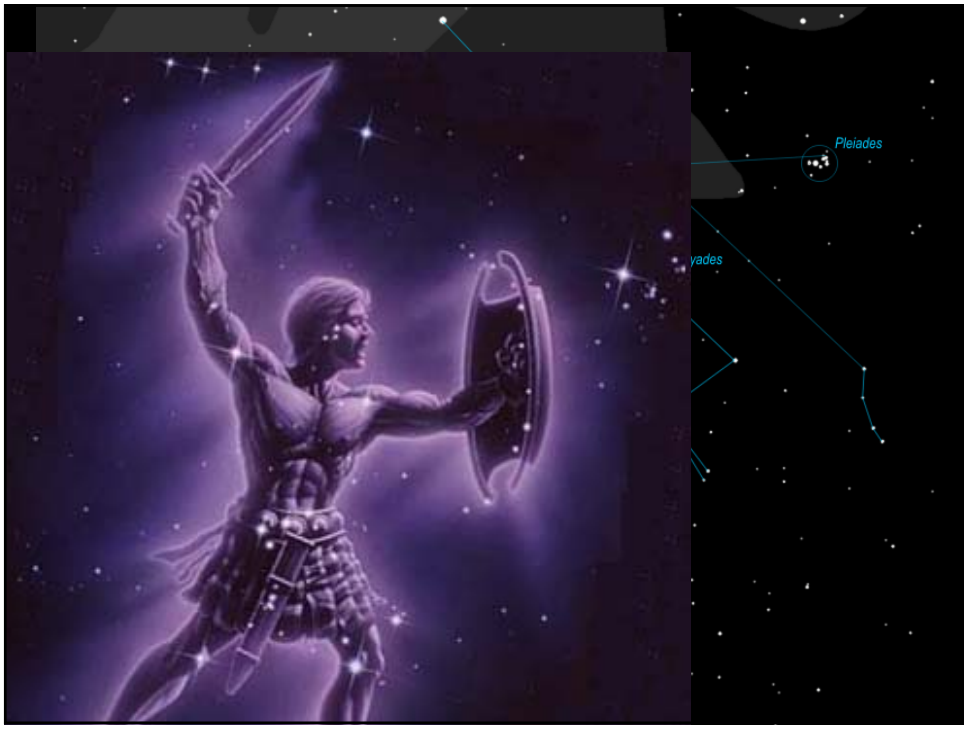
Astronomical Technology and the Exploration of the Universe

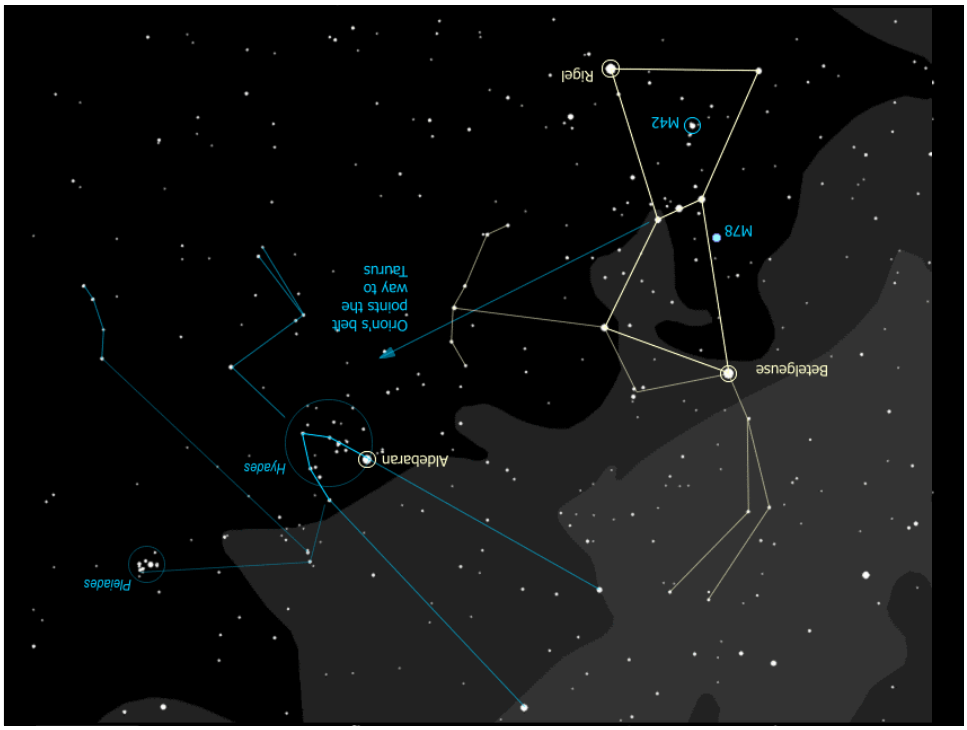
Prof André Buys

Naked eye astronomy

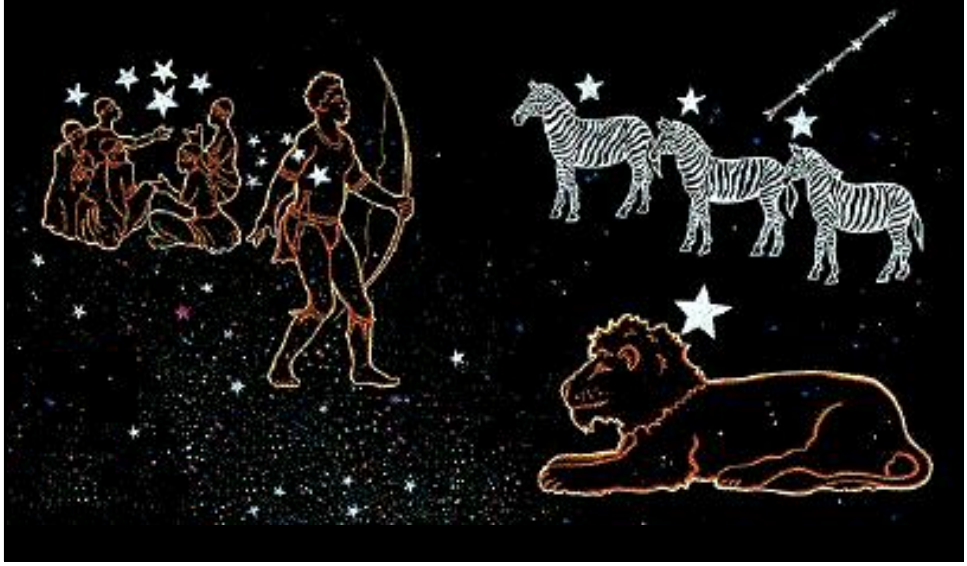
Naked Eye Astronomy

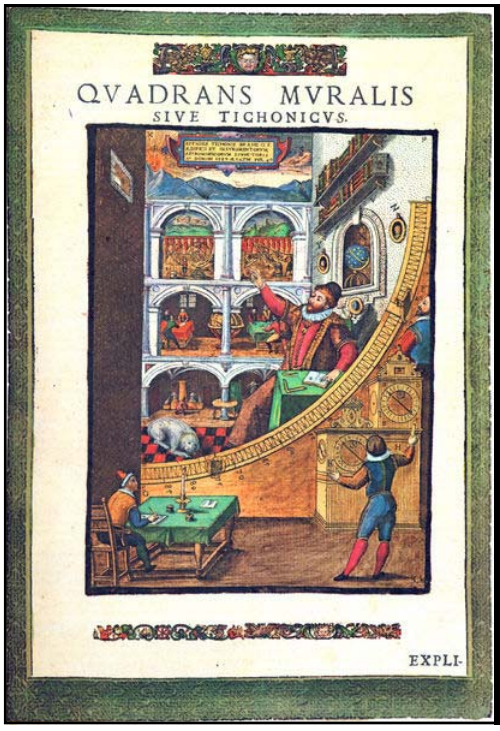
- The angular resolution of the naked eye is about 1′ (one arcminute).
- The naked eye can see:
  - about 1,500 stars in a dark sky (6th magnitude).
  - colours only in bright stars and the planets. The eye uses rods instead of cones at low light levels.
  - some star clusters: Pleiades, h/χ Persei, M13 and the Orion Nebula.
  - two true galaxies: Andromeda (M31) and Triangulum (M33).
  - five planets: Mercury, Venus, Mars, Jupiter, and Saturn.


Pleiades
yades


Rigel
M42
M78
Betelgeuse
Orion's belt
points the
way to
Taurus
Aldebaran
Hyades
Pleiades

The Namaqua legend of the daughters of the sky god.





Tycho Brahe (1546-1601)

The zenith of naked-eye astronomy

- His planetary observations were consistently accurate to within about 1'.
- His stellar observations were even more accurate, varying from 32" to 49" for different instruments.
- His records enabled Kepler to discover the laws of planetary motion, which provided evidence for the Copernican heliocentric theory of the solar system.

The dawn of astronomical technology

The optical telescope

Galileo Galilei (1564 – 1642)

Galileo is generally recognised as the inventor of the astronomical telescope.

Galileo's telescopes (1610)

In the Museum of the History of Science in Florence

Objective diameter: 51 mm
Focal length: 1,330 mm
Magnification: 14
Field of view: 15'

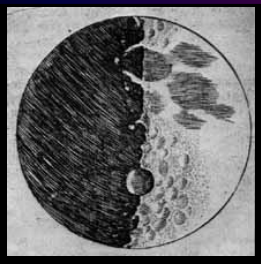
Objective diameter: 37 mm
Focal length: 980 mm
Magnification: 21
Field of view: 15'

Galileo's publishes his astronomical discoveries


SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
GALILEO GALILEO
PATRITIO FLORENTINO
PERSPICILLI
QVATVOR PLANETIS
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.

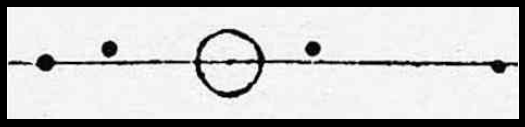
- Galileo published *Sidereus Nuncius* (Starry Messenger) in March 1610.
- In this work he announced the discovery of Jupiter's moons and other observations.

Galileo's observations



Moon

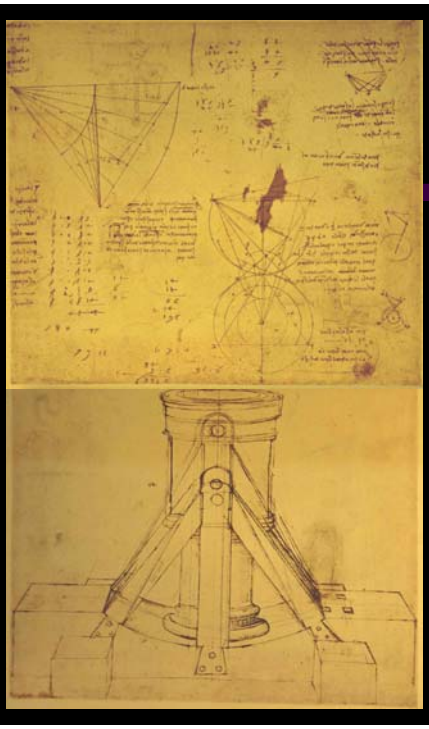
Phases of Venus



Jupiter's moons

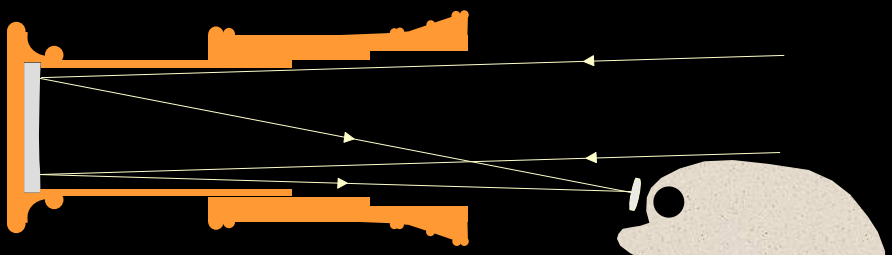
Saturn's rings

Atalay's proposition



On page 59(b) of Leonardo's *Codex Atlanticus* appears this drawing. Bülent Atalay proposed in 2005 that it is Leonardo's "telescope". The page also contains a "study of light reflection of a concave mirror".

Optical design of Leonardo's telescope



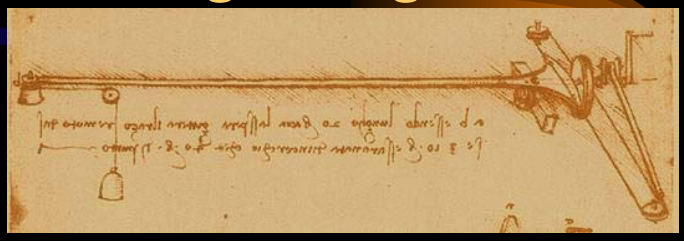
Mirror: Spherical concave speculum metal
Mirror diameter: 100 mm
Focal length: 500 mm
Focal ratio: f5

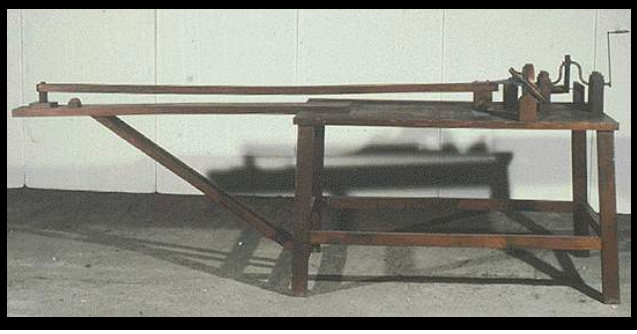
Eyepiece: Bi-convex glass (Handheld "magnifying glass")
Eyepiece diameter: 25 mm
Focal length: 15 mm
Magnification: 33x

Replica of Leonardo da Vinci's telescope

Leonardo's long focal-length sperical mirror grinding machine

Leonardo's drawing



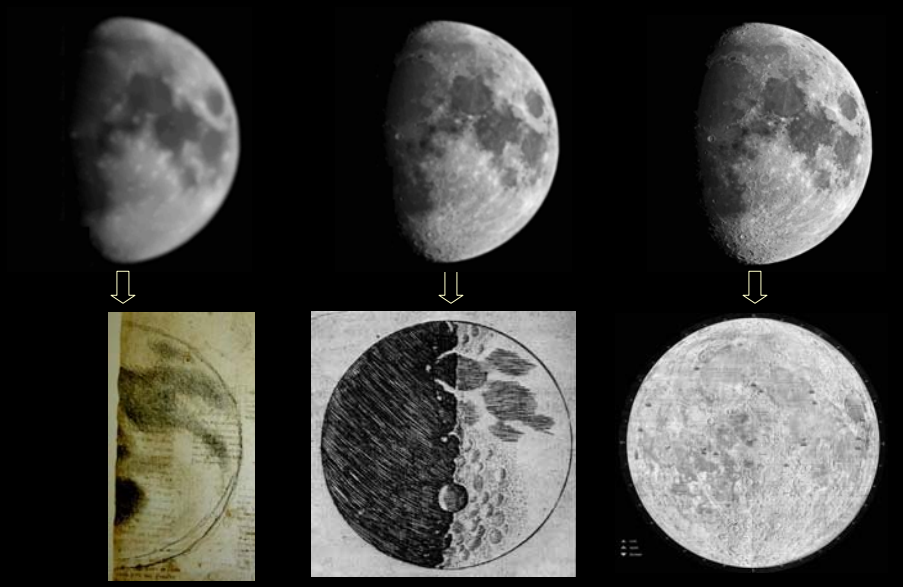


Working model

The quality of the optics determines what you see!

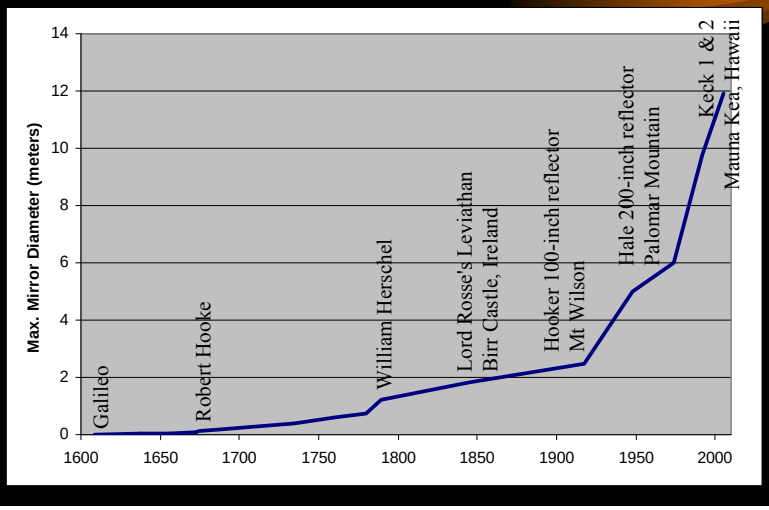
The moon Leonardo da Vinci saw in 1513 through his reflecting telescope.	The moon Galileo Galilei saw in 1609 through his refracting telescope.	The moon we see today through a modern amateur telescope.

We draw what we see…



Leonardo da Vinci | Galileo Galilei | Modern moon map

Aperture fever



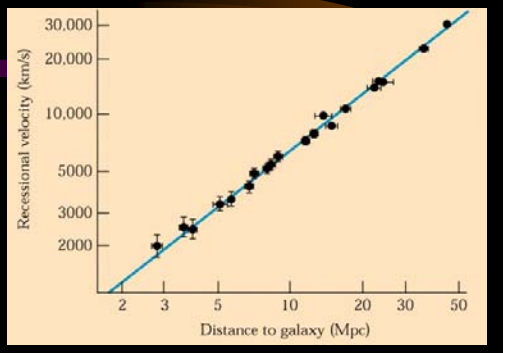
2 x 8.4 m Large Binocular Telescope, Mt Graham, Arizona, USA

2x 10 meter Keck Telescopes, Mauna Kea, Hawaii

Discovery of the expansion of the universe

- In 1908 Henrietta Swan Leavitt discovered the Cepheid variable stars - a standard candle for cosmic distance measurements.
- In 1912 Vesto Slipher observed the shift of spectral lines of galaxies (galactic redshifts)
- In the 1930's, Edwin Hubble discovered the relationship between the rate that galaxies were receding and their distances from us.

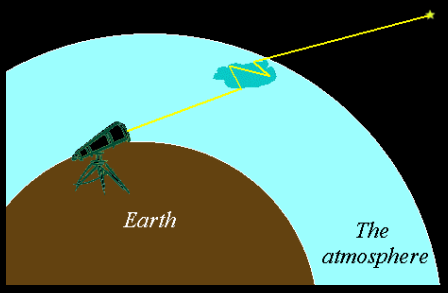
Hubble's Law



The 100 inch Hooker telescope at Mount Wilson Observatory that Hubble used to measure galaxy redshifts and the rate of expansion of the universe.

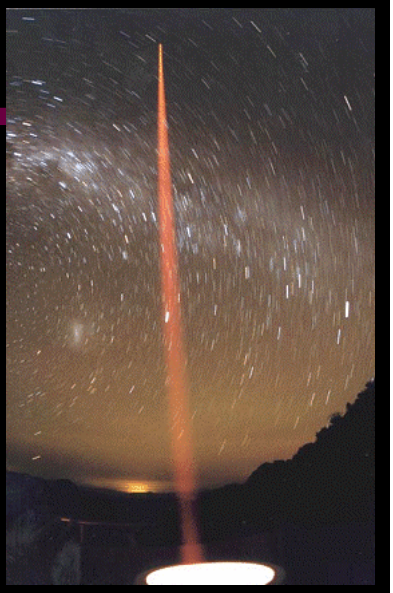
Limitations on the resolution of telescopes

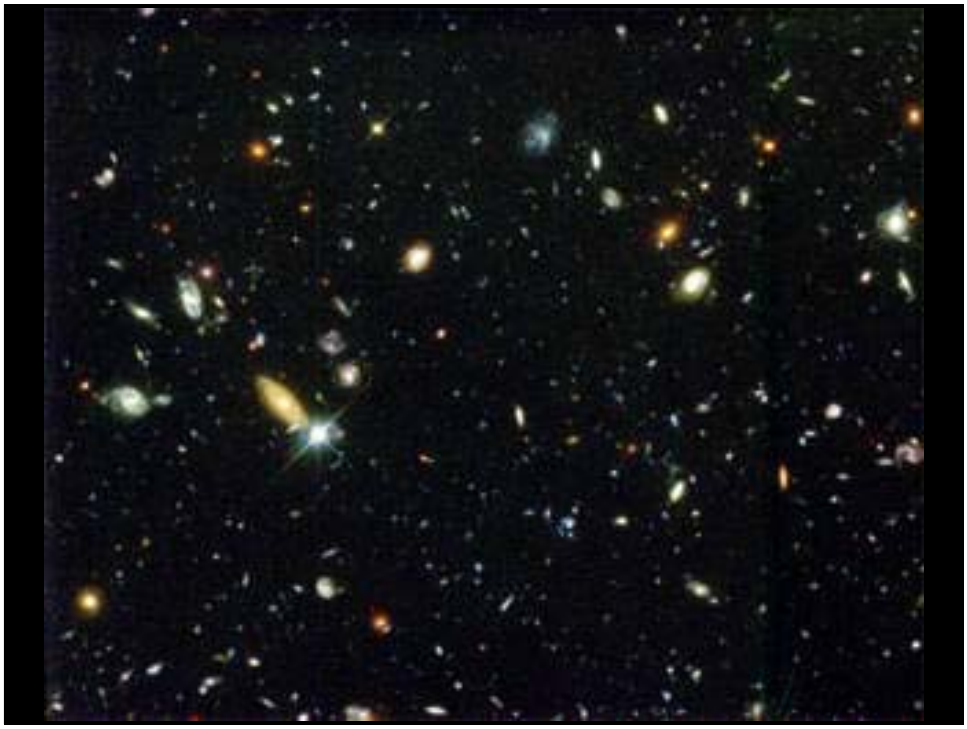
- Chromatic Aberration
- Geometrical Aberration
- Air Turbulence (Seeing) Aberration
- Diffraction Aberration

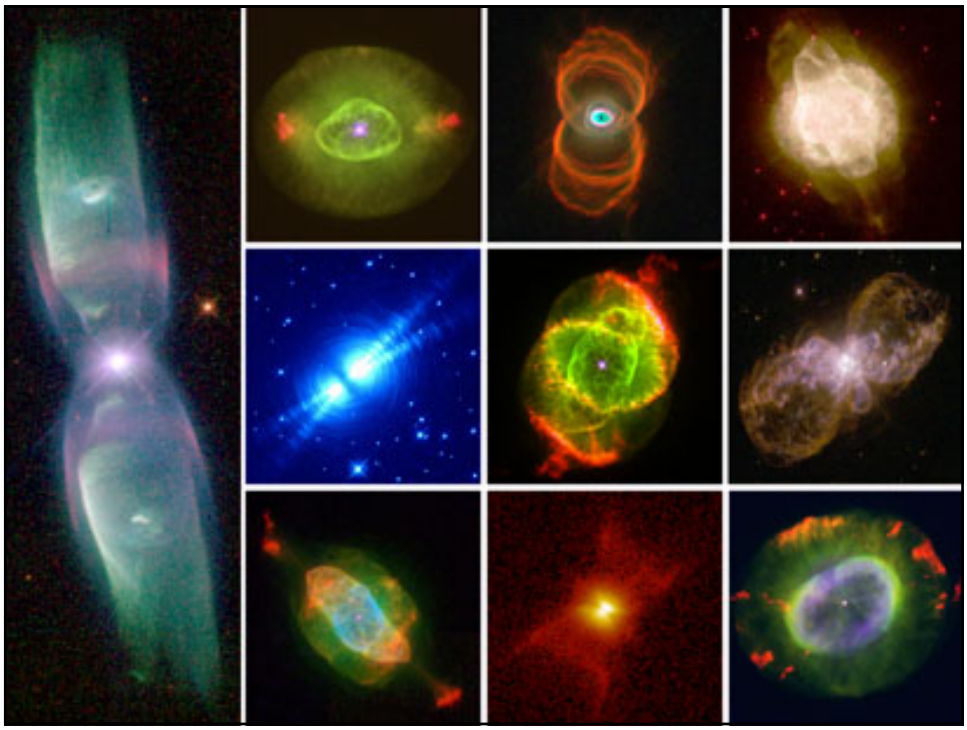


Adaptive optics

- Artificial guide stars formed by resonance fluorescence emission of laser light from the mesospheric sodium layer (90 km high) in the atmosphere.

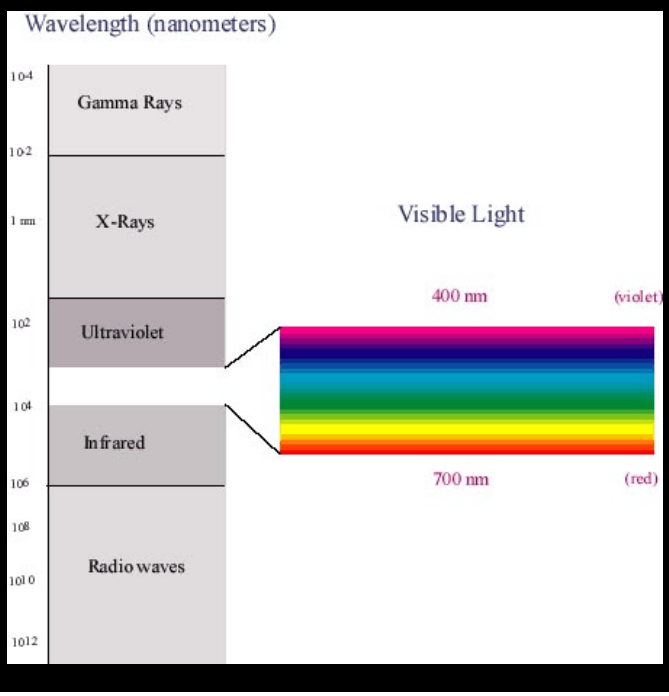


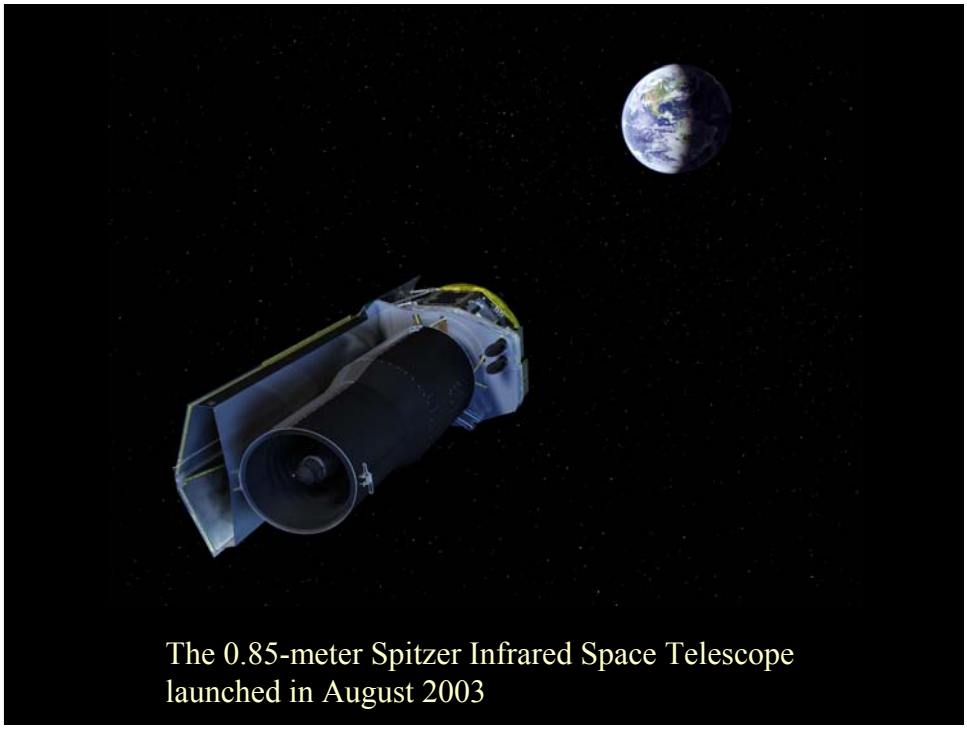




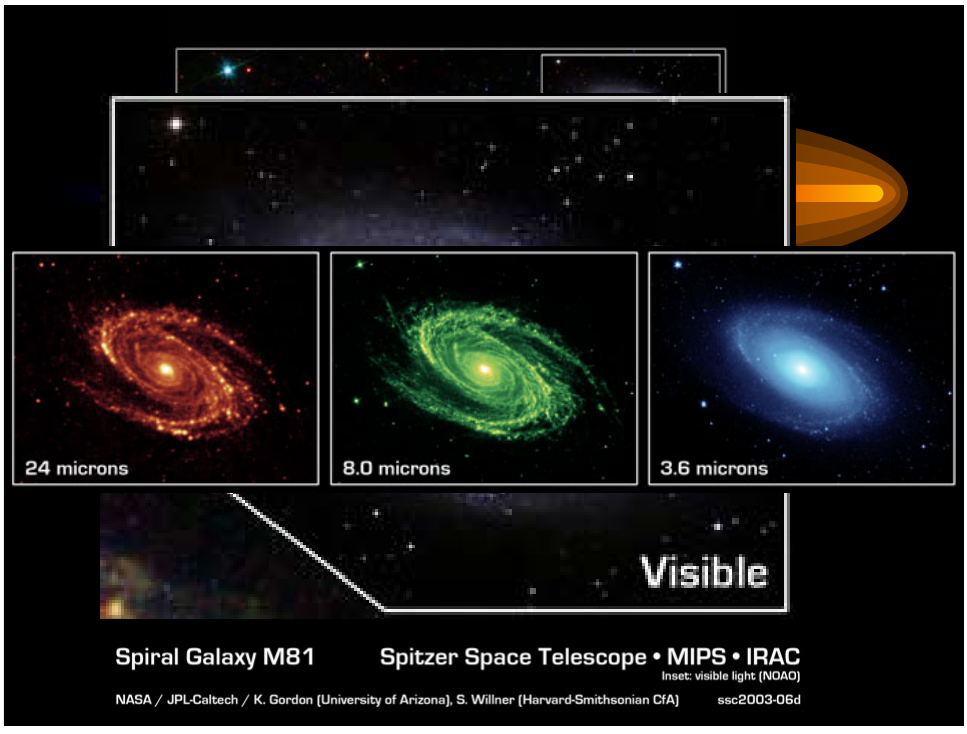
Expanding our vision

Exploring across the electromagnetic spectrum





The 0.85-meter Spitzer Infrared Space Telescope launched in August 2003



Radio Astronomy

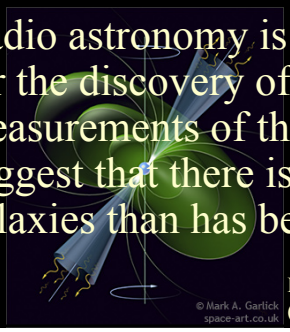
- In 19 Telephone Labo radio static origi laxy
- In 193 erable large diameter). He us signals.
- In 1946 Martin Ryle and Joseph Lade Pawsey development radio interferometry. This creates a combined telescope that is the size of the antennas furthest apart in the array.

Reber's original dish antenna

Jansky's rotating 20.7 MHz antenna

Radio Astronomy

- Radio astronomy has led to the discovery of several classes of new objects such as pulsars, quasars and radio galaxies.
- Radio astronomy is also partly responsible for the discovery of dark matter; radio measurements of the rotation of galaxies suggest that there is much more mass in galaxies than has been directly observed.



Pulsar at the center of the Crab Nebula (Chandra X-Ray Observatory)

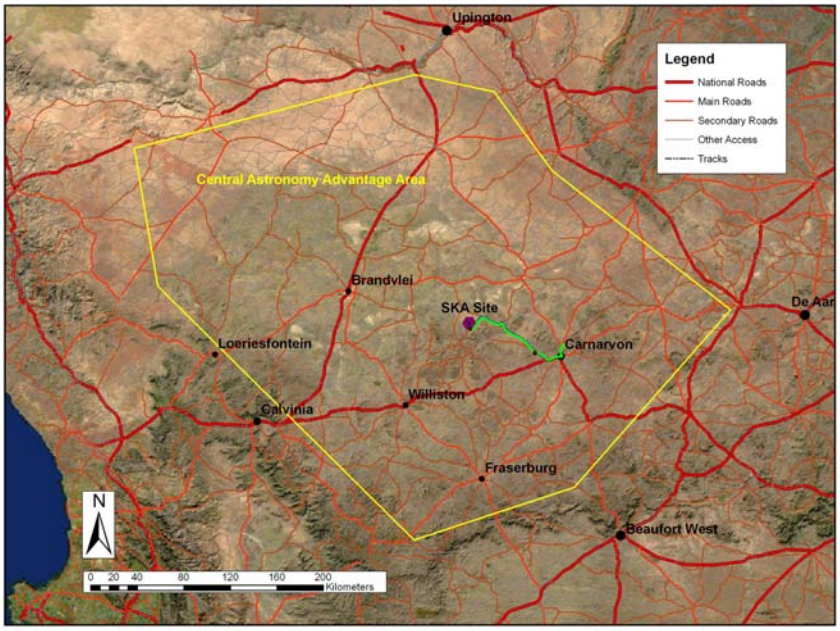
The Chandra X-ray Observatory

The Chandra X-ray Observatory launched in July 1999.

A dramatic new Chandra image of the nearby galaxy Centaurus A provides one of the best views to date of the effects of an active supermassive black hole. Opposing jets of high-energy particles can be seen extending to the outer reaches of the galaxy, and numerous smaller black holes in binary star systems are also visible.

Southern Africa's contribution

South Africa's Radio Astronomy Reserve



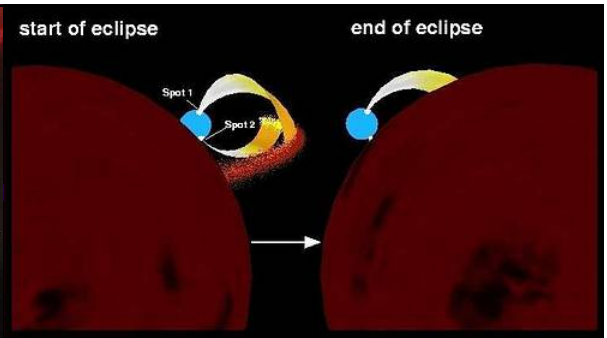
Southern African Large Telescope (SALT)

The SALT telescope currently has the largest mirror in the world (11 meters diameter).

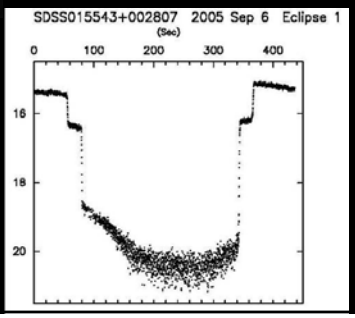
SALT's instruments

- The SALT imaging and acquisition camera (SALTICAM)
- The Robert Stobie Spectrograph (RSS)
- SALT High Resolution Spectrograph (SALT-HRS)

The artist Bob Watson's painting of a 'Polar' binary.

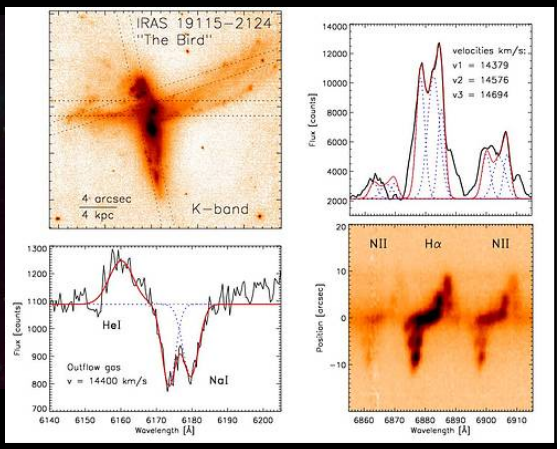


Earth Observer's view of a polar at the start (left) and end (right) of eclipse.



Sequence of brightness measurements of the polar.

The “Bird” (IRAS 19115-2124) three-galaxy collision about 650 million light years away as imaged by European Southern Observatory's Very Large Telescope (VLT) in Chile.

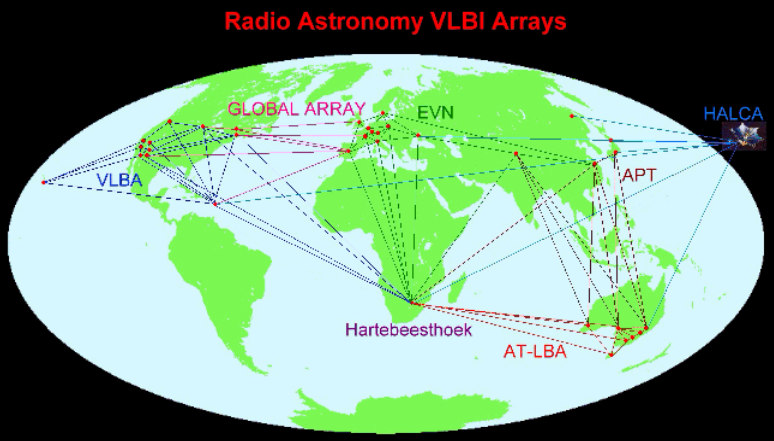


Scientists at SALT analysed light from different parts of the Bird using the Robert Stobie Spectrograph to show in detail how they were moving.

Hartebeesthoek Radio Astronomy Observatory

The 26-m Hartebeesthoek Radio Telescope

The Very Long Baseline Interferometry (VLBI) Technique
a Radio Telescope the size of the Earth

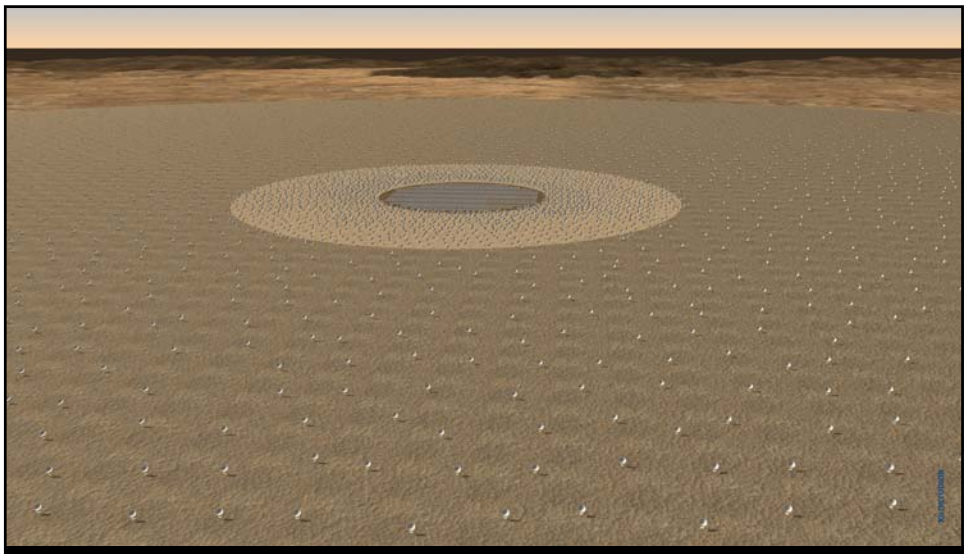


HartRAO co-operates with radio telescopes on other continents and in space to form a virtual telescope the size of the Earth - or even larger using the orbiting radio telescope HALCA. VLBI lets us see details much smaller than can be seen with the best optical telescopes. VLBI is used, for example, to map masers around stars in the Milky Way and the jets in quasars.

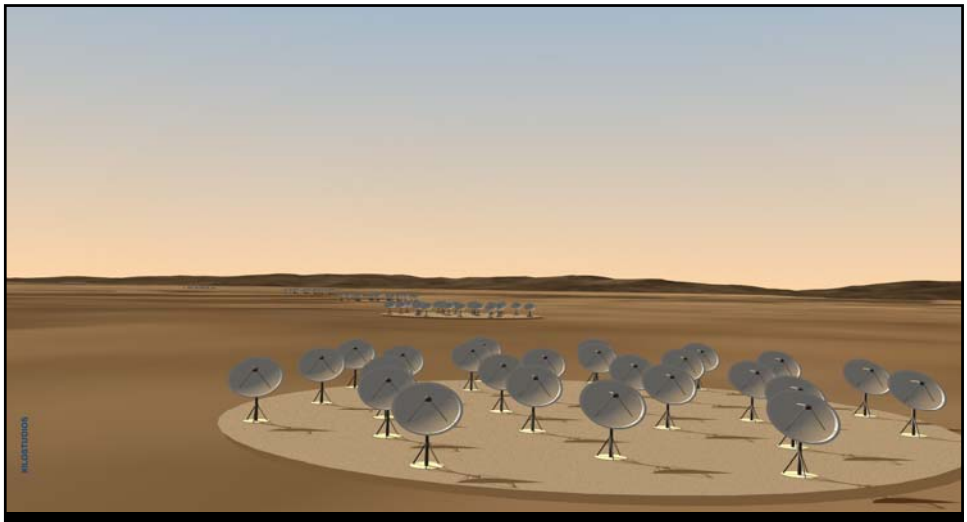
Square Kilometre Array

Australia and Southern Africa short-listed for SKA location

- Proposals for siting the SKA were received from Argentina/Brazil, Australia, China and Southern Africa on 31 December 2005.
- The International SKA Site Advisory Committee decided that the short-list of acceptable sites for the SKA will comprise Australia and Southern Africa.
- Additional studies of the characteristics of the short-listed sites will be carried out in 2007 and 2008. A final decision of the location of the SKA is expected thereafter.

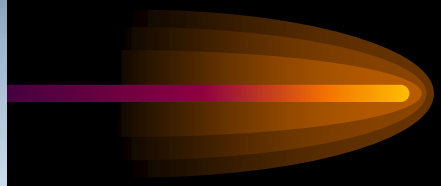


The central region of the the Square Kilometre Array.
At its heart lies a phased array capable of observing the whole sky and able to provide multiple beams so that several tasks can be carried out simultaneously. Surrounding this is the compact array of small dishes within a larger, more open, array.



The Outer Stations of the Square Kilometre Array

A view of some of the outer stations of the SKA. These will be arranged in a log-spiral pattern extending out to distances of up to 3,000 km. Those shown are relatively close together as they lie near the central compact region. At greater distances from the centre the spacing between the outer stations increases.



MeerKAT prototype dish at HartRAO.

H.E.S.S.
High Energy Stereoscopic System

High-energy gamma-ray stereoscopic telescope system located near the Gamsberg, Namibia, consisting of an an array of imaging atmospheric cherenkov telescopes.

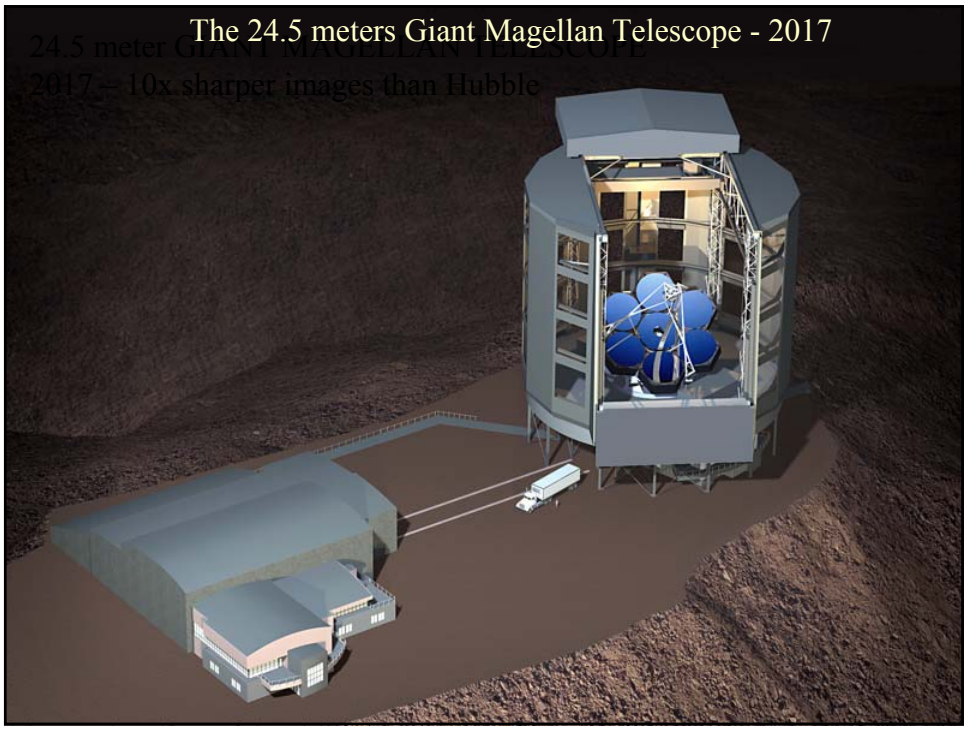
The future of astronomical technology

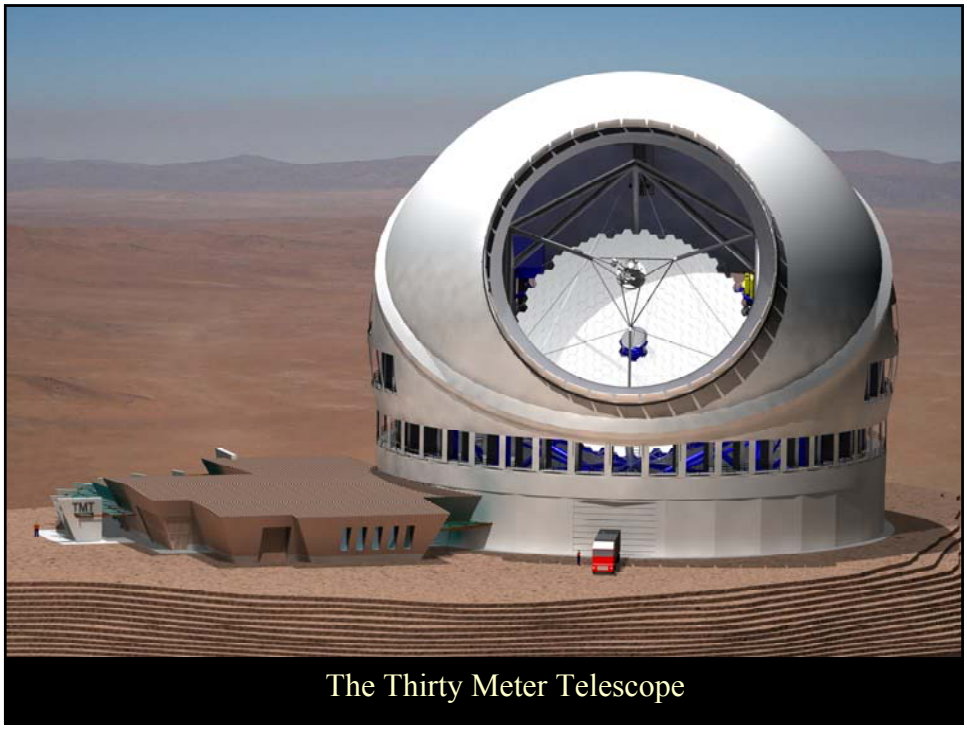
James Webb Space Telescope

The James Webb Space Telescope (JWST) is a 6.5 meters infrared-optimized space telescope, scheduled for launch in 2013.

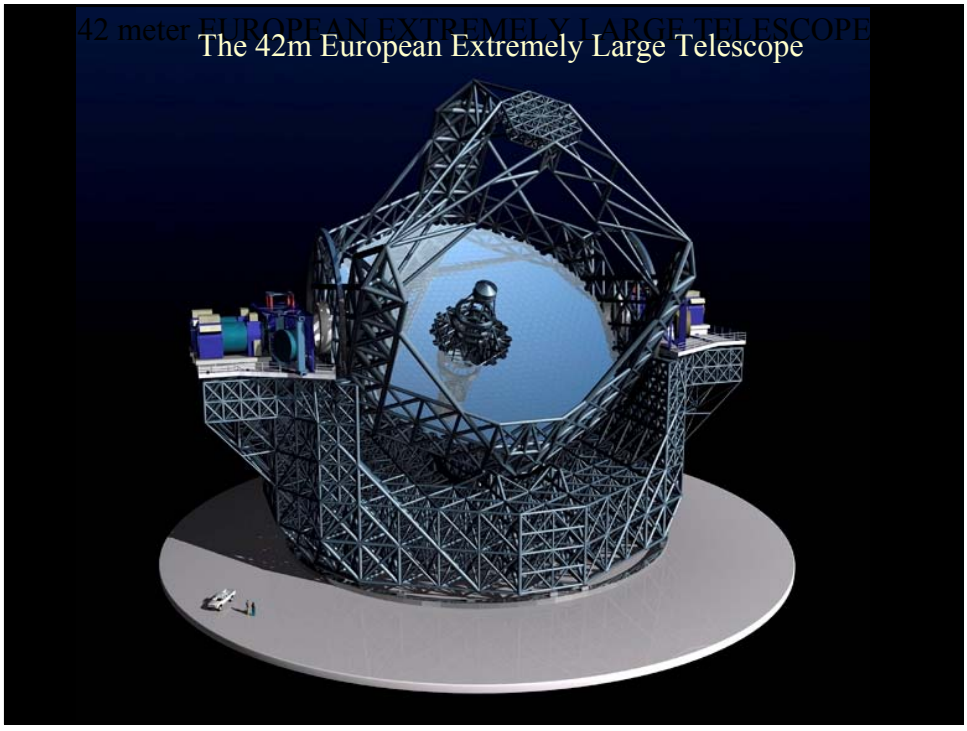
The 24.5 meters Giant Magellan Telescope - 2017

24.5 meter GIANT MAGELLAN TELESCOPE
2017 – 10x sharper images than Hubble

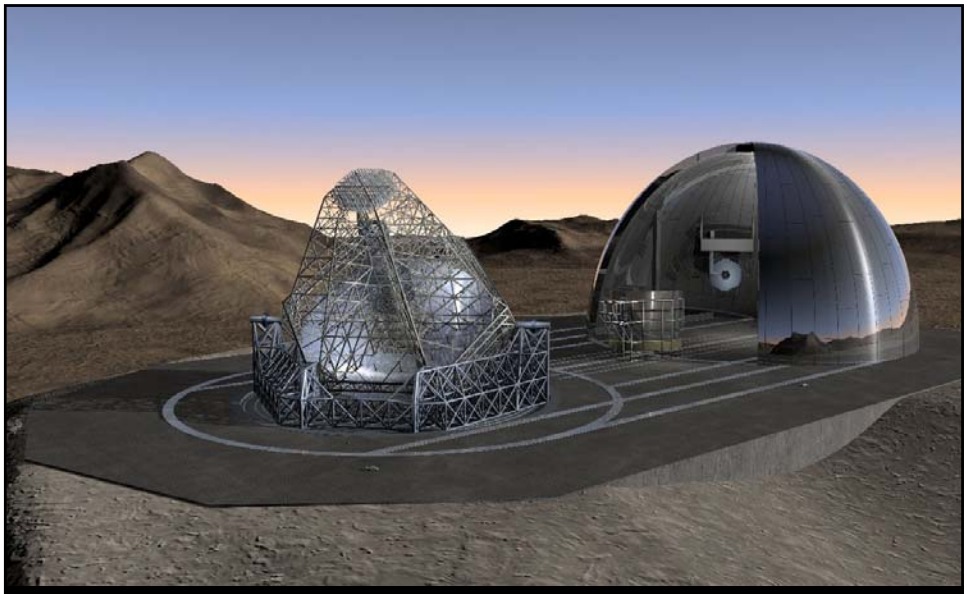




The Thirty Meter Telescope



The 42m European Extremely Large Telescope



100 meter OWL (Overwhelmingly Large) Telescope