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Evidence in Support of Dark Stars

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Abstract

Evidence in support of a compact stellar object termed a 'dark star', as distinguished from a relativistic 'black hole' will be presented. A brief historical review finds the prediction of *invisible stars* two centuries before their late twentieth century discovery.

It will be shown that a dark star and a stellar black hole have an identical event horizon radius, suggesting the equivalence of this entity.

The three event horizons of rotational dark stars and Kerr black holes will be reviewed, revealing similarities.

Calculations of the core average densities for a range 'black hole' masses will show the maximum neutron density will not be exceeded for larger than 8 solar masses. Furthermore, axial holes in the event horizons of rotational dark stars causing reduced core density, implies these entities to be ultra neutron stars.

Quandaries concerning GRT black holes will be elaborated.

Definitions:

- A 'd*ark star*' is an invisible compact stellar object with event horizon(s) allowing no solar particles to escape that is situated in Euclidean space and Absolute time.
- A General Relativity Theory (GRT) '*black hole*' is an invisible entity with event horizon(s) allowing no solar particles to escape and is modelled in a 4-dimensional relativistic curved space-time continuum.
- A '*stellar black hole*' is a stationary spherically symmetric GRT black hole.
- A '*stationary dark star*' is a stationary spherically symmetric dark star.

I. Introduction

In 1783 amateur astronomer John Mitchell delivered a paper to the Philosophical Transactions of the Royal Society announcing that 'invisible stars' could exist if massive enough. It was shown that an object with the density of the sun, yet five hundred times larger would exert a gravitational pull so great that "*all light emitted from such a body would be made to return toward it*."

Later in 1799, eminent French mathematician and astronomer, Pierre Laplace (1749-1827) delivered a paper on stars with gravitational fields so strong that light could not escape [1]. Laplace calculated that a star two hundred and fifty times the size of the Sun, with the same density, would be invisible. Laplace reasoned "*it is therefore possible that the greatest luminous bodies in the universe are on this account invisible*."

Both astronomers had predicted the existence of super-massive black holes two centuries before their late twentieth century discovery.

Mitchell and Laplace reasoned that the escape velocity of stellar particles, the speed necessary to escape a star's gravity, for a sufficiently large star would be greater than the speed of light. The 'dark star' would appear invisible to an observer against the night sky because light could not escape the gravitational pull. The predictions were based on Newtonian gravitation and the corpuscular theory of light.

In 1916, Karl Schwarzschild obtained an exact solution to GRT field equations for the gravitational field around massive bodies [2,3]. The solution contained a singularity at a certain radius that has become known as the ‘Schwarzschild radius’. French mathematician, Jacques Hadamard raised the significance of the singularity during a physics conference in Paris in 1922 but Albert Einstein insisted that a singularity could not exist in Nature and referred to it as the “*Hadamard disaster*”[4].

Einstein reconsidered a model of a star where the components of the star were orbiting masses, and showed that the orbital velocities would exceed the speed of light at the Schwarzschild radius. Einstein argued that the singularity could not occur in Nature based on the principle of relativity [5].

In 1934 Baade and Zwicky proposed that neutron stars were formed after supernova explosions and in 1967 Bell found the first radio pulsar, termed CP1919. It was later established that ‘pulsars’ were in fact rotating neutron stars [16].

At the death of a star a supernova explosion is known to leave behind a massive core of compressed neutrons. After the supernova explosion, a visible neutron star will be produced if the radius is greater than $2GM/c^2$. If the star formed following a supernova explosion has a radius that is equal to or less than $2GM/c^2$ then it will be invisible.

In 1939 J.R. Oppenheimer developed the first model of a GRT black hole [6,7]. To quote “*When all thermonuclear sources of energy are exhausted a sufficiently heavy star will collapse.. this contraction will continue indefinitely.*” The first model of a GRT black hole was founded by an unstable massive collapsed star core contracting to an infinitely compressed singularity of zero dimensions in finite time. The void black hole core nevertheless maintains a stable event horizon of fixed Schwarzschild radius for many millions of years and an ultra-powerful gravitational field.

The physical significance of the singularity of the GRT equations was debated for many decades and acceptance of the possibility of its existence did not occur until the late twentieth century. It was conjectured by astrophysicist S. Chandrasekhar that a star with greater than 3 solar masses eventually forms a different entity to neutron stars [1]. This entity was termed a ‘black hole’ by physicist John Wheeler circa 1950’s.

The surface at the Schwarzschild radius acts as an event horizon and neither light nor particles can escape through this surface from the region inside. A GRT black hole is a region of space that is an extreme warp of space-time continuum containing a singularity at its centre. There are three main types of black holes, that is, supermassive, rotational and stellar. Stellar black holes are non-rotating black holes that are rare in nature. The most prevalent are the rotational type and supermassive types are greater than 10^5 times larger than our Sun.

In 1963 New Zealand mathematician Roy Kerr, found solutions to the GRT case of a rotating star and it was considered that black holes should also rotate [8]. The Kerr solution found that a spinning black hole had event horizons at radii less than the Schwarzschild radius. The Kerr solution is used as a model of a black hole, but it can also be used to model the gravitational field around a neutron star.

In active galactic nuclei and in the centre of the Milky Way galaxy evidence for the existence of ‘black holes’ has been found [9-13]. A body evidence has also been found for the existence of rotational ‘black holes’ [9-13].

In 2010 a model for a rotational dark star with event horizons was developed [14]. A kinematical analysis of a particle in the gravitational field of a rotational dark star produced a cubic equation with exact solutions for 3 event horizon radii. These solutions correspond with astrophysical observations of ‘black holes’ [15].

2. Calculations of the Event Horizon of a Stellar Black Hole or Stationary Dark Star

2.1 Radius of a Stationary Dark Star

A particle cannot escape from a gravitational field when the escape velocity is equal to the speed of light because the momentum tends to infinity. A physical object cannot have an infinite momentum or energy and so becomes a physical impossibility. The radius of a dark star, R_D, can be calculated from the proper momentum, P_o:

$$P_o = m.v.\delta(t) \tag{2}$$

where m, mass of a high speed particle,
v, is the velocity
gamma factor, $\delta = 1/\sqrt{(1 - v(t)^2/c^2)}$,

From equation (2) the momentum becomes infinite when the velocity of the particle is equal to the speed of light, because the gamma factor tends to infinity.

$$\delta = 1/\sqrt{(1 - v(t)^2/c^2)} = 1/\sqrt{(1 - c^2/c^2)}$$

If v = c then $\delta \rightarrow \infty$ and $L_o \rightarrow \infty$

A particle falling in a gravitational potential can be described in the following terms:

$$v^2 = c^2 = 2GM/R$$

$$\therefore R_D = 2GM/ c^2 \tag{3}$$

where M is mass of stellar object, $G = 6.67 \times 10^{-11}$, $c = 2.998 \times 10^8$ m.s^{-1}

The dark radius, $R_{D,}$ describes a super-compacted physical object with a gravitational field that is so intense it cannot emit light, however, high-speed particles are emitted from the ergosphere. For example, the Sun with a mass of 2×10^{30} kg has a dark star radius of approximately 3 km. Hence, if the Sun's present mass decreased to a radius of 3 kilometres or less, from a present radius of 696,265 kilometres, a dark star would form and the solar wind consisting of high speed solar particles would cease to exist.

Similarly, gravitational attraction can act upon a particle of light or photon as shown by Einstein [4]. A dark star occurs when the escape velocity acting upon a photon in a strong gravitational field is equal to the speed of light. Using the escape velocity formula (1), and setting the velocity acting upon the particle equal to the speed of light we find the dark radius, $R_{D,}$ of a light wave is therefore identical to that of the physical particle:

$$v^2 = c^2 = 2GM/R$$

$$R_D = 2GM/ c^2 \tag{4}$$

2.2 Radius of a Stellar Black Hole

For General Relativity black hole initially a geometrical approach will be taken leading to an appreciation of the Schwarzschild Metric. The kinetic energy of an object of mass m with a velocity v is given by:

$$\tfrac{1}{2} mv^2$$

The gravitational potential energy for an object of mass M at a radius r is given by:

$$-GMm / r$$

For an object of mass m to escape its gravitational pull a mass M, it's kinetic energy must be greater than the magnitude of the gravitational potential energy. If the object has a maximum velocity, v = c, and the kinetic energy is equated with gravitational potential energy:

$$\tfrac{1}{2} mc^2 = GMm/r \tag{5}$$

A radius r is expressed in terms of mass and physical constants G and c, allows no particles to escape:

$$r = 2GM/c^2 \tag{6}$$

By normalising the units and letting $c = 1$, and also set $G = 6.67\times10^{-11}\ m^3kg^{-1}s^{-2} = 1$. If mass is defined in terms of meters and 1 second = 3×10^8 metres, then $G = 7.41 \times 10^{-28}\ mkg^{-1} = 1$. The process of setting c = G = 1 is referred to as geometrized units. If geometrized units are employed and m is not large enough to affect space-time, then:

$r = 2M$

Thus, if a massive static object, M, is condensed into a spherical region with a radius, r, as measured to be less than 2M, then that object is a black hole. This value of r, was derived using classical arguments, is the Schwarzschild radius, which coincides with the event horizon of a static spherically symmetric black hole.

The solution to Einstein's Field equations for an isolated spherically symmetric mass, M, with radius r_B at the origin of our coordinate system is the Schwarzschild Metric:

$$ds^2 = (1 - 2M/r)dt^2 - (1 - 2M/r)^{-1}dr^2 - r^2\, d\varphi^2 - r^2 \sin^2 \varphi.\, d\theta \quad (7)$$

For r = 2M, the metric coefficient at g_{11} is undefined and so at that point the equation is not valid. Additionally, the metric does not hold for r < 2M. The boundary condition does not hold for r = 2M because it is a singularity. However, the metric holds for r > 2M. The solution was derived on the assumption that only points outside of an isolated mass were considered. The Schwarzschild solution is valid for $r > \max\{2M, r_B\}$ where r_B is the radius of the spherical mass.

Hence, for a spherically symmetric mass M, $r_S = 2M$ is defined as the Schwarzschild radius. If the radius of the mass is less than the Schwarzschild radius, then the object is called a black hole. If the object is a black hole, then the Schwarzschild radius is also referred to as the event horizon. It can be seen that, despite the change of units, the Schwarzschild radius of a GRT black hole and a dark star radius are identical.

The question arises: *Could the GRT black hole and a dark star be one and the same stellar object*?

3. Event Horizon Solutions for Rotating Black Holes and Dark Stars

3.1 Plan Solutions for a Rotational Dark Star

As stated neither particles nor light can escape a gravitational field when the escape velocity is equal to the speed of light because the gamma factor tends to infinity. In this case the gravitational and rotational velocities of the particle sum as vectors. The new dark radius denoted, R_D, can be calculated from the vector sum of gravitational velocity, v_G, and rotational velocities, v_r, and equated with the speed of light. The vector sum of the velocities is the square of the moduli:

$$c^2 = |v_G|^2 + |v_r|^2$$

$$c^2 = 2GM/R + \omega^2.R^2$$

$$\therefore \omega^2.R^3 - Rc^2 + 2GM = 0$$

$$\therefore R^3 - c^2/\omega^2 R + 2GM/\omega^2 = 0 \quad (8)$$

The depressed cubic equation (8) has solutions:

$$R_D = \sqrt[3]{}(GM/\omega^2) + \sqrt{}((G^2M^2/\omega^2) - (c^6/27\omega^6)) + \sqrt[3]{}(GM/\omega^2) - \sqrt{}((G^2M^2/\omega^2) - (c^6/27\omega^6))$$

$$R_D = \sqrt[3]{}(GM/\omega^2) \pm \sqrt{}((G^2M^2/\omega^2) - (c^6/27\omega^6)) \quad (9)$$

and simplifying we let $M = GM/\omega^2$

$$R_D = \sqrt[3]{}(\ M \pm \sqrt{}(\ M^2 - (c^6/27\omega^6))$$

$$R_D = \sqrt[3]{}(\ M \pm \sqrt{}(\ M^2 - \alpha^2)\ \text{ if we let } \alpha = c^3/\sqrt{27}\omega^3 \text{ and } M = GM/\omega^2 \quad (10)$$

3.2 Elevation Solutions of Rotational Dark Star

The angular velocity of particles motion in a gravitational field diminishes to zero on the axis of rotation and is maximal in the ecliptic plane of the rotating black hole. Where θ is the angle aligned to the axis of rotation, the angular velocity is given by:

$v = \omega.R.\cos\theta$

The orthogonal view to the axis of rotation the event horizon radius denoted, R_C, for spiralling particles can be calculated from the vector sum of gravitational velocity, v_G, and the rotational velocity, v_r, equated with the speed of light:

$c^2 = |v_G|^2 + |v_r|^2$

$c^2 = 2GM/R + \omega^2.R^2.\cos^2\theta$

$\therefore \omega^2.R^3.\cos^2\theta - R.c^2 + 2GM = 0$

$$\therefore R^3 - R.c^2/(\omega^2\cos^2\theta) + 2GM/(\omega^2.\cos^2\theta) = 0 \qquad (11)$$

The cubic equation (6) has exact solutions:

$$R_C = \sqrt[3]{}(GM.\sec^2\theta/\omega^2) \pm \sqrt{}((GM\sec^2\theta/\omega^2)^2 - (\sec^2\theta c^6/27\omega^6)) \qquad (12)$$

Simplifying let $M_\theta = GM.\sec^2\theta/\omega^2$ and $\alpha_\theta = c^2.\sec^2\theta/3.\omega^2$

$R_C^3 = M_\theta \pm \sqrt{}(M_\theta^2 - \alpha_\theta^3)$

$$R_C = \sqrt[3]{}(M_\theta \pm \sqrt{}(M_\theta^2 - \alpha_\theta^3) \qquad (13)$$

Equation (13) provides exact solutions for a side elevation view of particles spiralling into a rotating dark star along the axis of rotation. A maximum of three event horizons occur for rotating dark stars. Event horizons for rotational dark stars correspond with astrophysical observation [15]. This solution has precedence in the ‘Onion skin’ model of active galactic nuclei consisting of orbiting plasma particles and light the phenomenon of the accretion disk occurs at 0° and 180° in side elevation along the X and Y axis.

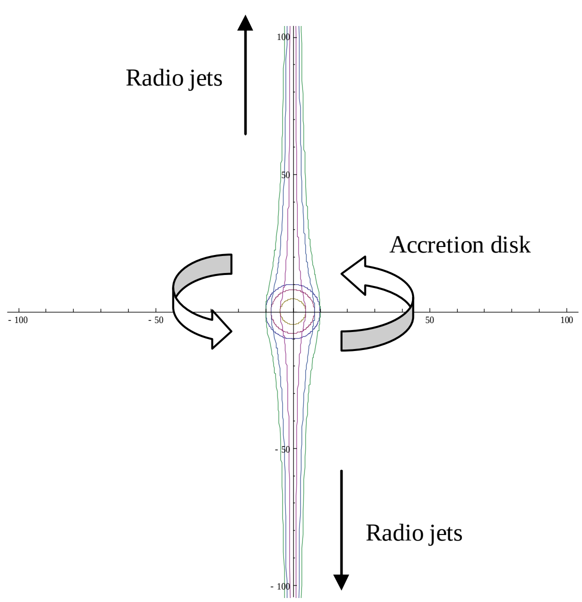

Figure 1. Elevation view of Rotational Dark Star with Accretion Disks and Radio jets.

3.2 Kerr Solution for a Rotating Black Hole

3.2.1 Moment of Inertia for the Maximally Rotating Kerr Case

For the maximally spinning case the angular velocity of the black hole is at the speed of light. The alpha, α', factor for the Kerr solution is now considered. α'= J/Mc and J = Iω where J is the angular momentum and I is the moment of inertia of the black hole. For the cases in which the event horizon is considered to be a spherical shell and a solid sphere the moments of inertia respectively are:

$I = 2/3MR^2$ (shell) or $I = 2/5MR^2$ (solid sphere)

$\alpha' = J/Mc = I\omega/Mc = (2\omega MR^2/3)/Mc$

$\alpha' = 2\omega R^2/3c$ (shell) or $\alpha' = 2\omega R^2/5c$ (solid sphere)

for maximally spinning case, $R = c/\omega$:

$\alpha' = 2R^2/3R = 2R/3$ (shell) or $\alpha' = 2R^2/5R = 2R/5$ (solid sphere)

$\therefore \alpha'^2 = 4R^2/9$ (shell) or $\alpha'^2 = 4R^2/25$ (solid sphere)

The Kerr inner and outer event horizons are not equivalent in this case:

$$R_{\pm} = M_g \pm \sqrt{(M_g^{\,2} - \alpha'^2)} \qquad (14)$$

The dependence of the solution for the event horizon radius and the alpha factor should also be noted. The moment of inertia, I, of the black hole could be calculated for a solid sphere or ring singularity and this will give different results for the alpha primed factor, α'.

3.2.2 Kerr Solution for Rotating Black Holes

The Kerr solution describes the GRT case of a rotating black hole and the 'maximally rotating' case that is event horizon rotation at the speed of light will be considered. According to Kerr an exact solution of Einstein's gravitational field equation for gravitational collapse and rotation in terms of inverse radius can be given fro the metric ds^2 [13]:

$$ds^2 = dx^2 + dy^2 + dz^2 - dt^2 + 2M_g(dt + dr)^2/r + 4aM_g/r^3(xdy - ydz)(dt + dr) + O(r^{-3}) \qquad (15)$$

A cubic dependence on radius occurs for singularities corresponding to rotating event horizons. Accordingly, for the cubic a maximum of three solutions are anticipated for the event horizons radii and a single Schwarzschild event horizon also occurs. The arbitrary constant 'a' is equivalent to the radius, R, of the 'ring singularity' such that:

$$R \equiv (x^2 + y^2) = a \qquad (16)$$

The radius of gyration of the ring singularity 'a' is unknown and unmeasurable as it is within the black hole itself. However, the 'aM_g' term is the angular momentum of the rotating body about the z-axis.

Derived from singularities of the Kerr solutions produce event horizons that are basically variations of the gravitational radius, m. The gravitational radius is termed, m, where $m = GM/c^2$. Please see Figure 2 for a diagram of the Kerr solution of a Rotational black hole. Inner and outer event horizons and a static limit or ergosphere, are described below:

Kerr inner and outer event horizon radii:

$$R_{\pm} = M_g \pm \sqrt{(M_g^{\,2} - \alpha'^2)} \qquad (17)$$

Inner and outer ergosphere radius:

$$R_{E\pm} = M_g \pm \sqrt{(M_g^{\,2} - \alpha'^2.\cos^2\theta)} \qquad (18)$$

where $R_g = M_g = GM/c^2$ and $\alpha' = J/Mc$ and $J = I\omega$ angular momentum of spherical stellar object.

Please compare similarities between the event horizon equations (10) and (13) for rotating dark stars with the event horizons defined in equations (17) and (18) of a rotating Kerr black hole.

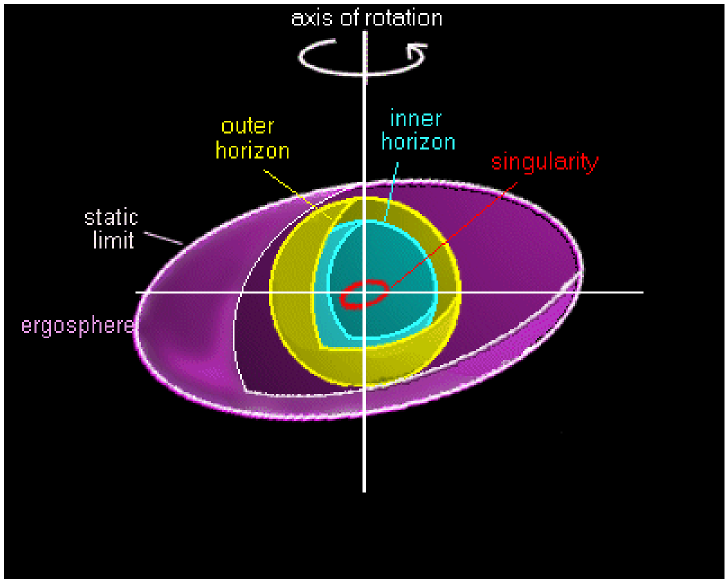

Figure 2. Kerr Model of a Rotational black hole

4. Neutron and Dark Stars

Neutron stars are one of the by-products of type II supernovae explosions. During an explosion, the outer layers of a star are blown off leaving a dense compact star , consisting predominatly of neutrons. Neutron stars have mass of between 0.1 and 3 solar masses.

Neutron stars are characterised by their rapid rotation and strong magnetic fields. The magnetic field is strongest along the axes of rotation of the pulsar. Pulsars have a regular rotation rate and emit regular pulses of radiation at regular intervals. Neutron stars are known to have extremely high nucleon density.

Neutron stars have the following characteristics [1,16]:

Typical Radius: 10 kilometres

Typical Mass range: 0.3 to 2.0 solar masses

Density range: 10^9 to 10^{17} kg/m^3

Spin rate maximum: 38,000 rpm

Pulsar period range: 1.4 milliseconds to 5 seconds

The pulse from a ‘pulsar’ is a moving beam of radiation directed from the axis of rotation of a neutron star at regular intervals. This phenomenon can be likened to the radio jets consisting of beams of particles directed from the accretion disk of rotational ‘black holes’. Dark stars, or black holes, are also the remnants of supernovae explosions for stellar objects greater than 3 solar masses.

Similar, to pulsars most black holes are not stationary but are in rotation and similar to pulsars, black holes have dual radio jets along the axis or rotation [17]. Dark stars exhibit similar behaviour and phenomena to neutron stars and it will be shown that the core densities of these objects are comparable.

4.1 Nuclear Sizes and Maximum Stellar Core Densities

Proton radius ≈ 0.87 x 10^{-15} m

The neutron has a varying radius and so the minimum radius will be employed [18].

Minimum neutron radius ≈ 0.87 x 10^{-15} m

Neutron mass = 1.675 x 10^{-27} kg.

Therefore, the density of a neutron is, 6.0725 x 10^{17} kg/m^3.

For maximally packed spherical neutrons in a cubic volume the ratio of solid to spatial volume is:

% spherical solid:cubic space = $(4/3\pi R^3)/(2R)^3 = 0.5236$

Please see Figure 3 for an illustration of maximally packed nucleons in a neutron star.

Figure 3. Maximally packed Neutrons in a Stellar Core

$\therefore$Maximum core density of a neutron star is = $0.5236 * 6.0725 \times 10^{17} = 3.18 \times 10^{17}$ kg/m^3.

The result above corresponds with the density of an atomic nucleus, that is, approximately 3×10^{17} kg/m^3 [19].

4.2 Core Density of a Stellar Black Hole or Stationary Dark Star

A 'stellar black hole' is a spherically symmetrical stationary entity with a defined Schwarzschild radius. Table 1 below is calculated from the Dark or Schwarzschild radius showing stellar average core densities of a range of small stellar black holes or dark stars. It will be shown that the average density of a stellar black hole exceeds the maximum density of a maximally packed stellar core of neutrons for relatively small types, but not for those greater than 8 solar masses.

Table 1. Core Average Densities of Stationary Dark Stars of Different Masses

Mass (in Solar Masses)	$R_D = R_s$ (m)	Core Average Density (kg/m^3)	Exceeds Maximum Core Density?	Core Composition
3	8905	2.028×10^{18}	yes	?
4	11,874	1.1409×10^{18}	yes	?
5	14,842	7.3019×10^{17}	yes	?
6	17,810	5.0707×10^{17}	yes	?
7	20779	3.7254×10^{17}	yes	?
8	23747	2.8523×10^{17}	no	Neutron
100	296840	1.8255×10^{18}	no	Neutron
1000	2968401	1.8255×10^{17}	no	Neutron
100000 (supermassive)	2.9684×10^8	1.8255×10^9	no	Neutron
1000000 (supermassive)	2.968×10^9	1.8255×10^7	no	Neutron or Hydrogen or Helium

Results of Table 1 can be summarized for stationary dark stars or stellar black holes:

- For less than 8 solar masses the stellar core cannot be densely packed neutrons on average.
- For greater than 8 solar masses the stellar core may be densely packed neutrons on average.
- For much greater than 8 solar masses in supermassive black holes or dark stars may contain compressed neutrons or typical stellar material.

The maximum core density of a neutron star is calculated to be of the order of an atomic nucleus, 3 x 10^{17} kg/m^3. However, it should be noted that core density increases towards the centre of gravity and decreases at the surface of the stellar object.

It has been found that for up to 7 solar masses the core average densities of a stellar black hole or dark star will exceed the maximum neutron core density. Hence, for these smaller mass stellar black holes or dark stars on average the core cannot contain neutrons, but at extreme densities exotic forms of matter such as quarks are possible [20].

GRT has hypothesised that for extreme densities the stellar core would collapse into a central singularity. This hypothesis, however, is unprovable due to the prohibition on scientific measurement beyond the event horizon.

Owing to the rotational momentum of infalling matter stellar black holes or stationary dark stars are rare in Nature. Candidate stellar black holes include: 4U 1543-475/IL Lupi, A0620-00/V616 Mon (mass ≈ 11.0 ± 1.9 times Solar mass), GRO J0422+32 (candidate smallest), M33 X-7 (candidate most massive).

4.3 Rotational Black Holes and Dark Stars

Rotating ‘black holes’ are the most prevalent. Derivations have shown that there exists axial holes in the event horizons of rotational dark stars. The extension of the stellar core of a dark star beyond the spherical or elliptical bounds of the black hole means that the maximum core nucleon density will not be exceeded. The dark star could be composed of neutrons and no central singularity would be required. Please see Figures 1 and 2 for dark star and black hole comparison.

GRT has also hypothesized semi-infinite axial singular lines in the event horizon of rotating black holes [21]. It has been shown that axial singularities break up the black hole, forming holes in the horizon. As a result, a tube-like region appears which allows matter to escape from the interior of black hole without crossing the horizon. It was argued that axial singularities lead to very narrow beams created in black holes by external electromagnetic or gravitational excitations may be at the origin of observable effects such as jet formation.

4.4 Supermassive Black Holes and Dark Stars

A ‘supermassive black hole’ may occur for super massive stellar objects of relatively low density. A wide event horizon would be generated by an extreme stellar mass, of 1.5 x10^8 solar masses, with relatively low densities of 1 x 10^9 Kg/m³. For example, the supermassive dark star observed at the centre of the Milky Way galaxy is 3.7 million solar masses and has a diameter of 890 x 10^6 Kilometres. In this case, typical stellar gasses of Hydrogen and Helium would be anticipated in the interior.

5. Quandaries Concerning GRT Black Holes

There exist fundamental differences in the characteristics of the model for a dark star and for a GRT black hole. For instance, the dark star radius describes a sphere in Euclidean space that contains a physical object from which light or matter cannot escape. The dark star can be modelled as an ultra neutron star with kinetic properties such as motion, rotation and the ability to emit particles from the accretion disk.

The GRT black hole is a mathematical model. The black hole could be described as an extreme warp in the space-time continuum where at an event horizon infinite curvature occurs. According to theory at the GRT event horizon time itself stops for a stationary observer and the core of a black hole is void. [10]

A variation with known scientific facts, however, can be found with Oppenheimer’s landmark paper entitled ‘*On Massive Neutron Cores’*, in the absence of the mass-radius relation [7]. Neutron stars are known to exist and be stable up to 2 solar masses (2Θ) [1]. To quote [7] “*For masses greater than 3/4Θ there are no static equilibrium solutions.. A discussion of the probable effects of deviations from the Fermi equation of state suggests that actual stellar matter after the exhaustion of thermonuclear sources of energy will, if massive enough, contract indefinitely, although more and more slowly, never reaching true equilibrium.”*

On the GRT black hole eminent astrophysicist S. Chandrasekhar writes [1] “*In the Newtonian theory this result of matter collapsing to an infinite denisty may be considered as reductio ad absurdum of the initial premises: a distribution of matter that is exactly speherically symmetric and the absence of any sustaining* *pressure are both untenable in practice. If either of these two premises is not exactly fulfilled, then the collapse to an infinite density will not happen."*

The surprising property of the GRT black hole model is that despite the implosion of the unstable collapsed star core, it nevertheless remains stable. Eminent English astronomer Arthur Eddington stalwartly rejected the contracting massive stellar core hypothesis and stated [1] "*I think there should be a law of nature to prevent the star from behaving in this absurd way"*.

For a rotating GRT black hole, space itself rotates around the accretion disk and particles are 'entrained' in this spatial motion at speeds near the speed of light [12]. The powerful effects of black holes are principally spatial and geometrical and particles move in geodesics curves following the minimum distance in a non-Euclidean space.

This mathematical theory presents difficulties for physical measurement as only physical phenomena and motion can be measured and space itself remains beyond measurement. For GRT the kinematic properties of space are intrinsic. For an observer, however, phenomenon in the accretion disk would be indistinguishable if a particle were moving in a fixed Euclidean space or if it was 'entrained' in a moving Non-Euclidean space.

Evidence for translational motion of a 'black hole' was recently presented in an online science magazine entitled [22]. The article reads "*Astronomers have found a supermassive black hole, with a mass of more than 1 billion suns, in a remote galaxy, which appears to be travelling in space at considerable speed, away from the centre of the galaxy*" and continues "*the remaining question is how can this black hole,… be pushed away from the centre of its galaxy at the speed of 670,000 miles per hour"?* Is it more plausible that the stellar entity moving with translational speeds of 670,000 miles per hour (1.072 x 10^6 Kilometres per hour) is a physical object, rather than a warp in the GRT space-time continuum?

For astronomy an invisible star or black hole presents an empirical difficulty in that phenomenon behind the event horizon cannot be directly observed and measured. This difficulty gives rise to inference and speculation. For example, astronomers observe the trajectory deflection of stars nearby to estimate the mass of the black hole.

The empirical scientific method requires that experimental data supports theoretical hypothesis. Regrettably, the phenomena within the GRT black hole 'event horizon' cannot be measured and so the method of scientific testing is incomplete and theory remains unresolved. Nevertheless, unequivocal descriptions can be found in GRT texts and journals of the properties of the interior of GRT black holes [10, 12].

The attributes of a space-time continuum within and near a black hole present difficulties. For GRT black holes, event horizons cause discontinuities in the space-time continuum and a discontinuity in the fabric of a space-time continuum at event horizons is oxymoron. Discontinuities in the space-time continuum contradict the notion of a space-time continuum itself.

For mathematics, a singularity occurs when an equation representing a physical quantity becomes infinite. An infinite quantity in the physical Nature is undefined or impossible. The relativistic field equation of gravitation, the solution contained a term of the form 1/(2M – r) where the value of *r* making this term singular has come to be known as the *Schwarzschild radius*. In 1922 Hadamard suggested that a singularity occurred at the Schwarzschild radius, and this was dubbed by Einstein the "*Hadamard disaster*" as an impossibility of Nature.

It was later revealed, however, that the 'singularity' was sourced merely in the construction of the relativistic equations in polar coordinates and for the event horizon a change of coordinates resolved the problem. The problem at the event horizon was merely a 'coordinate singularity'.

At the centre of large stellar masses a singularity has not been observed and similarly in the centre of a super-massive 'blach hole', a singularity is not anticipated. Furthermore, the notion of physical mass does not pertain to an infinitely compressed central GRT black hole singularity of point dimensions.

The model of GRT black holes is a product of the Non-Euclidean mathematical construction and without empirical support it remains hypothesis. Just as the singularity at the event horizon of a black hole was shown to be a mathematical device, the supposition of a void black hole core and extreme space-time curvature at the event horizon of a GRT black hole remains conjecture.

6. Conclusion

The radius of the event horizon of a stationary dark star has been shown to be identical with the Schwarzschild radius of a stellar black hole. Is this more than coincidence and could these stellar entities be identical? The formula for the event horizon radius of this compact stellar object is given as:

$R_D = R_S = 2GM/ c^2$

where G is the universal gravitational constant, M is the stellar mass and c is the speed of light.

It has been shown that the maximum average neutron core density will not be exceeded within a stellar 'black hole' or dark star for greater than 8 solar masses. This result implies a compact physical stellar core composed of neutrons.

The core density of a rotational dark star will be further ameliorated by extended axial event horizons expanding the volume of the stellar object. A physical stellar material would also be anticipated within the core of rotational dark stars.

A kinematical analysis of particles captured by a rotational dark star produced a cubic equation. Exact solutions of the cubic equation have been detailed in (10) and (13) and these event horizons correspond with astrophysical observation. The rotational dark star event horizons solutions show similarities with the rotating Kerr black hole.

The supposition of the collapse of physical matter into a singularity in the black hole core lacks empirical support. Similarly, a GRT black hole model remains conjecture.

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