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Luis Coronel's Theory of Impetus: The First 'Modern' Explanation of Free Fall Motion?

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Abstract

This paper examines the theory of impetus formulated by the Spanish philosopher Luis Coronel (ca. 1475–1531) and assesses its implications concerning the explanation of the acceleration of objects in free fall motion, arguing that Coronel provided what can be viewed as a modern explanation for this phenomenon. The paper begins by outlining the distinctive characteristics of medieval impetus theories preceding that of Coronel, and continues with a demonstration of how Coronel deviates from these earlier accounts due to a novel perspective on impetus, wherein impetus is equated with motion itself, and is no longer conceived as a cause of motion. Next, the various ramifications of this fresh outlook are considered, with particular emphasis on the case of free fall motion. The final section explores the influence of Coronel's theory, drawing comparisons between his ideas and modern views on impetus and inertia.

Keywords

motion – free fall motion – impetus – medieval physics – early modern physics

Introduction

Why do objects accelerate when they fall to the Earth? The task of explaining this observation has long perplexed scientists and philosophers. According to the picture we get from introductory physics textbooks, this phenomenon results from the interaction of an object's inertia with a gravitational field, which leads to an increase of momentum despite gravity remaining constant. This explanation stems from the fundamental principle that the acceleration of an object does not necessitate an increase in the force acting upon it. Instead, the same force, acting continuously on the same body, is sufficient to produce this effect.

Who, then, was the first to find this modern explanation of accelerated motion? While some attribute this view to Galileo, others favor Newton due to his more rigorously defined concept of inertia, despite his having a different conception of force. The consensus, nevertheless, has been that this type of answer was proposed in the seventeenth century.¹

One of the objectives of this paper is to argue for a revision of this date, suggesting that it should be moved back by a century, to around 1511 when the philosopher Luis Núñez Coronel (ca. 1475–1531), from Castile, in what is today Spain, published a work titled *Physical Investigations (Perscrutationes physice)*.² Luis Coronel was active during the same period as his brother, the logician Antonio Coronel. Having received his education in Salamanca, Luis relocated to Paris around 1500, where he studied under the guidance of John Mair. He served as a professor in Paris until the late 1510s, after which he returned to

¹ For a history of this problem, see Stillman Drake, *History of Free Fall, Aristotle to Galileo; with an Epilogue on π in the Sky* (Toronto, ON, 1989).

² Luis Coronel, *Perscrutationes physice* (Paris, 1511). Likely printed in Paris first, the work appears to have been edited in the same year by Simon Vincent in Lyons. Reference hereafter will be made to the more reliable edition of 1530, i.e., Luis Coronel, *Perscrutationes physice* (Lyons, 1530)

<https://books.google.fr/books?id=kr9uzalwXOgC&newbks=1&newbks_redir=0&printsec=frontcover&pg=PA5&dq=coronel&hl=fr&redir_esc=y#v=onepage&q&f=false>.

Spain, where he was anointed as Bishop of Seville. He later served also as Bishop of Las Palmas.³

In his work *Physical Investigations*, Luis Coronel synthesizes various influences, the most significant being the fourteenth-century Parisian philosophers John Buridan and Albert of Saxony, as well as the Oxford Calculators. Coronel presents a novel version of the medieval theory of impetus. Whereas medieval theories typically viewed the impetus as a *cause* of motion, Coronel identifies it with an effect and, more precisely, with motion itself. This redefinition brings about a significant shift in the understanding of the causes behind kinetic phenomena, especially variations in speed. Coronel's work provides what can be argued as an early expression of the modern explanation for the acceleration of freely falling bodies.

This revised perspective on the explanation of the cause of free fall motion does not claim to be either exhaustive nor a revelation, but it does wish to rectify a judgement that seems undeserved. In his brief entry on Coronel for the *Dictionary of Scientific Biography*, William Wallace unenthusiastically notes that his *Physical Investigations* contains "little original apart from the thesis that impetus is not really distinct from local motion."⁴ It is plain that Wallace did not fully appreciate the historical importance of this view and, at any rate, did not see its implications—although they are explicitly drawn by Coronel himself—

³ Very few studies have been devoted to Luis Coronel. On his life and some (partial) aspects of his philosophical work, see William A. Wallace, *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Dordrecht, 1981), 70–71, 81, 101–102; idem, *Causality and Scientific Explanation*, vol. 1 (Ann Arbor, MI, 1972), 132–135; Ricardo G. Villoslada, "La Universidad de Paris durante los estudios de Francisco de Vitoria, O.P. (1507–1522)," *Analecta Gregoriana*, 14/2 (Rome, 1938), 180–215, esp. 184–195; Marcel Bataillon, *Érasme et l'Espagne. Recherches sur l'histoire spirituelle du XVI^e siècle* (Geneva, 1937), esp. 148, 150, 152, 263–266, 275–276, 290, 293, 392–393.

⁴ William A. Wallace, "Coronel, Luis Nuñez," in *Dictionary of Scientific Biography*, ed. Charles C. Gillispie vol. 3 (New York, 1971), 420–421.

for the cause of acceleration in free fall motion. It was Pierre Duhem, in fact, who initially highlighted the original character of Coronel's theory of motion.⁵ After Duhem, Marshall Clagett acknowledged that Coronel "reported the impetus mechanics faithfully." Though he did not offer much further analysis, Clagett recognized after Duhem that Coronel's theory seemed to be the first to view impetus as an effect rather than as a cause, akin to the modern conceptions of impetus championed by figures like Galileo.⁶ Both Duhem and Clagett also acknowledged the resemblance between Coronel's notion of impetus and Descartes's concept of quantity of motion.⁷

This study has three main objectives. First, it seeks to offer a complete description of Coronel's theory of impetus, which has not been fully explored until now. Secondly, while accomplishing this task, it aims to reassess the scientific significance of this theory and its implications for the history of physics, particularly in its explanation of the acceleration of free-falling bodies, for which Coronel's theory provides an explanation similar to the modern view later proposed by Galileo. Thirdly, it aims to enhance our understanding of the intellectual environment that shaped the thinking of the Spanish philosopher Domingo de Soto, who is today recognized as the first to formulate an accurate description of the motion of free fall, and who—like Coronel—developed his theories within the John Mair circle in Paris.

The structure of this paper is as follows. We will first sketch the medieval backdrop of impetus theory, providing the essential context required for appreciating the uniqueness of Coronel's interpretation (section 1). Next, we will examine Coronel's specific definition of

⁵ Pierre Duhem, *Études sur Léonard de Vinci*, 3 vols. (Paris, 1906–1913), vol. 3, 150–153, 156–157.

⁶ Marshall Clagett, *The Science of Mechanics in the Middle Ages* (Madison, WI, 1961), 655–657. Similar remarks can be found in René Dugas, *Histoire de la mécanique* (Paris, 1950), 86–87.

⁷ Duhem, *Études*, vol. 3, 151; Clagett, *Science of Mechanics*, 657.

the concept of impetus, which constitutes a crucial element in his explanation of free-fall motion (section 2). We will then scrutinize the repercussions of this definition on the explanation and characterization of the motion of free fall and other types of motions (section 3). This will be followed, finally, with some reflections on how Coroneo's theory may have influenced those that followed, briefly comparing it with later perspectives (section 4).

1 Impetus as a Cause: The Medieval Theories of Impetus

The so-called medieval impetus theory never existed as a single theory.⁸ It was rather a collection of theories elaborated in different contexts, including commentaries on Aristotle's *Physics*, commentaries on Aristotle's *De caelo*, and, in the Latin world, commentaries on Peter Lombard's *Sentences*. The common goal of 'impetus' or impressed force theories was to explain certain properties of motion, in particular violent motions. The expression 'violent motion' refers to the motion of an object that goes against its natural inclination, e.g., the motion of a stone thrown upward that goes against its inherent tendency to fall down. In the *Physics*, Aristotle grappled with the challenge of elucidating this type of anti-natural motion (κίνησις παρὰ φύσιν / kīnēsis pará phúsin) that contradicted the intrinsic nature of objects.⁹ We know today that the earliest theories of impressed force, as documented by Simplicius, aimed to provide an explanation for this phenomenon. A heavy object may move upward when moved violently because some force is impressed on it by a mover. The object

⁸ On the medieval concept of impetus and the variety of theories associated with it, see the classic study of Anneliese Maier, *Zwei Grundprobleme der scholastischen Naturphilosophie, Studien zur Naturphilosophie der Spätscholastik*, vol. 2 (Rome, 1968), 113–314. More recently, see Jürgen Sarnowsky, "Concepts of Impetus and the History of Mechanics," in *Mechanics and Natural Philosophy before the Scientific Revolution*, ed. Walter R. Laird and Sophie Roux (Dordrecht, 2006), 121–145 and the bibliography contained in that volume.

⁹ Aristotle, *Physics* IV 8, 215a14–17; VIII 10, 266b27–267a20.

ceases its ascent and descends when this force is depleted, typically due to the resistance encountered from the surrounding medium, such as air.

In the context of Aristotelian physics, which rapidly gained prominence in late Antiquity and subsequently in medieval natural philosophy, the occurrence of violent motion, such as a stone moving upward upon being thrown, posed a challenge. This was primarily because it appeared to contravene two principles (or, more precisely, their combination) that were widely embraced. Let us refer to the first as the “principle of external causation,” and the second as the “principle of causal contact”:

Principle of external causation: Everything that is moved is moved by something else
(*Omne quod movetur ab alio movetur*)

Principle of causal contact: In a causal relationship, the agent and the patient must be in contact (*Agens et patiens sunt simul*)

One of the earliest, if not the very first report, of someone proposing a theory of this kind—Simplicius’ account of the ideas formulated by Hipparchus of Nicaea—mentioned it as an explanation of celestial motions.¹⁰ An important aspect of what historians refer to as the impetus theory is indeed that while it was originally devised to elucidate violent motion, several proponents of this theory in late Antiquity and the Middle Ages believed that this hypothesis could also account for a number of features of natural motion, including, as we will see, the accelerating motion of free fall. Such a hypothesis could also serve to explain how motion in a vacuum could occur, if such a vacuum did indeed exist and such motion

¹⁰ Clagett, *Science of Mechanics*, 514, 543–544.

was possible. In other words, the theory of impressed force or impetus belongs not only to different theoretical fields but, within physics itself, it addresses multiple problems: the violent motion of projectiles, motion in a vacuum, and natural motion.

How this theory passed from late ancient thinkers—mainly Philoponus—to Arabic philosophers including Ibn Sīnā (ca. 970–1037), Abu'l-Barakāt al-Baghdādī (ca. 1085–1165) and Ibn Bājjā (ca. 1085–1138) and then to the Latin world, with Francis of Marchia and Gerard Odo as its earliest defenders in the fourteenth century, is fairly well documented.¹¹ Equally well documented is the fact that later medieval theories of impetus, which will be the focus of our discussion regarding the immediate context of Coronei's views, were in disagreement about many points, including (1) the nature of the impetus, (2) the exact mechanism at stake when an impetus is impressed, and (3) the scope of the theory. Let us briefly touch upon all these points.¹²

(1) The nature of the impetus sparked significant debate. Whereas figures such as John Buridan defined it as a persisting force that diminishes only due to the resistance of the medium in which the object travels, others like Oresme conceived the impetus as self-expending. These dissensions extended to discussions about the ontological status of the impetus. Whereas Buridan conceived it as a quality impressed in the object and hence as a permanent thing (unlike successive entities like time or motion itself), Francis of Marchia defined its status as intermediary between permanent and successive entities.

(2) Some took the resistance of the medium in which the object moves to be responsible for the decrease of the impetus, whereas others saw the matter of the object

¹¹ For a synthetic survey, see Michael Wolff, *Geschichte der Impetustheorie. Untersuchungen zum Ursprung der klassischen Mechanik* (Frankfurt, 1978).

¹² This brief summary of the main differences between medieval interpretations of the impetus heavily draws on Maier, *Zwei Grundprobleme*, 113–314.

itself or its intrinsic qualities as the source of this resistance. In essence, there were debates about whether this resistance was externally or internally caused.

(3) Whereas most proponents of the impetus theory applied it primarily to material objects in motion, others like Francis of Marchia, in their commentaries on Peter Lombard's *Sentences*, extended it to psychological phenomena and even sacramental theology.¹³

Despite the numerous disagreements among proponents of the impetus theory, they shared a common belief, namely the view that the impetus is the *cause* of some type of motion, i.e., violent motion, with several authors extending this idea to celestial motions, particularly in the context of commentaries on Aristotle's *De caelo*.¹⁴ This consensus is further evidenced by the categorial classification assigned to impetus during that era: what historians of science usually call the "impetus" was rather called *vis* ("force") or *virtus* ("power") in the earliest Latin versions of this theory. The terminology of "impetus" only became established later, in fact. In response to objections formulated by his contemporary Albert of Saxony against an earlier version of his *Questions on Aristotle's Physics* (known as the *tertia lectura* version), John Buridan, in the fourth and final version of his *Quaestiones* composed in the 1350s, introduced the term "impetus" to designate what he had previously called *vis*.¹⁵ Thanks to the widespread dissemination of the final version of Buridan's

¹³ On Francis of Marchia's theory of impetus, see Fabio Zanin, "Francis of Marchia, *Virtus derelicta*, and Modifications of the Basic Principles of Aristotelian Physics," *Vivarium*, 44 (2006), 81–95, and Chris Schabel, "Francis of Marchia's *Virtus derelicta* and the Context of Its Development," *ibid.*, 41–80, who examines similar passages in Gerard of Odo, and the bibliography therein.

¹⁴ See Edward Grant, *Planets, Stars, and Orbs. The Medieval Cosmos, 1200–1687* (Cambridge, 1996), 548–551.

¹⁵ See, for example, John Buridan, *Quaestiones super octo libros Physicorum Aristotelis (secundum ultimam lectionem)*. *Libri III-IV*, ed. Paul J.J.M. Bakker and Michiel Streijger (Leiden–Boston, MA, 2016), IV, q. 9, 288–289. For more details on the evolution of Buridan's theory in relation to Albert of Saxony's views, see Jürgen Sarnowsky, *Die aristotelisch-scholastische Theorie der Bewegung: Studien zum Kommentar Alberts von Sachsen zur Physik des Aristoteles* (Münster, 1989), 50–51.

Quaestiones, the term *impetus* ultimately prevailed and endured into the modern era. As these observations indicate, the impetus was characterized by medieval authors as a force falling within the category of a quality.

Another significant aspect of medieval impetus theories followed from the preceding point: impetus was conceived as something *distinct* from the mobile and from motion as such. As a quality causing the motion of a mobile, the impetus—in its medieval elaboration—was necessarily something distinct from the mobile itself but, for the same reason, it was also something ontologically different from the motion. In Buridan’s ontology of motion—which holds particular significance in this context, as it forms the basis for Coronei’s theory—motion is considered a successive entity, i.e., an entity essentially extended in time, whose parts cannot exist simultaneously. By contrast, the impetus is a quality and hence a permanent entity (i.e., an entity whose parts all exist at the same time).

While the medieval notion of impetus has famously been likened to the modern concept of inertia, suggesting a certain degree of anticipation, these distinct characteristics set the medieval theories of impetus apart both from Newton’s concept of inertia and from the modern interpretation of impetus, as exemplified in the works of Galileo.¹⁶ In Galileo’s writings, as we will see in section 4 below, the impetus—or *impeto* in the Italian versions of his works—is neither something distinct from motion nor a cause of it. Instead, Galileo’s

¹⁶ See, for example, Anneliese Maier, “The Significance of the Theory of Impetus for Scholastic Natural Philosophy,” in *On the Threshold of Exact Science*, transl. David D. Sargent (Philadelphia, PA, 1982), 77: “There is no doubt that it *prepared the way* for the law of inertia. The theory of impetus occupies an important and enduring place in the history of natural philosophy and physics as an independent stage of development between Aristotelianism and classical mechanics. In this role of connecting link it furnished the illustrious founders of modern science with the point of departure for the development of their new theories.” But Maier is very careful to moderate this claim against former interpretations, such as that by Duhem, which she regards as exaggerated: “But this late scholastic theory has frequently been regarded as something more, namely, a true *anticipation* of the system of mechanics based on the law of inertia.”

impeto aligns more closely with the modern idea of kinetic energy, representing the energy possessed by a moving body but which is not, as such, really distinct from this moving body. With these elements in mind, let us now examine Luis Coronel's theory of impetus and his explanation of free fall motion.

2 Coronel's Theory of Impetus

2.1 *The nature of motion*

Coronel combines his impetus theory with another problem, namely, the ontological status of motion – a question that is, in fact, logically distinct from the issue of impetus. In the period in which Coronel formulated his theory, different factions held contrasting positions on this matter. The debate was epitomized by several renowned figures from the thirteenth and fourteenth centuries.

The first position, labeled by Coronel as the “realist” stance, posited that motion was a thing that was really distinct from the mobile and the different places it acquired successively when being moved. Advocates of this viewpoint included the Franciscan philosopher John Duns Scotus (ca. 1265–1308). According to this realist view, all types of motion are distinct from the things moved. Seen in this perspective, motion cannot be reduced to the thing in motion because, understood as successive process, motion cannot be identified with the new properties acquired by the object. An important argument for this view, which was articulated by Duns Scotus and was grounded in the Parisian condemnations of 1277, relied on the claim that it is possible for God to move the entire universe. Given that no place exists outside the universe, which one believed to be finite, the motion of the universe itself cannot consist in the acquisition of a new place. In this scenario, the universe itself would remain intrinsically unchanged. According to Duns

Scotus, this example demonstrated that motion *in general* could not be reduced to either the thing in motion or to the properties it gains through motion.¹⁷ Motion exists therefore as a real thing distinct from the object in motion. According to a second view, which Coronel ascribes to the Augustinian theologian Gregory of Rimini (ca. 1300–1358), motion is reducible to the distance travelled by a body.¹⁸ By contrast with the realist conception, “motion”—according to Gregory of Rimini’s view—is not a thing existing on top of the object of motion. Motion is rather reduced to *what* is acquired by a thing in motion. Gregory’s perspective reflects a reductionist approach to the essence of motion, which shares similarities with a third viewpoint outlined by Coronel. This third conception corresponds to what Coronel calls the “nominalist” position. According to this view, too, motion is not a thing as such. It is reducible to the *mobile* and does not refer to anything external to it. This type of position was advocated by William of Ockham (ca. 1287–1347), but Coronel often prefers to attribute it to “Nominalists” in general. Like Gregory of Rimini’s view, this conception constitutes a reductionist stance on the nature of motion, the main difference between the two views consisting in that to which motion is reduced (i.e., the properties acquired, according to Gregory, through motion vs. the mobile itself, according to the Nominalists).¹⁹

Coronel rejects all of these perspectives and instead favors what he terms a “fourth conception.” This fourth viewpoint aligns closely with the ideas put forward by John Buridan (ca. 1300–1358), which represents a kind of ‘middle way’ between the realist and nominalist interpretations of motion.

¹⁷ John Duns Scotus, *Quaestiones quodlibetales*, in *Opera omnia*, vol. 25 (Paris, 1895), q. 11, 441–442.

¹⁸ Coronel, *Perscrutationes physice*, III, 52rb.

¹⁹ *Ibid.*

While holding that a change is not different from the different states acquired by the mobile in the case of alteration and quantitative change (augmentation and diminution), Buridan believed that local motion is a thing really distinct from the different places acquired by a moving body. A key motivation for the position espoused by Buridan in the final redaction of his *Questions on Aristotle's Physics* was the argument already mentioned above, which involved God's capacity to move the entire universe.²⁰ But unlike John Duns Scotus, Buridan contended that this argument only establishes the reality of motion in the specific case of local motion, as no comparable arguments can be constructed for qualities and quantities. Local motion, for Buridan, was therefore a special type of motion that represents a real 'thing' irreducible to the mobile and the successive places it acquires. Coronel aligns himself with Buridan's perspective. He shares Buridan's belief that the realist position, which leads to an excessive proliferation of entities, necessitates a more parsimonious theory that introduces additional elements only when absolutely required. However, Coronel distances himself from the extreme positions advocated by Gregory of Rimini and the Nominalists, as they fail to provide—according to him—a satisfactory explanation for the phenomenon of local motion (in this regard, the Realists have a valid point).

Importantly, Coronel added arguments in support of his view on the nature of motion that would prove to be relevant to his theory of impetus. One of his arguments points towards the greater facility with which a person performs certain types of operations once accustomed to them. The fact that we acquire through repeated exercises some new habit (like writing or, more generally, moving our body in a certain way) can only be explained,

²⁰ Buridan, *Quaestiones super octo libros Physicorum Aristotelis*, III, q. 7, 76–79.

according to Coronel, by positing the reality of motion.²¹ Indeed, a real effect like a habit (that is, a quality acquired by a person) can only be produced by a real cause and be the term of a real process. If a habit is real, then the motion through which it is acquired must also be real.²² A similar line of reasoning draws on the empirical observation that local motion generates heat (heat being acknowledged as a real quality even by the most radical ‘Nominalists’ like Ockham, Buridan, or Gregory of Rimini).²³

2.2 Arguments supporting the impetus hypothesis

While following Buridan’s account of motion, Coronel includes—somewhat surprisingly—the impetus theory in his analysis of the ontology of motion, even though the impetus theory primarily addresses a separate issue, which is related to the *causes* of violent motion. The two problems of the ontological reality of motion and of the reality of the impetus are in fact logically distinct. As previously mentioned, philosophers such as John Duns Scotus and William of Ockham held opposing views on the existence of motion, but neither of them

²¹ Let us note that this idea, as such, does not originate with Coronel. The impression of a habitus in some bodily organ on the basis of repeated experiences such as writing was mentioned by Francis of Marchia in his discussion in favor of a *virtus derelicta* (cf. *Principium in quartum librum Sententiarum [redactio B]*, in Schabel, “Francis of Marchia’s *Virtus derelicta*,” a. 2, 74, ll. 378–383). The hypothesis that habitus can inhere in precise organs (and not only in the soul) to explain acquired capacities was not, however, intrinsically connected to an impressed force theory or to any specific view on motion. William of Ockham, for instance, admitted it without accepting the impressed force thesis or the reality of motion; see William of Ockham, *Quodlibeta septem*, ed. Joseph C. Wey (St Bonaventure, NY, 1980), III, q. 20, pp. 281–282, ll. 10–17. Coronel, in this context, accepts this view insofar as he sees in it an argument in favor of the reality of motion.

²² Coronel, *Perscrutationes physice*, III, 57ra–rb.

²³ *Ibid.*, 56vb–57ra.

embraced an impressed force theory.²⁴ Conversely, during the mid-fourteenth century, Parisian philosophers like Nicole Oresme (ca. 1320–1382), Albert of Saxony (ca. 1320–1390), and John Buridan all endorsed the impetus hypothesis. However, they remained divided when it came to their views on the actual existence of motion. For instance, Albert of Saxony refused to categorize motion as a real thing.²⁵ By addressing the issue of impetus within the context of a broader question concerning the reality of motion, Coronel appears to blend the two problems. This conflation is even more evident when he presents his arguments for his specific perspective on impetus, as we will see later.

Before entering into the details of his impetus theory and its consequences for the concept of inertia and the explanation of the motion of free fall, let us take a moment to outline the reasons why Coronel deems it essential to accept the impetus theory in the first place. According to him, there are three main arguments in favor of this theory, the first two of which are not especially original: (1) only the theory of impetus provides a good explanation of violent motion, and (2) this theory is the only one capable of explaining the acceleration of free-falling bodies.²⁶ Coronel's third argument in favor of the impetus hypothesis is more interesting and will be labelled here as the 'rest argument.' This argument, which was initially developed by Albert of Saxony to explain the trajectory of projectiles and was later refined by Marsilius of Inghen, is less widely known than the other

²⁴ Duns Scotus shows no signs of accepting this view, which is explicitly rejected by William of Ockham in his *Quaestiones in librum tertium Sententiarum [Reportatio]*, ed. Francis E. Kelly and Girard J. Etzkorn (St Bonaventure, NY, 1982), q. 4, 142–144.

²⁵ For a comparative overview of the positions advocated by the main Parisian master of that time, see Johannes M.M.H. Thijssen, "The Debate over the Nature of Motion: John Buridan, Nicole Oresme and Albert of Saxony, with an Edition of John Buridan's *Quaestiones super libros Physicorum, secundum ultimam lectionem*, Book III, q. 7," in *Evidence and Interpretation in Studies on Early Science and Medicine: Essays in Honor of John E. Murdoch*, ed. Edith D. Sylla and William R. Newman (Leiden, 2009), 186–210.

²⁶ Coronel, *Perscrutationes physice*, III, f57va–vb.

two.²⁷ The argument draws on the (false) assumption that a heavy body thrown upward will ‘rest’ at the top of its trajectory for a certain time before starting to fall down. But by “a certain time,” Coronel understands a time duration greater than an instant, according to his interpretation of a passage in Aristotle’s *Physics* which describes this type of motion.²⁸ Unless one admits the existence of an impetus, Coronel now argues, one will never be able to explain why a heavy object can rest at the top of its trajectory when thrown upward. Taking this assumption to be factually true, Coronel elucidates it by means of a hypothetical scenario. Before explaining what this was, it is important to remember that it was then common practice to assign numerical values to qualitative properties such as heat or heaviness, despite the absence of actual units of measurement for these properties. The scenario is as follows: let us take an object—say, O—and assume that this object O is heavy at degree 4. Let us say that the medium (air) in which the object is thrown is uniformly dense at degree 2. The medium thus opposes a resistance of degree 2 to the object’s motion. Now let us assume that someone throws the object O upward by impressing on it an impetus of degree 8. Following its launch at t_1 , object O will move in an upward direction, counter to its innate inclination to descend due to its inherent heaviness. This is made possible because the impetus (with a degree of 8) surpasses the combined resistance posed by the opposing forces of heaviness and the resistance of the surrounding medium ($8 > 4 + 2$). As a consequence of this resistance, the object will come to a halt at t_2 , marking the zenith of its trajectory. At this point, let us assume that the impetus has been reduced to

²⁷ Albert of Saxony, *Expositio et quaestiones in Aristotelis Physicam*, ed. Benoît Patar (Louvain-La-Neuve and Paris, 1999), vol. 3, VIII, q. 10, 1059; Marsilius of Inghen, *Abbreviationes super octo libros Physicorum Aristotelis* (Venice, 1521), 38ra; cf. (Ps-)Marsilius of Inghen, *Questiones subtilissime super octo libros physicorum secundum nominalium viam* (Lyon, 1518), VIII, q. 7, 84rb–va.

²⁸ Aristotle, *Physics* VIII 8, 262b22–28.

a degree of 6 due to the cumulative resistance from the object's own heaviness and the surrounding medium. The object will be at rest, because the value of the impetus now matches the combined resistance exerted by the object and the medium. ($6 = 4+2$). Due to the force exerted by the heaviness (which tends to move the object downward), the impetus will keep on decreasing at every instant. Let us say that at t_3 , the impetus has now dropped to degree 3. According to Coronel, the object will still be at rest at that moment because the force of heaviness is still insufficient to overcome the combined resistance posed by the impetus and the surrounding medium ($4 < 3 + 2$). Ultimately, at t_4 , when the impetus has dwindled to a degree of 1, the object will initiate its descent. This occurs because, at this point, the object's heaviness surpasses the combined resistance posed by the remaining impetus and the surrounding medium ($4 > 1 + 2$).

The key detail in this scenario is that O will be at rest at the top of its trajectory for some time and not just for one instant. Coronel suggests, in fact, that an object can remain at rest for an extended period, potentially even for hours or longer, if the appropriate balance of force and resistance is present. He contends that the only viable explanation for an object being stationary in such a manner at the peak of its trajectory is to introduce the concept of impetus, as demonstrated in this hypothetical scenario.

2.3 Nature and scope of the impetus

We have now seen why, for different reasons, Coronel believes it necessary to follow John Buridan's idea that some impetus should be postulated to explain the properties of motion. Let us now turn to Coronel's description of the nature of the impetus, which is one respect in which it differs from previous accounts:

It must be noticed that there is no other difference between impetus and local motion than between being more and less common so that every impetus is a local motion but not the other way around. Indeed, an impetus is a very intense motion. But we can nonetheless call every motion—be it intense or attenuated—an impetus. And not everything in motion moves quickly (*impetuose*), which should not be considered a problem because not everything moving by an impetus needs to move quickly, since a heavy [body] projected upward is moved by an impetus [when it comes] near its swing point, although [its motion] due to its slowness is attenuated (*remisso*) but not quick.²⁹

Coronel presents his own account of the impetus as a simplification of earlier views on the subject, following a principle of epistemological parsimony.³⁰ Whereas Buridan and his contemporaries viewed the impetus as a force really distinct from the object and from the object's motion, Coronel asserts that the impetus is nothing else than motion itself.

Let us note that the passage just quoted shows some ambiguity with respect to the exact relation between impetus and motion. In the strictest sense, an impetus is a quick local motion. But more broadly, *every* local motion can be called an impetus even when the object is moving slowly, as long as one is careful to distinguish between an impetus and

²⁹ Coronel, *Perscrutationes physice*, III, 58rb: "Animadvertendum est quod inter impetum et motum localem nullam aliam differentiam assignare quam inter magis et minus commune ita quod quilibet impetus est motus localis sed non e converso. Impetus enim est motus valde intensus sed sive remissus sive intensus fit motus possumus tamen dicere quod quilibet motus sit impetus et non quicquid movetur impetuose movetur quod non reputaretur inconveniens quia non oportet quod quicquid impetu movetur impetuose moveatur quoniam grave in sursum proiectum prope punctum reflexionis impetu movetur licet remisso sed non impetuose propter tarditatem." Unless otherwise stated, the translations are mine.

³⁰ *Ibid.*, 60rb.

quick (*impetuose*) motion. As is implied by the term “local,” Coronel confines the association of motion and impetus to motion in space and therefore does not consider other types of motions acknowledged in the Aristotelian tradition (such as quantitative changes and alterations) as impetuses. However, the identification of impetus and local motion encompasses all types of local motions, i.e., natural and violent, including those of animate things as well as inanimate ones:

Coming back to our proposition about motion, we say briefly [...] that local motion is nothing else than the impetus and that local motion occurs in three ways, namely naturally, violently, and progressively. Animal motion is also a progressive motion like the motion by which the hand, foot, or finger move. It is indeed shown that a heavy [body] falling down produces an impetus that is motion (*qui est motus*). Thus, I find the Subtle Doctor saying in the second distinction of the second [book of the *Sentences*] that a heavy [body] produces motion by the heaviness inhering in it. If again something is moved violently, we call its local motion an impetus. Progressive motion however is somewhat more difficult, and the cause of this difficulty is that in natural or violent motion or impetus one part of space serves for carrying the other part, at least some of its parts. And because of that, nothing can move naturally or violently in a uniform way within a uniform medium, other external obstacles or assistances taken apart [...].³¹

³¹ Ibid.: “Redeundo igitur ad propositum nostrum de motu dicimus breviter non stando an ad impetum requiratur certa intentio vel ne quod nihil aliud motum localem dicimus quam impetum et cum tripliciter contingat motum localem fieri naturaliter, videlicet violenter et progressive. Motus autem progressivus est motus animalis progredientis ut motus quo movetur manus vel pes vel digitus. Ostensum est enim quod grave descendens producit impetum qui est motus. Unde invenio Doctorem Subtilem in secundo dist. secunda

Several comments are in order here. The first concerns the meaning of Coronel's simplification of Buridan's theory. While the latter's model of violent motion required three things (the mobile, the motion, and the impetus), Coronel chooses to reduce it to *two* things by identifying the motion with the impetus. According to Coronel, the impetus is not distinct from motion because it is motion as such. This represents a notable departure from earlier explanations of impetus, which characterized it as a force applied to the moving object, serving as a cause of motion. Rather than being a cause of motion, the impetus here is the *effect* produced by a moving agent, this effect being motion itself. Motion is defined by Coronel as an accident of the mobile inhering in it, which is subject to intensification and attenuation and is permanent.³² This last qualification is interesting, as it shows another point of departure with respect to Buridan, who had defined local motion as a *successive* (i.e., a non-permanent) thing.³³ It thus reinforces the persisting character of the impetus (which is identical to motion) in the absence of external obstacles. A second point to note is that Coronel grants a universal scope to his theory of impetus. It applies not only to objects moving against their natural tendency but also to the natural motion of inanimate objects (i.e., objects moving in accordance with their natural tendency) and animal motions, which Coronel calls "natural" and "progressive" motions, respectively. As already noted, the extension of the impetus theory to natural motion is not new. Buridan himself, for instance,

dicentem grave per gravitatem sibi inherentem producere motum. Si autem violenter aliquid moveatur impetum ibi productum motum eius localem dicimus de motu tamen progressivo est aliquantulum difficilius et causa difficultatis est, quia in motu naturali sive violento motus vel impetus unius partis spacia deservit pro transitu alterius partis saltem secundum aliquas partes eius, et inde est quod per medium uniforme non contingit aliquid naturaliter vel violenter uniformiter moveri aliis impedimentis et iuvaminibus seclusis [...]."

³² Ibid., 58rb.

³³ Buridan, *Quaestiones super octo libros Physicorum*, III, q. 7, 79.

formed the hypothesis that the skies may be moved by such an impetus. Coronel relies on the “Subtle Doctor,” that is, John Duns Scotus, to claim that the accidental property of heaviness is that by which heavy bodies acquire an impetus while moving downward.

Much more original is the application of the theory to animal motions. In the passage just quoted, Coronel seems to conceive the impetus in the case of animal motion in the same way as in the case of inanimate objects, i.e., as another term for local motion as such. The only difference between animal motion and the motion of inanimate objects lies in the fact that animals are composed of different parts, which do not move together at the same time. The peculiarity of animal motion, which necessitates the continuous generation of a new impetus despite the animal’s speed remaining constant, comes from the fact that some parts of an animal move other parts of that same animal, which offer some resistance to the parts moving them. As was suggested earlier, Coronel saw the fact that we gradually get better at performing new tasks (as, for example, writing) after a few trials and experiences as an argument in favor of the reality of motion.³⁴ The soul is therefore able to generate a new impetus and the reality of that new impetus is evidenced by the persistence of habits or dispositions as its effects on the animal’s own being. Needless to say, the process by which the human soul, being an immaterial entity according to Coronel, can generate an impetus in the body to which it is attached remains obscure and is not further analyzed in his text. That said, Coronel’s concept of impetus is all the more remarkable as he seems to have envisioned a universal scope for his theory, which encompasses not only motions proper to the physical world but also features of animal psychology, including all these phenomena as various aspects of a same inertial tendency.

³⁴ Coronel, *Perscrutationes physice*, III, 57ra–rb.

3 Explanation of the Kinematic Properties of Motion

An analysis of how this theory is meant to explain the different types of motions observable in the physical world and their kinematic properties is now in order. Let us proceed following the different types of motions that Coronel distinguishes, i.e., natural, violent, and progressive or animal.

3.1 *Natural motion*

The first application of Coronel's impetus theory—namely, to natural motion—may be the most important one as regards its scientific implications. As I pointed out above, Coronel intends to streamline Buridan's theory of violent motion by reducing the number of entities involved, shifting from a three-term framework to a two-term model. In this new model, two things are sufficient to explain motion, i.e., the mobile and its motion or impetus. This reduction has a direct consequence for the explanation of the motion of free fall, which is the natural motion of a heavy body. Indeed, Coronel—like Buridan—thinks that the increase of velocity observable in such a motion is due to the increase of an impetus that is gradually acquired by the falling object. Since Coronel does not conceive this impetus as a force but simply as the object's motion, however, he does not attribute the increase of an object's velocity in the motion of free fall to an increase in the force acting upon it. On this point, Coronel departs not only from Buridan's theory of impetus, but also departs more broadly from the thesis—generally accepted in the late Middle Ages—that an increase in velocity must be caused by an increase of the force acting upon it or, more precisely, in the ratio between force and resistance.³⁵ Let us call this thesis the “proportionality principle”:

³⁵ Let us note that the term “ratio” is taken here in its general sense. Certain theories, such as the one attributed to Ibn Bājjā, posited that the increase in speed strictly follows the difference (of the form $m - n$)

Proportionality principle: An increase in the velocity of an object is always caused by a proportional increase in the ratio between the force and the resistance acting upon it.

Ancient and medieval natural philosophers were largely divided over how to interpret the way in which the force exerted upon an object and its velocity were related, that is, how to interpret this proportionality. By Coronei's time, the rule that was by far the most popular is nowadays associated with the name of Thomas Bradwardine. Bradwardine's rule stated that there exists a relation of *geometric* proportionality between the ratio of force to resistance and the velocity of an object rather than a relation of arithmetic proportionality (a view that was at the time attributed to Aristotle).³⁶ But despite debates regarding the nature of the proportionality involved in this rule, medieval authors agreed on the general principle that an increase of the ratio between force and resistance is always required for the increase of an object's velocity. This was denied, however, by seventeenth-century physicists after the integration of the principle of inertia into physics in the early modern era: given the inertial behavior of bodies, it is only necessary to exert a constant force on an object to induce an acceleration in its motion.

between the motive force and the resistance of the object in motion. Even though it also follows from this hypothesis that the ratio between the two increases as speed increases, its formulation generally relied on the notion of *excessus* (excess) to express this relationship.

³⁶ Thomas Bradwardine, *Tractatus de proportionibus*, ed. and transl. Henry L. Crosby in *Thomas of Bradwardine. His Tractatus de Proportionibus. Its Significance for the Development of Mathematical Physics* (Madison, WI, 1961). This rule and its reception have generated an extensive literature. Suffice it here to mention Clagett, *Science of Mechanics*, 421–503, and more recently Edith D. Sylla, "The Origin and Fate of Thomas Bradwardine's *De proportionibus velocitatum in motibus* in Relation to the History of Mathematics," in Laird and Roux, *Mechanics and Natural Philosophy*, 67–120 and its bibliography.

Unlike previous impetus-based accounts of the acceleration of the motion of free fall, Coronel's identification of impetus with motion resulted in the view that no force is added to a heavy object when it accelerates during its fall. Let us spell this out. What is the force acting on a falling body? In Coronel's view, it is the heaviness (*gravitas*) of the body, this heaviness being a quality inhering in it and remaining constant:

[...] We say that we are bound to affirm that heaviness (*gravitatem*) produces while falling down an impetus due to the difformity of the fall's velocity that is quicker at the end than at the beginning. Therefore, where there is no such difformity we do not need to attribute to heaviness the production of an impetus. And heaviness producing the fall successively in time has been called an impetus. If therefore the fall or locomotion (*transitus*) is instantaneous we do not need to call it the production of an impetus and, since a heavy [body] according to the Philosopher's saying in the fourth [book] of the *Physics* will move or will change instantaneously in the void, heaviness will not produce in such a case an impetus.³⁷

This passage indicates that Coronel attributes the natural downward motion of a heavy body to the force of heaviness. It also demonstrates how his theory is still indebted to the Aristotelian scholastic era. Coronel conceives indeed the motion of free fall as the effect of

³⁷ Coronel, *Perscrutationes physice*, III, 59va: "[...] Dicimus quod cogebamur dicere gravitatem descendendo impetum producere propter difformitatem velocitatis descensus quae velocior prope finem quam prope initium existit. Ubi igitur talis difformitas non contingit non oportet quod impetus productionem gravitati attribuamus. Et gravitas successive tempore descensus producere dicebatur impetus. Si ergo descensus vel transitus sit instantaneus non oportet quod impetum produci dicamus et cum grave secundum Philosophi sententiam in quarto *Physicorum* per vacuum movebitur vel mutabitur in instanti gravitas non produceret in tali casu impetum."

heaviness understood as a quality opposed to lightness. Heaviness and lightness are defined as qualities inhering in heavy substances (like earth or water) and light ones (like fire and air), respectively. Thus, the originality of Coronel's explanation of the acceleration of free fall motion does not lie in the type of force postulated to explain it but rather in the way this force can produce a certain effect given a body's tendency to remain in its state of motion.

But what is then acquired during acceleration? In a sense, nothing new is acquired during this process: no new substance, force, or accident. The accelerating body accumulates only some impetus, which is nothing else than motion. The accelerating body, in other words, acquires more motion.

Note that this account of the impetus would probably force Coronel to reinterpret the two Aristotelian principles of motion presented above, namely the principles of external causation and causal contact. He does not fully address this issue, however.³⁸ For the first principle, he maintains that a falling heavy object is moved by something else, if dropped by someone from a certain height, for instance. Whereas the person's dropping the object is its accidental cause, the object's heaviness is what moves the material substance essentially. This notion would appear to threaten the principle of external causation. Indeed, for Coronel, the heaviness is in an important sense *internal* to the object, since it inheres in it. But he also believes that a quality is ontologically distinct from its substrate of inherence, and that it may be separated from it even if this never happens in the normal course of nature (God could, for instance, separate the heat from a given fire or the heaviness from water). Even though the heaviness is in the body, it is nevertheless the cause that is acting

³⁸ Coronel refers only briefly to the principle *omne quod movetur ab alio movetur* in order to reject the idea that it necessarily implies an *extrinsic* mover, since the motion of a body can be explained by an internal cause, such as heaviness (see *ibid.*, 59vb).

upon it and producing its motion. The material body is moved by something that is ontologically distinct from it, although this cause happens to be located within the body itself.

As for the second principle, that of causal contact, Coronel maintains that the essential cause of the accelerated motion of a free-falling body is in contact with the body, as it is the heaviness inhering in it. Compare this to Buridan's theory, where the impetus represents the cause while being directly in contact with the effect. If these more conjectural observations hold true, then Coronel's theory of impetus may successfully maintain both the principles of causal contact and external causation and only drop the proportionality principle of the previous Aristotelian tradition. Despite his good old Aristotelian conception of heaviness as a property inhering in a substance, his view that a single force continuously applied to an object produces an acceleration when no resistance impedes its motion offers a "modern" explanation of the acceleration of free-falling bodies, which is structurally equivalent to the explanation provided by the principle of inertia in modern physics.

3.2 Violent motion

Violent motion represents the classical application of the theory of impetus. The implication of Coronel's own version of this theory is that no special force is impressed on the mobile when it is thrown upward. As Duhem has long ago pointed out, Coronel, in a sense, goes back to the Ockhamist account of motion that denies the existence of a *virtus impressa* or *derelicta*.³⁹ But there the resemblance with Ockham ends. Coronel maintains that the impetus, being identical with motion, is distinct from the mobile. It is not something,

³⁹ Duhem, *Études*, vol. 3, 150.

however, that adheres to the mobile in the manner of a force. The cause of a violent motion is, admittedly, a force, but this force is nothing but the effort that has caused the motion:

It is not because the projectile is held for a longer time that a more intense impetus is produced but because it is thrown with a greater effort (*conatu*) and, since the application of the conatus is successive, the impetus is produced successively.⁴⁰

It appears from this passage that, according to Coronel, the force or effort causing the motion is not something impressed on the mobile. The effort (which, interestingly, is designated here by the term *conatus*) is applied to the projectile so as to produce its violent motion, but the conatus as such is not something that continues to inhere in the projectile after it has been thrown.

Still, the impetus provides an explanation for why an object keeps moving when thrown violently. Indeed, Coronel's explanation of violent motion reveals that the impetus is conceptualized as a propensity for an object to maintain its current state. This tendency is counteracted by the opposing influences of the medium's resistance and the internal inclination of the body. It seems therefore that Coronel views the impetus as something whose corruption comes from the outside: namely, either the intrinsic properties of the moving body or those of the medium in which it moves. His constant appeal to Buridan when it comes to justifying the impetus theory confirms this stance and shows that Coronel

⁴⁰ Coronel, *Perscrutationes physice*, III, 58vb–59ra: “[...] Non enim ex eo quod magis et magis detinetur proiectibile intensior impetus producitur, sed ex eo quod cum maiori conatu impellitur, et quia appositio conatus successive sit successive producitur impetus.”

favors the view, advocated by Buridan, according to which the impetus is not self-expending or self-depleting, as some previous theories had postulated.

There are, however, two brief passages in Coronel's *Physical Investigations* that suggest that the impetus could come to an end "by its own nature" (*ex propria natura*)—an expression which tends to accompany the interpretation of impetus as self-expending.⁴¹ These two passages seem at first glance to conflict with all other passages where opposing factors (internal force of a body or the medium's resistance) are portrayed as the true causes of the diminution of the impetus. But in these two passages, Coronel is not presenting his own perspective but is rather considering alternative notions of impetus while addressing possible objections to his impetus hypothesis. In all other passages, Coronel makes it clear that the impetus is diminished by the resistance offered by the medium in which the object moves or by external objects. For instance, it is because of air's resistance that a wheel stops moving after some time when no external force is exerted upon it.⁴² Central to the inquiry into the intrinsic nature of the impetus was the enigma of what would occur to a body possessing some impetus if it were moving in a vacuum. Whereas those defenders—like Buridan—of the permanent nature of the impetus accepted the consequence that the body would keep moving forever, those inclined to seeing it as self-expending denied this consequence.⁴³ Unfortunately, this issue cannot help us determine Coronel's exact position, since he simply denies the possibility of an impetus in the void, in which the moving body would have to reach an infinite speed – a possibility that

⁴¹ See *ibid.*, 59ra; and 60rb: "[...] et sic cum impetus debeat consequenter remitti ex propria natura [...]."

Coronel, in this passage, spells out a doubt against his own view, meaning that it does not directly express his position.

⁴² *Ibid.*, 59vb.

⁴³ On this, see Anneliese Maier, "Das Problem der Gravitation," in eadem, *An der Grenze von Scholastik und Naturwissenschaft* (Rome, 1952), 235–240.

he rejects. Even if Coronel might have experienced some hesitation over his theory when faced with such thought experiments, it is obvious that they could not have the same meaning for him that they had for previous theories where the impetus was conceived as a quality.

It is possible to speculate that, despite his rejection of the self-expending hypothesis, Coronel's occasional tentative remarks about the cause of the diminution of the impetus might be attributed to his analysis of various types of motion. This question, in fact, is important. Indeed, it is an essential feature of Coronel's theory that he posits a difference between various species of impetus:

It must be replied clearly that the impetus by which a heavy [body] is moved upward is specifically distinct from the impetus by which it moves downward, because heaviness contributes to producing the second, as has been said. In the same way, the impetus by which something moves in a circular way is specifically distinct from the impetus by which it would move in a rectilinear way because, since these impetuses move in different ways, they must be conceived as [belonging] to different species.⁴⁴

This point stems directly from the distinction between different species of motions made in the Aristotelian tradition; it is this tradition, after all, which constitutes the framework of Coronel's natural philosophy. While Coronel identifies the impetus with local motion, he

⁴⁴ Coronel, *Perscrutationes physice*, III, 59rb: "Respondetur [...] signanter impetus quo grave in sursum movetur distinguitur specie ab impetu quo movetur deorsum quia ad productionem secundi ut dicebatur gravitas concurrat. Item impetus quo aliquid movetur circulariter distinguitur specie ab impetu quo recte moveretur quia postquam illi impetus diversimode movent diversarum specierum reputari debent."

follows Aristotle's analysis in *Physics* VII 4 in admitting the existence of different *types* or *species* of local motions – namely, circular and rectilinear. He also thinks that downward and upward natural motions belong to distinct species, since they arise from essentially different qualities. But he denies that lateral motions (i.e., motions that are horizontal relative to the terrestrial reference frame) having different directions belong to different species. It is Coronel's recognition of different species of motion, in fact, together with his identification of impetus with motion, that leads him to propose different types of impetus.

One of the most striking consequences of this new perspective on impetus lies in the paradoxical situations where an impetus is countered by the resistance of a medium. As we have seen, Coronel thinks that rest during an extended period of time is possible at the top of the trajectory in the case of an object that is moved violently upward. In this case, even though there is an impetus of a certain degree, this degree is not great enough to overcome entirely the opposing effect of the medium and of the active qualities present in the object. But according to Coronel, the object *still* possesses an impetus, even if the effect of this impetus is no longer observable as visible motion.

This position might puzzle readers who remember that the impetus was specifically defined as motion. The tension arises because Coronel inherits his "rest argument" from thinkers who shared his belief in the existence of impetus, but who conceptualized impetus as a force. Because of this, Coronel holds the remarkable view that in such a scenario the object can be described equivalently as either being in a state of motion or at rest:

And just as there is no incongruity in the projectile at the top [of its trajectory] being an impetus during the time of its rest at this point, that is, at the point of reflection, in the same way in a resting animal, which was progressively being moved, there is

an impetus which, if you want to call it “motion” during the time of rest, you will concede it to be existing [sc. this motion] in something at rest.⁴⁵

Albert of Saxony and Marsilius of Inghen had previously provided the same analysis of rest at the highest point of the trajectory as proper to an object that is thrown upward. But only Coronel claims that this state may be indifferently qualified as rest or motion, something following from his peculiar understanding of the impetus. This claim is rare enough to be worthy of note. The difference between motion and rest is a structural distinction of Aristotelian physics, on the basis of which the behavior of natural bodies is explained within this framework. One of the core differences between scholastic physics—still deeply indebted to Aristotelianism—and modern physics lies precisely in the rejection of any essential distinction between motion and rest with regard to the inertial behavior of bodies.⁴⁶

We must point out, however, that Coronel does not reject this distinction generally. To the contrary, his account of motion as a state opposed to rest remains quite steadfastly Aristotelian. Yet, in some special circumstances, like that of a violently moved body at the top of its trajectory, this distinction collapses. Coronel justifies this point by analogy with the motion of an animal which, while being progressive, may look as if it includes moments of

⁴⁵ Ibid., 60rb–va: “Et sicut non habetur pro inconvenienti in proiecto in sursum esse impetum tempore quietis in puncto, videlicet reflexionis (ut superius ostensum est) ita stat quod quiescente animali quod progressive movebatur sit in eo impetus quem si tempore quietis velles vocare motum concedas in aliquo quiescente motum existere.”

⁴⁶ This fundamental difference between modern and medieval physics does admit certain exceptions. In particular, Oresme and Buridan, in their respective commentaries on Aristotle’s *De caelo*, consider the hypothesis of a “relativity” of motion and rest. For a discussion of this idea and a translation of the relevant passages, see Clagett, *Science of Mechanics*, 583–609.

rest despite being in continuous motion. We must therefore dedicate a few words to this last case, as it enables us to get the complete picture of Coronel's theory of impetus.

3.3 Progressive or animal motion

The case of what Coronel calls "progressive" motion with reference to the motion proper to animate beings lies, in a certain sense, between that of natural inanimate beings and that of violently moved objects. In this specific case, there is neither acceleration nor deceleration. Unless the soul wants to move the body with a varied speed, it will move it with constant speed. Coronel's explanation of this fact is rather succinct, to say the least, but the motivation behind his claim seems to have been the following: Since an animal belongs to the class of heavy bodies, the soul will have to produce ever new impetuses to counter the effect of heaviness and thereby maintain continuous motion. The choice of the term "progressive" for characterizing this type of motion matches this property: although the motion of a moving animal may seem constant and continuous, it results from the successive production of new impetuses over a certain time. The main difference between this type of motion and the natural motions of inanimate bodies on the one hand, and violent motions on the other, lies in the fact that the production of the impetus, in the case of progressive or animal motion, is *immanent* to the substance, i.e., it is intrinsically produced by the soul and not received from some external agent:

We say that the soul is apt by nature, at least secondarily, to produce an impetus in the matter affected by some dispositions that it informs. It is said "secondarily" because of what was said at the beginning about its power (*virtute*), that is, the productive power of the soul toward external things. And because this soul is able by

nature to set itself in motion, the motion of the matter it informs (which is a certain impetus) follows its own motion. And in this way the soul pulling the body with itself (so to speak) produces in it an impetus which, be it intense or attenuated, does not move this matter more quickly than the soul wants when the impetus is not caused extrinsically. Sometimes, however, it happens that the impetus is so intense that the soul is not able to stop its great velocity. And we admit that new impetuses are constantly produced during the time of the progressive motion, and yet the locomotion (*transitus*) is uniform when the soul wants to move uniformly, which sometimes allows its matter to be moved following the high level of intensity of the impetus [...].⁴⁷

This passage illustrates well that, compared to Buridan and other earlier proponents of the impetus, Coronel disconnects the concepts of impetus and force and relates them differently to the speed of bodies. A constant force can produce an acceleration, according to Coronel, but it is also the case that the renewed application of a force when it comes to animal motion produces a uniform motion or impetus. While the soul may lose control over the body, in some special cases as suggested in the above passage, a soul willing to move its

⁴⁷ Coronel, *Perscrutationes physice*, III, 60rb: “[...] Dicimus quod anima apta nata est saltem secundario in materiam quibusdam dispositionibus qualificatam quam informat impetum producere. Secundario dicitur propter illud quod in principio dicebatur de virtute, videlicet anime productive ad extra, unde quia ipsa anima apta nata est seipsam movere ad motum eius motus ipsius materie quam informat (qui impetus quidem est) sequitur et sic anima secum trahens materiam (ut sic dicamus) impetum in eam producit qui sive intensus sive remissus sit non movetur ipsa materia velocius quam anima vult moveri quando impetus ab extrinsecis non est causatus, aliquando tamen contingit impetum esse tam intensum quod anima non valet magnam velocitatem prohibere, et fatemur quod novus et novus impetus producit tempore motus progressivi, et tamen uniformiter fit transitus quando anima vult uniformiter moveri que aliquando permittit quod secundum intensionis rigorem impetus sua materia moveatur [...]” Note that punctuation was added in the translation.

body uniformly will have to apply, in all other cases, a series of successive forces to generate a constant (or uniform) impetus. Although the passage does not make it explicit, it is clear that this fact stems from the necessity for an animal willing to move to counter the effect of its body's heaviness at each instant of its motion. According to Coronel, no natural or violent motion in a uniform medium can be uniform.⁴⁸ This proposition makes sense insofar as Coronel denies the possibility of a motion taking place in the void and that, in his view, all possible motions in a terrestrial reference depend both on the medium's resistance and on the intrinsic tendency of a body to move in a certain direction. Hence, only progressive or animal motion can exhibit uniformity in a uniform medium. In such cases, the force required for the animal to move must be applied repeatedly throughout the entire duration of the motion. The properties of animal motion derive from the soul's being the intrinsic cause of the impetus in this special case and from the soul's desire to move the body in a particular way (i.e., usually with a constant velocity). Despite not representing the most impactful application of impetus theory from the perspective of physics and its historical development, Coronel's insistence on making room for the psychological and biological dimensions of the impetus fits with his ambition to provide a general theory of impetus encompassing the whole variety of motions and their complex properties that we observe in nature.

4 Coronel's Impetus in Perspective: Similarities with Early Modern Theories and Potential Influences

Since the publication of William Wallace's works, it has been known that the first correct description of the motion of free fall was not to be attributed to Galileo Galilei, as has long

⁴⁸ Ibid., 58rb; 60rb.

been believed, but to the Spanish Dominican Domingo de Soto (1494–1560), who belongs to the next generation of thinkers related to the John Mair circle.⁴⁹ De Soto was the first to describe free fall as a “uniformly difform” motion (i.e., constantly accelerated) with respect to the time of motion. Wallace suspected that this description of motion may not have been Soto’s original discovery, as he seems to be repeating teachings common at his time.

Unfortunately, one does not find the technical expression “uniformly difform” in Coronel’s *Physical Investigations* with respect to local motion, despite its frequent appearance elsewhere in the work, where it is used with respect to qualities, dispositions, or material density.⁵⁰ This is unfortunate, because what Coronel proposed may be seen as a sound explanation of the accelerated motion of free fall. As we have seen, Coronel does use the term “difform” when describing the motion of free fall and, on the basis of his theory of impetus, he aims to demonstrate that in a uniform medium the acceleration has to be constant because of the cumulative effect of the impetus coupled with the constant effect of a body’s heaviness. Coronel thus possessed the necessary tools to arrive at the description of the motion of free fall that de Soto was to achieve somewhat later, which is also the correct description of the motion of a body subject to a constant force in a resistance-free medium, in addition to providing a good explanation for this particular type of acceleration.⁵¹ De Soto, by contrast, reached the correct description of the motion of free

⁴⁹ William A. Wallace, “The Enigma of Domingo de Soto: *Uniformiter difformis* and Falling Bodies in Late Medieval Physics,” *Isis*, 59 (1968), 384–401.

⁵⁰ Coronel, *Perscrutationes physice*, I, 15va; II, 24rb, 47va–vb; III, 65ra, 75rb, 75vb, 76va, 77ra, 81va–vb; VII, 123ra, VIII, 157rb–vb.

⁵¹ Let us note, however, that Coronel—like most of his contemporaries—never seems to consider the problem of the terminal velocity reached by a freely falling object due to the resistance of the air. He also denies the possibility of motion in the void, i.e., the only case where this description would be fully adequate, insofar as the motion of a simple (homogeneous) body in the void, according to him, would not be successive but

fall while not having any good explanation to offer for this phenomenon.⁵² We should not be surprised that de Soto does not appear to quote Coronel in his works, given that it was not customary at the time to cite one's contemporaries. Although they came from the same city, Segovia, and worked in Paris at the same time, it remains uncertain whether de Soto studied directly under Coronel there and, more generally, whether he had access to Coronel's works so as to build his own theory of motion on premises laid by his Spanish predecessor. His acquaintance, on the other hand, with the work of Juan de Celaya—one of Coronel's colleagues—is certain given that Celaya was de Soto's teacher at the Collège Sainte-Barbe. Unlike Coronel, Celaya faithfully sides with John Buridan's understanding of the impetus, which he sees as a type of quality. At the same time, however, he also discusses problems that Coronel addressed. This is the case, for instance, when he analyzes the key argument of the point of reflection in violent motions.⁵³ This is also the case when Celaya questions the existence of different species of impetus.⁵⁴

There exist strong stylistic and doctrinal similarities between Celaya's questions on the *Physics* and Coronel's *Physical Investigations*, as both works were heavily influenced by the methods of the Oxford Calculators, which involved the assigning of numerical values to objects and processes in order to facilitate a more precise examination of physical phenomena. These elements strongly suggest that, beyond being compatriots and colleagues moving in the same intellectual circles in Paris, the two Spaniards were in close

instantaneous (*Perscrutationes physice*, IV, 96rb), although he seems more hesitant regarding the hypothetical case of a mixed body moving in the void (*ibid.*, 101vb–102ra).

⁵² De Soto also endorses a theory of impetus but he goes back to the medieval understanding of this concept as a cause of motion; cf. *Super octo libros Physicorum Aristotelis quaestiones* (Salamanca, 1582), VIII, q. 3, 100b–101a.

⁵³ Juan de Celaya, *Expositio in octo libros Aristotelis* (Paris, 1517), VIII, 198ra.

⁵⁴ *Ibid.*, 201ra–rb.

intellectual contact.⁵⁵ Coronel's reflections on the process involved in accelerating free fall and on the related kinematic properties of motions were likely part of the intellectual background to which de Soto—via Celaya and the influence of others—was exposed. To this extent, this observation may help to shed light on what Wallace referred to as the “enigma” posed by Domingo de Soto.

The problem of the broader influence of Coronel's theory is even more difficult to assess, but it is likely that its impact was rather limited. Even though Coronel's *Physical Investigations* were edited several times between 1511 and 1530, the work is rarely quoted by sixteenth-century natural philosophers. Its unmistakably scholastic style, coupled with the intricacy of its approach to physical inquiries—as rooted in the tradition of the Oxford Calculators—, aligns with the Humanists' criticisms of “obscure scholasticism.” The scholastic style underwent, as is known, a rapid decline in the early decades of the sixteenth century in Paris, drawing the ire of figures like Juan Luis Vives (with whom Coronel nevertheless struck up a friendship⁵⁶). This decline may help to explain the seemingly limited influence of the *Physical Investigations*. Certainly, there are elements of Coronel's impetus theory that align well with the emerging theories of motion put forward by the prominent natural philosophers of his era. His idea—inherited from Albert of Saxony and Marsilius of Inghen—that the path of an object in violent motion can be analyzed as the observable result of a combination of various forces acting on the object, among which the impetus may be quantified, exemplifies this alignment with contemporary scientific thought. It

⁵⁵ See converging remarks in Richard J. Oosterhoff, “Decline of the Calculators in Paris c. 1500: Humanism and Print,” in *Quantifying Aristotle. The Impact, Spread and Decline of the Calculatores Tradition*, ed. Daniel A. Di Liscia and Edith D. Sylla (Leiden–Boston, MA, 2022), 328–351, here at 341.

⁵⁶ Cf. Maurice Kriegel, “Le parcours de Juan Luis Vives: du milieu judaïsant à l'option érasmienne,” *Revue de l'histoire des religions*, 215 (1998), 249–281, here on 273–274.

certainly matches the analysis of violent and curved motions already offered before him by Leonardo da Vinci (who spoke of a “composed *impeto*”), and developed a few years after him by Niccolò Tartaglia and Girolamo Cardano. This line of thinking was subsequently developed in a more advanced manner by Giambattista Benedetti and Bernardino Baldi.⁵⁷

One of the most interesting comparisons between Coronel’s use of the concept of impetus and later theories of motions is with the way Galileo employs this concept in his mature work *Two New Sciences* (published in 1638).⁵⁸ Galileo never cites Coronel and, as far as I can see, no trace of a direct influence of Coronel on Galileo can be found in the latter’s works. But the way in which the Italian polymath uses the concept of impetus is similar to the way in which it is used by Coronel. In the *Two New Sciences*, Galileo has Sagredo speak thus:

⁵⁷ The thesis of a continuous tradition among late medieval and early modern scientists of analyzing curved motion with the model of compound forces was advocated by Duhem, *Études*, vol. 2, 215–217. Cf. Niccolò Tartaglia, *Quesiti et inventioni diverse Nicolo Tartalea Brisciano* (Venice, 1546), I, q. 3, 11r–12r; Girolamo Cardano, *De subtilitate libri XXI* (Lyon, 1551), 98–99; Giambattista Benedetti, *Diversarum speculationum mathematicarum et physicarum liber* (Turin, 1585), *De mechanicis*, c. 17, 160–161; Bernardino Baldi, *In mechanica Aristotelis problemata exercitationes* (Mainz, 1621), 4.

⁵⁸ Galileo’s use of the notion of impetus has stimulated a vast scholarly literature; see Stillman Drake, “A Further Reappraisal of Impetus Theory: Buridan, Benedetti, and Galileo,” *Studies in History and Philosophy of Science*, 7 (1976), 319–336; idem, “Impetus Theory Reappraised,” *Journal of the History of Ideas*, 36 (1975), 27–46; idem, “Impetus Theory and Quanta of Speed before and after Galileo,” *Physis*, 16 (1974), 47–65. In these articles, Drake underlines the evolution of Galileo’s impetus between his early works and the *Two New Sciences*, holding that his later use of the concept is markedly different from the medieval theories, where his later use of the concept captures the essence of modern inertia. For an overview of the historiographical debates over the interpretation of Galileo’s impetus, see Wallace Hooper, “Inertial Problems in Galileo’s Preinertial Framework,” in *Cambridge Companion to Galileo*, ed. Peter Machamer (Cambridge, 1998), 146–174.

Sagredo: From this reasoning, it seems to me that a very appropriate answer can be deduced for the question agitated among philosophers as to the possible cause of acceleration of the natural motion of heavy bodies. For let us consider that in the heavy body hurled upwards, the force (*virtù*) impressed upon it by the thrower is continually diminishing, and that this is the force that drives it upward as long as this remains greater than the contrary force of its heaviness; then when these two [forces] reach equilibrium, the moveable stops rising and passes through a state of rest. Here the impressed impetus (*impeto*) is [still] not annihilated, but merely that excess has been consumed that it previously had over the heaviness of the moveable, by which [excess] it prevailed over this [heaviness] and drove the body upward. The diminutions of this alien impetus (*impeto*) then continuing, and in consequence the advantage passing over to the side of the heaviness, descent commences, though slowly because of the opposition of the impressed force (*virtù impressa*), a good part of which still remains in the moveable. And since this continues to diminish, and comes to be overpowered in ever-greater ratio by the heaviness, the continual acceleration of the motion arises therefrom.⁵⁹

This description of a heavy body thrown upward is based on the concept of impetus. As can be seen, it is close to Coronei's rest argument.⁶⁰ The two differences are (1) that Galileo does not consider rest as a state extended in time, and (2) that the object still possesses its initial impetus when the contrary effect of its heaviness has initiated its fall after having

⁵⁹ Galileo Galilei, *The Two New Sciences*, transl. Stillman Drake (Toronto, ON, 1989), 157–158.

⁶⁰ On Galileo's concept of impetus and its relation to earlier (medieval) theories of motion, see Carla Rita Palmerino, "Galileo's Use of Medieval Thought Experiments," in *Experiments in Methodological and Historical Contexts*, ed. Katerina Ierodiakonou and Sophie Roux (Leiden–Boston, MA, 2011), 101–125.

reached the highest point of its trajectory (which, according to the rest argument, would be conceivable but is not considered by Coronei).

In this passage, Galileo's impetus seems to retain something of its medieval identification to a force. Other passages of the *Two New Sciences*, however, show him using the concept of impetus as an effect of force similar to momentum. This is the case when Galileo says that a cannonball will acquire a certain impetus due to its fall and then tries to argue how this impetus should be measured and quantified:⁶¹

[...] It is highly probable that the heavy body falling from any height acquires that impetus, on arriving at the ground, which would suffice to drive it up to that height.

[...] Hence to get the cannonball to such a height as would suffice for its acquisition [by fall] of the impetus that is given to it by the powder (*fuoco*) on its emerging from the cannon, it should be enough to shoot it vertically upward with the same cannon and then see, in its falling back, whether it made a blow equal to that of the impact made nearby in emerging [from the cannon] [...].⁶²

"Impetus" here has clear affinities with the modern notions of "quantity of motion" or other concepts intended to capture a quantifiable magnitude that is not really distinct from the object's motion. For Galileo, in other words, the impetus has ceased to be a cause of motion and has become an effect. Whereas the medieval notion of impetus is definitely far away

⁶¹ On the role of projectile motion in the construction of Galileo's theory of free fall, see Jürgen Renn, Peter Damerow and Simone Rieger, "Hunting the White Elephant: When and How did Galileo Discover the Law of Fall?" *Science in Context*, 13 (2000), 299–419.

⁶² Galilei, *Two New Sciences*, 96.

from the modern idea of inertia, this new perspective on the impetus brings it much closer to the modern framing of the laws of nature. As Clagett puts it:⁶³

It is clear that when the ontology of impetus changed from some kind of force to an effect like quantity of motion or momentum in early modern mechanics—with the consequent abandonment of Aristotelian natural philosophy—Newton’s second law of motion and thus his definition of force were not far off.

Coronel’s theory of motion probably represents the first understanding of impetus as an effect similar to the quantity of motion. Obviously, one should not take Coronel for what he is not. As we have seen, his view on motion results from the amalgamation of two separate issues, one pertaining to the cause of motion and the other concerning its nature. Coronel does not fully conflate these issues but instead opts to address them together within a unified theory that combines impetus and motion. Though not completely devoid of ambiguity and unresolved issues, his account yields a sound causal explanation for the acceleration observed in free fall motion, which can be considered as one of the earliest “modern” explanations of this phenomenon, thanks to its innovative departure from the proportionality principle.

Can this theory be regarded as a forerunner of the principle of inertia? The attachment of Coronel’s conceptual framework to Aristotelian scholasticism, along with the wrong postulates of his theory and the vagueness of such a characterization, clearly warrant a cautious application of such a claim. Still, the significant implications of Coronel’s idea of motion suggest that it was likely much closer to this modern idea than earlier theories of its

⁶³ Clagett, *Science of Mechanics*, xxviii.

kind. In this regard, the potential influence of Coronel's ideas on subsequent authors—a question that remains largely unresolved to this day—undoubtedly merits the scrutiny of historians of physics.

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