Our Home the Milky Way Galaxy

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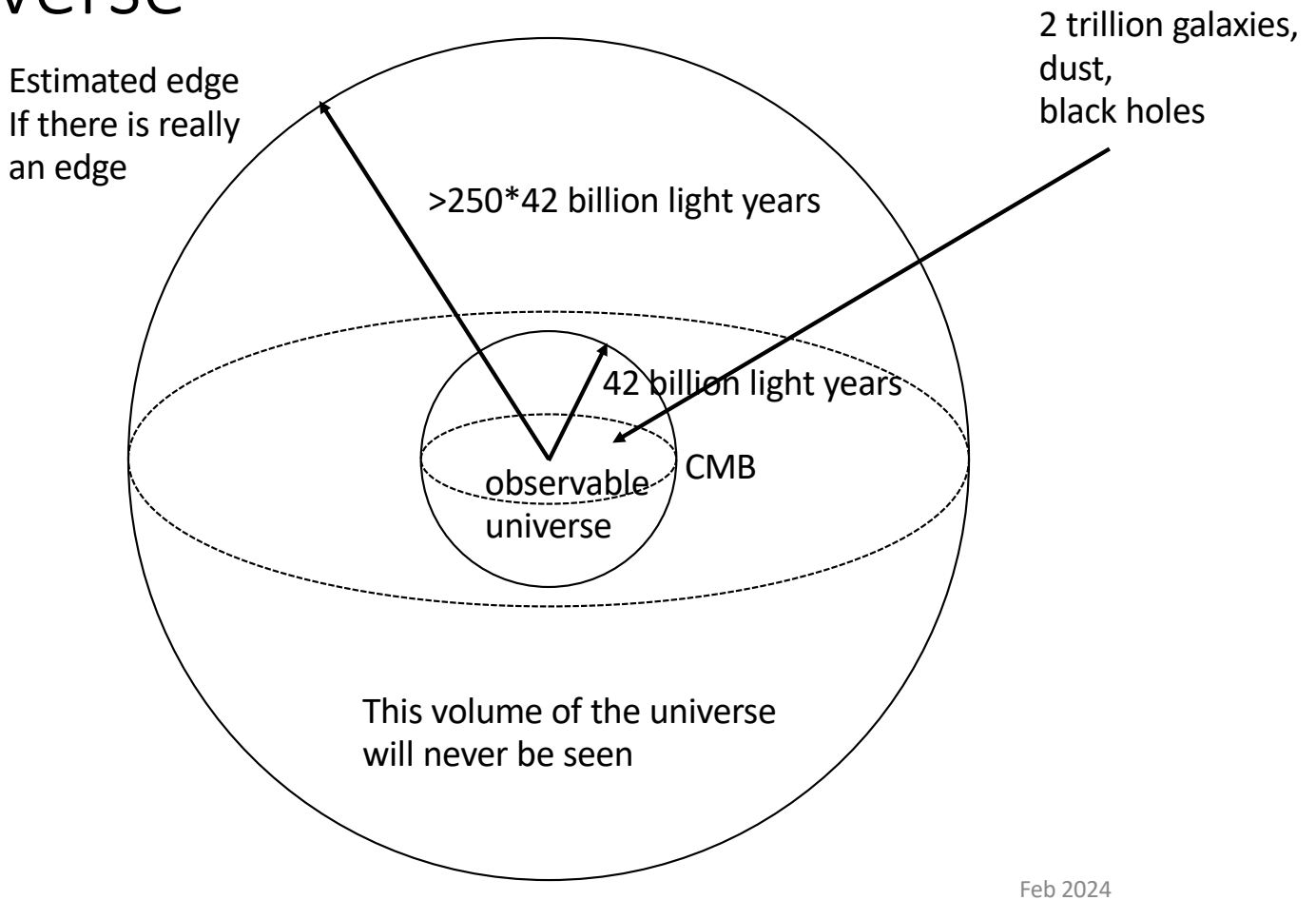
Outline

- The Universe
- The objects in the Universe
  - Stars
  - Black Holes
  - Galaxies
  - Clusters of Galaxies
  - Intergalactic Dust
- The Milky Way Galaxy (our Home)
  - The Stars of the Milky Way
- Our Solar System
  - The Sun ("Sol")
  - The eight planets of our Solar System
  - The uniqueness of the Earth in the Solar System
  - Why only Earth has life

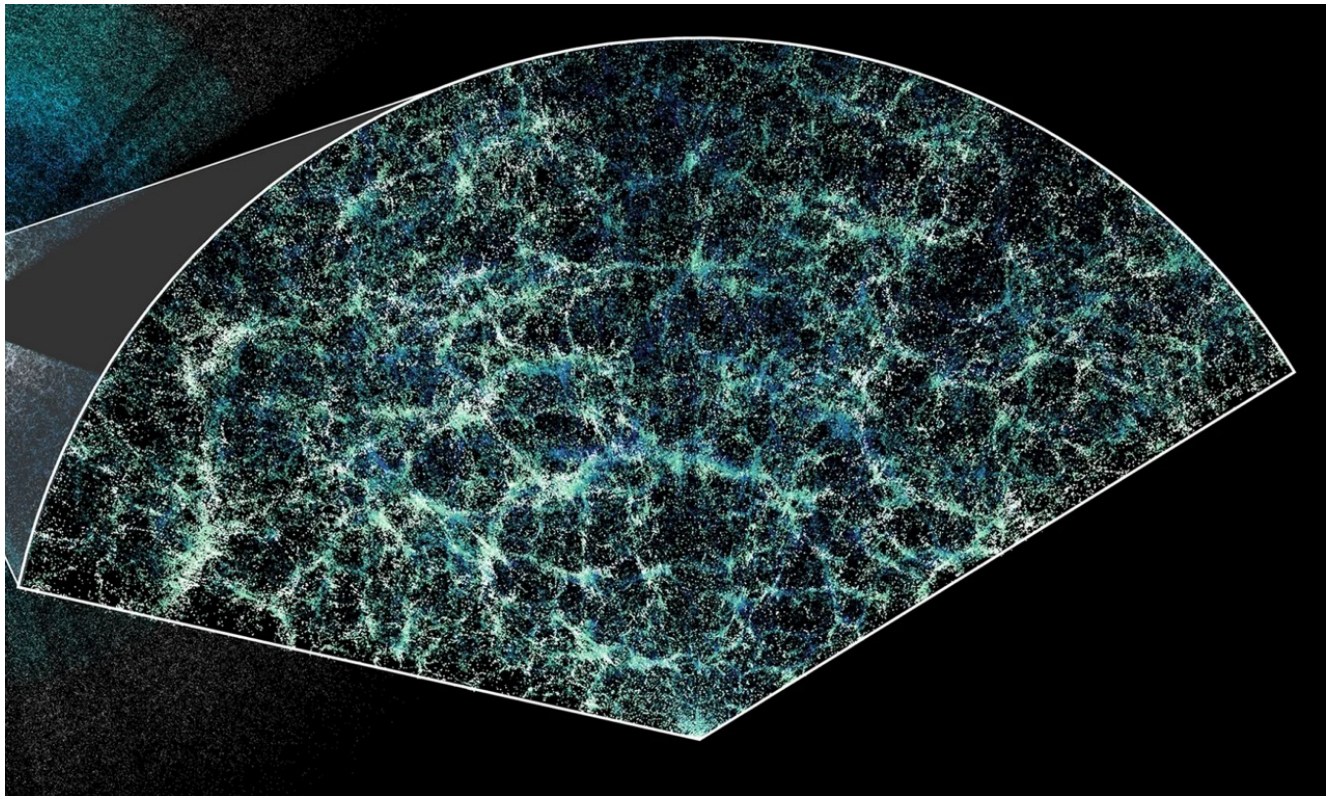
The Universe

- The Universe is about 13.7 Billion Years old
- In the 1920s, Edwin Hubble discovered that "Nebula" were really galaxies and the universe was expanding
  - Since the universe is constantly expanding, the radius of the universe is 46.5 Billion light years
  - When we talk about the radius of the universe, we mean the observable radius
  - That is the furthest away point that light can reach us today.
  - Today the word "Nebula" means a dust cloud where stars often form
- We don't know how big the universe is
  - It could be infinite
  - One estimate is that the radius is about 250 times larger than the observable universe
  - https://medium.com/starts-with-a-bang/ask-ethan-is-the-universe-infinite-or-finite-ec032624dd61
- Stars are clustered in regions of space are called Galaxies
- Between Galaxies there is mostly dust and empty space
- In 2020, it was estimated that there are around 2 trillion galaxies in the observable Universe.

The Universe



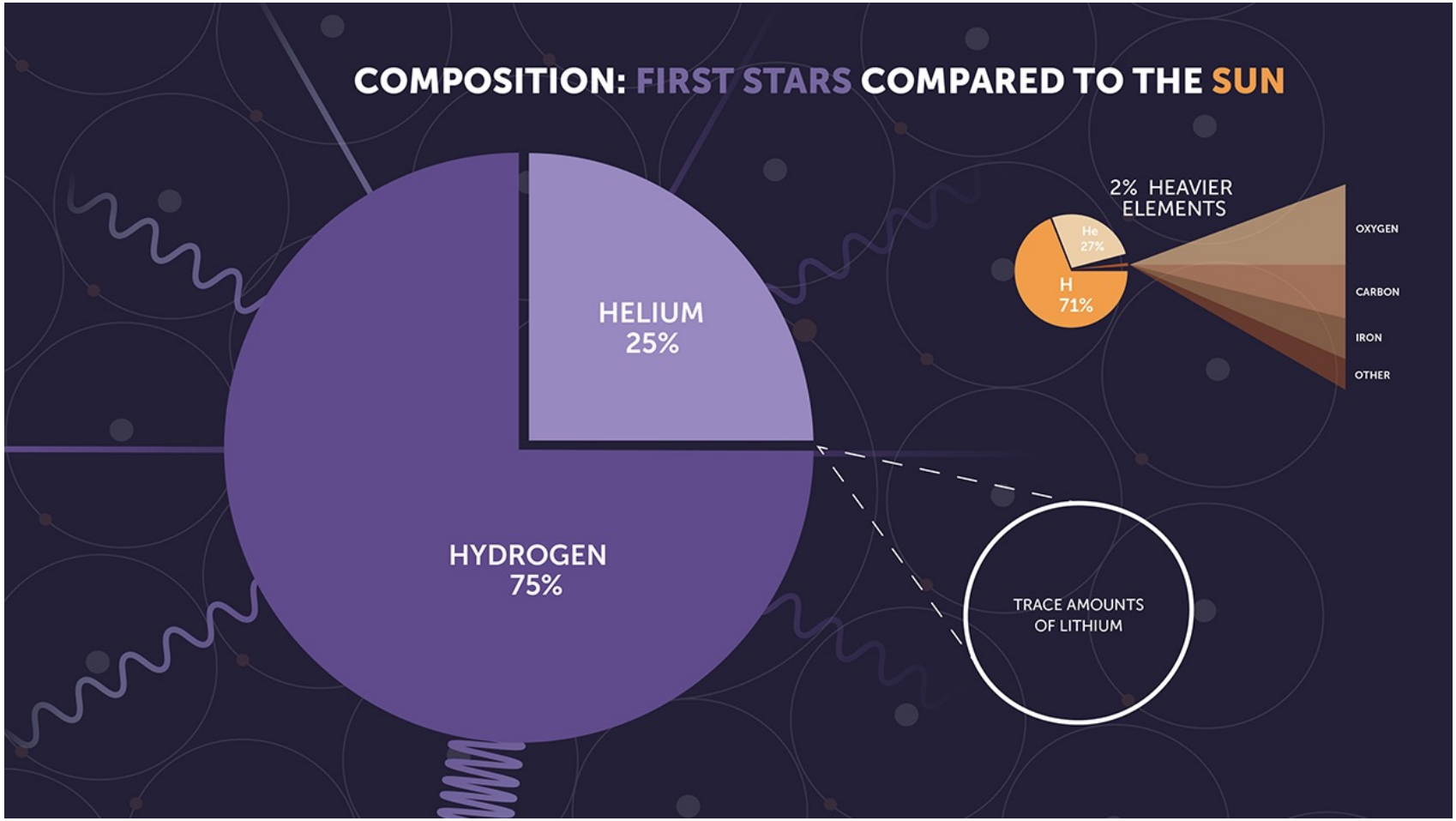
Partial Map of the Universe



From article in Quanta Magazine

Stars

- The first stars were made of Hydrogen and Helium with a little lithium
  - This is the what elements were created when the universe started
- Stars are so dense and hot that at the center, hydrogen atoms undergo nuclear fusion to make a Helium atom and energy is given off
- As the first stars exploded other elements were created by fusion
- That is how we have all the elements beyond lithium

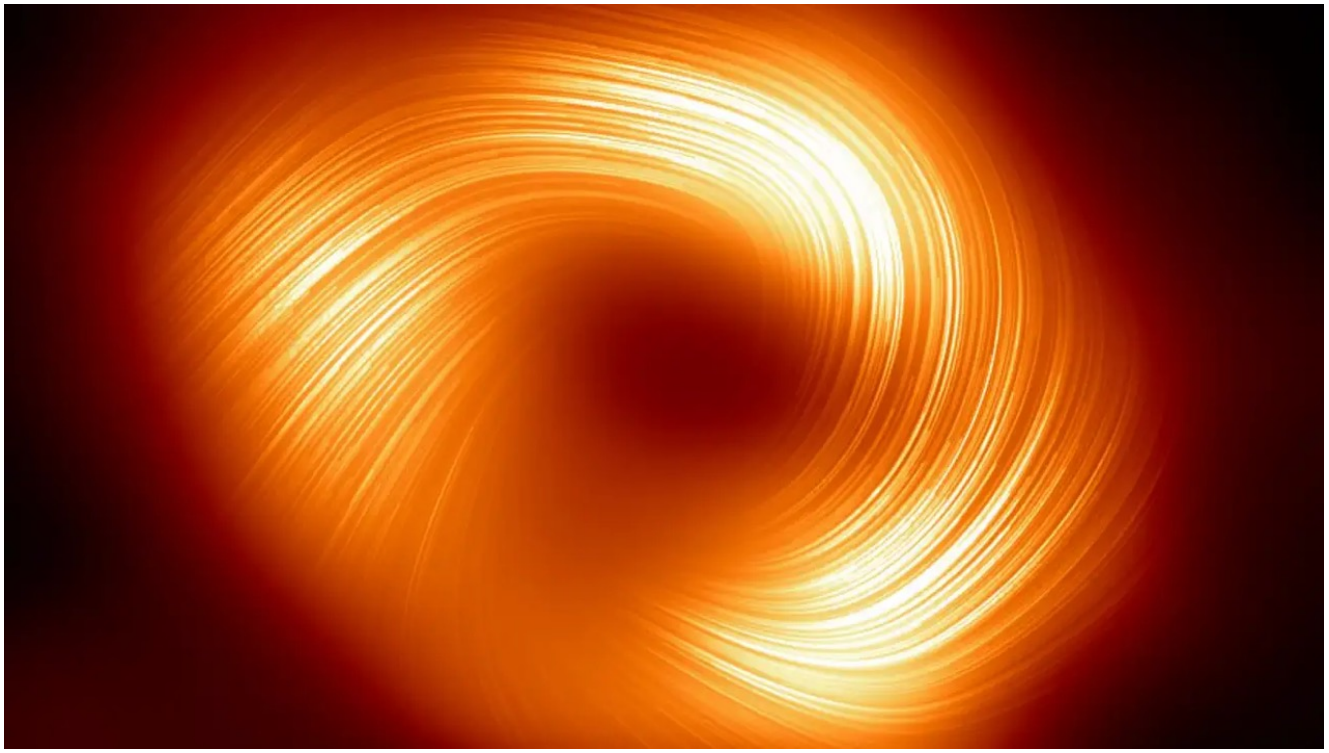


https://webbtelescope.org/contents/media/images/4353-Image

Black Holes

- Einstein when he postulated his theory of Relativity said that gravity can bend light
- When we describe an object (planet, star, black hole, etc.) we define the escape velocity of that object
  - The escape velocity is the speed that something needs to obtain to escape the gravitational pull of an object.
  - The escape velocity of the earth is 11.176 km/s or 24,923 mph.
  - The escape velocity of the Sun is 617.5 km/s.
- When an object is massive enough that its escape velocity to greater than the speed of light, we call that object a black hole.
- Most galaxies have a black hole at their center

Black Hole at center of Milky Way: Sagittarius A*



Sagittarius A* in polarized light

revealing magnetic field lines around the black hole. Image: EHT Collaboration

Galaxies

- Galaxies are groups of stars the are gravitationally bound to each other
- The stars orbit a center which most often contains a black hole
- Within the galaxy there are:
  - clouds of gas (nebula)
  - stars
  - baby stars just forming with planets
  - dead stars
- There are an estimated 200 billion to 2 trillion galaxies in the observable universe
- A galaxy can contain billions of stars

Clusters of Galaxies

- Galaxies are grouped into clusters
- A galaxy cluster, or a cluster of galaxies, is a structure that consists of anywhere from hundreds to thousands of galaxies that are bound together by gravity, with typical masses ranging from 10^{14} to 10^{15} solar masses.
- They form the second largest objects in the Universe
- The largest objects are superclusters (of which only one, the Shapley Supercluster, is known to be bound).
- How many clusters of galaxies are in the observable universe? We can ballpark it like this:
  - There are an estimated 200 billion to 2 trillion galaxies in the observable universe, and a typical cluster contains 100 to 1,000 galaxies.
  - So call it 1.1 trillion galaxies total and 550 galaxies, on average, per cluster.
  - That comes out to 2 billion galaxy clusters total — in the observable universe

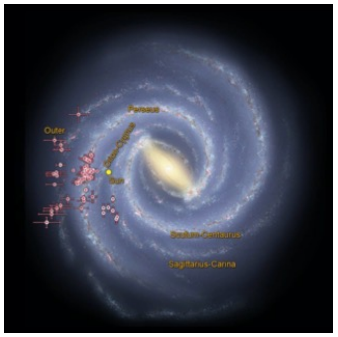
https://en.wikipedia.org/wiki/Galaxy_cluster
https://www.quora.com/What-is-a-Galaxy-cluster-How-many-galaxies-are-in-a-Galaxy-cluster

Intergalactic Dust

- Intergalactic dust is cosmic dust in between galaxies in intergalactic space.
- Evidence for intergalactic dust has been suggested as early as 1949, and study of it grew throughout the late 20th century.
- There are large variations in the distribution of intergalactic dust.
- The dust may affect intergalactic distance measurements, such as to supernovae and quasars in other galaxies.
- Intergalactic dust can form intergalactic dust clouds, known since the 1960s to exist around some galaxies.
- By the 1980s, at least four intergalactic dust clouds had been discovered within several megaparsecs of the Milky Way galaxy, exemplified by the Okroy Cloud.
  - 1 parsec = 3.26 light years = 19.2 trillion miles
  - 1 astronomical unit = 149,597,870,700 m ~ the distance from the sun to the earth

Our Home in the Universe is the Milky Way Galaxy

artist's rendition



- The Milky Way consists of
  - 1 main Galaxy (our home)
  - about 50 satellite Galaxies circling the main Galaxy
- The Milky Way is considered an average-sized galaxy.
- The Milky Way is a barred spiral galaxy
- It stretches for 105,700 light-years in diameter and may contain at least 100 billion planets and around 400 billion stars.
- Age estimate: 12.6 billion years
  - Several individual stars have been found with measured ages very close to the 13.80-billion-year age of the Universe.

https://en.wikipedia.org/wiki/Milky_Way

The Milky Way in the Night Time Sky In the Lut desert, in Kerman, Iran

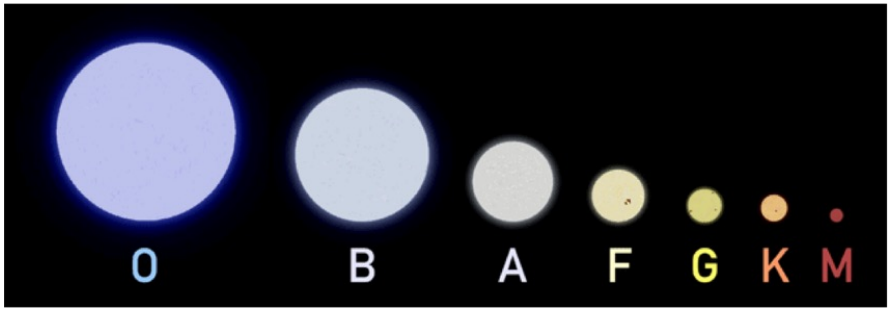
Another View of the Milky Way

- There are about 6000 individually visible stars without a telescope
- The furthest is about 6000 light years away

Types of Stars in Milky Way

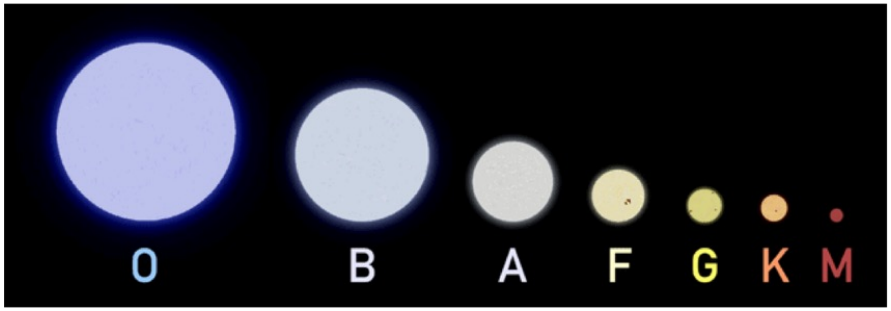
- Blue Stars
  - Type O or B
  - luminosities 100-1,000,000 times Sun
  - Lifetime 40 Million Years
- Blue Giants
  - Type O, B, or A
  - very rare
  - luminosities 10,000 of Sun
  - Lifetime 10-100 Million Years
- Blue Super Giants
  - Type OB
  - rare
  - luminosities 10,000-1,000,000 times Sun
  - Lifetime 10 Million Years

https://nineplanets.org/star/



Types of Stars in Milky Way

- Yellow Dwarfs (our Sun is one)
  - Type G
  - 10% of stars
  - luminosities 0.6-5.0 of Sun
  - Lifetime 4-17 Billion Years
- Orange Dwarfs
  - Type K
  - 10% of Stars
  - luminosities 0.08-0.6 of Sun
  - lifetime 15-30 Billion years
- Red Dwarfs
  - Type K or M
  - 73% of stars
  - luminosities 0.08-0.45 of Sun
  - Lifetime several Trillion Years



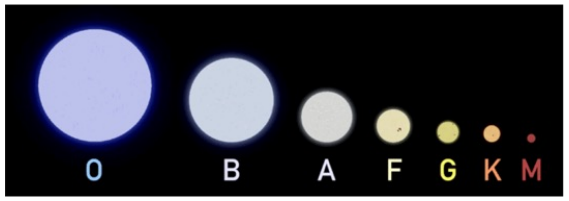
https://nineplanets.org/star/

Types of Stars in Milky Way

- Red Super Giants
  - Type K or M
  - 0.0001% of Stars
  - luminosities 1,000 to 800,000 of Sun
  - Lifetime 3-100 Million Years
- White Dwarf
  - Type D
  - 0.4% of stars
  - luminosities 0.0001-100 of Sun
  - Lifetime 4-17 Billion Years

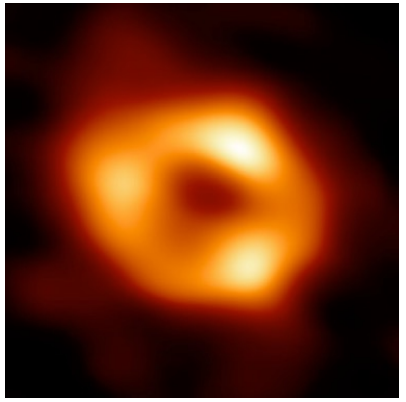
https://nineplanets.org/star/

- Neutron Stars
  - Type D
  - 0.7% of Stars
  - very low luminosities
  - lifetime 100,000-10 Billion years
- Brown Dwarfs
  - Type M, L, T, Y
  - 1% of stars
  - lifetime: Trillions of years
  - don't emit visible light

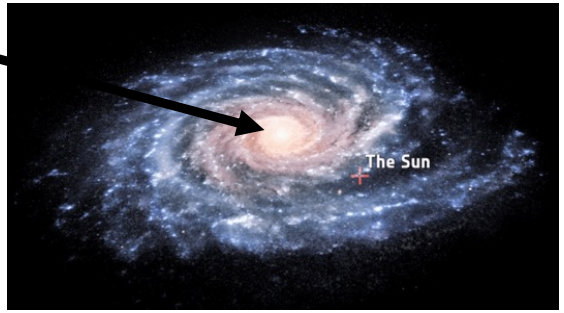


Regions of the Milky Way Galaxy - 1

- The nucleus
  - At the center is a massive Black Hole
  - Sagittarius A*, abbreviated Sgr A*, is the supermassive black hole at the Galactic Center of the Milky Way.
  - Extremely high stellar densities (around 10 million stars)
  - Radius 400 light years
- Central bulge
  - The bulge is a round, dense swarm of stars in the Milky Way center approximately 10,000 light years across.
  - The bulge is a round structure made primarily of old stars, gas, and dust.



https://wardsworld.wardsci.com/geology-earth-science/students-get-starstruck-with-these-facts-about-the-milky-way-galaxy



artist's rendition

Regions of the Milky Way Galaxy -2

- Disk
  - The disk is a thin distribution of stars and gas orbiting the nucleus of the Galaxy.
  - The disk is shaped like a pancake.
  - The Milky Way's disk is 100,000 light years across and 1,000 light years thick.
  - The familiar spiral arms of the Milky Way are located in the disk. It contains mostly young stars, gas, and dust, which are concentrated in spiral arms.
  - The disk is also where most of the present-day star formation occurs--our own adorable star nursery.

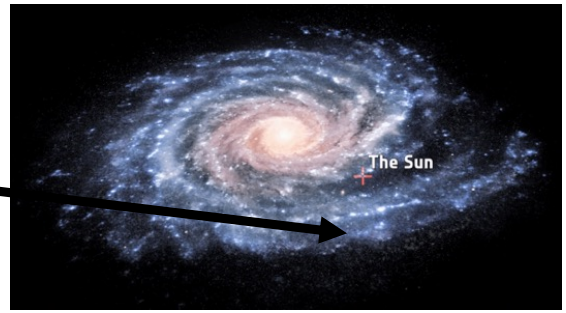
artist's rendition

https://wardsworld.wardsci.com/geology-earth-science/students-get-starstruck-with-these-facts-about-the-milky-way-galaxy

Basic structure of our home galaxy, edge-on view. The new results from ESA's Gaia mission. (real picture)

Regions of the Milky Way Galaxy - 3

- Spiral Arms
  - The spiral arms are curved extensions that begin at the bulge of a spiral galaxy, giving it a “pinwheel” appearance.
  - The spiral arms contain a lot of gas, dust, and young blue stars.
- Halo
  - The halo primarily contains individual old stars and clusters of old stars
- We're located about 27,000 light years away from the center of the Milky Way, and tens of thousands of light-years away from the outer rim.



artist's rendition

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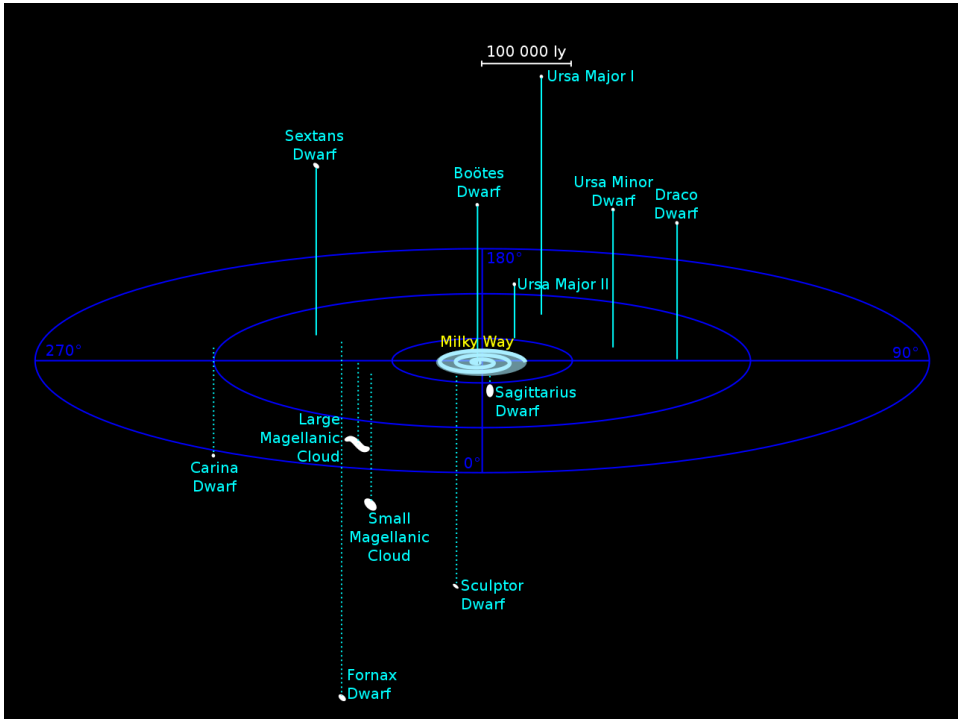
Satellites of the Milky Way

- There are 61 small galaxies confirmed to be within 420 kiloparsecs (1.4 million light-years) of the Milky Way, but not all of them are necessarily in orbit, and some may themselves be in orbit of other satellite galaxies.
- The only ones visible to the naked eye are the Large and Small Magellanic Clouds, which have been observed since prehistory.



https://en.wikipedia.org/wiki/Satellite_galaxies_of_the_Milky_Way

Habitable Zone of the Milky Way Galaxy

- Scientists have defined the galactic habitable zone as the region of a galaxy in which life might most likely develop.
- The concept of a galactic habitable zone analyzes various factors,
  - such as metallicity (the presence of elements heavier than hydrogen and helium) and
  - the rate and density of major catastrophes such as supernovae, and
  - uses these to calculate which regions of a galaxy are more likely to form terrestrial planets, initially develop simple life, and provide a suitable environment for this life to evolve and advance.
- In the case of the Milky Way, its galactic habitable zone is commonly believed to be an annulus (chubby ring)
  - with an outer radius of about 10 kiloparsecs (33,000 ly) and
  - an inner radius close to the Galactic Center (with both radii lacking hard boundaries).

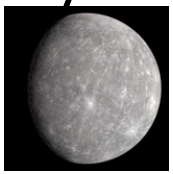
https://en.wikipedia.org/wiki/Galactic_habitable_zone

Our Solar System

Our Star is called "Sol"

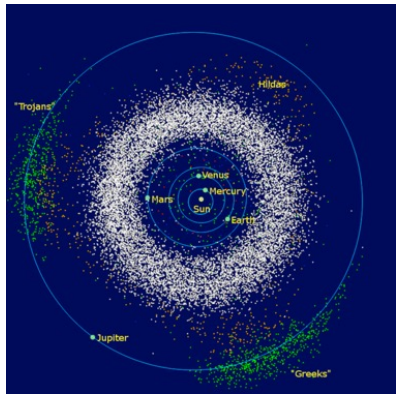
Our Solar System

- Mercury
  - too close
  - very hot

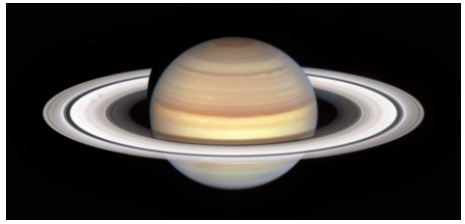


- Venus, Earth, Mars
  - In Habitable Zone

- Asteroid Belt
  - Most too small for atmosphere



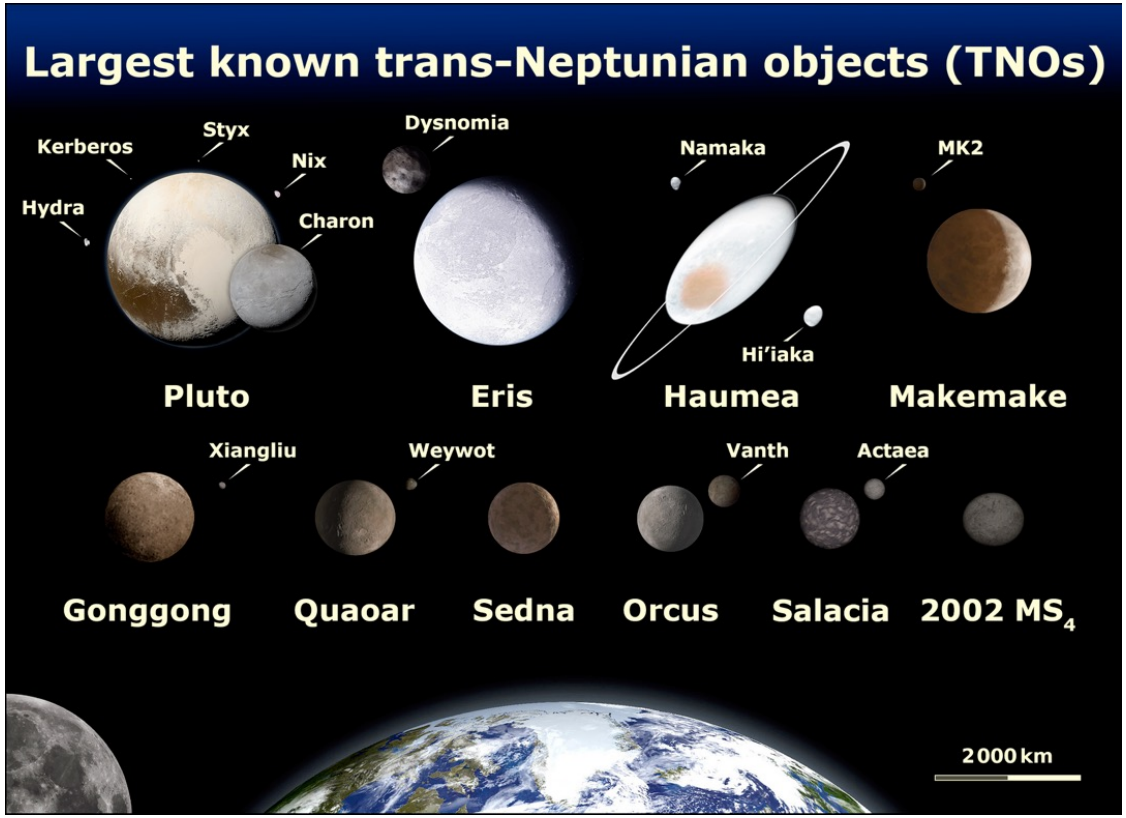
- Jupiter, Saturn (https://en.wikipedia.org/wiki/Gas_giant)
  - Gas Giants
  - Mostly Hydrogen and Helium



- Uranus, Neptune (https://en.wikipedia.org/wiki/Ice_giant)
  - Too Far
  - Too cold
  - Surface made up of various ices, such as water, ammonia, and methane
  - Atmosphere hydrogen, helium, methane

Our Solar System - 2

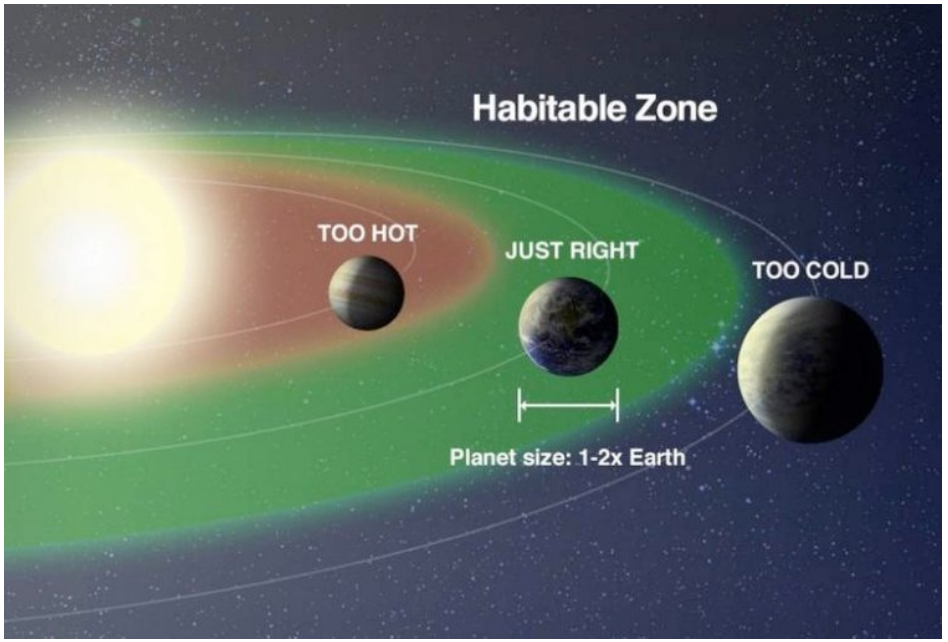
- Trans Neptune objects



Habitable Zone of Our Solar System

- The Habitable Zone is where life could occur
- There are three planets in the Habitable Zone of Our Solar System
- Only one of them currently has life
- There may or may not have been life on the other two in the past

- WHY?



Uniqueness of the Earth

- Solar System Specific
  - Orbiting a Stable Star
  - Minimal eruptions on Sun
- Earth Specific
  - Tilt of orbit
    - seasons
  - Magnetic field
    - protects planet from emissions from Sun and outer space
  - Distance from Sun
  - Presence of a large Moon
    - protects planet from astroids
    - stabilizes tilt of the earth
  - Plate Tectonics
  - Oxygen Atmosphere

Tilt of orbit

- Earth
  - between 22.0 and 24.5 degrees
  - currently 23.44 degrees
  - with a mean period of 41,040 years

https://en.wikipedia.org/wiki/Axial_tilt

- Mars
  - between 15 degrees and 35 degrees over a 124,000-year cycle
  - may swing from 0 degrees all the way up to 60 degrees. at intervals of a few tens of millions of years
  - currently 25 degrees

https://www.spacedaily.com/news/mars-water-science-00d.html

- Venus
  - currently 177.3 degrees
  - unknown on changes

Magnetic Field Strength

- Earth
  - Created by rotation of the molten core of the earth
  - 25 to 65 μT (0.25 to 0.65 gauss)
- Venus
  - no intrinsic magnetic field
  - small one caused by charged particles in ionosphere
- Mars
  - no intrinsic magnetic field

Results of having/not having Magnetic Field

- Earth
  - Keeps solar wind from eroding the atmosphere
  - Deflects charged particles

- Venus
  - solar wind broke up any water and lower mass atoms escaped leaving CO2
  - The may be volcanic action leading to additional CO2

- Mars
  - solar wind eroded Mars Atmosphere
  - leaving flimsy atmosphere of mostly CO2

Part 2 Presented by Pat

Interesting objects to Observe in the Sky

Extras

Quasars (Are Not Stars)

- Quasars are extremely luminous galactic cores where gas and dust falling into a supermassive black hole emit electromagnetic radiation across the entire electromagnetic spectrum.
- The gas and dust become luminous as a result of the extreme gravitational and frictional forces exerted on them as they fall into the black hole.
- Quasars are amongst the most luminous objects in the known Universe, typically emitting thousands of times more light than the entire Milky Way.
- The nearest quasars to Earth are still several hundred million light-years away, meaning that they are observed now as they were 600 million years ago.
- The absence of quasars closer to Earth does not mean that there were never quasars in our region of the Universe, but they probably existed when the universe was younger.

https://esahubble.org/wordbank/quasar/

Supernova

- A supernova is a powerful and luminous explosion of a star.
- A supernova occurs during the last evolutionary stages of a massive star, or when a white dwarf is triggered into runaway nuclear fusion.
- The original object, called the progenitor, either collapses to a neutron star or black hole, or is completely destroyed to form a diffuse nebula.
- The peak optical luminosity of a supernova can be comparable to that of an entire galaxy before fading over several weeks or months.

https://en.wikipedia.org/wiki/Supernova

Novas

- A "nova" ("Novae" or "novas") is an astronomical event that causes the sudden appearance of a bright, apparently "new" star that slowly fades over weeks or months.
  - hence the name "nova", which is Latin for "new"
- Causes of the dramatic appearance of a nova vary, depending on the circumstances of the two nearby stars.
- All observed novae involve white dwarfs in close binary star systems.
- As the two stars orbit each other, they sometimes get very close and the dwarf star will "steal" gas from the other star.
- This gas glows very brightly for a while.