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On Metaphysical Foundations of Physics:

Body, Laws of Motion, and Essential Gravity

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In loving memory of my mom

Contents

Acknowledgments **iv**

Curriculum Vitae **v**

Abstract **vi**

Introduction **1**

1 Newton's Early Metaphysics of Body: Impenetrability, Action at a Distance, and Essential Gravity **4**

1.1 Introduction 4

1.2 Impenetrability and Contact Action 6

1.3 De gravitatione 10

1.4 Newton at Large 21

1.5 The Bentley Correspondence 24

1.6 Conclusion 36

2 The Enchanted Palace Founded on Attraction: Du Châtelet on Essential Gravity **39**

2.1 Introduction 39

2.2 The Problem of Attraction 42

2.3 Against Essential Gravity 47

2.4 The Dilemma 56
2.5 Metaphysics and Physics 63

3 Kant's Metaphysical Principles for the Construction of Natural Philosophy 70

3.1 Introduction 70
3.2 Friedman's View 73
3.3 Conservation of Momentum 76
3.4 Directionality 78
3.5 The Third Mechanical Law 84
3.6 Construction 94

Conclusion 99

References 101

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Curriculum Vitae

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Abstract

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This dissertation examines the relationship between metaphysics and physics in the work of three figures from the early modern period—Isaac Newton, Émilie Du Châtelet, and Immanuel Kant. The first chapter draws on Newton's *De gravitatione* and correspondence with Richard Bentley to assess the status of action at a distance vis-à-vis the centrality of impenetrability in Newton's metaphysics of body and his consistent rejection of essential gravity. The second chapter turns to Du Châtelet's *Foundations of Physics* and explicates her arguments against attraction as an essential property of matter. The final chapter considers Kant's treatment of the motions produced by forces in the absence of a general recovery of Newton's laws in the *Metaphysical Foundations of Natural Science*.

Introduction

The early modern period is an especially rich vein for studying the relationship between metaphysics and physics. This dissertation will examine the work of three figures from this era—Isaac Newton, Emilie Du Châtelet, and Immanuel Kant—with an eye to how their conceptions of matter are leveraged to render physical phenomena intelligible.

I begin with Newton's *De gravitatione*. This manuscript is of special interest for its rare discussion of the nature of body. More in the spirit of his later speculations in the Queries to the *Opticks* than the mathematical definitions given in the *Principia*, Newton entertains a kind of being that he argues would be indistinguishable from those that we have come to call bodies. In so doing, he seeks to identify, if not the true essence of bodies, then some collection of properties capable of recovering our experience of bodies and falling within the limits of God's creative powers.

Notably, Newton supposes his hypothetical beings to be endowed with impenetrability as their first property. Howard Stein (1970) has taken this to reflect a deep asymmetry in Newton's account. Impenetrability occupies a privileged status among all candidate essential properties of bodies and implies that bodies may act through contact, while no such property is mentioned to similarly ground a capacity to act at a distance, such as an essential attractive or magnetic force. Stein argues on this basis that contact action enjoys a privileged status in Newton's thought that is denied to distant action, which explains Newton's rejection of essential gravity in his correspondence with Richard Bentley.

I take Stein's contention as the starting point for my first chapter and argue for the following claims: (i) impenetrability does not necessitate action through contact by itself, but requires further suppositions concerning the laws of motion; (ii) there is ample room in *De gravitatione* for distant action to be seated in the essence of body; and (iii) Newton is rejecting in his letters to Bentley, not action at a distance per se, but the notion that a body might act on another without a cause.

The second chapter picks up the question of the intelligibility of essential gravity in Du Châtelet's magnum opus, the *Foundations of Physics*. Du Châtelet balances two methodological prongs in the *Foundations*: a Leibnizian-Wolffian-inspired metaphysics through which she pursues a priori truths founded in the principles of our knowledge, accompanied by a close attention to the empirical intricacies of post-Newtonian physics. These two prongs seemingly come to a head as she considers the admissibility of Newtonian attraction. A staunch proponent of mechanism throughout the *Foundations*, Du Châtelet finally defends her stance with a demonstration of the incoherence of essential gravity. Gravitational attraction, she argues, is without sufficient reason absent a reduction to mechanical causes.

Katherine Brading (2019) evaluates these arguments against Newtonian attraction and deems them unsatisfactory. Du Châtelet, Brading contends, rules out action at a distance from the outset by requiring that remote changes in bodies be mediated by the transmission of a third being and, later, demanding that all essential properties be non-relational. Brading thus reads Du Châtelet as being guilty of begging the question and mounting a hollow defense of mechanical philosophy.

I resist this assessment of Du Châtelet's arguments and offer an alternative reading that reveals an unappreciated richness of her objections. I argue principally that (i) Du Châtelet does not reject Newtonian attraction by fiat, but rather argues substantively against it; (ii) it is her conception of essential properties that is the crux of argument and not the principle of sufficient reason; and (iii) this episode is not a clash between the two prongs of her method, but instead one of many instances in which Du Châtelet sees metaphysics and physics as together constraining the growth of natural philosophy.

The final chapter of the dissertation turns to Kant's *Metaphysical Foundations of Natural Science*. Kant here progressively explicates the concept of matter according to the headings of his table of categories and promises to thereby deliver the pure part of physics. As two notable fruits of this explication, Kant argues for the essentiality of both repulsive and attractive forces, and derives three laws of mechanics corresponding to the analogies of experience.

A number of commentators have remarked on the similarity these laws bear to Newton's laws of motion: they share in common principles of inertia and the equality of action and reaction. This correspondence has historically been taken by Michael Friedman (1994) as evidence, moreover, that Kant is laying a metaphysical foundation for Newton's *Principia*, in particular. While recent work has since called this correspondence into question, Friedman (2015) still holds fast to the centrality of Newtonian physics to the *Metaphysical Foundations*.

I follow the lead of Marius Stan (2012) and Eric Watkins (1997) in further sharpening points of divergence between Newton's and Kant's third laws and treatment of forces, and argue that this is symptomatic of a difference in core objectives. More specifically, I defend the following positions: (i) Kant's treatment of force consolidates a number of tools from across the *Metaphysical Foundations* to situationally address the motions of bodies in different contexts; (ii) as a refinement of Stan's objection to the generality of Kant's third law, I argue that Kant does not prove that momentum is conserved in all cases; and (iii) Kant is not interested in explicitly constructing concepts in the *Metaphysical Foundations*, but rather in providing principles for such constructions.

Chapter 1

Newton's Early Metaphysics of Body: Impenetrability, Action at a Distance, and Essential Gravity

1.1 Introduction

Throughout "On the Notion of Field in Newton, Maxwell, and Beyond," Howard Stein (1970) grapples with several curious statements Newton makes about action at a distance. Drawing particularly from Newton's *De gravitatione*, Stein begins to advance a reading on which Newton places action at a distance on par with action through contact. Yet in his closing treatment of the subject, Stein hesitates to make this point, withdrawing instead to the weaker position that Newton took the two kinds of action to be similar only in a limited sense, with primacy being granted to action through contact in another:

> In one sense—at the level of metaphysics and theology—there is no difference in status, given Newton's analysis, between action through contact and action at a distance [...] On the other hand, at the level of fundamental physics, the situation is not quite so parallel between the two modes of interaction. For Newton did consider impenetrability to be the *first basic property of bodies*; and this means that interaction by contact (should contact ever indeed occur) is a

> necessity—a direct consequence of the fact of impenetrability; whereas interaction at a distance would represent, so to speak, a *further* arbitrary decision of God. (Stein, 278)

An asymmetry arises, Stein contends, when one considers how Newton takes impenetrability to be the first property of bodies: by dint of being impenetrable, bodies must necessarily act through contact, and yet there is no analogous property of which action at a distance is a consequence. Accordingly, contact action occupies a privileged position—"at the level of fundamental physics"—denied to action at a distance.

At the heart of Stein's contention is the claim that impenetrability implies action through contact. By this, presumably something like the following is meant: Imagine that two impenetrable bodies happened to follow trajectories that would lead them to co-occupy some part of space provided they were penetrable. Now, a body is impenetrable just in case spatial overlap with other bodies is prohibited. As such, since the two bodies under consideration are indeed mutually impenetrable, it is necessary that at least one deviates from its trajectory upon encountering the other's boundary. It has only been posited that bodies are impenetrable—i.e. there is no other mechanism according to which bodies might act—and so the change must occur precisely at the moment of contact; which is to say, at least one of the bodies must suffer action through contact.

In what follows, I present a challenge to Stein's reading of Newton with respect to the question of action at a distance. I will begin by considering whether impenetrability really does imply action through contact and ultimately argue that such an implication is invalid because it hinges on one's laws of motion in three senses: it must be possible for contact to occur at all, the notion of a trajectory from which a body deviates only becomes coherent when accompanied by further conditions, and the necessity of introducing collision laws renders impenetrability otiose.

I then turn to a close reading of *De gravitatione* itself and consider whether Newton's account of body establishes contact action as prior to distant action in any sense. By pointing to certain ambiguities in the text, along with its self-professed uncertain and anti-Cartesian character, I argue that Newton did not aspire to a general, definitive account of the nature of body, but rather restricted attention to only what is required to mount an objection to Descartes's physics; leaving, in the process, ample room for action at a distance both within *De gravitatione* and in conceivable elaborations thereof.

By way of substantiating this reading and answering a natural objection, I then pivot to Newton's correspondence with Bentley and their remarks concerning the legitimacy of action at a distance. Although Newton is often seen as rejecting innate gravity on the grounds that it conflicts in some way with his metaphysics, I offer a more austere reading of these letters on which Newton is decrying a kind of action that is unmediated, and so alleged to take place without a cause. With this, I see a place being carved out for action at a distance mediated by an immaterial agent as a perfectly acceptable means of explaining natural phenomena.

1.2 Impenetrability and Contact Action

If Stein's central claim is that contact action is a necessary consequence of impenetrability, the question is not so much one of historical exegesis as of conceptual analysis. As such, we begin by suspending any inquiry into Newton's thoughts on the matter and consider only whether the alleged conceptual relationship stands on its own right. As stated above, it will be my position that impenetrability does not imply contact action by itself; rather, such an implication could only follow once certain assumptions have been made concerning one's laws of motion.

First and foremost, contact itself must be physically possible. Consider, for instance, a world in which approaching bodies stopped just shy of touching and were repulsed by some short-range force that altered their motions just as one would ordinarily expect. If all collisions were merely apparent and instead mediated by interactions of this sort, the impenetrability of bodies would be eminently respected, and yet the world would be without a single genuine instance of contact. Accordingly, one would be hard pressed to say that a body ever acted on another "through contact."

What examples of this character illustrate is that impenetrability is but a negative condition. When one says that bodies are impenetrable, this is a statement of a physical impossibility—bodies are prohibited from ever overlapping spatially—and this is neutral with respect to the mechanism by which this prohibition is enacted. Impenetrability could never by itself imply a species of interaction because it leaves open whether overlap is prevented through contact-based collisions, short-range repulsive forces, or some other means altogether. Put somewhat differently, one may think of impenetrability as a meta-condition or meta-law: when bodies are assumed to be impenetrable, one can only entertain as dynamically allowable those collections of trajectories in which bodies do not overlap. Impenetrability is a constraint, not on individual trajectories, but on which dynamics are physically possible.

One might object, however, that all this is beside the point. Stein's insight is not that impenetrability implies contact action in the form of a particular mechanism, rather the key is that the risk of overlap only ever occurs when a body reaches another's boundary. If impenetrable bodies collide, then—and only then—must something be done to cause a body to deviate from its trajectory. What is essential is not the way in which this change comes to be produced, but simply that a change is needed at the moment of contact at all.

This brings us to the second sense in which the alleged implication hangs on one's choice of laws. When one says that a change is needed at the moment of contact, one takes for granted certain further assumptions: namely, bodies are assumed to conserve their shape and size, be mobile, and obey a law of continuity or inertia. But if any one of these conditions is dropped, contact action, even in the limited sense just mentioned, fails to follow. If bodies may experience arbitrary distortions of their dimensions, for instance, contact may be prevented altogether by bodies appropriately shrinking and contorting themselves as they pass by each other; and if bodies never changed positions, action through contact would be ruled out trivially as motion itself would be impossible.

While it may be fair to grant the first two of these assumptions as natural when posing a question concerning how bodies act on one another; nevertheless, without some principle along the lines of a law of inertia or continuity, contact action would still not follow. Crucially, one would still lack the resources to speak of a body's trajectory from which it would be caused to deviate. For consider a collection of bodies that are required only to be impenetrable, mobile, and of a constant shape and size. One might imagine two ways in which these bodies could move, and even come into contact, without there being action of any kind. Nothing is to prevent these bodies, for example, from teleporting stochastically from one moment to the next in such a way that future states were underdetermined by those that came before. One would simply have to rule out configurations in which there was overlap while maintaining the number and dimensions of the collection of bodies to remain consistent with one's initial conditions. If this is what one meant by the mobility of bodies, the spatial contiguity of two bodies could in no sense necessitate their acting on each other for their subsequent positions would be completely independent of their current positions.

But perhaps this is too fanciful. Let us admit a law of continuity along with the aforementioned assumptions and permit bodies to move freely so long as they do so continuously. Even still, if bodies moved were to move randomly rather than inertially, a problem would remain. For consider what would happen were two bodies to come into contact in the course of their random motions through space. Being impenetrable, certain motions would be disallowed as neither body could pass into the other's volume; and yet, one might wonder whether either body is thereby acting on the other. It is true that the subsequent region to which each body moves is selected from a restricted set of possibilities, but one cannot speak of either body as having an original state of motion in which it would have persisted had they not come into contact. Neither body followed a trajectory from which it was forced to deviate, and so no action has taken place.

As a third and final note, even if impenetrability were to imply action through contact, the particular laws governing contact-based interactions would remain undetermined. A further act of the divine will would still be required for collisions to abide by any laws at all, let alone dynamics that would recover one's ordinary experience of bodies. This in itself is not especially remarkable and is acknowledged by Newton himself in *De gravitatione*, but once this fact is acknowledged, one may ask what ought to be included under the heading of such laws. In particular, one might ask whether the laws should themselves come equipped with a prescription for the conditions under which they become applicable. That is, if the laws are to govern the motions of bodies following a collision, should one's collision laws encompass a statement concerning what is to constitute a collision?

If so, the logical implication of contact action would seem to lose its fangs. Contact was supposed to have been a sort of breaking point, implicated by the fact of impenetrability alone, after which the motions of bodies would stand in need of further specification; and consequently, it would have been necessary for a special mode of interaction to be divinely instituted. Impenetrability, in other words, serves to pick out the collision of bodies as a physically salient condition prompting some lawlike change. But if the selection of such a condition might just as well be done in specifying the laws themselves, which specification is necessary regardless, what place remains for impenetrability?[1] Why not, in the interests of ontological parsimony, specify bodies purely in terms of which laws they follow and eschew the attribution of properties like impenetrability altogether?[2] Impenetrability, logically implying contact action or otherwise, looks to be superfluous in the face of laws conceived in this way.

[1]Bennett and Remnant (1978) pose a much more damning criticism of Newton's use of impenetrability:

> But this [making a space impenetrable] is a vacuous exercise of God's power—a purely idle exercise—because on any tolerable theory and certainly on Newton's it is of the essence of space that no part of it can overlap or intrude into any other part of it. So the alleged making-impenetrable has no effect at all: we are left with nothing but 'pure space': and so the endeavor to describe a creation of matter has failed. (Bennett and Remnant, 5)

Far from grounding contact action, impenetrability fails to even distinguish Newton's "bodies" from empty space on their reading.

[2]Brading (2012) sees Newton's account of body in the *Principia* as "law-constitutive:" bodies, on her reading, are precisely those entities that abide by the laws of motion. One might see a foreshadowing of this position in *De gravitatione* with Newton's inclusion of law-like behavior in the essence of body. This dependence on physical law, moreover, is rooted in the very creation of bodies—as opposed to merely being applied to pre-existing entities—and, therefore, suggests the ontological priority of physical law over body (a reversal of the relationship as understood in Schliesser (2010)).

To weave these arguments together, we may pose the following three-tiered objection to Stein's claim: The assertion that impenetrability implies contact action takes for granted that contact itself is physically possible. Requiring bodies to be impenetrable, however, is only a negative or meta-condition establishing a physical impossibility while remaining silent with respect to the manner in which it comes to be impossible. Furthermore, even granting the possibility of contact,[3] one would need bodies to move inertially for there to be a sense in which bodies deviate from prior states of motion or trajectories after colliding. At best, the claim could only be that impenetrability, along with non-trivial assumptions like a law of inertia, implies action through contact. Lastly, reflecting on the import of this logical implication vis-à-vis a notion of laws that includes a delineation of the conditions for their application seems to render impenetrability otiose. Only when property attribution is highly valued over the specification of robust laws is the alleged implication of consequence.

1.3 De gravitatione

Objections to the conceptual relationship above notwithstanding, there remains the historical question of whether Stein's claim accurately reflects Newton's own view in *De gravitatione*. How, after all, are we to make sense of Newton's privileging impenetrability as the first property of bodies? Did he understand this to imply anything with respect to the ways in which bodies might interact with one another? What role would impenetrability play otherwise?

In this section, I will argue that impenetrability is, for Newton, a causally efficacious property insofar as it is what enables bodies to act on one another. While this looks to be an exclusive endorsement of contact action, Newton conceives of the possibility of impenetrability by considering how God might prevent bodies from entering a given region through thought alone. This appeal to divine action is made, moreover, without mention of particular secondary causes or the means by which they must operate; and while the supposition

[3]Including the implicit stipulation that no other laws explicitly forbid contact.

of lawlike behavior is essential to his account, Newton does not say much about the domain or nature of such laws. Consequently, I see there being ample room for the impenetrability of bodies to be a product of either short-range repulsive forces or brute contact. With this in mind, let us then turn to *De gravitatione* and see what Newton himself has to say about these questions.

Before delivering a final definition of body, Newton narrates the creation of "a certain kind of being" through the gradual addition of qualities to an empty region of space until one arrives at a being about which "one can hardly say that it is not body" (Newton, 42). Importantly, however, Newton prefaces this narrative by confessing his ignorance of the extent of God's power, without knowledge of which he believes no explanation of body could be certain:

> Of [the nature of body], however, the explanation must be more uncertain, for [bodies do] not exist necessarily but by divine will, because it is hardly given to us to know the limits of the divine power, that is to say, whether matter could be created in one way only, or whether there are several ways by which different beings similar to bodies could be produced. (Newton, 2014a, 41)

Accordingly, Newton does not pretend to "say positively what the nature of bodies is," as this is something one could never know;[4] rather, his aspiration is to describe a certain species of beings that very well could have been created by God and about which one could "hardly say that it is not body" (Newton, 2014a, 42).

In keeping with this aspiration, Newton grounds the creation of these beings principally in an act of God, who "by the sole action of thinking and willing, can prevent a body from penetrating any space defined by certain limits" (Newton, 2014a, 42). That such an act is well within God's power is apparent, he argues, since we all experience the analogous capacity to move our respective bodies at will. With respect to the appearances presented

[4]One has, I think, good reason to believe that Newton is not merely being facetious when he qualifies his account in this way. Kochiras (2009), for instance, takes Newton to be engaged in a substantive reflection on the limits of an empirical investigation of the nature of body, and one, moreover, that is sustained through the writing of the *Principia*. On her reading, Newton is truly claiming that the essence of body, and substances more generally, cannot be known.

by such beings, Newton continues:

> If [God] should exercise this power, and cause some space projecting above the earth, like a mountain or any other body, to be impervious to bodies and thus stop or reflect light and all impinging things, it seems impossible that we should not consider this space really to be a body from the evidence of our senses (which constitute our sole judges in this matter); for it ought to be regarded as tangible on account of its impenetrability, and visible, opaque, and coloured on account of the reflection of light, and it will resonate when struck because the adjacent air will be moved by the blow. (Newton, 2014a, 42)

From the mere attribution of impenetrability, a space may be made to interact with ordinary bodies presumably just as if it were some highly massive, but otherwise unremarkable body. Furthermore, notice the causal character of the language Newton uses when he writes that such a space would "be impervious to bodies and *thus stop or reflect* light and all impinging things," or later, "be regarded as tangible *on account of its impenetrability*." The motions of bodies would be impeded, i.e. they would be forced to deviate from their trajectories, simply because the space is impenetrable. If perhaps in the qualified sense of delimiting the collision of bodies as a physically salient state prompting lawlike action, Newton would thus seem to endorse the claim that impenetrability implies contact action.

But this is too hasty. Taking Newton at his word, he understands a space to be made impenetrable through an exercise of God's will: in just the same way as we may move our own bodies—or he any body whatsoever—so too may God prevent a body from entering some region. Whether Newton understands by this that God directly intervenes on the world to maintain a body's impenetrability or whether this is done by means of some secondary cause seems, as far as the text of *De gravitatione* is concerned, to be an open question—if not unknowable in principle.[5] If Newton thinks it possible for God to "create beings similar to bodies which display all their actions and exhibit all their phenomena, and yet would not be bodies in essential and metaphysical constitution," it seems no more unreasonable for the

[5]That God would directly instantiate and sustain the impenetrability of bodies would be perfectly in keeping with Newton's theology. See the Leibniz-Clarke correspondence, particularly the discussions of God's governance and the nature of miracles with which Clarke ends his replies.

cause of a space's apparent impenetrability to be similarly underdetermined (Newton, 2014a, 41). For this reason, I find it unlikely that Newton would have thought bona fide contact a necessity; impenetrability accomplished via short-range repulsive forces or as an immediate effect of God's will would be just as causally efficacious as Newton's language suggests.

Furthermore, while the instantiation of impenetrability is the cornerstone of Newton's account, there is more to be said. Newton has only imagined the creation of a single body-like being and how it might interact with ordinary bodies. Whether such interactions occur in some lawlike fashion, and what form these laws might take, is left unspecified. Judging by Newton's insistence that we would nevertheless regard the impenetrable space as an ordinary body, it is plausible that these interactions proceed in a lawlike manner because the impinging ordinary bodies abide by laws of motion. In this sense, one might question even the qualified sense in which contact action would be implied: the space is experienced as a body by virtue not only of its impenetrability, but also the lawlike behavior of ordinary bodies.

Continuing with the narrative, even if such a being were not sensibly different from a body, Newton points out that it would nevertheless suffer from one noticeable defect—it would be immobile. But this is not without remedy:

> If we should suppose that that impenetrability is not always maintained in the same part of space but can be transferred here and there according to certain laws, yet so that the quantity and shape of that impenetrable space are not changed, there will be no property of body which it does not possess. (Newton, 2014a, 42)

The impenetrability of these beings is freed from the constraint of a single place. It is permitted to be transferred from one region to the next, becoming mobile and thereby "capable of reflecting and being reflected." Observe, further, that Newton here suggests that this transfer may take place according to certain laws.[6] Along with the final supposition

[6]Biener and Smeenk (2012) take this passage as indication that, while both elements are undeniably present in Newton's account, impenetrability is the more salient of the two, with their being governed by certain laws as of only auxiliary value. For the reasons given in the preceding section, however, I take Newton

that this space possesses the ability to "operate upon our minds and in turn be operated upon," this completes Newton's description of these body-like beings (Newton, 2014a, 42).

This last property is interesting in many respects,[7] but I mention it here only in passing. Principally, Newton writes that it allows the created beings to "excite various perceptions of the senses and the imagination in created minds" (Newton, 2014a, 43). There's a natural parallelism here with the notion of impenetrability as casually efficacious. Newton seems to have in mind two central questions: "How do bodies act on one another?" and "How do bodies act on minds?" The former is achieved by impenetrability, albeit with the supposition of lawlike behavior, and the latter by this third condition. That bodies might possess this property, Newton sees as a natural extension of his previous considerations of the powers of God: "For it is certain that God can stimulate our perception by means of his own will, and thence apply such power to the effects of his will" (Newton, 2014a, 42). In this way, we see that bodies come to possess their properties by means of the sustained application of God's power.

Newton has thus far narrated the creation of his body-like beings in three—if not temporally, then conceptually—distinct stages: make a space impenetrable, permit this impenetrability to move from place to place in accord with certain laws, and allow the space to act upon minds. But hardly a paragraph later, Newton formally defines bodies in a way that subtly departs from this structure:

> If they are bodies, then we can define bodies as *determined quantities of extension which omnipresent God endows with certain conditions.* These conditions are: (1) that they be mobile, and therefore [...] definite quantities which may be transferred from space to space; (2) that two of this kind cannot coincide anywhere, that is, that they may be impenetrable, and hence that oppositions obstruct their mutual motions and they are reflected in accord with certain laws; (3) that they can excite various perceptions of the senses and the imagination in created minds, and conversely be moved by them [...] (Newton, 2014a, 43)

to be acknowledging here that impenetrability by itself is not sufficient to recover the phenomenal experience of body.

[7] In particular, it has been a centerpiece in recent discussions of Newton's solution to the mind-body problem. See Gorham (2011), for instance.

All the same elements are present, but there has been some reshuffling. Whereas previously the clause "in accord with certain laws" made its appearance in the context of the mobility of the spaces, Newton here ties it to an explanation of what it is for a space to be impenetrable. Since the interaction is between "two of this kind" of being, lawlike behavior cannot emerge by trading on the laws of reflection for ordinary bodies. One must further specify that the subsequent changes proceed according to certain laws and not merely that these beings are impenetrable. Although not introduced as an independent condition in its own right, that these bodies behave according to certain laws is indispensable to Newton's account of body in *De gravitatione*.

But again, Newton makes use of the same sort of causal language in the second part of his definition as we noted above: "that two of this kind cannot coincide anywhere, that is, that they may be impenetrable, and hence that oppositions obstruct their mutual motions." While particular collision laws do not fall out as a consequence of impenetrability,[8] Newton does see the addition of impenetrability as implying the obstruction of opposing bodies. A collision, this is to say, must result in a change in the motions of these beings once they have been made impenetrable. More than anything we have seen yet, this suggests that Newton believed some sort of action must follow the contact of impenetrable bodies, which is the qualified form of Stein's claim. We must, however, appropriately qualify any conclusions drawn on this basis. Unlike the case where a single region was supposed merely to be impenetrable, here the created beings are imagined also to be mobile, to follow certain laws, and be capable of affecting minds. In the same spirit as the second objection levied in the preceding section, it is only when bolstered by these additional conditions that impenetrability might imply

[8]It is unclear when Newton last worked on *De gravitatione*. Many have argued for a dating sometime between the late 1660s and early 1670s (see, for instance, Hall and Hall (1962)), while a few have placed the work much later (see Dobbs (1991), or even Stein (1970)). A more recent paper by Ruffner (2012) surveys the literature on the topic and presents strong evidence against a late dating. If indeed an early work, one might wonder whether Newton means for Cartesian collision laws to fall out as a consequence of impenetrability. Ruffner (2012), while not drawing this inference, does point out that many of the definitions appearing in *De gravitatione* have "clear roots" in or have been "distilled" from those found in Descartes's *Principles*. Yet there is strong evidence against even a young Newton fully adopting the Cartesian system: as early as his 1666 manuscript *The Lawes of motion*, Newton had seriously explored alternatives to Descartes's physics.

contact action at all.

In a similar vein, it is not clear what Newton intends the scope of these "certain laws" to be. One must assuredly have laws for reflection since this is mentioned explicitly in the definition of body, but the mandate of lawlike behavior is much more vague as it appears in Newton's narrative. There, impenetrability is supposed to be "transferred here and there according to certain laws," i.e. it is the motions of bodies that must abide by laws. But one might construe Newton as meaning any number of laws if the only criterion is that they treat the motions of bodies. Coupled with Newton's continued insistence that "if all of this world were constituted out of these beings, it would hardly seem to be inhabited differently" and that "these beings will either be bodies, or very similar to bodies," it is not entirely far-fetched for Newton to have included under this heading even laws for gravitational and electromagnetic phenomena (Newton, 2014a, 43). In this case, far from contact action having some special status through its logical implication, distant action would pertain to the essence of body too.

An alternative, of course, is that the Newton of *De gravitatione* is a strict mechanist. If all bodily interactions could be derived from contact-based ones, then impenetrability accompanied by laws of reflection might indeed be sufficient to recover all corporeal phenomena. Far from problematic, it would then be natural for Newton to claim such beings were truly bodies. Henry (2011), for instance, reads the text in just this way: consonant with Stein's picture, Henry sees the theory of body sketched in *De gravitatione* as "entirely mechanical in the strict sense." Bodies are "passive and inert," and thought only to interact through their "motion and force of impact," without any mention of a capacity to act at a distance through "interparticulate forces" or "active principles" (Henry, 2011, 32).

To entertain this line for the moment, consider how Newton defines pressure and gravity. About the former, he writes:

> Pressure is the endeavor of contiguous parts to penetrate into each other's dimensions. For if they could penetrate the pressure would cease. And pressure is only between contiguous parts, which in turn press upon others contiguous to

> them, until the pressure is transferred to the most remote parts of any body, whether hard, soft, or fluid. And upon this action is based the communication of motion by means of a point or surface of contact. (Newton, 2014a, 51)

Unlike the preceding passages, Newton is here quite clear that pressure occurs between "contiguous parts," thereby allowing motion to be communicated "by means of a point or surface of contact." Similarly, while gravity is formally defined seemingly so as to be agnostic with respect to its physical cause—"Gravity is the force in a body impelling it to descend"—Newton goes on to say that "if the endeavour [conatus] of the aether gyrating about the sun to recede from its centre be taken for gravity, in receding from the sun the aether could be said to descend" (Newton, 2014a, 51). Regarding this gravitational aether, Henry compares it to "the swirling whirlpool of 'second matter' which Descartes deploys in his vortex physics," and considers it "entirely out of keeping with the theory of gravity that Newton developed after his correspondence with Hooke in 1679" (Henry, 2011, 29). And yet, of the nineteen definitions littered throughout the work, not a single one of them makes any mention of distant action.[9]

While the foregoing is compelling, I think these passages are better understood in the context of Newton's motivations for explicating a theory of body. The narrative of the creation of bodies appears in the midst of an extended digression in which Newton makes an objection principally to Descartes's conception of motion, and in its service, speaks of the nature of extension and body. At its outset, he qualifies his first set of definitions in the following way:

> Moreover, since body is here proposed for investigation not in so far as it is a physical substance endowed with sensible qualities, but only in so far as it is extended, mobile, and impenetrable, I have not defined it in a philosophical

[9] There is one caveat that deserves mention: Newton does refer to the force of gravity as being "in a body," which is odd if he means for gravity to be mediated by a mechanical aether. But just a few definitions earlier, Newton says that a force may be "an external one that generates, destroys, or otherwise changes impressed motion in some body, or it is an internal principle by which existing motion or rest is conserved in a body, and by which any being endeavors to continue in its state and opposes resistance" (Newton, 2014a, 50). Although the second disjunct is indeed an internal force, as one might have thought every force "in a body" would be classified, Newton looks to only have the internal force of inertia in mind.

> manner, but abstracting the sensible qualities (which philosophers also should abstract, unless I am mistaken, and assign to the mind as various ways of thinking excited by the motions of bodies), I have postulated only the properties required for local motion. (Newton, 2014a, 27)

The scope of Newton's investigation is not as general as one might have initially thought. Newton only means to treat of body "in so far as it is extended, mobile, and impenetrable," which is to say, as it bears "the properties required for local motion." Moreover, this comment is reiterated as he concludes his anti-Cartesian digression: "And so finally, since spaces are not the very bodies themselves, but are only the places in which bodies exist and move, I think that what I laid down concerning local motion is sufficiently confirmed" (Newton, 2014a, 50).

Newton's theory of body is tailored as a response to Descartes's doctrine of motion, and in particular, demonstrates the non-identity of extension and body. Without a means of distinguishing extension itself from corporeal extension, Newton thinks one cannot make sense of the space traveled by a body. On these grounds, Newton declares that Cartesian motion is not motion at all:

> Now since it is impossible to pick out the place in which a motion began [...] for this place no longer exists after the motion is completed [...] It follows indubitably that Cartesian motion is not motion, for it has no velocity, no determination, and there is no space or distance traversed by it. So it is necessary that the definition of places, and hence of local motion, be referred to some motionless being such as extension alone or space in so far as it is seen to be truly distinct from bodies [...] and lest any doubt should remain about the nature of motion, I shall reply to this argument by saying what extension and body are, and how they differ from each other. (Newton, 2014a, 35)

To speak of place as persisting, and with it the distance a body travels, one must be able to refer to "some motionless being such as extension alone;" and this, in turn, is only made coherent when extension and body are understood to be distinct. As such, Newton substantiates this distinction with an account of how bodies might be created that takes as essential more than mere extension.

This is all to say that *De gravitatione* is in dialogue with very particular interlocutors, and so certain questions come more immediately to the fore than others. Despite narrating the creation of beings that would ostensibly "sustain all the vicissitudes of corpuscles and exhibit the same phenomena," some matters seem to fall outside the scope of Newton's inquiry.[10] But I do not think one should fault Newton for failing to explicitly treat distant action or thereby brand the theory as strictly mechanistic—these are simply not the questions Newton here sought to address. We find Newton instead preoccupied with questions like the following: Is space distinct from body? What must be presupposed to make sense of motion? Must one posit a substantial subject like prime matter to ground substance? And is the existence and creation of bodies consistent with our understanding of God?

To supplement this picture, recall how Newton qualifies the character of his narrative at its outset:

> Of this [the nature of body], however, the explanation must be more uncertain, for it does not exist necessarily but by divine will, because it is hardly given to us to know the limits of the divine power, that is to say, whether matter could be created in one way only, or whether there are several ways by which different beings similar to bodies could be produced [...] and hence I am reluctant to say positively what the nature of bodies is, but I would rather describe a certain kind of being similar in every way to bodies, and whose creation we cannot deny to be within the power of God, so that we can hardly say that it is not body. (Newton, 2014a, 41-42)

Any explanation of the nature of body must necessarily be uncertain—for all we know, God could have created bodies in any number of ways. As such, Newton can at best tell of how bodies were possibly made and must remain open to the true essence of body being radically different from how he pictures it. But if this is only a probable story, it seems one cannot make firm judgments on its basis. Even if one were to interpret Newton's theory of body purely mechanistically and see impenetrability as implying action through contact, this would still not confer some special status upon contact action—for we do not know whether

[10]To mention another example, although *De gravitatione* treats of the weight and equilibrium of fluids and solids, Newton says that "the physical cause of fluidity is not to be examined here," and speaks of having "accomodated these definitions not to physical things but to mathematical reasoning" (Newton, 2014a, 53).

it is a consequence of the true essence of body. To one acquainted with such an essence, distant action may too be a consequence of the first properties of bodies.[11]

Taking stock of the ground covered, Newton does seem to make impenetrability the first property of his created beings to explain how it is that they might act on other bodies. This comes, however, with two caveats. First, Newton imagines spaces to become impenetrable simply through an act of God, leaving open the existence and particular nature of any secondary causes—God could just as well accomplish the feat of impenetrability by means of short-range repulsive forces as by brute contact. Moreover, it is essential to Newton's account that the created beings behave according to certain laws of motion, and ones which are of ambiguous scope to boot. It is not clear whether Newton means by this only laws of reflection and inertia, or also laws for such forces as, say, electricity and magnetism. When these two caveats are appreciated, one is left with a claim much weaker than Stein's: Newton sees contact action as being implied by impenetrability only when augmented by laws of motion and in the sense that the motions of colliding bodies must somehow be impeded. Accordingly, there appears to be room for distant action in even Newton's account: bodies might impede each other's motions via some repulsive force before contact, and laws of

[11] As it happens, this is Maupertuis's position. In the *Discours sur les différentes figures des astres* he entertains, remarkably, the same objection to attraction as does Stein (many thanks to Katherine Brading for bringing this to my attention):

> Here is another argument one may make against attraction. The impenetrability of bodies is a property concerning which philosophers on all sides are in agreement. This property possessed, a body that moves towards another would not be able to continue in its motion, without penetrating it; but bodies are impenetrable; it is necessary then for God to establish some law reconciling the movement of the one with the impenetrability of both; here then is the establishment of some new law made necessary in the case of impact. But two bodies remaining at a distance, we do not see that there is any necessity to establish a new law. (Maupertuis, 18) [translation my own]

Far from being fatal, however, Maupertuis thinks this objection fails to hit the mark:

> But if gravity were a property of the first order; if it were attached to matter, independently of its other properties, we would not see that its establishment was necessary, because it would not owe it to the combination of any other properties. (Maupertuis, 20) [translation my own]

Even if attraction does not follow as a logical consequence of the agreed-upon essential properties of body, it may nevertheless turn out to itself belong to the essence of body as a "property of the first order," and so be intelligible irrespective of these other properties. (See Downing (2012) for an extended discussion of this issue.)

attraction or repulsion, more broadly construed, might be included under Newton's "certain laws." Furthermore, the theory of body found in *De gravitatione* is provisional, and tuned, at that, to challenge the Cartesian doctrine of motion. One should be appropriately cautious when reading off implications for distant action when one's source is, even by the author's own lights, not the true essence of body. Action at a distance may yet be of just the same status as action through contact.

1.4 Newton at Large

I take the line of thought defended thus far to be a compelling reading of *De gravitatione*, but one might see it as standing in a curious tension with some of Newton's other writings. Stein, in particular, grapples with just this issue. Despite noticing textual support for the parity of contact and distant action, Stein is reluctant to carry its implications through because he sees it as running afoul of what Newton says later in life. We see this directly after Stein asserts that action through contact is a necessary consequence of impenetrability, with action at a distance requiring a further act of God:

> It is in this sense, I think, that Newton's repeated denials that he holds gravity to be essential to bodies have to be understood. And this consideration certainly influenced Newton to consider seriously the possibilities of such a force as gravity being caused by a material medium. But yet again on the other hand, some of the considerations advanced in the *Opticks* tend rather persuasively to the conclusion that there is no reasonable hope of reducing all the forces of nature to the effects of impacts of particles. Therefore, I think, Newton's views on this deep question in physics were in a state of considerable tension. (Stein, 1970, 278)

As Stein sees things, there are two bodies of evidence pulling in competing directions. On the one hand, Newton's study of optical phenomena showcases a clear departure from the mechanical philosophy of his time, with blatant appeals to action at a distance as the only available means of explanation.[12] It is cases such as these that inspire Stein to write, for

[12] One sees this most strongly in the Queries to the *Opticks*, especially Query 31. For an overview of the key passages, along with arguments corroborating Stein's reading, see Henry (1999).

instance, that "Newton gives many, and convincing, reasons for believing that the principal phenomena of matter depend upon fields of force, both attractive and repulsive, among the particles of bodies" (Stein, 1970, 270-271). But on the other, Stein sees excerpts from Newton's correspondence with Bentley as indicating a resistance to action at a distance. Principal among them, we see in the quotation above, is Newton's rejection of innate gravity coupled with his continued search for material causes of gravity.

With this perceived tension in mind, Stein's tripartite division of Newton's thought into the levels of metaphysics, theology, and fundamental physics is cast in a new light: such a division puts into place the necessary scaffolding to make sense of these two contrary strains. One may grant that "The arbitrariness in the specification of interaction fields [...] is no greater than the arbitrariness in establishing impenetrability, inertia, and laws of interaction by contact," and simultaneously maintain that "interaction by contact [...] is a necessity [...] whereas interaction at a distance would represent [...] a further arbitrary decision of God" (Stein, 1970, 278). The former claim lays out space for alternative explanations of phenomena should they not admit of an easy description by action through contact, while the latter expresses a steady commitment to action through contact as the primary form of interaction. In this way, one is able to reconcile passages from the *Opticks* with Newton's insistence upon his ignorance of the cause of gravity in the correspondence with Bentley. All that Stein has to say is that Newton does not harbor some deep abhorrence of action at a distance, and would just as well rely on such interactions in the absence of alternatives—which is to say, it is admissible as far as theology and metaphysics are concerned—but favors explanations that make use of action through contact because of a pre-theoretic bias at the level of fundamental physics—namely, that this latter species of interaction is a direct consequence of the first property of bodies and the other not.

But Stein's reading is, of course, not the only way of coherently situating the seemingly contradictory positions voiced throughout Newton's corpus with respect to distant action. Of special note is the conception of Newton's general program set forth by DiSalle in his

Understanding Space-Time:

> As Newton and his followers (especially Cotes) emphasized, the mechanistic theory is no presupposition of scientific reasoning about motion; as the *Principia* itself shows to the contrary, the laws of motion could be successfully applied completely independently of any assumptions about the ultimate physical basis of interaction. As Newton emphasized, we have no philosophical insight into the physical basis of impact, but only some empirical rules that it appears to follow. Indeed, as far as the underlying nature of the interaction is concerned—what it is in the "essential" properties of bodies that makes the interaction possible—we know as little in the case of impact as in the case of gravitational attraction [...] For in the Newtonian view, any interaction is physically intelligible as long as, and just to the extent that, it conforms to the laws of motion. The distinctive feature of Newton's program is precisely the careful separation of what physical inquiry must presuppose, in order to bring the actual motions within the grasp of the laws of nature, and what can be left open as an empirical question. (DiSalle, 2006, 41-42)

DiSalle's Newton, far from championing some mode of interaction over another, sees physical intelligibility as in no way a precondition for natural philosophy. One admittedly lacks an understanding of what it is in the essence of body grounding the possibility of action at a distance—and so too with action through contact—but this is beside the point. What one does have are empirical laws that appear to govern the motions of bodies both for impact and gravitational attraction. Whatever our state of knowledge regarding its underlying nature, "any interaction is physically intelligible as long as, and just to the extent that, it conforms to the laws of motion." In DiSalle's eyes, it is this realization, along with the accompanying insight that one may suspend judgment and leave open certain questions, that is the distinctive feature of the Newtonian program.[13]

[13]Stein, I should note, would come to at least hold this last belief. In his 1990 paper, "On Locke, 'the Great Huygenius, and the incomparable Mr. Newton,'" Stein draws attention to Newton's early optical investigations in which "he claimed (and justly) to have proved with what may be called 'experimental certainty,' and quite independently of any mechanical explanation of the nature of light, a set of propositions *about* that nature of far-reaching importance, and of a quite unprecedented character" (Stein, 1990, 26-27). He concludes the paper, moreover, with a discussion of a sense in which Newton's conception of science is "dialectical," reaching "'forward' to the greater mastery of phenomena, 'backward' to new principles" (Stein, 1990, 39). This is exemplified most simply, he writes, by the preface to the *Principia* where "what Newton offers is not a proposed *foundation* for physics, but a *framework within which physical investigation may be possible*," accompanied by the intimation "that such investigation may lead, not only to new laws and deeper causes, but to a revision of the framework itself" (Stein, 1990, 39).

Such an understanding of Newton at large sits very well with my more narrow treatment, and gives one hope of squaring Newton's remarks in the Bentley correspondence with his account of body in *De gravitatione*. In the next section, I shift attention to this correspondence to address the alleged incompatibility of the two texts.

1.5 The Bentley Correspondence

Newton's correspondence with Bentley is notoriously difficult to interpret decisively and has been a contested subject for generations of Newton scholars.[14] Over the past few years, it has received renewed attention as the centerpiece of a discussion of Newton's views on action at a distance in a string of papers by Janiak, Kochiras, Schliesser, Henry, and Ducheyne.[15] Attention, however, has thus far been concentrated on understanding Newton's remarks in light of three metaphysical principles: (1) the passivity of matter, (2) the locality of action, and (3) the requirement that explanations of natural phenomena be given in terms of secondary causes. Arguments have been made both that Newton held and rejected each of these principles, and, according to how these questions are thought to have been settled, influenced how each of these scholars has interpreted the correspondence.

While this way of arguing is powerful and has its proper place, I fear that it here distracts from a more fundamental concern and leads one to extend Newton's position beyond what the text supports. As such, I will advance a more austere approach to the Bentley correspondence; one that, as far as possible, considers what is written without appealing to Newton's adherence to—or inclinations towards—metaphysical principles in order to motivate a particular reading of the text. It will be argued that what Newton finds unphilosophical is action at a distance that is alleged to be unmediated; on such a conception, action is supposed to be communicated without providing a causal story as to how. Importantly, however, this

[14]One may find overviews of the relevant secondary literature over the past few decades in Henry (1999) and Ducheyne (2014).

[15]See especially: Janiak (2008), Kochiras (2009, 2011), Schliesser (2010, 2011), Henry (1999, 2011), and Ducheyne (2014).

criticism does not apply to action at a distance when understood as mediated by an immaterial agent like God, for instance. Lastly, I refrain from attributing to Newton a position with respect to the true cause of gravity—in keeping with his famous declarations of ignorance in this regard, Newton's letters to Bentley leave such matters undetermined.[16]

Before proceeding to the disputed excerpts of the letters, it is helpful to bear in mind the general context of their discussion. Much of Newton's correspondence with Bentley is spent occupied with questions in cosmology pertaining to how the universe, and the solar system in particular, came to be in its current configuration. Front and center is an investigation into whether one could derive "the frame of the world by mechanical principles from matter evenly spread through the heavens" (Newton, 2014b, 127). In the draft of the sermon Bentley sends to Newton for review, Bentley writes of his project:

> Proved, in the 6th sermon, that the present system of the world cannot have been eternal. So that matter being eternal (according to the atheists) all was once a chaos, that is, all matter was evenly or near upon evenly diffused in the mundane spaces. I proceed therefore in this 7th to show, that matter in such a chaos could never naturally convene into this or a like system. (Newton, 2014b, 128)

On the table are two positions: that of the atheists, who believe the universe to arise purely mechanically from a homogeneous distribution of matter; and Bentley's, upon which such a formation is impossible and could come about only by the action of a deity.

Now, Newton—if his letters are taken to reflect his true opinions—is a strong proponent of this latter camp. Towards the end of his first response,[17] Newton enunciates the problem quite clearly:

> To make this system, therefore, with all its motions, required a cause which understood, and compared together, the quantities of matter in the several bodies

[16]My position is broadly in agreement with the work of Ducheyne and Henry: what Newton finds so disagreeable is not distant action itself, but only with what he refers to as "essential gravity." However, I diagnose the nature of Newton's objection and subsequent statement of his own position differently: Newton objects to essential gravity as being supposed to occur without any cause—secondary or otherwise—not for fear of its theological consequences; and I do not see Newton as taking a stance with respect to the cause of gravity, rather than endorsing either divine superaddition or a necessary reliance on secondary causes.

[17]Dated December 10, 1692.

> of the sun and planets, and the gravitating powers resulting from thence; the several distances of the primary planets from the sun, and of the secondary ones from Saturn, Jupiter, and the earth; and the velocities with which these planets could revolve about those quantities of matter in the central bodies; and to compare and adjust all these things together, in so great a variety of bodies, argues that cause to be not blind and fortuitous, but very well skilled in mechanics and geometry. (Newton, 2014b, 122)

Furthermore, this line of thought seems to play a role more broadly in Newton's work. Earlier in the same letter, he says, in reference to the *Principia*, that "When I wrote my treatise about our system, I had an eye upon such principles as might work with considering men, for the belief of a deity, and nothing can rejoice me more than to find it useful for that purpose" (Newton, 2014b, 120). For Newton, the heavens are arranged so delicately and exhibit such complexity that it is inconceivable that they could come about by chance alone, but rather serve as strong evidence of the existence and intervention of a divine being.

Innate gravity figures into this conversation in two interrelated ways. It initially appears in the specific context of Bentley's first query. In Newton's response, he writes:

> As to your first query, it seems to me that if the matter of our sun and planets, and all the matter of the universe, were evenly scattered throughout all the heavens, and every particle had an *innate gravity* towards all the rest, and the whole space, throughout which this matter was scattered, was but finite; the matter on the outside of this space would by its gravity tend towards all the matter on the inside, and by consequence fall down into the middle of the whole space, and there compose one great spherical mass. (Newton, 2014b, 120) [Emphasis added.]

Newton continues by supposing instead that space is infinite, whereupon he says that rather than collapsing to a single mass, the matter in the universe would coalesce into several masses spread throughout the heavens.[18] This might be one way in which the sun and the fixed stars could be formed, Newton argues, were it not for the difficulty involved in the

[18] Just as in the line cited above, Newton is here assuming that the matter of the universe is homogeneous everywhere. The supposition that space be infinite does not change, in Newton's eyes, whether these masses will coalesce; but only whether they will coalesce into a single mass or a multitude thereof. One might take issue with this conclusion (one might contend, for instance, that a homogeneous distribution of matter spread throughout an infinite space would be a state of equilibrium), but I am here restricting attention simply to what Newton wrote to Bentley at the time.

requisite types of matter differentiating themselves and combining only with like matter to form either "shining" or "opaque" bodies. But of this difficulty, Newton writes, "I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary agent" (Newton, 2014b, 121).

This same thought is echoed in Newton's second letter,[19] but now in the context of how the planets could have arrived at their respective distances from the sun and maintained a nearly circular motion thereafter. As in the case above, he first begins with a positive account of what would be required if such a motion were to be produced, before turning to the particular point in the argument that fails to be satisfied.

> I answer, first, that if the earth [...] were placed anywhere with its centre in the *Orbis Magnus* [...] and there at once were infused into it both a gravitating energy towards the sun and a transverse impulse of a just quantity, moving it directly in a tangent to the *Orbis Magnus*, the compounds of this attraction and projection would [...] cause a circular revolution of the earth about the sun. But the transverse impulse must be a just quantity, for if it be too big or too little, it will cause the earth to move in some other line. Secondly, I do not know any power in nature which could cause this transverse motion without the divine arm. (Newton, 2014b, 126)

Newton here notes a discussion alleged to have originated with Plato in which it is suggested that the planets could have assumed their respective orbits had they descended from some distant place under the gravitation of the sun, provided that the sun's gravitating power were to instill a transverse motion precisely when each planet arrived at its proper place. Newton is left unimpressed by such a proposal, and responds that it would require the divine power now in two respects.[20] He concludes, that "gravity may put the planets into motion, but without the divine power it could never put them into such a circulating motion as they have about the sun" (Newton, 2014b, 126).

Although the gravity of the sun is not referred to here as innate, this topic is explicitly

[19] Dated January 17, 1693.

[20] The divine power is required doubly, Newton explains, to (1) "turn the descending motions of the falling planets into a side motion," and (2) "at the same time to double the attractive power of the sun" to bring about the observed motions of the planets (Newton, 2014b, 126).

raised in the subsequent sentence of the letter: "You sometimes speak of gravity as essential and inherent to matter. Pray do not ascribe that notion to me; for the cause of gravity is what I do not pretend to know, and therefore would take more time to consider of it" (Newton, 2014b, 126). With this in mind, it seems reasonable to interpret the two block quotations above as the sort of reasoning entertained by those Bentley calls the "atheists." A scenario is imagined in which celestial bodies exist in a particular initial arrangement and the consequences are traced out mechanically following the supposition that these bodies are infused with—or thought to have always possessed—a gravitational power. This gravity is referred to as innate in direct contrast with gravity as imbued in bodies by God. Unable to avail themselves of a divine entity, the atheists must instead argue for the plausibility of the formation of the heavens solely from the essential gravitation of matter, or else seek another explanation.[21]

Bentley draws this connection between the atheists' mode of argumentation and essential gravity somewhat more directly in his seventh sermon:

> (1) Now the design of all this is to show [...] that in the supposition of such a chaos, no quantity of common motion (without attraction) could ever cause those straggling atoms to convene into great masses & move, as they do in our system, a circular motion being impossible to be produced naturally, unless there be either a gravitation or want of room.
> (2) And as for gravitation, 'tis impossible that that should either be coeternal & essential to matter, or ever acquired by it. Not essential and coeternal to matter; for then even our system would have been eternal (if gravity could form it) against our atheist's suppositions & what we have proved in our last. For let them assign any given time, that matter convened from a chaos into our system, they must affirm that before the given time matter gravitated eternally without convening, which is absurd. (Newton, 2014b, 131)

Here the line of thought of the atheist is traced out quite nicely. A proponent of this secular camp might, on a first pass, imagine the world to come about through "common motion," i.e., from bodies moving rectilinearly. But one is met immediately with the trouble of explaining

[21] As will be seen shortly, one is not forced to choose between either an appeal to divine intervention or innate gravity. One could, for instance, explain gravity as an attraction produced by the interaction of matter with some material medium.

the production of circular motion, which is not derivable from the former. To surmount this difficulty, the atheist might turn to universal gravitation for an explanation. As soon as such an appeal is made, however, one is obligated to give an account of how bodies come to gravitate at all. It is natural at this juncture for the atheist to suppose gravity to be "essential & coeternal" to bodies. But, Bentley argues, this supposition is incompatible with a non-eternal world convening from a chaos. It would have to be the case that (1) matter was uniformly distributed throughout space, (2) each of these bodies gravitated towards one another, and yet (3) this configuration was stable. But this is impossible: for if all three conditions are met, then large bodies like stars and planets would never have formed by gravity alone; and if not, one must say that there was a time when bodies did not gravitate.[22]

If the atheist now replies that gravity need not be essential to bodies, but rather is acquired at some point in time, difficulties remain. Bentley continues:

> But then if gravitation cannot be essential to matter, neither could it ever be acquired by matter. This is self evident if gravitation be true attraction. And if it be not true attraction, matter could never convene from a chaos into a system like ours [...] In a word: if gravity be not attraction, it must be caused by impulse and contact; but that can never solve universal attraction, in all situations, lateral as well as descending &c according to the phenomena of your hypothesis. (Newton, 2014b, 131-132)

In explaining the origins of gravity as a property acquired by bodies, there are two avenues through which one may proceed: one might conceive of gravity either as "true attraction" or as produced by some confluence of mechanical causes. Bentley rejects the former outright. Presumably if gravity were true attraction, i.e., an instance of action at a distance, there would be no cause which could imbue matter with this force were it not a basic property of bodies. One could appeal neither to God nor to coming into contact with region-specific matter[23]—gravity would be, as it were, an occult force that came into being from nothing. As

[22]One might call these assumptions into question. This is, however, how Bentley presents the position of his opponents.

[23]Under the supposition that gravity is caused by "impulse and contact," it could very well be that the

for the alternative, if the atheist pronounces gravity to be at heart a contact force, perhaps caused by the motions of intervening matter, Bentley responds that such a force could never bring the world into its present arrangement—it cannot even explain gravitational phenomena after the solar system has assumed a stable configuration. As he writes to Newton in the following sentence, universal gravitation, as set forth in the *Principia*, is "impossible to be solved mechanically" (Newton, 2014b, 132).

This brings us to the second sense in which gravity is spoken of as essential in the correspondence. While innate gravity appears initially only as an assumption required by the atheists' cosmology, it is recast in Newton's larger discussion of the cause of gravity and how it is that bodies come to act upon one another by means of this force.[24] In his next letter,[25] Newton seems to respond to the passage of Bentley's just cited above with this other sense of essential gravity in mind.

> It is inconceivable that inanimate brute matter should, without the mediation of something else, which is not material, operate upon and affect other matter without mutual contact, as it must be, if gravitation in the sense of Epicurus, be essential and inherent in it. And this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers. (Newton, 2014b, 136)

medium responsible for gravitational attraction was localized to particular regions of space. If this were to happen, bodies outside these regions would not gravitate, but would suddenly acquire a gravitational force upon entering one of these regions. This, of course, does not help if one believes gravity to be true attraction.

[24]It is important to distinguish between these two contexts in which essential gravity appears. As we shall see, Newton seems to mean by essential gravity the same thing in both contexts—i.e. action across empty space without mediation—but takes issue with the notion here for new reasons. The concern in the first case is whether the world might be formed by innate gravity alone and is addressed with cosmological arguments, whereas the issue in the present context will be whether matter might act across empty space without mediation and is treated philosophically. Moreover, Newton does not seem to leverage conclusions drawn from the preceding discussion, but seems to consider this new matter on its own terms.

[25]Dated February 25, 1693.

This passage is particularly dense and lies at the very heart of the disagreements concerning Newton's thoughts on action at a distance. As such, I will take extra pains to carefully trace through what Newton has written.

Neglecting the qualifications made and simply reconstructing the main clause of the first sentence, one might take Newton to be making the following statement: "It is inconceivable that inanimate brute matter should [...] operate upon and affect other matter without mutual contact." Read in this way, Newton appears to be claiming that contact is a necessary condition for one body to act on another; or equivalently, that bodies never act at a distance. Importantly, however, this claim is conditioned by two subclauses: "without the mediation of something else" and "which is not material." The first of these subclauses can be understood as consistent with the naive interpretation of the main clause and modifying its meaning in a simple—and even expected—way: one might stipulate that bodies need not be in direct contact with one another, but may also exert their influence "by the mediation" of a chain of intervening bodies, the extremes of which touch the two bodies in question. But the second is puzzling. If Newton is allowing for bodies to affect one another via the extended contact of a medium, it is unclear at which stage something "which is not material" would ever be required. This medium would presumably be a material one on the naive view, operating by the mutual contact of contiguous parts; and would, if anything, reaffirm the material nature of this interaction.

Stein points to this sentence in *On the Notion of Field* and gives the beginnings of an alternate gloss.

> The arbitrariness in the specification of interaction fields—represented in Newton's account by the dependence upon God's fiat—is no greater than the arbitrariness in establishing impenetrability, inertia, and laws of interaction by contact. So when Newton tells Bentley, "It is inconceivable, that inanimate brute Matter should, without the Mediation of something else, which is not material, operate upon, and affect other Matter without mutual Contact," what he says truly expresses his views; and would still do so if he left out the words "without mutual Contact." (Stein, 1970, 278)

Rather than pointing to the inconceivability of interaction absent contact, Stein sees Newton as emphasizing the equivalence of action at a distance and action through contact. The crux of the statement is not the inclusion of "without mutual Contact," but rather "without the Mediation of something else." Stein must have in mind what Newton writes shortly after this sentence:

> That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. (Newton, 2014b, 136)

Here there is no mention of mutual contact being a necessary prerequisite of material interaction, but what has persisted is Newton's requirement that the interaction be mediated in some way. For one body to act upon another, there must be some mediating agent that enables the communication of their action and force.

While this thought seems mostly right, the second subclause mentioned above remains a source of confusion. If Newton meant only to deny the possibility of matter acting without something to mediate the action, why add the further constraint that it be immaterial? Looking to the second line of Newton's just cited above, one notices another peculiarity. Although Newton here drops the condition that the mediator be immaterial, the action at a distance spoken of is now action at a distance *through a vacuum*: "so that one body may act upon another at a distance through a vacuum without the mediation of anything else." Accordingly, one might understand Newton's objection to essential gravity, not to be made on account of the absence of a mediator simply—much less one that must necessarily be immaterial—but the absence of an immaterial mediator in the unique case where one body is said to affect another *in vacuo* without ever coming into contact. When one or both of these conditions are met, there is a ready explanation for how the first body acts on the second: either the body acts on the other by coming into contact with it or by the aid of a material medium. If, however, the bodies are supposed never to come into contact nor for there to be an intervening medium, all that remains is to invoke the will of some immaterial agent, like God; and if even this is rejected, the interaction must then be thought to take place without any cause at all. Newton, in objecting to essential gravity, is decrying an interaction that is alleged to take place without any means whatsoever of communicating the action of one body to the other.

This reading is confirmed and further specified in the last sentence of the passage: "Gravity must be caused by an agent acting constantly according to certain laws." To avoid the absurdity of Epicurean essential gravity, it is necessary that the communication of gravitational force be explained in terms of the lawlike action of a mediating agent. Rather surprisingly, however, Newton leaves the nature of such an entity—"whether this agent be material or immaterial"—an open question to be decided by his readers. Taking Newton at his word, it would then seem to be no less intelligible for gravity to arise by the action of some immaterial agent as it would be for the cause to be located in the surrounding matter. Put more pointedly, Newton is asserting that it would be just as permissible for gravity to be a genuine instance of action at a distance, provided it be immaterially-mediated, as it would be for the force to be reduced to a mechanical process.

Other commentators have interpreted this last sentence differently. Ducheyne and Henry, for instance, both take Newton to be referring here to the secondary cause of gravity after having established earlier in the passage that God was the primary cause of gravity (see Ducheyne, 2014, 684 and Henry, 1999, 40). Part of the interpretative difficulty lies in Newton's shift in speaking of "the *mediation* of something else" to "an *agent* acting." I have been reading Newton as simply using these terms interchangeably rather than signaling a change of reference. Throughout the passage, Newton does not otherwise refer to the "something else" that must mediate the interaction; if an agent is simply "that which acts," expressions in terms of "mediation" might be naturally read as "without the mediation of some agent" and the continuity of reference restored. What I take to be most salient, by contrast, is Newton's insistence that gravity have some lawlike cause, with his leaving the nature of that cause open indicating that its exact metaphysical constitution is not what is at issue.[26]

But setting aside how to properly parse Newton's language, Stein raises a further conceptual difficulty with the notion of gravity as immaterially mediated:

> This last qualification, "material or immaterial," is disconcerting; and when we read in a letter by Newton's protégé Fatio de Duillier, dated thirteen months after the letter in question to Bentley, that Newton is undecided between two opinions about the cause of weight—(1) that it is caused by the impacts of streaming cosmic particles, Fatio's own hypothesis (later taken up by Le Sage); (2) that it is caused by "an immediate Law of the Creator of the Universe"—I think we are apt to be not only puzzled but annoyed, and to feel that Newton is quibbling. In point of fact, I cannot altogether acquit him of this: it is the case, as I read Newton, that bodies attracting by an immediate law of God means for him exactly the same thing as direct action at a distance. I think Newton knew this equivalence clearly, and disguised it in his public utterances to avoid the unwelcome embroilments. (Stein, 1970, 273)

There is no difference, Stein contends, between gravity as effected by an immediate divine law and direct action at a distance, i.e. between gravity mediated by an immaterial agent and the Epicurean essential gravity to which Newton has been objecting. But such a contention misses the significance of Newton's ascribing to gravity a lawlike cause, and along with it, a deeper theological point. If the primary complaint against innate gravity was that it failed to explain how one body communicated its action to another, the same cannot be said of an immaterial agent. For Newton, calling upon the will of God is not some catch-all explanation one falls back upon for lack of alternatives; rather, it looks to be an indispensable component of any physical law.

If not for the reasons Stein suggests, "What sets this whole matter in a light that seems [...] to clear up all obscurities is the fragment *De gravitatione*" (Stein, 1970, 273). Recall how the very foundation of Newton's creation story rests upon such immediate laws of the creator. Bodies are defined in *De gravitatione* as "*determined quantities of extension which omnipresent God endows with certain conditions*" (Newton, 2014a, 43). A body is

[26] It is noteworthy that the preceding cosmological discussion, in which Newton finds himself "compelled to ascribe the frame of this system to an intelligent agent," seems to leave open whether the "divine arm" is to act directly or through some other means (Newton, 2014b, 126).

not a region of space merely in possession of a set of properties, it is one that *God endows* with those properties. Moreover, once so endowed, the effects of such properties remain inseparable from the divine will: Newton speaks of God, "by the sole action of thinking and willing," preventing bodies from entering certain spaces and thereby becoming impenetrable; and "stimulating our perception by means of his own will, and thence apply[ing] such power to the effects of his will" (Newton, 2014a, 42). Nor even is the very existence of bodies taken to be given independently of divine action: as Newton prefaces his account, "[a body] does not exist necessarily but by divine will" (Newton, 2014a, 41). The will of God is the keystone around which Newton's early metaphysics of body is built,[27] and shines through in Newton's later willingness to accept gravity as immaterially mediated.

In sum, the second sense of innate gravity to which Newton is here objecting is a conception of gravity wherein brute matter is held to exert an attractive force without providing any causal story as to how. The two bodies never come into contact, there is no connecting chain of bodies, nor does some material medium fill the intervening space. Furthermore, the presence of an immaterial medium is rejected, with no mention of a divine power whatsoever. It is in this sense that Newton calls action at a distance unphilosophical, and in this sense alone. This is starkly contrasted with the notion that one body may exert its influence upon another at a distance and in a vacuum, but via the mediation of an immaterial agent acting "constantly according to certain laws."[28] Gravity as action at a distance affected through the will of God is fundamentally distinct from essential gravity. While the former is seen as metaphysically justified in Newton's eyes—the embedding of a divine presence into a physi-

[27]On this note, see Janiak (2008) for a discussion of the relationship between Newton's theology and his metaphysics more broadly. Particularly illuminating is Janiak's attention to a bifurcation of Newton's metaphysics into a "divine" and "mundane" metaphysics. About the two, he writes: "Divine metaphysics, as we have seen, represents a fundamental conception of God's nature and relation to the natural world that is not subject to revision; hence it might be understood to represent a basic framework for all of Newton's thinking about the physical world, one that is never questioned as he progresses through numerous empirical and mathematical investigations. Mundane metaphysics concerns metaphysical issues not directly focused on the divine: the nature of motion, the existence of various types of forces in nature, the types of causation involved in natural change, and so on" (Janiak, 2008, 45).

[28]Ducheyne (2014) casts this distinction similarly as being between "robust action at a distance," on the one hand, and "non-mechanically mediated action at a distance," on the other.

cal law being part and parcel of such descriptions—proponents of the latter position merely stipulate gravity as a basic property of bodies without demonstrating how it is compatible with their nature. Newton's rejection of innate gravity should then by no means be taken as an exclusive endorsement of the mechanical philosophy, as understood, say, by Descartes or Huygens; his writings to Bentley ought rather to be understood as deepening what is meant by action at a distance so as to place it on the same footing as action through contact.

1.6 Conclusion

The use of impenetrability is striking in Newton's early metaphysics of body. It is the first basic property of his imagined beings, and with the mere addition of mobility and the capacity to affect minds, Newton sees a way of recovering all the phenomena ordinarily associated with matter. This makes it quite natural to imagine that impenetrability implies contact action, if not a whole slew of physical consequences. I have tried to argue here that impenetrability does not imply action through contact, and nor did Newton think it did; rather, the stipulation of lawlike behavior is what in fact enables this combination of properties to carry their intended weight. Newton himself, moreover, looks upon his account in *De gravitatione* as at best provisional, and only describes a kind of being sufficient to mount an objection to aspects of Descartes's physics. As such, ample room is left for action at a distance, and it would seem out of character for such an account to be taken to privilege one particular mode of interaction over another.

Similarly, a careful reading of Newton's correspondence with Bentley serves to clarify what is meant by action at a distance and sift out the faults peculiar to innate gravity. Newton, we find, objects to gravity as innate because bodies would thereby be supposed capable of affecting one another without any cause whatsoever. Gravity as action at a distance mediated by an immaterial agent, however, is fundamentally different from such an unphilosophical conception. Far from having no apparent cause, action at a distance *mediated* *by God* would be supported by what Newton deems the most legitimate causal power of all, and one whose inclusion goes without saying.[29] For this reason, when Newton writes of action at a distance, one should understand by the phrase, not some occult and impotent force, but this fully causally efficacious form of interaction that is just as metaphysically well-founded as any other.

Following Stein's lead, we have considered both *De gravitatione* and the Bentley correspondence in the case raised against action at a distance. There has been no indication, however, that Newton regarded distant action as somehow second-class in either text: his account of body does not endow contact action with a special status, nor does his rejection of innate gravity suggest a preference for contact-based explanations. With Stein's strongest bodies of evidence found lacking, we may accordingly reject the thesis they were intended to support: for Newton, there is no difference in status between action at a distance and action by contact. Now, in following the contours of Stein's argument, this paper has been confined to only two works of Newton's corpus; it remains to be demonstrated that this favorable reception was sustained throughout his life and not anomalous punctuations of an otherwise adverse attitude.[30] But for the time being, this paper hopefully provides a glimpse into just

[29] I have deliberately phrased such statements in terms of "God" or a "divine power" because this is how Newton writes in the Bentley correspondence. One might, however, have reasons to prefer a neutral rephrasing featuring "primitive laws of nature" or the like. Modulo the centrality of God as causal agent, Newton's position may be faithfully extended in these terms. For instance, one could say that it is a primitive law of nature that bodies gravitate. Unlike the atheists who suppose bodies to gravitate without any cause at all, this neutral "primitivist" might dodge Newton's complaints by properly reifying such laws.

[30] Of special note, of course, are Newton's *Principia* and *Opticks*. On the whole, however, I think one has good reason to be optimistic on both fronts. Regarding the former, Newton writes famously in the Author's Preface to the Reader of his suspicion that "all phenomena may depend on certain forces by which the particles of bodies, by causes not yet known, either are impelled toward one another and cohere in regular figures, or are repelled from one another and recede" (Newton, 1999, 382-383); while of the latter, we noted previously that Stein himself (as well as Henry (1999)) read the Queries with which the *Opticks* concludes as showcasing a remarkably positive attitude towards action at a distance.

As far as I can tell, the primary cause for concern would be Newton's distinction between the "active" and "passive" principles of a body in the Queries. In naming gravity an active principle while impenetrability and inertia rank as passive principles, one might take Newton to be instituting a fundamental difference between distant and contact action. For our purposes, however, this would seem to be a difference without consequence. A principle is active or passive merely according to whether it introduces motion into the world:

> The *Vis inertiæ* is a passive Principle by which Bodies persist in their Motion or Rest, receive Motion in proportion to the Force impressing it, and resist as much as they are resisted. By this Principle alone there never could have been any Motion in the World. Some other Principle was

how deeply Newton truly did consider the question, and that action at a distance was by no means abhorrent to his philosophy, but rather very much in keeping with the spirit of his thought.

> necessary for putting Bodies into Motion; and now they are in Motion, some other Principle is necessary for conserving the Motion. (Newton, 1952, 397)

The principles responsible for the introduction and conservation of motion, Newton calls "active" and considers "not as occult Qualities [...] but as general Laws of Nature, by which the Things themselves are form'd; their Truth appearing to us by Phænomena, though their Causes be not yet discover'd" (Newton, 1952, 401). That bodies possess either kind of principle appears to us equally from the phenomena, and both are required for bodies to have been created in a way consonant with experience. As Newton continues, "by the help of these [active] Principles, all material things seem to have been composed of the hard and solid Particles above-mention'd, variously associated in the first Creation by the Counsel of an intelligent Agent" (Newton, 1952, 402).

While a more complete treatment of this question would require a paper of its own—especially if one is to decisively meet the objection that passive principles more truly pertain to the nature of bodies, whereas active principles are only imposed thereupon—I see the foregoing as lending plausibility to a reading of the Queries to the *Opticks* on which a principle is designated as active or passive simply to indicate a division of labor regarding the roles such principles might play, and not to suggest the metaphysical priority of one over the other. Thanks to an anonymous reviewer for bringing this objection to my attention and encouraging me to further develop the position.

Chapter 2

The Enchanted Palace Founded on Attraction: Du Châtelet on Essential Gravity

2.1 Introduction

Du Châtelet devotes an entire chapter of her *Foundations of Physics* to questions concerning the nature and intelligibility of Newtonian attraction. Of particular note, she argues for two theses: (i) changes in motion induced by Newtonian attraction are without sufficient reason, and (ii) attraction cannot be an essential property. These arguments are given in two sections of chapter 16, and while the first has received ample attention in the literature—usually in the form of criticism—the connection between these two theses and the complexities involved with the second have yet to be fully appreciated.

Katherine Brading in her recent book, for instance, writes of the two arguments:

> With the argument set out thus, the problem seems to be that Du Châtelet rules out action-at-a-distance by fiat when she insists that something must travel from one body to the other in order for the first to cause a change in the second. I do not know how to recover her argument from this criticism. She offers a

> second argument, in which she asserts that not even God could know which way a body will move on the basis only of the properties of the bodies themselves. In this case, she seems to be ruling out the kinds of relational properties on which an action-at-a-distance interpretation of Newtonian gravitation rests. No justification for this is provided, and it is not clear to me whether her account of the attributes of bodies or the forces of bodies [...] allows one to be provided. In short, the arguments given in Chapter 16 seem to me to be not very good. (Brading, 2019, 93-94)

Brading goes on to cite in a footnote two other assessments in the literature: that of Karen Detlefsen, who writes that "The argument seems to be that if attraction (as some sort of *active* principle or force) were to be inherent in bodies, then bodies would always move, contrary to our experience of the physical world. There is no sufficient reason—an inherent *passive* principle within bodies, for example, to counteract the active force—to account for the brute fact that bodies are at rest" (Detlefsen, 2019, 123); and Harmut Hecht's, who writes that "In order to be able to understand how physical motion is possible under the primacy of gravity, one has to state a cause, i.e. a mechanical procedure. Simply referring to the process of attraction will not do the trick" (Hecht, 2012, 73).

On Brading's reading, Du Châtelet's arguments do not succeed because they implicitly assume what they try to prove: with the first argument, gravity as action at a distance is ruled out by Du Châtelet's assumption that bodies may only causally interact across space by the transmission of some third thing; and the second argument assumes that bodies do not possess essential relational properties without sufficient justification from her doctrine of essences. While on Detlefsen's and Hecht's, attraction as an active force runs afoul of the principle of sufficient reason: there would need to be a corresponding passive force to limit a body's motion under such a force—a reason for the particular motions of a body—and basic, non-mechanical explanations are incapable of providing the sufficient reason for natural phenomena, respectively.

One can find textual support for these positions in the *Foundations*. Du Châtelet gives an argument of the same style as Detlefsen's in chapter 8 for the inclusion of passive force in the essence of bodies: "Passive force was necessary so that the movement was carried out with sufficient reason" (Du Châtelet, 8.142), and it is crucial, for the first of the above theses that a body be "by its nature indifferent to motion and to rest" (Du Châtelet, 16.395). Moreover, Du Châtelet concludes her ninth chapter by remarking, just as Hecht points out, that "however difficult it may be to apply mechanical principles to physical effects, one must never abandon this manner of philosophizing, which is the only good one, because it is the only one with which one can make sense of the phenomena in an intelligible fashion" (Du Châtelet, 9.182). In this way, it is natural to construe Du Châtelet's arguments in chapter 16 as a dogmatic commitment to mechanical explanations of natural phenomena. Fueled by the principle of sufficient reason, they represent a contest between the two prongs of her methodology—the metaphysical and empirical.

In what follows, I resist this way of reading Du Châtelet's objections to Newtonian attraction. While there is some textual support for this way of thinking, it loses sight of the finer points of Du Châtelet's arguments in chapter 16, and thus confuses Du Châtelet's conception of the ideal interaction between metaphysics and physics. I will argue rather for the following three claims: (i) Du Châtelet does not rule out action at a distance by brute posit, but argues substantively against it; (ii) it is her doctrine of essences, and not the principle of sufficient reason, that is at odds with Newtonian attraction; and (iii) she sees metaphysics and physics as two ends of a single natural philosophy, which ought to mutually constrain the other's growth as they converge towards a common, middle ground.

To motivate seeking such an alternative, it is worth briefly pointing out what is at stake for Du Châtelet's natural philosophy in deciding these interpretive questions. Her arguments in chapter 16 are the only place in which she even attempts a defense of the mechanical philosophy. Whether she has sufficient warrant for her endorsement, then, rests entirely on how these arguments fare. Additionally, while she may have two methodological prongs in name, this is a rare moment where they seemingly come into conflict; and so, however the conflict is to be resolved, it is an invaluable datum for gauging their relative priority.

2.2 The Problem of Attraction

Du Châtelet's argument against Newtonian attraction is given in two sections of chapter 16. She begins the first with a thought experiment she attributes to "the Newtonians" in which two bodies are imagined to attract one another "through the void" and "according to a certain law" (Du Châtelet, 16.395). The bodies begin to accelerate as they are drawn to one another, and so at each moment undergo a change of state induced by their mutual attraction. "This change had its reason," Du Châtelet continues, "thus we must seek this reason, either in the moved body, or outside of it and in the exterior Beings that act on it" (Du Châtelet, 16.395).

After this invocation of the principle of sufficient reason, Du Châtelet reflects on the two logical possibilities and concludes that the cause of the bodies' change of state can neither be in the bodies themselves nor outside them. The first possibility is ruled out out by the law of inertia: neither body could "move itself or give itself a certain speed and a certain direction, being by its nature indifferent to motion, and to all directions and speeds" (Du Châtelet 16.395). The remaining possibility is equally impossible by construction: "for the space AB being void by supposition, and the Newtonians excluding all intermediary subtle matter or matter emanating from body B toward body A, nothing enters body A that is part of body B through which we could explain the change that happened in body A" (Du Châtelet, 16.395). With this, Du Châtelet concludes that "this change did not have sufficient reason, and even the Creator could not say (in this supposition) whether a body that is at rest will move, and according to which law, were He to judge only by what He can see and know in the body itself" (Du Châtelet, 16.395).

One might object to Du Châtelet's framing of the thought experiment as leaving out conceivable possibilities or too readily collapsing certain distinctions. She does not consider that the bodies' motion might be caused by both bodies jointly or involve some relation they bear to one another (Elder, 2021, 5). After all, Du Châtelet writes that the motions of the bodies must be determined by "abstracting away the attracting body and seeing only the attracted body and that which acts immediately upon it" (Du Châtelet, 16.395). It would appear that Du Châtelet has simply taken for granted that a body may only causally interact with another through contact, a mutually contiguous medium, or the transmission of a third substance. But this would seem to reject action at a distance before the argument has even begun (Brading, 2019, 93-94).

This rejection is especially perplexing given how Du Châtelet argues for the inclusion of active force among the essential principles of bodies:

> The extension that results from the composition is therefore not the only property that is suited to Bodies; the power to act must also be added. Thus, the force that is the principle of action finds itself spread throughout all Matter, and there cannot be any Matter without motive force, nor a motive force without Matter [...] (Du Châtelet, 8.141)

For Du Châtelet, all matter as matter must possess an active force to explain the possibility of their causal efficacy. This would seem, at least prima facie, to resemble Newton's speculation in the *Opticks* that bodies "have not only a *Vis inertiae*, accompanied with such passive Laws of Motion as naturally result from that Force, but also that they are moved by certain active Principles, such as is that of Gravity" (Newton, 1952, 401). Why in this case is Du Châtelet not led to similarly conclude that bodies possess an essential active force responsible for their gravitational attraction?[1]

[1] While not cited by Du Châtelet as reason to reject attraction, there is a notable asymmetry between the two cases. While the active force belonging to monadic simples is indeed responsible for their causal efficacy, this is not the basis on which Du Châtelet argues for its essentiality; it is rather the principle of indiscernibles:

> This principle banishes from the universe all similar matter, for if there could be two pieces of matter absolutely similar and identical, so that one might be put in the place of the other without it causing the slightest change [...] there would be no sufficient reason why, for instance, one of these particles was placed on the Moon and the other on the Earth [...] all things would remain the same. (Du Châtelet, 1.12)

Du Châtelet later locates the sufficient reason for original differences between the parts of matter in their active force:

> There must, therefore, be something in Matter from which this internal difference originates; but this difference cannot have an origin other than the internal force, or force tending toward motion, that is in all Matter, and that, diversifying to infinity, puts a real difference between all the parts of Matter. (Du Châtelet, 8.139)

So while a gravitational active force would here be recommended on empirical grounds, this first active force

Du Châtelet anticipates this question throughout the *Foundations* and reduces it to a bare appeal to God's will, such that the Newtonians' claim is either that bodies attract one another by the will of God or that bodies are thereby endowed with an attractive power. These appeals are not explanatory, she responds, since "the will of the Creator is the source of the actuality but not the possibility of things" (Du Châtelet, 8.162) and "the essences of things are not arbitrary, and they do not depend upon God" (Du Châtelet, 3.48). But these responses seem to miss the point. One may concede to Du Châtelet both these points and simply clarify the level at which God's will is to be exercised: God is not choosing to amend some pre-existing essence by superadding an attractive power, but rather choosing among candidate essences to instantiate one containing such a power over one that does not. Accordingly, a sufficiently sophisticated Newtonian would escape Du Châtelet's responses unscathed.[2]

Lastly, while Du Châtelet's assumes a Newtonian conception of attraction so that she may later reveal its bankruptcy, one might contend that she has misunderstood their position yet again. Many Newtonians, for instance, did not share Du Châtelet's conception of the vacuum. While she understands by this word a space devoid of all matter, including even "subtle matter or matter emanating" from a body, some Newtonians would nevertheless

is secured a priori by the principles of our knowledge.

[2]Du Châtelet's true opponent would seem to be someone of Locke's ilk rather than Newton's (see Downing (1997)). The position in question is that: (i) gravity is incompatible with the nature of matter, and (ii) that because matter seems to gravitate empirically, gravity must be superadded to the nature of matter. But consider, for instance, Newton's prefatory remarks to his explanation of the nature of body in *De gravitatione*:

> Of this, however, the explanation must be more uncertain, for it does not exist necessarily but by divine will, because it is hardly given to us to know the limits of the divine power, that is to say, whether matter could be created in one way only, or whether there are several ways by which different beings similar to bodies could be produced. And although it scarcely seems credible that God could create beings similar to bodies which display all their actions and exhibit all their phenomena, and yet would not be bodies in essential and metaphysical constitution, as I have no clear and distinct perception of this matter I should not dare to affirm the contrary, and hence I am reluctant to say positively what the nature of bodies is, but I would rather describe a certain kind of being similar in every way to bodies, and whose creation we cannot deny to be within the power of God, so that we can hardly say that it is not body. (Newton, 41-42)

have entertained the presence of immaterial substances—like minds or, in this case, some manifestation of God's will—to mediate the bodies' interaction even in a space devoid of material substance.[3] In a similar vein, Newton defines "accelerative force" in the *Principia* as "a certain efficacy diffused from the center through each of the surrounding places in order to move the bodies that are in those places" (Newton, 1999, 407). While it is certainly possible for such an "efficacy" to be instantiated materially, it need not be.[4] If the bodies' gravitational attraction were attributed to a non-material "efficacy," or force, such a cause would slip through the cracks of Du Châtelet's ontology.

If Du Châtelet's rejection of Newtonian attraction amounted only to what I have described above, then much of this criticism would be just. The spirit of the above objections is that Du Châtelet does not genuinely engage with the possibility of robust action at a distance, or the possibility that one body might causally interact with another across a vacuum and without the mediation of anything else. As matters stand, Du Châtelet has not addressed this possibility. But what the literature has failed to appreciate is that Du Châtelet's argument against Newtonian attraction does not end here, and that the apparent defects of this first section are repaired by the second.

Consider, first, a reply to this last objection about the nature of a vacuum. Du Châtelet could, for the sake of argument, admit immaterial substances into her ontology and weaken her conception of a vacuum to only exclude material substances. If the Newtonians then pointed to an immaterial mediator in the intervening space to explain attraction, so much the better for Du Châtelet. For she could accept such a cause as explanatory in much in the same way as a material medium. In requiring that only the two bodies be present in the example, Du Châtelet is signalling that she is tackling the hard case in which there is no mediation whatsoever and considering whether it would be coherent for a body to influence another even then.

[3]See Clarke's replies in his correspondence with Leibniz and Newton's letters to Bentley.

[4]Newton is, of course, characteristically agnostic and speaks here only of the mathematical cause of gravity (Newton, 1999, 407).

Du Châtelet is setting the stage in this way for the following dialectic. If one grants her construction, it follows that a sufficient reason for the changes of motion induced by Newtonian attraction has yet to be given. The only consistent solution is to locate the cause of gravity outside the bodies themselves, as, for example, in some subtle matter that pushes or pulls them together. If, on the other hand, one resists her winnowing of the possibility space, one is free to entertain novel causal powers in bodies that would enable them to interact directly across empty space. The explanatory task would not end here, however; one must still account for the possibility of such powers in an intelligible fashion. It is a sensitivity to this explanatory gap that is behind Du Châtelet's exclusion of action at a distance from her initial construction. Du Châtelet is not ruling out action at a distance by fiat, she is wary, rather, of falling into the contrary error of admitting it by fiat.

Du Châtelet's first example thus adopts the more modest scope of causal interactions in framing the question, and only in the second part of her argument considers the outstanding objection of direct action at a distance. As we shall see, Du Châtelet entertains essential gravity as the representative of choice in treating action at a distance. This is significant given the above dialectic. After declining Du Châtelet's construction, a persistent opponent might seek to tie attraction to the essence of bodies. When pushed to explain the possibility of attraction, such an opponent could then respond that it is constitutive of what it is to be a body. All bodies, as such, bear an essential attractive power that causes all bodies in the universe to be mutually drawn to each other. Given an understanding of the essence of bodies that acknowledges attraction as an essential property, it is perfectly intelligible for bodies to act at a distance. Du Châtelet, however, will preempt this line of reasoning by demonstrating that gravity cannot be an essential property at all.

2.3 Against Essential Gravity

In the following section,[5] Du Châtelet considers whether attraction might be a property of matter. Leaving behind the example from before, Du Châtelet now leads with the observation that attraction produces different effects in different places:

> on earth this attraction directs heavy bodies toward the center of the Earth, and on the Moon it makes them tend toward the center of the Moon, and on the other Planets toward the centers of those Planets, and it makes them arrive more or less quickly, according to the mass and the diameter of these Planets, as Mr. Newton has shown. (Du Châtelet, 16.396)

From this she gathers that while "attraction makes bodies move with a certain speed and in a certain direction," both this speed and direction will depend on the relative positions, distances, and masses of the interacting bodies. Consequently, "neither this direction nor this speed is necessary" since "the necessary can be possible in only one way" (Du Châtelet, 16.396). Du Châtelet concludes, therefore, that attraction does not produce necessary effects.

Du Châtelet next considers this result in light of her doctrine of essences introduced earlier in the *Foundations*. On her account, there are two senses in which one might interpret the claim that gravity is essential to body.[6] The first is as what she calls a primordial determination. For Du Châtelet, a being's primordial determinations are those that constitute its essence. By this she means those determinations that are "constant," or always present in the being, and moreover, "do not conflict with one another, and that do not follow necessarily from other antecedent determinations." These determinations are not only "the first thing that one is able to conceive in a Being," but they are what make a being possible and without them it could not subsist (Du Châtelet, 3.38).

Aside from primordial determinations, Du Châtelet believes there are two other kinds of determinations that may be found in a being. The possibility of these other determinations

[5] Du Châtelet makes some changes to this and adjacent sections in the second edition of the *Foundations* published in 1742, but they exclusively concern the style and delivery of the argument while leaving its content intact. For a discussion of some of the changes across the two editions of the text, see Hutton (2004).

[6] See Janiak (2018) for a more detailed discussion of Du Châtelet's chapter on essences.

is given by their compatibility with the being's essence: "Nothing that conflicts with the essence of a Being, that is to say, with the primordial and essential determinations, could be found in that Being, but all that is not contradictory to these determinations can be found in it" (Du Châtelet, 3.39). Among these non-contradictory determinations, some are "deduced from the essence" and so "are constantly in the Being and never leave it"—these Du Châtelet calls attributes or (non-primordial) properties—whereas others, which are the being's variable properties or modes, "can either be in it or not; and it is only their possibility that is necessary and invariable" (Du Châtelet, 3.39-40). So while a being's essence grounds the possibility of both attributes and modes alike, only "attributes have their sufficient reason in the essential determinations" (Du Châtelet, 3.42). This gives rise to a second sense in which gravity might be said to be essential to body, namely as an attribute or consequence of its essence.[7]

By definition, then, both primordial determinations and attributes must be necessary. These determinations either constitute the essence or are immediate consequences thereof, and so must always belong to a being for it to be what it is. For if they were to belong to a being only intermittently or in more than one way, the being's essence would change and it would then be a different sort of being. With this in mind, Du Châtelet points out the following contradiction:

> It follows from all that has just been said that, since the direction and the speed that result from the attraction are variable, attraction is not a property of matter. For properties being founded in the essence are, like the essence, necessary [...] Furthermore, attraction does not flow from the essence of the matter [...] Now, since attraction cannot be essential to matter, and since it does not flow from its essence, it follows that God could not give this property to matter. (Du Châtelet, 16.396)

[7]As a third sense, gravity could be understood as belonging to bodies as a mode. While Du Châtelet does not treat this possibility in the *Foundations*, her argument in section 44 shows it to be a non-starter for proponents of essential gravity. As a mode of body, the reason for gravity's actuality would not be found in the essence of body, that is, in its primordial determinations or attributes. For if it was, then it would itself be either a primordial determination or attribute, and not a mode. Therefore, the reason for gravity's actuality as a mode of body must instead be found either in antecedent modes, exterior beings, or some combination thereof. But this would be to say that essential gravity stemmed, not from the essence of body, but rather from something contingent in bodies or outside them.

In Du Châtelet's framework, proponents of essential gravity could claim one of three things: gravity is a primordial determination, an attribute, or else superadded by God. All three would be impossible, however, since essences and all properties "founded in the essence" are necessary. Gravity, with its non-necessary effects, is simply not the sort of property that could belong to the essence of any being whatsoever.[8] In a word, then, Du Châtelet's rejection of essential gravity, and with it action at a distance, amounts to the following: gravity cannot be essential to bodies because all essential properties are necessary whereas gravity depends on the relative positions, distances, and masses of the interacting bodies.

This position is reminiscent of how Newton reasons in his Rules for the Study of Natural Philosophy in the *Principia*:

> Finally, if it is universally established by experiments and astronomical observations that all bodies on or near the earth gravitate toward the earth, and do so in proportion to the quantity of matter in each body, and that the moon gravitates toward the earth [...] and that our sea in turn gravitates toward the moon, and that all planets gravitate toward one another, and that there is a similar gravity of comets toward the sun, it will have to be concluded by this third rule that all bodies gravitate toward one another [...] Yet I am by no means affirming that gravity is essential to bodies. By inherent force I mean only the force of inertia. This is immutable. Gravity is diminished as bodies recede from the earth. (Newton, 1999, 796)

Newton here draws a distinction between universal and essential properties. While there is abundant evidence for the universality of gravity—all observed bodies exhibit gravitational attraction in proportion to their respective quantities of matter—Newton refrains from calling gravity essential. In contrast to inertia, which "is immutable," "Gravity is diminished as bodies recede from the earth," i.e. the force of attraction varies with the distance of the interacting bodies. One need only read "immutable" as "necessary" and Du Châtelet's argument is retrieved: inertia is necessary while gravity is not, and so only the former can be an essential property.

[8]Note that, while one might argue that they follow from or are allied with her position, Du Châtelet's claim is distinct from either of the following: (i) the essence of body is incompatible with attraction, and (ii) essential properties must be non-relational. This is contra Brading (2019) and also pointed out in Meskhidze (2021).

There are a few ways in which Du Châtelet's argument departs from Newton's, however. While Newton only mentions gravity's dependence on distance, Du Châtelet also points to its dependence on mass, for the velocities produced, and the relative positions of the interacting bodies, implicitly for the variability in direction of attraction. While the first of these changes is a mistake on her part, or at least not straightforwardly apt, she expands virtuously on Newton's argument with her earlier chapters on essence and the nature of body. By thus clarifying the terms of the debate, she is able to more fruitfully ask whether gravity is essential to body and avoid the confusion wrought by the absence of such definitions in Newton's own writings.[9] Du Châtelet extols this virtue herself as motivation for her chapter on essences:

> Since I will be obliged to employ the terms "essence," "modes," and "attributes," often in this Work, and since it is quite common for those who utter them to have very different ideas of their meaning, I think that it will not be useless to define these ideas, and to teach you what you should understand by these words; for very important truths in Physics depend upon the true notions of essence and attribute. (Du Châtelet, 3.32)

This is all illustrated by comparing Du Châtelet's objections to attraction with her treatment of action by contact. "All the changes that happen in Bodies," Du Châtelet claims, "can be explained by these three principles, *extension*, *resisting force*, and *active force* [...] and that the nature of Bodies consists in them" (Du Châtelet, 8.145). For "through extension [...] we can understand why certain changes are possible in bodies," by their motive force "how they become actual," and "why some take place rather than others, and at one time

[9]See Janiak (2018) where this point is made persuasively and further contextualized. As a sample, consider this representative quotation:

> Nonetheless, if we focus on the aspect of nature that she analyzes in the most depth, viz. the force of gravity [...] we find a more creative perspective embedded within her work. Rather than providing a metaphysical foundation for Newton's physics, one hailing primarily from the thought of Leibniz and Wolff, we find that Du Châtelet regards Newton as failing to provide a clear characterization of the force of gravity and its relation to matter. Du Châtelet uses the resources of metaphysics to help provide that characterization. In so doing, she provides at once a more philosophical, but also a more systematic, physics than does Newton. (Janiak, 2018, 50)

rather than another" from their passive force (Du Châtelet, 8.145). Insofar as they spring from these three essential principles, Du Châtelet is thus committed to an endorsement of contact-based interaction as a standard and intelligible cause of bodily change.

But she also maintains—as developed in her chapters on motion—that collisions generate motions that vary in the usual ways according to the bodies' initial quantities of motion. In particular, Newtonian attraction and contact-forces would seem to share the following characteristics: they (i) vary in proportion to the interacting bodies' masses, both with respect to the intensity of the acting forces and the resistance of each body; (ii) are sensitive to the presence of other beings, whether it be across space or at the boundaries of bodies; and (iii) determine the directions of subsequent motions according to a lawlike procedure, e.g. by finding centers of gravity or considering the angle of impact. This is to say, there is a sense in which even the effects of Du Châtelet's paradigmatic cause of bodily change are possible in more than one way, and thus not necessary. If any of these characteristics are proper grounds for the disqualification of a property as essential, Newtonian attraction and action by contact would seem to suffer the same fate.

In what sense, then, is action through contact necessary and Newtonian attraction not? The key difference is in how and what it means that bodies possess active force. Consider Du Châtelet's definition of active or motive force:

> Motive Force, which is the principle of motion, makes bodies traverse a certain distance or makes them displace a certain number of obstacles, when it is not prevented from acting, depending on whether it is exerted more or less. But when its action is prevented by some invincible obstacle, then the force does not make the body upon which it acts traverse any space, but makes it strive; the force impresses upon the body a tendency to displace that obstacle, and to impress a motion upon it. (Du Châtelet, 20.518)

Notice how Du Châtelet begins by describing this force as a "principle of motion" that "makes bodies traverse a certain distance" but quickly qualifies her description: "when it is not prevented from acting." As experience attests, active force does not always produce motions, let alone the same motions. In fact, it is for this very reason that Du Châtelet argues for the inclusion of a passive force in bodies—a principle of change alone is insufficient to explain why particular changes occur. Observe, further, Du Châtelet's use of language like "makes it strive" or "a tendency to displace." The sense in which active force is necessary is not found in the motions it produces, but rather the degree to which it makes bodies strive or tend to motion.[10]

This is especially clear when Du Châtelet explains how dead force becomes living force:

> When the obstacles upon which motive force acts are not invincible, the action of this force upon these obstacles is to make them leave their place; and then the small degrees of motion that this force communicates, at each infinitely small instant, to the body upon which it acts, accumulate and are conserved therein, and this force compels the body to change place: in this case *dead force* changes into *living force*. (Du Châtelet, 20.534)

A body in motion possesses a certain quantity of motive force by virtue of its motion. As such, when a body participates in a collision, its motive force will manifest as a certain tendency to bring about motion. Regardless of the size, initial motion, or situation of the body with which it collides, this tendency will always be the same—it is a necessary property determined solely by the impinging body. The properties of the other body instead determine the obstacles to be overcome. In this way, collisions involving a given body will not generally have the same outcomes simply because the obstacles presented will vary from collision to collision.

For this reason, the apparent agreement between contact action and Newtonian attraction dissolves—or is at least complicated—for two of the above characteristics. While a body's active force can only bring about changes on contact, this need not be due to some special receptivity or awareness of other beings. Its active force is always present and corresponds to the same tendency to motion; it is merely consumed as the body encounters obstacles and thereby tends to bring about changes in motion. By contrast, direct action at a distance

[10] This could be stated alternatively in terms of infinitesimal distances traversed: "Powers can differ from one another with respect to the size of the masses they can transport, and with respect to the infinitely small space they can traverse with the transported masses in equal times" (Du Châtelet, 20.539).

would seem to require the selective exertion of a body's force at points of space occupied by others.[11]

The matter of directionality fares similarly. The sense in which the direction of contact action is necessary refers, not to something in the motions produced, but rather the grounds for the directionality of active force itself. It is true that both species of interaction are accompanied by law-like procedures for their resolution, but there is the prior question of how these forces are to be given in the first place and whether they will be well-defined. Since active force is had by virtue of a body's motion, the directional component of its action is already given naturally—the body will simply act in the direction of its motion. The body's motion and corresponding capacity to act, moreover, is not merely a contingent fact of our experience of body, but supervenes on properties of monadic simples:

> There are two sorts of motive force; Mr. Leibniz calls the force that is found in all Bodies, and the reason for which is in the elements, *primitive force*; and that which falls under our sense and originates in the collision of Bodies, from the conflict of all the primitive forces of the Elements, *derivative force*; this last force flows from the first, and is nothing but a Phenomenon, as I explained to you above. (Du Châtelet, 8.158)

The motive force of bodies arises out of the harmony of continually acting simples, each of which is continually acting through its own motion. These motions are unique, moreover, in the sense that they are what "grant an original difference in the parts of Matter" (Du Châtelet, 8.139). The directionality of a body's active force, thus, springs from the essential motions of their constituent monadic simples.

To ground the directionality of Newtonian attraction, it is tempting to think something like the following. Suppose that all parts of matter exert an attractive force. For the sake of simplicity, suppose further that this force extends out in all directions but does not vary with distance, i.e. a given body will be compelled to the same degree of motion no matter

[11] Perhaps this is not true for certain brands of action at a distance. If one understands bodies to be, or at least exert, fields, one could hold that they are in some sense present wherever they manifest their attractive force. Just as Du Châtelet's active force, the manifestation of this field could occur independently of other bodies, with motions following as a response to the fixed values of this field. But this, arguably, would not be direct action at a distance.

where it is located in space. Let this force, lastly, be along the straight line joining the interacting bodies' centers of mass. In this way, the attractive force of a body would be a general tendency to draw others toward it, such that a particular attracted body simply moves along the shortest path between them.[12] It is unclear whether the direction of this force ought to be called necessary.[13] It has some claim to this status insofar as the force would uniformly draw in bodies from all directions, but one might insist that this phenomenon is not a single action, but the aggregate of many, and so deem the force possible in more than one way.

All that remains of the alleged similarities, then, is the dependence of both interactions on mass. Unlike the previous two cases, appealing to the way in which a body possesses active force does not differentiate distant from contact action. Du Châtelet is consistent throughout the *Foundations* that both quantity of motion and active force are proportional to a body's mass. This is seen most clearly in her chapter on simple motion:

> There is yet another thing to consider in motion, namely, the quantity; for the quantity of motion in an infinitely small instant is proportional to the mass and the speed of the moving body, so that [...] of two bodies moving with equal speed, the one having the most mass has the motion motion; for the motion imparted to any body can be conceived of as divided into as many particles as this body contains of its own matter, and the motor force belongs to each of these particles that participate equally in the motion of this body, in direct proportion to the size [grandeur]. (Du Châtelet, 11.262)

And reaffirmed in her chapters on forces: "In the first instant in which the motive power remains applied to the body upon which it acts, the intensity of this power is the product of the mass by the initial speed" (Du Châtelet, 20.539). To remain faithful to even contact phenomena, Du Châtelet must be committed to this mass-dependency, and so it is not clear why she would point to it in the case against attraction.

[12]This is similar, for instance, to how Kant speaks of attraction in the *Metaphysical Foundations of Natural Science* with the caveats, of course, that he grounds attraction in the possibility of matter as filling a determinate volume and allows the force to vary with distance.

[13]If a somewhat dubious precedent, one is reminded of how Aristotle calls the circular motion of the celestial bodies natural (see his *Physics* and *On the Heavens*.

Furthermore, it would be natural for even the primitive active force of simples to scale with mass, even if Du Châtelet is not explicit about this herself. For while the derivative forces relevant in collisions are mere phenomena, they are nevertheless aggregates of the underlying simples' primitive forces:

> Matter and active force, which seem to us to be substances, are not really substances [...] but an aggregate, a composite of substances [...] For since each simple Being is continually in action, and this action having a relation or a harmony with the actions of all the simple Beings, all of these actions that conspire together must seem to the senses to be a single and unique action. (Du Châtelet, 8.152-155)

There must be something in the active force of simples answering to this dependency—or else one risks the same problem of regress that Du Châtelet takes pains to circumvent with extension[14]—and Du Châtelet has a convenient quantity at hand in the passive force belonging to each monadic simple. So while it is not impossible for primitive and derivative active force to differ fundamentally, this would only serve to complicate Du Châtelet's account without any clear benefit.[15]

With this, let us take stock of the arguments thus far. Du Châtelet's objection to essential gravity is that all essential properties are necessary, or possible in only one way, whereas gravity varies in intensity and direction with the situation, distance, and mass of bodies. This objection is further clarified by the comparison with action through contact. While the motions following both contact action and attraction change with the details of the interaction, there is a sense in which the active force of a body is necessary that would not

[14]Recall that the extension of bodies is ideal for Du Châtelet in the sense that it is born from the confused perception of non-extended simples. This is necessary, Du Châtelet claims, to explain the possibility of extension itself and avoid a descending appeal to smaller, extended parts (Du Châtelet, 7.134). See Stan (2018) and Jacobs (2020) for recent discussions of Du Châtelet's ideality of body and space.

[15]There is something to be said for the following ambiguity in the case of attraction. One might take the dependence of gravity on mass, not to be a mark of its uniformity across all equal portions of matter, but to reflect a fundamental dissimilarity in the attractive force exerted by different kinds of matter. Given that Du Châtelet believes that there are no homogeneous parts of matter, it is conceivable that simples could all exert attractive forces but to different degrees. In this way, mass might be a smoothing over of the different rates with which different simples exert this attractive force. However, there would still remain the empirical constraint of supporting the tripartite equivalence of passive gravitational, active gravitational, and inertial mass.

be shared by a corresponding attractive principle. The active force of a given body will always act in a single way irrespective of the circumstances of other beings; the variability of collision outcomes merely reflects differences in the obstacles posed by the colliding bodies, and so arise from the interplay of active and passive force. In the case of action at a distance, however, this same variability is indicative of a deeper variability in the action of a would-be attractive principle. While the foregoing complicates Du Châtelet's selection of mass, and perhaps direction, as signs of this underlying variability, that the force of gravity would be proportional to distance is telling. A principle of attraction would need to act, not in just one way, but in an infinite number of ways so as to vary at each point in space. It is for this lack of necessity that Du Châtelet maintains attraction cannot be an essential property, and so could neither belong to a candidate essence of matter nor be superadded by God.

2.4 The Dilemma

After thus explicating Du Châtelet's argument against attraction, a few conclusions may be drawn. First, some clarification regarding the nature of the dilemma as Du Châtelet sees things.

Despite her advertisements to the contrary, the principle of sufficient reason is not the lynchpin of Du Châtelet's objection to attraction—it is not what "destroys this enchanted Palace founded on attraction" (Du Châtelet, 16.395). This principle makes an appearance twice in Du Châtelet's arguments, but each time in a merely auxiliary role. Its first appearance is in the framing of the above dialectic as a demand that gravitational phenomena have a cause: "This change had its reason: thus we must seek this reason, either in the moved body, or outside of it and in the exterior Beings that act on it" (Du Châtelet, 16.395). The second is less perspicuous and serves to specify why non-essential gravity fails as a sufficient cause of attraction: "it follows clearly that this cause is not an admissible cause since it contains nothing by which an intelligent Being could understand why the speed and the direction (which are the relevant determinations of the Being under consideration) are what they are and not otherwise. For it is this alone that distinguishes a sufficient cause from an insufficient cause" (Du Châtelet, 16.396). The substance of her argument is rather that Newtonian attraction, as essential gravity, is incompatible with her doctrine of essences. Her argument fails or succeeds according to whether one grants that essences, and essential properties, must be necessary, or possible in only one way.

But this is not to say that the dilemma posed by Newtonian attraction is thus between the principles of her metaphysics and the leading physics of her day. If one looks for the principle of sufficient reason in her chapter on essences, one finds its presence strikingly absent. Its only explicit mention is in the following quotation:

> Thus when it is a question of admitting some properties in a Being, one must see if this property follows from its essence, that is to say, from the primordial determinations that make it possible; for insofar as a Being is considered alone, one must show its intrinsic possibility by the principle of contradiction, and its external possibility, or its actuality, by the principle of sufficient reason, and from there deduce the attributes of this Being, and the modes to which it is susceptible. (Du Châtelet, 3.50)

Moreover, while Du Châtelet is explicit on the theological implications of the principles of our knowledge, and derives properties of God from the principle of sufficient reason, the relationship between these principles and her doctrine of essences is less clear. Aside from the above quotation, Du Châtelet will more casually discuss the "sufficient reason," or sometimes only "reason," in the context of explaining the possibility of properties and such, but this is much in the same way as the stage setting in chapter 16. So, while the principles of sufficient reason and contradiction here ground the operative notions of possibility and necessity, along with their accompanying roots in God's understanding and will, she does not thereby deduce the claim that essential properties are necessary.[16]

[16]There is one notable exception that is repeated by Du Châtelet, namely that the principles of our knowledge imply that essences cannot be arbitrary: "Thus, one cannot conceive how such a great man as Descartes was able to think that essences were arbitrary, since this opinion is entirely overthrown by the principle of contradiction, which he himself had posited at the beginning of his Philosophy" (Du Châtelet, 16.49). This should be read with two qualifications, however: (i) the claim that essences are necessary

The defense of this claim is rooted rather in how Du Châtelet conceives of essential properties:

> When one wants to conceive how a Being is possible, it is not the variable determinations that one must consider, for these determinations, which subsist only sometimes, cannot number among those that constitute a Being, since this Being can subsist despite their variations [...] Since a Being becomes possible by its essence, when one wants to know the possibility of a Being, one must know its essence, that is to say, the way in which this Being can come about: thus, the essence is the first thing that one is able to conceive in a Being; and no Being could subsist without essence. (Du Châtelet, 3.38)

When Du Châtelet calls a property essential, she means that it is constitutive of the being, or such that the being would cease to be what it is were the property to be lost. Under this conception, it follows almost as a matter of definition that essential properties be held necessarily, or in a constant and uniform way. For any variation in its instantiantiation, if the property were to, say, alternately turn on and off or manifest differently as the being moved through space, would be a variation in the being's essence.

Du Châtelet's claim, then, of the necessity of essential properties would seem to be compatible with the principle of sufficient reason—it is in line with and defined in terms of her notion of the possible and necessary—but not a direct consequence thereof. In this way, Du Châtelet's objection to attraction takes on the form of the following dilemma: one must foreclose the possibility of gravity as an essential property in scientific theorizing or else revise one's conception of essences.

One such revision is close at hand. For instance, one could broaden the class of necessary properties to include properties that are instantiated according to fixed laws. Gravity would then have a fair claim under this broader definition to being a necessary, and so essential, property: the strength of a body's gravitational attraction varies inversely as the square of its distance from any other. In other words, one might grant Du Châtelet's claim that essential

is distinct from the claim that essential properties are necessary, and (ii) Du Châtelet later in chapter 16 connects this conclusion with the principle of sufficient reason and not that of contradiction: "for it is absolutely contrary to the principle of sufficient reason that essences are arbitrary" (Du Châtelet, 16.396).

properties are necessary and yet understand by their concomitant uniformity something more general. Beyond the simple uniformity of being everywhere identically-valued, one could call a property uniform insofar as all relevant beings manifest the property according to a single, unchanging distribution. Such properties might, furthermore, be imagined to enjoy the same pseudo-independence from other beings and multiplicity of effect as collisions born from the interplay of active and passive force. For suppose the property were always instantiated, just as a body's active force is always present, and merely brought about it effects when a sensitive being were to enter its sphere of activity. In such cases, the properties of the second body, in analogy with passive force, could determine the way in which it is affected by the first's constantly-acting property. This would seem to be a fine way of extending Du Châtelet's account of essences to accommodate the difficulties posed by gravitational phenomena.[17]

But this accommodation comes at a cost and holding to Du Châtelet's conception of essences is not without its appeals. Consider the matter in the following light: A suggestion along the lines of the above constitutes a fundamental revision of Du Châtelet's metaphysical system. But what circumstances, in general, warrant such a fundamental revision? More particularly, is this warrant to be found in the empirical case for gravitational attraction?

Du Châtelet raises a number of points that would encourage patience in the face of recalcitrant phenomena and disfavor an overly-hasty metaphysical overhaul. She reminds her audience, first, that mechanical explanations of gravity have not yet been exhausted:

> Knowing whether the matter that Mssrs. Descartes, Huygens, and others suppose is adequate to account for all the Phenomena remains a problem; but even if no supposed matter were adequate, the truth would not suffer at all from this, and it would not be less established that all these effects must come about by mechanical causes, that is to say, by matter and motion. (Du Châtelet, 16.399)

While individual models have been shown to be empirically inadequate, there has been no argument against mechanical models of gravity as such. For confusing arguments of the first

[17] This is arguably compatible with Newton's thought in *De gravitatione*. See Chen (2020).

variety with a proof of the second, she chastises her opponents:

> A fault into which some of the English, who were overzealous about attraction, have fallen, is to make all objections against vortices into demonstrations in favor of their view. Thus, when they destroyed some of the attempted mechanical explanations of the Phenomena that they themselves attribute to attraction, they then concluded, *that one must therefore attribute all these effects to the attraction of all matter* Keill's *Animal Secretion*; but this conclusion is in no way legitimate; for it is to make a leap in reasoning, which is not permitted in correct logic. (Du Châtelet, 16.399)

Accordingly, Du Châtelet insists that the search for a mechanical cause of gravity continue in the hope that, one day, the phenomena may be wrangled under true principles.

This hope is further bolstered by the comparative uncertainty of other explanations in physics. Electrical and magnetic phenomena, she reminds us, pose "a problem infinitely more difficult than that of the cause of planetary motion" and have yet to be successfully explained by even non-mechanical means (Du Châtelet, 9.181). But this is to be expected:

> When we say that we must try to provide reason for all natural effects through matter and motion, we do not mean that we are obliged to find this reason for all the Phenomena, nor to go back as far as the first reason for things; the feeble extent of our minds and the present state of the Sciences do not permit it. (Du Châtelet, 8.163)

The state of knowledge in physics, this is to say, is simply not sufficiently advanced for one to reasonably expect certain parts of nature to be well-understood. To prejudge, for instance, whether a novel fluid might exist and explain the phenomena, one must "know all the ways that matter can be moved, and all that can result from all its diverse motions, but we are still far from this. (Du Châtelet, 9.181)

Moreover, Du Châtelet's belief in monadic simples casts a pessimistic shadow over the whole enterprise of scientific inquiry itself.[18] For if the fundamental explanations of phe-

[18]This is tempered, however, by a persistent optimism in the steady accumulation of scientific knowledge over time. Consider what else she says regarding the absence of a theory of electricity:

> Nonetheless, can one dare conclude that it is impossible that electrical phenomena would be brought about by fluids, because one has not yet discovered the way in which these phenomena

nomena are to be found in the interactions of simples, it is conceivable that even future technologies would be unable to penetrate to such a small scale:

> The littleness of the individual parts of matter surpasses so strongly anything that our senses could discover, that there is no hope that we could ever know their qualities, motion, and shape, which makes us see how far we are from the simple beings from which solid parts are formed. (Du Châtelet, 9.183)

Meditating on this possibility, Du Châtelet often comments that physics may need to content itself with mesoscopic explanations that are necessarily false but of instrumental value regardless. She writes, for instance, "that we can stop at the Physical qualities, and make use of one Phenomenon or of several, of which we do not yet know the mechanical reasons (even though they have them), to provide reason for another Phenomenon that depends upon it" (Du Châtelet, 8.163).

This brings us to the sense in which Du Châtelet is a sophisticated mechanist.[19] Du Châtelet likens the case of attraction to that of elasticity, fire, cohesion, and so on, all of which are conceptual placeholders for complex processes that are only partially understood in a coarse-grained way (Du Châtelet, 9.179). Although she argues that attraction is without sufficient reason, Du Châtelet maintains that it has a role to play in science nonetheless:

> It is thus that we can, and that we must, make use of attraction as a Physical quality, for which the mechanical cause is unknown, to provide reason for other Phenomena that result from it. Thus, we can assert, for example, that the Sun attracts the Planets and other matter that surrounds them, since the Phenomena demonstrate it, provided that we do not make this attraction an inherent property of matter, and that we do not diver Philosophers from searching for the mechanical cause. (Du Châtelet, 8.164)

Here one is working with phenomena where the fundamental, underlying causes are not yet

> are produced? Doubtless no; we should not be discouraged because we have not been able to divine all the secrets of nature up to the present. The first sources may elude our researches forever, but in trying to divine them, we will not fail to make discoveries as they fall along the path. (Du Châtelet, 9.182)

[19]Brading (2019) makes a similar point.

understood but which might be governed at larger scales by well-supported empirical laws.[20] But rather than having this first ignorance impede scientific explanation of other implicated phenomena, Du Châtelet recommends the value of this second intermediate knowledge to make piece-wise progress on problems in physics.[21]

Now all this is not to say that Du Châtelet's metaphysics is immutable and the above dilemma specious, such that the empirical ought to always defer to the metaphysical. Du Châtelet, in an effort to assuage the "rebellion of the imagination against simple beings," pins the principle difficulty on our inability to "make perceivable images" or "represent by characters" simple beings (Du Châtelet, 7.135). This difficulty, she continues, is not restricted to the question of simple beings alone but plagues metaphysics in general. She here laments the absence of a metaphysical calculus whereby one might arrive at metaphysical truths systematically and with apodictic certainty just as in mathematics:

> Mathematical truths would be no different from simple beings; if signs had not yet been invented to represent them to the imagination, these truths would be no less certain. Perhaps some day a calculus for metaphysical truths will be found, by means of which, merely by the substitution of characters, one will arrive at truths as in algebra. (Du Châtelet, 7.135)

It is worth reflecting, in this connection, on the absence of a derivation from metaphysical principles of Du Châtelet's claim that essential properties must be necessary. While Du Châtelet never stresses this herself, the foregoing suggests that there are certain metaphysical propositions, which, owing to their distance from first principles and this lack of a proof system, may not be absolutely certain. Du Châtelet's doctine of essences, at least in part,

[20] As a further nod to her sophistication, consider how she cautions against the premature invention of even mechanical causes for phenomena:

> In this way, however difficult it may be to apply mechanical principles to physical effects, one must never abandon this manner of philosophizing, which is the only good one [...] Doubtless one must not abuse it, nor, in order to explain natural effects mechanically, invent motion and matter as one pleases [...] nor certainly without taking pains to demonstrate the existence of these matters and these motions. But neither must one limit nature to the number of fluids that we believe are needed for the explication of the phenomena [...] (Du Châtelet, 9.182)

[21] Consider, also, Du Châtelet's belief in the indispensability of hypotheses in scientific research, especially those that are later overturned (see chapter 4 of the *Foundations*).

may be one such aspect of her system.

2.5 Metaphysics and Physics

The foregoing, furthermore, clarifies the relation of metaphysics to physics in Du Châtelet's thought. At face value, the question of the admissibility of Newtonian attraction would seem to be one where the metaphysical and empirical prongs of her method come to a head. One must choose between the principle of sufficient reason and the leading gravitational research of the time. This is how Brading puts the state of affairs:

> We can summarize the overall argument concerning gravitation, and its upshot, as follows. In Chapter 15, Du Châtelet looks in detail first at planetary trajectories, concluding that there is insufficient empirical evidence to decide between the two theories, and second at the shape of the Earth, concluding that the empirical evidence favors Newton's theory. In Chapter 16, she argues against Newtonian universal gravitation on the basis of PSR. The outcome of deploying her two-pronged methodology is that the empirical evidence favors Newtonian universal gravitation whereas the principles of our knowledge favor vortex theory. Thus, at the time she was writing, the upshot was inconclusive, and Du Châtelet finished her chapter on Newtonian attraction accordingly [...] (Brading, 2019, 94)

Brading goes on to praise what she sees as Du Châtelet's methodological discipline. Although she refrains from crowning a victor, Du Châtelet has succeeded in assessing the available options on both sides of the debate according to the best empirical and metaphysical standards of her time, and thereby identified precisely what must be repaired for progress to be made (Brading, 2019, 94-95). Given Brading's critical reading of Du Châtelet's objections to attraction, this has the fortunate effect of saving Du Châtelet from her own bad arguments: rather than prematurely discarding an empirically-validated theory on dubious metaphysical grounds, Du Châtelet is methodologically vindicated and renders an invaluable service to the discipline.

But as we have seen above, this is to misunderstand Du Châtelet's position. Far from delivering a half-hearted verdict, she has emphatically rejected essential gravity as conceptually incoherent. Immediately following her case against attraction, she writes, “We cannot therefore avoid recognizing that attraction, if we understand by this word something other than a Phenomenon for which we are seeking the cause, would be absolutely without sufficient reason” (Du Châtelet, 16.397), and further affirms that “we must seek by means of the laws of Mechanics some matter capable of producing by its motion the effects that we attribute to attraction” (Du Châtelet, 16.398). She is confident, given the available arguments and data, that gravity will one day be explained mechanically; she is merely uncertain as to when this day will come, as we see with how she concludes the chapter: “perhaps a time will come when we will explain in detail the directions, motions, and combinations of fluids that bring about the Phenomena that the Newtonians explain by attraction, and this is a quest to which all Physicists must apply themselves” (Du Châtelet, 16.399).

The more interesting morale comes from reflecting on whether Du Châtelet is justified in her steadfast rejection. If the dilemma was whether to adopt a physical theory that ran afoul of the principle of sufficient reason, the answer would be straightforward. From its very introduction, Du Châtelet heralds the principle of sufficient reason as that “on which all contingent truths depend, and which is neither less fundamental nor less universal than that of contradiction,” and wields it in defense against even radical skepticism (Du Châtelet, 1.8). If Du Châtelet did not reject a theory that was without sufficient reason, her metaphysics would be utterly without substance. But this is not Du Châtelet’s dilemma—she is rather in the position of having to choose between Newtonian attraction and her less fundamental account of essences.[22]

Fielding this dilemma is complicated by the relative independence of Du Châtelet’s ac-

[22] As an aside, there are the seeds of an a priori derivation of the impossibility of distant action through the law of continuity. In chapter 1, Du Châtelet shows that the law of continuity is a consequence of the principle of sufficient reason. While its formal definition, “no being passes from one state to another without passing through the intermediate states,” is restricted to changes across time in both its proof and technical examples, its informal characterization is more ambiguous: “nothing happens at one jump in nature” (Du Châtelet, 1.13). She even draws a spatial analogy with the aphorism, “one does not go from one city to another without traveling along the road between the two” (Du Châtelet, 1.13). It is interesting that Du Châtelet does not attempt an extension of this law to spatial change and thereby ground the impossibility of action at a distance in the principle of sufficient reason from the outset.

count of essences from the rest of her metaphysics. Insofar as it is not a direct consequence of the principles of our knowledge, this doctrine is free-standing, and so does not enjoy the same apodictic certainty. Her critics might take this as an opportunity to call her arguments into question and claim that she had posed the debate unfairly by situating it within a deliberately antagonistic framework. But this is to treat Du Châtelet unjustly. Given the absence of a deductive system for metaphysics, this may be expecting too much of a philosopher. Just as one admits a tolerance for error in empirical matters, so too one might extend this grace to metaphysical propositions. In any case, while not rooted in the principle of sufficient reason, the claim that essential gravity ought to be necessary does stem from an explication of what it is to be an essential property, which is a close second place.[23]

To counterbalance this critique, Du Châtelet's remarks concerning the state of physics in the 17th century should not be go unheeded. At present, the onus is not on Du Châtelet to radically revise her metaphysical framework. Not even a hundred years separates her *Foundations* from the first publication of Newton's *Principia* and the physics of her time is not so enlightened as to call off the search for mechanical explanations of gravity. If attraction-based theories abounded and essential gravity was but the most recent in a long line of triumphant non-mechanical models, the situation would be different. But this is not the case. There are still many unexplored avenues by which gravity may yet be explained mechanically and the naturalness of Du Châtelet's conception of essential properties more than purchases patience in the face of the comparative lack of clarity in the field.[24] The ball is in the Newtonians' court to either supply an equally-compelling metaphysical system that accommodates distant action or else establish the impossibility of mechanical gravity.[25]

[23]It is worth noting that, by not tying her doctrine of essences to the principles of our knowledge, Du Châtelet's system trades certainty for flexibility. If, for instance, a no-go theorem were discovered that ruled out mechanical explanations of gravity, she may safely jettison her doctrine of essences while leaving the rest of the structure intact. In this way, the *Foundations* would not rest precariously on the arguments of chapter 16, but remain open to re-evaluation in light of new empirical data.

[24]Another way of looking at Du Châtelet's arguments is that they give reason to not cease inquiry after accepting Newton's theory of universal gravitation. Underpinning her arguments is the belief that sustained inquiry will reveal further subtleties to nature and possibly lead to novel physics.

[25]It is not clear whether, or under what conditions, Du Châtelet would actually abandon her doctrine of essences given her pessimissm concerning the possibility of complete knowledge of nature. Perhaps even

Lastly, there is even something misleading in framing Du Châtelet's objection to attraction as a dilemma between aspects of her metaphysics and physics. The ideal case for Du Châtelet would seem to be one in which natural philosophy approaches a question from both ends, as it were, and is guided by both metaphysics and physics in their respective regimes; and while she is skeptical that this would ever come to pass, if one were to conduct both endeavors perfectly, their claims would eventually coincide as their investigations met in the middle. This might happen, say, if a true metaphysical calculus were invented or a technological miracle extended observations to the smallest parts of matter. For, after all, Du Châtelet is objecting, not to a mathematical proposition or empirical observation, but to the metaphysical claim that gravity is essential to body. It is eminently appropriate to address this claim within a metaphysical framework that makes sense of what it is to be an essential property and not at all a contest between the two prongs of her method.

Two precedents in the *Foundations* corroborate this reading of Du Châtelet's methodology and her approach to gravitational attraction, namely her treatment of the plenum and physical atoms. Du Châtelet in each case argues from the principle of sufficient reason to some metaphysical conclusion—by way of the impossibility of its alternative—but later leverages some fact of our experience to motivate a parallel insight. Remarkably, Du Châtelet reconciles the two observations when others might see them as fuel for a debate between two mutually exclusive positions.

Consider, first, Du Châtelet's case for the plenum. She begins with an argument against the alternative: "The principle of sufficient reason banishes the void from the universe [...] because it contains nothing whereby we can understand why particles have a given shape as opposed to all other possible shapes, and why they are of a particular size" (Du Châtelet, 5.73). Yet, only a few chapters later, Du Châtelet remarks that "All bodies contain two types of matter, proper matter and foreign matter [...] for experience teaches us that bodies have different densities and different weights" (Du Châtelet, 9.177). A less conciliatory judge

centuries of failure to find a mechanical cause would not suffice and she would instead require a rigorous no-go theorem.

might take this to imply a contradiction—if equal volumes weigh different amounts, this must be because matters fill space unequally in proportion to how much empty space they contain. But Du Châtelet threads the needle:

> All matters, including even gold, the densest of all, have pores that are not filled with the same matter as their proper matter. And, *there being no point of absolute vacuum in the universe*, it is necessary that these pores be filled with foreign matter that is not weighed with these bodies, and which does not enter into collisions with them if they encounter other bodies in their path, but which fills all their interstices, and which moves among them with as much liberty as air through a screen, or water through a net. (Du Châtelet, 9.178) [emphasis added]

Du Châtelet holds fast to her metaphysical commitment and treats it as a constraint on theory building alongside the empirical contribution. It is from simultaneously acknowledging the necessity of the plenum and the common experience of density that she arrives at the conclusion that there must be both proper and foreign matter in bodies.

The case for physical atoms is made analogously. Du Châtelet, in keeping with her Leibnizian-Wolffian roots, sees extension and extended bodies as ideal in the sense that they arise from our confused representations of monadic simples. Her argument for the existence of such simples, and corresponding impossibility of atoms, is as follows:

> All bodies are extended in length, width, and depth. Now, as nothing exists without a sufficient reason, it is necessary for this extension to have a sufficient reason that explains how and why it is possible; for, saying *that there is extension, because there are small extended particles*, comes to saying nothing, since the same question will be asked about these small extended particles as about extension itself [...] it is necessary to come in the end to something that is without extension, that has no particles, to give a reason for that which is extended and has particles. (Du Châtelet, 7.120)

Yet again, the principle of sufficient reason prunes what is possible—extension must be divisible without limit.

But Du Châtelet also acknowledges the difficulties that come from this view when held by itself: "If matter were resolvable to infinity, it would be impossible that the same germs and the same seeds would consistently produce the same animals and the same plants, that plants and animals would always take exactly the same time to grow, that they would always conserve the same properties, and they they would be the same at present as they were before" (Du Châtelet, 9.172). With this in mind, she inserts the following qualification:

> One has seen above that indivisible atoms, or parts, of matter are inadmissible, if one considers them as simple, irresolvable and primitive matters, because one cannot give a sufficient reason for their existence. But as long as one recognizes that they derive their origin from simple beings, one certainly can admit them. For it is very possible, and experience renders it very likely, that there is a certain determinate number of parts of matter in the universe which nature never resolves into their principle, which remain undivided in the present constitution of this universe, and that all the bodies that compose the universe result from the composition and the mixture of these solid particles, so that one can regard them as elements endowed with shapes and internal distinctions that result from their parts. (Du Châtelet, 9.172)

We see Du Châtelet walk a fine line between the constraint from metaphysics that extension be infinitely divisible and the demand from experience that there be a basis for the regularity of nature.[26] Du Châtelet does not treat this episode as a collision between the two prongs of her method, rather she keeps in mind a hard-earned lesson from metaphysics as a guide to unraveling the mysteries of the natural world.

For Du Châtelet, natural philosophy is at its finest when it is nourished by the harmonious implementation of both prongs of her method. Nature is a plenum, and so there must exist subtle fluids whereby the phenomenon of density is explained; body must be resolvable into unextended simples to explain the possibility of extension, yet physical atoms in nature ground the uniformity of its effects; and Newtonian attraction ought to be countenanced as a half-way house for its explanatory power but never admitted in place of the true mechanical causes at work. While each of these pairings has the look of a contradiction, Du Châtelet

[26]This dual methodology, as is especially pronounced in this example, carries with it the risk of a sort of schizophrenia where metaphysical and empirical research develop in parallel but never intersect. In the worst of cases, these strands operate entirely in their own spheres such that a metaphysical world is imagined apart from the physical and each remains governed only by their respective laws and propositions without any meaningful cross-verification. Du Châtelet does not discuss this risk, let alone strategies for its mitigation. Perhaps this is but the cost incurred by admitting monadic simples to the *Foundations*.

strives to weave these threads together to gain a deeper understanding of the phenomena than either allows by themselves. Read in this light, Du Châtelet's objection to attraction emerges as not only a subtle defense of mechanism in the *Foundations*, but an invaluable contribution from metaphysics in its partnership with gravitational physics.

Chapter 3

Kant's Metaphysical Principles for the Construction of Natural Philosophy

3.1 Introduction

It has been argued, most recently by Michael Friedman, that Kant's ambition in his *Metaphysical Foundations of Natural Science*[1] is to explicate the metaphysical presuppositions of, specifically, Newtonian physics. In *Kant and the Exact Sciences*, Friedman opens his third chapter with a statement to this very effect:

> The science for which Kant aims to provide 'metaphysical foundations' in the *Metaphysical Foundations of Natural Science* is Newtonian science: in particular, the science of Newton's *Principia*. This is indicated by the many explicit references to Newton and the *Principia* scattered throughout the *Metaphysical Foundations*, and, more important, by its content—which centrally involves both Newton's laws of motion (especially in Chapter 3 or Mechanics) and the theory of universal gravitation [...] (Friedman, 1994, 136)

This connection is evidenced, Friedman writes, by the central position Newton's laws of motion and theory of universal gravitation occupy in Kant's work.

[1] When citing this work, page numbers will be given by page numbers of volume 4 of the Akademie Edition of Kant's *gesammelte Schriften*.

Nearly two decades later, in the Preface to *Kant's Construction of Nature*, we see Friedman largely holding to this reading—if mildly tempered:

> My reading of Kant's treatise is Newtonian, in so far as I place Newton's *Principia* at the very center of Kant's argument. This much is signaled in the text of the *Metaphysical Foundations* by the circumstance that the name of Newton occurs far more often than that of any other author—and most of these references, in fact, are to the *Principia*. For this reason, among others, the idea that Newton's *Principia* is paradigmatic of the natural science for which Kant attempts to provide a metaphysical foundation has often been simply taken for granted—by both Buchdahl and myself, for example. More recent authors, however, have begun to challenge this idea and, in particular, have brought to light previously underemphasized connections between Kant's argument in the *Metaphysical Foundations* and the Leibnizean tradition in which he received his philosophical education. This development, I believe, has been a healthy one, and there is one important issue on which I have accordingly changed my views significantly. Whereas I (along with many others) had assumed that the three mechanical laws of motion Kant articulates in his third chapter or Mechanics correspond closely to Newton's three Laws of Motion, I have now been convinced by the work of Erik Watkins and Marius Stan that this was a mistake. I shall discuss the issue substantively in what follows, but here I want to insist that this recent work has not compromised my overrriding emphasis on Newton's *Principia* in the slightest. On the contrary, the very close and detailed reading I now give of Kant's fourth chapter or Phenomenology is intended, among other things, to establish the depth and centrality of Kant's engagement with Book 3 of Newton's masterpiece beyond any reasonable doubt. (Friedman, 2015, xiv)

With a nod to work by Eric Watkins and Marius Stan, Friedman concedes one respect in which Kant's project may not be aligned with Newton's: namely, that the mechanical laws of the former do not perfectly correspond to the laws of motion of the latter. Nevertheless, Friedman remains steadfast in his evaluation of Newton's *Principia* as lying at the heart of Kant's treatise.

But considering the arguments of Watkins and Stan more closely, Friedman's response misses the strength of their objections. The question of whether Kant is able to recover Newton's laws is not orthogonal to Friedman's thesis, such that it may be dispatched by retreating to an emphasis on book three of the *Principia*; rather, as Watkins explains, it is of central importance:

> What this brief account of Newton's fundamental project in the *Principia* shows is that the laws of motion stated in Book 1 are absolutely fundamental to his entire argument. Even slight variations in their formulations could easily invalidate the derivations of the later books. Accordingly, significant changes in the laws of motion imply that one might not be able to carry out Newton's project. Thus, if eighteenth-century German thinkers made such changes, it would be natural to expect that their fundamental concerns were different as well. (Watkins, 1997, 315)

For Newton's arguments in Book three of the *Principia* to be successful, it is essential that one make use of his laws of motion or an equivalent substitute. Accordingly, one cannot concede a lack of correspondence between Kant's mechanical laws and Newton's, while still maintaining that the former are capable of supporting the latter's mechanics. If Friedman's reading of the *Metaphysical Foundations* is to stand, even on its most recent iteration, one must demonstrate that Kant has the conceptual and mathematical resources to support the propositions appearing in the *Principia*'s final book.

In what follows, I consider whether Friedman's Kant is capable of such a task. I will argue that, while there is indeed room for such an interpretation, it is only at considerable cost and requires major modifications to Friedman's reading. I begin with the question of how Kant grounds the mathematization of forces and the motions they produce, and show how Kant makes use of different elements from across the *Metaphysical Foundations* situationally to properly treat them in disparate contexts. Moreover, by analyzing the content of the third mechanical law and its dynamical analog, I reaffirm Stan's objection that Kant's proof of the third mechanical law is not a general proof of the conservation of momentum and understand it to be in service, rather, of demonstrating certain metaphysical truths. I take these difficulties, along with obscurities in Friedman's analysis of how Kant treats the directionality of moving forces, to pose a serious threat to Friedman's reading of Kant's large-scale goals for the *Metaphysical Foundations*. An alternative reading of Kant's project presents itself on which Kant is understood to only be providing principles for the construction of the subsidiary concepts of matter. This, I argue, squares nicely with Kant's own description of his project in the preface to the work, and reveals an important sense in which Kant's work must be understood within a framework that is neither Newtonian nor Leibnizian-Wolffian but uniquely Kantian.

3.2 Friedman's View

Much of the debate on the relationship between Kant's laws of mechanics and Newton's laws of motion has concerned the absence of Newton's second law, and whether Kant is able to treat force quantitatively without it. On this matter, Friedman's primary contention is that Kantian dynamical moving forces acquire the structure of Newtonian impressed forces without explicit reference to the second law. What he means by this is that Kantian moving forces come to possess the same mathematical structure—that of a vector—by being determined with respect to both direction and magnitude:

> That Kant's notion of dynamical moving force is explicitly causal or physical does not imply, however, that it lacks the mathematical structure of a Newtonian impressed force. For it is precisely a cause of a change of motion (addition of velocities) in the sense of the Phoronomy. Moreover, the entire point of the Phoronomy [...] is to explain how *motion* is possible as a mathematical magnitude with respect to both speed and direction. The first proposition of the Dynamics then introduces the notion of a dynamical force into Kant's treatise, and the note to the second explication refers back to the Phoronomy (implicitly) in arguing that only two possible kinds of dynamical moving force—attraction and repulsion—"can be thought" [...] The action of a dynamical force in Kant's sense—that is, the motion imparted by this force—thereby acquires the vectorial structure of a Newtonian impressed force. And, in particular, arguments based on the addition or composition of such vectors [...] can be thus carried over into Kant's framework. (Friedman, 2015, 373-374)

Friedman thus takes the demonstration of the vectorial structure of dynamical moving forces to be one of Kant's primary objectives, and sees this as instrumental in connecting the "pure part of physics" with Newton's *Principia*.

For Friedman's Kant to be successful in this demonstration, it must be shown that one may speak of direction and magnitude with moving forces. Directionality, Friedman argues, comes from an extension of Kant's treatment of forces in the Dynamics chapter. A moving force, for Kant, is simply a cause of motion, and can only be conceived of in one of two ways: a force may be repulsive and cause two points to move away from another, or attractive and cause two points to come together. Extending this way of thinking to physical interaction between massive bodies, as in the case of gravitational attraction or mutual deflection following a collision, Friedman argues that motion must be introduced along the line between the two bodies' centers (Kant, 498-499).

The issue of magnitude, however, is considerably more involved. When considering bodies as masses, i.e. in the mechanical sense, a change in their motion must be estimated by the product of that body's quantity of matter and its relative velocity. While there is a meaningful, phoronomical means of speaking of velocity as a quantity, it is still to be determined whether one may equally treat of quantity in matter. For Friedman, what this involves is the determination of a mathematically-precise measure applicable to all matter in the universe as such, which is to say, the conditions for the empirical application of the concept of quantity to matter. The key to such a determination, Friedman argues, is the first proposition of Kant's Mechanics chapter, which states that "The quantity of matter, in comparison with *every* other matter, can be estimated only by the quantity of motion at a given speed" (Kant, 537). While defined as "the aggregate of the movable in a determinate space" and further explicated as a "plurality of substances," quantity of matter only manifests itself in experience through the communication of motion, i.e. in its mutual action on other bodies (Kant, 537, 541).

In particular, Friedman points to two primary means in which quantity of matter is determined empirically in bodies: the phenomenon of weight and the collision of bodies. While each method is valid if applied to the appropriate class of objects, Friedman contends that Kant nevertheless requires a universal procedure of comparing quantities of matter applicable to all bodies in the universe:

> Thus, it is precisely by embedding the traditional statical concept of weight within the framework of universal gravitation that we are finally in a position to provide a generally valid measure of its quantity applicable to all matter as

> such [...] We do this, moreover, by the at the time controversial extrapolation of conservation of momentum (Newton's Third Law of Motion) from situations of static equilibrium in contact to dynamical equilibrium at a distance. (Friedman, 2015, 304)

So, Kant must validate a procedure extending the phenomenon of weight in terrestrial bodies, exemplified by the weighing of two bodies on a scale, to the case of celestial bodies interacting via gravitational attraction. This procedure, to Friedman, ties the conservation of matter to the conservation of momentum, and, as quantity of matter can only be known in the context of bodily interaction, instantiates the categories of substance and causality: a body must act casually for it to be a substance, and a causal power must always have a seat in some substance.[2]

Friedman thus sees Kant as building into the concept of matter just what is needed to support the notion found in the *Principia*:

> The purpose of Kant's dynamical theory of matter, by contrast, is to extract just those features of Newton's theory that make his concept of the quantity of matter (as the product of volume and density) into a mathematically precise measure applicable to all matter in the universe—and then to build just these features into the concept of matter itself. For, according to Kant, we must, at least in principle, already be in possession of such a mathematically precise concept in order properly to establish the empirical laws that are supposed to govern it. (Friedman, 2015, p. 380)

While others have presupposed that concepts such as matter, motion, and force are mathematically well-defined, Kant seeks to demonstrate that this is so from first principles independently of a brute posit of Newton's second law. In this way, Friedman sees Kant as giving a constructive account of the key concepts used in physics pertaining to the concept of matter.

[2]More on this conception: "Both Newton and Kant begin from what I have called a dynamical concept of quantity of matter linked to the possibility of compression, move to the traditional statical concept of weight, connect this concept of weight with the new mechanical concept of mass or 'force of inertia' via Galileo's law of fall, and finally extrapolate this last concept of mass into the celestial realm in the context of universal gravitation" (Friedman, 2015, 306).

3.3 Conservation of Momentum

Stan, in objecting to Friedman's initial understanding of the mechanical laws, raises the case of oblique inelastic collision as an instance of the communication of motion not covered by Kant's construction procedure:

> It is quite hard to see how to apply Kant's law beyond his chosen case. Consider the oblique impact of two homogeneous, non-rotating discs with velocities at an angle. To handle it, we must resolve their motions into two components: frontal (along the line of centers) and parallel (perpendicular to that line, and so parallel to each other). When bodies in pure translation collide, only their frontal components change. To find their motions post impact, for each body one must compose its ensuing frontal component with its (unchanged) parallel one. Yet attempts to tame oblique impact strain Kant's theory. His mechanics rests on 'moving forces,' and 'actions' are effects of such forces; but his silence about the *directions* of force and action leads to tension [...] I chose my example strategically, so as to highlight a problem for the 'equivalence thesis' that Kant's third law is fully equivalent to the *Principia*'s Second and Third Laws, hence could support Newton's mechanics. (Stan, 2012, 503)

In the special case Kant considers in the proof of the third law, the relative motion of the bodies occurs along the line connecting their centers, allowing for the straightforward determination of their subsequent motions by appealing to the persistent motion of the relative space of one of the bodies. However, with oblique collisions, where the direction of motion does not coincide with the line of centers, Stan claims that it is unclear how to resolve the appropriate components of the bodies' motions. For Kant to manage such cases, he must, first, establish that the action between the bodies will occur perpendicular to the plane of contact, and secondly, determine a principled means of decomposing the the bodies' quantity of motion between the direction of travel and the direction of action.[3]

The principal insight behind Stan's counterexample is that the proof of the third law fails to be completely general. Stan himself takes this to have two related consequences: (i) it

[3]While Friedman sees Kant as alluding to the direction of action being perpendicular to the plane of contact—citing an off-hand remark of Kant's in the dynamics regarding the reflection of light rays—our discussion of the directionality of moving forces will call into question whether Kant has the resources to decompose quantity of motion in the required way. Even granting Friedman's extrapolation, it still remains to be seen whether Kant's system could meet Stan's challenge of extending to rotating bodies.

challenges the thesis that Kant's third mechanical law is equivalent to Newton's second and third laws of motion, and for this reason, (ii) calls into question whether Kant's *Metaphysical Foundations* is capable of supporting Newtonian physics. Beyond the issue of the equivalence of Kant's and Newton's laws, there is a more pressing threat to Friedman's reading: if, as Friedman understands it, this proof is equivalent to a proof of the conservation of quantity of motion, or momentum, then this is only achieved for a proper subset of the required cases. Kant, that is, does not have a proof of the conservation of momentum that is valid for all physical interactions.

But recall that on Friedman's reading, Kant has inextricably tied quantity of motion, along with the law of its conservation, to quantity of matter and its conservation law:

> Indeed, the necessity of going beyond the characterization of quantity of substance as the aggregate of movables and appealing to quantity of motion as its empirical criterion has already been emphasized in the second explication and immediately following first proposition [...] the relevant aggregate of movables (acting in mass) can then be estimated or determined as a magnitude in general only by appealing to the quantity of motion (at a given velocity). Thus, as explained, the proof of the second proposition shows that only the representation of matter as a continuous and extended aggregate of movables in space enables us to demonstrate the permanence of matter as a realization of the schematized category of substance. But it is also true that this proof, by itself, does not explain how matter so defined acquires a mathematical (measurable) structure in such a way that a quantitative conservation law results. Just as the quantity of matter can only be determined as a magnitude by means of the quantity of motion, a precise mathematical conservation law only results for the quantity of substance by means of the conservation of momentum. (Friedman, 2015, 330-331)

And elsewhere, Friedman even relates this commitment to how the categories of substance and causality are instantiated with objects of outer sense: "Kant is committed to both a synthetic a priori conservation principle for the total quantity of matter corresponding to the category of substance and a synthetic a priori conservation principle for the total quantity of momentum corresponding to the category of causality" (Friedman, 2015, 328).

To salvage Friedman's reading, one cannot merely jettison the "equivalence thesis," one must either show that the conservation of motion is valid for the relevant cases Kant requires, or provide another account of the mathematization of quantity of matter that is independent of this conservation law. Once this is done, it then remains to be shown whether such resources are sufficient to ground Newton's mechanics. As we shall see, there is a way out, of sorts, for Friedman. Kant's choice cases for which the conservation of momentum is shown to hold do suffice to launch his argument for Kant's "Copernican conception." Yet, this comes at a price: I will argue that the lack of generality of the conservation of momentum suggests an alternative reading for Kant's work at large, placing an emphasis instead on principles for the construction of the concepts related to matter.

3.4 Directionality

As discussed above, Friedman sees Kant as having secured the directionality of forces in the Dynamics by asserting that changes in motion can only be thought as being produced along the line connecting the centers of two bodies. This is true for some cases, but not all. Consider what Kant writes before making this assertion:

> Only these two moving forces of matter can be thought. For all motion that one matter can impress on another, since in this regard each of them is considered only as a point, must always be viewed as imparted in the straight line between the two points. But in this straight line there are only two possible motions: the one through which the two points *remove* themselves from one another, the second through which they *approach* one another. but the force causing the first motion is called *repulsive force*, whereas the second is called *attractive force*. (Kant, 498-499)

It is important to note that Kant's claim is here qualified in two ways: the bodies must be conceivable as mere points and the motion is "impressed" [eindrücken] or "imparted" [erteilen] rather than "communicated" [mitteilen]. The cases in which these qualifications are naturally met are when spatially-separated bodies act on one another by means of an attractive or repulsive force at a distance. In the case of gravitational attraction, for instance, all the parts of the first body will attract all the parts of the second—and vice versa—in inverse proportion to the square of their distances such that the net interaction will proceed as if the bodies' masses were concentrated at their centers of mass. Here it is appropriate to idealize the interacting bodies as points and consider the force imparted by each body as occurring along the line connecting their centers.

Reflecting on these qualifications, however, Kant must not mean this statement to apply in all bodily interactions whatsoever. When bodies collide and act via "surface forces," for instance, neither qualification is met. Kant is explicit in the Mechanics that he is there considering matter insofar as it possesses and exerts moving force—i.e. as bodies or aggregates whose parts move and act together—rather than phoronomical points determinable merely by their relative speed and position.[4] Furthermore, Kant describes cases of impact as ones in which motion is "communicated" between two bodies rather than "impressed" or "imparted." The third mechanical law, after all, reads: "In all communication of motion, action and reaction are always equal to one another" (Kant, 544).

[4]In a rather dense passage, Kant describes a conception of quantity of motion that would seem to bridge the gap between the action of points and the action of aggregates:

> The quantity of motion of bodies is in compound ratio to that of the quantity of their matter and their speed, that is, it is one and the same whether I make the quantity of matter in a body twice as large, and retain the same speed, or double the speed, and retain precisely this mass. For the determinate concept of a quantity is possible only through the construction of the quantum. But in regard to the concept of quantity, this is nothing but the *composition* of the equivalent; so construction of the quantity of a motion is the composition of many motions equivalent to one another. Now according to the phoronomical propositions, it is one and the same whether I impart to a single movable a certain degree of speed, or to each of many movables all smaller degrees of speed, resulting from the given speed divided by the aggregate of movables. From this first arises a seemingly phoronomical concept of the quantity of a motion, as composed of many motions of movable points, external to one another yet united in a whole. If these points are now thought as something that has moving force *through its motion*, then there arises from this the mechanical concept of the quantity of motion. In phoronomy, however, it is not appropriate to represent a motion as composed of many motions *external to one another*, since the movable, as it is here represented as devoid of moving force, yields no other difference in the quantity of motion, in any composition with several of its kind, than that which consists merely in speed. (Kant, 538-539)

It is difficult to tell whether Kant's criticism in the last sentence of the passage is meant as a dismissal of the conception as a whole or whether it is only meant to demonstrate the importance of including the mechanical explication of matter as an aggregate that has moving force through its collective motion. If the latter is true, then this would suggest a way of extending Kant's dynamical prescription for identifying the direction in which forces will act: Forces act along the lines connecting pairs of points. In particular, then, the action of a force on a body, as an aggregate of points possessing moving force by virtue of their shared motion, will be given by the sum of the force's action on all of the body's points.

If the motions caused by forces are not generally characterized by Kant's statement in the Dynamics, how else is Kant to treat the directionality of forces when the above qualifications are not satisfied? One answer that Friedman sometimes suggests in *Kant's Construction of Nature* is that Kant may appeal to his proposition from the Phoronomy. This is curious at first glance and Friedman does not fully explain why such an appeal would be successful. Kant is adamant throughout the Phoronomy that his proof of the composition of motion should be distinguished from past attempts in that he has achieved a geometrical construction of this composition when others have given mechanical constructions:

> Geometrical *construction* requires that one quantity be the *same* as another or that two quantities in composition be the *same* as a third, not that they produce the third as causes, which would be mechanical construction [...] Therefore, all attempts to prove the above Proposition in its three cases were always only mechanical analyses—namely, where one allows moving causes to produce a third motion by combining one given motion with another—but not proofs that the two motions are the same as the third, and can be represented as such a priori in pure intuition. (Kant, 493)

A geometrical construction secures a means of comparing arbitrary motions with one another, such that one may claim, for instance, that a speed is twice that of another or composed of some number of smaller speeds. If one considers a motion caused by an external force exerted on a moving body, by contrast, this is no longer a question for Phoronomy but, rather, Mechanics. The new motion in question is here conceived of as caused or produced by the combination of two motions.

It needs to be demonstrated, then, that Kant's geometrical construction procedure may be extended beyond its phoronomical context to justify an analogous composition rule for motions produced by forces. I will argue that this extension is indeed legitimate, but only once certain conditions have been met. In making this case, Kant's discussion in the second remark following this proposition is illuminating. Kant here further emphasizes the distinction between phoronomical and mechanical constructions with the example of a body that is acted upon by some force while aboard a moving ship. Kant reaffirms that this combination of motions goes beyond what may be assumed in a phoronomical or geometrical construction, adding a novel condition:

> For two equal speeds cannot be combined in the same body in the *same direction*, except through external moving causes [...] But here it must always be presupposed that the body conserves itself in *free* motion with the first speed, while the second is added—which, however, is a law of nature of moving forces that can in no way be at issue here, where the question is solely how the concept of speed as a quantity is to be *constructed*. (Kant, 494)

It is conceivable, Kant grants, for two speeds to be combined in a single body "through external moving causes," but this requires a coherent notion of inertial trajectories from which bodies may deviate and according to which a body may be identified as moving freely. This, however, is a law of mechanics for Kant and so cannot precede the construction of "the concept of speed as a quantity."

A few sentences later, Kant resumes this thread and elaborates further:

> Finally, with respect to the composition of two motions with directions comprising an angle, this cannot be thought in the body in reference to one and the same space either, unless we assume that one of them is effected through an *external* continually influencing *force* (for example, a vehicle carrying the body forward), while the other is conserved unchanged—or, in general, one must take as basis moving forces, and the generation of a third motion from two united *forces*, which is indeed the *mechanical* execution of what is contained in a concept, but not its *mathematical construction*, which should only make intuitive what the object (as quantum) *is to be*, not how it may be *produced* by nature or art by means of certain instruments and forces. (Kant, 494)

Once more, we see that Kant is willing to entertain the composition of motions in the same body provided that "we assume that one of them is effected through an *external* continually acting force." To do so, however, is simply not the task of a mathematical construction. With the appeal to motions produced by forces, Kant says that one is considering "the *mechanical* execution of what is contained in a concept," and contrasts this with "its *mathematical construction*, which should only make intuitive what the object (as quantum) *is to be*."

Kant here is allowing for the composition of motions produced by forces to follow the parallelogram rule used in the proof of the proposition's third case. This allowance simply comes with a caveat. Kant still holds to a strong distinction between the construction of a quantity and its later mechanical application. The latter requires, at least, the assumption of moving forces as the basis of the changes in motion, the law of inertia to speak of the persistence of a body's relative motion, and for it to be demonstrated that motion possesses the requisite mathematical structure as a quantity. Once one has completed this geometrical demonstration, however, one is free to apply the principle behind the proposition for non-constructive purposes, such as the composition of motions caused by forces.

In support of this line, we see Kant's statements regarding curvilinear motion in the third remark to the proposition of the Phoronomy and, most significantly, the proof of the second proposition of the Phenomenology. In the latter, Kant writes:

> Circular motion (like all curvilinear motion) is a continuous change of rectilinear motion, and, since the latter is itself a continuous change of relation with respect to the external space, circular motion is a change of a change in these external relations in space, and is thus a continuous arising of new motions. Now since, according to the law of inertia, a motion, in so far as it arises, must have an external cause, while the body, at every point on this circle (according to precisely the same law), is striving, for its own part, to proceed in the straight line tangent to the circle, which motion acts in opposition to this external cause, it follows that every body in circular motion manifests, by its motion, a moving force. (Kant, 557)

With circular motion, a body is continually caused to deviate from its inertial trajectory by the influence of some external force, i.e. the body moves with a motion that is the combination of two different motions in the same space. One is able to speak of motions composed in this way because the aforementioned conditions are now in place: the change in the body's motion is induced by a moving force, the proposition of the Phoronomy has established the additive structure of motion, and one has secured the laws of inertia and equality of action and reaction in the Mechanics chapter.

Directly after concluding this proof, Kant embeds this proposition—and the accompanying conceptualization of circular motion—in the larger contexts of both the *Metaphysical Foundations* as a whole and the general metaphysics of the first *Critique*:

> This Proposition determines the modality of motion with respect to *dynamics*; for a motion that cannot take place without the influence of a continuously acting external moving force manifests, directly or indirectly, originally moving forces of matter, whether of attraction or repulsion. (Kant, 557)

Moreover, in later remarks and the text of the proposition itself, Kant states that circular motion is "an *actual* predicate" of matter, i.e. the way in which a matter's motion is determinable with respect to the second category of modality, actuality (Kant, 556, 558). Kant, therefore, needs to be able to make sense of a body's circular motion by this stage of the Phenomenology if he is to complete the correspondence between his explications of the concept of matter and the pure concepts of the understanding found in his table of categories.

Returning to the Phoronomy, Kant's discussion of circular motion is foreshadowed in the third remark to his first proposition and distinguished from his earlier treatment of rectilinear motion:

> Phoronomy, not as pure doctrine of motion, but merely as pure doctrine of the quantity of motion, in which matter is thought with respect to no other property than its mere movability, therefore contains no more than this single Proposition, carried out through the above three cases, of the composition of motion—and, indeed, of the possibility of *rectilinear motions* only, not curvilinear [ones]. For since in these latter the motion is continually changed (in direction), a cause of this change must be brought forward, which cannot now be the mere space. (Kant, 495)

Kant, we see, deliberately curtails the scope of the Phoronomy to only a single proposition. Since one is considering matter merely insofar as it is movable, one excludes forces as possible causes of motion and references to the quantity of matter when estimating quantity in motion. As such, curvilinear motion, which manifests moving forces as causes of continual changes in direction, falls outside the scope of the Phoronomy.[5] Regardless, then, of how Kant's demonstration of the additive structure of motion may be applied to force-induced

[5] We will return to this point in a later section, but it is worth noting how Kant is similarly deliberate in his presentation of the proof of the proposition of the Phoronomy. Although all three cases may be subsumed under the third, as the composition of motions in arbitrary directions, Kant has elected to present three cases as distinct to better draw out the connection with general metaphysics between this proposition and the category of quantity with its three moments: unity, plurality, and totality.

compositions of motions, this extension cannot take place within the Phoronomy alone—a satisfactory treatment of forces and the motions they produce must await the integration of elements from across the *Metaphysical Foundations*.

3.5 The Third Mechanical Law

We have seen that Kant believes he has successfully incorporated curvilinear motion into his broader metaphysical system. How exactly does he do so? Following Newton, to treat the curvilinear motion of an orbiting body one needs the resources to speak of (i) the motions generated by mutual attractive forces and (ii) the composition of these motions with the bodies' initial, inertial motion.[6] If Kant's phoronomical proposition may be extended in the suggested way, all that remains is to show how to construct the motions produced by forces. This, I will argue, is given by Kant's third law and its dynamical counterpart. Let us begin with an examination of the proof of Kant's third mechanical law.

With this proposition, Kant details a procedure for finding the motions of bodies, with respect to both their magnitude and direction, following certain kinds of interaction. This procedure, however, follows a strikingly different approach from that of the Phoronomy. Instead of considering a series of cases corresponding to the addition of arbitrary quantities of motion at arbitrary angles, as one might expect of a mechanical re-casting of the proof from the Phoronomy, Kant argues for the canonical distribution of motion between two interacting bodies in inverse proportion to their quantities of motion. Kant thereby restricts attention on metaphysical grounds to the special case in which the two bodies are seen as possessing equal, opposite, and collinear quantities of motion. To resolve the interaction entertained in the proof, Kant reduces the complex problem of combining arbitrary quantities of motion (as "estimated mechanically") to two simpler sub-problems: (i) what happens when two perfectly inelastic bodies meet with equal and opposite quantities of motion, and (ii) in what way is the motion of a relative space affected by the bodies' collision. Since the quantities

[6] See Proposition 1.1 of the *Principia* (Newton, 444).

of motion are equal and opposite, they cancel and the two bodies are brought to rest with respect to absolute space; meanwhile, the relative space continues in its motion unimpeded by the interaction of the bodies, thus giving their final motions.

How it is that Kant justifies his solution to (i) is unclear. In the proof of the first proposition of the Dynamics, Kant writes: "Now nothing can be combined with a motion, which diminishes it or destroys it, except another motion of precisely the same movable in the opposite direction (Phoron. Prop.)" (Kant, 497). Kant here cites the proposition from the Phoronomy, inferring thereby not only the additive structure of motion, but also this physical limitation on how one may diminish a body's motion. This is Kant's only explicit statement on how motions may be changed between the phoronomical proposition and the proof of the third mechanical law. But what is the intended scope of this limitation?

Kant writes that the new motion to be combined with the first must be in "the same movable," which accords well with the cases considered in the Phoronomy, but seems inapplicable to the mechanical communication of motion between distinct movables. Nevertheless, Kant continues in the following sentence, "Therefore, the resistance that a matter offers in the space that it fills to every penetration by other matters is a cause of the motion of the latter in the opposite direction" (Kant, 497). Kant, even in the Dynamics, would seem to be considering the interaction of the motions of more than one movable: the resistance offered by one body's filling of a space and the motion with which another impinges on the first. It is important, however, to register the difference between the first body's resistance, which strictly speaking is "the cause of a motion" and not a motion itself, and the bona fide motion of the second (Kant, 497). If the first body's motion is conceived of as inducing a new motion in the impinging body, then the phoronomical proposition regains applicability as the comparison between the newly induced motion and initial motion, both of which are attributed to a single movable.

The above reasoning seems to make sense of how a body may in principle affect another: through its essential repulsive (or attractive) force, a body may induce a new motion in another. Crucially, however, it is not required for the purposes of the Dynamics to determine the quantity of the induced motion. Whatever the quantity of the generated motion, it may be combined with the affected body's initial motion according to the procedure outlined in the Phoronomy. It suffices, at this point, to simply introduce and make coherent the notion of moving force as the cause of motion.

So, what then of the equal and opposite quantities of motion in the proof of the third mechanical law? Kant, again, does not demonstrate the equality of action and reaction by enumerating a general procedure for finding the motions produced by arbitrary forces; but by borrowing the metaphysical proposition that all external action is interaction, Kant is able to exploit the symmetry of the situation to circumvent this absence. Each of the colliding bodies will act on the other by means of their moving force. Since this is generated through their motion as masses, or the collective motion of all their parts, each body's action will be given by the product of their quantity of matter and speed (Kant, 537). Kant must then assume that the action of a body corresponding to some quantity of motion will bring about the same quantity of motion in another body.[7] If the affected body itself already possesses an equal and opposite quantity of motion, the new motion will manifest as a speed equal and opposite to the body's initial speed. But then, by the second case of the Phoronomy's proposition, these two speeds must cancel.

This all being said, does this construction procedure also resolve the motions of bodies that result from attractive forces? Kant concludes the proposition with a brief note that "the communication of motion through *impact* differs from that through *traction* only in the direction in which the matters resist one another in their motions" (Kant, 546). While this is all he says on the matter in the body of the proof, he leaves behind some hints in his footnote to the proof as he explains the apportionment of motion to the interacting bodies:

> But in mechanics, where a body is considered in motion relative to another, with regard to which, through its motion, it has a *causal relation*—namely, that to

[7] In the note to the first proposition of the Mechanics, Kant does write: "As the quantity of motion in a body relates to that of another, so also does the magnitude of their action" (Kant, 539).

> the moving body itself—in that it enters into community with [the body] either in its approach through the force of impenetrability or in its withdrawal through that of attraction, it is no longer the same whether I wish to ascribe a motion to one of these bodies, or an opposite motion to the space [...] For one body cannot act on the other through its own inherent motion, except either in approach by means of repulsive force, or in withdrawal by means of attraction. (Kant, 547)

Kant reminds us that the communication of motion concerns the causal relations bodies bear to one another in virtue of their motion. If a body is to communicate its motion to another, it must do so "in its approach through the force of impenetrability or in its withdrawal through that of attraction." In this way, each body may be said to act by means of "its inherent motion."

Kant, then, must only have a very limited class of interactions in mind when he speaks of the communication of motion. For instance, the following interaction would fail on several accounts: suppose the approach of two bodies was caused by their mutual gravitational attraction after having been placed at rest relative to one another. While this interaction is indeed caused by mutual attraction, neither body is exerting this attraction through their being in motion. Moreover, this interaction would take place continually, and with increasing strength, as the bodies grew closer together—a sharp contrast to the brief window in which motion is communicated via impact. These two bodies, Kant would say, only impart motion to the other.

The only positive example Kant gives of the communication of motion by attraction comes offhandedly in his remark to the first explication of the Mechanics:

> I will be forgiven if I do not here further discuss the communication of motion by attraction (for example, if a comet, perhaps, with stronger attractive power than the earth, were to drag the latter in its wake in passing ahead of it), but only that by means of repulsive forces, and thus by pressure (as by means of tensed springs), or through impact. For, in any event, the application of the laws of the one case to those of the other differs only in regard to the line of direction, but is otherwise the same in both cases. (Kant, 537)

The case Kant describes is of a comet that exerts an attractive force through its motion past, or withdrawal from, the Earth. The resolution of the motion communicated in such a case does indeed proceed analogously to that of impact. Again, since all external action is interaction, when the comet acts on the Earth, so too does the Earth act on the comet. As this action is produced, moreover, through their motion, one must apportion the motion equally between the bodies such that their speeds are inversely as their quantities of matter. The Earth, together with its relative space, must thus be thought of as moving away from the comet. Now, Kant believes that the bodies will exert their attractive forces on one another through their withdrawal, as if they were connected by a string, which becomes taut upon reaching its full length. Each body will tug the other back with a strength proportional to its motion and, their motions being equal, both come to be at rest with respect to one another as their motions cancel. Just as in the proof of the third law, the motion of the relative space remains unaffected by this interaction, and so the comet will appear to drag the Earth behind it at a fixed distance as they move with a common speed, equal and opposite to that of Earth's relative space.

Thus restricting which interactions constitute communications of motion makes good sense of two otherwise perplexing claims of Kant's. For one, Kant purports to have established the third law in a general sense:

> It follows, then, that *in all communication of motion* action and reaction are always equal to one another (that every impact can communicate the motion of one body to another only by means of an equal counterimpact, every pressure by means of an equal counterpressure, and every traction only through an equal counteraction). (Kant, 546-547)

If one expected the third mechanical law to be equivalent to asserting that momentum is always conserved, then considerations like those raised by Stan should make one immediately skeptical that Kant's proof is sufficiently general. Kant does not discuss how his construction procedure is applicable to more complex cases of impact, whether the complexity be from the bodies' non-trivial rotation, angle of collision,[8] elasticity, or otherwise. Yet the foregoing

[8]There is, however, an ambiguity in the language of Kant's proof that may license its extension to oblique inelastic collisions of circular discs with no rotation. The motion, or change of relation, of interest is along "the line lying between" the bodies (Kant, 545). Prima facie, this would seem to refer to the line along which

shows how Kant does not mean for this to be a universal demonstration of the third law, its purported validity "*in all communication of motion*" notwithstanding. Kant, in other words, may have accomplished his stated aims even without a thoroughgoing proof of the conservation of momentum. This, by itself, does not address the simplicity of Kant's treatment of the communication of bodies through impact—such cases are paradigmatic of bodily action through motion. However, it does suggest that Kant has in mind specific objectives in treating the third law, objectives that are perhaps not shared by either his Newtonian or Leibnizian-Wolffian predecessors.

Secondly, it is then much more reasonable for Kant to introduce a dynamical third law, "not insofar as one matter *communicates* its motion to another, but rather as it *imparts* this motion originally to it, and, at the same time, produces the same in itself through the latter's resistance" (Kant, 548). This is not a redundancy in Kant's system; the law does indeed concern the equality of action and reaction in a new class of interactions. A thorn remains, however: Kant's proof of this dynamical law does not refer to motions at all. In a similar fashion to the first half of the mechanical law's proof, Kant arrives at his result simply by leveraging the symmetry of the situation and equivalence of certain definitions. But by what procedure, then, does Kant resolve interactions in which one body imparts motion to another?

Kant is largely silent on this matter in the Mechanics,[9] but gives a clear statement in the

the bodies travel prior to impact. Consider, however, Kant's explanation as to why this line is relevant: "in that they are considered simply in relation to one another, in accordance with the influence that the motion of the one can have on the change of state of the other, abstracting from all relation to the empirical space" (Kant, 545). Kant is interested in the motion by which one body may have an influence on the other. But the only motions that would "oppose" one another in the case of an oblique collision, and so be capable of causing a change of state, would be the component of the bodies' motion lying along the line of impact. This decomposition of the bodies' initial motions in terms of components parallel and orthogonal to the line of impact is given by the proposition of the Phoronomy. Distributing the bodies' motion along this line in inverse proportion to their masses is equivalent to requiring that momentum be conserved in that direction. The communication of motion along the orthogonal components could be treated analogously as a separate collision problem, and be composed with the final parallel component to find the velocity of the system post-collision. Under this broader interpretation, Kant's Mechanics would indeed be capable of resolving simple cases of oblique collision. It remains to be shown how to handle cases of arbitrarily-shaped discs, but this is a promising application of the construction principle given in the proof of the third law.

[9]The one exception is a brief note at the end of the remark to proposition one, in which he explains how the estimation of a matter's quantity is mechanical even when motion is imparted by dynamical forces:

Dynamics:

> For although between two bodies, when one attracts the other, whether their matter be similar or not, the mutual approach (in accordance with the law of equality of interaction) must always occur in inverse ratio to the quantity of matter [...] it is a law of the *motions* that follow from attracting forces, [...] and it holds for all moving forces in general. (Kant, 514-515)

Kant, we see, does indeed understand the third law to imply a general procedure for resolving interactions in which motion is imparted: the mutual approach must be apportioned to the bodies inversely as their quantities of matter. While never explicated further by Kant, the following line of reasoning justifies this implication: Whenever a body imparts motion to another, by the dynamical third law, it will experience an equal reaction through the resistance this other body offers to its action. Equal forces, moreover, cause equal motions. Since quantity in motion is the product of a body's speed and quantity of matter, the bodies' mutual approach must then occur in inverse proportion to their quantities of matter.

The foregoing seems to accord well with what Kant writes in the *Metaphysical Foundations*, but the scattered nature of these remarks is peculiar. Why not include a proof along these lines immediately following his demonstration of the dynamical third law? Or if Kant believes the discussion in the Dynamics to be sufficient by itself, and so skips an extended discussion in the Mechanics, why does he not refer the reader to his earlier treatment or mention its main result? While Kant may have simply viewed the result as trivial, and so not deserving of explicit proof, Kant's silence in the Mechanics might also be taken to indicate that the result is not essential to his agenda. This is to say, it may not be Kant's aim in the Mechanics to derive the principles used to find the motions of bodies.

Consider Kant's discussion in the remark following his proof of proposition four. After noting his triumph over his predecessors who proved the third law by appealing to experience,

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> But since, in the case of this force [original attraction], the action of a matter with all its parts is exerted immediately on all parts of another, and hence (at equal distances) is obviously proportional to the aggregate of the parts, the attracting body also thereby imparts to itself a speed of its own inherent motion (by the resistance of the attracted body), which, in like external circumstances, is exactly proportional to the aggregate of its parts [...] (Kant, 541)

Kant rebukes the "transfusionists" for asserting that motion is communicated by brute posit:

> Moreover, they do not demonstrate what is properly meant in the law in question, and did not at all explain the *communication* of motion itself with regard to its possibility. For the term *transfer* of motion from one body to another explains nothing, and, if it is not meant to be taken literally (in violation of the principle that accidents do not wander from one substance to another), as if motion were poured from one body into another like water from one glass into another, then we here have precisely the problem of how to make this possibility conceivable—where the explanation thereof in fact rests on precisely the same ground as that from which the law of the equality of action and reaction is derived. (Kant, 550)

Kant's intention with this construction is to properly explain the possibility of the communication of motion, to make sense of how the motion of one body could possibly be the cause of that of another. Motion, as a predicate of matter, cannot be thought of as flowing or being transferred between bodies—for "accidents do not wander from one substance to another." To make sense of this possibility, one must rather conceive of such interacting bodies as moving with equal and opposite quantities of motion, such that there is an equal and opposite reaction to every action.

Seen in this light, the problem of bodily action is found at the very heart of Kant's fourth proposition. Discovering a procedure for calculating the motions following impact is of secondary importance—its real value is in identifying the preconditions for the communication of motion itself. The relevant question is not, what motions follow from impact, but how must we conceive of the mutual approach of two bodies for it to be possible for their impact to bring about any changes of motion at all. Once this framework is in place, the subsequent motions of the impacting bodies just follow as a natural consequence.[10]

This is further clarified by contrasting Kant's mechanical and dynamical third laws. The

[10]It is worth noting that Kant never mentions the conservation of momentum either in relation to the third law or elsewhere in the *Metaphysical Foundations*. Although Friedman reports the conservation of momentum as a requirement for the complex process through which he believes quantity of matter becomes mathematically well-defined and applicable to all bodies in the universe, only these two special cases of the conservation law are required: static equilibrium (as with balances) and mutual gravitational attraction. In this way, a more modest version of Friedman's thesis is salvageable even if one worked only with Kant's construction procedures as written.

mechanical formulation is enshrined as a proposition—a Law of Mechanics—while the other appears only in a note. Whence the difference? Could Kant not have included these two statements under a single law establishing the equivalence of action and reaction in all external action, just as he takes pains to distinguish three metaphysically distinct cases of the Phoronomy's proposition?[11] But while the possibility of the communication of motion requires demonstration within Kant's system, there is a sense in which the possibility of imparting motion by dynamical forces does not. Once Kant explicates matter as "the *movable* insofar as it *fills* a *space*," he derives the further consequences that (i) "Matter fills a space, not through its mere *existence*, but through a *particular moving force*" and (ii) "The possibility of matter requires an *attractive force* as the second essential fundamental force of matter" (Kant, 496, 497, 508). It is a given that matter is capable of causing motions through dynamical forces—these dynamical forces, defined as causes of motion, have already been shown to be essential to matter as such. Kant, therefore, need not establish this possibility as a further proposition in the Mechanics.

The dynamical statement of the third law is necessary, however, to complete Kant's demonstration that all interaction is, at the same time, reaction. We must not forget how Kant begins the proof of the third mechanical law:

> From general metaphysics we must borrow the proposition that all external action in the world is *interaction*. Here, in order to stay within the bounds of mechanics, it is only to be shown that this interaction (actio mutua) is at the same time *reaction* (reactio) [...] (Kant, 544-545)

Throughout the work, Kant is clear that the subject matter of the *Metaphysical Foundations* mirrors moments of the pure concepts of the understanding found in his table of categories, and in this particular case, the analogies of experience, as well: "The three laws of general mechanics [...] precisely answer to the categories of *substance*, *causality*, and *community*"

[11] Kant may wish to "stay with the bounds of mechanics" and take this to necessarily exclude the dynamical third law (Kant, 544). But as he himself points out, even the dynamical law, insofar as it has consequences for the motions of bodies following the imparting of motion, "constitutes only a principle of mechanics, but not of dynamics" (Kant, 515).

(Kant, 551). Bearing in mind how the communication of motion only refers to a narrow class of physical phenomena, Kant's mechanical law does not, by itself, establish that all external action necessitates an equal reaction. It is only when supplemented by the dynamical law that this metaphysical insight is realized in full.

Reviewing the metaphysical fruits of the work reveals a certain value to the inclusion of the equality of action and reaction, and exclusion of Newton's second law, from the ranks of Kant's laws of mechanics. We have seen a sense in which the third law has tremendous metaphysical import: it instantiates the analogy of experience that all external action is interaction, and rests on the same principle as that by which the communication of motion is made possible. The third law entails a certain understanding of what action is in the world. Friedman makes a similar observation:

> I have argued, on this basis, that the point of view of absolute space thereby necessarily involves mutually counterbalancing motions, in accordance with the equality of action and reaction, in all cases of interactions corresponding to true motions: uniform (and non-uniform) rectilinear motions arising in interactions via repulsive forces, and circular or rotating motions—where the latter, in Kant's view, also essentially involve (mutually balancing) attractive (centripetal) forces preventing a (rectilinear) escape along the tangent. (Friedman, 2015, 476)

The third law implies, not only that forces in the world come in pairs, but that all cases of genuine interaction necessarily involve counterbalancing motions or forces. We see this with Kant's speaking of motion as either actual or necessary in the Phenomenology: true motions may be distinguished from the merely possible by the presence of forces found in experience, or with cases of mutual action, by the bodies' necessary community.[12]

Newton's second law, by contrast, only reflects half of such relations: a force, perhaps even abstracted from any bodily source, is conceived of as acting singly to bring about

[12]Kant, however, seems to step back from wholeheartedly adopting this thesis. In speaking of the Scholium to the Definitions of Newton's *Principia*, he says that it is "a paradox" that "the circular motion of two bodies [...] can still be known by experience even in empty space [...] so that a motion, therefore, which is a change of external relations in space, can be empirically given, even though this space is not itself empirically given, and is no object of experience" (Kant, 557-558). Even if the actuality of some motion is given by dynamical reasoning, Kant still sees it as necessary to identify an empirical space in which this motion takes place.

changes in motion. Of course, there is a certain value to thinking in terms of lone, abstract forces. When one does not wish to commit to a particular causal explanation, or if there is no compelling candidate at hand, this way of proceeding allows one to remain agnostic with respect to the true mechanism or causal process behind some phenomenon. But Kant's acceptance of essential attractive and repulsive forces that act at a distance allows him to be much more bold and skip this halfway house. It still may be prudent to withhold assent between competing explanations absent sufficient evidence, but Kant need not reject out of hand the action of bodies across a distance, for instance, as with non-mechanical explanations of gravity. The third mechanical law, embedded within Kant's special metaphysics of body, makes it intelligible to assert that all phenomena in the world follow from the mutual action of pairs of bodies.

3.6 Construction

The foregoing naturally raises several questions regarding the nature of construction in the Metaphysical Foundations: What does Kant really mean by a construction? Granting some interpretation of this notion, which concepts is it that Kant is attempting to construct in the proof of the third law, and in the work more generally? In pursuing these questions, it is especially fruitful to consider the rare examples of constructions Kant gives in the work, both positive and negative, in light of how he describes his aims in the Preface.

As Kant explains in the Preface, science is a term of art referring to "a whole of cognition ordered according to principles" (Kant, 467). Every proper science must have what Kant calls a pure part, consisting of all the principles of the science that may be cognized a priori and in virtue of which the claims of the science attain apodictic certainty (Kant, 469). Since natural science concerns itself with determinate natural objects, whose existence cannot be given from their concepts alone, the pure part of science must necessarily involve mathematics, i.e. "rational cognition through construction of concepts" (Kant, 470). To demonstrate that it is possible to apply mathematics in, for example, the doctrine of body, one must introduce "principles for the construction of the concepts that belong to the possibility of the concept of matter in general" (Kant, 472). This, Kant says, calls for "an analysis of the concept of a matter in general," which is a task for pure philosophy (Kant, 472).

These last two remarks are essential to understanding Kant's *Metaphysical Foundations* and, stemming from differences of perceived emphasis, have inspired different readings of the work. One of the standard views, and perhaps the most natural, is to read Kant as saying that one arrives at the pure part of physics by constructing the concept of matter.[13] This is not without textual support and, prima facie, is quite plausible. As we saw just above, Kant claims that one must analyze the concept of a matter in general if one is to demonstrate how mathematics is applied to this concept; and if mathematical cognition consists in the consideration of intuitions, it seems straightforward that a representation of the concept of matter as an intuition would be a necessary condition for the mathematical cognition of the concept of matter.

Despite this position's seeming naturalness, Friedman has raised strong objections against it. Reconsidering the key passage above, Friedman instead emphasizes that Kant describes the construction as being "of the concepts that belong to" the possibility of the concept of matter. This, Friedman thinks, makes sense of Kant's rejection in the Dynamics of the possibility of constructing the concept of matter as filling a determinate space. To construct such a concept, Kant explains, the relative strengths of the fundamental attractive and repulsive forces of matter would need to be given a priori. But this, Kant continues, is something that could only ever be the product of empirical research:[14]

> For, aside from this, no law of either attractive or repulsive force may be risked on a priori conjectures. Rather, everything, even universal attraction as the cause of weight, must be inferred, together with its laws, from data of experience. Still less may such laws be attempted for chemical affinities otherwise than by

[13]See, for instance, Heis (2014) or McNulty (2015).

[14]In fact, particular force laws aside, Kant does not even demonstrate that these fundamental forces must vary in intensity with distance.

> way of experiments. For it lies altogether beyond the horizon of our reason to comprehend original forces a priori with respect to their possibility [...] (Kant, 534)

With Kant claiming the impossibility of some aspect of the construction of the concept of matter, Friedman contends that Kant's aim in the work must instead be to construct, not the concept of matter itself, but rather its constituent or partial concepts, which make the concept of matter possible. It is then necessary to analyze the concept of matter to discover which are the particular partial concepts in need of construction.

On this second reading, Kant's project is to determine the conditions under which the key concepts of physics may be treated mathematically. Whereas Newton takes for granted that terms like motion and force admit of the appropriate mathematical structure, Friedman's Kant sees it as necessary to first determine whether such concepts may be legitimately treated as quantities:

> Kant aims, more generally, to explain how the quantitative structure of each of the concepts required by the mathematical theory of motion becomes possible—and, in this way, to explain the application of mathematics in all of (Newtonian) mathematical physics. One of the most important goals of the Mechanics chapter, for example, is to explain how the concept of mass or quantity of matter becomes possible as a mathematical magnitude—to explain how, in Kant's terms, the quantity of matter of any body may be (mechanically) measured or "estimated" (537, Proposition 1). (Friedman, 2015, 32)

For Kant to be successful on Friedman's reading, then, he must have properly constructed the requisite partial concepts. While Kant does not enumerate these concepts in full,[15] a necessary condition would seem to be success with respect to those concepts he explicitly purports to construct: the composition of motion in the Phoronomy and communication of motion in the Mechanics.

[15] While not exhaustive, Kant does say the following: "Thus the mathematical physicists could in no way avoid metaphysical principles, and, among them, also not those that make the concept of their proper object, namely, matter, a priori suitable for application to outer experience, such as the concept of motion, the filling of space, inertia, and so on" (Kant, 472). Friedman often references this statement and notes its similarity to a list from the *Prolegomena*, which replaces "the filling of space" with "impenetrability." It is not clear, however, how to square this list with one containing key quantitative terms in physics like motion, matter, and force.

But I take the discussion of these constructions in the preceding sections of this paper to pose a serious challenge to Friedman's reading. For, as we have seen, there are meaningful senses in which Kant's constructions fail to generalize across all physical situations: the proposition of the Phoronomy does not explicitly treat the mechanical execution of the composition of motion, and the third mechanical law deals with only the simplest cases of, specifically, the communication of motion. Even if one charitably grants that "not *all* of these (partial) concepts can themselves be mathematically constructed," Friedman himself says that "the concept of motion [...] appears eminently capable of mathematical construction" (Friedman, 2015, 31). If Kant falls short even with respect to these constructions—which ought to be demonstrations of his program, par excellence—something must be amiss.

Rather than seeing this as a failure on Kant's part, however, there is a third way of understanding his project that sidesteps this difficulty. In a similar spirit to Friedman's deflection of the natural reading, it has yet to be appreciated how Kant begins the passage from the Preface discussed above: one must introduce "*principles* for the construction" of the concepts belonging to the possibility of the concept of matter. What Kant promises is not a construction of the concept of matter in general or even of its constituent concepts, but rather principles for the latter's construction.

Seen in this light, it is no great surprise that Kant's constructions would fail to acknowledge all the complexities of a collision or be perfectly situated for direct application in physics. Kant's constructions are better thought of as proofs of concept putting on display the principles according to which one must approach the partial concepts of matter. The constructions in the Phoronomy and Mechanics make intelligible the additive structure and communication of motion, respectively, by illustrating the conditions under which motions may be composed or bodies act through their motion. It is the reasoning behind the construction procedures that is to be generalized, for example, to the composition of motions caused by external forces and equality of action and reaction in the imparting of motion.

As Kant says after declaring that it is impossible for metaphysics to construct the dynamical concept of matter:

> This is now all that metaphysics can ever achieve towards the construction of the concept of matter, and thus to promote the application of mathematics to natural science, with respect to those properties whereby matter fills a space in a determinate measure—namely, to view these properties as dynamical, and not as unconditioned original positings, as a merely mathematical treatment might postulate them. (Kant, 535)

Kant, despite having made such a significant concession, nevertheless sees a role for metaphysics as a guide for natural philosophy: metaphysics is "to promote the application of mathematics" by laying the groundwork for an understanding of matter's filling of space as fundamentally dynamical. This is done by explicating the principles according to which one must understand the filling of space, i.e. by showing how a matter can only fill space by means of a repulsive force, which, together with an attractive force, must be tied to its essence. In doing so, Kant guarantees that natural philosophy will have a proper object about which to reason—one that will be amenable to mathematics and not merely free from contradiction.

On this conception of the *Metaphysical Foundations*, Kant is not paving the way for, specifically, Newtonian physics, or any other system of the world. He is not seeking to prove the assumptions of the *Principia* from first principles, nor is he meaning to construct the partial concepts of matter with the hopes of securing the quantitative structure of key physical concepts, like matter or force. His ambitions are both more modest and yet farther reaching. The task of constructing matter's constitutive concepts is not one for metaphysics; rather, what metaphysics ought to concern itself with are the principles behind such concepts that make their treatment in physics possible. If one is to treat colliding bodies, how must we understand this interaction for it to be intelligible? What must be true of the bodies and their motion for each to act on the other by means of this motion? Kant, we must not forget, is seeking the conditions under which the concept of matter becomes possible as an object of outer experience, and so we must look for a corresponding richness in a reading of the *Metaphysical Foundations*.

Conclusion

By way of conclusion, I briefly reflect on a thread that runs through the three works primarily discussed in this dissertation: the contested intelligibility of essential gravity.

The question of how to understand gravity presents itself as soon as Newton proposes a law of universal gravitation without an accompanying proposal of a physical cause. Newton adopts an patient agnosticism in the face of this uncertainty. His imagined creation of bodies leaves room for later amendments and qualifications in light of new observations and theoretical developments: these beings move "according to certain laws," which remain unspecified, and the conditions for their creation do not definitively constitute the essence of bodies for such knowledge is beyond human ken. Such metaphysical flexibility is coupled, moreover, with a freedom to appeal to God's will in explaining natural phenomena. Newton is therefore able to keep his options open and await further progress in the field.

While Du Châtelet's objections to Newtonian attraction are not directed at Newton himself—Newton is allied with Du Châtelet in emphatically rejecting essential gravity—she is critical of his willingness to countenance appeals to God's will and clarifies his discussions with her doctrine of essences. As we saw, she wields this doctrine in the case against attraction and rejects gravity as an essential property of body for failing to be necessary in the proper sense. Du Châtelet thus confronts her readers with a choice between granting a certain conception of essences and admitting attraction as an essential property of bodies. Du Châtelet herself is not willing to overturn her metaphysical system to accommodate properties that are necessary by dint of following certain fixed laws, and given the state of physics at the time, she is well within her rights to decline such a revision.

We see Kant, however, embracing both repulsive and attractive forces as necessary preconditions for matter to fill space. In a similar spirit to Du Châtelet's argument for the existence of monadic simples from the fact of extension, Kant argues for the necessity of an essential attractive force to explain how it is that bodies fill determinate volumes rather than expanding to infinity under purely repulsive forces. While Kant leaves many of the details of the laws governing these forces to be found empirically, he derives certain of their features a priori, such as the proportionality of attractive force to quantity of matter. Moreover, Kant's mechanical laws, which bear at least some relation to Newton's laws of motion, are deduced from the analogies of experience and the explication of matter as the moveable insofar as it has moving force. While perhaps not up to Du Châtelet's strict standards, this is a step towards a conception of matter where attraction is endowed with necessity and from which one arrives at concrete determinations about the laws they follow.

Newton, Du Châtelet, and Kant were all wrestling with the question of essential gravity. That much is clear from even a passing familiarity with their work. But the pivotal role played by Du Châtelet in this narrative has gone unappreciated in standard accounts of the history of philosophy of science. With the foregoing, we see Du Châtelet deftly simplify questions that originate with Newton and set the terms for how the debate is later picked up by Kant. It is my hope that this dissertation would contribute to a wider recognition of her place in this story as it is told to future generations of students.

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