Telescopes

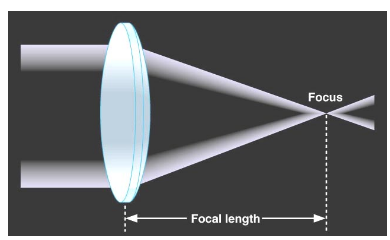
- Key parameters of telescopes
- Optical telescopes
- SOAR Telescope, MSU's window on the universe
- Radio telescopes
- Telescopes in space

- First Test is Thurs, Feb 1st
  - About 40 multiple choice questions
    - Some require working with models
  - Click on Study Guide, 2005 Test, Test1 2005 Answers on Syllabus.
  - Telescopes is not on test
  - How to study
    - Identify Big Ideas
    - Practice models & examples
    - Do 2005 test
    - Go over homework & clicker questions

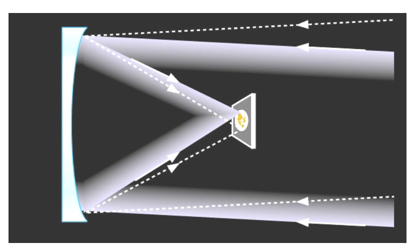
SOAR Telescope
Cerro Pachon, Chile

Purpose

- Telescope collects & focuses light onto a detector.
- Light collectors
  - Refracting telescope uses lens.
  - Reflecting telescope uses mirror.
- Your eye is a telescope.
  - Lens is the lens.
  - Retina is the detector.



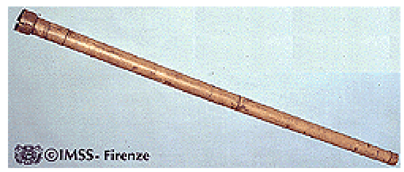
Using a lens (refractor)


Using a mirror (reflector)

Magnify & gather light

- Magnify image to see finer detail
- Smallest detail is limited by wavelength of light
  - Smallest angle is λ/D.
    - λ is wavelength of light
    - D is diameter of lens (or mirror)
- Gather more light to see fainter objects
  - Amount of light $\propto D^2$

- Telescope diameter is key parameter.
  - SOAR is a 4-m telescope
  - Galileo's 1-in telescope
- Q1 Your eye is a ___ telescope? (Look at your neighbor's eye.) A 1/8", B ½", C 1".



Galileo's telescope with 1" lens

Magnify & gather light

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    - λ is wavelength of light
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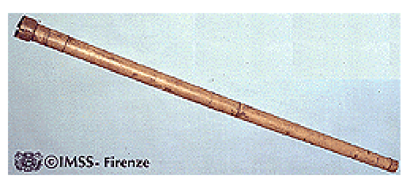
- Q2 A hawk can see a mouse while flying. I can't because
  a. I can't fly
  b. My eye is too small to see small details.
  c. My eye is too small to see the faint mouse.

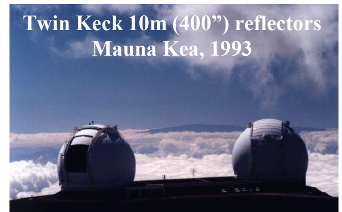


Galileo's telescope with 1" lens

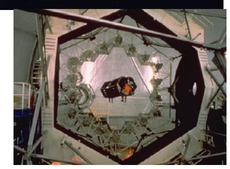
Some large ground-based optical telescopes

Lick 36" Refractor
1888

Mt. Palomar 200" Reflector
1948



Twin Keck 10m (400") reflectors
Mauna Kea, 1993



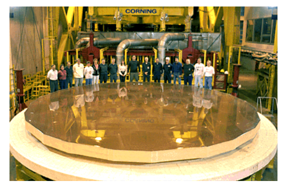
Light-gathering power

$\propto$ (mirror diameter)^2

Technological advances:

- Lenses ➔ mirrors.
- Thick mirrors ➔ thin mirrors.
- Passive support ➔ active
- Improved image quality.
- Now working on designs for 30-m diameter telescopes.

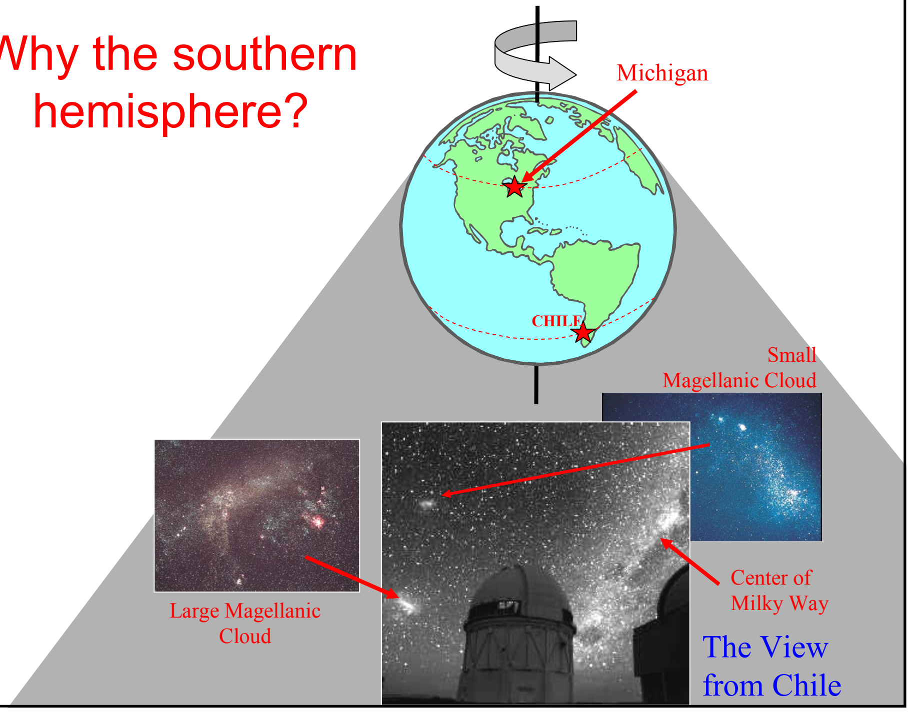
Europe's Very Large Telescope
(Four 8m telescopes)

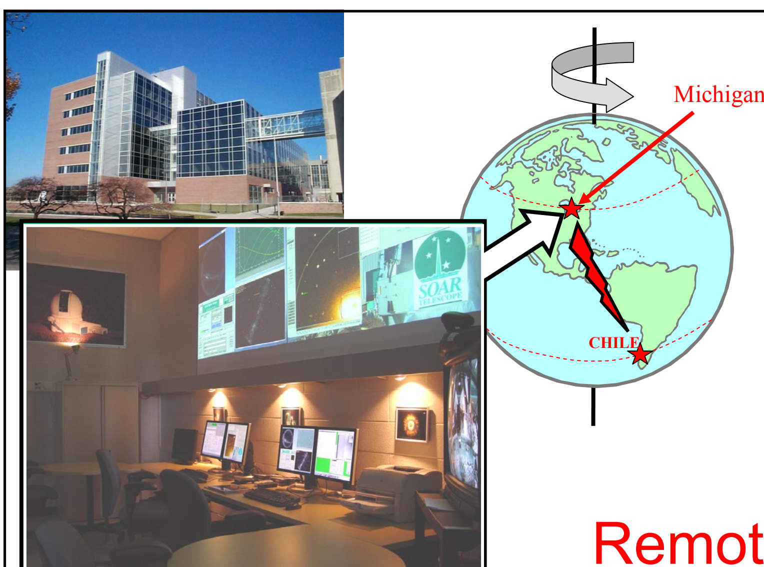


Mirror for Gemini 8m Telescope

SOAR An International Partnership

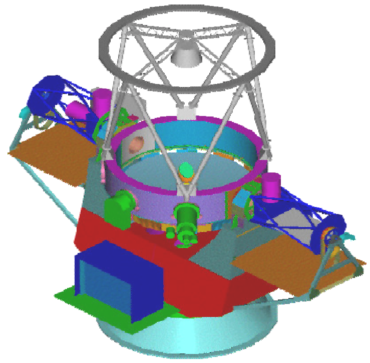
Why the southern hemisphere?



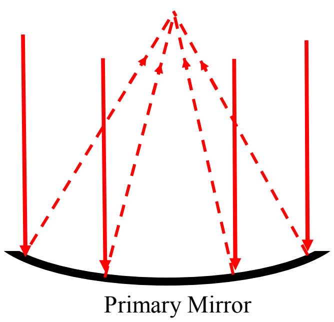


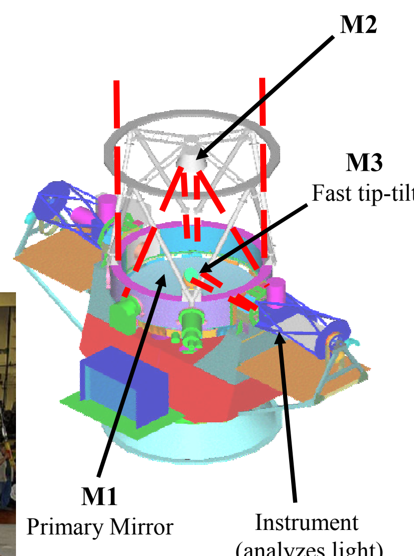
Remote Observing from MSU

The Telescope inside the Dome

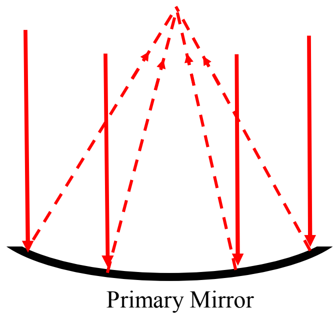


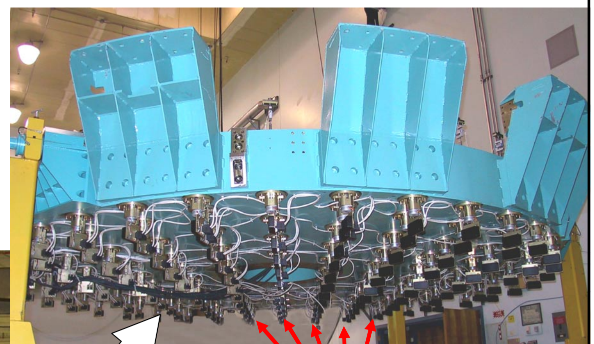
3-mirror optical path





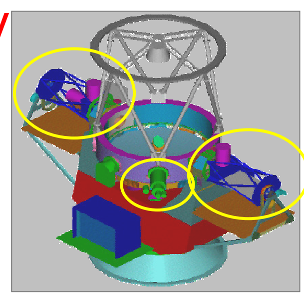
Must maintain mirror shape to 0.000001 inches.





120 computer-controlled force actuators.

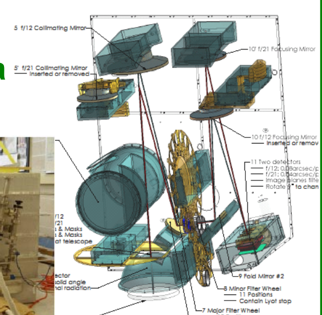
Telescopes carry many different instruments to analyze light.



SOAR's instruments:

- Optical spectrographs (2)
- Infrared spectrographs (2)
- Optical imager.
- Infrared imager.

The Spartan Infrared Camera



Spartan Infrared Camera

High Resolution Imaging for the SOAR Telescope

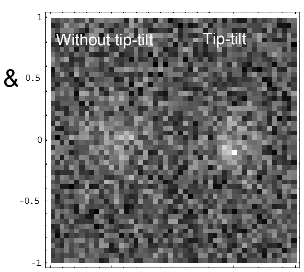
www.pa.msu.edu/~loh/SpartanIRCamera

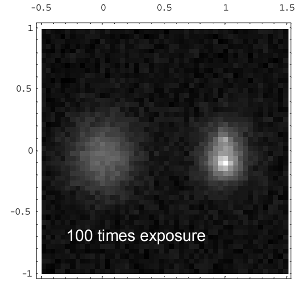
- The Spartan Infrared Camera is a $2.0M instrument funded by MSU, Brazil, SOAR, and the National Science Foundation.
- Primary technical goal:
  - Imaging with high angular resolution in the near infrared (1000-2500 nm) where
  - Tip-tilt correction of atmospheric turbulence produces sharpest images.
- Primary science goal for infrared:
  - Observe distant galaxies & supernovae
  - Center of Milky Way galaxy
- Designed and built by the MSU Physics-Astronomy Dept.

Spartan Camera with technicians D Baker (BS, ’04) & B Hanold (BS, ’06)

Tip-tilt Correction of Atmospheric Turbulence

- Tip-tilt correction
  - Method: Sense the position of a bright star & move a mirror to keep bright star centered. Repeat 60 times per second.
- Why use tip-tilt correction?
  - Simulated image of a double star.
  - Where is the double star?
  - Where is the fainter companion star?
  - In image with 100 times the exposure time
    - Do you see the companion?
    - Is the companion visible with natural seeing?
- With tip-tilt correction
  - Detail become visible
  - Fainter stars become visible

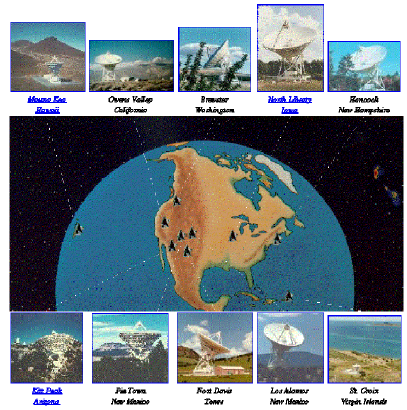




Radio telescopes

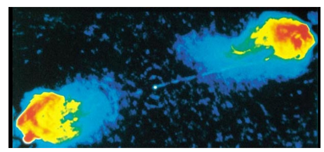
Angular resolution = $\frac{\text{wavelength}}{\text{mirror diameter}}$

- Radio wavelengths are large ➔ need large mirror diameter to see small-angle details.



Array of smaller telescopes simulates a huge aperture.

Arecibo, Puerto Rico
1000 ft. diameter, but same angular resolution as 1/30" optical telescope.

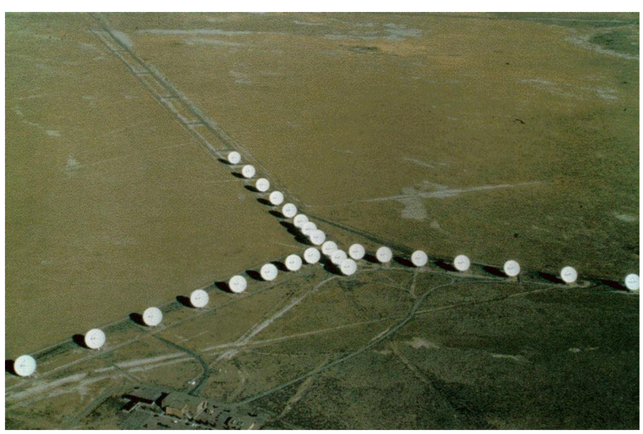


Radio galaxy Cygnus A

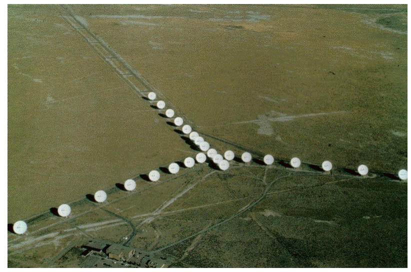
Very Large Array

Radio Telescope in New Mexico

- Another way to get a large diameter
  - Do not fill diameter with telescope.

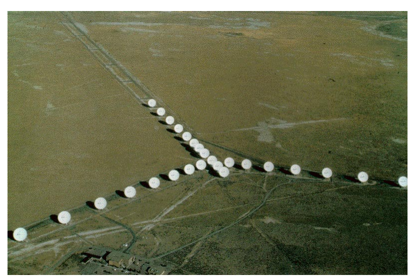


Key parameters of telescopes



- Fainter objects are visible with a larger telescope because
  - R1: a larger telescope collects more light.
    - Light gathering is proportional to telescope area.
  - R2: with the sharper images of a larger telescope, the light is more concentrated.
    - Angular resolution is proportional to λ/D
- Q3 The primary motivation for the VLA is
  a. R1
  b. R2
  c. Both R1 & R2 equally

Key parameters of telescopes



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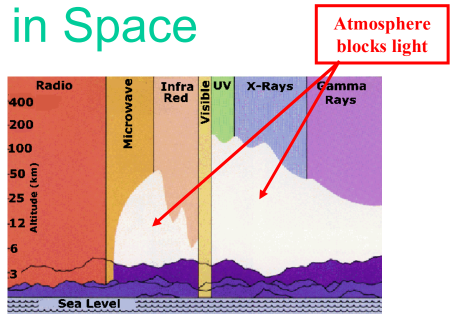
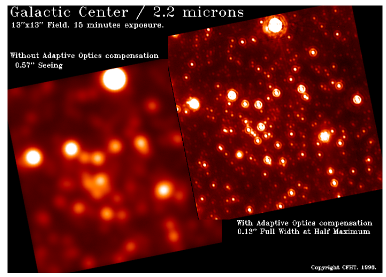
  - R2: with the sharper images of a larger telescope, the light is more concentrated.
    - Angular resolution is proportional to λ/D
- Q3 The primary motivation for 4-m SOAR vs 0.6-m MSU is
  a. R1
  b. R2
  c. Both R1 & R2 equally

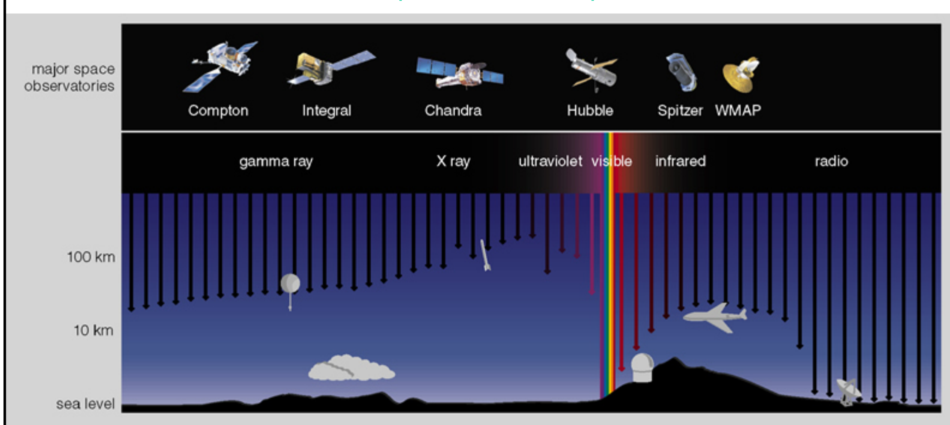
Telescopes in Space

- Atmosphere blocks light at many wavelengths
- Atmospheric turbulence smears out images.



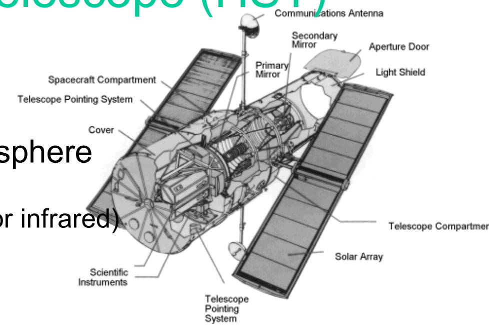


The NASA "Great Observatories" (and friends)



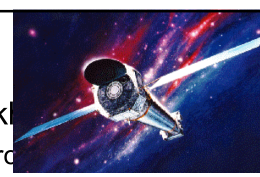
[Fig 5.22]

Hubble Space Telescope (HST)

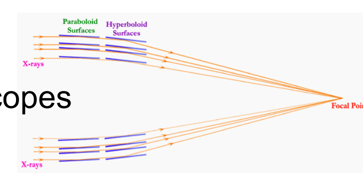


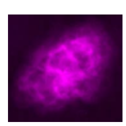
- 2.4m diameter mirror
- Ultraviolet/optical/infrared
- Above (most of) Earth's atmosphere
  - High angular resolution
  - Light not blocked in ultraviolet (or infrared)
  - Low earth orbit
    - 600 km (370 mile) altitude
    - 95 min orbits
    - Earth blocks view half of each orbit
    - But can be reached by shuttle to install new instruments
- Launched in 1990
- To be replaced by JWST in ~2008
  - HST will not last that long!
  - Rescue mission needed.

Chandra X-Ray telescope



- Named after Subrahmanyan Chandrasekhar
  - Figured out speed of light limits mass of neutron/white dwarf stars
- NASA "Great Observatory"
- Far better than previous x-ray telescopes
  - Many times higher angular resolution
  - More collecting area



	X-ray	Optical	Radio
Crab Nebula: Remnant of supernova that exploded in our Galaxy in 1054 AD			
Galaxy Cluster: Hydra A, 840 million light years away.