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Clockwork Universe

Rageena Joseph
HOD of Physics,
Newman College Thodupuzha, Kerala, India

***Abstract:** For centuries mankind believed that the universe is never changing and worked with the precision of a clock. The sun rises in the east and sets in the west. The moon waxes and wanes in 28-day cycles. The four seasons come and go with clockwork precision. However, Edwin Hubble's observations showed an expanding universe which meant universe had a beginning. We now know that conversion of matter to energy will one day lead to death of our sun and other stars and from the debris of dead stars new stars will arise. However, this cycle will eventually lead to a situation where stars become smaller and smaller and will not generate enough heat in its core to sustain a nuclear fusion reaction and the universe will wither into cold darkness. Ours is not a static clockwork universe. It is a dynamic ever-changing universe which is in its prime of life but destined to age and dies. This is the story we want to say in the article.*

***Keywords:** Deneb I, Like Proxima, Protostars Cosmic Microwave Background Radiation (CMBR the Hertzprung-Russel Diagram Proxima Centuari), the Light Messenger.*

INTRODUCTION

Newton's laws of gravity helped us to calculate the movements of planets around the sun. In the Greenwich Observatory, there is a model of solar system in which the sun and planets are connected to each other with metal rods representing Newton's invisible gravitational force which cause planets to revolve around the sun like clockwork. The inner planets are small and made of solid rock and outer planets are predominantly gaseous giants. Sun's heat causes any gas to escape to the outer region where it can collapse to form gaseous planets. However, there is something odd about the layout of the solar system. Mars is much smaller than earth. Venus is slightly less than the size of earth. If the order of planets were mercury, mars, Venus, earth and Jupiter, with mercury being innermost that would be an ascending order in terms of mass of planets. We have asteroids and comets in the asteroid belt. Comets should have been in the Oort cloud outside Kuiper belt at the periphery of the solar system. How did some comets get inside the asteroid belt? Jupiter is so massive compared to other planets that it is often called a failed star. There are several protostars the size of Jupiter. Even Proxima Centuari, our nearest star is smaller (but denser) than Jupiter. It is proposed that about 4.5 billion years ago in the early solar system the planets were formed by the bombardment of asteroids into each other. The presence of Jupiter in the neighborhood threw planets into wild circuits around the sun. During this period of late heavy bombardment, the earth was hit by another planet and earth's crust was smashed into small fragments which were united by gravity into the moon. This impact is thought to have given earth the 23.5 ^{0}tilt. This was fortunate because the earth's tilt gave us the seasons.

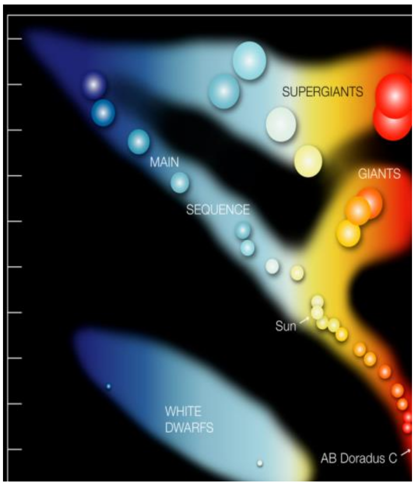
The light messenger

The story of the universe is written for us by the light messenger. The Greeks looked at the night sky and described different star systems called constellations. With telescopes stationed in the earth and outer space not only we can see the visible light but also ultraviolet, infrared, microwave and radio waves. Spectroscopy is widely used to discover what stars are made of. In fact, the element Helium (Helios is the sun in Greek mythology) was described from the absorption line in spectroscopy of sunlight before it was found on earth.

The Hertzprung-Russel diagram

The astronomers Ejnar Herzsprung and Henry Russell independently categorised about ten thousands stars near to earth in the Milky way into 3 groups by plotting their surface temperature (which is directly related to their colour- hot stars blue or white hot and cool stars red) against their true luminosity(their brightness if they were in the same distance from earth). 80 % of the stars lie in a sweeping line called the main sequence ascending from bottom right to top left. These are the stable stars in the prime of their life. On either side of the main sequence, there are 2 outcrops, white dwarfs to the right and red giants to the left which denotes the future of all main sequence stars.

Luminosity



Temperature

Edward Hubble by observing the red shift of stars and by plotting the velocity of receding stars against their distance showed that the speed of a galaxy is directly proportional to their distance. This meant the galaxies were closer together in the past, which implied a beginning for the Universe.

The beginning of the Universe

(The day without yesterday)

Time, space and matter are all thought to have come into existence 13.7 billion years ago, in an event called Big Bang. The Big Bang was not an explosion, but an expansion of space which happened everywhere. In its first moments the universe was infinitely dense, unimaginably hot and contained pure energy and the four fundamental forces of nature were united. Physicists do not know what happened in the first instance after Big Bang, known as the Plank Era, but at the end of this period gravity split from the other 3 fundamental forces of nature and this triggered the 'inflation'- a short period of rapid expansion. Then as the universe cooled the other 3 forces namely electromagnetic force, strong and weak nuclear force separated.

Origin of Mass

About 10^{-32}seconds after the Big Bang, the universe is thought to have been a soup of fundamental particles and antiparticles. These were continuously formed from energy as particle-antiparticle pairs, which then met and annihilated back to energy. Some of these particles still exist today as quarks, antiquarks, bosons and gluons. There was a slight preponderance of particle over antiparticles- that is about a billion and one particle to one billion antiparticles. When these later got annihilated, a residue of particles remained and these gave rise to matter in the universe. Within the microsecond quarks and muons combined to form heavier particles, mainly protons and a few neutrons. 100 seconds after Big Bang collisions between neutrons and protons lead to the formation helium nuclei and tiny amounts of other nuclei. Within the first 2-3 minutes, 98% of today's helium was formed. These reactions mopped up all the free neutrons. The remaining protons remained to uncombine to become nuclei of the Hydrogen atom. For hundreds of thousands of years, the universe continued to expand and cool, but it was too energetic for atoms to form. If electrons momentarily met with protons or helium nuclei, they were quickly split apart by photons, which were themselves trapped in a process of continual collision with free electrons. The scattering of photons meant that the photons could hardly travel any distance in a straight line. So no light came out of the early universe.

Some 300,000 years after Big Bang the universe cooled to about 2700^{0} C. Protons and helium nuclei began to capture electrons forming the first atoms, 90 % hydrogen and 10% helium. Electrons were now bound up in atoms and photons were released free to travel through the universe as radiation. This radiation can still be detected everywhere in the universe as Cosmic Microwave Background Radiation (CMBR). The small fluctuation we see today in the CMB denotes the small variation in density of matter in the early universe which led to the formation of stars and galaxies.

The story of the universe is the story of the life and death of stars. It is our story because we are made of stardust. During their lifetimes, stars pass through a series of stages, with the sequence and timing depending on the mass of the star. As a star passes through these stages all the 92 elements present in the universe are created. When the stars die they shed these elements into the interstellar medium enriching the matter for the future generation of stars and their children, the planets.

1. Birth of a star

In the night sky, we can see a large area of black cloud up to 300 light years across. These are called stellar nurseries. They remain unchanged for millions of years until a trigger such as two clouds bumping into each other or a distant cosmic event like the supernova explosion sending shockwaves into the cloud which cause a squeeze in the cloud sufficient for gravity to take over. Gravity cause this cloud of dust and gas to become denser and denser which in turn make it hotter and hotter until the center of the cloud reaches the critical temperature of 15 million 0C. Almost in a flash the core of the cloud light up. A star is born. In protostars less than 0.08 solar mass, the pressure, and temperature at the core do not get high enough for the nuclear reaction to begin. These protostars become brown dwarfs.

In stars, the size of the sun or smaller, the dominant energy producing fusion process is called proton-proton chain. This chain of high energy collisions fuses hydrogen nuclei via several intermediate stages into helium -4 nuclei. Energy is released in the form of gamma-ray photons. Positrons and Neutrinos are also produced.

The high energy at the core makes it rotate due to angular momentum. The leftover debris of the cloud from a disc around the new star. The revolving dust and gas stick together and the denser areas attract more debris due to gravity and grow to form planets. Most young stars, unless they are in a close binary system, are surrounded by planets.

2. Adulthood

Sun is a middle-aged star of medium size and therefore its energy production is in the middle range. That is why the sun is yellow. Massive stars are blue and dwarfs are red in accordance with the wavelength of the visible light VIBGYOR. Lower the wavelength higher the energy. Sun is a second or third generation star born 4.5 billion years ago. There are several large stars in the Milky Way. The vast blue giant Deneb is extremely hot and about 200,000 times more luminous than the sun and 20 times more massive. It burns its nuclear fuel at a ferocious rate and is likely to explode in supernova explosion within a few million years. On the other hand, red dwarfs like Proxima Centauri has the longest life span.

Beneath the surface of a star, a battle is raging between the inward pull of gravity and the outward pull off nuclear fusion. The sun is in stable equilibrium Variable stars like Cepheid variable fluctuate in its brightness. When Cepheid is relatively cool, it is unable to counteract the gravitational pull. When it contracts due to gravity it compresses the hydrogen in the core which heats up and nuclear fusion is accelerated which causes it to expand. Contraction phase compresses the outer layers of the star and makes it more opaque and dim. The bigger the star, the longer the period of variation in luminosity. In 1921 Henrietta Leavitt discovered a link between the period and luminosity of variable stars called Cepheid variables, and this calculation enabled Edwin Hubble to measure the distance to Andromeda Nova which contained a variable star, and thereby establish that Andromeda is a galaxy and not a cloud or nova inside Milky Way as was previously thought.

Galileo was the first to describe the black spots in the sun. They appeared and disappeared and by comparing sequential drawings of the sun Galileo concluded that the sun is not static but rotating. Sun's dot is due to solar flares caused by sun's twisted magnetic field and consists of a stream of highly energetic charged particles which can damage our power grid and satellites. Sun also produce solar wind made of energized particles which bounce off earth's atmosphere and cause Aurorae (northern and southern lights). At about 100 earth-sun distance they lose their energy and form a protective bubble to our solar system which stops the harmful galactic radiation and cosmic rays.

3. Red giants

Once a star with a mass less than half of our sun has used up the hydrogen in its core, it will convert the hydrogen in its atmosphere to helium and slowly fade away. They do not have enough temperature in its core to burn helium. When the sun like a star exhausts the hydrogen in its core, it starts burning hydrogen in its outer layers in a series of concentric shells and it will expand into a red giant. It is red because it is cooler than the white core. We can see the fate of our sun in the red giant Betelgeuse in the night sky.
In its dying days, the sun will expand and swallow Mercury and Venus and eventually our earth will be engulfed in a ball of fiery gasses in 5 billion years’ time. It will eventually collapse, and the temperature and pressure at its core initiate helium core burning producing carbon through the intermediate, unstable beryllium. Once all the helium in the core is converted to carbon, helium shell burning occurs and the star expands. In very massive stars this process is repeated until iron is produced until the core finally collapses to become a white dwarf. When the sun like a star has used up all its fuel it loses its outer atmosphere in spectacular planetary nebulae.

4. White dwarf

Inside the planetary nebulae, the remaining core containing carbon and oxygen will shine like a diamond, the diamond the size of earth called white dwarf. There is no nuclear fusion, the white dwarf simply radiates its remaining energy as light. The core of the dead star is held up against the force of gravity by a sea of electrons. Electrons behave according to Pauli's exclusion principle, which states that the electrons resist being squashed together leaving a super-dense blob of matter. White dwarfs are typically 0.6 to 1.4 times the mass of the sun. The upper limit of the mass of white dwarf is called Chandrasekhar limit, for which the Cambridge-based Indian astronomer got Nobel Prize. The Chandrasekhar limit is decided by 4 fundamental constants of nature such as Newton's gravitational constant, Planks constant, the speed of light and the mass of a proton.

5**. Black dwarf**

White dwarf eventually loses all its energy and gradually fades away into a black dwarf. We have not observed any black dwarf, but that is the prediction. It will be difficult to see them because they emit no detectable radiation.

6. Supernovae

Massive stars die spectacularly, blasting their outer layers off into space in a supernova explosion. When a star of more than ten solar masses reaches the end of its hydrogen -burning stage, it will eventually produce an iron core. Initially, this core is held by its internal pressure, but when the core reaches a mass greater than 1.4 solar mass, it starts collapsing forming a neutron star. Supernovae detonation occurs when the outer layers of the star, which has continued to implode impact on the rigid core and rebound back into space at speeds of 70 million km/h. This releases a massive amount of energy. During the supernovae explosion elements, heavier than iron are produced.

7. Neutron star.

Here the electrons are squashed so tightly into a proton by gravity that they can react together by weak nuclear force to produce a neutron. Neutrons like electrons obey Pauli's exclusion principle and resist being squashed together leading to a stable dead star. Neutron stars become so dense (dense like atomic nuclei) that they are only about 10km in diameter. Neutron stars have a mass between 0.1 and 3 solar masses. Beyond this limit a star core collapses further, to become a black hole. As the neutron star forms, the magnetic fields of the parent star contracts and grow in strength. Also, the rotation of the star increases due to the preservation of angular momentum. Neutron stars that emit directed pulses of radiation at regular intervals are known as pulsars.

8. Black hole.

It is a region of space containing at its center some matter squeezed into a point of infinite density called a singularity. It is of 2 types

1. Supermassive. It has mass equivalent into billions of suns and is seen in the center of most galaxies. Their origin is not understood. Scientists believe they are end products of galaxy formation.
2. Stellar mass. It is the collapsed remains of supergiant stars

Black holes can be detected only by the effect they have on objects around them. Light from far off objects can be bent around by a black hole. If a stellar mass black hole is a member of a binary system the material from the companion star will be pulled into it. The matter will not directly fall into a black hole due to rotational motion. Instead, it will first be pulled into an accretion disc around the black hole. Matter impacts onto the disc producing radiation which can be detected.

The end (the day without tomorrow)

In the early Universe, there were many massive stars. In the Milky Way, 90% of the stars are middle age stars and 80% of them are red dwarfs which gradually fade away. So there will be less and less material for new star formation. All the energy in the universe will eventually be stretched to low energy microwave and radio waves. The universe will become dimmer and dimmer. In the black holes, the mass will be crushed into oblivion. The temperature of the interstellar space is only 3 degree above absolute zero. With ever expanding universe, according to Second Law of Thermodynamics, the order in the universe fade away into complete disorder and absolute darkness.

CONCLUSION

Some scientists claim that there are eternal inflation and each time when it inflates a new universe is formed. There could be multiple universes in which case it is possible that universes may collide with each other. This can be tested by examining the CMBR data and look for any bruise or overlap of CMBR which may indicate a collision. So far no evidence of collision of our universe with another is found.

