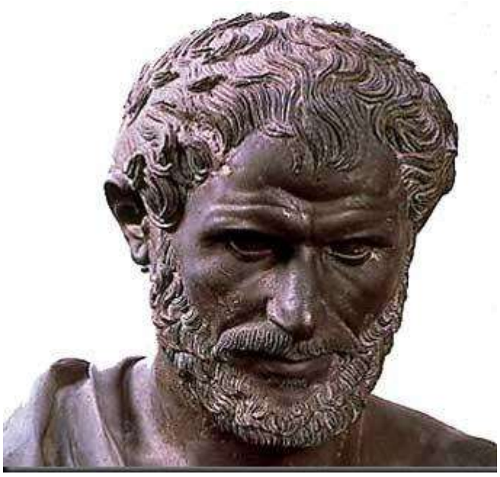
A1.0.1.- Aristotle



Aristotle is associated here with the representation of an absolute spacetime, in which each material body has a determined place and the natural laws show a tendency to occupy that place.

Every sensitive body is by its nature somewhere (Physics, Book 3, 205a: 10)

This concept allows to accommodate Aristotle's ideas about matter, which would consist of four sublunary elements (land, water, air and fire), and a supralunar element or ether, an element which is more subtle and lighter, more perfect than the other four, and above all, its natural movement is circular (dragging the stars around the Earth), unlike the natural movement of the other four, which is straight and vertical (a falling one, for land and water, and an ascendent one for the fire, which would relate to a negative weight as was later proposed by Stahl for his flogist until Lomonosov and Lavoisier discovered its absence).

After the recovery of Aristotelian philosophy, the term *ether,* just as the fifth material element recognized by Aristotle, began to be named accordingly (fifth element) which gave origin to the word *quintessence* (used in cosmology today to refer to dark energy).

On the other hand, Aristotle introduced a concept of time with a numeric character, associated with the idea of change and its measurement.

Time is the numbering of the continuous motion (Physics, Book 4, 223b: 1)

Aristotle introduced a certain notion of continuity in time to answer the paradoxes of Zeno, one of which, in the words of Aristotle, says

There is no movement, because what moves should get half of his way before reaching the end, and so on.

The answer given by Aristotle is that

... time is not composed of indivisible 'nows', no more than this or any other magnitude. (Physics, Book 9, 238b: 14)

However, the Aristotelian space lacked the property that is currently assigned to be isotropic, ie presenting the same properties in any direction: For Aristotle, it was evident that the vertical direction (up-down, where the natural movements of the four elements occur) was different in its properties from the horizontal (where any movement is not natural, but forced, ie product of displacement).

On the other hand, the dynamic concept of Aristotle made no difference between speed (or rate) and acceleration (or rate of change), and thus ensures that the most massive bodies fall faster, without considering it necessary to verify this experimentally.

The medieval scholastics refined Aristotelian the treatment of the movement through a series of assumptions, introducing the concept of speed as relationship between space and time:

"The proportion in the movements of the points is the same as the lines drawn in the same time." (7th Postulate, according to Fernandez et al., 08)

C1.2.1. Aristotle

Figura 1.2

We begin with the display of the *invisible* component of spacetime, which is the *time.* The vertical axis is used for it, representing changes due to the passage of time in two of the elements which were traditionally used for its measurement: a clock and our own planet Earth (Figure 1.2).

Both of them, despite being immobile, undergo a series of changes: the movement of the needles on the clock (indicating hours, minutes and seconds), and the rotation of the planet (which serves to define the day). We underline once again that the vertical dimension in these diagrams do not indicate any shift, but only the passage of time (in relation to the measurement of time, see Annex 1: A1.1.1).

Figura 1.3

Perpendicular to the axis of time, lies a horizontal axis (Figure 1.3) in which we represent the *space*.This space has only one dimension (as in a train track). In fact, it is known from the time of the Greeks (Euclid) that space has three dimensions. However, by this simplification we will be able to view most relativistic effects directly and without losing accuracy in the results, so you will earn much more than you lose (in relation to the spatial distance measurement, see Appendix 1: A.1.1.2).

We can now join the temporal and spatial axes in the same figure, so getting a "spacetime diagram" (Figure 1.4). It is crucial in these diagrams, to take care of what should NOT be read in them:

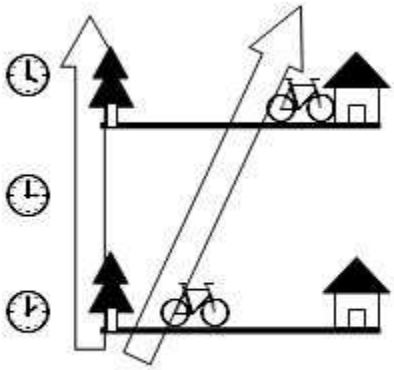


Figura 1.4

- do not look at this chart only as a functional relationship between two variables, depending on one another. The relationship between space and time, now has a geometric character and therefore, as we shall see, richer in interpretations.

- Do not observe it either as a flat chart or a road map, since we are describing a mono-dimensional reality, not a bi-dimensional one. To see this more clearly, we can think of the real world as if it were a horizontal opening that will be moving up as time passes. At all times, the reality is contained in that only one spatial dimension of the horizontal opening (in relation to the interpretation of the spacetime diagrams, see Annex 1: A1.1.0).

What you CAN observe and measure in these diagrams are certain physical quantities, as space and time (obviously) or speed (which would be indicated by the arrows in Figure 1.4). We must remember that the arrow on the left, vertical, means that there is no movement. It would be only show the passage of time (clock) without the object (tree) being in movement. And this is no more than a definition of *being at rest.*

Therefore: *Vertical Line = Rest.*

Now you can see how the tilted line indicates the displacement of an object (bicycle) as time passes. Thus, an inclined line indicates MOTION.

Even more: If the bike went faster, it would cross a larger space at the same time, so that the line would have greater inclination (it would be more "*lying*"). Thus, the slope of the line towards the horizontal gives us a measure of the speed of an object (in relation to measure of speeds, see Annex 1: A1.1.3).

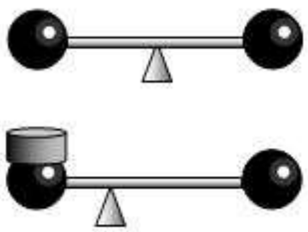


Figura 1.5

We insist that, if the line is vertical, its inclination is zero, so its speed will also be. And when v = 0, the object is at rest, it does not move vertically. To see how we can use the spacetime diagrams to measure other physical magnitudes, we will first observe Figure 1.5, which represents the law of levers in a graph.

In top, we have two equal masses joined by a wand, and the small triangle in the middle represents the balance point of the set (fulcrum). At the bottom we joined a further mass on the left, and to restore the balance we had to move the fulcrum to the left. Thus, using a spatial diagram two masses can be compared. If we take one of them as a unit, and we measure the distances of each of the masses to the fulcrum (arms), we could measure the value of the other mass directly in the figure, using the equality of the products of each mass by their respective arm (law of levers.)

In fact, Figure 1.5 does not contain spacetime diagrams but simple designs of a lever with two masses (situation in which time plays no role, and the vertical direction could represent gravitational attraction). Let's see in Figure 1.6, in a very schematic way, how we can apply this same idea in the spacetime diagrams. To do this, instead of joining the two masses by a bar, we force them to move against each other at the same speed, to collide so that they are "embedded" (inelastic collision).

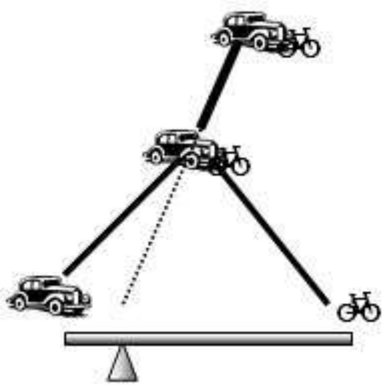


Figura 1.6

If the two masses were equal, after the collision the set will not move (remember: a vertical line in spacetime).

In Figure 1.6, the masses of the bicycle and the car are not equal, so that after the collision the car "drags" the bike to the right.

If we extend back in time the line of the set after the collision, we will have the position of the center of mass (CDM) before the collision, and we can apply, in the same way as before, the law of levers to compare one mass with the other. In the figure, it is seen that the CDM is displaced toward the car, which indicates that this mass is greater than the bike. If both masses were equal, the final set would be at rest (vertical), the CDM would be right in the middle of the figure, and that was exactly what happened in the first of the levers, which had both equal masses (in relation to the mass measurement, see Annex 1: A1.1.4).

Once we have clear how to interpret spacetime diagrams in a physical way, we proceed to establish its fundamental unit of representation: the *unit cell.*

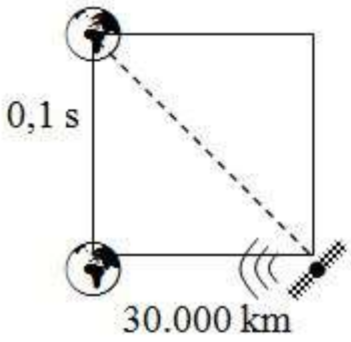


Figura 1.7

Since the Special Relativity (SR) treats the speed of light in a special way, we select units for space and time in which the speed of light (c) is the unit. Since light travels 300,000 km in a second, we can directly select these units, and we would have what we will cal the “Earth-Moon Reference System" (EM RS) (in relation to this EM RS, see Annex 1: A1.1.5). You can also select other units, as a tenth of a second for the time and the space that travels the light at this time, which is 30,000 km. In this case, we would have a cell unit suitable for the analysis of the transmission of signals from the satellites used for the GPS system *Galileo,* placed in orbits with radii of these dimensions (the satellites of the American system are somewhat lower: 20,000 km).

In Figure 1.7, we can see a square that represents the cell unit of this system. The vertical sides of the square represent 1/10s, and the horizontal sides the distance between the Earth and the *Galileo* GPS satellites. A diagonal line of dots indicates the sending of a signal, at the speed of light, from the satellite to Earth. We emphasize once again that this line does not represent a ray of light (where many photons pass over time), but that would be the line corresponding to a single photon, leaving the satellite at a certain time and reaching the GPS receiver at the Earth after 0.1 s.

We can here view one of the most important features of the spacetime diagrams:

The fact that in them the light is represented diagonally.

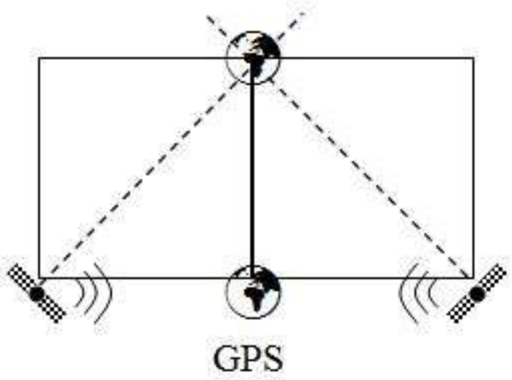


Figura 1.8

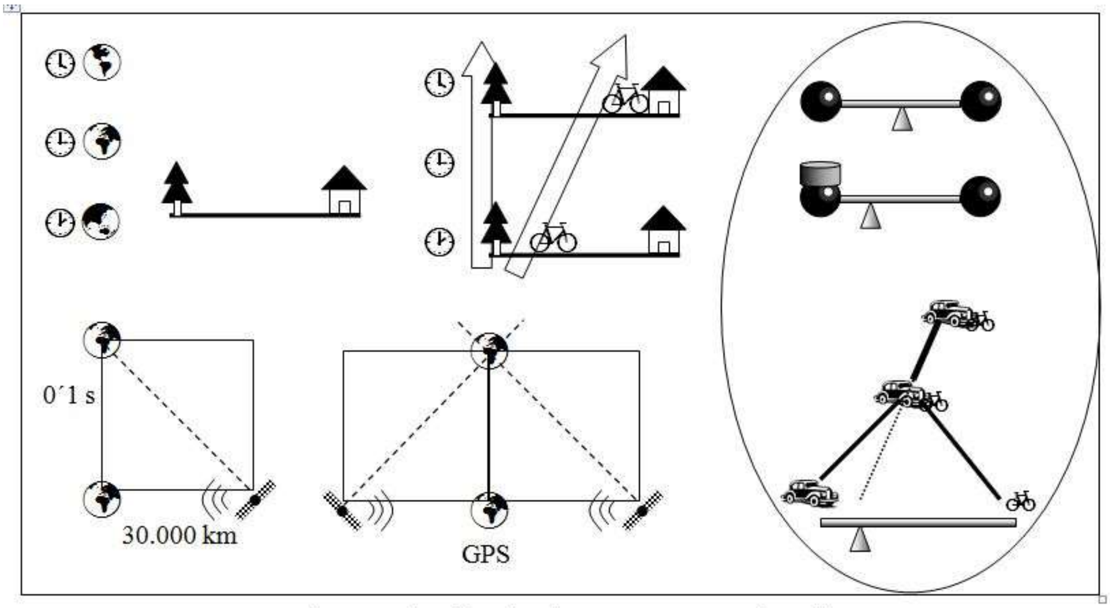
This is a *physical* property of light, its speed, while at the same time it is also a *geometric* property of figures which will be discussed below, and it will be essential to take this always into account.

Spacedtime is coated by a plethora of these unit cells, like tiles on a wall.

Taking together two of these cells, we can describe a in simplified way the operation of the GPS satellites to pinpoint locations on land accurately. Two satellites send simultaneously their signals, and the GPS device measures the difference in arrival time of each of these pulses. If there is no difference, as in Figure 1.8, it means that we are just at the midpoint between the two satellites. It the signal of one of them comes before than the other one, this would mean that we are closer to this satellite than to the other, and by the time difference the GPS can calculate how far away from the midpoint we are. In fact, given that the situation is three-dimensional, more satellites are needed to assure at all times that at least four signals from different satellites will be received. But the basic foundation is always the same: the differences in arrival time of several signals that were sent simultaneously are enabling GPS receivers to determine their position in relation to the positions of the sending satellites and, therefore, on Earth's surface, since the positions of the satellites are known with great accuracy at all times.

In connection with the figure of Aristotle and his ideas about space, time and speed, see Annex 1: A1.0.1.

In Table 1.1, we can view all the figures seen so far. We have in this way a synthetic picture for the representation of physical reality by spacetime diagrams.



Cadro 1.1: visualización do espazotempo aristotélico

At the top left of the picture we observe the representation of time, space and speed. At the bottom left you can see the unit square of spacetime, where the scales of space and time are such that the speed of light is diagonal, and we can see also how to join two of these unit squares to represent the operation of the GPS satellites.

We can observe on the right side that the patterns of levers and collisions are collected in a single "balloon" We thus emphasize the set of figures associated with the measurement of mass and the corresponding effects.

We call this set of figures with the name of *Aristotle* to underline the fact that this Greek scholar was the first to theorize about these issues, as well as the absence of relativistic concepts in them, because we are using a *motionless* spacetime framework.