
‘S GRAVESANDE AND THE RELATION BETWEEN PHYSICS AND THEOLOGY

Steffen Ducheyne*

Free University of Brussels (Vrije Universiteit Brussel), Centre for Logic and Philosophy of
Science, Pleinlaan 2, Room 5B425, B-1050 Brussels, Belgium

(Received 16 February 2012, revised 26 February 2013)

Abstract

In the eighteenth century, the relation between Science and Theology underwent a complex series of transformations. In this essay, I seek to show how during the first half of the eighteenth century Newtonian-inspired natural philosophers began to redefine the scope of Physics and that, by doing so, they came to reposition, albeit oftentimes quite subtly, God's position within the domain of Physics. In the paper at hand I shall focus on Willem Jacob's Gravesande (1688-1742).

Keywords: Gravesande, newtonianism, physics, theology, physico-theology

1. Introduction

Isaac Newton's work testifies of the intimate rapport between natural philosophy and Theology. In the General Scholium, which was added to the second edition of the *Principia mathematica philosophiae naturalis* (1713), Newton insisted that “[t]his most elegant system of the sun, planets, and comets could not have arisen without the *design* and dominion of an intelligent and powerful being.” [1] (*italics added*). Newton pointed out that we know God “by his properties and attributes and by *the wisest and best construction of things and their final causes*” [1, p. 942] (*italics added*). In the *Opticks* Newton underscored similar physico-theological considerations: “Such a wonderful Uniformity in the Planetary System must be allowed the Effect of Choice. And so must the Uniformity in the Bodies of Animals, they having generally a right and a left side shaped alike, and on either side of their Bodies two Legs behind, and either two Arms, or two Legs, or two Wings before upon their Shoulders, and between their Shoulders a Neck running down into a Back-bone, and a Head upon it; and in the Head two Ears, two Eyes, a Nose, a Mouth, and a Tongue, alike situated. Also the first Contrivance of those very artificial Parts of Animals, the Eyes, Ears, Brain, Muscles, Heart, Lungs, Midriff, Glands, Larynx, Hands, Wings, swimming Bladders, natural Spectacles, and other Organs of Sense and Motion; and the Instinct of Brutes and Insects, can be *the effect of nothing else than the Wisdom and Skill of a powerful ever-living Agent; [...]*” [2] (*italics added*).

* E-mail: steffen.ducheyne@vub.ac.be

In view of these considerations, Newton concluded in the General Scholium that “to treat of God from phenomena is certainly *a part* of natural philosophy” [1, p. 943] (italics added). Upon being asked by Napoleon Bonaparte about the place of God in his system of the world in 1802, Pierre Simon Laplace famously answered “I have no need of that hypothesis” [3]. Why did God play such pivotal role in Newton’s natural philosophy but not in Laplace’s physics? In other words, what happened between 1713 and 1802? In this essay I obviously cannot provide an answer to this complex historical problem. My aim here is rather modest: I seek to show how during the first half of the eighteenth century Newtonian-inspired natural philosophers began to redefine the scope of Physics and that, in doing so, they came to reposition, albeit quite subtly, God’s position within the domain of Physics. In this essay, I will focus on the Dutch natural philosopher Willem Jacob’s Gravesande (1688-1742), who is best known for the highly influential eighteenth-century Newtonian textbook which he wrote: *Physices elementa mathematica experimentis confirmata, sive introduction ad philosophiam Newtonianam* (first edition: 1720-1721, second edition: 1725; third edition: 1742). In this essay, I do not claim that there is a direct genetic link between ‘s Gravesande’s and Laplace’s views. Rather, my view is that Laplace’s position could become an option after a complex series of reconceptualisations of God’s position within the realm of Physics and that, as it happened, ‘s Gravesande, amongst many others, played an important role in this process.

2. ‘s Gravesande’s ‘learned ignorance’

Before I address ‘s Gravesande’s views on the scope of Physics (*physica*), in this section I shall briefly probe into the epistemological position which he developed and articulated in his physical work. ‘s Gravesande began by emphasizing what he valued in Newton’s manner of studying the physical world. Once Newton had established in Book III of the *Principia* that gravitation explains the celestial and terrestrial motions, he refused to speculate any further about the cause of gravity. By contrast, non-Newtonian natural philosophers had based their explanations of physical phenomena on idle speculations. Since Physics considers ‘the Works of supreme Wisdom’, ‘s Gravesande urged that one should proceed prudently, refrain from hypotheses, and embrace, what he called, ‘a learned Ignorance’. In the preface to the first edition of his *magnum opus* (1720), he stated: “We must take care not to admit Fiction for Truth, for by that means we shut out all further Examination. No true Explanation of Phenomena can spring out of a false Principle: And what a vast difference there is betwixt learning the Fictions of whimsical Men, and examining the Works of the most wise God! Since an Enquiry into Divine Wisdom, and the Veneration inseparable from it, is to be the Scope of a Philosopher; we need not enlarge upon the Vanity of reasoning upon fictitious Hypotheses. Nature herself is therefore attentively and incessantly to be examined with indefatigable Pains. That way indeed our Progress will be but slow, but then our Discoveries will be

certain; and oftentimes we shall even be able to determine the Limits of human Understanding. *What has led most People into Errors, is an immoderate Desire of Knowledge, and the Shame of confessing our Ignorance; but Reason shou'd get the better of that ill-grounded Shame, since there is a learned Ignorance that is the Fruit of Knowledge, and which is much preferable to an ignorant Learning.*" [4, 5] (italics added)

In line with his 'learned Ignorance', 's Gravesande underscored the limited scope of human knowledge and, correspondingly, the limited scope of *physica*. Although we can acquire knowledge of some of the properties of things, he argued, we cannot know their substances or essences: "What Substances are, is one of the Things hidden from us. We know, for instance, some of the Properties of Matter, but we are absolutely ignorant in what Subject they are inherent." [4, vol. I, p. iii] According to 's Gravesande, we only know substances by their attributes (cf.: "Ideas ipsarum Substantiarum non habemus, has tantum per Attributa novimus. [...] Attributa cuidam subjecti inhæere concipimus, quod ipsa est Substantia, quam ideis assequi non possumus." [6]). Correspondingly, he argued that it is illusory to think that we can obtain a complete knowledge of things: "Who dares affirm that there are not in *Body* many other Properties, which we have no Notions of? And whoever could certainly know, that besides the Properties of *Body* which flow from the Essence of Matter, there are not others depending upon the free Power of GOD, and that extended and solid Substance (for thus we define *Body*) is endowed with some Properties without which it could exist? We are not, I own, to affirm or deny any thing concerning what we do not know. *But this Rule is not followed by those, who reason in physical Matters, as if they had a complete Knowledge of whatever belongs to Body, and who do not scruple to affirm, that the few Properties of Body which they are acquainted with, constitute the very Essence of Body.* [...] We must give up as uncertain what we find to be so, and not be ashamed to confess our Ignorance." [4, vol. I, p. iii-iv; 5, vol. I, p. iv] (italics added)

It seems that here 's Gravesande was targeting Descartes who had argued that body and being extended are identical and that, as a consequence, the essence of matter is *res extensa*.

Up to this point, 's Gravesande's strain of thought sounds quite Newtonian. In the General Scholium Newton endorsed a similar epistemological perspective: "We see only the shapes and colors of bodies, we hear only their sounds, we touch only their external surfaces, we smell only their odors, and we taste only their flavors. But there is no direct sense and there are no indirect reflected actions by which we know innermost substances [...]" [1, p. 942] (italics added) Yet, if we take a closer look, important differences begin to emerge, as will be shown in the next section.

3. 's Gravesande's view on the scope of Physics and its theological repercussions

Let us now turn to 's Gravesande's views on the scope of Physics. As we will see, 's Gravesande's disciplinary reorganization within the realm of Physics was accompanied by an expurgation of potentially controversial and theologically-laden issues associated with Newton's natural philosophy: he warned that the search for gravity's cause is a futile endeavour, he did not engage with the issue of Newton's so-called 'Active Principles', and he pleaded ignorance on the issue of whether gravity is essential to matter.

's Gravesande recorded that *physica* is "conversant about *natural Things* [i.e. bodies] and their *Phænomena*". Phenomena are defined as "*all Situations, and Motions, of natural Bodies, not immediately depending upon the Action of an intelligent Being, and which may be observed by our Senses*" [4, vol. I, p. 1]. Accordingly, the purpose of the latter definition is to exclude acts of volition from Physics. It implies that, while the study of the muscular motion "proceeding from the Action of the Muscles" pertains to Physics, the study of the "Action of the Mind," which ultimately produces these motions, does not, because it relates to causes which are "entirely unknown," i.e. unobservable [4, vol. I, p. 48]. Whatever is entirely unknown is not a natural phenomenon, 's Gravesande stressed. Physics restricts itself to the observable motion of bodies and, correspondingly, it does not address the mind-body problem. In his *Essais de métaphysique*, 's Gravesande pointed out that the mind-body problem pertains to Metaphysics [7]. Physics also '*explains natural Phænomena, i.e. treats of their Causes*' and it is here that, according to 's Gravesande, the laws of nature come into play: "When we enquire into these Causes, we must consider Body it self in general; then we must discover by what Rules the Creator of all things pleas'd that all their Motions should be perform'd." [4, vol. I, p. 2]. Once we have established the laws of nature, "we cannot penetrate farther into the Knowledge of Causes" [4, vol. I, p. v]. 's Gravesande defined a law of nature as "*the Rule and Law according to which God thought fit that certain Motions should always, i.e. in all Cases, be perform'd*" [4, vol. I, p. 2]. According 's Gravesande, Physics does not meddle with "the first Foundation of Things", and restricts itself to uncovering "[h]ow the whole Universe is governed by those Laws, and how the same Laws run thro' all the Works of Nature, and are constantly observed with a wonderful Regularity" [4, vol. I, p. i-iii].

In line with the empiricist strands in his thinking, 's Gravesande denied that we have epistemic access to the realm of causation, which remains observably hidden from us. Consequently, with respect to us ('nostrorespectu'), a law of nature is "every simple Effect, which continues the same upon all Occasions, whose Cause is unknown to us, and which we find cannot flow from any Law known to us, tho' perhaps it may from a more simple Law, unknown to us [omnis effectus simplex, qui in omnibus occasionibus idem est, cujus causa nobis est ignota, & quem videmus ex nullâ Lege, nobis notâ, fluere posse, quamvis fortè ex simpliciori Lege, nobis ignotâ, fluat]" [4, vol. I, p. 2; 5, vol. I,

p. 2-3]. Correspondingly, when we consider the law of universal gravitation from this perspective, gravity is to be considered, not as a cause, but only as an effect [4, vol. II, p. 320].

's Gravesande's statement that Physics 'explains' phenomena is somewhat puzzling. *Prima facie* he seems to be taking over Newton's causal talk. However, it is vital to realize that, immediately after introducing causal talk in his *Physices elementa*, he provided a highly revisionist reinterpretation of our causal talk in Physics and he stressed, in contrast to Newton, that Physics is the study, not of causes, but of universal effects. Newton, by contrast, urged that "the main Business of natural Philosophy is to argue from Phaenomena without feigning Hypotheses, and to deduce Causes from Effects" [2, p. 369]. In emphasizing that Physics is the study of the universal effects, 's Gravesande was restricting the scope of natural philosophy as it was originally envisioned by Newton. 's Gravesande's causal revisionism in Physics does not mean, however, that he endorsed the view that causal talk is entirely meaningless, for he addressed causation in his metaphysical work. In his metaphysical work, he discussed the nature of causation, which he characterized in necessitarian terms [7, vol. II, p. 176-180]. A cause is necessary to produce its effect: "[a]d causam autem proprie dictam referimus, omne quod requiritur ad Effectum Præstandum; quare illa necessario hunc producit" [6, p. 32]. Viewed from this perspective, 's Gravesande causal revisionism within the realm of Physics can, and in my opinion should, be seen as the result of his attempt to eliminate from Physics what he considered as metaphysical issues.

Since the realm of causation is hidden from us, 's Gravesande pointed out that "it matters not, whether any thing depends immediately upon the Will of God, or is produc'd by an intermediate Cause, of which we have no Idea" [4, vol. I, p. 2]. In view of this, the search for the cause of gravity is a futile endeavour. How gravitational forces operate is simply beyond human comprehension: "We have said that the Gravity which we have hitherto explained is to be taken for a Law of Nature, because we don't know the Cause of it; and because it depends upon no Cause that is known to us, which will evidently appear, if we attend to what follows. [...] [I]f gravity depends upon any known Law of Nature, it ought to be referred to a Stroke from an extraneous Body; and because Gravity is continual, a continual Stroke would be required. If there be such Sort of Matter continually striking against Bodies, it must of Necessity be fluid, and very subtile, so as to penetrate all Bodies; for Bodies, that are any how shut up in others, are heavy. Now let a Mathematician consider, whether a Fluid so subtile, as freely to penetrate the Pores of all Bodies, and so rare, as not sensibly to hinder the Motion of Bodies (for in a Place void of Air the Motion of a Pendulum will be continued very long) can impel vast Bodies towards one another with so much Force? Let him explain how this Force increases in such a Ratio of the Mass of the body towards which another is carried*. Lastly let him shew, what seems most difficult the me, how all Bodies, in any Situation whatsoever (if the Distance, and the Body towards which the Gravitation is, remain the same) are carried with the same Velocity*;

that is how a Liquid which can only act on the Surfaces, either of the Bodies themselves, or their internal Particles, to which it is not hindered from coming by the Interposition of other Particles, can communicate such a Quantity of Motion to Bodies which in all Bodies exactly follows from the Proportion of the Quantity of Matter in them; and which in this Chapter we have proved to obtain every where in Gravity [...]. Yet we don't say, that *Gravity does not depend upon any Stroke*, but that it does not follow from that Stroke, *according to any Laws known to us*, and we confess that we are intirely ignorant of the Cause of Gravity.” [4, vol. II, p. 326-327; 5, vol. II, p. 996-997]

Because gravitational interaction does not allow for a mechanical explanation, it simply defies our understanding. In denying the fundamental impossibility of unravelling the cause of gravity, 's Gravesande defended a stance more radical than the one originally endorsed by Newton. In the speculative parts of his natural philosophy, i.e. in the Queries of the *Opticks*, Newton proposed a hypothesis on the cause of gravity. More precisely, in Query 21 he introduced an extremely subtle 'elastick' ether endowed with strong inter-particular repulsive forces as a possible explanation or cause of gravity [2, p. 350-352]. Newton was clearly aware that such ether was entirely conjectural, for in the Advertisement added to the 1717 edition of *The Opticks* he observed that he was “not yet satisfied about it [i.e. about his explanation of gravity] for want of Experiments” [2, p. cxxiii]. Although Newton never succeeded in establishing the cause of gravity in a way that could meet his own sophisticated methodological desiderata, he was not unsympathetic to the idea that the cause of gravity could in principle be discovered through extensive empirical research. For 's Gravesande the search for the cause of gravity was simply a futile exercise, given our inability to unravel nature's causes.

With respect to the laws of nature, 's Gravesande furthermore emphasized that we are at loss “whether they flow from the Essence of Matter, or whether they are deducible from Properties, given by GOD to the Bodies which the World consists of, but no way essential to Body; or whether finally those Effects, which pass for Laws of Nature, do not depend upon external Causes, which even our Ideas cannot attain to.” [4, vol. I, p. iv; 5, vol. I, p. v]. For Newton such questions were issues of the greatest importance. For instance, it was of vital theological importance to him to show that gravity is not an essential quality of matter [8]. In his commentary to the third rule of philosophizing, Newton wrote that he was “by no means affirming that gravity is essential to matter” [1, p. 796] and in the Advertisement to the second edition of the *Opticks* he remarked that he did not “take Gravity for an essential Property of Bodies” [2, p. cxxiii]. If gravity is essential to matter, then this implies that matter is self-activating and that it does not require active principles for its motion – a view which was unacceptable to Newton. Such active principles were installed and regulated by divine mediation, he maintained [2].

By eliminating metaphysical and theologically-laden issues from his *magnum opus*'s Gravesande was carefully restricting the scope of natural philosophy and gradually turning it into Physics [9]. Furthermore, *by*

radicalizing Newton's empiricism, 's Gravesande came to ban from Physics certain questions, which Newton had previously conceived of as being important and meaningful.

However, the preceding paragraph does not at all imply that 's Gravesande's was running an anti-theological or anti-metaphysical agenda. As will become clear in the next section, 's Gravesande was convinced that although Theology, on the one hand, and Physics, on the other, followed different methods, both could establish certain knowledge. I shall also show that 's Gravesande ultimately considered theological considerations as providing the foundation of the certainty of Physics.

4. Two kinds of certainty in 's Gravesande's thought

Given his preoccupation with certainty, it was crucial for 's Gravesande to elaborate on how certainty is established in Physics. In order to understand his approach on the matter, we should turn to 's Gravesande distinction between mathematical and moral certainty. The immediate perception of certainty is called mathematical or moral 'evidentia' [6, p. 137]. A peculiar feature of 's Gravesande's thought on certainty is that he maintained that, despite the fundamental difference between mathematical and moral certainty, the persuasion arising from both is *equally certain*, i.e. both kinds of certainty do not leave room for doubt – at least when due care is taken. In the words of 's Gravesande: "But although these Foundations differ, tho' mathematical Evidence does not agree with moral, yet a different persuasion does not proceed from thence. I can no more deny my Assent to such Things, as are drawn from the Foundations of moral Evidence which I have explain'd, when due Care is taken, than to those which are prov'd by a mathematical Demonstration." [4, vol. I, p. xlvi; 5, vol. I, p. lv-lvi]

Giambattista Gori has pointed out that 's Gravesande's views on the matter were indebted to Humphry Ditton's *A Discourse concerning the Resurrection of Jesus Christ* (1712) [10], in which the author wrote: "Coroll. Therefore it may be as absurd, to deny some Propositions, which admit only of Moral Proof, as to deny others capable of strict Geometrical Demonstrations. For the Absurdity is heightned in proportion to the Evidence of the Proposition denied. So that if two Propositions of an equal Evidence, tho of different Nature, are propos'd; the Absurdities of denying them will be equal. And since some Moral Propositions may be equally evident with some *Geometrical* ones, 'twill be as absurd to deny the former as the latter. Because I say, 'tis the Evidence or Plainness of Propositions, and not the Subject Matter, which makes it absurd to deny them." [11]

's Gravesande owned Ditton's book and he was very likely the author of the anonymous review of Ditton's book [12], which appeared in the journal which he co-founded, the *Journal littéraire de la Haye* [7, p. lvii-lviii; 10, p. 218].

Now, let us turn to mathematical certainty. A mathematician is not at all examining “whether or no the Ideas, about he reasons, agree with any thing being;” rather he is concerned with the relations between ideas themselves, ‘s Gravesande explained [4, vol. I, p. xxxix]. The foundation of mathematical certainty is the perception of Ideas, which “brings its own Conviction with it” [4, vol. I, p. lxvi]. Mathematical demonstrations depend on “the comparison of Ideas, and their Truth is evinced by implying a Contradiction in a contrary Proposition,” he observed [4, vol. I, p. vi]. True mathematical propositions are, in other words, true by necessity, for their negation leads to a contradiction. The necessity of mathematical truths corresponds what ‘s Gravesande calls absolute necessity (*necessitas absoluta*) in his *Introductio ad philosophiam, metaphysicam et logicam continens* (1736), namely a truth of which the contrary is absolutely impossible [6, p. 18]. Mathematically certain truths do not depend on the constitution of the Universe nor on the will of God [13].

What is striking about ‘s Gravesande’s views is the fact that he thought that mathematical certainty, is not the prerogative of Mathematics alone [14]. For instance, in *Metaphysics*, in *Logic*, and in the foundational parts of *Ethics* one reasons from ideas alone and by deduction one establishes mathematically certain propositions. (For ‘s Gravesande metaphysics contained three important topics: causation, liberty and God [7, vol. II, p. 175-215].) According to ‘s Gravesande, “the Part of Pneumatology [i.e. the study of intelligences] which treats of GOD,” for instance, is “wholly conversant about Ideas, and deduc’d from such Notions, of which the Mind can in no wise doubt” [4, vol. I, p. vi, xli]. In his *Oratio de evidentia*, he provided a metaphysical argument for the existence of God, which, in his mind, was mathematically certain: “I think; *i.e.* there is something Intelligent; from thence I infer that the first Cause of this is eternal, and infinitely exceeds in Intelligence that Intelligence which it has created; upon which account I am oblig’d to attribute a Power to it by which a Mind may be form’d, *i.e.* infinitely exceeding all that I can frame any Idea of to myself. This appears at the first View; if I consider the thing with Attention, I easily perceive, that there is an Intelligence without beginning, whose Being can be attributed to no external Cause; that it must therefore be *Self-existent*; and that nothing can put an End to its Perfection, and that there is only *one* such. It is plain then that GOD is *one, eternal, of infinite Knowledge*; and that his Power is confin’d within no Bounds. Which Things being demonstrated, hence other Things flow that are discover’d of GOD. For instance, *infinite Goodness* is deriv’d from *infinite Wisdom*. For it is easy to prove that all that is oppose’d to it proceeds from a Defect of Understanding, and can be only in a limited Intelligence.” [4, vol. I, p. xli-xlii; 5, vol. I, p. xlvi-xlvii]

On the basis of this argument, ‘s Gravesande established God’s necessary existence and his attributes (to wit, infinite, self-existent, and infinitely powerful, wise and good) *a priori*.

While mathematical certainty depends, as we have seen, “on such an Evidence as brings along its own Conviction along with it”, moral certainty depends on the external aids which God has given: to wit, the senses, testimony,

and analogy, which are the 'fundaments' of moral evidence. Reasoning by analogy refers to making inductive generalizations. Physical truths do not partake in mathematical certainty, for "when the Question is about natural Things, the first Requisite is, that our Ideas agree with those Things, *which cannot be proved by any mathematical Demonstration.*" When dealing with empirical matters, "a contrary Proposition is not always impossible" [4, vol. I, p. vi] (*italics added*). Physical truths are thus contingently true. According to 's Gravesande, the difference between mathematical and moral certainty is as follows: "You see that moral Evidence, and the Persuasion thence arising, relates to the Agreement between the Ideas in our Mind, and the Things themselves external to us; whist mathematical Evidence is conversant about the Agreement which is between the Comparison of Ideas and the Idea of this Comparison. [...] When we are conversant about Things external to us, we do not acquire an Idea of a thing by the Perception of it; Things themselves don't act upon our Minds, we can't conceive how they shou'd. Therefore we can't deduce the Foundations of moral Evidence from a simple Examination of the Mind, and of Things consider'd by themselves. We have Assistancess external to the Things themselves, by which we acquire Ideas of Things themselves, by which we acquire Ideas of Things external to us." [4, vol. I, p. xlvi; 5, vol. I, p. lii]

Analogical arguments "are daily taken for granted as undoubtedly true, without any previous Examination; because every body sees that they cannot be called into question without destroying the present Oeconomy of Nature" [4, vol. I, p. vii]. Without the use of analogy human life would result in chaos. Imagine a society in which we cannot be certain that the sun will rise tomorrow or that a "*Building, this Day firm in all its Parts, will not of itself run to Ruin To-morrow*" [4, vol. I, p. vii]. However, 's Gravesande was not merely justifying analogy from its success in everyday contexts, for in his opinion the reliability of analogy ultimately results from God's infinite goodness [6, p. 148]. In this context he observes that it would be a contradiction to suppose "that God intended these [i.e. the senses, testimony and analogy] to be the Foundations of Persuasion, and that they shou'd not lead us to Truth, when we make use of them with due Care" [4, vol. I, p. lxvi-xlvi]. The reliability of the senses, testimony and analogy follows *with mathematical certainty* from the infinite goodness of God: "If moral Evidence, which we have from God, was not firm, and sufficient to make us give our Assent to it, we cou'd, by a mathematical Demonstration, prove God not to be good." [4, vol. I, p. xlix] Furthermore, analogy is guaranteed by the fact that God governs the universe by invariable laws: "Now there being numerous Cases of that kind, where one may affirm or deny with equal certainty; it follows that there are many Reasonings very certain, tho' altogether different from the mathematical ones. And they evidently follow from the Establishment of Things, and therefore from the pre-determined Will of GOD. [...] All these Reasonings are grounded upon Analogy; and there is no doubt that our Creator has, in many Cases, left us no other way of Reasoning, and therefore it is a right Way. But the Foundation of Analogy is this, That the Universe is govern'd by unchangeable Laws." [4, vol. I, p. vi-vii; 5, vol. I, p. vii-viii, ix]

Given these unchangeable laws, “Analogy stands upon a good Foundation, and being taken away, all Things in Physicks are uncertain, and the whole human Race wou’d soon be extinct” [4, vol. I, p. xlvi]. In other words, for ‘s Gravesande the certainty of Physics was ultimately grounded in theological considerations: the reliability of the senses, testimony and analogy follow *a priori* from God’s infinite goodness [10, p. 281-282; 15; 16].

For ‘s Gravesandethen there were two kinds of certainty: moral certainty and mathematical certainty. The former is the kind of certainty that is established in Physics; the latter is the kind of certainty that is established in *a priori* sciences such as Metaphysics and Theology. *Although ‘s Gravesande refrained from theologically-laden topics within the realm of physics, theological considerations were in his view ultimately the foundation of the certainty established in Physics.*

5. ‘s Gravesande on design and final causes

In his *Oratio inauguralis, de matheseos, in omnibus scientiis* (1717), which ‘s Gravesande delivered when he became professor of Mathematics and Astronomy at the University of Leiden, he had argued against the alleged conduciveness towards atheism of studying nature mathematically [13]. Characteristically, mathematicians only admit what can be proven by rigid demonstration and, because of this, some of them have been tempted to cast doubt on the truths of Scripture. Such aberrations are a consequence of a misguided use of Mathematics, not of the use of Mathematics *per se*, ‘s Gravesande underscored, for not everything can be subjected to reason. In his *Oratio de evidentia* (1724), he pointed out: “While they [i.e. misguided mathematicians] contend that nothing is to be taken for Truth but what is prov’d by mathematical Demonstration, in many things they take away all Criterium of Truth, while they boast that they defend the only Criterium of Truth.” [4, vol. I, p. xxxvi, xxxix-xl]

In his early years, ‘s Gravesande was embrative of physico-theology. In his essay *Démonstration mathématique du soin que Dieu prend diriger ce qui passé dans ce Monde, tirée du nombre des garçons & des filles qui naissant journellement* (1712), the twenty-four year old ‘s Gravesande concluded: “There is only one Being [i.e. God] that could give rise to the birth of boys and girls precisely in the proportion according to which they are born” [7, p. 236]. However, in his mature work ‘s Gravesande did not pay significant attention to final causes and physico-theology [17, 18]. According to ‘s Gravesande, we are not only ignorant about the essences of things, but also about God’s intentions and design of the world. In his *Essais de métaphysique* he wrote: “I am too limited to get an complete idea of the plan of the Universe” [7, vol. II, p. 205] (*italics added*). When he referred to God in his *Physiceselementamathematica* he did not draw on arguments from design or on God’s instalment of final causes. He did, however, emphasize that Physics sets God’s wisdom ‘before our Eyes’: “The Study of Natural Philosophy is not however to be contemned, as built upon

an unknown Foundation. The Sphere of human Knowledge is bounded within a narrow Compass; [...]. [...] Though many Things in nature are hidden from us, yet what is set down in Physics, as a Science, is certain. From a few general Principles numberless particular Phænomena or Effects are explain'd and deduced by mathematical Demonstration. [...] How much soever may be unknown in Natural Philosophy, it still remains a vast, certain, and very useful Science: It corrects an infinite Number of Prejudices concerning natural Things, and divine Wisdom; and as we examine the Works of God continually, sets that Wisdom before our Eyes; and there is a wide Difference betwixt knowing the divine Power and Wisdom by a metaphysical Argument, and beholding them with our Eyes every Minute in their Effects.” [4, vol. I, p. v; 5, vol. I, p. v-vi]

In this piece of text, 's Gravesande also underscored that physical inquiry can supplement metaphysical arguments for divine power and wisdom. However, he did not endorse the idea that Physics provides us with insight into God's design of the world. 's Gravesande did not deny that there was a divine design. In *Essais de métaphysique*, 's Gravesande wrote: “Everything that happens, happens as a result of the will of God [...], either immediately, or by a series of causes & effects, which God by His infinite intelligence has foreseen, because the chain is necessary [...].” [7, p. 201]. Rather, 's Gravesande thought that humans are too ignorant to obtain knowledge about God's design of the world.

Emphasis on the harmonious relation between mathematics and religion was a topic of great concern in the Dutch Republic, where the dangers of Spinoza's deductive approach were perceived as a great danger [17, 19]. Because of the views on liberty which he developed in his *Introductio ad philosophiam*, 's Gravesande was accused of Spinozism [17, p. 219-220; 20]. However, 's Gravesande views on the matter did not agree to Spinoza's. In the chapter *De fato* in *Introductio ad philosophiam*, 's Gravesande argued that humans are free because they have the capacity to act on reasons and rational deliberation (cf.: “Quamdiu, quænos ad agendum movent, in ipsam Intelligentiam, quà Intelligentiam, agunt; ita ut tantum agamus, quia volumus, & determination voluntatis persuasionem, ex judicio, aut atrocino, deductam, pro fundamento habeat, *nulla Mechanica, aut Physica, Necessitas concipi potest, & non Fato regimur*” [6, p. 50] (italics added)). That 's Gravesande maintained that “every human volition is mechanically determined”, as Jonathan I. Israel states [17, p. 218] (italics added), is quite incorrect. He did claim that, when our physical constitution is out of order, mechanical causes determine our decisions. However, when our physical constitution is fine, we truly act upon reasons (cf.: “Hæc ita sese habent, quamdiu Mentem sanam in Corpore sano Homo possidet. Tunc hicce verè liber est: ut agat, Mens rationibus persuaderi debet, ut velit; & eo sensu, ipse actionum suarum auctor est” [6, p. 55]). Those who admit of fatality are blind to the fact that we act on our ideas, 's Gravesandeargued [6, p. 50-51]. Now at this point, he explicitly referred to Spinoza's views on fatality and as an illustration he quoted from what is now known as Spinoza's famous Letter 58, in which he had argued that freedom is illusory [6, p. 51-52]. After

quoting from the letter, ‘s Gravesande reiterated his conclusion: our actions are determined by reasons and not by mechanical causes [6, p. 53].

In Spinoza’s work, fatality applies to the way in which the world is created as well. In Proposition 33 of his *Ethica*, Spinoza stated that “[t]hings could have been produced by God in no other way, and in no other order than they have been produced” [21]. Spinoza’s *Ethica* was published in *Opera posthuma* (1677), which ‘s Gravesande owned. In explicit opposition to this opinion, Samuel Clarke argued in his *A Demonstration of the Being and Attributes of God*, a work which ‘s Gravesande also owned, that God “is not a necessary Agent, but a Being indued with Liberty and Choice” [16, p. 131]. Moreover, according to Clarke, “’Tis evident He must of Necessity (meaning, not a *Necessity of Fate*, but such a *Moral Necessity* as I before said was consistent with the most perfect Liberty,) *Do* always what he *Knows* to be *Fittest to be Done*: that is, He must Act always according to the strictest Rules of Infinite Goodness, Justice and Truth, and all other *Moral Perfections*.” [22] The position which ‘s Gravesande developed in his *Essais de métaphysique*, which was intended for “un petit nombre de personnes”, is similar to Clarke’s. ‘s Gravesande emphasized that: “Nothing can determine God’s power except his own will; he can therefore do everything which he wants and, hence, what he wants, he does; nothing can prevent him from doing so, because it is a consequence of his own existence” [7, vol. II, p. 197]. He stated, furthermore, that it is by no means physically necessary that God created the world in the way it is, but that God is nevertheless bound by moral necessity to create the world in a way that is consistent with his attributes: “For what concerns His physical power, God can do anything that is not self-contradictory [...]. But if we pay attention to His moral power, it is clear that it is contradictory that He would do something else than what He wants; He thus can only do what He wants. But it is contradictory that He would not want what is consistent with His attributes, or that He would want something else; it is therefore a contradiction that God would have another will than the one which He has, and consequently it is even contradictory that He would do something else than what He does, and in this moral sense God can only do what He does.” [7, vol. II, p. 208] (italics added).

6. Conclusion

In this essay I have brought the complex interrelation between ‘s Gravesande’s physics and theology to the fore. I have shown that ‘s Gravesande came to eliminate certain theologically-laden issues from the realm of Physics by re-conceptualizing its scope. ‘s Gravesande did so, not because he was running an anti-theological agenda, but because he was convinced that given our human ignorance it is impossible to obtain knowledge about such issues. I have furthermore shown that, according to ‘s Gravesande, God’s infinite goodness provided the foundation of the certainty of physics. Finally, I have explained why, given the emphasis he put on human ignorance, ‘s Gravesande was reluctant to rely on final causes and on arguments from design.

Correspondingly, regardless of his own sincere theological convictions, 's Gravesande contributed significantly to the secularization of natural philosophy and to the establishment of Physics. 's Gravesande's case is therefore highly relevant if we seek to understand what happened between 1713 and 1802.

Acknowledgement

The author is indebted to Eric Schliesser for useful discussion.

References

- [1] I. Newton, *The Principia, Mathematical Principles of Natural Philosophy*, University of California Press, Berkeley, 1999, 940.
- [2] I. Newton, *The Opticks, or A Treatise of Reflections, Refractions, Inflections and Colours of Light*, Dover, New York, 1952, 402.
- [3] R. Hahn, *Pierre Simon Laplace, 1749-1827*, Harvard University Press, Harvard, 2005, 172.
- [4] W.J. 's Gravesande, *Mathematical Elements of Natural Philosophy, Confirm'd by Experiments: Or, an Introduction to Sir Isaac Newton's Philosophy*, translated by J.T. Desaguliers, 6th edn., vol. I, Printed for T. Longman e.a., London, 1747, i-ii.
- [5] W.J. 's Gravesande, *Physices elementa mathematica experimentis confirmata, sive introduction ad philosophiam Newtoniam*, 3rd edn., vol. I, Apud Johannem Arnoldum Langerak, Johannem et Hermannum Verbeek, Leidiae, 1742, i-ii.
- [6] W.J. 's Gravesande, *Introductio ad philosophiam: metaphysicam et logicam continens*, Apud Johannem et Hermannum Verbeek, Leidiae, 1736, 8.
- [7] J.-N.-S. Allamand, *Oeuvres philosophiques et mathématiques de M^r. G. J. 's Gravesande*, vol. II, Marc Michel Rey, Amsterdam, 1774, 181.
- [8] S. Ducheyne, *The main Business of Natural Philosophy: "Isaac Newton's Natural-Philosophical Methodology*, Series: Archimedes, New Studies in the History and Philosophy of Science and Technology, vol. 29, Springer, Dordrecht, 2012, 37, 235.
- [9] J.L. Heilbron, *Experimental Natural Philosophy*, in *The Ferment of Knowledge, Studies in the Historiography of Eighteenth-Century Science*, G.S. Rousseau and R. Porter (eds.), Cambridge University Press, Cambridge, 1980, 362.
- [10] G. Gori, *La fondazione dell'esperienza in 's Gravesande*, Firenze, La Nuova Italia, 1972, 218, 247, 249.
- [11] H. Ditton, *A Discourse concerning the Resurrection of Jesus Christ*, Printed by J. Darby, London, 1712, 153.
- [12] ***, [Review of *A Discourse concerning the Resurrection of Jesus Christ*], *Journal littéraire*, 1 (May-June 1713) 391-435.
- [13] W.J. 's Gravesande, *Oratio inauguralis, de matheseos, in omnibus scientiis, praecipue in physicis, usu, nec non de astronomiae perfectione ex physica haurienda*, Apud Samuelem Luchtmans, Lugduni Batavorum, 1717, 11.
- [14] P. Brunet, *Les physiciens Hollandais et la méthode expérimentale en France au XVIII^e siècle*, Albert Blanchard, Paris, 1926, 63.
- [15] C. de Pater, *Lias*, 21(2) (1994) 257-294.
- [16] E. Cassirer, *The Philosophy of the Enlightenment*, English translation, Beacon Press, Boston, 1965, 257.

- [17] J.I. Israel, *Enlightenment Contested, Philosophy, Modernity, and the Emancipation of Man 1670-1752*, Oxford University Press, Oxford, 2006, 216.
- [18] E. Schliesser, HOPOS: The Journal of the International Society for the History of Philosophy of Science, **1(1)** (2011) 101-128.
- [19] E. Jorink, *Honouring Sir Isaac, or, Exorcizing the Ghost of Spinoza: Some Remarks on the Success of Newton in the Dutch Republic*, in *Future Perspectives on Newton Scholarship and the Newtonian Legacy in Eighteenth-Century Science and Philosophy*, S. Ducheyne (ed.), Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten, Brussels, 2009.
- [20] ***, *Lettre à monsieur G. J. S'Gravesande, professeur en philosophie à Leide, sur son introduction à la philosophie et particulièrement sur la nature de la liberté*, J. F. Bernard, Amsterdam, 1736.
- [21] E.M. Curley, *The Collected Writings of Spinoza*, Vol. I, Princeton University Press, Princeton, 1985, 436.
- [22] S. Clarke, *A Demonstration of the Being and Attributes of God: More Particularly in Answer to Mr. Hobbs, Spinoza, and their Followers. Wherein the Notion of Liberty is Stated, and the Possibility and Certainty of it Proved, in Opposition to Necessity and Fate*, W. Botham, for J. Knapton, London, 1705, 236.