

De ontwikkeling van de observationele sterrenkunde

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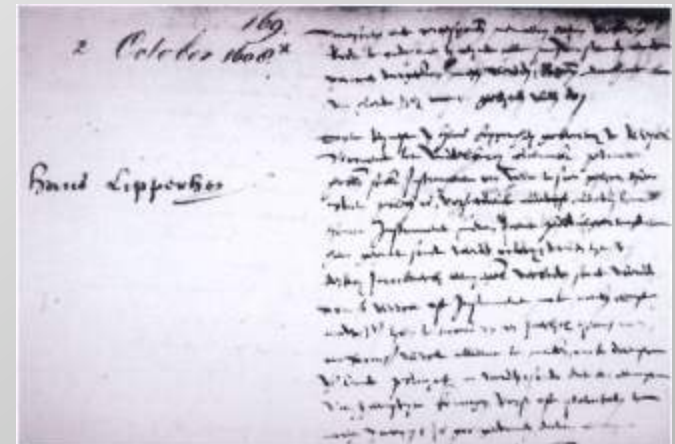
Hoogleraar Observationele astrofysica en instrumentatie

Hans Lipperhey (1570-1619)



Delft (mei 2014) telescoop ~1625

"Hollandsche kijker" (1608)



Ambassadeurs uit Siam bezoeken Prins Maurits op 10 september 1608



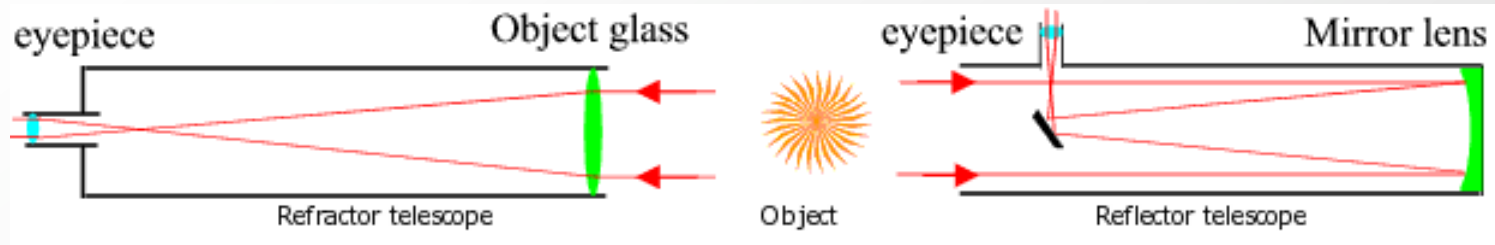
Nieuwsbrief (Zoomers 2008):

- Delegatie uit Siam
- Onderhandelingen 12-jarig bestand (de Spinola)
- Sterrenkijker Hans Lipperhey

"Een paar dagen voor het vertrek van de Spinola bood een opticien uit Middelburg een paar lenzen aan aan Zijne Excellentie, ..., waarmee het mogelijk was om de ramen van de kerk in Leiden te zien. ... Zelfs sterren die niet met het blote oog kunnen worden gezien."

Prins Maurits (1567-1625)

Telescopen



$$\frac{h_2}{h_1} = \frac{f_1}{f_2} = M$$

$$E = D \cdot \frac{f_{oc}}{f_{obj}} = \frac{D}{M}$$

Vergroting ($M < 100$ vanwege "seeing")

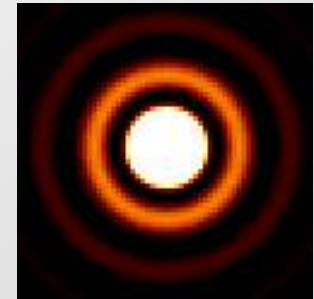
Uittree pupil (beeld dat oculair vormt van objectief)
Gegeven $D \rightarrow$ limiet op M

Vergroting belangrijk voor het waarnemen van de
Maan, planeten, ...

Versterking (concentratie) is wat telt voor puntbronnen
en zwakke objecten

Scheidend vermogen

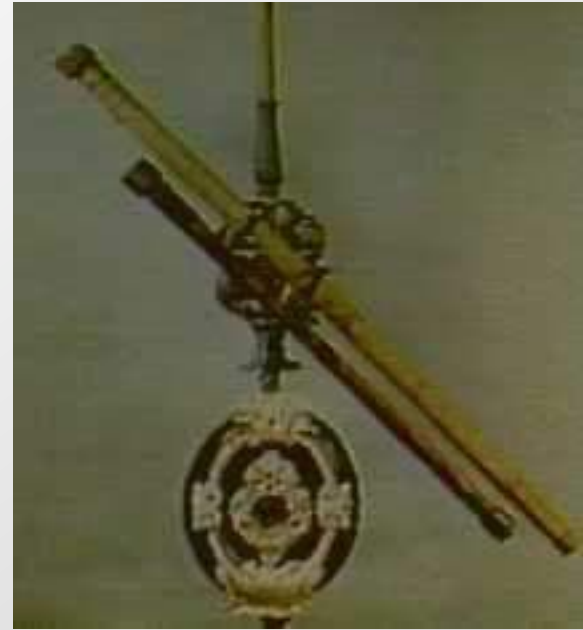
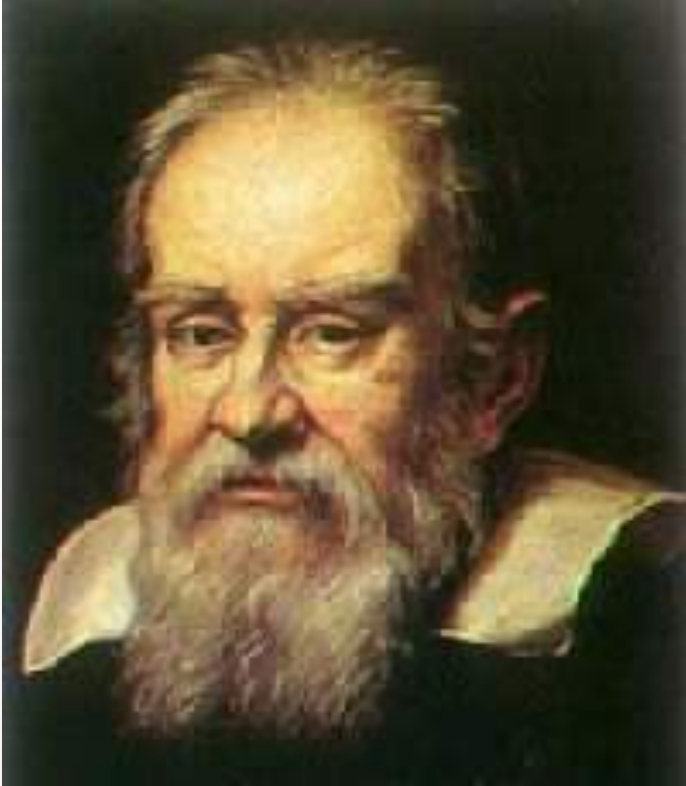
$$\Theta = 1.22 \frac{\lambda}{D}$$



Airy disk

Θ : afstand (in boogmaat) tussen helder centrale beeld en eerste donkere ring

Galileo Galilei (1564-1642)

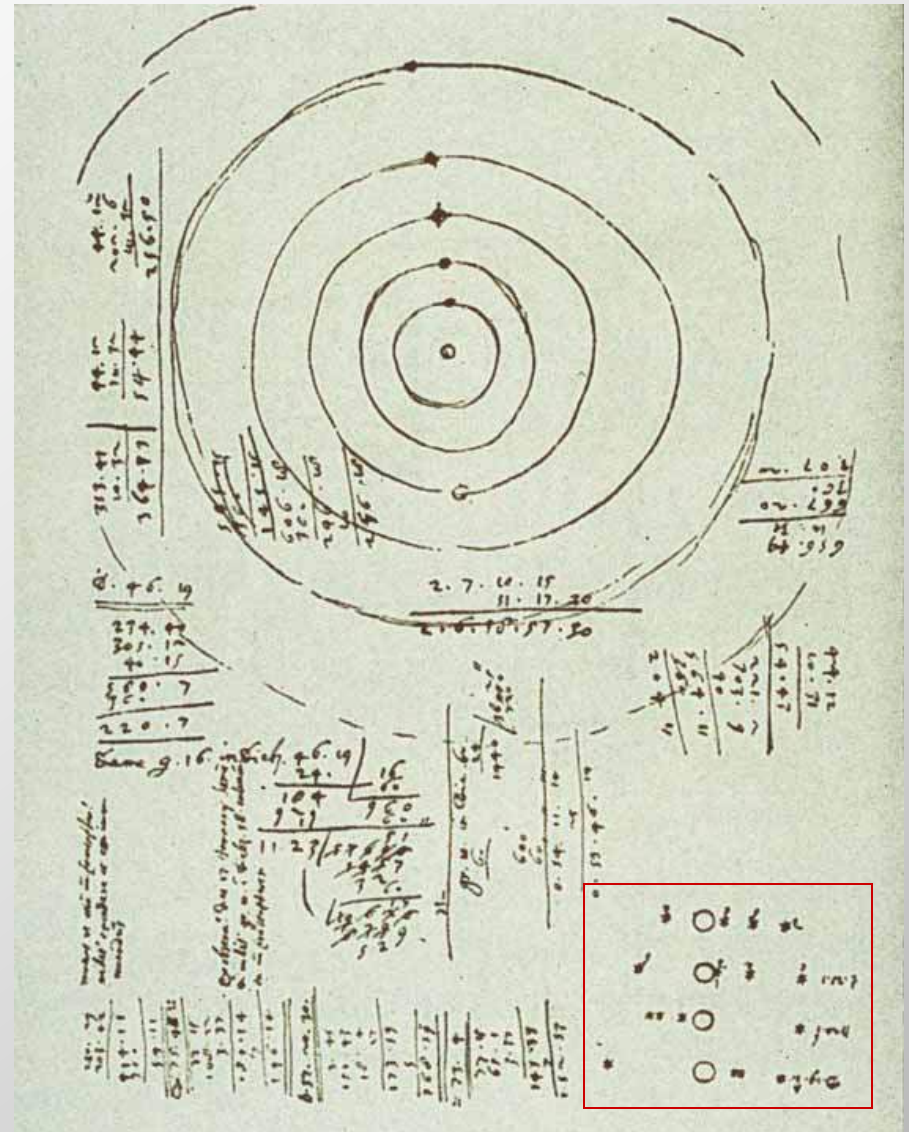


Telescoop van Galilei

San Marco



Sidereus Nuncius (1610)



Jupiter + manen

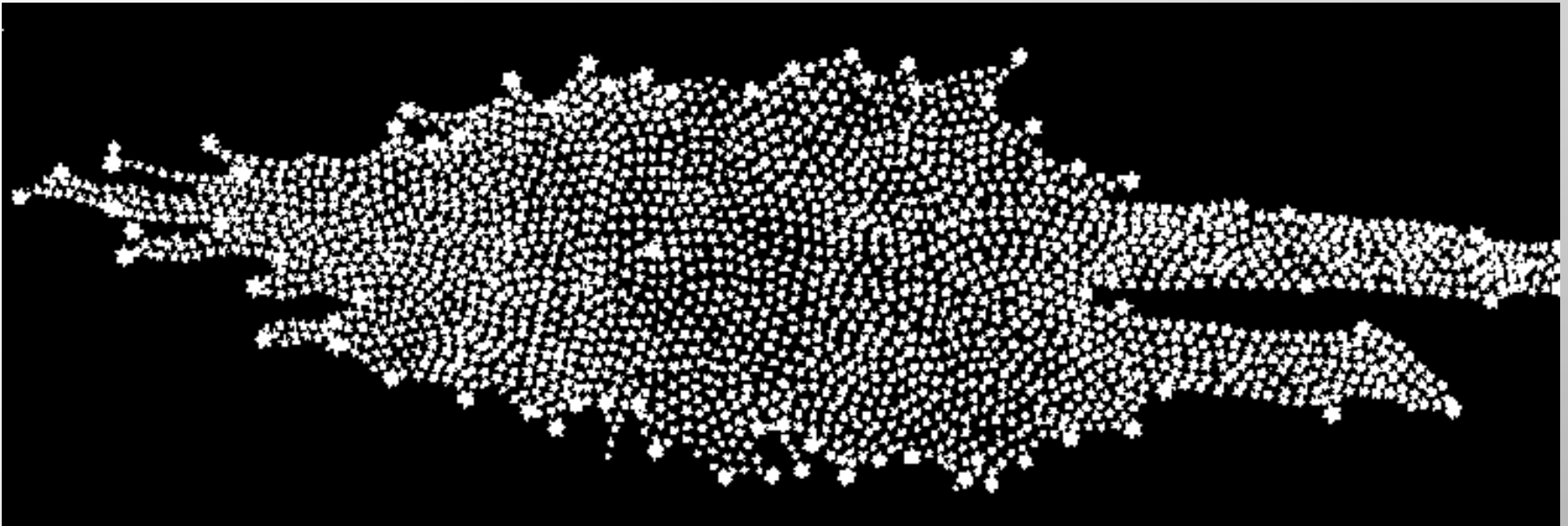
Sir William Herschel (1738-1822)



"40-foot telescope" (1789)

- Stertellingen in ca. 130 velden in een vlak loodrecht op de melkweg:
80 eenheden naar polen
450 eenheden in het vlak

± 100 miljoen sterren
Zon * in centrum
afwijking (rechts) in
richting Scorpio (extinctie)



Jacobus Cornelis Kapteyn (1851-1922)

- Opgave: herleid de sterdichtheid als functie van de afstand uit de verdeling van sterren over hun schijnbare helderheid in een bepaalde richting
- Benodigd: intrinsieke helderheidsverdeling van sterren
Lichtkrachtfunctie
- Methode: statistische aanpak; de gemiddelde eigenbeweging van sterren neemt af met de afstand



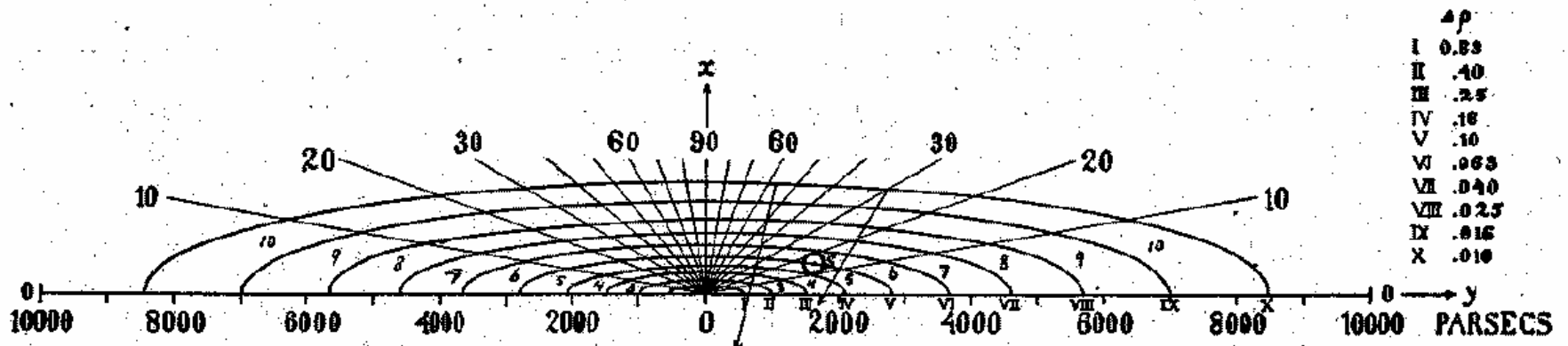
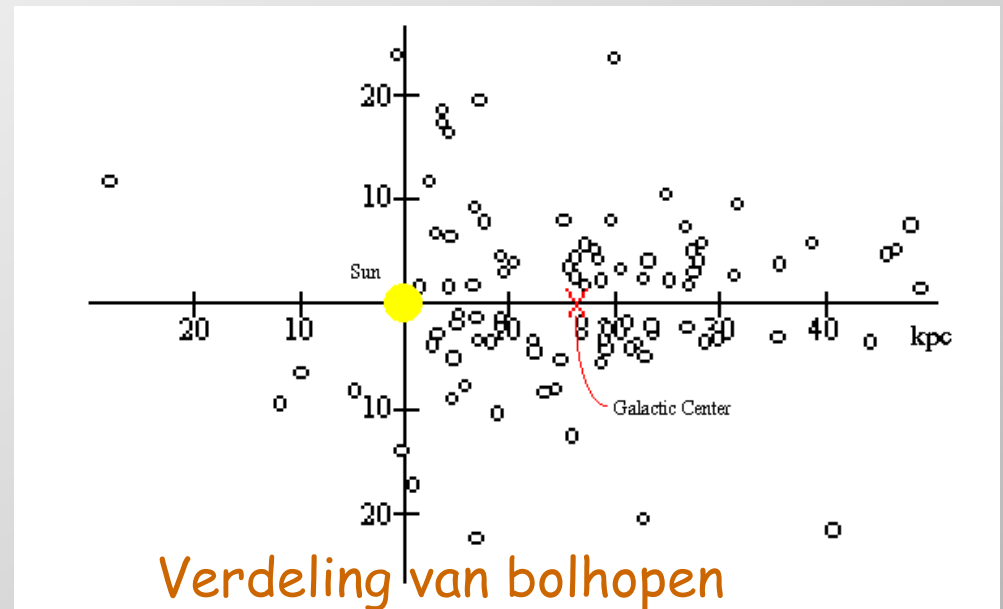


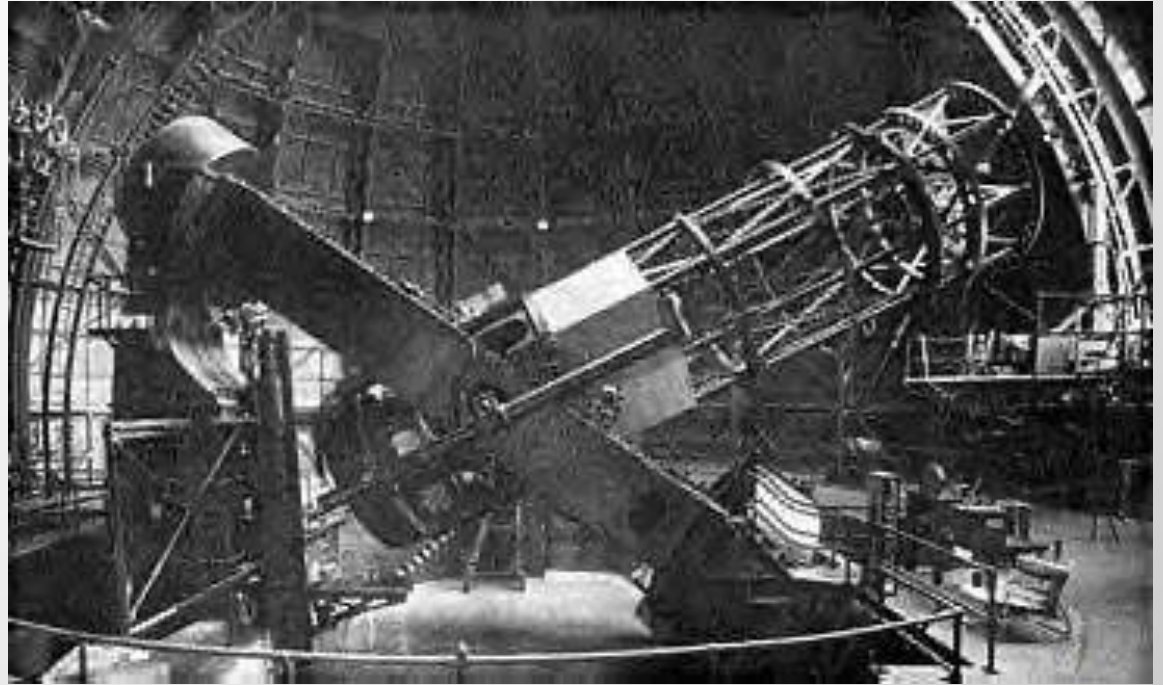
FIG. I

Kapteyn (1922): Sterrenstelsel heeft straal van 3000 pc en een dikte van 1000 pc; de Zon bevindt zich op 650 pc van het centrum

Shapley (1885-1972): Afstand tot centrum melkweg bedraagt 13.5 kpc in de richting van Sagittarius



100" Hooker telescope (1918)



Mount Wilson Observatory

Edwin Hubble (1889-1953)

Edwin Hubble (1889-1953)

- Grootste telescoop: 100 inch Mount Wilson
- Ontdekt (1924) afzonderlijke sterren in Andromeda (M31) en M33: Cepheiden → afstand 2×10^6 lichtjaar
- Spectra van vele sterrenstelsels → roodverschuiving
 - Melkwegstelsels bewegen van elkaar weg
 - $v = H \times r$
- Classificatie sterrenstelsels



Edwin Hubble bij de 48 inch
Telescoop op Mount Palomar

Anton Pannekoek Observatorium





M 57, Ring nebula in Lyra, L + Ha + OIII + SII
M 97, Owl nebula in Ursa Major, L + Ha + OIII + SII

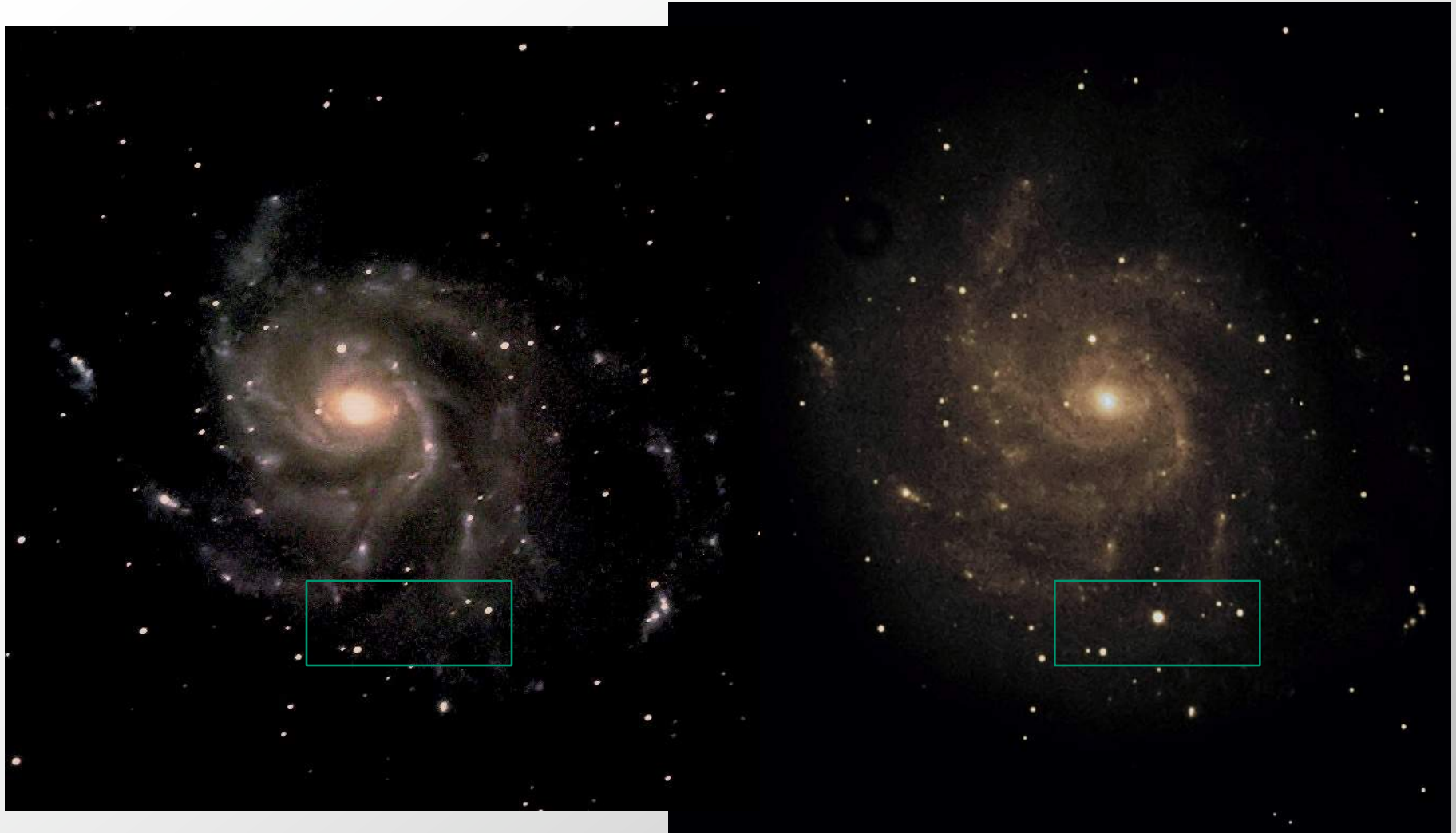
AP0
Amsterdam



Whirlpool Galaxy in Canes Venatici, L + Ha + V + B

AP0
Amsterdam

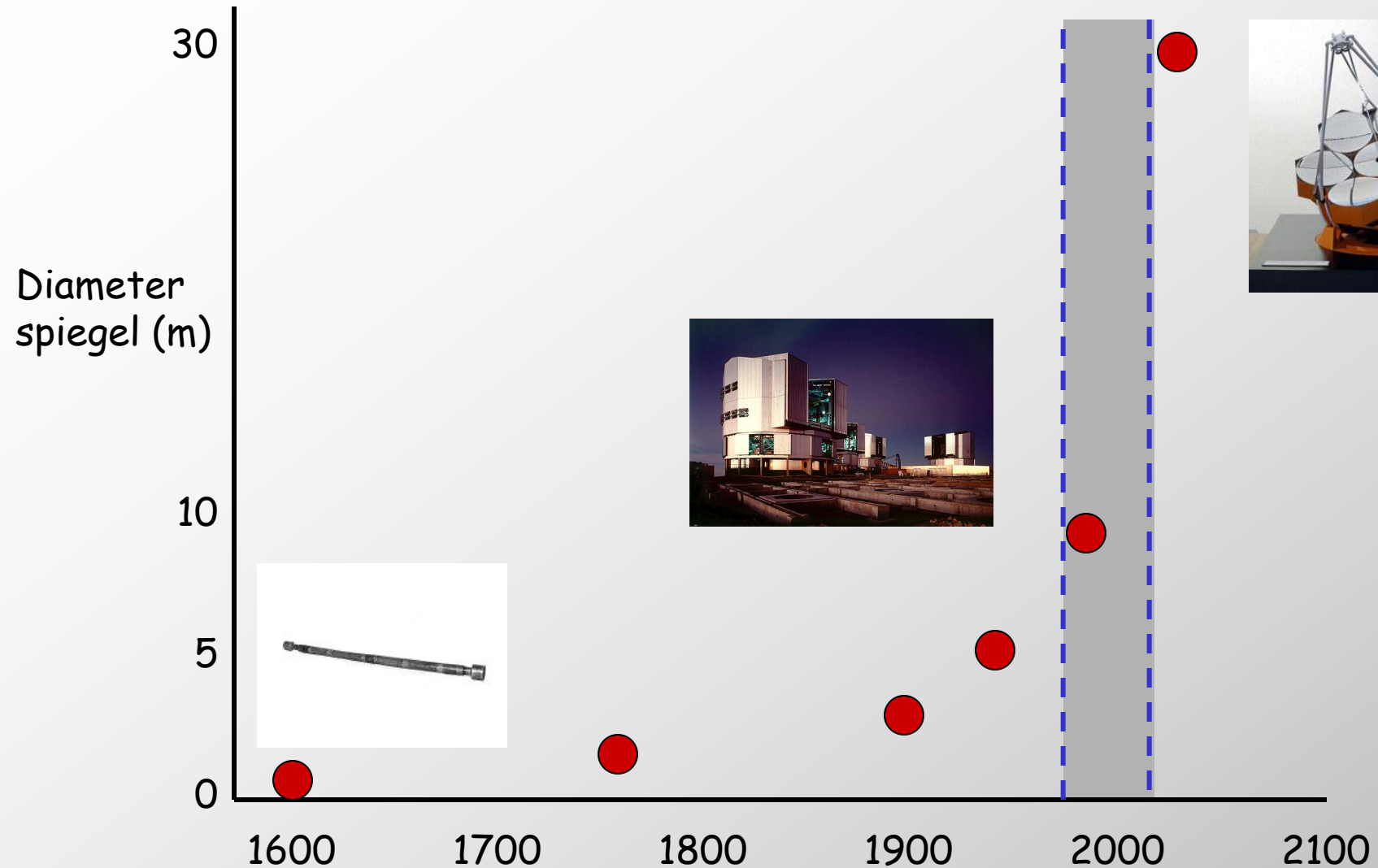
Supernova in M 101



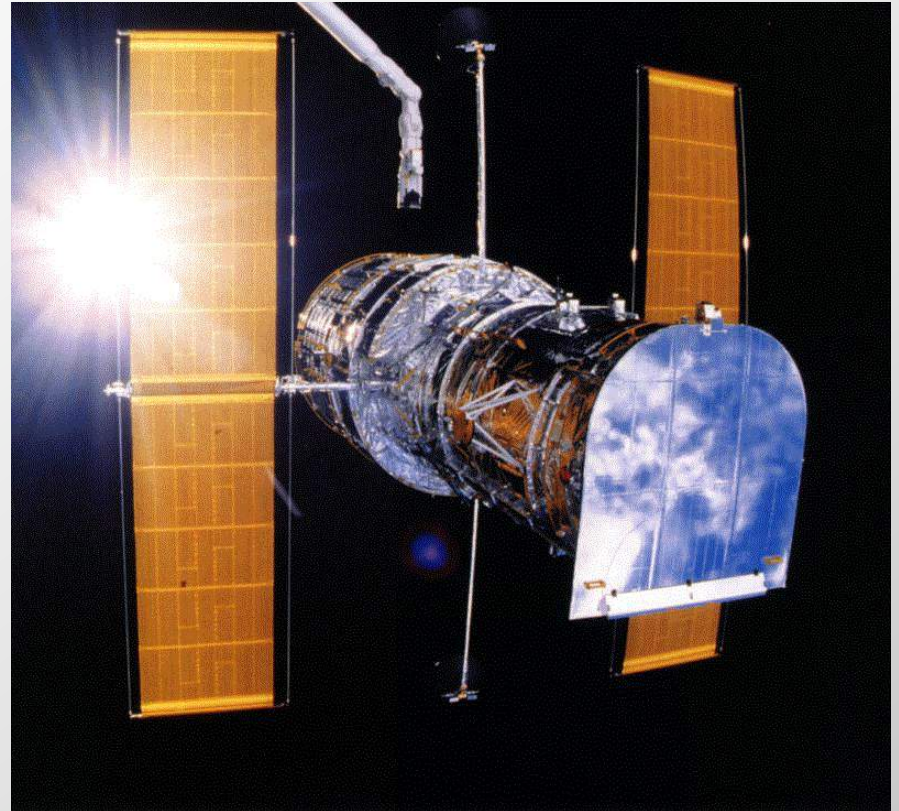
2010

2 september 2011

Ontwikkeling telescoop



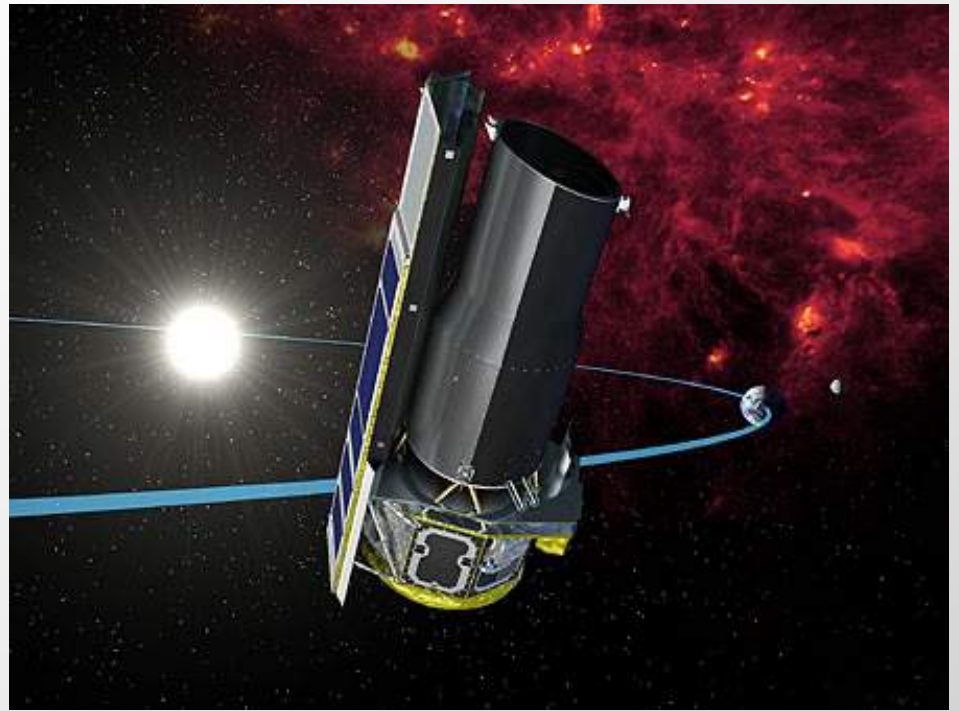
Ruimtevaart



NASA Hubble Space Telescope

Lancering Atlas-Centaur raket (BeppoSAX)

Spitzer Space Observatory
(8 - 200 μm)



XMM-Newton
(2 - 20 keV)



Red: Spitzer Space Telescope; Yellow: Hubble Space Telescope; Green & Blue: Chandra X-ray Observatory

Radiotelescoop Dwingeloo

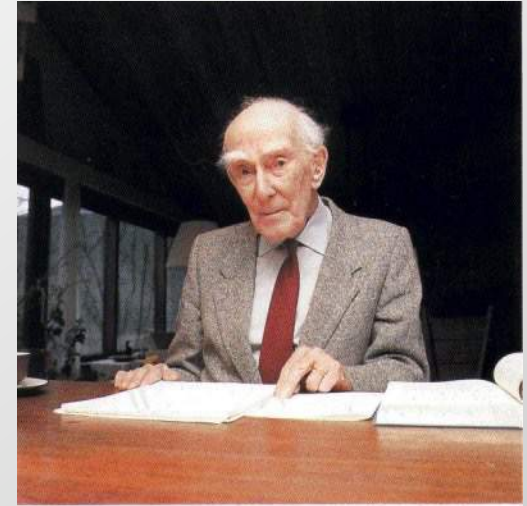


“Luisteren naar de hemel”

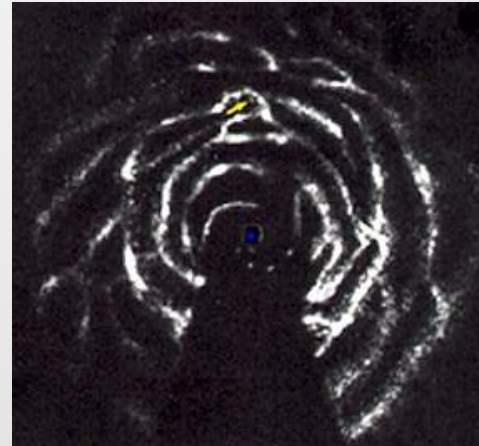
Koningin Juliana en
Jan Oort bij de opening
van de 25m radiotelescoop
in Dwingeloo (17 april 1956)

Lindblad (1895-1968) en Jan Oort (1900-1992)

- Kapteyn: "sterstromen"
- Lindblad en Oort (1927):
gevolg van differentiele rotatie
van ons Melkwegstelsel →
"plaatje" Melkwegstelsel



Jan Oort



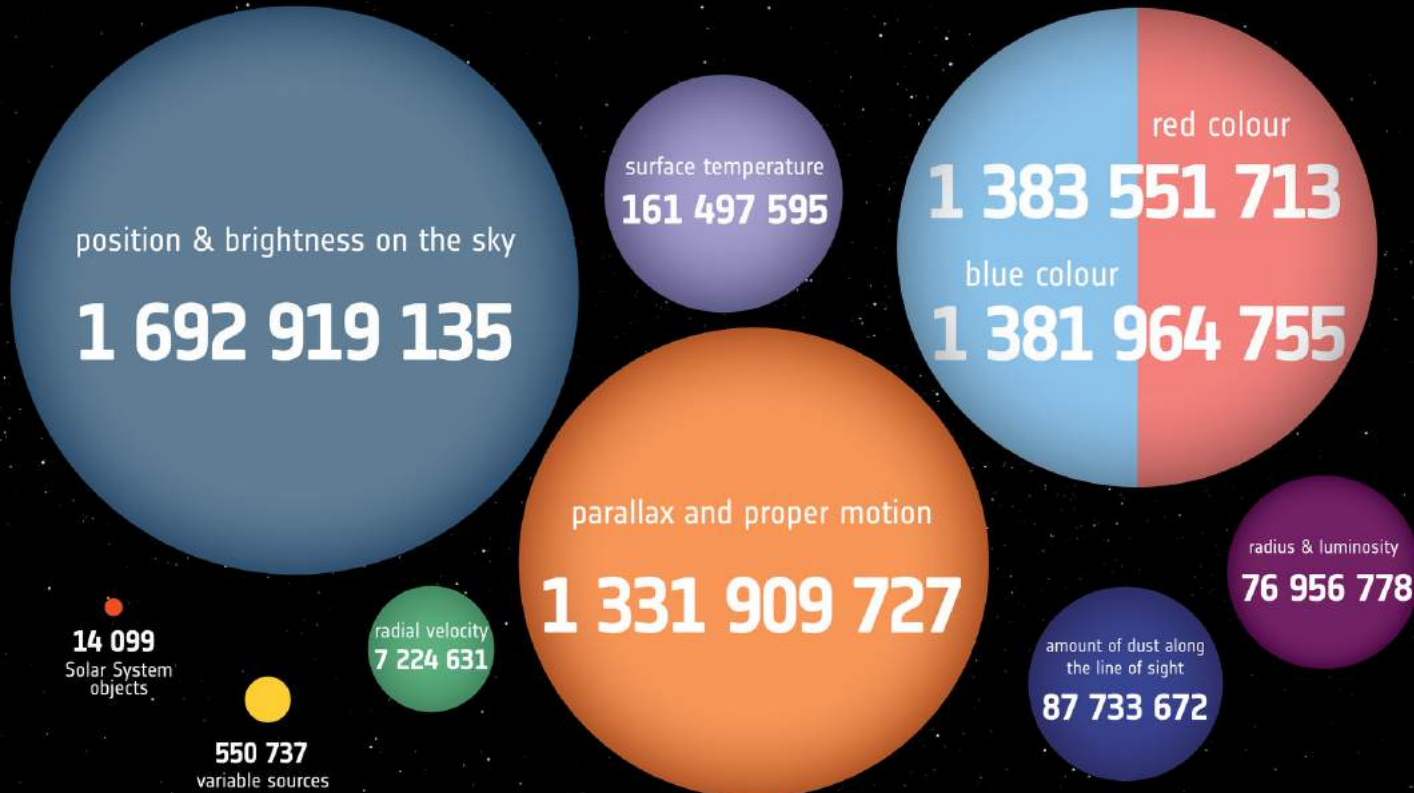
Snelheden interstellair waterstof gas worden gemeten met nieuwe radio telescopen; hier de opening van de 25m telescoop in Dwingeloo door Koningin Juliana

Gaia map of the Milky Way

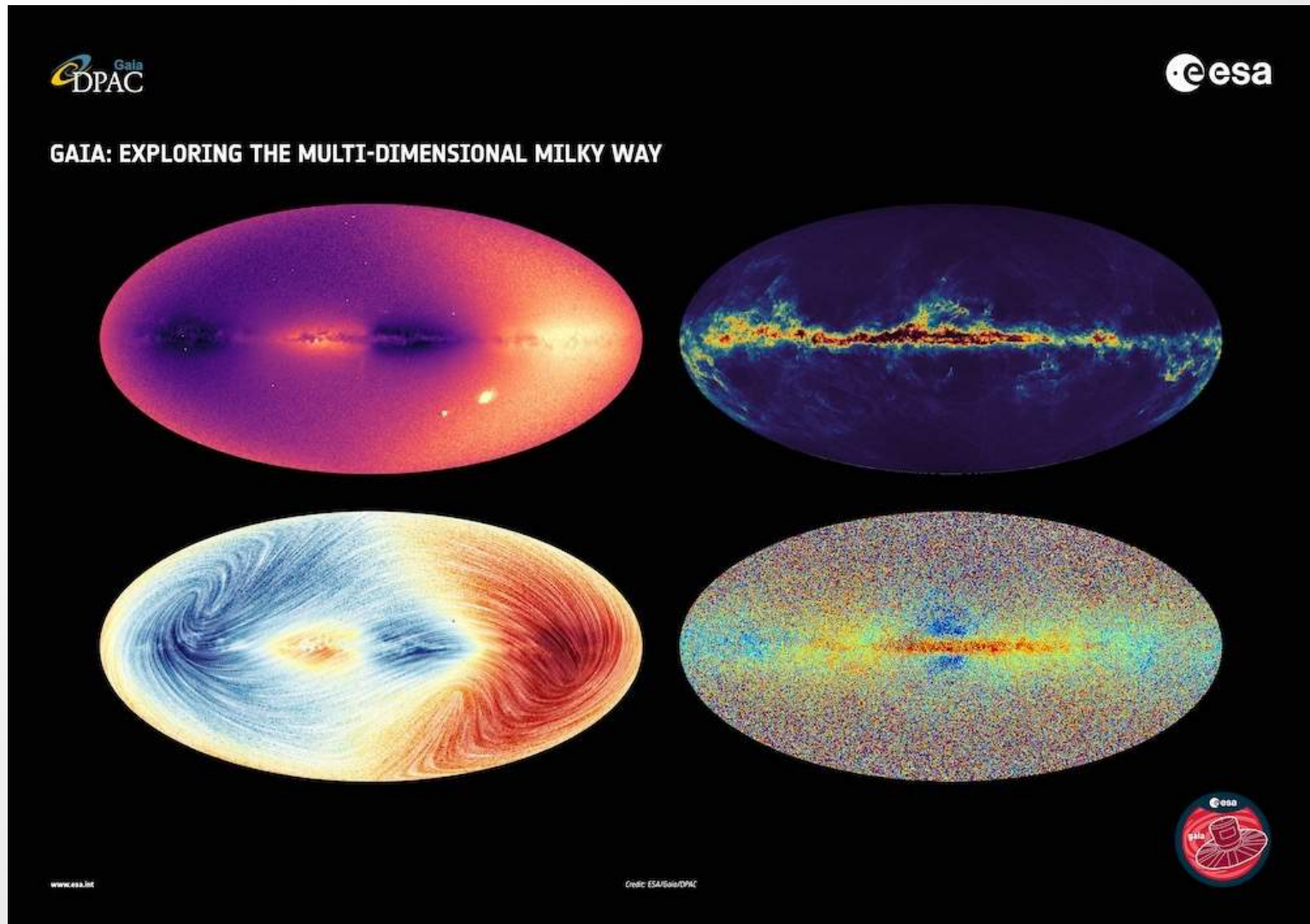


Gaia Data Release 2

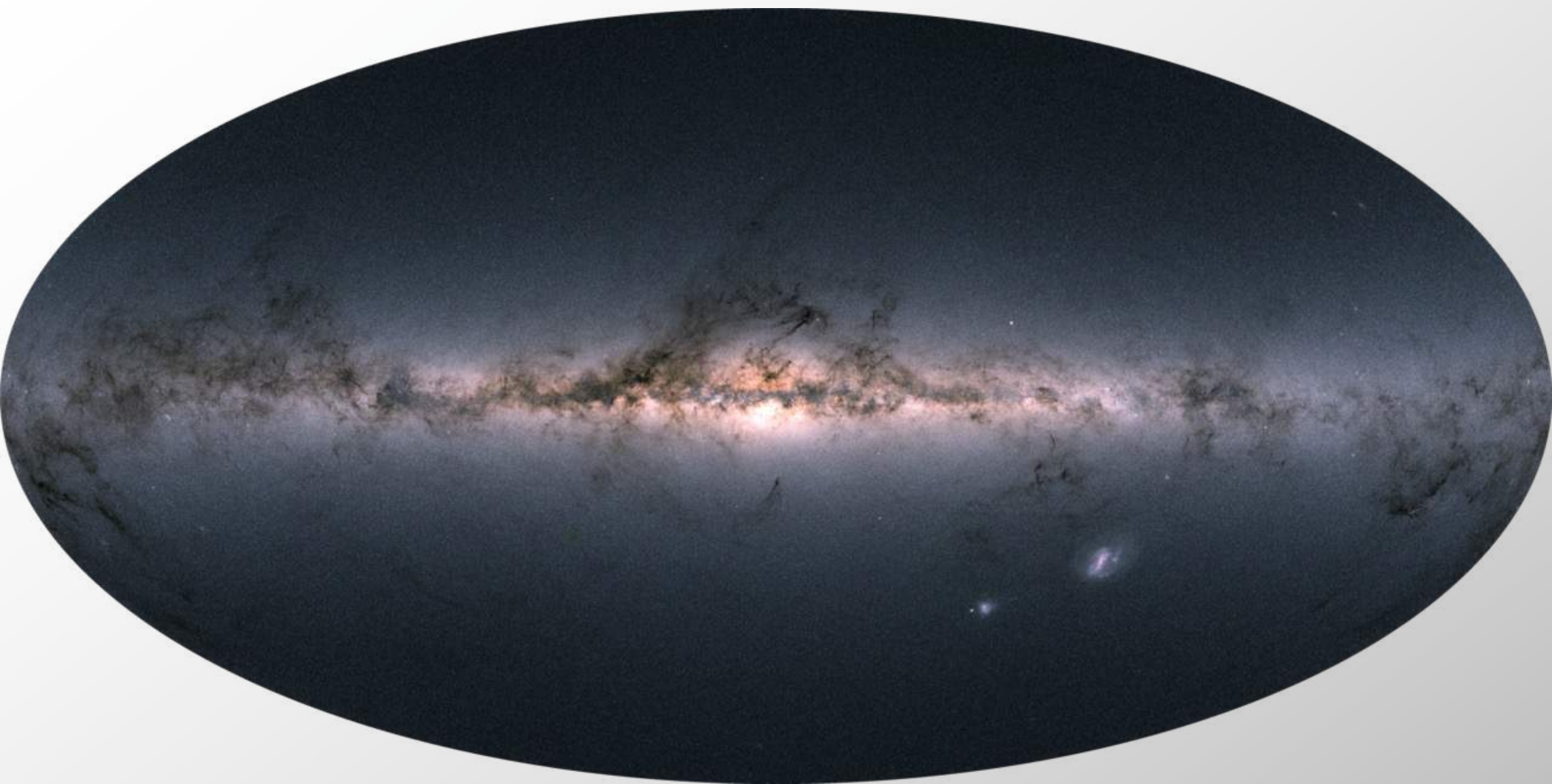
→ HOW MANY STARS WILL THERE BE IN THE SECOND GAIA DATA RELEASE?



Gaia Data Release 3: radial velocities & binarity



13 juni 2022



Very Large Telescope ESO Paranal, Chili



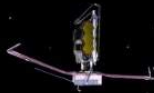
Westerbork radio telescoop



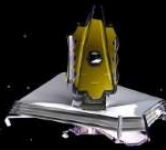
James Webb Space Telescope



Lansering 25 december 2021

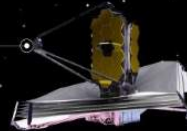


Initial sunshield deployment

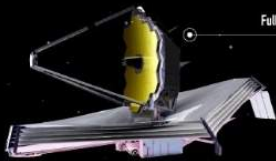


Tensioning and separation of sunshield's layers

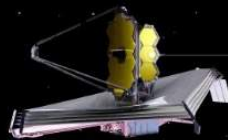
Secondary mirror support unfolds



Fully unfolded



Two primary mirror lateral wings deploy



Webb's Unfolding Sequence

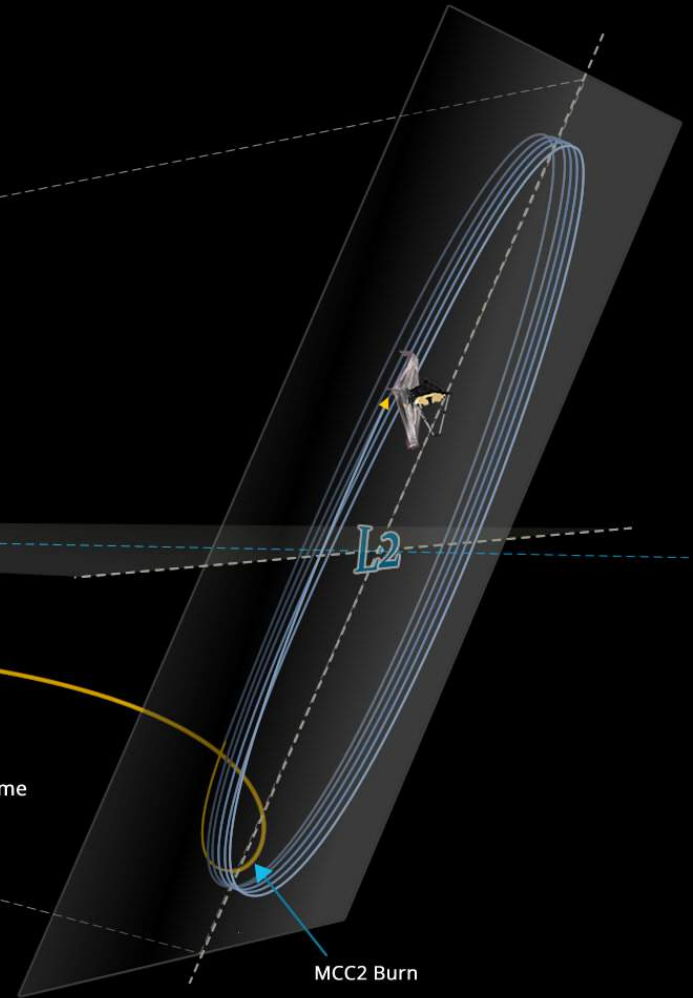
Sun



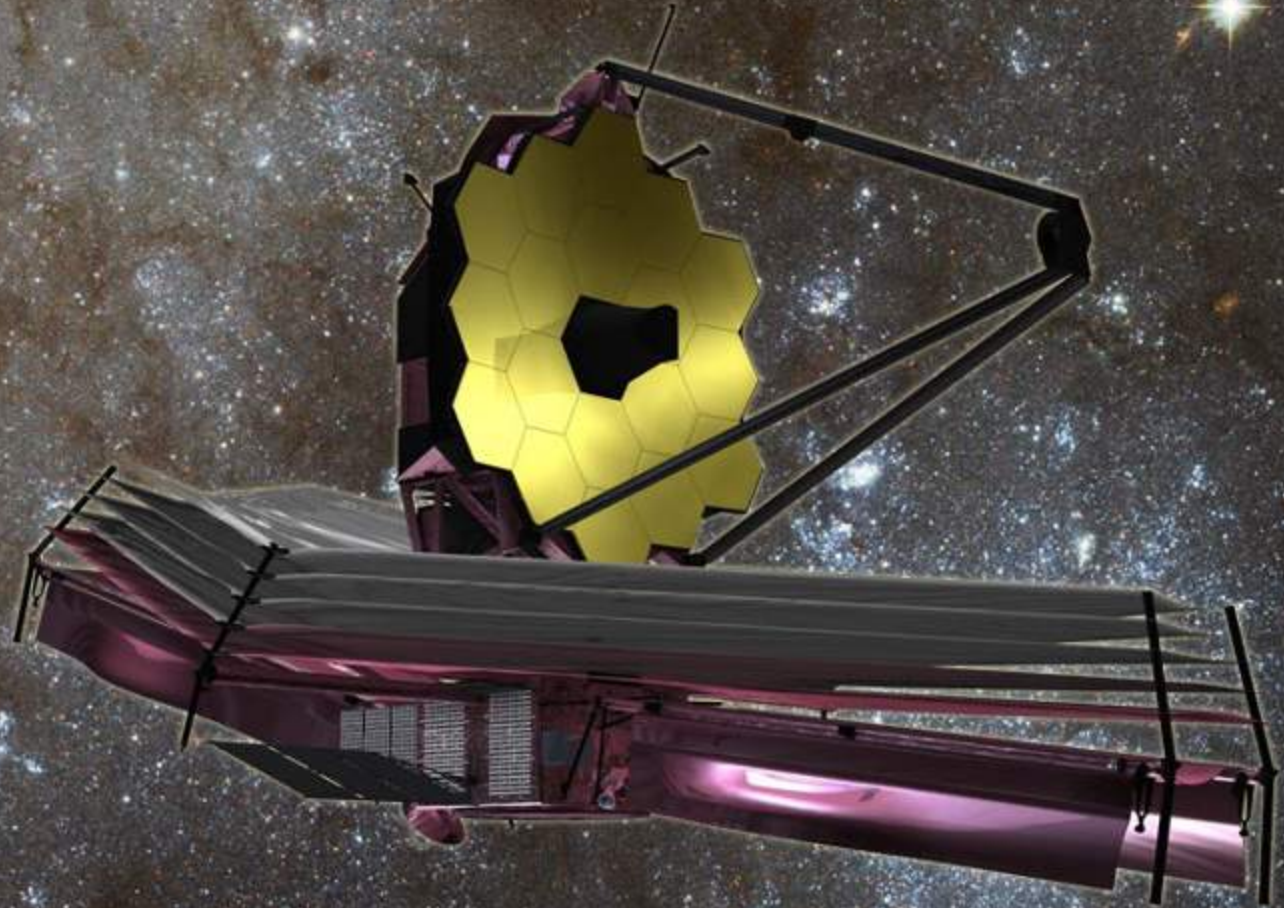
Earth/L2 Frame

L2

MCC2 Burn



James Webb Space Telescope



European Southern Observatory

(Belgie, Denemarken, Duitsland, Engeland, Finland, Frankrijk, Italië, Nederland, Oostenrijk, Polen, Portugal, Spanje, Tsjechie, Zweden, Zwitserland)



La Silla



Paranal



Garching

CERRO PARANAL - THE VLT SITE



Geographical Coordinates:

24 deg 37 min S, 70deg 24 min W

Altitude above sea level:

2635m

Distance from coast:

12 km

Road distances:

130 km to Antofagasta

1200 km to Santiago

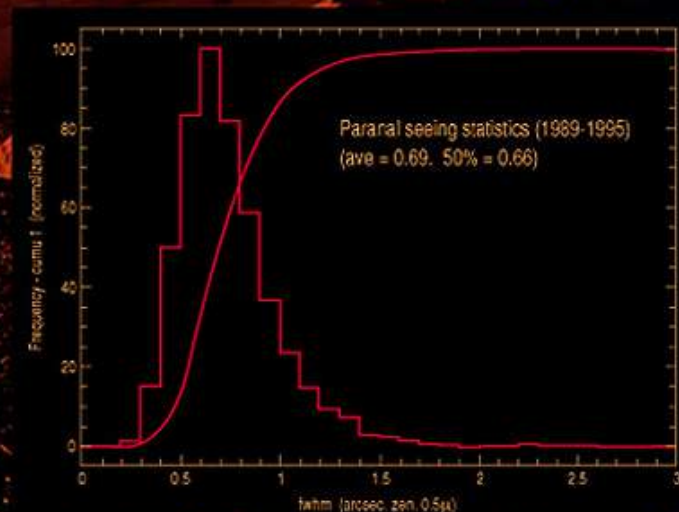
600 km to La Silla

CERRO PARANAL - THE VLT SITE

No. of clear nights:
350

Seeing:
The 50 % fractile 0.66" FWHM

Water Vapour:
The precipitable water vapour is less than
1 mm for 8.2% of the night time



CERRO PARANAL - THE VLT SITE



Temperature:

-8° to 25°C (Measured 1985-1998)

Temperature gradient during night:

-0.4°C/h (Typical)

Humidity:

5-20% (Typical)

Rainfall:

100 mm/year (Max.)

Paranal History



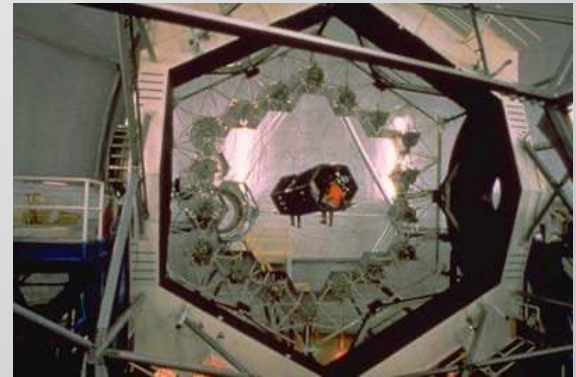
Building an 8 meter telescope

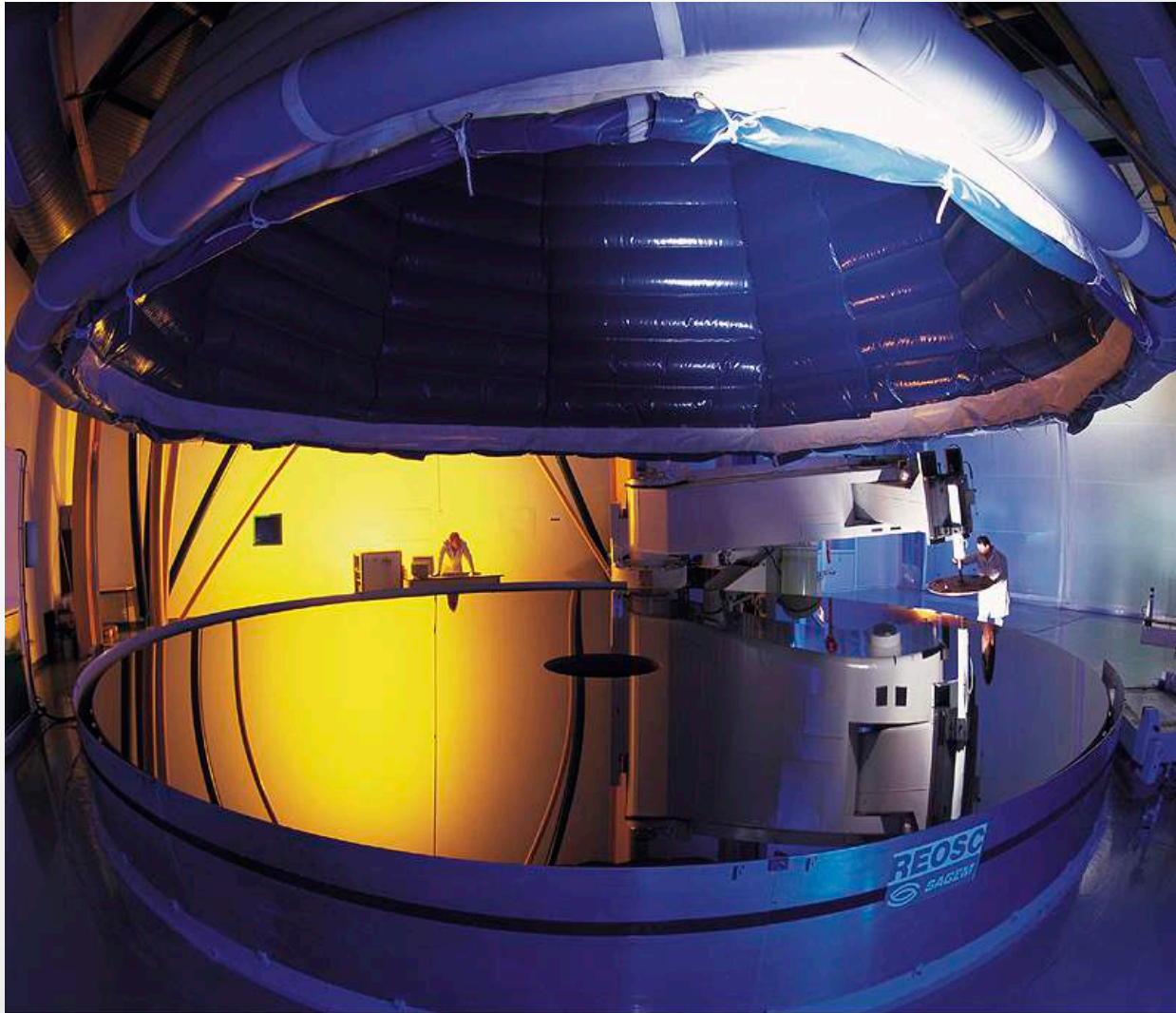


Schott, Germany



Keck 10m, Hawaii





The Polished Fourth VLT 8.2-m Mirror at REOSC

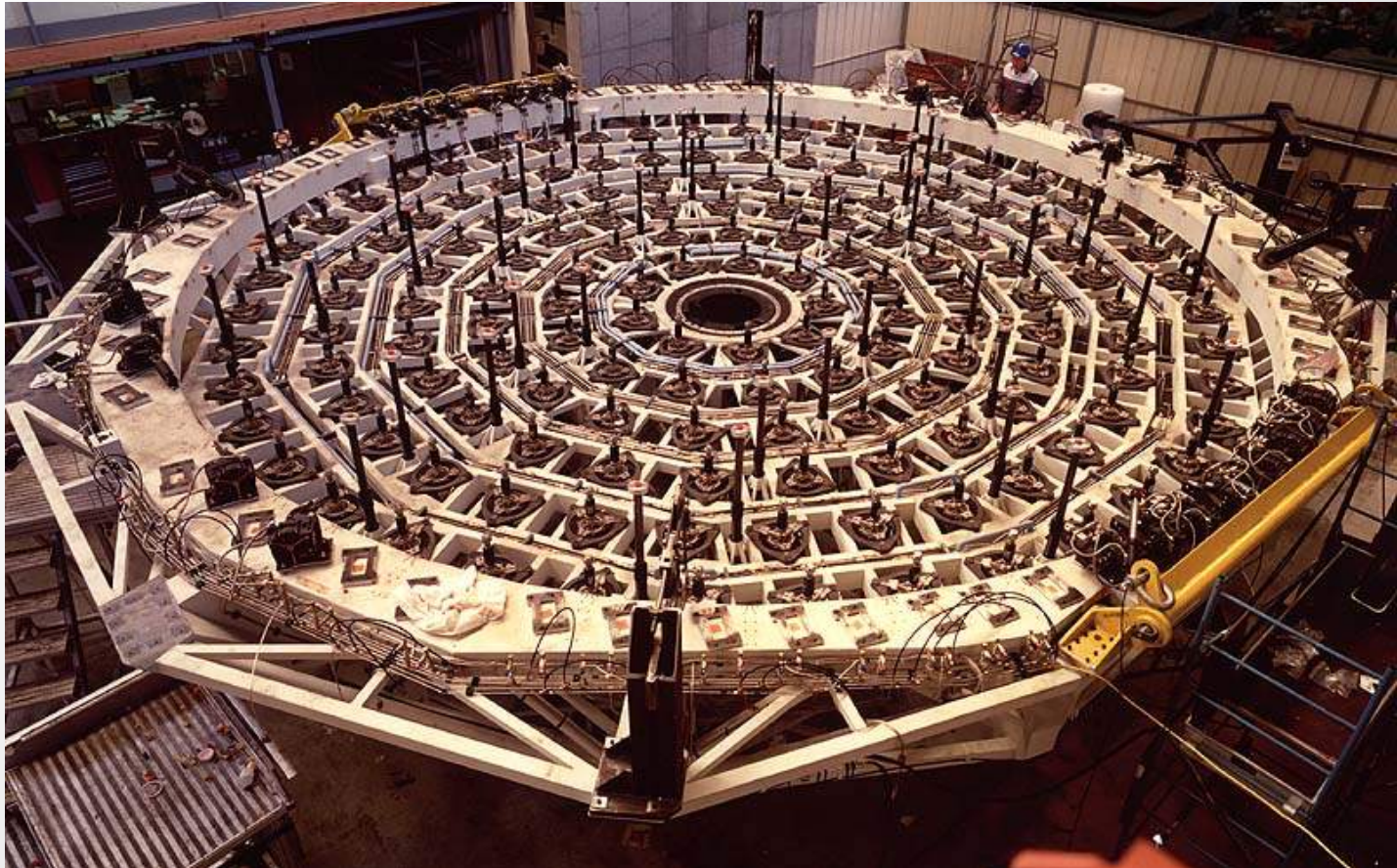
Photo: SAGEM

ESO PR Photo 44/99 (14 December 1999)

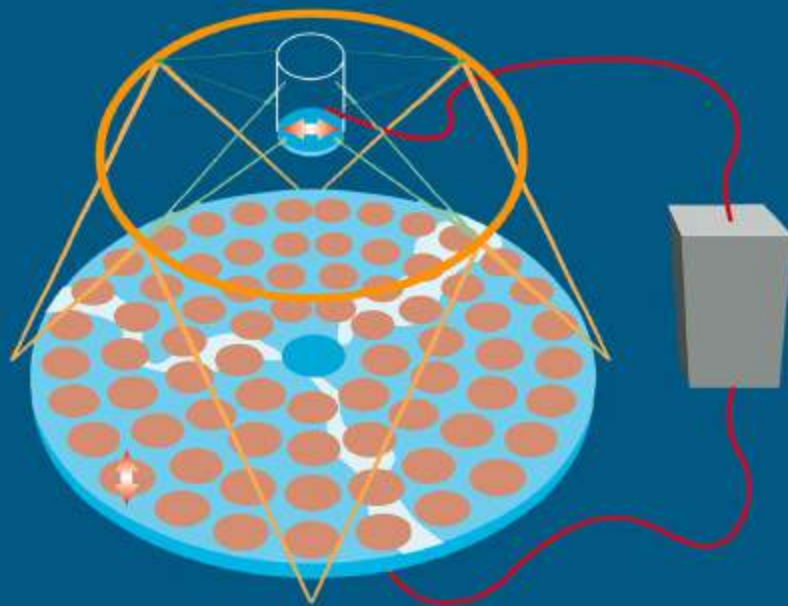
European Southern Observatory



M1 mirror cell



ACTIVE OPTICS

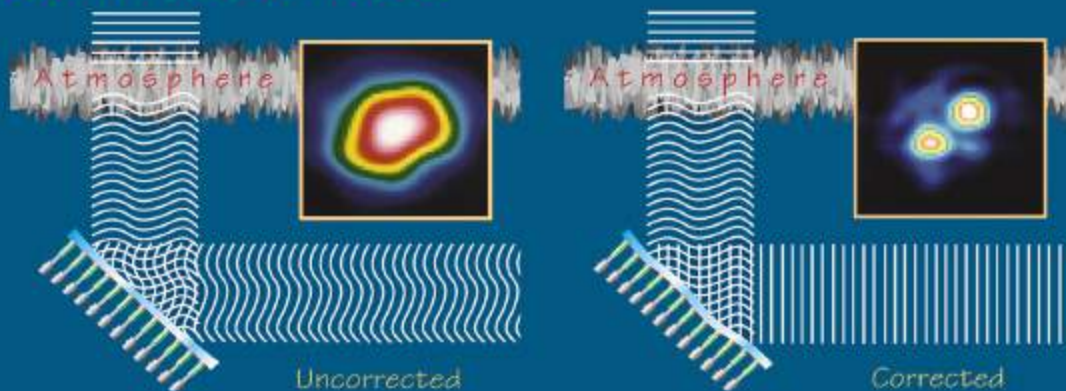


Correction of the deformation/
displacement of the primary and
secondary mirrors caused by:

- gravitation
- polishing inaccuracies
- tube flexure, etc.

Correction is achieved through
an active computer controlled
mirror support

ADAPTIVE OPTICS



Correction of the deformation of
the wavefront (of the light)
caused by turbulence

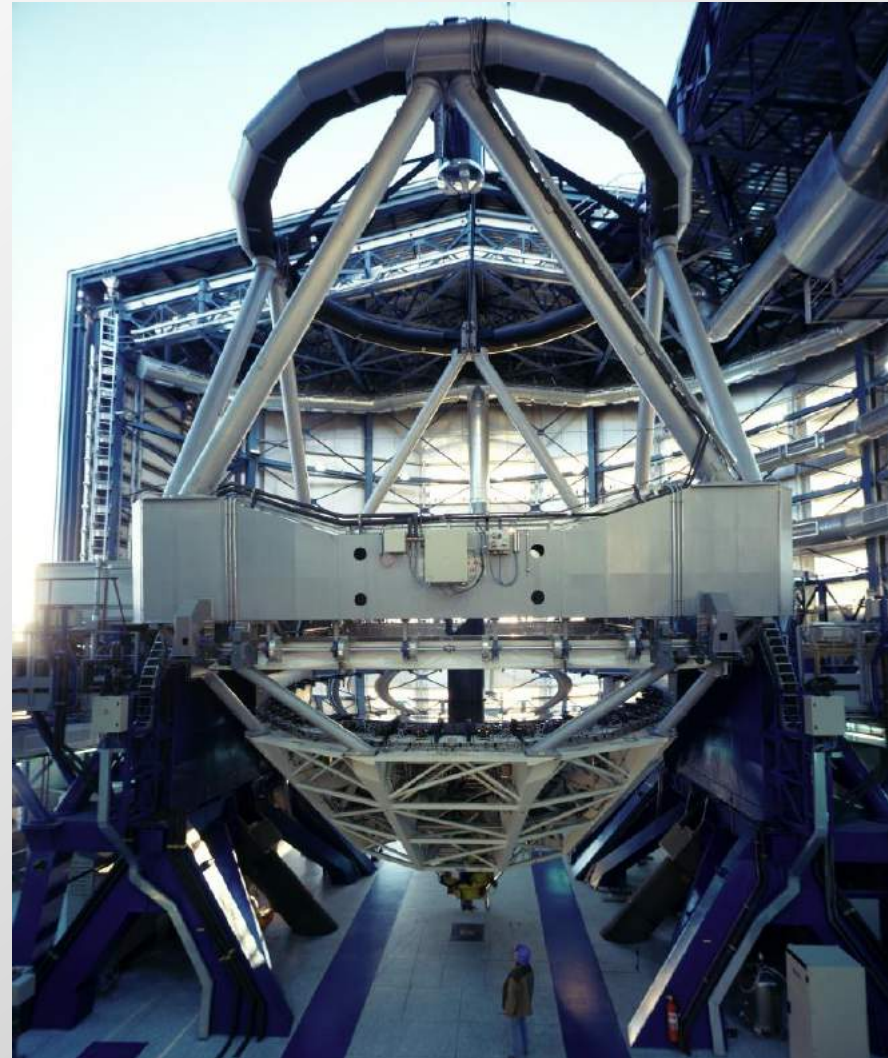
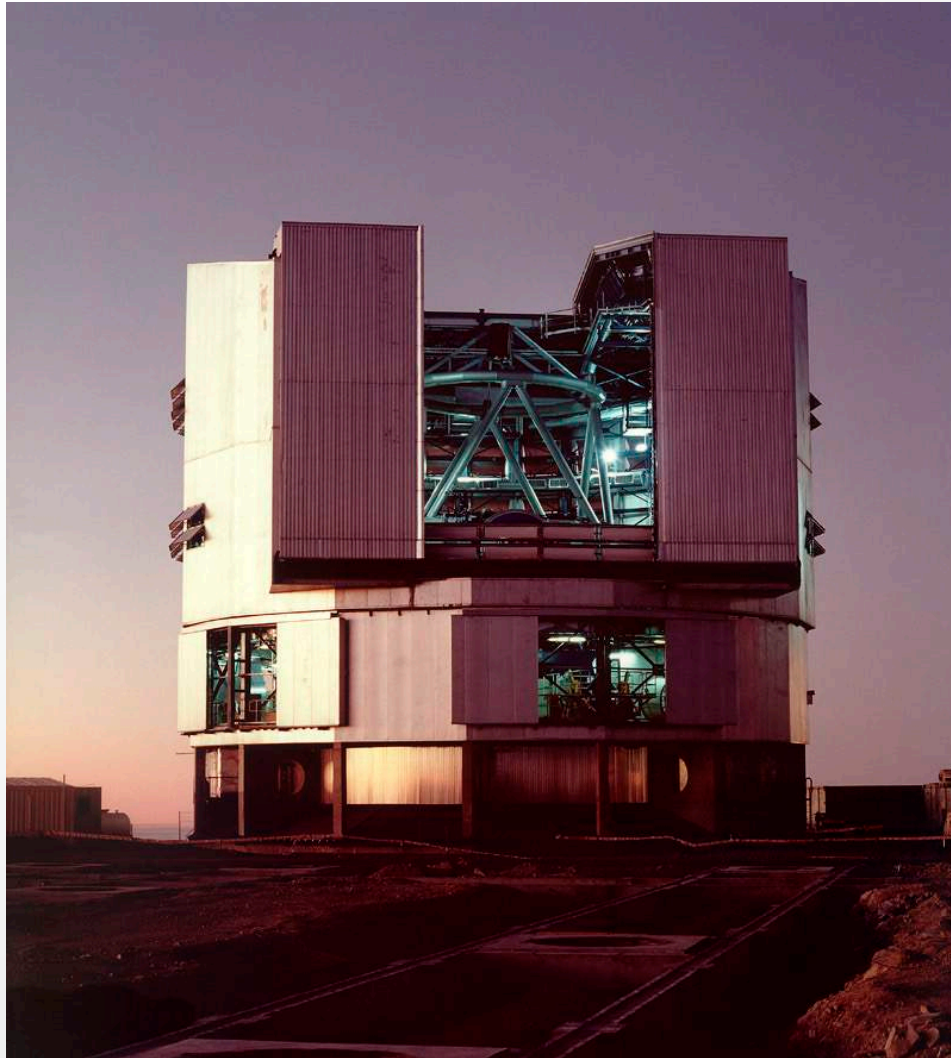
Correction is achieved by means
of a flexible mirror in front of the
detector (+ tip/tilt secondary
mirror)

Transport 8m spiegel naar Paranal





VLT Kueyen



Paranal Infrastructure

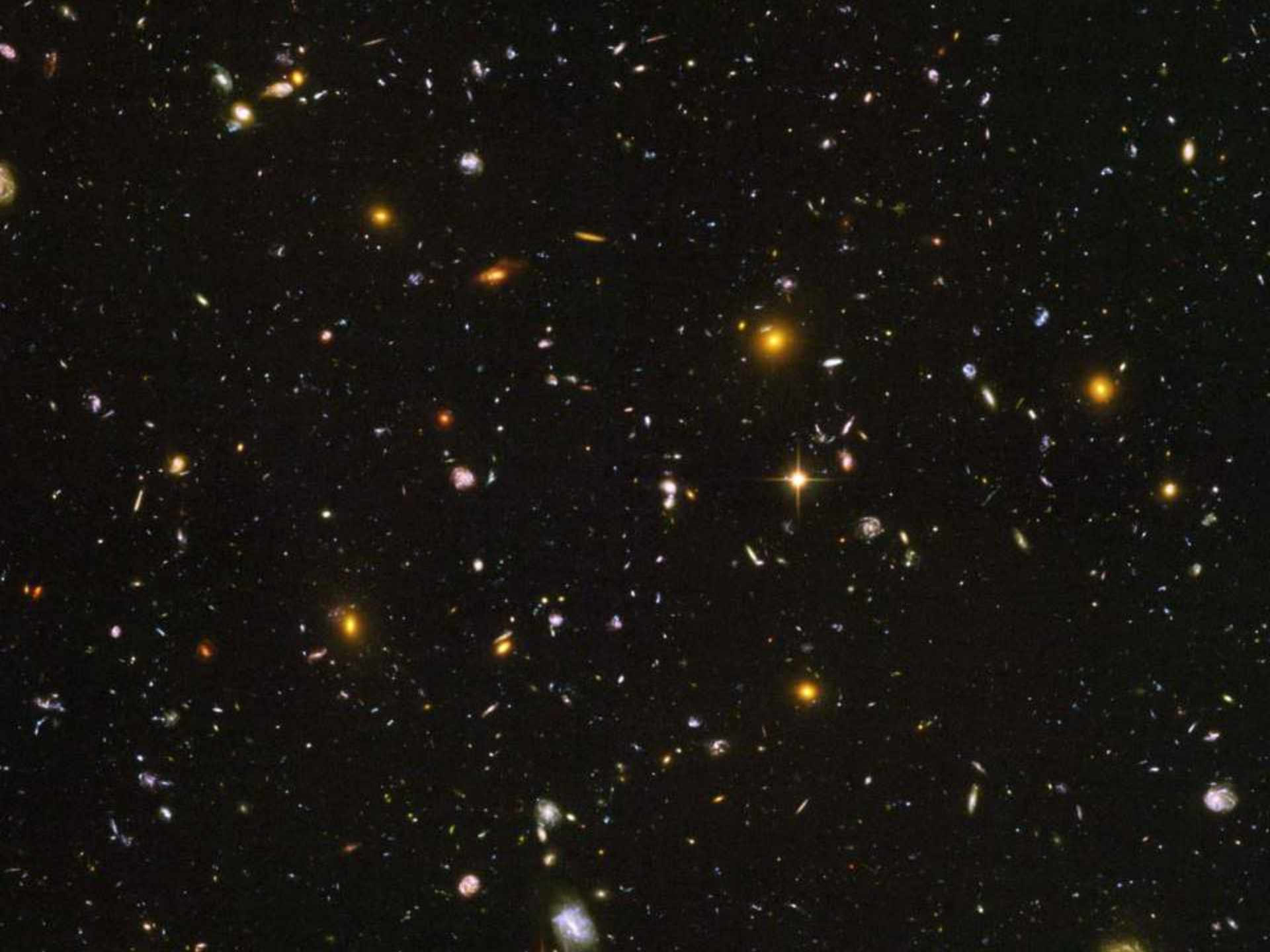


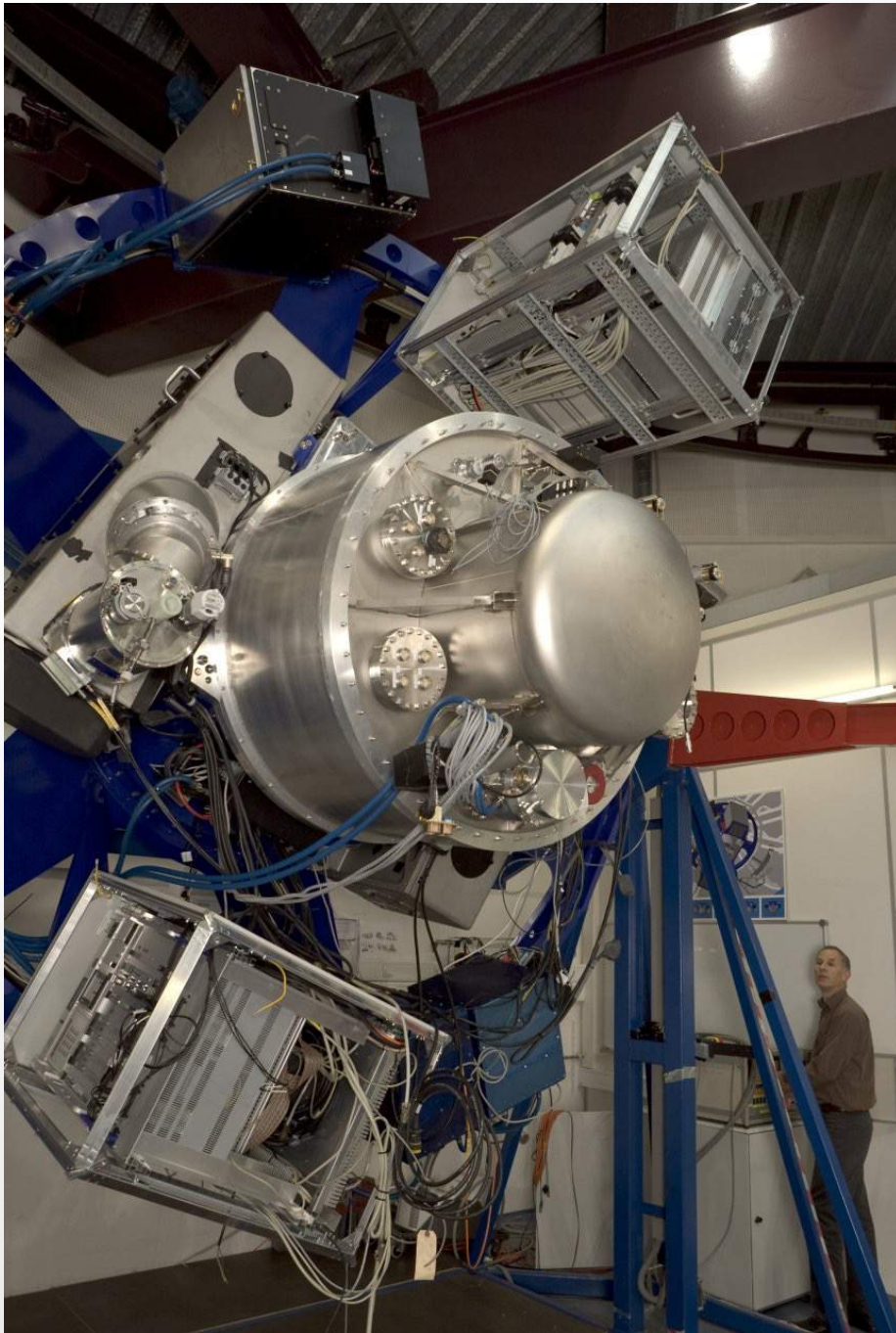
Quantum of Solace









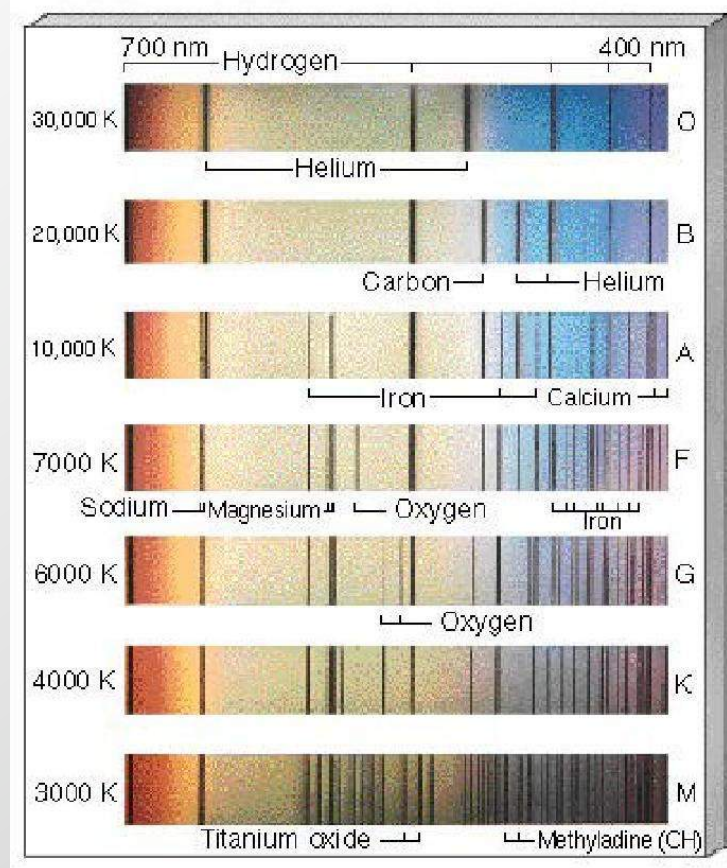
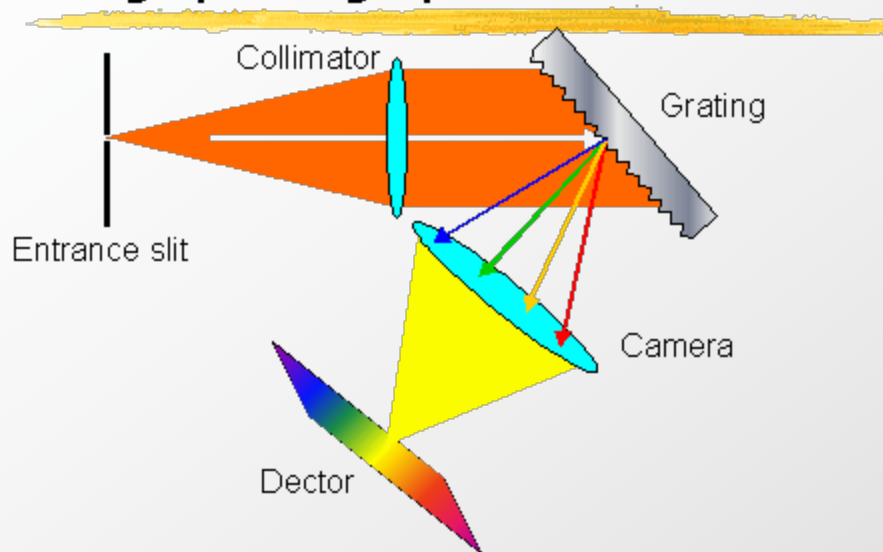


VLT/X-shooter

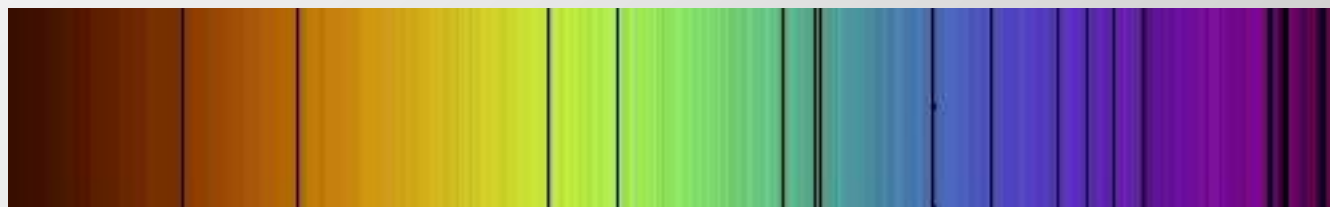
“De krachtigste spectrograaf van de wereld”

X-shooter: a cross-dispersed echelle spectrograph

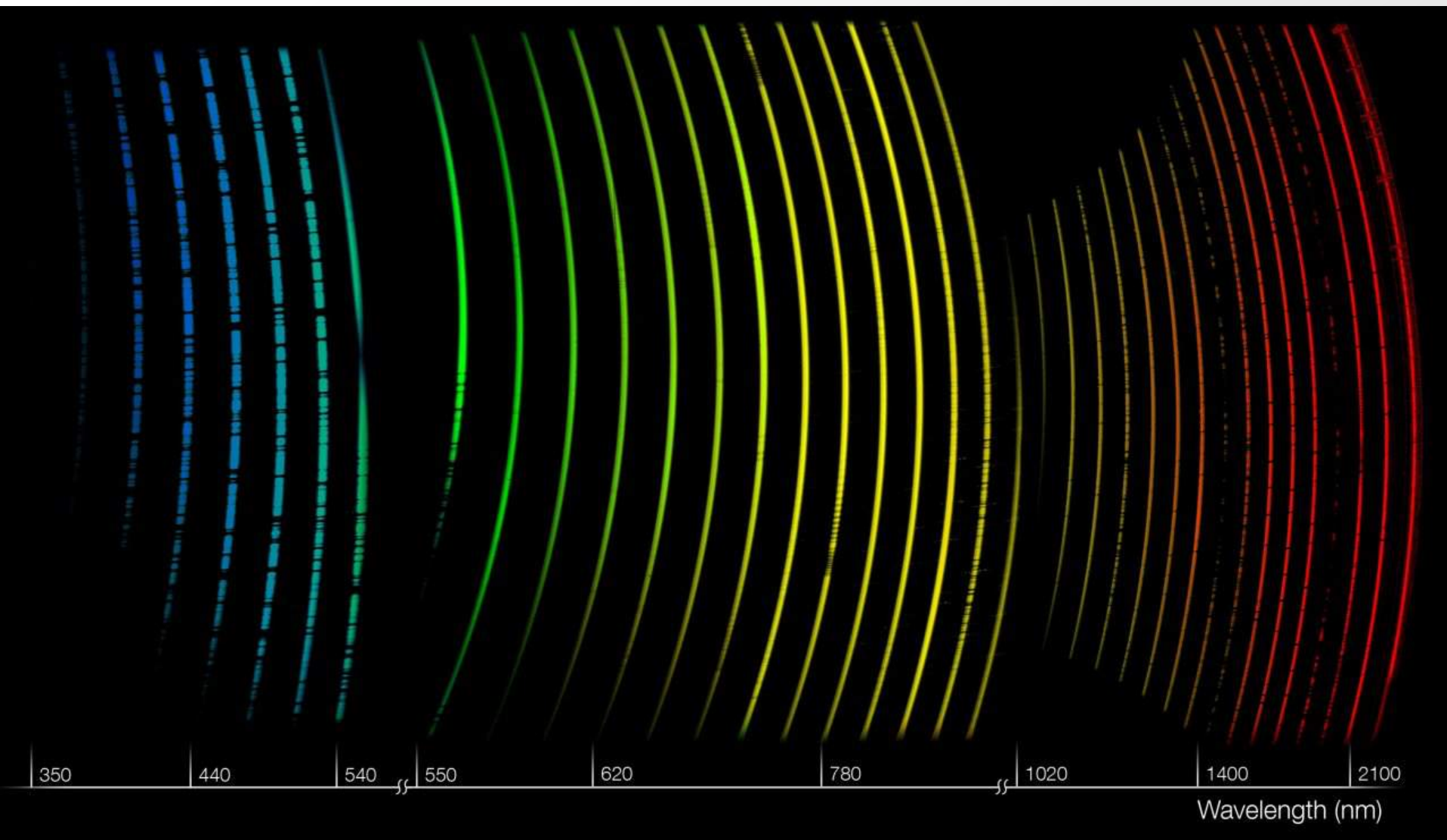
Grating spectrograph



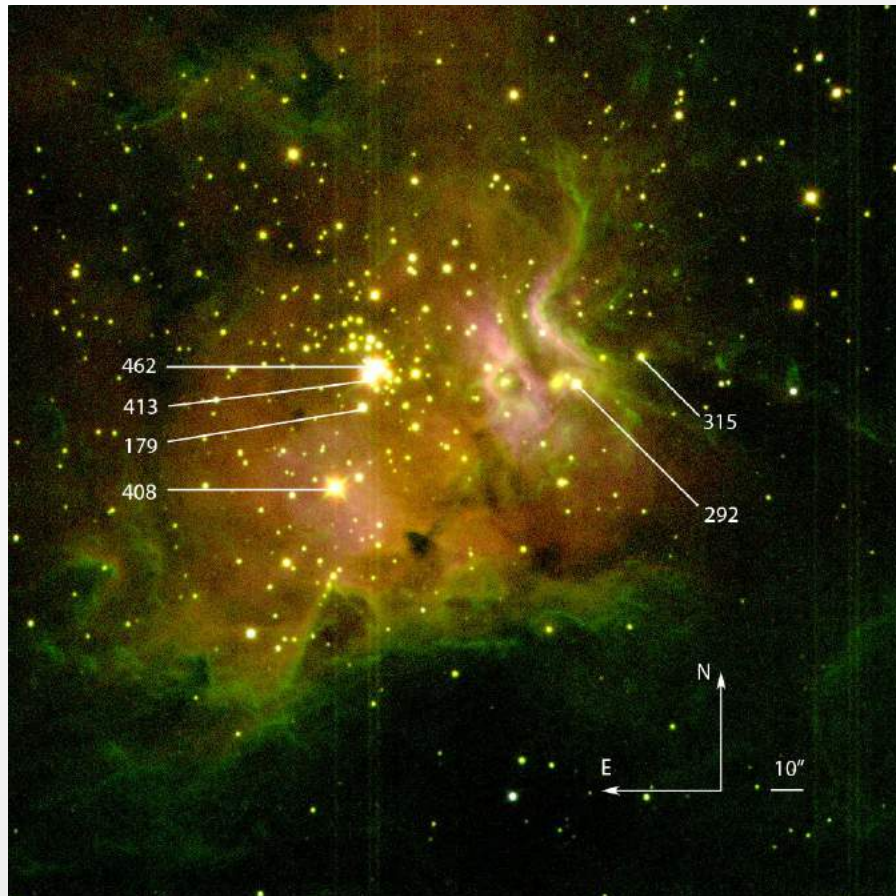
Anton Pannekoek (1873-1960)



Solar spectrum



VLT/X-shooter spectra van zich nog vormende zware sterren

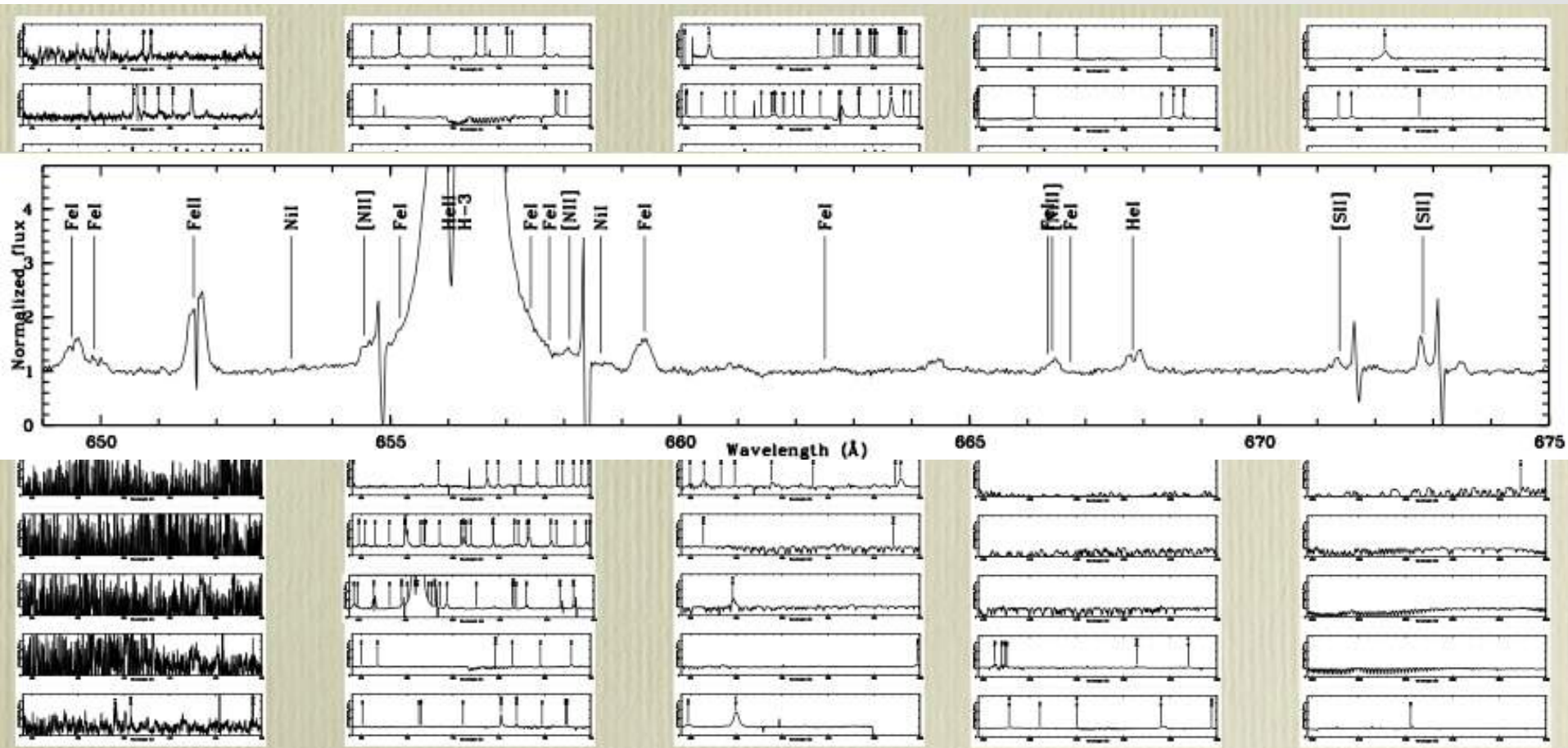


IRAS 08576-4334 (NTT/SOFI)



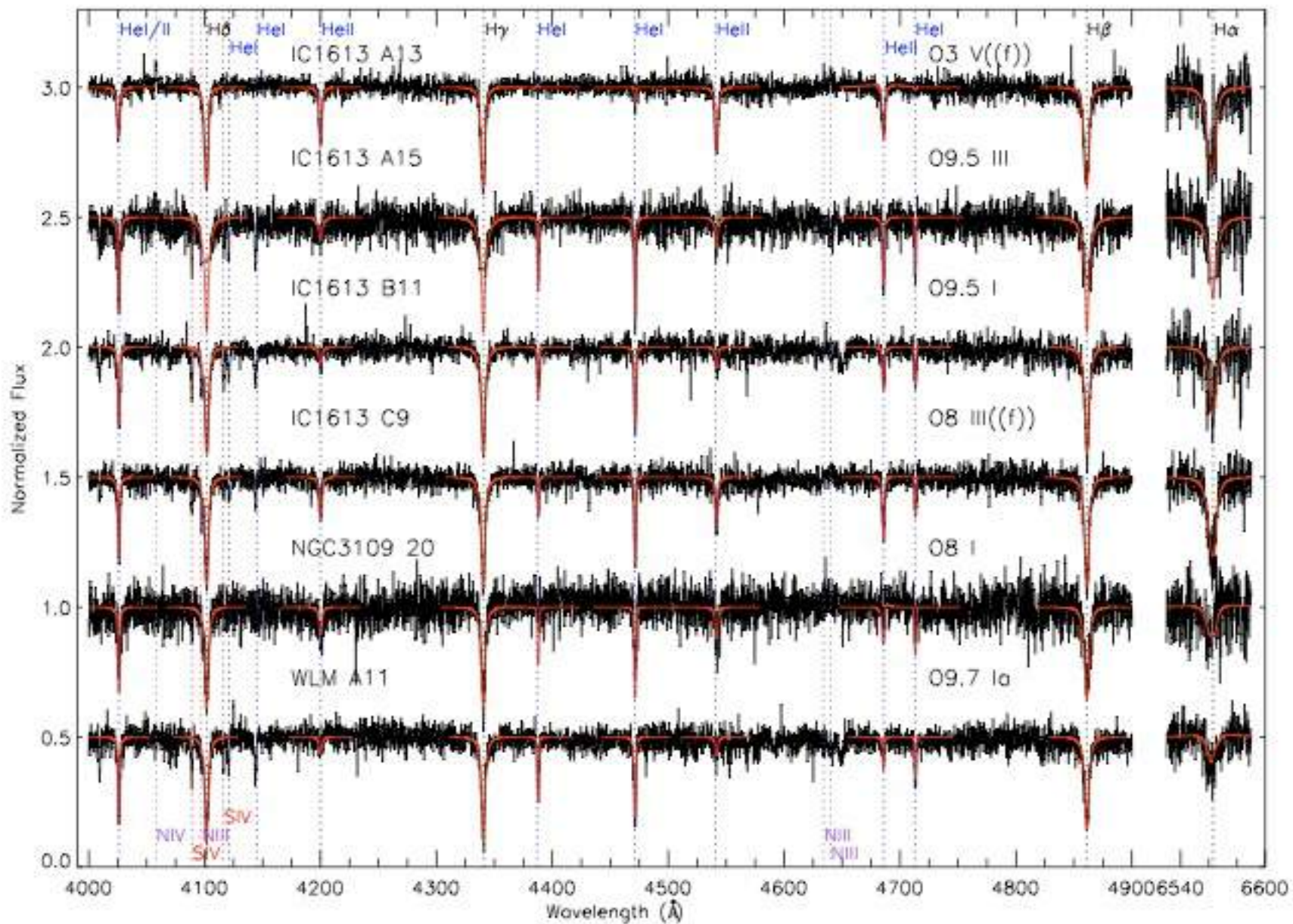


X-shooter spectrum 300 - 2500 nm



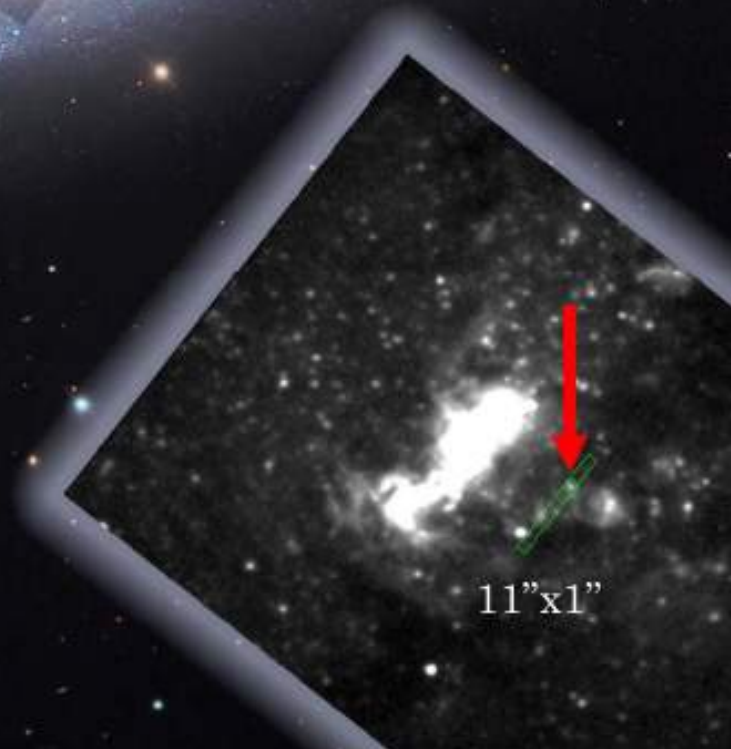
IC1613: *dwarf irregular* Lokale Groep
(afstand 2 miljoen lichtjaar)





Eerste VLT/X-shooter spectrum van zware sterren
buiten de Lokale Groep: NGC 55

32'.4

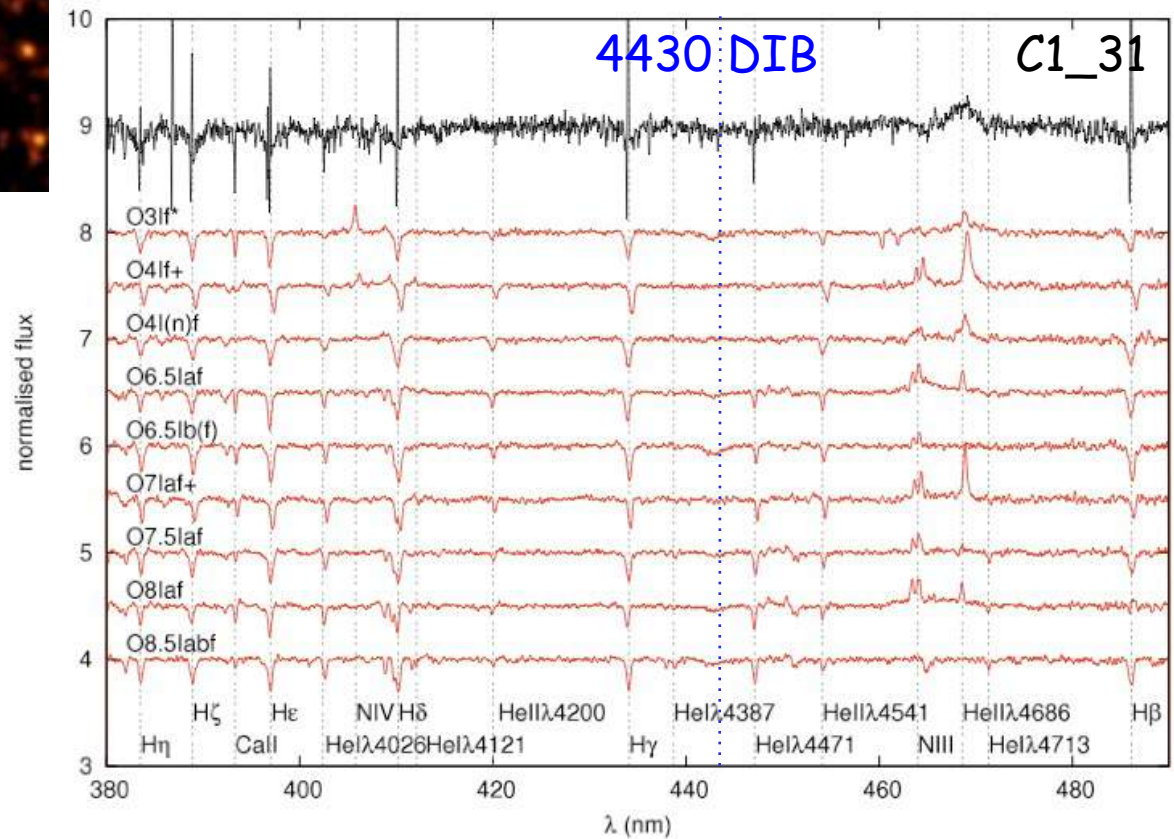
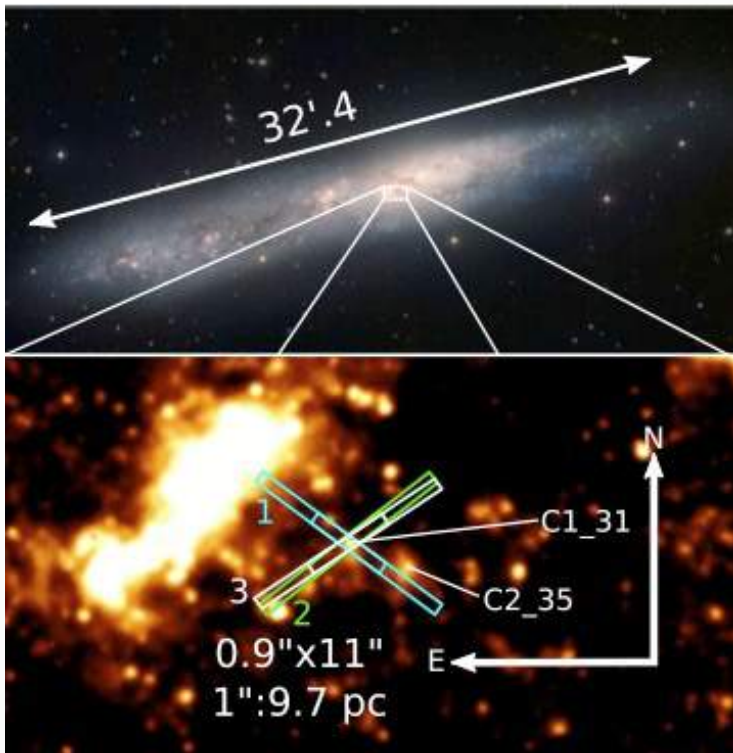


Hartoog et al. 2012,
MNRAS 422, 367

NGC55

$d = 2 \text{ Mpc}$

$Z = 0.2-0.7 Z_{\odot}$



Obtaining spectra of O stars in Local Group (and beyond)

$M_V \sim -6$

Resolving power $R \sim 10,000$

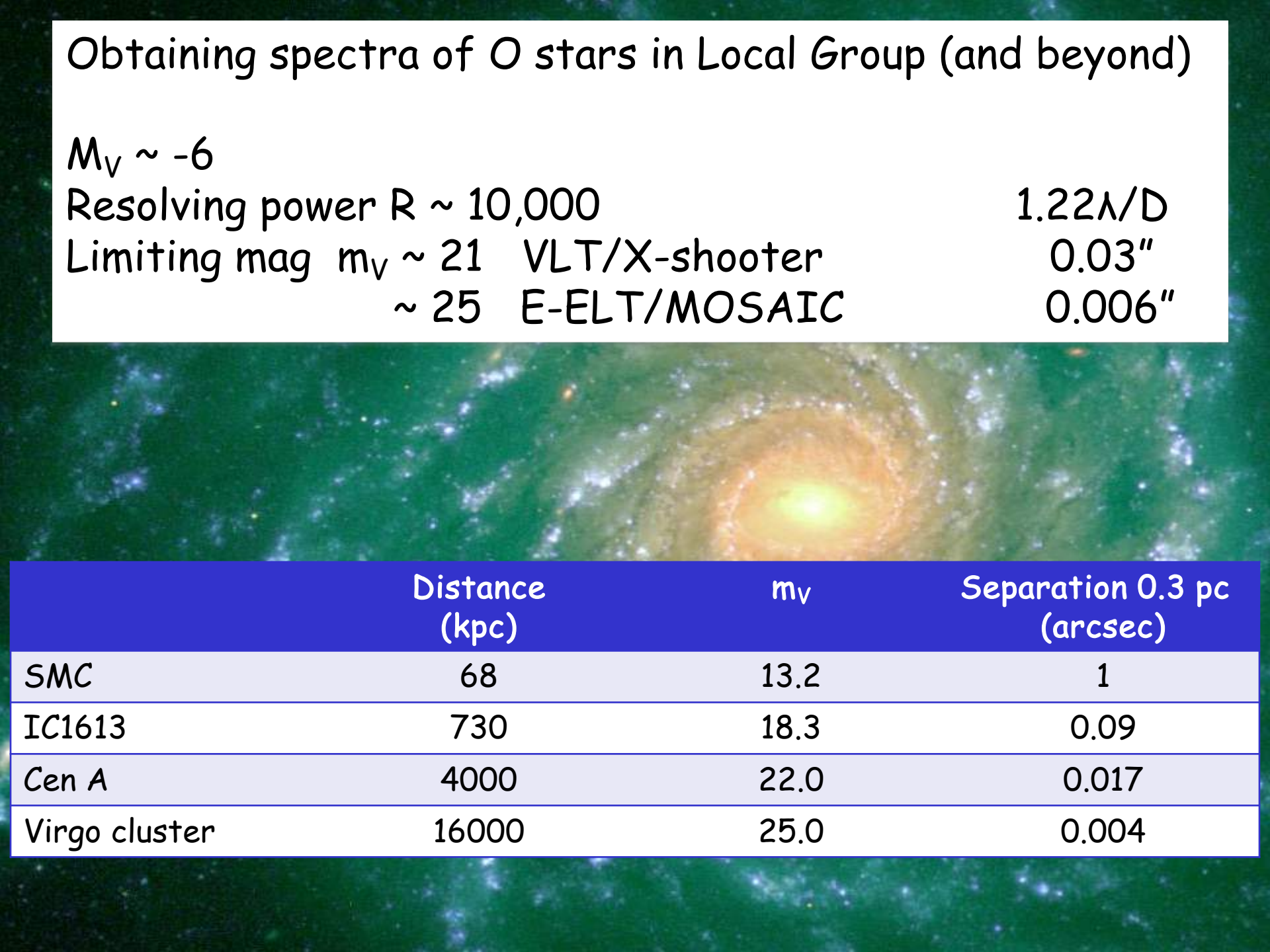
$1.22\lambda/D$

Limiting mag $m_V \sim 21$ VLT/X-shooter

$0.03''$

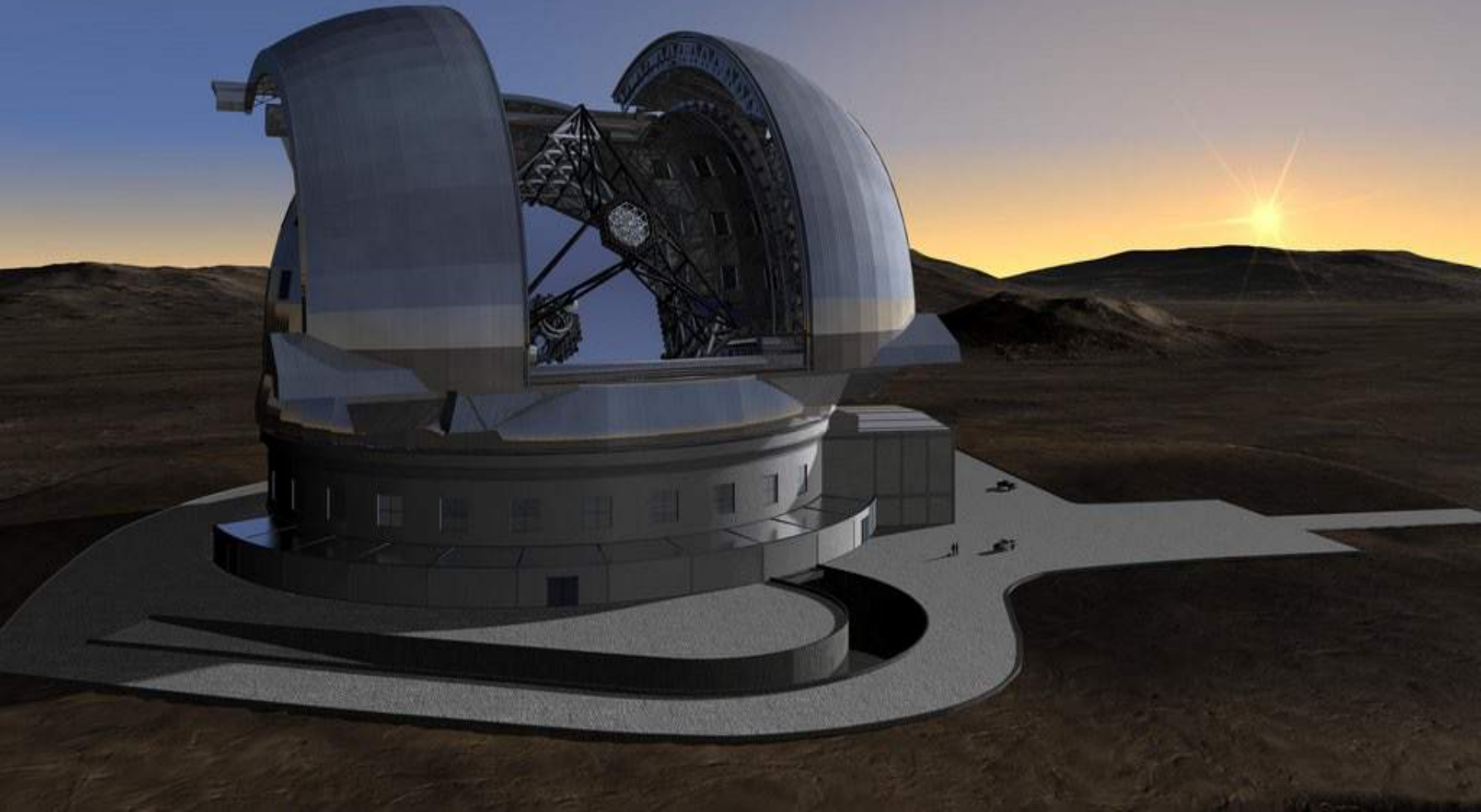
~ 25 E-ELT/MOSAIC

$0.006''$



	Distance (kpc)	m_V	Separation 0.3 pc (arcsec)
SMC	68	13.2	1
IC1613	730	18.3	0.09
Cen A	4000	22.0	0.017
Virgo cluster	16000	25.0	0.004

European ELT

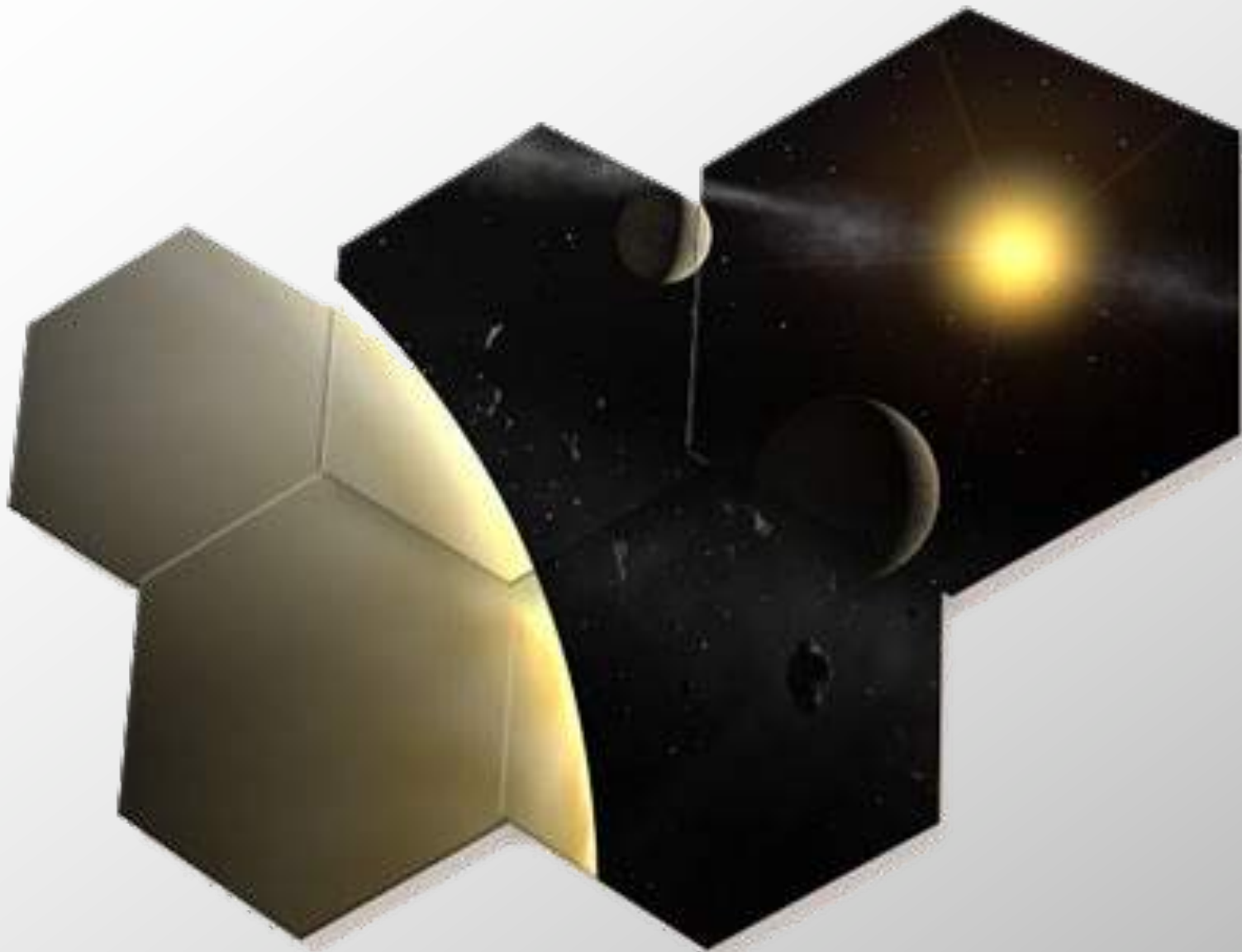


Preparing a revolution

400 jaar na de uitvinding van de telescoop in de
Gouden Eeuw van de sterrenkunde



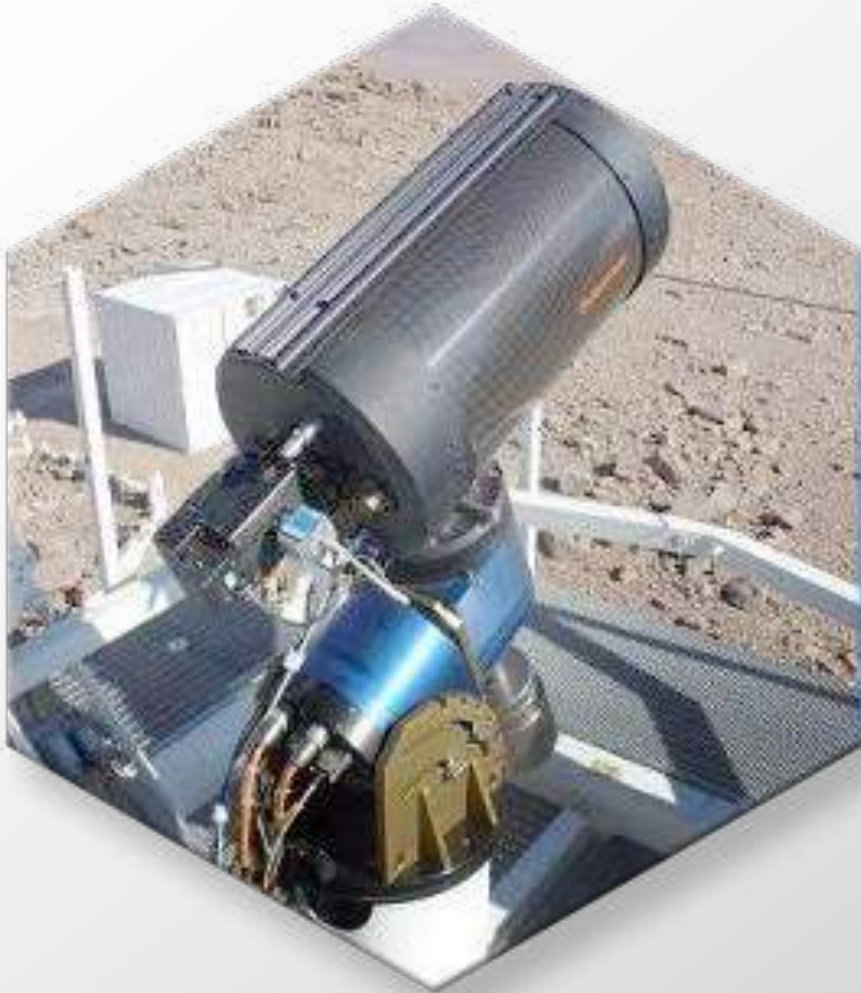
Zijn we alleen?



De eerste objecten in het heelal



Een plek vinden

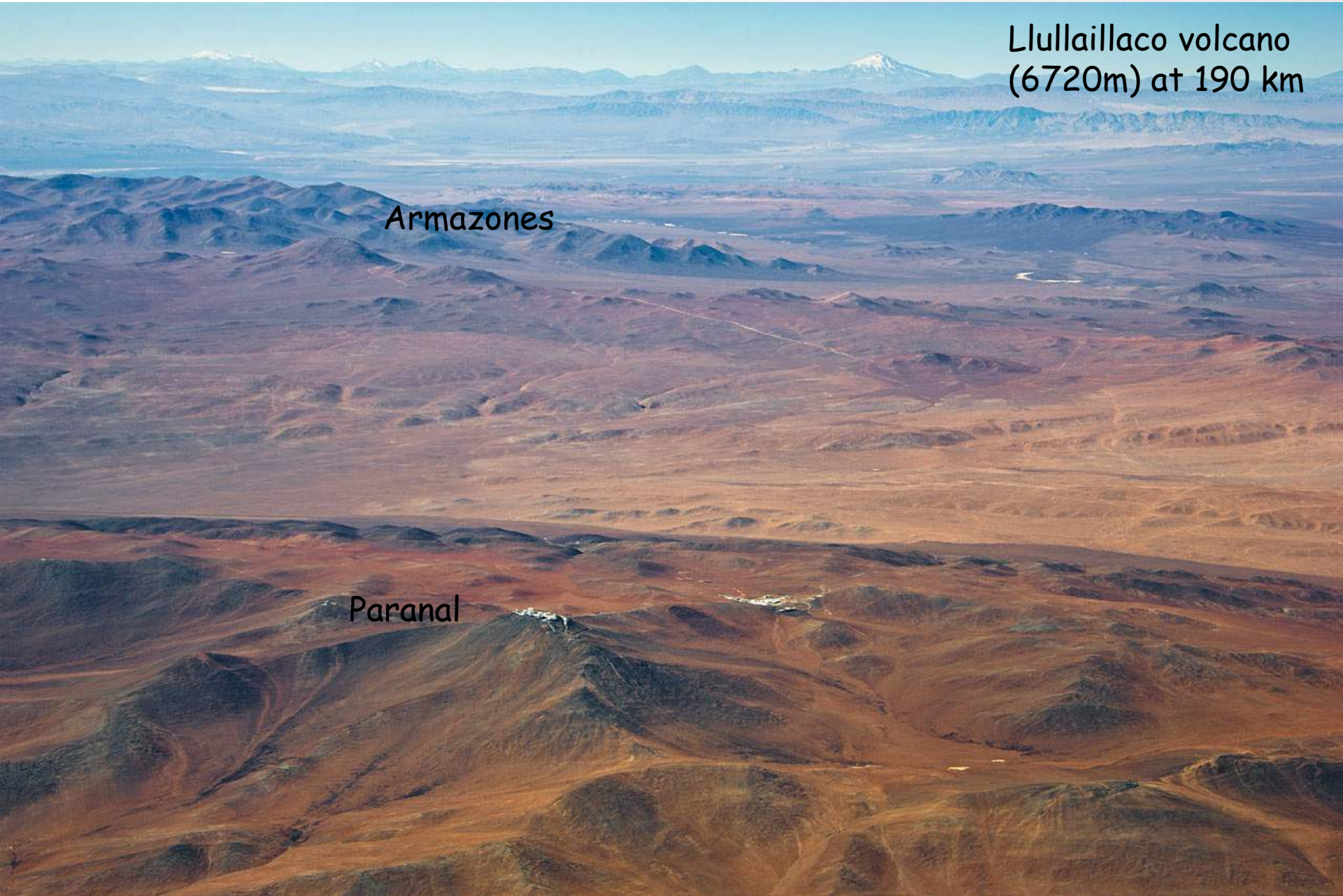


Paranal Armazones area

Llullaillaco volcano
(6720m) at 190 km

Armazones

Paranal



Cerro Armazones





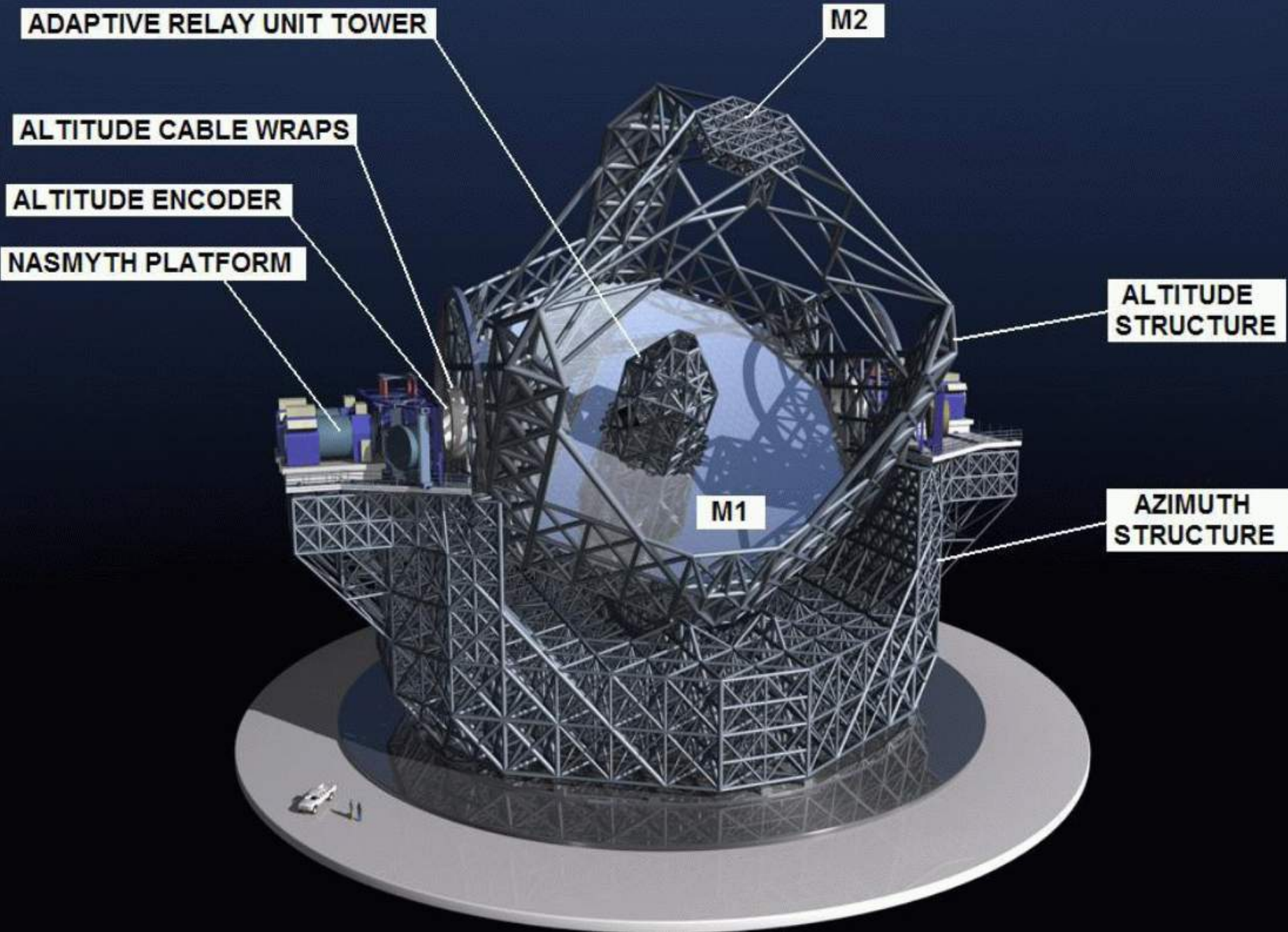
Extremely Large Telescope

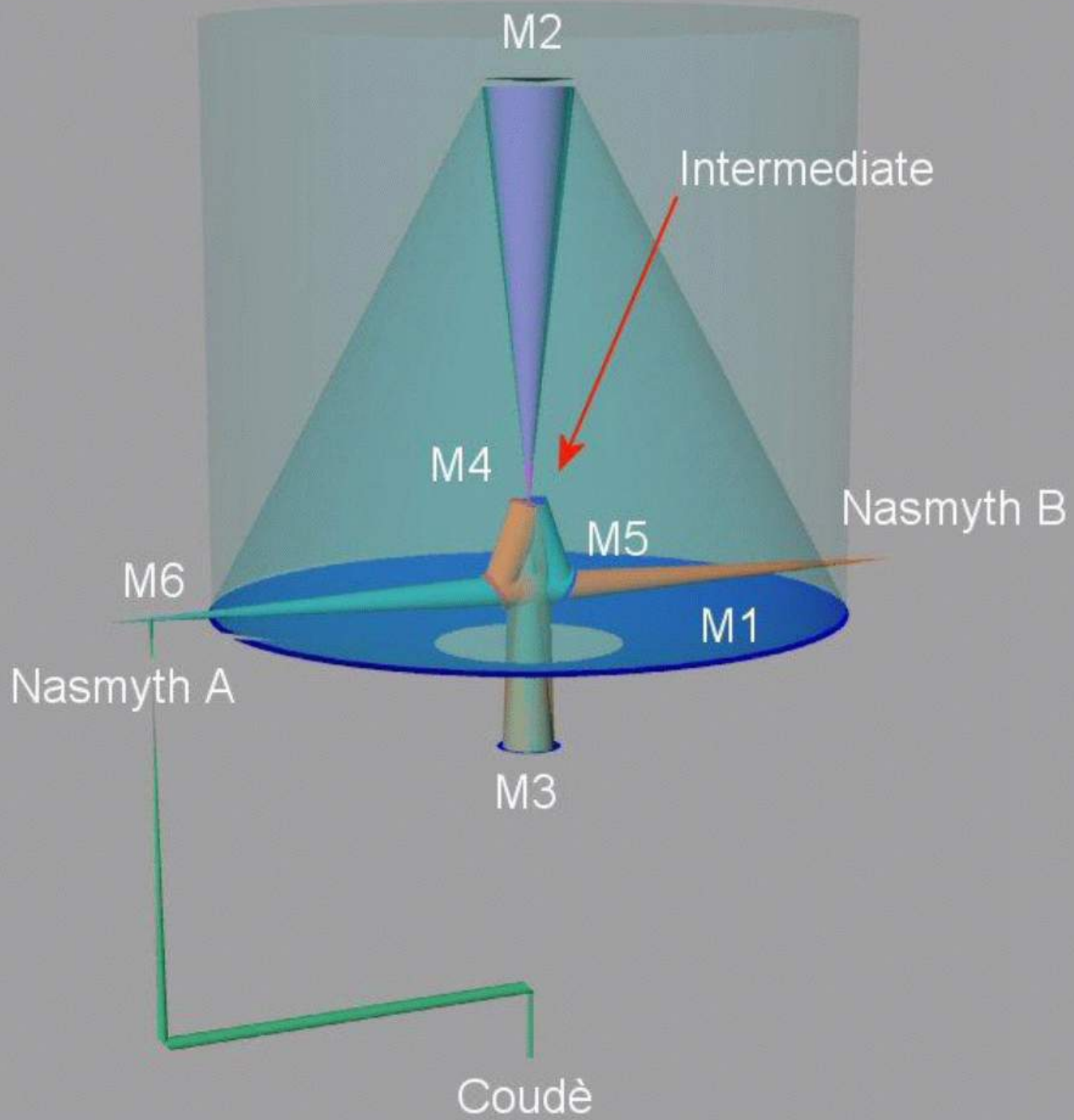


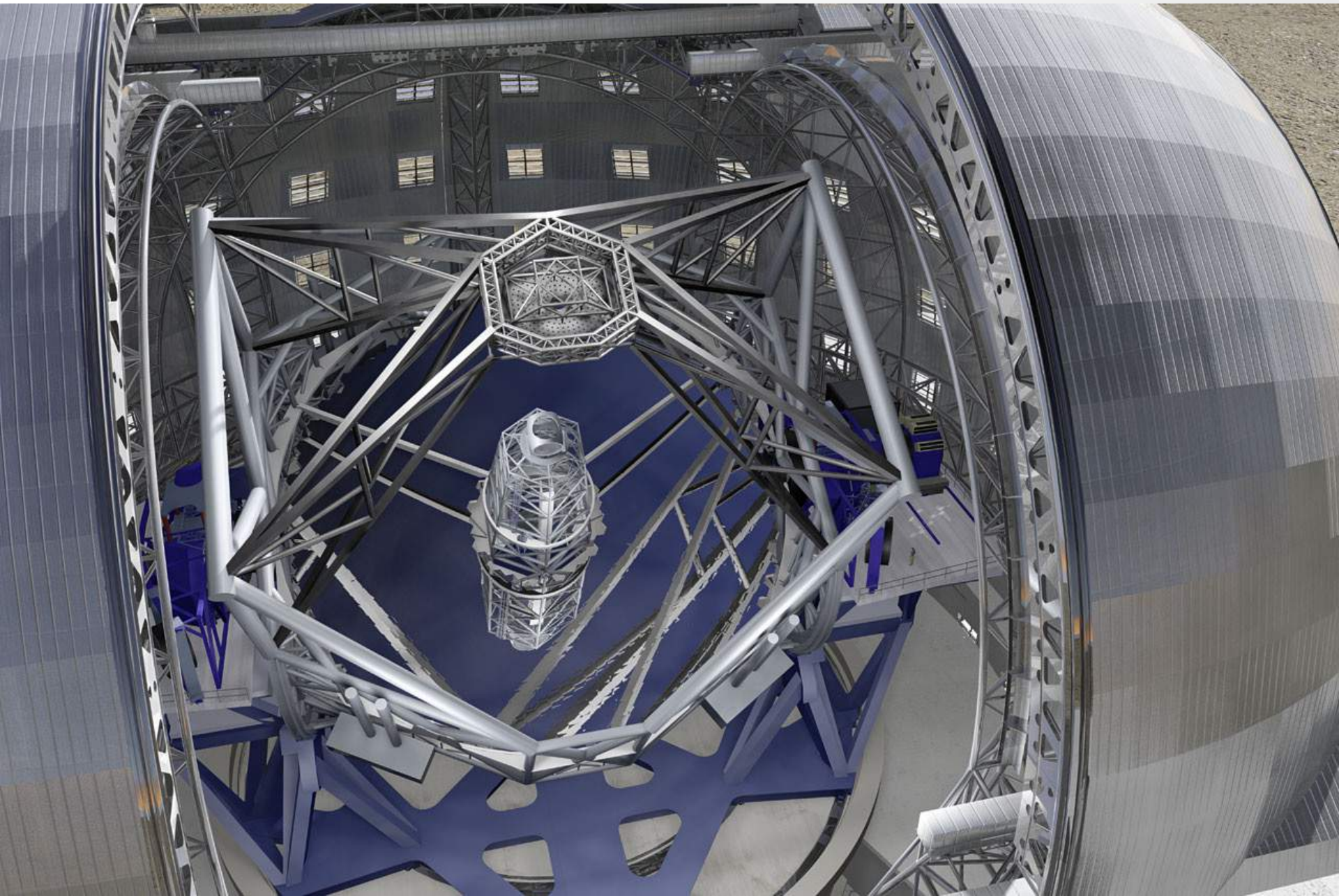
Dome klaar in 2026; *first light* 2028



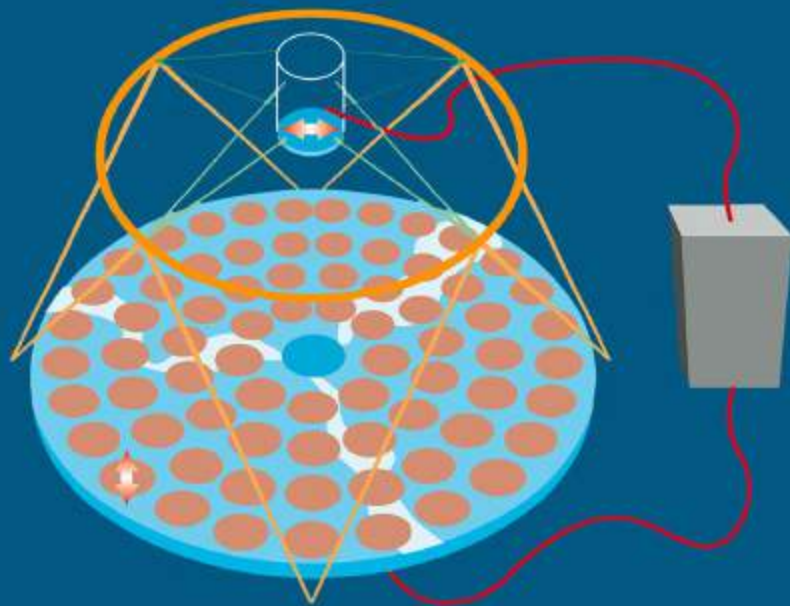
november 2023







ACTIVE OPTICS

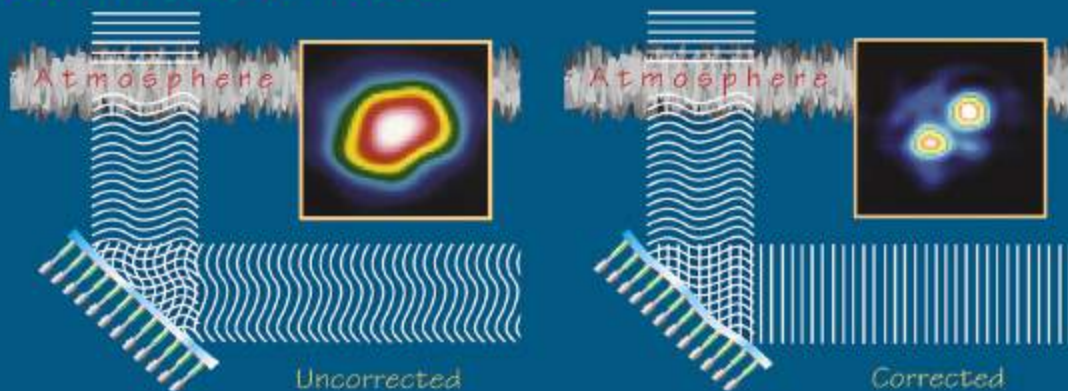


Correction of the deformation/
displacement of the primary and
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- gravitation
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Correction is achieved through
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mirror support

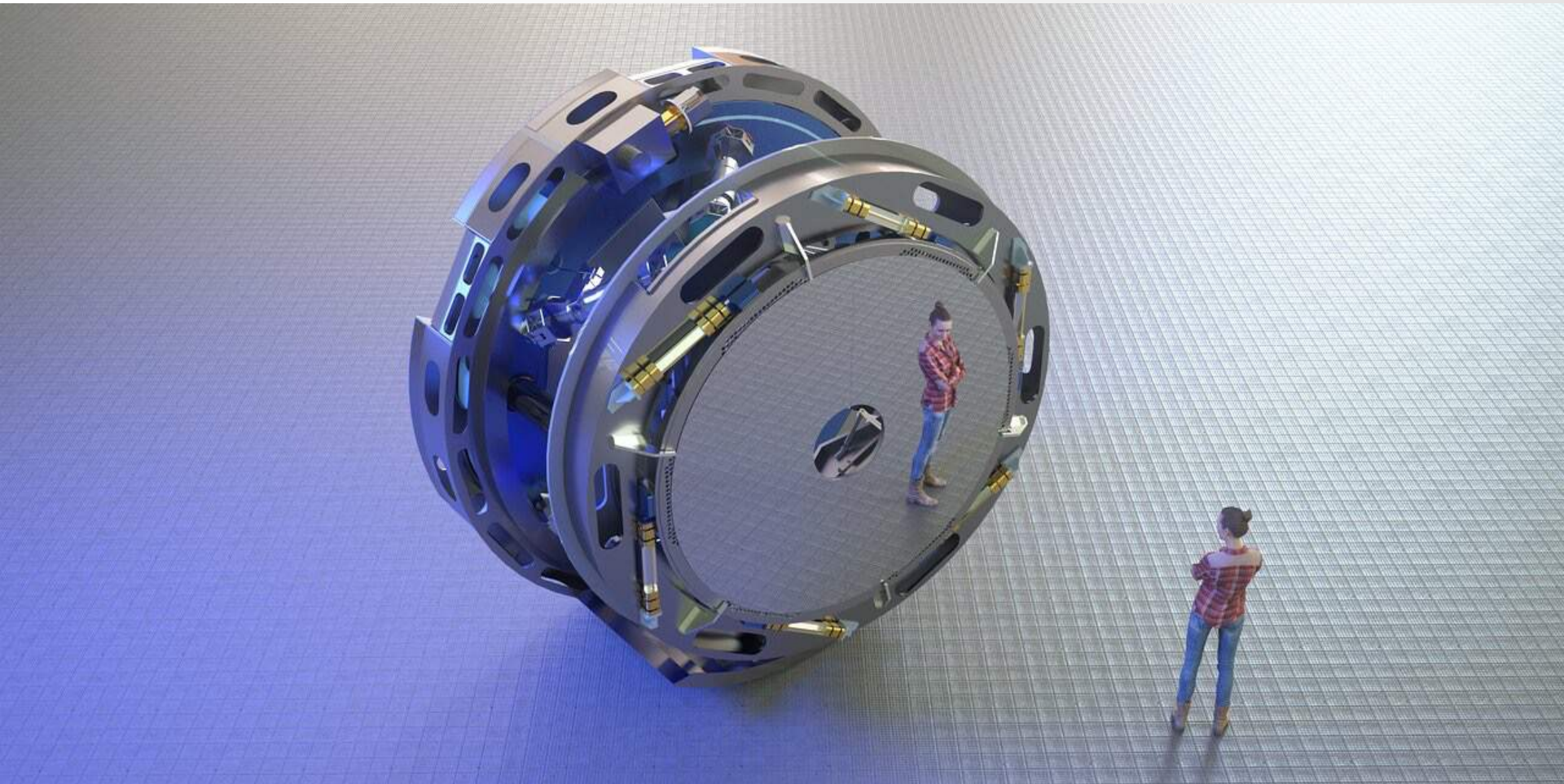
ADAPTIVE OPTICS



Correction of the deformation of
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caused by turbulence

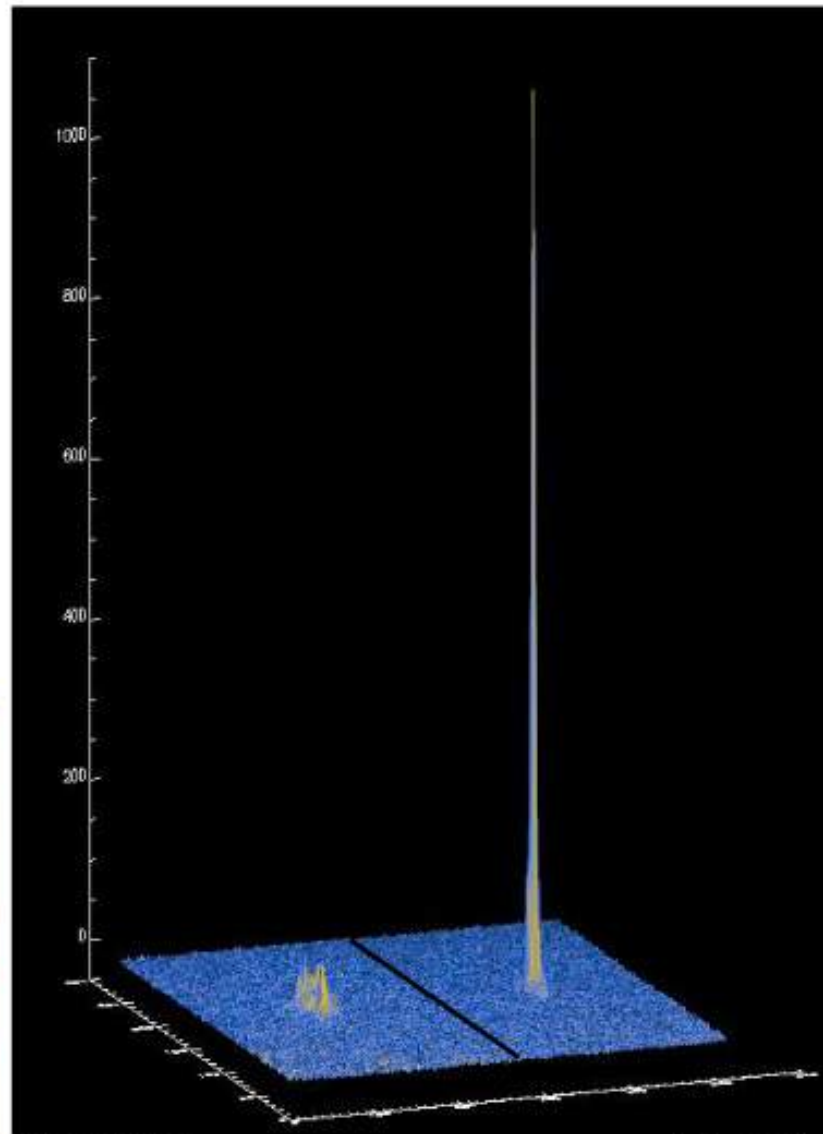
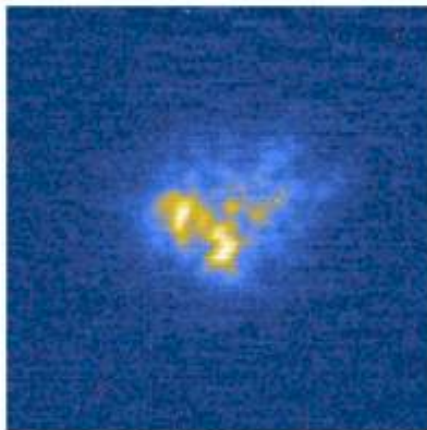
Correction is achieved by means
of a flexible mirror in front of the
detector (+ tip/tilt secondary
mirror)

M4: grootste adaptieve spiegel ooit gebouwd



2.4m 6 Zerodur segmenten silicon carbide
veranderingen met 50 nm precisie (kleiner dan een virus) 1000x per seconde

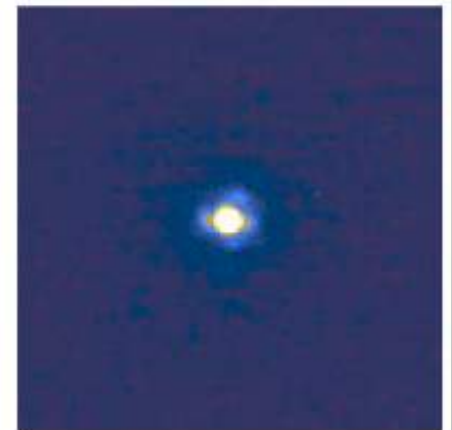
Uncorrected image
FWHM: 0.50"



Left: uncorrected

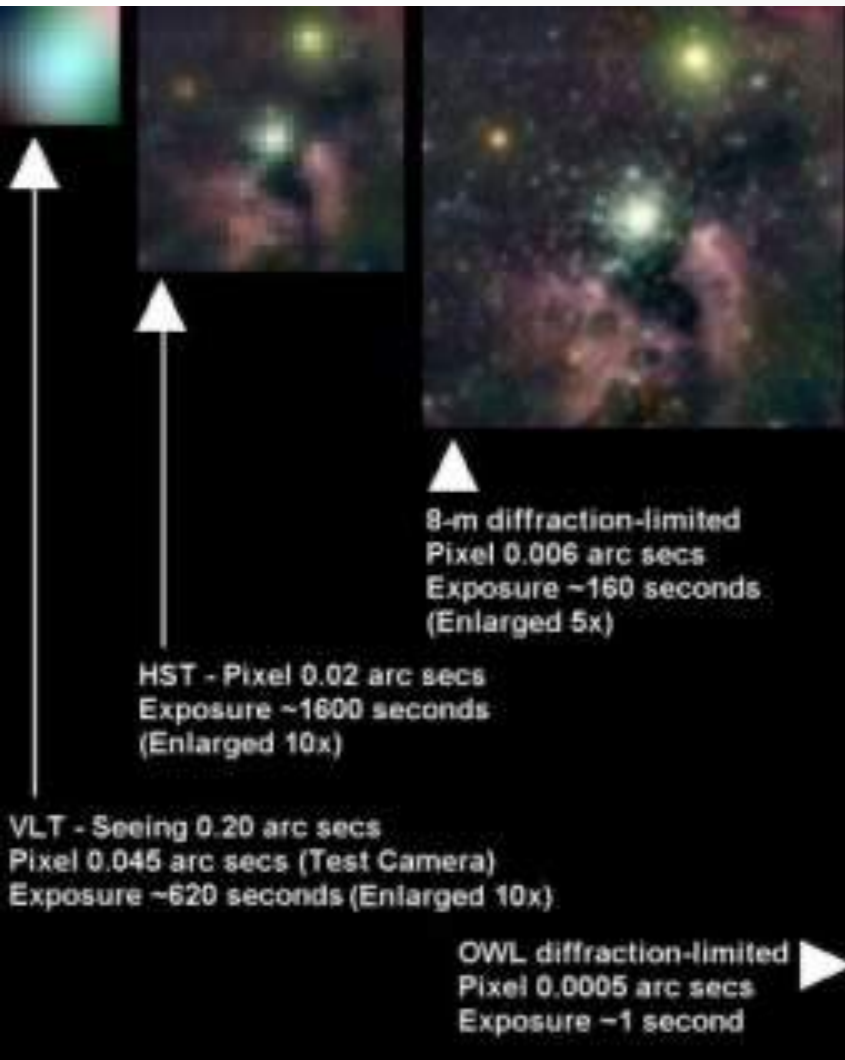
Right: corrected

AO corrected image
FWHM: 0.07"



"First Light" for NAOS-CONICA at VLT YEPUN
(November 25, 2001)





8-m diffraction-limited
Pixel 0.006 arc secs
Exposure ~160 seconds
(Enlarged 5x)

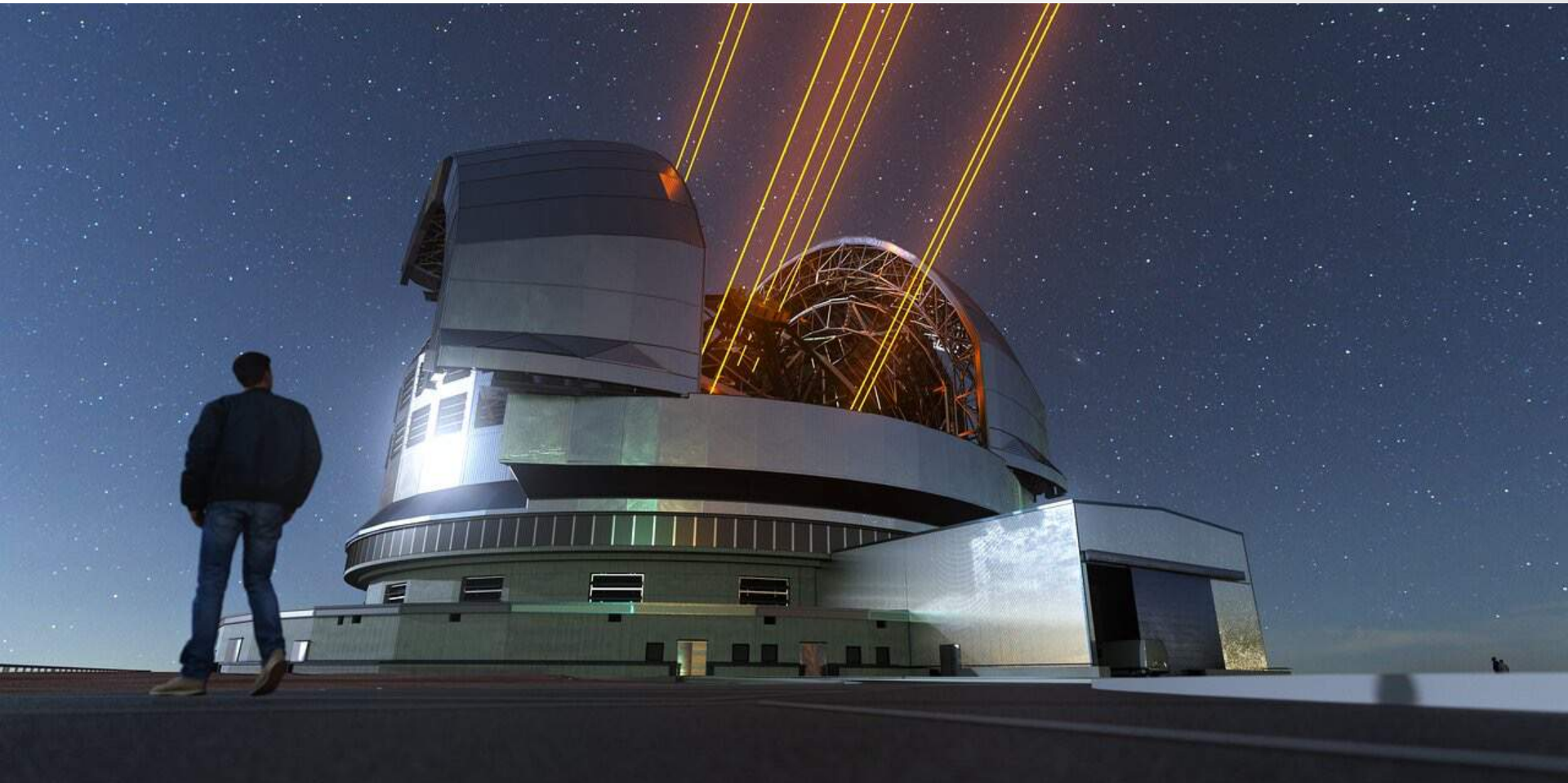
HST - Pixel 0.02 arc secs
Exposure ~1600 seconds
(Enlarged 10x)

VLT - Seeing 0.20 arc secs
Pixel 0.045 arc secs (Test Camera)
Exposure ~620 seconds (Enlarged 10x)

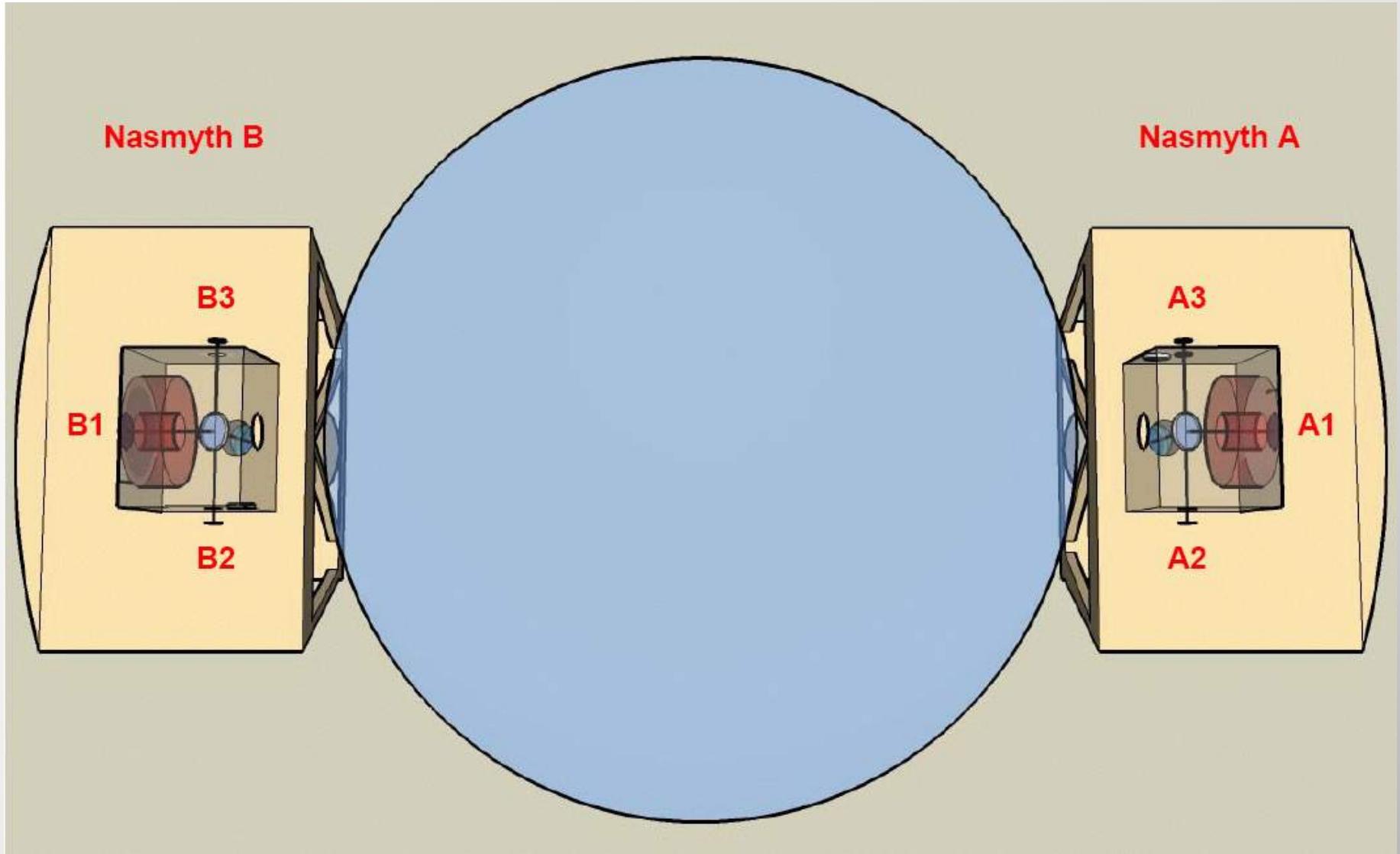
OWL diffraction-limited
Pixel 0.0005 arc secs
Exposure ~1 second

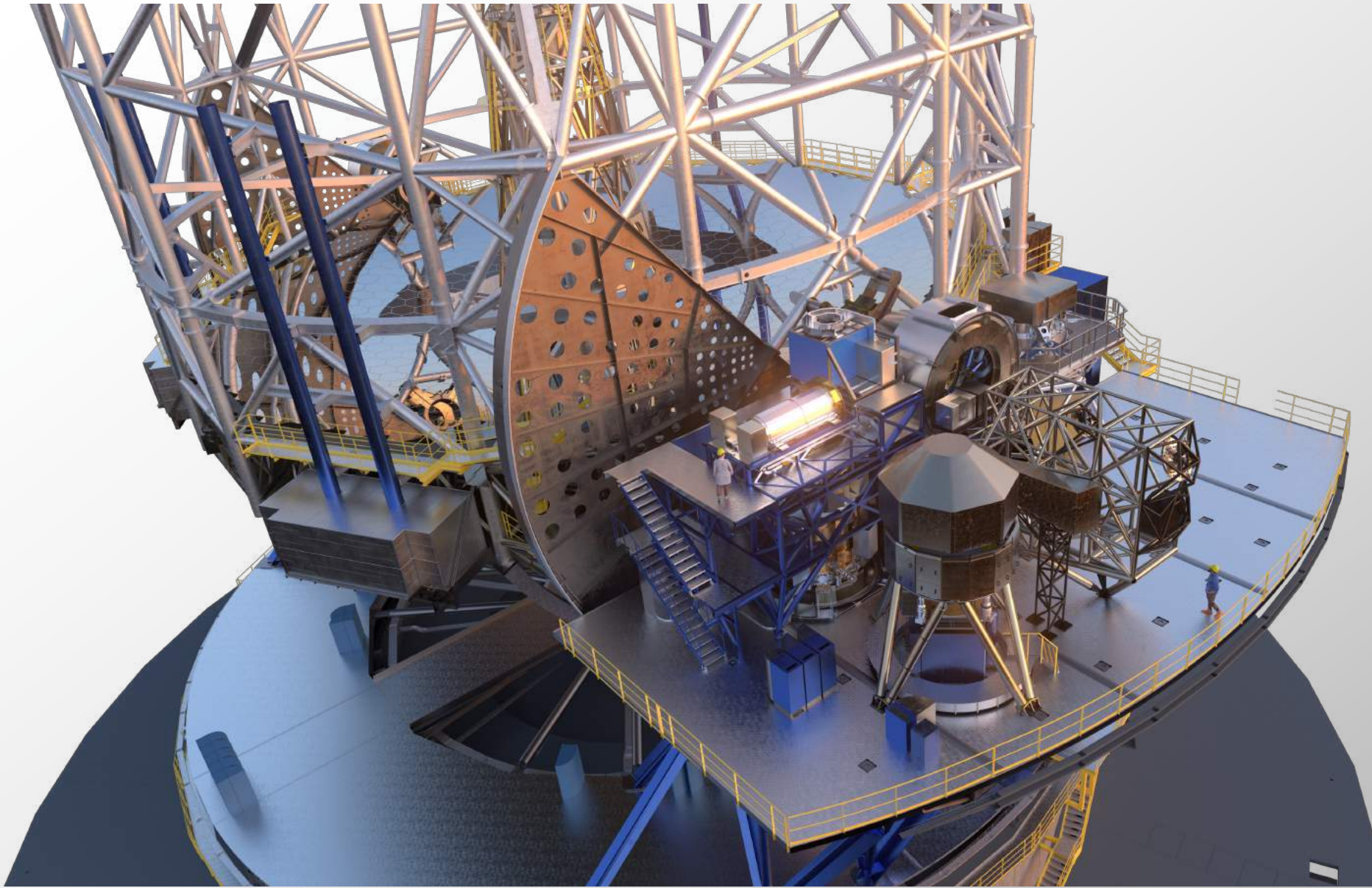


Laser Guide Star system



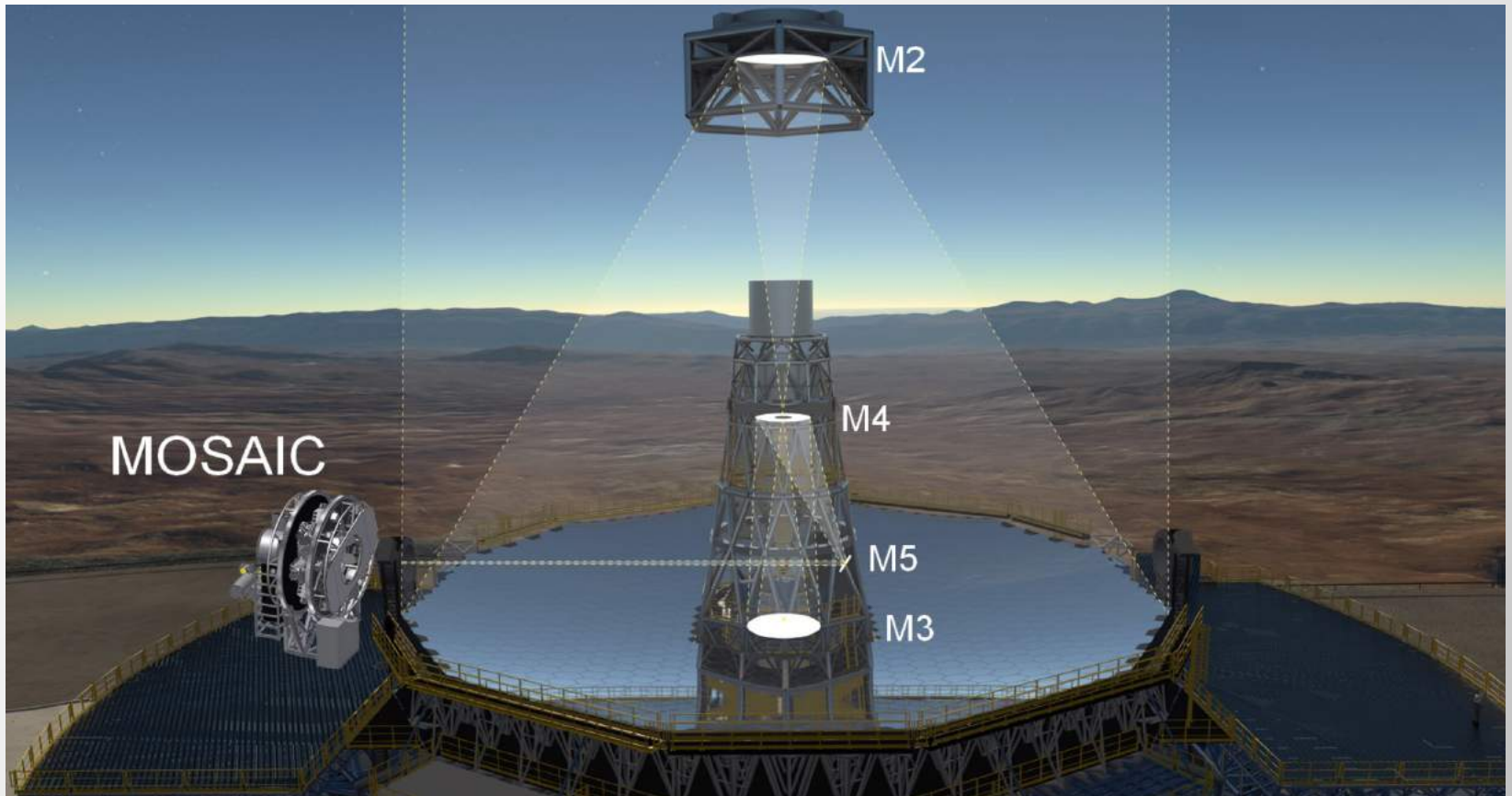
Nasmyth platforms



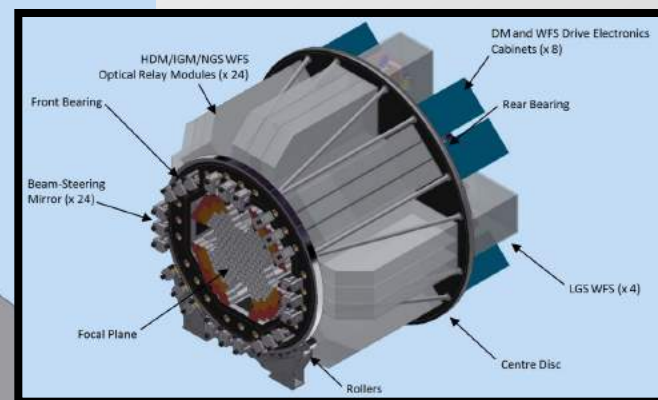
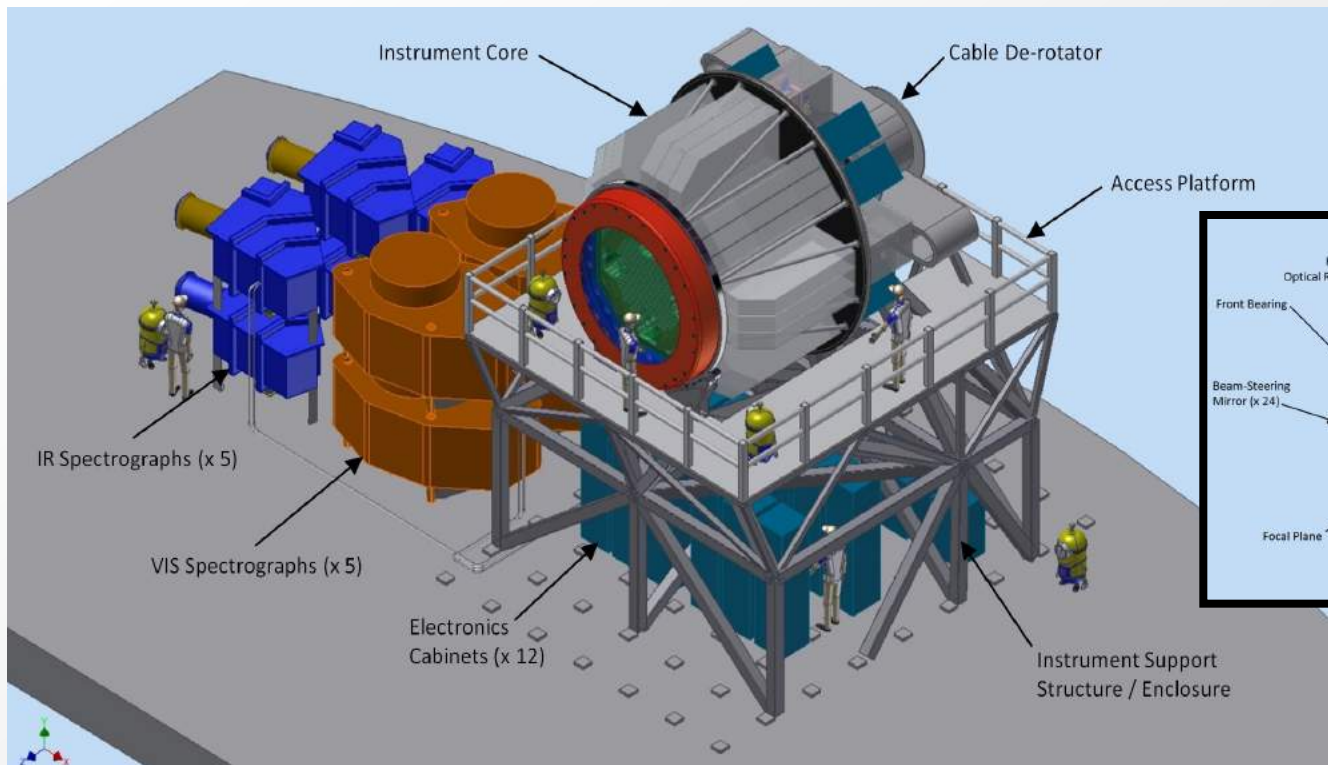




MOSAIC on ELT



MOSAIC



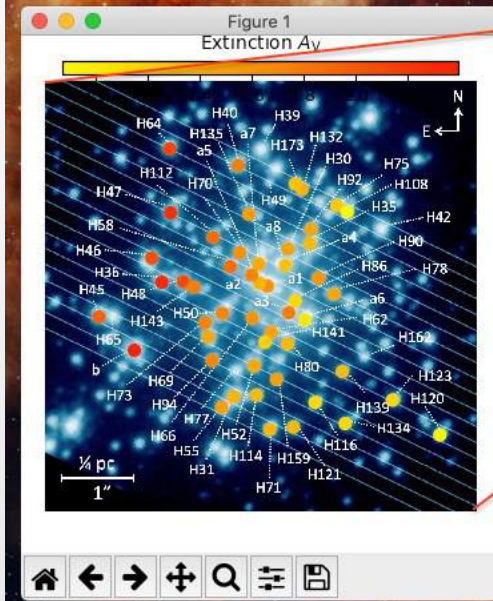
Masse	29.5 Tons
Volume	9.8m(W)x6.85m (L) x 8m (H)

MOSAIC consortium



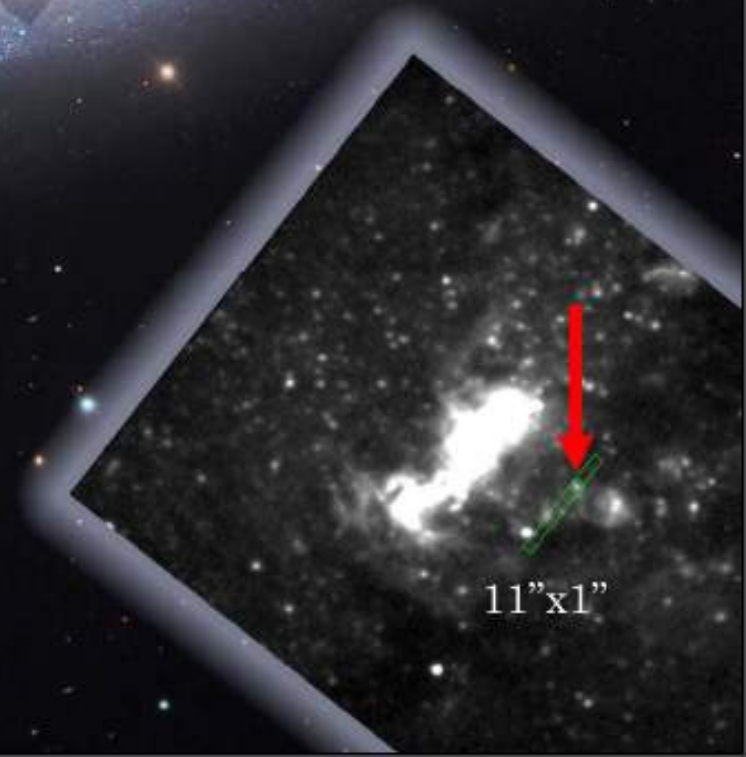
Toledo 2017

Sterpopulaties in andere melkwegstelsels

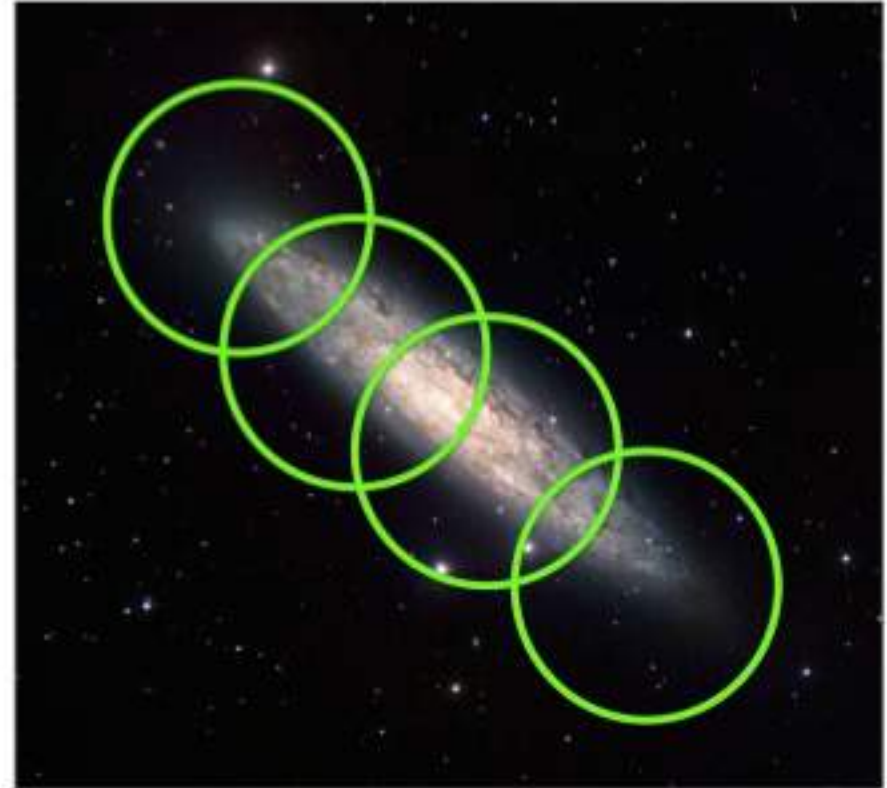
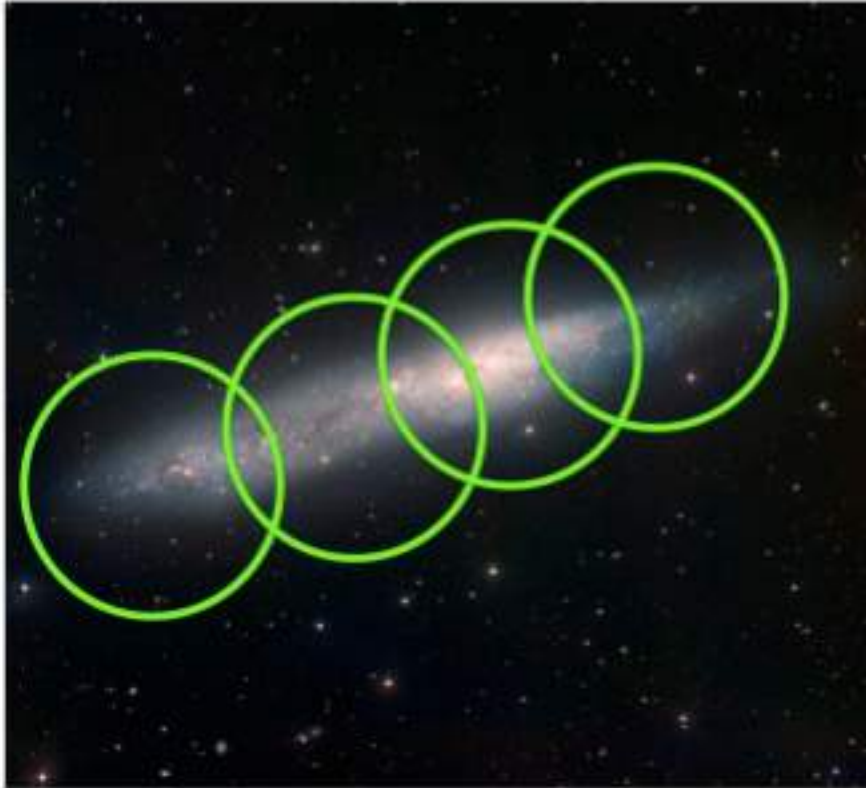


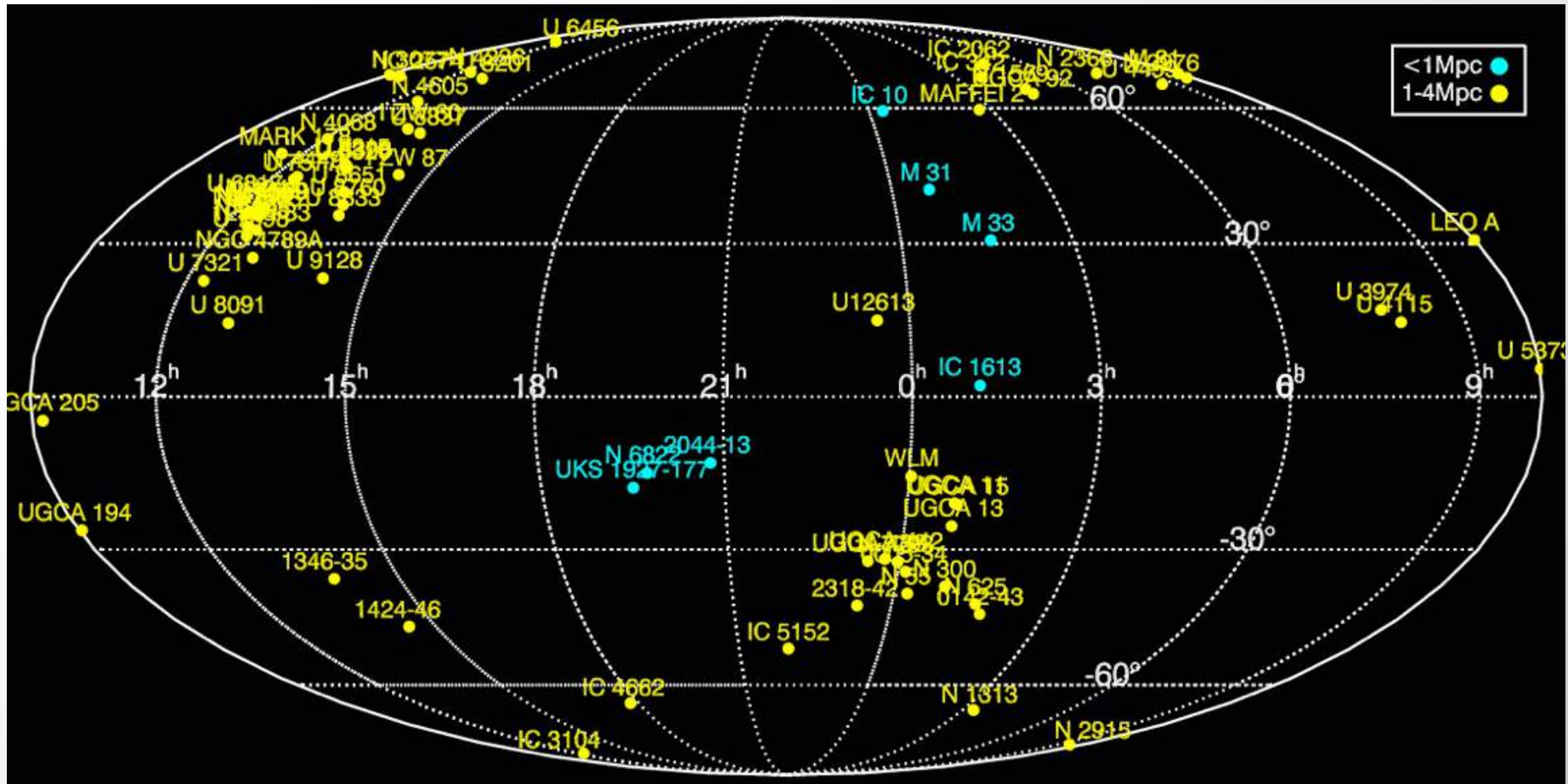
Resolved stellar populations in NGC 55

32'.4

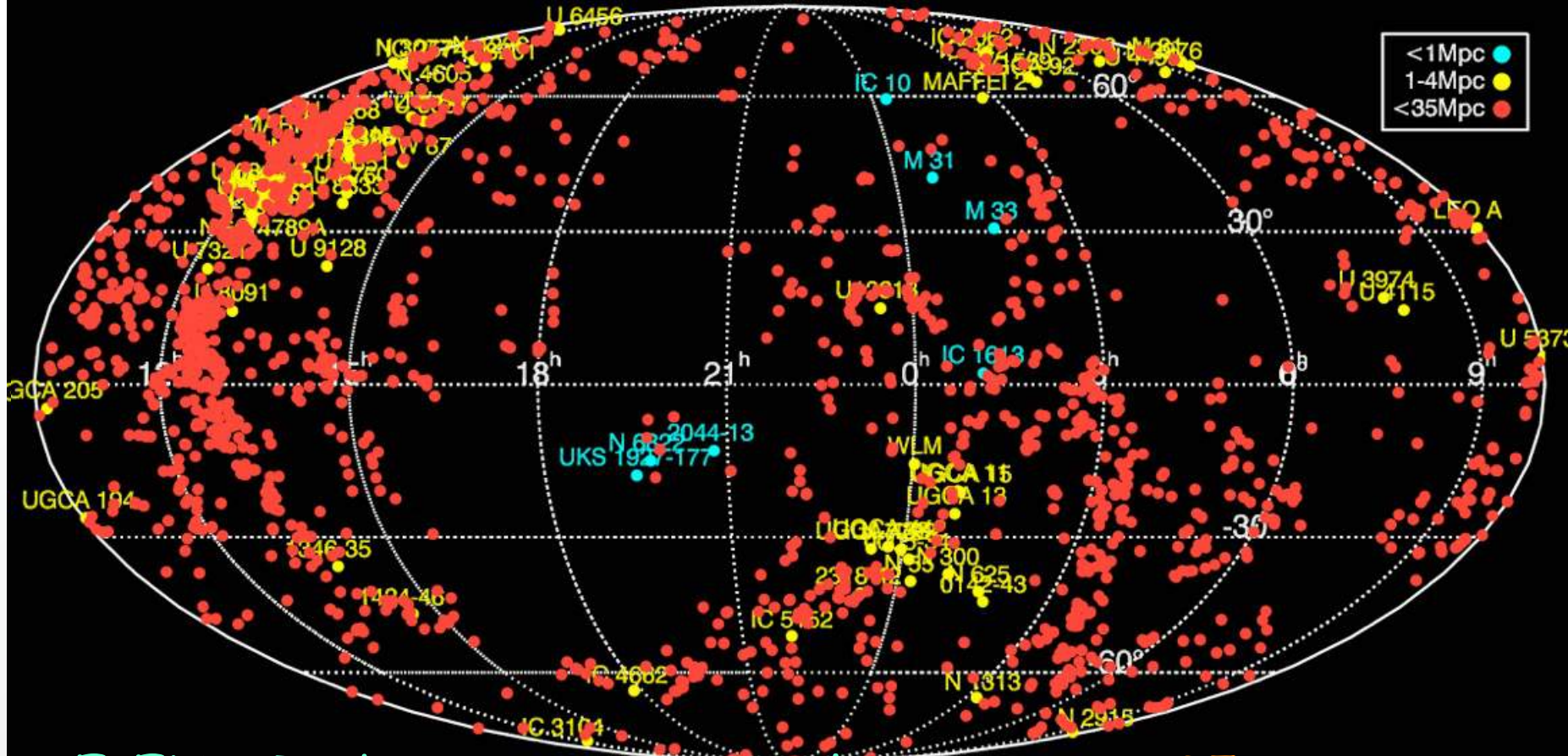


MOSAIC pointings in NGC 55





Evolved red giants in galaxies out to 4Mpc
number of observable targets ~100



E-ELT: Red supergiants in galaxies out to 35 Mpc

number of observable targets increased to ~1500!!

