STFC: Industrial Impact and development of Giant Telescopes

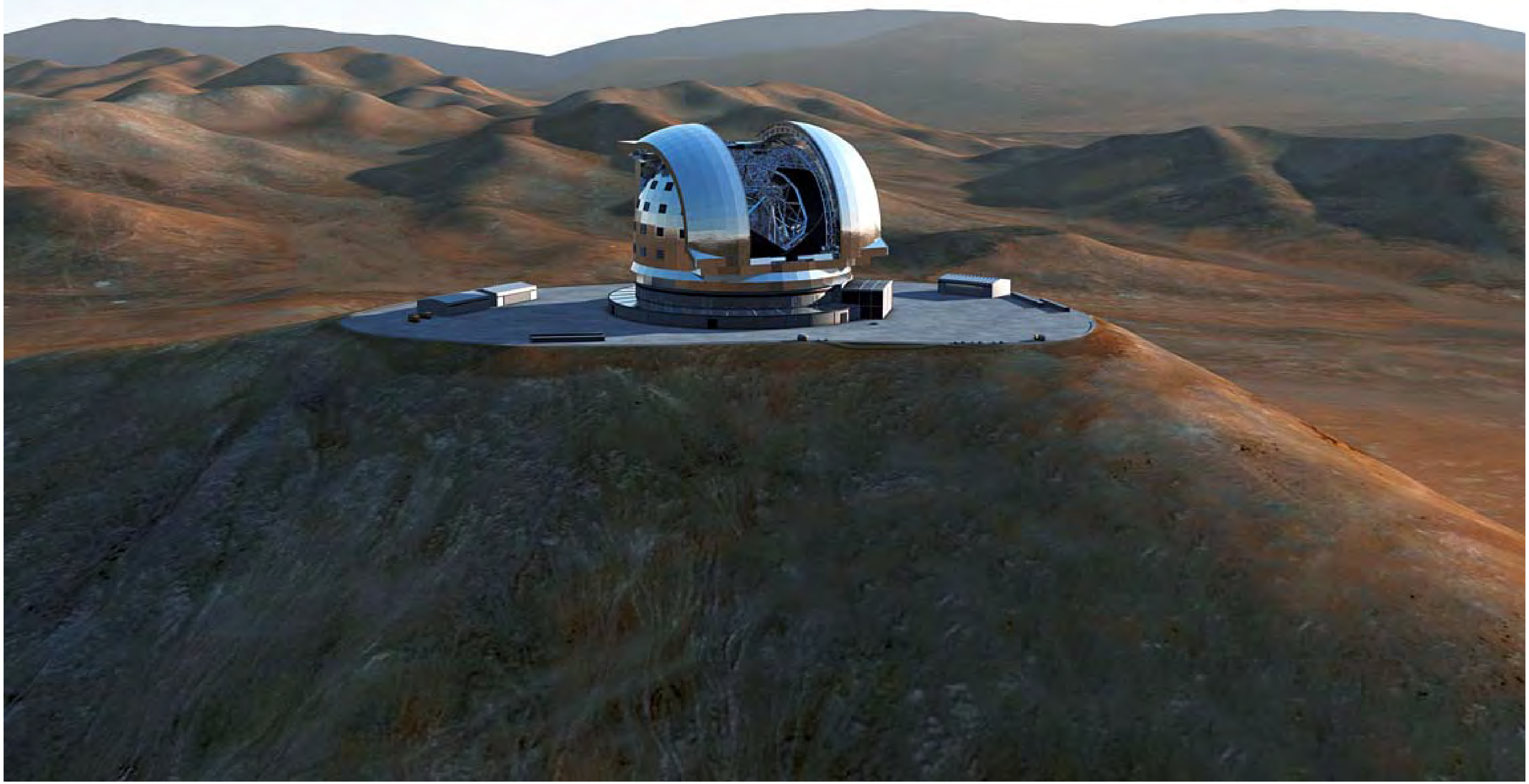
Cardiff

11th March 2013

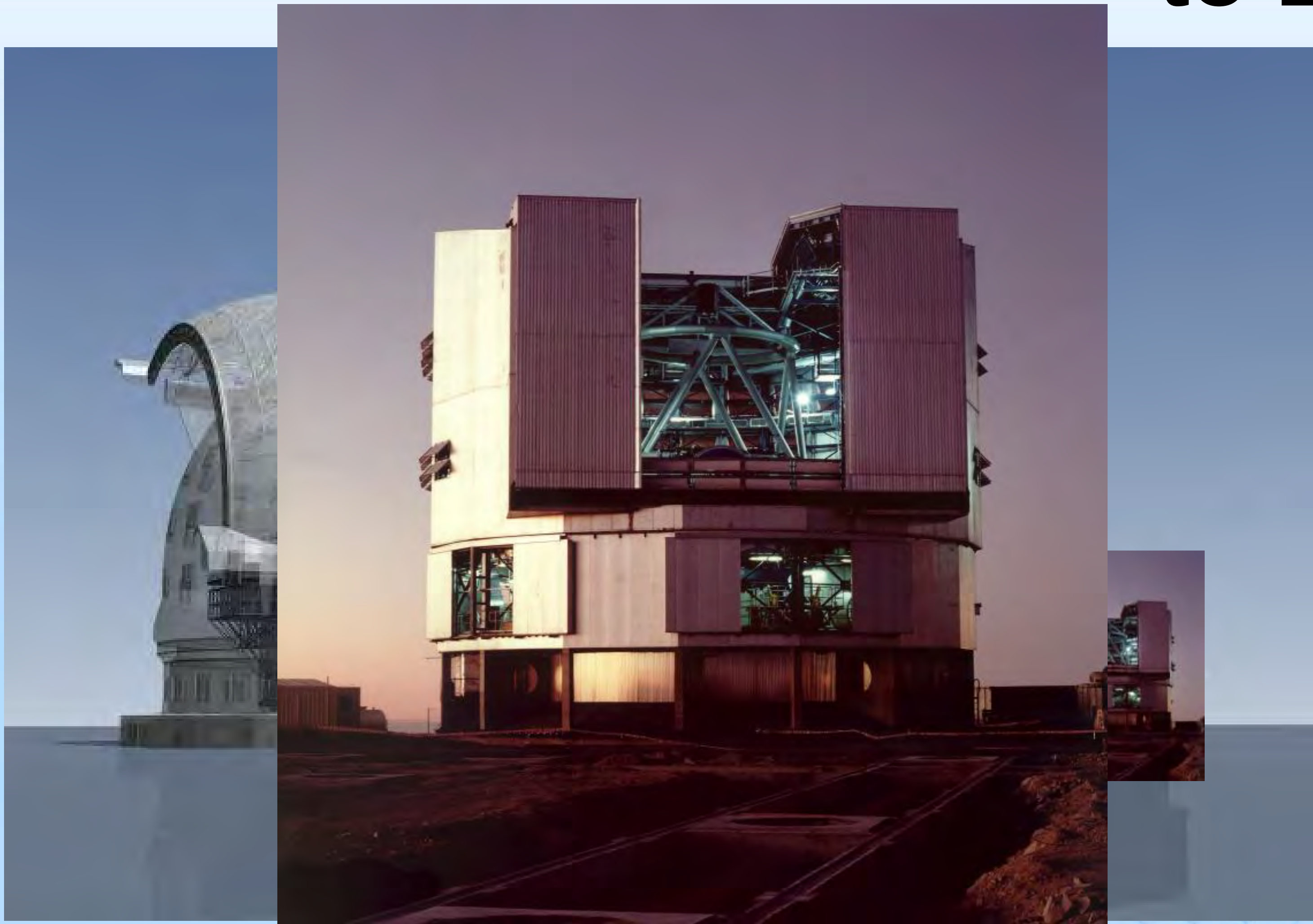
Prof. Colin Cunningham

UK ELT Programme Director

Science & Technology Facilities Council
UK Astronomy Technology Centre

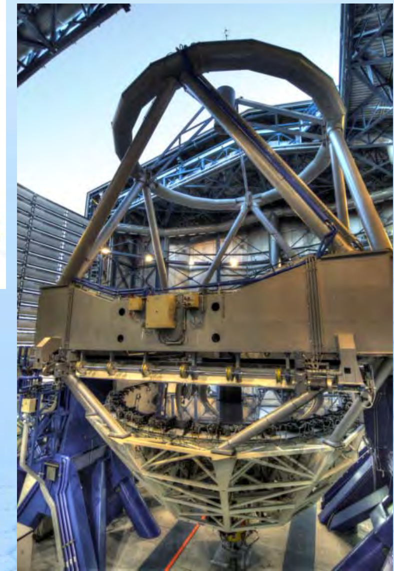


Why do we want to go from VLT **to ELT?**

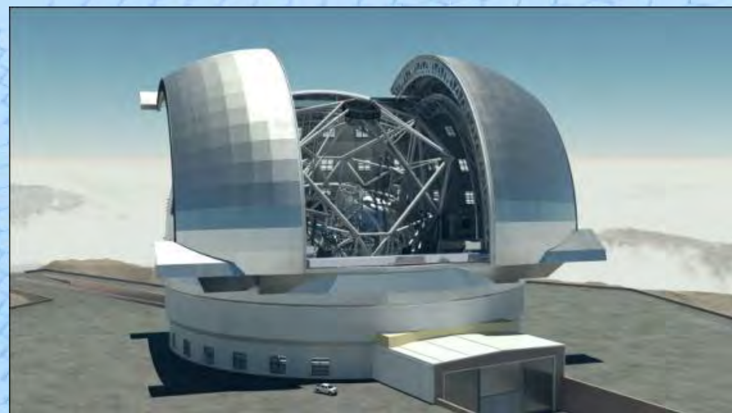


Telescope sensitivity is proportional to aperture area

Galileo's telescope 40 times more sensitive than a dark adapted eye



8 m telescope 1million times more sensitive than a dark adapted eye



39 m telescope 22 times more sensitive than VLT (at least)

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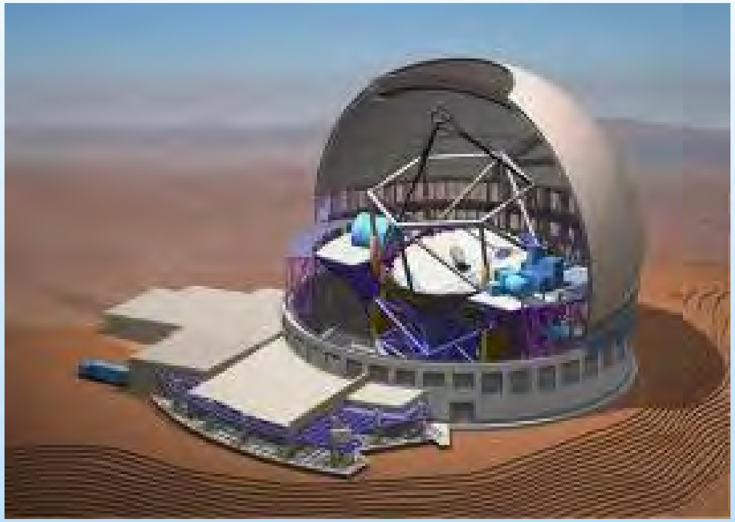
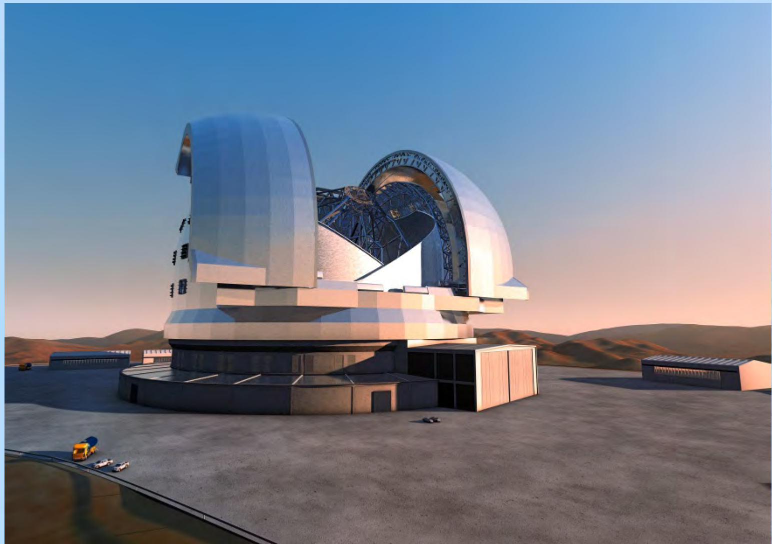
Future Giant Telescopes



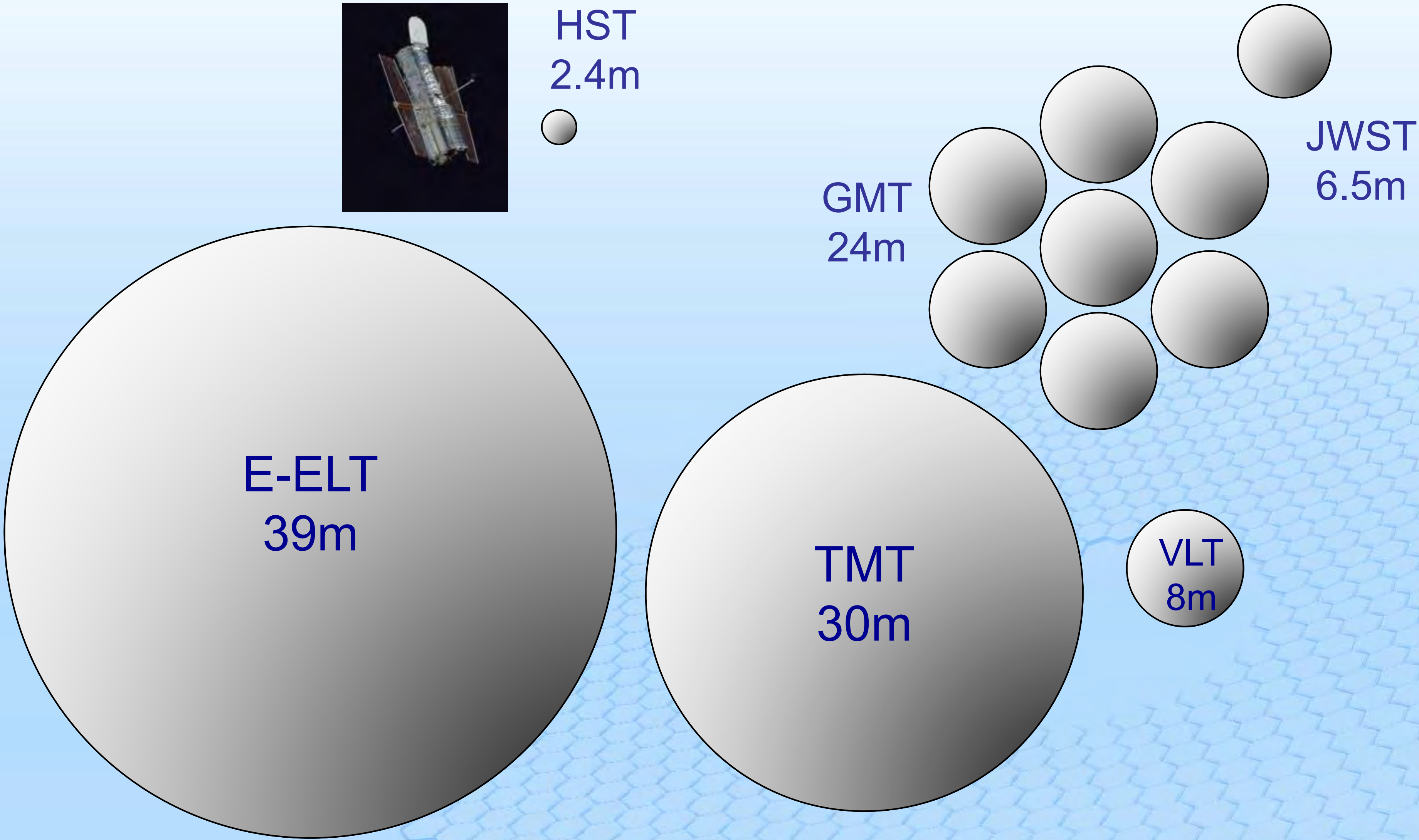
Thirty-Meter Telescope

Giant Magellan Telescope - Carnegie Observatories
Artwork by **Todd Mason**



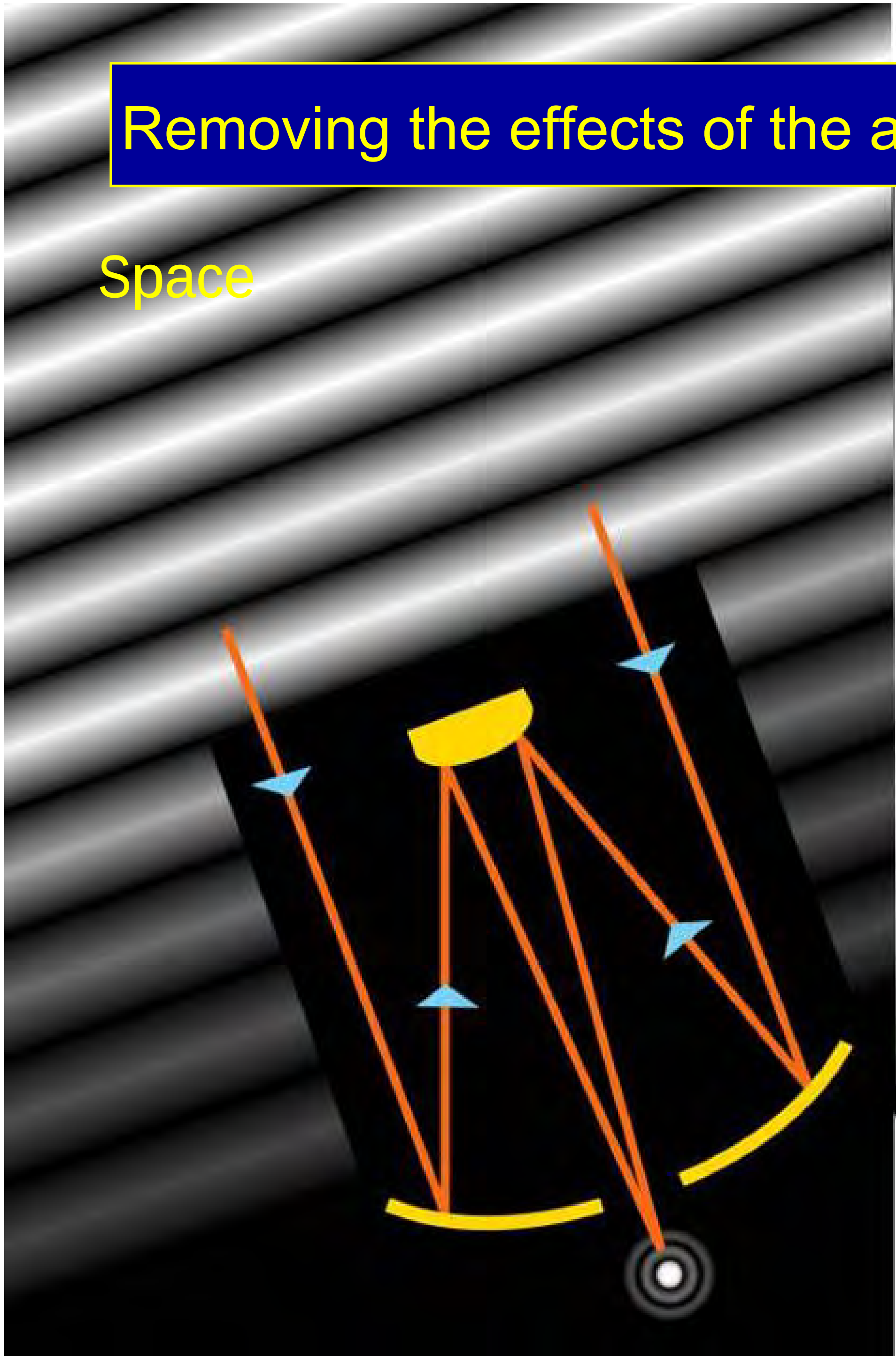
European ELT

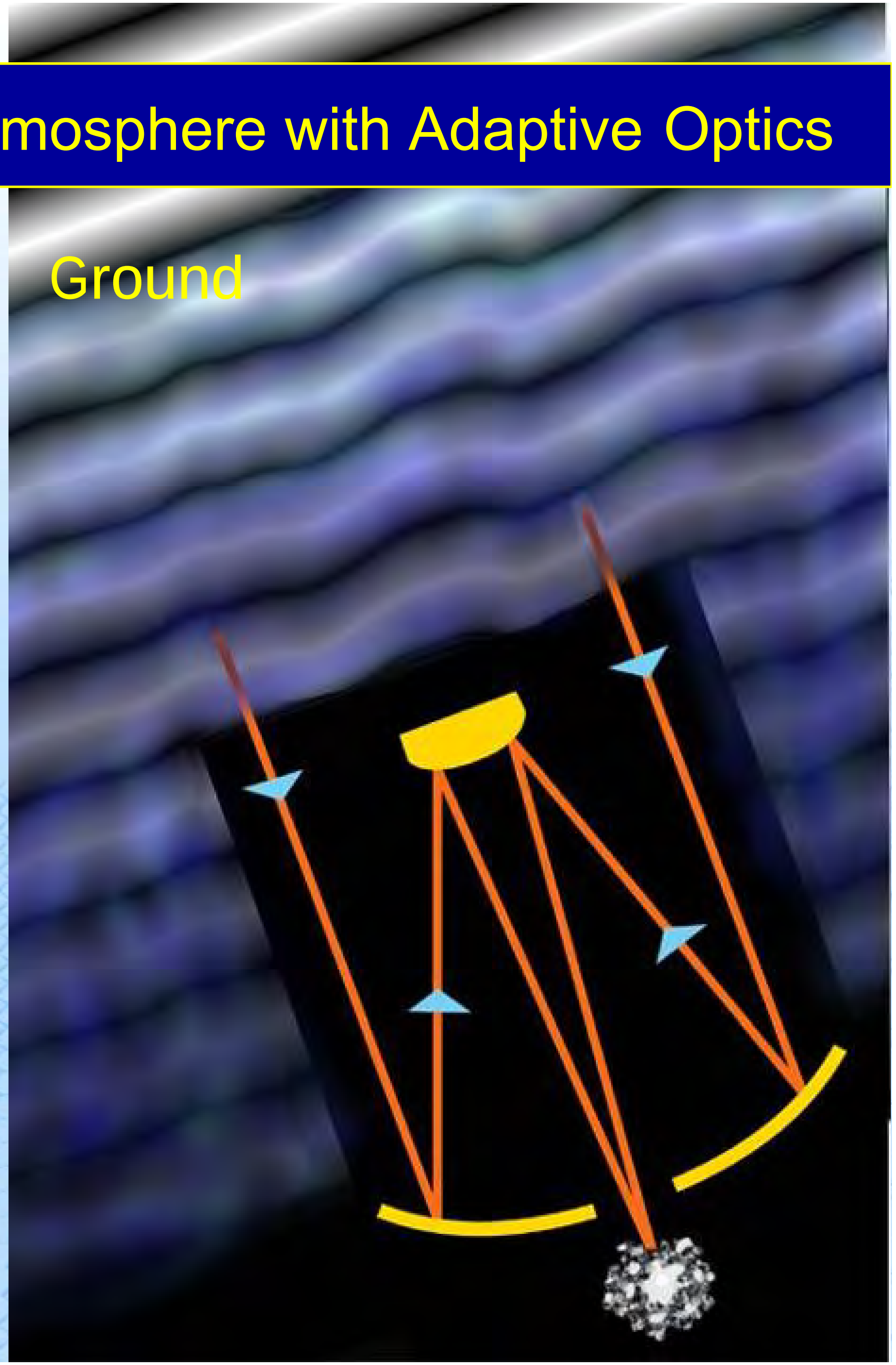
Telescope primary mirrors

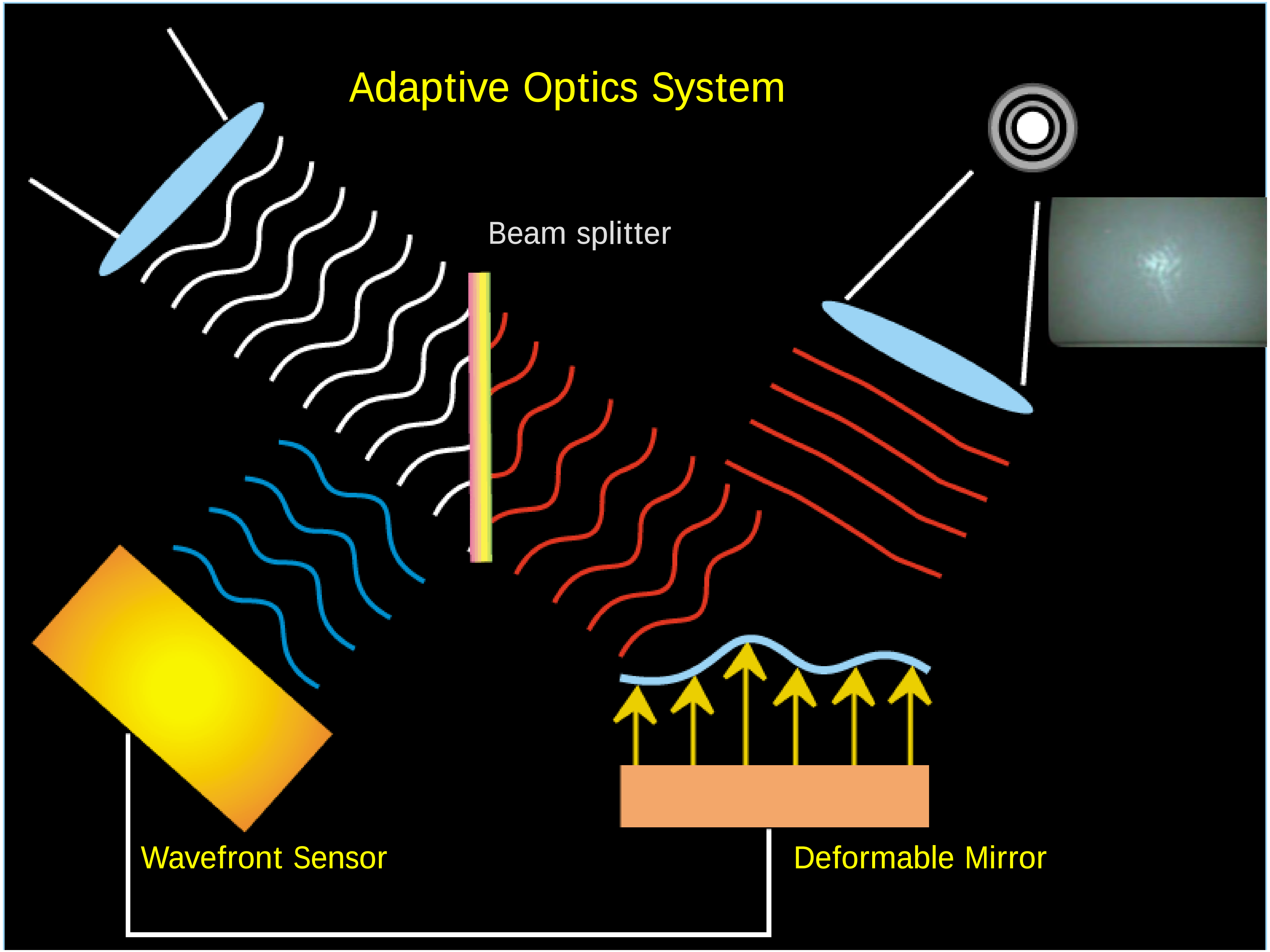


More collecting area = higher sensitivity
Bigger diameter = higher resolution (with AO)

Removing the effects of the atmosphere with Adaptive Optics



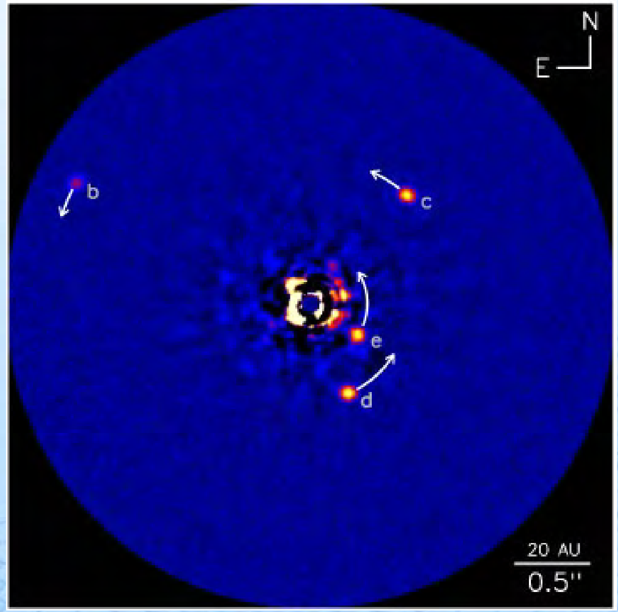



Adaptive Optics System
Beam splitter
Wavefront Sensor
Deformable Mirror

Impact of Adaptive Optics: exoplanets

HR 8799: 140 light years away, 1.5 times the size of our Sun and five times more luminous

Gemini North adaptive optics image shows two of the three confirmed planets
- **~7 Jupiter-mass planet orbiting at about 70 AU**
- **~10 Jupiter-mass planet orbiting the star at about 40 AU**



Keck AO follow-up AO image showing third & fourth planets!

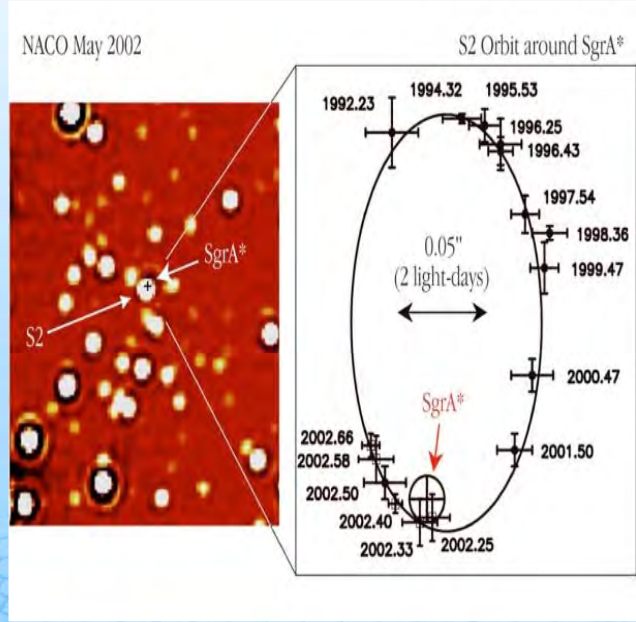
Gemini Observatory, NRC-HIA, C. Marois, and Keck Observatory

The Milky Way

The Centre of the Milky Way

What the E-ELT will bring

- E-ELT enables astrometry at ~50 μarcsec.
- Trace stars at ~100 R_S (Schwarzschild radius) around the Black Hole in Milky Way centre (10x closer than currently possible)
- Orbital velocities ~ 1/10 speed of light
- Test various post-Newtonian effects of Special and General Relativity



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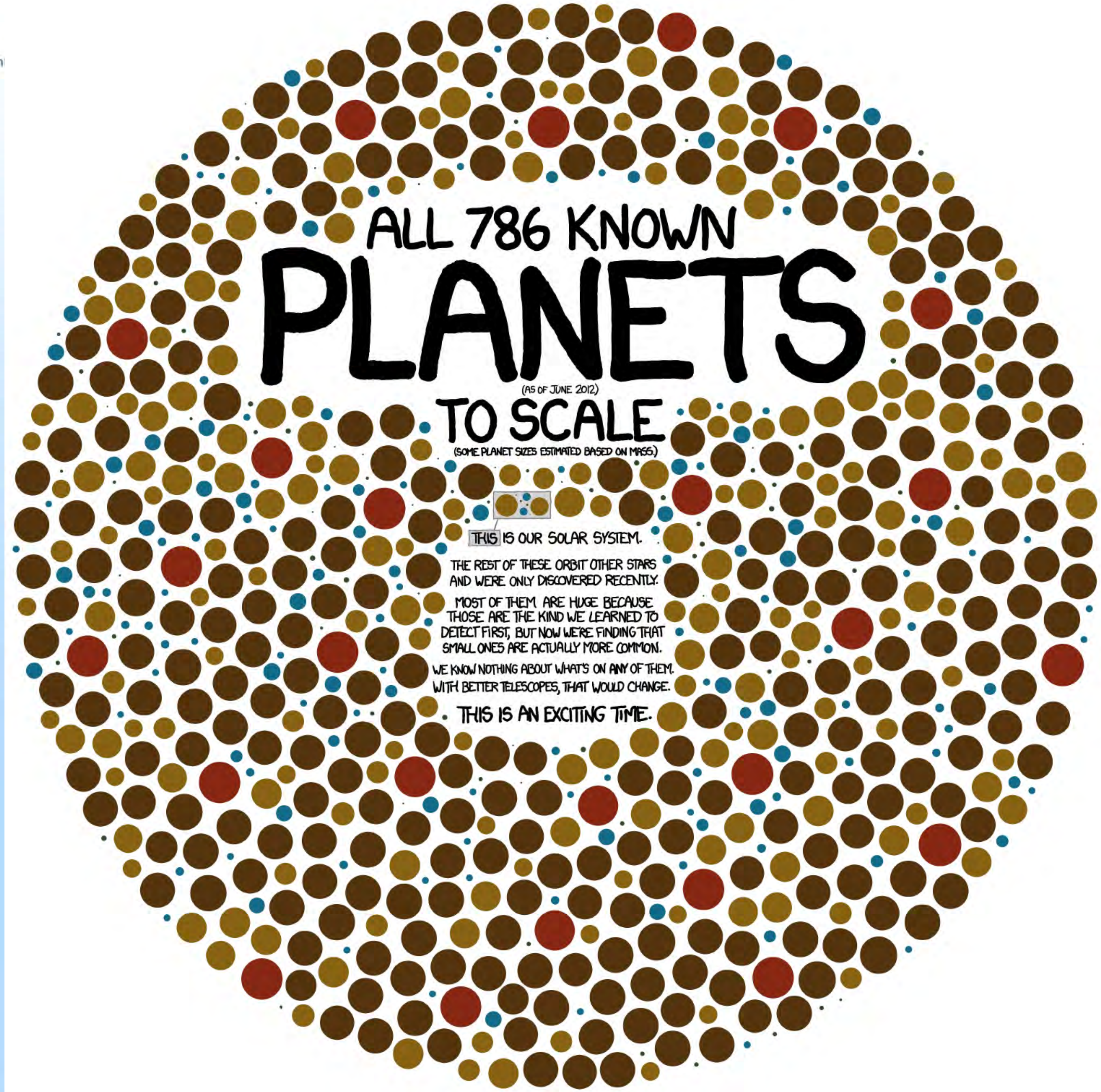
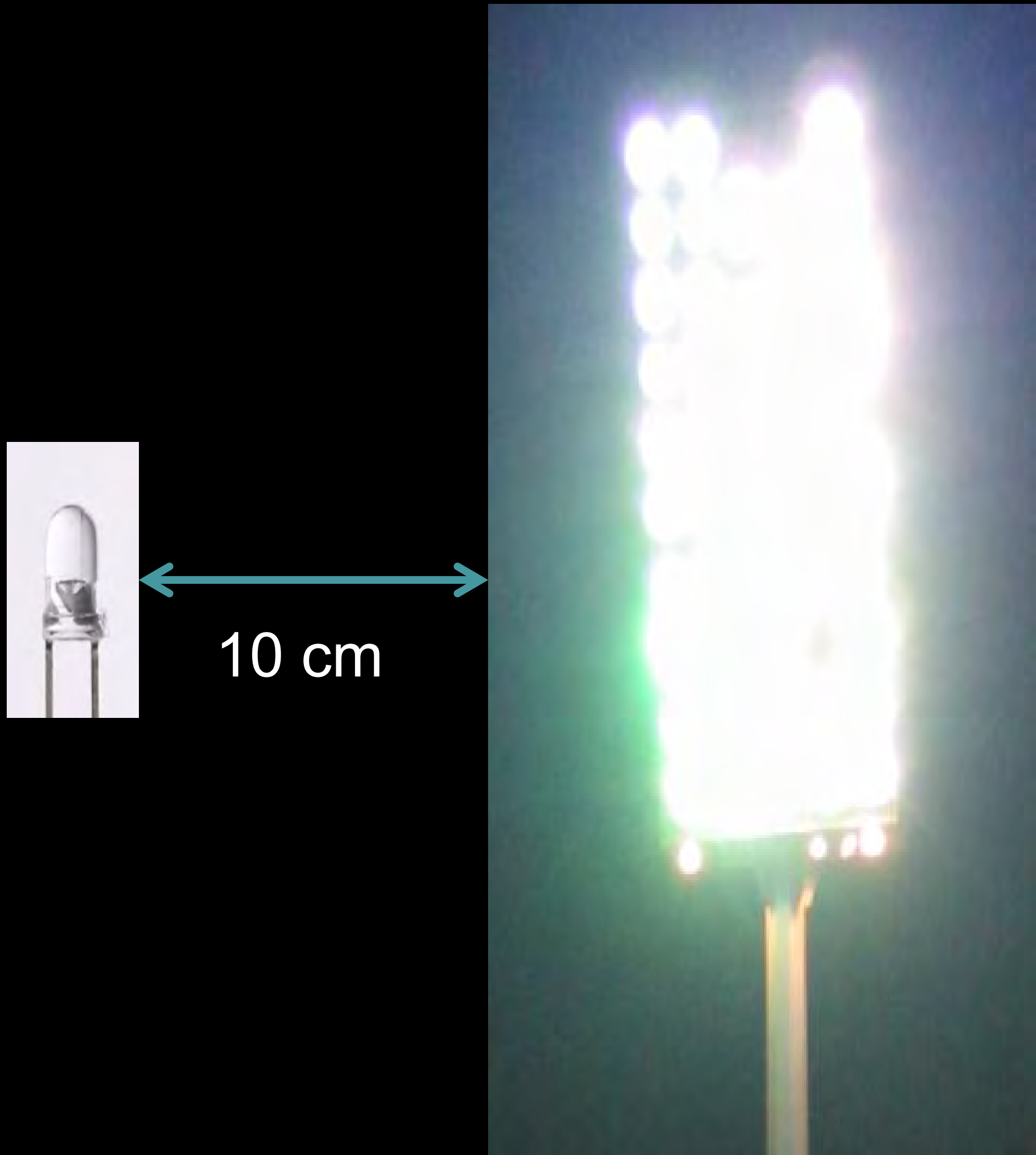
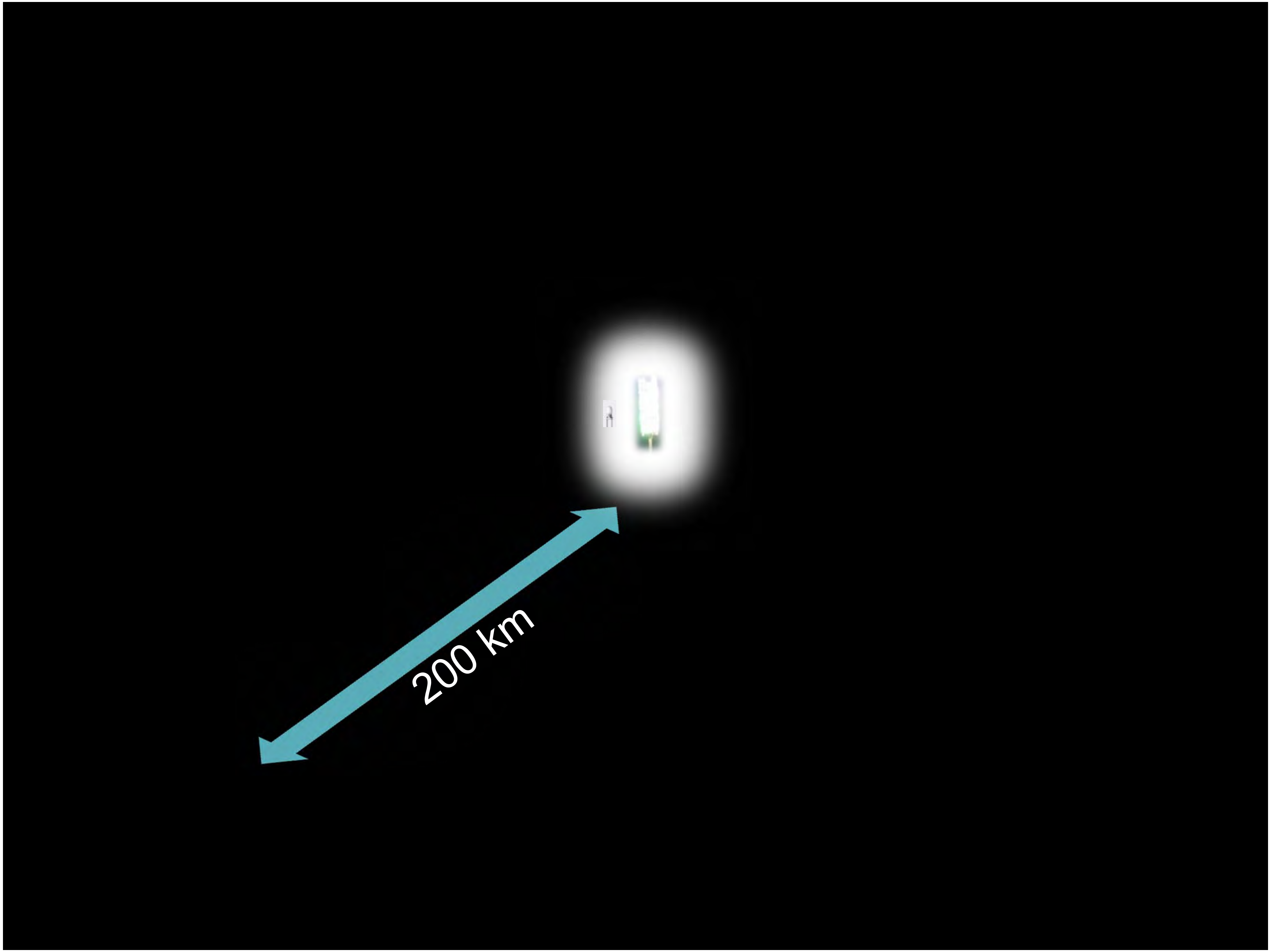


http://xkcd.com/

NASA’s Kepler Mission

- Recently, Kepler scientists announced 461 new planet candidates, bringing the satellites' total haul to 2,740
- Suggest that 17% of stars host a planet up to 1.25 times the size of the Earth, in close orbits lasting just 85 days or fewer - much like the planet Mercury
- That means our Milky Way galaxy hosts at least 17 billion Earth-sized planets.


10 cm


200 km

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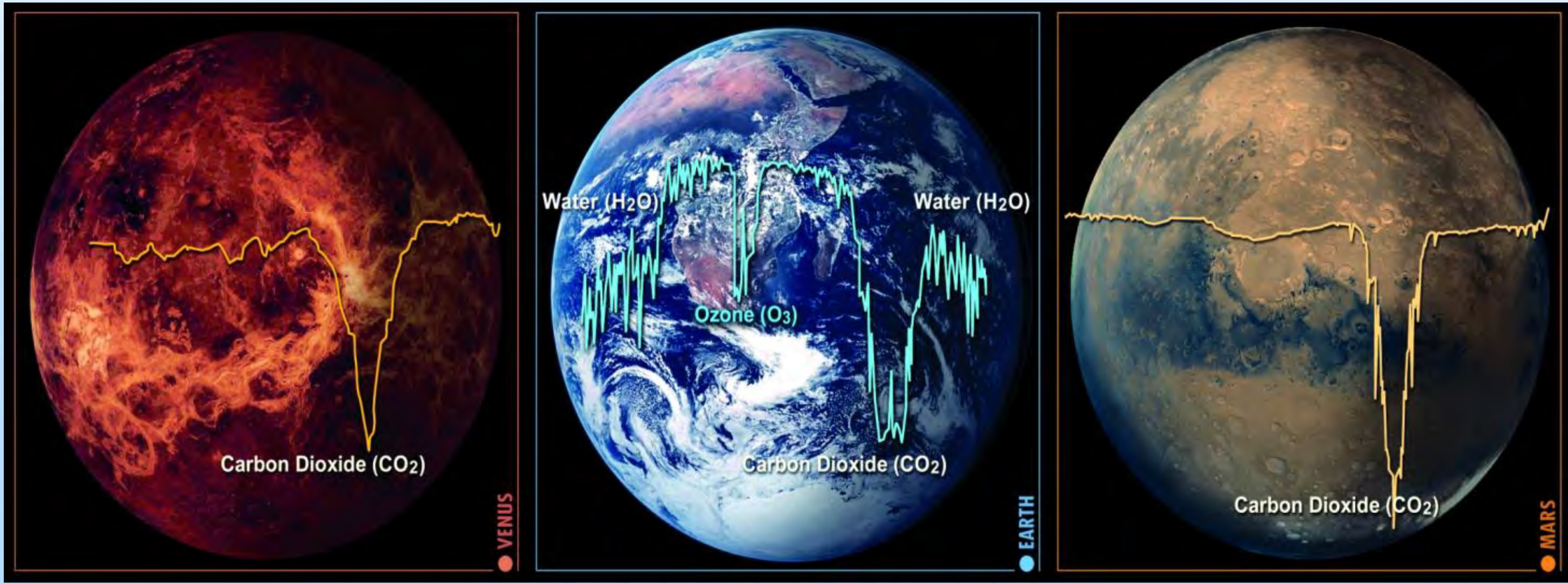
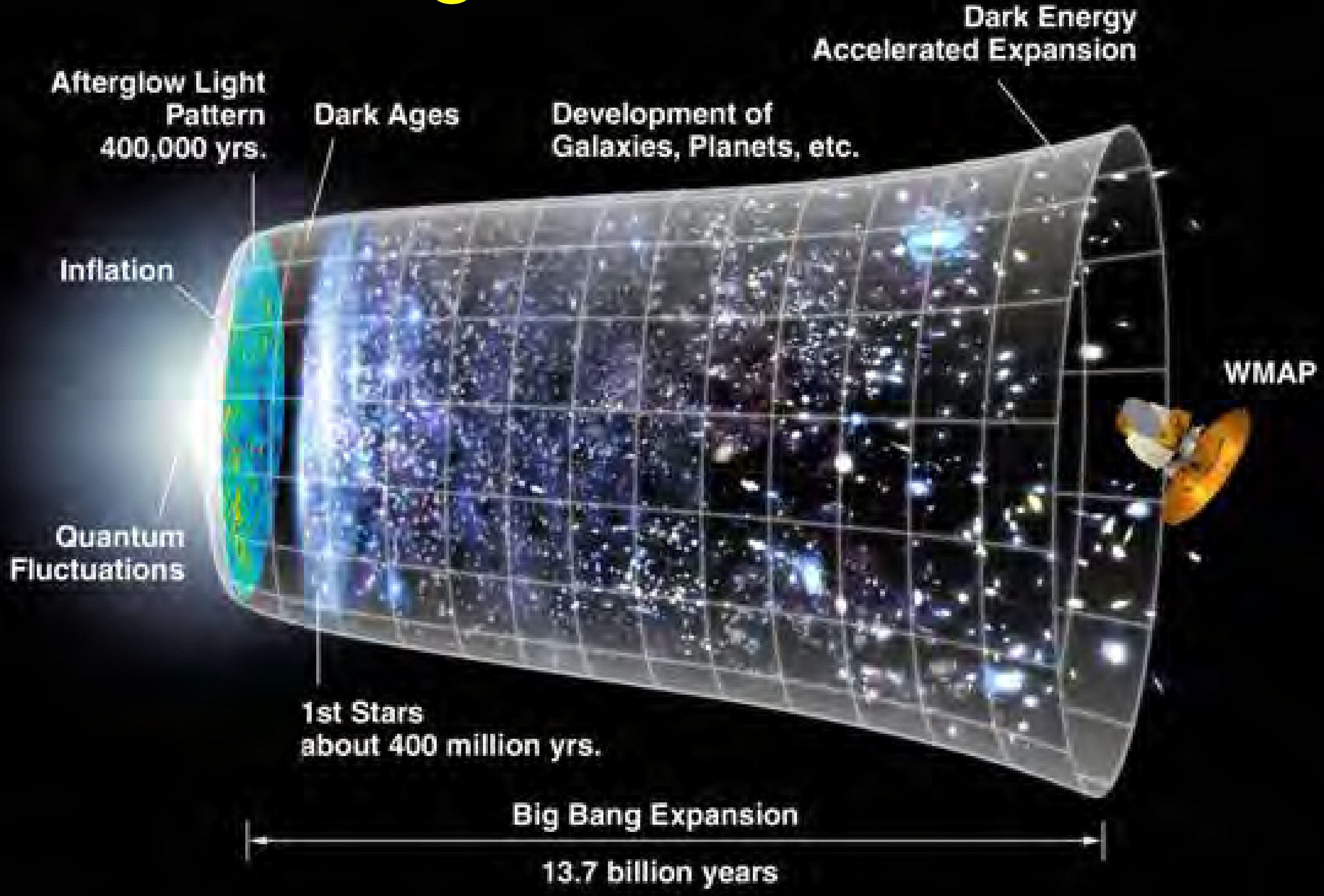
Probing Exoplanet Atmospheres



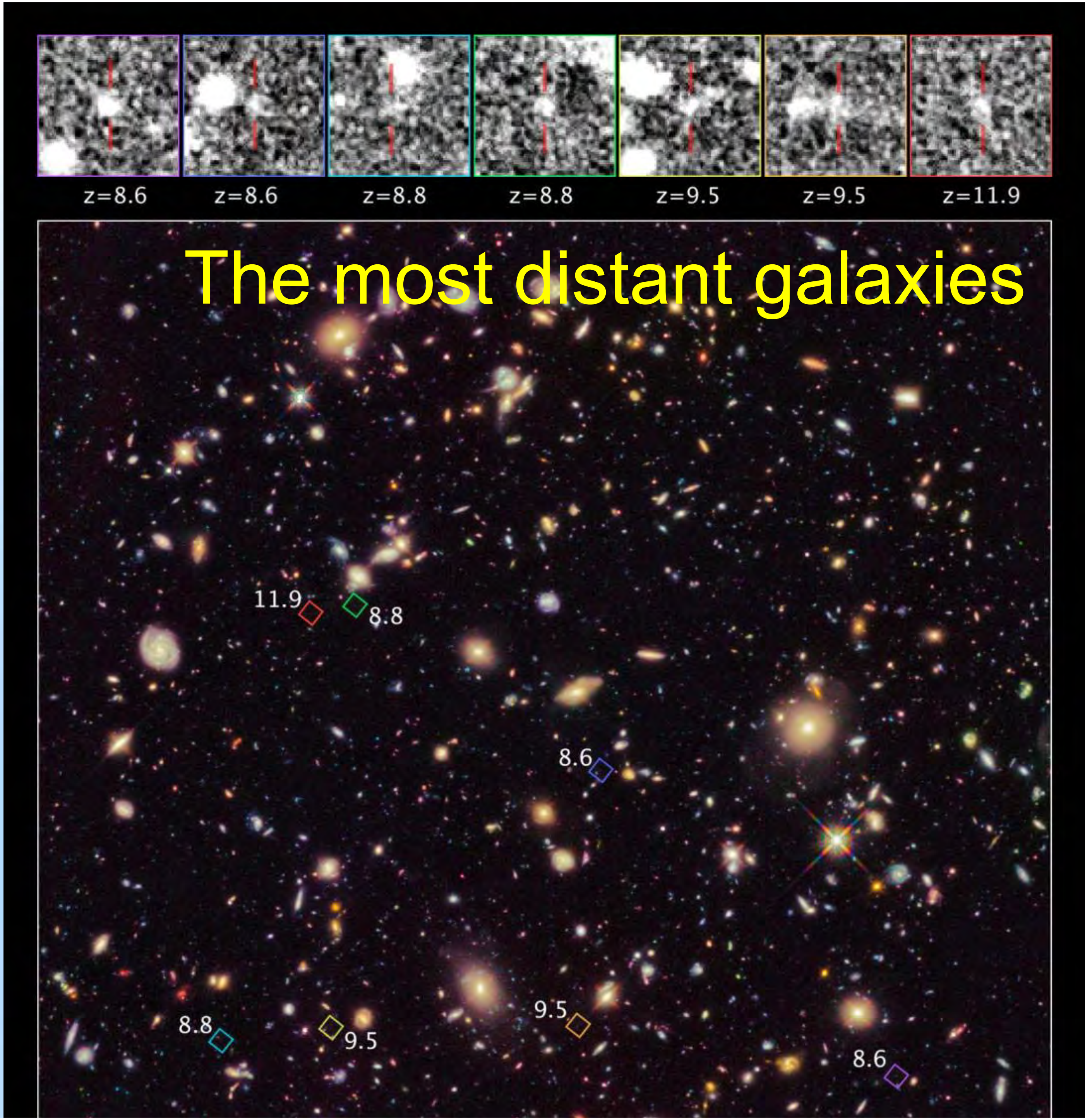
High Red Shift Universe



Hubble Ultra Deep Field

Z=11.9

13.1billion years for light to reach us

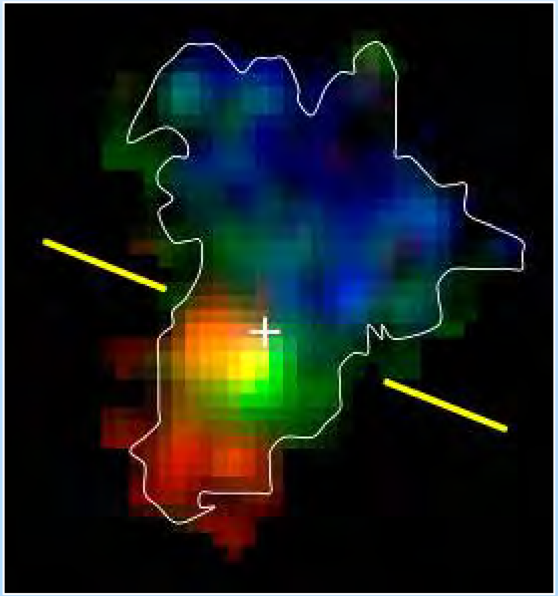


Richard Ellis (Caltech, USA) and Ross McLure (University of Edinburgh, UK)

Watching Galaxies Form at high red-shift (1 < z < 5)

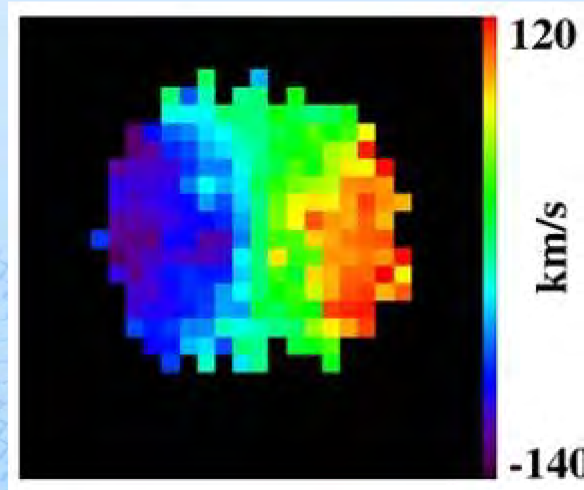
- Mergers or ordered rotation?
- Distinguish via velocity maps

E-ELT can get to z ~ 4 (1.4 billion yrs since BB)



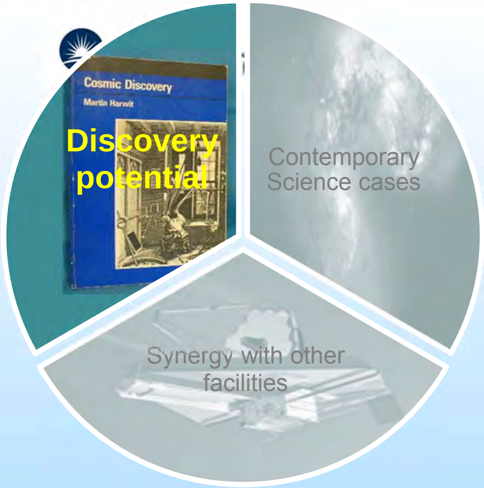
Massive, rotating disk galaxy 3 billion yrs after the Big Bang (10.5 billion yr from us)
Observed with Adaptive Optics + Integral Field Unit on VLT (Genzel et al 2006)

0.5 arcsec



Simulation (M. Puech): typical rotating disk
42-m ELT, 10-hr integration, MOAO

- Large, representative sample requires multiple-Integral Field Units fed by AO: see later talk on EAGLE



Discovery Potential

E-ELT excels in collecting power *and* angular resolution

39 m telescope with **Adaptive Optics** will deliver

5× better angular resolution (1/D)

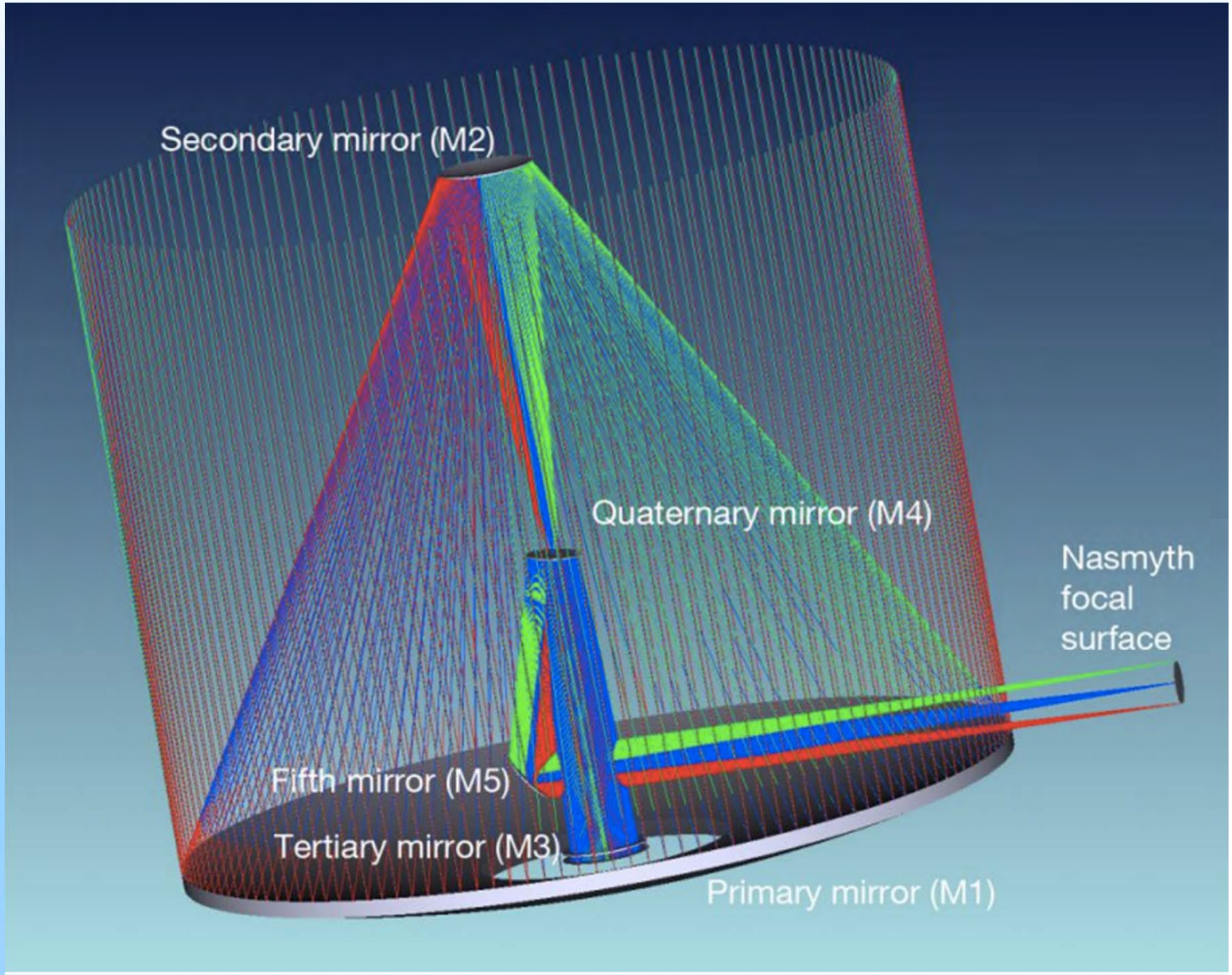
up to **500**× faster exposure time ($1/D^4$)

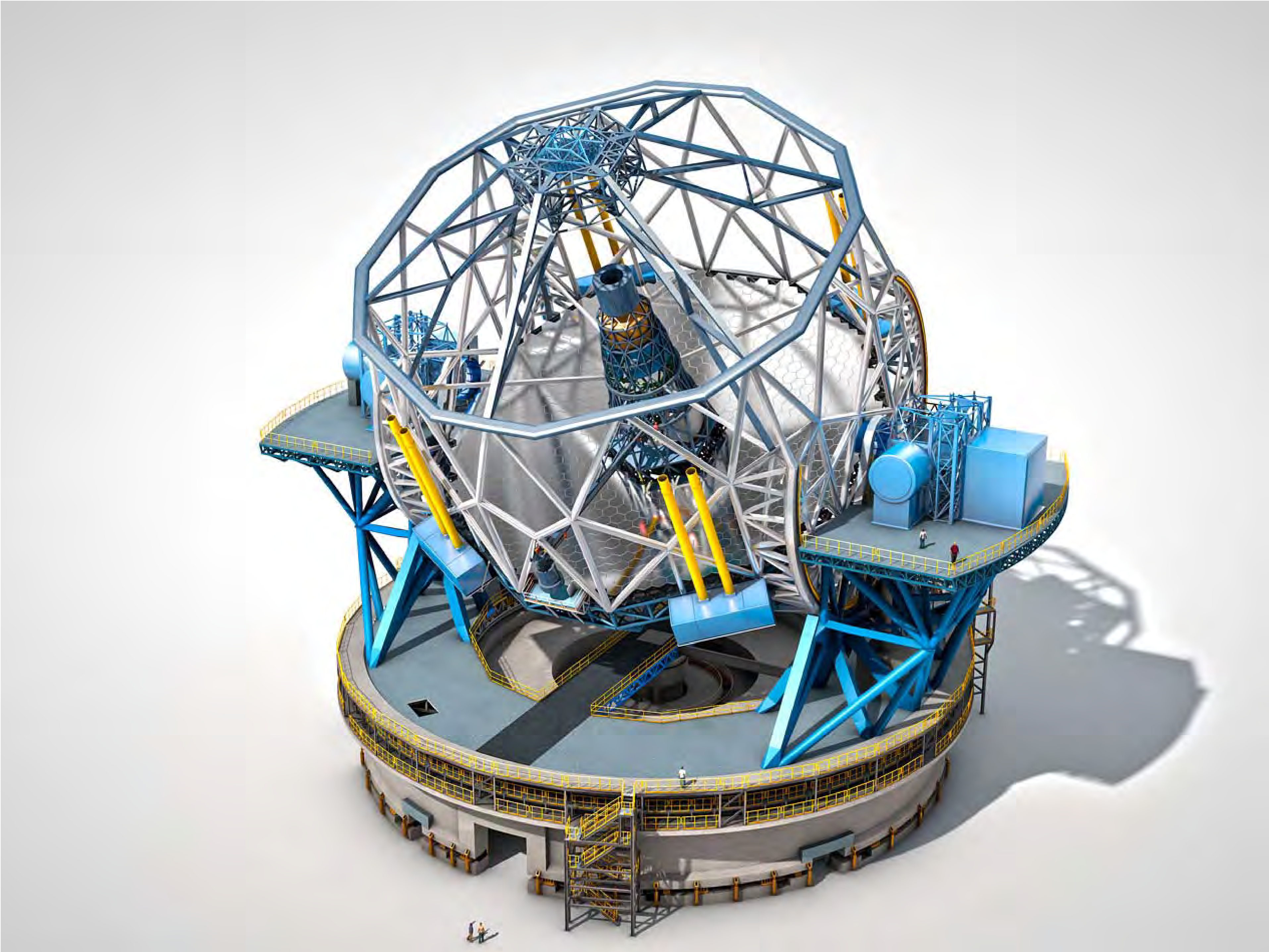
than existing 8m telescopes

Unprecedented sensitivity and angular resolution

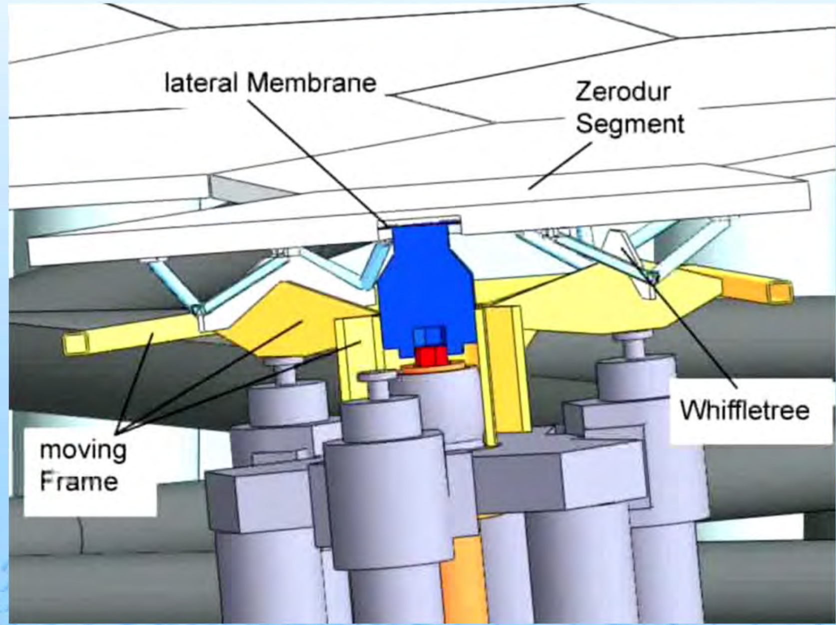
Prepare for the unexpected….

5-mirror design

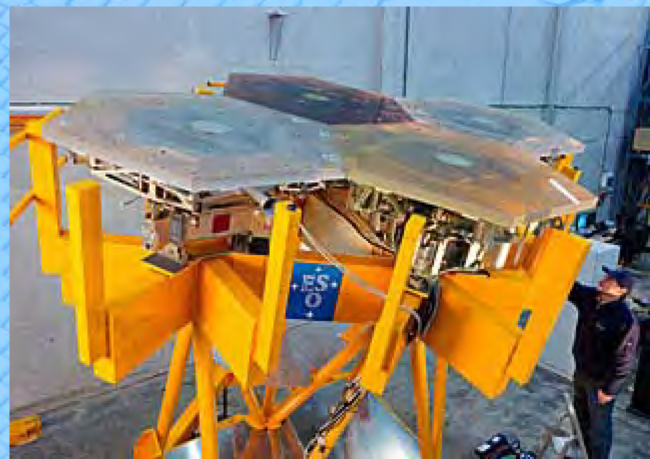


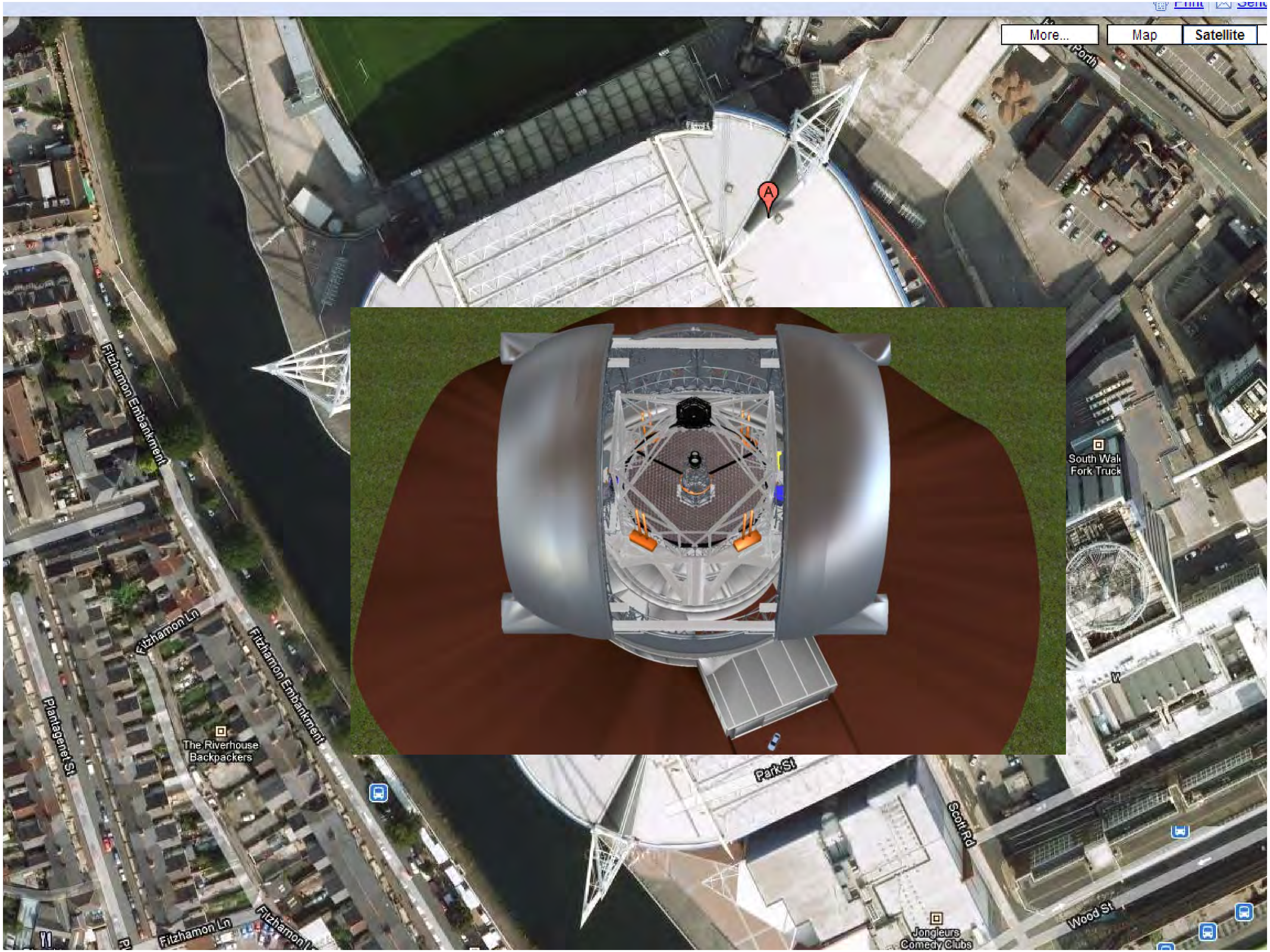


The E-ELT 39.3m primary mirror



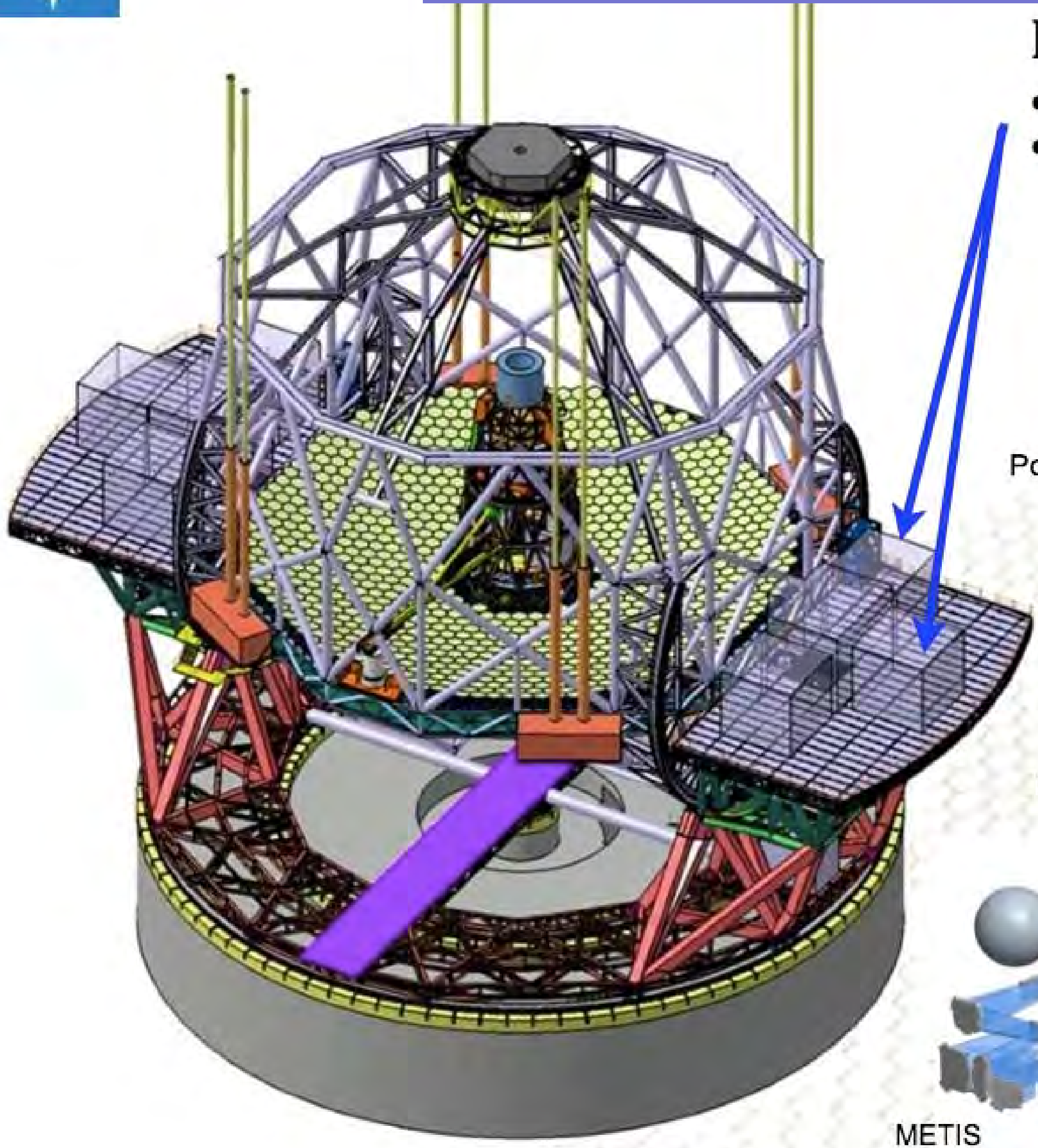
- Hexagonal in shape, 1.4m across
- 1-3 segments will be removed each day for cleaning & recoating
- Low thermal expansion glass (Zerodur)




More...
Map
Satellite
A
Fitzhamon Embankment
Fitzhamon Ln
Fitzhamon Embankment
Plantagenet St
The Riverhouse Backpackers
Park St
Scott Rd
Fitzhamon Ln
Jongleurs Comedy Clubs
Wood St

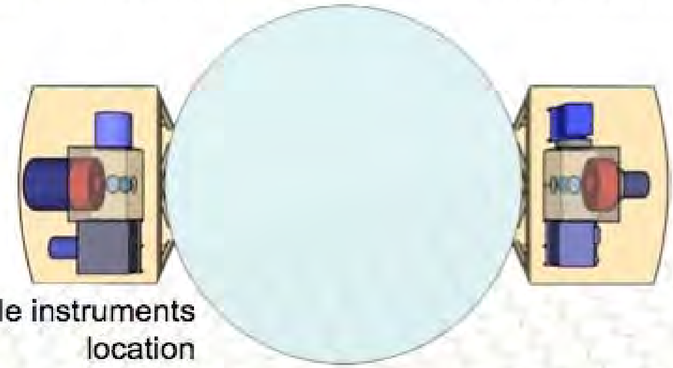
Site: Paranal and Cerro Armazones

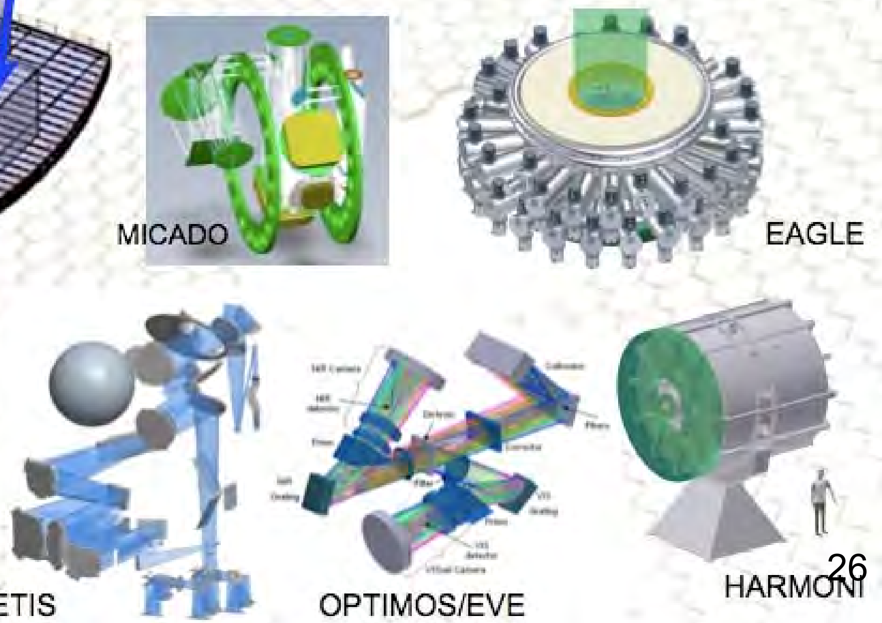
E-ELT Instruments



Instrumentation

- 8 instrument concepts Phase A concluded
- 2 post-focal AO modules Phase A concluded





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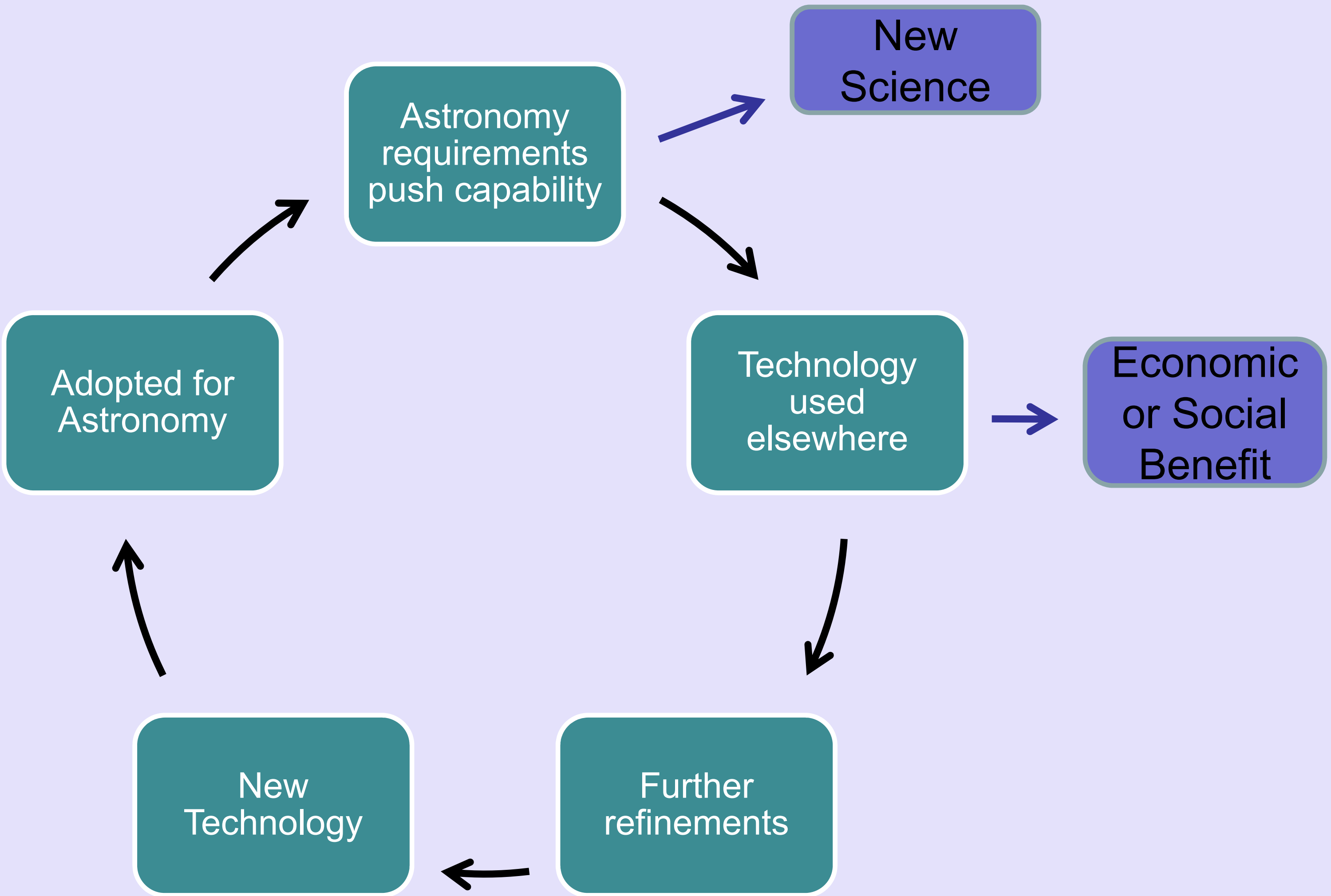
Astronomical Technology and Industry

Development of spectacle lenses in Holland led to Galileo’s telescope

Telescopic aberrations led to understanding of further optical corrections

Astigmatism correction proposed by Astronomer Royal, George Airy :
“On a peculiar Defect in the Eye, and a mode of correcting it” 1827

Cycle of Innovation



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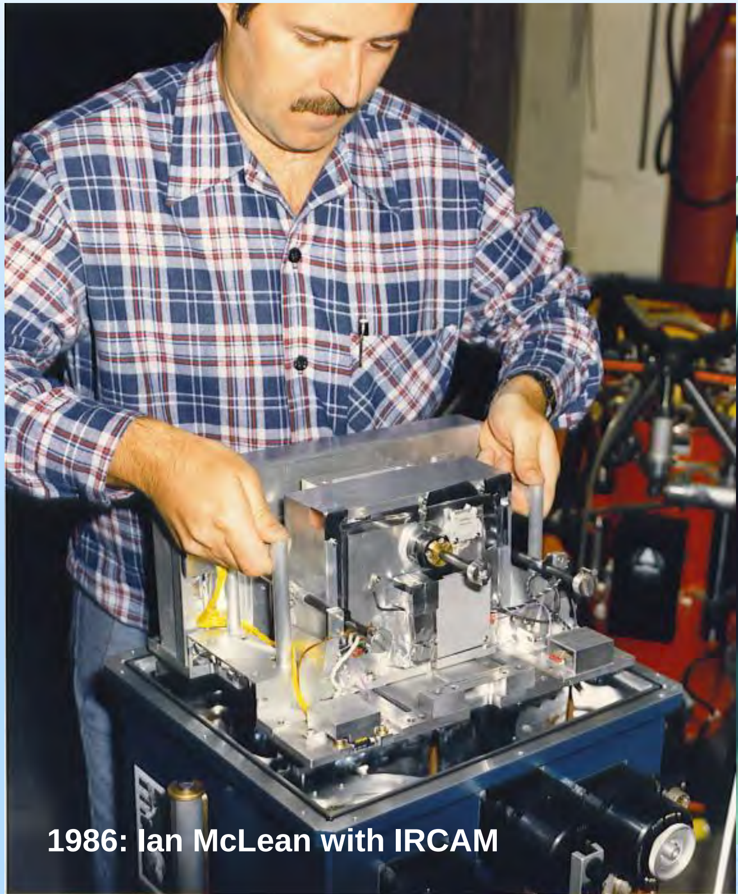
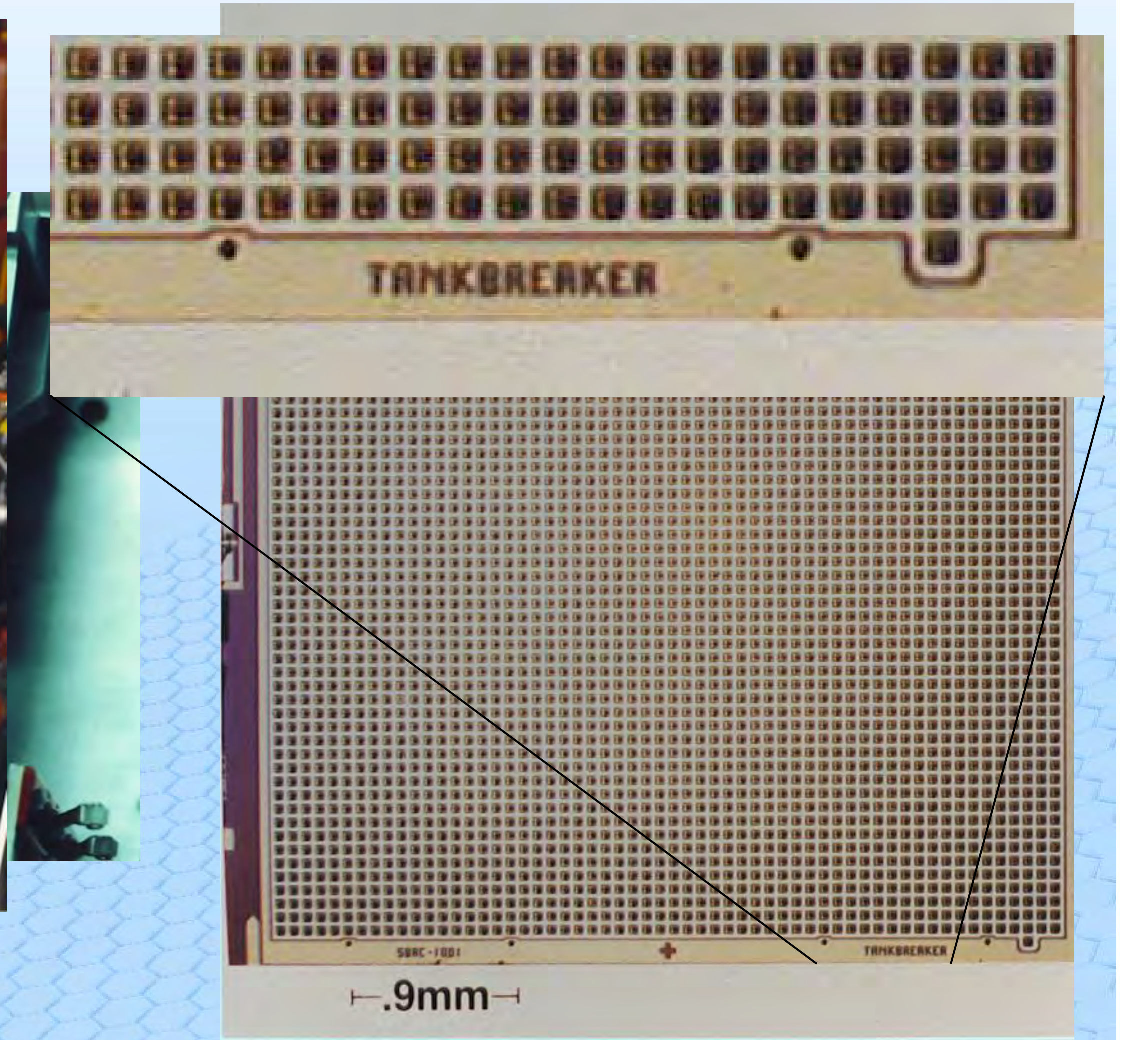
The first digital infrared camera for astronomy (1986)





58 x 62 = 3,596 pixels

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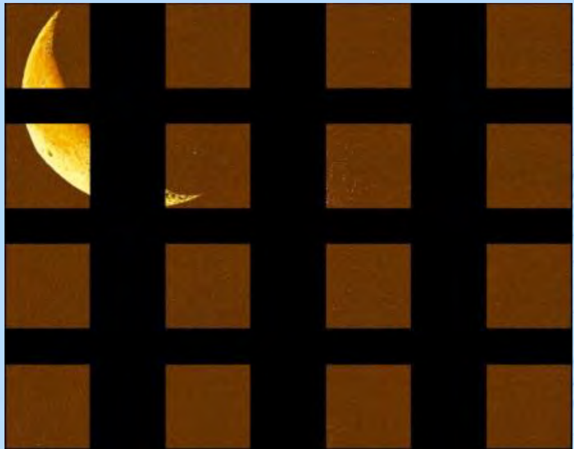
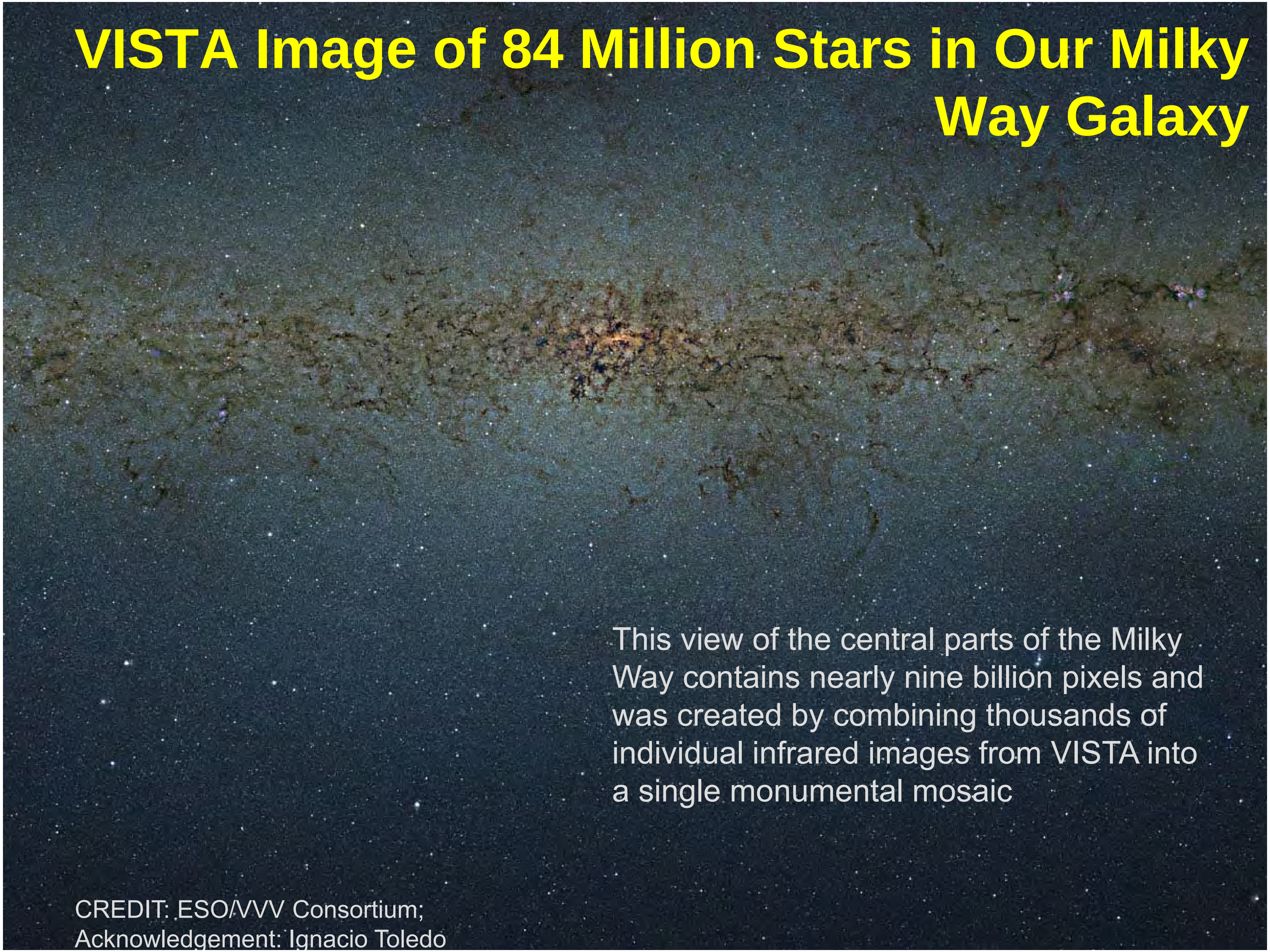
VISTA: World's biggest IR camera



The VISTA IR camera focal plane array consists of a mosaic of 16 2k x 2k IR arrays – 64 million pixels
Huge (1.65 degrees) field of view.



VISTA Image of 84 Million Stars in Our Milky Way Galaxy

This view of the central parts of the Milky Way contains nearly nine billion pixels and was created by combining thousands of individual infrared images from VISTA into a single monumental mosaic

CREDIT: ESO/VVV Consortium;
Acknowledgement: Ignacio Toledo

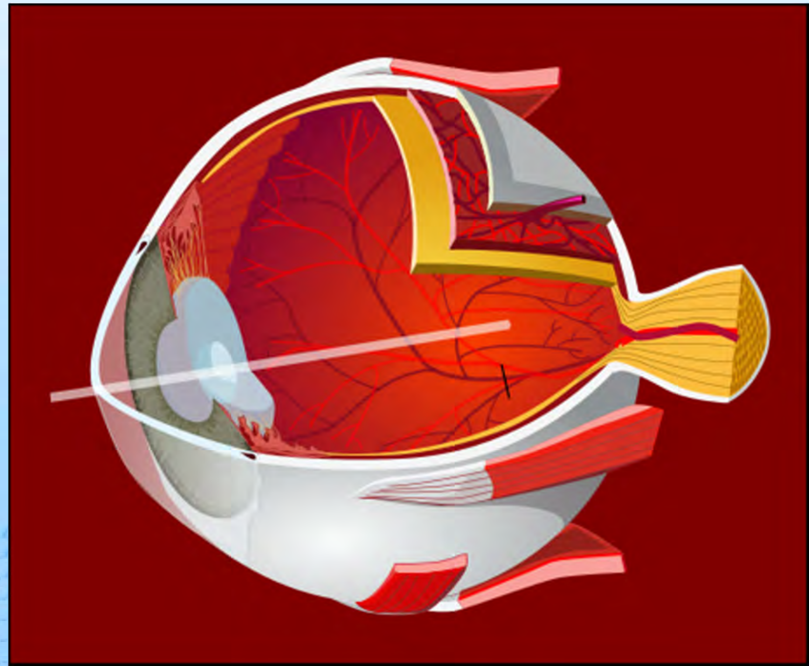
Adaptive Optics & the Eye

Now important in medical imaging and microscopy:

Imaging and spectroscopy of the retina, lens and cornea:

Diagnosis of diseases of the eye
- Diabetic Retinopathy
- Macular Degeneration
- ………

Window into the circulation and nervous system



Retinal imaging with AO

AO allows imaging of individual cones in the retina to investigate human vision

The colour images show the distribution of S, M and L-type cones in two people within the range of normal vision

The graphs compare the cone responses to light in subjects with normal (left) and abnormal (right) vision, with no L-cone absorption

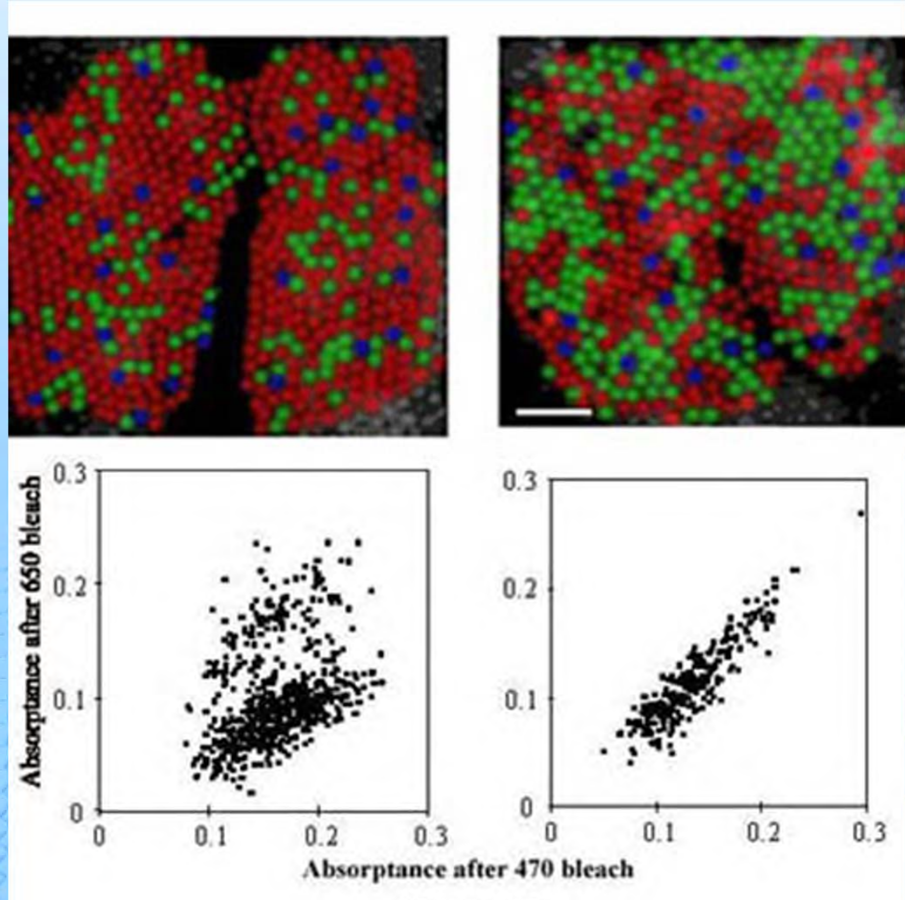


Figure 12

(Courtesy of David Williams, Rochester)

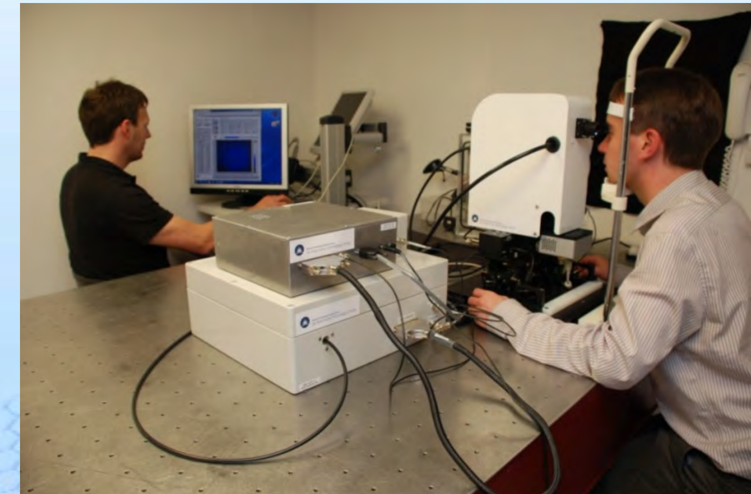
UK ATC/Cardiff Univ. Retinal Densitometer Trials Successful

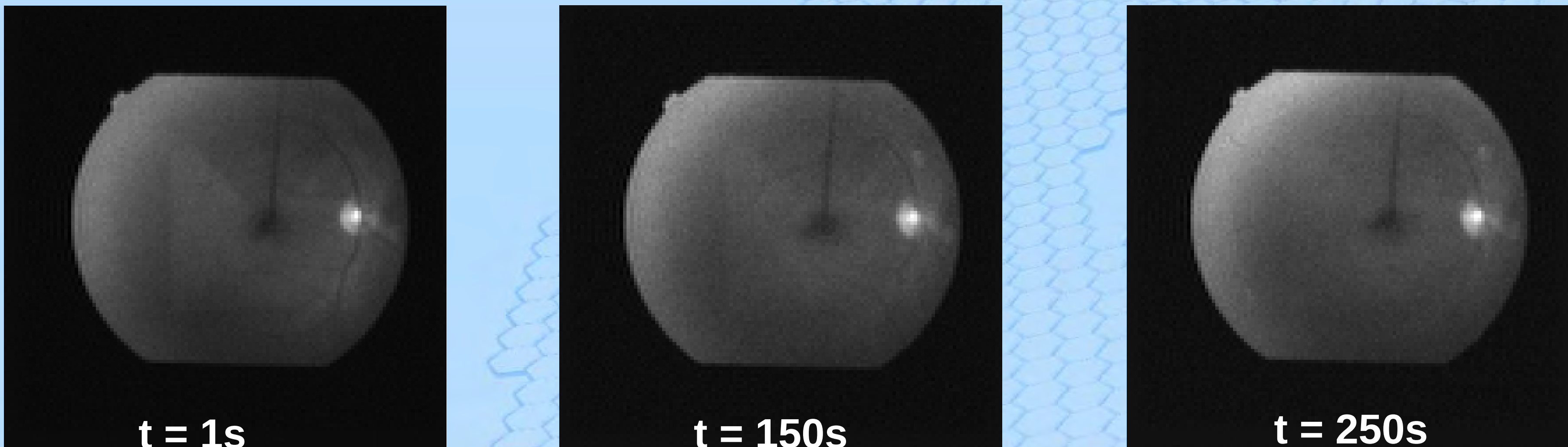
*Initial patient trials show excellent potential as a diagnostic tool for **Age-related Macular Degeneration** (AMD) - Leading cause of blindness in the UK*

Measures **Dark Adaption** of **Retina**

Unique Instrument:

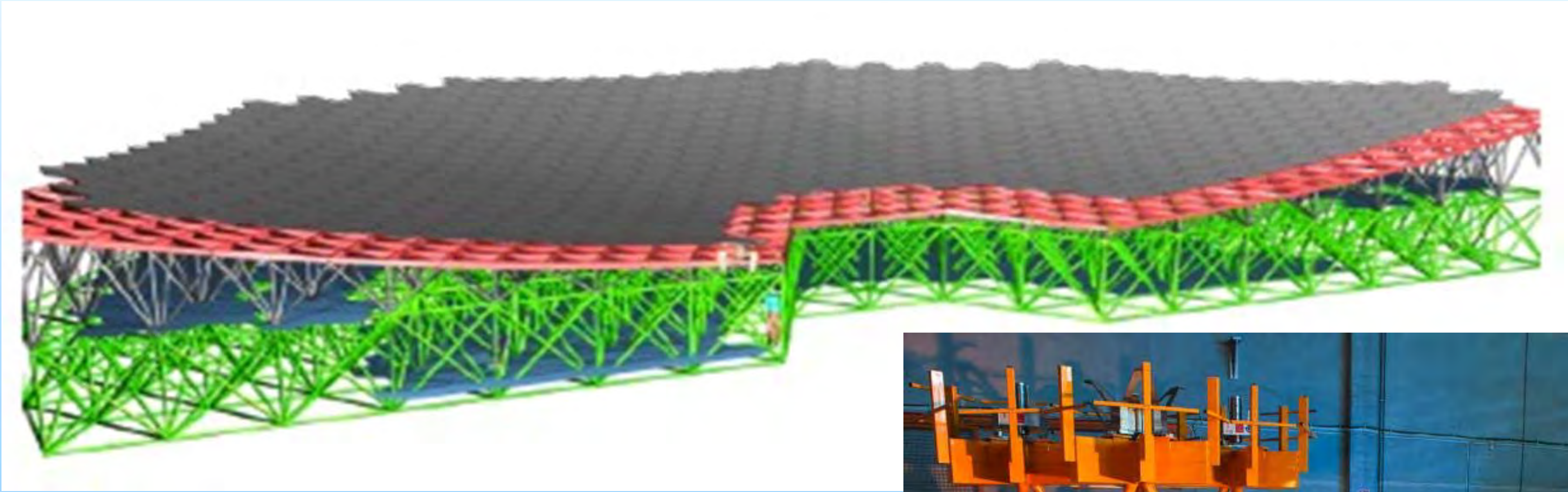
- *Multi-spectral*
- *Spatially resolved*
- *Fast measurement*
- *Non-invasive*
- *Objective*

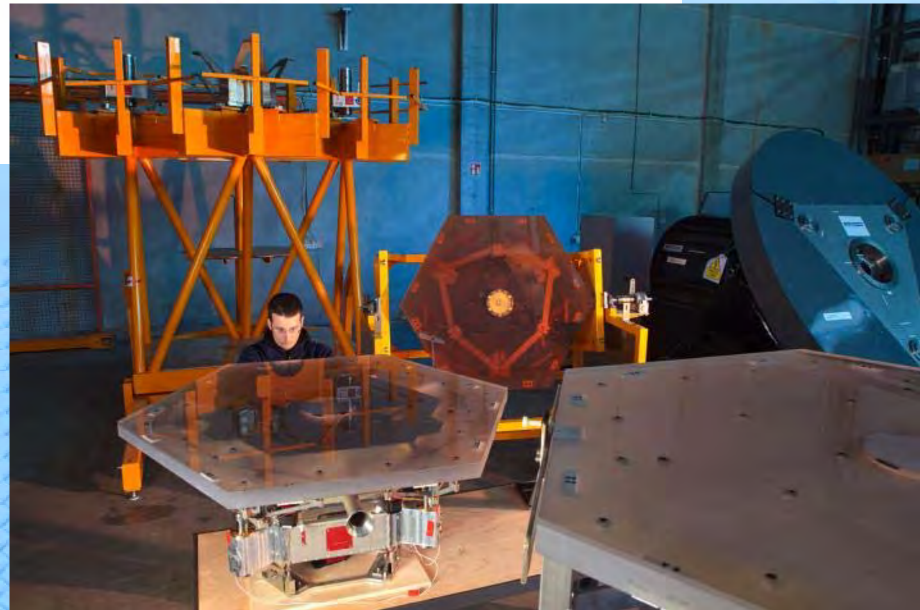




UK ATC & School of Optometry & Vision Sciences, Cardiff University, & Bristol Eye Hospital

E-ELT Primary Mirrors





Form accuracy 20 nm RMS, roughness ~ 1 nm RMS
on segments of 1.4 metres

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Other applications of precision surface forming

- Artificial knee joints
  - Enhance joint Lifetime using hard on hard bearing combination
  - Needs improved Surface Finish

ZEEKO Ltd
Polishing Machine

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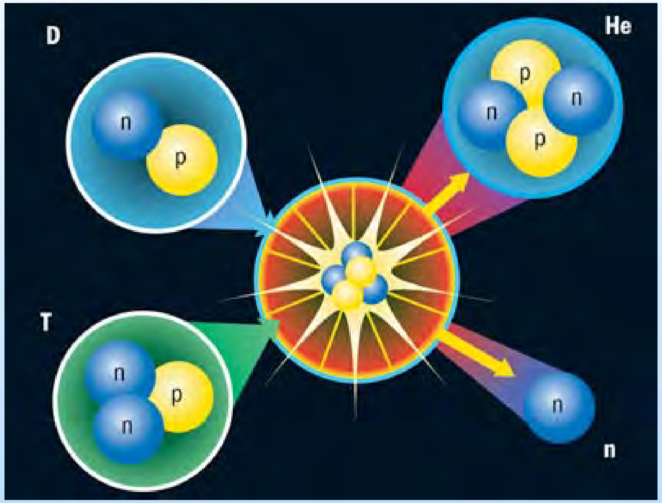
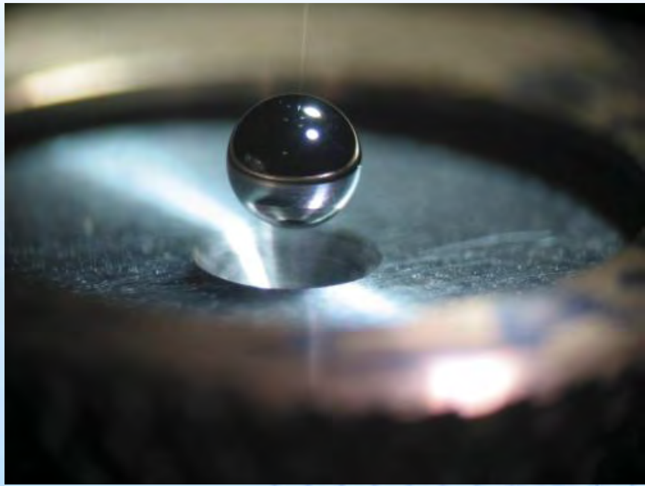
Next Generation Energy: Laser Fusion



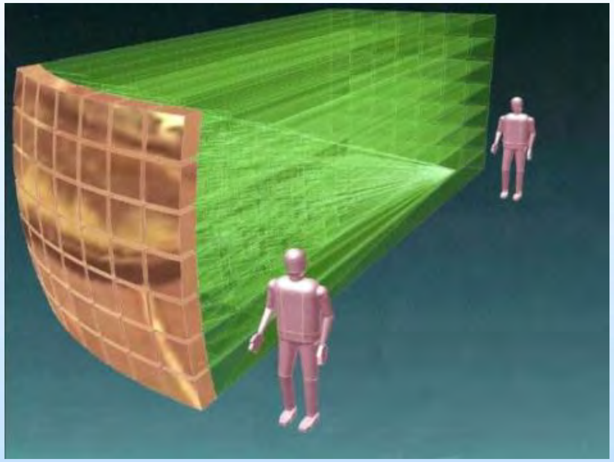


- Inputs:
  - Deuterium: from water
  - Tritium: from lithium
  - High power (TW), concentrated lasers
- Outputs
  - Power
  - Helium
  - Neutrons
- Safe?

Lifetime Electricity For 1 person in UK

Mike Dunne, Physics World, 2010

Laser Fusion Facilities



National Ignition Facility, LLNL, USA (>37500 optics)
Laser MegaJoule, CEA, France

Now planned,
HiPER, Rutherford Appleton Lab?

- **HiPER needs high peak power / high average power optical components**

ELT Developments help enable this:

- **high volume and low cost optics**
- **Lower susceptibility to laser damage**

Ref: HiPER, RAL

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Impact of the E-ELT: Inspiration

- Cultural and symbolic impact of doing inspirational science
- Attracting the next generation into careers in science, technology and engineering

Royal Society 350th Anniversary Exhibition

Funding a €1Billion Telescope

- Delta Phase B design
  - Reduced Primary Mirror from 42m diameter, saving ~ 200 segments
  - Aimed at *reducing* risk/cost and *increasing* contingency
  - Cost estimate: 1083 M€* including contingency, ESO staff costs and instrumentation
- E-ELT construction decision by ESO Council:
  - New Member State contribution from Brazil: 250 M€
  - Agree 2% year-on-year increase over decade
  - Extraordinary contribution by 14 Member States: 250 M€
    - Payments spread over up to ten years

* 2012 value

Project Status: June & Dec 2012 ESO Council

UK Astronomy Technology Centre

- Austria, the Czech Republic, Germany, the Netherlands, Sweden, Switzerland, Belgium, Finland, Italy and France voted in favour of the start of the E-ELT programme
- One country remained in favour *ad referendum*: the United Kingdom
- The remaining three Member States are actively working towards joining the programme in the near future: Denmark, Portugal &Spain
- Brazil has still to finally ratify ESO membership
- **Spending on elements of the project other than the initial civil works will not commence until the contributions pledged by the Member States exceed 90% of the 1083 million Euro cost-to-completion**

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largest union. Page 5; www.ft.com/eu

Crisis model a 'myth'
Reykjavik policy makers say an "Icelandic model" for handling a financial collapse is a myth – even as it is invoked as a possible template for Cyprus's international rescue. Page 5

UAE arrests Islamists
The United Arab Emirates has arrested eight more Islamists ahead of today's trial of 94 nationals on charges of trying to overthrow the state. Page 7

Cypriot banks suffer
Cypriot banks have suffered "substantial outflows" from depositors who have been spooked by speculation over forced losses. Page 5

Italian gas cut
Clashes between rival Libyan militias near a seaside pumping station briefly cut off a source of natural gas to Italy over the weekend. www.ft.com/world

Israel PM seeks time
Benjamin Netanyahu has asked Shimon Peres, Israel's president, for two more weeks to form a government after his efforts to build a majority were foiled by rivals. www.ft.com/world

Separate section
FTfm
Fund management update

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tions for non-compliance.
Brigitta Moser-Harder, an activist shareholder who spearheaded the Yes campaign together with entrepreneur Thomas Minder, said the result, one of the most emphatic ever in a Swiss referendum, sent a clear signal to companies within and beyond Switzerland's borders.
"The EU is already capping bankers' bonuses and now the Swiss people have spoken very clearly as well. The message to

haps, and h pass since drugs group give its dep SFr72m ($76 Ursula Fra No campaign marked "a de was once a on corporate

Wolfgang Mün Lex, Page 16
John Authers

Planet seeker

Britain will play a leading role in building and operating the world's biggest eye on the sky, the European Extremely Large Telescope in Chile, after a UK government decision to invest £88m in the €1.1bn project. With its 39-metre mirror, the E-ELT might provide the first direct images of planets orbiting distant stars and indicate whether any of them host life.

Report, Page 4

£3bn has f

By Jim Pickar

A £3.3bn sc councils that ing of new fallen flat, acc by a former minister.
The New designed to pr of large num distributing which oversee
At a time of government f is worth £3.3b years, spread local authoriti
Yet the £1.3 far may sim councils whe have been buil by official fig Nick Raynsfor
The total n tial planning 14 per cent

World Markets
STOCK MARKETS — Mar 1 — Feb 22 — Wk's chg%
CURRENCIES — Mar 1 — Feb 2 — $ per € — 1.298 — 1.31

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vests £88 million in world's largest ever al telescope


npression E-ELT

The UK research base and industry will play a leading role in one of the biggest global science collaborations in history, after the UK government confirmed long-term investment in the European Extremely Large Telescope (E-ELT) to be built in Chile.

The E-ELT will make huge strides toward our understanding of the Universe, the effects of dark matter and energy and planets outside of the solar system. Its 39 metres in diameter mirror will collect 15 times more light than any existing telescope and it will produce images 16 times sharper than the Hubble space-based telescope.

The £88 million investment will ensure UK scientists and engineers, supported by the Science and Technology Facilities Council (STFC), will be heavily involved in the construction and operation of the telescope and its instruments, set to be the most advanced of its kind. UK industry has already won £9 million worth of contracts, and that figure is predicted to increase as much as ten-fold before 2023 when construction is expected to be completed.

Universities and Science David Willetts said:

ficant investment reaffirms the government's commitment to cutting edge science. It will UK plays a leading role in a ground-breaking international project and our world-class ase has access to the latest equipment. Not only will this new telescope considerably owledge of the universe, its construction will drive growth and innovation for UK industry. space is one of our eight great technologies. To top it off, the advances in technology that rom this hugely challenging project will be a real asset to the UK and have knock-on effects ectors and areas of research."

to significantly enhanced worldwide scientific knowledge, the E-ELT will benefit the UK in other nology developed for astronomy is already being applied across many sectors, including extending tificial knee joints, diagnosing eye diseases, improving the performance of industrial lasers and research.

Colin Cunningham, from STFC's UK Astronomy Technology Centre (UK ATC) who is leader of the Project Office said:

of scientists and engineers have built strong positions over the last few years to enable them to make major contributions to the instruments, telescope engineering and optical systems. We

Early Contracts

- Early contracts for the project have already been placed:
  - Detailed design study for the very challenging M4 adaptive mirror of the telescope
  - Detailed design work for the route of the road to the summit of Cerro Armazones
- Some of the civil works are expected to begin this year
  - preparation of the access road
  - levelling of the summit

The European Extremely Large Telescope

The public web pages: **http://www.eso.org/public/astronomy/projects/e-elt.html**
UK Project pages: **http://www.roe.ac.uk/elt/index.html**
Construction Proposal **https://www.eso.org/sci/facilities/eelt/docs/e-elt_constrproposal.pdf**

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