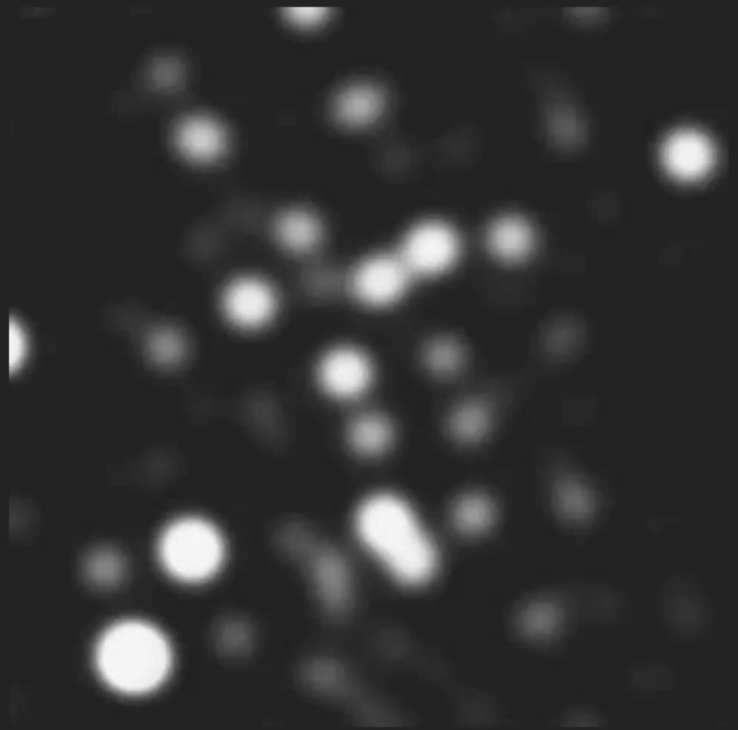

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2. mm Interferometry with ALMA

A universe of cold gas and molecules

The Chajnantor Plateau 5000 m

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An International Project

- ALMA is a collaboration between
  - Europe (14 member states of ESO)
  - North America (USA, Canada), and
  - East Asia (Japan, Taiwan)
- In Chile, the *Joint ALMA Observatory* commissions and operates ALMA
- ALMA costs ~1.2 billion €, shared among the partners
- World's most powerful radio interferometer

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ALMA features

- ALMA has the collecting area of a football field (~7000 m^2)
- 66 antennas
  - 50 x 12m antennas from Europe and North America
  - Compact Array of 4 x 12m and 12 x 7m antennas from Japan
- separations from 15m to 16km
- Low-noise, wide-band SIS receivers
- Digital correlator giving wide range of spectral resolutions

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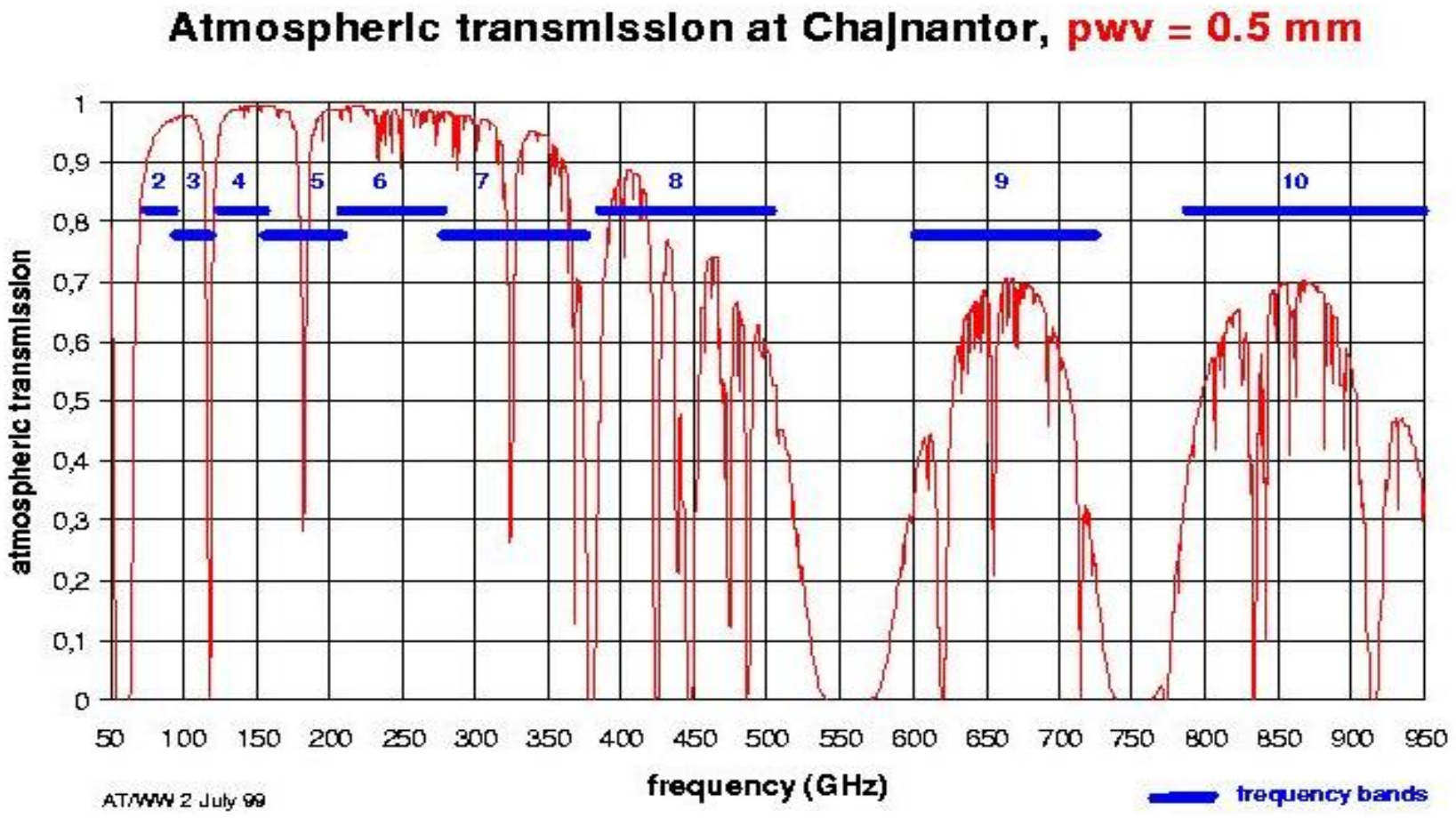
ALMA Frequency Bands



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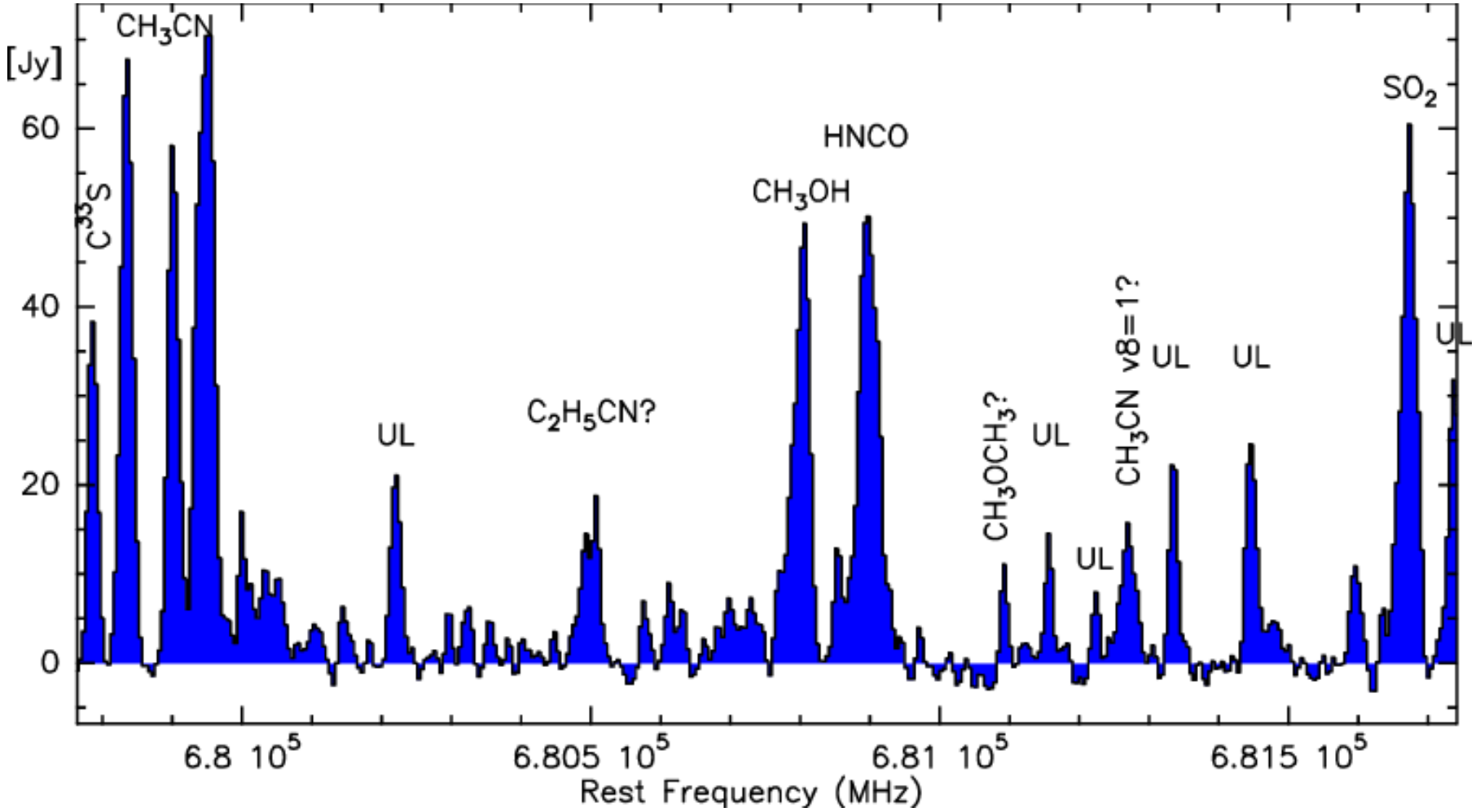
Cold universe full of molecules



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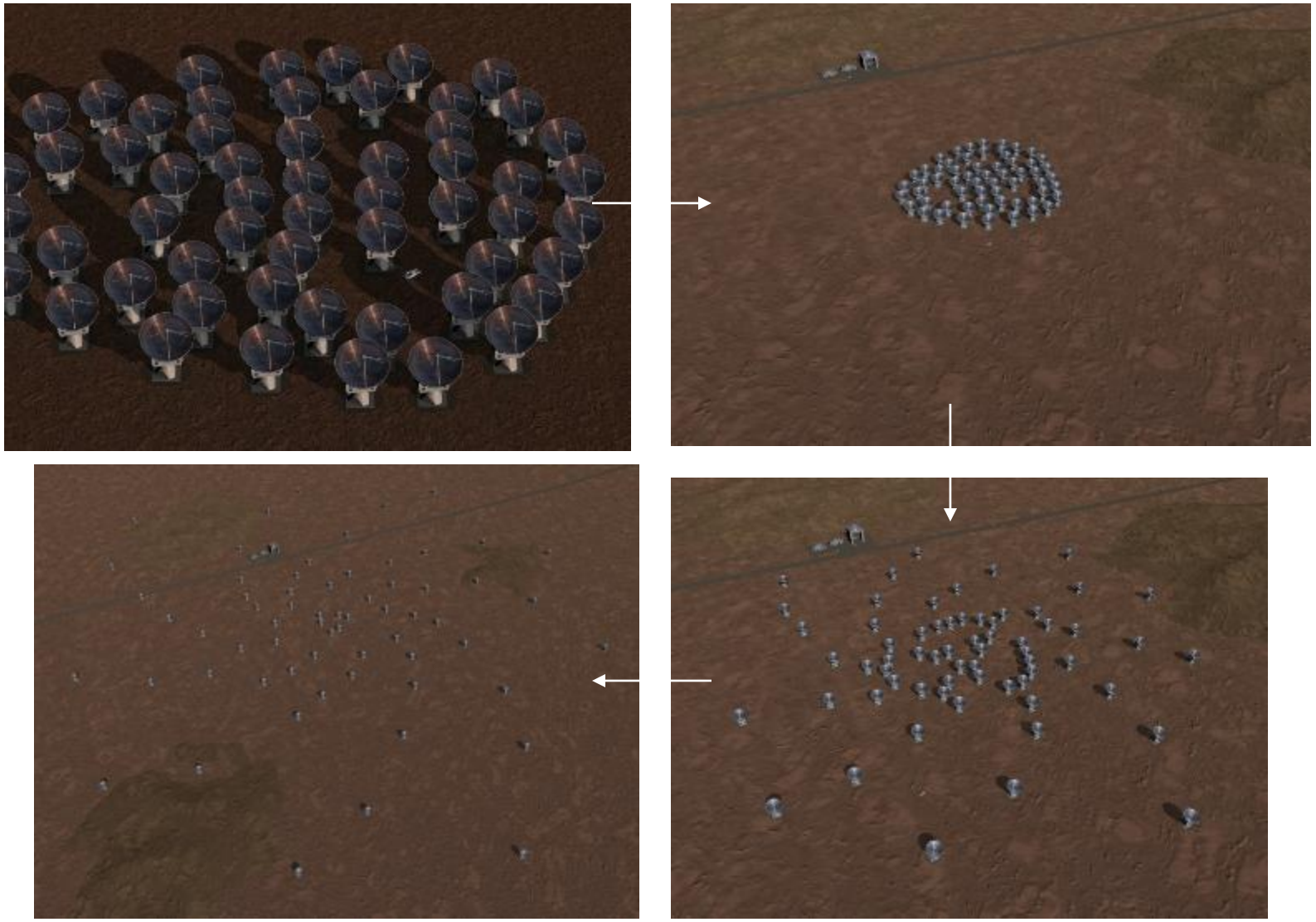
192 antenna interferometry stations



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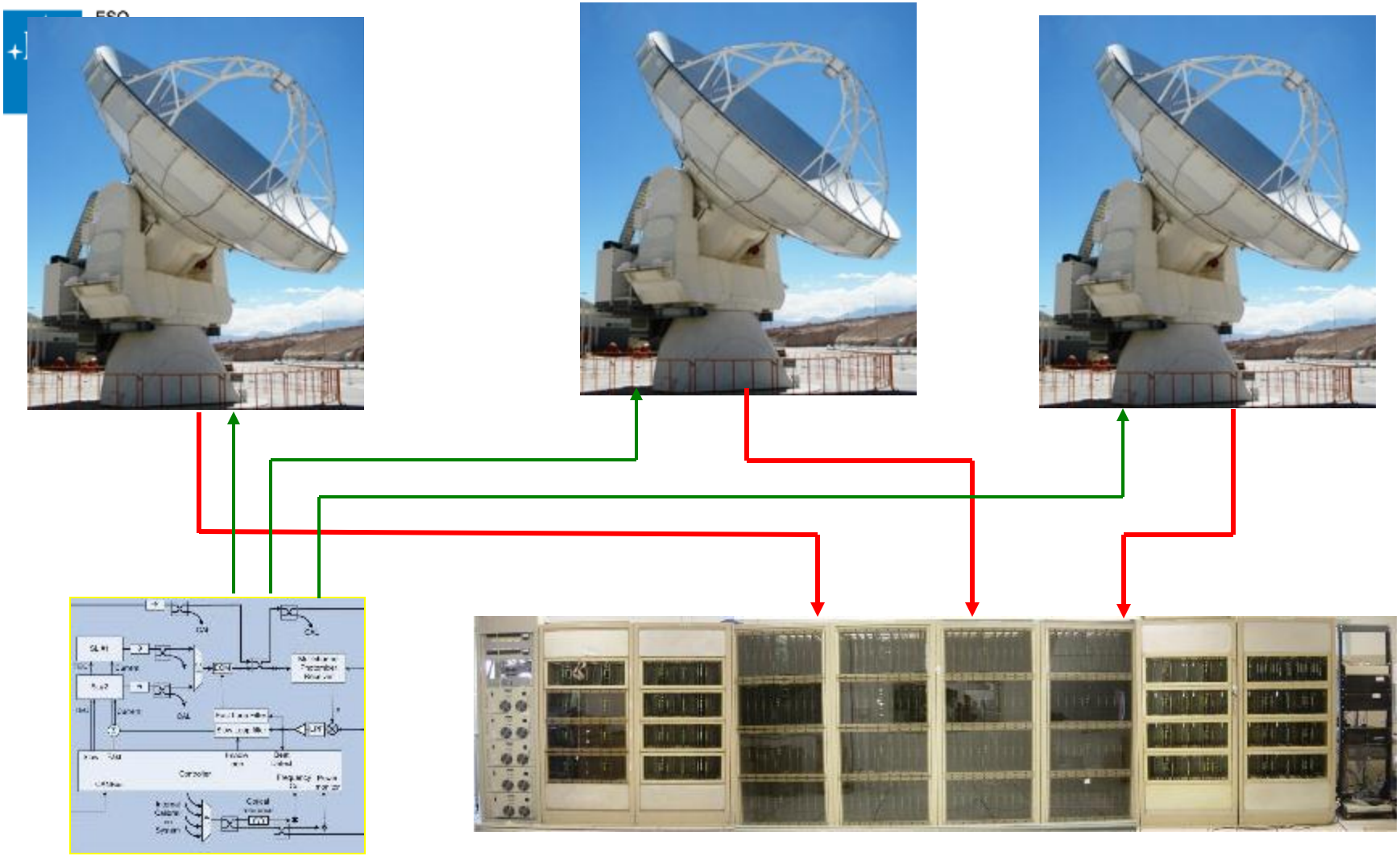
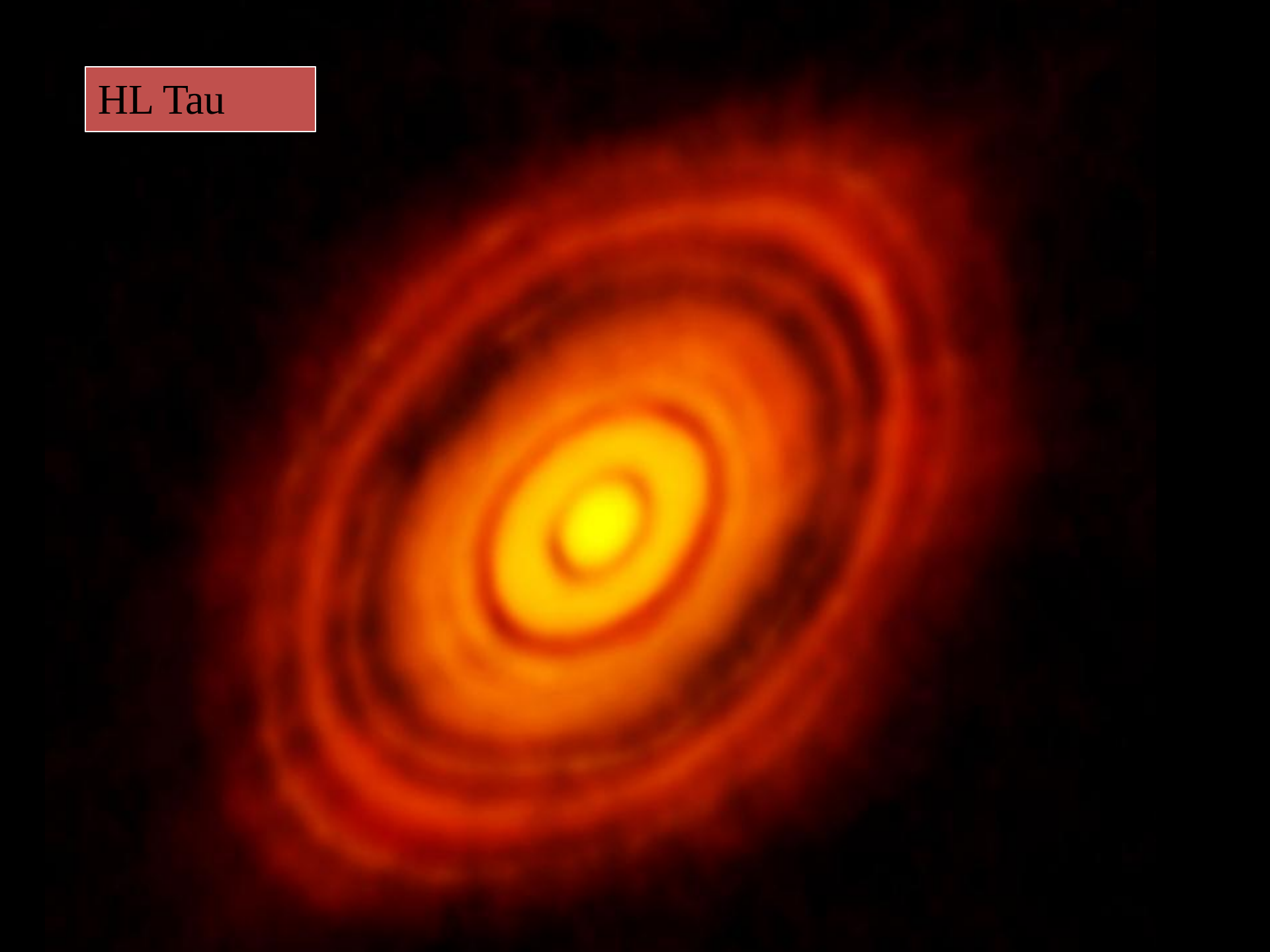


- Signals are amplified, digitized and combined in the "correlator" – a big digital processor. 120 Gb/s per antenna
- Extensive use of photonics for this and to synchronize the receivers which has to be done at the femtosecond level.


HL Tau

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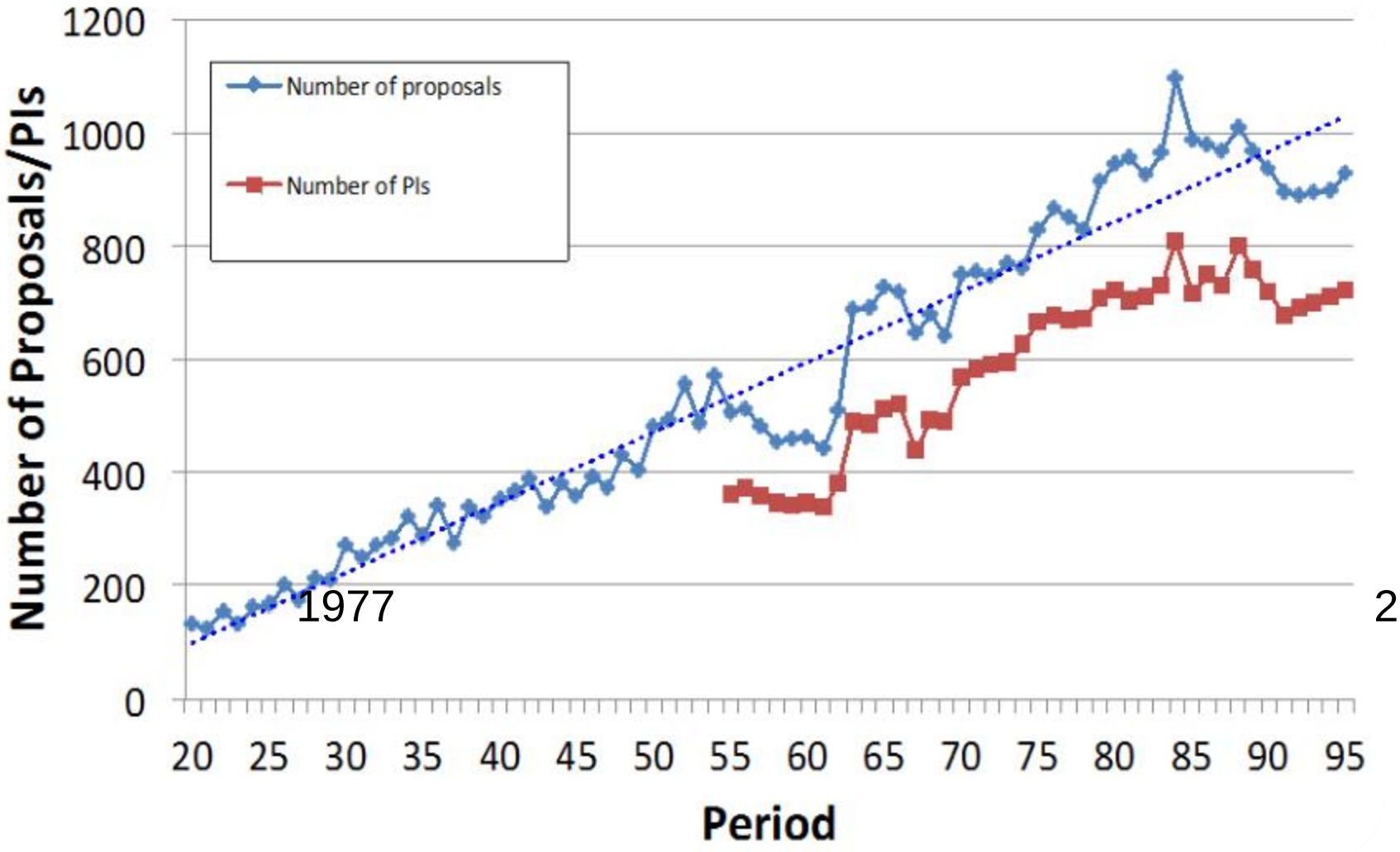
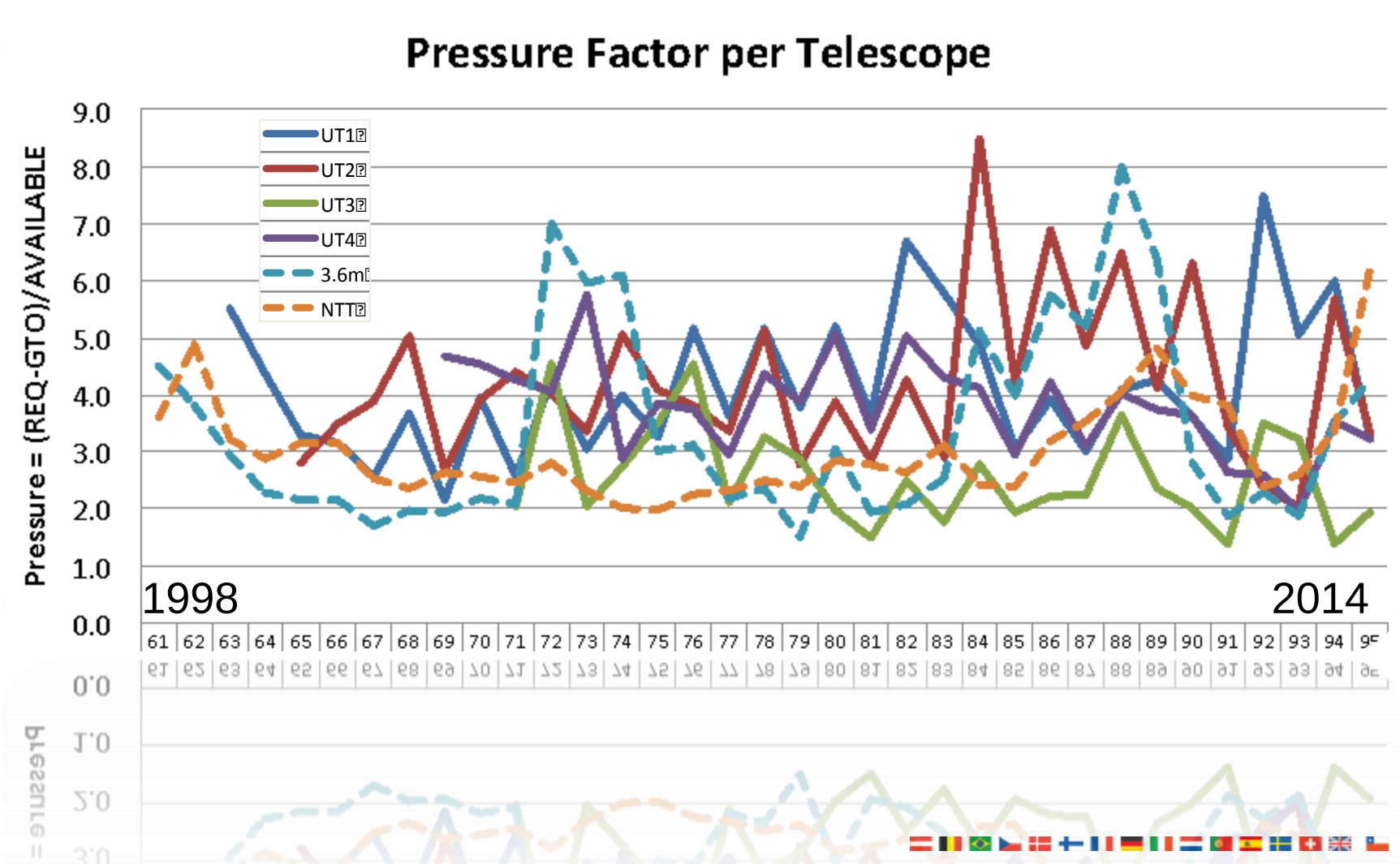
3. Metrics of success

Interest from the community (demand)



Available time (supply)



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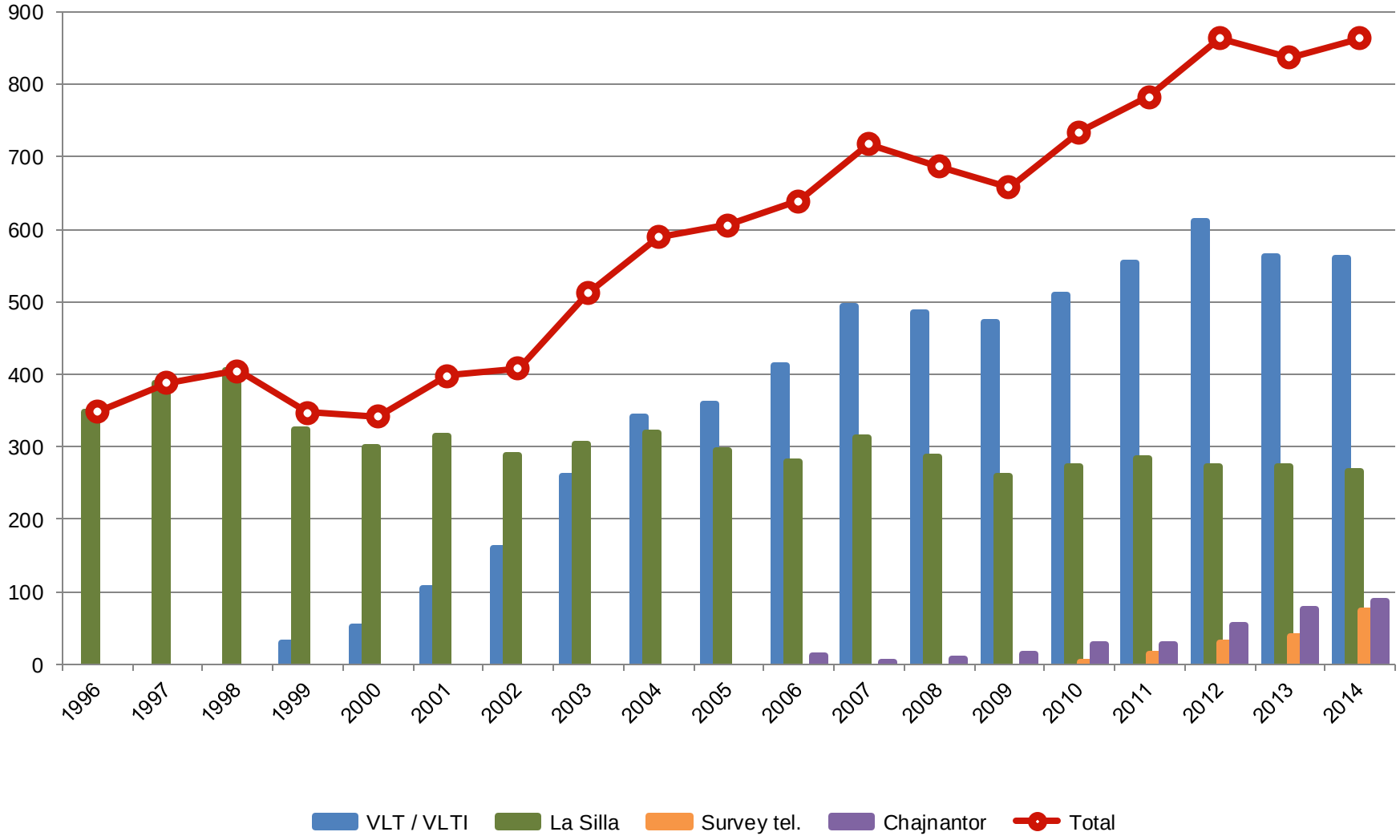
Scientific papers per year (output)



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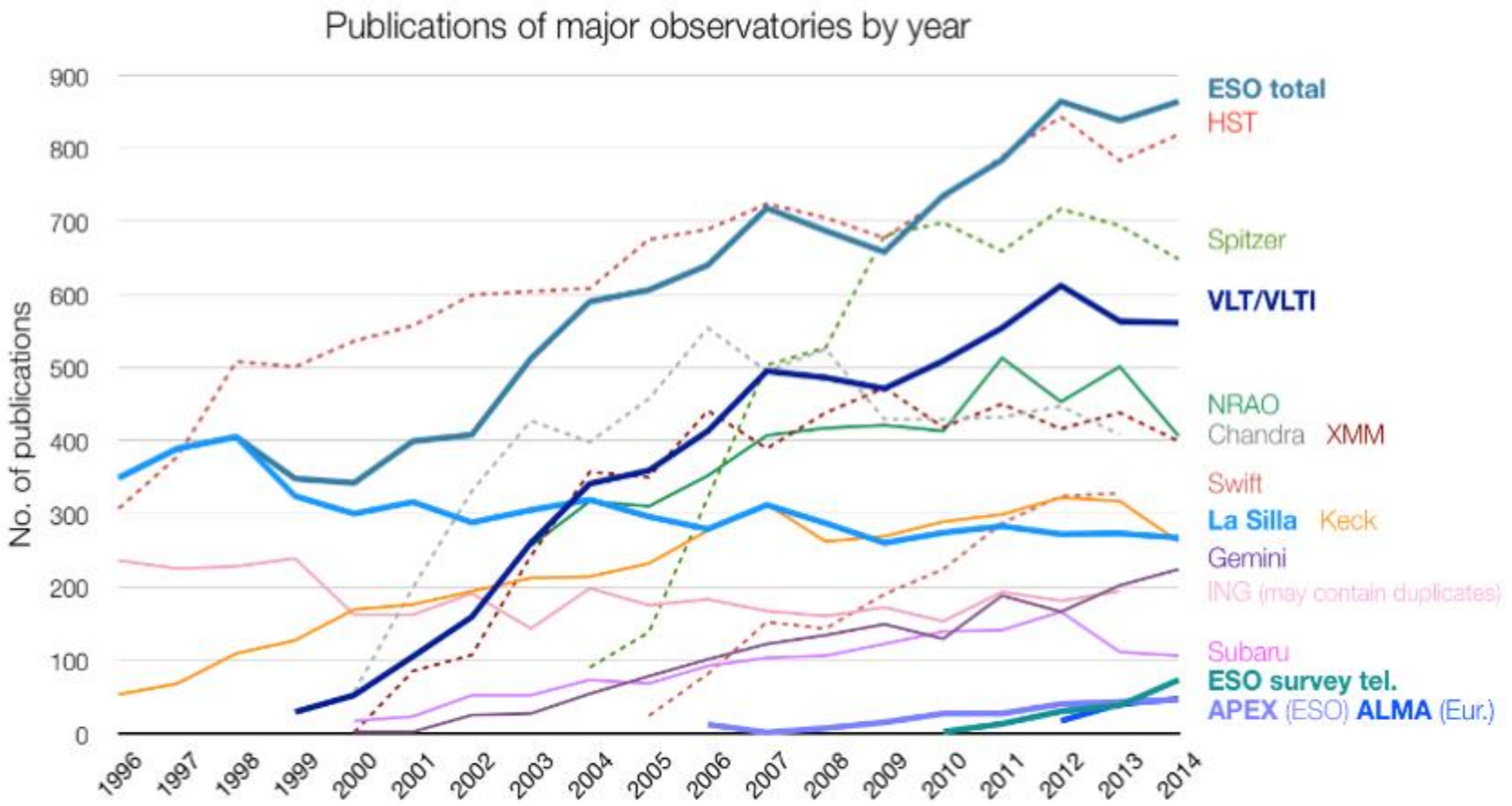
Comparative output



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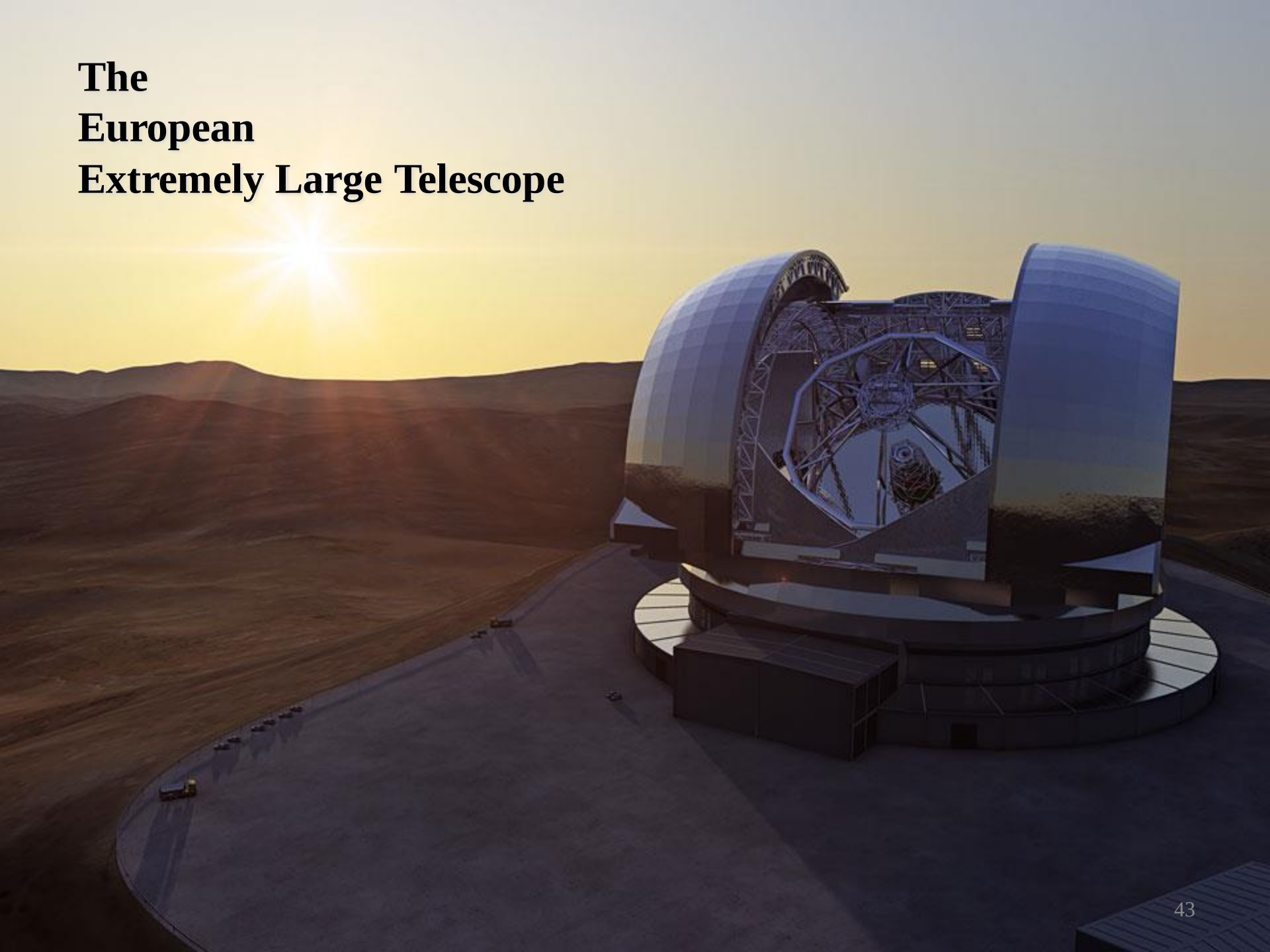
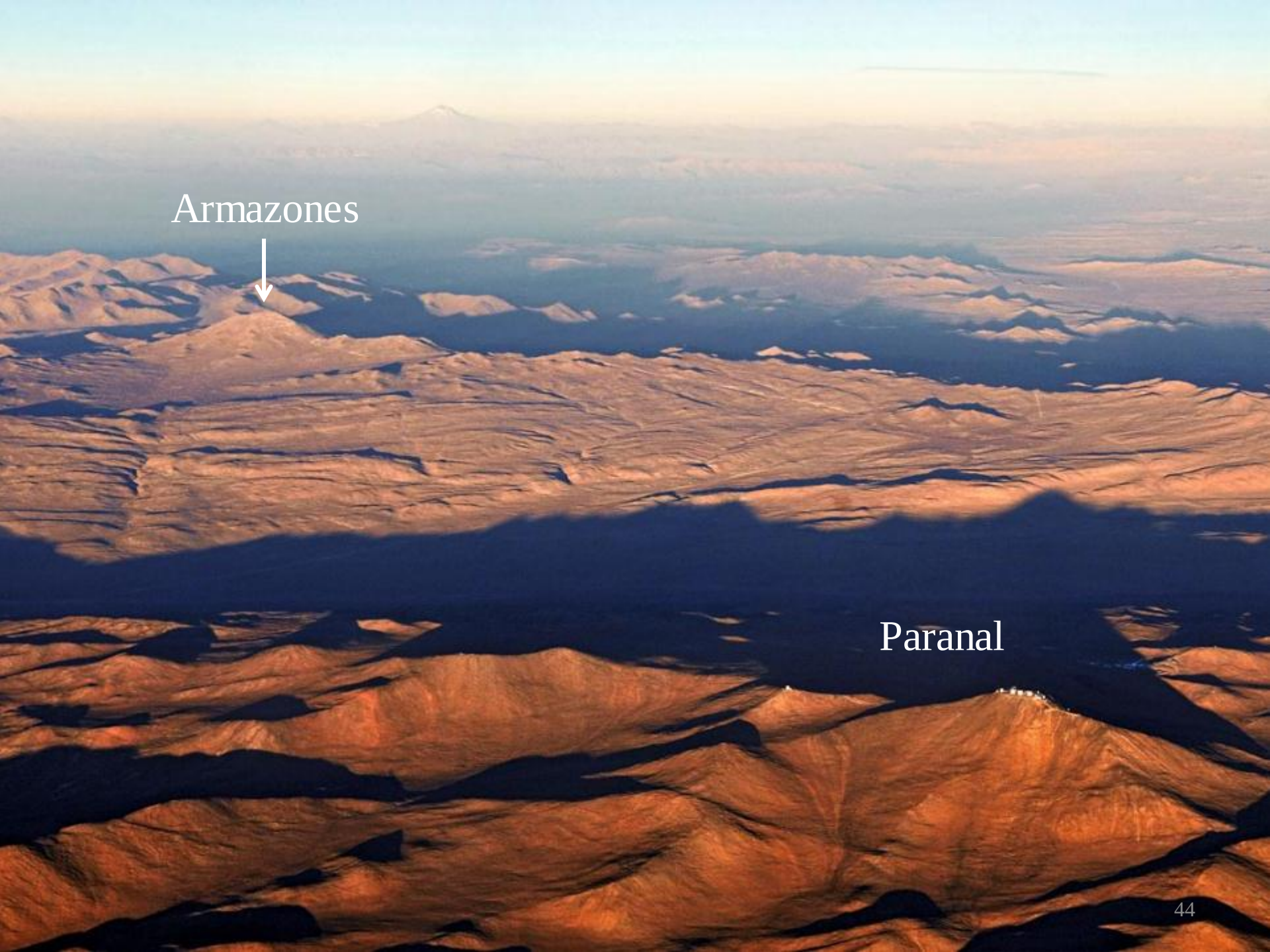
4. The E-ELT

biggest optical/IR telescope in history

The European Extremely Large Telescope




Armazones
Paranal

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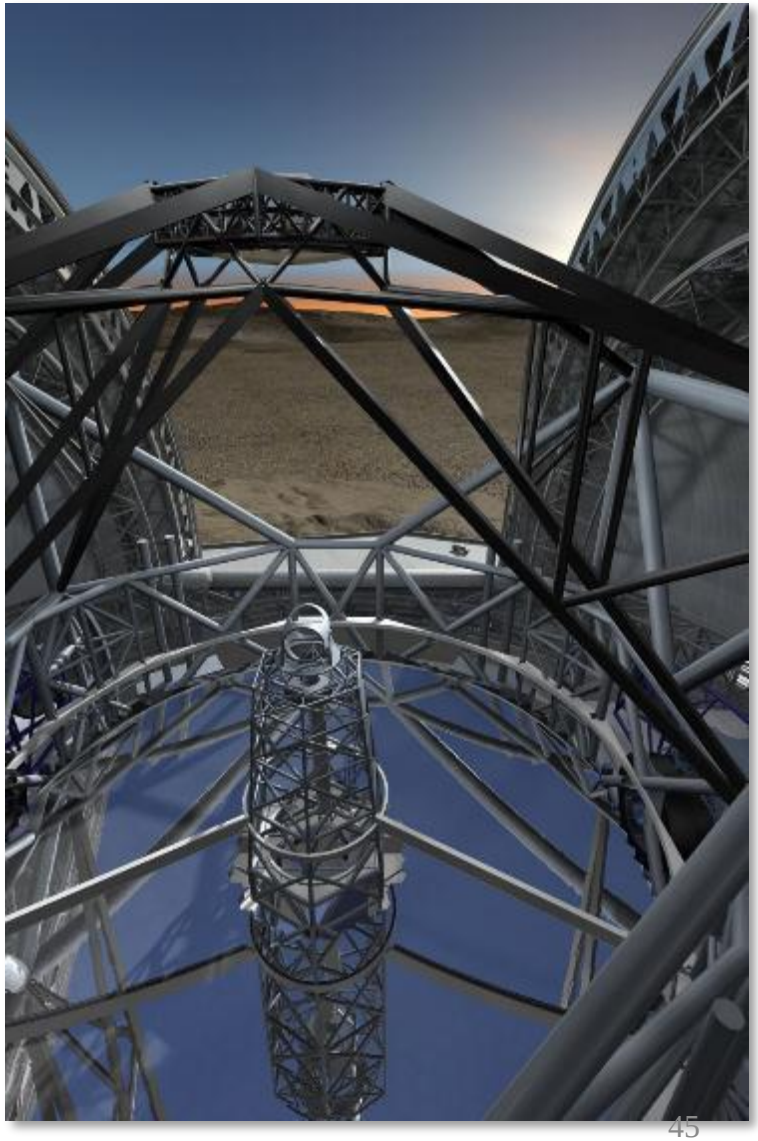
The E-ELT

- 40-m class telescope: largest optical-infrared telescope in the world.
- Segmented primary mirror.
- Active optics to maintain collimation and mirror figure.
- Adaptive optics assisted telescope.
- Diffraction limited performance.
- Wide field of view: 10 arcmin.
- Mid-latitude site (Armazones in Chile).
- Project approved in Dec 2012
- Construction started in 2013



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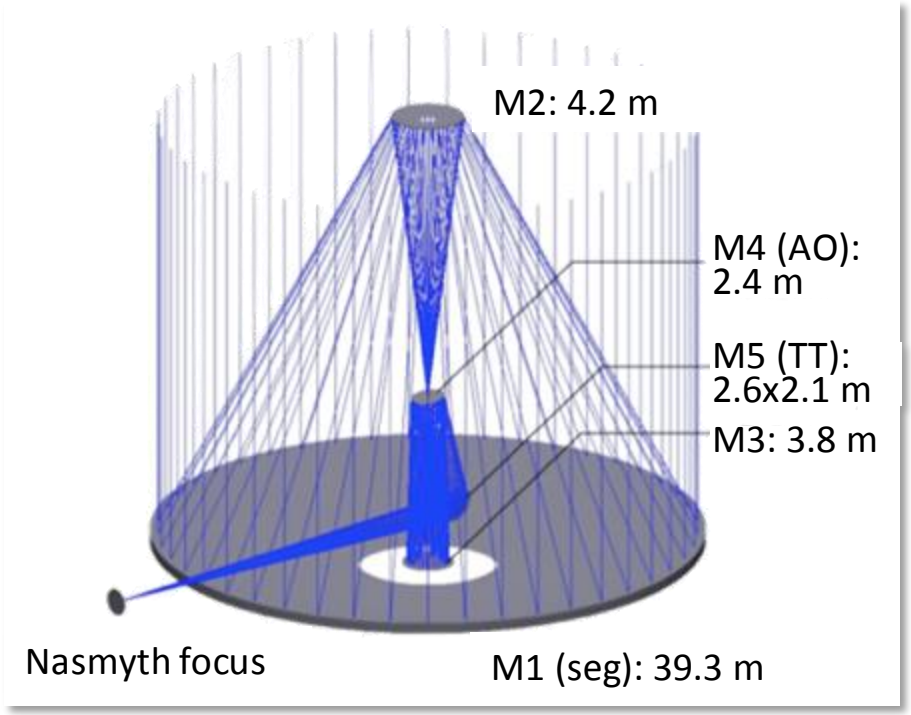
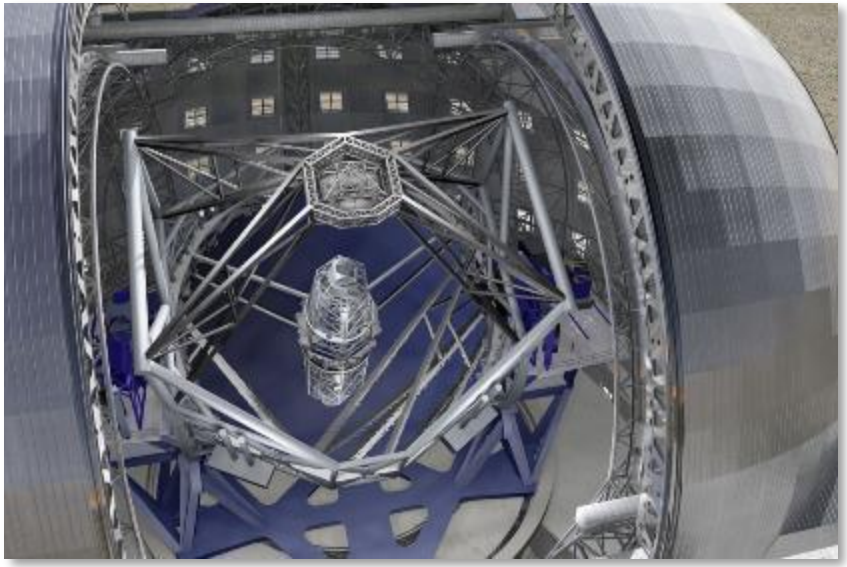
The Telescope

- Nasmyth telescope with a segmented primary mirror.
- Novel 5 mirror design to include adaptive optics in the telescope.





- Two instrument platforms nearly the size of tennis courts can host 3 instruments each + Coudé lab.
- Multiple laser guide stars, launched from the side.
- Nearly 3000 tonnes of moving structure.

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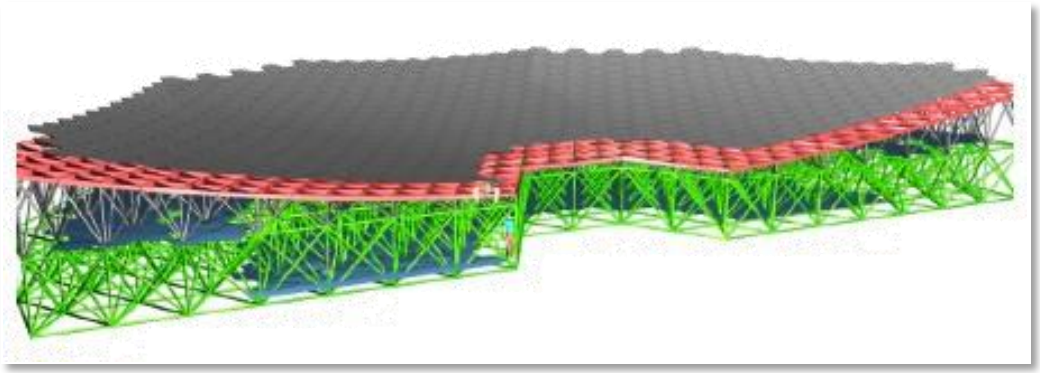
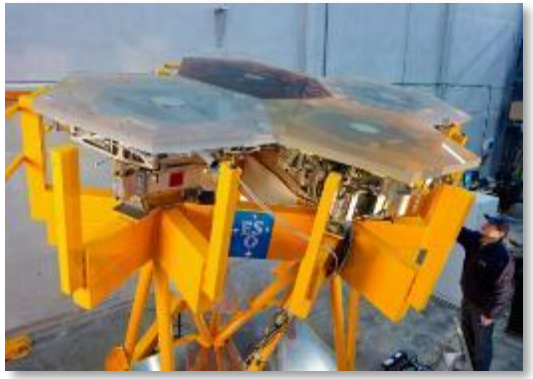
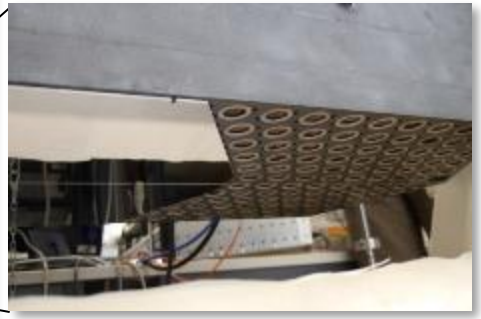
The Mirrors

M1: 39.3 m, 798 hexagonal segments of 1.45 m tip-to-tip: 978 m^2 collecting area





M4: 2.4 m, flat, adaptive
6000 to 8000 actuators



M5: 2.6 x 2.1 m, flat, provides tip-tilt correction

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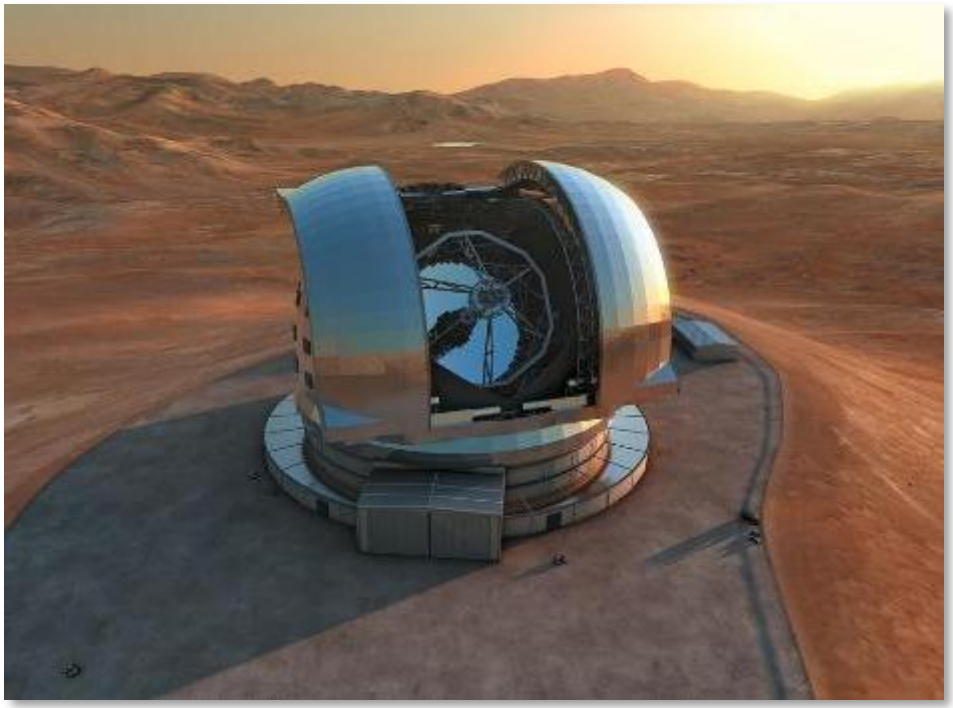
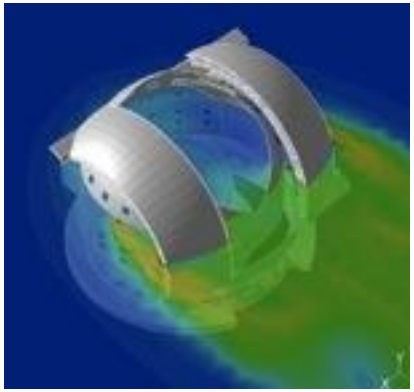
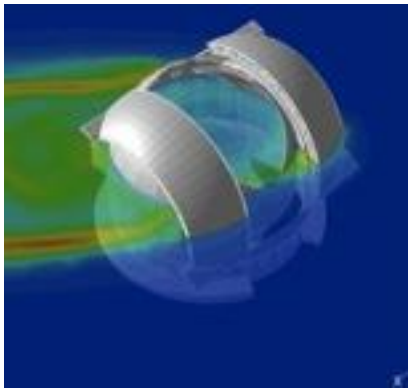
The Dome

- Classical design.
- Diameter = 86 m, height = 74 m.
- ~3000 tonnes of steel.
- Fully air-conditioned and wind shielded.







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End & Questions