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A Neo-Aristotelian Approach to a Unified Theory of Physics

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Abstract. The core task of this paper is to demonstrate the heuristic merits of the Aristotelian philosophy of science as compared with the strict empiricism in constructing and justifying a unified theory of physics. The impetus for the study was the question of whether the success of the Dynamic Universe (DU) theory as a candidate for such a unification could be explained by energy as its basic notion (Suntola, T. 2018a, 2018b, 2020, 2021, 2022, 2024), while the other unificatory attempts (string theories, inflation theory, and loop quantum gravity), all based on the notion of force, appear to fail. DU's reliance on Aristotle's methodology of first principles and his potentiality-actuality metaphysics soon invited to explore DU's Aristotelian presuppositions as an explanatory ground for its seeming success. A major weakness of empiricism is its rejection of metaphysical reflection, necessary for the revolutionary paradigm change in the unification project. While the empiricist negative stand towards metaphysics is based on its narrow conception of basis of knowledge and logical reasoning and the principle of methodological unity, Aristotelian solutions to these problems are difficult to refute. The Stagirite's methodology of Saving the Appearances (SA), little known outside Aristotle scholarship, exposes ways of expanding the knowledge basis to make room for metaphysical knowledge. SA is valuable to our purposes here also by yielding a heuristic model for the discovery and justification of a unified theory of physics. Aristotle's argument for the reality of potentiality in the form of an inference from a fact of life to its necessary presuppositions illustrates how to expand the empiricist premises-conclusion notion of logic. To specify the object of physics, the Aristotelian genus–species structure of reality exposes that the definition of the genus *proximum* constitutes the highest first principle of a theory. Applying Aristotle's metaphysical notions of change and motion (*dunamis*, substance–attribute, matter–form), the genus *proximum* in DU turns out to be mass as prime substance, mass defined as the substance for the expression of energy. To conclude, I shall point to the need for modifying the Aristotelian metaphysical categories to allow room for the holism in DU. Having studied the heuristic principles underlying the DU theory, the paper contributes both to the emerging studies of the Meta-Empirical argument forms in physics and the recent Neo-Aristotelian approach in the philosophy of physics.

1. Introduction

When I was first introduced to Tuomo Suntola's Dynamic Universe (DU) theory as a promising candidate for a unified theory of physics, I came to understand that it has quite knowingly been

developed with certain Aristotelian ideals of science in mind. A chief guideline has been to combine metaphysical and empirical research, as indicated in the title of Suntola's *The Short History of Science or the Long Path to the Union of Metaphysics and Empiricism* (2018b). This shows prominently in the explicit adoption of Aristotle's *dunamis* metaphysics, the idea of actualization of potentialities, as a description of the principle of conservation of energy. As the most abstract postulate of DU, the conservation of energy principle exemplifies the Aristotelian ideal to identify a few first explanatory principles of physical phenomena, on which the rest of the theory is based. The third Aristotelian ideal is to build an intelligible theory of physical phenomena, which in this case means that DU does not distort our common-sense conceptions of time or distance.

I soon learnt that by adopting energy as its basic concept, DU deviates from other attempts at a unified theory of physics, such as string theories and loop quantum gravity, which aim to formulate general laws for gravity, and electromagnetic, weak and strong nuclear forces. This raised the question of whether the Aristotelian philosophical approach could explain how energy as DU's basic concept has lead to its success in the unification of physical phenomena, investigated by several partial theories (Kallio-Tamminen, T. 2020, 2024, Styrman, A. 2016, 2018, 2020, 2024). Since physical theories are not deducible from abstract philosophical principles, the term 'explanation' here obviously cannot refer to the empiricist covering law model (Hempel, C. G. and P. Oppenheim (1948/1965). A hermeneutic approach to explanation, *i.e.*, by putting matters in their wider context, is more apt here (Gadamer, H-G. 1998, Roth. W. D. and J. D. Mehta 2002).

This paper aims to contribute to the recent Neo-Aristotelian philosophy of physics by further analysing Aristotelian heuristic methods relevant to DU (Sfendoni-Mentzou, D. Ed. 2018, Simpson, W. M. R., R. C. Koons, and N. J. Teh Eds. 2018, Koons, R. C. 2024). The analysis also contributes to the emerging philosophical study of meta-empirical confimation of physical theories (Dawid, R. 2013, 2022, Curiel, E. 2024, Hetzroni, G. unpublished). To expose the peculiarities of the Aristotelian philosophy of science, I shall compare it with the empiricist approach, underlying the dominant contemporary physical theories.[1] The crucial issue here is the epistemic status of metaphysics. The unification of contemporary physical theories necessarily presupposes metaphysical reflection to construct a unified picture of reality, as two major theories, quantum mechanics and the theory of relativity, are widely considered to be built on mutually inconsistent assumptions. To demonstrate how metaphysics forms a natural part of scientific theorizing, I shall present the Logical Positivists' ideal of science from the 1920s and 1930s and their arguments against metaphysics (section 2.) and explore how Aristotle would respond to them (sections 3. and 4.).

The Positivists' rejection of metaphysics is based on three arguments, one concerning the basis of knowledge, the other the scope of logic, and the third methodological unity. The primary one is the strict empiricist epistemology, according to which singular observations form the basis of generating and justifying scientific knowledge. Aristotle's conception of the knowledge basis of science and metaphysics can best be clarified through his Saving the Appearances (SA) methodology, only recently identified in the history of philosophy (Owen, G. E. L. 1968/1987, Nussbaum, M. 1986, Irwin. T. 1988, Barnes, J. 1994, Cleary, J. 1994, Kakkuri-Knuuttila, M-L. and E. Vaara 2007, Mäkinen, J. and M-L. Kakkuri-Knuuttila 2013) (section 3.). Here the term 'appearance' (*phainomenon*) has a wider scope than in empiricism, in which appearances are confined to observations (Bogen, J. and J. Woodward 1988). In addition to observations, the

[1] Von Wright, G. H. (1971) presents the Aristotelian and the Galileian philosophies as two chief traditions in Western philosophy.

appearances in the Aristotelian SA cover theorizations of various kinds, everything to be critically assessed.[2] Being a method for presenting and justifying a theoretical synthesis of prevalent knowledge of a mature field of research, SA is most relevant to the pursuit of a unified theory of physics. To illustrate the functioning of SA, I have chosen the *eudaimonia* argument of the *Nicomachean Ethics* Book I. The theory-building task for Aristotle is clearly analogous to the task of a unified theory of physics, in spite of the heavy use of mathematics in the latter case. In section 5.. I shall briefly point out how the DU theory solves the matter-wave dispute in quantum mechanics in the Aristotelian manner. Going deeper into the issue to what extent and in which manner Suntola's book *Dynamic Universe: Toward a Unified Picture of Physical Reality* (2018a) follows the guidelines of the Aristotelian SA methodology has to be left to future research.

In addition to its strict empiricist epistemology, the Logical Positivist's rejection of metaphysics relies on a narrow understanding of logic, whereas Aristotle has a much wider notion of rational reasoning. For the empiricist, logic is restricted to inductive generalization and formally valid inferences. Logic for Aristotle is not, as often assumed, limited to the three-term two-premise syllogistics of the *Prior Analytics* (Malink, M. 2019, Kakkuri-Knuuttila, M-L. and M. Perälä to appear). His textbooks of dialectic and rhetoric, the *Topics* and the *Rhetoric* present hundreds of forms of informal reasoning (Smith, R. 1997, Kakkuri-Knuuttila, M-L. 2005, Kakkuri-Knuuttila, M-L. 2012). These do not, however, include his important metaphysical argument form from an empirical fact to its necessary presuppositions. This kind of reasoning bears some resemblance to Kant's transcendental deduction and is explicitly excluded by the Logical Positivist's rejection of synthetic *a priori* knowledge. An example of such an argument in Aristotle's *Metaphysics* will be given in the treatment of potentiality (section 4.5.).

The third premise in the Logical Positivists' rejection of metaphysics is a consequence of their ideal of methodological unity. As just pointed out, metaphysical knowledge may require its own argument forms, so there is no reason to neglect the possibility of contextual methodological tools. Aristotle often emphasizes a similar point by noting that different argument arenas require different levels of exactness (*Nicomachean Ethics* I 3, 1094b19-22, *Metaphysics* VI 2, 1027a20-23, *Physics* II 5, 197a19).

Finally, I shall draw from Aristotle's metaphysics to gain an understanding of energy as DU's basic concept. First, I shall rely on the genus-species division which underlies the Aristotelian classification of sciences as well as the internal structure of each particular science (section 4.1.). As each science has its distinct highest genus, *genus proximum*, we may thus inquire after the highest genus in physics today. How would energy, measurable in joules, or force, measurable in Newtons, fare as the *genus proximum*? We may, second, adopt the Aristotelian specification of physics as the investigation of the first causes of motion and change. This leads, third, to his metaphysics of motion and change, involving the categories of *dunamis*, substance and attribute, form and matter as well as prime matter (sections 4.2.-4.5.).

The highest genus in DU turns out to be mass as the prime substance; mass in general understood as the substance for the expression of energy (section 5, Suntola, T. 2018a, Kallio-Tamminen, T. 2024). DU's holism manifests itself already in the notion of mass as prime substance, the only capacities of each mass point being to generate gravitation potential over the rest of the space and to sense the gravitation potential of the mass of the rest of the space as gravitation energy. From this prime substance are generated physical particles as mass-wave

[2] This implies that Aristotle was neither an epistemological foundationalist (Hasan, A. and R. Fumerton 2022) nor a coherentist (Olson, E. 2023).

resonators (Suntola, T. 2018a, Kallio-Tamminen, T. 2024). Thus the notion of mass as prime substance exposes the fundamental role of energy in comparison with force in DU. To further elaborate the holistic assumptions of DU, I shall introduce the System of Nested Energy Frames, which links each local energy object to the rest of the space.

Section 6. summarizes Aristotle's heuristic tools for the project of constructing a unified theory of physics discussed in the paper. An important implication is that, because of DU's holistic metaphysics, Aristotle's categories of motion and change are not sufficient as such. This shows most clearly in the notion of substance, which for Aristotle is something that exists independently of other existing things. In DU, however, there are no such independent beings, as everything is influenced by everything else already at the deepest physical level. How to modify the ancient categories of motion is another issue left to future research.

2. Empiricism and Rationalism in Physics

2.1 The Empiricist Rejection of Metaphysics

The empiricist philosophy of science grew side by side with the radical developments in physics at the beginning of the Modern Age in criticism of the commentary tradition of the Medieval universities.[3] Since its early stages, empiricism has been an important inspiration and justification for the pursuit of new knowledge growing out of observation and experience. However, empiricist philosophy is inadequate in the face of two, partly overlapping, questions in contemporary physics. One is the fact of physical theories with little or no empirical support and the other is the task of creating a unified theory of physics. The common element here is the quest for appropriate heuristic tools; on the one hand, to demonstrate or critically assess the pursuit-worthiness of the theories without empirical evidence and, on the other, to clarify the methodological challenges in generating a unified theory. The emphasis here is on the latter issue, in particular, the relevance of metaphysics to the unification task.

This subsection will present three premises in the Vienna Circle Logical Positivists' rejection of metaphysics as intelligible knowledge, formulated during the 1920s and 1930s. One of these concerns epistemology, the other the concept of logic, and the third the ideal of methodological monism. Sections 3. and 4. then highlight the opposite Aristotelian views to demonstrate natural ways to refute the empiricist assumptions.

Interestingly enough, a negative attitude towards metaphysics has been a core element in large part of the empiricist philosophy of science. Already David Hume targeted a harsh criticism against metaphysics in the concluding comment in his treatise *Enquiry Concerning Human Understanding*:

> When we run over Libraries, persuaded of these Principles, what Havoc must we make? If we take in hand any Volume; of Divinity or School Metaphysics, for Instance; let us ask, *Does it contain any abstract Reasonings concerning Quantity or Number? No. Does it contain any experimental Reasonings concerning Matters of Fact or Existence?* No. Commit it then to the Flames: For it can contain nothing but Sophistry and Illusion (Hume, D. 1751/1900, 214). (Ital. orig.)

[3] Recent research in the history of philosophy has shown the view of the dark medieval period to be a myth. The medievalists produced, for instance, complex theories of epistemic and modal logic, then forgotten and newly invented as late as 1950s and 1960s. One of the logical contributions is the idea of simultaneous possibilities, now adopted as the paradigmatic view, in contrast to the Aristotelian statistical notion of modality (Hintikka, J. 1973, Knuuttila, S. 1993).

We may note that Hume's exhortation is based on two components of human knowledge, empirical facts and reasoning. We shall next take a look at how the Humean argument was modified in the early 20th century to reach a similar conclusion.

The Logical Positivists have had a great influence on philosophy, as well as, in natural and social sciences. It is said that Western philosophy still is to a great extent connected to the Positivist movement. The core group was the Vienna Circle with its Thursday afternoon meetings, led by the philosopher-physicist Moritz Schlick; the other members consisted of both scientists and philosophers.[4] The Positivist approach spread to North America when its proponents fled the Nazi regime during the 1930s. The Vienna Circle members shared their disappointment with the academic conflicts among the prevailing metaphysicians and the political situation in Europe. Their heroes were Ludwig Wittgenstein with his revolution in philosophy and Albert Einstein with his revolution in physics, a somewhat strange pair. This subsection explains Wittgenstein's and the next one Einstein's detachment from Machian empiricism.

Wittgenstein's *Tractatus Logicus Philosophicus* (1924) was carefully studied in the Thursday meetings and his conception of philosophy as criticism of language was keenly adopted. Language, instead of the world, became the focus and philosophy's chief task was to demarcate meaningful, scientific, and unintelligible, non-scientific use of language. The major target was, in particular, the abstract theorizing of Kant and Hegel, doomed as metaphysics. This conception spread to the so-called *linguistic turn* in philosophy and, somewhat later, in the social sciences as well (Foucault, M. 1980, Alvesson, M. and D. Kärreman 2000).

One could sense echoes of positivist influence in some methodological remarks at the *Physics and Reality Conference* at the University of Helsinki June 4-6, 2024. The statement that reality is what we measure brought to mind operationalism, left behind in the philosophy of science a while ago (Hanson, N. R. 1958, Boyed, N. M. and J. Bogen 2021, Chang, H. 2021). Operationalism still has a stronghold in physics, for instance, in defining time with the help of atomic clocks in the theory of relativity. Another comment that, because of applying mathematical methods, physics is an exact science, may be traced to the Positivist conception of mathematics as the ideal language of science. This argument is a fallacy of equivocation, however. Mathematical exactness is not transferrable to physical interpretations of the equations, but relies largely on qualitative considerations (Kakkuri-Knuuttila, M-L. 2000). A further claim that reality is what our theories describe appears to reflect the rationalist realist stand of Einsteinian style, to be discussed in section 2.b.

The Positivists' strict empiricist epistemology was expressed in two theses, both with close affinities to Ernst Mach's corresponding views. Their semantic thesis is the *meaning postulate*, stating that all meaningful statements are translatable to a language referring to singular observations.[5] In a similar vein, Mach did not accept Newton's notion of absolute space (Holton, G. 1968).[6] The methodological thesis is the *verification postulate*, according to which all

[4] My presentation of the Vienna Circle is based for a great part on Uebel, T. (2024). Other members of the Vienna Circle were the philosopher Rudolf Carnap, the philosopher-sociologist Otto Neurath and the physicist Friedrich Waissman. The Finnish philosopher Eino Kaila often visited their meetings (Manninen, J. and F. Stadler 2010).

[5] The Vienna Circle members differed in their views about the observation language. Schlick was a phenomenalist, Neurath a physicalist. Carnap's internalism was a stand in between: language can be freely chosen and truth remains a matter internal to the language.

[6] Operationalism follows by combining the meaning postulate and the assumption of mathematics as the ideal language.

meaningful statements are to be verified by observations. This, again, resembles Mach's principle that 'where neither confirmation nor refutation is possible, science is not concerned' (1883/ 1960, 587, cited from Uebel, T. 2024).

In addition to the strict empiricist epistemology, the Logical Positivists had a narrow conception of logic, inspired by the *Tractatus'* way of distinguishing empirical and mathematical-logical knowledge. In this manner, they specified Hume's division of sources of knowledge into perceptions and reasoning (Hume, D. 1751/1900). For Wittgenstein, logic and mathematics say nothing about empirical reality, as they consist of analytical truths, *i.e.*, tautologies, based on the meaning of the logical and mathematical terms. Synthetical truths, in contrast, have empirical import and their truth is based on observation. Thus, they could reject metaphysics from the realm of knowledge by excluding Kant's transcendental deduction leading to synthetic *a priori* knowledge.

The third premise in the Vienna Circle's argument against the possibility of metaphysics is the methodological unity postulate. This states that all scientific knowledge is to follow the same methodological ideals as natural sciences, such as those implied by strict empiricism, the narrow scope of logic, mathematics as the ideal language of science, the hypothetico-deductive model of hypothesis testing, the nomothetic view of explanation, and the regularity view of causation (Uebel, T. 2024). Thus metaphysics, to be an intelligible area of research, is supposed to follow the same methodological ideals as empirical research, which clearly is impossible. The next subsection on Einstein's philosophical reflections will already point to problems in the Positivist rejection of metaphysics. The Aristotelian alternative will then be given in sections 3. and 4.

2.2. Empiricist and Rationalist Elements in Physics

It may come as a surprise that, together with Wittgenstein, Einstein was another hero of the Logical Positivists (Ryckman, T. A. 2024). Wittgenstein's *Tractatus* focused on the limits of everyday language and, in consequence, the limits of our world. Einstein's theory of relativity, in contrast, expanded the limits of language and modified our worldview with the help of mathematical tools, leaving philosophers puzzled about how to interpret it. Einstein's own philosophy of physics was not fixed, instead, he seems to have reflected upon metaphysical and epistemological issues throughout his whole career. Following the three stands in his philosophical thinking, as presented in Gerald Holton's historical study (Holton, G. 1968), exposes how metaphysical and ontological considerations infiltrate into one's conception of physical knowledge (comp. Howard, D. A. and M. Giovanelli 2019). We may distinguish three conceptions of physical theories, their metaphysical status and relations to empirical knowledge, and views of concept formation. These considerations neatly reveal how the Logical Positivist attempt to leave metaphysics outside intelligible thinking is bound to fail. Interestingly enough, Einstein's rationalist stand opens the avenue to the contemporary problems that the Meta-Empirical approach in the philosophy of physics aims to solve.

Einstein first adopted Mach's empiricist philosophy of science with a phenomenalist epistemology. emphasizing personal sensations as a source of knowledge. For Mach (1883), the task of science was no more than systematization of sensations in an economic manner. Concept formation reduces to abstraction, which shows in his rejection of theoretical terminology, such as atoms and absolute space. In assessing the philosophical position of the special theory of relativity, Einstein first focused on the operationalist conceptualization of time in terms of simultaneous events, measurable with clocks.

> The 'time' of an event is that which is given simultaneously with the event by a stationary clock located at the place of the event (Einstein, A. 1905, 894, cited in Holton. G. 1968, 641-642).

The operationalist attitude may explain the enthusiasm of the Logical Positivists towards the theory of relativity, as they saw the rejection of Newtonian absolute time and distance as a victory over metaphysics (Ryckman, T. A. 2024). Einstein failed, however, to see that the assumptions of a constant velocity of light to each observer and the principle of relativity violate Mach's philosophy for not being reducible to sensations. He even defended his alleged adherence to Mach's philosophy by arguing that the theory of relativity is based on generalizable facts. As such facts, he lists obvious theoretical principles, such as:

> The impossibility of the perpetuum mobile, the first law of Newton, the constancy of light velocity, the validity of Maxwell's equations, the equivalence of inertial and gravitational mass … (Einstein's letter to Michele Besso April 28, 1918, Holton, G. 1968, 645)

Einsteins's second philosophical position involves acknowledging a creative component not only in the discovery of mathematical physical theories, but already in everyday thinking.[7] In his Herbert Spencer lectures at Oxford in 1933 he discusses the relation between the empirical and rationalist components in physics:

> The structure of the system is the work of reason; the empirical contents and their mutual relations must find their representation in the conclusions of the theory. In the possibility of such a representation lie the sole value and justification of the whole system,… which cannot be justified either by the nature of that intellect or in any other fashion *a priori*. (cited from Holton, G. 1968, 650)

As for metaphysics and epistemology, this means accepting a deeper level of reality than what can be directly observed. Creative rational thinking is required to develop new concepts and theories in addition to abstraction.[8] Accordingly, the mathematical equations of physical theories no longer need to be mere descriptions of empirical regularities, but regularities operating at higher levels of reality. At this point, Einstein still is an empiricist, as the empirical implications remain the criterion of the truth of the theory.

Einstein's third philosophical stand gives the intellect and the *a priori* a new role. Holton interprets this approach as rationalist realism, by which he means an epistemological view, according to which the nature of reality can be achieved by means of reason. This reminds us of the early rationalists Rene Descartes with his argument for the existence of God and Gottfried

[7] This is illustrated in a popular article in connection with a bodily object: 'Considered logically this concept is not identical with the totality of sense impressions referred to; but it is a free creation of the human (or animal) mind. On the other hand, this concept owes its meaning and its justification exclusively to the totality of the sense impressions which we associate with it.' (Einstein, A. 1936/2004, 23)

[8] Important forms of concept formation in physics and mathematics, relevant to functional relations, are idealization, i.*e.*, abstracting from a host of causal factors and extrapolation, *i.e.*, inferring that some property continues over the whole space (Nevanlinna, R. 1963). Further forms of physical concept-formation are needed in case of part-whole metaphysics.

Wilhelm Leibniz with his view that mathematics can be reached by merely rationalist means.[9] One rationalist component in physics comes in the form of the so-called argument from laws, which involves drawing existential statements on the basis of mathematical symbols of the equations meant to describe reality. [10]

Already in his 1933 Spencer Lectures Einstein defended the ancient view of the mathematical structure of nature. The corresponding epistemological idea is that mathematical reasoning is the way of grasping physical reality:

> Nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover, by means, of purely mathematical constructions, those concepts and those lawful connections between them which furnish the key to the understanding of natural phenomena. … I hold it true that pure thought can grasp reality, as the ancients dreamed. (cited Holton, G. 1968, 650)

Pure thought, based on empirically informed intuition, working on mathematical equations, thus is the tool for finding the physical laws.

Describing his own philosophical development, Einstein wrote:

> Coming from sceptical empiricism of somewhat the kind of Mach', I was made, by the problem of gravitation, into a believing rationalist, that is, one who seeks the only trustworthy source of truth in mathematical simplicity. The logically simple does not, of course, have to be physically true; but the physically true is logically simple, that is, it has unity at the foundation. (Einstein's letter to C. Lanzos January 24, 1938, cited Holton, G. 1968, 657-658)

Rationalist realism does not, as such, require any particular forms of concept- or theory-generation. For Einstein, it meant simplicity, expressed in mathematical equations, and diminishing the role of empirical evidence in relation to mathematical imagination.[11]

Einstein also expressed elements of traditional theological rationalism when saying that physical reality is created by God, to be grasped by human reason. As reality itself is rational, the rational human mind can get a hold of it. Such a rationalist epistemology presupposes no particular metaphysical or physical structure of reality, its only metaphysical claim being the theological origin of reality. Likewise, rationalism involves no particular views of concept formation or the structure of theories.

In today's perspective, Holton's comment that physicists generally attempt to steer a middle course between an attachment to empirical data and mathematics seems over-optimistic. The heavy criticism against the many-worlds, string, and inflation theories, claiming them be mere speculations without any empirical evidence, indicates a turn to the rationalist approach (Kragh, H. 2010, Smolin, L. 2006, 2014). It has been argued that the high evaluation of mathematics and

[9] The Merton college calculators in Oxford and Nicole Oresme in Paris during the 14th century could be counted as early rationalist realists for having developed the 'Galileian law' of free fall on the basis of geometrical argument (Sylla, E. D. 2011).

[10] Having made some transformations in the equations of the quantum mechanics Bohm argued for the existence of the quantum potential (Bohm. B. and B. J. Hiley 1993, Kakkuri-Knuuttila, M-L. in review).

[11] This reflects, for instance, in the present notion of physical laws as mathematical equations. In DU, in contrast, the basic physical law is the conservation of energy, more exactly, the zero-energy principle (Suntola, T. 2018a, 2018b).

suppression of qualitative thinking particularly since the 1940s favours 'virtuosity in calculating over reflection on hard conceptual problems' (Smolin, L. 2006, xxii). This criticism has given rise to the present search for Meta-Empirical Confirmation in the philosophy of physics. Instead of relying on theological arguments, this type of research explores forms of reasoning in physical theorizing to assess the pursuit-worthiness of specific physical theorizing (Dawid, R. 2013 and 2022, Curiel, E. 2024, Hetzroni, G. unpublished). Its emphasis on the significance of theoretical thinking forms an important counterpoise to the strict empiricist reliance on observations. The suggestion in this paper is to link explicitly epistemological and ontological assumptions with physical postulates and observations into a coherent whole. In the next two sections, we shall look at how Aristotle copes with such challenges. The purpose is not to search for ready solutions to contemporary physics, but to identify heuristic models to be modified to suit the present forms of theorizing.

3. The Relevance of the Aristotelian Saving the Appearances Methodology to the Unification of Physics

To overcome the strict epistemological confines of the Logical Positivists, we need not go back to the Ancient Greeks, since the criticism against the meaning and verification postulates as criteria of meaningful statements rose within the Positivist movement itself. The verification principle was soon attenuated by Rudolf Carnap (1928), who observed that universal propositions, *i.e.*, the standard form of a scientific hypothesis, cannot be verified. He suggested, instead, the principle of testability. He then showed that dispositional properties, such as the solubility of salt in water, cannot be fully expressed in observational terms (Carnap, R. 1936/1937). The next move was to accept the division of scientific language into observational and theoretical terms, linked by so-called correspondence rules (Carnap, R. 1939). This development led Carl Hempel (1951) to the holistic view that only theories, not singular statements, can be deemed meaningful or meaningless. As a result of recognizing the theory-ladenness of observations (Hanson, N. R. 1958, Boyed, N. M. and J. Bogen 2021) and, more importantly, the paradigm-dependence of scientific theories (Kuhn, T. 1962/2012), the quest for distinguishing meaningful and meaningless statements finally lost its appeal. This led to the post-positivist phase in the philosophy of science, the implications of which to physics are yet to be explored. The claim here is that the Aristotelian philosophy of science is a rich source for coping with epistemological and methodological issues, including the role of metaphysics in physics, in particular in generating a unified theory of physics (comp. Frank, T. 1963).

In this section, I shall present Aristotle's *Saving the Appearances* (SA) methodology to cope with the issue of the possibility of metaphysics as a form of genuine knowledge. The SA methodology has only recently been brought to light and is so far little known outside a limited circle of Aristotle scholars. Together with some metaphysical organization principle, it offers heuristics for generating, presenting, and justifying a unified theory of a mature science. The exciting thing here, not studied so far, is that the underlying epistemology of SA lies outside the empiricist-rationalist dichotomy. Like the empiricist and rationalist epistemologies, the traditional Aristotle interpretation is individualist. However, the starting point of research in SA consists of a knowledge basis chosen by social criteria.[12]

The knowledge basis of SA is not confined to observations or empirically informed intuition but also includes previous theories relevant to the topic on hand, in addition to relevant

[12] For contemporary versions of social epistemology O'Connor, C., S. Goldberg, and A. Goldman (2024).

metaphysical assumptions.[13] This follows from a proper understanding of Aristotle's concept 'appearance' (*phainomenon,* Greek), which is to be distinguished from its empiricist use for observations (Duhem. P. 1908/1969). For Aristotle, *phainomenon* simply means how something appears to us, either in observation or in theoretical reflection (Owen, G. E. L. 1968/1987, Nussbaum, M. 1986, Irwin. T. 1988, Barnes, J. 1994, Cleary, J. 1994, Kakkuri-Knuuttila, M-L. and E. Vaara 2007, Mäkinen, J. and M-L. Kakkuri-Knuuttila 2013). For most purposes, *phainomena* (plural) coincide with the set of *endoxa*, a term coined by Aristotle. Its literal meaning is opinions of reputable men, which explains the epistemic status of *endoxa* as respectable starting points for theoretical inquiry. Adopting something like Aristotle's understanding of appearances as the basis of theory formation is not so strange in the context of physics as one might initially think of. One only needs to be reminded of Einstein's defence of loyalty to Mach's epistemology by citing as empirical facts such theoretical suppositions as the impossibility of the perpetuum mobile, the first law of Newton, the constancy of light velocity, the validity of Maxwell's equations, the equivalence of inertial and gravitational mass (Holton, G. 1968).

Aristotle describes his SA in methodological comments, such as the following in connection with his discussion of Socrates' rejection of weakness of will:

> Here, as in all other cases, we must set down the appearances (*phainomena*) and, first working through the puzzles, in this way go on to show, if possible, the truth of all the reputable opinions (*endoxa*) about these affections or, if this is not possible, of the greater number and the most authoritative. For if the difficulties are resolved and the reputable opinions (*endoxa*) are left in place, we will have done enough showing (*Nicomachean Ethics* VII 1, 1145b2-7, trans. W. D: Ross).

The idea is that, after collecting and critically scrutinizing the appearances concerning the topic under investigation, one is to generate principles that cover those parts of the appearances that have endured the criticism. This yields five heuristic principles for systematic problem solving (Nussbaum, M. 1986, Kakkuri-Knuuttila, M-L. and E. Vaara 2007, Mäkinen, J. and M-L Kakkuri-Knuuttila 2013):

1. Collect the *endoxa* (*phainomena*) concerning the topic under investigation.
2. Identify problems, in particular conflicting views and gaps in knowledge.
3. Assess critically the conflicting views.
4. Construct new concepts and principles to solve the conflicts and fill the gaps.
5. Justify the new concepts and principles by showing that they solve the problems and save the part of the *endoxa* (*phainomena*) that endured the criticism.

The underlying epistemological stand of the SA methodology thus challenges both the interpretations of Aristotle as an empiricist who presents inductive generalizations from observations to first principles and as a rationalist who relies on intuitive insight.[14] Both

[13] I use the term 'knowledge basis' to refer to the starting points of investigation. which are to be critically assessed, as 'foundation' usually refers to some unchanging set of beliefs.

[14] One source for the empiricist interpretation is *Posterior Analytics* II 19, 103b3-5 in which Aristotle uses the term *epagôgê* for the process from observation to the first principles of science. However, it is a

empiricist and rationalist elements are needed, but previous theories are included in the theory generation and justification process as well. This emphasizes the social nature of research in SA in contrast to standard individualist interpretations of Aristotle and the individualism in empiricist and rationalist epistemologies.

For illustrative purposes, I have chosen the *eudaimonia* argument in the *Nicomachean Ethics* I chapters 4-8 because it illuminates how Aristotle applies his metaphysical principles and philosophy of science of the *Posterior Analytics* simultaneously with the SA methodology. Here we may find the four research questions: Whether it is? Does it exist? What is its cause? What is it? The first question involves a nominal definition, and the explanatory question asks for the definition of the thing (*Posterior Analytics* II 1-2, Barnes, J. 1975/1993, Charles, D. 2000). One may also keep in mind Aristotle's theory of four causes, which include in addition to the effective cause the final cause, matter, and form (*Physics* II 3 and *Metaphysics* V 2, Hankinson, R. J. 1998). Furthermore, the definition of *eudaimonia* is given in a syllogistic form and thus offers a demonstration (*apodeixis*, *Posterior Analytics* I 2, Charles, D. 2000). The definition also involves the metaphysical assumption of potentiality and actuality (*Metaphysics* IX 1-7). The *eudaimonia* argument thus neatly illustrates the suitability of the heuristic value of SA for constructing solutions to problems in various areas of research, including physics.

The *Nicomachean Ethics* begins with the claim that every action and inquiry is thought to aim at some good. We are then given examples of hierarchies of good things to conclude that there must be some highest good, either one or several. This may be considered as responding to the 'Does it exist'? question, and the task of ethics turns out to determine the highest human good. Giving the nominal definition, he notes that the highest good is often called *eudaimonia*, recently translated as 'flourishing life'. To specify the highest good, some criteria are needed, such as peculiarity to human beings and completeness. The relevant views about good human life, pleasure, wealth, and honour (SA move 1.), are not singular observations as the strict empiricist would require, but popular opinions of different groups of people. The problem arises because of the several candidates conflict with each other (SA move 2.) Aristotle criticizes each of these views in turn for not satisfying the criteria (SA move 3.). Pleasure fails to fulfil the criterion of being peculiar to human beings since animals also have pleasurable experiences. Wealth cannot form the definition of *eudaimonia*, since wealth is not an end in itself but a means for other things. Further, honour fails to be a stable characteristic of a person, since it depends on those who honour more than on the person himself. The search for a definition ends with the characterization of *eudaimonia* as active life according to virtues in harmony with reason (SA move 4.). The term 'active' here is significant and points to the possibility that one possesses virtues but does not realize them. Finally, the definition is shown to satisfy the required criteria, solve the problems, and save those parts of the appearances that have endured criticism (SA move 5.). As generosity presupposes some wealth, a reasonable amount of wealth is required for a life according to virtues. Finally, for a virtuous person, life according to virtues is pleasurable and he is likely to be honoured as well.

Aristotle's *eudaimonia* argument highlights how to solve theoretical problems in a systematic manner in any field of research to save the sound parts of previous beliefs and theorizing. The

mistake to read *epagôgê* here in the empiricist manner as inductive generalization here, as it remains unclear whether it refers to concept formation or generation of propositions (Barnes, J. 1975/1993). In fact, *epagôgê* in Aristotle has several senses. See Frede, M. (1999) for a rationalist reading of Aristotle and Gasse-Windgate, M. (2020, 2021) for an empiricist reading.

argument also illustrates the merits of expanding the empiricist knowledge basis from observations to include previous theorizing. One may suggest that the underlying rationality assumption of SA is why not benefit from the existing knowledge as much as possible when generating new theories and hypotheses. As will be seen in subsection 4.5, this kind of knowledge basis also gives room for metaphysical knowledge.

A further methodological point with wide implications is that the meaning of *eudaimonia* changes as a result of the argument process. Typically, in SA argument, the initial more or less reflected meanings converge to a theoretical concept with a specified meaning which then functions as the highest principle in Aristotle's ethics. As an example of the SA methodology in DU, I shall briefly discuss the notion of particles as mass-wave resonators (Kallio-Tamminen, T. 2024), as it solves the much-discussed problem of the particle-wave nature of matter. The DU evidently offers a rich source for detecting similar argument structures.

Adding some metaphysical organizing principle for combining the first principles attained by the SA methodology, yields heuristics for generating a unified theory of any mature field of research. As will be seen in the next subsection, for Aristotle the genus-species classification forms the organizing principle, to be replaced by the part-whole principle in DU (section 5.). To conclude this section, one may add that since Aristotle's virtue ethics has lived through the test of centuries, both the SA methodology and DU gain Meta-Empirical support.

4. Aristotelian Metaphysics of Physics

4.1. Division of Sciences Based on Genus – Species Classifications

A fundamental issue to be raised in generating a unified theory of physics is what physics is about. To respond, it is not sufficient to say simply that the topic of physical inquiry is physical phenomena. The question is exactly what physical phenomena are. In other words, how to distinguish physical aspects of reality from the rest of the world? This leads to the question of the division of sciences. For a realist, the question concerns the structural features of reality which allow its dissection to objects of separate sciences, such as physics, chemistry, biology, history, sociology, ethics, etc.

Being the first in Western philosophy to distinguish different fields of study, Aristotle had to cope with this issue. He began by criticizing his teacher Plato's theory of ideas as models of material things and good human life. For Plato, the highest idea is simultaneously a model of goodness, beauty, and justice. Aristotle argued against such a supposition of a unified science, stating that goodness cannot be a single idea, as goodness for human beings, horses and knives, for instance, are different things (*Nicomachean Ethics* I 6). A classification of these various things is needed to specify the goodness in each.

Classifications are familiar also to Plato, however, who offers the method of collection and division as a tool for solving conflicts. In the dialogue *Phaedrus*, Socrates describes the significance of this method to rhetoric and, as we can see, speech for him is a serious affair, resembling scientific inquiry:

> **Socrates:** But I think you could say this much anyway: every speech must be constructed just like a living creature with a body of its own, so that it is neither headless nor footless; instead it should be written possessing middle and extremities suited to one another and to the whole. … The ability to cut it up once more on the basis of forms, according to its natural joints, without trying to shatter a single part by going about it like a bad butcher... (*Phaedrus* 264c-265e)

Aristotle had to face issues of classification in several contexts. For instance, his textbook of dialectic, the *Topics*, includes hundreds of forms of reasoning concerning the predicables genus, species, special property, accidental property, and definition (Smith, R. 1997, Kakkuri-Knuuttila, M-L. 2005, Kakkuri-Knuuttila, M-L. and M. Tuominen 2012). Since genus-species chains of natural things are finite, each classificatory system is bound to have its highest genus (*genus proximum*). The highest genera yield a natural classification of sciences, and the genus-species classification gives the internal structure of each empirical science (Knuuttila, S. 1981). In ethics, *eudaimonia* as flourishing human life forms the topic and highest genus for Aristotle. Being defined in terms of virtues, the task of ethical inquiry is to present and define the whole class of ethical virtues. These consist of two theoretical virtues, theoretical wisdom and practical reason, and a host of virtues of character, such as, courage, magnanimity, sociability, temperance and justice as illustrated in Figure 1.

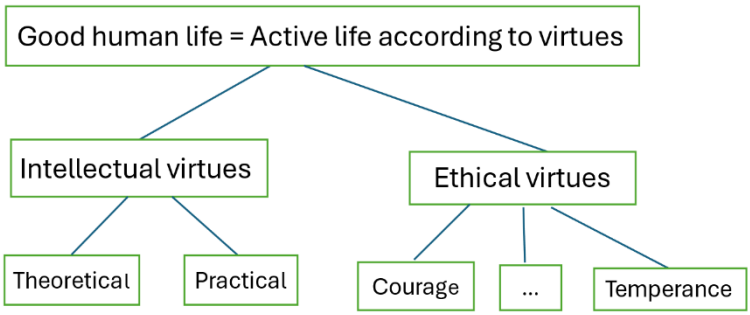

Figure 1. Genus-species structure in Aristotle's *Nicomachean Ethics*.

Adopting mathematics to the methodological resources of science does not, as such, require modifications to the Aristotelian methodological tools. It only adds a rich arsenal with its peculiar challenges to theorize about means of measurement and the interpretation of measurement results and, most importantly, develop suitable mathematical theories. Applying the language of mathematics in no way swipes away the qualitative aspects of empirical sciences, however. To put it briefly, mathematical relations hold for kinds of things if the field of study is meant to speak about the real world at all (Koons, R. C. 2024). As already pointed out, the genus-species classification is not the only possible chief organizing principle as, e.g. in DU, it is replaced by the part-hole classification, as illustrated by the System of Nested Energy Frames (see Figure 3).[15]

4.2. Introducing the Chief Metaphysical Categories of Motion

A main claim of this paper is that the empiricist philosophy of science has little to offer in support of generating a unified theory of physics because of its explicit rejection of metaphysics. However, being implicitly tied to an atomistic view of reality, the empiricist position is bound to remain incoherent. Presently interest in Aristotle's *Metaphysics* is rising in philosophy, including philosophy of physics (Sfendoni-Mentzou, D. Ed. 2018, Simpson, W. M. R., R. C. Koons, and N. J. Teh Eds. 2018). The notions of potentiality and actuality, already mentioned in connection with the *eudaimonia* argument, is one of the two basic metaphysical distinctions of *dunamis* (possibility,

[15] The research paper as a journal article, is not a proper model for laying out the details of a complex holistic theory, such as DU. Instead, the research paper is rather developed to test singular hypothesis according to the hypothetico-deductive model (Swales, J. 1990, Kakkuri-Knuuttila, M-L. and A. Kylänpää 2012).

potentiality, power, capacity, capability), relevant to causal analysis of motion and change (Harré, R. and E.H. Madden 1975, Ingthorsson, R. 2002, Kistler and Gnassoudou Eds. 2007, Meincke, A. S. Ed. 2020). Related pairs are substance–attribute and matter–form (Sfendoni-Mentzou, D. 2018, Tahko, T. 2021, Koons, R. C. 2024).

The mutual relations of these ancient metaphysical categories of motion and change can be clarified as follows. Here I shall use the term 'capacity' for *dunamis*, even though 'power' is the usual translation in philosophical discussions of the metaphysics of causation. Power, however, suits poorly in the context of physics, since today it is commonly accepted that *dunamis* is to be understood as energy.[16] Substances are combinations of matter and form[17] (*Metaphysics* VII 3, 1029a29-30) and an object's essence (*ousia*) is the same as its form, *i.e.*, the what it is to be that kind of thing (*to ti ên einai*) (Witt, C. 1989, Sfendoni-Menzou, D. 2018). Matter is taken to be the underlying substrate and form is the structure that gives the object its species identity and capacities.

The illustrate the ubiquity of these categories, I shall use the same example of paper airplane as in the *Physics and Reality Conference*. The paper airplane has the capacity (*dunamis*) to fly when thrown in the air, but as long as I hold it in my hand, this capacity is not exercised, and its flying remains a mere potentiality. To be actualized, another capacity is needed, the capacity of my arm to make it fly. Here we already have two chief metaphysical features of capacity, relevant to natural philosophy, the potentiality–actuality distinction and the notion of full power as comprising of an active and a receptive component, today often called 'partner powers' (*Metaphysics* IX 1-5, *Physics* III 1- 3, Heil, J. 2020, Witt, C. 2003). The capacity to fly is a substantial property of the paper airplane and belongs to it through its material and particular shape. If I draw a heart or a flower on paper, its property as an airplane is not modified; the drawing is just an additional accidental attribute. But if I tear the paper into pieces, the substantial form is destroyed and we no longer have an airplane, merely pieces of paper. The material is saved, but if I take matches and burn the paper, the material is destroyed. Some other materials with their peculiar forms are left, however (*Metaphysics* Books VII and IX, Witt, C. 1989).

4.3. Explaining Movement and Change

Aristotle distinguishes two kinds of movement with the help of the substance–attribute and matter-form distinctions. To highlight the use of these categories as critical tools, we may take a look at his account of the Eleatic rejection of motion. In *Physics* I 3 and 8, Aristotle argues that Parmenides' claim that reality is one and change is impossible follows because of the failure to distinguish different uses of 'to be' and 'being'. Presuming, for instance, that there are only white things, there are still many, as there are several white objects. Further, whiteness is not the same as that to which whiteness belongs (*Physics* I 3 186a23-b4). Aristotle's comment already includes a solution of the Eleatic paradox:

> For what is cannot come to be (because it *is* already), and from what is not nothing could have to be (because something must be underlying). (*Physics* I 8, 191a29-31, trans. R. P. Hardie and R. K. Gaye)

[16] How *dunamis* relates to physical forces and powers still waits for clarification.

[17] Charles, D. (2023) offers a detailed study of the history of interpretations of the Aristotelian conception of the unity of matter and form (hylomorphism), according to which all material objects are hylomorphic in the sense of comprising two essential elements: matter and form.

The insight here is that, for motion to be possible, there has to be something that remains unchanged during the change.

The core idea of substance is that it is ontologically prior to the other categories of being, such as, quality, quantity, location, position, etc. (*Categories* 4, 1b26-27, *Topics* I 9, 104a22-24). As a summary of books VII and VIII of the *Metaphysics*, Aristotle notes:

> We have treated of that which *is* primarily and to which all the other categories of being are referred – i.e. of substance. For it is in virtue of the formula of substance that the others are said to be – quantity and quality and the like… (*Metaphysics* IX 1, 1045b26-28).

This explains why substance remains unchanged when these other categories change (*kinêsis*).[18] The matter–form distinction is relevant to the *metabolê* type of change, which involve the generation or corruption of some substance.[19]

This is not the place to go into the numerous recent interpretations of power conceptions of causation, related to Aristotle's notion of *dunamis*. I shall only briefly expose the metaphysical structure of cause with the help of the two metaphysical distinctions of capacities, already mentioned. For Aristotle, cause is the event in which objects with partner powers meet. The empiricist would say, in contrast, that the cause of the stationary billiard ball starting to move is the event that it was hit by the moving ball. Such a description yields the Humean regularity view of causation with no explanation of why the regularity holds (Ingthorsson, R. D. 2002). In the *dunamis* metaphysics, cause is the actualization of the full capacity, consisting of the meeting of the moving billiard ball with the active capacity (kinetic energy) and the stationary ball with the capacity to sense the active capacity. In case the stationary ball is nailed to the billiard table, it lacks the capacity to respond to the touch of the moving ball.

4.4. Prime Matter

The notion of prime matter follows from the hierarchical structure of matter–form combinations. Further attempts to destroy the material of my paper plane does not end up with nothingness, instead, at the bottom of the hierarchy has to be some prime matter (*protê hulê*, *Metaphysics* VIII 4, 1044a15-24). Being the substrate of all change, prime matter is without any form, unchangeable, neither generated and nor perishable (*Physics* I 9, 192a28-32).[20] Aristotle scholars have discussed the ontological status of prime matter, whether it is a mere theoretical assumption or whether it has some kind of reality (Sfendoni-Mentzou, D. 2018, Koons, R. C. 2024). Aristotle himself states somewhat ambiguously that prime matter is real as it has a single capacity (*dunamis*) which is to receive any (first level) form. This does not, however, imply existence independently of form:

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[18] Accepting elementary particles as substances, in spite of their very short lifetime, involves a change in the ancient notion of substance. For instance, the lifetime of photons is about 0.8×10^{-16} seconds at the decay of a neutral pion (Sfendoni-Menzou, D. 2018).

[19] While Aristotle sometimes distinguishes *kinesis* and *metabolê*, the first being change in the attributes of substance and the latter being substantial change, he often uses them as equivalent (Sfendoni-Menzou, D. 2018).

[20] The four elements (water, earth, fire, air) form a puzzle in Aristotle, since they may change into one other, but these are not substantial changes. The elements have no essences, only properties, such as, cold–hot, moist-dry (*Generation and Corruption* II 2-4).

> …the prime matter and the form are one and the same, the one potentially, the other actually (*Metaphysics* VIII 6, 1045b18-20, trans. W. D. Ross, modified)[21]

The reality of prime matter lies in its nature as pure potentiality to acquire forms of various kinds (*Metaphysics* VII 3, 1029a2-30). Its likeness to substance lies in its receptive capacity to combine with forms, though the potentiality concerned is not efficient causality and does not take place in time.[22] The account of the combination of prime matter and form is suggested to be given as a teleological explanation (Sfendoni-Mentzou, D. 2018), not a historical but an ontological one (Peramatzis, M. 2011). This is sufficient for Aristotle's purposes, since for him the structure of universe is eternal (*Physics* I 9, 192a28-29).

It is worth pointing out that the Aristotelian notion of prime matter has raised interest in recent philosophy of physics. For instance, Werner Heisenberg wrote in his *Physics and Philosophy* that

> The matter of Aristotle is certainly not a specific matter like water or air, nor is it simply empty space; it is a kind of indefinite corporeal substratum, embodying the possibility of passing over into actuality by means of form… [In modern physics we have] actually the final proof for the unity of matter. All elementary particles are made of the same substance, which we may call energy or universal matter: they are just different forms in which matter can appear (Heisenberg, W. 1965, 129-130).

More recently in her treatment of Aristotle's dynamic concept of nature, Sfendoni-Menzou suggests that quarks could be candidates for prime matter,

> for they have a mode of being, which consists in their always being the constituent elements of other particles, such as protons or neutrons. So, we could say, that when quarks pass to actuality, they exist in the form-of-proton just as *protê hulê* exists actually in some particular species form (Sfendoni-Mentzou, D. 2018, 48-49).

Both these proposals assume the metaphysical priority of prime matter along with an atomistic notion of substance and matter–form in the Aristotelian manner. In DU, in contrast, mass as prime substance is defined as a holistic notation.

4.5. Metaphysical Argument

The Logical Positivists' rejection of metaphysics is a consequence of three assumptions: a strict empiricist conception of the knowledge basis, a limited view of logical reasoning, and the ideal of methodological unity, according to which there is just one scientific methodology. Aristotle's view of the knowledge basis has already been discussed in section 3. Now we shall turn to his notion of metaphysical reasoning and analyze the argument for the potentiality–actuality distinction to identify an argument from an empirical fact to its necessary presuppositions. The analysis demonstrates that the *dunamis* ontology is no weird invention, but a presupposition of our everyday thinking and acting. As a strict empiricist, Hume argued (using the term 'power'), that

[21] See also: …matter exists in a potential state (*dunamei*), just because it may attain to its form; and when it exists actually (*energeiai*), then it is in its form (*en tô eidei*). (*Metaphysics* IX 8, 1050a15–16, transl. W. D. Ross)

[22] Comp. discussion of time in Aristotle's account of motion and change in Sfendoni-Menzou, D. (2018).

there are no causal capacities or, at least we cannot have knowledge about them. Neither can they be observed, nor can we have logical arguments for their existence (Hume, D. 1751/1900). Thus, to talk about causal capacities should be rejected as unscientific and metaphysical.[23] Yet, how to achieve this in practice has not been properly addressed by the empiricists and would certainly be a difficult task.

I shall take up my favourite argument to demonstrate the absurdity of the rejection of potentialities:

> There are some who say, as the Megaric school does, that a thing can act only when it is acting, and when it is not acting it cannot act, *e.g*. he who is not building cannot build, but only he who is building, when he is building; … It is not hard to see the absurdities that attend this view. … a man will not have the art [of building] when he has ceased to use it, and yet he may immediately build again; how then will he have got the art? (*Metaphysics* IX. 3, 1046b29-1047a3, trans. St. Makin)

The situation to be assessed is not an observation in the strict empiricist manner. We are depictured a familiar situation with a builder who takes a rest during his working day but, simultaneously, a whole set of common-sense knowledge about arts is activated. We know that to build houses involves combining mental and bodily skills and learning all this takes time. With such background understanding, it is absurd to say that the capacity to build disappears when the builder stops working. Further, it would be equally strange to ask for an explanation of how he regains the skill back. The builder's skill is at times exercised and at other times unexercised. The builder being here a mere illustration, the practical knowledge involved forms part of our way of life and is difficult to refute by the strict empiricist.

The form of reasoning bears some resemblance to Kant's transcendental deduction, explicitly excluded by the Logical Positivist in rejecting synthetic *a priori* knowledge. This makes clear that metaphysical knowledge may have its own argument forms, and we have to accept methodological plurality at least of some kind. The empiricist hypothesis-testing method is clearly out of place in metaphysics. This brief passage thus vindicates that the potentiality-actuality distinction is no mere philosophical invention, but a discovery about the objective structure of reality and a necessary component of human skills and human knowledge and action in general.[24]

Now we have seen how Aristotle's philosophy of science refutes the three premises in the empiricist rejection of metaphysics. The argument for potentiality also illustrates that metaphysical categories lie at the background of all our empirical knowledge and beliefs, an insight, the history of philosophy has had to discover again.

5. Aristotelian Elements in the Dynamic Universe (DU) Theory

Having elaborated Aristotle's view of first explanatory principles and the metaphysical categories underlying the explanation of physical motion and change, we are now ready to look at Suntola's Dynamic Universe Theory to see how the Aristotelian philosophy of science helps to understand the dominant role of energy in DU in comparison to that of force. Before moving forward, a word

[23] For debates about Hume's position Read, R. J. and K. A. Richman Eds. (2000).

[24] Bhaskar, R. (1975) offers a similar argument for the existence of what he calls 'causal powers' as a necessary condition of the rationality of scientific experiments. Experiments bring to light patterns of events which would otherwise remain hidden in the midst of several simultaneous causes (also Johansson, I. 2004).

of warning is in place. The differences between Aristotelian and contemporary physics necessarily implies that the Aristotelian metaphysical categories no longer apply without modification. The use of the Aristotelian categories here has to be understood in an analogical manner, an analogy in need of thorough philosophical investigation.

Just as the definition of *eudaimonia* in ethics, the highest first principle of physics for Aristotle specifies the object of the study by determining the genus *proximum*, its definition laying out the relevant causal factors. Analogously, a unified theory of physics needs a highest explanatory first principle to integrate the phenomena studied by the various subfields of physics and cosmology. In DU, this is the principle of conservation of energy, more exactly the zero-energy principle. It states that in energy transformations, the sum of energy released and received is constant and equals zero (Suntola, T. 2018a, 2018b).[25]

Clearly, energy as such cannot be a basic principle of physics, for energy does not exist by itself, independently of some substance - to use an Aristotelian term. To be real, there has to be some substance, the property of which energy can be. In DU, mass is defined as the substance for expressing energy (Suntola, T. 2018a). This is illustrated by the unit of energy, Joule [kg·(m/s)^2]. Mass exists in various forms, and now we are looking for mass without any particular form, corresponding to Aristotle's prime matter. Whether Suntola accepts prime matter without any qualifications in the Aristotelian lines is an open question, but at least we find prime substance in DU.

Mass as prime substance is not a particle of any kind as it is abstracted from all specific properties, except that of being the substance for the expression of energy. To be an explanatory causal factor, such a prime substance carries gravitational potential and, as a full *dunamis*, mass possesses two complementary capacities. The active *dunamis* is the capacity of each point to generate gravitational potential over the whole rest of space, and the receptive *dunamis* is the capacity to sense the gravitational potential of the mass of the rest of space as gravitational energy. The actualization of potential energy into the energy of motion, $E_m = E_g$ or $M_{tot}c^2 = -GM_{tot}^2/R$ generated in the contraction process, creates what is called the rest energy of mass in contemporary physics (Suntola, T. 2018a, 2018b, 2020, 2021, 2022, 2024).[26] Such a gradual buildup of the rest energy replaces the instant appearance of mass and energy in the Big Bang in standard cosmology and is followed by the ongoing expansion process.

One indication of the relevance of the Aristotelian Saving the Appearances methodology in DU is the concept of particles, as described by Kallio-Tamminen (2024) in this issue. The particles form the next metaphysical layer and are described as mass-wave resonators in which standing mass waves are created by waves propagating in opposite directions. This solves the problem of the relation of mass and waves, much discussed in quantum mechanics (Kallio-Tamminen 2014, 2024). Material objects as the third metaphysical layer are then combinations of particles as illustrated in Figure 2. One may add that here ontological and epistemic priority coincide, as material objects are defined in terms of particles which again are defined in terms of mass as prime substance.[27]

So far it is clear that the Aristotelian perspective clarifies the fundamental role of energy in DU in comparison to force. It is important to note that while the potential energy field is a scalar

[25] One may see an anticipation of the principle of zero-energy principle in G. W. Leibniz (1695/2017, Suntola, T. 2018b).
[26] R is the radius of the 3-sphere space.
[27] For Aristotle's distinctions of priority Peramatzis, M. (2011).

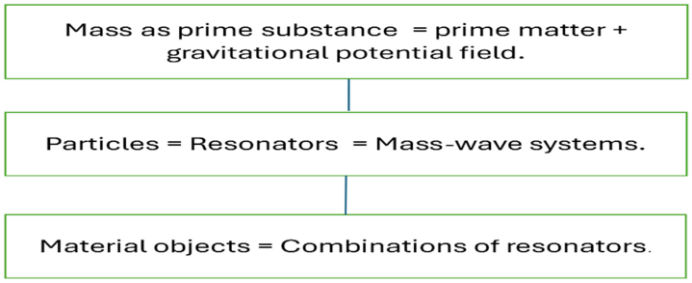

Figure 2. Ontological priority of mass as prime substance.

physical field, the force field is a mathematical vector field with no direct physical counterpart. The value of a point of the force field is determined only if values of nearby points are determined. It is from the mathematical equations of energy that one may then infer the properties of forces. The DU notion of mass thus implies that just as there is no need to postulate the existence of photons (Kallio-Tamminen, T. 2024), there is no need to postulate the existence of gravitons.[28] This clarifies further that, in DU, energy is ontologically and epistemically prior to force.

The most significant property of DU is that the notions of mass and energy comprise a holistic conception of physical reality with clear affinities to Leibniz's theory of monads in which each monad reflects the whole (Leibniz, G. W. 1714/1898, Suntola, T. 2018a). How the DU holism is transferred to all levels of physical reality is expressed in the System of Nested Energy Frames, Figure 3. The System is based on the insight that, in contrast to standard physics, there are two motions, one being the expansion *of* space and the other being local motion *in* space.

The zero energy principle implies that $E_{rest(0,0)}$ is the source for any local motion in space. Figure 3. describes the energy structure of space as a system of nested energy frames starting from hypothetical homogeneous space as the universal frame of reference and proceeding down to local frames in space. The mathematical equations on the right side in Figure 3. express the amount of energy transferred from one level to the next lower level. Here the symbol δ_n ($\delta_n = GM_n / r_n c^2$) is the gravitational factor in the *n*:th frame and β_n ($\beta_n = v_n / c$) is the velocity factor of the moving object in the *n*:th frame.

The hierarchical system is described as follows:

> Any local frame is obtained via the release of rest energy and global gravitational energy in the parent frame. A state of motion in a local frame is related to the state of rest in the frame; the kinetic energy is obtained against the release of potential energy in the frame. A state of gravitation in a local frame is related to the gravitational state as it were without the local frame (or mass center) in a specific location in space. (Suntola, T. 2018a, p. 36)

Consequently, the amount of rest energy becomes smaller the deeper we go into the structure of reality.

The holistic ontology of DU implies major deviations from the Aristotelian metaphysics and the presuppositions of contemporary standard physics, both of which are atomistic. In DU, holism is expressed in the notion of mass as the substance for expressing energy and the System of Nested Energy Frames linking local to the whole. The atomistic worldview of Newtonian mechanics is well known (Kallio-Tamminen, T. 2004) but the holism-atomism issue in Aristotle has not raised

[28] Private discussion with Suntola, T. November 2024.

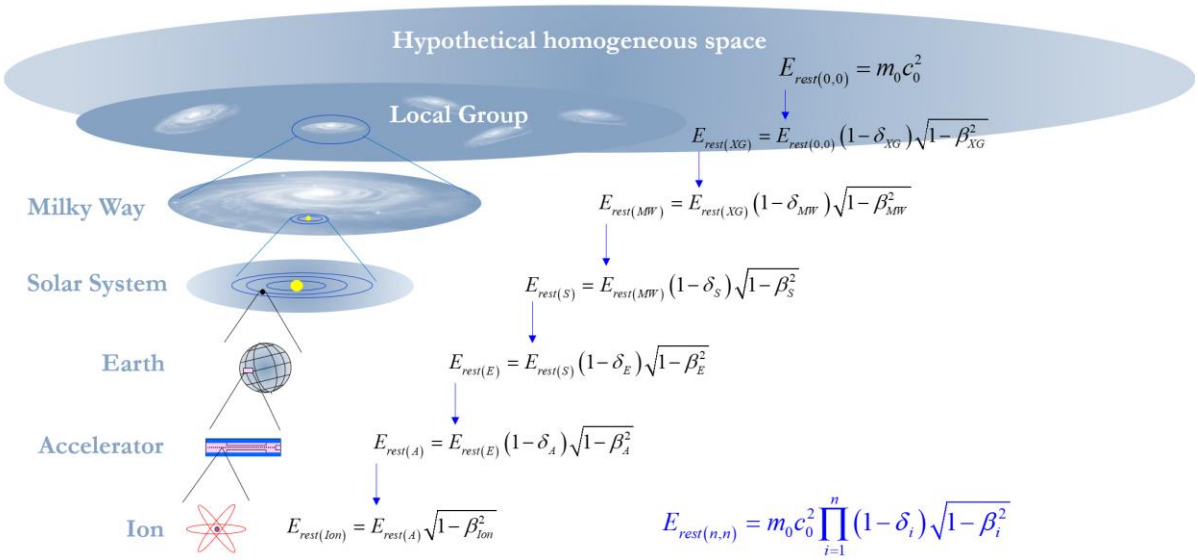

Figure 3. Holism in DU: The System of Nested Energy Frames (Suntola, T. 2024).

much scholarly interest. It is well known that Aristotle's notion of substance implies atomism, as the substance is defined as something that has an independent existence. However, his notion of full *dunamis* comprises two complementary *dunamei*, an active and a responsive one, which implies a relational view of reality.[29] The need to make room for holism in physics, as required by DU, is a challenge for philosophers to develop metaphysical categories of motion and change that allow relational physical properties and part-whole holism.

Another implication of holism in DU is that even though the Aristotelian genus-species classification helped to identify the task of physics as a particular field of study, it cannot form the chief organizing principle in DU. It is to be replaced by the whole-part structure, as demonstrated by the System of Nested Energy Frames. Thus, the System of Nested Energy Frames (Figure 3.) has ontologically, epistemologically, and methodologically an analogical structuring role in DU as the genus-species structure of virtues in the *Nicomachean Ethics* (Figure 1.). This implies another challenge for philosophical studies to analyze how the physical genus-species relations are reflected in the mathematics of DU.

One important classical epistemological ideal of science is the intelligibility of explanations and descriptions of phenomena investigated. Evidently, the System of Nested Energy Frames involves a full replacement of the observer-centered frame of reference of special and general relativity. There is no need to go deeper into this topic here, as I may point to the work by Styrman in this issue (Styrman, A. 2024, also 2016, 2018).

This brief presentation of the Aristotelian background of the basic postulates of Suntola's Dynamic Universe Theory may be taken as evidence of the heuristic merits of the Aristotelian philosophy of science in comparison with the strict empiricist philosophy of science. Having adopted the ideal of first explanatory principles and the potentiality-actuality metaphysics, Suntola has succeeded in developing a promising candidate for a unified theory of physics. I have

[29] Aristotle's notion of substance remains problematic, as he fails to distinguish internal and external relations (*Categories* 7 and *Metaphysics* V 17, Hood, P. H. 2004).

shown in this section how the notion of mass as prime substance for the expression of energy in DU satisfies the Aristotelian methodological requirement of the highest first principle by determining the scope of physics and giving the causes of physical motion. It is also of significance that DU deviates from several other attempts at a unified theory by adopting the notion of energy as its basic concept instead of force.

6. Conclusion

The paper has shown that, in comparison with the empiricist philosophy of science, the merits of the Neo-Aristotelian approach in generating and justifying a unified theory of physics are numerous. The traditional empiricist heuristic tools reduce to the hypothetico-deductive model which has little to say how to discover fruitful hypotheses (subsection 2.a). The closely related rationalist version of the philosophy of science does not fare any better (subsection 2.b). A chief weakness of the empiricist tradition is its rejection of metaphysics, though metaphysical assumptions are unavoidable, and metaphysical reflection is particularly necessary in a revolutionary project, such as building a unified theory of physics. Therefore, I have taken seriously the challenge and demonstrated how Aristotle could respond to each of the three premises in the empiricist rejection of metaphysics. At each issue - knowledge basis of science, the scope of logical reasoning, and methodological monism or pluralism - empiricism advocates a narrow view as compared with that of Aristotle. I shall not repeat the summary of these points given in the introduction but conclude the paper by listing the methodological tools available in the Aristotelian tradition.

The Aristotelian SA methodology, together with some organizing principles, is presented as a heuristic for generating, presenting, and justifying a unified theory in a sufficiently developed field of research, such as contemporary physics (Section 3.). Discovery of theories being a back-and-forth process, SA is best seen as an idealized model for theory development: collecting the relevant prevalent knowledge, scrutinizing it critically to find gaps and conflicts, constructing new notions and principles, and finally justifying the new ideas by showing how they solve the problems and save the part of the previous views that endured the criticism. During this process, one may utilize Aristotle's other scientific instruments, such as the ideal of explanatory first principles and the metaphysical categories. The meaning of 'principle' (*archê*) as beginning, origin, and first cause is revealing here (Liddell and Scott 1989). One metaphysical tool is the genus-species classification, which offers a framework both for the division of sciences and the internal structure of a particular science (4.a). The metaphysical categories for explaining motion and change in terms of *dunamis* (translated as capacity here), substance and attribute, and matter and form offer further methodological tools for physics (section 4.b-d).

To test my initial hypotheses, I have applied two Aristotelian metaphysical conceptions - the genus-species classification to determine the scope of physics and the categories of motion and change - to the Dynamic Universe Theory (DU) (Suntola, T. 2018a, 2018b, 2020, 2021, 2022, 2024). It turned out that DU is immersed deeper in the Aristotelian philosophy of science than Suntola's ideals of explanatory first principles, the potentiality-actuality distinction, and an intelligible theory without distorting our commonsense conceptions of time and distance. The Aristotelian concept of prime matter, in particular, turned out helpful in understanding the role of energy as DU's basic category instead of force. Thus, we have a contextual explanation of DU's success in comparison with alternative candidates for a unified theory of physics.

Since DU is a holistic theory, the genus-species classification has a subsidiary role in the structure of the theory, as hole-part relations constitute the major organizing principle. Aristotle's notion of the substance being atomistic, the ancient metaphysical categories of motion are not applicable as such but in need of philosophical scrutiny. Thus the paper highlights the fruitfulness of cooperation between physics and philosophy about issues of concept and theory formation (Comp. Kakkuri-Knuuttila, M-L. 2023).

The paper contributes to the recent Neo-Aristotelian approach in the philosophy of physics and studies of Meta-Empirical argument in physics. The underlying research questions in the latter are diametrically opposite, however. The challenge in the Meta-Empirical approach is to study the pursuit-worthiness of physical theories that have little or no empirical evidence. In contrast, DU has all available empirical evidence, critically assessed and corrected to form a coherent theory along the lines of the Aristotelian SA methodology.

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