GREGOR SCHIEMANN

THE LOSS OF WORLD IN THE IMAGE: ORIGIN AND DEVELOPMENT OF THE CONCEPT OF IMAGE IN THE THOUGHT OF HERMANN VON HELMHOLTZ AND HEINRICH HERTZ[1]

In searching for the origins of current conceptions of science in the history of physics, one encounters a remarkable phenomenon. A typical view today is that theoretical knowledge-claims have only relativized validity. Historically, however, this thesis was supported by proponents of a conception of nature that today is far from typical, a mechanistic conception within which natural phenomena were to be explained by the action of mechanically moved matter.

Two of these proponents, Hermann von Helmholtz and his pupil Heinrich Hertz, contributed significantly to the modernization of the conception of science. Paradigmatic for their common contribution to this development is the way in which they employed the concept of *image*. By considering the origin and the different meanings of this concept we may trace a line of development which begins with Helmholtz's original claim that a universally and forever valid theory provides a unique representation of nature. It continues with the realization that the status of scientific knowledge is capable of revision; and it arrives at Hertz's admission that a variety of theories over a domain of objects is possible, at least at times.[2]

1. PICTORIAL ASPECTS OF THE SIGN
ELEMENTS OF HELMHOLTZ'S CONCEPTION OF SCIENCE UNTIL ABOUT 1870

Throughout his life Helmholtz stood for an empiristic conception of science. That meant that science should derive its knowledge by the generalization of specific experience through the method of induction. On this basis Helmholtz began in the 1860s to characterize the laws known through natural science by the concept of *image* [*Bild*].[3]

Before then, Helmholtz had trusted that scientific theories could do much more than merely provide an image of the world. According to his early scientific and popular lectures, theoretical natural science did not merely comprehend empirical lawful regularities, but also discovered the substantial causes of the appearances, which are, according to Helmholtz, completely determined mechanically (1889, 4f.; 1882, 2:608f.; 1903a, 1:40f. and 45). The concept of the image always implies a separation of the represented from the representation.[4] On Helmholtz's early views, however, scientific theories penetrate their objects, so to speak, exploring their inner structure. Like probes they yield glimpses of hitherto unseen worlds, and they are therefore true in the objective sense (1889, 7; 1903a, 1:41).

D. Baird et al. (eds.), Heinrich Hertz: Classical Physicist, Modern Philosopher, 25–38.

Helmholtz initially placed this objectivity in strict opposition to the merely subjective testimony of sensory perception in the life-world; this perception does not have any immediate access to reality but consists in the psychological processing of sensations. The peculiarity of the sensations is determined by the constitution of the sense organs. Their specific manner of excitation is triggered only by external stimuli. Because the sensations do not bear any resemblance to these stimuli, he labeled them and the perceptions which they trigger "signs" or also "symbols" (1882, 2:608; 1903a, 1:41ff.).[5]

By using the expression "sign," Helmholtz points to a particular analogy: he compares the sensations with the characters of written script. In doing so he suggests that the internal sensations resemble the external world as little as, for instance, the name of a person resembles the person itself (1882, 2:608 et passim). But the analogy has its limits. While a name can designate various persons or objects, the signs of sensation satisfy a one-to-one correspondence, which I will call *sign-constancy*: to one sign of sensation should always correspond at most one thing (1882, 2:608; cf. 1903a, 1:41ff.).[6]

The contrast between the sign-character of perceptions and a scientific cognition of reality is founded on Helmholtz's understanding of causality. According to him scientific statements have the same causal structure as the real happenings in nature. In contrast, the psychological process producing the sensory perceptions is irreducibly determined by acausal elements. Helmholtz envisions a changeable, open-ended learning process that is not free of errors (e.g., hallucinations). In it, an autonomous subject steps into the relationship between sign and signified in a constitutive manner, creating what may be called a triadic relation. Whether a sign has been understood correctly can be judged only in relation to its successful application. Therefore the subject needs to be accorded a certain scope of action which Helmholtz equates with freedom of the will (1903a, 1:114; 1856, 427ff. and 797f.). In contrast to Kant, Helmholtz supposes that those phenomena determined by freedom of the will cannot be completely explained causally (1882, 1:13).[7]

Sensory perception can therefore become an object of science only partially, to the extent that it agrees with the law of causality. Thus, in order to penetrate into reality science must probe, in each individual case, whether what the senses declare to be similar or different is in fact similar or different (1903a, 1:40). The sensations that are expressed in script fail to contain objective truth whenever they fail to be causally connected.

With the introduction of the concept of the image, Helmholtz signals a departure from his critical view of the truth-content of signs of sensation. In 1856, in the first edition of his *Handbook of Physiological Optics*, he partially suspends his previous strict opposition of objective and subjective knowledge in order to ground the truth-claims of scientific statements. Going beyond the afore-mentioned sign-constancy, he now postulates the temporal congruence of sign and signified in a theory of perception:

> The only relation in which there can be real agreement between our perceptions and reality is the temporal sequence of events with its various peculiarities. Simultaneity, succession, the regular recurrence of simultaneity and succession can happen in our sensations just as well as in the events. (1856, 445)

In addition to sign-constancy, a second non-causal congruence of sign and signified is herewith established. While the first concerns the relation of sign to object, the latter relates the temporal structure of the signs to that of the object's properties. Through this congruence in temporal sequence, the signs change their character significantly. They break the scientific monopoly on truth and can give information about "the true essence of things," as Helmholtz says now (1856, 446). In order to denote the sign's more inclusive relation to reality, Helmholtz speaks for the first time in his *Handbook* about "images":

> Thus the representations of the external world are images of the lawlike succession of natural events. (1856, 446)

Helmholtz here uses the concept of image in the sense of a strict representation [*Abbild*]. The temporal constitution of the presupposed causal structure of the world is reproduced without distortion in sensory perception. Originating in the theory of perception, this concept of the image soon serves to provide a new determination of the task of science. The object of science is now to "discover and combine into a law" the temporal structure which is inserted into perception (1903a, 1:319f.). Scientific knowledge, insofar as it consists in statements of causal law, becomes the pure presentation of the pictorial component of sensory perception. From now on Helmholtz will emphasize that natural laws have the character of a representation of "natural phenomena ... with respect to succession in time" (1903a, 1:395; cf. 1903a, 2:222f. and 358; 1885, 586). As science's relation to reality becomes restricted to the perceptible, science loses its unrestricted access to reality. Because laws can only picture the non-intuitive and mathematical relations between properties of objects, natural science can no longer claim to reach the objects themselves, the substantial reasons for the phenomena.

While he uses the expression "sign" throughout for a characterization of sensory perception and sensation, Helmholtz's use of the concept of the image fluctuates. Most of the time he interprets it in the sense just elucidated, namely as strict representation, but occasionally also in the sense of a sign.[8] When he tries in some passages of his public speeches to illustrate the relation between sign and image by drawing on the example of the arts, one has the impression that he places the concept of image in a third, more comprehensive meaning above the concept of sign.[9] In this interpretation, the concept of image is akin to the concept of a work of art. It has a content which extends beyond the relationship of equality or similarity, and this content belongs only to the image but not to its object. It is subject to all kinds of intentional shaping and is therefore meaningless for science.

2. SIGN-ASPECTS OF THE IMAGE

ELEMENTS OF HELMHOLTZ'S CONCEPTION OF SCIENCE AFTER ABOUT 1870

Until roughly the end of the sixties Helmholtz endeavoured to justify the truth-claim of scientific knowledge. During the seventies, there occurs a change in the development of Helmholtz's philosophy of science which points in a completely

different direction: on the basis of his theory of perception he begins to relativize the claim to validity which hitherto he had held absolute. The conceptual distinction between sign and strict representation becomes less and less marked. The truth-conditions for signs, which always depend on some success of an action, begin to hold more and more for the scientifically established representations of reality as well. The psychological processes determining the creation of signs become elementary conditions of cognition which in principle can no longer be transcended by scientific cognition.

The possible background and motives for this profound change are various; Helmholtz never explicitly addressed them. Among the most important ones, I wish to mention these: Helmholtz followed a general trend in the natural sciences during the second half of the nineteenth century towards an increasing hypothesization of scientific propositions; this change of his conception of science is related to a crisis of his mechanistic conception of nature, which was to have been a representation of the first causes of nature; and finally this change must be understood as part of the extension of his theory of perception towards a comprehensive theory of knowledge.[10]

In his second speech of 1892 about Goethe's scientific work, Helmholtz found the "final result" of his epistemology summarized in the sentence by Goethe, "All things transitory are only symbols [*Gleichnis*]." To this Helmholtz adds:

> That is, what occurs in time and what we perceive through the senses, we know only in symbols. I hardly know a more pregnant way to express the final result of our physiological theory of knowledge. [...] All knowledge of the laws of nature is inductive, and no induction is ever totally complete. We feel [...] our inability to penetrate further [into nature] as a kind of anxiety. (1903a, 2:358)

The nature of "transitory things" is still considered to consist in their temporal causal structure; this is represented in perception, the sign-character of which Helmholtz here refers to as "symbol" [*Gleichnis*]. Until roughly the end of the sixties, Helmholtz assumed that this structure is expressed in the experimentally and inductively established laws of nature and that it can be entirely reduced to mechanical laws. But now it is no longer possible to complete this reduction if the process of induction cannot be completed, i.e., if there is a remnant of the true causal structure or its representation in perception which eludes science. The content of perception is now richer than the laws known by science, which always remains incomplete in regard to reality. But the knowledge of laws neither changes its causal structure nor its formal mode of presentation (1882, 2:640ff., 3:176). What are subjected to change are its conditions of validity. The relationship of representation can be assumed only as an idealized relationship and can be ascertained only approximately (1903a, 2:243, 393, and 183f.; 1882, 2:642).

When comparing Helmholtz's concept of image with that of Hertz, it is important to realize that Helmholtz expands his original conception of signs, which is rooted in a theory of perception, into a naturalistic theory of knowledge. This process finds its most pointed expression in a new determination of thought, which Helmholtz had originally viewed as a high court of cognition that would ensure

agreement with reality.[11] But already towards the end of the seventies he was convinced that in principle thinking is not free of the sign-character.

> ...[with this psychological processing of cognition] we are obviously dealing with an elementary process that lies at the bottom of all really so-called thinking, even if the critical review and completion of the particular steps may be missing here, a critical review and completion that enters the scientific formation of concepts and deductions. (1903a, 2:233)

Now all that the scientific formation of concepts and logical deductions from statements of law can accomplish is already predetermined in "every particular step" by the psychology of perception. Under these conditions, no autonomy free of experience adheres to thought (which will be Hertz's point of departure). Thought cannot be an independent court for validity but is part of the domain of an empirical science which can only approximate the ideal of truth.[12]

The aspects discussed so far concern that side of the representation that is inserted into sensory perception and that can be presented as law. However, the mode of existence of the represented, of causally structured reality, also became increasingly questionable for Helmholtz. Well into the seventies he had made the realistic assumption of a reality independent of cognition. In a central passage of his 1878 speech "The Facts of Perception," however, Helmholtz relativizes his realism. He recognizes idealism as an equal and irrefutable epistemological alternative and refers to both realism and idealism as "metaphysical hypotheses" (1903a, 2:238f.).

Briefly, the change in the determination of representation and represented is that Helmholtz becomes increasingly uncertain about the supposed congruence between them. The scientific representation of the world loses its indubitable reference to the world and diminishes in permanence and sharpness. One can also consider this as the outcome of a subordination of thought to the conditions of relating to experience, a relationship to which Helmholtz, in contrast to his early conception of science, now accords only approximative validity.

3. IMAGE-MULTIPLICITY OF SIGNS
HERTZ'S PHILOSOPHY OF SCIENCE IN THE *PRINCIPLES OF MECHANICS* (1894)

Just like Helmholtz, Hertz uses the concept of image to point to the only agreements that can exist between the external world and one of its representations. From sign-constancy and from the simultaneity of sign and signified Helmholtz had derived the claim that all scientific knowledge of laws has the character of a representation. In Hertz's philosophy of science there is also talk of representations. To him, scientific theories are "images" which merely satisfy a "first fundamental requirement" (PM 2) in relation to the external world: in the "necessary consequents of the images in thought" they can agree with the "necessary consequents in nature of the things pictured" (PM 1).[13]

Hertz does not give any criterion for the representation of objects, however, besides the congruence of "consequents." He restricts the relation between the presentation and the presented to the predictions which can be deduced from a theory and tested by experience. Neither the content of a theory, nor its principles, concepts and laws, but only its results can still be linked to the external world. Contrary to Helmholtz, Hertz did not advocate an inductivist conception of science, but a deductivist one.

This additional step towards a loss of truth in theoretical cognition is reflected in the change of meaning of the concept of "image." In contrast to Helmholtz, whose representations concerned merely the temporal structure of reality, Hertz's concept of image postulates elements of theory which have no cognizable connection to what they present and which for Helmholtz would have merely been "signs" or "symbols." To one reality, which Hertz, too, conceives realistically, can now correspond a multiplicity of theories. The world seems remote and the concept of representation inappropriate. If Hertz uses it anyway, this expresses his hope that the gap between presentation and what is presented may only be transitory, and his hope that the surmised mechanical cause of all phenomena can yet be found. Closer scrutiny reveals how this mechanistic objective, which he shares with Helmholtz, influences the determination of his concept of image. It also reveals how this shared objective does not preclude a modernization of the concept of science that goes further than Helmholtz's.

In an article on the seventieth birthday of Helmholtz, Hertz mentions as a third "title to fame" besides the invention of the ophthalmoscope and the discovery of the Principle of the Conservation of Force, Helmholtz's work on the physiology of the senses, and emphasizes "how closely these investigations are connected with the possibility and legitimacy of all natural knowledge" (Misc 336f.). Although he never explicitly refers to Helmholtz's theory of signs or to his concept of image, it can be assumed that Hertz was aware of both and recognized their significance for philosophy of science.

Tellingly, Hertz goes on in his article to present Helmholtz's theory of perception in a manner best suited to its early stage of development. He believes that he finds support in Helmholtz for his own view of sensory sensation as a passive mediator between two entirely separate worlds. He does not at all consider the psychological mechanism involved in the processing of sensations as that elementary process of which Helmholtz later said that it "lies at the bottom of all really so-called thinking."[14] In his article, Hertz poses rather schematically the following question:

> Is the manifold of these relations [mental conceptions formed by the visual sense] sufficient to portray all conceivable manifolds of the external world, to justify all manifolds of the internal world? (Misc 336)

Three years later Hertz provides the answer in the *Principles of Mechanics*, the introduction to which can be considered his contribution to the philosophy of

science. There he says that a "universe conformable to law" cannot simply result from perceptions that are triggered by sensations (PM 25). This already contains both the essential contrast with Helmholtz's conception of representation and the point of origin for Hertz's multiplicity of images. While the mind may recognize certain regularities in perception, it cannot derive from them a complex of laws that encompasses the external world. Hertz relates this to representations in the life-world which proceed from immediate sensory perceptions, and he relates it equally to scientific knowledge. In their relation to the world, both life-world representation and scientific knowledge satisfy only the "first fundamental requirement." Only their necessary consequents correspond with nature. Therefore, Hertz designates both as "images."[15]

Scientific knowledge differs from representations in the life-world only in that science requires possible criteria for the evaluation of images to be formulated explicitly.[16] The difference between the two had already been continually diminished by Helmholtz. It now appears to be only a matter of degree. This impression is strengthened by the fact that one does not find in Hertz a distinction comparable to Helmholtz's persistently upheld division between sign and representation. In Hertz's work, the word "sign" generally represents the views, expressions and connections that are contained in images, be they images of the life-world or of science (PM 7, §297).

But it would be a mistake to assume that Hertz equates, in their pictorial aspect, scientific theories and representations in the life-world. A first, though hardly perspicuous clue is provided by Hertz himself when his first mention of the unrestricted possibility of representing one object by means of "various images" is made only in regard to representations in the life-world (PM 2, §297).

Why does this possibility exist and to what extent does it obtain in science too? Hertz first addresses the former question: representations are "not yet uniquely determined" by the agreement of consequents necessary in thought and consequents necessary in nature (PM 2). The supposition of an autonomous mental capacity (shared by all humans) is implicitly involved here. This capacity need not stand in any relationship to real objects or to its properties. It does not, by self-imposed prescriptions deprive itself of multifarious possibilities of representation. This supposition would have been unthinkable within Helmholtz's later conception of science. Can Hertz's supposed freedom of mind unfold in science? Or does it face restrictions which ultimately lead back to Helmholtz's injunction to create a uniquely valid theory?

The three famous criteria and their elucidations used by Hertz to evaluate the images of science embody the encoded answer to these questions. While the first two criteria, which I wish to call liberal-rational, permit a multiplicity of images, the third establishes a rather conservative order among the possible images of a domain of objects.

The first criterion of "permissibility" formulates a minimal condition on the form of images: images may not "implicitly contradict the laws of our thought [and] shall be logically permissible" (PM 2). Hertz accords greatest significance to this criterion (PM 33f.). However, he is rather reluctant to specify more precisely what

he means by "laws of thought." He basically rests content with the broad statement that "the nature of our mind" can be decided upon "with validity for all time" (PM 3). Whatever these properties might be, once recognized or established they are equally valid for all images.

Not only do Hertz's remarks on the further determinations of the laws of thought remain vague overall, but they are also not free of contradictions, thus violating the criterion itself. For example, one can learn from the introduction and the main body of the *Principles of Mechanics* that he wishes to prescribe more than the laws of propositional logic to constrain the freedom of mind in science. In the first part of the main body he claims that he develops his groundwork of mechanics (his "image" of mechanics) exclusively by means of propositions that are "*a priori* judgements in Kant's sense" (PM §1). However, he adheres to this statement only with his introduction of the concept of time. As soon as he comes to the concept of space, he no longer cares about the difference between synthetic and analytic judgements.[17]

Even when unsatisfied, the claim to a transcendental philosophy yields the necessity that images that fail to satisfy Kant's conditions of the possibility of experience are impermissible. But it seems that Hertz considers the a priori character of an image rather as a peculiarity of that particular image.[18] This is all the more strange since he applies the criterion of permissibility also to the totality of the multiplicity of images:

> In order that an image of certain external things may [...] be permissible, not only must its characteristics be consistent amongst themselves, but they must not contradict the characteristics of other images already established in our knowledge. (PM 22f.)

If one disregards his perhaps merely verbal commitment to a justification of science along the lines of transcendental philosophy, what remains as the most important minimal condition on the form of the images is the demand for freedom from contradictions. The certainty that those sequences of thought at a remove from the world can be in contact with nature at all may be called the Platonic element of Hertz's conception of science.[19] The second criterion shows now that this contact must be highly constrained and that ample scope therefore remains for theories in spite of the logic prescribed to them.

The second criterion of "correctness" imposes a minimal constraint on the content of permissible images:

> We shall denote as incorrect any permissible images, if their essential relations contradict the relations of external things, i.e. if they do not satisfy our first fundamental requirement. (PM 2)

This criterion restricts the agreement of consequents necessary in thought and consequents necessary in nature ("first fundamental requirement") to "essential relations." "Essential" in this context are exactly those successions which, for whatever reason, claim to be empirically verifiable. For correctness is "perfect," he says, when:

> all those characteristics of our image, which claim to represent observable relations of things, do really and correctly correspond to them. (PM 9)

But this perfection need not be permanent. Much more radically than Helmholtz, Hertz assumes that all empirical knowledge is capable of revision. According to Helmholtz's later conception of science, empirical statements served as an only approximately valid but yet increasingly better confirmed basis of validity for theoretical knowledge (Helmholtz 1903a, 2:22, 186, 233). In contrast, Hertz remarks:

> that which derives from experience can again be annulled by experience. (PM 9)

In contrast to its permissibility, the correctness of a theory cannot be decided "for all time." Thus the agreement of consequents necessary in thought and consequents necessary in nature is deprived of any absolute claim to validity. It is questionable in this context why Hertz also considers incorrect theories (as well as incorrect representations) as images. Why should they be images, if they stand in contradiction to the world? In contrast to Wittgenstein's conception, their logical structure is by no means in itself an image of the world.

Since images do not consist of essential relations only, they can be idle and lead to consequents "superfluous or empty" (PM 2).[20] In spite of this description Hertz does not believe it is possible to do without them. Though he includes them among those elements of the image which one "can arbitrarily add or take away," he considers them as an inescapable consequence of the mental origin and character of images (PM 3).

The image of mechanics that Hertz presents as his own serves as the best example that the choice of which statements should be released for empirical verification and which should not is to some degree arbitrary. For the purpose of a mechanistic explanation of the inanimate world, he introduces a new type of inert mass, and postulates that one of its properties is to be unobservable (PM 25f.).[21] In stressing in this and other passages that those "hidden" [*verborgen*] masses are invisible only to the naked eye, Hertz leaves open the possibility of verifying their properties indirectly through physical measurement. Some of these properties are solid connections [*starre Verbindungen*] between masses which provide for constant distance and for "approximately ... invariable relative accelerations between the masses" (PM 41). At the end of his introduction he writes: "Now, if we could perceive natural motions with sufficient accuracy, we should at once know whether in them the relative accelerations ... are only approximately invariable" (PM 41). Here Hertz even speaks of a "decisive battle" [*Entscheidungskampf*], which has to be "fought out" [*ausgefochten*] against other thinkable explanations like those which do not assume hidden masses (PM 41).

First of all Hertz assumed hidden masses only for the purpose of explanation. But if it were possible to verify these hidden masses empirically then, as matters stand, the respective theoretical statements would attain the character of necessary consequents. In this respect, however, Hertz expressed reservations. His remarks did not in principle exclude the possibility that hidden masses could be the subject of experience.[22] Nonetheless, the preoccupation with hidden masses which continued in physics for some time after Hertz died was governed by the continuing

hope that further clues to the nature of these masses might be obtained through a more precise examination of electrodynamic phenomena, in particular those relating to the so-called ether.[23]

The criterion is thus primarily directed against incorrect relations that are contained in theories and cannot be converted by definition into inessential ones.[24] One can see that the criterion does not introduce a serious restriction on the multiplicity of theories. It is rather an encouragement to shield statements which disagree with experience from an empirical test. Had Hertz left it at these first two criteria, he would have closely anticipated a currently widespread liberal attitude towards philosophical evaluation of scientific theories.

The characteristic feature of merely permissible and correct images is that none of them can claim to come closer to its objects than any other. They are equivalent representations of objects. If the domain of objects encompasses all of reality, or – if you will – the truth, and if the only access to this reality consists in equivalent presentations, then the concept of the image itself comes to an end, together with the realistic conception of a reality that exists independently of images. It no longer makes sense to talk about a relation if one of its two components, namely the external world, has completely collapsed into the other.

The full significance of the far-reaching change introduced with Hertz's third criterion of "appropriateness" becomes clear only against the background of this scenario. With this criterion Hertz drastically restricts the conditions under which multiple theories become possible. He subordinates them to a process of adaptation and selection which maximizes the predictive scope and empirical content of theories. The multiplicity of theories is considered not as a permanent state but as a state of beginning or transition, in a development which is directed at the minimization of equivalent presentations. Along with Helmholtz, Hertz assumes that this development approximates the goal of a (mechanical) theory which alone is valid in its time.

Hertz uses "distinctness" to refer to the maximization of predictive scope:

> Of two images of the same object that is the more appropriate which pictures more of the essential relations of the object, – the one which we may call the more distinct. (PM 2)

As long as other objects are disregarded, it is characteristic for Hertz's concept of object that it corresponds rather well to a consilience of a variety of predictions all related to one object within a single image. It corresponds rather less well to the occurrence of such predictions across various images. This theoretical call for unification holds not only for special domains of objects in natural science, but for the totality of natural phenomena in general, at least in the inanimate world:

> We should remember that [when discussing appropriateness] we are considering the whole range of present physical knowledge. (PM 10)[25]

But while the mind has to strive towards a unified image of nature, it can bring one about in a variety of ways. That is why it is possible to start from different sets

of principles in the derivation of predictions. Beyond this, any number of "inessential" or "empty" statements are permitted. The maximization of empirical content is directed against this last rest of a superfluous content of images. Hertz refers to this criterion as "simplicity":

> Of two images of equal distinctness the more appropriate is the one which contains, in addition to the essential characteristics, the smaller number of superfluous or empty relations, – the simpler of the two. (PM 2)

Hertz is convinced that in the course of time we can "finally succeed in obtaining the most appropriate" images (PM 3). If this formulation already suggests the substitution of the multiplicity of images by a single image of reality, this is indeed what Hertz considered possible. About his own proposal for an image of mechanics he says:

> Whether the presentation here given to this problem is the only possible one, or whether there are other and perhaps better possible ones, remains to be seen. (PM xviii)

For Hertz, it is certain that the most appropriate image, if it is possible at all, can only be a mechanical one. The highly complicated image proposed by himself would become significantly simpler if it turned out that all empty consequents proved to be essential. Implicitly, he assumes an agreement between his image and a mechanical structure hidden behind the phenomena.

The criterion of appropriateness restricts the multiplicity of permissible and correct images to such an extent that it relieves them of their relativized equal standing. But this criterion also leaves the images that remain as a kind of knowledge that is capable of revision and that may, if only for a while, grasp in a simpler manner a world that is forever separated from mind.

4. CONCLUSION

Compared to Helmholtz, Hertz departed more clearly from the aim of a complete (mechanistic) explanation of nature, which is still recognized by both as the ideal of cognition. While Helmholtz excluded as a matter of principle the justified coexistence of several theories over a domain of phenomena, the whole objective of Hertz's philosophy of science is precisely to justify this coexistence, at least for the current state of inquiry.

In regard to reality, which both had postulated in a realist manner, there occurred a far-reaching loss of truth that began with Helmholtz and continued with Hertz's philosophy of science. Initially, theories were not images of the world, because they themselves invaded their objects and thus came into possession of the truth. With the introduction of the concept of image, scientific theories become distant from the world: they are merely representations of a lawful structure, of the causal relations between real objects. (Helmholtz is much closer to Wittgenstein's later image-theory of meaning than is Hertz.) What appeared to Helmholtz as an obvious

consequence of this knowledge (the prediction of future phenomena) becomes for Hertz the remnant of what truth natural science can know about the world. The structure of this knowledge need no longer be determinate, as it was for Helmholtz; different images of a domain of phenomena, which can include the whole (inanimate) world, are now possible and can mutually relativize their validity.

If one takes as a benchmark, not the tradition preceding both physicists, but the subsequent development of the conception of science, Helmholtz appears, roughly speaking, to stand closer to the present in one respect. He proposes much more forcefully than Hertz the now broadly accepted removal of the distinction between a priori presupposed laws of thought and those empirical propositions that are capable of revision. With him, thinking loses its function of safeguarding assertions and becomes subject to the uncertain conditions of experience. Against this loss of validity, Helmholtz places a non-negotiable set of assumptions concerning reality which will legitimate the representational character of laws. With Hertz the situation is inverted. While he acknowledges no absolute support in reality for claims to validity, he takes the laws of pure thought, though no longer sharply determined, to be absolutely valid, and he sees in them a unified point of reference that effectively limits the multiplicity of images.

These tendencies towards relativitized claims to validity, which face and complement each other in the relationship between Helmholtz and Hertz, are united in the subsequent development of the philosophy of science. Just as thought could no longer be kept distinct from experience, so it proved impossible to secure experience independently of arbitrarily fixed theoretical presuppositions.

By focusing on the concept of image, I have addressed an aspect of Helmholtz's and Hertz's thought which, though it is of great importance for their respective philosophies of science, is only of limited significance for their work as a whole. The fact that, in terms of their respective claims of validity of scientific knowledge, Helmholtz and Hertz both appear to be in a single line of development, is due to their congenial approach. How close they were would be more apparent if one considered the relationships that existed between their respective philosophies of science and specific work in their fields of interest.[26] (The fact for example, that Hertz could directly refer to Helmholtz's work with his concept of hidden masses.)

But the philosophy of science has to go beyond the results of specific scientific inquiries and be understandable without reference to their respective contexts. The contrasts between the two scientists are revealed by the independent uses they made of the concept of image within their philosophies of science. There are basic differences between Helmholtz's inductivist and Hertz's deductivist conception of science, between the multiplicity of theories excluded by Helmholtz and permitted by Hertz, between the content of the reality referred to by mechanical principles and laws of nature on Helmholtz's account and the emptiness of the reality referred to by scientific theories on Hertz's, and finally between Helmholtz's view that experience is capable of producing knowledge and Hertz's insistence that experience can annull it.

Institut für Philosophie, Humboldt Universität zu Berlin, Berlin, Germany

NOTES

[1] I would like to thank Alexander Goroncy and Alfred Nordmann for translating my text.

[2] The origin and first development of this concept is predominantly documented by several lectures in which Helmholtz talks about the tasks and methods of science (1889 and 1903a, including the lecture about Goethe's science), also in both editions of his *Handbook of Physiological Optics* (1856 and 1885). Hertz presented his view of the concept of image in the famous introduction to his *Principles of Mechanics*. For a comparison between Helmholtz's and Hertz's concept of image see Majer 1985.

[3] For Helmholtz's conception of science see Cahan 1993b and Schiemann 1997, Chap. B.II.3 and Chap.B.III. In Helmholtz's view induction is a method of inferring general laws from particular experience. It is the foundation for the discovery and the justification of natural laws (cf. 1903a, 1:169ff., 2:338ff.; 1856, 447f.).

[4] For the concept of image in German philosophy in the 19th century see Schlüter, D. and W. Hogrebe, "Bild," in J. Ritter and K. Gründer (eds.), *Historisches Wörterbuch der Philosophie* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1971).

[5] For Helmholtz's theory of perception, in which he develops the concept of sign see Hatfield 1990, Steven Turner, *In the Eye's Mind: Vision and the Helmholtz-Hering Controversy* (Princeton: University Press, 1994), Theo C. Meyering, *Historical Roots of Cognitive Science* (Dordrecht: Kluwer, 1989), and Schiemann 1997, Chap.B.II.3a.

[6] I take the expression *sign-constancy* from Meijering *op. cit.* (note 5).

[7] Among these he includes with certainty the phenomena of the human and social sciences (1903a, 1:171), with reservations he includes some phenomena of the inanimate world (1856, 454), and to a certain degree he finally includes sensual perceptions. Helmholtz's understanding of causality reflects an empiricist position that is basically different from Kant's idealistic position.

[8] In the sense of representation: 1856, 446; 1903a, 2:222 ("For of the image one demands some sort of similarity with the depicted object") and 358. In the sense of sign: 1903, 2:222 ("Images of the things delivered to us by the senses"); 1885, 590 and 599 ("the totality of perspectival images").

[9] "An *image* must be *similar* in some respect to an object. A statue, for example, has the same bodily form as the human being after which it is modeled; a painting has the same color and perspective projection. For a *sign*, it is sufficient that it appear whenever that which it signifies makes an appearance, the correspondence between them being restricted to their appearing simultaneously." (1903a, 1:393; similarly, though without mentioning simultaneity, in 1903a, 2:222)

[10] Changes in Helmholtz's conception of science have often been discussed, see e.g. Benno Erdmann, *Die philosophischen Grundlagen von Hermann von Helmholtz' Wahrnehmungstheorie* (Berlin: Abhandlungen der Preussischen Akademie, philosophisch-historische Klasse, 1921); Hörz and Wollgast 1971; König 1968; Buchwald 1994b; Gary Hatfield, "Helmholtz and Classicism: The Science of Aesthetics and the Aesthetics of Science" in Cahan 1933a, pp. 552–558; Heidelberger 1994; and Schiemann 1994 and 1977, Part B. For the increasing hypothesization of scientific propositions in the nineteenth century, see Diemer 1968, and Herbert Schnädelbach, *Philosophie in Deutschland 1831–1933* (Frankfurt: Suhrkamp, 1983).

[11] Helmholtz's view of thought as a high court is expressed not only by his position on causality but also by his views on logic and mathematics in Helmholtz 1903a, 1:175f.

[12] Helmholtz already believed in 1868 that his work on the physiology of the senses had intervened for the first time "into the hitherto inaccessible field of mental processes" (1903a, 1:268).

[13] For Hertz's concept of image, see D'Agostino 1990, and Majer 1985.

[14] Cf. pp. 28f.

[15] Hertz also speaks of "symbols" and, in agreement with his realism, about "virtual" or "seeming images [*Scheinbilder*]" (PM 1).

[16] As a part of this, the descriptions used in the images and their possible reference to experience need to be rendered distinct (PM 2f.).

[17] "The space [...] is therefore the space of Euclid's geometry, with all the properties which this geometry ascribes to it. It is immaterial to us whether these properties are regarded as being given by the laws of our internal intuition, or as consequences of thought which necessarily follow from arbitrary definitions." (PM §2).

[18] Nowhere in his very detailed critiques of the other images of mechanics does he mention that they do not satisfy the principles of transcendental philosophy (PM 4ff.).
[19] This interpretation is directed against the supposition that Kantian philosophy played an important role in Hertz's thinking. See, for example, Kuczera 1983, D'Agostino 1990, Hacker 1986. Cf. note 7.
[20] Hertz applies the term 'hypotheses' to these "inessential" relations (PM 25f.).
[21] Therefore, this is an inessential relation (cf. PM 39f.)
[22] Hertz's uncertainty on the epistemological status of hidden masses is stressed by D'Agostino 1990, p. 60.
[23] For Hertz's ether theory and its influence in German physics, see Breunig 1988 and Grigorjan and Polak 1964.
[24] A theory would thus be incorrect if one of its statements did not agree with the Principle of Conservation of Energy, but could still be related to experience.
[25] For the restriction to the inanimate, see PM 38.
[26] Cf. Mulligan 1987, Buchwald 1994a, and D'Agostino 1971.