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 $\frac{\lambda}{D}$.
    - $\lambda$ 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

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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.
Some large ground-based optical telescopes

Light-gathering power
\[ \propto (\text{mirror diameter})^2 \]

Technological advances:
- Lenses \( \Rightarrow \) mirrors.
- Thick mirrors \( \Rightarrow \) thin mirrors.
- Passive support \( \Rightarrow \) active
- Improved image quality.
- Now working on designs for 30-m diameter telescopes.

SOAR An International Partnership

- National Optical Astronomy Observatory
- Cerro Pachón, Chile
- MICHIGAN STATE UNIVERSITY
- THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
- Brazil
Why the southern hemisphere?

The View from Chile

Michigan

Small Magellanic Cloud

Center of Milky Way

Large Magellanic Cloud

Remote Observing from MSU
The Telescope inside the Dome

3-mirror optical path

Primary Mirror

M1

Primary Mirror

M2

Fast tip-tilt

M3

Primary Mirror

Instrument (analyzes light)

Primary Mirror

14 feet diameter

4 inches thick
Must maintain mirror shape to 0.000001 inches.

Primary Mirror

14 feet diameter
4 inches thick

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
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.

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 \( \Rightarrow \) need large mirror diameter to see small-angle details.

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

Array of smaller telescopes simulates a huge aperture.

Radio galaxy Cygnus A

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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 \( \lambda/D \)
• Q3 The primary motivation for the VLA is
  a. R1
  b. R2
  c. Both R1 & R2 equally

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• 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 Subrahmanvan 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

Crab Nebula:
Remnant of supernova that exploded in our Galaxy in 1054 AD

Galaxy Cluster:
Hydra A, 840 million light years away.