Newton and Leibniz on Non-substantival Space

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ABSTRACT. The aim of this paper is to analyze Leibniz and Newton's conception of space, and to point out where their agreements and disagreements lie with respect to its mode of existence. I shall offer a definite characterization of Leibniz and Newton's conceptions of space. I will show that, according to their own concepts of substance, both Newtonian and Leibnizian spaces are not substantival. The reason of that consists in the fact that space is not capable of action. Moreover, there is a sense in which space is relational, because their parts are individuated only by means of their mutual relations.

Keywords: Spacetime philosophy, Leibniz, Newton, substance.

1. Introducción

In many recent philosophical discussions about the nature of space, the question of whether space is a substance or not appears again and again. Newton and Leibniz are often credited with putting forward the modern form of the debate and for defending opposite views about this issue.[1] It is clear that Newton and Leibniz disagree in their conception of space and time. However, it is not easy to say precisely in what respects they disagree. To the best of my knowledge, nobody was able to identify of what exactly the disagreement consists. Very frequently, it is argued that they endorse a substantival and a relational conception of space and time, respectively. This does not help very much, unless we define clearly both doctrines in general. I do not intend to address this topic here. Nonetheless, I shall offer a definite characterization of Leibniz and Newton's conceptions of space and time. I will show that, according to their own concepts of substance, both Newtonian and Leibnizian spaces are not substantival. Moreover, there is a sense in which both are also relational, in that their parts are individuated only by means of their mutual relations.

The aim of this paper is to analyze Leibniz and Newton's conception of space, and to point out where their agreements and disagreements lie with respect to its mode of existence. I do not intend to offer here a complete account of both conceptions of space. That would be the subject matter of a book-length essay. The fundamental question I would like to address is whether space is substantival or not. This has been the subject of extensive debate in present day philosophy of space and time, and, to a large extent, it is yet unsettled. Space is said to be substantival if it is a substance.

[1] See, among many others, Sklar (1976), Earman (1986) and (1989), Maudlin (1993), and Hoefer (1996). Huggett (1999) is a good reading of historical sources.

Needless to say, the answer to this question depends on the particular concept of substance one holds. In the first two sections, I shall show that both Newton and Leibniz think that space is not a substance, according to their own ideas of substance. The reason is the same for both, and consists in the fact that space is not capable of action. We find here a surprising similarity between them, which has gone unnoticed until now. In the next section, I shall argue that they agree on all topological and metrical properties of space, because they simply assume that the structure of physical space is Euclidean. In the final section, I shall state what I think is the fundamental disagreement between Newton's and Leibniz's metaphysics of space and time.

2. Newton's absolute space is not a substance

Newton's characterization of space in his famous *Scholium* to the VIII Definition of the *Principia* might lead us to think that he conceives of space as a substantival being, although he never says that explicitly.[2] However, his unfinished work *De gravitatione* - whose date is unknown, although it was surely written before the *Principia*- leaves no doubts about the falsehood of that idea. Newton there affirms that space or extension (he uses both terms as synonymous) "has its own mode of existence, which fits neither substances nor accidents." (*De gravitatione* 99; hereafter abbreviated as *Dg.*). Our task here is to show why, according to Newton, space is not a substance and which is its proper mode of existence.

Newton begins his discussion of the nature of space by saying that: "Perhaps it is strongly expected that I should define extension as substance, accident or nothing at all." (*Dg.* 99). Then, he proceeds to reject each one of these traditional categories, because he believes that space does not fall into any of them. For our purposes, it is useful to reverse the order of his arguments and to start with the category of nothingness.

At first sight, it might seem strange to think that space is nothing at all. Nevertheless, the identification of void or empty space with non-being was one of the main theses in the early Greek Atomism. It originated in Democritus (DK 67 A6, A7, A8; 68 A 37-38, A44-45), and it passed to Epicurus, Lucretius and the whole atomist tradition. Very probably, Newton was well acquainted with this idea, given the revival of classical atomism in the 17th century. Newton's plausible sources are Lucretius, Gassendi and Charleton, although it is doubtful that he would have been able to read them extensively before the redaction of *De Gravitatione*. In any event, I think we have to read this argument as directed against the atomist identification of space with non-being. Newton gives us two arguments. First: "No idea of nothing is given […] but all we have an extremely clear idea of extension, abstracting affections and properties of a body so that there remains only the uniform and unlimited extension of space in length, breadth and depth". (*Dg.* 99-100). Accordingly, we are able to form by abstraction a clear idea of empty space as different from mere nothingness. Second: "nothing

[2] Many philosophers of space and time refer to Newton's space indistinctly as absolute space or substantival space (for example, Norton 1992, p. 227). John Earman points out that substance is one sense of absoluteness, among many others (Earman 1989, p. 11).

has no properties […], but the idea of space is associated with many of its properties" (*Dg.* 99-100). The possession of such properties not only implies that space is something, but also shows us what it is. Newton proceeds then to enumerate several properties of space that he probably considers as essential properties. Space is continuous or infinitely divisible, infinite, motionless, eternal, immutable, and uniform, among other things[3]. The simple fact that space has these properties is enough to prove that it is a determinate being.

The following argument is directed against the idea that space is an accident of another substantial being. Newton's concept of accident is not made explicit in the text, but clearly he assumes that an accident is something that is not able to exist by itself without a subject in which it inheres. Consequently, we cannot conceive of an accident, such as a color, as existing without another subject, a colored body. Following a well-established metaphysical tradition, Newton accepts that the impossibility of thinking the separate existence of something is a sufficient criterion to recognize that the entity in question is not a substance. According to Newton, we can conceive of space as a being that exists by itself:

> Moreover, since we can clearly conceive extension existing without any subject, as when are imagined spaces outside the world or places empty of body, and we believe <extension> to exist wherever we imagine there are no bodies, and we cannot believe that it would perish with the body if God should annihilate that body, it follows that <extension> does not exist in the mode of an accident inherent in some subject. (*Dg.* 99).

The independence of space with respect to bodies is essential to understanding the Newtonian concept of space, but this fact does not imply that space is a substance. Newton is just trying to prove that space is not an accident, or a relational property, inherent in bodies. He also assumes that space is not an accident of another kind of entity, for instance, a non-corporeal being such as God. We shall return to this point later.

In *De gravitatione* Newton offers us two very different arguments in order to prove that space is not a substance. The first says that: "<extension> Is not a substance […], because it is not absolute in itself, but it is as it were an emanent effect of God, or a disposition of all being" (*Dg.* 99). This theological argument is not of our main concern here, in order to compare Newton and Leibniz's conceptions of space. But it deserves some comments. The concept of emanation is an essential part of the Neoplatonic metaphysics, and Newton probably borrowed it from the Cambridge Neoplatonists, in particular from the works of H. More.[4] As conceived by Newton, emanation is different from creation. He clearly asserts that space is eternal and uncreated (*Dg.* 111), but matter and bodies were created by God "in an empty space out of nothing" (*Dg.* 109). However, space is in some sense ontologically dependent upon God, but unlike creatures. The use of the word "effect" suggests that there is a kind of

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[3] We cannot analyze these properties here. For a detailed commentary see M. F. Biarnais commentary on Newton *De la gravitation,* pp. 111-128.

[4] The degree to which More influenced Newton has been the object of discussion between scholars. See Koyré (1958), Westfall (1980) and Hall (1992).

causal dependence of space from God. In any case, emanation is a very special kind of causation because it is a necessary production that is simultaneous with its cause.[5]

The outcome of the argument is that space is not a substance because it somehow depends on God to exist. But this is also true of every creature, including physical bodies and human souls. Therefore, in an absolute sense there is no substance apart from God. In that case, the discussion about the substantival character of space is pointless. It is not in this absolute sense of substance that space may or may not be a substance. The non-univocal nature of the word "substance" was commonplace in Scholastic thought. Aquinas, for example, adopted the view according to which we call God and the creatures substances only by analogy (ST I, q 4, a 3; I q 13, a 1-6). Descartes clarified further this point saying that when we speak of substances among the created things we are referring to those things which do not need another created thing to exist (*Princ. phil.* I, 51-52). In general, substance is that which does not depend on other things that depend on God. It is this relative sense of substance that is relevant for the problem of substantival space.

Newton's second argument concludes that space is not a substance in the same sense in which bodies or human souls are said to be substances. For our purposes, this is the most important argument. The text runs as follows:

> …on the other hand <extension is not a substance> because it is not the subject of the proper affections that denote substance, namely actions, such as thoughts in the mind and motion in body. For although philosophers do not define substance as an entity that can act upon things, yet all tacitly understand this of substances, as it is evident from the fact that they would readily allow extension to be a substance if only it were capable of being moved and of sharing in the actions of body. And on the contrary they would hardly allow that body is a substance if it could not be moved nor excite in the mind sensation or perception in any way. (Dg. 99).

Newton argues that space is not a substance because it is not capable of action. The argument assumes as a premise that every substance is capable of action. Newton is not very explicit about his concept of substance. He invokes the agreement between the philosophers on this point, but such agreement is not easily found. We cannot identify the referred philosophers with certainty, but at least we know that Descartes is one of them. In fact, *De gravitatione* begins with a criticism of Descartes' conception of space in Part II of *Principia philosophiae*. In Part I § 51 of this work, Descartes states his famous definition of substance as "a thing that exists so that it needs no other thing in order to exist". It is true, at least according to Descartes, that the concept of action is not a part of the definition of substance. On the other hand, it is not clear whether, according to Newton, capability of action is a necessary or a sufficient condition of substance, or both. His argument only demands a necessary condition: if something is not capable of action, then, it is not a substance. However, his example suggests he thinks the converse of this statement also holds, and capability of action is at the same time a sufficient condition of substance. So, it seems that Newton takes here substance and capability of action as equivalent concepts, anticipating the Leibnizian

[5] This point has been debated by Mc Guire (1990) and Carriero (1990). In my view, the difficulties of Newton's concept of emanation arise from the obscurity of the Neoplatonic concept itself.

characteristic definition of substance as a being capable of action. The concept of action is conceived here in a broad sense that includes passion, that is, the power of producing a change in other entities and of being affected by them. For instance, a body is capable of action because it can move other bodies and is capable of being moved by them.

The key question is why space is not capable of action. In this respect Newton is something hermetic and says only that: "space is eternal in duration and immutable in nature, and this because is the emanent effect of an eternal and immutable being." (*Dg.* 104). We can make sense of Newton's words if we assume that created entities do not share divine attributes, but emanations or uncreated things share at least some of God's properties, such as immutability. If space is actually immutable, it cannot produce any change in other entities, nor is it able to be changed in any way. Immutability implies, then, incapacity of exerting any action or passion. Inertial motion shows that space lacks the power of changing the state of motion of bodies. A body at rest or in uniform motion remains unchanged unless a force acts upon it. This means, in Newton's words, that "space does not have force of any kind which might impede or assist or in any way change the motion of bodies." (*Dg.* 104). As a consequence, a body cannot be affected in any way by its mere position in space, nor can it affect the space itself occupies or traverses. There is no possible interaction between space and bodies or other kinds of substances. We shall see later where the physical reasons for the immutability of space lie.

Newton has, thus far, proven, granting his arguments are sound, that space is neither a substance nor an accident. This negative conclusion is not original. The idea that space does not fit in the Aristotelian categories was advocated by many philosophers, both Scholastics and non-Scholastics, during the 16th century. We can find a clear expression of it in the opusculum *De spacio physico*, published in 1587 by Francesco Patrizi as part of a larger work, *Pancosmia*. There he says that: "categories serve well for worldly things; space is not among worldly things, it is other than the world. It is the accident of no worldly thing, whether body or not, whether substance or accident, it is prior to them all […]. Hence it must be treated in a different way from the categories."[6] Very similar expressions are found in G. Bruno's *De immenso e innumerabilis* (1591) and, in the context of a different argument, in Pedro de Fonseca's commentary of Aristotle's *Metaphysics* (probably published in 1589-90).[7] Moreover, Bruno also affirms that space lacks causal powers saying that: "space is neither active nor passive […] and receives neither forms nor qualities" (*De immenso*, 232). We can easily recognize in these quotations some of Newton's characteristic positions of *De gravitatione*.

It is not likely that Newton was familiar with these works when he wrote *De gravitatione*. Nevertheless, just a few years before this work was likely written, P. Gassendi, making explicit references to Patrizi, affirmed in his *Syntagma philosophicum* (1658) that: "space and time must be considered real things, or actual entities, for although they

[6] *De spacio physico*, pp. 240-241 of the Brickman translation.

[7] See Grant (1981), pp. 186 and ff.; 205 and ff. All references to Fonseca's work come from Grant.

are not the same sort of things as substance and accident are commonly considered, they still actually exist and do not depend upon the mind like a chimera."[8] Gassendi's ideas were divulged in English by Walter Charleton in his *Physiologia Epicuro-Gassendo-Charltoniana* (1654), where he states that: "<in vacuum> there doth intercede something incorporeal, such as we understand by spatium, intercapedo, distantia, intervallum, dimensio, which is neither substance nor accident."[9] We cannot be sure that Newton read Charleton's book, but it does seem likely.[10]

For Newton Space is something real, in spite of not being a substance. He adds, "<it> is something more than an accident, and approaches more to the nature of substance." (*Dg.* 99). We have seen that space differs from substances in the fact that it is not capable of action. Then, in what respect is it like substances? Newton has a clear answer to this question: space is similar to substances because "we can conceive of space existing without any subject when we think of a vacuum." (*Dg.* 111). Space is a thing capable of separate and autonomous existence, and it does not need another created thing in order to exist. Space fits Descartes' definition of substance. But it is clear, from the arguments stated above, that Newton does not endorse that conception of substance. To be capable of existing without another subject is not for him a sufficient condition of being substance. Nevertheless, it is a necessary condition of substance. We have already seen that Newton accepts that accidents are not substances precisely for the reason that they do not fulfill this condition.

There is no doubt that Newton considers that space, unlike accidents, is able to exist independent of any other thing, apart from God. In particular, the existence of space does not depend on the existence of bodies that are located in it. According to Newton, there is no conceptual impossibility in thinking that space is absolutely devoid of matter. We can perfectly conceive of the idea of a global vacuum, that is, an empty universe. Newton expresses this idea saying that: "Although if space is empty of body, nevertheless it is not empty of itself; and something is there, because spaces are there, although nothing more than that." (*Dg.* 104). Many years later, Samuel Clarke –probably on behalf of Newton himself- will put this thesis in a simpler form: "Space is not bounded by bodies, but exists equally within or without bodies" (C 4, 8).

The conception of space as existing by itself is coherent with Newton's theological ideas about creation. If God created the world in a preexistent space, that space had to be a global vacuum before creation. Given that we can conceive of space as existing by itself, Newton concludes that "something of substantial reality corresponds <to it>." (*Dg.* 111). We are now able to understand in which respect space approaches to the nature of substance. A real substance is not only capable of action, but also has independent existence from other substances. Bodies (and souls) satisfy both conditions. Accidents satisfy none of them. Space (and time) satisfies the latter condition,

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[8] *Syntagma*, pp. 384-385 of the Brush translation.

[9] Quoted by Hall (1992), p. 262.

[10] Westfall (1980) maintains that Newton had read Charleton's work and probably Gassendi's (p. 89), and he points out that Gassendi's influence on Newton is evident throughout *De gravitatione*.

but not the former, and for that reason is not a true substance. Nonetheless, space is not an accident either, because it is able to exist by itself. Only in this respect is space similar to substances. The ontological character of space is, in the end, an intermediate state between substance and accident. This is a *status* for which traditional metaphysics, inherited from Scholastic thought, has no definite ontological category.

None of these ideas was entirely new or original when Newton wrote *De gravitatione*. The mental experiment that consists of asking whether space is able to subsist when the universe is destroyed comes from late Scholastics. We can find it in the works of Buridan, Oresme, Albert of Saxony, and many others.[11] The annihilation of the world was regarded as possible, but, of course, it could only be caused by God's infinite power. T. Bradwardine was one of the first to give an affirmative answer to the question, saying that "void can exist without body, but in no manner can it exist without God."[12] F. Patrizi was much more explicit concerning the possibility of a global vacuum and stated that "if the world should be completely destroyed and become nothing […], the space in which the world is now contained as locus, will remain entirely empty."[13] Finally, P. Gassendi drew from this argument the conclusion that space and time are independent of bodies in the sense that they are able to exist without them: "…place and time do not depend upon bodies and are not corporeal accidents […]. If there were no bodies, there would still remain both an unchanging place and an evolving time."[14] Doubtless, as these quotations show us, we have to regard Newton's philosophy of space as the outcome of a long tradition that considered space as a real thing, capable of existing by itself, but at the same time, lacking all the essential properties of a real substance.

3. Leibniz and non-substantival space

It is a well-established fact that, according to Leibniz, space is not a substance.[15] He repeats time and again this thesis in many essays and letters. In his correspondence with Clarke, he says he has "many demonstrations, to confute the fancy of those who take space to be a substance, or at least an absolute being." (L 3, §5). However, he elaborates only one main argument, or family of arguments, based upon the principles

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[11] See Grant (1981), Chapter 3, especially pp. 42 and ff., for detailed references; and Grant (1974) for the translation of relevant texts.

[12] Bradwardine, *De causa Dei*, p. 179 (translated in Grant 1974, 557).

[13] Patrizi, *De spatio physico*, Brinkman's translation, p. 240. Moreover, Patrizi clearly affirms that if substance is conceived of as something that exists or subsists *per se*, space is a substance: "it is very clear that space is above all a substance, but not the 'substance' of the category. For it is not an individual substance, because it is not composed of matter and form. Neither is it a genus, for it is predicated neither of species nor of individual things. It is a different sort of substance outside the table of categories." (*ibid.* p. 241). Space is neither a primary substance, an individual, nor a secondary substance, a species or a genus. These are the two senses of 'substance' in Aristotle's *Categories* (*Categ.* 5, 2a 13-19).

[14] Gassendi, *Syntagma philosophicum*, p.182, Brush's translation, p. 384.

[15] I consider here only the final stage of Leibniz's conception of space and time (after 1690, approximately). With respect to the evolution of his thoughts about this subject see Hartz and Cover (1988).

of sufficient reason and identity of indiscernibles. We do not need to analyze those arguments here, because they have received extensive comments both by historians of philosophy and space-time philosophers. Moreover, such arguments do not provide a useful way to compare Newton and Leibniz's conceptions of space. As we have seen above, the Newtonian argument in *De gravitatione* rests on his concept of substance, but Leibniz' letters to Clarke offer other kind of arguments, which are completely independent of any particular conception of substance.

In any event, it is possible to find in Leibniz another argument against the substantival character of space. It is an argument explicitly based on his conception of substance, and proceeds along lines very similar to those of the Newtonian argument. Leibniz' version of the argument can be stated as follows: Something is a substance if and only if, it is capable of action; space is not capable of action: therefore, space is not a substance. The reasoning is identical to Newton's argument, except for a small variation in the first premise. But this is rather a rational reconstruction. Nowhere in the Leibnizian works can we find such a clean expression of the argument. Nevertheless, some texts are sufficiently explicit. In a passage of his *Nouveaux essays*, in which the concept of place is discussed, Leibniz says that "it makes place involve something over and above what we attribute to space, to which we deprive of any agency. Thus viewed, space is no more substance than time is." (NE, II, XIII, 17). Again, in a letter to De Volder, in which the principles of atomism are rejected, Leibniz writes: "thus, I have concluded that neither atoms are given, nor space is a substance, nor prime matter, which in itself is separated from any activity, must be counted between substances." (To De Volder, 7-6-1701, GP II, 225). In both passages Leibniz contends that space is not a substance because it lacks capability of action. He states explicitly the conclusion and the second premise of our reconstructed argument. However the first premise remains implicit. Very probably, he did not state it because he considered it to be obviously true.

The equivalence between the concepts of substance and capability of action is one of the main metaphysical insights of the Leibnizian philosophy. He claims not only that all substance is capable of action, but also that everything that is able to act is a substance. Some of his mature essays are almost entirely devoted to establishing this thesis.[16] And in his last works, he defines substance simply as "a being capable of action" (GP VI 598). According to this definition, capability of action is a necessary and sufficient condition to being a substance. But Leibniz goes further and affirms that this capability is actualized in every moment, so that every substance is always in activity. The very existence of a substance consists in its activity, and any interruption of its action would imply the destruction of the substance itself. Leibniz is very clear and explicit about the reciprocal implication between substance and actual activity. He says, for instance, that "not only every thing which acts is a single substance; but also every single substance does act without interruption, not excepting body itself, in

[16] Among others, *De ipsa natura*, (GP IV, 504-516); and *Specimen dynamicum*, (GM VI, 235-254) In Cassini (1995) I have given more references and a more complete discussion of this point.

which there never is absolute rest (GP IV, 509); and also that "every substance acts, and every agent is called substance. Moreover, it can be shown from internal metaphysical principles that what does not act, it does not exist, for, the power to act without a prime act is nothing at all" (GP VII, 326).

Some remarks on Leibniz's concept of action are in order here. Newton thinks that a body exerts an action when it changes the state of motion of another body. We can conceive of this idea of action in general as a causal relation between substances (or events, conceived of as changes of properties inherent in substances). Obviously, Leibniz is not able to endorse that causal conception of action. For him, bodies are not true substances, but only well founded phenomena and causal relations are not real, but merely ideal, like every relation between phenomena. At the level of real substances, there are no causal relations at all. Simple substances or monads are not susceptible of entering in causal interactions. For that reason, action (and passion) cannot be a change produced by one substance in the state of another substance. Action is, therefore, an internal change that spontaneously occurs to each individual substance. And, given that the only change that monads are able to undergo is a continuous flow of perceptions, the activity of every substance is nothing more than a relentless change in its representations. For Leibniz, this is the proper concept of action, as he expresses it, for example, in the *Nouveaux essays*:

> I have already said that, in a metaphysically rigorous sense, taking action for what happens spontaneously to the substance and arising out of its own depths, everything that is properly a substance only acts, for, everything comes to it from itself (apart from God), and it is not possible that a created substance has an influence upon any other. (NE II, XXI, 72; GP V, 195).

It is evident now, that Leibniz concludes that space is not a substance because he assumes that every substance is a being in activity, and thinks that space lacks any capability of action. There is complete agreement between Newton and Leibniz on this point. However, their respective concepts of action are quite different. The common general feature of both conceptions is the idea that action and passion imply a change in the state or properties of an individual substance. For Newton, space is not a substance because it is not able to causally affect other things, nor is it able to be affected by them. For Leibniz, space is not a substance because it is not able to have perceptions or representations, and *a fortiori*, it is not able to change spontaneously from one perception to another. Newton thinks that space is causally inert, and Leibniz, in turn, thinks that it lacks vital force. In any event, space is not able to undergo changes in its properties. At the bottom of this agreement about the non-substantial character of space lies, as we shall see below, the common assumption according to which space in immutable.

Is there any sense in which space approaches to the nature of substance according to Leibniz? The answer is negative. In the first place, Leibniz's concept of substance does not include the notion of being in itself or independent existence. Since his earlier writings, Leibniz criticized the Cartesian conception of substance as something that needs no other thing to exist. In a critical comment of Spinoza's *Ethica*, written in 1678, Leibniz claims that to say that substance is which is in itself is obscure, because

it is not clear what does "to be in itself" means (GP I, 139). Later, in his critical thoughts about Descartes' *Principia philosophiae*, of 1692, he argues that created substances not only need other substances to exist, but they also need their own accidents. Ultimately, substance and accident depend upon each other, and for that reason independent existence is not a proper criterion to discriminate between them (GP VI, 364). Finally, in a late dialogue between Philarete and Ariste (probably 1710-11), Leibniz rejects the Cartesian definition of substance saying that we can find things that exist in themselves, are independent of other things, yet they are not substances, such as life, force, and antitipy. (GP VI, 58). This last argument, if sound, proves at most that independent existence is not a sufficient condition of substance. However, if substance does depend on its accidents to exist, as the former argument contends, then, independence is not a necessary condition of substance either.

In any event, it is clear that Leibniz does not allow the independent existence of space (or time), and therefore, space cannot approach to the nature of substance in the Newtonian sense. According to Leibniz, space and time are nothing more than a kind of order between physical phenomena. His characterization of space as order is repeated many times with almost the same words: "For space is nothing but the order of existence of things possible at the same time, while time is the order of existence of things possible successively" (to De Volder, 6-30-1704, GP II, 269. Similar expressions appear, among other places, in GP III, 612; GP IV, 568; and GM VII, 17). As a consequence of this conception, space and time are not able to subsist with independence of matter. On this respect, Leibniz says that "extension is nothing but an abstraction and demands something which is extended. It needs a subject; it is something relative to this subject, like duration" (GP VI, 584). The subjects on which space and time depend are material bodies and physical events of such bodies. Consequently, a global vacuum is for Leibniz something impossible, that is, in a universe completely devoid of matter, there can be neither space nor time. In his fifth letter to Clarke, Leibniz draws this conclusion and puts it as follows: "I do not say that matter and space are the same thing. I only say there is no space where there is no matter and that space in itself is not an absolute reality" (L5, §62, GP VII, 406). It follows that, contrary to Newton's belief, space and time are not eternal and do not preexist the creation of bodies, souls, or any other creature. Leibniz is absolutely clear on this point: "If there were no creatures, there would be neither time nor place, and consequently no actual space" (L5, § 106, GP VII, 415).

Leibniz does not admit the existence of vacuum in general, either local or global. However, whereas a local vacuum is logically possible, although does not exist in fact, a global vacuum is for him a sort of conceptual impossibility. A local vacuum can be conceived of as a possible location of bodies, but only in relation to some occupied places, that is, other bodies. Leibniz express this idea as a contrast between the possible and the actual: "In fact, time and place are only kinds of orders; and an empty place within one of these orders (called vacuum in the case of space) if it occurred, would indicate the mere possibility of the missing with respect to the actual" (NE II, IV, 5; GP V, 115). On the other hand, to suppose the possible existence of a global

vacuum, that is, an empty universe, is the same as to admitting that space is a self-subsisting entity, a substance in the Cartesian sense. Leibniz relates the concepts of vacuum and substance in the following way: "I still believe that there is no vacuum and even that there is no substance which can be called space, i.e., that there is no subject having only the attribute of extension" (GP VI, 585). Given that the existence of space depends upon the existence of extended bodies, a global vacuum is not logically possible because it contradicts the very concept of space.

4. Common assumptions about the geometrical structure of space

In spite of their different conceptions about the ontological status of space, Newton and Leibniz agree on all geometrical properties they attribute to space and time. The language of present geometry was not available for them, and for that reason their terminology is sometimes confusing from our perspective. I shall review the main properties of space following the expressions they employ to describe them. Then, I will analyze their descriptions by means of the language of modern geometry.

First of all, we have already seen that Newton and Leibniz agree on conceiving space and time as immutable entities, unable to undergo changes in their properties. That is the reason why they lack all capability of action, both in the Newtonian and the Leibnizian sense.

Newton offers in *De gravitatione* a more or less systematic list of the properties he attributes to space (*Dg.* 110-105; 111).[17] For my present purposes, only four properties are relevant: continuity, infinity, immutability and uniformity. I will quote Newton's statement of each property without discussing his arguments. While Newton does not use the word "continuity", this is the property of space he refers to when he says that:

> … spaces are everywhere contiguous to spaces, and extension is everywhere placed next to extension, and so there are everywhere common boundaries to contiguous parts; that is, there are everywhere surfaces limiting solids on this side and that; and everywhere lines in which parts of the surfaces touch each other; and everywhere points in which the continuous parts of lines are joined together. (*Dg.* 100).

Infinity of space is clearly stated as: "Space extends infinitely in all directions. For we cannot imagine any limit anywhere without at the same time understand that it is given space beyond it" (*Dg.* 101). Here space is conceived of as having no limits, and consequently as being infinite. In turn, S. Clarke, in his correspondence with Leibniz, relates the infinity of space to its indivisibility: "Infinite space is Intensity […] Infinite space is one, absolutely and essentially indivisible" (C3 §3; GP VII, 368). Indivisibility of space is also present in *De gravitatione* (100), but in a very different way.

We have seen above that, according to Newton, "space is eternal in duration and immutable in nature" (*Dg.* 104). This same idea appears, in slightly different language, appears in the *Principia* as a description of absolute space: "absolute space, in its own nature, without relation to anything external, remains always similar and immovable." (Scholium to Definition VII). In this famous passage, immutability of space is related

[17] For a detailed comment on each property see M.F. Biarnais edition of *De gravitatione*.

to its immovability, a property that Newton also considers in *De gravitatione* (103). In the same vein, Clarke affirms that "Space is immense, and immutable and eternal; and also is duration." (C4 § 10; GP VII, 383). In all these passages, the eternity of space seems to derive from the fact that it is immutable, and consequently, not able of be generated or destroyed by things other than God.

Newton summarizes the properties of space and time in the following list: "extension is eternal, infinite, uncreated, uniform throughout, not in the least mobile, nor capable of inducing motion in bodies or change of thought in the mind" (*Dg.* 111). So far, we have encountered all of them, except uniformity. Newton does not define or explain this concept in *De gravitatione*, but it is widely discussed in the Leibniz-Clarke correspondence. Clarke puts it as: "space is uniform or alike and one part does not differ from another" (C3 §5: GP VII, 369); or in this equivalent way: "all places being originally alike" (C4 §18; GP VII, 385). The general idea of uniformity is that a determinate region of space does not differ from any other region with respect to its geometrical properties. This concept is explained in greater detail in Leibniz's letters to Clarke, so I will postpone its analysis for later discussion.

Nowhere does Leibniz offer a systematic enumeration, not to mention an analysis, of the properties of space and time. Nonetheless, we can find in different parts of his works a statement concerning the four properties we have found in Newton' essay. In a long passage of his *Metaphysical foundations of mathematics*, Leibniz asserts the infinity and continuity of space and time:

> Time can be continued to infinity. For since a whole of time is similar to a part, it will be related to another whole of time as its part is to it. Thus it must be understood as capable of being continued into another greater time. Similarly, solid space or amplitude can also be continued to infinity, since any of its parts can be taken as similar to the whole. In that way a plane and a straight line can also be continued to infinity. In the same manner is showed that space, as well as a straight line and time, or, in general, any continuum can be subdivided to infinity. (GM VII, 22).

Leibniz does not think, like Newton, that space is eternal. Given that space is not able to exist apart form material objects, the creation of matter also implies the creation of space. And the same holds for time. God's creation of the universe is not, as Newton believed, the creation of things in a preexistent space and time. Consequently, time necessarily has a beginning and cannot be infinite with respect to the past (L 5 §57-60). Space, time, bodies, and the rest of the universe have the same beginning in the instant of creation.

Leibniz remarks time and again that space is uniform, meaning that one part of space is absolutely indiscernible of any other part. The reason for the indiscernibility is that, considered in themselves, all parts of space are identical. One point is exactly like any other point, and one region is like any other region.[18] We are able to distinguish one place from another by means of the things that are located in each one of them, but taken in themselves, all parts of space are identical. The same holds for the parts of time. A few quotations suffice to settle this point:

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[18] Of course, Leibniz's metaphysics does not permit such identity, and that is the reason why Leibniz denies reality to space.

> Space is something absolutely uniform, and, without the things placed in it, one point of space does not absolutely differ in any respect whatsoever from another point of space. (L3 §5: GP VII, 364).
>
> The parts of time and place taken in themselves are ideal things, and therefore they perfectly resemble one another like two abstract units. (L5 §27; GP VII, 395).

The agreement between Leibniz and Newton on the properties of space is not coincidental. On the contrary, it rests upon the common assumption that the geometrical structure of physical space is Euclidean. Of course, they had no other available option in their epoch. At the risk of being anachronistic, it is useful to shift to the language of modern geometry in order to clarify this point. Leibniz and Newton think of physical space as a model of the Euclidean geometry and of physical time as a model of an Euclidean straight line. Consequently, they agree about all topological and metrical properties of space and time. Needless to say, they lacked this mathematical distinction. Moreover, they did not have a complete knowledge of all geometrical properties of space, which belong to each category.

With respect to topological properties, the tridimensionality of space is taken for granted and neither Newton nor Leibniz made it explicit. Two topological properties are expressly stated: space is continuous and unbounded, both for Newton and Leibniz. The metrical property of infinity (in the sense of having an infinite volume) is not distinguished from the topological property of unboundness. The argument given by Newton (*Dg.* 101), according to which space is infinite because it has no limits or is unbounded, rests on this mistake.[19] In general, unboundness does not imply infinity, so that the argument is not valid without restrictions. It holds for Euclidean space, which is both infinite and unbounded, but not, for instance, for Spherical space (S^3), that is finite, but unbounded.

With respect to metrical properties, Newton and Leibniz agree on the uniformity of space. This is not a definite geometrical property from the point of view of modern geometry. Nevertheless, their characterization of uniformity shows that the properties of space they are referring to are homogeneity and isotropy. The idea, as they put it, that every part of space is alike any other part is a rough approximation at these concepts. Homogeneity and isotropy are metrical properties, which, as we should expect, are essential to Euclidean space.[20]

A long-standing traditional conception of time is summarized in Newton's dictum according to which "time is a simple and uniform continuum, like a straight line" (NE II, XIV, 16). This analogy carries with it the implication that time has all the topologi-

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[19] This argument does not come from Newton, but it has a long history in Greek thought, for example, in the atomistic tradition.

[20] Homogeneity and isotropy of space can be characterized in terms of groups of transformations as follows: i) a space is homogeneous if it is symmetric under a translation of any distance in any direction; and ii) a space is isotropous if it is symmetric under a rotation of any angle centered on any point. Translations and rotations are the transformations that form a group of symmetry called precisely Euclidean groups. Of course, there also exist many Non-Euclidean spaces that are homogenous and isotropous.

cal and metrical properties of an Euclidean straight line. Actually it is more than an analogy. It is assumed that real physical time is a model of an Euclidean straight line and, therefore, all the properties of the line are true of physical space. Newton implicitly agrees with Leibniz on this point. Nonetheless, as we have seen before, time is not eternal for Leibniz, at least in the direction of the past, because it was created. In this respect it differs from a straight line, which is infinite in all directions.

5. Reality versus ideality of non-substantival space

We can recapitulate our conclusions saying that Newton and Leibniz share two fundamental assumptions about the nature of space: first, with respect to its geometrical structure, they agree that space is Euclidean and, consequently, they agree about all its topological and metrical properties; and second, with respect to its ontological status, they believe that space is not a substance because it is not capable of action, and it does not have this capability because it is immutable.

Where do they disagree? Their disagreement lies in metaphysical and theological subjects. First, Newton and Leibniz conceive the relation between God and space in different ways. For Newton, space is eternal and uncreated, and God's creation of things happened in a preexistent space. For Leibniz, space is created and not eternal, and God's creation of the world was also the creation of space and time.

As we have seen above, a major metaphysical disagreement concerns the independent existence of space with respect to material things. Newton affirms and Leibniz denies that space subsists where there are no bodies at all, that is, in a globally empty universe. Actually, this explains their theological disagreement about the relation between God and space. Leibniz clearly grasped this point: "I objected that space, taken for something real and absolute without bodies, would be a thing eternal, impassible, and independent upon God." (L5, §36, GP VII, 398). Leibniz's idea of God does not allow entities able to exist apart from God. However, this is certainly not the case, given that space is neither a substance nor an entity with its own mode of existence. Leibniz does not identify matter with space or extension, but he considers them to be inseparable; where there is matter there is also space, and vice versa, where there is space there is also matter. The same interrelation holds for time and motion or change in general. So, Leibniz contends:

> I do not say that matter and space are the same thing. I only say there is no space where there is no matter and that space itself is not an absolute reality. Space and matter differ as time and motion. However these things, though different, are inseparable. (L5 §62; GP VII, 406).

Matter is a necessary and sufficient condition for the existence of space. It is not temporally prior to it, but, in a certain sense, it is ontologically prior. On the contrary, space, being the order of material things, which exist simultaneously, depends on bodies and cannot exist without them. Of course, given that there are many different bodies or material things, it is not possible to conceive of the existence of those bodies without an order between them. And once order relations are established, space is also

given.[21] We can say that, to the extent that space depends on matter to exist, it is not absolute, but a relative entity, its existence being derivative of matter. Extension or space is not a subject in itself, but it is relative to something extended. We can abstract extension from extended bodies, and conceive of the idea of extension in itself, but this idea does not correspond to any real entity. In this respect, Leibniz plainly says that "extension is nothing but an abstraction and demands something which is extended. It needs a subject, it is something relative to this subject, like duration." (GP VI, 584).

This ontological dependence of space upon matter shows that creation cannot occur in some place of space or in some moment of time, because this would assume that space and time are preexistent entities. But, as they are not, Leibniz is able to solve the problem in an elegant way:

> Thus it appears how we are to understand that God created things at what time he pleased, for this depends upon the things which he resolved to create. But things being once resolved upon, together with their relations, there remains no longer any choice about the time and the place, which of themselves have nothing in them real, nothing that can distinguish them, nothing that is at all discernible. (L5 §57, GP VII, 405).

As this last quotations shows, the deepest ontological disagreement between Newton and Leibniz is about the reality of space, and not about its substantival character. In one word, Newton conceives of space as a real thing, whereas Leibniz claims that space is not real at all, but a mere ideal entity. Newton attributes reality to space for the simple reason that it is able to exist by itself, with independence of bodies. This fact confers to space "something of substantial reality" (*Dg.* 111), although not a complete substantival character, for, as we have seen, it does not fit in Newton's concept of substance. Leibniz, in turn, has many different reasons to deny that space is real and to think that it is ideal. The first reason is that space is not able to exist without matter and, therefore, it cannot possess the kind of reality that Newton attributes to it. It does not follow from this fact that space must be ideal, because not every dependent entity, such as an accident is ideal.

The second Leibnizian reason is that space is continuous, and all continuous entities are not real but ideal. This is the result of Leibniz' attempts at solving the problem he called "the labyrinth of the continuum".[22] Leibniz asks himself haw an extended line can possibly be composed of unextended parts, such as points. The same problem arises for every continuous entity. Leibniz' response consists in denying that continua are composed of actual parts. They are simple entities without actual parts. A line, for instance, does not contain an infinity of points, but rather it is infinitely divisible, i.e.,

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[21] The situation would be different if the universe consisted of only one material thing, say a particle, or a compact sphere. In such a case, space and time cannot exist as order relations between different things. However, Leibniz accepts as an evident truth that there exist many different things in the universe. Moreover, the fact that we perceive a manifold is for him the first axiom of all empirical knowledge. ("quod varia a me percipiantur", *De principiis*, Couturat, p. 183).

[22] We cannot analyze this problem here. For a detailed inquiry see Mc Guire (1976), and Leibniz's texts quoted there.

an infinity of points is potentially contained in it. The same holds for space and time. Leibniz is very clear about this point in a letter to Princess Sophia:

> …time is not a substance, because an hour, or any other part of time, never exists complete and with all its parts together. It is nothing but a principle of relations, a foundation of the order of things, in so far as one conceives their successive existence, or without existing together. It must be the same in the case of space. It is the foundation of the relation of the order of things, but in so far as one conceives of them as existing together. Both of these foundations are true, although they are ideal. (to Sophia, 10-31-1705; GP VII, 564).

The last reason I will discuss here is that space is relational and all relations are ideal. Leibniz' doctrine of the ideality of relations is rather obscure and has been the object of lively discussions between modern commentators. I cannot address this topic here.[23] Suffice to say that, according to Leibniz, relations between substances – or aggregates of individual substances- are not real but ideal, that is, they are beings of reason that do not exist by themselves, but depend on the mind for their existence. It does not follow from this fact that they are fictitious entities. Relations are the result of a process of abstraction from perceived things, and for that reason they are well founded in phenomena. In a famous passage of his correspondence with Clarke, Leibniz carefully explains how the concept of space is formed from perception of relations between bodies (L5, §47, GP VII, 4.). This text has been extensively commented, so I will give a few short quotations.[24] Leibniz characterizes the order relation between coexistent bodies as distance or situational relations. Then, he affirms that "in order to have an idea of place, and consequently of space, it is sufficient to consider these relations, and the rules of their changes, without needing to fancy any absolute reality out of things whose situation we consider." (L5 §47, GP VII, 400). This sentence expresses the essence of the relationist program, which has never been completely successful.[25] On the other hand, in the same paragraph Leibniz adds that "this can only be an ideal thing; containing a certain order, wherein the mind conceives the application of relations" (L5 §47, GP VII, 401). It follows from this that for space, or any other entity, to be relational is a sufficient condition to being ideal, and consequently not real.

In a remarkable passage of *De gravitatione*, Newton says that space and time are relational systems because their parts are individuated exclusively by means of their relative order and positions:

> Just as the parts of duration are individuated by their order, so that (for example) if yesterday could change places with today and become the later of the two, it would lose its individuality and would no longer be yesterday, but today; so the parts of space are individuated by their positions, so that if any two could exchange their positions, they would also exchange their identities,

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[23] See, among others, Ishiguro (1972) and (1990); Mates (1986); and Wong (1990). Leibniz's remarks on relations are far from systematic, and there is no single essay in the Leibnizian corpus entirely devoted to this subject. The most important texts have been conveniently collected by Benson Mates (1986), pp. 210-211 and 222-226.

[24] See, for example, Broad (1946); Alexander (1956); Vailati (1997).

[25] For modern assessments of the relationalist program see, Hooker (1971); Sklar (1976); Earman (1989) and Nerlich (1994).

> and would be converted into each other as individuals. It is only through their reciprocal order and positions that the parts of duration and space are understood to be the very ones that they truly are; and they do not have any other principle of individuation besides this order and position. (*Dg.* 103).

Here, Newton's conception of space as a relational system is in many respects very close to Leibniz's relationalism. Both think that one part of space is exactly alike any other part, and that the different parts of space are individuated only by their mutual relations. Nonetheless, a strong difference between them remains. Newtonian space is a self-subsistent entity, which in itself does not depend on matter. In this sense, although it is not a substance, it is as real as bodies, souls or any other substantial entity. Leibnizian space, on the contrary, is a relational system that is not able to exist by itself, apart from bodies. Space arises as a consequence of relations of order between bodies. And, if these relata were suppressed, space itself would disappear. Space can be abstracted from the relational system of ordered bodies, but it cannot exist without them. On the other hand, empty space is ideal in the sense that it depends on the mind to exist. We are able to conceive such a thing as space in itself, but this kind of entity is ideal because it has a mind-dependent existence. In the end, Leibniz believes that space is a product of mind or a mental entity, while Newton conceives of it as a real thing, which is independent both of bodies and souls. This is, in my view, the fundamental difference between Newton's and Leibniz' conceptions of space.

Many contemporary philosophers of space and time understand the concept of substance as involving simply independent existence or reality. Consequently, they argue that space is substantival if it is able to exist with independence of any other entity.[26] It is still an open question as to whether that definition of substance is satisfactory.[27] In particular, it is not clear how self-subsistence and activity relate to each other, whether as necessary or sufficient conditions of substance, or both. In any event, if we were to adopt the concept of substance as self-subsistent being, we should say that Newtonian space is substantival, whereas Leibnizian space is not.[28] However, it should be clear that Newton's absolute space is not a substantival entity according to his own concept of substance, defined exclusively as capability of action. Newton does not differ from Leibniz on this point.

The concept of substance comes from traditional metaphysics and is loaded with connotations arising from different doctrines. Consequently, it results highly equivocal

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[26] Carl Hoefer, for example, writes: "… a modern-day substantivalist thinks that space-time is a kind of thing which can, in consistence with the laws of nature, exist independently of material things (ordinary matter, light, and so on) and which is properly described as having its own properties, over and above the properties of any material things that may occupy parts of it." (Hoefer 1996, p. 5). On the origins of the neologism "substantival" space see Jammer (1993), pp. 216-217. Contemporary philosophers often use the terms "substantival" and "absolute" space as synonymous (for example, Callender and Hoefer 2002, pp. 173-179), but it should be clear that they are not.

[27] Ayers (1991), pp. 85-90, includes capability of action in his characterization of substance. Rosenkrantz and Hoffman (1991) elaborate a sophisticated account of independent existence as criterion of substance.

[28] This is Earman's conclusion (Earman 1989, p. 113).

when used in modern philosophical debates. We have made an effort to clarify just one historical example of the application of this concept, but, given that many obscurities persist, perhaps it is reasonable to dispense with the notion of substance in present philosophy of space and time.

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