Continuity of Change in Kant’s Dynamics

Michael Bennett McNulty

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1. Philosophical and Historical Puzzles Surrounding Kant’s Dynamism

Immanuel Kant’s justification for his theory of matter has been a topic of scholarly scrutiny since his MAN was first published in 1786. According to Kant’s preferred, dynamical conception, natural phenomena are grounded in fundamental forces expressed by matter. By means of such forces, bodies impede or augment others’ motions. In contrast, the opposed mechanical model appeals to the shape, size, and impact of absolutely impenetrable corpuscles in a background empty space. Thus, for the mechanist, motions change due to collision. Kant titles these, respectively, the “metaphysical-dynamical” and the “mathematical-mechanical modes of explanation” (MAN, 4:524f.).[[1]](#footnote-1) Whereas he characterizes Johann Heinrich Lambert and René Descartes as paradigmatic partisans of the latter view (MAN, 4:497, 533; V-Meta/Mrongovius, 29:932; and V-Meta/L1, 28:209), Kant especially credits Isaac Newton with the former (V-Meta/Mrongovius, 29:935).[[2]](#footnote-2) Despite Kant’s unequivocal endorsement of the dynamical approach to physical explanation, philosophical and historical quandaries persist, to wit: what is the nature and status of his justification for dynamical philosophy, and are there historical antecedents for Kant’s rejection of mechanical philosophy?

In Kant’s own day, Abraham Kästner, in his anonymously published review of MAN, advanced similar questions and challenged the justification for the dynamical theory of matter, sardonically asking whether Kant had truly given decisive reasons to reject the mechanists’ alternative: “**Must** one think of a moving force in a wall, because at the wall one cannot progress further?” (Anonymous 1786, pp. 1915f.).[[3]](#footnote-3) To this day there is widespread scholarly disagreement regarding the grounding for Kant’s dynamic theory of matter and his reasons for rejecting mechanism. Some, including Carrier (1990, p. 181n.), Westphal (1995, pp. 391–95), and Pollok (2001, pp. 234f.), maintain that Kant’s introduction of moving forces at the expense of mechanical philosophy is wholly unjustified.[[4]](#footnote-4) Other interpreters contend that Kant has coherent arguments against mechanical philosophy, yet they are neither definitive nor *a priori*. Rather, Kant is to be understood as giving non-decisive reasons to prefer dynamical philosophy as a research program. In different ways, Butts (1986, pp. 193f.) and Friedman (2013, pp. 115f., 569) defend this sort of interpretation. Others, such as Warren (2001a, 2001b) and arguably Brittan (1986, pp. 79–81), take Kant’s dismissal to rest on *a priori*, metaphysical considerations and therefore to arbitrate conclusively in dynamism’s favor.[[5]](#footnote-5) Such is the state of philosophical disagreement with respect to Kant’s dynamical theory of matter.

Part of the difficulty lies in Kant’s own apparent ambivalence regarding the status of mechanical philosophy and his hesitancy to dismiss the view. In MAN, Kant claims to present *a priori* principles governing the nature of matter, as such (4:471f.). The dynamical theory of matter is an essential component of this account, grounding important tenets including the mechanical laws presented in the third chapter of the book. For there to be *a priori* principles of physics beyond the bare kinematic theory described in the Phoronomy, Kant’s dynamism must admit of *a priori* demonstration. Such considerations provide strong evidence that the dynamic theory of matter must be knowable *a priori*, and thus that the competitive, mechanical theory admits of *a priori* refutation. Yet, at the same time, whenever Kant assembles the elements of a definitive, principled disproof of mechanical philosophy, he backs off of it. In both the Anticipations of Perception and the Third Analogy of KrV, Kant appears to have ample justification to reject mechanical philosophy and, in particular, its posits of absolute impenetrability and empty space. However, in neither does he explicitly dismiss mechanical philosophy, and, indeed, he goes to lengths to *deny* that he is thereby disproving the theory. More confounding, in several passages directly concerned with natural philosophy, including some in the General Remark to the Dynamics of MAN, Kant appears to carve out conceptual space for mechanical explanations. It is no wonder that there is little agreement among scholars regarding Kant’s dynamism; Kant himself appears to be of two minds.

Additionally, there are various accounts of the historical antecedents for Kant’s physical theory. Partially in virtue of Friedman’s (1986, 1992) pioneering work, Kant’s physics has been classically conceived as of a kind with Newton’s. And, indeed, the only philosopher explicitly identified as a dynamist by Kant is Newton. Yet some recent commentators, such as Pollok (2001, pp. 226f.), Warren (2001b, pp. 63f.), and Stan (2013), highlight broadly Leibnizian veins in Kant’s thought. Throughout his more recent volume on Kant’s MAN, Friedman (2013) himself pays more attention to the Leibnizian backdrop than before. Indeed, Leibniz’s own physical theory, developed especially in his “Specimen Dynamicum,” is a clear example of a dynamical theory of matter, explaining natural phenomena by means of a system of forces.

In this paper, I clarify the reasoning behind Kant’s dynamical theory of matter, which resolves the aforementioned philosophical quandaries and clarifies the historical inspiration for the theory. My principal thesis is that Kant’s argument for dynamism hinges on his denial of mechanical philosophy, which, in turn, rests on his endorsement of Leibniz’s law of continuity. In particular, Kant believes that all alterations in nature must be continuous and occur through degrees; mechanism violates this edict, insofar as upon impact absolutely impenetrable atoms would take on new motions *instantaneously*. Furthermore, I demonstrate that this commitment is grounded in the *a priori* metaphysics of KrV. In this regard, Kant is rehearsing a notable argument marshaled by Leibniz himself against mechanism in various works. Although other commentators, including Schäfer (1966, pp. 81–89), Brittan (1986, pp. 80f.), Pollok (2001, p. 237), and Warren (2001b, pp. 68f.), have noted hints of continuity in Kant’s physical theory, they fail to appreciate the depth of his commitment to continuity and its essential role of justifying the dynamic theory of matter. On the one hand, Schäfer and Brittan both stop short of the thesis that Kant’s dynamism is *justified* by considerations of continuity and, moreover, fail to recognize the specific, crucial role for the continuity of *alteration* in the theory’s justification. On the other hand, Pollok and Warren explicitly claim that continuity *cannot* ground Kant’s material theory. Thus, I offer a new understanding of the basis for the dynamical theory of matter, one that highlights heretofore under-appreciated debts to Leibniz and thereby contributes to the aforementioned trend in scholarship on Kant’s theory of science.

In section 2, I explain Friedman’s interpretation, according to which mechanical philosophy violates Kant’s assumed continuity of accelerations. Friedman’s account is inspirational for my own, as it raises considerations of continuity, although he leaves unexplained the justificatory basis for Kant’s commitment to continuity. In section 3, I provide the Leibnizian backdrop to Kant’s argumentative use of continuity, demonstrating that Leibniz offered various refutations of mechanism based on continuity. In section 4, I show the Kant endorsed the law of continuity throughout his philosophical career and recognized its implications upon the theory of matter. This commitment puts him in position to rehash one of Leibniz’s arguments against mechanical philosophy. In the course of this section, I also systematize Kant’s inharmonious, irregular discussions of continuity, a result of independent utility for scholars. Finally, in section 5, I consider two difficulties that face my account: first, Warren’s competitive interpretation, according to which mechanical philosophy is explanatorily insufficient for Kant and, second, the aforementioned ambivalence in Kant’s views on mechanical philosophy, which appears to put pressure on my claim that the theory is metaphysically incoherent. To buttress my account, I describe the conceptual space in Kant’s system for mechanical explanations. I contend that such explanations, though metaphysically problematic, can be posed and considered as merely hypothetical explanations resting on ideas of reason, according to Kant.

1. Friedman and Considerations of Continuity

Friedman (2013, pp. 114–7) conceives of Kant’s dynamism as supported by considerations of continuity. However, although Friedman’s account demonstrates the conditional claim that if changes to velocity are continuous, then dynamism must be correct, it fails to clarify the basis for Kant’s claim that such is the case. Moreover, Friedman appears to suggest that Kant’s arguments against mechanism are inconclusive and based on the empirical success of Newtonian physics. In this section, I explain Friedman’s account and argue that Kant’s arguments against mechanism must be understood as definitive and as grounded in metaphysics.

The first proposition of Kant’s Dynamics asserts that “Matter fills a space, not through its mere *existence*, but through a *particular moving force*” (MAN, 4:497). For Kant, the filling of space is thus due to matter’s expression of a repulsive force, characteristic of all matter, which attenuates motion of incoming objects. Directly subsequent to this proposition, Kant attaches a remark on mechanical philosophy, criticizing the mechanists’ explanation of the filling of space, which appeals to the purported absolute impenetrability of matter. The relative impenetrability of a body, according to the mechanical approach, is explained by the relative proportion of absolutely solid matter to empty space within it. Kant rejects this account, alleging that only a *force*—and not mere existence of matter—can explain why bodies slow down, halt, or reflect upon contacting a filled space.

 Friedman understands the objection to rest on an inconsistency between mechanical philosophy and Kant’s account of the mathematical representation of motions. Imagine the case of one body, with a velocity, *v*, impacting another at rest. Upon striking the latter body, assume that the first reflects back with velocity *–v* (in an ideal inelastic collision). According to Friedman’s understanding of Kant’s kinematic theory, presented in MAN’s Phoronomy, changes in velocity can only be represented as *continuous*, so the impacting body goes through a steady, temporally extended change of velocity from *v* to *–v*. Hence, at a moment during this change, the reflecting body must possess a velocity of 0. Were matter absolutely impenetrable, however, velocities would *discontinuously* change in impact. That is, the first body, when encroaching on the boundaries of the second, would be instantaneously denied entrance to the second body’s space and immediately take on a velocity of *–v*. There would be no continuous slow-down and turn-around for the moving body. Indeed, were an absolutely impenetrable atom to reflect off another at rest, during no instant would the first have a velocity of 0. The failure of mechanical philosophy that Kant points out in the remark to first proposition of the Dynamics, according to Friedman, is thus that the acceleration of a body impacting an absolutely impenetrable space cannot be mathematically constructed according to the account presented in the Phoronomy. This objection, however, does not conclusively rule out mechanical philosophy; it merely demonstrates inconsistency between absolute impenetrability and Kant’s kinematical theory (Friedman 2013, p. 116). For Friedman, dynamical philosophy is simply an alternative research program, whose superiority “rests, in the end, on nothing more nor less than the empirical success of Newton’s theory in comparison with the opposing mechanical philosophy” (p. 569, see also 258).

 Friedman’s interpretation raises two interpretive questions. First, what is the basis for Kant’s continualist argument against mechanical philosophy? In particular, at the most fundamental level, are mechanical explanations deficient insofar as they are *metaphysically* incoherent, or because, properly speaking, we cannot *mathematically* construct an instantaneous change of motion? Second, what is the force of Kant’s anti-mechanical argument? Does it provide definitive, *a priori* evidence against mechanical philosophy (and, derivatively, for dynamism), or is it inconclusive, as Friedman would have it, providing pragmatic reasons to prefer the dynamical approach to explanation. In the remainder of this section, I argue that Kant is clear that the ultimate basis for his arguments against mechanical philosophy must be metaphysical. Throughout the course of the remainder of the article, I detail the status and components of Kant’s metaphysical argument against mechanism stemming from the law of continuity and contend that it is conclusive.

 There is unequivocal evidence that Kant believed the problem with mechanical philosophy to be metaphysical, *not* mathematical. In a passage from the General Remark to the Dynamics, Kant states clearly that mechanical philosophy is mathematically adequate and, indeed, mathematically *superior* to the dynamical approach.

And here the mathematical-mechanical mode of explanation has an advantage over the metaphysical-dynamical [mode], which cannot be wrested from it, namely, that of generating from a thoroughly homogeneous material a great specific variety of matters, which vary both in density and (if foreign forces are added) mode of action, through the varying shape of the parts and the empty interstices interspersed among them. For the possibility of both shapes and empty interstices can be verified with mathematical evidence. By contrast, if the material itself is transformed into fundamental forces […] we lack all means for *constructing* this concept of matter, and presenting what we thought universally as possible in intuition. (MAN, 4:524f.)

Here Kant suggests that the mechanical explanans, in contrast to those of the dynamical approach, are mathematically constructible. To construct a concept mathematically, for Kant, “means to exhibit *a priori* the intuition corresponding to it” (KrV, A713/B741). For example, I might construct the concept of triangle by drawing a triangle, which then serves for the derivation of universal facts about triangles. As Kant notes in the passage, mechanical explanations proceed via the postulation of various sizes and shapes of impenetrable spaces and empty interstices. So, to illustrate the view, Kant elsewhere describes a Cartesian-mechanical explanation of the dissolution of limestone by acetic acid as resting on the “sharp” shape of the atoms of the acid (V-Ph/Danziger, 29:105). The crucial point is that whatever shape these atoms (or the spaces among them) may have, they describe geometric spaces, which admit of mathematical construction.[[6]](#footnote-6) If acidic atoms are, say, tetrahedral, one may exhibit their shape in intuition by drawing a tetrahedron. When Kant observes that “the possibility of both shapes and empty interstices may be verified by mathematical evidence,” he means that the shapes and sizes of filled and empty spaces utilized in mechanical explanations are mathematically constructible. (Indeed, the position is titled the “*mathematical*-mechanical mode of explanation,” which suggests its mathematical sufficiency.) Thus, understanding Kant’s rejection of mechanical philosophy as having a purely mathematical basis conflicts with other of his claims.

 Additionally, throughout MAN, Kant routinely derides mechanical philosophy for its *metaphysical* failings. In the General Remark to the Dynamics, Kant claims that it rests upon an “empty concept (of absolute impenetrability)” and “unconditioned original positings” (4:525, 534), and earlier in the Dynamics he asserts that absolute impenetrability is an “occult quality” (4:502). Such remarks suggest that Kant thought of the mechanists’ absolute impenetrability as a non-instanceable concept—one that is necessarily incapable of applying to objects of experience. A mathematically based interpretation hence sits uneasily with such metaphysically tinged objections to mechanical philosophy. In the remainder of the paper, I produce the metaphysical grounds for the rejection of mechanical philosophy and explain why they are conclusive.

1. Leibniz’s Continualist Arguments against Mechanical Philosophy

Friedman rightly calls attention to the disconnect between Kant’s kinematics and mechanical philosophy and helpfully highlights considerations of continuity. As I suggest above, Kant’s anti-mechanical stance is best understood as resting on an *a priori* metaphysical principle. In this section, I detail Leibniz’s arguments against mechanical philosophy, as they provide the backdrop for Kant’s disproof of the theory.

 Throughout his career, Leibniz harshly criticized Cartesian physics, famously alleging that the theory conserves the wrong quantity—*vis motrix* (*mv*) instead of *vis viva* (*mv*2/2) (L, 455–58; AG, 49–51).[[7]](#footnote-7) But additionally, Leibniz, like Kant after him, opposes the mechanists’ explanation of the communication of motion as well as their appeal to the absolute impenetrability of matter. Some of these challenges are based on his law of continuity, according to which “*nature never makes leaps*” (NE, 56). For Leibniz, continuity is understood as a structural property holding between a quantity and its parts. A quantity is structurally continuous when between any two of its parts, there is a third, intermediate part; that is, when the quantity is *dense* (Crockett 1999). As Jorgensen (2009, pp. 224–29) explains, there are various versions and manifestations of this law; two instantiations, in particular, concern me presently. First, according to Leibniz, there is *conceptual continuity* in the world; all particular cases that continuously vary among themselves must be subsumed under some general reasoning. So, for example, there must be one set of laws of motion that apply to all continuously variable particular cases, regardless of the particulars’ idiosyncrasies. Second, there is *spatiotemporal continuity* in the world. That is, all alterations in space and time—including changes of the attributes of any phenomenon—must occur gradually and through degrees.

Leibniz offers two principal objections to mechanical, or corpuscular, philosophy stemming from the law, both of which receive mention in a number of his works. First, Leibniz claims that the Cartesian physical laws are irregular, in violation of the conceptual continuity of nature. He details this line of thought in part II of “Specimen Dynamicum” (AG, 133f.). There Leibniz imagines two bodies, *A* and *B*, colliding and calculates the subsequent motion of *B* according to Descartes’ laws of motion. Leibniz observes that, if we vary the preceding motion of *B* with respect to *A* and plot the resulting velocities of *B* after the collision, we find dramatic gaps in the graph. For instance, there is a significant discontinuity between *B*’s resulting velocities when it begins at rest versus when it has a minuscule velocity toward *A*.[[8]](#footnote-8) Leibniz complains that God would not have made laws as erratic as these and objects that such gaps violate the law of continuity. The problem is that Descartes’ laws treat the particular cases—wherein *B*’s velocity relative to *A* varies—according to *different laws*. But, according to Leibniz, conceptual continuity entails that there can be no principally dissimilar treatment of particular cases of motion: all must fall under the same general reasoning. Thus, in “A Brief Demonstration,” he asserts that, in order to avoid such pitfalls and abide the law of continuity, any legitimate physical theory must treat rest as infinitesimal motion—thereby one law must apply to all cases (L, 539–41).[[9]](#footnote-9)

Second, Leibniz objects to the “false hypothesis of the hardness of bodies” (L, 541). Were bodies absolutely solid, as the mechanists would have it, when two bodies, *A* and *B*, collide, their motions change instantaneously, in violation of spatiotemporal continuity. Hence “assuming [that no change happens through a leap], it also follows that atoms cannot exist” (AG, 131f.). Rather, Leibniz holds that matter must deform and recoil in impact. He also suggests this line of thought in his presentation of the law of continuity in the *New Essays*.

There is much work for [the law of continuity] to do in natural science. It implies that any change from small to large or vice versa, passes through something which is, in respect of degrees as well as of parts, in between; and that no motion ever springs immediately from a state of rest, or passes into one except through a lesser motion […] Despite which, until now those who have propounded the laws of motion have not complied with this law, since they have believed that a body can instantaneously receive a motion contrary to its preceding one. (NE, 56)

Here, again, Leibniz rejects the idea that motions alter instantaneously, which he takes to be a characteristic commitment of the theory of atoms.

Thus, for Leibniz the law of continuity plays a crucial role in the foundations of physics, entailing that rest is a special case of motion, implying that matter deforms and springs back in impact, and ruling out absolute solidity as an explanatory basis.[[10]](#footnote-10) In “Specimen Dynamicum,” Leibniz ultimately prefers a dynamic conception of matter that rests on the passive, active, primitive, and derivative forces (see AG, 119–21).[[11]](#footnote-11)

1. Kant on Continuity

Kant knew of Leibniz’s views on the law of continuity as well as its deployment against the mechanists. Although part I of Leibniz’s “Specimen Dynamicum”appeared in *Acta Eruditorum* in 1695, part II was published during neither his nor Kant’s lifetimes. Kant read the *Nouveaux Essais* upon its publication in 1765, and “A Brief Demonstration” and “A General Principle” were both available to him.[[12]](#footnote-12) Indeed, in GSK (written and published in 1746–49), Kant quotes from part I of “Specimen Dynamicum” and generally demonstrates comprehension of many key aspects of Leibnizian physics (GSK, 1:17f.). After presenting his objections to Leibniz’s views on the *vis viva* controversy, Kant writes the following.

What I have now demonstrated is a very precise consequence of the law of **continuity**, whose extensive utility has perhaps not yet been sufficiently recognized. Herr von **Leibniz**, discoverer of this law, used it as a touchstone whose test **Descartes’s** laws failed to pass. I consider it to be the greatest proof of his excellence that he is almost the only one to offer a means of fully revealing the most fundamental law of all mechanics and displaying it in true form. (GSK, 1:37)

So strong is Kant’s commitment to the law of continuity that he complains that even Leibniz did not go far enough in his application of it. Had Leibniz fully appreciated the law, says Kant, he would have avoided a mistaken understanding of *vis viva*. Kant moreover maintains that the law of continuity is foundational to physics—it reveals “the most fundamental law” of mechanics—which further demonstrates the esteem which he holds for the principle.

 Throughout his career, Kant remains enthusiastic, to say the least, about the law of continuity. In his 1770s metaphysics lectures, he reiterates the significance of the law, writing that it “is no metaphysical whim, but rather a law that is spread through the whole of nature,” and that it “is the first law of nature, whose necessity can be comprehended *a priori*” (V-Meta/L1, 28:203), while, in MSI, he classes continuity among the “first postulates of pure time” (2:402). Throughout various writings, Kant asserts that space and time (KrV, A169/B211; Refl 3801, 17:296; Refl 6338a, 18:664), sensations and their correlative causes in objects (KrV, A170/B212), matter (MAN, 4:505), moments of accelerations (Refl 6338a, 18:664), alterations of appearances (MSI, 2:399f.; KrV, A208f./B254; Refl 6338a, 18:665), changes of motion (Refl 3801, 17:297; Refl 6338a, 18:664), inner states (MAN, 4:471), and conceptual hierarchies (KrV, A658f/B686f.; Refl 3801, 17:297) are all continuous. Moreover, references to the Leibnizian backdrop also occur throughout MAN. In the Phoronomy, Kant explicitly characterizes rest as an infinitesimally small motion, an echo of Leibniz’s position (4:486).[[13]](#footnote-13) In the General Remark to the Mechanics, Kant endorses a particular instantiation of the law of continuity, according to which mechanical communication of motion occurs bit-by-bit through an extended duration and not at an instant (4:552f.).

Kant’s enthusiastic, yet unsystematic, discussions of continuity generate certain confusions. In a few instances, where Kant catalogues the laws of continuity, he presents different lists of laws. Furthermore, his terminology admits of a troubling sort of mutability. For instance, what goes by the name of the dynamical law of continuity in one context is identified as the mechanical law of continuity in another. Similar ambiguities occur with respect to the mathematical, geometric, physical, cosmological, and logical laws of continuity. There are also justificatory issues in Kant’s account of continuity. Whereas Leibniz or Baumgarten could appeal to the Principle of Sufficient Reason as the basis for *all* the manifestations of continuity, no such option is open to Kant; deriving a substantive, metaphysical law of appearances (like that regarding the continuity of their alterations) from the Principle of Sufficient Reason is anathema to Kant. Ultimately I show that, for Kant, the various aspects of continuity admit of different degrees and grounds of justification and exhibit a sort of interdependence.

In section 4.1 I describe Kant’s account of the fundamental sorts of continuity and explain their genesis and justification within his philosophical system. I especially focus on Kant’s commitment to the *a priori* law of the continuity of alterations, as I demonstrate in section 4.2 that a particular instantiation of this principle—namely, the dynamic law of continuity—grounds his anti-mechanical position. According to the dynamic law, motions of bodies can change only gradually through intervening degrees instead of instantaneously. Kant’s affirmation of this thesis puts him in position to reiterate one of Leibniz’s arguments against mechanical philosophy. I go on to show that Kant recognized the import of the dynamic law of continuity within physics throughout his philosophical career and remained steadfastly committed to the law’s truth. Finally, in section 4.3, I explain how these considerations decide in favor of his preferred, dynamical theory of matter. I argue that, for Kant, the inference to dynamical philosophy is a disjunctive syllogism: either dynamical philosophy or mechanical philosophy is correct, mechanical philosophy is false, insofar as it violates an *a priori* law of nature (the dynamical law of continuity), therefore dynamical philosophy is true.

* 1. The System of Continuity

For Kant, there are four fundamental aspects of continuity and four associated laws. He maintains the continuity of spaces and times, intensive magnitudes, alterations, and conceptual species. The principles of the first three sorts of continuity are *a priori* and metaphysical, whereas the cosmological law of continuity, governing concepts, is a regulative principle of reason. In all cases, Kant conceives of continuity analogously to Leibniz: something is continuous when, between any two of its instances, there exists a third, intermediate individual. Kant holds that continuity is thus equivalent to both infinite divisibility and lacking a fundamental unit (V-Meta/L1, 28:201, 204). Although, as I noted above, Kant’s writings exhibit an unfortunate irregularity regarding continuity, there is nonetheless widespread evidence for the centrality and fundamentality of these notions of continuity. Although my account of the four sorts of continuity is based largely on various references with KrV, I demonstrate that these laws can be found throughout his published and unpublished writings. The point of this section is to systematize Kant’s views on continuity under these four headings, and explain the differences in their justification.

* + 1. Spatiotemporal continuity

Kant regularly claims that space and time are continuous magnitudes. That is, between any two particular spaces or times there exists a third of the same kind. So, between any two points of space or moments of time, there is another—no spaces or times are ‘next to’ each other. Derivatively, there are no particular discrete units or minima of either space or time; space does not consist of particular finite volumes nor time of finite durations. Any particular space or time, no matter how small, itself contains additional, smaller spaces or times, respectively.

In KrV, we especially find Kant advocating spatiotemporal continuity in the Axioms of Intuition and the Anticipations of Perception. According to the principle of the former, “**All intuitions are extensive magnitudes**” (KrV, B202). Extensive magnitudes, for Kant, are those that are made up of parts; intuitions are such, insofar as they are spatial and/or temporal magnitudes, which consist of elements of the same sort (KrV, B202f.). This implies that any particular extension or duration—no matter how large or small—consists of yet smaller spatial or temporal parts and, further, that space and time are continuous (between any two units of one sort, there must exist another). In the Anticipations of Perception, Kant explicitly states (apparently depending on the considerations of the Axioms) that “Space and time are *continuous magnitudes*” (KrV, A169/B211). Moreover, Kant makes crucial use of the continuity of time in his argument for the continuity of alterations in the Second Analogy, where he takes as premise the claim that “Between two instants, there is always a time” (KrV, A208/B253). Insofar as the law of spatiotemporal continuity follows from the principle of the Axioms of Intuition, it, like the principle, is an *a priori* law of nature.

Moreover, the continuity of space and time is a longstanding commitment of Kant’s. He offers a proof of the infinite divisibility of space in his early MonPh (1:478f.), according to which, there are no simples in space and between any two spatial points, there is an intervening third. In MSI (2:399), Kant claims that “*Time is a continuous magnitude*,” where such a magnitude is “not composed of simples.” Lecture notes from the 1770s attribute to Kant the view that that space and time are continuous magnitudes: “between two moments there is a time, just as between two points there is a line” (V-Meta/L1, 28:201). In Refl 3801 (1764–66), Kant asserts the continuity of space and time under the heading of the mathematical law of continuity (17:296), while in Refl 6338a (1793–94) this law goes by the name of the geometric law of continuity (18:664). In the latter, Kant explains that by dubbing space and time continuous magnitudes, he means that they are homogeneous, or made up of parts of the same sort, thereby echoing the thesis from the Axioms of Intuition.

* + 1. Continuity of Intensive Magnitudes

In the Anticipations of Perception of KrV, Kant claims that the real—that which corresponds to a sensation of the object—is an intensive magnitude. Intensive magnitudes have continuous degrees and, unlike extensive magnitudes, they are not made up of distinct parts. For instance, that in the object that causes my sensation of the light of the sun is an intensive magnitude, insofar as the degree of the sensation is comparable to others—it is brighter than the moon’s illumination, for instance—and admits of continuous variation.[[14]](#footnote-14) Between any two degrees of illumination, it is possible for there to be another, intermediate degree. In general, Kant claims, “between reality in appearance and negation there is a continuous nexus of many possible intermediate sensations, whose difference from one another is always smaller than the difference between the given one and zero, or complete negation” (KrV, A169/B211), and he states explicitly that intensive magnitudes are “continuous magnitudes” (A170f./B212).

 That qualities corresponding to sensation are intensive magnitudes has application to natural science. For instance, in MAN, Kant claims that velocities are intensive magnitudes, which influences his kinematic theory (4:493).[[15]](#footnote-15) In Refl 6338a, Kant describes a dynamic law of continuity, according to which “the moment of accelerative force is a continuous quantity” (18:664). I understand this to mean that moments of acceleration—the speed imparted in an instant by a force (MAN, 4:551)—is an intensive magnitude. That is, there is no smallest unit or quantum of acceleration, no particular modicum of speed imparted to an accelerating body in a moment. Similarly, in the Anticipations, Kant mentions that moments of gravity are, too, intensive magnitudes (KrV, A168f./B210).

* + 1. Continuity of Alterations

In the Second Analogy of KrV, in which Kant demonstrates that “All alterations occur in accordance with the law of the connection of cause and effect” (B232), he also derives a corollary: “the law of continuity of all alteration,” according to which alterations proceed through all intermediate degrees.

**No difference** of the real in appearance is **the smallest**, just as no difference in the magnitude of times is, and thus the new state of reality grows out of the first, in which it did not exist, through all the infinite degrees of reality, the differences between which are all smaller than that between 0 and *a*. (KrV, A208f./B254)

This law of continuity of alterations is, like the principle of the Second Analogy, itself, an *a priori* law of the immanent physiology of nature, or general metaphysics: *any* alteration to *any* object of experience must occur through degrees, and not, as it were, by a leap.[[16]](#footnote-16)

In the Second Analogy, Kant bases the continuity of alterations upon spatiotemporal continuity and the continuity of intensive magnitudes. Consider a particular case of an alteration of an object from bearing determination *a* to bearing that of *b*. The difference between these two states must be one of degree, according to the Anticipations. Further, there must be a last moment, *t1*, that the object bears *a*, as well as a later moment, *t2*, which is the first in which the object bears *b*. Since time is continuous, there also must be a time, *t3*, between *t1* and *t2*. By the above, at *t3*, the object can be neither *a* nor *b*, but rather must have an intermediate degree *c*. Since realities are continuous, intensive magnitudes, the intermediate value, *c*, must exist. By this same line of reasoning, there must be other intermediate values for all of the infinite moments in the interval (*t1*, *t2*).[[17]](#footnote-17)

Kant commits himself to the continuity of alterations throughout his corpus. In Refl 3801, Kant refers to the principle of the continuity of alterations as the “physical law of continuity,” according to which states or grades are continuous magnitudes (17:297). He specifically singles out a physical implication of this law: the direction of a body’s motion changes through all the intermediate directions. In MSI, Kant claims that the “metaphysical” law of continuity, according to which “*All changes are continuous* or flow,” follows from the continuity of time (2:399f.). In his 1770s metaphysics lectures, Kant endorses this law, claiming that “a thing never goes immediately from one state into another, but rather through all intermediate states, and thereby the alteration of the state of a thing is possible,” which is similarly grounded in the continuity of time (V-Meta/L1, 28:201). Another pronouncement is found in Kant’s 1782–83 metaphysics lectures: “There is no step over from one appearance, quality, to another, without a transition through infinitely many intermediate degrees” (V-Meta/Mrongovius, 29:863). In Refl 6338a (18:665), Kant calls this principle the “transcendental law of continuity,” while in MAN (4:553) it is the “metaphysical law of continuity,” both of which emphasize its apriority and necessity vis-à-vis appearances. Hence, the law of continuity of alteration, upon which rests his anti-mechanical argument (see section 4.2), is an abiding doctrine of Kant’s metaphysical system.

* + 1. Cosmological continuity

Near the end of the appendix to the Transcendental Dialectic, in which Kant discusses the positive, regulative use of reason, he explicitly refers to a law of continuity of forms and associates it with Leibniz and Charles Bonnet (KrV, A688/B696). The law of continuity of forms is one of three principles that collectively characterize a systematic body of knowledge, or science. According to the principle of homogeneity, all concepts stand under common, higher genera. The principle of specification holds that each concept admits of division into distinct, lower species. And according to the principle of continuity of forms, there is “**affinity** of all concepts, which offers a continuous transition from every species to every other through a graduated increase of varieties” (KrV, A657f./B685f.). According to this law, between any two species under a common genus, there must be an intermediate, third species: “all varieties of species bound one another and permit no transition to one another by a leap, but only through every smaller degree of distinction, so that from each one can reach another; in a word, there are no species or subspecies that are proximate (in the concept of reason), but intervening species are always possible, whose difference from the first and the second species is smaller than their difference from each other” (KrV, A659f./B687f.).[[18]](#footnote-18) Moreover, Kant is quick to add that, in virtue of the affinity of the continuously varying species, there is a unity among their properties and powers. So, for instance, insofar as the shapes of orbits continuously vary under the common concept of a conic section, the paths of heavenly bodies admit of unified explanation through a single set of laws: those of gravitation (A662f./B690f.). Whereas Jorgensen titles this commitment “conceptual continuity” in Leibniz’s system, Kant calls this sort of continuity “cosmological” (Refl 3801, 17:297; Refl 6338a, 18:665). He affirms this law throughout his metaphysics lectures (see V-Meta/L1, 205), though he also occasionally refers to it as “physical continuity” (see V-Meta/Dohna, 28:662f.; V-Meta/Herder, 28:42).

However, the law of cosmological continuity is, like those of homogeneity and specification, merely *regulative*, for Kant. That is, “reason can follow [these principles] only asymptotically, as it were, i.e., merely by approximation, without ever reaching them” (A663/B691). That is, no actual, extant body of knowledge satisfies the description of systematic unity. Any actual doctrine is merely finite and admits of gaps, namely missing species and genera. Nevertheless, the principles serve as guiding edicts for the development of our sciences. We *seek* to fill out our conceptual hierarchies and to achieve a parsimonious, unified set of laws governing all the relevant phenomena, though we can only ever asymptotically approach this goal. Kant echoes this sentiment in Refl 6338a: after presenting the cosmological law of continuity, he hastens to add that the principle concerns only the *possibility* of such intervening concepts, not their actuality (18:665). Thus, the ideal of a completely continuous, gapless body of knowledge remains a *mere* ideal that we can only ever approximate.

That the cosmological law is regulative implies that it is of a very different sort from those laws considered above. The other laws of continuity are transcendental and *a priori*: for instance, that an alteration proceeds continuously through all intervening degrees is a constitutive property of alterations of appearances. In contrast, that, say, our physical laws bear a systematic unity, although desirable, is not necessary or constitutive of such. This idiosyncrasy of Kant’s conception of cosmological continuity in comparison with the other sorts plays an important role in my examination of his arguments against the mechanists in section 4.2.

* 1. Dynamical Continuity

In this section, I explain that Kant accepts a *dynamical* law of continuity that decisively legislates against mechanical philosophy. This dynamical law is a particular instantiation of the law of continuity of alteration and holds that changes in the motion of bodies must occur through degrees. That Kant accepts this law puts him in position to endorse the second of the aforementioned Leibnizian refutations of mechanism, according to which the instantaneous changes of motion effected by collisions of absolutely impenetrable corpuscles are impossible. This section hence demonstrates my disagreement with Pollok and Warren, who maintain that continuity can play no role in Kant’s disproof of mechanism, as well as Schäfer and Brittan, who overlook the critical role of the continuity of *alteration* in Kant’s argument. Additionally, I explain that since the systematic unity of the laws of nature is a merely regulative ideal, for Kant, that the laws of mechanical philosophy are unsystematic, as Leibniz observed, provides no decisive reason for rejecting the approach.

Due to the scope of the law of continuity of alterations, physical phenomena fall under its purview. In the Second Analogy, Kant proves that *all* alterations to objects of experience must be continuous and, therefore, that physical alterations—those of objects of *outer* experience—must likewise be continuous. Moreover, accelerations, being alterations of the motions of bodies, must similarly take place in time and through degrees. Kant himself appreciates this instantiation of the general law. Notes from Kant’s 1762–64 metaphysics lectures report him affirming a “mathematical” law of continuity, according to which “if a body is brought from rest into motion, then it goes through all the smallest degrees of speed up to the highest degree of speed with which it has power” (V-Meta/Herder, 28:42). According to lecture notes from the 1770s, Kant claims that it is a law of nature, “whose necessity can be comprehended *a priori*,” that velocity involves a continuous, extended development through degrees: “No body moves immediately with velocity at once; rather it must go through infinitely many degrees of velocity which are ever larger, and come ever closer to the determined velocity” (V-Meta/L1, 28:203). In Refl 6338a, Kant affirms a “mechanical” law of continuity, according to which a change to the motive state of a body—a change to motion, velocity, or direction—must occur through all intermediate degrees (18:665).[[19]](#footnote-19)

Regularly, this dynamical law of continuity takes the form of the claim that motion must occur along *curves*. After his proof of the law of continuity in MSI, Kant infers that all motion proceeds on curves: there are no sharp, discontinuous changes of motion (2:399f.). This thesis purports to answer Kästner’s objection to the law of continuity. Kästner claims that defenders of the principle must prove that “*the continuous movement of a point along all sides of a triangle is impossible*” (MSI, 2:400). Kant takes on the challenge, demonstrating the requested impossibility by noting that in such a case the moving body would have simultaneous, opposed determinations of motion at the vertices of the triangle—that is, it would be going in two directions at once. Hence, such a sharp change of motion is impossible, and “a body does not change its direction in a motion which is continuous, except along a line no part of which is straight, in other words, along a line which is a curve” (ibid.). In his 1782–83 metaphysics lectures, Kant echoes the claim from MSI that motion occurs only along curved lines: “Everything in the world is according to the law of continuity, therefore also all motion according to curved lines” (V-Meta/Mrongovius, 29:921, cf. 29:864).[[20]](#footnote-20)

In his lectures from 1792–93, Kant repeats his claim that bodies never move in sharp angles, now titling this thesis “the dynamic law of continuous *motion*,” where “Continuous motion (which is perduring) cannot take place at an angle (b c a) for between two moments there is always a time, since it is in the state of transition” (V-Meta/Dohna, 28:662). The parenthetical “(b c a)” refers to Figure 1 (under this image is an apparent attribution to Leibniz). The point is that an object cannot move from *b* to *c* to *a* in successive moments, for this would be discontinuous, sharp, angular motion. Rather, there must be moments in which the object takes up intermediate positions between *b* and *c* and *c* and *a*, respectively.

*a*

*b*

*c*

Figure 1: Discontinuous Motion

Thus, Kant accepted the dynamic law of continuity, according to which motions change gradually through all intermediate degrees and not instantaneously. This law is a clear instantiation of the principle of continuity of alteration, which is itself an *a priori* law of nature. Additionally, Kant recognized the opposition between absolutely hard bodies and dynamic continuity in his NLBR (1758). Although, in this work, he is generally more tentative with respect to the law of continuity, Kant writes that the sudden change of motion associated with mechanical philosophy is “instantaneous and contrary to the law of continuity” (NLBR, 2:23).[[21]](#footnote-21)

In virtue of these considerations, Kant is in position to countenance the second of the aforementioned Leibnizian challenges to mechanical philosophy.[[22]](#footnote-22) Namely, since mechanical philosophy involves instantaneous, discontinuous changes of matter, it violates the dynamic law of continuity. Because absolutely impenetrable corpuscles and their instantaneous changes of motion thus violate an *a priori* law of nature, they are not objects of possible experience. However, that there is conceptual continuity in the world (what Kant calls cosmological continuity or continuity of forms), upon which the first of Leibniz’s objections described above rests, is, as I explained above, a merely regulative principle for Kant. That there are laws of nature governing natural phenomena is a transcendental condition of the possibility of experience, but that these laws of nature are systematically ordered, stand in a hierarchy, and apply generally to continuously varying cases is knowable neither *a priori* nor empirically.[[23]](#footnote-23) Since conceptual continuity is thereby only ideal and not known, Kant cannot accept the objection to mechanical philosophy based upon its assumption. That said, Kant undoubtedly would find problematic the conceptual irregularity that Leibniz observes in Cartesian mechanics, but only in the sense that it conflicts with the appropriate progress of scientific inquiry.

4.3 The Inference to Dynamism

With a substantive, metaphysical denial of mechanical philosophy, the stage is set for Kant’s inference to his dynamic theory of matter. This argument is a disjunctive syllogism resting on the inadequacy of the mechanical theory. Kant believes that mechanism and dynamism are the only options for explanation of corporeal phenomena, setting up the disjunction.[[24]](#footnote-24) So, in the General Remark to Dynamics of MAN, Kant opposes mechanical and dynamical philosophy as the options for physical explanation (4:523–5) and writes that in explaining the specific variety of matter, “one can take only two paths in this connection: the *mechanical* […] and an opposing *dynamical* path” (4:532).

Although it is clear that Kant is committed to the exhaustivity of these views, the ground for this assumption appears questionable. Kant thinks of the situation as follows. He conceives of the proper natural science of matter as “either a pure or applied *doctrine of motion*” (MAN, 4:477) and believes that there are two ways of explaining phenomena of motion. A particular motion or change thereof is to be explained by appeal either to other, already existing motions or to powers to change motion by augmenting or diminishing it—that is, moving forces. These two explanatory modes correspond to mechanical and dynamical philosophy, respectively.[[25]](#footnote-25) Notes from Kant’s metaphysics lectures report that mechanical philosophy “derives all alterations of the world from the figure of its fundamental particles, […and a]ll motion [is] derived from others that one already assumed.” Dynamical philosophy, on the other hand, rests on “powers assigned to motions, as Newton assigned attraction, a power that, without any motion of itself, at rest, sets all others in motion” (V-Meta/Dohna, 28:664f.). So, for Kant, there are two and only two bases for physical explanation: pre-existing motions and moving forces. Mechanical philosophy and dynamical philosophy are hence the exclusive and exhaustive modes of explanation.[[26]](#footnote-26)

Therefore, Kant had adequate grounds for an *a priori* proof of his dynamic theory of matter. Due to the exhaustivity of dynamical and mechanical philosophy, physical phenomena are explicable by appeal either to fundamental forces or to the impacts of absolutely impenetrable corpuscles. Since the latter violates the dynamic law of continuity—a consequence of an *a priori* principle of general metaphysics—dynamism is the only viable mode of explanation.

Given the magnitude of evidence attesting to Kant’s recognition of the continuity-based proof of dynamical philosophy, the relative lack of explicit mention of continuity in the Dynamics of MAN is not too concerning for my account. The relevant line of thought—that the law of continuity is true and implies the impossibility of the mechanists’ instantaneous changes of motion—is recurrent in *many* of Kant’s works, including pre-Critical texts written in the 1740s, the pivotal philosophical treatises of the 1770s and the 1780s, and metaphysics lectures and *Reflexionen* spanning from the 1760s to the 1790s. Although Kant does not make explicit this disproof of mechanism in the Dynamics of from MAN, its prominence in other writings demonstrates its centrality to his thought.

Thus, my metaphysical, continualist understanding of Kant’s rejection of mechanical philosophy best makes sense of his expressed views. In particular, the account conforms with Kant’s claim that mechanical philosophy is mathematically adequate though metaphysically incoherent. As I have shown, there is no fundamental, mathematical problem with mechanical philosophy, according to Kant.[[27]](#footnote-27) Rather, the complication is that the theory violates the dynamic law of continuity, which is grounded on the *a priori*, metaphysical law of the continuity of alterations.

1. Further Reflections: Explanation & Hesitancy

In this section, I reflect upon my thesis that Kant’s dynamical philosophy is justified by the metaphysics of continuity. In particular, I raise and address two issues that appear to put pressure on my view. First, I consider Daniel Warren’s interpretation of Kant’s rejection of mechanical philosophy, according to which the metaphysical-dynamical approach is explanatorily superior to its mechanical counterpart. I conclude that there is evidence for his view and that various considerations marshal against mechanism. That said, due to the strictures and ends of Kant’s *a priori* foundations for physics, the basic argument against the mathematical-mechanical mode of explanation must be based on *a priori*, metaphysical considerations. Second, I examine and diagnose Kant’s hesitancy to dismiss mechanical philosophy, apparent in the General Remark to the Dynamics of MAN and passages from KrV. I explain that, although mechanical philosophy is metaphysically deficient for Kant, he nevertheless carves out conceptual space for the approach. According to Kant, the mechanists’ foundational notions—absolute impenetrability and empty space—are ideas of reason, which, although they cannot be instantiated in experience, can nevertheless be utilized in hypothetical explanations.

* 1. Explanation

Based upon Kant’s comments on the dynamical and mechanical modes of explanation in his metaphysics lectures, Warren (2010, pp. 206–10) alleges that the rejection to mechanical philosophy is based on its explanatory defects.[[28]](#footnote-28) Although I concur that Kant thought of dynamical philosophy as superior in this respect to its mechanical counterpart, in this section I argue that explanatory defects are insufficient for Kant’s definitive rejection of mechanical philosophy. Rather, it must be based on *a priori* metaphysical grounds—namely, the law of continuity.[[29]](#footnote-29)

 Warren contends that, for Kant, a mathematical-mechanical explanation gives rise to an infinite explanatory task. This is due to the fact that any mechanical explanation presupposes prior existing motions. That is, when one explains a physical phenomenon mechanically, she appeals to the motion of particular, absolutely impenetrable corpuscles. However, this motion would itself admit of further explanation in terms of other motion, and so on. The crucial difference between the modes, according to Warren, is that mechanical philosophy can thereby never explain the *origin* of motion; whereas the dynamical approach, by utilizing an explanans of another type—namely, powers—is capable of such an explanation. So the dynamical mode of explanation is “more satisfactory and complete” than its mechanical correlate (V-Meta/Mrongovius, 29:935).

 Although I concur that, in Kant’s eyes, mechanical philosophy offers insufficient explanations of natural phenomena, Warren’s interpretation is too weak to capture what Kant had in mind in MAN. The problem facing Warren is that considerations of explanation lack the *a priori* weight to justify adequately this pivotal component of Kant’s natural science.

 MAN purportedly consists of that which can be known *a priori* about objects of outer sense. In the Architectonic, Kant divides rational physiology of nature—the doctrine that seeks *a priori* knowledge of objects of possible experience—into rational physics and rational psychology, the former of which consists of *a priori* facts about objects of outer sense (KrV, A845–47/B873–75). Moreover, in the preface to MAN he echoes this division and makes clear that the book is concerned with developing rational physics (4:467f.). Indeed, Kant claims that MAN *exhausts* the *a priori* knowledge possible of objects of outer sense (4:473–76). Among the book’s *a priori* propositions are the claims that there exist fundamental forces of attraction and repulsion (respectively, 4:499, 508) and the laws of mechanics (4:540, 543, 544).

 As I suggested above, the core of Kant’s *a priori* physical theory presented in MAN is based on Kant’s dynamical theory of matter and the associated rejection of mechanical philosophy. Were Kant’s dynamism not justified *a priori* and were mechanical philosophy a viable alternative, various core propositions of the book would lack adequate, *a priori* justification. Not only would the purportedly *a priori* propositions of the Dynamics describing the fundamental forces and infinite divisibility of matter want for necessity, so too would those of the Mechanics. Kant bases his mechanics, which concerns the communication of motion among matters, upon the foundation of his dynamical theory and its dual fundamental forces: “all mechanical laws presuppose dynamical laws, and a matter, as moved, can have no moving force except by means of its repulsion or attraction, on which, and with which, it acts immediately in its motion, and thereby communicates its own inherent motion to another” (4:536f.). Thus, critical components of Kant’s rational physics turn on his anti-mechanical thesis that matter fills its space dynamically.

 Warren’s account, however, cannot give *a priori* justification to Kant’s dynamics. Note that the dynamical mode of explanation fails to hold a clear advantage over its mechanism in this respect. Kant himself notes (and Warren observes that) a dynamical explanation *also* gives rise to infinite regress: “with either explanation one never comes to an end” (V-Meta/Mrongovius, 29:936). Dynamical explanations are simply “more satisfying and complete” than the mechanical, according to Warren. However, Kant never offers any sort of meta-theoretical principle to the effect that an explanatorily preferable theory is more likely true. Moreover, given that his dynamic theory and its fruit are supposed to be *a priori*, Kant would require an *a priori* principle that an explanatorily superior theory *must* be true. Not only is such a principle not forthcoming in Kant’s works, it is implausible that Kant would have endorsed such a strong principle. More plausibly, Kant likely thinks that the dynamical explanations are more probably true than the mechanical in virtue of their explanatory superiority. But were this the ground for his dynamical theory, it would insinuate contingency into the very heart of Kant’s supposedly *a priori* physics. In addition, as I noted above, throughout MAN, Kant states definitively that the problem with mechanical philosophy is a metaphysical one. Warren’s interpretation sits uncomfortably with such claims; it is difficult to see how the explanatory defects of mechanical philosophy could be thought of as metaphysical in nature. Moreover, these observations constitute a partial response to Friedman (2013, p. 569), who suggests that Kant’s dynamic theory of matter is justified by the empirical success of Newtonian physics, and Duncan (1986, p. 287), who claims that dynamism is to be preferred for being more “fruitful” in producing detailed physical laws. Were Kant’s position against the mechanists so contingent, the entire edifice of his rational physics would crumble.

I concede that Warren presents convincing evidence that Kant thinks of explanations framed in terms of forces as superior. I add that Kant derides mechanical explanations as yielding “the imagination far too much freedom to make up by fabrication for the lack of any inner knowledge of nature” (MAN, 4:532) and asserts that “The [set of] principles that assumes physical atoms as the first basic parts, is the philosophy of the lazy” (V-Meta/Mrongovius, 29:932).[[30]](#footnote-30) Yet, for the reasons outlined above, it is implausible that such considerations would have served as the *basis* for his anti-mechanical stance.[[31]](#footnote-31)

* 1. Hesitancy

Curiously, multiple times throughout the Critical corpus, Kant backs away from a full-scale repudiation of mechanical philosophy. In the Anticipations of Perception, Kant claims that he can there offer no *a priori* disproof of absolutely hard atoms (KrV, A173f./B214–16). In the Third Analogy, he declines to refute the existence of empty space (A213f./B260f.). In the General Remark to the Dynamics, Kant notes the mathematical advantages that mechanical philosophy holds over the dynamical approach and suggests that there can be no disproof of mechanical philosophy’s core concepts (MAN, 4:532–35). In the General Remark to the Phenomenology, Kant claims that dynamically empty space—space in which there is no expressed repulsive force—cannot be shown to be impossible (4:563) and that those who purport to decide the problem resort to dogmatism and “plainly metaphysical presuppositions” (4:564). In his metaphysics lectures, Kant presents mechanical philosophy alongside dynamical philosophy as a particular methodology for physics (V-Meta/L1, 28:210; V-Meta/Dohna, 28:664f.). More interestingly, in other lectures, Kant claims that “the correct mode of explanation is dynamical physics, which includes *both* [mechanical and dynamical explanations] in itself” (V-Meta/Mrongovius, 29:935f., my italic emphasis). Kant thus apparently makes room for mechanical philosophy within his system.

If my interpretation is correct and Kant recognized an *a priori*, metaphysical argument against mechanical philosophy, why the hesitation? Relatedly, what conceptual room is there for mechanical philosophy in Kant’s theoretical philosophy, if its core concepts—absolute impenetrability and empty space—are not possibly objects of experience? In this section, I am especially concerned with the latter question. I contend that absolute impenetrability and empty space are ideas of reason and that their utilization in explanation falls under the regulative use of reason. Although we can never experience empty spaces and absolutely impenetrable spaces due to considerations of continuity, we can still think them and conceive of the world *as if* it is so structured. Thereby, Kant leaves open the door to his mechanical opponents’ explanations.

Butts (1986, pp. 193f.) is similarly interested in Kant’s hesitation to conclusively repudiate mechanical philosophy. He argues that, for Kant, dynamism and mechanism constitute alternative research programs, or ways of unifying and systematizing scientific knowledge. There is room in Kant’s system for this dual approach to science, according to Butts, because the fundamental explanatory grounds of *both* dynamism and mechanism are constituted by ideas of reason.[[32]](#footnote-32) In the theoretical context, ideas are concepts that are beyond the possibility of experience, but they are postulated by reason to systematize and to explain completely our cognitions (KrV, A310–20/B366–77). Whereas the transcendental ideas of reason (the soul, the world-whole, and God) are derived from the syllogistic forms (A321f./B378f.), there are other ideas, whose objects are beyond the possibility of experience and which are postulated by reason in order to explain and to order our cognitions, especially in the scientific context.[[33]](#footnote-33) For instance, Kant thinks of Newtonian absolute space (MAN, 4:563), the chemical elements (KrV, A645f./B673f.), and biological species (A317f./B374f.) as ideas that systematize their respective domains. Absolute space, for example, though it is beyond the possibility of experience and is hence a mere idea of reason, makes comprehensible the notion of *actual* motion.[[34]](#footnote-34) Butts thinks that the mechanical and dynamical research programs similarly postulate ideal entities—absolute impenetrability and empty space, on one hand, and fundamental forces, on the other—as hypothetical grounds for their respective modes of natural explanation.

Although Butts’ suggestion is compelling, the fundamental forces of attraction and repulsion are decidedly *not* ideas. As I explained above, for Kant, the propositions of MAN are *a priori* theses applying to all outer objects of possible experience. Brittan notes (1986, p. 89) that Kant is clearly committed to the claim that the fundamental forces have a sort of objective validity that atoms, absolute space, and empty space cannot achieve. Furthermore, Okruhlik (1986, p. 315) explains that a central goal of MAN is grounding realism with respect to gravitational force. Since Kant identifies the fundamental attractive force with gravitation, in order to achieve this objective, he cannot claim that the fundamental attractive force is a mere idea and thereby beyond the possibility of experience.

Nevertheless, the notion that absolute impenetrability and empty space—the basic concepts of mechanical explanations—are ideas of reason is a fruitful one that reveals the conceptual space for mechanical philosophy in Kant’s system. Indeed, Kant himself suggests that these notions are ideas.

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 to a determinate measure—namely, to view these properties as dynamical, and not as *unconditioned original positings*, as a merely mathematical treatment might postulate them. (MAN, 4:534; my italic emphasis)

In this passage, Kant claims that one advantage dynamism holds over mechanism is that the latter rests on “unconditioned original positings.” By this, he means ideas of reason, for such are concepts of the unconditioned (KrV, A307f./B364; see also Bxx, A409/B436). Other considerations also support the claim that empty space and absolute impenetrability are ideas of reason. On one hand, in Refl5662 (1788–90), Kant writes that “empty space is a mere idea” (18:321).[[35]](#footnote-35) Notes from his metaphysics lectures also attribute to Kant the notion that empty space, whether intra- or extramundane, is not an object of our experience: a vacuum in the world would be a gap and “a gap would at the same time also be a leap; and that this latter does not take place has already been proved earlier” (V-Meta/Mrongovius, 29:922). This is a plain reference to the law of continuity, according to which are no such leaps in nature. On the other hand, as I demonstrated above, since absolutely impenetrable spaces would involve discontinuous changes of motion and all alterations in experience must be continuous they, too, cannot be experienced.

But these core mechanical notions are not, for this reason, illegitimate. Kant is clear that though ideas are beyond the possibility of experience, insofar as they are logically consistent, we can *think* them. This is a crucial aspect of Kant’s system as he makes clear in the Discipline of Pure Reason in its Polemic Use (KrV, A738–69/B766–97). That the soul, the world-whole, and God are ideas means that we can think and believe about them and, for this reason, atheism and materialism have no hold on the Critical philosopher (A741/B769). That ideas are beyond the limits of experience means that *neither* their existence *nor* their nonexistence can be proven. For Kant, that we can think the transcendental ideas—and ideas more generally—serves for a variety of theoretical and practical purposes. For instance, in the appendix to the Transcendental Dialectic, he discusses the theoretical, regulative use of ideas: they allow us to systematize and comprehend the knowledge generated by the understanding (A642–68/B670–96).[[36]](#footnote-36)

So that absolute impenetrability and empty space are not objects of possible experience does not doom them to the status of the false and the impossible. The mechanist may still *think* of her world as structured according to absolutely impenetrable corpuscles impacting in an empty space. In the end, we can only know facts about the objects of experience. Empty space and absolute impenetrability are ideas, and hence beyond the possibility of experience, but this, alone, does not rule out the possibility that empty spaces *ground* our experiences at some deeper level. This is why Kant writes in the Third Analogy that “I do not in the least mean hereby to refute empty space; that may well exist *where perceptions do not reach*, and thus where no empirical cognition of simultaneity takes place; but it is then hardly an object of our possible experience at all” (A214/B261, my italic emphasis). That is, Kant means to say that although one cannot *experience* anempty space, such may nonetheless exist *beyond* the limits of experience.

Jankowiak (2013, pp. 405–8) makes a helpful observation along these lines. He explains that in the Anticipations of Perception Kant allows for the possibility that the ultimate constituents of reality are discrete (atoms or corpuscles), while all objects of perception have a degree.[[37]](#footnote-37) That is, it is possible that everything that we experience bears intensive magnitudes and (apparently) expresses forces, while at a deeper level, the world consists of discrete atoms, each bearing a particular, constant degree. Analogously, the Antinomies show that things in themselves may, very well, be metaphysically simple and that in the noumenal realm we may be free, though in the realm of experience, objects are composite and alterations are determined.[[38]](#footnote-38)

So there is room in Kant’s transcendental philosophy for the mechanical philosophers’ explanations. While these explanations do not appeal to actual objects of experience (and for this reason, Kant would think them deficient) they nevertheless may be posed as a way of systematizing and making sense of physical sciences. Kant undoubtedly would also provide additional objections to mechanical explanations besides their metaphysical shortcomings: as Warren noted and I discussed above, Kant finds mechanical explanations to be unsatisfying. All that said, his hesitancy with regards to mechanical philosophy is legitimated insofar as its basic notions are ideas of reason, which are beyond the possibility of experience.

1. Conclusion

Thus, to answer Kästner and to motivate Kant’s dynamic theory of matter, one “**must**” think of a moving force in the wall because the only other alternative (that it fills its space through its mere existence, as the mechanical philosopher would have it) is metaphysically incoherent, violating the *a priori* dynamical law of continuity.[[39]](#footnote-39) Nevertheless, Kant has room in his theoretical philosophy for one to consider the possibility that the wall is made up of inexperienceable, inaccessible atoms, which, in some sense, ground the observed phenomena. This account not only reveals a Leibnizian vein in Kant’s philosophy of science but, in addition, demonstrates the substantive role that reason and its ideas can play in natural philosophy.

References

In the paper, the following abbreviations are used for Kant’s works.

GSK = *Gedanken von der wahren Schätzung der lebendigen Kräfte*

KrV = *Kritik der reinen Vernunft*

MAN = *Metaphysische Anfangsgründe der Naturwissenschaft*

MonPh = *Metaphysicae cum geometria iunctae usus in philosophia naturali, cuius specimen I. continet monadologiam physicam*

MSI = *De mundi sensibilis atque intelligibilis forma et principiis*

NLBR = *Neue Lehrbegriff der Bewegung und Ruhe*

OP = *Opus postumum*

Refl = *Reflexionen*

V-Meta/Dohna = *Metaphysik Dohna*

V-Meta/Herder = *Metaphysik Herder*

V-Meta/L1 = *Metaphysik L1*

V-Meta/Mrongovius = *Metaphysik Mrongovius*

V-Meta/Volckmann = *Metaphysik Volckmann*

V-Ph/Danziger = *Danziger Physik*

As is standard, references to KrV refer to the first and second edition page numbers (A/B). References to Kant’s other works are to the *Akademie* edition of his collected writings (Kant 1900–) and include a volume and page number. For English translations, I have used those available in Cambridge University Press’ series of Kant’s writings, where available.

The following abbreviations are used for references to the English translations of Leibniz’s works.

 AG = *Philosophical Essays*, ed. Ariew and Garber

 L = *Philosophical Papers and Letters*, ed. Loemker

 NE = *New Essays*, ed. Remnant and Bennett

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1. Throughout the paper, I also refer to metaphysical-dynamical mode of explanation as “dynamism” and “dynamic philosophy,” whereas the mathematical-mechanical mode is additionally denoted by “mechanism” and “mechanical philosophy.” Kant also holds that the latter is equivalent to atomism and corpuscular philosophy (MAN, 4:532f.). Generally, in Kant’s writing, “mechanism” and its forms have a somewhat wide array of meanings, depending on context. For a discussion and agglomeration of this array, see van den Berg (2014, pp. 69–75). [↑](#footnote-ref-1)
2. In different senses, Gottfried Wilhelm Leibniz, Herman Boerhaave, and Roger Boscovich are dynamists. For a discussion of Kant’s dynamism in relation to Boerhaave’s and Boscovich’s respective formulations, see Carrier (1990, pp. 176–80). For more on Boerhaave’s influence on Kant’s early physical theory, see Massimi (2011). [↑](#footnote-ref-2)
3. Although the review was anonymously penned, it is now known that Kästner was the author (Förster 2000, p. 183n.). [↑](#footnote-ref-3)
4. Westphal, in particular, echoes some of Kästner’s earlier skepticism regarding Kant's argument for dynamism. [↑](#footnote-ref-4)
5. That said, for Brittan (1978, p. 156), dynamical philosophy also suffers from defects insofar as fundamental forces cannot be mathematically constructed and it is hence, at best, a hypothesis. [↑](#footnote-ref-5)
6. The details of Kant’s views on the mathematical construction of natural concepts are extremely obscure and controversial. For varying interpretations of his conception of the application of mathematics to natural science, see, for example, Brittan (1978, p. 103), Nayak and Sotnak (1995), Friedman (2013, pp. 26–33), McNulty (2014), and van den Berg (2014, pp. 15–51). [↑](#footnote-ref-6)
7. For more on Leibniz’s role in the *vis viva* controversy, see Iltis (1971). For additional Leibnizian arguments against Cartesian mechanics, see L (458–63, 538–43) and AG (117–38). [↑](#footnote-ref-7)
8. Ariew and Garber provide a visual depiction of the discontinuities Leibniz has in mind. [↑](#footnote-ref-8)
9. For another discussion of this objection to Cartesian mechanics, see Jorgensen (2009, pp. 229–32). [↑](#footnote-ref-9)
10. Carrier (1990, p. 176) notes that Boscovich, another dynamist, also traces his anti-mechanical position to the Leibnizian principle of continuity. [↑](#footnote-ref-10)
11. Wilson (1982) diagnoses Leibniz’s progressive falling out with atomism, observing that his anti-atomic stance developed from a confluence of factors and not merely his commitment to first principles, such as the law of continuity. [↑](#footnote-ref-11)
12. Christian Wolff and Alexander Baumgarten, with whom Kant was well acquainted, comprise two other forerunners to his views on continuity. In his *Deutsche Metaphysik*, Wolff asserts that nature takes no leaps, explaining that “all alterations of bodies occur bit by bit, and therefore all events come about bit by bit through determinate degrees” (1747, p. 425). In his *Metaphysica*, Baumgarten defends a version of the principle of continuity as a corollary of the principle of sufficient reason. He defines an “absolute leap” as an event lacking a proximate (immediate) sufficient ground and writes “That which would exist without any proximate sufficient ground […] would exist through pure chance […] and hence an absolute leap is impossible […] and must not be posited in this or in any world” (Baumgarten 2013, p. 172). A violation of continuity, or a leap, is impossible for Baumgarten insofar as it would have no sufficient reason. Baumgarten, too, rejects the doctrine of atoms, though not explicitly on the grounds of continuity. He claims that the indivisibility of atoms is impossible (2013, pp. 180f.). For more on Kant’s views on continuity, especially in relation to Baumgarten’s cosmology, see Watkins (2001, pp. 76–81). [↑](#footnote-ref-12)
13. This claim is also found in Refl 40 (14:148), Refl 4666 (17:630), and V-Meta/Mrongovius (29:921). [↑](#footnote-ref-13)
14. Warren (2001b, pp. 22–30) explains that intensive magnitudes are essentially those whose degrees are determined through their effects. Hence the intensive magnitude of the sun that causes my sensation of brightness is determined through the intensity of my sensation. See also Jankowiak (2013) for an illuminating reading of the argument of the Anticipations of Perception. [↑](#footnote-ref-14)
15. In virtue of motion’s being an intensive magnitude—one not consisting of parts—Kant believes that composite motions cannot be represented merely through the concatenation of vectors (MAN 4:493–95). This would be to treat the composite motion as an extensive magnitude, or one composed of parts. [↑](#footnote-ref-15)
16. Warren (2001b, p. 69n.) suggests that one lacks justification for applying the concept of continuity, because one cannot experience all of the infinite states that make up a continuous change. Thus, that a particular change is continuous cannot be empirically verified. Warren’s objection, however, puts the cart before the horse. The law of continuity does not commit Kant to the idea that changes need be experienced *as* fully continuous (as Warren tacitly assumes). Rather, Kant’s claim that changes are fully continuous at most commits him to the idea that each individual state in a continuous change is *in principle* experienceable. An analogy with causation is useful here. Just as one need not experience the cause of an alteration to know that it has some temporally precedent cause, one need not experience each particular degree of alteration to know that the alteration is continuous. No empirical confirmation of continuity is required: we already possess *a priori*, metaphysical validation that all changes are continuous. [↑](#footnote-ref-16)
17. A similar proof of the law can also be found in V-Meta/L1 (28:201). Some commentators have expressed skepticism with regards to Kant’s law of continuity of alteration and its purportedly *a priori* basis (Bennett 1966, pp. 176–80; Guyer 1987, pp. 204f.). I, like Paton (1936, pp. 2:284–89), maintain that Kant had ample ground for justifying the law of continuity, although an in-depth discussion of his Critical proof would take us astray. In an unpublished manuscript, Jankowiak offers a detailed, illuminating examination of the warrant for the law of continuity of alteration and evaluates Kant’s various attempts to prove the principle. For my purposes, the crucial point is simply *that* Kant thinks the law of continuity to be an *a priori*, universal law of nature. [↑](#footnote-ref-17)
18. See Watkins (2013) for an argument for the thesis that the law of continuity of forms especially concerns species under a shared genus. [↑](#footnote-ref-18)
19. This ‘mechanical’ law of continuity is, I maintain, distinct from the mechanical law of continuity discussed in MAN (4:552). That mechanical law of MAN *presupposes* the dynamical theory of matter and furthermore concerns transfer of motion in impact. [↑](#footnote-ref-19)
20. Subsequently Kant cites Newton’s insight from the *Opticks* that light reflecting off of a mirror must slow down, rest, and accelerate away (similar references are also found in V-Meta/Herder (28:41f.) and V-Meta/L1 (28:204)). Although in this paper I especially emphasize the Leibnizian backdrop for Kant’s theory of nature, clearly Newton was also influential for Kant in this context. [↑](#footnote-ref-20)
21. Kant’s tentativeness appears to be a transitory. By the 70s and 80s, Kant’s strong endorsement of the law of continuity in its many forms is reinstated, as I have shown. [↑](#footnote-ref-21)
22. Pollok (2001, p. 237) denies that the continuity can bear argumentative weight in Kant’s argument for dynamism. According to Pollok, Kant’s appeal to the “striving [*Bestrebung*] to penetrate” in the first proposition of the Dynamics (MAN 4:497)—an infinitely small moment of acceleration—presupposes both the existence and continuity of the fundamental forces, which Kant has not yet proven at the outset of the Dynamics. This is entirely accurate; the argument against mechanism based on the moment of acceleration (and the mechanical law of continuity) presupposes Kant’s dynamical theory of matter (see note 19). However, Kant’s anti-mechanical stance may legitimately rest on the continuity of *alteration* (as I contend), for it is proven in the Second Analogy of KrV as a general feature of possible experience. [↑](#footnote-ref-22)
23. See also V-Meta/Mrongovius (29:921f.). [↑](#footnote-ref-23)
24. A proviso: elsewhere Kant suggests that the modes of explanation are a bit more various (V-Ph/Danziger, 29:104f.). First, he distinguishes physical explanations—which deal with causes and effects—from teleological explanations—which have to do with means and ends. Subsequently, he distinguishes three types of physical explanation: mechanical, dynamical, and organic, where according to the latter, “one explains something through the capacity for sensation of a being” (29:105). Because they involve sensory capacities, only a fraction of natural occurrences admits of organic explanation. So, when considering physical attributes exhibited by *all* matter, there are two viable modes of explanation: mechanical and dynamical. [↑](#footnote-ref-24)
25. Kant describes this line of thought most clearly in OP. There he explains that there are philosophical foundations of natural science—which explain motions via powers—and mathematical foundations—which explain powers via motions (see OP, 21:481f.). As Friedman (1992, pp. 222–42) has argued, this distinction is meant to be the same as that between dynamical and mechanical philosophy. Thus, this way of presenting the distinction is cleanest and makes clear the exhaustivity of the disjunction (there are only two possible directions of explanation between powers and motions). However, there is some controversy regarding the interpretation of these passages from OP and the identification of the two distinctions: Tuschling (1971, pp. 90f.), Westphal (1995, pp. 409–15), and Edwards (2000, pp. 229–41) attack Friedman’s interpretation, while I support it (McNulty 2016, pp. 72–82). [↑](#footnote-ref-25)
26. Reflecting on similar passages, Warren (2010) argues that mechanical philosophy is, for Kant, explanatorily deficient, insofar it only explains motions by appeal to other motions. I discuss his interpretation below in section 5.1. [↑](#footnote-ref-26)
27. Indeed, Leibniz himself calculates quantities of motion according to the Cartesian system and asks the reader to imagine a graph of these values in the “Specimen Dynamicum.” [↑](#footnote-ref-27)
28. Van den Berg (2014, pp. 73f.) also conceives of Kant’s objection to mechanism as resting on explanatory considerations. He contends that were space-filling simply analytic of matter—that is, were matter to fill its space through its mere existence, as the mechanist would have it—we would lack a genuine explanation of it. [↑](#footnote-ref-28)
29. Elsewhere, Warren (2001b) has offered a different metaphysical understanding of Kant’s rejection of mechanical philosophy. He contends that, in Kant’s eyes, the mechanists attempt to explain material phenomena—paradigmatically, that of space-filling—via absolutely inner determinations. However, insofar as the mechanical account involves such inner determinations, it constitutes an attempt to describe things-in-themselves, and is thereby metaphysically deficient (pp. 70–73). This insightful account from Warren is well grounded in Kant’s texts, and reveals fascinating details of his views on the nature of things-in-themselves and the relation between metaphysics and physics. I, hence, mean not to dismiss Warren’s metaphysical characterization in order to replace it with my own. Rather, I maintain that both lines of thought are present in Kant’s anti-mechanical thought. Furthermore, I intend for my argument to correct Warren’s all-too-hasty dismissal of the law of continuity as the basis for Kant’s views (p. 70; see also 2001a, pp. 112f.). As I have shown, considerations of continuity are central to Kant’s thought throughout his corpus and, especially, in the context of the metaphysical foundations for physics. [↑](#footnote-ref-29)
30. This is a comment on a passage from Baumgarten (2013, p. 180) in which he makes the same claim. [↑](#footnote-ref-30)
31. Considerations of explanatory success may, however, have influenced Kant’s claim that chemistry “must proceed dynamically instead of mechanically” in Refl 63 (14:481). Whereas Kant presents *a priori* proofs of the existence of the *physical* dynamical forces, he admits that that whether *chemical* forces—those “capable of effecting a complete dissolution of matter” (MAN, 4:530)—are actually found in nature is unknown. Thus, dynamism lacks the definitive metaphysical superiority vis-à-vis mechanism in the context of chemistry. I thus conjecture that the explanatory defects of mechanism highlighted by Warren may have influenced Kant’s recommendation for a chemistry based on forces. A bit more speculatively, Kant might have also thought that mechanical philosophy’s irregular laws (discussed above) entail that dynamical explanations are to be preferred in chemistry. [↑](#footnote-ref-31)
32. Schäfer (1966, pp. 83–85) also contends that the discrete (mechanical) and continuous (dynamic) representations of matter rest on ideas, for Kant. He supports his view by tracing these two approaches to the thesis and antithesis, respectively, of the Second Antinomy; Falkenburg (1995, pp. 22f.) and Malzkorn (1998, pp. 392–409) echo this identification. I note only that in MAN, mechanism is treated as an *explanatory* thesis, distinct from either side of the Second Antinomy. Furthermore, Kant offers additional arguments against mechanism in MAN, revealing that he did not take the Second Antinomy to provide a conclusive disproof of this mode of explanation. [↑](#footnote-ref-32)
33. For accounts of these ideas and the contribution of reason to scientific cognition, see Buchdahl (1966, 1971), Wartenberg (1979), Rauscher (2011), and McNulty (2015). [↑](#footnote-ref-33)
34. See Friedman (1992, pp. 141–49; 2013, pp. 474–509). For more on Kant’s conception of absolute space, see Palter (1971). [↑](#footnote-ref-34)
35. This claim is also found in Refl 5341, from the late 70s or 80s (18:156). In the General Remark to the Phenomenology, Kant claims that absolute space is an idea of reason (MAN, 4:559), and absolute space, for Kant, is “[e]mpty space in the *phoronomical* sense” (MAN 4:563). However, the empty space relevant for our present concerns is empty in the *dynamical* sense—that is, space that does not, to *any* degree, resist the motion of incoming bodies. [↑](#footnote-ref-35)
36. Kant even goes as far as to claim that the regulative use of ideas of reason presupposes transcendental principles that are simultaneously necessary for the use of the understanding (KrV, A650f./B678f.). That said, there is a great deal of conflicting literature on the appropriate understanding of the transcendental status of reason’s principles, a small fragment of which includes Morrison (1989), Schiemann (1992), Grier (2001, pp. 263–301), Ostaric (2009), and Pickering (2011). [↑](#footnote-ref-36)
37. This sort of possibility is similar in a sense to Leibniz’s metaphysical picture (see Crockett 1999). Leibniz, too, disagrees with mechanism and holds that at the fundamental level reality consists of discrete simples (i.e. monads). Nevertheless, at the phenomenal level, bodies and their changes are continuous. [↑](#footnote-ref-37)
38. I also thank Jankowiak for raising the following difficulty. It appears problematic to claim that mechanical philosophy could be true in the noumenal realm, for it involves spatial content—its impenetrable and empty spaces—and space is a form of *phenomena*. While I agree that there is difficulty in sorting out where, exactly, ideas of absolutely impenetrable and empty spaces belong in Kant’s system, I assert *that* Kant countenanced such as regulative ideas, despite spatial content, is clear (as I demonstrated above). Moreover, in the General Remark to the Phenomenology, Kant claims unequivocally that absolute space is an idea of reason: “It cannot be an object of experience, for space without matter is no object of perception, and yet it is a necessary concept of reason, and thus nothing more than a mere *idea*” (MAN, 4:559). Kant thus allows for the formation and consideration of ideas that both refer to objects beyond the possibility of experience and contain spatial content. The nature of these ideas and their relations to noumena and phenomena are topics that demand further treatment but that also lie beyond the scope of the present paper. [↑](#footnote-ref-38)
39. This is not to say that Kästner, a notable critic of the law of continuity, would have been satisfied by this response. [↑](#footnote-ref-39)