Black Holes

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8A (Self, Society, and Technology)

April 5th, 2007

What are Black Holes?

Black Holes have puzzled scientists and astronomers over the decades, perplexing even Einstein, recognized as the greatest and most innovative man of the century. It is a universal and astronomical phenomenon, otherwise known as a tear in the fabric of space-time, in which nothing, not even the fastest matter known to mankind, can escape its powerful grasp (Couper & Henbest, 1996). It is even known that this natural wonder was predicted by the theory of general relativity itself (Black Holes, 2007). Scientists currently believe that a black hole is a region within the space time continuum in which nothing, not even light, can escape (Black Holes, 2007).

To understand the principles of the gravity presented by black holes, picture a sheet of flexible fabric stretched out, so it looks like a carpet (Black Holes, n.d). This extended material represents the fabric of space time. Space-time was the theory hypothesized by Albert Einstein, which stated that throughout the entire universe there lies an invisible length of fabric (Relativity, n.d). Much like if a baseball is placed on top of the carpet, and a planet on the fabric of space time, there will inevitably be a dent where it has landed. But say a larger object, one with a greater mass, like a bowling ball, was placed on the carpet. It would be plain to see a dent obviously larger than the one previously created (Black Holes, n.d).

Again, if you changed the size of the object, and took the entire weight of a bowling ball, and were to compact to the size of a pinhead, the density of the object would greatly grow (Black Holes, n.d). The dent created by this mass would logically, be much larger than that created by the bowling ball, due to the concentration of mass in a tighter space (Couper & Henbest, 1996). Let’s say a ping pong ball is place directly besides the indentation formed by the bowling ball. Immediately, the ping pong ball should fall into the crease. Just like the little experiment presented, gravity of the black holes functions in almost identically (Black Holes, n.d). In fact, that is how the theory of general relativity portrays gravity in our world.

Scientists think that a black hole is but an extremely compact concentration of matter so great that, its gravitational pull prevents even light from escaping. The particularity with black holes is that at one point, due to its strong gravitational pull, you would require an escape velocity that exceeds even the speed of light (Couper & Henbest, 1996). The definition of an escape velocity is the speed that it takes for an object to escape another object's gravitational pull (Couper & Henbest, 1996). In theory, black holes can be of any size, but its density is far greater than even what man can imagine (Black Holes, 2007).

The term singularity is used commonly among scientists when describing the center of a black hole (Couper & Henbest, 1996). Amazingly, within this singularity, lies the entire mass of a red giant. Red giants are large celestial bodies, and those that later form black holes are usually 10 times as heavy as the sun we revolve around (Couper & Henbest, 1996). Again, the size of the singularities is in question, for some scientists believe that the singularity may be around 35-40 miles across, while others imagine it to be a point so tiny, that it cannot be viewed by the naked eye (Couper & Henbest, 1996).

What is an Event Horizon?

Most commonly known as the point of no return, the event horizon is an astronomical point that has puzzled even Stephen Hawking, famous for his controversial theories towards black holes. It is a sphere surrounding the singularity of a black hole (Couper & Henbest, 1996). This outline is made up of millions and millions of photons. In the region where the photons are located, the gravity is too strong to allow them to escape, but not strong enough to pull them into the black hole (Couper Henbest, 1996). The photons remain motionless, unable to move. This radius is known as the event horizon (Couper & Henbest, 1996). It is important to remember that the event horizon is the point that if crossed, the speed needed to escape exceeds the speed of light. That doesn't mean that there is no gravitational pull on the other side of this wall of photons. If not passed the event horizon, escape is still possible, yet very unlikely (Couper & Henbest, 1996).

The event horizon was, surprisingly, not discovered by Stephen Hawking, but by another man named Karl Schwarzschild (Couper & Henbest, 1996). This physicist and astronomer used Albert Einstein's theory of general relativity to create an equation that proved the existence of a "magic circle" through which nothing could escape. The name: "Magic Circle" was later changed to event horizon (Couper & Henbest, 1996).

Stephen Hawking believed that in space, there are many virtual matter particles (Ferguson, 1991). They are invisible, but prove to exist due to their reactions effects on objects around them. Around the region of the event horizon, these particles, traveling in pairs (positive and negative), were attracted to the mysterious outline. The negative particle would be caught inside the event horizon, and sucked into the black hole. Thus, this originally virtual particle was made into a real particle (Ferguson, 1991). We must acknowledge the fact that this process is being repeated constantly and in large numbers all around the black hole. To the observers of black holes, these positive particles are seen as a sort of radiation (Ferguson, 1991). Hawking called this the Hawking Radiation. This proves that a black hole can get smaller and eventually evaporate. However, this contradicts with his first theory that states that black holes can never get smaller due to the placement and functions of the photons that make up the event horizon. But to any thinking person, this statement doesn't make any sense. If nothing can escape the black hole, it is impossible for it to get smaller and disappear. But Hawking came up with another statement that proved this contradiction wrong. According to Ferguson, 1991, when the black hole changes the virtual particles into real particle, it loses energy. When the black hole takes this NEGATIVE energy in, it takes the energy OUT of the black hole, therefore making it smaller because when something has less energy, it has less mass (Ferguson, 1991). Hence, Albert Einstein's famous equation: $E=mc_2$

How do Black Holes form?

For the past century, the debate over the size and shape of black holes has raged on, to no prevail. Yet, the majority of all scientists agree on one fact, the fact that black holes are formed in two very different manners (Black Holes, 2007). The most commonly known method of the formation of black holes is from the collapse of stars 10 or more times the mass of our sun, known as stellar black holes (Black Holes, 2007; Couper & Henbest, 1996). But, through the alternative formation process of these mystical marvels, they can turn out to be millions or even billions times the size of even the biggest star within the Milky Way (Black Holes, 2007). These supermassive black holes are called just that, due to its unparalleled size.

With our current knowledge and technology, it is thought that most, if not all, of the galaxies in the universe contain supermassive black holes at their center (Black Holes, 2007). This is thought to be due to the manner in which these grand phenomena form. When the interstellar matter of the galaxy collects within its heart, these billions, if not trillions, tons of these particles are brought together (The Columbia Encyclopaedia. 2006). Soon enough, these particles implode upon itself due to the extensive force of gravity upon its surface, and then begin the new life as a black hole (The Columbia Encyclopaedia. 2006). Although they carry the same names, stellar black holes and supermassive black holes are different in many key aspects. The greatest difference between these two types, apart from the size difference, is the strength of the tidal forces at the event horizon (Supermassive Black Holes, 2007). Tidal forces are when an object and its utter molecular structure are distorted due to the pull of gravity. Thus, a sphere during the process of tidal forces would appear much like an ellipse, rather than a perfectly circular sphere (Supermassive Black Holes, 2007). This bizarre event occurs, for the singularity is such a far distance away, the extreme distortion would appear farther on, in the tear of the space-time continuum (Supermassive Black Holes, 2007).

The more commonly known and abundant black holes; scientifically known as stellar black holes, form in a much more complex fashion. Predicted by the theory of general relativity itself, these black holes first step to creation is the making of a large celestial object, a star (Black Holes, 2007; Couper & Henbest, 1996). Stars are formed when thinly spread atoms of dust and gas clump together and eventually become the makings of a star. A nuclear furnace activates, within the core of the star, which results in the bright and shining stars we see in the sky of today (Couper & Henbest, 1996). Inside the star, it rapidly burns its hydrogen atoms to create helium atoms, for the fuel which keeps it burning for millions of years. This force created by this internal furnace equalizes the pressure of the gravity pushing inwards on this large object. The process of pressure outwards of hydrogen duel burning and gravity equalize (Chang, 2004; Black Holes, n.d). Yet, after a long period of time, which can reach up to billions of years, the sun will run out of hydrogen fuel to burn (The Columbia Encyclopaedia. 2006).

Once the star has reached this point in its life, gravity takes over (Chang, 2004; Couper & Henbest, 1996). Gravity squeezes the star’s core even tighter than before, thus the outer layers of the star bloat out to huge proportions (Couper & Henbest, 1996). According to Couper & Henbest, 1996, the sudden inflammation can reach up to 100 times its previous dimensions. It is now technically termed a red giant. It is on this point that the lives of stars smaller than 10 times the size of our sun, and those greater split off. Those smaller slowly “shed” its outer layers off into space, which leaves an uncovered star core which is at the mercy of gravity. A cosmic smoke ring, made out of interstellar matter forms around the core, and is called the planetary nebula (Couper & Henbest, 1996; The Columbia Encyclopaedia. 2006). But, much like the outer layers of the red giant, the planetary nebula slowly drifts away, and leaves the sole star core, now known as a white dwarf (The Columbia Encyclopaedia. 2006). The matter of this retired star is so tightly packed that, with its molecular structure, a matchbox sized chunk would weight equivalently to an elephant (Couper & Henbest, 1996). There the white dwarf remains, no longer shining, but drifting aimlessly in our universe.

Heavyweight stars, those which weigh 10 times heavier than the sun, are a totally different story (Couper & Henbest, 1996). At the stage of the red giant, they turn against their internal iron core to fuel their needs. Yet the moment they try to compress the iron, havoc breaks out. The red giant immediately collapses into itself, and, next to the Big Bang, gives way to the second largest explosion in the universe, acknowledged today as a supernova (Couper & Henbest, 1996; Narlikar, 1982). Strangely, once the star commences its implosion, the process of the collapse cannot be stop, until it reaches the point of a pulsar or a black hole (The Columbia Encyclopaedia. 2006).

A pulsar is but a super dense neutron star, which was too light too become a black hole, yet was massive enough to continue through the process of the supernova explosion (Couper & Henbest, 1996). It has been shown that the material that makes up this rare celestial body is so dense due to the external pressure of gravity, that a pinpoint sized matter with this density could weigh as much as one million tons. For comparison, this would be two times the weight of today’s biggest existing super tanker (Couper &

Henbest, 1996). Yet, due to the atomic structure of the pulsar, it prevents itself from imploding (collapses) into itself, from the pressure of gravity (Couper & Henbest, 1996).

Yet, in the rare cases that the star is too big even to support the structure of a pulsar, it becomes a black hole (The Columbia Encyclopedia. 2006). To show the extent of the shrinking from a star to the black hole, I will put forth two examples. According to Couper & Henbest, 1996, for earth to convert into a black hole it will be required for it to be shrunk into a sphere one inch across. And according to Black Holes, 2007, for the sun to grow an event horizon and a singularity, it would need to contract into a ball with a diameter of 3km! It is thus I conclude the creation of one of the greatest wonders of the universe today.

The Discovery/Predictions of Black Holes

Although the conception of a black hole was considered by centuries, the first real evidence of a black hole came in 1970. On that year, a satellite by the name of Uhuru, the Swahili word for “freedom”, was manufactured and launched by American scientists (Couper & Henbest, 1996). It was officially launched in Kenya, celebrating its seven years of independence. Soon after, a very bizarre sighting was made, for the Uhuru detected many X-ray sources, where it showed both gas and energy was being stolen from a star, and from there was sucked into a nearby object (Couper & Henbest, 1996). The first proof of black holes had been found, for the black hole was in the process of stealing both the light and fuel from its neighbouring star (Couper & Henbest, 1996). But more than two centuries ago, one scientist hypothesized that one day, such evidence would appear (Couper & Henbest, 1996).

The year was 1784, one of the most memorable dates in black hole history, for John Michell, an English geologist, first wondered if gravity would ever be powerful enough to affect light (Black Holes, 2007). So he put forth a paper that calculated that if a body was so big, it would be able to suck up both light and anything around it (Couper & Henbest, 1996). 15 years after John Michell had released his article, a French mathematician named Pierre Simon Laplace backed him up with two of his own books (Couper & Henbest, 1996; Black Holes, 2007). Yet, for their ideas to even be plausible, they needed have a star so large, that the escape velocity would reach higher than the speed of light. With an initial speed slower than the need escape velocity, light or any other matter would be sucked right back (Thorne, 1994).

It was only until 1915, when Albert Einstein released his article about general relativity, that another great leap was made for the field of black holes. It was thanks to this article that a strong argument about black holes was made (Black Holes, 2007). Even though Albert Einstein was the very person who wrote the publication that supported the existence of black holes, Einstein continued to decline the possibility of such an amazing wonder (Thorne, 1994). Just a few months later, physicist Karl Schwarzschild released an equation which proved that the existence of black holes was very much possible (Black Holes, 2007).

What is the Relationship between Black Holes and Einstein’s Theory of General Relativity?

Albert Einstein is famous for his theories about relativity in the universe. His thoughts and beliefs are some of the very few certainties that scientists can rely on (General Relativity, 2007). Created in 1915, the theory of general relativity stated that gravity isn’t a force, but a distortion in space (Couper & Henbest, 1996). Einstein thought of the universe as a sheet of extremely flexible fabric that was stretched out, so that it looked like a carpet in the air. This fabric represents the fabric of space time, the never ending fabric of space time (Black Holes, n.d). If a bowling ball is placed on this material, there will inevitably be a deformation in the fabric. Now, if a ping pong is placed next to the dent in the fabric, the ball will instantly fall into the cavity. But if all the matter inside the bowling ball was to be compressed to be the size of a pinhead and then placed on the fabric, the indentation will be considerably deeper. Again, if the ping pong ball was placed next to the dent, it will instantaneously fall in. However, the speed at which it falls will be significantly greater (Black Holes, n.d). That is how Einstein believed gravity in all respects worked. The larger the object, the greater, the mass, the greater the distortion, therefore there will be a greater the gravitational attraction (Couper & Henbest, 1996). The mass of the bowling ball inside the pin head would be a good example of a black hole. The denser the object, the greater the distortion is in the fabric of space time, the greater the gravitational pull (The Columbia Encyclopedia. 2006). The space time continuum is length x width x height x time. The only difference between this example and reality is that in reality, everything is in 3-D (The Columbia Encyclopedia. 2006).

Who Contributed to the Knowledge of Black Holes?

Stephen Hawking

Stephen William Hawking was born on January 8, 1942 to Frank Hawking and Isobel Hawking. Brother to two younger sisters, Philipa and Mary, and one adopted brother named Edward (Stephen Hawking, 2007). Stephen was born in Oxford, but shortly after his birth, his family relocated to London (Stephen Hawking, 2007). When Stephen was 11 years old, his family moved to St Albans in Hertfordshire, where he attended St Albans school. He was a good, but not exceptional student. Because of his love for science, he enrolled at University College, Oxford, with an intention of studying math (Stephen Hawking, 2007). His father, noticing that his son's choice was not the best; he jumped in and persuaded Stephen to take physics instead. After three years of very little work, Hawking was awarded a first class honours degree in Natural Science (Stephen Hawking, 2007). A strange aspect about Stephen Hawking's study behaviour, was that the never wrote any notes down on paper. He later went to Cambridge University to study cosmology. After gaining his PhD, he became first, a research fellow, and later, a professional fellow at Gonville and Caius College (Couper & Henbest, 1996). After leaving the Institute of Astronomy in 1973, Stephen went to teach at the Department of Applied Mathematics and Theoretical Physics. His knowledge in science in general, earned him the position of Lucasian Professor of Mathematics; a position once held by the great Isaac Newton (Ferguson, 1991).

Throughout the course of Stephen Hawking's life, he has worked on the basic laws which govern the universe. Alongside a man named Roger Penrose, he demonstrated that Albert Einstein's theory of relativity implied that space and time would have a beginning in the Big Bang, and an end in black holes (Couper & Henbest, 1996). To completely understand this, he proved that it was necessary to unify general relativity, quantum theory, and other scientific theories developed during the first half of the 20_{th} century. But while researching using these complex theorems, he was struck with an idea. He concluded that black holes should not be completely black (Ferguson, 1991). Discovering that there was some sort of energy being emitted from the black hole in the form of radiation. He called it Hawking Radiation. He later concluded that if this radiation kept flowing from the black hole for a long enough time, it would eventually evaporate and disappear (Ferguson, 1991).

For much of his adult life, Stephen Hawking has been confined to a wheelchair due to amyotrophic lateral sclerosis, also known as Lou Gehrig's disease (Ferguson, 1991). He was incapable of walking, talking, feeding himself, or writing by the time he was a Lucasian Professor at Cambridge University. Professor Hawking has 12 honorary degrees, was made a champion of honour in 1989 (Ferguson, 1991). He is the recipient of countless medals, awards, and prizes, a Fellow of the Royal Society and a Member of the US National Academy of Sciences (Ferguson, 1991). The solutions that Stephen Hawking has provided us with about the universe and how it works has truly set research in cosmology in motion. He is an essential character for the advancement in science, and will be remembered as well as Isaac Newton himself.

Karl Schwarzschild

Karl Schwarzschild was born on October 9th, 1873, in Frankfurt am Main, Germany to Henrietta Sabel and Moses Martin Schwarzschild. Karl was the oldest of six children, having 4 brothers and 1 sister. Because of his Jewish ethnicity, he attended a Jewish primary school in Frankfurt until he was 11, and later entered the gymnasium there. It was during that period, that he developed an interest for telescopes which later lead to a love for astronomy. He would save his money to buy the materials needed to construct a telescope. Luckily, his Karl's father was friends with Professor J, Epstein, who was a well known professor at the Philanthropin Academy, and he even had his own private observatory. It was because of the excellent relationship between the two that Karl had with Epstein that he mastered celestial mechanics by the age of 16. It was because to his understanding, that he wrote two papers on the orbits of double stars while still at the gymnasium. Schwarzschild later studied at the University of Strasbourg, and later at the University of Munich where he obtained his doctorate.

The next few years were spent studying science and the many aspects of space. He worked on ways to determine the apparent brightness of stars using photographic plates, measuring stellar magnitudes, radiation pressure of the sun, what the tails of comets were made of, and the transport of energy through a star by radiation. Although his contributions were not very well known, every discovery is vital when it comes to astronomy.

One of his most famous and well known contribution to science was something called the Gravitational Radius, or the Schwarzschild radius. This is a characteristic radius associated with every mass. This “rule” states that if any spherical mass were to change and to acquire that radius, no known force could prevent it from collapsing into gravitational singularity. This gravitational singularity is also known as a black hole. Schwarzschild obtained this solution just a few months after Einstein discovered the theory of general relativity. The equation for this radius is $r_s = 2Gm/c^2$. r_s would be the Schwarzschild radius, G would be the gravitational constant, m is the mass of the gravitating object, and c is the speed of light. Although this equation proved the existence of black holes, their existence was still debated for decades. The surface at the Schwarzschild radius acts as an event horizon. He stated his discoveries in a paper written in Russia. He was the first to give exact solutions to Einstein’s equations of relativity. Einstein later stated: *I had not expected that one could formulate the exact solution of the problem in such a simple way.* Karl Schwarzschild was a very important contributor to the advancement of astronomy, and proved the existence of black holes.

Bill Unruh

Bill Unruh was born on August 28, 1945 at Winnipeg, Manitoba (Bill Unruh, 2001). With more than 5 awards to his name, this exceptional professor and physicist has contributed much to the knowledge of black holes (Bill Unruh, 2001). Bill Unruh is greatly acclaimed for the creation of the Unruh effect (Bill Unruh, 2007). This theory states that if an observer is in the process of accelerating, he will observe black-body radiation, where as an immobilized observer would observe no such thing (Bill Unruh, 2007). In other words, the man who is accelerating will find himself in a warm background, a hotter colour on a thermal reading scan which indicates hotter atmosphere around him (Bill Unruh, 2007).

Bill Unruh's main area of research in the field of astronomy is the study of black hole evaporation (Bill Unruh, 2001). This was a discovery first made by Stephen Hawking, which still remains a mystery to the societies of today (Bill Unruh, 2001). Bill Unruh also greatly deals with sonic black holes, which are artificially produced phenomena, which mimic the many principles and functions of black holes which suck in light. Yet sonic black holes are able to trap sound, which enables scientists to study the true characteristics of black holes, if there really are black holes somewhere out there in the universe.(Sonic Black Holes, 2007)

Israel Werner

Born on October 4th, 1931, Israel Werner has contributed greatly to the astronomical knowledge of our present day scientists (Israel Werner, 2001). As a child, this renowned Canadian physicist grew up in Berlin, Germany, and then moved to Cape Town, South Africa where he spent of his childhood (Israel Werner, 2001). He now resides in Victoria, British Columbia, but during the majority of his working life, he spent in living in Edmonton, Alberta (Israel Werner, 2001; Israel Werner, 2007).

During the year 1967, Israel Werner published an article trying to prove that black holes are one of the simplest principles in the universe (Israel Werner, 2001). In 1990, Israel Werner led a research with Eric Poisson, attempting to figure out what's happening inside of a black hole (Israel Werner, 2001; Israel Werner, 2007). One of the most puzzling questions that still shake the world is that if a black hole evaporates, what becomes of all the information stored within the black hole (Israel Werner, 2001)? Does it evaporate with the world, or does there still remain a connection stored within it that contains the "lost" information (Israel Werner, 2001). With his expertise, he has even co-edited two volumes about black holes and its science, and has become one of the most renowned cosmology professors in the world (Israel Werner, 2001; Israel Werner, 2007)!

What are the controversial theories behind black holes?

Naked singularity is a very peculiar phrase, as it is as much a topic. This theory states that it may be possible for a black hole to form without an event horizon, which ultimately sucks up all the light, so as we cannot see the singularity within its core (Couper & Henbest, 1996; Naked Singularity, 2007). If this theory is proven true, it would be possible to observe a singularity without anything blocking our view, such as the obvious nuisance, the event horizon (Naked Singularity, 2007). In 1965, a British mathematician by the name of Roger Penrose proved that every black hole must and will always contain a singularity (Couper & Henbest, 1996). For without it, a black hole wouldn't have been able to form in the first place (Naked Singularity, 2007). Yet, when he heard of the theory of naked singularities, Roger Penrose immediately created a cosmic censor. This was essentially a hypothesis which tested against the naked singularity theory (Cosmic Censor Hypothesis, 2007). There are two different versions of this hypothesis, the weaker and the stronger. The weaker cosmic censor hypothesis simply states that in essence, a naked singularity would be observable, but anyone who has ever observed it shall be sucked in anyways (Cosmic Censor Hypothesis, 2007). The stronger hypothesis essentially states that no singularities, even those who are naked, are ever visible to any observer (Cosmic Censor Hypothesis, 2007).

There is only one theory that explains the formation of naked singularities (Couper & Henbest, 1996; Naked Singularity, 2007). Once a body has imploded to become a black hole, only those which spin in a sideways manner have the chance of becoming a naked singularity (Naked Singularity, 2007). Due to the sideways rotation, it creates a strong electric field (Couper & Henbest, 1996). As the electrical charge starts to grow, and the spin increases with it, the inner event horizon and the outer event horizon merge and collide (Couper & Henbest, 1996). The theory then states that once the collision follows through, all that remains is an unclothed singularity. If this is in fact possible, it may give scientists a chance to understand more about this natural wonder, which has graced the universe for billions of years (Naked Singularity, 2007).

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