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Light Velocity in General Relativity

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Abstract: It is shown that the velocity of light in general relativity depends not only on a gravitational potential but also on a direction. Moreover, its change across a gravitational field is half as much the generally accepted value (presenting its change along the field).
Keywords: general relativity, light velocity, theory, gravitational potential.

As known, gravity's influence on light propagation was proposed by Einstein [1,2]. At first, he obtained the following formula for light velocity c_1 in a place with the gravitational potential Φ

$$c_1 = c\left(1 + \Phi/c^2\right) \quad . \tag{1}$$

Since according to Einstein [2], "…the light velocity in a gravity field is a place function, it is not difficult to prove that light rays propagating across the gravity field must be bent with the aid of Huygens's principle."

Based on (1), he obtained the value of α_1=0.83″ for the deflection of the light ray passing by the Sun. In four years he added a factor of 2 to this result [3]. The deflection value calculated on the basis of general relativity (GR) (taking the space curvature into account) was α_2=1.7″. This corresponds to the light velocity (see, e.g., [4-6]):

$$c_2 = c\left(1 + 2\Phi/c^2\right) \quad . \tag{2}$$

One can also find a simplified calculation of α_2 in Bowler's book [6].

Now, we want to pay attention to a very important problem that is for some reason passed over in GR. The only exception is Einstein's early remark [7]: "The light velocity does not depend on direction but changes with changing gravitational potential" that leans upon formula (1). In order to reply to the question of light velocity's dependence on direction, for instance, in a central-symmetric gravitational field, we consider the known Schwarzschild metric form:

$$ds^2 = \left(1 + 2\Phi/c^2\right)c^2 dt^2 - \frac{dr^2}{1 + 2\Phi/c^2} - r^2\left(d\Theta^2 + \sin^2\Theta d\varphi^2\right) \quad . \tag{3}$$

For light rays

$$ds^2 = 0 \quad . \tag{4}$$

Hence we obtain that light propagating across the gravitational field (dr=0) has the following (tangential) velocity:

$$c_t \cong c\left(1+\Phi/c^2\right)=c_1 \quad . \tag{5}$$

Along the field direction ($d\Theta$=$d\varphi$=0), its (radial) velocity, one would think must remain

$$c_r = c(1+2\Phi/c^2)=c_2 \quad . \tag{6}$$

But as directly seen from the first Einstein remark [2], *just the tangential velocity* c_t *is used to calculate the gravitational bending of light*. Therefore, the calculated value of deflection in GR, one would think must remain near α_1 although the officially recognized (and measured? [8]) α_2 is two times larger.

Conclusion: As was shown, the radial light velocity is used when calculating the gravitational deflection of light. The use of the 'right' tangential velocity gives the value of deflection as being half as much as Einstein's calculated value.

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