Astro 233: Coming Attractions

• Keep an eye on our website for updates to links and references

• The lecture slides are linked there also!

• The first paper will be due on Thursday Sep 14\textsuperscript{th}.
  • The version posted on the web site will contain some useful links.
  • It will be graded as a draft.
  • See Melissa for help! Send her email if you need to meet with her at another time.
What is the purpose of a telescope?

1. A telescope acts like a light bucket, to gather photons.
   - The bigger a telescope is, the more photons it can catch.
What is the purpose of a telescope?

2. In addition to gathering light, a telescope allows a more detailed view of the structure of a celestial object and/or to discern the presence of multiple objects. This is called the telescope’s **angular resolution**.
What is the purpose of a telescope?

2. In addition to gathering light, a telescope allows a more detailed view of the structure of a celestial object and/or discern the presence of multiple objects. This is called the **ANGULAR RESOLUTION**.

**Minimum angular separation of two objects that can be seen as separate**

Remember there are 206,265 seconds of arc in one radian (a useful number to remember).
5.1 Telescope Design

Modern optical telescopes are all reflectors:

• Light traveling through lens is refracted differently depending on wavelength
• Some light traveling through lens is absorbed
• Large lenses can be very heavy, and can be supported only at edge
• Lens needs two optically acceptable surfaces, mirror needs only one
**Diffraction Limit**

\[
\theta = \frac{1.22 \times \text{wavelength (cm)}}{\text{diameter of telescope (cm)}}
\]

Example: Hubble Space Telescope HST
The diameter of the telescope is 2.4 m = 240 cm
Let's find the diffraction limit at 5000 Angstroms.

\[
\theta = \frac{1.22 \times 5000 \, \text{Å} \times 10^{-8} \, \text{cm/Å}}{240 \, \text{cm}} = 2.54 \times 10^{-7} \, \text{radians}
\]

= 2.54 x 10^{-7} radians X 206,265 arcsec/radian

= 0.05 arc seconds

Remember there are 206,265 seconds of arc in one radian (a useful number to remember).
Diffraction Limit

Example: Arecibo 305 meter telescope
The diameter of the telescope is 305 m = 30500 cm
Let's find the diffraction limit at 21 cm.

\[ \Theta = \frac{1.22 \times 21 \text{ cm}}{30500 \text{ cm}} = 8.4 \times 10^{-4} \text{ radians} \]

\[ = 8.4 \times 10^{-4} \text{ radians} \times 206,265 \text{ arcsec/radian} \]

\[ = 173 \text{ arc seconds} = 2.88 \text{ arc minutes} \]
The “seeing” of an image is a measure of its quality or sharpness. This is often quantified as the “point spread function” (PSF): the angle subtended by an unresolved (point-like) object in the image.
Atmospheric Seeing

- An image obtained with a telescope on the ground is also affected by **ATMOSPHERIC SEEING**, that is, blurring of the image by turbulence in the Earth’s atmosphere.

- Space-based telescopes are not affected by atmospheric seeing.

Stars “twinkle” because of atmospheric turbulence. Planets are (not quite) point sources and do not twinkle.

- The **seeing** of an image is a measure of its quality or sharpness.
- Because stars are so far away, they appear as points of light in our images.
- The seeing then is the angular extent of a star in an image.
- The seeing is always bigger than either (1) the diffraction limit or (2) the atmospheric seeing, whichever is greater.
The “seeing” of an image

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- Because stars are so far away, they appear as points of light in our images.
- The seeing then is the angular extent of a star in an image.
- The seeing is always bigger than either (1) the diffraction limit or (2) the atmospheric seeing, whichever is greater.
Diffraction Limit

Example: Palomar 5 meter telescope
The diameter of the telescope is 5 m = 500 cm
Let's find the diffraction limit at 5000 Angstroms.

\[ \Theta = \frac{1.22 \times 5000 \, \text{Å} \times 10^{-8} \, \text{cm}/\text{Å}}{500 \, \text{cm}} = 1.22 \times 10^{-7} \, \text{radians} \]
\[ = 1.22 \times 10^{-7} \, \text{radians} \times 206,265 \, \text{arcsec}/\text{radian} \]
\[ = 0.025 \, \text{arc seconds} \]

But, since Palomar is only at 6000 feet elevation, its resolution is ATMOSPHERIC SEEING limited, typically not better than 1 arcsecond.
The Palomar 5-meter Hale Telescope

- Located in northern San Diego County, California
- Owned and operated by Caltech
- Cornell is 1/8th partner (gets 1/8th of the nights for observing)
- Useful especially for spectroscopy, infrared imaging and adaptive optics/high resolution studies.
The Palomar 5-meter Hale Telescope
The Palomar 5-meter Hale Telescope
The PHARO Adaptive Optics System
5.4 High-Resolution Astronomy

Solutions:

• Put telescopes on mountaintops, especially in deserts
• Put telescopes in space
• Active optics – control mirrors based on temperature and orientation
# Large optical telescopes

<table>
<thead>
<tr>
<th>Telescope</th>
<th>Location</th>
<th>Best seeing</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hubble</td>
<td>space</td>
<td>~0.1&quot;</td>
<td>Near diffraction limit</td>
</tr>
<tr>
<td>Typical ground based optical</td>
<td>Palomar or Arizona</td>
<td>~1&quot;</td>
<td>Atmospheric seeing</td>
</tr>
<tr>
<td>Best ground based optical</td>
<td>Mauna Kea or Chile</td>
<td>~0.7&quot;</td>
<td>Atmospheric seeing</td>
</tr>
<tr>
<td>+ adaptive optics</td>
<td>Mauna Kea or Chile</td>
<td>~0.4&quot;</td>
<td>Some correction for atmospheric seeing</td>
</tr>
<tr>
<td>Future adaptive optics</td>
<td>Mauna Kea or Chile</td>
<td>~0.1&quot;</td>
<td>Maximum correction for atmospheric seeing</td>
</tr>
</tbody>
</table>
Different telescopes provide different clues

Images

Wide field | High resolution

Morphology: appearance, structural details
Astrometry: position, relative to other objects
Photometry: apparent brightness
What are the major advances that Hubble predicts the 200-inch telescope will offer to astronomers?
Was he correct?