The Planck Length from Light Deflection, Orbital Velocity or Gravitational Red-Shift, Independent of knowing Big G ?

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Abstract

In this paper we show that it is possible to find and measure the Planck length with no knowledge of big G, at least hypothetically. All that is needed to find the Planck length is 1) an observation of the orbital velocity, or the gravitational red-shift or the light deflection, 2) the mass of the object causing the deflection (that in some cases can be found without knowledge of G), 3) the radius , 4) the Planck constant, and 5) the speed of light. This approach strengthens our view that Newton's big G is a universal composite constant consisting of the Planck length, the Planck constant, and the speed of light. In other words, we can derive big G directly from what we consider more fundamental constants.

Key words: Planck length, Big G, gravity, deflection of light, orbital velocity, gravitational red-shift, Planck constant, speed of light, mass.

1 Introduction and Challenge

The Planck length was first introduced by Max Planck in 1906, see [1]. The Planck length is given as

$$l_p = \sqrt{\frac{\hbar G}{c^3}} \approx 1.616229 \times 10^{-35} \text{ meter} \tag{1}$$

This shows the Planck length as a function of Newton's [2] big G, the reduced Planck constant, and the speed of light. Haug [3, 4, 5] has recently suggested that big G is a universal composite constant that can be written in the form

$$G = \frac{l_p^2 c^3}{\hbar} \tag{2}$$

Using this formula for big G simplifies and quantifies a long series of equations in Newton's and Einstein's conception of gravity. It has recently come to our attention that McCulloch 2014 [6] has derived a similar formula for big G based on Heisenberg's uncertainty principle

$$G = \frac{\hbar}{m_p^2} \tag{3}$$

Since $m_p = \frac{\hbar}{l_p}\frac{1}{c}$, the Mcholloch 2014 and the Haug 2016 formulas are basically the same

$$G = \frac{\hbar}{m_p^2} = \frac{\hbar}{\left(\frac{\hbar}{l_p}\frac{1}{c}\right)^2} = \frac{l_p^2 c^3}{\hbar} \tag{4}$$

Haug [4] has derived this formula from dimensional analysis as well as from Heisenbergs uncertainty principle, using his newly-introduced maximum velocity formula for matter [7]. Mcholloch has derived it from Heisenbergs uncertainty principle relying on a quite different method. The argument in favor of writing big G in this way is also grounded in the fact that it helps us quantize and simplify a long series of formulas from Einstein's and Newtons gravitational theory without changing their values.

Both of these proposed formulas (Haug and McCulloch) for big G may be criticized for appearing to lead to circular arguments that have no solution, at least at first glance. Until recently, the Planck length has only been known to be found by using big G. From this perspective, l_p seems to be a derived constant from the more fundamental constant, big G. Therefore, it may not seem sound to claim that

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big G can be a function of the Planck length. Here we will challenge this view by pointing out several ways of potential finding the Planck length independent of knowing big G.

Haug [4, 10, 8] has also suggested that there may be a maximum velocity for matter just below the speed of light given by

$$v_{max} = c\sqrt{1 - \frac{l_p^2}{\bar{\lambda}^2}} \tag{5}$$

This formula can be solved with respect to the Planck length.

$$l_p = \bar{\lambda}\sqrt{1 - \frac{v_{max}^2}{c^2}} \tag{6}$$

The reduced Compton wavelength of an electron, for example, can be found independently of big G, see [9]. Still, for any observed subatomic particle this speed is just below c, but far above the rate that has been attained for particle acceleration in the Large Hadron Collider (LHC). This new way of finding the Planck length is only a theory at this time. However, by assuming that this represents the maximum velocity of anything containing matter, then a series of infinitys challenges will disappear, see [11].

2 The Planck Length from Gravitational Light Deflection

By assuming $G = \frac{l_p^2 c^3}{\hbar}$ we can rewrite Einstein's gravitational light deflection formula

$$\begin{aligned} \delta &= \frac{4GM}{c^2 r} \\ \delta &= \frac{4\frac{l_p^2 c^3}{\hbar}M}{c^2 r} \\ \delta &= \frac{4 l_p^2 M c}{\hbar r} \end{aligned} \tag{7}$$

This we can solve with respect to l_p, which gives us

$$l_p = \sqrt{\frac{\hbar r \delta \frac{\pi}{648000}}{4Mc}} \tag{8}$$

where δ is the observed bending of light in arcseconds, r is the radius from the center of the mass bending on the light to the point at which the light passes the object, M is the mass of the object, c is the speed of light, and $\hbar$ is the reduced Planck constant.

To give an example: for the Sun, the observed light bending is 1.75 arcseconds or $\frac{1.75}{3600}$ of a degree. The radius of the sun is 696,342,000 meters and the mass of the Sun is $M_s \approx 1.98810^{30}$ kg. We can plug this into the formula above and obtain

$$l_p = \sqrt{\frac{\hbar r_s \delta_s \frac{\pi}{648000}}{4M_s c}} = \sqrt{\frac{\hbar \times 696342000 \times 1.75 \times \frac{\pi}{648000}}{4 \times 1.98810^{30} \times c}} \approx 1.6162 \times 10^{-35} \tag{9}$$

For large objects, we are still dependent on big G to find the mass of the object. However, for small objects on Earth we can find the mass without knowing big G. If we can measure the light deflection around smaller objects, we should be able to find the Planck length independently of big G. Unfortunately, the measurement tools are not accurate enough for this today. Even so, it is possible (at least hypothetically) to calculate the mass of the Earth or the Moon by finding out what elements they consist of and what their densities are. Theoretically one could drill a hole all the way to the center of the Moon and in this way obtain element and density samples. Based on those samples, one could then likely calculate the mass of the Moon.

If we know the mass, independent of calculations related to Newtonian gravity and big G, and then were able to measure incredibly small deflections of light related to the Earth or the Moon or even smaller size objects, then we could, in principle, determine the Planck length independently of knowledge of big G. As previously stated, this would be extremely challenging in terms of ascertaining the results with accurate measuring devices, but this type of challenge has arisen with a number of predictions in physics over decades of research, experimentation, and analysis. So it possibly deserves further investigation and eventually the technology may be accurate enough to apply as well.

3 The Planck Length from Orbital Velocity

We can also find the Planck length from orbital velocity. The orbital velocity is given by

$$\begin{aligned} v_o &= \sqrt{\frac{GM}{r}} \\ v_o &= \sqrt{\frac{\frac{l_p^2 c^3}{\hbar} M}{r}} \\ v_o &= \sqrt{\frac{l_p^2 c^3 M}{\hbar r}} \end{aligned} \tag{10}$$

Solved with respect to the Planck length we get

$$\begin{aligned} v_o &= \sqrt{\frac{l_p^2 c^3 M}{\hbar r}} \\ l_p &= \sqrt{\frac{v_0^2 \hbar r}{c^3 M}} \end{aligned} \tag{11}$$

We can find the Planck length from knowing the orbital velocity of a satellite. This again would require knowledge of the mass of the Earth (or the mass we are measuring orbital velocity around). Again technically we could hypothetically find the mass of the Earth or the Moon by drill a hole all the way to the center of the Earth and in this way obtain element and density samples and in this way find the mass of the Earth independent on any knowledge of big G.

4 The Planck Length from Gravitational Red-Shift

Gravitational deflection is hard to measure very accurately. Our technology to measure gravitational red-shift is (likely) much more accurate. This involves gravitational time dilation that today can be measured with very accurate optical clocks. In a weak gravitational field (like we have on the Earth, and even on the surface of the Sun) we have

$$\begin{aligned} \lim_{r\to+\infty} z(r) &\approx \frac{2GM}{c^2 r} \\ \lim_{r\to+\infty} z(r) &\approx \frac{2\frac{l_p^2 c^3}{\hbar} M}{c^2 r} \\ \lim_{r\to+\infty} z(r) &\approx \frac{2 l_p^2 M c}{\hbar r} \end{aligned} \tag{12}$$

Solved with respect to the Planck length we get

$$l_p = \sqrt{\frac{\hbar r z(r)}{2Mc}} \tag{13}$$

We could even measure the gravitational red-shift between two different altitudes on the surface of the Earth or smaller size objects like the Moon or even onboard of big spherical space station. For gravitational red-shift measured from two different radius related to the same mass (object) we have the following formula that works very well in low gravitational fields

$$\begin{aligned} \frac{\lambda_2 - \lambda_1}{\lambda_1} &\approx \frac{1 + \frac{2GM}{c^2 r_1}}{1 + \frac{2GM}{c^2 r_2}} - 1 \\ \frac{\lambda_2 - \lambda_1}{\lambda_1} &\approx \frac{1 + \frac{2\frac{l_p^2 c^3}{\hbar} M}{c^2 r_1}}{1 + \frac{2\frac{l_p^2 c^3}{\hbar} M}{c^2 r_2}} - 1 \\ \frac{\lambda_2 - \lambda_1}{\lambda_1} &\approx \frac{1 + \frac{2\frac{l_p^2 c}{\hbar} M}{r_1}}{1 + \frac{2\frac{l_p^2 c}{\hbar} M}{r_2}} - 1 \end{aligned} \tag{14}$$

Solved with respect to the Planck length we get

$$l_p = \sqrt{\frac{\frac{\lambda_2-\lambda_1}{\lambda_1}\hbar r_1 r_2}{2 - cMr_1 + cMr_2 - \frac{\lambda_2-\lambda_1}{\lambda_1}cMr_1}} \tag{15}$$

In other words we can find the Planck length simply from gravitational red-shift observations, the mass of the object, the reduced Planck constant and the speed of light.

5 Conclusion

We have shown how the Planck length can be found from an observed light deflection, orbital speed or gravitational red-shift. To do this we also need to know the mass of the object, the reduced Planck constant, the speed of light, and the radius related to the measurments. This strengthens our argument that the Planck length is a real fundamental constant and that big G is a universal composite constant, consisting of three even more fundamental constants, namely the Planck length, the reduced Planck constant, and the speed of light.

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