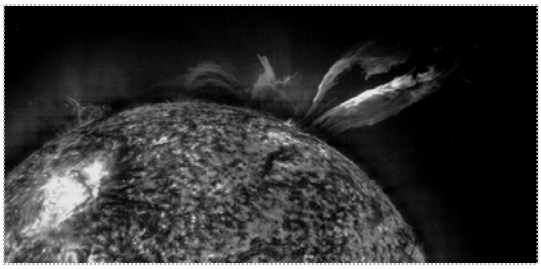
ASTR 1120: Stars & Galaxies



Prof. Juri Toomre TA: Ben Brown

Lecture 6 Mon 24 Jan 05

zeus.colorado.edu/astr1120-toomre

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*

- *Planetarium #1* this Wed Jan 26: Go directly to Fiske Planetarium (near Kittredge)
- *"City of Stars"* -- Survey of our galaxy, objects and clusters within, stellar evolution; great show

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 *D.*

- *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 it 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.

D. $c = \lambda \cdot f$ *Radios*

- *You are listening to a radio station broadcasting at a frequency of 97 Mhz. Which is true?*
- D. The radio waves are causing electrons in your radio's antenna to move up and down 97 million times per second.

Wavelength = Speed of light / frequency
= 3.0 x 10^{10} cm sec^{-1} / 9.6 10^{7} sec^{-1}
= 312 cm

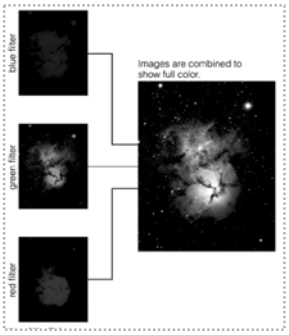
Instruments in the Focal Plane

How astronomers use light collected by a telescope:

1. *Imaging* *REMINDER*
   - 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)

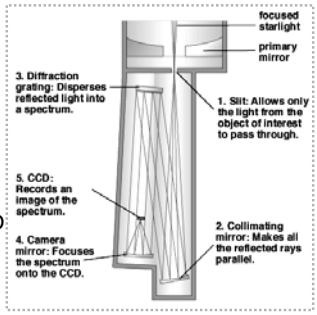
Imaging (Digital with CCDs)

- *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



Why BIG TELESCOPES are needed, and are now reflectors

BIG TELESCOPES (OPTICAL)

- COLLECT MORE LIGHT FROM FAINT OBJECTS
- RESOLVE TWO THINGS CLOSER TOGETHER (SMALLER SEPARATION BETWEEN TWO DISCERNIBLE IMAGES)

BIG APERTURE TELESCOPES ARE REFLECTORS (MIRRORS)

1. CAN SUPPORT MIRROR FROM BACK, NOT JUST FROM EDGES AS ON LENS
   (BIGGEST LENS ~ 1 m. DIAMETER
   BIGGEST MIRROR ~ 6 m, 10 m BEING BUILT)
2. MIRROR ONLY NEEDS ONE VERY GOOD OPTICAL SURFACE TO BE (PAINSTAKINGLY) GROUND, NOT FOUR AS IN ACHROMATIC (2 ELEMENT) LENSES
3. CAN RECOAT MIRROR SURFACE EASILY WITH HIGHLY-REFLECTIVE ALUMINUM
4. LENS HAS TO BE OPTICALLY PURE AND HOMOGENEOUS THROUGHOUT, BUT MIRRORS CAN BE OF ANY MATERIAL THAT HOLDS ITS SHAPE
   FUSED QUARTZ, ZERO EXPANSION PYROCERAMICS

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!

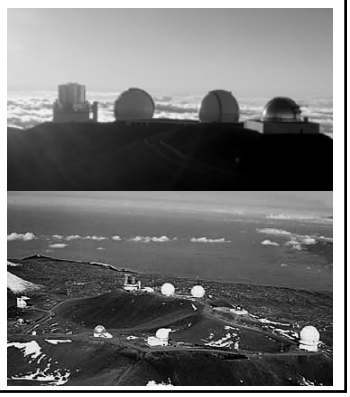
Stop "uplight", glare: wastes billions of $$ in energy, use "low pressure sodium"

Several famous observatories are now useless…

LA Basin View from Mt. Wilson Observatory, 1908 and 1998

Quest for Good Weather and Seeing

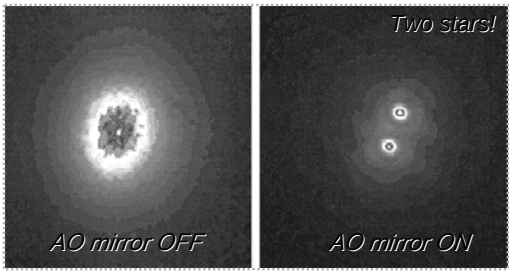
- Mauna Kea, Big Island of Hawaii, 14,000' elevation, middle of the Pacific
- Dry, high, dark and isolated. Best on the planet?



Sites in Arizona, Chile, Canary Islands, Europe….

Adaptive Optics (AO) – "de-twinkle" stars

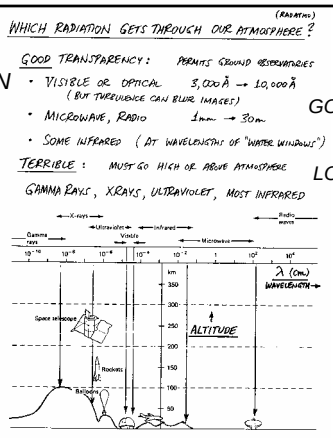
- Wavefronts of star light are deformed by atmosphere
- Can distort shape of mirror (very fast) to correct for distortions by atmosphere – *hot new technology*



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

Which RADIATION gets through our ATMOSPHERE ?

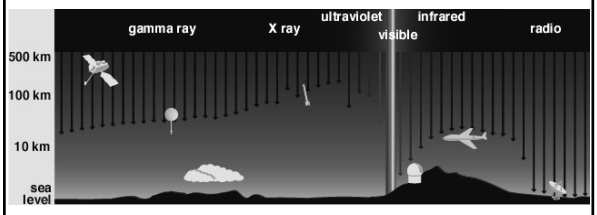


GOOD

LOUSY

Atmospheric Absorption of "Light"

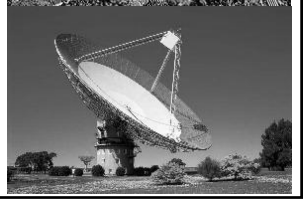
- Earth's atmosphere absorbs most types of light (not entirely bad, or we would be dead!)
- Only visible, radio, and some IR and UV light get through to the ground



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

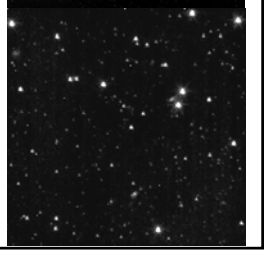


Infrared Telescopes

- *INFRARED* can be absorbed by molecules like H_20, CO_2, 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 <u>Infrared</u> 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

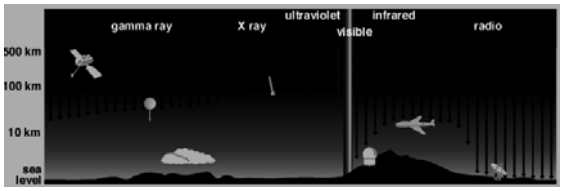


UV, X-rays and Gamma-rays

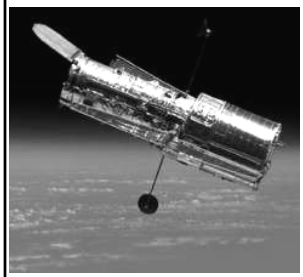
- These all have enough energy to ionize electrons out of atoms or break apart molecules

  → Heavily absorbed by the atmosphere

- Space or high altitude (balloon, rocket) observatories are necessary



Space Based Telescopes



Hubble Space Telescope (HST) optical, UV

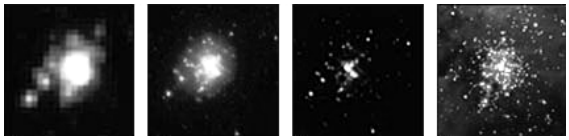
Chandra X-ray Observatory

- *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)

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)



A *B* *C* *D*

HUBBLE TROUBLE

repaired by astronauts inserting corrective optics from Boulder