Գալիլեո Գալիլեյը և աստղադիտակների զարգացման պատմությունը

Արեգ Միքայելյան
ՀՀ ԳԱԱ Վ. Համբարձումյանի անվան Բյուրականի աստղադիտարան (ԲԱ)

ԲԱ սեմինար
15.02.2024, Բյուրական, ՀՀ

Galileo's Biography

1564 – Galileo was born on 15 February in Pisa, Italy

1572 – Galileo's fam,ily moved to Florence (without Galileo)

1574 – Galileo also moved to his family to Florence

1575-1578 – Education in the Vallombrosa Abbey, about 30 km southeast of Florence

1580-1585 – Studies at Medical University of Pisa, also Geometry

1589 – Galileo was appointed to teach at the Chair of Mathematics in Pisa

1590 – Galileo's book; Treatise on Motion

1592-1610 – University of Padua (Republic of Venice); Galileo taught Geometry, Mechanics, and Astronomy

1593 – Galileo constructed a thermometer, using the expansion and contraction of air in a bulb to move water in an attached tube

1599 – Galileo extramarital relations (civil marriage) with Marina Gamba; 3 children: Virginia (1600), Livia (1601), Vincenzo (1606)

1604 – Kepler Supernova, Galileo's interest to Astronomy

1609 – Galileo builds his first (refracting) telescopes (similar to Hans Lippershey's one): $3^{\times}$ and $32^{\times}$

Galileo's Biography

1609-1610 – Galileo's telescopic discoveries

1610 – Galileo's book "Star Messenger" ("Sidereus Nuncius")

1610 – Galileo moves to Florence (Herzog Cosimo II Medici's invitation)

1614-1616 – Galileo's accusation by the Church ("Galileo's affair", Pope Paul V)

1623 – Cardinal Maffeo Barberini (Galileo's supporter) became the Pope

1632 – Galileo's book "The Dialogue Concerning the Two Chief World Systems" ("Dialogo sopra i due massimi sistemi del mondo")

1633 – home arrest (till his death) and abandoning his ideas

1638 – Galileo's last book publication in the Netherlands

1638 – Galileo became blind

1642 – Galileo passed away on 8 January in Arcetri, Italy, buried in the Basilica of Santa Croce, Florence

1642 – Galileo's son, Vincenzo, sketched a clock based on his father's theories

1979 – Pope John Paul II launched an investigation into the Catholic Church's condemnation of Galileo

1992 – Galileo was recognized right by Vatican


27/2/04
17/3/04
22/3/04
27/3/04
3/4/04
13/4/04
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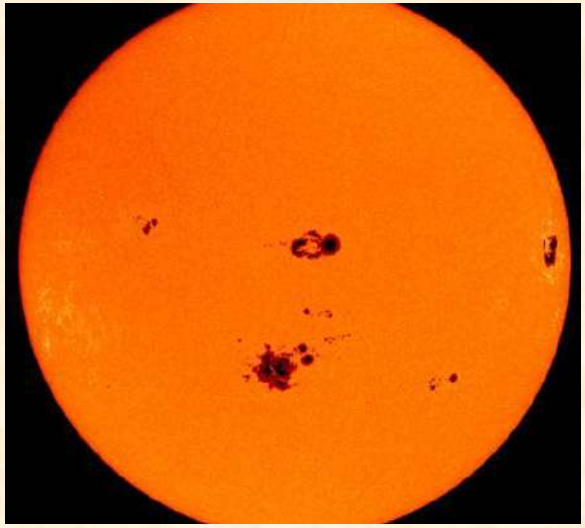
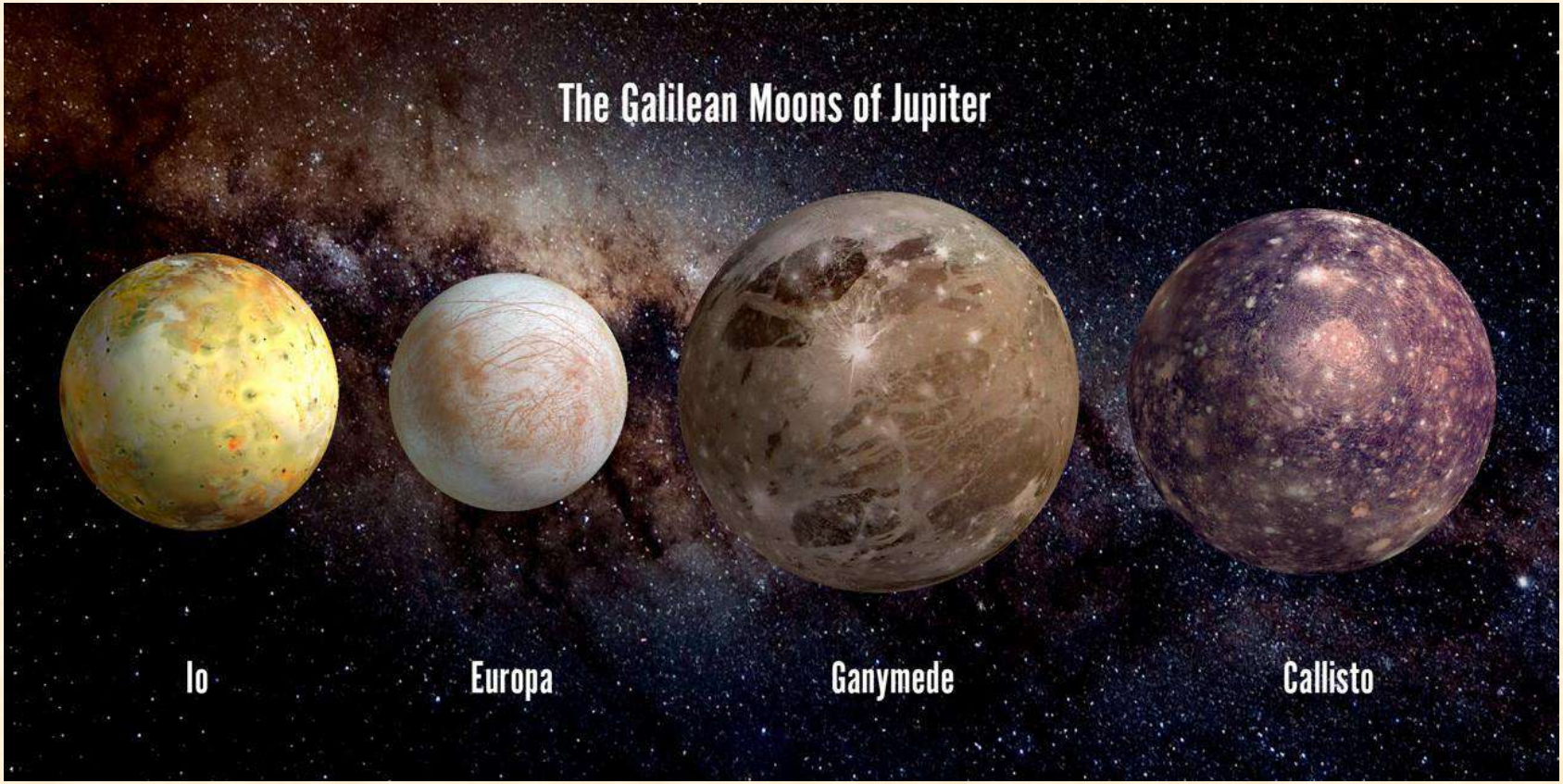
8/6/04




The Galilean Moons of Jupiter
Io
Europa
Ganymede
Callisto

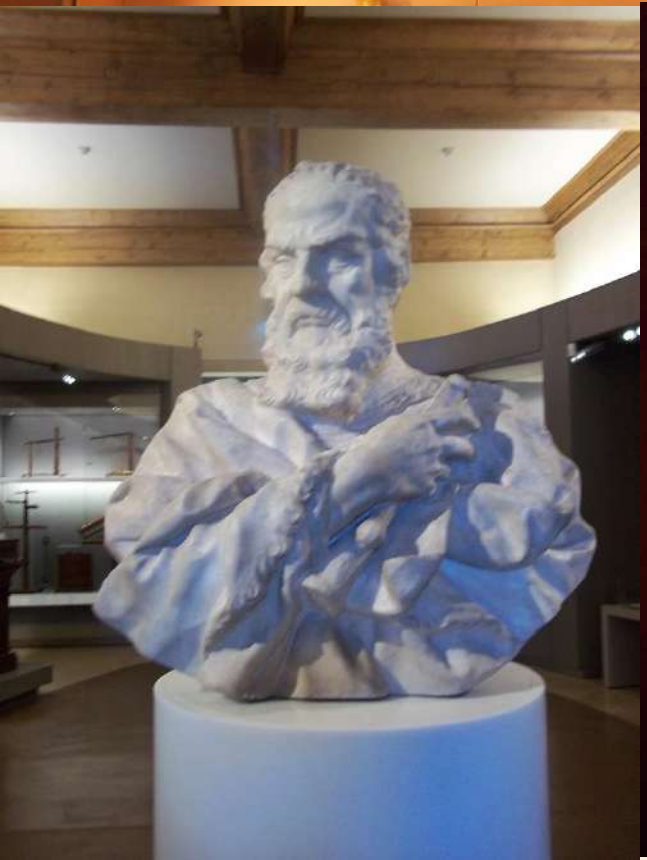
Galileo's Astronomical Discoveries 1609-1610

- Resolving Milky Way into stars
- Lunar mountains, valleys and craters
- Sunspots
- Sun's rotation with 1 month period
- Venus' phases and its motion around the Sun
- Jupiter's 4 moons (satellites); Galilean (Jovian) Moons: Io, Europa, Ganymede and Callisto
- Saturn's rings

After Galileo's name

- Jupiter's **Galilean Moons**
- Principle of relativity in classic mechanics and coordinate transformation
- **Lunar crater** (-63º, +10º)
- **Mars crater** (N. lat. 6º, W. long. 27º)
- Jupiter's moon Ganymede's 3200 km diameter region
- **Asteroid #697**
- NASA **Space probe Galileo** (1989-2003)
- European navigation satellite system project "Galileo"
- **Unit of acceleration Gal** in CGS system: 1 Gal = 1 cm/s^2
- Scientific-popular and entertaining TV program "Galileo" broadcasted in several countries
- Pisa airport after Galileo
- **UNESCO IYA-2009** due to Galileo's discoveries
- Galileo's museum in Florence



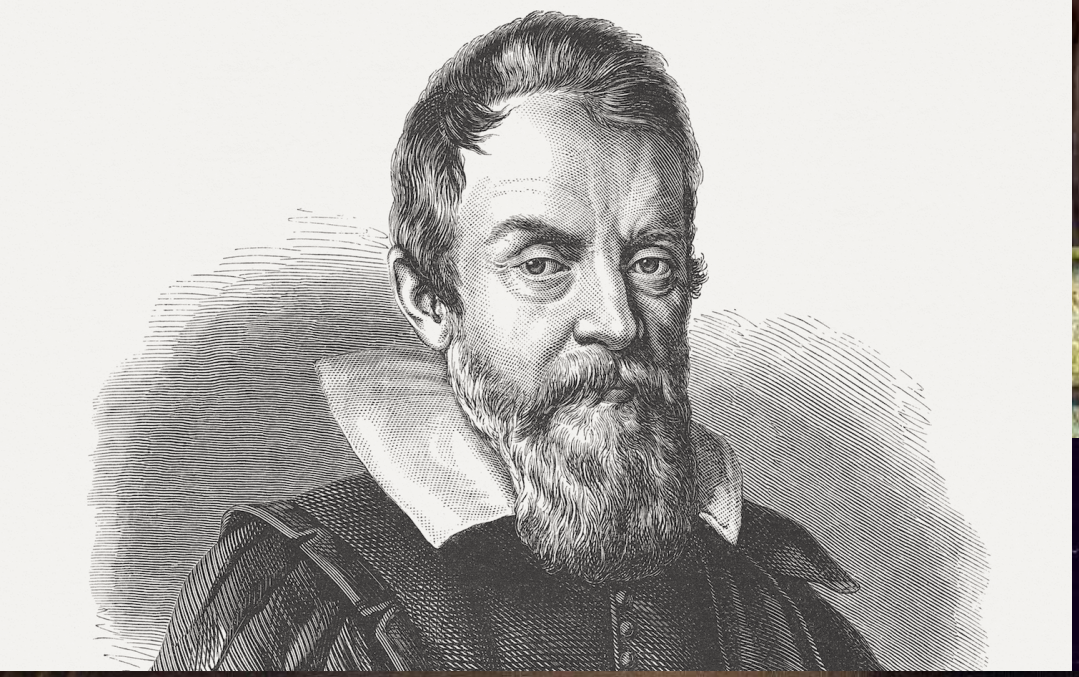


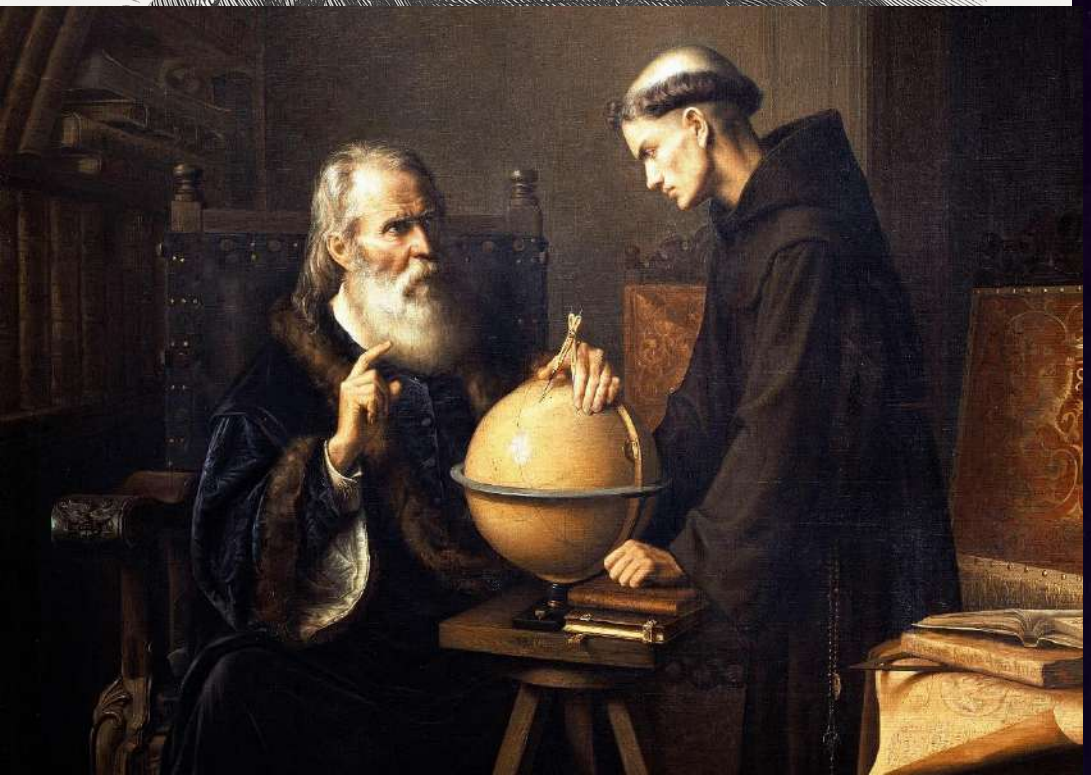

The Moti
Time, Dis
and Traje

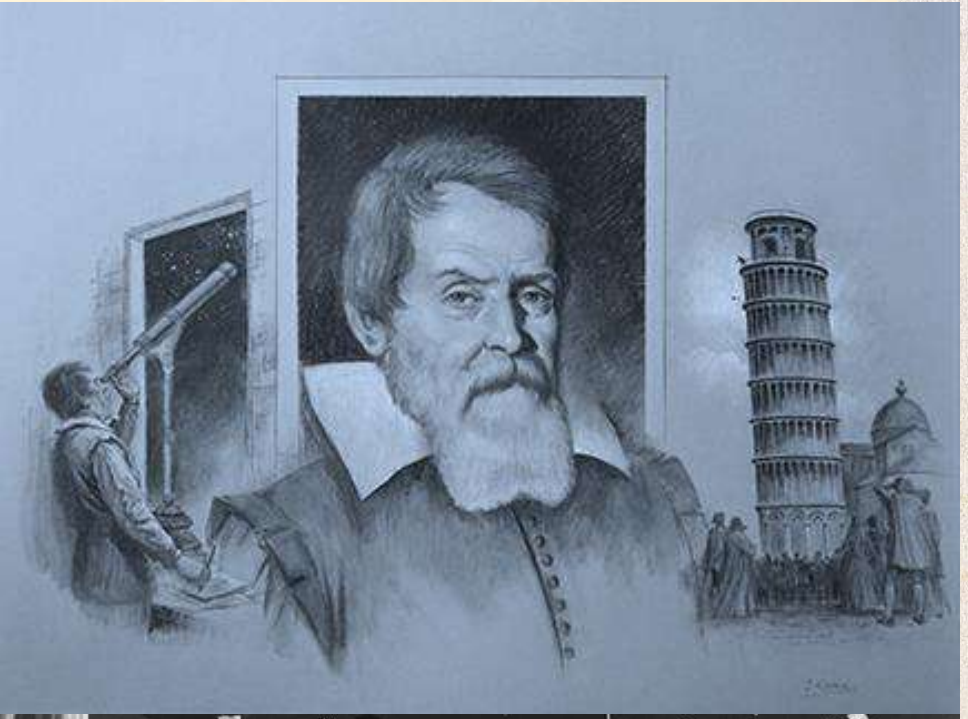

PONENTE
Libeccio
OSTRO
Scirocco
LEVANTE
GRECO

Գալիլեյի ժամանակակիցները +

- **Nicolaus Copernicus** (Poland, 1473-1543) – astronomer
- Pope Gregory XIII (Italy, 1502-1585)
- **Tycho Brahe** (Denmark, 1546-1601) – astronomer
- Miguel de Cervantes (Spain, 1547–1616)
- Francis Bacon (England, 1561-1626)
- **Galileo Galilei (Italy, 1564-1642)** – astronomer +
- William Shakespeare (England, 1564-1616)
- Tommaso Campanella (Italy, 1568-1639)
- Hans Lippershey (Netherlands, 1570-1619) – 1st telescope
- Jacob Metius (Netherlands, 1571–1628) – 1st telescope
- **Johan Kepler** (Germany, 1571-1630) – astronomer
- Johan Bayer (Germany, 1572–1625) – astronomer
- Willebrord Snellius (Netherlands, 1580–1626) – astronomer
- Zacharias Janssen (Netherlands, 1585-1632) – 1st telescope
- Cardinal Richelieu (France, 1585-1642)
- Jan Hevelius (Poland, 1611-1687) – astronomer
- Jean-Baptiste Colbert (France, 1619-1683)
- Blaise Pascal (France, 1623-1662)
- Giovanni Domenico Cassini (Italy, 1625–1712) – astronomer
- Christiaan Huygens (Netherlands, 1629-1695) – astronomer +
- James Gregory (Scotland, 1638-1675) – astronomer

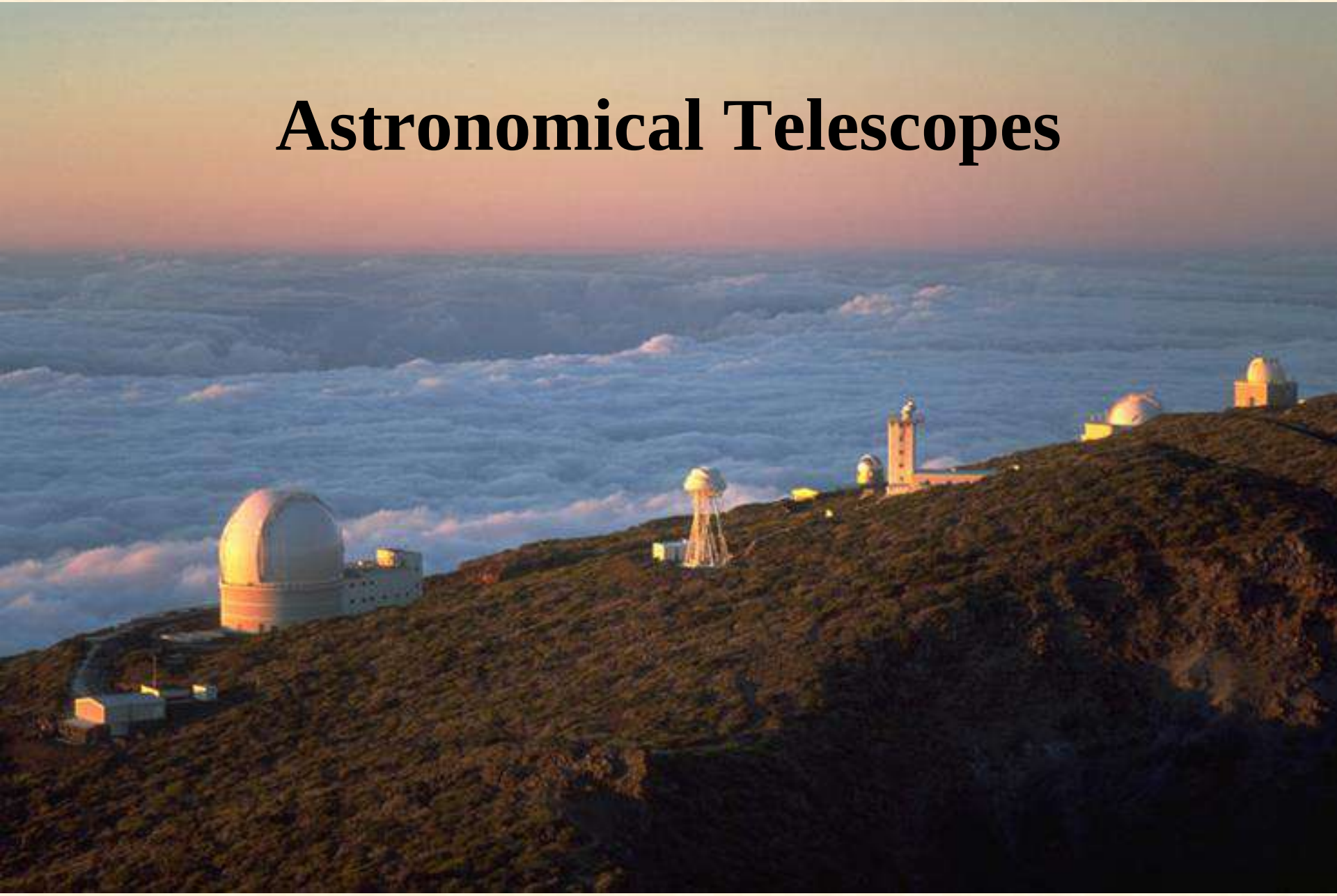






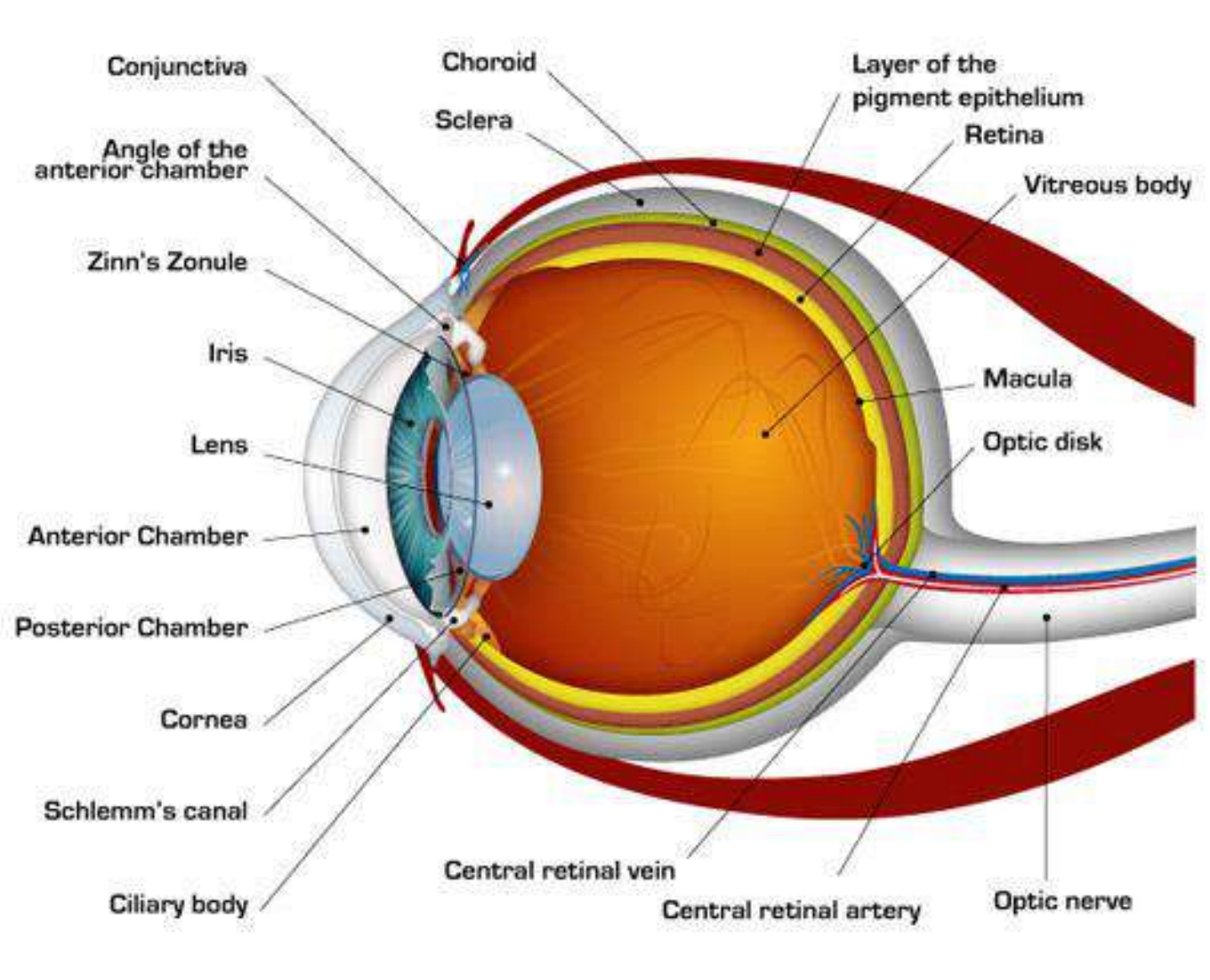

Castelli scolpì
Asioli disegnò
Spagnoli incise
GALILEO GALILEI

Astronomical Telescopes



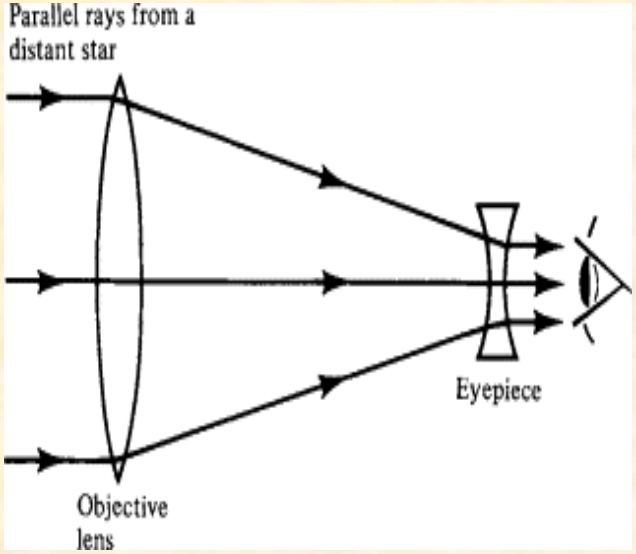
The human eye: 7 mm lens and a supercomputer

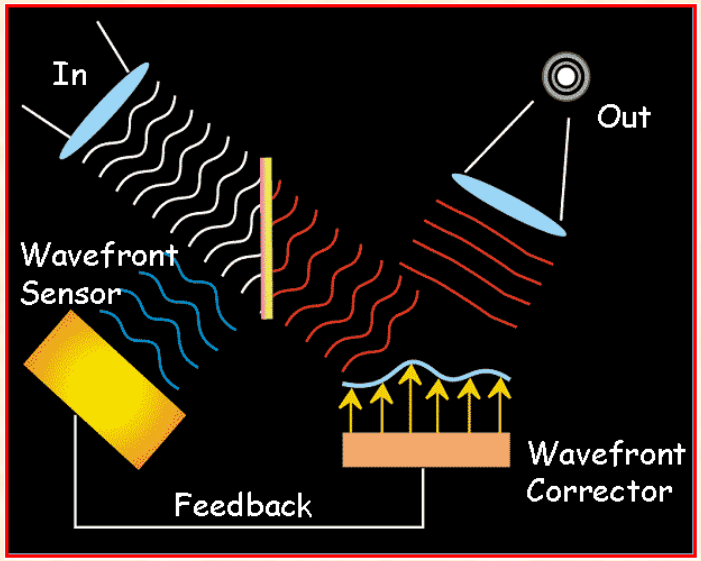
1 arcmin resolution, extreme dynamic range, limiting magnitude ~6^{m}



Astronomical Telescopes and Technology

Hans Lippershey, Galileo Galilei, Christiaan Huygens, Isaac Newton, Laurent Cassegrain, William Herschel, Léon Foucault, Bernhard Schmidt, George Willis Ritchey, Henri Chrétien, Guido Horn D'Arturo, Horace W. Babcock





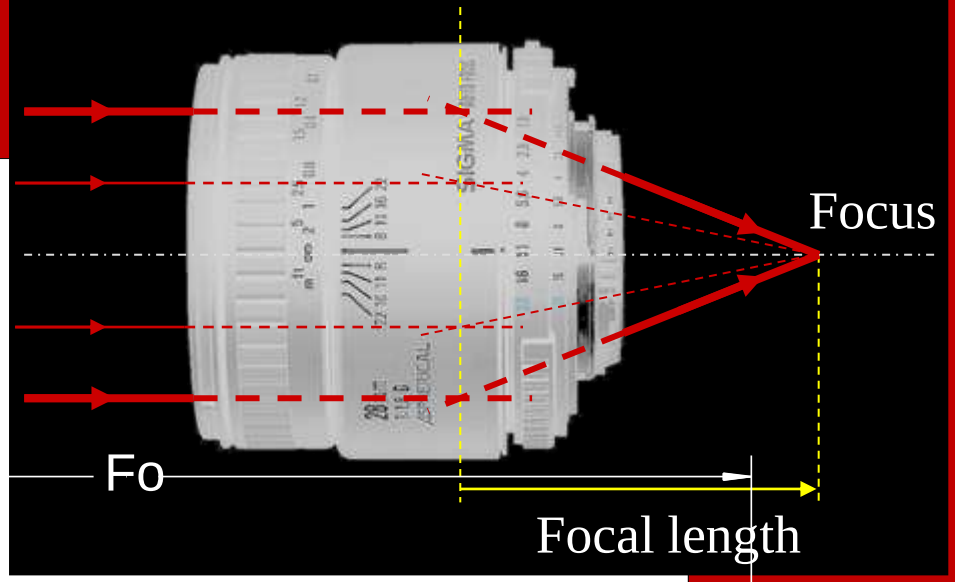
Hans Lipperhey's patent application on 25 September 1608 for the "spy glasses"

Galileo's telescope

Diameter 15 and 30 mm

Venice, 1609

Galileo's telescope



Angular magnification G=Fo / Fe

Focal ratio N=Fo / D

Basic Properties of Telescopes Optics

Aperture = D, Focal Length=f, Focal ratio=F=f/D
For telescopes of the **same design** the following holds.

- Light collecting power – proportional to D^2
- Theoretical angular resolution – proportional to 1/D (1.22 λ/D)
- Image scale (″/mm) – proportional to 1/f (206/f, ″/mm, if f in m)
- Total flux of an object at focal plane – also proportional to D^2
- Surface intensity of an extended source at focal plane - proportional to $1/F^2$
- Angular Field of View (FoV) – normally bigger for smaller F, wide fields need special designs

Eyepieces

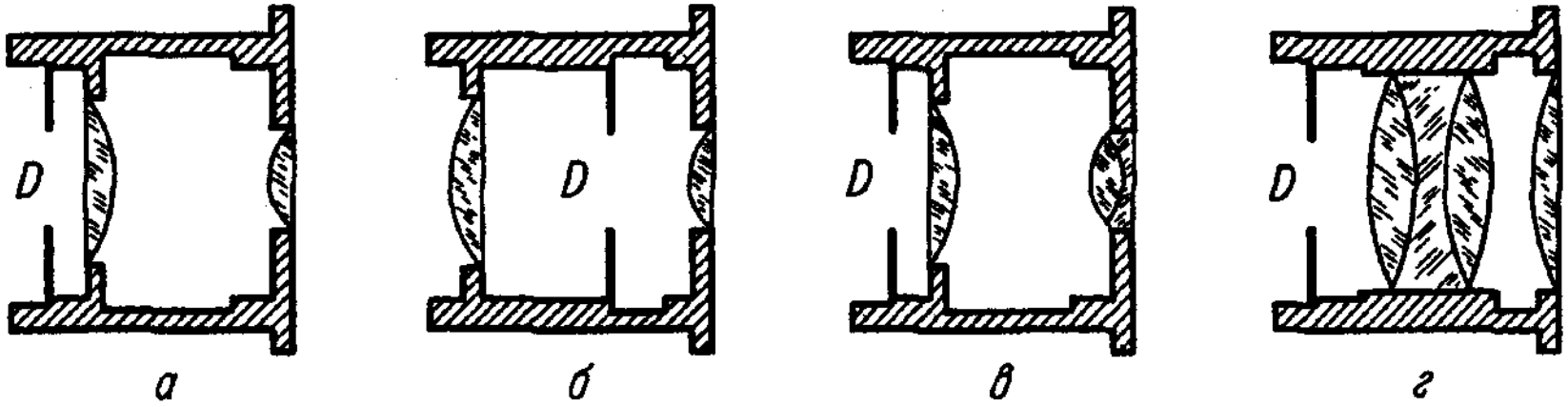
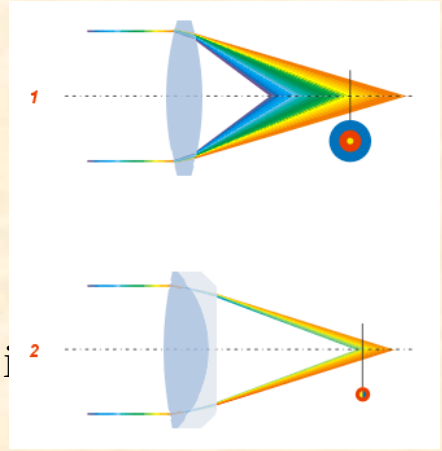


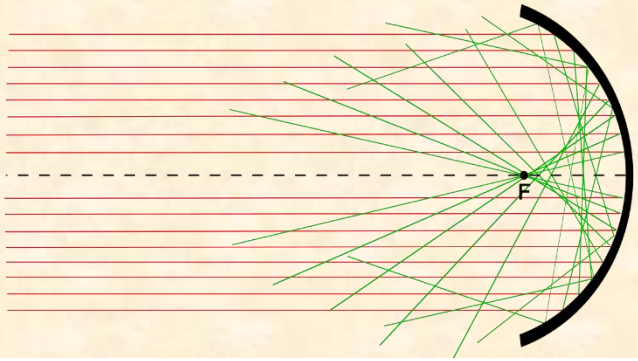
Рис. 195. Окуляры Рамсдена (*а*), Гюйгенса (*б*), Кельнера — ахроматический (*в*) и Аббе — ортоскопический (*г*)

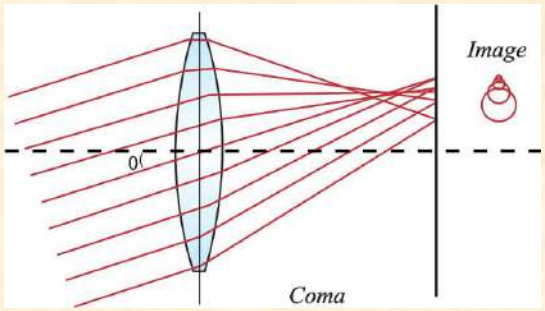
Telescope Aberrations

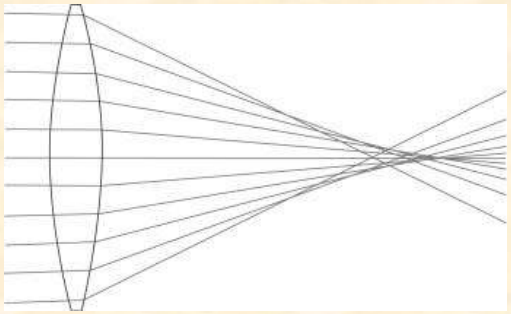
Basic chromatic and monochromatic (Seidel) aberrations:

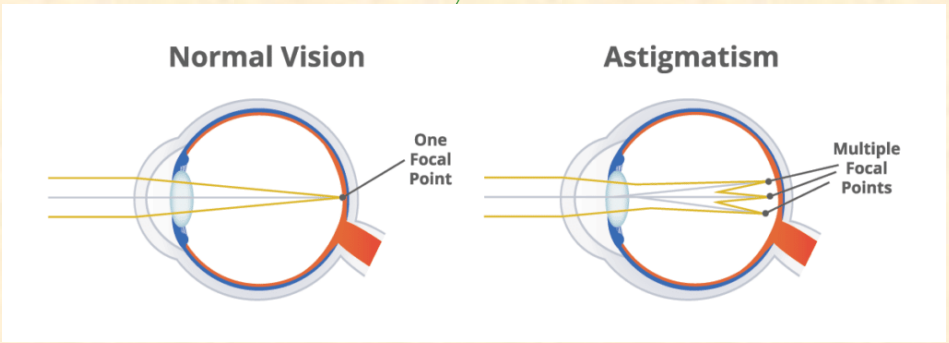
- **Chromatic aberration** (refractors)
- **Spherical aberration** (spheric mirrors)
- **Coma**
- **Astigmatism**
- **Petzval field curvature** (affects the position, not the quality of i
- **Distortion** (affects the position, not the quality of images)

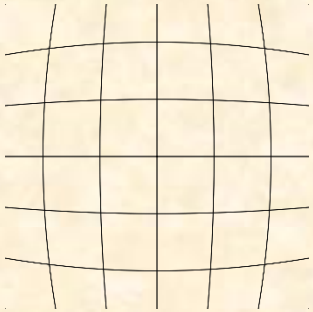


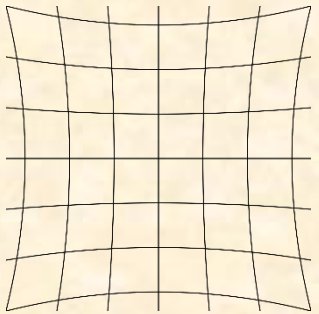




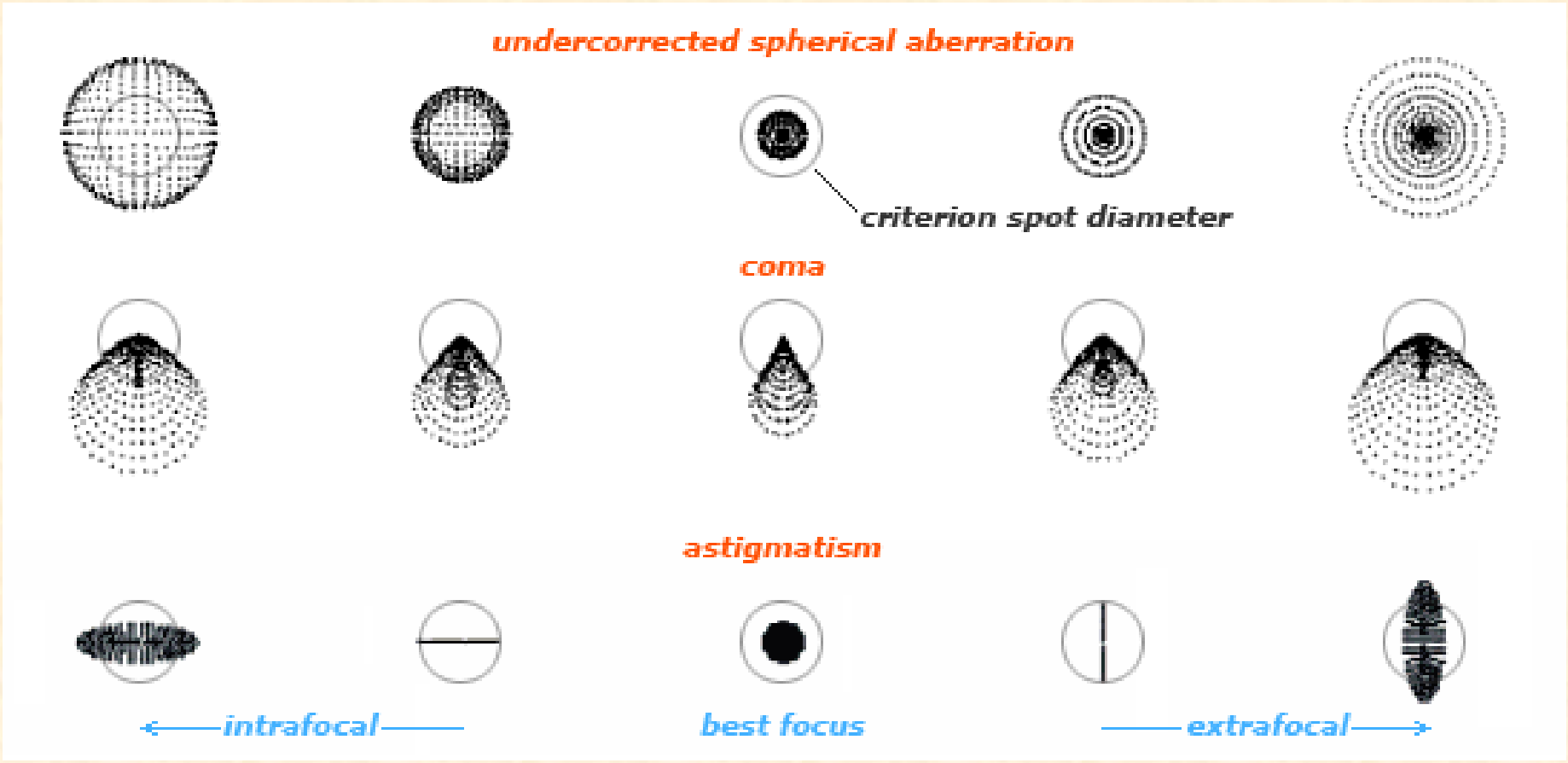








Optical Aberrations



Spot diagrams

Spherical Aberration

Coma

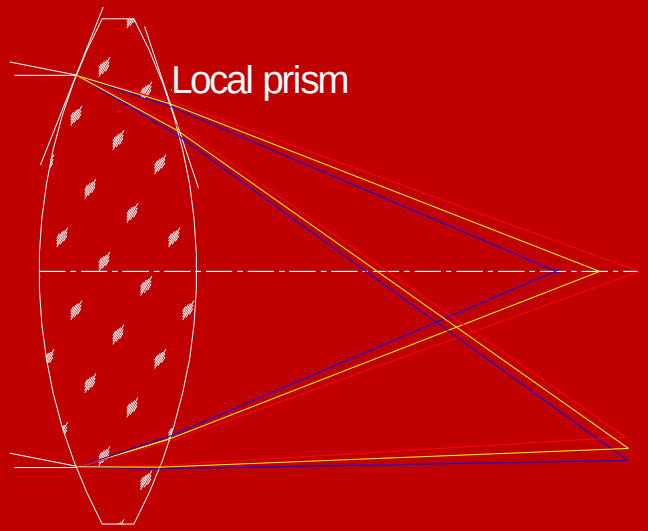
Astigmatism

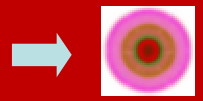
Refracting

- Chromatic aberrations
- Spherical & field aberrations

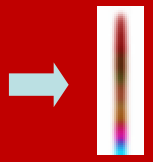
Reflecting

- Spherical & field aberrations
- 4 times tighter manufacturing tolerances



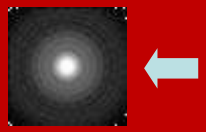


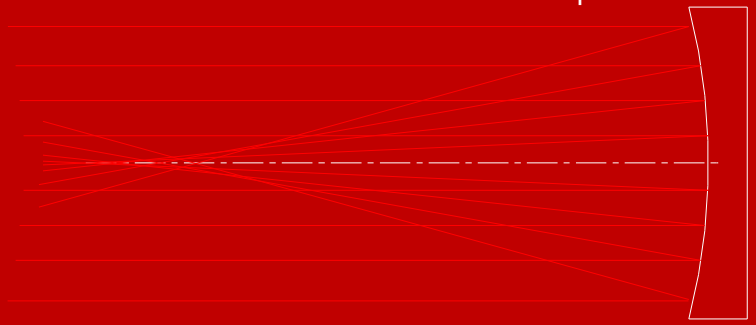
Axial chromatism



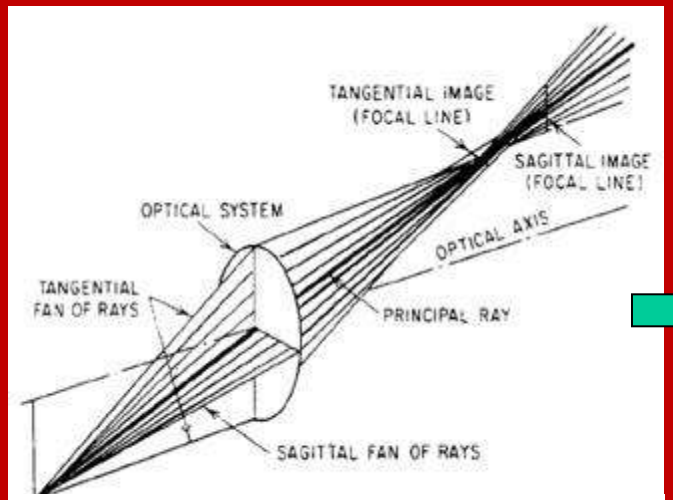
Lateral chromatism

Spherical aberration

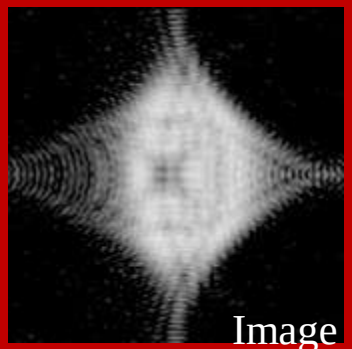


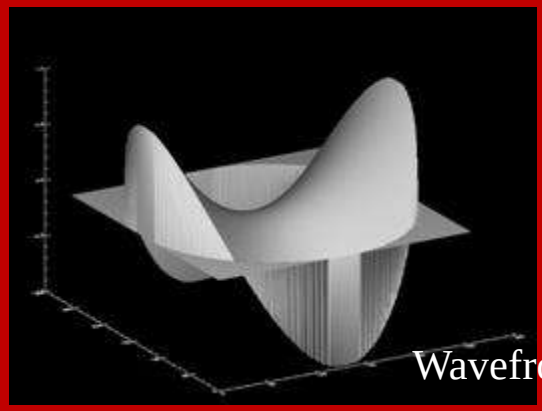


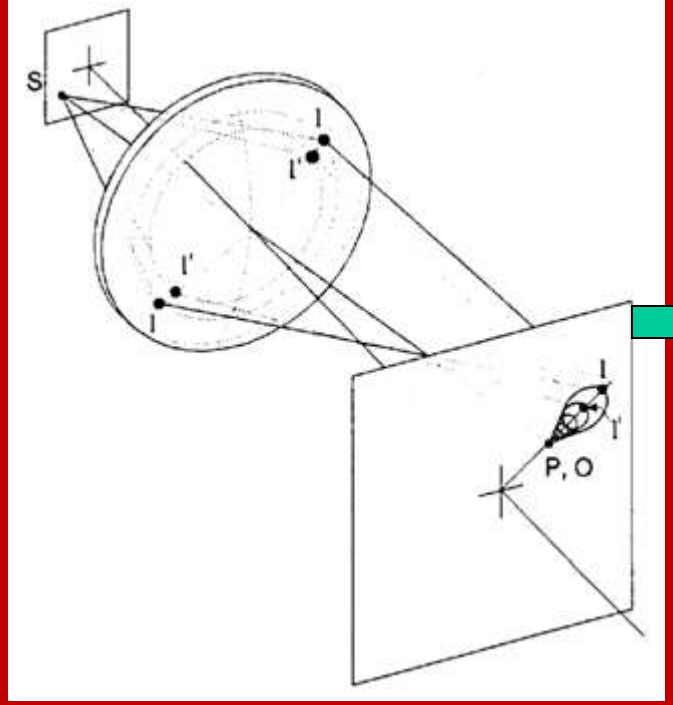
Field aberrations



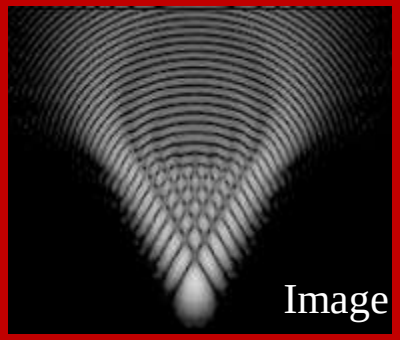
Astigmatism

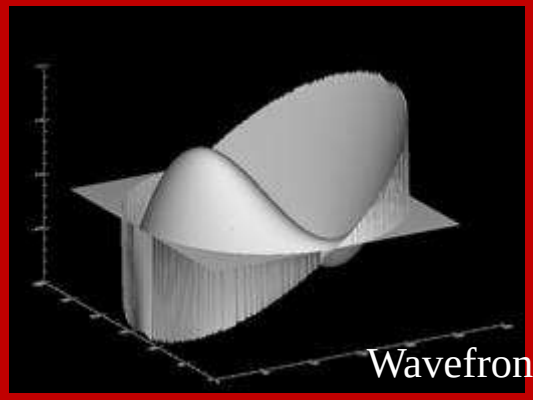






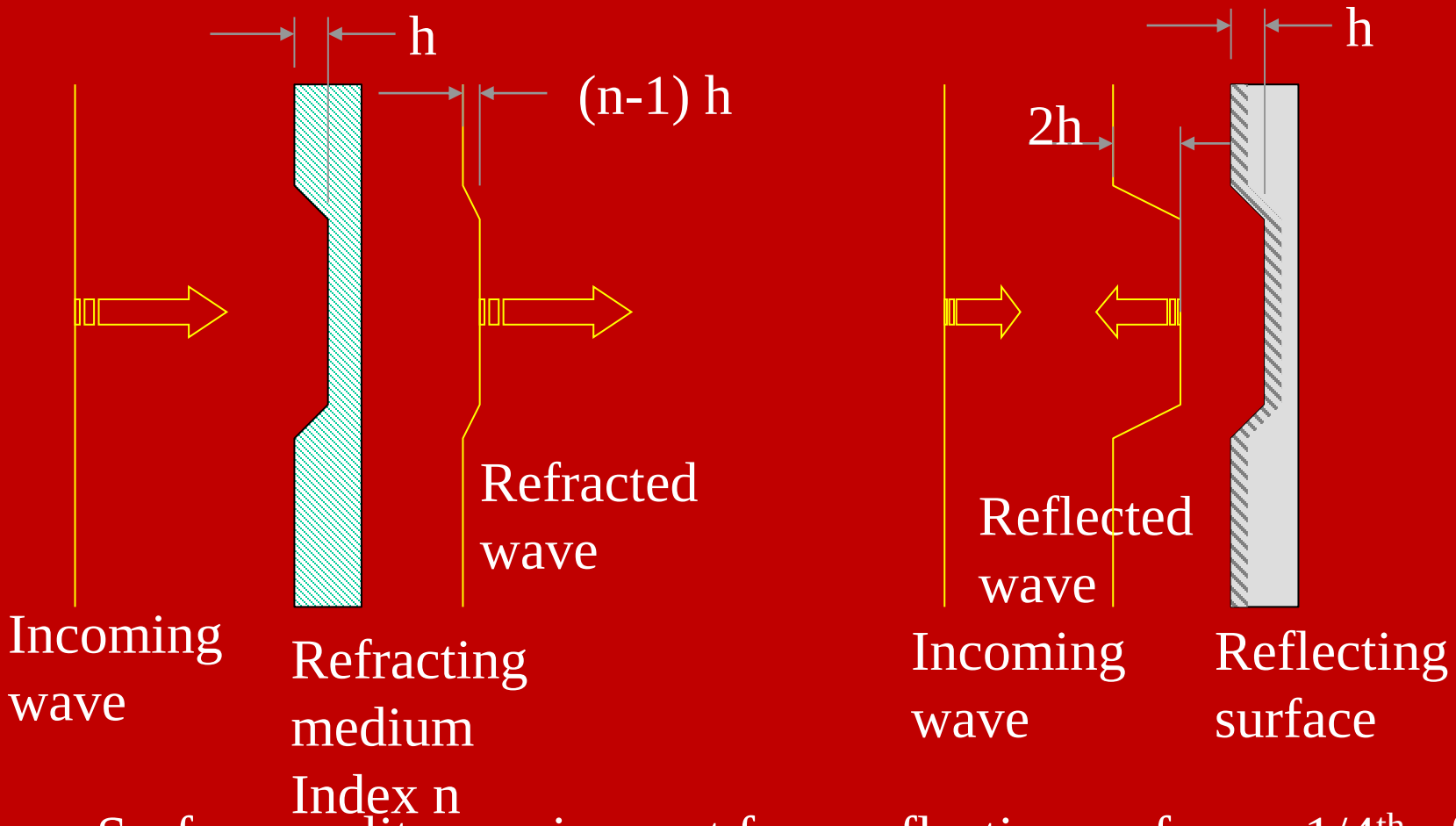
Coma



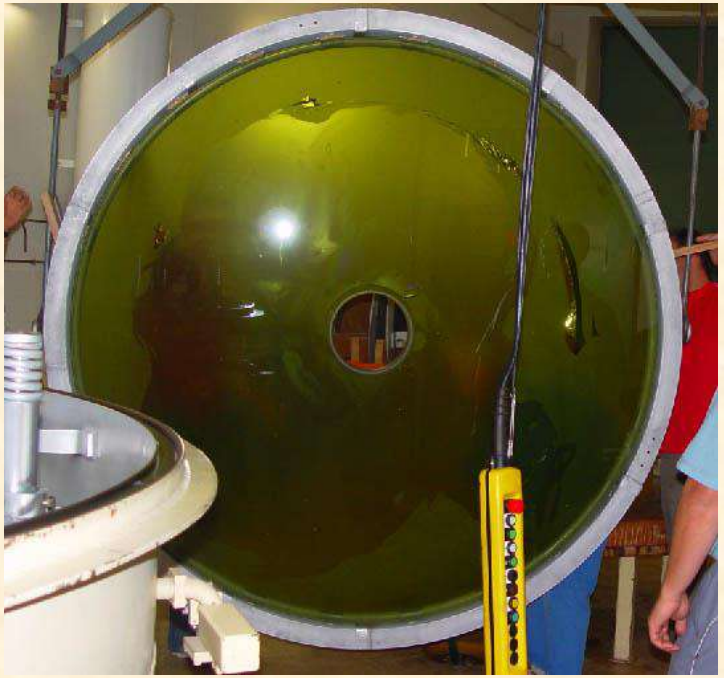


- Refractors
- Reflectors

Surface tolerances



Surface quality requirement for a reflecting surface ~ 1/4th of surface quality requirement for a refracting one



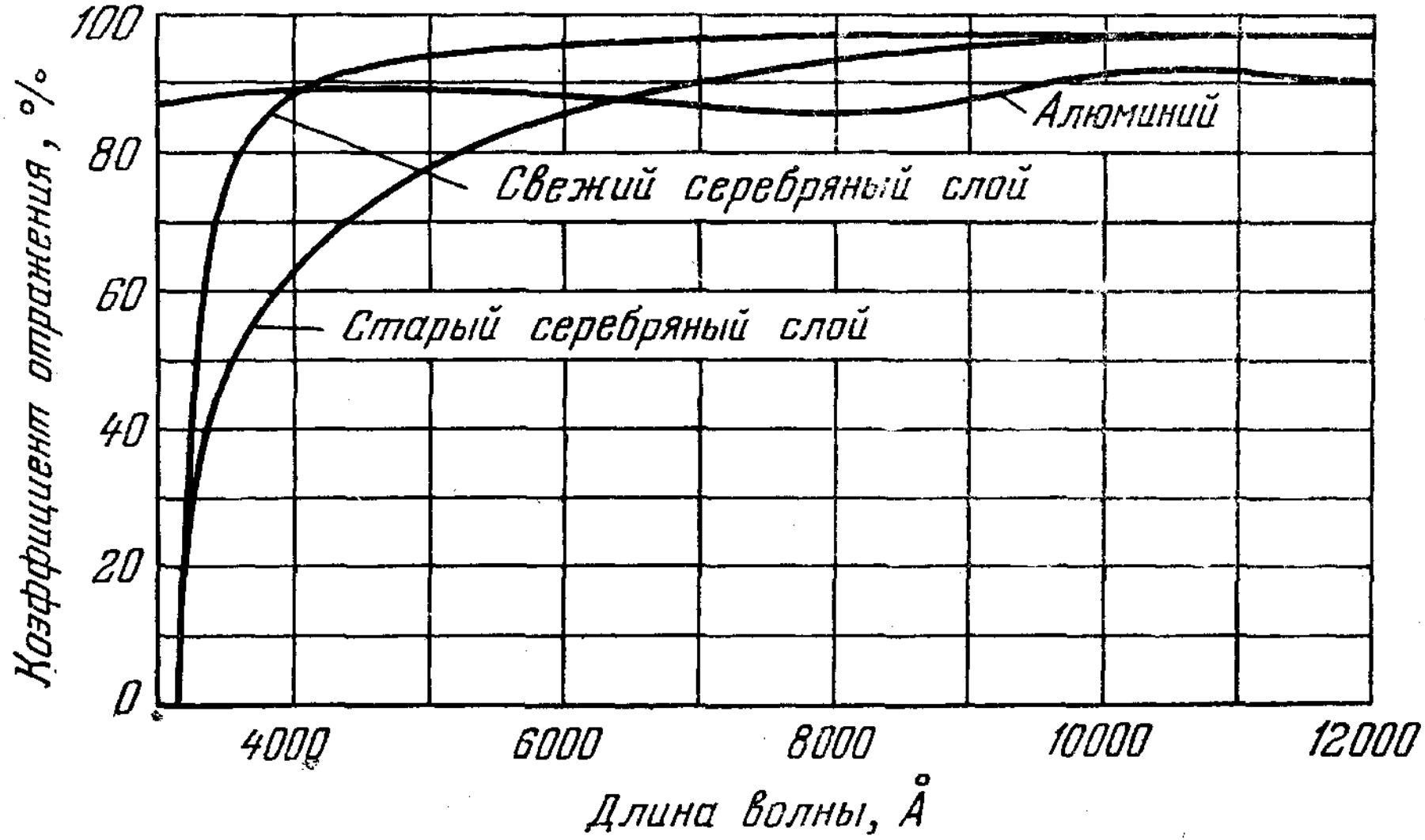
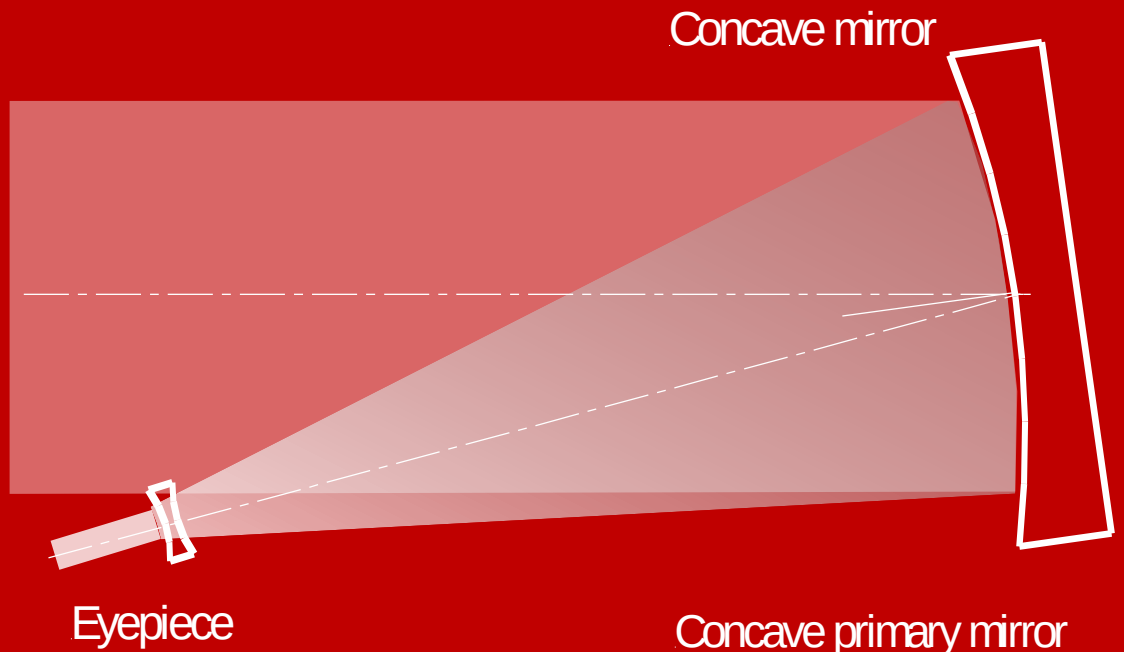
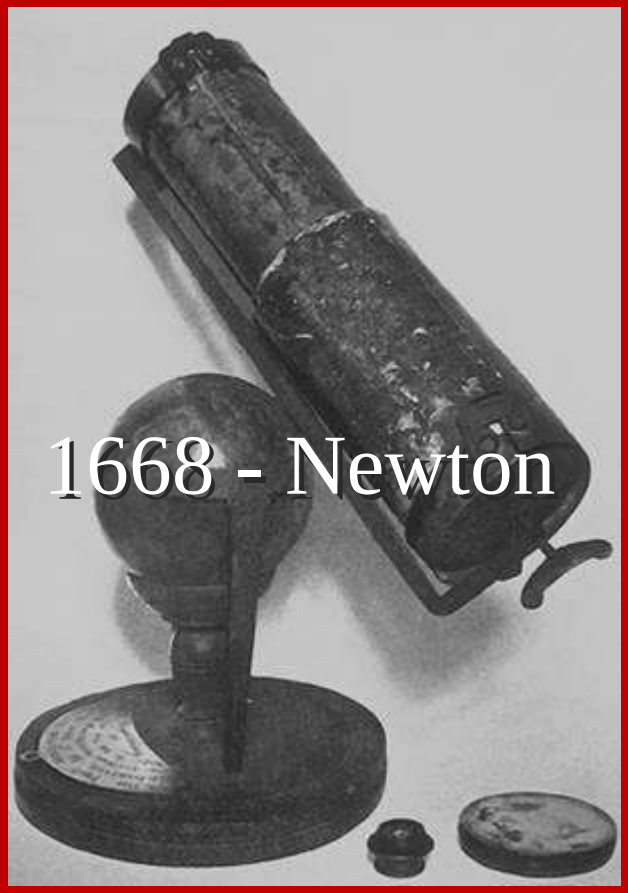


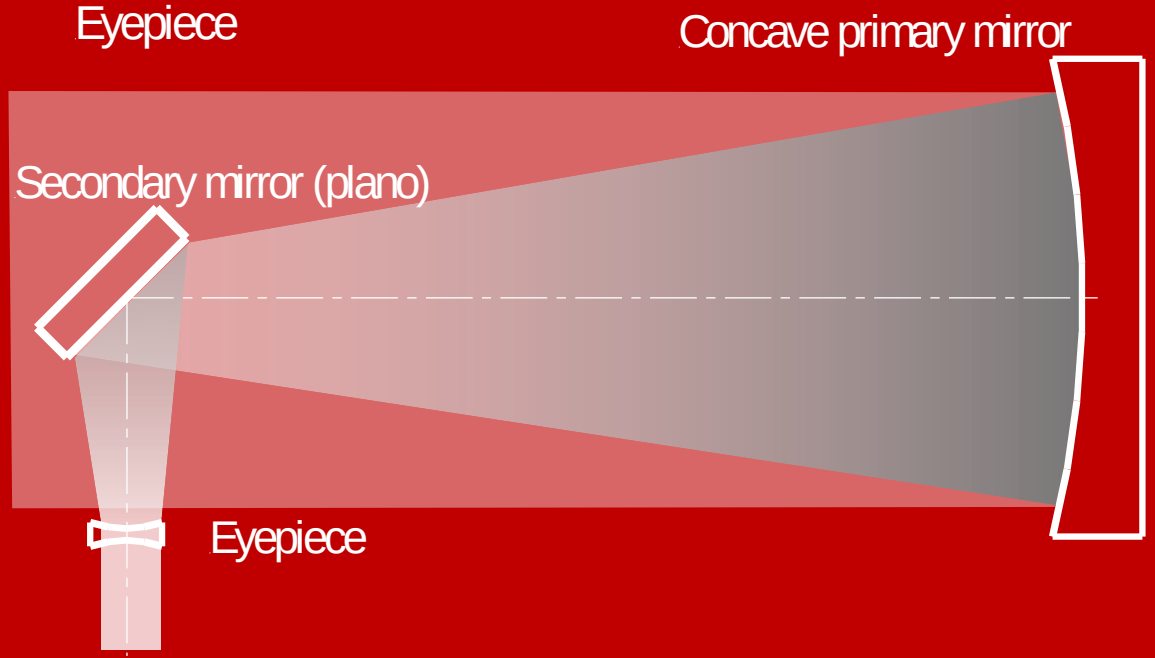
Рис. 15. Отражательная способность разных металлических слоев в зависимости от длины волны падающего света.

Reflecting telescopes – the early years 1608-1672

1616 - Zucchi





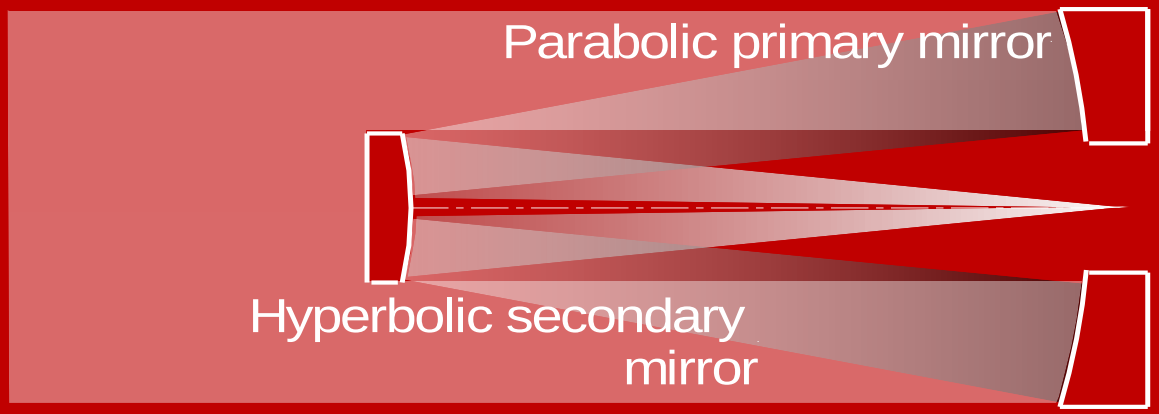


The early years 1608-1672

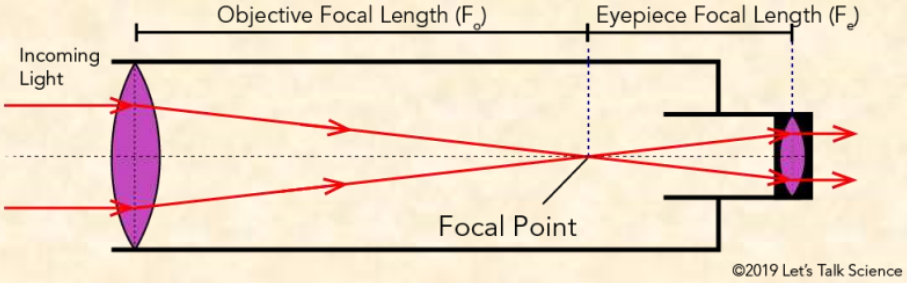
Gregorian

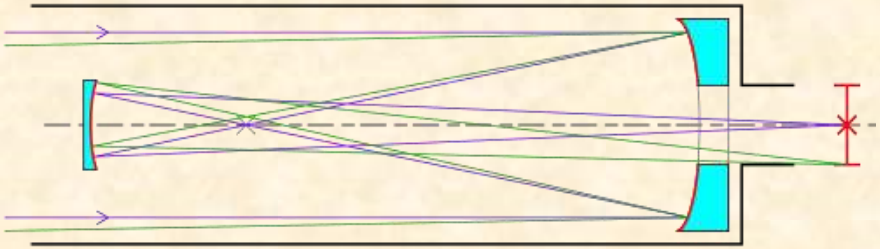
The early years 1608-1672

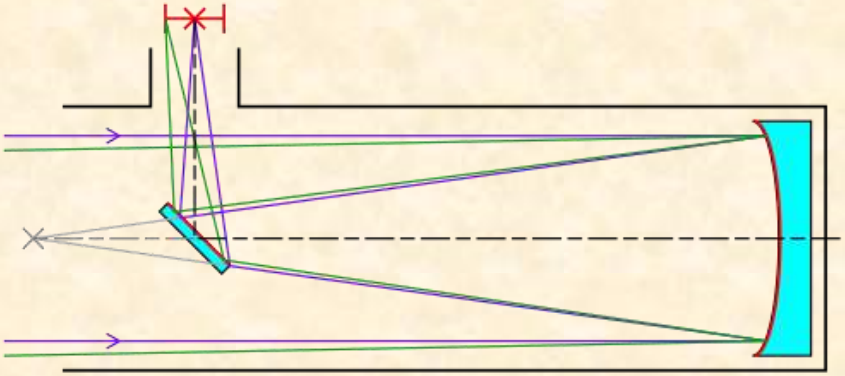
Cassegrain

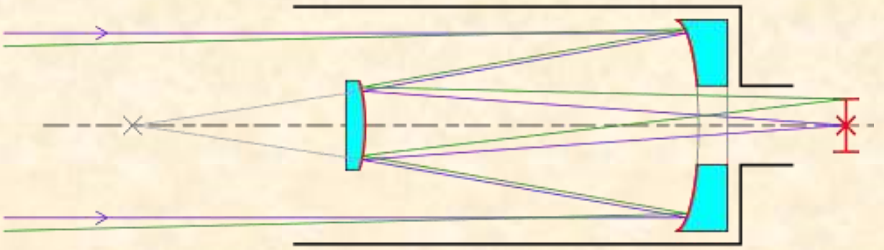


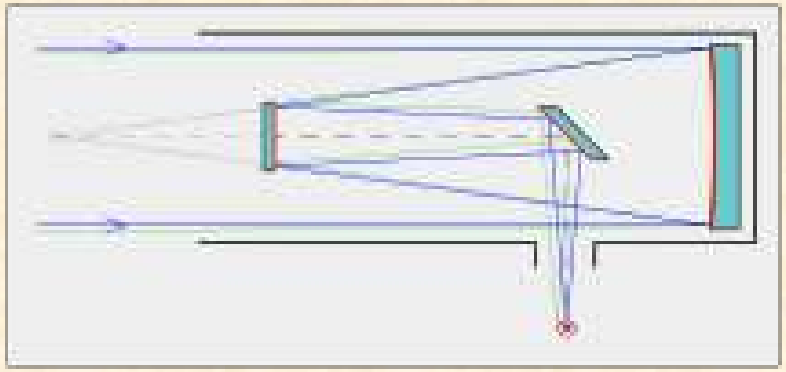
The theory of the reflecting telescope (mirrors shape) will remain unchanged until 1905.

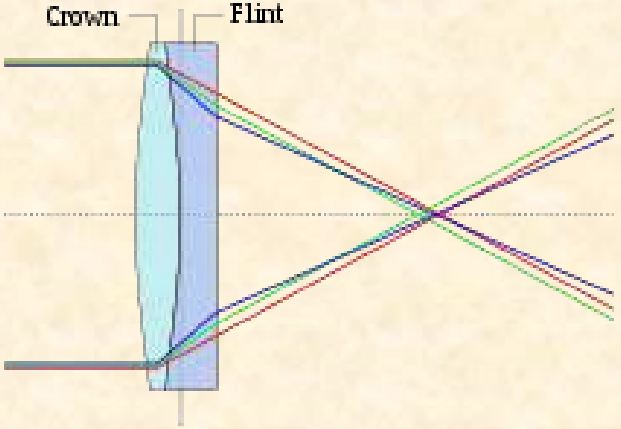




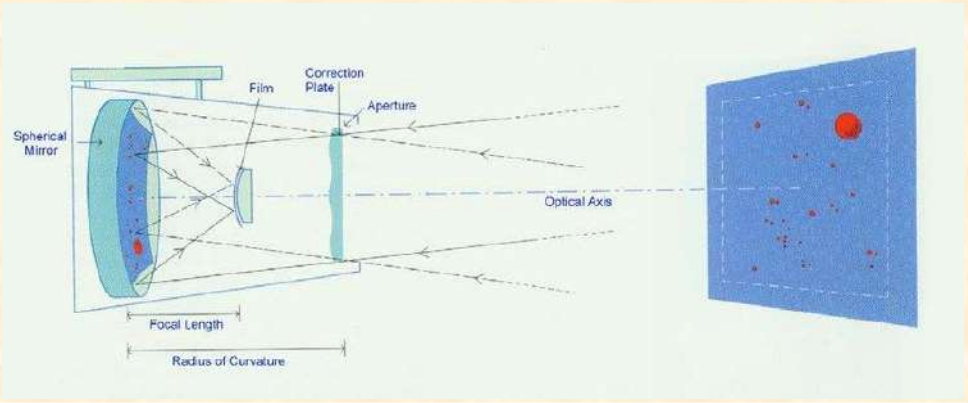


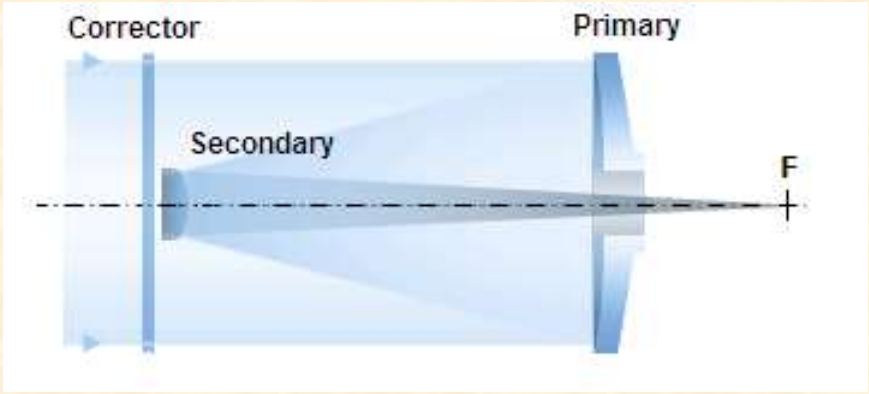


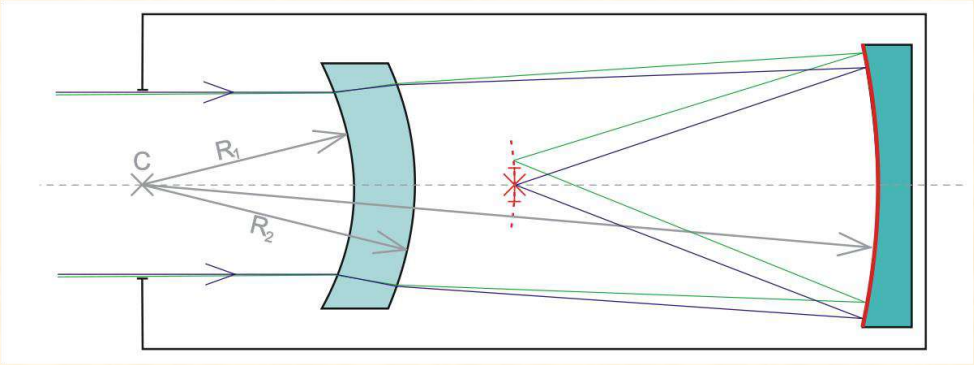


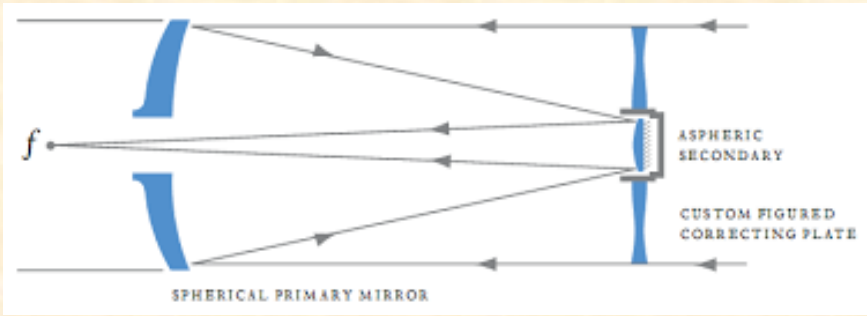


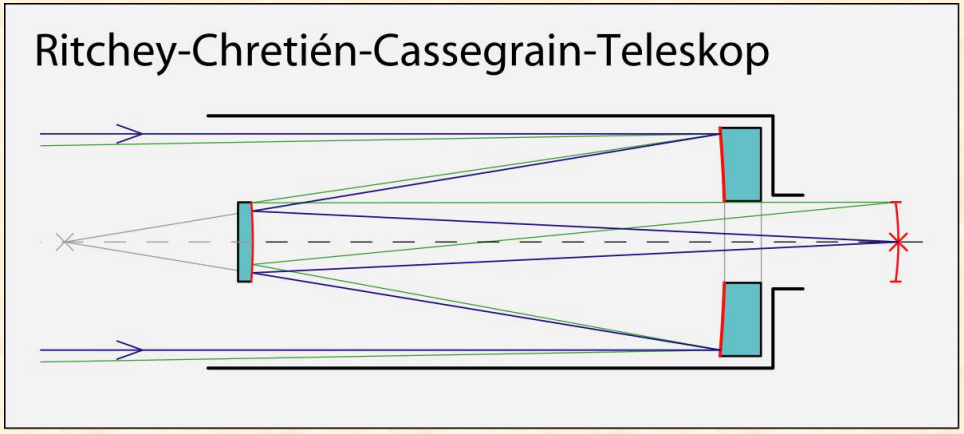
Refracting; Gregorian, Newtonian, Cassegrain, Nasmyth, achromatic telescopes

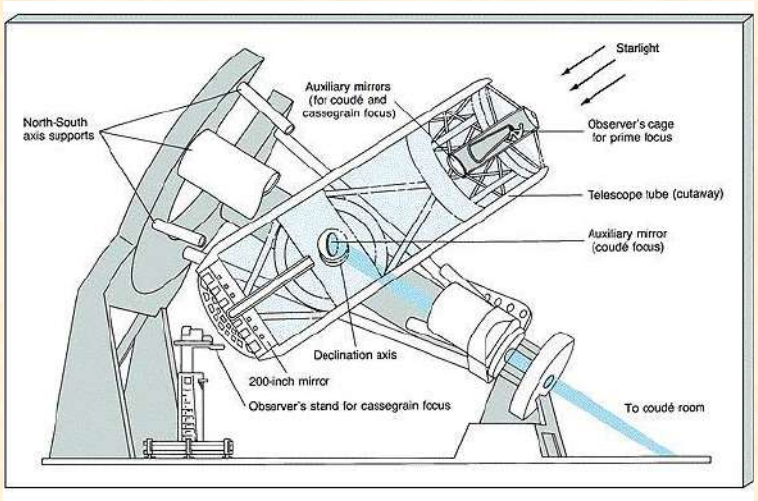






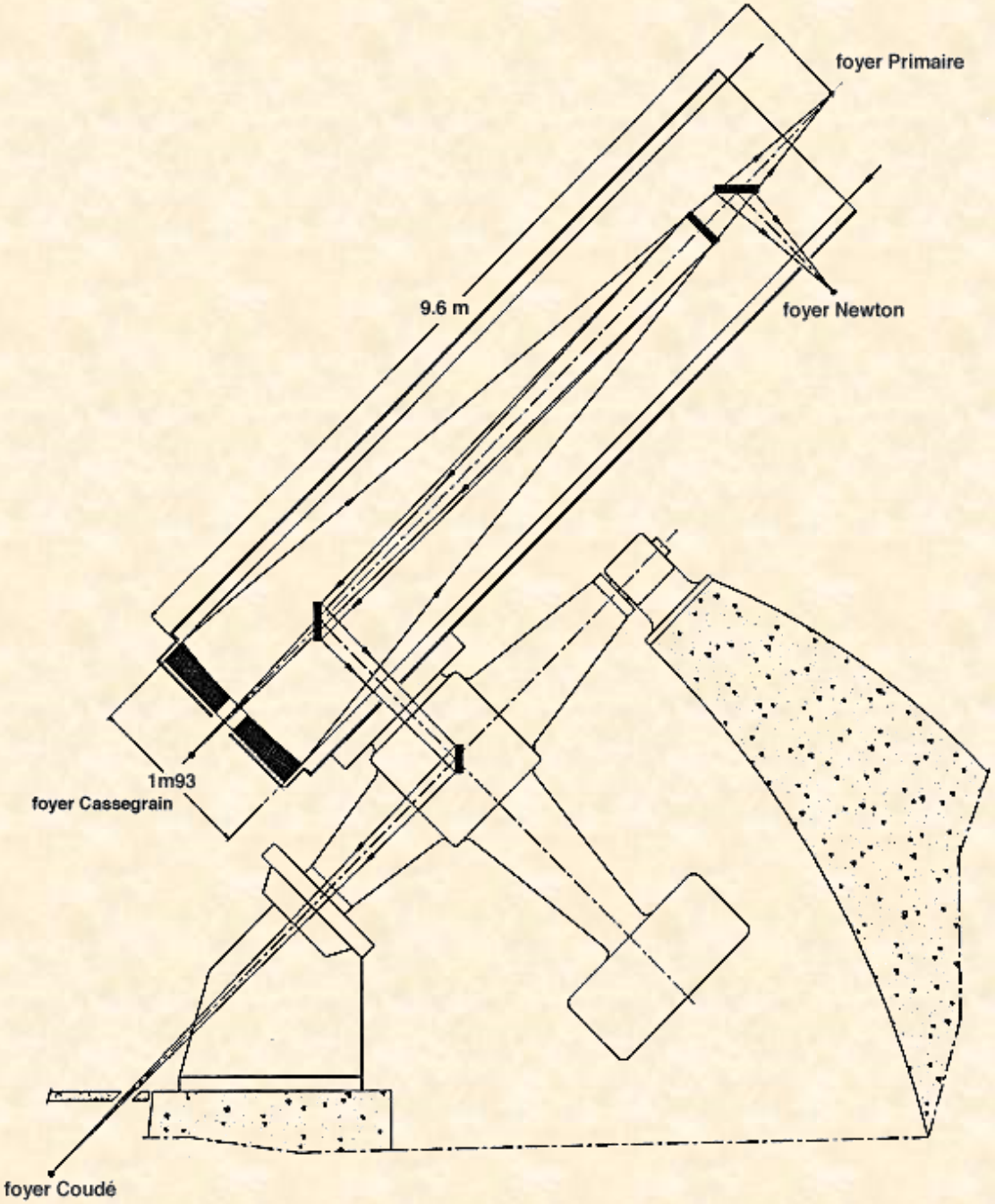






Schmidt, Schmidt-Cassegrain, Maksutov (meniscus), Ritchey-Chretien, Ritchey-Chretien-Cassegrain telescope systems and Coude foci

Telescope Mount Types


foyer Primaire
9.6 m
foyer Newton
1m93
foyer Cassegrain
foyer Coudé

Diameter (0.1m)

9
8
7
6
5
4
3
2
1

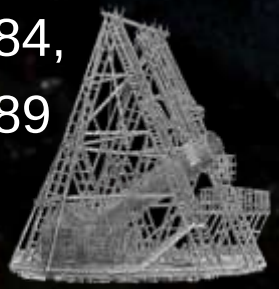
1600
1700
1800
1900

Galileo, 1609

Newton, 1668

Hadley, 1721

Herschel, 1784, 1789



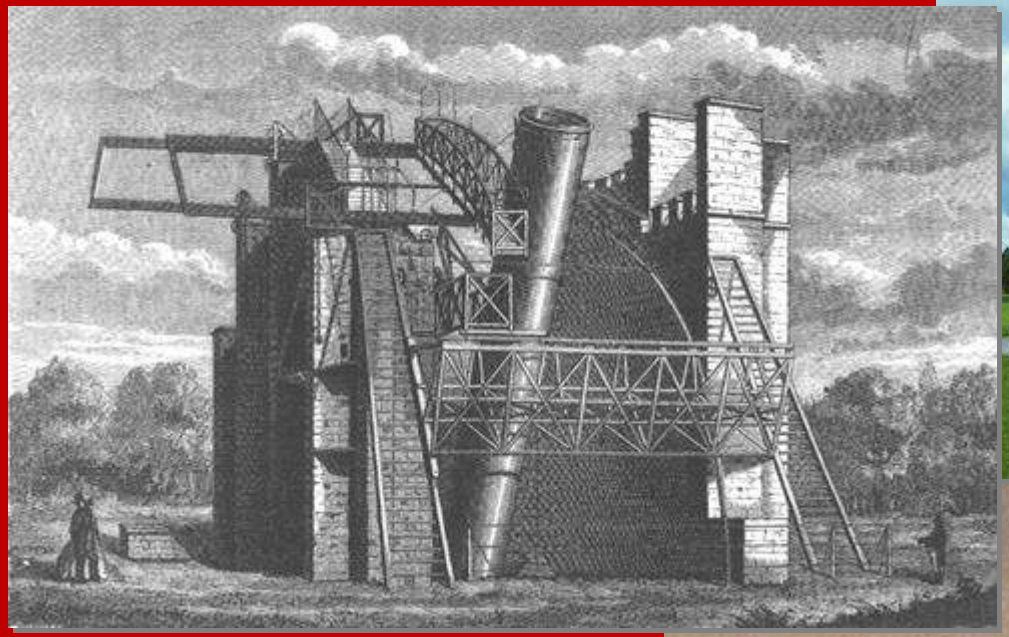
Lord Rosse, 1845

Foucault, 1857; 1861

Nasmyth, 1845

Lassel, 1861

Fraunhofer, 1824



Lord Rosse 1.82-m, 1845
F/9 Newton focus
Astatic supports
Byrr Castle, Ireland

Diameter (m)

9

8

7

6

5

4

3

2

1

1900

1950

2000

1908
Mt Wilson

1917
Mt Wilson

1948
Palomar

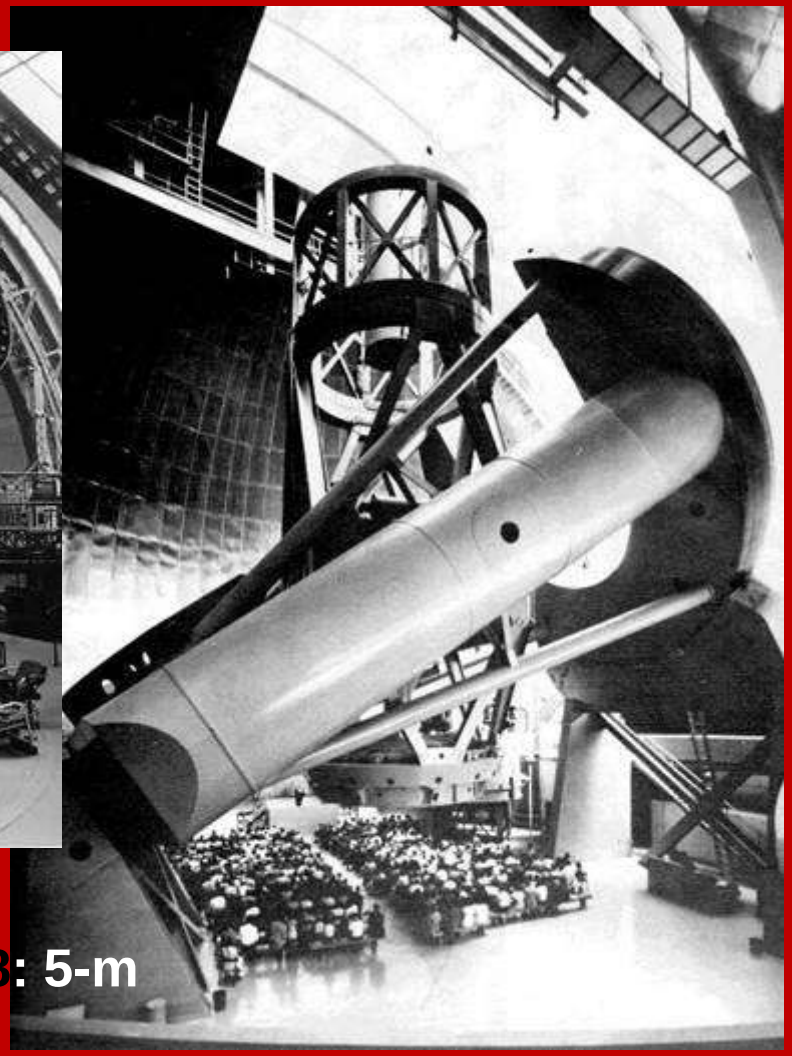
1974 - BTA

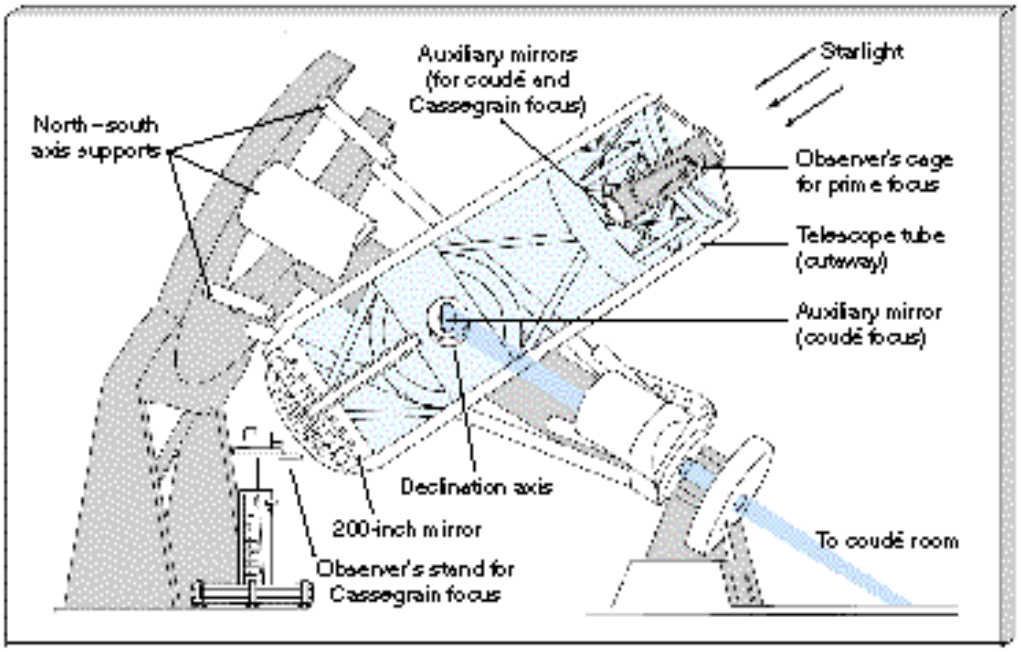
1989
NTT

1994
Keck

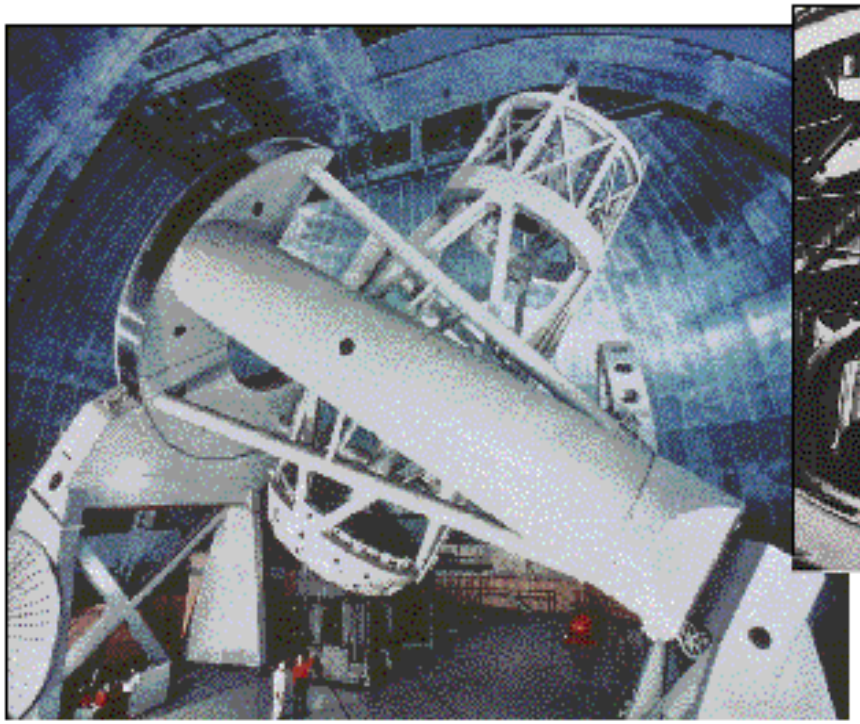
1998
VLT

The American century




Auxiliary mirrors
(for coudé and
Cassegrain focus)
Starlight
North–south
axis supports
Observer's cage
for prime focus
Telescope tube
(cutaway)
Auxiliary mirror
(coudé focus)
Declination axis
200-inch mirror
To coudé room
Observer's stand for
Cassegrain focus

(a)

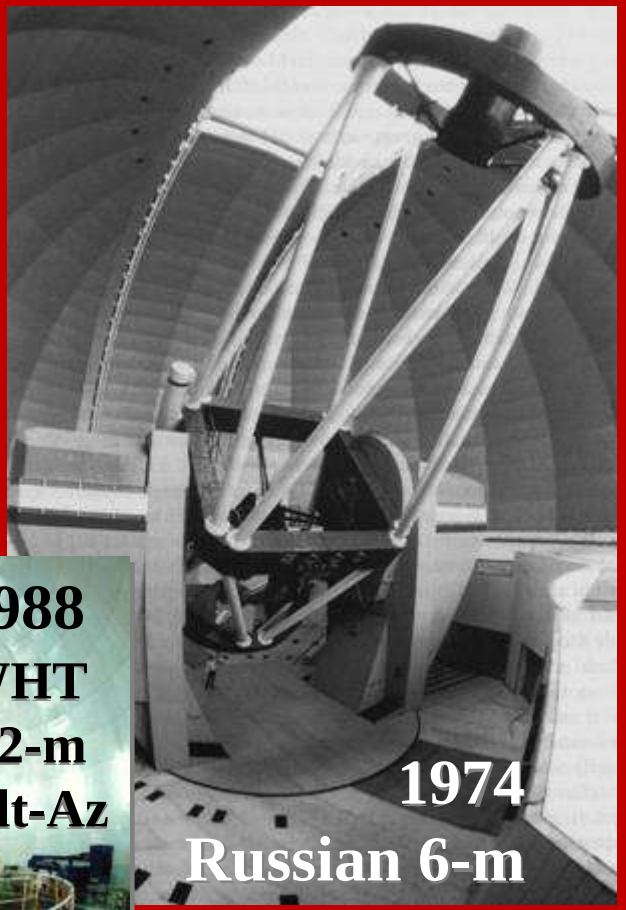


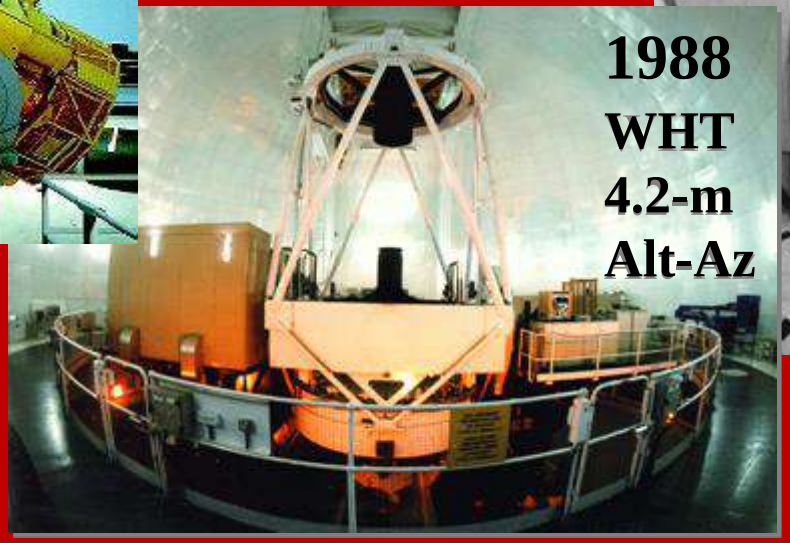
(b)

(c)

Mt. Palomar Observatory 200-inch Hale telescope

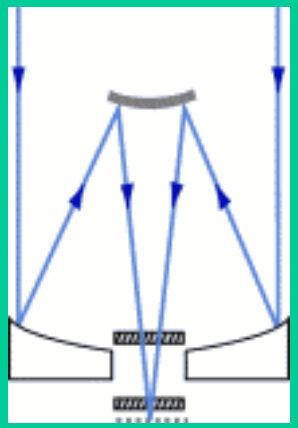
After Palomar

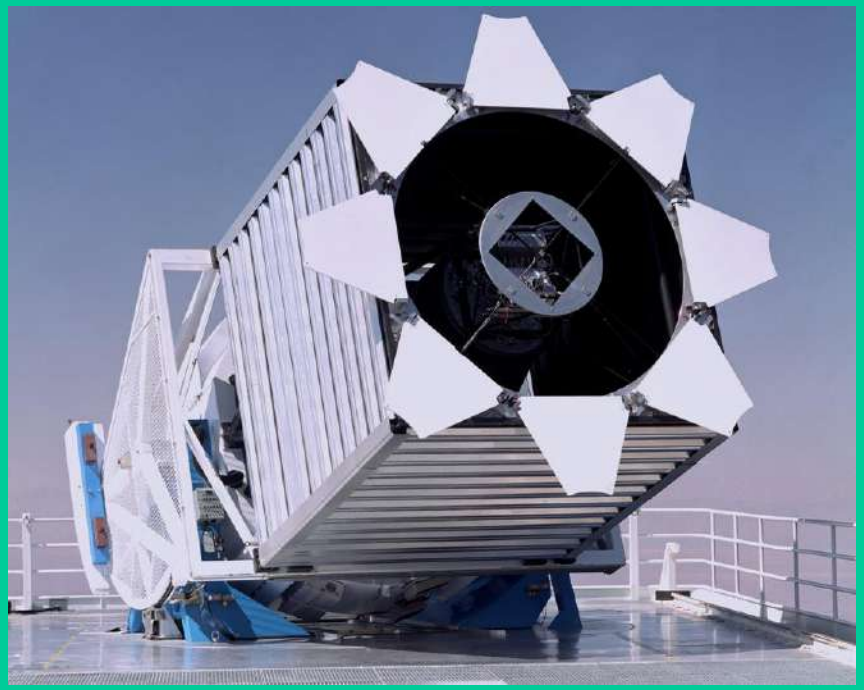


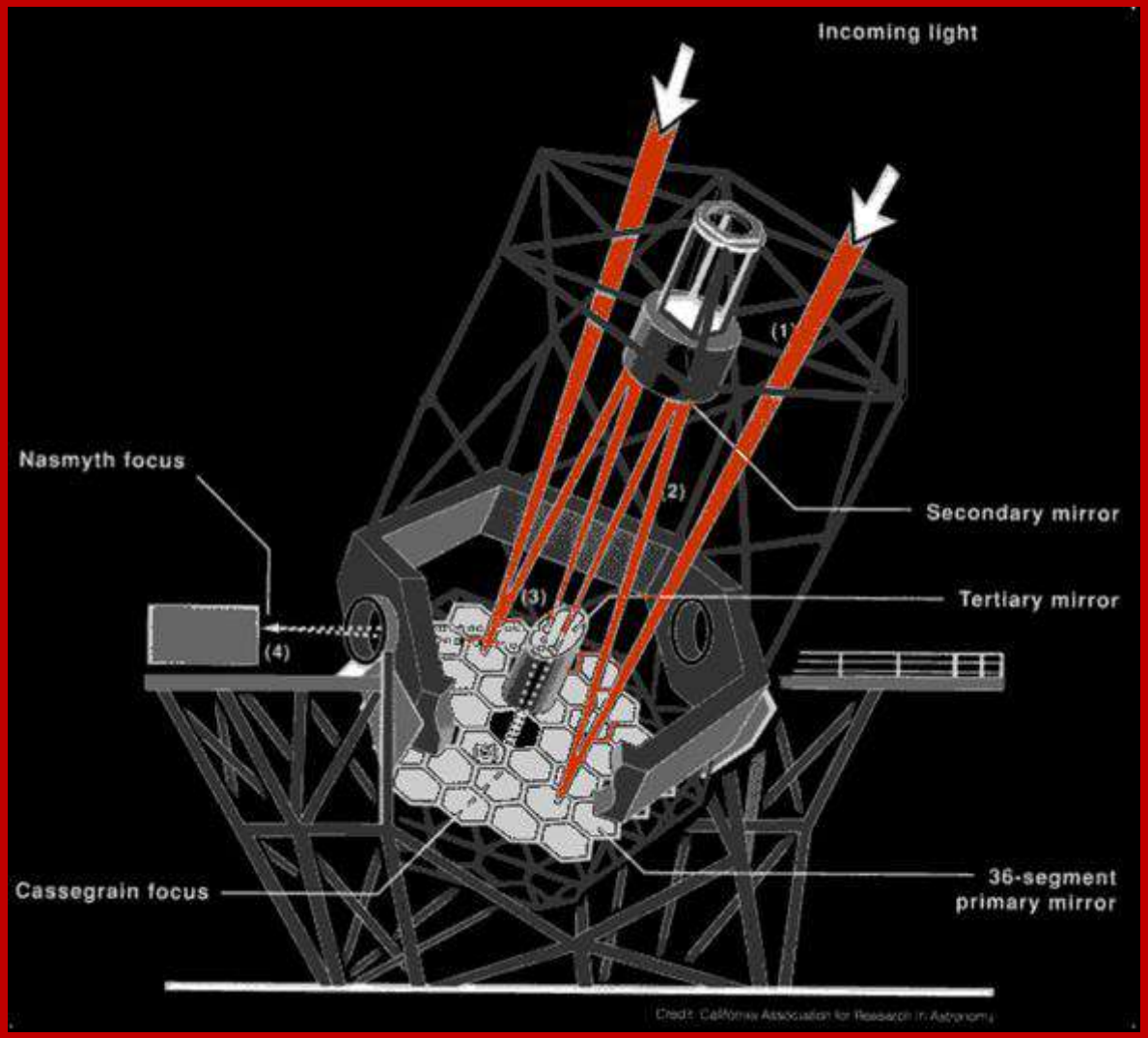


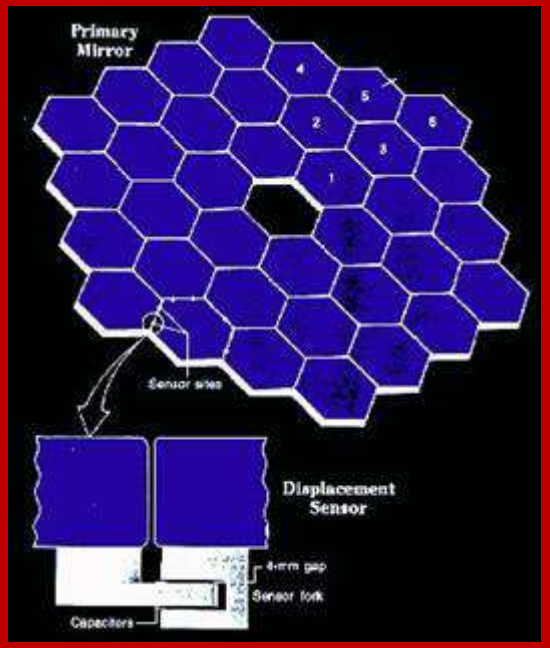
The SDSS Telescope

- 2.5 meter F/5 reflector
- Very wide (~3 degree) field of view
- Alt-az mount
- Drift scanning

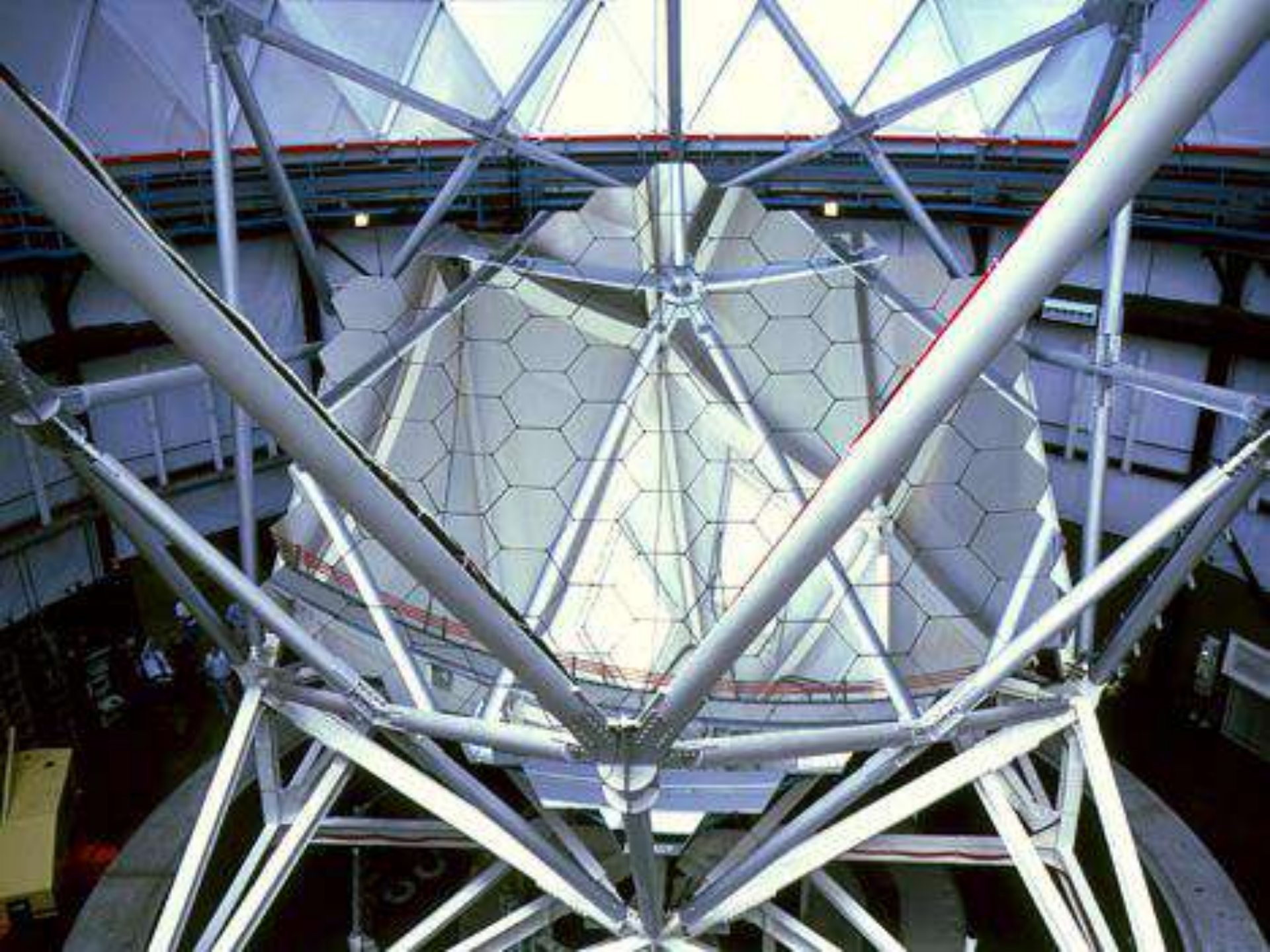


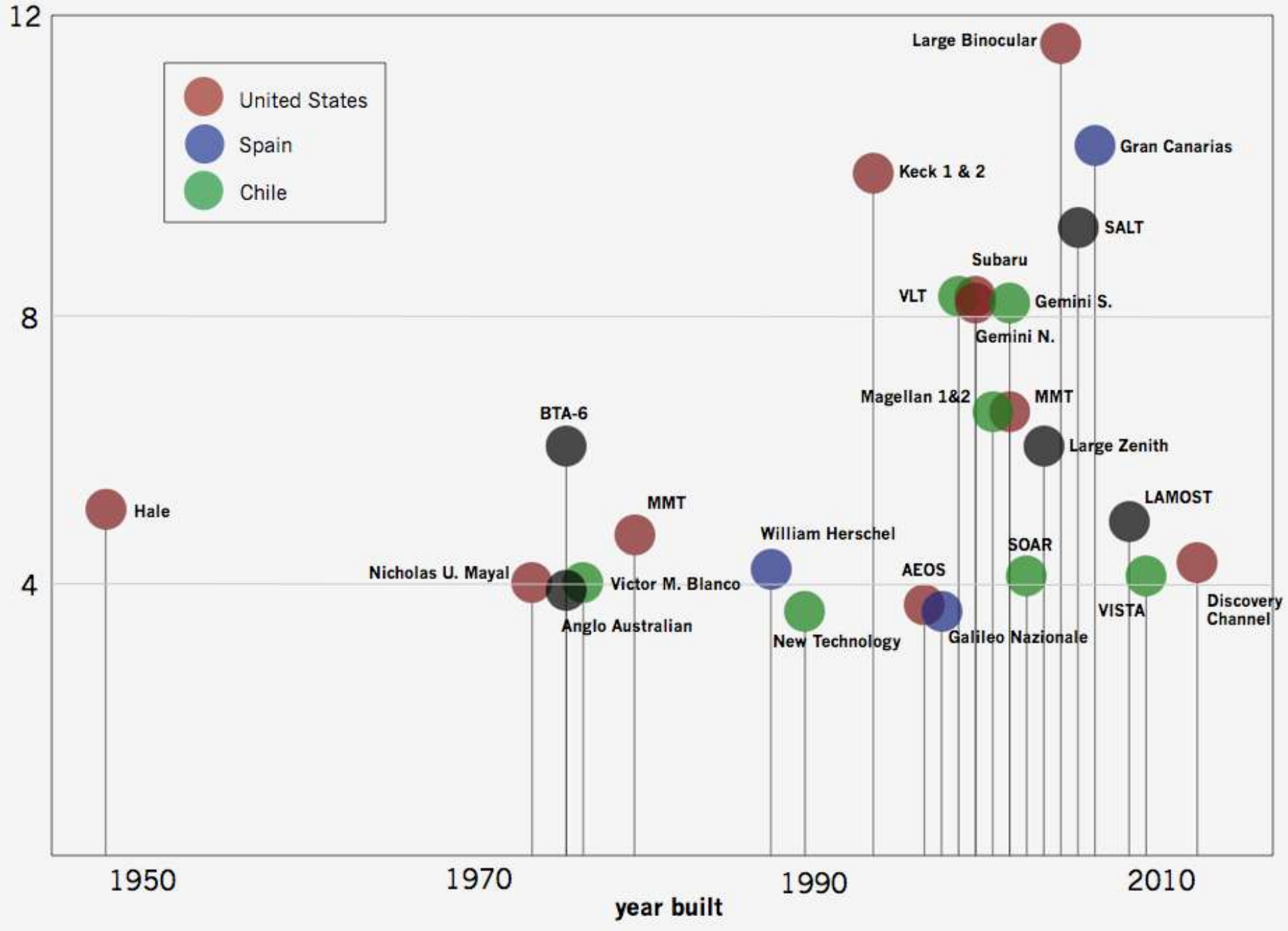


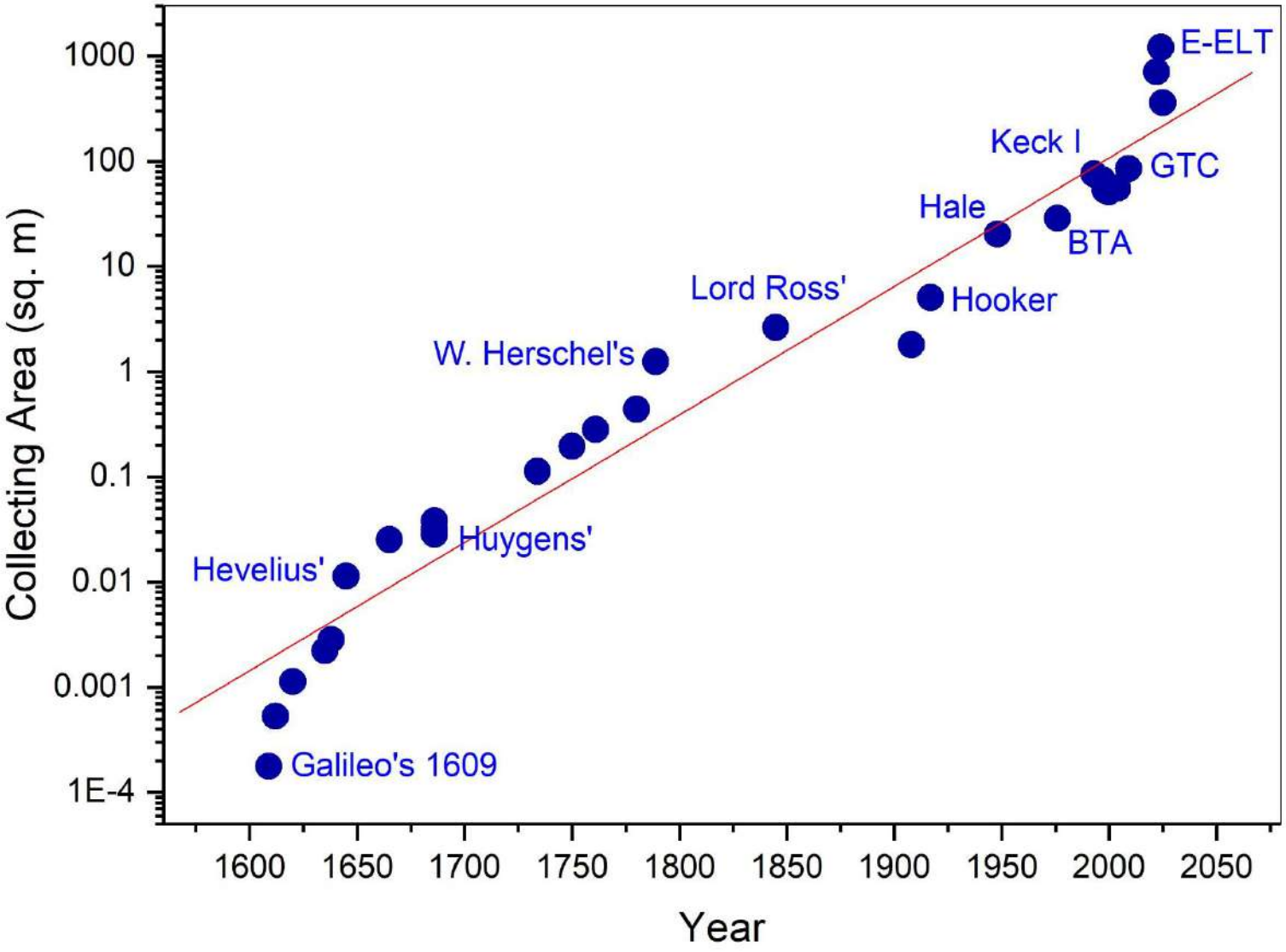




Segmentation – Keck 10-m telescopes



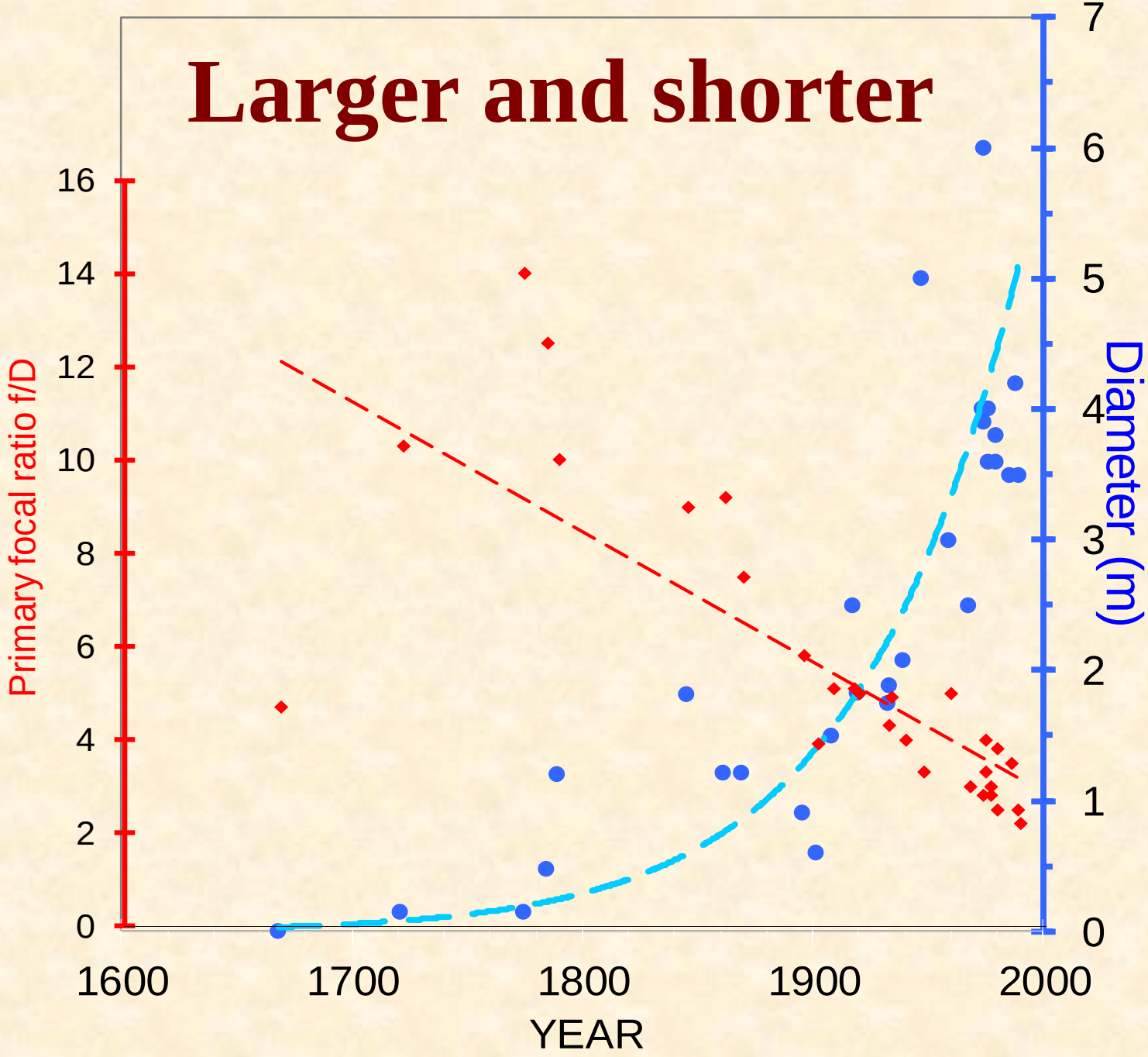

12
8
4
United States
Spain
Chile
Large Binocular
Gran Canarias
Keck 1 & 2
SALT
Subaru
VLT
Gemini S.
Gemini N.
Magellan 1&2
MMT
BTA-6
Large Zenith
LAMOST
Hale
MMT
William Herschel
SOAR
Nicholas U. Mayal
Victor M. Blanco
AEOS
VISTA
Discovery Channel
Anglo Australian
New Technology
Galileo Nazionale
1950
1970
1990
2010
year built


Collecting Area (sq. m)
1000
100
10
1
0.1
0.01
0.001
1E-4
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050
Year
E-ELT
Keck I
GTC
Hale
BTA
Lord Ross'
Hooker
W. Herschel's
Huygens'
Hevelius'
Galileo's 1609

Size and limiting magnitude

Telescopes	Year	Objective		Collecting Area	Limiting
		cm	inch	m^2	magnitude
Human eye		**0.7**	0.3	0.00005	6
Galileo's first telescope	1609	**1.5**	0.6	0.0002	7.66
Galileo's largest telescope	1620	**3.8**	1.5	0.0014	9.67
Typical amateur telescope		**10**	3.9	0.01	11.78
Huygens' largest refractor	1686	**22**	8.7	0.05	13.49
James Short's reflector	1750	**50**	19.7	0.25	15.27
John Michell's reflector	1780	**75**	29.5	0.56	16.15
Herschel's 40-foot telescope	1789	**126**	49.6	1.59	17.28
Leviathan of Parsonstown	1845	**183**	72.0	3.35	18.09
HST	1990	**240**	94.5	5.76	18.68
Hooker telescope	1917	**254**	100.0	6.45	18.80
Hale Telescope	1948	**508**	200.0	25.81	20.31
JWST	2021	**650**	255.9	42.25	20.84
VLT single	1998	**820**	322.8	67.24	21.34
GTC	2007	**1040**	409.4	78.54	21.86
ELT	2028	**3930**	1547.2	1544.49	24.75

Larger and shorter



Astronomical Telescopes and Technology

Leonardo da Vinci and **Girolamo Fracastoro** – first telescope designs (15?? and 1538)

Hans Lippershey – the first telescope (1608)

Galileo Galilei – telescope was used for sky observations (1.5cm, 1609), the 3.8cm

Isaac Newton – the first reflector, Newtonian system (1668)

Laurent Cassegrain – Cassegrain optical system (1672)

Christiaan Huygens – the biggest telescopes of the 17th century (22cm, aerial, 1686)

Chester Moore Hall – the first achromatic telescope (1729-1733)

John Dollond – chromatic aberration and spherical aberration were corrected (1757)

William Herschel – pioneered the use of astron. spectrophotometry, using prisms and T measuring equipment to measure λ distribution of stellar spectra. Discovered IR radiation

John Herschel – first astrophotography, the Moon (1840)

John Adams Whipple and **William Cranch Bond** – first photo of a star, Vega (1850)

Karl August von Steinheil and **Léon Foucault** – introduced depositing a layer of silver on telescope mirrors (1856-1857)

Léon Foucault – method of testing reflecting telescope mirror to detect its shape (~1860)

Bernhard Schmidt – the first wide-field telescope (1930)

George Willis Ritchey and **Henri Chrétien** – coinvented the Ritchey–Chrétien reflecting telescope system (1930)

Guido Horn D'Arturo – idea of combining small mirror tassels, the first segmented mirrors (1932), active optics (1935), Active and Adaptive Optics implementation (1980s)

Dmitri Maksutov – Maksutov telescope with meniscus corrector plate (1941)

Horace W. Babcock – Adaptive Optics (AO) was first envisioned by (1953)

J. Janesick and **B. Smith** – first CCD images (Jupiter, Saturn, Uranus) (1976, inv. 1969)

World Largest Ground-Based Telescopes

1040	Gran Telescopio Canarias (GTC)	2267	La-Palma, Canarias, Es/US/Mx
982	Keck I Telescope	4145	Mauna Kea, Hawaii, USA
982	Keck II Telescope	4145	Mauna Kea, Hawaii, USA
920	Hobby-Eberly Telescope (HET)	2071	Mt. Fowlkes, TX, USA
910	South African Large Telescope (SALT)	1798	SAAO, South Africa/USA
840	Large Binocular Telescope 1 (LBT)	3170	Mt. Graham, AZ, USA
840	Large Binocular Telescope 2 (LBT)	3170	Mt. Graham, AZ, USA
830	Subaru Telescope	4139	Mauna Kea, Hawaii, Japan
820	VLT Antu (Sun)	2635	Cerro Paranal, Chile, ESO
820	VLT Kueyen (Moon)	2635	Cerro Paranal, Chile, ESO
820	VLT Melipal (Southern Cross)	2635	Cerro Paranal, Chile, ESO
820	VLT Yepun (Venus)	2635	Cerro Paranal, Chile, ESO
819	Gemini North Tel. (Gillett) (GNT)	4213	Mauna Kea, Hawaii, USA
819	Gemini South Tel. (GST)	2722	Cerro Pachon, Chile, USA
650	Walter Baade (Magellan I)	2516	Las Campanas, Chile, USA
650	Landon T. Clay (Magellan II)	2516	Las Campanas, Chile, USA
650	MMMT (former 6×1.8)	2606	Mount Hopkins, AZ, USA
605	Bolshoy Tel. Azimutalnyi (BTA)	2070	Mt. Pastukhovo, Caucasus, Russia
600	Large Zenith Telescope (LZT)	395	Maple Ridge, BC, Canada
508	Hale Telescope	1900	Mount Palomar, CA, USA
425	S. Obs. Astrophys. Research (SOAR)	2701	Cerro Pachon, Chile, Brazil/USA
420	William Herschel Telescope (WHT)	2400	La-Palma, Canarias, UK/Nl
420	Large sky Area M.-Obj. fiber Sp. Tel.	960	Xinglong, China
410	Vis. & IR Surv. Tel. for Astr. (VISTA)	2635	Cerro Paranal, Chile, ESO
401	Victor Blanco	2200	Cerro Tololo, Chile, USA
400	Intl Liquid Mirror Telescope (ILMT)	2450	Manora Peak, Nainital, India

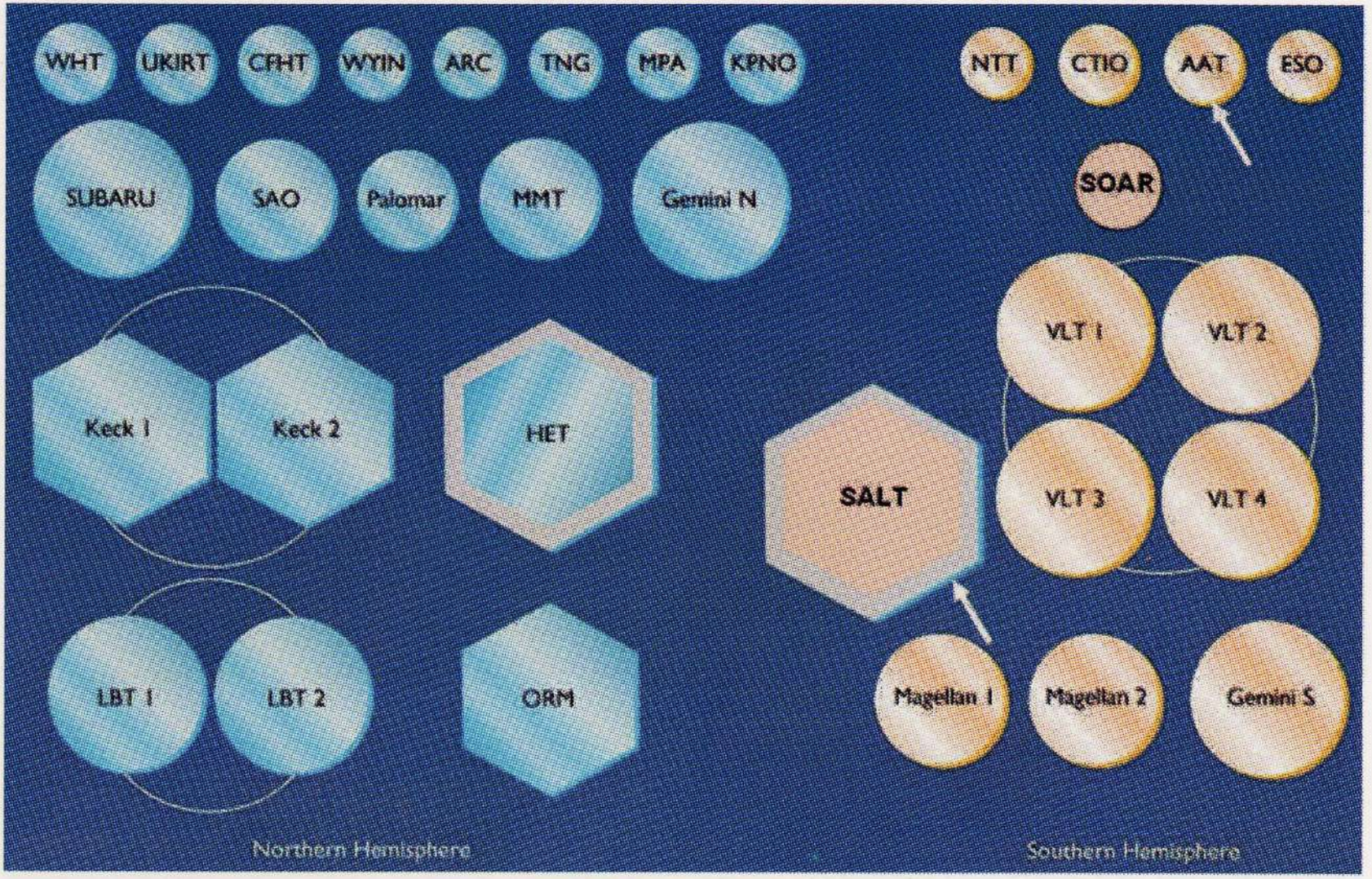
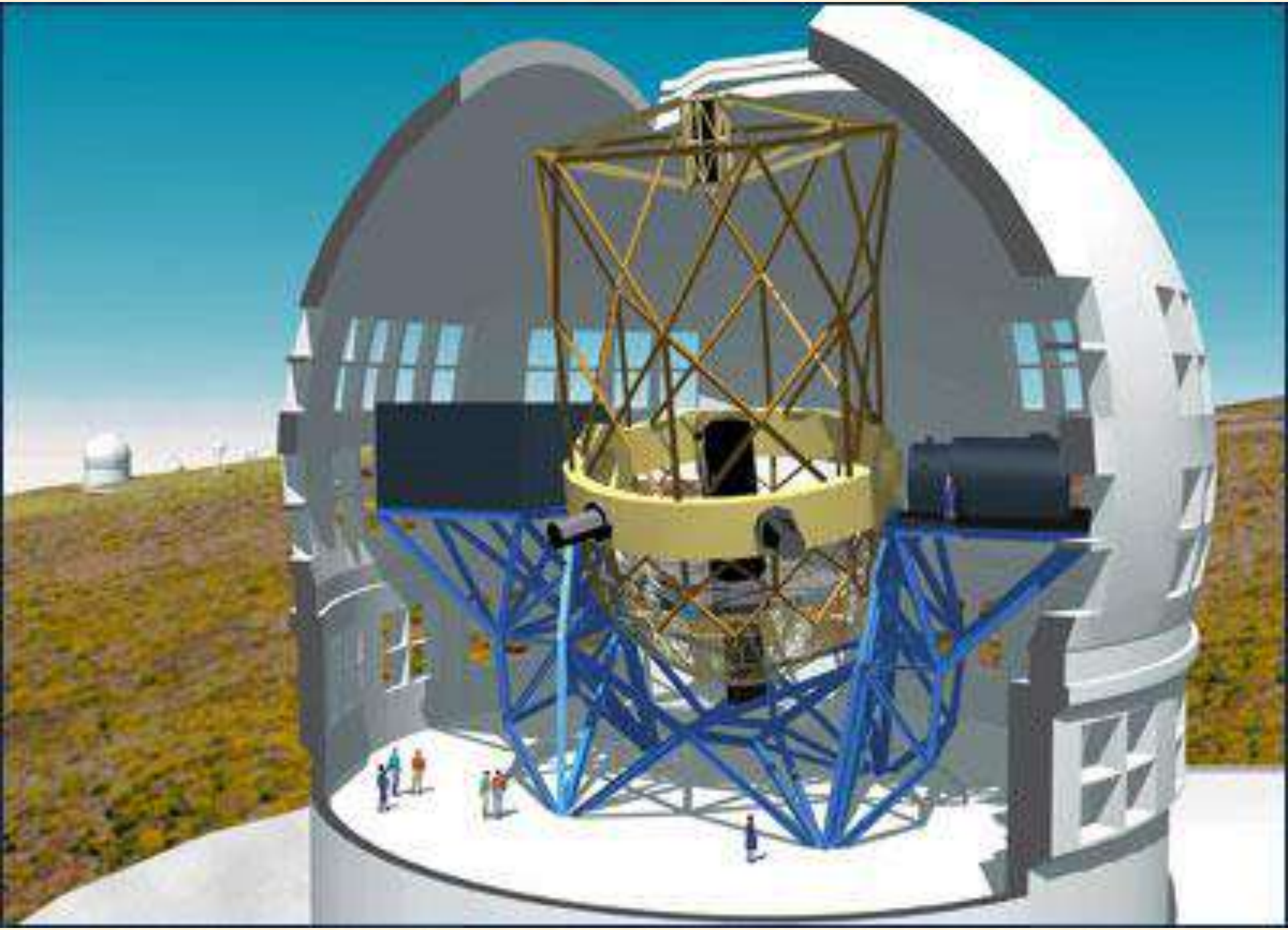
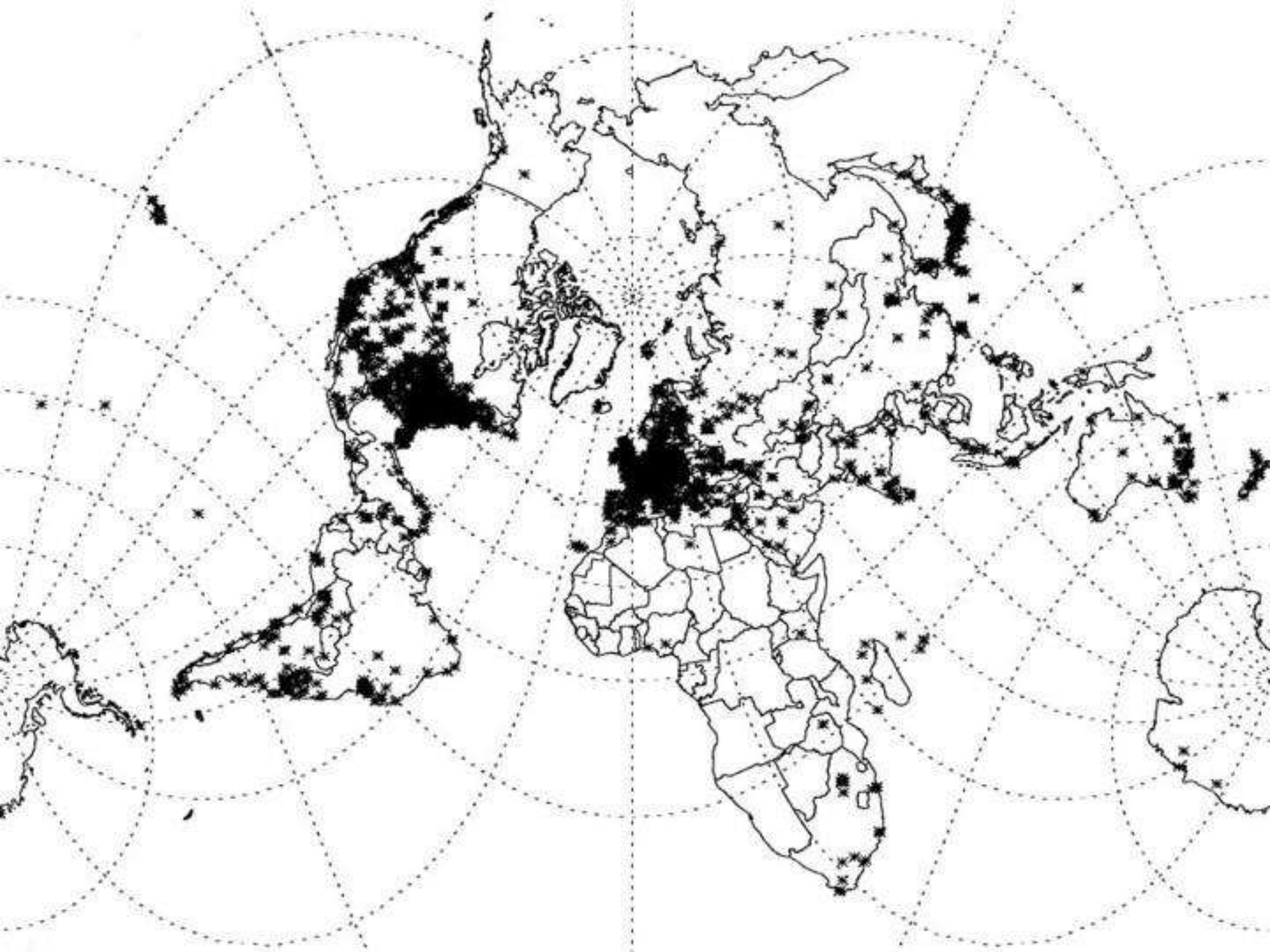


Figure 3. World's major telescope mirrors. With the exception of the two telescopes indicated with white arrows (the Anglo Australian Telescope and the 9m effective aperture South Africa Large Telescope all others are located in Chile (refer to Table 1 for diameters).





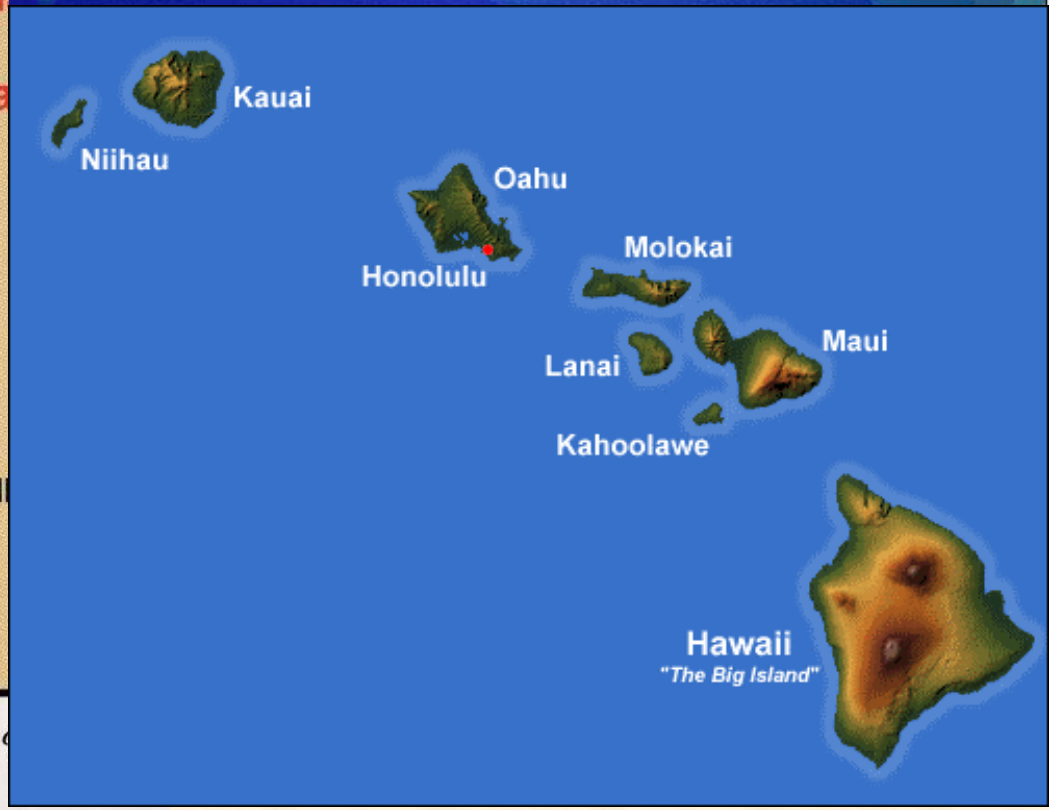
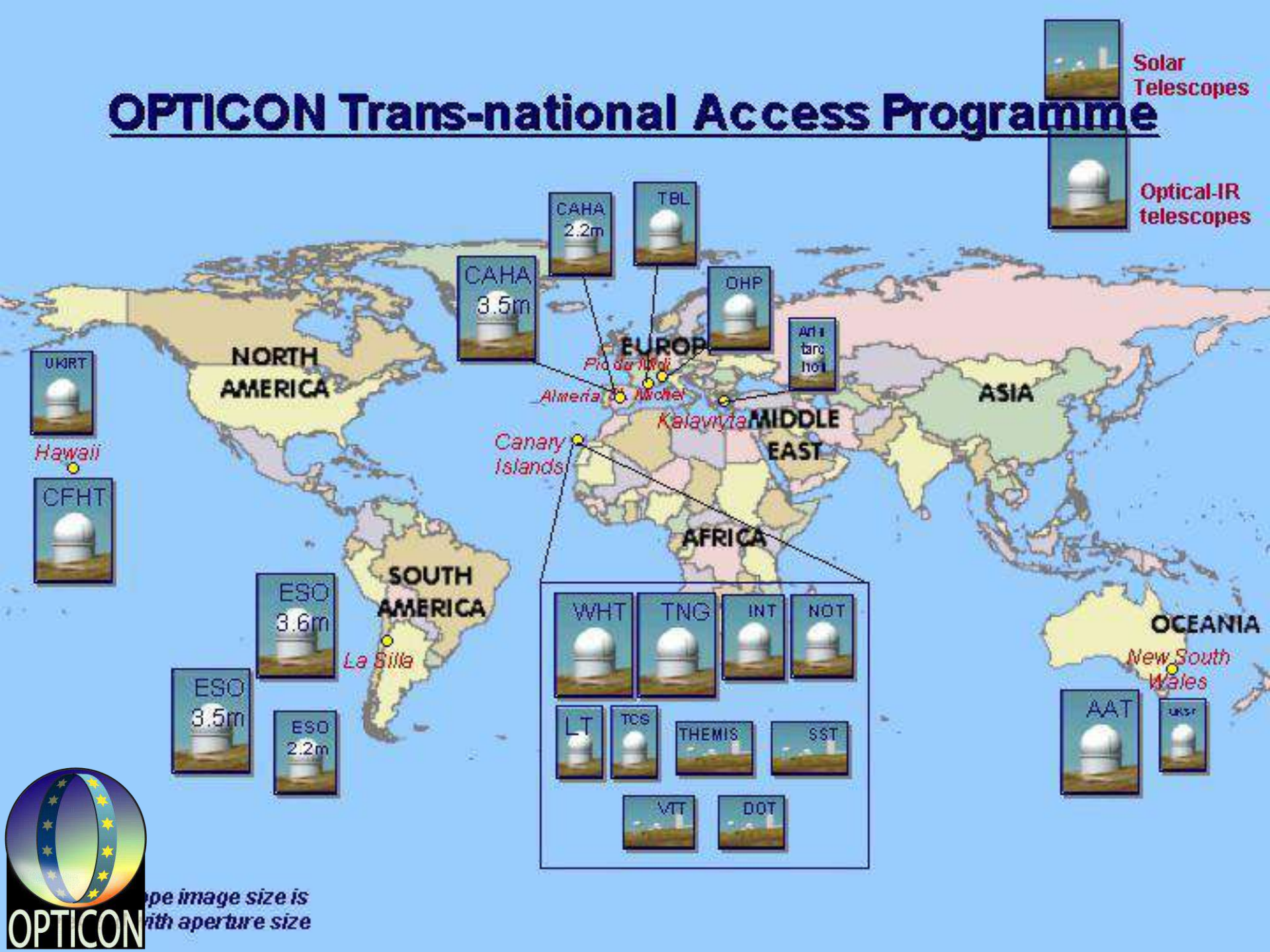


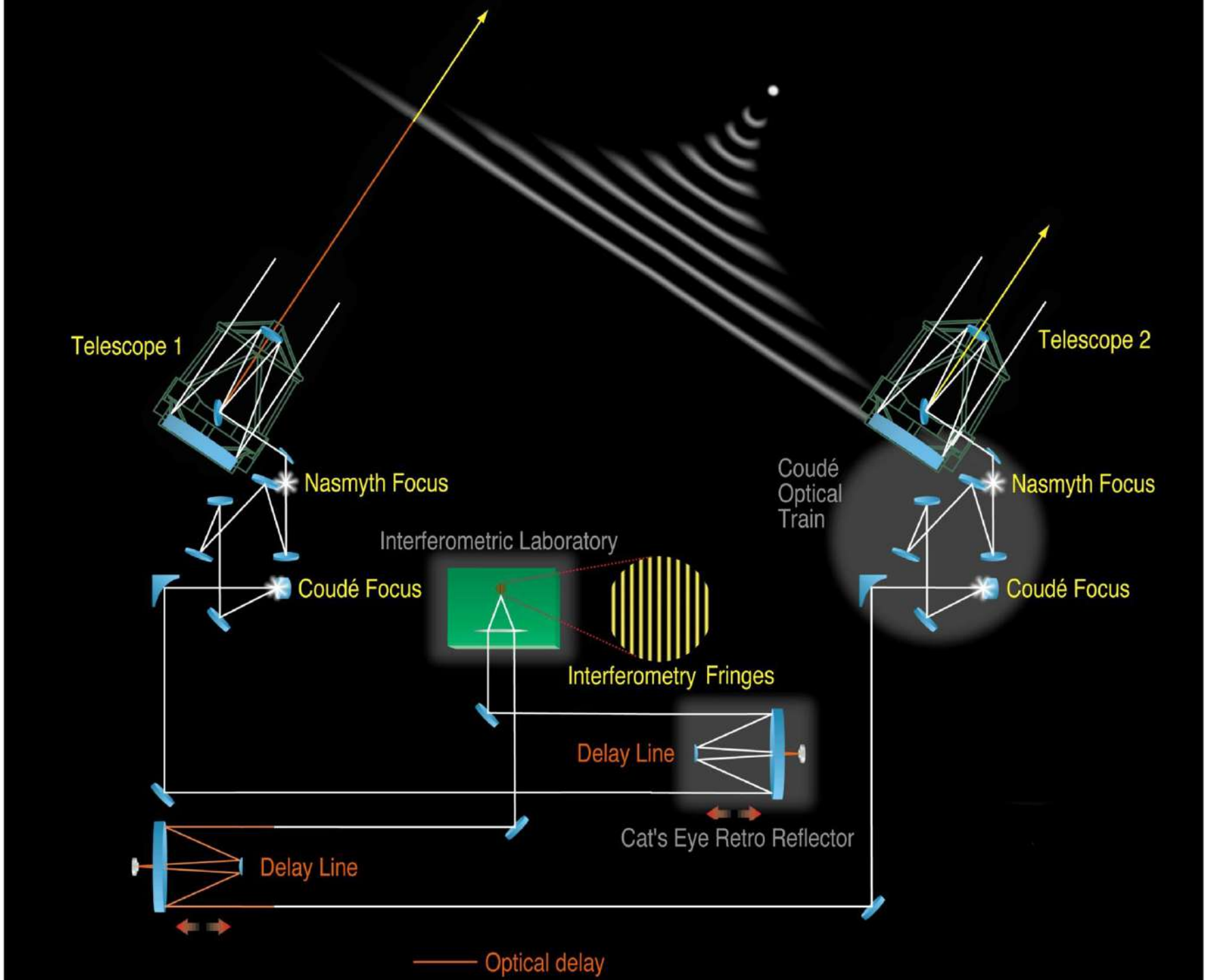
Figure 2. Geographical location in Northern Chile of International Observatories listed in Table 1.

OPTICON Trans-national Access Programme



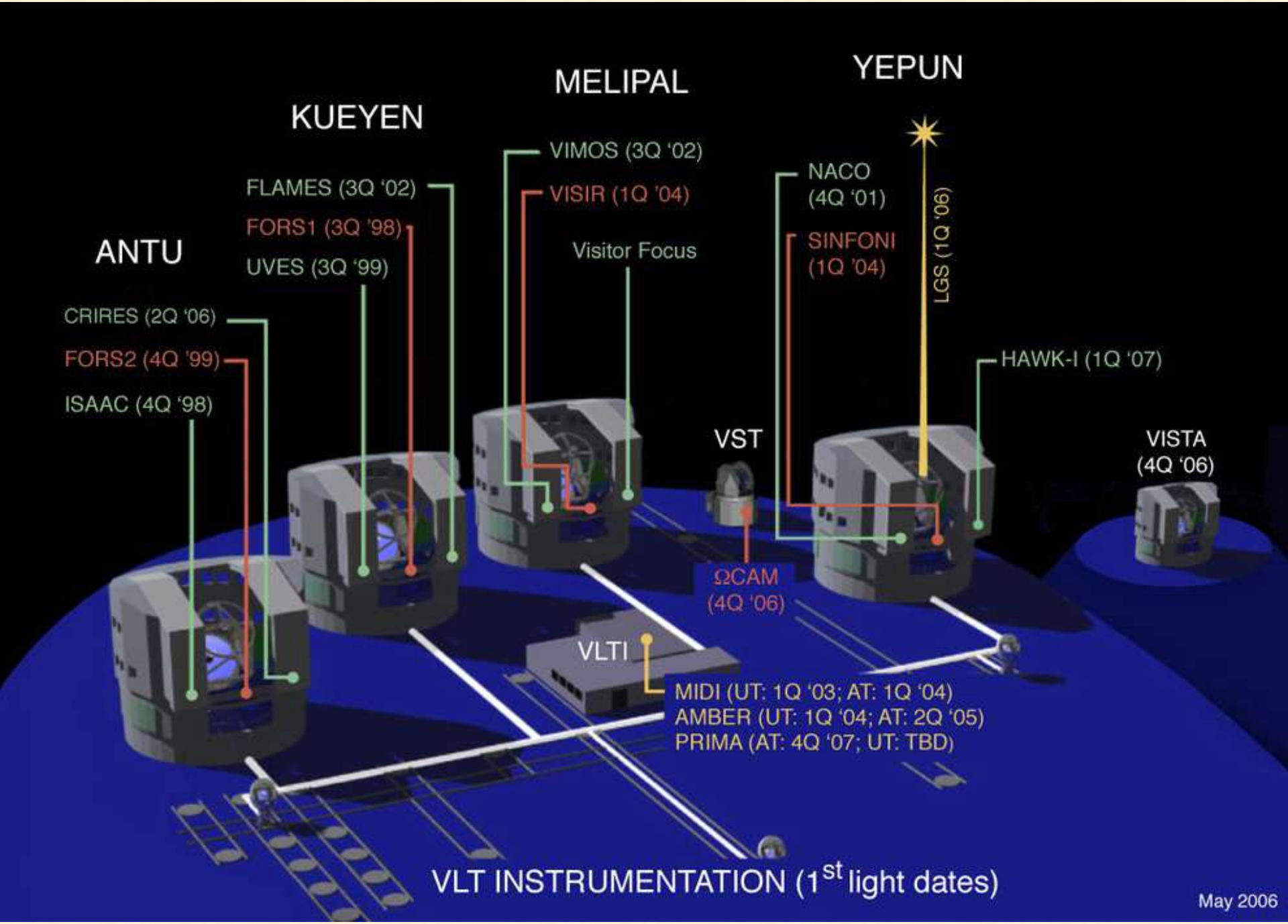
OPTICON

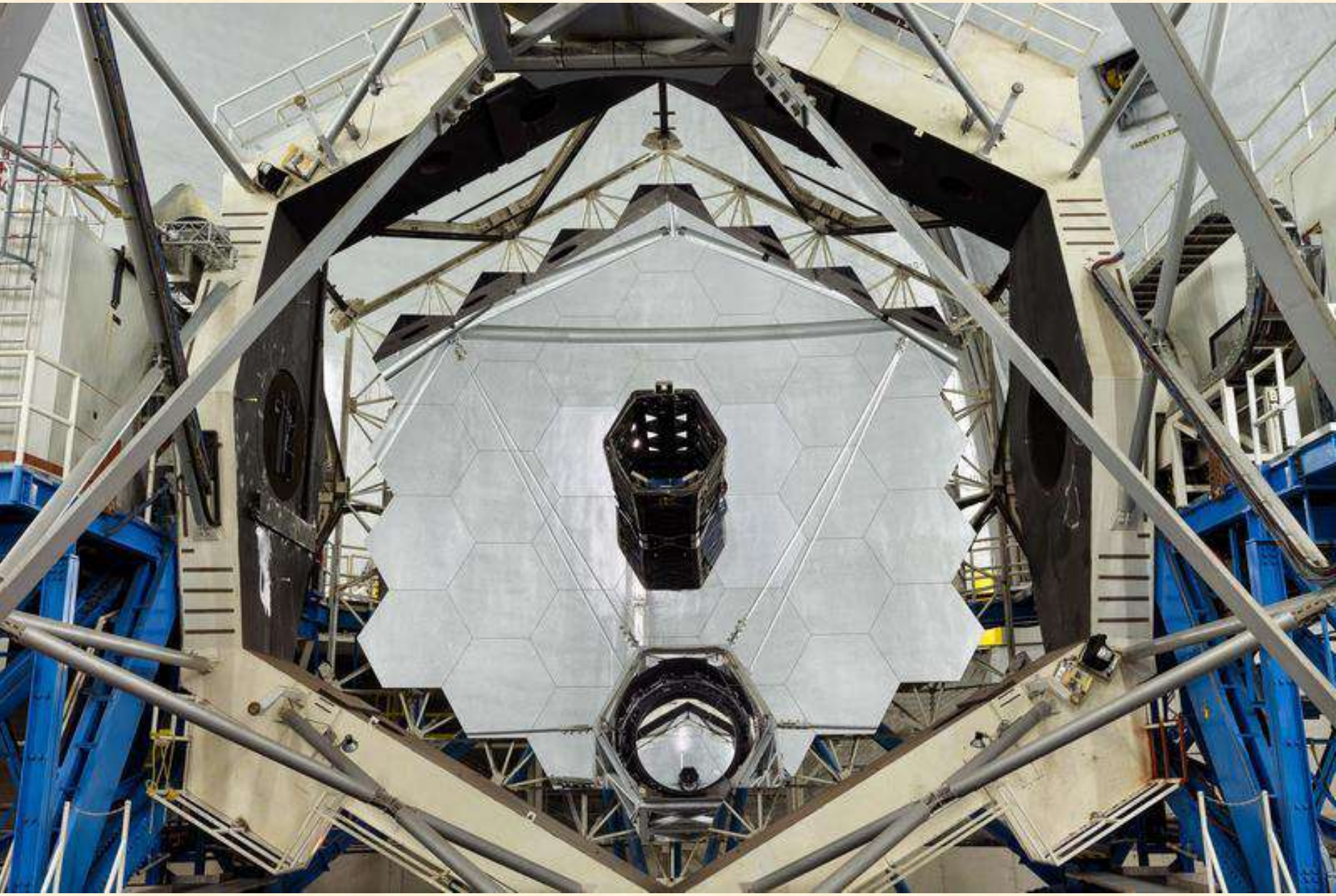
...pe image size is ...ith aperture size

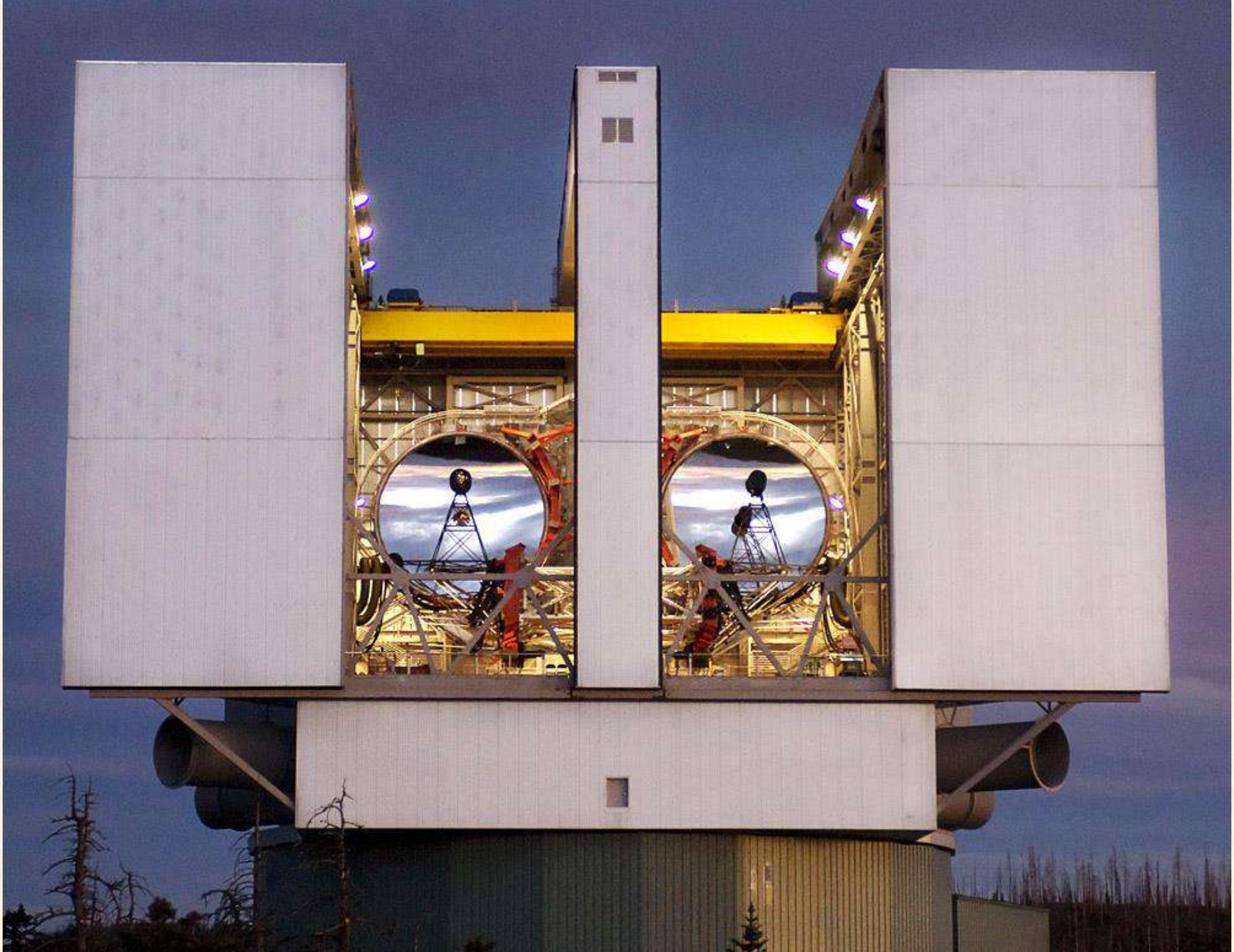

Telescope 1
Telescope 2
Nasmyth Focus
Nasmyth Focus
Coudé Optical Train
Interferometric Laboratory
Coudé Focus
Coudé Focus
Interferometry Fringes
Delay Line
Cat's Eye Retro Reflector
Delay Line
Optical delay

Largest Optical Interferometers

1640	**Very Large Telescope (VLT, VLTI, 4×8.2m), baseline 130 m (max)**		
820	UT1 Antu (Sun)	2635	Cerro Paranal, Chile, ESO
820	UT2 Kueyen (Moon)	2635	Cerro Paranal, Chile, ESO
820	UT3 Melipal (Southern Cross)	2635	Cerro Paranal, Chile, ESO
820	UT4 Yepun (Venus, “Evening Star”)	2635	Cerro Paranal, Chile, ESO
1389	**Keck Interferometer (2×9.8m), baseline 85 m**		
982	Keck	4145	Mauna Kea, Hawaii, USA
982	Keck II	4145	Mauna Kea, Hawaii, USA
1188	**Large Binocular Telescope (LBT, LBTI) (2×8.4m), baseline 22 m**		
840	Large Binocular Telescope 1 (LBT)	3170	Mt. Graham, AZ, USA
840	Large Binocular Telescope 2 (LBT)	3170	Mt. Graham, AZ, USA
1158	**Gemini Interferometer (2×8.1m), baseline 10,614 km**		
819	Gemini North (Gillett)	4213	Mauna Kea, Hawaii, USA
819	Gemini South	2722	Cerro Pachon, Chile, USA
919	**Magellan Telescopes (2×6.5m), baseline m**		
650	Walter Baade (Magellan I)	2516	Las Campanas, Chile, USA
650	Landon Clay (Magellan II)	2516	Las Campanas, Chile, USA


MELIPAL
YEPUN
KUEYEN
VIMOS (3Q '02)
VISIR (1Q '04)
NACO
(4Q '01)
SINFONI
(1Q '04)
LGS (1Q '06)
FLAMES (3Q '02)
FORS1 (3Q '98)
UVES (3Q '99)
Visitor Focus
ANTU
CRIRES (2Q '06)
FORS2 (4Q '99)
ISAAC (4Q '98)
HAWK-I (1Q '07)
VST
VISTA
(4Q '06)
ΩCAM
(4Q '06)
VLTI
MIDI (UT: 1Q '03; AT: 1Q '04)
AMBER (UT: 1Q '04; AT: 2Q '05)
PRIMA (AT: 4Q '07; UT: TBD)
VLT INSTRUMENTATION (1st light dates)
May 2006





World Largest Ground-Based Telescopes

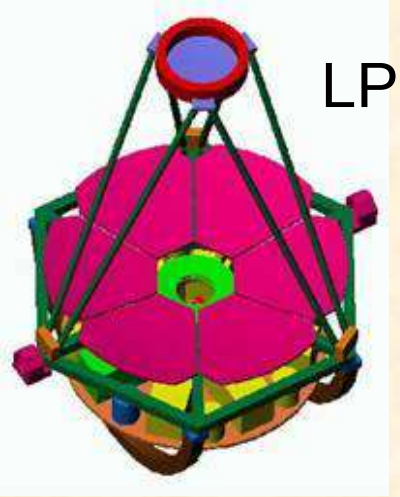
Distribution by sizes and continents

Size	Europe	Asia	Africa	Australia	Oceania	N.America	S.America	Total
m								
>9			2		2	1		5
>8			2		4	3	5	14
>5	1		2		4	6	7	20
>4	1	2	2		6	7	10	28
>3	2	4	3	1	10	14	12	46
>2.5	3	5	5	1	10	18	14	56
>2	9	10	6	2	12	28	16	83
>1.5								
>1								

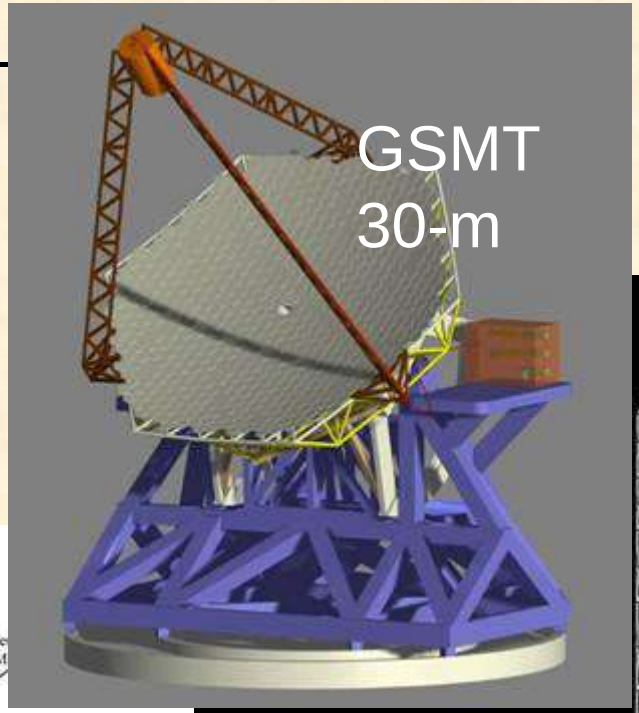
Largest Telescopes in Eurasia, Africa and Australia

1040	Gran Telescopio Canarias (GTC)	2400	La-Palma, Canarias, Es/US/Mx
920	South African Large Telescope (SALT)	1798	SAAO, South Africa/USA
605	Bolshoy Tel. Azimutalnyi (BTA)	2070	Mt. Pastukhovo, Caucasus, Russia
420	William Herschel Telescope (WHT)	2400	La-Palma, Canarias, UK/Nl
420	Large sky Area M.-Obj. fiber Sp. Tel.	960	Xinglong, China
400	Intl Liquid Mirror Telescope (ILMT)	2450	Manora Peak, Nainital, India
389	Anglo-Australian Telescope (AAT)	1164	Siding-Spring Mt., NSW, UK/Aust.
360	Telescopio Nazionale Galileo (TNG)	2387	La Palma, Canary Islands, Italy
360	Devasthal Optical Telescope	2540	Manora Peak, Nainital, India
350	Calar-Alto Obs. 3.5m Telescope	2168	Calar Alto, CAHA, Germany/Spain
340	Iranian National Telescope (INO340)	3610	Mt. Gargash, Isfahan Province, Iran
264	Zerkalnyi Tel. G.A. Shayna (ZTSh)	605	Mangush, Crimea, Ukraine
264	**Zerkalnyi Tel. Armyanskyi (ZTA)**	**1406**	**Mt. Aragatz, Armenia**
256	Nordic Optical Telescope (NOT)	2382	La Palma, Canary Isl., Spain
250	Isaac Newton Telescope (INT)	2336	La Palma, Canary Isl., Spain, UK
400	Obs. of Eastern Anatolia (OEA) tel.	3170	Karakaya Hill, Erzurum, Turkey
380	Timau National Obs. Telescope	1300	Timau Mt., W. Timor, Indonesia

Extremely Large Telescopes

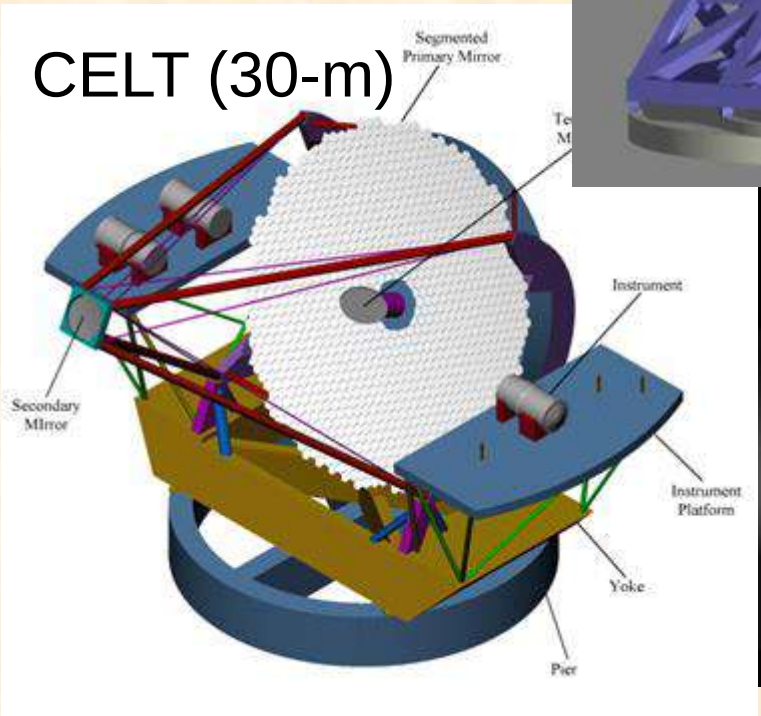


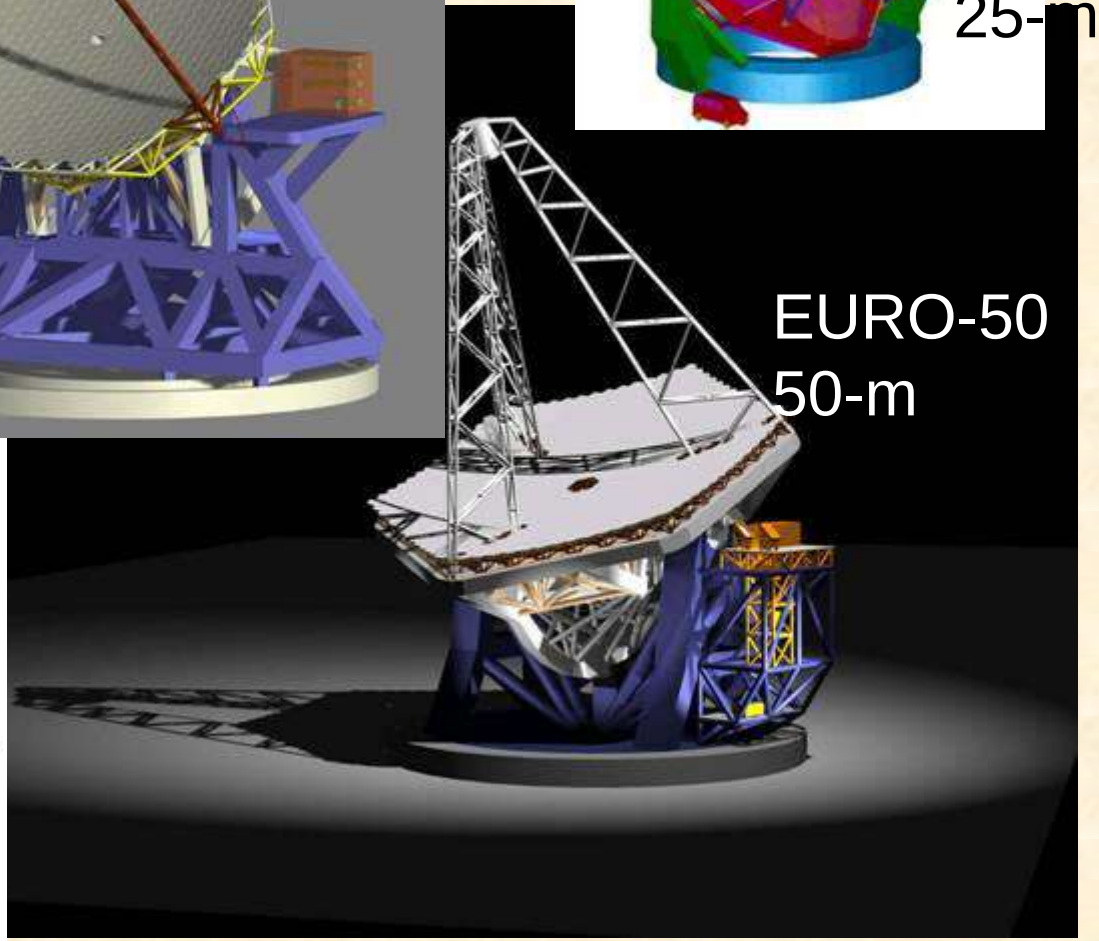
LPT (20-



HDRT
25-m

CELT (30-m)





Future Largest Telescopes

3930 Extremely Large Telescope (ELT) 3046 m

ESO / Cerro Armazones, Antofagasta Province, Antofagasta Region, Chile

Secondary 4.09 m, Tertiary 3.75 m, Angular resolution 0.005 arcsecond

Collecting area 978 m^2, Focal length 743.4 m, Expected 2028

3000 Thirty Meter Telescope (TMT) 4050 m

TMT Intl Obs., Mauna Kea Obs.-s / Mauna Kea, Hawaii County, Hawaii, USA

USA, Canada, Japan, China and India, Expected ? (halted since 2015)

Secondary 3.1 m, Tertiary 2.5m × 3.5m, Collecting area 655 m^2, Focal length f/15

2545 Giant Magellan Telescope (GMT) 2516 m

USA / Atacama Desert, Coquimbo Region, Atacama Region, Chile

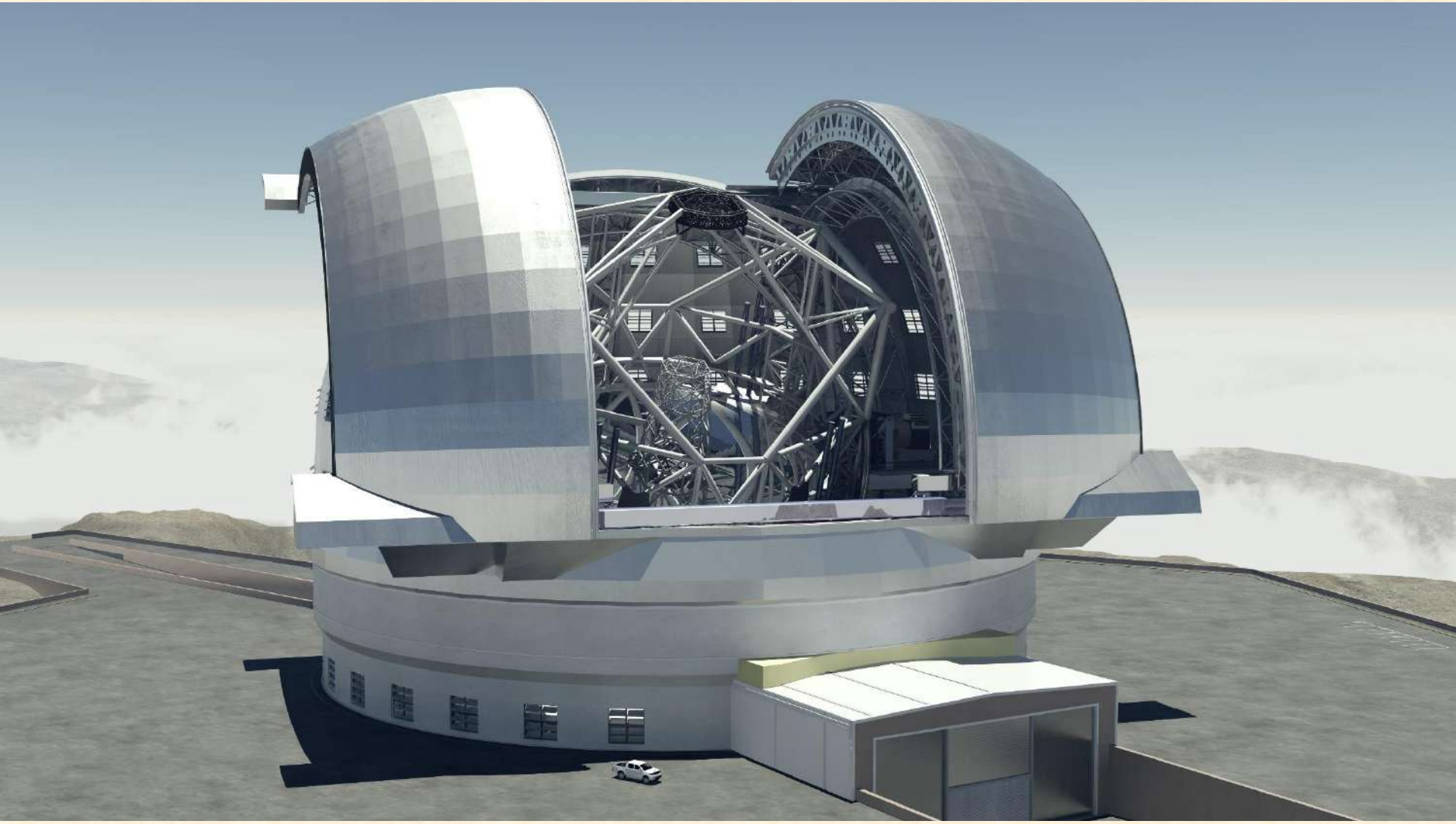
Secondary 3.2 m, Angular resolution 0.01 arcsecond, Collecting area 368 m^2

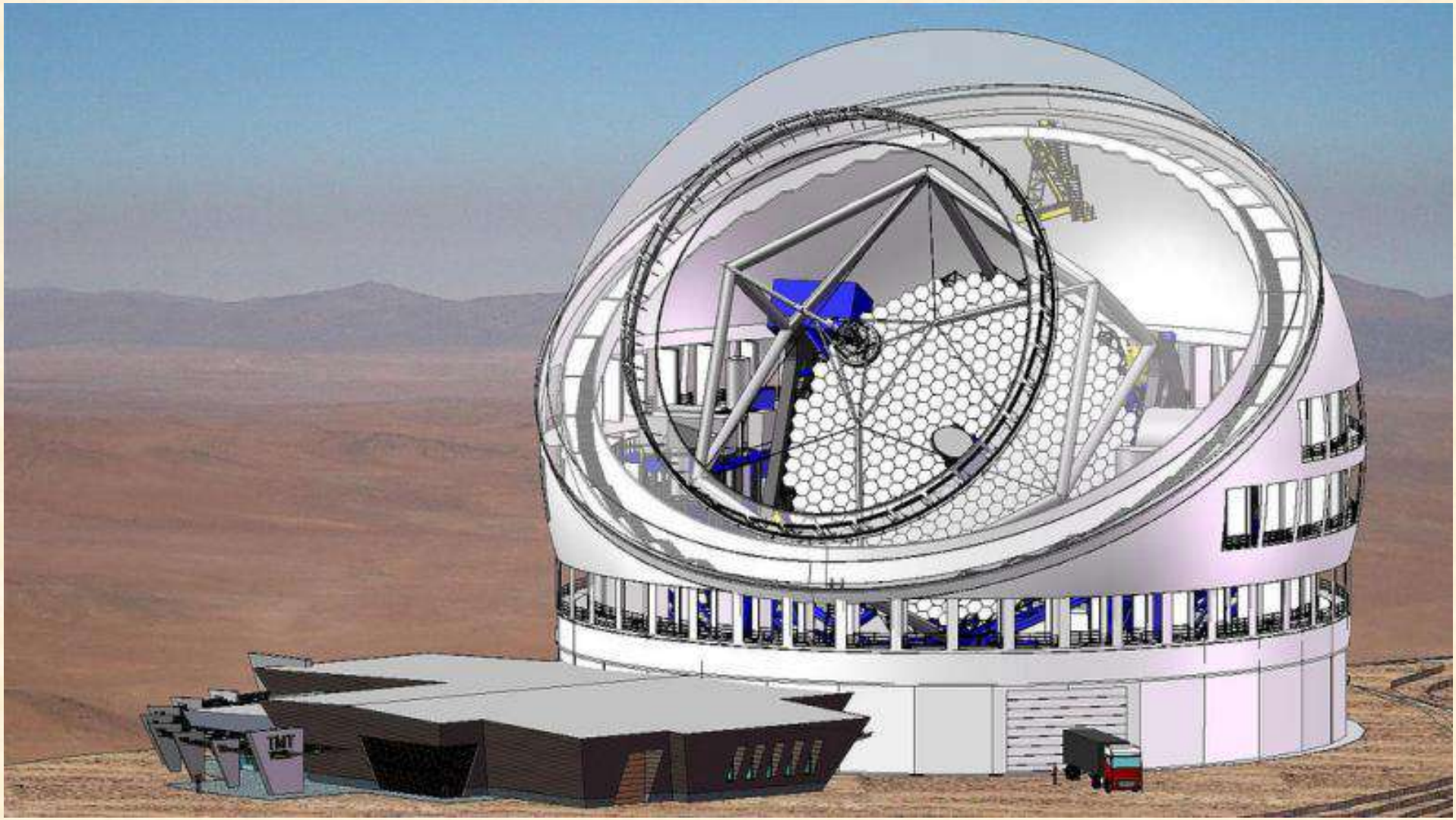
Focal lengths 18 m and 202.7 m, Expected 2029

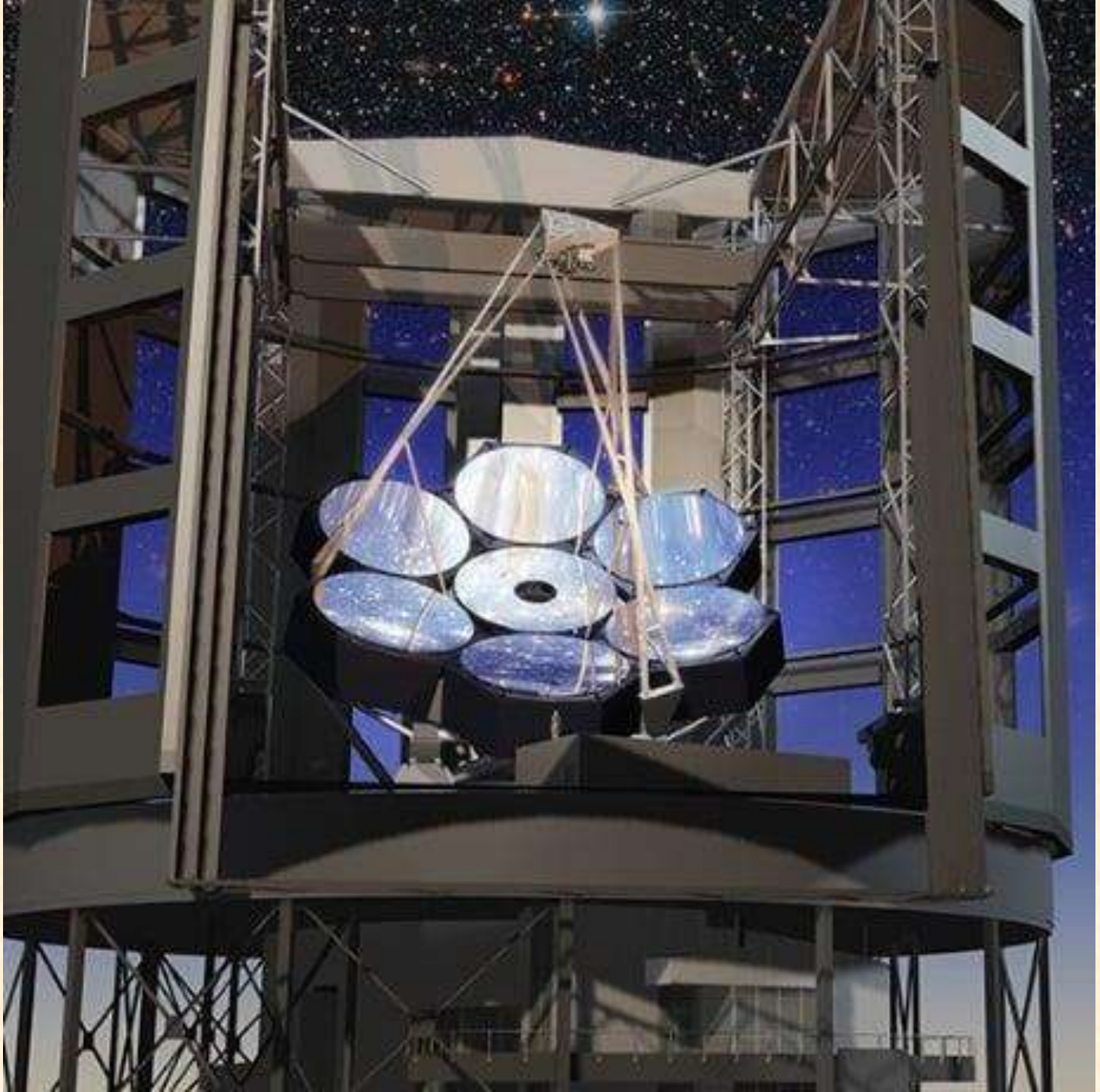
842 Vera Rubin Telescope (LSST) 2663 m

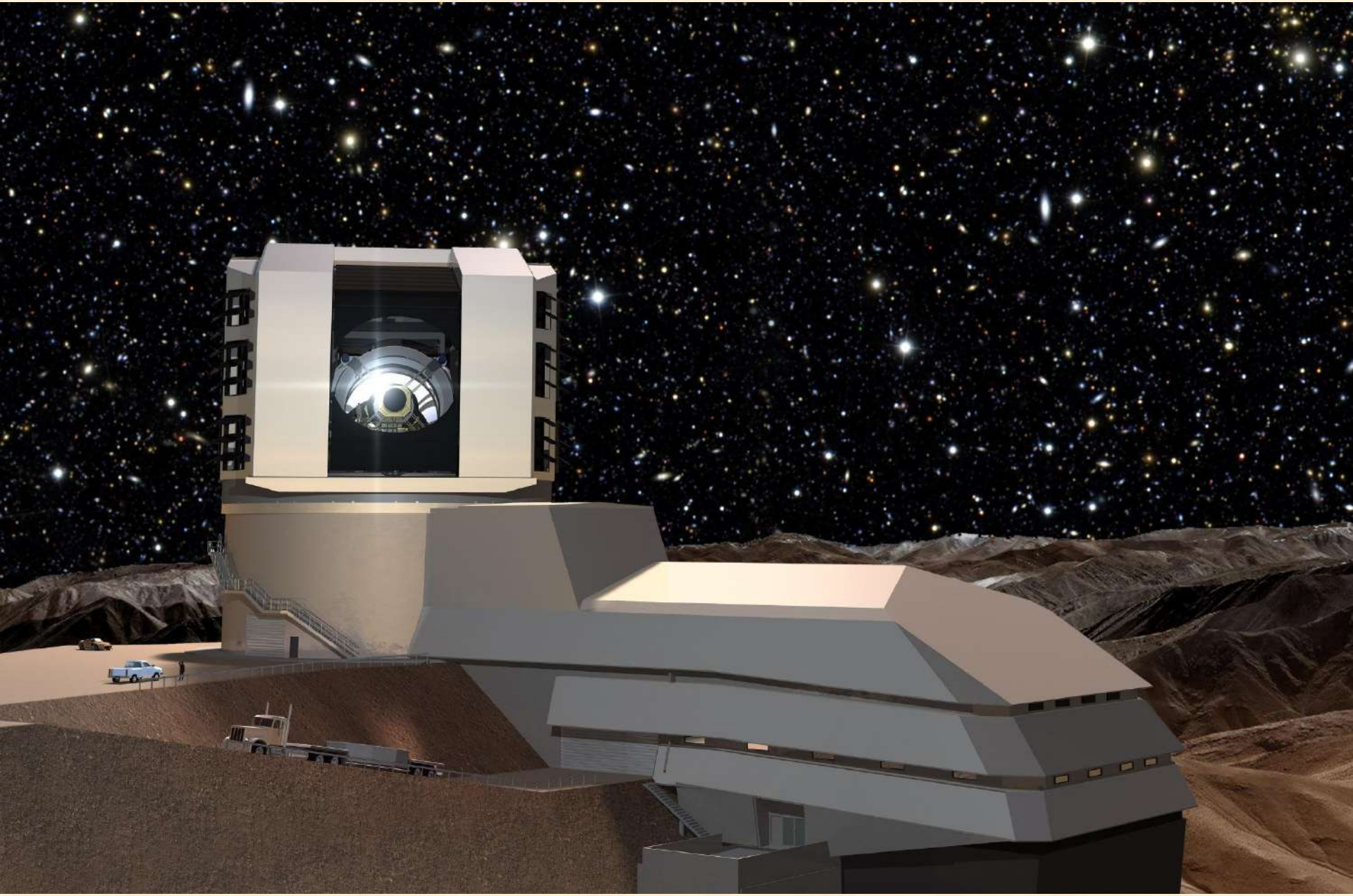
Vera C. Rubin Observatory, USA / Elqui Province, Coquimbo Region, Chile

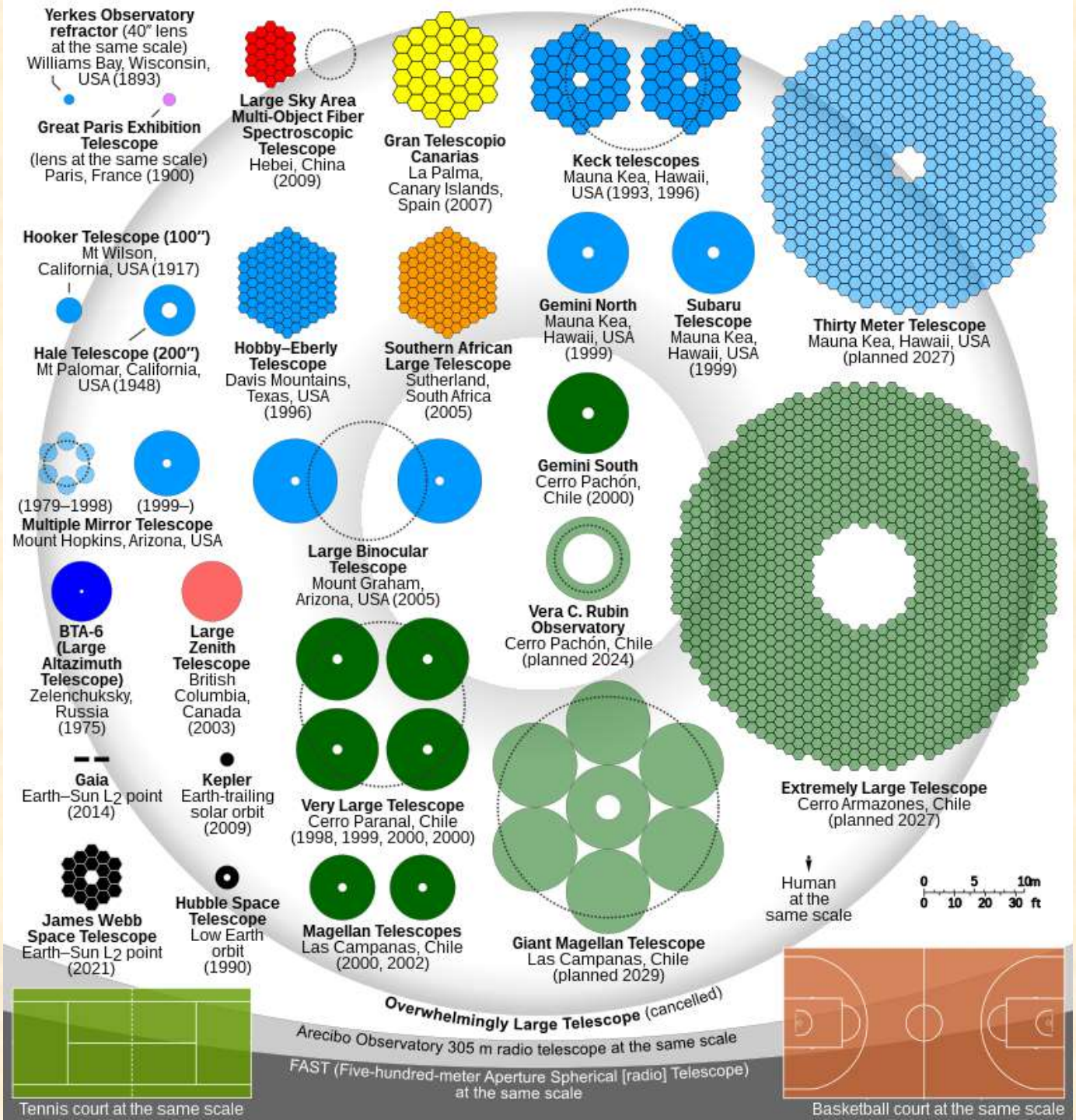
Scmidt type telescope, Secondary 3.420 m, Tertiary 5.016 m, Angular resolution 0.7″, 0.2″ pixel size, Col. area 35 sq. m, Focal lengths 10.31 m and 9.92 m, Expected Jan 2025



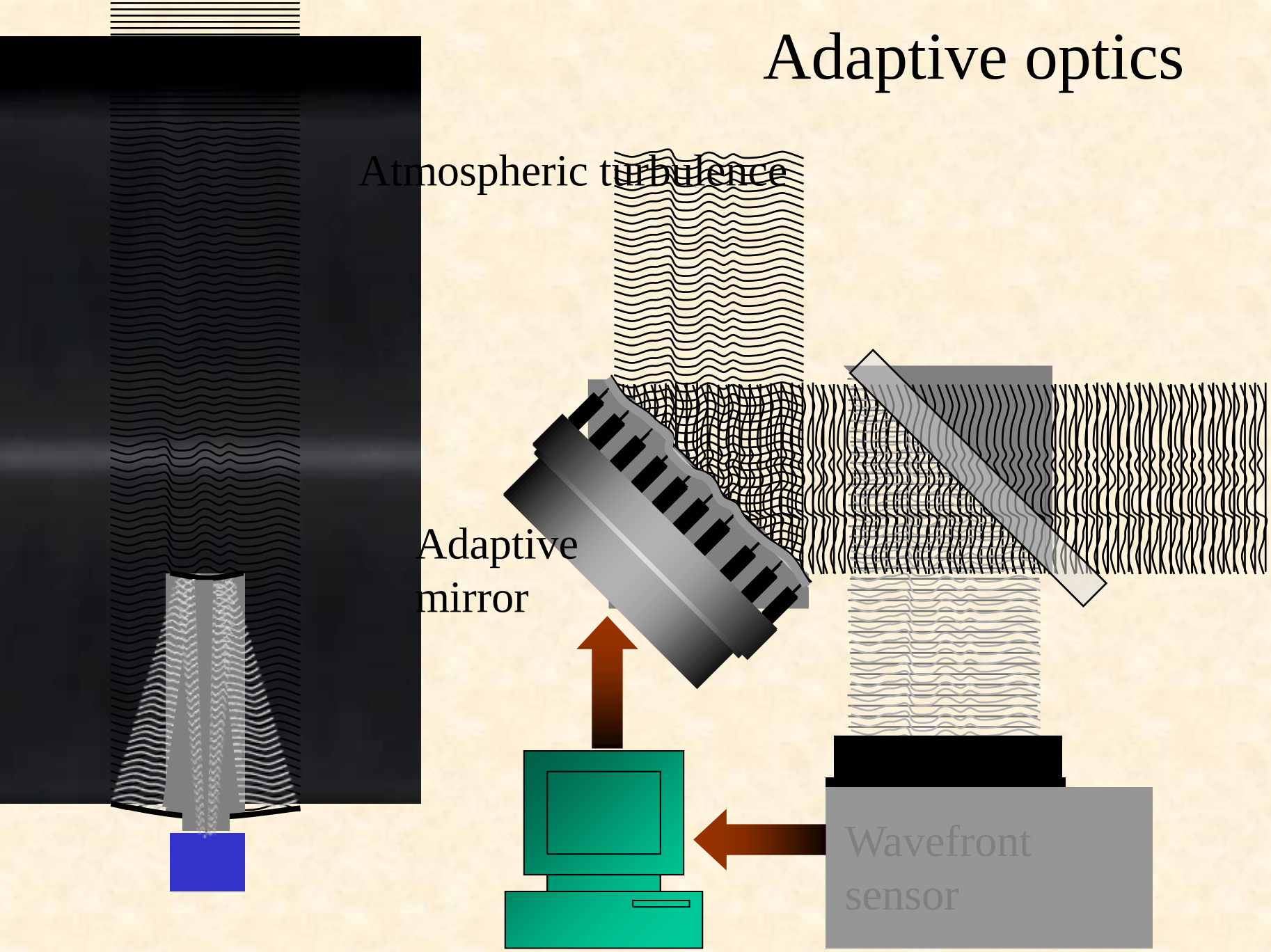

TMT

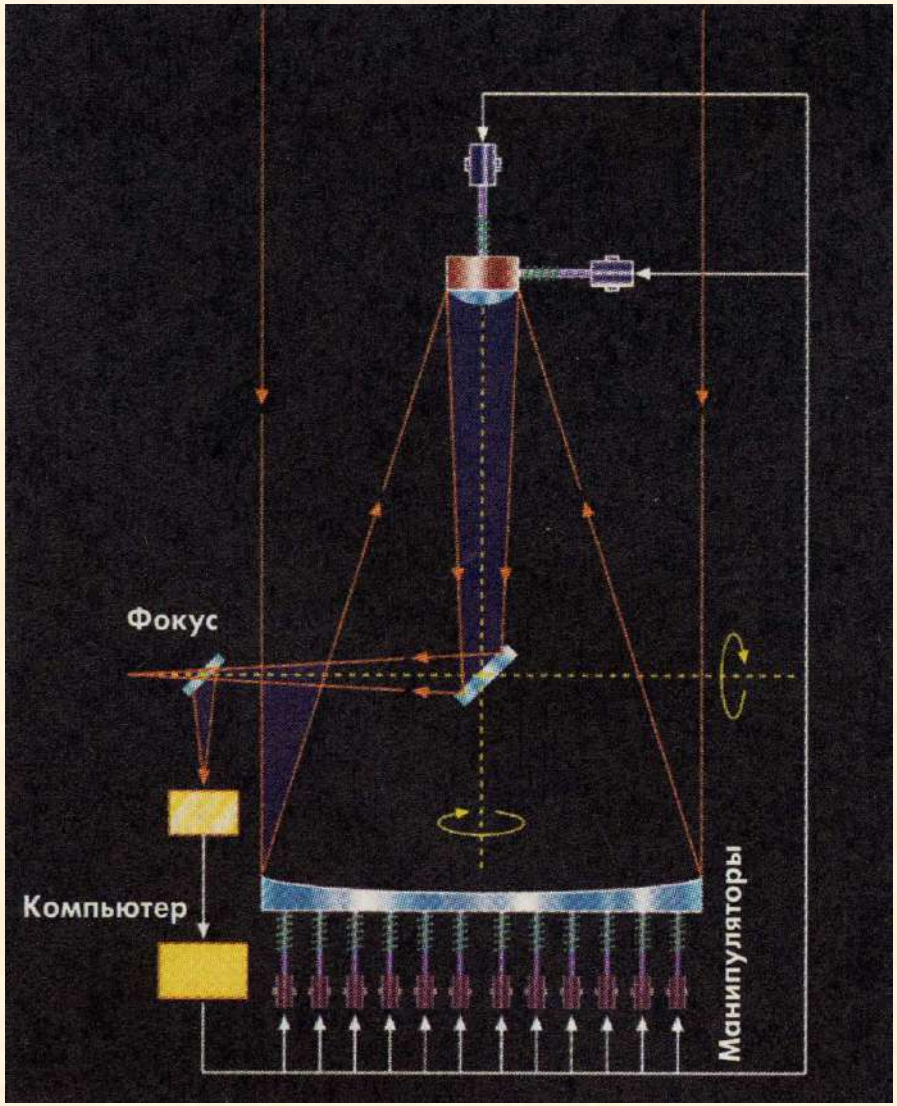


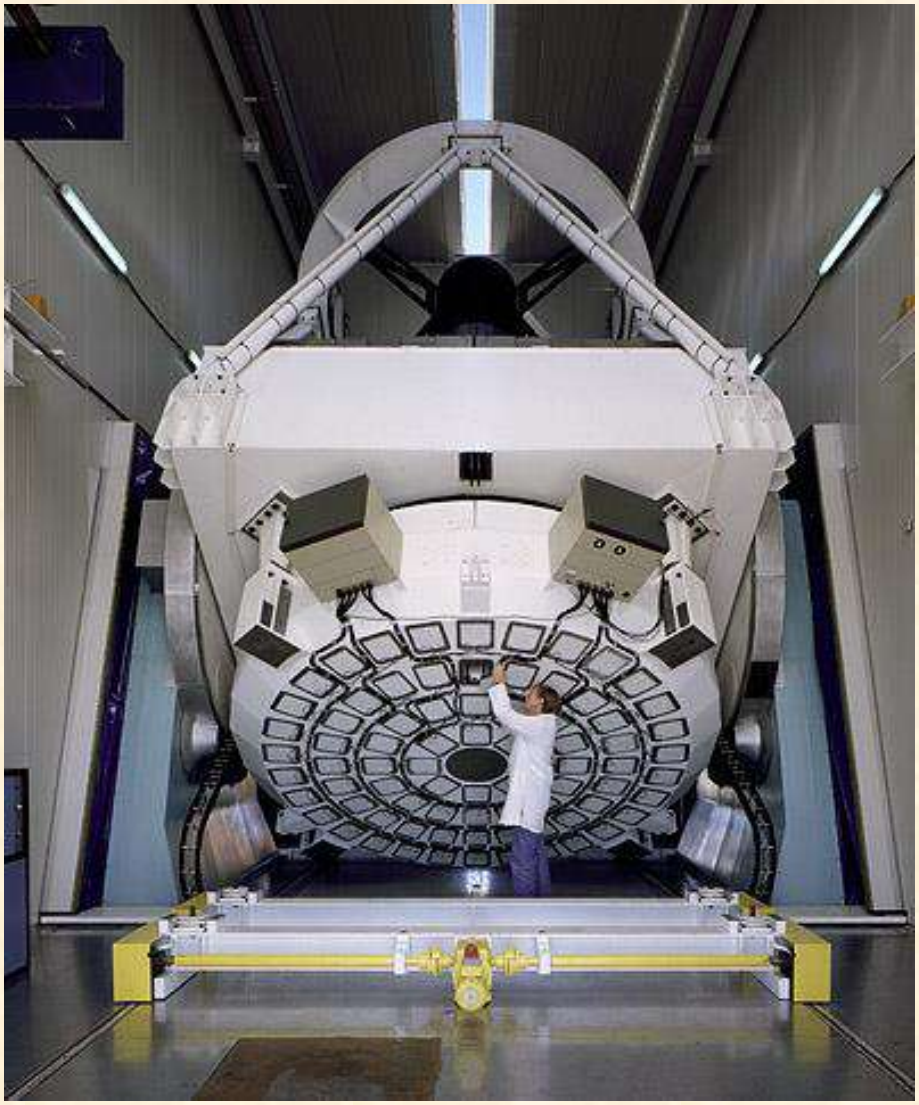



Yerkes Observatory refractor (40″ lens at the same scale)
Williams Bay, Wisconsin, USA (1893)
Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China
(2009)
Gran Telescopio Canarias
La Palma, Canary Islands, Spain (2007)
Keck telescopes
Mauna Kea, Hawaii, USA (1993, 1996)
Thirty Meter Telescope
Mauna Kea, Hawaii, USA
(planned 2027)
Hooker Telescope (100″)
Mt Wilson, California, USA (1917)
Hale Telescope (200″)
Mt Palomar, California, USA (1948)
Hobby–Eberly Telescope
Davis Mountains, Texas, USA
(1996)
Southern African Large Telescope
Sutherland, South Africa
(2005)
Gemini North
Mauna Kea, Hawaii, USA
(1999)
Subaru Telescope
Mauna Kea, Hawaii, USA
(1999)
(1979–1998)
(1999–)
Multiple Mirror Telescope
Mount Hopkins, Arizona, USA
Large Binocular Telescope
Mount Graham, Arizona, USA (2005)
Gemini South
Cerro Pachón, Chile (2000)
Vera C. Rubin Observatory
Cerro Pachón, Chile
(planned 2024)
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia
(1975)
Large Zenith Telescope
British Columbia, Canada
(2003)
Gaia
Earth–Sun L2 point
(2014)
Kepler
Earth-trailing solar orbit
(2009)
Very Large Telescope
Cerro Paranal, Chile
(1998, 1999, 2000, 2000)
Extremely Large Telescope
Cerro Armazones, Chile
(planned 2027)
James Webb Space Telescope
Earth–Sun L2 point
(2021)
Hubble Space Telescope
Low Earth orbit
(1990)
Magellan Telescopes
Las Campanas, Chile
(2000, 2002)
Giant Magellan Telescope
Las Campanas, Chile
(planned 2029)
Human at the same scale
0 5 10m
0 10 20 30 ft
Overwhelmingly Large Telescope (cancelled)
Arecibo Observatory 305 m radio telescope at the same scale
FAST (Five-hundred-meter Aperture Spherical [radio] Telescope) at the same scale
Tennis court at the same scale
Basketball court at the same scale

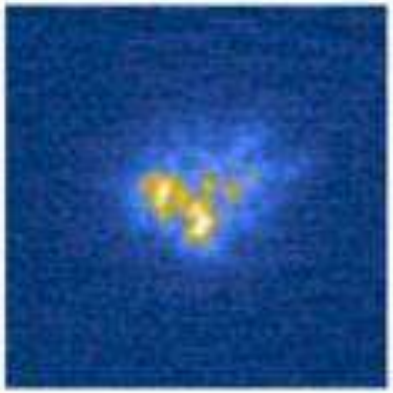
Adaptive optics

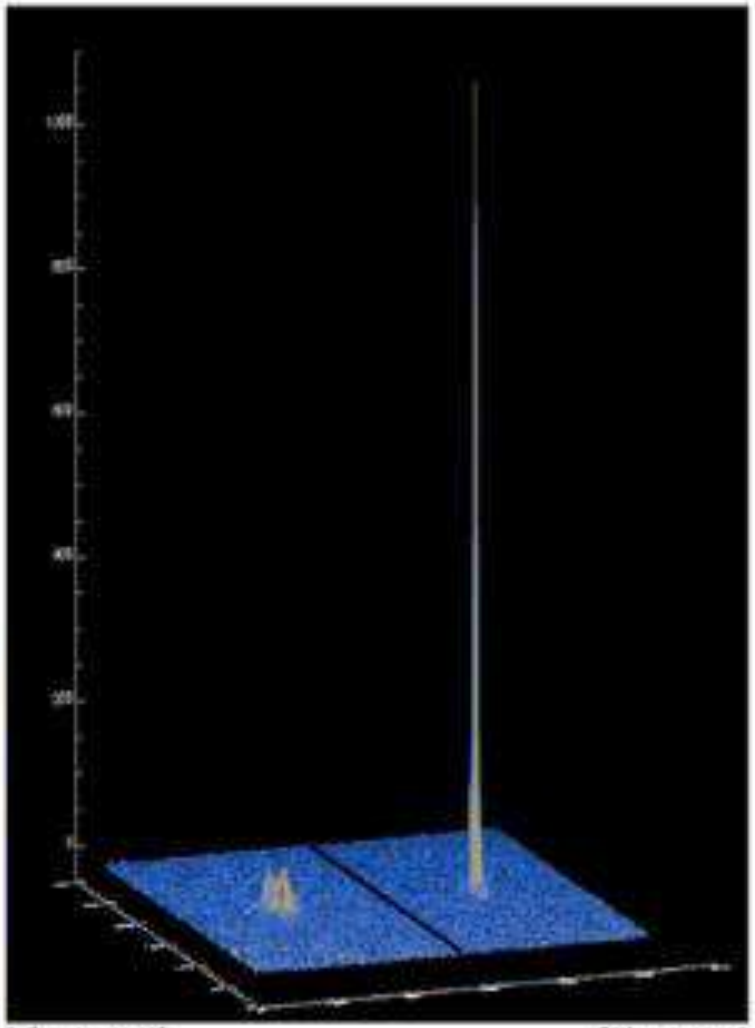



Фокус
Компьютер
Манипуляторы

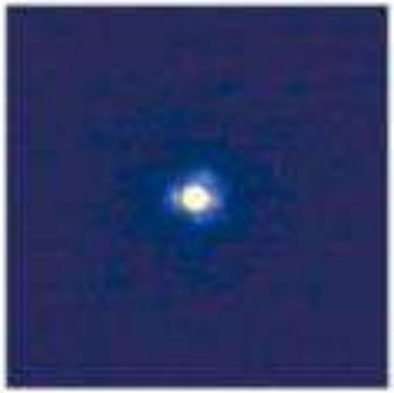


Uncorrected image
FWHM: 0.50"





AO corrected image
FWHM: 0.07"



Left: uncorrected

Right: corrected

Largest Historical Schmidt Telescopes

Telescope name	Corr. cm	Mirror Cm	Foc. cm	Focal ratio	Field deg	Plate Cm	Scale "/mm	Location	Country	Alt. m	Year
Alfred-Jensch	134	203	410	1:3.0	3.4x3.4	24x24	50.3	Tautenburg	Germany	331	1960
Samuel Oschin	122	183	307	1:2.5	6.6x6.6	36x36	67.2	Mt. Palomar	USA	1706	1948
UK Schmidt	122	183	307	1:2.5	6.6x6.6	36x36	67.2	Siding-Spring	Australia	1131	1973
Kiso Schmidt	105	150	330	1:3.1	6.0x6.0	36x36	62.5	Kiso	Japan	1130	1974
ESO Schmidt	102	162	306	1:3.0	5.5x5.5		67.4	Cerro La Silla	Chile	2400	1969
Jurgen Stock	102	152	301	1:3.0	5.5x5.5	29x29	68.5	Llano del Hato	Venezuela	3600	1976
Kvistaberg Schm.	102	135	300	1:3.0	4.6x4.6	24x24	68.8	Kvistaberg	Sweden	33	1964
BAO 1m Schmidt	102	132	213	1:2.1	4.1x4.1	16x16	96.8	Byurakan	Armenia	1397	1960
Uccle Schmidt	84	117	210	1:2.5			98.2	Uccle	Belgium	105	1958
Hamburg Schmidt	81	122	240	1:3.0	5.5x5.5	25x25	86.2	Calar Alto	Spain	2160	1955
Baker-Schmidt	81	91	300	1:3.7			68.8	Bloemfontein	S. Africa	1387	1950
Baldone Schmidt	80	120	240	1:3.0	4.8x4.8	24x24	85.9	Baldone	Latvia	75	1967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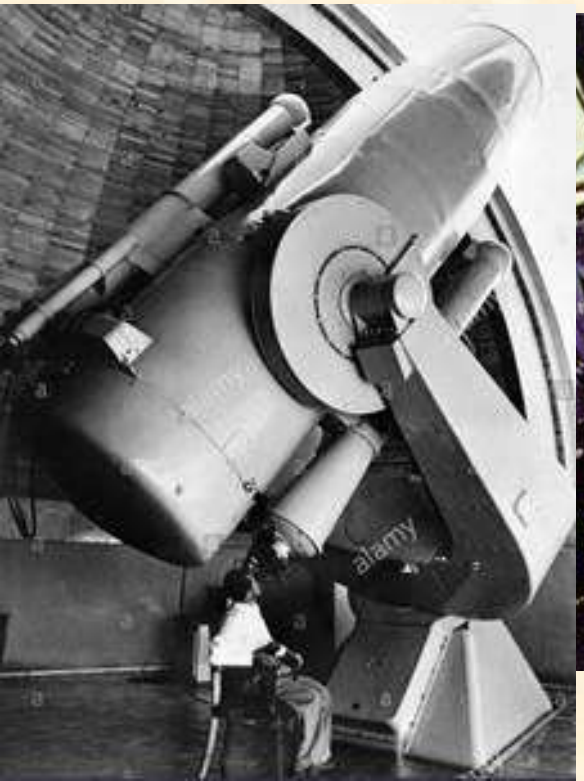
alamy

Latest Wide-Angle Telescopes

- **VLT Survey Telescope (VST), ESO**; Diameter 2.6m, Altitude: 2,635 m, Angular resolution: 0.216 as, Coordinates: 24°37′41″S 70°24′18″W / 24.628°S 70.40489°W, Focal length: 14.416 m, Location: Cerro Paranal, Chile, Telescope style: Ritchey–Chrétien telescope
- **Visible and Infrared Survey Telescope for Astronomy (VISTA), ESO**; Diameter: 4.1m, Altitude: 2,518 m, Angular resolution: 0.34 as, Coordinates: 24°36′57″S 70°23′51″W / 24.615833°S 70.3975°W, Focal length 12.1m, Location: Cerro Paranal, Chile, Telescope style: Ritchey–Chrétien telescope
- **Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST), China**; Diameter: 4.20m, Secondary diameter 6m, Collecting area 18.86 m^2, Focal length 20 m, Location Xinglong, China, Altitude 960m, Telescope style: Schmidt
- **Vera Rubin Telescope (LSST – Large-aperture Synoptic Survey Tel.), USA**; D 8.417m, Location Elqui Province, Coquimbo Region, Chile, First light exp. in Jan 2025, Altitude 2,663 m, Ang. res. 0.7″ median seeing limit; 0.2″ pix size, λλ 320–1060 nm, Coll. area: 35 sq. m

Small/medium-size *vs* big telescopes

pros and cons

Characteristics	Small/medium-size	Big
Collecting area D^2	**poor**	**good**
Limiting magnitude	poor	good
Cost	affordable	high
Number of telescopes	big	small
Observing time pressure	small	big
Number of objects	big	small
Mobility	no/yes	no
Resolving power 1.22 λ/D	**poor**	**good**
Field of view	**big**	**small**
Equipment	portable	dedicated
Weight (deformations)	small	big
Observing costs	small	big
Maintenance costs	small	big
Collaborative projects	many	few
Software systems	standard	dedicated
Robotic mode	yes	no

Additional subjects

- **Radio telescopes**
- Telescopes in other wavelength ranges
- Solar telescopes
- **Space Telescopes**
- Cosmic Rays, Neutrino, Gravitational wave and other telescopes
- **Robotic telescopes**
- Reducers, Spectrographs, etc.
- Receivers
- Image reduction, processing and analysis
- Astronomical Spectroscopy


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