Facts About the Universe

by: Joshua '25

Chapter Four: The Elementary Particles

Elementary particles are the building blocks for the entire universe. Everything in the universe depends on these particles. The particles take on many roles, whether it's creating the photons we perceive as light or making protons and neutrons. In total, there are 17 elementary particles in the universe. These 17 types of particles are divided into three groups, depending on their properties. There are quarks, leptons, and bosons.

First, there are quarks. Quarks are the nuclear family of the elementary particles. All of the standard models of particle physics is built on it. Protons and neutrons, the particles that make up the nuclei of atoms are made up of quarks. Two up quarks and one down quark make a proton. Two down quarks and one up quark create a neutron. Quarks only exist together as the building blocks of other particles. They are what we call "confined." The more you try to pull them apart, the more they try to stay together. Quarks have never been observed by themselves, and they come in six types. There are the up quarks, down quarks, charm quarks, strange quarks, top quarks, and bottom quarks. Each type of quark has its unique properties. However, only the up and down quarks are the ones that make solid matter. The rest decay over time into other quarks. The charm, top, and bottom quarks all decay into down quarks while a strange quark decays into up quarks. Together, quarks and electrons are the matter particles. They make up everything you see. Quarks are also extremely tiny. We cannot see the quarks themselves. We know they exist. All we can see with the most powerful tools is a blurry sphere of influence.

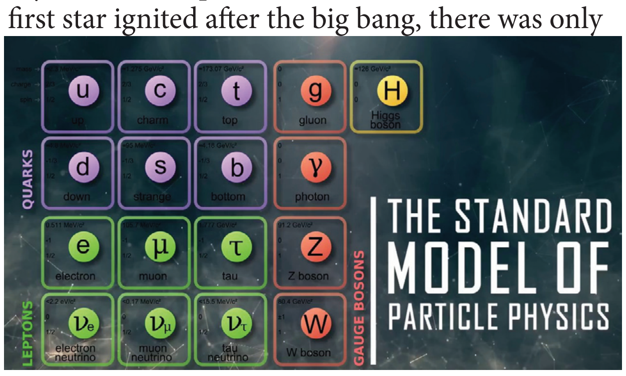
Next, there are the leptons. The leptons group consists of muon and tau particles as well as the electron. By far, the electron is the best-known lepton. Each particle in this group has an associated neutrino particle. For instance, the electron particle has another particle version of it called the electron neutrino. Altogether, the lepton group consists of six particles, the electron, the tau particle, the muon particle, the electron neutrino, the tau neutrino, and the muon neutrino. Charged leptons, like the electron, can combine with other particles to create new composite particles. The other leptons, the neutrino particles, rarely interact with anything and aren't observed much.

Finally, there is the boson group. The boson group consists of five particles. There is the photon, the gluon, the Z boson, the W boson, and the Higgs particle. Bosons are unique in the fact that they aren't made by matter fields like quarks and leptons. Bosons are caused by force fields. They are particles that follow Bose-Einstein statistics. In quantum statistics, Bose-Einstein statistics describe one of two possible ways in which a collection of non-interacting, indistinguishable particles may occupy a set of available discrete energy states at thermodynamic equilibrium. Bosons do several important things like creating light to keeping quarks together.

All elementary particles are under the rules of the four forces of the universe. These four forces are gravitational force, electromagnetic force, strong nuclear energy, and weak atomic force. The forces are like rules, telling what the particles can do and how they can do it, and the elementary particles are like the pieces. These four forces help particles assemble into all the big things in our universe. The particles and the rules are like the tinker toys of existence.

Chapter 5: Fusion and the Elements

Fusion is a very complex process in which different atoms are smashed together to create new and heavier elements. These processes created every natural component of the universe. Before the first star ignited after the big bang, there was only hydrogen and helium.

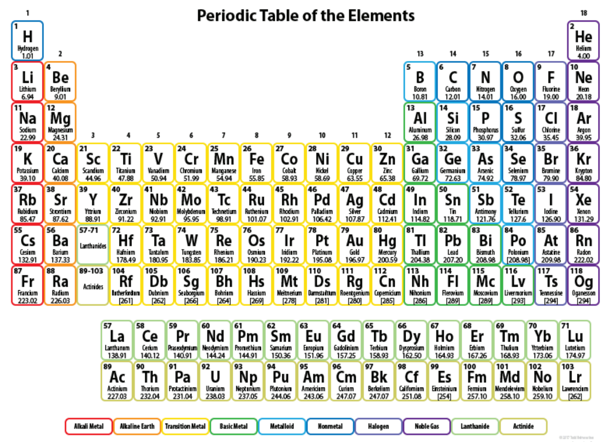


When the first star was created, it started making new elements. The first star then died. The elements it had been fusing in its core were spewed out into space. As more and more stars formed, the number of elements kept growing. The new stars took the elements from the dead stars and created more and more elements with it. These older elements got recycled into new elements.That's how astronomers figure out the age of stars. If a star is metal-poor, then it is an old star. If a star is metal-rich, then it is a young star. A star's metallicity can also determine what types of planets orbit that star. Astronomers can estimate metallicities through measured and calibrated systems that correlate photometric measurements and spectroscopic measurements. Photometry is a technique of astronomy where astronomers measure the stellar flux of a star. Flux describes an effect that appears to pass or travel (whether it moves or not) through a surface or substance. Spectroscopic measurement measures the interaction between matter and electromagnetic radiation.

Seven base elements make up all the other natural elements in the universe. Those elements are hydrogen, helium, carbon, neon, oxygen, silicon, and iron. A neutrino is primarily a matter particle. A positron is an antimatter particle. A position and a neutrino counteract each other out. Hydrogen is fused into helium in the proton-proton chain reaction branch 1. Helium is then blended into carbon through the triple-alpha process. The CNO Cycle is where nitrogen and oxygen are combined. They release a lot of gamma rays and energy. Then, there are the helium capture reactions. The helium capture reactions involve helium fusing with another element to create a heavier element.

For the fusion of heavier elements, there are the two densest found in stars. Silicon and iron are the most substantial elements that can be fused by a star. Not all stars produce the same elements. The diversity of elements produced and how heavy they are depends on the type of star. A smaller star like a red dwarf can only produce hydrogen and helium. They don't have enough heat and pressure to fuse heavier elements in their cores. A massive star like a blue giant or a blue supergiant can create hydrogen, helium, carbon, neon, oxygen, silicon, and iron. Their temperatures and pressures are far higher than the red dwarfs. The mass of a big star makes it much easier to make new elements. The most significant gravity combined with all the fusion going on allows the more prominent stars to create such elements. Red Dwarfs can only fuse hydrogen and helium via the Proton-proton chain reaction branch 1. A medium-mass star like the Sun can fuse hydrogen, helium, carbon, nitrogen, and oxygen. The Sun by mass is 70% hydrogen, 28% helium, and 2% carbon, nitrogen, and oxygen. It fuses using proton-proton chain reaction branch 1, the triple-alpha process, and a minor branch of the CNO cycle.

Blue giants merge all of the seven base elements. The proton-proton chain reaction branch 1, the triple-alpha process, the CNO cycle, the helium capture reactions, and the heavy elemental fusion are all fusion processes that happen in those giant stars. Once a giants star reaches iron, they cannot fuse anymore. Fusing iron doesn't create any energy. Iron starts to build up at the center of the star until the amount of iron reaches a critical amount. The balance between radiation and gravity is suddenly broken. Radiation decreases while gravity becomes more and more immense. The core collapses within a fraction of a second.



All elements except for artifici al elements are created from stars. You only need a few base elements from the stars to create every other element. Most natural elements in the universe are found on earth (unless more elements have formed since the planet has formed). The y are just in differ ent quantity. Ther e are rare earth metals like neodymium that are hard to fin d, and there are widespread elements like oxygen that are everywhere. Theun stable elements created by humans don't have stable isotopes. The y are called synthetic elements. Humans produce these new elements by injecting something else into a natural element. Artifici al elements have half-lives ranging from 15.6 million years to a few hundred microseconds. Tha t's much shorter than the lives of the natural elements with stable elements. Many elements are named afterp laces. Darmstadtium, Moscovium, and Tennessine are all artifici al elements named afterp laces. Ther e are 118 elements in total. Eleven of them are synthetic. Ther est of the elements are natural.

Do you have any questions about the Universe?
Email *(redacted)* and Mrs. Gage will forward your question on to Joshua!

Chapter 6: The Classes of Stars

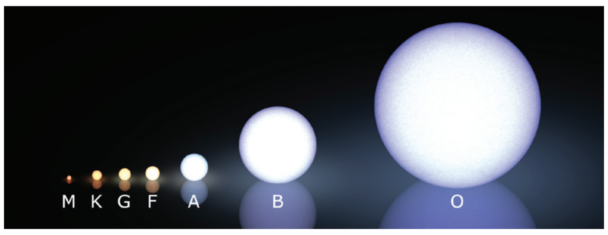
There are seven main types of stars. These stars are the most widely recognized types. The first class of stars is called the M-class star, otherwise known as a red dwarf. These stars are very small cool, and dim. Red dwarfs have 0.08-0.45 solar masses, and they have a 4940.33 degrees Fahrenheit surface temperature. Red dwarfs are very common in the universe. 20 out of 30 0f the nearest stars are red dwarfs. 76.45% of all stars in the universe are red dwarfs. Red dwarfs are much easier to make than other stars because they require much less material to make.

The second class of stars is called a K-type star, otherwise known as an orange dwarf. These stars are hotter and larger than red dwarfs. Orange dwarfs have 0.45-0.8 solar masses and a surface temperature of 6740.33 degrees Fahrenheit. Orange dwarfs are the second most common stars but, nowhere near as typical as the red dwarfs are. They make up 12.1% of all stars in the universe.

The third class of a star is the G-type star. The G-type star is known as a yellow dwarf. Our Sun is a G-type star. Yellow dwarfs are about twice as hot as red dwarfs are with a surface temperature of 9940.73 degrees Fahrenheit. They have 0.8-1.04 solar masses. These stars are not that common, making up just 7.6% of all stars in the universe.

The next type of star is the F-type star. They are slightly bigger and brighter than the Sun. These stars are just called yellow stars. Yellow stars have 1.04-1.4 solar masses, and they have a surface temperature of 12140.33 degrees Fahrenheit. They are also rare. Only 3% of stars in the universe are of this type of star.

The fifth type of star is called the A-type star. These blue stars have a surface temperature of 17540.33 degrees Fahrenheit, and they have 1.4-2.1 solar masses. They are rarer than the G-type



Here are the seven most widely recognized stars.

stars with only 0.6% of all stars being A-type stars.

The sixth class of a star is the B-type stars. They are much larger than all the previous classes of stars. They are around four times hotter than the Sun with a surface temperature of 35540.33 degrees Fahrenheit. They are also more massive. A B-type star has 2.1-16 solar masses. These stars are scarce. Only 0.13% of stars are B-type stars.

The last star classes of the major classes of stars are the O-type star. They are known as blue supergiants. These giants are super hot. On average, a blue supergiant is five or six times hotter than the Sun with a surface temperature of 53540.33 degrees Fahrenheit. They are the black hole creating stars. The blue supergiants have at least 16 solar masses. These stars are scarce. Only 0.00003% of all stars are O-type stars. Next, there are six minor classes of stars. These stars are much less known than the major types of stars. The first three of the six are either tiny red dwarfs or brown dwarfs. The rest of the stars are massive stars.

First, there is the Y-type dwarf, otherwise known as a Y-dwarf. They are considered as brown dwarfs. Brown dwarfs are failed stars that didn't gather enough mass to get the temperatures to fuse anything. They are tiny with only 0.001 solar masses. The Y-dwarfs aren't very hot. They only have a temperature of 250 degrees Fahrenheit.

The next class of brown dwarf is called a T-type dwarf. They are also called methane dwarfs. This type of brown dwarf has that names because methane is prominent in their spectra. They are also tiny, with only 0.015 solar masses. The brown dwarfs are hotter than the Y-dwarfs with a surface temperature of 1880 degrees Fahrenheit.

Next, there are the L-type brown dwarfs. They are also called L-dwarfs. Some of these celestial bodies can support hydrogen fusion and are thus are stars. However, many of them are too cool to support fusion, so; they are brown dwarfs. On average, the surface temperature of the dwarf is 2950.33 degrees Fahrenheit. These stars are slightly less massive than a red dwarf with 0.07 solar masses. If research is correct, then T and L dwarfs may be the most common type of body in the universe. They may be more numerous than all the other classes combined.

The fourth type of star is a C-type star or a carbon star. These stars are large and cool red giants. What sets them apart from all the other red giants is the fact that they have more carbon than oxygen in their atmospheres. There are three solar masses packed in the giant star. They are cool with 3140.33 degrees Fahrenheit surface temperature.

The fifth star is the S-type star or simply the S-Star. They are huge with 1.5-5 solar masses, and they aren't very hot in stellar terms with a surface temperature of 5840.33 degrees Fahrenheit for such a massive star. These stars are cool giants with approximately equal quantities of carbon and oxygen in its atmosphere.

The last class of the six classes of the minor classes is the W-type star. These stars are known are Wolf-Rayet Stars. The amount of stellar wind is very unusual. Those stars are scarce, and they live for a short time. They are also massive and very hot. The stars contain 15-200 solar masses while its surface temperature ranges from 53540.33 degrees to 359540.33 degrees.

Chapter 7: The Lives of Stars

A low mass star has an incredibly long life span. They are small stars that use up their fuel very slowly over trillions and trillions of years. This can apply for both M and K class stars. A k-type star goes through the same process as an M class star does. They don't have as long of a lifespan. Not a single red dwarf has reached its later development stages. The universe isn't old enough. Every single one of the trillions of red dwarf stars out there is all still in their main sequence. These dwarfs are convective, meaning that their fuel of hydrogen and Helium constantly mix throughout their lifetime. That's what makes the smaller star more efficient than the other larger stars.

Red dwarfs might outlive every other type of star in the universe. When a red dwarf dies, it isn't a very spectacular event. They quietly become blue dwarfs. Blue dwarfs are like red dwarfs in many ways. However, they fuse Helium instead of hydrogen. But, their lifespans are much shorter than red dwarfs because a blue dwarf doesn't have the temperatures or pressures to fuse heavier elements.

During the transition between red dwarfs and blue dwarfs, the star will lose a portion of its mass. After five billion years, the blue dwarf will become a white dwarf. Blue dwarfs become white dwarfs because the radiation of the dwarf overpowers gravity. The dwarf sheds its outer layers. This is the stage were the star loses most of its mass.

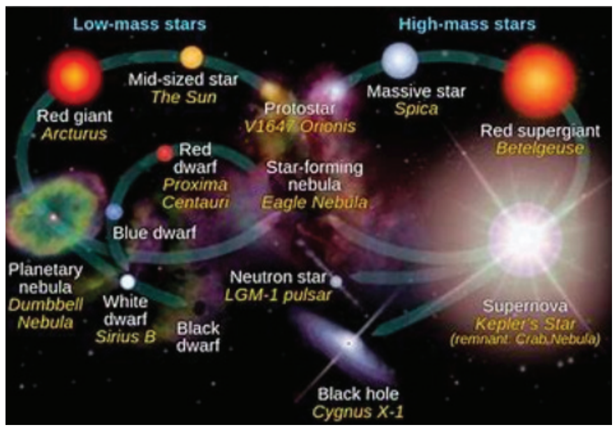
Now, the white dwarf is about the size of the earth. But, a white dwarf contains around half of the mass of the star that it came from. This means that white dwarfs are very compact. They are also very hot. White dwarfs can be up to 40 times hotter than the temperature of the Sun. It's filled up of mostly degenerate gasses of the helium-4 nuclei. Fusion stops happening. Without a source of energy, a white dwarf will slowly cool over trillions of years. The reason why it takes such a long time to cools is the fact that all the heat from a white dwarf is clustered inside. The heat is so tightly packed that only heat on the outer layer can escape into space.

Once a white dwarf cools down, it will become a black dwarf. Black dwarfs are inactive spheres with no more energy left to give. They will be both dark and cold. We don't know what happens to black dwarfs afterward. There are two main theories of what will happen. If protons have a limited lifespan, then black dwarfs will slowly evaporate over trillions of years. If protons don't have a limited lifespan, black dwarfs will probably turn into pure spheres of ion via quantum tunneling. Quantum tunneling is the quantum mechanical phenomenon where a subatomic particle passes through a potential barrier. This happens over a timespan so ridiculously long that calling it forever would be okay.

Stars that are in between red dwarfs and blue giants are medium mass stars like our own Sun. They don't have as long of a life span as the red dwarfs do but, they still live much longer than the bigger stars. This can apply to stars that fall in the G, F, and A classes. A star with a medium mass uses up its fuel at an average rate. They are in the middle between convective and non-convective. The Sun does circulate some of its elements in a cycle, but some elements start to build up in the Sun's core. Medium-mass stars burn hydrogen and Helium during their main sequence period. The main sequence period for medium mass stars usually lasts for a few billion years. The Sun's main sequence stage lasts for around 10 billion years. It is currently halfway through this stage.

Once there are no lighter elements, the medium mass star will start to fuse heavier elements. This is the point where a medium mass star will come off the main-sequence stage and become a red giant. The core of the medium mass star will get denser and hotter while the outer layers expand. A medium mass star will stay being a red giant for a few billion years. The Sun will remain at that stage for 5 billion years.

Then, the Sun will shed its outer layers and create a unique pattern. We call this a planetary nebula. More than half of the Sun's mass will be lost into space. What remains of the medium mass star is its core. The remaining core is a white dwarf. In this case, radiation wins over gravity. The white dwarfs of medium mass stars are very similar to the white



dwarfs of the smaller stars. They might have a little bit more mass. Both white dwarfs will take trillions of years to cool, and both will end up as black dwarfs. Quantum tunneling will also take place if the theory that the proton doesn't decay is true. High mass stars are extremely massive stars that are many times the size of our Sun. They glow extremely bright, but they use up their fuel very quickly. This can apply for B and O class stars. A high mass star only lasts for a few million years. The radiation of a massive star has to keep up with its gravity. A massive star has a different way of fusing elements than the other lower-mass stars. Massive stars are non-convective. They build up the elements in their core after they are fused. This is a very ineffective way to burn up the fuel, which is why they have much shorter lives than the rest of the other smaller stars. Blue giants and supergiants stay on the main sequence stage for 77-100 million years. Then, they transition into the red supergiant phase. Like the medium mass stars, the big star's cores become hotter and denser as the outside layers of the stars expand more and more. This allows the blue stars to create some of the heaviest elements in the universe. The red giant phase lasts for around 50-25 million years. When a massive star can no longer produce radiation through fusion because of all the iron in the core, the balance is broken. The star collapses on itself and explodes in a supernova blast. These events are incredibly energetic. A supernova blast could produce as much energy as the Sun can in its entire lifetime. At peak luminosity, a supernova lasts for around 100 seconds. In this situation, gravity wins over radiation. If the star has 8-25 solar masses, then the star will end up as a neutron star. If the star has more than 25 solar masses, then it will end up as a black hole. After a supernova explosion, the remaining core of the dead star with 8-25 masses forms a neutron star. Neutron stars compress 1.4 to 3 solar masses from the remaining core material into a sphere with the diameter of only 10 miles across. A typical neutron star has a gravitational field that is trillions of times stronger than earth's magnetic field. The magnetic field is so strong that the crust of a neutron star is under a lot of strain. Neutron stars compress matter together so tightly that gravity overcomes the repulsive force between electrons and protons. The resulting structure of the star is complex, with a solid crystalline crust about half a mile thick encasing a core of superfluid neutrons and superconducting protons.

After a supernova explosion of a star with a mass greater than 25 solar masses, a black hole appears. Black holes are some of the strangest and least known things in the universe. They have interesting properties. The accretion disk of a black hole is extremely hot while the event horizon of a black hole is very very cold. If you looked at a black hole, what you would be seeing is the event horizon. Anything that crosses the event horizon needs to be traveling faster than the speed of light to escape. In other words, it is impossible. Gravity is almost infinitely strong at the core, which means that anything that gets too close gets ripped into its elementary particles. Not even light can escape black holes.