**Topics for Today**

- Twinkle and absorption by our atmosphere
- What light gets through, what does not
- Telescopes in space – and why
- Radio and x-ray telescopes do it differently
- Start Chapter 15 – Our Nearest Star

**Reading for Next Class**

- Read Chap 15, _The Sun_, in detail
- Friday lecture goes from the center of the Sun to its outermost layers
- Come see us if you need any help or advice about anything in this course

**Clicker Q: Radio Waves**

- You are listening to a radio station broadcasting at a frequency of 97 MHz. Which is true?
  - A. The radio waves from the station have a wavelength of 97 million meters.
  - B. The “radio waves” received by your radio are not light waves, but rather a special kind of sound wave.
  - C. The radio station broadcasts its signal with a power of 97 million watts.
  - D. The radio waves are causing electrons in your radio’s antenna to move up and down 97 million times per second.

**Instruments in the Focal Plane**

How astronomers use light collected by a telescope:

1. **Imaging**
   - use camera to take pictures (images)
   - photometry → measure amount and color (with filters) of light from object

2. **Spectroscopy**
   - use spectrograph to separate light in detail into its different wavelengths (colors)

3. **Timing**
   - measure how amount of light changes with time (sometimes in a fraction of a second)
**Imaging (Digital with CCDs)**

- Filters are placed in front of camera to allow only certain colors to be imaged
- Single color images are superimposed to form “true color” images.

**Spectroscopy – analyzing the light**

- Spectrograph reflects light off a grating; finely ruled, smooth surface
- Light (by interference) disperses into colors
- This spectrum is recorded by digital CCD detector

**Problems in Looking Through Our Atmosphere**

- Many wavelengths are absorbed (just don’t make it through to surface)
- Turbulence in atmosphere distorts light:
  - stars appear to “twinkle”
  - angular resolution is degraded
- Man-made light is reflected by air particles, yielding bright night sky
  - this is light pollution

**Light Pollution**

90% of Earth’s population cannot see the Milky Way

**How many light bulbs does it take to screw up an astronomer?**

An immediately curable pollution: simply turn the lights off!

Stop "uplight", glare: wastes billions of $$ in energy, use "low pressure sodium"

Several famous observatories are now useless…

LA Basin View from Mt. Wilson Observatory, 1908 and 1998
**Quest for Good Weather and Seeing**

- Mauna Kea, Big Island of Hawaii, 14,000’ elevation, middle of the Pacific
- Dry, high, dark and isolated. Best on the planet?

**Adaptive Optics (AO) – “de-twinkle” stars**

- Wavefronts of star light are deformed by atmosphere
- Can distort shape of mirror (very fast) to correct for distortions by atmosphere – hot new technology

**Understanding Clicker Q**

A.

- Which BEST describes two advantages of telescopes over eyes?
  - A. Telescopes collect far more light with far better angular resolution
  - B. Telescopes collect more light with far greater magnification
  - C. Telescopes collect more light and are unaffected by twinkling
  - D. Telescopes have much more magnification and better angular resolution

**Atmospheric Absorption of “Light”**

- Earth’s atmosphere absorbs most types of light (not entirely bad, or we would be dead!)
- Only visible, radio, and some IR and UV light get through to the ground

To observe other wavelengths, must put telescopes in space!
So what gets through our atmosphere?

• **RADIO WAVES**: mostly get through
  - Thus radio telescopes are built on the ground
  - Weather is not an issue - radio waves come right through the clouds

Infrared Telescopes

• **INFRARED** can be absorbed by molecules like H₂O, CO₂, CO, etc.
  - Absorption is in specific wavebands, leaving "windows" where we can see above the atmosphere
  - Combination of ground-based, airplane, balloon, rockets, satellite...

SIRTF: Space Infrared Telescope Facility now SPITZER

• Launched 25 August 03
• Trails behind Earth to get away from Earth's thermal spectrum
• 0.85m aperture, T ~ 5.5 K
• Cooled with liquid helium, 2-5 years worth

UV, X-rays and Gamma-rays

• These all have enough energy to ionize electrons out of atoms or break apart molecules
  → Heavily absorbed by the atmosphere
• Space or high altitude (balloon, rocket) observatories are necessary

Space Based Telescopes

• **VISIBLE and UV**: visible: atmosphere is transparent but turbulent (seeing)
  - HST: Small (2.5 meters), diffraction-limited
  - Low orbit accessible by Shuttle, refurbishing means long lifetime (1990-2007+?)
  - Costs: $5 billion over 20 years, or 10 - 100 times more than ground scopes

Hubble Space Telescope (HST)

Chandra X-ray Observatory

Hubble Space Telescope (HST)
**HST Sharpness of Images**

- **HST Resolution:** 0.05 arcseconds (D)
- Compare with “best seeing” ground based observations at 0.5 arcseconds (B), and “typical” 2 arcsecond seeing (A)

**HUBBLE TROUBLE**

- Repaired by astronauts inserting corrective optics from Boulder