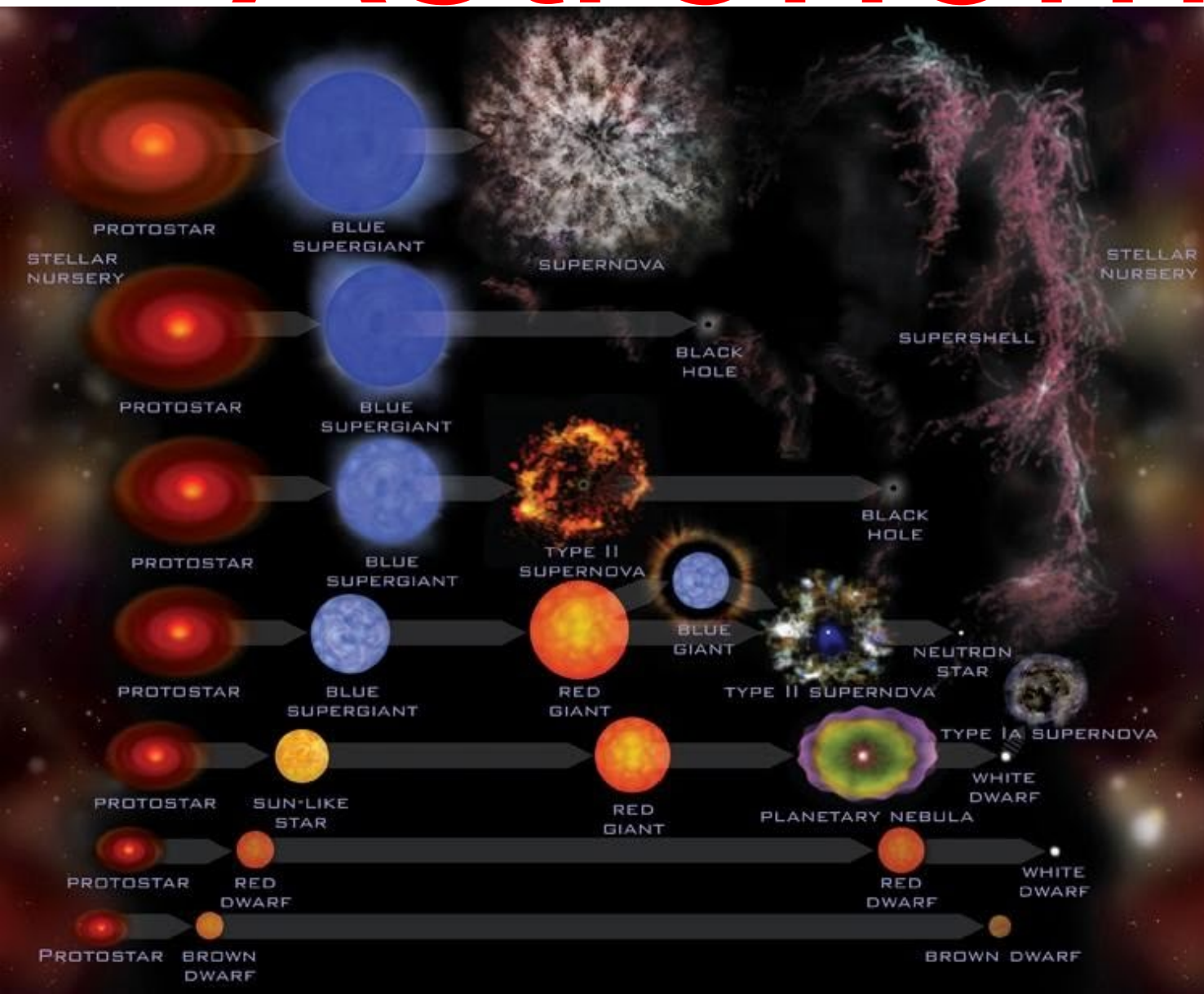


Astronomy

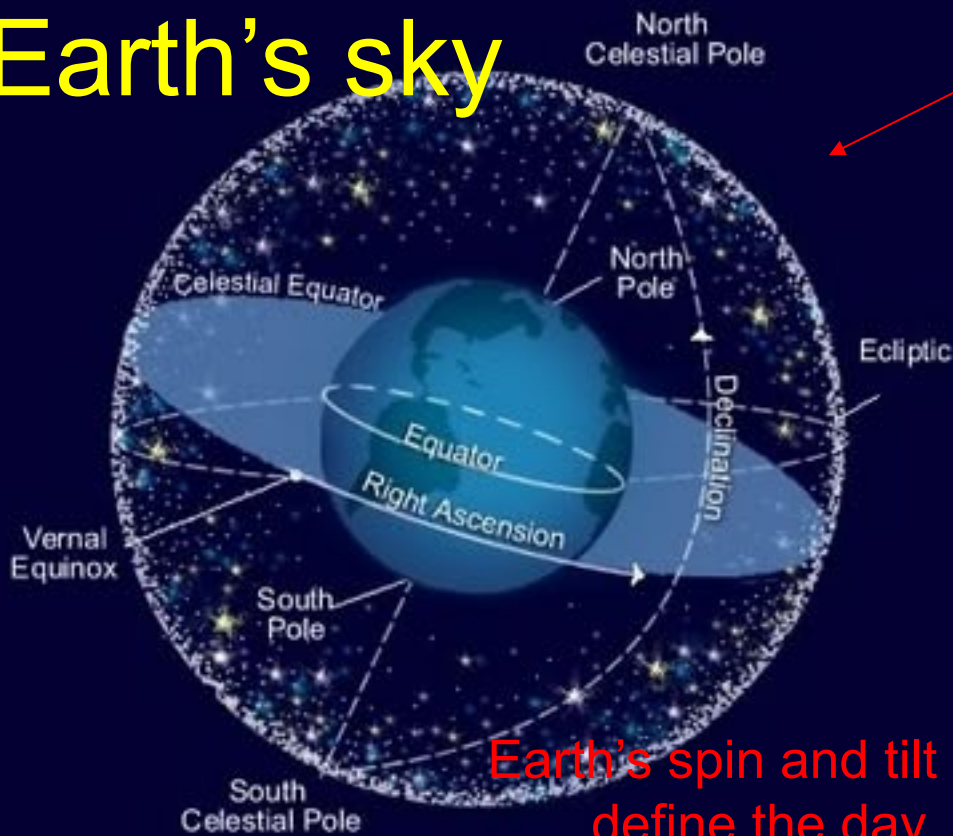
The Study
of Planets,
Stars, and
Galaxies.

By Michael
Marron
of the
Phoenix
Astronomical
Society

PASAZ.org
6/3/2016

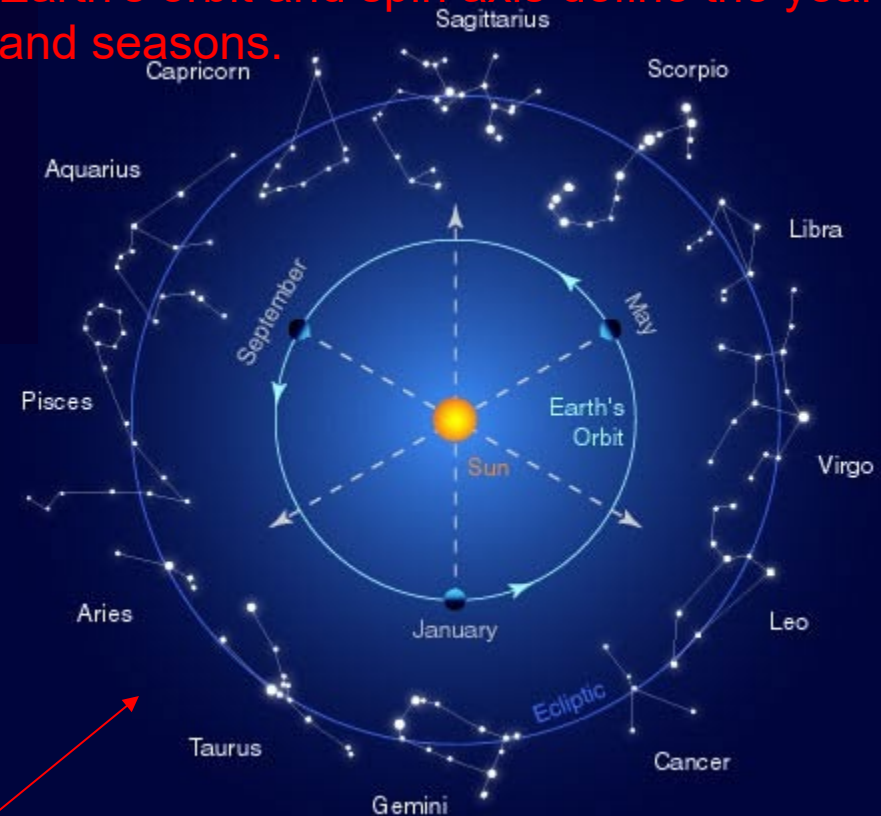


Earth's sky



The Earth's axial tilt is 23° to its orbital plane (the Ecliptic). It takes a year for us to go once around the Sun and the axial tilt gives us the four seasons. In the northern hemisphere the axial tilt points to Polaris so all the stars and the Sun appear to rotate around Polaris every 24 hours due to Earth's spin.

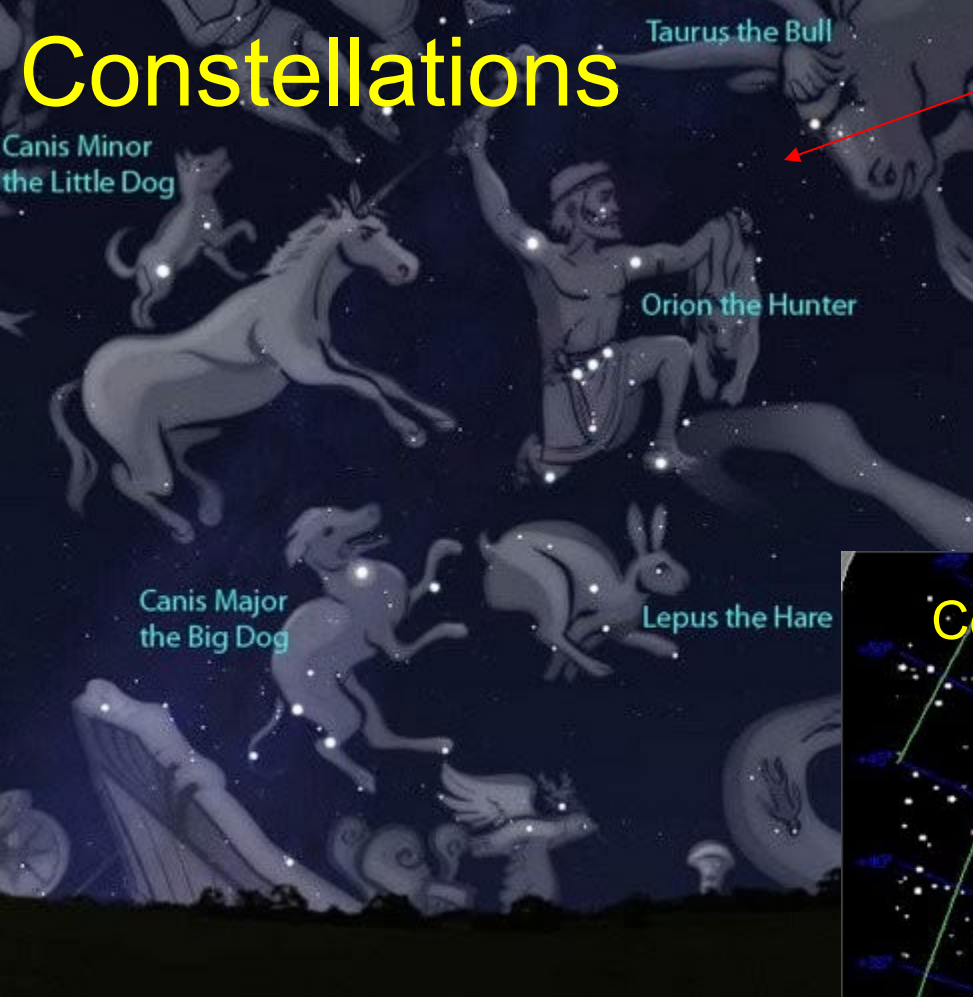
Earth's orbit and spin axis define the year and seasons.



Earth's spin and tilt define the day.

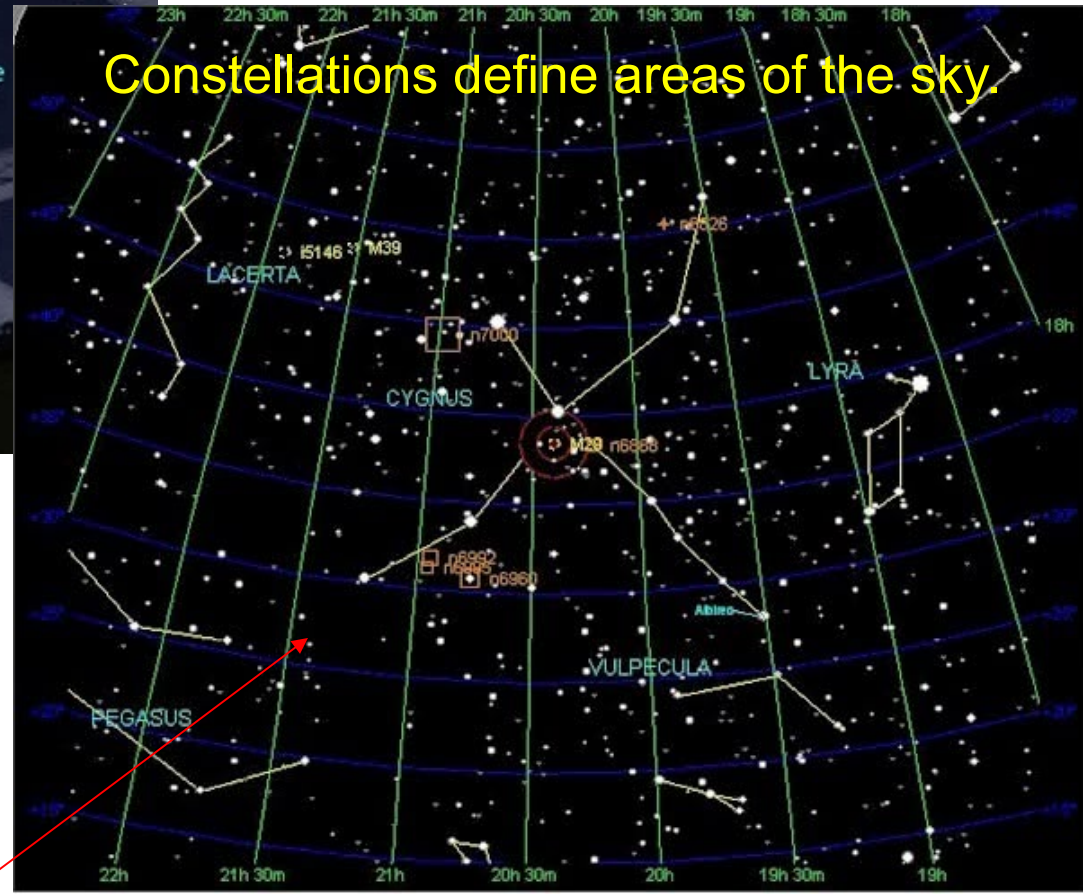
The zodiacal constellations lie in the Ecliptic so as the year progresses the Sun appears to be within each constellation in succession. We are about a constellation and a half away from the horoscope signs assigned to your birth dates. Astrology is a 4,000 year old Sumerian superstition when they thought the year was 365 days not 365.25. Over time a six week error of the Sun's true position relative to the zodiac accumulated. Astrology slowly evolved into the science of Astronomy.

Constellations



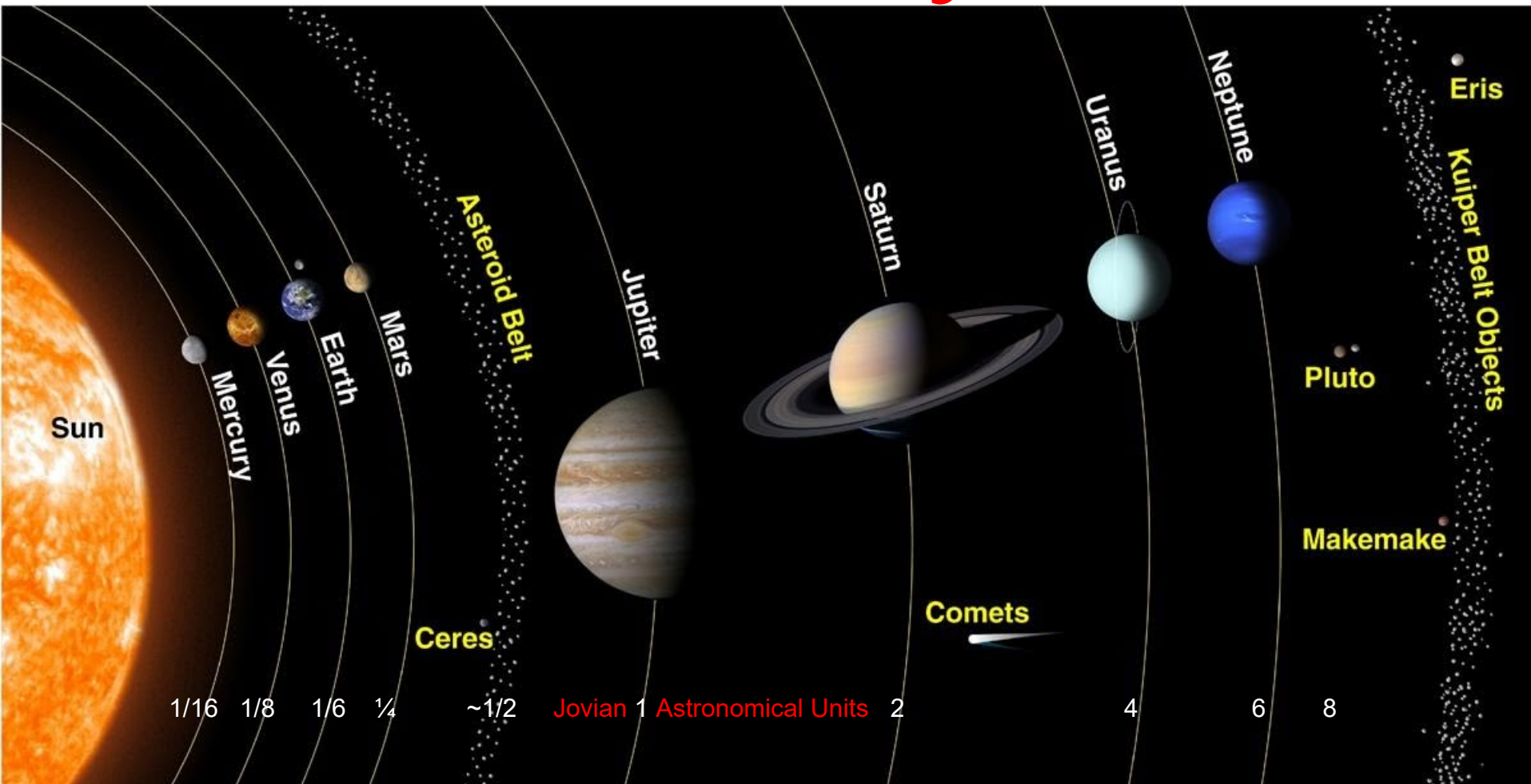
The imaginations of ancient populations connected the random assemblages of the 6,000 brightest stars into various constellations with memorable stories. They used the stars for their fundamental clock and calendar. This sky is still used for planting, harvesting, navigation, astronomy, building & street alignments. Months were based on the lunar cycle.

Constellations define areas of the sky.



In modern astronomy we have longitude, latitude, equatorial, and ecliptic lines dividing the sky. Constellations now define areas of the night sky. Any astronomical object found inside the area borders of the Cygnus constellation is considered part of Cygnus such as the nearby black hole star Cygnus X-1 first found in the X-ray spectrum, or distant galaxies such as Cygnus A* (3C405) 720,000,000 ly away.

Our solar system



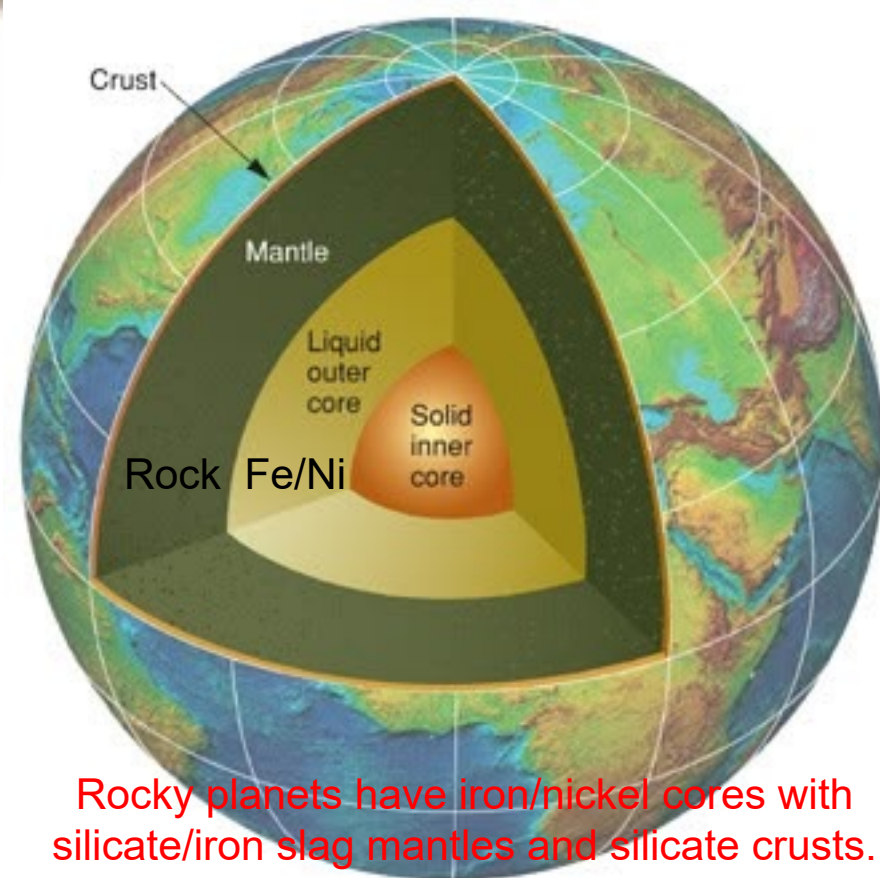
While there continues to be discoveries of hundreds of exoplanets around other stars we have now examined much of our solar system with space probes which gave us better information about our Sun, planets, moons, comets, and asteroids. Jupiter sets the stable orbits. A string of any length can give the orbital proportions for the outer planets (to Pluto) by folding it. Mark 1st fold point for Uranus, mark next folds for Neptune and Saturn. Fold to the Saturn mark for the Jupiter mark. Fold to the Jupiter mark for the Asteroid Belt (AB). Fold to the AB mark for Mars. Fold to the Mars mark to get Venus. Fold the Venus mark to the Mars mark and you get Mercury and Earth.

The solid planets

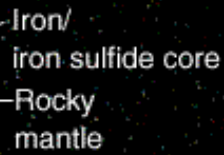


The solar system began as part of a hot giant molecular cloud complex of interstellar stardust and gas. A supernova fifty light years away made a radioactive shell of gas that struck this cloud. The presolar grains melted into dirty droplets called chondrules that accumulated into asteroids or planetesimals.

Inside of Jupiter's orbit are the planets, moons, and big asteroids that typically have iron/nickel cores, rock and iron mantles, with differentiated silicates as crustal material. Big impacts brake the stony material from large asteroids exposing the cast iron/nickel cores, the stony iron meteorites from the mantle, and the crustal stony meteorites. Many of the smaller asteroids and the biggest (Ceres) remain primitive and undifferentiated. Undercooked calcium aluminum inclusion (CAI) chondrites display isotope decay from the supernova blast impact melting local stardust 4.6 billion years ago. A six to 4.6 billion year history of the supernova star is in a carbonaceous chondrites' presolar grains.



Rocky planets have iron/nickel cores with silicate/iron slag mantles and silicate crusts.



- Icy crust
- Rocky mantle
- Iron/iron sulfide core

The
Many large rocky planets: the super-Earths, the super-Earths, and the super-Earths.

- Ice/rock mixture

Jupiter's
largest
moons.

The impact that made the Moon 4.5by melted the entire Earth's surface so crustal solidification began only 4.2by ago.

Origin of Earth's Moon

Many large round worlds are not currently classified as planets: the solar system's major moons, the largest asteroids, and large Kuiper belt objects. These are the ones spacecraft have visited.

Images from: United Nations (moons), Cassini (Saturn's moons), Voyager 1 (Jupiter and Neptune's moons), New Horizons (Pluto), Dawn (asteroids) Data from NASA/JPL/CIRES/UCAL/APS/DGND, processed by Ted Stryk, Georgian Upernivik, Emily Lakdawalla, and Jason Perry. Earth's Moon photo by Gar Avallone, Montage by Emily Lakdawalla. The Planets Source: <http://img.thesolarsystem.org>

14

Europa

Ganymede

Callisto

The Moon

Mimas Enceladus Tethys Dione Rhea

Mimas Enceladus

10

Tethys

Dione

Also

Miranda Ariel Umbriel Titania Oberon

Mirand

1

10

Triton

Pluto Charon

Pluto

Charon

Proteus Vesta Cere

Vesta

Ceres

Worlds of stone and ice

Jupiter

Saturn

Gas Giants

Uranus

Neptune

Earth →

← Pluto

The gas giants are failed stars that are too small to fusion the mostly hydrogen and little helium they have retained from birth. What we see are cloud tops deeply imbedded in a larger but transparent hydrogen atmosphere.

Inside Gas Giant SATURN

Saturn is the most distant planet which can be seen with the unaided eye. When Galileo became the first person to look at Saturn through a telescope in 1610, he saw strange ear-like shapes at the sides of the planet. His telescope was not sharp enough to reveal that the shapes were actually rings.

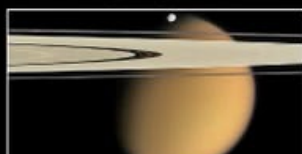
THICK ATMOSPHERE
96.5% carbon dioxide,
3.5% nitrogen plus
trace gases.

**GRAVITY 1.1
OF EARTH**



EARTH 10ft
SATURN 9.4 ft
dunk dunk

MAGNIFICENT RING SYSTEM
composed almost entirely of
water-ice chunks that are
under 30 ft (10 m) in diameter.



Saturn's moons Titan and tiny Epimetheus orbit beyond the ring system in this Cassini photo.

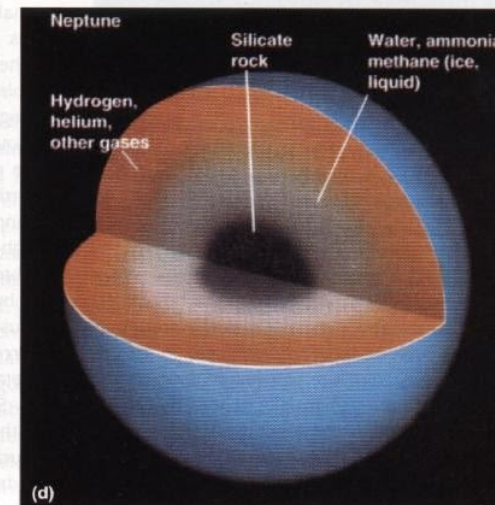
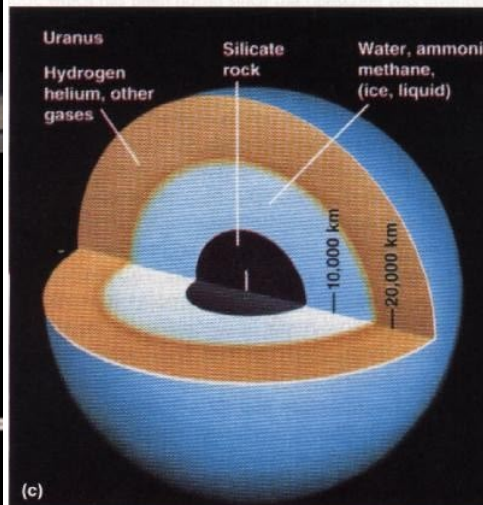
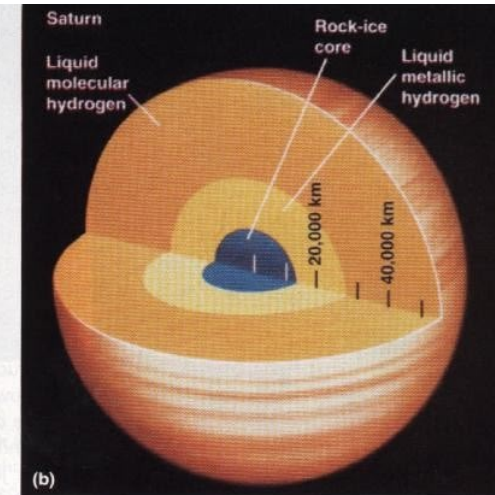
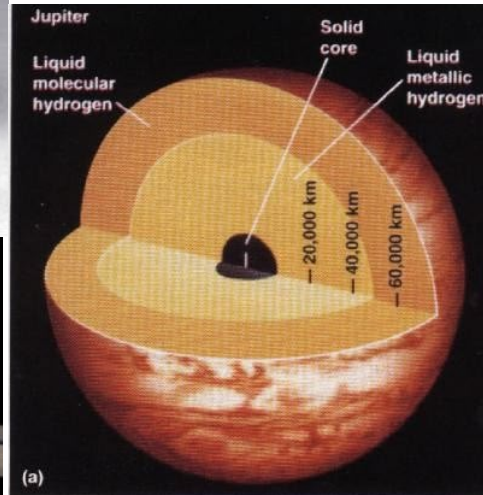
TINY CORE OF ROCK AND METAL
The solid core of Saturn may be the
size of Earth. It is surrounded by
thick layers of metallic hydrogen.



Saturn is oblate, meaning that it is wider at the equator than at the poles. Saturn's equatorial diameter of 74,898 mi (120,536 km) is about 9.4 times that of Earth.

SOURCE: NASA, ESA, Space Telescope Science Institute

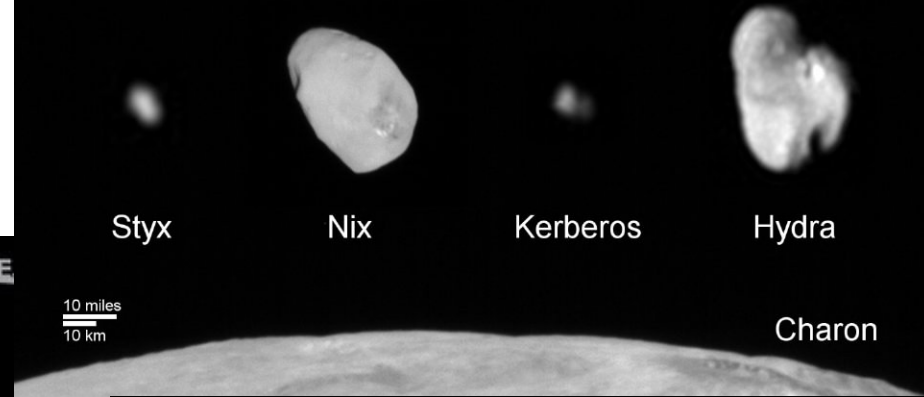
KARL TATE, SPACE.COM



Internal structures of the four gas giant planets. (a) Jupiter and (b) Saturn have small rocky cores and layers of hydrogen under increasing pressure lower in the atmospheres. (c) Uranus and (d) Neptune have insufficient pressure to create hydrogen in the liquid metallic state, but as on Jupiter and Saturn, differentiation has caused the heavy elements to sink and form a rocky core. For scale, note that Earth is slightly smaller than the rocky cores of each of these giant planets.

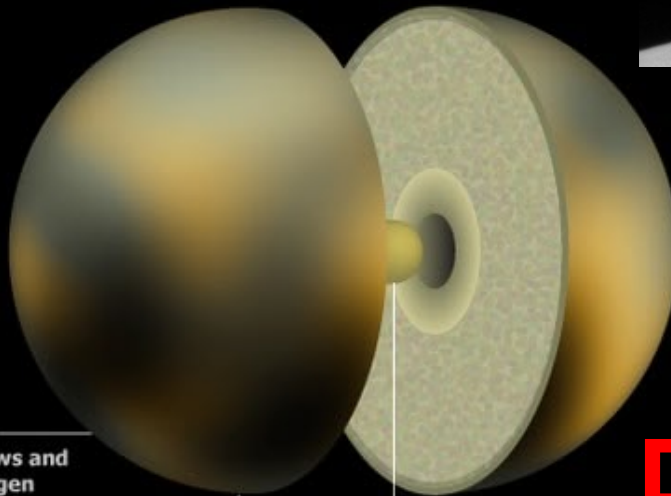
Beyond Neptune are the icy dwarf planets where Pluto and its moons are typical objects. Various ices dominate these objects rich in organic and inorganic compounds. Pluto has a thin nitrogen atmosphere when it is closest to the Sun.

Charon and the Small Moons of Pluto



Inside Dwarf Planet PLUTO

Discovered in 1930 and once considered a major planet, Pluto was reclassified as a dwarf planet in 2006. Pluto is sometimes considered a double planet system because its moon, Charon, is about half Pluto's size. It takes Pluto 248 years to orbit the Sun.



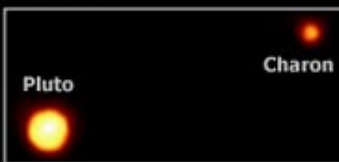
TEMPORARY ATMOSPHERE
Occurs when surface ice thaws and evaporates into mostly nitrogen with some methane.

GRAVITY
0.066 OF
EARTH



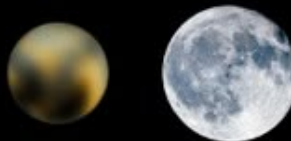
Note: Drawing not to scale

SURFACE CONDITIONS
AIR PRESSURE: Minimal
TEMPERATURE: -375°F (-225°C)
WINDS: When atmosphere is present.



This image of Pluto and Charon was taken in 1994 shortly after the Hubble Space Telescope's optics had been repaired.

ROCK CORE Pluto's rocky core is probably surrounded by a mantle of ice, with methane and nitrogen frost coating its surface.



Pluto's diameter of 1,485 miles (2,390 km) is two-thirds that of the moon.

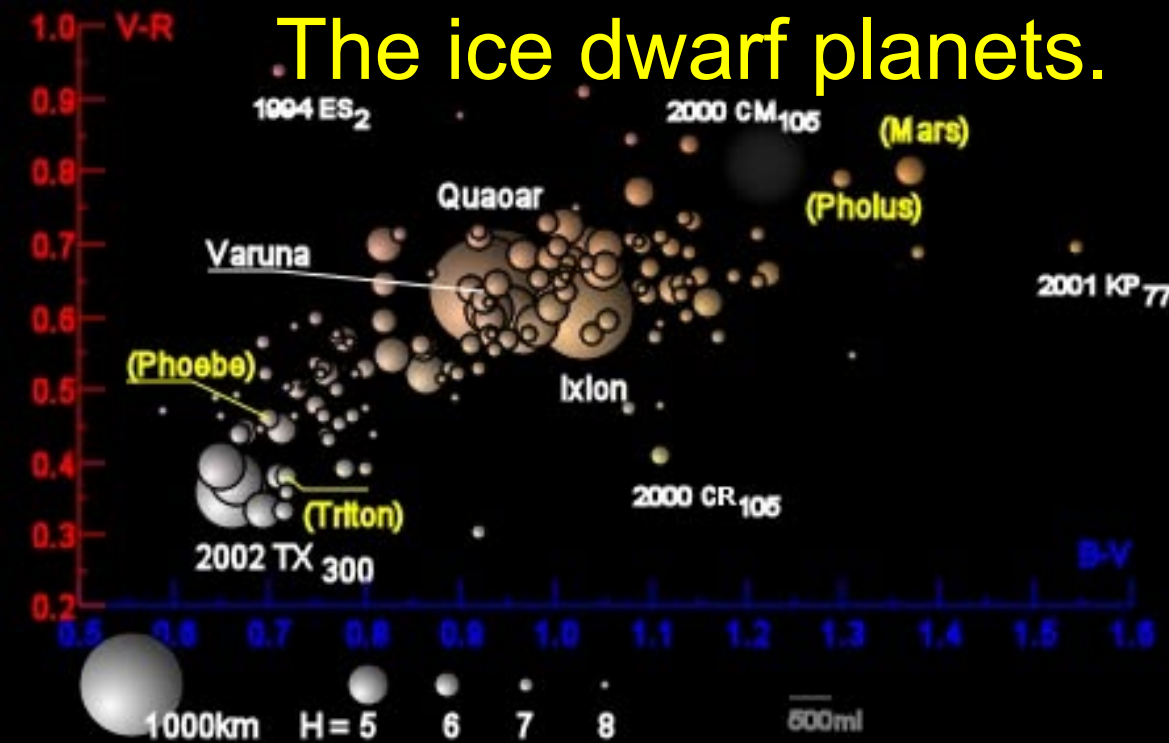
ROSS TORO, SPACE.com

Pluto

Charon

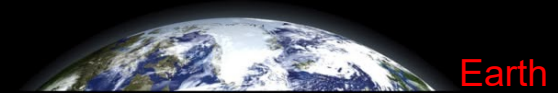
Pluto

The ice dwarf planets.



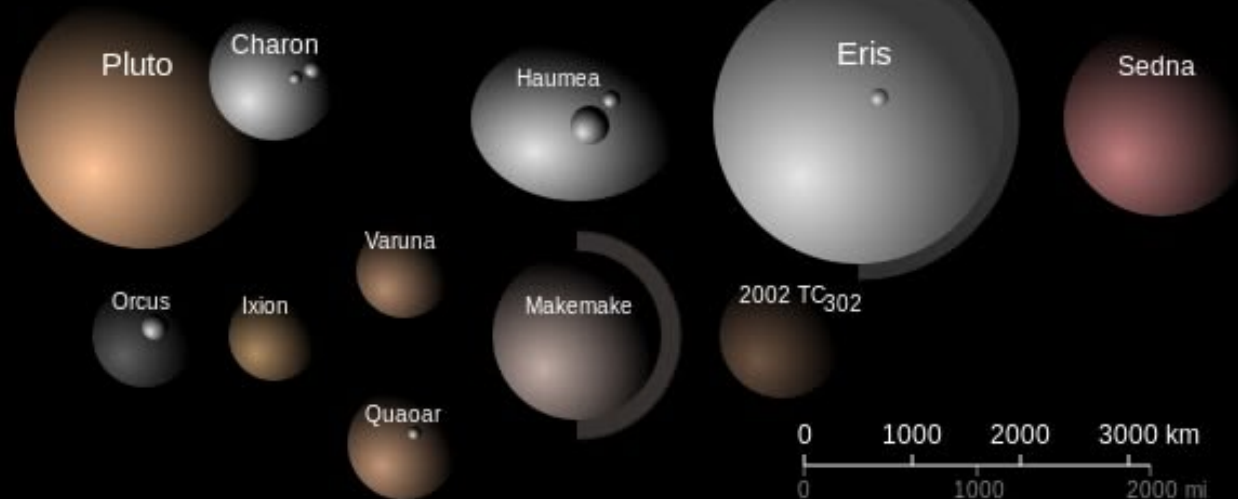
The surface of these objects vary from bright ices of water and carbon dioxide to radiation damaged carbon and nitrogen compounds of great variety.

Largest known trans-Neptunian objects (TNOs)



Earth

Ice worlds beyond Neptune.

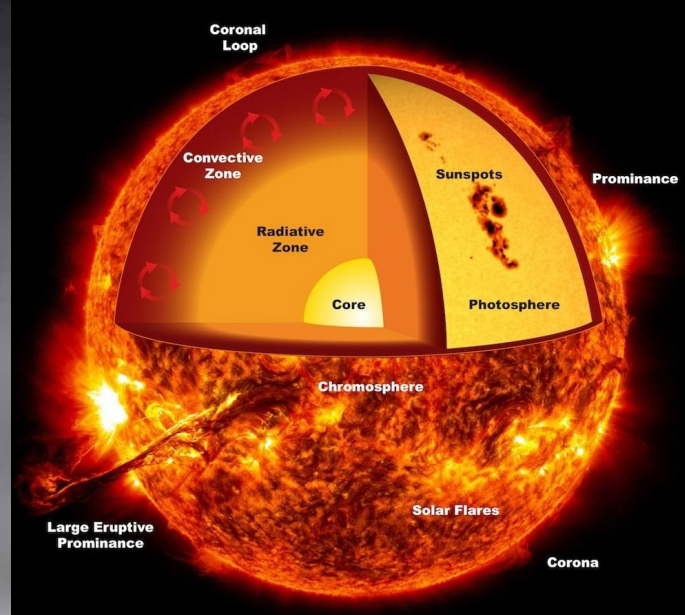


Colors of trans-Neptunian objects. Mars and Triton are not to scale. Phoebe and Pholus are not trans-Neptunian.

At least two of the trans-Neptunian objects (Eris & Makemake) are large and warm enough to have thin atmospheres like Pluto.

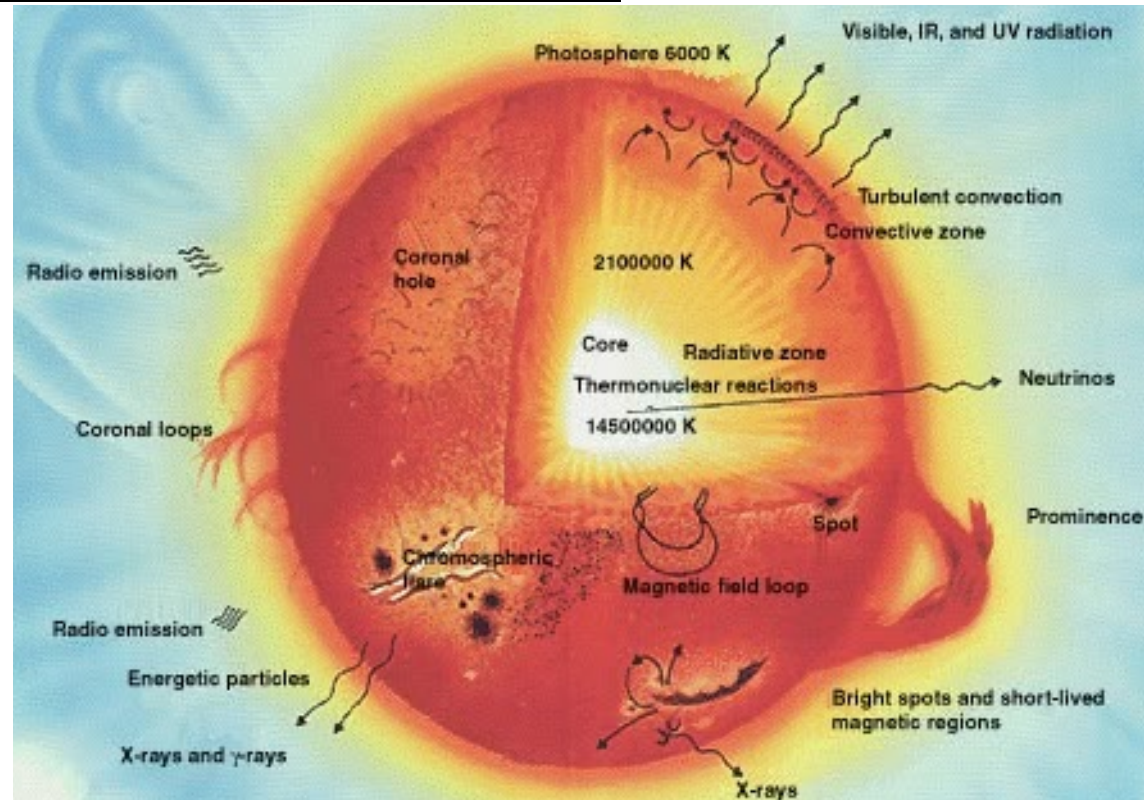
Our star the Sun.

The size relationship of the Sun to the other planets.

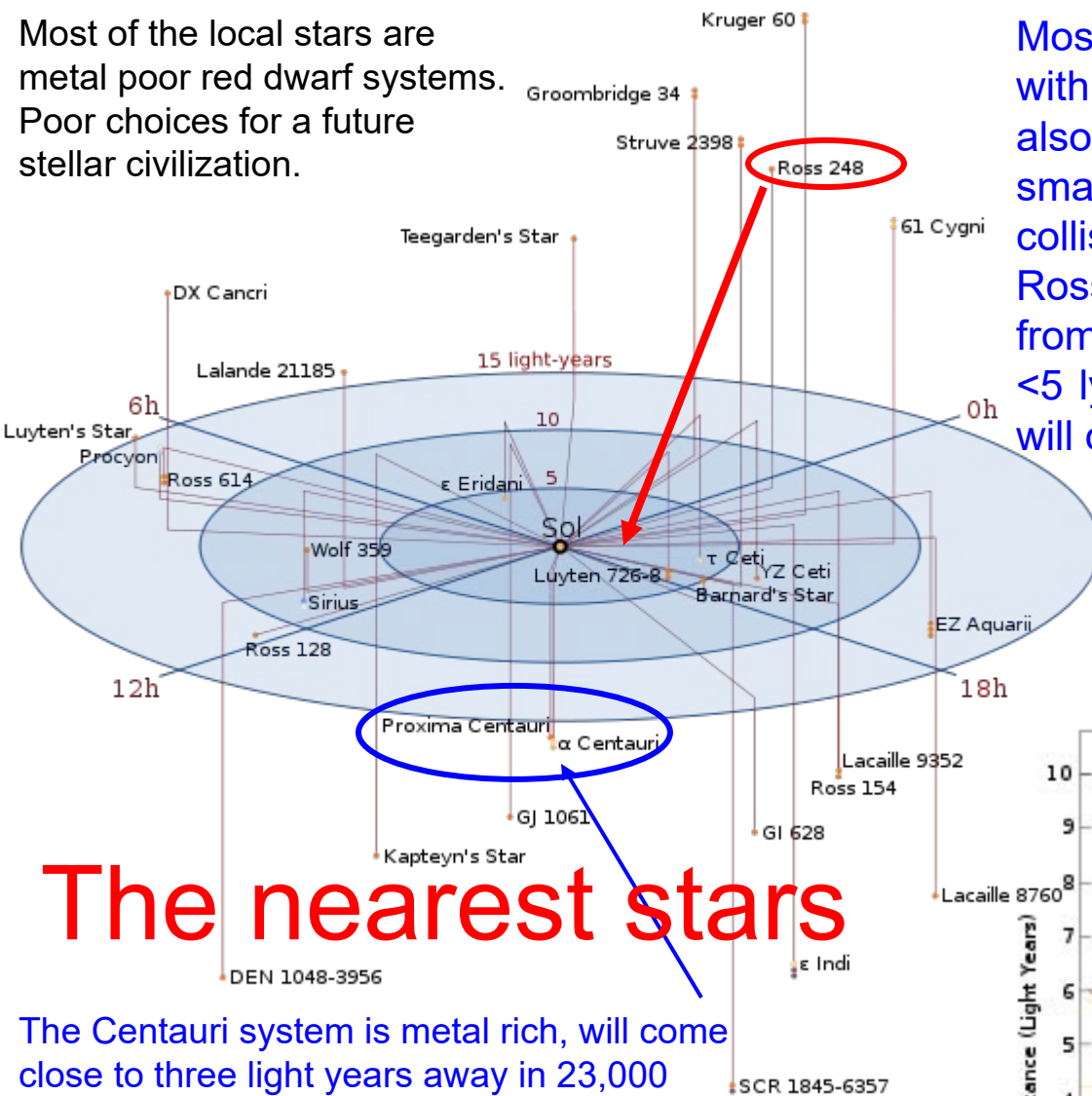


Because Jupiter is almost two percent of the mass of the solar system it pulls the barycenter of the entire solar system to a point $1/5$ of a solar radius above the Sun's surface that faces Jupiter. The Sun and all planets orbit this barycenter, not the Sun's center.

The Sun is a slightly larger than a typical normal star in that it burns both hydrogen and helium into heavier elements. Iron requires higher temperatures to burn into the heavier elements so iron is the ash that settles to the Sun's core. The photosphere is where light from fusion reactions finally escapes into space, it is not a surface. If you consider the solar wind the atmosphere of the Sun then most icy planets discovered orbit inside this Heliosphere.



Most of the local stars are metal poor red dwarf systems. Poor choices for a future stellar civilization.



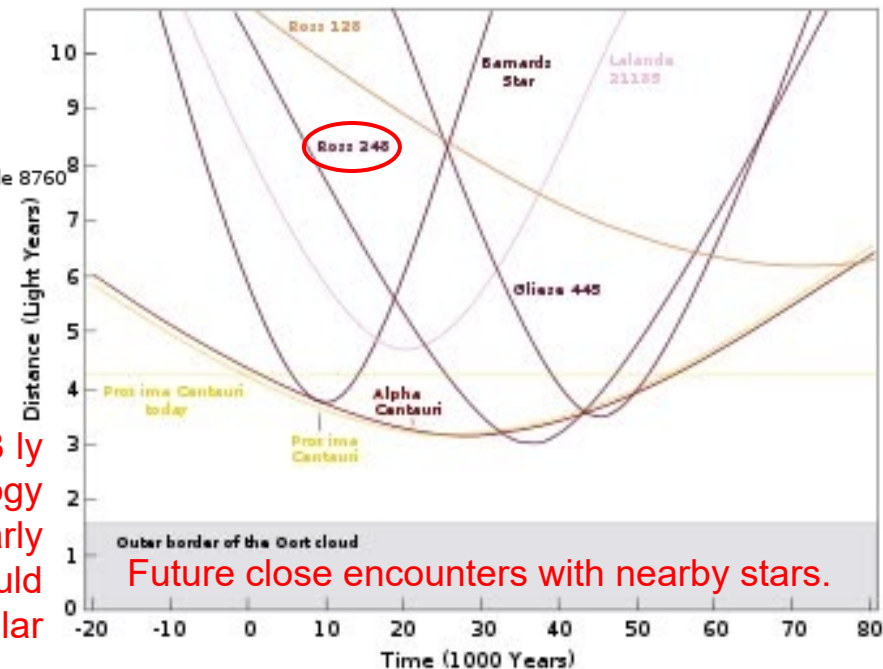
The nearest stars

The Centauri system is metal rich, will come close to three light years away in 23,000 years, will slowly recede, and has planets.

Measurements show that Ross 248 may come as close as 3 ly in 38,000 years which is how far and fast current technology would allow us to go in interstellar space. This star's nearly polar orbit would mean that for millions of years this star would be below the Milky Way disk far from any future interstellar empire. As a population II star Ross 248 has little of value.

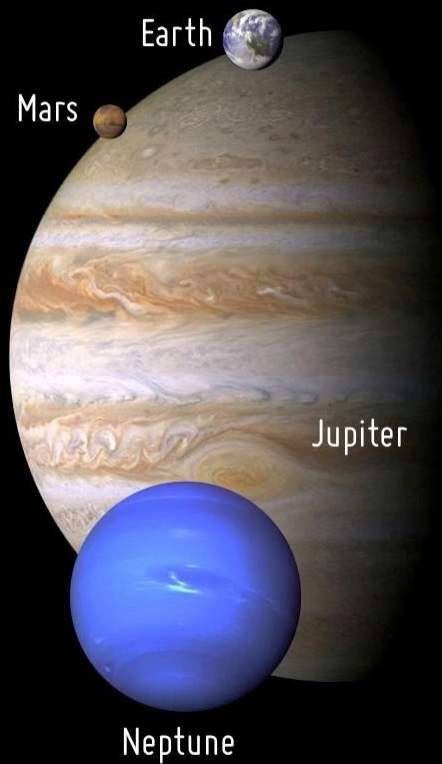
Most local stellar neighborhood stars orbit with the disk of the Milky Way galaxy while also bobbing up and down. Ross 248 is a small, ancient, red dwarf star from a recent collision with the Sagittarius Dwarf Galaxy. Ross 248 is plunging through the local disk from the north. Five approaching stars will be <5 ly in the next 50,000 years but Ross 248 will come the closest at 3 ly in 33,000 years.

Rocky planets have been found around red dwarf systems but they may be very low in the heavy elements needed for life and industry. Metal rich, population II stars like Alpha Centauri is 1st choice.



Potentially Habitable Exoplanets

Ranked by Distance from Earth (light years)



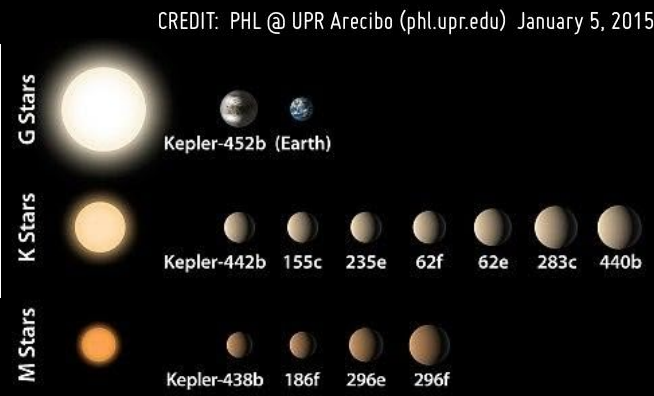
Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance is between brackets. Planet candidates indicated with asterisks.

The hunt for exoplanets has just begun and thousands have been discovered. This is the current list of Earth like planets found that are in the Goldilocks habitable zone of the star they orbit and the their distance from us in light years.

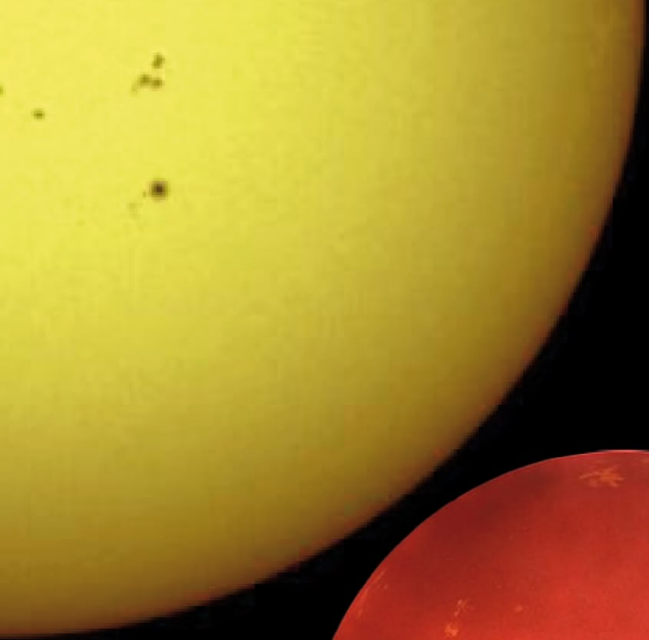
The type of stars found with habitable planets.

Kepler's Small Habitable Zone Planets

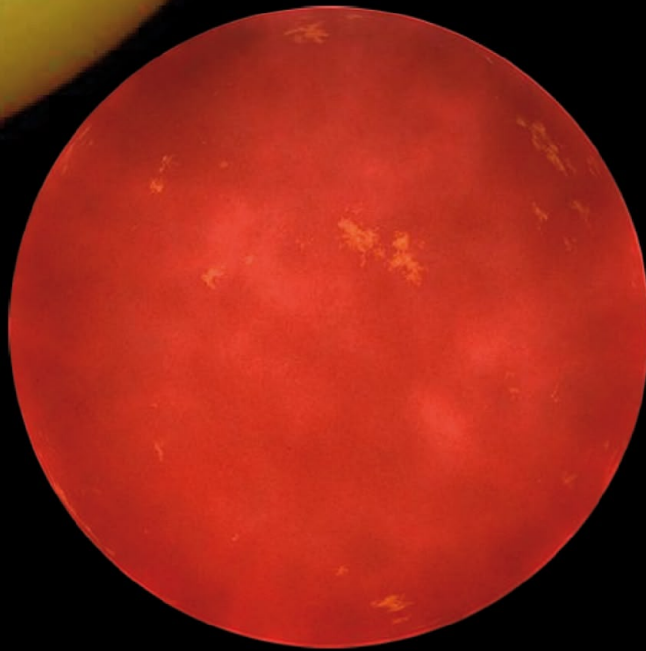
Planets enlarged 25x compared to stars



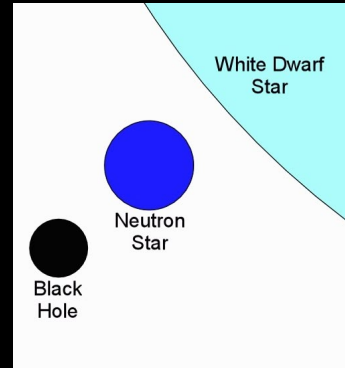
Red dwarf stars are much older and smaller than our Sun that slowly burn their remaining hydrogen for billions of years until they fade away. Brown dwarfs are typically eight times as massive as Jupiter with a higher density but with similar diameters. Most of the remaining older, metal poor, population II stars are red and brown dwarfs simply because these stars live so long.



Sun



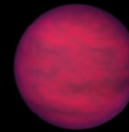
Gliese 229A



Small stars



Teide 1



Gliese 229B



WISE1828



Jupiter

5,800 K

G2 star

3,600 K

red dwarf
star

2,600 K

young
brown dwarf

950 K

old
brown dwarf

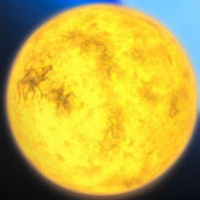
300–500 K

ultra-cool
brown dwarf

125 K

planet

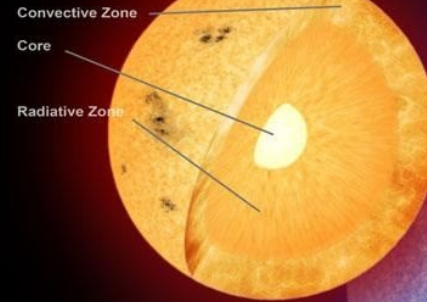
red dwarf



yellow dwarf (Sun-like)



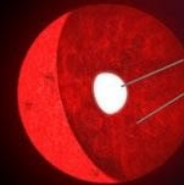
| blue dwarf



Core

Radiative Zone

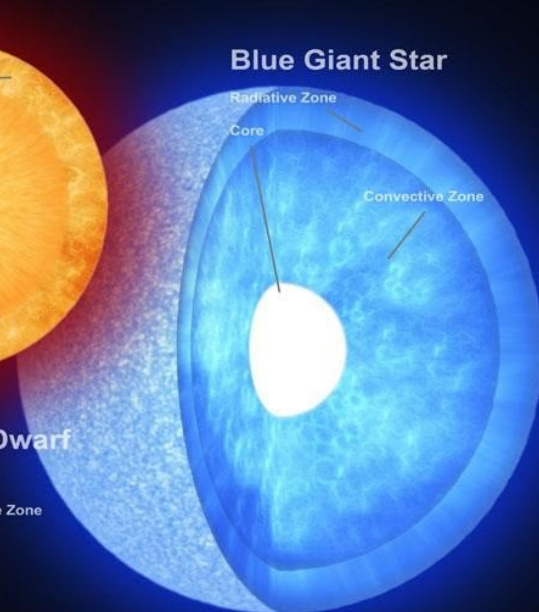
Radiative Zone



Red Dwarf

Core

Convective Zone



Blue Giant Star

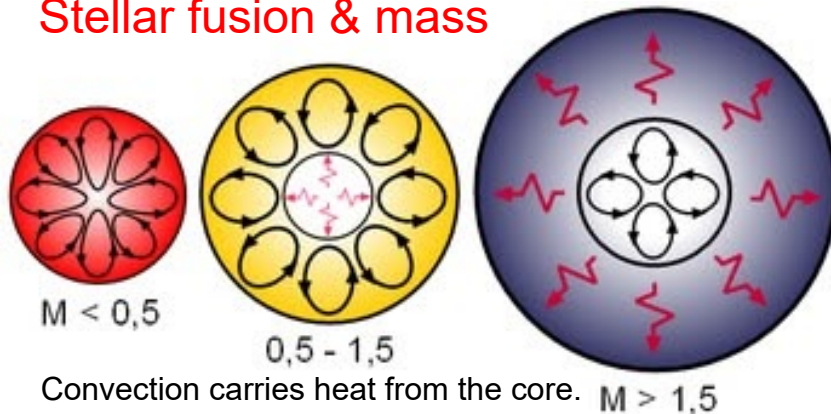
Radiative Zone

Core

Convective Zone

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Stellar fusion & mass

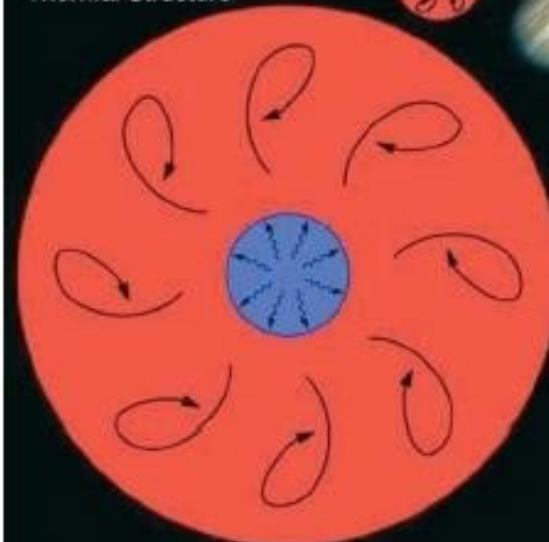


Convection carries heat from the core. $M > 1.5$

Gliese 752A
Thermal Structure

Gliese 752B (VB10)
Thermal Structure

Jupiter
to scale



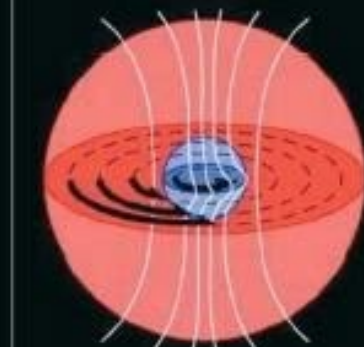
Key

Convection

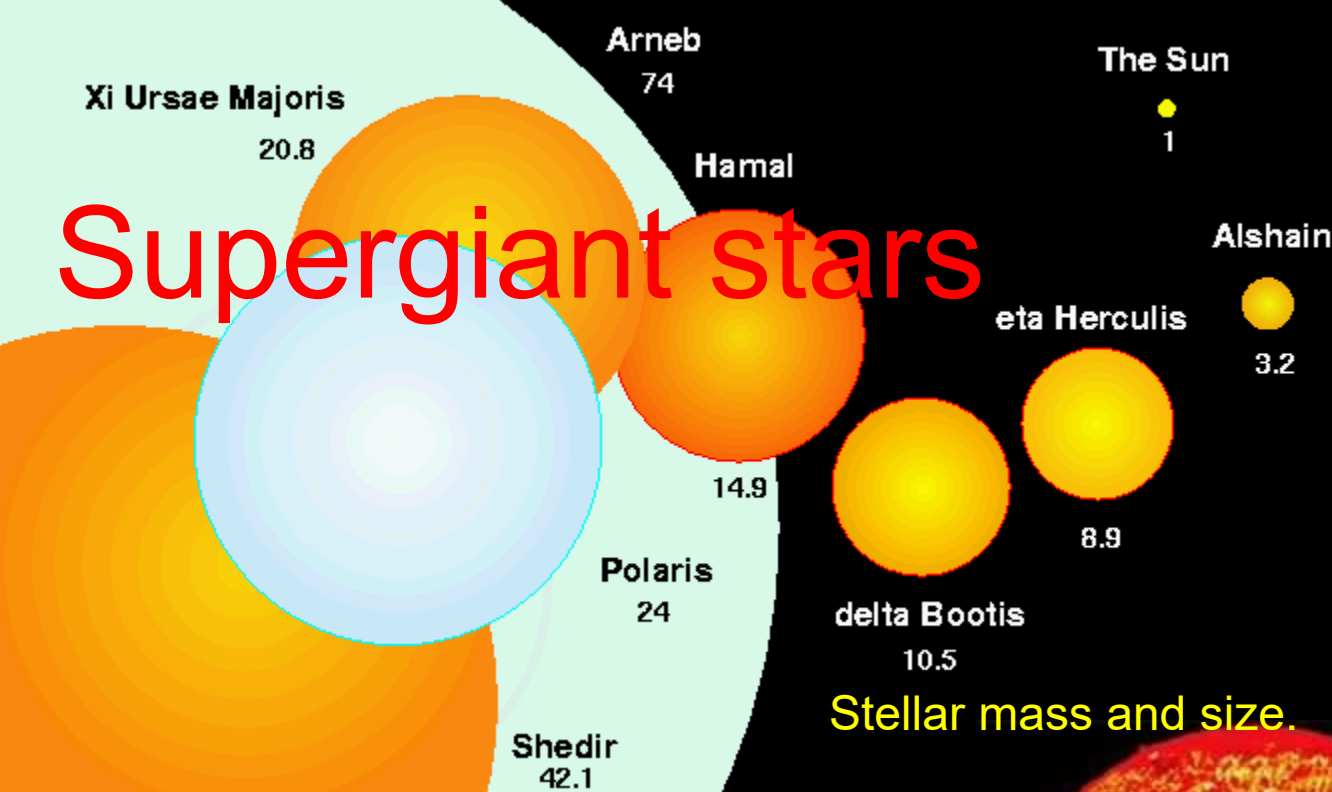
Radiation

Rotation

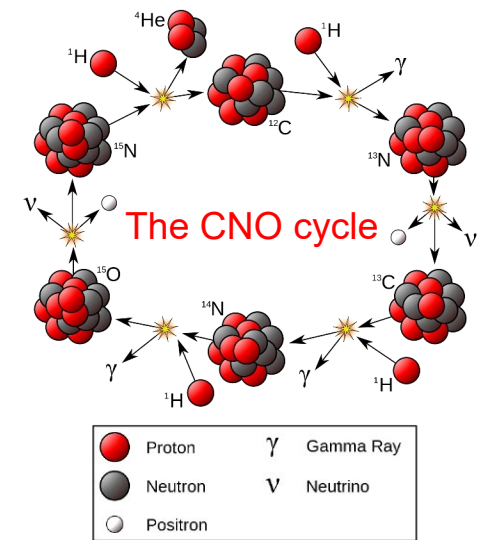
Magnetic Field

Gliese 752A
Rotation and Magnetic Dynamo
Standard Model

Supergiant stars

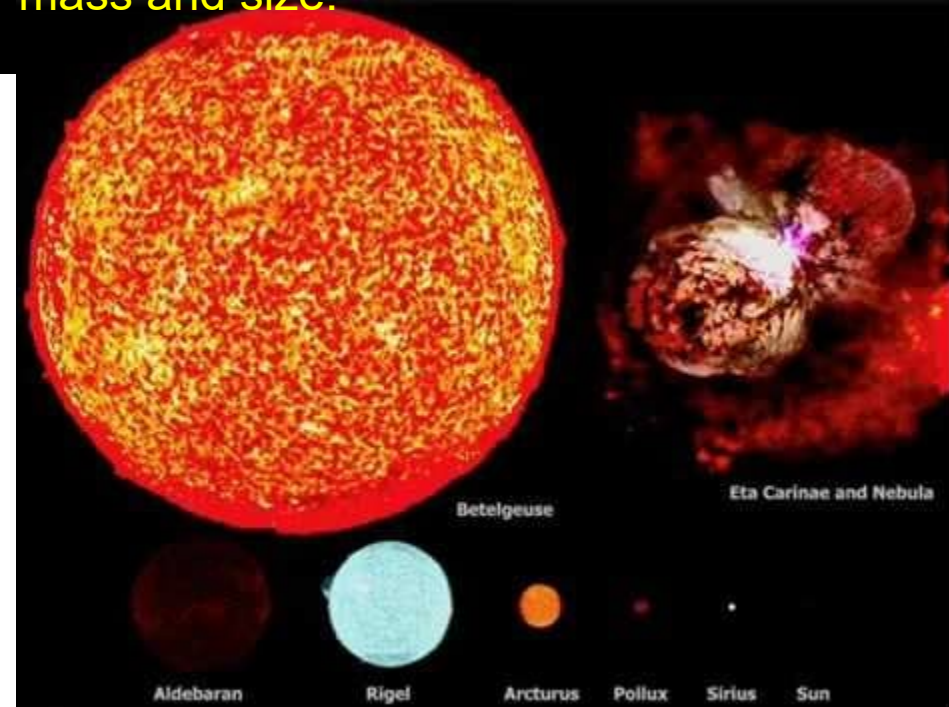


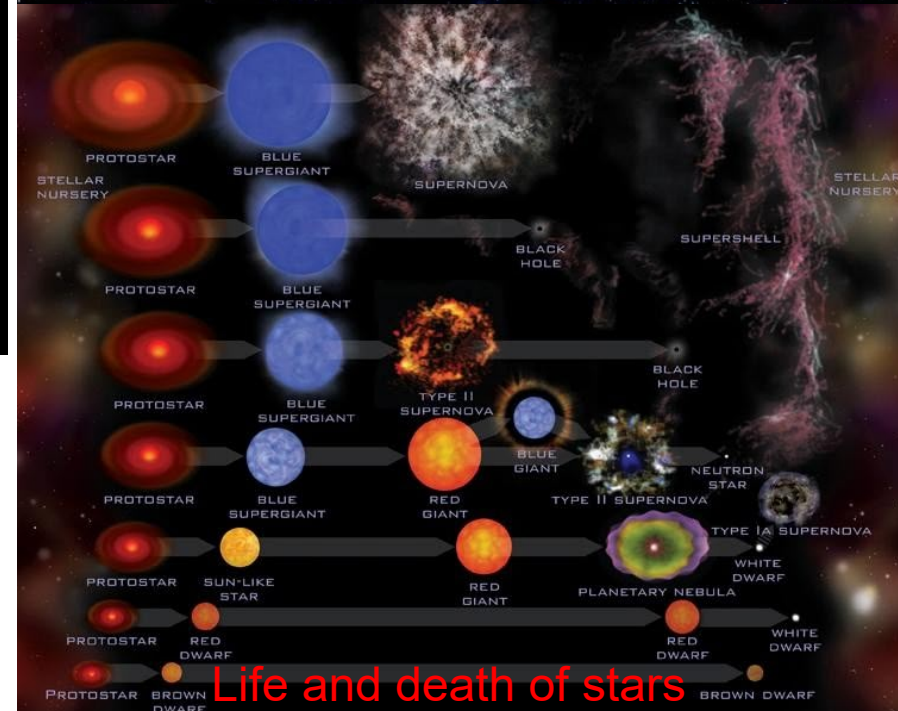
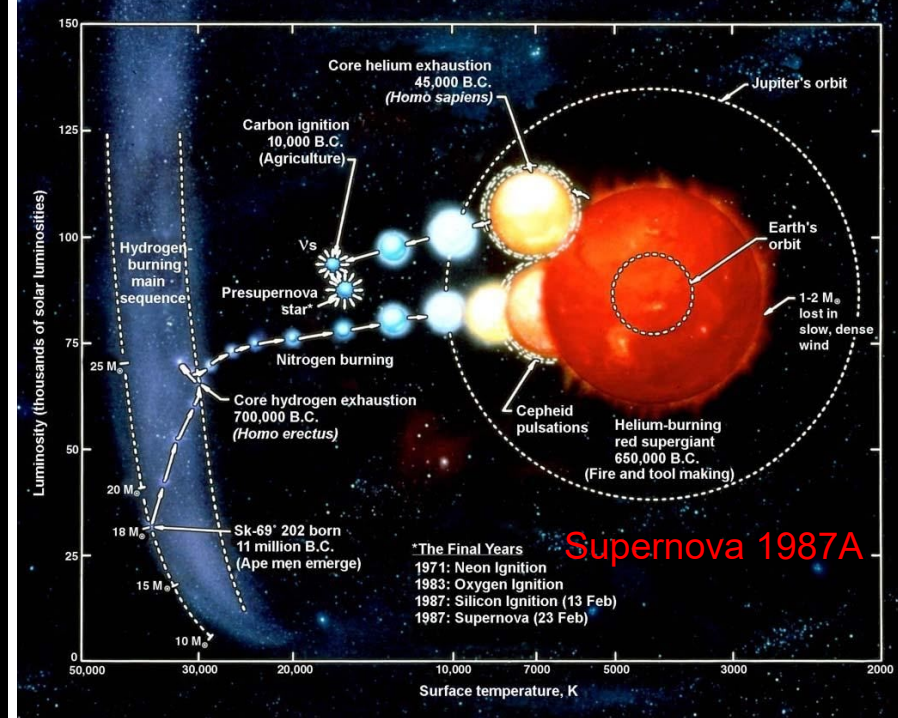
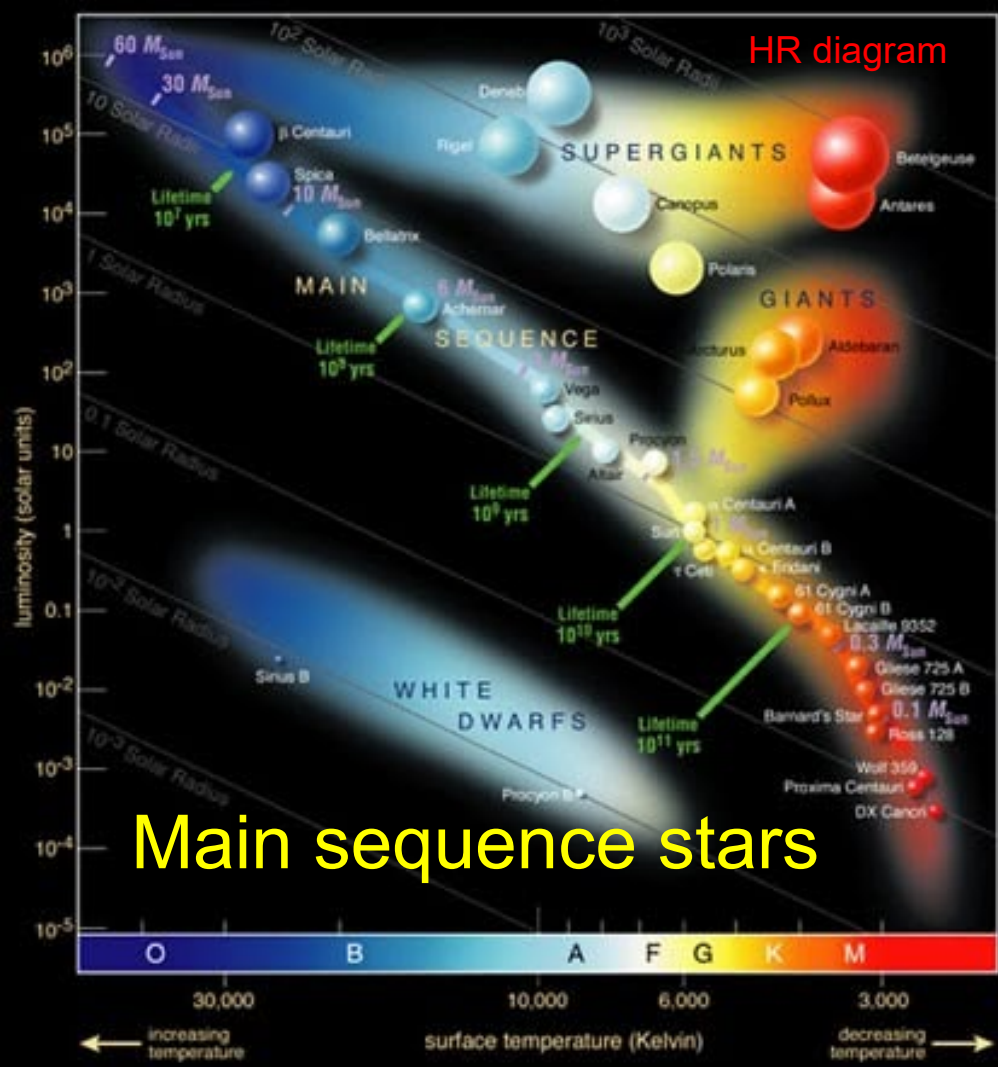
Stellar mass and size.



The stars that are massive enough to burn carbon, nitrogen, and oxygen are typically much bigger and hotter than our Sun.

Eta Carinae (not shown to scale) is buried in fifteen solar masses of an eruption called a supernova impostor in March 1843. It is a binary system in which the larger star is 120 solar masses and the secondary is 30 solar masses. This is the largest normal star in our galaxy only 7,500 light years away. In other galaxies these type of stars have exploded as hypernovas which rip apart that area of the galactic disk. This radiation disaster could happen today.

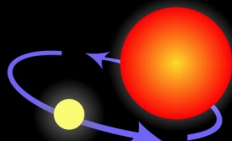




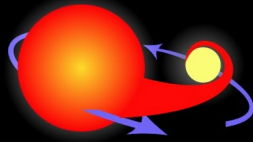
The progenitor of a Type Ia supernova



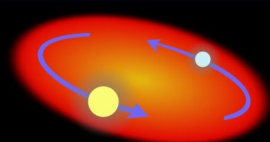
Two normal stars are in a binary pair.



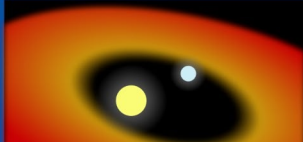
The more massive star becomes a giant...



...which spills gas onto the secondary star, causing it to expand and become engulfed.



The secondary, lighter star and the core of the giant star spiral toward within a common envelope.



The common envelope is ejected, while the separation between the core and the secondary star decreases.



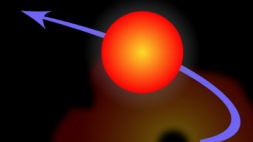
The remaining core of the giant collapses and becomes a white dwarf.



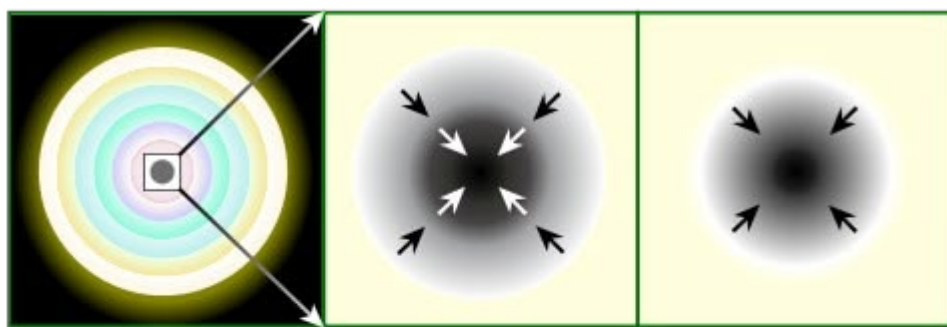
The aging companion star starts swelling, spilling gas onto the white dwarf.



The white dwarf's mass increases until it reaches a critical mass and explodes...



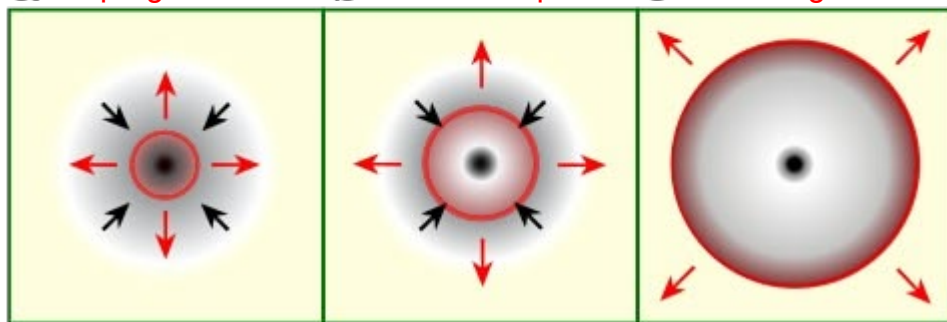
...causing the companion star to be ejected away.



a Supergiant star

b Core collapse

c Fe & Ni ignite



d Ignition of layers

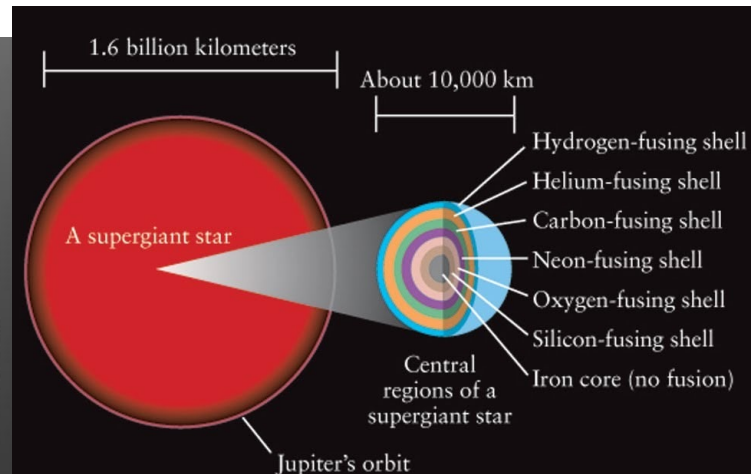
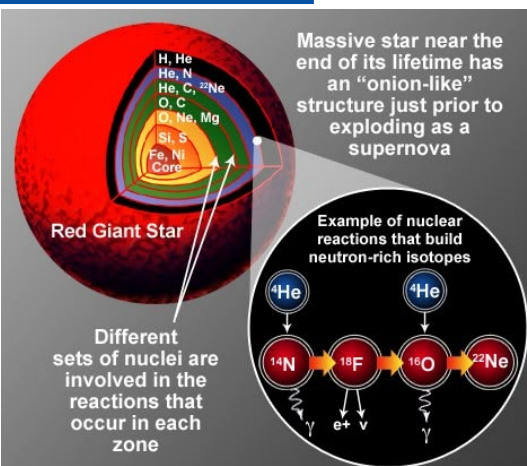
e Fusion Vs gravity

f Supernova

Large to very large stars' initial supernovae can be as bright as the output of all .5 trillion normal stars of our galaxy combined with neutron stars or black holes remnants.

Supergiant stars supernova

A supernova can be triggered by a mass transfer in a binary system or the iron at the core became a catalytic poison that dampened the fusing until unstoppable core collapse. In both cases the compressed core heated up until all elements begin to fusion. Only supernovas are hot enough to burn iron into the heavier elements.



Structure of the Crab Nebula

1 Unusually bright pulsar near the center powers everything

2 Pulsar's strong magnetic field accelerates and energizes nearby electrons

5 Shock waves transform stellar leftovers into subtle, visible filaments that encase the system

Astronomy: Roen Kelly

3 Lit-up electrons, called a "synchrotron nebula," fill much of the inside

4 Synchrotron nebula pushes against the remains of progenitor star, creating shock waves

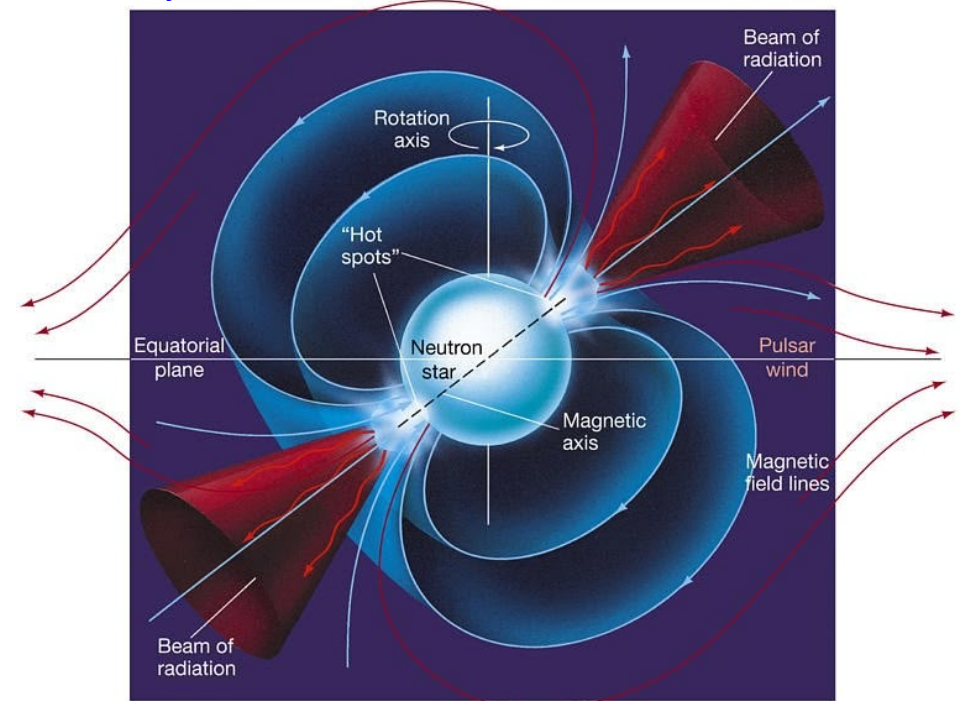
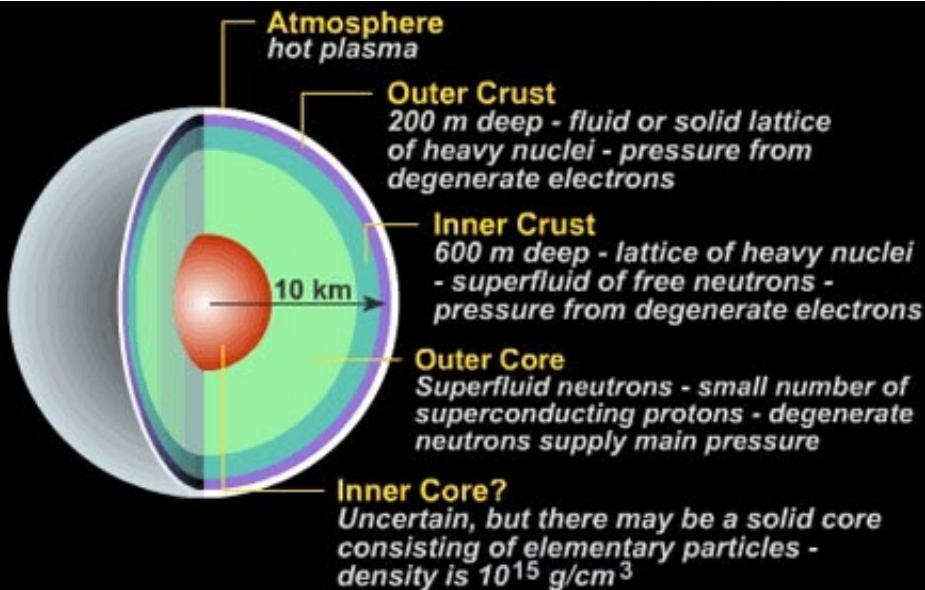
Neutron stars

Neutron stars that could fit inside downtown Phoenix with more mass than the Sun were condensed by supernova explosions that punched the electrons into the protons creating a superfluid of neutrons. These pulsar stars have strong magnetic fields that make very powerful relativistic jets.

Crab Nebula & pulsar.



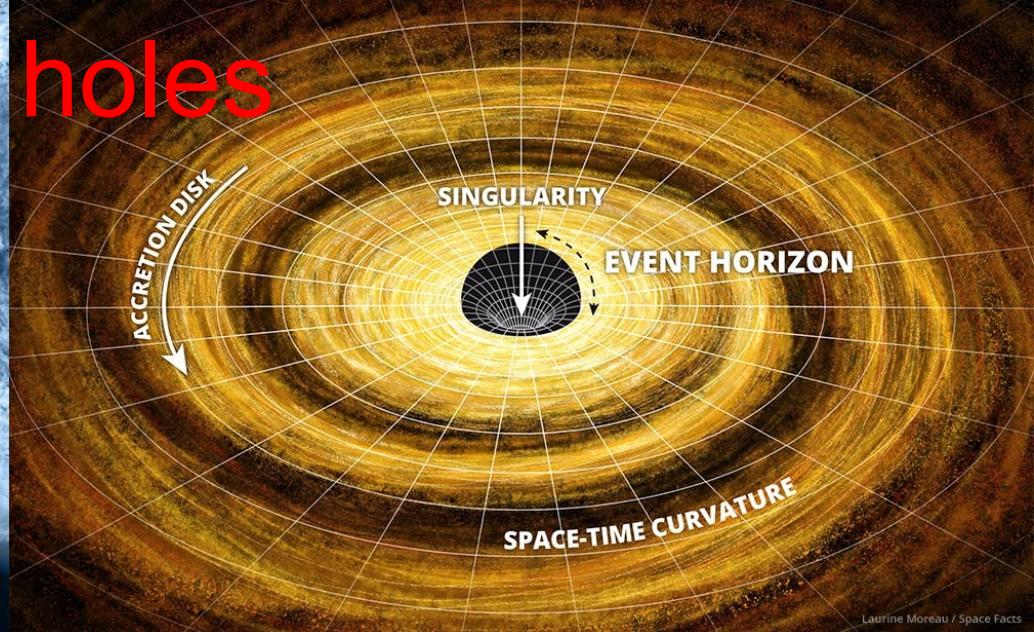
Crab nebula's neutron star



Black holes

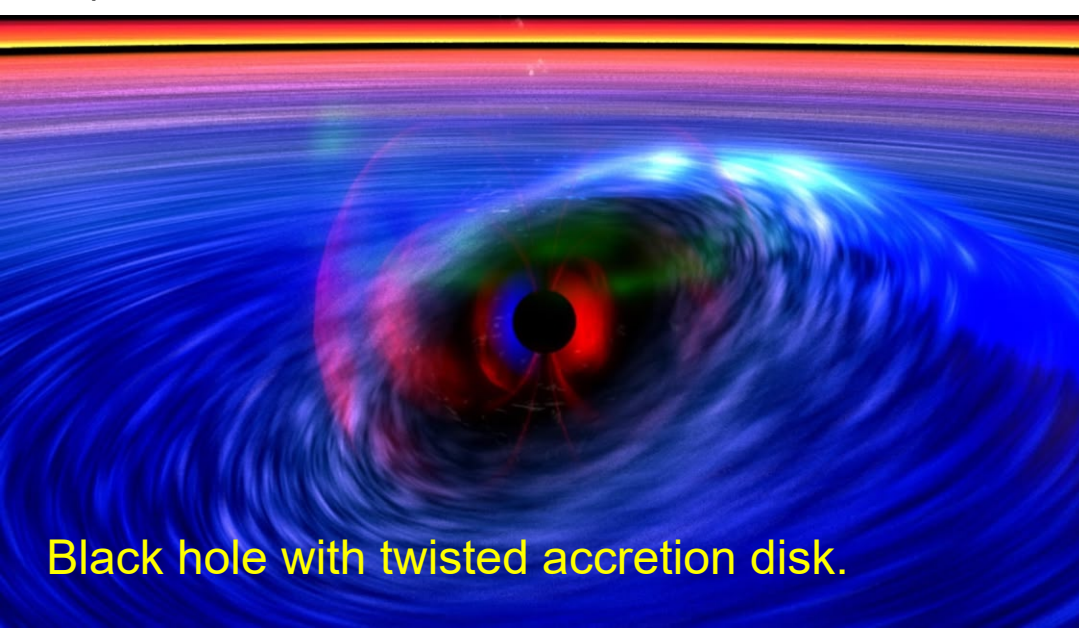


Black holes with a binary star have fast jets.

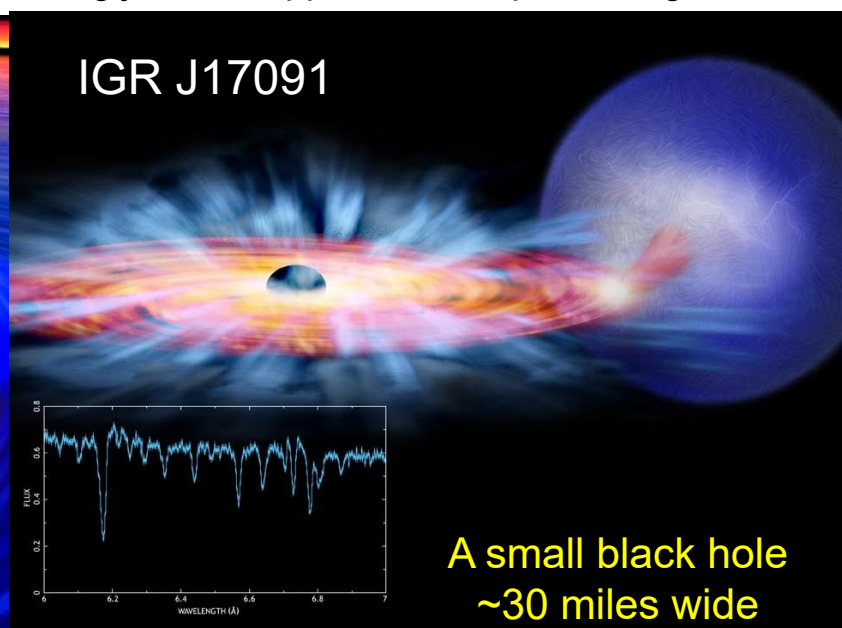


Laurine Moreau / Space Facts

IGR J17091 with a stellar wind of 3% c and a mass about six times the Sun's is one of the small black holes discovered. If our Sun was made into a black hole the event horizon would be less than 4 mi or 6 km in diameter. Typically the largest stars have supernova explosions powerful enough to crush neutrons into a singularity. If a companion star remains it can feed the accretion disk and make strong jets that approach the speed of light.



Black hole with twisted accretion disk.

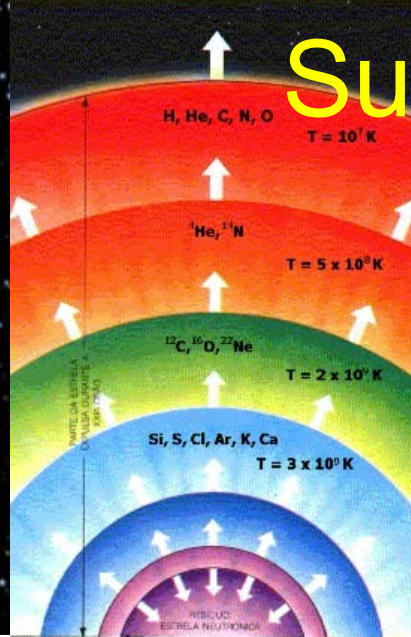


IGR J17091

A small black hole
~30 miles wide



Tycho's Supernova

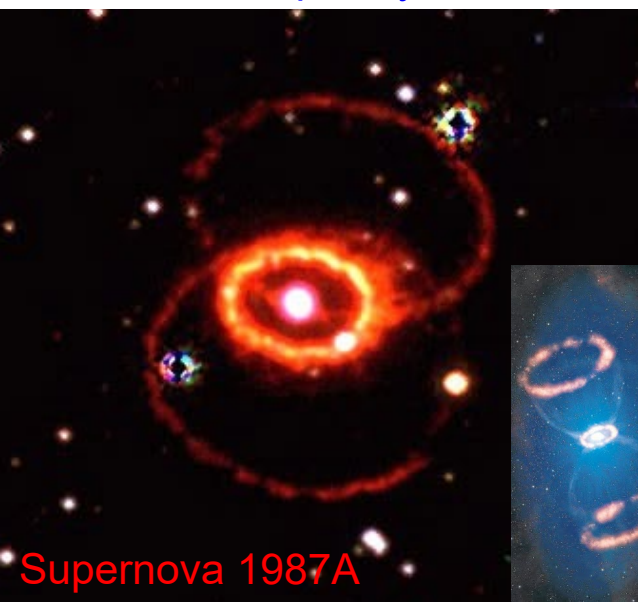


Supernova shells



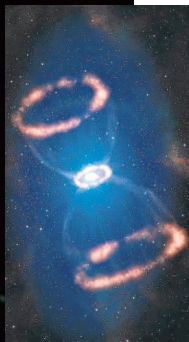
Puppis A

Ignition of an isotopic layer that the star's gravity cannot hold gently and spherically blows it apart. Stars that die as nova's do not burn elements beyond iron so they scatter the lighter elements. Iron needs a supernova worth of energy to burn into the heavier isotopes. Core collapse is more violent and could completely scatter all the elements of a massive star. The magnetic giant stars have



Supernova 1987A

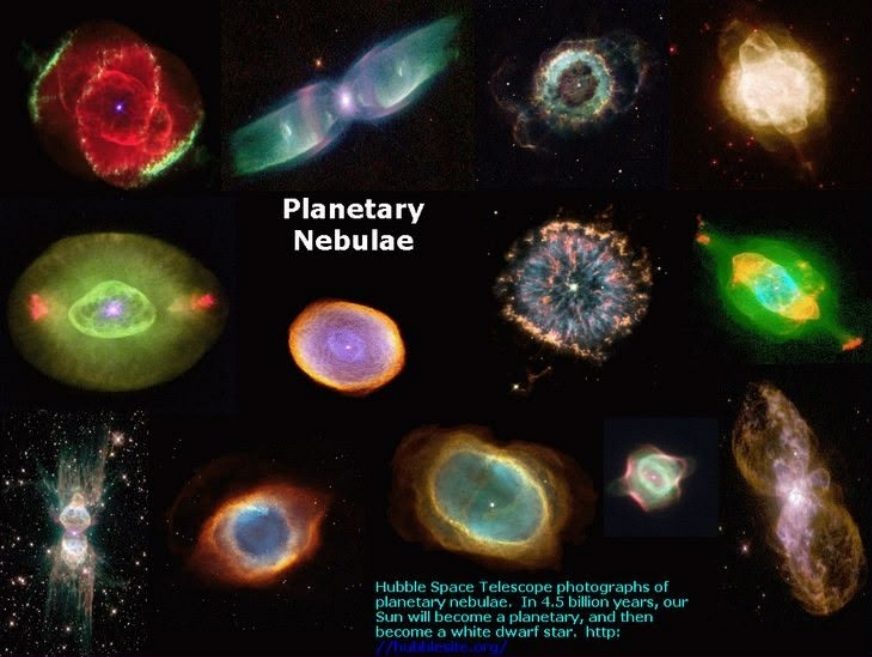
circumpolar hot zones in the cone shaped pinch between the polar and equatorial magnetic fields.



When these polar rings fusion isotopes that the star can't gravitationally hold you get hourglass shaped nebulas.



Cat's Eye Nebula



When small stars try to ignite their helium ash at the end of their hydrogen burning phase they die as gentle spherical novae. Larger stars have the mass to gravitationally hold together when the transition to helium burning makes them red giant stars. The ignition of the CNO cycle of burning at the magnetic poles of sun like stars is too much for these stars and their polar novae made dumbbell or hourglass shaped nebulae with dwarf star remnants.

Novas & Supernovas

Early astronomers could not get these clear images and first thought of nebulae as planets. These were later called planetary nebulae even though it was realized they have nothing to do with planets. The smallest stars never blow up but very slowly the hydrogen burning peters out and they cool from white dwarfs, to red dwarfs, or become dark objects known as brown dwarfs that barely burn.



Young open cluster stars

Element rich open cluster stars
are 8 billion years old or less.

NGC 28

LH 95

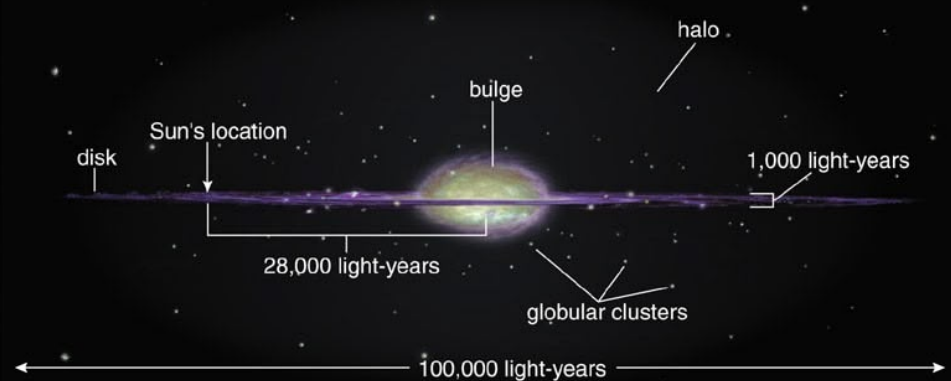
The dusty stellar nurseries of the disk of our galaxy makes associations of metal rich population I stars called open clusters when supernova shells compress the gas. The Pleiades is an open cluster you can see without a telescope. Once made they tend to orbit the galaxy as a group but do slowly disassociate with time.

Ancient globular cluster stars



The center of a a globular cluster

Globular cluster population II stars are typically ancient red dwarf stars with few elements heavier than helium. Globular clusters have nearly polar orbits that takes them far outside the disk of the galaxy. The clusters' many stars orbit the common gravitational center of the globular. Each time the globular penetrates the disk some of it's stars are stripped away by close encounters with disk stars and this adds to the galactic disk's collection of these metal poor older population II stars made 10 to 13.5 Bya.



Milky Way Galaxy

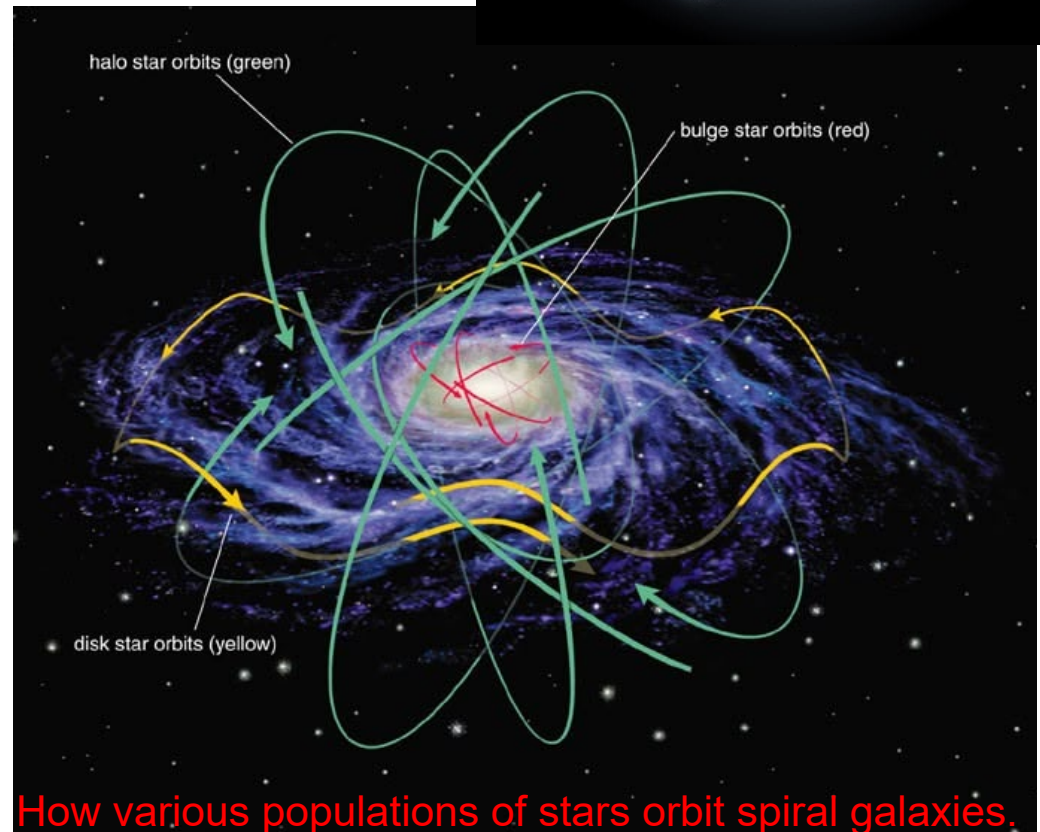
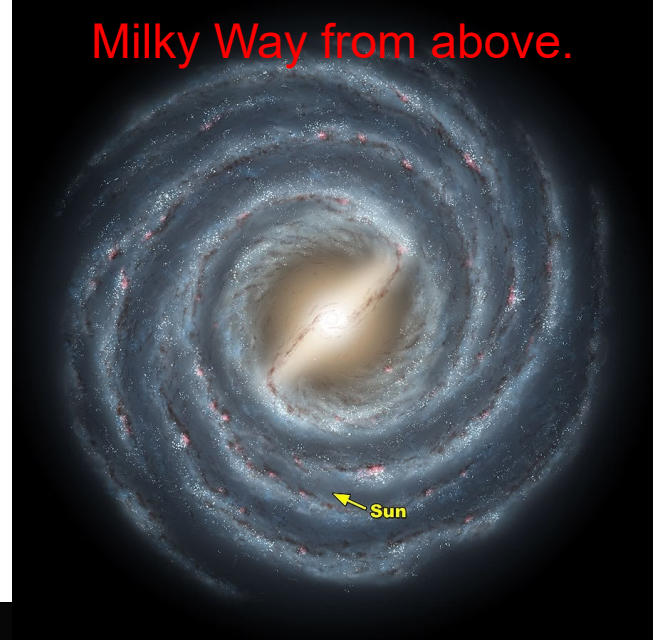


Milky Way as it should be seen here on Earth.

It does not require a telescope to see the vast dark clouds of gas and dust that hide some of the 1.5 trillion stars that make up our Milky Way Galaxy.

The bulge at the center of our Milky Way Galaxy is a bar, making us a barred spiral galaxy. The older stars in the bulge and halo have polar orbits, while the disk is a mix of old and new stars that bob in equatorial orbits.

Milky Way from above.



How various populations of stars orbit spiral galaxies.

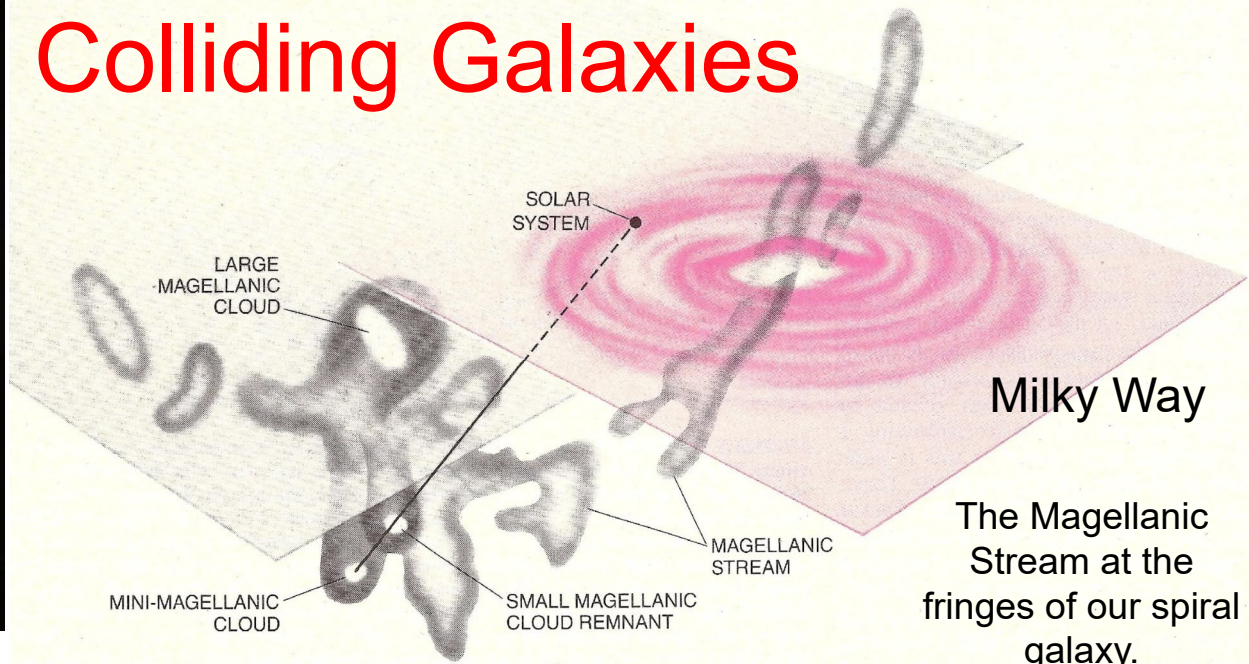


The billions of spiral galaxies that fill our universe have a range of shapes.

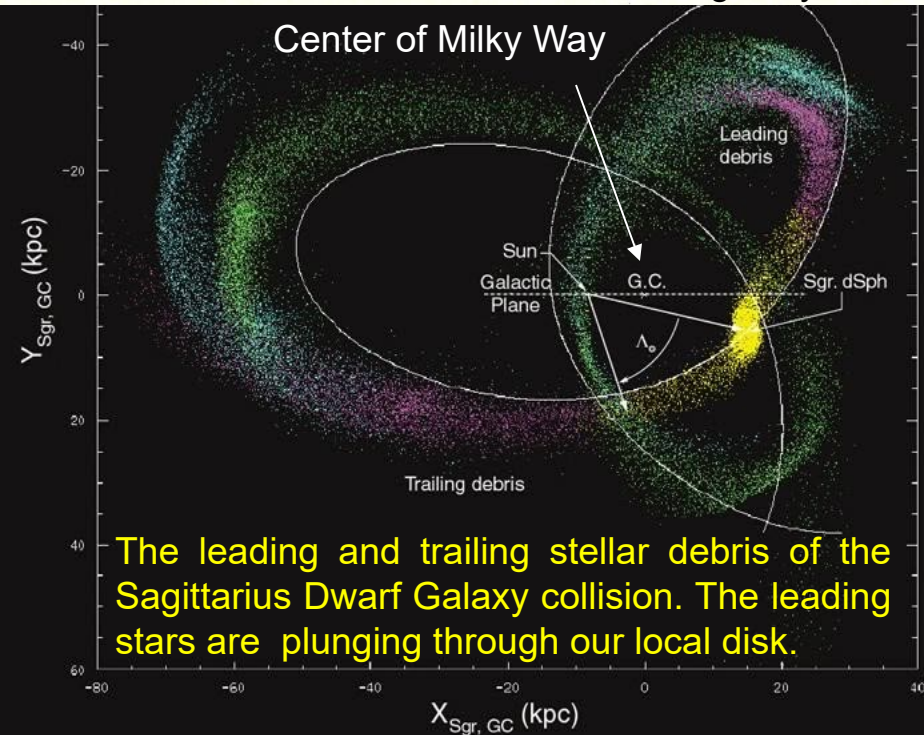


Spiral Galaxies

Colliding Galaxies



Spiral galaxies do collide and our galaxy will hit the larger Andromeda spiral galaxy in four billion years and even then few stars will collide. It is far more common for dwarf galaxies to collide with spiral galaxies such as what the Large and Small Magellanic Clouds are now doing to our galaxy. Our local stellar neighborhood is getting the leading edge of tidally torn stars from the impact of the Sagittarius Dwarf Galaxy on the other side of our galaxy. There is a storm of very faint stars coming at us from the north galactic plane.



If we could cut away the outer layers of M-87 as in this cross section, we might glimpse an accretion disk at the nucleus, the jet streaming from the accretion disk in a narrow column along the galaxy's spin axis, and bright, ionized regions along the jet, which some astronomers believe represent zones of interaction between the hot plasma and the interstellar medium. Painting by Michael Carroll.

Giant Elliptical Galaxies
do not have new stars.

M87 in Virgo

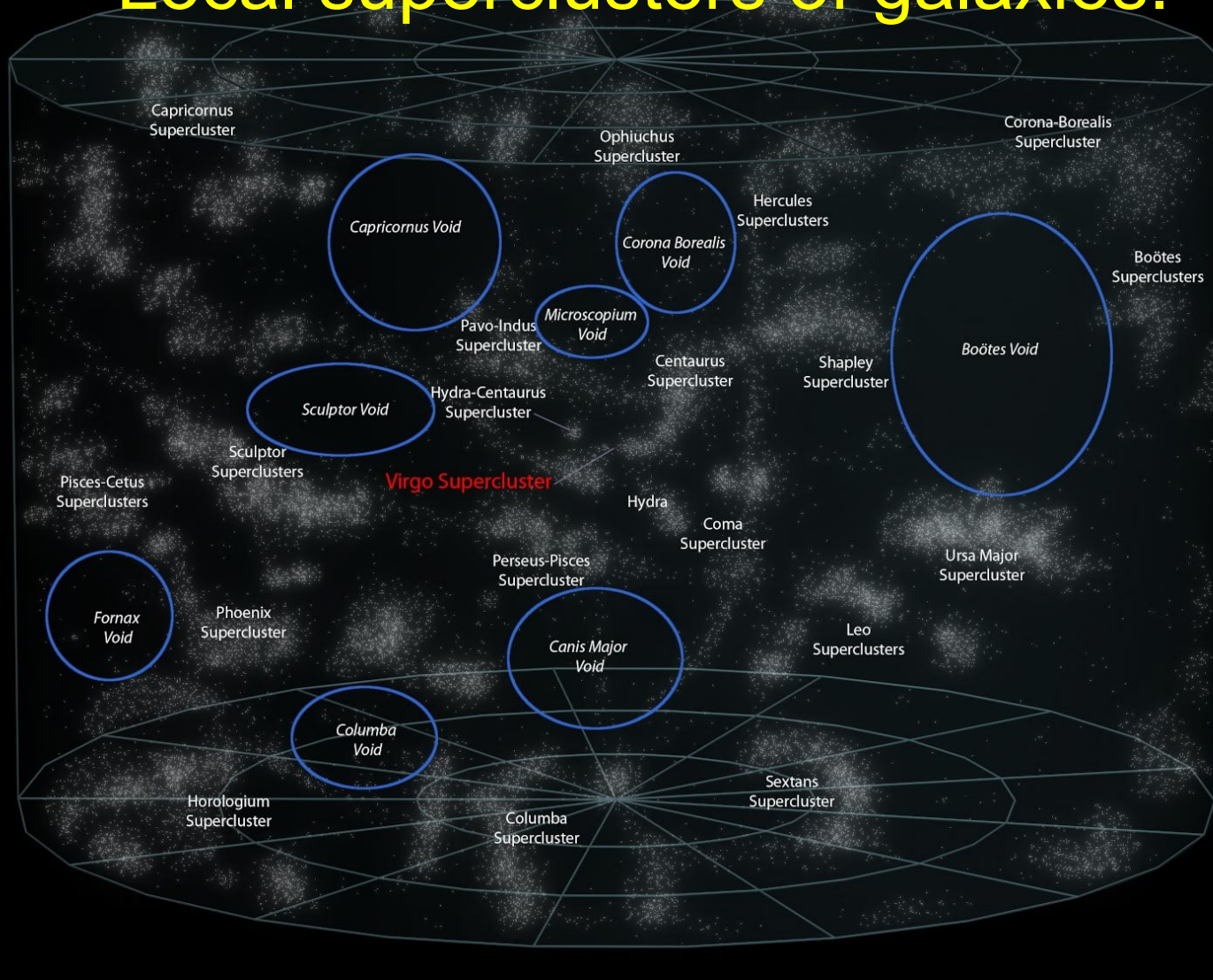
The biggest giant elliptical (cD) galaxies are tens of thousands of times the mass of our galaxy. Made of ancient population II stars usually in globular cluster associations they have quasar activity at the central

black hole that makes massive relativistic particle beams. Giant elliptical galaxies are the heart of superclusters of galaxies.



Giant Elliptical Galaxies

Local superclusters of galaxies.

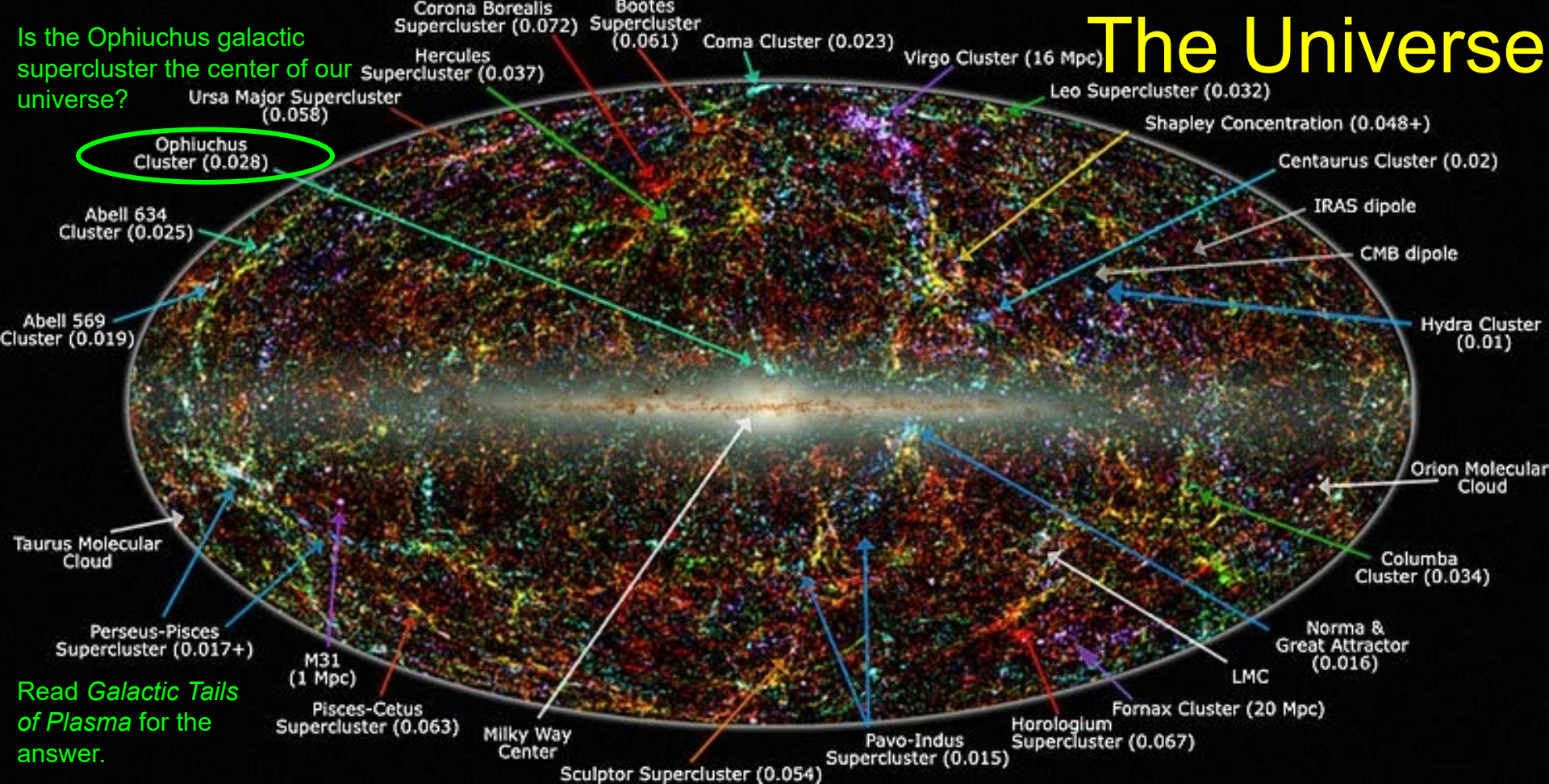


Deep space galaxies.

Star

Massive giant elliptical galaxies like M87 are the centers of clusters and superclusters made of hundreds to thousands of spiral and dwarf galaxies. Superclusters of galaxies merge into great walls of galaxies with great voids between them. Except for one Milky Way star every object is a distant galaxy in this Hubble deep space photograph.

The Universe



There are probably more than 170 billion (1.7×10^{11}) galaxies in the observable universe, and possibly more in a theoretical wider multiverse. Most are 1,000 to 100,000 parsecs in diameter and usually separated by distances on the order of millions of parsecs (or megaparsecs). Intergalactic space (the space between galaxies) is filled with a tenuous gas of an average density less than one atom per cubic meter. The majority of galaxies are organized into a hierarchy of associations known as groups and clusters, which, in turn usually form larger superclusters. At the largest scale, these associations are generally arranged into sheets and filaments, which are surrounded by immense voids.

Panoramic view of the entire near-infrared sky reveals the distribution of galaxies beyond the Milky Way. The image is derived from the 2MASS Extended Source Catalog (XSC)—more than 1.5 million galaxies, and the Point Source Catalog (PSC)—nearly 0.5 billion Milky Way stars. The galaxies are color coded by 'redshift' obtained from the UGC, CfA, Tully NBGC, LCRS, 2dF, 6dFGS, and SDSS surveys (and from various observations compiled by the NASA Extragalactic Database), or photo-metrically deduced from the K band ($2.2 \mu\text{m}$). Blue/purple are the nearest sources ($z < 0.01$); green are at moderate distances ($0.01 < z < 0.04$) and red are the most distant sources that 2MASS resolves ($0.04 < z < 0.1$). The map is projected with an equal area Aitoff in the Galactic system.

The End of the universe is not in sight.

Centaurus A

The jets of Centaurus A

This image of the central parts of Centaurus A reveals the parallelogram-shaped disk of old stars and dust around the center.