

## Telescopes

- The science of astronomy was revolutionized after the invention of the telescope in the early 17th century
- Telescopes and detectors have been constantly improved over time in order to look at fainter and more distant objects
- A telescope can be thought of as a 'light bucket' - collecting and gathering photons into a useful image

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## Optical Telescope Design

- Telescopes must be able to collect light and concentrate it to a single point, or focus
- Traditionally, optical telescopes (which gather visual light) have used either lenses or mirrors to focus light
- A reflecting telescope uses mirrors
- A refracting telescope uses lenses

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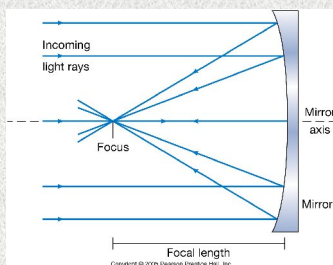
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## Reflecting Telescope

- A reflecting telescope uses a series of mirrors to bring light to a focus
- The largest mirror is called the primary
- The mirror surface is curved such that all light will be bounced back to a single point
- No matter where light hits the mirror, it should reflect to the focus



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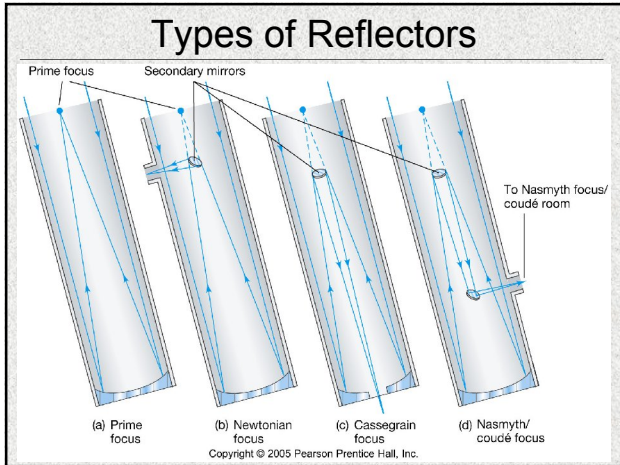
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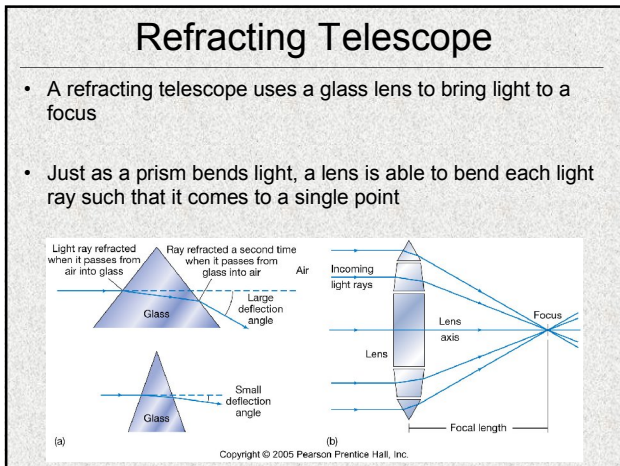
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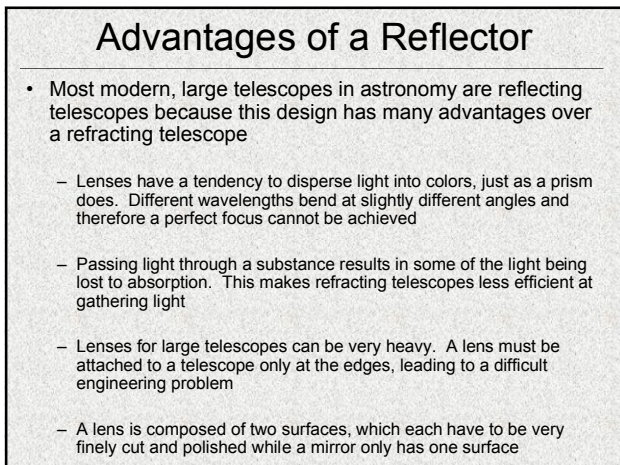
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## Detectors

- The job of the telescope is to collect the light, but another device must be used to form an image
- In the early days of astronomy, film or emulsion plates were used to form an image
  - Chemical reactions occur when light strikes the surface (old film cameras)
- Over the past couple decades, image acquisition has been revolutionized by the invention of charge-coupled devices (CCD's)

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## CCD's

- Charge-coupled devices are small arrays of silicon (just like your digital camera)
- Each unit of the array is a picture element, or pixel
- When a pixel is hit by a photon, an electrical charge is created
- The amount of light directly corresponds to the strength of the built up charge
- The array is then read out with each pixel carrying a charge
- A computer then translates this charge information into an image

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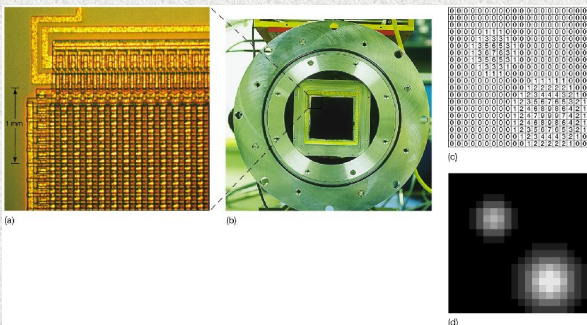
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## CCD's



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## Advantages of CCD's

- Charge-coupled devices are much more efficient at trapping light than film or plates
  - This gives astronomers the ability to see much fainter objects
  - Also, it takes less time to expose on a given object
- Since the information is already digital, it is much easier to transfer and analyze

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## Types of Measurement

- *Astrometry* - the precise measurement of an object's position over time (parallax, proper motion, planetary motion, etc)
- *Photometry* - the measurement of an object's brightness over time (how many photons is the object emitting)
- *Spectroscopy* - the measurement of an object's spectra (what is the object made of? how fast is it moving?)

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## Does size matter?

- In general, the bigger the telescope, the better observations you can make
  - The bigger the bucket, the more photons you can catch
- The light gathering power of a telescope is directly proportional to its collecting area
- If you double (2X) the diameter of your mirror (or lens), you quadruple ( $2^2 = 4X$ ) your light gathering ability

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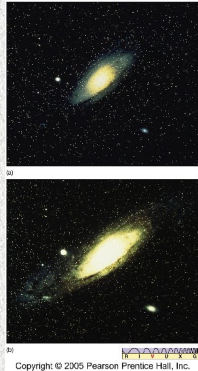
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## Light-Gathering Power

- The images to the right are of the Andromeda Galaxy
- Each was taken using the same exposure time
- The bottom picture was taken with a telescope twice as large as the top picture



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## Resolving Power

- Resolution is a measure of a telescope's ability to distinguish two very close objects as separate entities
  - From 100 yards, you can't tell whether someone is holding up 2 fingers or four
- The larger the telescope, the easier it is to separate objects into two distinct shapes
- In astronomy, we wish to see as many of the small details as possible

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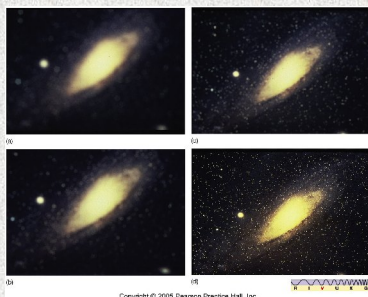
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## Resolving Power

- Again, each image to the right is of the Andromeda galaxy, but each at a different resolution
- Resolution is usually expressed as the smallest angle where two objects can still be distinguished
- The sequence at right goes from resolutions of 10', 1', 5" and 1"
  - The smaller, the better



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## Atmospheric Limitations

- The main obstacle to astronomical observations on the Earth is our atmosphere
- As we saw earlier, the atmosphere blocks out many wavelengths of light (ultraviolet, X-ray, gamma rays)
- The atmosphere also blurs and smears images through turbulence
  - Think about the wavy pattern seen over hot blacktop

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## Atmospheric Seeing

- Turbulence and currents in the atmosphere spread out the light from the stars
  - What should be a pinpoint of light becomes a small disk
- The term seeing is used to describe the atmospheric conditions
  - Less disturbance in the atmosphere results in better seeing conditions
- This is why most major observatories are located at high elevations or very dry areas
  - Kitt Peak (Arizona), Mauna Kea (Hawaii), Andes Mnts (Chile)

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## Telescopes at Other Wavelengths

- In the last century, many telescopes have been built to monitor other wavelengths of light
- Many of these instruments were not intended for astronomical use
  - Scientists investigating sources of radio noise (static) found that objects in the sky (and the sky as a whole) emitted radio waves
  - Satellites searching for illegal nuclear tests discovered astronomical objects which emit gamma rays

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## Radio Telescopes

- Radio waves are relatively unaffected by the Earth's atmosphere, clouds, rain, and even sunlight
- This means radio astronomer can observe at almost any time, during the day/night, clouds, rain, etc

Green Bank,  
West Virginia



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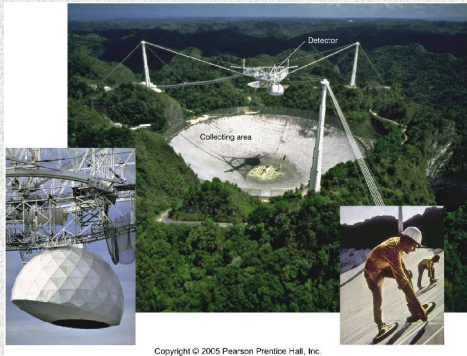
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## Radio Telescopes



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Arecibo Observatory, Puerto Rico

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## Space Telescopes

- Most wavelengths around the infrared, ultraviolet, X-ray, and gamma rays are inaccessible on Earth
- The past few decades has seen a flurry of space telescopes dedicated to making observations at these wavelengths
- Outside the atmosphere, there are relatively few restrictions on what you can observe

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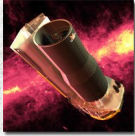
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## Space Telescopes



Infrared  
Spitzer Space Telescope



Visible - Ultraviolet  
Hubble Space Telescope



X-Ray  
Chandra Telescope

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## Interferometry

- One way astronomers can gain resolving power is to combine the information from an array of many telescopes
- Two smaller diameter telescopes placed a mile apart can provide the resolution of a telescope with a mile diameter
- With proper precautions, the light from the two telescopes can be brought together and create an interference pattern
  - If the light is in phase, constructive interference occurs and the signal is strengthened
  - If the light is out of phase, destructive interference occurs and the signal is canceled out

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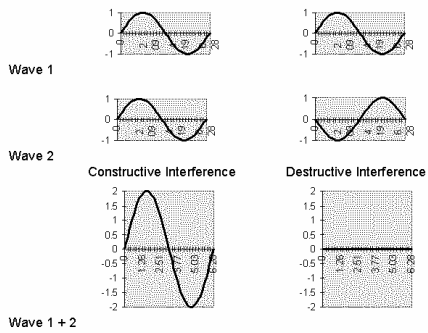
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## Interference

• If you have more than one wave, or if one wave is split into pieces and recombined, then the waves can add together. The two extreme cases are *Constructive Interference*, where the waves are in phase and they add up together, and *Destructive Interference*, where the two waves are exactly 180° out of phase and they cancel each other out.




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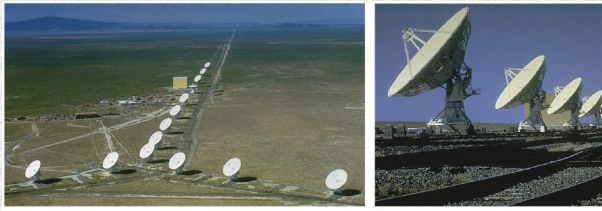
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## Radio Interferometers



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The Very Large Array (VLA), New Mexico

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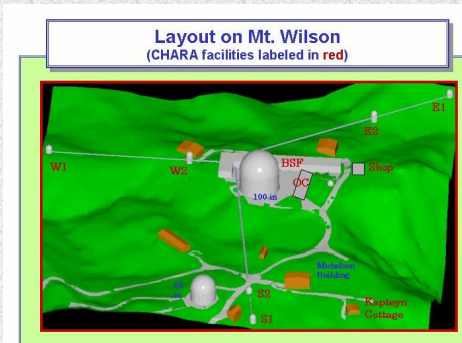
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## Optical Interferometers

Center for High Angular Resolution Astronomy

CHARA was built by GSU and is the most powerful optical interferometer in the world



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