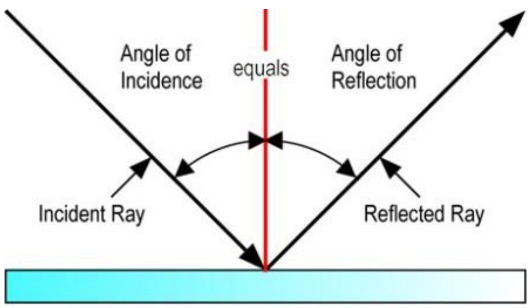
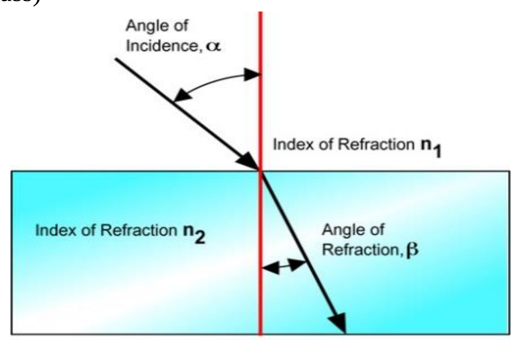
Chapter 3
Telescopes
The Tools of Astronomy

3.1 Optical Telescopes

- A Telescope is a device whose primary function is to capture as much radiation as possible from a given region of the sky and concentrate it into a focused beam for analysis.
- Reflecting and Refracting Telescopes
  - Optical telescopes fall into two categories
    - Reflecting Telescopes use a curved mirror to gather and concentrate a beam of light
      - Reflection is the bouncing of radiation off a reflective surface (like a mirror)
    - Refracting Telescopes use a lens instead of a mirror to focus the incoming light
      - Refraction is the bending of a beam of light as it passes from one transparent medium (like air) into another (like glass)

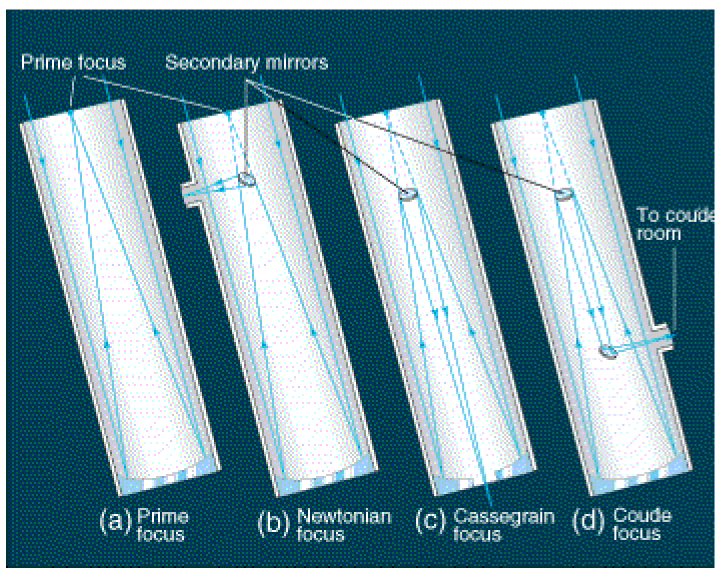


Reflection of Light



Refraction of Light

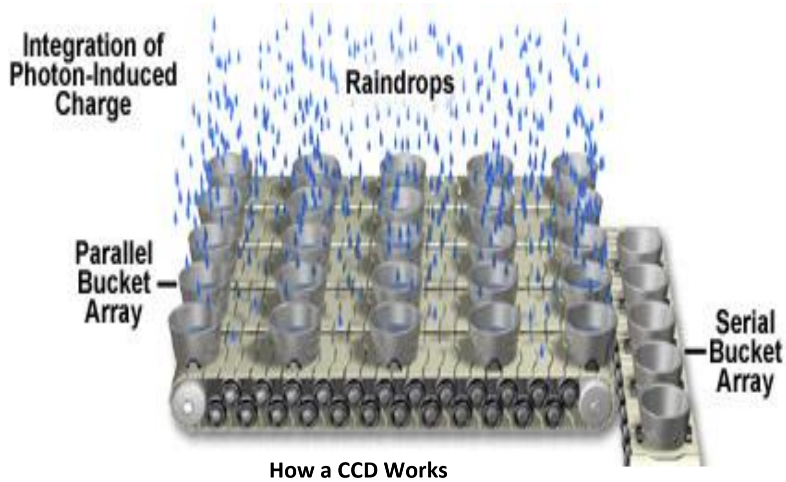
- Types of Reflecting Telescopes
  - A Newtonian Telescope is a telescope where the beam of light is intercepted by a flat secondary mirror before reaching the prime focus and is reflected through an eyepiece on the side
    - Must work on the side or above the telescope
  - A Cassegrain Telescope is a telescope where the beam of light reflected by the primary mirror toward the prime focus is intercepted by a convex secondary mirror, sending it back down the tube and through a small hole at the center of the primary mirror.
    - Work from behind the telescope



- Hubble Space Telescope
  - Hubble is a space-based Cassegrain telescope that is the most technologically advanced instrument ever created by the human race.
  - Its ability to see both distances and details is far greater than in the history of mankind and it has led to the rewriting of many theories as well as the creation of new theories due to its remarkable amount of information it can collect.

The Hubble Telescope

- Detectors and Image Processing
    - A Charge-Coupled Device (CCD) is a computer chip that measures the amount of light striking the surface of the chip which creates a charge based on the intensity (amount) of light striking each pixel in the device.
        - Home video and picture cameras have these devices in them that give us the much better resolution images than older "exposure" cameras do.



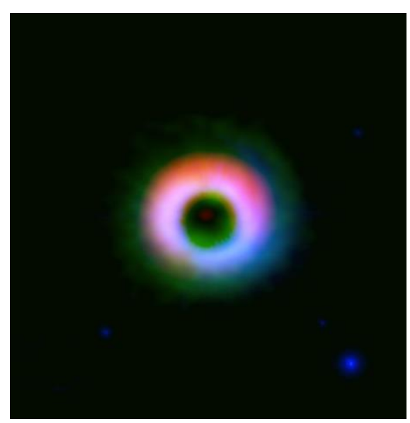
How a CCD Works

3.2 Telescope Size

- Light-Gathering Power
    - Exposure Time is the amount of time spent gathering light from a source
        - The more time spent, the more differences in amount of light coming can separate, allowing us to get a better image of what we see
    - Collecting Area is basically the size of the telescope
        - The bigger the collection area, the more information that is collected, leading to a better image of what we see
            - Because our mirrors are circular, a 5-m mirror will produce 25 times more brightness than a 1-m mirror
- Resolving Power
    - Angular Resolution is the use of angles to help distinguish nearby objects from one another
        - The larger the angle being observed, the greater the parallax, which allows us to have a much better idea of which objects are where, rather than a blur of light.
    - Diffraction-Limited Resolution is the limit of a telescope to resolve an image
        - A combination of the diffraction caused by the size of the mirror and the wavelength of the radiation being measured go into the calculation.
            - Diffraction is directly proportional to the wavelength
            - Diffraction is inversely proportional to the size of the telescope mirror

3.3 High Resolution Astronomy

- Atmospheric Blurring
    - As learned in chapter 2, the atmosphere absorbs and bends light as it travels through the atmosphere, causing blurring when we receive it on the ground
    - Seeing is the term used to describe the effect s of atmospheric blurring
        - A star does not appear as a single point, but rather a single point surrounded by a circle of light, that is just that star's radiation being blurred by the atmosphere.
    - Seeing Disk is the term used to describe the circle that a star's light is spread out over due to atmospheric blurring
        - If there is very little seeing disk, the astronomer would say it is "good seeing"
        - If there is a very large seeing disk, the astronomer would say it is "bad seeing"


Seeing Disk of Object in Space

- New Telescope Design
    - New telescopes are designed to overcome the issues of measuring accurately from our atmosphere
    - Active Optics is the technique of controlling the environmental mechanical fluctuations in the properties of the telescope itself.
        - Controlling airflow and temperature are things that can affect the image of a telescope
        - Telescopes have air-conditioning!!!
    - Adaptive Optics actually deform the shape of a mirrors surface by a computer while the image is being exposed to undo the effects of atmospheric blurring
        - If the computer detects the blurring to increase, it will bend the mirror to counteract the blurring by the atmosphere
        - Similar to your auto-focus on your home camera that will automatically zoom in/out based on the computer detecting the blurriness of the main object in the lens

3.4 Radio Astronomy

- Essentials of Radio Telescopes
    - A Radio Telescope measures the radiation in the radio region of the EM spectrum
        - Radio waves tend to be much more difficult to get resolution from due to their very large wavelengths, so the radio telescopes tend to be very large to try and offset this.

False Color Radio Telescope Image of the Milky Way Galaxy

- The Value of Radio Astronomy
    - False Color is the use of a range of colors to represent information from a non-visible source
        - They use the range of colors from red to blue to indicate severity (strength) of whatever you are looking at.
            - Weather maps use false color to show where the weather is best/worst
- Interferometry
    - Interferometry is a technique used to produce radio images of much higher angular resolution than can be achieved with even the best optical telescopes
        - It is a way of using the destructive and constructive interference measured by different telescopes to improve image
    - An Interferometer is a combination of instruments connected that are measuring the exact same thing in space and using that data to obtain a very detailed resolution of the object being measured
        - Two 1-m radio telescopes connected to one another, yet separated by 50 miles can give the same resolution as a single radio telescope that has a 50 mile diameter!!!
            - The distance between the telescopes becomes the diameter of what would be a very large telescope

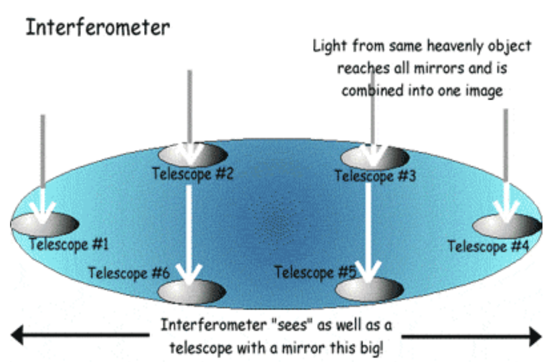
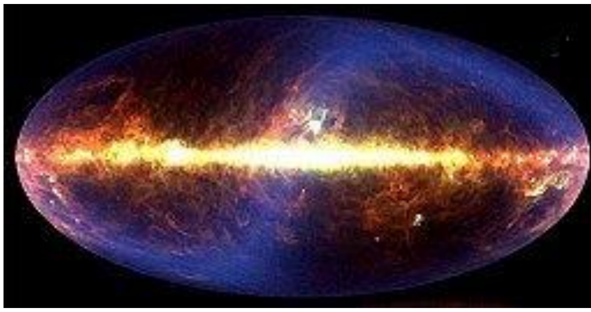


Diagram of How Interferometer Works

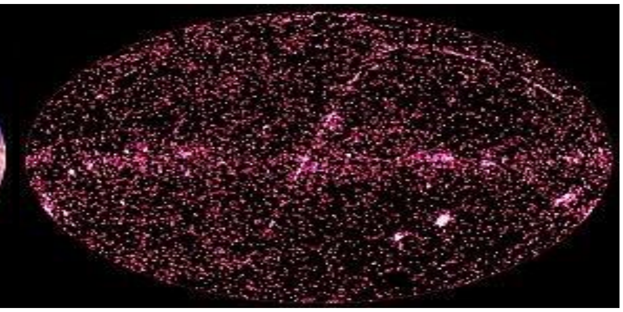
3.5 Space-Based Astronomy

- Remember that the atmosphere absorbs most of the electromagnetic spectrum except for the optical and radio windows
    - Measuring other regions of the EM spectrum require the instrument to be located in space

- Infrared and Ultraviolet Astronomy
    - An Infrared Telescope measures radiation in the infrared range of the EM spectrum
    - An Ultraviolet Telescope measures radiation in the ultraviolet range of the EM spectrum

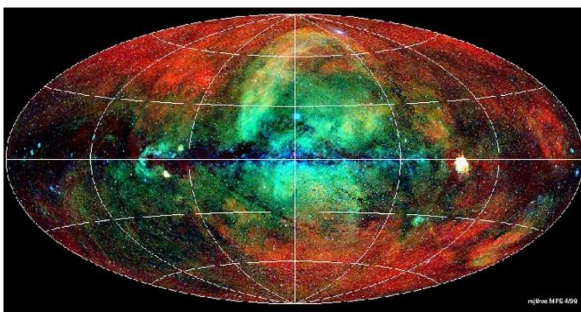


Infrared Image of Milky Way Galaxy

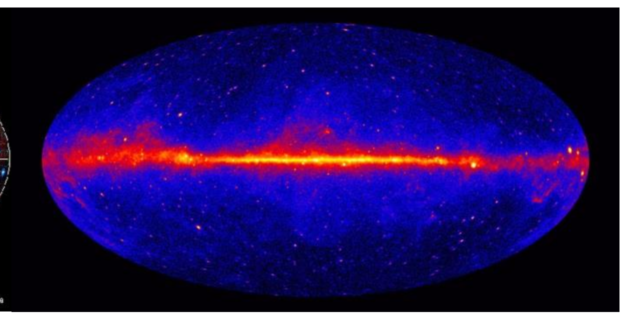


Ultraviolet Image of Milky Way Galaxy

- High-Energy Astronomy
    - A High-Energy Telescope measures the highest energy regions of the EM spectrum
        - Measures X-Rays and Gamma Rays



X-Ray Image of Milky Way Galaxy



Gamma Ray Image of Milky Way Galaxy

- Full Spectrum Coverage
    - The combination of all the different information collected by the different types of telescopes is combined and analyzed giving us a very detailed and accurate view of the Universe to look at
        - All of the things we know about our Universe come from the information we are able to gather using the knowledge of electromagnetic radiation, how it works, and how to collect it.

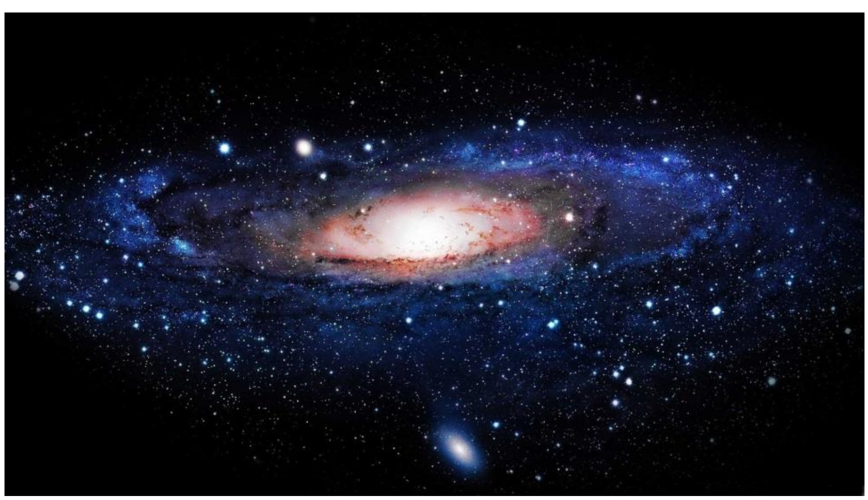


Image of the Milky Way Galaxy