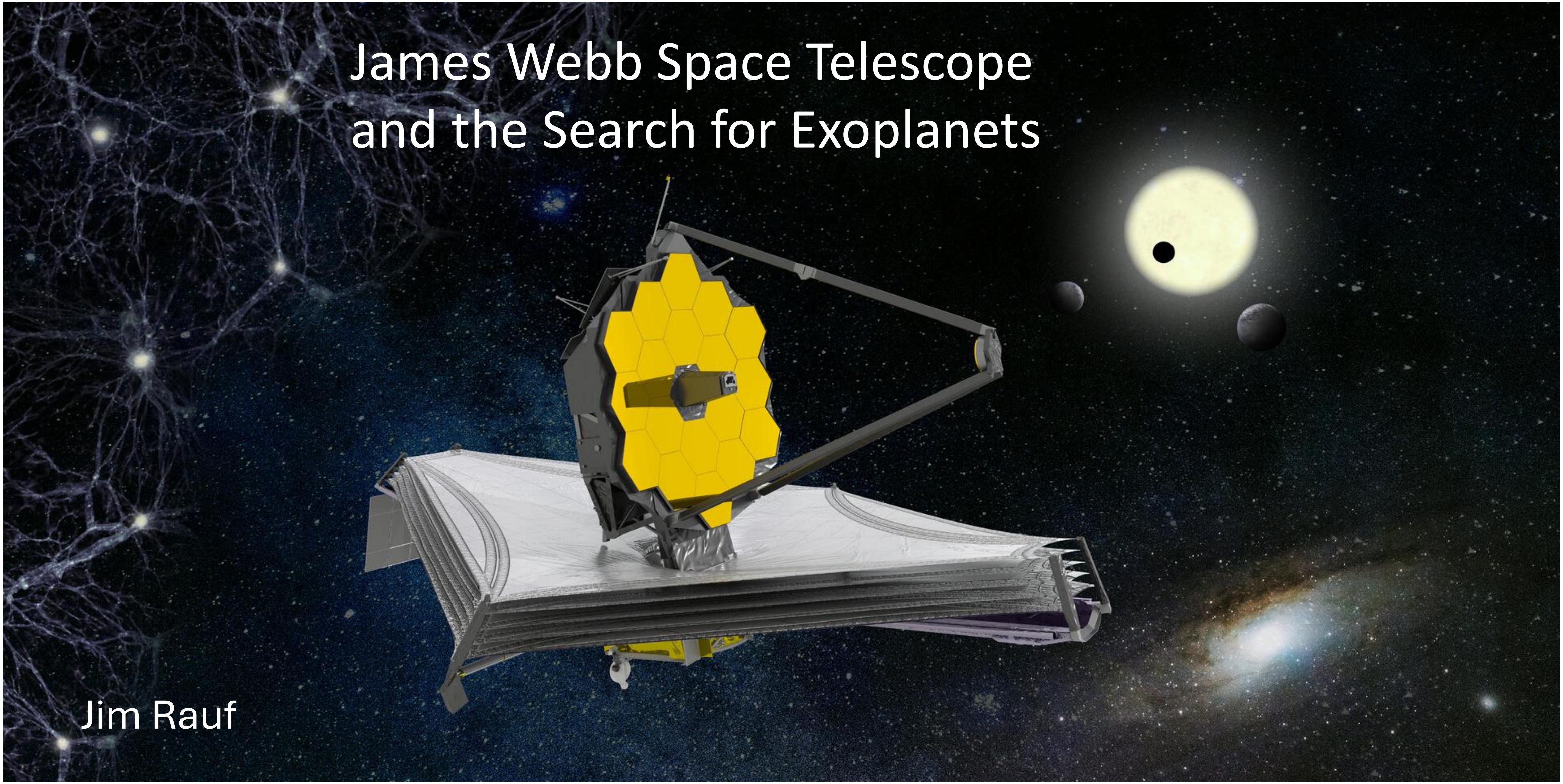
James Webb Space Telescope and the Search for Exoplanets



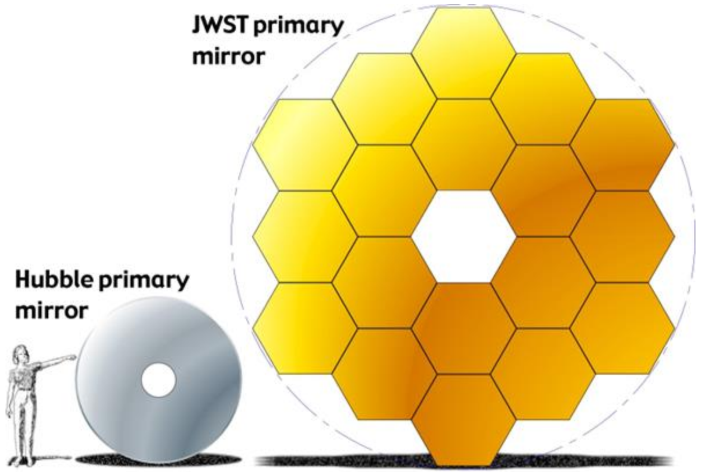
Jim Rauf

James Webb Space Telescope (JWST) History

- Scientists from **NASA** and the **Space Telescope Science Institute** needed a telescope to follow up on discoveries made by the **Hubble Space Telescope (HST)**
  - **HST** was put into **low earth orbit (LEO)** in 1990
- During the mid-1990s an **infrared telescope** with a large mirror roughly 13 feet , was formally proposed and approved
- Construction began in 2004
- The 18-segment **primary mirror** was completed by 2011
- By the end of 2015, **JWST's** four scientific instruments were delivered to **NASA's Goddard Space Flight Center** in Greenbelt, Maryland

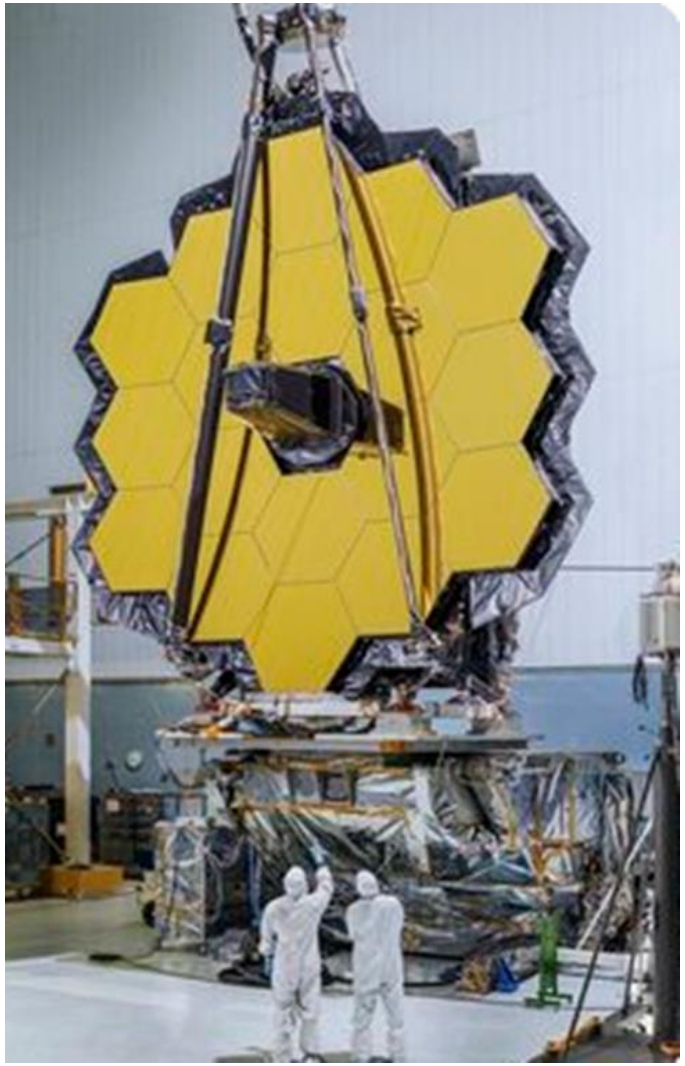
  Mid-Infrared Instrument (MIRI)
  Near-Infrared Camera (NIRCam)
  Near-Infrared Spectrograph (NIRSpec)
  Near-Infrared Imager and Slitless Spectrograph/Fine Guidance Sensor (NIRISS/FGS)

- They and the entire **Integrated Science Instrument Module (ISIM)** completed cryogenic testing
- In 2018, all elements of **JWST's** flight components were delivered to **Northrop Grumman** in Redondo Beach, California
- **JWST** was launched into space December 25, 2021, atop an **Arianne 5** booster

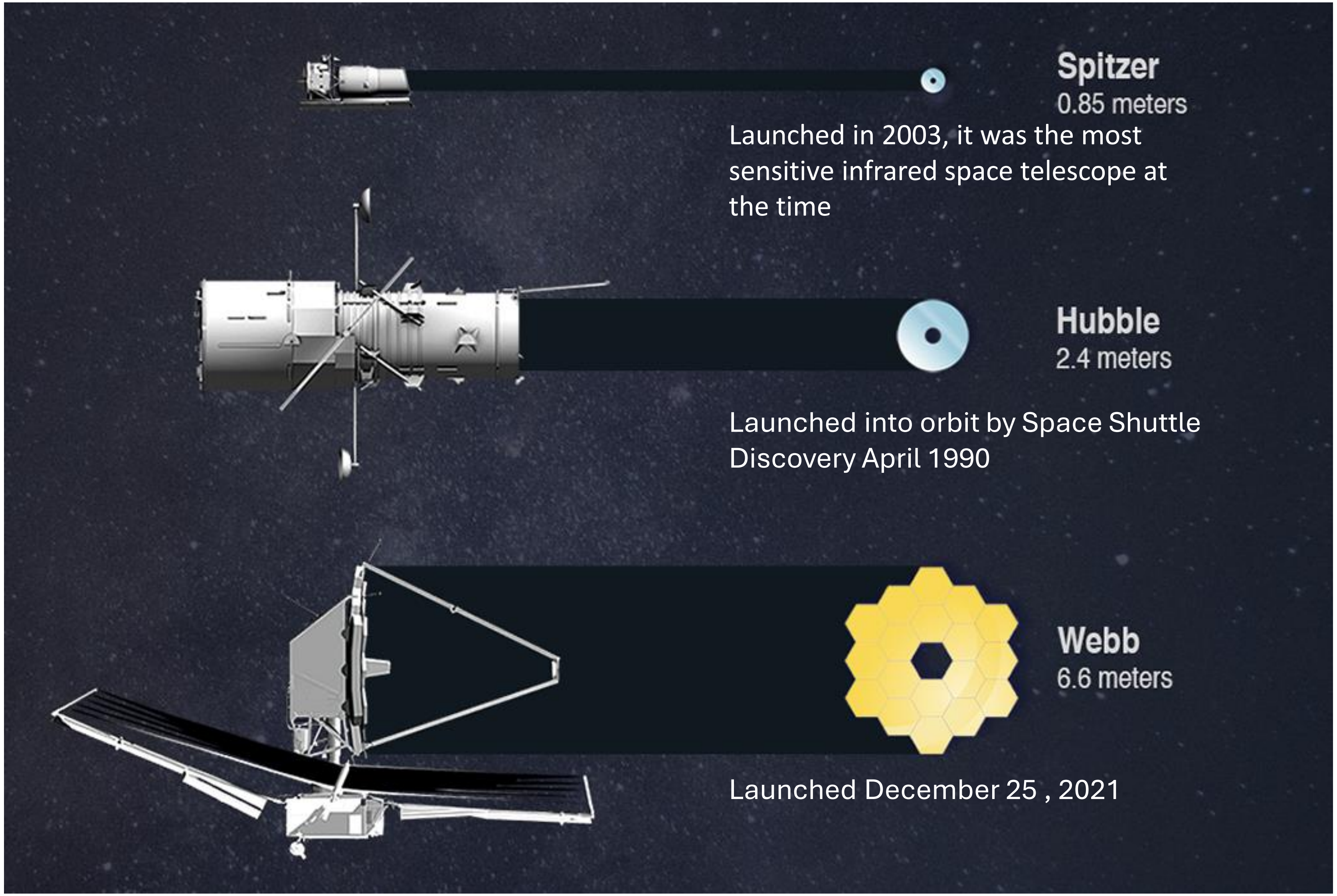


James Webb Space Telescope (JWST)

- The **JWST** is the largest, most complex observatory ever sent into space
- Final cost **$10 billion**
  - Initial budget **$ 1 billion**
- **JWST's** innovative design tackles the two main challenges for an **infrared telescope:**
- It needs a **very large mirror** to collect enough light, and it has to be **kept cold** to keep unwanted sources of infrared (heat) from interfering with the light being observed
- **JWST'**s key components are:
  - An enormous **primary mirror** to collect infrared light
  - A supersized **sunshield** to keep the telescope cold
  - **Four scientific instruments** to conduct its ambitious science operations



James Webb Space Telescope (JWST)



Launched in 2003, it was the most sensitive infrared space telescope at the time

Launched into orbit by Space Shuttle Discovery April 1990

Launched December 25 , 2021

Spitzer in earth trailing orbit around the Sun

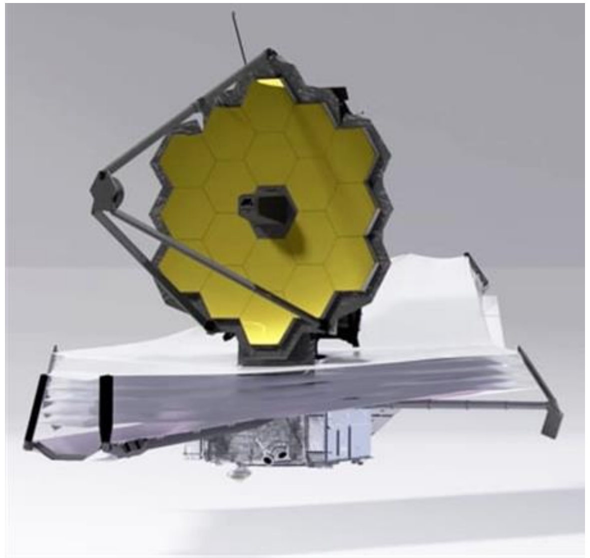
It detected light from an **exoplanet**, the first telescope to do so

HST LEO ~336 miles above earth

JWST's four science instruments are optimized to detect **infrared** light

James Webb Space Telescope (JWST)

- The size of the **mirror** and **sunshield** present a challenge:
- **JWST** must fit into the limited space within the **Arianne 5** launch vehicle
- The telescope is designed to neatly fold upon itself for launch
- Then complete a complicated series of steps to unfurl on its way to its observation post ~one million miles from Earth at **Lagrange point 2 (L2)**



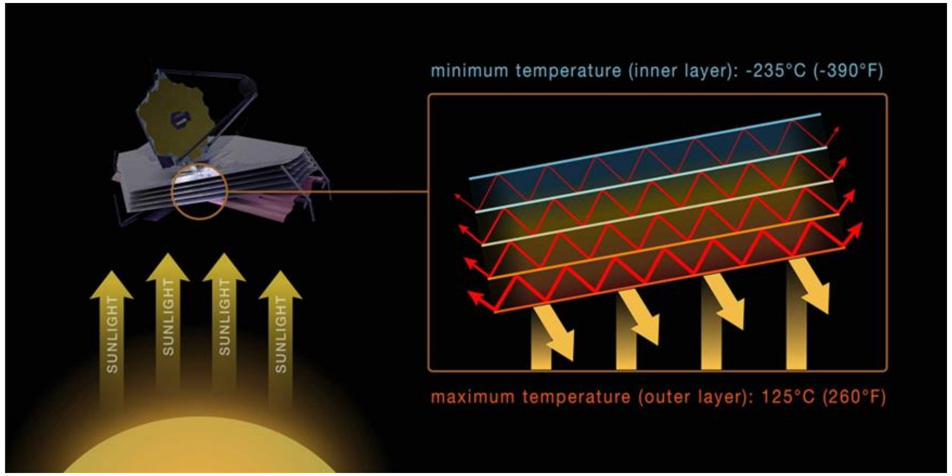
James Webb Space Telescope (JWST)

Launch Date:	**December 25, 2021 07:20am EST (2021-12-25 12:20 GMT/UTC)**
Launch Vehicle:	**Ariane 5 ECA**
Mission Duration	**5 - 10 years**
Total payload mass:	Approx 6200 kg, including observatory, on-orbit consumables and launch vehicle adaptor.
Diameter of primary Mirror:	**6.5 m (21.3 ft) approximately**
Clear aperture of primary Mirror:	25 m^2
Primary mirror material:	**beryllium coated with gold**
Mass of primary mirror:	705 kg
Mass of a single primary mirror segment:	20.1 kg for a single beryllium mirror, 39.48 kg for one entire primary mirror segment assembly (PMSA).
Focal length:	131.4 meters
Number of primary mirror segments:	**18**

Optical resolution:	~0.1 arc-seconds
Wavelength coverage:	0.6 - 28.5 microns
Size of sun shield:	**21.197 m x 14.162 m (69.5 ft x 46.5 ft)**
Temp of sun shield layers:	**Layer 1:** **Max temperature 383K = approx 231F** **Layer 5:** **Max temperature 221K = approx -80F** **Min temperature 36K = approx -394F**
Orbit:	1.5 million km from Earth orbiting the **L2** Point
Operating Temperature:	under 50 K (-370 °F)
Gold coating:	Thickness of gold coating = 100 x 10^{-9} meters (1000 angstroms). Surface area = 25 m^2. Using these numbers plus the density of gold at room temperature (19.3 g/cm^3), the **coating is calculated to use 48.25g of gold**, about equal to the mass of a golf ball. (A golf ball has a mass of 45.9 grams.)

James Webb Space Telescope (JWST)

Sunshield made of five thin layers of Kapton E with aluminum and doped-silicon coatings , about the thickness of a human hair, to reflect the sun's heat back into space



The five-layer design **insulates** the telescope, keeping light from the Sun, Earth, and Moon from overheating the mirror and scientific instruments

None of the layers touch, preventing conduction of heat from one layer to another

The gaps allow the infrared radiation to flow outward

JWST Launch Vehicle

The **Ariane 5** rocket is a heavy lift two-stage rocket with two solid fuel boosters

The total launch mass of the vehicle is of the order of 770,000 kg (1,700,000 lb)

The **JWST** had a launch mass of about 6,500 kg (14,300 lb) and a design lifetime of 5 to 10

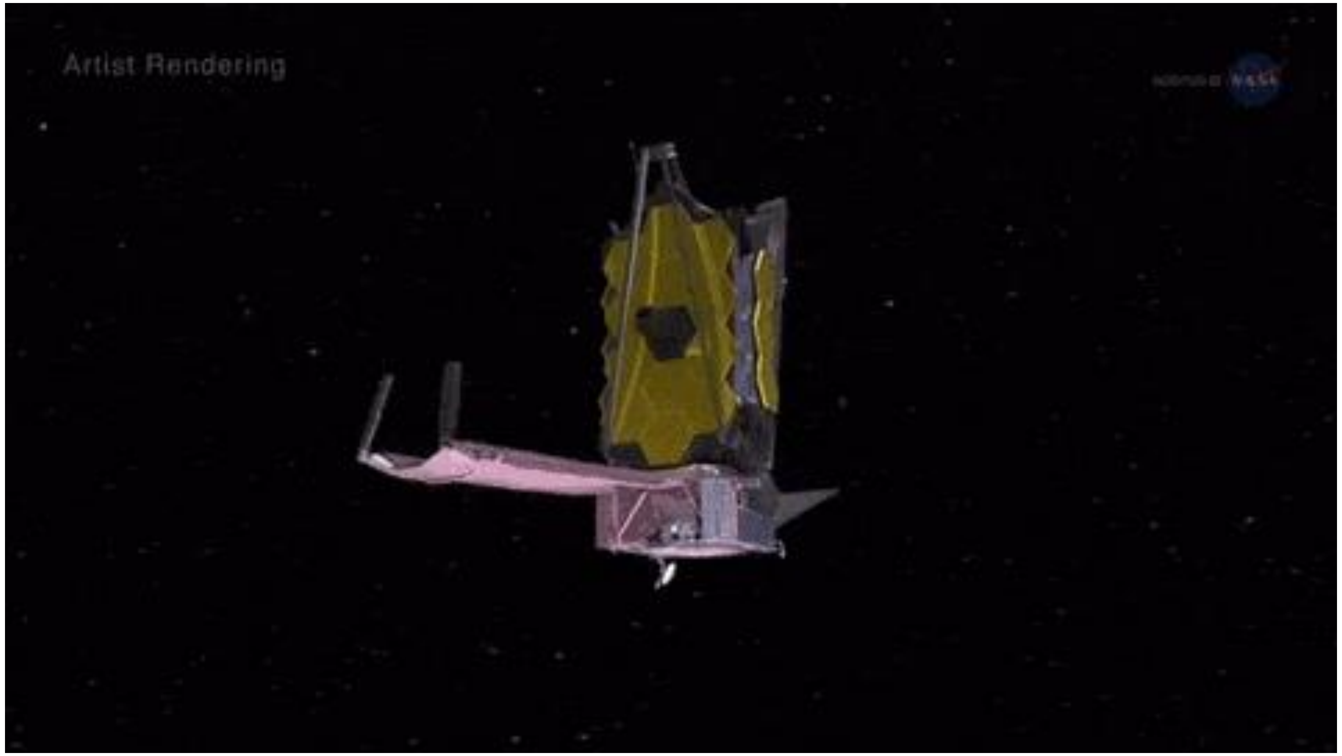
The launch is one of the **European Space Agency (ESA)** contributions to the project

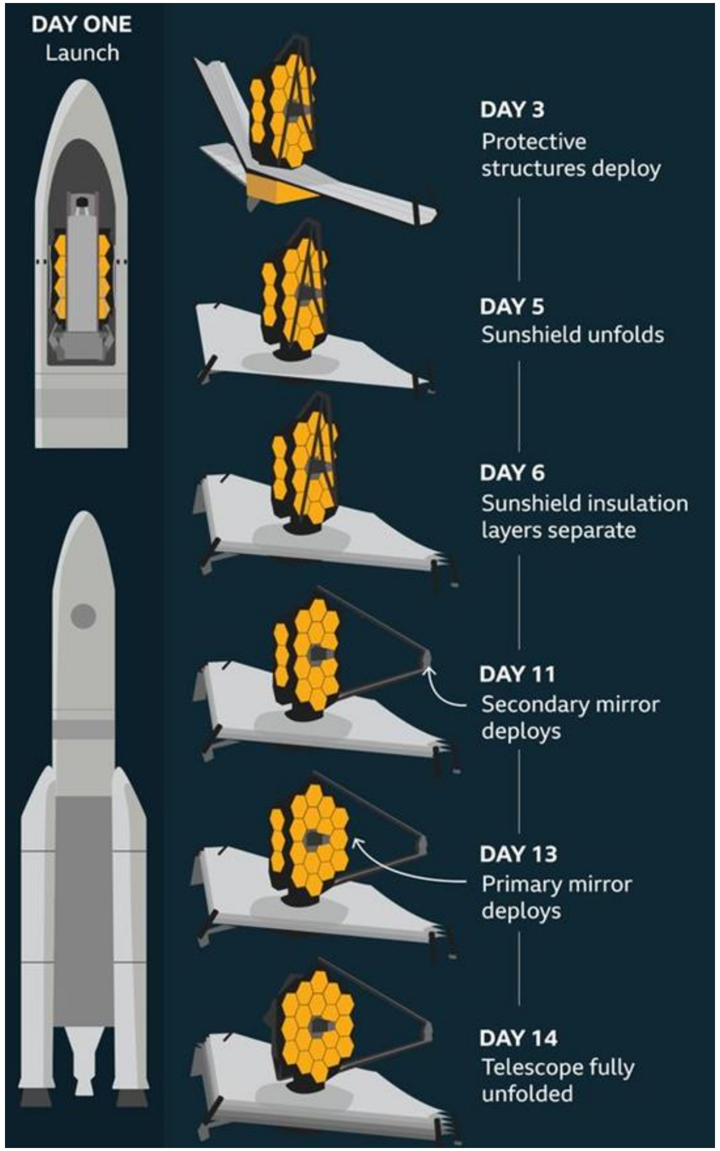
In exchange, **NASA** guaranteed European scientists a fraction of observing time on **JWST** (roughly 15%)

NASA asked for the launch vehicle, launch services and science instruments

James Webb Space Telescope (JWST)

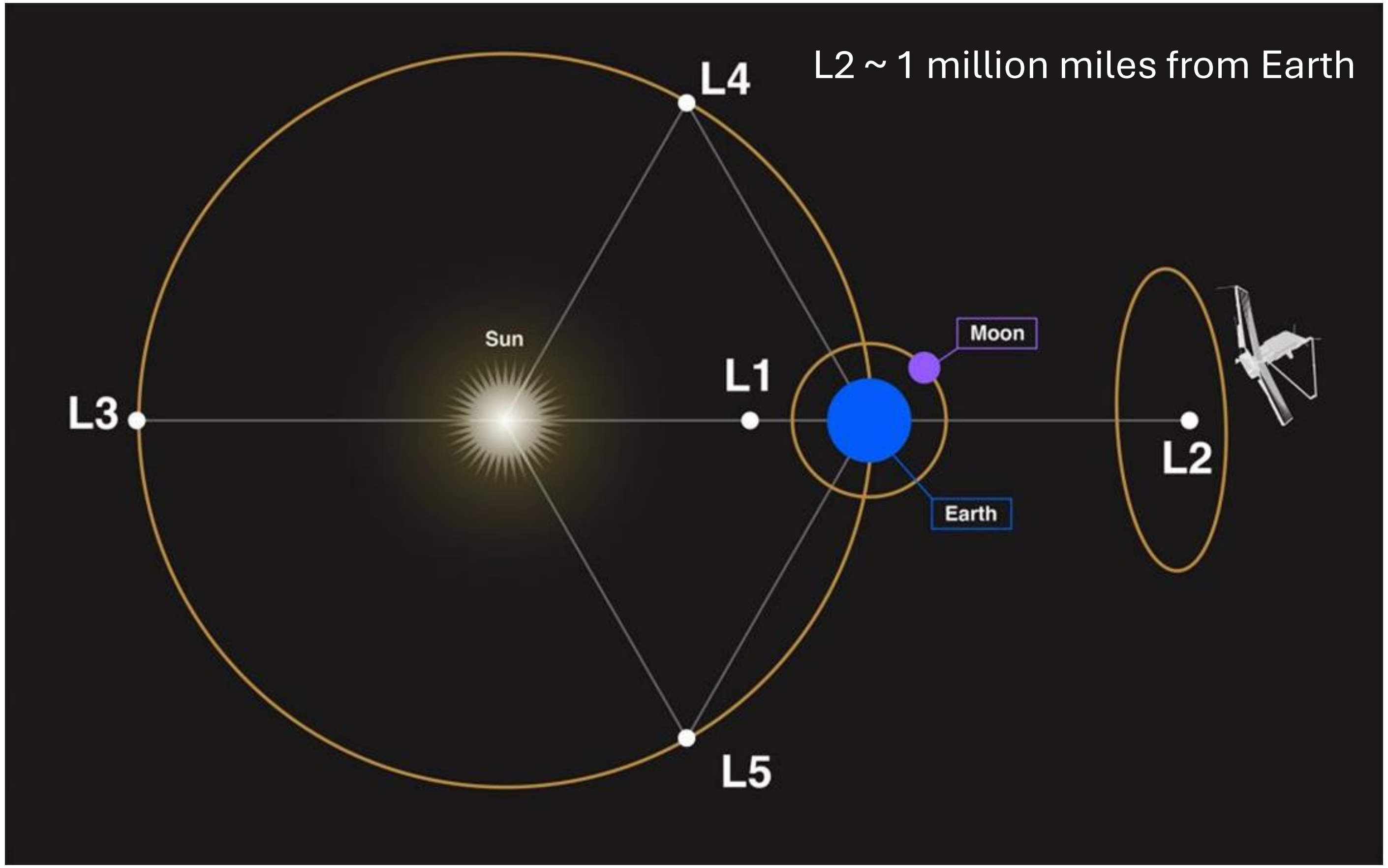
Unfolding





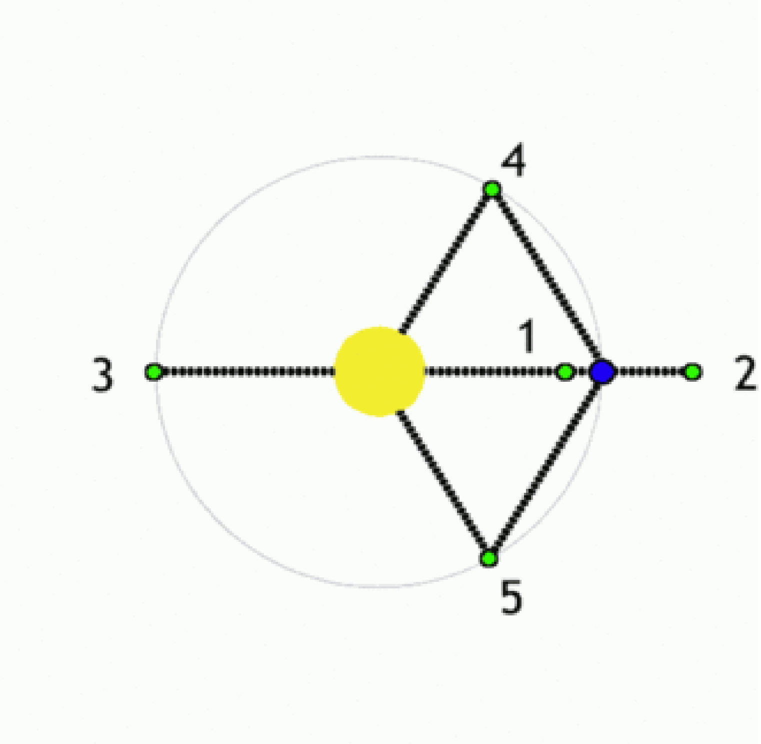
James Webb Space Telescope (JWST) L2 Orbit Location

- A **Sun-Earth Lagrange point** is a region in space where the **gravitational pull of the Sun and Earth combine such that small objects in that region have the same orbital period** (length of year) **as Earth**
- **JWST** is not located directly at **L2**, but instead moves in a **halo orbit** around **L2**, roughly perpendicular to its orbit around the Sun
- **JWST** orbits **L2** at a distance of roughly 500,000 kilometers (300,000 miles), completing one halo orbit every 168 days
- To maintain its halo orbit around **L2, JWST** will need to reposition itself periodically using its thrusters



James Webb Space Telescope (JWST) L2 Orbit Location

- **JWST's** observation post near **L2** gives it a clear view of the sky with **continuous communication** with Earth, far from sources of bright light and heat that impede instrument function
- At **L2**, **JWST** is far beyond Earth's atmosphere, which absorbs (blocks) most infrared light from celestial objects, and is far enough from the Sun, Earth, and Moon for the sunshield to be effective
- Because **L2 moves with Earth** as Earth orbits the Sun, **JWST'**s relative position with respect to Earth does not change significantly over the course of the year
- This simplifies communication between Earth and **JWST** and makes it possible for JWST's sunshield to block the Sun, Earth, and Moon at all times
- JWST's halo orbit around **L2** keeps it out of the shadows of Earth and the Moon, reducing temperature fluctuations and allowing it to maintain **solar power**
- **JWST** is too far from Earth for a servicing mission



James Webb Space Telescope (JWST)

Scientific Goals:

JWST studies various aspects of the universe, including the **formation of stars** and **galaxies**, the evolution of planetary systems, the **potential for life on exoplanets**, the **characterization of exoplanet atmospheres**, and the **early universe shortly after the Big Bang.**

Infrared Observations:

JWST specializes in observing the universe in the infrared spectrum, allowing it to peer through cosmic dust and see objects that are otherwise obscured in visible light

Collaboration:

JWST is a multinational collaboration involving **NASA, ESA,** and **CSA**, with contributions from scientists, engineers, and technicians from multiple countries.

Primary Mirror:

Primary mirror is 6.5 meters (21 feet) in diameter, made up of 18 hexagonal segments that will work together to collect and focus light

Sunshield:

The telescope's instruments and sensitive detectors are protected by a five-layer, tennis court-sized sunshieldwhich helps maintain the telescope's temperature

Orbit:

The **JWST** is positioned at the second **Lagrange point (L2),** located about 1.5 million kilometers (approximately 1 million miles) from Earth

This location provides a stable environment and minimizes interference from Earth and the Sun

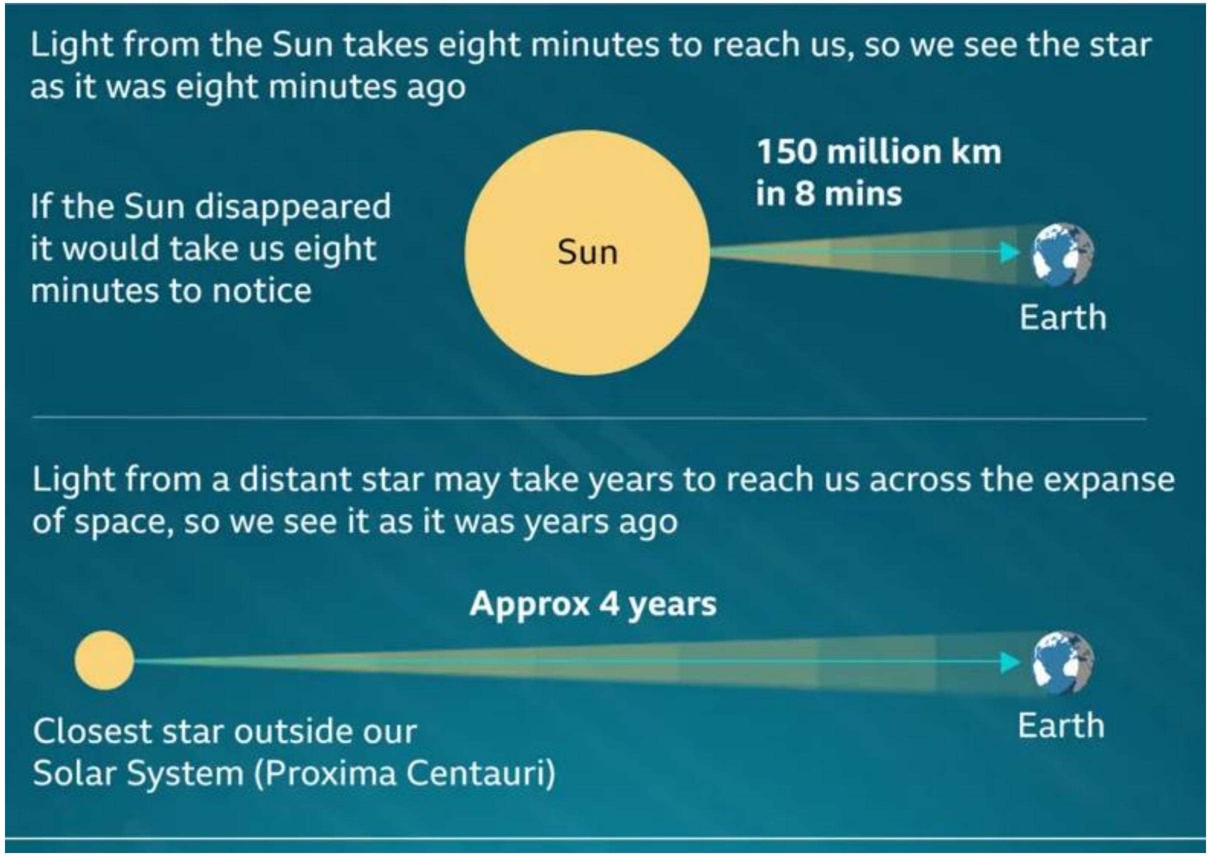
Launch and Operations:

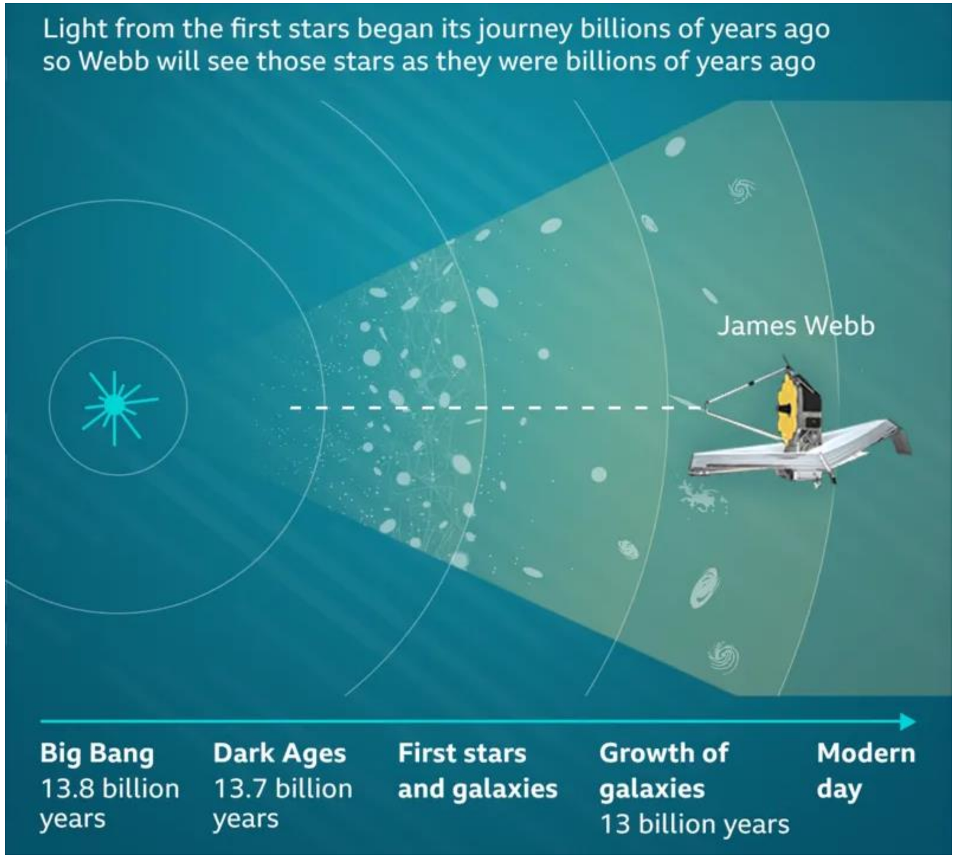
The telescope was launched on December 25, 2021, via an Ariane 5 rocket from French Guiana

After launch, a series of deployment stages and rigorous testing were conducted.

JWST mission is expected to last for many years

James Webb Space Telescope (JWST)





James Webb Space Telescope (JWST)

Scientists working with data from the **James Webb Space Telescope (JWST)** have obtained the first full spectra of some of the **earliest starlight** in the universe

The images provide the **clearest picture** yet of **very low-mass, newborn galaxies**, **formed less than a billion years after the Big Bang**

This suggests the tiny galaxies are central to the cosmic origin story

JWST Recent Finding

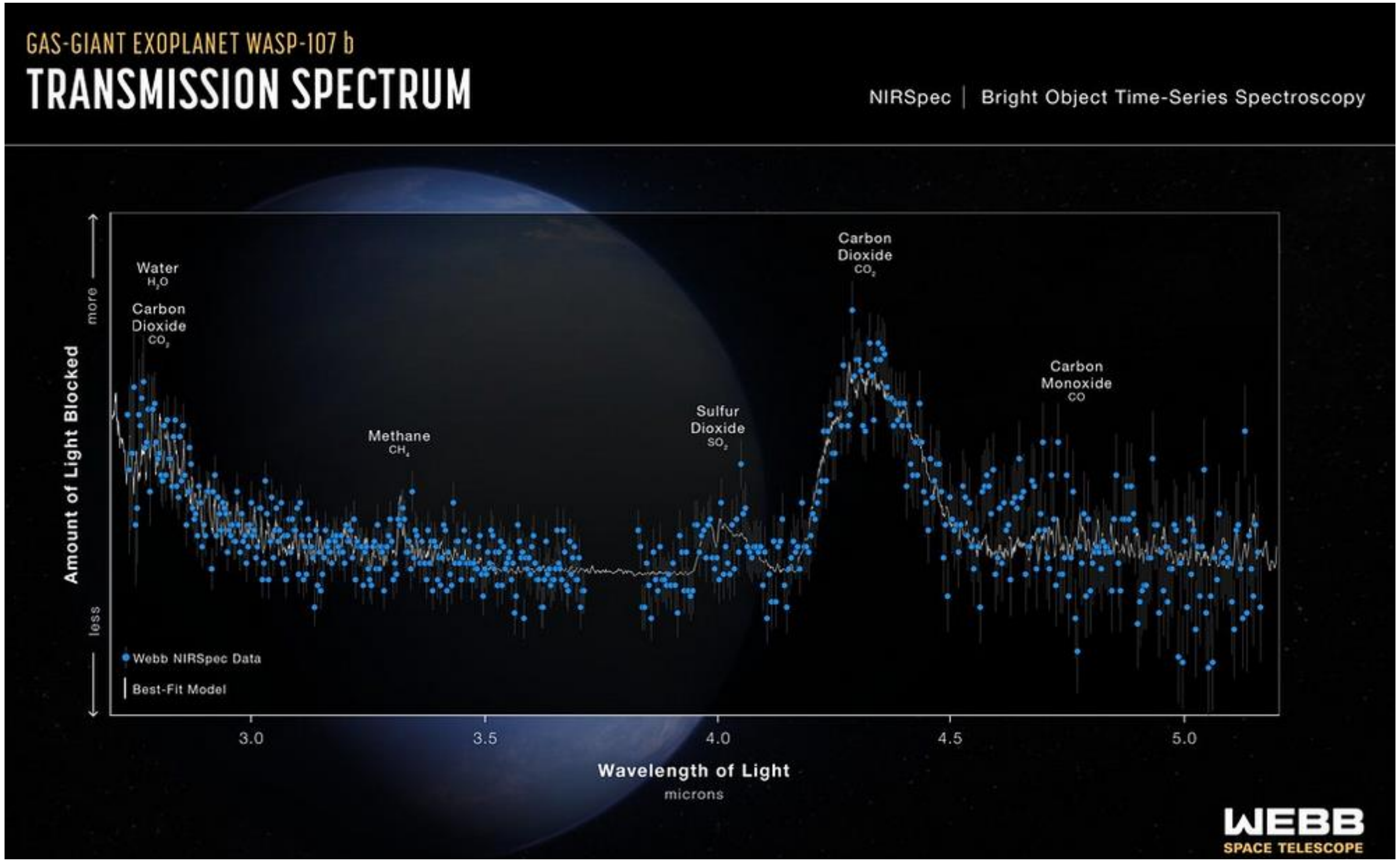
Warm Gas-Giant Exoplanet WASP-107 b Transmission Spectrum (NIRSpec)
Webb's NIRSpec (Near-Infrared Spectrograph), shows the amounts of different wavelengths (colors) of **near-infrared starlight blocked by the atmosphere** of the gas-giant exoplanet **WASP-107 b**

It is possible to calculate the amount of each wavelength that is blocked by the atmosphere

Since each molecule absorbs a unique combination of wavelengths, the transmission spectrum can be used to establish he abundance of various gases

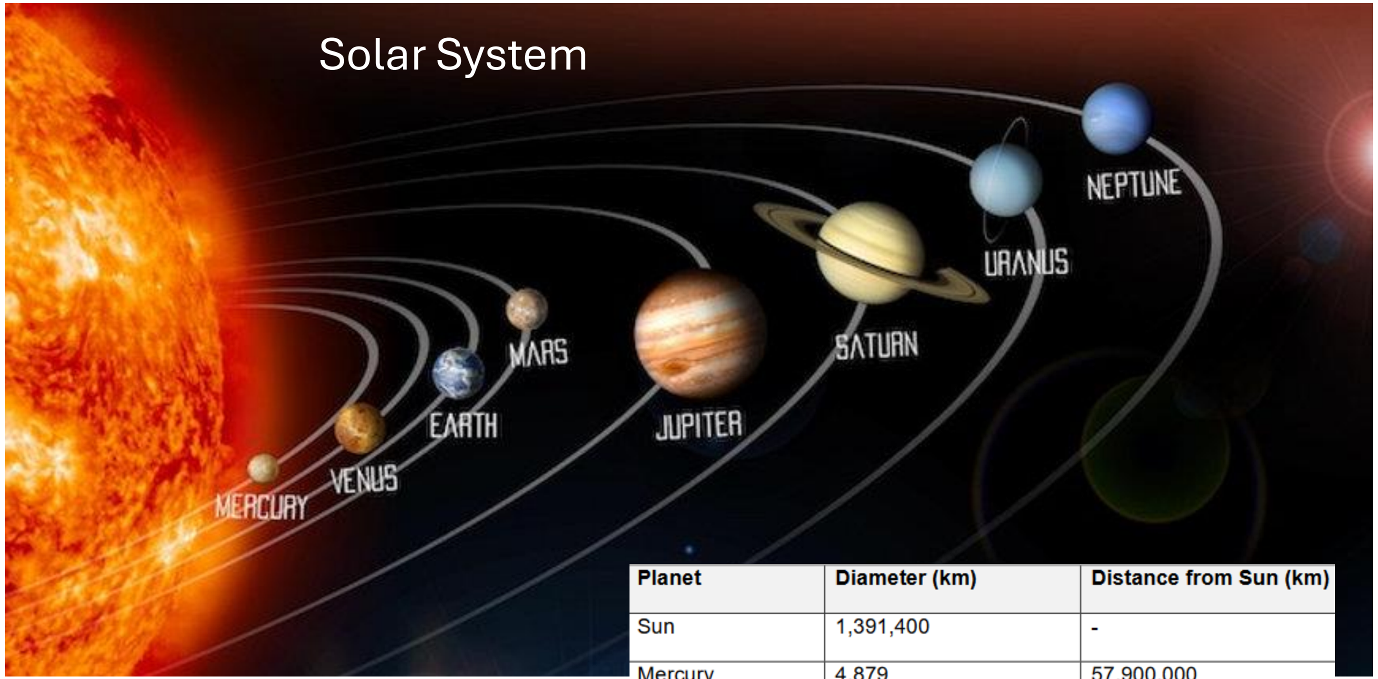
This spectrum shows **clear evidence** for **water (H_2O), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4),** and **sulfur dioxide (SO_2)** in the planet's atmosphere

This allows searchers to estimate the interior temperature and mass of the core



Extrasolar Planets Or Exoplanets

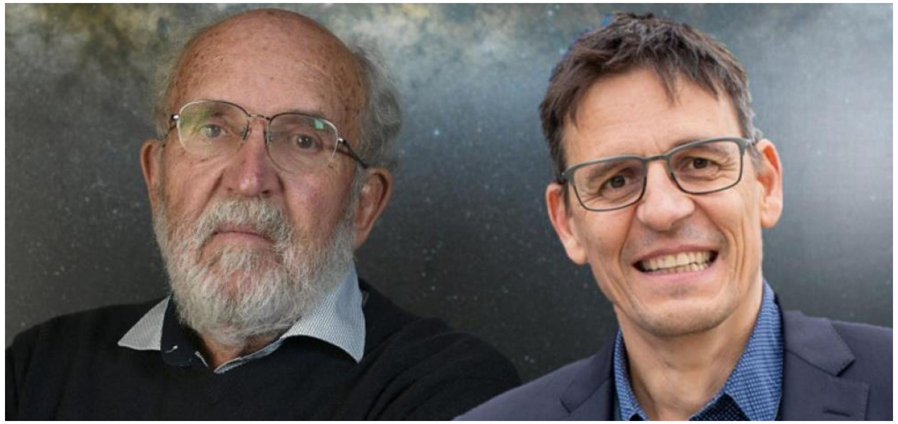
- An **exoplanet**, or **extrasolar planet**, is a planet outside of our solar system that usually orbits another star in our galaxy
- Most of the exoplanets discovered so far are in a *relatively small* region of our galaxy, the **Milky Way**
- "Small" meaning within **thousands of light-years** of our solar system
    - One light-year equals 5.88 trillion miles, or 9.46 trillion kilometers
- **Milky Way Galaxy** is ~100,000 light years in diameter
    - ~5.88×10^{17} miles



Planet	Diameter (km)	Distance from Sun (km)
Sun	1,391,400	-
Mercury	4,879	57,900,000
Venus	12,104	108,200,000
Earth	12,756	149,600,000
Mars	6,792	227,900,000
Jupiter	142,984	778,600,000
Saturn	120,536	1,433,500,000
Uranus	51,118	2,872,500,000
Neptune	49,528	4,495,100,000

Exoplanets First Discovery

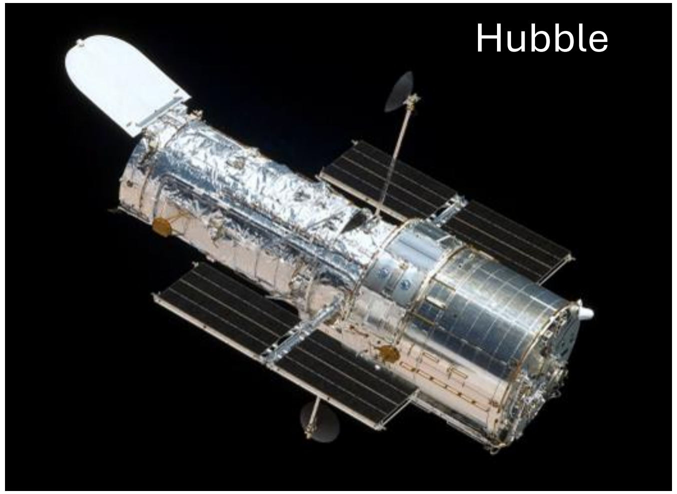
- Scientists (**Isaac Newton**) have speculated about the existence of **exoplanets** well before technology developed to confirm their existence
- Late in the 20th century looking for exoplanets was not an acceptable task for astronomers
- Studying **brown dwarf** stars was **OK**
- October 1995 **Michael Mayor** and **Didier Queloz** reported a planet orbiting a **Sun like** star, **51 Pegasi**, some 50 light years from the Sun



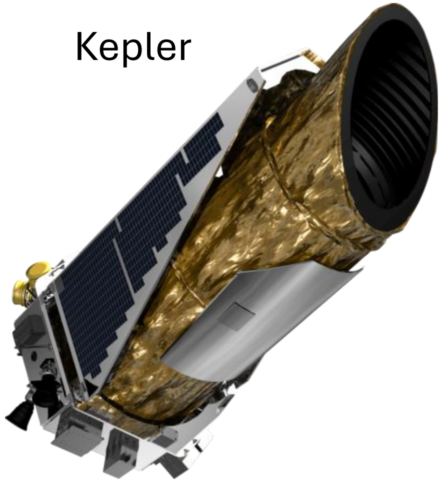
- They detected the planet by studying how it was making its host star wobble –using a detection method known as **radial velocity**
- The planet , **51 Pegasi b**, had a mass about ½ that of **Jupiter** and an orbital period of 4.23 earth days-incredibly close to its host star
- Two more planets were found in data that had not yet been analyzed:
- **70 Virg b** and **47 UM ab**
- Both were more massive and closer to their stars than expected
- **Hot Jupiters**
- **Michael Mayor** and **Didier Queloz** shared the Noble Prize in physics in 2019

Exoplanets

- The **Milky Way** galaxy is estimated to have formed 10 to 12 billion years ago
- There are estimated to be 100 million to 400 million stars in the **Milky Way** galaxy
- **Hubble Telescope** observations -estimated 100 billion to 200 billion galaxies in the **visible universe**
- **NASA's Kepler Space Telescope** observations- more planets than stars in the galaxy
- More than 10,000,000,000,000,000,000 planets
    - 10^{18} planets



Kepler



Exoplanets -- Ways to Find an Exoplanets

- **Transit method**
  - Eclipses
- **Radial Velocity method**
  - Stars wobble
- **Direct Imaging method**
  - Taking photos
- **Gravitational Lensing method**
  - Light bent by gravity
- **Astrometry method**
  - Tiny star movements

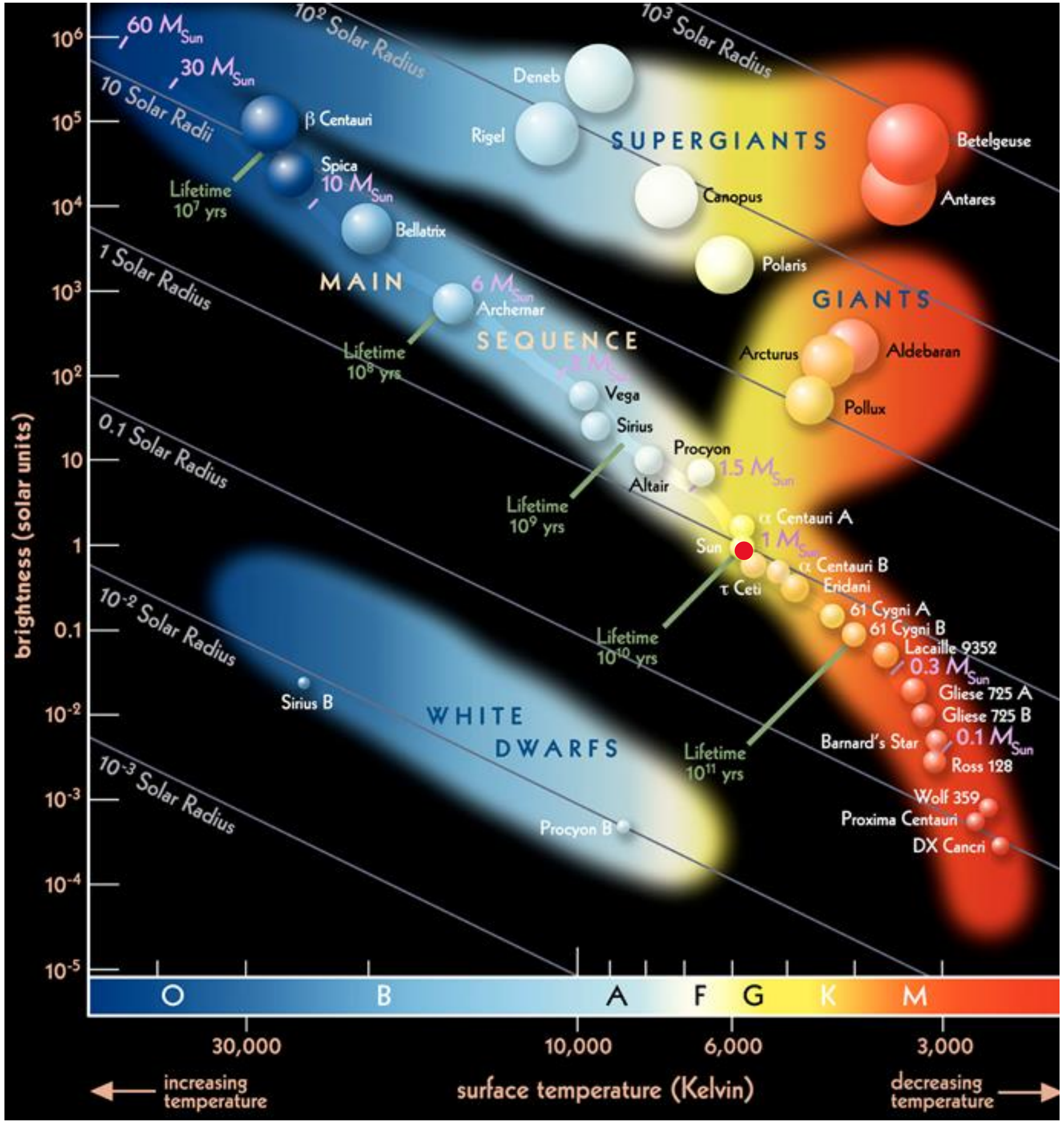
- Finding exoplanets involves sophisticated instruments
- These instruments make use of various **laws of physics** and characteristics of stars
- Direct observation or **direct imaging**, is extremely difficult because of the great distances involved with most exoplanets
- Many of the characteristics of exoplanets are **inferred** based on laws of physics
- Estimates of numbers of exoplanets in the galaxy or universe are based on a **very small sample** of discovered exoplanets

Hertzsprung–Russell diagram

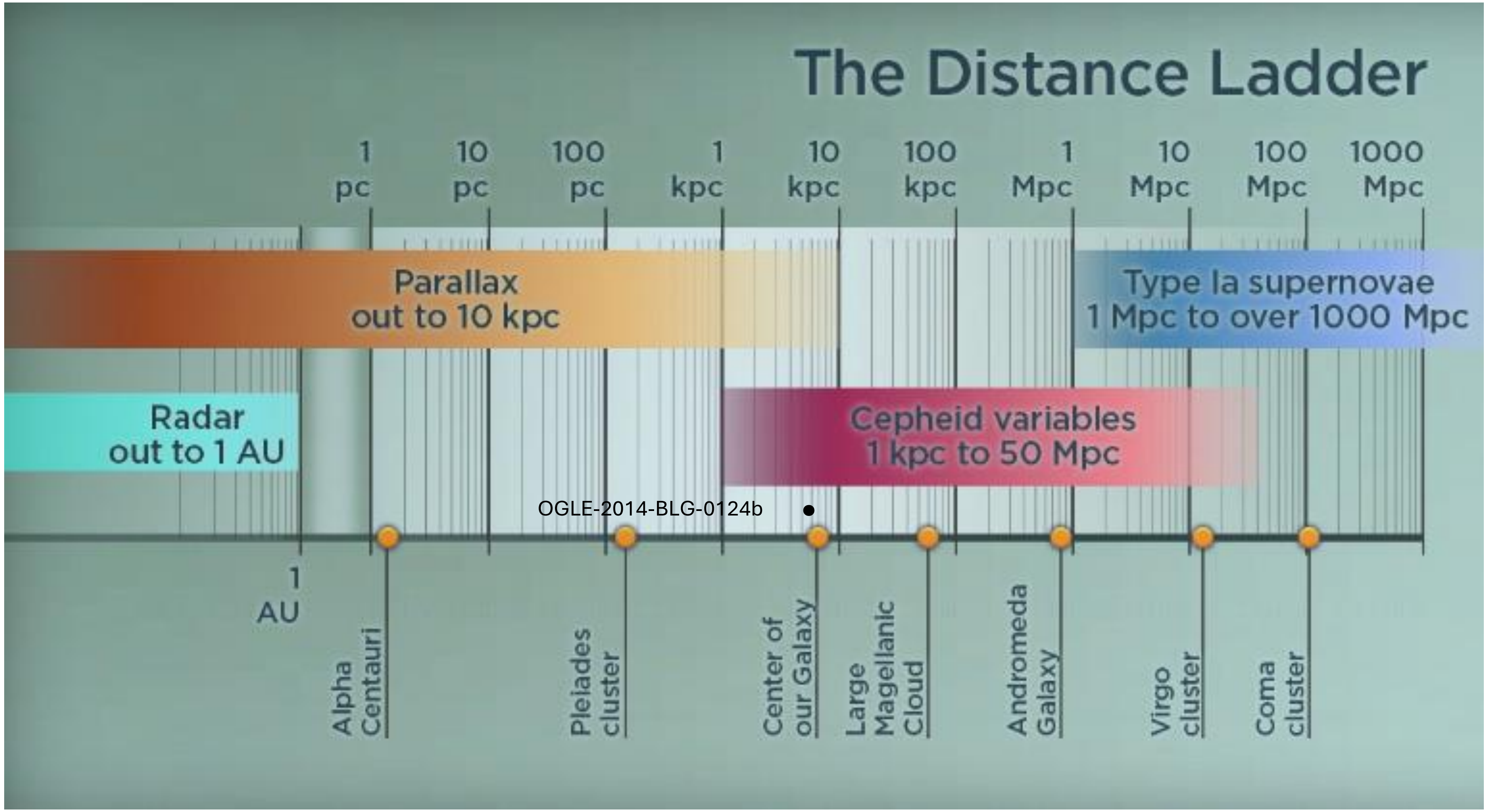
H-R diagram is a scatter plot of **stars** showing the relationship among the stars':

- Absolute magnitudes (luminosities)
- Stellar classifications
- Effective surface temperatures K
- Solar radii
- Solar masses

● The Sun

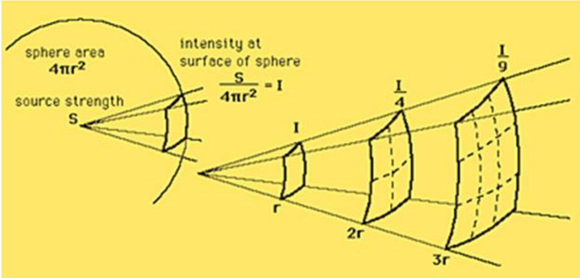


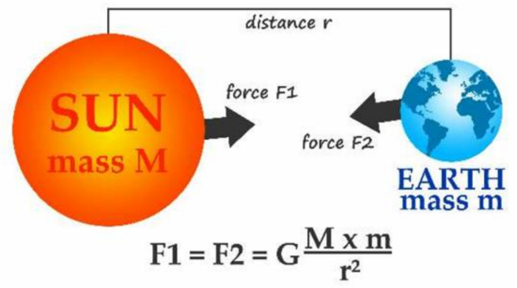
Exoplanets Distances



The parsec is approximately equal to 3.26 light-years or 19.2 trillion miles
Parsec is defined as the distance at which 1 au subtends an angle of one arcsecond
Proxima Centauri, is about 1.3 parsecs (4.2 light-years) from the Sun

Exoplanets – Some Physics

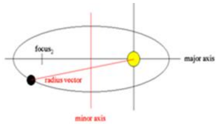




Gravity-it's not just a good idea--- it's the Law

First Law

Each planet moves in an elliptical orbit with it's star (Sun) at one focus

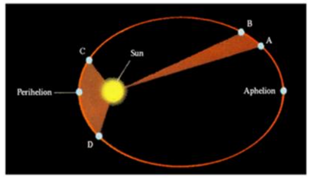


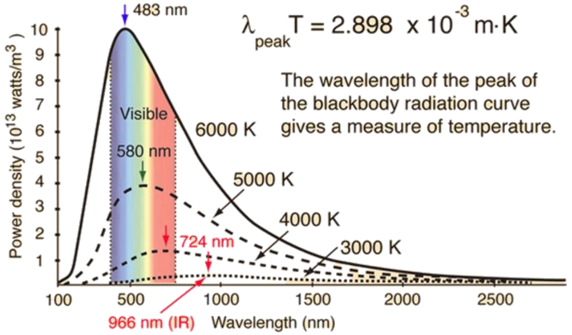
Second Law

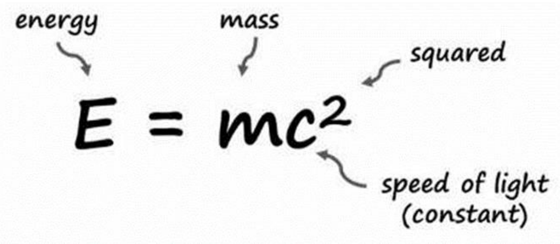
(law of equal areas): an orbiting object will take the same amount of time to travel between points A & B as it takes to travel between points C & D

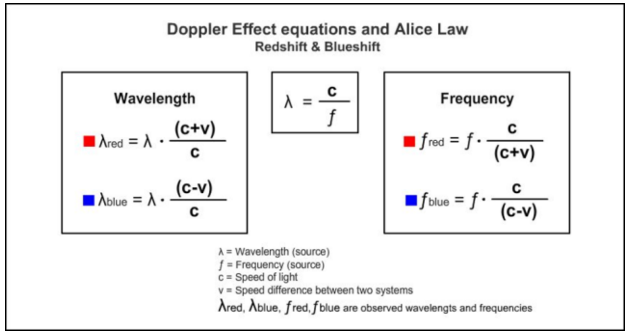
Third Law

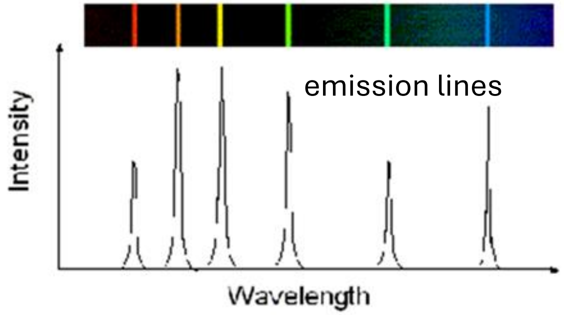
(law of harmonics): The square of a planet's orbital time is proportional to its average distance from the star (Sun) cubed.

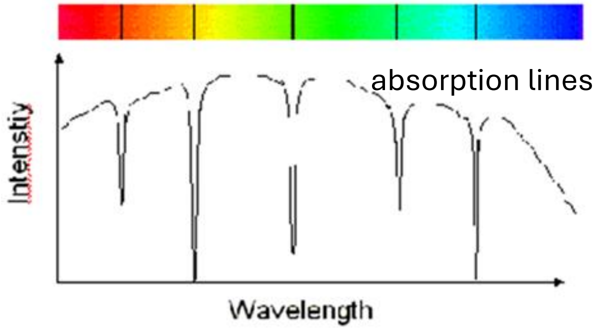






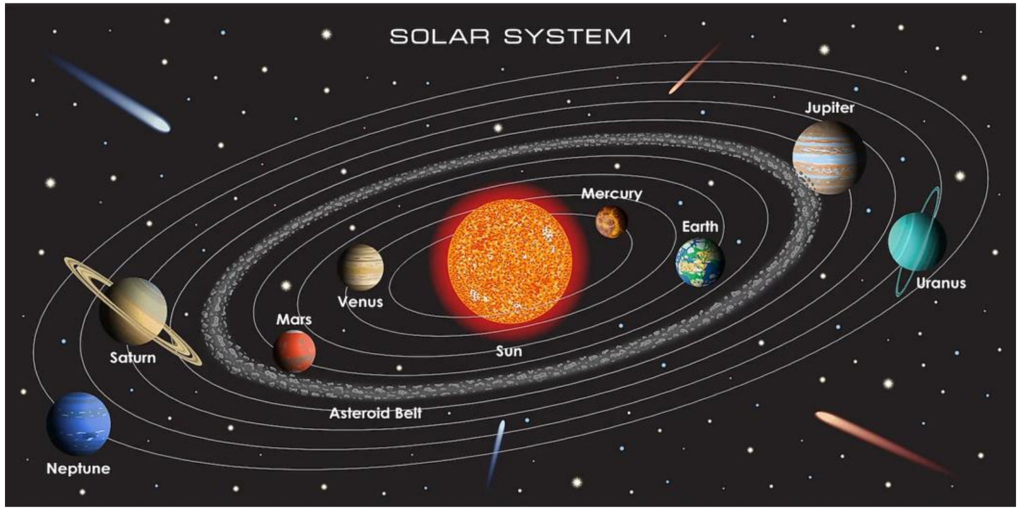




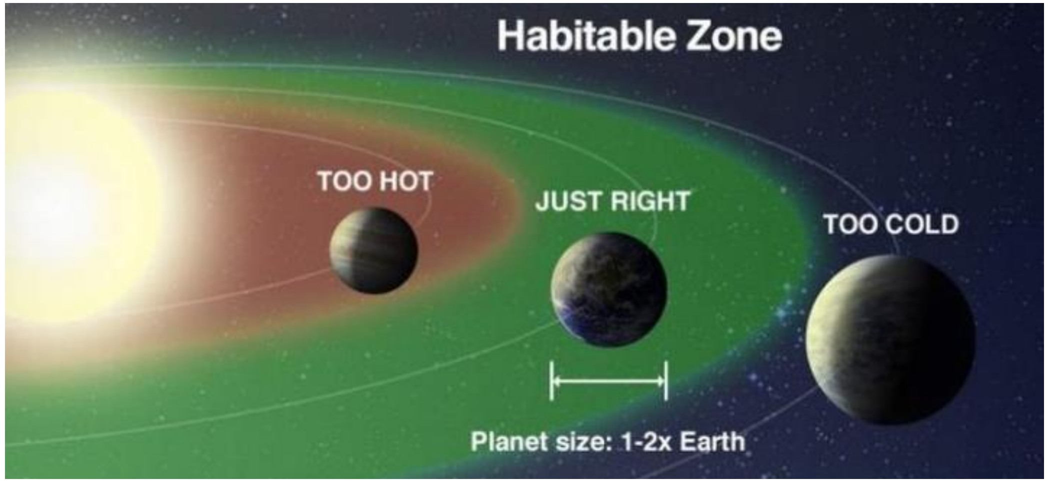


Exoplanets Theory of Planet Formation

- The variety of exoplanets and their star systems sheds new light on the theories of **solar system formation**
- Star systems with **Jupiter**-sized (big) exoplanets **near host stars** support the theory that planets move during/after formation
    - Gas giants form near their stars and migrate out to greater orbital distances?
    - Did **Jupiter** do this?



- One goal is to find a planet that **supports life**
- Intelligent or otherwise
- Another is to locate planets that might serve as a **home for the human race** when the Sun exhausts it hydrogen fuel and expands to engulf the earth's orbit-5 billion years in future
- Planet must be in star's "**Habitable Zone**"
- Liquid water on its surface

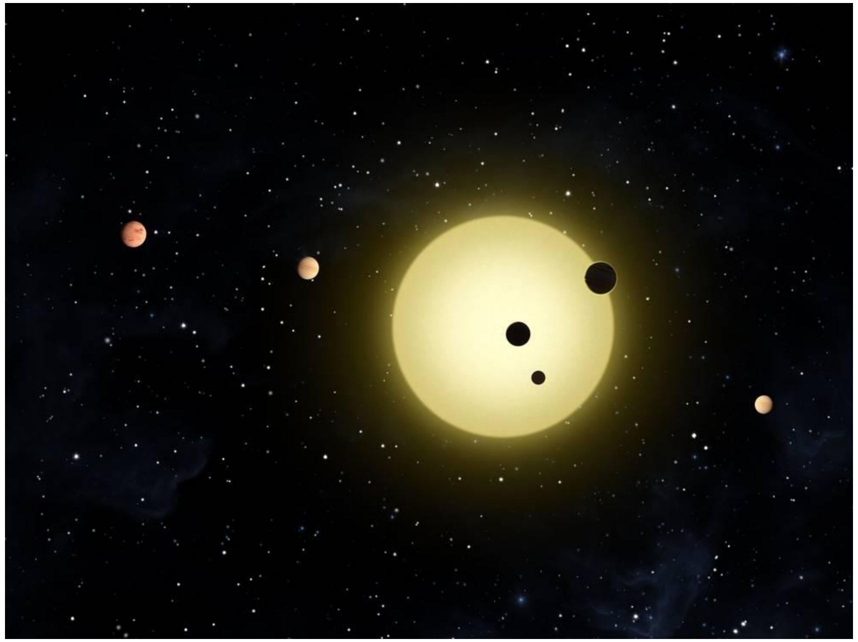


Exoplanets Naming

- Stars have names or identifying numbers e.g. **Proxima Centauri**
- Exoplanets have a string of numbers to identify them e.g. **HR 2562 b**
- The first string of characters denotes the star-system to which it belongs
- That text is followed by a letter **a** for the star around which the planets orbit

  (it is often omitted)
- The rest of the letters **b**, **c**, **d**... denote the **order of discovery** of the planets
- **Kepler 11** is a yellow dwarf star
- **Kepler 11** planets are Kepler 11-b,11-c,11-d,

  11-e,11-f, and 11-g



- **Kepler-11** system was the first compact solar system discovered by **Kepler Space Telescope**
- It revealed that a system can be tightly packed, with at least five planets within the orbit of Mercury, and still be stable
- It touched off a whole new look into planet formation ideas and suggested that **multiple small planet systems**, like our solar system, **may be common**

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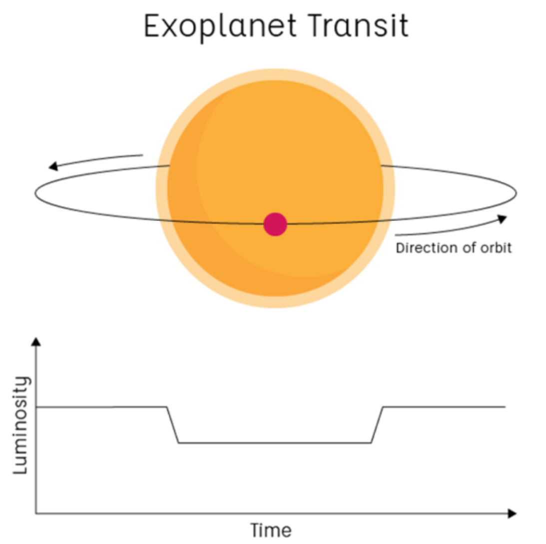
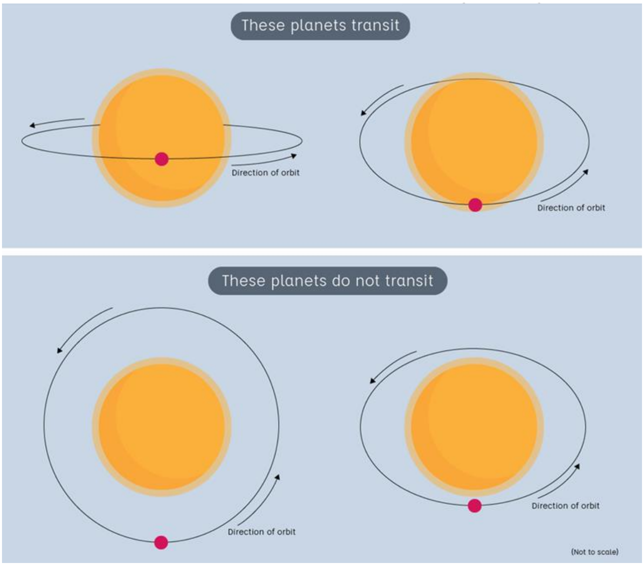
Exoplanets – Instruments

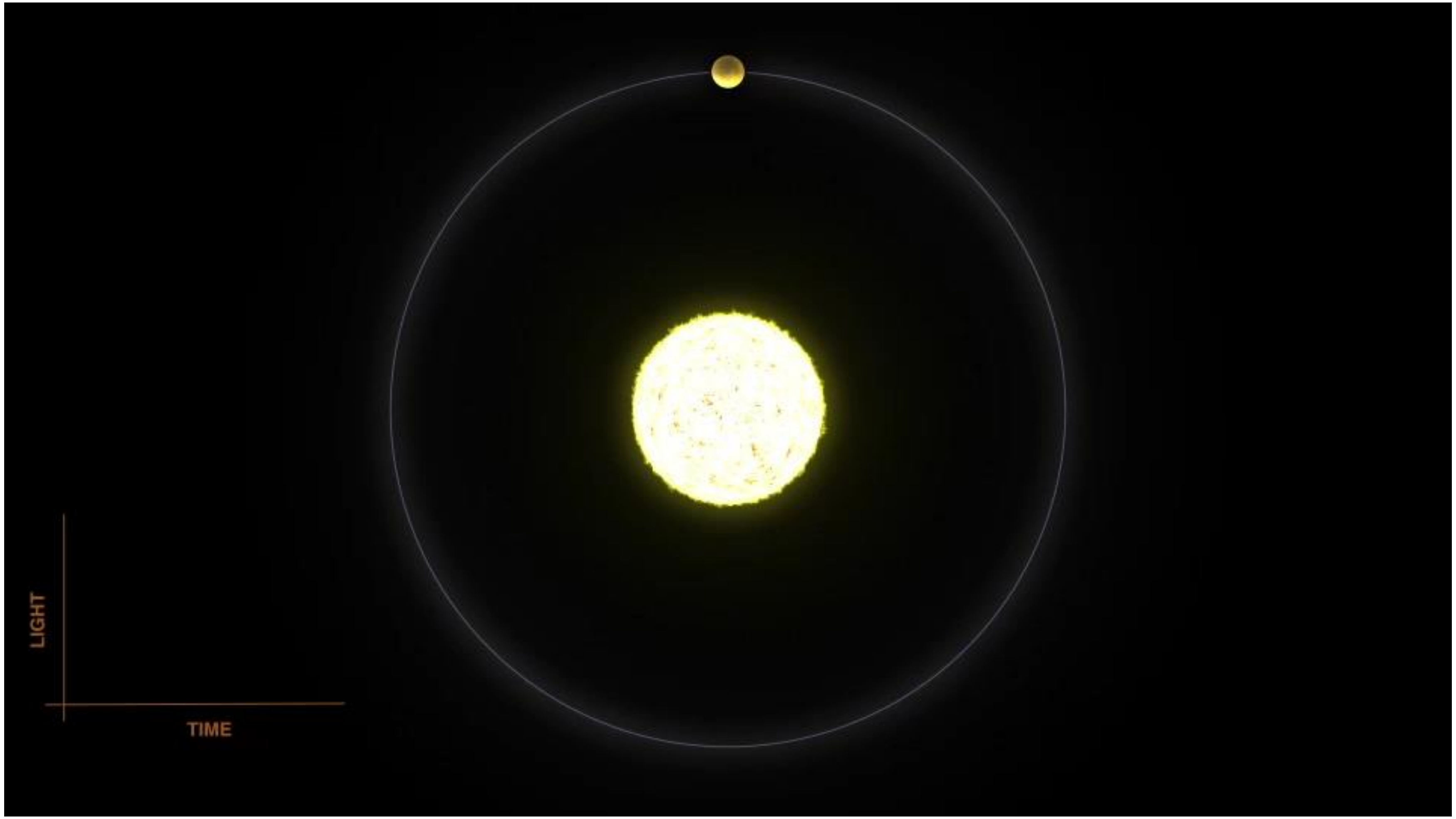
Exoplanets – Transit Method

- The **transit method** detects a periodic decrease in a star’s light flux when a planet passes in front of the star and blocks some light
- The **transit method** has discovered more exoplanets than other any other method
- It represents the best option for finding *earth-like* planets with current technologies
- This method allows for determining the *composition of the planet’s atmosphere* by studying the high-resolution stellar spectrum of the light from the star that passes through the upper atmosphere of the planet
- This method has a bias towards discovering *large planets orbiting close to their stars*



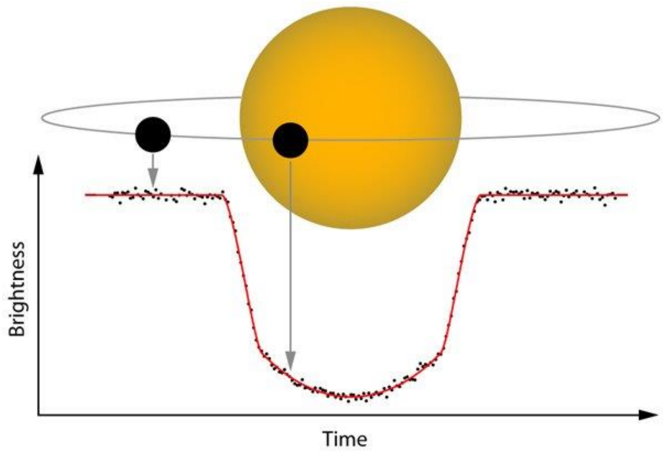


Exoplanet Transit Method Single Planet



Exoplanet Transit Method Multiple Planets

Exoplanets – Transit Method

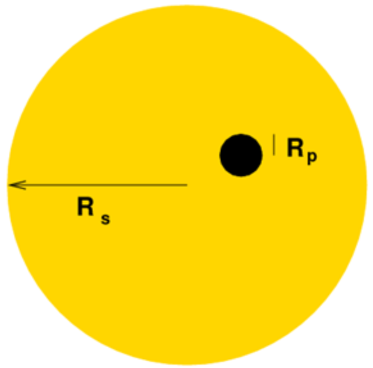


- 1-**Depth** - what fraction of the light was blocked during the transit?
- 2-**Duration** - how long did it last?
- 3-**Period** - how long does it take the planet to complete one revolution of its star?

Given only the transit light curve one can deduce:

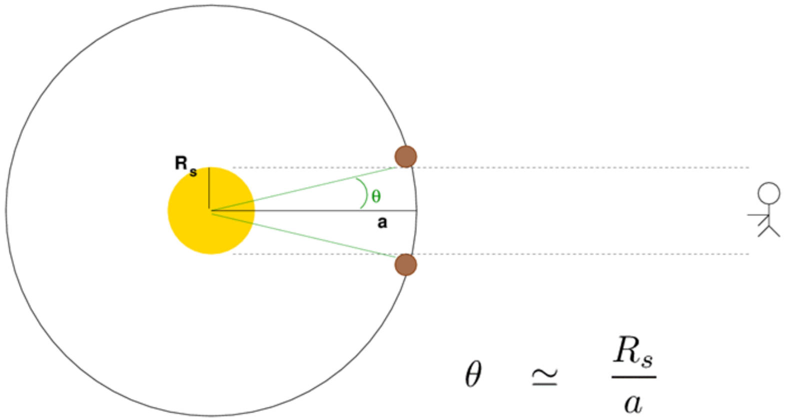
δ = fractional depth of transit
T = duration of transit
P = period of transits

The relative sizes of the host star and the planet are related to the depth



$$\delta = \left(\frac{R_p}{R_s}\right)^2$$

Exoplanets – Transit Method



$$\theta \simeq \frac{R_s}{a}$$

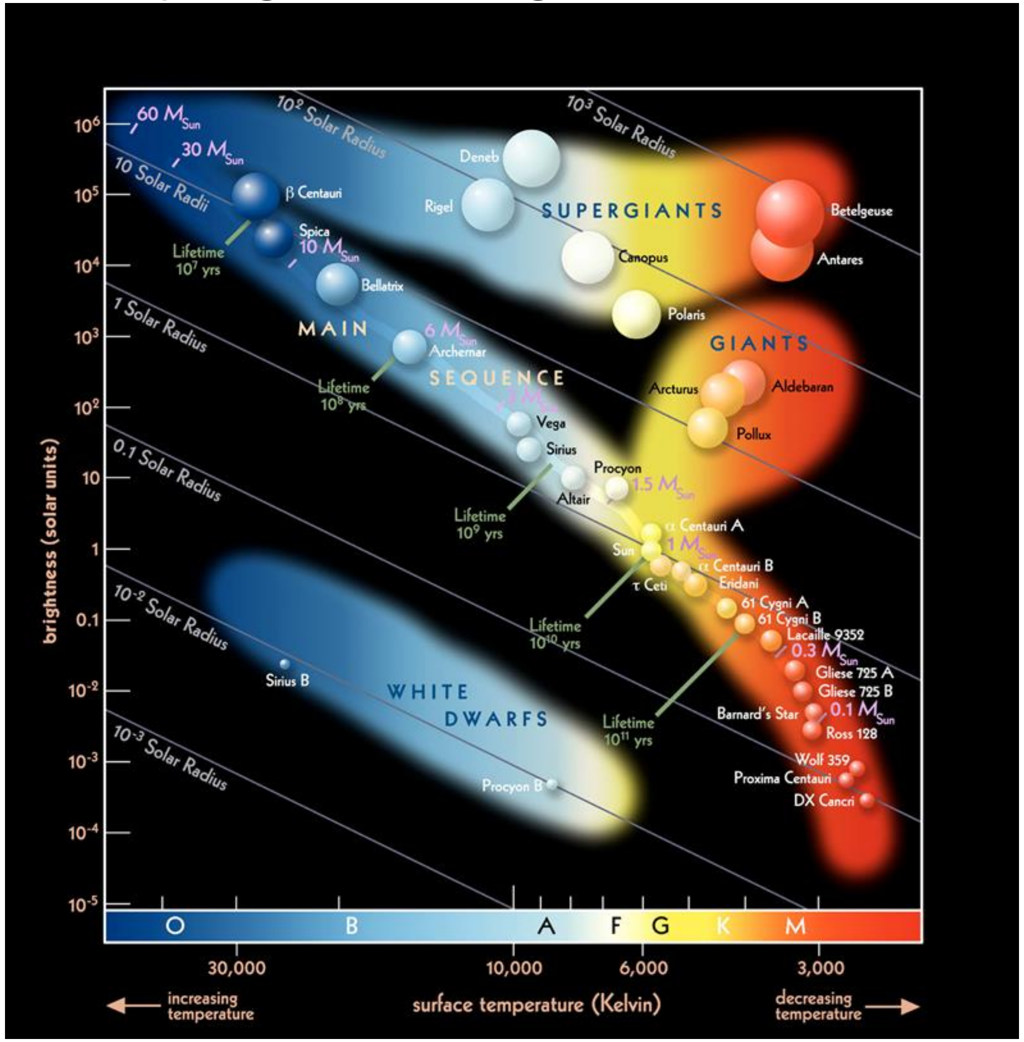
$$2\theta = \frac{T}{P}$$

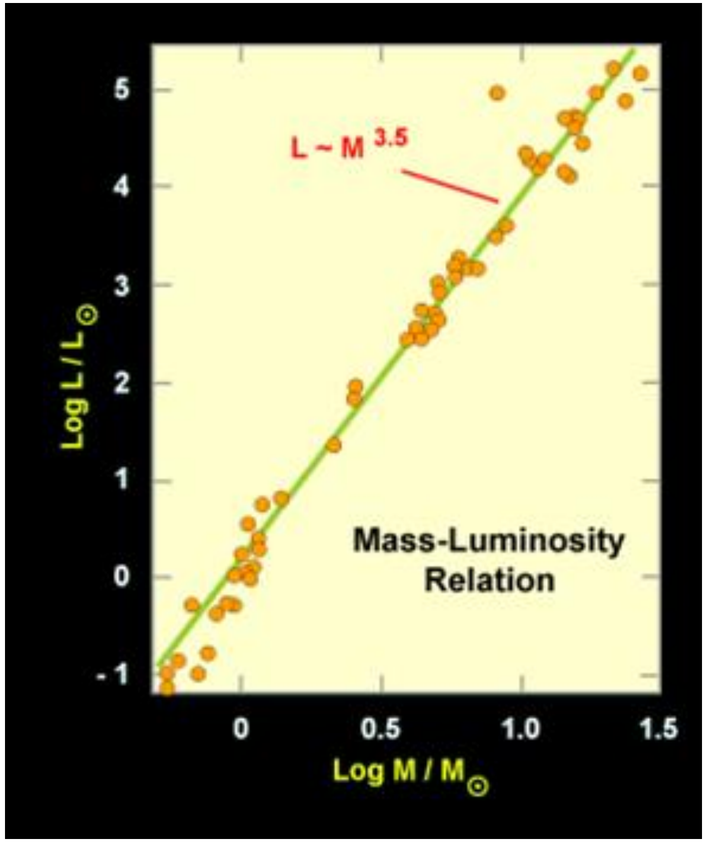
- If we compare the duration T of the transit to the period P of revolution, we can find a different ratio involving the radius of the host star, **Rs**
- The angle **θ** can be related to a **ratio** of **distances**, but also to a ratio of **times**

- Once the **distance** to a star is determined
  - Parallax method
  - Cepheid variables
- Its **mass** can then be determined
- The star's **apparent luminosity** (how bright it is as seen from the Earth) is measured
- Knowing the stellar distance , the actual brightness or **luminosity** of the star can be determined
  - Inverse square law
- Since **luminosity** is directly related to **mass** for a given star type (**Hertzsprung-Russel diagram**), the star's mass can be determined

Exoplanets – Transit Method

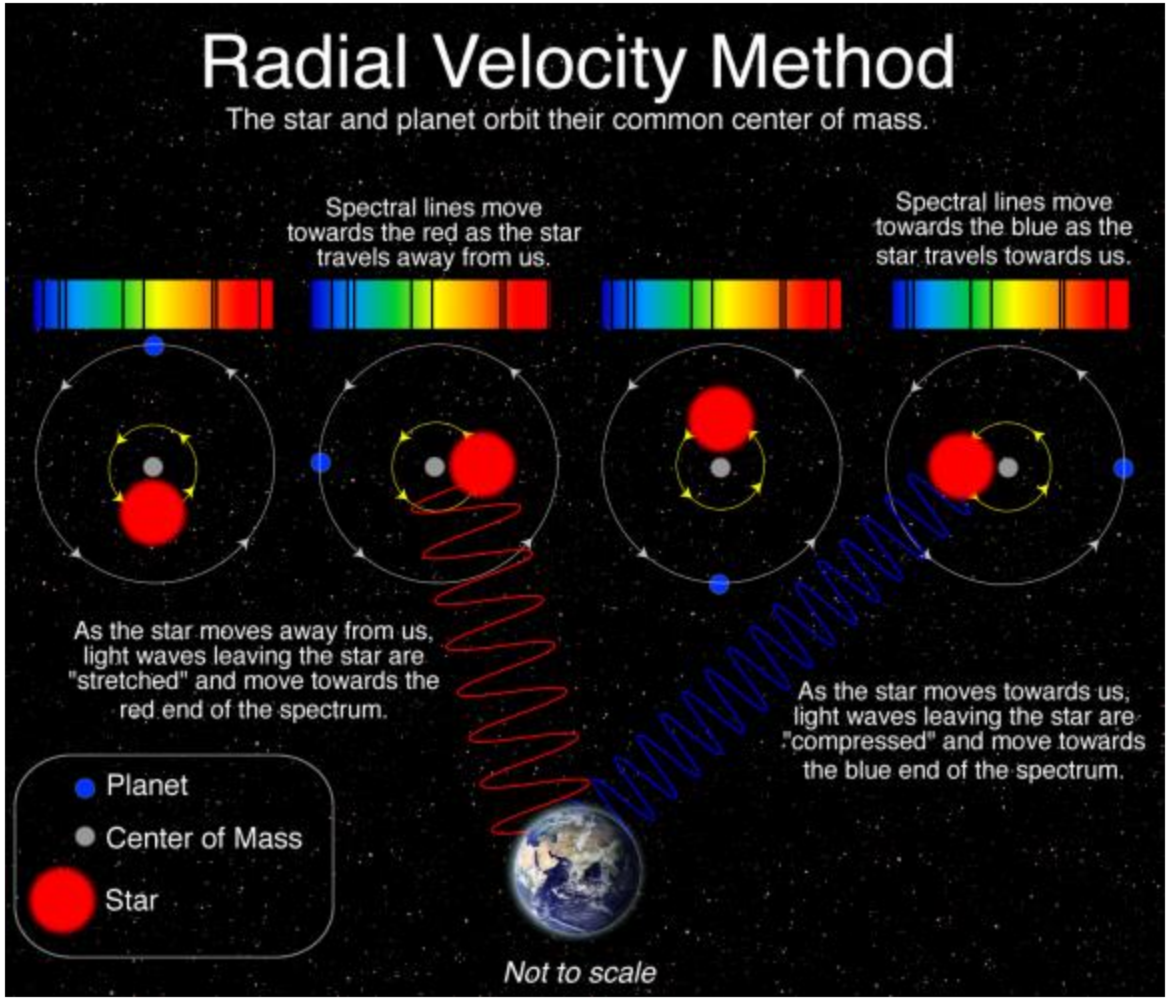
Hertzsprung–Russell diagram





Exoplanets – Radial Velocity

- The **Radial Velocity Method** does not of looking for signs of planets themselves - it observes a star for signs of movement
- A **spectrometer** is used to measure the way in which the star's spectral lines are displaced due to the **Doppler Effect**
- **Light from the star** is shifted **towards the red** or **blue** end of the spectrum (**redshift/blueshift**)
- **Redshift** – indicates the star is moving away from Earth
- **Blue shift –** indicates the star is moving toward Earth
- Based on the star's **velocity**, astronomers can determine the presence of a planet or system of planets



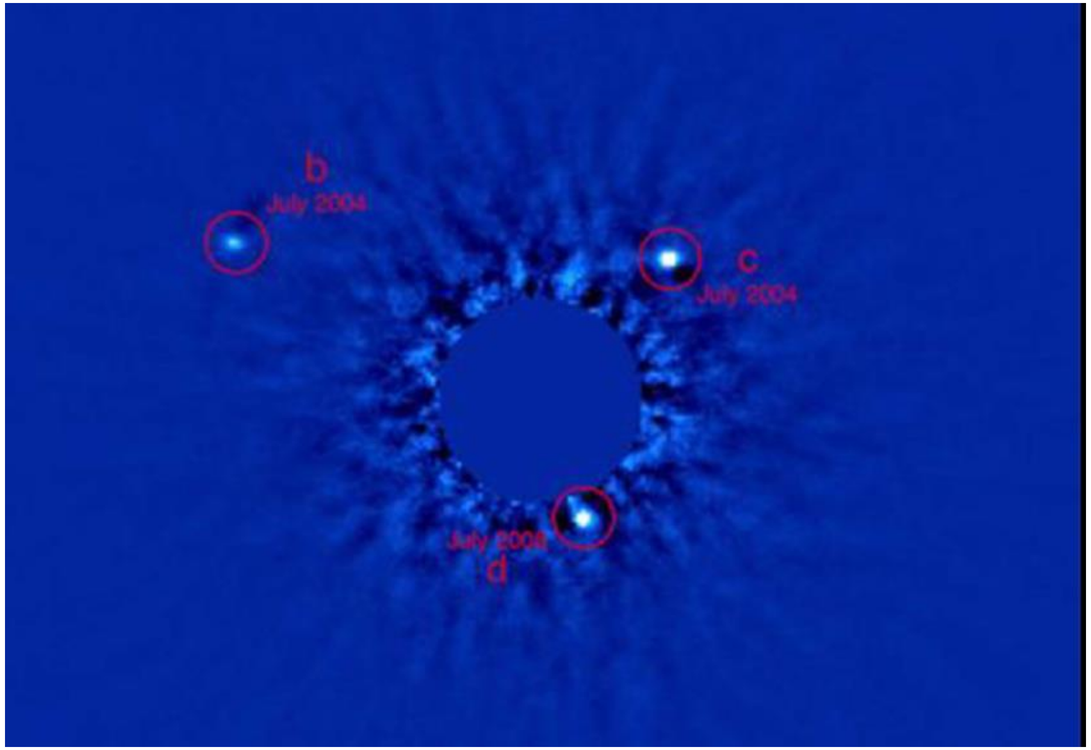
Exoplanets – Radial Velocity

- Until 2012, the **Radial Velocity Method** was the most effective means of detecting exoplanets
- Since then the **Transit Method** has become more productive in “finding” exoplanets
- The **Radial Velocity Metho*d*** remains a highly effective method
- It has had a high success rate for identifying exoplanets in both nearby and distant star systems
- Nearby - **Proxima b** and **TRAPPIST-1**‘s seven planets
- Distant - **COROT-7c**
- It is often **used in conjunction** with the Transit Method **to confirm** the existence of exoplanets and place constraints on their size and mass
- It is generally used to look for low-mass planets around stars that are within 160 light-years from Earth
- It can detect gas giants up to a few thousand light years away
- Low mass stars are more affected by the gravitational tug of planets and because such stars generally rotate more slowly (leading to more clear spectral lines)
- The **Radial Velocity Method** is well-suited for the study of *Earth-like planets* that orbit within the *habitable zones* of red dwarf stars

Exoplanet Radial Velocity Method

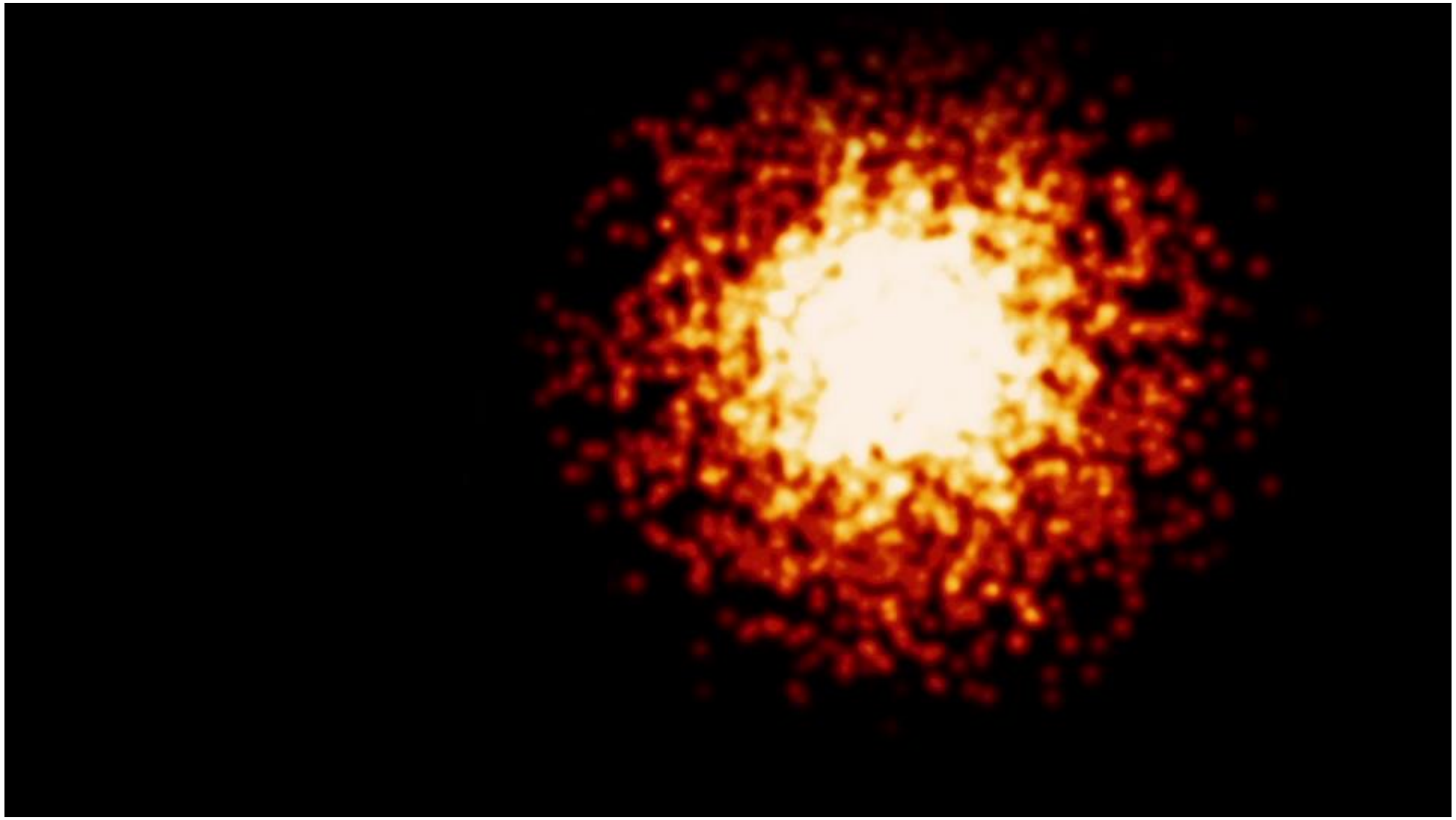
Exoplanets – Direct Imaging

- **Direct imaging** -- consists of capturing images of exoplanets directly by searching for the light reflected from a planet's atmosphere at **infrared** wavelengths
- At **infrared wavelengths,** a star is only likely to be **about 1 million times brighter than a planet reflecting light**
- At **visible light wavelengths**, a star is **typically a billion times brighter than a planet's reflected light**
- So far, only a handful of planets have been discovered by **Direct Imaging**
- While challenging compared to indirect methods, this method is the most promising when it comes to **characterizing the atmospheres** of exoplanets
  - Chemical composition via spectroscopy
- Direct imaging allows astronomers to actually see the exoplanet



- So far, ~ 55 planets have been confirmed using this method
- Larger telescopes should yield more direct imaging confirmed exoplanets

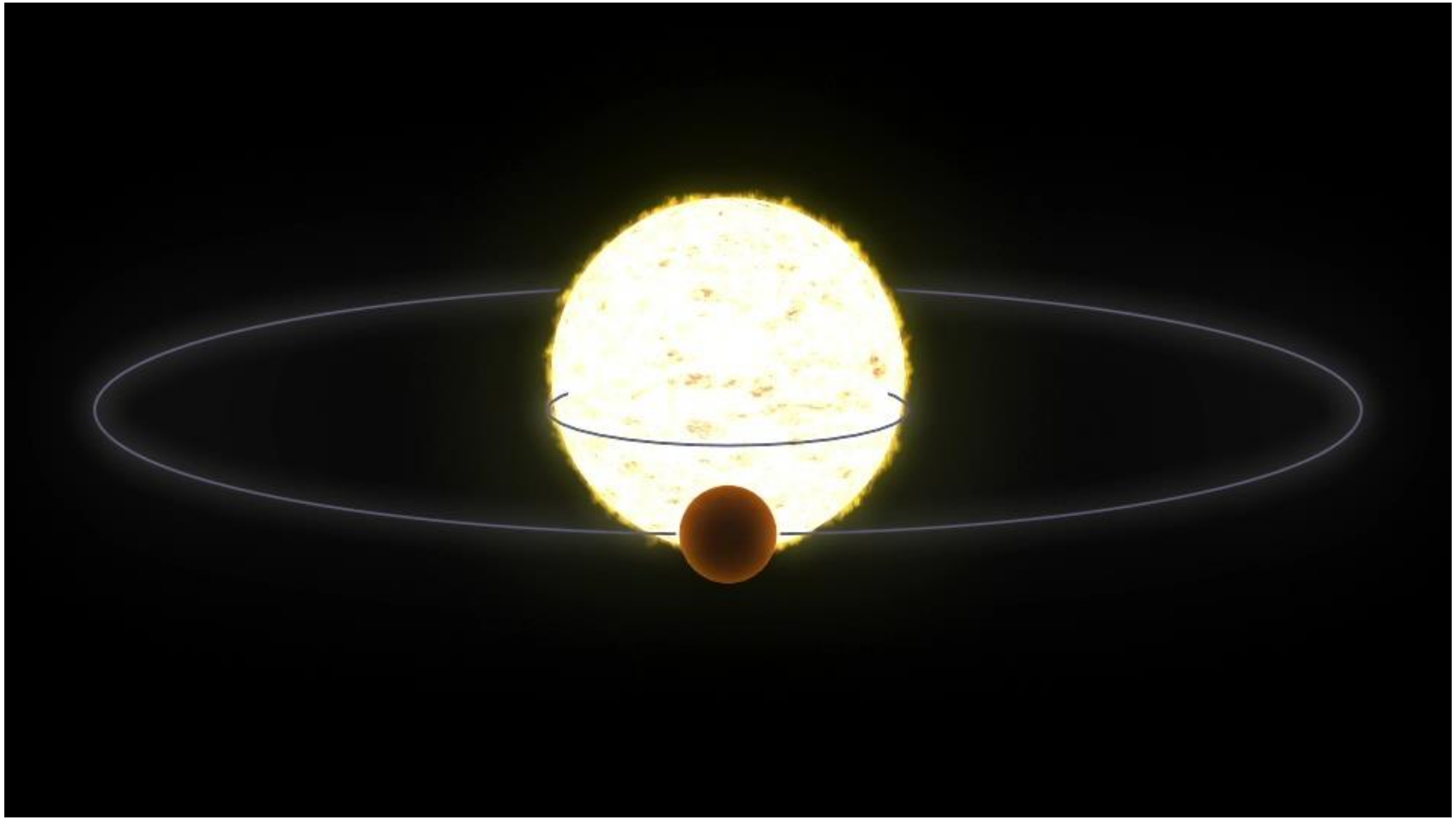
Exoplanet Direct Observation



Exoplanets -- Astrometry

- **Astrometry method-**- consists of precisely measuring a star's position in the sky, and observing how that position changes over time
- Originally, this was done visually, with hand-written records
- Late in the 19th century, the use of photographic plates greatly improving the accuracy of the measurements
  - It also created a data archive
- If a star has a planet, then the gravitational influence of the planet will cause the star itself to move in a tiny circular or elliptical orbit
- Effectively, star and planet each orbit around their mutual center of mass (**barycenter**)
- Since the star is more massive, its orbit will be much smaller
- The mutual center of mass (barycenter) may lie within the radius of the star
- It is easier to find high mass planets around low-mass stars

Exoplanet Astrometry



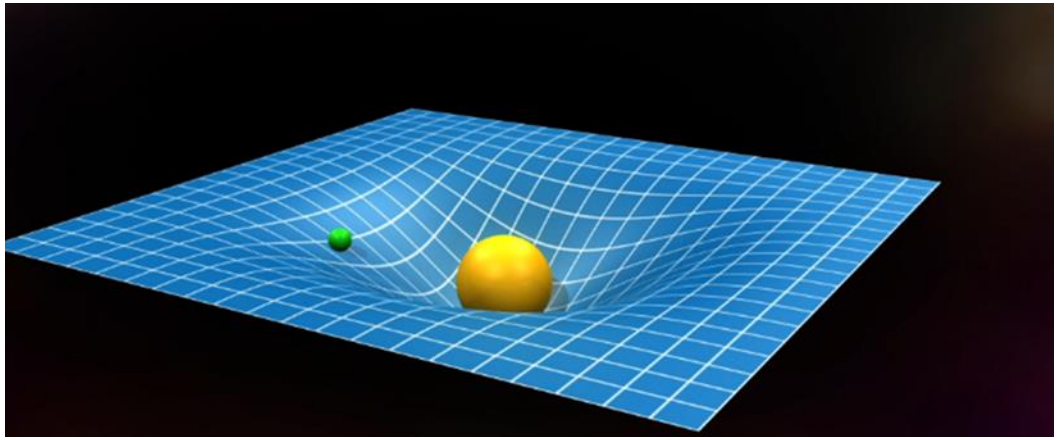
Exoplanets – Gravitational Microlensing

- Gravitational lensing method-- is a result of **Einstein's General Theory of Relativity (GR)**

Einstein's field equations

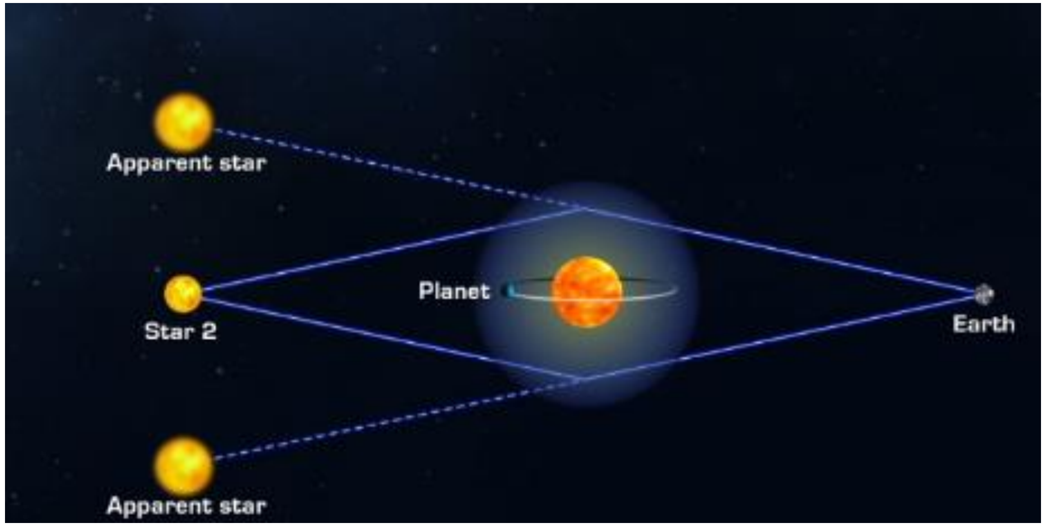
$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

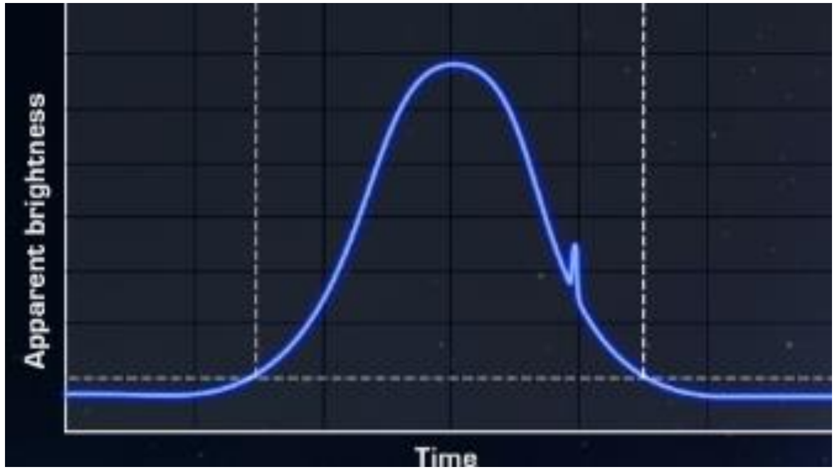
- **GR** characterizes space as "**space time**" and suggests that **space time is deformed by the presence of mass**
- This leads to the deflection or **bending of light** as the light photons pass near a large mass
- Gravitational lensing can be used to detect objects that range from the mass of a planet to the mass of a star
- **Microlensing** allows the study of objects that emit little or no light



- According to GR planets' orbits move in a straight line relative to space time that is curved
- Einstein's GR has been confirmed numerous times since its publication
- It was first confirmed by Arthur Edington in 1919 during **solar eclipse**

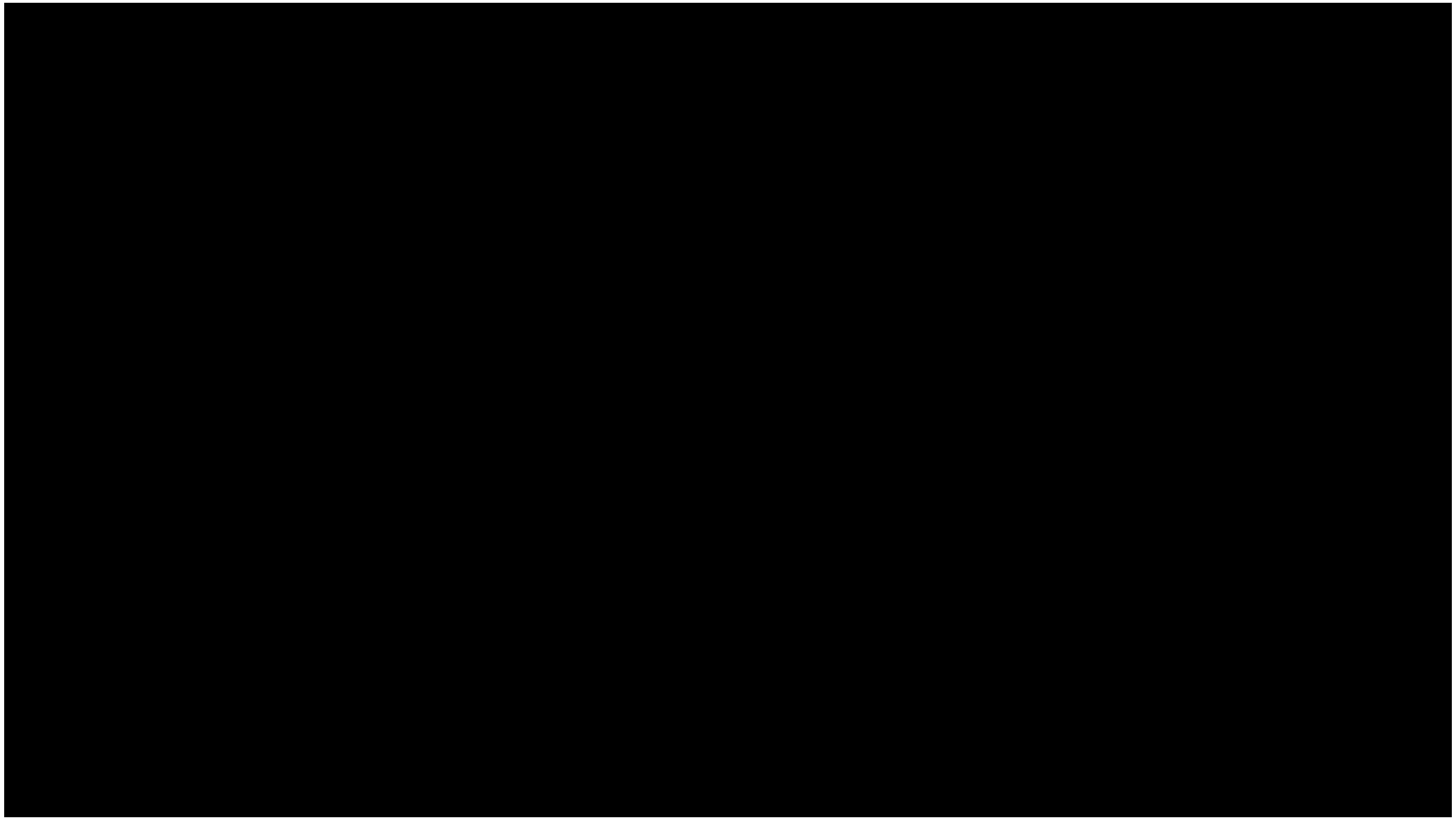
Exoplanets – Gravitational Microlensing





- Planet orbiting foreground star
- **Adds to overall mass of the foreground star**
- Shows up as a “blip” in brightness
- More massive planet longer duration of the blip
- Duration tells mass
- Timing indicates something about where planet is located around the star

Exoplanet Gravitational Lensing



Exoplanets - Characteristics

NASA data (6-1-24)

- 5,638 confirmed exoplanets
- 4,237 planetary systems
- 904 have more than one planet
- Thousands of candidate exoplanets

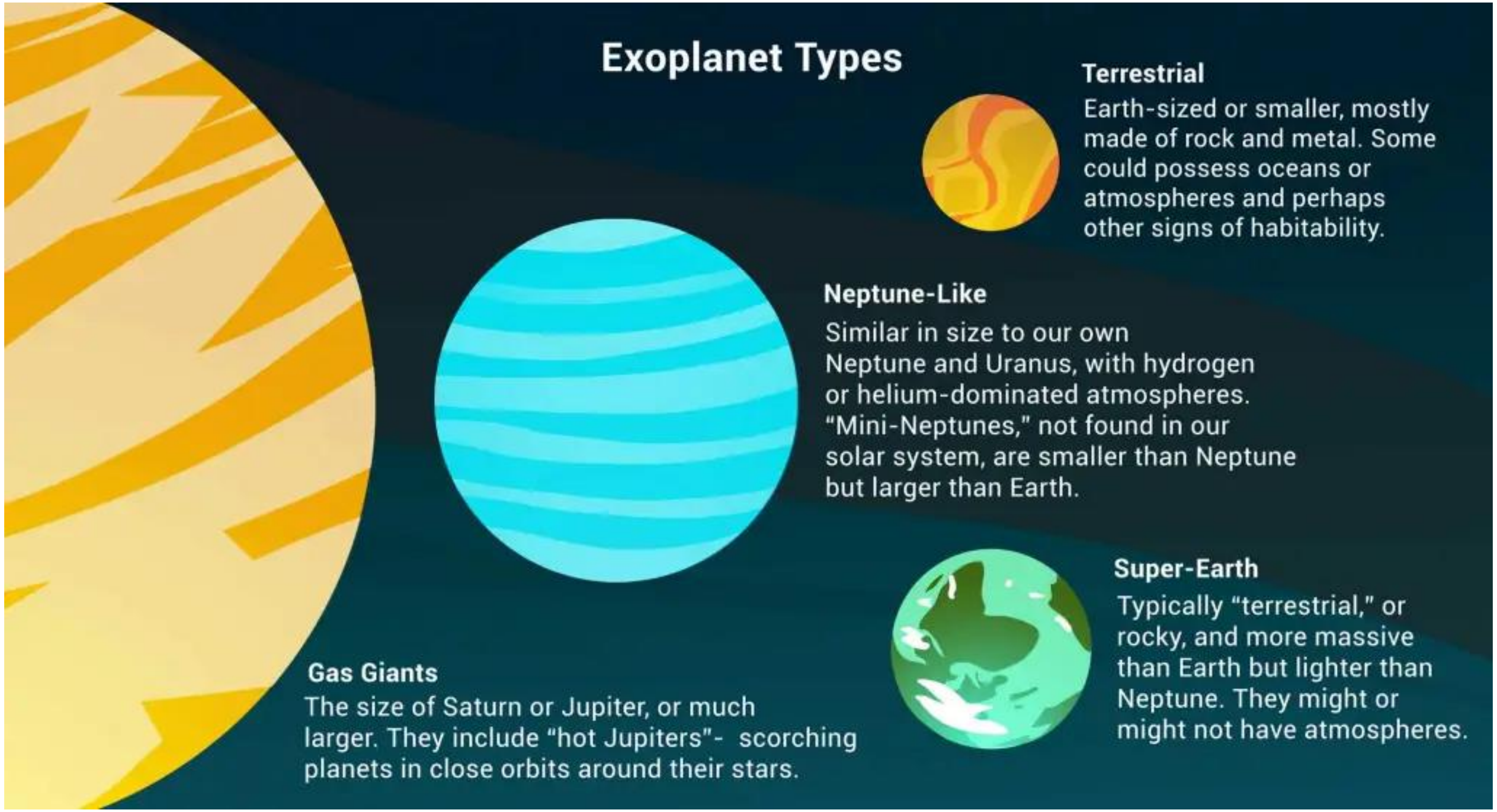
Discovery Methods

• Transit	4,158 (74.2%)
• Radial Velocity	1,078 (19.3%)
• Direct Imaging	20 (1.4%)
• Gravitational lensing	10 (3.9%)
• Astrometry	(0.05%)

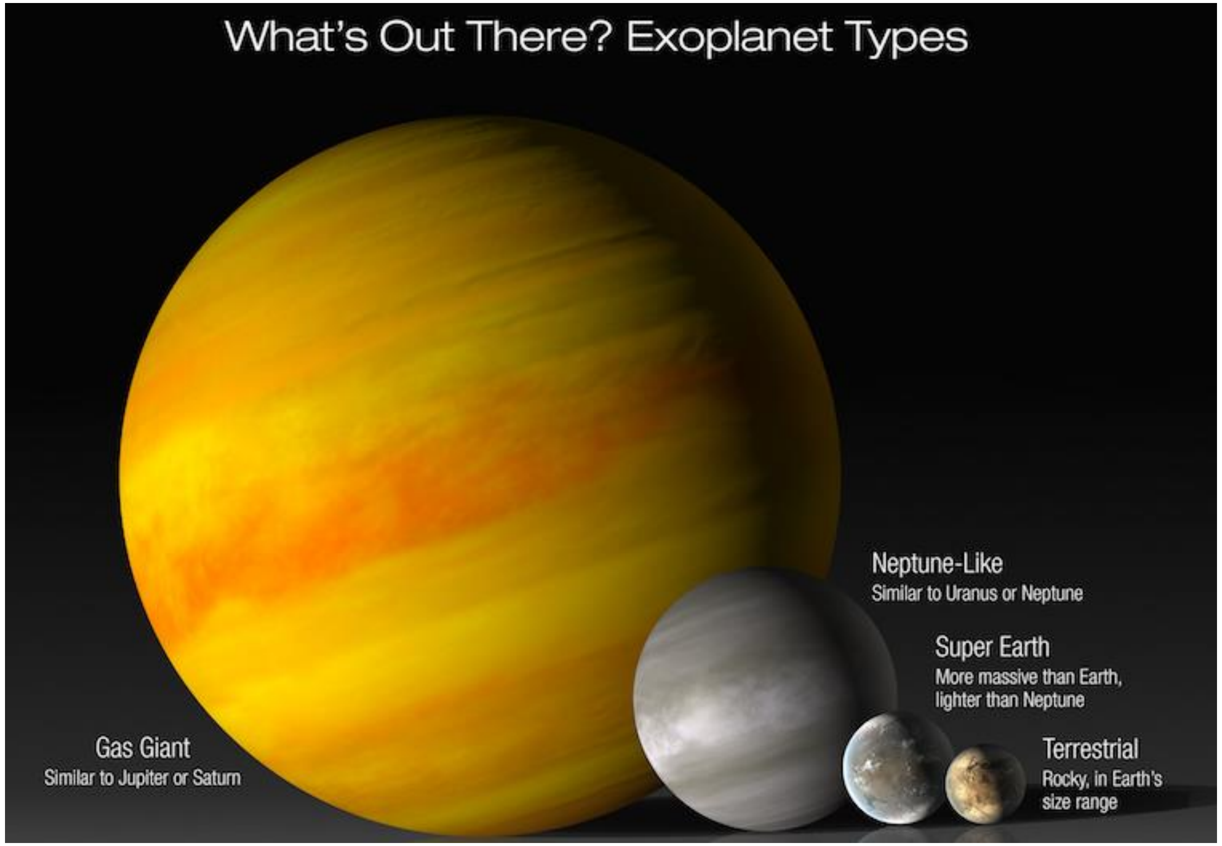
Planet Types

• Gas Giant	(1,808)
• Neptune-like	(1923)
• Super Earth	(1,808)
• Terrestrial	(1699)
• Unknown	(7)

Exoplanets - Characteristics



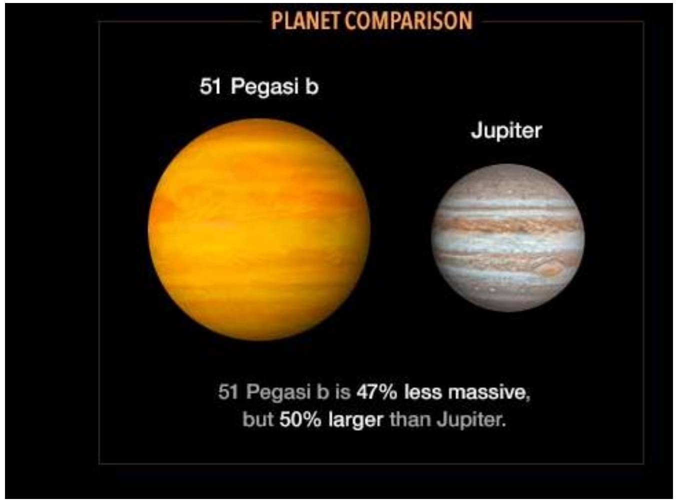
Exoplanets – Characteristics



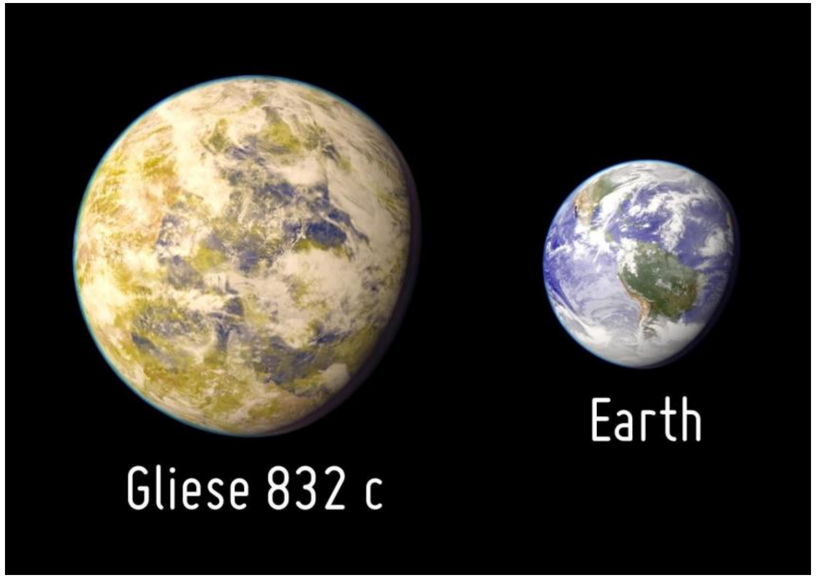
- Among the over 5,600 confirmed exoplanets discovered are a large variation in planet types
- **Terrestrial** - (rocky) planets-like earth
- **Super earths** – larger than earth but not necessarily rocky
- **Neptune like** – large as/ice planets
- **Gas giants** – large gas giants – larger than Jupiter
- Many of these exoplanets orbit their stars with **short periods** – they are very close to their stars and have very high surface temperatures
- Many exoplanets are quite unlike planets in the solar system- both in size, composition and orbital positions

Exoplanets – Characteristics

- **Gas Giants**
- Are large planets mostly composed of *helium* and/or *hydrogen*
- These planets, like **Jupiter** and **Saturn** in our solar system, don't have hard surfaces and instead have swirling gases above a **solid core**
- Gas giant exoplanets can be much larger than **Jupiter**
- And much closer to their stars than anything found in our solar system **Hot Jupiters**

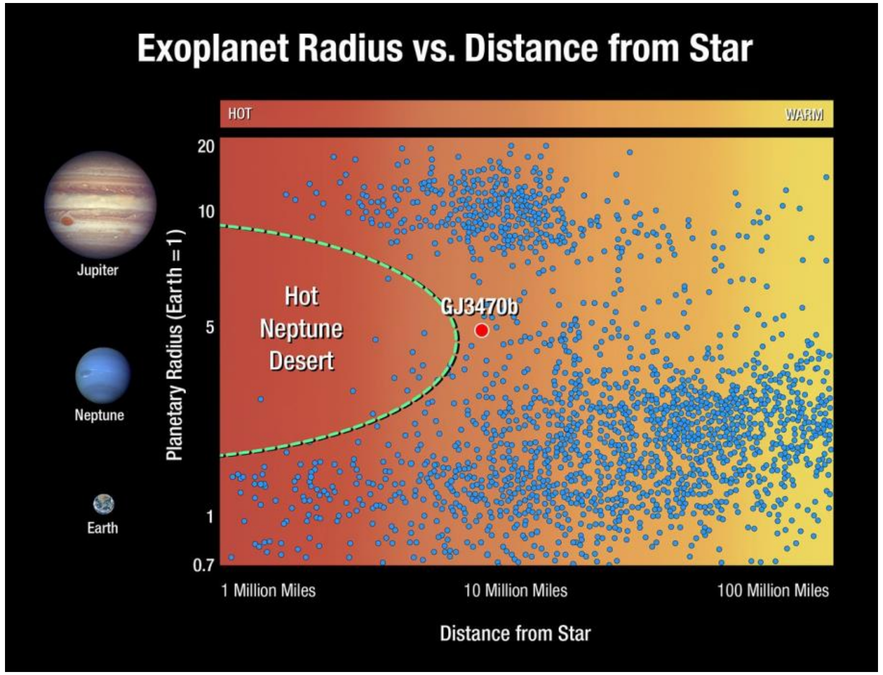


- **Super-Earths** – are planets unlike any in our solar system –they are more massive than Earth yet lighter than ice giants like Neptune and Uranus
- They can be made of gas, rock or a combination of both
- They are between twice the size of Earth and up to 10 times its mass

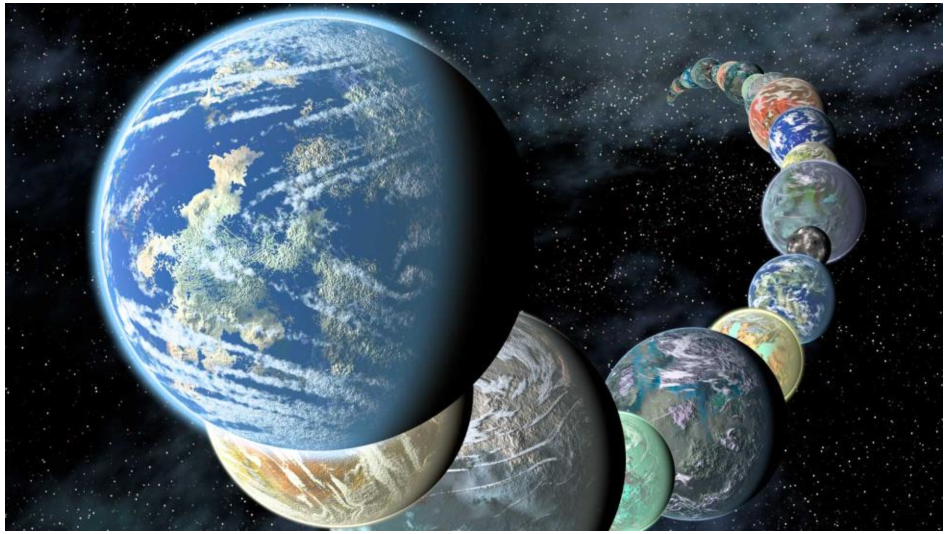


Exoplanets – Characteristics

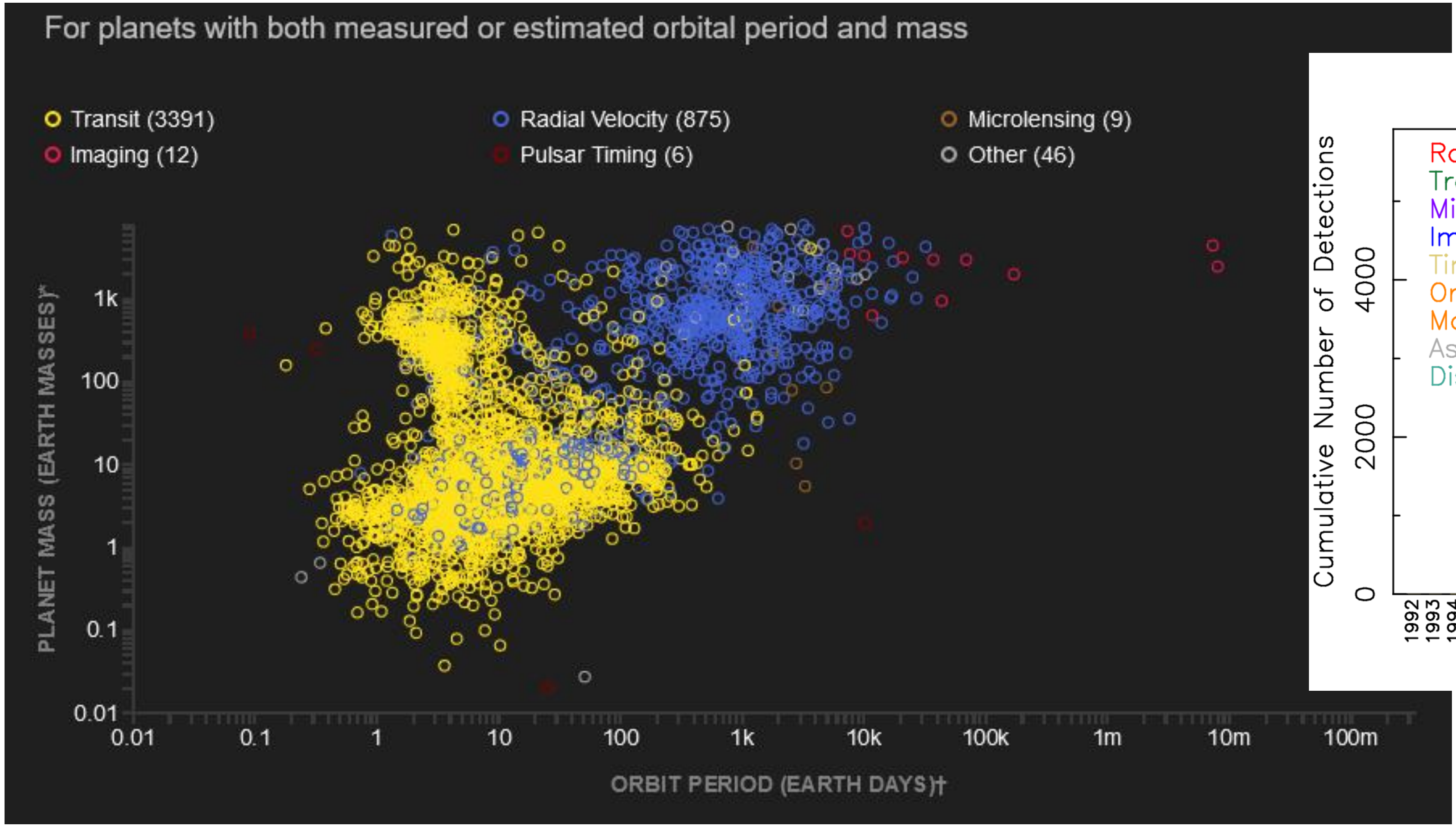
- **Neptune like** exoplanets are similar in size to **Neptune** or **Uranus** in our solar system
- **Neptunian** planets typically have hydrogen and helium-dominated atmospheres with cores or rock and heavier metals

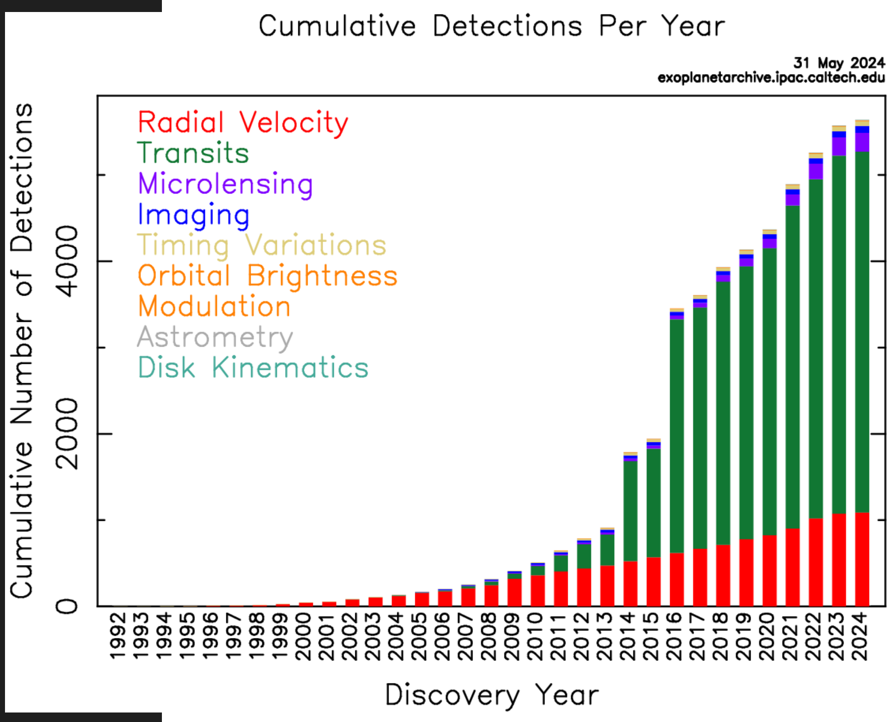


- **Terrestrial exoplanets** are rocky, planets like **Earth, Mars, Mercury** and **Venus**
- Exoplanets between half of Earth's size to twice its radius are considered terrestrial
- Others may be even smaller
- Exoplanets **twice the size of Earth** and larger are considered **super-Earths**
- They may be rocky as well



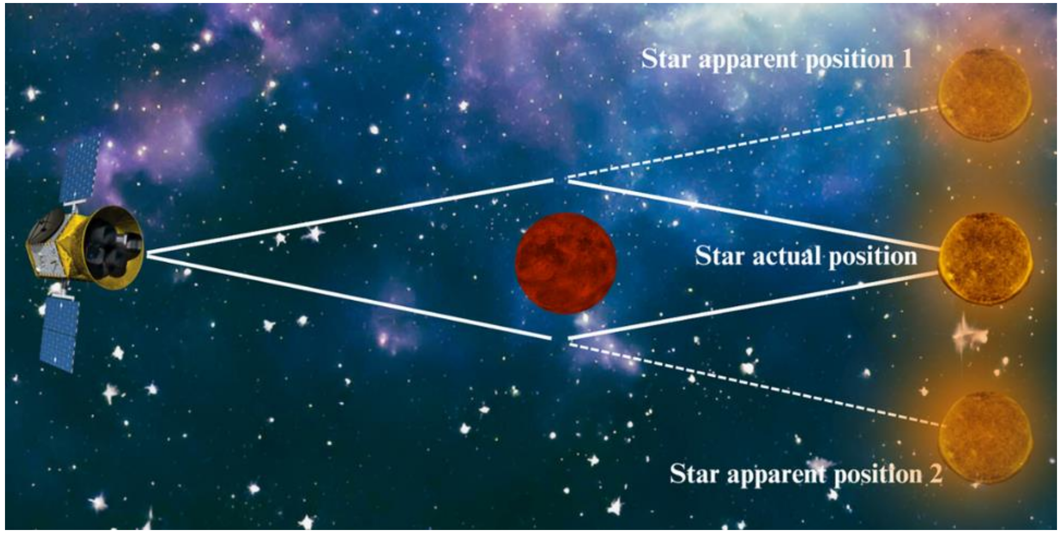
Exoplanets – Characteristics





Exoplanets Recent Discoveries?

- **Rogue planets** have very little mass, so the lensing effect is weak and thus called "**microlensing.**"
- It can cause a brightening of a background source that is visible to astronomers, indicating the presence of a rogue planet.



NASA's Chandra X-ray Observatory may have been detected a planet transiting a star outside of the Milky Way galaxy

The possible **exoplanet candidate** is located in the spiral galaxy **Messier 51 (M51),** about 28 million light years away

It was "detected" by observing a decrease in brightness of X-ray received from as it transits a source of X rays from X ray binaries – neutron star or black hole

Exoplanets

- The variation of the exoplanets' characteristics- **mass**, radii, **orbital position**, etc have shown:

  Our solar system seems to be unusual

  Our solar system is **not** the model for **exoplanet star systems**

  Theories of **star systems' formations** need to be revised

- The numbers of exoplanets discovered in the **very small section of the Milky Way galaxy** suggest that the galaxy and the universe are **teeming with exoplanets**

- The number of **earth like terrestrial planets** in their **stars' habitable zones** is probably less than ~ 2% of exoplanets (based on a small sample of the galaxy surveyed)

Exoplanets

Stay tuned for more exoplanet discoveries as more data is analyzed and improved ground-based and space-based telescopes come online