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PHENOMENOLOGICAL LAWS AND THEIR APPLICATION TO SCIENTIFIC EPISTEMIC EXPLANATION PROBLEMS

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1. *Introduction*

Scientific knowledge has both a practical function (prediction and manipulation) and a theoretical one (understanding). By analyzing the nature of explanations, philosophers have tried to describe what we have to do with our scientific theories, laws, etc., in order to make them contribute to a better understanding of the world. However, explicating what explanations are is not sufficient for clarifying how science fulfils its theoretical function: we also need an account of the construction process of explanations. The aim of this article is to present a part of such account: I will describe how phenomenological laws (laws describing the covariance between observable variables) may be used to solve *scientific epistemic explanation problems* (SEE-problems).

The structure of the article is straightforward. In section 2, I develop a conception of phenomenological laws. In section 3, I clarify what constructing and solving a SEE-problem consists in. Section 4 contains a method for applying phenomenological laws to solve SEE-problems.

Clarifying how scientific entities of all conceivable types (laws, theories, distribution functions, etc.) may be used to solve explanation problems of various kinds (epistemic, causal, functional, etc.) is impossible within the limits of one article. Therefore, I discuss only one type of entity and one type of explanation problem. However, the method for applying phenomenological laws to SEE-problems which I develop in section 4, is a good starting point for discussing the other entities and problems. In section 5, I will discuss the heuristic value of the particular method presented in section 4.

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2. *Phenomenological laws*

2.1 My conception of phenomenological laws will consist of a definition (section 2.2) and an epistemological framework (section 2.4). In section 2.3, I present two examples.

2.2 An *object-moment* is a couple of an object and a point of time. A *modality* is a series of properties which are defined so that an object-moment cannot posses more than one of the properties. When *D* is a set of object-moments, the modality $G_1, \ldots, G_n$ is called *characteristic of domain D* if and only if each element of *D* necessarily possesses one of the properties of the modality. A modality is called *experimental* if there exists an experiment by means of which it can be determined which of the component properties an object possesses.

An *attribute space* is a couple of a "general kind" and an interval of $\mathbb{R}$. Examples of "general kinds" are length, age, weight, temperature, etc. Attribute spaces will be written as (K, I). Property G is a *region of (K, I)* if and only if it can be defined by associating a subinterval of I with the general kind K. A *partition* of an attribute space is a set of mutually exclusive and jointly exhaustive subintervals of I. The attribute space (K, I) is *characteristic of domain D* if and only if with its partitions it is possible to define modalities (consisting of regions of (K, I)) which are characteristic of *D*. An attribute space is *experimental* if and only if some of its partitions allow us to define experimental modalities (as partitions consisting of extremely small intervals never define an experimental modality, we cannot require that all definable modalities are experimental).

A *phenomenological law* is a couple of a formula and an interpretation. The formula has the form $Y_1 = f(Y_2, \ldots, Y_n)$, where $n \geq 2$. The *interpretation* consists of (i) a set of object-moments (the *domain* of the law) and (ii) *n* experimental attribute spaces that are characteristic of the domain of the law. Each of the attribute spaces is associated with one of the variables of the formula. Phenomenological laws can be formally represented as:

$$\langle Y_1 = f(Y_2, \ldots, Y_n), \langle D, (K_1, I_1), \ldots, (K_n, I_n)\rangle\rangle$$

D is the domain of the law. (K_i, I_i) is the attribute space associated with the *i*th variable in the formula.

2.3 My first example is the law of reflection of light (cf. H. Grayson-Smith

(1967) p. 270):

> Light is reflected so that the reflected and incident rays make equal angles with the normal to the reflecting surface.

This law may be formally represented by the expression $\langle i = r, \langle L, (K_i, [0, 90[), (K_r, [0, 90[)\rangle\rangle$. In the domain L, the objects of the object-moments are systems of an incident and a reflected light ray. The general kind K_i is "angle with the normal to the reflecting surface made by the incident ray". K_r is "angle with the normal to the reflecting surface made by the reflected ray".

My second example is the law of the simple pendulum. A simple pendulum consists of a mass (the *pendulum bob*) at the end of a string or rod. The law is:

> The period of a simple pendulum equals the product of 2π and the square root of the quotient of the pendulum's length and the acceleration due to gravity.

The length of a pendulum is the length of the string or rod. The period of a pendulum is the time the bob needs to make a complete oscillation. The law of the simple pendulum may be formally represented by means of the expression $\langle P = 2\pi\sqrt{l/g}, \langle S, (K_P,]0, +\infty[), (K_l,]0, +\infty[)\rangle\rangle$. g is the acceleration due to gravity. In the domain S, the objects of the object-moments are pendulums. K_P is the period of the pendulum, K_l its length.

2.4 The *knowledge situation* of an individual X at t_β is the set of all sentences and other symbolic constructions (e.g. laws as defined in 2.2) X consciously accepts as true at time t_β. Knowledge situations are finite and not deductively closed.

A scientific entity (theory, law, etc.) is regarded as *empirically adequate* if and only if it has passed some empirical tests; as we do not need a precise definition of empirical adequacy in this article, I will not discuss the nature of these tests. Assigning the status "empirically adequate" to a phenomenological law or another scientific entity is a sufficient but not necessary condition for acceptance. The *primary scientific knowledge* of X at time t_β consists of all theories, phenomenological laws, distribution functions, etc., to which X at t_β assigns the status "empirically adequate".

Probability statements have the form "In domain D holds: the relative frequency of class G in class F equals r" and are written as $P_D(G \mid F) = r$. D is called the domain of the probability statement, G its object class, F its reference class and r its frequency number. A probability statement is given the status *scientifically founded* if and only if we have established that it is derivable from our primary scientific knowledge. Assigning the status "scientifically founded" to a probability statement is sufficient but not necessary for accepting it.

The *epistemic status(es)* assigned to a sentence or symbolic construction reflect(s) the reasons why we accept it as true; "empirically adequate" and "scientifically founded" are examples of epistemic statuses. A description of the *epistemic state* of X at t_β consists of (i) a description of the knowledge situation of X at t_β, and (ii) a survey of the epistemic statuses which X at t_β assigns to the sentences and symbolic constructions he consciously accepts as true. The epistemic state of X at t_β will be formally represented by $E_{X,\beta}$. Arbitrary epistemic states will be written as E_α.

Accepting a probability statement has direct practical relevance: our behaviour depends on which probability statements we accept and reject. Accepting a phenomenological law has epistemic relevance instead of direct practical: if we accept a law, we enter into an epistemic commitment. By assigning the status "empirically adequate" to a law, we enter into an additional, more specific epistemic commitment. In the subsequent paragraphs, I will clarify what these commitments consist in. I first discuss laws in which the formula has the form $Y_1 = f(Y_2)$ and then the more complex laws.

Derivability of probability statements from phenomenological laws in which the formula has the form $Y_1 = f(Y_2)$ is defined as follows:

(DER) (1) Let $\langle Y_1 = f(Y_2), \langle D, (K_1, I_1), (K_2, I_2)\rangle\rangle$ be a phenomenological law. The probability statement $P(G_j \mid F_i) = 1$ is derivable from this law if and only if:
(a) G_j is a region of (K_1, I_1),
(b) F_i is a region of (K_2, I_2), and
(c) the subinterval of I_1 which defines G_j includes the subinterval of I_1 which is the image under f of the subinterval of I_2 that defines F_i.

(2) Let $\langle Y_1 = f(Y_2), \langle D, (K_1, I_1), (K_2, I_2)\rangle\rangle$ be a phenomenological law. The probability statement $P(G_j \mid F_i) = 0$ is derivable from this law if and only if:
(a) G_j is a region of (K_1, I_1),

(b) F_i is a region of (K_2, I_2), and
(c) the subinterval of I_1 which defines G_j and the subinterval of I_1 which is the image under f of the subinterval of I_2 that defines F_i, are disjoint.

The image under f of an interval [a, b[is the interval [f(a), f(b)[. If condition (1c) is satisfied, all members of the second subinterval are also members of the first; the intervals may be identical. If condition (2c) is satisfied, the subintervals have no common members.

The commitment one enters into by assigning the status "empirically adequate" to a phenomenological law with two variables is:

(COM) Let $\langle Y_1 = f(Y_2), \langle D, (K_1, I_1), (K_2, I_2)\rangle\rangle$ be a phenomenological law. By giving this law the status "empirically adequate", one agrees to assign the status "scientifically founded" to any probability statement of which it has been proved that it is derivable from it (in the sense laid down in (DER)).

The commitment we enter into by *accepting* a phenomenological law with two variables, is analogous but more general: we agree to accept probability statements of which has been proved that they are derivable from the law.

To obtain the equivalent of (DER) for laws with more than one variable, we have to replace the condition that F_i is a region of (K_2, I_2) with the condition that F_i is a complex property which is the intersection of a series of properties $F_2, ..., F_n$ (F_2 being a region of (K_2, I_2), F_3 of (K_3, I_3), etc.). In the conditions *1c* and *2c*, the image under f of the interval corresponding to F_i is to be replaced with the image under f of the set of n-1 intervals which characterize the complex property.

I call the set of all probability statements to which X at t_β assigns the status "scientifically founded" the *effective explanatory knowledge* of X at time t_β. A person's *potential explanatory knowledge* consists of all the probability statements that are derivable from his primary scientific knowledge (the exact meaning of derivability depends on the type of entity; for each type, an equivalent of (DER) can be formulated). From most entities of our primary scientific knowledge, a large (sometimes infinite) number of probability statements is derivable. But for each entity, each individual is acquainted with only a small number of statements for which he knows a proof of derivability. So there is always a discrepancy between a person's effective explanatory knowledge and his potential explanatory knowledge:

the former is only a small fraction of the latter. I will use the law of the simple pendulum to illustrate this discrepancy. Consider the statements $P_S(P_{2.01} \mid L_{1.000}) = 1$ and $P_S(P_{2.01} \mid L_{2.000}) = 0$, where $P_{2.01}$ is the formal representation of "... has a period in the interval [2.005, 2.015[", $L_{1.000}$ of "... has a length in the interval [0.9995, 1.0005[" and $L_{2.000}$ of "... has a length in the interval [1.9995, 2.0005[". These statements are derivable from the law of the simple pendulum. Even if we consider only intervals of the same size as in these examples, an infinite number of probability statements can be derived from the law.

3. *Scientific epistemic explanation problems*

3.1 In order to clarify what SEE-problems are, the concept of *SE-explanans* has to be introduced. I will do this in section 3.2. The definition of SEE-problems follows in section 3.3.

3.2 In order to define what SE-explanantia are, we need an auxiliary concept, viz. *E-triple*. E-triples (epistemic triples) consist of two singular sentences and one probability statement. Singular sentences have the form "Object *a* has property *G* at time *t*". In a singular sentence, a property is attributed to an object-moment; their formal representation is G(a, t).

E-triples are defined as follows:

(ET) $\langle S_1, S_2, W \rangle$ is an E-triple for the singular sentence G(a, t) if and only if
(1) W is a probability statement with object class G which is not a theorem of the probability calculus and which is not analytic,
(2) S_1 is a singular sentence in which the property D (the property that determines the domain of W) is attributed to (a, t),
(3) S_2 is a singular sentence in which the property F (the property that determines the reference class of W) is attributed to (a, t), and
(4) the frequency number of W is not equal to 0.

A probability statement is analytic if it is necessarily true because of the meaning of the terms occurring in it.

Some E-triples are SE-explanantia, others are not. The distinction is drawn by means of two epistemic statuses: "scientifically founded" (see section 2.4) and "empirically founded", a status which may be assigned to singular sentences. A singular sentence is given the status *empirically founded* if and only if our own observations contain sufficient evidence for it or we have good reasons to believe that someone else has gathered sufficient observational evidence for it. Assigning the status "empirically founded" to a singular sentence is a sufficient but not necessary condition for accepting it.

The definition of *SE-explanans* is:

(SE) If $\langle S_1, S_2, W\rangle$ is an E-triple for the singular sentence S_E, then person X is justified in calling this triple a SE-explanans for S_E if and only if
(1) his epistemic state is one in which W has the status "scientifically founded",
(2) his epistemic state is one in which S_1 and S_2 have the status "empirically founded".

3.3 Consider an individual X who at time $t_ß$ compiles a list of all E-triples for S_E which he may call SE-explanantia for S_E, and subsequently gives himself the task of changing his epistemic state to the effect that an additional SE-explanans for S_E emerges (i.e. to the effect that a particular E-triple which in the initial epistemic state did not meet the criteria of (SE), and therefore is not on the list, does meet the criteria in the new epistemic state). This individual will be said to have confronted himself with a *scientific epistemic explanation problem*.

Every SEE-problem can be represented by means of a scheme of the following form:

S_E
$\langle S_1, S_2, W\rangle$
$\langle S_1, S_2', W'\rangle$
$\langle S_1'', S_2'', W''\rangle$, etc.

S_E is the explanandum sentence, i.e. the sentence for which an additional SE-explanans is to be found. The triples listed in the scheme are the SE-explanantia for S_E that are already available to X. They constitute the *reference list* of the SEE-problem.

A SEE-problem has been solved if and only if the epistemic state has been appropriately modified and an additional SE-explanans has been constructed.

4. *Solving SEE-problems by means of phenomenological laws*

4.1 When we try to solve a SEE-problem, the first step consists in choosing the scientific entity we will use. The entity we choose must be *adequate* for solving the problem. A phenomenological law is *adequate for solving a SEE-problem* if and only if it meets the following requirements:

(AD) (1) It belongs to our primary scientific knowledge.
(2) The object-moment (a, t) (= the object-moment occurring in the explanandum sentence of the SEE-problem) belongs to the domain of the law.
(3) The property G (the property assigned to (a, t) in the explanandum sentence) is a region of the attribute space which is associated with Y_1.

For every type of scientific entity, a set of conditions of adequacy like (AD) can be formulated. If our primary scientific knowledge contains more than one entity that is adequate for solving the problem we consider, additional selection criteria (besides the conditions of adequacy) are needed. I will not discuss them here. In the subsequent sections, my starting point will be that an adequate phenomenological law has been chosen to solve the SEE-problem. In 4.2, I present a method for solving an SEE-problem by means of such law. Section 4.3 contains an example in which the law of the simple pendulum (cf. section 2.3) is applied to a SEE-problem.

If we are confronted with a problem for which no adequate entities are available, we have to enlarge our primary scientific knowledge. A particular way of enlarging this knowledge must be mentioned here. Condition 3 of (AD) implies that the law $\langle P = 2\pi\sqrt{l/g}, \langle S, (K_P, [0, +\infty[), (K_l, [0, +\infty[)\rangle\rangle$ is adequate for solving SEE-problems concerning periods of pendulums if it belongs to our primary scientific knowledge. On the other hand, the law $\langle l = g(P/2\pi)^2, \langle S, (K_l, [0, +\infty[), (K_P, [0, +\infty[)\rangle\rangle$ violates the third condition: if it is part of our primary scientific knowledge, it is adequate for solving problems concerning lengths of pendulums, but not for solving problems concerning periods. However, if the second law is regarded as empirically adequate, the reasons we have for assigning this status to it will also be sufficient to justify assigning this status to the first law. In general, a law which with respect to a SEE-problem satisfies the first two conditions of (AD) and requirement (3') below, can always be transformed into a law which is adequate for solving the SEE-problem:

(3') The property G is a region of one of the attribute spaces of the law.

4.2 My method for solving a SEE-problem by means of a phenomenological law consists in consecutively executing a construction procedure and an implementation procedure.

In the *construction procedure*, the law we have selected for solving our problem is used to construct an *explanation scheme*. Explanation schemes consist of a singular sentence, a disjunction of *m* singular sentences and a list of *m* schematic probability statements (schematic probability statements are probability statements in which the frequency number is replaced with a question mark). Explanation schemes have the following form:

(ES) $D(a, t)$

$$F_1(a, t) \vee F_2(a, t) \vee \ldots \vee F_m(a, t)$$
$$P_D(G \mid F_1) = ?$$
$$P_D(G \mid F_2) = ?$$
$$\vdots$$
$$P_D(G \mid F_m) = ?$$

$F_1, \ldots, F_m$ is a modality which is characteristic of D and is called the *antecedent-modality* of the explanation scheme.

The construction procedure is:

(CON) (1) Formulate a singular sentence in which it is claimed that object-moment (a, t) (= the object-moment occurring in the explanandum sentence) belongs to the domain of the law.
(2) To function as the antecedent-modality of the explanation scheme, choose a modality which satisfies the following conditions:
(a) none of its members functions as reference class in the probability statement of one of the SE-explanantia in the reference list of the SEE-problem we are trying to solve, and
(b) each member is a complex property which is the intersection of a series of properties $F_2, \ldots, F_n$ (F_2 being a region of (K_2, I_2), F_3 of (K_3, I_3), ...).
If no modality satisfying these conditions can be found, interrupt the procedure. Otherwise, execute the steps 3 and 4.
(3) Use the antecedent-modality chosen in (2) and the object-

moment (a, t) to write down a disjunction of singular statements of the type required for an explanation scheme.
(4) Formulate a series of schematic probability statements in which the domain and the object class are always respectively D (the domain of the theory) and G (the property attributed to (a, t) in the explanandum sentence) and in which each element of the antecedent-modality selected in step 2 functions as reference class exactly once.

If the procedure has to be interrupted after step 2, the SEE-problem cannot be solved by means of the phenomenological law we have selected. To solve the SEE-problem, we have to use a different adequate entity; if our primary scientific knowledge does not contain an alternative, we have to enlarge it.

In the *implementation procedure*, we gradually transform the explanation scheme we have constructed by means of (CON) into an E-triple. It consists of two parts. The first part consists of the following steps:

(IMP_1) (1) Take the explanation scheme

$D(a, t)$
$F_1(a, t) \vee F_2(a, t) \vee \ldots \vee F_m(a, t)$
$P_D(G \mid F_1) = ?$
$P_D(G \mid F_2) = ?$
$\vdots$
$P_D(G \mid F_m) = ?$

that has been constructed by means of (CON).
(2) Check whether there is a F_i for which $F_i(a, t)$ has the status "empirically founded". If so, go to step 3. If not, execute step 2'.
(2') Try to modify your epistemic state to the effect that one of the sentences $F_i(a, t)$ has the status "empirically founded". If you succeed, execute step 3; otherwise, stop trying to implement the explanation scheme.
(3) Remove the disjuncts and schematic probability statements which do not contain the property F_k (= property for which the sentence $F_k(a, t)$ has the status "empirically founded").

If we have to interrupt this procedure after step 2', the SEE-problem cannot be solved by means of the explanation scheme we have constructed. If this problem occurs, we may go back to step 2 of (CON) and choose a different antecedent modality. If this solution fails, we may choose a different adequate entity to solve our SEE-problem; if our primary scientific knowledge does not contain an alternative, we can enlarge it.

If we do not have to interrupt the procedure after step 2', (IMP_1) results in a modified explanation scheme of the following form:

(MES) D(a, t)
$F_k(a, t)$
$P_D(G \mid F_k) = ?$

Modified explanation schemes are the input of the second part of the implementation procedure. Before we can formulate this second part, the idea of scientifically instantiating a schematic probability statement by means of a phenomenological law has to be clarified.

Instantiating a schematic probability statement is the activity of replacing the question mark with a frequency number. Let $\langle Y_1 = f(Y_2, \ldots, Y_n), \langle D, (K_1, I_1), \ldots, (K_n, I_n)\rangle\rangle$ be a phenomenological law. The schematic probability statement $P(G_j \mid F_i) = ?$ is *scientifically instantiated by means of this law* if and only if it is instantiated by means of the subsequent procedure:

(SI) (1) Determine which subinterval of I_1 defines property G_j.
(2) Calculate the interval $f([x_2, y_2], \ldots, [x_n, y_n])$.
(3) If the interval obtained in step 1 includes the one obtained in step 2, replace the question mark with the number 1. If the intervals are disjoint, replace it with the number 0.

By executing (SI), we do not merely obtain a probability statement: the three steps constitute a proof that the output is derivable (in the sense laid down in (DER) or its equivalent for phenomenological laws with more than two variables) from the law that is considered. There are two possible relations between the first and second interval that are not covered by the step 3. If the second interval strictly includes the first, no frequency number is obtained. The same problem occurs when the none of the intervals includes the other while they have at least one common member. So there are two cases in which (SI) does not lead to the desired result, viz. an instantiation of the schematic probability statement.

The second part of the implementation procedure consists of two steps:

(IMP_2) (4) Try to instantiate the schematic statement occurring in the modified explanation scheme obtained in step (3) of (IMP_1) scien-

tifically by means of the phenomenological law which was the input of step 2 of (CON).
(5) Replace the schematic statement of the modified explanation scheme with the instantiation obtained in step 4.

Step 5 can not be executed in the two cases where (SI) does not lead to the desired result. If it can be executed, (IMP_2) results in the following E-triple:

$D(a, t)$
$F_k(a, t)$
$P_D(G \mid F_k) = p_k$

The triples we obtain by consecutively executing (CON), (IMP_1) and (IMP_2) are always SE-explanantia: condition 2 of (AD) and step 1 of (CON) jointly guarantee that D(a, t) has the status "empirically founded"; that $F_k(a, t)$ has this status is guaranteed by the steps 2 and 2' of (IMP_1); finally $P_D(G \mid F_k) = p_k$ has the status "scientifically founded" because of the interaction of three factors: (i) the statement has been obtained by means of (SI), (ii) the steps of (SI) constitute a proof of derivability, and (iii) by assigning the status "empirically adequate" to a law, we enter into commitment (COM) or its equivalent for more complex phenomenological laws. Furthermore, the triple we obtain always solves the SEE-problem we are considering. This is a result of the fact that explanation schemes we take as input for (IMP_1) always satisfy the following conditions of relevance:

(REL) (1) The object class of the schematic probability statements corresponds to the property attributed in the explanandum sentence of the problem.
(2) None of the SE-explanantia of the reference list of the explanation problem is an implementation of the explanation scheme.

That the first condition is fulfilled is a consequence of step 4 of (CON). The second condition of relevance is satisfied because of condition *a* in step 2 of (CON) and the fact that the procedure is interrupted if no suitable antecedent modality is found.

4.3 To illustrate the method developed in 4.2, we consider the SEE-problem with explanandum sentence "Object *a* at time *t* has a period of 2.01 sec ($\pm$0.005 sec)" (formally: $P_{2.01}(a, t)$) and empty reference list. Object *a* is a pendulum. The law $\langle P = 2\pi\sqrt{l/g}, \langle S, (K_P, [0, +\infty[), (K_l, [0, +\infty[)\rangle\rangle$ is empirically adequate; the property $P_{2.01}$ is a region of (P, [0, $+\infty$[) and *a* is an element of S. Therefore, this law is adequate for solving our SEE-problem.

If we take $\langle P = 2\pi\sqrt{l/g}, \langle S, (K_P, [0, +\infty[), (K_l, [0, +\infty[)\rangle\rangle$ as input for (CON), we obtain an explanation scheme consisting of the singular sentence S(a, t), a disjunction of potential lengths of *a* at *t*, and a series of schematic probability statements in which the property $P_{2.01}$ constitutes the object class and the potential lengths alternately constitute the reference class.

To implement this scheme, we first determine the length of *a* at *t*. In the rest of this example, we will assume that *a* at *t* has a length of 1.000 m (±0.5 mm). On this condition, the third step of (IMP_1) results in the following modified explanation scheme:

$$S(a, t)$$
$$L_{1.000}(a, t)$$
$$P_S(P_{2.01} \mid L_{1.000}) = ?$$

To complete the implementation, the schematic probability statement of this modified explanation scheme has to be scientifically instantiated by means of the law $\langle P = 2\pi\sqrt{l/g}, \langle S, (K_P, [0, +\infty[), (K_l, [0, +\infty[)\rangle\rangle$. The interval which defines the property $P_{2.01}$ is [2.005, 2.015[. As $2\pi\sqrt{0.9995/g} = 2.00596$ and $2\pi\sqrt{1.0005/g} = 2.00696$, the second step of (SI) yields the interval [2.00596, 2.00696[. As the first interval includes the second one, the third step of (SI) yields the statement $P_S(P_{2.01} \mid L_{1.000}) = 1$. In step 5 of ($IMP_2$), this statement is used to transform the modified explanation scheme into the following E-triple:

$$S(a, t)$$
$$L_{1.000}(a, t)$$
$$P_S(P_{2.01} \mid L_{1.000}) = 1$$

This triple is an SE-explanans and solves our SEE-problem.

5. *The heuristic value of the method*

The definition of SEE-problems entails that an enlargement of our effective explanatory knowledge and/or the set of singular sentences we regard as empirically founded is necessary for solving such problem. Because of the discrepancy between potential and effective explanatory knowledge, enlarging the latter is often possible without enlarging the former. The method for solving SEE-problems by means of phenomenological laws which I have developed in section 4, is based on this possibility: the phenomenological law we select to solve the problem already belongs to our primary scientific knowledge. A first aspect of the heuristic value of the method I presented is that the general idea of solving SEE-problems by reducing the discrepancy may be elaborated for other types of scientific entities. Developing a definition of the type of entity involved and constructing equivalents of (DER), (COM) and (SI) are the most important steps of such elaboration; however, minor adaptations to (CON) are sometimes necessary too.

The second aspect of the heuristic value of the method relates to the other types of explanation problems. Firstly, the epistemological framework I used to define SEE-problems may function as a paradigm for e.g. a framework for defining causal explanation problems; in this framework, causal statements (statements asserting causal connections between events) would replace probability statements. Secondly, the epistemological framework developed in section 2.4 can function as a paradigm for analogical frameworks in which the relation between scientific entities and causal statements is laid down; for instance, we could define derivability of causal statements from phenomenological laws, instead of derivability of probability statements.

6. *Concluding remarks*

The method I have developed is not unique: there are other ways to solve a SEE-problem by means of a phenomenological law. In general (leaving aside the different entities we may use) there are two ways to solve a SEE-problem. The first way consists in selecting an adequate scientific entity, using this entity to construct an explanation scheme and implementing this explanation scheme. In the method presented in this article, this first general way to solve SEE-problems is elaborated for cases in which the entity which is chosen is a phenomenological law. If the SEE-problem we want to solve is similar to one we have already solved (i.e. if the present problem differs from a solved one only with respect to the object-moment that is involved), a second general way is available. This second way consists in (i) adapting the explanation scheme which has been used to solve the similar problem, and (ii) implementing the adapted explanation scheme. Adapting and implementing the explanation schemes which (at their first use) were derived from phenomenological laws is a second way in which phenomenological laws can be used to solve SEE-problems.

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