19. THE PROBLEM OF MASS IN HEGEL

The way in which Hegel develops the categories of place and motion leads on to his exposition of matter, which he presents as the existent unity of space and time. In his early work, he also takes these categories to be basic to the reciprocal relation between motion and matter. He argues that a change in position can only be meaningful if it is possible to relate it to a point in space which remains unaffected by it. In his view, the spatio-temporal being determining place constitutes the essential nature of materiality. Matter is therefore mass, and the realization of place is the essence of mass.

Given such an exposition, one might well ask for the exact meaning being attached to the word "mass". Although the question is left unanswered in the *Philosophy of Nature*, there is evidence in his Jena writings that Hegel was by no means unaware of its importance. The paradigm he uses to answer it is that of circular motion and rotation, which he often associates with the movement of the planets. In the first instance, however, he employs it in the much more fundamental sense of the property of rotation, which involves the centre of rotation remaining self-identical. Rotation is therefore motion in one and the same place.

Building on this basic principle he accounts for such movement as the "representation of rest in motion". The unity of rest and motion realized in this way serves him as a model for the massivity of matter. This in turn provides him with a starting-point for a discussion of the theoretical principles underlying the concept of mass.

What is more, this conceptual framework makes possible the discussion of the phenomena of inertia and of the massless matter which is empirically realized in light. What is important here is the symmetrical character of circular motion. It is a well-known fact that the symmetry of physical being in respect of variation in time gives rise to the law of the conservation of energy. Basically, such a principle of symmetry is already implied at this point.

The concept of mass or rest-mass, to use a term current in contemporary science, is still an open question in physics, since it is still not possible to

M. J. Petry (ed.), Hegel and Newtonianism, 249–265.

explain the mass values of elementary particles.[1] It is true that research has yielded an immense amount of information concerning the micro-structure of matter, but we still do not understand the essence of massivity, and the extent to which it is related to inertia or the possibility of rest. As something which is to all intents and purposes not notional, the phenomenon of mass has always been a matter of fundamental difficulty in the philosophy of nature. Most of the important philosophers – Plato, Kant, Schelling and Hegel – have tried their skill at dealing with it. Can philosophy help physics in this respect? Of course not! Philosophy is not a matter of making empirical investigations superfluous, nor should it ever attempt to do so. Its task is to lay bare the principles underlying nature. And as long as it has not done this, the essence of nature will remain incomprehensible, even in those fields in which it is being empirically investigated.

It seems to me that in respect of theoretical principles, Hegel's *Philosophy of Nature* opens up possibilities which hitherto have remained very largely unutilized. This is certainly true of his analysis of the problem of mass, which only concerns part of the problem of matter. Although his conception of gravity and gravitation ought also to be kept in mind in this connection, it is mainly the character of the time-bridging identity of matter, the potentiality it has for rest, its massivity, with which we shall be concerned.

The line of argument relating to this in the main text of the *Encyclopedia* is too condensed, and therefore needs to be clarified. What is more, since there is no really elaborated theory of the dialectic of nature, it is not only desirable but necessary to take a look at some of Hegel's original intuitions, which in many cases lost their distinctness in his later works, or fell victim to the exigencies of his system. Philosophy makes use not only of reasoning but also of intuition. In respect of the mass which offers persistent resistance to a notional solution, it is important to find a suitable image for developing a first approximation to the understanding of the question. According to Hegel, the metaphors of circular and gyratory motion are well-suited for this. Here it is essential to clarify what we can gain by a structural interpretation of such ideas. I also think that an attempt has to be made to bring out the contemporary relevance of the topic. Doing so is always a delicate matter, but it is a must if undertakings of the present kind are to be anything more than philological expositions of Hegel's philosophy, if they are to make a real contribution to reflection on the foundations of physics.

In what follows, I shall first give a brief review of the arguments put forward in the *Encyclopedia*; then I shall analyse Hegel's interpretation of circular and gyratory motion and discuss the possibility of bringing out the

[1] Jammer, M. 1964, p. 242; Feynman, R.P. 1988, p. 171.

relevance of his ideas; finally, I shall draw certain conclusions in respect of the principles involved in comprehending the divisibility of matter, and in putting forward a philosophical interpretation of the theory of relativity.

A. MATTER

Hegel's view of matter is the outcome of his concept of motion, which has therefore to be briefly sketched. He maintains that the categories of space and time are basically interrelated: everything spatial necessarily has a reference to other things in space. It is, however, a reference which remains simply implicit in merely spatial relations. This immanent differentiation is made explicit in the concept of change, that is, in time. Change, however, only takes place in space. This reciprocal relation between the categories of space and time means that both have to be thought of as elements of a unity which contains everything. The concrete significance of this is that the point, the fundamental determination of space, has to be supplemented by a temporal element. This gives rise to the category of place, which in Hegel's view has not only a spatial but also a temporal significance. His concept of place, therefore, always carries the extra connotation of change. At the level of mechanics, this is simply a spatial and not yet a qualitative change. As such a place always involves a change in place, it is in fact motion.

This poses a problem, however, for a change of place, or motion, can only occur in relation to a spatial point, which remains at rest, and is therefore unaffected by the change. Motion and rest belong together in a dialectical manner. How, then, is a place specified as being at rest? From a formal point of view, since a single place remains identical in time, it does not change. The negative element of change, contained in the concept of place is here negated again. The place in rest is therefore the negation of a negation, which is intro-reflexion or being-for-self. The nature of this being-for-self endows the single place at rest with a self-identity which bridges time, and so constitutes a single being-for-self. In Hegel's view, it is this that constitutes the primary nature of materiality, which is conceptualized as inert, corpuscular, single mass. First and foremost, therefore, inert matter or mass constitutes place, that is, its own place, which retains its self-identity in time.[2]

Here mass is understood as a synthesis of an isolated existence in space and a being-for-self which remains identical in time. Hegel associates this being-for-self with the impenetrability of matter, with its having an independent resistant existence and therefore being something tangible and visible. Place

[2] Hegel *Encyclopedia* § 261 Addition, MM 9.60 Addition; tr. Petry I.237. Cf. Hegel MM 9.64f.; § 263 tr. Petry I.244.

has already been characterized as a spatio-temporal synthesis. According to Hegel, however, this is only "the posited identity of space and time", their explicit conceptional connection. Beyond such matter is "the *immediate identically existent unity*" of both, that is, a being in space which is real since it remains identical in time, and has a spatio-temporal existence, a real "existing being-for-self".[3]

How is one to regard such an "immediate existent unity" of space and time? It is this question alone which will now be considered. Hegel's very brief remarks in the 1830 *Encyclopedia* do not supply much information on the subject. The line of argument he develops concerns the phenomenon of gravity, which he sees as the primary determination of material bodies, and as presupposing massivity. Incidentially, gravity must not be confused with gravitation, which in Hegel's usage signifies the gravitationally structured properties of systems of bodies. When we deal with the concept of mass, we shall consider the premise underlying his conception of gravity and gravitation, which in the *Encyclopedia* itself is not given any further consideration.[4]

B. CIRCULAR MOTION

The Additions to the *Encyclopedia*, which have their origin in earlier works or in Hegel's lectures, are of particular importance in throwing light on this subject. The relevant passages in this case originate from his Jena writings. The paradigm he uses in order to illustrate the problematic unity of space and time is that of circular motion. His argument runs as follows:[5]

The circular motion which returns to itself is "in its exteriority equally closed ... as the point", that is, its starting- and its final-point coincide. According to Hegel, this has important structural consequences: circular motion is therefore:

> the present and the past and the future, which form a whole. It is the neutrality of these dimensions which makes the past in exactly the same sense a future, since *what follows* becomes *what has been.* Only thus is their necessary paralysis posed in space: it is the re-established immediacy.

Present, past, future, "have become a unit within circular motion; this unit is the spatial or existent unity of these meanings". On the basis of the topological

[3] Hegel *Encyclopedia* § 261, MM 9.57; tr. Petry I.237. Hegel MM 9.56; tr. Petry I.237. Hegel MM 9.60 Addition; tr. Petry I.240.

[4] Hegel *Encyclopedia* § 266, MM 9.68ff.; tr. Petry I.248. Hegel MM 9.82, § 269ff.; tr. Petry I.260. On the concept of mass in the *Encyclopedia*, see Falkenburg, B. 1987, pp. 210ff.

[5] Wandschneider, D. 1982. Kap. 4.4, 4.5; Ihmig, K.-N. 1989, pp. 140ff.

connection of the circular line, the advance from the starting-point is also a return to the same point. In this way, a motion into the future is also a return into the past. Past, present and future, which Hegel refers to as the dimensions of time, are united and brought into a synthesis as it were. As "the *relation* of present, past and future", the whole is "*something permanent*". The pure present would not be permanent, and could not explain the time-bridging being-for-self of mass, which is characterized by the paralysis of the time dimensions in circular motion.[6]

In its state of unity, circular motion remains related to one and the same point, that is, its centre – which remains unchanged within the motion. Circular motion is therefore that, "which is extinct in itself", or "in its centre".[7]

This is certainly an extraordinarily suggestive illustration of the unity of the determinations of space and time. The primary determination of space is the point, which is seen as the possibility of localization. Motion contains a temporal element. Since circular motion represents the co-existence of spatial-point and temporal-change in one state, it is the paradoxical form of motion in a single place, of localized motion. Hegel therefore characterizes it as "positing time *in* place and place *in* time". The centre is here to be regarded as "the restoration of *place* as being immobile" – not of the point in space from which the argumentation started, however, but as the result of a synthesis of the determinations of space and time. "It is the restored concept of duration, the motion which is extinct in itself. The mass, the permanence that has condensed of its own accord, is posited."[8]

Mass is therefore essentially spatio-temporal. Although it exists in space, it also has temporal existence as something which has duration. In order to assure ourselves of the temporal being of mass, we cannot simply put a clock beside it, for we might very well ask what would happen if we took the clock away? Mass must therefore possess a temporal nature from the very start. It must in itself be motion, a motion, however, which also remains at the same point in space. In this sense, circular motion serves Hegel as a model for a time-bridging being-for-self of massive matter:

> The being-for-self is not this immediacy, however, for its concept is that of a motion returning into itself. What has duration is for itself, being nothing but what it is; it is self-unification ... Mass therefore consists of this continual motion, being simply immediate.

Matter and motion therefore belong basically together: "Just as there is no

[6] Hegel GW 7.211. Hegel GW 8.20. Hegel *Encyclopedia* § 259, MM 9.51; tr. Petry I.259. Hegel GW 8.19. Hegel GW 8.20.

[7] Hegel GW 8.22. Hegel GW 8.21.

[8] Hegel GW 8.20. Hegel GW 8.22.

motion without matter, so there is no matter without motion." The spatio-temporal being-for-self of mass is to be understood as a connection of rest and motion in one and the same state of affairs.[9]

This interpretation was taken up by the advocates of dialectical materialism, who reduced the structure to a handy formula. Engels was the main proponent. According to him, "it is easy enough: motion is the being of matter. Never and nowhere has there been matter without motion, nor could this ever be the case. Matter without motion is just as inconceivable as motion without matter." What remains only a mere assertion in Engels, carrying no conceptional consequences, corresponds to Hegel's basic attempt to relate matter to the structure of space and time itself by using the concept of motion – "the *immediate identically existent* unity of both".[10]

Naturally enough, Hegel also considers the movement of the planets in connection with circular motion. He had already dealt with the subject in his *Dissertation* of 1801.[11] It is not the empirical aspect of the problem which is of primary interest to him. He believes that he has also discovered in these forms of motion a general principle of material being. This is evident from certain of his statements: "the whole form of the solar system constitutes the concept of matter;" and "the determinations of form constituting the solar system are the determinations of matter itself."[12] On the other hand, he also tries to establish on this basis a kind of a priori understanding of the Keplerian laws. For him, the principle of circular motion is of primary philosophical importance. Incidentally, it can, in fact, be regarded as the basic configuration of his system.

Because of its reference to a centre which is at rest, Hegel in his earliest writings on the subject regards circular motion as a model for massivity, for the time-bridging identity, duration and locality of mass. He sees it as a reference point for motion that remains at rest. One might object to this that since circular motion is still motion, it itself presupposes a reference point which is at rest. On the other hand, the reference point itself has to be constructed by means of circular motion. The possibility of a mass which is at rest can only be made intelligible by the model of circular motion. This is a vicious circle, and the realization that it is may be the reason why we find no reference to circular motion in Hegel's later expositions of the concepts of motion and matter.

[9] Hegel GW 8.22. Hegel *Encyclopedia* § 261, MM 9.60 Addition; tr. Petry I.240.
[10] Engels, F. 1971, p. 55. Hegel *Encyclopedia* § 261, MM 9.56; tr. Petry I.237,15.
[11] Hegel DOP.
[12] Hegel *Encyclopedia* § 271, MM 9.107 Addition; tr. Petry I.282,28. Hegel MM 9.108 Addition; tr. Petry I.283.

C. GYRATION

The shortcomings of this reasoning could only be overcome by managing to conceive of rest and motion as being one. Although this is the intention in the model of circular motion, in this case rest and motion still fall apart. In celestial corporality Hegel recognizes a more perfect form of circular motion, which he calls gyratory, and which can be observed empirically in the celestial spheres or bodies.[13]

Here too he is especially interested in the principle involved. Compared with "the circular motion from which it originated", gyration has certain new qualities. The rotation it involves is no longer the motion of a single point on a circular path around a centre lying outside this point, but the circular motion of a whole spatially-extended system around an axis which lies inside it. What Hegel is evidently trying to say here, is that this intrinsic motion, which is characteristic of celestial bodies, makes the essence of mass more obvious, shows "how rest and motion exist in their substance or in mass". Mass is not an entity "which carries the principle of rest and motion outside itself", but a "substance which rests in motion and moves in rest". Is it possible to verify this in detail with the help of the model of gyratory motion? Only purely *kinematic* relations are of importance here, since the *dynamic* aspects which are here apparent on account of centrifugal force already presuppose the existence of mass.[14]

I have already observed that it is typical of gyratory motion that a spatially extended system such as a sphere should rotate as a whole. What we have here, therefore, is not only a single point moving in an otherwise empty circular path, but all the points of the sphere performing co-axial gyrations together. If a section is made through the sphere vertical to its axis, the plane forms a circular area revolving around its centre during rotation, that is, revolving around its piercing point. If we consider all possible planes of the section, the rotation consists of "nothing but moving sections", and all the points on them are in circular motion. Seen from this point of view, the rotation is not one but an infinite multitude of circular motions: "it is the previous motion, posited or multiplied".[15]

The decisive characteristic here is that the whole system of all the points of the rotating sphere remains unchanged. During an infinitesimal rotation, every point occupies the position of its predecessor, so that altogether nothing is changed. Mathematically speaking, the system is transformed into itself, being invariant with respect to rotation. Consequently, no change of position

[13] Hegel GW 8.24. Hegel GW 8.25. Hegel GW 7.217 *inter alia.* Hegel GW 8.24.
[14] Hegel GW 8.25. Hegel GW 8.24.
[15] Hegel GW 8.27. Hegel GW 8.26.

can be established, since all points keep the same distance from each other. There is no starting-point, nor is there any final point in the motions. The rotation effects no change of position in the system as a whole and unlike circular motion no longer refers to a presupposed fixed-point. Since all rotation is self-contained, Hegel can describe it "as a motion which refers to itself".[16]

In accordance with this model of a motion referring to itself, mass is now characterized as the "unity of rest and motion". The whole is motion at rest. It is intrinsic motion, so to speak, and is self-contained. This perfect being-in-itself is its solidity, its self-identity. Solidity or massivity is therefore also a matter of time-bridging identity. It is "the motion which is taken up and preserved as identical with itself". In the supplements to his *Jena Logic*, Hegel also says that motion is bound within form. Here *form* obviously has the same meaning as *body*, which in its turn is identical with *mass*.[17]

As distinct from simple circularity, rotation is therefore a motion which, since it refers to itself, involves no change of place. It is, so to speak, an intrinsic motion. The question therefore arises as to how gyration can actually be determined as motion. A rotation too can only be known as a real motion on account of its reference to something unmoved which is independent of it. Hegel is well aware of this fact: "the rotation can only be recognized by means of a point which lies outside it, which means that in order for it to be real the point has to be necessary". The rotation of the Earth, for example, only becomes apparent in relation to a fixed star. Is it not the case, however, that one has already presupposed a mass as a point of reference? If the rotation is to be identified, a permanent mark has to be attached to the rotating system. Is this not a reoccurrence of the problem which appeared in the model of circular motion?[18]

The question of what it is that actually rotates in gyratory motion gives rise to a similar difficulty. It is obviously mass itself which rotates, and for this the model of gyratory motion has yet to provide an explanation. Is this yet another vicious circle? In dealing with gyratory motion, Hegel is thinking predominantly of celestial bodies which actually exist. He points out that celestial corporality, as it is actually realized, brings out a principle of materiality which in everyday experience, in the perception of a common stone for example, remains hidden. His consideration of this point must not be regarded simply as a description, but as a radical reconstruction of

[16] Hegel GW 8.26ff. Cf. also Hegel GW 7.219ff. *pass.*

[17] Hegel GW 8.25. Hegel GW 8.26. Hegel GW 8.35. Hegel GW 7.241. Hegel GW 6.22. Hegel GW 7.228. Hegel GW 7.241.

[18] Hegel GW 8.27.

matter.[19]

In this fundamental respect, his term *gyratory motion* can no longer be understood as referring to real motion: "the difference here in what is motion is not real, it is not a difference in mass", that is to say, it is not to be seen in relation to a point of reference having mass. Consequently, he also speaks of the "unreality of a sphere which is in gyratory motion". He observes that "the motion here does not yet have any reality as motion", being "motion which is taken up and preserved". What meaning, then, can still be attached to the concept of motion?[20]

Hegel's answer is that motion "refers to itself". He elucidates this by saying that "the whole is at rest, but the whole is just as much motion". The rotating system

> is the totality of motion. Although its time and revolution are involved in it, it withdraws down into itself below something which is higher. It therefore realizes a higher state of being-in-itself ... This sphere, which only moves for itself, is therefore posited for itself. It is absolute rest, which has no difference within itself.

In other words, it is not real motion in time; for as such it would presuppose a fixed point of reference. It refers to itself, and as such is also rest. In this form, it cannot be a real motion, of course, but may possibly be a kind of virtual motion, which is in fact also an unchangeableness. Is anything like this at all conceivable?[21]

I think that one has simply to follow out this line of thought in order to recognize its consequences. Let us take another look at the structural elements of gyratory motion. There are the properties which have already been established for circular motion. Firstly, it is motion which returns into itself and therefore has duration; as a synthesis of past, present and future it is extension in time:

> It is something absolutely simple moving within itself; it is not a change of place, and is not now materially present with respect to a before and an after of what has been or has to be moved; it has reconciled the bad reality of time seen in the separation of its elements.

Secondly, the axial pole which remains at rest during the motion also defines a permanent place. The separation of time is therefore brought into a synthesis, despite space also being included. This is then the unity of space and time

[19] Hegel GW 8.24. Hegel GW 7.250.

[20] Hegel GW 8.26, similar Hegel GW 7.217. Hegel GW 8.27. Hegel GW 7.248.

[21] Hegel GW 8.27f. Hegel GW 8.33. Hegel GW 7.217.

which Hegel regards as basic to place or locality.[22] Circular motion itself is the synthesis of these two syntheses. Thirdly, as has been indicated, beyond the properties of circular motion there is a new property, specific to rotation. If the moved system is symmetrical with respect to rotation, as it is in the case of a sphere, it transforms itself into itself in any rotation on its axis. Consequently, the rotation does not change anything, its result is identity. Since such a process no longer has a definite direction in time, it may be said to be temporally neutral. As has already been observed, this property is based on the fact that rotation represents a whole system of circular motions, which by working steadily together describe a change which changes nothing of the whole. One could speak of a synthesis of many circular motions, which integrate in such a way into identity.

Our line of argument may therefore be summarized as follows: the principle of circular motion corresponds to a synthesis of two other syntheses, duration and locality. Beyond that, the principle of gyration has to be comprehended as a synthesis of many circular motions, that is, as a synthesis of syntheses, of pairs of syntheses. We have, therefore, a threefold synthesis containing the other syntheses of duration, locality and their interconnection. The result of this synthesis is identity; not simply identity, however, but an identity which only comes into being through non-identity, an identity which contains change and temporality as its basic elements. Because of this temporality, which is taken up and preserved, it is not the timeless identity of logic, but one which is simply neutral with respect to time. It is a being which, although it is in time, does not fall victim to it, remaining during the course of time as a self-identical being-for-self. As such it contains extension in time and locality.

Hegel's image of gyratory motion has now been replaced by a statement concerning structure. To interpret this as a threefold synthesis is certainly the outcome of a somewhat forced analysis. As has already been observed, however, it is also important that philosophy should decipher in a discursive manner the intuitive elements we find in the thinking of the young Hegel, many of which are neglected in the later writings. The corresponding line of argument in his *Encyclopedia* leads on to a conception of material mass as an existent unity of space and time. What is to be understood by this remains open to discussion. The considerations developed here with the help of the models of circular and gyratory motion can provide us with certain leads. Massivity might be conceived of as the "unity of the moments of rest and motion", or more explicitly: as a self-identical being-for-self which is neutral with respect to time, and which contains the features of an extension in time

[22] Hegel GW 7.248f. Hegel *Encyclopedia* § 261, MM 9.56; tr. Petry I.237,5.

and of spatio-temporal locality.[23]

The conditional form has been chosen here on purpose. I want to emphasize this point once more, because we are dealing with a model. By this I mean that the condensed argumentation of the *Encyclopedia* should first be made comprehensible by starting from an intuitively conceived structure which is then rationally reconstructed. My aim has been to examine the heuristic value of this model, and to bring out certain prominent principles, which may help us to find a starting-point for solving the riddle of material being.

D. EXEMPLIFICATION

It would be extraordinarily satisfying if one could also provide an exemplification in modern physics of the interpretation thus developed. In the first place, one would have to think of the fundamental particles out of which matter, as we now understand it, is composed. It has to be expected that the structural elements of massive matter will appear in their purity only in relation to these particles, and not in relation to accidental macroscopic conglomerates. One is therefore obliged to concentrate on elementary-particle physics.

What immediately strikes one here is the conception of spin.[24] This is a quality typical of elementary particles, which in certain contexts represents something resembling an intrinsic rotation. The related angular momentum has specific values for different types of particle. Important consequences result from the difference between half-integral and integral spins. Particles with a half-integral spin, so called fermions, are fundamentally incapable of existing together in the same state. This offers an explanation for their impenetrability. It is questionable, however, whether the physical character of massivity is involved in such an explanation, for particles with integral spin, the so-called bosons, also have mass: mesons, for example, although they are composed of other particles, quarks, with a half-integral spin. Whether something like this is generally true is still empirically undecided. As for the rest, it now looks as if there are also massless particles with a half-integral spin – neutrinos, for example. Looking at the matter from an empirical point of view, one can therefore get no clear idea of the relation between spin and mass.

If we free ourselves from the concrete image of gyratory motion, another physical interpretation of intrinsic motion offers itself. A particle is in any case a spatial localization of energy. As a result of Heisenberg's uncertainty

[23] Hegel GW 8.23.

[24] Bethge, K. and Schröder, U.E. 1986.

relation, however, this energy is not exactly fixed, but is subject to permanent fluctuations around the average, which in this case would correspond to the mass of the particle. This means that energy quanta are constantly being emitted and re-absorbed. Consequently, the particle is always surrounded by a cloud of fluctuating virtual particles as they are called.[25] According to the uncertainty-relation, however, one must not think of the particles and the cloud as existing independently. The elementary particle is nothing other than the continual production and disintegration of such a cloud, which in this way determines its surroundings or field, that is, its interaction with other particles. Seen from this point of view, the particle is not a static being within a field which is independent of it, but consists of a continual production of its own field. It is nothing other than the interaction with its own field, it is self-interaction. One modern physicist has observed that: "being and event are inseparable ideas because of the phenomenon of self-interaction ... being exists, because there is process. One can hardly think of a more radical break with the classical doctrine of the foundations of the world."[26]

If this emission-absorption model is accepted as an interpretation of mass, one has to be aware that there are serious objections to it. It is a physical model for the relation between a *charge* connected with a mass and the field of this charge. It is not a model for mass itself. One might object to this, that the mass itself has to be comprehended in terms of charge; the theory of quarks offering some advantages in this respect. Another objection arises from the fact that the concept of a particle is already presupposed. Although this is true, the interpretation does endow the concept of mass with a dynamic nature: mass is a steady emission and re-absorption of the particles of a field. It is possible here that the particles of the fields themselves, at the most elementary level, are principally without mass, as for example in the case of photons and gluons, the quanta of the electro-magnetic or quark field. At present, however, this is an hypothesis which is empirically undecided.

This emission-absorption model also provides an illustration of the previously mentioned concept of an identity which is neutral in respect of time. Here, in accordance with the uncertainty relation, emission and absorption processes compensate each other around an average. The whole process therefore has no temporal direction; but in the end it is an identity which is neutral in respect of time. The young Hegel was already aware of something like this. In respect of the appearances of comets, he speaks of matter as: "a motion of opposed currents, which immediately take each other up and preserve each other. Although the motion extinguishes itself, this extinction

[25] Davies, P. 1987, pp. 138ff.

[26] Ford, K.W. 1966, p. 208.

is identical with its reinstatement, since it is the fall into the quiescent motion which gives rise to this whirl." Elsewhere: "At first, matter disintegrates ... into a multitude, which remains related to the unity and which has no existence in separation from this unity. It is a common medium into which everything which leaves this context will immediately return." The concept of a field is anticipated here by that of a medium, or "the force of mass". Hegel also considers: "the relation of the *determinate* being to its *centre*", adding that, "only this determination of the *concept* is *force*". In the emission-absorption model this relation to the centre corresponds to the fluctuation of quanta of energy around an average, that is, to the field which surrounds the mass.[27]

Another illustration of mass as an intrinsic motion which is at the same time rest, would be the idea that a particle can also be comprehended as a wave.[28] Although such exemplifications by means of concrete events are certainly a help to our imagination, they also constitute the weakness of such models, since they presuppose real processes and real points of reference.

An abstract interpretation which avoids this disadvantage is that of gyratory motion regarded as a so-called symmetry transformation, a conception of great importance in modern physics. We understand by it a certain group of variations in a physical system which leave the system as a whole invariant. As we have seen, it is precisely this that is typical of the rotation of a system with a high degree of symmetry, like that of the sphere. According to the well-known Noether-theorem, certain invariants of this kind are connected with the conservation of a related physical quantity.[29] It is important that the conservation in time of the total energy of a system should be comprehended as a consequence of the invariance in respect of a time-shift. The conservation in time of the total momentum of a system corresponds to the invariance in respect of translations in space. Many conservation laws in physics may be explained in this way.

It seems to me that the abstract interpretation of gyratory motion as such a symmetry transformation is probably what Hegel was driving at. The operation of symmetry is indeed not a real motion but a virtual variation of a system which leaves its functional unity as an invariant, and which is also associated with the conservation of a certain quantity in time – of energy, for example. Similarly, the rotational axis of a sphere can be comprehended as a quantity of conservation in respect of a rotation around the axis. It is in this way that Weizsäcker grasps the law of the conservation of energy as a

[27] Hegel GW 8.28. Hegel GW 8.36, similar Hegel GW 7.326. Hegel GW 7.238. Hegel GW 7.240. Hegel GW 8.36. Hegel GW 8.29.

[28] Ludwig, G. 1969; especially the contributions of E. Schrödinger and L. De Broglie.

[29] Weyl, H. 1955; Wigner, E.P. 1967; Bethge, K. and Schröder, U.E. 1986; Genz, H. 1987; Roman, P. 1961, Ch. IV, 1; Schmutzer, E. 1972.

modern interpretation of what Kant sees as the postulate of the "persistence of substance". On the other hand, although Hegel's argumentation does not actually refer to an explicit principle, it already carries an implicit reference to the principle of symmetry. If we try to penetrate the aphoristic veneer of such formulations as "the atom is in reality only centre", we shall find in Hegel's philosophy of nature a surprisingly modern pattern of thought.[30]

In this context, one has to refer to the outstanding importance which principles of symmetry have assumed in recent theoretical approaches to the structure of matter. One has to remember that nowadays a particle is simply identified with its symmetries. With explicit reference to the Platonic doctrine that particles are the embodiment of mathematical symmetries, Heisenberg maintains that *in the beginning was symmetry* is certainly more correct than the thesis of Democritus that in the beginning was *the particle*: "The elementary particles embody the symmetries; they are the simplest representations of these symmetries, they are, however, only their consequences".[31]

Can we say, then, that abstract symmetries are that which constitutes concrete matter? Formulated like this, it does not sound a very plausible proposition. According to the theory of relativity, matter consists of energy. What, then, is energy? It is certainly not the same as mass, since there is massless energy – electro-magnetic radiation for example. Since mass is also something like a configuration of energy, an energetic system so to speak, the concept of symmetry is certainly relevant to understanding it. Symmetry enables us to think of systemic conservation within a change, which according to Hegel is essential to any understanding of mass. We can say, therefore, that whatever energy may be, mass is an energetic structure characterized by certain symmetries.

Symmetry is basically the invariance of a whole system in a state of variation. It is the identity of the system under such varying conditions as, for example, a time-shift. Such a system therefore turns out to be an internally determined and independent functional whole. Symmetry is therefore the expression of the specific autonomy of a system, the regularity of its behaviour in a certain respect. According to Noether's theorem, it is the existence of the corresponding quantity of conservation, the conservation of energy during a time-shift for example. It is, therefore, a specific embodiment of the autonomy of the system, or as one could put it with Hegel: "existent being-for-self", the existence of its being-for-self.[32]

Such an interpretation of the model of gyratory motion as related to the concepts of symmetry and quantity of conservation, is certainly extremely

[30] Cf. Weizsäcker, C.F. v. 1971. Teil IV, 2. Hegel GW 6.24, spaced in the original text.

[31] Plato, *Timaeus*, 53c ff.; Schulz, D.J. 1966; Heisenberg, W. 1973, p. 280.

[32] Hegel *Encyclopedia* § 261, MM 9.60 Addition; tr. Petry I.240.

suggestive. It would, however, be a mistake to regard it as the final truth concerning physics. It remains too metaphorical, and I think we can profit more from its heuristic significance. Certain structural relations important in the concept of mass can be illustrated by means of it, and it clearly provides us with a basic understanding of them.

It has become apparent that the synthetic structures are mainly those which can be modelled by gyratory motion. This is only natural, since we are dealing here with a system or comprehensive entity. The aspect of symmetry is an immediate expression of this fact. With regard to mass, that is, in respect of fundamental particles, massivity has to be seen as an integral property. It is obviously decisive for the logic of massivity, that it should have the comprehensive character pertaining to a system.

E. RELATIVITY

This point of view has an immediate implication in respect of the well-known problem of the divisibility of matter. If the fundamental particles have to be regarded as integral entities, the concept of divisibility no longer makes sense here. There are, of course, compound masses. It seems to me, however, that the assumption of the existence of infinitely small and indivisible particles involves no contradiction, and may even be regarded as necessary in the light of the Hegelian considerations developed here. Any attempt to divide such elements would not result in smaller particles, as might be expected, but in the generation of new elements which are the same in principle as the original ones. The supposed division is in fact a multiplication, the process of which is governed by the principles of symmetry and by the laws of conservation associated with them. Such processes have been empirically familiar for some time now.[33]

The model which has been discussed here, and which has been borrowed from the early writings of Hegel, can therefore help us to understand mass as an integral unity. In accordance with it, mass might be characterized as an intrinsic functional whole, or as the unity of rest and motion. This unity has a time-bridging identity, a being-for-self, which defines a real place. It is only under these conditions that the common concept of motion employed in mechanics has any real meaning. From this premise we can now draw certain conclusions concerning the concepts of motion and matter.

In so far as mass defines a real place, every mass can be a point of reference for motion. Mass as such is by definition at rest, although in relation to another mass it can of course be in a state of motion. In so far as mass is not fixed

[33] Bethge, K. and Schröder, U.E. 1986.

as motion or rest, since according to its concept it is defined as the unity of rest and motion, "rest and motion are taken up and preserved in mass. Mass is indifferent to both of them, being just as capable of motion as it is of rest." Hegel exploits the fact that in German the words for *carrier* and *inert* have a common root, and punningly asserts that mass is *inert* because it is the *carrier* of both motion and rest: "In so far as it is at rest, it is at rest and does not of its own accord turn into motion; if it is in motion, it is simply in motion, and does not of its own accord turn into rest. Rest and motion are therefore infused into it by another being." They are there on account of an external influence, which might help to explain the resistance which mass offers to acceleration.[34]

It is therefore part of the concept of mass, that it can be both in motion and at rest. Mass moved can also be regarded as at rest, can have different states of motion according to its point of reference. One might say that precisely because mass is capable of rest, its motion is always relative, or that the motion of mass is identical with relative motion. Here we have the classic principle of the relativity of motion. A decisive modification here is, however, that in this argumentation the principle can only be applied to the motion of mass.

This has a surprising corollary, which throws light on the central point of the special theory of relativity. The motion of something which is not mass, of light for example, cannot be a relative motion. Consequently, something which is not mass cannot be at rest, but can only be in motion. If it were not, it would be mass in contradiction of its own concept, the character of mass, and would be governed by the principle of relativity. As something which is not mass, it can only be in motion, and this motion cannot be a relative motion. It must, therefore, be an absolute motion, one which is independent of any specific point of reference. Although Hegel does in fact draw this conclusion, he provides no explicit argumentation for it. He simply states that the being of light is "the absolute velocity". Findlay is therefore justified in maintaining that one can find a flavour of relativity physics in some of the things he says about light.[35] Thinking critically about contemporary science, and more particularly in opposition to Newton's corpuscular theory of light, Hegel anticipates one of the crucial principles of modern physics.

As I have already observed, mass or massivity are only one aspect of matter. It is simply this one topic that has been treated here. In more general terms, the problem of gravity and gravitation is directly related to that of

[34] Hegel GW 8.23. Hegel GW 8.23. Hegel *Encyclopedia* § 264, MM 9.64; tr. Petry I.244. Hegel GW 8.23. Hegel § 265, MM 9.66 Addition and MM 9.66f.; tr. Petry I.246.

[35] Hegel GW 8.35. Hegel *Encyclopedia* § 275 Addition, MM 9.112 Addition; tr. Petry II.12.30. Findlay, J.N. 1964[2], p. 279.

matter. This is, however, a separate topic, and to enter into it would be to go beyond of the scope of the present paper.[36]

I shall simply conclude, therefore, by observing that a consideration of basic principles such as that carried out here, is a matter of particular interest not only to philosophy itself, but also to anyone reflecting philosophically on physics, especially if the situation being dealt with has not yet been clarified empirically but appears to be worthy of close attention. It is important to investigate a philosopher of Hegel's rank, not only in an historical and philological manner, but also in respect of the ways in which his thoughts might be developed from a systematic point of view.

[36] Falkenburg, B. 1987, ch. 5.; Ihmig, K.-N. 1989, pt. III; Wandschneider, D. 1982, pp. 190ff.