Inertia and infinity in the physics of Giordano Bruno

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Abstract: *This paper remembers Giordano Bruno and his notion of an infinite inertia before Galileo's works and its implications on Modern Cosmology.*

Key words: *Giordano Bruno, history of science, infinite universe, modern cosmology*

Resumo: *O presente artigo relembra Giordano Bruno e seus estudos sobre a noção de uma inércia infinita anterior aos trabalhos de Galileo e as implicações desses estudos para a Cosmologia Moderna.*

Palavras-chave: *Giordano Bruno, história da ciência, universo infinito, cosmologia moderna.*

1 In search of an infinite inertia: Bruno, Galileo, Descartes and Newton

Giordano Bruno of Nola (il Nolano) was burnt alive by the Holy Inquisition on the 16th February 1600 in the Campo dei Fiori, Rome, after seven years in prison. Inquisitorial accusations were grounded on an alleged "conspiracy" against Catholic orthodoxy based on Aristotelian and Thomistic metaphysics. For the latter, God is first cause, immovable motor and absolute perfection. Since he conceived God as immanent in the universe and identical to it, Bruno was accused of pantheism and animism. God was considered not as the creator of the universe, but as the world itself. Further, he maintained the idea of an infinite and unlimited universe, with a great diversity of inhabited worlds. Bruno's tenets toppled the central position and the immobility of the earth, besides the exclusiveness of mankind in the Universe (BRUNO, 1995).

The sources of Bruno's ideas range from Greek atomist philosophers, Democritus, Epicurus (EPICURO, 1960), Lucretius, Heraclitus ("Did we swim or not in the same river?"; "Do we exist or not?" (BORNHEIM, 1993), Marsilio Physinus, Pico della Mirandola, Nicholas of Cusa (CUSA, 1942; KOYRÉ, 1986a,b) and the hermetic tradition widely diffused in the Renaissance.

The bases to comprehend the genesis of the "inertia" concept will be provided. In a revolutionary way, Bruno explains the system of references (geocentrism and heliocentrism) and, in a special manner, inertia in La Cena delle Ceneri. It is the start of a winding path that will lead to the notion of inertia, one of the most fundamental concepts of Physics. Below is the dialogue between the characters.

> "[Smith]: You have pleased me a lot and magnificently opened to me the hidden secrets of nature (...). You gave an answer to the argument on the winds and the clouds. You may also infer the answer to the other Aristotelian argument in the second book *On the Heavens and the World* when you said that it would be impossible for a stone to be thrown upwards and fall to the earth along the same perpendicular line. This happens because the great speed of the Earth westward would leave the stone behind. Since the movement occurs on Earth, the Earth's movement would be completely changed in verticality and obliquity: different are the movements of the ship and of things on the ship. If this were not correct, it could be concluded that when a ship sails with a certain speed, no one would take anything from one place to another in a straight line on board. It would be impossible to jump and fall on one's feet on the same place from where one jumped."
>
> "[Theophilus]: All things on Earth move with the Earth. If one throws an object from a certain place outside the Earth but in its direction, the object would lose perpendicularity due to the Earth's movement. This would apply to the ship AB that sails up a river. [See Fig. 1. Original illustration does not correspond exactly to text because of the wind.] If

> somebody throws a stone from the shore *C* in a rectilinear trajectory, the stone will miss the ship in proportion to the speed of the water current. However, if someone stands near the ship's mast, the ship may sail at full speed and the shot will never miss. Similarly, a stone or some object thrown would not fall in a straight line from point *E* on top of the mast ... as far as point *D* at the base of the mast, or on the ship's body. Thus, if a person on board a ship throws a stone in a straight line from point *D* to point *E*, the stone will return below according to the same rectilinear trajectory. This happens at whichever movement of the ship, unless she inclines" (BRUNO, 1987, p. 129-130).

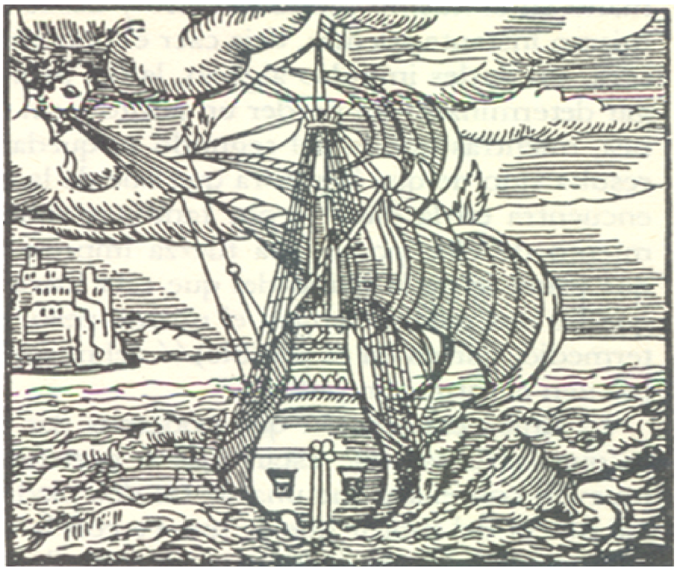

Figure 1. "Bruno's ship"

Since the Middle Ages, the "imaginary" experiment on the ship was a constant in the writings of philosophers. Reference to the gedankenexperiment may be observed in passages from the Nominalist philosophers Oresme and Buridan, even though we cannot say that Bruno knew their work.

> "A person, unaware of the ship's movement, is on board a ship sailing at great speed eastward. If that person put his hand downwards describing a straight line against the ship's mast, it would seem to him that his hand was moving exclusively along a rectilinear movement. According to this opinion, it would seem to us that an arrow rises and falls in a straight line .... This opinion may be thus argued: If a man on board that ship is going westward at less speed than the ship is sailing eastward, it would seem to him that he is nearing the west, when actually he would be moving eastward. Similarly, in the case above, all movement would seem to be as if the Earth were still. ... I will thus conclude that one

cannot show by each and every experiment that the Heavens and not the Earth moves in its daily rotation” (ORESME, 1377).

Further:

“Someone is on board a moving ship and imagines she is still. If he observes another ship which actually is still, it would seem to him that the other ship is moving (...). Thus, we also suppose that the sphere of the sun is always still and the Earth is revolving with us on it. Since we imagine that we are still, like the man in the quick-moving ship who does not perceive either his own movement or the ship's, it seems to us that the sun rises and sets, similarly to what it does when it moves and we remain still” (BURIDAN, 1988).

Copernicus also mentions the ship and compares her movement to the Earth's:

“Why do we refuse to admit that rotation is apparent in the heavens but real on earth? Actually things happen in the same manner. (...) When a ship sails in good weather, all that is outside her is seen by the sailors as moving according to the reflection of the same movement. On the other hand, they think that they are still, together with all the things beside them. The same happens with the Earth's movement, and thus it seems that the whole Universe is going around” (COPERNICUS, 1984, chap. VIII, Bk. I, p. 41).

In spite of all these references, Bruno's almost complete notion of the inertial system is much better structured that that of his predecessors. Oresme and Buridan almost arrived at Bruno's point. However, they decided in favor of the Earth's immobility. Copernicus's badly structured physics is inadequate to his new astronomy. The notion of the inertia system will come to maturity only with Galileo Galilei, whilst the notion of inertia's physical current will reach its apex with René Descartes and, at last, with the first movement axiom proposed by Sir Isaac Newton, the law of inertia or Newton's First Law.

We will quote a long passage from Galileo's *Dialogo sopra i due massimi sistemi del mondo*. In it he employs the example of the ship to build his notion of inertia. He speaks about the Earth's daily movement before he tries to form a new discourse for the principle of inertia. [Galileo's idea of inertia is wrong, since the interlocutor chooses the notion of circular inertia, as may be seen further on in the passage]. Galileo wrote:

SALVIATI: You say, then, that since when the ship stands still the rock falls to the foot of the mast, and when the ship is in motion it falls apart from there, then conversely, from the falling of the rock at the foot it is inferred that the ship stands still, and from its falling away it may be deduced that the ship is moving. And since what happens on the ship must likewise happen on the land, from the falling of the rock at the foot of the tower one necessarily infers the immobility of the terrestrial globe. Is that your argument?

SIMPLICIO: That is exactly it, briefly stated, which makes it easy to understand.

SALVIATI: Now tell me: If the stone dropped from the top of the mast when the ship was sailing rapidly fell in exactly the same place on the ship to which it fell when the ship was standing still, what use could you make of this falling with regard to determining whether the vessel stood still or moved?

SIMPLICIO: Absolutely none; just as by the beating of the pulse, for instance, you cannot know whether a person is asleep or awake; the pulse beats in the same manner in sleeping as in waking.

SALVIATI: Very good. Now, have you ever made this experiment of the ship?

SIMPLICIO: I have never made it, but I certainly believe that the authorities who adduced it had carefully observed it. Besides, the cause of the difference is so exactly known that there is no room for doubt.

SALVIATI: You yourself are sufficient evidence that those authorities may have offered it without having performed it, for you take it as certain without having done it, and commit yourself to the good faith of their dictum. Similarly it not only may be, but must be that they did the same thing too - I mean, put faith in their predecessors, right on back without ever arriving at anyone who had performed it (GALILEI, 1966, p. 144)

(...)

SALVIATI: Now tell me: Suppose you have a plane surface as smooth as a mirror and made of some hard material like steel. This is not parallel to the horizon, but somewhat inclined, and upon it you have placed a ball which is perfectly spherical and of some hard and heavy material like bronze. What do you believe this will do when released? Do you not think, as I do, that it will remain still?

SIMPLICIO: If that surface is tilted?

SALVIATI: Yes, that is what was assumed.

SIMPLICIO: I do not believe that it would stay still at all; rather, I am sure that it would spontaneously roll down.

SALVIATI: Pay careful attention to what you are saying, Simplicio, for I am certain that it would stay wherever you placed it.

SIMPLICIO: Well, Salviati, so long as you make use of assumptions this sort, I shall cease to be surprised that you deduce such false conclusions.

SALVIATI: Then you are quite sure that it would spontaneously move downward?

SIMPLICIO: What doubt is there about this?

SALVIATI: And you take this for granted not because I have taught it to you but all by yourself, by means of your own common sense.

SIMPLICIO: Oh, now I see your trick; you spoke as you did in order to get me out on a limb, as the common people say, and not because you really believed what you said.

SALVIATI: That was it. Now how long would the ball continue to roll, and how fast? Remember that I said a perfectly round ball and a highly polished surface, in order to remove all external and accidental impediments. Similarly I want you to take away any all other accidental obstacles, it there are any.

SIMPLICIO: I completely understood you, and to your question I reply that the ball would continue to move indefinitely, as far as the slope of the surface extended, and with a continually accelerated motion. For such is the nature of heavy bodies, which *vires acquirunt eundo*; and the greater the slope, the greater would be the velocity.

SALVIATI: But if one wanted the ball to move upward on this same surface, do you think it would go?

SIMPLICIO: Not spontaneously, no; but drawn or thrown forcibly, it would.

SALVIATI: And if it were thrust with some impetus impressed forcibly upon it, what would its motion be, and how great?

SIMPLICIO: The motion would constantly slow down and be retarded being contrary to nature, and would be of longer or shorter duration according to the greater or lesser impulse and the lesser or greater slope upward.

SALVIATI: Very well; up to this point you have explained to me the events of motion upon two different planes. On the downward inclined plane, the heavy moving body spontaneously descends and continually accelerates, and to keep it at rest requires the use of force. On the upward slope, force is needed to thrust it along or even to hold it still, and motion which is impressed upon it continually diminishes until it is entirely annihilated. You say also that a difference in the two instances arises from the greater or lesser upward or downward slope of the plane, so that from a greater slope downward there follows a greater speed, while on the contrary upon the upward slope a given movable body thrown with a given force moves farther according as the slope is less.

Now tell me what would happen to the same movable body placed upon a surface with no slope upward or downward.

SIMPLICIO: Here I must think a moment about my reply. There being no downward slope, there can be no natural tendency toward motion; and there being no upward slope, there can be no resistance to being moved, so there would be an indifference between the propensity and the resistance to motion. Therefore it seems to me that it ought naturally to remain stable. But I forgot; it was not so very long ago that Sagredo gave me to understand that is what would happen.

SALVIATI: I believe it would do so if one set the ball down firmly. But what would happen if it were given an impetus in any direction?

SIMPLICIO: It must follow that it would move in that direction.

SALVIATI: But with what sort of movement? One continually accelerated, as on the downward plane, or increasingly retarded as on the upward one?

SIMPLICIO: I cannot see any cause for acceleration or deceleration, there being no slope upward or downward.

SALVIATI: Exactly so. But if there is no cause for the ball's retardation, there ought to be still less for its coming to rest; so how far would you have the ball continue to move?

SIMPLICIO: As far as the extension of the surface continued without rising or falling.

SALVIATI: Then if such a space were unbounded, the motion on it would likewise be boundless? That is, perpetual?

SIMPLICIO: It seems so to me, if the movable body were of durable material.

SALVIATI: That is of course assumed, since we said that all external and accidental impediments were to be removed, and any fragility on the part of the moving body would in this case be one of the accidental impediments.

Now tell me, what do you consider to be the cause of the ball moving spontaneously on the downward inclined plane, but only by force on the one tilted upward?

SIMPLICIO: That the tendency of heavy bodies is to move toward the center of the earth, and to move upward from its circumference only with force; now the downward surface is that which gets closer to the center, while the upward one gets farther away.

SALVIATI: Then in order for a surface to be neither downward nor upward, all its parts must be equally distant from the center. Are there any such surfaces in the world?

SIMPLICIO: Plenty of them; such would be the surface of our terrestrial globe if it were smooth, and not rough and mountainous as it is. But

> there is that of the water, when it is placid and tranquil" ... (GALILEI, 1966, pp. 147-148)

Descartes answered questions about the interaction (collisions) of the bodies only by going beyond mathematical principles and further into the realm of metaphysics (UC DAVIS, 1998). He claimed that in a situation such as that just described, the total quantity of motion would be preserved, as it is throughout the universe. The principle of the conservation of the quantity of motion is derived from a property of God (who is the source of motion in the universe). God is immutable (unchanging) and so would not create a world in which the quantity of motion is mutable. This argument is obviously quite speculative and would not be considered scientific. The law of inertia (bodies conserve their current state of rest or motion insofar as they are not hindered from so doing) is also justified on the basis of God's immutability.

The principle of inertia marks an inversion of the Aristotelian explanation of motion (UC DAVIS, 1998). When a projectile loses physical contact with what moved it initially, its continued motion does not need to be explained by supposing that something else is pushing it. Rather, it is the loss of motion that requires explanation. Further, Descartes held that the motion continues in a straight line. Applied to heavenly bodies, this implies that their (roughly) circular motion is not basic, as with the Greeks, but in need of explanation. It should be noted that Descartes's principle of inertia is preserved in Newton's physical explanation of the world.

Before defining his first axiom, or the Law of Inertia, Newton, presents in the *Principia* his definitions and then the modern concept of inertia. Newton wrote:

"Definition 1: the quantity of matter is the measure of the same arising from its density and magnitude conjointly."

"Definition 2: the quantity of motion is the measure of the same arising from the velocity and the quantity of matter conjointly."

"Definition 3: the inherent force of matter is the power of resisting, by which each and every body, to the extent that it can, perseveres in its state either of resisting or of moving uniformly in a straight line." (Bellow this definition, Newton clarifies the notion of 'inherent force', explaining: "Whence the inherent force can also be called by the extremely significant name, 'force of inertia'. A body exercises this force only in the alteration of its status by another force being impressed upon it, and this exercise falls under the diverse considerations of resistance an impetus ... Common opinion attributes resistance to things at rest and impetus to things in motion, but motion and rest, as they are commonly conceived, are distinguished from each other only with respect (to each other), nor are those things really at rest which are commonly seen as if at rest.")

"LAW 1: That every body continues in its state of resisting or of moving uniformly in a straight line, except insofar as it is driven by impressed forces to alter its state.

Projectiles continue in their motions except insofar as they are slowed by the resistance of the air, and insofar as they are driven downward by the force of gravity. A top, whose parts, by cohering, perpetually draw themselves back from rectilinear motions, does not stop rotating, except insofar as it is slowed by the air. And the greater bodies of the planets and comets preserve their motions, both progressive and circular, carried out in spaces of less resistance, for a longer time." (NEWTON, 1960)

Figure 2 shows Galileo's and Newton's ideas in their demonstration of what happens when a ball falls from an inclined plane. Independent of its inclination, it will always seek the top of the immediately ascending plane. In a plane without any inclination ($\theta = 0$), the ball (free from all impediments and accidents) will slide *ad infinitum* (by inertia) with the same speed with which it began its descendent plane. At present the following equations are sufficient to show the above:

$$v = a \cdot t$$
$$v = g \cdot \sin\theta \cdot t$$
$$t = \frac{v}{g \cdot \sin\theta}$$

Therefore, when the angle is equivalent to zero ($\theta \to 0$), time will be infinite, $t \to \infty$.

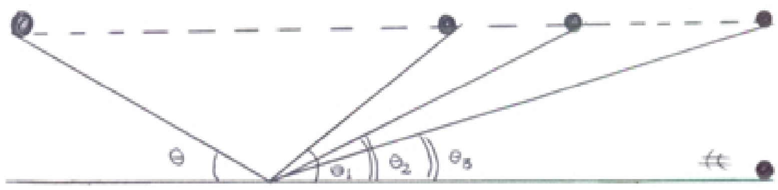

Figure 2 - Inclined planes and the inertia

2 The acentric labyrinth and the philosophical barrenness of modern cosmology

The following section borrows the title of R. G. Mendoza's book *The Acentric Labyrinth: Giordano Bruno's Prelude to Contemporary Cosmology*, published in 1995 (MENDOZA, 1995). The book is based on the parallel between Bruno's ideas and the model of an inflationary Universe, known as the Big Bang. I refute categorically such parallelism (remembering the brunian conception of infinity linked with the physical notion of inertia). The Big Bang universe is the negation of infinity. It is the heir of logic positivism thought to have been overcome many years ago (DANHONI NEVES, 1999, p. 149-201) and boils down to an impoverishment of philosophy, science, especially, metaphysics.

Insisting on the impoverishment of metaphysics, I would like to analyze once more the "horizon" theme of modern cosmology. To describe the extreme uniformity of Cosmic Background Radiation (CBR: radiation identified as "the remains of a great explosion that gave rise to the Universe"), the inflationary model tries to solve what is commonly known as the horizon question. A summary is given below.

Let's consider a gas enclosed in a box. If energy is added to one side of the box, there is a rise in temperature. A certain period of time is necessary so that gas particles transmit information on increase of energy moving around at an average great speed. Finite time passes before these collisions take the information on the increased energy through the box. Now, let's imagine that the box will expand more quickly than the particles it contains. Only a tiny region of the box will find the added energy and this section will have a different temperature than the rest of the box. The quickest information is that communicated by the speed of light. In the extreme primordial universe the regions expanded so quickly that they became quickly and greatly separated. At a given time, light may travel as far as a certain maximum distance, called horizon distance. After one second, light should have traveled a second of time for a *horizon distance* of 300,000 km. The regions of the Universe were separated almost one hundred times this distance. How could these regions have developed at the same temperature when there was not any communication between them? (ZELIK, 1993).

The model of the inflationary Universe solves the horizon problem through inflation. The Universe evolves from a smaller region (by 10^{50} or more) than that of standard Big Bang. Before the start of the *inflation era* the Universe was much smaller that its horizon distance. The whole Universe has the same temperature. Therefore, inflation makes things bigger and preserves a uniform temperature. Actually, in the past as in the present, CBR is extremely uniform.

The theories of elementary particles known as GUT (Grand Unified Theory) and SUSY (Super Symmetries) are necessary for the construction of this model. The former (actually there are numberless theories under this title, aiming at the physical unification of all gravitational, electromagnetic and nuclear forces. It was Einstein's dream) needs a fall of symmetry during the transition of the Universe at a critical temperature of approximately 10^{27} degrees. Modern physics is based on the principles of conservation. One of the most important is the principle of barionic conservation (protons and neutrons), in which the number of barions minus the number of antibarions is left unchanged (the problem of a small excess of matter over antimatter is important since it gives equilibrium to the cosmos in its galaxies). However, GUT requires a symmetry break: for instance, the proton should fall to an estimated average life of 10^{31} years. (At present, such estimates are 10^{33} years: after an experiment to detect the fall, after the explosion of a supernova, nothing was found!)

Guth and Steinhardt (1984) emphasize that "from the historical point of view, probably the most revolutionary idea is that all matter and energy in the observable universe may have emerged from almost nothing". Such a statement could end with the phrase "Believe it or not!"

Another factor that ought to be insisted on concerning such strange theories as GUT and SUSY (strange names, too!) is that modern and more potent particle accelerators approximately reach 10^3 Gev, whilst verifiable levels of energy for the above theories range between 10^{15} and 10^{17}. It will be correct to say that these theories will never be verified in laboratories or even in catastrophic astrophysical events (supernovas). When Gamow (DANHONI NEVES, 1999) stated his first ideas on an expanding universe, he employed known physical laws (for a period of about

200 seconds). At present, a universe of approximately 10^{-45} seconds has been produced! In these circumstances Reeves says: "Up to now nobody has established a coherent theory that simultaneously embodies Einstein's general theory of relativity and quantum mechanics. We do not even know whether such a theory is possible. To hide its ignorance, astrophysics states that at 10^{-43} seconds the Universe was born. (REEVES, 1986, p. 241).

Going back to the singularity question (zero point of the Big Bang theory), which is ultimately the aim of modern cosmology and elementary particles physics, dominated by the strange and exotic theory of a universe created from a dimensionless point, with infinite temperature, pressure and density, Marmet's question is worth recording: "The Big Bang model deals with a primordial atom containing the concentrated mass of the Universe in a next to zero volume. The primordial atom represents the most extreme example of a black hole that may be imagined. Since it is known that nothing may be emitted from black holes, how could the primordial atom expand itself?" (MARMET, 1991).

Marmet's question expresses the surprise of a cosmology that struggles with a minimum but with a finite maximum, floundering in a positivist model of science. The horizon problem of modern cosmology takes us to Bruno's vision of the Vesuvius from Mount Cicala, near his dear Nola during his childhood. Modern cosmologists and physicists mix up the "volcano" with the end of the world (the limit of an inflated universe), building realities where illusions of knowledge abound and no philosophy is encountered. They blur the infinite comprehension of the Universe that lies further and further, beyond the horizon.

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