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Elastic force in Kant's early works

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Abstract
This paper argues that the notion of elastic force is an important and overlooked thread running through a number of Kant's writings from 1754 to 1764. After presenting the historical context, I argue that the key aspects of Kant's early understanding of physical elasticity can be found in *On Fire* (1755) and show how Kant attempts to explain a wide range of phenomena through elasticity. On my account, one aim of his account of physical monads is provide metaphysical grounds for elastic phenomena. Finally, I examine Kant's hints that minds can be understood through an analogy with elastic physical phenomena.

Keywords: Kant, precritical period, natural philosophy, *On Fire*, elasticity

La fuerza elástica en los primeros trabajos de Kant

Resumen
Este artículo defiende que la noción de fuerza elástica es un importante hilo conductor que se ha pasado por alto en un número de escritos kantianos desde 1754 a 1764. Tras presentar el contexto histórico, explicaré que los aspectos cruciales de la temprana comprensión kantiana de la elasticidad física se encuentra en *On Fire* (1755), y mostraré cómo Kant trata de explicar una gran cantidad de fenómenos a través de la elasticidad. A mi juicio, uno de los objetivos de su reflexión sobre las mónadas físicas es el de facilitar la base para los fenómenos elásticos. Finalmente, examinaré la sugerencia de Kant de que las mentes pueden ser entendidas a través de una analogía con los fenómenos físicos elásticos.

Palabras clave: Kant, periodo pre-crítico, filosofía natural, *On Fire*, elasticidad

Introduction

Between 1754 and 1764, Kant wrote on a remarkably wide range of topics for very diverse audiences. In the local Königsberg weekly newspaper, which primarily published small adverts for buying, selling and borrowing goods, Kant serialised essays on the rotation and age of the earth and on the causes of earthquakes.[2] He issued pamphlets, advertising his lectures, on other natural-philosophical topics and on logic. The subjects of books Kant published over the decade include a "Newtonian" account of the formation and constitution of the universe, the possible grounds of the proof of God, and the introduction of negative magnitudes into philosophy.[3] He wrote three Latin works to meet formal requirements at the University of Königsberg, on the nature of fire, metaphysical principles of

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[2] These essays appeared in the *Wochentliche Königsbergische Frag- und Anzeigungs-Nachrichten* in 1754, nos. 23-24 and 32-37 and 1756, nos. 4-5 and 15-16. My citations of Kant's works generally follow the Cambridge edition, modified where I consider necessary. Translations of other foreign-language primary and secondary texts, if no translation is listed in the bibliography, are my own.
[3] In addition, Kant published the *Observations on the Feeling of the Beautiful and the Sublime* (1764), a short book in a primarily anthropological vein that I will not discuss here.

cognition, and physical monads. Kant submitted an essay to the Berlin Academy prize competition on the methods of metaphysics and mathematics, which resulted, in 1764, in his first publication outside Königsberg.

Commentators have often considered whether any common thread runs through this apparently eccentric assortment of early works. Michael Friedman and Martin Schönfeld propose a narrative that unifies the precritical period, according to which Kant attempts to fuse the results of Newtonian natural science with metaphysical foundations that fundamentally transform aspects of Leibnizian-Wolffian metaphysics (Friedman 1992: 1-52; Schönfeld 2000).[4] This usefully highlights Kant's early interest in natural philosophy, to which he dedicated more published pages than to metaphysics in 1754-1764. However, Friedman's and Schönfeld's broad narrative of Kant's early "Newtonianism" risks obscuring themes that run through the early works but fit less easily into the opposed paradigms of Newtonian physics and Leibnizian-Wolffian metaphysics, as typically understood.

This paper will trace one such theme through Kant's early writings. It is striking how often in these works Kant refers to elasticity or elastic force [*Elastizität, elastische Kraft* or *Federkraft*] or uses examples of elastic phenomena. Kant conceives of air as a fundamentally elastic medium, and its elasticity is key to his accounts of fire, winds and the sun. His explanations of earthquakes present the earth, like the sun, as self-active from within. The *Physical Monadology* (1756) concludes with an account of the metaphysical basis of elastic media. Kant even toys with presenting minds as analogous with elastic physical phenomena. I will present an account of Kant's writings from 1754-1764 that shows the significant role that Kant accords to elastic force for explaining a diverse range of phenomena. A central text for understanding Kant's early interest in elasticity is, on my account, his short Latin dissertation *Meditationum quarundam de igne succincta delineatio* (1755, hereafter *On Fire*).

The paper is divided into six sections. Section 1 provides a brief overview of how elastic force has been treated in the literature on Kant's precritical natural-philosophical works. Sections 2 and 3 set out what I take to be the most important natural-philosophical context for *On Fire* and Kant's early discussions of elastic force. This is, firstly, seventeenth-century experimental work on the elastic "spring of the air" (section 2) and the debates on whether Leibniz's principle of equipollence is transgressed by the phenomenon of fire (section 3). Section 4 presents Kant's 1755 account of fire, which I consider key to understanding Kant's broad conception of elastic force: I show that it has the structure of what Kant will later call "relative spontaneity". In section 5, I discuss how Kant attempts to explain various physical phenomena through elastic force in subsequent works of 1754-1764. This culminates in another little-known text, a 1764 review of a book by Johann Esaias Silberschlag, which gives a sense of how Kant thought the explanatory function of physical elasticity could be raised to the "heights of metaphysics" in order to explain various physical phenomena. Finally, section 6 turns to Kant's short-lived account of spontaneous *mental* activity as analogous with the spontaneity of elastic physical phenomena. Although Kant would soon thereafter (in 1766) reject such an analogy between physical and mental spontaneous forces, the passages reveal an intriguing aspect of Kant's early interest in physical elasticity and relative spontaneity.

1. Elastic force in scholarship on Kant's early natural philosophy

The literature on Kant's early writings has not emphasised Kant's early concern with elasticity. Schönfeld makes merely passing references to elastic force in his account of Kant's precritical period (see Schönfeld 2000: 47, 84-5, 112, 169). He dismisses *On Fire* as "neither scientifically sound nor

[4] I discuss aspects of Friedman's more nuanced later account below.

philosophically important" (Schönfeld 2000: 84). For a study that reflects Kant's regular references to physical elasticity, we must go back to Erich Adickes' magnum opus on Kant's natural-scientific writings, *Kant als Naturforscher* (1924/25). However, despite noting the many points at which Kant refers to elastic phenomena,[5] Adickes does not discuss elasticity as a recurrent theme in Kant's early works. We can turn briefly to Adickes' study to see that his oversight is due to a presupposition guiding his account of Kant's natural science, a presupposition that still informs some current scholarship.

The second volume of *Kant als Naturforscher* dedicates two hundred pages to Kant's "general ether theory" and specific phenomena including heat, fire, light and magnetism (Adickes 1925: 3-205). Although Kant considers the ether to be an elastic medium, Adickes explicitly discusses elasticity only in relation to "the problem of elasticity" (1925: 140). The "problem" is here the strictly natural-scientific one of explaining how physical bodies can be elastic.[6] In his long discussion of *On Fire*, which notes the role of the elastic matter of fire, Adickes includes a discussion of theories of elastic phenomena among Kant's contemporaries, and foregrounds the question of whether they can be mechanically explained. Most natural scientists took elastic force to be a derivative cause, which was in general explained mechanically; Musschenbroek fought against the mechanical theory, but offered no alternative, claiming there was not enough empirical data to determine the issue (Adickes 1925: 37). For Adickes, Kant's "*Theorie der Elastizität*", if it had been fully realised, was a "hermaphrodite" [*Zwitterbildung*], eclectically combining these earlier views (1925: 38).

Whilst revealing that Kant consistently discusses heat, air and fire in terms of elasticity in his early works, then, Adickes reduces Kant's discussions to the question of whether the phenomena of elastic bodies can be explained on a broadly mechanical basis through an ether theory (1925: 141-2). He fails to note that Kant's regular references to elasticity are not restricted to the attempt to explain elastic *bodies*, but instead appear in reflections on a wide range of topics, including air, fire, the sun, monads and even minds. Adickes overlooks the breadth of Kant's conception of elasticity arguably because the central question of *Kant als Naturforscher* is whether Kant is a *Naturwissenschaftler* or a *Naturphilosopher* (1924: 5). Adickes argues that Kant should be considered a natural philosopher, and although he says some positive things about this approach,[7] he generally judges Kant harshly for not being a natural scientist, particularly for failing to sharply determine concepts, which is the "conditio sine qua non" of the method of mathematical physics (1924: 25).[8] It is certainly true that the concept of elasticity that appears in Kant's early writings does not meet the standards of clarity of nineteenth-century mathematical physics. Nevertheless, it is in this broader natural-philosophical, not natural-scientific, sense that Kant employs the term in 1754-64. I will contend that Kant's early interest in elasticity deserves attention on its own terms, rather than being

[5] For example, alongside his account of Kant's ether theory, Adickes discusses the role that elastic air and the elastic force of fire plays in Kant's description of the sun in the *Universal Natural History*, and notes that Kant's theory of winds is based on a conception of air as a sea of elastic matter possessing a *Federkraft* (1925: 276, 329).

[6] Adickes draws on the distinctions that Kant makes in the later *Metaphysical Foundations of Natural Science* (1786) between expansive elasticity (a body returning to its original size after compression) and attractive elasticity (a body returning to its original size after being stretched) (1925: 141; see MAN AA 04: 529-30). The explanation of these elastic phenomena in the General Remark to the Dynamics chapter of the *Metaphysical Foundations* is a narrow problem in comparison to the way Kant uses the term in his early works.

[7] As a natural philosopher, Adickes affirms that Kant had a "deductive and architectonic-constructive mind", an "extraordinary force of synthesis" and a "capacity to discover similarities, inner connections" among apparently disparate things (1924: 40, 51).

[8] "Because [Kant] did not think in clear formulae, his thoughts often wandered aimlessly here and there, commingling completely different things without consciousness of their variety. Thus emerged, in place of the distinct determinateness of true natural science, in which one knows without anything further what is meant, an unclear vagueness [*unklare Verschwommenheit*]" (Adickes 1924: 29). See Adickes' criticism of Kant's ambiguous use of the term "moment" (1924: 29). His conclusion stresses Kant's "great terminological indeterminacy", which even extends "to the *termini technici* of mechanics (like moment, force and so on)" (1924: 483).

dismissed as unscientific or subsumed under the question of the existence or non-existence of the ether.[9]

Adickes' approach persists in some recent scholarship. Having claimed that *On Fire* is neither scientifically nor philosophically significant, Schönfeld states that it is only of interest in relation to "the question which it raises about Kant's Newtonian conversion […] How was it possible for Kant to be a Newtonian and to endorse the ether?" (2000: 84). Schönfeld is interested in the Latin dissertation on fire only insofar as it aligns with his narrative of Kant's Newtonianism, and he is thus drawn, like Adickes, to read *On Fire* only in terms of whether Kant supported the ether theory.

Two recent studies that take seriously Kant's early interest in elasticity are by Michela Massimi, and Massimi and Silvia De Bianchi. Massimi provides an innovative account of the influence of a tradition of "speculative Newtonian experimentalism" on Kant's works of 1755, an influence that does not primarily stem from the Newton of the *Principia*, but rather "the much more controversial Newton of the *Opticks*, who ruminated on chemistry and on the possible ether-mechanism behind chemical phenomena" (2011: 541). This reaches Kant, on Massimi's account, via the Leiden school (including 's Gravesande, Musschenbroek and Boerhaave) and, particularly, Stephen Hales (2011: 536). These experimental Newtonian chemists and life scientists "dealt with the matter of fire, wondered about the elasticity of air, and believed in an ethereal fluid as the repository of repulsive force (interchangeably with air)" (Massimi 2011: 541). I will discuss Hales, as a particularly important influence on Kant, in section 2.

Massimi and Bianchi claim, with reference to works published before and after the period that I will consider – namely, *Thoughts on the True Estimation of Living Forces* (1747) and the *Metaphysical Foundations of Natural Science* (1786) – that "a central aspect of Kant's view of nature" is that "the natural power that bodies would possess in their state of rest – which would explain both their ability to *resist* penetration by other bodies and their ability to *cause* motion in other bodies – is nothing but some primordial elasticity" (2013: 488). On their account, Kant sought to identify the physical cause of primordial elasticity over the years following the *True Estimation*: "Kant embarked on a journey to investigate the physical cause of elasticity in air (particularly through the experiments of Stephen Hales on vegetable and animal fermentations) as well as in some primordial fine cosmic matter (in *Universal Natural History*)" (2013: 488). In what follows, I will build on these suggestive but brief indications in the papers by Massimi and Bianchi to provide an account of Kant's reflections on elasticity in 1754-64.[10]

Friedman's commentary on the *Metaphysical Foundations* contains a section on "matter as an originally fluid and elastic medium" that argues, like Massimi and Bianchi, for a connection between Kant's early interest in elasticity and the matter theory of the *Metaphysical Foundations*. Friedman notes the significance of *On Fire* for Kant's early account of elastic media (2013: 134-6, 140). He identifies a break between 1756 and 1786 in Kant's move from the *Physical Monadology*'s conception of an original elasticity located in discrete force-centres, to the account in the *Metaphysical Foundations* of matter as an elastic continuum in which all the parts of space occupied by matter exert expansive force (2013: 138-42). My discussion will not here extend to the *Metaphysical Foundations* as I consider Kant's early reflections on elastic forces worthy of close attention in their own right.

[9] It seems to be an anachronistic, nineteenth-century scientific perspective that leads Adickes to subsume Kant's various discussions of elastic phenomena to the question of an "ether theory". At the time Adickes wrote *Kant als Naturforscher*, the notion of ether had fairly recently been experimentally and theoretically disproved by Michelson and Morley and Einstein. Adickes' focus on Kant's affirmation of the ether – a key example of a pseudoscientific notion at the time he was writing – may well be an attempt to support his central claim that Kant had a philosophical, not a natural-scientific disposition (1924: vi, 4-5).

[10] Excepting a brief discussion in section 3, I will set aside True Estimation and its concern with the proper calculation of the results of elastic and inelastic physical collisions. For more on elastic force in *True Estimation*, see Howard (forthcoming).

2. The elastic force of the air in eighteenth-century natural philosophy

Christian Wolff's textbooks and dictionaries of the physical and mathematical sciences show the broad conception of elastic force that was common in the period. Elasticity was considered not only a property of bodies that can be stretched or compressed but a property of a broader class of physical phenomena including, most notably, the air. In his 1716 *Mathematisches Lexicon*, Wolff defines elastic force as the force of a body to strive to expand, and to actually expand when resistance is removed from it.[11] Alongside this corporeal elasticity, the entry points to the significance of the term for the science of "aerometrie". Wolff states that elasticity is one of the primary properties of air and thus the basis of many effects in nature. Wolff's early *Aerometrie elementa* (1709) examines experiments on air pressure and provides a similar definition of elastic force.[12] The *Anfangs-Gründe aller Mathematischen Wissenschafften* (1710) and the abbreviated *Auszug* (1717), which Kant used as his textbooks for the mathematics and mechanics lectures that he taught from 1755 to 1763, discuss the *elastische* or *ausdehnende Kraft der Luft* in the aerometrie chapters (Wolff 1710: 885; 1717: 266). Johann Georg Walch's *Philosophisches Lexicon* (1726) follows the definition in Wolff's *Mathematisches Lexicon* almost to the letter, but adds more detail on experimental results (1726: 703-5).

Both Wolff and Walch refer to Otto de Guericke's experimental work with air pumps, and Wolff's *Deutsche Experimentalphysik* (1727) devotes over 350 pages to air-pumps, the properties and effects of the air, and the air concealed in bodies (Wolff 1727: 107-460). Kant had a direct interest in this experimental tradition. He owned Boyle's *Opera varia* (1677), which contained a Latin translation of the *New Experiments Physico-Mechanical, Touching the Spring of the Air* (1660) (see Warda 1922: 33). Boyle's treatise takes it as a matter of fact that "the air hath a notable elastical power" (1772: 44). A more obscure source, highlighted by Hans-Joachim Waschkies, is the German translation of Guilleame Amontons' *Von einigen Eigenschaften der Luft* (1748), a study of properties of the air and the thermometer, which Kant cites in preparatory work for *On Fire*. The translator's introduction to Amontons' book states that "one should imagine the air as if compounded of innumerable small springs [*Federn*] furnished with an expansive force" (see Waschkies 1994: 171).

Stephen Hales' *Vegetable Staticks* (1727) is a particularly significant source for Kant's reflections on elastic force. Kant owned the 1748 German translation, and refers to it in no less than five works of 1754-1756.[13] Hales' book is a compendium of his experiments, through which he attempts something like a Newtonian physics of the "force of the Sap" and the way that plants "imbibe and perspire" moisture (Hales 1727: iii, ii; see also 358). Having found that plants absorb a lot of air, Hales is led to dedicate by far the largest chapter of *Vegetable Staticks* to an "analysis of the air" with a particular focus on its elastic nature (Hales 1727: iv; 155-317). He writes in the preface that

> there is diffused thro' all natural, mutually attracting bodies, a large proportion of particles, which, as […] Sir *Isaac Newton* observes, are capable of being thrown off from dense bodies by heat or fermentation into a vigourously elastick and permanently repelling state: And also of returning by fermentation and sometimes without it, into dense bodies; It is by this amphibious property of the air, that the main and principle operations of Nature are carried on. (Hales 1727: v)

[11] "Elater, vis elastica, die elastische Kraft ist die Kraft eines Körpers, dadurch er sich weiter auszudehnen trachtet, auch würcklich ausdehnet, wenn der Wiederstand gehoben wird" (Wolff 1716: 577).
[12] "*Elater est vis, qua corpus compressum cessante, vi comprimente ad eam reducitur molem, quam ante compressionem obtinuerat, aut certe ad majorem ea, quam in statu compressionis habuerat*" (Wolff 1709: 8).
[13] See Warda 1922: 28. Kant refers to Hales in FEV, AA 01: 208; NTH, AA 01: 326; DI, AA 01: 381; PND, AA 01: 407-8; GNVE, AA 01: 457. Martin Carrier seems mistaken to claim that "[o]ffenbar sind Kant die Experimente Hales' und die durch diese eingeleitete vermehrte Gewichtung der Repulsion im Newtonianismus unbekannt" (Carrier 1990: 172n11). Waschkies emphasises the importance of Hales for *On Fire* (1994: 172-3, 191-2).

The "amphibious property" of the air is the fact that it has an expansive elasticity but can nevertheless be compressed by fermentation or heat into a fixed state (see also Hales 1727: 315). Hales' regular references to Newton are almost always, as in this passage, to Newton's more speculative remarks on the forces of particles and the ether in the *Opticks* (see Massimi 2011). Whereas Newton limits his discussion of "elastick force" to the Queries of that work ([1730] 1952: Query 21, 352; see also Query 31, 387, 395-396), Hales makes elastic air central to his account because he considers it the vehicle for nature's "main and principle operations". Hales concludes that as air, "found so manifestly to abound in almost all natural bodies", is "so operative and active a principle in every chymical operation" that we might "with good reason adopt this now fixt, now volatile Proteus among the chymical principles, and that a very active one" (1727: 315-316). Kant had such an interest in this tradition of experimental research into the elasticity of air that he had his own "Elaterometer" built, with which he (unsuccessfully) sought to conduct his own experiments.[14]

3. Fire and Leibniz's principle of equipollence

A further important context for Kant's claims in *On Fire* is the debates around fire in relation to Leibniz's principle of equipollence. This principle, which Leibniz introduced in 1676, states that in any causal series the entire effect must be equal to the full cause (see Mercer 2004: 434-435; Lærke 2015: 123-130). It was in Leibniz's view a "law of nature" that should lead to progress in physics and in his new science of dynamics (Antognazza 2009: 173-174, 249-250).[15] The phenomenon of fire seems to threaten the principle, as Leibniz acknowledged in a letter to Malebranche, published in the *Nouvelles de la république des lettres* in July 1687: "[i]t is true that in composite things a small change can sometimes bring about a great effect. So a small spark, for example, which falls into a large mass of gunpowder can demolish an entire city". Leibniz's letter does not clarify the issue, merely stating that this can be "explained by [his] general principles" (Leibniz 1989b: 353).

The problem of whether fire transgresses the principle of equipollence inspired the Paris Academy of Science's 1738 essay prize on *La nature et la propagation de feu*, among the winners of which was Euler (see Adickes 1922: 334; 1925: 67-68). In his contribution, Euler argues that fire is the result of an external force freeing the highly subtle, elastic matter of fire that is compressed inside the tiny parts of bodies (Euler 1752: 5-21; see Adickes 1922: 336-337).[16] Euler distinguishes the matter of fire from the ether or the matter of light: the former is much finer and more elastic. The matter of fire is explosively freed from its bounds, and it flings the particles of the part of the body in all directions like projectiles. The matter of fire bursts out with ever-greater strength, triggering the same process in other tiny parts of the body (Adickes 1922: 336-337). In this way Euler seeks to account for the apparent imbalance between cause and effect in the case of fire, through an internal, spontaneous process that is merely initiated by an external force.

[14] Kant's friend and early biographer Wasianski describes in detail the construction and failings of this device. It is called an "Elektrometer" in the printed version of Wasianski 1804. However, Adickes points out that the term is changed throughout by Wasianski in his personal copy to the term "Elaterometer" (1924: 8n1). This fits Wasianski's description of it as an "air-elasticity-meter" [*Elastizitätmesser der Luft*]. Wasianski notes that Kant had the Elaterometer made around ten years before Wasianski began to assist Kant (Wasianski 1804: 249). This could either refer to the early 1760s or the late 1780s: Wasianski first assisted Kant as his amanuensis around 1773-4, then became his daily helper in 1799 after Kant was forced to dismiss his servant Lampe (Wasianski 1804: 195).

[15] For the claims about the "law of nature" and its utility for physics and dynamics, see the letter to Bayle of 9 January 1687, quoted by Antognazza, and the "Preliminary specimen" to the *Dynamica de Potentia et Legibus Naturae Corporeae* (1689/91) in Leibniz 1989a: 106.

[16] Boyle has a similar account in *New Experiments, touching the Relation betwixt Flame and Air* (1672), which was translated in the *Opera varia* that Kant owned. See Massimi 2011: 533n68.

Kant's familiarity with Leibniz's principle of equipollence is evident in his first work, *Thoughts on the True Estimation of Living Forces* (1747).[17] In the third chapter, Kant introduces "vivification" as an attempt to explain what happens when bodies change from possessing *potential* moving force (dead force) to *actual* moving force (living force). Without entering into the complexities of Kant's discussion we can note that, on his account, bodies with living force can sustain their own motion indefinitely on the basis of their "inner striving" (GSK, AA 01: 143-144). Living force is thus for Kant an internal, self-active force that grounds a body's motion. Kant then provides a complex account of vivification, in which a body infinitesimally accumulates "elements" of immanent striving.[18] What is important for our purposes is that a body with living force "does not get this force from the *external cause* that had set the body in motion, but rather that, after the external *trigger* [*Anreizung*], this force has its source in the body's *inner natural force* itself" (GSK, AA 01: 148, my emphasis). Kant here attempts to ensure that the principle of equipollence is not transgressed when the force of a body shifts from dead to living force. He does so by claiming that the external force is not a cause but merely a "trigger", and that the living force springs from forces internal to the body.[19] Indeed, in his first work Kant is consistently concerned with adhering to Leibniz's "great law of mechanics that *effectus quilibet aequipollet viribus causae plenae* [any effect has the same power as the forces of its complete cause]" (GSK, AA 01: 106).[20]

4. Elasticity and equipollence in *On Fire*

These two contexts – experimentally-based conceptions of the elastic force of the air and the debates on whether fire transgresses the principle of equipollence – are key to Kant's claims in his short Latin dissertation, *On Fire*, submitted to the Albertina in Königsberg in 1755. The treatise seeks to explain the nature of fire on the basis of a fundamental elastic matter.[21] Kant claims that "every body consisting of solid parts is held together by some elastic matter [*materia […] elastica*] as the bond of its unity" (DI, AA 01: 375). This elastic matter connects particles in a body and is the intermediary through which particles press or pull upon each other.[22] Kant seeks to prove that "this elastic matter, which is present between the elementary parts of a fluid body, is nothing other than the matter of heat [*materiam caloris*]" (DI, AA 01: 372). By extension, the matter of heat is the matter of fire (DI, AA 01: 376). The matter of heat or fire is glossed further as "the ether (the matter of light) compressed by a strong attractive (adhesive) force of bodies into their interstices" (DI, AA 01: 377). The elastic matter of fire is thus the ether, held by attractive forces between particles of a body.

Kant's account is similar to that of Euler's Paris Academy prize essay in depicting an elastic matter of fire bound between tiny parts of a body. Given Kant's esteem for Euler, it is highly likely

[17] Kant's first book attempts to resolve the *vis viva* controversy between Cartesians and Leibnizians about the proper measure of force in physical collisions. On the Cartesian view, force should be measured by the product of the quantity of matter and the velocity: in modern notation, mv. For the Leibnizians, force is the quantity of matter times the *square* of the velocity: mv^2. Leibniz named the Cartesian measure, mv, "dead force", and his own measure, mv^2, "living force". For a detailed account, see Schönfeld 2000: 17-35.

[18] Kant outlines his theory of vivification in §§117-124 (GSK, AA 01: 141-148).

[19] Earlier in the work Kant carefully distinguishes triggering or occasioning from causality: "Although this exertion of mechanical force […] has been *triggered* [*veranlaßt*] by the force transferred into body *B*, it still is not an *effect* [*Wirkung*] of this force. *We must very carefully avoid the conflation of these two aspects.* […] [T]he motion that is produced is not the real effect of force, which actually only occasioned it, and consequently it can still be greater than this motion without violating the fundamental law of mechanics" (my emphasis; GSK, AA 01: 103).

[20] Massimi and Bianchi show that Mairan's dispute with Du Châtelet and the former's view that "springiness [*ressort*] is a true machine of nature" inform Kant's concern in *True Estimation* with elasticity and the Leibnizian principle of equipollence (2013: 488-490). In my view, Massimi and Bianchi's claim that Mairan's position is a "critique of the Leibnizian principle" underestimates the extent to which Leibniz himself posited elasticity as the ground of the self-movement of bodies, as they partly acknowledge (2013: 491, 490n56); see Howard (forthcoming).

[21] For the historical background to what Adickes calls the "Stoff- oder Substantialitätstheorie" of heat, which contrasts with the "Vibrations- oder Bewegungstheorie" that later became dominant, see Adickes 1922: 329-51.

[22] Propositions IV and V characterise this elastic matter through the laws of physical elastic bodies. On Kant's atomism in this text, see note 43 below.

that he read the latter's prize-winning essay.[23] It is in direct contrast to Euler, however, that Kant equates the matter of fire with the ether or matter of light.[24] He provides three justifications for this: firstly, that dense bodies attract light, bodies always collide with the matter of light, and the matter of light is elastic and so can be compressed into the interstices of bodies; secondly, that there is a correlation between the capacities of bodies to refract light and to absorb heat; and thirdly, that the transparency of glass might indicate that it contains a large quantity of the matter of light, which could result from the long burning process by which it is produced (DI, AA 01: 377-8). Kant's justifications refer to the authority of Newton, through two references to the *Opticks*, and Euler, through a reference to his *Nova theoria lucis et colorum* (1746), in order to defend a view that runs counter to Euler's own account of fire.[25]

Kant diverges further from Euler by linking fire to the conceptions of elastic air discussed above. Vapours are important to Kant's account: these "particles torn from the surface of fluids" possess the "remarkable and peculiar property" that the particles "strongly repel each other" (DI, AA 01: 379-80). This means that "it is the nature of vapours […] to show elastic force" (DI, AA 01: 382). Air is such an elastic vapour, reduced to the "maximum subtlety" or the greatest distance between particles, and with a "strong elasticity" (DI, AA 01: 382). Kant defines flame as the ignition of vapour, which frees the elastic matter of heat from the interstitial attractive forces of bodies: "[f]lame is […] vapour brought to that degree of fire that it flashes with light and goes out only when there is insufficient fuel" (DI, AA 01: 383). This fuel is oil, "which, by virtue of its elastic motion [*motui elastico*], serves as its most active principle" (DI, AA 01: 383). Kant is yet further from Euler in his account of the ignition of vapour and the function of oil: Euler considers the matter of heat, once freed from its bounds within the body, to be sufficient to explain fire. Oil plays a dual role in Kant's treatise: he proposes that it is "the bond, as it were the glue, of concrete bodies, indeed the true magnet of etherial matter which holds all bodies together";[26] and, once the body is ignited and the matter of heat escapes, oil fuels the body's flame (DI, AA 01: 377).

A key aspect of Kant's account of fire, which he does adopt from Euler, is the idea that elastic repulsive forces overcome the attractive, interstitial forces of bodies when the body is ignited. But Kant's description is more complex as he contends that the matter of fire escapes from its bounds between the body's particles and greatly expands in the form of vapour. This ignited elastic vapour, with the elastic motion of the oil that serves as fuel, produces the phenomenon of flame.

Like Leibniz and the contributors to the Paris Academy of Science's 1738 essay prize, Kant is concerned with the question of whether fire transgresses the principle of equipollence, because a small spark can lead to a great conflagration: "at first glance this phenomenon appears opposed to the basic law of mechanics that the effect is always equal to the cause" (DI, AA 01: 383-4). However, he adds:

> One should not wonder that the effects of a little cause should be so immensely great, for the spring of the confined ether, when freed in this manner from the bonds of attraction, surpasses the effect; and one recognizes that the kindling [*sollicitationem*] [of fire in another body] by a small flame is *not, properly speaking, the cause* [of these great effects]; they depend upon the attraction of oil, the subtile division

[23] For Kant's esteem for Euler, see for example his letter to him of 1749, not included in the Academy edition: Kant 1999: 45-46.
[24] Friedman points out that Kant refers to Euler's wave theory of light when equating the matter of heat with the ether (DI, AA 01: 378; Friedman 2013: 135n51). Friedman does not however note that Euler distinguishes the matter of heat from the ether in his prize essay on fire.
[25] On the references to Newton and Euler, see the editors' notes in Kant 2012: 713n10-12. Kant's references to Newton may well be based on Hales 1727: 300.
[26] DI, AA 01: 382. Kant follows the contemporary view that the active principle of oil is acid, which he also calls, with reference to Hales, a "salty principle" (DI, AA 01: 381).

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> of its enclosed matter giving occasion for its liberation with great violence [*semet magna violentia expediendi copiam fecit*] (DI, AA 01: 384, my emphasis).

The cause of fire on Kant's account is not merely the spark that ignites it. It is also the attractive force that holds the matter of heat between the particles, and the elastic force that seeks to escape these bonds. If these forces, invisibly operative within the body at rest, are taken into account, then the cause and effect are equal in the case of fire, and Leibniz's metaphysical principle is not transgressed. It is the inner forces of a combustible body, and particularly the elastic force or "spring of the confined ether", that explains how the effect appears to exceed the cause, in the case of the fire that develops from a small spark.

We can note that Kant's explanation of how fire conforms to the principle of equipollence proceeds by ascribing a spontaneous quality to flammable bodies that can be called "relative spontaneity". The distinction between absolute and relative spontaneity, which is now a commonplace in the literature, is drawn in Kant's metaphysics lectures of the late 1770s (V-Met-L1/Pölitz, AA 28: 267-270).[27] Absolute spontaneity is unconditioned – "self-activity from an *inner principle* according to the power of free choice" – whereas relative spontaneity [*spontaneitas secundum quid* or *spontaneitas automatica*] is self-causality but "under a condition". A thing with relative spontaneity "moves itself according to an inner principle", but "the inner principle [is] determined by an external principle" (V-Met-L1/Pölitz, AA 28: 267). Kant's usual example is "a turnspit, which, when once it is wound up, also accomplishes its movements of itself" (KpV, AA 05: 97; see also V-Met-L1/Pölitz, AA 28: 267). The air, the matter of heat and other "spring-like" physical phenomena are spontaneous in this relative sense, as they require an external impetus, but, in order to make up the full cause of the resulting effect, an internal activity must be added to this external one.

As a natural-philosophical account of fire, the Latin treatise was a mixed success, even for its time.[28] What is important for our purposes is the explanatory role of elastic force in the treatise.[29] The elastic force in *On Fire* is not the strict notion of elasticity as used in modern physics, which designates the capacity of physical *bodies* to return to their original shape after being stretched or compressed. Rather, the 1755 dissertation conceives of elastic force as a broader property of the matter of heat, the ether, vapours and air. Furthermore, the notion of elastic force provides a basis for Kant to explain how there can be natural reactions in which the effect appears to be greater than the cause, without this transgressing the principle of equipollence. The next section will examine how, over the decade following *On Fire*, Kant extended the explanatory scope of the notion of elastic force to various other natural phenomena.

5. Elastic forces of various physical phenomena in Kant's works of 1754-1764

Almost simultaneously with the submission of his Latin dissertation on fire, Kant published the *Universal Natural History and Theory of the Heavens* (1755). This ambitious cosmogony and cosmology seeks to explain the formation and structure of the universe on the basis of Newtonian mechanical principles. The opening chapters describe the first formation of matter, planets, moons and comets. Chapter seven is followed by a supplement, titled "General Theory and History of the

[27] Wilfred Sellars was among the first to foreground relative spontaneity in Kant: Sellars 1970: 23. See also Allison 1990: 60-64; Sgarbi 2012.
[28] See Adickes' critical evaluation in Adickes 1925: 1-77, particularly 10-15, 21-25, 34-36, 59-60, 69-77.
[29] In emphasising elastic force I diverge from Adickes and Jeffrey Edwards who foreground the concept of the ether in their accounts of *De igne*. I consider that it is elasticity, as the defining property of the ether or the matter of heat or fire, that is most important to the treatise's argument. I discuss Adickes' position in the Introduction, above; Edwards foregrounds the ether due to its significance for the "ether proofs" of the *Opus postumum* and Edwards' central notion of a material transcendental condition. See Edwards 2000: 117-118.

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Sun in General". Kant considers why the "middle point of the attraction" in a planetary system has to be a "fiery body" (NTH, AA 01: 323). He ascribes to the sun's fire the same characteristics that earthly fire possesses in the Latin dissertation: it "is *active out of itself* instead of diminishing or exhausting itself by transference […] [it] thereby acquires more strength and fierceness and thus requires only material and feeding for its maintenance in order to continue on and on" (NTH, AA 01: 325, my emphasis). The fire of the sun is fed by the "elastic force of the liquid element of air" (NTH, AA 01: 326). As with *On Fire*, Kant bases his explanation on elastic forces *inside* the body, in this case the sun.[30] Kant discusses the concern that the sun will use up the air that surrounds it, and he speculates that the sun contains deep chasms or caverns, in which air is locked and periodically released to stoke the sun's fire, and "matters […] like saltpetre" inside the sun's caverns that "are inexhaustibly productive of elastic air" (NTH, AA 01: 326). In this picture, the sun is a self-active source of heat at the centre of the planetary system, driven by the elastic nature of air.

In 1756 Kant published three essays on earthquakes, in response to the Lisbon earthquake of November 1755. This event is famous for spurring thinkers, notably Voltaire, to question the philosophical doctrine of optimism; but Kant's contributions display his interest in elastic forces and spontaneous activity in nature. He locates the source of earthquakes in "subterranean conflagrations" (GNVE, AA 01: 445), or the "fire of the subterranean vaults" (FBZE, AA 01: 465). The second essay ruminates on the "beneficial effects from this subterranean fire", one of which is the gentle warming of the earth from within, the other being that volcanos provide "a certain active principle, volatile salts […] [and] an immeasurable amount of sulphurous vapours", which "enter into the composition of plants, to move and develop them" (GNVE, AA 01: 447f). The earth, like the sun of the *Universal Natural History* and again drawing on *On Fire*'s account of fire, is spontaneously active from within.[31]

A similar idea appears in Kant's 1754 essay on the question of whether the earth is aging. Kant considers four possible opinions on the reason for the earth's aging, and guards against too hastily rejecting the fourth: that "the ever-effective force, which, as it were, constitutes the life of nature, and which, although imperceptible to the eye, is active in all generation and the economy of all three realms of nature, gradually becomes exhausted" (FEV, AA 01: 211). This would be a "subtle though universally active matter which, in the products of nature, constitutes the active principle" and Kant contends that this is "not so opposed to sound natural science and observation as one might think" (FEV, AA 01: 211). This active principle is evident in the *spiritus rector* of the chemists and the "volatile acid […] which constitutes the active principle in most kinds of salts, the essential part of sulphur and the leading principle of the combustible element of fire", which the second earthquake essay claimed to be provided by volcanos to the advantage of plants (FEV, AA 01: 212).[32] Although Kant does not here refer to elastic force, the "active principle" of fire is precisely the elastic matter of the 1755 Latin dissertation.

In extending his reflections on fire to various other physical phenomena, Kant echoes aspects of Du Châtelet's entry to the 1738 Paris Academy competition.[33] Kant's specific account of

[30] Kant's explanation of the sun is far removed from Wolff's. Wolff considers sunbeams not to be warm themselves, and to only heat bodies on earth by merely setting in motion the matter of heat that is already present in the body. Wolff makes a sharp distinction between the matter of light, which emanates from the sun, and the matter of heat (a distinction that Euler retains in his *Dissertatio de igne*, as noted above). Kant does not follow this in the works of 1755. See Wolff 1723: 193-5.

[31] Waschkies notes that a relation between the elasticity of air, fire and earthquakes is already proposed by Guilleame Amontons (1994: 171-172).

[32] Kant goes on to call this active principle the "Proteus of nature": he may well be drawing on Hales, who writes of air, after his discussion of its elasticity: "may we not with good reason adopt this now fixt, now volatile Proteus among the chymical principles, and that a very active one, as well as acid sulphur […]?" (Hales 1727: 316).

[33] Du Châtelet's contribution was published alongside those of Euler, Lozeran du Fiesc, Crequy, and Voltaire in the *Recueil* of 1752. Kant does not refer to Du Châtelet's essay in *On Fire* – nor does he refer to Euler's prize-winning entry – but, as *True Estimation* reveals, he was well aware of her work (see GSK, AA 01: 67-68, 92, 124, 128, 130-133).

fire does not seem to have been influenced by Du Châtelet's essay on its nature and propagation,[34] but his claims about the sun and the earth are similar to her broader speculative claims about fire. Du Châtelet claims that there is a "central fire" in every body and every point in space: "this fire contained in the bosom of all bodies vivifies them, animates them, fertilises them, maintains the motion between their parts, and prevents them from condensing entirely" (1752: 167). Fire is thus "a spirit of life that animates [matter]" (Du Châtelet 1752: 113).

In the context of Kant's interest in broadly elastic phenomena in 1754-55, we can reread the *Physical Monadology* (1756) as an attempt to provide a metaphysical basis for physical elasticity. The work develops Baumgarten's notion of a monad as a physical point, to depict monads as dynamical spheres of activity. On the basis of fundamental repulsive force and a corresponding attractive force, Kant explores various properties of physical bodies.[35] The final proposition of the text is that "[t]he elements of a body, even when they are posited on their own, possess a perfect elastic force which is different in different things; and they constitute a medium which is, in itself and without the admixture of a vacuum, primitively elastic" (MoPh, AA 01: 486). The elements or physical monads that make up *all* bodies are elastic, and they constitute an elastic medium.

Whilst there is a great difference between the atomism of *On Fire* and the dynamic physical monadology of 1756, in both cases Kant seeks to conceptualise an elasticity at a fundamental level of bodies.[36] The corollary to Proposition XIII states that elements can "be compressed, and they constitute bodies which can also be compressed […] This is the origin of the bodies or media which are elastic. And among such bodies one may already legitimately include aether, that is to say, the matter of fire" (MoPh, AA 01: 487). Kant seeks to explain elasticity, not in the narrow sense of elastic physical bodies but as a broad notion that includes the ether or matter of fire of the Latin dissertation. The *Physical Monadology* can therefore be considered an attempt to provide a metaphysical basis for the spontaneous elastic force of the various physical phenomena addressed in Kant's essays of the period.[37]

An idea of the way that Kant might have hoped to ground natural-scientific knowledge on his physical monadology can be gleaned from his *Review of Silberschlag's work: Theory of the fireball that appeared on 23 July 1762*, published in the *Königsbergsche Gelehrte und Politische Zeitung* in 1764. On Kant's account, Silberschlag has an account of corporeal substances that echoes Kant's own physical monadology: "the presence of corporeal substances in space is actually a sphere of activity that has a dynamical sphere and a centre point" (AA 08:450). Silberschlag seeks to establish this, according to Kant, "[t]hrough reasons that seem very significant but insufficiently developed" (AA 08:450). Kant summarises the physical phenomena that Silberschlag seeks to explain on the basis of his dynamical conception of physical substance:

[34] Du Châtelet takes positions that Kant will oppose: she claims that heat and light are independent of one another (1752: 119), implies that fire can be equated with heat when discussing the fire contained by the "spirit of wine" and by water (1752: 114), gives a very different account of the emergence of fire (1752: 122), and claims that fire is not the cause of elasticity but destroys it (1752: 142).

[35] Proposition IX thereby explains contact; X, determinate volume; XI, mass or inertial force; and XII, differences in density.

[36] On Kant's shift in early 1756 from an atomistic to a dynamic conception of matter, see Adickes 1924: 162-163; 1925: 9-10.

[37] This overlooked aim of the *Physical Monadology* does not replace but rather supplements what are more commonly taken to be the work's aims. Kant seeks to contribute to the early eighteenth-century debates around the possibility of physical monads on a methodological level, by reconciling the geometrical understanding of space, as infinitely divisible, with the monadological doctrine of indivisible simple substances (MoPh, AA 01: 475). Eric Watkins notes that an easily-overlooked aspect of Kant's "official solution" to the problem of physical monads is that he is "trying to articulate in a detailed way how the spatial and physical properties of bodies are supposed to be derived from (metaphysical) forces" (2005: 110, 112). Beyond Watkins' discussion, which is tied to his general concern with causality, I propose that we take seriously that the *Physical Monadology* concludes with the physical property of elasticity. Friedman makes a similar point when he argues that the "striking corollary" with which the *Physical Monadology* ends implies that "Kant intends the metaphysical theory of 1756 to fit together smoothly with the physical theory of 1755" (2013: 137).

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> From the differences between these spheres and the forces that act in them, he derives elasticity, density, the oscillation of the air and the aether, the tone, the light, colours and warmth, and similarly also the attraction of matters, according to the [specific] differences of the substances. All of this is applied to air and its changes […] (AA 08:450).

In addition, Silberschlag seeks to explain mists, fog, clouds, and rain, and divides the regions of air, from lowest to highest: the dust atmosphere, the watery atmosphere, "then the phlegmatic and phosphorescent atmosphere, which contains oily, resinous and rubbery parts, and is the workshop of shooting stars, fireballs, and fiery meteors", and "finally, the spiritual atmosphere […] in which the very extensive fiery air, such as the Northern Lights, is produced" (AA 08:450).[38] The phenomena that Silberschlag explains are physical, but Kant nevertheless notes approvingly that, in a manner "unusual for natural scientists", Silberschlag "feels compelled to take a path into the heights of metaphysics" (AA 08:450). We can take Kant's enthusiasm for Silberschlag's treatise to indicate its proximity to Kant's own ambitions at this time: the elucidation of many phenomena through the forces underpinning physical elasticity.[39]

There is therefore a common thread running through the apparently heterogeneous and eccentric works of 1754-1764, which has not been recognised in the literature. Kant is consistently concerned with the explanation of physical phenomena on the basis of elastic forces, drawing on experimental research into the properties of air and applying the theory of fire set out in his short Latin dissertation. Kant explains the phenomena of the sun and of earthquakes alike on the basis of the elastic forces of air. He approves of Silberschlag's attempt to explain the full range of atmospheric phenomena on the basis of the dynamic forces of elements. From this perspective, the *Physical Monadology* can be understood as an attempt to ground elastic forces in the more fundamental forces of physical monads. In each case, Kant is concerned with the basis of a relative spontaneity in nature, in which hidden forces inside bodies allow us to explain how effects can exceed their apparent causes without transgressing the principle of equipollence.

6. From physical elastic forces to mental spontaneity

This is not, however, the end of the story. In passages in works of 1755 and 1763, Kant draws an intriguing connection between this conception of elastic force and the activities of minds, which he at this point understands on broadly Leibnizian lines. Kant will not retain this position after 1766, but it is nevertheless a noteworthy moment in the development of his thought.

The *New Elucidation of the First Principles of Metaphysical Cognition* (1755) brings together physical and mental forces in what at first sight is a very different context: an exploration of the principle of sufficient reason, or as Kant calls it after Crusius, the determining ground (see Watkins 2005: 112-113). At the end of section two Kant argues that the principle entails that the "quantity of absolute reality in the world" (PND, AA 01:407) is unchanging, because there is nothing in an effect that was not in its cause. This is defended through an example of a collision between two elastic bodies; as with the *Physical Monadology*, we can consider Kant's interest in these metaphysical questions to be in part motivated by a desire to explain elastic physical phenomena. Kant notes that these very elastic phenomena might be taken to disprove the principle of the

[38] Kant had already used the notion of elasticity to explain atmospheric phenomena in the notes on the winds that advertised his 1756 summer semester lectures: the earth's atmosphere is depicted as "a sea of fluid, elastic material" (TW, AA 01: 491). The preface to the *Universal Natural History* similarly presents winds as a result of a property of the air: it moves "through its elasticity and mass" between warmer and cooler regions (NTH, AA 01: 224).

[39] Watkins notes in his editorial introduction that "[w]hile it is uncertain exactly what motivated Kant to respond to this work in this way, the review is clearly positive" (Kant 2012: 409): my account offers a reason for Kant's positive review.

conservation of absolute reality, because "[v]ery frequently we see enormous forces issue from an infinitely small initiating cause", such as the explosion of gunpowder or the burning of forests as a result of a tiny spark. Kant repeats the explanation we have seen in other early works:

> In these cases, however, the efficient cause of the enormous forces is a cause which lies hidden within the structure of bodies. I refer, namely, to the elastic matter either of air, as in the case of gunpowder (according to the experiments of Hales), or of the igneous matter, as is the case with all inflammable bodies whatever. The efficient cause is, in these cases, unleashed [*manifestatur*], rather than produced, by the tiny stimulus. Elastic forces which are compressed together are stored within; and if these forces are stimulated just a little, they will release forces which are proportionate to the reciprocal pressure exercised in attraction and repulsion (PND, AA 01:407-408).

Again, the calculus of cause and effect must take into account the immanent elastic forces that require only a small stimulation to explode out of the attractive forces that constrain them.

Kant now goes further when seeking to forestall a second objection: that our *mental capacities* could transgress the law of the conservation of absolute reality in the world:

> Certainly the forces exercised by spirits and the perpetual advances of these forces to higher perfections seem not to be governed by this law. But they are, in my opinion at least, nonetheless subject to [it]. Without doubt, the infinite perception of the entire universe, which is always internally present to the soul, albeit only obscurely, already contains within itself all the reality which must inhere in the thoughts, which are later to be illuminated in a stronger light (PND, AA 01:408).

Kant presents the conservation principle as governing both physical elastic forces and the infinite but obscure forces of the soul. The view that mental forces contain the "infinite perception of the entire universe […] albeit only obscurely" is recognisably that of Leibniz's *Monadologie* (1714). For Leibniz, a mind, a higher-order monad, is a "perpetual living mirror of the universe", which "represents the whole universe" but only in a confused or obscure manner.[40] Kant's Leibnizian account of minds depicts mental forces as structurally equivalent to physical ones: in both cases, a huge effect can be triggered from a tiny cause, due to dormant, potential internal forces.

The same claim appears in *Attempt to Introduce the Concept of Negative Magnitudes into Philosophy* (1763). The work presents a philosophical notion of a negative magnitude, on the basis of a distinction between logical and real opposition. Whereas a logical opposition results in "nothing at all", a real opposition yields "something" (NG, AA 02: 171). One of Kant's examples of a real opposition is taken from physics. A body at rest can be considered a result of real opposition in two ways: a moving body meeting an equal and opposite force results in rest (NG, AA 02: 171); and determinate bodies are themselves constituted through an equilibrium of attractive and repulsive forces (NG, AA 02: 199). Kant contends that conceiving of such real oppositions as negative magnitudes reveals the value of introducing this mathematical notion into philosophy.[41]

[40] *Monadologie* §56, §62, in Leibniz 1989a: 220-21. Published translations of the *Monadologie* had been available in German since 1720 and Latin since 1721.

[41] Specifically, Kant provides examples from four domains of philosophy in which negative magnitudes can assist our understanding: i) the dynamical conception of material substance as in the *Physical Monadology:* the "true force" of repulsion, which grounds the impenetrability of bodies, as "negative attraction" (2:179-180); ii) psychology: pleasure as a "positive ground" that cancels pleasure, hence "negative pleasure" (2:180-182); iii) moral philosophy: vice as "negative virtue" (2:182-184); iv) natural science: coldness as negative heat, with warming and cooling explained by the "real passage of the elemental fire", where

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As in the *New Elucidation*, Kant broadens his discussion from physics to psychology, noting that the concept of a philosophical negative magnitude "can be extended far beyond the limits of the material world" (NG, AA 02: 199).[42] His example is that of a man of learning in a moment of relaxation, who, asked generally to share his knowledge with you, will say that his mind is presently empty: "[b]ut stimulate him by asking him a question or expressing a view of your own, and his learning will reveal itself in a series of activities" (NG, AA 02: 199). The state of mental inactivity is just like the state of rest of a body: it is not a contradiction or logical negation; rather mental activity and counteracting relaxation are two opposed forces, and the former can be stimulated to overcome the latter.[43] Kant then returns to the analogy between the relative spontaneous forces in fire, or here gunpowder, and the activities of minds:

> Thus it is with the thunder which, invented by art for our destruction and carefully preserved in the arsenal of a prince ready for a future war, lies in menacing silence until, touched by a treacherous spark, it explodes in lightening and lays waste to everything around it. Tensed springs [*Spannfedern*], constantly ready to explode, lay dormant within it, the prisoners of powerful forces of attraction, waiting to be released by the stimulus [*Reiz*] of a spark of fire. There is something imposing and, it seems to me, profoundly true in this thought of *Leibniz*: the soul embraces the whole universe with its faculty of representation, though only an infinitesimally tiny part of these representations is clear. […] The force of thought possessed by the soul must contain the real grounds of all concepts, in so far as they are supposed to arise in a natural fashion within the soul (NG, AA 02: 199).

More explicitly than in the *New Elucidation*, Kant draws an analogy between the spontaneous force of fire's elastic matter and mental forces. In this 1763 text, Kant contends that Leibniz's notion of a faculty of obscure representations is "profoundly true", insofar as the real grounds of all concepts are already present in the soul, and mental stimulation can trigger the illumination of obscure representations. Like elastic physical phenomena, minds possess a relative spontaneity, in that internal forces can be unleashed by a minor stimulus.

Kant will go on to reject both Leibniz's account of the faculty of obscure representations, and the possibility of knowledge of the mind through an analogy with physical forces. Both shifts are evident in *Dreams of a Spirit-Seer* (1766). In a footnote, Kant gives a much more circumspect account of the Leibnizian "faculty of obscure representations": rather than affirming this conception as "profoundly true", Kant says only that if philosophers reject Leibniz's view, it is incumbent on them to provide an alternative account of the inner ground of external relations. Kant states that he himself "cannot specify in what that inner activity consists", and so by 1766 has taken an agnostic stance towards Leibniz's doctrine of the faculty of obscure representations (TG, AA 02: 328).[44] Furthermore, Kant denies that our knowledge of physical forces can increase our understanding of mental activity: he states that it is natural that soul-body community is incomprehensible, because

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the latter is a "subtle and elastic fluid" set in motion by attractive force (2:184-188). Kant's first and fourth examples draw on interests familiar from his texts of the 1750s.

[42] Earlier Kant writes, "in what concerns the cancellation of an existing something, there can be no difference between the accidents of mental natures [*geistigen Naturen*] and the consequences of effective forces [*wirksamer Kräfte*] in the physical world" (NG, AA 02: 191).

[43] The only commentator, to my knowledge, to emphasise that the forces of *Negativen Größen* are psychological as well as physical is Zinkin 2012: 397-414. I do not however follow Zinkin's presentation of negative magnitudes *as themselves* forces; rather, I take Kant to introduce negative magnitudes as conceptual tools for *conceiving of* forces, both of physical bodies and minds.

[44] Kant's agnostic position will develop, by 1770, into a dismissal of what he calls the Leibnizian-Wolffian philosophy's "merely logical" distinction between sensibility as confused cognition and the understanding as distinct cognition. See MSI, AA 02: 394f; KrV, A 44/B61-2.

"our concepts of outer actions are derived from matter, and always connected with the conditions of pressure or impact, which do not occur here" (TG, AA 02: 328).[45]

By 1766, then, Kant rejects both the analogy between physical elasticity and mental spontaneity, and any straightforwardly Leibnizian account of the latter. Nevertheless, his explorations of this analogy in 1755 and 1763 reveal the extent of his enthusiasm for the explanatory potential of elastic force at this time. The passages show that Kant reflected on at least an analogical connection between the elastic matter, with which he explained diverse physical phenomena in his natural-philosophical works of the 1750s and 1760s and which I propose he sought to metaphysically ground on his physical monadology, and the relative spontaneity of minds, understood on Leibnizian lines. If, as commentators have argued, Kant continues to ascribe a *relative* spontaneity to the understanding in the *Critique of Pure Reason* (Sellars 1971: 23-25; Ameriks 1991; Sgarbi 2012: 60), it is instructive to see that in the 1750s and early 1760s his ascription of relative spontaneity to the mind appears in the context of an analogy between Leibniz's faculty of obscure representations and the relative spontaneity of elastic matter, air and fire.

Conclusion

The period of 1754-64 sees Kant explore elasticity and elastic forces in an increasingly broad sense. On my account, *On Fire* provides an important insight into how Kant considered the elastic matter of air and fire to be connected. This provides the basis for the explanation of various physical phenomena in other texts of the decade. The *Physical Monadology* can be read as an attempt to provide a dynamic metaphysical ground for elasticity. On my account, Kant's review of Silberschlag indicates Kant's ambitions to extend the physical monadology to the "heights of metaphysics". But whilst Silberschlag's metaphysical heights remain within the realm of physics, the *New Elucidation* and *Negative Magnitudes* explore a yet-more metaphysical extension of the explanatory potential of physical spontaneity. Kant suggests in these works that the mind, understood on Leibnizian lines as possessing an infinite but predominantly obscure *Vorstellungskraft*, can be compared to the potential force contained in the elastic matter of fire. Although he will reject the use of such analogies in 1766, the passages in Kant's works of 1755 and 1763 give an intriguing insight into how he was then exploring a common relative spontaneity in the physical and psychological domains.

In closing, we can return to the comparison with Adickes' *Kant als Naturforscher* that was introduced in section 1. Regarding elastic force in Kant's early works, Adickes discusses only how Kant's view fits into contemporaneous debates around the cause of elasticity in physical bodies and the question of whether this should be explained by a notion of the ether. I hope to have shown that, regardless of the later developments in Kant's discussions of elasticity in the critical period or the significance of the ether-concept for his final drafts, in 1754-64 Kant is interested in elasticity as a means of explaining the increase in force that occurs in immanent self-activity without transgressing the principle of equipollence.

In this regard, Adickes' question of whether Kant should be considered a *Naturwissenschaftler* or a *Naturphilosopher* is still relevant. No commentator today would argue that Kant is a natural scientist in the modern sense; nor would anyone judge Kant's failure to achieve natural-scientific standards of rigour as harshly as Adickes does. Nevertheless, current scholarship could emphasise even further that Kant's early writings on nature are *natural-philosophical* works.

[45] The Mrongovius lecture notes (1782-1783) make this point explicit: "[a]ll efforts are … in vain that want to make the faculties of the soul distinct through bodily intuition. We find not the slightest analogy between thinking and matter" (V-Met/Mron AA 29: 904).

This entails that the distinction between Kant's "theoretical" and "natural-scientific" writings dissolves, enabling a deeper appreciation of Kant's multifaceted early philosophy.[46]

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