Lunar Laser Ranging Test of the Invariance of *c*: a Correction

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In the APOLLO test, a speed of light was found, which seemingly supports a Galileian addition theorem of velocities [1]. However, the reported difference of 200 ± 10 m/s is based on a simple error. The correct evaluation of this test leads to the known value of c within the given precision. This correction does not mean an impossibility of detecting spatial anisotropies or gravitational waves.

The Apache Point Lunar Laser-ranging Operation (APOLLO) provides a possibility of directly testing the invariance of light speed [1, 2]. Gezari [1] reported a difference of 200 ± 10 m/s to the known value ($c = 299,792,458$ m/s according to [1]), which is in accordance with the speed of the observatory on the earth to the retro-reflector on the moon. That would support rather a Galileian addition theorem of velocities than the local invariance of light speed. - Let us follow up the path of light, Figure 1.

The way from the Apache Point Observatory (APO) to the retro-reflector and back to APO assumed by Gezari (see also Figure 2 in [1]) is $D_{LB} + D_{BR}$ (dotted lines). Gezari [1] wrote:

> Note that the Earth and Moon are moving together as a binary system at $\sim 30 km/s$ in that frame, as the Earth orbits the Sun, and relative to each other at much smaller speeds of order $\sim 10 m/s$ due to the eccentricity of the lunar orbit.

This "much smaller speed" may be the vertical speed of the moon relative to the earth. However, the moon moves irregularly in the used frame. This motion is not straight-line, that means, there is no relativity of motion between earth and moon. Therefore, we have to consider the horizontal speed (speed of revolution) of $v_{hor} \approx 1$ km/s . In the test constellation, the moon covers smaller distances parallel to the earth than the earth itself, Figure 1. It is false to set a unitary velocity of the "binary system" of ~ 30 km/s . If we define a "binary system" with power (what is an unfortunate step), this unitary velocity becomes here smaller.

Therefore, the path of light from APO to retro-reflector is shorter than assumed by Gezari. It is now D'_{LB} (full line), because the earth takes another position in the chosen frame at launch, see Figure 1. – The elapsed time $t_{LB} + t_{BR}$ was measured correctly but the calculation of the light speed gave a false (greater) value. As well, the way back via D_{BR} does not differ from that reported by Gezari. With it, the difference of the path of light is (Figure 1)

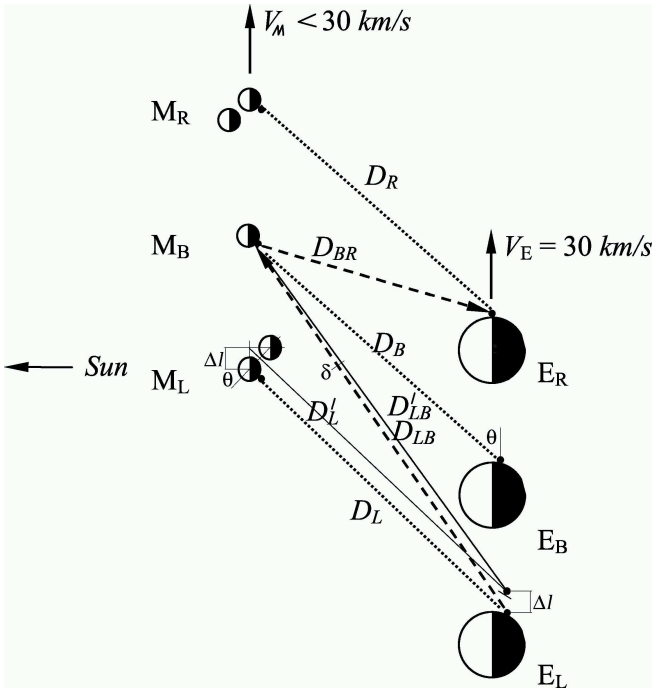

Figure 1: Corrected path of light

$$D_{LB} - D'_{LB} \approx \Delta l \cos\theta \tag{1}$$

with

$$\Delta l = v_{hor} \cdot t_{LB} \cdot \sin\theta \quad , \tag{2}$$

i.e.

$$D_{LB} - D'_{LB} \approx \frac{1}{2} v_{hor} \cdot t_{LB} \cdot \sin 2\theta \quad , \tag{3}$$

with the numerical values

$$D_{LB} - D'_{LB} < \frac{1}{2} \text{ km/s} \cdot 1.3\text{s} \approx 650\text{m} \quad . \tag{4}$$

This difference becomes maximal with $\theta = 45°$.

The reported value of the light speed c has to be corrected for a difference (with the ratio of path difference to whole path)

$$\Delta c < \frac{300000\text{km/s} \cdot 650\text{m}}{780000\text{km}} \approx 250\text{m/s} \quad . \qquad (5)$$

We get the reported difference of 200 m/s for $\theta = 27^\circ$ and for $\theta = 63^\circ$. That means a coincidence within a tolerance of $\pm 20\%$. – Thus, we have to take this result as negative regarding a verification of a violation of *local* invariance of c.

This from now on negative result does *not* rule out the possible existence of spatial anisotropies, as dependences of stochastic processes on direction [3] or measurements with gas interferometers [2] demonstrate. The observed effects like anisotropic light speed in gas could be based on anisotropic material properties, which come from anisotropic metrics. The reason is explained in [4]:

The universal (according to author's opinion) field equations as quoted in [4, 5] (Equ. (1),(2),(3) in [5]) involve 10 independent equations for 14 components of metrics and electromagnetic vector potential. If one considers only gravitation, that become 6 independent equations for 10 components of metrics. This means, four components of metrics are ambiguous *in first order*. Since our existence is time-like, these ambiguous components are space-like. For example in central-symmetric and time-independent solutions, vertical metric (first order) results according to

$$\gamma_{(vert)} = +\frac{\kappa\, m}{4\pi\, r} \quad , \qquad (6)$$

which comes from Equ. (35) in [4], during horizontal metrics can have any value, i.e. Equ. (35) in [4] is correct only for $\gamma_{(vert)}$. On the earth is $\gamma_{(vert)} \approx 1.5 \times 10^{-9}$, but $\gamma_{(hor)}$ could be just zero. – An upgrade APOLLO equipment could be suited for direct detection of such differences in metrics, if exist.

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