Laws of Nature, Exceptions and Tropes
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Résumé

Je propose une théorie réaliste des lois, en termes de “tropes” (ou instances de propriétés), qui évite les problèmes de “l’analyse du meilleur système” et le “problème de l’inférence” qui se pose au réalisme des universaux. J’analyse le concept de situation exceptionnelle, caractérisée comme une situation dans laquelle un objet particulier satisfait l’antécédent mais non le conséquent de la régularité associée à la loi, sans pour autant réfuter la loi. Pour tenir compte de cette possibilité, il faut concevoir les propriétés mises en relation par une loi, comme dispositionnelles et non nécessairement manifestes.

Abstract

I propose a realist theory of laws formulated in terms of tropes (or property instances) that avoids both the problems of the "best-systems-analysis" and the "inference problem" of realism of universals. I analyze the concept of an exceptional situation, characterized as a situation in which a particular object satisfies the antecedent but not the consequent of the regularity associated with a law, without thereby falsifying that law. To take this possibility into account, the properties linked by a law must be conceived as dispositional and not necessarily manifest.

1. Introduction

Realist and anti-realist conceptions of laws of nature have at least one point in common : They both consider it to be a necessary condition for the existence of a law that there be some universal correlation between states of affairs which can be formulated by a universally quantified material implication of the form[1]

(1) $(\forall x)(Fx \rightarrow Gx)$.

or, if two objects are involved :

(1a) $(\forall x)(Fx \rightarrow (\exists y)Gy)$.

Among other things, realists and anti-realists with respect to laws diverge in their explanation of what makes one universally quantified implication express (or be entailed by[2]) a law of nature while another taking exactly the same form expresses only an accidental correlation. To take Goodman's famous example,

(2) "All coins in my pocket are made of silver"

can be expressed by the same formula - namely (1) - as

(3) "All electrons attract positive charges",

yet only the latter expresses a law.

I shall begin this paper with a list of desiderata which a satisfactory theory of laws of nature should be able to meet. The search for a realist conception is motivated by some important problems faced by regularity theories, and in particular by the so-called "best system" analysis of laws, which John Earman ([Earman 1984], [Earman 1993]) has called, in honour of its principal defenders, the "Mill-Ramsey-Lewis view".

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[1] I follow tradition in attempting to shed light on the nature of laws in general, by studying the properties of laws which have a very simple logical form. I thereby sidestep some important issues. To be able to represent e.g. probabilistic laws, one or both of the predicates F and G must be interpreted as expressing the objective chance to have a given property, rather than that property itself. In order to represent conservation laws, it is necessary to introduce quantification over time. If F is the property of having a determinate amount of some conserved quantity, the conservation law for that quantity should guarantee the following generalization : $(\forall t)(\forall t')(\forall x)(Fxt \rightarrow Fxt')$. In the paper, I shall consider the implications of the fact that such a generalization may be false if the system is not isolated.

[2] According to realists of universals, such as Armstrong, laws are not identical to universal correlations; rather, a law *entails* a universal correlation. I shall say more about this doctrine below. Before, I keep speaking of universally quantified statements “expressing” laws.

Then I turn to the analysis of laws which [Dretske 1977], [Tooley 1977] and [Armstron 1983] have proposed in the framework of realism of universals. While being able to solve the problems faced by the best system analysis, realists of universals face a different and serious difficulty which [van Fraassen 1989] has called the "inference problem". The crucial claim made by realists of universals is that laws are relations between universals. But to make good their explanation of how such laws produce regularities on the level of concrete particulars exemplifying those universals, they have to postulate a relation that spans the gap separating a relation between universals and states of affairs involving particulars. The inference problem arises because this postulate calls for justification on an even higher ontological level, and thus leads to an infinite regress.

This is motivation enough to look for an alternative account which is realist but avoids universals. Realism with respect to laws is the view that the reality of laws is independent of our epistemic attitudes, in particular our actual and future theories aiming at identifying them. According to realism, laws are discovered rather than invented, and there may be laws we perpetually ignore, and laws about which we are wrong. Now realism about universals is not the only form of realism in this sense. I propose to elaborate the idea of conceiving laws as relations between tropes. Tropes can be characterised as abstract particulars, or as instantiated properties.

Then, I introduce the concept of an exceptional situation, characterized as a situation in which some particular satisfies the antecedent but not the consequent of the regularity associated with a law, without thereby falsifying that law. These "exceptions" constitute a serious problem for all theories which hold either that a law *is* a universal correlation between particulars (as regularity theories do) or at least *entails* such a universal correlation (as realism of universals and one version of the trope theory [Fuhrmann 1991] do).

I examine some strategies (none of which takes tropes into consideration) which have been proposed in order to cope with the difficulty posed by exceptional or "abnormal" situations. [Cartwright 1983] and [Schiffer 1991] take the position that law statements expressing a regularity which admits of exceptions are false. [Armstrong 1983] and [Pietroski & Rey 1995] argue that the problem of exceptional situations characterises a specific class of laws, called respectively "oaken laws" and "*ceteris paribus* laws", and try to interpret those laws as having a special, and complex, logical form different from (1) (or 1a). However, this is misleading insofar as the problem concerns

almost all laws, even of physics. As I try to show, the idea of solving the problem by attributing to laws a new and complex logical structure leads to unacceptable consequences.

My proposal for a solution to the problem posed to theories of laws by exceptional situations is the following. It is not the logical form of laws but their subject matter that must be changed. In realist terminology, the idea is that the properties linked by a law are dispositional rather than manifest. This conception enables us to explain why there are situations in which a particular manifests the antecedent but not the consequent of a valid law. Manifest properties are produced by the interaction of many dispositions so that a disposition produced by one property according to a certain law may be hindered from manifesting itself by a stronger disposition produced by another property by virtue of the same or a different law. This idea can be spelled out in both of the two main rival realist conceptions, in terms of universals and in terms of tropes. However, the trope theory of laws is preferable because it has the explanatory virtues of realism without being, as is Realism of universals, victim of the inference problem[3].

2. The best systems analysis and the motivation for a realist account

What makes (2) and (3) statements of a fundamentally different type? The following features constitute a list of explananda for any satisfactory theory of laws. In statements expressing a law of nature - as (3) does - , but not in those expressing a mere coincidence - as (2) does -

1. the predicates F and G which refer to the properties linked by the law occupy *opaque positions*.

2. Law statements may serve as premises in scientific *explanations* and *predictions*;

3. can be *confirmed* by situations in which both F and G are exemplified.

4. Laws as (3), but not universal coincidences as (2) confer *modal force* on the implication of the consequent by the antecedent;

5. can contribute to determine the truth-value of *counterfactual conditionals*.

[3] The present paper elaborates some aspects of the account of laws I defend in [Kistler 1999].

The numerous efforts of explaining the difference between lawful and accidental universal correlations make up an important literature in philosophy of science and metaphysics. The antirealist strategy is to look for the difference by analysing the logical role a statement plays in the framework of a theory (see, e.g., [Braithwaite 1958]). Statement (3) e.g. can be derived from definitions and principles of physical theory whereas (2) cannot[4].

According to a widely accepted non-realist account of laws, namely the one Earman ([Earman 1984, 229f.], [Earman 1993, 416]) has called the "Mill-Ramsey-Lewis theory", (causal) laws are the "consequences of those propositions which we should take as axioms if we knew everything and organised it as simply as possible in a deductive system" [Ramsey 1929, 150]. In Lewis' words, a (contingent) "generalisation is a law of nature if and only if it appears as a theorem (or axiom) in each of the true deductive systems that achieves a best combination of simplicity and strength" [Lewis 1973, 73]. The fact that the best-system analysis invokes only criteria of coherence and avoids postulating special nomological facts over and above the set of empirically accessible particular facts, has the following implausible consequences which constitute arguments against this account[5].

First, there is a subjective element in the establishing of the balance between maximal simplicity and maximal strength. There seems to be no way of justifying a decision between a rationalist view giving more weight to simplicity and an empiricist view giving more weight to strength. But if this is so, there may not be any unique ideal theory which is *objectively* privileged over its competitors.

Second[6], it is one of the aims of the construction of scientific theories to find out which predicates denote natural properties, and to justify the rejection of artificial properties like the one denoted by "grue"[7]. Thus, a scientific theory cannot rely on this distinction from the beginning. Now it may turn out that the use of some such grue-like predicate simplifies a given theory without

[4]Antirealists have recently been led to consider that the very idea of a law of nature bears a commitment to realism, and thus to claim that science not only discovers no laws (this is the realist's basic intuition) but that it doesn't even invent or construct any. See, e.g., [van Fraassen 1989].

[5] They are due to [Armstrong 1983] and [van Fraassen 1989].

[6] Cf. [Van Fraassen 1989, 53f.].

[7] This predicate famously invented by Goodman [Goodman 1955] applies to objects that have been observed before some instant *t* if they are green and to other objects if they are blue.

diminishing its strength. In that case the Ramsey-Lewis approach is condemned to accept the conclusion that the grue-like predicate denotes a natural property after all[8].

Third[9], the best deductive system has grown out of a systematisation of observed facts and regularities. What reason do we have to think that this system can cover counterfactual situations, in particular possible situations in which there are novel properties which have not been encountered in the course of establishing the "best deductive system", as could happen for artificial chemical elements or new biological species?

Fourth, the Ramsey-Lewis account makes coherence alone determine the truth value of law statements. This has the undesirable consequence that if science ends up with more than one system of equal maximal simplicity and strength which do not have any axioms in common, this implies that there aren't, after all, any fundamental laws of nature.

Fifth, the Ramsey-Lewis account excludes on a priori grounds the possibility of a law 1) whose statement cannot be deduced from other axioms or theorems already established and thus has to be itself considered as an axiom and 2) which is instantiated very rarely in the actual history of the universe. Such a law would - by property (1) - diminish the simplicity of the system, but by property (2) would enhance its strength only very weakly. On the Ramsey-Lewis account, such a regularity couldn't be a law, but a contingent fact to be included in the “initial conditions”. Yet it seems implausible to exclude the possibility that it be a law in spite of its properties (1) and (2), on the basis of purely a priori considerations.

These aren't of course knockdown arguments against the best systems analysis[10]. Nevertheless, I think they are powerful enough to motivate a serious attempt to construct a realist analysis which doesn't face problems of this kind.

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[8] Anti-realists can of course reject this argument as question-begging and insist that what it is for a property to be natural, non-grueish, just *is* playing a successful role in scientific theory. To avoid begging the question, the argument must be supplied by an independent criterion of what it is for a property to be natural. I cannot try to provide one here, but have done so elsewhere [Kistler 2002].

[9] Cf. [Armstrong 1983, 69], [Van Fraassen 1989, 47].

[10] David Lewis himself has not been moved by these arguments. Yet he admits having no solution to the objections attacking the best system-analysis for its subjective nature. He just tries to put the burden of proof on the objectors: in order to give their objections strength, they are liable to show that it is plausible that the possibilities they put forward have a chance of arising - Lewis doesn't contest that they are logically possible. Awaiting such a demonstration, he recommends simply to suppose that they don't arise: "If nature is kind to us, the problem needn't arise" [Lewis 1994, 479]. Otherwise, he says, "I'd blame the trouble on unkind nature, not on the analysis; and I suggest we not cross these bridges unless we come to them" [Lewis 1994, 479]. John Roberts has proposed to construe the expression "law of nature" as token-reflexive, i.e. as an expression whose extension depends on the speaker using it and the standards the speaker employs in judging what is the "best system". True, this "indexical best-systems account" [Roberts 1999, S503]

3. The realist account in terms of universals and the inference problem

Within a realist framework, the difference between (2) and (3) is objective and independent of our knowledge about the regularities involved, and *a fortiori* independent of our theories involving them. The realist takes it that this objective difference requires an explanation which is equally objective, i.e. makes no mention of our epistemic attitudes towards the regularities to be explained. He has to choose between two main options: Realism of universals and realism of tropes. The realist explanation put forward by [Dretske 1977], [Tooley 1977] and [Armstrong 1983] posits a relation between universals which is then used to explain their universal coinstantiation. (2) differs from (3) in that (3), but not (2) is backed by "a relationship between the universal properties F-ness and G-ness" [Dretske 1977, 252]. Armstrong expresses this "backing" with the following formula:

(4) "$N(F,G) \rightarrow (\forall x)(Fx \rightarrow Gx)$" [Armstrong 1983, 85].

Arguably, the realist of universals can explain all the explananda on our list. In formula (4) the positions occupied by F and G on the right-hand side of the main implication are transparent whereas those on the left-hand side are opaque for F and G appear there as individual constants referring to the universals F and G, and not as predicates as they do on the right-hand side (This was our requirement # 1, see above).

The realist of universals argues that the postulate of a relation between universals permits him to *explain why* it is possible to explain why all Fs are G in case the correlation is nomic, and why no such explanation is available in case the correlation is, on the contrary, accidental. This explanation is provided by the main implication in (4). There is no corresponding implication of (1) by something else in the case of accidental uniformities (# 2). (Similarly for confirmability, # 3).

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makes the laws independent of any *particular* standards. However, it seems to me that his thesis that what is a law depends on the speaker's choice of standards makes the notion of law relativistic, and thus *less* objective than Lewis' own"chauvinistic [...] rigidified best-systems analysis" [Roberts 1999, S503-505] in which what it as law depends on *our* standards.

Furthermore, not only does the law N(F,G), i.e. the relation between universals, (materially) imply that each object x which possesses F also possesses G, but that it *must*. The universal generalisations backed by laws, and only they, have the modal force of necessity[11] (# 4).

This is also what explains the fact that a law covers counterfactual situations. Understood as a relation between universals, a law holds in all possible worlds sharing the laws of the actual world[12], i.e. differing from it only in contingent facts. These are precisely the worlds we have to look at in order to evaluate counterfactuals (# 5).[13]

The realist position which explains laws in terms of relations between universals faces an important problem which van Fraassen has called the "problem of inference" and which leads the realist of universals to an infinite regress of the type of Plato's "Third Man"[14]. It arises from the need to justify the realist's explanation of how a law implies a universal correlation between the

[11]Cf. Dretske [Dretske 1977, 264). On the realists' problem of explaining how *necessary* relations between particular states of affairs can be implied by *contingent* second-order states of affairs (which is what realists as Dretske and [Armstrong 1983] take laws to be), see [Kistler forthcoming, a].

[12] The thesis that laws themselves are contingent threatens to make the realist account of how laws ground the truth of counterfactuals tautologous, because it makes it necessary to add the qualification that laws hold only in those possible worlds in which they hold. On this count, it is easier to explain how laws ground the truth of counterfactuals, by supposing that laws are metaphysically necessary (cf. [Shoemaker 1980], [Shoemaker 1998], [Ellis 2001]). I have defended the thesis of the necessity of laws on independent grounds elsewhere [Kistler forthcoming, b], but I cannot repeat the argument here.

[13]According to David Lewis, counterfactuals are evaluated with the help of intuitions concerning the closest possible world W among all those in which, contrary to what is the case in the actual world, the antecedent is true. The counterfactual is true if and only if the consequent is true in W. Lewis argues that W, for a given counterfactual, is in general a world in which a "small, localized, inconspicuous miracle" [Lewis 1973, 75] has occurred just before the event described by the antecedent because such a violation of *law* allows the class of particular *facts* preceding the event described by the antecedent to resemble exactly their actual counterparts, and because this greater factual resemblance may often outweigh the perfect lawful resemblance with the actual world of another non-actual worlds without any miracles and in which the entire past is factually different from the actual world. However, it seems to me that, first, every small miracle apt to change a single fact must involve the violation of many laws, e.g. at least the violation of both the conservation laws of energy and momentum, and second, that the very idea of a small miracle puts Lewis before a dilemma: Either a world with a miracle however small is inconsistent in that its own laws both hold and do not hold (if they hold, there can be no miracle, and if they do not hold there can be no miracle either because a miracle violating a given law L presupposes that L is indeed a law), or the "miraculous" world is consistent in that the "miracle" is not really a miracle but rather a lawful event in a world whose laws differ from our actual laws, and therefore only *appears to us* as miraculous. But in that case, we lose the clear intuition that such a world is closer to the actual than a world with many but only factual differences with respect to actuality, for the least difference in laws entails many factual divergences throughout the entire history and future. Furthermore, the idea of judging that a miraculous world is closest to the actual world creates a difficulty for the evaluation of counterfactuals which it was its role to contribute to. This is the problem that we do not seem to have any clear-cut intuitions about miraculous worlds, i.e. worlds in which our laws do not hold. To judge what happens in a non-actual world W, our only foothold seems to be the supposition that the laws of W are the same as our actual laws, otherwise just anything could happen in W, and there is no intuitive ground for judging that the consequent of the counterfactual is true in W rather than false (or false rather than true). This is my reason for saying that only "homonomic" non-actual worlds can help us evaluate counterfactuals.

[14] Cf. [Van Fraassen 1989, 103].

instances of the properties it links, i.e. the first implication in Armstrong's formula (4). How can it be that a relation between two objects of second order, namely the universal properties F and G, can entail an implication relation between the states of affairs Fx and Gx which have the first order object x as a component? From a logical point of view, such an implication cannot be justified. To justify the (first) implication in (4) it is necessary to postulate a further relation whose relata are the law N(F,G) and the individual objects x. If one conceives of the relation between the universals F and G as a second order relation, this new relation would have to be at least of third order. But then the problem of justifying how a relation of third order can have logical consequences on the level of first and second order relations arises anew, which is the beginning of an infinite regress. Furthermore, it is fatal for the realist because it cancels the explanatory advantage which he claims the theory in terms of universals provides, and which constitutes the major motivation for the explanation of the laws of nature in these terms.

If the law-founding relationship N(F,G) relating the universal properties F and G does not provide the explanation which motivated its postulation in the first place - i.e. if the pretended explanation is shown to be logically invalid - the realist conception of laws in terms of universals loses its major justification.

4. Exceptional situations

Realist theories of laws share with regularity theories the following problem. The validity of most laws – with the possible exception of fundamental physical laws - is compatible with the existence of exceptional situations[15]. Such situations constitute a problem for all theories which either identify a law with a universal generalisation of the form (1) or (1a)(as the regularity theory does) or hold that the former at least implies the latter (as the Realist of universals does). The fact that they imply (1) makes these accounts incapable of explaining why exceptional situations do not refute the laws with respect to which they are exceptional.

The laws with the simplest logical structure are those expressing a relation between different properties of one and the same object.

[15]Cf. [Canfield and Lehrer 1961, 207], [Lakatos 1970, 98], [Hempel 1988].

Let, e.g., P_l be the predicate "is a pendulum of length l"[16] and F_l be the predicate "has a period of $T(l) = 2\pi\sqrt{l/g}$ ". ("g" designates the gravitational acceleration on the surface of the Earth.) Let L(P) be the law that all P_l are F_l. Then if L(P) was equivalent to the universal generalisation

U(P) $(\forall x)(P_1x \rightarrow F_1x)$

where the domain of x is the set of all concrete objects, one could build the following deductive argument (I) : let b be a pendulum of length l. According to U(P) all such pendulums have a period T(l).

(I) P_1b

$(\forall x)(P_1x \rightarrow F_1x)$

$\therefore Fb$

But there is another well warranted generalisation which when added to the major premise U(P), leads to a contradiction even if the first premise is true.

Let A, said of an object satisfying P_l, mean that its maximum angle is 45°[17].

Let L(Angle) be a law according to which pendulums of length l which swing with a maximum angle of 45° have a period $T^*(l) \neq T(l)$. Thus, this law implies that pendulums of length l satisfying A do not satisfy F_l. The corresponding generalisation could be written :

U(A) : $(\forall x)((P_1x \wedge Ax) \rightarrow \neg F_1x)$.

But now we can build the following argument (II) which is valid just as (I).

(II) $P_1b \wedge Ab$

$U(P) \wedge U(A)$

$\therefore F_1b \wedge \neg F_1b$

On the assumption that the particular premise $P_1b \wedge Ab$ is true, it follows that at least one of U(P) and U(A) must be false. In this case it seems clear that the blame should be put on U(P) which is too general as it stands because pendulums with large amplitudes falsify it. Other situations which are exceptional with respect to this law arise: 1. If a pendulum doesn't swing in empty space, but is subject to frictional forces, 2. if a pendulum is made of iron, and a magnet is in its proximity.

[16]In realist language, we say that P_l denotes the property of being a pendulum of length l.

[17]The period of a pendulum diverges from T(l) well below 45°. The criterion for the quality of the approximation given by L(P) is the quality of the linear approximation of f(x) = sin(x) by f(x) = x.

Similar arguments can be constructed for most laws, both in the special sciences and in physics. Nevertheless, a situation like the one described is not taken to falsify the law L(P) (nor the law L(A)). Thus, it seems desirable to find a way of interpreting the relation between a law and the situations it commands which allows us to stick to the truth of the law, notwithstanding the existence of situations like the one described.

We can do this by distinguishing between manifest and dispositional properties[18]. Manifest properties are causally efficacious: the falling of a fragile vase as well as its hitting the ground are manifest in this sense. Their being manifest makes them directly observable. However, the vase can possess the property of being fragile without ever falling or breaking, and without manifesting itself in any way by being causally responsible for anything. Something can have a dispositional property at a time when this property is not causally efficacious in any way. It is controversial whether dispositional properties are *sometimes* efficacious, in bringing about their manifestations, e.g., whether the vase's fragility causally contributes to its breaking when the vase hits the ground[19]. However, what makes a property like fragility dispositional is that it is possible that at some times, it does not exert any causal influence.

Let us then conceive of the law L(P) as linking the property P_1 to a dispositional property whereas the corresponding universal generalisation U(P) bears on manifest properties. This implies putting some distance between the law and its impact on concrete particulars exemplifying their antecedent. In other words, it is not possible to directly use the law itself in a deductive argument (III) analogous to (I). (III) is not valid:

(III) $P_1 b$

$L(FF)(P_1 \rightarrow F_1)$

[18]Mumford ([Mumford 1998a, chap. 10], [Mumford 1998b]) has presented the hypothesis of the existence of laws of nature and the hypothesis of the existence of real dispositions as alternative and rival approaches to the explanation of change. Similarly, Cartwright thinks that "we must admit capacities", and that "once we have them we can do away with laws" [Cartwright 1989, 8]. While I agree with Mumford and Cartwright that real dispositions (or capacities) are needed to solve the problem of exceptions, I disagree with his view that dispositions make laws explanatorily useless. When we explain why a particular electron moved as it did by reference to the link between its being an electron and its having the disposition to move in a certain way according to the electric field present at its location, it is only the generality of the fact that all other electrons would have the same disposition in that situation, that makes the account explanatory. [Cartwright 1999] has recently turned to a realist account of *ceteris paribus* laws, according to which such laws describe *local* regularities that exist in specific circumstances, in particular experimental arrangements, that she calls "nomological machines".

[19] Among others, Armstrong ([Armstrong 1968], [Armstrong 1997]) holds that dispositions (or dispositional properties) can be causally efficacious, [Prior, Pargetter and Jackson 1982] argue that they cannot.

$\therefore F_1 b$

The task is to conceive of the law in a way which permits us to say that all the premises of (III) are true although its conclusion may be false - as in the situation described above. Formally, this is possible if (III) is an enthymeme. It isn't a valid deduction as long as it isn't completed by additional premises[20].

Since the existence of exceptional or "abnormal" situations with respect to a given law L, i.e. situations in which the antecedent of L is satisfied but not its consequent, but which nevertheless do not falsify L, has been acknowledged, several proposals have been put forward in order to accommodate this fact in a coherent general theory of laws. The accounts I shall consider have one thing in common: they all treat the possibility of admitting for exceptional situations as a property of a certain type of laws, called by different authors "special science laws" (Fodor), "*ceteris paribus* laws" (Cartwright, Schiffer, Pietroski and Rey) or "oaken laws" (Armstrong). I shall argue that one should rather conceive of exceptions as situations in which a law of the simple logical structure (1) or (1a) is at work but doesn't manifest itself directly.

One strategy that has been proposed in order to deal with the problem of exceptions is to complete the antecedent of the law statement in a way to exclude all possible interfering factors. Canfield and Lehrer have called this the "completeness condition" [Canfield and Lehrer 1961, 207]. The problem with this idea is that laws completed in this way "are incapable of being written down explicitly simply because the number of provisos implicit in any law is indefinitely large" [Giere 1988, 40]. The fact that it is impossible to state explicitly a list of requirements on a given situation which would ensure that it obeys a given law has led a number of authors to think that laws facing this problem are either vacuous ([Giere 1988], [Lange 1993]), unexplanatory if completed with an unspecific *ceteris paribus* clause [Cartwright 1983], or false if explicitly stated, in which case the purported law simply does not exist ([Schiffer 1991], [Earman and Roberts 1999])[21]. As long as one

[20] It is important to note that the number of these premises is indefinite. This has, in particular, the consequence that they can't be explicitly enumerated. As long as one overlooks this fact, one runs the risk of being "trapped in the idea that the '*ceteris paribus* clause' is a premise which is joined *conjunctively* with the obvious premises" [Lakatos 1970, 98; Lakatos' emphasis]. Lakatos detects this "confusion" in [Canfield et Lehrer 1961] and [Stegmüller 1966] before he admits that his own phraseology may sometimes generate the same misunderstanding.

[21] [Earman and Roberts 1999] and [Woodward 2000], [Woodward 2001] argue that there is no coherent way to construe the notion of a non-strict or *ceteris paribus* law, and then point out that there are ways to make sense of the aim of the special sciences, which do not presuppose ascribing to them the aim of discovering laws. Rather, according to Woodward, special sciences, and biology in particular search for "invariant generalizations" [Woodward 2000, 199], rather than for laws. According to Earman and Roberts, statements that philosophers have erroneously interpreted as

looks for a logical form of laws whose antecedent contains an explicit specification of the situations in which the consequent will be realised, it is indeed inevitable to draw one of these conclusions. As Schiffer puts it, "if it were claimed that some special-science ceteris paribus sentence expressed a ceteris paribus law, then the challenge would be [...]: to specify the true proposition expressed by the sentence that would prove the existence of the law" [Schiffer 1991, 15f.]. Schiffer points out that there is no specific proposition expressed by a law statement fulfilling the "completeness condition" because the number of provisos is indefinitely large. Below, I shall add my own reason for rejecting the idea that, in order to be equivalent to a true universal statement of type (1), law statements must or can be supplemented by a completing clause. Yet these reasons do not justify rejecting the notion of the very existence of laws (nor of the existence of a restricted subclass of non-strict laws), for there is a different way to solve the problem of exceptions to valid laws.

Geoffrey Joseph has proposed a substitute for the "completeness condition" which has often been conceived as a *ceteris paribus* clause: It is not that other things must be *equal* in order for a law to be valid, it is rather, Joseph says, that other constraints have to be *absent*. Thus, he considers the hypothesis that laws are made literally true by *ceteris absentibus* clauses. "Were it the case that all other factors were absent, then given certain initial conditions, certain resultant conditions would obtain" [Joseph 1980, 777][22]. However, this proposal faces a serious problem: it requires to consider the logical structure of law statements to be counterfactual, which - as Joseph himself points out - has unacceptable consequences. If the law is only true *ceteris absentibus* then it is vacuous in the actual world for the factors stated in the antecedent are never instantiated alone. Furthermore, if factors F1 and F2 are antecedents of two laws which interfere in the actual world, then the possible worlds where one law is instantiated are different from those possible worlds where the other is true. For in no possible world can F1 and F2 *both* be *exclusively* present.

Joseph gives two more reasons for rejecting the *ceteris absentibus* proposal. First, the possible worlds in which our laws are instantiated differ from the actual world not only in fact but also in law. Thus laws are more precisely counterlegals : they are instantiated in possible worlds

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ceteris paribus laws, are “vague claims” that are formulated before any satisfactory theory of a domain has been found. They are characteristic of “work-in-progress theories” [Earman and Roberts 1999, 471].

[22]This is also Cartwright's interpretation of the content of *ceteris paribus* statements. She states, e.g., the law of gravitation as follows : "If there are no forces other than gravitational forces at work, then two bodies exert a force between each other which varies inversely as the square of the distance between them, and varies directly as the products of their masses" [Cartwright 1983, 58].

with different laws from ours. But this means that we lose our grip on the identity of the laws we are talking about. What is worse, it seems incoherent to say of a law L both that it is valid in our world and that it is instantiated only in worlds whose laws differ from those valid in the actual world. The basic hypothesis of the *ceteris absentibus* account which is that our law statements are not instantiated in the actual world, seems incompatible with the idea that these laws are nevertheless valid in the actual world. A further reason to reject the *ceteris absentibus* proposal is that it forbids us, on pains of circularity, to analyse counterfactuals in terms of laws, for on this account laws themselves are counterfactual and even counterlegal.

The second proposal considered by Joseph is promising, indeed I think more so than Joseph himself judges it to be. Rather than in changing the logical form, it consists in changing the subject matter of laws. Each single field law of physics, e.g., is not intended to accurately describe the actual trajectory of particles. The subject matter of each of these laws is its own distinctive field: gravitational, electromagnetic etc. "We must consider each field law as giving only one component of the total force. [...] Each individual field law would be interpreted not as a statement linking the sources of the field to the behaviour of objects subject to the field, but instead as a statement linking the sources of the field to the field itself, conceived as a physical entity distinct from the objects upon which it acts" [Joseph 1980, 779]. Joseph then goes on to reject this proposal as well. His reason is that, as history of science teaches us, the subject matters of the different laws are not independent. It would be an error to think that it is possible to correctly describe reality by simply juxtaposing the laws governing the different kinds of fields and forces generated by them. "The reconciliation of the theories of mechanics, gravitation, and electromagnetism was not achieved through any simple manoeuvre such as logically conjoining them or pooling their respective standard models." [Joseph 1980, 780]. Or, in other words, "they do not fit together [...] into a single consistent theory demonstrably possessing a physical model." [Joseph 1980, 780].

To overcome the difficulty pointed out by Joseph, I propose to distinguish between the concept of, say, electrical charge, as elaborated by physical theory, and the real property designated by the predicate "electrical charge". We don't know the property perfectly well as long as we haven't discovered all the laws governing the behaviour and interactions of the particles possessing that property. Joseph is right to note that we can be certain of this ignorance to the extent that

different theories aiming at characterising different properties cannot be satisfied by any single model. But the following picture is compatible with this ignorance: every property is characterised[23] by the set of dispositions to behave and interact, that it bestows on the particulars possessing it. These dispositions are determined by the laws of nature in which the property participates[24]. A theory can be seen as providing implicit definitions of its theoretical predicates. But what these definitions describe is not the real property itself but a concept intended to match as well as possible with that property. In general, the match between the concept implicitly defined by a theory and the property is imperfect. In that case reality is not a model of the theory.

Drawing the distinction between the concepts elaborated by a theory and the real properties those concepts are intended to capture, characterises realism with respect to those properties and the laws governing the dispositions characterising them (and the particulars possessing the property). Realism implies that it is possible that we ignore the existence of some properties (maybe even fundamental ones), and that we are possibly wrong about the exact nature of those properties we know something of ("the exact nature" here always means: the set of dispositions regulating the behaviour and interactions of the particulars possessing the property). In a realist framework, Joseph's objection would strike only the thesis (which nobody holds) that science has already reached its endpoint: that we already perfectly know the laws of nature. More reasonably, our law statements are hypotheses using concepts and conjecturing relations between them which only imperfectly correspond to real properties and their relations. Reconciling our different theories requires modifying them, but this modification may lead to a convergence of the models of each theory towards a single consistent model, i.e. reality.

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[23]This is a neutral term intended to bypass the debate between categoricalism and dispositionalism (Cf. [Ellis and Lierse 1994], [Mumford 1995], [Armstrong 1997, chap. 5], [Molnar 1999]). Is the link between the property and the disposition it bestows on the particular possessing it contingent or necessary? In other words, does the property simply consist of its dispositions (dispositionalism) or is it contingently linked to it, contingently that is by laws of nature which hold in our world but need not hold in every possible world (categoricalism)?

[24]The conception defended here takes up suggestions of [Coffa 1968] and [Cartwright 1983]. Coffa proposed to interpret laws (of the type admitting for exceptions) as "laws of tendency, stating the contribution of a certain factor to a given process" [Coffa 1968, 281f.]. Yet Coffa underestimates the complexity of the interactions between different properties and different laws even if he is right in noting that there are some rare laws which do not allow for exceptions - as Newton's law stating the equivalence of force and the product of acceleration and mass - and which can therefore be considered as equivalent to their associated universal generalisation. Cartwright's suggestion according to which "the laws we use talk not about what bodies do, but about the powers they possess" [Cartwright 1983, 61] is also compatible with the present proposal, as long as one abstracts from the theoretical commitments this claim is associated with in Cartwright's work, in particular her opposition between fundamental and phenomenological laws, the latter but not the former being capable of literal truth and of causal efficacy, which in turn is used in "effective strategies".

Pietroski and Rey's proposal takes into account the fact that we cannot explicitly state which situations are regular with respect to a given law and which are exceptional. But according to these authors, admitting for exceptions is a property characterising a certain class of laws, called "*ceteris paribus* laws" which possess a specific complex structure. In order for such a law to be true, it must contain a clause quantifying over all possible interfering factors. In each situation where the consequent isn't exemplified although the antecedent is, there is some explanation or other, in terms of an interfering factor H explaining why the consequent isn't exemplified. They give the following example:

"A chemist holding that cp(PV = nRT) [where "cp" means "*ceteris paribus*"], is committed to the following: if a gas sample G is such that $PV \neq nRT$, there are independent factors (e.g. electrical attraction) that explain why $PV \neq nRT$ with respect to G. [...] C- abnormal[25] instances are to be expected. But such instances must be explicable by citing the factors ignored, else the putative cp-law is either vacuous or false. [...] If a putative cp-law is such that all its C-abnormal instances can be explained by citing independent factors, [....] the cp-law is true. But if there are inexplicable C-abnormal instances, the putative cp-law is either vacuous or false." [Pietroski and Rey 1995, 91/2].

This account is not meant to be verificationist. A cp-law[26] can be true even if we never find the interfering factor in some C-abnormal situation. Such a situation doesn't objectively falsify the law even if the interfering factor responsible for the non-satisfaction of the consequent is unknown. As realists, Pietroski and Rey hold that we can be wrong about whether the law is falsified by such a situation or not, and that this is an objective difference (about which we may be ignorant in a given situation).

Pietroski and Rey's account faces the following difficulty: they don't make it perfectly clear whether their analysis of the cp-clause is intended to be epistemological or ontological, i.e. whether it expresses the way we describe, predict and explain situations with the help of laws or whether it means that the laws themselves have a so much more complex structure than the simple universal generalisation of the type (1) or (1a).

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[25]C-abnormal instances occur in what we have called exceptional situations. [Pietroski and Rey 1995] give a rather complex formal characterisation of the concept of a C-abnormal instance, but the basic idea is I hope captured by what I say in the text.

[26]"cp" always stands for "ceteris paribus".

Pietroski and Rey use the metaphor comparing cp-clauses with "cheques written on the bank of independent theories" [Pietroski and Rey 1995, 89]. This suggests an epistemological reading: to make good the cheque, it must be cashed some day by some actually formulated theory. Given that they consider the cp-clause as a part of the law itself, the truth conditions of the law become dependent on explicitly formulated theories. This interpretation of Pietroski and Rey's proposal would burden them with the difficulties of nominalistic accounts of laws - in particular the best systems analysis of laws. However, this is not, if I understand them well, the interpretation intended by these authors. But if one follows the alternative ontological interpretation, one arrives at a picture of laws whose consequences are equally implausible. In fact, on an ontological reading, their analysis of ceteris paribus laws appears as an elaboration of Armstrong's conception of oaken laws, and inherits its difficulties.

Just as Pietroski and Rey, Armstrong takes it to be a property *of* a law to be either strict or cp. He expresses this by the terminological distinction between "iron laws" and "oaken laws". A law is iron if there are no exceptions to it, otherwise it is oaken. Armstrong spells out the concept of an oaken law in the following formula:

(6) "It is a law that Fs are Gs, except where Fs are Hs, are Js, and Ks ... and so on for an infinite set of distinct properties." [Armstrong 1983, 28].

There seem to be two options for interpreting this distinction: either the question whether a law has exceptions or not is external to it, i.e., with respect to that law it is just an accidental fact, or it is internal, i.e., a property of the law itself. On the first alternative, the distinction between iron and oaken seems *ad hoc* and unjustified. If it isn't the laws themselves which somehow permit or prevent the possibility of exceptional situations, the distinction doesn't really bear on them, but rather on the accidental fact of which sort are the situations in which the antecedent of the law happens to have been exemplified so far. Due to another accident, a given law can switch category. When an exceptional situation arises for the first time, the law ceases to be iron and becomes oaken. So let us consider instead that being iron and being oaken are properties of the law itself.

This leaves us with two major difficulties. Armstrong's conception fails with respect to its primary aim of finding a criterion justifying the distinction between the two types of laws. Formula (6) is incapable of establishing that oaken laws are any different from iron laws. A particular

situation satisfies the antecedent in Armstrong's formula (6) only if it is not exceptional, namely if the properties H, J, K etc. which are responsible for eventual exceptions to the law N(F,G) are absent. This means that, by definition, there cannot be any exceptions to the law thus formulated. In the end, Armstrong's proposal leads to transforming oaken laws by stipulation into iron, i.e. exceptionless ones, by integrating into its antecedent the requirement that potential exception-provoking factors be absent.

Next, Armstrong's proposal faces the difficulty of all *ceteris absentibus* theories, that it makes laws expressed by a formula of type (6) vacuous. But there is a another, stronger argument against Armstrong's strategy to eliminate the problem of exceptional situations by explicitly mentioning their absence in the antecedent. The various factors H, J, K, etc. which are potentially responsible for exceptional situations with respect to the law N(F,G), have this potential of interference in virtue of other nomic links between H and F, between H and G, between J and F, and so on. Not only do these factors already form an open disjunction with an indefinite number of terms, but the laws linking them to F and G, the antecedent and consequent of the main law N(F,G) are themselves of the type of (6): They are themselves subject to exceptions. This puts Armstrong on a slippery slope[27] which leads to depriving the very notion of a law of its content. For at the end, following the logic of Armstrong's proposal (6), each single law turns out to contain a large number of other laws. Appearances to the contrary notwithstanding, the truth conditions of laws are holistic. But the concept of a law of nature makes sense only insofar as a law is what determines regularities across the diversity of situations. If in the limit there is only one law which equally governs *all* situations, the very distinction between regularity and diversity loses its content.

Pietroski and Rey's elaboration of Armstrong's proposal in which they substitute a quantificational structure for Armstrong's points of suspension "...." has the merit of making this difficulty more clearly visible. Each law - among those concerned by our problem - contains an existential quantification running over all "otherwise nomological" [Pietroski and Rey 1995, 92][28] properties H. Furthermore what is decisive about these "interfering factors" H is that they can "explain" the non-occurrence of the consequent of the main law. This explanatory capacity appears

[27]Cf. [Canfield and Lehrer 1961] who propose a similar argument in a nominalistic framework.
[28]This qualifier is intended to exclude Goodmanian predicates like "grue" from those denoting genuine natural properties.

as an unanalysed constituent in Pietroski and Rey's formula of the logical structure of cp-laws. But, at least if we stick to a realist interpretation of explanation which seems to be in the spirit of Pietroski and Rey's account, each potentially interfering factor H will be able to interfere and its presence will be part of an explanation of non-G in virtue of *other* laws, linking H to non-G. Thus they are, just as Armstrong, at the beginning of a slippery slope: not only are there infinitely many potentially interfering factors H, but their potential interference is covered by just as many laws in general different from the law one started with, and each of those laws will in general also be a cp-law with another clause quantifying over interfering factors, and so on. In the end, laws appear to be holistic, in the sense that the truth conditions of each law depend on those of many, if not all, other laws. A single law cannot be discovered or stated in isolation from many other laws because its very content depends on those other laws. I take this consequence to be in conflict with the notion of a law as an objective feature of nature which is responsible for uniformity on a background of variety.

Note that this problem is in a sense worse then the one raised by Duhem and Quine's thesis that law statements cannot be tested independently of the whole theory they are part of. If Armstrong or Pietroski and Rey are correct, not only is it impossible to test law statements independently, but their very content is dependent on many other laws. In other words, not only our epistemic access to laws, i.e. the testing procedure, is holistic as Duhem and Quine argue it is, but the very content of the laws is holistic too.

There is a variant of the strategy put forward by Armstrong and Pietroski and Rey which is a quite familiar move in reaction to the existence of non-falsifying exceptional situations. Consider once again the pendulum law L(P).

It is tempting to protect the law from falsification by such situations by introducing the qualifier "classical" into the law statement, thus restricting its validity to "classical pendulums" only. All pendulums not obeying the law count by definition as non-classical pendulums which thus do not satisfy the antecedent predicate "is a classical pendulum of length l". This move can be interpreted in two ways: either one considers that it makes a *convention* of the validity of the law, or one considers the word "classical" as an abbreviation for Armstrong's clause stating that an infinite conjunction of potential sources of exceptions are absent, or for Pietroski and Rey's existential

quantification over them. It seems to me that both possibilities obscure the difference between regular and exceptional situations instead of contributing to its explanation. Making it a convention deprives the law at least partly of its empirical content while the second option results, as we have seen, in making the law's truth conditions holistic.

5. Laws allowing for exceptions

I shall now sketch a theory of laws in terms of tropes. The idea is to localise the constraint exercised by a law on the situations falling under it, not at the level of universals nor at the level of concrete objects, but on the level of the tropes which are the ultimate constituents of concrete particulars[29]. Tropes are properties as they are instantiated by particulars, "property instances" or, in other words, abstract particulars[30]. I shall treat as equivalent the locutions "the particular *a* consists of the tropes in set E" and "the particular a possesses the tropes in set E". Among the tropes a particular possesses some are manifest and some are dispositional[31]. The first are actually causally efficacious, notably when they are observed, the second are only potentially efficacious. Laws of nature are dependence relations among such tropes which are partly dispositional. We can postulate that laws have the simple logical structure of the universally quantified material implication (1) or (1a) on the condition that the domain over which the variable x ranges is fixed in an unusual way. I propose to let this domain be constituted, not by the set of all concrete particular objects but by the set of tropes constituting these objects. The material implication of the consequent by the antecedent means that the disposition referred to by the consequent of a law is present in every situation in which the antecedent is present.

Why do we need to assume that some of the tropes related by a law are dispositional? A disposition cannot be reduced to its manifestations even though its manifestations are what ultimately justifies postulating its existence[32]. A disposition doesn't necessarily manifest itself and

[29]I cannot enter here into the debate about whether a particular is merely a bundle, whether it has substance over and above its tropes, or whether the role played by the traditional substance can be overtaken by a nucleus constituted by tropes internally related to each other. Cf. [Armstrong 1989], [Armstrong 1997], [Martin 1993], [Simons 1994].
[30]Cf. [Williams 1953], [Campbell 1990], [Armstrong 1989, [Armstrong 1992], [Bacon 1995].
[31] Peter Lipton [Lipton 1999] has made a similar proposal. However, Lipton does not specify whether the dispositions that non-strict (or ceteris paribus) laws refer to, are tropes or universals.
[32]Cf. [Carnap 1936], [Spohn 1997], [Mumford 1998a].

its not manifesting itself doesn't mean it isn't present[33], but postulating its existence can explain a manifestation characteristic of that disposition. The difference between the presence of a disposition and its manifestation is precisely what permits us to explain how a situation may be exceptional with respect to a law in that its antecedent is satisfied but not its consequent, and how the law may still remain valid. If we conceive of the consequent as designating a dispositional property, we can explain such situations in the following way: the consequent is satisfied as well as the antecedent, but it doesn't manifest itself because it is overridden by other dispositions imposed on the same particular at the same time, due to other tropes according to the same law, or according to different laws. Given the possibility of several dispositions competing with each other for manifestation, we can say that each disposition imposes a constraint on the manifest properties of the particular at a given time[34]. The possibility of a disposition not to manifest itself because it is overridden by other dispositions is responsible for exceptional situations. This happens, e.g., if a pendulum not only contains the trope designated by "the length of this pendulum", but also the trope "this pendulum's consisting of iron" when an external magnetic field is present. The second trope can then be responsible for the pendulum's behaving in an exceptional way and in particular for its not having the period T which the law L(P) prescribes it to have. Such situations are not exceptions *to the law itself* and do not falsify it because the consequent disposition is present in any case, but they are exceptions *to the generalisation* associated with the law. This is because the generalisation bears over the manifest properties of the particulars, and an exceptional situation is one in which the antecedent property is manifest but not the consequent. Universal material implications can express valid laws having exceptions if one takes the domain of the variable x in (1) or (4) to range over tropes which are partly dispositional. It is only if one takes the domain of this variable to be the set of all concrete objects, that a law statement linking F to G is falsified by exceptional situations in which a concrete object possesses the property F, but not the property G.

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[33]This is what Prior *et al.* call "the distinctness thesis". Interestingly, they count the existence of what we call exceptional situations as an argument for that thesis. "Even if there is only one causal basis of fragility, say bonding a, it may happen that although all fragile objects have a, some objects that have a are not fragile. This would be the case if there were an internal structural property S which swamped the effect of having a." [Prior *et al.* 1982, 253].

[34]It may turn out to be possible - but whether or not it actually does is an empirical issue - to classify these constraints in orthogonal dimensions such that all the tropes imposing conflicting constraints are represented within the same dimension. Dispositions belonging to different - orthogonal - dimensions would not come into conflict with one another. The constraints imposed by the dispositions belonging to one dimension can then be ordered according to their magnitude, to explain the resulting manifest property of the particular.

To speak of "normal and abnormal conditions" instead of exceptional and regular situations may be misleading because this terminology wrongly suggests[35] that normal conditions occur more often than abnormal ones. The relevant distinction is rather between situations in which the disposition manifests itself (more or less clearly) and others where it does not. The frequency of situations where a disposition manifests itself and situations where it doesn't is likely to be the opposite of what talk of normal conditions suggests: situations in which the pendulum law or the free fall law manifest themselves (by manifesting a correlation to a very good approximation of the antecedent property with the consequent) are rare in nature or even exclusively to be found in laboratory environments[36]. But the point is not simply to reverse the sense of the dependence of the "normality" of conditions on frequency, but to recognise that the truth of a law is independent of the frequency of situations in which it manifests itself.

Thus we can rescue the traditional conviction that laws are exceptionless. To do this we have to distinguish the law from the corresponding generalisation bearing on manifest properties. The generalisation has exceptions, which comes to saying that taken literally, it is false. The law, as distinct from the generalisation associated with it, may be stated in a simple logical form - without reference to other laws, possible interfering factors etc., and nevertheless may be literally true, the truth-maker being a relation between tropes, the consequent being dispositional and thus not always manifesting itself.

This proposal could not pretend to solve the problem of exceptions but only to indicate a direction in which it might be possible to construct such a solution. To yield a complete solution, the present proposal would have to be complemented by a theory of dispositional properties which I do not attempt to provide here. The task of that theory would be to explain how and when a dispositional property manifests itself, and how exactly several dispositional properties jointly determine a manifest property. However, I do not think that the reference to dispositional properties has the consequence that the laws with a dispositional consequent are immunised against refutation, or "vacuous", as they are in the traditional cp-account, for the reason that observation does not *directly* allow to decide whether or not the consequent is exemplified in a given test situation.

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[35]This interpretation is explicitly intended by [Spohn 1997].

[36] Pietroski and Rey explicitly reject a probabilistic interpretation of cp-laws for similar reasons. As they say, "it often turns out that 'ideal' circumstances are not merely rare, they are nomologically impossible." [Pietroski and Rey 1995, 84].

Dispositional properties are theoretical properties, and the predicates designating them cannot, as [Carnap 1936] and [Hempel 1965] have shown, be operationally defined by simple material test conditionals. Whether or not a theoretical, or not directly observable, property is exemplified by a given object cannot be judged by a simple observational criterion, but depends in the end on the application of a - more or less holistic - inference to the best explanation. Only in a strict verificationist framework does this imply that dispositional predicates do not have a well determined meaning or do not designate objective properties.

6. Laws, accidental regularities, and the "inference problem"

It is the fact that the consequent of a true law statement refers to *dispositional* tropes that allows us to explain, as we have tried to do in the preceding section, how a law can be valid although there are many situations that are exceptions to it. But it is the fact that the consequent of a true law statement refers to (dispositional) *tropes* that allows us to explain, as I shall try to show now, all the differences between laws and accidental universal regularities, and nevertheless to escape the "inference problem" (introduced in § 3 above). The account of laws sketched in the preceding section has a realist explanation of the difference between (2) and (3).

(2) "All coins in my pocket are made of silver"

(3) "All electrons attract positive charges",

In the case of (2) there is no dependence relation between the tropes referred to by the antecedent and consequent, whereas there is such a nomic dependence in the second case. The competing realist accounts of [Armstrong 1983] and [Fuhrmann 1991] also derive

(1) $(\forall x)(Fx \rightarrow Gx)$.

by postulating relations on a deeper ontological level, but in doing so they both fix the domain of the universally quantified variable x in formula (1) to consist of concrete objects. Neither Armstrong's nor Fuhrmann's theory does justice to the complexity of the relation between a) relations among the properties (tropes) themselves and b) the behaviour of the concrete objects possessing these properties.

Let us have a look at Fuhrmann's proposal of a trope theory of laws. It turns out that his version cannot overcome the difficulty of accounting for exceptional situations. Fuhrmann conceives of the nomic relation as a consequence of a relation between tropes which has the logical structure of the part-whole relation. Fuhrmann analyses the concept of law in the following way: " 'All Fs are Gs' expresses a true basic law of nature if and only if the predicates 'F' and 'G' correspond to resemblance classes of tropes and N(F,G) is contingently true." [Fuhrmann 1991, 73]. N(F,G), the relation of nomic necessitation N between resemblance classes of tropes is defined thus:

(5) "N(F,G) iff $(\forall x)(x \in F \rightarrow (\exists y)(y \in G \wedge y \leq x))$ " [Fuhrmann 1991, 72].

The crucial relation "$\leq$" between the tropes x and y "exhibits the characteristics of a *part of* relation" [Fuhrmann 1991, 65].

Fuhrmann doesn't tackle the issue of exceptions explicitly, but his conception excludes their possibility in principle for if the existence of a law linking F and G is based on a "$\leq$"-relation between tropes x and y belonging to the resemblance classes characterising respectively F and G, then all individuals containing a trope of type F will necessarily contain a trope of type G. Yet it avoids the inference problem by conceiving laws as relations between tropes. Tropes are particulars just as the concrete objects of which they are the ultimate constituents and whose behaviour they determine in virtue of their lawful relations to other tropes. Thus the trope theory avoids the ontological gap leading to the inference problem, i.e. the gap between the law itself and its manifestation in the regular behaviour of particulars.

If one accepts to supplement the trope theory with the distinction between a disposition and its manifestation, it seems to inherit the explanatory virtues of realist theories while avoiding the inference problem that threatens Realism of universals. As all realist accounts, the trope theory does not identify a law with an empirical regularity. It explains why some regularities - like (3) - are nomic with the hypothesis that these regularities result from the manifestation of a lawful dependence between tropes. Other regularities - like (2) - are accidental because they are not manifestations of underlying dependence relations between tropes.

A trope theory doesn't encounter van Fraassen's "inference problem" because it takes both the entities whose relatedness founds nomicity and the entities whose behaviour is determined by those

nomic relations as first order particulars[37]. Tropes are *abstract* particulars (like: the length of this pendulum) whose relations are called for to explain the behaviour of *concrete* particulars (such as this pendulum).

Finally, let us check whether our proposal meets all of the adequacy criteria we imposed on any acceptable account of laws (cf. section 2 above). The referential opacity of law statements is explained by the fact that the universally quantified variable x in (1) is interpreted as ranging over tropes. It may be a law that all F are G, and an accidental truth that G and H have the same extension. Then it is true that all F are H, but it need not be a law. By the criterion of truth preservation on substitution of coreferential terms, the statement "it is a law that all F are G" is opaque in the positions occupied by F and G. Tropes, being properties, can differ even if they are extensionally equivalent, i.e. if they are contained in exactly the same concrete particulars. Substituting H for G in the statement "it is a law that all F are G" does not preserve its truth value if there exists a dependence relation only between tropes of type F and G, but not between those of type F and H (#1).

As other realist accounts, trope theory explains why laws, but not accidentally true universal generalisations, may be part of scientific explanation and prediction (#2), and objects of confirmation (#3). A law can non-vacuously explain or predict particular manifestations of a given phenomenological regularity because it differs from that regularity itself. An accidental generalisation just states a regularity and thus cannot explain that same regularity. The link between a disposition and its manifestation must itself be lawful. It is only on this condition that laws as construed by trope theory will help in explaining and predicting. If laws are relations between tropes, they can be tested, and our belief in their truth can be justified, only indirectly, by the predictions which can be derived from them concerning the properties of concrete objects. But the detailed account of how several dispositions present at the same space-time point result in some well determined manifest property must be left to scientific enquiry. In classical mechanics, for example, the net force acting on a given point is calculated by vector addition of the component forces. In quantum mechanics, all sources of interference on the behaviour of a given system are part of the Hamiltonian describing the state of that system; and perturbation theory permits

[37] [Fuhrmann 1991] shows that this is also true of his version of trope theory.

incorporating the influence of these factors in the prediction, using the strength of the factors acting in the situation as an ordering principle.

One item on our list of explananda for any acceptable theory of laws is perhaps more difficult to interpret. Does our account in terms of tropes vindicate the intuitive idea that laws confer modal force on their instantiations (#4) ? The very phenomenon of exceptional situations obliges us not to interpret this modal force as bearing upon the manifest properties of particulars. It cannot be necessary that the behaviour of all freely falling bodies obey the law of free fall because this isn't even actually the case. In other words, the free fall law doesn't describe the behaviour of falling bodies in all possible worlds, for the actual world is a counterexample.

But, on the other hand, it is essential to the concept of law that its domain of validity extend beyond actuality and also cover merely possible situations. It is only thus that laws can contribute to the determination of the truth value of counterfactuals (#5).

The solution lies in attributing necessity to the dependence relation between dispositional tropes. The relation between the *manifest* properties referred to by the antecedent and the consequent of a true law statement isn't even that of actual let alone necessary universal correlation, but the underlying *dispositions* are linked with necessity. This is what makes laws relevant to the evaluation of counterfactuals. If these counterfactuals bear on the manifest behaviour of objects in possible but non actual situations, a law may not be sufficient as a truthmaker for the counterfactual because the possible situation may be exceptional, but the law is sufficient as a truthmaker for counterfactual statements bearing on the presence of dispositional properties[38].

References

Armstrong, David M.
1968 *A Materialist Theory of the Mind*, London: Routledge, 1993.
1983 *What is a Law of Nature*, Cambridge: Cambridge University Press, 1983.
1989 *Universals. An Opinionated Introduction*, Boulder, CO: Westview Press, 1989.
1992 Properties, *in* [Mulligan, Kevin (ed.), *Language, Truth, and Ontology,* Dordrecht: Kluwer, 1992, 14-27].
1997 *A World of States of Affairs*, Cambridge: Cambridge University Press, 1997.

Bacon, John

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1995 *Universals and Property Instances. The Alphabet of Being*, Aristotelian Society Series, Vol. 15, Oxford: Blackwell, 1995.

Campbell, Keith
1990 *Abstract Particulars*, Oxford: Blackwell, 1990.

Canfield, John and Lehrer, Keith
1961 A Note on Prediction and Deduction, *Philosophy of Science*, 28, 204-208.

Carnap, Rudolf
1936 Testability and Meaning, *Philosophy of Science*, 3, 420-471.

Cartwright, Nancy
1983 *How the Laws of Physics Lie,* Oxford: Clarendon Press, 1983.
1989 *Nature's Capacities and their Measurement,* Oxford: Clarendon Press, 1989.
1999 *The Dappled World, A Study of the Boundaries of Science*, Cambridge: Cambridge University Press, 1999.

Coffa, José A.
1968 Discussion: Deductive Predictions, *Philosophy of Science* 35, 279-283.

Dretske, Fred
1977 Laws of Nature, *Philosophy of Science*, 44, 248-268.

Earman John
1984 Laws of Nature: The Empiricist Challenge, *in* [Bogdan, Radu J. (ed.), *D.M.Armstrong*, Profiles, Vol. 4, Dordrecht: Reidel, 1984, 225-269].
1993 In Defence of Laws: Reflections on Bas van Fraassen's *Laws and Symmetries*, *Philosophy and Phenomenological Research*, 53, 413-419.

Ellis, Brian, and Lierse, Caroline
1994 Dispositional Essentialism, *Australasian Journal of Philosophy*, 72, 27-45.

Ellis, Brian
2001 *Scientific Essentialism*, Cambridge: Cambridge University Press, 2001.

Fuhrmann, André
1991 Tropes and Laws, *Philosophical Studies*, 63, 57-82.

Giere, Ronald N.
1988 Laws, Theories, and Generalizations, *in* [Grünbaum, Adolf and Salmon, Wesley (eds.), *The Limitations of Deductivism*, Los Angeles: University of California Press, 1988, 37-46].

Goodman, Nelson
1955 *Fact, Fiction, and Forecast*, Indianapolis: Bobbs-Merrill, 1965.

Hempel, Carl G.
1965 Empiricist Criteria of Cognitive Significance: Problems and Changes, *in* [C.G. Hempel, *Aspects of Scientific Explanation*, New York: Free Press, 1965, 101-122].

1988 Provisos: A Problem Concerning the Inferential Function of Scientific Theories, *in* [Grünbaum, Adolf and Salmon, Wesley (eds.), *The Limitations of Deductivism*, Los Angeles: University of California Press, 1988, 19-36].

Joseph, Geoffrey
1980 The Many Sciences and the One World, *Journal of Philosophy*, 77, 773-791.

Kistler, Max
1999 *Causalité et lois de la nature*, Mathesis, Paris : Vrin, 1999.
2002 The Causal Criterion of Reality and the Necessity of Laws of Nature, *Metaphysica*, 3 (1), 57-86.
forthcoming, a, Le combinatorialisme et le réalisme nomologique sont-ils compatibles ?, *in* [Monnoyer, Jean-Maurice (ed.), *La structure du monde : objets, propriétés, états de choses*, Paris : Vrin].
forthcoming, b, L'identité des propriétés et la nécessité des lois de la nature, *Cahiers de Philosophie de l'Université de Caen*, 38/39 *: Le réalisme des universaux.*

Lakatos, Imre
1970 Falsification and the Methodology of Scientific Research Programmes, in [Lakatos, Imre, *The Methodology of Scientific Research Programmes*, Philosophical Papers, Vol. 1, Worrall, John and Currie, Gregory (eds.), Cambridge: Cambridge University Press, 1978, 8-101].

Lange, Marc
1993 Natural Laws and the Problem of Provisos, *Erkenntnis*, 38, 233-248.

Lewis, David
1973 *Counterfactuals*, Oxford: Basil Blackwell, 1973.
1994 Humean Supervenience Debugged, *Mind*, 103, 473-490.

Lipton, Peter
1999 All Else Being Equal, *Philosophy*, 74, 155-168.

Martin, C.B.
1993 Power for Realists, *in* [Bacon, John, Campbell, Keith and Reinhardt, Lloyd (eds.), *Ontology, Causality, and Mind*. Cambridge: Cambridge UP, 1993, 175-186].

Molnar, George
1999 Are Dispositions Reducible?, *Philosophical Quarterly*, 49, 1-17.

Mumford, Stephen
1995 Ellis and Lierse on Dispositional Essentialism, *Australasian Journal of Philosophy*, 73, 606-612.
1998a *Dispositions*. Oxford: Clarendon Press, 1998.
1998b Laws of Nature Outlawed, *Dialectica*, 52, 83-101.

Pietroski, Paul and Rey, Georges
1995 When Other Things Aren't Equal: Saving Ceteris Paribus Laws from Vacuity, *British Journal for the Philosophy of Science*, 46, 81-110.

Prior, Elizabeth W., Pargetter, Robert and Jackson, Frank

1982 Three Theses about Dispositions, *American Philosophical Quarterly*, 19, 251-257.

Ramsey, Frank P.
1929 General Propositions and Causality, *in* [Ramsey, Frank P., *Philosophical Papers,* Mellor, D.H. (ed.), Cambridge University Press, 1990, 145-163].

Roberts, John
1999 "Laws of Nature" as an Indexical term: A Reinterpretation of Lewis' Best-System Analysis, *Philosophy of Science*, 66 (Proceedings), S502-S511.

Schiffer, Stephen
1991 Ceteris Paribus Laws, *Mind*, 100, 1-17.

Shoemaker, Sydney
1980 Causality and Properties, *in* [Shoemaker, Sydney, *Identity, Cause, and Mind*, Ithaca (N.Y.), Cornell University Press, 1984, 206-233.]
1998 Causal and Metaphysical Necessity, *Pacific Philosophical Quarterly*, 79, 59-77.

Simons, Peter
1994 Particulars in Particular Clothing: Three Trope Theories of Substance, *Philosophy and Phenomenological Research*, 54, 553-575.

Spohn, Wolfgang
1997 Begründungen a priori - oder: ein frischer Blick auf Dispositionsprädikate, *in* [Lenzen, Wolfgang (ed.), *Das weite Spektrum der analytischen Philosophie: Festschrift für Franz von Kutschera*, Berlin: de Gruyter, 323-345].

Stegmüller, Wolfgang
1966 Explanation, Prediction, Scientific Systematization and Non-explanatory Information, *Ratio*, 8, 1-24.

Tooley, Michael
1977 The Nature of Laws, *Canadian Journal of Philosophy*, 7 (4), 667-698.

van Fraassen, Bas
1989 *Laws and Symmetry*, Oxford: Clarendon Press, 1989.

Williams, Donald
1953 On the Elements of Being, *Review of Metaphysics*, 7, 3-18 and 171-192.

Woodward, James
2000 Explanation and Invariance in the Special Sciences, *British Journal for the Philosophy of Science*, 51, 197-254.
2001 Law and Explanation in Biology: Invariance is the Kind of Stability that Matters, *Philosophy of Science*, 68, 1-20.