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SOMMARIO

KANT AND THE DEMARCATION CHALLENGE: THE BACKGROUND DEBATE ON IMPROPER SCIENCE

Arnaud Pelletier

Abstract · This article explores the historical background of the Kantian demarcation between non-science, improper science and proper science. It is argued that Kant's claim that «a doctrine of nature will contain only as much proper science as there is mathematics capable of application there» ensued after a long series of responses to the demarcation challenge preceding Kant's, which responses attempted to distinguish between proper mathematics and proper natural science. The article suggests that the unusual expression «improper (*uneigentliche*) science» is a direct response to the conception that proper (*eigenthümlich*) natural science is independent of any mathematics. Finally, it defends the notion that this tripartition is already at work in Kant's first articles on physics and that it is this division that lies in the background of the Kantian project to bring metaphysics onto the path of science.

Keywords: Natural Science, Mathematics, Improper Science, Metaphysics, Newton.

The search for a demarcation line between science and non-science is one of the most constant concerns in Kant's writings. In this respect, one immediately recollects the second preface to the *Critique of Pure Reason* in which Kant points to the changes in methods that have established the different sciences in order to conceive of a reformed method that could similarly place metaphysics «on the secure path of a science».[1] A year earlier, in the preface to the *Metaphysical Foundations of Natural Science,* Kant had proposed another demarcation within the sciences themselves, namely between properly called science (or proper science: *eigentliche Wissenschaft*) and improperly called science (or improper science: *uneigentliche Wissenschaft*). Galileo's mathematical physics and Stahl's phlogistic chemistry – which are presented in the *Critique* as examples of illuminations that established the path to science – are, in contrast, distinguished in the 1786 book as proper and improper science, respectively. Kant, thus, implements a fundamental tripartition between non-science, science and proper science. To place metaphysics on the path of a science is to distinguish it both from non-science and from proper science. It is, therefore, not surprising that Kant sometimes compares metaphysics with the processes of chemistry or biological science: these are precisely the sciences that he considers to be improper and that he also distinguishes from both non-science and proper science.

It is commonly agreed that the formulation of these demarcations, and the projects related to them, belong to the critical turn. In this respect, it is legitimate to think of

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[1] Immanuel Kant, *Critique of pure reason*, Cambridge, Cambridge University Press, 1998, p. 107 and 110 (preface B ix and xv). In the following, the abbreviation AA refers to the volume and pagination in *Kants gesammelte Schriften*, edition of the Preußische Akademie der Wissenschaften, Berlin, De Gruyter, 1900. All translations are mine if not otherwise stated.

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the *Metaphysical Foundations* in the immediate context of the *Critique of Pure Reason*. However, the desire to draw a demarcation not only between non-science and science but also between improper and proper science goes beyond the critical context. On the one hand, this demarcation is part of a debate on the role and amount of mathematics in physics spanning the entire 18th century, which is found mainly in the pedagogical textbooks on physics that Kant used for his lectures. On the other hand, this demarcation mirrors an interest that pervades Kant's first articles on natural science in the 1750s – to which after this time he almost never referred again and which are, thus, largely ignored and misunderstood by commentators. This article aims to show that there is a broad but consistent line between Kant's *Metaphysical Foundations* and the pre-Kantian debate on the specific limits of natural science, already mirrored not only in Kant's early text on natural science but also in the background of his project to place metaphysics on the path of a science.

The first section examines how the demarcation proposed in the *Metaphysical Foundations* directly responds, firstly, to Newton's demarcation (and his rejection of metaphysics). The second section recalls the general framework of the debate on the need for mathematics in the natural sciences. The third section indicates how the more particular question of the amount of mathematics necessary within physics is mirrored in the *Metaphysical Foundations*. The fourth section considers the different responses to the demarcation challenge in the physics textbooks in use before Kant. The fifth section proposes a reassessment of Kant's first physics articles in the light of this issue and these debates.

1. Newton and Kant's Prefaces: the demarcation challenge

In his treatise, Newton proposes mathematical principles that describe force-motion relationships, without forging hypotheses about the real nature of the causes of the forces. Newton does not consider *why* mathematical propositions are true but he finds that *this is the case*, namely, that the mathematically knowable fits the empirically knowable. It is a matter of noting that bodies have such qualities and such forces but not of asking why.

Right from the preface of *Principia*, Newton draws boundaries designating the domains of natural philosophy – which he most often simply calls «philosophy». He first distinguishes practical mechanics – which demonstrate how motions are produced by instruments – from rational mechanics – which provide rigorous geometrical demonstrations of the motions of bodies, regardless of particular empirical circumstances, that is, as they apply to all bodies and forces whatever they may be.[1] The whole of natural philosophy is not reduced to rational mechanics alone, and this presents not only problems but also solutions that can then be geometrically treated. Newton states, accordingly, that «*geometry* is founded on mechanical practice»; hence, the ensuing definition:

> Rational mechanics will be the science, expressed in exact propositions and demonstrations, of the motions that result from any forces whatever and of the forces that are required for any motions whatever.[2]

[1] See Isaac Newton, *The Principia. Mathematical principles of natural philosophy*, translated by I. Bernard Cohen and Anne Whitman, Oakland, University of California Press, 1999, p. 234. [2] *Ibid.*, p. 28.

Having established this double perspective on natural philosophy, Newton announces that the treatise «concentrate[s] on *mathematics* as it relates to natural philosophy»,[1] and «consider[s] these forces not from a physical but only from a mathematical point of view».[2] Thus, the principles of natural philosophy that are considered «are not, however, philosophical but strictly mathematical».[3] We can, therefore, summarise this presentation by stating that Newton uses a tripartition to delimit three bodies of knowledge: natural philosophy, rational mechanics and the strictly mathematical principles (of rational mechanics).

It is the status and possibility of this last component that Kant will question in the *Metaphysical Foundations*. The problem for Kant is by no means that Newton's strictly mathematical component ignores the real qualities of the bodies. Newton admits that forces are dependent upon the qualities of the bodies;[4] that immutable qualities can be recognised in the bodies which cannot be increased, decreased or removed, for example, mobility;[5] that other qualities which are perceived as possessing a certain degree in our sense experience can be ascribed through induction to all bodies (for example, hardness, gravity); and that these qualities are the foundation of natural philosophy.[6] Kant's concern is rather to clarify the implicit metaphysics of Newton's *Principia Mathematica* – including within its «strictly mathematical» part. The question is that of the implicit claim within Newton's title: what guarantees the application of mathematics to nature as so successful? And of precisely what must the concept of matter consist for such an application to be possible?

By only using an implicit concept of matter, argues Kant, the physicist risks conveying misconceptions, or of taking for granted – for example, the existence of an absolute space – what is, in fact, only a metaphysical foundation necessary for a certain type of explanation. The fact that Newtonian physicists claim to do without metaphysics is not a conclusive argument for Kant, for they may well be relying upon implicit metaphysical assumptions, even if they do not realise they are doing so:

> Hence 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.[7]

In other words, what Newton calls the «strictly mathematical» point of view – and what Kant also calls «pure mathematics»[8] – does not involve making any metaphysical hypothesis about the nature of the qualities and causes of forces, but it does require clarification of the metaphysical principles that justify the application of mathematics to the appearances of outer sense. The expressions «mathematical physics» or «applied mathematics» are misleading to Kant because they suggest that the application of

[1] *Ibid.*, p. 27. [2] *Ibid.*, p. 234. [3] *Ibid.*, p. 439.

[4] *Ibid.*, p. 234: «For it is reasonable that forces directed toward bodies depend on the nature and the quantity of matter of such bodies, as happens in the case of magnetic bodies».

[5] *Ibid.*, p. 441 (Book 3, Rule 3 for the study of natural philosophy): «Those qualities of bodies that cannot be intended and remitted [increased and diminished] and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally».

[6] *Ibid.*, p. 442: the «least part of all bodies is extended, hard, impenetrable, movable, and endowed with a force of inertia […] is the foundation of all natural philosophy».

[7] Immanuel Kant, *Metaphysical foundations of natural science*, translated by Michael Friedman, Cambridge, Cambridge University Press, 2004, p. 8 (AA 4, 472). [8] *Ibid.*, p. 52 (AA 4, 514).

mathematics, or the junction of mathematics and physics, do not pose any problems. However, mathematics cannot be applied directly to physics without assuming some metaphysical conceptions:

> This small amount [of metaphysics] is still something that even mathematics unavoidably requires in its application to natural science; and thus, since it must here necessarily borrow from metaphysics, need also not be ashamed to let itself be seen in community with the latter.[1]

For Kant, the explanation for this inevitable metaphysics takes the form of «a complete analysis of the concept of a matter in general».[2] By posing the problem of the legitimacy of Newton's title – namely the problem of the application of mathematics to natural philosophy – Kant simultaneously poses a problem of demarcation: not between experimental and rational physics; nor between physics and metaphysics; but between mathematisable (proper) and non-mathematisable (improper) physics. Let us begin with the characterisations of the latter:

> The doctrine of nature can be better divided into *historical doctrine of nature*, which contains nothing but systematically ordered facts about natural things (and would in turn consist of *natural description*, as a system of classification for natural things in accordance with their similarities, and *natural history*, as a systematic presentation of natural things at various times and places), and natural science. Natural science would now be either properly or improperly so-called natural science, where the first treats its object wholly according to a priori principles, the second according to laws of experience. Natural science would now be either *properly* or *improperly* so-called natural science, where the first treats its object wholly according to *a priori* principles, the second according to laws of experience.
>
> What can be called *proper* science (*eigentliche Wissenschaft*) is only that whose certainty is apodictic; cognition that can contain mere empirical certainty is only *knowledge* improperly so-called (*uneigentlich so genanntes Wissen*). Any whole of cognition that is systematic can, for this reason, already be called *science*, and, if the connection of cognition in this system is an interconnection of grounds and consequences, even *rational* science.[3]

It may be noted that the Newtonian tripartition of natural philosophy, rational mechanics and strictly mathematical principles gives way to another tripartition which is not unrelated: the historical doctrine of nature (which is not a science), rational science (which can be improper) and proper science itself.[4] Proper science appears to be the most restrictive specification of a body of cognition through three criteria: systematicity, objective grounding and apodictic certainty.[5] Proper science is not mere knowledge (*Wissen*) endowed with empirical certainty (and, thus, does not belong to a historical doctrine of nature); but it is a system (and thereby is a science, *Wissenschaft*), which provides a rational interconnection of grounds and consequences (and thereby is a *rational* science), which moreover provides apodictically certain cognition by relying on *a priori* principles (and this finally qualifies it as a *proper* science).

[1] *Ibid.*, p. 11 (AA 4, 479). [2] *Ibid.*, p. 8 (AA 4, 472). [3] *Ibid.*, p. 4 (AA 4, 468).

[4] I leave aside here the distinction between natural description and natural history, due to Kant's reading of Buffon. At the end of volume XIV of his *Histoire naturelle*, Buffon devotes a section to the degeneration of animals where he considers non-reversible variations of species, and thus imports into the natural historical project - understood as a description - the consideration of a true historicity. See also: THIERRY HOQUET, *History without Time: Buffon's Natural History as a Nonmathematical Physique*, «Isis», 101/1, 2010, pp. 30-61. In a note in *Of the different races of human beings* (1775), Kant states that «we still lack almost entirely» a natural history (AA 2, 434).

[5] See HEIN VAN DEN BERG, *Kant's conception of proper science*, «Synthese», 183, 2011, pp. 7-26.

On the one hand, the distinction between non-science (*Wissen*) and science (*Wissenschaft*) is rather loose here (where the sole criterion of systematicity is mentioned);[1] on the other hand, the demarcation between science and proper science is extremely restrictive. Thus, according to the Kantian criteria, what are now called political, social or human sciences would be part of a historical doctrine of nature. However, Kant confines himself to the natural sciences alone and mentions a well-known consequence: according to these criteria, phlogistic chemistry – founded by Johann Joachim Becher and developed by his student Georg Ernst Stahl – is certainly a science but an improper science – in reality, so improper that «it should therefore be called a systematic art rather than a science».[2] Chemistry meets all the requirements except the last one: it is systematic; it exposes the rational necessary interaction of matters (I leave aside here the debated question of where the necessity of empirical laws comes from), but it relies on *a posteriori* principles established through experimental practice.[3] The important point is that there is no application of mathematics to the empirical laws of chemistry, that is, there is no mathematical construction of the interactions between the matters.[4]

Through this restrictive conception of proper science, Kant engages in a debate on the foundations of natural science: to those who defend the need for a mathematical or metaphysical foundation, he replies that a metaphysical foundation is required for there to be any application of mathematics. This is his answer to the question: *How* is the application of mathematics possible? Yet this question does not exhaust the debate. It is preceded by two background questions: (1) *Is* mathematics necessary for natural science at all? (2) *How much* mathematics is needed in natural science? It is also in the light of these questions – which alone exceed the framework of the critical philosophy – that we must understand the demarcation challenge.

2. Background question (1): Is mathematics necessary for natural science?

Let us briefly recall here two answers (to the above question) that appeared in 1716, the year of Leibniz's death, in the *Physica Divina* of the Thomasian Andreas Rüdiger, and in the *Mathematisches Lexicon* of Christian Wolff.

There were certainly many points of controversy in evidence between the Wolffians, Thomasians and Newtonians. The major issue was the relationship between physics and metaphysics: Wolff reproached the Thomasians and Newtonians – more than he reproached Newton himself, by the way – noting their proclaimed rejection of any metaphysical foundation actually gave rise to a very bad metaphysics.[5] On the other hand, when it comes to thinking about the possibility of mathematical physics,

[1] I join H. Blomme here when he writes that there is no real or strict systematicity without apodicticity: «When taken in the strict sense, to talk of an empirical system would entail a contradiction in terminis» (Henny Blomme, *Kant's Conception of Chemistry in the Danziger Physik*, in *Reading Kant's Lectures*, edited by R. Clewis, Berlin, de Gruyter, 2015, p. 492).

[2] Kant, *Metaphysical foundations*, *op. cit.*, p. 4 (AA 4, 468).

[3] On chemistry, see: Michael Friedman, *Kant and the exact sciences*, Cambridge, Harvard University Press, 1992, pp. 264-290; Michael Bennett McNulty, *Kant on Chemistry and the Application of Mathematics in Natural Science*, «Kantian Review», 19/3, 2014, pp. 393-418; Martín Arias-Albisu, *The Methodological Prescriptions of the «Appendix to the 'Transcendental Dialectic' of Kant's Critique of Pure Reason and the Foundations of Improper Science*, «Studia Kantiana» 15/2, 2017, pp. 5-26.

[4] Kant, *Metaphysical foundations*, *op. cit.*, pp. 5-7 (AA 4, 469-471).

[5] See Christian Wolff, preface to Stephen Hales, *Statick der Gewächse*, Halle, Renger, 1748 [pp. 3-4].

Wolff sided with the Newtonians against the Thomasians. This is the point we briefly educe.

Indeed, Andreas Rüdiger argues that we are unable to provide mathematical explanations within natural philosophy: Natural science (*Physica*) has to exist without neither mathematical nor metaphysical foundation, will never achieve mathematical certainty and has to be satisfied with probable knowledge. He, thus, opposes what Wolff first called the «mathematical method» and then the «demonstrative method» in philosophy. The reason for this is as follows. For Rüdiger, the principles of nature were instituted by God and remain in part unknowable to us. Physics can, therefore, formulate probable propositions regarding the essence of things, and mathematics – which only deals with quantities – cannot be of any help. Moreover, mathematical physics is harmful to faith and leads to atheism when it forgets that physics is divine. For Rüdiger, however, one should not fall into superstition and idolatry, which would attribute more divinity than is necessary to natural things. This is how the title of the treatise is justified – divine physics is the middle path between atheism and superstition – as well as his astonishing definition of physics:

> Physics is the doctrine by which we probably know the principles, at first sight insensible, that God has used to establish the sensible nature, so that by carefully turning to the natural things we treat, we can respond with a virile assurance to atheists and idolaters.[1]

In agreement with his master, Christian Thomasius, Rüdiger argues that the primitive wisdom of the ancient Hebrews, including with regard to physics, has been gradually obscured and corrupted throughout history – mathematical physics being only the most recent of all these corruptions.[2] Why, then, is mathematics inadequate for physics? The reason is that mathematics provides genetic explanations, that is, it can explicate how figures are produced in geometry and how numbers are generated by addition in arithmetic so that all the consequences can be deduced from these genetic explanations.[3] This model can be compared to the Leibnizian characterisation of a real definition as a (either *a priori* or *a posteriori*) demonstration of the possibility of the essence of a thing.[4] Except, for Rüdiger, precisely this kind of genetic explanation is impossible for natural things, the genesis of whose essence remains beyond the reach of mathematics.[5] Physics remains a probable doctrine and there is no metaphysical or mathematical foundation to remedy that.

Facing this assertion of the inadequacy of mathematics and physics, Wolff points out that mathematics is necessary if only to understand certain phenomena: «Without geometry and arithmetic», he writes, «neither the natural laws of motion nor the

[1] Andreas Rüdiger, *Physica divina, recta via, eademque inter superstitionem et atheismum media ad utramque hominis felicitatem, naturalem atque moralem ducens*, Frankfurt, Andreae, 1716, Book 1, Chapter 1, Section 4, § 77, p. 28.

[2] *Ibid*., p. 2 and 63. See Martin Mülsow, *Idolatry and Science: Against Nature Worship from Boyle to Rüdiger, 1680-1720*, «Journal of the History of Ideas», 67/ 4, 2006, pp. 697-712; Arnaud Pelletier, *Philosophie pour le monde et sagesse hors du monde: Les limites de la revendication éclectique chez ChristianThomasius*, «Dialogue», 57/4, 2018, pp. 695-717.

[3] Rüdiger, *Physica divina*, *op. cit.*, I, 1, § 67, p. 24: «Possunt [mathematici] determinare genesin figurae, & ex hac genesi, tanquam primo figurae factae principio, omnium consectariorum dependentiam ostendere.»

[4] Leibniz, *Philosophical Essays*, translation R. Ariew and D. Garber, Indanapolis, Hackett, 1989, p. 26.

[5] Rüdiger, *Physica divina*, *op. cit.*, I, 1, § 68, p. 24: «At hoc ipsum in physica nullatenus procedit doctrina. Nam geneses rerum naturalium in hominis potestate haud sunt, nec ab hominibus ullum vel abjectissimum ens naturale fieri potest.»

power of forces can be known» and for this reason he advocates a greater use of mathematics in disciplines that are precisely known as «applied mathematics» (*angewandte* or *anbegrachte Mathematik*), namely artillery, mechanics, hydrostatics and some others.[1] In doing so, he assumes a common nominal division between pure mathematics – which deals with imaginary or fictitious entities, that is, with things in the mind and not with things that actually exist outside the mind – and mixed mathematics, which deal with things outside the mind from a mathematical point of view. In his *Mathematisches Lexicon*, he distinguishes, on the one hand, pure, simple or *proper* mathematics and, on the other hand, impure, mixed or *applied* mathematics: «*Mathesis pura sive simplex, die eigentliche Mathematik*» (which corresponds to geometry, arithmetic and algebra); «*Mathesis impura sive mixta, die angebrachte Mathematik*».[2] Thus, the natural sciences are part of applied mathematics, that is, mixed in the sense that they contain both a proper mathematical part and a non-mathematical part.

The very name of mixed mathematics, thus, raises not only the problem of the articulation of the two parts (the question *how?*) but the question of the respective quantities of both parts: *how much* proper mathematics in natural philosophy? This question is well reflected in the central claim of Kant's preface.

3. *Nur so viel Wissenschaft*: two readings and one claim

Indeed, the most famous claim in the preface to the *Metaphysical Foundations* is as follows:

> I assert, however, that in any special doctrine of nature there can be only as much *proper* science as there is *mathematics* therein (*Ich behaupte aber, daß in jeder besonderen Naturlehre nur so viel* eigentliche *Wissenschaft angetroffen werden könne, als darin* Mathematik *anzutreffen ist*).[3]

There are two possible ways to interpret the quantitative restriction of *nur so viel* (translated by *only as much* in English). The first is to interpret it as meaning *nur genauso viel*, that is, as exactly identifying the amount of proper science with the amount of mathematics: «there can be exactly as much proper science», and so on. The second is to interpret it as meaning *nicht mehr als*, that is, as indicating the maximum threshold of proper science that can possibly be found in a doctrine of nature: «there can be no more proper science», and so on. If we are attentive to the modalities of the sentence, we must infer that the amount of mathematics which *is actually* to be found (*anzutreffen ist*) determines the amount of proper science that *could* [*possibly*] be found within it (*angetroffen werden könne*). Moreover, if we are even more attentive, we observe that this modality is removed at the end of the paragraph and that an exact correspondence between the proportion of mathematics and the actual (and no longer «possible») proportion of proper science itself is established:

> And, since in any doctrine of nature there is only as much proper science as there is a priori knowledge therein, a doctrine of nature will contain only as much proper science as there is mathematics capable of application there (*Und da in jeder Naturlehre nur so viel eigentliche Wis-*

[1] Christian Wolff, *Anfangsgründe aller Mathematischen Wissenschaften anderer Theil, welcher die Artillerie, Fortification, Mechanick, Hydrostatick, Aerometrie und Hydraulick in sich enthält*, Halle, Renger, 1757, p. 748.

[2] Christian Wolff, *Mathematisches Lexicon*, Leipzig, Gleditsch, 1716, respectively col. 868 and 866.

[3] Kant, *Metaphysical Foundations*, *op. cit.*, p. 6 (AA 4, 470).

senschaft angetroffen wird, als sich darin Erkenntniß a priori befindet, so wird Naturlehre nur so viel eigentliche Wissenschaft enthalten, als Mathematik in ihr angewandt werden kann).[1]

The modality has changed between both statements: what could be found (*angetroffen werden könne*) becomes what will be contained (*wird enhalten*) and is actually applied (*angewandt kann*). It could be argued that the transition from one statement to the other is not so much a transition from a maximum limit to an exact overlap but rather a transition from the simple possibility of applying mathematics (*antreffen*) to the real application of mathematics (*anwenden*). In fact, between these two statements, Kant has explained the meaning of the condition thus posed: by mathematics, we must not understand a discipline in the strict sense (for instance, Wolff's proper mathematics) but rather a cognition by means of constructing concepts in pure intuition (and independently of any sensitive intuition).[2]

However, regardless of Kant's internal reasons for ultimately interpreting the claim as meaning *nur genauso viel*, the two readings at least agree that there is no proper natural science beyond the applicability of mathematics. However, this claim («*Ich behaupte aber*») must be read in the light of an external debate on the genuine character of natural science beyond the applicability of mathematics. In fact, it is a common question, which is systematically addressed in the prefaces of the German physics textbooks of the 18th century, which more or less all bear the title *Principles of Natural Philosophy* (*Anfangsgründe der Naturlehre*).[3] The question is first and foremost pedagogical: how much mathematics is it necessary to introduce in order to teach physics to a beginner? However, this question then meets that of the limits of the concept of *Naturlehre*, which does not yet have commonly fixed boundaries.

In what follows, I translate *Naturlehre* as natural science, knowing that no uniform translation is possible since the challenge of the debate is precisely to delimit a broad sense (which can correspond to historical doctrines) from a narrow sense (which, sometimes but not always, corresponds to mathematical physics).

4 Background question (2): How much (applied) mathematics is required in (proper) natural science?

Kant taught physics courses from three textbooks: Johann Peter Eberhard's text (1753) was used in the 1750s and 1760s, Johann Christian Polycarp Erxleben's text (1772) was used for six courses given between 1776 and 1788, and Wenceslaus Johann Gustav Karsten's text (1783) for the 1785 course. The question of the role and quantity of mathematics is explicitly addressed at the beginning of these treatises.

On the one hand, Erxleben warns that he discloses only the simplest mathematical knowledge required for the basic elements of physics but that a thorough discussion of the natural science (*Naturlehre*) would require much more mathematics.[4] He then raises the issue of boundaries:

[1] *Ibid*.

[2] See Konstantin Pollok, *Kants 'Metaphysische Anfangsgründe der Naturwissenschaft'. Ein kritischer Kommentar*, Hamburg, Meiner, 2001, p. 84.

[3] The term «principles» (*Anfangsgründe*) does not refer here to *mathematical* principles, but to *introductory* (sometimes non mathematical) elements.

[4] Johann Christian Polycarp Erxleben, *Anfangsgründe der Naturlehre*, Göttingen und Gotha, Dieter-

But where are the limits of natural science and mathematics? Pure mathematics considers the quantities only separately; the bodies it deals with are only *abstracta*; applied mathematics, however, is actually composed of the different parts of natural science and only considers, as much as can be done, quantity in the bodies around us. Natural science cannot really exist without mathematical doctrines, and its considerable extensions are due to the mathematicians.[1]

This simple claim is completed by a bibliographical reference to Kästner's *Anzeige seiner nächsten Vorlesungen über Mathematik und Physik* (Göttingen, 1768). Abraham Gotthelf Kästner – to whom Erxleben dedicated the *Anfangsgründe* – holds a more radical thesis. In the text in question, republished under the title *Ueber die Verbindung der Mathematik und Naturlehre* in which he justifies the joint teaching of physics and mathematics, Kästner defends that a part – and only a part – of *Naturlehre* is called applied mathematics.[2] The designation of applied mathematics is justified by the fact that it has been possible to establish connections between phenomena from the experiments to determine causes and effects and to deduce (*herleiten*) a number of consequences even beyond the phenomena that were initially observed. In other words, apart from applied mathematics, the doctrine of nature is only a collection of observations or experiments, as is the case for electricity or the magnetic doctrine: «Except for applied mathematics, we know almost nothing for certain other than what experience immediately teaches us and what one can infer from it».[3] The real knowledge of natural things is then identified with their mathematical knowledge:

So without mathematics, one can get to know precisely and usefully nothing considerable of nature: And if one cannot teach anything that one does not understand properly, then one cannot teach others in any part of the natural sciences without mathematical insights.[4]

If we now turn to Karsten, the first thing he says in his preface is that he is satisfied that he has been able to convince at least some colleagues not to confuse *Naturlehre* with applied mathematics anymore, and, in particular, he regrets that this confusion has led to the unjustified exclusion so far of chemistry from natural science – in particular the new anti-phlogistic, pneumatic chemistry he exposes.[5] This statement, thus, opposes Erxleben and testifies to the fact that *Naturlehre* did not have fixed boundaries in Germany in the 1780s. Indeed, in the preface to his previous manual, entitled with no originality *Anfangsgründe der Naturlehre* (Halle, 1780), Karsten begins by refusing this habit of confusing what he called two sciences:

It has long been customary that in the manuals of natural science almost everything is exposed, only under a different name, which must also be dealt with in the textbooks of applied mathematics.[6]

ich, 1772, preface. Eberhard held very close views: on the one hand, he claims to set geometrical demonstrations aside as much as possible, on the other hand he acknowledges «that physics without geometry is like a body without soul» (Johann Peter Eberhard, *Erste Gründe der Naturlehre*, Erfurt and Leipzig, Renger, 1753, preface, s. p.). Consequently, he distinguished between *Naturlehre* - which addresses the cause of forces - and applied mathematics - which is concerned with the measurement of forces (*ibid.*, Einleitung, § 3, p. 4).

[1] *Ibid.*, Einleitung in die Naturlehre §3, pp. 2-3.

[2] Abraham Gotthelf Kästner, *Vermischte Schriften* Altenburg, Richter, vol. 2, 1771, p. 87.

[3] *Ibid.*, p. 88.

[4] *Ibid.*, p. 91.

[5] Wenceslaus Johann Gustav Karsten, *Anleitung zur gemeinnützlichen Kenntniß der Natur, besonders für angehende Aerzte, Cameralisten und Oeconomen*, Halle, Renger, 1783, pp. iv-viii.

[6] Wenceslaus Johann Gustav Karsten, *Anfangsgründe der Naturlehre*, Halle, Renger, 1780, preface.

Karsten refers to a confusion that has long been the case but is no longer so widespread: in fact, both Eberhard and Erxleben distinguish between *Naturlehre* and applied mathematics. However, where both recognise the latter as part of the former, Karsten sees them as two distinct sciences: *Naturlehre* establishes the properties (including quantitative properties) of bodies by means of experiments and provides an explanation thereof; but the mathematical theory of the measurements and calculations of phenomena are up to the mathematicians.[1] With this separation of disciplines, what properly (*eigenthümlich*) constitutes natural science must be independent of a mathematical theory and must, therefore, be presented independently:

> Perhaps it is possible to gradually arrive at a situation where a textbook of natural science is dedicated – either entirely or for the most part – only to those doctrines which are proper to science (*solche Lehren, die der Wissenschaft eigenthümlich sind*). […] After leaving aside all that is dealt with under the name of mathematics, there would be nothing left of natural science except the doctrines of fire, electricity, magnetism, and a few others.[2]

The proper *Naturlehre* can, thus, integrate – contrary to the view held by Erlxeben – doctrines where no sufficient regularities can be derived (*herleiten*) from the phenomena so that they actually resist the application of mathematics. The magnetic doctrine is given again as an example, for no regularity in the magnetic declination could have been observed to this point, and, therefore, no mathematical theory thereof. It may seem astonishing to consider that the proper part of natural science is precisely that which is out of the reach of mathematics. The main idea, however, seems to gather not only the doctrines that are *not subjects* of applied mathematics yet but also the *non-mathematical* core of the other parts of applied mathematics. This would roughly correspond to what Kant calls rational improper science, namely, the rational articulation of grounds and consequences concerning the phenomena, whether or not it is a subject of applied mathematics. In accordance with this conception, Karsten even evokes the idea of a physics textbook entirely devoid of mathematics:

> For this reason, I have been very inclined for some time to try once to make a manual of natural science, which should not contain any applied mathematics but only what is proper to natural science (*nur das eigenthümliche der Naturlehre*). Because I had to fear, however, that such an arrangement (...) would not be welcomed; I have thus stuck to what is now commonly received.[3]

It is, therefore, this project to denounce the abuses (*Mißbrauch*) of applied mathematics in *Naturlehre* to which he still refers in 1783.[4] However, the essential feature this time is no longer a separation from mathematics but to convince that the three commonly received parts of the *allgemeine Naturlehre* – which he calls: Natural history, chemistry and physics (or *Naturwissenschaft*) – must no longer be considered as separate sciences but, on the contrary, as interconnected.[5]

In this debate, it is clear that what Karsten identifies as proper to natural science corresponds to what Kant will call improper science (which their different assessments of chemistry show). Karsten – although he suggests that his position is marginal – is

[1] *Ibid.*, Section 1, § 22, p. 16.
[2] *Ibid.*, preface.
[3] *Ibid.* It can be assumed that Karsten does not think of a simple introduction for children, such as the works of the very prolific Johann Heinrich Samuel Formey (*Abrégé de toutes les sciences à l'usage des enfans de six ans à douze*, Potsdam, 1764-1778; *Abrégé de physique*, Berlin, 1770-1772).
[4] Karsten, *Anleitung*, *op.* cit., preface, p. iv.
[5] *Ibid.*, p. ix and xv.

neither the only nor the first to have, thus, delimited the proper core of natural science by seeking the causes of phenomena. Johann Andreas Segner had already stated that the very broad concept of natural science in general (*Naturlehre überhaupt*) refers to two things: on the one hand, the collection of all properties and changes in bodies that can be sensed (called *Naturgeschichte*); and on the other hand, the establishment of a connection between the grounds (*Gründe*) of those properties and the effects one can derive from them, which is then called natural science in the strict sense (*Naturlehre im engern Verstande*). Thus:

> Either one is content with noticing [the qualities and changes in sensible bodies] and thereby with placing the bodies in different classes; or one also seeks the ground of that which is perceived in the bodies and tries to derive their effects from it. Those observations make up natural history […]. But the propositions which impart to us the ground of these qualities, and which make understandable the effects of the bodies, belong to natural science taken in the narrow sense.[1]

To conclude this overview, I would like to suggest that Kant's claim in the preface also aims to put an end to the different responses to the demarcation challenge. This old debate had continued because the boundaries of *Naturlehre* were not fixed. Thus, the preface does not merely respond to Newtonians (who think they are giving up metaphysics in the natural sciences); nor to Thomasians (for whom there is no mathematical natural science because no genetic explanation is possible); nor to those whom, on the contrary, identify natural science with applied mathematics (since Kant conceives mathematical knowledge as the possibility of a construction of concepts in intuition, providing a kind of equivalent to the genetic knowledge for which the Thomasians were asking); but also to those who conceive that the proper part of the *Naturlehre* is understood as the general, rational conceptual core of the explanation regardless of the pure empirical evidence and of its exact mathematical expression. It is perhaps explicitly in reaction to those who see this as the proper (*eigenthümlich*) part that in 1786 Kant used the unusual expression «improper (*uneigentlich*) science». Nonetheless, the concern for a critical delimitation between proper and improper science dates back to Kant's first articles on the physics of Earth and the Heavens.

5. Reassessing Kant's early articles in light of the demarcation challenge

In this last section, I simply indicate that the status of the articles that Kant wrote around the *Theory of the Heavens* (1755) has often been misjudged as a result of failing to take the demarcation challenge into account. I defend the view that even if Kant at the time did not have the distinction between proper science and improper science (simply because he did not have his new characterisation of mathematical knowledge), those articles explicitly display Kant's reflections on the impossibility of a proper scientific treatment of some questions in natural science, which, therefore, only belong to the *Naturlehre* in an improper sense. In this respect, these articles already manifest Kant's interest in a 'critical' delimitation between non-science, improper science and proper science.

[1] Johann Andreas Segner, *Einleitung in die Naturlehre*, Göttingen, Vandenboeks, ³1770, § 3 (and similarly in the first edition of 1746, § 2, p. 2).

I will limit myself here to three articles: *Examination of the Question whether the Rotation of the Earth on its Axis* (1754); *The Question, Whether the Earth is Ageing, Considered From a Physical Point of View* (1754); *On the Causes of the Earthquakes, on the Occasion of the Calamity that befell the Western Countries of Europe towards the End of Last Year* (1756).[1]

A commonly shared interpretation reproaches these articles for not being scientific «enough», thus, demonstrating that Kant does not have any real scientific competence and for containing improbable, even absurd propositions. This is Erich Adickes' interpretation. He suspects that the valid (sometimes revolutionary) propositions attributed to Kant – for example his argument in favour of the slowing down of the Earth's axial rotation, which he was the first to correctly formulate – are not scientific achievements properly speaking but rather astute hypotheses. In addition, he criticises Kant for only being interested in subjects upon which no experimental verification can be carried out to confirm - but also to refute - his hypotheses. He concludes that Kant lacked the «constitution of mind» to be scientific in the true sense[2] and that many of his errors testify to the fact that he was *only* a philosopher:

> The fact that his efforts failed at some points or even brought him into conflict with the laws of mechanics, and that some errors, miscalculations, false assumptions were made, simply indicate that he did not approach his task as a natural scientist but as a natural philosopher.[3]

Without in any way sharing the same arguments, Eric Watkins points out that all these articles do not fall within the very restrictive meaning that Kant belatedly gives to (proper) science: «Many of these writings do not, technically, count as natural science for Kant».[4] Watkins also recalls that the very word *Naturforschung* can be understood in the broader sense of an investigation of nature. This is correct, but I think it should be noted that the common denominator of all his articles is precisely to indicate that the issues addressed – which were topical issues – can only relate to *Naturlehre* in the broad sense and not to natural science in the narrow sense or to what he then calls the «obligations of a natural scientist». Thus, the question of the ageing of the Earth is, of course, not *addressed* from a strictly mathematical point of view in the manner of Newton,[5] nor is it *addressed* from a physical point of view but it is *examined* from the physical point of view: it is a question of examining the preliminary issue of the possibility of its proper scientific treatment. The first obligation of the *Naturkündiger* is indeed to determine whether the question meets the usual requirements of the experimental and theoretical physics. Kant asserts explicitly that those questions are not to be answered from a proper scientific point of view:

> I have reflected on this question, and since I have considered it only from its physical perspective, I have recently tried to draw up my thoughts on this matter, while realizing that by the [very] nature of the question this perspective cannot bring it to that degree of perfection which the prize-winning treatise must have.[6]

[1] For more details, see my presentation of those articles in Kant, *Principes métaphysiques de la science de la nature, suivis des premiers articles sur la physique de la terre et du ciel*, Paris, Vrin, 2017, pp. 237-377.

[2] Erich Adickes, *Kant als Naturforscher*, Berlin, de Gruyter, vol. II, 1925, p. 483 (§ 389): «The view that Kant, in the whole constitution of is mind, was not at all a scientist in the true sense of the word (*durchaus kein Naturwissenschaftler im eigentlichen Sinn*) has been confirmed everywhere.»

[3] *Ibid.*, p. 489.

[4] Eric Watkins in Immanuel Kant, *Natural science*, edited by Eric Watkins, Cambridge, Cambridge University Press, 2012, p. xviii.

[5] Newton, *op.* cit., Book 1, Def. 8, p. 54.

[6] Kant, *On the rotation of the Earth* (1754), in *Natural science*, *op. cit.*, p. 160 (AA 1, 185).

I have not treated the question posed about the ageing of the Earth decisively (*entscheidend*), as would be required by the enterprising spirit of a sanguine *Naturforscher*, but critically (*prüfend*), as is required by the very nature of the question.[1]

The *Naturforscher*'s obligation to the public is to give an account of the insights yielded by observation and investigation. I do not propose to satisfy this obligation in its entirety, and leave it to that person, *if such a one should arise*, who can claim to have observed the Earth's interior with exactness.[2]

Kant advocates here a critical physics, which examines a range of possible but non-exclusive hypotheses in the light of theory and observations, given the very lack of reliable data and, thus, of a possible mathematical treatment. It is rightly called *critical* (*prüfend*) to the extent that it addresses the demarcation challenge. In fact, this physics is explicitly separated from natural history on one side and a dogmatic physics on the other side, which aims hastily, but also arbitrarily, at deciding (*entscheiden*) on these matters. In this way, it precisely attains the place of the late improper science, between natural history and proper science. In doing so, Kant can rightly present himself «as a physicist» (*als Naturkündiger*)[3] examining issues from a physical point of view: he opens a perspective that is neither that of the natural philosopher nor that of the natural scientist (in the true sense of the word as he determines it) but that of the *improper* natural scientist.

Conclusion

In this article, I have attempted to reconstruct the historical perspective pertaining to the central claim of the *Metaphysical Foundations'* preface. I argued that Kant was well aware of the different responses to the demarcation challenge and intended to put an end to it. I suggested that the unusual expression of «improper science» was a direct response to Karsten's conception of a proper natural science that was independent of any mathematics. If the boundaries of the *Naturlehre* had been so discussed, it was because a single delimitation of non-science and science was not enough, and a third term had to be introduced between improper science and proper science. The background debate was indeed filled with tripartitions: natural philosophy, rational mechanics and strictly mathematical principles (Newton); natural history, *Naturlehre* and applied mathematics (Erxleben, Karsten, Segner – though with different articulations); and the historical doctrine of nature, rational science and proper science (Kant). Finally, I have suggested that this tripartition between non-science, science and proper science was already at work in Kant's first articles and should not be forgotten when it comes to understanding the Kantian project of bringing metaphysics onto the path of science.

[1] Kant, *Whether the Earth is ageing* (1754), in *Natural science*, *op. cit.*, p. 181 (AA 1, 213).
[2] Kant, *On the causes of earthquakes* (1756), in *Natural science*, *op. cit.*, p. 330 (AA 1, 419). My emphasis.
[3] Kant, *Whether the Earth is ageing* (1754), *op. cit.*, p. 169 (AA 1, 197).

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