The Ontology of Patterns in Empirical Data

James W. McAllister[†‡]

This article defends the following claims. First, for patterns exhibited in empirical data, there is no criterion on which to demarcate patterns that are physically significant and patterns that are not physically significant. I call a pattern physically significant if it corresponds to a structure in the world. Second, all patterns must be regarded as physically significant. Third, distinct patterns must be regarded as providing evidence for distinct structures in the world. Fourth, in consequence, the world must be conceived as showing all possible structures.

1. Introduction. Philosophy of empirical science has long been confronted by the problem that empirical data—the outcomes of observations and measurements—seem too complex, random, and variable to perform the role assigned to them, namely, to ground scientific knowledge of the fundamental constitution of the world. The solution to which philosophers have repeatedly turned consists in hypothesizing that empirical data sets are made up of two components: a relatively simple component that corresponds to structures in the world and a more complex component that does not. According to this solution, by decomposing data sets correctly and discarding the second component, an empirical scientist can detect which structures the world contains.

Twenty years ago, James Bogen and James Woodward (1988; Wood-

†To contact the author, please write to: Institute of Philosophy, University of Leiden, P.O. Box 9515, 2300 RA Leiden, The Netherlands; e-mail: j.w.mcallister@phil.leidenuniv.nl.

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ward 1989) put forward the most rigorous and sophisticated version of this solution yet. Drawing on the metaphor of signaling theory, they proposed that we conceive of an empirical data set as the sum of a pattern and a noise term. The pattern corresponds to what they call a "phenomenon": a universal and stable structure in which the world is articulated. The pattern constitutes evidence of the existence and nature of this phenomenon, by virtue of being caused by it. The noise term accounts for the remainder of the data set.

Bogen and Woodward assumed that their account was consistent with, and provided support for, a view of the fundamental constitution of the world to which philosophers, virtually without exception, have held. This is the view that the world has a single, univocal structure, which scientists identify by examining empirical data. In this article I argue that, to the contrary, the claim that evidence of structures in the world takes the form of patterns exhibited in empirical data sets is incompatible with the view that the world shows a single structure. Instead, it leads ineluctably to a quite different and unexpected conclusion—that the world shows all possible structures (McAllister 2009).

2. How to Identify Physically Significant Patterns. Everyone agrees that, mathematically, there is no limit to the number and variety of ways in which an empirical data set can be decomposed into a pattern and a remainder. A string of numbers, for example, can be expressed as the sum of any string whatever and a second string that matches the discrepancy between the two. This means that, mathematically, any data set can be said to exhibit all possible patterns. How does this fact bear on the proposal to treat patterns in data sets as evidence of structures in the world?

An intuitively attractive response is to say that whereas the patterns exhibited in empirical data sets are infinitely numerous and varied, they fall into two classes: patterns that correspond to, are caused by, and constitute evidence of structures in the world and patterns that do not. I shall call patterns of the former class "physically significant patterns." We may conjecture, furthermore, that the former class is much smaller than the latter. For example, Bogen and Woodward assumed that relatively few patterns that can be picked out in empirical data sets correspond to what they call phenomena.

If patterns exhibited by empirical data sets fall into these two classes, there must be a fact that distinguishes physically significant patterns from other patterns. What is this fact? Whereas Bogen and Woodward did not explicitly address this question in their articles 20 years ago, it is clear that we must answer it if our account is to be complete and credible.

In trying to specify the respect in which physically significant patterns differ from other patterns, we operate under two restrictions. First, we

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may not appeal to a knowledge, belief, expectation, or assumption that the world contains a particular structure. The partition between the two classes is supposed to tell us which patterns we should accept as indicating the existence of structures in the world: it is inadmissible, therefore, to base the partition on the outcome that the world contains a certain structure. Second, a specification of the difference between physically significant and other patterns must refer exclusively to intrinsic facts about these patterns. The specification may not appeal either to stipulations or to contingent facts about human knowers, such as our cognitive interests, pragmatic preferences, or the historical development of science. This is because we presume that the demarcation of patterns that have and patterns that lack physical significance depends solely on the structure of the world and not on our decisions or on contingent facts about us knowers. For example, we may not stipulate that patterns have physical significance only if they are exhibited in data sets with a noise level of no more than 10%: our choice of an arbitrary threshold value cannot serve as a guide to ontology.

Still, these two restrictions allow several possible accounts of the difference between patterns that have and patterns that lack physical significance. There are three main proposals: that the difference lies in properties of the noise terms with which patterns are exhibited in empirical data sets; that the difference lies in values of quantitative parameters that characterize individual patterns, such as a pattern's mathematical form or degree of algorithmic complexity; and, finally, that the difference lies in relations among distinct patterns exhibited in empirical data sets.

Let us begin with the proposal that the noise terms of physically significant patterns differ from those of other patterns. We might suppose, for example, that patterns exhibited in empirical data sets with noise that is low, that shows no patterns of its own, or that is uncorrelated with the pattern itself are physically significant. This proposal is implausible because it suggests that properties of something that is only incidentally associated with a pattern—the noise with which it is exhibited in a data set—determine whether the pattern corresponds to a structure in the world. For any pattern that is exhibited in a data set with a noise term that has some desirable characteristic, we can generate other empirical data sets in which the same pattern is exhibited with a noise term that lacks this characteristic—a noise term that is high, shows patterns of its own, or is correlated with the pattern. This suggests that the difference between physically significant and other patterns does not lie in the properties of noise.

This proposal is also undermined by evidence from scientific practice. Modern science recognizes physically significant patterns with widely differing noise terms. Scientists have successfully attributed physical signif-

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icance to patterns that are exhibited with low and high noise and to patterns that are exhibited with noise that shows patterns of its own, including correlations with the pattern picked out from the data.

Research into the speed of rotation of the earth offers an illustration. The empirical data, customarily expressed as "length of day" values, show multiple patterns, each of which geophysicists regard as providing evidence of a real physical effect. These include a linear increase of between 1 and 2 milliseconds per century, attributed to changes in the earth's oblateness and to tidal dissipation in the atmosphere and oceans; a pattern with an amplitude of a few milliseconds and a period of around a decade, attributed to torques on the core-mantle boundary; fluctuations with an amplitude of around 0.5 milliseconds and a period of between 1 and 2 years, attributed to oscillations in stratospheric winds; fluctuations with an amplitude of around 1 millisecond and a period of up to a year, attributed to exchanges of angular momentum between the solid earth and the atmosphere; a fluctuation with an amplitude of around 0.2 milliseconds and a period of between 40 and 50 days, attributed to meteorological effects; and several fluctuations with amplitudes of around 0.1 milliseconds and periods of a few days, attributed to tidal and other geophysical phenomena (Dickey 1995).

The noise terms associated with patterns in this list have every characteristic that could conceivably be regarded as indicating a lack of physical significance: high values, patterns of their own, and correlations with the pattern. Consider the last pattern in the list, which has an amplitude of 0.1 milliseconds. Since this pattern accounts for around 1% of the overall variability of the data set, a scientist who picks out this pattern is willing to regard 99% of the variability as noise. Moreover, this noise term shows patterns of its own: in fact, it is the sum of all the other patterns listed and a further residual noise term. This means also that this noise term is not randomly distributed: to mention just one departure from randomness, it contains a component corresponding to a linear increase of between 1 and 2 milliseconds per century. Despite all these features, geophysicists have not hesitated to regard the pattern exhibited with this noise term as physically significant: indeed, they believe they have identified the structures in the world—namely, tidal and other geophysical phenomena—to which this pattern corresponds, which cause this pattern, and for which this pattern provides evidence.

The list of patterns given above also undermines the second proposal, that physically significant patterns differ from other patterns in the values of quantitative parameters that characterize them, such as mathematical form and degree of algorithmic complexity. The list contains patterns with widely different mathematical forms, degrees of algorithmic complexity, and other quantitative parameters.

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Some might object that empirical data on the speed of rotation of the earth are exceptionally complex and that more ordinary empirical data sets show fewer patterns. This is not the case. It is usual for empirical data sets to exhibit multiple patterns on different scales and with different noise levels, each of which is regarded by scientists as evidence of a distinct structure in the world. Further examples are data on cosmic microwave radiation, earth atmospheric temperature, and human plasma cortisol levels (McAllister 2007).

From these examples, I conclude that whatever the difference may be between patterns that are physically significant and patterns that are not, it does not lie in different values of quantitative parameters that characterize patterns and noise terms.

3. Robustness. The third and final intuitively plausible proposal is that physically significant patterns differ from other patterns by virtue of standing in certain relationships to one another. These relationships give to the patterns that participate in them the property of robustness, which single patterns lack. This proposal is put forward, for example, by Katherine Brading (2010).

Two relationships might be thought to play this role. In the first, which I will call projectability, a pattern detected in one data set is later found to be reproduced also in a second data set. In the second relationship, which I will call consilience, patterns exhibited in data sets of different kinds provide evidence of the same structure in the world.

The suggestion that projectability is a sign of physical significance is based on the appealing intuition that a pattern that leads to a successful prediction has a stronger claim to correspond to reality than a pattern that does not. But what does the discovery that a pattern is projectable amount to? Saying that a pattern $P(x)$ is projectable from one data set A to another data set B means that if $P(x)$ is exhibited with a noise level of $n\%$ in A, it is found to be exhibited with a noise level no higher than $n\%$ also in B. This outcome provides no reason for thinking that $P(x)$ has a stronger claim to correspond to a structure in the world than another pattern $Q(x)$ that is not projectable. The fact that the noise level with which $P(x)$ is exhibited in B is no higher than the noise level with which it is exhibited in A, whereas this does not hold for $Q(x)$, sheds no light on the ontological question of whether $P(x)$ and $Q(x)$ are physically significant. For projectability to offer a criterion to distinguish patterns that are physically significant from patterns that are not, it would have to be supplemented with grounds for thinking that patterns are physically significant if and only if they are exhibited with a noise level no higher than $n\%$. In short, the appeal to projectability, far from offering a solution to the problem before us, requires such a solution.

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The second relationship is consilience: patterns in data sets of different kinds agree on the structures that exist in the world. The determination of Avogadro's number is probably the most famous case of consilience: empirical data sets on such apparently unrelated phenomena as Brownian motion, x-ray diffraction, and electrolytic decomposition exhibit patterns that agree on the number of molecules in a mole (Salmon 1984, 214–20). Consilience, however, strengthens our belief in the existence of certain structures in the world only because each of the patterns considered is physically significant. In other words, consilience is not a factor in virtue of which a pattern acquires physical significance, whereas it might otherwise lack it, but a factor in virtue of which patterns that have physical significance stand in a certain agreement with one another, whereas they might otherwise be unrelated. Evidently, then, consilience cannot be the respect in which physically significant patterns differ from other patterns: patterns already have physical significance before entering into relations of consilience.

On these grounds, I conclude that the property of robustness and, more generally, relationships among patterns do not constitute the respect in which physically significant patterns differ from other patterns.

4. Individuating Structures. If we are unable to specify a respect in which physically significant patterns differ from other patterns in empirical data sets, we should consider the possibility that no such partition exists. All patterns then fall into the same class. Since denying physical significance to all patterns in empirical data sets would shut our epistemic access to the world and make empirical science impossible, it is more fruitful to conclude that all patterns exhibited in empirical data sets are physically significant or constitute evidence about structures in the world. This conclusion holds irrespective of the magnitude or other properties of the noise with which patterns are exhibited in data sets.

If, mathematically, empirical data exhibit all possible patterns, and if all these patterns constitute evidence about the world, what precisely does this evidence establish? In particular, how many distinct structures does this evidence suggest the world contains?

An answer to this question will be provided by a criterion for individuating structures in the world. If our individuation criterion counts the structures that cause two distinct patterns in data as distinct, a one-to-one relation between structures and patterns will hold; if our criterion in some cases counts those structures as the same, a one-to-many relation will hold.

Now, our sole possible epistemic access to structures is through the patterns in empirical data that they cause. I therefore suggest that we make our individuation criterion for structures follow our individuation

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criterion for patterns in data: if two patterns differ, then the structures that caused them differ also. On this criterion, there are as many distinct structures in the world as there are distinct patterns in empirical data.

The alternative view that, in some cases, multiple distinct patterns are caused by the same structure is open to three objections. First, this view is empirically unmotivated. This view envisages a taxonomy in which patterns are attributed to a smaller number of structures. However, there is no empirically detectable fact that can weigh for or against any such taxonomy. Second, this view does not amount to a coherent alternative. A structure that manifests itself in multiple distinct patterns in data must be regarded as complex: it has multiple facets, each of which causes one of the patterns. If we are willing to go this far, we may equally identify each facet with a structure in its own right. Third, this view is not stable. If we assume that a structure is able to cause multiple patterns in data, then simplicity considerations will favor saying that the world in its entirety consists of just one structure, which causes all the patterns in data that we are capable of picking out. Then, the option of saying that this structure has as many facets as the patterns that we discern in empirical data becomes all the more compelling.

These arguments support the conclusion that distinct patterns in empirical data constitute evidence of, and in this sense correspond to, distinct structures in the world. Coupled with the finding that, mathematically, empirical data show all possible patterns, this suggests that empirical data constitute evidence for the proposition that the world contains all possible structures.

5. How Structures Coexist in the World. I call a world that contains all possible structures "radically polymorphous." The thesis that the world is radically polymorphous seems to conflict with most theorizing in philosophy of science and with our everyday conceptions of the world. Nonetheless, I believe that the empirical data themselves show that the world is radically polymorphous. In this section, I discuss how the thesis should be interpreted and try to allay some possible misgivings about it.

How should we conceptualize the simultaneous existence of all structures in the world? Since our sole possible evidence that the world has some structure takes the form of patterns in empirical data sets, I suggest allowing our understanding of structures in the world to be guided by our understanding of patterns in data. As we have seen, an empirical data set exhibits all possible patterns with various noise levels. Patterns are superposed on one another and exist simultaneously in data: they are all present in the same data set, available to be picked out or to be disregarded. The fact that we pick out one pattern in a data set does not establish that alternative patterns do not exist. We ought to conceive of

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structures in the world in the same way. Whereas we habitually think of a structure as ruling out other structures, in actuality all structures exist simultaneously in the world, available to be picked out or to be disregarded.

Some might find my position a form of relativism, but this characterization is inaccurate. Relativism would involve saying that the world has one structure for one observer and a different structure for another observer. By contrast, I hold that the world has all structures absolutely: all structures are objectively real for all observers. Whatever its inadequacies, therefore, this is no relativism.

In any concrete situation, of course, observers pick out just one pattern at a time from the infinitely many available in empirical data. The observer is normally guided in the choice by two preferences. The first is a preference for patterns of a certain form. For example, an observer may choose to pick out a pattern consisting of a horizontal straight line from a graphical plot of a data set. This choice may be suggested or constrained by previous choices to pick out certain other patterns in other data sets. In this sense, the choice of a pattern of a particular form may be empirically motivated, although no history of earlier choices of patterns establishes that the latest pattern chosen has any more claim than any other pattern to correspond to a structure in the world.

The second preference is for a noise level. An observer may tune in to patterns that are exhibited in a data set with higher or lower noise. A preference for a noise level enables the observer to choose whether to focus on patterns that follow the variance of the data more or less closely. In many cases, we describe a pattern that is exhibited with lower noise as corresponding to smaller-scale structures in the world and patterns exhibited with higher noise as corresponding to larger-scale structures.

Preference for a noise level is built into the human senses and into all observational instruments. For example, the human sense of sight has a preference for a noise level that ensures that we interpret visual data in terms of structures of a size of approximately 1 meter. If the preferred noise level were lower, we would focus on smaller-scale structures, becoming more aware of the irregularities of a tabletop, for example. If the preferred noise level were higher, we would lose sight of many smaller objects altogether and would see regions of space as empty. Structures on these alternative scales—irregularities of tabletops, emptiness of spaces—are self-evidently present too, but human observers in everyday circumstances usually focus on them less than on midsize structures.

Neither an observer's preference for patterns of a certain form nor the preference for a certain noise level, of course, has any bearing on the question of whether the world contains just one structure or, as I maintain, all possible structures. That question is decided exclusively by two factors:

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which patterns are exhibited in empirical data, and what evidential significance these patterns have. Indeed, observers would not need preferences for patterns of a certain form and for a certain noise level if the empirical data showed that the world had a unique structure.

What, finally, are the implications for Bogen's and Woodward's concept of "phenomenon"? We have two options. First, we can apply this label to every structure that the world contains. This is conceptually consistent but makes the term so broad as to be superfluous. Alternatively, reasoning in the spirit of Bogen and Woodward, we can use the label "phenomenon" to designate the particular structure that is at the focus of a certain research project. This label shifts from structure to structure depending on the research project pursued, just as what counts as the partition between pattern and noise in a data set depends on the project (McAllister 1997).

6. Responses to Cosymposiasts. Before concluding, I trace my further agreements and differences with the other contributors to this symposium.

Paul Teller (2010) emphasizes, among other things, that even what is labeled, for the purposes of a certain research project, as the noise term in an empirical data set contains information about some structure in the world, albeit not one that lies at the focus of that project. I agree. I take Teller's observation as confirming in part my view that there is no component of any empirical data set that does not constitute evidence about the structure of the world.

Bogen (2010) offers a purported counterexample to my assumption that in order to gain empirical evidence about the structure of the world, scientists must decompose empirical data sets into a pattern and a noise term. As Bogen describes, György Buzsáki investigated the statistical features of electroencephalography (EEG) data and, without decomposing those data into pattern and remainder, found that they approximated pink noise. I have three responses to Bogen's objection. First, the assumption that empirical evidence about the structure of the world is contained in patterns rather than in the global value of empirical data underlies not only my approach but also that of Bogen and Woodward themselves. Second, I agree that it may be useful to ascertain the statistical features of empirical data: I have argued in the same vein that empirical data are algorithmically random strings (McAllister 2003). Third, however, analyzing the statistical features of empirical data constitutes at most a preliminary phase of research, which must then proceed by decomposing data into pattern and noise. Bogen's case confirms this: in the work for which he is best known, Buzsáki (2006) studied brain rhythms with different periodicities, ranging from the circadian cycle to 600-hertz neuronal oscillations. Identifying these rhythms required him to decompose EEG data in different ways into pattern and noise, just as geophysicists have

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decomposed data on the speed of rotation of the earth into multiple patterns.

Woodward (2010) suggests that I misunderstand statistical principles. He distinguishes the activity of describing features of data sets, or descriptive statistics, from the activity of inferring from data to stable features of the world, or statistical inference. Woodward claims that I discuss the former activity, whereas he explains how scientists carry out the latter activity. I agree that we are talking about different things: I am investigating whether there is a respect in which physically significant patterns in data differ from other patterns, whereas Woodward describes how scientists handle empirical data with the aid of various methodological precepts. This becomes clear when, later, Woodward writes that scientists require the error (which corresponds to what I call the noise term) associated with a pattern to exhibit neither correlation with the pattern nor autocorrelation, that is, a pattern of its own. I grant that scientists sometimes require this, but do patterns that satisfy this requirement have any greater claim to correspond to structures in the world than other patterns? Woodward does not address this question. I argued in section 2 that the answer is negative.

Brading (2010) views my approach as a form of skepticism and a challenge to scientific realism, but I do not see it straightforwardly as either of these. First, skepticism is presumably the thesis that our knowledge about a certain domain is less secure or less extensive than other approaches assume. I am not a skeptic with respect to structures in the world: I believe that we have generally abundant empirical evidence of them in the form of patterns in empirical data and that we can gain knowledge about them by analyzing these patterns as scientists do. The sole peculiar feature of my view is that I think that the world contains all possible structures, rather than just a minimal set. This distinguishes my approach from the skepticism of, say, Nelson Goodman (1983, 59–83), who believes that the world has a unique structure but that empirical evidence grossly underdetermines it. I find scientific realism untenable inasmuch as it maintains that the world has a unique structure and that there is a single true theory of the world, but I have no quarrel with the realist tenet that a high degree of empirical adequacy is evidence of a theory's closeness to the truth.

Finally, several audience members and a referee of this journal objected that I assume that empirical data sets themselves are the sole resource available to scientists in their attempts to distinguish signal from noise. They pointed out that in real scientific practice, scientists analyze data sets in light of assumptions about what structures the world contains, how the data have been produced, and what patterns in them are significant. This is true. However, there are only two possible sources of these

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assumptions: the analysis of previous empirical data sets and stipulation—for example, the stipulation that we should pick out patterns consisting of the constancy of some physical parameter. If the source is the former, appealing to these assumptions merely advances the problem to an earlier time: in those previous data sets, what distinguishes physically significant patterns from other patterns? If the source is the latter, we can rule out that stipulations can make the difference between physically significant and other patterns. In both cases the challenge remains.

7. Conclusions. This article has sought to show that if one assumes that empirical evidence about the structure of the world takes the form of patterns exhibited in empirical data sets, one is led ineluctably to the conclusion that the world contains all possible structures.

Whereas the thesis that the world is radically polymorphous appears at first sight to conflict with our everyday experiences and with the findings of science, I have argued that this thesis is actually required to make sense of the nature of empirical data and, especially, of its inexhaustibility. Whereas more work is needed to explore the implications of this view, it seems to suggest a new conceptualization of the way multiple structures coexist in the world.

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