Top Ten Signs
Your Astronomy Instructor May Be Nuts
as enumerated by Prof. Lee Carkner, Augustana College

10) The title of every lecture is: "Man, Them Stars is Hot!".
9) His so called "telescopes" are really just paper towel rolls covered in aluminum foil.
8) To illustrate the vastness of the universe, he makes everybody walk to De Moines.
7) Thinks he's married to the overhead projector.
6) Your grade is based entirely on how many ping-pong balls you can fit in your mouth.
5) His so called Drake Equation video is really just an old episode of Alf.
4) He makes everyone wear a soup pot on their head to protect the class from "Klingon mind control lasers".
3) About 90% of all classes involve dressing monkeys up to look like Jan Oort.
2) When you go to his office hours he is always hiding under the desk so that the "space squirrels" can't get him.
1) The only observing advice he ever gives is, "Keep an eye out for the mothership."

- Next homework due Oct 24th– this Friday at 11:50 am.
- There will be another make-up nightime observing session in November. Stay tuned.

Outline

- Light. What is a spectrum?
- Infrared Light
- The windows of the atmosphere.
- All you wanted to know about telescopes, but were afraid to ask.
  - Light gathering
  - Resolution
  - Magnification
- Reflectors
- Refractors

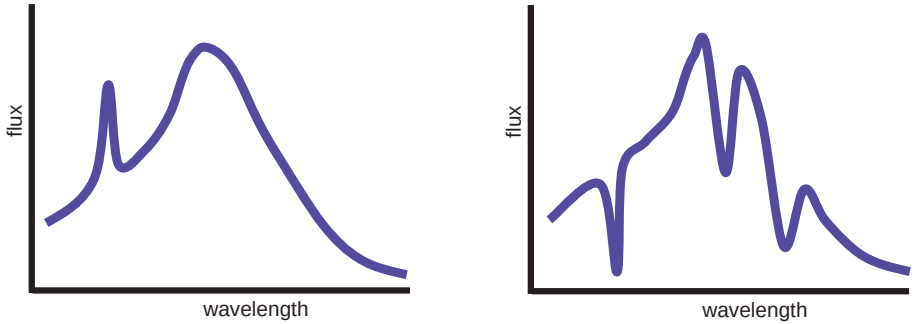
Last Time:
Decoding Starlight

Light is an Electromagnetic Wave

- Wavelength λ = ***color***
- Intensity = ***brightness***

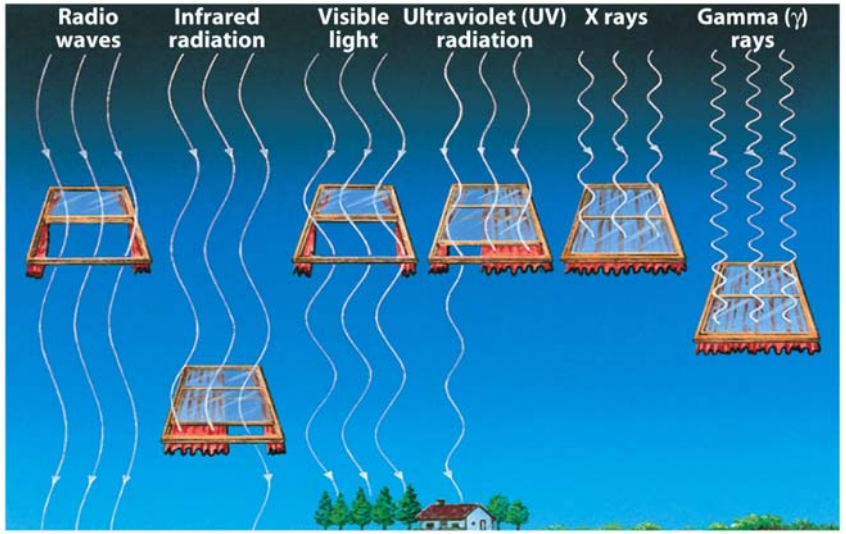
The spectrum

The "spectrum" of a light source also refers to the fractional contribution of all of the different wavelengths to its total light output.



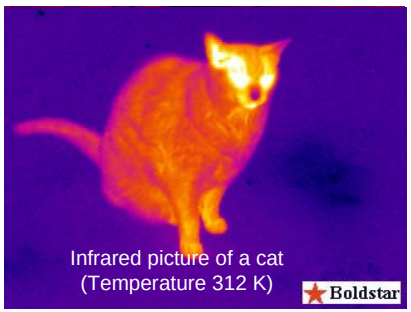
Emission **Absorption**

The atmosphere absorbs some wavelengths and not others



Blackbody Radiation

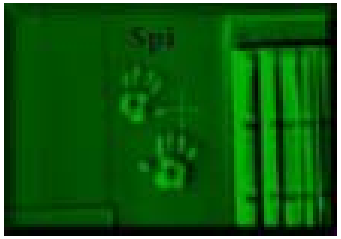
- Light that objects emit because of their temperature is called **blackbody radiation**
- Blackbody radiation is composed of a continuous spectrum of wavelengths
- The **hotter** an object gets, the **more intense** and **shorter wavelength** (bluer) its blackbody radiation becomes



Visible-light picture of a stove element
(Temperature ~ 400 K)

Glowing Bodies

- So, everything we know is in fact giving off light– as long as it has a temperature, it is glowing.
- The higher the temperature the shorter the wavelength it glows in– compare the person in the bottom left (near infrared) and a light bulb (in the visible).



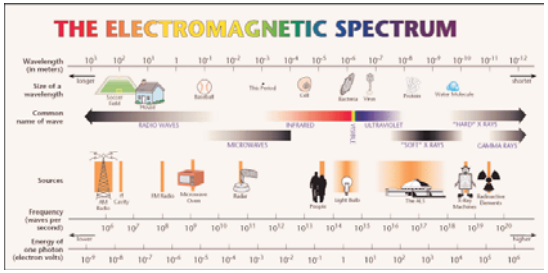
http://www.x20.org/thermal/thermal_weapon_sight_TIWS320.htm

We need telescopes to observe Starlight



The Electromagnetic Spectrum

- Electromagnetic waves can have wavelengths outside of visible range
- Astronomical objects usually emit light at many wavelengths
- *Need telescopes which work at these wavelengths*

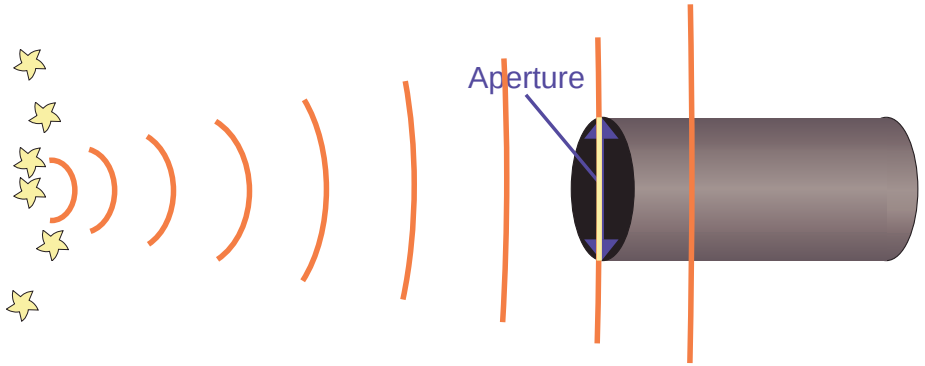


Telescopes: Requirements

- Need to gather as much light as possible
- Extract maximum possible information
  - Form image
  - Take spectrum

Telescopes

- A **telescope** collects light
- The larger the **aperture**, the more light can be collected in a given amount of time



Telescope Functions
1. *Light Gathering*

- Top priority since most celestial objects are dim
- Collect, concentrate light
- Telescope is “light bucket"

- Key: collecting area
- Human eye– few mm,
- Keck telescope– 10 m
  - 10 million times larger than eye
  - Can see things 10 million times fainter than eye can!

Telescope Functions
2. *Resolution*

Want to reveal details of objects

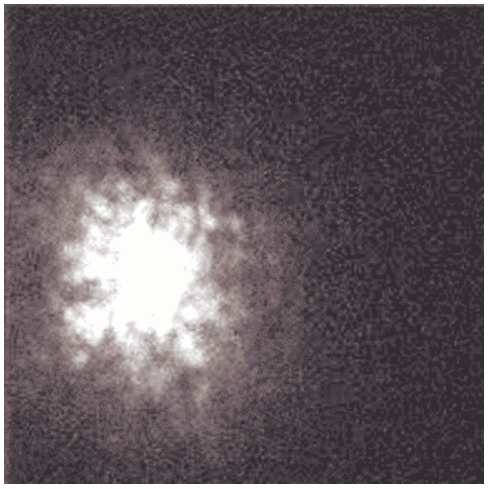
Angular resolution:

- Measures finest detail that is not smeared out
- Smallest angle for which two stars aren’t smeared together to one
- e.g., human eye resolution = 1 arc min = 1/60 deg
- Hubble telescope resolution < 0.1 arc sec
  (1 arc sec = 1/60 arc min = 1/3600 deg)

2. *Resolution–*
Twinkle, Twinkle, Little Star

Note: turbulence in the atmosphere “jiggles” image

- As seen from ground: star “twinkle”
- Additional smearing for ground-based telescopes



http://antwrp.gsfc.nasa.gov/apod/ap000725.html

Telescope Functions
3. *Magnification*

make image larger

often least important issue

- no good to magnify blurry image

Size Matters

- All of telescope functions
  - Light collecting
  - Angular resolution
  - Magnification
- **Improve** as the **diameter** of the scope– its lens or mirror– **increases**
- *Bigger is better*!

Focusing

For distant objects: light rays arrive in parallel

Telescope job:
- ✓ collect rays over large area
- ✓ focus to a point
- ✓ then re-straighten over smaller area: brighter

Telescope Types

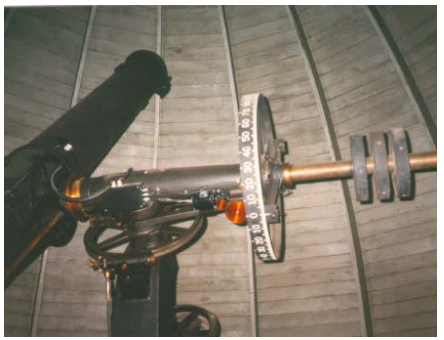
- Optical (visible light)
  - Refracting
  - Reflecting
- Radio, infrared, ultraviolet
  - Reflecting
- X-ray
  - Reflecting (grazing incidence)

Refracting Telescopes

Refraction
- Bending of light rays
- when go from air to water, air to glass, etc.

Lens
- Curved glass
- Light bent to focus

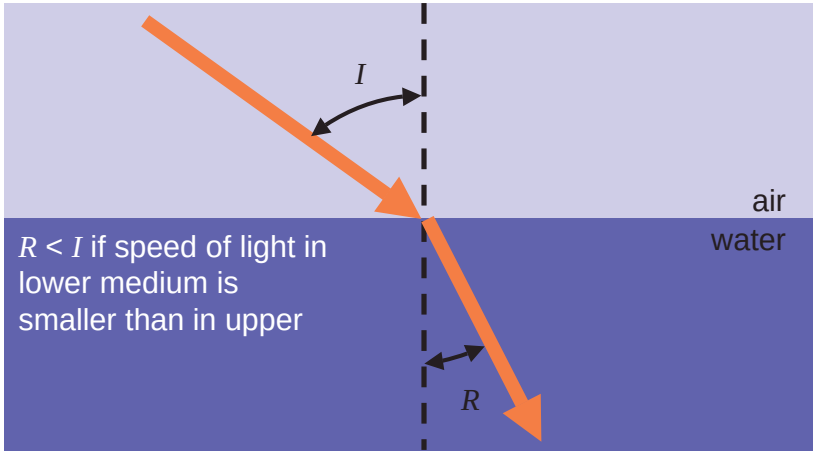
Problems:
- Spherical aberration
  - Spherical lens gives imperfect focus
- Sag
  - Large lens distorted as hangs
  - Limits lens size
- Limited wavelengths



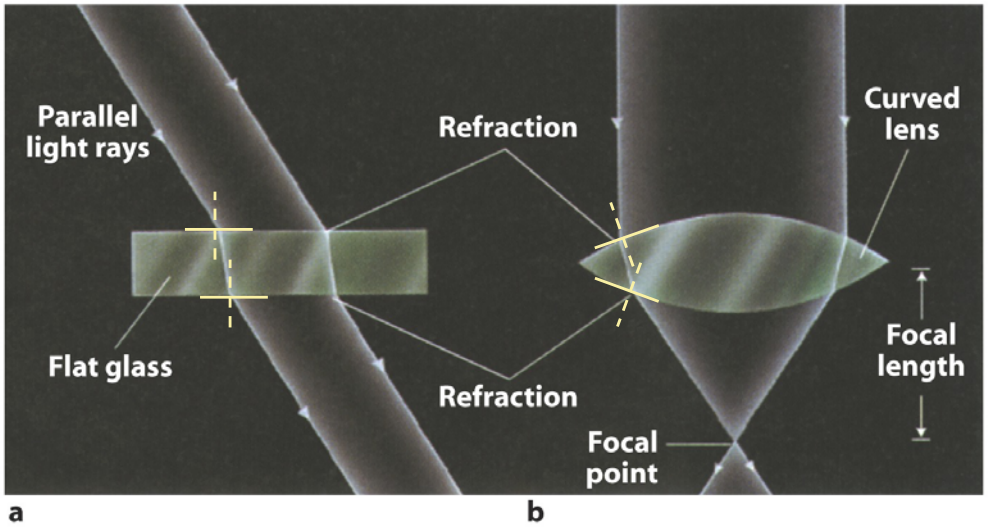
The Mighty UIUC 12-inch refractor

Refraction

- Light travels more slowly in transparent materials than it does in vacuum
- When passing from one medium to another (e.g. air to water), light is bent (**refracted**)

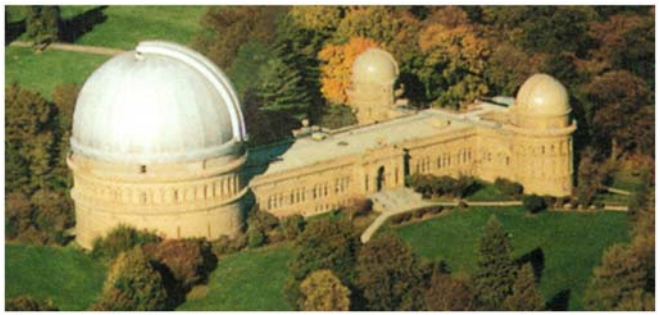


Refraction by plates vs. by lenses

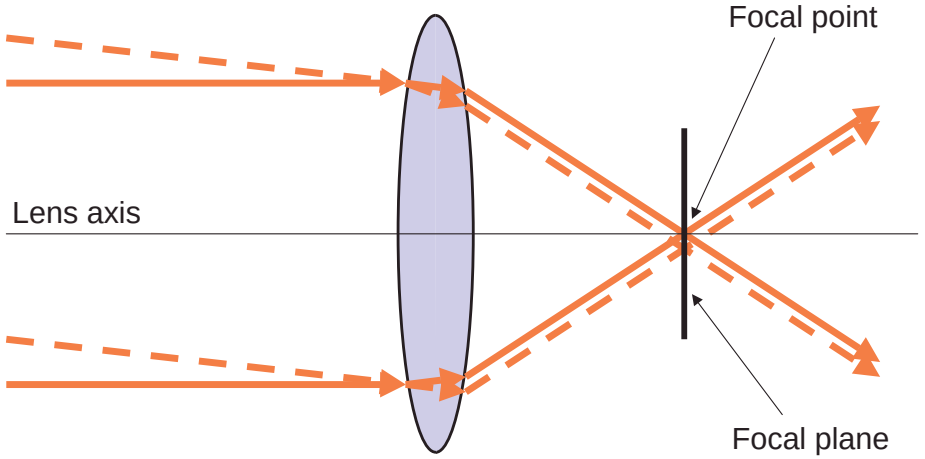


Yerkes Observatory, Williams Bay, WI

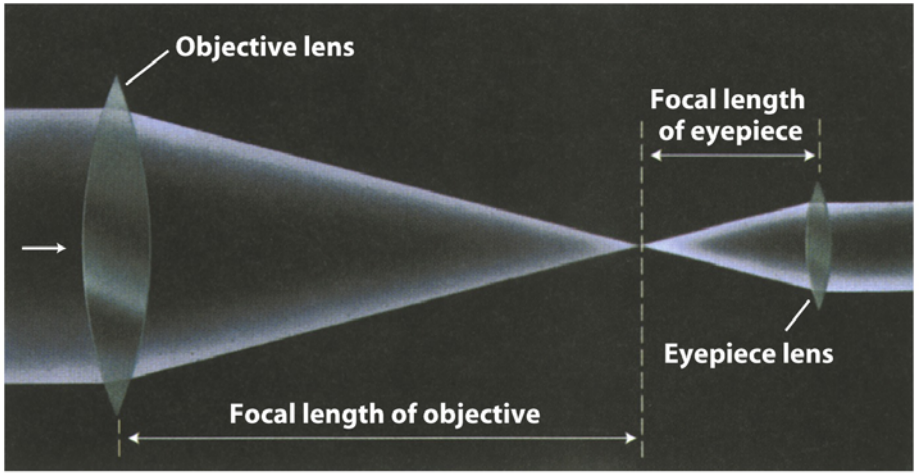
- 40-inch refractor
- Completed 1897
- Still largest refractor in the world



Focusing by lenses



A refracting telescope uses at least two lenses



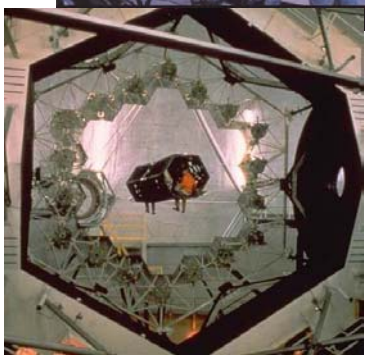
Reflecting Telescopes: Mirrors

curved mirror can focus

- Sag: no problem
  can support from below
- Spherical aberration
  still a problem

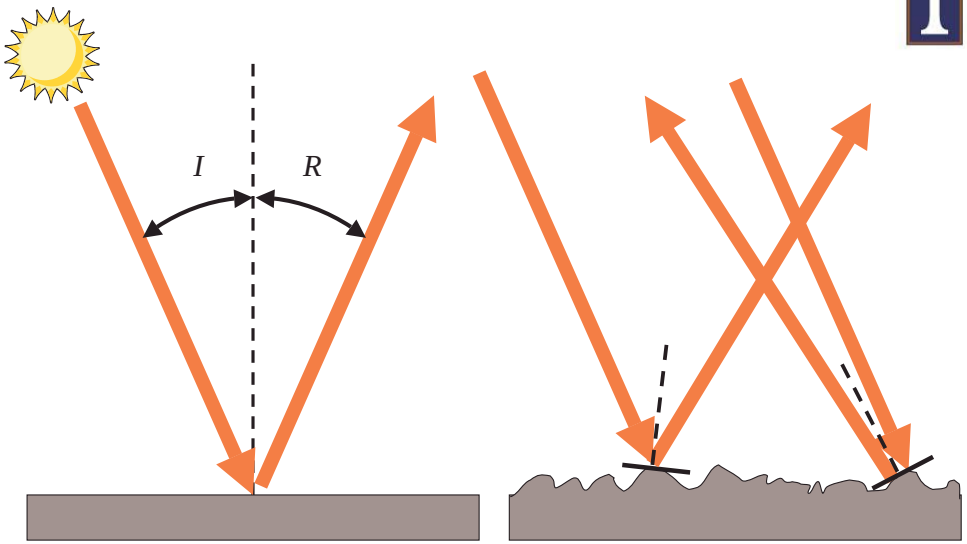
Hubble Telescope Mirror (2.4 m)

For the last century all large professional telescopes are reflectors



Keck Telescope Mirror (10m)

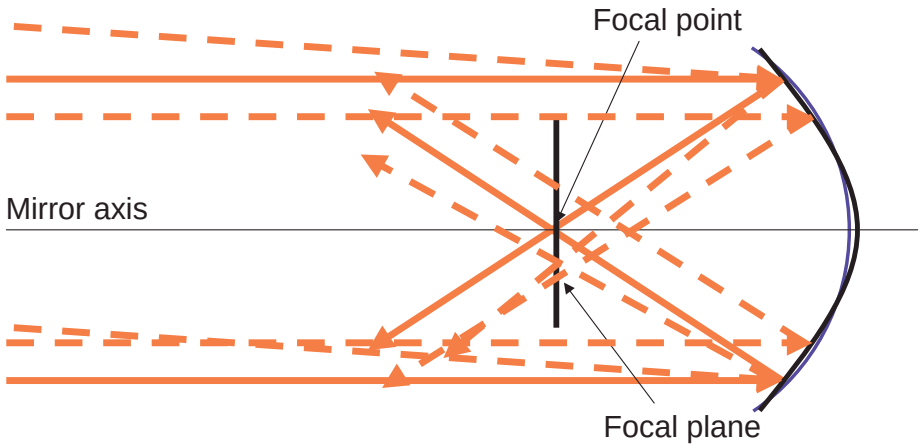
Reflection



Smooth surface **Rough surface**

Angle of incidence I = Angle of reflection R

Focusing by mirrors



Spherical aberration

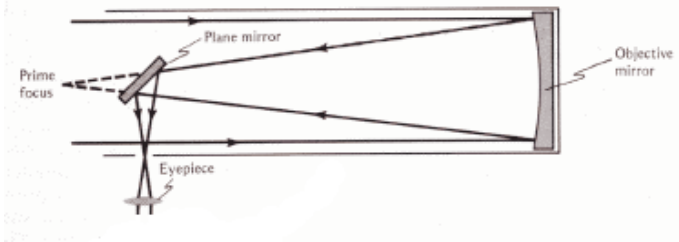
Occurs when section of a sphere is used instead of a paraboloid

Keck Observatory, Mauna Kea, HI

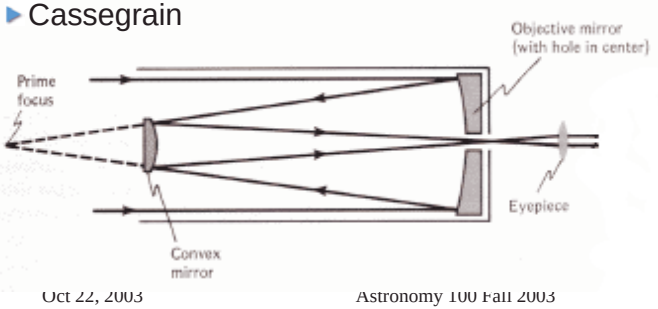
- Twin 10-meter reflectors
- Completed 1993 & 1996
- Largest reflectors in the world

Reflecting telescope designs

- Newtonian

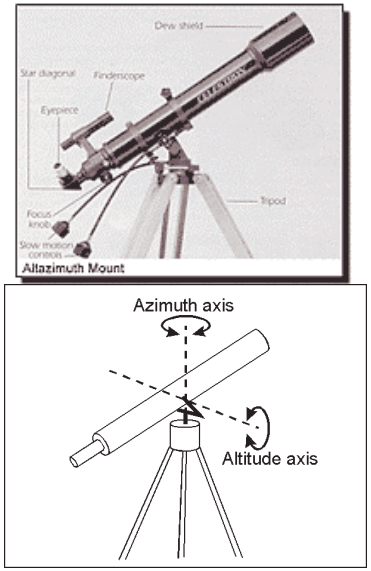


- Cassegrain

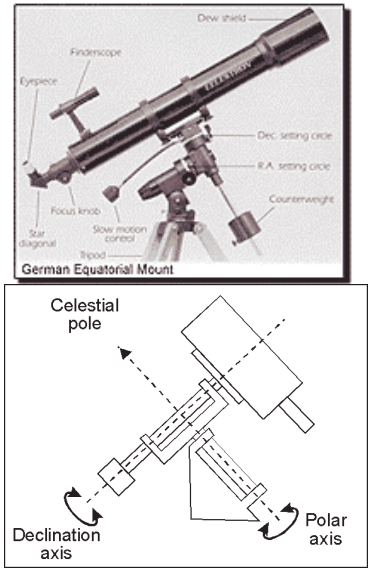


Telescope mounts

Altitude-azimuth (alt-azimuth)



Equatorial

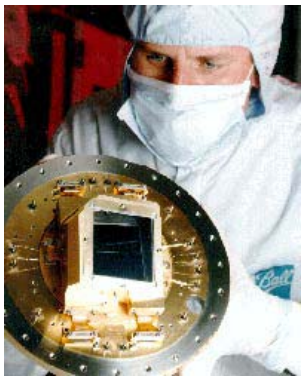


Light Detection

Once light collected need detector

human eye
- least sensitive
- no permanent record

photographic film
- telescope as camera
- accumulates light: see dimmer objects
- gives permanent record



Hubble Telescope CCD

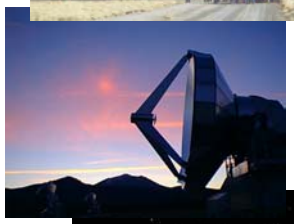
Electronic “film” (CCD)
- much more sensitive
- detector of choice!
- all modern professional astronomy done this way
- bonus: digital data great for computers!

"Invisible" Astronomy

Want to measure all EM radiation
- not just visible light

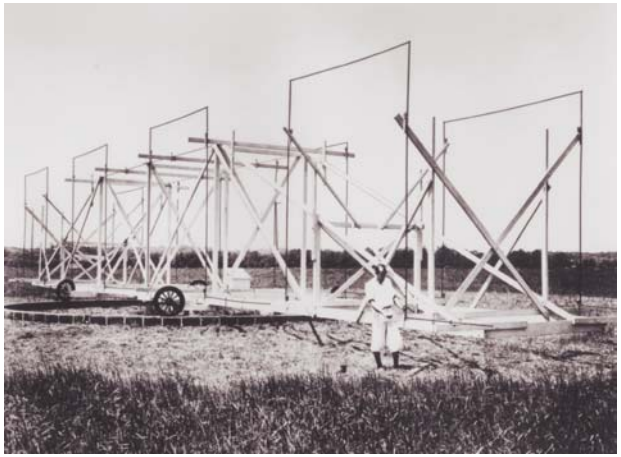
ex: radio waves
- emitted by planets, stars, gas
- measure with "radio telescopes"
- large radio antennas

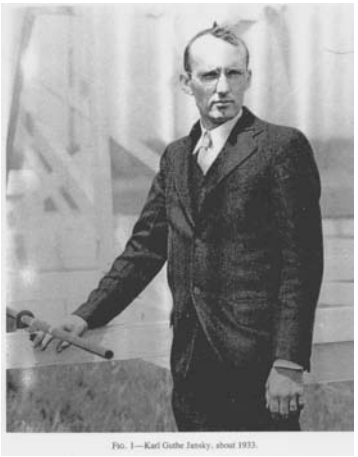
also X-rays, high-energy gamma-rays
- Can't do this on ground
  - absorbed in the atmosphere
- Have to go to space
- Use satellites in orbit
  - With detectors made of lead, crystals



Radio telescopes

First detection of cosmic radio sources by Karl Jansky at Bell Labs (1932)



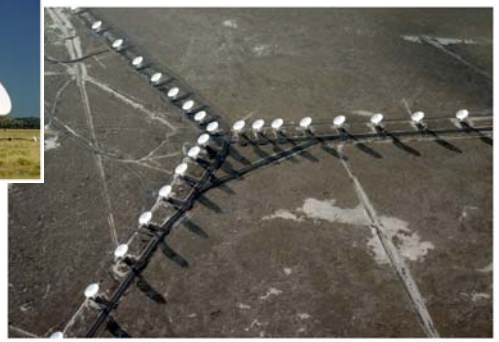


Radio telescopes

Pioneering work by Grote Reber (died 2002)

Arecibo Observatory, Puerto Rico

Very Large Array, near Magdalena, NM



BIMA

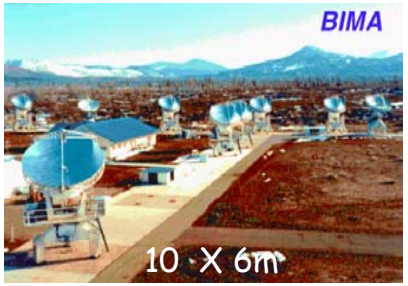
A millimeter array of telescopes owned and operated by UC Berkeley, UIUC, and UMd in Hat Creek, California. Wavelength of 3 millimeters – frequency of 115 GHz. Works night and day. Why?

BIMA

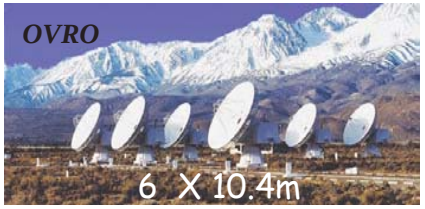
BIMA

BIMA

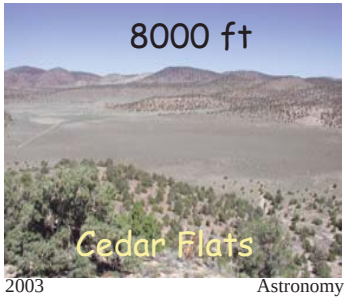
The Future -- 2005



+



+



=

CARMA

Combined Array for Research in Millimeter-Wave Astronomy