Telescopes

Astronomy

Introduction

Telescopes

- Section 1: Telescopes
- Section 2: Resolving Power
- Section 3: Detecting Light
- Section 4: Telescopes on the Ground and in Space
- Section 5: Observatories

Section 1: Telescopes

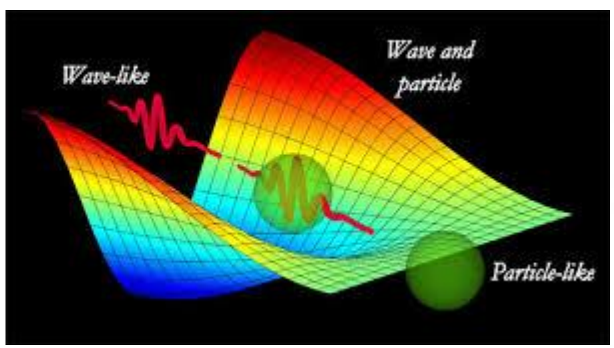
Introduction

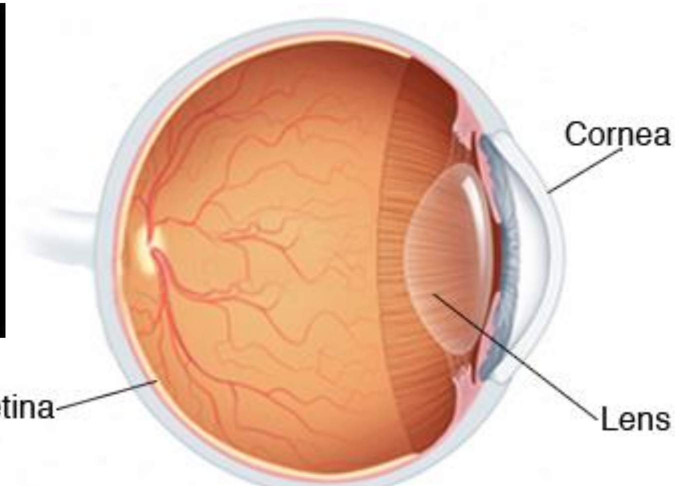
- A telescope enables an astronomer to observe things not visible to the naked eye
  - Human eye sight can't see:
    - Faint objects
    - Fine details
    - Long distances
  - We rely off of light input in order to see images
    - No light = no sight
- Telescopes increase the image details for distances and adds light to help us see

Section 1: Telescopes

Light-Gathering Power

- In order for us to see, *photons* emitted or reflected from it need to strike the retina of the eye
- Photon – particle of light
- We can only see based on the number of photons coming in
- Some telescopes "collect" and "funnel" photons in to our eye

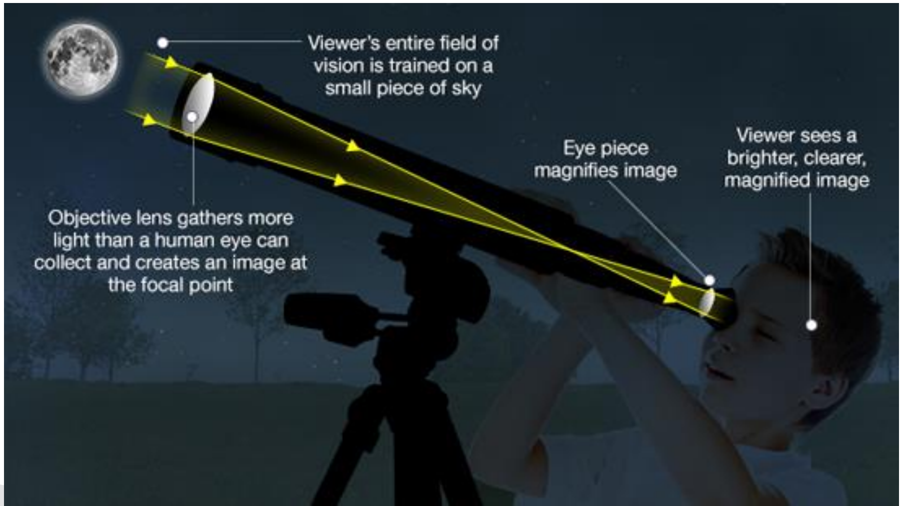




Section 1: Telescopes

Light-Gathering Power

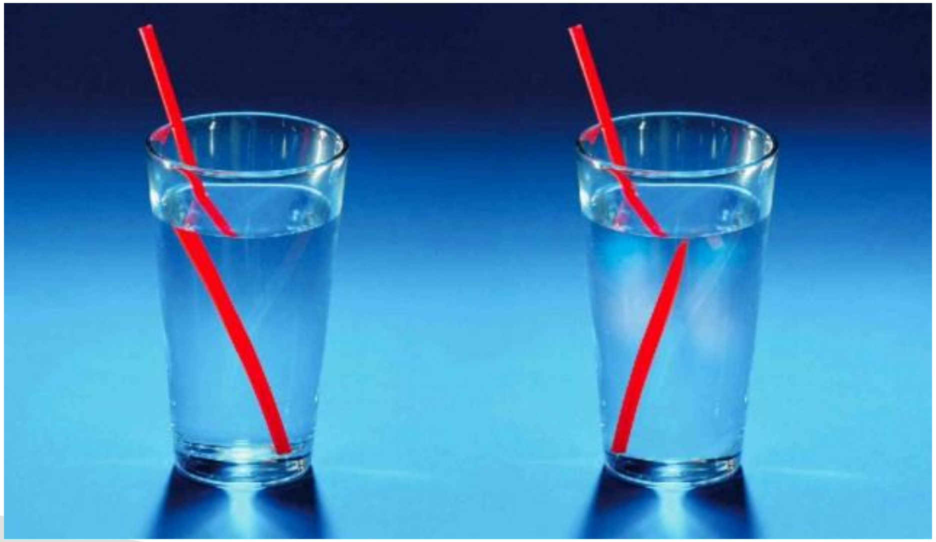
- Light – Gathering Power – a large diameter mirror used in telescopes to help collect and funnel photons
- These give us brighter images
- The bigger the lens or mirror, the more photons can be caught (πr^2)
  - An increase from 4 to 6 m in diameter means a difference in size and capability
    - $2^2 = 4$ compared to $3^2 = 9$



Section 1: Telescopes

Focusing Light

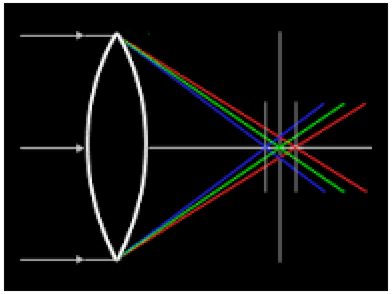
- Once light has been gathered, it needs to be focused
- Refractors – refracting telescopes where light is gathered and focused by a lens
- Refraction – bending of light rays
  - This happens when light moves from one substance to another
    - Ex: air to water

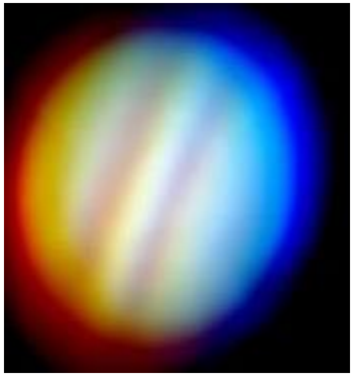


Section 1: Telescopes

Focusing Light

- Having lenses in large telescopes can have disadvantages:
  - Extremely expensive and tough to fabricate (make)
  - The lens has to be connected on the edges and it causes it to sag which distorts the images
  - Transparent materials bring light of different colors to focus at slightly different distances from the lens
    - Chromatic Aberration – color flawed images

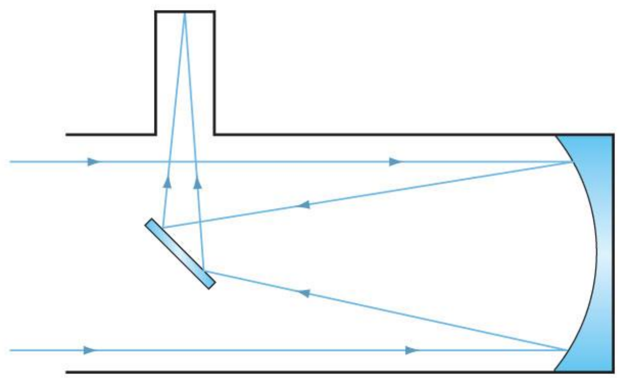


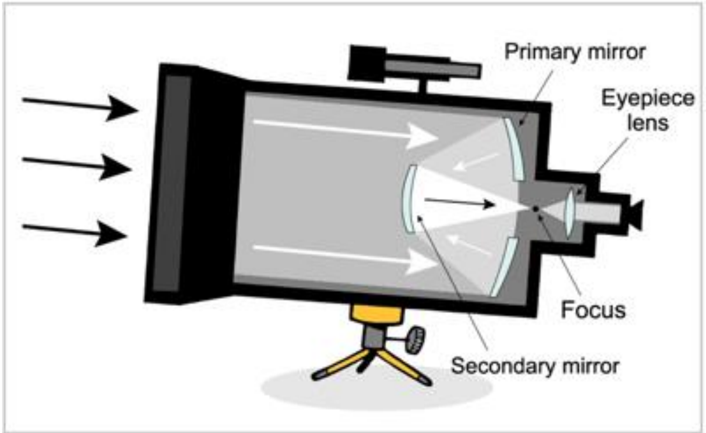


Section 1: Telescopes

Focusing Light

- Having lenses in large telescopes can have disadvantages (cont.):
  - Many lens materials completely absorb short wavelength light
- Most modern telescopes use mirrors to help with the issues lenses cause
- Reflectors – telescopes that use mirrors to reflect light





Section 1: Telescopes

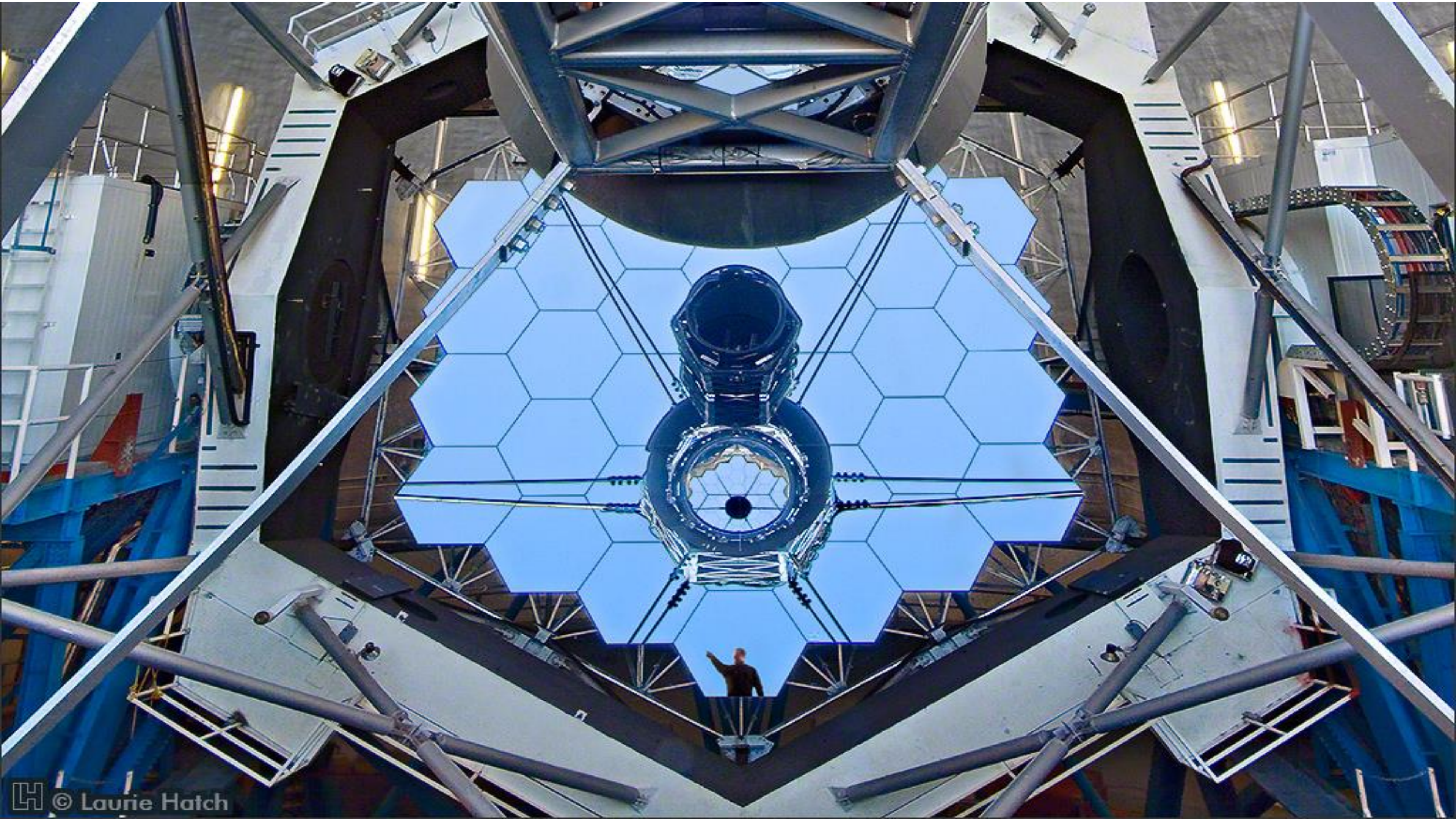
Focusing Light

- The mirrors on reflectors hare made of glass have been shaped to a smooth curve, polished, and then coated with a thin layer of aluminum or some other highly reflective metal
- Because the light doesn’t pass through the mirror, the colors don’t get distorted
- Also, the mirror can be supported from the back and won’t sag

Winner across the board!

Section 1: Telescopes

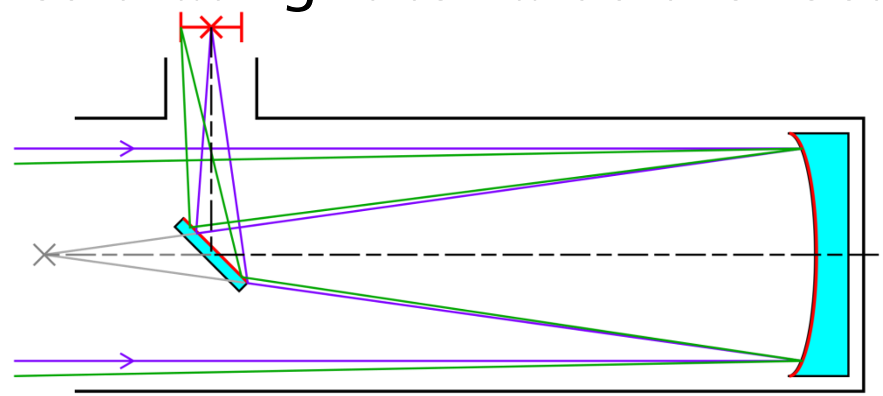
UCLA Galactic Center’s Reflector

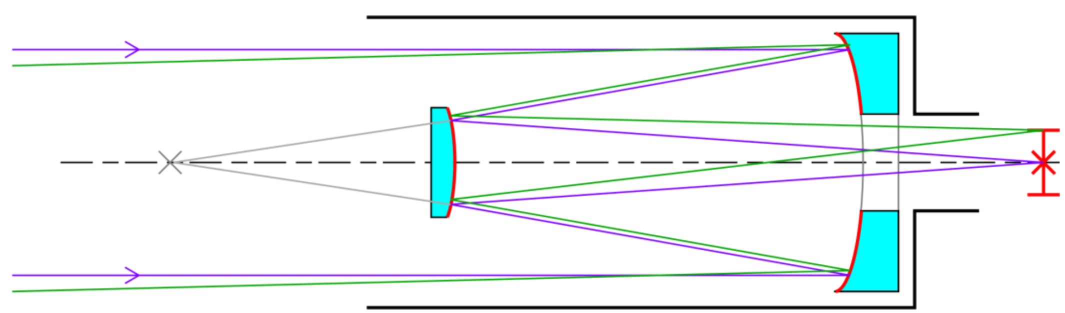


Section 1: Telescopes

Focusing Light

- In order for the mirror system to work, you need at least two of them
  - The primary mirror reflects the incoming light
  - The secondary mirror angles that light towards the focus (eye piece)





Section 1: Telescopes

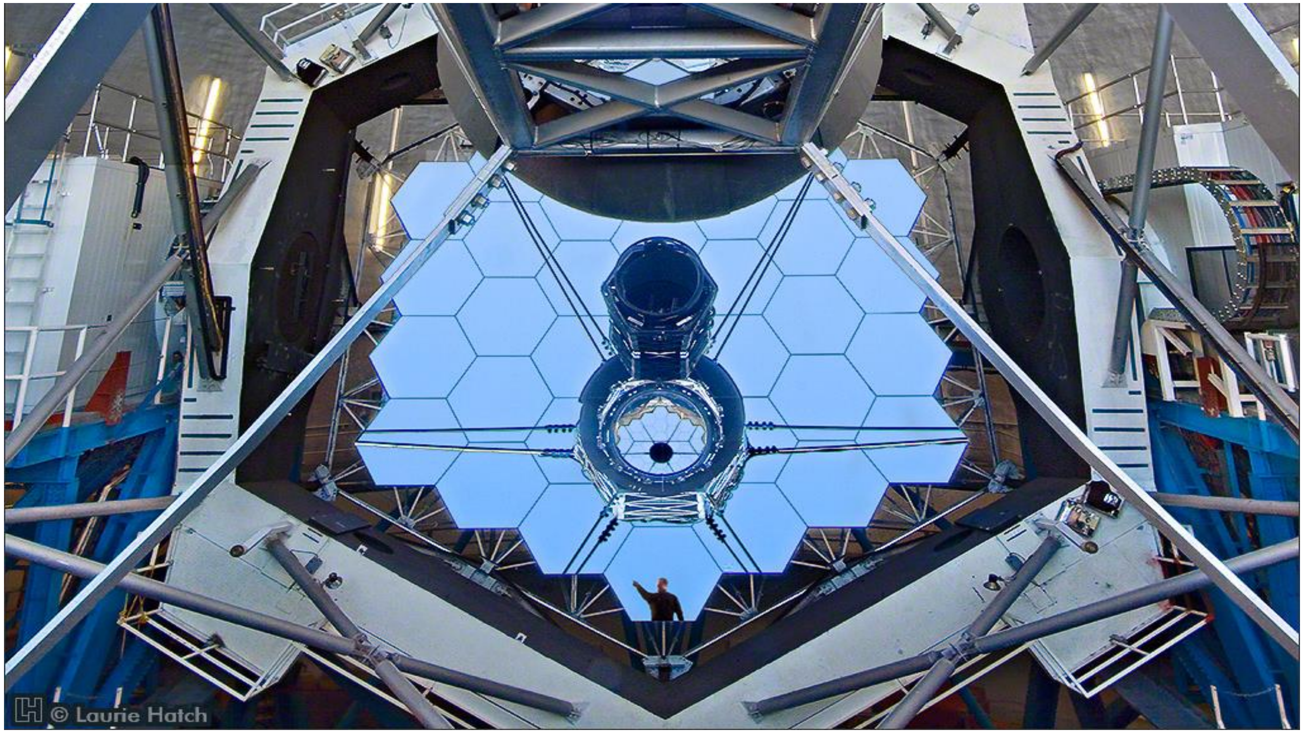
Focusing Light

- Most telescopes are mounted on big pivots that allow them to focus on objects as they travel across the sky
  - trying to get the telescope to move smoothly with all of the mirrors in the correct locations to keep the sharp image is quite a challenge and requires a lot of engineering
- When they move, it causes the glass in the mirror to sag, especially in really big reflectors
- A lot of the current reflectors are using multiple smaller mirrors instead of one large one to fix that problem

Section 1: Telescopes

Focusing Light

- Lasers are used to keep the mirrors aligned properly as the reflector moves



Section 2: Resolving Power

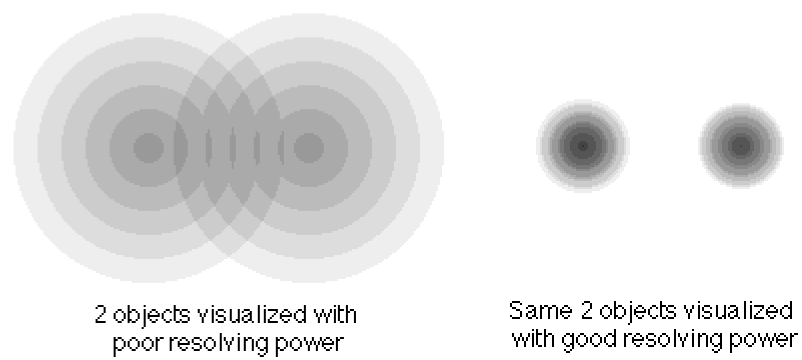
Introduction

- Stars and other objects that lie very close together (land formations on planets, actual planets from far away, etc.) may be two distinct objects but can be visualized through our eyes as one
  - They'll blend or mesh together if small enough or far enough away

Section 2: Resolving Power

Resolving Power

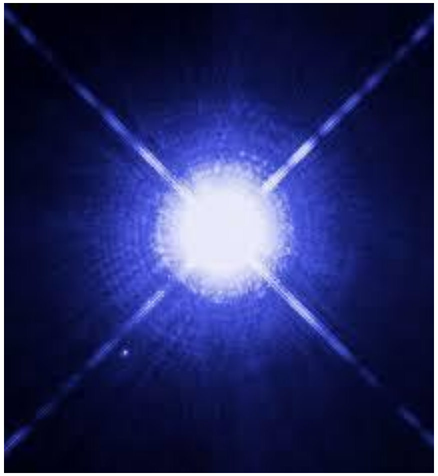
- Resolving Power – a telescope's ability to distinguish objects or details on those objects
- Limited by the wave nature of light
  - Ex: two stars that are only separated by a small angle (from our view) may have light waves that cross (this is why we see them as one), so for the scope to distinguish them, the light waves have to be careful not to cross completely and blend together



Section 2: Resolving Power

Resolving Power

- Diffraction – situation where small, secondary, light waves are produced when bigger ones pass through an opening
- 1 source of light becomes surrounded by rings of secondary light that can even sort by color wavelength



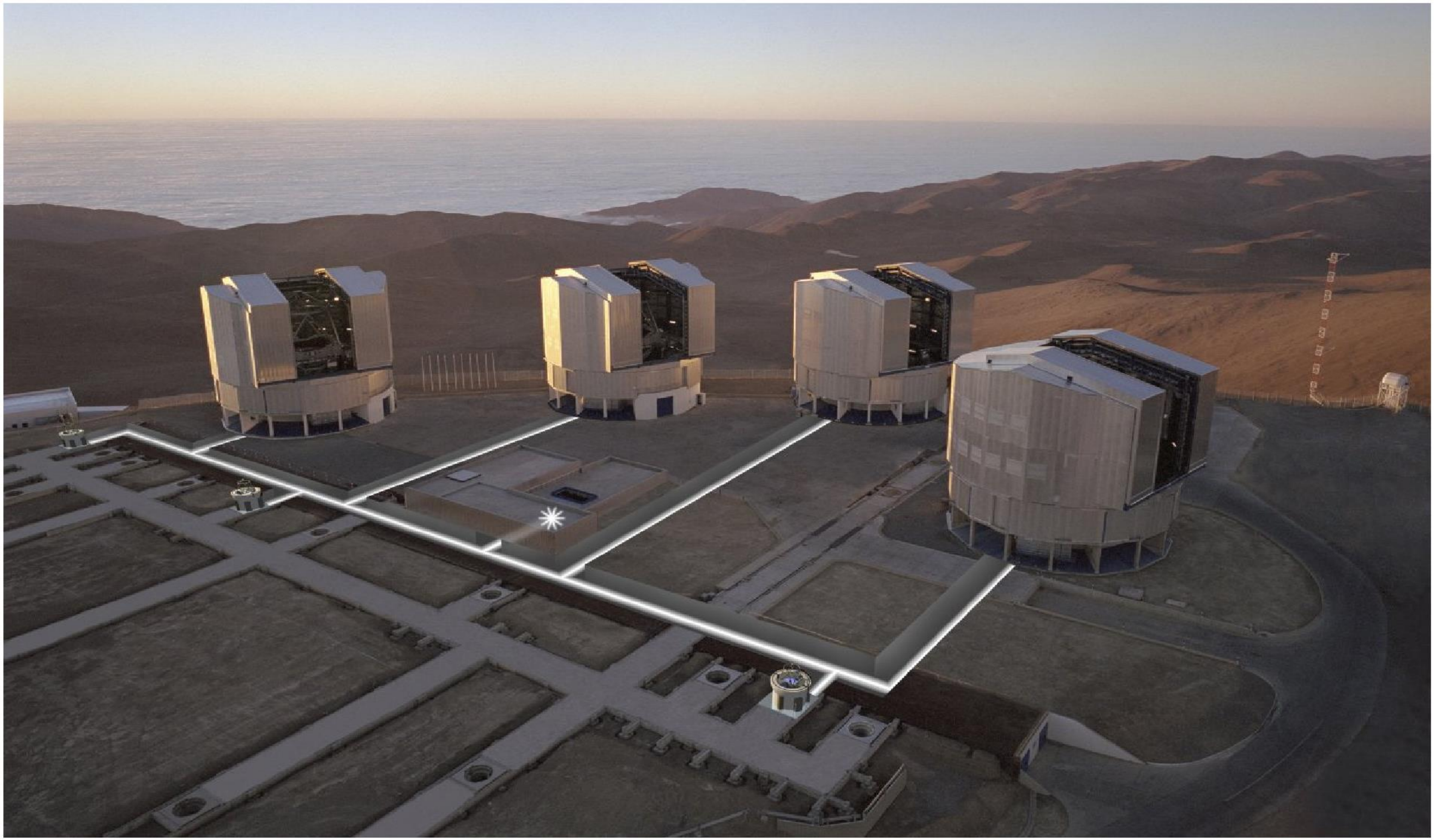
Section 2: Resolving Power

Resolving Power

- Diffraction effects cannot be completely eliminated, but they can be reduced
  - Enlarge the opening through which the light passes so that the waves don't mix as much
- Interferometer – two or more widely spaced telescopes that direct the light to a common detector that combines the separate light beams

Section 2: Resolving Power

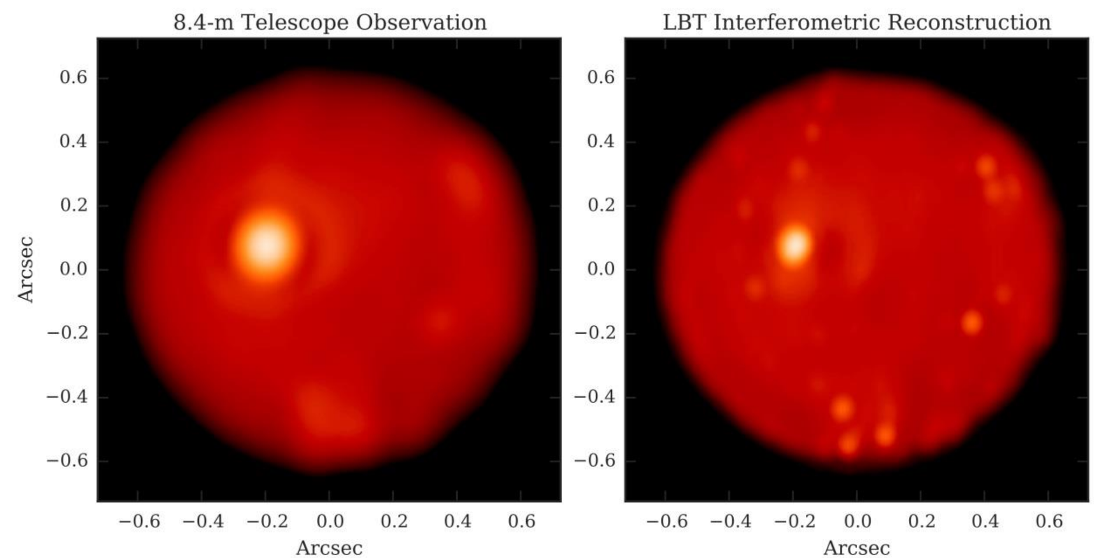
The Very Large Telescope Interferometer (VLTI)



Section 2: Resolving Power

Resolving Power

- The interferometer is named for it ability to separate waves that “interfere” with each other
- Important to remember: the strength of the telescope is one thing, but the ability to separate, through the use of a interferometer, can be more valuable



Section 3: Detecting Light

Visible Light

- Once light gets collected, it must be detected and recorded
  - Old days: an astronomer detected the light that was collected through the eye piece of the telescope and recorded the light by sketching the image that was seen through the scope
- Many celestial objects are too small and too faint for us to see with our own eyes
  - At most, many of the celestial objects emit just a few photons of light by the time they reach us

Section 3: Detecting Light

Visible Light

- If you were to look at a near galaxy through a large observatory scope, it may take several hours of light capture to assemble a picture
- To see faint objects, astronomers use different kinds of detectors that are able to store light in some way to create images
  - Can be done both chemically with photos and digitally with detectors like ones in video camcorders

Section 3: Detecting Light

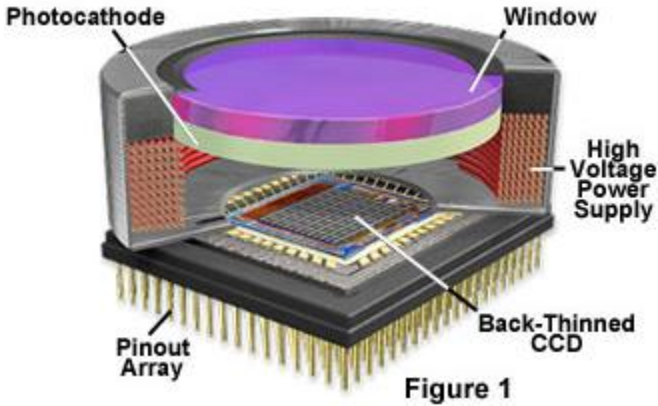
Visible Light

- From the late 1800s to the 1980s, astronomers usually used photographic film to record the light from the bodies they were studying
  - Film absorbs photons that cause a chemical change, making the film dark where the light hit and thus creating the photograph
  - Not very effective though… it took hours to capture and even longer to develop
- Today: almost all electrical detectors

Section 3: Detecting Light

Visible Light

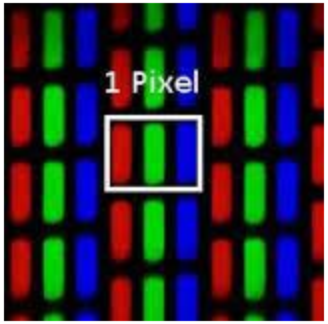
- Charge-Coupled Device (CCD) – electronic detector that can make pictures virtually indistinguishable from photographs in their detail and with a sensitivity to faint light
  - Approximately 20x greater
  - The light coming in strikes a semiconductor surface which allows electrons to move within the material
  - The surface is divided into a bunch of small squares called *pixels* where the electrons are stored

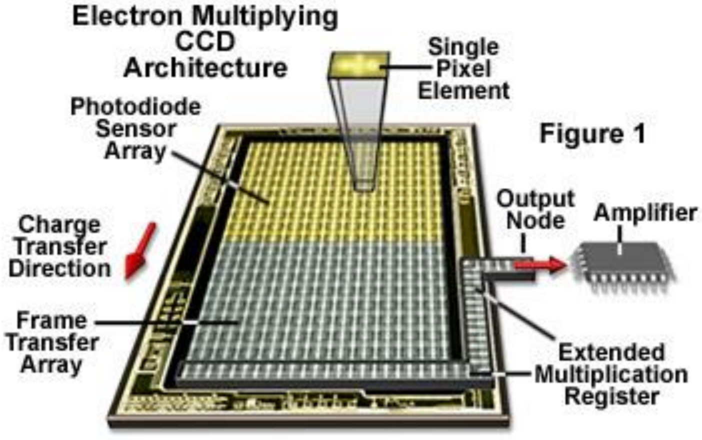


Section 3: Detecting Light

Visible Light

- The number of electrons in each pixel is proportional to the number of photons hitting it
- The device is then connected to computer that scans the detector, counting the number of electrons in each pixel and generating a picture
  - Similar to how TV pixels are small dots all put together to create the image you see on the screen





Section 3: Detecting Light

Visible Light

- CCDs are extremely efficient and can record 75% of the photons striking them, allowing astronomers to record images much faster than with film
- Because they are digital images, they can be altered by sharpening them, removing extraneous light, and enhancing contrast to help produce a great image

Section 3: Detecting Light

Observing at Nonvisible Wavelengths

- The visible light we see is a small portion of the full electromagnetic spectrum
- Many celestial objects give off wavelengths we can't see because it doesn't fall within the visible light spectrum
  - Ex: cold gas clouds emit (give off) radio waves so we use radio detectors to compile those images

Section 3: Detecting Light

Observing at Nonvisible Wavelengths

- Radio telescopes are radio receivers with large mirrors (just like the light ones) that funnel radio waves
  - These can also be aligned into interferometers that cross over entire continents!
    - This is because the radio waves are so long

Section 3: Detecting Light

Observing at Nonvisible Wavelengths

- Many different celestial objects radiate infrared energy
- This is tricky…
  - Astronomers can use infrared telescopes, but the telescopes themselves have the ability to give off dangerous infrared energy
  - These scopes have to be in really low temperatures and away from any shielding (walls) to allow that infrared to collect around it

Section 3: Detecting Light

Observing at Nonvisible Wavelengths

- X rays are even tougher…
  - X rays are easily absorbed by mirrors if they hit directly
  - If they hit at a shallow, horizontal angle, they can be reflected
    - Very similar to how a rock can skip on water
- X ray scopes are curved funnels that gradually direct the photons towards the detector

Section 3: Detecting Light

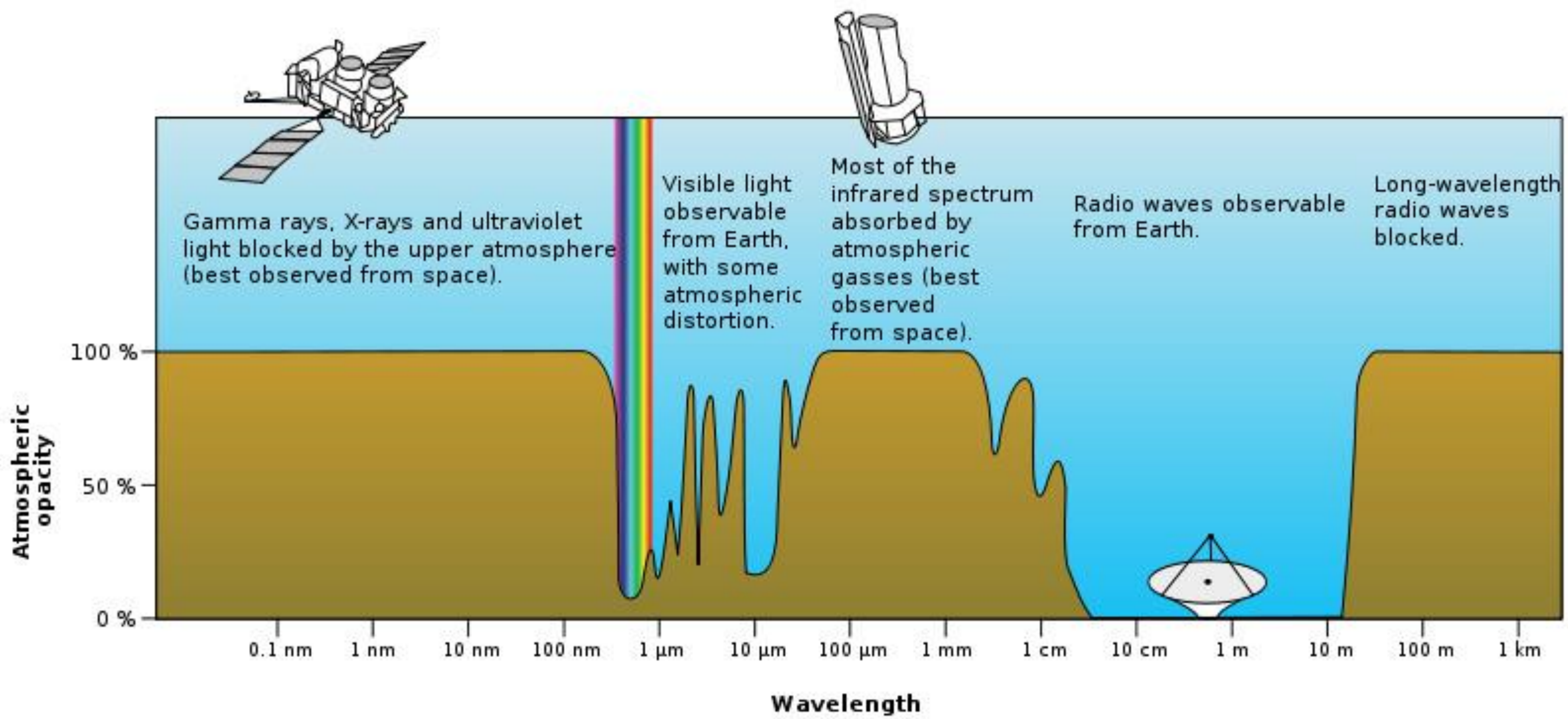
Observing at Nonvisible Wavelengths

- Because we can't see x rays and infrared, we use false colored images to form images with these
- The colors represent different amounts of radiation
  - It's translated to "color"
- Most of the wavelengths we can't see have a hard time getting through Earth's atmosphere
- Best option: put them up in space!

Section 4: Telescopes on the Ground and in Space

Introduction

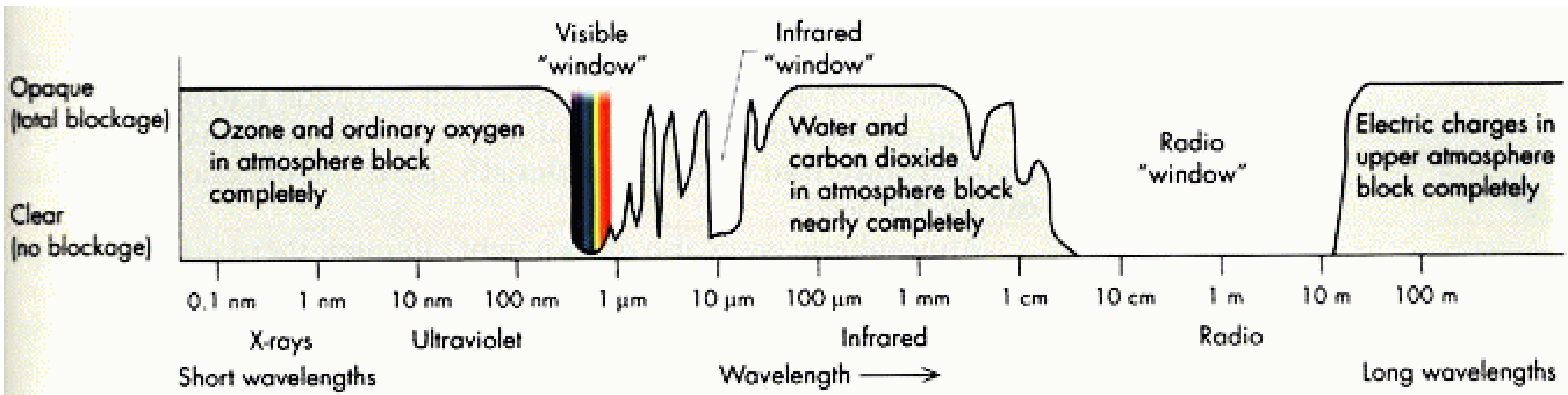
- Atmospheric Window – the wavelength region that gives one the ability to peer out into space from the ground



Section 4: Telescopes on the Ground and in Space

Introduction

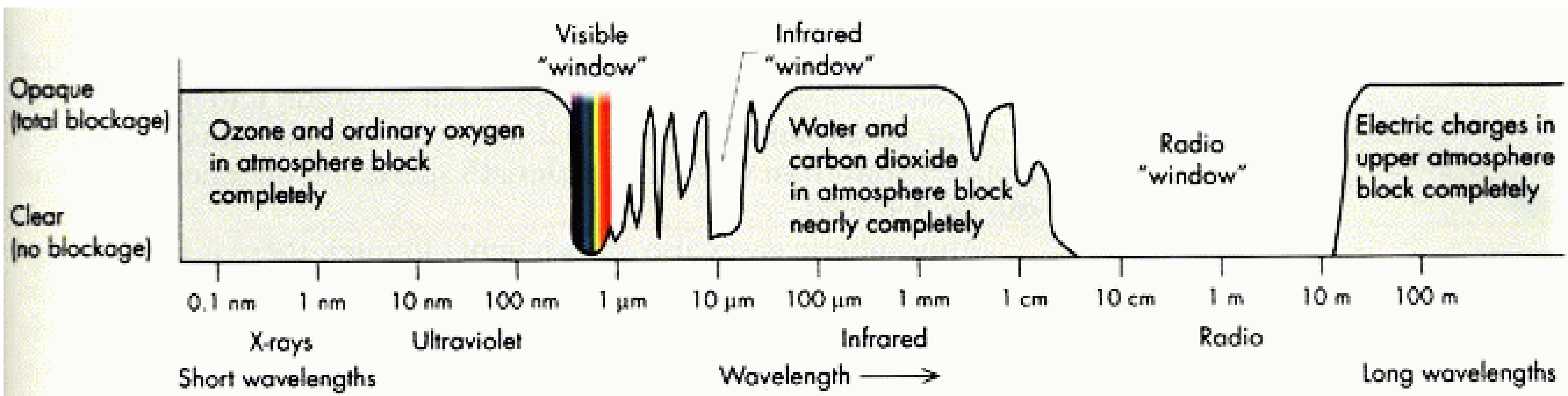
- Gases in our atmosphere absorb infrared, UV, and shorter wavelengths
  - Ozone
  - Carbon dioxide
  - Water



Section 4: Telescopes on the Ground and in Space

Introduction

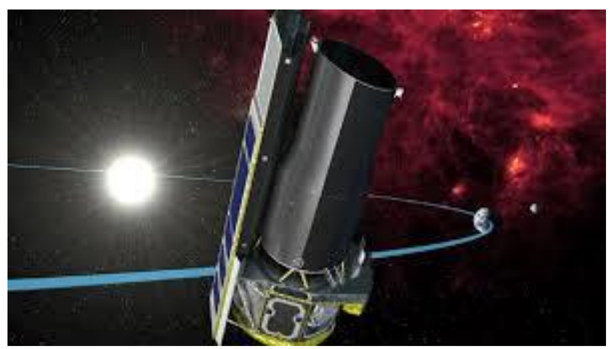
- Because the atmosphere can absorb so many different wavelengths, it is important for satellites and detectors to get out past the atmosphere and go to space



Section 4: Telescopes on the Ground and in Space

Introduction

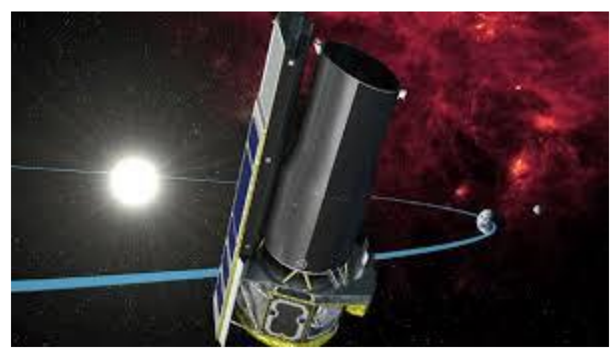
- Some of the scopes out there designed to detect these absorbed wavelengths:
  - Hubble Space Telescope (HST)
  - Extreme Ultraviolet Explorer (EUVE)
  - Spitzer Infrared Space Telescope
  - Chandra X ray Telescope Satellite



Section 4: Telescopes on the Ground and in Space

Introduction

- Some of the scopes could be launched and will work for very long periods of time, others will fall short
  - Ex: Spritzer – Infrared
    - The Spritzer scope needs liquid helium to keep it cool enough to detect infrared
    - Once the liquid helium ran out, it can no longer detect those waves
    - It collects minimal information in regards to gamma and X-ray, but that's it



Section 4: Telescopes on the Ground and in Space

Atmospheric Blurring

- Most popular scope: Hubble Space Telescope (HST)
  - Can observe at visible wavelengths and portions of infrared and ultraviolet
  - Contains a primary mirror that's 2.4 meters in diameter
  - Smaller than most land scopes
  - Puts out fully detailed images because it can dodge the "blurring" of the atmospheric components
    - Water
    - Dust
    - pollution

Section 4: Telescopes on the Ground and in Space

Atmospheric Blurring

- Stars have always been known to "twinkle"
- Scintillation – a situation where atmospheric irregularities refracts (bends) the star's light
  - Atmospheric variations can be in density caused by small temperature changes
  - Because of this, the pathways of light can change direction and cause blending to occur with light from other directions
  - Ex: looking at a penny under moving water
    - The penny looks like it's dancing when in reality it's the light bending and causing that view to be recorded by you

Section 4: Telescopes on the Ground and in Space

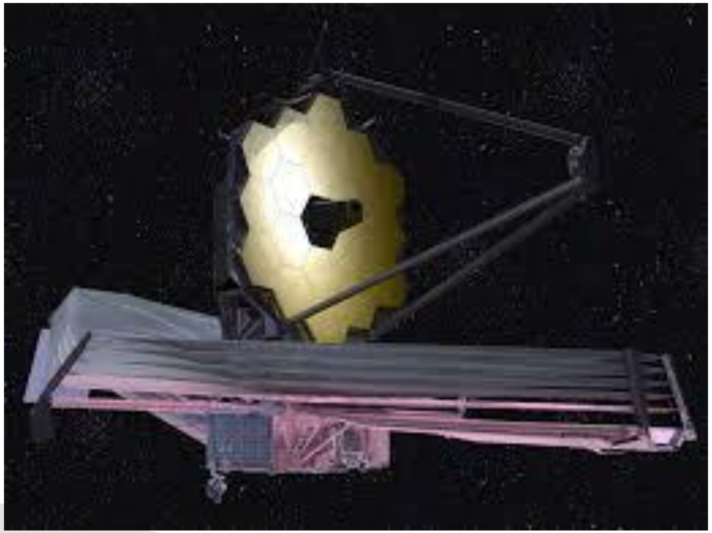
Atmospheric Blurring

- Scintillation of Sirius Over a Period of Time
  - Notice the color expansion and bended light pattern

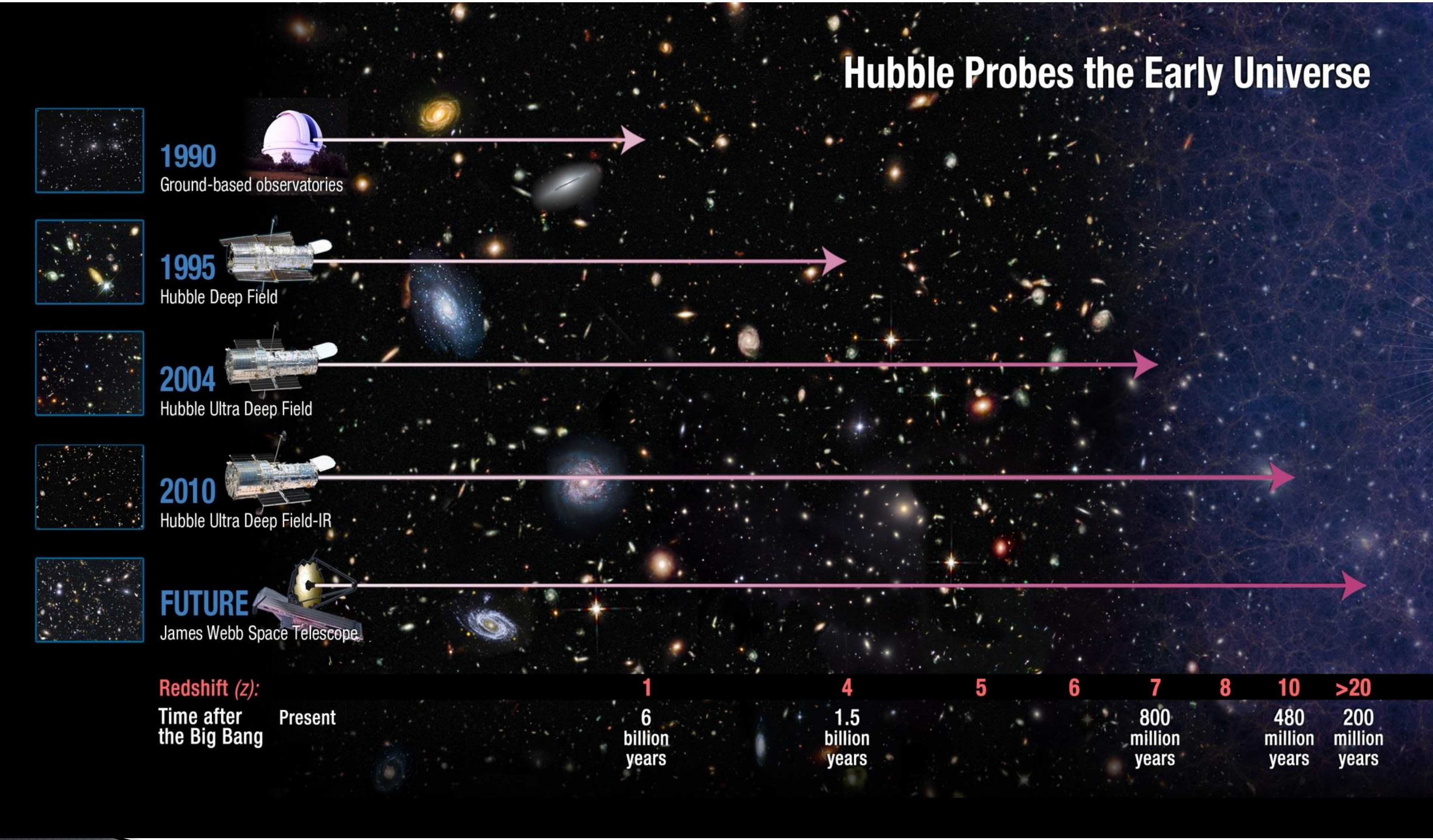
Section 4: Telescopes on the Ground and in Space

Atmospheric Blurring

- Seeing – the distortion of light by means of the atmospheric changes
- This gets eliminated once you get past the atmosphere
- Continued repair to the Hubble allows it to stay as the #1 viewing tool in space
  - The launch of the Webb Telescope will replace it (fingers crossed!)



Section 4: Telescopes on the Ground and in Space



Section 4: Telescopes on the Ground and in Space

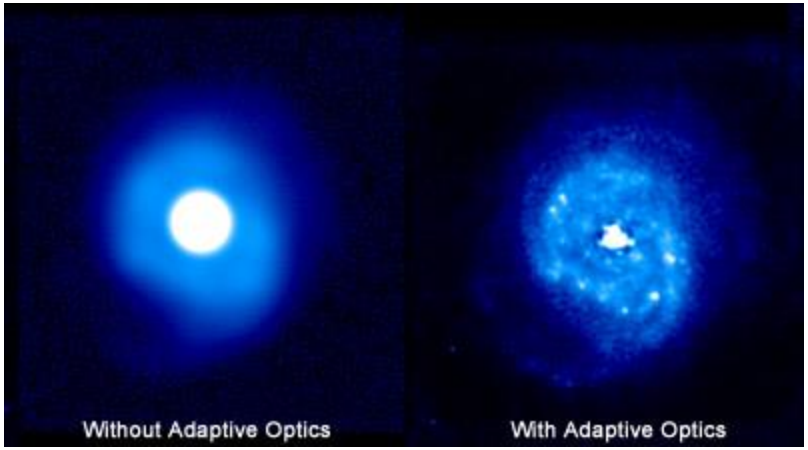
Space Telescopes vs Ground-Based Telescopes

- There are ways to go about fighting the distortion from the atmosphere if on the ground
- Astronomers compare the object being studied to a known star
  - knowing exactly how the known star is being distorted, helps astronomers compare those same changes to the object being studied
  - Hard part: it's tough to get a good comparison star to be close to the object being studied
  - Fix: use a laser!

Section 4: Telescopes on the Ground and in Space

Space Telescopes vs Ground-Based Telescopes

- A powerful laser beam is projected into the sky to create an artificial star for comparison
  - the distortions of the artificial star image are recorded by a computer and adjusted by actuated mirrors
- Adaptive Optics – using actuators (moving motors) on correcting mirrors that cancel out the distortions created by the atmosphere



Section 4: Telescopes on the Ground and in Space

Space Telescopes vs Ground-Based Telescopes

- These types of techniques give us great images without the hassle and expenses of launching into space
- They also give us the opportunity to construct large scale telescopes, much greater in size than ones that would need to go to space
- Location is still very important!
  - Good spots: American Southwest, Australia, Hawaii, etc.

Section 4: Telescopes on the Ground and in Space

Space Telescopes vs Ground-Based Telescopes

- Unforeseen obstacle: light pollution
  - Light pollution makes it really difficult to be able to see
  - Most of this light pollution leaks from urban areas
  - With increases in world wide population and technology, light pollution is getting exponentially higher

Section 5: Observatories

Introduction

- The major telescopes used by astronomers are extremely expensive to manufacture
- Some of the largest ones are national or international facilities because of their expense
  - Many colleges and universities have their own observatories for research and instruction
- Some large private groups have them, too
  - Ex: Carnegie Institution

Section 5: Observatories

Introduction

- There are observatory telescopes on every continent, including Antarctica
  - The cold and extremely dry air gives leeway to great shots of the sky

Section 5: Observatories

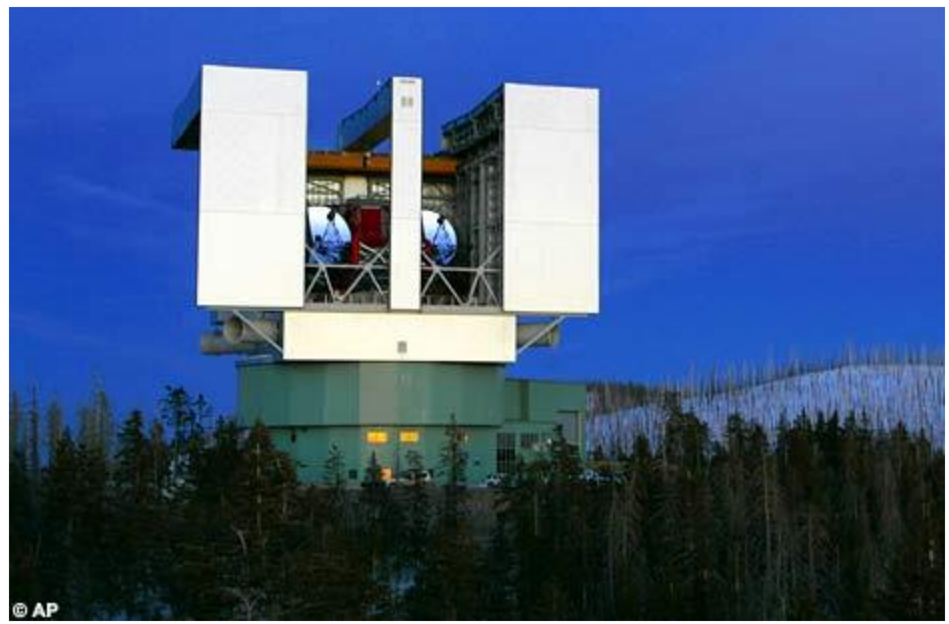
Introduction

- Twin Keck Telescopes
  - Two 10-meter scopes
  - Can operate individually or as an interferometer
  - Located in Hawaii

Section 5: Observatories

Introduction

- Large Binocular Telescope
  - Located in Arizona
  - 8.4 m each
  - Even though it's one major unit, it can be used as an interferometer, too



Section 5: Observatories

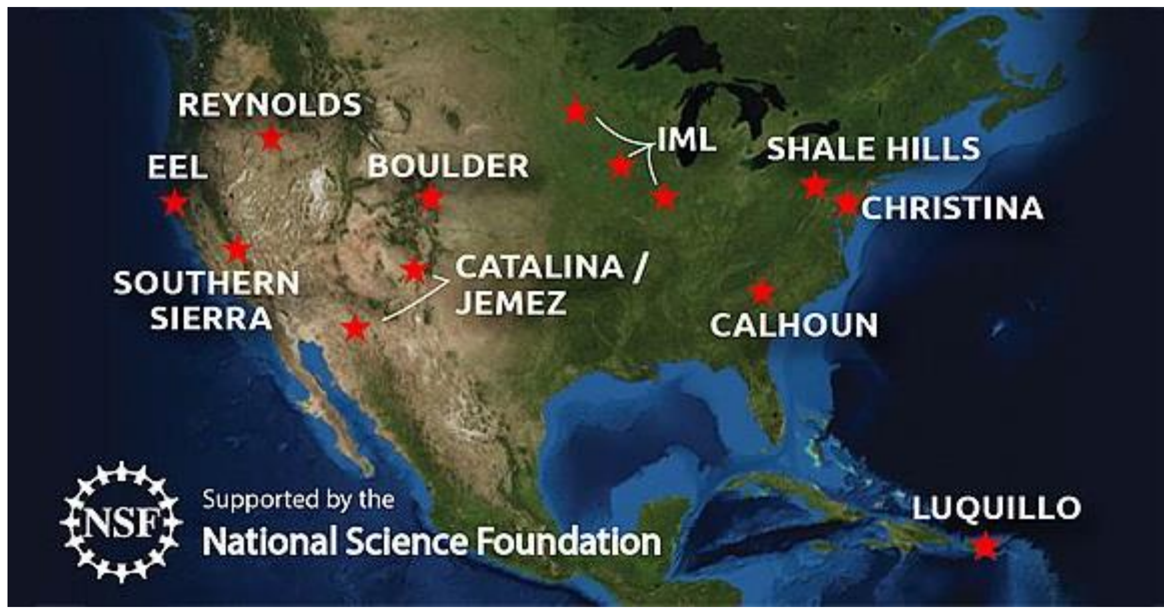
Introduction

- Very Large Telescope (VLT)
  - Four telescopes
  - 8.2 meter scopes
  - Work together as an interferometer
  - Located in Chile

Section 5: Observatories

Introduction

- With the high expense construction, the ability to study the sky is a global effort
- Observatories from all over the globe share their data in order to help advance the field of astronomy



Section 5: Observatories

Going Observing

- In order for an astronomer to use the observatory scope, a proposal has to be submitted explaining what he/she wants to focus on and why
- They also have to show that the scope's dimensions and capabilities are what's needed to study the object
- Proposals are screened by a committee that then allocate telescope time according to the scientific merits of the proposals

W. M. KECK OBSERVATORY
On the summit of Mauna Kea, Island of Hawai'i

Going Observing

- The runs that get approved are set up for several nights in a row and are subject to whatever conditions may be present
- Some runs get great results, some are at a total loss due to storms or other inclement weather
- Mostly all scopes are run by computers and software, allowing the observer to control the scope from an observation room or even from another location – most efficient

Section 5: Observatories

Computers

- Being able to operate a computer and program software are more valuable skills in astronomy than knowing how to use a telescope
- Computers are used to:
  - Solve equations
  - Move the telescope
  - Feed the information to detectors
  - Convert the data obtained by the scope
  - Communicate with other astronomers and observatories