Light-speed Acceleration Radius

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Abstract

Introduced and discussed is what is termed the light-speed acceleration radius. This is the radius of a spherical gravitational object at which an object (particle) at rest will accelerate to the speed of light in the Planck time. Because the Planck time is likely the shortest possible time interval and the speed of light is the maximum possible speed, this is the radius for the maximum gravitational field as measured by gravitational acceleration. This radius differs from the Schwarzschild radius except for so-called micro black holes.

Keywords: gravitational acceleration, Planck time, Schwarzschild Radius, black holes, interior black holes.

1 Light-speed Acceleration Radius

The gravitational acceleration g for a spherical object of mass M and radius R is given by the well-known formula

$$g = \frac{GM}{R^2}, \tag{1}$$

where G is the universal gravitational constant. We ask the following question: for what radius will a particle (object) at rest relative to M be accelerated to the speed of light c in the Planck time t_p? This we can answer by setting up the equations

$$\begin{aligned} g t_p &= c, \\ \frac{GM}{R^2}\frac{l_p}{c} &= c \end{aligned} \tag{2}$$

and then solving them for R to obtain

$$R_c = \frac{\sqrt{GMl_p}}{c} = \sqrt{\frac{l_p^3}{\bar{\lambda}}} = l_p\sqrt{\frac{l_p}{\bar{\lambda}}}, \tag{3}$$

where $\bar{\lambda}$ is the reduced Compton wavelength [1] of the gravitational mass M. We refer to this radius R_c as the *light-speed acceleration radius*. In 1899, Planck [2, 3] introduced the Planck units, and many (if not most) physicists consider the Planck length l_p to be the shortest possible length and the Planck time t_p to be the shortest possible time; see [4–6], for example. In recent years [7–10], it has been shown that the Planck length and time can be obtained totally independently on any knowledge about G, and so also the rightmost part of (3) can be used practically.

For a mass greater than the Planck mass, the Compton wavelength is shorter than the Planck length, which can at first seem to be inconsistent with the assumption that the Planck length is the shortest possible length. In our view, masses greater than the Planck mass are surely composite masses. Masses much smaller than the Planck mass can also be composite masses, such as the proton,[1] but there can likely be masses up to the Planck mass that have a single physical Compton wavelength; see [13]. A composite mass does not have a single "physical" Compton wavelength, but all the elementary particles making up the composite mass have a Compton wavelength. The Compton wavelength of the composite mass is then an aggregate of these and is given by

$$\bar{\lambda} = \frac{1}{\frac{1}{\bar{\lambda}_1} + \frac{1}{\bar{\lambda}_2} + \frac{1}{\bar{\lambda}_3} + \cdots + \frac{1}{\bar{\lambda}_n}}. \tag{4}$$

This reduced Compton wavelength is identical to that given by $\bar{\lambda} = \frac{\hbar}{mc}$ and is fully consistent with standard mass addition, i.e., $m = m_1 + m_2 + m_3 + \cdots + m_n$.

For a given radius, the mass of the gravitational object must be

$$M = \frac{R_c^2 c^2}{Gl_p} = \frac{\hbar}{l_p^3}\frac{R_c^2}{c} \tag{5}$$

[1] Interestingly, the radius of a proton is four times its reduced Compton wavelength [11]; see also [12].

for the gravitational acceleration to take a rest-mass particle to speed c in the Planck time at this radius. We obtained this by simply solving (3) for M. For a radius $R_c = l_p$, we see that this is the Planck mass $m_p = \frac{\hbar}{l_p}\frac{1}{c}$. This naturally means that the Planck acceleration a_p [14] when acting on a particle for one unit of Planck time takes the particle from zero to c, i.e.,

$$a_p t_p = c. \tag{6}$$

Because nothing with rest mass can travel at speed c, the Planck acceleration seems inconsistent with standard physics because it cannot be applied to any particle if the shortest possible time interval is the Planck time. A particle with mass traveling at speed c would have infinite kinetic energy, and it would require infinite energy to accelerate to this speed under this view. However, this is consistent with our new theory on collision space-time, where the Planck-mass particle is the collision between two photons. This collision takes the Planck time. The two photons colliding are mass, but then dissolve into light (pure energy) again, and therefore can move with the speed of light (because photons have no mass); see [15]. The Planck acceleration over the Planck time can be seen as an acceleration that rips matter (mass) into pure energy in the Planck time.

2 Light-speed Acceleration Radius, Schwarzschild Radius, and Haug Radius

The Schwarzschild radius [16, 17] divided by the light-speed acceleration radius is

$$\frac{R_s}{R_c} = \frac{\frac{2GM}{c^2}}{\frac{\sqrt{GMl_p}}{c}} = \sqrt{\frac{2GM}{c^2 l_p}} = \sqrt{\frac{2l_p}{\bar{\lambda}}}. \tag{7}$$

Because we have $\bar{\lambda} < l_p$ for any mass larger than the Planck mass, this means in general that the light-speed acceleration radius is less than (inside) the Schwarzschild radius. This is no surprise; for example, for a super-massive black hole, the escape velocity is c at the Schwarzschild radius, but the gravitational acceleration field at the Schwarzschild radius can still be much lower than that on the surface of Earth. One can therefore consider whether the light-speed acceleration radius tells us something important about the interior of black holes. That nothing can escape from inside the Schwarzschild radius of a black hole is only partly true. Again, the gravitational acceleration at the Schwarzschild radius and even somewhat inside the Schwarzschild radius of a gigantic black hole is very small. An escape velocity of c means that nothing can escape the gravitational object without having its velocity boosted after its initial speed. The escape velocity implies that the escaping object receives no additional boost in acceleration, such as that from rocket engines, for example. As long as an object that carries fuel and propulsion is outside the light-speed acceleration radius, it can potentially escape the black hole by turning on its engine.

Assume a black hole with one solar mass. Its Schwarzschild radius is approximately 2960 m, while its light-speed acceleration radius is approximately 1.5×10^{-16} m, which is not too far from the reduced Compton wavelength of a proton (2.1×10^{-16} m). We are not indicating that there is any relation here to protons; we simply mention this to give a feeling for the approximate size of a sphere with a radius equal to the light-speed acceleration radius.

The Haug radius [18] is the radius at which the escape velocity is c and so is similar to the Schwarzschild radius, but where one in the derivation of the escape velocity takes into account relativistic mass. The Haug radius is given by

$$R_h = \frac{GM}{c^2}, \tag{8}$$

which is half of the Schwarzschild radius. Compared to the light-speed acceleration radius, we have

$$\frac{R_h}{R_c} = \frac{\frac{GM}{c^2}}{\frac{\sqrt{GMl_p}}{c}} = \sqrt{\frac{2GM}{c^2 l_p}} = \sqrt{\frac{l_p}{\bar{\lambda}}}. \tag{9}$$

For the Planck mass, we have $\bar{\lambda} = l_p$, and we see that the Haug radius and the light-speed acceleration radius are the same. This is not the case for the Schwarzschild radius and the light-speed acceleration radius, which are equal in the case of a quarter of the Planck mass and not the whole Planck mass. However, a quarter of the Planck mass has a Schwarzschild radius that is half of the Planck length, which then goes against the assumption that the shortest length is the Planck length. In a recent paper [19], we pointed out that the escape velocity taking into account relativistic mass seems to give a much better fit for micro black holes with respect to the Planck scale than does Einstein's [20] general theory of relativity and its Schwarzschild metric, and the present result is in line with that.

3 Conclusion

We have presented a radius at which the gravitational acceleration when acting on an object at rest over the Planck time will accelerate it to the speed of light. For a black hole, this radius is inside the black hole; the exception is a so-called micro black hole, for which its radius and the light-speed acceleration radius are the same. This seems to be the radius at which the gravitational force is so strong that matter is accelerated so rapidly that it is ripped apart into energy (light).

References

[1] A. H. Compton. A quantum theory of the scattering of x-rays by light elements. *Physical Review*, 21(5): 483, 1923. URL https://doi.org/10.1103/PhysRev.21.483.

[2] M. Planck. *Natuerliche Masseinheiten*. Der Königlich Preussischen Akademie Der Wissenschaften, 1899.

[3] M. Planck. *Vorlesungen über die Theorie der Wärmestrahlung*. Leipzig: J. A. Barth, p. 163, see also the English translation "The Theory of Radiation" (1959) Dover, 1906.

[4] T. Padmanabhan. Planck length as the lower bound to all physical length scales. *General Relativity and Gravitation*, 17, 1985. URL https://doi.org/10.1007/BF00760244.

[5] R. J. Adler. Six easy roads to the Planck scale. *American Journal of Physics*, 78(9):925, 2010. URL https://doi.org/10.1119/1.3439650.

[6] S. Hossenfelder. Can we measure structures to a precision better than the Planck length? *Classical and Quantum Gravity*, 29, 2012. URL https://doi.org/10.1088/0264-9381/29/11/115011.

[7] E. G. Haug. Finding the Planck length multiplied by the speed of light without any knowledge of G, c, or h, using a Newton force spring. *Journal Physics Communication*, 4:075001, 2020. URL https://doi.org/10.1088/2399-6528/ab9dd7.

[8] E. G. Haug. Demonstration that Newtonian gravity moves at the speed of light and not instantaneously (infinite speed) as thought! *Journal of Physics Communication.*, 5(2):1, 2021. URL https://doi.org/10.1088/2399-6528/abe4c8.

[9] E. G. Haug. Using a grandfather pendulum clock to measure the world's shortest time interval, the Planck time (with zero knowledge of G). *Journal of Applied Mathematics and Physics*, 9:1076, 2021.

[10] E. G. Haug. Measurements of the Planck length from a ball-clock without knowledge of Newton's gravitational constant G or the Planck constant. *European Journal of Applied Physics, accepted and forthcoming*, 2021.

[11] O. L. Trinhammer and H. G. Bohr. On proton charge radius definition. *EPL*, 128:21001, 2019. URL https://doi.org/10.1209/0295-5075/128/21001.

[12] L. S. Levitt. The proton Compton wavelength as the 'quantum' of length. *Experientia*, 14:233, 1958. URL https://doi.org/10.1007/BF02159173.

[13] E. G. Haug. Collision space-time: Unified quantum gravity. *Physics Essays*, 33(1):46, 2020. URL https://doi.org/10.4006/0836-1398-33.1.46.

[14] G. Scarpetta. *Letter Nuovo Cimento*, 51, 1984.

[15] E. G. Haug. *Quantum Gravity Hidden In Newton Gravity And How To Unify It With Quantum Mechanics*. in the book: The Origin of Gravity from the First Principles, Editor Volodymyr Krasnoholovets, NOVA Publishing, New York, 2021.

[16] K. Schwarzschild. Über das gravitationsfeld eines massenpunktes nach der einsteinschen theorie. *Sitzungsberichte der Deutschen Akademie der Wissenschaften zu Berlin, Klasse fur Mathematik, Physik, und Technik*, page 189, 1916.

[17] K. Schwarzschild. 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*, page 424, 1916.

[18] E. G. Haug. A new full relativistic escape velocity and a new Hubble related equation for the universe. *Accepted and Forthcoming in Physics Essays*, 2021. URL https://hal.archives-ouvertes.fr/hal-03240114.

[19] E. G. Haug. Three dimensional space-time gravitational metric, 3 space + 3 time dimensions. *Journal of High Energy Physics, Gravitation and Cosmology*, 7:1230, 2021. URL https://doi.org/10.4236/jhepgc.2021.74074.

[20] A. Einstein. Näherungsweise integration der feldgleichungen der gravitation. *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin*, 1916.