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A Treatise on Astronomy and Space Science

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Abstract* — Astronomy and Space Science has achieved a tremendous enthuse to ardent humans from the early primitive era of civilization till now a days. In those early pre-history days, primitive curious men looked at the sky and got surprised and overwhelmed by the obscure uncanny solitude of the universe along with all its terrestrial bodies. This only virulent bustle of mankind regarding the outer space allowed him to open up surprising and splendid chapter after chapter and quench his thrust about the mysterious universe. In the present paper we are going to discuss several important aspects and major issues of astronomy and space science. Starting from the formation of stars it ended up to black holes – which are a present day most hot topic as well as almost an open research area in astronomy and astrophysics and space science. While discussing those many things automatically astrophysics and space science came into the scenario which has also been detailed as and when needed.

Keywords* — Astronomy, Astrophysics, Space Science, Planet, Star, Nebula, Galaxy, Super Galaxy, Binary Star, Chandrasekhar Limit, Red Giant, White Dwarf, Supernova, Neutron Star, Black Hole, Singularity, Event Horizon, Black Hole Entropy, Naked Singularity, Space Time Curvature, Space Time Interval, Light Cone, Time

I. INTRODUCTION

Astronomy and astrophysics [1,2,3,4] is that branch of science which deals with the terrestrial bodies and physics of space where these are situated. From the pre-history era of civilization till the present day, this universe along with its terrestrial members surprised the mankind and created much curiosity in them to know about those. The spectrum of the types of these heavenly bodies is quite large. It starts from the nearest neighbor of earth – the satellite 'moon' and ends up to the furthest terrestrial bodies like all kinds of stars, black holes, nebulas, galaxies super galaxies etc., some of which are possibly billions to trillions light years away from us.

We have organized the paper in this way. Section II discusses preliminaries of astronomy and origin of universe. Section III presents galaxies and super galaxies. Section IV details star formation and different types of stars. Section V discusses supernova formation and formation of neutron star, pulsar and quasar. Section VI presents black holes and their different variations. Section VII details naked singularity of a rotating black hole. Section VIII discusses black hole entropy. Section IX details space time, space time curvature, space time interval and light cone. Section X presents the general and special theory of relativity. Section XI details the different definitions of time from different viewpoint as well as different types of time. Last but not least Section XII is the conclusion which sums up all the previous discussions.

II. PRELIMINARIES OF ASTRONOMY

According to Big Bang Theory [1,3,4,8], our universe originated from initial state of very high density and temperature. Since that time it is continuously expanding. The Big Bang to originate the universe occurred 13.73±0.1 billion years ago. The theory of Big Bang is also called the theory of expanding universe.

While we are able to visualize at best only approximately two to three thousand stars by our naked eye, even with the help most extremely powerful radio telescope, merely trillions of stars and other terrestrial bodies are visible. The star which is nearest to our sun is 'Proxima Centaury' and even that is four light year away from the sun. An assembly or a gathering of a group or cluster of billions of stars at some place in sky is called a galaxy. The size of a galaxy may be tremendously as huge such as the end to end distance of some galaxy may be several trillions of light years. Our sun along with our earth and other planets are within such a galaxy which is the well-known 'Milky Way' galaxy. Inside any galaxy along with stars there may exist large number of huge clouds of dusts and gaseous elements – either dark or bright. These are called Nebulas. From these clouds gradually stars are formed in course of time.

III. GALAXIES AND SUPERGALAXIES

In clear sky one can observe a milky band which is the manifestation of the diffused light of some billions of stars which is called galaxy [1,3,8]. As already told in previous section, the sun is situated in our galaxy which is called the Milky Way Galaxy.

All the galaxies are enormously far away from one another. As for example, the distance between our galaxy 'Milky Way' and our nearest galaxy 'Andromeda' is as large as 20 billion light years.

Galaxies may be isolated in space (Singleton Cluster) or form either a small galaxy cluster or a large galaxy cluster (e.g. Virgo Cluster).

A gathering or a group or a cluster of large number of galaxies is called ‘super galaxy’ or a ‘galaxy cluster’. Thus a super galaxy may be viewed as a ‘galaxy of galaxy’ [1]. Our galaxy "Milky Way", "Andromeda" along with approximately twenty four such other galaxies forms one super galaxy. In one such super galaxy "Hydra" there is several thousand galaxies housed inside.

Conventionally galaxies may be classified according to either their (1) Shape or (2) Size [1,8].

(1) Shape: In this method galaxies are classified based on their shape or appearance. This type of galaxy classification is called Hubble Classification. From this angle of view there are broadly five different galaxy types visualized, namely

- Elliptical
- Spiral
- Lenticular
- Disk
- Irregular

Two main (prominent) galaxy shapes are (i) Elliptical Galaxies (E type) and (ii) Spiral Galaxies (S, SB and S0 type). Elliptical Galaxies have smooth, mostly centrally concentrated star distribution. Spiral Galaxies in their turn are subdivided into ordinary spirals (S type) and barred spirals (SB) [1,8].

(2) Size: From the size angle of view, galaxies range from dwarfs (less than one million stars within it, diameter only a few light years) to super giants (with over a trillion stars, with diameter over 6×105).

Two different theory of galaxy formation are probable as below:

- Bottom Up Hierarchical Method
- Top Down Hierarchical Method

Most popular theory of galaxy formation is Bottom Up Hierarchical Method [8]. With this theory, the first galaxies of the Universe from the early gas (creating stars inside) were small. These small galaxies gradually clubbed or clustered together to result larger ones. Thus obviously, larger galaxies we see in the sky are much younger than the smaller ones.

According to other theory of Top down Method, the universe originally had one and only one terribly huge size galaxy which was continuously broken down into smaller galaxies. Contrary to the bottom up theory, according to this the larger galaxies are much older than the smaller ones.

We compute the distance of a galaxy from its recession velocity from earth (measured with the help of redshift of the galaxy) according to "Hubble's Law" [1,8]. According to this law the recession velocity of any galaxy is directly proportional to its distance from earth. Also the shape and size of a galaxy, which is say five billion light years away from earth is actually the view of the galaxy at a time, five billion years ago. Similarly the view of a galaxy at a distance of three trillion light years away from us is really the view of that galaxy of three trillion year ago.

IV. FORMATION OF DIFFERENT TYPES OF STAR

Nebulas are dense gaseous cloud of size approximately 1,000 light years which usually forms stars. In general there are two different types of Nebula namely Diffuse (Irregular) and Planetary (Regular) Nebulas. The diffuse Nebulae are in their turn sub divided into dark and luminous. The luminous one may be divided into Reflection and Emission type. The Emission type may be either of Supernova Remnants or Normal i.e. local concentration of hot gas ionized by the high energy radiation of nearby hot stars.

The planetary nebulae [1,4,8] are usually regular shaped one and formed by the shells or materials ejected symmetrically and uniformly by the concerned central stars at certain critical stage of evolution.

Stars are classified [1,8] as below:

(1) Evolutionary stage
(2) Spectra – indicating surface temperature
(3) Populations.

(1) Evolutionary Stage:

(a) *Pre Main Sequence Star* – also called proto stars, not yet hot enough for the initialization of hydrogen burning.

(b) *Main Sequence Star* – Producing energy by hydrogen burning or by other nuclear fuels like helium, nitrogen, oxygen, carbon burning (in the case of giants and super giants)

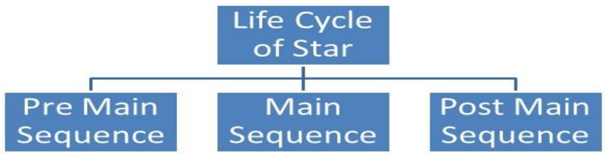

Fig. 1 Life Cycle of Star

(c) *Post Main Sequence Star* – These may be red giant, white dwarf, neutron star, pulsar, quasar, black hole, depending on their mass. During transition from Main Sequence to Post Main Sequence, if the mass of the star (with burnt nuclear fuel) is much more than 1.44M (Chandrasekhar Limit) then a Supernova Explosion occurs.

This Supernova is a violent explosion with which the star ends their life of Main Sequence. Star becomes over a billion or trillion times brighter than Sun for several weeks and even a month. Even it may outshine the galaxy within which the Supernova star exists.

Both neutron star and black holes are formed consequent to the Supernova explosion with the remnants of the star. Whether a neutron star or a black hole would result depends on the mass of the remnants of the star after Supernova. If the mass is exceeding 1.44M but is not exceeding 2M, then neutron star is formed while if the mass is more than 2M a black hole is likely to be formed. (M = Solar Mass also called Astronomical Mass).

At the main sequence, usually star produces energy by the nuclear fusion of hydrogen to form helium. These thereby enter into Post Main Sequence. But some giants and super giants (stars) may also burn some other nuclear fuel like helium, nitrogen carbon etc. to continue their term in Main Sequence. The maximum possible mass of a (main sequence) star is approximately 120M. If the mass of the star is above this it would be blown down by its own radiation. The minimum mass is 0.08M. Below this mass the object never becomes hot enough (due to gravity) at their cores to initiate hydrogen burning.

(2) Spectra:
We can also classify stars by their spectra [1,8]. This indicates their surface temperatures.

Harvard Classification Scheme: Stars are categorized as O,B,A,F,G and K according to their decreasing surface temperature. The types were further sub classified from hottest (0) to coolest (9).

(3) Populations:
Third way to perform classification is by populations [8]. Populations I, Populations II, Populations III indicates gradually lower abundances of heavy elements in stars. This indicates gradually greater age of the star.

Binary Stars

Usually any gaseous body rotating with extremely high speed elongates gradually, and as motion continues, concentration of mass takes place not at the centre but at two particular points on its longest axis. Eventually the gaseous body is split up into two separate parts. These are termed as Binary Stars [1,4,8]. These are Physical Binary Stars. There is another type of Binary namely ‘Optical Binary’. If two stars situated at large distance are in the same ‘line of sight’, they form Optical Binary, also sometimes called ‘Virtual Binary’.

V. SUPERNOVA, NEUTRON STAR, PALSER AND QUASER

If the mass of the main sequence star is beyond the "Chandrasekhar Limit" i.e. 1.44M, (M = Solar Mass or Astronomical Mass) then the fusion process is so extremely rapid that the longevity of the star is at best 1 million years, while those within that limit might possess that as high as 5 million years. The mass of our sun is within ‘Chandrasekhar Limit’ [1,4,8] which in its Post Main Sequence would be converted to ‘Red Giant’ and ultimately to ‘White Dwarf’.

For stars much beyond Chandrasekhar Limit, lying in Post Main Sequence, there is no fusion process and only force acting on the star is the huge gravitational force which attempts to very rapidly collapse the star creating sudden huge heat generated in the star. At this time, the outer shell of the star becomes so hot that the energy cannot be radiated away as quickly as is required to keep up or maintain the structure of the star. With this heat, the star suffers a violent explosion, formally called "Supernova Explosion". Supernovae are extremely bright and some of them may even be visible in broad day light. The “Bull Galaxy” houses the ‘Crab Nebula’. The ‘Crab Nebula’ was originally formed through one Supernova burst [4,8]. Supermassive stars (mass much more than ‘Chandrasekhar Limit’) in Post Main Sequence may even undergo more than one Supernova.

The remnants of a Supernova burst are always converted into a Nebula. After burst, as the mass reduces to within ‘Chandrasekhar Limit’, the central star may be ultimately converted into a White Dwarf in the same process a red giant is reduced to a White Dwarf.

Even after the Supernova burst, in the case the mass is above ‘Chandrasekhar Limit’ (and is not too much so as to undergo another Supernova) it would not be converted to ‘Red Giant’ and “White Dwarf’. Rather through huge gravity all the electrons will collapse with central protons in an atom and the nucleus would be only charge less neutrons. Thereby the whole Post Main Sequence star in this case would be the combination of neutron particle with huge density. It is also possible so happen that the post main sequence star having mass two times that of the sun may have diameter of only 25 km.

The neutron particles now (according to Pauli Exclusion Principle) will apply opposite pressure to resist any further collapse. The gravitational collapse of the star is balanced by the degeneracy pressure of the neutrons. This is what we call the neutron star.

A pulsar or a pulsating star is one variation of neutron star with comparatively extremely large size.

Due to its huge mass, the gravitational forces try to further collapse the neutrons in the pulsar star, while the neutrons try to resist the force. So a pulsar periodically expands and collapses.

This periodic expansion and contraction creates and emits radio and light waves with frequency of approximately 30 cycles per second [4,8].

The source of huge amount of radio and light waves is called a Quasar. This is a very large pulsar and is nothing but extremely large neutron star.

So a pulsar is a subset of neutron star, which in its turn is a superset of quasar. That is all pulsars are neutron stars, but all neutron stars are not pulsars. Similarly all quasars are pulsars, all pulsars are not quasars.

Through continuous huge collapse (due to gravitational force) and expansion (due to opposite pressure exerted by neutrons) due to its large size, huge amount of radiation is periodically emitted.

The size of the Quasar may be so large that it is 10 million times that of the sun.

VI. BLACK HOLES

Long ago a French mathematician P. Laplace imagined a terrestrial body from his simple intuitive idea that if a body is so massive that its escape velocity is greater than the velocity of light, then as light cannot come out of it, the terrestrial body looks dark.

In the year 1960 John Wheeler innovated and used the term 'Black Hole' for such a terrestrial body.

How the matter and light behaves in the presence of huge gravity was revisited with the help of Theory of Relativity of Albert Einstein which was developed in the year 1915. In the presence of huge gravitational field we need to extend Newtonian Gravitation with heavily distorted and random space time of General Relativity of Albert Einstein.

In the case the mass of the main sequence star is exceeds 'Chandrasekhar Limit' and is sufficiently large (say > 2M) then even after Supernova explosion, the remnants of the star (initially a Neutron Star) is huge enough to create huge gravitational collapse. During this type of collapse, fresh heat would be emitted. However this heat is not sufficient to restrict the collapse. With this the star continuously and rapidly collapses. Even the neutrons, exerting opposite force (according to Pauli Exclusion Principle) cannot prevent the collapse, because of the huge gravity. The entire mass of the star collapses to a point of infinite density. The star thereby forms a 'Singularity' [2,4,20,21,22,23].

The radius of the collapsing star is formally called "Event Horizon" of "Black Hole". The Event Horizon is a mathematical concept such that from within the surface area of the event horizon even the light cannot come out to the outer world. This implies that any event within the Event Horizon surface is completely hidden or translucent, due to extremely large gravitational force of the Black Hole.

We may try to think about what happens inside the Event. But till date what is there inside is a completely unanswerable question. At best we can guess that due to huge gravity of the singularity, everything including light rushes towards the singularity.

Types of Black Hole

1) ***Schwarzschild Black Hole:*** *Non Rotating Black Hole without electrical charge. Shape is spherical.*

2) ***Reissner -Nordstrom Black Hole:*** *Non Rotating Black Hole with electrical charge. Spherical in shape.*

3) ***Kerr Black Hole:*** *Rotating and Uncharged Black Hole. Elliptical in Shape.*

4) ***Kerr-Newman Black Hole:*** *Rotating and Charged Black Hole. They are also Elliptical in Shape.*

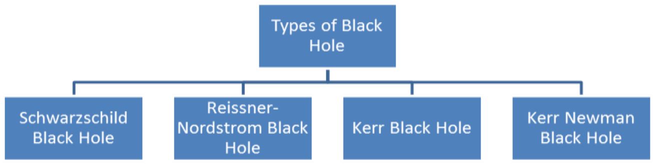

Fig. 2 Different Types of Black Hole

The spectrum (or simply range) of the size of a black hole is interestingly very large. At one extreme end of the spectrum there lies 'Mini Black Hole' of very small mass (even less than that of an asteroid) having Schwarzschild radius of 10^{-10} m (satisfying Schwarzschild equation as told next), while at the other extreme end, there lies "Supermassive Black Holes" of mass 10^5 M (recall that M = astronomical mass = mass of the sun).

It is guessed that giant "Supermassive Black Holes" (of mass $\geq 10^5$ M) exists at the centre of each galaxy. The logic in support of this is that, these black holes at the centre of all the galaxies create the requisite gravitational force to bind and unite all the stars and cosmic bodies and create their movement in their particular respective orbit.

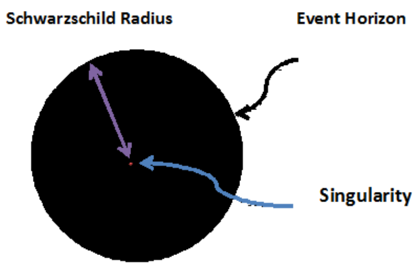

Fig. 3 A Schwarzschild Black Hole

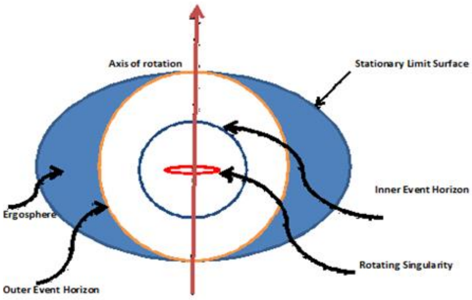

Fig. 4 A Kerr Black Hole

Three different parts of a black hole are:

a) Event Horizon: This is the surface area of the Schwarzschild radius. This part is seen from outside. It appears as a black, spherical surface with a very sharp boundary. In the case of a rotating black hole there are two event horizon namely outer event horizon and inner event horizon – while in the case of a stationary black hole there is one and only one event horizon.

b) Event Horizon Interior: This is the inside of the surface area of the event horizon. Here the geometry of space time is too much random, irregular, heavily curved.

c) Singularity: It's located at the centre of the black hole, and it has an enormous infinite density. That's the place that matter goes when it falls inside the event horizon.

d) Ergo sphere: This is an additional part in the case of any rotating uncharged or charged black hole like Kerr or Kerr Newman Black Hole [1,2,20,21,22,23]. This is the region found in those types of black hole, from where photon (light) particles can neither come out nor move inside the event horizon, but rotates along with the black hole and creates visible radiation.

Now we will calculate the escape velocity for any mass form the mass 'M' having the radius 'R'. Thence we will calculate the Schwarzschild Radius i.e. the radius of the event horizon of a stationary (not rotating black hole).

A. Expression for Escape Velocity

Let the mass of the object is 'm', the mass of the earth is 'M', the constant of Gravitation is 'G' and the radius of earth (assumed spherical) is 'R'. Now the object will only escape when its Kinetic Energy equals its Potential Energy. Thus

$$\frac{1}{2}mv^2 = \frac{GMm}{R} \dots\dots\dots\dots (1)$$

Giving the escape velocity 'v' as:

$$v = \sqrt{2GM/R} \dots\dots\dots (2)$$

In general we can similarly calculate the escape velocity for any terrestrial body of mass M and radius R, which would be given by the above equation (2)

Thus the escape velocity of any terrestrial object is dependent on the mass as well as the radius of the object.

B. Expression for Schwarzschild Radius

For a Schwarzschild Black Hole [4] (Non Rotating Black Hole), the light cannot come out of the black hole (like all other types of black hole). If in equation number 2 we replace 'v' by the velocity of light 'c' (since the escape velocity of the black hole is just slightly above the velocity of light), we get the radius [1,4,8] of the Schwarzschild Black Hole (formally called Schwarzschild radius) as below:

$$c = \sqrt{2GM/R} \dots\dots\dots\dots (3)$$

$$R = \frac{2GM}{c^2} \dots\dots\dots\dots (4)$$

This is the upper limit of the radius of the mass 'M' such that the mass is the mass of a Black Hole. Alternatively it is a Black Hole of mass "M" having the radius "R".

Now a rotating black hole [20,21,22,23] is elliptical and for a rotating black hole, for the same mass 'M' the radius (actually major /minor axis) is smaller than that of its stationary or non-rotating counterpart. The major / minor axis of the rotating black hole gradually decreases as the speed of rotation increases (for the same mass 'M').

If the speed of rotation of the black hole is too large [24,25,26,27,28], then the two event horizon (actually for any rotating black hole there are two event horizons – outer and inner) coincides and falls on the singularity and it is possible to visualize the central singularity from outside. This is formally called 'Naked Singularity'. This is discussed in the next section.

VII. NAKED SINGULARITY

It is possible to visualize the uncanny rotating singularity (rotating in an elliptical path) of any rotating Kerr Black Hole form outside. Before justifying the how the visualization of the singularity is possible from outside let us present some vital issues regarding a rotating black hole:

A. Rotating Black Hole's Event Horizon Surface Area is less than that of Stationary Black Hole

For the same mass, a Kerr (rotating uncharged) / Kerr Newman (rotating charged) Black Hole's event horizon surface area is less than that of Schwarzschild (stationary) Black Hole. This is because of the fact that due to angular velocity (and thereby angular momentum) of the singularity of the rotating black hole, the photon particles which had to be just inside the surface area of the event horizon of stationary black hole, moves around outside (ergo sphere) the rotating event horizon (outer), with an angular velocity. So while in case of stationary black hole, those photon particles along with others inside, were also dragged inside the singularity, in the case of rotating black holes, a major portion of huge gravitation to those photos is used up to create their rotation and thereby angular velocity and angular momentum. Thus the outer photons (close and just inside the event horizon of stationary black hole) are visible from outside (in the ergo sphere) in the case the black hole is rotating. This makes the surface area of the event horizon of rotating black hole decrease with the increase of speed or rotation of any rotating black hole. These photons which are now just outside the new event horizon (for the case of rotating black hole) crates an elliptical region called 'ergo sphere'. The more is the speed of rotation, the larger is the size and eccentricity of the elliptical ergo sphere.

B. The event horizon of any rotating black hole (Kerr/ Kerr Newman) is elliptical

This is because of the fact that any rotating black hole has to rotate along its axis or rotation. At the two 'poles' the photon particles require lesser angular velocity and angular momentum (angular momentum = mvr = m(2πr/t)r = 2mπr2/t) and thereby uses up a lesser portion of gravitation on it due to singularity. So in the pole region, lesser number of photons are visible from outside and they mostly remain inside the event horizon. On the other hand, the photon particles at the equator requires larger angular velocity and angular momentum and thereby uses up a larger portion of gravitation. So more number of photon particles would be visible from outside at the equator. This makes the event horizon of any rotating black hole elliptical in shape. The eccentricity depends on the speed of rotation of the black hole. [If 'a' is the major axis and 'b' is the minor axis then eccentricity = $\sqrt{a^2 - b^2}\ /a$]

C. There are two event horizons (outer and inner) of any rotating black hole

The photon particles which are just outside the event horizon of any rotating black hole are naturally visible from outside. This region where the visible photon particles are lying and rotating along with the singularity is also elliptical with the same reasoning as above. This visible region of photon particles is called 'ergo sphere'.

Now there are some photons just inside the outer event horizon up to a certain extent from the event horizon. As these are comparably far away from the singularity and possess angular velocity, they cannot be dragged down towards the singularity. At the same time they cannot cross this outer event horizon and make them visible. This creates another event horizon – which is called inner event horizon. Inside the inner event horizon, all photon particles destiny is the singularity due to its huge gravity. So in between outer and inner event horizon, the rotating photon particles can neither cross the outer nor inner event horizon. And with the same logic as before, due to the rotation of black hole, the inner event horizon also happens to be elliptical.

D. For a high speed rotating Kerr /Kerr Newman Black Hole it is possible to see the singularity from outside.

Now it would be easy to explain how it is possible to observe the singularity of high speed rotating black hole from outside the event horizon! – which is called Naked Singularity.

For any rotating black hole, as the speed of rotation increases, outer and inner event horizon merges together and ultimately falls onto the singularity. The physical interpretation of merging and falling onto the singularity is - the photon particles just inside the outer event horizon is released outside (in the ergo sphere) making them visible and making the surface area of outer event horizon smaller. Outer event horizon comes closer to inner one. At the same time the photon particles inside the inner event horizon are released outside. This makes both the outer and inner event horizon come closer to the singularity and eventually fall onto it.

Ultimately all the photon particles surrounding the singularity are visible from outside and are visible.

As there is no barrier like any event horizon to restrict photon particles to come away from singularity, the singularity is visible from outside. This type of singularity in the case of rotating (uncharged or charged) black hole is formally called ***"Naked Singularity".***

We can justify that the presence of electrical charge in rotating black hole (e.g. Kerr Nordstrom black hole), simply aggravates the situation. This means that for the same mass, even with lesser speed of rotation, an electrically charged black hole will form a *Naked Singularity*.

VIII. BLACK HOLE ENTROPY

A. Entropy

In thermodynamics, the entropy is a measure of amount of thermal energy per unit temperature in the system unavailable for doing any useful or fruitful work. As work is available only from ordered motion of the molecules, the entropy is therefore a measure of molecular randomness or disorder of any system.

Also ordering or association measures the amount of information in the system, the lesser the entropy of the system, the more is the information content of the system and vice versa.

In information theory, the entropy of a dataset 'D' measures the total amount of disorder or variation in terms of the number of different classes or categories in that dataset.

B. Black Hole Entropy

According to Stephen Hawking, the total entropy of a black hole has two different components, namely entropy due to geometric structure of the black hole and entropy due to thermal radiation and scattered matter at the outskirts or periphery of the black hole. Thus any loss of mass and entropy (corresponding to geometric structure of the black hole) due to particle antiparticle pair energy absorption of quantum effect is balanced by the increase in thermal radiation and matter at the outskirt of the black hole and thereby increase in entropy. Thus the total entropy of a black hole is ever non decreasing [1,2,3,4].

Some of us may be very unwilling to consider the outskirt of any black hole as a part of it [1]. For them the entropy due to thermal radiation outside the black hole is not a part of black hole entropy and goes beyond any consideration. In addition, the two entropies which are added together to establish non decreasing entropy are qualitatively different – one due to geometric structure and another due to thermal radiation outside. Thus the entropy of a black hole must decrease with time.

To still validate the non-decreasing entropy of any black hole, we in [1] introduced the concept of 'Reverse Entropy' inside any event horizon. This reverse entropy increases with 'matter association' and 'contraction' of universe inside the event horizon – unlike 'Forward Entropy' conventionally called 'entropy', which increases with 'matter dissociation' and universe 'expansion'. Inside any event horizon, the universe is ever contracting and there is always matter association towards the singularity due to its abnormally huge gravity. Thus when any particle of particle antiparticle pair fall inside the event horizon due to quantum effect, there is definitely an increase of reverse entropy, while the forward entropy (due to geometric structure) decrease. This makes the total entropy non-decreasing.

IX. SPACE TIME CURVATURE, SPACE TIME INTERVAL AND LIGHT CONE

A. Space Time

Space and time are not different independent dimensions of any object – rather they are two different components of a single unique dimension, called 'space time' [1,3,8] of the object. It is comprised of four dimensions out of which the spacial position of the object is described by the conventional three coordinates 'x', 'y' and 'z' and the time by another coordinate. So the space time of the event P of an object is a point on the trajectory (world line) of the object and is represented by P(x,y,z,t). There is no absolute measure of either 'space' or 'time' of any object. Therefore we cannot absolutely measure the 3D position of an event of observation without measuring the 'time' of the observation. Similarly we cannot absolutely measure the time of occurrence of an event which is independent of the position of observation. The object which is under observation is having a particular 'space time' – similarly the observer is also having his own 'space time'.

Suppose an astronaut is moving away from earth and coming back with a spacecraft with an extremely high velocity say of the order of light. (Of course an object cannot move with the velocity of light, because in that case its mass would be infinite and thus it would cease any movement). Say the time measured by the astronaut for the to and fro journey is 5 Sec.

Observation 1: On coming back after his to and fro journey, the astronaut will find that the earth along with all its belongings has grown older by say (approximately) 50-60 years. This is because of the fact that the time of 5 Sec. of the astronaut (corresponding to his huge velocity) is different from the time of 50-60 years of earth (corresponding to its comparably low velocity).

Observation 2: If an observer from earth is watching the movements of the spacecraft, he would have the feeling that the spacecraft is moving very slowly (in comparison to its actual velocity). On the contrary, if the astronaut is watching the movement of any object on earth, he would have the feeling that it is moving very fast (in comparison to its actual velocity in earth).

Observation 1 and *Observation2* are due to the fact that every object has its own 'space time' which is completely different from others. It visualizes the outer world according to its own way.

Conclusively the dimension 'space time' of an object is totally relative and is dependent on the 'space time' dimension of the position of observation.

B. Space Time Curvature

The universe is described in a four dimensional coordinate system called 'space time'. In that coordinate system every terrestrial object must have some 'space time' of its own. The trajectory of an object – which keeps track of the histories of the events and predicts the future events is called the 'world line' [1,8].

If we represent time along the z axis and for simplicity space by only two dimensions x and y, then the look of space time of an object is analogous to a fabric lying in x y z 'space time'. The simplicity is needed, because of the fact that we will not be able to visualize 3D space and time (total 4 dimensions) in the same plot. The size and position of the fabric varies from one object to another – because each object is having its own space time.

Let us further simplify the situation by considering the space along the x axis and time along the y axis. Thus the space time fabric is two dimensional (2D).

Several Observations:

Observation **-** *1*

If the object moves with infinite velocity (even much larger than that of light i.e. the object enters the 'Event Horizon' of a super-giant Black Hole and rushes towards the singularity of infinite density), then naturally the time of the object almost freezes (T = 0) and the fabric (reduces to a straight line) coincides with the x axis. The coordinate of any event in the 'world line' of the 2D 'space time' is (X,0), where X is the space of the event in the world line in the 'space time' of the object. (Of course there is one world line in the space time).

In the actual 4D 'space time' scenario, inside the event horizon, since the direction of space cannot be controlled in any way, while the time can be, the role of space and time are reversed there, and space becomes 1D, while time becomes 3D. We may easily move back to past or forward to future inside the event horizon.

Observation – 2

If the object is stationary, then the fabric (also reduces to a straight line) coincides with the time (y) axis. The space of the object reduces to zero (X=0). The coordinate of any event in the 'world line' in the 2D 'space time' is (0,T), where T is the time of the event in the world line in the 'space time' of the object. (Of course there is one possible world line in the space time)

Observation – 3

If the object is in motion with a moderate velocity (considerably less than that of light) then its space time makes an angle to the x or y axis. The angle depends on the velocity of the object. The coordinate of any event of the object in the world line of the space time would be (X,T) where T is finite.

Observation – 4

If the object (moving at a velocity lesser than that of light) is under the influence of gravity of another object, then the fabric of space time of the object is a curved surface and as usual makes an angle with x y plane (in 3D space time, where time is along z axis). A hole appears in the fabric near the second object. This is the 'Space Time Curvature' of the first object.

C. Space Time Interval – Light Cone

Four dimensional (4D) space time distance (space time interval) tells us whether the object moves from one event (say the present event) A to another event (i) B, (ii) C or (iii) D (future event) at a speed:

(i) Lesser than that of Light

(ii) Equal to that of Light

(iii) Greater to that of Light

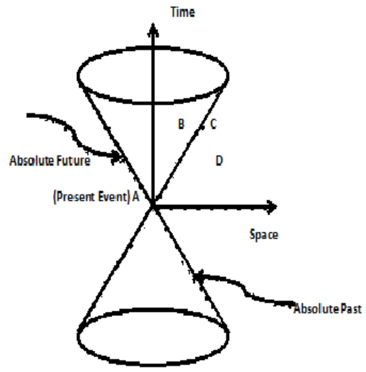

Fig. 5 Light Cone indicating the location of matter particle B (inside the cone) and wave particle C or D (either on the surface or outside the surface of the cone

The space time interval between two events $P(x_1,t_1)$ and $Q(x_2,t_2)$ is given by:

$$S_2 = (X_2 - X_1)^2 - c^2 \ (X_2 - X_1)^2$$

[After dimension normalization of time to distance; 'c' is the velocity of light]

Here we have simplified the situation by considering that the space is represented by only one dimension 'x' and the time by another dimension 't'.

In general, if we consider space is 3 dimensional, then the space time interval (also called four dimensional distance) between two events $P(x_1,y_1,z_1,t_1)$ and $Q(x_2,y_2,z_2,t_2)$ would be:

$$S_2 = (X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2 - c^2 \ (X_2 - X_1)^2$$

Consider any two events (including the present event A) which is either inside or outside the Light Cone.

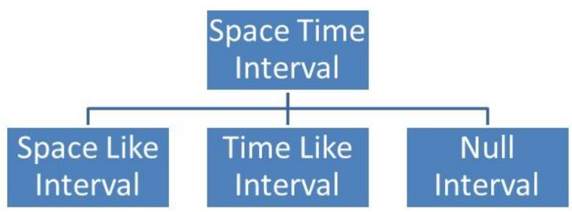

Fig. 6 Three Different Space Time Interval

Space Time Interval S is such that:

1) Space Like Interval indicates S2 > 0: Space Dominates Time; Object moves from event P to even Q at a speed greater than that of Light

2) Time Like Interval indicates S2 < 0: Time Dominates Space; Object moves from event P to event Q at a speed lesser than that of Light

3) Null Interval indicates S2 = 0: None of Space and Time Dominates the Other; Object moves from event P to event Q at a speed equal to that of Light. Thus:

i) If the world line of the object moving from event P to event Q is inside the Light Cone (Past, Present or Future) then the moving object is a Matter particle object moving at a speed lesser than that of Light.

ii) If the world line of the object moving from event P to event Q is on the surface of the Light Cone (Past, Present or Future) then the moving object is a Light (photon) particle object moving at a speed of Light.

iii) If the world line of the object moving from event P to event Q is outside the Light Cone (Past, Present or Future) then the moving object is a wave particle object moving at a speed greater than that of Light.

X. GENERAL AND SPECIAL THEORY OF RELATIVITY

A. General Theory of Relativity:

Space and time [1,3,8] are affected by the gravitational fields of objects i.e. gravitational field changes the geometry of 'space time'. This causes the 'space time' to be curved.

Supportive Observations:

- Light is bent in a gravitational field under the influence of gravity.

  [Sunlight bends while passing across Jupiter].

- Redshift of light caused by gravity. (Redshift is due to the fact that Light wavelength is stretched apart and the frequency reduces)

  [(a)Redshift in light spectra of nearby stars at the limb of sun observed during total solar eclipse,

  (b) Redshift in light spectra from 'red giants']

B. Special Theory of Relativity:

i) Space is dependent on velocity

ii) Time is dependent on velocity

iii) Mass is dependent on velocity

iv) 'Space time' of an object is dependent on the position ('space time') of observation

v) Only the speed of light in vacuum is constant in the universe.

vi) Mass of an object is related to its energy content by the famous Einstein equation:

$E = m \times c^2$
Where
m = mass of the object
c = velocity of light in vacuum

Example1: If you are an astronaut in a spacecraft moving at the velocity of the order of light, you will observe everything in earth moves tremendously fast, while from earth one will see you moving very slowly.

Example2: An object rushes towards a Black Hole with tremendous velocity (due to huge gravitation of Black Hole). But while you observe this phenomenon from earth, you have the feeling that the object moves towards it very slowly. You see the incident according to your own 'space time' - more simply according to your own velocity of movement.

XI. TIME

Here in this section first of all we will define time [1,2,3,4,8] from different viewpoints. Next we will present the different types of time.

A. Different Definitions of Time:

It is difficult to define time because time is not a physical concept of phenomena for realization. So it is also difficult to specify the direction of flow of time, until and unless we correlate time with any physical concept.

There are broadly there different definitions of time [1] in each of which we correlate time with any physical phenomena or concept. These are:

1) *Thermodynamic Definition of Time*

2) *Cosmological Definition of Time*

3) *Psychological Definition of Time.*

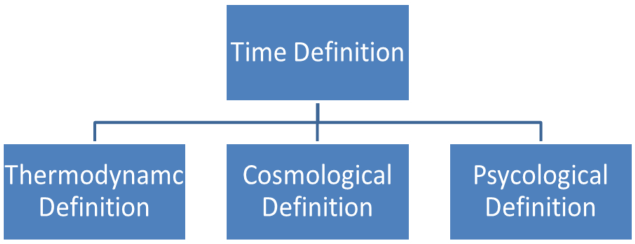

Fig. 7 Different Time Definitions

In Thermodynamic definition of time, time is proportional to entropy of a known system (say our universe) and is flowing in the direction of increasing flow of entropy of our universe. During the Big Bang , the time as well as the entropy of the universe was zero and constantly it is increasing and ultimately it will end up the increase in entropy and start the process of decreasing the entropy, through which the direction of flow of time would be also get reversed then.

In Cosmological Definition of Time, the time is proportional to the amount of expansion of our universe and the direction of flow of time is in the direction of expansion of our universe. During Big Bang the time measured was zero as the expansion was zero, while when the universe would stop expansion and start contraction the direction of flow of time would get reversed.

In Psychological Definition of Time, time is flowing from past to future via present. The past is what we can remember. The future is what we cannot remember but imagine only. The present is what we can neither remember nor imagine. So in this concept of time, time is flowing in the direction from what things we can remember to what things we can imagine via what things we can neither remember nor imagine.

We know that the arrow of time (i.e. the direction of time flow) in time like interval (i.e. outside the event horizon of any black hole) is dependent on the direction of increase of entropy. But the arrow or direction of time is just the reverse inside the event horizon of any black hole due to the nature of contracting universe as well as decreasing entropy there. Thus if the time is flowing in the direction of increase of entropy, it is flowing in the direction of decrease of entropy inside the event horizon of any black hole. Similarly it may be guessed that every physical phenomenon is just the opposite or reverse inside a black hole event horizon [1]. Thus the property of entropy is also reversed [1] inside the event horizon of any black hole. This has been discussed in earlier section.

B. Different Types of Time:

An object may have two different types of time [1] – namely

(1) Proper Time
(2) Reference Time

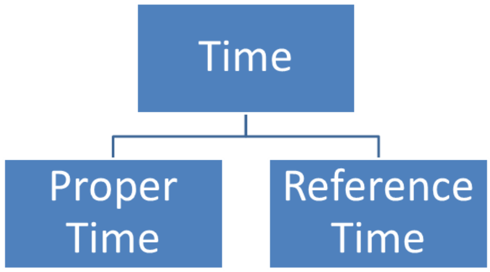

Fig. 8 Proper and Reference Time

Suppose there are two persons sitting in chairs in the same room. They start measuring the space time of one object say a cupboard in the room. They will measure exactly the same space time of the cupboard.

Now suppose one person starts moving, while the other one is still sitting. Now they will measure different space time of the same cupboard and will disagree on both space and time (and thereby 'space time') of the concerned object. There is a significant difference between one, say time measured by the two persons.

Why this thing happens? This is because of the fact that both space and time has to be measured in a relativistic manner. Both are dependent on the velocity of the object.

Proper Time**:** The proper time of an object is the time measured by one observer, when the observer is at rest.

In that case the 'space time' coordinate system used by the observer is absolute.

Reference Time: The reference time of an object is the time measured by one observer, when the observer is in motion.

In such a case the observer uses his own reference 'space time' coordinate system. Needless to say, this reference 'space time' coordinate system of the observer is related to his velocity.

C. Time Dilation Due to Gravity:

If

T = time measured by someone on a terrestrial object (of huge gravity, say neutron star, black hole etc.)

t = time measured in space of no gravity region.

M = mass of the terrestrial object

R = distance of the observer in space from the terrestrial object

Then

$$T = t \times \sqrt{1 - 2\,GM/Rc^2}$$

If the object is say a neutron star of Mass M = 1.9*10 30 kg.
and R = 20 km, then with natural constants G and c as below:

G = 6.67*10-11 Ntm2/kg2

c = 3 * 108 m/sec

T = 0.92*t

This means that every second in that terrestrial object is actually 0.92 sec. in space observatory. From the observatory if we look at the terrestrial object, we will find that everything is going on very slowly there. Time is dilated due to huge gravity.

XII. CONCLUSION

In the present exposition on Astronomy and Space Science we made every sincere attempt to elaborately explain the different marvels of astronomy which would create some enthuse to ardent humans and motivate them in astronomy astrophysics and space science. Curiosity and eagerness in astronomy within mankind started from early pre-history days when zealous men visualized the sky with quite amazement and overwhelmed by the obscure uncanny solitude of the universe along with its terrestrial bodies. This curiosity and bustle still continues till today and has made possible the advancement of research in different traits of astronomy, astrophysics and space science to disclose a lot of mystery hidden within the vast splendid universe. In this paper several important aspects and major issues of astronomy, astrophysics and space science have been discussed in a simple and well readable manner understandable by everybody even without any prerequisite in astronomy. At the same time every attempt has been made to keep up a balance between breadth and depth of the content. While we started from the formation of stars we went up to some depth of black holes – which is presently one most hot topic as well as an open research area in astronomy and space science. From beginners to researchers of astronomy, this study of this paper may be an enjoyable one.

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