Laboratorio di Astronomia

Modern Telescopes

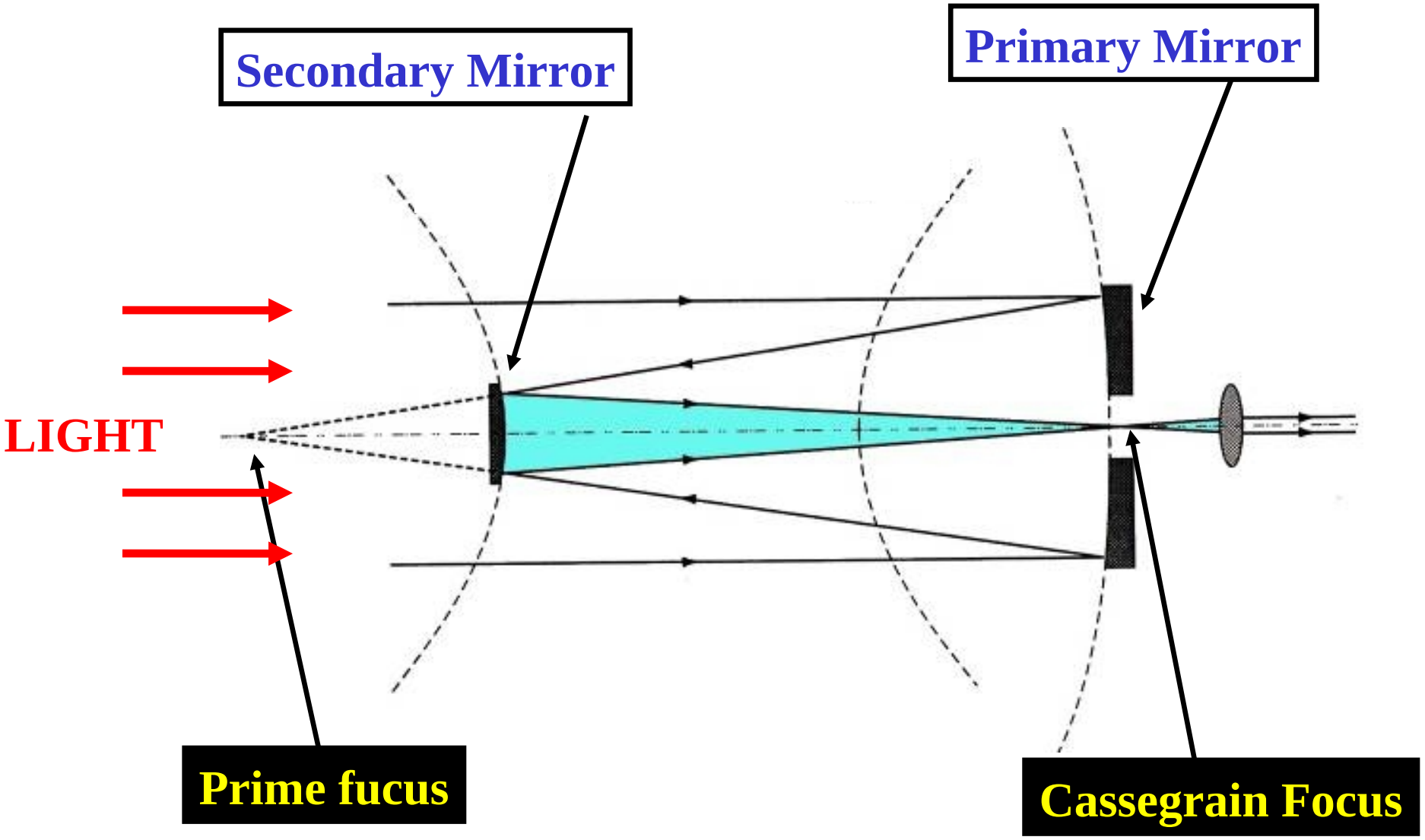
Laurea in Astronomia
AA 2025/26

Alessandro Pizzella
Dipartimento di Fisica ed Astronomia

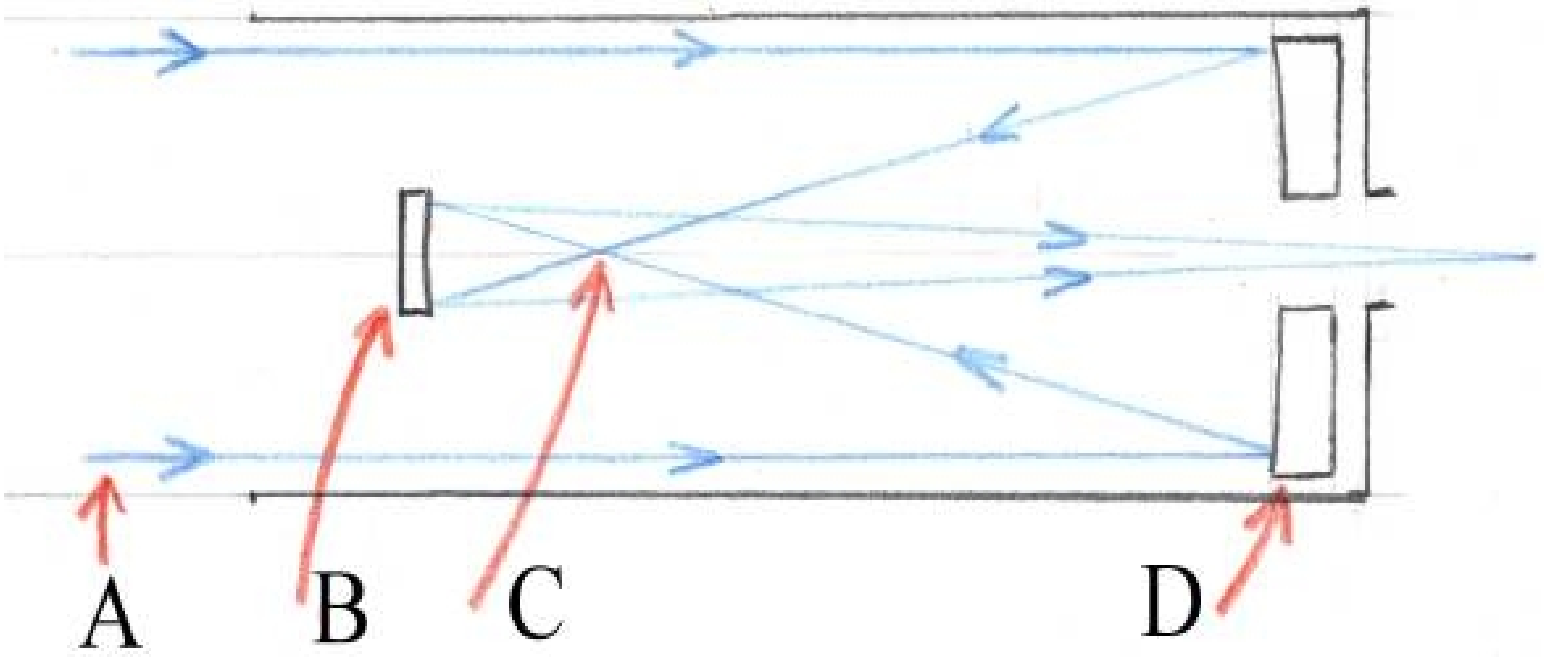
Telescope optics

- Simple scheeme of a standard telescope
- main ground based Telescopes
- other telescopes (radio, Cherenkov, Space)

Cassegrain / Ritchey-Chretien



Gregorian Telescope



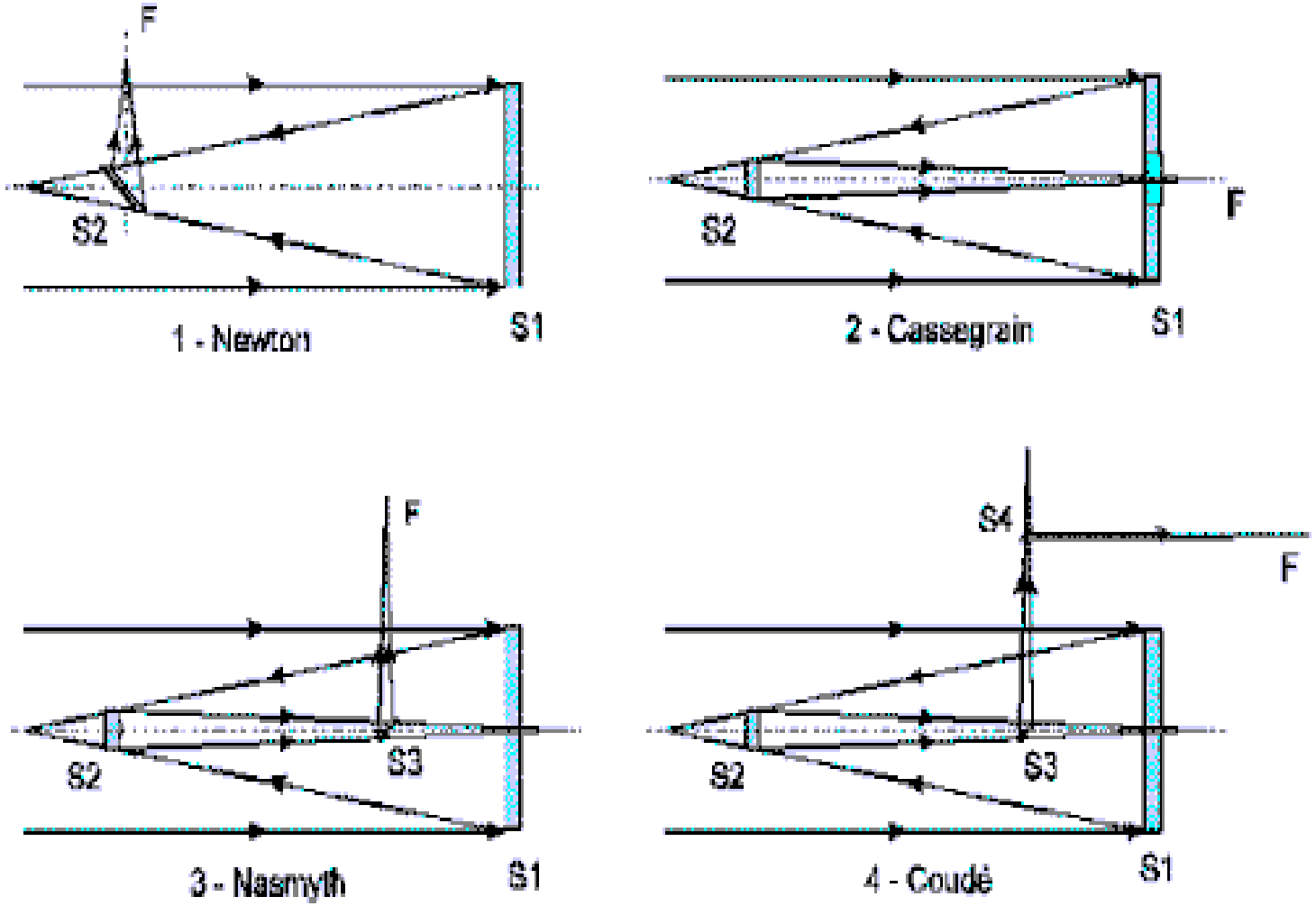
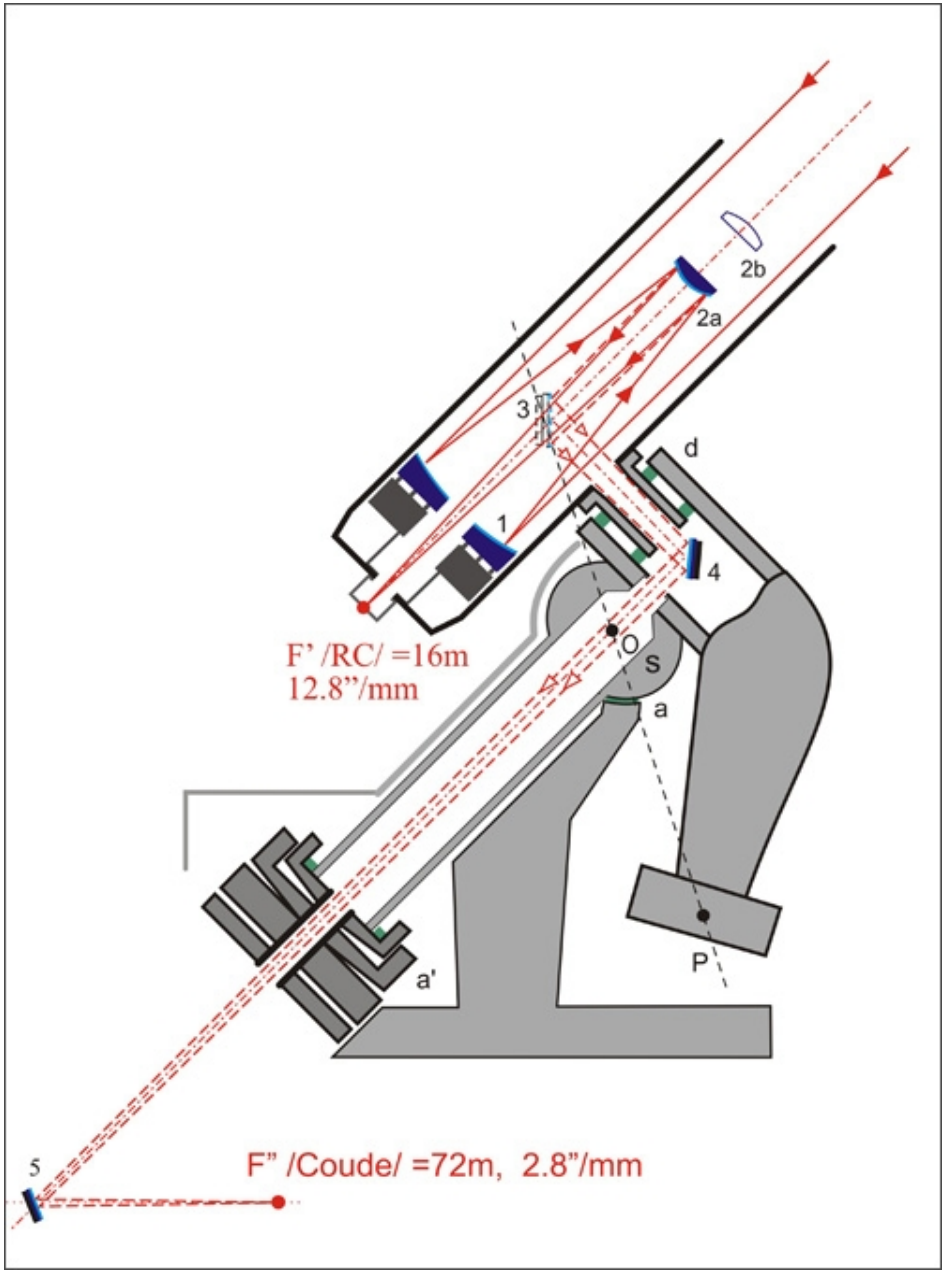
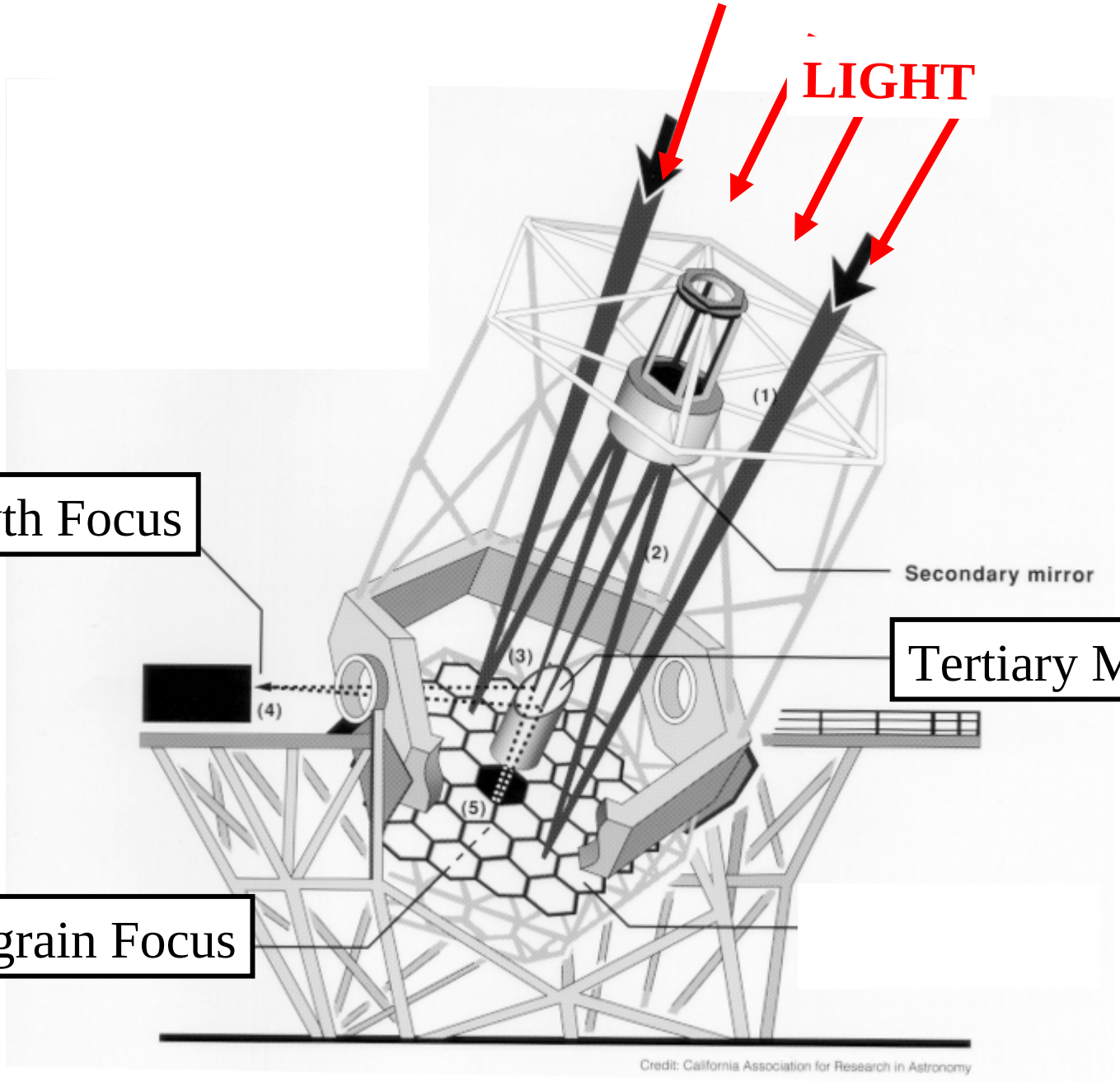


Figura 3 - Schemi ottici dei riflettori


2b
2a
3
1
d
4
F' /RC/ =16m
12.8"/mm
O
S
a
a'
P
5
F" /Coude/ =72m, 2.8"/mm



Nasmyth Focus

Tertiary Mirror

Cassegrain Focus

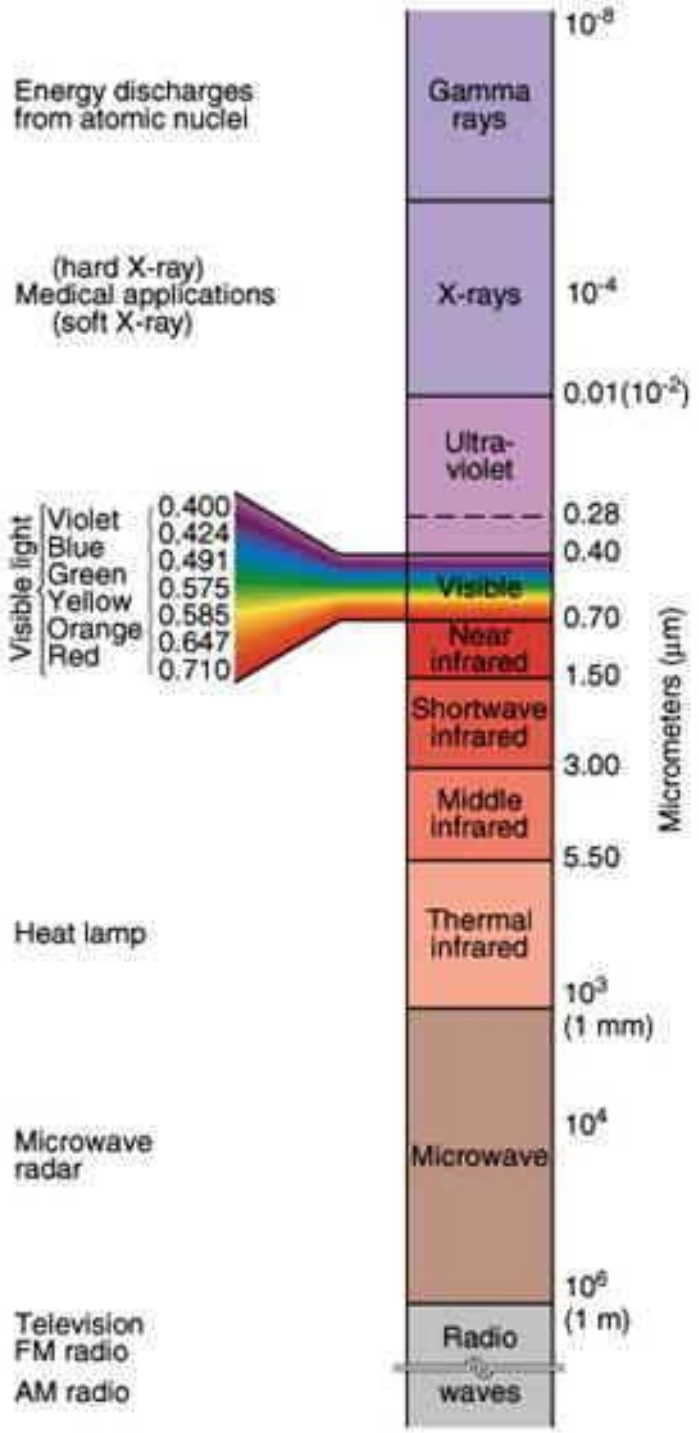
The importance of the size of the Primary Mirror

More light is collected:

Area $\propto$ radius^2

Better image resolution (Airy disk) :

$$\sin\theta = 1.22\frac{\lambda}{D}$$


Energy discharges from atomic nuclei
Gamma rays
10^{-6}
(hard X-ray)
Medical applications
(soft X-ray)
X-rays
10^{-4}
0.01(10^{-2})
Ultra-violet
0.28
0.40
Visible
0.70
Near infrared
1.50
Shortwave infrared
3.00
Middle infrared
5.50
Thermal infrared
10^{3}
(1 mm)
10^{4}
Microwave
10^{6}
(1 m)
Radio waves
Micrometers (μm)
Visible light
Violet
Blue
Green
Yellow
Orange
Red
0.400
0.424
0.491
0.575
0.585
0.647
0.710
Heat lamp
Microwave radar
Television
FM radio
AM radio

The importance of the size of the Primary Mirror

More ligth is collected:

Area $\propto$ radius^2

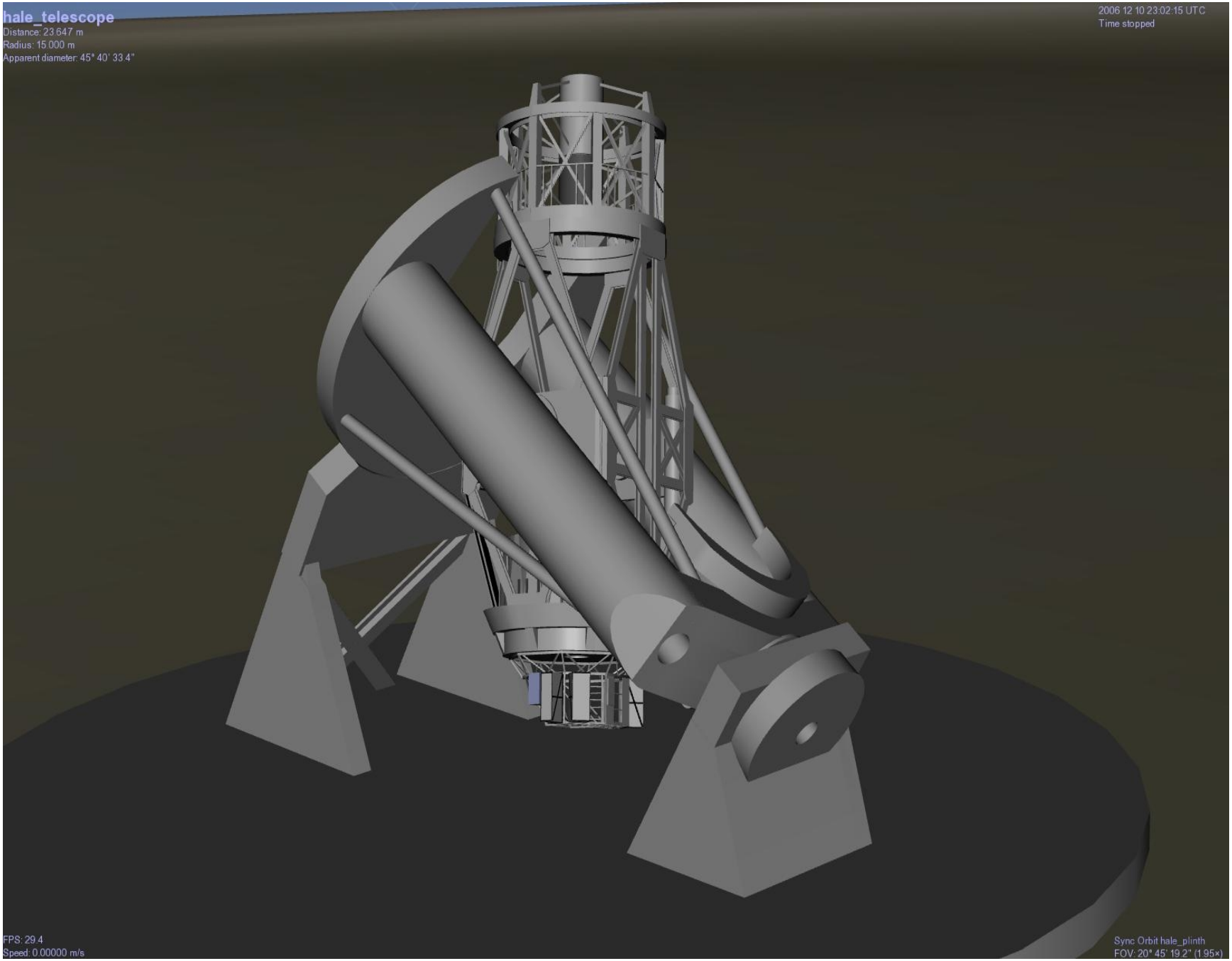
Better image resolution: $$\sin\theta = 1.22\frac{\lambda}{D}$$

Es.: lambda = 600nm; D=5mm ->600/5000000*1.22 -> theta= 0.0084°=30”

D=5m → 600/5000000000*1.22 → theta =0.03”

Mt.Palomar
Hale Telescope
Built in 1948
Diameter = 5m
15 tons




hale_telescope
Distance: 23.647 m
Radius: 15.000 m
Apparent diameter: 45° 40' 33.4"
2006 12 10 23:02:15 UTC
Time stopped
FPS: 29.4
Speed: 0.00000 m/s
Sync Orbit hale_plinth
FOV: 20° 45' 19.2" (1.95×)

Mt. Palomar Telescope has been for many years the most powerfull telescope.
Mirrors larger than 5 meters in diameter can not retain their shape because of their own weigth

Remedy

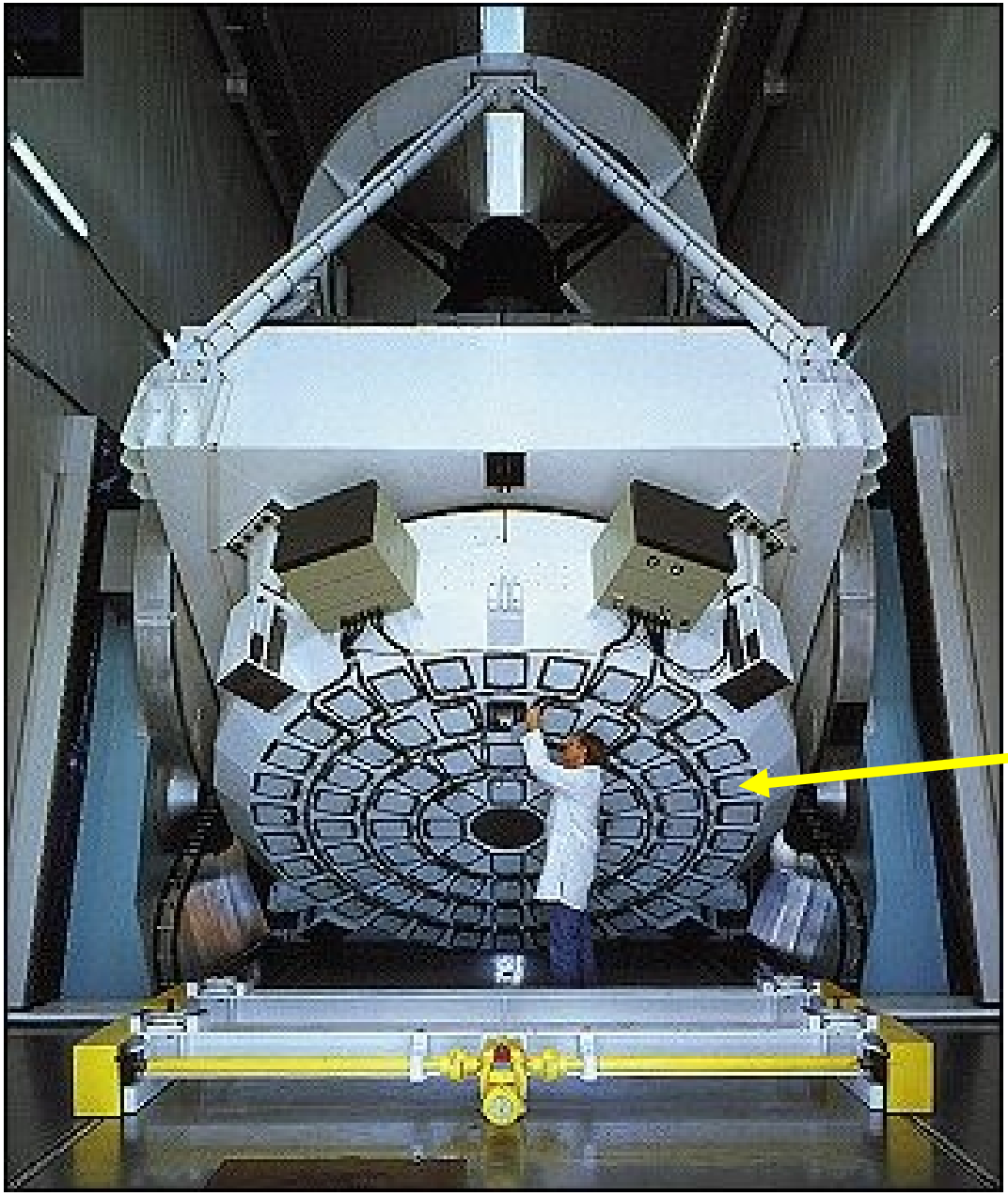
Thin mirrors easy to blend and actuators that mantain the optimum: active optics.

1989 New Technology Telescope
European Southern Observatory – La Silla



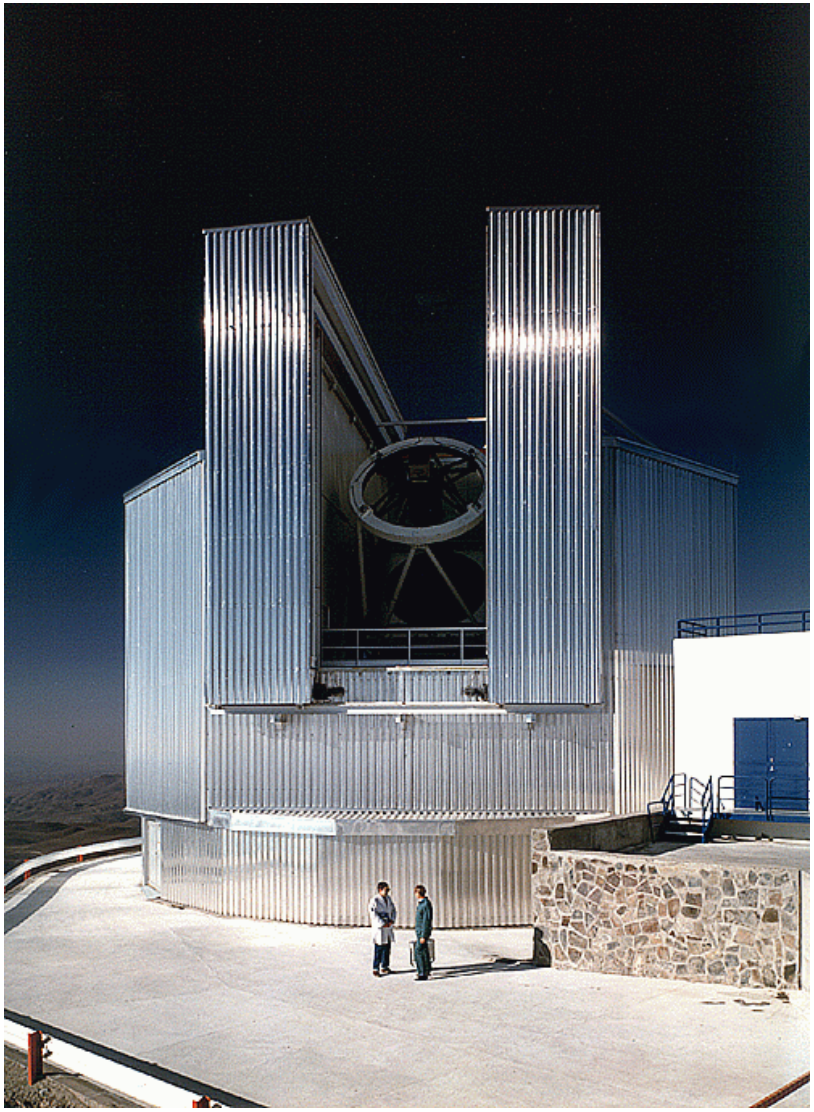
La Silla

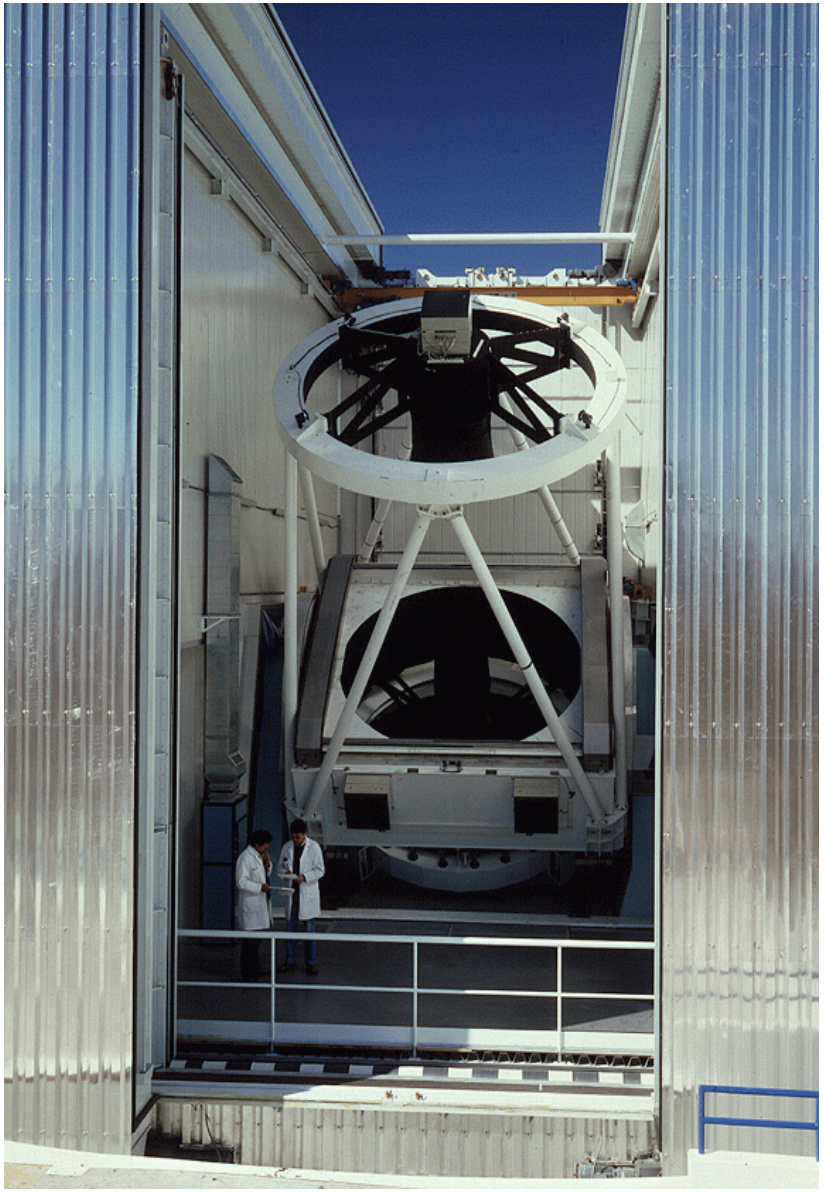

Venezuela
Guyana
Colombia
Suriname
RR
AP
Ecuador
RN
AM
PA
MA
CE
PB
PI
PE
AC
Brasil
Brazil
TO
AL
RO
Perú
MT
BA
SE
GO
Bolivia
MG
MS
ES
Paraguay
SP
PR
RJ
Chile
SC
RS
Uruguay
Argentina



3.58 meters
2 Nasmyth foci

75 actuators



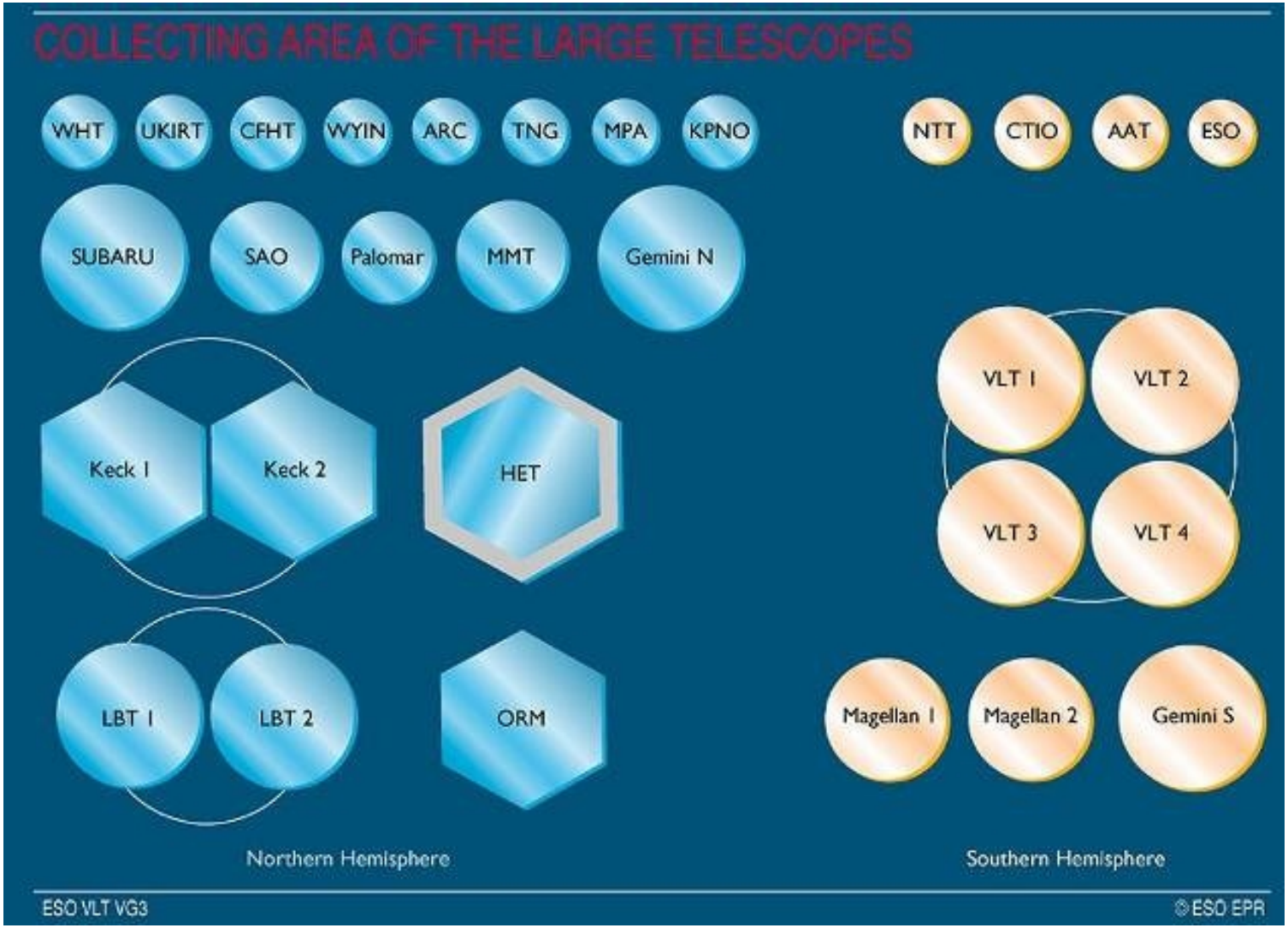


TNG – Telescopio Nazionale Galileo
La Palma, Canarie, Spagna

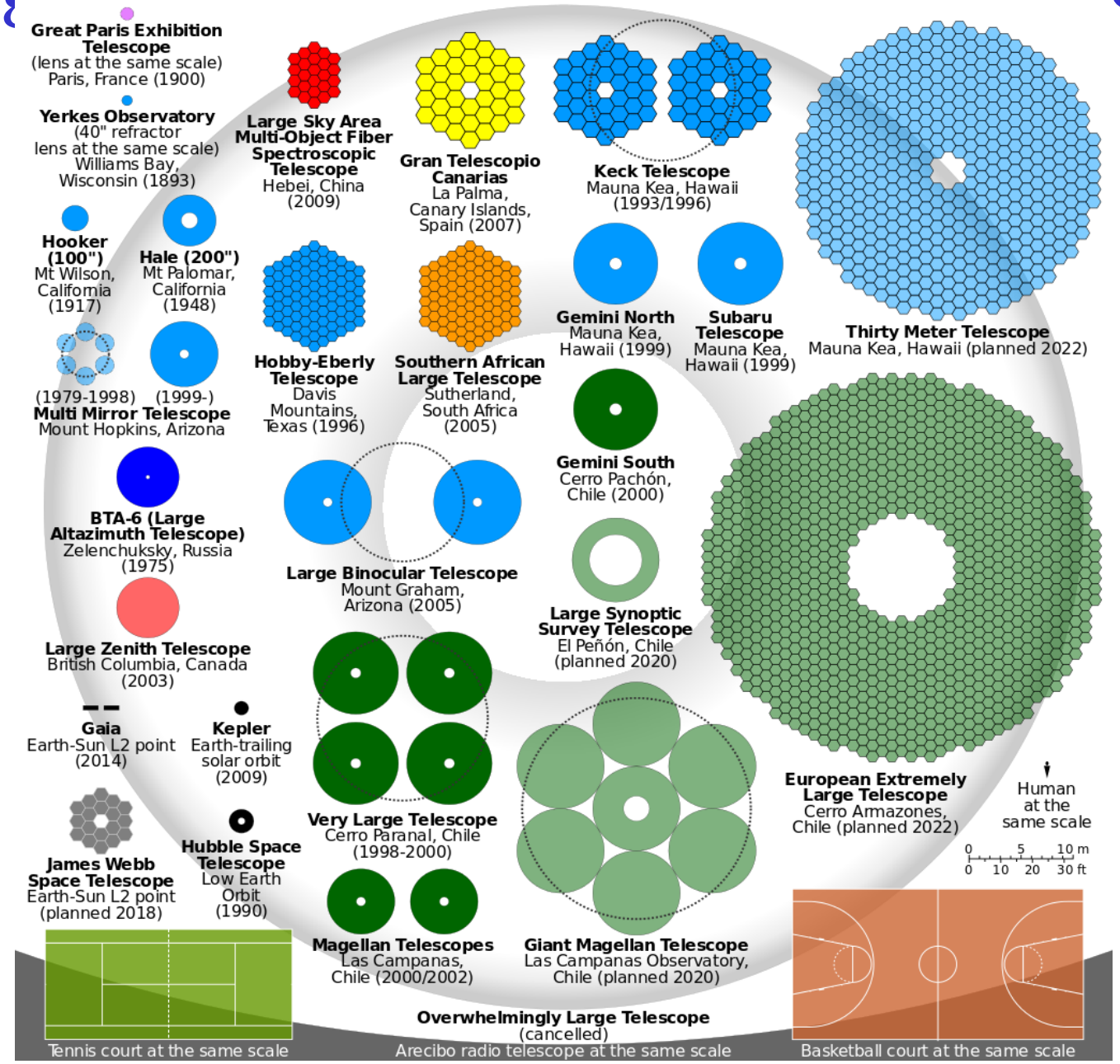


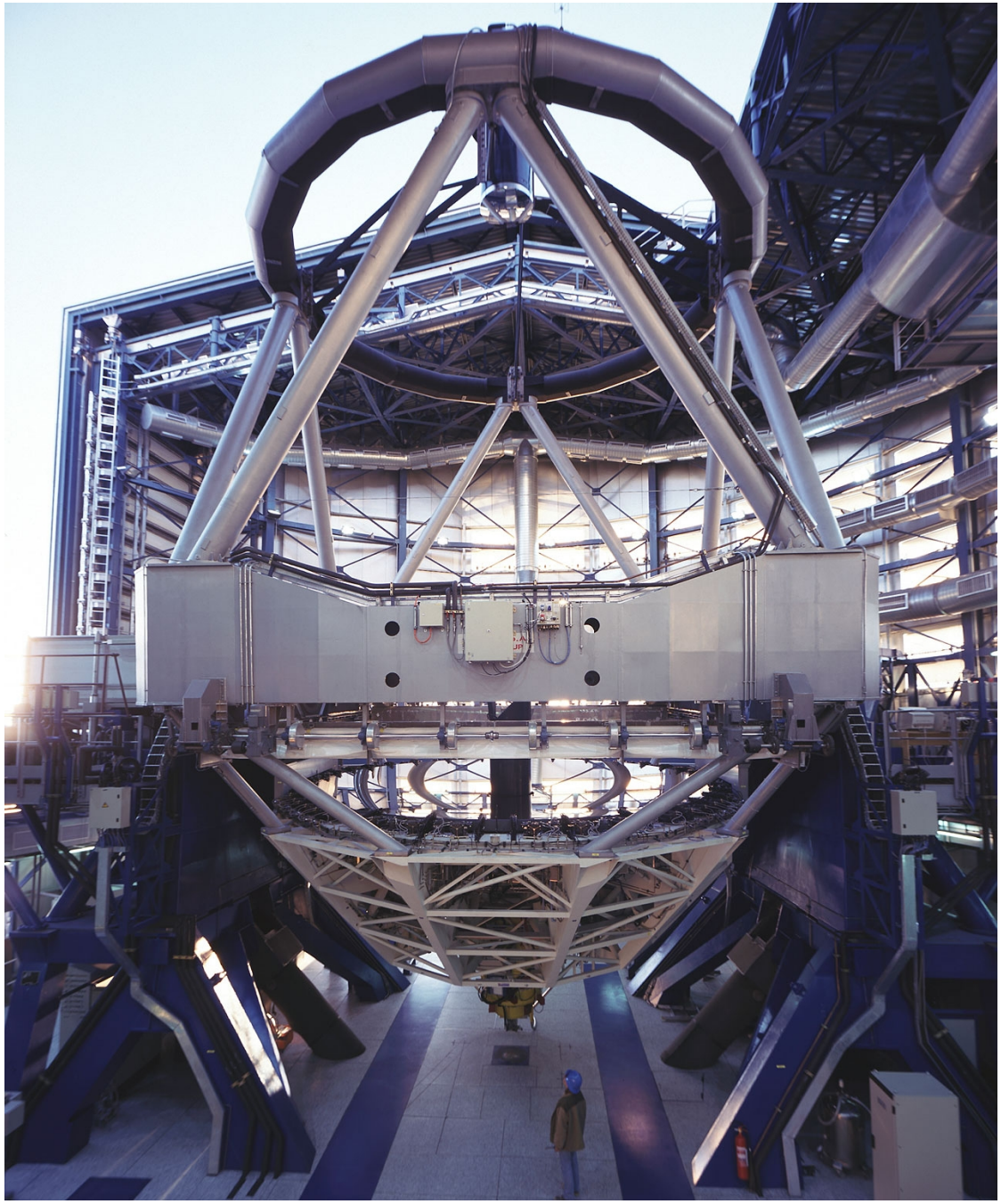


Big telescopes around the world



Big telescopes around the world





1997 VLT
Very Large
Telescope

European S.
Observatory
Cerro Paranal

4x8.2m

Paranal

La Silla

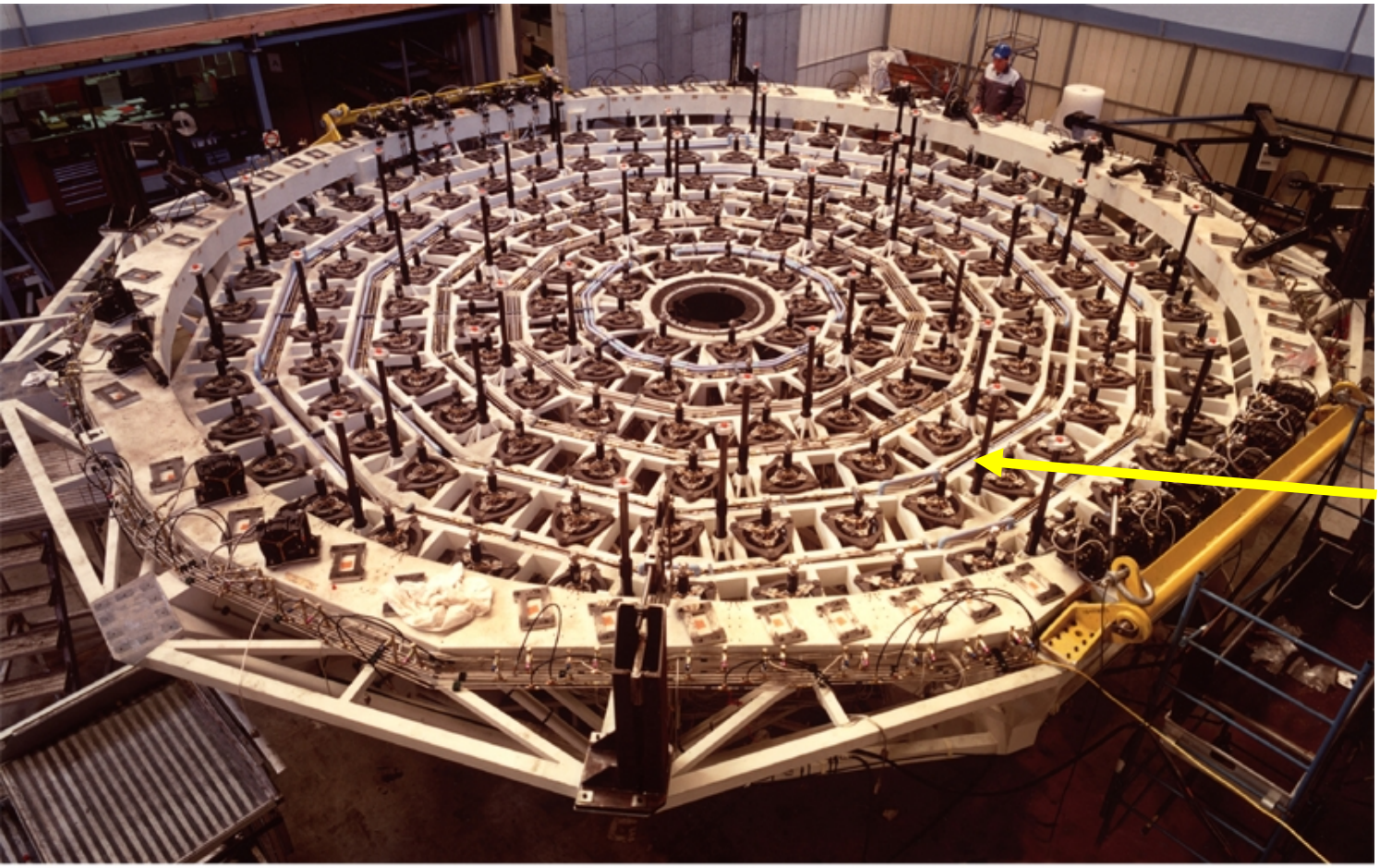




VLT at Paranal

ESO PR Photo 43a/99 (8 December 1999)

© European Southern Observatory



150 actuators
8.2m x 17cm
22 tons

Active Mirror Supports in VLT M1 Cell

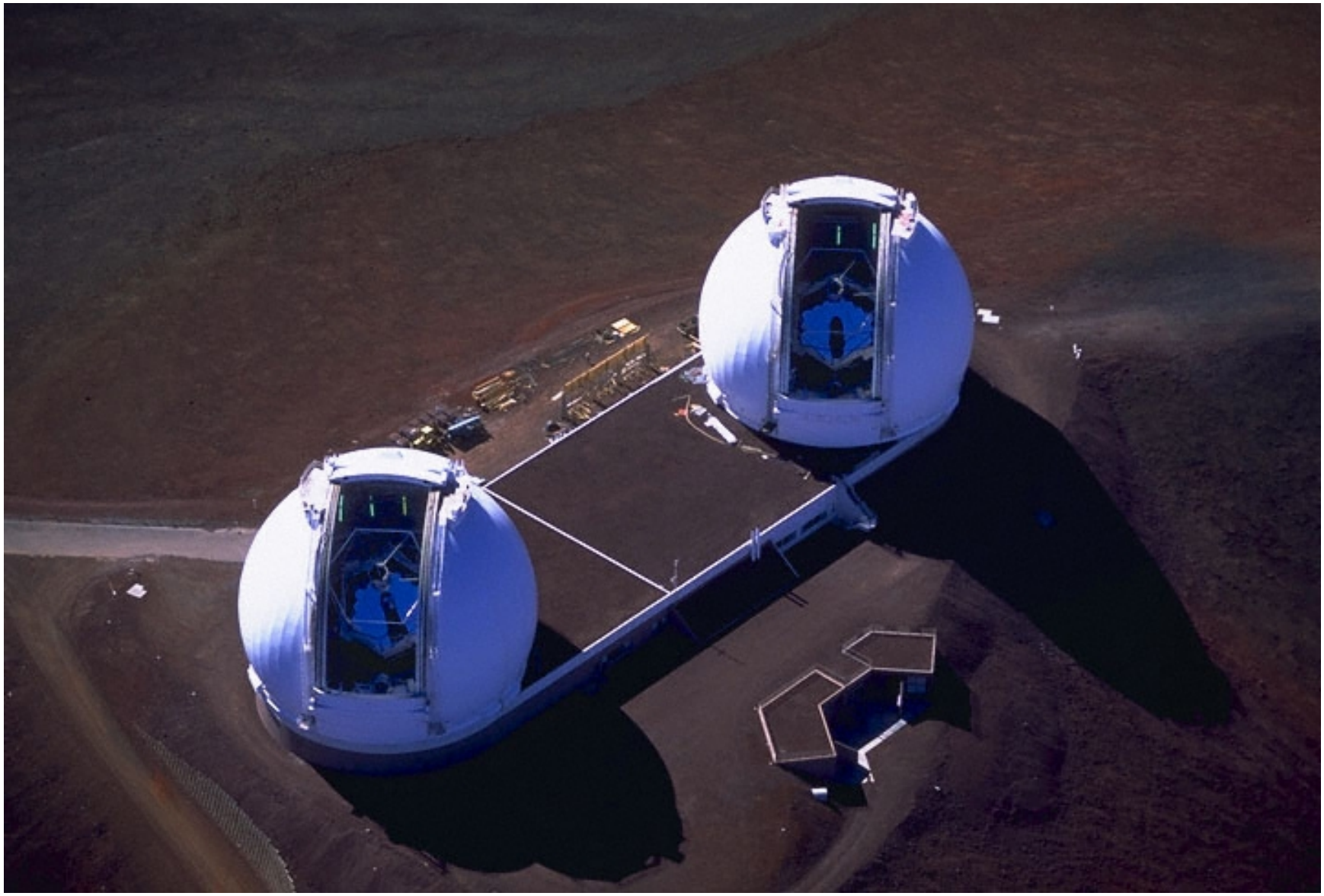
ESO PR Photo 34a/99 (13 August 1999)

© European Southern Observatory

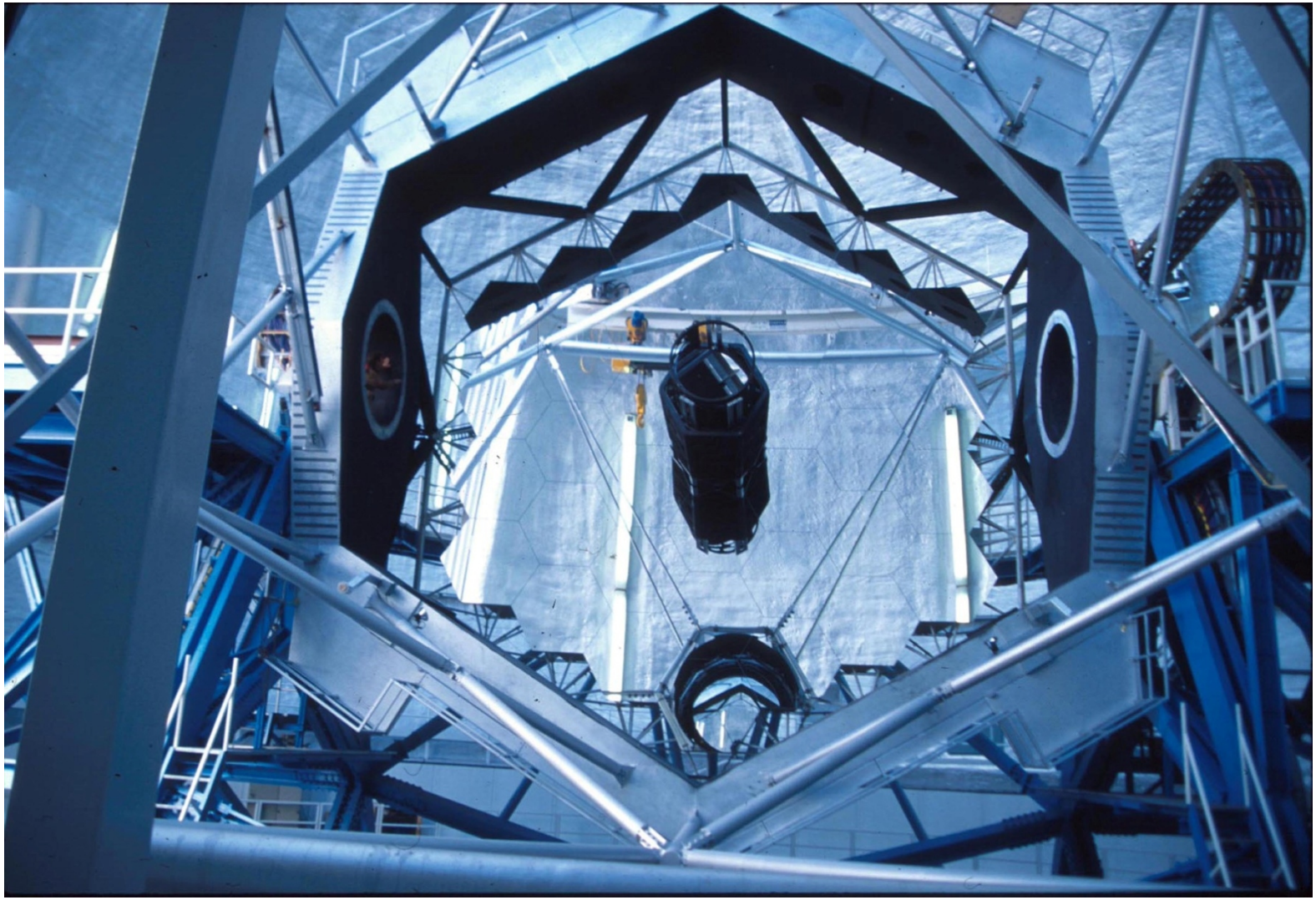
Mauna Kea, Hawaii , 4200m a.s.l. - Keck I e II



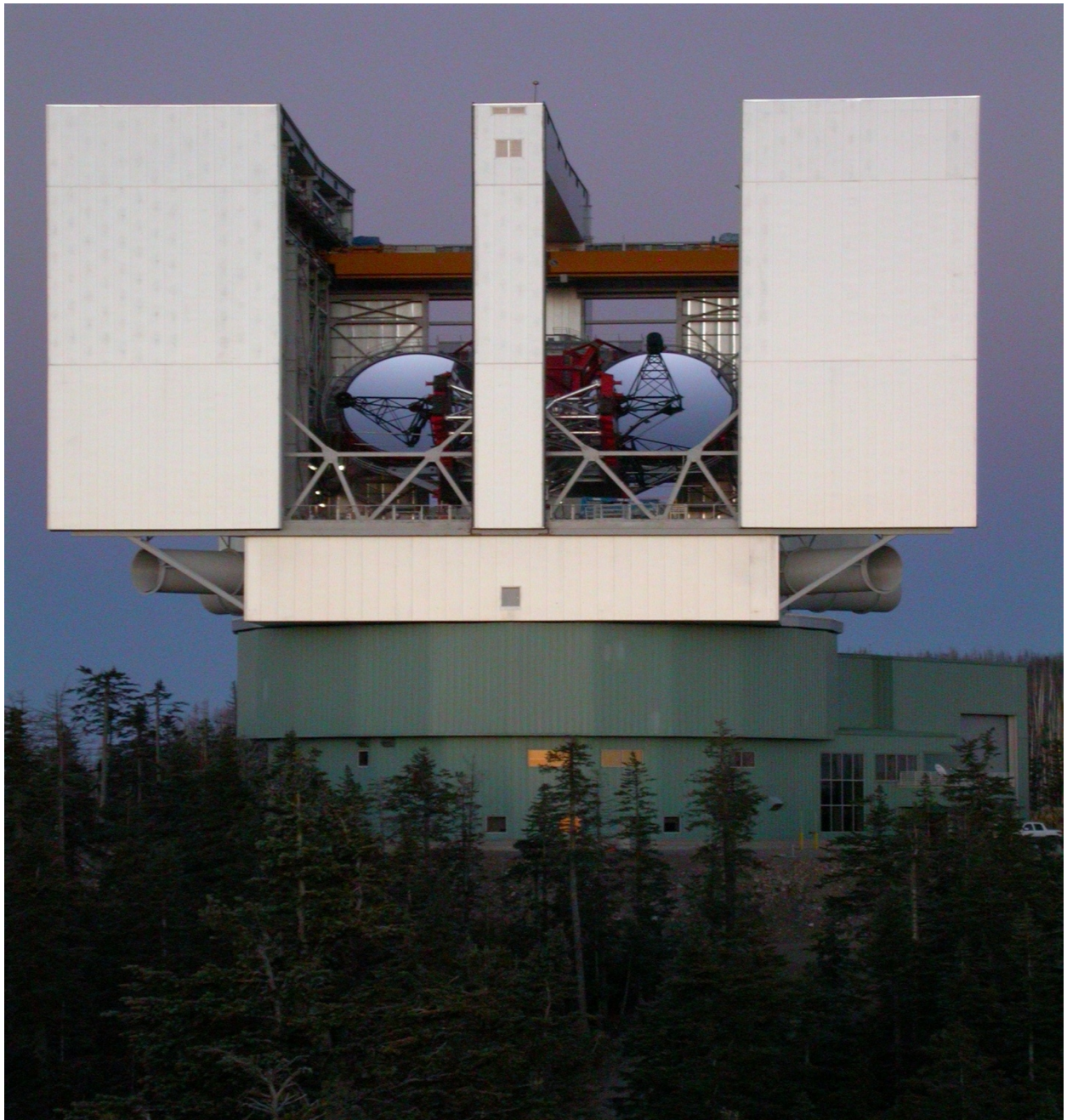
Keck I e II – 10m



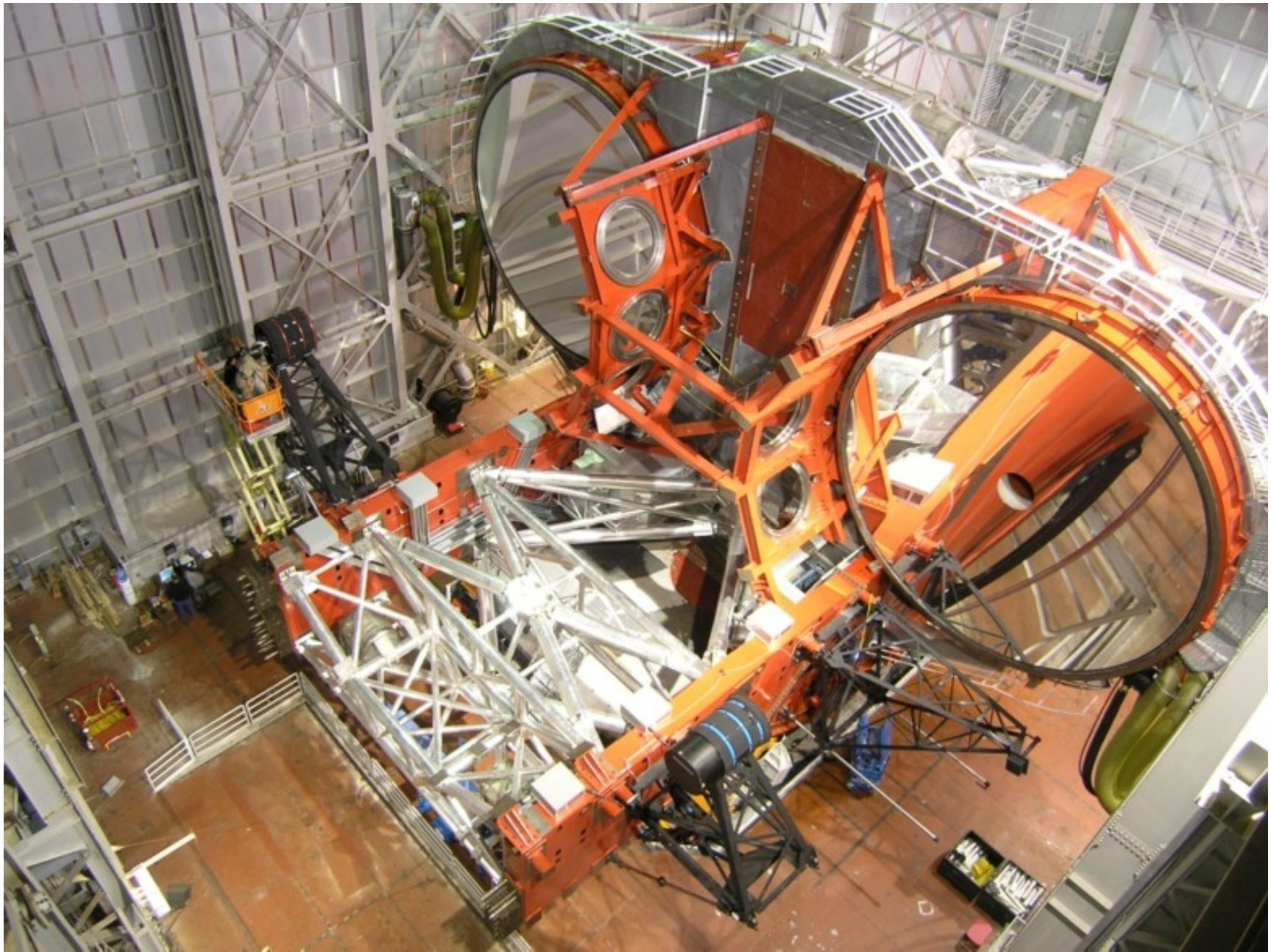
Mosaic of 36 esagonal mirrors



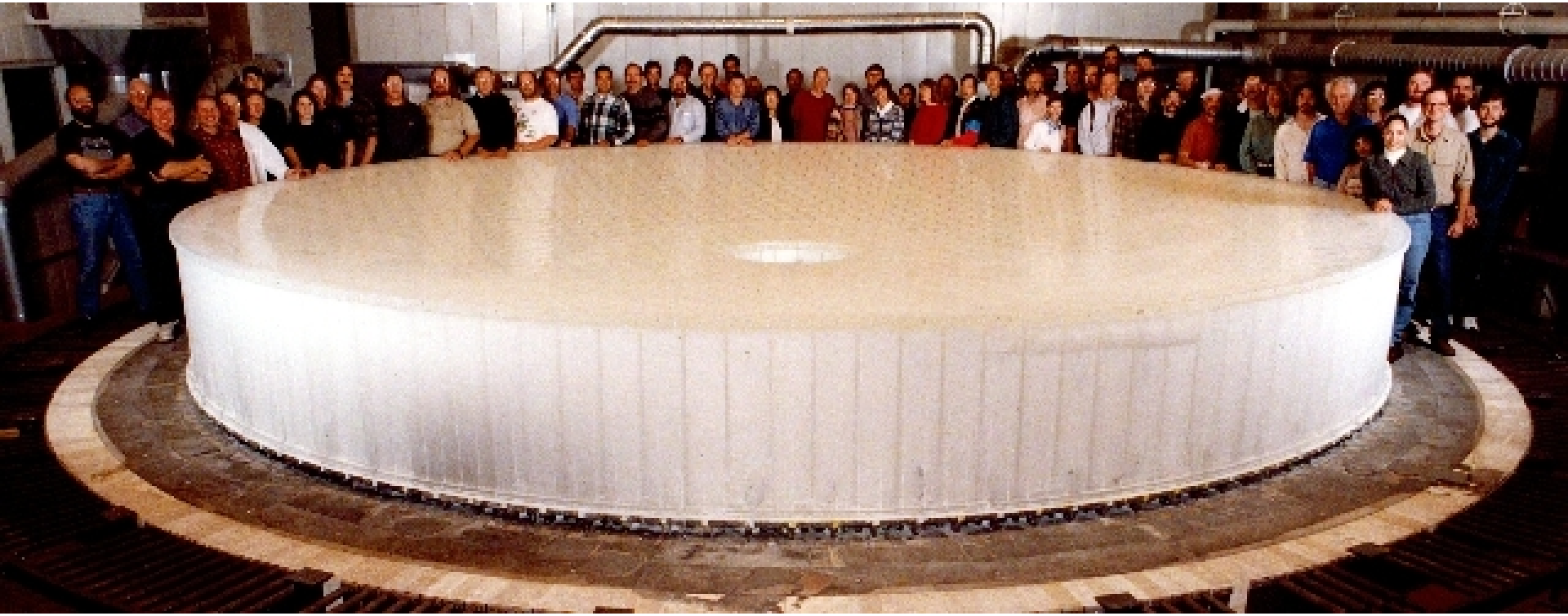
LBT (USA, Germany, Italy,), Arizona, 2 x 8.4m



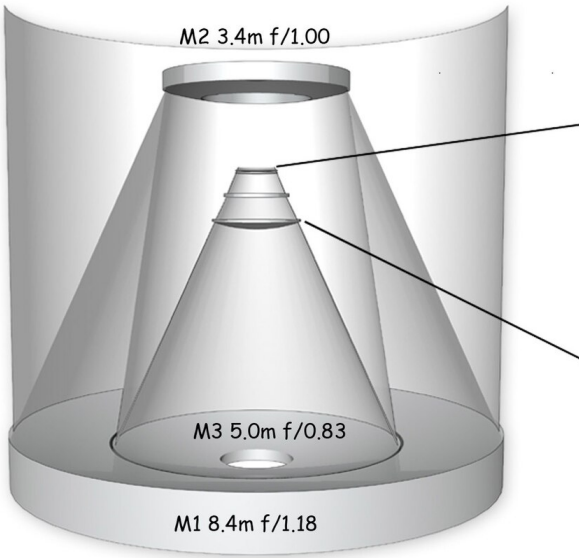
2 x 8.4m in one mounting – has (almost) the resolution of 22m mirror



One of the LBT mirrors



Vera Rubin Observatory
Legacy Survey of Space and Time (LSST)

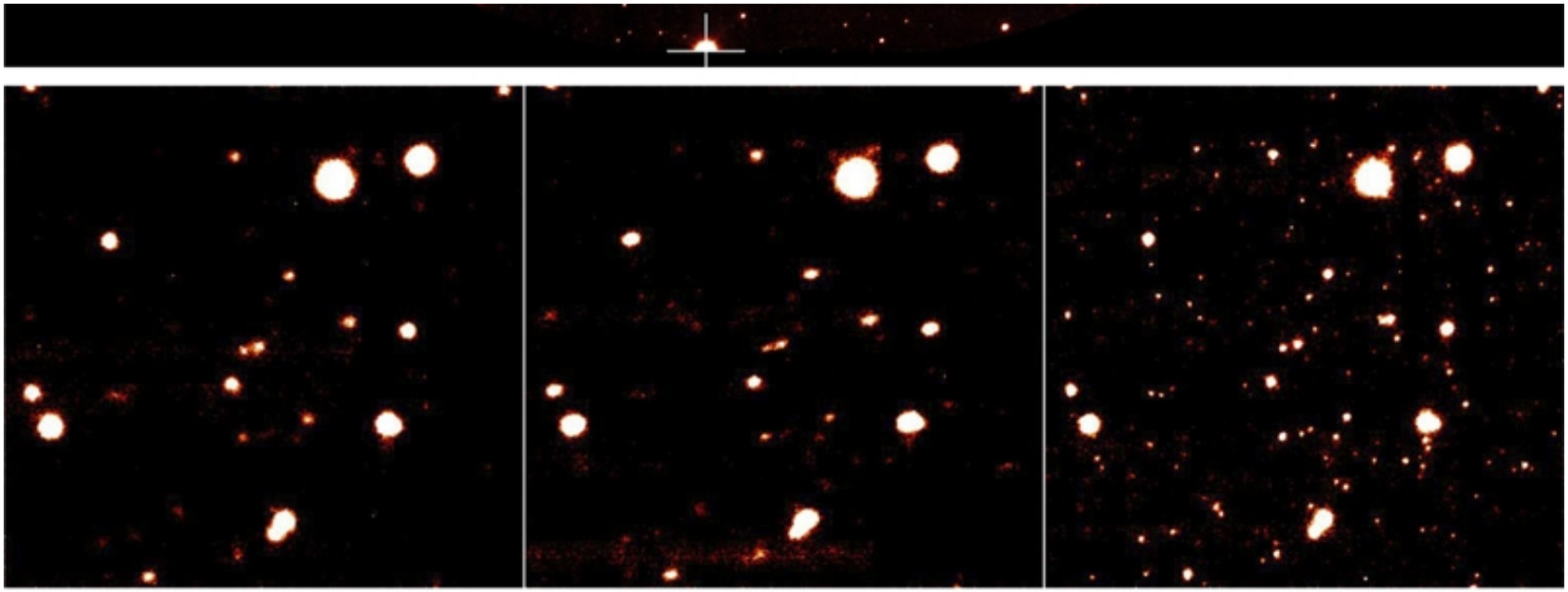








In a sharp image we can see fainter objects



Comparing AO Techniques

ESO Press Photo 19e/07 (30 March 2007)

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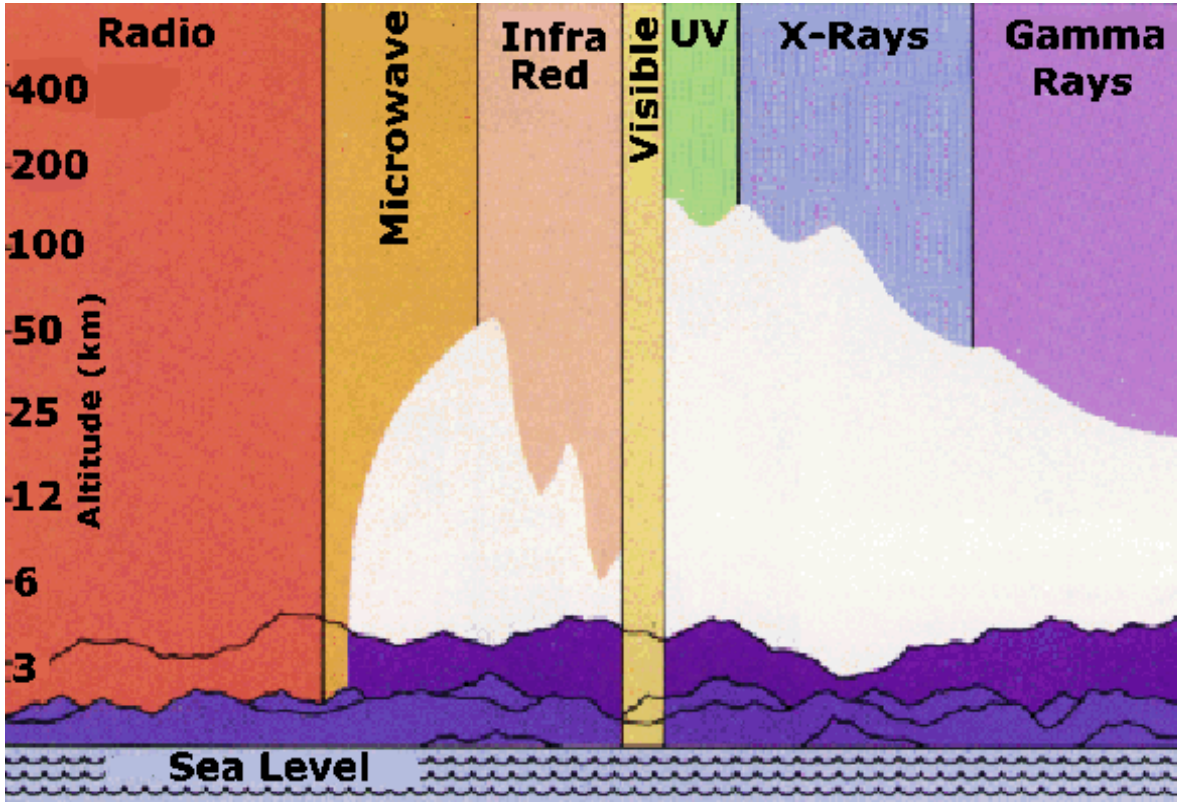
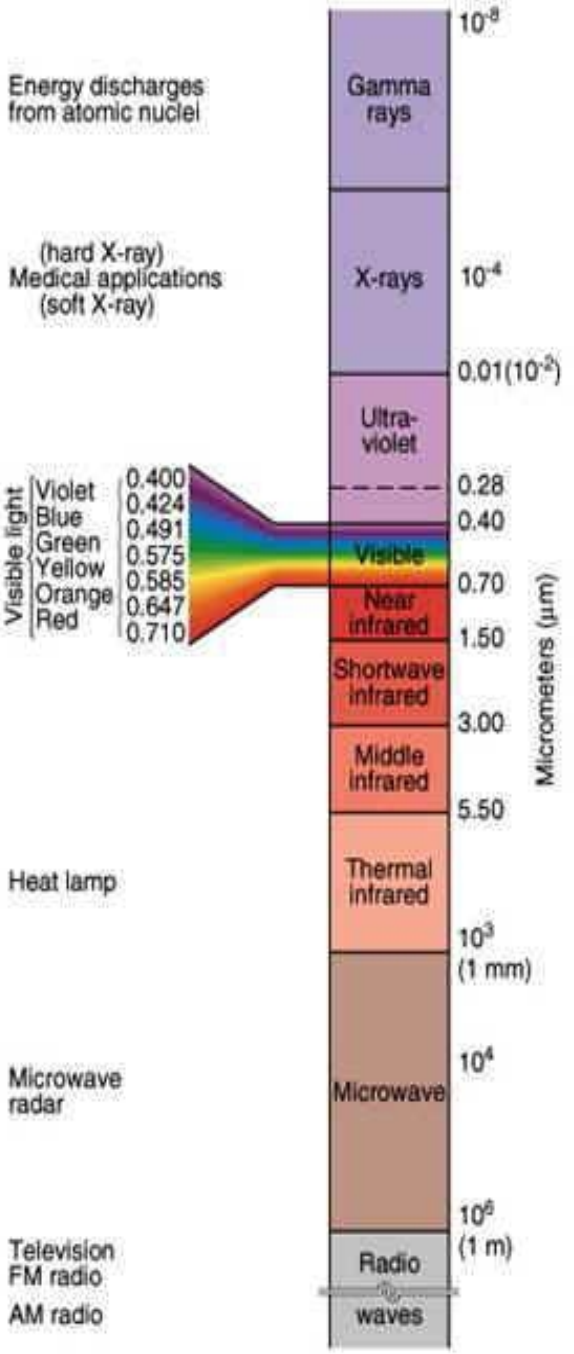
Atmospheric Transparency





ALMA – Atacama Large Millimeter/submillimeter Array
- 50 12-m antennas, baselines up to 16 km.
- to be completed in 2013
-located on the Chajnantor plain, altitude of 5000 meters. Exceptional atmospheric transparency at millimeter/sub-millimeter wavelengths (dry air)

The design of ALMA is driven by three key science goals:

-The ability to detect spectral line emission from CO or CII in a normal galaxy like the Milky Way at a redshift of z=3, in less than 24 hours,
- The ability to image the gas kinematics in protostars and in protoplanetary disks around young Sun-like stars in the nearest molecular clouds (150 pc),
- The ability to provide precise high dynamic range images at an angular resolution of 0.1 arcsec.
- ALMA will be a premier tool for studying the first stars and galaxies that emerged from the cosmic "dark ages" billions of years ago.





1974 Arecibo, Puerto Rico
natural hill - 305m



$$\sin\theta = 1.22\frac{\lambda}{D}$$

Es.: lambda=21cm; D=300m → 21/300000*1.22 → theta= 0.056°=3.4’

Effelsberg, Germany

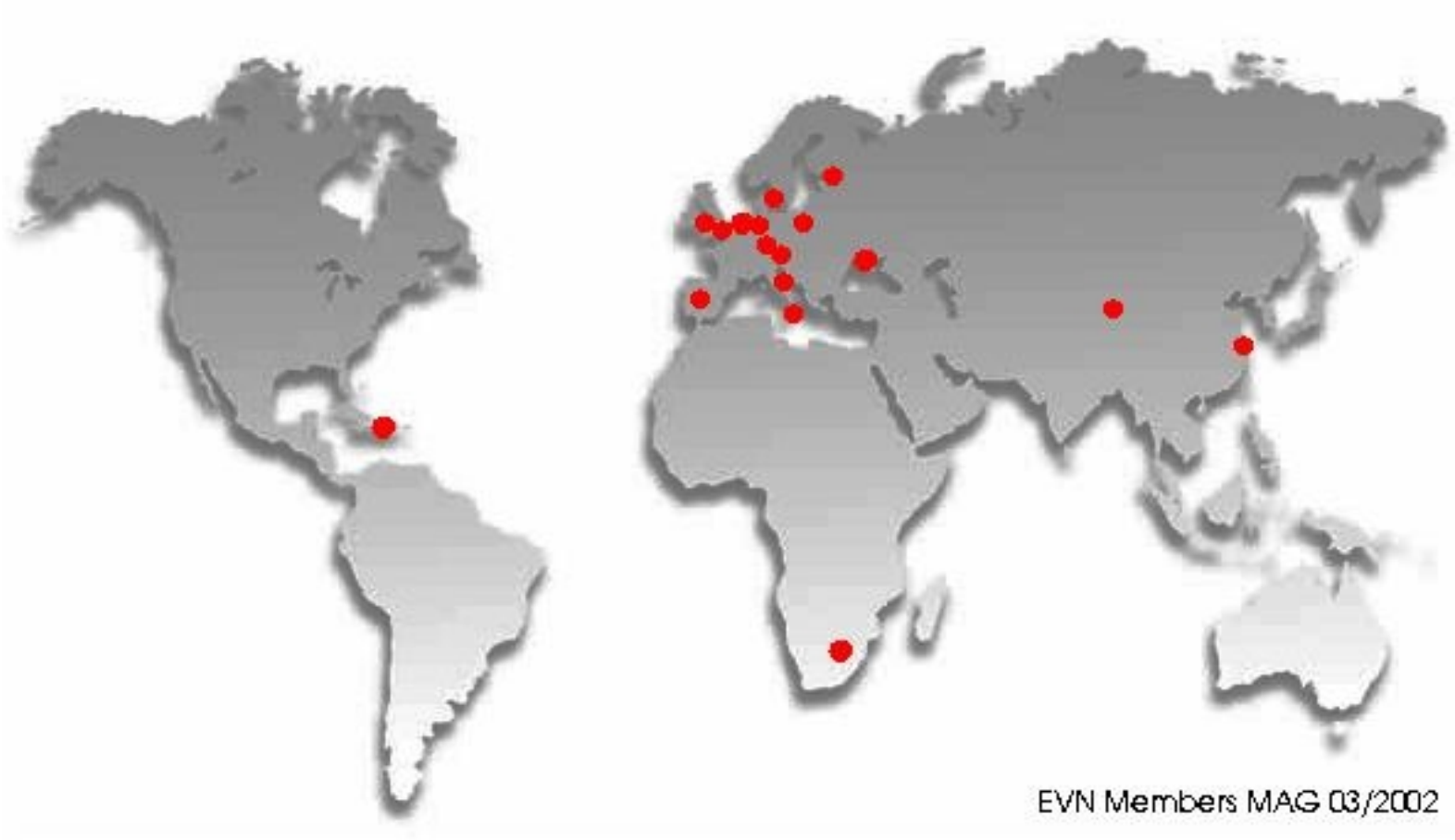
100m



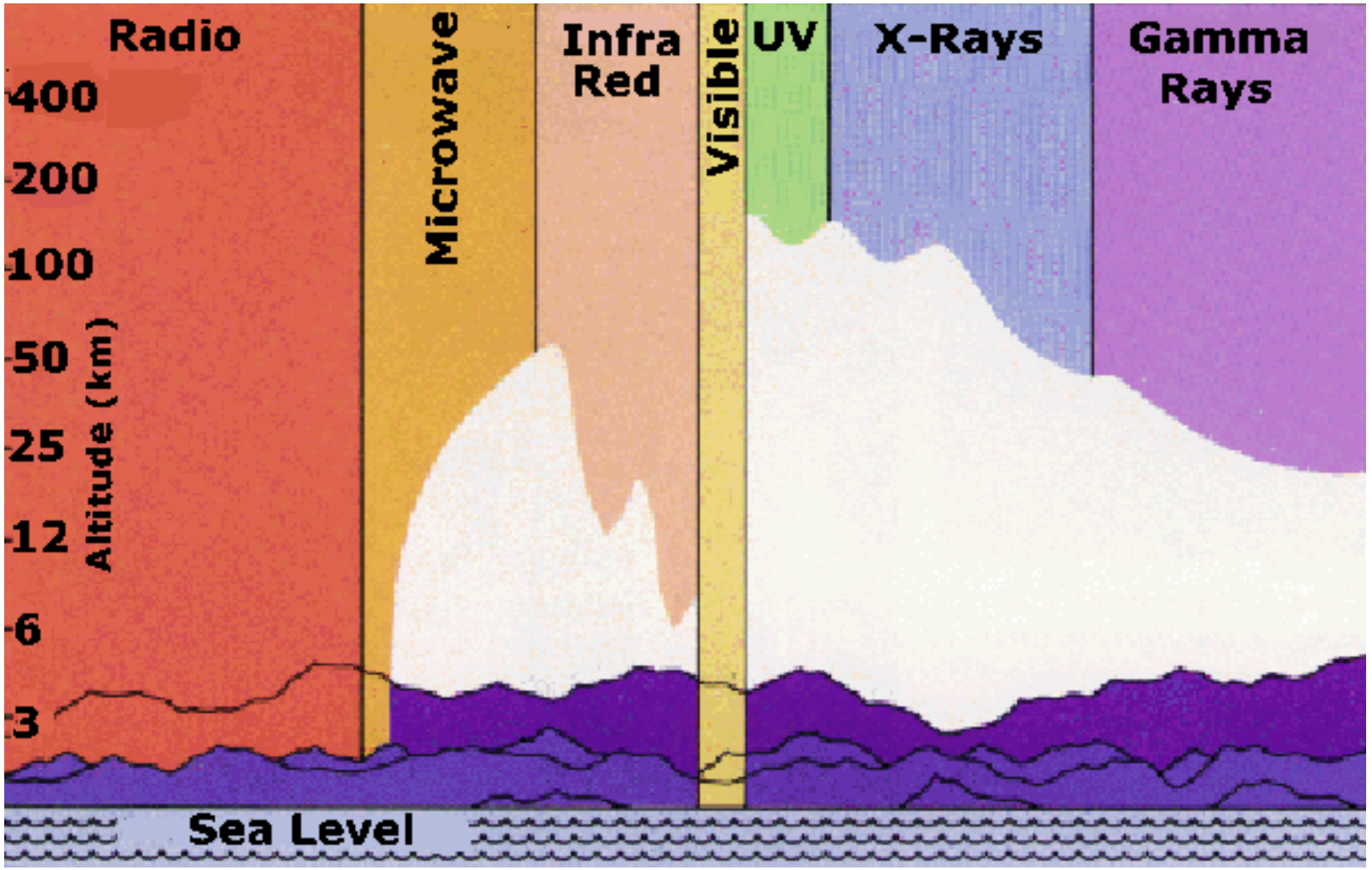
VLA, Socorro, New Mexico;
27 antennas of 25m each, the array is 21km in radius



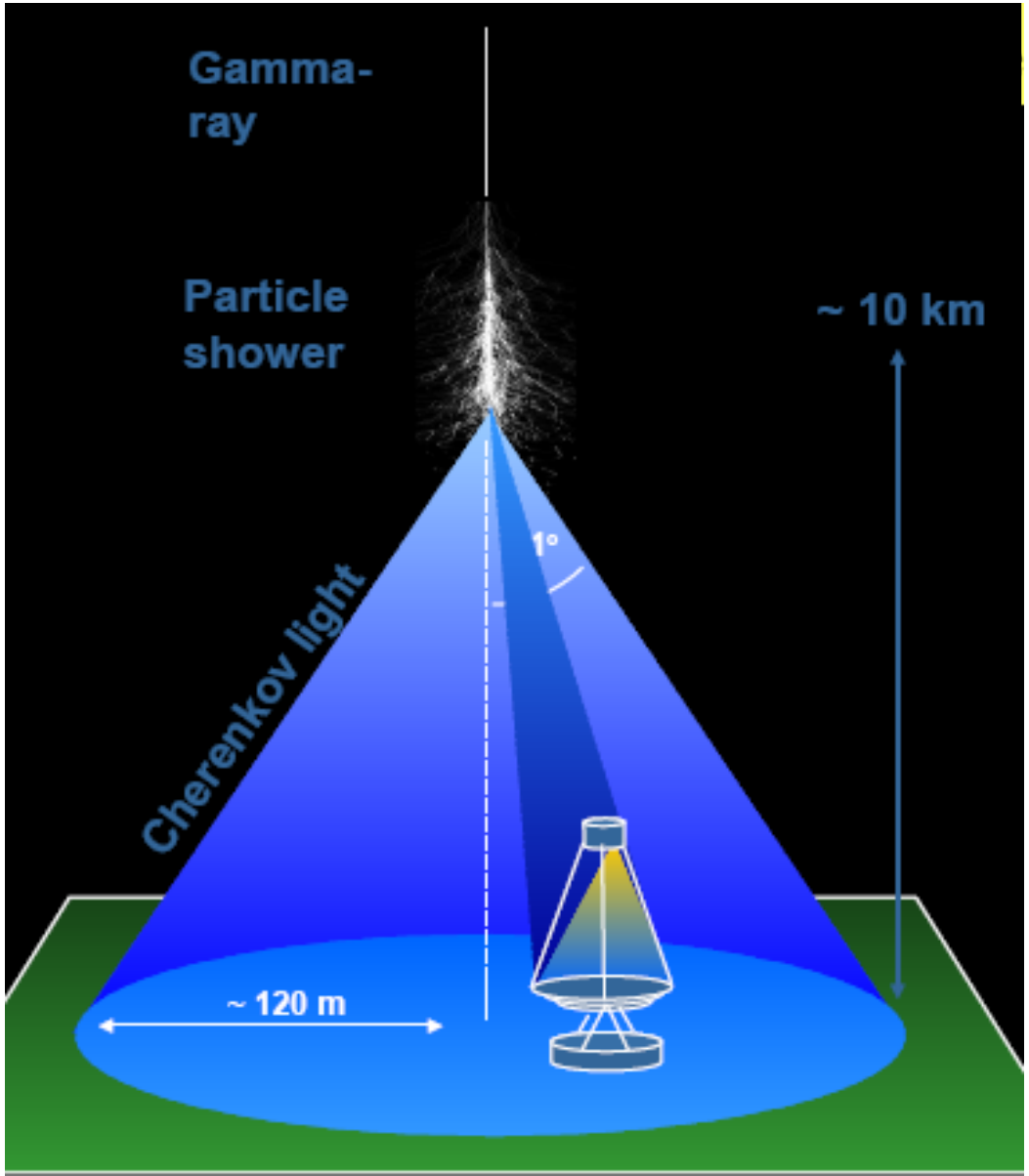
EVN (European Very-long-baseline Network)



Atmospheric Transparency



Cherenkov Telescopes – hard Gamma ray



Large collecting surface, high sensitivity.
A good optical quality is not needed.
The telescope needs only to find the position from which the particle shower is coming from





MAGIC – la Palma, 100 meter

Above the Atmosphere

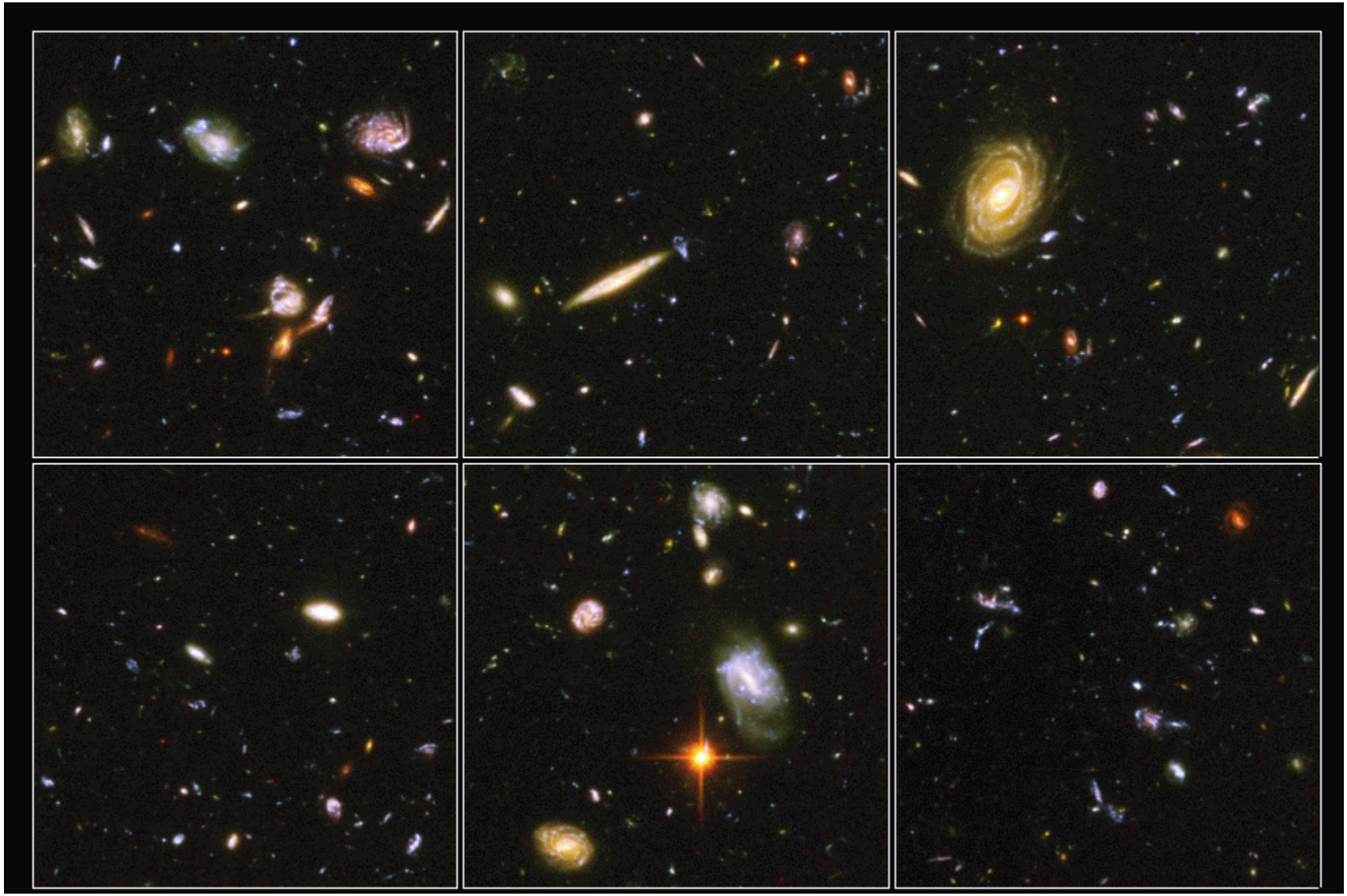
To avoid atmosphertic turbolence

To avoid atmospheric opacity

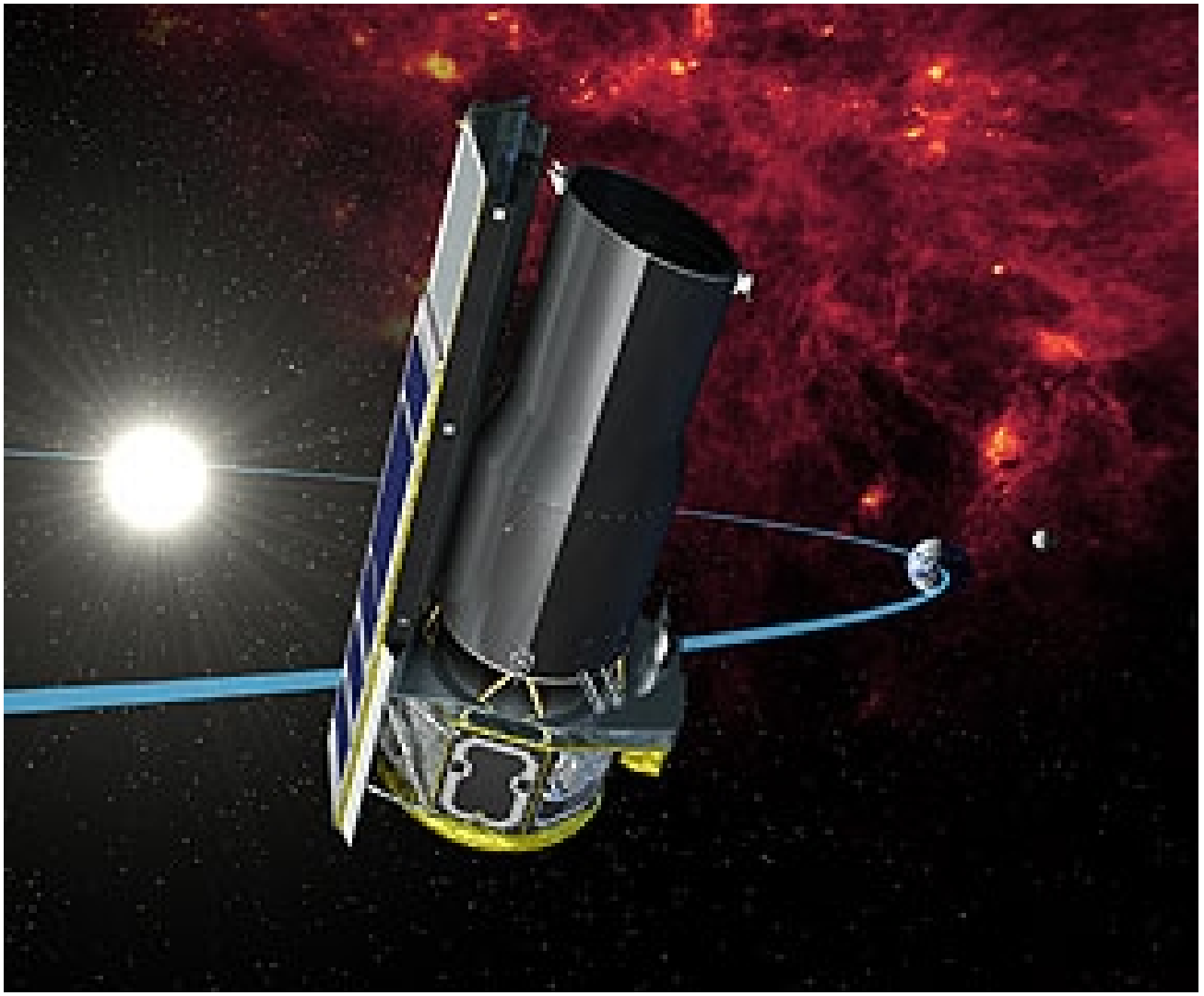
HST - Hubble Space Telescope 2m – UV, visibile, NIR NASA 1990- 2030?



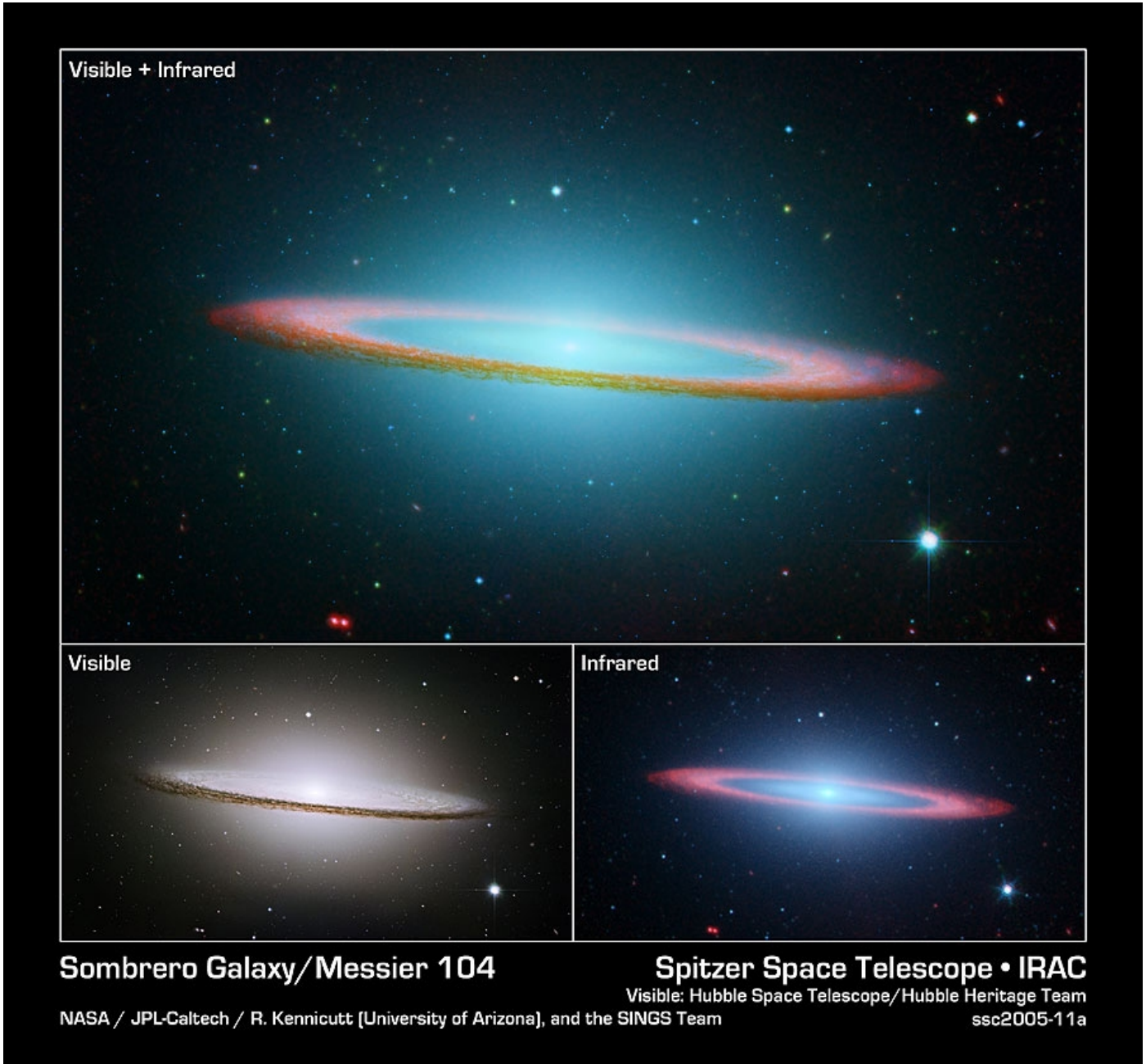
Hubble Ultra Deep Field



Spitzer – 85 cm – infrared NASA 2003-2006-2020



The Sombrero galaxy



GALEX – 50cm - Ultraviolet – NASA 2003-2009



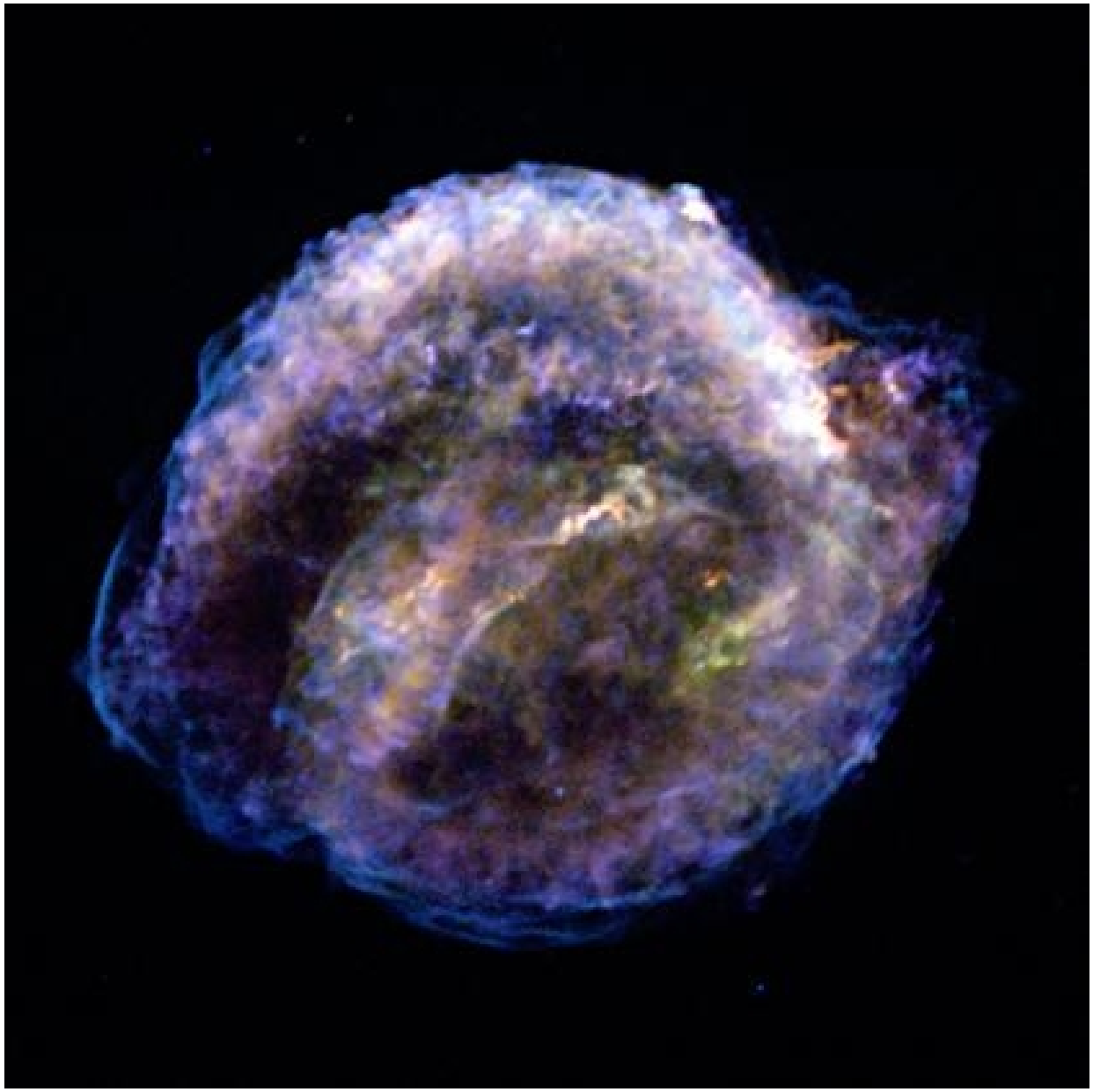
Andromeda as seen by da GALEX



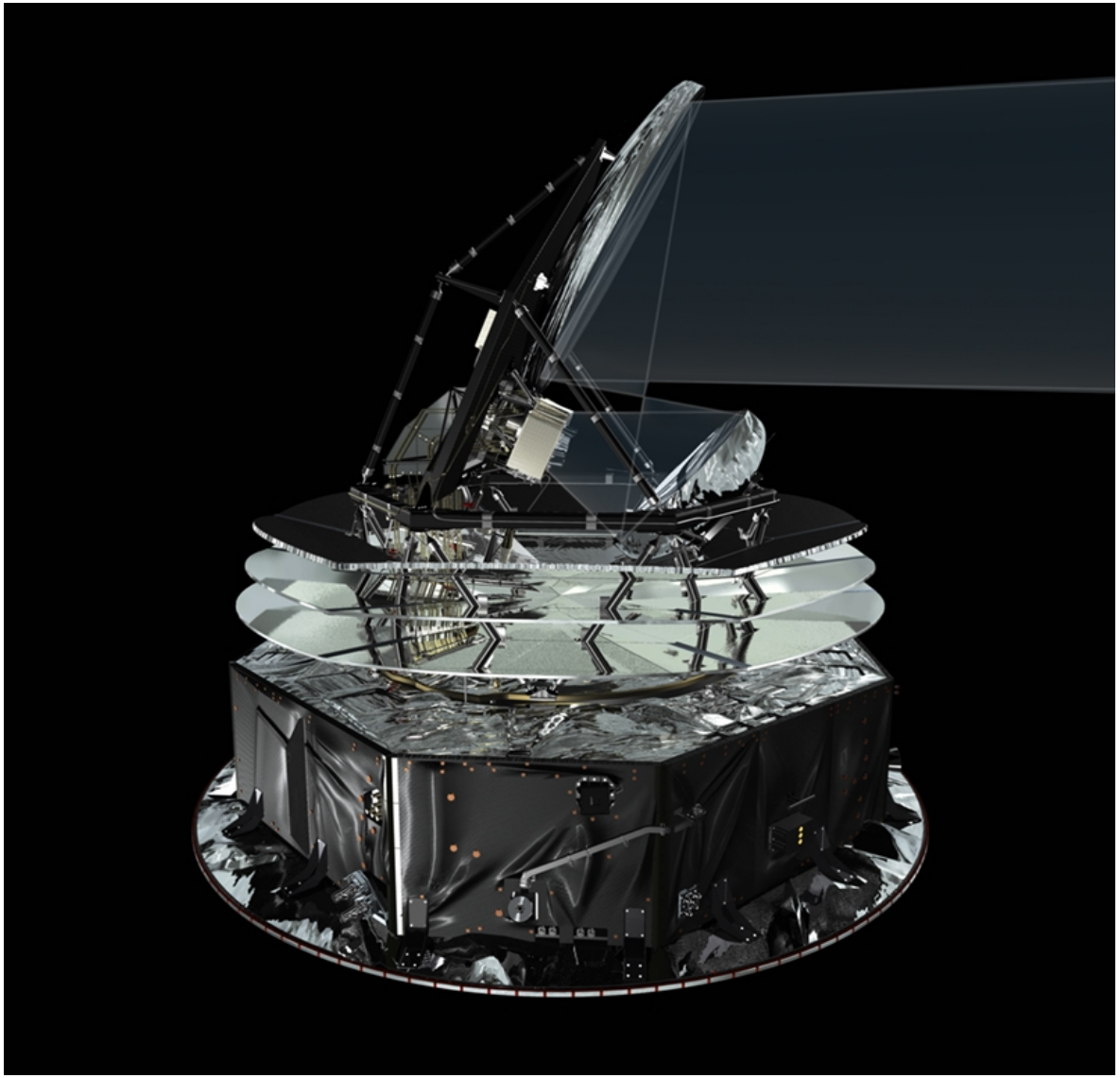
NASA Chandra – 1.2m, X-ray
1999-



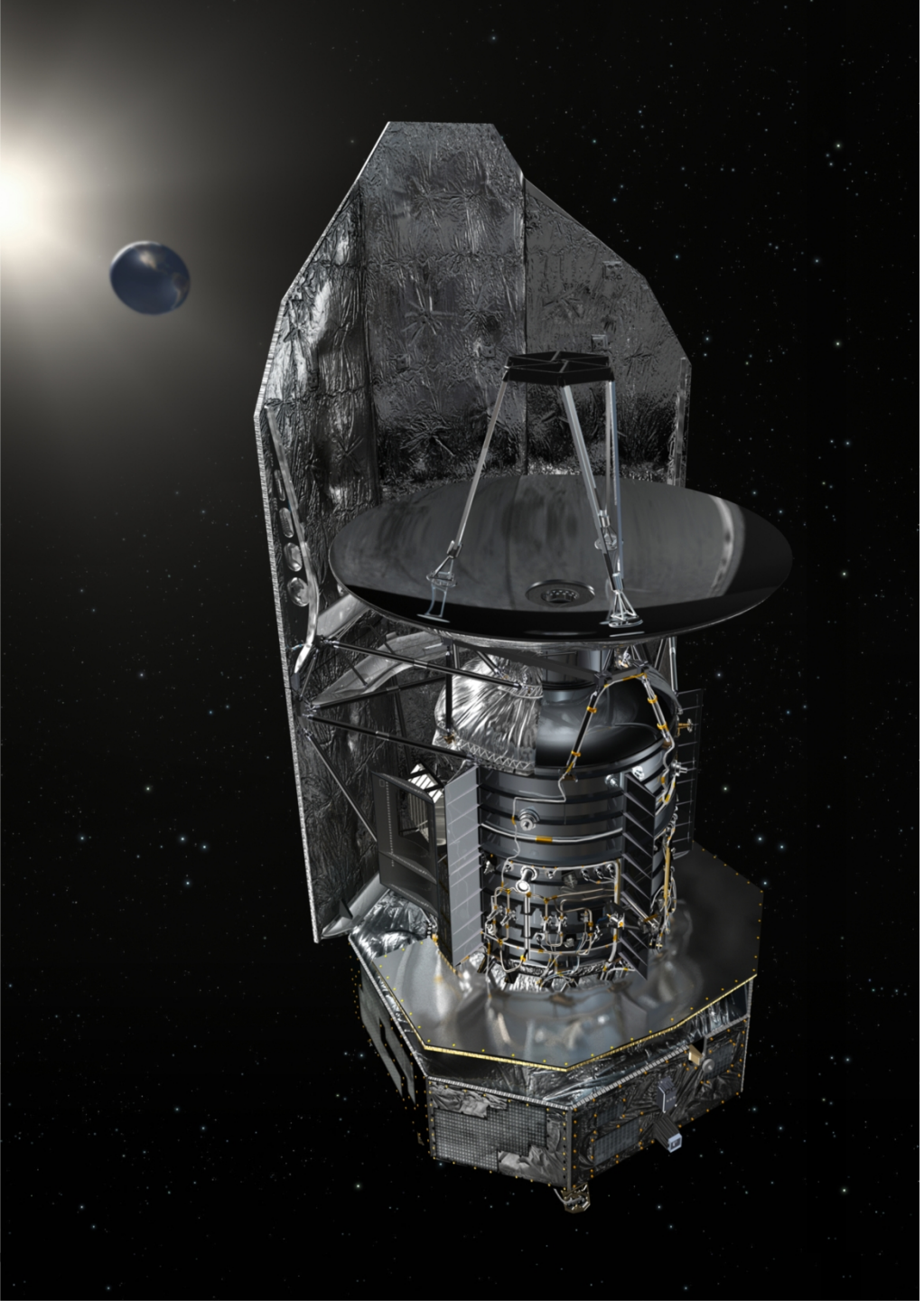
The remnants of the Kepler Supernova



2009 - Plank



Study of the cosmic microwave background



Herschel

ESA 2009-2013

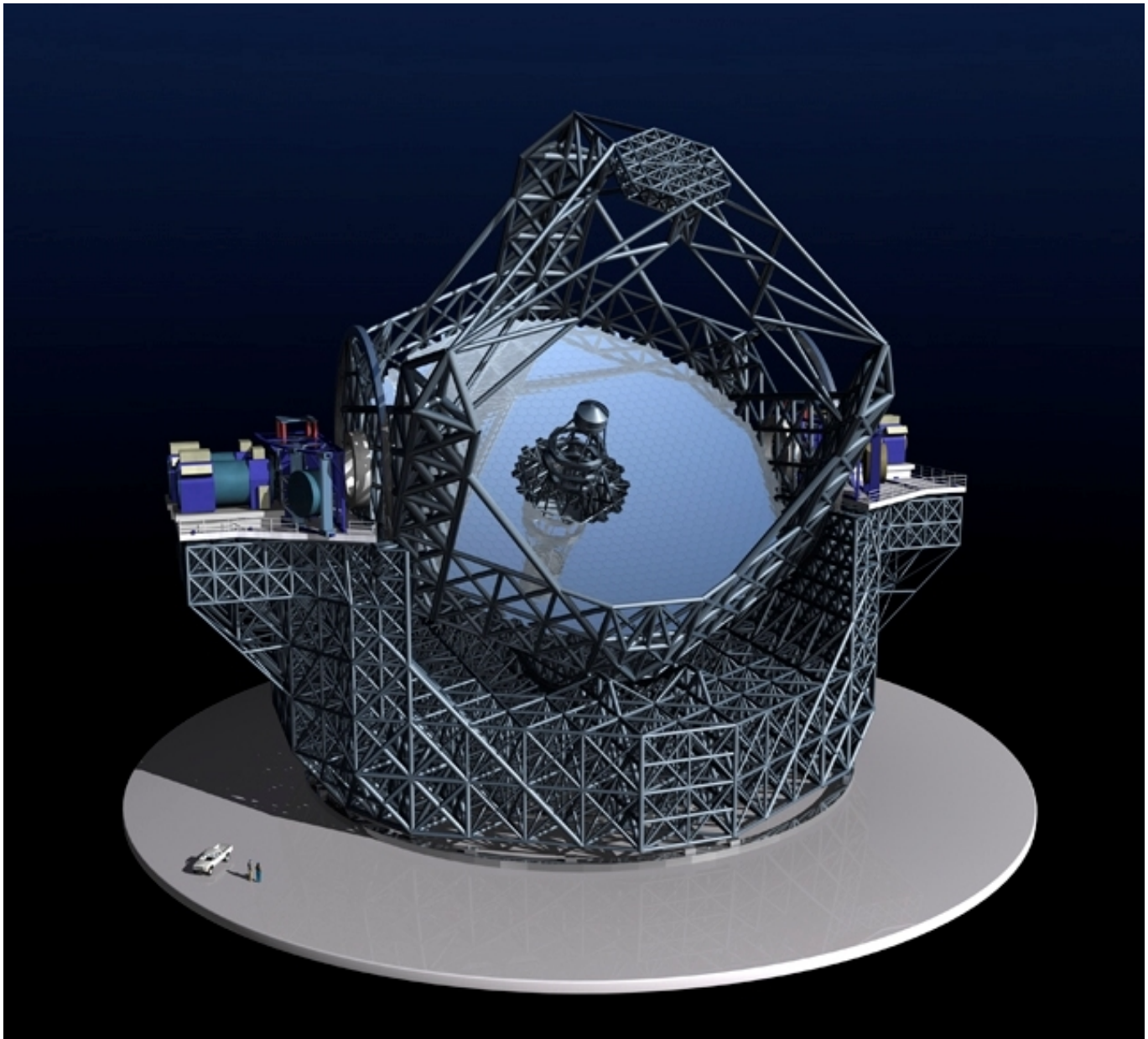
3.5-m diameter mirror

Infrared

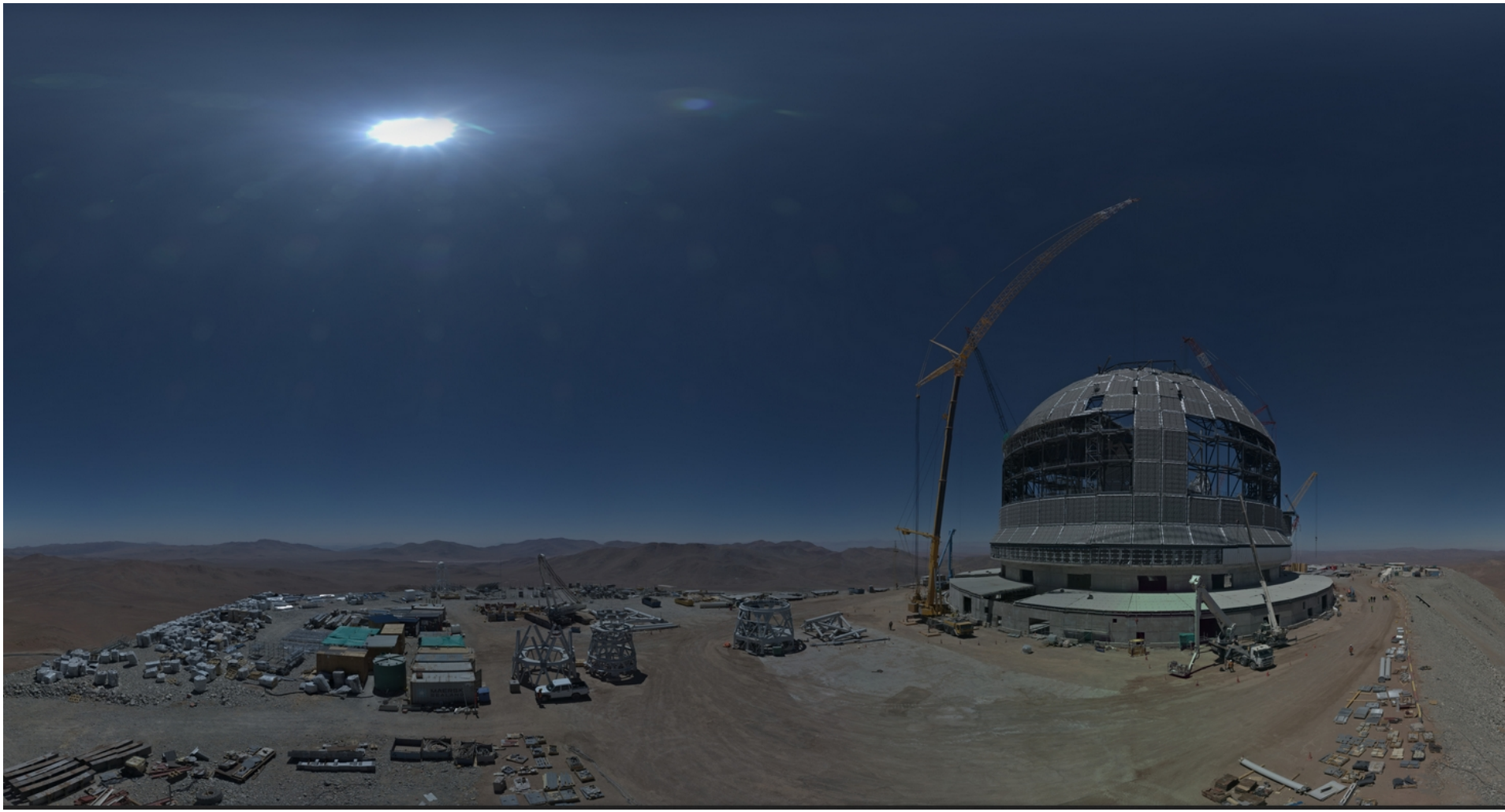
NASA 2022 – JWST James Web Space Telescope 6.6m – from Visible (R-band) to infrared



ELT – Extremely Large Telescope
39 metri – visibile - 2028



ELT – Extremely Large Telescope
39 metri - visibile



ELT – Extremely Large Telescope
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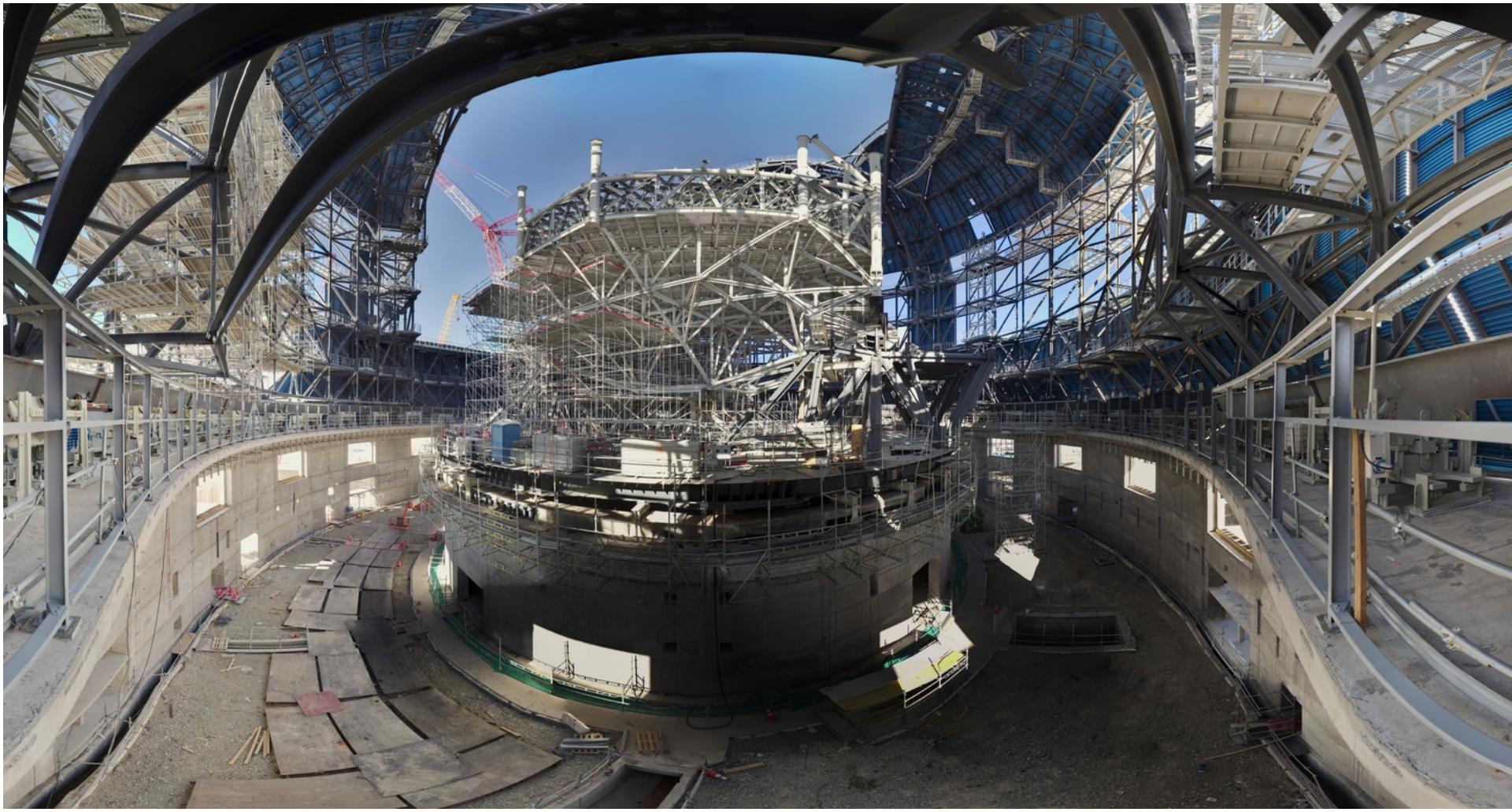

ELT – Extremely Large Telescope
39 metri - visibile