Telescopes

Goals & Outcomes

• **Appreciating** science in general, and astronomy in specific.
• **Understanding** how knowledge is gained and be critical of what you see and hear. You will begin to ask “How can we test that?” when forming hypotheses or “How do we know that?” when reading new information.
• Learn some simple astronomical nomenclature/terminology.
• Learn about some problems astronomers and astrophysicists are trying to solve, and understand the methods scientists are using to try to solve these problems.
• Explain how electromagnetic radiation and astronomical instruments are used to reveal the properties of stars and galaxies.
Big Picture

• What do telescopes do?
• What must happen for eyes or a telescope to “see” an object?
• Why are telescopes better than human eyes?
• What are limits of using telescopes, both on Earth and in space?
• How are telescopes from across the world used simultaneously to get the best pictures?

Usage of telescopes

• Astronomers use telescopes to do 3 things:
  1. __________ (taking ______________)
  2. __________ (like with did with the ________ ________________)
     • Analyze ________________
     • Two things equivalent to wavelength?
       • ______________ (if using visible light)
       • ________________
     • How do they do this?
     • _________________
  3. ________________ – watching things _______.
     • How do they do this?
     • ________________.
Purposes of telescope

- _____________________
- _____________________
- _____________________
- _____________________
- _________ to _____________________
  – That’s only when people look through them.
  – Astronomers mostly use telescopes to
    - _____________________
    - _____________________! (Although that’s fun!)
  – See _____________________

How this works in

- Teacher drawing of eye, as we see them
  – Purpose of pupil, iris.
  - _____________________
    - When is pupil most dilated? Contracted?
    - ______________ pupil = ______________. Need this when ...
  - _____________________.
- See figure 6.1, page 181 for “inside” view
- Next, after gathering light, need to
  - ______________. What does that for human telescopes?
- See figures 6.3 and 6.4, page 182 for
  - _____________________ by the human eye
- After _____________________ light, what must a telescope do?
- What detects light in the human telescope?
  - _____________________
Seeing things

• Whether you “see” (__________) an object depends on only one thing:
  • ________________ by a ________

• This depends on several things:
  1. ________________ (Why apparent?)
  2. ________________
  3. ________________
  4. ________________
  5. (Angular) ________________

• More details about each of these coming up.

Apparent brightness

• What affects how bright light ________________?
  1. ________________ objects appear ________
     • (__________ for light; see p. ________, chap __)
  2. ________________ (which means …)
     • We’ve talked about what determines ________________:
       1. ________________
       2. ________________
     • If you forgot, review ________________
  3. ________________
     • What can cause this?
     • We’ll ignore this for most of the semester
REVIEW: What were 2 processes that emit light?

• Thermal (continuous) from…

• and emission lines from …

• What happens if you heat up a thermal emitter?
• What happens if you heat up an emission line source?
• Does it change which emission lines are emitted? [ask neighbor]

Light collecting area

• English: size of _____________________
• For eyes, this is determined by size of _____
• For ‘scopes, determined by size of ______________
  – Astronomers _____________________ anymore.
  – See pages ________ if you want to know why. (Not much to read there – lots of pics on those pages)

• What matters is the _______, not the ________.
  – Telescope that has double the diameter collects how much more light? [hold up right # of fingers]
  – Telescopes with 10x diameter collect ________ more light.
  – Book talks about this on pages ______________.
Light area, continued

• Human eye diameter?
  – ____________

• Hubble space telescope?
  – ____________________________
  – ______ diameter of human eye → __________ more light

• Biggest visible light telescope?
  – Keck. ___________ (_____ ft – size of ________________).
  - See p. _____, figure __________. What’s orange thing in middle?
  – Spain’s GTC is a tiny bit bigger (10.4 m)
  – __________ was biggest (5 m) for about 50 years. Go
  visit! It’s only 2-3 hours away, driving.

• Building __________ approx _____ ________!
 [_______________ more light than ______________]

Telescopes often have 2 mirrors (sometimes more). Which mirror
determines how much light can be detected?

0  1. Primary (first one light hits)
0  2. Secondary (2nd one light hits)
0  3. It could be either one
0  4. Not enough information provided
Exposure Time

- Human eye detector:
  - How long are eye pictures?
  - How many?

- Old cameras detector:
  - How long can film be exposed to light?

- New cameras detector
  - How long can CCD be exposed to light?
  - More light than human vision

Efficiency of light detector

- Human eye:
  - Detects

- Film:
  - Detects \( \sim \) \% 

- CCD
  - Detects \% 
  - Extra benefit: results are digital – can be processed!

- Mirrors reduce telescope efficiency to \% overall.
- Telescopes ONLY have more light gathering capability due to.
Resolution and focus

• To get _________ and _________, light must be _________. What that means:
  – Light from _________ should be _________ ____________.
• _________ = how many _____ the equipment ________
  ________________
• _________ = ____________________
  – People need glasses because light isn’t focused on the eye detectors; it is spread out when it lands on the rods and cones.
• What do things look like when you don’t wear your glasses?
  – _____ the _____ is ______. _____ to “___” the message.

Bad vs. Good focus

M100 Galactic Nucleus

Hubble Space Telescope
Wide Field Planetary Camera 2

Wide Field Planetary Camera 1
Wide Field Planetary Camera 2
Bad vs. Good focus part 2

HUBBLE SPACE TELESCOPE
FAINT OBJECT CAMERA
COMPARATIVE VIEWS OF A STAR

BEFORE COSTAR
AFTER COSTAR
Resolution – diffraction limit

• Previous pics – caused by __________________ error. __________ mistake. Very expensive. Required space shuttle visit.

• Nature has natural limit caused by ___________________
  – Example: why you can __________________ even if you can’t ____________________________

• __________________________ depends on __________________ things:
  – __________________________ bend more. (__________________________)
  – Size of A) _______ through or B) size of _______ hole/object → bend waves more. (Has harder time “squeezing” through small hole)

• Smallest amount of bending light (______________) is called the “______________”. __________________

• See pages ________________ (p. _____ – all math)

For math people only

• Light bends by changing direction.
• Specified by an angle
• Bending angle = (1.22) * WL / d
  – D = size of hole or object light hits
  – Angle = units of radians (not degrees)
  – Book has equivalent formula using different units on page 185 “Mathematical Insight”
Which kind of light diffracts the least? (i.e. is EASIEST to focus)?

0  1. Radio
0  2. Infrared (IR)
0  3. Visible
0  4. Ultraviolet (UV)
0  5. Gamma rays

Which kind of light gives the best resolution in diffraction-limited telescopes?

0  1. Radio
0  2. Infrared (IR)
0  3. Visible
0  4. Ultraviolet (UV)
0  5. Gamma rays
Which telescope has the best (smallest) diffraction limit, giving the sharpest pictures?

1. Big visible light telescope
2. Small visible light telescope

Animations to help see diffraction

- From MasteringAstronomy website OR the CD that came with your book:
- Diffraction Rings
- Effect of wavelength on angular resolution
Atmospheric effects

- Atmosphere does 3 things to light:
  1. __________________________
     • ___________ caused by ___________. Caused by _____.
     • Why LA skies have _______ – too much _______; stars get __________________________ light, similar to why we can’t see many s_________ during ________ sky.
  2. ______________________. See fig _____, page ___ now.
     • Which forms reach ground? Which forms are absorbed? (Any guesses what absorbs most of the ________?)
  3. First song you ever learned as a kid:
     • Stars _______. _______________, and as a result, _______________________. Technically called “__________.”
     Caused by air speed/temperature differences.
     • You can see this yourself. Look at air over __________ or over __________________. Similar to “mirages” and it causes mirages to be wavy.

Compensating for “seeing”

- “_________” limits ______________ telescopes
- _______ (not _______) causes _______. How to reduce _______________?
  – Where are most telescopes built?
  – Extra advantages to being on ______________________?
- Where put a telescope to ______________________?
- ______________________ to ______________________ changes. (100s times per second!)
  – Called “____________________________.”
  – Expensive.
  – Requires fast computers and quickly moving parts
  – Most new big telescopes use this.
Twinkled vs. compensated

• See also figure 6.20 page 194.

Why we use non-visible telescopes

• Why is it hard to do astronomy using light that is not visible to the human eye?
• Even using digital cameras, not human eyes…
• Here’s what you see if you try:
Sirius binary system

What you’d see through a visible light telescope. Ignore the spikes  
X-ray image & visible image superimposed

Interferometry

• Which form of light DIFFRACTS most?
• Would that make images sharp or blurry?
• What else determines amount of diffraction?
• __________________________.

• Technique is called __________. (2+ telescopes “interfere” signals.)
• ________ best for i________________

because radio wavelength is ______________
 – Biggest interferometer is literally size of ______________: 
  use __________________________________ of Earth
 – Big one in New Mexico: VLA (_________________).
  See fig 6.30. In many commercials and movie Contact.

• Gives us ______________ images, even better than ____________ telescope! (but in _______)!
Big telescopes

• Visible light: Keck. 10 meters.
• Radio light: Arecibo, in Puerto Rico. 305 m
  – Not steerable.
  – See figure 6.24, page 197.
  – Seen in “Golden Eye” (James Bond)
• Other telescopes aren’t big yet.
• X-ray & gamma-rays REALLY hard to focus.
  – Best current X-ray telescopes about as good as
    visible light scopes on the ground

Putting it all together

• 5 things affected amount of light detected:
  1. ____________________ _____________________
  • Can’t control with telescope.
  2. ____________________ _____________________
  • ____________________ times more light than human eye
  3. ____________________ _____________________
  • ____________________ times more light than human eye
  4. ____________________ _____________________
  • ____________________ times more light than human eye
  5. (Angular) ____________________ _____________________
  • ____________________ _____________________
  • ____________________ times more light than human eye

Why do we use telescopes? Combining everything above,
telescopes get ____________________ times more light.
Distances: can see ____________________ times further.
Things you DON’T need to know from chapter 6

- Two basic designs of telescopes (pp. 187-188)
- Details about non-visible light. But you should understand the big picture. (pp. 196-top of 199)
- You SHOULD know the big picture about interferometry (rest of page 199 & 200)