**Stars:**

Stars are huge celestial bodies made mostly of hydrogen and helium that produce light and heat from the churning nuclear forges inside their cores. Aside from our sun, the dots of light we see in the sky are all light-years from Earth. They are the building blocks of galaxies, of which there are billions in the universe. It’s impossible to know how many stars exist, but astronomers estimate that in our Milky Way galaxy alone, there are about 300 billion.

**Birth of a Star:**  
The life cycle of a star spans billions of years. As a general rule, the more massive the star, the shorter its life span.

Birth takes place inside hydrogen-based dust clouds called nebulae. Over the course of thousands of years, gravity causes pockets of dense matter inside the nebula to collapse under their own weight. One of these contracting masses of gas, known as a protostar, represents a star’s beginning phase. Because the dust in the nebulae obscures them, protostars can be difficult for astronomers to detect.

As a protostar gets smaller, it spins faster because of the conservation of angular momentum—the same principle that causes a spinning ice skater to accelerate when she pulls in her arms. Increasing pressure creates rising temperatures, and during this time, a star enters what is known as the relatively brief T Tauri phase.

Millions of years later, when the core temperature climbs to about 27 million degrees Fahrenheit (15 million degrees Celsius), nuclear fusion begins, igniting the core and setting off the next—and longest—stage of a star’s life, known as its main sequence.

Most of the stars in our galaxy, including the sun, are categorized as main sequence stars. They exist in a stable state of nuclear fusion, converting hydrogen to helium and radiating x-rays. This process emits an enormous amount of energy, keeping the star hot and shining brightly.

**The Brightness of a Star:**

Some stars shine more brightly than others. Their brightness is a factor of how much energy they put out–known as luminosity–and how far away from Earth they are. Color can also vary from star to star because their temperatures are not all the same. Hot stars appear white or blue, whereas cooler stars appear to have orange or red hues.

**Types of Stars:**

The type of stars includes;

* Main Sequence
* White Dwarf
* Dwarfs
* Supergiants.

Supergiants may have radii a thousand times larger than that of our own sun.

**The ‘Death’ of a Star:**

As stars move toward the ends of their lives, much of their hydrogen has been converted to helium. Helium sinks to the star's core and raises the star's temperature—causing its outer shell of hot gases to expand. These large, swelling stars are known as red giants. But there are different ways a star’s life can end, and its fate depends on how massive the star is.

The red giant phase is actually a prelude to a star shedding its outer layers and becoming a small, dense body called a white dwarf. White dwarfs cool for billions of years. Some, if they exist as part of a binary star system, may gather excess matter from their companion stars until their surfaces explode, triggering a bright nova. Eventually all white dwarfs go dark and cease producing energy. At this point, which scientists have yet to observe, they become known as black dwarfs.

**The Explosion of a Star:**

Massive stars eschew this evolutionary path and instead go out with a bang—detonating as supernovae. While they may appear to be swelling red giants on the outside, their cores are actually contracting, eventually becoming so dense that they collapse, causing the star to explode. These catastrophic bursts leave behind a small core that may become a neutron star or even, if the remnant is massive enough, a black hole.

Because certain supernovae have a predictable pattern of destruction and resulting luminosity, astronomers are able to use them as “standard candles,” or astronomical measuring tools, to help them measure distances in the universe and calculate its rate of expansion.

{ Zuckerman, C. (2019, March 20). Everything you wanted to know about stars. Retrieved February 29, 2020, from <https://www.nationalgeographic.com/science/space/universe/stars/#close>}

**Types of Stars**

* **Main Sequence:**

Main sequence stars fuse hydrogen atoms to form helium atoms in their cores. About 90 percent of the stars in the universe, including the sun, are main sequence stars. These stars can range from about a tenth of the mass of the sun to up to 200 times as massive.

Stars start their lives as clouds of dust and gas. Gravity draws these clouds together. A small protostar forms, powered by the collapsing material. Protostars often form in densely packed clouds of gas and can be challenging to detect.

 Main sequence stars are powered by hydrogen fusion. Fusion produces an outward pressure that balances with the inward pressure caused by gravity, stabilizing the star.

**How long will a Main Sequence Star live?**

How long a main sequence star lives depends on how massive it is. A higher-mass star may have more material, but it burns through it faster due to higher core temperatures caused by greater gravitational forces. While the sun will spend about 10 billion years on the main sequence, a star 10 times as massive will stick around for only 20 million years.

A red dwarf, which is half as massive as the sun, can last 80 to 100 billion years, which is far longer than the universe's age of 13.8 billion years. (This long lifetime is one reason red dwarfs are considered to be good sources for planets hosting life, because they are stable for such a long time.)

**When a Main Sequence Star dies:**

Eventually, a main sequence star burns through the hydrogen in its core, reaching the end of its life cycle. At this point, it leaves the main sequence.

Stars smaller than a quarter the mass of the sun collapse directly into white dwarfs. White dwarfs no longer burn fusion at their center, but they still radiate heat. Eventually, white dwarfs should cool into black dwarfs, but black dwarfs are only theoretical; the universe is not old enough for the first white dwarfs to sufficiently cool and make the transition.

Larger stars find their outer layers collapsing inward until temperatures are hot enough to fuse helium into carbon. Then the pressure of fusion provides an outward thrust that expands the star several times larger than its original size, forming a red giant. The new star is far dimmer than it was as a main sequence star. Eventually, the sun will form a red giant, but don't worry — it won't happen for a while yet.

{Redd, N. T. (2018, February 24). Main Sequence Stars: Definition & Life Cycle. Retrieved February 29, 2020, from <https://www.space.com/22437-main-sequence-stars.html>}

* **White Dwarf Star:**

White dwarf stars mark the evolutionary endpoint of low to intermediate mass stars like our Sun. Fusion processes in the cores of these stars cease once the helium has been converted to carbon, since the contracting carbon core does not reach a high enough temperature to ignite. Instead, it contracts until it squeezes all of its electrons into the smallest possible space they can occupy. The resulting electron pressure arises due to quantum mechanical effects and stops gravity from compressing the core further. A white dwarf is therefore supported by the pressure of electrons rather than energy generation in its core.

**How Black Dwarfs ‘Form’:**

Once the core has stopped contracting, the white dwarf has a temperature of over 100,000 Kelvin and shines through residual heat. These young white dwarfs typically illuminate the outer layers of the original star ejected during the red giant phase and create a planetary nebula. This continued radiation from the white dwarf, coupled with the lack of an internal energy source, means that the white dwarf begins to cool. Eventually, after hundreds of billions of years, the white dwarf will cool to temperatures at which it is no longer visible, and it will become a black dwarf. With such long timescales for cooling (due mostly to the small surface area through which the star radiates), and with the age of the Universe currently estimated at 13.7 billion years, even the oldest white dwarfs still radiate at temperatures of a few thousand Kelvin, and black dwarfs remain hypothetical entities.

**The Mass of a White Dwarf:**

Another curious property of white dwarfs is that the more mass they have, the smaller they are. The Chandrasekhar limit of around 1.4 solar masses is the theoretical upper limit to the mass a white dwarf can have and still remain a white dwarf. Beyond this mass, electron pressure can no longer support the star and it collapses to an even denser state – either a neutron star or a black hole. The heaviest observed white dwarf has a mass of around 1.2 solar masses, while the lightest weighs only about 0.15 solar masses.

{ Swinburne University of Technology. (n.d.). White Dwarf: COSMOS. Retrieved February 29, 2020, from http://astronomy.swin.edu.au/cosmos/W/White Dwarf}

* **Dwarf Star:\*\*\*\***

A dwarf star is a star that is not a giant or supergiant, it rests in-between. Some dwarf stars are much smaller, less massive with a smaller radius than normal stars such as main sequence stars. The categories of dwarf stars are; white dwarf, red dwarf, brown dwarf, and black dwarf. Our star, the sun, is a dwarf star of the category yellow dwarf.

**The Mass of a Dwarf Star:**

A dwarf star has a mass of up to about 20 sols, and a luminosity (a.k.a. intrinsic brightness) of up to about 20,000 sols (‘sol’ is a neat unit; it can mean ‘the mass of the Sun’, or ‘the luminosity of the Sun’).

If this is the case, then every star is a dwarf star! This is Because most stars are on the main sequence (which means almost all have luminosities below 20,000 sols), and only a tiny handful of main sequence stars are more massive than 20 sols. In addition, once a star has burned through all its fuel, it becomes a white dwarf and eventually a black dwarf, all of which are dwarf stars by this definition.

{ Tate, J. (2015, December 25). Dwarf Star. Retrieved February 29, 2020, from https://www.universetoday.com/46729/dwarf-star/}

**Red Dwarf Star:**

Red dwarf stars make up the largest population of stars in the galaxy, but they hide in the shadows, too dim to be seen with the naked eye from Earth. Their limited radiance helps to extend their lifetimes, which are far greater than that of the sun.

Scientists think that 20 out of the 30 stars near Earth are red dwarfs.

The term "red dwarf" does not refer to a single kind of star. It is frequently applied to the coolest objects, including K and M dwarfs — which are true stars — and brown dwarfs, often referred to as "failed stars" because they do not sustain hydrogen fusion in their cores.

**Formation and Characteristics:**

Red dwarfs form like other main-sequence stars. First, a cloud of dust and gas is drawn together by gravity and begins rotating. The material then clumps at the center, and when it reaches the critical temperature, fusion begins.

Red dwarfs include the smallest of the stars, weighing between 7.5% and 50% the mass of the sun. Their reduced size means that they burn at a lower temperature, reaching only 6,380 degrees Fahrenheit (3,500 degrees Celsius). The sun, by comparison, has a temperature of 9,900 F (5,500 C). The low temperatures of red dwarfs mean they are far, far dimmer than stars like the sun.

Their low temperature also means that they burn through their supply of hydrogen less rapidly. While other, more massive stars burn through only the hydrogen at their core before coming to the end of their lifetimes, red dwarfs consume all of their hydrogen, inside and outside their core. This stretches out the lifetime of red dwarfs to trillions of years; far beyond the 10-billion-year lifetime of sun-like stars

**Classifying a Red Dwarf:**

Scientists occasionally have difficulty distinguishing a red dwarf star from a brown dwarf. Brown dwarfs are cool and dim, and likely form the same way red dwarfs do, but brown dwarfs never reach the point of fusion because they're too small, and therefore, they're not considered stars.

"When we observe a red dwarf and measure its atmosphere, we don't necessarily know whether it's a brown dwarf or a star — young brown dwarfs look almost exactly like ultracool stars," said Adam Burgasser, an astronomer at the University of California, San Diego.

To figure out whether a celestial object is a brown or red dwarf, scientists measure the temperature of the object's atmosphere. Fusion-free brown dwarfs are cooler than 2,000 Kelvin (3,140 F or 1,727 C), while hydrogen-fusing stars are warmer than 2,700 K (4,400 F or 2,427 C). In between, a star could be classified as a red dwarf or brown dwarf.

Sometimes, chemicals in the object's atmosphere can reveal clues about what's happening at its heart. According to Burgasser, the presence of molecules like methane or ammonia, which can only survive at cold temperatures, suggests that an object is a brown dwarf. Lithium in the atmosphere also suggests that a red dwarf is a brown dwarf rather than a true star.

But scientists may still use the term red dwarf to describe how a celestial object looks — small and dim — even if the object is actually a brown dwarf, Burgasser said.

**Habitable Planets surrounding Red Dwarf Stars**

Planets form from the material left over in a disk after their star has been created. Many red dwarfs have been found with planets surrounding them, though enormous gas giants are rare. Because red dwarfs are dimmer than stars like the sun, it is easier to find small planets that may surround these dimmer objects, making red dwarfs a popular target for planet hunting.NASA's Kepler space telescope (which operated between 2009 and 2018) and Transiting Exoplanet Survey Satellite, or TESS (which started operations in 2018), have surveyed many red dwarf stars for possible Earth-like planets.

Since the planets examined by TESS are near bright stars that tend to be close to Earth, it's easier for ground telescopes to follow up on the observations. In April 2019, TESS investigators announced they had found their mission's first Earth-size planet, although its conditions are not ideal for life as we know it.

For a long time, scientists thought red dwarfs were uninhabitable. Their limited light and heat meant that the habitable zone — or the region where liquid water could form on planets around a red dwarf — would be very close to the star, putting the planets in range of harmful radiation from the star. Other planets may be tidally locked to the star, with one side constantly facing the sun, causing one side to be too warm, and the other to be too cold.

In 2016, a potentially habitable planet was found orbiting Proxima Centauri (Earth's closest star). And in 2019, astronomers announced the possibility of a second planet orbiting far outside the star's habitable zone.

**The Death of a Red Dwarf:**

Tiny red dwarfs may have an extended lifetime, but like all other stars, they'll eventually burn through their supply of fuel. When they do, the red dwarfs become white dwarfs — dead stars that no longer undergo fusion at their core. Eventually, the white dwarfs will radiate away all of their heat and become black dwarfs.

But unlike the sun, which will become a white dwarf in a few billion years, red dwarfs will take trillions of years to burn through their fuel. This is significantly longer than the age of the universe, which is less than 14 billion years old.

**Alpha Centauri:**

The closest star to Earth are three stars in the Alpha Centauri system. The two main stars are Alpha Centauri A and Alpha Centauri B, which form a binary pair. They are an average of 4.3 light-years from Earth. The third star is Proxima Centauri. It is about 4.22 light-years from Earth and is the closest star other than the sun.

Alpha Centauri A and B orbit a common center of gravity every 80 years. The average distance between them is about 23 astronomical units (AU) — a little more than the distance between the sun and Uranus. Proxima Centauri is about one-fifth of a light-year or 13,000 AUs from the two other stars, a distance that makes some astronomers question whether it should be considered part of the same system.

Proxima Centauri may be passing through the system and will leave the vicinity in several million years, or it may be gravitationally bound to the binary pair. If it's bound, it has an orbital period around the other two of about 500,000 years.

**The Binary System of Stars**

To the naked eye, the two main stars shine as one, making them the third brightest "star" in our night sky. The two separate stars can be seen through a small telescope; one of the finest binary stars that can be observed. Proxima Centauri is too faint to see unaided, and through a telescope it appears about four diameters of the full moon away from the other two.

By itself, Alpha Centauri A, also known as Rigel Kentaurus, is the third brightest star in the night sky; just a bit dimmer, by 0.02 of a magnitude, than Arcturus. Alpha Centauri A is a yellow star of the same type as the sun, and it is about 25 percent larger. Alpha Centauri B is an orange type star, slightly smaller than the sun. Proxima Centauri is a red dwarf about seven times smaller than the sun, or one-and-a-half times bigger than Jupiter. All three stars are older than the sun by 4.85 billion years old, which is about 4.6 billion years old.

The system is in the Southern sky and is not visible to observers above the latitude of 29 degrees north — a line that passes near Houston, Texas, and Orlando. In the Southern Hemisphere, it's easy to find because the cross-piece of the Southern Cross (from Delta to Beta Crucis) points the way.

{Redd, N. T. (2019, June 6). Red Dwarfs: The Most Common and Longest-Lived Stars. Retrieved March 1, 2020, from https://www.space.com/23772-red-dwarf-stars.html}

* **Brown Dwarf Star**

Despite the name, brown dwarfs are not very brown. These objects, with masses ranging from 12 times that of Jupiter up to half the mass of the sun, emit light on their own, the only difference is the emitted light is not very much. The largest and youngest ones are quite hot, giving off a steady glow of warm light. From a distance, those stars would look indistinguishable from their stellar cousins, the red dwarfs. The smallest and oldest ones, by contrast, are barely visible, emitting radiation firmly in the infrared part of the spectrum. Brown Dwarf stars cannot be seen without the help of night-vision goggles.

Brown dwarfs glow mildly, with dim magenta hues. This makes them rather unique in the galactic cast of characters.

Decidedly unlike the stars, brown dwarfs don't glow from the heat of nuclear fires raging in their hearts. Instead, their light and heat are simply leftovers from their initial formation. The objects were birthed from collapsing clouds of gas and dust (just like the stars, only less of it), and that gravitational collapse released a tremendous amount of energy, but the energy got trapped in the infalling material, locked inside for tens of millions of years, though the heat slowly radiates away into space in the form of lukewarm light.

As this heat escapes, the brown dwarf continues to dim, sliding from fiery red to mottled magenta to invisible infrared. The greater the mass at the object's birth, the more heat it can trap and the longer it can mimic a proper star. But the ultimate fate is the same for every brown dwarf, regardless of its pedigree.

**Inner Core of a Brown Dwarf Star:**

It takes a certain threshold in mass (around 80 times that of Jupiter) to reach the frenetic temperatures and pressures in the core of an object that are needed to fuse hydrogen into helium, which is what it takes to make a star, but there's a much lower threshold, around a mere 13 times the mass of Jupiter, where a different sort of fusion can take place.

In this much-cooler setup, deuterium (which is just a single proton and a single neutron glued together in a nucleus) can get smacked by a stray proton, converting the deuterium into helium-3 and releasing a tiny bit of energy. Proper stars go through a brief deuterium-burning phase as they're getting warmed up, but brown dwarfs can keep the process going longer, since they don’t ever switch over to full-blown hydrogen fusion.

However, it doesn't last forever. The biggest brown dwarfs use up all their deuterium in a few short millions of years. The reason for this is that the interiors of these creatures aren't neatly separated into distinct layers.

In stars like our sun, you have a dense peach-pit core of hydrogen and helium, surrounded by a layer of plasma dominated by radiative energies, with that layer surrounded by a churning, boiling soup. But in the smallest stars and brown dwarfs, there is no core per se, only a single tip-to-tail shell of convection, able to transport material in and out from the innermost reaches to the edge of space and back again.

Any deuterium anywhere in a large brown dwarf will eventually find itself dragged to its doom at the center of the brown dwarf and hungrily converted into helium-3. (In an object with layers, some deuterium might lurk elsewhere without being consumed).

In the case of smaller brown dwarfs, they quickly cool down, dropping their internal temperatures below the threshold needed to sustain the reactions.

{ Sutter, P. (2019, January 3). Brown Dwarfs: The Coolest Stars or the Hottest Planets? Retrieved March 1, 2020, from https://www.space.com/42790-brown-dwarfs-coolest-stars-hottest-planets.html}

**Black Dwarf Star**

The ultimate stage of stellar evolution for many stars is a black dwarf. Because they emit no heat or light, these objects would be a challenge to detect if they existed today. However, black dwarfs take quadrillions of years to form. At less than 14 billion years old, the universe is still too young to have created any black dwarfs.

A main sequence star that lacks the mass necessary to explode in a supernova will become a white dwarf, a 'dead' star that has burned through all of its hydrogen and helium fuel. But the white dwarf remains hot for some time, much like a stove burner still emits heat even when it has been turned off.

After an extremely long time, all of the leftover heat will have radiated away. No longer emitting heat or light, the white dwarf will become a black dwarf. Because it emits no radiation, it is nearly impossible to see. However, the black dwarf would still retain its mass, allowing scientists to detect the effects produced by its gravitational field.

**Simply a Theory:**

At the moment, black dwarf stars are strictly theoretical. Scientists have calculated that a white dwarf will take at least a hundred million billion years to cool down and become a black dwarf, according to astronomer Ethan Siegel.

Even if a white dwarf had formed at the moment of the Big Bang — which is impossible, since a star must pass through several evolutionary stages that take at least a billion years total — it would still be a white dwarf today, having not yet sufficiently cooled.

{Redd, N. T. (2018, December 13). Black Dwarf Stars: The (Theoretical) End of Stellar Evolution. Retrieved March 1, 2020, from https://www.space.com/23799-black-dwarfs.html}

* **Supergiant Star:**

The supergiants are the most massive stars out there, ranging between 10 to 70 solar masses, and can range in brightness from 30,000 to hundreds of thousands of times the output of the Sun. There are two types which are: red and blue. They have very short lifespans, living from 30 million down to just a few hundred thousand years. Supergiants seem to always detonate as Type II supernovae at the end of their lives.

**Red Supergiant:**These are stars with many times the mass of the Sun, and one of the best-known examples is Betelgeuse, in the constellation of Orion. The Betelgeuse star has 20 times the mass of the Sun, and puts out about 135,000 times as much energy as the Sun. It’s one of the few stars that have ever had their disk imaged; astronomers estimate that it’s 1,000 times the radius of the Sun. With that size, Betelgeuse would engulf the orbits of Mars and Jupiter in our Solar System. Astronomers guess that Betelgeuse is only 8.5 million years old, and they expect that it will detonate as a supernova within the next 1000 years or so. When it does finally go off, the supernova explosion will be as bright as the Moon in the night sky.

**Blue Supergiant:**  
Blue supergiants are much hotter than their red counterparts. A good example of a blue supergiant is Rigel, also in the Orion constellation. Rigel has a 17 times the mass of the Sun, and 66,000 times the luminosity of the Sun – it’s the most luminous star in the neighborhood. It’s not as large as a red supergiant, with only 62 times the radius of the Sun.

**{** Cain, F. (2015, December 25). Supergiant Star. Retrieved February 29, 2020, from https://www.universetoday.com/25325/supergiant-star/}