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RESEARCH ARTICLE

Missing Link in Galactic Evoluton, Obscene Growth of Black Holes and Naked Singularities

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Abstract

This article gives an elementary review of missing link in Galactic evolution and obscene growth of black holes. Known models of collapse resulting in the formation of black holes and naked singularities are summarized.

Introduction

Modern astrophysics is opening a book of puzzles to the scientists. The black hole is one of these latest puzzles of astrophysics. Although the general theory of relativity and gravitation predicts the inevitable formation of black holes in the galaxy, they have not yet been observationally demonstrated.

On a clear summer evening if one looks upon the vault of the sky, one may see the fascinating view of the milky band stretching from one corner of the vault to the other. The ancients attained the holy meaning to it of being the heavenly way along which the gods travel in their chariots. But we now know that this milky band is the manifestation of the along the equatorial plane of the stellar system or the galaxy to which our solar system belong. This is our galaxy, also called the Milky Way galaxy. The Milky Way spans more or less over the entire heavens following the course of a great circle around the celestial sphere.

The brightest section of the Milky Way is its southern half lying between the two constellations- Agro and centaurs'. The width of the Milky Way varies considerably. It is widest in the Scorpio and Sagittarius regions, while in the Taurus and Auriga regions both the width and the brightness are much reduced. Some regions of the Milky Way have thicker assemblage of gas and dust which obscure the stars behind them. The Galaxy is a disk shaped spiral of type $S_{b.}$ The study of the structure of our galaxy and the physical and dynamical properties of its various constituents has assumed great importance in the current astrophysical research. Astronomers believe that such studies may ultimately reveal the mystery behind the process of formation and evolution of galaxies in general and the role played by the stars cosmic rays, magnetic field, stellar evolution, nucleosynthesis, interstellar gas and dust and unseen matter etc. in particular. The stars constitute the major portion of the total luminous mass of the galaxy and they are the principal 'action' of the highly interesting 'galactic- drama.' The contribution of the gas to the total luminous mass may be taken to be 5 to 10 percent. The cosmic ray particles are confined by the magnetic field of the galaxy; otherwise they would have left the system within a period of about 10^5 years since the evolution of the galaxy.

(A) Missing link in Galactic evolution:

The new species in the cosmic zoo is a super-heated, dust shrouded object called a "hot-DOG," which may represent a missing link in the evolution of Galaxy. A full sky survey by Nasa's Wide Field Infrared Survey Explorer(Wise) telescope turned up about 1000 hot, dust-obscured galaxies or hot DOGs, each of which pump out as much light as 100 trillion sun-like stars. These objects are rare, accounting for about one in 100,000 light sources and are difficult to field since most of their energy is masked by dust.

Astronomers believe that hot DOGs, which are twice as warm as similar galaxies, may be a transitional state between disk-shaped galaxies such as the Milky-Way and elliptical galaxies. Most of the hot DOGs found by Wise are about 10 billion light years away, which means that they were formed when the universe was a fraction of its present age.

Scientists suspect conditions in the early universe were more conducive for seeding and growing these hot galaxies, but they are not ruling out that the phenomenon could occur today. ‘There is either just a weird set of circumstances that rarely comes up for only a very short period of time, ‘that allows hot DOGs to form, said wise project scientist Peter Eisenhardt of Nasa’s Jet Propulsion Laboratory in Pasadena,California.As the galaxies do not have enough stars to account for all their heat, scientists suspect that they may contain unusually active super-massive black holes, which are regions of space so dense with matter that not even light can escape the grip of its gravity.

At times, black holes freed on surrounding material, providing telltale signs of their existence. All galaxies are believed to host a black hole, though some, such as Sagittarius A-located at the centre of the Milky-Way are relatively dormant, at least at the present time. Scientists estimate Sagittarius A contains 4 million times the mass of the sun. Other black holes are substantially larger, approaching 10 billion times the Sun’s mass. Among the 563 million infrared objects detected by wise during its two-year mission are millions of super massive black holes.

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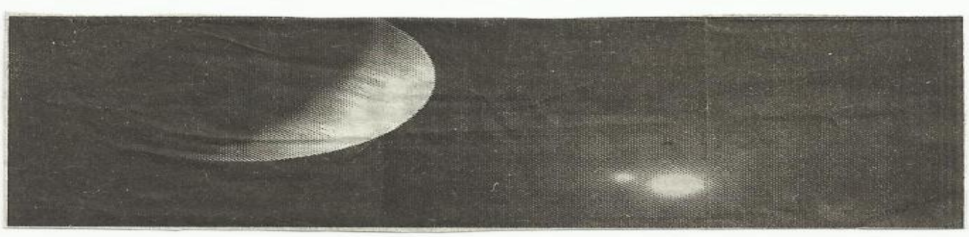
A black hole has been appropriately described by Chandrasekhar as the most beautiful macroscopic object known to man. Only a few parameters suffice to describe the most general black hole solution, and these objects have remarkable thermodynamics properties. Further, excellent observational evidence for their existence has developed over the years (Rees 1998).Thus, there can be no doubt about the reality of black holes, and the gravitational collapse of very many sufficiently massive stars must end in the formation of a black hole.

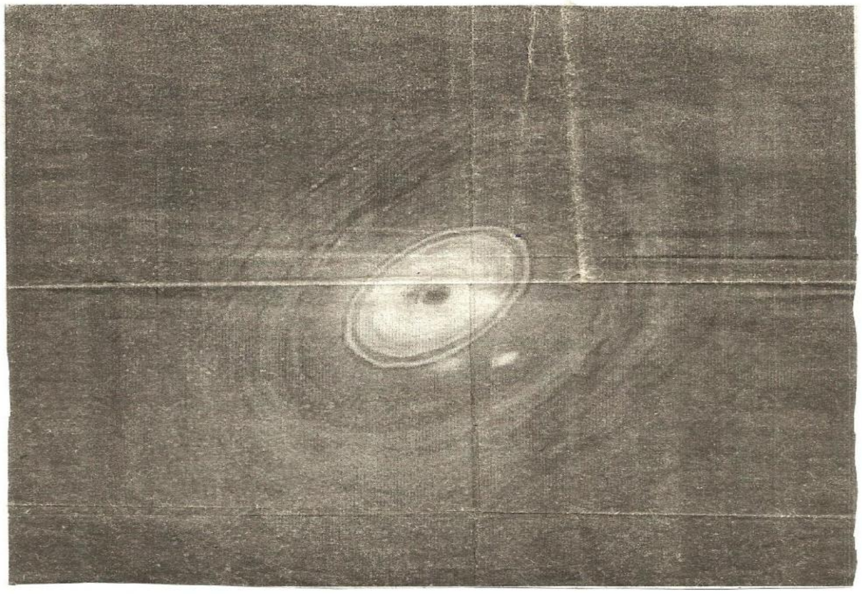
(A) Obscene Growth of Black Holes:

A black hole is a place in space where gravity pulls so much that even light cannot get out. The gravity is so strong because matter has been squeezed into a tiny space. This can happen when a star is dying.

Because no light can get out, people cannot see black holes. They are invisible. Space telescopes with special tools can help find black holes. The special tools can see how stars that are very close to black holes act differently than other stars. Black holes can be big or small. Scientists think the smallest black holes are as small as just one atom. These black holes are very tiny but have the mass of a large mountain. Mass is the amount of matter, or “Stuff”, in an object.

Another kind of black holes is called “Stellar”. Its mass can be up to 20 times more than the mass of the Sun. There may be many, many stellar mass black holes in Earth’s galaxy is called the Milky Way. An artist’s drawing shows the current view of the Milky Way galaxy. Scientific evidence shows that in the middle of the Milky Way is a super massive black hole. Image Credit: NASA/JPL-Caltech.





The largest black holes are called “Super massive”. These black holes have masses that are more than 1 million Suns together. Scientists have found proof that every large galaxy contains a super massive black hole at its centre. The Super massive black holes at the centre of the Milky Way galaxy are called “Sagittarius A”. It has a mass equal to about 4 million Suns and would fit inside a very large ball that could hold a few million earths.

Scientists think the smallest black holes formed when the universe began. Stellar black holes are made when the centre of a very big star falls in upon itself, or collapses. When this happens, it causes a supernova. A supernova is an exploding star that blasts part of the star into space. Scientists think super massive black holes were made at the same time as the galaxy they are in. A theory about why black holes become so hugely massive has been put forth by astronomers from university of Leicester, UK and Monash University, Australia.

Andrew King, Professor of Physics from Leicester, said: “Almost every galaxy has an enormously massive black hole in its centre”, the journal monthly notices of the Royal Astronomical Society reported.

Our own galaxy, the Milky Way, has one about four million times heavier than the Sun. “But some galaxies have black holes a thousand times heavier still. We know they grew very quickly after the Big-Bang.” said King. “These hugely massive black holes were already full grown when the universe was very young, less than a tenth of its present age,” added King, according to a university statement. Black holes grow by sucking in gas. This forms a disc around the holes and spirals in, but usually so slowly that the holes could not have grown to these huge masses in the entire age of the universe.

“We needed a faster mechanism, so we wondered what would happen if gas came in from different directions,” said Chris Nixon, also at Leicester. Nixon, King and their colleague Daniel Price in Australia made a computer simulation of two gas discs orbiting a black hole at different angles. After a short time the discs spread and collide, and large amounts of gas fall into the hole. According to their calculations black holes can grow 1000 times faster when this happens.

“If two guys ride motorbikes on a wall of death and they collide, they lose the centrifugal force holding them to the walls and fall,” said King. The same thing happens to the gas in these discs, and it falls in towards the hole. This may explain how these black holes got so big so fast.

“We don’t know exactly how gas flows inside galaxies in the early universe, but I think it is very promising that if the flows are chaotic it is very easy for the black hole to feed.” said King.

A clear understanding of the black hole physics and mechanics posed serious problems until a few years ago. But recently, the gate way to understanding these complicated problems has been opened to meaningful theoretical investigations, thanks to the very significant works in the field by Penrose, Hawking, Bardeen, Lyn din-Bell, Chandrasekhar and several others. It is now understood that a black hole may capture mass from the surrounding space by its intense gravitational pull. The probability for such capture becomes almost certain, if the black hole be the member of a binary system consisting of a normal star. Owing to the intense gravitational pull the black hole will then draw gas from the upper atmosphere of the companion. This gas will form a rotating disc around the black hole by virtue of the conservation of angular momentum which the captured matter originally possessed.

Frictional force will dissipate the kinetic energy of matter, particularly of that in the inner part of the disc, where by the centrifugal balance will be upset and the matter will spiral towards the black hole to be sucked in by it ultimately, in the same manner as atmospheric friction brings down the artificial satellites to the surface of the earth.

(C) Naked Singularities:

We consider the gravitational collapse of physically reasonable classical matter, whereby "physically reasonable" is meant that the matter satisfies one or more of the energy conditions (weak energy condition, string energy condition and the dominant energy condition). Also most of the collapse studies that have been carried out so far deal with spherical collapse even this simplest of system is poorly understood, in so far as cosmic censorships is considered. It is of course true that spherical collapse, if allowed to proceed to completion, results in a Schwarzschild black hole. However, a spherical collapsing system can also admit time like or null singularities which can be naked. From the point of view of an observer falling with the star this can happen if a singularity forms inside the star (say at its centre) before the boundary of the star enters its Schwarzschild radius. Such a singularity can be naked.

We assume that as the collapse starts, If the star cannot shed off most of its mass, the collapse continues with increasing speed, thereby producing more and more intense gravitation field and reducing the size of the star. In this process a stage is reached when the radius R_S of the star of mass M is given by

$$R_S = \frac{2GM}{C^2},$$

Where C is the speed of light. R_S is called the Schwarzschild radius. When the radius has been attained, the object will have such a strong gravitational field that it will prevent even light from escaping out of its influence. The Schwarzschild radius has therefore been called the event horizon (meaning that any event within it remains hidden from view as one below the horizon) and the resulting object as the black hole. In a spherically collapsing star all the material will simultaneously reach the centre within a period of about 1 μsec after choosing the event horizon. The entire mass thus shrinks to a point of infinite density, which forms a singularity.

The exact solution of Einstein equations for spherical collapse with a general form of matter is not known, collapse of matter with various equations of state has been studied. In the following pages, we review some of these results.

(i)Spherical dust collapse:

The model of gravitational collapse is due to Oppenheimer and synder showed that the collapse of a homogeneous dust sphere results in the formation of a black hole (by dust is meant an idealized perfect fluid for which the pressure is zero). It was thought that the formation of black hole will not be affected even if the specialized assumptions of this model (homogeneity, sphericity, dust equation of state are relaxed). When the assumption of homogeneity is relaxed, there is an exact solution of Einstein equations the Datt-Tolman-Bondi solution, which describes collapse of a dust sphere with non-uniform initial density. Two kinds of singularities can result shell crossing and shell focussing. While the former have a Newtonian analog, at least some of the latter appear to be purely relativistic origin. It has been shown by various authors (for detailed references see sing 1996; also see Dwivedi and Joshi 1997; Herrera et al. 1997) that the shell focusing singularities can be of both the black hole and naked type, depending on the initial conditions. Now, consider the collapse of a dust sphere, starting from rest, and having an initial density profile near the centre given by

$$\rho(R) = \rho_0 + \rho_1 R + \frac{1}{2}\rho_2 R^2 + \frac{1}{6}\rho_3 R^3 + \ldots\ldots\ldots\ldots\ldots$$

It shows that the singularity is naked if ρ_1 is less than zero, and also if ρ_1 is equal to zero and ρ_2 is less than zero. If both ρ_1 and ρ_2 are zero and ρ_3 is negative, then we define a dimensionless quantity $\varepsilon = |\rho_3| / \rho_0^{5/2}$. The singularity is naked if $\varepsilon \geq 25.48$ and covered if ε is less than this number. If ρ_1 , ρ_2 and ρ_3 are all zero, the singularity is covered, the Oppenheimer Synder collapse being a special case of this. It is known that the collapse of null dust (directed radiation), described by the Vaidyh space-time, also gives rise to both black hole and naked singularity solutions, depending on the rate of in fall (for references see Singh 1996).

(ii) Spherical Collapse with general form of matter:

There is a certain degree of similarity in the collapse behaviour of dust, fluids and scalar fields in all cases some of the initial data lead to black holes, while other data lead to naked singularities. This would suggest an underlying pattern which is probably characterized, not by the form of matter, but by some invariants of the gravitational field. Hence investigations of collapse which put no restriction on Tik apart from an energy condition should prove useful.

An attempt in this direction was made by Dwivedi and Joshi, 1994. They assumed a general T_k^i obeying the weak energy condition, and also that the collapsing matter forms a curvature singularity. In the commoving co-ordinate system, matter is described by its energy density and the radial and tangential pressures. These three functions describing the metric enter a set of five Einstein equations, which are coupled with an equation of state in order to close the system. The geodesic equation for radial null geodesics is written in the limit of approach to the singularity, and it is shown that the occurrence of a visible singularity is equivalent to the occurrence of a positive real root for the geodesic equation, suitably written. Since this equation depends on free initial data, it follows that for a subject of the initial data there will be positive real roots and the singularity will be visible.

(iii) Properties of Naked Singularities:

There are now sufficiently many known examples of naked singularities for one to enquire about properties of such singularities. It may be that there are well defined laws of 'naked singularity mechanics' just as there are the laws of black hole mechanics (though there is no indication at the moment that such a thing is true). At present there is only some scattered knowledge about properties like curvature strength, stability of the Cauchy horizon and red shift.

Examples of both weak curvature and strong curvature naked singularities have been found (Singh, 1996). While space-time cannot be extended through the latter kind of singularity, it may possibly be extendible through a weak singularity. For a discussion of extendibility see Clarke, 1993. If the Cauchy horizon accompanying naked singularities were to be unstable that could be evidence in favour of cosmic censorship. However, examples of stable as well as unstable Cauchy horizons are known in classical collapse. (See Penrose, 1998 for some more discussion on Cauchy horizon stability).

The red shift of the null rays emanating from a singularity can be shown to be infinite, in the known examples, assuming that the standard red shift definition can be used all the way up to a singularity. In this sense, naked singularities are as black as black holes themselves. However, this does not appear to be a good way to preserve censorship because ultimately quantum effects near the naked singularity must be taken into account, and these will serve to distinguish a black hole from a naked singularity. It can also be shown in a straight forward way that any self focusing naked singularities that might form in spherical collapse are necessarily mass less (Lake, 1992; Cooper stock et al. 1997). It can be said that if a naked singularity forms, its most significant property is that regions of extremely high curvature are exposed. This will have observable consequences which will be essentially unaffected by the other properties can only have secondary importance.

Conclusion:

A clear understanding of the black hole physics and mechanics posed serious problems until a few years ago. But recently, the gateway to understanding these complicated problems has been opened to meaningful theoretical investigations thanks to the very significant works in the field by Penrose, Hawking, Bardeen, Lynden-Bell, Chandrasekhar and several others. It is now understood that a black hole may capture mass from the surrounding space by its intense gravitational pull. The probability for such capture becomes almost certain, If the black hole be the member of a binary system consisting of a normal star. Owing to the intense gravitational pull the black hole will then draw gas from the upper atmosphere of the companion. This gas will form a disk around the black hole by virtue of the conservation of angular momentum which the captured matter originally possessed. Frictional force will dissipate the kinetic energy of matter, particularly of that in the inner part of the disk, whereby the centrifugal balance will be upset and the matter will spiral towards the black hole to be sucked in by it ultimately in the same manner as atmosphere friction brings down the artificial satellites to the surface of the earth.

The works of Penrose and Hawking have shown that a still more efficient process of gravitational radiation can be achieved when two black holes come in contact and merge together. In this case, the two event horizons also merge together to be enveloped by a common event horizon. When this happens, the theory predicts that the total surface area of the event horizon of the final black hole will increase. In an ideal case, let the two black holes be of equal mass, M, and the resulting black hole be of mass $M^{/}$. Now, since the surface area of the event horizon is proportional to the square of the mass (the radius being proportional to the mass). We should have, according to the above theory, $M'^2 > 2M^2$

Whence, $M' > \sqrt{2}M$.

Which corresponds to a maximum efficiency of $(1-1/\sqrt{2}) \approx 0.29$ for the conversion of original rest mass energy to the radiation energy. This is the upper limit of conversion efficiency in the case of non rotating black holes. It has been proved also that under certain conditions, if a mass is accreted by a rotating black hole, then before it is finally sucked in, about 43 percent of its rest mass energy may be converted to radiant energy and this is the maximum limit of conversion efficiency so far known.

According to Sir William Herschel's investigation, we know that the shape of the galaxy is that of a much flattened spheroid having a few open ring like structures called spiral arms. The sun lies very close to the equatorial plane of this system at an approximate distance of 10 kpc from the centre. In order to maintain stars and gas in their orbits the galaxy should possess a very high rotation which develops the centrifugal force necessary to balance the gravitational attraction exerted by the large mass of the central core. A large number of globular clusters surround the galaxy and are moving in elongated orbits around the galactic centre. Groups of stars and star clusters are born in the clouds of dark matter in this great conglomeration. These newly born stars lie mostly close to the galactic equator where the parent material out of which they form is concentrated. The life spans of these stars are different and depend on the rate of using their fuel which again depends on their masses and chemical compositions. During their life time hydrogen is converted into heavier element in their inner parts while a part of the matter from the surface layers is ejected into interstellar space in course of their evolution. Thus, the aspect of the galaxy is changing during a time scale short compared to the galactic life time. (See Basu Baidyanath, "An introduction to Astrophysics".

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