European Studies in Philosophy of Science 12

Brigitte Falkenburg

Kant's Cosmology

From the Pre-Critical System to the Antinomy of Pure Reason

Springer

European Studies in Philosophy of Science

Volume 12

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ISSN 2365-4228 ISSN 2365-4236 (electronic)
European Studies in Philosophy of Science
ISBN 978-3-030-52289-6 ISBN 978-3-030-52290-2 (eBook)
https://doi.org/10.1007/978-3-030-52290-2

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

In memory of my brother

Preface

This book provides a systematic investigation of Kant's philosophical development from his pre-critical to his critical cosmology. It studies Kant's theoretical philosophy as it was expressed in his pre-critical metaphysics and cosmology, through the critical turn, to the antinomy of pure reason, focusing on his principles of metaphysical theory formation. The book has three parts. The first sets out the methodological approach that underlies Kant's pre-critical project to reconcile the principles of Wolff's system of metaphysics and Newtonian physics (Chaps. 1 and 2). The second part examines the way in which Kant transformed the foundations of his precritical metaphysical system in the course of his critical turn and explores his reasons for this transformation (Chaps. 3 and 4). The third part analyzes the cosmological antinomy of the *Critique of Pure Reason* and its relation to transcendental idealism (Chaps. 5 and 6). Finally, an extensive appendix sets out the crucial systematic concepts behind Kant's pre-critical and critical metaphysics of nature.

Kant's pre-critical work of the years 1755/1756 includes several writings on natural science and the foundations of metaphysics. From the systematic point of view taken in this book, the *Theory of the Heavens*, the *New Elucidation*, and the *Physical Monadology* are of decisive importance. Together, these three writings promised to lay the foundations of an all-encompassing metaphysics of nature. The *Prize Essay* published in 1764 defended the "analytic" method of metaphysics employed in this endeavour. But by this time, Kant had already begun to realize that the foundations of his pre-critical system were untenable. His development from the *Dreams of a Spirit Seer* of 1766 to the *Inaugural Dissertation* of 1770, and through his so-called silent period to the first *Critique*, is generally thought to be well understood. However, controversy remains concerning the genesis of the antinomy of pure reason, while, in addition, the structure and significance of the cosmological antinomy for Kant's critical philosophy has often been misunderstood. I hope that my attempt at a systematic reconstruction of these matters will shed more light on the specific role played by the doctrine of the antinomy within Kant's critical metaphysical project.

This book is an enlarged and completely revised English version of my *Kants Kosmologie* published 20 years ago. The motivation behind that book was to clarify the reasons why, in his critical period, Kant rejected his early work on the foundations of physics and metaphysics. The work he rejected included his impressive cosmology of 1755, which in a certain sense laid the foundations for modern physical cosmology as a well-established discipline of physics. This cosmology contained a theory of the formation of the solar system from a matter vortex, still considered essentially correct today, which he then extrapolated to an impressive cosmogony and added a physico-theological proof of the existence of God. In view of this theory, Kant's critical turn raises two questions. First, why did he reject not only this metaphysical addendum to that impressive cosmogony but the entire project of a physical cosmology itself, claiming that any theory of the whole universe must turn out to be contradictory? Second, does Kant's doctrine of the cosmological antinomy still provide lessons for modern physical cosmology, and if so, what?

Twenty years ago I could not give a definitive answer to the second question, nor do I attempt to do so in the present book. Instead, I focus on the first question, seeking to work out Kant's development more precisely and to clarify the significance of the antinomy for his critical project. Therefore, here I omit the topics of the last chapter of my previous book, which will have to be addressed in a separate book on Neo-Kantian approaches to modern physics. Other changes include the correction of several errors in my earlier book, a restructuring of the presentation in order to make the line of reasoning more transparent, and the addition of new material.

Parts I and II of the present book contain many new details concerning Kant's pre-critical "analytic" method of metaphysics, its analogy to Newton's inductive methodology, the collapse of the pre-critical system, and Kant's critical turn. Part I focuses on the structure and methods of the pre-critical system. The contents of Chap. 1 are now presented in a more systematic way, particularly concerning Kant's early attempt at reconciliation in the *True Estimation*, its consequences for his pre-critical metaphysical project, the structure of the 1755/1756 system, and the methodological challenges posed by the quest to unify the principles of Newtonian physics and metaphysics in Wolff's style. Chapter 2 studies the analytic and synthetic methods employed by Kant in his 1755/1756 trilogy that provided the foundations for his pre-critical system, the background of these methods in early modern science and philosophy, and what he made out of them in the *Prize Essay* of 1764. Particular emphasis is laid on the methodological analogy between metaphysics and Newtonian science, which also sheds new light on the proof structure employed in the *Only Possible Argument*.

Part II investigates the collapse of the pre-critical system and the critical turn. Chapter 3 investigates how the distinction between logical and real grounds affected the foundations of the pre-critical system, culminating in the *Dreams* of 1766

and the 1768 argument from incongruent counterparts. The latter gave rise to the puzzling result that Kant saw himself as left without any tenable concept of space as a real entity, be it absolute or relational. His way out was the 1770 theory of space and time as forms of pure intuition. From a modern logical point of view, however, his solution was sufficient but not necessary to resolve the puzzle of 1768. Chapter 4 takes a closer look at Kant's critical turn. From Neo-Kantianism to recent interpretations, it has been argued that Kant's 1770 *Dissertation* resolved the cosmological antinomy. This traditional view is rejected here, given that in 1770 Kant was far from stating the later antinomy of pure reason. Rather, he continued to attempt to reconcile the cosmological concept of traditional metaphysics with his new theory of space and time as pure forms of intuition. It was only after 1772, in the course of developing his critical theory of cognition, that he discovered the mathematical antinomy. His notes on metaphysics of 1773–1775 indicate that he then realized that in cosmology only the metaphysical concept of a potential infinite applies, in contrast to the mathematical concept of an actual infinite.

Part III examines Kant's critical cosmology, which to a large extent consists only in the critique of traditional cosmology. My logical reconstruction of the cosmological antinomy in Chap. 5 remains essentially the same as in my 2000 book, but I now hope to have presented Kant's arguments and their assessment in a clearer way. Detailed investigation again leads me to reject certain influential views concerning several alleged fallacies in Kant's reasoning, which miss the point that Kant consciously constructed the antinomies based on traditional cosmological arguments, some of which he himself adhered to in his pre-critical metaphysics, including the 1770 *Dissertation*, and which from his critical point of view turn out to be fallacious. Chapter 6 takes up some ideas from my 2000 book, but most of it is new. In particular, it contains a detailed analysis of the experiment of pure reason, which the preface to the second edition of the first *Critique* presents as an argument in favour of transcendental idealism. This thought experiment can be understood as a transcendental argument against transcendental realism. From a modern point of view, it seems weaker than Kant claimed: it proves only that transcendental idealism is sufficient, but not necessary, for avoiding the antinomy, just as Kant's way out of the 1768 puzzle was. However, his thought experiment does at least demonstrate that the doctrine of cosmological antinomy has an anti-naturalistic impact. Therefore, my main conclusion about the function of the antinomy of pure reason within Kant's critical project is that it is the critical correlate of his pre-critical physico-theology.

The foundations for this book were laid 25 years ago, when I wrote large parts of the underpinning German version during my stay at the Wissenschaftskolleg zu Berlin in the academic year 1995/1996. The remainder of my Heisenberg fellowship granted by the Deutsche Forschungsgemeinschaft subsequently enabled me to continue my discussions with Peter Mittelstaedt on the topics of this book and their relations to the philosophy of physics, at the Universität zu Köln.

After my appointment to the Technische Universität Dortmund in 1997, I was able to deepen my work on Kant's argument from incongruent counterparts, the cosmological antinomy, and the analytic-synthetic methods of early modern science and philosophy through several research projects: the project *Functions*

and Limitations of Intuition in Physics (MWF of Nordrhein-Westfalen, Project IVA-6000, 1998–2001) with Renate Huber; a three-year cooperation on the *Functions of Intuition in Mathematics and Physics* with Michael Hallett and Emily Carson from McGill University (Montreal), which was supported by the German–American Academic Council (TransCoop Program 1998–2000); and the research project *Hypotheses non fingo: Newtons Methodenlehre*, supported by the Deutsche Forschungsgemeinschaft (DFG FA 261/5-1, 2002–2003) with Karl-Norbert Ihmig.

Over the next decade and a half, I was able to continue my work on Kant only sporadically, due to teaching and administrative obligations as well as research projects on other topics. Yet, over this period, on the occasion of talks at conferences or other universities, or when inviting colleagues to Dortmund, I nevertheless had many stimulating discussions about Kant's theory of nature. Of those over the years who gave me the opportunity to present my work on Kant, made critical comments on it, or provided me with important insights, I would like to mention Claus Beisbart, Silvia De Bianchi, Cinzia Ferrini, Tobias Häusler, Dietmar Heidemann, Katharina Kraus, Michela Massimi, Hernán Pringe, Helmut Pulte, Peter Rohs, Simon Saunders, Jürgen Stolzenberg, Thomas Sturm, Dieter Sturma, Violetta Waibel, and Brigitta von Wolff-Metternich, not to forget Michael Wolff who first instructed me about the logical structure of Kant's antithetic of pure reason, when I was a PhD student in Bielefeld many years ago.

In addition, I would like to thank Christian Feldbacher-Escamilla, Andreas Hüttemann, Oliver Scholz, Gerhard Schurz, and Ansgar Seide from our research group *Inductive Metaphysics*, supported by the Deutsche Forschungsgemeinschaft (DFG FOR 2495), for drawing my attention to the parallels and differences between the traditional analytic-synthetic method, inductive metaphysics from the late nineteenth to the early twentieth century, and creative abduction, as well as the parallels between Kant's experiment of pure reason and transcendental arguments. I would also like to thank Kristina Engelhard for carefully reading parts of the book and critically commenting on them, Benedict Young for his patient and constructive language corrections, and the Deutsche Forschungsgemeinschaft for supporting this work as well as two related conferences in our research project *Kant and Inductive Methods in Eighteenth Century Metaphysics* (DFG FA 261-15/1, which is part of FOR 2495).

To Dennis Dieks, Maria Carla Galavotti, and Wenceslao J. Gonzalez, the Editors of the European Studies in Philosophy of Science, I am grateful for the opportunity to publish the book in this series; I also express my gratitude to Christopher Wilby and Deepthi Vasudevan from Springer for their support in preparing the contract and guiding the publishing process, and to the publishers of my previous work on Kant and for the permission to reuse material. This gratitude extends of course to the publisher of the original German version of the book, Klostermann, as well as to the various publishers who gave permission to make use of several articles of mine written after that book: while some of these articles were based on the previous German book, others presented entirely new material that I again include here.

Finally, the translation tool *DeepL* (https://www.deepl.com/translator) helped me a great deal with the passages I took from previously published German material, and I hope in return to have helped train it on Kant's terminology.

Berlin, Germany
May 2020

Brigitte Falkenburg

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Citations, Abbreviations, and Previously Published Material

Citations

References to Kant's works are given as follows: The *Critique of Pure Reason* is cited according to the pages of the first (A) edition and second (B) edition. All other works are cited according to the German standard edition *Kants gesammelte Schriften*, ed.: the Deutsche (formerly: Königlich-Preußische) Akademie der Wissenschaften, Vols. 1–29, Berlin 1900–, in the form (volume:page).

All translations are taken from the Cambridge Edition of the Works of Immanuel Kant, unless explicitly stated otherwise. In particular, the following volumes are quoted:

Theoretical Philosophy 1755–1770, transl. and ed.: D. Walford in collab. with R. Meerbote, Cambridge University Press, 1992.

Lectures on Logic, transl. and ed.: J. M. Young, Cambridge University Press, 1992.

Religion and Rational Theology, transl. and ed.: A. W. Wood and G. di Giovanni, Cambridge University Press, 1996.

Critique of Pure Reason, transl. and ed.: P. Guyer and A. Wood Cambridge University Press, 1998.

Critique of the Power of Judgment, ed.: P. Guyer, transl. by P. Guyer and E. Matthews, Cambridge University Press, 2000.

Theoretical Philosophy after 1781, ed.: H. Allison and P. Heath, transl. by G. Hatfield and M. Friedman, Cambridge University Press, 2002.

Notes and Fragments, ed.: P. Guyer, transl. by C. Bowman, P. Guyer, and F. Rauscher, Cambridge University Press, 2005.

Anthropology, History, and Education, ed.: G. Zöller and R. B. Louden, transl. by M. Gregor et al., Cambridge University Press, 2007.

Natural Science, ed.: E. Watkins, transl. by L. W. Beck et al., Cambridge University Press, 2012.

Abbreviations

For Kant's writings, I use the following abbreviations:

True Estimation Thoughts on the true estimation of living forces and assessment of the demonstration that Leibniz and other scholars of mechanics have made use of in this controversial subject, together with some prefatory considerations pertaining to the force of bodies in general (1749)

Theory of the Heavens Universal natural history and theory of the heavens or essay on the constitution and the mechanical origin of the whole universe according to Newtonian principles (1755)

On Fire Succinct exposition of some meditations on fire (1755)

New Elucidation A new elucidation of the first principles of metaphysical cognition (1755)

Physical Monadology The employment of metaphysics combined with geometry in natural philosophy, of which sample I contains the physical monadology (1756)

Plan and Announcement Plan and announcement of a series of lectures on physical geography with an appendix containing a brief consideration of the question: Whether the West winds in our regions are moist because they travel over a great sea (1757)

New Doctrine New doctrine of motion and rest and the conclusions associated with it in the fundamental principles of natural science while at the same time his lectures for this half-year are announced (1758)

Only Possible Argument The only possible argument in support of a demonstration of the existence of God (1763)

Negative Magnitudes Attempt to introduce the concept of negative magnitudes into philosophy (1763)

Prize Essay Inquiry concerning the distinctness of the principles of natural theology and morality (1764)

Dreams Dreams of a spirit-seer elucidated by dreams of metaphysics (1766)

Directions in Space Concerning the ultimate ground of the differentiation of directions in space (1768)

Dissertation On the form and principles of the sensible and the intelligible world (Inaugural Dissertation) (1770)

CPR Critique of Pure Reason (A: 1781, B: 1787)

Prolegomena Prolegomena to any future metaphysics that will be able to come forward as science (1783)

MFNS Metaphysical foundations of natural science (1786)

To Orient Oneself What does it mean to orient oneself in thinking? (1786)

CPJ Critique of the Power of Judgment (1790, 1793)

Progress What real progress has metaphysics made in Germany since the time of Leibniz and Wolff? (1793/1804)

Conflict of the Faculties The conflict of the faculties (1798)

Logic Immanuel Kant's Logic. A Manual for Lectures, edited by Gottlob Benjamin Jäsche (1800)

Previously Published Material

Material from the following publications of mine has been used in this book:

Kants Kosmologie. Die wissenschaftliche Revolution der Naturphilosophie im 18. Jahrhundert, Frankfurt am Main:Vittorio Klostermann 2000.

"Kants Naturalismus-Kritik", in: K. Engelhard and D. Heidemann (eds.), *Warum Kant heute?* Berlin: de Gruyter 2004, 177–206.

"Die Funktion der Naturwissenschaft für die Zwecke der Vernunft", in: V. Gerhardt and T. Meyer (eds.), *Kant im Streit der Fakultäten*, Berlin: de Gruyter 2006, 117–133.

"Intuition and Cosmology: The Puzzle of Incongruent Counterparts", in: E. Carson and R. Huber (eds.), *Intuition and the Axiomatic Method*, Dordrecht: Springer 2006, 157–180.

"From Kant's Early Cosmology to the Cosmological Antinomy", in: Silvia De Bianchi (ed.), *The Harmony of the Spheres*, Newcastle upon Tyne: Cambridge Scholars Publishing 2013, 48–70.

"Kant and the Scope of the Analytic Method", in: *Studies in History and Philosophy of Science* 71 (2018), 13–23.

"Was beweist Kants Experiment der reinen Vernunft?", in: Violetta L. Waibel et al. (eds.), *Natur und Freiheit: Akten des XII. Internationalen Kant-Kongresses*, Berlin: de Gruyter 2018, 641–659.

"The Function of Natural Science for the Ends of Reason", in: P. Órdenes and A. Pickhan (eds.), *Teleologische Reflexion in Kants Philosophie*, Berlin: Springer 2019, 93–109.

Part I
The Pre-critical System

The first part of this book focuses on the origins of Kant's systematic philosophy. It is well known that his pre-critical project was to reconcile the principles of Wolff's system of metaphysics with those of Newton's physics. Here, the methodological principles according to which Kant attempted to do so are examined in detail.

Chapter 1 reconstructs the systematic problems of Kant's pre-critical reconciliation project and the unifying principles he employed in order to resolve them. His first writing, the *True Estimation* published in 1749, remained in the eclectic tradition of his day; but with the writings of 1755/1756 he then sought to escape from eclecticism. Together, the *Theory of the Heavens*, the *New Elucidation*, and the *Physical Monadology* aimed at establishing the foundations of a system of metaphysics in Wolff's style. In view of the manifest conflict between the principles of Leibniz's metaphysics and the foundations of Newton's physics, this project was most ambitious. Kant faced a complex unification problem that involved various levels of theory formation, ranging from physics to metaphysics, from atoms to monads, from space, time, and matter to the principle of sufficient reason, from the assumption of divine intervention in the world to the system of pre-established harmony.

Chapter 2 investigates Kant's "analytic" method, its background in the analytic-synthetic methods of early modern science and philosophy, and the ways in which the *Theory of the Heavens*, the *New Elucidation*, and the *Physical Monadology* employed several variants of this method in order to bridge the discrepancies between Newtonianism and Wolffianism. His defence of the "analytic" method of metaphysics in the *Prize Essay* (1764) is of particular interest. There, Kant compares the "analytic" method of metaphysics to Newton's inductive method. But to talk in a one-sided way of his "analytic" method neglects the fact that Kant did indeed insist on a two-step methodology, in analogy to the analytic *and* the synthetic part of Newton's method of analysis and synthesis as explained by Newton in his *Opticks*, which itself traces back to ancient geometry (Pappus). In parallel to defending the use of this method in metaphysics, however, Kant also became increasingly aware of its limitations.

Chapter 1
Physics and Metaphysics

> *But how can metaphysics be married to geometry, when it seems easier to mate griffins with horses than to unite transcendental philosophy with geometry?* (1:475)

This chapter investigates Kant's pre-critical writings until 1764 with regard to the unifying strategy that stands behind them. Kant scholars have long emphasized that the main goal of Kant's pre-critical philosophy was to reconcile the diverging metaphysical and physical theories of his time. This approach has been called the "irenic" model. Here we seek to examine the underlying systematic principles to which he appealed, paying attention to the unificational methodology that was characteristic of his philosophical beginnings. Although Kant's first attempt to reconcile two apparently incompatible positions—his treatment of the *vis viva* debate in the *True Estimation of Living Forces*—was unsatisfactory and eclectic, in some crucial respects it set the course for his later work. Compared to Kant's debut, the pre-critical writings of the years 1755/1756 are a milestone in systematicity: as Schönfeld (2000) has shown in detail, they contribute to the project of an all-encompassing philosophy of nature, including theories of the interaction of body and soul, human freedom, and God as the ultimate cause of the world. However, Schönfeld neglects the systematic aspects of Kant's pre-critical project. The young Kant wanted to establish a system of metaphysics in Wolff's style, including Leibniz's principle of sufficient reason, which was compatible with Newton's physics. The present investigation focuses on the methodological problems of this ambitious and demanding task. Given that Wolff's metaphysics and Newton's physics were incompatible at several levels of theory formation, Kant faced a complex unification problem. Wolff's (or Leibniz's) metaphysical principles and the laws of Newton's physics conflicted with regard to the concepts of space and time (relative vs. absolute), force (internal vs. external), the constitution of matter (continuum theory vs. atomism), and the underlying general principles (Newton's belief in divine intervention vs. Leibniz's system of pre-established harmony). The 1755/1756 writings tackled different parts of this multi-level unification problem.

B. Falkenburg, *Kant's Cosmology: From the Pre-Critical System to the Antinomy of Pure Reason*, European Studies in Philosophy of Science 12,
https://doi.org/10.1007/978-3-030-52290-2_1

In order to establish the principles of a coherent system of metaphysics, Kant could not just resolve the above conflicts one by one. He had to employ criteria of systematicity, adequacy conditions, and a well-defined philosophical method. The philosophically relevant cornerstones of the project were the *Theory of the Heavens*, the *New Elucidation*, and the *Physical Monadology*.

1.1 The Reconciliation Principle and First Attempt

The supreme methodological principle of Kant's pre-critical philosophy is the requirement to *reconcile* opposite positions (Adickes 1897; Erdmann 1884; Riehl 1924; Hinske 1970; Friedman 1992). In the light of Kant's later pre-critical project, it is tempting to understand this as a rudimentary *principle of unification*. *True Estimation*, Kant's very first work, finished in 1747 but published only in 1749, sought to exhibit the compatibility of the Cartesian and Leibnizean positions as regards the *vis viva* controversy. Following Bilfinger, a Wolffian, Kant endorsed a principle of locating truth on the middle ground between opposing views, by conceding certain points to both parties:

> If men of sound understanding put forward entirely opposed opinions, and if neither of both of the parties may be presumed to have ulterior motives, then the logic of probability requires that we should look above all for a certain intermediate position which concedes that both parties are to some extent right. (1:32)

Kant's pre-critical approach of mediating between opposite views has been called his *irenic model* of dealing with the metaphysical debates of his time (Hinske 1970, 123). From the above quotation, however, it seems the methodological principle of reconciling opposite points of view does not really go beyond the commonplace that the truth lies somewhere in between them. Indeed, Kant's way of reconciling the opposing positions based on this principle was not convincing at all, as his contemporaries noted—in particular his academic teacher Martin Knutzen, as well as Leonard Euler to whom he sent the draft of the *True Estimation*—and as Kant scholars today still emphasize (Calinger 1979; Schönfeld 2000).

1.1.1 The Vis Viva Controversy

The *vis viva* controversy had been ongoing in the Academy of St. Petersburg since 1725, with the participation of Christian Wolff and others (Calinger 1968, 1969; Schönfeld 2000, 19–35). Its subject was the "true" measure of the force of mechanical motions. The dispute stemmed from a passage of Descartes's *Principia philosophiae* (1644) and Leibniz's criticism of it (Leibniz 1686).[1] Descartes himself

[1] See Mach (1883, 285–289), Dugas (1950); Iltis (1971), Wolff (1987, 304–312), Friedman (1992, 3–4).

did not yet have a concept of mass, but the Cartesians reinterpreted his measure of force in (Newtonian) terms of momentum mv. Wolff and the Wolffians proposed Leibniz's "living force" mv^2, which is proportional to the quantity known as kinetic energy today, as the correct measure of force. Leibniz himself made the distinction between the Cartesian measure mv, which he called *conatus*, the "living force" mv^2 or *vis viva*, and the "dead force" or *vis mortua*, an infinitesimal magnitude of statics, from which the "living force" is obtained via integration over the path of a motion. According to him, only the *vis viva* is the correct dynamic quantity (Leibniz 1695). In hindsight, the Cartesian measure of force corresponds to the time integral, and the Leibnizian measure to the path integral of Newton's force. Hence, both measures are dynamic quantities which both derive from the axioms of Newton's mechanics. This resolution was indicated in the first edition of d'Alemberts *Traité de Dynamique* published in 1743, a book that was not known to Kant when he wrote the *True Estimation*. Historians of science emphasize that d'Alembert gave the full explanation only in the second edition of his *Traité de Dynamique*, published in 1758 (Iltis 1970; Schönfeld 2000). Hence, to a certain extent Kant may be absolved from having suggested a solution on his own and having ignored the contemporary state of the art.

In order to concede the respectively correct points to both parties, Kant's approach was to clarify the relation between mathematics, or mathematical physics, and metaphysics. Given that the dispute about the correct measure of force stemmed from diverging metaphysical presuppositions concerning the concept of matter, his approach responded precisely to the origin of the controversy. For Descartes (and Newton), forces are external and bodies on their own have only inertial motions. For Leibniz, on the contrary, forces are internal, due to the internal activities of the monads underlying all the phenomena of the material world. From a modern point of view, d'Alembert's solution to the dispute had the advantage of abstaining from any metaphysical questions and basing itself on mathematical physics alone. For Kant, a young scholar of the German Leibniz–Wolff school of academic philosophy who was not well trained in mathematics, this way out of the controversy was not obvious.

Both Newton and Leibniz independently criticized Descartes's purely geometrical corpuscular theory of matter. Although they did so for quite different reasons, their respective criticisms made both introduce *dynamic concepts* into physics. But Newton's and Leibniz's concepts of—external or internal, respectively—force were incompatible. According to Leibniz, active and passive forces are inherent to a substance or monad. The monads change their inner states only according to these internal forces, and there are no external interactions between the monads. Quite on the contrary, Newton's mechanics is based on the principle that any change of the state of motion of a body is due to an external cause. This principle bears a debt to Descartes's corpuscular philosophy. According to the law of inertia, a body does not change its state of motion as long as no external force acts upon it. Only Newton's concepts of mass, momentum, force, and gravity give rise to a physical dynamics in the modern sense, and it was on the basis of *this* theory that d'Alembert decided the *vis viva* controversy. His solution demonstrated in particular that both

measures of force, the Cartesian as well as the Leibnizian, find their place and make sense within Newton's mechanics. In this way, d'Alembert resolved the controversy about the "true" measure of force by completely detaching the concept of a dynamic quantity from Leibniz's concept of force, and by demonstrating that the quantities that were under debate both belong to Newton's mechanics. The quantities mv and mv^2 simply express different dynamic aspects of a single unified and coherent account of mechanical motion.

1.1.2 Kant's Eclectic Reconciliation

Kant, however, tried it the other way round. In the *True Estimation*, he proposed to maintain the contrary dynamic concepts by restricting the scope of both, i.e., by attributing them to different mechanical phenomena. His suggestion was as follows. The Cartesian measure mv only holds for mechanical motions which stem from the impact of external forces, and which without such an external impact come to rest. Today, such motions are associated with the dissipation of energy. In contrast to them, Kant attributed Leibniz's measure of force mv^2 to so-called "free" motions, for which, as we know today, energy and momentum are conserved (*True Estimation*, §§15–17, 1:28–29).

The shortcomings of Kant's arguments are well known (Schönfeld 2000, 36–55) and need not be repeated here. From a modern point of view, it looks ad hoc to restrict the respective scope of both measures of force in such a way. Kant's solution looks like a case of "piecemeal physics" in Nancy Cartwright's sense (Cartwright 1999). Kant finally introduces a concept of "intension" in order to resolve the *vis viva* controversy (*True Estimation* §117, 1:141–142). It is tempting to trace this concept back to the metaphysical concept of *vis insita* or *vis inertiae* (inertial force), which Newton employed in his *Definition III* of the *Principia* in order to justify the law of inertia. However, both concepts should not be confused or identified; Kant's account is rather based on the *vis insita* of Georg Erhard Hamberger, professor of medicine in Jena (see Massimi and De Bianchi 2013, 487). And in the *True Estimation* he took up the contemporary discussion between the Cartesians and the Leibnizeans, but not yet the principles of Newton's mechanics.

In 1747, Kant defines the "intension" such that force is the product of velocity and intension. He considers this quantity to be a measure of the inherent disposition of matter to maintain a motion. This recalls Leibniz's concept of *vis activa primitiva*, as a primitive activity of matter to resist any change of its state of motion. Kant's "intension" is a mass-independent intensive quantity, unlike Newton's *vis insita* or *vis inertiae*, which is an extensive quantity proportional to mass.[2] On these

[2] See the explanation to *Definition III* in the *Principia* (Newton 1726, 404) compared to § 100 and § 117 of the *True Estimation* (1:110, 1:141–142). Kant interprets the "intension" as the cause of the "living force". In this way, the *vis viva* seems to obtain the status of a Leibnizean *vis*

grounds, he employs his concept of "intension" or *vis insita* as some kind of dynamic principle in order to settle the question of to which kinds of phenomena the Cartesian measure of force applies, and to which not. The intension of a body upon which an external force acts is only instantaneously put into effect, because its disposition to maintain its motion is counteracted. Hence, its force is proportional to velocity (Cartesian measure mv). On the contrary, the intension of a body upon which no external force acts is permanently put into effect, because its disposition to maintain its motion is not counteracted. Hence, Leibniz's *vis viva* holds without any restriction for it, and its force is proportional to the square of velocity (Leibnizean measure mv^2).[3]

Interpreted in such terms, Kant's unsuccessful attempt to combine Descartes's and Leibniz's incompatible concepts of force to a certain extent becomes comprehensible. However, this approach has no coherent foundations. It gives rise to a hybrid dynamic conception: to a half-Leibnizean, half-Cartesian concept of internal forces which are dispositions to maintain the state of motion of bodies, on the one hand, and external forces which counteract these internal forces and change the state of motion, on the other. The concept of *vis insita* seems to serve as a metaphysical principle for deriving the application conditions for the Leibnizean measure of force, and that of *vis inertiae* for deriving the Cartesian measure. Based on this, Kant seems to identify Leibniz's *vis viva* with an internal force which is some kind of *vital principle* of matter in motion, and the Cartesian *conatus* with a merely mathematical description of the result of the effect of an external force, in a "genuine pre-Newtonian" approach that even gave rise to "Cartesian echoes" in his later dynamics (Massimi and De Bianchi 2013, 490–491; see also Ferrini 2018).

Although Kant expends great effort to stick to his principle of combining physics and metaphysics, his 1747 approach still lacks what he would much later, in the *Critique of Pure Reason*, call the *systematicity* of scientific knowledge. What is missing is the reduction of both concepts of force to *uniform* theoretical principles, that is, to a consistent dynamics that is embedded in a coherent metaphysical framework. Kant's 1747 work remains eclectic, in accordance with the philosophical tendencies of his time.

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activa derivativa which derives from the "intension"; see also § 120 (1:143–144). It is questionable whether Kant really has Leibniz's distinction between *vis activa primitiva* and *vis activa derivativa* in mind here; but his terminology in § 117 suggests this interpretation. There, he distinguishes the "external phaenomenon of force", i.e., motion as the phenomenological effect of the derivative force, and the "basis of activity", i.e., the primitive force as the metaphysical cause of this phenomenon (1:141).

[3] See the arguments at 1:141–144, which cannot be analyzed here. Presumably his concept of "intension" has also to be understood against the background of the contemporary discussion on the infinitesimal in the calculus. The way in which this concept is related to the Wolffian doctrine of quantities should also be taken into account. See the *prima matheseos intensorum principia* in §§ 165–190 of Baumgarten's *Metaphysics* (Baumgarten 1757, 17:61–66), to which Kant's later concept of an intensive magnitude makes reference.

1.2 The Legacy of the *True Estimation*

After the *True Estimation*, Kant did not publish anything for almost a decade, before he reappeared with his 1754 articles about the rotation and the ageing of the earth (1:183–191, 1:193–213). In the years from 1749 to 1754 his focus of attention shifted from Cartesian physics to the principles of Newton's mechanics. His ambitious project of reconciling physics and metaphysics in a more comprehensive sense was taking shape, and he must have become aware how complex and difficult it would be to bridge the discrepancies between Newton's physics and Wolff's metaphysics. The systematic implications of this task are explained in more detail in the next Section (1.3). Before we turn to this, let me sketch how the approach of the *True Estimation*, despite being unsuccessful, shaped his further philosophical thinking. Kant's much more successful writings of the years 1755/1756 indeed continue some views already expressed in the *True Estimation*, which were crucial for his life-long project of unifying physics and metaphysics. To them belong general convictions concerning the relation between physics and metaphysics, as well as more specific views.[4]

Kant's most stable assumptions about the relation between physics and metaphysics were shaped by the academic tradition of Wolff's metaphysics, in which he grew up. According to this tradition, cosmology belongs to metaphysics; and physics deals with concepts and laws which relate to cosmology in the manner of lower-level to higher-level principles. Obviously, physics is an empirical science, whereas metaphysics is not. But the question of how the fundamental concepts physics apply to the phenomena was, for Kant, a metaphysical problem, not a question of empirical research. Hence, for him, in the case of rival physical concepts, what called for metaphysical clarification were the conditions under which the concepts apply to the phenomena. And this was what he had already tried in the case of the *vis viva* controversy, by restricting the respective scopes of both controversial concepts. Later, he became aware that his 1747 attempt had lacked systematicity. What remained, however, was his view that the application conditions of physical concepts have to be clarified by appeal to metaphysical considerations.

It is exactly in this point that Kant's pre-critical as well as critical theories of nature differ from empiricism. For Kant and his followers, the question of under which conditions the concepts of physics apply is not a matter of empirical knowledge but rather a matter of the non-empirical, or metaphysical, presuppositions concerning how to use these concepts. And these presuppositions are closely related to the fundamental concepts of physical dynamics, i.e., the concepts of space, time, and force.

Kant had focused on the concept of force from his very beginnings. The concept of space only came to his attention much later (and the concept of time only in the course of his critical turn). For a long time he affirmed a relational conception

[4]Massimi and De Bianchi (2013) and Ferrini (2018) show that they include Cartesian influences on his later dynamics of the *Physical Monadology* and the *MFNS*.

of space, in accordance with Leibniz's criticism of Newton's concept of absolute space. Albeit in a critically refined version, this relational concept is still present in the *CPR*. In the *True Estimation*, Kant defended a relational account of space which was based on a theory of material substances interacting due to their internal forces:

> It is easy to show that there would be no space and no extension if substances had no force to act external to themselves. For without this force there is no connection, no order, and, finally, without order, no space. (§ 9, 1:23)

According to the young Kant, space is "the sum-total of substantial relations" (Schönfeld 2000, 42), just as for Leibniz. But for the young Kant space was real (and not just ideal, as Leibniz thought), though relational (and not absolute, as it was for Newton).[5] He retained this view until the argument from incongruent counterparts occurred to him, in 1768 (see Sect. 3.4). In the *New Elucidation* of 1755, he supported this concept of interacting material substances via a principle of coexistence, which differentiates his view from the Wolffians' system of *physical influence*. The hybrid concept of force of 1747, too, continued to have an effect on the 1755/1756 cosmology and atomistic theory of matter. The *Theory of the Heavens* employs animist metaphors in order to express the motions of celestial bodies and atoms according to the laws of Newton's mechanics. There, Kant denominates the attractive and repulsive forces of matter as a "source of life" or as principles of self-organization, according to which matter develops from an initial state of absolute chaos to stars and galaxies:

> The elements have essential forces to put each other into motion and they are a source of life for themselves. Matter immediately endeavours to form itself. The dispersed elements of the denser type collect all the matter of lesser specific weight from a sphere around themselves by means of attraction [...]. Nature, however, has still other forces in store which are expressed primarily when matter is dissolved into its particles, by which forces they can repel one another and, by their conflict with the attractive force, bring about that motion that is, as it were, a continuous life in nature. (1:264–265)

The earlier concept of intension, however, is eliminated from the 1755/1756 concept of force.[6] Now Newton's concept of the *vis insita* or *vis inertiae* seems to play a role in it, as a principle which in Kant's 1755/1756 writings serves to form the bridge between Leibniz's and Newton's dynamic principles. This is indicated in the preface to the *Physical Monadology* by Kant's remark that

[5] Unlike Vuillemin (1955), but in conformity with Adickes (1924), Friedman (1992, 12 n. 9), too, emphasizes that Kant in 1755/1756 combines Newton's view of a *real* (and not just ideal) space and Leibniz's view of a *relational* space.

[6] Hermann Cohen, in his book on the infinitesimal method, claims that this concept of 1747 is still operative in Kant's critical concept of an intensive magnitude (Cohen 1883, Part II, § 77). Given that Kant revised his concept of force in the writings of 1755/1756 and 1758 (see below), this is improbable. The concept of an intensive magnitude is rather an alteration of the 1747 concept, which seems to be rooted in Wolff's doctrine of *matheseos intensorum*. See also n. 3 above and Kant's notes 3571, 3839, or 4050 on metaphysics (17:64, 17:308, 17:398).

> [. . .] the principle of all internal actions, in other words, the force which is inherent in the elements, must be a moving force, and one, indeed, which operates in an outward direction, since it is present to what is external [. . .] (1:476)

Here, Kant identifies the "force which is inherent in the elements" (*vim elementorum insitam*) with a *moving* force, which acts *externally*. In the *True Estimation*, on the contrary, he had sharply criticized the concept of a "moving force" (§ 2; 1:18) and he distinguished the motion of a body as an "external phenomenon" from the "intension" as the "basis of activity" (§ 117; 1:246). The *Physical Monadology* dispenses with this distinction, which was presumably related to Leibniz's account of primitive and derivative forces.[7]

In 1758, in his *New Doctrine*, Kant also criticized Newton's concept of *vis inertiae*, claiming "that the force of inertia has been invented unnecessarily" (2:20). Henceforth he would eliminate any metaphors of living forces as sources of life from his theory of nature, and in particular, from the excerpt of the *Theory of the Heavens* which he authorized to publish in 1791 (Herschel and Gensichen 1791; Ferrini 2004). In 1758 Kant no longer takes up the *vis viva* controversy, presumably due to his former lack of success. Perhaps by then he had become aware of d'Alembert's resolution.[8] His new insight was accompanied by criticism of Newton's concept of absolute motion, which he had used in his 1755/1756 theory of matter without questioning it. In 1786, in the "Phenomenology" part of the *Metaphysical Foundations of Natural Science*, he replaces Newton's concept of absolute motion by the weaker concept of "true" motion, which is based on a relational concept of space and the dynamic difference between rectilinear uniform motion and circular motion (*MFSN*, 4:556–558). In the "Dynamics" part of the *MFNS*, no trace remains of his earlier views about the attractive and repulsive forces as vital principles of matter. Quite on the contrary, in his critical theory of nature Kant considers the law of inertia to be a principle of *lifelessness*, which indicates the inability of material bodies to change their state of motion on their own. In the "Mechanics" part of the *MFNS* he explicitly identifies inertia with the "lifelessness" of matter and rejects any conflation of this principle and the concept of life (4:544).

[7] In 1756 Kant no longer maintains this distinction. This is due to his criticism of Leibniz in the *New Elucidation* of 1755, and in particular the *principle of succession* established there. This principle is incompatible with Leibniz's doctrines of monads and of pre-established harmony. According to Kant's new view, a substance may only undergo changes due to the nexus with *another* substance and not on its own. For this principle and the criticism of Leibniz associated with it see Laywine (1993, 32–35) where it is also suggested that Kant's proof of it is related to the possibility of an objective temporal order in the world.

[8] The dispute continued for decades, however. In the history of scientific concepts it continued to have an effect up to the late nineteenth century. In particular, Hegel's natural philosophy of the 1830 *Encyclopedia* uses a concept of "absolutely free" motion (Hegel 1830, § 268) which is based on distinctions similar to those rejected by Kant in 1758. Indeed, this contributed substantially to the odd impression which Hegel's philosophy of nature gave to later readers. Meanwhile, in physics, kinetic energy was commonly called "living force" until the end of the nineteenth century—Mach, for example, uses this expression throughout his 1883 book (Mach 1883), and not just in his historical account of the origins of the *vis viva* controversy in Descartes's and Leibniz's writings.

1.3 Parting from Eclecticism

In 1755/1756, Kant strengthened his unsatisfactory reconciliation principle of 1747 by adding a *systematicity requirement*. With the *Theory of the Heavens*, the *New Elucidation*, and the *Physical Monadology* he wanted to reconcile Wolff's system of metaphysics with the principles of Newton's physics. Wolff's system had four parts: a *metaphysica generalis*, which contained the general principles of metaphysics, such as Leibniz's principle of sufficient reason; and a *metaphysica specialis* with three sub-disciplines, "rational cosmology", "rational theology", and "rational psychology", which took as their subject matter the World, God, and the soul, respectively.

The metaphysical controversies between Wolffians and Newtonians primarily concerned the relation of Newton's physics to the "rational cosmology" of Wolff's metaphysics. But there were additional controversial issues, in particular concerning theology, as the Leibniz–Clarke debate showed. The philosophical attempts of the time to settle the debates were eclectic, arbitrarily combining certain elements of the respective opposing theories, rather than attempting to establish the principles of a unified theory or metaphysical system in Wolff's sense.

Against this eclectic background, Kant was far from sketching the plan of a metaphysical system in 1755/1756. To escape from eclecticism was a difficult task. He set himself the goal of framing a systematic and all-embracing *theory of everything* encompassing God and the World, which linked cosmology (as a theory of the constitution of matter, physical forces, and the universe as a whole) to rational theology (i.e., the doctrine of God), rational psychology (i.e., the doctrine of an immortal soul), and the general principles of Wolff's metaphysics (above all, Leibniz's principle of sufficient reason). Nor did Kant at this point use the expression "system" in the sense of an architectonics of metaphysics. In his pre-critical writing, the term "system" is above all used in the sense of a metaphysical or scientific doctrine, and sometimes also of a classification system. The *Theory of the Heavens* furthermore brings into play the structure of the solar system (see Appendix A.1.3).

In his reaction to the academic controversies of the 1750s, however, he only succeeded step by step to escape from contemporary eclecticism. In addition, he was dealing with the topics of these controversies as an unknown young scholar in Königsberg: worrying about the conflict between his own views and contemporary Pietism, he published the *Theory of the Heavens* anonymously (Schönfeld 2000; Calinger 1979). Even though he did not sketch the plan of a system of metaphysics in Wolff's style in 1755/1756, he must have already had such a system in mind. Important hints to his pretensions are given by the scattered ambitious remarks in his pre-critical writings, comparing himself in particular with Descartes, for example in the preface to the *Theory of the Heavens* (1:228). Indeed, his 1755/1756 writings represent his first moves in a systematic direction. As Schönfeld (2000) observed, the cosmology of the *Theory of the Heavens*, the metaphysical principles of the *New Elucidation*, and the matter theory of the *Physical Monadology* do not simply complement each other in various respects; rather, they represent a threefold

systematic attempt to establish crucial links between the parts of a Wolffian system of metaphysics. The *New Elucidation* aims to settle the metaphysical foundations of such a system; the *Theory of the Heavens* outlines a physical cosmology that makes the bridge to rational theology; and the *Physical Monadology* makes the bridge between this cosmology, which is based on an extended Newtonian mechanics, and a Wolffian theory of physical monads.

In 1747, Kant had forced the combination of the rival dynamic concepts of Newton's and Leibniz's physics in an ad hoc way, based on a hybrid concept of force, by simply restricting the applicability domains of the dynamic concepts at play in the debate. In 1755/1756, he attempted to realize his reconciliatory project in a more coherent way. To do so, he needed a uniform concept of force which was thoroughly compatible with the mathematical description of mechanical phenomena. The systematic basis for this more coherent approach to a metaphysics of nature, or the cosmology part of an all-embracing system of metaphysics, was provided by his very first metaphysical writing, the *New Elucidation* (presented in 1755 in a public dispute at the faculty of Königsberg).

Thus, the *Physical Monadology* of 1756 does not simply continue the reconciliatory project of the *True Estimation*. It belongs to a new, systematic approach to reconciling Newton's physics and Wolff's metaphysics, which was much more ambitious. Kant now proposes to supply metaphysics with new principles, which serve to resolve not just a particular philosophical debate, but rather the whole gamut of contemporary metaphysical controversies. To do so, the *New Elucidation* already takes some decisive steps towards dispensing with the principles of Wolff's metaphysics.[9] Indeed, a non-eclectic unification of the incompatible doctrines of Wolff and Newton could not be achieved without substantially modifying *both* positions.

1.3.1 A First Systematicity Requirement

A first *systematicity requirement* appears in the *Theory of the Heavens*, which substantially strengthens the reconciliation principle of 1747. His further elaboration of this principle would henceforth distinguish Kant from contemporary eclecticism. Balancing the reasons for the law-like organization of the celestial bodies according to the principles of Newton's theory of gravitation, on the one hand, and the problem that in empty space gravitation seems to be an action at a distance, on the other, he strengthens his weak reconciliation principle of 1747 as follows:

> An impartial examination shows that the reasons are equally strong on both sides and both are to be regarded as being completely certain. However, it is just as clear that there must be

[9] Walford (1992) emphasizes that the *New Elucidation* attacks Wolff's position. In contrast, the otherwise instructive comparison of the *True Estimation* and the *Physical Monadology* by Hinske (1970, 42) neglects the systematic rupture between the former and the latter.

> a concept in which these apparently mutually conflicting reasons can and should be united and that we may seek the true system in this new concept. (1:262)

Here, he presents himself as convinced of the existence of an integrative concept which gives rise to a "true system", that is, a coherent cosmological theory capable of unifying the opposing theoretical doctrines. And then he proposes his theory of the genesis of the solar system and its extrapolation to a natural history of the universe, which is based on a theory of structure formation in the early universe with the initial state of a matter distribution as a rotating nebula.

This "true system" is a physical theory that embraces the whole universe. It has to be understood against the background of the prominent opposing metaphysical doctrines of the time. In the preface to the *Theory of the Heavens*, Kant discusses the positions of the "free thinker" and the "defender of religion". He associates the former with Epicurus's atomism (1:222), and hence with a materialistic or naturalistic world view, which he characterizes as "blind mechanism". The corresponding contemporary position was French materialism, which explained the law-like structure of the solar system in naturalistic terms. It was represented in particular by La Mettrie, who had become a member of the Berlin Academy in 1748 (Calinger 1969). The opposing view in the dispute is neither Wolffianism nor the teleological view of nature proposed in the preface of the *Theory of the Heavens*, but the Newtonian view that only repeated actions of God explain the stability of the planetary motions. According to Newton and his followers, God created the world, but has still to intervene in the course of the universe in order to counteract the dissipation of the kinetic energy of the celestial bodies and keep the planetary motions stable.[10] They explain the initial conditions of the law of gravitation, i.e., the mass, position, and velocities of the celestial bodies in the solar system at a given time, by interventions of God rather than by the laws of physics.

Hence, the higher-level goal of the *Theory of the Heavens* is to resolve the metaphysical controversy between the French defenders of materialism (free thinkers, like La Mettrie) and the British defenders of divine intervention into the world (apologists of religion, like Clarke, who shared Newton's views). Given that both referred to Newton's mechanics in support of their arguments, Kant seeks an integrative Newtonian conception of the processes in the universe, from which the arguments of both parties derive. The means to do so, in Kant's view, is already provided by Newton's mechanics, or (more precisely) by an extension of it. The unifying concept or principle is Newton's concept of universal gravitation, and the "true system" is the theory of structure formation in the universe according to the laws of Newton's mechanics. In Kant's view, Newton's theory is stronger and has a larger scope than Newton himself and his followers were aware. Accordingly, he complements it by the assumptions of repulsive forces and by adequate initial conditions. His own theory of structure formation in the universe fills the explanatory gaps in Newton's theory of the solar system, which made Newton and his followers resort to divine intervention. This approach combines anti-Newtonian tendencies

[10] See Leibniz and Clarke (1715/1716).

with Newtonian commitments (Watkins 2013). In order to justify this "true system" (which is indeed a landmark theory of physical cosmology), Kant extrapolates the "systematic constitution" of the solar system (that is, the approximate restriction of the planetary motions to the ecliptic) to the large-scale structure of universe, and to the constitution of the universe as a whole (*Theory of the Heavens* 1:290–291; see Sect. 2.2.1 and Appendix A.1.3). On the other hand, Kant insists that his way of extending Newton's theory to larger and larger scales, up to the entire universe, does not commit him to materialism or naturalism.

In this way, he strengthens the conciliatory commonplace of 1747 (i.e., to concede points on both sides, and look for the truth in between) by the requirement to do so in a systematic way, according to uniform principles. The reconciliation principle of 1755 represents a quest for a unifying conception which supports the best reasons *in favour of* the claims of the two opposing doctrines.

This requirement is contrary to Kant's later methodological principle of finding the strongest reasons *against* a position, the *skeptical method* (see Sect. 4.3.2). The skeptical method is the procedure of countering a position in order to either defeat or confirm it by dispelling all conceivable objections. It is a touchstone for the tenability of arguments and reasons which are to be integrated into a coherent theory according to a unifying principle. Kant did not realize before the mid 1760s that he was in need of such a touchstone. When Swedenborg's writings drew his attention to the unwanted spiritualist consequences of his 1755/1756 system, he wrote the *Dreams* of 1766 (see Sect. 3.2), which Reich (1958, XII) and Kaulbach (1982, 100) consider as the first demonstration of the skeptical method. A further, decisive example of it was Kant's use of the "analytic" method in the *Directions of Space* of 1768, which demonstrated that even with regard to the concept of space the system of 1755/1756 could not be the "true system" (see Sect. 3.4 and Chap. 4).

1.3.2 The Project of Unifying Physics and Metaphysics

Prior to this turning point, for a decade he presumably thought that he had managed to reconcile the principles of Wolff's metaphysics with the laws of Newton's physics. In all modesty, he was convinced he had mastered the difficult metaphysical task mentioned at the beginning of this Section (1.3). At the end of the *Preliminary considerations* of the *Physical Monadology*, he noted

> [...] that anyone who is able to deduce these two principles from the very nature and fundamental properties of the elements will have made a substantial contribution towards explaining the inner nature of bodies. (1:476)

The "two principles" in dispute are the opposite doctrines he there wanted to unify, namely the infinite divisibility of a space filled with matter, and the internal forces of simple material substances (see Sect. 1.4.3). The self-assessment indirectly expressed here was not unjustified. The pros and cons of Wolff's metaphysics and Newton's physics conflicted at several levels and came in several theoretical variants.

1.3.2.1 A Multilayered Problem

From a systematic point of view, Kant faced a multilayered problem. The application conditions of the concepts of mathematical physics were at the same time adequacy conditions of the metaphysical principles underlying rational cosmology. As a part of the *metaphysica specialis* of Wolff's system of metaphysics, cosmology ought to be compatible with the principles of general metaphysics. But in view of the success of Newton's mechanics, it also had to be compatible with the principles of physics as an empirical science. The reconciliation of Newtonian physics with a Wolffian system of metaphysics entailed three levels of theory formation *(horizontal unification)*, and, in addition, their deductive connection *(vertical unification)*:

1. *Mathematical description (geometry):*
   At this level, two conflicting features of Newton's mathematical description of the phenomena, on the one hand, and Wolff's geometrical account of material substances, on the other, had to be reconciled.
   (i) *Atoms vs. continuum*: The continuum properties of space filled by matter emphasized by Euler were in conflict with Wolff's assumption of point-like monads. This is the question Kant wanted to settle with the *Physical Monadology*. The conflicting positions were, however, exactly the other way round in the Leibniz–Clarke correspondence. Leibniz had defended the infinite indivisibility of matter (which Euler now defended on Newtonian grounds, in accordance with his approach to continuum mechanics), and Clarke Newton's atomism (which proposed impenetrable corpuscles, in contrast to Wolff's point-like physical monads).
   (ii) *Absolute vs. relational concept of space and time*: To this complex field of debate was added the controversy about the absolute or relational nature of space and time, which was also initiated by the Leibniz–Clarke correspondence. On this point, Wolff shared Leibniz's criticism, and Kant was on the side of Leibniz and Wolff.

2. *Dynamical principles (metaphysica specialis):*
   At this level, the dynamic principles of Newton's physics had to be reconciled with the cosmology part of Wolff's metaphysics.
   (i) *External vs. internal forces*: Newton's concepts of inertia and external forces were incompatible with Leibniz's and Wolff's conception of internal forces. Within physics, d'Alembert had resolved the *vis viva* dispute exactly in the sense of the systematicity requirement of Kant's *Theory of the Heavens* (see Sect. 1.3.1), that is, by reducing both measures of force to different aspects of the principles of Newton's mechanics. But this solution did not resolve the question of how both concepts relate to Wolff's cosmology and his conception of monads.
   (ii) *Action at a distance vs. physical influence*: On the side of Newtonianism, there was the additional dispute of whether forces are actions at a distance or whether gravitation is due to immediate interactions of mechanical ether particles, as proposed in Descartes's vortex theory, a theory of close-range