

Transversal: International Journal for the Historiography of Science 2018 (5): 84-99  
ISSN 2526-2270  
www.historiographyofscience.org  
Belo Horizonte – MG / Brazil  
© The Author 2018 – This is an open access article

## **IDTC Dossier**

### **Methods and Cognitive Modelling in the History and Philosophy of Science-&-Education**

#### **How to Teach History of Philosophy and Science: A Digital Based Case Study**

Andrea Reichenberger<sup>1</sup>

#### **Abstract:**

The following article describes a pilot study on the possible integration of digital historiography into teaching practice. It focuses on Émilie Du Châtelet's considerations of space and time against the background of Leibniz's program of analysis situs. Historians have characterized philosophical controversies on space and time as a dichotomy between the absolute and relational concepts of space and time. In response to this, the present case study pursues two aims: First, it shows that the common portrayal simplifies the complex pattern of change and the semantic shift from absolute-relational concepts of space and time to invariance and conservation principles. Second, against this background, I present the *Online Reading Guide on Émilie Du Châtelet's Foundations of Physics*, a teaching and research project designed to help navigate Du Châtelet's *Institutions physiques* (1740/42). This project makes Du Châtelet's important text visible to a broad audience and allows for a more critical and deeper view on classical topics of the history of philosophy and science in a more accessible way than traditional introductions.

#### **Keywords:**

Digital Historiography; Teaching History of Philosophy and Science; Émilie Du Châtelet; Early Modern Philosophy; Space and Time

Received: 25 January 2018. Reviewed 10 September 2018. Accepted: 27 September 2018.

DOI: <http://dx.doi.org/10.24117/2526-2270.2018.i5.o8>



This work is licensed under a Creative Commons Attribution 4.0 International License.

---

## **Introduction**

For a long time, the history of philosophy and science was told as a history of geniuses and their pioneering discoveries and groundbreaking insights. There is currently a movement

---

<sup>1</sup> Andrea Reichenberger [Orcid: 0000-0001-5007-935X] is a Postdoctoral Researcher at the Faculty of Arts and Humanities – Department of Social and Human Sciences – Institute of Philosophy: Center for the History of Women Philosophers and Scientists at Paderborn University. Address: Technologiepark 21, Room: TP21.2.31, 33100 Paderborn, Germany.  
E-mail: andrea.reichenberger@upb.de

toward correcting this historical bias. The past twenty-five years have seen an explosion of a re-discovering, re-reading and re-forming the history and historiography of philosophy and science.

In this regard, a number of studies have emphasized, in many different ways, that a well-founded historiography of science can test and falsify philosophical theories about science. From this perspective, the philosophy of science is an empirically testable discipline. Historiography is therefore understood as a science of science, or meta-science, in a close analogy to our understanding of natural sciences. As Jouni-Matti Kuukkanen puts it, “The key idea is testability; that historical case studies perform the role of empirical validation or falsification of the philosophical models of science. In this way, case studies were meant to provide ‘a reality check for philosophy of science’” (Kuukkanen 2018, 186). Contrary to this approach, it is argued that philosophical analyses of past science are better described as hermeneutic procedures than as exercises of testing theories (Schickore 2018).

These debates are by no means new, but have a long history of their own. Throughout the twentieth century, the epistemological and methodological waves and turns within the history and historiography of philosophy and science revolved around the questions of qualitative or quantitative methods, verifiability, evidence, truth, objectivity, and interpretation.

Strangely enough, these debates are still going on today without considering the role and challenge of digital humanities and digital history. It would go beyond the scope of this contribution to offer a wide-ranging analysis and discussion on how the history of science should be written and what factors should explain theory changes by means of a digital-based historiography. The purpose of my contribution is a practical one. I want to show how a digital-based historiography of philosophy and science not only invites us to broaden our toolset for the study of history but also to expand our analytical horizons and to conduct research that moves beyond traditional historical descriptions and techniques. I want to present a case study that shows how historical research and teaching practice can be combined in order to question and correct classical doctrines and established patterns of thought and to reveal at the same time women’s contributions into the historiography of sciences. Whether this approach offers an instrument for testifying philosophical models of science should be left open for discussion. In any case, this approach should be both, a hermeneutic procedure and a critical instrument for learning from history and teaching history of science and philosophy.

The overall topic of the case study is space and time in early modern philosophy. The focus lies on Émilie Du Châtelet (1706–1749).<sup>2</sup> A critical engagement with her work on the *Foundations of Physics (Institutions physiques 1740/42)* allows us to recover and re-evaluate the historical debate on space and time in the 18<sup>th</sup> century as presented in classical textbooks. Against this background, an Online Reading Guide is presented, which is currently being developed as part of a project on digital humanities at Paderborn University, called “Center for the History of Women Philosophers and Scientists”, supported by the Ministry of Higher Education and Research of North Rhine-Westphalia, Germany. The Online Reading Guide on Émilie Du Châtelet’s *Foundations of Physics* pursues the objective to present an online tool that helps students, teachers and researchers in navigating this highly complex work and to make this important historical document visible to a broad audience. With the help of this tool, it is also possible to introduce in the history of the space-time debate beyond entrenched clichés, as will be shown here.

---

<sup>2</sup> Émilie Du Châtelet (1706–1749) is best known for her work on the *Foundations of Physics*, or *Institutions physiques* (Du Châtelet 1740, first edition; Du Châtelet 1742, second edition), and for her translation of and commentary on Isaac Newton’s *Principia*, published posthumously in 1756 and 1759 (Du Châtelet 1759). It would go beyond the scope of this article to discuss her works in detail. For further reading see, e.g., Hagengruber (2012); Reichenberger (2016); Zinsser (2006).

## The Debate on Space and Time in Early Modern Philosophy: The Standard Reading

There are virtually no introductions to the philosophy and history of physics that do not address the relational-absolute position of space and time as a dichotomy (see, e.g., Carrier 2009; DiSalle 2006; Wüthrich 2017). In his foreword to Max Jammer's book *Concepts of Space. The History of Theories of Space in Physics*, Albert Einstein summarized the age-old controversy over the nature of space as follows:

- (a) space as the positional quality of the world of material objects;
- (b) space as the container of all material objects.

In the case of (a), space without a material object is inconceivable. In the case of (b), a material object can only be conceived of as existing in space; space then appears as a reality which in a certain sense is superior to the material world. (Jammer 1954, xiii)

John Stachel speaks about a “conflict between two views of the nature of space” (Stachel 2006, 220) and distinguishes between the absolute concept and the relational concept in the same manner: “The absolute concept: Space is a container, in which matter moves about. [...] The relational concept: Space has no independent existence. It is just a certain set of positional relations between material entities” (Stachel 2006, 220). The Leibniz-Clarke correspondence, as one always reads, documents the difference between the (Leibnizian) relationalist view and the (Newtonian) absolutist view of space. If Stachel is right, then it was the “Newtonian conception of space that triumphed in spite of the cogent arguments of Leibniz and Huygens against it” (Stachel 2006, 201) – at least up to Einstein's theory of relativity.

In fact, the absolute-relational dichotomy does not do full justice to the complexity of the historical and conceptual debate regarding space and time. Even decades ago John Earman, among others, has advocated that “the absolute-relational contrast is far from being a dichotomy” (Earman 1989, 14). Further, he has emphasized that questions regarding the nature of motion should not be confused with questions regarding the space-time-structure. The question was not only whether absolute space and time really exist but (also) whether a material object can only be conceived of as existing within space and time. The difficulty lay in specifying what was meant by “material objects,” “points,” “events,” “masses,” etc. and how bodies move and interact. My aim is not to retell the entire history of the space-time problem, but to integrate Émilie Du Châtelet in this context in order to show how her example can be used in teaching practice to make the complexity of this debate and its interconnectedness with invariance and conservation principles visible.

## Émilie Du Châtelet on Space and Time: Beyond the Standard Reading

At the beginning of the fifth chapter of her *magnum opus*, the *Institutions physiques* (Du Châtelet 1742), Du Châtelet stresses that the question of the nature of space is one of the most famous, controversial and essential questions in physics and metaphysics. Then she contrasts the absolute vs. relational view of space: Some argue that space is nothing over and above things; space cannot be a real thing-in-itself, it is a mental abstraction, an ideal being, the order of coexisting things; and there is no space without bodies. Others disagree. They maintain that space is absolute and real. Space has to be distinguished from the bodies placed in it. Space is impalpable extended, penetrable, and not solid, a universal vase, or vessel, within which bodies are placed:

Some have said: Space is nothing over and above things, it is a mental abstraction, an ideal Being, it is nothing other than the order of things as they coexist, and there is no space without bodies. Others have, on the contrary, maintained that Space is an absolute Being, real, and distinct from the bodies placed in it, i.e. an impalpable, penetrable, non-solid extension, the universal vessel that receives the Bodies that are placed in it; in a word, a kind of immaterial and infinitely extended fluid, in which the Bodies swim. (Du Châtelet 1742, § 72)<sup>3</sup>

Du Châtelet argues, in line with Leibniz, that space cannot be real and absolute because this assumption was in conflict with the principle of sufficient reason:

if Space is a real Being and subsistent without Bodies that could be placed in it, it makes no difference in which part of this homogeneous Space one places them, as long as they keep the same order among them: therefore there would not have been any sufficient reason why God would have placed the Universe in the location where it is now, rather than in any other, since he could have placed it 10,000 leagues further away, and put the East where the West is; or indeed he could have reversed it, so long as he kept things in the same place in relation to each other. (Du Châtelet 1742, § 74)<sup>4</sup>

Leibniz used this thought experiment at the beginning of his third letter to Clarke:

Now from hence it follows (supposing space to be Something in itself, besides the Order of Bodies among themselves) that 'tis impossible there should be a Reason, why God, preserving the same Situations of Bodies among themselves, should have placed them in space after one certain particular manner, and not otherwise; why everything was not placed the quite contrary way, for instance, by changing East into West. (Leibniz 1717, 59)<sup>5</sup>

Leibniz' argument is a *reductio ad absurdum* argument, by constructing a situation in which God has to make a choice lacking a sufficient reason. Contrary to Clarke, who argued that

---

<sup>3</sup> The following translations are based on the online-translation presented by the Notre Dame Group under the direction of Katherine Brading. URL: <https://www.kbrading.org/translations>. Consulted September 1, 2018. In the footnotes the quotations are rendered in the original language based on the Amsterdam edition (Du Châtelet 1742), here: "Quelques-uns ont dit: l'Espace n'est rien hors des choses, c'est une abstraction mentale, un Être idéal, que ce n'est que l'ordre des choses entant qu'elles coexistent, & qu'il n'y a point d'Espace sans corps. D'autres au contraire ont soutenu, que l'Espace est un Être absolu, réel, & distinct des corps qui y sont placés; que c'est une étendue impalpable, pénétrable, non solide, le vase universel qui reçoit les Corps qu'on y place; en un mot, une espèce de fluide immatériel & étendu à l'infini, dans lequel les Corps nagent."

<sup>4</sup> "car non seulement il n'y auroit, comme vous venez de le voir, aucune raison de la limitation de l'étendue; mais, si l'Espace est un Être réel & subsistant sans les Corps, & qu'on puisse les y placer; il est indifférent dans quel endroit de cet Espace similaire on les place, pourvu qu'ils conservent le même ordre entre eux; ainsi il n'y auroit point eu de raison suffisante pourquoi Dieu auroit placé l'Univers dans la place où il est maintenant, plutôt que dans toute autre, puisqu'il pouvoit le placer dix mille lieues plus loin, & mettre l'Orient où est l'Occident; ou bien enfin le renverser, en faisant garder aux choses la même situation entre elles."

<sup>5</sup> The French edition by Des Maizeaux (1720, § 5, 32) reads as follows: "quil est impossible qu'il y ait une raison pourquoi Dieu, gardant les mêmes situations des corps entre eux, ait placé les corps dans l'Espace ainsi et non pas autrement et pourquoi tout n'a pas été pris à rebours (par exemple), par un échange de l'orient et de l'occident."

God is entirely free to do as he pleases, Leibniz emphasized that everything God does must be done for a reason. If there is no sufficient reason for God's acting in a particular manner, then he is no more than an all-powerful tyrant inventing arbitrary standards and acting in arbitrary ways. If there were indiscernibles, God would have violated the principle of sufficient reason, by choosing without reason between equally good alternatives. So, it would be absurd for God to act against reason because this would mean to act against his own nature. Against this background, Du Châtelet comes to the following conclusion:

Mr. Leibniz's reasoning against absolute Space is therefore irrefutable, and one is forced to abandon this Space, if one does not wish to renounce the principle of sufficient reason; that is to say, to renounce the foundation of all truth. (Du Châtelet 1742, § 74)<sup>6</sup>

As in the case of space, Du Châtelet argues that the common notion of time as an absolute being, immutable, eternal, and subsisting by itself, is misleading. To substantiate this claim, Du Châtelet refers to Leibniz's famous question as to why God had not created the universe a thousand years earlier or later (Du Châtelet 1742, § 96). For one posits temporal relations as existing of instants among absolute time, that is independent of things and their states, there is no way of deciding which instants they occupy. Instants, i.e. temporal units, or points, cannot be distinguished from one another. Thus, any point of time is identical to any other point in time, only distinguishable by the things placed within it. If time is a substance, then it would matter when God decided to create the world at a particular instant of time and one could ask what sufficient reason God had for creating it at the time he chose rather than creating it earlier or later. God's creation itself must have a final cause which helps to actualize the best of all possible worlds which is lacking if the creative act had occurred earlier or later. Clarke, who claimed to agree with the principle of sufficient reason, replied that "this sufficient Reason is often the simple or mere Will of God" (Clarke 1717, 61). Leibniz felt misunderstood. God's will should always be in accordance with the principle of the sufficient reason. God can never act without sufficient reason.

Like Leibniz, Du Châtelet draws an analogy between space and time: space is the order of coexisting things; time is the order of successive things.<sup>7</sup> We observe, as Leibniz said, a series of coexisting things. We abstract from these observations and thus gain the concept of space. Du Châtelet also deals with the question of the representation of space and time, i.e., how we came to form our ideas of extension and gain the concept of space and time through abstraction (Du Châtelet 1742, § 80).

To illustrate the crucial role of abstraction Du Châtelet compares the concepts of space and time with the concept of number: Space is an abstraction of coexisting things as numbers are an abstraction of things numbered. It would be meaningless to speak about numbers without things that can be numbered. Analogous, space would be meaningless without postulating entities (beings) that act in space and time.

Thus, space is not the extension of a thing, any more than duration is its time. Like the number is different from the numbered thing, time is different from the measured thing. While extension and duration, therefore, must always belong to some actual things, space and time are relations belonging to possible things. Space and time express possibilities.

---

<sup>6</sup> "Ainsi le raisonnement de Mr. de Leibnits contre l'Espace absolu est sans replique, & l'on est forcé d'abandonner cet Espace, ou de renoncer au principe de la raison suffisante, c'est-à-dire, au fondement de toute vérité."

<sup>7</sup> "J'ay marqué plus d'une fois, que je tenois l'Espace pour quelque chose de purement relatif, comme le Temps; pour un ordre des Coexistences, comme le Temps est un ordre de Successions. Car l'espace marque en termes de possibilité, un Ordre des choses qui existent en même temps, en tant qu'elles existent ensemble; sans entrer dans leurs manieres d'exister" (Des Maizeaux 1720, § 4, p. 31).

Thus, possible coexistences constitute space, successive existences constitute time (Du Châtelet 1742, § 105).

In Leibniz's theory, space does not anymore constitute an independent background, but rather takes the form of a geometrical object itself. Leibniz's aim was to represent the relations among geometrical figures directly, without recourse to the Cartesian co-ordinates and equations of ordinary analysis. The basis for his new approach to space was to define an *extensum* (extended thing) in terms of "situs", i.e., situation. Initially, "situs" denotes a disposition of smallest parts or unities in relation to the whole. The basic relations are those of *equality*, *similarity* and *congruence*. Congruence presupposes co-existence. This leads Leibniz to a new definition of *extensum* as a whole with co-existing parts that have a mutual situation and to a more sophisticated characterization of space in terms of *extensum* and *situs*: it is the ordering of situations that constitute space.

Leibniz's theory remained, however, fragmentary. In 1715 Leibniz presented some crucial ideas of his new foundational program in his *Initia rerum mathematicarum metaphysica* (Leibniz 1715). He defined time, duration, space, extension and situation in quasi-axiomatic form: Time, Leibniz said, is the order of existence of those things which are not simultaneous. Duration is the magnitude of time. If the magnitude of time is uniformly and continuously diminished, time disappears into a moment, whose magnitude is zero. Space is the order of coexistents or the order of existence among things which are simultaneous. The extension is the magnitude of space. It is wrong to confound extension with what is extended, as is commonly done, and to regard it as a substance. If the magnitude of space is uniformly and continuously diminished, it disappears into a point whose magnitude is zero. Situation is a mode of coexistence. It not only involves quantity but quality too. Quantity, or magnitude is that which can be recognized in things only by their compresence or simultaneous perception. Leibniz distinguishes between quality, or form, and quantity, or magnitude, and he says that similar things are those that do not differ with respect to qualities.

Leibniz's considerations help to explain the connection between his analysis situs, his theory of space and time and his metaphysical monadology, i.e., an ontology of individual substances whose perceptions are representations from a given point of view. The philosophical problem, for which Leibniz sought a solution, is known as the labyrinth of the continuum: Can that which is spatially extended consists of unextended and partless units? Leibniz's solution – extended objects can be divided ad infinitum, but this infinite divisibility takes place only at the phenomenal level –, presupposes a metaphysical realm. It is often overlooked that Leibniz's space-time relationalism stands and falls with the metaphysical postulate that space and time have their reason, or ground, in the actions of simple substances (see Schepers 2006/2007). These real units are what Leibniz called entelechies, or forms, and which ground the laws of motion in the phenomenal world. Substances are metaphysical points, endowed with a spontaneous internal activity, which Leibniz called primitive active force.

Du Châtelet was obviously familiar with Leibniz's idea of an analysis situs, also known as geometric characteristics, although it is difficult to reconstruct what she really knew about it. In this context, Du Châtelet's comparison between space and numbers offers not only a better illustration of the relationship between space and things. It helps to understand the crucial differences, as Du Châtelet explains, between "location," "place" and "situation": Firstly, *location* is not the placed thing itself, but it differs from the placed thing as an abstract thing from its concrete counterpart. The location of a being is its determined manner of coexisting with other beings (Du Châtelet 1742, § 88). It can be absolute or relative. Absolute location is the one that suits a being insofar as we consider its manner of existing with the whole universe considered as immobile; and its relative location is its manner of coexisting with some particular beings. Imagine, for example, a person inside a ship which is sailing at constant speed. Since the ship is moving at a constant speed and direction the person will

not feel the motion of the ship. The relative location of the person and of everything that is on this boat does not change at all but their absolute location is constantly changing due to every part of the boat also changing its manner of existence equally with respect to the shore, which we regard as immobile. However, if the person walks on the boat, the person changes his relative location and absolute location at the same time.

Secondly, we call *place* the assembly of several locations, that is to say, all the locations of the parts of a body taken together (Du Châtelet 1742, § 92). Finally, we call *situation* the order that several coexistent non-contiguous things maintain through their coexistence, such that taking one of them as the first, we give a situation to others that are far away in relation to that one. Thus, taking a house in a city as the first, all the others acquire a situation with respect to this house, because they are separated from each other, and because we can determine their situation by their distance from that which we took as the first. Therefore, two things have the same situation with respect to a third when they are at the same distance (Du Châtelet 1742, § 93). It is no coincidence that at this point Du Châtelet attaches great importance to the distinction between space and time and the measurement of spatial and temporal distances:

Time is usually represented by the uniform movement of a point that describes a straight line, because the point is there a successive being, present successively at different points, creating by its flow a continuous succession to which we attach the idea of time. We also measure time by the uniform movement of an object. (Du Châtelet 1742, § 93)<sup>8</sup>

Uniform motion, i.e., motion in a straight line, plays a crucial role for the geometrical representation and construction of a body's motion in space and time. By means of motion, time is measurable. Du Châtelet reminds of traditional methods of time measurement, e.g., through the movement of celestial bodies, and she highlights Christiaan Huygens' construction of pendulum clocks as a milestone on the way to a more precise time measurement (Du Châtelet 1742, § 107). The measurement of time allows us to distinguish past, present, and future events and to give to ourselves and others an idea of what we mean by such a portion of time, e.g., the annual and daily course of the Sun, the vibrations of a pendulum, minutes, hours, days, and years; but it is quite possible that other things have been used as measurements by other peoples. The only one that might be universal is what is called an infinitesimal small instant of time (Du Châtelet 1742, § 114). What is that supposed to mean? Leibniz's differential calculus and Newton's method of fluxions were both methods of calculating the motion of an object; both methods presuppose and require the notion of a finite rate of change at each instant. This is analogous to the notion that a moving body has an instantaneous velocity at a given moment in time. Under this conception, every motion is conceived of as beginning from a point, or an instantaneous moment, and ending at another point, or an instantaneous moment. For practical purposes of measurements, the position from which we make an observation has to be taken as invariant, although there is no fixed point in space and time to which everything must be related.

This explains why motion has to be distinguished from time: time (not to be confused with its measurement) is ideal; motion is real and actual (Du Châtelet 1742, § 109). Interestingly, in Chapter 11 Du Châtelet defines motion as the passage of a body from the place it occupies to another place (Du Châtelet 1742, § 211) in accordance with Newton (in

---

<sup>8</sup> "On représente ordinairement le tems par le mouvement uniforme d'un point qui décrit une ligne droite, parce que le point est l'Être successif, present successivement à différens points, & engendrant par la fluxion une succession continue à laquelle nous attachons l'idée de Tems. Nous mesurons aussi le Tems par le mouvement uniforme d'un objet."

contrast to Leibniz) and distinguishes three kinds of motion: (i) absolute motion (*le mouvement absolu*), (ii) relative common motion (*le mouvement relatif commune*), and (iii) proper relative motion (*le mouvement relatif propre*). Absolute (real) motion is the motion of a body relative to other bodies which are assumed to be immobile (Du Châtelet 1742, § 213). Relative common motion is defined as that which a body experiences, when it is at rest, in relation to the bodies which surround it. Du Châtelet adds that this is the case in which the absolute place of the bodies changes, though their relative place stays the same; this is what happens to a pilot who sleeps at the tiller while his ship moves, or a dead fish carried along by the current (Du Châtelet 1742, § 214). Relative proper motion is the one experienced, when, being transported with other bodies in a common relative motion, one nonetheless changes one's relationship with them, as when I walk on a sailing ship (Du Châtelet 1742, § 215). What follows is Du Châtelet's version of Galileo's ship, based on the principle of relativity according to which there is no internal observation (i.e., without looking out the window) by which one can distinguish between a system moving uniformly from one at rest. Hence, any two systems moving without acceleration are equivalent, and unaccelerated motion is relative, i.e., dependent on the observer (in its modern term: reference system).

Du Châtelet's classification of different kinds of motion is based on the foundational problem of how one should be able to distinguish between real and apparent states of motion (and rest). The laws of motion provide the determination of real states of motion, that is the change in velocity. In Newtonian physics, the changes in velocity are caused by impressed forces. Leibniz agreed that true motions can be distinguished from merely apparent ones by the identification of causes. On several occasions, Leibniz had referred to the relativity of motion as implying the phenomenality of motion. Nevertheless, he did not reject the reality of motion. The reality of the phenomena of motion derives from their being founded in force. This is in accordance with Newton. In Leibniz's sense, however, the concept of force has a different meaning. Forces that are determined as the causes of bodies acting and being acted upon by one another are derivative forces, i.e., instantaneous modifications of something permanent, namely form, or substance.

To be more precise, motion does not just mean changing place or position, but changing the situation. This assumption presupposes more than just the dynamic conception of a point moving and producing a line, which can be extended to the motion of a line generating a surface; it presupposes the existence of force. The true reason for the change, i.e., the cause of motion, is the force. Motion – in a Leibnizian sense – is relative only if it is considered in abstraction from the force. Neither space nor time, but the force is the real and absolute quantity, which justifies and explains absolute motion. “Force” in this sense refers to the quantity  $mv^2$ , or “living force”, which is conserved in all interactions. Du Châtelet concludes:

Thus, in order to make certain that a Being has changed its place, and in order for this change to be real, the reason (cause) for its change, that is to say the force that produced it, must be in the Being at the moment at which it moves, and not in the coexisting Beings. This is because if we ignore where the true reason for change lies, we also ignore the reason why these Beings changed place. (Du Châtelet 1742, § 88)<sup>9</sup>

---

<sup>9</sup> “Ainsi, pour que l'on puisse assurer qu'un Être a changé de lieu, & pour qu'il en change réellement, il faut que la raison de son changement, c'est-à-dire, la force qui l'a produit, soit en lui dans le moment qu'il se remue, & non dans les coexistans; car si on ignore où est la véritable raison du changement, on ignore auili lequel de ces Etres a changé de lieu.”



If there were nothing more to motion than a change of position relative to other bodies, then there would be no real motion. Real motion requires, in addition to the relative change of place, a cause (force, action) of that relative change. In his *Principia*, Newton had suggested that the absolute, or true motion of bodies is to be defined relative to absolute space and time, and to be discovered by its properties, causes and effects. For Newton “place” was “the part of space that a body occupies, and it is, depending on the space, either absolute or relative” (Newton 1999, 409). Newton added: “I say that part of space, not the position (situs) of the body or its outer surface” (Newton 1999, 409). In his correspondence with Clarke, Leibniz favored an alternative concept of space and time, based on the concept of the position/situation of a body. Newton had maintained that “absolute motion is the change of position of a body from one absolute place to another” (Newton 1999, 409).<sup>10</sup> Leibniz argued that real, or absolute motion is to be defined with respect to the active forces that he took to be inherent and absolute.

At first glance, Du Châtelet just adopts Leibniz’s relationalism, arguing against Newton’s absolute space and time. However, it is worth taking a closer look. Leibniz agreed with both, Newton and Clarke, that neither space nor time were substances (none of them advocated space-time-substantialism). In his correspondence with Leibniz, Clarke defended Newton’s opinion that space and time were attributes of God, who was the only self-existent substance, and he simply identified time with the duration of all things. Leibniz disagreed. For him, space and time were neither substances nor attributes, but relations and insofar ideal, not real. The ultimate constituents of reality are monads, or simple substances which Leibniz identified with powers, or forces.

The crucial problem with which the later generations struggled was: How does the world of our experience fit into Leibniz’s account of reality? Our everyday experience is of extended objects causally interacting, but, for Leibniz, at the fundamental level there is no inter-substantial causation and there are no extended substances. How, then, is the world of our experience related to the world as it really is? This was also a crucial problem for Du Châtelet who tried to understand Leibniz’s approach to space and time, searching at the same time for a successful integration of Leibniz’s living force, its measure and its conservation, into a coherent theory of motion.

From today’s perspective, it seems obvious that Leibniz established a rudimentary expression for the conversion of potential energy to kinetic energy, at least if we concede that Leibniz used the word “living force”, or *vis viva*, to signify what we would call “work”. From today’s perspective, the dispute about the question of whether the force of bodies in motion, striking each other, is proportional to the simple velocity of the motion or proportional to the square of the velocity, was wrongly posed. Both quantities are conserved, the product of mass and velocity as well as the quantity of the product of mass, multiplied by its velocity squared. The first refers to what is now called momentum, the second to the kinetic energy of a moving body. In 18<sup>th</sup> century mechanics was not clear at all what exactly are forces and how they produce different kinds of motion. Force was not only understood as the cause of acceleration (external to matter), but also as the cause of uniform rectilinear motion, i.e., of inertial motion (intrinsic to matter). Du Châtelet could not make this clear (see Reichenberger 2018). Further, it is a matter of dispute whether Christian Wolff influenced Du Châtelet more than Leibniz. It was and is widely known that Leibniz’s *Initia rerum mathematicarum metaphysica* was written in response to Wolff’s *Elementa matheseos universae*, published in 1713 (Wolff 1713). Wolff adopted some of Leibniz’s definitions in his *German Metaphysics* (Wolff 1720) and in his *Ontology* (Wolff 1730). However, Wolff rejected

---

<sup>10</sup> “Locus est pars spatii quam corpus occupat, estque pro ratione spatii vel absolutus vel relativus. Pars, inquam, spatii; non situs corporis, vel superficies ambiens. [...] Motus absolutus est translatio corporis de loco absoluto in locum absolutum” (Newton 1726, Scholium: III, IV).

Leibniz's concept of monads. Wolff's simple beings are indivisible physical points equipped with (indeterminate) active and passive forces that underpin physical forces of motion and resistance, not metaphysical points, endowed with a vital activity or spontaneous action and perception, linked to spirits of souls (see Stan 2018, 485). Du Châtelet affirmed that bodies interact and that the elements' action and resistance is the sufficient ground of corporeal inter-agency. Was this a fundamental misunderstanding of Leibniz's philosophy? One could argue the point. With regard to an important point, however, Du Châtelet went beyond Leibniz and Newton. Once again, Wolff might be her source. "Du Châtelet ends with a definition of substance as 'durable, modifiable subject', namely, that which 'conserves' and 'keeps constant' essentials and attributes as its modes vary and succeed one another" (Stan 2018, 480).

According to Du Châtelet, common notions of "substance" given by the Scholastic philosophers, by Descartes and by Locke have proven to be wrong. The Scholastics defined "substance" as *Ens quod per se subsistit et sustinet accidentia*, that is to say, a being which subsists by itself. But it's not clear at all, what it is to subsist by oneself (Du Châtelet 1742, § 51). Descartes and others defined "substance" as a being which exists in such a way that it does not need any other being for its existence. Now, as one can plainly see, Du Châtelet says, that this returns to the untenable Scholastic definition of "substance", and that furthermore, if one takes this definition rigorously, one is solely left with God as the only one true Substance. After all, Locke's definition of "substance" is also misguided, i.e., that substance is no other thing than a subject which we do not know. By contrast, Du Châtelet defines "substance" as follows:

One can define Substance like this: that which conserves (preserves) the essential determinations and constant attributes, while its modes vary and succeed each other. (Du Châtelet 1742, § 52)<sup>11</sup>

This definition is remarkable insofar as it opened the door from Leibniz's "substantiation of force" (Thönes 1908, 17) to our modern understanding of the principle of invariance under transformation. Loose talk about whether space and time is either relative or absolute often leads to serious philosophical and historical misinterpretations. It is a commonplace to think that Leibniz favored relationalism, whereas Newton maintained that space and time are absolute. This standard reading is not very convincing, because it is under-specified and it overlooks the complexity of meanings of basic concepts and foundational issues regarding space and time. A closer look at Du Châtelet's considerations on space and time help to deepen our understanding not only of Leibniz's criticism of Clarke's defense of Newton's space and time but also towards the usually neglected background of analysis situs. The lesson we can learn from Du Châtelet is a subtle semantic shift from absolute-relational concepts of space and time to invariance principles, related to conservation laws.

---

<sup>11</sup> "l'on peut définir la Substance, ce qui conserve des déterminations essentielles, et des attributs constans, pendant que les modes y varient et se succèdent." Compare, at this point, Christian Wolff, who writes in his *Ontologia*: "Subiectum perdurable et modificabile dicitur substantia" (Wolff 1730, § 768). Substance means: "substantia est subiectum determinationum intrinsecarum constantium atque variabilium" (Wolff 1730, § 769); or: "Quod in se continet principium mutationum, substantia est" (Wolff 1730, § 872).

## How to Teach the History of Space and Time in Early Modern Philosophy: Beyond the Standard Reading

It is not easy to integrate the results presented in the foregoing chapter into teaching practice. Although more and more scholarship on Du Châtelet's philosophy is emerging, it is not yet sufficiently understood what role she played in the context of already well-researched philosophers, specifically Newton, Leibniz and Kant, and the position she takes on key themes, such as space and time, within the history of philosophy. In order to establish Du Châtelet as an independent philosopher and reconstruct her philosophical approach by examining her writings and her discussions of the relevant works of her time, it is important to integrate her work in courses taught at universities on the history of philosophy and science or the Early Modern Period. But how? One cannot assume that students can speak several (old) languages or can read manuscripts. Up till now, there is no critical edition of her *Institutions physiques*. In 2009, Isabelle Bour and Judith Zinsser published a partial translation of Émilie Du Châtelet's *Foundations of Physics* (Zinsser and Bour 2009). Since 2014, faculty and students at the University of Notre Dame have worked to complete the translation. So, a lot has been done in recent years to overcome the void in research on Du Châtelet's philosophy.

As an alternative and complement to these traditional publishing and teaching activities, the *Online Reading Guide on Émilie Du Châtelet's Foundations of Physics* is currently designed to help navigate Du Châtelet's *Institutions physiques* (1740/42). This teaching and research project is part of the project *Center for the History of Women Philosophers and Scientists* at Paderborn University, Germany. It aims to make this important historical and highly original document visible to a broad audience. The project is unique in the growing research field of digital humanities, but it may hopefully provide a model for future projects in online teaching practice.

Each chapter of the Reading Guide is structured as follows: Firstly, the content of the chapter is summarized. Secondly, the content is commented on in the footnotes. Thirdly, the works of authors named in the *Institutions physiques* are provided with a link (if the works can be ascertained from the text). Fourthly, central passages of the text are quoted literally. Each quote links to the corresponding page of the original Amsterdam edition *Institutions physiques de Madame la marquise du Châstellet adressés à Mr. son fils* (1742). Deviations from the Prault edition *Institutions de physique* (1740) are not mentioned if they are negligible. Occasionally, text passages have been switched. It should also be mentioned that phrases or sentences have been added to some parts of the text. Insofar as these additions are substantively and contextually relevant, reference is made to them. Faithfulness to the original French text is guaranteed. No silent corrections of typographical or other errors are applied, and punctuation and style are reproduced. All quotations are linked to the corresponding manuscript-page of the National Library of France. The manuscript is online accessible on BnF Digital Library Gallica (see Fig. 1).

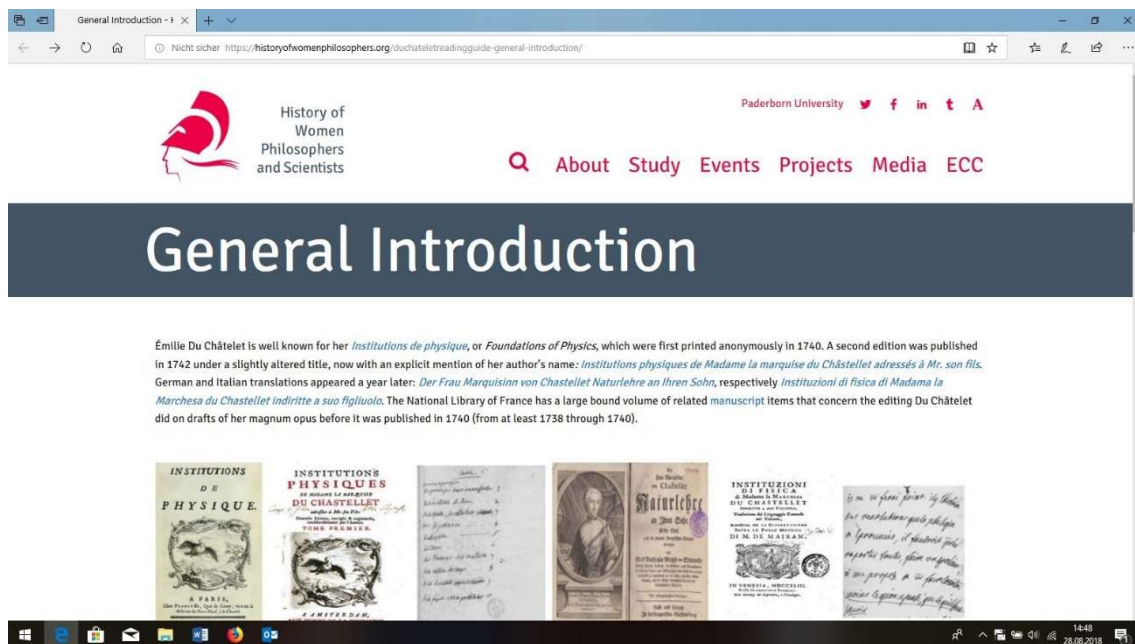


Fig. 1: Online Reading Guide on Émilie Du Châtelet's *Foundations of Physics*: General Introduction. Project History of Women Philosophers and Scientists, Paderborn University, Germany.  
URL: <https://historyofwomenphilosophers.org/duchateletreadingguide-general-introduction/>.

Let's have a look at examples for integrating the Online Reading Guide into teaching practice by means of the following two questions and possible sample answers:

1. What resolution of Zenon's paradox does Du Châtelet offer? (see Du Châtelet 1742, Chapter 9, § 171)

Du Châtelet argues that Zenon's paradox against the possibility of motion does not prove that motion is impossible, but at best that Achilles never catches up with the tortoise. However, this is also wrong due to the paradox being based on a false assumption as Grégoire de Saint-Vincent has shown. In his *Opus geometricum quadraturae circuli sectionum conii* (1647),<sup>12</sup> Grégoire de Saint Vincent resolved Zeno's Achilles paradox, by summing an infinite geometric series. The flaw in Zeno's argument is his unstated assumption that the sum of an infinite cannot be finite.

2. John Keill claimed to be able to prove that empty space exists. Reconstruct his argument on the basis of Du Châtelet's analysis in Chapter 5, § 73 of her *Institutions physiques*.

John Locke distinguishes pure space from the bodies that fill it. In his *Essay Concerning Human Understanding* (1690; French translation 1700, revised edition 1720) he defined impenetrability as the criterion for distinguishing space and bodies: bodies are impenetrable, space is penetrable. Another difference between space and bodies is that we cannot see and touch space, but we can see and touch bodies. John Keill held the same opinion. In his book *Introductiones ad veram Physicam* (1701) he goes even further. He claimed to be able to prove that a larger amount of empty space exists, even within matter itself, than impenetrable corpuscular matter (Keill 1720, 117). Christian Wolff rejected Keill's argument. He maintained

<sup>12</sup> Users have the possibility to click directly on Grégoire de Saint Vincent's *Opus geometricum quadraturae circuli sectionum conii* (1647) in the text. The link goes to the page of the ETH Zurich Library, where one can view the original online document or download it as a pdf file.

that the so-called “*materia subtilissima*” did not increase the weight of the body. According to the Archimedean principle, the bodies would lose as much weight as the weight of the volume of the fluid they displaced (*Aerometriae Elementa* 1709). Keill countered in a letter to Wolff printed in January 1710 (*Acta eruditorum* Jan. 1710, 11–15). Wolff answered promptly. His reply appeared in the same journal one month later (*Acta eruditorum* Feb. 1710, 78–80). Johann Bernoulli I intervened. In a letter to Wolff (26 April 1710), he agreed with Wolff that Keill’s argumentation was wrong. However, Bernoulli I argued differently from Wolff: If the greater weight of the lead ball would be due to the fact that it loses less weight in the “*fluidum subtilissimum*” than the cork ball of the same size, then the resulting weight difference would be so small that it would not be observable. Lead and cork thus have almost the same specific weight, which contradicts experience as well as Keill’s argumentation. The latter was based on the assumption that the weight of the body is proportional to the quantity of matter (see Fig. 2).<sup>13</sup>

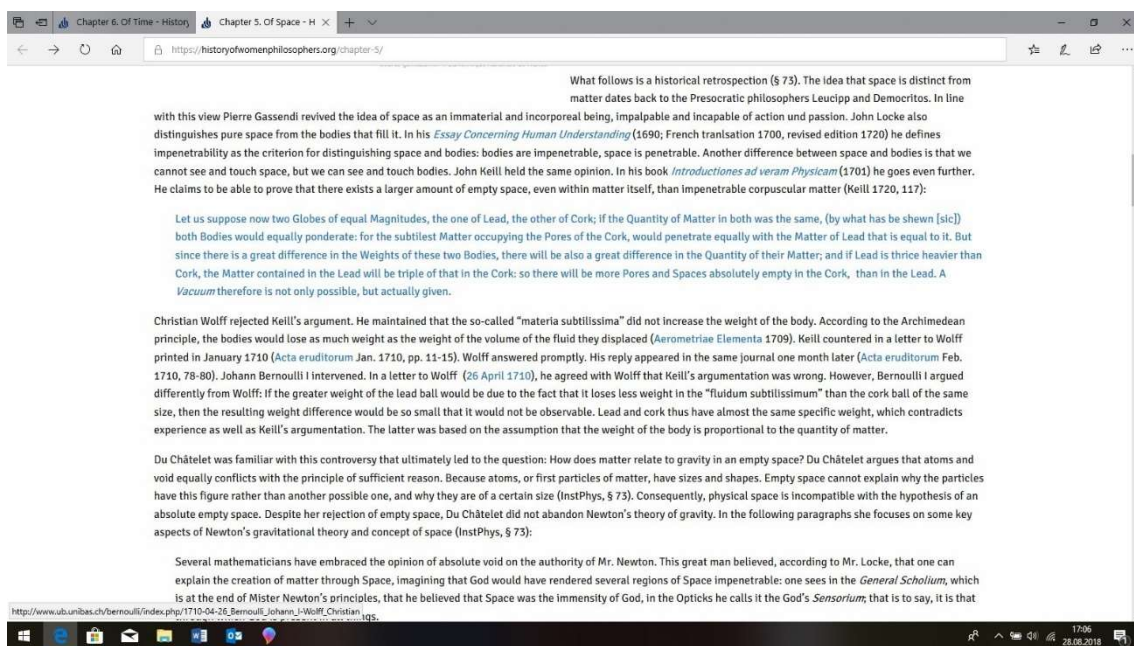


Fig. 2: Online Reading Guide on Émilie Du Châtelet’s *Foundations of Physics*: Chapter 5. On Space. Project History of Women Philosophers and Scientists, Paderborn University, Germany. URL: <https://historyofwomenphilosophers.org/chapter-5/>.

## Conclusion

The case study presented here is one of the many ways how one can teach the history of philosophy and science in a time when digital resources and methods are becoming increasingly important. In contrast to quantitative historiography, cliometrics, and statistics, this approach offers a qualitative analysis regarding a classical philosophical topic: the problem of space and time. By means of this example, it should be made clear that the

<sup>13</sup> Again, users have the possibility to click directly on John Locke’s *Essay Concerning Human Understanding* (1690), John Keill’s *Introductiones ad veram Physicam* (1701), Christian Wolff’s *Aerometriae Elementa* (1709), Keill’s letter to Wolff printed in January 1710 in *Acta eruditorum* Jan. 1710, 11–15, Wolff’s response in *Acta eruditorum* Feb. 1710, 78–80, and Johann Bernoulli’s letter to Wolff from April 26, 1710. All links go to online documents.

portrayal of controversies on space and time in the philosophy of science as a dichotomy between absolutism and relationalism simplifies the complex pattern of change. In today's digital age it is possible to make this expert knowledge accessible to everyone in a fast, simple and visualized way, as the digital project of the *Online Reading Guide on Émilie Du Châtelet's Foundations of Physics* aims to demonstrate exemplarily.

## Acknowledgment

The author wishes to thank the anonymous reviewer for highly useful comments and suggestions, which significantly helped to improve this contribution and the ideas expressed in it, although any errors are my own. This work is part of the research project *Center for the History of Women Philosophers and Scientists* at the Faculty of Arts and Humanities, Department of Social and Human Sciences, Institute of Philosophy, Paderborn University (Germany), financially supported by the Ministry of Higher Education and Research of North Rhine-Westphalia, Germany.

## References

- Bernoulli, Johann I. 1710. Letter to Christian Wolff from April 26, 1710.  
URL: [https://www.ub.unibas.ch/bernoulli/index.php/1710-04-26\\_Bernoulli\\_Johann\\_I-Wolff\\_Christian](https://www.ub.unibas.ch/bernoulli/index.php/1710-04-26_Bernoulli_Johann_I-Wolff_Christian). Consulted September 1, 2018.
- Carrier, Martin. 2009. *Raum-Zeit*. Berlin/New York: de Gruyter.
- Clarke, Samuel. 1717. *A Collection of Papers, Which passed between the late Learned Mr. Leibnitz, and Dr. Clarke, In the Years 1715 and 1716*. London: Knapton.
- de Saint-Vincent, Grégoire. 1647. *Opus geometricum quadraturae circuli sectionum conii*. Antverpiae: Apud Ioannem et Iacobum Meursios.  
URL: <https://www.e-rara.ch/zut/content/titleinfo/2705188>. Consulted September 1, 2018.
- Des Maizeaux, Pierre. 1720. *Recueil de diverses pièces sur la philosophie, la religion naturelle, l'histoire, les mathématiques, etc. par Mr. Leibnitz, Clarke, Newton et autres Auteurs célèbres*. Amsterdam: H. Du Sauzet.
- DiSalle, Robert. 2006. *Understanding Space-Time: The Philosophical Development of Physics from Newton to Einstein*. Cambridge/New York: Cambridge University Press.
- Du Châtelet, Emilie, and Newton, Isaac. 1759. *Principes mathématiques de la philosophie naturelle de Newton: Par feuë madame la marquise Du Chastellet*. 2 vols. Paris: Desaint et Saillant.
- Du Châtelet, Emilie. 1738. *Manuscript Institutions de Physique*. Bibliothèque Nationale Français: ffr. 12.265.  
URL: <http://gallica.bnf.fr/ark:/12148/btv1b60007500/f1.image.r=Institutions%20physiques>. Consulted September 1, 2018.
- Du Châtelet, Emilie. 1740. *Institutions de physique*. Paris: Prault.
- Du Châtelet, Emilie. 1742. *Institutions physiques de madame la marquise Du Chastellet adressés à M. son fils. Nouvelle édition, corrigée et augmentée considérablement par l'auteur*. Amsterdam: Aux dépens de la Compagnie.  
URL: <http://reader.digitale-sammlungen.de/resolve/display/bsb10130894.html>. Consulted September 1, 2018.
- Earman, John. 1989. *World Enough and Spacetime – Absolute Versus Relational Theories of Space and Time*. London: MIT Press, Cambridge, MA.
- Hagengruber, Ruth (ed.). 2012. *Émilie du Châtelet between Leibniz and Newton*. Dordrecht et al.: Springer.

- Jammer, Max. 1954. *Concepts of Space. The History of Theories of Space in Physics*. Harvard University Press, Cambridge, MA.
- Keill, John. 1710. Letter to Christian Wolff. *Acta eruditorum* Jan., 11–15. URL: <http://www.izwtalt.uni-wuppertal.de/Acta/AE1710.pdf#page=14>. Consulted September 1, 2018.
- Keill, John. 1725 [1701]. *Introductiones ad veram Physicam*. Lugduni Batavorum: Apud Joh. et Herm. Verbeek.  
URL: <https://www.e-rara.ch/zut/wihibe/content/titleinfo/453961>. Consulted September 1, 2018.
- Kuukkanen, Jouni-Matti. 2018. Editorial: Can History be Used to Test Philosophy? *Journal of the Philosophy of History* 12(2): 183–190.
- Leibniz, Gottfried Wilhelm. 1715. *Initia rerum mathematicarum metaphysica*. In: *Mathematische Schriften*, ed. by Carl Immanuel Gerhardt, vol. 7. Hildesheim: Olms, 17–29.
- Locke, John. 1700 [1690]. *Essai philosophique concernant l'entendement humain*. Sur la quatrième édition, revue, corrigée, & augmentée par l'auteur. Amsterdam: Henri Schelte.  
URL: <https://www.e-rara.ch/doi/10.3931/e-rara-24288>. Consulted September 1, 2018.
- Newton, Isaac. 1726. Scholium. In: *Philosophiae Naturalis Principia Mathematica*. London: Apud Guil. & Joh. Innys. The Newton Project.  
URL: <http://www.newtonproject.ox.ac.uk/view/texts/normalized/NATP00085>. Consulted September 1, 2018.
- Newton, Isaac. 1972 [1726]. *Philosophiae Naturalis Principia Mathematica*. 3rd ed., with variant readings. 2 vols., ed. by Alexandre Koyré & I. Bernard Cohen. Cambridge: Cambridge University Press.
- Newton, Isaac. 1999. *Mathematical Principles of Natural Philosophy*. 3rd ed., trans. by I. Bernard Cohen and Anne Whitman, assisted by Julis Budenz. With an introductory “Guide to Newton’s *Mathematical Principles of Natural Philosophy*”, by I. Bernard Cohen. Berkeley: University of California Press.
- Reichenberger, Andrea. 2016. *Émilie du Châtelets „Institutions physiques“*. Über die Rolle von Prinzipien und Hypothesen in der Physik. Wiesbaden: Springer.
- Reichenberger, Andrea. 2018. Émilie Du Châtelet’s Interpretation of the Laws of Motion in the Light of 18th Century Mechanics. *Studies in History and Philosophy of Science Part A* 69: 1–11.
- Schepers, Heinrich. 2006/2007. Neues über Zeit und Raum bei Leibniz. *Studia Leibnitiana* 38/39: 3–18.
- Schickore, Jutta. 2018. Explication Work for Science and Philosophy. *Journal of the Philosophy of History* 12(2): 191–211.
- Stachel, John. 2006. Albert Einstein: A Man for the Millenium? *A Century of Relativity Physics: XXVIII Spanish Relativity Meeting - ERE 2005. Proceedings of AIP Conference Series, Vol. 841, held 6-10 September, 2005 in Oviedo, Spain*. Edited by Lysiane Mornas and Joaquin Diaz Alonso. Melville, NY: American Institute of Physics, 195–227.
- Stan, Marius. 2018. Emilie du Chatelet’s Metaphysics of Substance. *Journal of the History of Philosophy* 56(3): 477–496.
- Thönes, Adelheid. 1908. *Die philosophischen Lehren in Leibnizens Théodicée*. Halle: Niemeyer.
- Wolff, Christian. 1710. Letter to John Keill. *Acta eruditorum* Feb., 78–80.  
URL: <http://www.izwtalt.uni-wuppertal.de/Acta/AE1710.pdf#page=83>. Consulted September 1, 2018.
- Wolff, Christian. 1713. *Elementa matheseos universae*. Halle: Regner.
- Wolff, Christian. 1720. *Vernünfftige Gedancken von Gott, der Welt und der Seele des Menschen, auch allen Dingen überhaupt*. Halle: Regner.

- Wolff, Christian. 1730. *Philosophia prima, sive ontologia*. Frankfurt/Leipzig: Regner.
- Wolff, Christian. 1709. *Aerometriae Elementa*. Leipzig : Lanckisch.  
URL: <http://digitale.bibliothek.uni-halle.de/vd18/content/titleinfo/9598483>.  
Consulted September 1, 2018.
- Wüthrich, Christian. 2017. Philosophie der Physik. In Simon Lohse, Thomas Reydon (eds.): *Grundriss Wissenschaftsphilosophie: Die Philosophien der Einzelwissenschaften*. Hamburg: Meiner, 221-228.
- Zinsler, Judith P. and Bour, Isabelle. 2009. *Emilie Du Châtelet. Selected Philosophical and Scientific Writings*. Chicago: University of Chicago Press.
- Zinsler, Judith P. 2006. *La dame d'esprit: A Biography of the Marquise Du Châtelet*. New York, NY: Viking.

## Further Internet Sources

- English Translation of Émilie Du Châtelet's *Foundations of Physics*. Notre Dame Group; direction: Katherine Brading. URL: <https://www.kbrading.org/translations>. Consulted September 1, 2018.
- Online Reading Guide on Émilie Du Châtelet's *Foundations of Physics*. Project Center for the *History of Women Philosophers and Scientists*, Paderborn University, Germany.  
URL: <https://historyofwomenphilosophers.org/projects-2-0/du-chatelets-foundations-of-physics>. Consulted September 1, 2018.