Lesson 4 - Telescopes

READING ASSIGNMENT

- Chapter 5.1: Optical Telescopes
- Chapter 5.3: Images and Detectors
- Chapter 5.2: Telescope Size
  - Discovery 5-1: The Hubble Space Telescope
- Chapter 5.4: High-Resolution Astronomy
  - More Precisely 7-1: Why is the Sky Blue?
- Chapter 5.5: Radio Astronomy
- Chapter 5.6: Interferometry
- Chapter 5.7: Space-Based Astronomy
- Chapter 5.8: Full-Spectrum Coverage

SUMMARY OF MAJOR SPACE TELESCOPES

Read Discovery 5-1 and Chapter 5.7.

Infrared

Infrared Astronomy Satellite (IRAS)

- 0.6-meter diameter mirror
- far infrared (FIR)
- 1983 - 95

Infrared Space Observatory (ISO)

- 0.6-meter diameter mirror
- FIR
- 1995 - 98

Hubble Space Telescope (HST)

- NASA's 1^{st} "Great Observatory"
- 2.5-meter diameter mirror

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- near infrared (NIR) / optical / near ultraviolet (NUV)
- 1990 - present

Spitzer Space Telescope (SST)

- NASA's 4^{th} "Great Observatory"
- 0.85-meter diameter mirror
- FIR
- 2003 - present

Visible

HST

Ultraviolet

International Ultraviolet Explorer (IUE)

- NUV
- 1978 - 96

HST

Extreme Ultraviolet Explorer (EUVE)

- far ultraviolet (FUV) / soft X-rays
- 1992 - 2000

Far Ultraviolet Spectrographic Explorer (FUSE)

- FUV
- 1999 - 2007

Galaxy Evolution Explorer (GALEX)

- NUV
- 2003 - present

X-rays

Einstein Observatory

- 1978 - 80

Röntgen Satellite (ROSAT)

- 1991 - 99

Chandra X-ray Observatory (CXO)

- NASA's 3^{rd} "Great Observatory"
- 1999 - present

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X-ray Multi-Mirror Newton Satellite (XMM-Newton)

- European equivalent of a "Great Observatory"
- 1999 - present

Gamma rays

Compton Gamma-Ray Observatory (CGRO)

- NASA's 2^{nd} "Great Observatory"
- 1991 - 2000

Swift Gamma-Ray Burst Explorer

- 2004 - present

Fermi Gamma-Ray Space Telescope

- Equivalent of a "Great Observatory"
- 2008 - present

MATH NOTES

Light-Gathering Power

Read Chapter 5.2.

- LGP = light gathering power, or the rate at which a telescope collects light
- A = collecting area, or the area of a telescope's mirror
- D = diameter of a telescope's mirror
- LGP is proportional to A.
- A is proportional to D^2.
- Hence, the following is true.

$$\text{LGP is proportional to } D^2 \tag{1}$$

Example: UNC's new 4.1-meter diameter SOAR telescope[1] in the Chilean Andes collects light how many times faster than UNC's old 0.6-meter diameter Morehead Observatory telescope[2] in Chapel Hill?

Solution: Since LGP_{SOAR} is proportional D^2_{SOAR} and LGP_{MO} is proportional D^2_{MO}, then $\frac{\text{LGP}_{\text{SOAR}}}{\text{LGP}_{\text{MO}}} = \left(\frac{D_{\text{SOAR}}}{D_{\text{MO}}}\right)^2 = \left(\frac{4.1 \text{ m}}{0.6 \text{ m}}\right)^2 = 47$. Hence, the SOAR telescope collects light 47 times more quickly than the Morehead Observatory telescope.

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- LG = light gathered
- t = integration time, or the total amount of time that a telescope's camera records the collected light
- LG is also proportional to LGP $\times$ t.
- Hence, the following is true.

$$\text{LG is proportional to } D^2 \times t\text{LG is proportional to } D^2 \times t \tag{2}$$

Example: How much more light does one collect with the SOAR telescope in 1 minute than with the Morehead Observatory telescope in 47 minutes?

Solution: Since LG_{SOAR} is proportional to $D^2_{\text{SOAR}} \times t_{\text{SOAR}}$ and LG_{MO} is proportional to$D^2_{\text{MO}} \times t_{\text{MO}}$, then $\frac{\text{LGP}_{\text{SOAR}}}{\text{LGP}_{\text{MO}}} = \left(\frac{D_{\text{SOAR}}}{D_{\text{MO}}}\right)^2 \times \left(\frac{t_{\text{SOAR}}}{t_{\text{MO}}}\right) = \left(\frac{4.1\text{ m}}{0.6\text{ m}}\right)^2 \times \left(\frac{1\text{ min}}{47\text{ min}}\right) = 1$. Hence, the SOAR telescope collects just as much light in 1 minute as the Morehead Observatory telescope collects in 47 minutes.

Resolving Power

Read Chapter 5.2, Chapter 5.4, and Chapter 5.6.

- θ = resolving power, or the angle over which a telescope smears out a point of light
- λ = wavelength of observed light
- D = telescope diameter

$$\theta = 0.25" \times \frac{(\lambda/1\mu\text{m})}{(D/1\text{m})} \tag{3}$$

- Note: Without adaptive optics, no ground-based optical telescope can resolve light better than about an arcsecond because of atmospheric blurring effects.
- For radio telescopes, λ is usually measured in cm and θ in arcminutes. Hence, you might find this, equivalent, form easier to use.

$$\theta = 40' \times \frac{(\lambda/1\text{cm})}{(D/1\text{m})} \tag{4}$$

- I love radio astronomy[3]. This program can now be taken for Experiential Education credit as ASTR 111L!

[3]http://www.physics.unc.edu/~reichart/erira.html

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EXERCISE 7

I have built six robotic telescopes in the Chilean Andes, called PROMPT[4], and I am helping others to build similar telescopes around the world. They are called robotic telescopes because no humans are required (except when something breaks). Here is a simple web page[5] that will allow you to request observations of popular southern sky objects with my telescopes in Chile. The password is "astro101". Once PROMPT observes your first object for you, it will email you the image and then allow you to request another observation. Observe at least three objects!

If you enjoy this, consider taking ASTR 101L. Most of the labs involve carrying out observations with these and the other robotic telescopes of the Skynet Robotic Telescope Network[6].

HOMEWORK 4

Download Homework 4 from WebAssign. Feel free to work on these questions together. Then submit your answers to WebAssign individually. Please do not wait until the last minute to submit your answers and please confirm that WebAssign actually received all of your answers before logging off.

[4]http://www.physics.unc.edu/research/astro/prompt.php
[5]http://skynet.unc.edu/morehead/authorize.php
[6]http://www.physics.unc.edu/∼reichart/pamphlet.pdf

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