Aura Heydenreich

Epistemic Narrativity in Albert Einstein's Treatise on Special Relativity

A Narratological Approach to “The Electrodynamics of Moving Bodies”. The Process of Interformation (Part I)

Abstract: The following two chapters offer an analysis of the scientific modeling process of Albert Einstein's treatise on special relativity “Zur Elektrodynamik bewegter Körper” from 1905 [“On the Electrodynamics of Moving Bodies” (1989)]. The first chapter reconstructs both Einstein's scientific modeling process and its narrative strategies for the development of the special theory of relativity. Besides considering the argumentative and descriptive discourse levels of Einstein's treatise, my paper analyzes the employed narrative strategies and their epistemic functions. Hereby main issues of a proposed narratology of science are discussed. How can concepts be transferred from classical narratology to science narratology in order to explore the epistemic functions of narrativity in scientific treatises? What is the epistemic function of the factual ‘we-narrator’ as a principle of form-organization in a scientific treatise? Can one elaborate on techniques of internal and external focalization not only in literary texts, but also in Einstein's thought experiments? How can one (re-)define concepts of post-classical narratology like eventfulness, experientiality and tellability when addressing scientific discourses? The first chapter shows how the techniques of internal and external focalization are employed by Einstein in thought experiments for the reconceptualization of time and space and for the demonstration of the relativity of simultaneity. The second chapter analyzes the same treatise from a systematical perspective and takes Einstein's metatheoretical reflections in “Physics and Reality” into consideration in order to describe the process of interformation, its semiologic foundations and the resulting epistemic transformations.

Einstein's treatise “On the Electrodynamics of Moving Bodies” is considered one of the most important contributions to twentieth-century physics, and as the founding document of special relativity theory. The statements of special relativity theory were fundamental, because they reconceptualized basic categories of space, time, mass and energy in physics. On the basis of Einsteinian principles, in 1908 Minkowski succeeded in showing how space and time could

be mathematically unified in a four-dimensional space-time continuum (Min-kowski 2012 and 1909; cf. also 1908).¹

In order to be able to examine the processes of modeling² in literature and science, it is necessary to define a space of signs and symbols in which both operate. Only when this commonality can be assumed one can examine in a next step the way in which the processes of semiosis differ in literature and natural science and whether there are nevertheless possibilities of intersecting their spheres of modeling practice.

Models are understood here according to Gelfert (2016; cf. 2017) as functional entities that can be configured symbolically, semiotically, mathematically, diagrammatically or aesthetically. With Morgan and Morrison (1999a, 1999b), they exhibit an explorative dimension in theory development and thus function as mediators between denotation and representation up to experimental simulation and the exemplification of new symbolic correlations. With Knuuttila (2005), models can also be understood as “epistemic tools,” as epistemic artefacts. They make it possible to configure the knowledge relevant to understanding of a certain area formally, medially, symbolically or materially in order to re-correlate it and reinterpret it accordingly. From the perspective of philosophy of science the correlations between models and fictions have been explored by Roman Frigg (2009, 2010) and Mauricio Suárez (2009, 2010).

From Lotman’s (1977) perspective, the arts and sciences operate as secondary modeling systems in the space of the semiosphere. Since Lotman (1973) also mentions the term “scientific languages” (cf. Schönle 2006) in addition to the term “natural languages” in his cultural semiotic theory, I propose to start from the following assumptions: According to Lotman, literature uses the primary modeling system of language as a communication system and secondary modeling processes for its aesthetic modeling design. Physics, on the other hand, I would add, uses language as a communication system, measurement for scale comparison using numbers, and technical experimental methods: This is its system of primary modeling. As a secondary modeling system, physics draws on mathematical operations and codes, which it uses for theoretical modeling. It also seems consequent to investigate the cultural semiotic space

¹ I am grateful to Michael Sinding for the translation of this paper. Also I am grateful to thank Klaus Mecke for the exchange of ideas on the process of interformation in physics and literature, to Christine Lubkoll, Alexander Laska, Lothar Ley, Benjamin Specht, Clemens Heydenreich, and Miriam Rückelt for having read and discussed this paper with me thoroughly.

² The poetics of modeling is also topical in contemporary literary studies: Cf. Erdbeer 2015; Balke et al. 2014; Wendler 2013; Matuschek and Kerschbaumer 2015; Erdbeer et al. 2018a, 2018b.

in which secondary modeling systems operate: the semiosphere proposed by Lotman (2005). Etymologically, the concept of the semiosphere can be derived from the Greek words 'σημείον,' 'sêmeion' = 'sign' and 'σφαῖρα,' 'globe,' 'sphere' = 'space.'

The unit of semiosis, the smallest functioning mechanism, is not the separate language but the whole semiotic space of [...] culture [...]. This is the space we term *semiosphere*. The semiosphere is the result and the condition for the development of culture; we justify our term by analogy with the biosphere, as Vernadsky defined it, namely the totality and the organic whole of living matter and also the condition for continuation of life.

(Lotman 2000, 124–125)

In the following, the semiosphere shall be defined as a field continuum of signs, sign functions and sign correlations, which comprises: The entirety of all linguistic signs, mathematical, graphic and diagrammatic symbols; the totality of the sign relations and sign functions existing between them; the entirety of the codes that regulate the meaning of signs; finally, all agents as sign users who use sign functions and sign relations in processes of modeling and communication, representation and signification. A field of the semiosphere is a semio-logical manifold that allows correlations. I propose to define physics and literature as different fields of the semiosphere that differ from one another due to their own logic of using signs. That's why in *Physica Poetica* (Heydenreich 2022) I proposed to analyse them as different semio-logical fields. The hyphenated notation of the term "semio-logic" marks that the two fields, physics and literature imply *different logics of using signs*, that means that they use different syntactic, semantic and pragmatic codes and practices for their processes of semiosis. Theoretical physics as well as literature are considered semio-logical manifolds of the semiosphere. I examined the semio-logical practices of both fields at length in my monography *Physica Poetica* (Heydenreich 2022) which is to appear in this series of publications. The aim there was to define the sign-, symbol- and culture-theoretical properties of these semio-logical fields that allow both the analyses of the phases in which the modeling practices of the two fields differ fundamentally from one another *globally*, and the description of those special areas and phases in which the modeling practices of both fields can be intersected *locally*.

An important thesis for this is that although the two fields of literature and physics can be conceptualized on a theoretical level on the basis of their functional difference, certain semio-logic practices (in certain historical contexts, under certain conditions, in concrete individual texts) can be linked locally. This induces crossing a borderline and opening up a field continuum for enabling intersection. The dialectics between system and process dynamics can be observed in the magnifying glass of the dialectic between mathematical

codes and narratives (cf. Koschorke 2004). When it comes to the sedimentation and consolidation of the systems, both fields in metasemiotic communication rely on the consolidation of their own rule systems and practices. This is achieved through the metasemiotic communication at the center of the field that propagates the clear demarcation from the other semiotic environment. But it is precisely the boundary that serves to functionally stabilize the identity of the system that registers the essential differences between the two semio-logical fields, and unfolds a countervailing metasemiotic dynamic. It takes note of the rule systems of both semio-logical fields, compares them and plays them off against each other. As Albrecht Koschorke (2018, 86–100) indicated, the boundary thus proves to be a subversive mechanism against the metasemiotic communicative practices of the center of the system. This also includes the implementation of new modeling techniques that have not been practiced before.

I assume that the semiosphere is the space of signs that allows both. On the one hand it allows the specialization of the fields according to their own rules, which are centrally reflected metasemiotically and systematically codified. On the other hand it also allows the selective entanglement of the fields at their borders, where exactly the opposite metasemiological debates are being held – about the possibilities and consequences of crossing borders and entangling them with a different semio-logical field. I suppose that both fields interact with one another in order to test alternative practices of using signs and in order to undermine and interrogate the habitualized frames and epistemic practices. Then it can be shown that by recurring to the epistemic and semio-logic practices of the other field, frames in the own field can be reorganized: namely by new semantic and/or formal correlations and transformation relations. I am going to show that Einstein uses narrative techniques in his relativity paper as complementary techniques to the theoretical modeling in order to de-habitualize former epistemic practices and in order to establish new ones.

In this study I propose the concept of interformation for the processual modeling correlation between spheres of discursive practice that use different codes: physics and literature. The concept of interformation is to be understood in distinction to that of information. In the case of information, many communication models assume that sender and receiver use the same code, so that the transmission of a message can function without problems. In the case of interformation, however, the transmission of the message does not function according to this well-known model – because the two semio-logical fields use signs differently. Not all syntactic, semantic and pragmatic codes can be considered as given. Some of them emerge during the modeling process, during the intersection between the two fields. That's why interformation is a process of reframing and reconceptualization based on transfers that lead to

interchanges between the two fields and their modeling and epistemic practices.³ Interformation provides the necessary procedures to perform the intersection process between the two different spheres of discursive practice. As we can see in the case of Einstein's theory of relativity, the concept of interformation also functions in crossing the borders between two theoretical paradigms. The analysis of Einstein's texts will allow me to describe this intersection in depth. A question posed is how far features of narrativity can be attributed to Albert Einstein's modeling process of special relativity theory, and especially, which framing and embedding-techniques, which focalizing- and perspectivization-techniques it uses in order to develop the special relativity theory. The thesis here is that Einstein uses descriptive, explicative and narrative techniques as textual strategies and integrates them in order to develop the special theory of relativity. Finally, it remains to be shown how narrative framing techniques are combined with modeling strategies of theoretical physics.

My reading neither provides the logical reconstruction of special relativity theory from the perspectives of either philosophy of science or history of science, nor can it address the mathematical foundations of theoretical modeling, even if it considers certain aspects of these. Here I can only refer to the comprehensive literature on these topics, as well as the works by which my reading is supported. From the field of physics, these are the reconstruction of Max Born in *Einstein's Theory of Relativity* (1965) [*Die Relativitätstheorie Einsteins* (2001)] as well as the textbooks of theoretical physics on special relativity theory by Ulrich Schröder and Claus Lämmerzahl, *Special Relativity* (1990) [*Spezielle Relativitätstheorie* (2014)], and Wolfgang Nolting's *Theoretical Physics* (2017) [*Grundkurs Theoretische Physik* (2016)]. Also helpful is the approach to the presentation of relativity theory from Nicholas Woodhouse (2003, 2016) and Franz Embacher (2010), which stands in the tradition of John Wheeler's (Misner et al. 1973) and Hermann Bondi's (1964) accounts.

From the cultural-philosophical point of view, I base my reading on Ernst Cassirer's epistemological observations in *Einstein's Theory of Relativity* (2003) [*Zur Einsteinschen Relativitätstheorie* (2001)] (cf. Ryckman 2005, 1999). From the point of view of the history of science my work relies on Miller's (1981) comprehensive account, *Albert Einstein's Special Theory of Relativity: Emergence (1905) and Early Interpretation (1905–1911)*, which historically contextualizes the scientific genesis of the special theory of relativity, presents the preliminary work

³ For a detailed theoretical presentation of the concept of interformation and the processes of mutual transfer between the semio-logical fields of physics and literature with historical case studies on scientific and literary texts by Johannes Kepler, Durs Grünbein, Raoul Schrott, Richard Powers, Thomas Lehr, Dietmar Dath, Carl Sagan and Kip Thorne cf. Heydenreich 2022.

of Hendrik Lorentz (1892, 1895, 1904a, 1904b) and Henri Poincaré (1900a, 1900b, 1901, 1902) as well as Walter Kaufmann's (1901, 1902) experiments, and reconstructs the early interpretations of the theory. In addition, I consulted the science-historical studies of Peter Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time* (2003a; cf. also 2003b) and Klaus Hentschel's *Interpretations and Misinterpretations of Special and General Relativity Theory by Einstein's Contemporaries* [*Interpretationen und Fehlinterpretationen der speziellen und der allgemeinen Relativitätstheorie durch Zeitgenossen Albert Einsteins*] (1990), which reconstructs the reception of the theory through Neo-Kantianism, Critical Realism, the Husserl school of Phenomenology as well as Logical Empiricism.

Bas van Fraassen's essay "Literate Experience: The [De-, Re-] Construction of Nature" was published in an issue of the journal "Versus" (Dusi and Nergaard 2000) devoted to intersemiotic translation: "I am an avid Eco's reader, and never more avid than on the subject of interpretation. [...] My main guiding question will be: does the theory and practice of text interpretation give us, yes or no, a clue, a telling, parallel, or fruitful analogy for the scientific study of nature today?" (Van Fraassen 2000, 331) Building on Eco, he even introduced the concept of "*literate experience*" (Van Fraassen 2000, 331) and asked the question whether literary theory can be made fruitful for the study of scientific texts. In terms of my analysis this also implies to concentrate on the modeling and narrative strategies that can be analyzed in original publications in natural science.⁴ Granted, this is an unusual approach. In the professional culture of physics, it is not at all common to read and analyze original historical works. Arthur Miller remarked on this:

While the works of literary authors are commonly considered to be an integral part of our cultural milieu, this distinction is generally not granted to scientific authors. It is difficult, for example, to imagine a teacher of English who has never read one of Shakespeare's plays. But few people today, including physics researchers, teachers of physical science or philosophers of science have carefully read Einstein's relativity paper of 1905, although it is brief, requires little mathematics, but had immense effects on intellectual and societal pursuits in the twentieth century. While many different in-depth analyses of the works of high literature are available to humanistic scholars, physicists have virtually no access to analyses that guide the reader.⁵ (Miller 1981, 5)

⁴ On this distinction between system-oriented and process-oriented approaches, cf. Van Fraassen's chapter "Measurement as Representation: Relating the views 'from above' and 'from within'" (Van Fraassen 2013, 184–190).

⁵ This quotation is only intended to prove that this practice of *close reading* of primary texts is unusual in physics. It does not suggest that the existing gaps will be closed through the present work. This is what Miller has done. The literary-critical approach proposes this practice of close readings of original texts, because it concerns the concrete process of modeling and specific narrative practices.

For literary scholarship, Christina Brandt formulated in the De Gruyter Handbook *Narrative [Erzählen]* the following research desideratum:

A deeper narratological analysis of forms of narration in the scientific field remains yet a desideratum. This applies to fundamental analyses of the forms and functions of factual narration in natural-scientific discourse as well as to more specialized sub-fields. Thus for example the historical development of scientific forms of narration in cultural-historical context is a scarcely studied area.⁶ (Brandt 2017, 217)

Let's start with the analysis of the argumentation of Einstein's treatise on special relativity theory.

1 The contradiction between mechanics and electrodynamics in “On the Electrodynamics of Moving Bodies”

In the 1905 treatise, which announced the birth of special relativity theory, Einstein compares the rule-guided practices of two distinct, theoretically and experimentally established fields of physics – mechanics and electrodynamics – and identifies possible contradictions between them. Defining principles of these fundamental theories of physics are shown to be incompatible with one another. Einstein claimed that even though there were extensive commonalities between the two fundamental physical theories – mechanics and electrodynamics – there were also great contradictions. For example, the Galilean relativity principle did not apply to Faraday's law of induction.

The first half of Einstein's treatise, the first five sections, are devoted to mechanics, and the second half, with the last five sections, to electrodynamics.

Yet electrodynamics developed from the background of mechanics: Coulomb and Ampère, for example, used the principles and equations of the Newtonian theory of action-at-a-distance when they set out the first theoretical models for describing electricity and the relationships between electricity and magnetism. James Clerk Maxwell, who achieved the complete modeling of electrodynamics

⁶ Transl. by MS. “Eine tiefergehende narratologische Analyse von Erzählweisen im naturwissenschaftlichen Feld bleibt jedoch weiterhin ein Desiderat. Dies betrifft sowohl grundlegende Analysen von Formen und Funktionen des faktualen Erzählens im naturwissenschaftlichen Diskurs als auch speziellere Teilgebiete. So ist beispielsweise die historische Entwicklung von naturwissenschaftlichen Erzählweisen im kulturhistorischen Kontext ein noch kaum erforschtes Feld” (Brandt 2017, 217).

as field-theory, was also still concerned, in both of the early treatises that later led to the derivation of his famous field equations (“On Faraday’s Lines of Force,” 1856, and “On Physical Lines of Force,” 1861a, 1861b, 1862a, 1862b) with models that stood in the dynamic tradition of mechanics.⁷ He later emancipated himself from this and formulated electrodynamics as field theory: “A Dynamical Theory of the Electromagnetic Field” (Maxwell 1865, 1881)

Einstein proposed a cross-over of principles: if the speed of light in vacuum had a definitive value in electrodynamics, this and its consequences should also be accepted for the measuring and modeling practices of mechanics, i.e., also apply to moving and stationary bodies in mechanics. If movement and rest were considered relative in mechanics, this relativity principle should also apply to the laws of electrodynamics. In the following I will quote the English version of Einstein’s “Electrodynamics of Moving Bodies” in the current text and the German version in the footnotes:

The considerations that follow are based on the principle of relativity and the principle of the constancy of the velocity of light, two principles that we define as follows:

1. The laws governing the changes of the state of any physical system do not depend on which one of two coordinate systems in uniform translational motion relative to each other these changes of the state are referred to.
2. Each ray of light moves in the coordinate system “at rest” with the definite velocity V independent of whether this ray of light is emitted by a body at rest or a body in motion.⁸ (Einstein 1989 [1905], 143)

Einstein already states at the beginning of his treatise that these postulates are seemingly contradictory, but that the modeling process will show why the intersection of two principles is a necessity for the development of the theory:

We shall raise this conjecture (whose content will be called the “principle of relativity” hereafter) to the status of a postulate, and shall introduce, in addition, the postulate, only

⁷ For the methodology and systematics of these modelings, cf. the presentation by Siegel 1991.

⁸ “Die folgenden Überlegungen stützen sich auf das Relativitätsprinzip und auf das Prinzip der Konstanz der Lichtgeschwindigkeit, welche beiden Prinzipien wir folgendermaßen definieren. 1. Die Gesetze, nach denen sich die Zustände der physikalischen Systeme ändern, sind unabhängig davon, auf welches von zwei relativ zueinander in gleichförmiger Translationsbewegung befindlichen Koordinatensystemen diese Zustandsänderungen bezogen werden. 2. Jeder Lichtstrahl bewegt sich im ‘ruhenden’ Koordinatensystem mit der bestimmten Geschwindigkeit V , unabhängig davon, ob dieser Lichtstrahl von einem ruhenden oder bewegten Körper emittiert ist” (Einstein 1905, 895).

seemingly incompatible with the former one, that in empty space light is always propagated with a definite velocity V , which is independent of the state of motion of the emitting body. These two postulates suffice for arriving at a simple and consistent electrodynamics of moving bodies on the basis of Maxwell's theory of bodies at rest.⁹

(Einstein 1989 [1905], 140–141)

I consider the intersection of these two postulates – the relativity principle and the constant velocity of light – which stem from two different theoretical frames, mechanics and electrodynamics – as the first step in the process of interformation. The interformation process is based on the abduction, i. e. the inference, that the intersection of principles and modeling practices will ground a new theory that solves the initial anomaly through a new transformation relation: the Lorentz transformation. I will show in this and the next paper that the process of interformation is mediated by narrative strategies and that its final result is epistemic transformation.

In the following I will examine the narrative functions, representational forms and framing strategies in Einstein's "On the Electrodynamics of Moving Bodies." It has been repeatedly pointed out that the thought experiments (Elgin 2007; Frappier et al. 2013) that are carried out in Einstein's treatise for the reader's imagination have a narrative structure. Bruno Latour (1988) has presented a reading of Einstein's popular-scientific writing on the theory of relativity from the perspective of Science and Technology Studies, which draws on the Greimassian concepts of "shifting in" and "shifting out." Against a sociological background of argumentation, Latour focuses on the practices used by the narrator to gain power. I will focus on Einstein's main scientific treatise on special relativity theory and my argument is not sociological oriented. It relies on cultural-semiotics and narratology and moves in another direction. My analysis aims to illuminate the epistemic function of narration in the process of interformation. From what points of view could one claim that Einstein's paper uses narrative techniques? What function do these narrative techniques have in the epistemic process of interformation?

To clarify this, I first have to problematize the concept of narrativity, in order to discuss, against the background of current research approaches, under

9 "Wir wollen diese Vermutung (deren Inhalt im folgenden 'Prinzip der Relativität' genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche Voraussetzung einführen, daß sich das Licht im leeren Raume stets mit einer bestimmten, vom Bewegungszustande des emittierenden Körpers unabhängigen Geschwindigkeit V fortpflanzt. Diese beiden Voraussetzungen genügen, um zu einer einfachen und widerspruchsfreien Elektrodynamik bewegter Körper zu gelangen unter Zugrundelegung der Maxwellschen Theorie für ruhende Körper" (Einstein 1905, 891–892).

what conditions narrativity can be attributed to a scientific text such as Einstein's treatise "On the Electrodynamics of Moving Bodies." The concept of narrativity has been travelling since the *narrative turn*, from literary studies to historiography (White 1973, 1978, 1999; Fulda 1996, 2005; Jaeger 2000, 2009), psychology, cognitive science, political science, sociology, anthropology, and medicine (Charon 2006; Brown et al. 2010). This inflationary broadening of the term "narrative" has evoked many skeptical reactions. I cite Gerald Prince as one representative voice:

One says 'narrative' instead of 'explanation' or 'argumentation' (because it is more tentative); one prefers 'narrative' to 'theory,' 'hypothesis,' or 'evidence' (because it is less scientific); one speaks of a 'narrative' rather than 'ideology' (because it is less judgmental); one substitutes 'narrative' for 'message' (because it is more indeterminate).

(Prince 1999, 45)

Peter Brooks attempts, on the other hand, to relativize such skeptical positions somewhat and to develop arguments for why the intense broadening of the concept is understandable:

While I think the term has been trivialized through overuse, I believe the overuse responds to a recognition that narrative is one of the principal ways we organize our experience of the world – a part of our cognitive tool kit that was long neglected by psychologists and philosophers.

(Peter Brooks, quoted in Safire 2004, 36)

The controversy sketched here was taken as an opportunity by the narratological research to problematize the concept of "narrativity." For the classical narratology the core definition of "narrative" rests on two pillars: sequentiality and temporality (cf. Rudrum 2005, 199–200, 202). In Genette's terms: "one will define narrative without difficulty as the representation of an event or sequence of events" (Genette 1982, 127).

H. Porter Abbott points out that the concept of "narrativity" (Abbott) was hardly thematized in the context of classical structuralist narratology. Abbott's conclusion is echoed by Wolf Schmid in his *Narratology* (2010) [*Elemente der Narratologie* (2014)]. Classical narratology concentrated on a minimal condition of a definition of "narrative," namely that "at least *one* change of state must be represented" (Schmid 2010, 2).¹⁰ Forster (1974, 93) had coined the classic example: "The king died and then the queen died." Genette undercut Forster's example and deleted the second sentence. The remaining sentence, "The king died," should suffice for a minimal definition of narrative (Genette 1988, 20; cf. also

¹⁰ "dass mindestens *eine* Veränderung *eines* Zustands in einem gegebenen zeitlichen Moment dargestellt wird" (Schmid 2014, 3).

1994, 203). Marie-Laure Ryan (2007, 24) emphasized that while both criteria are indeed necessary for a minimal definition of narrative, they are not yet sufficient to define the category of narrativity; and moreover, the outlined definition should allow one to distinguish between a scientific and a metaphorical use of the term.

In this context, Gerald Prince (2008, 19–20) points to the need to differentiate between two distinct questions. The first is, “What is a narrative?,” and aims at an extensional definition. The *explanandum* is here conceived as a noun, refers to entities and indicates a class of objects that can be defined as “narratives.” The second question that can be posed is, “What is narrative?” and refers to an adjectival use of the word. It concerns a quality, features of narrativity, and not an entity that is to be defined. This question aims at a gradual definition of narrativity that presents a bundle of relevant features that may be ascribed to a text to a certain degree, without thereby denying that the text can also manifest other features. Thus Jean-Michel Adam (1999) in *Le récit*, for example, identifies a narrative level of signification alongside to other textual levels, the descriptive and the explicative, which can co-exist in the same text. Seymour Chatman also argues in the same vein, distinguishing three types of textual types, which can co-exist in the same text in different dominance-relations: argumentative, descriptive and narrative: “The text-types routinely operate *at each other's service*” (Chatman 1990, 10–11). In this paper I'll refer at the term in its adjectival use.

Marie-Laure Ryan also emphasizes that for contemporary narratology, the definition of structuralist narrative research, which limited its decisive criterion to mere sequentiality, is not sufficient. In the *Cambridge Companion to Narrative*, Ryan proposes a pluricriterial definition of narrativity that unifies various dimensions: the spatial, temporal, mental, formal and pragmatic dimensions.

Rather than regarding narrativity as a strictly binary feature, that is, as a property that a given text either has or doesn't have, the definition proposed below presents narrative texts as a fuzzy set allowing variable degrees of membership [...]. In a scalar conception of narrative, definition becomes an open series of concentric circles which spell increasingly narrow conditions [...].
(Ryan 2007, 28)

The spatial dimension presupposes that a diegetic world is represented. The temporal dimension includes two criteria, which provide that the diegetic world is situated in a certain time, and undergoes a significant transformation caused by extraordinary events. The mental dimension assumes that the figures represented in the world are intelligent actants, while some of the events represented therein can be attributed to the actants as intentional acts. The fourth, formal and pragmatic dimension subsumes the criterion that the event-sequence

be represented as a holistic causal chain. At least some events should be attributable to the “storyworld” as facts. As a last pragmatic communication criterion, it is required that the story should have communicative relevance and a certain significance (Ryan 2007, 29). David Rudrum urges that the pragmatic dimension of narrativity should be somewhat more strongly emphasized. He proposes a definitional approach very strongly oriented to Wittgenstein’s *Philosophical Investigations*:

The question of use is therefore intimately bound up with the question of social practices and conventions. Generally, competent members of a linguistic community are able to recognise the use for which a narrative is intended and respond appropriately [...] Once again, the key factor in making these classifications is the use to which the text is put.

(Rudrum 2005, 199–200, 202)

2 Epistemic narrativity

The present work also takes the position that narrativity is not to be understood as an essentialist criterion, but rather conceptualized gradually and pragmatically. For the analysis of Einstein’s treatise I would like to plead for a functional approach to narrativity. I wish to show how scientific texts functionalize narrativity epistemically, and still argue theoretically. And that’s why I propose to speak about epistemic narrativity as one dimension of scientific texts.

Recent research in postclassical narratology, which has opened up phenomenological, cognitive, cultural-studies, context-oriented approaches, discusses the category of “narrativity” very intensively (Prince 1999, 2008; Ryan 1992, 2007). It also has perspectivized it transgenerically and transmedially (Ryan 2013, 2015; Nünning 2002; Wolf 2017). Why should narrativity not be explored from the perspective (Ryan 2011) of a narratology of science? What would a narratology of science look like, one that operates with the concepts of the space-time continuum, the world-lines of observers, the boundaries of their horizons of perception, and with the concept of interformation?

It is interesting to pose this question about a future project of an interformative narratology of science, because it may be observed that Einstein’s treatise proposes disruptive concepts that not only contradict everyday common sense, but also contravene many postulates of classical physical theory, which before Einstein were considered reliable knowledge. All the more does narrativity play a decisive role – which raises the question of what kind of *emplotment* is convincing and has mathematical and physical, cultural and pragmatic relevance, in order to give meaning to the new symbolic organization of the experience of reality.

According to Porter Abbott, Greimas is the sole great exception of structuralist narratology because unlike all other classical narratologists he problematizes not only narration but also the category of narrativity. Greimas gives a pioneering definition of narrativity as “*the organizing principle of all discourse*” [“*le principe organisateur de tout discours*”] (Greimas and Courtés 1979, 249; *Italics by AH*). Groundbreaking, says Abbott, is the crucial Greimasian criterion of narrativity as “disruptivity” (cf. Greimas 1987, 104):

It is also important to note that, for Greimas, narrativity is a disorganizing as well as an organizing force in that it disrupts old orders even as it generates new ones. It is ‘the irruption of the discontinuous’ into the settled discourse [...] ‘into discrete states between which it sets transformations.’ (Abbott, § 9)

This central criterion of narrativity as disorganizing and reorganizing force is decisive for the concept of epistemic narrativity which I propose through the present narratological reading of Einstein's treatise. The concept can be correlated with Goodman's and Elgin's concept of “creation as reconfiguration,” which will be discussed in my next chapter in this volume.¹¹

Monika Fludernik, Peter Hühn and Wolf Schmid also criticized the definitional approaches of classical narratology, which relied only on temporality and sequentiality as defining features of narrativity, and propose the following criteria. Monika Fludernik introduced the concept of “experientiality” in her “natural narratology” approach: “narrativity should be detached from its dependence on plot and be redefined as the representation of experientiality” (Fludernik 1996, 109). Programatically related to this is Fludernik's critical statement, that she has never been convinced by Forster's (1974, 14) minimal definition “The king died and then the queen died of grief” as an exemplary form of narrativity. For Fludernik (1996, 14), in the context of her “natural narratology” approach, narrativity is not an inherent property of texts, but rather appears as an effect of discourse. In the line of cognitively oriented narratology this is rather a matter of dynamic interaction between text and reader, as Fludernik states: “I concentrate on the structural properties of conversational storytelling [...] and on the dynamic interaction or dialectic between the *news value of the tale* and its impact on the experiencer's retrospective evaluation (reportability vs. narrative ‘point’)” (Fludernik 1996, 15; *italics by AH*).

Labov had also earlier drawn attention to the criterion of “reportability,” the “narrative point,” as Bruner remarks: “Labov's great credit is to have recognized

¹¹ Cf. Aura Heydenreich's paper “Albert Einstein's ‘Physics and Reality’ and ‘The Electrodynamics of Moving Bodies’” in this volume.

that narrative structures have two components: ‘what happened and why it is worth telling.’” (Bruner 1991, 12) Fludernik refers to these additional criteria of narrativity, which have found their way into postclassical narratology and are very intensively discussed:

For the narrator the experientiality of the story resides not merely in the events themselves but in their [...] exemplary nature. The events become tellable precisely because they have started to mean something to the narrator. It is this conjunction of experience reviewed, reorganized, and evaluated (‘point’) that constitutes narrativity.

(Fludernik 2003, 245; cf. 1996, 70)

Can we provide criteria for why the facts set out in this scientific article are tellable? Which is their narrative-point? In what respect the concepts of the special theory of relativity have changed the way in which we experience and organize reality?

The thought experiments are designed as narratives in order to propose new ways of measuring time and space, that have not been practiced before, and yet to make them experientable for the human frame of reference. The reader is the addressee of the immersive thought experiments that are included in Einstein’s text.¹² The reconceptualization of fundamental concepts is experimented: the relativity of simultaneity, time dilation, length contraction, the relativity of mass. New measurement narratives and their results are performatively presented to the reader by the actions of observer figures in thought experiments. These are thus experientable for them and should lead to revision and reorganization of their entire space-time conceptions. The immersive function of experientiality is necessary to cognitively mediate and thus epistemically plausibilize and legitimize the new concepts and the new world-model associated with them. This requires an *emplotment*, which constructs experientiality at least as a discourse effect.

In the following, Matías Martínez’s (2017) definition in the De Gruyter handbook on *Narrative [Erzählen]*, and the features he identifies, will be used in order to discuss how far the criteria that are mentioned in the narrative research for the term “narrativity” also apply to Einstein’s treatise. I choose Martínez’s definition because it pursues an integrative definitional approach, which takes into account the criteria of classical as well as postclassical narratology, includes the level of *discours* as well as that of *histoire*, and incorporates syntactic, semantic and pragmatic dimensions.

Martínez starts from classical narratology’s minimal definition of narrative as event-representation. Under “event-representation” he subsumes three necessary defining features of “narrative:” temporality, concreteness and contiguity.

¹² On the narratological category of immersion, cf. Ryan 2001, 2015.

Martínez (2017, 3) extends this minimal definition, however, into a formula with the variable x , and summarizes: “narrative = event-representation + x .” The component “ x ” stands as a placeholder for nine further criteria that are problematized in narrative research – with the aim of arriving at a comprehensive, transgeneric and transmedial definition of narrativity that is sufficiently differentiated to handle the levels of *discours* (criteria 1–2: doubled temporality, focalization), *histoire* (criteria 3–7: causality, intentionality, completeness, emplotment, experientiality) and the pragmatics of narration (criteria 8–9: tellability, conversational constraints such as detailing, relevance, condensation, point, etc.).¹³

In the following, I will explore the above stated criteria where appropriate, and also draw on further relevant positions in narrative research, in order to illuminate the category of epistemic narrativity in science. The first criterion is that of “temporality,” as the “event-representation is representation of a time-course. Every event is structured as such through a ‘before vs. after,’ through a sequence of chronologically ordered events: $e_1 \rightarrow e_2 \rightarrow e_3 \rightarrow \dots \rightarrow e_n$ ” (Martínez 2017, 2).¹⁴ Because hardly any literary text can do without a dimension of temporality, it is important to know by which narrative strategies Einstein's text redefines temporality. This aspect is also relevant from the meta-perspective of narratology, which identifies temporality as the fundamental criterion of narrativity. Einstein's treatise breaks with the old definitions of temporality in the old knowledge systems and shows that no chronology can be absolutely given. Temporality is always defined relative to a certain reference system. Einstein makes the proposal of a new symbolic order of organization of temporality, as I will show in section 3.2.

With the criterion of concreteness, Martínez's definition implies that “every narrative represents ‘mimetically,’ that is, represents singular and concrete objects and situations” (Martínez 2017, 2).¹⁵ This also holds true for the thought experiments that are represented in “On the Electrodynamics of Moving Bodies” as it will be shown in this paper.

13 Cf. Martínez 2017, 3–6 (“Sie beziehen sich auf Aspekte der Darstellung (*discours*, Kriterien 1–2), des Geschehens (*histoire*, Kriterien 3–7) und der Pragmatik (Kriterien 8–9) des Erzählens. (1) *Doppelte Zeitlichkeit* [...] (2) *Vermittlungsinstanz* [...] (3) *Kausalität* [...] (4) *Intentionalität* [...] (5) *Ganzheit* [...] (6) *Ereignishaftigkeit* [...] (7) *Experientiality* [...] (8) *Tellability* [...] (9) *Konversationelle Zugzwänge* [...])”).

14 Transl. by MS. “Geschehensdarstellung ist Darstellung eines Zeitverlaufs. Jedes Geschehen ist als solches durch ein ›vorher vs. nachher‹, durch eine Sequenz chronologisch geordneter Ereignisse strukturiert: $e_1 \rightarrow e_2 \rightarrow e_3 \rightarrow \dots \rightarrow e_n$ ” (Martínez 2017, 2).

15 Transl. by MS. “Jede Erzählung stellt ›mimetische‹, das heißt singuläre und konkrete Gegenstände und Sachverhalte dar” (Martínez 2017, 2).

Martínez identifies “contiguity” as another necessary criterion: “The represented events must [...] be related to one another spatially, temporally or causally” (Martínez 2017, 2).¹⁶ With respect to this criterion too, it is remarkable to observe what is epistemically initiated in Einstein’s treatise. The criterion of contiguity therefore acquires a very profound new meaning, because Einstein succeeds in demonstrating, on the basis of considerations of mathematical symmetry, that space and time are not to be conceptualized as separate, but rather as related to one another mathematically and physically as a spacetime-continuum – as demonstrated by the symmetry relations of the Lorentz transformation. The following analysis is devoted to this logical and equally narrative-performative demonstration, step by step.

A further crucial feature of narrative is the existence of a narrative voice. For factual texts the narratological theory proposes the initiation of a factual pact (Fludernik 2020, 62) in analogy to Philippe Lejeunes (1989) “autobiographical pact” and to the “fictional pact” of the institutional theory of fictionality (Köppe 2014). The factual pact describes the “default assumption that a text [...] as a [scientific] treatise is, by definition, taken to be making statements about the real world” (Fludernik 2020, 62; added by AH).

Genette (1990) states that one clear distinction between factual and fictional narration is the identity between author and narrator ($A = N$) in case of factual narration and the distinction between the empirical author and the textually encoded narrator ($A \neq N$) for fictional texts. The narratological analysis of scientific texts has to deal with the problem, that both the position of the “intellectual creator of the text written for [scientific] communicative purposes” (Schönert, § 1; added by AH) and the narrative voice as the “inner-textual (textually encoded) highest-level speech position” (Margolin, § 1) have to be addressed with appropriate, well differentiated terms. Since I analyse Einstein’s treatise as an argumentative text type that displays features of epistemic narrativity besides the argumentative and the descriptive dimensions of the text, I propose to use the term writing/narrating instance to address both the descriptive/argumentative and the narrative dimensions of the text.

The following parameters of the narrator are to be observed, in order to describe how it constitutes the principles of form-organization (Bekhta 2017) of the text “On the Electrodynamics of Moving Bodies.” A first criterion is the explicitness of voice representation – the “degree of narratorhood” (Chatman 1978), the openness or concealment of the narrative voice. A second criterion is

¹⁶ Transl. by MS. “Die dargestellten Ereignisse müssen [...] räumlich, zeitlich oder kausal aufeinander bezogen sein” (Martínez 2017, 2).

its relation to the narrated world. To these are added, third, the representational logic of the narrative levels. Fourth, finally, is the question of the presentation of the addressees. All of these parameters help to answer the question of who tells, sees, perceives, mediates on the various narrative levels, and thus conducts the informative process. At the following point in “Electrodynamics of Moving Bodies” the writing/narrating instance enters the stage of theoretical-physical modeling: precisely at the point at which the process of interinformation begins, Einstein states:

We shall raise this conjecture (whose content will be called the “principle of relativity” hereafter) to the status of a postulate, and shall introduce, in addition, the postulate, only seemingly incompatible with the former one, that in empty space light is always propagated with a definite velocity V , which is independent of the state of motion of the emitting body. These two postulates suffice for arriving at a simple and consistent electrodynamics of moving bodies on the basis of Maxwell's theory of bodies at rest.¹⁷

(Einstein 1989 [1905], 140–141)

Einstein's treatise presents a plural narrative voice in we-form, which in narratological research has so far been rarely problematized, as Uri Margolin (1996), Monika Fludernik (2011) and Natalya Bekhta (2017) have pointed out.¹⁸

The voice presents itself to be recognized as a “we-instance.” It is a voice who opens up a process of factual scientific communication, and acts as mediator for a factual-narrative that sets out well-grounded knowledge (Klein and Martínez 2009). Of course, this is a common gesture for scientific publications around 1900. It would be perceived as *pluralis auctoris* or as a gesture of modesty. Is the scientific authority of already institutionalized expert discourse apostrophized by the “we?” Certainly the collective “we” also implies that scientific expert community that has agreed on common principles, codes and modeling practices, which the we-instance here subsumes under the principles of mechanics and electrodynamics. It stands for the culturally accepted and/or scientifically sanctioned state of knowledge at the time of the beginning of the modeling configuration. It will accompany the reader as a mediator through this process throughout the entire treatise.

¹⁷ “Wir wollen diese Vermutung (deren Inhalt im folgenden ‘Prinzip der Relativität’ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche Voraussetzung einführen, daß sich das Licht im leeren Raume stets mit einer bestimmten, vom Bewegungszustande des emittierenden Körpers unabhängigen Geschwindigkeit V fortpflanze. Diese beiden Voraussetzungen genügen, um zu einer einfachen und widerspruchsfreien Elektrodynamik bewegter Körper zu gelangen unter Zugrundelegung der Maxwellschen Theorie für ruhende Körper” (Einstein 1905, 891–892).

¹⁸ See also the recent Special Issue of *Style*: Bekhta 2020. Therein: Fludernik 2020.

However, this writing/narrating instance asks more of the reader than many other “we-narrators” of its time. For it is precisely this collective “functional-narrator” that organizes the factual narrative discourse in such a way, as it generously integrates the other actors of the scientific field. But in the course of this treatise the same factual narrator will carry out reconceptualizations that will catapult physics into spheres beyond the conceptual frames, codes and modeling practices that held before 1905.

The factual narrator becomes the abstract organizing principle of the discourse, which performatively demonstrates the necessity of reconceptualization of the physical knowledge. The “we-narrator” is thus also an epistemic narrative instance, which formulates the implicit hope that a mathematical form will be found that supports the new relativistic modeling strategy, so that the rhetorical strategy of inclusion through the personal pronoun in the first person plural becomes epistemically plausible. In this respect the “we-narrator” as an epistemic narrator also implies a “you,” the addressee. The entire logical and rhetorical argumentation strategy of the text is aimed at this abstract “you.” Interestingly, by this scientific discourse strategy, addresser and addressee coincide in the “we” figure, they seem to merge – if only partially. Yet can the reader, the addressee, also truly feel subsumed under this “we?” What mathematical and narrative strategies does the mediating voice use to convince them? How do they complement one another? A “strategy of immersion” for the addressee is needed.

Also: the “we-voice” is ascribed a certain epistemic profile. It is a functional narrator, which continually changes its epistemic profile in the light of new thought experiments and arguments. This epistemic narrator is thereby carefully and complexly configured, as will be shown. One can observe how this epistemic profile is first constituted as a voice in the context of the conventional theoretical frame in the extradiegetic level of narration and then becomes the shaping principle of theoretical frame-transformation within the intra- and metadiegetic narration. It is precisely the introduction of new frameworks that gives it the possibility to continually reconfigure itself as an epistemic narrative voice. This change in the narrator’s epistemological profile will be traced through the following reading. At the same time, this will show the narrative framing techniques through which interformation is accomplished.

3 Narrative levels

Narrative levels (also referred to as diegetic levels) are – according to John Pier – “an analytic notion whose purpose is to describe the relations between an act of

narration and the diegesis, or spatiotemporal universe within which a story takes place" (Pier 2014, § 1). I'll first give an overview on the levels and then discuss them in detail in a close reading.

The first-order narrative level one can call the "primary level" (with Wolf Schmid) or the "extradiegetic level" (with Gerard Genette). The writing/narrating instance here sets a framework, by crossing the principles from one theoretical frame to the other: the principle of relativity is transferred from the theory of mechanics to that of electrodynamics, while the principle of the constant velocity of light is transferred from the electrodynamics to the measurement rules of mechanics. Then he introduces inertial systems, determines the position of coordinate-systems in space, defines the geometrical structure of space and the necessary conditions for the definition of simultaneity. At the same time, he determines a rule-guided practice for the measurement of times, distances and for the observation and measurement of electromagnetic processes for both observer-figures of the second, the intradiegetic level. The extradiegetic narrating instance speaks from the perspective of a mathematical space that is not yet well-defined, because it oscillates between Euclidean space – that of the Newtonian frame – and a possible non-Euclidean space that is yet to be defined.

The secondary intradiegetic level on which the observers act, sets a new framework, that of the performative thought experiment. The events unfold here directly before the mind's eye of the reader. They involve a special observational and experimental design, in which the constancy of the speed of light becomes the principle of measurement for the re-conceptualization of simultaneity. This new measurement practices have never been used before. Certain conditions are introduced for this reason: a mathematically homogeneous and isotropic space has to be introduced as a setting for this thought experiment. In addition, the reference-frames of the observer-figures who carry out the measurements have to be defined. These reference-frames are inertial systems, uniformly moving or stationary systems that do not accelerate. This is the second framework of experimental arrangement of the intradiegesis, in which observers perceive light-events, make measurements and announce measurement results from their own reference-frames. The criterion of perception points to the text's focalization-structure, in Genette's terminology, or perspective-structure, in Wolf Schmid's (2010; 2014, 132–140) text-inference model. The third level of modeling, on which the Lorentz transformation is introduced, is here designated as the "metadiegetic level" (following Genette), or the "tertiary level" (following Wolf Schmid).

The third metadiegetic level therefore constitutes the turning-point of knowledge, because on this level of theoretical modeling it can ultimately be determined that the space can no longer be Euclidean in its fundamental geometry, as

the space has been assumed on the first, extradiegetic level. It will only later – in 1908 – receive a name from the mathematician Minkowski: it is the mathematical four-dimensional Minkowski space. Minkowski's geometry is based on the symmetry of the Lorentz group demonstrated by Einstein in this treatise. Minkowski space is fundamentally different from extradiegetic Euclidean space throughout, in that in this new world, as Minkowski himself called it, space and time unite as dimensions into a four-dimensional space-time continuum. We have to consider here the epistemic transformation of the fundamental space time relations. 1909 Minkowski makes explicit reference to the space-time continuum that Einstein had theoretically constituted in his treatise:

The views of space and time which I want to present to you arose from the domain of experimental physics, and therein lies their strength. Their tendency is radical. From now onwards space by itself and time by itself will recede completely to become mere shadows and only a type of union of the two will still stand independently on its own.¹⁹

(Minkowski 2012 [1909], 39)

Here again we have to address a specific problem of science narratology. While for the “classical narratology” in Genettian terms new diegetic levels are opened by new narrators, I would propose to consider if in this type of texts new narrative levels can be legitimized by fundamentally new conceptions of space and time and implicitly so by the hint of the necessity of the transformation of the epistemic profile of the narrating instance that narrates such a thought-experiment and of its addressee. So while the extradiegetical space has to be conceptualized as a Newtonian space in the Newtonian theoretical frame, the intra- and metadiegetic spacetime relations have to be conceptualized as relativistic spacetime relations.

Furthermore, I would like to show that this ternary architecture of narrative levels, so carefully designed by Einstein, undergoes a metaleptic transgression at the end of the treatise: The metadiegetic inner level is turned outwards. It becomes indeed the point of departure, the so-called ‘extradiegetic level’ for all important theories that operate in the frame of relativistic physics after Einstein's treatise from 1905. In order to constitute themselves as fundamental laws of nature, they can no longer avoid considering non-Euclidean, Minkowskian space geometry, and have to be covariant under the Lorentz transformation. These are lasting requirements that Einstein settled with his treatise on the special relativity theory.

19 “Die Anschauungen über Raum und Zeit, die ich Ihnen entwickeln möchte, sind auf experimentell-physikalischem Boden erwachsen. Darin liegt ihre Stärke. Ihre Tendenz ist eine radikale. Von Stund' an sollen Raum für sich und Zeit für sich völlig zu Schatten herabsinken und nur noch eine Art Union der beiden soll Selbständigkeit bewahren” (Minkowski 1909b, 1).

3.1 Primary level: Extradiegetic

3.1.1 The relativistic reformulation of mechanics

The first step of modeling in the text is devoted to reconceptualizing the classical definition of the time-conception in physics. Einstein first asserts that the concept of time in physics is not rigorously logically defined. The way that he chooses here is that of transition from an absolute concept, as Newton had defined it, to a relational functional concept that is appropriate to the new relativistic theoretical frame of physics.

Before the beginning of the definition of simultaneity, Einstein determines the elements that will be incorporated in the construction of the modeling of his theory: these include the kinematics of rigid bodies, clocks, and electromagnetic processes, i.e. light. The extradiegetic level is still situated in the Newtonian space, as the functional, epistemic narrator puts it:

Consider a coordinate system in which the Newtonian mechanical equations are valid. To distinguish it verbally from the coordinate systems that will be introduced later on, and to visualize it more precisely, we will designate this system as the “system at rest.”

If a material point is at rest relative to this coordinate system, its position relative to the latter can be determined by means of rigid measuring rods using the methods of Euclidean geometry and can be expressed in Cartesian coordinates.²⁰

(Einstein 1989 [1905], 141)

Although the argumentation aims at repurposing highly abstract concepts, it does so by using a very concrete setting, concrete material objects and reference values and very simple observer figures, who are defined throughout only by the fact that they wear a watch, in order to be able to read out the time. When it comes to the motion of rigid bodies, everything is already understood by the laws of mechanics – so it is claimed. One needs only apply these laws consistently – also taking electrodynamical processes into account. But that's the catch. Michelson and Morley's experiments on the speed of light – revealed that the speed of light remains constant everywhere and is thus independent of the motion of the body that emits it. This principle now had to be unified consistently with the

²⁰ “Es liege ein Koordinatensystem vor, in welchem die Newtonschen mechanischen Gleichungen gelten. Wir nennen dies Koordinatensystem zur sprachlichen Unterscheidung von später einzuführenden Koordinatensystemen und zur Präzisierung der Vorstellung das ‘ruhende System.’ Ruht ein materieller Punkt relativ zu diesem Koordinatensystem, so kann seine Lage relativ zu letzterem durch starre Maßstäbe unter Benutzung der Methoden der euklidischen Geometrie bestimmt und in kartesischen Koordinaten ausgedrückt werden” (Einstein 1905, 892).

remaining principles of mechanics, even at the cost of reconceptualizing some other codes. The solidarity between addresser and addressee is accepted so long as one sticks on the common ground of well-known principles, codes and practices of modeling: “If we want to describe the *motion* of a material point, we give the values of its coordinates as a function of time” (Einstein 1989 [1905], 141).²¹ This is a practice that has held in physics since the introduction of the Cartesian coordinate system. Yet now the epistemic narrator begins to reconceptualize the physical signification of time. An empirically adequate concept of time can only be obtained according to Einstein, if one firstly, ties it to events, secondly, correlates it with the concept of simultaneity, and thirdly, measures it with the help of the natural constant light velocity.

However, we should keep in mind that for such a mathematical description to have physical meaning, we first have to clarify what is to be understood here by “time.” We have to bear in mind that all our propositions involving time are always propositions about *simultaneous events*.²² (Einstein 1989 [1905], 141)

3.2 Secondary level: Intradiegetic

In order to bring this before the reader’s mind’s eye, the treatise opens a second narrative level: that of a thought experiment. In terms of representational logic, this is an intradiegetic level. Protagonists of this narrative are figures as observers, who carry out measurement actions in their own world, and consider and evaluate the results in their own and different reference-systems. If the primary “we-narrator” had a conative function, which comments on and evaluates the measurement activities of the observers, then the observers have a performative function: they perform the measurements – indeed fictive, but immersive – directly before the eyes of the reader. The mode of distance in which the narrator operates varies with that of the proximity in which the observer figures act. To this extent the passages in which the observers carry out the measurements performatively before the eyes of the reader can be regarded as *mimesis* passages, which are embedded in the overall process of the *diegesis*. Note that this is not a

²¹ “Wollen wir die Bewegung eines materiellen Punktes beschreiben, so geben wir die Werte seiner Koordinaten in Funktion der Zeit” (Einstein 1905, 892).

²² “Es ist nun wohl im Auge zu behalten, daß eine derartige mathematische Beschreibung erst dann einen physikalischen Sinn hat, wenn man sich vorher darüber klar geworden ist, was hier unter ‘Zeit’ verstanden wird. Wir haben zu berücksichtigen, daß alle Urteile, in welchen die Zeit eine Rolle spielt, immer Urteile über *gleichzeitige Ereignisse* sind” (Einstein 1905, 892–893).

matter of the Platonic concept of *mimesis* as “imitation,” but rather of Aristotle's *mimesis praxeos* – a practice that serves to produce and establish evidence. On the specific narrative techniques of “we-narrators” in literary texts, Fludernik (2011, 101) also asserts that it is a characteristic of “we-narrative” to undermine and counteract the systematic border between the extradiegetic and intradiegetic. Fludernik points out referring to Marie Laure Ryan's (2001) concept of immersion:

One can achieve a sliding scale by noting that in [...] we texts the barrier between the diegetic and extradiegetic levels is already porous since the first person narrators [...] share an existential core with a narrator or narratee on the extradiegetic plane. [...] The successful strategy of you and we narratives has been to draw the reader into the text by way of imaginative *immersion*.
(Fludernik 2011, 122)

3.2.1 Relativity of simultaneity

From here on, the concept of “simultaneity,” previously taken for granted in the history of physics, is put into question. Einstein asks persistently: What does “simultaneity” actually mean? In doing so, he asserts that every judgement about time can fundamentally only be made when one makes a judgement about simultaneity. The comparison of two reference-systems with one another is also necessary for the determination of time, because it always inevitably relates two different events to one another. I cite Einstein's original paper: “If, for example, I say that ‘the train arrives here at 7 o'clock,’ that means, more or less, ‘the pointing of the small hand of my clock to 7 and the arrival of the train are simultaneous events.’” (Einstein 1989 [1905], 141)²³

Now a new problem arises for Einstein: It is not enough to define the time of an observer's reference-system by the display of his personal clock. It is important to correlate measurements of two observers that observe the same event but are placed in different inertial frames of reference. Would the clock of the first observer suffice as a measuring instrument to indicate the proper-time of another observer who is not located in the same place? Could one correlate two observations of the same event-sequence with one another in this way? The obvious solution would be to provide both observers with their own clocks. However, this, according to Einstein would do nothing but introduce a possibility of

²³ “Wenn ich z. B. sage: ‘Jener Zug kommt hier um 7 Uhr an,’ so heißt dies etwa: ‘Das Zeigen des kleinen Zeigers meiner Uhr auf 7 und das Ankommen des Zuges sind gleichzeitige Ereignisse’” (Einstein 1905, 893).

defining the time of the first observer A, on the one hand, and the time of the second observer B, on the other hand. One would still have found no reliable rule that correlated or even related both times with one another. The two time records are thus not only defined independently from one another, they could also be different. The problem is formulated as follows in Einstein's paper:

Such a definition is indeed sufficient if time has to be defined exclusively for the place at which the clock is located; but the definition becomes insufficient as soon as series of events occurring at different locations have to be linked temporally, or – what amounts to the same – events occurring at places remote from the clock have to be evaluated temporally.²⁴ (Einstein 1989 [1905], 142)

Next, the presentation makes recourse to techniques of focalization. If one assumes that at point A there is an observer who reads from his clock and marks the point of time at which a beam of light arrives, one finds that he does not arrive to the same measurement result with that of observer B, who reads from his clock the time at which a light signal reaches him. The horizons of perception and knowledge of each observer are – from a narratological perspective – internally focalized. In the language of physics, a science narratology concept of internal focalization is stated like this in the “Electrodynamics of Moving Bodies:”

To be sure, we could content ourselves with evaluating the time of the events by stationing an observer with the clock at the coordinate origin, and having him assign the corresponding clock-hand position to each light signal that attests to an event to be evaluated and reaches him through empty space. But as we know from experience, such an assignment has the drawback that it is not independent of the position of the observer equipped with the clock.²⁵ (Einstein 1989 [1905], 142)

Einstein proposes to equip the internally focalized figures with a criterion for time-measurement that allows them to both perform precise time-measurements

24 “Eine solche Definition genügt in der Tat, wenn es sich darum handelt, eine Zeit zu definieren ausschließlich für den Ort, an welchem sich die Uhr eben befindet; die Definition genügt aber nicht mehr, sobald es sich darum handelt, an verschiedenen Orten stattfindende Ereignisreihen miteinander zeitlich zu verknüpfen, oder – was auf dasselbe hinausläuft – Ereignisse zeitlich zu werten, welche in von der Uhr entfernten Orten stattfinden” (Einstein 1905, 893).

25 “Wir könnten uns allerdings damit begnügen, die Ereignisse dadurch zeitlich zu werten, daß ein samt der Uhr im Koordinatenursprung befindlicher Beobachter jedem von einem zu wertenden Ereignis Zeugnis gebenden, durch den leeren Raum zu ihm gelangenden Lichtzeichen die entsprechende Uhrzeigerstellung zuordnet. Eine solche Zuordnung bringt aber den Übelstand mit sich, dass sie vom Standpunkte des mit der Uhr versehenen Beobachters nicht unabhängig ist, wie wir durch die Erfahrung wissen” (Einstein 1905, 893).

relative to their own reference-systems and to correlate these with one another. How is this possible? By first recoding the times of the two observer-figures, and second, correlating them with fundamental physical principles, such as the constancy of the speed of light. The following diagram (Fig. 1), which represents a light-clock, illustrates the arrangement of the thought experiment.

Fig. 1: A photon is sent from the upper mirror to the lower mirror. The observer measures the time for the photon travel from the upper mirror to the lower mirror and back while moving with the photon.

“Zeitdilatation.” <https://physikunterricht-online.de/wp-content/uploads/2017/02/Lichtuhr.jpg>. *Physikunterricht Online*. February 2017 (9 Juli 2021).

Thus it is possible to stipulate definitionally that the time required for a beam of light to travel from the first observer-location t_A to the second observer-location t_B , is equal to the time required by a beam of light to return back to point t'_A once it is reflected from t'_B . This may be modelled in the symbolic form-relation:

$$t_B - t_A = t'_A - t'_B$$

Equipped with this equation for synchronicity, Einstein examines the validity of the proposed equivalence-relation, which has to fulfil three criteria. First is the criterion of reflexivity (i.e. identity): $t_A = t_A$. Second is the criterion of symmetry: if the clock in A is synchronous with the clock in B, then one can implicitly conclude from this that the clock in B is also synchronous with the clock in A. And finally there is the criterion of transitivity, the transfer of the synchronicity-relation to a third element: If the clock in A runs synchronously with both the clock in B and the clock in C, then the clock in B also runs synchronously with the clock in C.

To summarize: This section of Einsteins's treatise proposes a definition of simultaneity that reconceptualizes “time” as a concept. Einstein converts time into an ‘operational concept’ of physics.²⁶ For this sake he has to recode, to re-semiotize it according to a new sign relation. The sign function is not only constituted through one watch, but through two watches, whose informations are correlated through the speed of light. The constancy of the speed of light is the determinant factor that generates the sign function between the two watches. The definition of time can not be realized without a physically reasonable definition

²⁶ Cf. Winfried Thielmann's paper “Concept Formation in Physics from a Linguist's Perspective” in this volume.

of “simultaneity.” However, a rational definition of simultaneity can only be operationalized by resorting to the principle of the constancy of light velocity. The second and fourth sections of Einstein’s paper uses epistemic narrativity in order to perform this re-semiotization, this re-coding of time. More than that, thought-experiment measurements and epistemic narrativity show that the concept of absolute time is not necessary anymore, as well as that of absolute simultaneity.

Through this new definition of synchronization of clocks it becomes clear that two observers will not, as a rule, have the same perception of one and the same event, if they are located in different reference-systems as inertial-systems moving parallel to one another. For it is light that conveys the information about the occurrence of the event. But light has only a limited velocity. The information cannot reach both observers simultaneously if they are located in different inertial-systems, at rest or in motion. Therefore a tertiary modeling level is needed, in order to transform the places and times of the coordinate-axes of the two observation frames into one another and thereby to correlate the observers’ perception and knowledge horizons. As Einstein puts it:

Here,

$$\text{velocity} = \frac{\text{light path}}{\text{time interval}},$$

where “time interval” should be understood in the sense of the definition in § 1.²⁷

(Einstein 1989 [1905], 143–144)

The epitome of Einsteinian interformation process is conceptually concentrated in the notation of the above-cited fraction, ‘light path / time interval.’ This also signals the change in the codes of the measurement narrative. Although clocks are still in use, another relevant quantity is added, the speed of light. It is the natural constant that enables the comparison between the two running clocks. It stands in the numerator of the upper fraction, while time-interval stands in the denominator. The duration that light takes to travel a certain distance always remains constant in a vacuum, independent of direction and reference-system. This is why the speed of light becomes the relevant quantity for the time measurement, because it is a natural constant. Clock-time is the relevant first-order measurement of the proper-time of the observers in their own frames of reference. But we need a second-order correlation between these two proper

27 “Hierbei ist Geschwindigkeit = $\frac{\text{Lichtweg}}{\text{Zeitdauer}}$, wobei ‘Zeitdauer’ im Sinne der Definition des § 1 aufzufassen ist” (Einstein 1905, 895).

times and their spacetime structure, that means their world-lines, and this is the constancy of the speed of light. Only the second-order correlation that is granted to the intersection of principles of electrodynamics to mechanics opens up the third level of modeling – that of the Lorentz transformation relation.

The speed of light is the relevant second-order correlation, to relate the measured proper-times of the two observers. An epistemic break arises between the new Einsteinian-Lorentzian concept of local-time and the old Newtonian-Kantian concept of absolute time. The determination of the time of occurrence of an event is now dependent on the constancy of the speed of light. The light-path defines the event's duration as relative to the reference-frame of the observer. In this way Einstein demonstrates that there is no absolute simultaneity and he proposes a threefold time-conception: The local-time or proper-time as a first order time indication, the second-order correlation between local times and the third-order transformation relation between the two local times.

3.2.2 Internal and external focalization: Time dilation

The fourth section repeats the thought experiment of the second section, now under the application of the Lorentz transformation. That's why it is titled: "The physical meaning of the equations obtained concerning moving rigid bodies and moving clocks" (Einstein 1989 [1905], 151).²⁸ Again this concerns the measurement of the amount of time it takes a beam of light to make its way back and forth between two mirrors.

In order to understand the point of this thought experiment let us assume that the above shown clock moves past the earth in an imaginary rocket at a very high velocity (close to the speed of light). Two different observers, as shown in the two graphics below, now observe the path of the light beam and its arrival at the original mirror. In the first graphic (Fig. 2) the moving observer S' performs his time-measurement from inside the rocket, moving with the light-clock. His frame of reference can be defined as internally focalized from within the rocket. Observer S' calculates the path of the light between the two events – the first event of light emission from the first mirror, and the second of the re-arrival of the light beam back at the first mirror – as twice the distance of the path of the light, divided by the speed of light: $t' = \frac{2d}{c}$.

²⁸ "Physikalische Bedeutung der erhaltenen Gleichungen, bewegte starre Körper und bewegte Uhren betreffend" (Einstein 1905, 903).

Fig. 2: Internally focalized measurement: A photon is sent from the upper mirror to the lower mirror. The observer measures the time for the photon travel from the upper mirror to the lower mirror and back while moving with the photon.

“Zeitdilatation.” <https://physikunterricht-online.de/wp-content/uploads/2017/02/Lichtuhr.jpg>. *Physikunterricht Online*. February 2017 (9 Juli 2021).

Now the second observer S is shown in the graphic below (Fig. 3), who watches the flight of the rocket from the Earth, as an external observer. He focalizes the rocket-flight and the beam-light measurement externally and measures a different duration for the same event.

Fig. 3: Second measurement frame, externally focalized: Moving light clock from the perspective of the earth observer.

“Zeitdilatation.” <https://physikunterricht-online.de/wp-content/uploads/2017/02/Lichtuhr.jpg>. *Physikunterricht Online*. February 2017 (9 Juli 2021).

The Earth-observer S fulfills an externally focalized measurement-act from the Earth. Accordingly, the light takes a longer time to travel from the starting-mirror to the end-mirror and back, because the light-clock in the rocket moves in the mean time, as the ‘static’ observer sees it from earth. For this static observer on the earth, light does not take a straight doubled path ($2ct'$) back and forth as for observer S' , but rather a diagonal doubled path ($2ct$), which is longer than the path (ct') that the moving observer measures. The path that the Earth-observer measures can be calculated using the Pythagorean theorem: $(ct)^2 + (ct')^2 = (vt)^2$. The time-duration t that the light needs to travel from the starting-mirror to the end-mirror and back measured by the externally focalizing observer (S) is longer than the time t' that is measured by the internally focalized observer that is moving with the light-clock (S'), because the latter is in

the same inertial reference frame as the rocket. The relation between t (the time measured by the external focalizer) and t' (the time measured by the internal focalizer) is:

$$t = t' \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

This is how the relativistic concept of time dilation is explained. The factor on the right side of the above equation is the Lorentz factor, where v symbolizes the velocity of the rocket, c the light velocity. The special relativity theory states that the light velocity is the highest possible velocity that has been ever measured. So the velocity of the rocket v is always smaller as the light velocity c . That's why t , the time measured by the external focalizer will have a longer duration than t' , the time measured from the internal focalized reference system. And that's why Einstein can conclude that simultaneity is relative.

Thus it also turns out that clocks carried by observers in moving coordinate-systems read from the external perspective of an observer in a stationary system run more slowly. Light establishes the semiotic sign-correlation by conveying information about the occurrence of an event. But the speed of light is also limited. Information can not reach both observers with equal speed, if one of them is at rest and the other is moving. The observers observe the same event at different time, depending on how far they are from the light source. This difference will always exist. Time information is always given relative to one's own reference-system. For the constancy of the finite speed of light prevents absolute simultaneity and makes clear that each reference-frame has its proper-time.

3.2.3 Event-horizons of the observers and their space-time boundaries

Minkowski showed in 1908 that the causal structure of four-dimensional space-time is defined by space-like, time-like, and light-like vectors marked by the arrows in the graphic below (Fig. 4).

The lower light cone represents the past of the observer, with all events and processes that he could in principle perceive. The upper light cone represents the future. Light forms the light cone, the light-like vectors are identified by the surface lines of the cone. The light-like vectors limit the event-horizon of every observer located on a world-line. The middle axis of the light cone symbolizes the time-like difference-vector. The boundaries of the light cone are the limits of the observer's perception horizon, so they are the limits of the world of the

Fig. 4: Diagram: Light cone in 2D space plus one time dimension. The forward-cone is in positive time-direction. The observer of an event E is located at the intersection of past and future cones (present).

“Light cone.” https://upload.wikimedia.org/wikipedia/commons/thumb/1/16/World_line.svg/800px-World_line.svg.png. *Wikipedia: The Free Encyclopedia* (9 Juli 2021).

observer. This is the epistemic result of the intradiegetic thought-experiment: It shows the boundaries of the observer’s perception. All events that occur within the light cone can reach him. Events that occur outside the light cone cannot reach the observer’s perception in principle. An observer who acts only on the level of the empirical, and has no symbolic framing-structure, cannot know what happens outside of his event-horizon, due to the empiric limitation of its event-horizon within the four-dimensional Minkowski world, as described in the above diagram. This is postulated by the theory of relativity.

Thus the thought experiment is necessary as a symbolic fictional narrative which reveals what has to be assumed as factual in the future. The function of the epistemic narrative is to demonstrate the empiric limitations of the perception of the internally focalized observer due to the boundaries of the light cone, that means due to the fundamental structure of the space-time in the theory of relativity. This space time structure sets the limited event-horizon of the internally focalized observer and his measurements. The epistemic narration also shows – immersively – the consequences that are to be drawn from this limitation: the necessity of the existence of a tertiary mathematical, formal modeling level, that allows to transform the empirical coordinates into abstract mathematical coordinates. This puts at disposal a transformation relation that establishes a

correlation between the space-time coordinates of the two observers who are situated at different space-time points.

3.3 Tertiary level: Metadiegetic

In Genettian terminology, any further narrative level after the extradiegetic and intradiegetic levels is called a “metadiegetic” level. I will call this third level a tertiary metadiegetic narrative level. What changes here is the semio-logical code for the conceptualization of space and time. While the extradiegetical level is still situated in a Newtonian space-time structure with Euclidian geometry, the metadiegetical level unites time and space due to the Lorentz transformations and their symmetry-group.

3.3.1 Lorentz transformation

The *third section* (§3) of “Electrodynamics of Moving Bodies” demonstrates the compatibility of the two fundamental principles of mechanics and electrodynamics, which initially appeared incompatible: the principle of relativity and the constancy of the speed of light. It then becomes clear that this compatibility is indeed possible, but only on the assumption of an internal recoding: by the replacement of the Galilean transformations of mechanics with the Lorentz transformations of electrodynamics. Under this condition, the principle of relativity can be retained, and also apply to electrodynamics (Schröder 1990 and 2014). For this, one must introduce a different transformation relation from that which originally applied on the extradiegetic-level, in the world of the primary narrator. The transformation relations of the extradiegetic level were still Galilean transformations. The transformation relations of the tertiary narrative level are Lorentz transformations. Where does the difference lie? And why is this important?

According to Einstein, the Lorentz transformations state: if an observer moves with constant velocity in direction x then the coordinates (x, y, z for space and t for time) that he assigns to an event can be correlated and transformed into the coordinates (x', y', z', t') of a second observer of the same event, if the form of the equations that constitute the Lorentz transformation remains invariant. The two reference-systems of the two observers have to coincide with one another at time $t = t' = 0$. Then the two coordinate systems differ from one another in the x' and t' directions by the so-called “Lorentz factor,” which is on the right side of the two equations of the Lorentz transformation shown below.

$$t' = \frac{t - \frac{v}{c^2}x}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$y' = y$$

$$z' = z$$

The system of equations of the Lorentz transformation has several functions: it offers the possibility of operating with different observer-times as proper-times, because the equation-system correlates and transforms them into one another. It justifies the legitimacy of the proper-time of each individual observer-system in his frame of reference as an inertial-system. It also justifies why the phenomena of Lorentz contraction and time dilation are not necessarily paradoxical, but rather each has its validity, even when this contradicts classical mechanics.

The Lorentz transformation stands for a mathematical modeling practice that is inscribed with the fundamental postulate that no observer and no observation-system may be favored in its horizon of knowledge and perception. It postulates principally the equivalence of all inertial systems as far as their observations, perceptions and knowledge concerns, provided that they respect the new rule-governed practice of measurement. Through this transformation relation, the measurement results of both observers can be objectively correlated, even if their event horizons drift apart. Thus, primary context-dependence can be considered together with secondary operational context-independence, and can be integrated into a symbolic configuration on three different levels, while the third level reveals the appropriate transformation relation for the space-time coordinates from one frame of reference to the other. According to this the primary difference of the measurements results is validated as objective due to the different frames of reference and due to the limited event-horizon of the observers. This limit is imposed by the fundamental space-time structure of the universe. This difference on the primary level can be accepted because there is a mathematical transformation relation that establishes objectivity in spite of the differences on the primary level. Thus symbolization in the mathematical code of the secondary level is a necessary condition for context-independent objectivity that is finally achieved through the Lorentz transformation relation on the tertiary level. Later this new theoretical model can become factual, if the mathematical model is validated – i. e. cannot be falsified – by repeated

experiments. But this future factuality is also mediated through functional epistemic narrativity, that's what is argued here.

Let's summarize the narrative thought-experiment and its epistemic results: First, there is the internally focalized observer in the rocket and the externally focalized observer on the earth. They observe the occurrence of the light events, perform their measurements and make their time-specifications. Each observer observes, however, not only the events of his own internal frame of reference, but also the occurrence of events in the external frame of reference. The problem is, that the internal and external focalized measurement results of the same event are not identical. The two different observers measure different time-durations: On the one hand there is the internally coded proper-time measured by the observer within the rocket. On the other hand there is another measurement result of the same light-signal-event measured by the earth-observer. This is an externally focalized measurement, from the stationary frame of reference of the earth.

The narrative instance functions as "reflector," compares the measuring results of the two observers with one another and demonstrates the conundrum that observers who measured the same light-events happening at the same time have arrived at different interpretations of the measurement results. That's why the epistemic narrator functionally reconceptualizes the concept of simultaneity in physics by defining it in terms of the constancy of the speed of light. The functional epistemic narrator has, however, as a we-narrator, the peculiar quality that he contradicts the conventional categorizations and metaleptically transgresses the boundaries between narrative levels (Fludernik 2011, 122). He thus can show that the two different measurements, which on the first level of modeling diverge empirically, can be correlated objectively through the precise Lorentz transformation that is introduced on a tertiary level. This rule for the transformation of space-time coordinates between the two frames of reference is based on the symmetry-relation that is essentially mathematically coded and that functionalizes the symbolic operations of the secondary modeling level, that of mathematics.

The implied reader in turn observes both the results of the measurement procedures, which are different for simultaneous events, as well as the observation, evaluation and reflection process of the epistemic narrator in relation to the differences between the measurement results. The result of the thought experiment can be specified in three points. A: Simultaneity is relative. B: Time dilation and space contraction exist objectively and can be measured. C: Time specification is only possible relative to one's own reference system. Each observer has an autonomous proper-time, which, however, does not remain monadically uncorrelated, but rather can be related to the proper-times of other observers, without any need

to assume the Newtonian absolute time – but through using the Lorentz transformation relations.

Einstein's treatise demonstrates through this thought experiment that first-order quantities – those of primary measurement-modeling – can be different from one another in different reference-systems, on the condition that the second-order operational system based on mathematics opens the formal possibility to apply the third-order transformation rules. From this third order frame of modeling, that of transformation, one can understand why the measurement results of both observers are objective in spite of the difference between them. The delation is due to the reference system of observation, due to the specific structure of spacetime and due to the constancy of the speed of light.

3.3.2 The relativistic reformulation of electrodynamics

The *second part* of the Einsteinian treatise is devoted to electrodynamics. On the one hand, this is confronted with the theory of mechanics. On the other hand, this leads to Einstein's demand that the principle of relativity – now in its form as modified in the third section – is also valid for the Maxwellian equations of electrodynamics, due to the Lorentz transformations. If the requirement of the principle of relativity is correct for the Maxwellian equations, then the same laws would have to apply for moving as well as stationary inertial systems. For this purpose, the demonstration of the covariance of the Maxwell equations with respect to the Lorentz transformation is required and demonstrated. The equations for moving and stationary systems are consistent with one another, except for one factor, the so-called Lorentz factor, which interestingly has the same form as the equations that determine the coordinates of space and time. This results in an important consequence: the Lorentz transformations are valid for both the equations of mechanics, that is, for the movement of bodies in time and space, and for the equations of electrodynamics, that is, for the laws of optics, electricity and magnetism. Thus these fundamental Lorentz transformation relations connect mechanics with electrodynamics. Einstein summarizes the changes that accompany this in the formulation of electrodynamics in the following revision:

1. If a pointlike unit electric pole is in motion in an electromagnetic field, there will act on it, in addition to the electric force, an "electro-motive force" which, if we neglect terms multiplied by the second and higher powers of v/V , equals the vector product of the velocity of motion of the unit pole and the magnetic force, divided by the velocity of light. (Old mode of expression.)

2. If a pointlike unit electric pole is in motion in an electromagnetic field, the force acting on it equals the electric force present at the location of the unit pole, which is obtained by transforming the field to a coordinate system that is at rest relative to the unit electric pole. (New mode of expression.) (Einstein 1989 [1905], 159)²⁹

It follows that electric and magnetic fields are subject to the principle of relativity as Einstein formulates it. At the beginning of his treatise Einstein has pointed out that the following asymmetry within the Faradayan law of induction was a problem: That an *electric field* arises *around* a moving magnet when it is moved along a stationary conductor, while an *electromotoric force* would arise *within* a moving conductor when this approaches a magnet. Einstein proves in his treatise that this asymmetry now proves to be relative, too, since the electromotoric force appears only from the view of the moving observer. Because the speed of light is in any case invariant with respect to moving or stationary systems, and because the Maxwell equations show that electromagnetic waves are light, thus Einstein's newly formulated principle of relativity is compatible with the principle of the constancy of the speed of light.

Another important result of the thought experiment within the relativity theory: 'Lengths of objects' can also no longer be described as absolute, but rather only as relative quantities. The length of a body in motion appears to be shortened for a stationary observer, as Einstein demonstrates in this treatise: "A rigid body that has a spherical shape when measured in the state of rest thus in the state of motion – observed from a system at rest – has the shape of an ellipsoid of revolution" (Einstein 1989 [1905], 152).³⁰ Such descriptions are in principle possible only relative to one's own inertial system. However, there is the

29 "1. Ist ein punktförmiger elektrischer Einheitspol in einem elektromagnetischen Felde bewegt, so wirkt auf ihn außer der elektrischen Kraft eine 'elektromotorische Kraft,' welche unter Vernachlässigung von mit der zweiten und höheren Potenzen von v/V multiplizierten Gliedern gleich ist dem mit der Lichtgeschwindigkeit dividierten Vektorprodukt der Bewegungsgeschwindigkeit des Einheitspoles und der magnetischen Kraft. (Alte Ausdrucksweise.) 2. Ist ein punktförmiger elektrischer Einheitspol in einem elektromagnetischen Felde bewegt, so ist die auf ihn wirkende Kraft gleich der an dem Orte des Einheitspoles vorhandenen elektrischen Kraft, welche man durch Transformation des Feldes auf ein relativ zum elektrischen Einheitspol ruhendes Koordinatensystem erhält. (Neue Ausdrucksweise)" (Einstein 1905, 909–910).

30 "Ein starrer Körper, welcher im ruhenden Zustand ausgemessen die Gestalt einer Kugel hat, hat also im bewegten Zustande – vom ruhenden System aus betrachtet – die Gestalt eines Rotationsellipsoides" (Einstein 1905, 903).

Lorentz transformation, that allows for very precise transformations from one coordinate-system to another, without any observer absolutizing their own observation and ignoring that of others.

The principle of relativity states that primary modeling, measurements and observations can in principle only be made by specifying one's own reference-system. Quantities and lengths then appear differently from the perspective of different reference-systems. There is nothing that needs to be fixed here; it does not endanger the process of objectivization in physics because there exist covariant transformation relations. The fundamental constraint of the theory of relativity is the covariance relation. It states that all reference-systems that move uniformly and without acceleration are aequivalent in their measurements and specification of quantities if there exists a covariant transformation relation. In general relativity theory, this basic postulate of equality will apply to all reference-systems, including all accelerated systems. The differences that arise in the measurements of quantities are only first-order differences that are legitimized by the relativity principle. Due to the relativity principle and the Lorentz covariance relation the differences that arise in the measurements and observations are legitimate because they are conditioned by the structure of space-time. There is no "absolute instance" that provides *one* "correct measurement." All we can have is a covariant transformation relation. Due to the interformation process which includes this tertiary modeling configuration, Newton's conceptions of absolute space and absolute time proved to be just habits of thought and explained to be dispensable.

3.3.3 Reconceptualization of mass: Equivalence between mass und energy

Einstein uses the *ninth section (§9)* to show that the mass of bodies too, which in classical physics was still regarded as unchangeable, can only be specified relative to certain reference-systems, in the conceptual reference-frame of the theory of relativity, and that in addition they appear differently from different perspectives. A body at rest is granted its resting mass. But viewed from a moving body, that same body is ascribed a "dynamic mass" that does not coincide with the resting mass. In this respect, another fundamental law of mechanics of conservation of mass is revised by Einstein. Since it can now be assumed that a moving body also changes its mass, the law of conservation of mass can likewise no longer apply. Along with the length and volume of a body, a further "primary quantity," which Galilei had postulated as an objective quantity for the grounding of physics, now proves to be relative according to the theory of

relativity.³¹ But in this case too, the argument does not follow that thus “everything” proves relative. Mass is transformed into field-energy. Other quantities are now deemed invariant, laws of conservation of relativistic momentum and the conservation of energy apply here. Invariance is raised to a new level of modeling, at which other symmetry-group-laws apply. The new symmetry-group opens up new freedom of transformation.

Einstein dedicates the last, *tenth section* (§10) of his treatise to this famous statement, the equivalence of mass and energy. The concrete formula, however, which thanks to its formal simplicity became the icon of modern science, $E = mc^2$, is first introduced in a later essay.³² Yet the recognition remains that in relativistic physics mass can be considered as a special form of (field-)energy, as the “stationary energy,” or “resting energy” of a body.

Here finally the interformation process between the two theories, i. e. the intersection of principles and modeling practices stemming from mechanics and electrodynamics mediated through epistemic narrativity comes to a final result. Two concepts, that stem from both theories, “mass” from the mechanics and “energy” from the electrodynamics, are proved to be equivalent through one equation $E = mc^2$ and the mediation relation of the speed of light: when you accelerate a physical object to the speed of light, than its mass transforms into energy.

4 Summary of narratological analysis

Turning back to Martínez' catalogue of criteria of narrativity, another possible feature has to be mentioned, that of causality: “It is often required of well-formed narratives that the events must not only follow upon one another chronologically but also follow from one another causally. Changes of state would thus be motivated through a cause-effect connection” (Martínez 2017, 4).³³ It is beyond question that Einstein's factual narrative also meets this criterion. However, it

³¹ For a consideration of this problem of primary and secondary qualities in classical and modern physics from the philosophy of science, cf. the chapter by Van Fraassen: “Appearance vs. Reality in the Science” in Van Fraassen 2013, 270–276.

³² Fadner recounts the historical development of the mass-energy relation in Fadner 1988.

³³ Transl. by MS. “Von wohlgebildeten Erzählungen wird häufig verlangt, dass die Ereignisse nicht nur chronologisch aufeinander, sondern auch kausal auseinander folgen müssten. Zustandsveränderungen wären so durch einen kausalen Ursache-Wirkungszusammenhang motiviert” (Martínez 2017, 4).

also surprises its readers by undermining the classical causality-relations of Newtonian mechanics and by replacing them with new, surprising causality-relations based on the Lorentz transformation relations: for example, that the mass of a body can decrease and turn into energy due to its increasing acceleration toward the speed of light. This causal relationship was not imaginable to the scientific community before Einstein. The conceptualization of mathematical equivalences between mass and energy and the equivalence between space and time are considered worth telling, i. e. narratable, due to the disruption of previously accepted causality-relations – and indeed not only for the scientific community, but also for the wider cultural semiosphere.

Let's resume the argumentation so far: Considered in terms of representational logic, the first level of narration and argumentation is that of the extradiegesis, in which the we-narrator introduces the problem and sets out the principles that underlie the theoretical modeling and argumentation. In addition, the writing/narrating instance comments and reflects on the different results of the repeatedly varied thought experiments in the intradiegesis, before and after the transformation. The thought experiment is located on the second level of the diegesis. It presents the relativity of measurements of each individual observer and the context-dependency of their horizons of perception and knowledge. The third narrative level is the level of metadiegesis. One can also call it "interdiegesis," because it establishes a connection between the world lines of the two observers. The Lorentz transformation correlates the world-lines of the two reference-systems with one another while preserving the differences of perception.

Considered in terms of functional logic the primary narrative level has a denotative function, the second level of the thought experiment has a performative and exemplificatory function, while the third level has a transformative function. All three together are part of the process of interformation, the process of creation as reconfiguration: Einstein correlates the principles of two theoretical fields, that are in certain respects incompatible, reworks their measurement and modeling practices and recodes them to a new, relativistic theory, through the introduction of the Lorentz transformation relation.

It is important to keep in mind the following: The level of metadiegesis is worked out during the process of modeling. The goal is to legitimize it logically to the extent that it does not remain an internal modeling only. Its mathematical legitimization and its narrative plausibilization through the thought experiment lead it to undergo a metamorphosis through metaleptic transgression. After it is tested and if it cannot be falsified, it becomes the starting point, the theoretical frame, the 'extradiegetic level' for the future. As long as no experiment falsifies the theoretical prediction, the theoretical model can be validated

as a fact. It became the standard assumption for all subsequent relativistic theoretical modelings in physics after 1905, which from then on must take into account the relativistic Lorentz transformation. New physical theories can advance to fundamental laws only when they have taken into account this newly established symbolic code of the theory of relativity.

Einstein succeeded in actually operationalizing the definition of time in physical terms, and thus in revising the classical definition of absolute time. By superposing the principle of relativity with the principle of the constancy of light velocity, physics ensures the experimental controllability of the new interformative configuration. Narrative relates the mathematical model to the reference frame of human experienceability and simulates possible experimental designs to test this new emerged view on reality through the theory of relativity. If this succeeds, then the mimesis-dimension of the model can be reversed. Thus it would no longer be a retrospective model of reality, but a prospective model, which offers a new epistemic access to reality. It is in such cases of fundamental conceptual changes that mathematics is complemented by narrative strategies in an interinformation process. The function of narrativity is to provide a system of observation that makes visible the epistemic, experiential and experimental structures of the new theoretical conceptions and the structures of creation as reconfiguration.

4.1 Eventfulness and tellability

The feature of “tellability” can indeed be ascribed to the Einsteinian treatise, because the text presents wholly new concepts as: the relativity of simultaneity, time dilation, the fourdimensional space-time and the equivalence of mass and energy. All four are disruptive concepts in the sense of Greimas and Porter Abbott, for they lead to subversion of old physical knowledge systems and implicitly to the reorganization of the experience of reality.

Wolf Schmid and Peter Hühn have declared the criterion of eventfulness to be the most important defining criterion of narrativity. Both build on Lotman's conception of literature as a secondary modeling system and from his definition of the “sujets” of narratives. That is a type of change of state of a special kind, which Lotman defines in terms of the categories of space and with reference to semantic fields: “an event in text is the shifting of a persona across the borders of a semantic field” (Lotman 1977, 233; 1972, 336). Yet as a cultural semiotician, Lotman naturally intends not only the transgression of a topographical border, the border can also be of a pragmatic, ethical, psychological or epistemological nature. Wolf Schmid has adopted and developed Lotman's concept of event:

In today's narratology the concept of an event is somewhat more widely understood than with Lotman. An event is not necessarily the violation of a norm. It does not necessarily consist in the deviation from what is lawful in a given narrative world, the fulfilment of which maintains the order of this world. [...] An event can also consist in a figure making a new recognition, revises a wrong understanding, committing to new values. [...].³⁴

(Schmid 2017, 66–67)

Schmid emphasizes in *Narratology* as well as in his *Mental Events: Changes of Consciousness in European Narrative Works from the Middle Ages to Modernity* [*Mentale Ereignisse: Bewusstseinsveränderungen in europäischen Erzählwerken vom Mittelalter bis zur Moderne*] (2017), that this feature of eventfulness applies not only to literary-fictional texts in a narrow sense, but also to argumentative and descriptive texts. Schmid additionally specifies to what extent eventfulness may be attributed to descriptive and factual scientific texts:

[...] the resultant narrativity is related not to what is described but rather to the presence that describes and the way in which it does so. The changes that take place in this case are related not to the *diegesis* but to the *exegesis*; they are changes in the consciousness of the describing authority [...].³⁵

(Schmid 2010, 6)

I deal with the criteria of disruption of knowledge systems, eventfulness and tellability because they are important for the analysis of the epistemic narrativity of Einstein's text, as a mode that complements descriptive and argumentative discourse modes. Einstein's treatise concerns the transgression of a cognitive boundary in the sense that principles and modeling practices that were previously contradictory are intersected in his treatise. The abduction process and the introduced Lorentz transformation led – through the mediation of epistemic narrativity – to epistemic transformation. This is the quintessence of the process of interformation.

Schmid extends the concept of change of state from classical narratology by specifying criteria with which one can identify high eventfulness and a

34 Transl. by MS. "In der heutigen Narratologie wird das Konzept des Ereignisses etwas weiter gefasst als bei Lotman. Ein Ereignis ist nicht notwendig die Verletzung einer Norm. Es besteht nicht notwendig in der Abweichung von dem in einer gegebenen narrativen Welt Gesetzmäßigen, dessen Vollzug die Ordnung dieser Welt aufrechterhält [...] Ein Ereignis kann auch darin bestehen, dass eine Figur eine neue Erkenntnis macht, ein falsches Verständnis revidiert, sich zu neuen Werten bekennt. [...]" (Schmid 2017, 66–67).

35 "[...] Das ist [...] eine Narrativität, die nicht auf das Beschriebene, sondern auf den Beschreibenden und seine Deskriptionshandlung bezogen ist. Die Zustandsveränderungen, von denen hier erzählt wird, beziehen sich nicht auf die *Diegesis*, sind nicht *diegetische* Veränderungen, sondern beziehen sich auf die *Exegesis*. Es handelt sich bei den *exegetischen Zustandsveränderungen* um Veränderungen im Bewusstsein der beschreibenden oder erzählenden Instanz [...]" (Schmid 2014, 7).

correspondingly high diegetic tellability. The first condition for Schmid (2017, 68) is that of facticity (in the context of the fictive world, of course, Schmid adds). This criterion of facticity holds true for Einstein's text doubly, perhaps triply. Time dilation and length contraction, both of which violate all possible codes, rules and experiments of physics before 1905, are first presented in fictional thought experiments and then substantiated by arguments. They cause a disruption of the tradition of knowledge systems, a violation of the semantic rules of the entire semiosphere. They are subsequently demonstrated through numerous experiments. The criterion of facticity for eventfulness and tellability would thus not only be fulfilled but also re-interpreted. Through his theory, Einstein forces the reader to a new logical investigation, verification and testing of hitherto assumed facticity. Through the thought experiments represented, he induces a reconceptualization of previous definitions of factuality, a rethinking of what can potentially be declared factual.

Wolf Schmid's second criterion is that of resultativity. Events are "not only begun, but rather are resultative, i.e. in the narrative world of the text they arrive at a conclusion" (Schmid 2017, 70).³⁶ Insofar as this is possible in an argumentative text of a theoretical nature, in which one cannot carry out any practical experiments, Einstein's text not only presents the relativity of simultaneity, time dilation and length contraction, as well as the non-existence of the ether, it also anchors them epistemologically, at the argumentative level, through the mathematical model of the Lorentz transformation.

The third criterion of narrativity and eventfulness is that of relevance. For Schmid the "concept of relevance is relative," for one must ask, "Relevant for whom? [...] Trivial, everyday changes do not constitute an event." The concept is thus level-specific and context-sensitive. This question also arises, of course, in the case of special relativity theory. For its validity is limited to phenomena that can be attributed a velocity approaching the speed of light. In everyday life one cannot perceive this. That's why these phenomena have long considered to be hardly conceivable for the common-sense intuition. However, on an epistemological basis, time and space are no longer distinguishable from one another. They merge into a four-dimensional space-time continuum, as Einstein showed. Furthermore, the relativity and context-dependency of the proper-time of each observer in each reference-system is of the highest cultural relevance, as the cultural reception of the theory of relativity has demonstrated.

³⁶ Transl. by MS. "nicht nur begonnen, sondern sind resultativ, d. h. gelangen in der jeweiligen narrativen Welt des Textes zum Abschluss" (Schmid 2017, 70).

“The eventfulness of a change of state increases to the degree that a revision of the achieved state is improbable” (Schmid 2017, 79).³⁷ Thus Schmid defines the criteria of consecutivity and irreversibility. Of course, one could cite whole libraries of literature to prove the consequences of special relativity theory. At this point it is sufficient, however, to state that it has not yet been refuted. As long as special relativity theory is valid, all further fundamental theories of physics will rely on it.

Summing up the previous section, I find it important from the view of literary scholarship to show how physics works with this ternary argumentation-structure on well-defined levels, and argues in a differentiated way, because this makes clear that even for physics the way to objectivity is in principle only possible by taking into account the specific differences of reference-systems and their perspectives.

Einstein’s treatise uses functional epistemic narrativity to performatively demonstrate the epistemological consequences of superimposing the principle of relativity with the constancy of the speed of light. The narrative structure first creates the conditions for observation from different perspectives. This grants the addressee epistemic access to the statements of the theory of relativity, so that he can reflect on their epistemological consequences. For the principle of relativity is based on the existence of two reference-systems of observation and the difference between them. Einstein asks then: is there then a possibility of correlating these observations with one another, by taking into account their difference and context-dependency yet nevertheless grant the measurement results objectivity? This possibility exists, as Einstein shows, but it is not guaranteed either by empirical means or by the primary modeling of the measurement narrative. Mathematical modeling in correlation with epistemic narrativity of the thought experiments that legitimate the re-conceptualization of spacetime opens up this view of objectification of two correlated relative observations. It connects the principle of relativity with a principle of covariance, which guarantees the objectification of observation on a tertiary level. This covariance cannot be absolutized either, however. Every covariance always applies, as Felix Klein (1974) has shown in his *Erlanger Programm*, under a transformation group. This transformation relation is symbolically configured on the third level of modeling.

This is the most important aspect showed through the analysis of the process of interformation. That we can observe context-dependency on the primary

37 Transl. by MS. “Die Ereignishaftigkeit einer Zustandsveränderung nimmt in dem Maße zu, wie eine Revision des erreichten Zustands unwahrscheinlich ist” (Schmid 2017, 79).

level of modeling; at the level of denotation, the difference remains. But at the same time it can go beyond denotation on the second level of modeling, on the level of mathematical exemplification. Mathematics and the epistemic narration are the semio-logic premisses for the creation of that correlation that enables the third-level transformation relation between domains that had not previously been connected in this way. This configuration is only valid, however, when the third modeling level³⁸ exists, which sets up a configuration in which a symmetry-transformation makes comprehensible why the *difference* on the denotation level *as well as the second-order equivalence* on the exemplification level are legitimate, because there exists the Lorentz transformation relation that correlates both measurements in the context of the new theory of special relativity. It shows symmetry-relations that make possible the covariant transformation from one domain to another.

My way of reading the Einsteinian treatise comes to the conclusion that it is important always to jointly conceptualize primary modeling in its relativity and context-dependency, and secondary/tertiary modeling in its covariance and context-independence. They mutually condition one another. The theory as a whole will be successful if the contradiction that exists between the context-dependency of primary modeling and the context-independence of secondary/tertiary modeling is not “resolved,” but rather the tertiary meta-level makes recognizable why the differences on the primary level are as necessary as the equivalences due to the existence of the Lorentz transformation relation.

The Lorentz transformation mediates between the coordinates of the world-lines of internally focalized observers. Thus one can say of the observer-figures that they are indeed internally focalized, but nevertheless could exchange their results with one another through this transformation relation. Through the Lorentz transformation, the horizons of knowledge and perception of the two observers are objectively correlated such that they can retain their subjective observations from their own world-lines, from their subjective horizons of knowledge and perception, without absolutizing relativity into relativism. However, the internal focalization of the first system and the external focalization of the second observer system need not fall apart into opposites, if they contradict one another. For there is a third way, a possibility of mediation, of transformation from one reference-system into the other. This ensures that both reference-systems are held equal in their possibilities of perception as well as knowledge.

³⁸ See the next chapter for a detailed consideration of the systematical and semiological functions of the first, second and third modeling level in physics.

If I repeat the foregoing perhaps somewhat too frequently it is because it seems necessary to me, insofar as many popular-scientific presentations of the theory of relativity portray the first-order differences at the level of primary physical effects, and neglect the associated and simultaneously given, indeed necessary, second-order equivalence relative to the space-time structure conditioned by third-order transformation relation. This is a serious problem, because it leads to the fact that the theory of relativity – partly under the influence of the name that Planck had chosen for it (*nomen est omen*) – in the popular discourse could degenerate to the slogan “everything is relative.” Einstein himself warned against confusing the principle of relativity with relativism.

4.2 Towards an interformative narratology of science

In his 1923 Nobel Prize speech, Einstein looks back on the development of the theory of relativity and as a starting-point for his reflections, beyond the already represented principle of relativity, sets an epistemological constraint, which is important for our analysis. It states that one must always be able to attribute meaning and reference to the concepts introduced by theoretical physics. Thus, “concepts and distinctions are only admissible to the extent that observable facts can be assigned to them without ambiguity (stipulation that *concepts and distinctions should have meaning*). This postulate, pertaining to epistemology, proves to be of fundamental importance” (Einstein 1967 [1923], 482; italics by AH).³⁹

In the case of special relativity theory, mathematical equivalences are established between the three dimensions of space and one dimension of time, as well as between mass and energy. The quantitative equivalence is established in the symbolic form of numbers, which symbolize in a purely monoplanar way according to Hjelmslev.⁴⁰ This is only possible because the system of

³⁹ “Ferner erweist sich das erkenntnistheoretische Postulat als fundamental: Begriffe und Unterscheidungen sind nur insoweit zulässig, als ihnen beobachtbare Tatbestände eindeutig zugeordnet werden können. (Inhalts-Forderung für Begriffe und Unterscheidungen)” (Einstein 1923, 1).

⁴⁰ For Hjelmslev, the criterion of mono- or bi-planarity is decided by the existence of two levels of language, which are governed by different codes that are not congruent. An example is the verb-form “am,” which is coded at the sound-level by phonetic rules, and at the content level by morphological rules (verb, first-person, singular, indicative). “But when we wish to decide to what extent a game or other quasi-sign-systems, like pure algebra, are or are not semiotics, we must find out whether an exhaustive description of them necessitates operating with two planes, or whether the simplicity principle can be applied so far that operation with one plane is sufficient. The prerequisite for the necessity of operating with two planes must be

numbers is free from empirical denotation. Numbers establish a quantitative equality between qualitatively different things, due to the fact that modeling by mathematics is monoplanar: there is no referential relation to reality beyond the symbolic form of mathematics. Functional concepts are thereby symbolically defined, they are only mathematically modeled, and receive no adequate semantic correlate. The language of physics in this phase of modeling is submitted somewhat to the monoplanarity of the symbolic system of mathematics.

When it comes to processes of communication, theory presupposes a broad-based concept of semiotization. This encompasses not only symbolically operational mathematics, but also meanings that show correspondences in the world of the language user. Thus this concerns the mathematic, semantic and pragmatic integration of new theoretical concepts. The interformative process makes visible the need to constitute a new frame for the theory of relativity. This new frame is the product of secondary and tertiary modeling, which will now take precedence over the previous measuring practices of experimental physics. Central concepts of space, time and energy have to be re-semiotized. That means, that also the prior primary level of modeling has to be recoded and transformed from Newtonian mechanics into relativistic mechanics, because new measurements and experiments rules have to be introduced here. For the reconceptualization of the measurements and experimental practices epistemic narrativity has a key function. Narrative unifies the double-layeredness of theoretical modeling – between physics and mathematics – in its very own particular way: because it can perform test-simulations that function multi-planarly, according to different sets of rules on the syntactic, semantic and pragmatic level. This is its essential epistemic flexibility. In her definition of narrativity, Marie Laure Ryan states:

Most narratologists agree that narrative consists of material signs, the discourse, which convey a certain meaning (or content), the story, and fulfill a certain social function. This characterization outlines three potential domains for a definition: discourse, story, and use. These domains correspond, roughly, to the three components of semiotic theory: syntax, semantics, and pragmatics. (Ryan 2007, 24)

This is one of the fundamental problems that a narratology of science or especially the narratology of physics would have to deal with: Can we eventually

that the two planes, when they are tentatively set up, cannot be shown to have the same structure throughout, with a one-to-one relation between the functives of the one plane and the functives of the other. We shall express this by saying that the two planes must not be *conformal*" (Hjelmslev 1961, 112; cf. also 1974, 108–109).

suppose that the mathematical form of the model could correspond to that, what we call *discourse*, while the semantic “physical meaning” could correspond to the *histoire*? Then we would deal with an intricate problem here: From the perspective of an interformative narratology of science, one could argue that with respect to the development of the theory of special relativity there is a crucial asymmetry between the operations of the so-called “*discourse*” and “*histoire*” level. If we analyze the “*discourse*” level of the mathematical Lorentz transformation relations one realizes that Einstein continues the tradition established in the electrodynamics. The Lorentz transformations existed in the electrodynamics and had been introduced by the physicist Hendrik Antoon Lorentz. Einsteins transfers them to the mechanics and revises the measurement practices of space and time. On the syntactic level of formal discourse nothing is paradox, the transfer is profoundly logical.

One could claim that the crucial changes in worldview, the essential disruption and the so much discussed paradoxies occur on the level of ‘*histoire*’ of the theory of relativity: The reconfiguration of the physical meaning of spacetime, mass and energy. These concepts have to be re-semiotized according to new sign functions that are not commensurable with the previous semantic codes. The new proposed codes have to incorporate mathematic equivalence relations whose epistemologic consequences seem paradox from an experimental and an experiential point of view.

The central question is: How can the new concepts be re-semiotized semantically? How can the new semio-logical codes can be made transparent from an experimental and an experiential point of view? Here narrativity plays a key epistemic role, because it can perform both the disorganization of the old sign functions and the reorganization of new sign functions grounded on semio-logical codes that relativity theory establishes. Without these complete semiotic spectrum of physical concepts – with their syntactic, semantic and pragmatic dimensions, the theory cannot be established.

So the seemingly paradox of the special relativity theory is that on the level of ‘*mathematical discours*’ Einstein’s modeling process is still partially committed to the theoretical tradition. He preserves the principle of relativity of mechanics, but transfers it to the other theoretical field of electrodynamics. He preserves the Lorentz transformation that was valid for electrodynamics, but requires it also for mechanics. Rule-guided interpolation is ensured, because it is well understood which modeling practices are to be intersected. On the mathematical, formal, *discours* level we analysed this double transfer. But what results from the interformation no longer corresponds to the rules of the discursive formations that have entered the interformation process. How is the result of

interformation to be read and interpreted from the perspective of the semantics and pragmatics?

A new framework of symbolic reorganization of reality has been established through exemplification, “representation as” and “creation as reconfiguration” due to the Lorentz transformation relation. To generate this new framework, it was not only necessary to do the maths, but it was also necessary to set up a narrative system of third-order observation that allows to show the following: The new operational concepts, space-time as a four-dimensional continuum, the relativity of time and length, the equivalence between mass and energy, are mathematically modelled within the special relativity theory and re-sort the conceptual categories in new ways by introducing new equivalences and new differences that have emerged from interformation. But how do these new concepts can get adequate semantic correlations and comply to Einstein's constraint to have “physical meaning?”

Interformation is performed by *mathesis* and *diegesis*. *Mathesis* operates logically-syntactically but mono-planar in Hjelmslev conception. The whole modeling configuration has to follow the same system of rules – coherently. *Diegesis* can operate multi-planarly and display different ruling codes on different levels in order to simulate possible reconceptualizations of the ‘physical meaning’ of the theory. The operational results in the mathematical setting of the Lorentz transformation are logically comprehensible after the interformation. The tensions and resistances play out at the semantic level. For the concept of space-time can indeed be mathematically unified in a four-dimensional space-time manifold, as Minkowski (2012, cf. also 1909a) demonstrated this in the context of the 1908 lecture before the Mathematical Society in Cologne. But what does the four-dimensional space-time manifold mean for the broader semiosphere? How does one deal with the space-time continuum, given that everyone's primary everyday intuition very well (and with good reasons) continues to distinguish between space and time? The tensions and resistances play out at the semantic level of creating new correspondance relations to the experiential human realm. That is a matter of interpretation. Then of course the question arises: How does one re-establish connections between the operational concepts and the perceptible “phenomena of reality?” Which semiotic codes are now to be applied? How can logical-mathematical operations be semiotized? Does conventional language have the necessary semio-logical repertoire for this?

Mathematical modeling has no claim to semanticity. Primary physical modeling is tied to measurement and facticity. Scientific discourse therefore relies on thought experiments. The narrative thought experiment is performed in order to simulate different transformations and to reflect on their epistemological

consequences and their “physical meaning.” Although the theoretical model is not yet mature enough to generate experiments for its validation or falsification, it nevertheless suffices to sketch a narrative simulation that performs future experimental practices symbolically. In this way the semanticity of the *diegesis* comes into play. Narrative techniques makes it possible to construct a simulative symbolic world: a thought experiment that can be verified or falsified later on by real experiments. The semantic and pragmatic rules of correspondence to experimental practices and their empiric referents are established subsequently through new narrative thought experiments that recode and reframe the previous operational definitions of physics. Mathematics configures the objects of reflection on the semio-logical stage of the mathematical discourse, while narratives configure the structure of observation, visualization and reflection on the semio-logical stage that simulates experientiality.

Mathesis and *diegesis* would ideally work hand in hand, to take on the functions of interformation and transformation. *Diegesis* needs mathematics, in order to logically ground the transformation. But *mathesis* in turn needs *diegesis* in order to lend the new model semantic and pragmatic shape. Mathematics does not operate in a multi-planar way, using the syntactic, semantic and pragmatic dimension. *Diegesis*, the narrative process and its framing techniques, proves to be important at this point. *Diegesis* can configure a framing-structure of conceptualization that makes the re-ordering of knowledge systems plausible. Through its technique of *emplotment*, narration adopts this function through the thought experiment. It enacts performatively an imaginative test-simulation of the new theoretical model, even when this still unfolds under the *caveat* of fictionality. And it does so by exemplifying measurement narratives that are potentially accessible from a human experiential frame of reference. This is the epistemic function of narrativity in Einstein’s treatise: it provides the discursive form for the exemplification of the transformation of codes – measuring and mathematical modeling codes and practices. It does so “in terms that are assimilable to a human experiential frame of reference” (Walsh 2020, 421). Due to narrativity the semio-logical spectrum that has been split for the purpose of formal theoretical modeling can be reconfigured. It bridges the gap between the scientific theoretical modeling that can not be simulated on the formal syntactic level without a correlation to the semantic and pragmatic frame of reference – that means, in Einstein’s terms, without a connection to the new “physical meaning” that reorganizes our view on reality. The correspondence relation changes its direction. One starts to seek empirically for something that hasn’t been measured or observed before, but that is predicted by the theoretical model. The theoretical model gives a hint to that what should be sought for, what can finally be found through empiric experiments. The process of

interformation supposes a controlled intersection of known principles and practices. But what results logically and semiologically from the cross-over surpasses the earlier modeling levels by one dimension. A new order of knowledge comes forth, although the orders of knowledge that were intersected were known. The emergent order is more than the sum of the previous orders. Thus new codes also emerge through the process of interformation and the process of interformation becomes a matrix of transformation of knowledge-systems; that is its epistemic function.

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