



400 Years Since Galileo

Invention of the Telescope



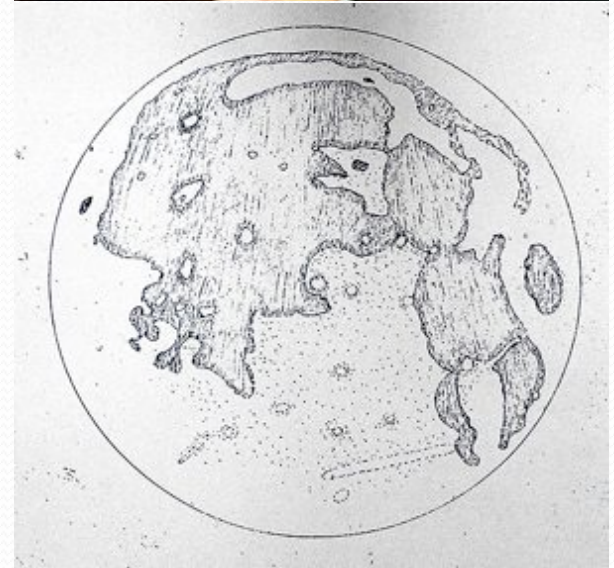
Who Really Invented the Telescope?

- 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



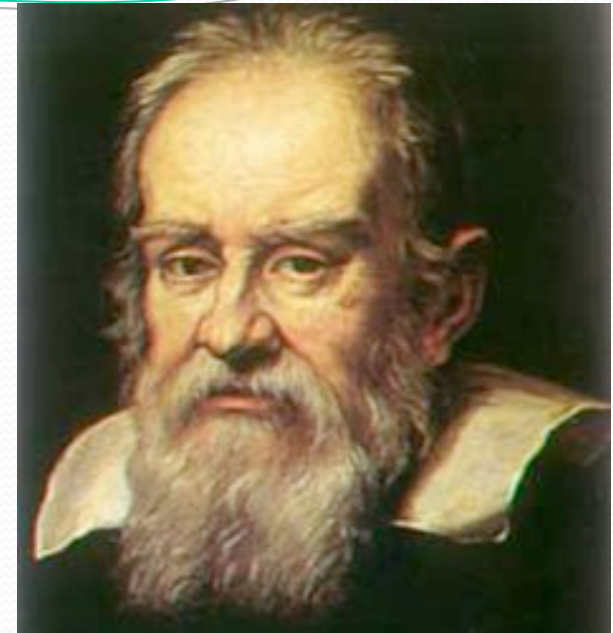
Thomas Harriott

- 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



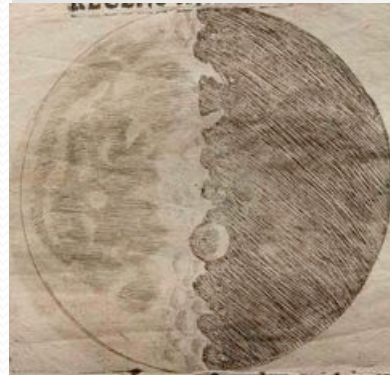
Galileo Galilei

- “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



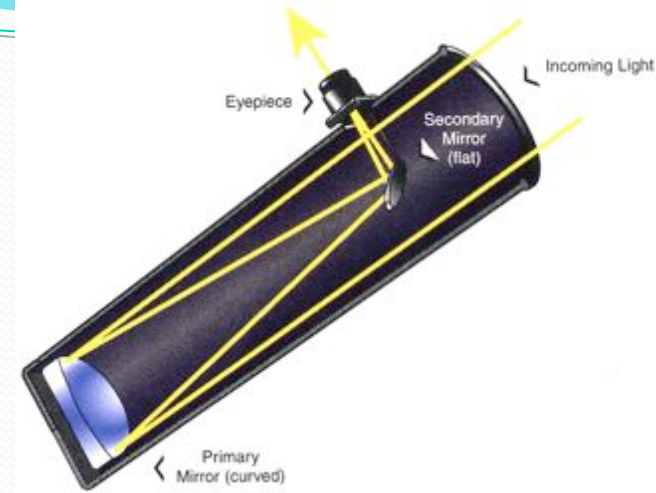
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Galileo Explains His Discoveries to the Pope



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



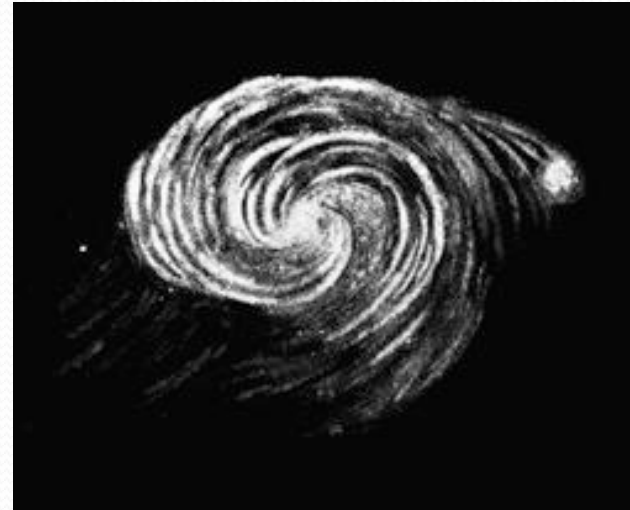
Leviathan of Parsonstown

- 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



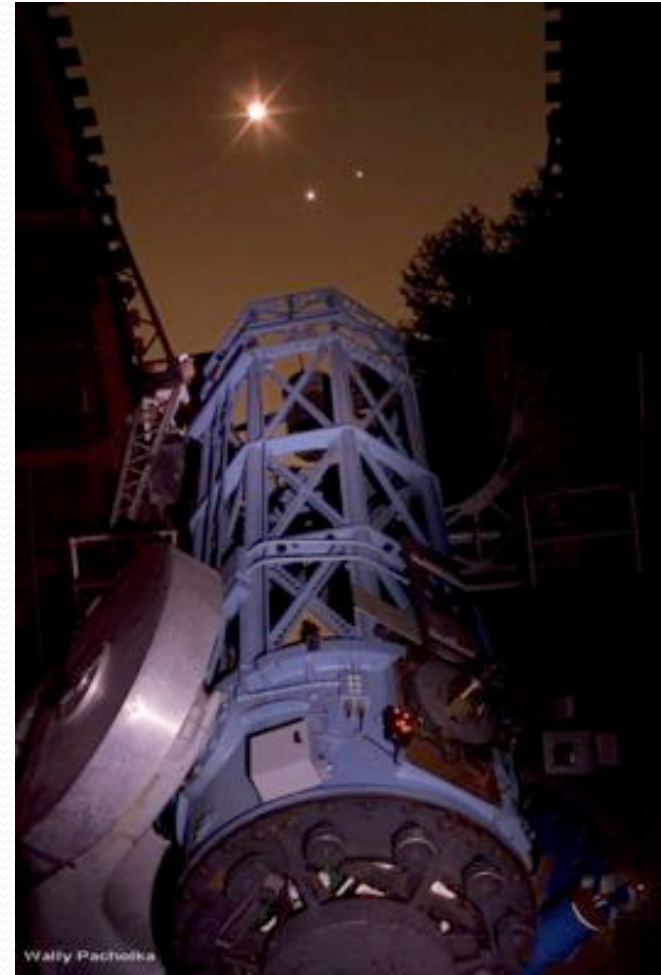
Big Reflectors Coming: Part One

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



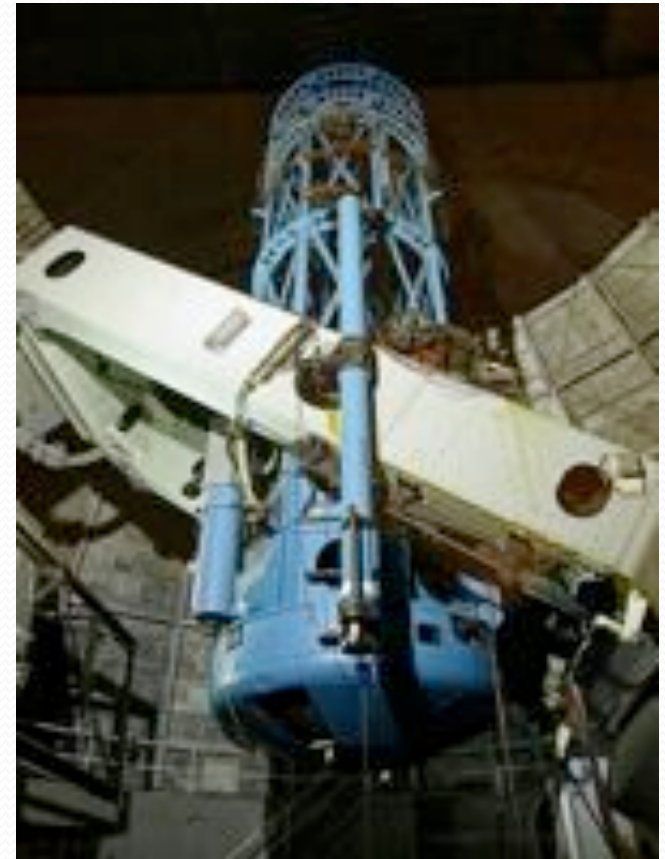
The 60" Reflector

- 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



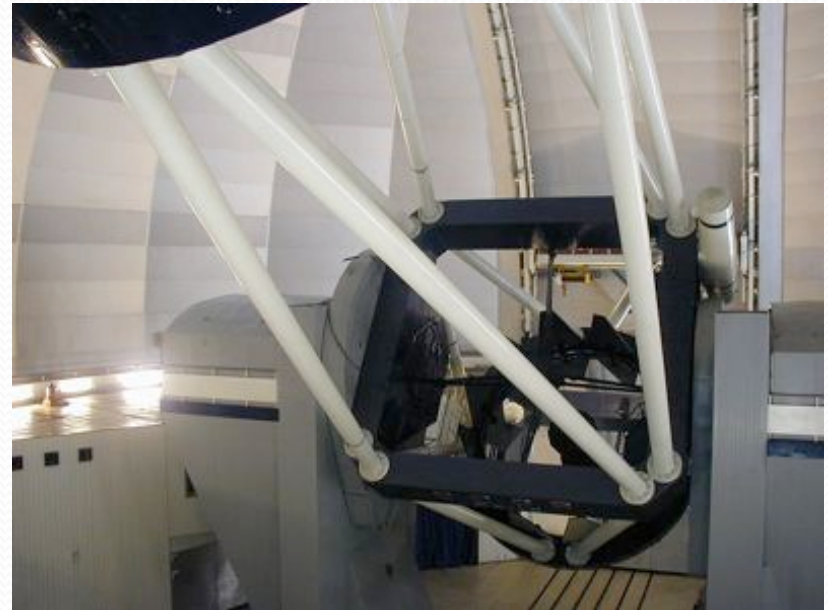
Hale 200" Telescope

- 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

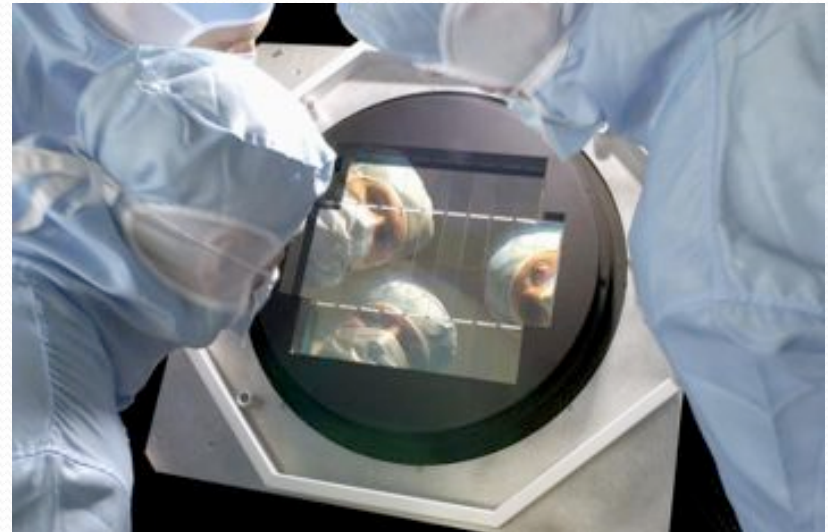


Technological Problems of Larger Telescopes

- 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!

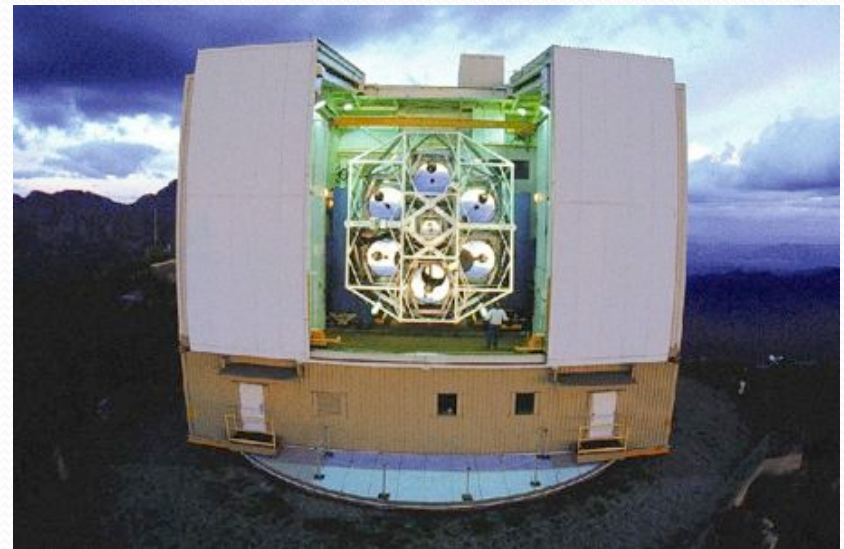
The CCD Revolution

- 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



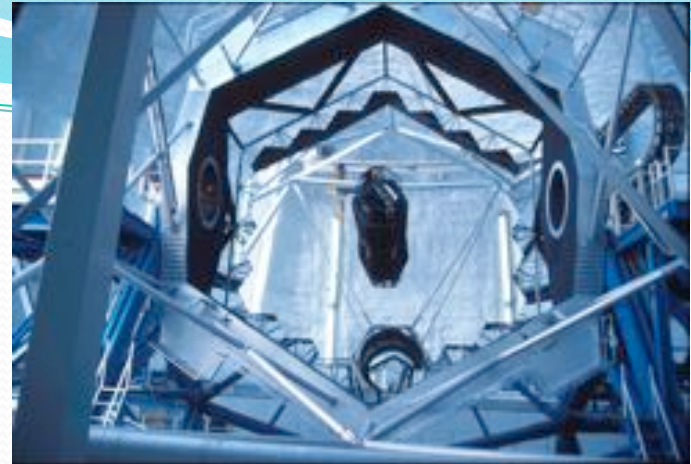
Multiple Mirror Telescope

- 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



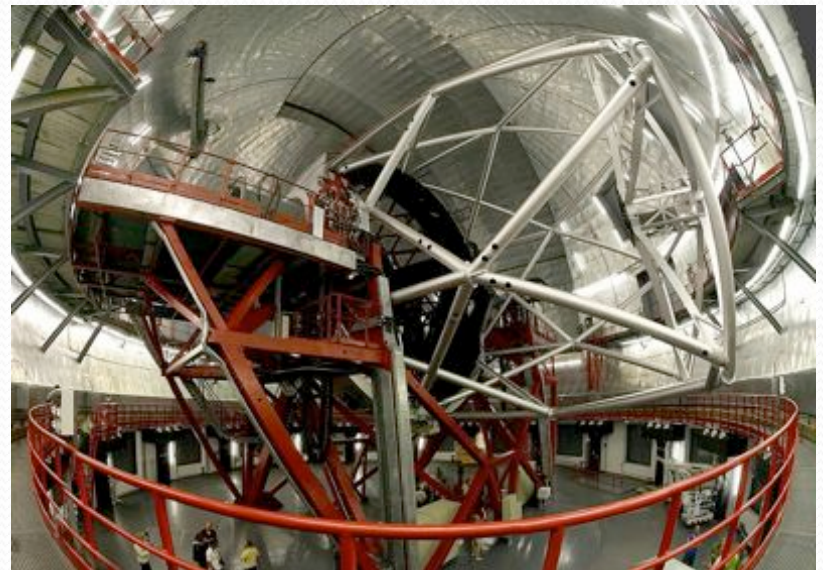
Keck Telescopes

- 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



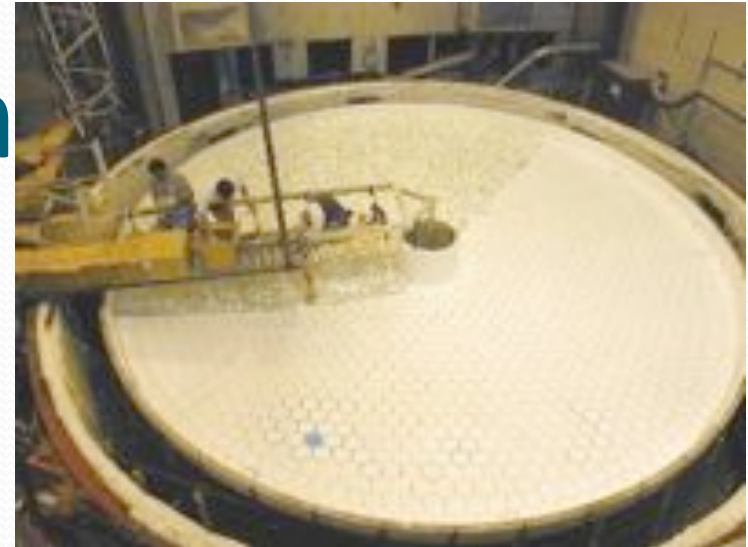
Grand Telescope of the Canaries

- 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



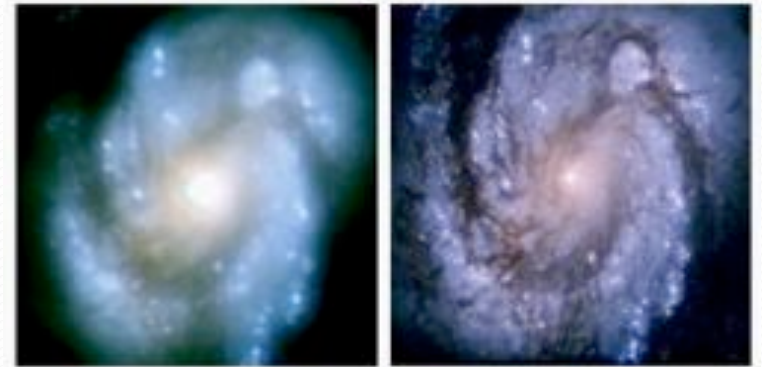
Go To Space!

- 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

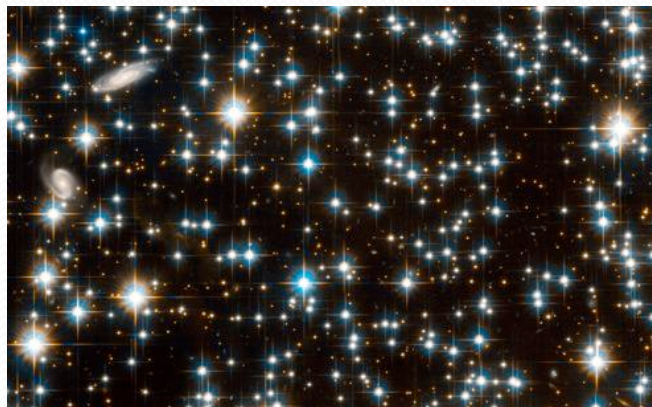
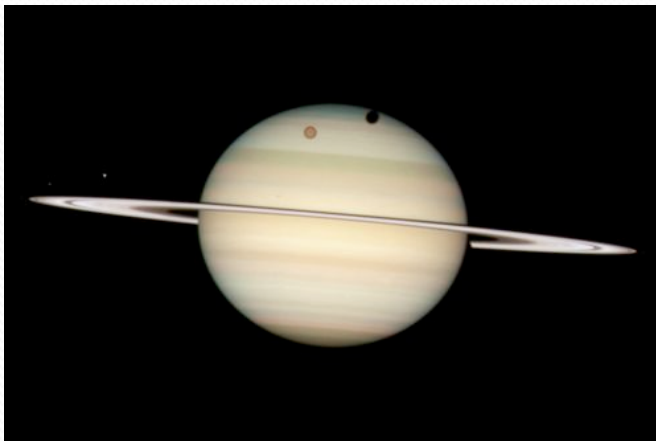


Hubble's Problem

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

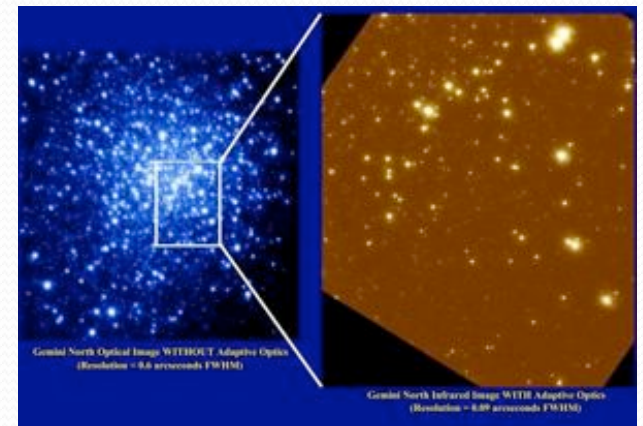
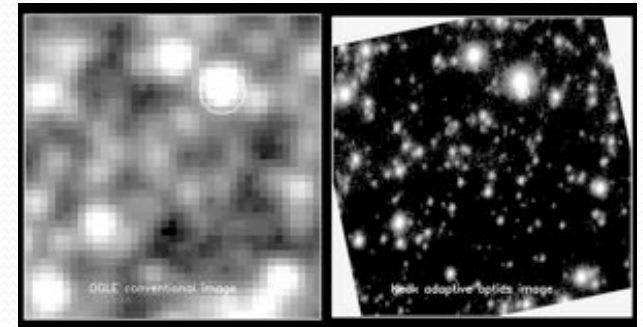


Pretty Hubble Pictures



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



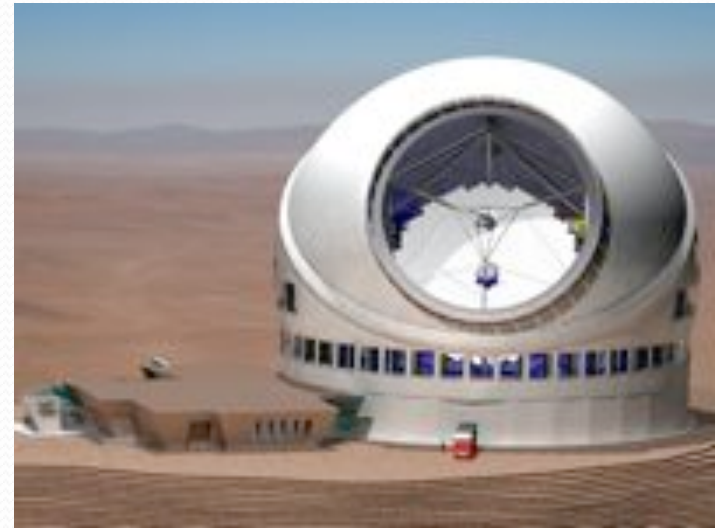
The GMT

- 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



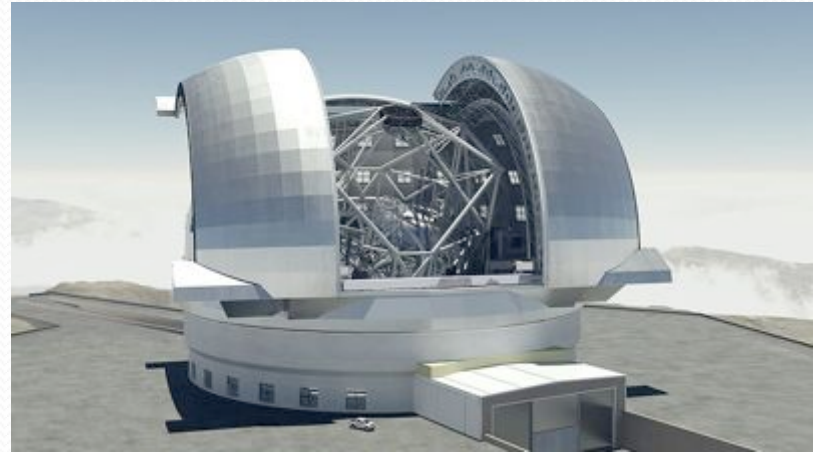
The Thirty Meter Telescope

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



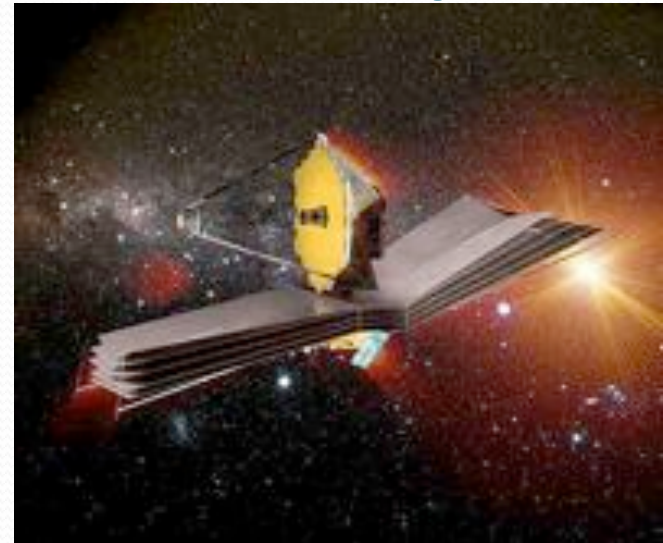
European Extremely Large Telescope

- 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



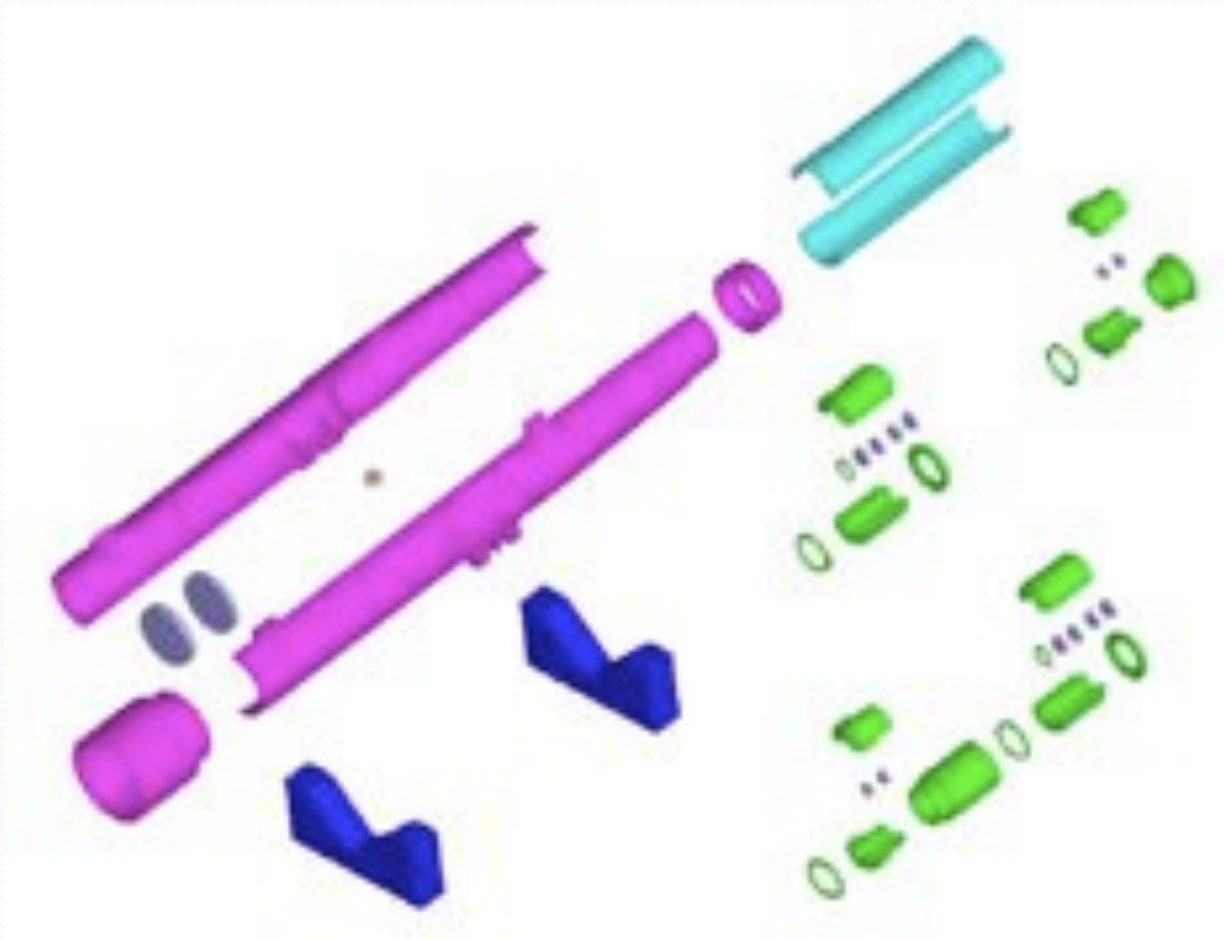
Galileoscope



- \$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?

