On the Behaviour of Light in a Spherically Symmetric Aether Field

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The formulae for the bending of light and retardation of light signals near point masses are obtained in a very simple and natural way making use of classical optics. This is accomplished by characterizing the aether density in each point through a refraction index and assuming that the velocity of light is inversely proportional to this index. The results agree with General Relativity and with made experiments.

1. Introduction

Gradually more and more physicists become convinced that the formulae of Special Relativity may consistently be interpreted in terms of *real effects* (the so-called Lorentz-Larmor Aether Theory); there are also many physicists who think that this interpretation offers great advantages with respect to the orthodox interpretation [1]. There seems, however, still to be wanting a simple theory of gravitation fitting into this framework.

The object of this note is not to develop any complete theory of gravitation, this not being made in a trice, but to treat a simple example of the behaviour of light in a gravitational field (we hope to be able to treat material bodies in a subsequent paper). We shall thereby make use of an idea of Podlaha who in a recent article asserted "that the formula for the bending of light in a gravitational field can be found simply at using the laws of physical optics" [2]. Our object is to prove this assertion for the bending of light in a central field produced by a point mass. We will also derive a formula for the retardation of a light (radar) signal passing near such a mass.

2. The Bending of Light

Aether in the absence of gravitation is assumed to be homogenous and isotropic. When a gravitational field is present, however, the aether has different density in different points and a refraction index is to be assigned to each point exactly as is the case in the theory of optics when the medium is inhomogenous. Here we shall only be interested in the spherically symmetric field produced by a point mass, where we assume the refraction index to be given by

$$\varrho(r) = 1 + k/r \tag{1}$$

in first approximation. In this formula r denotes the distance from the center and k is a constant given by $k = 2\,M\,G/c_0^2$, where M stands for the value of the point mass, G for the Newtonian gravitational constant, and c_0 for the velocity of light in vacuo far from all masses. Note that G is multiplied by a factor of 2.

Assuming that the propagation of light in the aether obeys the laws of classical optics, we may apply Bouger's theorem [3]. This theorem tells that the quantity $B = \varrho(r)\,r \sin\alpha$ is invariant in a spherically symmetric medium, α here denotes the angle between the ray of light and the radius. From this theorem the following equation in polar coordinates (ϑ, r) for the light ray may be derived [3]:

$$\vartheta = \int \frac{\mathrm{d}r}{r\sqrt{\varrho^2(r)\,r^2/B^2 - 1}}\,. \tag{2}$$

Inserting the expression for ϱ, we obtain

$$\vartheta = \int \frac{\mathrm{d}r}{r\sqrt{(r+k)^2/B^2 - 1}}\,, \tag{3}$$

where $B = r_0\,\varrho(r_0) = r_0 + k$, and r_0 is the minimum distance ray-point mass.

Integration (substitution $r + k = B\cosh t$) gives:

$$\vartheta = \frac{2}{\sqrt{1 - k^2/B^2}} \operatorname{arctg} \frac{r + \sqrt{(r+k)^2 - B^2}}{B\sqrt{1 - k^2/B^2}}\,. \tag{4}$$

Our interest concerns the deviation of a light ray coming from minus infinity and going to plus infinity. We obtain:

$$\begin{aligned} \Delta\vartheta &= 2\int_{r_0}^{\infty} \frac{\mathrm{d}r}{r\sqrt{r^2\,\varrho^2(r)/B^2 - 1}} - \pi = \frac{4}{\sqrt{1 - k^2/B^2}} \\ &\quad \cdot \left(\pi/2 - \operatorname{arctg} \frac{1}{\sqrt{1 + 2\,k/r_0}}\right) - \pi \\ &= \left(\frac{1}{\sqrt{1 - k^2/B^2}} - 1\right)\pi + \frac{4}{\sqrt{1 + k^2/B^2}} \\ &\quad \cdot \operatorname{arctg} \frac{\sqrt{1 + 2\,k/r_0} - 1}{\sqrt{1 + 2\,k/r_0} + 1} = 2\,k/r_0 + O(k^2/r_0^2)\,. \end{aligned} \tag{5}$$

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We see that the bending of light will be in the direction of the gravitating mass and will be $4\,M\,G/c_0^2\,r_0$ in the first approximation. This aether theoretic result agrees with the predictions of General Relativity and the results of made experiments [4].

3. The Retardation of Light Signals

In order to derive a formula for the retardation of a light signal passing near a point mass, it is enough to make use of the well-known optical fact that the velocity of light is inversely proportional to the refraction index, i. e.

$$c(r) = c_0/\varrho(r). \tag{6}$$

Let a light signal be sent from A to B and back passing at the distance r_0 from a point mass M. Let a denote the distance A – M and b the distance B – M. We assume $a \gg r_0$ and $b \gg r_0$. In first approximation the light paths may be considered straight. We thus obtain the following expression for the time T_A needed for a light signal to pass from A to M:

$$\begin{aligned} T_A &= \int_0^a \frac{dx}{c(\sqrt{r_0^2+x^2})} = \frac{1}{c_0}\int_0^a (1+k(r_0^2+x^2)^{-1/2})\,dx \\ &= \frac{1}{c_0}(a + k\ln(a/r_0 + \sqrt{a^2/r_0^2+1})) \\ &\approx \frac{1}{c_0}(a + k\ln 2\,a/r_0). \end{aligned} \tag{7}$$

The expression for the time needed from M to B is exactly analogous: just write b instead of a. Since the time needed from A to B for a light signal undisturbed by gravitation is simply $(a+b)/c_0$, we thus obtain the following expression for the delay ΔT experienced by a light signal passing from A to B and back:

$$\begin{aligned} \Delta T = \frac{2\,k}{c_0}(\ln(a/r_0 + \sqrt{a^2/r_0^2+1}) + \ln(b/r_0 \\ + \sqrt{b^2/r_0^2+1})) \approx \frac{2\,k}{c_0}\ln 4\,a\,b/r_0^2. \end{aligned} \tag{8}$$

The aether theory thus predicts that a light (radar) signal passing near a (point) mass will be retarded by the amount $4\,G\,M/c_0^3 \ln 4\,a\,b/r_0^2$ in first approximation.

This result is in agreement with the predictions of General Relativity and with made experiments.

4. Conclusion

Let us remark that the two problems treated here are very simple examples of the behaviour of light in gravitational fields (inhomogenous aether). In general the aether density will be given by a more complicated function $\varrho(\boldsymbol{r}, t)$, not symmetric in $\boldsymbol{r}$ or/and depending on t. Here the formula (2) will not be applicable; it will consequently be necessary to have recourse to Fermat's principle (variational methods). The calculations will sometimes be very complicated, but it should in principle always be possible to calculate the light path using classical optics provided that the form of the function ϱ is known. Note, however, that when results of higher approximation are desired, it is, at the comparison of theory and experiment, necessary to take into account the fact that the lengths of material meters and the frequencies of material clocks also depend on the aether densities.

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[1] Here should be especially mentioned the work by G. F. Fitzgerald, H. A. Lorentz, J. Larmor, H. Poincaré, E. Wiechert, H. E. Ives, J. Palacios, K. C. Kar, G. Builder, S. Prokhovnik, P. Lorenzen, G. Cavalleri, and M. F. Podlaha. For references cf. E. T. Whittaker, A History of the Theories of Aether and Electricity, London 1951, 1953; G. H. Keswani, Brit. J. Phil. Soc. **15,** 286 (1964); **16,** 19 (1965); S. Prokhovnik, The Logic of Special Relativity, Cambridge 1967; M. F. Podlaha, Nuovo Cim. **66 B,** 9 (1981); T. Sjödin, Nuovo Cim. **51 B,** 229 (1979); Z. Naturforsch. **37 a,** (1982), in press.

[2] M. F. Podlaha, Indian J. Theor. Phys. **28,** 19 (1980).

[3] A. Maréchal, Optique géometrique générale, in: S. Flügge (ed.), Handbuch der Physik, Springer, Berlin 1956, **34,** 44–171.

[4] Let us note that also Einstein in his first attempt to derive a formula for the bending of light in a gravitational field made use of optical principles (E. Einstein, Ann. Phys. **35,** 898 (1911)). He, however, negated the existence of the aether and so could not use the concept of aether density. He further made the — historically excusable — mistake of using the Newtonian gravitational constant G instead of $2\,G$ and so obtained a wrong result.

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