Scientific challenges and technological limitations

in optical and infrared ground-based astronomy

1. Telescopes
   Martin Cullum, ESO, Garching

2. Instrumentation
   Colin Cunningham, UKATC, Edinburgh

1. Telescopes: talk overview

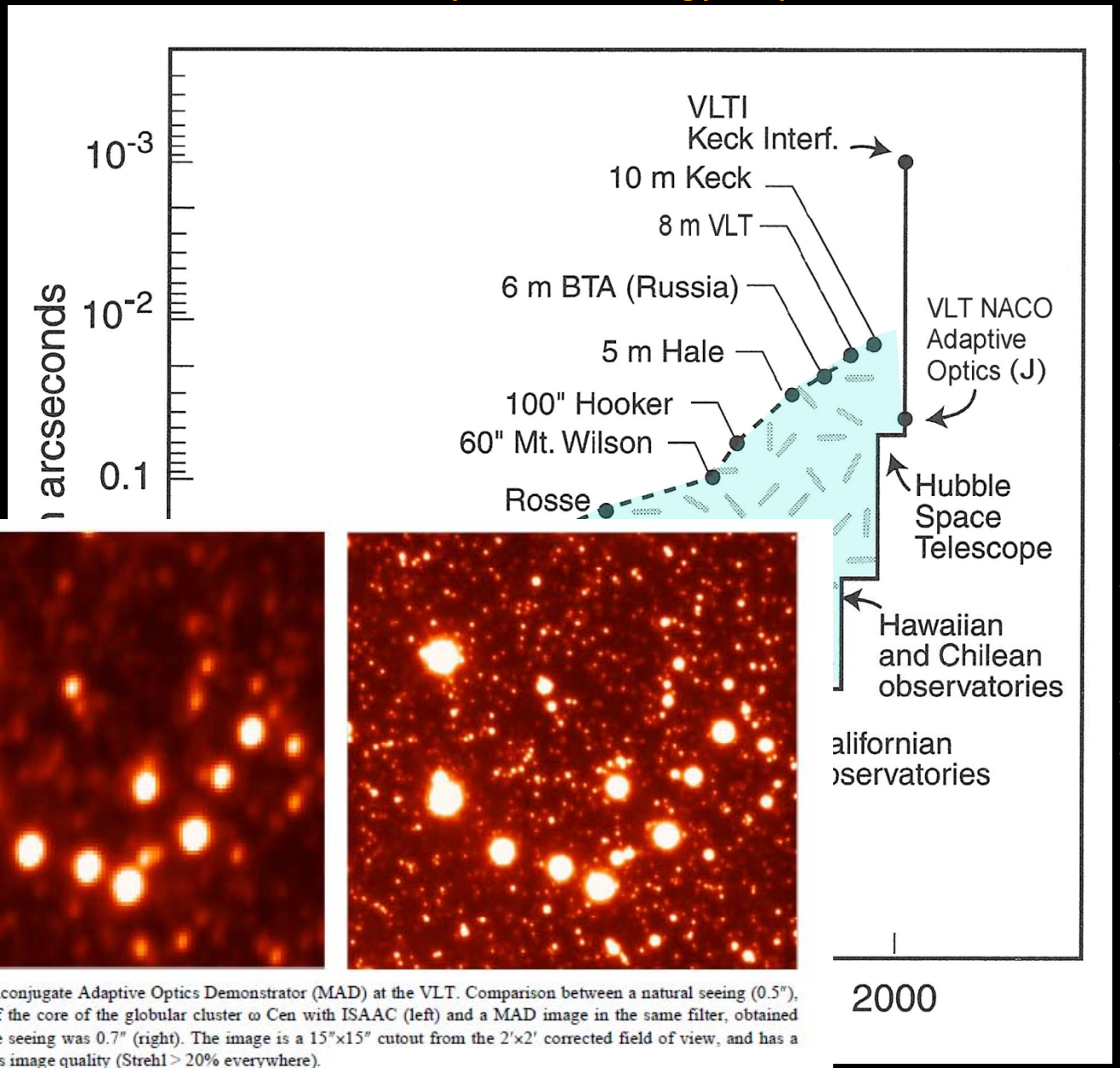
- Scientific Challenges
- Telescopes – progress and limitations
- Why do we need large ground-based telescopes?
- Cost and performance scaling
- Current technology drivers

Scientific Challenges

- Faintest, most distant objects
  - First light Galaxies,
    - How did the universe re-ionise ?
    - How did early galaxies form?
- High Dynamic Range, High Resolution
  - Direct detection of ‘super Earths’
  - Early stellar populations
- High stability
  - Precision Doppler shifts
    - Planetary Doppler shifts
    - Direct measurement of expansion rate of universe

Telescopes – progress and limitations

Why is technology important?



←100 m Ø

← 2 m Ø

← 20 cm Ø

← 5 cm Ø

← 2.5 cm Ø

Figure 10. Multiconjugate Adaptive Optics Demonstrator (MAD) at the VLT. Comparison between a natural seeing (0.5″), K band image of the core of the globular cluster ω Cen with ISAAC (left) and a MAD image in the same filter, obtained while the outside seeing was 0.7″ (right). The image is a 15″×15″ cutout from the 2′×2′ corrected field of view, and has a very homogenous image quality (Strehl > 20% everywhere).

Adapted from
Bely 2002

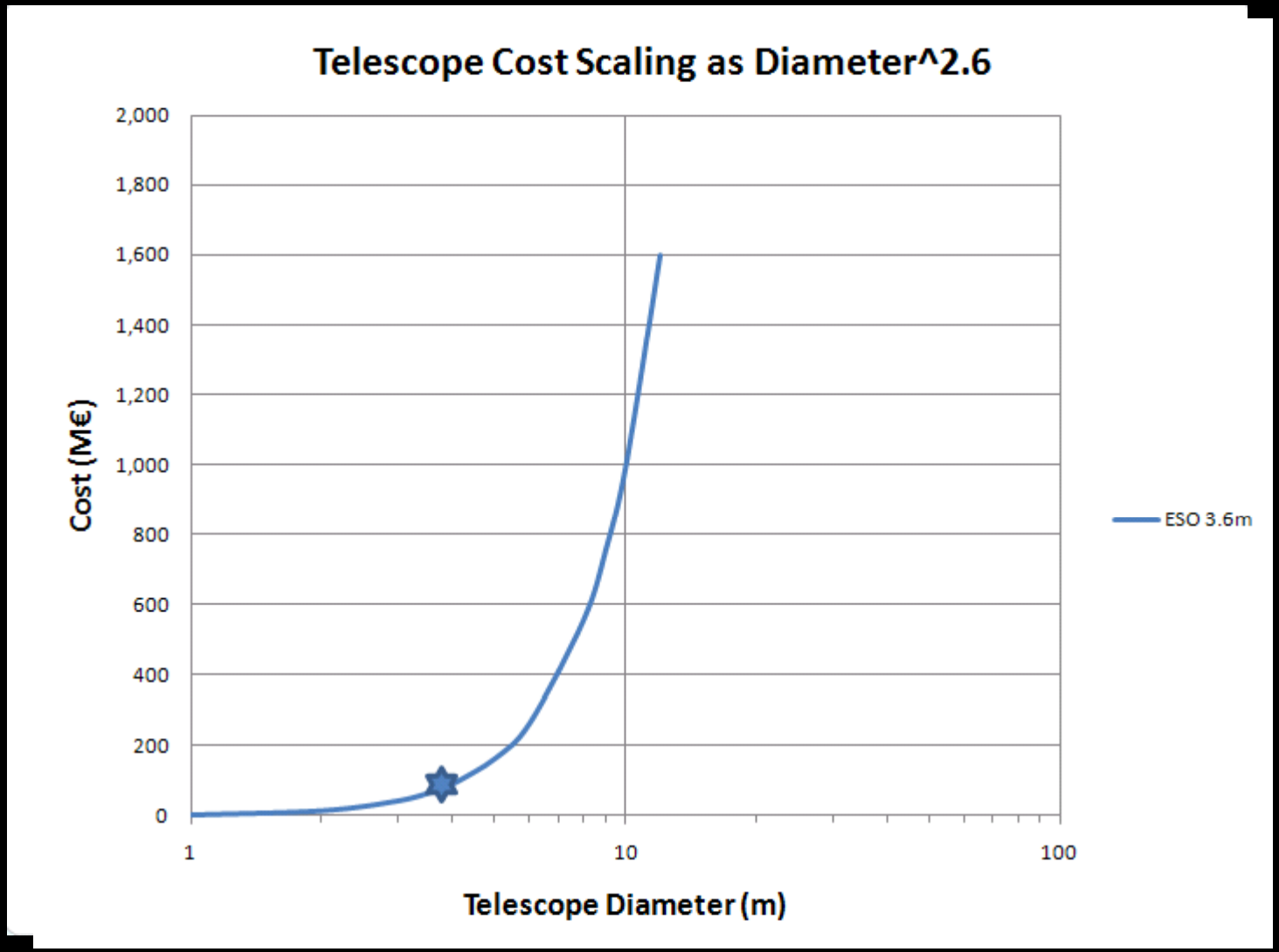
Why do we need large ground-based telescopes?

- Greater collecting area:
  - Extremely faint objects
  - Very high dispersion imaging
  - Short transient phenomena
- Greater resolution:
  - Smaller diffraction limit (achieved with AO)
  - Improved S/N for unresolved objects
- Complementary to space telescopes (HST, JWST, Herschel, Planck, XMM, etc..)

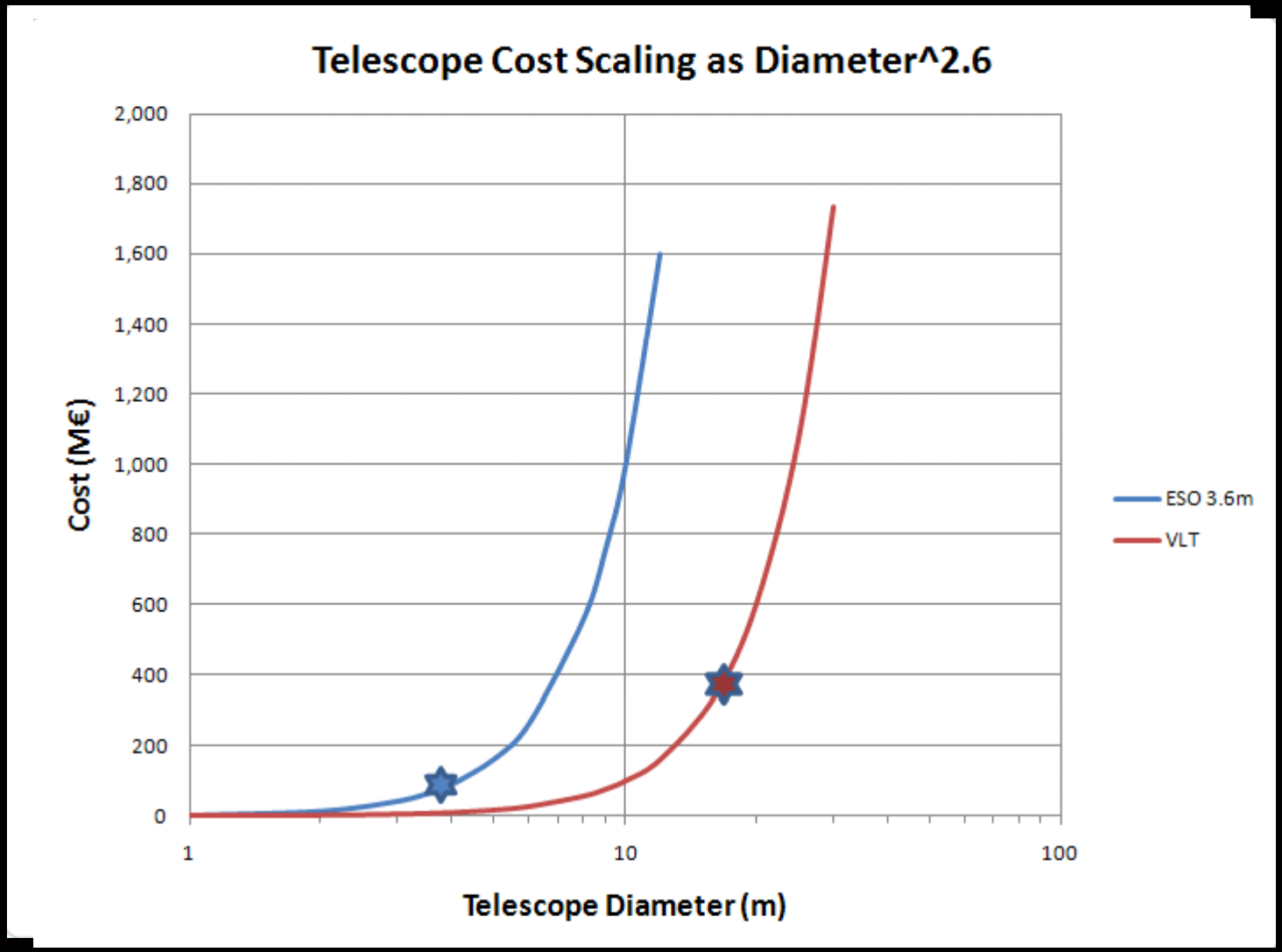
Cost and performance scaling

- Cost
  - For given technology, telescope cost α $D^{2.4}$ - $D^{2.7}$
  - Photons α D^2 so why not many small telescopes?
  - To dramatically increase the diameter we need to change the technology to make it affordable
- Performance

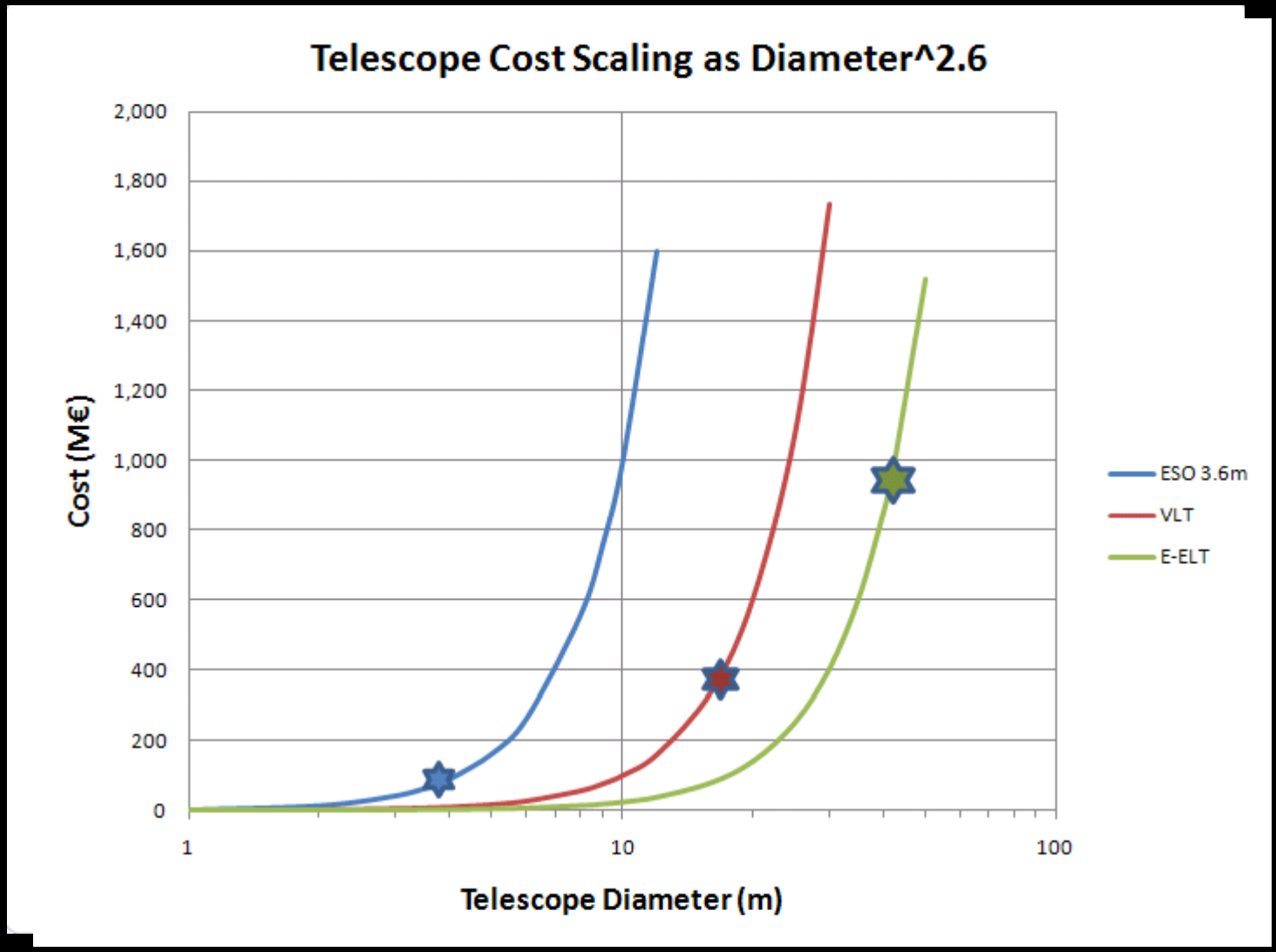
Telescope cost scaling



Telescope cost scaling



Telescope cost scaling



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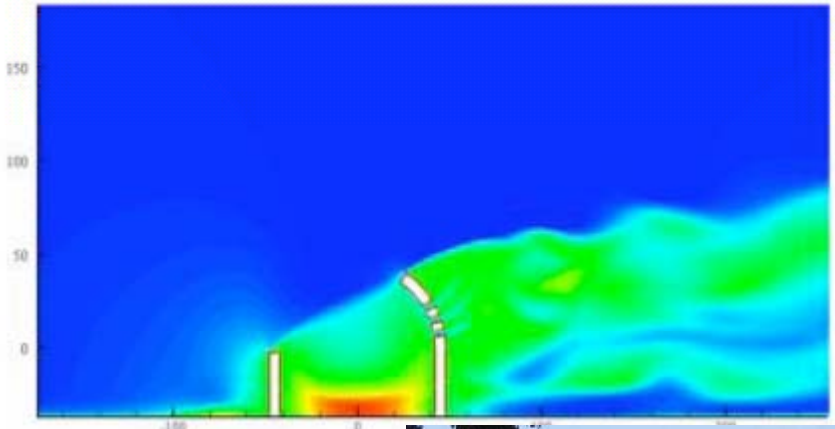
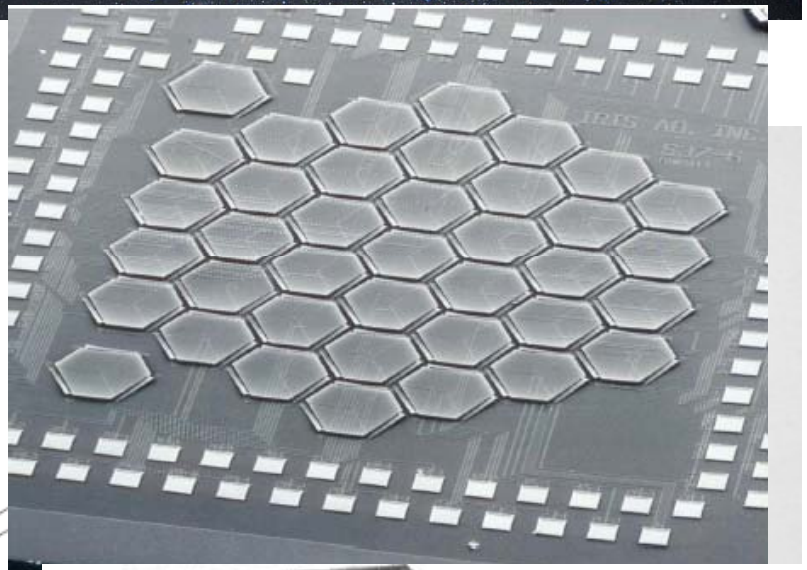
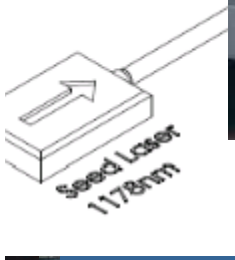
- Performance
  - Resolved objects: sensitivity α D^2 (although obs. may not be possible with smaller telescope)
  - Pre- or post-detector combination not efficient for large arrays of smaller telescopes
  - Diffraction limited/background limited: α D^4
  - Fourth order photon statistics: α D^8

Key technologies for ground-based telescopes

- Telescope design and fal
  - Obtaining contrast rati
  - Wind rejection (CFD, v
    SiC prototypes). Much







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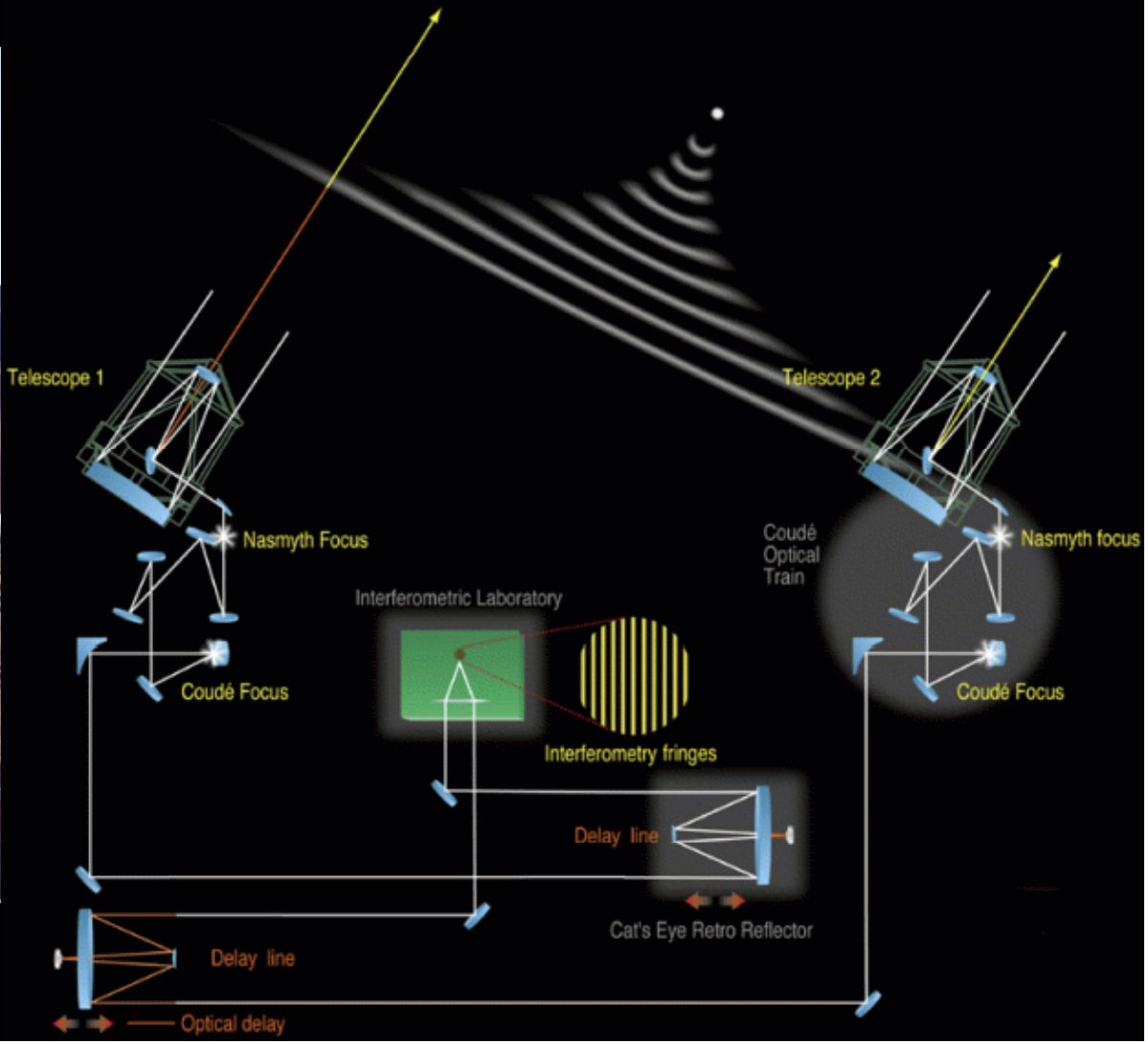
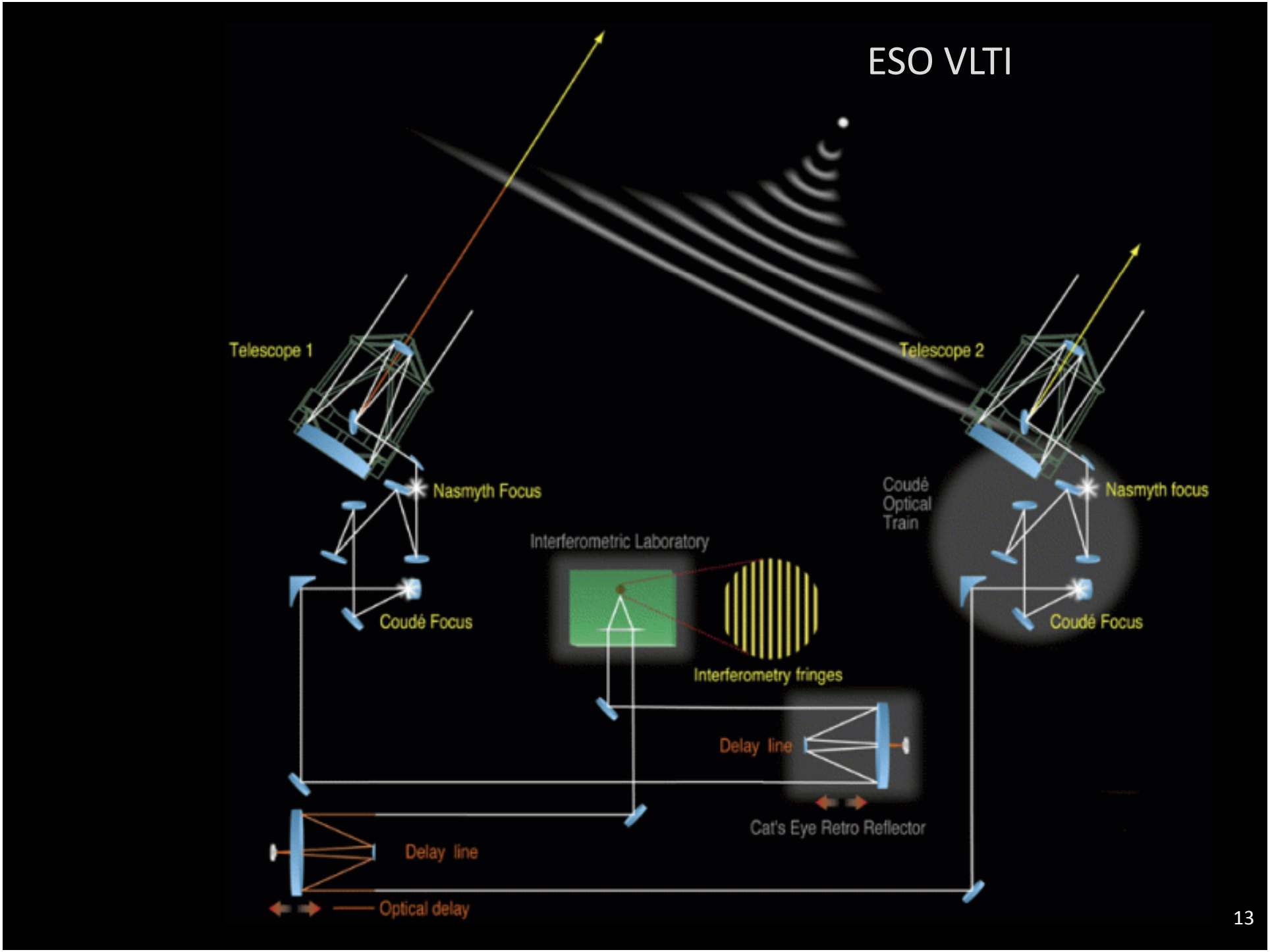
ESO's VLTI
Very Large Telescope Interferometer

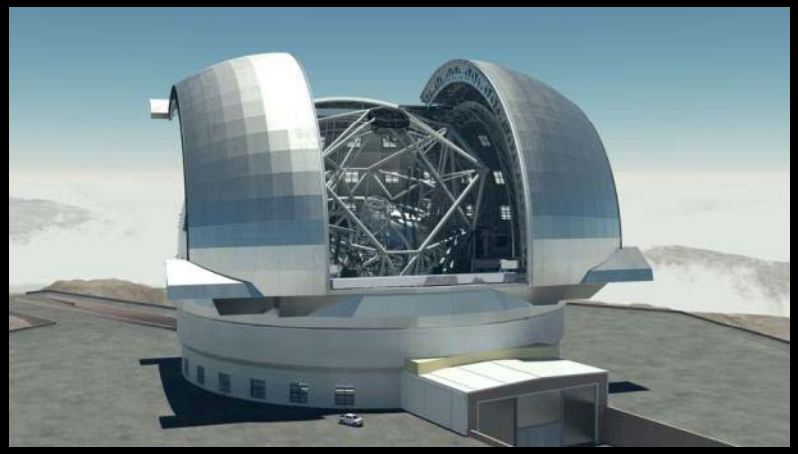


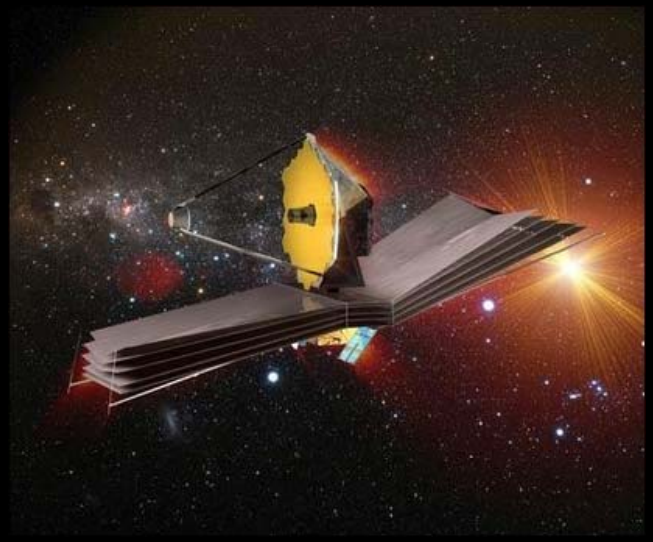
ESO VLTI


Telescope 1
Telescope 2
Nasmyth Focus
Coudé Focus
Interferometric Laboratory
Interferometry fringes
Coudé Optical Train
Nasmyth focus
Coudé Focus
Delay line
Cat's Eye Retro Reflector
Delay line
Optical delay

Ground-based Telescopes

- Technically challenging
  - But can take more risks than in space
- Still a tendency to be conservative on technology adoption





Multidisciplinary character of KETs

- Cross-links with military, environment and biomedical applications
  - Adaptive optics in the eye
  - Adaptive optics for laser optimisation
  - Adaptive optics for free-space communication
  - Earth observing – multi-spectral imaging
  - Skin Cancer detection – multi-spectral imaging