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SHORT REVIEW ON BLACK HOLES

Socience
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ABSTRACT

A black hole is a region of space whose escape velocity has a value that exceeds the speed of light, that is, black holes are known as celestial bodies where gravity is so high that nothing can escape from within, the light and the matter can enter, but cannot leave. Pierre Laplace and John Mitchell first suggested the concept of black hole, and since then, many scientists have worked and formulated the basic principles of this theory. This article presents a brief historical review of the theory of black holes, from his mathematical formulations, to the present day. The biggest challenge is to observe them and prove their existence since they do not emit any light.

As mentioned by CRAWFORD [1], a black hole is a region of space that contains so much mass concentrated that no object can escape its gravitational pull. According to gravitational theory when we are on the surface of a planet and we shoot a projectile up, it will rise for a while, but eventually the acceleration due to gravity on the planet will make it go down again. However, if we throw the projectile with a large enough force, could make it escape the gravity of the planet, he would continue to rise forever. The speed at which you need to throw an object so that it escape from the gravitational attraction of the planet is called "escape velocity". The escape velocity depends on the mass of the planet, and if the planet is extremely massive, its gravity will be very intense, and the escape velocity may be very high. In the case of the Earth, for example, the escape velocity is about 40,000 km/h. [*(24,855 mph)*translator's note*]. Now consider, hypothetically, an object with extremely large mass, concentrated in an infinitely small radius that its escape velocity is greater than the speed of light. In this case, nothing can escape the gravitational field of the object. Even a ray of light would be pulled back by gravity and would be unable to escape. The idea of a mass concentration so dense that even light trapped stays, goes well in the past, to Laplace in the 18th century. Pierre Simon Laplace [1] originally proposed the concept of an object from which light cannot escape, in 1795. Using the theory of gravity of Newton, Laplace calculated that if an object to be compressed into a small enough radius, the escape velocity of that object would be faster than the speed of light. The French mathematician Laplace [1] conceived the notion of such an object in the year 1799. Although he did not mention the term black hole, he was worried about the idea that the escape velocity property would exceed the speed of light. In 1783, John Mitchell [1] in their studies would have predicted that if a star possessed much mass occupying a very small volume, not even light would be able to escape this compact object. Parallel studies also occurred in France by the mathematician Pierre Simon Laplace, but only included in the first two editions of his book *"The system of the world."* Mitchell and Laplace reached, independently of the other, quite similar conclusions. KARL SCHWARZSCHILD [2] in 1916 finds the solution of Einstein's equations that includes black holes without rotation and Hans Reissner along with Gunnar Nordström, in 1918, obtained the solution of Einstein's equations corresponding to static black holes with electric charge.

In 1930, EDMUND STONER [2] found that the density of white dwarves varies with the square of the mass and found a density of an order of magnitude higher than previously observed. Therefore, Wilhelm Anderson [2] postulated that the electrons are relativistic and the density is considerably small. In fact, Anderson found a critical mass, when the density became infinite. Stoner described then, what is now known as the Anderson-Stoner state equation for white dwarves. CHANDRASEKHAR [2], in 1931, postulated there was a limit to the repulsion that the exclusion principle can provide. The theory of relativity limits the maximum difference in the velocities of the particles of matter of the star at the speed of light. This means that when the star becomes sufficiently dense, the repulsion caused by the principle of exclusion will be less than the pull of gravity. He calculated that a cold star, with a mass greater than one and a half times the mass of the sun, could not hold up against its own gravity.

In 1938, HANS BETHE and CHARLES CRITCHFIELD [3] concluded that the stars are similar to large furnaces, in which lighter atomic nuclei fuse, resulting in heavier elements. During the process occurs release of large amounts of energy and a large percentage is in the form of light. When the star ages, the fusion reactions are no longer sufficient to generate high pressure and, therefore, it undergoes a contraction effect of its own gravitational force, then generating the collapse. In 1939, Julius Oppenheimer and Hartland Snyder [3] conclude that star to collapsing, may give rise to black holes. Black holes are born when stars die. Not any star, but very heavy stars, with masses greater than the sun. When the stars cease to generate heat and radiation, they begin to implode due to self-gravity. In heavy enough stars, the process continues indefinitely, until a huge amount of matter is trapped in a minimum volume.

In the 1960s, began a golden period for the studies of black holes. ROY KERR [4], in 1963, finds the solution of Einstein's equations for black holes with rotation. KERR found a set of solutions to the equations of general relativity that described rotating black holes. These black holes spin at a constant rate; its shape and size depend on its mass and this rate of rotation. According to the theory, black holes are somewhat simpler objects than we imagine, all we need to characterize them is its mass and its rotation. In this theory, the stars are aging collapse into a rotating ring of neutrons that produce sufficient centrifugal force to prevent the formation of a singularity. ROGER PENROSE [5] in 1965, using modern mathematical techniques, shows that, in the context of general relativity, black holes that originate classically always have a singularity inside. JOHN WHEELER [5], in 1967, coined the term black hole to characterize the final stage of collapse of a massive star, with more than three solar masses, which not even light can escape. Before Wheeler had created this designation, it was said that the gravitational collapse of a star gave rise to what is meant by frozen stars, expression that was especially popular among the community of Soviet physicists. The joint efforts of Roger Penrose, Stephen Hawking and Werner Israel [5] then came a body of ideas that describe, with a remarkable degree of internal consistency, the conditions, mechanisms and the result of gravitational collapse, as well as the very structure of space-time and characterization of the so-called singularities. Between 1965 and 1970, these physical innovative mathematical techniques used to demonstrate a number of theorems based on the classic model of the structure of space-time that predicted, when verified certain conditions, the occurrence of singularities in the structure of space-time. It should invoke the hypothesis of cosmic censorship in order to obtain, in fact, the pattern of gravitational collapse model. The result is a uniqueness of collapse, but a black hole arises only if the uniqueness appears surrounded by an event horizon, i.e. a boundary of a region that cannot send signals to infinity outside. In 1969, Penrose [6] introduced the so-called "conjecture of the cosmic censor", according to which every singularity formed from a gravitational collapse is hidden (or "censored") inside an event horizon. Studies developed by physicist STEPHEN HAWKING [6] in 1974 showed that there are mechanisms by which black holes can convert their mass into energy or particles. Thus, there are conditions in which black holes become bright. An ordinary star that revolves around one of these objects can have captured by the black hole its matter in the form of rotating discs. A spiral trajectory that stuff works around the black hole and heats to the point of emitting X-rays. Thus, in binary systems they can be detected thereby. In 1975, HAWKING made an important discovery in which black holes can evaporate, losing in the process a small amount of mass, which could also be an indication of its presence. In 2004, Hawking says that the information contained in the black hole does not disappear and can give clues to watch him.

THE PHYSICS OF BLACK HOLES

To understand the origin of stellar black holes, one has to return to the theory of fusion [7], which consists of the merger of smaller atoms, such as the hydrogen in greater atoms, such as the helium. In most of the star's life, its fuel is hydrogen, but a given instant the source of hydrogen decreases so that prevents this type of mechanism to continue working the same way. The stars are stable for a long time, for all its mass tend to collapse due to gravitational attraction. This breakdown does not occur only because the energy released by the fusion reactions balances the gravitational force. However, when the hydrogen level decreases beyond a threshold it begins to be an imbalance between the two forces. If the initial mass of the star is between 0.8 and 10 times the solar mass, when the fuel decreases to a critical point, the star expands as a super-giant generating a process known as white dwarf. When the initial mass of the star is 10 to 25 solar masses, after its hydrogen decreases to the critical point, the star explodes in a supernova. What will be in place is called neutron star that has a mass of about 1.4 times the Sun's mass and radius of around 20 km. When the mass of the original star is more than 25 times the mass of the Sun, after exploding in a supernova, what will be left on the star place is a black hole. This type of black hole is known as stellar as it has its origin in a very massive star. Moreover, the process of formation of supermassive black hole [8] is subject of controversy but there are three versions, which are the strongest candidates for providing the explanation of its origin. In one, they would be as old as the oldest galaxies; they would have been formed from the collapse of a huge amount of material forming the center of galaxies. In another possible explanation, these black holes have been formed with a much smaller mass than actually observed, but its mass had increased as were capturing dust and stars through its intense gravitational field. There is still the possibility of being formed when two galaxies have merged, and black holes in the center of these galaxies with much less mass than supermassive also merged, creating this type of black hole [8].

What happens to the light into an intense gravitational field enough to cause diversion? By going through a much denser star than the Sun, the light would be bent toward the star. When the star density is sufficient, the path of light would be so upset toward the star that it could no longer escape this gravitational field, getting this form imprisoned within it while going through a kind of border. All that would pass by the star neighborhood would be drawn into by his incredible power to bend space-time. This approach limits of a celestial body before being sucked into is known as the event horizon, a term coined in 1950 by the Austrian Wolfgang Rindler [9]. In the center of the collapsing star, a star forms a point where gravity is infinitely strong and the laws of physics no longer make sense, what we call a singularity, and the structure of space and time no longer makes sense. Involving a singularity we have the event horizon, a sphere that separates the strangeness of the black hole from the outside world, which, if exceeded leaves nothing escape. Near a black hole, this distortion of space is extremely severe and causes to have some very strange properties. In particular, a black hole has something called event horizon [9], which is a spherical surface that marks the boundary of the black hole. You can pass through the event horizon in the direction of entry, but then cannot get out more. In fact, a cross time the event horizon, you're doomed to move inexorably closer and closer to the 'singularity' at the center of the black hole. You can think of the event horizon as a place where the escape velocity equals the speed of light. Outside the event horizon, the escape velocity is less than that of light, so if you fire your rockets hard enough you can get the energy to escape the black hole. What makes the most complex thing is the theory of Stephen Hawking, who predicts that black holes evaporate slowly. After all, if evaporated, all that remains is the pure singularity, something extremely abstract. However, to counter this, physicists proposed the Cosmic Censorship Conjecture [10]. The event horizon, the boundary of space-time region, which it cannot escape, acts almost like a one-way membrane around the black hole in which objects can fall into it, but nothing, ever, can get out the same way. The event horizon is the path through space-time, traveled by light that is trying to escape from the black hole, and nothing can move faster than the light. As nothing could go inside the gravitational field, when the region in question would be observed from Earth, we would see only a dark space, without having the possibility to know that there is a super mass star [10].

The value of the potential energy U, a particle of mass **m** under the action of the gravitational field of a celestial body mass **M** is given by the expression . In this expression, G is the universal gravitational constant and r is the distance between the particle and the center of mass of the celestial body. The lower initial speed necessary for a free up particle's gravitational field action of a celestial body, to be launched from the surface thereof, is called escape velocity v_e. At that speed, the initial kinetic energy of the particle and equal to the value of its gravitational potential energy surface of this celestial body. Black holes are celestial bodies in general, extremely dense. At any instant, the radius of a black hole is smaller than the radius **R** of another celestial body of the same mass, to which the exhaust velocity of a particle corresponding to the speed of light in vacuum **c**. Thus, we can determine the minimum density of a black hole, in **R** function, from **c**, and from constant **G**.

For the particle escape the gravitational pull it must reach to infinity, where your energy is zero (E = 0). Therefore,

$$E = U + K = 0$$

$$\frac{GMm}{r} + \frac{mv_e^2}{2} = 0$$

$$\frac{mv_e^2}{2} = \frac{GMm}{r}$$

$$\frac{v_e^2}{2} = \frac{GM}{r}$$

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For a black hole, v_e = c, where c = speed of light in vacuum.

$$c^2 = \frac{2GM}{r}$$

The density of an object is given by . Therefore, m = ρ.V.

$$c^2 = \frac{2G\rho V}{r}$$

Considering the high density, we can consider the black hole as being a sphere with volume $V = \frac{4}{3}\pi r^3$, resulting in:

$$c^2 = \frac{2G\rho 4\pi r^3}{3r}$$

$$c^2 = \frac{8G\rho\pi r^2}{3}$$

Thus, the density of a black hole can be calculated by:

$$\rho = \frac{3c^2}{8\pi G r^2}$$

SCHWARZSCHILD METRIC

Karl Schwarzschild [15] found the solution to the problem in 1915, only one month after publication of the Theory of Albert Einstein's General Relativity. For Schwarzschild external gravitational fields of spherical bodies relate called the event horizon. In his analysis neglects to any rotating mass, and any electrical charges, it can be considered a good approximation to the stars of the event, planets or a black hole. A Schwarzschild black hole [15], also known as "Static Black Hole" cannot be distinguished from any other except by its mass. A massive body without rotation and without electrical charge that has the smaller radius than the Schwarzschild radius necessarily will be a black hole. The solution to the Einstein field equations must be valid for any body of mass **M**.

The Schwarzschild analysis has become a first exact solution to Einstein's field equations for the flat space.

In Schwarzschild coordinates, the metric could be placed as follows:

$$ds^2 = c^2\left(1 - \frac{2GM}{c^2 r}\right)dt^2 - \left(1 - \frac{2GM}{c^2 r}\right)^{-1} dr^2 - r^2 d\Omega^2$$

where **G** is the universal gravitational constant, **M** is defined as the mass of the object and

$$d\Omega^2 = d\theta^2 + sin^2\theta d\emptyset^2$$

corresponds to a solid angle element. The constant

$$r_s = \frac{2GM}{c^2}$$

is understood as Schwarzschild radius and plays an important role in the Schwarzschild solution.

Let us consider also a black hole with a mass equal to the mass of our sun. What is the radius of the black hole,

$$v_e = c = \sqrt{(2GM_S/r)}$$

and the radius is called the radius Schwarszchild, or event horizon radius:

$$R_{Schw} = \frac{2GM}{c^2}$$

$R_{Schw\,(sol)}$ = 3 km

On the General Theory of Relativity the geometry of space is altered by the presence of mass [19]. An area to mass is curved (non-Euclidean), while the empty space is flat (in other words, Euclidean).

In some cases we can visualize the deviation of Euclidean geometry by mapping a subspace "curved" belonging to the four dimensions of space-time (Figure 1).

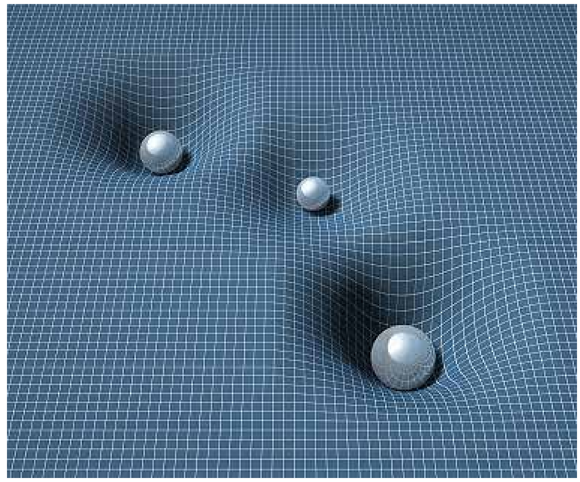

Figure 1 - deformation of space-time caused by the presence of mass
(Source: http://pensantesociedade.blogspot.com.br/)

HOW TO DETECT BLACK HOLES

How to watch an object, which, as its name indicates, does not emit any light? For now, the evidence of black holes are indirect [10] as it can only be detected their effects on nearby matter to him, since they are visible. Although we cannot see black holes, we can detect or guess the presence of one by measuring its effects on the objects around you. Some of these effects can be visualized by observing the mass of objects orbiting around black hole or spiral going into the nucleus. What is sought is a kind of gas disk-shaped vortexes that behaves as if near a large mass. You then estimate the mass of the black hole by looking at the effect it has on the visible object. Through the general theory of Einstein's relativity can say that gravity can bend space. Therefore, an object with immense gravity as a galaxy or black hole between the Earth and a distant object could bend the light from the object into a focus, similar to making a lens. In double-star systems, black holes have a star as a companion [11]. Both are orbiting the black hole while swallowing will matter to her companion disappear. The gravity of the black hole makes its companion star turn around, so, the stronger the gravity, the faster the orbit. The light deviation produced by the approach or departure from the source reveals to Star orbital speed and thus the mass of the black hole. The mass of the two bodies indicate how they orbit around each other. In the case of the black hole have more mass than the star that circulates around, the center of gravity or balance point is closer to the hole. In pairs with similar masses, the balance is in the middle. If the star has more mass, the center of gravity is inside. Many black holes have objects around them and observing the behavior of these objects, we can detect the presence of a black hole. We use the movement of the measures of the objects around a suspected black hole to calculate its mass. Such a huge mass for a disk might indicate that a black hole inside. When matter falls into a black hole from a star that accompanies it, it becomes very hot and is accelerated. Overheating of the raw emits X-rays that can be detected by X-ray orbiting telescopes such as Chandra X-Ray

Observatory, for example. The Cygnus X-1 star is a powerful X-ray source, considered a good candidate for a black hole [12], as a group of experimental astronomers and physicists show abundant evidence that Cygnus X-1 houses a black hole. In addition to X-rays, black holes can also eject materials at high speeds to form jets. Many galaxies have been observed with such jets. Currently, it is believed that these galaxies have supermassive black holes, billions of solar masses, in their cores, which produce jets. An example [12] is the galaxy called M87.

Another method being tested to detect black holes, based on facts provided by the theory of general relativity, which indicates the phenomenon of gravitational waves [13] as indicators of the black hole. Gravitational waves are produced when a large concentration of mass and energy interact and produce violent changes in the gravitational field. In our universe, these waves are associated, for example, the phenomena of the type of supernova explosions and collisions between neutron stars and black holes. Gravitational waves produced by a deranged black hole has a specific range of frequencies that are not issued by any other physical system. An important device to study gravitational waves (8) is the Advanced Laser Interferometer Gravitational Wave Observatory, ALIGO, as the name describes, using a giant laser interferometer and high precision to measure any variation that may be associated with gravitational waves. An interferometer is a device that compares two laser light beams from different directions and so are able to determine the minimum oscillation beams. In the case of the observatory of gravitational waves, minimal changes in the interferometer mirrors separated by a kilometer away [*(1,093.6 yd)**translator´s note] may be detected and studied (8).

On the other hand, to detect cosmic emissions expelled by black holes X-rays, we have the Telescopic Nuclear Spectroscopic, nicknamed NuStar, which is circulating in the Earth's orbit. At a later stage, it will examine clusters of galaxies, supernova explosions and certain regions of space where particles are accelerated to nearly the speed of light, such as around black holes. The investigation of supernovae is especially important because they serve as a ruler to measure the rate of expansion of the universe. The NuStar [8] will detect how many black holes are hidden, what size they are, and where they are. The NuStar complements the X-ray Observatory Chandra, NASA, and the European telescope XMM-Newton. Both study cosmic X-rays in low energy wave bands.

ADDING FUEL TO THE FIRE

The English physicist Stephen Hawking, one of the creators of the modern theory of the black hole, published an article online recently [20], even without review by other scientists, which states*: "There are no black holes."*

The statement puts more fuel to the discussion that attempts to reconcile the theory of relativity (which explains the macroscopic world) with Quantum Mechanics (which explains the microscopic world).

The existence of black holes was proposed from the general theory of relativity. In 1974, Hawking proposed that, in the Event Horizon, particles would escape as radiation, and it would become known as Hawking Radiation. Therefore, the black hole should slowly evaporate and disappear, causing it to obey the Second Law of Thermodynamics - which states that the entropy (disorder) of a system could never diminish. If the hole just swallowed the matter without returning anything, the entropy of the universe would be compromised. The report in the journal Nature [20], which said the new study Hawking, recalls that the proposal of the radiation generated further questions, among them the paradox that became known as the wall of fire.

By Quantum Mechanics, the Hawking Radiation does not simply dissipate but form a "wall of fire" surrounding the event horizon. The problem is that you cannot be one thing or another. Although scientists do not yet know how, to run the world, the

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