Abstract
The trial and condemnation of Giordano Bruno was mainly based on arguments of philosophical and theological nature, and therefore different from Galilei's. Such elements contribute to unfairly devalue the scientific contribution of Bruno and do not properly account in particular for his contribution to physics. This paper discusses the contribution of Bruno to the principle of relativity. According to common knowledge, the special principle of relativity was first enunciated in 1632 by Galileo Galilei in his *Dialogue concerning the two chief world systems*), using the metaphor today known as “Galileo's ship”: in a boat moving at constant speed, the mechanical phenomena can be described by the same laws holding on Earth. We shall show that the same metaphor and some of the examples in Galilei’s book were already contained in the dialogue *La cena de le Ceneri* (The Ash Wednesday Supper) published by Giordano Bruno in 1584. In fact, Giordano Bruno largely anticipated the arguments of Galilei on the relativity principle. It is likely that Galilei was aware of Bruno’s work, and it is possible that the young Galilei discussed with Bruno, since they both stayed in Venezia for long periods in 1592.

Keywords: Giordano Bruno, principle of relativity, Galileo Galilei, Heliocentric system.
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1 Introduction

The principle of relativity states that it is impossible to determine whether a system is at rest or moving at constant speed by experiments internal to the system, i.e., there is no internal observation by which one can distinguish a system moving uniformly from one at rest. This principle played a key role in the defence of the heliocentric system, as it made the movement of the Earth compatible with everyday experience.

According to common knowledge, the principle of relativity was first enunciated by Galileo Galilei (1564 – 1642) in 1632 in his *Dialogue concerning the two chief world systems* [1], using the metaphor known as “Galileo’s ship”: in a boat moving at constant speed, the mechanical phenomena can be described by the same laws holding on Earth.

Many historical aspects of the birth of the relativity principle have received little or scattered attention. In this short note, we put together some elements showing that Giordano Bruno largely anticipated [2] the arguments of Galilei on the relativity principle. In addition, we briefly discuss the silence of Galilei on Bruno and the relation between the lives and careers of the two scientists.

2 Galilei and the principle of relativity

The *Dialogue concerning the two chief world systems* is the source usually quoted for the enunciation of the principle of relativity by Galilei. However, its publication in 1632 was certainly not a surprise,
as Galilei had expressed his views much before, in particular when lecturing at the University of Padova from 1592 to 1610. Some aspects of the evolution of Galilei’s ideas, from the Trattato della sfera (1592) [3] in which the Earth is still placed at the centre of the Universe, towards the Dialogo, passing through his heliocentric correspondence with Kepler from 1597 onwards [4], are examined for example in [5, 6].

In February 1616, the Roman Inquisition condemned the Copernican theory as being “foolish and absurd in philosophy”. The month before, the inquisitor Monsignor Francesco Ingoli addressed Galilei with the essay Disputation concerning the location and rest of Earth against the system of Copernicus [7]. The letter listed both scientific and theological arguments against Copernicanism. Galilei replied only in 1624. In his lengthy reply, he introduced an early version of “Galileo’s ship” metaphor, and discussed the experiment of dropping a stone from the top of the mast. Both arguments, as we shall see, had been previously raised by Bruno, and will be later used again by Galilei, although with small differences, in the Dialogo.

In the Dialogo sopra i due massimi sistemi del mondo, Galilei discusses the arguments then current against the idea that the Earth moves. The book is a fictional dialogue between three characters. Two of these, Salviati and Sagredo, refer to real figures disappeared since a few years at the publication of the book. The first plays the role of the defender of the Copernican theory, putting forward Galilei’s point of view; the second, a Venetian aristocrat, educated and liberal, willing to accept new ideas, acts as a moderator placed between Salviati and the third character, a certain Simplicio, fierce supporter of Aristotle. The name of the latter (reminiscent of “simple-minded” in Italian) is in itself a clear indication of the Galilean dialectics, designed to destroy the opponents. Simplicio, despite being one of the most famous commentators of Aristotle, manifests himself with an embarrassing simplicity of spirit. Galilei uses Salviati and Simplicio as spokespersons of the two clashing chief world systems; Sagredo represents the discreet reader, the steward of science, the one to whom the book is addressed: he intervenes in the discussions asking for clarifications, contributing conversational topics, acting like a science enthusiast.

In the second day, Galilei’s dialogue considered Ingoli’s arguments against the idea that the Earth moves. One of these is that if the Earth were spinning on its axis, then we would all be moving eastward at hundreds of miles per hour, so a ball dropped down from a tower would land west of the tower that would have in the meantime moved a certain distance eastwards. Similarly, the argument went, a cannonball shot eastwards would fall closer to the cannon compared to a ball shot westwards, since the cannon moving East would partly catch up with the ball.

To counter such arguments Galilei proposes through the words of Salviati a gedankenexperiment: examine the laws of mechanics in a ship moving at a constant speed. Salviati claims that there is no internal observation which allows to distinguish between a system smoothly moving and one at rest. So two systems moving without acceleration are equivalent, and non-accelerated motion is relative:

“Salviati – Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction. When you have observed all these things carefully (though doubtless when the ship is standing still everything must happen in this way), have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still. In jumping, you will pass on the floor the same spaces as before, nor will you make larger jumps toward the stern than toward the prow even though the ship is moving quite rapidly, despite the fact that during the time that you are in the air the floor under you will be going in a direction opposite to your jump. In throwing something to your companion, you will need no more force to get it to him whether he is in the direction of the bow or the stern, with yourself situated opposite. The droplets will fall as before into the vessel beneath without dropping toward the stern, although while the drops
are in the air the ship runs many spans. The fish in their water will swim toward the front of their bowl with no more effort than toward the back, and will go with equal ease to bait placed anywhere around the edges of the bowl. Finally the butterflies and flies will continue their flights indifferently toward every side, nor will it ever happen that they are concentrated toward the stern, as if tired out from keeping up with the course of the ship, from which they will have been separated during long intervals by keeping themselves in the air. And if smoke is made by burning some incense, it will be seen going up in the form of a little cloud, remaining still and moving no more toward one side than the other. The cause of all these correspondences of effects is the fact that the ship’s motion is common to all the things contained in it, and to the air also. That is why I said you should be below decks; for if this took place above in the open air, which would not follow the course of the ship, more or less noticeable differences would be seen in some of the effects noted."

Note that Galilei does not state that the Earth is moving, but that the motion of the Earth and the motion of the Sun cannot be distinguished (hence the name of relativity):

“There is one motion which is most general and supreme over all, and it is that by which the Sun, Moon, and all other planets and fixed stars – in a word, the whole universe, the Earth alone excepted – appear to be moved as a unit from East to West in the space of twenty-four hours. This, in so far as first appearances are concerned, may just as logically belong to the Earth alone as to the rest of the Universe, since the same appearances would prevail as much in the one situation as in the other.”

3 Giordano Bruno and the principle of relativity

In April 1583, nine years before the then 28-years old Galilei was called to the University of Padova, Bruno went to England and lectured in Oxford, unsuccessfully looking for a teaching position there. Still, the English period was a fruitful one. During that time Bruno completed and published some of his most important works, the six “Italian Dialogues”, including the cosmological work La cena de le Ceneri (The Ash Wednesday Supper, 1584) [2].

This book consists of five dialogues between Theophilus, a disciple that exposes the theories of Bruno; Smitho, a character probably real but difficult to identify, possibly an English friend of Bruno (perhaps John Smith or the poet William Smith) – the Englishmen has simple arguments, but he has good common sense and is free of prejudice; Prudencio, a pedantic character, and Frulla, also a fictional character who, as the name in Italian suggests, embodies a comic figure, provocative and somewhat tedious with the proposition of stupid arguments.

In the third dialogue, the four mostly comment discussions heard at a supper attended by Theophilus in which Bruno – called in the text “il Nolano” (the Nolan), because he was born in Nola near Naples – was arguing in particular with Dr. Torquato and Dr. Nundinio, representing the Oxonian faculty. Bruno starts by discussing the argument related to the air, winds and the movement of clouds. He largely uses the fact that the air is dragged by the Earth:

“Theophilus – [...] If the Earth were carried in the direction called East, it would be necessary that the clouds in the air should always appear moving toward west, because of the extremely rapid and fast motion of that globe, which in the span of twenty-four hours must complete such a great revolution. To that the Nolan replied that this air through which the clouds and winds move are parts of the Earth, because he wants (as the proposition demands) to mean under the name of Earth the whole machinery and the entire animated part, which consists of dissimilar parts; so that the rivers, the rocks, the seas, the whole vaporous and turbulent air, which is enclosed within the highest mountains, should belong to the Earth as its members, just as the air does in the lungs and in other cavities of animals by which they breathe, widen their arteries, and other similar effects necessary for life are performed. The clouds, too, move through happenings in the body of the Earth and are based in its bowels as are the waters. [...] Perhaps this is what Plato meant when he said that we inhabit the concavities and obscure parts of the Earth, and that we have the same relation with respect to animals that live above the Earth, as do in respect to us the fish that live in thicker humidity. This means that in a way the vaporous air is water, and that the pure air which contains the happier animals is above
the Earth, where, just as this Amphitrit
\[\text{[ocean]}\] is water for us, this air of ours is water for them. This is how one may respond to the argument referred to by Nundinio; just as the sea is not on the surface, but in the bowels of the Earth, and just as the liver, this source of fluids, is within us, that turbulent air is not outside, but is as if it were in the lungs of animals."

The Dialogue than moves to discussing the argument of projectiles. He starts by explaining the Aristotelian objection of the stone sent upwards:

"Smitho – You have satisfied me most sufficiently, and you have excellently opened many secrets of nature which lay hidden under that key. Thus, you have replied to the argument taken from winds and clouds; there remains yet the reply to the other argument which Aristotle submitted in the second book of On the Heavens\(^2\) where he states that it would be impossible that a stone thrown high up could come down along the same perpendicular straight line, but that it would be necessary that the exceedingly fast motion of the Earth should leave it far behind toward the West. Therefore, given this projection back onto the Earth, it is necessary that with its motion there should come a change in all relations of straightness and obliquity; just as there is a difference between the motion of the ship and the motion of those things that are on the ship which if not true it would follow that when the ship moves across the sea one could never draw something along a straight line from one of its corners to the other, and that it would not be possible for one to make a jump and return with his feet to the point from where he took off."

Bruno then gives, in Theophilus’s speech, the following reply (referring to Figure 1 in the text):

"Theophilus – With the Earth move [...] all things that are on the Earth. If, therefore, from a point outside the Earth something were thrown upon the Earth, it would lose, because of the latter’s motion, its straightness as would be seen on the ship AB moving along a river, if someone on point C of the riverbank were to throw a stone along a straight line, and would see the stone miss its target by the amount of the velocity of the ship’s motion. But if someone were placed high on the mast of that ship, move as it may however fast, he would not miss his target at all, so that the stone or some other heavy thing thrown downward would not come along a straight line from the point E which is

\(^1\)Amphitrite was in Greek mythology the wife of Poseidon and, therefore, the goddess of sea.
\(^2\)See \[8\], Section 296b.
at the top of the mast, or cage, to the point D which is at the bottom of the mast, or at some point in the bowels and body of the ship. Thus, if from the point D to the point E someone who is inside the ship would throw a stone straight up, it would return to the bottom along the same line however far the ship moved, provided it was not subject to any pitch and roll.”

He then continues with the statement that the movement of the ship is irrelevant for the events occurring within the ship and explains the reasons for that:

“[…] If there are two, of which one is inside the ship that moves and the other outside it, of which both one and the other have their hands at the same point of the air, and if at the same place and time one and the other let a stone fall without giving it any push, the stone of the former would, without a moment’s loss and without deviating from its path, go to the prefixed place, and that of the second would find itself carried backward. This is due to nothing else except to the fact that the stone which leaves the hand of the one supported by the ship, and consequently moves with its motion, has such an impressed virtue [impetus], which is not had by the other who is outside the ship, because the stones have the same gravity, the same intervening air, if they depart (if this is possible) from the same point, and arc given the same thrust.

From that difference we cannot draw any other explanation except that the things which are affixed to the ship, and belong to it in some such way, move with it: and the stone carries with itself the virtue [impetus] of the mover which moves with the ship. The other does not have the said participation. From this it can evidently be seen that the ability to go straight comes not from the point of motion where one starts, nor from the point where one ends, nor from the medium through which one moves, but from the efficiency of the originally impressed virtue [impetus], on which depends the whole difference. And it seems to me that enough consideration was given to the propositions of Nundinio.”

The experiments carried out in a ship are thus not influenced by its movement because all the bodies in the ship take part in that movement, regardless of whether they are in contact with the ship or not. This is due to the “virtue” they have, which remains during the motion, after the carrier abandons them. Bruno thus clearly expresses the concept of inertia, using the word “virtù”, in Italian meaning “quality”, which is carried by the bodies moving with the ship – and with the Earth.

4 Discussion

We have seen that Bruno in La cena de le Ceneri anticipates to a great extent the arguments of Galilei on the principle of relativity. In fact, his explanation does contain all the fundamental elements of the principle. The idea that the only movement observable by the subject is the one in which he does not take part, together with the notion of the composition of movements, alien to Aristotelian mechanics, was present before in the works of Nicole de Oresme (1325 – 1382) and similar arguments were used by Copernicus (1473 – 1543). The main missing ingredient was the idea of inertia, which explains the fact that projectiles move along with Earth. What is new in Bruno, and what brings him almost exactly to where Galilei stood, is thus a clear concept on inertia.

The arguments and metaphors used in discussions concerning the world systems were common to different authors. They were largely derived from Aristotle, Ptolemy and their commentators, often used without referencing and sometimes attributed to the wrong source. For example, Aristotle in his On the heavens uses as experimental argument the one of the object sent upwards. Oresme, in his comment to this work, used a modified version of this experiment in which an arrow is sent upwards in a ship – probably introduced by an earlier commentator. Nevertheless, the description by Galilei of exactly the same ship experiment that Bruno used in the Cena makes it very likely that Galilei knew this work. The use of the dialogue form with a similar choice of characters can also be seen as a possible sign of the influence of Bruno in Galilei.

On the other hand, Galilei never mentioned Bruno, and in particular there is no reference to him in Galilei’s large corpus of letters. Some authors have commented on Galilei’s silence about Bruno putting forward reasons of prudence. As pointed out in this can hardly explain the absence of any mention also in his personal correspondence. Furthermore, although Galilei himself
never mentions the name of Bruno in his personal notes and letters, several of his correspondents do mention the Nolan. Martin Hasdale, in a letter to Galilei from 1610, tells him that Kepler expressed his admiration for Galilei, although he regretted his failure to mention in his works Copernicus, Giordano Bruno and several Germans who had anticipated such discoveries – in particular Kepler himself[3]. “This morning I had the opportunity to make friends with Kepler [...] I asked what he likes about that book of yourself and he replied that since many years he exchanges letters with you, and that he is really convinced that he does not know anybody better than you in this profession. [...] As for this book, he says that you really showed the divinity of your genius; but he was somehow uneasy, not only for the German nation, but also for your own, since you did not mention those authors who introduced the subject and gave you the opportunity to investigate what you found now, naming among these Giordano Bruno among the Italians, and Copernicus, and himself.”

We can thus say that Galileo Galilei was probably aware of the work by Giordano Bruno on the Copernican system. When Galilei arrived in Padova, in 1592, it is also possible that the two scientists met: Bruno was guest of the noble Giovanni Mocenigo in Venezia, and Galilei was living between Padova and Venezia. In 1591, Bruno had unsuccessfully applied for the chair of Mathematics that was assigned to Galilei one year later. Although a confirmation that such a meeting occurred might be difficult to find, it remains hard to believe, given the motivations and characters of the two men and the circumstances of their lives during those years, as well as the size of the literate and scientific community in those days, that they failed to discuss on the arguments concerning the defense of the Copernican system.

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References

[1] Galileo Galilei, “Dialogo sopra i due massimi sistemi del mondo”, Firenze 1632; translation is taken from Stillman Drake, University of California Press, 1953.
[2] Giordano Bruno, “La cena de le Ceneri”, London 1584; translation is taken from Stanley L. Jaki, The Hague/Paris: Mouton, 1975.
[3] Galileo Galilei, “Trattato della sfera”, Roma 1656 (apparently written in Padova in 1606).
[4] Galileo Galilei, Carteggio, Edizione Nazionale delle opere di Galileo Galilei, voll. 10-18.
[5] Roberto de Andrade Martins, “Galileo e o princípio da relatividade”, Cadernos de História e Filosofia da Ciência (9):69-86, 1986.
[6] E. Giannetto, “Da Bruno ad Einstein”, Nuova Civilità delle Macchine 24 n.3 (2006), pp. 107-137.
[7] Monsignor Francesco Ingoli, “De situ et quiete terrae contra Copernici systema disputatio” (Disputation concerning the location and rest of Earth against the system of Copernicus), Roma 1616; translated in [http://arxiv.org/abs/1211.4244](http://arxiv.org/abs/1211.4244)
[8] Aristoteles, “Peri ouranou” On the heavens, ca. 350 BC.
[9] Nicole de Oresme, “Le livre du Ciel et du Monde”, Paris 1377 (manuscript).
[10] Nicolaus Copernicus, “De revolutionibus orbium celestium”, Nuremberg 1543.
[11] Maurice Clavelin, “La philosophie naturelle de Galilée”, Colin, Paris 1968.

[3]Letter from M. Hasdale to G. Galilei [3].