On Gravitational Collapse (Revised)

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Abstract: Gravitational collapse of diffuse material has been investigated using a new solution of Einstein's equations of general relativity. This obviates the theory of black-hole formation developed for the standard vacuum solution of Schwarzschild. The bodies which now form have reasonable physical properties, such as nuclear hard core density in collapsed stars, or 10^4kg/l in galactic centres. Accreting material converts to kinetic energy then radiation so that a singularity cannot be produced.

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1. Introduction

A recent article has revealed that the observed precession of planet Mercury's orbit is no longer compatible with standard General Relativity theory, [1]. That is, the orthodox vacuum solution with its concomitant spacetime curvature interpretation may not be physically meaningful. Consequently, black-hole singularities cannot exist so the end state of stellar evolution theory needs to be reconsidered in the light of a new solution of Einstein's Equations.

Some years ago [2] it was shown how Einstein's equations could be interpreted in straight-forward physical terms by explicit introduction of gravitational field energy as gravitons, analogous to the electromagnetic field. These field gravitons produce the gravitational force by momentum exchange interactions, all conducted in flat spacetime. Metric tensor components then describe the variation in dimensions and time-rate or energy of particles in a gravitational field, not the spacetime curvature. Agreement with the ideas found in Special Relativity theory and accelerated frames is thereby guaranteed, and gravity is no longer detached from other forces. The old problem of justifying the equality of spacetime manifold curvature $R_{\mu\nu}$ and physical matter $T_{\mu\nu}$ is rendered obsolete. Consequently, mass particles and their field gravitons are expressions of the same material, energy, existing in empty flat spacetime.

2. Building a massive body from diffuse matter.

In reference [2], Einstein's equations were solved for the exterior solution of the spherically-symmetric static field of energetic gravitons in polar coordinates. The line element was then found to be

$$ds^2 = -\frac{dr^2}{(1-GM/c^2r)^2} - r^2 d\theta^2 - r^2 \sin^2\theta d\varphi^2 + \left(1-\frac{GM}{c^2r}\right)^2 dt^2 \quad . \qquad (1)$$

Logically, it was derived that the gravitational field induces mass particles to fall by converting their own mass (potential energy) into kinetic energy. Upon impact, the particle KE is radiated away, leaving the particle with reduced rest mass

$$m_r = m_o(1-GM/c^2r) \quad . \qquad (2)$$

Thus, some mass is lost to radiation so additional free diffuse mass is required to build a body of mass M up to its ultimate gravitational radius ($R_0 = GM_0/c^2$). As an example, if the final density is to be nuclear hard-core density (ρ_n) throughout, then let [$M = (4/3)\pi\rho_n r^3$]. And for an originally diffuse mass element (dm), only

$$dM = dm(1-GM/c^2r) \quad , \qquad (3)$$

is added to M. Upon eliminating (*r*), this may be integrated to find the total amount of diffuse mass required to build a body of mass M:

$$M_T = \int dm = \int_0^M \frac{dM}{[1-(M/M_0)^{2/3}]} \underset{M \to M_0}{\longrightarrow} \infty \quad . \tag{4}$$

Thus, it is impossible to build a body up to its gravitational radius because infalling matter is increasingly less effective at adding mass. Figure 1 illustrates the amount of diffuse matter necessary to build the body up to any particular mass M.

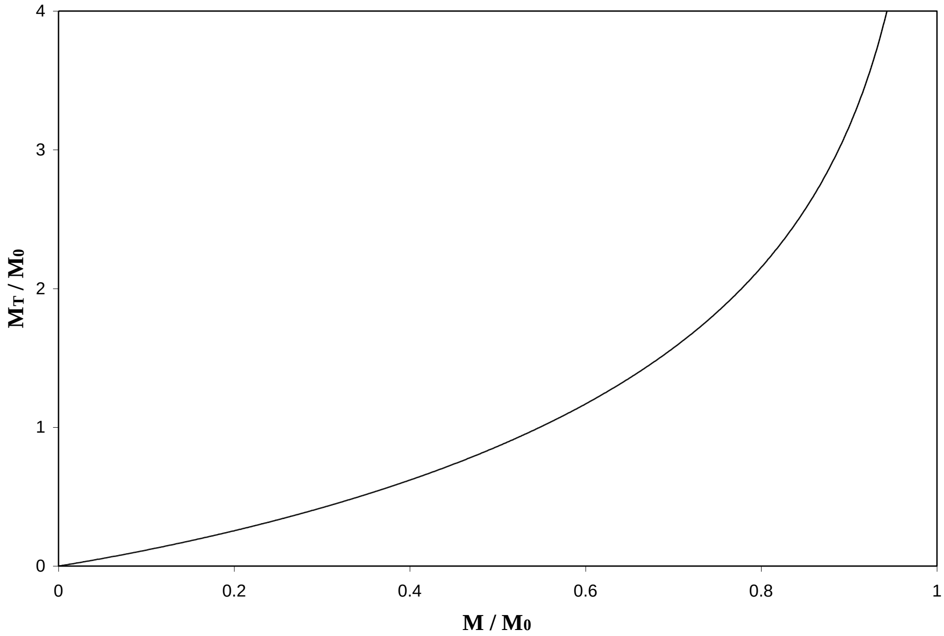

Figure 1 The total diffuse mass M_T necessary to build a body from zero to mass M, relative to the maximum possible body mass M_0 .

If during the building process the core material should collapse to a denser state, the mass to kinetic energy to radiation conversion will continue further and still prevent a singular surface from forming. This means that it is impossible to build the black-holes peculiar to the Schwarzschild solution. More energy is actually liberated by this process of accretion than that predicted by the Schwarzschild solution. Energetic γ-rays may be produced by total conversion of infalling matter, and these may subsequently leave the gravitational field *without* loss of energy, see reference [2 Section 3].

The bulk density of collapsed bodies increases through that of quasars, galactic centres, white dwarfs, neutron stars, and quark stars. For bodies approaching their gravitational radius, their masses may be related to mean densities ρ_o as follows. Let

$$R \approx GM/c^2, \quad \text{and } M = (4/3)\,\pi\rho_o R^3, \tag{5}$$

then upon eliminating R,

$$M \approx c^3\left[G^3(4/3)\pi\rho_o\right]^{-1/2}. \tag{6}$$

Thus, body mass must *decrease* with increasing density because infalling matter converts to free radiation more and more as it compacts, see Figure 2. It follows that a stable body with relatively low density must be supported by internal kinetic energy and radiation pressure. Collapse will cease when the core material is able to resist self-gravity. A final body of nuclear density (say 10^{15}kg/*l*) has a mass around $12M_\Theta$, while another of quark density (say 10^{22}kg/*l*) has four times Jupiter's mass. In the Galaxy core the density is around 10^4kg/*l*, while the huge core of M87 has only 0.0035kg/*l* density. Collapsing bodies can act like photon factories, unless they collapse violently and blast their material into space. When there is no further accretion of matter, the body will cool, eventually appearing dark but gravitationally active.

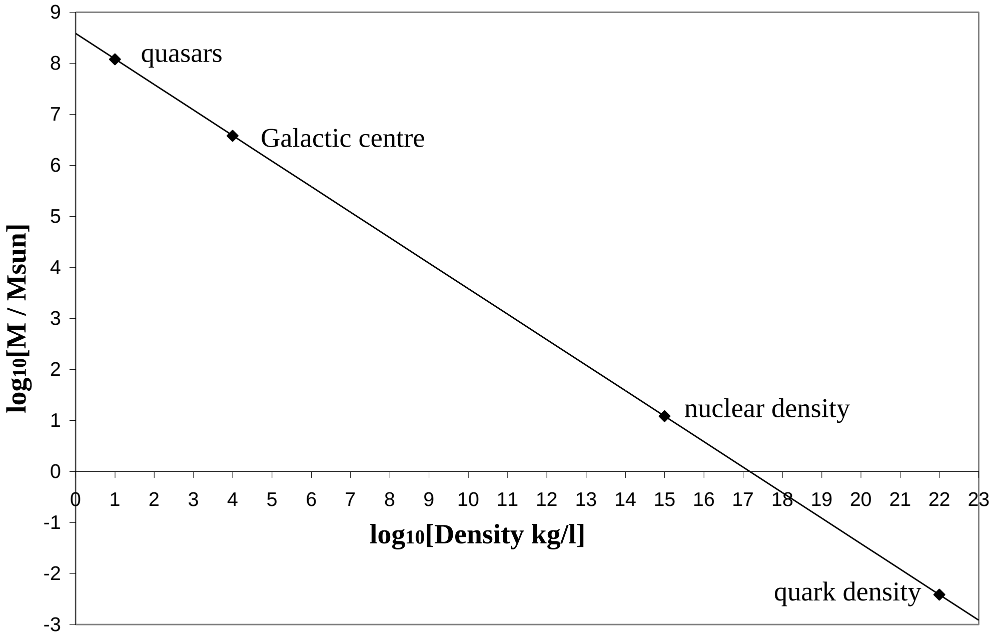

Figure 2 Variation of body mass (in units of Solar mass) with density, for bodies at their gravitational radius.

3. Interior properties of a massive body

The interior properties of a collapsed body may be calculated using the new solution of Einstein's equations, (see [2] Section 16). For example, a black-hole of mass $4\times10^6 M_\Theta$ has been predicted at the centre of our Galaxy; see [3-5]. It could be re-named a 'black-corps' because it is really a dark body near to its final radius ($R \approx GM/c^2 \approx 5 \times 10^6$km), with average density around 10^4 kg/*l*. This very high density implies that the material would behave like a fluid in hydrostatic equilibrium. In contrast, quasars are commonly believed to contain black-holes of up to $10^8\ M_\Theta$, but these would be black-corps with terrestrial density around 10 kg/*l* .

The line element for the interior of a spherically-symmetric static body consisting of a "perfect fluid" will be expressed in isotropic form as:

$$ds^2 = -e^{\mu}\left(dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta d\varphi^2\right) + e^{\nu} dt^2 \quad . \tag{7}$$

For the energy-momentum tensor components we shall take the mechanical *local* hydrostatic pressure p_o and constant *local* mass density ρ_{oo} :

$$T_0^{11} = T_0^{22} = T_0^{33} = p_o \quad \text{and}, \quad T_0^{44} = \rho_{oo} \quad . \tag{8}$$

Solution of Einstein's equations then yields the spatial metric tensor component:

$$e^{-\mu/2} = (1 + kr^2/4), \quad \text{for} \quad k = 8\pi\rho_{oo}/3 \quad , \tag{9}$$

and temporal metric tensor component:

$$e^{\nu/2} = \left[\frac{3e^{\mu_m/2} - 1 - e^{\mu/2}}{3e^{\mu_m/2} - 2}\right] \quad , \tag{10}$$

where $e^{\mu_m/2}$ pertains to the maximum radius r_m at the surface. Both these equations automatically designate the centre of the fluid sphere as the coordinate reference frame of special relativity. On going from the surface towards the centre of the body, a material element is compressed isotropically according to Eq.(9), and slows down internally according to Eq.(10), due to loss of potential energy (mass). The local (pressure/density) ratio increases on going from the surface inwards:

$$\frac{p_o}{\rho_{oo}} = \left[\frac{e^{\mu/2} - e^{\mu_m/2}}{3e^{\mu_m/2} - 1 - e^{\mu/2}}\right] \quad . \tag{11}$$

Figure 3 illustrates the variation of central pressure of a body (where $e^{\mu/2} = 1$), in terms of its actual size r_m relative to its theoretical gravitational radius R_0 .

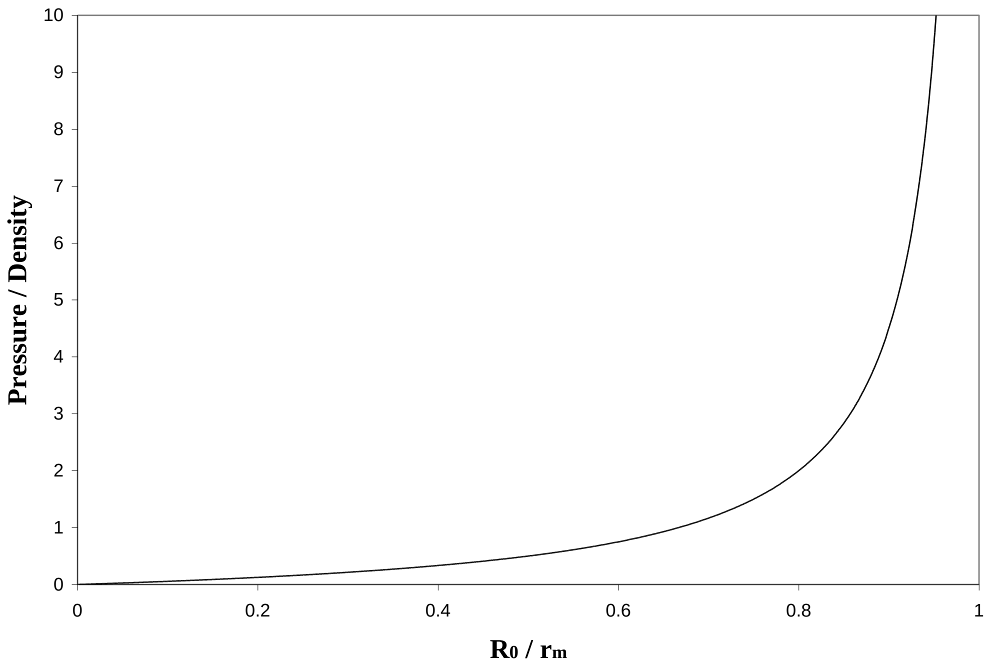

Figure 3. Pressure / density ratio at the centre of a massive body in hydrostatic equilibrium. A body of mass M and maximum radius r_m has a theoretical gravitational radius $R_0 = GM / c^2$.

These results are interesting because the body material behaves reasonably, even though an *exterior* observer would lose sight of the ultimate black-corps. In the most extreme case, the time-rate at the centre would slow to zero relative to the surface time-rate, when in Eq.(10) we have:

$$3e^{\mu_m / 2} - 2 = 0 \quad . \tag{12}$$

After introducing Eq.(9) and practical units, this means:

$$\left(\frac{G}{c^2}\right)\frac{4\pi}{3}\rho_{oo}r_m{}^2 = 1 \quad , \tag{13}$$

which is compatible with Eq.(5), although ρ_{oo} is the locally measured constant density. Particle energy varies with $e^{\nu/2}$, so a test particle could lose all of its mass on falling from the surface to the centre, whereas particle size varies with $e^{-\mu/2}$ by a factor of 3/2 only.

According to Eq.(11) the local pressure experienced by particles increases inwards and could cause them to rupture then collapse suddenly to a denser state. The consequent release of radiation energy would probably cause some outer material to be blown away, while inner material would be compressed, as predicted for a super-nova event.

4. Conclusion

The new solution of Einstein's equations has been employed to describe how gravitational collapse of diffuse material may produce very dense bodies of low luminosity. During the contraction, mass converts to kinetic energy which is lost from the system as radiation upon impact with the stationary core. Thus, black-hole theory really has been built on stellar buffoonery, as put in plain words by Eddington.

Acknowledgements

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