TODAY’S LESSONS

The Experiment

How to empirically determine the minimum aperture size needed to resolve closely-spaced objects & fine details

This Talk

Why you’ll always need a telescope bigger & better than that: nothing ever works as expected
REFRACTORS VS. REFLECTORS

- **Refractors** use lenses
  - Problematic, no longer used for research
- **Reflectors** use mirrors
  - Most modern telescopes are reflectors
REFRACTOR ISSUES:
CHROMATIC ABERRATION

Lens' focal length varies with wavelength of light being focused – violet light refracts most, red least.

This fix works for hobbyists, but results are not research-grade.
The Yerkes Telescope (U of Chicago), the world’s largest refractor:

- 63 ft (19.2 m) long
- Tube alone is 6 tons – sagging is a problem
- 90 ft (27 m) high dome
- Only 40 in (1.02 m) in diameter!
REFLECTORS ARE ADAPTABLE (& COMPACTABLE)

Telescopes at the CTO use the Cassegrain focus.
SPHERICAL ABERRATION

- Spherical optics (lenses & mirrors) are easy & cheap to make - **HOWEVER** - focal length varies with distance from center of optic

- **Solution 1 ($$$)**: use a **parabolic** optic

- **Solution 2 ($)**: use a corrective lens → make a Schmidt Cassegrain Telescope
• Parabolic optics focus all incoming light to 1 point no matter where it hits the optic, **BUT ONLY IF** all rays enter ⊥ to optic’s center
  - Otherwise, focal length depends on proximity to edge

• **Ideal Solution ($$$)$**: use hyperbolic optics (like parabolic but a little more open) → make a Ritchey-Chrétien (RC) telescope
  - Nearly all major research observatories use RC reflector telescopes

• **Alternative**: more corrective lens

**Bottom line – nothing ever works [perfectly].**
ASTRONOMICAL SEEING (WHY STARS TWINKLE)

Actual star size:

![Image of star twinkle](image)

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Diagram:

- Actual star size:
- Earth's atmosphere:
- Plane wavefronts:
  - Infinite distance
- Corrugated wavefronts:
  - Small aperture
  - Large aperture
**RESOLVING POWER RECAP**

\[
\sin \theta = 1.22 \frac{\lambda}{D}
\]

Bigger aperture $\rightarrow$ less diffraction $\rightarrow$ smaller Airy patterns $\rightarrow$ better resolution
MAGNIFICATION

- Ratio of the focal lengths of the 2 optics
- **Magnification is unitless**
- Unlike aperture size, greater magnification doesn’t really improve image quality

\[ M = \frac{f_{\text{telescope}}}{f_{\text{eyepiece}}} \]
The Sun & full Moon are both about 0.5° or 30′ across
DAWES’ LAW

- \( D = \frac{114}{\theta} \)
- \( h \) = linear separation of objects in the image (same units as \( \ell \))
- \( \theta \) = angular separation
- \( \ell \) = distance to the target (same units as \( h \))

\[
\theta = 2.063 \times 10^5 \left( \frac{h}{\ell} \right) \text{arcseconds}
\]
PROCEDURES (1/2)

1. Measure **distance** $\ell$ from target to aperture
   - Linear separation $h$ is given in the manual.

2. Measure the **aperture diameter**, $D$, when the image (either stars or “canals”) just becomes unresolved (the 2 objects appear to start touching). **One person should adjust the telescope iris, one should measure the aperture, & one should record the data point.**
   - Don't bump the telescope or you'll have to remeasure $\ell$!
   - Don't let your ruler touch the iris diaphragm—the metal leaves are easily dislodged & time-consuming to fix!

3. Repeat step 2 until you have **5 trials each** for the binary star AND the “canals”
4. Average your results from the previous step to obtain **2 experimental aperture sizes**—1 each for resolving the stars & the “canals”.

5. Calculate the **Dawes’ Limit (D)** using your previously-measured values for distance \( l \) & linear separation \( h \); these are your predicted aperture sizes needed to resolve the stars or “canals.”

6. Calculate the **% error** between your averaged experimental values & the predicted values you calculated using Dawes’ Limit.

7. List **3+ sources of error** (uncertainty) in this experiment (remember your dos & don’ts!)
ONE MORE THING!

- Use the worksheets from the lab manual for this lab, pages 3.5 to 3.8.
- Answer all questions, show work, & round answers to the correct significant digits.
- Keep your worksheets in a safe place so you can refer to them for your double formal lab report.

Reminders:

- Read “The Astronomical Telescope II” for next class
- NO night lab next Monday (we don’t want to keep you from seeing astronaut Scott Kelly!)