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

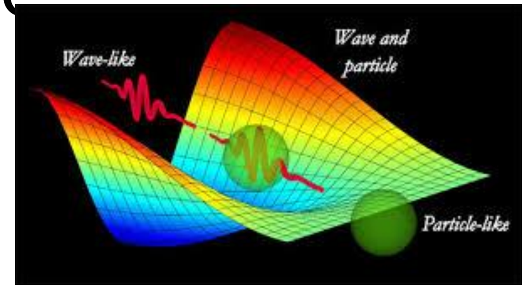
Introduction

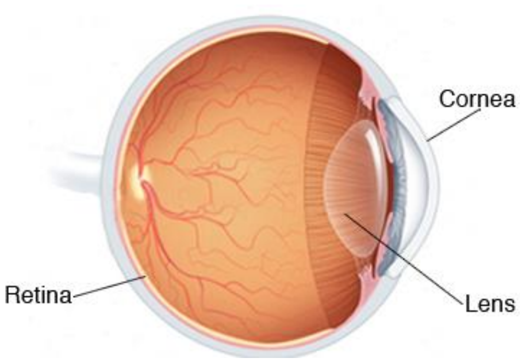
- A _________ enables an astronomer to observe things not visible to the naked _________
  - Human eye sight can't see:
    - _________ objects
    - Fine details
    - Long distances
  - We rely off of light input in order to see images
    - No light = no _________
- Telescopes increase the image _________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

Section 1: Telescopes

Light-Gathering Power

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

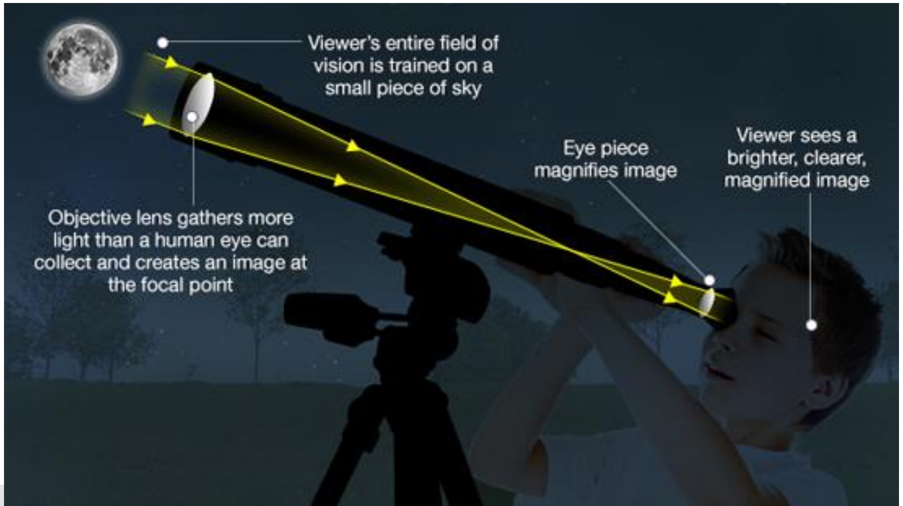




Section 1: Telescopes

Light-Gathering Power

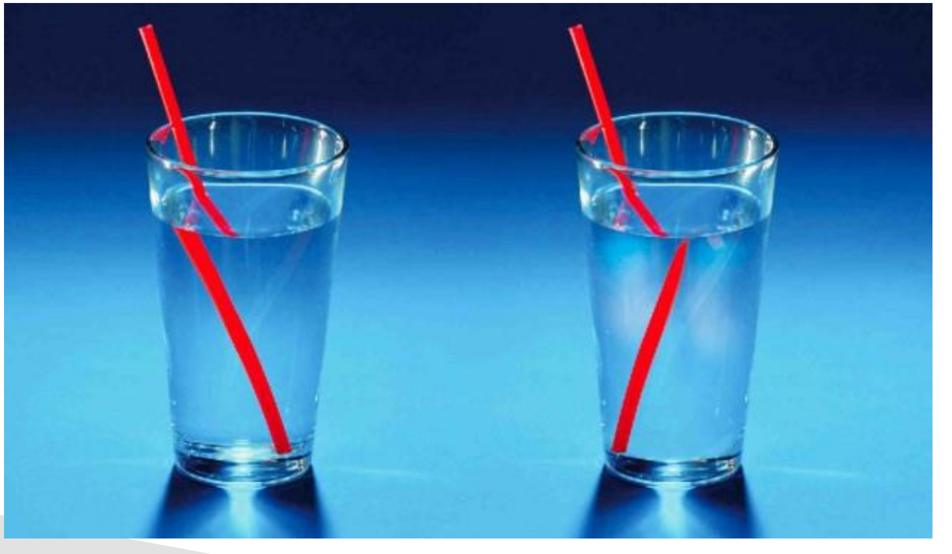
- Light – Gathering Power – a large __________ mirror used in telescopes to help collect and funnel __________
- These give us brighter __________
- The bigger the lens or mirror, the more photons can be caught (πr^2)
  - An increase from 4 to 6 m in diameter means a difference in size and capability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



Section 1: Telescopes

Focusing Light

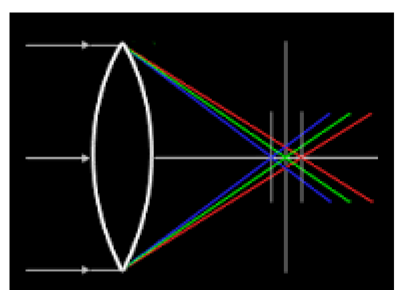
- Once light has been gathered, it needs to be focused
- Refractors – refracting telescopes where __________ is gathered and focused by a __________
- Refraction – __________of light rays
  - This happens when light moves from one substance to another
    - Ex: air to water

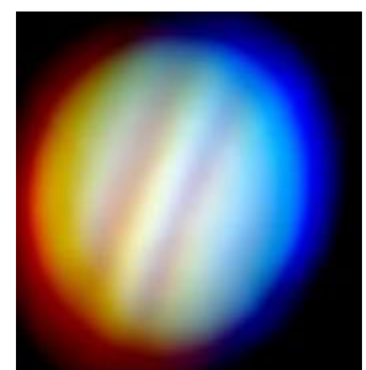


Section 1: Telescopes

Focusing Light

- Having lenses in large telescopes can have disadvantages:
  - Extremely __________ and tough to fabricate (make)
  - The lens has to be connected on the __________ and it causes it to __________ 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

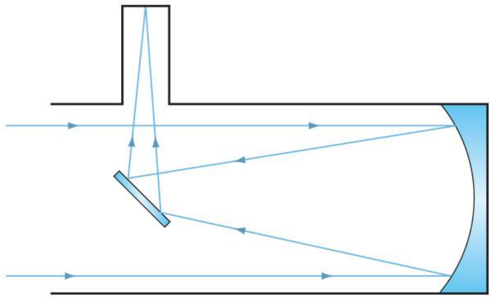


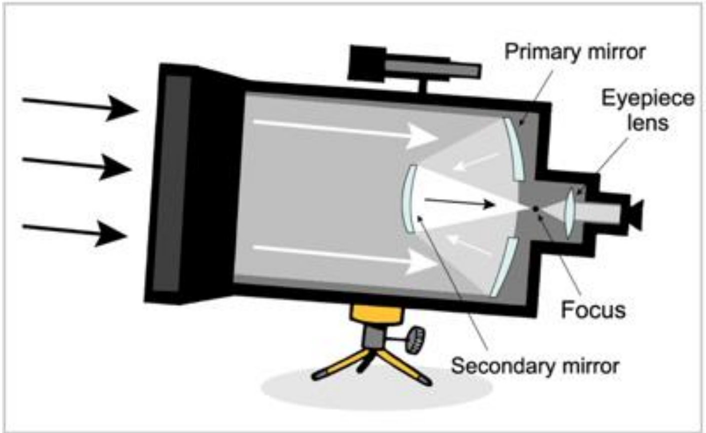


Section 1: Telescopes

Focusing Light

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





Section 1: Telescopes

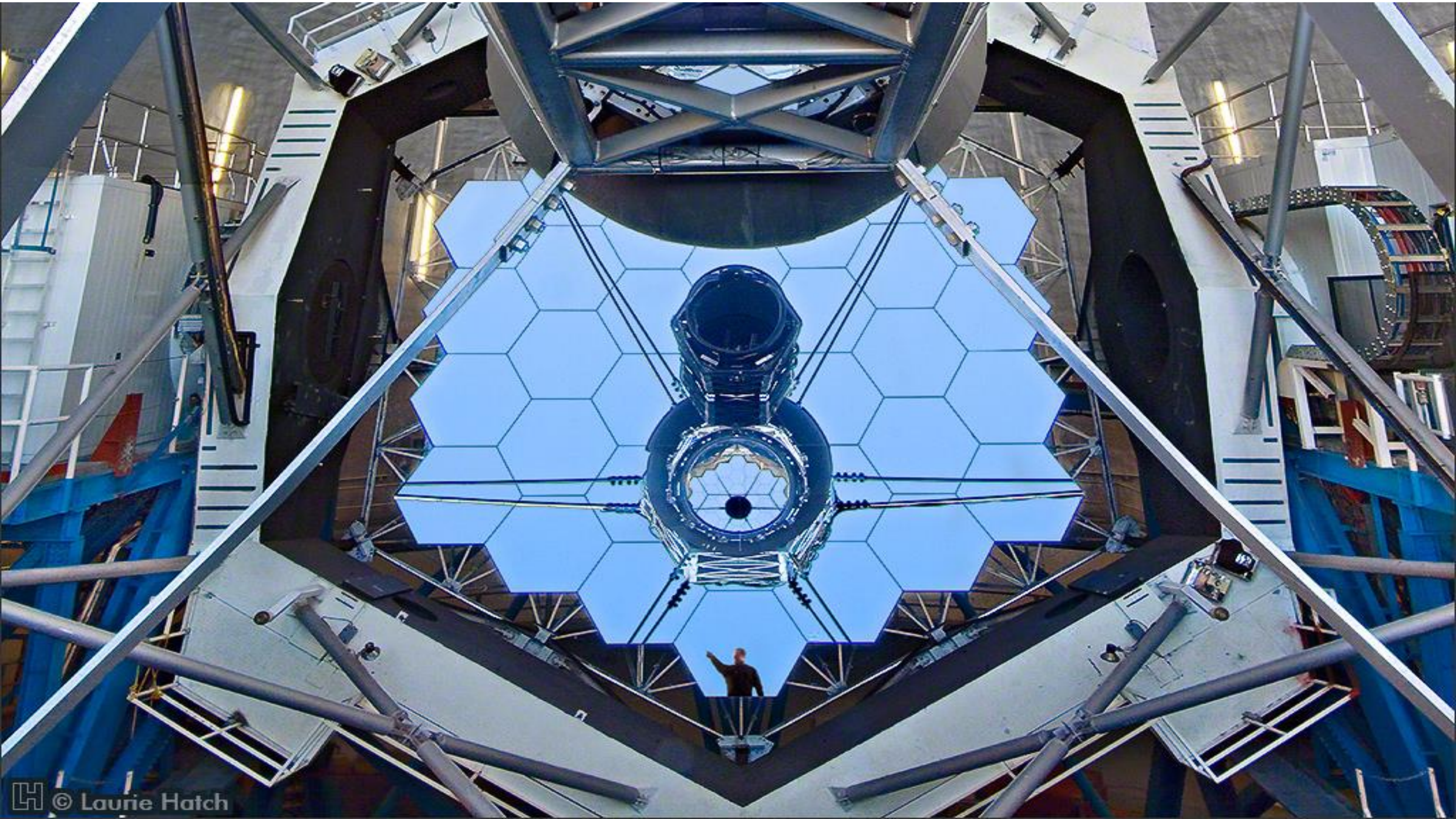
Focusing Light

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

Winner across the board!

Section 1: Telescopes

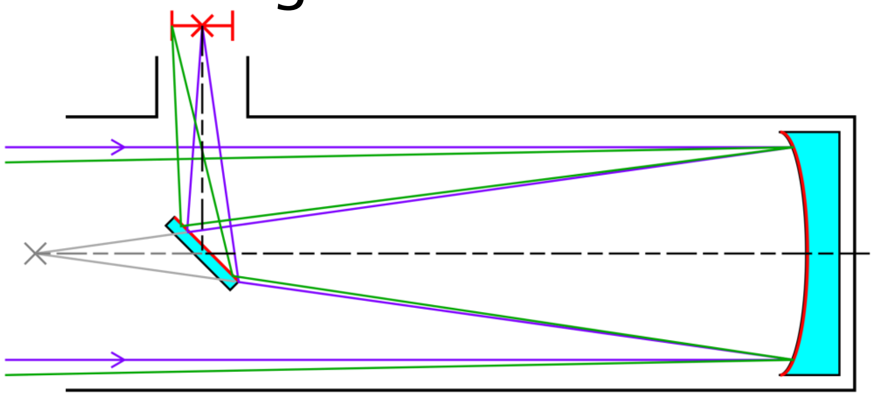
UCLA Galactic Center's Reflector

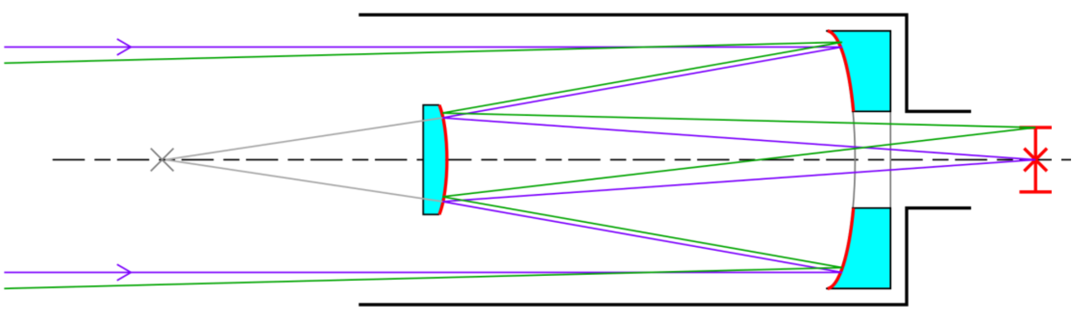


Section 1: Telescopes

Focusing Light

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





Section 1: Telescopes

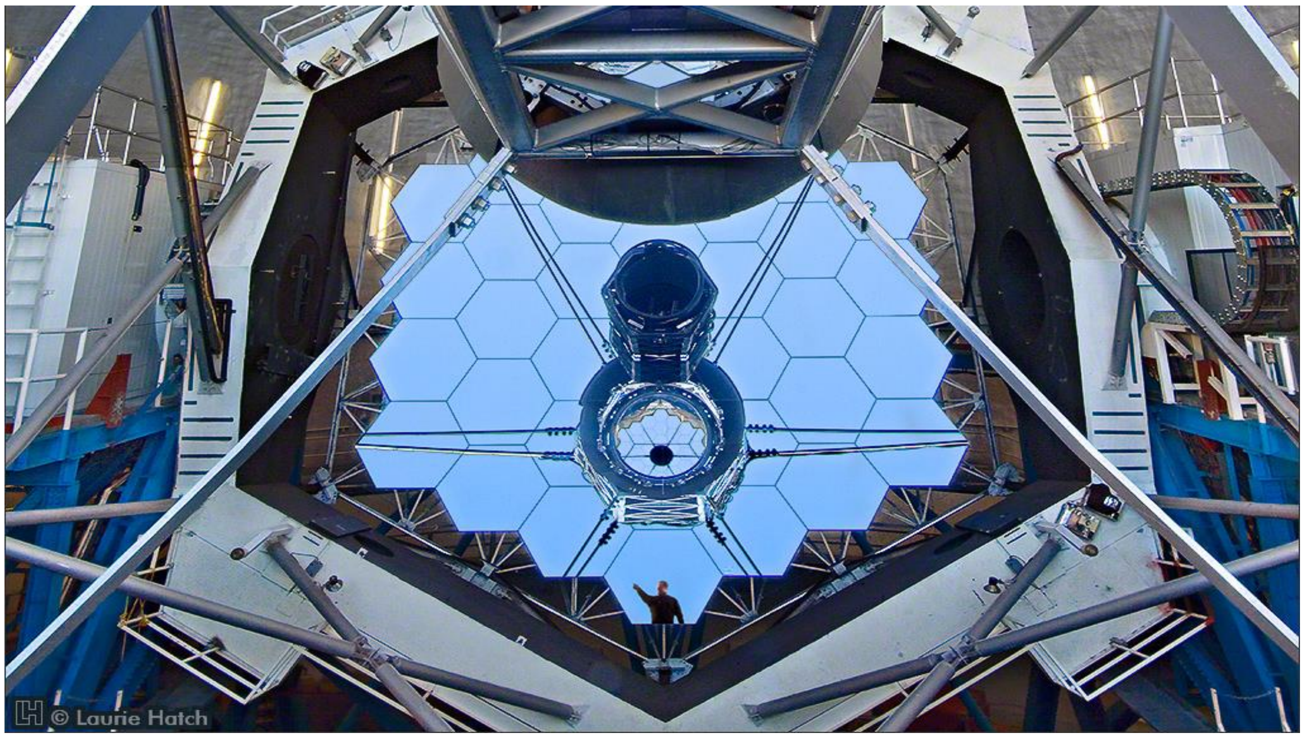
Focusing Light

- Most telescopes are mounted on big _________ that allow them to _________ 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 _________
- When they move, it causes the glass in the mirror to _________ , especially in really big reflectors
- A lot of the current reflectors are using multiple _________ mirrors instead of one large one to fix that problem

Section 1: Telescopes

Focusing Light

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



Section 2: Resolving Power

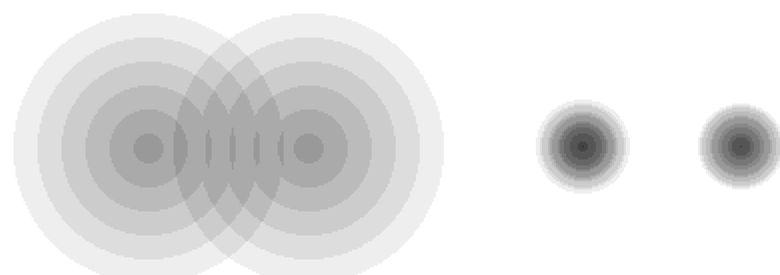
Introduction

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

Section 2: Resolving Power

Resolving Power

- Resolving Power – a telescope's ability to __________ objects or details on those objects
- Limited by the wave nature of __________
  - 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



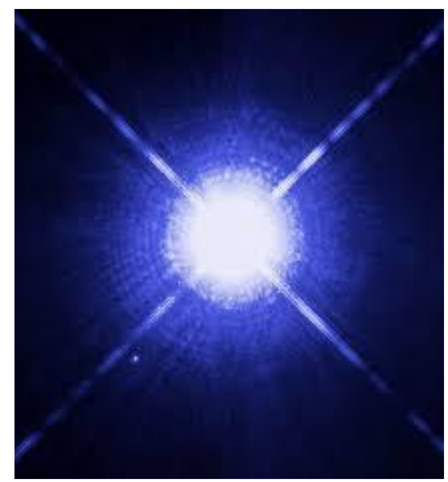
2 objects visualized with poor resolving power

Same 2 objects visualized with good resolving power

Section 2: Resolving Power

Resolving Power

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



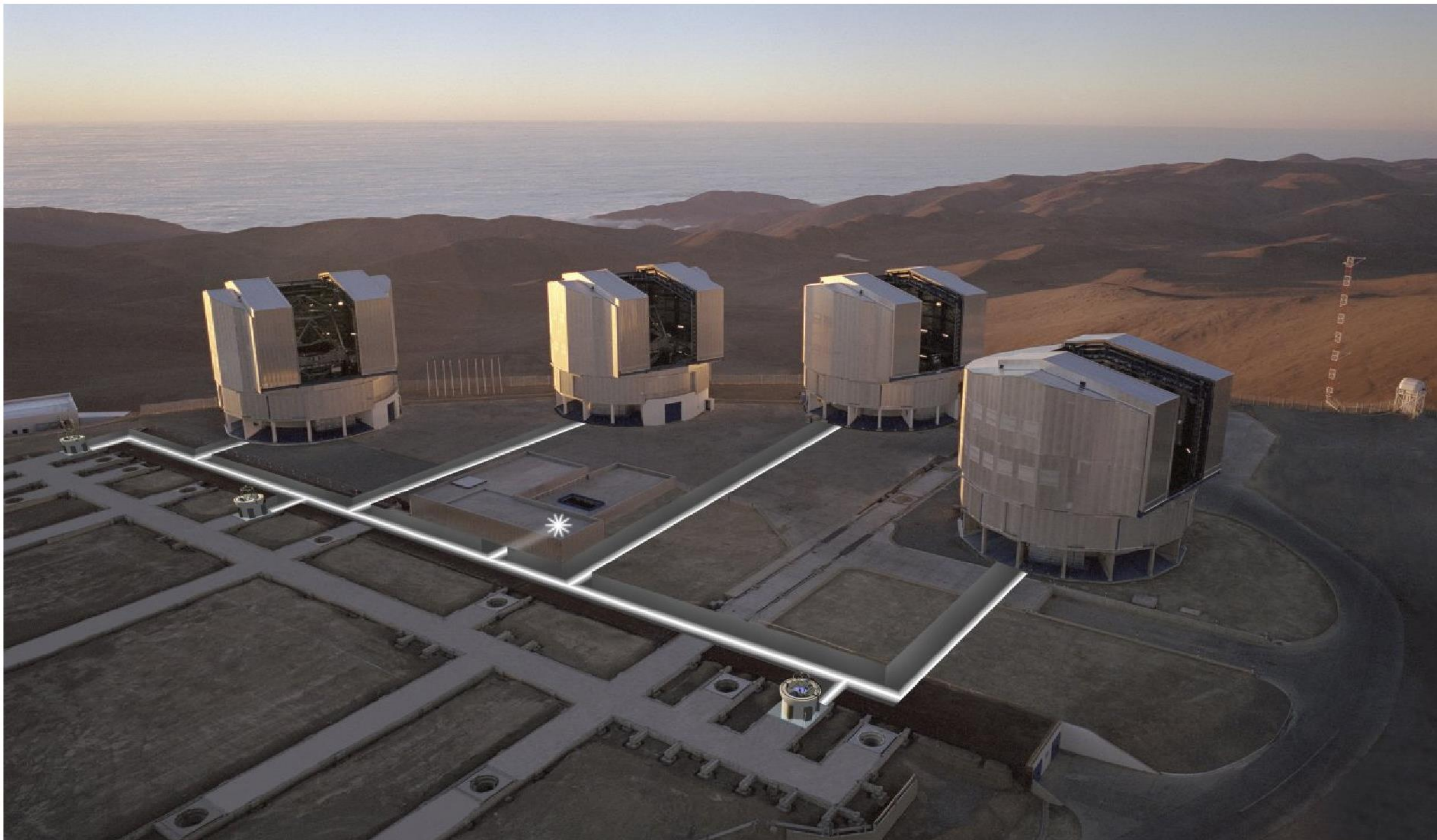
Section 2: Resolving Power

Resolving Power

- Diffraction effects __________ 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 __________ that direct the light to a common detector that combines the separate light __________

Section 2: Resolving Power

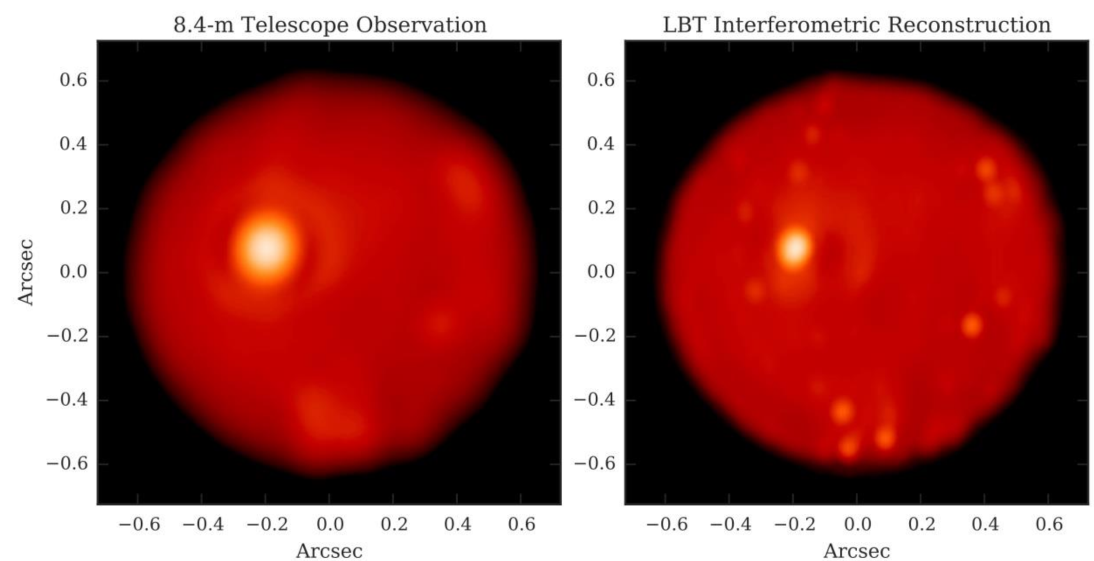
The Very Large Telescope Interferometer (VLTI)



Section 2: Resolving Power

Resolving Power

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



Section 3: Detecting Light

Visible Light

- Once light gets collected, it must be _________ and recorded
  - Old days: an astronomer detected the light that was collected through the eye piece of the telescope and recorded the light by _________ 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 _________ 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 _________ 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

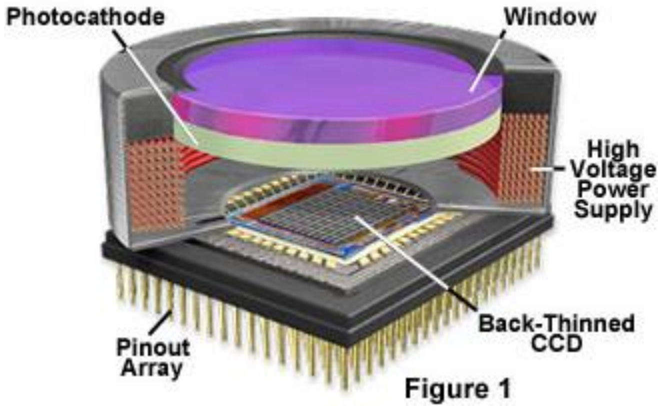
Visible Light

- From the late 1800s to the 1980s, astronomers usually used _________ 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 _________ detectors

Section 3: Detecting Light

Visible Light

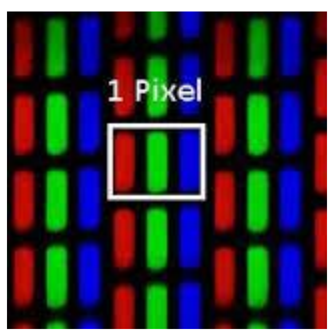
- Charge-Coupled Device (CCD) – __________ detector that can make pictures virtually __________ from photographs in their detail and with a sensitivity to faint light
  - Approximately __________ greater
  - The light coming in strikes a semiconductor surface which allows electrons to move within the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

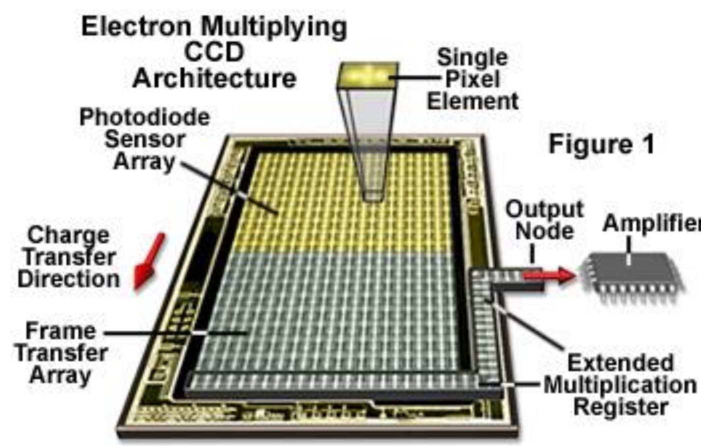


Section 3: Detecting Light

Visible Light

- The number of electrons in each _________ 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 _________ pixels are small dots all put together to create the image you see on the screen

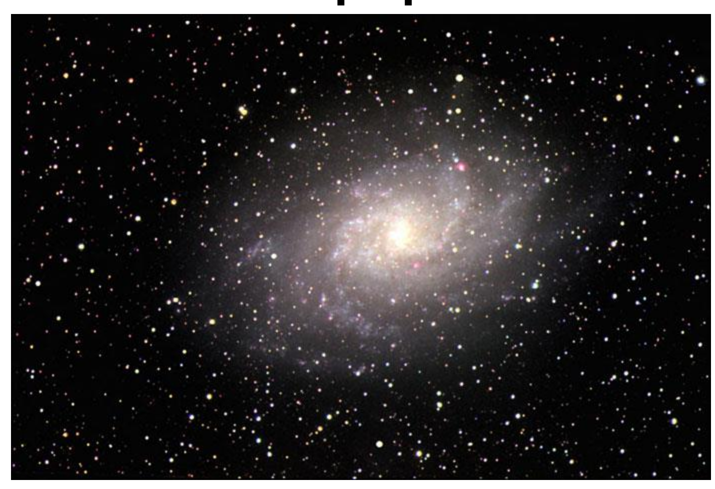




Section 3: Detecting Light

Visible Light

- CCDs are extremely efficient and can record _________ of the photons striking them, allowing astronomers to record images much faster than with film
- Because they are _________ 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 _________ portion of the full electromagnetic spectrum
- Many _________ 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

- __________ telescopes are radio receivers with large mirrors (just like the light ones) that funnel radio waves
  - These can also be aligned into __________ 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 _________ energy
- This is tricky…
  - Astronomers can use infrared telescopes, but the telescopes themselves have the ability to give off _________ infrared energy
  - These scopes have to be in really low temperatures and away from any _________ (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 _________ if they hit directly
  - If they hit at a _________ , horizontal angle, they can be reflected
    - Very similar to how a rock can skip on water
- X ray scopes are curved _________ that gradually direct the photons towards the detector

Section 3: Detecting Light

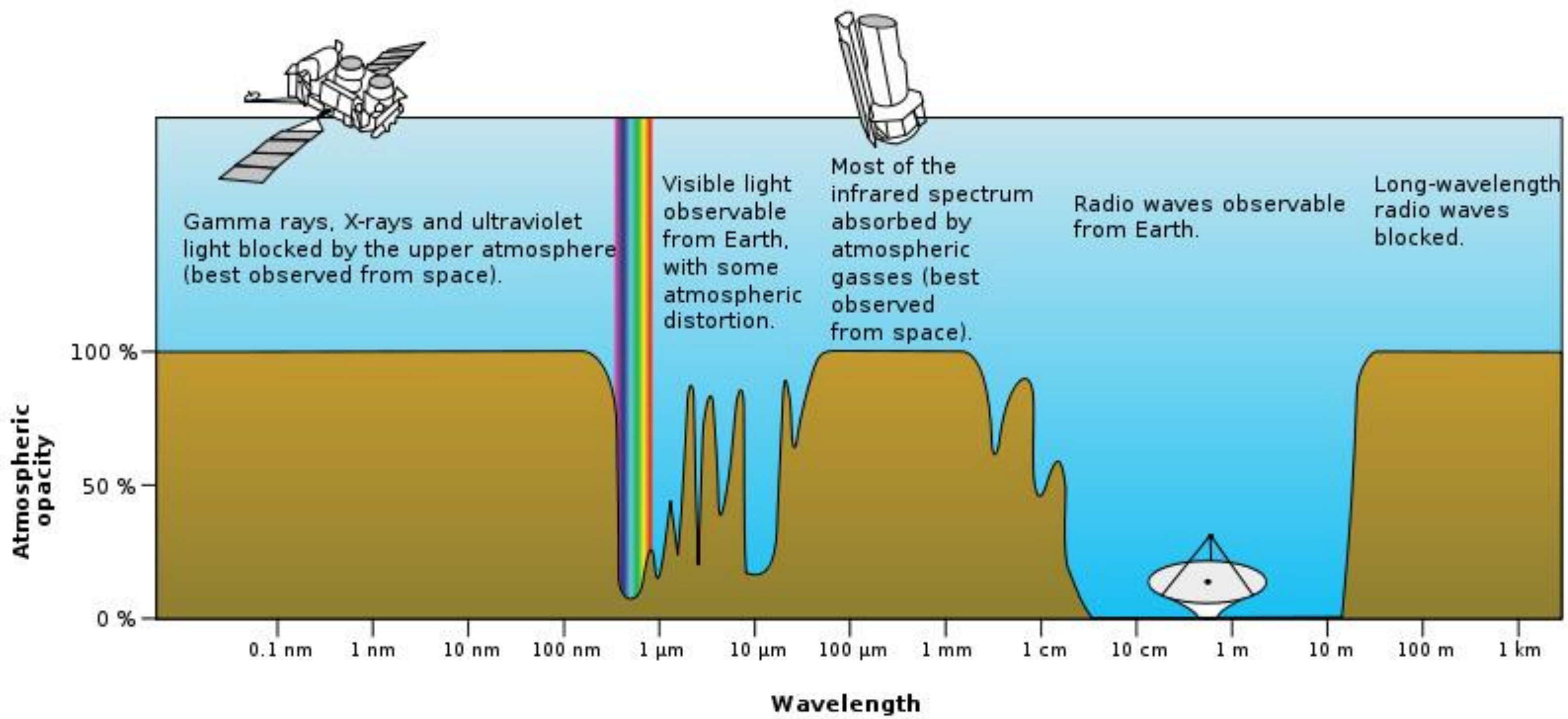
Observing at Nonvisible Wavelengths

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

Section 4: Telescopes on the Ground and in Space

Introduction

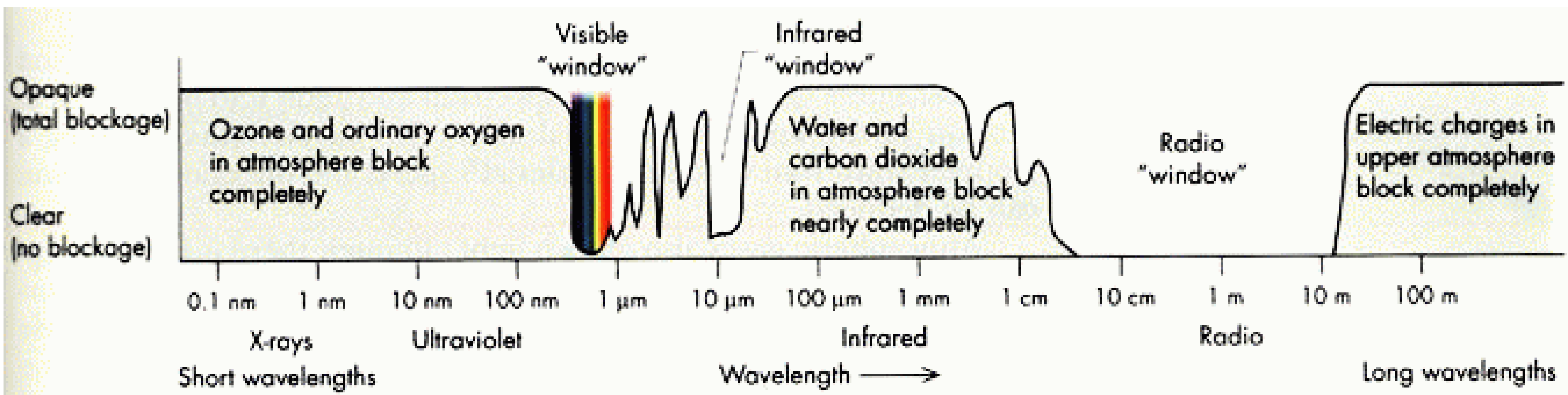
- Atmospheric Window – the __________ region that gives one the ability to peer out into space from the ground



Section 4: Telescopes on the Ground and in Space

Introduction

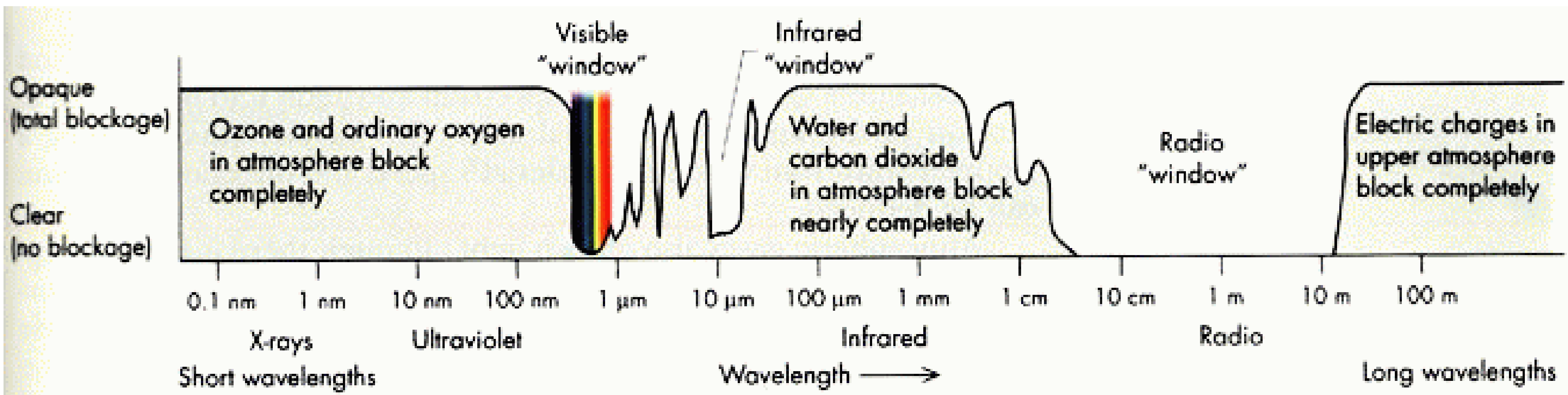
- __________ in our atmosphere absorb infrared, UV, and shorter wavelengths
  - Ozone
  - Carbon dioxide
  - Water



Section 4: Telescopes on the Ground and in Space

Introduction

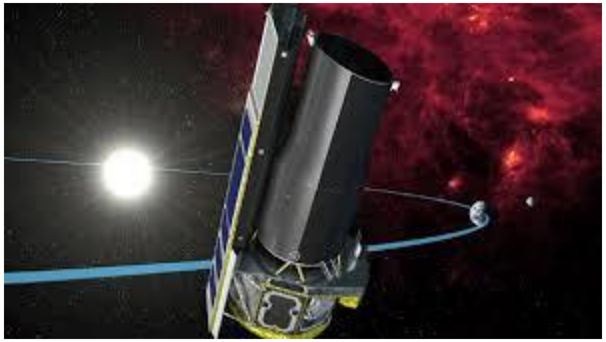
- Because the _________ can absorb so many different wavelengths, it is important for satellites and _________ to get out past the atmosphere and go to space



Section 4: Telescopes on the Ground and in Space

Introduction

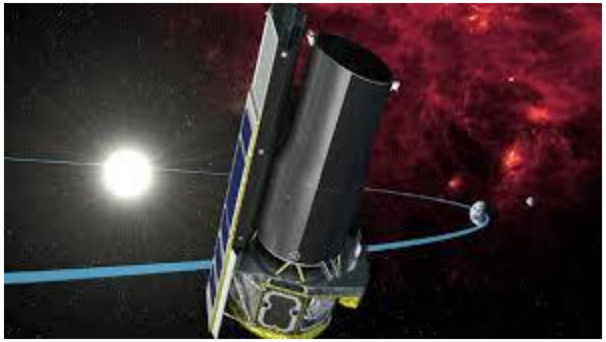
- Some of the scopes out there designed to detect these absorbed _________ :
  - _________ Space Telescope (HST)
  - Extreme _________ Explorer (EUVE)
  - Spitzer _________ Space Telescope
  - _________ X ray Telescope Satellite



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 – __________
    - The Spritzer scope needs liquid helium to keep it cool enough to detect infrared
    - Once the liquid _________ ran out, it can no longer detect those waves
    - It collects minimal information in regards to gamma and X-ray, but that's it



Atmospheric Blurring

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

Section 4: Telescopes on the Ground and in Space

Atmospheric Blurring

- Stars have always been known to "__________ "
- Scintillation – a situation where atmospheric __________ 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 __________ 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

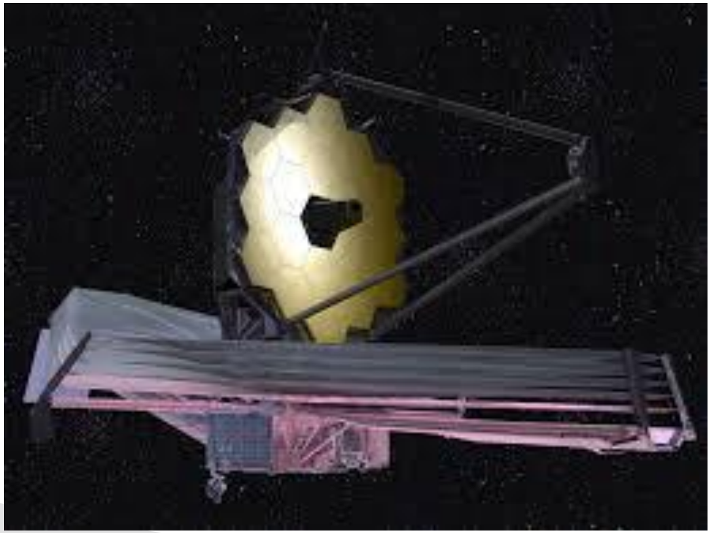
Atmospheric Blurring

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

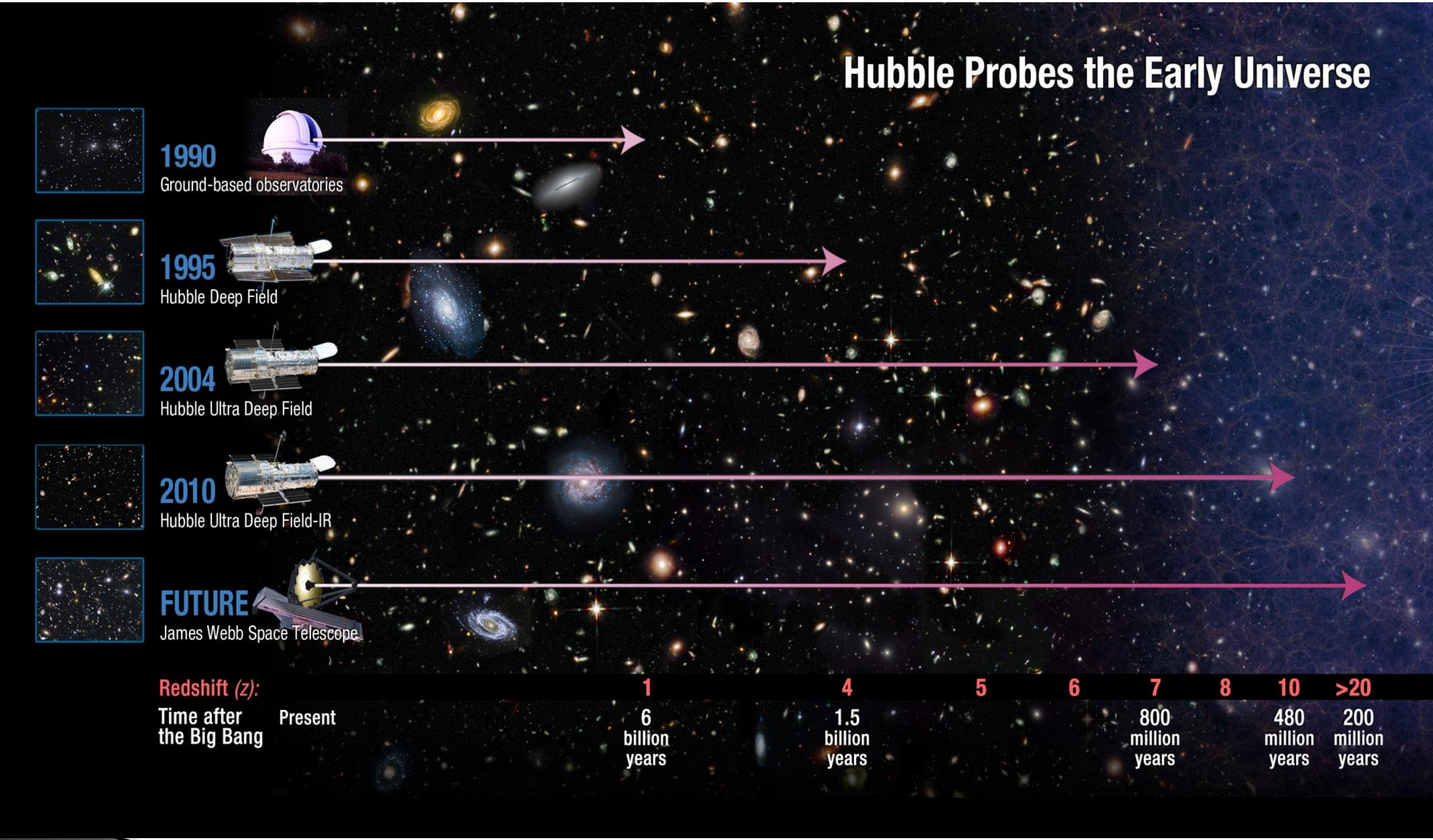
Section 4: Telescopes on the Ground and in Space

Atmospheric Blurring

- Seeing – the __________ of light by means of the atmospheric changes
- This gets __________ 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 _________ Telescope will replace it (fingers crossed!)



Section 4: Telescopes on the Ground and in Space



Section 4: Telescopes on the Ground and in Space

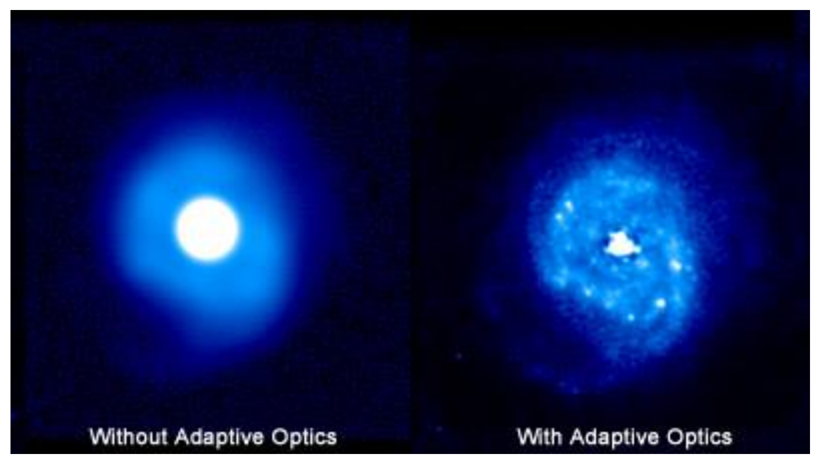
Space Telescopes vs Ground-Based Telescopes

- There are ways to go about _________ the distortion from the atmosphere if on the ground
- _________ 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 _________ star to be close to the object being studied
  - Fix: use a _________ !

Section 4: Telescopes on the Ground and in Space

Space Telescopes vs Ground-Based Telescopes

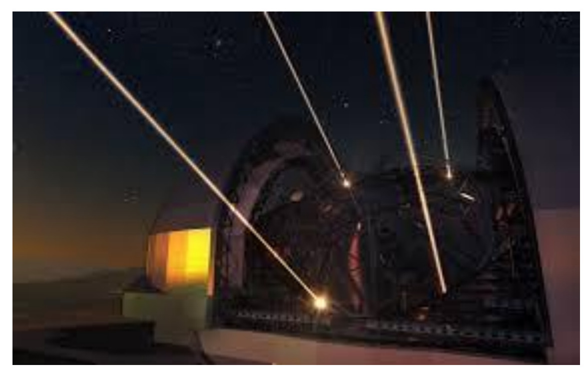
- A powerful laser __________ is projected into the sky to create an __________ star for comparison
  - the distortions of the artificial star image are recorded by a computer and adjusted by actuated mirrors
- Adaptive Optics – using __________ (moving motors) on correcting mirrors that cancel out the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



Section 4: Telescopes on the Ground and in Space

Space Telescopes vs Ground-Based Telescopes

- These types of techniques give us great _________ without the hassle and expenses of _________ into space
- They also give us the opportunity to construct large scale _________ , much greater in size than ones that would need to go to space
- _________ 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: _________ pollution
  - Light pollution makes it really difficult to be able to see
  - Most of this light pollution leaks from _________ 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 _________ to manufacture
- Some of the largest ones are national or _________ facilities because of their expense
  - Many colleges and universities have their own observatories for research and instruction
- Some large _________ groups have them, too
  - Ex: Carnegie Institution

Section 5: Observatories

Introduction

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

Section 5: Observatories

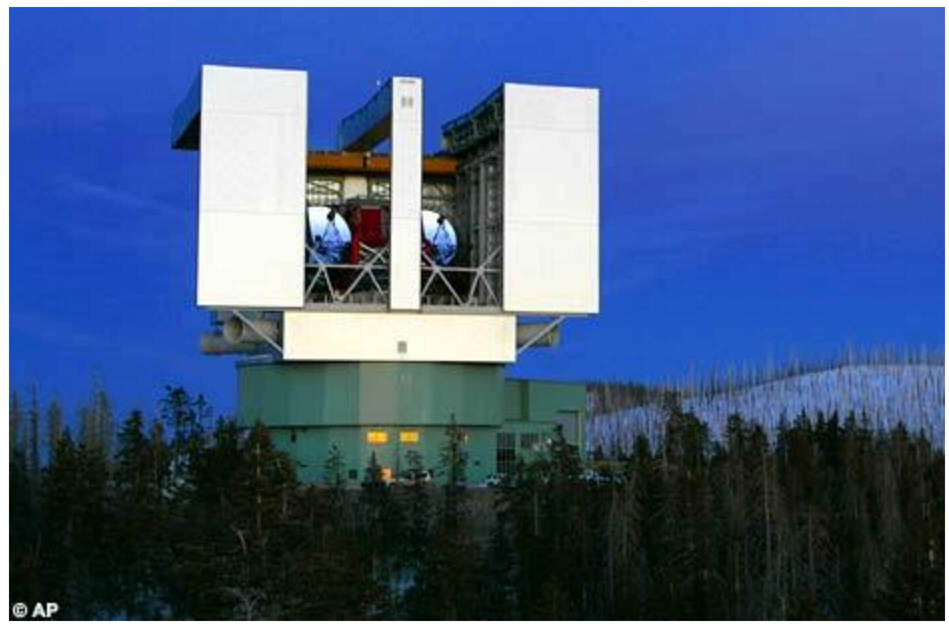
Introduction

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

Section 5: Observatories

Introduction

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



Section 5: Observatories

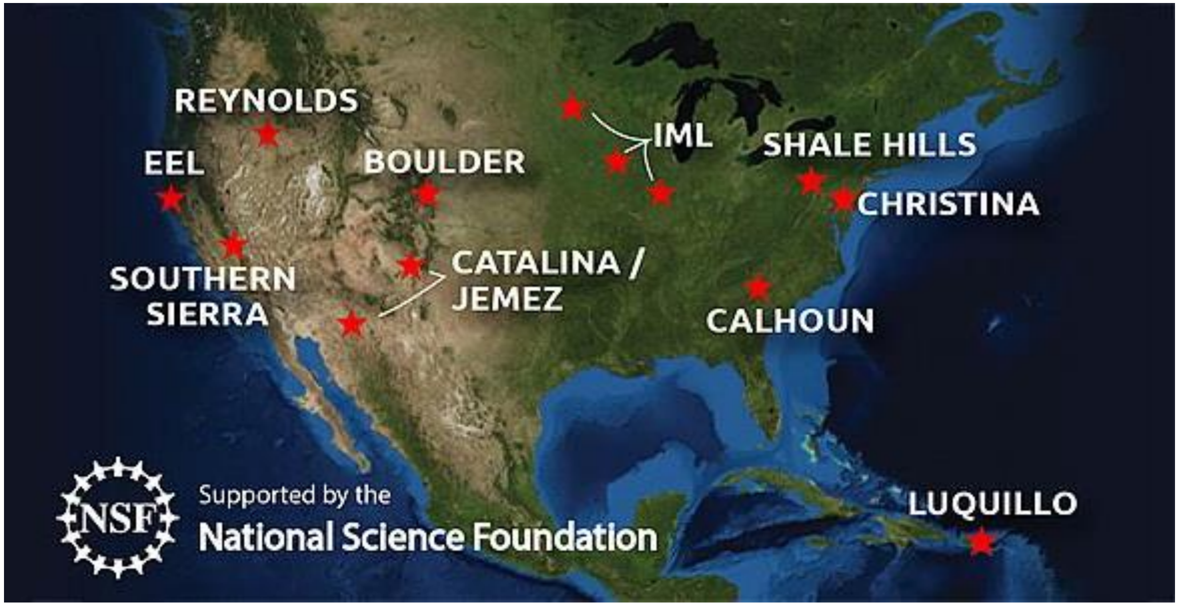
Introduction

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

Section 5: Observatories

Introduction

- With the high expense _________ , the ability to study the sky is a _________ effort
- Observatories from all over the globe share their _________ 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 _________ has to be submitted explaining what he/she wants to focus on and _________
- They also have to show that the scope's _________ and capabilities are what's needed to study the object
- Proposals are screened by a _________ 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

Section 5: Observatories

Going Observing

- The runs that get __________ are set up for several __________ 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 __________ and software, allowing the observer to control the scope from an observation room or even from another location – most __________

Section 5: Observatories

Computers

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