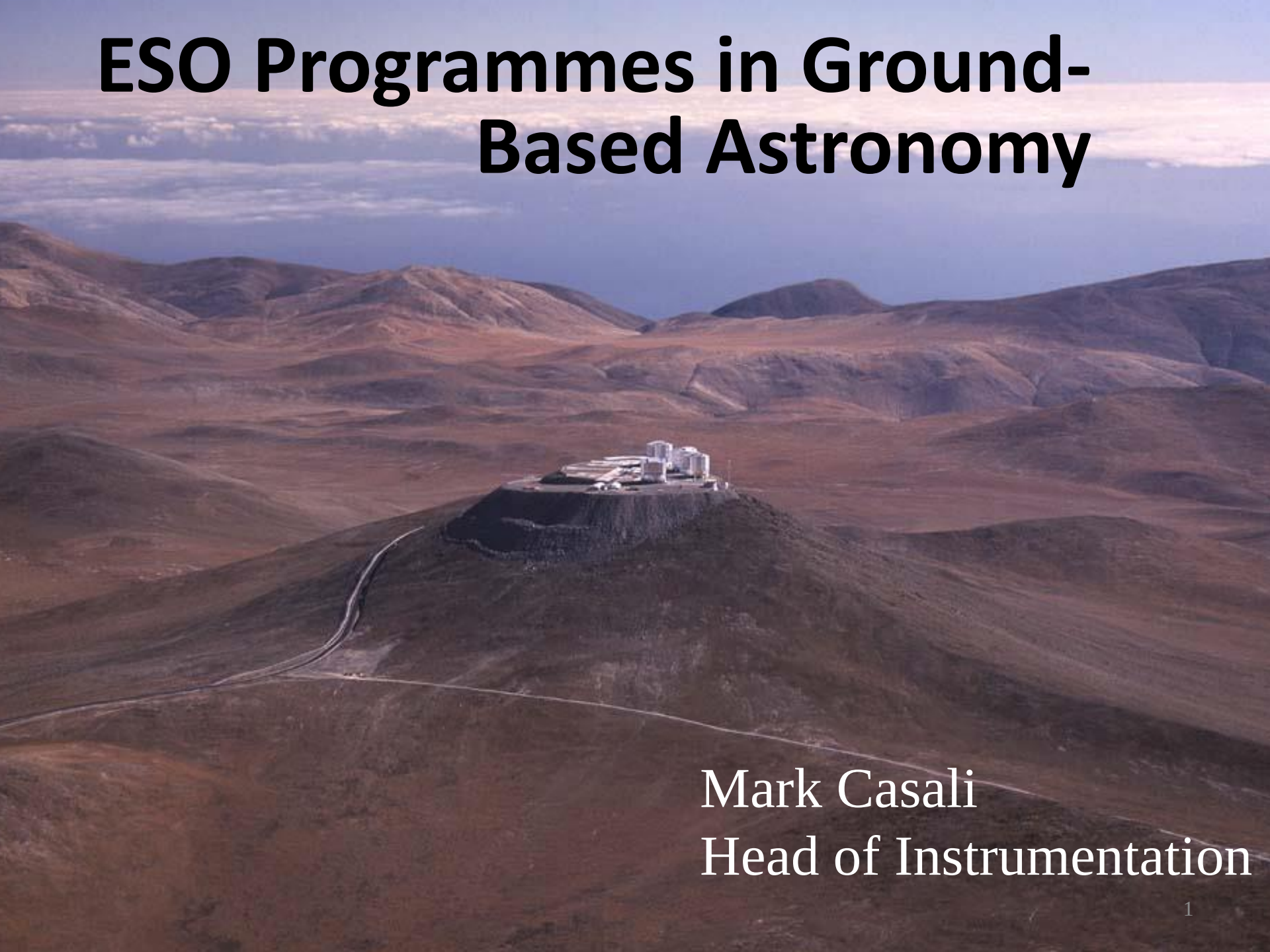
ESO Programmes in Ground-Based Astronomy



Mark Casali
Head of Instrumentation

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Summary of Programmes

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

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1. Optical / IR facilities and instruments

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Cerro Paranal Observatory

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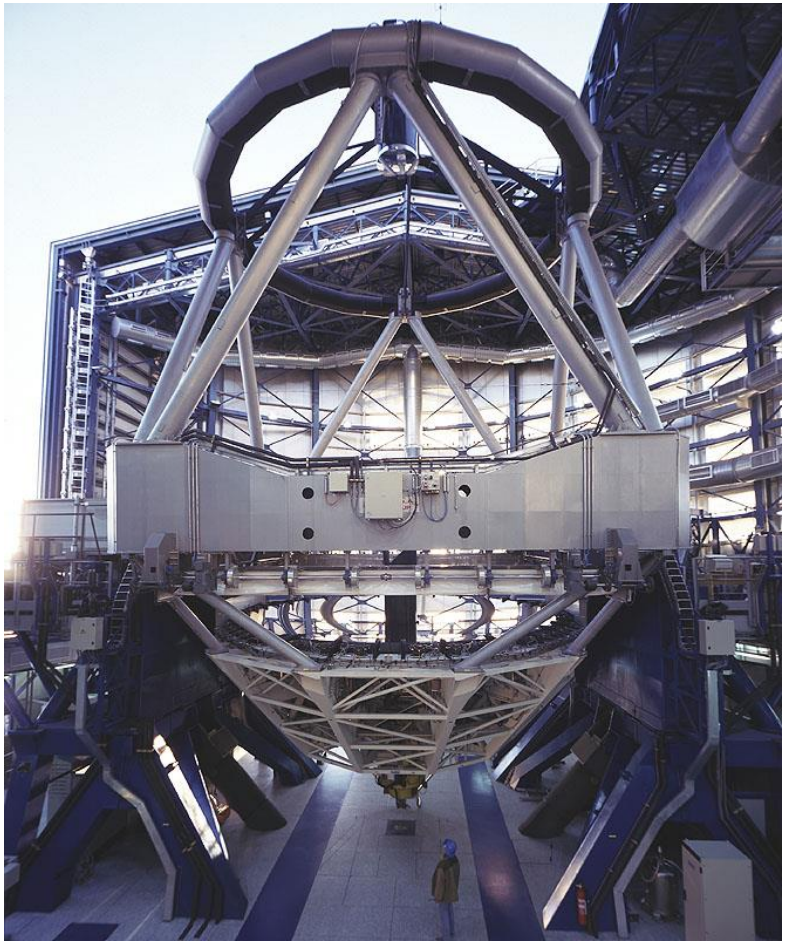
VLT : 4 x 8.2m telescopes

- 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



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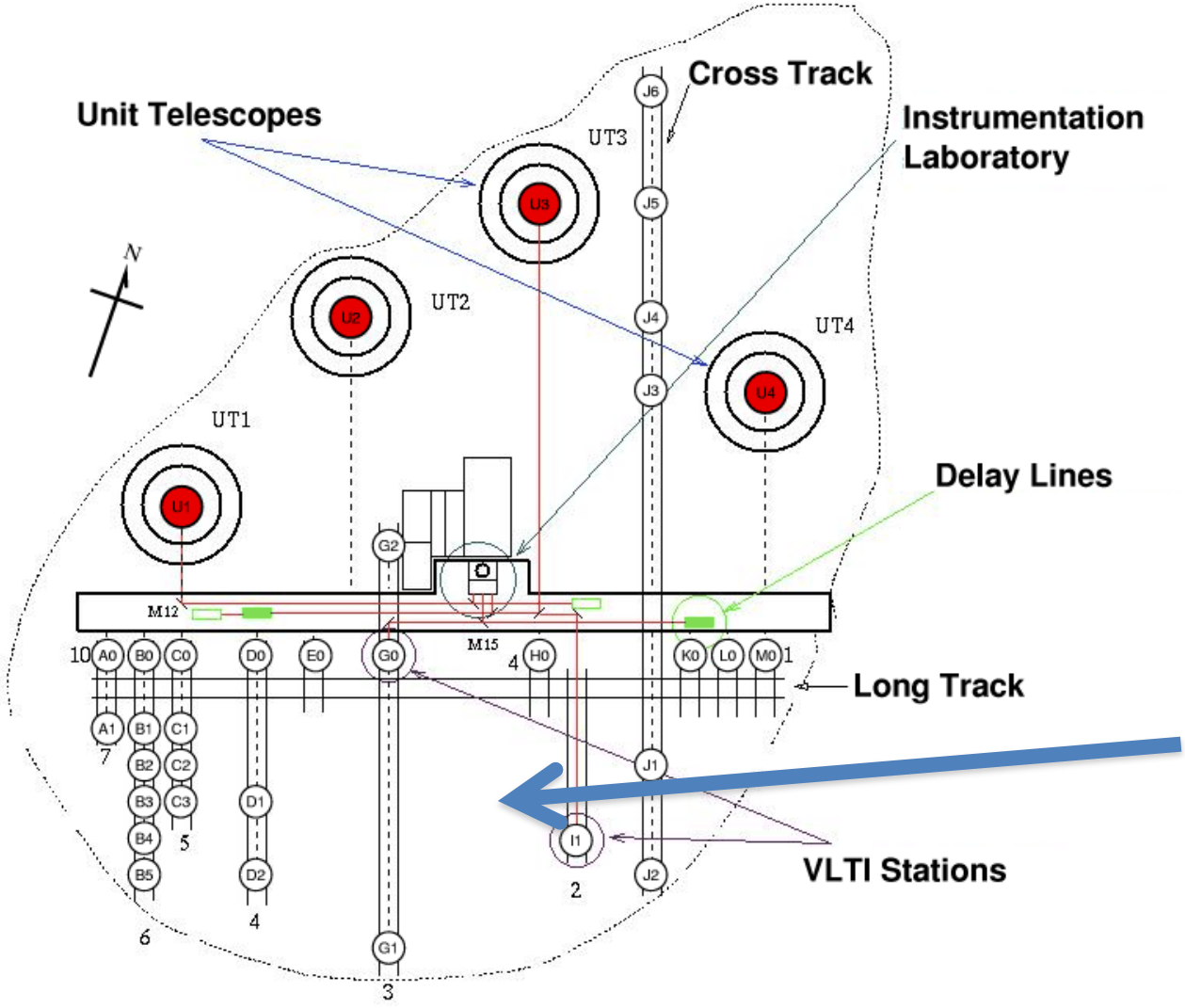
VLT interferometry



Four 1.8 m movable Auxiliary Telescopes for interferometry

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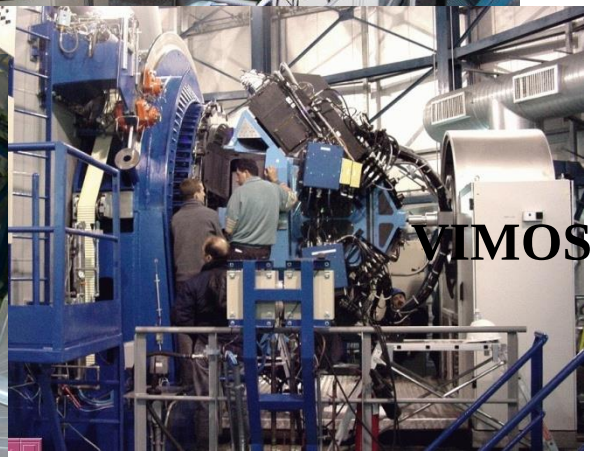
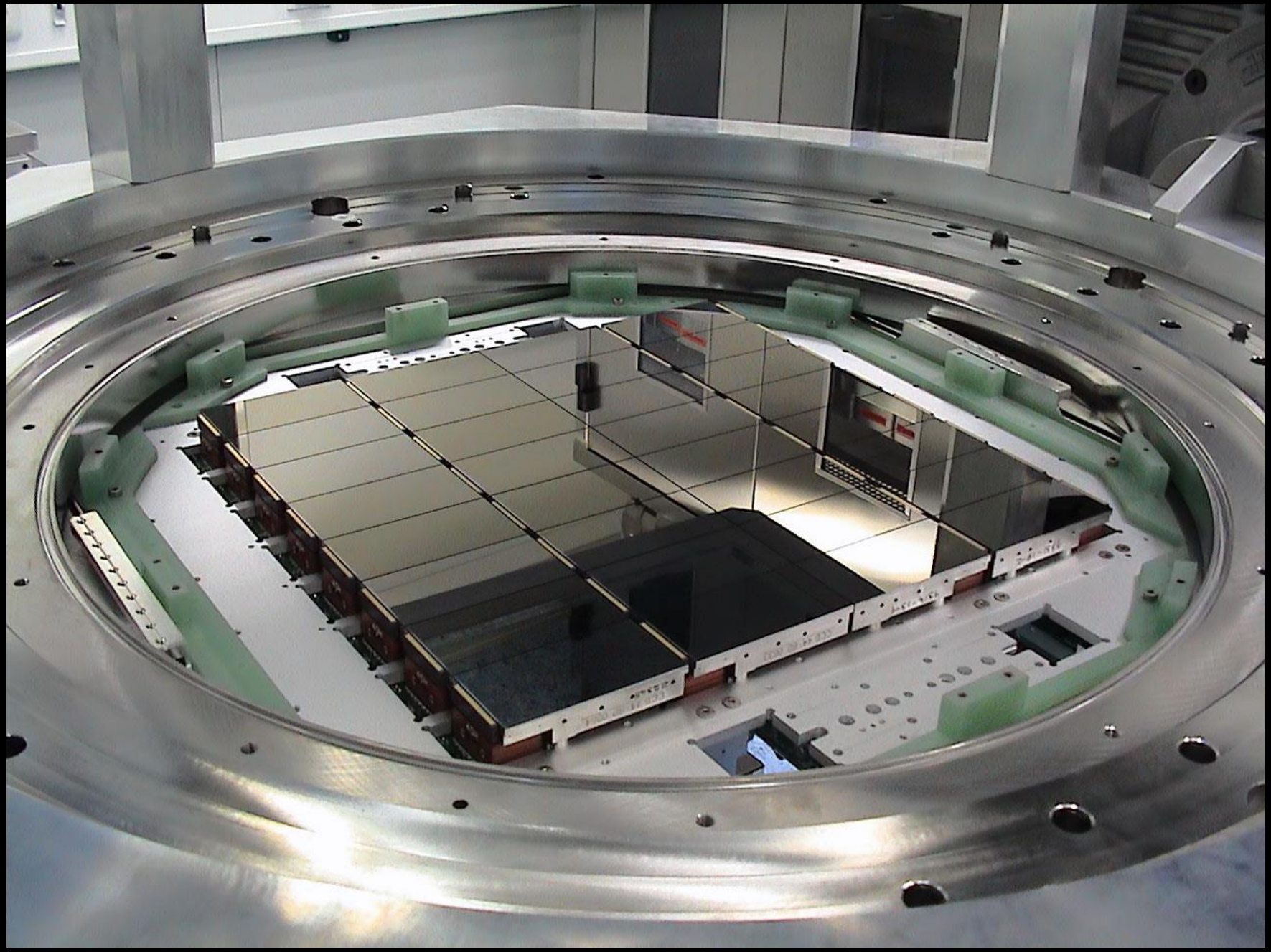
Instrumentation at the VLT from the visible up to 28 microns



and many more……



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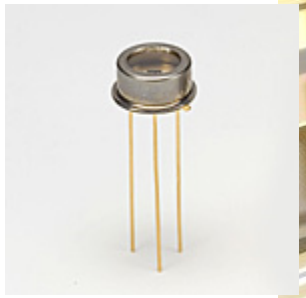
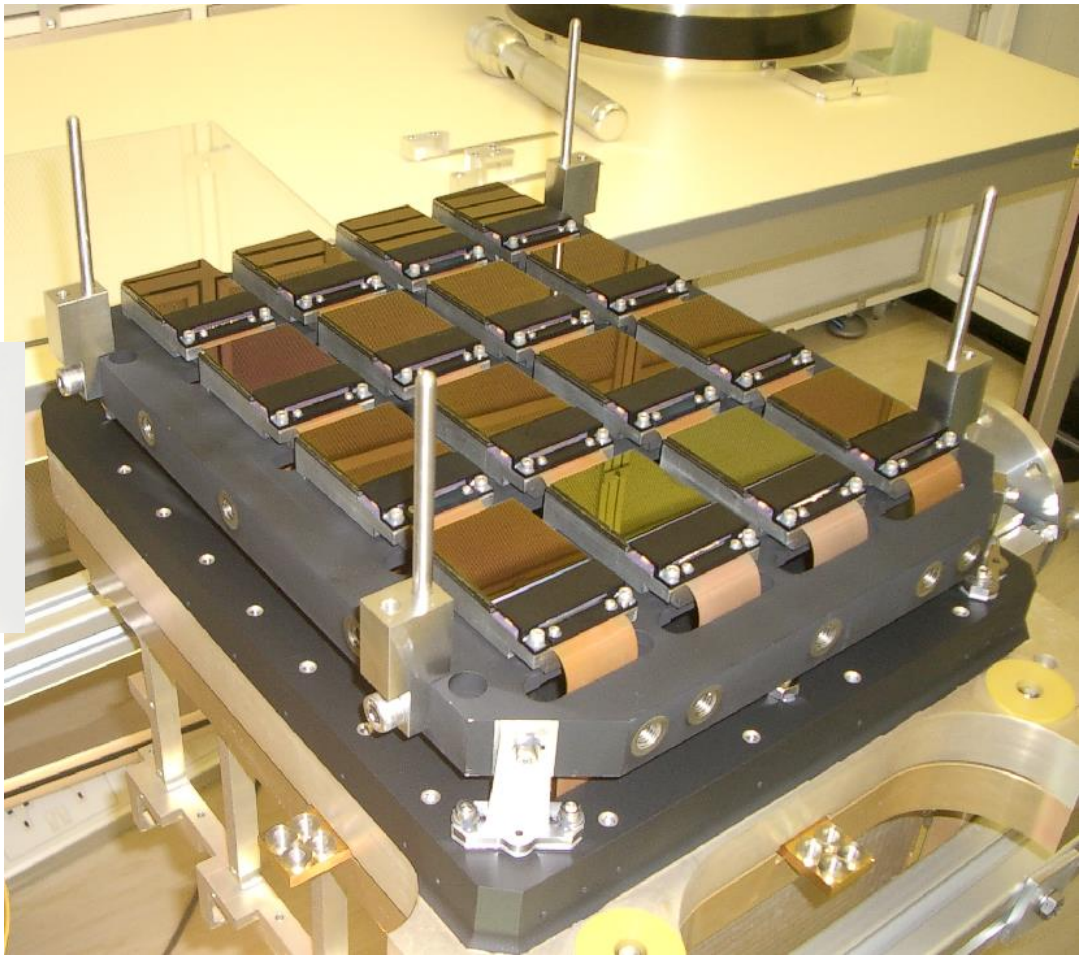
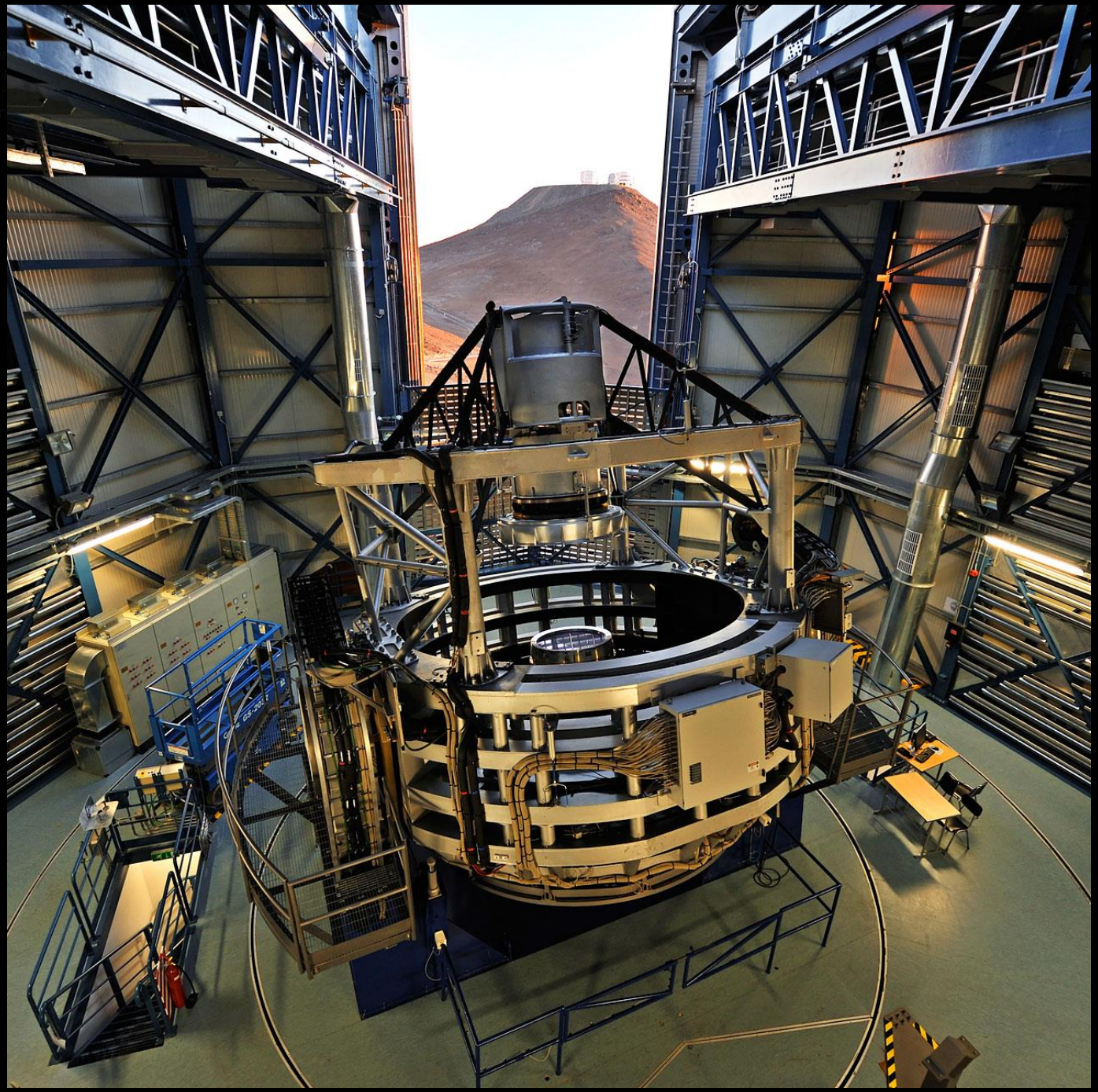
Giant VISTA IR focal plane
16 x 2k x 2k HgCdTe



1986



2008 VIRCAM



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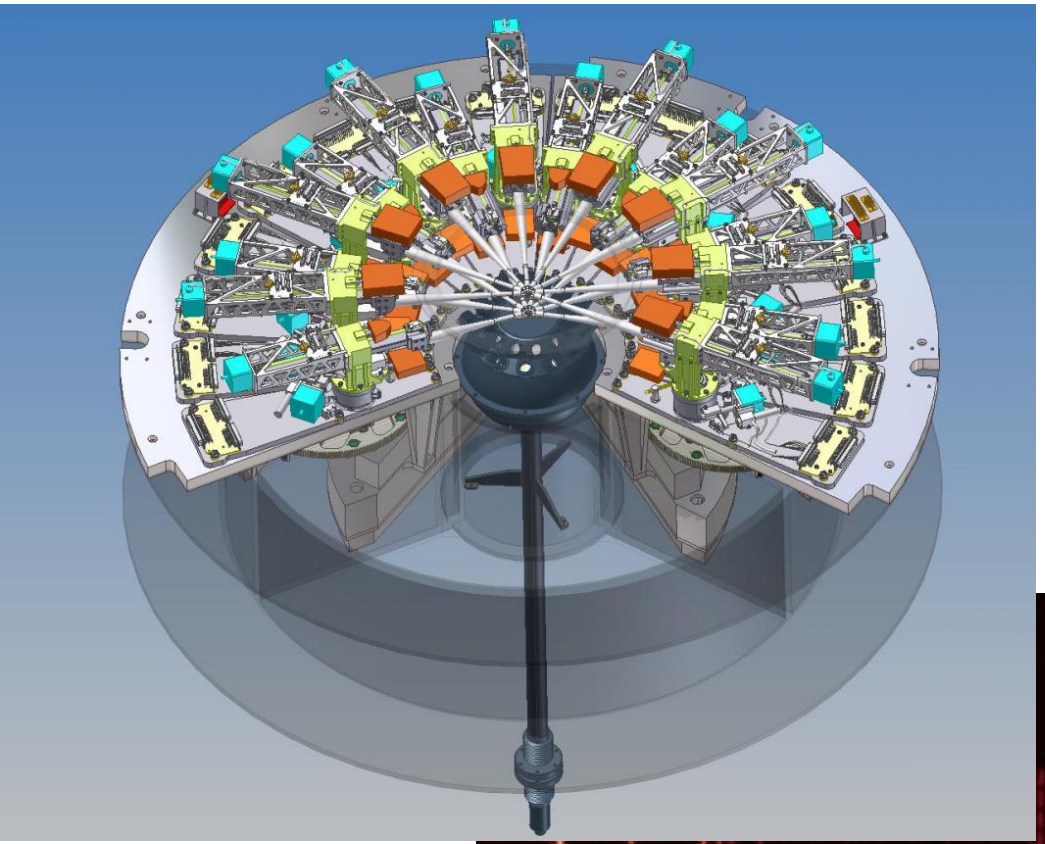
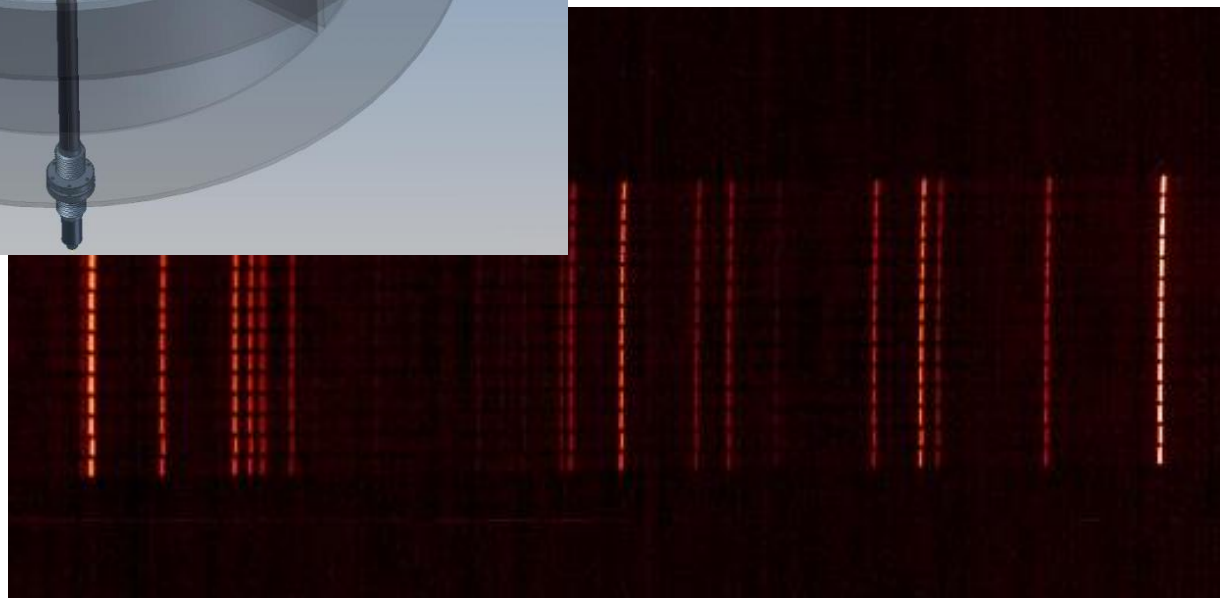
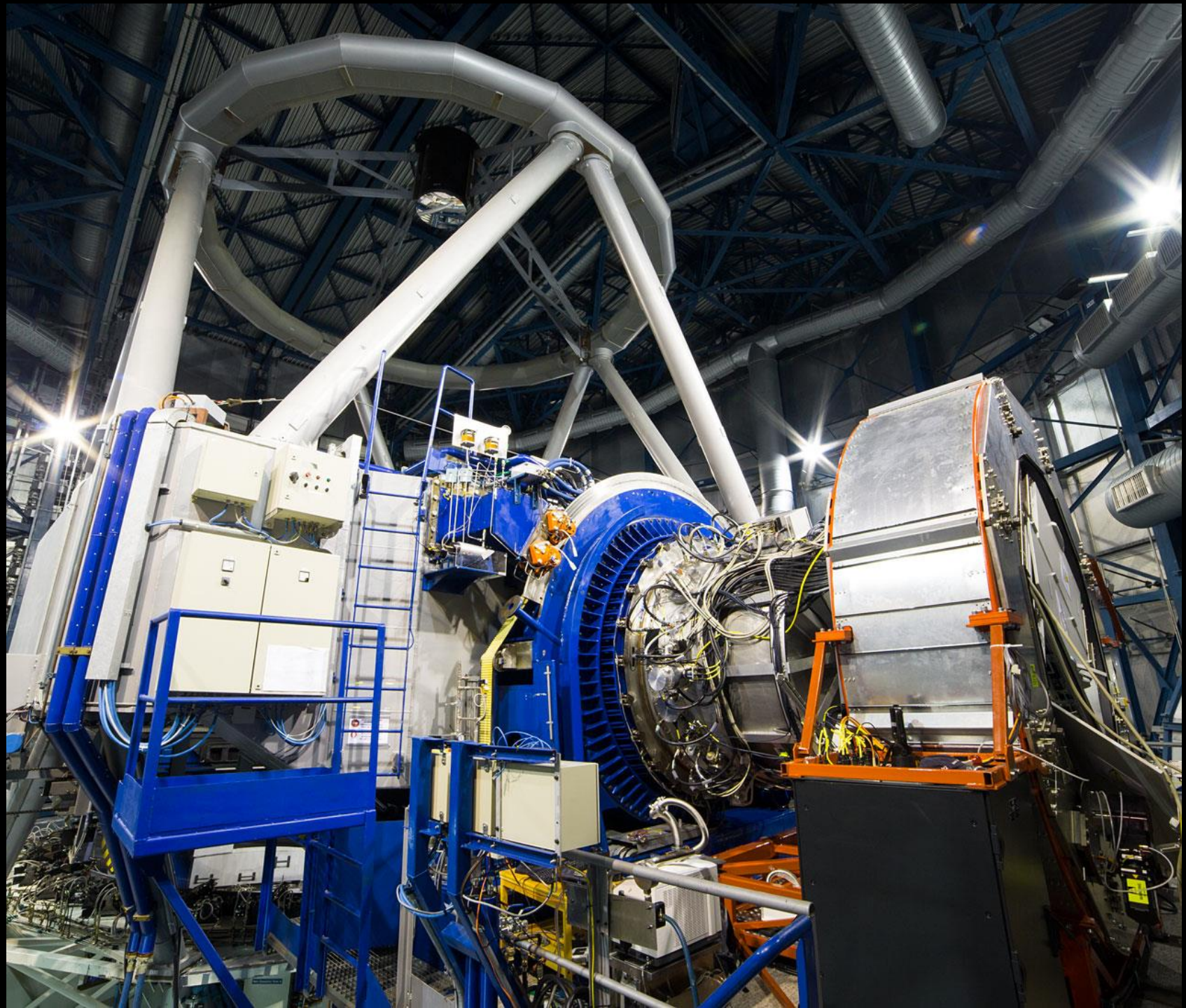
Spectroscopy with KMOS



24 2.8x2.8” IFUs. 0.2” sampling.
3 spectrographs (H2RG)
24 cryogenic pick-off arms, operating on 7.2’ field
1 to 2.5 micron operation





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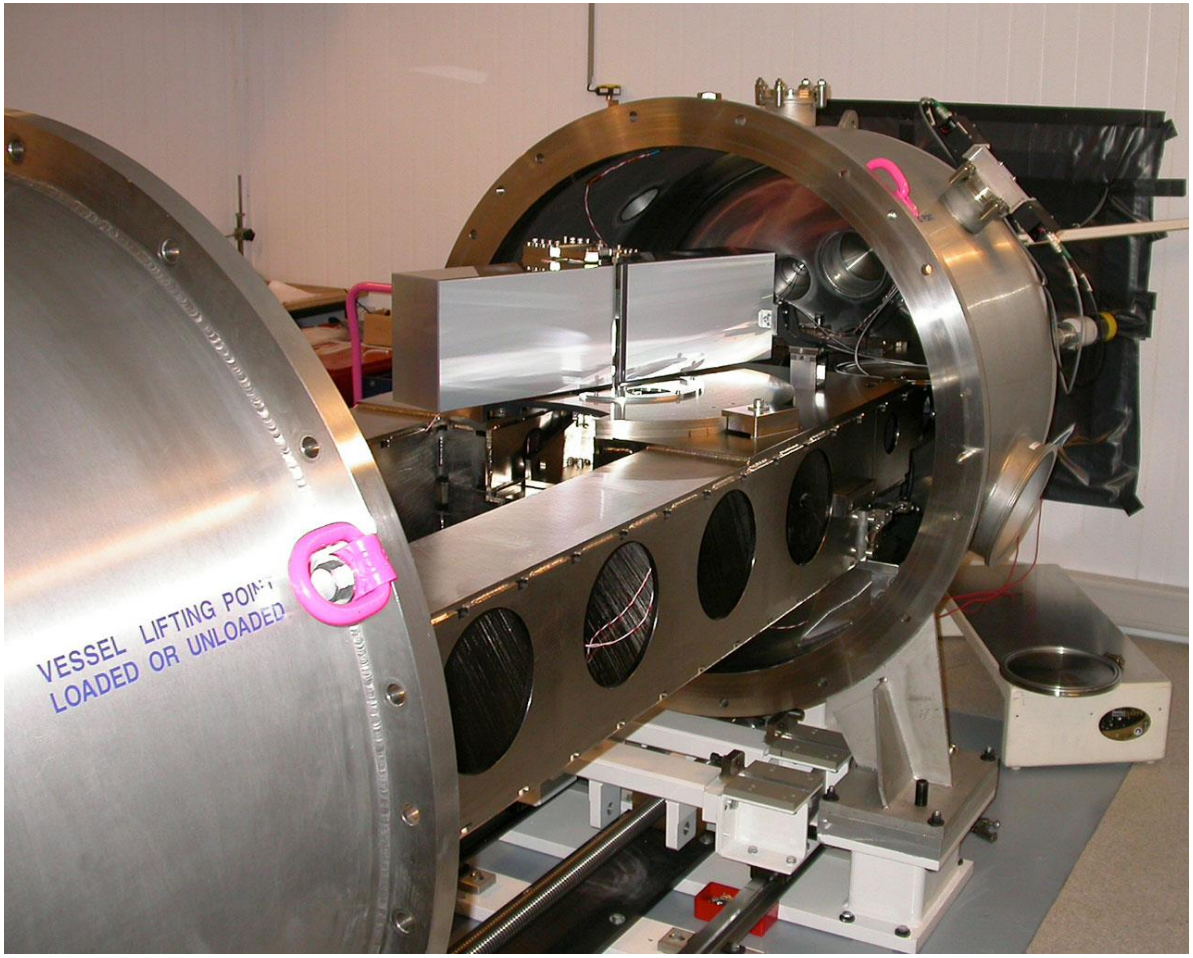
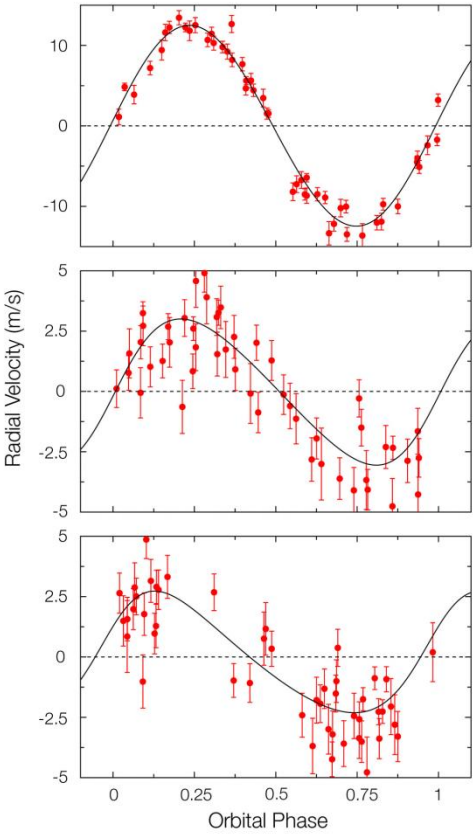
High stability - HARPS





<1 m/s stability

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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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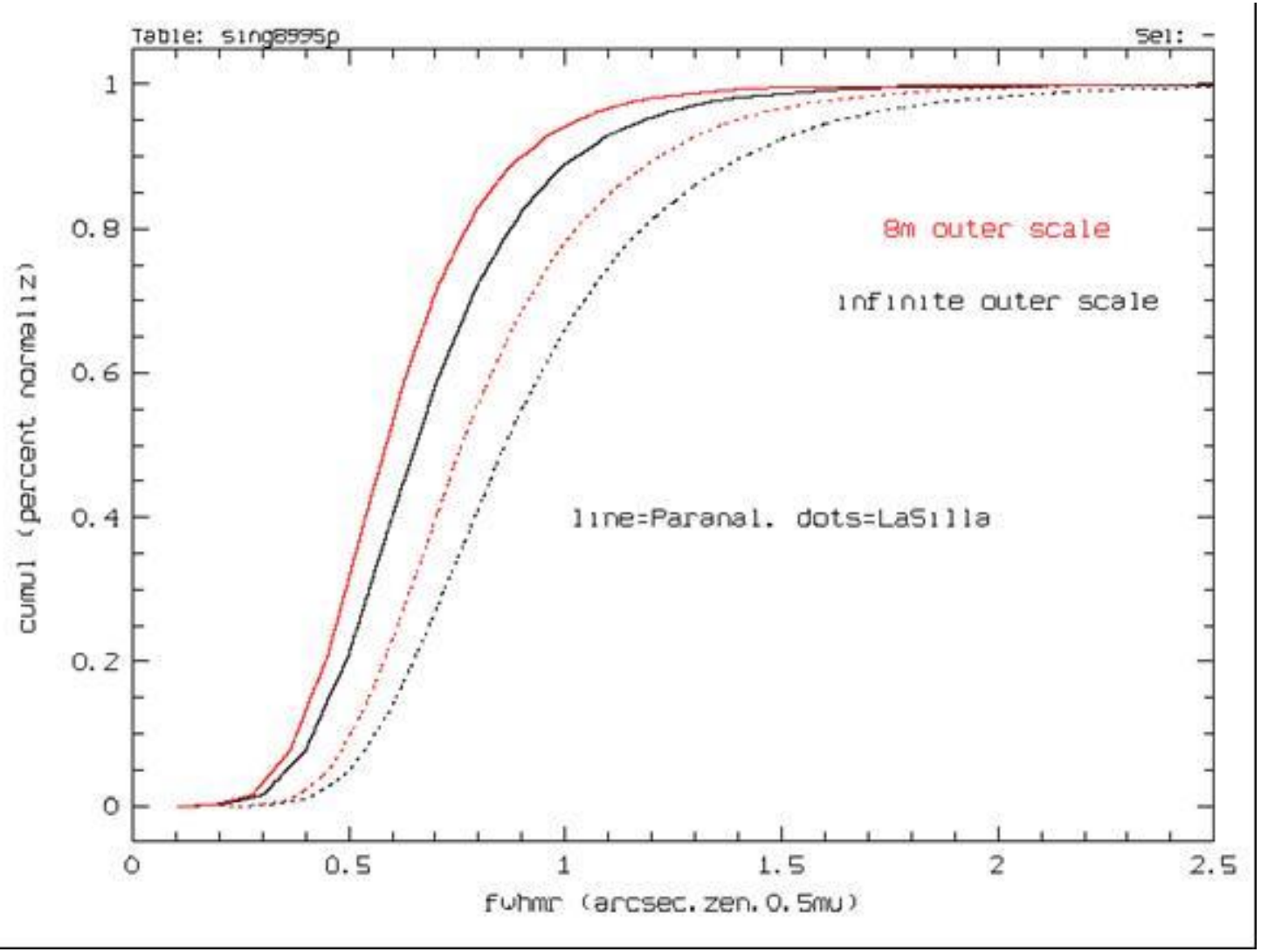
Free Atmospheric image quality



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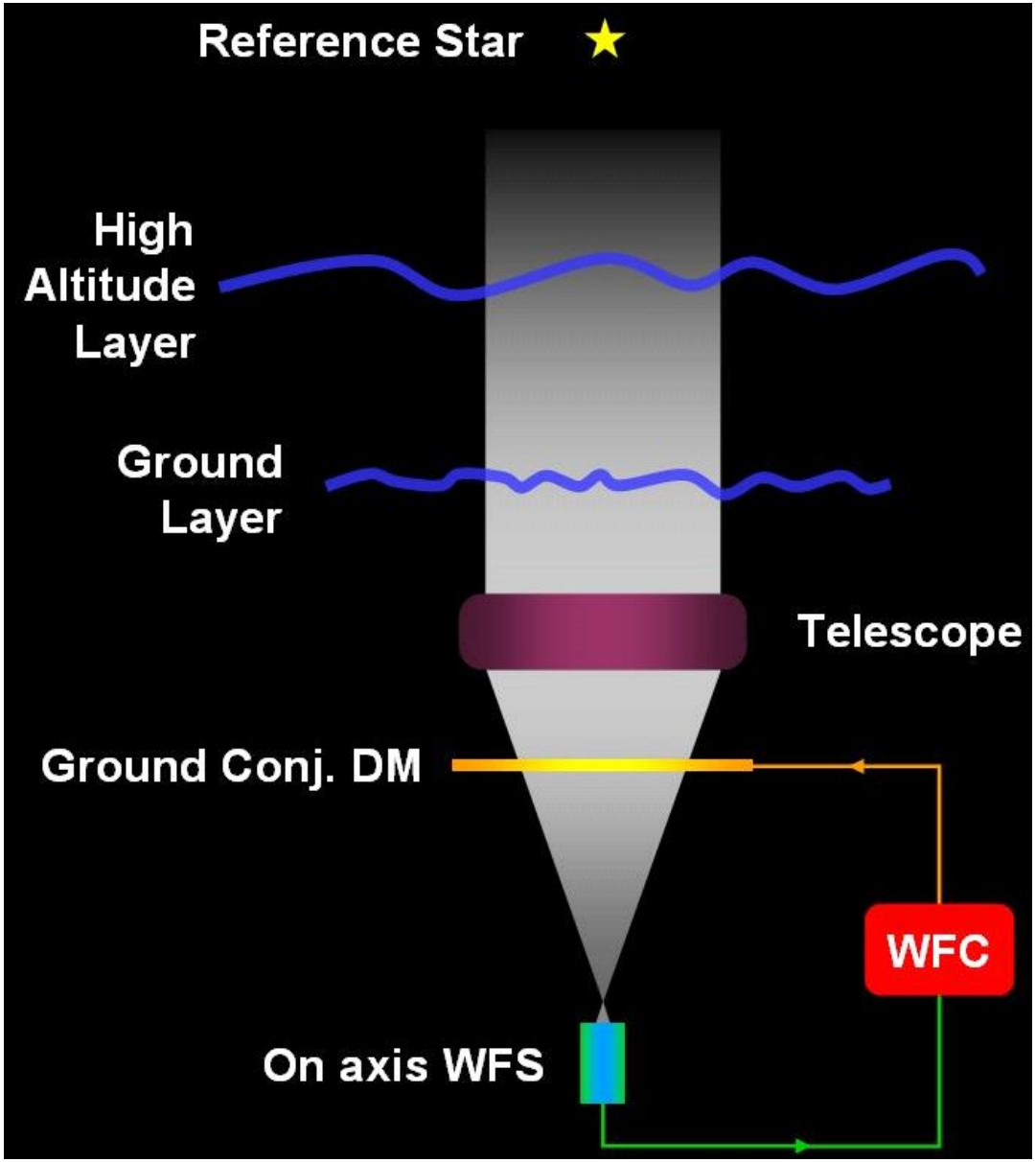
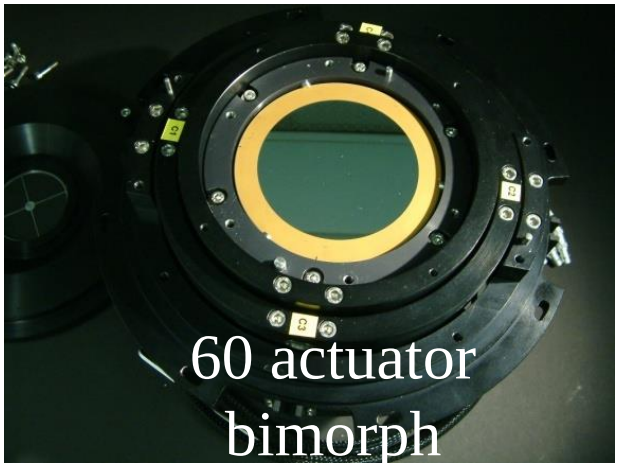
At the diffraction limit



Development of Piezo DM technology



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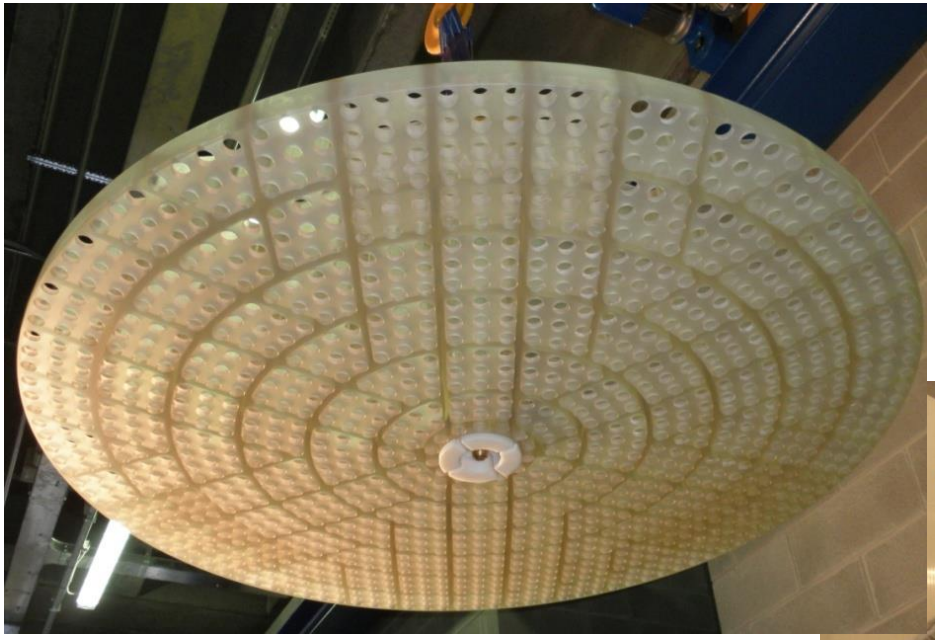
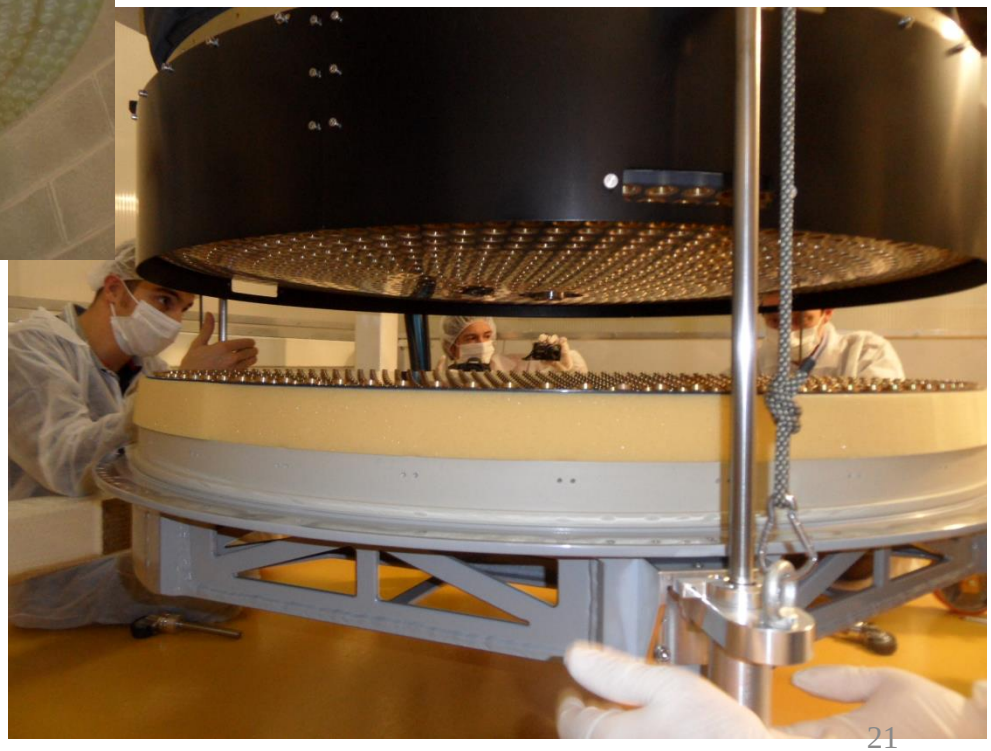
Voice Coil DMs





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

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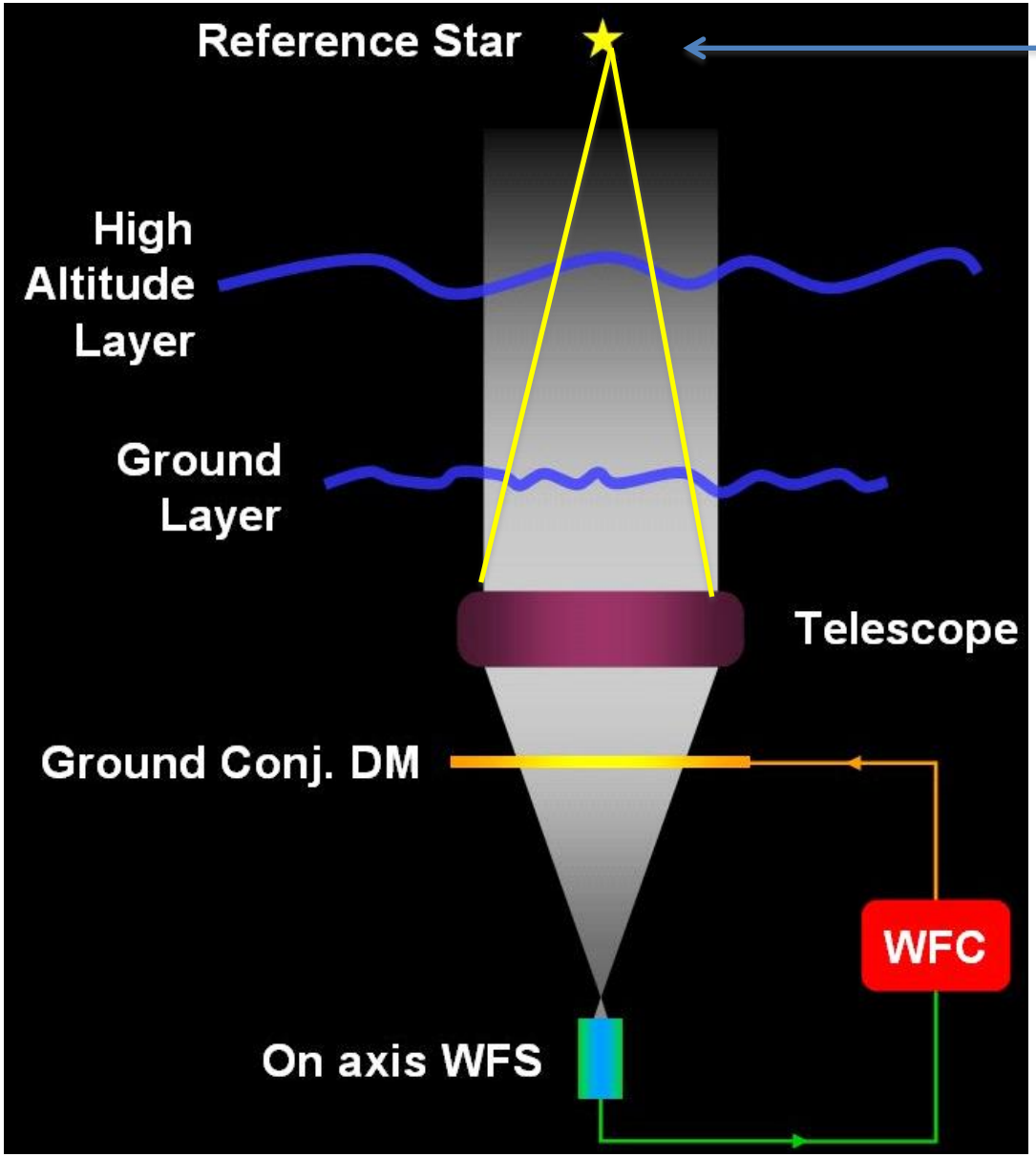
Laser Reference Star



Na layer

589nm

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Lasers

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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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At the diffraction limit – Naos-Conica

185 element DM

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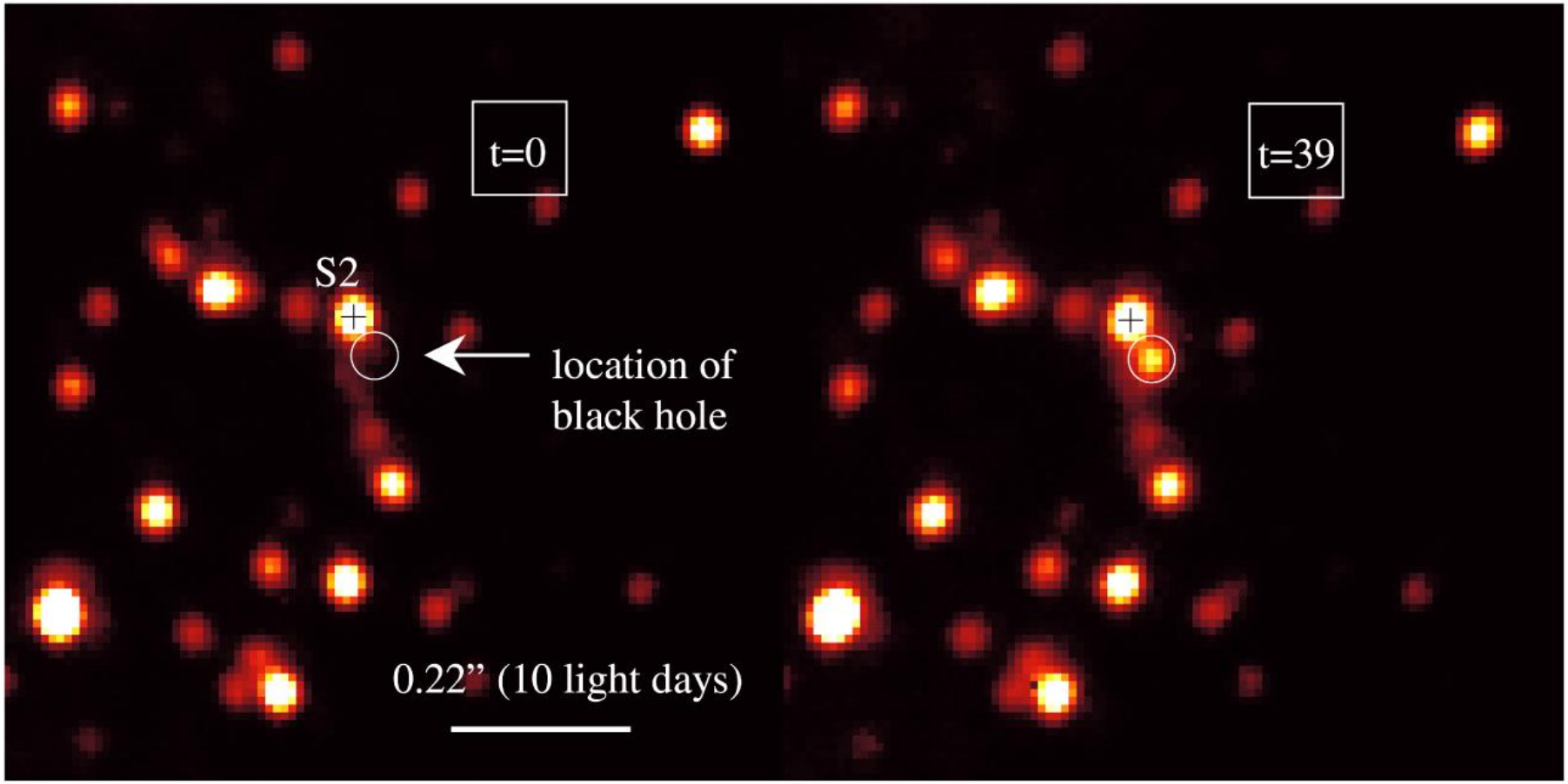
3M solar mass BH at Galactic Center



Near-IR Flare from Galactic Centre (VLT YEPUN + NACO)

ESO PR Photo 29a/03 (29 October 2003)

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2. mm Interferometry with ALMA

A universe of cold gas and molecules

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Atacama Large Millimetre (& submillimetre) Array

- ALMA is the world's largest ground-based astronomy project
- Interferometer at mm and sub-mm wavelengths
- In final construction in the Atacama desert

- Three sites in Chile
  - **ALMA Operations Site (AOS)**: high, dry site, Chajnantor Plateau (5000m)
  - **Operations Support Facility (OSF)**: Technical base (2900m) near San Pedro de Atacama
  - **Santiago** headquarters

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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

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ALMA features

- ALMA will have 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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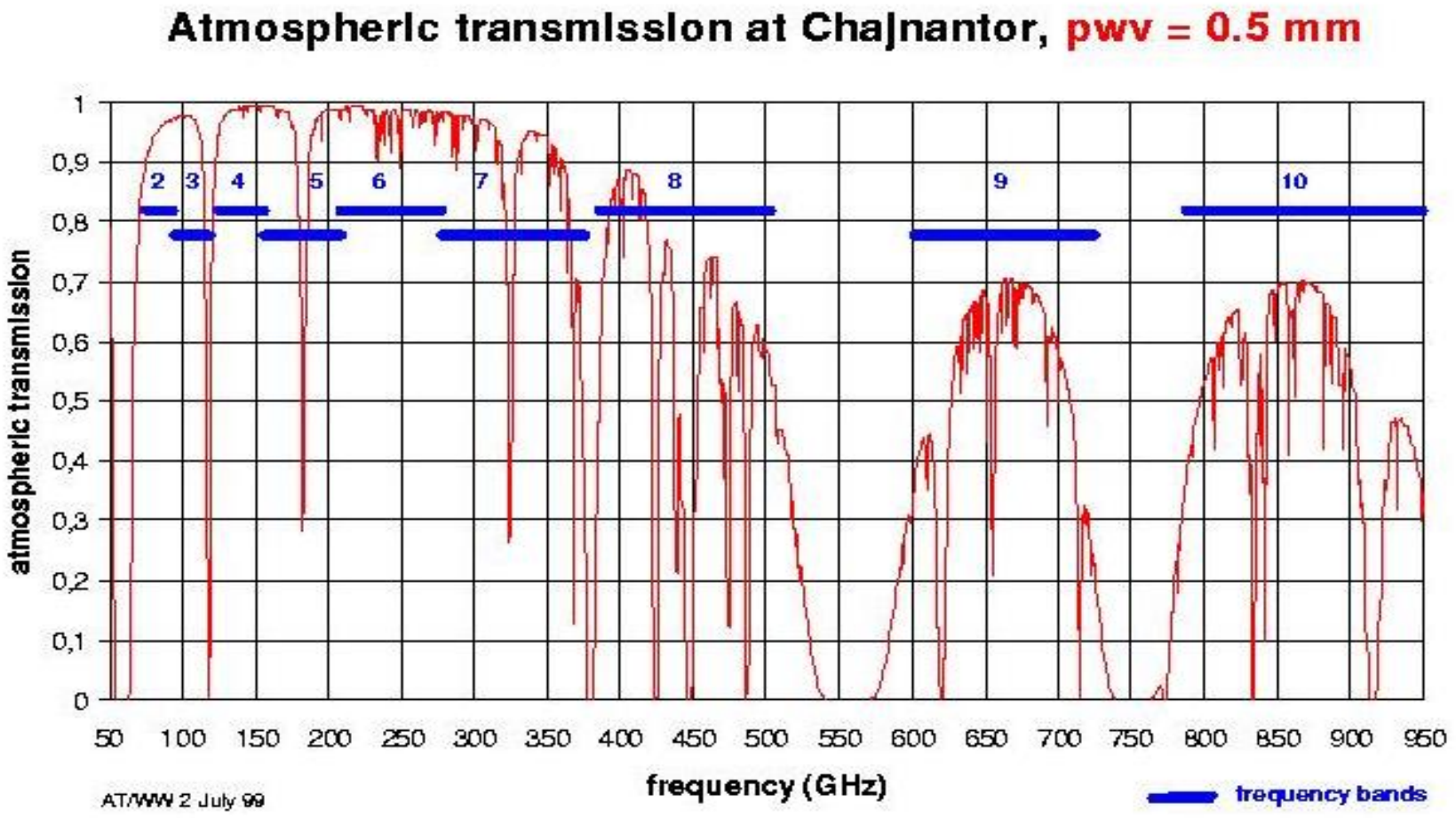
ALMA Frequency Bands



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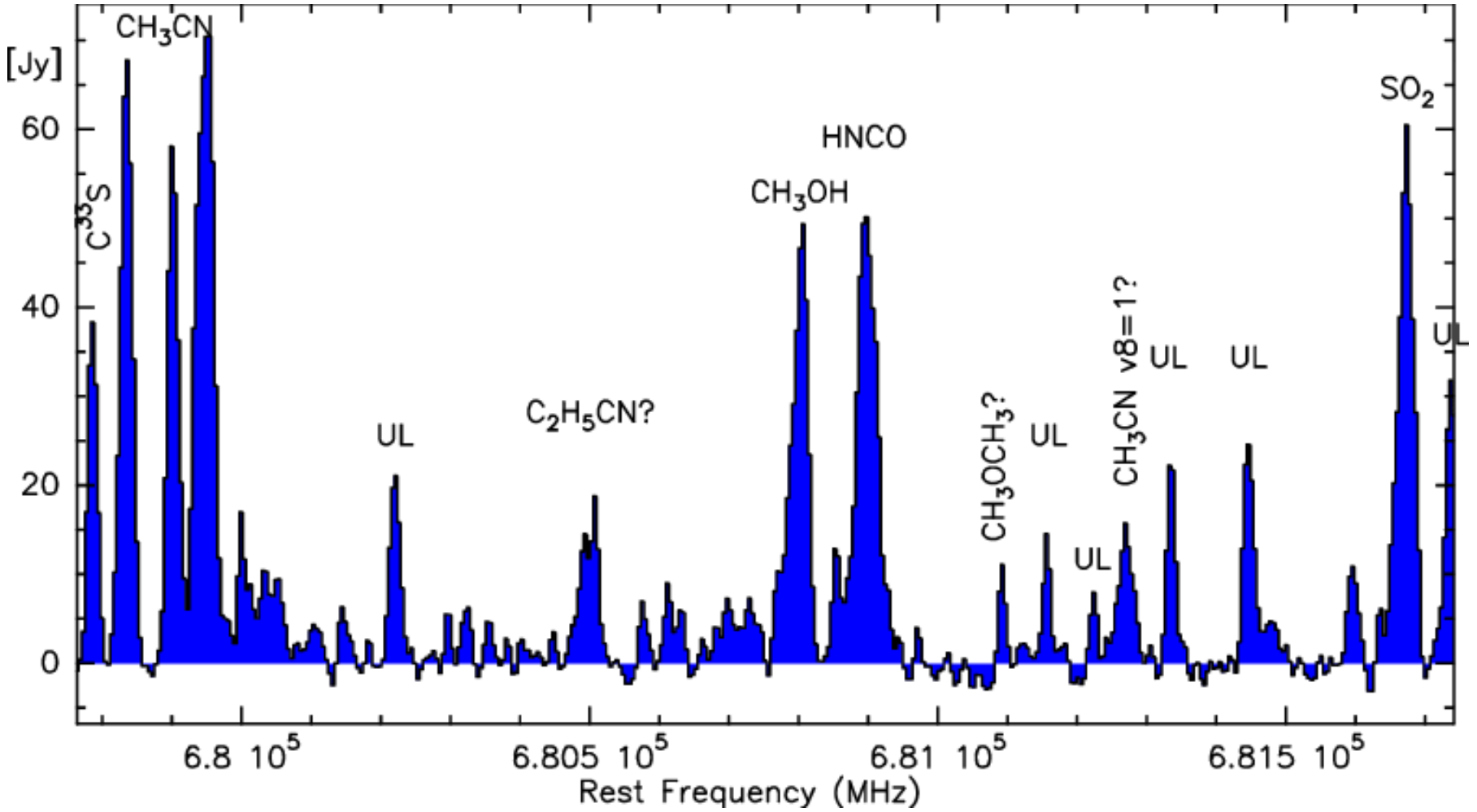
Cold universe full of molecules



The Early

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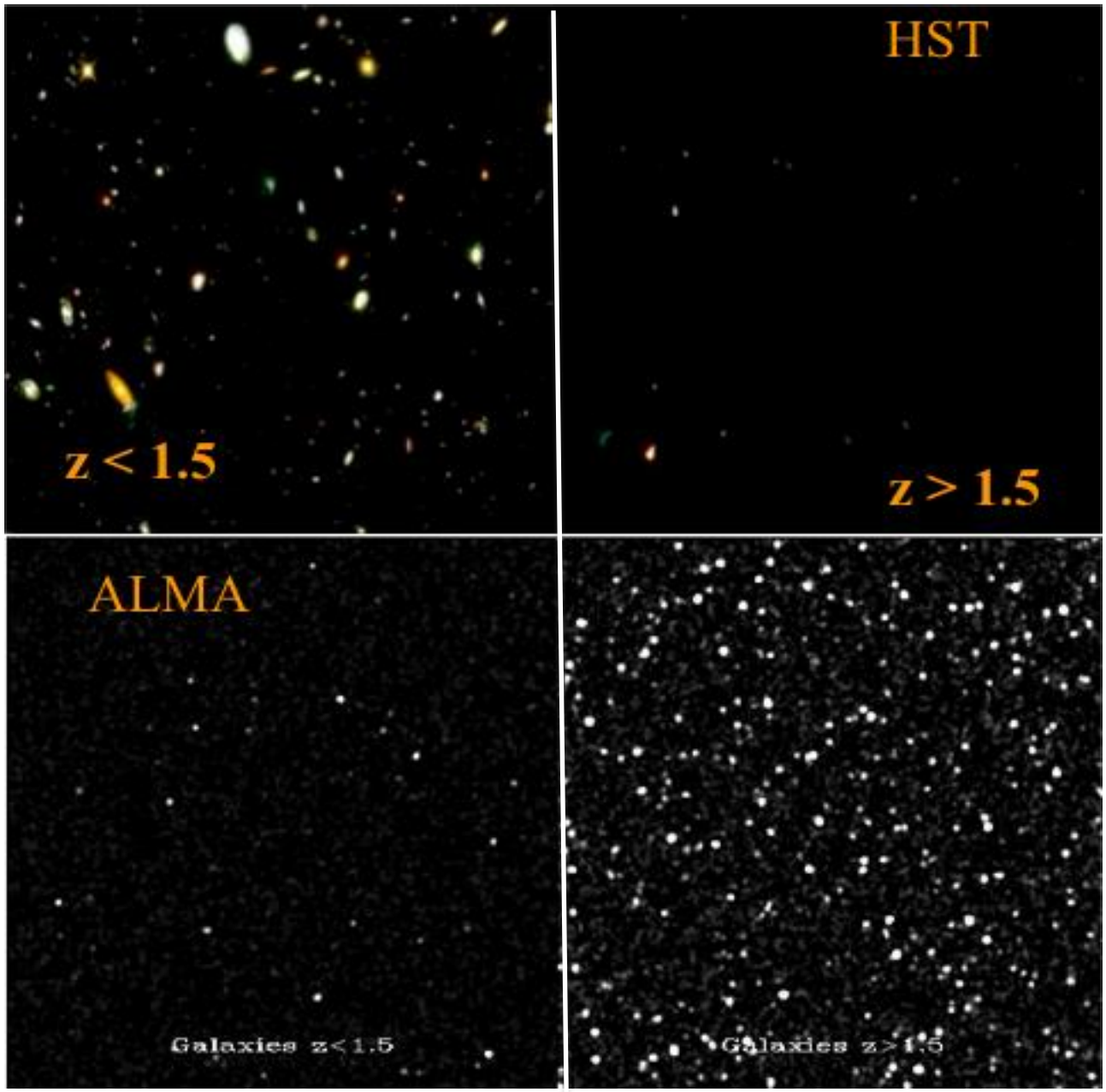

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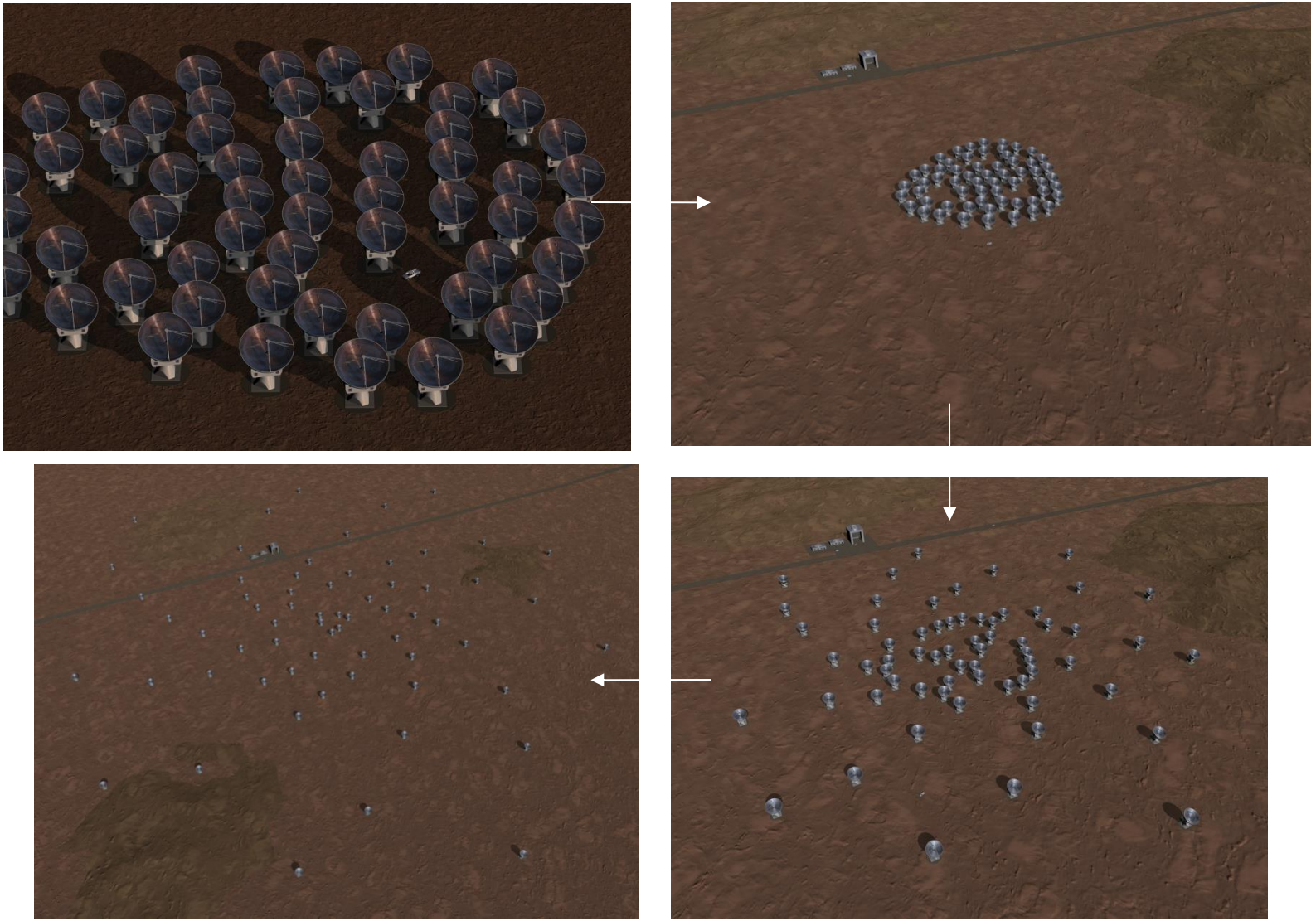
192 antenna interferometry stations



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First antenna to 5000m (17 Sep 09)

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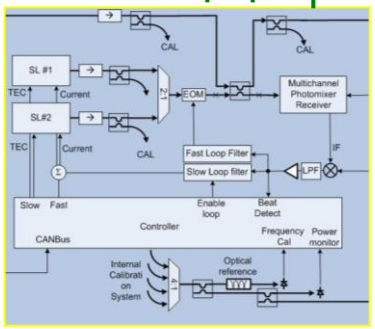
Lonely road



- 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.

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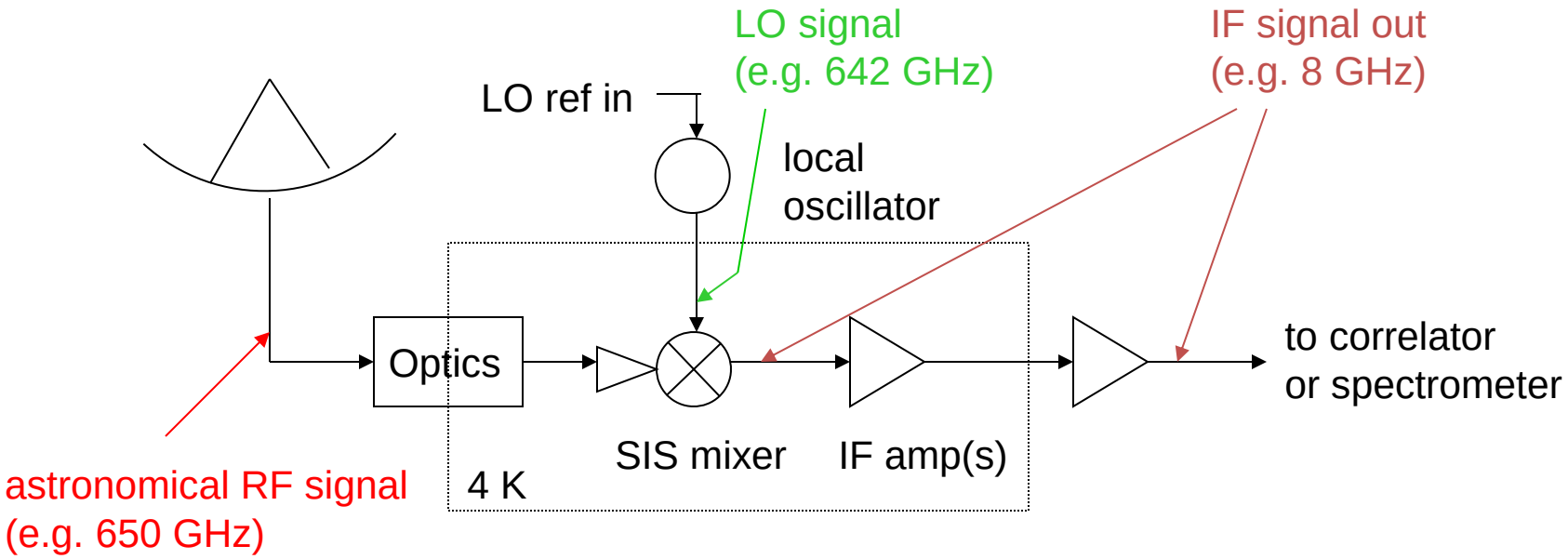
Block Diagram of a Heterodyne Receiver

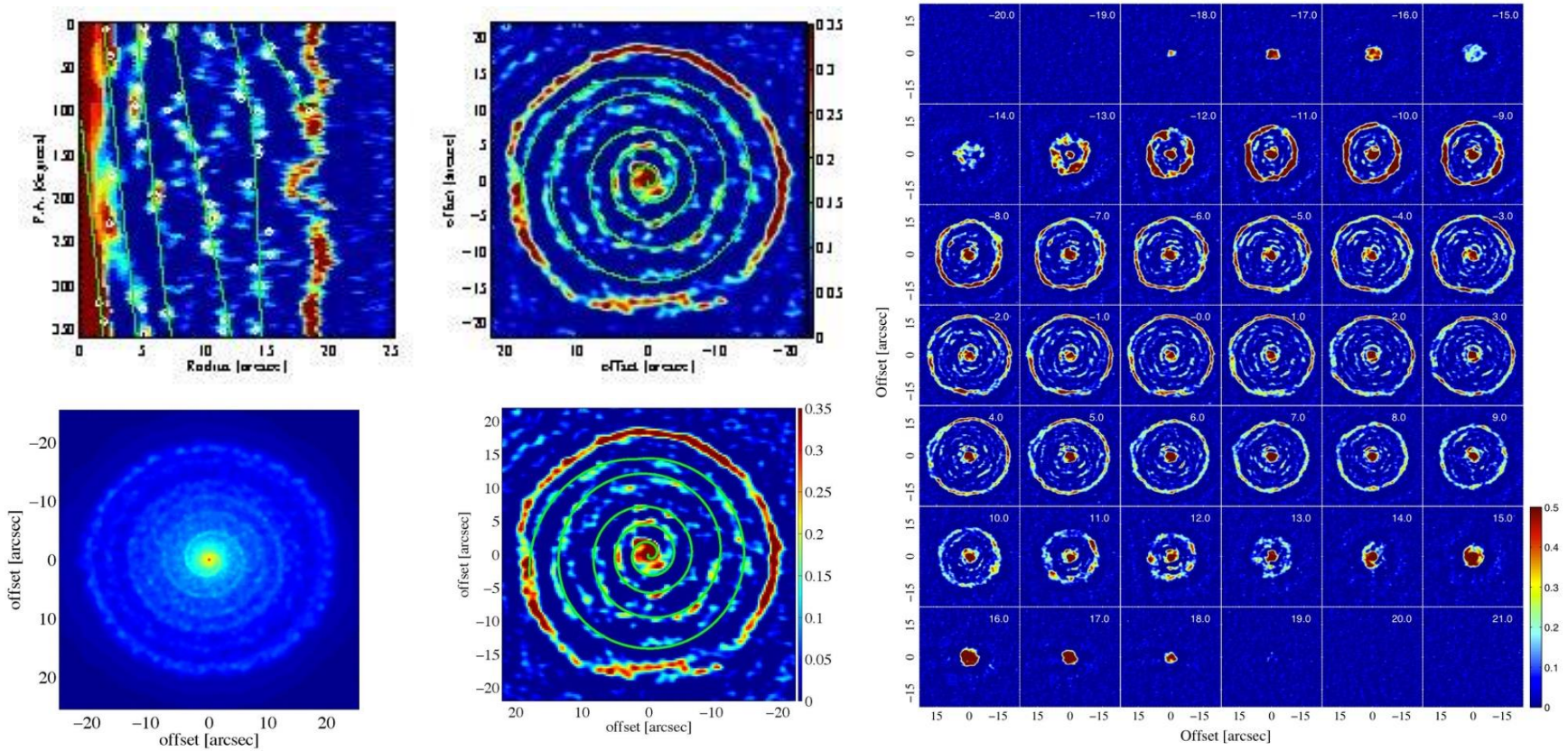


Components:

- Optics
- Mixer
- Local Oscillator (LO)
- IF amplifier(s)
- Dewar and cryogenics
- Bias electronics

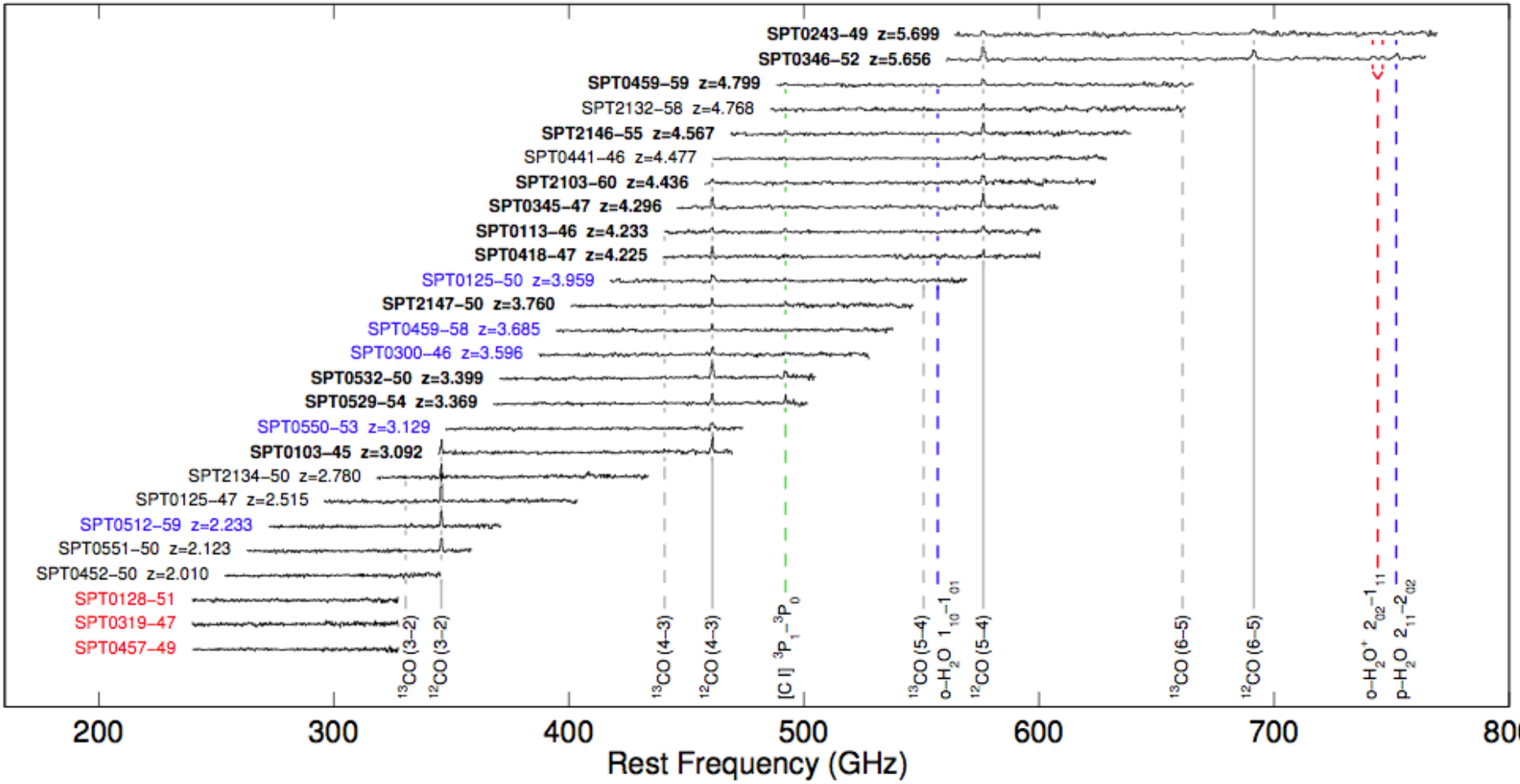
Spiral wind

- ALMA Observations of the Carbon AGB star
  - Maercker et al. 2012, Nature



First spectroscopic redshift survey with ALMA

ALMA Cycle 0 Band 3
100 GHz compact configuration
26 sources
5 tunings in the 3 mm band
10 minutes per source



Bold = unambiguous redshift from ALMA

black = single lines with ALMA, confirmed with C+ or CO(1-0) with APEX or ATCA

blue = single line detected with redshift, most likely redshift from photo-z

red = no line detected

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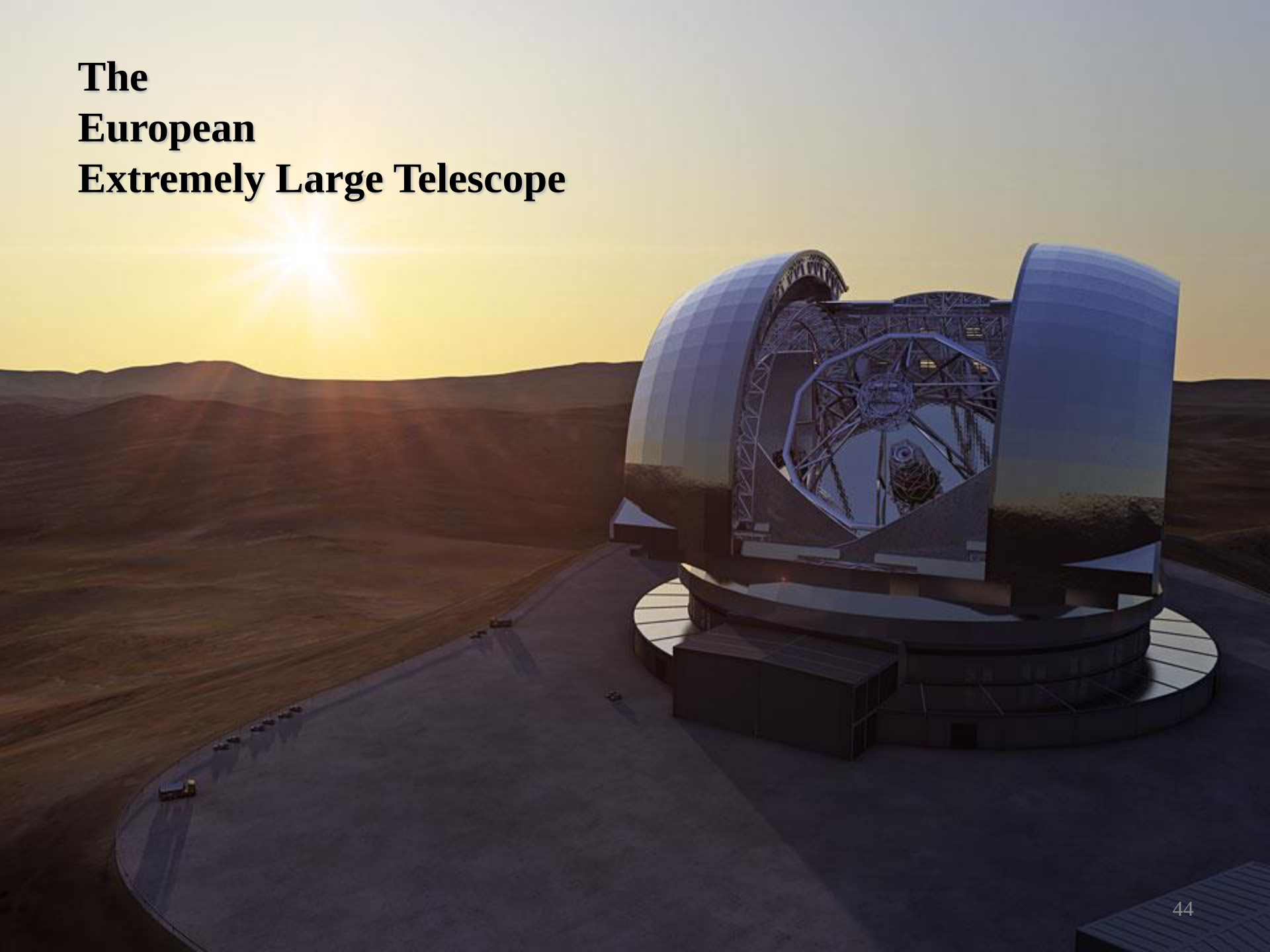
3. The E-ELT

biggest optical/IR telescope in history

The European Extremely Large Telescope




Armazones
Paranal

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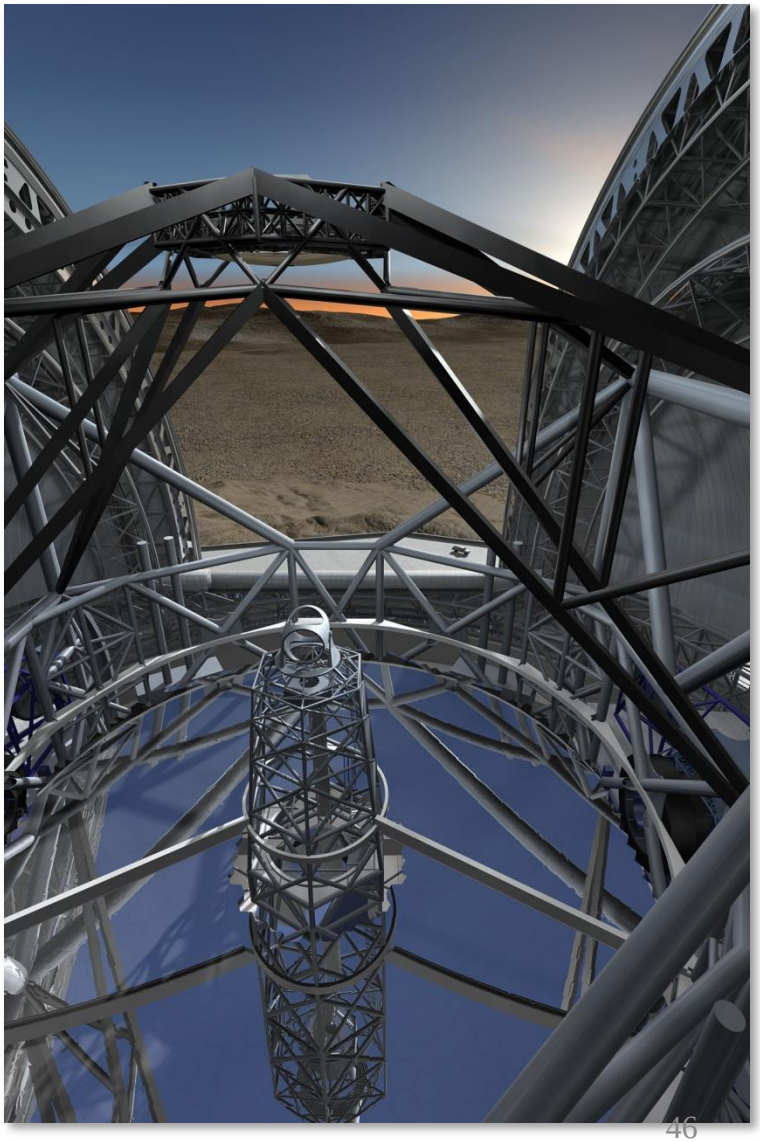
The E-ELT

- 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 fully approved in Dec 2012.
- Construction started in 2013.



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The E-ELT Project

- Top priority of European ground-based astronomy (on Astronet and ESFRI lists).
- Cerro Armazones in Chile selected as the E-ELT site in April 2010.
- Detailed Design Phase completed in 2011. Construction Proposal published in Dec 2011.
- Instrument Roadmap (Nov 2011): 2 first-light instruments + plan for 1st generation.
- Project fully approved in Dec 2012.
- Construction started in 2013.
- Start of operations early next decade.
- Construction cost: 1083 M€ (including first-light instrumentation).

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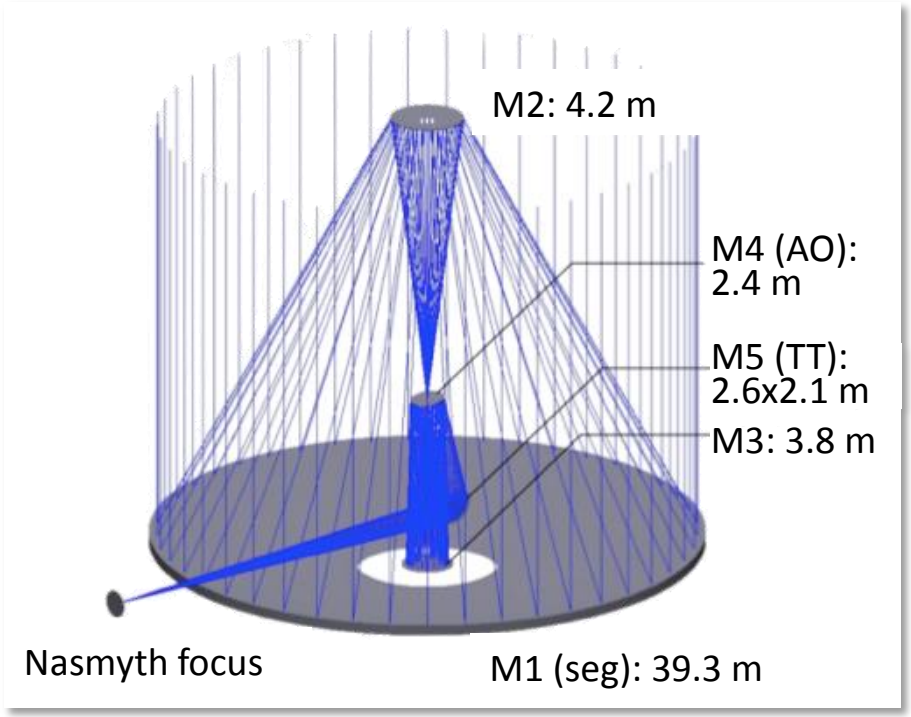
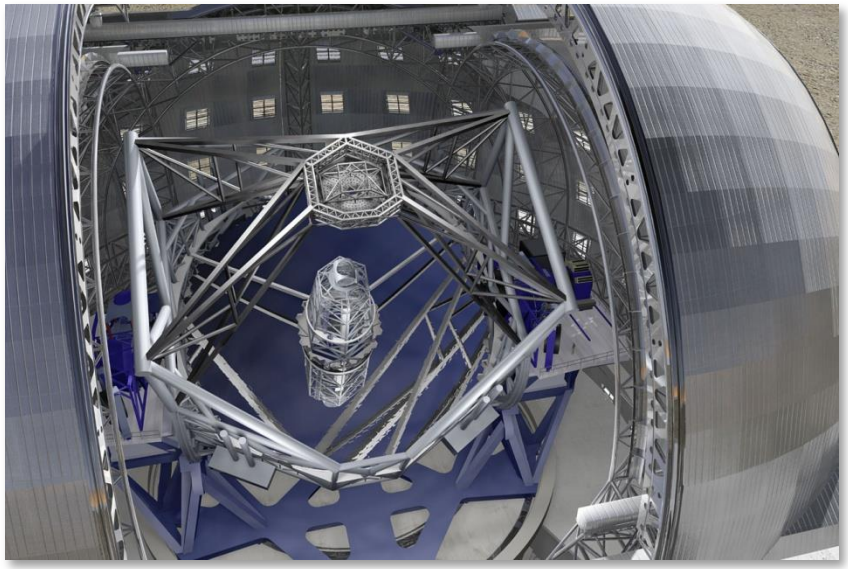
The Telescope

- 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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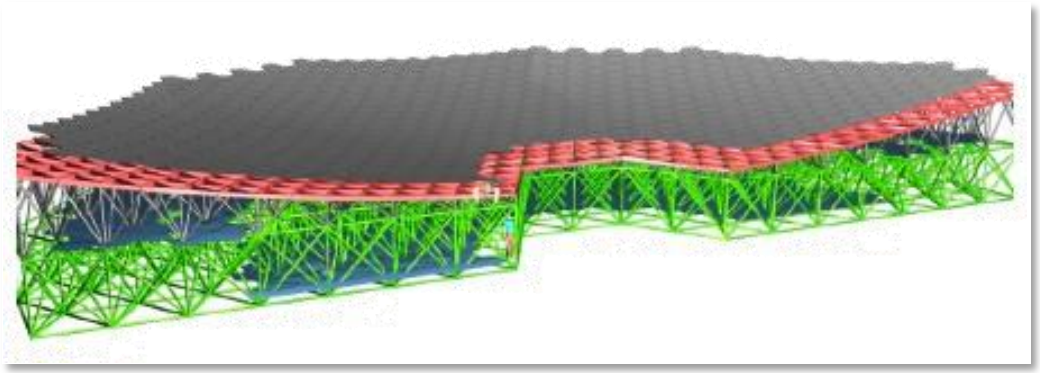
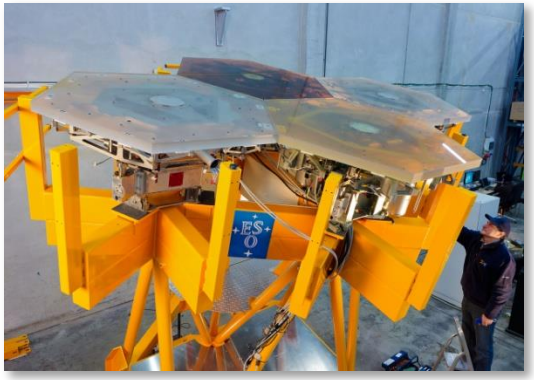
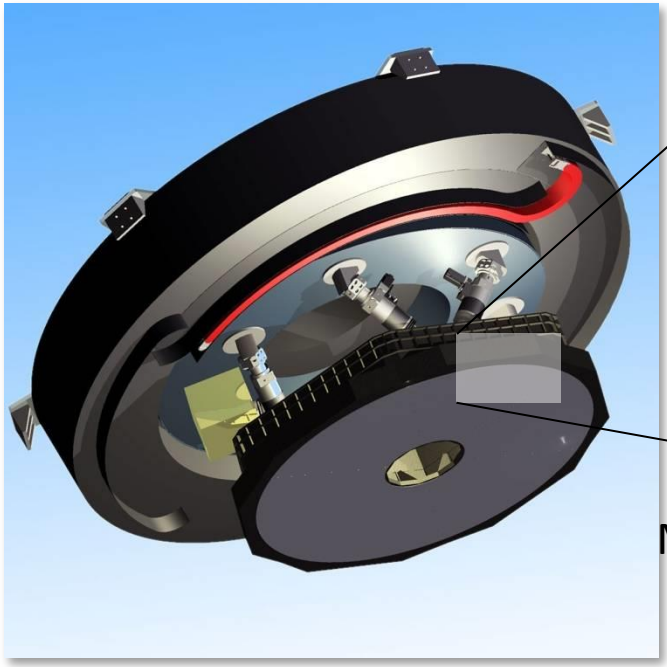
The Mirrors

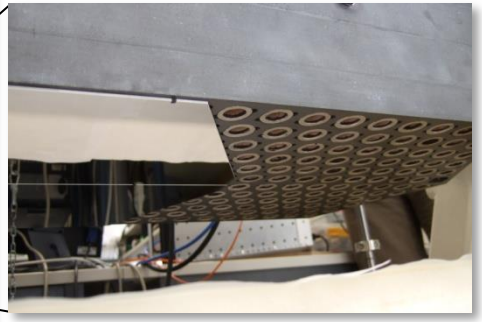
M1: 39.3 m, 798 hexagonal segments of 1.45 m tip-to-tip: 978 m^2 collecting area







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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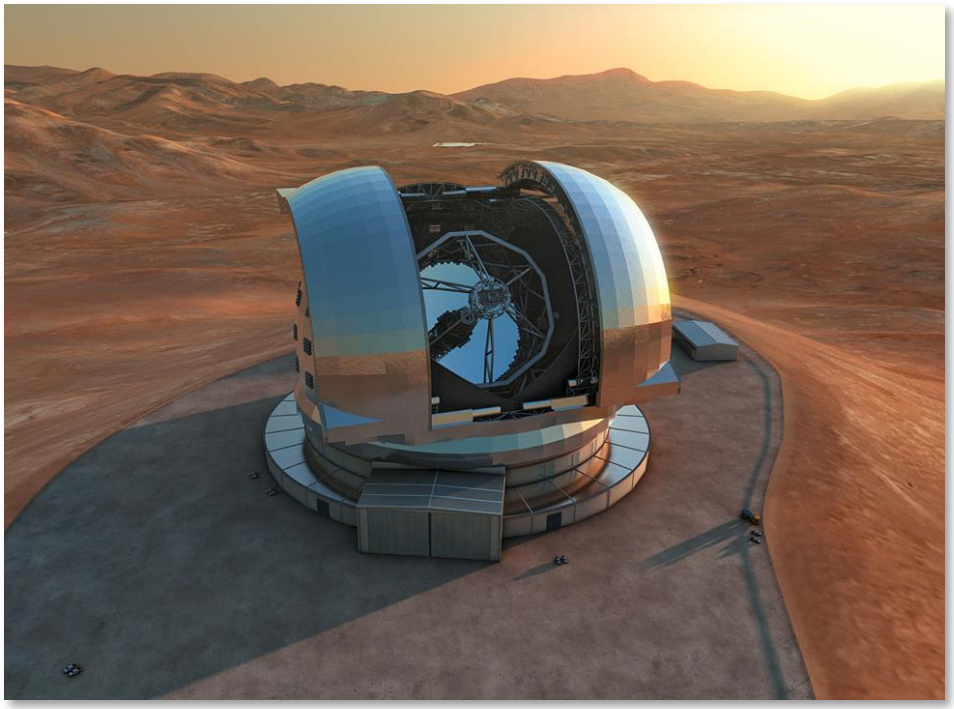
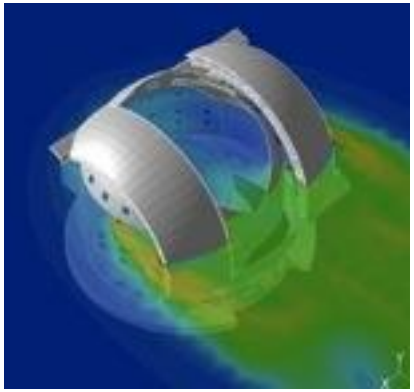
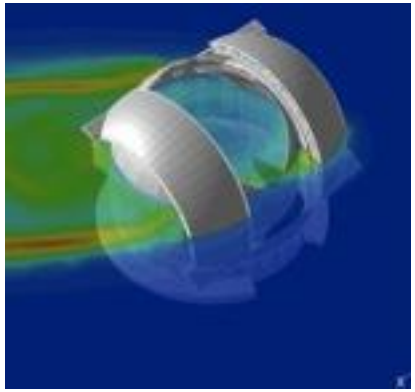
The Dome

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







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Programmes into the 2020s