

# Science and the Principle of Sufficient Reason: Du Châtelet *contra* Wolff

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*Abstract:* I argue that Émilie Du Châtelet breaks with Christian Wolff regarding the scope and epistemological content of the principle of sufficient reason, despite his influence on her basic ontology and their agreement that the principle of sufficient reason has foundational importance. These differences have decisive consequences for the ways in which Du Châtelet and Wolff conceive of science.

Principles of sufficient reason dictate that everything in a certain domain has a reason or ground. Already among early modern rationalists, there was disagreement over how such principles are to be understood and what might follow from them. While their domain might encompass everything in general, many early modern thinkers preferred principles with a more restrictive scope. As the noncommittal reference to reasons *or* grounds in my formulation suggests, opinions also differed on what epistemological and metaphysical consequences could be drawn from principles of sufficient reason (Carraud 2002).

Émilie Du Châtelet prominently discusses a Principle of Sufficient Reason (PSR) in her 1740 *Institutions de Physique*. The PSR plays a systematically important role in her account of understanding and of science, and also backs more specific philosophical commitments.

Du Châtelet sometimes called the *Institutions* her *Essay on Metaphysics*, and its metaphysical commitments are plainly influenced by Christian Wolff, who took his own PSR to have decisive consequences for science.<sup>2</sup> The *Institutions* largely adopts his ontology of substances, accidents, and modes, as well as his idea that some fundamental substances, though not mind-like, are simple and non-spatiotemporal (1720, §900; 1725a, I.23; Stan 2018).

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<sup>2</sup> She used this title when sending a copy of the work to crown prince Frederick, soon to become Frederick II, in April 1740 (Du Châtelet 2018, I:576). By January 1737, Du Châtelet possessed a French translation of the first 190 sections of Wolff's 'German Metaphysics,' which Frederick had commissioned (for details see Neumann 2014). She also corresponded with Wolff himself. Unfortunately, their letters are now mostly lost (Droysen 1909; Böttcher 2013, 251–54; Reichenberger 2016, 67–72). The surviving letters show that Wolff facilitated the rapid publication of a German translation of the *Institutions* (Du Châtelet 2018 II.30; II.71; II.482).

Wolff also seems to have influenced the dynamics of the *Institutions*, which embraces Leibnizian *vis viva* and argues against action at a distance (Reichenberger 2016, 230–244; Stan 2017, 2018). Finally, some of Du Châtelet’s arguments for the PSR seem to be influenced by Wolff.

So it would be natural to assume Du Châtelet and Wolff have similar conceptions of the PSR and its consequences. This assumption is common in the literature on Du Châtelet.<sup>3</sup> In fact, as I will argue, this natural assumption is incorrect.

The issue has broader significance. Both philosophers, for example, take the PSR to play a pivotal role in science. Each takes *understanding* to be an epistemic aim of science, and the PSR spells out what understanding amounts to. Because Wolff and Du Châtelet were influential, their views on the PSR are also of broader historical interest. Du Châtelet’s conception of hypotheses, which builds in her account of the PSR, was influential in France and Germany.<sup>4</sup> Wolff inspired a philosophical school. As late as 1790, Kant felt the need to respond at length Eberhard’s defense of a Wolffian account of the PSR.

I focus on laying out three key points of difference between Wolff’s and Du Châtelet’s conceptions of the PSR.

First, Du Châtelet takes the PSR to have a distinctively narrow scope (see section I). She takes the PSR to range over contingent proposition or truths. Wolff takes the PSR to range over possible properties, rather than propositions, and some of the relevant properties exist necessarily.

Second, Du Châtelet has a different conception of the reasons and type of understanding stipulated to exist by the PSR. Therefore, she has a different account of the principle’s epistemological and explanatory implications (section II). Her principle, in the first instance, concerns our understanding of truths or propositions, rather than possible properties. Understanding is conceived in terms of answers to questions and need not be transitive. Wolff, by contrast, takes paradigmatic reasons to be properties and causal relations. These include the active causal powers of substances. He makes scientific understanding depend on a true account of such properties. For Wolff, causal relations are always based in the active causal powers of substances. Therefore, this causal understanding requires accurately representing essences and their associated natural kinds. Since causal relations are transitive, and scientific understanding involves truly representing such relations, scientific understanding for Wolff is transitive as well.

Third, Du Châtelet consequently declines to draw three important Wolffian implications for scientific inquiry from the PSR (section III). Wolff defines science as a demonstrative system, one that is maximally certain and truly describes fundamental essences by way of real definitions. Wolff’s PSR plays a key role in backing this ambitious conception of science: it is needed to prove that real essences exist, and shows that we can represent these essences and their connections in a unified deductive scientific theory. By contrast, since Du Châtelet’s PSR only pertains to the contingent, ranges over propositions rather than their referents, and fails to guarantee a grasp of transitive real grounding relations, it is not apt to

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<sup>3</sup> See Heilbron (1982, 37), Moriarty (2006, 204), Reichenberger (2012, 162), and Prunea-Bretonnet (2018).

<sup>4</sup> See Reichenberger (2016), Böttcher (2019), and Paganini (forthcoming).

back such an ambitious conception of science. Though she thinks the PSR plays a pivotal role in scientific practice, Du Châtelet does not endorse Wolff's ambitious conception of science.

## I. SCOPE

Wolff's PSR, we will see in this section, ranges over the *properties* of all possible objects, including necessary properties. These also include the causal powers of actual concrete substances.

Meanwhile, Du Châtelet takes the PSR to range over *truths* rather than properties, and specifically over contingent, not necessary, truths. So she has a distinctive conception of what might be called the *objective* scope of the PSR. It also bears mentioning that Du Châtelet restricts the kind of rational agent for whom the PSR legitimately holds, though this question of the *subjective* or agential scope of the PSR will not be my focus here.<sup>5</sup>

We can begin with Wolff's definition of philosophy in general as the science of the possible. Given that actuality entails possibility, philosophy is also the science of the actual (1720, §15; 1726/1965, §29; Ecole 1997, 171–74). General metaphysics or ontology deals with the possible in general, while special metaphysics concerns specific domains of possible entities (Vollrath 1962; Courtine 1990).

What is possible is determined by simple positive properties of possible beings, and compatibility and incompatibility relations among these properties.<sup>6</sup> These properties and relations make up essences that can be grasped by our faculty of understanding and expressed by real definitions (1720, §277; §544). It is in virtue of standing in compatibility relations that simple properties combine into consistent essences. In turn, anything possible in this internal sense is a being: "*quod possibile est, ens est*" (1730/2001, §135; 1720, §16). That is, if compatibility relations obtain between some properties, then these properties constitute an individual being (1730/2001, §§134–35). The internal possibility of individuals I focus on here must be distinguished from the question of their *compossibility*, that is, which collections of possible individuals make up possible worlds (Leibniz 1969, 661–62).

Wolff regards a being or *ens* in this sense as a possible individual substance: if actualized, an *ens* would have being *per se*, though as a mere possibility it inheres in the divine intellect (1730/2001, §771). For example, Julius Caesar is a possible individual substance or *ens per se*. Caesar is an *ens* independent of God's choice whether or not to create a world that actually contains Caesar.

For Wolff, essences are the source of necessity in the actual created world. His principle of sufficient reason stipulates that the resulting necessary connections are understandable in principle (Wolff 1720, §33–34; §38; §176). These necessary connections

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<sup>5</sup> On the limited agential scope of the PSR in Du Châtelet, in contrast with Descartes and Leibniz, see Amijee (2021) and Wells (2021). Wolff's position on this issue is hard to pin down. He sometimes links the PSR and the principle of contradiction to the "nature of human beings" (1724, §30; 1730, §27; §§827–35). But given that Wolff thinks these primary principles legitimately hold for God, on a charitable reading, such passages concern how we humans discover these principles (1720, §952–53; §981)

<sup>6</sup> Wolff assumes that some simple positive properties are mutually incompatible (1720, §163). Meanwhile Leibniz sometimes suggests, as at 'Monadology' §45, that all simple positive properties are internally compatible, just because they are unanalyzable and "without any negation" (1969, 647; 167–68). This suggestion was enthusiastically taken up by Baumgarten, who appealed to it in an ontological argument (Henrich 1960, 64–5).

include the relations by which essences ground other properties of substances: the attributes or *propria*. If *F* is an attribute or *proprium* of *x*, then *F* is wholly grounded in *x*'s essence, and *F* is just as “necessarily” present in *x* as is *x*'s essence itself (1720, §44; cf. Du Châtelet 1740, III.42). In contemporary terminology, Wolff's essence–*proprium* distinction is hyperintensional, since it cannot be captured modally. He instead draws the distinction in terms of explanatory asymmetry. Essential properties explain or ground *propria*, but not vice versa.

Wolff also takes up the idea, already found in Aristotle, that general metaphysics articulates the principles of beings in general (Aristotle 2016, 1005a27–36). Wolff's two principles of ontology are the principle of contradiction and the PSR. These principles hold at least of all possible finite entities.

Since Wolff takes the principle of contradiction to have ontological significance (1720, §12), we might expect it to fix all necessary properties of possible finite entities. But in his view, the principle of contradiction cannot always settle whether it is possible for a being to have a certain set of properties. The principle of sufficient reason is also needed. For example, a round square is logically impossible, but a table can be square at one time and round at another (1720, §13; 1730/2001, §774). So when we turn to a more controversial case, such as Wolff's thesis that even God could not give a body a power to think, a mere appeal to the principle of contradiction will not settle the issue (1720, §738–41). We need further justification for taking this case to be like that of the round square, rather than that of the table that changes shape over time, and Wolff thinks this justification will appeal to the PSR.

What Wolff seems to be confronting here—though he is not explicit about it—is the fact that compatibility and incompatibility relations among possible properties cannot be explicated merely in terms of analytic concept containment and the principle of contradiction. The putative analytic truth *All bodies are extended*, for example, presupposes that the property *<extended>* is contained in the set of compatible properties holding of all bodies. It must be possible for an individual to exist that exemplifies every property in this set. So the compatibility of *<extended>* with other properties of body is not itself an analytic truth. Likewise, even granting that the principle of contradiction has ontological significance, the underlying compatibility or incompatibility of primitive properties will not depend on the principle of contradiction alone.<sup>7</sup>

To handle this, Wolff turns to the PSR. His PSR explains both the compatibility relations among simple properties, and the way in which essences ground their consequences (1720, §§29–30). Yet he is still dealing with the consequences of substantive facts about essences. Substantive facts about essences are necessary, and the grounding relations they bear to their consequences are necessary as well (1720, §32; §10; §§35–38). Therefore, his PSR holds of necessary as well as contingent properties.

For illustration, let's return to Wolff's table example. Since the table is made of matter, its essence is its mode of composition out of simple substances or elements (1720, §59; §603; §611, 1725b, §1, 1737, §221). Its mode of composition fixes the table's attributes, such as

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<sup>7</sup> On this point see Kant (1992, 2:77–82) and Russell (1900/1992, 16–23). Muratori and Meliadò (2021) discuss the ontological and theological import of the principle of contradiction among northern Renaissance thinkers who may have influenced Wolff.

size, shape, and filling space (1720, §73). As “grounded in” the “essence” of a merely possible table (“*in seinem Wesen gegründet*”), these attributes follow necessarily, whether or not the table actually exists. That is, since the essence of a possible table is based on essential properties of possible simple substances, the very possibility of the table is grounded in these simple substances. Yet Wolff stresses that the elements provide not just a logical ground but a “sufficient reason” for the possibility of composite entities (1730/2001, §673).

Although Wolff connects the PSR with contingency in a few passages (e.g. 1737, §117), he is not restricting its scope to contingent facts. Rather, he is indicating that the PSR ranges over both contingent facts and necessary facts. The deeper point is that the principle of contradiction, which only ranges over necessary facts, cannot sufficiently determine God’s choice to create the actual world. Divine choice is further determined by the PSR and by the desire to create the greatest perfection (1720, §981; §989; cf. Leibniz 1969, 311).

Why does Wolff accord the PSR such a broad scope? Unlike Leibniz, Wolff claims to derive the PSR solely from the principle of contradiction and the definition of ‘sufficient reason’ (Look 2011, 210–12; Perin 2015).<sup>8</sup> Therefore, Wolff’s PSR is supposed to inherit the logical necessity and maximal generality of the principle of contradiction.

There is evidently some instability in Wolff’s position. While he claims to derive the PSR from the principle of contradiction, we’ve seen that he also presents it as having substantive non-logical implications. Moreover, while Wolff’s PSR holds of some divine properties, God’s necessary existence is singled out as not apt for further explanation (Wolff 1725a, I.47; cf. Leibniz 2001, 309). The array of simple positive properties of possible beings also seems to lack “further reason,” aside from the nature of the divine understanding (1720, §32). This implies that some properties are not subject to the PSR, despite Wolff’s official presentation of the PSR as maximally general and logically necessary.<sup>9</sup> For our purposes, these problems can be left aside. The key point is that even if Wolff’s PSR is not maximally general, and if Wolff’s arguments for his position are obscure, his PSR is still much *more* general than Du Châtelet’s.

A more direct objection to my reading might be suggested by a passage where Wolff equates the PSR with the principle that nothing comes from nothing (1720, §30). An *ex nihilo nihil fit* principle appears to be restricted to actual, concrete things that come into being and pass away. If so, Wolff’s PSR would have a restricted scope as well. But appearances are misleading. Wolff in fact defines ‘nothing’ as “that which neither is, nor is possible” (§28). Wolff exploits this definition to argue that it is a *logical* truth that nothing comes from nothing. Denying the *ex nihilo* principle turns out to be “contrary to the principle of

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<sup>8</sup> Leibniz also regards the PSR and the principle of contradiction as foundational (Leibniz 1969, 646; 2001, 303–5). Leaving aside the disputed question whether Leibniz takes the PSR to be demonstrable, he presents it as logically contingent, at least in its unrestricted form (Bender 2016, 232–42; Pikkert 2021). So Leibniz would not agree with Wolff that the PSR follows merely from the principle of contradiction and the definition of ‘sufficient reason.’ A further complication is that Wolff seems to think the in-principle analyzability of concepts into simple components—which he regards as a Leibnizian doctrine—supports the logically necessary status of the PSR (Tonelli 1976; Leduc 2013).

<sup>9</sup> Compare Schopenhauer’s objection to cosmological arguments: the PSR “is not so obliging as to allow itself to be used like a hackney cab, which one can send off after one reaches one’s destination. It is much more like the broom brought to life by Goethe’s sorcerer’s apprentice, which once set in motion will not stop running” (1813/2012, 41).

contradiction” (§28; Ecole 1997, 91). This principle ranges over atemporal possibilities which are not efficiently caused. Wolff identifies the *ex nihilo* principle with the PSR in order to support his view that the PSR is itself a logical truth, so the objection fails.

Let’s turn to Du Châtelet. She too takes the principle of contradiction and the PSR to be the fundamental principles of philosophy, and of our reasoning in general. Yet her PSR ranges in the first instance over *truths*, specifically over judgments or propositions that an “intelligent being” can “understand” (1740, I.9).<sup>10</sup> True propositions correspond to facts or objects—at least on the plausible assumption that Du Châtelet endorsed a correspondence account of truth.<sup>11</sup> So, indirectly, the PSR often has implications for how facts and objects hang together. For example, Du Châtelet stresses that there must be a sufficient reason for motion, and refers to the PSR in her second law of motion (1740, XI.227–229). Nevertheless, the definition of ‘sufficient reason’ will need to make reference to agents that can understand or cognize truths. That motion has a sufficient reason is not just a physical fact, but a complex conjunction that also includes facts about the capacities of intelligent beings.

Moreover, Du Châtelet’s statement of the PSR refers to understanding. In the next section, I argue that on her view, truth is neither necessary nor sufficient for understanding. The key point to note for now is that if understanding does not necessarily involve truth, propositions can enable understanding even when they do not truly represent objects and facts.

Du Châtelet also restricts which truths fall under the PSR. She holds that “all contingent truths,” rather than all truths in general, “depend” on the PSR (1740, I.8; III.45; III.45). Neglecting the distinctive need for a principle of contingent truths led ancient thinkers into error on “the most important points of philosophy” (I.7). Necessary truths in logic and mathematics, as well as necessary truths about essences, by contrast depend merely on the principle of contradiction (I.7–8; III.41; 1738–40, fol. 27r; compare Leibniz 1969, 677).

It could be that for Du Châtelet, *only* contingent truths depend on the PSR. But my argument requires only the weaker claim that the primitive essential properties of possible things, and their compatibility or incompatibility relations, do not fall under the PSR’s scope. Like Leibniz and Wolff but unlike Descartes, Du Châtelet takes an intellectualist view on the essences of possible things (III.48–49; cf. Descartes 1897–1919, I:145; I:152). Essences are the way they are, and that is not apt for further explanation. Nevertheless, the essences of possible things are contained or grounded in the divine understanding (1740, II.25; 1742, III.50; 1738–40, fol. 64v). Thus, some truths about God are not apt for further explanation. They do not fall under the scope of the PSR (1740, III.41). By contrast, it is contingent that God chooses to

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<sup>10</sup> Du Châtelet draws metaphysical consequences from the PSR. This might be taken to indicate that her PSR has a metaphysical aspect or “face” (Brading 2019, 38), alongside non-metaphysical aspects or modes of presentation (as Maja Sidzińska has suggested in conversation). My view, which I can’t fully defend here, is that these metaphysical consequences depend on intermediary premises, especially concerning God as creator. Creation depends not just on the PSR but on God’s freely choosing to create the most perfect and plentiful world. The PSR is therefore not sufficient to bridge the gap between truths in God’s understanding and facts in the created world.

<sup>11</sup> The influential Port-Royal *Logic* sometimes treats truth as correspondence between singular ideas and objects, rather than between propositions and facts (Arnauld and Nicole 1996, 32; 92–93). Küne (2003, 94–112) discusses such ‘objectual’ accounts of correspondence truth, which date back at least to Aristotle.

create the actual world, actualizing some essences rather than others (II.23). The contingent truths describing this choice do fall under the PSR.

## II. CONTENT

Wolff and Du Châtelet each connect the PSR to understanding or comprehension.<sup>12</sup> But they mean different things by this—as might be expected, given that they take the principle to range over different kinds of subject matter. I’ll defend a reading of Wolff on which reasons, the objects of understanding, include concrete causal powers and relations. For Du Châtelet, meanwhile, reasons are in the first instance truths or propositions.

I argued above that Wolff’s PSR ranges very widely over properties. Now I want to focus on a more specific case: real grounding relations among actual things. By this I mean a relation of dependence that is not merely logical and semantic. For example, a real grounding relation obtains between efficient causes and their effects, whereas logical consequence is a grounding relation that holds between truths. For current purposes, we can assume that Wolff distinguishes real grounding relations from logical and semantic relations, even if he closely ties the semantic to the metaphysical.<sup>13</sup> We’ll see that Wolffian reasons include real grounds: the active causal powers of substances. These powers in turn underwrite relations of cause and effect.

Wolff does distinguish between reasons and causes. He cautions against equating his principle of sufficient reason with the scholastic “axiom” that nothing is without a cause (*nihil esse sine causa*) (1730/2001, §71). Wolff may seem, as on a reading defended by Schopenhauer (1813/2012), to be sharply differentiating logical or semantic reasons from efficient causes. But when we examine his denial that reasons should be identified with efficient causes, it becomes clear that Schopenhauer’s reading is not tenable. Instead, neither reasons nor causes should be read as merely semantic: both reasons and causes are involved in the causally efficacious features of the concrete world.

To see this, consider one of Wolff’s examples of the application of the PSR: “If I investigate how it transpires that everything grows quickly in a garden, and find that it is to be attributed to the warmth of the air, then the warmth is the reason [*Grund*] of the fast growth, and the air, insofar as it is warm, is the cause [*Ursache*]; the fast growth, however, finds its reason in...the action of the warmth” (1720, §29; the translation follows Dyck 2020, 101, with modifications).

Here we want to explain the rapid growth of plants in a garden. We assume that this growth does not depend solely on the self-sufficient action of the plants themselves, but has external grounds (§104). Roughly, the plants are growing rapidly because the nearby air is

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<sup>12</sup> Du Châtelet uses the verb ‘*comprendre*’ (1740, I.8). Wolff employs ‘*begreifen*’ and, in his Latin ontology, ‘*intelligere*’ (1720, §30; 1730, §68ff.). Given the way Wolff connects the PSR to knowledge of essences, it is noteworthy that medieval Latin thinkers, appealing to a spurious etymology, sometimes depict *intelligere* as *reading* (*legere*) into the essence of a thing (e.g. Aquinas, *De Veritate* I.12).

<sup>13</sup> Bouton (1996) and de Boer (2020, 25) instead suggest that Wolff collapses semantic and real grounding relations. There is no need to settle this interpretive question here. Given that Du Châtelet does not collapse these types of relation, a ‘collapse’ reading is in no conflict with—and might well strengthen—my thesis that there are major differences between Wolff and Du Châtelet regarding the content and implications of the PSR.

warm. This is a rough answer because in Wolff's view, it states both an efficient cause and a reason.

Considering a few other features of Wolff's account of causation will be helpful at this point. All changes are grounded in causal powers or forces (*Kräfte*) (Wolff 1720, §115). Strictly speaking, the bearers of causal powers must subsist by themselves, rather than through others (§115). God, souls, and simple elements are the only beings that subsist in themselves. So in metaphysical strictness, only God, souls, and simple elements are causally active (§116). What I've called real grounding relations must ultimately be based in these primary substances, which we usually cannot observe.<sup>14</sup>

How can Wolff characterize the warm air in the garden as a cause, given that the air is a mere composite and not a primary substance? He treats material entities, such as plants or the air, as substances by courtesy or *phenomenal substances*. This allows material entities to be described as bearing causal powers and engaging in causal activity, by analogy with fundamental substances.<sup>15</sup> So Wolff's statements that if *x* is a phenomenon, *x* is not *real* should be interpreted as restricting unqualified reality to fundamental, primary substances (1737, §225). In a looser sense, phenomenal substances are comparatively real. For example, they are more real than dreams or figments of the imagination.

So in the passage quoted above, given his theory of causality, Wolff is plausibly identifying the *cause* with a phenomenal substance, namely the air around the plants. The *reason* for the rapid growth of the plants, meanwhile, is not the air itself but the "action of" the air's warmth. This is the active exercise of a causal power. Although the air bears the power, it is not the air as such but *its exercise of* the power that brings about effect we seek to understand.

This reading is supported by another of Wolff's examples. An architect plans the construction of a house (1730/2001, §881). The existence of the house depends on the architect as its cause (*causa*). The reason (*ratio*) for the building, meanwhile, is not the architect as such but the architect's "idea" of the house, plus the intention to build it (§881).

In contemporary terminology, we might call a Wolffian reason a causal difference-making feature. In Wolff's examples, reasons are contingent causal properties of substances. If the same air were cool, it would not have the effect of making the garden grow more quickly. And the architect might make different plans, such that a different house would be built.

We needn't resolve all interpretive questions about Wolff's reason-cause distinction to see that reasons, on his view, have mind-independent causal consequences. Reasons are in

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<sup>14</sup> A key exception is privileged first-person access to our souls, although this is not relevant to the example under consideration here (1720, §6–7; §§194–97; 1725a, V.1–2). As de Vleeschauwer (1932, 676) explains, Descartes's ideas were integrated into the Scholastic curriculum in German lands, and influenced Wolff on this and other points.

<sup>15</sup> For the view that material beings—though they are not primary substances—can be treated as phenomenal substances with causal powers, see Wolff (1725a, I.48, 1720, §59; §64ff.; §76; §593, 1730, §784; §789; §794; 1737, §164–5; §177; §199); compare Leibniz (1989, 87–88), Du Châtelet (1740, II.20; II.21; III.52; VIII.156), and the early Kant (1992, I:141; I:148). Phenomenal substances have only a derivative essence: their mode of composition out of simples.

an important sense causal, although we've seen that Wolff distinguishes them from causes. Reasons only mediately serve as the basis for knowledge, inference, and so forth.

An important consequence is that the reasons relevant to the principle of sufficient reason are transitive. This follows from the transitivity of efficient causation (and of some other real grounding relations, such as composition). Consider a billiard cue that causes a white ball to move, which then sets a red ball in motion by colliding with it. The cue, Wolff would say, is the transitive cause of the red ball's motion. This is so in virtue of the cue's exercise of a causal power (in this case a nonfundamental, phenomenal power) (1720, §607). So the causal powers of the cue are both a ground or reason for the white ball's motion and, transitively, a ground or reason for the motion of the red ball. A proper scientific account of these motions requires accurately representing transitive causal relations and the underlying substances and powers. There is only a restricted epistemic role for propositions that do not represent substances, powers, or real grounding relations.

Turning to Du Châtelet, we've seen that on her view, the reasons invoked by the PSR are in the first instance propositions or judgments. The PSR is a "source of our reasonings [*raisonemens*]," as opposed to a source or principle of real grounding relations (1740, 25). Or, in the terminology of the Port-Royal *Logic*, the PSR is a rule for thoughts or judgments, and for mental acts associated with them (Arnauld and Nicole 1996, 15; 23). The reason for the proposition that the plants in the garden grow quickly would be, in the first instance, the proposition that the air is warm.

Du Châtelet does speak of *truths* in this context. Propositions in science aim at the truth, and so are sensitive to real grounding relations. So in some cases, such as in the billiard-ball example, her account will coincide with Wolff's. Both philosophers agree that understanding the motion of the billiard balls at least requires giving a more or less true account of efficient causes. Du Châtelet would grant that, as Leibniz put it, "a reason in the realm of truths" often "corresponds" to, or represents, a "cause" (Leibniz 1996, 475)

If we look at Du Châtelet's account of the PSR, however, we find that a proposition's truth is neither sufficient nor necessary for it to "make us understand" as the PSR requires (1740, I.8). These are important differences from Wolff's account. A proposition's truth, first, is not *sufficient* for understanding because many truths are trivial, vacuous, or unexplanatory (1740, I.8–9). Identifying a cause or ground for a given effect need not provide a reason for that effect. For a putative cause may not enable us to "understand" the "possibility" of that effect in an adequate way (1738–40, fol. 32r; 1740, I.8–10; Detlefsen 2019; Wells 2021). Du Châtelet holds that our understanding of a truth can be advanced by fitting it into a broader theory or account. Such a broader account includes, for example, counterfactual information.

Second, it is not *necessary* for a proposition to be true for it to contribute to understanding. Strictly false propositions can provide a "reason" for what is observed, and can enable understanding (1740, IV.56). In contemporary terms, this account of understanding is *non-factive* (Elgin 2007).

This point comes out clearly in Du Châtelet's discussions of mathematical propositions. Mathematical objects are fictional abstractions from real, physical things and relations among them (V.86). Yet mathematical representations are indispensable for both everyday and scientific understanding (V.86; Wells forthcoming). The understanding that the

PSR stipulates to be possible need not be complete or comprehensive.<sup>16</sup> So even if mathematical knowledge falls short of what an ideal intellect might be able to accomplish, it still yields understanding.

Another example can be drawn from Du Châtelet's discussions of practical reasons for action, which she also links to the PSR (1740, I.8; I.II). Actions are explained in terms of agents' reasons and motivations. The reasons she has in mind may be subjective or standpoint-relative, rather than objectively conclusive reasons for action in general.<sup>17</sup> Even subjective reasons and motivations, however, aren't always transparent to the agent. Du Châtelet holds that we are persistently under the spell of practical illusions when we act. Agents' understandings of the reasons for their actions are frequently illusory, not veridical. Luckily for us, as Marcy Lascano (2021) has discussed, these illusions are often beneficial. Some illusions may even be practically indispensable. So there is a sense in which illusions enter into an understanding of our own actions, even if what they contribute is not a true description of our motivations.

An objection to my reading might take inspiration from Du Châtelet's theological commitments. While God freely chooses to create the world, the content of this choice is partly determined by the PSR (1742, II.25). This might suggest that if we reflect on the PSR a priori, we can attain determinate knowledge about the real world (cf. Leibniz 1969, 442).

As Karen Detlefsen (2019, 121–23) has argued, however, Du Châtelet is wary of such inferences. There is an important difference between establishing that the world was created in accordance with the PSR, and knowing determinately how this occurred. Moreover, even though the PSR is “primitive” or essential to our way of making the world intelligible, it does not follow that all possible worlds would be intelligible to us through the PSR (1740, I.8).<sup>18</sup> On Du Châtelet's view, it is logically and metaphysically possible for God to have created a world that is inexplicable to the minds in it, even if a perfectly good God would not choose to do so (II.23; II.28; 1989, 494–96).

So on her view, a relation of fit obtains in the actual world between cognitive agents like us, for whom the PSR holds, and extramental things that could be explained by us. It is logically and metaphysically contingent that this fit actually obtains. For Du Châtelet, the contingency of this fact is our best, and perhaps only, source of evidence that the universe was freely created by a supreme and benevolent intelligence (1740, II.23).

The PSR only guarantees the *possibility* of understanding (1740, I.8–9). The most accurate way to understand the PSR's meaning, Du Châtelet adds, is in terms of the

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<sup>16</sup> Du Châtelet may have revised early versions of the *Institutions* to clarify this point. The manuscript's definition of sufficient reason builds in *full* understanding (“*une raison qui fasse pleinement comprendre*”) (1738–40, fol. 28r; emphasis added). The published definition refers only to a reason that provides “us” with understanding, leaving room for incomplete understanding (“*une raison qui nous fasse comprendre*”) (1740, I.8). On the significance of the reference to reasons that satisfy *us*, see also Amijee (2021, 5).

<sup>17</sup> More precisely, the reasons discussed at *Institutions* I.8 are clearly subjective, whereas it is plausible that I.II treats objective reasons (as Julia Borchering has argued in work in progress). On subjective and objective reasons for action, see for example Southwood (2008).

<sup>18</sup> As Jacobs (2020, 68n13) notes, Du Châtelet often uses ‘necessary’ to mean what's primitive or essential to a kind rather than to express *de dicto* necessity (e.g. 1740, III.47). So the PSR may be necessary just in the sense of being primitive or essential to our kind of cognition. She may be influenced by the conception of *de re* necessity articulated in Descartes's 1648 “Comments on a Certain Broadsheet” (1897–1919, VIII B:347–54).

impossibility of strictly proving that any given truth about phenomena is inexplicable: we cannot prove that any given truth *lacks* a sufficient reason (I.9). As such, despite the “primitive” character of the PSR, it is psychologically possible to believe that even the *actual* world is unintelligible. We may, for example, wrongly take the overall course of the world to be based on “chance” or even on “nothing” at all (1740, I.8).<sup>19</sup>

This negative formulation of the PSR allows for the possibility that we never achieve understanding of certain features of the world. It remains an open question, for example, whether we will actually attain causal explanations of gravity, electricity, and magnetism, although natural scientists shouldn’t give up hope in this “quest” (*recherche*) (1740, XVI.399; VIII.162; IX.182–85; XVI). Such explanations won’t be found, on her view, merely by reflecting on how a wise God would have created gravity or electricity.

Du Châtelet, unlike Wolff, would not take the grounds relevant to the principle of sufficient reason to be reliably transitive. Explanations further our understanding, and understanding involves answering questions. Specifically, she links understanding to answering questions about “how and why” phenomena take place (1740, I.8). The answers are often contrastive, in that they indicate why some other possibilities did *not* obtain. Successful answers to such questions may be relative to particular kinds of agent: for example, to the cognitive capacities of finite knowers (I.8–10).

Judgments of explanatory success may be further relativized to the data available during a certain historical period. For centuries, Ptolemaic astronomy was the best available cosmological system given the empirical data and mathematical techniques available (1740, IV.57–58; V.86). And Du Châtelet mixes her criticisms of Descartes’ mechanistic hypotheses with an acknowledgment that “necessarily,” there is a high chance of error early in the development of a scientific discipline (IV.54). Analogously, often one “cannot” find the best path to a destination except by trying out many options (IV.54). With better data and more advanced mathematics, better explanations eventually become available.

In turn, there is no reason to expect that transitivity will always obtain among explanations or states of understanding, if these are taken to be answers to ‘how’- and ‘why’-questions. Since every such question has a more or less specific scope that limits the set of relevant answers, success in answering these questions will not be reliably transitive.<sup>20</sup> We saw that for Wolff, by contrast, understanding truly represents transitive real grounding relations, and inherits their transitive structure.

To be sure, one can frame success in answering such questions in terms that are context- and subject-independent. Wolff, Leibniz, and (perhaps) Aristotle did so.<sup>21</sup> But it is

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<sup>19</sup> Du Châtelet may, however, consider it psychologically impossible to regard *each and every* occurrence in everyday life as groundless (1740, I.8–9). Like Arnauld and Nicole (1996, 7), she doubts that radical skeptics sincerely apply their skepticism to foundational beliefs involved in everyday life; similar doubts were later raised by Hume in §XII of the *Enquiry Concerning Human Understanding*.

<sup>20</sup> In the recent literature, Daly (2005, 94ff.) and Thompson (2019) helpfully discuss transitivity in the context of explanation and real grounding.

<sup>21</sup> Wolff takes the PSR to indicate why certain essences are possible, in terms of possible properties and their (in)compatibility relations (1726/1965, §29, §31, §33). Leibniz mostly elaborates such ideas privately, as in a 1706 draft letter to Sophie, Electress of Hanover (2011, 355ff.), though they are mentioned without further explanation in some published works (e.g. ‘Monadology’ §32). On why-questions in Aristotle, see further Lennox (2021).

uncontroversial that for Du Châtelet, success in answering how- and why-questions depends on features of our cognitive capacities, and perhaps on other contextual features as well.<sup>22</sup> This is so even though explanations that successfully enable understanding, and the theories into which they are systematized, need not *represent* cognitive capacities or contextual facts. Explanations may primarily represent causal features of the physical world, even though they do not enable understanding solely in virtue of this representation.

### III. CONSEQUENCES

Wolff takes the PSR to have important implications for science. He regards science as deductive. It is supposed to yield universal and certain knowledge, which gets at real essences. These are key features of what might be called the *Wolffian paradigm* of science, to borrow a phrase from Lanier Anderson (2005). I have in mind a set of views plausibly drawn from Wolff's foundational works from the 1710s through 1730s, such as the 'German Metaphysics,' *Discursus Praeliminiarius*, and revised editions of the 'German Logic.'<sup>23</sup>

Like many of his readers, Du Châtelet sees Wolff as advancing this ambitious paradigm of science.<sup>24</sup> But she denies that Wolff or anyone else has achieved a deductive method in metaphysics (1740, Avant-Propos.XII; 2018, I:592–93). She does not, in fact, accept Wolff's model of science. This is in part because of her different conception of the scope and content of the PSR. To be sure, her account of empirical science is also shaped by other philosophical commitments that raise obstacles to science in the strict Wolffian sense. Here I focus on what follows, or does not follow, from each philosopher's conception of the PSR.

Science for Wolff is a single, integrated system of knowledge. So science includes philosophy as well as more familiar empirical disciplines. Complete certainty, rather than mere likelihood or probability, is required throughout science in the proper sense. Certainty is to be achieved by deductions from real definitions that express essences, which Wolff takes to be as rigorous as Euclidean proofs (de Vleeschauwer 1932; Frketich 2019). As he puts it: "By science...I mean the habit of demonstrating propositions, i.e., the habit of inferring conclusions by legitimate sequence from certain and immutable principles." (1726/1965, §30–31; cf. §135, 1725a, Vorbericht.2; VII.1). Or elsewhere: "We *know* something when it is derived from indubitable first principles by means of correct inferences. And one calls the facility in deriving what one maintains from indubitable principles, by means of correct inferences, *science*." (1720, §361 [tr. Dyck 2020, 114]).

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<sup>22</sup> "Du Châtelet's conception of a sufficient reason...seems to make what qualifies as a sufficient reason contingent on human psychology: the kind of reason that satisfies us at once time need not be the reason that satisfies us at another time" (Amijee 2021, 5; see also Brading 2019, Detlefsen 2019, and Wells 2021).

<sup>23</sup> The 'German Metaphysics' is the work Du Châtelet knew best, by her own account. She writes to Johann II Bernoulli on June 30, 1740 that she read the 'German Metaphysics' and consulted it directly while writing the *Institutions*, whereas she learned about Wolff's Latin works through select extracts (Du Châtelet 2018, I:586; I:393; cf. Neumann 2014).

<sup>24</sup> For a comparable reading of Wolff, see an anonymous early review of Du Châtelet's *Institutions*, which describes Wolff's method in terms of rigorous Euclidean demonstrations. Though "difficult" to "follow," this method leads to maximal certainty and "solidity" ("Institutions de Physique" 1741, 299). A generation later, the unsigned preface to the English translation of the 'German Logic' frames Wolff's contribution as bringing geometrically rigorous demonstrations to philosophy, succeeding where Descartes and Spinoza failed (Wolff 1770/2003, xlvi–xlii).

The second quotation indicates that Wolff links his conceptions of knowledge [*Wissen*] and science [*Wissenschaft*]. All knowledge is either an indubitable first principle or is “deduced from undoubted grounds through correct syllogisms,” as part of rational science (1720, §361). Here we see the influence of traditional ideals of deductive *scientia* or *epistēmē*, dating back to Aristotle’s *Posterior Analytics* and *Topics*.<sup>25</sup>

In the order of discovery, Wolff grants, we often begin with perceptual experience. This point has been stressed in recent scholarship (Kreimendahl 2007; Dunlop 2019; Engelhard 2021). But for Wolff, perception is uncertain, and deals with singular or particular things (Wolff 1725a, V.2; VI.9–10). So in the order of justification and explanation, first principles must precede experience: “We philosophize in order to acquire certain knowledge of the things which we know confusedly by the senses and by reflection on ourselves.” (1726/1965; §56; cf. §33; §125). For Wolff, certain knowledge is achieved by demonstratively giving “a reason why” what we experience occurs, by way of the PSR (1726/1965, §31). “Science comes from reason,” whereas there is “no reason at all” in experience, which lacks the rational connections and “insight” demanded by the PSR (1720, §381–83; §368–71). Furthermore, the PSR validates the truth of all perceptual experience. “Without the principle of sufficient reason there can be no truth,” Wolff claims, because it is needed to distinguish objective perceptions from mere illusions or dreams (1720, §§142–45; 1730/2001, §77; Lovejoy 1906).

Wolff’s PSR underlies not only the form but also the content of rational science. Wolffian rational science is built up of syllogistic inferences in broadly Aristotelian logic (1725a, VI.iff.). These syllogisms typically put monadic natural kind predicates in analytic containment relations, though Wolff departs from Aristotle in allowing for predicates of higher adicity (Frketich 2019, 339n.16). Natural kind predicates represent the essences of things via real definitions (1720, §177).<sup>26</sup> For Wolff, relations of grounding or dependence among substances also flow from facts about their essences (1730/2001, §851–57).<sup>27</sup> Our knowledge of essences via real definitions can be completely certain, unlike merely probable empirical results (1726/1965, §125). Therefore, it meets the strictures of scientific knowledge.

The PSR is central to this account of essence, and to the claim that rational science truly represents essences. Wolff offers a proof that things have essences. The PSR is a key

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<sup>25</sup> See also Descartes’s *Rules*, especially II, V, and VII (1897–1919, X:362–93). For the *longue durée* history of this deductive model of science, see de Jong and Betti (2010) and Pasnau (2017). As Serene (1982) stresses, however, many medieval Aristotelians did not think natural science requires deductive explanations from essences. In this respect, the medieval conception of *scientia* was less ambitious than that of Descartes or Wolff.

<sup>26</sup> Wolff is a nominalist in the sense that on his view, all beings are completely determined and hence must be individuals, not universals (1730, §226; §235). These individuals need not, however, be spatiotemporally located or causally active. Some individuals are merely possible and are grounded in the divine intellect (1720, §973; §1067). Abstract *possibilia* can be instantiated by concrete particulars and hence play a similar philosophical role to traditional universals.

<sup>27</sup> For Wolff, *x* depends on *y* iff there is a reason in *y* for what is in *x*, where what is ‘in’ a being is an intrinsic property (1730, §851). This allows Wolff to hold both that there are asymmetric transitive relations between substances, and that these inter-substantial relations are grounded on substances’ intrinsic properties. That is, all relations between substances *x* and *y* are allegedly grounded in facts about dependence or independence, and in turn, facts about dependence or independence are grounded in what is *in x* and *y*. Therefore by transitivity of grounding we get the striking conclusion that all relations between *x* and *y* are grounded in what is ‘in’ *x* and *y* (§857).

premise in the proof (1720, §§32–38).<sup>28</sup> It also underlies his distinction between real and nominal essences by guaranteeing that finite things have real essences and can be given real definitions (1725a, I.47). For Wolff, a real essence involves not just independent essential properties that we can “enumerate” individually, but also irreducible compatibility and incompatibility relations among these properties (I.48). These internal relations allow us to rationally comprehend why the essence must be the way it is.

In turn, essential properties ground attributes and (the possibility of) modes, thus providing “reason” for them; a central job of rational science is to characterize these grounding relations (1725a, I.48; 1720, §§30–38; §176; §381; 1730/2001, §248). Some passages even suggest that a thinker who knew all the essential properties of actual substances would be able to logically deduce all the other worldly facts, and likewise for other possible worlds (1720, §105; 1725a, V.15).

Wolff’s conception of *scientia* has important implications for empirical science. “Metaphysics,” he asserts, “must precede physics” (1720, §95; 1730/2001, §75). The core concepts of physics, such as body, matter, and motion, are defined “in general cosmology and ontology,” understood as branches of metaphysics: these metaphysical concepts “contain the reason” for fundamental truths of physics (§94; 1726/1965, §§94–95). Since physics “depends upon ontological principles,” all of its causal demonstrations must be given metaphysical grounds (1720, §94). Metaphysical grounds are necessary if physical propositions are to be “demonstrated accurately.” (1720, §94).

There are several reasons for this. Recall that no truth is possible, on Wolff’s account, unless the PSR is used as a criterion to distinguish it from dream or illusion. Sophisticated scientific experiments are no exception. Furthermore, experiments depend on perceptual justification. So they are only ever about particulars (1720, §325; 1726/1965, §54). But scientific *demonstrations* must yield general conclusions, in Wolff’s view. He concludes that “the things which are demonstrated in physics,” namely general propositions, are merely “confirmed” or “illustrated” by “experiments” (1726/1965, §107).

The priority of metaphysics over empirical science can be illustrated by several examples. One is Wolff’s skepticism about Newtonian forces, including gravitation. Wolff denies that Newton’s *Principia* contains paradigms of physical explanation. One reason for this is that he regards Newton as a mere mathematician. As Katherine Dunlop summarizes, Wolff thinks that only “metaphysics proves what is assumed in mathematics” (2013, 465n.35). On Wolff’s reading, Newton mathematically described the regularities of motions, but failed to provide a causal and metaphysical account of nature. Hence Newtonian forces, like other mathematical objects, are merely “imaginary” (Wolff 1731/2001, 316).

Wolff concludes that key planks of Newton’s system, including gravitation, are unproven and indeed unprovable: they must remain mere hypotheses (1737, §§321–23; Stan 2017). Inferences from the properties of mathematical objects to the properties of things even

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<sup>28</sup> In a nutshell, Wolff begins by assuming that the compatibility of the properties of any (finite) possible thing is subject to the PSR (1725a, I.48). If this assumption is granted, Wolff can set up a reductio. Suppose a given possible thing did *not* have an essence. Then nothing would ground why its properties hang together the way they do, and it would be a brute contingent fact that the thing has these properties (1725a, I.47; 1720, §32). Wolff regards this consequence as a violation of the PSR for the properties of a finite possible thing, contradicting the argument’s assumption. Therefore, by reductio, any given possible thing *does* have a real essence.

lead to contradiction (1730/2001 §110–11). Since on Wolff’s view Newton’s theory is merely mathematical and imaginary, contradictions arise if it is taken to describe physical causes.

Wolff is drawing on his doctrine that possible substances are the proper subject matter of philosophy and science. Imaginary mathematical objects are not substances. Geometrical objects, for example, do not exist in nature and are no more than imaginary “images” (*Bilder*) (1725b, §4; De Angelis 2018, 346–48). Ontology is prior to mathematics, including even the first principles of Euclidean geometry (Buchenau 2013, 32–33). Wolff draws the surprising further conclusion that mathematical statements do not, strictly speaking, have a place within the deductive system of science (1726/1965, §6, §17–18; §36). The claims of mathematics only serve to make the contents of the scientific system clearer and more distinct.

What sort of metaphysical proof does Newton fail to provide, according to Wolff? Wolff offers his own derivations of the properties of matter and the laws of mechanics. These putative derivations rely on the PSR in several ways. Sometimes Wolff invokes the PSR at the level of matter or phenomenal substance, as in his attempt to derive a law of inertia, or his justification of the law of the equality of action and reaction (1720, §609; 1737, §346).

Wolff also appeals to the PSR to forge inferential links between the more fundamental level of simple substances and the phenomenal level of matter (1720, §59; §76; §86; §697). We have adequate a priori knowledge of fundamental, simple elements merely by reflection (“*durch Überlegung*”) (1720, §86). The effects of simple substances are “comprehensible in themselves” (§128). With the help of the PSR, we can achieve a priori derivations of general properties of matter—including place, extension, shape, divisibility, mobility, and continuity—from the properties of simple substances (§§50–58).

Furthermore, Wolff uses inferences from the properties of simple substances to establish principles of mechanics and dynamics. For example, he tries to prove that matter cannot move itself from the premise that simple elements possess a force of resistance (1720 §§607–608; 1737, §196). Here too Wolff invokes the PSR, and seems to regard at least some principles of mechanics and dynamics as provable a priori. As Eric Watkins summarizes, in both the ‘German Metaphysics’ and the later *Cosmologia Generalis*, “Wolff’s laws [of mechanics] are supposed to be evident on the basis of...primitive, non-empirical principles (such as the principle of contradiction and the principle of sufficient reason)” (2019, 96).<sup>29</sup>

Metaphysics even plays a key role in scientific propositions that are supported by experimental evidence. Wolff considers an air-pump experiment where a bladder expands as the air outside it is pumped away. He probably has in mind an experiment first performed by Roberval in 1648 (Webster 1965, 448–51). At the time, discussion centered on whether the experiment rules out a macroscopic void in the air-pump (Shapin and Schaffer 1985, 82–91). Especially pertinent for Wolff’s discussion, however, is Roberval’s suggestion that the experiment shows air to have a power of resilience, such that it expands when released from compression.

The general scientific conclusion Wolff derives from this experiment is expressed by the following syllogism:

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<sup>29</sup> See further Leduc (2015, 12–13) and Stan (2017). Certain passages suggest Wolff takes it to be demonstrable that simple substances follow the same laws of motion as matter (1737, §365; Rutherford 2004).

(P1) Everything that begins to expand when resistance is removed has an elastic or expansive force.

(P2) All air begins to expand when resistance is removed.

(C) All air has an elastic or expansive force.<sup>30</sup>

Notice that neither premise follows directly from a single experiment. Wolff lays this out in detail, introducing further syllogisms to prove each of the premises. The Roberval experiment supports the minor premise in the syllogism that is supposed to prove (P2). Even here, however, Wolff's derivation appeals to a non-obvious and theory-laden corollary, rather than to a direct description of the experimental observation itself (1725a, IV.25 Corr.).

Next, a general, non-empirical major premise is needed to derive (P2), which applies to all air, from a particular experimental result (1725a, IV.25 Ax.2). Only later does Wolff make explicit the crucial underlying assumption that nature is uniform, in virtue of the stable essences of natural kinds such as air and water (V.15). Given this uniformity assumption, he assures us, we can correctly move from "individual propositions" to "universal" generalizations (V.15; Frketich 2019, 342n.22).<sup>31</sup> Wolff's uniformity assumption is a priori rather than warranted by the air-pump experiment itself.<sup>32</sup>

Finally, Wolff presents (P1) as a priori. It is not supported by the Roberval experiment. Instead, Wolff's definition of 'elastic force' yields (P1) with the help of a further axiom as minor premise. Axioms, for Wolff, are immediate logical consequences of definitions, where definitions hold universally for corresponding natural kinds (V.13; IV.XLII; 1717, vol. 1, pt. 1, §31). In this case, the axiom asserts that if some *x* expands when resistance is removed, that *x* exerts a continuing endeavor of expansive force, and thereby falls under the definition of 'elastic force' (1725a, IV.25 Ax.1). This axiom might seem partly empirical. But given Wolff's definition of 'axiom,' it must merely make explicit a constituent mark that is analytically contained in the concept of elastic force (Anderson 2005; Leduc 2013).

Setting aside further details, this example illustrates how Wolff regards a properly scientific demonstration as moving from universal premises to a universal conclusion (in the Aristotelian sense of a conclusion ranging over every member of a natural kind). Wolff frames the syllogism about the air-pump as an illustration of how the methods of

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<sup>30</sup> This is a charitable reconstruction of the main syllogism in Wolff (1725a, IV.25; for further details see Frketich 2019, 340–2). While Wolff's original wording is ambiguous, he seeks a valid universal affirmative categorical syllogism (mood Barbara), showing that "air" in general "has an elastic force" (IV.25). He would not accept a particular affirmative conclusion—*Some air has an elastic or expansive force*, mood Darii—since this is consistent with most air lacking this force. So the minor premise needs to be universal. Anderson (2005, 39–40) reads the syllogism as invalidly deriving a universal conclusion from particular premises. But there is no need to ascribe such a gross error to Wolff, given his later acknowledgment that a natural uniformity principle is needed to support the minor premise (see footnote 30 below). That is, Wolff is aware that a particular confirming instance is insufficient to support a generalization, and appeals to a metaphysical assumption to bridge the gap.

<sup>31</sup> Wolff's confidence is remarkable. For on his view, the essence of water or air is just a mode of composition out of simple elements. Given this metaphysical picture, there might well be no single uniform natural kind *air*, but a spectrum of kinds (*air-1*, *air-2*, etc.), corresponding to slightly different modes of composition.

<sup>32</sup> That is, it meets standard criteria for apriority, such as being empirically indefeasible, necessary, and justified independent of perceptual experience. Wolff associates these criteria with knowledge through *pure reason* (1720, §382). I focus on the philosophical position Wolff is committed to, rather than on how he uses the term 'a priori.' Dunlop (2019, 167) suggests that Wolff idiosyncratically uses 'a priori' to cover even some empirically defeasible perceptual experience.

mathematical proof apply in empirical cases. Despite its links to experiment, the air-pump syllogism is a “geometrical demonstration” that uses “the same method” as Euclidean geometry (1725a, IV.24–25).

Wolff sees such demonstrations as maximally “convincing”: just like Euclid’s proofs, they yield certainty if we “attend to” them properly (IV.20). This allegedly mathematical method plays a key role in Wolff’s response to the objection that syllogistic demonstrations cannot yield new knowledge, but only restate or clarify what is contained in the premises (IV.24).<sup>33</sup> Mathematics shows that new theorems can be “discovered by means of...syllogisms” (IV.24; VI.6–7). So deductive inference can be ampliative, rather than merely clarifying our existing concepts.

We can now turn to Du Châtelet’s conception of science, which diverges from Wolff’s in several ways. This is in part because of her different conception of the PSR.<sup>34</sup> First, Du Châtelet does not take the PSR to support a deductive conception of science. One reason for this is that her PSR ranges over propositions and is satisfied by answering how- or why-questions in a way that enables understanding.<sup>35</sup> As I’ve argued, the answers to such questions are not transitive. Therefore, Du Châtelet’s conception of scientific understanding is not transitive, either, but depends on which how- and why-questions are being asked. Furthermore, I’ve argued that she does not take truth to be either a necessary or sufficient condition for the scientific understanding mandated by the PSR. As such, a model of science based on truth-preserving deductions from first principles will be neither necessary nor sufficient for understanding.

A second difference between the two philosophers is that for Du Châtelet, unamended non-deductive inferences and extrapolations can meet the demands of the PSR. The two philosophers seem to agree that a merely probable hypothesis only supports conditional, probabilistic claims, rather than maximal certainty (Wolff 1726/1965, §125; Rey 2016, 344–45). Unlike Wolff, however, Du Châtelet denies that it is possible for us to attain full certainty about the physical world (1740, IV.67). The claims of well-established physical theories do not differ in kind from hypotheses: they are defeasible even when highly probable. This does not conflict with her PSR, which is tied to a relatively permissive notion of understanding, rather than certain knowledge.

The point is illustrated by numerous discussions of scientific results in the *Institutions*. Du Châtelet endorses a generalization from Galileo’s experiments to claims about “all bodies, no matter their nature” (1740, XIII.300), and an extrapolation from local principles to a

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<sup>33</sup> This ancient skeptical worry about deduction was revived by modern authors such as Descartes (1897–1919, IXB:13–14).

<sup>34</sup> In Wells (2021), I further discuss the positive role of the PSR for Du Châtelet’s *Institutions*.

<sup>35</sup> Another difference—independent from whether the PSR ranges over propositions—is that unlike Wolff, Du Châtelet does not take the PSR to be derivable merely from the principle of contradiction and the definition of ‘sufficient reason.’ But in my view, Wolff could have adopted the same views on the PSR, and drawn the same consequences for science, even if he had not regarded the PSR as derivable from the principle of contradiction. Wolff thinks the PSR guarantees that the world is exhaustively structured by essences and real grounding relations; science truly represents these relations by an exhaustive system of deductively linked propositions. These metaphysical and epistemological consequences need not require the PSR itself to be a logical truth. I thank a referee for pressing me to clarify these issues.

general theory about the porosity of bodies (X.195).<sup>36</sup> Chapter XV of the *Institutions* devotes a detailed discussion to Newton’s line of argument for universal gravitation in the *Principia*, and displays a detailed understanding of his methodology (Detlefsen 2019, 110n.28). Newton’s arguments, such as the moon test, are presented as establishing *causal* conclusions in a convincing though non-deductive way (1740, XV.351–359; XVI.388). With the moon test, Newton showed that “it is the same force that keeps the moon in its orbit, and which makes bodies fall here below; and this force decreases as the square of the distance to the center” (XV.359; XV.362).

This example clarifies how Du Châtelet differs from Wolff on the epistemic value of probabilistic claims. Newton, she states several times, “demonstrated” a “universal law” of gravitation (1740, XV.344; 1738, 540). He did so even though the causes of gravity itself have not been discovered. We’ve seen that Wolff, by contrast, regards it as contradictory to predicate Newtonian forces of material objects such as the moon or earthly bodies.

In turn, important solutions to previously inexplicable problems in cosmology and terrestrial physics are “necessary corollaries of the universal attraction spread throughout matter” (XVI.388; cf. 1739, 137). Du Châtelet presents these corollaries as causal: universal gravitation explains “effects” (XVI.389). Examples include bodies falling towards the earth and the deviation of the shape of the earth from sphericity. These results “are deduced marvelously well from attraction in inverse ratio of the square of the distances” (XVI.389). Nor is this a purely mathematical procedure: Du Châtelet gives a causal and dynamical explanation of why the shape of the earth is deformed from sphericity (XV.375).

Nevertheless, Du Châtelet does not take it to be shown that attraction is either an essential property of matter, or a necessary consequence of matter’s essence (1740, V.76; XV.340; XVI.399). The second edition of the *Institutions* is more decisive, stating that attraction cannot be basic, even at the level of phenomena. We should instead assume that attraction is caused by a massless, quasi-material ether that has not yet been observed (1742, XV.340; XVI.398–99). This hypothesis is in part motivated by the principle of sufficient reason (1742, XV.340). But it would need to be tested empirically (XVI.341–42; 1738, 538–39).

By contrast, Samuel Clarke’s suggestion that gravity is directly “impressed upon” matter “by God” *cannot* be tested empirically, in her view, and fails to make gravity intelligible in accordance with the PSR (Rohault and Clarke 1723, II.97).<sup>37</sup> As Detlefsen observes, for Du Châtelet hypotheses “aim at identifying real causal truths about the natural world and are not mere (instrumental) calculating devices” (2019, 106). This aptly describes her stance on the ether hypothesis, which if empirically supported would causally underpin Newton’s law of gravitation.

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<sup>36</sup> See further Du Châtelet (1740, Avant-Propos.V–VI; XIII.300; XIV.321–27; XVI.388–89). Some of these cases indicate Du Châtelet may accept Newton’s third and fourth rules of reasoning, though not necessarily as primitive principles. For example, she describes Newton’s famous double-pendulum experiment as a “demonstration that the quantity of proper matter of bodies” *in general* “is directly proportional to their weight” (XIV.322). She endorses reasoning from particular experiments to a physical relationship that (probably) applies to “all bodies” (XIV.322), and does not explicitly ground this reasoning in her basic principles of contradiction and sufficient reason.

<sup>37</sup> By 1738, Du Châtelet owned Rohault’s work, with Clarke’s extensive additions (Du Châtelet 2018, I.367).

Let's consider why Du Châtelet is so confident in a causal rather than merely mathematical or instrumental interpretation of Newtonian gravitation. Although Newton's theory does not provide an account of the underlying causes of gravitation, or what she calls an explanation "in detail," it provides a sufficient "general" or "physical" explanation (1740, XVI.389; 1742, IX.181).<sup>38</sup> Newtonian attraction is on the same footing as elasticity or heat (1742, IX.181). Such "physical" properties are "often sufficient" for causal explanations of effects, even if deeper questions about the nature of the causes remain unanswered (IX.181). In particular, physical explanations stand firm even when what she calls "mechanical explanation[s]" are not provided (IX.181).<sup>39</sup>

She applies this point to cases of macroscopic mechanistic explanation. We explain how a pocket watch works by appeal to its functional parts (1742, IX.182). Yet this explanation is not based on a thoroughgoing account of underlying microscopic mechanisms. Rather, it takes "qualities" of the watch's parts for granted: "malleability, ductility, elasticity," and so on (IX.182). She also considers the example of an air pump, the action of which can be "very well" explained, as well as quantified, even if we do not know exactly what causes air's elasticity (IX.181). No one would deny, she thinks, that in these cases we acquire a *causal* "explanation" of how the pump or watch functions (IX.182). Indeed, this explanation has equal "certainty" to one based on the underlying microscopic mechanisms (IX.182).

Du Châtelet thus presents gravitation as an indispensably useful "given" that will be needed, for the foreseeable future, in physical explanations (1740, VIII.163). While it is worth seeking deeper causes of gravitation, this is a "new question," which need not be settled in order "to explain the effect" of a physical property such as gravitation (VIII.163).

The same point seems to hold for Du Châtelet's treatment of the laws of mechanics. Her account is certainly influenced by Wolff and other rationalists. For example, she suggests that if her second law of mechanics were denied, a violation of the principle of sufficient reason would follow (XI.229). However, this violation only obtains if a number of substantive empirical assumptions about the nature of matter and motion are granted. Unlike Wolff, Du Châtelet does not seek to derive the laws of mechanics from ontology and general cosmology by way of the principle of sufficient reason.

A third major difference between Wolff and Du Châtelet concerns the knowledge of essences and its role in science. Du Châtelet's PSR, unlike Wolff's, does not guarantee knowledge of essences. So her PSR does not license a conception of science that is primarily based on deductions from essences. This follows from the scope of Du Châtelet's PSR, in conjunction with how she conceives of truths about essences. She holds that truths about essences are necessary *de dicto*. Her PSR ranges over contingent truths, however, and not over necessary truths about the essences of finite things. Therefore, her PSR is silent about our knowledge of necessary properties of the essences of finite things. Given that the PSR is

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<sup>38</sup> I am indebted here to work in progress by Qiu Lin.

<sup>39</sup> Du Châtelet is not a Cartesian mechanist (Iltis 1977, 37; Detlefsen 2019, 116–17). The PSR, she holds, shows active force to be an essential property of matter (1740, VIII.139). Her worries concern not the causal activity of matter but its action at a distance across a void: she considers this to be unintelligible (1742, XVI.395–99). So she seems to understand mechanical explanation as explanation by contact action. This position may be linked to her relational account of space. On the other hand, Newtonian absolutists such as Clarke also saw action at a distance as unintelligible. For further discussion see Rey (2016), Stan (2017), Janiak (2018), and Brading (2019).

closely linked to her conception of science, it follows that her account of science does not regard it as primarily aiming at knowledge of essences. By contrast, we saw that Wolff takes science to truly describe essences, and does so in part because of specific features of his PSR.

Appreciating this feature of Du Châtelet's PSR is crucial for reconciling her version of rationalism with her pessimism about our knowledge of essences. For if she accepted Wolff's version of the PSR and the robust knowledge of essences that accompanies it, her account of the PSR would be in tension with her epistemological claims about essences.

Du Châtelet is pessimistic about our knowledge of essences for several reasons, which I can only sketch here. Matter is essentially spatiotemporal, and space and time essentially depend on our perceptual and imaginative capacities (1740, VIII.152).<sup>40</sup> We cannot know the mind-independent essence of matter, because there is no such essence. The active forces treated in physics are “phenomena resulting from the confusion that reigns in our organs, and in our perceptions,” even if they are in some inscrutable sense also grounded in simple substances (VIII.153; VII.133–4). Our concepts of force do not represent actual essences in any detail, since essences proper belong to fundamental substances.

Nor do we have determinate a priori knowledge of simple substances, on her view. By reasoning back from the properties of bodies, we can discover some of their most general properties. For example, the bodies we perceive must be grounded in non-composite and causally efficacious substances. But we will never perceive, or experimentally observe, these simple substances (1742, IX.183). So we cannot give quantitative precision to these properties in any particular case, or define how they constrain physical possibilities (III.48). Even if we were able to gain more detailed knowledge of the essence of these substances, we could not straightforwardly deduce the essential properties of matter, since the latter is essentially dependent on our perceptual capacities.

Du Châtelet does not take this predicament to warrant skepticism. She denies that proper scientific knowledge must truly describe real essences. Here she breaks with Wolff, who thinks we can and do have knowledge of real essences, and that this is constitutive of science. Her position is also different from Locke's. Having denied that we can obtain knowledge of real essences, Locke draws pessimistic conclusions for the prospects of a “Science of natural Bodies”; this science is understood not as mere “experimental Knowledge” but as a general, demonstrative account of real essences (1975, IV.iii.29).<sup>41</sup>

Instead, Du Châtelet takes there to be a division of labor between metaphysics and natural science proper. Metaphysics deals with necessary truths about essences, which stand in logical relations of entailment to one another. Natural science or *physique* in the broad sense is instead concerned with modes—the changing determinations of substances—and how things actually stand with modes does *not* follow, even in principle, from an account of essences and attributes (1740, III.43–6). Even if we did have a detailed positive grasp of

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<sup>40</sup> See Du Châtelet (1740, VI.79, VIII.137, VIII.153–5, XI.212) and for further discussion Jacobs (2020). These texts tell against Stan's (2018) reading, on which the existence of matter for Du Châtelet is not mind-dependent, but is grounded in the composition of non-mind-like simple substances. Stan's reading would bring her closer to Wolff, who takes bodies as mind-independently composed of simple elements (Wolff 1737, §176; §219–222).

<sup>41</sup> See also Locke (1975, II.xxx; II.xxxi; IV.iii.28; IV.iv.4; IV.ix.1). Locke defines the real essence of *x* as “that foundation from which all” *x*'s “properties flow” (III.iii.18). This bears comparison to Wolff's account of an essence as the ground of a substance's attributes and modes.

fundamental essences, it would have little import for natural science. As such, it is no great loss for natural science per se that we do not have such a grasp. Her version of the PSR, and its associated conception of science, do not strictly require determinate knowledge of fundamental essences, in a way that would conflict with her denial that we actually have knowledge of this kind.

This divide between empirical science and metaphysics is a major departure from Wolff's unified conception of *scientia*. Moreover, Du Châtelet takes empirical natural science, and not metaphysics, to contribute most of the determinate content of our understanding of the world. Legitimate metaphysics, she contends, consists only of what is obvious to anyone who can properly use their cognitive faculties (1740, Avant-Propos.XII). Even what is evident in this way is often "obscure," and she cautions that any metaphysical claims ranging beyond this domain concern what human beings "can never know" (Avant-Propos.XII). The obviousness of legitimate metaphysics need not mean that it is trivial. But the role of metaphysics will be general and methodological: it will not deliver a determinate theory about the world.

#### IV. CONCLUSION

Du Châtelet's principle of sufficient reason differs from Wolff's in several significant respects. Wolff's conception of the principle of sufficient reason informs how he his views on science. Correspondingly, Du Châtelet comes to adopt views on rational science, explanation, and understanding that also differ from Wolff's. Her perspective on the PSR removes a major motivation for adopting the Wolffian scientific paradigm, allowing her to pursue a different approach to principles of scientific reasoning. This approach is arguably better equipped than Wolff's to account for the success of non-deductive reasoning and the stability of less-than-certain scientific theories.<sup>42</sup>

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