

THE NOTION OF 'AETHER': HEGEL VERSUS CONTEMPORARY PHYSICS

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ABSTRACT: Hegel's historically transient notion of 'aether', developed and finally abandoned again during his short period of time at the University of Jena in the early years of the 19th century, has received comparatively little attention so far – much less than, for example, his *Phenomenology of Spirit*, or his later systematic works which he published after his departure from Jena. In modern and contemporary physics, however, notions comparable to Hegel's 'aether' have become interesting again in the context of quantum theory. In the main part of this essay we recapitulate and explicate the notion of 'aether' in Hegel's early works. Finally we briefly compare the Hegelian notion to novel concepts of 'aether' which might possibly be appropriate in the context of contemporary quantum physics. Such a juxtaposition would well have matched Hegel's own intentions, as he had always been acutely aware of the latest developments in the natural sciences during his own lifetime. In conclusion we can state that, in spite of a number of differences, both notions of 'aether' can be metaphysically characterised as a fundamental 'reality of possibility'.

KEYWORDS: Hegel, Philosophy of Nature, Metaphysics, Ontology, Aether, 19th Century, 20th Century, Philosophy of Science, School of Copenhagen, Quantum Physics, Cosmology.

"Es steht gegenwärtig allen Wissenschaften eine Wiedergeburt in Ansehung ihrer Begriffe und der Geistlosigkeit bevor, die wissenschaftlichen Inhalt in bloßes Material verwandelt und die Begriffe, deren sie zu handhaben gewöhnlich nicht einmal weiß, unkritisch und bewußtlos handhabt"

– HEGEL (1807) [17].

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1. MOTIVATION

Beyond mere observations and collections of data the work of science is to a large extent the formulation of *theories* in the context of which those observations and data become meaningful [3](chpt. 7). Theories, however, cannot be found as objects in nature. As inhabitants of Popper's well-known *World III* their 'nature' is conceptual-linguistic; this also includes the formalised languages of mathematics and logics. The scientific and philosophical quality of theories depends thus strongly on the applicability, accuracy and appropriateness of the *notions* and *concepts* [3](chpt. 2) without which no scientific theory could ever be expressed and formulated. The 'mental discovery' and development of appropriate concepts is thus as much part of the work of science as the empirical discovery of facts in observations or experiments. Hegel's famous quote, cited from [17] at the beginning of this essay, is precisely about the importance of the above-mentioned careful and meta-theoretically well-reflected 'concept work' within the framework of the modern sciences – although Hegel's own notion of 'science' was not yet the same notion of 'science' to which we are historically used since only the late 19th century [38] [39].

The speculative nature-philosophical notion of '*aether*', which had been important during Hegel's early days at the University of Jena, and which might –perhaps– become relevant again (in some new form) for the discipline of theoretical physics in the not-too-far future, is the main topic of our essay. As far as the continuous relevance of Hegel's nature-philosophical speculations for our 21st century is concerned, we agree with the philosopher Manfred Gies where he wrote that *Hegel, in his thoughts about the notions of 'space', 'time', and 'matter', had reached insights which touch precisely those points at which the discipline of physics possibly reaches its own methodological barriers* [9](p. 51). The claim that contemporary theoretical physics –or at least a prominent part thereof– is in the state of a noteworthy 'speculative crisis' was made by Reiner Hedrich some years ago [15].

In modern physics in the early years of the 20th century, Albert Einstein had finally rejected the ontic existence of an aether substance as a carrier substrate for electromagnetic waves. This step ended a severe difficulty in the physics of his time. Two of its three disciplines, mechanics and electrodynamics, seemed to contradict each other on an issue of fundamental importance. Mechanics was based on the Newtonian concept of absolute space and time. Velocities had no absolute meaning in this theory because they always had to be measured with respect to a reference frame which could itself be moving. According to electrodynamics, however, the velocity of light was factually absolute. The electromagnetic 'aether' concept had been invented to avoid this contradiction between those two theories, which were otherwise so successful. Upon close inspection, however, the physical properties of this postulated aether turned out to be unacceptably peculiar. Einstein had solved that problem by giving up the absolute structure of Newtonian space and time, introducing the concept of a space- time with a structure dependent on the observer. Electromagnetic waves do not need a carrier substrate, as time-dependent

electric fields induce magnetic fields and vice versa. They sustain themselves and are not elastic deformations of a medium such as sound or water waves. What is now called 'classical mechanics' was later developed into quantum mechanics. Subsequently the concept of quantisation was extended to *field theory*. While Newton had assumed that forces in mechanics acted instantly at a distance, electrodynamics describes forces as the actions of fields propagating through space and time according to their own dynamical laws. Following quantum mechanics, field theory was quantised in a second step, leading to *quantum electrodynamics*. In modern physics, the fundamental forces are all described by quantum field theories, except for gravity. In quantum field theories, excited states of fields are described as particles. One example is the photon, which is the particle associated with the electromagnetic field and mediates the electromagnetic interaction. Historically, severe mathematical difficulties hampered the development of quantum field theory. In the form that it has attained now, quantum field theory describes the occurrence of measurable fields and particles by considering all possible configurations and their probabilities. These possible field and particle configurations emerge from what is called the 'ground' or 'vacuum state' of the theory, with a probability described by a fundamental quantity termed the 'action' of the theory. Quantum field theories are now the most successful theories of physics. Their predictions, in particular those of quantum electrodynamics, have been experimentally tested and validated to extraordinary precision. The vacuum of the quantum field theories with its rich structure has been compared with a *modern version of the aether*, which is now in agreement with the theory of special relativity.

Many other differences notwithstanding, there is one astonishing similarity between Einstein in the early 20th and Hegel in the early 19th century: *Both Einstein and Hegel eventually abandoned the theoretical notion of 'aether'*, and both of them did so for the very same two reasons, namely:

- from an *empirical* point of view, no compelling evidence for the ontic existence of an aether substance was available to them, whereby both of them were well aware of that lack, and, even more importantly:
- from a *theoretical* point of view, the conceptual *notion* of 'aether' eventually turned out to be superfluous to them, i.e.: it could be safely cut away by means of Ockham's Razor without tarnishing the explanatory power of the philosophical or theoretical 'systems' which those two thinkers had in mind.

However, in spite of Einstein's and Hegel's historic status of 'authority', the question remains open whether or not *their* final decision against 'aether' must necessarily remain forever correct. *If*, for example, contemporary quantum physicists could present plausible new evidence for the ontic existence of *something* for which the theoretical term 'aether'

would be a highly appropriate identifier, then we would also have sufficient philosophical-historical motivation –in agreement with Gies [9]– for re-inspecting the historical semantics of Hegel's notion of 'aether', which had almost fallen into oblivion for many decades, and which was so-to-say 're-discovered' only in recent times. For all these reasons the *explication of Hegel's philosophy-historical notion of 'aether'* will constitute the main topic of this essay.

Georg Wilhelm Friedrich Hegel, the main philosopher of the era of German idealism, arrived at the University of Jena in the year 1801, and left the university and the town in the year 1807. During those few years in Jena, Hegel worked on the manuscripts and drafts of his later 'system' which was published in a considerably revised form only after Hegel had left the town. For this reason it makes sense to call Hegel's time in Jena his 'proto-systematic' phase. Hegel's proto-systematic manuscripts of that era –which were, by the way, never released by himself during his own lifetime– contained several metaphysical reflections on his nature-philosophical concept of 'aether', particularly in the years 1802-1806. Typical for Hegel's approach to philosophizing there was no essential difference between 'aether' (as a theoretical notion) and *aether* (as an ontic entity), because Hegel's meta-philosophy (on which all his philosophy was based) postulated an ultimate identity of idea and being. In Hegel's later –systematic– publications (after Jena) on the philosophy of nature, the German *word* <<Äther>> (as a lexical object) does not play a prominent role in his texts any more, such that it seems plausible to classify the *notion* of 'aether' as one of Hegel's particularly proto-systematic concepts.

It is almost certain from today's perspective that Hegel, therein following Kant, regarded himself to be what we would nowadays call a 'philosopher of science', though the very notion of 'science' in the early years of the 19th century differed considerably from the notion of 'science' as we understand it today – it was only in the era after Hegel that our high-modern notion of 'science' historically emerged [38] [39]. In such a role and situation Hegel was well aware of the epistemological importance of key concepts and basic notions for the meta-scientific foundations of any science. Moreover, Hegel already had some science-historical insights typically attributed to the 20th century (particularly Kuhn) as far as the possibility of *crisis* and 're-birth' in the metaphysical and conceptual foundations of the sciences are concerned. The science-philosophical rationale behind Hegel's speculative metaphysics of nature was clearly expressed by Hegel himself, namely in his editorial preface on the maxims of his own *Journal of German Literature* (1807), in which he explicitly declared that he intended to work against a particular tendency in the sciences of his own era – a tendency of degrading their contents to '*mere material*' in combination with an '*un-critical and un-conscious usage*' of their theoretical terms; see Hegel's original words quoted from [17] as our motto at the beginning of this essay. Apparently Hegel regarded such a situation as a noteworthy science-philosophical (not to say: 'paradigmatic') crisis, and

demanded in that context the above-mentioned critically reflected 're-birth' [17] of science. As we can read further in [38] [39], all sciences subsequently changed, indeed, their own character profoundly in the century after Hegel's death, albeit in a very anti-Hegelian manner for which Hegel's own idealistic philosophy could not have provided much meta-theoretical support any more.

Before we can explicate the historical semantics of Hegel's proto-systematic notion of 'aether' in some detail, we shall illuminate (for the sake of further historical clarity) some of the philosophy-historical background of Hegel's doctrine, followed by a brief recapitulation of related comments and interpretations which several well-known Hegel-experts have already published on this topic. This recapitulation of 'related work' will be followed by a presentation of Hegel's original 'aether' texts which are still to a large extent 'unknown' (in comparison to his well-known and widely circulated 'classical' texts). With that recapitulative explication of Hegel's 'aether' speculations, the central purpose of our essay will be fulfilled. To conclude this essay, and to re-connect its conclusion with its physico-philosophical introduction, we shall finally offer a few further thoughts concerning the 'usefulness' (or otherwise) of Hegel's speculative 'aether' doctrine for an adequate contemporary philosophical understanding of some of the fundamental features of quantum theory.

2. OVERVIEW OF THE PHILOSOPHY-HISTORICAL BACKGROUND

The influences –'attractive' or 'repulsive'– onto Hegel's speculative idealistic philosophy of nature, from a variety of earlier philosophical sources, are already well researched and comprehensively documented [41]. Particularly relevant in the context of the 'aether' doctrine were Plato, Aristotle, Newton, Kant, and Schelling. Further names are omitted only for the sake of brevity at this point, as an in-depth discussion of all those influences, similarities and differences is outside the intended scope of this essay.

In spite of this variety of influences, which Hegel partly took further and partly refuted, a number of particularly strong features of *neo-Aristotelism* have been identified in Hegel's doctrines [30](pp. 86, 94) [31](pp. 255, 258) [34](p. 136) [42], whereas it seems difficult to judge from today's perspective exactly which ones of the various writings by *Leibniz* –who had developed an 'aether' doctrine, too– were already available to Hegel at the beginning of the 19th century [34](p. 132). Indeed already in the year 1837, very soon after Hegel's death, Karl Mager had classified Hegel as '*the German Aristotle*' [27], in spite of (for example) Hegel's new type of triple-step dialectics which Aristotle's classical tertium-non-datur logic did not have: for further details see [11] (which has been used as the basis of this essay).

Aristotle had mentioned 'aether' [37] in his recapitulations of older doctrines that had been taught by Anaxagoras, who had imagined aether as fire, and Empedokles, who had

imagined aether as air [1]. In his own cosmology, different from the cosmology of Anaxagoras and Empedokles, Aristotle postulated a *fifth*, non- or extra-terrestrial 'element' (a.k.a. '*quinta essentia*') which would constitute the material substance of the stars in the 'supra-lunar' realm, and which was imagined to spin around itself in eternal rotations [1]. In the ancient Indian philosophy, which presumably had some influence onto the classical Greek philosophy, a related concept had been known as '*akasha*', denoting the substance of space [37]. This fifth Aristotelian 'element' became soon identified with the substance of aether [23]. That was not merely regarded as 'yet another element' among several others; it was also *valued* as a *supreme* element of 'divine' worthiness, especially because of its eternity, its constant, continuous, non-changing self-equality and self-identity (w.r.t. which its periodic-rotational locomotion was not regarded as 'change') [23]. Last but not least: the fifth element was also believed to play the role of an *ultimate substrate* which would enable the mutual transformations of the variable four terrestrial or sub-lunar 'elements' (earth, water, fire, air) into each other, similar to Plato's earlier speculations on element-transformation in the book of *Timaeus*.

Before Aristotle developed his later *dualist* doctrine on the two principles of cosmology –namely the principle of eternal and inert matter, plus the principle of the 'unmoved mover'– he had assumed a *monist* position according to which motion would inhere in matter as such. Similar to Aristotle's earlier monist doctrine, Hegel, too, conceived the *quinta essentia* as actively automotive, which is consistent with Hegel's ontological monism by-and-large. By implication Hegel was thus forced to *co-consider* the divine, transcendent, constant, eternal aspects of aether together with its mundane, immanent, variable, temporal aspects. This apparently inconsistent combination of aspects seemed to become possible only within the methodological framework of his dynamic triple-step dialectics. Otherwise, for the sake of consistency, Hegel would have been forced to give up either the Aristotelian principle of auto-motion, or the Aristotelian principle of the eternity of matter. Neither of these two options, however, would have been compatible with Hegel's over-arching nature-philosophical Aristotelism.

Because Aristotle had conceived the periodic cosmic rotation motion as 'constant' and eternal [7], whereas at the same time he empirically observed various alternations between motion and rest in our terrestrial ('sub-lunar') realm, Aristotle attempted to solve this dilemma by postulating an ontic tri-partition of the entire universe into:

- the un-observable 'unmoved mover' as the transcendent primordial source of motion,
- the eternally-constantly moving (rotating) stellar sphere, and
- our 'sub-lunar' realm characterized by the observable (and de-facto observed) alternations between motion and rest during the course of natural history [7],

whereby it did not seem to bother Aristotle that our naked-eye perception of apparent 'rest' might possibly be an illusion, due to our empirical ignorance of matter-inherent micro-motions for which our sensual capabilities do not suffice.

According to the discussions in [24] and [42], Hegel followed Aristotle faithfully in his speculative partitioning of the cosmos into a stellar and a 'sub-lunar' realm. Consequently also Hegel's concept of 'aether' was strongly connoted with mental images of the outer spheres of the universe. However, Hegel's notion of 'aether' had, at the same time, some distinctly *spiritual* aspects which cannot easily be attributed to the *quinta essentia* in its traditional Aristotelian context. This difference is due to Hegel's metaphysical monism in contrast to the late Aristotle's dualism. Therefore, in Hegel's speculative notion of 'aether', the separate Aristotelian notions of *νοῦς* (spirit) and '*prima materia*' had to be regarded as *unified*: see [11] for further details.

In summary: all the classical Aristotelian metaphysical concepts of spirit, matter, nature, substance, energy, motion, etc., have their repercussions in Hegel's notion of 'aether' during his proto-systematic years (1802-1806) at the University of Jena. All those various concepts and notions were forged together into Hegel's notion of '*the absolute*' (i.e.: the one which does not depend on anything else for its being) with which 'aether' was then almost identified. Thereby Hegel, as a philosopher of nature, was positioned somewhere between the classical Aristotelian 'researcher' of nature (observer) and the classical Aristotelian 'metaphysicist' (speculator). Such an intermediate position was implied by Hegel's desire to grasp nature as a whole in anti-empiricist metaphysical terms, however without ignoring the de-facto state of the art in the natural sciences of the early 19th century. Indeed Hegel had been a keen follower of the scientific developments and innovations happening in his own era (and maintained an impressive private library to this end).

Last but not least for this section, as far as Hegel's knowledge of Isaac *Newton's* physics and metaphysics is concerned (who's concept of 'aether' was not un-similar to the one by Leibniz), we can learn from [34](p. 131) how Hegel had *critically* discussed Newton's attempt at using 'aether' to explain observable phenomena of gravity. Newton's concept of 'heavy' aether was thus *not* something which Hegel had in mind for his own doctrine. Hegel was also well informed about Newton's calculus of infinitesimal mathematics –until today some of the most important 'theoretical tools' in the pure as well as in the applied physical sciences– although he had *criticised* Newton for his allegedly unjustified conflation of pure and applied mathematics [31](p. 264): the lines of geometric representations of planetary motions, on paper, are indeed *not* sufficient to prove the physical existence of far-ranging and *ubiquitous* forces of gravitation – something which must have considerably threatened Hegel's pre-Newtonian division of the cosmos into two spatially separate and essentially different (sub- and supra-lunar) realms [42](pp. 303-306). In other words: whilst

both Newton and Hegel had been seeking for appropriate nature-philosophical notions and concepts at meta-empirical levels of abstraction and generality, Hegel could not accept the language of infinitesimal mathematics as the language in which those nature-philosophical concepts should ultimately be formulated. Moreover: whereas Newton's 'aether' was meant to be somehow 'integrated' into a mathematically formalisable system of far-ranging universal forces, Hegel's 'aether' was not compatible with such kind of 'mechanistic' ideas. At the very root of the philosophical difference between Hegel and Newton sits the ancient Aristotelian question whether or not the realm of 'mechanics' is included in the realm of 'genuine nature': see Schiemann [35] for comparison.

By implication we can thus say that the type of 'aether' which Einstein had rejected in the early years of the 20th century about hundred years after Hegel –see section 1 of this essay– was conceptually related much more closely to the 'Newtonian' than to the 'Hegelian' type. In other words: Einstein's aether-critique belongs into a different ontological category and can thus *not* be utilised to invalidate the kind of 'aether' which the early Hegel of Jena had in mind. Therefore: *if* the *late* Hegel's rejection of his own earlier 'aether' concept would, in hindsight, appear as (at least partly) erroneous or premature –a generally not unusual possibility in the history of philosophy at which Eugen Fink [5] [6] had hinted (albeit in a different context)– then the *early* Hegel's notion of 'aether' could well remain a justifiably interesting object of modern metaphysical considerations.

3. RELATED WORK ABOUT HEGEL'S AETHER DOCTRINE

Because of the double function of Hegel's 'aether' –namely: to signify some form of primordial sprit as well as some form of primordial matter in a dynamic-dialectic union– it is not surprising that –depending on their own hermeneutic presuppositions and interests– some Hegel-scholars have emphasized in their own interpretations the matter-related aspects of Hegel's 'aether', whilst other scholars have emphasized its non-material aspects (particularly w.r.t. the overarching motivations of Hegel's speculative idealism as a whole). In this discourse we are currently aware of only rather few comments from the English-speaking academia (which we are going to recapitulate next), and several more comments from the German-speaking academia (which shall be summarized thereafter). It also seems that there has not yet been much 'cross-fertilization' between those two different language groups up to now.³

³ Because of our own language barriers, any possibly existing further related work on this topic in other languages (e.g.: Italian, French, Russian, etc.) has remained unknown to us so far.

3.1. FROM SOURCES IN ENGLISH

According to Magee, Hegel's aether doctrine should be regarded as a form of *theosophy*, though it appears in the terminological guise of rational philosophy [26]. This interpretation seems at least possibility-compatible with Moog's pointer (see below) to the poet Hölderlin in [28], as well as with Hegel's youthful days at the theological seminary of Tübingen. From Magee's point of view, Hegel's references to the state of the art in the natural sciences of his own era (i.e.: the early 19th century) are *not* to be regarded as particularly relevant: those science-terminological signifiers should thus be considered as 'code words' for something different outside the realm of science. Similar to Wahsner (see below), Magee claimed that Hegel would have faithfully believed in traditional Aristotelian doctrines in an almost religious fashion [26], and that Hegel's aether doctrine could only be understood properly in the context of *hermetic-esoteric* theosophy. Similar to Moog and Büttner (see below), Magee has also pointed out the conceptual links between Hegel's aether doctrine and Plato's Timaeus-cosmology. With several references to Harris [12] [13] [14], Magee also discussed in [26] how 'aether' in Hegel's speculations was something *capable of forming itself*. This is compatible with Schall's hint (see below) at Spinoza's concept of '*causa sui*' which Hegel must have been very familiar with, (due to his well-known expertise in the history of philosophy).

In a book review by Ramsey for the scientific journal 'Foundations of Chemistry' we can find a small but nevertheless relevant hint to Hegel's aether doctrine: *Hegel rejected atomism, and Kant tried to argue that the aether was a-priori* [33]. This remark of Ramsey's implies clearly that Hegel's 'aether' must *neither* be regarded as any kind of gas-like particle cloud – Hegel believed indeed, such as Leibniz, in a universal continuum or 'plenum' – *nor* as merely a knowledge-enabling epistemological 'category' associated with a Kantian transcendental ego.

Most recently an essay by Shannon in this journal [40] has shed new light onto the deep relationship between Hegel's *Phenomenology of Spirit* and Hegel's third nature-philosophical system draft (Jena III). Shannon's essay intended to make the connection between the phenomenology and the natural philosophy of 1805-1806 explicit, and to identify how Hegel had used the natural sciences of his own era in the preparation of his philosophical 'system' [40](p. 101). According to Shannon, Hegel was committed to designing a system of philosophy which incorporated the natural science of his era [40](p. 102). However, Shannon also hinted at a development or evolution of attitude in Hegel from his first system draft (Jena I) to his third one (Jena III). Thereby only the latest system draft shows a strong commitment to the natural sciences, whereas his earlier drafts had been considerably more esoteric: "*The NP*" –i.e.: natural philosophy– "*was the first part of System III to be written. Unlike the earlier version 1804-5, this one is more empirical and has no discussion of God, only a brief treatment of aether, and the ideal elements appear only from the processes of the real elements*" [40](p. 102). "*The NP*" –in the Jena III draft– "*begins with Hegel's concept of*

absolute matter, which as in the System II version is called 'aether', but almost immediately thereafter Hegel turns to the concepts of space and time which are explicitly Kantian" [40](p. 103). 'Aether' in Jena III, according to Shannon, is associated with *light* which, though being material, is nevertheless a phenomenon apart from other matter. Such 'aether' in Jena III is a '*divine element*' [40](p. 110), "*from which the cosmos receives its impetus to grow and evolve*". In this context Shannon also stated that Hegel had borrowed this particular notion of 'aether' from Newton and the Platonists of Cambridge (such as Henry More), who had supported such a 'divine element' against the mechanism of Descartes [40](p. 110). In summary: "*If we understand Hegel's commitment to natural philosophy and science as essential to the understanding of his philosophical project, we should also be able to correct the common mistake that he is merely an idealist who has no appreciation of nature and material causations, or worse that he was opposed to scientific constructions*" [40](p. 131).⁴ The 'semantic shifts' in key concepts of Hegel's manuscripts from 'Jena I' via 'Jena II' to 'Jena III', as observed by Shannon, had also been noticed by Schall some time ago – see below.

Last but not least a new Hegel-book by Ronald Schleyer, which shall also cover Hegel's aether doctrine, seems to be forthcoming [36], in which Schleyer intends to show a connection between Hegel's ideas and Jacob Böhme's thoughts about the 'wheel of God' and 'eternal nature'.⁵

3.2. FROM SOURCES IN GERMAN

In his book [28], Moog issued a warning against any contemporary (1920s-1930s) attempts at interpreting Hegel's metaphysical philosophy of nature merely empiristically from a perspective of the exact natural sciences. Moog's warning included the 'aether' as a key concept of Hegel's philosophy of nature during his time at the university of Jena. Moog drew comparisons between Hegel's philosophical notion of 'aether' and the romantic poet Hölderlin's (1770-1843, fellow disciple with Hegel at the seminary of theology in Tübingen) poetic figure of 'aether', as well as between Hegel's aether doctrine and Plato's Timaeus-cosmology [28]. Similar to the later Magee (see above), Moog strongly emphasized the metaphysical and speculative aspects of Hegel's aether doctrine. Hegel had often been ridiculed by empiricist scientists because of some fundamental misunderstandings: Hegel had used the 'usual' words and terms, however often 'charged' with very different and

⁴ Nowadays it is often forgotten that Newton was indeed (as mentioned by Shannon) *both* a scientist in the modern sense, *and* an esoteric alchemist. From this perspective it is plausible to assume (with Shannon) that also Newton's notion of 'aether' –like Hegel's– might have had some 'spiritual connotations' in addition to its presumed ontic-material existence. To us it is unknown whether Hegel had already been aware of Newton's alchimistic-esoteric side, or whether Hegel had only known Newton as a man of the exact sciences. For Hegel's critique of Newton's concept of 'aether' –particularly its material 'heaviness' in the context of Newton's theory of gravity– please recall section 2 of this essay.

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Personal communication from Ronald Schleyer, via e-mail.

unusual meanings. If the 'usual' meaning behind the words is naively presumed, then Hegel's writings cannot be properly understood, said Moog [28].

In [21], Horstman discussed the purpose, the role, and the function of Hegel's aether doctrine as a whole in the wider context of Hegel's speculative philosophy. Though Horstman did not discuss in [21] the finer details of Hegel's aether doctrine, he mentioned that Hegel's conceptual separation of the notions of 'nature' and 'spirit' began to emerge particularly during the time in Jena [21], whereas in Hegel's earlier philosophy (before Jena) such a distinction had not been so clearly evident. In that context, Hegel's notion of 'aether' should be regarded as a philosophical 'bridge concept' without which the systematic cohesion between the concepts of 'nature' and 'spirit' would disappear [21]. Ten years later, in [22], Horstmann pointed out that all three of Hegel's system drafts (Jena I, Jena II, Jena III) have in common the explanation of all natural phenomena, and their processes, by means of essentially two explaining factors which Hegel had identified as 'aether' and 'matter' [22]. Thereby, 'aether' was used to denote the *structure of 'the absolute'* where this initially feature-less 'absolute' was considered as enhanced by further features of reality. In other words, Hegel's 'aether', according to Horstmann, signifies a kind of *'absolute in materialization'*, i.e.: a metaphysical principle unfolding itself into the non-metaphysical reality [22]. On those premises the aim of speculative philosophy of nature is to re-interpret all observable natural phenomena in those primordial metaphysical terms.

In [2], Büttner has examined Hegel's aether doctrine from the perspective of a Luhmann-kind-of system philosophy.⁶ From such a system-philosophical perspective, Hegel's 'aether' (which, as we should remember, was associated with spiritual qualities) is said to play the role of an 'observer' which 'observes' the self-unfolding of the self-conscious spirit during the course of its history. Moreover Büttner also compared in [2] Hegel's notion of 'aether' with Plato's concept of *χώρα* (chora) in the book of Timaeus, thereby coming to conclusions similar to Moog's in [28]. Last but not least Büttner argued that only the mere *word* <<Äther>> (as a lexical entity), however *not* the *concept* of 'aether' (semantically) would have vanished out of Hegel's systematic philosophy published after his departure from Jena [2].

The main topic of Kern's essay [24] was the notion of 'matter as force' in Hegel's neo-Aristotelian philosophy of nature. In this context Kern also discussed the notion and role of Hegel's 'aether' which, according to Kern, should be understood as closely related to Hegel's own particular notion of 'force' [24]. With an intention similar to Moog's [28], Kern wrote his essay in defence of Hegel's metaphysical philosophy of nature against superficial empiricist critiques which did not take the semantic peculiarities of Hegel's

⁶ System philosophy, a.k.a. systemic philosophy, is philosophy *about* systems, *not* to be confused with *systematic* philosophy, or a philosophical system such as Hegel's, which attempts at dealing with the entirety of all that exists.

terminology into account. Unlike Moog, however, Kern also pointed out the role of Hegel's nature-philosophical metaphysics as a 'philosophy of science' in relation to the empirical natural sciences of Hegel's own time, of which Hegel had been keenly aware. Similar to Wahsner (see below), Kern criticized some particularly anachronistic Aristotelian aspects in Hegel's philosophy of nature, especially the ad-hoc division of the entire cosmos into a 'stellar' and a 'sub-lunar' sphere [24]. This, according to Kern, would have some peculiar implications for Hegel's science-philosophical notion of 'force' -can the same force permeate two supposedly separate cosmic realms?- and hence also for his force-related notion of 'aether'. However, unlike Wahsner (see below), Kern has regarded those peculiarities as rather 'minor', such that they would not undermine the philosophical value of Hegel's metaphysics of nature as a whole [24].

In [25], similar to [21], Kimmerle briefly explained Hegel's aether doctrine and its function in the larger context of his proto-systematic philosophy. Kimmerle particularly mentioned that Hegel's notion of 'aether' as 'absolute matter', in combination with the related notion of 'time', would constitute 'bridge concepts' connecting Hegel's philosophical logics and metaphysics with Hegel's philosophy of nature [25]. Contrary to Büttner (see above), Kimmerle decidedly asserted the vanishing of 'aether' as a *notion* (i.e.: not merely as the grapheme <<Äther>>) out of Hegel's systematic philosophy after Jena.

In his essay on Hegel's philosophical interpretation of the solar system [29], Neuser analysed particularly the conceptual relations between Hegel's notions of 'aether' and 'motion'.⁷ According to Neuser it is *not* as if Hegel would have simplistically identified aether and motion as one and the same. Instead, the relation between aether and motion in Hegel's philosophy of nature is more subtle, such that the aether should be regarded as the '*form of motion*' [29], i.e.: something which is (onto)logically prior to motion, in a role of its enabler. Obviously this nature-philosophical thought of Hegel's is closely related to the well-known Aristotelian notion of the 'unmoved mover'.

Schall's essay about Hegel's notion of 'aether' and its logical implications [34] is one of the most comprehensive contributions to the discourse on this topic to date, and is thus too long for an adequate recapitulation within the limited page-space of our essay. One key topic of Schall's interpretation was Hegel's characterization of 'aether' *both* as 'absolute matter' *and* as 'absolute spirit' which Schall discussed in comparison against Spinoza's ontological concept of '*causa sui*' (with which Hegel had been well familiar). Schall's essay also contains an interpretation of the 'speaking' that Hegel had attributed to the aether in its dialectic-reflexive relation to itself. Schall's essay ended with a discussion of why the

⁷ At this point we allow ourselves to remind the readers of the connection between aether and circular motion in the writings of Aristotle, the general connection between the notions of 'motion' and 'time' in physics, as well as the connection between the notions of 'time' and 'aether' in the early writings of Hegel.

notion of 'aether' eventually vanished out of Hegel's systematic philosophy after Jena [34]. Last but not least Schall's essay is also interesting from a historical semantics point of view, because Schall has exposed a subtle *semantic shift* in Hegel's notion of 'aether' [34] between Hegel's early work in Jena (shortly after his arrival) to his late work in Jena (shortly before his departure). In other words: even during the comparatively short historical period of 1802-1807 the *meaning* of the word <<Äther>> in Hegel's manuscripts (Jena I, Jena II, Jena III) was *not* continuously the same. This semantic shift already during Hegel's time in Jena might also explain the eventual vanishing of <<Äther>> out of Hegel's systematic publications after Jena.

Wahsner's essay [42] appears to us as a somewhat polemic account of Hegel's 'scholasticism' and dogmatic Aristotelism. In emphasizing the dogmatic and esoteric features in Hegel's philosophy of nature, Wahsner's contribution points into a direction similar to the later work by Magee (see above). Though Wahsner's essay was mainly written about Hegel's speculative geo-centrism [42], she also made in that context several skeptical remarks about Hegel's aether doctrine. According to Wahsner, Hegel's aether doctrine was not only *systematically unnecessary* but also *incompatible with his speculative geo-centrism* [42]. According to Wahsner, the vanishing of Hegel's <<Äther>> from his systematic philosophy after Jena would thus be due to the above-mentioned incompatibilities. If Hegel wanted to rescue the internal consistency of his philosophy of nature as a whole, then he would have been forced to abandon either his dogmatic geo-centrism, or his notion of 'aether' as it was. Because of his faithful belief in the Aristotelian doctrine of geo-centrism –for comparison see Magee– Hegel would rather have sacrificed his notion of 'aether', in order to repair the internal consistency of his systematic philosophy of nature [42].⁸

Frercks wrote his article about Hegel's aether doctrine in a summaric style [8], for a recent lexicon on Hegel's philosophy [4]. The gist of Frercks' article is that Hegel's 'aether' should be understood as an epistemically or gnostically deficient, *unconscious or unaware mode of the absolute spirit* prior to its dialectic unfolding in the course of history [8]. Unlike, for example, Moog (see above), Frercks also emphasized the science-philosophical relations between Hegel's aether doctrine and the physical sciences of Hegel's own era (the early 19th century), of which Hegel had been acutely aware. Frercks, too, concluded his article with several remarks on the question why Hegel eventually gave up his 'aether' concept in his systematic philosophy after Jena [8]. Unlike Büttner (see above), Frercks decidedly argued that not only the lexical unit <<Äther>> but indeed the semantic *notion* of 'aether'

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We may add at this point that the inconsistency mentioned by Wahsner is rooted in the aether's ubiquity on the one hand, and the presumed essential difference between the sub- and supra-lunar cosmic realms on the other hand: *if* the aether is ubiquitous, then the two speculatively presumed cosmic realms *cannot* be 'essentially different' in their ultimate ground of reality.

has vanished from Hegel's later systematic philosophy, because of having become conceptually and systematically obsolete [8]. This 'cut' with 'Ockham's razor' did *not* logically depend on the ontic question of whether or not aether existed factually as a physical substance – a question which was and remained empirically unanswered throughout Hegel's entire lifetime.

Recently an entire book has been published on Hegel's concept of 'time' and its relation to his notions of 'space' and 'motion' [10], in which Grießer provided many comments also on Hegel's aether doctrine. Needless to say that a whole book does not lend itself well to a brief recapitulation within the limited page-space of this essay. Grießer's book, which also includes several references to a number of essays published in [41], is currently the most comprehensive interpretation of Hegel's aether doctrine as far as we know. The book covers all of Hegel's proto-systematic manuscripts (Jena I, Jena II, Jena III). Throughout his book, Grießer particularly emphasized the spiritual connotations of 'aether', for example where he explicated that spirit, as aether, is something which has already unfolded itself into nature and spirit [10](p. 41). Moreover, according to Grießer, 'aether' is primordially merely an empty or void '*abstraction of space*' – compare this to Descartes' 'res extensa' – whereas in its 'later' form of matter it is '*essentially motion*' [10](p. 154). Anyway and nevertheless, 'aether' is and remains the '*spirit of nature*' which thus differentiates and concretises itself [10](p. 159). In other words: 'real matter' versus 'absolute matter' (i.e.: 'aether') must not be confused with each other [10](p. 160), although Hegel had never accepted Descartes' ontological separation of 'res extensa' versus 'res cogitans' as two ultimately different substances. Also in his manuscript Jena III, as interpreted by Grießer, Hegel had emphasized clearly that 'aether' is the notion of 'motion' and 'pure spirit' [10](p. 195). Moreover Grießer pointed out that the 'virtual volatility' [10](p. 380) of the aether has the consequence that *for us* (i.e.: from our immanent temporal perspective) it has '*always already*' – similar to a historical-hermeneutical a-priori – separated itself into space and time, such that only the intellectual 'eye' of philosophical speculation is able to 'see' what is 'behind' our empirically evident reality of space and time.

4. HEGEL'S ORIGINAL AETHER TEXTS 1802-1806

With the most relevant related work, interpretations and comments about Hegel's aether doctrine already recapitulated in the previous section, it will be sufficient in this section to summarise only very briefly where (in which texts) Hegel had written what about his notion of 'aether' (with its historically evolving semantics) during the years 1802-1806 at the University of Jena. There are mainly four sources of varying 'richness', namely Hegel's:

- published essay on natural law (the printed *Naturrechtsaufsatz*),

- 1st unpublished system draft (hand-written manuscript 'Jena I'),
- 2nd unpublished system draft (hand-written manuscript 'Jena II'),
- 3rd unpublished system draft (hand-written manuscript 'Jena III').

Moreover there exists also one very short hand-written remark in Hegel's personal diary in which he had associated 'aether' with 'purity' and 'clarity', connoted with 'absence of confusion' [11]. Those four main sources can be found in [16] [22] [19] [20]. As it will be shown more explicitly in the subsequent sub-sections of this section, Hegel's own idea of 'aether' was not consolidated, i.e.: during Hegel's rather short stay in Jena, in which three subsequent philosophical 'system designs' were drafted, also Hegel's notion of 'aether' was subject to subtle yet notable semantic shifts (as discussed in the previous section) from draft to draft. All in all it seems to have been a difficult problem for Hegel to cover with only one universal notion –'aether'– a too wide spectrum of too diverse philosophical 'objects' ranging from the timeless divine absolute to the mundane realm of the natural science quarrels of his own era.

4.1. NATURAL LAW ESSAY

Hegel wrote and published his essay on natural law [16] during a time when he had not yet fully developed his finer distinctions concerning 'matter' and 'spirit' in his philosophical notion of 'nature' [21]. During the writing of [16], Hegel's idea of nature included *both* aspects: matter and physical phenomena on the one hand, as well as spirit and cultural phenomena on the other hand [21]. Only from such a broad perspective of 'nature' (which included even society and culture) Hegel's mentioning of 'aether' in an essay in philosophy of law can make any sense. In that essay Hegel mentioned 'aether' only three times, namely [16]:

- in a context of 'earth' (*Erde*) together with 'absolute morality' (*Sittlichkeit*),
- in a context of 'simple' or 'non-composite' substance (*einfache Substanz*), and
- in the context of our solar system with its sun and planets.

In [16], especially the connection between 'aether' and an 'absolute morality' is interesting; this particular association did not occur in Hegel's later drafts (Jena I, Jena II, Jena III) any more. This association between 'aether' and an absolute morality was (as far as we know) not previously discussed by any other Hegel-scholars (see above: Related Work). As mentioned above, this very early notion of 'aether' was still strongly influenced by Spinoza's notion of 'substance' as *causa sui*.

4.2. FIRST SYSTEM DRAFT (JENA I)

Also in Hegel's first system draft [22], wherein the notion of 'aether' was not yet much elaborated, we can find only a few hints at what aether was supposed to be. In that manuscript, Hegel characterized 'aether' as:

- self-referential 'idea of the there-being' (*Dasein*) retreated back into its own notion (*Begriff*),
- absolute matter,
- pure spirit,
- *not* sensual (empirical),
- notion as pure notion in itself,
- simplicity (not composite),
- self-identity,
- beatific (*selig*),
- unmoved rest,
- substance and being of all things,
- infinite (unlimited) elasticity devoid of any particular form or definedness,
- not 'permeating' everything but *being* everything,
- a 'non-there-being being' with an inherent tendency towards 'flowing into there-being',
- space,
- 'light' (possibly metaphorically with a deeper epistemological or gnoseological meaning; see below),
- the 'pure spheres' (of celestial mechanics),
- life.

Those ideas, which appeared merely as sketches in Jena I, were considerably finer described in Hegel's subsequent manuscript.

4.3. SECOND SYSTEM DRAFT (JENA II)

Hegel's second system draft [19] of 1803-1804 is the richest source as far as his proto-systematic 'aether' philosophy is concerned. Earlier texts, such as his above-mentioned essay on natural law [16] and his first system draft (Jena I), do not yield much about his notion of 'aether' [34], and the same can also be said about Hegel's systematic texts (after Jena) in which Hegel recapitulated only briefly his earlier 'aether' ideas from a distant and self-critical retrospective position [34]. The main part of Hegel's aether doctrine in Jena II can be found between his sub-chapter on the 'absolute spirit' and his sub-chapter on the reality of motion in [19]. In those parts Hegel has described a dialectic 'unfolding' of the aether from 'spirit' to 'motion' in twenty-four metaphysical assertions in which the lexical unit <<Äther>> can be found in twenty-five occurrences. As it was further discussed in [11], those twenty-four assertions dealt with the following metaphysical and nature-philosophical topics:

- aether and spirit,
- aether and the primordial origin,
- aether as the idea of God,
- aether and all-everything (universe),
- aether as its own self-awareness,
- aether as its own utterance,
- the notion and essence of the aether's reality,
- the aether's reflexive identity,
- the aether's infinity,
- the generation of a one-point out of aether's contraction,
- aether and the stars,
- aether as the origin of space and time,
- aether and motion,
- aether as its own differentiation and self-separation,
- aether as absolute matter,
- aether and motion,
- aether and the ultimate topic of philosophy,

- aether as light and force,
- aether as light and as absolute aether,
- aether with regard to motion and the earth.

As it was already noted by Magee (see above), those metaphysical assertions were written by Hegel in a remarkably dense, speculative, 'dark' and hermetic style. Moreover we must always keep in mind that the difference between something and the *notion* of such a 'something' ultimately collapses throughout Hegel's speculative philosophy, which makes it difficult for us to grasp those matters analytically. Nevertheless it seems fair to say that Hegel had attempted in [19] to design a systematically coherent philosophy of the universe from first metaphysical principles, such as to contain and comprise different related concepts such as 'one' (unity) and 'many' (diversity), 'spirit' and 'matter', 'space' and 'time', 'motion' and 'rest', 'light' and 'force', etc.

In accordance with the philosophical-methodological programme of German idealism in the late 18th and early 19th century, Hegel attempted to rationally 'deduce' those nature-philosophical concepts by 'pure reasoning' out of a primordial concept, the 'absolute'. In this context it seems that Hegel's 'aether' in [19] was both a synonym and a more concrete metaphor for that abstract and rather un-imaginable notion of the metaphysical 'absolute'. On the other hand, however, Hegel's intentions towards a contemporary 'philosophy of science' (in the context of the early 19th century) can also be detected 'between the lines' of particularly those parts of [19] in which the aether's relations with physical phenomena such as light and force were described.

4.4. THIRD SYSTEM DRAFT (JENA III)

Already in his third system draft [20] of 1804-1805, written almost immediately after Jena II, Hegel had considerably shifted the focus of his 'aether' presentation from the previously rather 'spirited' concept to a notably more 'physical' one. At the same time we can also see that the textual volume of Hegel's 'aether'-related elaborations in Jena III [20] is considerably smaller than the related elaborations in Jena II [19]. This seems to imply that Hegel had already started to 'downgrade' in his latest proto-systematic draft the relevance of the 'aether' concept, perhaps already in anticipation of his later systematic texts (after Jena). Anyway, Hegel's 'aether' elaborations in [20] treated the following topics in five metaphysical assertions, in which the *word* <<Äther>> can be counted in six occurrences:

- In the first assertion, Hegel characterized the aether as absolute matter, or as *the idea as being in the form of its concept*.

- In the second assertion, Hegel conjectured that the aether *is everything*, in explicit contrast to merely 'permeating' everything, whereby the aether is constant in an invariable state of being in 'un-stainable clarity'.
- In the third assertion, Hegel characterized the primordial aether as something which is *'not yet* itself, which is *'not yet* its own truth'. Hegel thus alluded to the aether's further unfolding during the history of the universe, whereby the primordial aether is still lacking any determined attributes.
- In the fourth assertion, Hegel expressed briefly and concisely the *identity of space and the aether* in its more concrete form of being.
- In the fifth assertion, Hegel spoke about the *'totality of matter' in the form of light*, which is one of most fundamental *products of aether out of itself*, though not identical with the primordial aether as such.

In this quite brief and concise aether doctrine of Hegel's third system draft [20], Hegel has thus presented aether as absolute matter with *two* different *types* of aspects:

- 'spirit' and 'space' were presented as the aether's more *abstract* (or general) aspects, whereas
- 'light' and 'force' were presented as the aether's more *concrete* (or particular) aspects.

Also in this context we must not forget Hegel's amalgamating identification of philosophical notions and concepts with the things themselves which those concepts were to represent. In other words: by his philosophising about concepts in the fashion of speculative idealism, Hegel believed to make true assertions about the actual world. Anyway, also in his third system draft [20] Hegel used the notion of 'aether' as a unifying primordial concept from which all further aspects of the spiritual and physical world should be 'derived' by the method of dialectic speculation. Once again we can sense Hegel's science-philosophical intentions only 'between the lines' of those parts of [20] in which the links between 'aether' on the one hand, and physical notions such as 'light' and 'force' on the other hand, were addressed. Particularly the identification of 'aether' and 'space' in Hegel's third system draft reminds us of the 'spatial substance', *akasha* [37], in the ancient Indian philosophy.⁹

⁹ To which, by the way, also the quantum physicist Erwin Schrödinger felt strongly attracted.

To which, by the way, also the quantum physicist Erwin Schrödinger

4.5. INTERMEDIATE SUMMARY

The previous sections of our essay have sufficiently demonstrated that the Hegel of 'Jena III' was not the same as the Hegel of 'Jena I' any more, such that the question for 'the genuine' Hegel –an esoteric theosophist, or a rational philosopher of science?– will not soon meet its definitive answer. Nevertheless it seems fair to say that aether, according to Hegel, is not any usual substance within space and time. 'Aether' in Hegel's manuscripts rather denoted a *principle of genesis* through which space and time are coming into being in the first place. 'Light' (associated with the aether) as a metaphysical term in Hegel's philosophy of nature does not only denote an immanent electro-magnetic phenomenon but also –like in 'enlightenment'– a transcendent self-awareness and self-recognition of a primordial spirit-in-nature. The 'volatility' or 'fluidity', which Hegel had attributed to the aether, indicates its non-observability: from our immanent vantage point, inside our empirical world of there-being (*Dasein*), the aether has 'always already' (*immer schon* – like a hermeneutical a-priori) unfolded itself into our space-time which includes all observable things and phenomena. Nature as it appears *for us* (not per-se) is thus 'only' an immanent 'echo' of the transcendent aether's 'speaking' to itself. Aether as such, in its very own essence, can never be known outside the realm of speculative meta-physics – remember the Kantian 'thing as such' (*Ding an sich*) for comparison.

The historical fact that the aether doctrine has by-and-large vanished out of Hegel's systematic publications after his departure from Jena might possibly be explained by any of the following two hypotheses (or both of them together):

- *Internal motivation* – due to the semantic shifts of (and in) the notion of 'aether' itself, while Hegel was thinking and re-thinking about it in Jena, and its (eventually) very strong association with the notions of time and space, 'aether' became inherently obsolete in the 'architecture' of Hegel's philosophy of nature, which could henceforth be based immediately on the notions of space and time alone.
- *External motivation* – due to his familiarity with the 'state of the art' of the natural sciences of the early 19th century, in which no empirical evidence in favour of an immanent existence of an aether substance had been found so far, Hegel might have felt doubts (in spite of his 'official creed' of anti-empiricist idealism) concerning the 'gap' between the empirical sciences and his metaphysics of nature, which was always intended to serve also as a *clarifying* philosophy of science for those sciences. If the 'dumb' sciences of Hegel's own era were to 'come to their senses', such as to critically reflect their own basic notions and concepts about which they had not been consciously aware so far –see again the motto cited at the beginning of this essay– then it would not have made much sense if Hegel would have urged those scientists to

'reflect upon' their sciences in meta-theoretical terms that could not anyhow be 'linked' semantically to those scientists' own experiences and theories.

Whether or not Hegel still continued to believe silently and privately in his unpublished Aristotelian 'creed' (as suggested by Wahsner and Magee), and simply did not dare to 'confess' such a 'creed' publicly [11] in his post-Jena-publications (such as to protect his academic reputation and 'job-security' in an increasingly anti-metaphysicist and anti-speculative academic atmosphere [38] [39]) is a question which had to remain outside the scope of this essay.

5. CONCLUDING REMARKS FROM A PERSPECTIVE OF MODERN PHYSICS

As Moog already remarked in [28], Hegel had often been ridiculed for his speculative texts which did not seem to make any sense to later readers any more. Not only did Hegel often use his key words with a deliberately metaphorical semantics which differed considerably from the usual meaning of those words in 'ordinary language' [28]; also our notion of what is 'science' has changed profoundly since the beginning of the after-Hegeler era of high modernity [38] [39]. Prima facie our situation thus looks like this: Hegel, in his philosophy of nature during his stay in Jena 1802-1807, had written some speculative comments about a 'science' that is not our science any more, and he did it in an almost 'private' esoteric-hermetic language that is not our language any more. As mentioned above: where Hegel said 'light' he did not necessarily speak about a visible electromagnetic phenomenon. 'Light' in Hegel's manuscripts can also refer metaphorically to mental or spiritual capacities of awareness or recognition (*Erkenntnis*), related to the traditional notions of 'enlightenment', 'lumen naturale', and the like [10](p. 53). Thus, towards the end of our essay, the question arises: *Can Hegel's neo-Aristotelian and idealistic 'aether' speculations still be anyhow 'valuable' for philosophical reflections regarding some of the most fundamental concepts in contemporary physics, such as the vacuum state of the quantum field theories?* A brief claim of relevance in favour of Hegel's philosophy of nature with regard to contemporary physics was briefly made by Gies in the concluding section of [9], however without many technical details and without any particular reference to Hegel's 'aether' speculations.

Before we can attempt any answer to that question we need to recall briefly some of the most important 'features' of modern physics –especially quantum physics– in the following sub-section of this section. Thereafter, finally, a more 'philosophical' conclusion can be provided.

5.1. CHARACTERISTIC FEATURES OF MODERN PHYSICS

It is an important aspect of modern physics, not just of quantum physics, that *the observer determines part of what can be observed*. This realisation began with Einstein's theory of special

relativity which gave up the Newtonian concept of absolute space and time. Two observers, for example, do not generally perceive the same time differences between events; the time differences they measure depend on their relative state of motion.

In the *Copenhagen interpretation* of quantum mechanics, which was developed mainly by Bohr, Born and Heisenberg, and which was sharpened by the intense and legendary discussions between Bohr and Einstein, *quantum mechanics does not allow any statements on physical entities as such*. Rather, it is confined to statements on *possible results of future measurements* on physical systems, on their *probabilities* and on the *evolution* of these probabilities in time. Quantum physics is thus a theoretical framework for predicting future observations of the physical world rather than describing the physical world itself. For example, quantum mechanics gives up the notion of the 'track' of an electron in space. Rather, it allows to predict the probability for an electron to be found at a certain position, or with a certain momentum. States of physical objects are mathematically characterised by certain mathematical objects, the so-called *state vectors*. Quantities observable on physical objects, for example their energy, are represented by *operators* transforming state vectors into new state vectors, thereby allowing for example to calculate the probability for any of the possible energy values to result from an energy measurement.

In *quantum field theory*, this idea is applied to *fields*. To give a simple example, let us have a look at how quantum electrodynamics describes the interaction between light and an electron. Light, in the broad sense of electro-magnetic radiation, is represented by the electro-magnetic field in the theory while the electron is represented by a so-called Fermion field. The dynamics of these fields, and their interaction, are encoded by the so-called 'action' of the theory. In other words: quantum field theories take the level of abstraction one level further. It had been realised by Faraday and Maxwell in the 19th century that certain physical phenomena are best described as fields, that is, as functions assigning a value of a physical quantity to every point in space and time. The electric field thus assigns an electric field strength to each point in space and time which, when multiplied by the charge of a test body, returns the electric force acting on that body. Electric and magnetic fields occur together, can partly be transformed into each other, and together form the electro-magnetic field. These electro-magnetic fields reveal their own dynamics as described by Maxwell's equations. All known physical interactions are nowadays formulated as field theories. Quantum field theories treat fields in the same way as quantum mechanics treats particles: also these theories do *no longer attempt to describe a reality in itself*, but rather a probability of measurements. The electro-magnetic field, in our example, is decomposed into operators which, when applied to a suitable state vector, return the probability for a certain field value to be measured. Since fields themselves depend on space and time, these field operators must depend on space and time as well. In other words: In its modern formulation, quantum field theory studies all conceivable

configurations of the fields under consideration, in our exemplary case of the electromagnetic and the electron fields. The probability of these configurations is, again, determined by the above-mentioned 'action' of the theory. Those configurations are by far the most probable for which the action is extremal, either maximal or minimal. Measurements on certain field configurations are described by transitions of the field states between a well-defined initial and a final state.

As mentioned above, each of the field operators allows to determine the probability for a certain property of the field to be measured at the given position at the given time. These operators appear in pairs, composed of the so-called *creation and annihilation operators*. The creation operator acts on the vacuum state of the quantum field theory and turns it into an excited state, characterised by the presence of a so-called field quantum. In quantum electrodynamics, for example, the field quanta are the photons, the particles of light. The creation operator of quantum electrodynamics thus allows calculating the probability for a photon with a certain energy and momentum to be detected at a specified point in space and time. Likewise, the annihilation operator acts on an excited state and lowers the number of field quanta by one. If the excited state contains only one field quantum, the annihilation operator turns it into the vacuum state. In this way, the vacuum state of a quantum field theory is the state from which the variety of phenomena described by the theory can be generated by means of creation operators, and to which the theory returns when all excitations are removed by annihilation operators.

In a similar manner, the initial and the final states of a quantum-physical process could be given by an electron (instead of the above-mentioned photon) entering the section of space and time where the experiment is being carried out with a certain momentum, and by an electron leaving this section with another momentum. The interaction between the electro-magnetic and the electron fields would then have to mediate this scattering event. The incoming and the outgoing electron are *not considered as being present in an absolute sense*, but as appearing in a suitable measurement. Again, quantum field theory thus asks: what is the probability to measure in a certain volume of space during a certain time interval an incoming electron with a certain momentum? And what is the probability to repeat such a measurement with an outgoing electron in a nearby volume, at a slightly later time, with a different momentum? In the modern formalism of quantum field theory, these probabilities are quantified by applying previously mentioned creation operators to the vacuum state of the theory. Of course this term is not meant to insinuate that the application of the operator would in fact create an electron from the vacuum. Rather, it quantifies the probability for measuring the specified electron in otherwise empty space and time. Thus, *all physical entities present in a quantum field theory enter the stage by applying the relevant creation operators to the vacuum state*. Their interactions are then represented by applying certain interaction operators, the so-called vertex and loop terms,

to the combined fields. The result of these operations are probabilities for the measurements of the events described that way.

In summary, it cannot be emphasised enough that *modern physics does not attempt to describe reality in itself*, but measurements or perceptions of reality in well-defined experiments. As mentioned above, quantum electrodynamics does not ask, and does not give an answer to a question like: is there a photon flying along a certain trajectory? Rather, it allows to answer questions like the previously mentioned probability questions, whereby the answer is given by applying suitable field operators to the vacuum state of the theory. Moreover: those quantum field theories, which are technically all *gauge theories* with spontaneously broken symmetries, are extraordinarily *successful* as the *standard model* of particle physics has demonstrated. Only a few 'puzzles' (in Kuhn's terminology) are unsolved to date within this standard model, of which the finite neutrino masses and their mass hierarchy is perhaps the most substantial one.

However this standard model of quantum physics is driven to its limits especially by contemporary *cosmology*. If cosmological measurements are interpreted in the framework of Einstein's general relativity theory, then the conclusions are inevitable that by far the largest proportion of *matter* in the universe must be *dark*, and that the dominant form of *energy* is not contributed by matter. The standard model of particle physics, however, cannot accommodate dark matter even if evidence substantiates that the super-symmetric sector is moved to ever more adventurous energy scales by the Large Hadron Collider (LHC) experiments. From this perspective, the dark matter confronts us with another face of the difficulty which the standard model of particle physics has with *gravity*:

- *either* we have to accept dark matter for real,
- *or* we need to modify the law of gravity.

The unanswered question about the nature of dark energy comes in addition.

In this context a *conceptual 'crisis'* could be seen in the dilemma that the best available theory of space-time, the general relativity theory, refuses –in a hitherto unsolvable manner– to be combined with the quantum field theories, which are constructed to describe the complete matter and energy content of the space-time, and do so excellently as far as the *known* forms of matter and energy are concerned. In this context the notion of '*vacuum*' reappears: it is the richly structured *ground state* of all quantum field theories, to which a finite energy density needs to be assigned. Whereas everywhere else in physics only energy *differences* are important (rather than absolute energies), the *absolute* energy density enters into general relativity. The vacuum of the quantum field theories should therefore act as a source of gravity. If this property is granted to the vacuum, however, then it turns out that the structure of space-time would change in a way completely incompatible with all empirical evidence from observations so far.

In other words: this *incompatibility* of the vacuum of the quantum field theories with the structure of space-time could thus perhaps be seen as the most profound 'crisis' of modern physics to date. This theoretical dilemma is not merely a technical matter of ever more sophisticated experiments and apparatus-supported observations; it is also, and very much so –like in Hegel's historic era more than two hundred years ago– an issue of the science-philosophical *adequacy of the concepts and notions* 'behind' those empirical observations and facts.

5.2. SYNTHESIS

In the language of the quantum field theories, as explained above, the observables of the theories are represented by operators which, when acting on the vacuum state of the respective theory, return probabilities for these observables to be measured with certain values. In this abstract sense, a resemblance can be constructed between the vacuum state of a quantum field theory and Hegel's *aether*, even though all spiritual connotations of Hegel's concept must (of course) remain absent from quantum field theory.

Looking at both Hegel's thoughts and at the metaphysical presuppositions behind the Copenhagen interpretation of quantum physics, the 'philosophical eye' of a speculative mind will 'see' –in spite of all other differences– particularly one common trait in both of them: a common trait which can only be circumscribed paradoxically as a '*reality of possibility*'. According to the theoretical insights of nowadays quantum physics, the (virtual) *vacuum state* of a quantum field is, in a well-defined mathematical sense, the *prototype of all observable manifestations* of such a field. Hegel's aether, too, is not so much 'real' per-se; rather it is the initially unlimited and undetermined *potential of becoming* anything and everything else. In a similar manner, an electron or a field in Copenhagen-style quantum physics 'is' not anything as such or per-se; rather it is a potentiality for the generation of such-and-such observable effects and measurements in the future.

Hegel would readily admit that his concept of a primordial aether is nothing which we could ever experience empirically: Everything which we are able to experience empirically has 'always already' (*immer schon* – a term from philosophical hermeneutics) 'fallen out' of the primordial aether which is accessible only to the 'inner eye' of the speculative philosopher. In a similar manner the School of Copenhagen does not accept (rightly or wrongly) the idea of any 'existence' per-se beyond the very act of a measurement. For example: the phenomenon that we might want to call 'electron' has, according to the School of Copenhagen, 'always already' fallen out of its metaphysical state of a Kantian 'thing as such' (*Ding an sich*), which is only intelligible to the mind of the speculative philosopher.

Finally at this point we can also see a peculiar commonality between Hegel, the School of Copenhagen, and *Kant*, against whom Hegel had originally designed his own

speculative system of philosophy: also Kant would have readily admitted that to a 'thing as such', conceived as a 'generator' or *causa ultima* of all phenomena empirically observable *for us*, we cannot attribute any 'reality' except as an inevitable 'thought-necessity' (*Denknotwendigkeit*) in the epistemological categories of the philosophising mind. Where Thomas of Aquinas had spoken of some '*transition from possibility to reality*' in his *Summa Theologiae*, he had already touched upon a deep and paradoxical onto-philosophical problem, namely: *does mere possibility already 'possess' some kind of its own 'existence'?* This is indeed the root-problem beneath Hegel's concept of creation out of aether, as well as beneath the School of Copenhagen's ideas concerning the production of objective measurements out of 'something' the essence of which remains ultimately concealed.

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