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Life Cycle of High Mass Star

Sabir Sadiq*

Kurdistan Space Agency, Shiladoze, Duhok, Kurdistan
Email: sabirhassansadiq@gmail.com

Abstract

In the present work, I shall explain the gravity and life cycle of a high mass Stars. Mathematical equations are important factors to describe the role of a gravity as a dark fabric distortion. The space of Universe is not empty at whole, but it is completed by a dark fabric matter and energy that distorted under the stress of a high mass Stars from their Birth to a Death. Dark fabric is warping strongly under the effect of Neutron Stars and black holes. Blue Supergiant stars are high mass Stars where their masses are very high may burn their fuel very quickly to produce new heavy atoms, and release tremendous amount of energy, and plasma. All main sequence stars in such high mass may die and expand to become a red supergiant when their fuel of fusion exhausted at the final stages of a star's lifetime. Supergiant stars may die and explode with a big and luminous explosion that named a supernova. The remnant core of high mass stars may become a neutron star or black hole according to the mass of an exploded stars.

Keywords: Nebula; Gravity; High mass stars; Dark Fabric matter and energy; Nuclear fusions.

1. Introduction

Birth and death of High Mass Stars are important to know the fate of all massive Stars. Star may dies depending on its mass and size. A High mass star's death occurs urgently as a supernova when it burns its fuel quickly because of its high mass, gravity, and temperature conditions, the remnant core of such stars named a neutron star or a black hole according to the mass of a dead star. High mass stars can be classified into a supermassive star or supergiant star, both properties are suitable for such high mass stars. A supergiant star is a star of relatively high size, mass, gravity, temperature, and luminosity as compared to low mass stars. Supermassive stars have the mass more than 3 times the mass of Sun or 200 times the mass of a solar mass stars, and size million times larger. Fortunately, nuclear fusion takes place at the heart of both solar mass stars and supergiant stars.

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* Corresponding author.

Low mass star has enough mass, pressure, and temperature to fuse several atoms to produce heavy atoms for a long time, otherwise supergiant stars have very high mass, density, pressure, and temperature to produce maximum numbers of heavy atoms at brief time, their fuel maybe ended, the supergiant stars will expand and explode at final stages of their life cycles. The surface temperature of a low mass star is very low as compared to supergiant stars.

The mass, gravity, pressure, and the temperature of a Star are active factors for producing energy and new atoms at the heart of Stars when starting with a nuclear fusion process. [1] Stars are formed from stellar nebula when sufficient amount of mass and energy collapsed inward under their gravitational pull, and heating the gas to many million kelvins in order to start with a nuclear fusion when the protostar star becomes a main sequence Stars. High mass Star may explode as a supernova when its fuel was used mostly in a nuclear fusion process, the Crab Nebula is an example of such exploded high mass stars. Crab Nebula contains the Pulsar at its core. A pulsar is a highly magnetized rotating neutron star that emits beams of electromagnetic radiation out of its magnetic poles.

In this research work, the life cycle of a high mass stars and gravity are main objectives of our study. Another aim of this study is to discuss the ultimate fate of all high mass stars after their explosion and death.

2. Stellar Nebula

A nebula is a giant cloud of dust and gas distributed in a large space. It is the place of birth and death for Stars, Planets, and celestial objects. The Orion Nebula is a place where massive stars formed from. Orion Nebula is one of a visible nebula that located in the Milky way galaxy. Stars that we believe to be young are always found close to clouds of interstellar dust and gas that named nebula, we argue that such clouds of cosmic matter and energy must be contracting slowly under its self-gravity, giving rise to increasingly compact condensations, temperature, and density some of which eventually collapse down to stellar size to form a protostar in the first steps of a star formation. [2] The protostar formed from crucial amount of mass were condensed together in the dense region of a nebula. Bright point in the nebula disc is an evidence of a new star formation. Nebula consists of Helium, Hydrogen gas and dust particle. Hydrogen is a main fuel of fusion for low mass stars and high mass stars at the beginning of nuclear fusion processes when started at the core of stars.

Fig. 1 shown clearly the protostars were formed from Carina Nebula [3]. Carina Nebula was one of the first clear images that collected by JWST. There are many bright and hot points shown clearly in the disc of a Carina Nebula, they are clear evidences of new born stars were formed from this magic nebula. The protostar is a first step of a star's formation and evolution, it is still gathering gas and dust particles to increase the pressure and temperature of its heart, and ignite nuclear fusion in next steps when becomes a main sequence star. Gas and dust particles are two important factors to feed all types of protostars in the disc of a stellar nebula. Protostar can't grow without additional fuel, it is much needed to collect high enough mass from its surrounding to increase its gravity, density, central pressure and temperature. Nuclear fusion takes place at the centre of all main sequence stars.

Figure 1: Birth of Stars in a Carina Nebul

3. High Mass Stars

High mass star is a star with a big mass where nuclear fusion takes place at its heart under massive conditions of pressure and temperature. High mass star may end its fuel during several millions of years. The sun is a main sequence star, its mass not very high like supermassive stars, it is only an average star. The sun will die like any low mass stars in the Universe after five billion years when its fuel of hydrogen isotopes spent slowly and ended entirely, it will become a red giant. High Mass Stars with masses more than three and eight times of the mass of a Sun. The cores of high mass stars are so large and hot, then the fuel is burnt out, they cannot be stabilized even by degenerate pressure, it will collapse further. High mass stars can have many successive stages of a nuclear fusion of elements in a core to produce heavy atoms and lighter elements are fused in shells around the core. The nuclear fuels of high mass stars may runout quickly, they may expand into outside to become red supergiant stars. The red supergiant will expand more and more to become a supernova, and its remnant may become a Neutron star, or black hole according to the mass of dead stars. There are six stages of a high mass stars from birth to death.

Dark fabric matter and energy was distorted slightly under the stress of a stars where their structure still consists of ordinary matter and atoms such as protostars, main sequence stars, red giant stars, and supernova. Furthermore, the dark web matter and energy is warping very strongly under the pressure of compact objects such as Neutron Stars, and black holes. Compacted stars are drowning deeply into the structure of a dark fabric. Black hole falls down deeply into a dark fabric matter to make a long tunnel as shown here clearly in the following second figure. Super distortions and curvatures occurred in the body of a dark fabric matter when it exposed strongly to the stress of compact stars. The structure of Protostars, main sequence stars, red supergiant Stars, and supernovae stars are still consisting of atoms and molecules are not dense and compact much enough to distort strongly the shape of a dark fabric. In another hand, the structure of Neutron stars, and black holes are consisting of collapsed inward atoms and denser matter, that is why they are so dense objects of the Universe, and dark fabric is steeply distorted and compacted around them, even radiation particles could be captured and

curved strongly in the region that much closed to the border of these two compacted stars. [4] Dark fabric matter represents the space matter and gravity, eq. (1), and MATLAB program was used to draw the shape of a gravity as the dark fabric distortions in three dimensions (x,y,z) as shown here in a second figure:

$$z = \frac{1}{\cosh(x^2+y^2)} - \frac{\coth(x^2+y^2)}{\tan(x^2+y^2)} \quad \textbf{(1)}$$

Suppose: $-\frac{\pi}{2} < x < \frac{\pi}{2}, -\frac{\pi}{2} < y < \frac{\pi}{2}$.

Dark fabric matter and energy gives to stars an additional stress and gravity to become much denser and homogeneous. Also, Stars are making like tunnels and curvatures inside the structure of a dark fabric to attract and collect gas and dust particles. Dark fabric could be distorted easily under the stress of all celestial objects. The massive and denser objects may make deeper tunnels in the body of a dark fabric. Dark fabric itself not so compact, dense or combined to obstacle the journey of an ordinary matter and energy, it is oscillated and evaporated quickly when celestial objects interacted with it. Dark fabric was distorted differently during life cycle of high mass stars from a step of formation to supernova explosion. The distortion of a dark fabric depends on the density and mass of celestial objects.

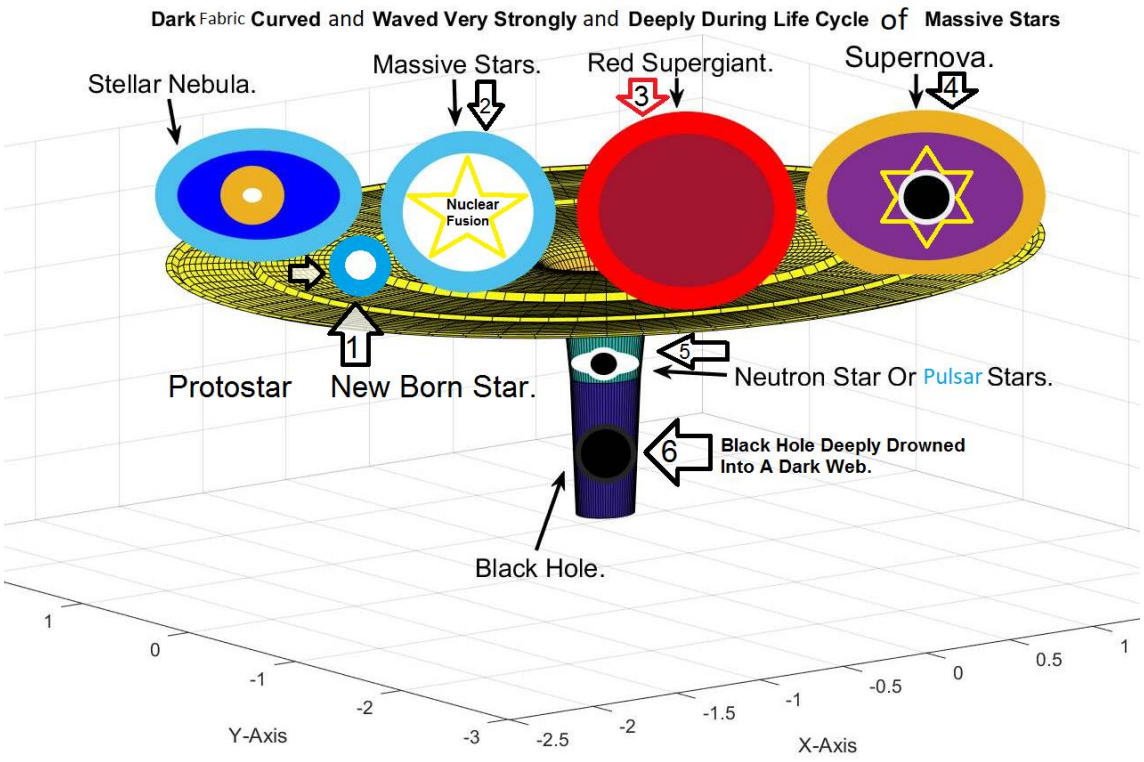

Figure 2: Life Cycle of a High Mass Stars

3.1 Protostar

Protostar was formed at first stages of a star's life; it is formed from a stellar nebula in a violent region of the Universe. Both of low mass stars and high mass stars are formed from gas and dust of nebula. A protostar is still gathering mass from its surrounding to grow more, and become much massive and denser. The protostellar phase is the earliest one in the process of a stellar structure and evolution. For high mass star, its process lasts about 50,000 years to 1000,000 years, formation and evolution of some protostars exceeded many million years according to the place and nebulae formed from. Star formation begins as small compressed molecular clouds called dense cores.[5] Each dense core is initially in hydrostatic balance between self-gravity, which tends to compress the object inward, and both hot gas pressure and thermal pressure, which tends to inflate it outward. Protostar is gathering much mass to ignite nuclear fusion, all of Stars, and planets are formed from nebulae. As the dense core collecting enough mass and energy from its surrounding, the self-gravity begins to overwhelm radiation pressure, and internal collapse begins to compress inward the core of protostar. A protostar looks like a star but its core is not yet dense or hot enough for fusion process to start, its phase ends when becomes a main-sequence star after hydrogen fusion producing a helium atom since nuclear fusion was started at its deep core.

3.2 Main Sequence Star

Main sequence star is a second stage of a star's evolution when hydrogen isotopes fused to form helium atoms. Nuclear fusion takes place at the heart of a main sequence stars to produce some new atoms and release energy. Nuclear fusion is a nuclear reaction process that occurred naturally in the heart of low mass stars and high mass stars under high pressure, gravity, and temperature's conditions, where light mass atoms fused together to form atoms with high masses, and release radiations with different wavelengths. Sun, Sirius A, and Alpha Centauri A are all main sequence stars. The Sun and Solar System were formed from the gravitational collapse of a giant molecular cloud.[6] The currently accepted method by which the planets, asteroids, comets, and natural satellites was formed from an accretion disc, then they began as the dust and gas clouds in orbit around the central protostar.[7] When the Sun or any other star gathering enough mass from its surrounding, its density and high opaques may not allow radiation to escape from the heart of star, as a result its temperature may increase high enough to begin a nuclear fusion processes. [8] The Sun is a main sequence Star, its core's temperature was reached 15 million kelvin and nuclear fusion continuous at its centre more than 5 billion years ago, and next 5 billion years coming.

The best model states that a main sequence star was formed from a dense gas fluid that hot enough in a state of hydrostatic balance, when the inward acting force is the gravity which balanced by outward acting force of a thermal pressure. The ideal balance between gravity force and thermal pressure was kept the Sun and any other stars from explosion more than millions of the years. Dark fabric is another important factor that protecting stars and planets from explosion and perturbation. Dark fabric is acting and interacting directly with an ordinary matter and energy of the whole visible Universe. Dark fabric gives to the Stars, satellites, and Planets an additional pressure and weight, for this reason their shapes are stayed spherical at whole. Celestial objects are drowning deeply into a dark fabric to capture enough mass and energy from its surrounding, Stars and planets got spherical shapes when gathering enough mass and energy. Dark fabric is an important factor for

the evolution of stars and planets and any high mass objects of the Universe. Dark fabric matter is a hidden hands were acting directly in the formation and evolution of the Stars, and planets.

Stars are main sources of energy and electromagnetic radiation that transferred many billion light years after an interaction with a dark fabric matter for a long time. Sound is a mechanical wave needs to a medium to transfer. Light is an Electromagnetic wave can move through the medium and space too. The space is not empty at whole, the vacuum between Galaxies, Stars, Planets, Sun, Earth, all celestial objects, and stellar systems, are filled with a dark fabric matter and energy. Dark fabric is another building block beside our visible Universe.

Speed of light through dark fabric in space is 300,000 km/sec, it is a limited velocity and lazy particle to move in this speed into the edge of the Universe at short time, because light particle interacted and collided with many dark fabric particles were distributed in the road. Light can't move with a giant speed because of dark fabric particles were obstacle its motion. Scientists believed that the diameter of a known visible Universe is about 93 billion light years, it means that the light particle needs to 93 billion years to travel from one side of the Universe to another side.

Fig. 3 explained that the cosmic dark fabric was warped and distorted under the pressure of high mass stars during nuclear fusion processes. Nuclear fusion in the core of Stars takes place when two hydrogen isotopes fused together and produced helium atom, the produced atom has a lower mass, because some of its mass converted into an energy according to Einstein's law of energy conversion. Nuclear fusion keeps the hydrostatic balance in the stars because the thermal pressure equals to the gravity. Cosmic fabric distorted and waved actively during nuclear fusion process that leads to keep hydrostatic balance, and spherical shape of the stars. The Stars have spherical shape because of a tussle between the gravity and thermal pressure. The gravity is caused by the mass of Star itself and dark fabric that surrounding it from outside.

In this research, we have to learn basic production of stellar energy from nuclear fusion that began in the heart of stars. The Stars are main source of energy in the visible Universe. [9] Hydrogen fusion requires extremely very high temperature at least 15 million℃ for solar mass stars. Our Star the Sun needed hydrogen fuel for burning, at every second it burns about 700 million tons of hydrogen isotopes to form 695 million tons of helium atoms with conversion about 5 million tons of its mass into an energy according to Einstein's famous equation of energy conversion. In the heart of all high mass stars more than billion tons of hydrogen isotopes, and other massive atoms fused together to form another different heavy atom with releasing many million tons of their masses into energy according to Einstein's equation of energy. The Sun is a low mass star, it can produce helium atom and high energy from fused hydrogen isotopes when nuclear fusion started at its core. Furthermore, high mass stars have high capacity to produce many heavy atoms during nuclear fusion at their hearts and surrounding shells. Heavy atoms like Silicon fused together in the core of supermassive stars under very high pressure and temperature effect to produce heavy atoms like Iron. Hydrogen, helium, Carbon, Neon, and Oxygen fusion occurred in upper shells to produce new atoms. The temperature and pressure in these outer shells of high mass stars are enough to start with a nuclear fusion. Low mass stars like the Sun can produce only helium atom from hydrogen isotopes when nuclear fusion started at the core of Sun, otherwise, heavy mass stars like the Sirius A or Rigel star can produce many heavy atoms when chains of nuclear fusions are continuous at

different shells of such massive Stars. Rigel is a blue and hot supergiant star, its surface temperature incredibly high, and its central temperature very high as compared to a solar mass star.

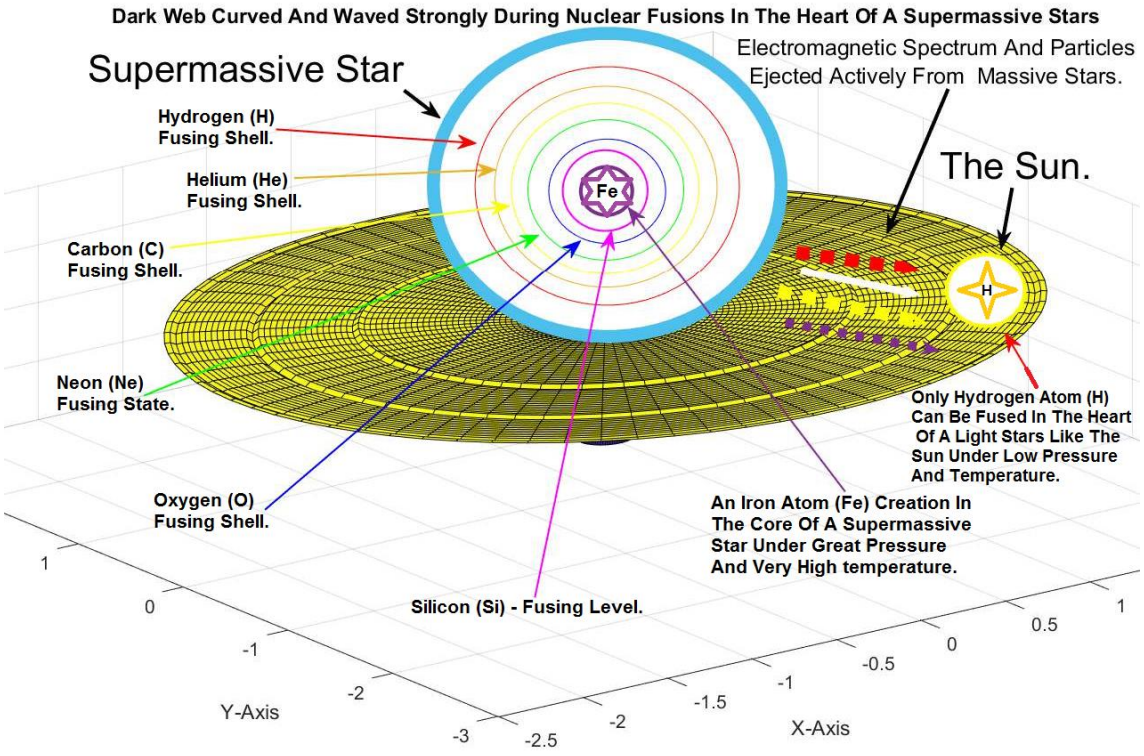

Figure 3: Nuclear Fusion Processes

Supergiant stars have masses from 2 to 200 times the mass of the Sun (M⊙), and luminosities from about 1,000 to over a million times the Sun (L⊙). They vary greatly in radius, usually from 20 to 700, or even in excess of 2,000 solar radii (R⊙), as a result only a single supergiant star needs to many million Suns to fill it. Supergiant star has huge central pressure and temperature, as a result chains of nuclear fusions are working together at its core to form many types of atoms as light and heavy atoms at once. Low mass stars like Sun are needed to lower pressure and temperature to produce new atoms from hydrogen isotopes, high mass stars much needed to additional pressure and temperature to produce low and heavy atoms from much violent fusion processes in the different regions inside the Star's heart. In the fusion process changes in the balance of mass was occurred partially, the total mass of a produced matter is lower than the total mass of a reacted atoms. The missing mass was converted into an energy shape according to a well-known Einstein's equation of energy conversion as written as below when the speed of light c is constant in space:

$$E = mc^2 \qquad (2)$$

Where E is the energy in unit joules, m is the missing mass in kilograms, and c is a speed of light in m/s, speed of light in vacuum equals to $3\,x\,10^8$ meters per second. The sun produces huge amount of energy when

hydrogen isotopes are fused and converted into helium nuclei. According to eq. (2) about 5 million tons of Sun's mass converted to energy at every second, and it equals to $(4.5\ x\ 10^{26}\ Joules\ )$. There is enough matter in the sun to keep its fusion process more than five billion years, the hydrogen fuel supply may run out, but not in this moment. Following nuclear Fusion of two light nuclei such as those of Deuterium and Tritium (H^2 and H^3) fuse together to form a heavier nucleus is a helium atom ${}_2^4He$ plus a neutron and 17.6 Mev that produced from reaction [10]. Hydrogen fusion equation could be written as:

$$\boldsymbol{H^2 + H^3 \rightarrow {}_2^4He + {}_0^1n + 17.6\ MeV} \qquad \textbf{(3)}$$

Because of the strong Coulomb's repulsion force between the deuterium and tritium (H^2 and H^3) nuclei very large kinetic energy of 1MeV is needed to get the nuclei close enough together for the attractive nuclear forces to become effective and causes fusion to begin successfully. The foundation of power from the hydrogen fusion has the potential for future use because of the much abundance of such fuel and the absence of some of the hazardous presented by fission reactors and nuclear bombs. Hydrogen fusion maybe used artificially in sooner future to generate huge amount of electric power. Most stars are still producing energy from nuclear fusion processes. The nuclear fusion is a reaction that feeding solar atmosphere with extra heating and luminosity. The photosphere layer is the most visible to the human eyes, the temperature of a photosphere layer reaches (5800 ℃), chromosphere region its temperature may become a (10,000 ℃), and corona is the outermost hotter layer of a Star's atmosphere, its temperature exceeded many millions of kelvins. Sunspots are darker appearing areas on the photosphere, and they seem to fluctuate in frequency over about an 11-year cycle. They appear darker because they are cooler regions of solar atmosphere where temperature changed from 3,000 °C to 4,000 °C relative to the surrounding that reached to 6,000°C. The Sun's corona lies above the chromosphere but extends millions of kilometers into an outer space. It is shown clearly during a total solar eclipse, but it is also observable by a Coronagraph, Coronagraph is a useful telescope that designed to block out the direct light from a star and Sun. Spectroscopic measurements indicate very strong ionization in the corona region and a plasma temperature which excess of high degree that reaches more than 2000000 kelvins, much hotter than the photosphere and chromosphere layers. The "corona" is a Latin word means 'crown'. High mass stars may become a red supergiant, when its fuel runout and fusion process suspended at the third stage of its life. The stars are hot plasma spheres and luminous objects in the heaven. They radiate radiations in all directions with different frequencies and wavelengths. The star's luminosity L can be calculated mathematically by using eqs. (4) and (5). The stars have their different effective temperatures. The surface temperature of a Sun is about 5800 kelvins, and other high mass stars may exceed 30,000 Kelvins. High mass stars have hotter surface temperature as compared to the low mass star's temperature. In fact, high mass star has nuclear fusion of different atoms to produce many new atoms, and to feed its outer atmosphere with an additional temperature. [11] The luminosity of a high mass stars is higher than that the low mass stars, because high mass stars have large area of fusion, and hotter surface temperature as compare to any low mass stars. The Stefan–Boltzmann equation used largely to determine the luminosity of stars:

$$\boldsymbol{L = \sigma A T^4} \qquad \textbf{(4)}$$

$$\boldsymbol{L = \sigma 4\pi r^2 T^4} \qquad \textbf{(5)}$$

Where **L** is the luminosity of Stars, ***A*** is the surface area of a Luminous Stars, the radius of stars **r** that determined and measured in meters, where the radius of Sun is 696,340 km, ***T*** is the effective surface temperature of Stars and black body radiations that measured in kelvins, and $\boldsymbol{\sigma}$ is the Stefan–Boltzmann constant with a value 5.670374419×10^{-8} $W\cdot m^{-2}\cdot K^{-4}$. According to eq.(5) Sun's luminosity is calculated mathematically and defined by the International Astronomical Union to be ($L\odot = 3.828\times10^{26}$ W). This value is same as that calculated by eq. (2) before founded it by Einstein's equation of an Energy. The luminosity can be determined mathematically by eq. (2) and eq. (5). High mass star maybe used most of its fuel urgently to expand into outside and become a red Supergiant at the third stages of its life. Nuclear fusion in the heart of high mass stars is going actively. Stars are fuelled by thermonuclear fusion, where high temperature and pressure overcome atomic nuclei's natural electric repulsion, and allowing atoms to fuse into new heavier elements. Stars are luminous and glow much enough when nuclear fusion in the heart of stars support it. The nuclear fusion is a main source of energy and luminosity for all stars. Following an equation that make comparisons between the luminosity of stars with different masses and Sun:

$$\boldsymbol{L = L\odot(\frac{M}{M\odot})^{3.5}} \qquad \textbf{(6)}$$

Where L is the luminosity of stars as compared to the luminosity of a Sun $L\odot$. M is the mass of stars, and ($M\odot = 2\ x10^{30}\ kg$) is the mass of Sun. The luminosity of a star is a measure of its energy output, and therefore a measure of how rapidly it is using up its fuel supply during nuclear fusion processes at second stages of star's life that named a main sequence star. The luminosity of stars is directly proportional with a mass of a star M, where the luminosity of star may increase when its mass or surface temperature increased. Luminosity is a measure of radiated electromagnetic power from luminous objects, where an energy E that lost per unit time t by stars, and luminous objects according to following equation:

$$\boldsymbol{L = \frac{dE}{dt} = \frac{E}{t}} \qquad \textbf{(7)}$$

Luminosity refers to the total amount of energy produced by different luminous celestial bodies such as (stars, galaxy) per unit time, luminosity maybe measured in joules per second or Watts in SI units. After 10 billion years the Sun may become a red giant.

$$\boldsymbol{t = \frac{E}{L} = 10^{10}\ years\ (\ M/(M\odot)(L/L\odot)^{-1}} \qquad \textbf{(8)}$$

From eqs. (6) and (8) yields to following new equation that make comparisons between the lifetime of stars with lower and higher masses and Sun:

$$\boldsymbol{t = T\odot(\frac{M}{M\odot})^{-2.5}} \qquad \textbf{(9)}$$

$$\boldsymbol{t = T\odot(\frac{M\odot}{M})^{2.5}} \qquad \textbf{(10)}$$

Where ***t*** is the Lifetime of stars as compared to the Lifetime of a Sun $\mathbf{T\odot}$, where Lifetime of a Sun is so

long about 10 billion years ($\mathbf{T\odot=10^{10}}$ years). M is the mass of star, and M$\odot$ is the mass of Sun. The Lifetime of star ***t*** is inversely proportional with a mass of star M, where the Lifetime of star may decrease when its mass increased. For star with a mass 20 solar masses, and its lifetime becomes ($t = 5.59 \times 10^6$ years).

3.3 Red Supergiant Star

Red supergiant has the largest radius of all known stars in the visible Universe. It has lower surface temperature below 4,000 K. This is very cool for a star and makes them to shine with a red colour. The star Betelgeuse in the constellation of Orion is a red supergiant star.[12][13] Red supergiant evolves from large main sequence star when its fuel exhausted and nuclear fusion suspended at its heart. Betelgeuse is a red supergiant and one of the largest stars much visible to the naked eyes. It is usually the tenth-brightest star in the night sky after a Rigel star, it is the second brightest star in the constellation of Orion. The Orion Nebula is located around 1,350 light-years away from Earth.

Red supergiant is a third stage of Star's evolution, when the fusion processes was suspended at the core of a such expanded star after its fuel of fusion runout and its size expanded like a big ball of a cold plasma. The red supergiant is a star that its outer layers may expand outward, when its core contracts inward reversely, also its surface temperature will decrease to become cooler to reach 3700 K and will glow with a very reddish colour. The star has now become a red supergiant star such as a Betelgeuse has a great radius, and size, it is a big sphere of plasma, when its radius expanded into space, and its heart may contract inward deeply to form new stage of the star's life is a Supernova. Supernova is an exploded and evaporated star.

3.4 Supernova

Supernova is a powerful and luminous explosion of Stars that formed from dead supergiant star [14]. Supernova was formed in the stage four of a star's lifetime, it is an exploded star when a high mass star roughly exploded as a big explosion at the final stage of its life, after its outer layers sheds and expanded into the space, and its core become denser, and squeezed into the centre to form a compact object, outer layers of gas and dust are spreading out into space, forming a stellar nebula which is often in the shape of a luminous ring or bubbles. [15] The remnant core of a Supernova may become a Neutron star or a black hole according to the mass of an exploded star. Normally, Neutron star is a much-squeezed star that formed from the death of a high mass star in the stage five of the final life step of a massive star. Most of materials in the body of all birds, insects, animals, human and microbes were come from the remnants of supermassive stars after violent explosions. All light and heavy atoms were coming from stars after their deaths. Gasses and materials will eject quickly into deep distant sides of the Universe. Most of celestial objects were formed from remnant of high mass stars after explosion. The death of high mass stars will give to another celestial objects a new birth and evolution. Most planets and satellites were formed after supernova death. Supernova is the source of energy and life for all living creatures. Without the support of supernova our exist in this Universe will be impossible or in another way. Atoms and energy from supernova are strong factors for the life of all creatures and whole mankind. The Iron and another heavy atom in our body were come from supernova remnants. Unfortunately, the low mass stars like the Sun can't produce heavy atoms, because its mass and pressure not high enough to do that. We are lucky here to

survive because of heavy atoms were support our life and the life of all creatures for many billion years. Low mass stars like the sun needs to another 5 billion years to explode and support life with few low mass atoms, fortunately high mass stars formed and exploded more than billion years ago and supported the creatures to be formed and develop more than millions of years ago. We are the supernova remnant when its outer layers ejected into space. All of Neutron stars or black holes maybe formed from the remnant core of supernova according to the mass of an exploded stars.

3.5 Neutron Star

Neutron star is a fifth stage of a star's evolution, when the fuel of massive stars runout and it is expanding quickly into space, but its core squeezed to form such compacted body named neutron star. High mass star with mass around 1.44 times the mass of the Sun will shrink inward when nuclear fusion at the core of such star ceased entirely to keep the hydrostatic balance between thermal pressure and gravitational pressure. The gravitational pressure may press on electrons very strongly to push on them with high speed to collide with protons and produce neutrons mostly in the structure of all Neutron stars. Thermal pressure will push on stellar shells outward to explode, and gravity may press inversely on the structure of all stars to shrink inward into the centre to produce denser state of matter is white dwarfs, neutron stars, and black holes with different masses and density. The remnant core of a normal supernova called Neutron stars when high star with mass around 1.44 the mass of a Sun died at the final stages of its life. In such star the neutron degeneracy kept the Neutron star in this state, sometimes called the Neutron star, Magnetar or Pulsar. Pulsar name (from pulsating radio source) is a highly magnetized rotating neutron star that emits beams of electromagnetic radiation out of its magnetic poles into space. [16] The remnant core of a planetary nebula named a White Dwarf. A white dwarf, also called a degenerate dwarf star which composed mostly of electron-degenerate matter, it is a remnant core of a planetary nebula after its shell's expansion outward and its core's contraction inward. The Neutron star is a small and dense star, its mass is higher than the mass of the Sun, while its radius is only 5 or 10 kilometers. Neutron star's luminosity comes from the emission of a thermal energy; no fusion takes place in the heart of it. Nearest known white dwarf is Sirius B, at 8.6 light years away from Earth, but Neutron star can be found in places much away from our solar system. Neutron Stars are thought to be the final evolutionary state of stars whose mass is not high enough to press on its heart further to become a black hole. When a Fusion of carbon, oxygen, and silicon was suspended entirely in the core a main-sequence star, such a star with a high mass may expand to become a red supergiant. If a red supergiant star has insufficient mass to generate new heavy atoms with central temperature around 1 to 20 billion Kelvins, carbon, oxygen, and silicon maybe formed in such a high temperature. Usually, Neutron stars are mostly composed of neutron particles according to a Chandrasekhar limitation. Chandrasekhar limit for a massive star that having a mass 1.44 times the mass of a Sun does not form a white dwarf star, but instead of it was continues to collapse inward and becomes much contract and dense object that named a Neutron star, but blows off its gaseous envelopes outward into the space in a supernova explosion. [17] When the star runs out of its nuclear fuel, the density in the interior increases with a pressure, but the temperature does not change much, the neutrons become degenerate to form the radiations with different frequencies.

When the mass of a star approaches the Chandrasekhar limit is about 1.4 the mass of the Sun, its gravity

attempts to squeeze the star into a smaller volume, forcing electrons to collide with protons to produce mostly Neutrons in a Neutron stars, the density of neutron stars may exceed trillion tons per meter cubic or about (1 x 10^{17} kg/$m^{3)}$. Neutron star is a more compacted object, and so denser than a white dwarf Stars. When the mass of a star exceeds the Chandrasekhar limit, the pressure exerted by the electrons to travel into higher levels with a speed closed to light, the star may collapse into a much denser state to produce Neutron Star or black hole. The black hole may be born in the final steps of a high mass star. The escape velocity inside an event horizon of a black hole exceeded the speed of light, especially inside an inner event horizon region where the cosmic fabric matter and energy strongly distorted and compacted. The captured particles inside an event horizon are in quantum entanglement and fluctuation.

3.6 Black Hole

Black dwarf is a final stage of a star's steps of evolution. Black hole is a remnant core of a high mass star after its death. Neutron star may become a black hole in a stage six when it tears additional mass from its companion star to exceed a Chandrasekhar limit. After mass and stress of Neutron star increased high enough, it may collapse inward further and further to become closed star on itself and become a dark massive object that named a black hole. Black hole is a compact star; its density and gravity incredibly strong even light can't escape from its powerful gravitational field. The gravitational field is a compacted dark fabric of a Universe around black hole, even light or particles can't pass through such super distortion and gravitation of a black hole by normal speed of light is c about 300,000 km/s. Dark fabric particles are so compacted and distorted around the heart of black hole that named a Singularity, even light can't break that compacted gravitational wall by speed of light in space. In fact, nuclear fusion was suspended in the heart of a high mass star for a long time after it becomes a red supergiant star in the final stages of a star's life. Black hole is a powerful object of the Universe, it has the ability to capture and collect gas, dust particles, and electromagnetic radiations from its surrounding when materials fall down into its gravitational field. Materials may orbit the black hole in the bright region named accretion disc, they become luminous, glow clearly, and radiate different types of electromagnetic radiations when materials interacting together during direct frictions and collisions were occurred directly between them.[18] When materials fall into the capture of a black hole, it may accelerate them to evaporate and radiate radiations. The speed of materials may reach close to the speed of light or exceed it in the border of a black holes, for this reason materials will radiate energy and show for us the real location and existence of black holes. Black hole is the great cleaner and accelerator of the visible Universe, because it has the capacity to capture materials and accelerate them to incredible speed, and make materials to collide together strongly. Black hole may grow more and more when collecting high enough gas, light and dust particles from its surrounding. Black hole may become a supermassive black hole when maximum number of black holes are merging together in a violent environment or collecting additional amount of matter during its cosmic journey. The giant collision between two black holes may form a new black hole with a higher mass or split them totally or partially into very small pieces in the size of grains or atoms named tiny black holes. Tiny black holes are the remnant of high mass black holes formed from their violent collisions or produced in the region where cosmic fabric strongly distorted and closed together to form such compact objects. Black Hole is a region of a cosmic fabric matter and energy where the gravitational field is so strong even subatomic particles, and electromagnetic radiations such as photon of light or gamma rays can't escape easily from its powerful distortion and attraction. Black hole may

build a pure tunnel in the structure of a cosmic fabric that attract all types of matter and energy towards it to fill it, and to save the general balance of a whole Universe. All types of matter and can make tunnels in the fabric of a Universe according to its mass, density and energy. The singularity of a black hole or black hole itself much compacted and distorted world, for this reason its tunnel that it formed in the body of a dark matter is very homogeneous and bounded, for this reason particles to escape through it was needed to additional energy and contracted wavelengths to break its quantum tunnels. Particles were escaped from such compacted and distorted world have the energy which incredibly high, nothing can capture or obstacle them from motion easily. In the past, the theory of general relativity predicted that a sufficiently compact mass and energy can deform spacetime to form a compacted object named a black hole.[19] The boundary of a black hole very compacted where no chance for any objects or radiations to escape from it directly is called the Event Horizons. The event horizon is a dark region in the centre of a different black holes, such as tiny black holes, black dwarfs, stellar black holes, supermassive black holes, and even Supergiant black holes. Black holes can grow and expand more and more when gathering materials from space or merging together in giant collisions, the cosmic fabric matter may vibrate strongly during such powerful collisions were occurred in the nature.

Black hole is a remnant core of a died Star that has high density and gravity, nothing can escape from its giant gravity easily even light particles, because the Cosmic fabric incredibly curved, distorted and compacted in that region around the singularity that named event horizon.[20][21] In fact, black hole is a great regression region where all types of matter and energy sucked violently into its centre. General structure of a Black hole consists of a much-compacted region named a singularity in the heart of a black hole, event horizons, Photosphere or Ergosphere, and accretion disc are surrounding the singularity from outside. Singularity is a great regression region that located at the centre of a black hole, where all types of matter and energy incredibly crushed, distorted, and compacted at this tiny point, it is a no return region because the density and gravity incredibly high in this combined region, the distance between particles in this region is very tiny and narrow even light can’t pass throughout it easily. Light needs to many years to escape from this violence environment. Escape velocity inside singularity closed to the speed of soul. Singularity is a much-compacted region in the Universe where all physics laws are failed to describe this region at this moment. According to my concept, singularity is only compacted matter in the tiny size with great density, where cosmic fabric strongly distorted and the time was much closed at here. The singularity surrounded by an internal event horizon; it is a dark region because light can’t reach into our eyes directly from this region. Fortunately, outer an event horizon that named external event horizon the radiation can escape successfully with a speed 300,000 km/s to reach our eyes, because in this distant region of the singularity the cosmic fabric is not so compact to capture light particle forever. The photon sphere is a spherical boundary of zero thickness in which photons may move on tangents to that sphere would be trapped in a circular orbit around the black holes. A photon’s sphere or photon circle is an area or a region of space where gravity is so strong that photons are forced to travel in orbits around black hole, it is sometimes called the last stable photon orbit. The ergosphere is a region located outside a rotating black hole's outer event horizon, the size of the Ergosphere is the distance between the ergosurface and the event horizons. An accretion disk is another region of a black hole’s structure (often a circumstellar disk) formed by diffuse materials in orbital motion around any massive central body, the central body is typically Stars, nebulae, protostars, Stellar systems, Neutron Stars, and Black holes. The Gravity, Friction, cosmic fabric distortion, uneven irradiance,

magnetohydrodynamic effects, angular momentum, and other forces of nature induce instabilities causing orbiting materials in the disk to spiral inward towards the central body. According to the conservation law of an angular momentum, all materials are speeding up in their motions to orbit in an elliptical or perfect circular path around centre of massive object.[22] The Gravitational and frictional forces compress the density of materials, increase the collisions between them, and raise the temperature of the materials, causing the emission of electromagnetic radiations in different frequencies, and wavelengths, those around compact objects such as neutron stars and black holes emit in the X-ray and gamma radiations are other parts of an electromagnetic spectrum. Black hole as anything in the Universe has its limited life circle that began from death of stars to die or evaporate after collision with one another in the long coming future. Eventually, the black hole may develop and expand its event horizon more and more when collecting and swallowing any type of matter and energy in its long journey. The density of objects can be calculated mathematically by following equation:

$$\boldsymbol{\rho = \frac{M}{V}} \qquad \textbf{(11)}$$

Where ρ is a density, M is the mass of star and celestial objects, V is the volume of Stars. Stars and planets have spherical shapes where their volumes can be calculated by following equation:

$$\mathbf{V = \frac{4}{3}\pi r^3} \qquad \textbf{(12)}$$

Where r is radius of spheres and circles.

4. Results and Discussion

Everything in the Universe has its own history of creation and destruction. Star like anything in the Universe has its own history of formation and evolution from Birth to Death.[23] In the first stage of a stellar formation and evolution called protostar, it is created from giant Stellar nebula when it has a limited mass, density, pressure, and temperature that not high enough to start with a nuclear fusion process at its core. The protostar has lower density, and brief time to grow, but its radius and luminosity are 100 to 1000 times the radius and luminosity of the main sequence stars. Protostar is gathering high enough mass from its surrounding after few millions of years may start with a nuclear fusion at its heart in the second stage of a star's formation and evolution that named a Main sequence star, it has hotter and denser centre to start with a nuclear fusion. The Sirius A is an example of a main sequence stars, and it has the mass around 2 times that of the mass of the Sun, at the heart of both a Sun and Sirius A nuclear fusion takes place for a long time ago when their central pressure, density, and temperature incredibly increased and ready for that. Sirius A is one of the brightest and luminous stars in the night sky for a long time was well-known by mankind. The average density of the Sirius A is $563\ kg/m^3$, its surface temperature reaches 9,950 kelvins, its radius 1.19 million kilometers, its luminosity about 25.3 L$\odot$, and its life time may exceed billions of years. Nuclear fusion in the heart of high mass stars may suspend after next millions or billions of years when its nuclear fuel runout at whole, the new stage of star's life may start that named a red supergiant star in the third stages of a star's lifetime. Red supergiant has a limited density, pressure, and temperature, but its radius, volume, and surface Area are so giant as a result its luminosity is hundreds of times bigger than the luminosity of any main sequence stars. Its surface temperature decreased which shown

clearly in red colour, also its life time about 10 million years, it has short lifetime as compared to the age of a Main sequence stars. The surface of a red supergiant stars may expand outward more and more, and its core will squeeze inversely to become a supernova in the fourth stages of a Star's lifetime. Supernova is a greatest luminous stellar explosion, and its radius increases high enough to become 1000,000,000 times luminous as the Sun, the density of supernova is very low about 1.7×10^{-10} kg/m^3, and its lifespan very short is about 20,000 years.

Furthermore, the Neutron star was born from the remnant core of a Supernova in the fifth stage of a high mass star's death, it is one of the compacted objects, and its density very high exceeds $1.0\ x\ 10^{17}$ kilogram per meter cubic because its radius very short about 5 to 10 kilometers. But lifetime of a neutron star may reach 2 billion years to stop from further radiation emissions when its density and pressure increased and its size squeezed inward to become a black hole in the stage sixth of a star's lifetime.[24] Black hole is the final fate of a high mass star's evolution. It is a dark and cold sphere of a denser star in the Universe. Its radius is only 9000 meters for black hole with three solar masses, its Surface temperature is changeable from 0 to infinity kelvins, sometimes it emits no visible light, only a very faint infrared radiation, Because of its small size and high compacted mass, its density is very high, over 1000,000 trillion times that of the Sun. Its radius and surface area are very low, as a result its luminosity is very low about 0 watt to infinity watts. It can be detected in the space because its accretion disc may emit radiations when captured any types of materials or radiations from its surrounding. Sometimes black hole stayed as a silent dark sphere with zero emission of radiations, its luminosity is zero for that moment. Also, its luminosity incredibly increases to infinity level, when it is gathering high enough mass from its surrounding or tears any companion star to radiate like hot object. The life time for a black hole may exceed to infinity number more than 1000 trillion years to evaporate fraction of it. The black hole is much stable state of matter and energy, it is very compacted and combined object of the nature. It may need to incredible time to be annihilated and evaporated in the future, if not merged together or effected by other powerful force of the nature to accelerate its evaporation. It still a theoretical object of the Universe. It may be produced from the dead core of high mass star. The remnant of died stars will survive to be annihilated entirely for more than next trillion years coming according to stellar structure evolution theory. Black holes are exploding inward to keep its shape much smooth for a long time. Compact stars like black holes maybe evaporated and annihilated during rapid collision and accidents.

Everything in the nature will die in the future urgently or lately. In fact, the death of most black holes will exceed to many trillion years, because black hole can grow more and more to become a supergiant black hole after collecting much enough mass from its surrounding. Black hole is not evaporated easily, but it may grow higher than that to decay. Its continuous growth by collecting dust and gas from its surrounding much suitable reason to support the development and stability of any black holes. The annihilation and evaporation of any compact stars may need to next billions of years, compact objects are much stable and complex objects of the visible Universe. The urgent evaporation of such bodies needs to a violent force of nature. The density of all Stars was determined by using eq. (11). Luminosity of all main sequence Stars with different masses was determined by using eq. (6), and lifetime of Stars mathematically calculated by using eq. (10). The fate of stars and general properties of stars changeable according to mathematical equations and environment where stars formed from. There is nothing constant forever in this great Universe, the mass, density, luminosity, and lifetime

of stars changeable from the seconds were stars formed, and died in the long future coming. Lifetime of stars is different according to mass and density of stars.

Table 1: General Properties of High Mass Stars from Birth to Death

Stellar Objects	**Density = ρ (kg/m^3)**	**Luminosity = L (*Watt*)**	**Life Time = T ($Years$)**
Protostar	$1.4\ x\ 10^{-12}$	$4.0\ x\ 10^{30}$	0.5 million to 7.0 million
Sirius A	563	$1.016\ x\ 10^{28}$	1.0 billion
Red supergiant Like Betelgeuse	0.000012	$5.0\ x\ 10^{30}$	10.0 million
Supernova	$1.7x10^{-10}$	$4.0\ x\ 10^{35}$	20,000
Neutron Star	$1.0\ x\ 10^{17}$	$2\ x\ 10^{27}$	2 billion
Black hole	$2\ x\ 10^{18}$	0 - infinity	More than 1000 trillion

5. Conclusion

Life cycle of a high mass stars and their properties were explained in detail. Eventually, it may be concluded high star has its own life cycle when it was born from a stellar nebula as a protostar that formed in the first stages of a star's formation, and it may die in the final stages of a star's evolution when it becomes a red supergiant, supernova, Neutron star, or black hole after star's death entirely. The Universe is filled with a low mass and high mass stars. Both of Sirius A and Rigel are two high mass stars and much luminous stars in the night sky. Unfortunately, lifespan of a high mass star not so long as low mass stars. High mass stars have short lifetime may collapse as supernova to distribute different types of atoms into space when its fuel of burning was runout entirely at a brief possible time. The protostar, main sequence star, red supergiant star and supernova are contained with an ordinary matter and energy where dark fabric was much slightly distorted and warped under their limited density and stresses. In another hand, the dark fabric is warping very strongly under the effect of a compact stars such as Neutron stars and black holes, they are two small, dense and very smooth objects of the Universe were drowning steeply into the structure of a dark fabric. Neutron stars is a remnant core of a high mass stars where nuclear fusion was stopped at its heart for a long time, but its luminosity and temperature were come from its own neutron degeneracy. Neutron degeneracy may not sustain for a long time, and neutron star may squeeze inward entirely to become a black hole is a final step of a star's evolution. Black hole is gathering additional mass from its surrounding to grow more and more when its singularity radius deeply squeezed inward to become much dense and compact, and its event horizon, and accretion disc are expanding outward to become a supermassive black hole. The supermassive black hole may grow more and more when its mass was increased

after collecting plus mass from its surrounding or collided with another black holes at its journey to produce another monster of black holes that named supergiant black hole. Supergiant Black hole has the ability to swallow many galaxies at once. The fate of Universe is swimming towards to the biggest monster of the Universe is a supergiant black hole that developed after collecting much enough mass and energy from its surrounding. Supergiant black holes have very large accretion disc, and strong gravitational field to capture any types of matter and energy in distant places. High mass black holes have strong effect on the cosmic fabric distortions, and objects have higher angular momentum in the accretion disc of such powerful celestial objects to save the conservation law of angular momentum.

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6.Conflict of Interest

Authors declare that they have no conflict of interests.

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References

[1]. A. P. Boss; R. H. Durisen (2005). "Chondrule-forming Shock Fronts in the Solar Nebula: A Possible Unified Scenario for Planet and Chondrite Formation". The Astrophysical Journal. 621 (2): L137–L140. arXiv:astro-ph/0501592. Bibcode:2005ApJ...621L.137B. doi:10.1086/429160. S2CID 15244154.

[2]. Stahler, S. W. & Palla, F.(2004). The Formation of Stars. Weinheim: Wiley-VCH. ISBN 3-527-40559-3.

[3]. JWST, NASA, and ESA.(2022). https://astronomynow.com/2022/07/12/webb-stellar-nursery-in-carina/

[4]. Sadiq, Sabir, and Anuar Alias. "Black holes formations and dark fabric distortions." American Academic Scientific Research Journal for Engineering, Technology, and Sciences 87, no. 1 (2022): 168-187.

[5]. Thierry Montmerle; Jean-Charles Augereau; Marc Chaussidon (2006). "Solar System Formation and Early Evolution: the First 100 Million Years". Earth, Moon, and Planets. Springer. 98 (1–4): 39–95. Bibcode:2006EM&P...98...39M. doi:10.1007/s11038-006-9087-5. S2CID 120504344.

[6]. A. P. Boss; R. H. Durisen (2005). "Chondrule-forming Shock Fronts in the Solar Nebula: A Possible Unified Scenario for Planet and Chondrite Formation". The Astrophysical Journal. 621 (2): L137–L140. arXiv:astro-ph/0501592. Bibcode:2005ApJ...621L.137B. doi:10.1086/429160. S2CID 15244154.

[7]. S Pfalzner, M B Davies, M Gounelle.(2014). "The formation of the solar system". Max-Planck Institut fur Radioastronomie, Auf dem H ¨ ugel 69, 53121 Bonn, Germany ¨,. Lund Observatory, Department of Astronomy and Theoretical Physics, Box 43, 22100 Lund, Sweden. IMPMC, Museum National d'Histoire Naturelle, Sorbonne Universit ´ es, CNRS, UPMC & ´IRD, 57 rue Cuvier, 75005 Paris, France.

[8]. Woolfson, M. (2000). "The origin and evolution of the solar system" (PDF). Astronomy & Geophysics. 41 (1): 12. Bibcode:2000A&G....41a..12W. doi:10.1046/j.1468-4004.2000.00012.x. Archived (PDF) from the original on 11 July 2020. Retrieved 12 April 2020.

[9]. LeBlanc, Francis. (2010). An Introduction to Stellar Astrophysics. Université de Moncton, Canada. John Wiley & Sons. ISBN 9780470699560(pbk.).

[10]. Simona E. Hunyadi Murph EMAIL logo and Melissa A. Murph. (January 27, 2022). " Nuclear fusion: the promise of endless energy". Physical Sciences Reviews Journal. https://doi.org/10.1515/psr-2021-0069.

[11]. Markus J Aschwanden.(2005). Physics of the Solar Corona An Introduction with Problems and Solutions. ISBN 3-540-30765-6 Springer-Verlag Berlin Heidelberg New York.

[12]. Sarah L E McDonald, Ben Davies, Emma R Beasor. (27 November 2021). "Red supergiants in M31: the Humphreys–Davidson limit at high metallicity ". Monthly Notices of the Royal Astronomical Society, Volume 510, Issue 3, March 2022, Pages 3132–3144, https://doi.org/10.1093/mnras/stab3453.

[13]. Levesque, Emily M.; Massey, Philip; Olsen, K. A. G.; Plez, Bertrand; Josselin, Eric; Maeder, Andre; Meynet, Georges (2005). "The Effective Temperature Scale of Galactic Red Supergiants: Cool, but Not as Cool as We Thought". The Astrophysical Journal. 628 (2): 973–985. arXiv:astro-ph/0504337. Bibcode:2005ApJ...628..973L. doi:10.1086/430901. S2CID 15109583.

[14]. Kiss, L. L.; Szabo, G. M.; Bedding, T. R. (2006). "Variability in red supergiant stars: Pulsations, long secondary periods and convection noise". Monthly Notices of the Royal Astronomical Society. 372 (4): 1721–1734. arXiv:astro-ph/0608438. Bibcode:2006MNRAS.372.1721K. doi:10.1111/j.1365-2966.2006.10973.x. S2CID 5203133.

[15]. Ritter, Andreas; Parker, Quentin A.; Lykou, Foteini; Zijlstra, Albert A.; Guerrero, Martín A. (1 September 2021), "The Remnant and Origin of the Historical Supernova 1181 AD", The Astrophysical Journal Letters (in German), 918 (2): L33, arXiv:2105.12384, Bibcode:2021ApJ...918L..33R, doi:10.3847/2041-8213/ac2253, hdl:10261/255617, ISSN 2041-8205, S2CID 235195784, retrieved 8 November 2021

[16]. Robert Fisher, Pritom Mozumdar, and Gabriel Casabona. (2019). "Carbon Detonation Initiation in Turbulent Electron-degenerate Matter".The Astrophysical Journal, Volume 876, Number 1. DOI 10.3847/1538-4357/ab15d8.

[17]. Golam Mortuza Hossain & Susobhan Mandal. (13 January 2022). "The methods of thermal field theory for degenerate quantum plasmas in astrophysical compact objects". Springer Journal, DOI: https://doi.org/10.1007/s41614-021-00062-0.

[18]. Nadis, Steve (2 December 2019). "Black Hole Singularities Are as Inescapable as Expected". quantamagazine.org. Quanta Magazine. Retrieved 22 April 2020.

[19]. Ajit Kumar Mehta, Alessandra Buonanno, Jonathan Gair, M. Coleman Miller, Ebraheem Farag, R. J. deBoer, M. Wiescher, and F. X. Timmes. (2022). " Observing Intermediate-mass Black Holes and the Upper Stellar-mass gap with LIGO and Virgo". The Astrophysical Journal, Volume 924, Number 1. DOI 10.3847/1538-4357/ac3130.

[20]. Y. Yang, I. Bartos, G. Fragione, Z. Haiman, M. Kowalski, S. Márka, R. Perna, and H. Tagawa. (2022). "Tidal Disruption on Stellar-mass Black Holes in Active Galactic Nuclei". The Astrophysical Journal Letters, Volume 933, Number 2. DOI 10.3847/2041-8213/ac7c0b.

[21]. Aoto Utsumi, Ken Ohsuga, Hiroyuki R. Takahashi, and Yuta Asahina. (2022). " Component of Energy Flow from Supercritical Accretion Disks Around Rotating Stellar Mass Black Holes". The Astrophysical Journal, Volume 935, Number 1. DOI: 10.3847/1538-4357/ac7eb8.

[22]. Montgomery, Colin; Orchiston, Wayne; Whittingham, Ian (2009). "Michell, Laplace and the origin of the black hole concept". Journal of Astronomical History and Heritage. 12 (2): 90–96. Bibcode:2009JAHH...12...90M.

[23]. Andrew, J. S. & Hamilton. (2020). General Relativity, Black Holes, Cosmology.

[24]. Clery D (2020). "Black holes caught in the act of swallowing stars". Science. 367 (6477): 495. Bibcode:2020Sci...367..495C. doi:10.1126/science.367.6477.495. PMID 32001633. S2CID 210984462.