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On the Idea of Black-Holes - Their Characterization Along with an Attempt to Classify them Properly

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Abstract: ***The term 'Black-Hole' is very common to almost all people in the world at present. A black-hole (B-hole) is one from which even light cannot come out from its surface. How many types of B-holes are possible in the universe and which of them are to be recognized as real B-holes and why? What will be the composition, density and volume of a B-hole? Is it possible for a B-hole to attain singularity? All these things are discussed below.***

Keywords: Black-hole, Escape velocity, Event Horizon, Neutron Star, Singularity, Big-Bang, Gravitational Collapse, Schwarzschild's Radius

1. Introduction

According to its literal meaning, a black-hole (B-hole)[1] may be defined as a system which should appear black and at the same time it should behave as a hole. This means that no light can come out from that system so that it appears black and at the same time, each and every material body, passing by it, should suddenly fall into that system, i.e. it will behave as a hole. It is also even told that a state of singularity[1] should exist within a B-hole. But how can all these properties be achieved by such a system?

It is our common experience that when a material body, irrespective of its mass and size, is thrown above from our earth's surface it will go up, attain a certain height and will come back to the ground. If the velocity is increased continuously it will go up higher and higher; but finally it will come back to the ground. After the invention of the laws of gravitation by Newton, we came to know that if the velocity of the above particle exceeds a certain critical value, it will never come back to the ground i.e. it will go into the deep space leaving completely our earth and that very critical velocity is known as the escape velocity (V_E). All particles moving upward with a velocity (V) less than escape velocity (V_E), i.e. V<V_E, will always come back to the earth and those moving upward with a velocity ($V^/$) greater than V_E, i.e. $V^/$>V_E, will never come back. The value of escape velocity of our earth is nearly 11.3 km/s. Thus, for each and every celestial object in the universe there should be a definite value of escape velocity. There are particular different values of V_E for moon, sun, mars, jupiter and stars etc. Previously, it was thought that nothing can be sent outside our earth, because our old technology was unable to help a material body attain such high velocity greater than V_E. But our modern technology can do it easily now and thus we have sent many satellites and also many space probes towards moon, venus, mars etc. The value of escape velocity depends on mass and size of an object. If the mass increases or size decreases, the value of V_E increases and if V_E of a celestial object becomes greater than velocity of light (c); i.e. V_E>c, where c = 3x10^{10}cm/s, then even light cannot escape from it -such an object is known to us as a Black-Hole (or, B-hole). Since, no light can come out from that object it appears black to us and at the same time any substance, passing by it, will suddenly fall into it due to its extremely strong gravitational pull, i.e. that object will behave as a hole. Since any form of electromagnetic radiation including visible light cannot come out from it, no information can be obtained from it and hence that object will remain totally outside of our knowledge and view. Again, as the height (i.e. the distance from the surface of that object) increases the value of V_E decreases; thus there should be an imaginary boundary surface far above the actual surface of a B-hole where V_E just becomes equal to the velocity of light; V_E=c. Since, no information regarding any event or incident occurring below this imaginary boundary surface can come out to outer world, that very boundary surface is termed as "Event Horizon" [2]of a B-hole. The boundary surface ABCD in Fig.1 is the event horizon of the B-hole EFGH. Above event horizon any incident, say occurring at P (where V_E<c), will be detected from outside the B-hole because light signal can come out from there to outer world. Below event horizon ABCD (where V_E>c) any incident, say occurring at Q, cannot be detected form outside, because light signal cannot come out from there to outer world. The whole zone inside the sphere ABCD will be totally unseen and unknown for ever to outer world. Here, light is meant for whole spectra of electromagnetic radiation, i.e. from long wave, km wave, radio wave to γ–radiation (gamma-radiation) via visible zone. On each point on the boundary surface ABCD, the value of V_E is just equal to 'c', i.e. V_E = c.

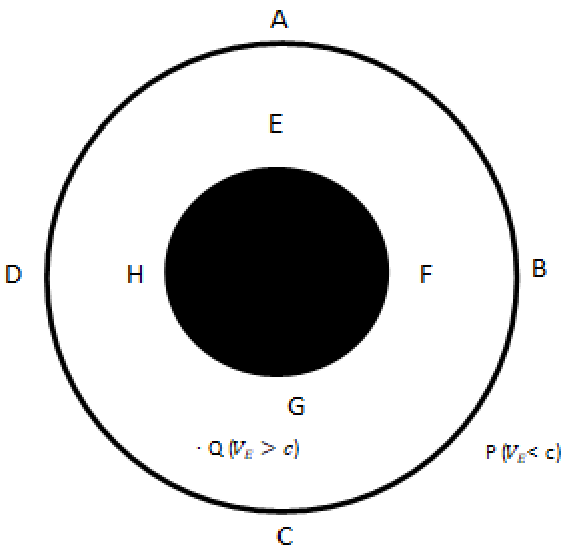

Figure 1: Cross-Sectional View of a Spherical Black-Hole

Almost all the celestial objects are spherical in shape and hence a B-hole may also be assumed to be of spherical shape. For any celestial object to be converted into a B-hole, it is necessary to attain a critical radius so that on its surface V_E just becomes equal to 'c' i.e. V_E= c and this critical value of radius is known as Schwarzs child's Radius (SR). The necessary and sufficient condition of a material body to behave as a B-hole is just to attain the SR. An object having radius greater than SR can never behave as a B-hole. But in reality there may be many B-holes having radii much less than SR. So, the radius of any black-hole (R_B) should be equal to or less than SR, i.e. $R_B \leq$ SR.

From the well-known gravitational equation of Newton (1), the equation (2) for

$$F= \frac{Gm^1m^2}{r^2} \quad \text{.......................... (1)}$$

escape velocity (V_E) can be obtained easily as

$$V_E = \sqrt{\frac{2GM}{R}} \quad \text{..................................(2)}$$

If V_E = c , then R = SR , so that

$$SR = \frac{2GM}{c^2} \quad \text{..................................(3)}$$

Here, F = Gravitational force of attraction between two objects having masses m_1 and m_2 situated at a distance 'r' and 'G' being the gravitational constant, R = Radius of our earth and M = mass of the earth. This equation for SR can also be applied to any object having mass 'M', where 'G' and 'c' remain the same.

Now let us see how many types of B-holes can be possible and which type is actually known to us as B-holes; while other types cannot be taken as B-holes, but why? Moreover, we have to see what types of B-holes have so far been discovered and whether those findings will actually justify our concept regarding B-holes or not?

2. Calculations

If contraction is allowed to continue freely under gravity and if there be nothing to prevent it, then each and every substance, irrespective of its mass, can attain SR and eventually becomes a B-hole. Now, let them undergo such free contraction under gravity to attain SR. Using above equation (3) one can easily calculate SR, volume, density etc. for material bodies of different masses. Their masses are expressed in gram (g), radius (SR) incentimetre (cm), volume in cubic-centimetre (cc) and density (d) in gram per cubic-centimetre (g/cc). In Table-I, such theoretically calculated values of various objects are shown. Here, the value of 'G' is taken as 6.67 x 10^{-8} dyne cm^2g^{-2} and c = 3 x 10^{10} cm/s.

Here,
10^{-27}g = Approximate mass of electron
9.11 x 10^{-28} g = Actual mass of electron
10^{-24}g = Approximate mass of proton
1.66 x 10^{-24}g = Actual mass of proton
10^{28}g = Approximate mass of Earth
5.972 x 10^{27}g = Actual mass of Earth
10^{34}g = Approximate mass of Sun
2 x 10^{33}g = Actual mass of Sun
10^{46}g = Approximate mass of Milky-Way Galaxy
6 x 10^{45}g = Actual mass of Milky-Way Galaxy
10^{56}g = Approximate mass of our Universe (U-1)
10^{72}g = Mass of an imaginary Universe (U-2)
10^{100}g = Mass of another imaginary Universe (U-3)
It may be noted here that U-2 contains 10^{16} U-1 and U-3 contains 10^{44} U-1 or 10^{28} U-2. Again here, 1 LY = 1 light year = Nearly10^{18} cm.
1 BLY = 1 billion light year = 10^9 LY = 10^{27} cm (Appx.)

Table I: Comparison of SR, Volume and Density of Different Objects with varying masses

Mass (in g) (comparable object)	SR (in cm)	Volume (in cc)	Density (in g/cc)
$\mathbf{10^{-27}}$(Electron)	1.48 ×$\mathbf{10^{-55}}$	1.36×$\mathbf{10^{-164}}$	7.35×$\mathbf{10^{136}}$
$\mathbf{10^{-24}}$(Proton)	1.48 ×$\mathbf{10^{-52}}$	1.36×$\mathbf{10^{-155}}$	7.35×$\mathbf{10^{130}}$
1.00	1.48 × $\mathbf{10^{-28}}$	1.36×$\mathbf{10^{-83}}$	7.35×$\mathbf{10^{82}}$
$\mathbf{10^{28}}$ (Earth)	1.48	13.6	7.35×$\mathbf{10^{26}}$
$\mathbf{10^{34}}$ (Sun)	1.48 × $\mathbf{10^{6}}$	1.36×$\mathbf{10^{19}}$	7.35×$\mathbf{10^{14}}$
$\mathbf{10^{46}}$ (Milky-Way Galaxy)	1.48 × $\mathbf{10^{18}}$	1.36×$\mathbf{10^{55}}$	7.35×$\mathbf{10^{-10}}$
$\mathbf{10^{56}}$(U-1)	1.48 × $\mathbf{10^{28}}$ (14.8 BLY)	1.36×$\mathbf{10^{85}}$	7.35×$\mathbf{10^{-30}}$
$\mathbf{10^{72}}$ (U-2)	1.48 × $\mathbf{10^{44}}$	1.36×$\mathbf{10^{133}}$	7.35×$\mathbf{10^{-62}}$
$\mathbf{10^{100}}$ (U-3)	1.48 × $\mathbf{10^{72}}$	1.36×$\mathbf{10^{217}}$	7.35×$\mathbf{10^{-118}}$

From Table-I, it is clear that there is a possibility of each and every substance to be converted into a B-hole, if gravitational collapse can continue freely up to any degree. Then, the Universe would have contained only B-holes and no other object, but actually the Universe is full of various kinds of objects along with few B-holes. So, this possibility does not exist. There must be some opposing force which can prevent the gravitational collapse for less massive objects, but for extremely large massive objects nothing can prevent or stop the said collapse leading to the creation of B-holes. Again, a simple question arises, "How far the contraction can go on?" As the contraction goes on, density increases rapidly and on attainment of SR the value of density becomes nearly $\mathbf{10^{136}}$ g/cc for an electron and $\mathbf{10^{27}}$ g/cc for an earth-like object. Is it possible for any object to attain such extremely high value of density? If not, is there an upper limit of density? Let there be an upper limit of density beyond which contraction under gravity (or by any other means) is not possible, then each and every object cannot attain SR and hence they can never be converted into B-holes. The average density of nuclear matter is in the order of 10^{14} g/cc and let the upper critical value of density be 10^{14} g/cc (D_C), then contraction can go on upto this value of density (D_C). Now, let us calculate volume, radius, escape velocity (V_E) for different objects of varying masses just after attainment of the density of nuclear matter (D_C). These are shown in Table-II.

Table II: Possibility of different objects to be Black-Holes after attaining critical density (D_C)

Mass (M) (in g)	Volume (in cc)	Radius (in cm)	SR (in cm)	Escape Velocity (in cm/s)
1.00	1 x 10^{-14}	1.33 x 10^{-5}	1.48 x 10^{-28}	1.00 x 10^{-1}
10^{14}	1.00	6.2 x 10^{-1}	1.48 x 10^{-14}	4.64 x 10^{3}
10^{28}	10^{14}	2.88 x 10^{4}	1.48	2.15 x 10^{8}
10^{34}	10^{20}	2.88 x 10^{6}	1.48 x 10^{6}	2.15 x 10^{10}
2.71 x 10^{34}	2.71 x 10^{20}	4.0145 x 10^{6}	4.017 x 10^{6}	2.998 x 10^{10} (= c)
10^{46}	10^{32}	2.88 x 10^{10}	1.48 x 10^{18}	2.15 x 10^{14}
10^{56} (U-1)	10^{42}	6.2 x 10^{13}	1.48 x 10^{28}(=14.8 BLY)	4.63 x 10^{17}
10^{72} (U-2)	10^{58}	1.34 x 10^{19}(=13.4 LY)	1.48 x 10^{44}	9.98 x 10^{22}
10^{100} (U-3)	10^{86}	2.88 x 10^{28}(=28.8 BLY)	1.48 x 10^{72}	2.15 x 10^{32}

1. Discussion

According to the theory of 'Big-Bang' our universe has started its present life through an extremely violent explosion known as 'Big-Bang' which took place some 14 to 15 billion year ago. So, at present the age of our universe is around 14 billion year. From the very beginning of the universe light has started to travel towards all directions of space (around 360^0) from the point of Big-Bang and can travel a maximum distance of 14 BLY till now, producing a spherical universe of radius 14 BLY (=1.4x10^{28} cm) and maximum volume of nearly 10^{85} cc. It has been estimated that approximate mass of our universe is around 10^{56} g having an average density of matter of nearly 6 x 10^{-30}g/cc. It has also been estimated that the mass of our own galaxy, i.e. Milky-Way Galaxy, is nearly 10^{46}g and thus our universe (U-1) contains nearly 10^{10} galaxies[3] each like ours one. But actually there are many bigger and also some smaller galaxies than ours one in the universe (U-1).

Now, let us analyse the results of Table-I and Table-II. However, at first, let us look into the results of Table-II. If further contraction is not possible after attainment of critical density (D_C), then each and every material body cannot be converted into B-hole. The critical mass (M_C) is 2.71 x 10^{34} g, which means that a material body having mass (M) less than M_C, i.e. M<M_C, can never be a B-hole, because such bodies (M<M_C) cannot attain SR even after attaining D_C. Our sun having mass around 2 x 10^{33} g, can never be transformed into a B-hole and only those stellar bodies with masses (M) greater than or equal to M_C (i.e. M≥M_C) can be transformed into B-holes through such contraction provided the maximum attainable density is D_C. Again there arises a burning question - whether all such stellar bodies having masses greater than M_C can attain critical density (D_C) or not during their collapse under gravity? If not, even they can be converted into B-holes just after attaining SR, because for such massive objects (M>M_C), the SR values are always larger than critical radius (CR), where CR is the radius at critical density. For such objects (M>M_C), SR can be easily achieved without attaining D_C, while for less massive objects (M<M_C) SR can never be achieved even on attainment of D_C at CR and they can never become B-holes. Again, if the assumption that the limiting highest density of matter of 10^{14} g/cc may not be correct and D_C may have either higher value or lower value than 10^{14} g/cc, then corresponding changes will take place. If, D_C has higher value than 10^{14} g/cc., then smaller objects (M<M_C) may be converted into B-holes, because then the value of M_C will also be smaller than previous value. Our sun and even other smaller objects can be converted into B-holes. Secondly, if D_C has much smaller value than 10^{14} g/cc., changes will occur accordingly. However, this possibility is very small. As the value D_C is attained within atomic nucleus and hence it can be easily attained within a B-hole; although, it is not necessary that a B-hole must attain the value of D_C. So, this second possibility of having D_C<10^{14} g/cc can be discarded.

It has been also reported that there are a good number of neutron stars in the sky and hence it can be said that their detection is quite feasible with the help of our modern technology. From their name 'Neutron Star'[2], it can be assumed that they are made by only neutrons having no proton and electron and they should have the density of nuclear matter i.e. 10^{14}g/cc (=D_C). Thus, the whole neutron star is nothing but a single nucleus of only neutrons. Since, the neutron stars are visible and detectable by us, they must have masses less than M_C, otherwise they would have been converted into B-holes, because for M>M_C, SR>CR. For objects M<M_C, SR cannot be achieved even after attaining D_C and hence they cannot be B-holes. If, a neutron star with M>M_C having also critical density (D_C) be detected as a visible star, then there must be something wrong in the idea of B-holes, otherwise there must be no neutron star with M>M_C in the universe.

Now, let us analyse the results of Table-I. For an object of mass 10^{56} g, which is assumed to be the probable mass of our universe, the value of SR is 1.48 x 10^{28} cm (= 14.8 BLY) and this SR value is the probable radius of our universe (U-1). It has a volume of 1.36 x 10^{85} cc and density of 7.35 x 10^{-30} g/cc -miraculously these are the accepted values of volume and density of our present universe respectively. So, our universe is nothing but a B-hole, rather a super B-hole. If our universe becomes a B-hole, then presence of any other such B-holes and even other bigger B-holes like U-2 (10^{72} g), U-3 (10^{100} g) etc. cannot be detected by us; because, no communication by any means can be made between any two such B-holes. Then, what is the actual case? It can never be ascertained whether the actual universe contains only one universe like ours one (U-1) or many universes like ours and even bigger ones? This question still remains unanswered.

Being a B-hole our universe (U-1) contains large number of galaxies, stars, planets, living world in some planets like our earth, molecules, atoms, etc. and all physical laws are well defined here. Hence, there is no question of existence of singularity within our universe. A system should be said to have attained singularity, according to its literal meaning, only when it should contain only one type (i.e. single type) of particles and must not contain any other 2nd type particle. Again, according to the General Theory of Relativity, in a system with a state of singularity, space-time curvature[1] will be infinite, all physical laws will break down and their separate existence will vanish, i.e. they become indistinguishable from one another. It will have infinite density, infinite gravitational field etc. All types of physical measurements will fail within such system. All such indications of singularity are totally absent in our universe and similarly this is also true for all objects with masses greater than M_C attaining SR (i.e. they are also B-holes). Therefore, the idea that there must be a state of singularity within a B-hole is totally meaningless.

If the mass of an object particularly of a neutron star is so large that it can overcome the neutron pressure, then contraction under gravity will continue further, when separate existence of neutrons will vanish, rather neutrons will be fused together and the whole star will be converted into a single particle, the nature and character of which are still unknown to us. It will be converted into a B-hole with a state of singularity within it, because it contains only one particle. Our universe (U-1) like objects with masses nearly 10^{56} g are also B-holes because they have attained SR; they can exist for billions of years (the age of our universe is nearly 14 billion year). This means that their contraction is stopped and probably the opposing force here will be photon pressure. Similar will be the case for all objects with masses from 10^{56} g to 10^{100} g and even to any larger value upto infinite mass. In the same way, separate B-holes will be obtained where gas pressure, electron pressure, neutron pressure etc. will stop further contraction, but they are all perfect B-holes as they can attain SR. In each case, there should be separate M_C values. All such B-holes may not attain singularity. All such B-holes may contain different types of particles and even stars, galaxies, planets etc. (the case of our universe U-1). To become a B-hole it is necessary to have actual radius (AR) just equal to SR, i.e. AR=SR, but then their densities will have much lower value than D_C (=10^{14} g/cc). To behave as a B-hole it is not necessary to attain D_C, but only to attain SR and even there may not be any fixed value of critical density, i.e. density may have any value. To clarify this point let us consider the case of our own Milky-Way Galaxy (MWG) with a mass of 10^{46} g, SR value of 1.48 x10^{18} cm (i.e. 1.48 LY) (SR = AR), volume of 1.36 x 10^{55} cc and a density of 7.35 x 10^{-10} g/cc (Table - I) and it must behave as a B-hole. In Table - II, it has been shown again that it (MWG) has density of 10^{14} g/cc (i.e. D_C), volume of 10^{32} cc, AR of 2.88 x 10^{10} cm (AR << SR) and V_E of 2.15 x 10^{14} cm/s. Hence, it is clear that our MWG having any value of AR (actual radius) in between 1.48 x10^{18} cm and 2.88 x10^{10} cm and having any value of density in between 7.35 x10^{-10} g/cc and 10^{14} g/cc, must behave as a B-hole. Similar will be the case of all objects having M ≥ M_C. In all such cases of B-holes with AR ≤ SR, there will be no singularity within them, but they all will behave as perfect B-holes because no information about them can be obtained by any outside observer by any means. Therefore, why should they not be called as perfect B-holes and why should they not exist in the universe?

Now-a-days, astrophysicists all over the world frequently speak about the B-holes which are ideal in nature, i.e. they have infinite density, infinite space-time curvature having singularity within them and it seems from their views that other types of B-holes are not present in the universe and are also not known to us. Now, let us critically discuss about the case of the so-called ideal B-holes. Is it possible for an object having requisite mass to be compressed under gravity into a point mass with zero volume, zero diameter, infinite density, infinite space-time curvature? If so, then who will and what will prove it and how? If not, then the existence of such so-called ideal B-holes is questionable -- whether they will exist at all or not? Even if they exist, then all B-holes in the universe originated from objects having different requisite masses, obviously larger than critical mass, will be of same size i.e. having zero volume. Then, the idea that larger objects will produce larger B-holes and smaller objects will create smaller B-holes will no longer exist. What will be the state and fate of the matter within such ideal B-holes with zero volume? What will be the mechanism of conversion of matter into a B-hole? Since, no information from such B-holes can be obtained by any outside observer, nobody can say or even predict about the nature of matter within it. Such B-holes must not be the ultimate fate and state of matter, it should not exist for ever - one day it will be destroyed either through explosion or through any other means. Then, what will be the mechanism of reverse transition of B-hole into normal matter as we notice it around us. If all ideal B-holes are of same size, they will be indistinguishable from one another. If not, then it has to be decided that there must be an upper limit of density of matter within B-holes, may it be that of nuclear matter (d = 10^{14} g/cc) or even any higher value; at the same time there should be a critical value of mass also. The new values of critical density and critical mass are yet to be determined and only then the idea that bigger objects will produce bigger B-holes and smaller objects smaller B-holes will remain valid.

2. The Crucial Question

The interesting questions are - how many types of B-holes are possible and which of them are actually present in the universe and finally which of them are actually taken as B-holes by us and why? While other types are not taken as B-holes and again why?

The following types of B-holes are possible theoretically:-

Type- I: These B-holes are all point masses having singularity, infinite density (no upper limit of density), i.e. all the matter of an object is confined within a point. Again, they may be of two types.

Type-IA: When there is no opposing force, all objects with mass range from zero plus to infinity are compressed to point masses to become B-holes.

Type-IB: When there exists some opposing forces, then all objects cannot be compressed into point masses; there should be critical mass value (M_C) and only those objects with M≥M_C will be converted into such type B-holes. All such B-holes (Type-IA and IB) are identical in all respect i.e. they are all indistinguishable from one another because they are all point masses having zero volume, infinite density and singularity. Is it possible at all that such a B-hole would exist in the universe?

Type-IIA: When contraction upto a point mass is not possible, then there should be an upper limit of density (D'_C) such that D'_C>D_C and neutrons are fused together into a single particle (still unknown to us) to produce a B-hole with v≠0, r≠ 0.Such B-holes will have different size and volume with singularity.

Type- IIB: When compression of matter produces neutrons only as the ultimate product i.e. neutrons cannot be further fused together to produce a single particle (as in type-IIA), then all B-holes will contain only neutrons. Then there should be a critical mass value (M_C) and critical density will be D_C (= $\mathbf{10^{14}}$ g/cc). Objects of different masses will produce such B-holes of different size and volume; however singularity will be present in all such B-holes.

Type- III: Actual condition of an object to become a B-hole is just to attain SR here, i.e. only AR ≤ SR, where AR is the actual radius. There should be only a critical mass value (M_C) and no critical density value i.e. d<D_C. Any of the opposing forces mentioned previously can stop the contraction under gravity yet various types of B-holes can be obtained. They may be of IIIA, IIIB, IIIC....types depending on the nature of opposing forces such as photon pressure, gas pressure, electron pressure respectively. No singularity will be present in such B-holes. Examples of Type-IIIA B-holes are U-1, U-2, U-3 etc. upto objects having infinite mass.

It has been established that a super massive B-hole[4] is present at the centre of our Milky-Way Galaxy (MWG) and due to the influence of its gravitational pull all stars in MWG rotate around it. Even our MWG may contain large number of B-holes situated randomly within it, in addition to that in the centre. Our universe U-1 is itself a B-hole and it contains nearly $\mathbf{10^{10}}$ galaxies each like our MWG and even larger ones and hence U-1 contains millions and millions of B-holes within itself. This is nothing but the case of "Black-holes within a Black-hole" and similar is the case of U-2, U-3... etc. and so on.

3. Conclusion

From the above discussion it becomes clear that the so-called ideal B-holes of type-IB are not the actual B-holes rather their existence is questionable; all other types viz. IIA, IIB, and III must be accepted as B-holes and their existence is quite feasible.

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