



400 Years Since Galileo

Invention of the Telescope



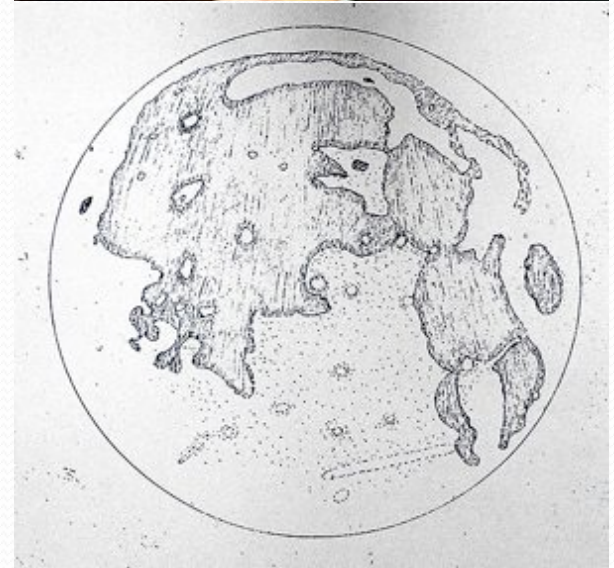
Who Really Invented the Telescope?

- Hans Lippershy (1570-1619)
- German-Dutch Lens maker
- Settled in Middleberg in the Netherlands
- First to apply for a patent for the telescope
- Magnification of 3x



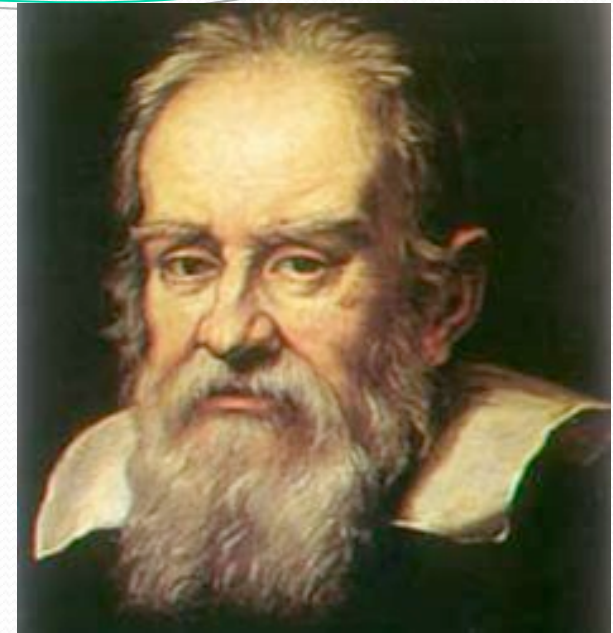
Thomas Harriott

- Designed ships and was navigator for Sir Walter Raleigh
- First to observe the Moon telescopically and sketch what he saw July 26, 1609
- Four Months before Galileo
- He did not publish his work



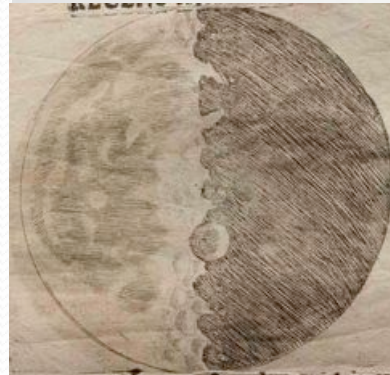
Galileo Galilei

- “The Father of Modern Astronomy”
- Based his first telescope on Lippershy’s Design
- Built several improved versions
- Published first results in March of 1610



Galileo's Big Discoveries

- Moon craters
- Phases of Venus
- Moons of Jupiter
- “Appendages” of Saturn
- Sunspots

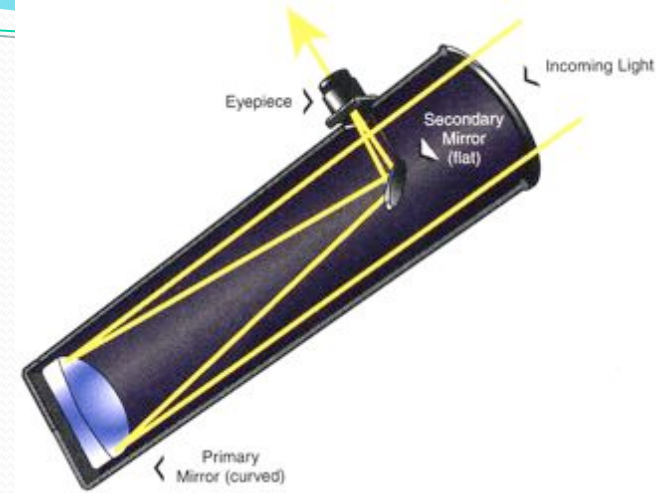
A table of handwritten astronomical observations, likely Galileo's notes on Jupiter's moons. The table is organized into two columns and several rows, with numbers 1 through 17 on the left and right sides. Each row contains small circles and dots representing celestial objects and their positions or movements.

Galileo Explains His Discoveries to the Pope



Isaac Newton

- Realized you could use a mirror instead of lenses to make a telescope
- Design became known as a Newtonian Reflector
- No color fringing like with a refractor (chromatic aberration)



William Herschel

- 1738-1842
- Constructed over 400 telescopes in his life
- Two most famous were the 18.5" diameter (20 foot telescope) and the 49.5" diameter (40 foot telescope)



Herschel's Discoveries

- The planet Uranus
- 2 Moons of Saturn (Enceladus and Mimas)
- 2 Moons of Uranus (Titania and Oberon)
- Discovered binary stars orbit each other
- Discovered the Solar System is moving through space (and which direction!)
- Coined the term asteroid
- Discovered infrared radiation



Behind Every Great Man...

- William's sister, Caroline Herschel (1750-1848)
- Constant Observing companion
- Discovered 8 comets
- Published Catalogue of Stars in 1798
- Received Royal Astronomical Society Gold Medal in 1828



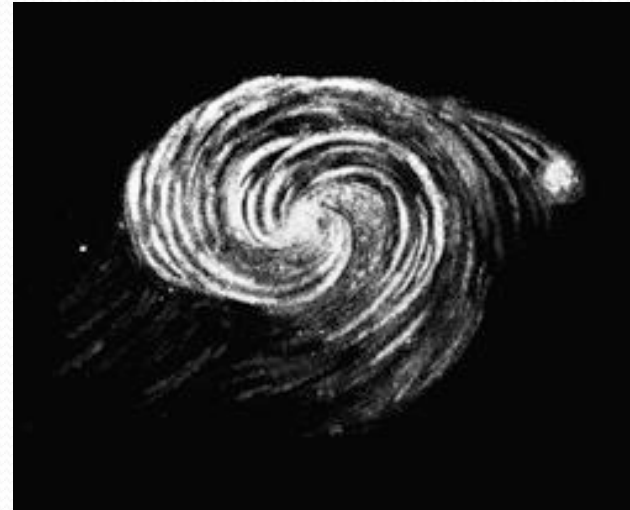
Leviathan of Parsonstown

- Built by William Parsons (3rd Earl of Rosse)
- Completed in 1845
- 72 inch mirror
- Would be world's largest telescope until 1917
- Has been reconstructed and you can visit it today



Parson's Research

- Interested in Nebula
 - Were they gas?
 - Collections of stars?
 - Other Galaxies?
- Discovered spiral structures in nebula (later found to be spiral galaxies)



John William Draper

- Photochemist Englishman who moved to Virginia
- Took first photograph of the Moon in 1840
- First steps into the era of astrophotography



The Era of the Great Refractors

- Alvan Clark and Sons fabricated lenses for the world's largest refractors
- Include the 24" Lowell Observatory telescope, the 26" USNO telescope, the 36" Lick Telescope and the 40" Yerkes telescope



Hitting a Roadblock

- Refractors use lenses which can only be supported at the edge
- Lenses eventually fail under their own weight
- Larger lenses have more chromatic aberration
- 1.25 meter Great Paris Exhibition Telescope considered a failure



A Breakthrough in Mirrors...

- Old telescopes used speculum mirrors
 - Speculum tarnishes easily
 - Reflects only 66% of light (at best)
- 1856 Karl August von Steinheil and Léon Foucault invented silvering
 - Thin layer of silver deposited on a mirror
 - Reflected 90% of light hitting it
 - Tarnishes more slowly
 - Now we use aluminum



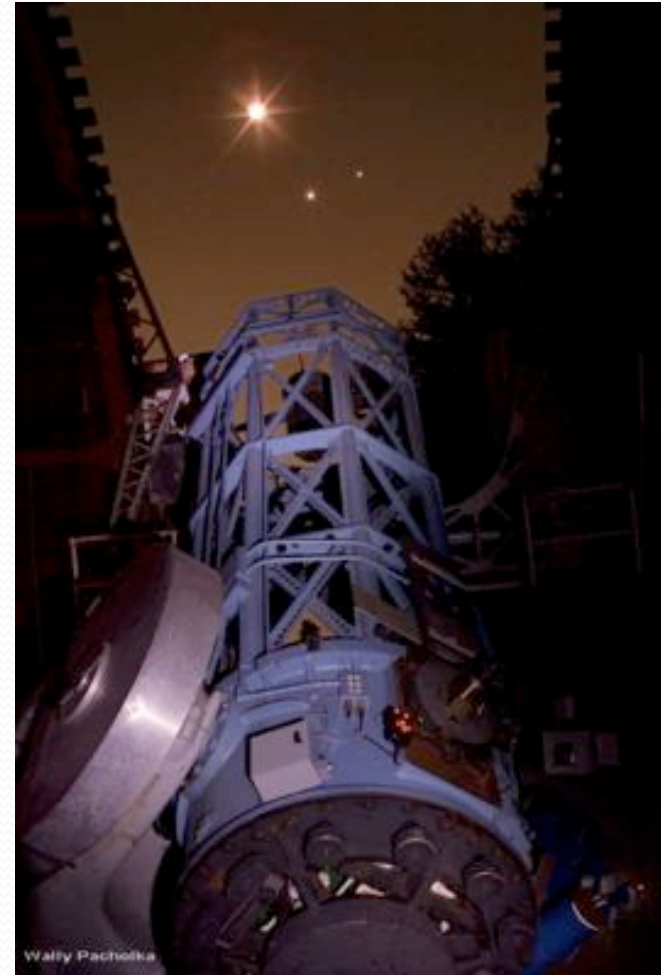
Big Reflectors Coming: Part One

- Early to mid 1900's saw great strides
- Larger mirror blanks could be cast
- Many new reflectors were built
- Migration of telescopes to mountaintops



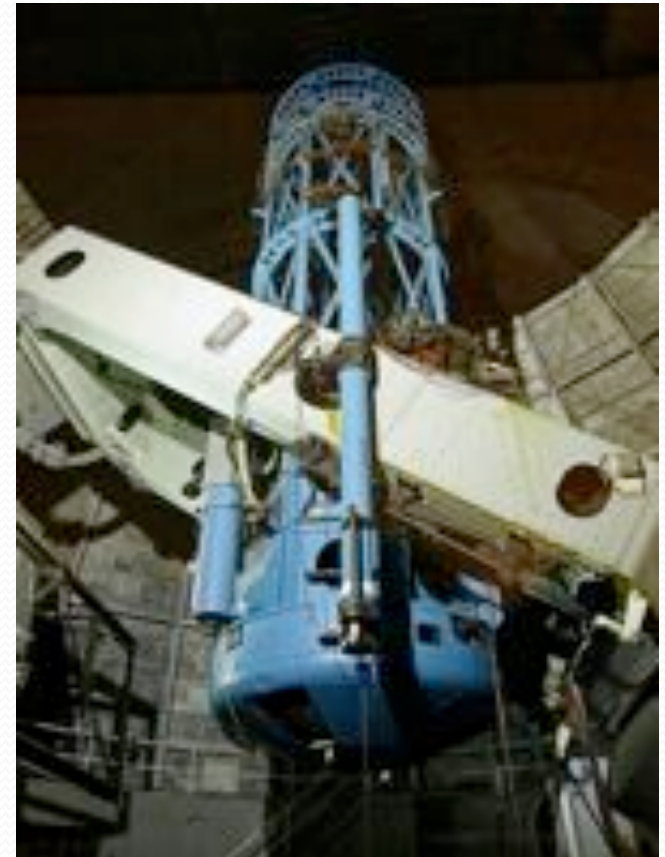
The 60" Reflector

- Spearheaded by George Ellery Hale
- Mirror grinding took two years
- First light December 8, 1908
- Largest telescope in the world when complete
- Available for public use today on Mount Wilson (near Los Angeles)



Hooker 100" Telescope

- Another Hale project on Mount Wilson
- First Light November 2, 1917
- Instrumental in Hubble's discovery of an expanding universe
- Deactivated in 1986 but restarted observations in 1992 with an adaptive optics (AO) system



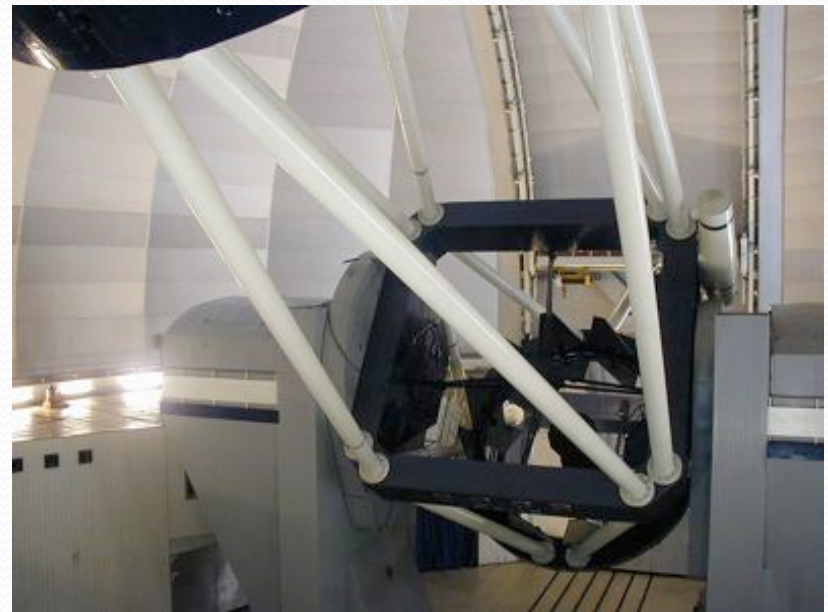
Hale 200" Telescope

- Hale's last big project
- Mirror cast in 1934 (after three tries)
- Built on Mount Palomar
- Construction interrupted by WWII
- Completed in 1948
- Largest in world until 1975



Large Alt-Azimuth Telescope

- 6 meter telescope in Russia
- Used the first computer controlled Alt-az mount
- Technical issues and poor site selection hampered its early research
- Primarily used for spectroscopy

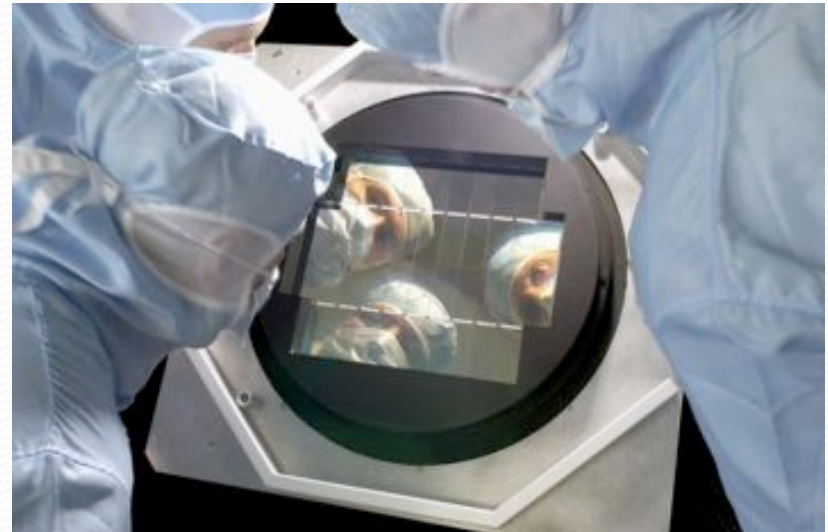


Technological Problems of Larger Telescopes

- Single piece mirrors over ~6 meters are too heavy, take too long to cool down at night
- Large mirrors sag under their own weight
- Resolution does not improve much as Earth's atmosphere distorts the image
- Fortunately, each problem has a solution!

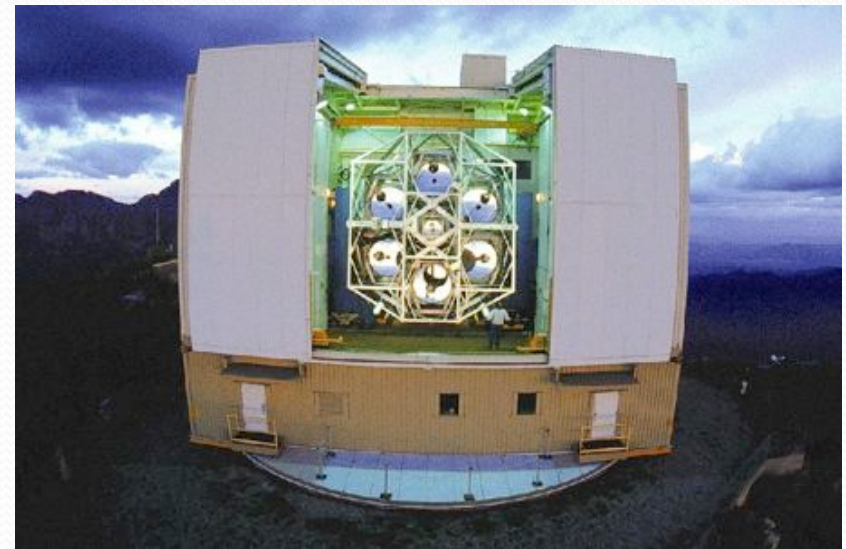
The CCD Revolution

- Charge Coupled Device invented in 1969 at Bell Labs
 - Much more sensitive to light
 - Digital data is easy to work with, store, transfer, etc
 - CCD cameras quickly became the preferred method of astronomical imaging
 - Current CCD cameras have hundreds of millions of pixels
 - Widely used in consumer electronics
 - Nobel prize for CCD invention in 2009



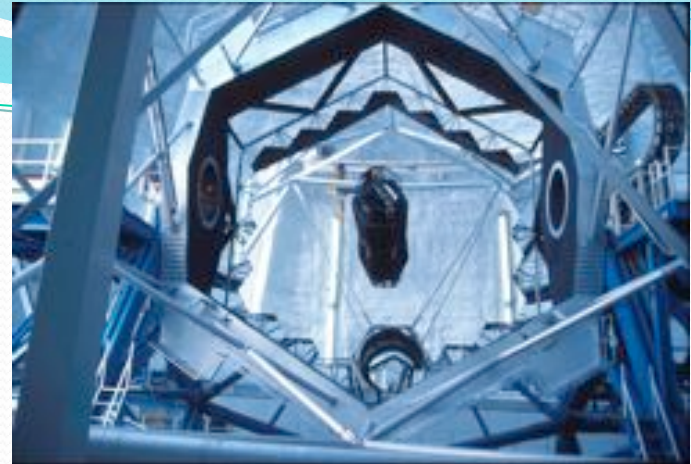
Multiple Mirror Telescope

- MMT completed in 1978
- Used six 1.8 meter mirrors on one mount to make a large mirror
- Performed like one 4.5 meter mirror
- Six mirrors were replaced with one large 6.5 meter mirror in May 2000



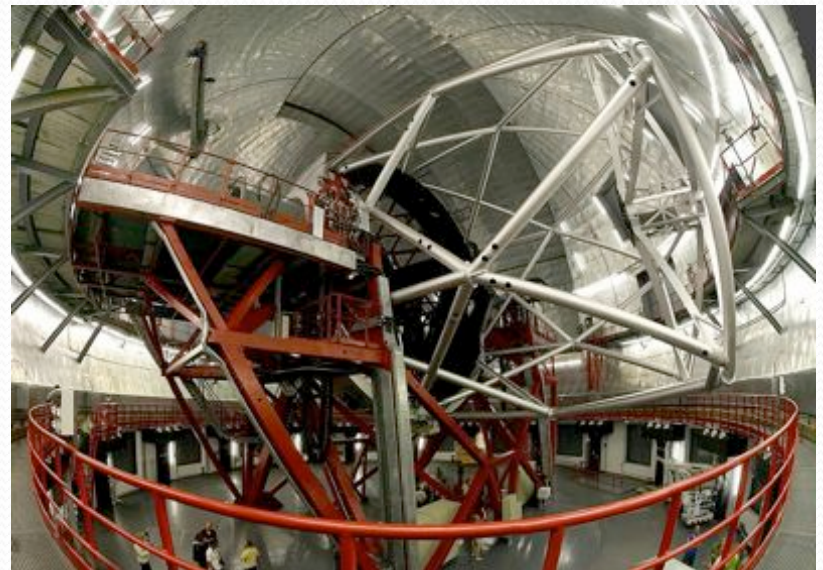
Keck Telescopes

- Completed in 1993
- Each use 36 small hexagonal mirrors to make one 10 meter mirror
- Light from each can be combined to form one REALLY large telescope



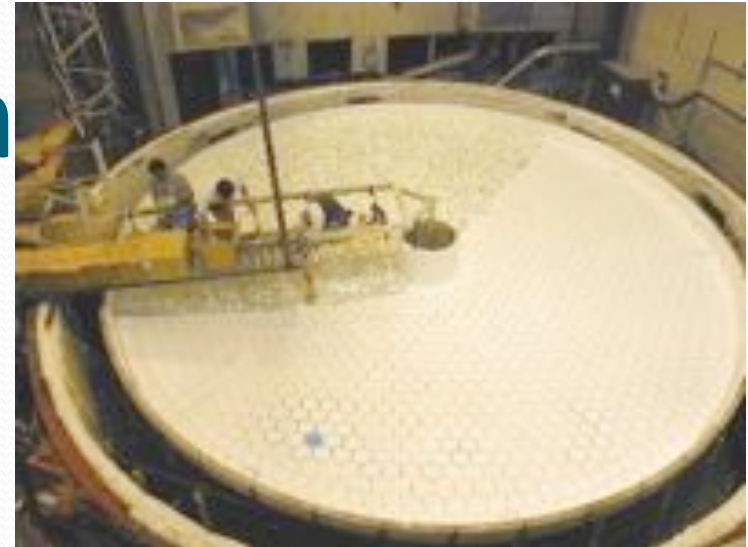
Grand Telescope of the Canaries

- 10.4 meter diameter segmented mirror telescope
- Started observations in July 2009
- Largest segmented mirror telescope (for now!)



New Mirror Design

- Mirrors are now cast in a rotating furnace
- Have a honeycomb design
- Mirrors are 85% lighter
- Can make single mirror up to 8.4 meters in diameter
- Used in several telescopes and more coming online



The Large Binocular Telescope

- Located on Mount Graham in Arizona
- Uses two 8.4 meter mirrors from the Steward Mirror Lab
- Light gathering area of an 11.8 meter telescope
- Resolution of a 22 meter telescope
- First mirror installed in 2004, second mirror in 2006



The Very Large Telescope

- Four 8.2 meter telescopes in Chile
- Can combine light from all four telescopes
- PLUS four 1.8 meter telescopes can be added to the mix



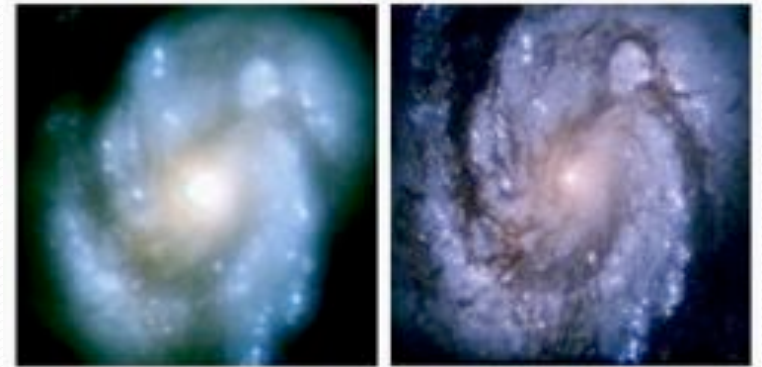
Go To Space!

- Get above Earth's atmospheric distortions
- Hubble is a 2.4 meter telescope (limited by Shuttle's cargo bay size)
- Better resolution than anything on the ground!
- Launched in 1990

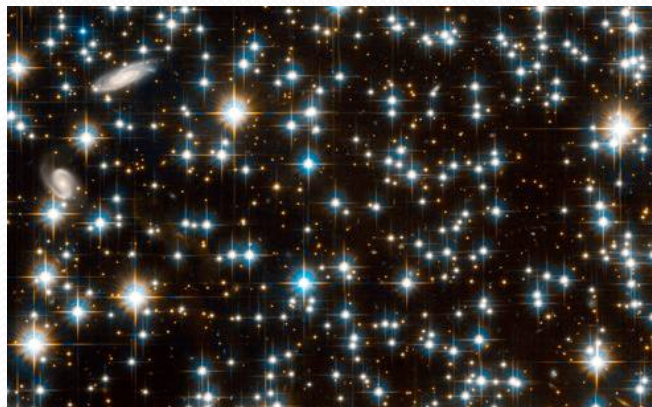
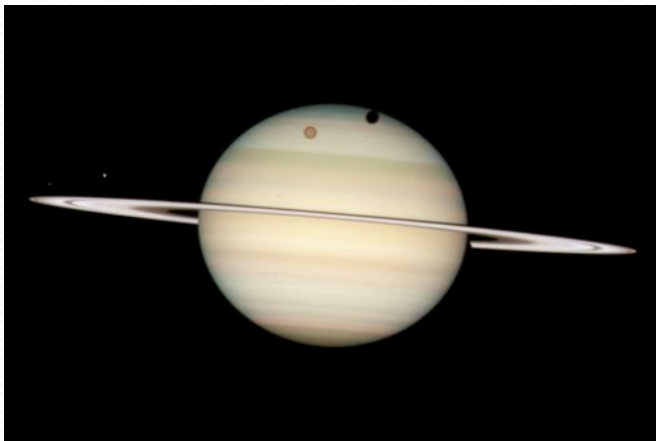


Hubble's Problem

- Mirror was ground to the wrong shape
- Less than width of human hair off!
- Repaired by Shuttle mission in 1993

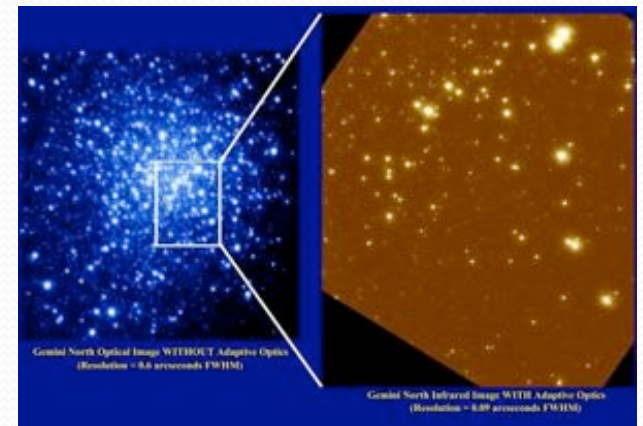
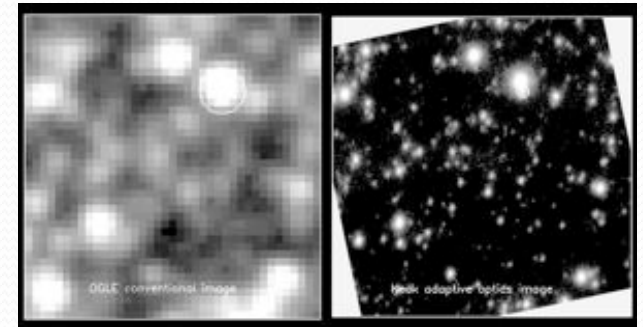


Pretty Hubble Pictures



Adaptive Optics

- Theory was developed in 50's and 60's
- Technology developed for "Star Wars" in the 1980's
- Astronomers used it to correct their images
- Measure distortions created by the atmosphere
- Use deformable mirror to cancel them out
- Can make them almost as good as the Hubble Space Telescope from the ground



The Future: The LSST

- Large Synoptic Survey Telescope
- Built in Chile ~2014
- 8.4 meter telescope will survey the entire night sky every three nights
- Generate terabytes of data per night
- All data will be publicly available within seconds



The GMT

- Giant Magellan Telescope will be built in Chile
- Will use seven 8.4 meter mirrors
- Will use adaptive optics
- Resolving power of 24.5 meter telescope
- 10 times sharper than Hubble
- Expected completion 2016

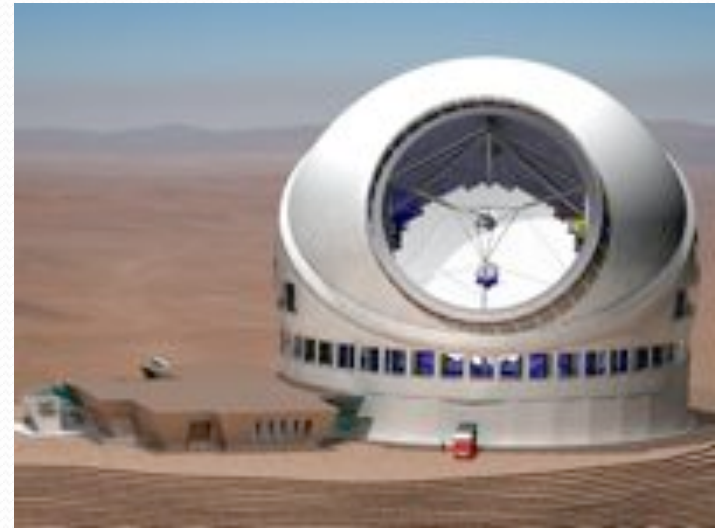


Giant Magellan Telescope Organization



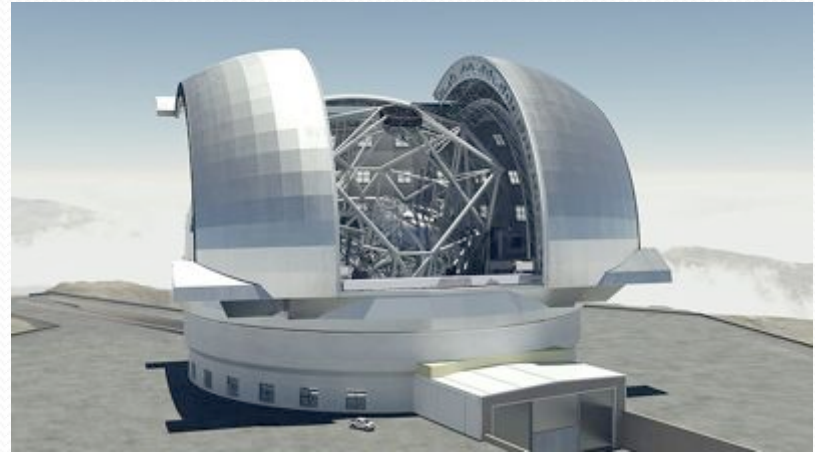
The Thirty Meter Telescope

- 30 meter diameter mirror composed of 492 individual segments
- Will incorporate adaptive optics
- Expected completion 2018 on Mauna Kea in Hawaii



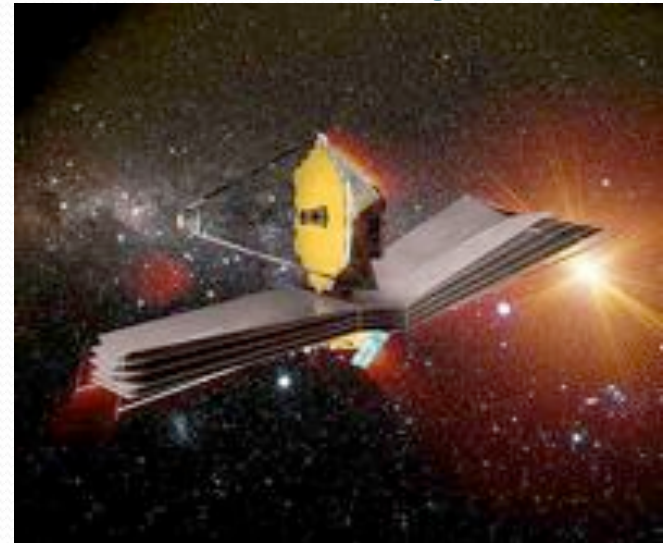
European Extremely Large Telescope

- 42 meter diameter telescope
- About 1000 1.4 meter hexagonal segments
- Site TBD
- Targeted completion ~2018



James Webb Space Telescope

- 6.5 meter space telescope
- Folding segmented mirror
- Will observe mainly in infrared
- Targeted launch in 2014





What can they do?

- See the earliest stars and galaxies
- Image planets around other stars
- Take spectra of atmospheres of extrasolar planets
- See fine detail in distant galaxies
- Make precise measurements of dark energy
- Raise new questions we have not yet thought to ask!

What if I Want a Telescope?

- Get binoculars first!
- Learn the night sky
 - www.stellarium.org (Free planetarium program!)
- Go to local star parties to use other telescopes before buying



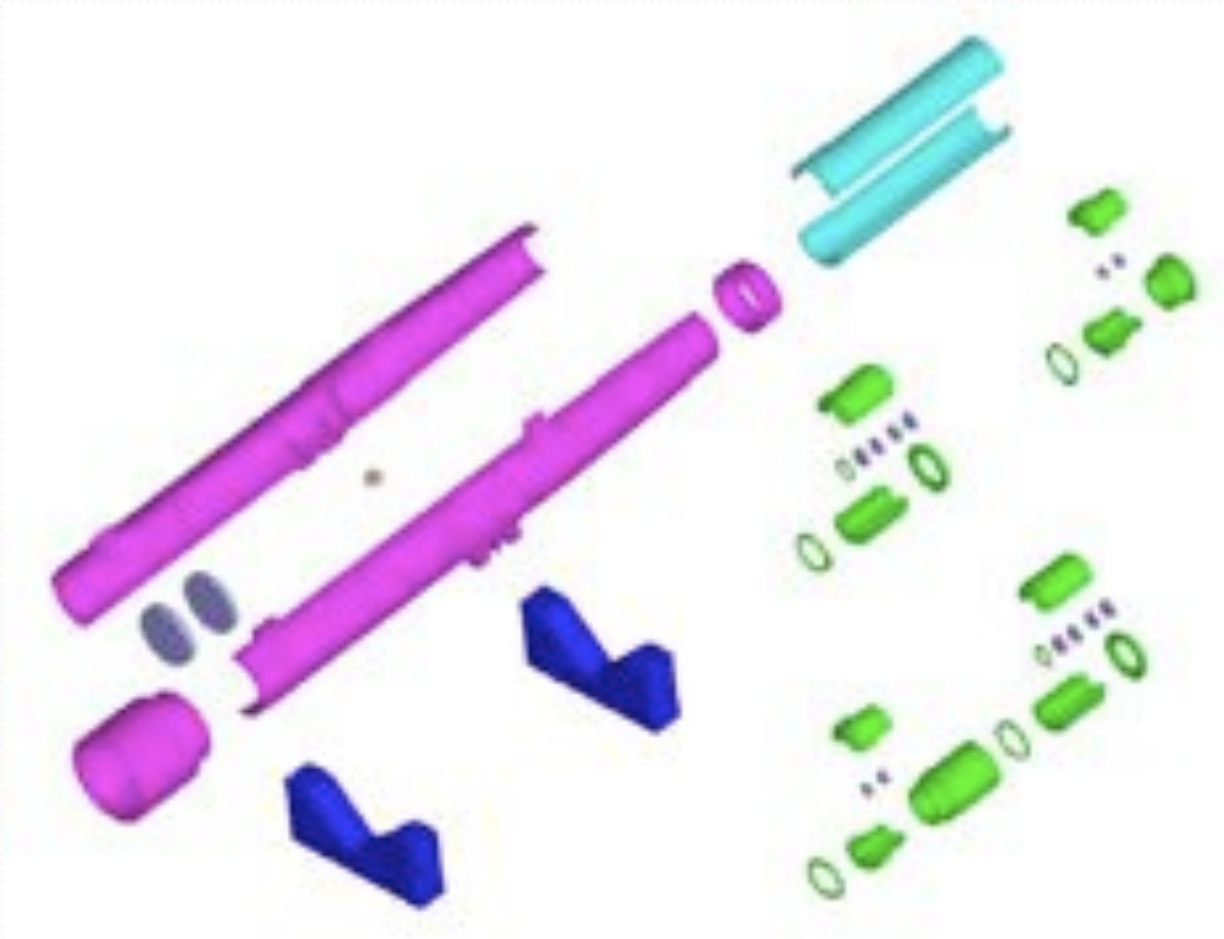
Galileoscope



- \$30 each (\$24 in lots of 100)
- Orders are being taken with delivery starting about now
- <http://www.galileoscope.org>



Kit also serves as an optical bench and incorporates a Galilean telescope as well



View through Galileoscope



Image courtesy of Dr A. Jaunsen, Inst. of Theoretical Astrophysics, University of Oslo

Saturn by R. Sparks at 25x using afocal projection and a very cheap digital camera on automatic settings (flash off).

What will the next 400 years bring?

