1.-Michelson-Morley

Eppur si muove...
Attributed to Galileo

INTRODUCTION

1 Scientific literature makes use of certain keywords, as 'nothingness' or 'vacuum' whose meaning is, at least, confusing. This circumstance add unnecessary difficulties to some fundamental discussions. To say, for example, that '*the energy of the universe comes from a quantum fluctuation of the vacuum*' means that the vacuum fluctuates and then that it is not nothing but something that fluctuates (whenever that nothingness is nothingness and then cannot fluctuate).

2 This chapter is not free of some of those conflicting words, but his goal is not to clarify their meaning. As is usual in these cases we will make use of their intuitive standard meaning.

3 Apart from an introductory discussion on the vacuum and the luminiferous aether that includes Michelson-Morley experiment, we will discuss here the independence of the trajectory of a photon with respect to the relative motion of its emitting source, as well as the hypothetical existence of a medium for the propagation of light

EMPTY SPACE?

4 Aether (or ether), the fifth aristotelian element, was invented to avoid the problems posed by the vacuum.[1] It was assumed to fill the whole universe and, naturally, was considered the medium through which light propagates, once its electromagnetic nature was known. In the next section we will examine Michelson-Morley experiment that was intended to detect the absolute motion of the Earth through the luminiferous aether.

5 We now know that light propagates through the vacuum and through different material media. And we also know its speed through the vacuum is a universal constant, c = 299792.458 Km/s, derived from two other universal constants: the electromagnetic permeability (μ_o) and permittivity (ϵ_o) of the vacuum. Recall that (Chapter **??**):

$$c = \frac{1}{\sqrt{\mu_o \epsilon_o}} \tag{1}$$

So that, in line with what pointed in 1, the vacuum or empty space has also physical attributes as electromagnetic permeability and permittivity.

6 These reasons, among others, led Einstein to realize that empty space was not nothing. For him spacetime was of an absolute nature although space and time separately were always relative.

7 The vacuum can also fluctuate at the quantum level. The dark energy, for instance, is assumed to be a consequence of those fluctuations. It has also the ability to incessantly create and annihilate quantum virtual particles. It could even be filled with several types of material condensates [10]. The estimated mass-energy density of the vacuum is $2 \times 10^{-152}\ g/cm^3$.

8 The above data, among others, point in favor of substantivalism in the controversy substantival vs. relational theories on the nature of physical space. See for instance [8]. And for a historical background on the theories of space see [5], [9], [7].

[1] See for instance [1], [9], [11], [4], [6], [10], [2].

9 When we say that light propagates through the vacuum we are saying it propagates through a physical entity whose essential nature is still unknown.[2] But it is a physical entity, not nothingness. With the intention of avoiding unnecessary discussions, confusions and continuous explanations, from now on that physical entity will be referred to as 'q-space'. From the perspective of a CALM, q-space would be the fabric of sits where all objects evolve.

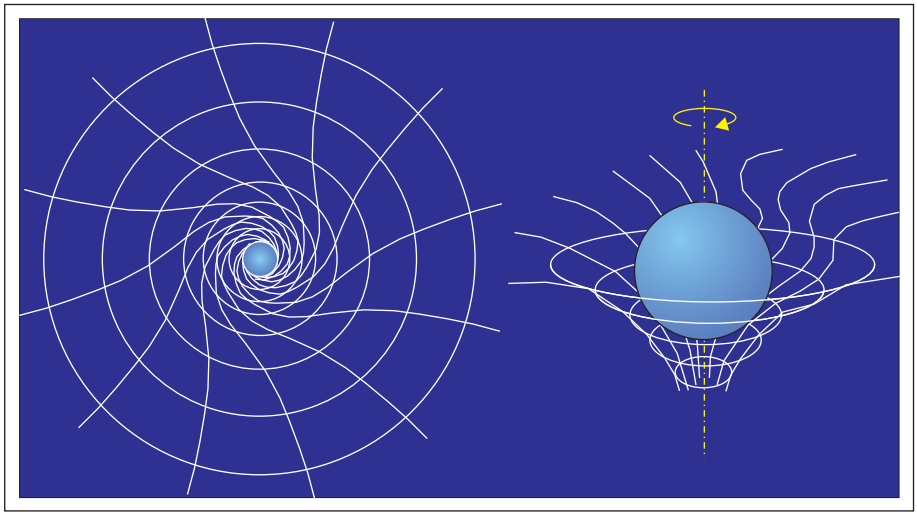

Figure 1.1: Frame dragging by the spinning of a massive object.

10 Though not directly related to the objective of this chapter, the question on how ordinary matter and q-space could interact with each other, particularly the question on how q-space is affected by the motion of ordinary matter, is related to the main objective of this book: the controversial on the analog vs digital paradigm. That question makes us recall the classical discussions on the interaction of the luminiferous aether and the celestial bodies and then the Michelson-Morley-like experiments.

[2] In contemporary physics it is usual to refer the motion of a celestial body to the fixed stars, to the *inertial space* or to the CMB (Cosmic Microwave Background).

11 A point of note regarding the interaction between q-space and material objects is the so called *frame dragging*, the possibility that a massive spinning object as our Earth, drags and distorts spacetime. This is a prediction of the general theory of relativity that has been recently confirmed by the Gravity Probe B satellite [3]. We can therefore conclude by confirming that, according to Einstein and many other authors, q-space is not nothing but a physical entity with a significant variety of physical properties.

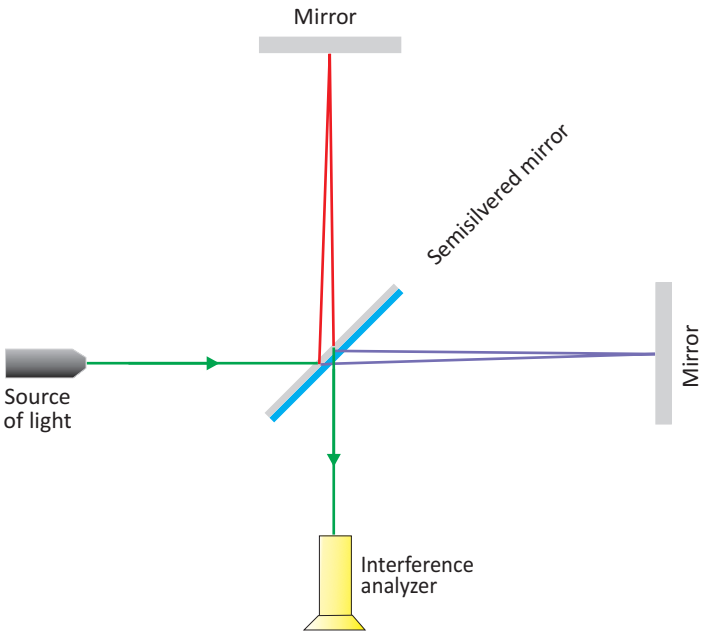

Figure 1.2: Schematic diagram of the Michelson-Morley interferometer.

MICHELSON-MORLEY EXPERIMENT

12 One of the best known experiments in the history of science is the Michelson-Morley experiment, carried out for the first time in 1887 and repeated in different ways about thirty times since then, the last

of which in 2010. The objective of the original experiment was to detect the aether wind, or aether drift, caused by the motion of the Earth. Or to put it in other terms, to detect the absolute motion of the Earth through the hypothetical luminiferous aether. Basically, the apparatus used by Michelson and Morley was an interferometer that analyzed the interference of two rays of light travelling in orthogonal directions.

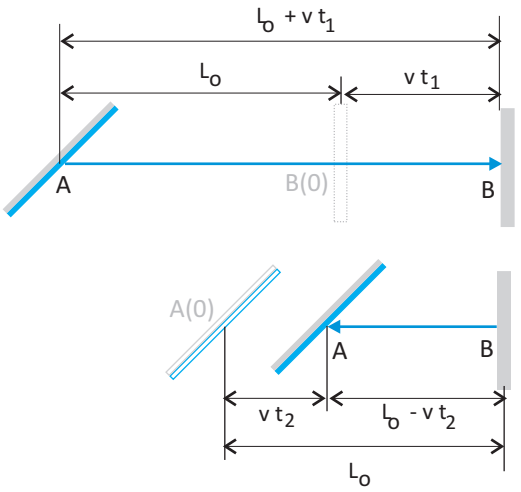

Figure 1.3: The travel of light along the horizontal arm. $B(0)$ is the position of the mirror B when light leaves the semi-silvered mirror A; $A(0)$ is the position of A when light leaves B.

13 The Earth moves around the sun at near 30 Km/s, but it also moves with the solar system around the center of our galaxy, and our galaxy moves around the center of its group of galaxies (the Local Group) and the Local Group moves with its supercluster (Local or Virgo Supercluster) and . . . We don't know exactly how the Earth moves but this will not be relevant to our discussion. So, without going into further details, let us analyze the schematic argument behind Michelson-Morley experiment. Assume one of the arms of the apparatus, whose proper length is L_o, moves in the same direction as the Earth, whose velocity is v. Assume the ray of light that moves parallel to this arm take a time t_1 to go to from A to B (Figure 1.3)

and a time of t_2 to go from B to A. We will have:

$$ct_1 = L_o + vt_1 \tag{2}$$

$$ct_2 = L_o - vt_2 \tag{3}$$

Therefore:

$$t_1 = \frac{L_o}{c - v} \tag{4}$$

$$t_2 = \frac{L_o}{c + v} \tag{5}$$

$$t_1 + t_2 = \frac{2cL_o}{c^2 - v^2} \tag{6}$$

$$= \frac{\frac{2L_o}{c}}{1 - \frac{v^2}{c^2}} \tag{7}$$

where $t_1 + t_2$ is the time light takes to complete its journey from A to B and from B to A.

14 In the arm orthogonal to the direction of v, light travels from A to E and then from E to A, being AE and EA the hypotenuses of two equal right triangles whose legs are L_o and vt_3, where t_3 is the time light takes to go from A to E as well as from E to A (Figure 1.4). The orthogonality between AE and AD and DA makes it inevitable Pythagoras classic theorem, and we will have:

$$(ct_3)^2 = L_o^2 + (vt_3)^2 \tag{8}$$

$$t_3^2(c^2 - v^2) = L_o^2 \tag{9}$$

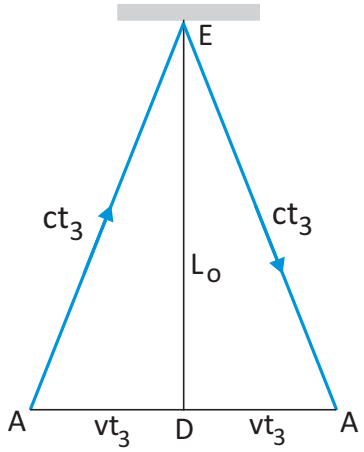

Figure 1.4: The travel of light along the vertical ARM.

$$2t_3 = \frac{2L_o}{\sqrt{c^2 - v^2}} \tag{10}$$

$$= \frac{\frac{2L_o}{c}}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{11}$$

where $2t_3$ is the time light lasts in completing its journey along this vertical arm.

15 By comparing (7) with (11) we immediately conclude that the ray moving along the horizontal arm lasts more time in completing its journey than the ray moving along the vertical one:

$$\Delta t = (t_1 + t_2) - 2t_3 \tag{12}$$

$$= \frac{\frac{2L_o}{c}}{1 - \frac{v^2}{c^2}} - \frac{\frac{2L_o}{c}}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{13}$$

$$= \frac{2L_o}{c}\left(\frac{1}{1-\frac{v^2}{c^2}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right) > 0 \qquad (14)$$

Being Δt detectable from the interferences between both orthogonal rays.

16 Although Δt is experimentally detectable it was, and continue to be, undetected in significant terms. A question, however, remains open: is that motion intrinsically undetectable or is this 'undetectability' a consequence of the way q-space is modified by the motion of the Earth? Recall the frame dragging effect. We will return to this experimental discussion in the last section of this chapter.

DO PHOTONS INHERIT RELATIVE MOTION?

17 We will now discuss the way the trajectory of a photon is observed from different inertial frames. Assuming the speed of a photon is independent of the velocity its emitting source is observed, we will come to a new relativistic conflict that seems not to have a solution on the basis of the continuum spacetime hypothesis. As we will see, that conflict reopens the question on the possibility of absolute motion, now through the fabric of a discrete space composed of minima indivisible units (sits). This possibility would also resolve the problem of the relativistic aberration of a laser beam we examined in the previous chapter.

18 Let RF_o be a lab where an emitting source S emits a photon whose vertical trajectory starts at the origin O of RF_o. (Figure 1.5). Let E be the point of the lab's ceiling where the photon impacts. We have already examined this situation (see Chapter **??**) and know the (relativistic) reason for which an observer in RF_o will observe the photon follows the vertical trajectory OE: if that were not the case a special frame would exist with respect to which he could measure the absolute velocity of RF_o.

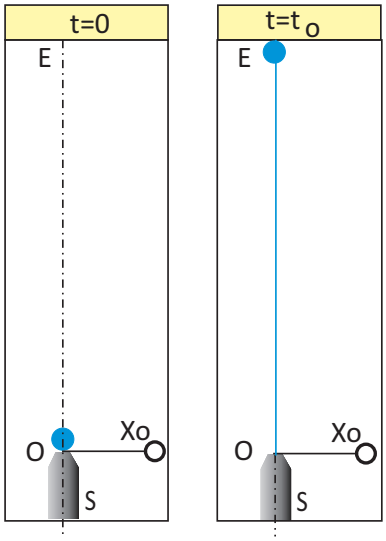

Figure 1.5: Vertical trajectory (OE) of a photon as seen from RF_o, the proper frame of its emitting source S. The photon is emitted at instant 0 (left) and reaches the endpoint E at instant t_o (right).

19 Suppose that RF_o is a spacecraft whose constant velocity relative to a certain celestial body B is intentionally changed by a short acceleration to another constant velocity. Once reached the new velocity, the observers in the craft will observe B moving with respect to them at the new velocity... although they know the reasons of the change.

20 If in these new conditions S emits a new photon in the same vertical direction as the previous one, the observers in the craft would appreciate the new photon follows the same vertical trajectory OE, as if the photon also inherits the change in relative velocity of the spacecraft with respect to B. At least in this sense, the photon behaves the same way as any material object mechanically linked to the craft.

21 Let now RF_u and RF_v be two inertial reference frames that move relative to RF_o in the same X_o direction although with different velocities u and v respectively, being v greater than u. As usual, we assume S emits the photon at instant $t = 0$ when the origins of the spacetime

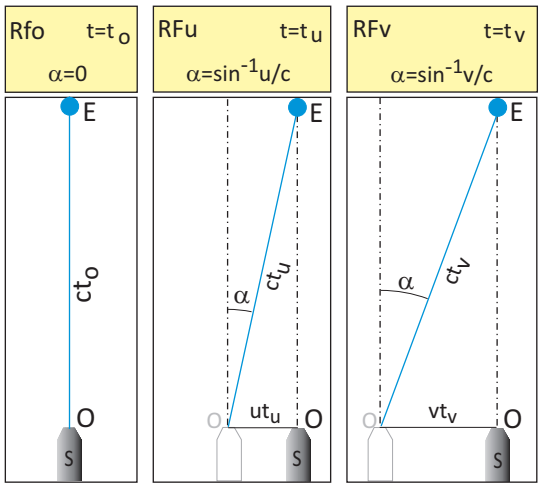

Figure 1.6: Trajectory OE followed by the photon from the perspective of RF_o, RF_u and RF_v.

diagrams of the three frames coincide. Assume it takes the photon a time t_o to traverse the vertical distance OE in RF_o while this time is t_u in RF_u and t_v in RF_v. We will have:

$$\gamma_u = \frac{1}{\sqrt{1-\frac{u^2}{c^2}}} < \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma_v \tag{15}$$

$$t_u = \gamma_u t_o < \gamma_v t_o = t_v \tag{16}$$

Therefore, the horizontal displacement of the endpoint E with respect to the initial point O in RF_u is ut_u while in RF_v that displacement is vt_v, that obviously is greater than the first one.

22 Notice that in each frame RF_o, RF_u and RF_v the photon follows a different trajectory: vertical in RF_o inclined by an angle $sin^{-1}u/c$ in RF_u, and by an angle $sin^{-1}v/c$ in RF_v. They then follow trajectories that depend upon the relative motion of its emitting source. In this sense, again, photons behave in the same way any massive body

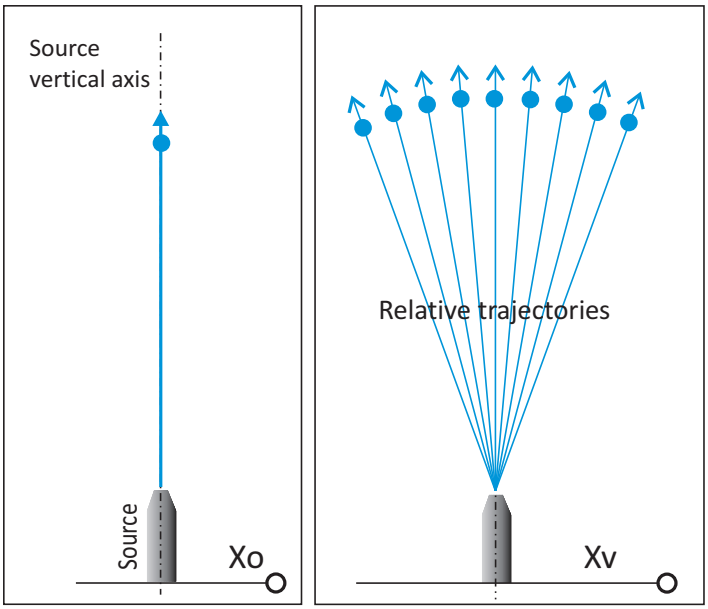

Figure 1.7: Relative trajectories of a photon emitted vertically in the proper frame of its emitting source as seen from different frames that move relative to the source in a direction perpendicular to its vertical axis (emitting direction).

mechanically linked to RF_o.

23 Only the speed of the photon (an scalar magnitude) is observed as independent of any reference frame. Its velocity (a vectorial magnitude) is not observed as independent of the velocity of the relative motion of the proper frame RF_o of its source. As seen from each frame, the photon inherits the horizontal component of its velocity from the horizontal velocity of the relative motion of RF_o (see Figure 1.8):

$$c_x = \frac{vt_v}{t_v} = v \tag{17}$$

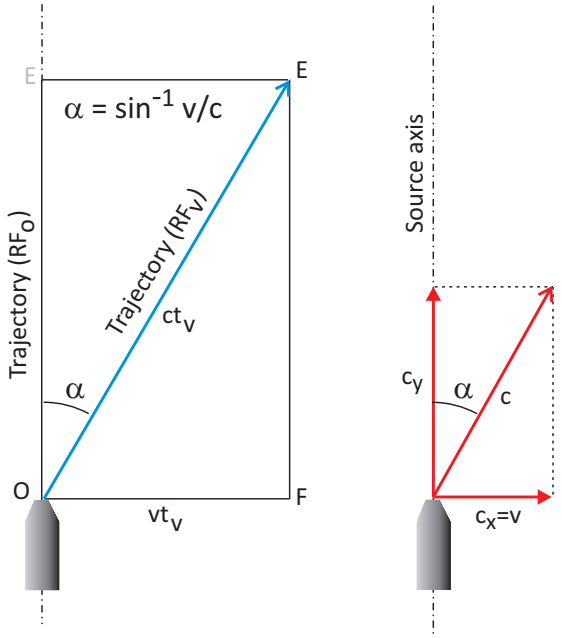

Figure 1.8: The vectorial components c_x and c_y of c from the point of view of RF_v. Note the angle α depends on the relative velocity v.

$$c_y = \frac{ct_o}{t_v} = \frac{ct_o}{\gamma t_o} = \gamma^{-1} c \tag{18}$$

And then

$$c = \sqrt{c_x^2 + c_y^2} \tag{19}$$

$$= \sqrt{v^2 + \gamma^{-2} c^2} \tag{20}$$

$$= \sqrt{v^2 + \frac{c^2 - v^2}{c^2} c^2} \tag{21}$$

$$= \sqrt{v^2 + c^2 - v^2} = c \tag{22}$$

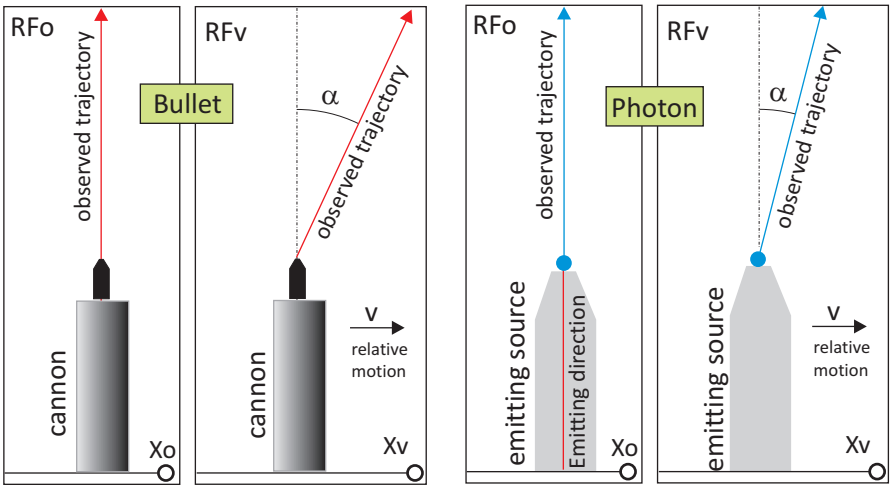

Figure 1.9: As in the case of the bullet, the only way to explain α is to assume the photon inherits the relative velocity v of its emitting source. Although there is a significant mechanical difference between the bullet and the photon: while the first is a massive object mechanically linked to the firing device, the second is not.

24 The fact that, being independent of the relative velocity of its emitting source, the velocity of a photon always inherits the horizontal component of the relative velocity of its emitting source as the horizontal component of its own velocity, seems not to be a very satisfactory conclusion.

25 On the other hand, if the trajectory of our photon were the same for all observers in R_o, RF_u, RF_v etc. would not be the photon moving through a sort of absolute medium? Perhaps the fabric of indivisible units of space (sits) of q-space?

IS THERE AN EXCLUSIVE MEDIUM FOR THE PROPAGATION OF LIGHT?

26 Aether, in its many theoretical variants, has always been present in the history of physics. One of those variants was the luminiferous aether, the medium through which light was assumed to propagate. As is well known, the special theory of relativity proved it to be unnecessary. But, as is also well known, quantum mechanics and elementary particle physics made it born again like a Phoenix from its ashes. Although now it is not the luminiferous aether, but an still unknown quantum hyperactive entity: q-space.

27 Light propagates through q-space. But not only through q-space, although with different speeds it also propagates through ordinary matter (transparent fluids and solids). Now then, ordinary matter is composed of atoms that are basically empty,[3] i.e. occupied by q-space. Though this atomic q-space is modified by the presence of the subatomic particles (and its associated fields of forces) with which light interacts, it might be reasonable to propose q-space, modified or not, as the medium through which light propagates.

28 Ordinary matter also moves through q-space, and does it freely (first law of mechanics). This means that no sort of 'wind' is to be expected from the motion of ordinary matter bodies through q-space. Superfluids, as the luminiferous aether filling up space and ordinary matter, are no longer necessary; physical space (q-space) should suffice. q-Space could be the active fabric where all physical phenomena take place.

29 If q-space is distorted in some way by the motion of massive bodies as the Earth, does this distortion in turn affect the way light propagates through the q-space surrounding a massive body? If that were the case, could it explain the impossibility to detect absolute motion through q-space by means of light-based instruments? Perhaps only experiments performed far away from all massive objects could be capable of finally determining if absolute motion is or is not detectable.

[3] 99.9999999999999% of the atomic volume is assumed to be empty

30 In the continuum model of spacetime we need an arbitrary point, or set of points, to describe motion. For this reason, in the continuum spacetime only relative motion is possible, unless we could identify in physical terms each point of the physical space, which is impossible because points are geometrical devices without physical meaning.

31 If q-space were discrete and composed of indivisible quantum units (as the sits of a CALM) each of those quantum units would have its own physical identity. In those conditions, to move through the fabric of sits would be absolute or relative motion? This question reopen the discussion on the possibility of absolute motion and its experimental detection from the new perspective of the digital paradigm.

32 That said, we must recognize we ignore all on this issue. For example:

- Could it be possible to detect a sit? To identify a sit? To measure the state of a sit?
- How fluctuates the sate of a sits?
- Are the sits adjacent to one another or there exist something else between them?
- Do the sits have definite shapes? Are they deformable?
- Does digital Pythagoras theorem hold in the fabric of sits?
- How many sits are affected by the motion of a simple photon?
- And how many and in which way by the motion of a massive body as the Earth?
- How does this altered q-space affect the propagation of light?
- Is that alteration the cause of the 'undetectability' of the absolute motion of the Earth by light-based instruments?
- etc. etc.

But if q-space is actually discrete these and many other related questions will have to be posed sooner or later.

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