Star formation

Rabea Kahkahni

In the midst of nowhere, the universe occurred with elementary particles scattered everywhere. Soon after 380,000 years the universe gradually cools down to the extent that electrons are able to combine with their hydrogen nuclei. This epoch is known as the recombination era and within, photons are able to move freely as electrons lose their electrostatic attraction. As such, the universe became momentarily transparent before turning pitch black.

The sparking question ‘where did the light go’ may occur to you. The light became what we now call CMB: *Cosmic Microwave Background*. Let me unravel the interesting story behind!

In 1995, a number of astronomers pointed out their radio telescopes to the sky. To their surprise, they heard some strange noise coming from different points in the sky. The peculiarity and oddness of the event made them think that bird poop was interfering with their data, but of course, that wasn’t the case. The light the universe emitted from the recombination era has since been traveling through the expanding universe. In its odd fashion, the light has stretched to the microwave spectrum.

The snapshot from a young university student tells us that matter is evenly distributed because the coming light looks nearly the same everywhere we look in the sky. Due to cosmic inflation: the exponential expansion of space in the early universe, the effect would look like pulling out a carpet to flatten the wrinkles. However, there were some fluctuations and perturbations in density. Gravity turned out stronger in these denser spots which enabled the area to collect matter, subsequently leading to the formation of stars and galaxies.

At denser spots, gravity was able to collect matter by compressing it tightly, thereby creating high pressure and heat. When the heat reached a temperature around 10,000 °C, protons could fuse together with a part of them turning into energy. This huge release of heat prevented the gas cloud from collapsing again (example: in the atmosphere, the hot gas goes up when it’s heated by earth’s temperature, whereas cold gas goes down) and this is how the first star popped out and lighted up the universe after the universe turned completely black. Serving as the basis of a masterpiece, the fundamental elements of hydrogen and gravity propelled the formation of a star.

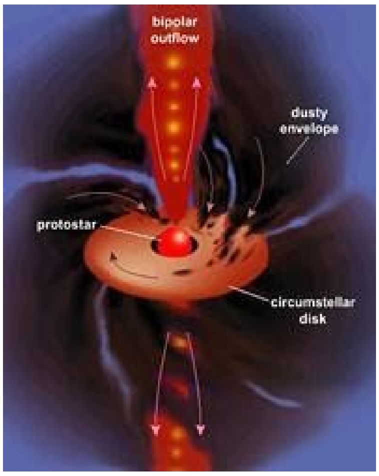
How it currently forms:

First, stars form in a nebula, known as the nursery of stars. As a huge cloud of gas and dust is congregated by gravity, the gas actually wants to break free but the gravity pulls it close to the region expected to form the nebula. As the gas is being compacted, the pressure and temperature steadily increase. However, there’s a kind of balance between the pressure that wants to free the gas and the gravity pulling things back together.

To divide the formation of stars into steps : first, we have a huge cloud of gas, within it, clumps form in the denser spots. This process can be viewed as clouds forming within a bigger cloud with each clump possessing a core that draws matter to its center so it becomes a protostar (baby star). Secondly, the protostar grows in mass, the gravity becomes stronger which accelerates the collapse of gas in its center, and the surrounding gas and dust become a rotation disk, while the inner part of the disk feeds the star with more mass. Therefore, the heat and the pressure of the protostar's center get higher and higher.

When it reaches the temperature needed to thermonuclear fusion, which is the process that occurs when two atoms combine to make a larger atom, elements such as hydrogen and helium start to fuse and give birth to other elements. For example, when two hydrogen atoms fuse they give helium.

At the same time, the young star is emitting a strong stellar wind in the form of gas and dust, and some of it is channeled out through the poles. This jet of matter prevents the infall of new mass, and now the baby star becomes a young star since its mass is fixed and future evolution set.



Types of stars:

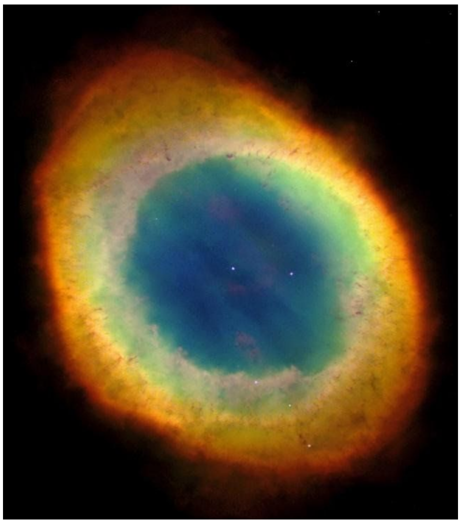
Witnessing the night sky with glistening stars homogeneously appearing in similar sizes, we cannot differentiate them. However, when looking through a telescope we can see so many underlying differences such as the color that depends on temperature, which is symbiotically connected to the luminosity of the star. The mass of a star is represented by its luminosity and age. A relatively low mass star would appear fainter and live longer because it fuses elements in its core at a slower rate, whereas a high mass star would be brighter but live longer because it fuses elements in its core at a higher rate. In general, more mass means more pressure in the core followed by more fusion that gives more energy, thus, more brightness.

The faintest type of star is the brown dwarf, created when a protostar, a star at its early phase, doesn't reach enough mass to begin nuclear fusion. This star has a mass between that of a giant planet and that of a small star. More massive brown dwarfs can fuse lithium or deuterium, but astronomers differentiate them from normal stars because they can't fuse hydrogen.

We'll follow that by red dwarfs that are more luminous and massive than brown dwarfs that encompass 40%-50% the mass of our sun. The fusion of gas in their core is really centered, which means it only happens at the very center. There the gas is convective which means that the hot gas rises up and cools to finally fall back in the center. This process explains the long life of this type of star, it can live up to a trillion years (1 000 000 000 000).

Stars at around the mass of our sun work differently: they have a bigger and more massive core. There isn't any convection of gas because it stays in the core so they run out of fuel more quickly, thus they live shorter compared to less massive stars.

To explain their lifetime, we'll take as an example our sun. The star fuses hydrogen into helium, which leads into the increase of the latter. Therefore, the mass of the core increases so it gets hotter and the hot gas shines more brightly, so the luminosity increases as well. The extra heat resulting from the fusion moves to the outer layer. However, the sun will eventually run out of hydrogen, and the helium that remains won't be hot enough to produce fusion. Whilst this, the outer layer can become hot enough to fuse hydrogen that's outside the core. This fusion adds up heat, thus, hot gas expands and this is how our sun will become a red giant as it expands more and more. This expansion makes the sun lose its mass, as at the same time the core gets smaller and more compacted. At this stage, it is hot enough to create helium fusion, which gives carbon. After that, the sun will run out of helium and carbon will be left. This time no more fusion; it's the end of the giant ball of gas which will eventually blow off all its outer layers letting a single tiny core called a white dwarf (below).



This is a hot, little and dense ball that has the size of the earth but contains much more mass; a single cubic centimeter of it has a mass of a million gram. This naked core is composed of carbon nuclei, electrons, and some other elements left after the bang. As you may know, same charge repels each other; electrons work under the same principle. what happen in the core is that the electrons create a pressure because they are squeezed together (electrons hate that). The more you squeeze them the higher is the pressure. This pressure is really strong which makes it the primary force supporting the white dwarf since the nuclear fusion is no longer possible.

Also, the white dwarf is really hot; it has a temperature around 100000°C, and it also emits radiations that may affect the surrounding gas that have been blown off. It subsequently creates something incredibly beautiful called planetary nebula.

What about giant stars like a blue supergiant that has mind-blowing masses? They have cores with a temperature around 5000000°C which can fuse even more elements than do stars like the sun. When the star runs out of hydrogen, it uses helium. When there is no more helium, the star uses carbon which is created by the fusion of helium. With carbon fusion, neon, magnesium and sodium are created. Notice a pattern? The core creates heavier elements as it runs out of one of its fuels. Those elements accumulate which make the core even denser and hotter. This process enables the core to fuse one element after another. After the use of carbon, it'll fuse Neon giving birth to oxygen and more magnesium, and then the oxygen will be accumulated and used as a fuel to create silicon. At this stage, the star is in trouble.

When the other elements fuse, energy is created and transformed into heat that supports the star by preventing the infall of the tremendous amount of mass on the core. Silicon is different,

when it fuses into iron, energy is rather sucked up. In other words, it makes the core lose its energy. Its resistance, meaning that the gravity becomes stronger and that makes all the surrounding gas that has been expanding collapse in a thousandth of a second, all the mass falls above the core; that's a supernova. At this point two things can happen: the star is less than 20 times the sun's mass it will transform into a neutron star, if it is more than that it'll become a black hole.

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