

# KANT'S NEWTONIANISM: A REAPPRAISAL

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## 1. NEWTONIANISM AND KANT'S QUEST FOR METAPHYSICS

Kant's engagement with physics, and in particular with Newton's physics, crosses the whole of his writings, documenting a lifelong intellectual enterprise which connects the lesser-known writings of the young student to the late private reflections of the great critical philosopher. Indeed physical issues are the main topics of Kant's first published works, from the *Gedanken von der wahren Schätzung der lebendigen Kräfte* (1747) to the magisterial dissertation *De igne* (1755) and his first book, the *Allgemeine Naturgeschichte und Theorie des Himmels* (1755), which is explicitly "based on Newtonian principles". Between 1754 and 1758 Kant published eight shorter writings about physical problems. Moreover concepts and principles of Newtonian physics – such as attractive and repulsive forces, and the law of universal gravitation – play a major role in the early academic writings on metaphysics, the *Principiorum primorum metaphysicorum nova dilucidatio* (1755) and the *Monadologia physica* (1756), which was conceived as a first part of a project concerning "the use in natural philosophy of metaphysics combined with geometry". This intertwining of physics and metaphysics becomes the object of a methodological reflection in the philosophical writings of the 1760s, where e.g. Kant – with reference to Newton's application of negative quantities to the study of attractive and repulsive forces – defends the "important consequences" of applying the propositions of mathematics in philosophy (NG, AA 02: 169.08ff.) and even suggests the adoption of Newton's scientific method as a model for metaphysics (UD, AA 02: 286.08-10).

With the development of critical philosophy, as Kant was appointed as professor of Logic and metaphysics, this engagement with physics is by no means reduced. This is documented not only by the overwhelming quantity of manuscript reflections and the uninterrupted teaching activity on physics, but most importantly by several references to physics in the three

*Critiques*, a systematic book on the “pure part” of physics – the *Metaphysische Anfangsgründe der Naturwissenschaft* – and more short writings such as *Über die Volkane im Monde* (1784) and *Über den Einfluß des Mondes of die Witterung* (1792). Kant’s close attention to the ongoing developments in natural science is all the more striking if one considers his statements about how busy was his activity in the years of criticism. But the very fact that he devoted his last years (1796-1800) to the unfinished project of a “transition from the Metaphysical Foundations of Natural science to physics” (the *Opus postumum* of the Akademie Ausgabe) can leave no doubt about his conviction of the relevance of physics for his system of philosophy.

Notwithstanding this massive textual evidence the basic motivations behind Kant’s engagement with physics, and with Newton’s physics in particular, have been often misunderstood. To be sure Kant had a largely self-taught and non-professional training in mathematics and physics and Erich Adickes’ pioneering survey of his work as a “scientist” (*Naturforscher*) notably led to highlight his occasional mistakes and to a general dismissive judgment about his being an amateur scientist with an inappropriate inclination to a priori reasoning.<sup>1</sup> Successive scholarship has correctly restored the inseparable connection of physics and metaphysics in both the “precritical” and the “critical” period, but yet the precise role of Newton’s physics for the elaboration of Kant’s *philosophical* ideas has been usually left in the background. Nonetheless it is possible to provide a general characterization of this role: there is indeed a single main motivation, which – in spite of the many theoretical changes – joins the early attempts at introducing action-at-a-distance in a monadological framework to the systematic treatment of “pure” and “empirical” physics in the critical period, and that is the development of a completely new metaphysics of nature. In the precritical works, where metaphysics is supported by independent evidence, this role is limited to an empirical *corroboration* of metaphysical concepts: a typical example is the interpretation of “universal gravity” as the “external phenomenon” of the interaction among substances in the *Nova dilucidatio* (ND, AA 01: 08-13). In the critical system the connection with physics is *essential* to the foundation of metaphysics. Basically speaking the reform of metaphysics can be effected *by means of* a foundation of empirical physics, which moreover – according to Kant – is in itself an intrinsic necessity. This double objective is expressed by the idea of a “pure part” of physics, which is also called “metaphysics of corporeal nature”. As Kant puts it in the *Metaphysische Anfangsgründe*, which expounds this new part of metaphysics and can be considered as the culmination of this lifelong research, the separate exposition of the new metaphysics does not depend only on the “inner necessity to isolate” the metaphysical principles from the mathematical and the empirical premises.

A separated metaphysics of corporeal nature does excellent and indispensable service for *general* metaphysics, in that the former furnishes examples (instances *in concreto*) in which to realize the concepts and propositions of the latter (properly speaking, transcendental philosophy), that is, to give a mere form of thought sense and meaning (MAN, AA 04: 478.15-20).

Kant himself introduces this claim by observing that the aim of general metaphysics does not lie in this “realization”, but is rather “to attain cognition of that which lies wholly beyond the boundaries of experience, of God, Freedom and Immortality”. To show how this intuitive

realization of metaphysical concepts is provided by pure physics alone, and therefore *only* by means of its empirical conditions (intuition of matter in space), is thus a crucial step for Kant's project of applying the traditional ideas of metaphysics in the *completely different* (noumenal) field of practical philosophy. This missing crucial step is also easily characterized: transcendental philosophy has been able to "prove" (*Beweisen*) the objective reality of categories, and this has been possible precisely because this philosophical proof is independent from any particular intuition; nevertheless, because of the same reason, philosophy still needs a sensible intuition of the "real object", in order to provide "sense and meaning", that is a particular reference to pure concepts; and this sensible representation – or "exhibition" (*Darstellung; exhibitio*) – is precisely the task of pure physics.<sup>2</sup>

In this wider systematic framework, which Kant first expounded in the *Architectonic* chapter of the first *Critique*, we can see how pure physics connects transcendental philosophy to empirical physics. But this is not enough in order to understand how Kant's understanding of *Newton's* physics plays a role for this connection. For the crucial "exhibition" is to be provided by pure physics on the ground of the simple "empirical concept of matter", without entering into further empirical details, thus providing new synthetic a priori (not pure) principles.<sup>3</sup> Indeed Kant writes that metaphysics can certainly not "extend natural knowledge (which takes place much more easily and surely through observation, experiment and the application of mathematics to outer appearances)" (MAN, AA 04: 477.26-27). But the point is that, according to Kant, physical theory cannot draw its validity only from empirical grounds, nor can it apply mathematics to phenomena without postulating specific philosophical principles. Physics is rather to be seen as a stratification of concepts and principles, which can (and must) be considered top-down from the most abstract level of transcendental philosophy (with its concepts of quantity, reality, substance etc.) to the more empirical level of experimental physics. To put it in a formula, there is no *merely* empirical physics; there are of course empirical *concepts* and *laws*, which no a priori theory can ever anticipate, but all these concepts and laws cannot be separated from a wider theoretical framework, where they correspond to more abstract categories and principles. As we will see – and this is the point where Newton's theory receives an exemplary role – Kant considers the rational mechanics of the *Principia mathematica* and the fragmentary theory of matter of the *Opticks* as the best examples for the understanding of this point. Indeed Kant spells out this "indispensability claim" in the *Preface* to the *Metaphysische Anfangsgründe*, where he writes that physicists *could not* ever proceed without metaphysics, "albeit unconsciously", and the sentence which expresses this claim makes an implicit reference to Newton's famous rejection of hypotheses in the general *Scholium* of the *Principia mathematica*:

All natural philosophers who have wished to proceed mathematically in their occupation have always, and must have always, made use of metaphysical principles (albeit unconsciously), even if they themselves solemnly guarded against all claims of metaphysics upon their science. Undoubtedly they have understood by the latter the folly of contriving possibilities at will and playing with concepts, which can perhaps not be presented in intuition at all, and have no other certification of their objective reality than that they merely do not contradict themselves. All true metaphysics is drawn from the essence of the faculty of thinking itself, and is in no way fictitiously invented [*erdichtet*] on account of not being borrowed from experience. Rather, it contains the pure action of thought, and thus a priori concepts and principles, which first bring the manifold of empirical representations into the law-governed connection through which it can become

*empirical cognition*, that is, experience. Thus these mathematical physicists could in no way avoid metaphysical principles, and, among them, also not those that make the concepts of their proper object, namely, matter, a priori suitable for application to outer experience, such as the concept of motion, the filling of space, inertia, and so on. But they rightly held that to let merely empirical principles govern these concepts would in no way be appropriate to the apodictic certainty they wished their laws of nature to possess, so they preferred to postulate such [principles], without investigating them with regards to their a priori sources (MAN, AA 04: 472.13-35).

This crucial passage makes clear how close is the connection between the realization of a “true metaphysics” (alternative to the unsuccessful attempts of Leibniz and Wolff) and the non-empirical justification of Newtonian physics.<sup>4</sup> Thus one implication of these lines is that Newtonian physics, in Kant’s view, does not form an independent body of scientific knowledge in itself, but intrinsically needs metaphysical principles in order to obtain its intended objective meaning. Indeed Kant usually talks about Newtonian *principles* – which is non-committal about their independent objective validity – and avoids the expression ‘Newton’s physics’, which may suggest a full disciplinary autonomy. And he even argues, in the final paragraph of the *Preface*, that it would be “not unimportant” that the new metaphysical principles may be “brought into union” with mathematical principles in physical treatises (MAN, AA 04: 478.25-31). Kant’s view, as I will show in the next section (§2), is actually stronger, even though here he expresses his proposal to physicists with modesty: in the light of the metaphysical part of physics Newton’s original understanding of the basic concepts and principles of physics has to be significantly *corrected* in many points, and Newton can be shown to have been “at variance with himself”. Therefore we can conclude that the philosophical engagement with the elements of Newtonian physics – that is basic concepts, laws and method – is inseparable from Kant’s general philosophical quest for a new metaphysics and moreover leads to an original reassessment of those very elements.

These points have been often missed in Kantian scholarship, which has been dominated by the idea that Kant would have merely provided a “foundation” or “justification” of Newtonian physics.<sup>5</sup> It is an irony that the persistent legacy of Kant’s criticism in Neokantian philosophy and thereby in the whole of XX<sup>th</sup> century epistemology has played a negative role for the correct understanding of this aspect of Kant’s thought, precisely among those who were more interested in the pursuit of his general approach. The basic reason of this is the urgent need to defend criticism in the context of XX<sup>th</sup> century physics, thereby underscoring the validity of Kant’s approach *beyond* the historically contingent boundaries of the science of his time. For example Cassirer considered the *Metaphysische Anfangsgründe* as a mere “transcription” of Newtonian mechanics, where Newton’s laws of motion would play the role of “determinate expressions [*Ausprägungen*]” of the transcendental *Analogies of Experience*, and therefore as a work of limited interest if compared to the first *Critique*, which could still offer indispensable insight in XX<sup>th</sup> century physics.<sup>6</sup> Similarly Gerd Buchdahl, whose work highlighted once more the importance of Kant’s metaphysics of nature among American scholars, considered the reference to Newtonian physics as a contingent circumstance with no “probative” value, which could be systematically cut off from the transcendental foundation of natural science in general.<sup>7</sup> The occasional talk about Kant’s “foundation” of Newtonian science, suggested by the standard translation of the title of

the *Metaphysische Anfangsgründe*, provides the most recent version of this historically mistaken separation of the physical theory from its philosophical justification.<sup>8</sup>

The basic idea behind these approaches was to separate a general epistemological framework from its strictly scientific content, constituted by the historically given physical theories. A similar approach was also attempted by Kuhn with his theory of paradigms, which he eventually presented as a Kantian “relativized a priori”, since it allows of historically changing sets of principles and theories which are “constitutive of the possible experience of the world”.<sup>9</sup> According to Kuhn the exposition of a paradigmatic theory can be basically contained in a single book – Newton’s *Principia* are among his examples<sup>10</sup> – and it includes basic metaphysical commitments, which could be contrasted by revolutionary theories, hence forming a full-fledged theoretical system. From the point of view of contemporary philosophy of science Kuhn’s theory has to face many different theoretical problems, such as the problem of connecting different and successive theories without endorsing relativism and the problem of the underdetermination of scientific theories and the existence of empirical equivalents, one of whose consequences is the fact that scientific theories do not constrain a single ontological interpretation. This second kind of problem can usefully introduce the correct understanding of Kant’s original philosophical approach to Newton’s physics, which, as we have seen, does not begin from the admission that the latter is a *given scientific* theory. Indeed Kant’s whole idea of a metaphysical foundation of Newton’s physics, rather than being an idiosyncratic conviction of an academic metaphysician, was certainly corroborated by the fact that there was at his time *no single paradigmatic conception of Newtonian physics*, that is no entirely shared view of the principles of the new physics and the status of its basic concepts.<sup>11</sup>

Newton himself was responsible for the ambiguity of his theory. On the one hand, as it is well known – and as Kant acknowledges in the above quoted lines from the *Preface* to the MAN – Newton wanted to eliminate all kind of hypotheses from “experimental philosophy” and provided in his “rules of philosophizing” a method for studying phenomena without getting committed to hypotheses about their causes. This methodological approach was primarily designed to defend his introduction of the force of universal gravity, without facing the issue of hypotheses about its cause (“mechanical, physical, or metaphysical”) and the very title of the *Philosophiae naturalis principia mathematica* implies the attempt to avoid the Cartesian, highly hypothetical approach to natural philosophy, with which Newton was very familiar. This experimental and mathematical approach was adopted in the popular textbooks by ‘sGravesande (1720) and Muschenbroek (1734), whose “positivistic” formulation of Newton’s physics, focusing on the “effect” of gravity and leaving open the way to different kinds of hypotheses about its action, played a major role for winning the resistance against gravity among Cartesian mathematicians and physicists and thereby introducing the latter in the Continent (Kant himself was very familiar with these textbooks).<sup>12</sup>

Yet Newton himself, as it is well known, allowed of non-empirical concepts of physics such as absolute space and atomic particles, and made reference to God’s existence and activity for the justification of these concepts. Moreover, he generally held that the very mathematical order of nature depended on God’s wise action and occasional intervention in the motion

of bodies, and even allowed of a possible explication of his more original physical concept, universal gravitation, by means of God's action. Finally, even though these metaphysical issues were meant to remain on the background of proper physical investigation, Newton's theory of matter was itself highly undeveloped and hypothetical, as he made clear in the *Queries* to the different editions of the *Opticks*, where he oscillates between various mechanistic hypotheses about the role of ether and a dynamical approach grounded in the concept of microscopic repulsive and attractive forces – setting the background for an alternative between forces and fluids which crosses the whole XVIII<sup>th</sup> Century and is still markedly evident in Kant's writings.

The metaphysical background of Newtonian natural philosophy, even though it was treated in marginal sections of Newton's masterworks, was largely debated in the famous correspondence between Leibniz and Clarke (published in 1717), which sets a fundamental background for Kant's entire natural philosophy. But here Clarke, in clarifying the philosophical and theological background of "mathematical principles" against the charge of materialism, was not defending a commonly accepted view among the Newtonians. For instance Roger Cotes (whose views were, again, quite familiar to Kant) considered attraction as a "primary" property of matter.<sup>13</sup> The Jesuit mathematician Rudjer Bosovich also moved from the ontological acceptance of action at distance, considering the Cartesian theory of action at contact as contrary to the law of continuity, and attempted to reconcile a "Leibnizian" view about monads with Newton's mechanics by providing a theory grounded on point-like monads as the centres of Newtonian attractive and repulsive forces.<sup>14</sup> This theory itself was subject to different interpretations: it was famously endorsed by Priestley, who considered it as a possible scientific ground of materialism<sup>15</sup>, while in Germany it had been reviewed by Mendelssohn, who was rather interested in the defence of a spiritualistic monadology.<sup>16</sup> Kant's own "physical monadology" of 1756 was a similar and independently developed attempt of reconciling the Newtonian and the Leibnizian view.

Indeed this problem of reconciling Newton and Leibniz, and in particular of inserting Newtonian concepts and laws in a monadological background, was central in the context of early XVIII<sup>th</sup> century Germany, which sets the closest reference system for Kant's original reception of Newtonianism. Let us briefly consider three cases: Wolff, Maupertuis and Euler.

Wolff, starting from his preface to the translation of the exchange between Clarke and Leibniz (which moreover introduced the technical term of 'materialism' in German philosophy), insisted on the latter's polemical argument about Newtonian principles being conducive to materialism.<sup>18</sup> His own metaphysics, which was grounded on the existence of immaterial souls and simple (point-like) physical elements, would counter this risk, thereby limiting the value of Newtonian principles to the subordinate domain of "applied mathematics": Newton's doctrines, though mathematically valuable, lacked a metaphysical foundation of their basic concepts and principles.<sup>19</sup> Thus Wolff included Newton's *leges motus* in his metaphysical *Cosmologia generalis* (1731) and thereby in a metaphysical framework grounded on the principle of sufficient reason and the existence of immaterial substances. Against this background several academic philosophers adopted different versions of dynamical influx, and – elaborating on a Leibnizian idea – started from the phenomenon of impenetrability for an understanding of monadic

interaction: this was the context for Kant's eventual (and original) introduction of *Newtonian* attractive and repulsive forces in this metaphysical debate.<sup>20</sup>

Maupertuis, which was appointed President of the Berlin Academy of Sciences and moved to Berlin in 1745, played a major role for the introduction of Newtonianism in Germany. His *Discours sur la different figure des astres* (1732) was the first non-technical endorsement of attraction on the Continent, containing a very clear statement of the “equal unknowability” argument about attraction and impulse.<sup>21</sup> Throughout his scientific writings, and in particular in his book eventually titled *Système de la nature*, Maupertuis paid remarkable attention to the issue of reconciling Newtonian physics with typically Leibnizian ideas, attributing perception to elementary parts of matter and eventually oscillating between materialism and skepticism regarding the ultimate ground of natural phenomena.<sup>22</sup> In 1747 Maupertuis promoted the prize essay completion “on the doctrine of monads” as one of the first official actions of the reconstituted Academy. The resulting debate was precisely the occasion for the composition of Kant's *Monadologia physica*. On the whole Maupertuis remained a constant and explicit reference point in Kant's writings throughout the 1750s and 1760s, where the latter elaborated his new philosophical elaborations of Newton's mathematical concepts.

An alternative approach was represented by Euler, which was the most important physicist of the time in Germany and also a major influence for Kant's early work. Euler tried to develop and expand the core of Newton's mathematical physics in a broadly Cartesian framework, dismissing monads and “active forces” (as contrary to the law of inertia) and admitting impenetrable particles as the grounds of moving force.<sup>23</sup> Even though Euler was mainly a mathematician, he adopted a dualistic metaphysics by resorting to God's creative act as the ground of the existence of souls and impenetrable particles. His theory of a universally distributed ether, filling the spaces between particles of matter and being the substratum of fire and light, was adopted by Kant throughout his whole philosophical career. More generally Euler's physico-mathematical research on continuum dynamics provided an exemplary scientific source for Kant's mature theory of matter, which – contrary to Newton's and Euler's view – was based on the primacy of the fluid and continuous on solid and discrete state of matter.<sup>24</sup>

As it is shown by the examples of two major scientists such as Maupertuis and Euler the wide diffusion of an “instrumentalist” approach to physics, even though it was practically adopted by most scientists in the second half of XVIII<sup>th</sup> Century, was no guarantee of avoiding the metaphysical issues of Newtonian science. Indeed even French physicists such as Lagrange, who would try to dispose of metaphysics in their expositions of rational mechanics and generally had a dismissive attitude towards metaphysics, eventually postulated the objective validity of differential equations, thus implicitly admitting a metaphysical realistic presupposition.<sup>25</sup>

In the light of this historical context it appears quite natural that Kant could try to connect the need for a deeper philosophical understanding of the most successful physical theory of his time to his general philosophical project of reforming metaphysics. Thus Kant's early attempt of connecting metaphysics and mathematics (in the 1750s) is not adequately described as an attempt at reconciling Leibniz and Newton, but rather as a matter of reforming metaphysics by adopting the *exterior form* of a systematic and demonstrative science, according

to Wolff's example, while rethinking the latter's basic principles in the light of the successful empirical discoveries made by Newton. For this ambitious task both Wolffian metaphysics and Newtonian physics would not appear as paradigmatic sciences, but rather as doctrinal clusters which lack the capacity to provide truly scientific knowledge on their own and therefore still lack an adequate scientific exposition.

Moreover, on the background that we have sketched so far, we cannot be surprised by the fact that Kant rejected many theses that were originally defended by Newton, such as the existence of absolute space, the atomistic composition of matter, the non-essentiality of gravity to matter, the hypothetical status of repulsive force. Kant also proposed a different justification of many concepts introduced by Newton in the definitions of the *Principia*, namely space, time, mass, moving force. On the whole, he shared Wolff's judgment about Newton's physics being "no philosophy", but tried to make sense of it by carefully following Newton's own empirical and mathematical reasoning in the *Principia* and the *Opticks*. It is a remarkable expression of both his critical approach and his allegiance to Newton that Kant – contrary to many enthusiastic Newtonians – questioned the infallibility of the master and eventually recognized the need for a new theoretical organization of the principles of Newton's theory, in which hypotheses would play a minimum role (though not a negligible one, as we will see in the next paragraph).

## 2. RETHINKING NEWTON: MOVING FORCE AND MATERIAL SUBSTANCE IN THE *METAPHYSISCHE ANFANGSGRÜNDE DER NATURWISSENSCHAFT*

The *Metaphysische Anfangsgründe der Naturwissenschaft* are explicitly presented by Kant as a complement to Newton's *Principia mathematica*, and contain several direct quotations from Newton's book. Indeed Kant's program in this work is precisely to show how Newton's argument in the *Principia* presupposes philosophical (i.e. metaphysical) concepts and principles, and yet does not provide a justification of this presupposition. This conviction will be still crucial for Kant's unfinished project of a "Transition from the MAN to physics": here, in a Draft of Introduction, Kant even argues that Newton, with his title, is in "contradiction with himself", and that the correct title should have been *Scientiae naturalis principia mathematica*, thereby leaving room for the *philosophical* principles (OP, AA 22: 512.08-17). That physics has three kinds of inseparable elements – metaphysical, mathematical and empirical – is a basic assumption of Kant's understanding of physics in the years of criticism, and in the MAN, in particular, it is supported by means of a very detailed and deep understanding of Newton's text and by the detection of occasional inadequacies in Newton's methodological assessment of his own results.<sup>26</sup> Nonetheless Kant's claim that Newton's original exposition has to be emended can also be traced back to the underlying systematic function of the "metaphysics of corporeal nature" as a means to provide the exhibition of metaphysical principles (§1). I will show this by considering how the physical concepts of moving force and quantity of substance are introduced in Kant's argument.

Newton's hypothesis of microscopic attractive and repulsive forces for the explanation of different phenomena such as cohesion, capillarity, elasticity, chemical bond was of course very well known and debated since its first publication in the *Queries* of the *Opticks* (in the second, Latin edition of 1706<sup>27</sup>) and constituted a central issue for Newtonian scientists, since it was partially inconsistent with the hypothesis of ether, first introduced in the *Queries* of the 1717/18 edition for the explanation of different optical, electrical and gravitational phenomena. Kant's attempt to make sense of both hypotheses in a coherent theoretical framework may be considered therefore as merely an example of this Newtonian legacy, lacking moreover significant experimental and mathematical details. But this attempt, in the first full-fledged exposition of the *Monadologia physica*, belongs to the project of connecting the metaphysics of monads to empirical physics and still bears distinct signs of its Leibnizian roots. Repulsive active force is demonstrated as a condition for the filling of space, and this filling is explained as a "sphere of activity" surrounding a point-like monad (MP, prop. VI, AA 01: 480.36-39). The contrary attractive force is needed in order to put a limit to this repulsive action, which would push monads at infinite distances. The volume occupied by the monad is determined by the different laws of the respective forces. Repulsive force, being diffused in a three dimensional volume, is proportional to  $1/r^3$ , whereas attractive force, being dependent on the distance, is proportional to  $-1/r^2$ , where  $r$  is the distance from the monad. This dynamic interplay results in a status of equilibrium, corresponding to the boundary of corpuscles (prop. XII), which are the material substances of Newtonian mechanics. The latter's "quantity of matter" depends on a specific *vis inertia* (prop. XI), while their aggregation results in the formation of "ether" or "fire matter" (prop. XIII). In this perspective, the *Monadologia physica* builds a bridge between the *Nova dilucidatio* and the empirical hypotheses of *De igne*, the *Allgemeine Naturgeschichte* and *Neuer Lehrbegriff der Bewegung und Ruhe*, where forces, ether and inertia appear in a physical context.<sup>28</sup>

This early dynamical theory is still quoted by Kant in the prize-essay of 1764 as an example of metaphysical argument (UD, AA 02: 286-288). The reason of its abandonment is the development of Kant's critical arguments against the objective validity of the cosmological concept of simple substance, whose ultimate exposition is to be found in the discussion of the *Second Antinomy*. In this process Kant recovers the distinction between the Wolffian and the original Leibnizian monadology (e.g. KrV A 439/B 467; A 442/B 470). The former is grounded on "physical points", which are spatial but unextended and therefore cannot be the object of empirical intuition; the latter is grounded on the pure intellectual concept of a simple substance, which cannot be localized in space (being space the form of sensible objects) and whose basic attribute is representation. The latter view, according to Kant, is a more consequent metaphysical doctrine, because it is purely intellectual, but nonetheless non-spatial monads cannot be an object of cognition either.

In the light of this revolutionary framework, in the *Metaphysische Anfangsgründe*, Kant has to completely rethink his physical dynamism. He starts from the empirical concept of matter, which contains the concepts of movability, extension, impenetrability, and inertia; then he analyses this concept "[1] in relation to the pure intuitions in space and time, and [2] in accordance with laws that already essentially attach to the concept of nature in general" (MAN,

AA 04: 472.9-11). This means that [2] the basic properties of matter have to be “carried through all the four of the indicated functions of the concepts of understanding (in four chapters)” (MAN, AA 04: 478.07-08) and [1] that the understanding has to “trace back all other predicates of matter belonging to its nature to this [motion]”, as the “basic determination of something that has to be an object of the outer senses” (MAN, AA 04: 476.09-13). The result is an inquiry into the possibility of mathematical physics: “in order to make possible the application of mathematics to the doctrine of body, which only through this can become natural science, principles for the construction of the concepts that belong to the possibility of matter in general must be introduced first”.<sup>29</sup>

This complex stratification of theoretical levels, which connects the general functions of the understanding to the empirical concept of matter, hence leading to the formulation of new synthetic a priori (but not pure) principles, can be detected in each of the four chapters of the book.<sup>30</sup> The *Dynamics* chapter, in particular, regards the construction of the empirical concept of impenetrability, which is empirically given by means of the sense of touch (MAN, AA 04: 510.04-11). It corresponds to the category of quality and (on the transcendental level of “general metaphysics”) to the concept of the “real” in the phenomenon (KrV, A 166/B 207). The corresponding metaphysical concept, which connects the transcendental level to the doctrine of bodies, is the “filling” of space, which appears in the first *Definition* of the *Dynamics* (MAN, AA 04: 496.07-09). This concept, “in accordance” with the *Analytic of Principles* has to have both an intensive and (being in space) an extensive magnitude – thereby excluding the simple monad. Its treatment “in relation to the pure intuitions of space and time” will consist in an investigation of the condition of this filling, that is resisting a penetrating motion, as different from the more general, merely geometrical concept of “occupying a space” (MAN, AA 04: 497.02-13). This leads to the introduction of a fundamental repulsive force of matter in *Theorem 1* – which I will analyse in a moment – and thus first establishes a possible connection of impenetrability with a mathematical law.

But before going on with this survey of the *Dynamics* chapter we have to take into consideration a crucial passage in the *Preface* of the work, regarding the “excellent and indispensable service” which metaphysics of corporeal nature does for the general metaphysics: that is, to put an end to the “well-known disputes, or at least obscurity, in the questions concerning the possibility of a conflict of realities, of intensive magnitude, and so on, in which the understanding is taught only by examples from corporeal nature what the conditions are under which such concepts can alone have objective reality” (MAN, AA 04: 478.10-15). As it is suggested by the reference to intensive magnitude, the example chosen by Kant regards in particular the task of the *Dynamics* chapter, hence the connection of impenetrability to a possible mathematical construction. To be sure, the explanation of the properties of substance by means of a real conflict was already a central point in Kant’s metaphysical inquiry since the essay on negative magnitudes (and here Kant also made a direct reference to the importance of applying Newton’s theory of negative magnitudes to attractive and repulsive forces: AA 02: 169.13-17). But this task, as Kant has made clear in the *Amphiboly*, must be now realized without resorting to monads, that is by allowing of (1) merely spatial distinction between substances, (2) “real opposition [*Widerstreit*]” between their properties, (3) the primacy of

outer relations (in particular “forces, that are active in space”) and (4) of space and time over the determination of substances by inner properties (See KrV, A 263/B 319-A 268/B 324). Thus the *Dynamics* chapter can be seen as an application of this transcendental “reflection” on the concepts of metaphysics, which are now ultimately rooted in the revolutionary content of the *Transcendental Aesthetic*. In the second edition of the *Critique* Kant will close the circle, as it were, by writing in the second *General Remark* to the *Aesthetic*: “everything in our cognition that belongs to intuition [...] contains nothing but mere relations [*Verhältnisse*], of places in one intuition (extension), alteration of places (motion), and laws in accordance with which this alteration is determined (moving forces)” (KrV, B 66-67). Let us now consider, in the light of this “relational” background and the relevance of the issue of the conflict of realities, the introduction of repulsive and attractive forces in the *Dynamics* of 1786 and how the implicit metaphysical background of this chapter influences Kant’s rethinking of Newtonian physics.

In *Theorem 1 (Lehrsatz)* Kant argues that “Matter fills space, not through its mere existence, but through a particular *moving force*” (MAN, AA 04: 497.15-16). The *Proof* – as we now expect – connects this property to the concept of motion, arguing as follows: penetration into a space is a motion; resistance to motion is the cause of its diminution or change to rest, which – according to *Phoronomy’s* single *Theorem*, which has been proved by means of pure intuition – can only be effected by a motion in the opposite direction. Now, since matter (empirical datum) resists the penetration by other matters in the space that it fills, this resistance is the cause of the motion of the latter in the opposite direction. But the cause of a motion is a moving force, thus matter fills its space through a moving force.

In the first *Remark* Kant immediately confronts an alternative view, defended by “Lambert and others” (AA 04: 497.30ff). According to this view matter fills space by means of an original property of “solidity” and thus can be attributed the property of resistance already by means of its concept, merely in accordance with the law of contradiction. But the admission of absolute solidity was also very common among physicists. Newton’s “solid and massive particles” created by God can be included in this hypothesis, and this may indeed be considered as one example of how Kant intends to emend Newton’s justification of first principles by means of induction.<sup>31</sup> More recently, Euler had defended a similar claim, also defending (similarly to Lambert) the reverse view that moving force is grounded on impenetrability.<sup>32</sup> In the *Remark* Kant is primarily concerned with the mistaken idea that the “principle of contradiction” may be sufficient to explain resistance: here he is making reference to the different foundation of physical cognition provided by his esteemed colleague Lambert in his *Architectonic*, where solidity is a fundamental ontological concept which underlies the axiomatization of the concept of moving force.<sup>33</sup> But the core of his argument, as the following lines make clear, regards not merely Lambert but more generally the way physicists connect impenetrability to mathematical constructions. Kant’s objection is as follows:

Here the mathematician has assumed something, as a first datum for constructing the concept of matter, which is itself incapable of further construction. Now he can indeed begin his construction of a concept from any chosen datum, without engaging in the explication of this datum in turn. But he is not therefore permitted to declare this to be something entirely incapable of any mathematical construction, so as thereby to obstruct us from going back to first principles in natural science (MAN, AA 04: 498.09-15).

This argument is directed against the apodictic certainty of the hypothesis of absolute impenetrability, and therefore seems merely to argue for the *possibility* of the dynamistic view. Kant is aware that his dynamism does not correspond to the most common view among physicists and this *Remark* is probably meant to address this problem and open the way to a better acceptance of the new hypothesis. In the *General Remark to Dynamics*, which discusses the connection between the *a priori* demonstrative section of the chapter and empirical physics, Kant discusses at length the contrast between the “dynamical” construction of different densities of matter by means of an originally different degree of repulsive force and the “mechanical” method of explanation, grounded on atoms (endowed with “absolute impenetrability”, “absolute homogeneity” and “absolute insurmountability” of their cohesion) and interposed vacuum.<sup>34</sup> In these passages Kant is describing the “solid, massy, hard, impenetrable, movable particles” endowed with active powers of the *Opticks*, therefore the concluding charge that to admit absolute impenetrability is “to rest on the pillow of occult qualities” (AA 04: 532.18-19) presents a first striking criticism of Newton. It must be remarked, though, that this is according to Kant a criticism inspired by the example of Newton himself, which is presented in a physical lecture as representative of the “dynamical method of explanation” (as contrary to the mechanical method followed by Descartes)<sup>35</sup> and hence would have been here led to an inconsequence by mechanistic philosophers. Indeed Kant’s criticism is only apparently Leibnizian in inspiration<sup>36</sup>, and is rather grounded on the same argument that has led to the rejection of monads in the *Amphiboly*: the absolute (vs relational) character of solidity.

In order to understand the non-hypothetical status of Kant’s alternative explication of density, which requires a combination of *two* fundamental forces, we have to come back to the demonstrative section of the *Dynamics*. In *Lehrsatz 5* Kant introduces the fundamental attractive force, as a necessary limiting factor to the action of repulsive force (again, the proof is basically grounded on the construction of an opposite movement, which has to contrast repulsion, and whose cause is attractive force). In *Lehrsatz 7* he argues that this force acts immediately at distance and in the *Remark 2* he explicitly claims that Newton, when he denied that gravity is an essential property of matter, was set “at variance with himself” by the attacks of the mechanistic philosophers: for he could not have established that the attractive force of the planets is proportional to their quantity of matter without assuming that they “attracted other matter merely as matter, and thus according to a universal property of matter” (AA 04: 515, 32-37).<sup>37</sup> Again Kant boldly contrasts the dominant view in physics and, with a second (now explicit) criticism of Newton, concludes *a priori* that the essentialist view must be true. Building on this new *a priori* foundation of the theory of gravitation, in the *Preface* to the second edition of the *Critique* Kant will even write that “the central laws of the motion of the heavenly bodies established with certainty what Copernicus had assumed at the beginning only as a hypothesis”, thus elevating the Copernican hypothesis to apodictic certainty.<sup>38</sup>

Having thus introduced his two fundamental forces, in the *Note 2 to Theorem 8* Kant argues that “only an original attraction in conflict with the original repulsion can make possible a determinate degree of the filling of space” (MAN, AA 04: 518.06-08). As Kant explains in the *General remark*, this possibility depends from the fact that “attraction rests on the

aggregate of matter in a given space, whereas expansive force, by contrast, rests on the degree of filling of this space, which can be very different specifically”, that is, attraction depends on the homogeneous (extensive) quantity of matter, while the same quantity of matter can have a different degrees of repulsive force, thereby filling different volumes of space (MAN, AA 04: 524.02-04; compare AA 04: 533-534). Again, this perspective involves a reform of Newton's foundation of natural philosophy, where density was treated as an elementary property in the definition of the quantity of matter: now the originally different “degree of repulsive force” is the basic quantity, and density arises from its interplay with attraction.<sup>39</sup>

On the whole the *Dynamics* chapter seems to establish *wholly a priori* the rectification of the Newtonian views of *impenetrability*, *gravity* and *density*, and to derive this threefold criticism from the proofs of the fundamental forces. But if we include in this picture the discussion about dynamical and mechanical methods in natural philosophy in the *Remarks*, with the several passages about the *non-necessity* of absolute impenetrability, we need to slightly modify our conclusion. In fact, when we come to the domain of empirical physics, the confrontation between dynamism and mechanism appears to be not so easily settled without entering into hypothetical arguments.

In the *General Remark* Kant compares the respective advantages of the two methods with regards to the actual construction of specific densities and he argues that “the mathematical-mechanical mode of explanation has an advantage over the metaphysical-dynamical [mode]”, namely that “the possibility of both shapes and the empty interstices can be verified with mathematical evidence” (MAN, AA 04: 525.06-07). In other words, one can construct atoms and void in pure intuition.

By contrast, if the material itself is transformed into fundamental forces (whose laws we cannot determine a priori, and are even less capable of enumerating reliably a manifold of such forces sufficient for explaining the specific variety of matter), we lack all means for *constructing* the concept of matter, and presenting what we thought as possible in intuition (AA 04: 525.07-11).

In other words, we *cannot* construct matter a priori by means of fundamental forces in pure intuition, contrary to what happens with atoms and void, because, as Kant puts it in metaphysical language, we cannot “comprehend their possibility” (AA 04: 524.39); what we can do is to infer the action of fundamental forces, and, given the *possibility* of a different degree of repulsive force, think of possible laws, which only empirical inquiry will be able to establish. As regards the advantages of dynamism, indeed, Kant argues as follows: having been shown that the mechanistic explanation is not necessary, the field of the natural scientist is “indirectly enlarged” (AA 04: 524.21), for he can now conceive of a dynamical explanation of specific densities. Therefore Kant will conclude that dynamical natural philosophy “is much more appropriate and conducive to experimental philosophy, in that it leads us directly to the discovery of matter's inherent forces and their laws, while restricting our freedom to assume empty interstices and fundamental particles of determinate shapes” (AA 04: 533.21-26). On the whole, mechanism appears as an *a priori* method, which postulates atoms and voids in pure imagination, whereas dynamism is open to new experiments and discoveries.

But this perspective of the discovery of new laws is precisely the point where Kant's transition from *metaphysical* dynamics to *physical* dynamism comes to a problematic point. The dynamical natural philosophy of the MAN is much different from its precritical version and it presents new serious problems in its mathematical application – as Kant admits in the *Remarks* to *Theorem 8*, which I will discuss in a moment. But in order to understand this point we have to start considering one more theorem of the *Dynamics* chapter.

*Theorem 4* argues that: “Matter is *divisible to infinity*, and, in fact, into parts such that each is matter in turn” (MAN, AA 04: 504.21-22). Remember that in the *Monadologia Physica* Kant similarly defended infinite divisibility of space, taking position with the “mathematicians” against the Wolffians, but he claimed that point-like monads as centres of forces could nonetheless be admitted as undivided and simple. The novelty in Kant's present argument is given by the single word *parts*. In the light of transcendental philosophy we cannot allow of material points – which can be no object of experience – and thus material substance is always associated to a determinate volume (compare KrV A 441/B 469; MAN, AA 04: 508). This is the reason why Kant devotes the *Remark 1* to a critique of the views of the (physical) “monadist”, arguing that the filling of space is dependent on the repulsive action of “every part of space”, since there is no privileged point of repulsion and without resisting action even the smallest parts space would always be penetrated by the expansion of matter (MAN AA 04: 504-505). Indeed Kant now conceives matter as an originally elastic fluid, a “quantum continuum” (MAN, AA 04: 521.30), whose physical subdivision must be explained by means of dynamical processes.

But from this move, which is constrained by transcendental philosophy, results a new problem for Kant's new theory of forces as compared to the precritical one. In this latter theory, as we have seen, the conflict of attractive and repulsive force determined the volume, while the “force of inertia” of a body, “which is called its mass”, determined the mechanical property of resisting and communicating motion (MP, Prop. XI, AA 01: 485.20-21). Here Kant, following Newton's and Keill's observation that a disseminated ether should have a negligible density in order to allow of the free motion of celestial bodies, but (already) rejecting the method of explaining this different density by means of atoms and void, explained the *different density* of materials by means of the originally different *force of inertia* (MP, Prop. XII, AA 01: 485.05-07). Now, in the MAN, Kant abandons the concept of a “vis inertiae”, as contrary to the lifelessness of matter, and tries to derive *different density* from the interplay of attractive and repulsive forces. The repulsive force is now a *superficial* force (MAN, AA 04: 516.09-10) which is propagated by a *volume* of matter, and it makes no sense to talk of *finite* distances between repulsive points. But this also means that Kant now *gives up* the attempt at explaining the determinate volume of matter by means of the law of conflicting forces, which was only possible on the ground of this finite distance – and was, indeed, a typical advantage of any physical monadology.<sup>40</sup> Now Kant presents again that hypothesis of a law derived from mere geometrical arguments (in *Remark 1* to *Theorem 8*), substituting finite with “infinitely small distances” (AA 04: 520.15), but comments (in *Remark 2*) that this construction now presents a “difficulty” (AA 04: 521.14): indeed, the distances among parts of matter are merely imaginary, since repulsive parts are actually in contact, and they correspond to the distance “into which

the same quantum of moving force would need to have diffused, in order to act immediately on this point at the determinate distance” (AA 04: 522.21-23). Moreover Kant has to admit that his law of repulsion (as proportional to  $1/dr^3$ ) is different from the empirical Mariotte's law for fluids, which he thus tries to consider as related to the action of heat-matter and therefore as less fundamental. Finally, he comments:

I do not want that the present exposition of an original repulsion to be viewed as necessarily belonging to the goals of my metaphysical treatment of matter. Nor do I want this latter (for which it is enough to have presented the filling of space as a dynamical property of matter) to be mixed up with the conflicts and doubts that would afflict the former” (MAN, AA 04: 522.39-523.04).

Now, since Kant openly admits the difficulty, there is no reason to doubt that he must have good reasons to draw this conclusion and to separate the metaphysical proof of fundamental forces from its empirical and mathematical application. But this means that the model of conflicting forces must not end in a blind alley and there must be a different way conducting from metaphysical to empirical dynamics.

Indeed Kant, being aware of this drawback of his new theory, has already introduced this alternative. By introducing the original attraction (in the lines following a passage quoted above), and before presenting his previous geometrical argument about the ratio of forces, he writes (*Note 2 to Theorem 8*):

Since every given matter must fill its space with a determinate degree of repulsive force, in order to constitute a determinate material thing, only an original attraction in conflict with the original repulsion can make possible a determinate degree of the filling of space, and thus matter. Now it may be that the former flows from the individual attraction of the parts of the compressed matter among one another, or from the uniting of this attraction with that of all the matter in the universe [*aller Weltmaterie*] (MAN, AA 04: 518.04-11):

The last sentence introduces a new hypothesis, grounded on the existence of a “World-matter”, which Kant presents again in the *Phenomenology* chapter, when he discusses the concept of empty space, coming back to the open issue of its non necessity (and logical possibility). Here he writes that

[...] even if no merely logical reason for rejecting this kind of empty space were to be found here, there could still be a more general physical reason for expelling it from the doctrine of nature – that of the possibility of the composition of matter in general, if only this were better understood. For if the *attraction* assumed in order to explain the cohesion of matter should only be apparent, not true attraction, and were merely the effect, say, of a *compression* by external matter (the aether) distributed everywhere in the universe, which is itself brought to this pressure only through a universal and original attraction, namely, gravitation (a view that is supported by several reasons), then empty space within matter, although not logically impossible, would still be so dynamically, and thus physically [...] (MAN, AA 04: 563.35-564.07).

The possibility of ether as a matter whose “repulsive force must be thought as incomparably larger in proportion to its inherent attractive force than any other matter known

to us” has been already discussed at the end of the *General Remark to Dynamics*, where Kant presents it as:

the only assumption that we make, simply *because it can be thought*, but only to controvert an hypothesis (of empty spaces), which rests solely on the pretension that such a thing cannot be thought without empty spaces. For, aside from this, no law of either attractive or repulsive forces may be risked on a priori conjectures (AA 04: 534.12-17).

Now, let us try to sketch an overview of this complicated solution to the problem of matter and empty space. According to Kant, the action of repulsive and attractive forces – as *causes* of motion – can be concluded *a priori*. Moreover, the existence of empty space and absolute solid atoms is comparable to an obscure quality. Therefore he admits that some conflict must explain the specific densities. But since the monadological way of deriving a law of forces is no longer possible, he thinks that the hypothesis of ether (which is “supported by several reasons”: e.g. Euler’s wave-theory of light, which Kant endorses) may play a role in this explanation. This additional element in Kant’s transition from pure to empirical dynamism appears as a problem, not only because it is hypothetical. Even with the admission of ether as a hypothetical material we would still be left with a problem: for the “determinate degree” of the filling of space, in the demonstrative part of *Dynamics*, has to be derived from the conflict of *forces*, while now the ratio between mass and volume would depend on the action of a hypothetic material; but the very filling of *this* cosmic material – which Kant considers as a ponderable one, thus as having a determinate mass – would be merely postulated and not derived from a dynamical conflict (though, at least, a physical hypothesis about originally different materials would replace Newton’s metaphysical postulates).<sup>41</sup> Kant’s *Dynamics* of 1786, therefore, appears as a set of demonstrative propositions, which openly challenge some basic postulates admitted by Newton (about solidity, gravity and density), but which lack a clear way of application to empirical physics – and this, I suggest, is a deeper reason of Kant’s insisting on the mere (physical) *possibility* of dynamism as an alternative to mechanism, which starts immediately after the first proposition of the chapter and appears again in the final lines of the *General Remark* and at the end of the *Phenomenology* chapter.

In the light of this long analysis of the *Dynamics* chapter we can finally understand how crucial is the metaphysical background for the conception of Kant’s dynamical theory of matter, as alternative to the Newtonian in its different variants. Indeed, the main philosophical drawback of mechanism (as I have suggested above) is that it introduces an *absolute* property – that is, a non-relational one. But a relational explanation of the filling of space, such as the one grounded on fundamental forces (with the possible supplement of ether), is precisely the representation of the “conflict of realities” which Kant’s metaphysics needs, after its exclusion of monads with their absolute properties. Now Kant, after having eliminated point-like (Wolffian) and non-spatial (Leibnizian) monads, is trying nonetheless to develop a dynamism which could lead to a law of forces. But with this move he can no longer connect his metaphysical principles about “possible constructions” to *any available* theory of mathematical physics. Rather than providing a metaphysical foundation of Newton’s mechanics, then, Kant has come to the point of considering the latter as an insufficient theory *on metaphysical grounds*.

A confirmation of these conclusions comes from the manuscripts of the *Opus postumum*. Here Kant painstakingly reflects on the conflict model, trying to combine forces with ether.<sup>42</sup> And as he finally tries to demonstrate the existence of ether as a “World matter”, this is no longer the hypothetical material of previous reflections (and of contemporary natural science, with its “several reasons”), but rather an “a priori given” substratum for the representation of possible dynamical interactions and of the physical object in general. The (necessary) conflict of realities, thus, still lacks an exemplary physical instantiation, and Kant merely anticipates a system of *possible* physical properties for empirical inquiry (“a priori thought”, “empirically given”: OP, AA 21: 289-290), including cohesion and solidity. Now this open conclusion of the dynamical theory may appear as a kind of step back to a Cartesian kind of natural philosophy, as it has been claimed about the early *Allgemeine Naturgeschichte*<sup>43</sup>, or as perfectly integrated in the open status of XVIII<sup>th</sup> Century Newtonian theory of matter. The unpublished reflections on contemporary concepts of chemistry, such as heat-matter, support the latter view, being a striking representation of how Kant’s quest for a metaphysical foundation of physics has led, as it were, with Newton beyond Newton, to the philosophical admission of the need for a physical theory which was still not there.<sup>44</sup>

### 3. GRAVITY AND THE LIMITS OF KNOWLEDGE

Besides his reflection on the properly physical doctrines of Newtonianism Kant also devotes a lifelong meditation on the exemplary meaning of the latter for philosophical knowledge in general, focusing on the Newtonian concept of force and its connection with the intrinsic limitation of possible knowledge. Thus, in the prize-essay of 1764, Kant compares the “true metaphysical method” to Newton’s method in natural science, according to which we explain natural phenomena by deriving them from particular laws, “even though one does not have insight into [*einsieht*] their first principle [*Grund*] in bodies” (UD, AA 02: 286.19-20).<sup>45</sup> In the *Träume eines Geistersehers*, after having questioned our supposed knowledge of the “spiritual force” and defined metaphysics as a “science of the limits of reason”, Kant first suggests that we may analogically extend Newton’s method to the understanding of the “moral sentiment”, that is the “constraining of our will to harmonize” with the “rule of the general will”, thereby conceiving this sentiment as a “phenomenon of that which takes place within us, without establishing its causes” and thus without feigning an intelligible world (TG, AA 02: 335.12-17).

In such elaborations we find, again, the beginning of a deeply original insight into a widely debated issue in contemporary philosophy, which will find its culmination in critical philosophy. Drawing from Newton’s own statements in the *Principia* and the *Opticks* about the ignorance of the “cause of gravity” and the sufficiency of experimental philosophy<sup>46</sup>, the admission of attractive force on the Continent was accompanied by the argument that we do not know the cause of mechanical impulse at contact either, and therefore we can feel free to accept gravitation as an empirically grounded concept of physics. For example – as we have seen (§1) – Maupertuis made use of precisely this argument for his seminal defence of gravity, which played a major role for the diffusion of Newtonianism in France and Germany.

Furthermore, this idea of a fundamental limitation of our knowledge of physical causes was already a diffused topic in Cartesian natural philosophy, and the same argument could be connected to scepticism as well as to many kinds mechanistic and materialistic hypotheses.<sup>47</sup>

In German philosophy, in particular, the interpretation of “force” (being also a translation of the English word ‘power’) could not avoid a reference to the Leibnizian and Wolffian metaphysics, where the concept of force connected physical and psychological phenomena in a single doctrinal body. Even after the decline of Wolffian orthodoxy this analogy was a matter of discussion among German philosophers: Lambert called the concept a “transcendent” one, “since it represents similar things in the physical and intellectual world”, i.e. “forces of knowledge, forces of desire and moving forces” (according to Lambert all these forces were objects of knowledge, the former two by means of consciousness, the latter by means of the sense of touch).<sup>48</sup> Eventually the concept of a “force or faculty” was elaborated by Kant in criticism, where it denotes the condition of an empirical synthesis according to a law, whose metaphysical ground remains unknown, and therefore the condition of any philosophical knowledge in general.

The mature development of the doctrine of “fundamental forces” of matter, in the *Metaphysische Anfangsgründe der Naturwissenschaft*, is the opportunity for a new general assessment of this crucial point, which is nicely connected to the discussion in our previous section (§ 2). In the *General Remark to Dynamics* – right after the above quoted passage on the hypothesis of ether as a condition for the rejection of empty space and the conclusion that “no law” of forces can be conjectured a priori – Kant writes:

Rather, everything, even universal attraction as the cause of weight, must be inferred, together with its laws, from data of experience. Still less may such laws be attempted for chemical affinities otherwise than by way of experiments. For it lies altogether beyond the horizon of our reason to have insight into [*einsehen*] original forces a priori with respect to their possibility; all natural philosophy consists, rather, in the reduction of forces and faculties [*Vermögen*] that explain the actions of the former, although this reduction proceeds only up to fundamental forces, beyond which our reason cannot go. And so metaphysical investigation behind that which lies at the basis of the empirical concept of matter is useful only for the purpose of guiding natural philosophy, so far as this is ever possible, to explore dynamical grounds of explanation. For these alone permit the hope of determinate laws, and thus a true rational coherence of explanations (MAN, AA 04: 534.15-30).

The physical assessment of the concept of force can be thus summarized. In order to introduce the concept of force we have first to detect a “real conflict”, and thereby the action of a cause, since physically speaking force is the “cause of a movement” (e.g. MAN AA 04: 497.26-27). A second condition must be the possibility to connect this action to a law. As we have seen, this second step has been excluded by Kant from the domain of metaphysics, though the latter plays a fundamental role for the exclusion of absolute positions and the stimulation of empirical investigations. So the above quoted passage is followed by the general conclusion:

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* (my emphasis) (AA 04: 534.31-36).

Insofar Kant's investigation is an interpretation of Newton's defence of the concept of force, which emends the latter from the disguised metaphysics lying behind its pretended mathematical purity. But there is a third step in the assessment of the concept, which addresses the – typically Leibnizian – idea of investigating the supersensible ground of the force by means of a logical and metaphysical theory of substance. Kant declares that we cannot “have insight into [*einsehen*] the possibility of forces”, thus rejecting this line of inquiry. This rejection is best understood if we highlight Kant's use of his technical language about the different degrees of knowledge, as it is developed in logical lectures. Here Kant, in the section concerning the logical perfection of knowledge, articulates a hierarchy of degrees of knowledge considered according to its object, which in the published *Logik* is as follows (Log, AA 09: 64-65): to represent (Vorstellen = *repraesentare*), to perceive (Wahrnehmen = *percipere*), to be acquainted (Kennen = *noscere*), to cognize (Erkennen = *cognoscere*), to conceive (Verstehen = *intelligere*), to have insight (Einsehen = *perspicere*), to comprehend (Begreifen = *comprehendere*). Here we are interested in the last three degrees of knowledge, which overcome mere cognition by concepts (*Verstehen*) adding further distinction, because these are the degrees which cannot be accessible by knowledge, being the latter grounded on forces and faculties.<sup>49</sup> To have insight is “to cognize with reason”, and thus by means of inferences, hence knowing something “from universal principles according to its grounds” and thus cognize “not only that it is so [...] but that it must be so” (Logik Dohna, AA 24: 730.35-37). The application of this concept to physical knowledge presents a subtle interpretative issue, since Kant makes examples of knowledge *ex principiis* drawn from chemistry, and generally admits that “with few things do we get this far”, thus admitting that we *can* have insight into something. But with the “possibility” of forces we are concerned not with the inference of *forces from phenomena* (which is perfectly possible), but with the inference of a ground of the forces themselves – and this is what is excluded by Kant. The negative reference is to the (broadly speaking) Leibnizian-Wolffian idea of deriving forces from the concept of substance.

A confirmation of this reading is given by the discussion of comprehending (*Begreifen*), as the a priori cognition through reason. Hereby is meant a deductive inference from grounds to consequences, and thus a perfect rational knowledge, which is never accessible to men. The example discussed in the *Logik Jäsche* – which will be crucial for our discussion in the last paragraph of this paper – is geometrical knowledge. The mathematician can comprehend (relatively) that “all lines in the circle are proportional”, but not (absolutely) “how it happens that such simple figure has these properties”. The reason for this limitation is that we do not know the reasons of the basic properties of space, such as tridimensionality. This suggests that the limitation of dynamical knowledge, which we are trying to explain, depends on the doctrines of the *Transcendental Aesthetic* and its rejection of the metaphysical explanation of space (and time) as phenomena grounded on immaterial substances, and thus of logical and intuitive knowledge.

But there is more to this limitation of comprehension than this geometrical side. Kant argues more generally that we can have a knowledge which is “relative, i.e. sufficient to a certain purpose”, thus also making a reference to issues of moral and religion, were we can follow the guidance of reason, even though we do not properly comprehend its ideas (such as God and freedom).<sup>50</sup>

Both these examples – the geometrical and the moral-religious – introduce to Kant’s extension of the discussion of force beyond the field of natural knowledge, which is expressed in several passages of the critical writings. For example, in his discussion of freedom in the *Kritik der praktischen Vernunft*, Kant writes that “all human insight is at an end as soon as we have arrived at basic powers or basic faculties [*Grundkräften und Grundvermögen*] for there is nothing through which their possibility can be conceived, and yet it may not be invented and assumed at one’s discretion”. Here Kant’s point is that, in moral, “the objectivity of the law cannot be proved by any deduction”, although it is “firmly established of itself” (KpV, AA 05: 46.37-47.20).

In the 1780s Kant will take different opportunities to reassess his philosophical view of the limits of cognition through the concept of fundamental force. E.g., in his essay on the use of teleological principles he would argue that to know something on the basis of forces does not mean to reduce it to a *Grundkraft* and eventually to a substance, from whose concept these forces could be “derived” (*abgeleitet*) (ÜGTP, AA 08: 181.24-39). The reason why our knowledge cannot go beyond the concept of a fundamental force or faculty is that this concept is uniquely defined “through the relation of a cause to an effect”, and it is not possible to “come up with any other appellation for it than the one taken from the effect and expressing only this relationship” (ÜGTP, AA 08: 180.27-30). This situation – which is obviously inspired by Newton’s treatment of gravity<sup>51</sup> – is now presented as a fundamental feature of “true metaphysics”, which “can do nothing else than reduce the fundamental forces [*Grundkräfte*] which experiences teaches it [...] to the smallest possible number, and to look for the pertinent *fundamental force* in the *world*, if it is a matter of physics, or *outside the world*” (ÜGTP, AA 08: 180.18-27).<sup>52</sup> The latter case has been discussed in the *Transcendental Dialectic*, with negative result, regarding a transcendental ground of the world, and thus represents an insuperable limit of knowledge. Contrary to what happens with the knowledge of body, we cannot apply our concepts of causality to our relation with this merely thought ground.<sup>53</sup>

That all these apparently dispersed passages are rooted in Kant’s original confrontation with Newton is made explicit in a well known analogy, which Kant puts in the foreground in the *Preface* to the second edition of the *Critique*, precisely in the paragraph where he presents transcendental idealism as an “experiment of pure reason”, and discussed the antinomies and the possibility to fill the empty concept of the unconditioned “through practical data of reason”. In a footnote Kant writes:

In the same way, the central laws of the motion of the heavenly bodies established with certainty what Copernicus assumed at the beginning only as a hypothesis, and at the same time they proved the invisible force (of Newtonian attraction) that binds [*verbindende*] the universe, which would remain forever undiscovered if Copernicus had not ventured, in a manner contradictory to the

senses yet true, to seek for the observed movements not in the objects of the heavens but in the observer (KrV B xxii).

Here the complex analogy drawn by Kant between philosophy and physics comes to a culmination and synthesis. The proof of the force of attraction is compared to the proof of liberty, thus positing a parallelism between the two entirely distinct domains of philosophical legislation, that is physics and moral. This philosophical approach is contrasted to the presumed rational knowledge of the unconditioned, which dominated traditional metaphysics, most recently in its Leibnizian and Wolffian versions. At the same time, by putting this passage in the context of the *Preface*, Kant is highlighting the crucial role of his *Transcendental Aesthetics*, which indeed determines the originality of his “limitation thesis” as compared to the widely diffused analogous theses in contemporary philosophy and science. For it is precisely with his new hypothesis on space and time that Kant, after having long investigated a possible *deductive* explanation of space and time, eventually embarked on the search for a completely new metaphysics.<sup>54</sup> And here we come back to the example of geometrical knowledge in the discussion of comprehension and the limits of knowledge. It is precisely because we do not (deductively) know the reason of the properties of space and cannot gain any insight about these properties by means of any metaphysical theory – neither by the Leibnizian monadological approach, nor by means of the different kind of metaphysical speculations suggested by Newton's texts, which Kant took seriously in early writings – that we cannot gain insight into the possibility of forces and cannot “risk on a priori conjectures” any law of attractive and repulsive forces. Hence we cannot formulate any hypothesis about the supersensible, and we cannot lament the ignorance of any “mystery” (or missing “inner” property of things). This point is finally made in a footnote to the *Religion*:

The **cause** of the universal gravity of all matter in the world is equally [to the cause of freedom] unknown to us, so much so that we can even see that we shall never have cognition of it, since its very concept presupposes a primitive moving force unconditionally residing in it. Yet gravity is not a mystery; it can be made manifest to everyone, since its law is sufficiently cognized. When **Newton** represents it as if it were the divine presence in appearance (omnipresencia phaenomenon), this is not an attempt to explain it (for the existence of God in space involves a contradiction) but a sublime analogy in which the mere union of corporeal beings into a cosmic whole is being visualized, in that an incorporeal cause is put underneath them – and so too would fare the attempt to have insight into the self-sufficient principle of the union of rational beings in the world into an ethical state, and to explain this union from that principle (RGV, AA 06, 138.25-37).

On the whole Kant developed an original view of Newtonianism, both on the physical and the philosophical level, purging Newton's original thought from dogmatical doctrines (such as the absolute solid bodies and the activity of God in the physical world), and setting his own transcendental theory of space and time as the true condition for the very possibility of formulating hypotheses. In this process the Newtonian theory of gravity had to be defended from the charge of presenting yet another occult quality, and Kant realized this defence in the framework of criticism by means of his new foundation of natural philosophy in the *Metaphysische Anfangsgründe*. Only after having reached this point – and connected the

empirical theory of gravity to the a priori theory of matter – he returned in number of texts to the wider analogy between gravitation and freedom, which would remain a central pillar of his philosophy until his last writings.<sup>55</sup>

**ABSTRACT:** The article examines different aspects of Kant’s Newtonianism, focusing on Kant’s attempt in the *Metaphysische Anfangsgründe der Naturwissenschaft* to realize a new “pure part” of physics, complementary to Newton’s “mathematical principles”. The first section regards the philosophical objectives of Kant’s engagement with Newtonian physics, highlighting the role of physics for the “exhibition” of metaphysical concepts and criticizing the view that Kant’s intention would have been to provide a “foundation” of Newton’s physics. The second section provides an example of Kant’s original reappraisal of Newton’s physics, focusing on the concepts of material substance and force. The third section shows how Newton’s thesis about the limited (but sufficient) knowledge of gravity represented for Kant the main example of a general limitation of philosophical knowledge.

**KEYWORDS:** Kant – Newton - Metaphysics of bodily nature – Substance – Force.

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## NOTES

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1 See ADICKES' very informative footnotes to voll. XIV and XXI-XXII of the Akademie Ausgabe and Adickes 1924-1925, e.g. I, p. 2ff., 17ff., 49ff.

2 The crucial importance of the physical “exhibition” for the unity of Kant’s system is discussed in a paragraph of the MAN, AA 04: 477.14ff. (whereof the above quotations were extracted) and in a parallel passage of the new *General Note to the Analytic of Principles* (KrV B 288-294). This parallelism is most significant since the new edition of the *Critique* was published one year after the MAN: after successfully finishing this new work, Kant felt the need to highlight its transcendental background in the wider philosophical framework of the *Critique*. On the difference between *Beweisen* and *Darstellen* (or *Demonstrieren*, *ostendere*) compare e.g. KU, AA 05: 343.08-16 For a detailed account of this crucial systematic issue see PECERE (2009), p. 187-202).

3 See below footnotes 28-29 and the paragraphs to which they are appended.

4 Compare Michael Friedman’s comment to these lines: “The aim of the *Metaphysical Foundations*, accordingly, is to apply Kant’s revised version of metaphysics in the Leibnizian tradition – derived from the form and principles of the pure understanding – to explain how it first becomes possible to apply mathematics in the Newtonian style to our actual experience of sensible nature” (FRIEDMAN, 2013, p. 259). This comment underscores the top-down aspect of pure physics, but in the light of the quoted passages from the *Preface*, the reverse bottom-up aspect appears of equal importance both historically and systematically: Kant’s “revised” metaphysics could not be realized without this connection to physics as the exemplary domain of application of categories. This second point is also clearly spelled out by Friedman 2006, p. 322: “the application of categories to objects of experience in general is only possible by means of, and, as it were, *through* their a priori application to pure natural science”. As I will add in the following lines, this application also involves a partial *modification* of Newtonian physics itself in its original formulation.

5 The first term is already used in the sympathetic reading by Fries, which – well aware of the reception of Kant’s dynamism in Schelling’s and Hegel’s *Naturphilosophie* – still recognizes the critical aspect of Kant’s Newtonianism: the MAN are “the complete philosophical foundation [*Begründung*] of Newton’s physics, and the liberation of the latter from the prejudices of atomism”. See FRIES (1837-1840, I, § 150, p. 550). An example of the use of the term “justification” in the misleading context of early XX<sup>th</sup> century axiomatic “analysis of science” is given by REICHENBACH, when he ascribes to Kant a “philosophical justification [*Rechtfertigung*]” of Galilei’s and Newton’s exact science. REICHENBACH (1920, p. 41). Here Reichenbach was also influenced by the Neokantian reading which I discuss in this paragraph.

6 Kant’s aim in the *Metaphysische Anfangsgründe* would have been to provide a “philosophical foundation [*Begründung*] of the presuppositions of the Newtonian natural science”, the result being actually a “philosophical transcription [*Umschreibung*] of the latter presuppositions” (*Zur Einsteinschen Relativitätstheorie. Erkenntnistheoretische Betrachtungen*, CASSIRER 1998-2009, vol. 10, p. 52). The connection with the *Analogies of experience* is in CASSIRER, *Kants Leben und Lehre*, in \_\_\_\_\_. (1998-2009, vol. 8, p. 214).

The latter claim is also literally wrong since – as it has been pointed out many times in the literature – the *Mechanics* chapter of the MAN does not provide a corresponding treatment of Newton's three laws, but presents three metaphysical laws, one regarding the conservation of material substance and the others corresponding (though not being identical with) to Newton's laws of inertia and reciprocal action.

7 BUCHDAHL (1986, p. 127-161).

8 Most significantly Friedman, in his most recent book on the *Metaphysische Anfangsgründe*, dispels any ambiguity and refers to Kant's "engagement with the largely Newtonian science of his time" (FRIEDMAN, 2013, p. ix, my emphasis).

9 KUHN (1993, p. 331). Kuhn was presenting a version of the idea originally advanced (and later rejected) by REICHENBACH (1920).

10 KUHN (1962, p. 10).

11 For an overview of the many varieties of "Newtonian" natural philosophy in the XVIII<sup>th</sup> century it is still worth reading HEILBRON (1982, chapters 4-6). See footnote n. 17 below for Newtonianism in Germany.

12 'sGRAVESANDE (1720-21); MUSSCHENBROEK (1734). Kant possessed a copy of the latter work in a German translation of the second edition (*Grundlehren der Naturwissenschaft*. Leipzig, 1747). WARDA (1922, p. 35). On the diffusion of this approach in physical textbooks see LIND (1992, p. 158-161).

13 COTES, R., *Editor's Preface* in NEWTON (1726/1999, p. 392).

14 BOSCOVICH (1758/1763, § 2, reconciling Leibniz and Newton, §§ 17-19, action at contact vs law of continuity). On Boscovich's theory and its influence see ULLMAIER (2005).

15 See the brief summary of the exchange between Priestley and Boscovich in SHAFFER (1990, p. 283-284). Priestley's dynamical theory, expounded in the *Disquisitions Relating to Matter and Spirit* (1777), bears striking similarities to Kant's mature theory in the *Dynamics* of 1786. For a first overview see HEIMANN-McGUIRE (1971, p. 270-274).

16 MENDELSSOHN (1759).

17 On the diffusion of Newtonianism in XVIII<sup>th</sup> century German philosophy and physics see CASINI (2000, p. 251-282). On Wolff and Euler in particular see CASINI (2014).

18 See Leibniz' first letter in LEIBNIZ (1717/1957, p. 23). On Wolff and materialism see RUMORE (2013, p. 76ff).

19 See WOLFF (1717, p. 975).

20 These philosophers include in particular Knutzen, who according to the first biographers introduced Kant to Newton's physics, and Gottsched, who connected "moving forces" of the monads with the filling of space (exactly the idea developed by Kant in his *Gedanken* and *Monadologia physica*), GOTTSCHED (1755, I. § 400). See WATKINS (1995).

21 *Discours sur les différentes figures des astres où l'on essaye d'expliquer les principaux phénomènes du ciel* (1732; 1742<sup>2</sup>), in MAUPERTUIS (1768, I, p. 98).

22 *Système de la nature*, in MAUPERTUIS (1768, I, § XIV, p. 147; § XVIII, p. 149); *Lettres*, VIII: "Sur les monades", in Maupertuis 1768, I, p. 264 The German translator of the former work noticed the proximity between Maupertuis and Leibniz in his preface (*Versuch von der Bildung der Körper*. Leipzig 1761, [s.p.], conducted on the first edition titled *Dissertatio inauguralis metaphysica de universali naturae systemate*, Erlangen 1752).

23 See PECERE (2009, p. 82-84, 492); CASINI (2014). Also compare the references to Euler's texts in footnote n. 32 below.

24 FRIEDMAN (2013, p. 130-142).

25 On the latter point see MARINUCCI (2011, p. 49-98). Both D'Alembert and Lagranges mocked the German Academy of Science for the prize competition of 1777 on the "fundamentum virium". See LAGRANGE (1867-1892, vol. XIII, p. 332, 336).

26 Kant's subtle reading of Newton's arguments is most carefully emphasized in FRIEDMAN (1992 and 2013).

27 The action of short-range attractive and repulsive forces is already discussed in the first edition of 1704, with reference to light, but the 1706 edition goes much further, by attributing a role to these kinds of forces for the explanation of the above mentioned phenomena.

28 On the unity of these early works see SCHONFELD (2000).

29 Both the justification of a "complete analysis of the concept of matter" and the definition of motion as a "basic determination" raise some interpretative issues. For a full examination of this methodological background see PECERE (2009, p. 321-343, p. 370-391; for a discussion of the main interpretations, p. 392-446).

30 Synthetic a priori “metaphysical principles” are grounded on the empirical concept of matter, and hence different from transcendental principles. Compare KU, AA 05: 181.

31 The reference is to *Query 31* in NEWTON (1730/1952, p. 400). Note that Kant made reference to *Query 31* in a passage of the essay on the *Negative Magnitudes* (quoted above), where he criticized Crusius precisely for ignoring Newton’s fruitful application of negative magnitudes to attractive and repulsive forces (NEWTON, 1730/1952, p. 395). Here Kant argues, for the first time, that impenetrability cannot be derived by analysis, and depends from a “real opposition”. Crusius can be included among “Lambert and others”, since he claimed that “compensation between substances is unthinkable”. (CRUSIUS 1745, § 402).

32 EULER. *Recherches sur l’origine des forces* (1752), §§ 11-21. In : EULER (1911ss., s. II, 5, p. 114). The same argument can be found in the *Lettres a une princesse d’Allemagne* (1768), n. LXXVII. In: EULER (1911 s. III, 11, p. 166-168).

33 LAMBERT (1771, §§ 81, 94). See FRIEDMAN (2013, p. 121-130).

34 MAN, AA 04, 523-525; 533-535. That the “real” in space must not be regarded as everywhere homogeneous was already argued in a parallel passage of the *Critique* (KrV A 173-174/B 215-216).

35 *Danziger Physik*, AA 29: 106.08-09.

36 Leibniz himself had accused Newton of endorsing a “lazy” philosophy; Fifth writing to Clarke, § 24. In: LEIBNIZ (1717/1957, p. 133).

37 Kant is here making reference to Newton’s method for estimating the mass of the planets in Book III, prop. 8 of the *Principia*, which assumes the proportionality between gravitational force to gravitational and inertial mass (See already NTH, AA 01: 244-245). He also quotes Newton’s denial of the essentiality of gravity, in the *Advertisement* to the 1717 edition of the *Opticks*, which in turn contains a reference to *Query 21*, where gravity is explained mechanically by means of the different density of the ether. See NEWTON (1730/1954, p. 350).

38 KrV B xxii. Copernicus’ astronomy had been considered as an example of a hypothesis in logical lectures (see Log, AA 09: 86; Wiener Logik, AA 24: 887-888; Logic Blomberg, AA 24: 221). In this perspective CAPOZZI (2002, p. 680) underlines the absence of Copernicus’ heliocentrism in the discussion of hypotheses of the Logik Dohna Wundlacken (AA 24: 746-747), which regards lectures of the 1790s.

39 Compare NEWTON (1726/1999, p. 493).

40 Think of Boscovich’s attempt at defending the “law of continuity” and explain the boundary of particles on the ground of point-like monads. The possibility of this kind of mathematical construction is now excluded by Kant’s criticism of its metaphysical presupposition.

41 This was already Kant’s strategy in the *Allgemeine Naturgeschichte* (NTH, AA 01, 262-264). According to Kant, that gravity depends on “God’s immediately sustaining it” was the basic tenet of “those who proclaim themselves to be followers of Newton” (e.g. Bentley) (ND, AA 01: 415.14-16).

42 TUSCHLING (1971) has been the first to point out how Kant was looking for a different model of the conflict of forces. For example, TUSCHLING (1971, p. 100) argues that in *Theorem 1* of the *Dynamics* Kant had postulated a discrete volume, whose explanation depended on the action of the hypothetical ether. Though Tuschling’s analysis is not entirely correct his thesis has stimulated further investigations on the problematic continuity between the *Metaphysische Anfangsgründe* and the *Opus postumum*. Eckart FÖRSTER (2000, p. 48-74), provides an intriguing account of Kant’s research for a new conflict model. I also agree with Förster’s reconstruction that Kant’s understanding of this problem was connected to the problem of the “gap” in the system, which he was intending to fill with the new work. But in my view this would regard not – as Förster argues (p. 70-73) – the already established doctrine of transcendental schematism, but rather the intuitive “exhibition” of general metaphysical concepts – such as “reality” – which had been the systematic objective of the MAN. For my own account see PECERE (2009, p. 667-729). For the gap (*Lücke*) see Kant’s letters to Christian Garve, 21 September 1798 (AA 12: 254) and to Johann Kiesewetter, 19 October 1798 (AA 12: 256).

43 MAMIANI (1991, p. 1-10).

44 Indeed this problem would still be addressed in XX<sup>th</sup> century physics. “Kant’s problem” of a dynamical explanation of mass in the *Metaphysische Anfangsgründe* was explicitly addressed by Hermann Weyl in his field-theoretical physics: “The theory of the fields has to explain why the field is granular in structure and why these energy-knots preserve themselves permanently from energy and momentum in their passage to and from”. This objective – which Weyl later would abandon because of technical difficulties – is connected in a footnote to Kant’s doctrine that “matter fills space not by its mere existence but in virtue of the repulsive force if all its parts” (WEYL, 1921/1952, p. 202-203). A connection of Kant’s dynamism with successive physical theories had been already argued by Marburg Neokantianism (see PECERE, 2007).

45 One example of this method is precisely the inference from impenetrability to fundamental forces of matter, which is presently conceived by Kant as analytical (AA 02: 287).

46 NEWTON 1726/1999, *Scholium generale*, p. 943 (on the sufficiency of Newton's account of gravity and the rejection of hypotheses); NEWTON 1730/1954, *Query* 31, p. 401 (on gravity being manifest and not occult).

47 For an overview of how the concept of force was connected to the issue of the weakness of reason and the ignorance of causes in Cartesian, Newtonian and Lockean traditions see Tonelli 1966. For the example of Maupertuis see TONELLI (1987, p. 8-16, p. 26-27, p. 30-34, p. 92-104, p. 126-130).

48 LAMBERT (1764, § 48, p. 484-485).

49 For the explanation of Kant's logical concepts see CAPOZZI (2002, p. 536-540).

50 These examples are explicitly made in the Wiener Logik, AA 24, 846.

51 See a passage from the *Religion* which, by introducing a parallel between the belief in miracles and scientific cognition, introduces the example of gravity, distinguishing between bottom-up (*abwärts*) and top-down (*aufwärts*) cognition and arguing for the sufficiency of the former – the “secundum quid” explanation of phenomena – and the impossibility of the latter, which is equivalent to the attempt “to have insight into the causes of the forces acting according to these laws” (RGV, AA 06: 88.18-28). Also see KrV A 649/B 677.

52 In this passage Kant is commenting on still another case, that is the concept of organism and the corresponding “formative drive” (according to the hypothesis by J.F. Blumenbach), which we are allowed provisionally to admit insofar as we proceed in our investigations by means of merely mechanical laws.

53 KU, § 88, AA 05: 483. Compare KrV A 613-614/B 641-642.

54 For my full reconstruction of this transition in the development of Kant's thought see PECERE (2009, p. 34-153). Here I argue that the origin of the transcendental turn lies in Kant's giving up the originally Leibnizian project of a metaphysical explanation of space and time. TONELLI (1963) already argued that Kant's turn in 1769 resulted from the difficulty of describing the field of sensible intuitions by means of genus and species, rather than from the discovery of the Antinomies. In the present context, it is important to observe that Kant's first publication of the theory of space and time as forms of phenomena included a reference to a “law of the human mind” (*animi legem*) (MSI, AA 02: 398.19).

55 Thus in one of the last sheets of the *Opus postumum* (dated about 1800) he writes: “Newtonian attraction through the empty space and the freedom of man are reciprocally analogous concepts, categorical imperatives, *ideas*” (OP, AA 21: 35.04-06).<sup>1</sup>

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