Outside spacetime III: An axiom-free relativizing of Newtonian physics predicts the black holes' Schwarzschild radius (without interior singularities)

Ramzi Suleiman [1, 2, 3]

1. Triangle Research & Development Center, Israel.
2. Department of Psychology, University of Haifa, Israel
3. Department of Philosophy, Al Quds University, Palestine.

Abstract

Many previous attempts have been undertaken to produce a singularity-free solution to the black hole problem. This effort included many "Bardeen black hole" models, as well as quantum mechanical, and string theory models. The present paper describes a new solution based on a relativistic extension of Newton-Galileo physics, termed Information Relativity theory. For a purely gravitational, spherical black hole, the theory yields a black hole radius that equals the Schwarzschild radius, *but without an interior singularity*. Moreover, for a typical galaxy with a supermassive black hole residing at its center, the model produces a simple expression for the galaxy's dynamics in its dependence on redshift. According to the emerging dynamics, a galaxy's supermassive black hole is part of a binary system, together with a naked singularity at redshift $z = 2^{-1/2} \approx 0.707$, suspected to be a quasar with extreme velocity offsets or an active galactic nucleus (AGN). Another redshift, $z \approx 2.078$, is also predicted to be associated with quasars and AGNs. The derived results are contrasted with observational data and with a recent ΛCDM model. Taken together, the produced galaxy dynamics and the aforementioned results could shed some light on the role of supermassive black holes in the evolution of the galaxies in which they reside.

The success of Information Relativity in reproducing the Schwarzschild radius of black holes, together with previous successful predictions of the phenomena of light bending, gravitational redshift, dark matter, and dark energy, attest the possibility of constructing a simple cosmology, based only on physical variables, without the notion of space time and its geodesics.

Keywords: Black hole, Singularity, Schwarzschild radius, Relativity, Binary system, Galaxy structure.

1. Black Holes - A Brief History

The term "black hole" was coined by John Wheeler in 1964, but the possibility of its existence within the framework of Newtonian physics was conjectured by John Michell in 1784, who argued for the possible existence of an object massive enough to have an escape velocity greater than the velocity of light [1]. Twelve years later, Simon Pierre LaPlace also predicted the existence of black holes. Laplace argued that "It is therefore possible that the largest luminous bodies in the universe may, through this cause, be invisible" [2].

A better understanding of black holes, and how gravity and waves intermingle, had to wait until 1915, when Albert Einstein delivered a lecture on his theory of General Relativity (GR) to the German Academy of Science in Berlin. Within a month of the publication of Einstein's work, Karl Schwarzschild, while serving in the German Army on the Russian front, solved Einstein's field equations for a non-rotating, uncharged, spherical black hole [3, 4]. For a star of a given mass, M, Schwarzschild found the critical radius R = $\frac{2\,G\,M}{c^2}$, where G is the gravitational constant and c is the velocity of light, at which light emitted from the surface would have an infinite gravitational redshift, and thereby infinite time dilation. Such a star, Schwarzschild concluded, would be undetectable by an external observer at *any* distance from the star.

Our understanding of the processes involved in the evolution and decay of black holes is largely due to quantum mechanical and thermodynamic theories. Early in 1974, Stephen Hawking predicted that a black hole should radiate like a hot, non-black ("gray") body [5]. Hawking's theory of black holes, is consistent with Bekenstein's generalized second law of thermodynamics [6], stating that the sum of the black-hole entropy and the ordinary thermal entropy outside the black hole cannot decrease. According to this prediction, black holes should have a finite, non-zero, and non-decreasing temperature and entropy.

The first X-ray source, widely accepted to be a black hole, was Cygnus X-1 [7]. Since 1994, The Hubble Space Telescope, and other space-crafts and extremely large ground telescopes [see, e.g., 8, 9], have detected numerous black holes of different sizes and redshifts. We now know that black holes exist in two mass ranges: small ones of ($M \lesssim 10\ M_\odot$) ($M_\odot$, solar mass), believed to be the evolutionary end points of the gravitational collapse of massive stars, and supermassive black holes of $M \gtrsim 10^6\ M_\odot$, responsible for the powering of quasars and active galactic nuclei (AGN) [10, 12]. Supermassive black holes, residing at the centers of most galaxies, are believed to be intimately related to the formation and evolution of their galaxies [10- 14].

2. Pathology and Previous Solutions

As mentioned above, the solution to Einstein's field equations [3, 4] yields a critical hole radius of R = $\frac{2\,GM}{c^2}$. However, Schwarzschild's solution suffers from a serious pathology, because it predicts a singularity whereby the fabric of spacetime is torn, causing all matter and radiation passing the event horizon to be ejected out to an undefined spacetime, leaving the black hole empty, thus, in violation of the laws of thermodynamics and contradiction with quantum mechanics [e.g., 15-16]. Many believe that the black holes (and the Big Bang) singularities mark a breakdown in GR.

Attempts to solve the singularity problem are aplenty. Bardeen was the first to propose a regular black hole model [17]. In 1968, he produced a famous model, conventionally interpreted as a counterexample to the possibility that the existence of singularities may be proved in black hole spacetimes without assuming either a global Cauchy hyper-surface or the strong energy condition. Other regular "Bardeen black holes" models have been also proposed [e.g., 18-23], but none of these models is an exact solution to Einstein equations [24]. Other solutions to produce singularity-free black hole come from string theory [e.g., 25, 26], and quantum mechanics [e.g., 27-31]. As examples, Ashtekar and others [27-28] proposed a loop quantum gravity model that avoids the singularities of black holes and the Big Bang. Their strategy was to utilize a regime that keeps GR intact, except at the singularity point, at which the classical spacetime is bridged by a discrete quantum one. Although the solution is mathematically difficult, its strategy is simple. It begins with semi-classical state at large late times ("now"), and evolves it back in time, while keeping it semi-classical until one encounters the deep Planck regime near the classical singularity. In this regime, it allows the quantum geometry effects to dominate. As the state becomes semi-classical again on the other side, the deep Planck region serves as a quantum bridge between two large, classical spacetimes [27].

3. The Proposed Solution

Here I propose another solution to the spherical supermassive, gravitational black hole. The solution is based on a new relativity theory, termed Information Relativity theory (IR). First, I give a brief description of the theory. Then I utilize it to derive a dynamical equation for a typical galaxy with a supermassive black hole (e.g., the Milky Way), and a solution to the black hole radius. The resulting radius turns out to be equal to the Schwarzschild radius (R= $\frac{2\,G\,M}{c^2}$), but ***with no singularity at the interior***. Moreover, the proposed solution predicts that supermassive black holes, residing at the center of galaxies, are part of binary systems, with naked singularities at redshift z = $2^{-\frac{1}{2}} \approx 0.707$, suspected to be quasars with extreme velocity offsets or active galactic nuclei (AGNs).

A complete formulation of Information Relativity theory (IR) and its applications to various field in physics, including small particles physics, quantum mechanics, and cosmology, are detailed elsewhere (e.g., 32-36). In principle, information relativity theory is nothing more than relativizing Newtonian physics, which we accomplished by taking into account the time travel of information from one reference frame to another. The theory is also local-realistic, with no uncertainties. It is formulated only in terms of physical observables, with no axioms (e.g., constancy of c) nor hypothetical constructs (e.g., spacetime, quantum states). It is important to note that, in the framework of information relativity, the scale of the system is of no importance. The theory takes a unifying approach toward physics by using the same set of equations, without any free parameters, to explain and predict both quantum and cosmological phenomena. In several previous articles, we showed that, not only does the theory reproduce quantum theoretical results, it also explains them in simple mechanical terms.

Note that, unlike special relativity theory, in which the relativity of time is achieved by axiomatizing constancy of light velocity, relativizing time and other physical entities in information relativity theory is a force majeure of the fact that information does not pass between two points in configuration space instantaneously but rather suffers delay, which depends on the spatial distance between the two points and the velocity of the information carrier.

The rationale behind the theory is extremely simple and straightforward. It could be illustrated as follows: Consider the case where information from a moving body is transmitted to a stationary observer by light signals. Assume that the start and end of an occurrence on the body's reference frame are indicated by two signals sent from the body's moving reference frame to the stationary observer. Because the lights velocity is finite, the two signals will arrive to the observer's reference frame in delays, which are determined by the distances between the body and the observer, at the time when each signal was transmitted. Suppose that the moving body is distancing from the observer; in this case, the termination signal will travel a longer distance than the start signal. Thus, the observer will measure a longer event duration than the event duration at the body's reference frame (time dilation). For approaching bodies, the termination signal will travel a shorter distance than the start signal. Thus, the observer will measure a shorter event duration than the event duration at the body's reference frame (time contraction). It is obvious from the above description that no synchronization of the clocks at the two reference frames is required. For the simple case of transverse motion with constant velocity v, expressing the above-mentioned example in the language of mathematics yields the following equation:

$$\frac{\Delta t}{\Delta t_0} = \frac{1}{1-\beta} \tag{1}$$

where Δt is the events time duration as measured by the observer, Δt_0 is the events time duration at the body's rest-frame, and β is the relative velocity, $\beta = \frac{v}{c}$. Derivations of the transformations of length, mass, and energy, detailed elsewhere [34], are depicted in the second column in Table 1. Notice that, for $\beta \to 0$ (or $v \ll c$), the wave energy density $e_w \to 0$, and all other transformations of time, distance, mass, and kinetic energy reduce to the classical Newtonian terms.

Table 1

Theory transformations for the case of inertial motion

Physical Term	Relativistic Expression In Velocity	In Redshift	
Time (sec)	$\frac{\Delta t}{\Delta t_0} = \frac{1}{1-\beta}$	z +1	(1)
Time (round trip)	$\frac{\Delta t}{\Delta t_0} = \frac{2}{1-\beta^2}$	$\frac{2(z+1)^2}{2z+1}$	2)
Distance (m)	$\frac{\Delta x}{\Delta x_0} = \frac{1+\beta}{1-\beta}$	2z +1	(3)
Mass density (kg/m³)	$\frac{\rho}{\rho_0} = \frac{1-\beta}{1+\beta}$	$\frac{1}{2z+1}$	(4)
Kinetic energy density e_k	$\frac{1}{2}\rho_0\, c^2 \frac{1-\beta}{1+\beta}\,\beta^2$	$\frac{1}{2}\rho_0\, c^2 \frac{z^2}{(z+1)^2(2z+1)}$	(5)

Because our objective is to apply the theory to the cosmology of black holes, we derive the theory transformations in terms of redshift z, instead of recession velocity β. For this end, consider an observer on Earth who receives redshifted waves emitted from a receding celestial object (e.g., a star, black hole, galaxy center, etc.). Assume that the recession velocity of the celestial object, at the time the wave was emitted, was equal to v. Using Doppler's formula, we can write:

$$z = \frac{\lambda_{ob} - \lambda_{em}}{\lambda_{em}} = \frac{f_{em} - f_{ob}}{f_{ob}}$$

(6)

Where λ_{em} (f_{em}) is the wavelength (frequency) of the wave emitted by the celestial object and λ_{ob} (f_{ob}) is the wavelength (frequency) measured by the observer on Earth. We also have $f_{em} = \frac{1}{\Delta t_{em}}$ and $f_{ob} = \frac{1}{\Delta t_{ob}}$, Where Δt_{em} *and* Δt_{ob} are the time intervals corresponding to f_{em} and f_{ob}, respectively.

Substitution in eq. 6 gives:

$$z = \frac{\frac{1}{t_{em}} - \frac{1}{t_{ob}}}{\frac{1}{t_{ob}}} = \frac{\Delta t_{ob}}{\Delta t_{em}} - 1 \tag{7}$$

From eq. 1 we have: $\frac{\Delta t_{ob}}{\Delta t_{em}} = \frac{1}{1-\beta}$, where $\beta = \frac{v}{c}$. Substitution in eq. 7 yields:

$$z = \frac{1}{1-\beta} - 1 = \frac{\beta}{1-\beta} \tag{8}$$

And the recession velocity in terms of redshift is:

$$\beta = \frac{z}{z+1} \tag{9}$$

For blue-shift the same equation holds except that we must replace β by - β. Substituting eq. 9 in the transformations depicted in the middle column in Table 1 yields the transformation as functions of the redshift z depicted in right side column of the table.

Black holes in Information Relativity theory

Figure 1 depicts a schematic representation of a supermassive black hole with mass M and radius R residing at the center of its host galaxy.

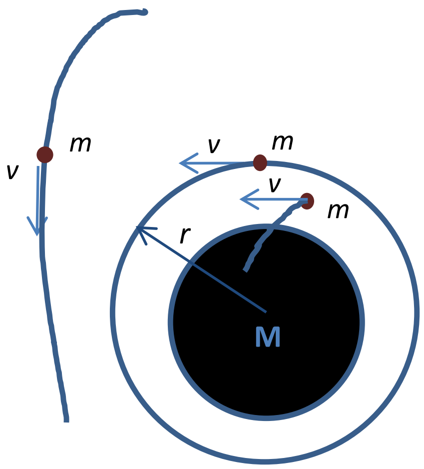

Figure 1. Three particles near a black hole

The figure also depicts three hypothetical particles, with equal masses and velocities, at different distances from the center of the black hole. The more distant particle is deflected toward the black hole, but due to its large distance from the hole, it escaped its gravitating force and continue its travel in space. By contrast, the closest particle to the black hole experiences a strong enough gravitational force and is sucked into the black hole. The third particle passes at a critical distance from the hole, at which its gravitating force is sufficient to sustain it rotation around the hole at radius *r*. For such particle, the acceleration $|\vec{a}|$ supporting a uniform radial motion with radius *r* should satisfy:

$$a = |\vec{a}| = \frac{v^2}{r} = \frac{c^2}{r}\beta^2 \tag{10}$$

The force supporting such motion, according to Newton's second law, could be expressed as:

$$F = \frac{\partial P}{\partial t} = \frac{\partial(mv)}{\partial t} = m\frac{\partial(v)}{\partial t} + v\frac{\partial(m)}{\partial t}$$
$$= m\,a + v\frac{\partial(m)}{\partial v}\frac{\partial(v)}{\partial t} = m\,a + v\,a\frac{\partial(m)}{\partial v} = (m + v\frac{\partial(m)}{\partial v})\,a \tag{11}$$

Substitution the term for *m* using eq. 4 in Table 1, and deriving *m* with respect to *v* yields:

$$F = \frac{1-2\beta-\beta^2}{(1+\beta)^2}\ m_0\ \mathrm{a} \qquad 12)$$

Substitution the value of *a* form Eq. 10 in Eq. 12 yields:

$$F = \frac{1-2\beta-\beta^2}{(1+\beta)^2}\ m_0\ \mathrm{a} = \frac{1-2\,\beta-\beta^2}{(1+\beta)^2} m_0\ \frac{v^2}{r} = m_0\,c^2\,\frac{1-2\,\beta-\beta^2}{(1+\beta)^2}\beta^2\,\frac{1}{r} \tag{13}$$

Using Newton’s general law of gravitation, we get:

$$\mathrm{G}\,\frac{m_0\,M}{r^2} = m_0\,c^2\,\frac{1-2\,\beta-\beta^2}{(1+\beta)^2}\beta^2\,\frac{1}{r} \qquad 4)$$

Solving for r yields:

$$r = \frac{G\ M}{c^2}\ \frac{(1+\beta)^2}{1-2\ \beta-\ \beta^2}\ \beta^2 \tag{15}$$

For a light photon, $\beta\ = 1.$ Substitution in eq. 15 yields:

$$r\ (\beta\ = 1) = R = \frac{2\ G\ M}{c^2} \tag{16}$$

Which exactly equals the Schwarzschild radius, ***but with no interior singularity***. Interestingly, the solution in eq. 15 has a naked space-like singularity at β satisfying:

$$1 - 2\ \beta -\ \beta^2 = 0 \qquad 17)$$

Which solves for:

$$\beta = \sqrt{2}\ \text{-}1 \approx 0.4142 \tag{18}$$

With corresponding redshift of:

$$\mathrm{z} = \frac{\beta}{1-\beta} = \frac{1}{\sqrt{2}} \approx 0.7071 \tag{19}$$

It is worth noting that the predicted exterior singularity is in space and not in spacetime. In information relativity theory, including in its present application to the black hole problem, the three dimensional space, and time are treated as independent, and separate physical variables, just like they are treated in classical physics and in the first formulation of special relativity theory.
To express the equation of motion (eq. 15) in terms of redshift, we substitute the value of β from Eq. 9 in eq. 15 and solve for r, yielding:

$$r = (\frac{G\ M}{c^2})\ \frac{z^2(1+2z)^2}{(1+z)^2\ (1-2z^2\ )} \tag{20}$$

Figure 2 depicts the ratio r, normalized by $\frac{GM}{c^2}$, as a function of z.

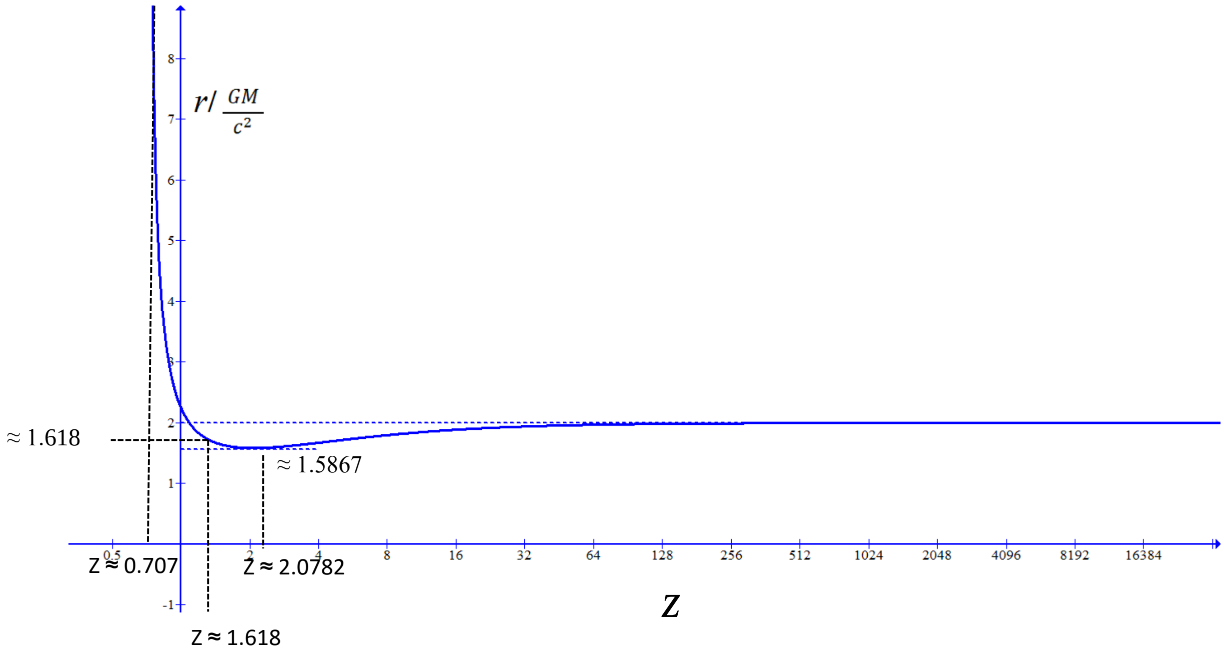

Figure 2. r / $(\frac{GM}{c^2})$ as a function of redshift

As shown by the figure, for very high redshifts r converges to $2\frac{G\,M}{c^2}$ (the Schwarzschild radius). Moreover, the result in eq. 19 has some interesting properties: (1) r has a naked *spatial singularity*, at $z = \frac{1}{\sqrt{2}} \approx 0.707$, (2) It displays a striking Golden Ration symmetry, such that for z = φ ≈ 1.618, r / $(\frac{G\,M}{c^2}) \approx 1.618$, (3) It has a point of minimum in the range between the above mentions redshifts. To find the point of minimum we derive r / $(\frac{G\,M}{c^2})$ with respect to z and equate the result to zero, yielding:

$$4\,z^4 - 2\,z^3 - 10\,z^2 - 6\,z - 1 = 0 \qquad 1)$$

Which solves at $z_m \approx 2.078$, yielding $r_m \approx 1.5867\,(\frac{G\,M}{c^2})$.

The prediction of an extreme galactic activity at $z \approx 0.7071$ is supported by many observational studies, which reported the detection of quasars, blazars and other AGNs at $z \approx 0.707$ [e.g., 37-40]. For example, Steinhardt et al. [38] reported the discovery of a Type 1 quasar, SDSS 0956+5128, with extreme velocity offsets at redshifts z = 0.690, 0.714, and 0.707. The prediction of AGNs at z ≈ 2.078 is also confirmed by observations [e.g. 41, 42].

We also compared the dynamical dependence of r on redshift (eq. 20) with the dynamics reported in [43] for a cosmology of Ω_M = 0.3 and Ω_Λ = 0.7, H_0 = 70 km s^{-1} Mpc^{-1}. Figure 3a depicts the predicted radius r (in *Km*) as a function of redshift for intermediate and massive black holes and Figure 3b depicts comparable results reported in [43]. Comparison of the two figures, despite differences in scaling, reveals a remarkable similarity between the two.

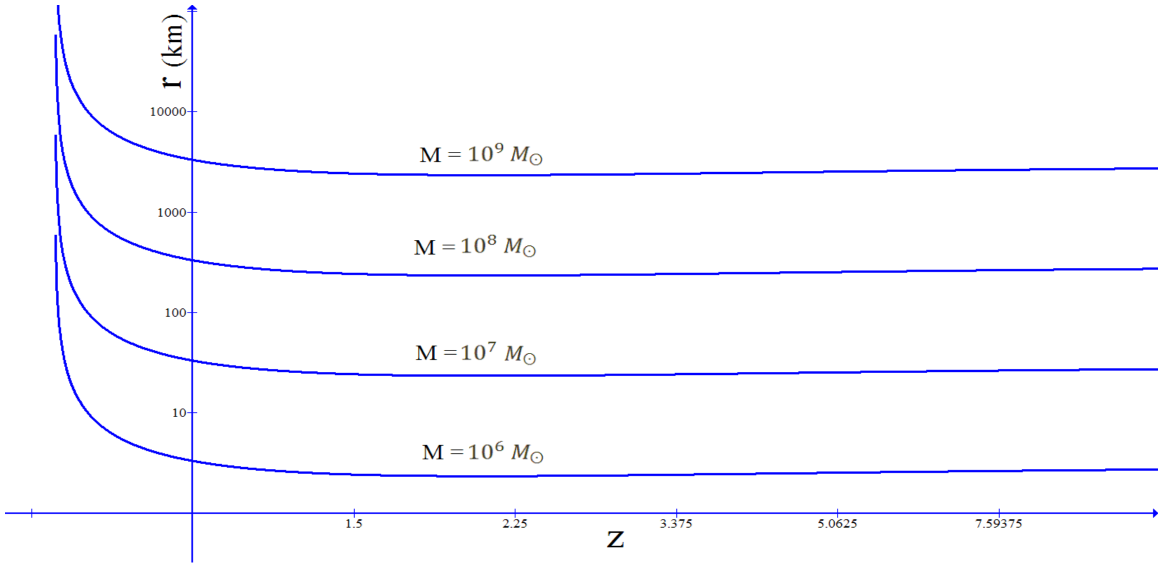

Figure 3a

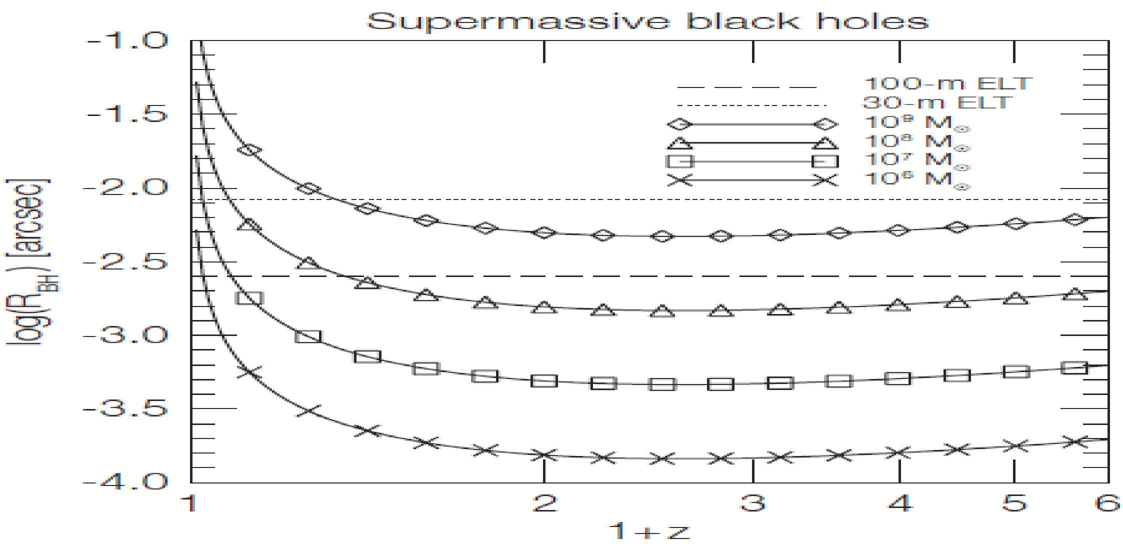

Figure 3b

Figure 3. Predicted r as a function of z (Fig. 3a) and comparable results based on ΛCDM model ($\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, $H_0 = 70$ km s^{-1} Mpc^{-1}) reported by Hook (2005) [45] (Fig 3b).

6. Summary and Concluding Remarks

The singularity problem of the Schwarzschild's solution to the black hole radius has prompted many attempts to produce singularity-free or singularity-avoiding solutions. Such attempts include what is known as the "Bardeen black hole" models [e.g., 16-23], as well as quantum mechanical models [e.g., 26-30] and string theory models [e.g., 24, 25]. A minor portion of this literature was discussed in section 2.

An additional solution was proposed here, based on a straightforward extension of Galileo-Newton mechanics, termed information relativity theory. For the non-rotating, purely gravitational, spherical black hole we were able to reproduce the Schwarzschild radius, without the troubling interior singularity. No less important, the theory yields a simple equation for the dynamics of a typical galaxy with a supermassive black hole. Investigation of the emerging dynamics suggests that a galaxy's supermassive black hole is part of a binary system, comprised of the black hole and a spatial singularity at redshift $z \approx 0.707$, suspected to be a quasar with extreme velocity offsets, or an active galactic nucleus (AGN).

The produced model is successful in making several interesting predictions. The point of singularity at $z \approx 0.7071$ confirms with several observations reporting the detection of quasars and AGNs at the predicted redshift [e.g., 37-40]. The prediction of galactic activity at $z \approx 2.078$ is also confirmed by observations reporting the existence of quasars and AGNs at $z = 2.078$ and $z = 2.08$ [41-42]. Taken together, the derived dynamics, and the aforementioned results, shed some light on the intimate relationship between supermassive black holes, and the evolution of the galaxies in which they reside.

The present paper adds to two previous papers in which we demonstrated that Information Relativity succeeds in reproducing the predictions of General Relativity theory for two other phenomena: light bending near massive objects [44], and gravitational redshift [45]. In a recent paper, we also showed that theory yield a simple quantum cosmology of the universe [46], and provides plausible explanations for dark matter and dark energy, which confirm with recent observations-based ΛCDM cosmologies.

Taken together, our theoretical results attest the possibility of constructing a simple unifying physics, based only on physical variables, without the notion of space time and its geodesics.

References

[1] Michell, J. (1784). On the Means of discovering the Distance, Magnitude, etc. of the Fixed Stars, in consequence of the Diminution of the velocity of their Light, in case such a Diminution should be found to take place in any of them, and such Data should be procurred from Observations, as would be farther necessary for that Purpose. *Philosophical Transactions*, 74: 35-57.

[2] Laplace, P. (1796). *Exposition du System du Monde*, Paris: Cercle-Social.

[3] Schwarzschild, K. (1916). Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie, *Sitzungsberichte der Deutschen Akademie der Wissenschaften zu Berlin, Klasse fur Mathematik, Physik, und Technik*, pp 189.
[4] Schwarzschild, K. (1916). Über das Gravitationsfeld einer Kugel aus inkompressibler Flussigkeit nach der Einsteinschen Theorie, *Sitzungsberichte der Deutschen Akademie der Wissenschaften zu Berlin, Klasse fur Mathematik, Physik, und Technik*, pp 424.
[5] Hawking, S. W. (1974). Black Hole Explosions? *Nature*, 248: 30-31.
[6] Bekenstein, J. D. (1973). Black Holes and Entropy. *Physical Review D* 7: 2333-2346.
[7] Bowyer, S. et al. (, 1965). Cosmic X-ray Sources, *Science* 147 (3656): 394–398.
[8] Xiong, D. R., & Zhang, X. (, 2014). The connections between bulk Lorentz factor, black hole mass and accretion in Fermi FSRQs. *Astrophysics and Space Science* (DIO: 10.1007/s 10509).
[9] Ferrarese ,L., & Ford, H. (2005). Supermassive Black Holes in Galactic Nuclei: Past, Present and Future Research. *Space Science Reviews*, 116 (3-4): 523-624.
[10] John Kormendy, J., & Richstone, D. (1995). Inward bound – The search for supermassive black holes in galactic neuclei. *Annu. Rev. Astron. Astrophys*. 33:581-624.
[11] Doeleman, S., et al. (2012). Jet-launching structure resolved near the supermassive black Hole in M87. *Science*, 338: 355 - 358.
[12] Ferrarese, L., & Merritt, D. (2000). A fundamental relation between supermassive black holes and their host galaxies. *The Astrophysical Journal*, 539: L9–L12.
[13] Chokshi, A., & Turner, E. L. (1992). Remnants of the quasars. *Mon. Not. R. Astr. Soc*. 259: 421 - 424.
[14] Di Matteo, T., Springel, V., & Hernquist, L. (2005). Energy input from quasars regulates the growth and activity of black holes and their host galaxies. *Nature*, 433, 604-607.
[15] Bekenstein, J. D. (1981). Universal upper bound on the entropy-to-energy ratio for bounded systems. *Physical Review D* 23, 287-298.
[16] Bardeen, J. M., Carter, B., & Hawking, S. W. (1973). The four laws of black hole mechanics, *Communications in Mathematical Physics*, 31, 161-170.
[17] Bardeen, J. (1968). In *Proceedings of GR5*, Tiflis, U.S.S.R.
[18] Borde, A. (1994). *Phys. Rev*. D., 50, 3392.
[19] Borde, A. (1997). *Phys. Rev*., D55, 7615.
[20] Ay´on–Beato, E. (1993.). *Asymptotic Behavior of Scalar Fields Coupled to Gravity, Graduate Dissertation, Faculty of Physics*, Havana Univ.
[21] Barrab`es, C., Frolov, V.P. (1996). *Phys. Rev*., D53, 3215.
[22] Mars, M., Mart´ın–Prats, M.M., Senovilla, J.M.M. (1996). *Class. Quant. Grav*., 13, L51.
[23] Cabo, A., Ay´on–Beato, E. (1999). *Int. J. Mod. Phys*., A14, 2013.
[24] Ayon-Beato, E., Garcia, A. (1998). Regular black hole in general relativity coupled to nonlinear electrodynamics. *Phys. Rev. Lett*., 80, 5056.

[25] Tseytlin, A.A. (1995). *Phys. Lett*., B363, 223.
[26] Callan, Jr. C. G., & Maldacena, J. M. (1997). D-Brane Approach to Black Hole Quantum Mechanics. *Nuclear Physics* B, 489, 65–94.
[27] Ashtekar, E., & Bojowald, M. (2006). Quantum geometry and the Schwarzschild singularity. *Class. Quantum Grav.* 23, 391, doi:10.1088/0264-9381/23/2/008.
[28] Ashtekar A., Pawlowski, T., & Singh, P. (, 2006). Quantum nature of the big bang: An analytical and numerical study. *Phys. Rev. Lett*., 96, 141301.
[29] Bojowald, M. (2001). Absence of singularity in loop quantum cosmology. *Phys. Rev. Lett.* 86, 5227 - 5230.
[30] Ashtekar A, Bojowald M and Lewandowski J. (, 2003). Mathematical structure of loop quantum cosmology. *Adv. Theor. Math. Phys*. 7, 233–268.
[31] Hawking, S. W. (1975). Particle creation by black holes", *Communications in Mathematical Physics*, 43, 199-220.
[32] Suleiman, R. (2013). The dark side revealed: A complete relativity theory predicts the content of the universe. *Progress in Physics, 4,* 34-40.
[33] Suleiman, R. (2016). Information relativity theory solves the twin paradox symmetrically, *Physics Essays*, 29, 304-308.
[34] Suleiman, R. (2017). Information Relativity: The Special and General Theory. DOI: 10.13140/RG.2.2.36312.29442
[35] Suleiman, R. (2017). Dark Matter and Dark Energy as Quantum Entities, Paper presented at 2017STARS2017 & SMFNS2017 Cuba, 3-13 May, 2017. DOI: 10.13140/RG.2.2.23613.26085.
[36] Suleiman, R. (2016). A relativistic model of matter-wave duality explains the results of the double-slit experiment. *Poster presented at the 5th International Conference on New Frontiers in Physics ICNFP2016*. Crete, 6-14 July 2016.
[37] K. Hurley, K. *et al.* (2000). Interplanetary network localization of GRB 991208 and the discovery of its afterglow. *The Astrophysical Journal Letters*, 534, (doi:10.1086/312645).
[38] Steinhardt, C. L., et al. (2012). SDSS 0956+5128: A broad-line quasar with extreme velocity offsets. *ApJ*, 759 24, doi:10.1088/0004-637X/759/1/24.
[39] Calderone, at al. (2012). B2 0954+25A: a typical Fermi blazar or a γ -ray loud Narrow Line Seyfert 1? *Mon. Not. R. Astron. Soc*. 424, 3081–3093.
[40] Xiong, D.R., & Zhang, X. (2014). The connections between bulk Lorentz factor, black hole mass and accretion in Fermi FSRQs. *Astrophysics and Space Science*, DOI 10.1007/s10509-014-1967-y.
[41] Matsuoka, M. (1999). X-ray observations of high-z radio loud/quiet quasars. *A & Space Res*. 23, 1151- l 154.

[42] Elíasdóttir, Á., et al. (2009). Dust extinction in high-z galaxies with gamma-ray burst afterglow spectroscopy: the 2175 Å feature at z= 2.45. *The Astrophysical Journal*, 697:1725–1740.
[43] Hook, I. M. (2005). The science case for the European Extremely Large Telescope: The next step in mankind's quest for the Universe. *The Messenger*, 121, 2-10 *(http://www.astro-opticon.org/networking/elt.html).*
[44] Suleiman, R. (2017). Outside Spacetime I: the degree of solar light bending, as good as general relativity. Manuscript submitted to the *Canadian Journal of Physics*.
[45] Suleiman, R. (2017). Outside Spacetime II: An axiom-free relativizing of Newtonian physics predicts the gravitational redshift as good as general relativity. Manuscript submitted to the *Canadian Journal of Physics*.
[46] Suleiman, R. (2017). Dark Matter and Dark Energy as Quantum Entities. Manuscript submitted to *Astronomical Notes*.