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Existence problems in philosophy and science

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Abstract We initially characterize what we'll call existence problems as problems where there is evidence that a putative entity exists and this evidence is not easily dismissed; however, the evidence is not adequate to justify the claim that the entity exists, and in particular the entity hasn't been detected. The putative entity is elusive. We then offer a strategy for determining whether an existence problem is philosophical or scientific. According to this strategy (1) existence problems are characterized in terms of causal roles, and (2) these problems are categorized as scientific or philosophical on the basis of the epistemic context of putative realizers. We argue that the first step of the strategy is necessary to avoid begging the question with regard to categorization of existence problems, and the second step categorizes existence problems on the basis of a distinction between two ways in which an entity can be elusive. This distinction between kinds of elusiveness takes as background a standard account of inference to the best explanation. Applying this strategy, we argue that the existence of a multiverse is a scientific problem.

Keywords Existence · Inference to the best explanation · Pseudoscience · Multiverse

A number of theoretical physicists have proposed that there is a multiverse described as encompassing indefinitely many pocket universes each produced by a mechanism such as eternal inflation (for example, see Susskind 2007 and Vilenkin 2007). We'll call this proposal the multiverse hypothesis. However, despite the proposal of this

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hypothesis by scientists, it is controversial whether the multiverse hypothesis is a scientific hypothesis.

We'll show that the multiverse hypothesis presents what we'll call an existence problem. Preliminarily, we'll characterize existence problems as problems where there is significant evidence that a putative entity exists; we'll say that 'significant' evidence is evidence that is not easily dismissed. However, the evidence doesn't adequately justify the claim that the entity exists, and in particular the entity hasn't been detected. We'll then develop a strategy for distinguishing philosophical and scientific existence problems and address the categorization of the multiverse hypothesis from the standpoint of this strategy.

Admittedly, for both philosophers and scientists the category opposing science is often understood to be pseudoscience, not philosophy. Nevertheless, the demarcation between science and pseudoscience is the wrong framework for addressing doubts about the scientific categorization of the multiverse hypothesis (as well as hypotheses of entities in other highly theoretical areas of physics). Pseudoscience involves claims contrary to accepted scientific claims, as well as either a lack of effort to support these claims, or efforts to support these claims by use of methods contrary to accepted methods of science (Hansson 2008). But the multiverse hypothesis does not contrast with science in either of these ways. There is as yet no *accepted* scientific doctrine relevant to the multiverse hypothesis. Furthermore, proponents of the hypothesis do strive to support it by accepted methods of science, not on the basis of cherry-picked examples or other contravening methods (for example, see Vilenkin 2007 and Smolin 2007). And while there is some concern that the hypothesis is unfalsifiable, and thus counts as pseudoscience according to Karl Popper's well known but controversial criterion, this concern is not that the multiverse hypothesis is trivial–always confirmed–in the way that Popper's examples of unfalsifiable claims are. Rather, the worry about categorizing multiverse hypothesis as scientific is that it is an *intractable* problem–a problem which relevant experts don't understand how to address leaving open the possibility that they never will. However, that they don't understand how to address the problem leaves a number of possibilities open, including that current understanding is severely limited but can develop in ways that make the problem tractable. As we'll argue in Sect. 2.1, intractable existence problems are better understood as philosophical problems than as pseudoscience. Thus, a distinction between scientific and philosophical existence problems provides a better framework for addressing the categorization of the multiverse hypothesis than the demarcation between science and pseudoscience.

In the aftermath of W. V. O. Quine's rejection of the analytic-synthetic distinction, it is commonly claimed that there is no sharp distinction between philosophical and scientific epistemology. As Michael Devitt and Kim Sterelny pithily put it: "[Philosophy] is not an intellectual police force. It is empirical and fallible" (1999, p. 275). For the purposes of this paper, we'll assume that this common claim is correct. In particular, we'll assume that philosophy and science share fundamentally similar epistemic methods; thus, for example, philosophical problems are not distinctive in requiring a priori methods.

Nevertheless, it is intuitive that some problems resist solution in a way that is distinctive of philosophical problems. Our focus will be to develop a strategy for distinguishing philosophical and scientific existence problems which both captures the intuition

that philosophical problems resist solution in a distinctive way and also coheres with the idea that philosophy and science are epistemically continuous. Indeed, one feature of our strategy will be to allow that an existence problem can transition from philosophical to scientific. And although this transition involves a shift between radically different sorts of epistemic context, it does not involve a shift between fundamentally different sorts of epistemic method.

Of course, if the same problem can be philosophical and scientific at different times, then there must be a way of identifying the problem that is independent of its categorization as philosophical or scientific. Drawing upon an idea developed by D. M. Armstrong (1968, chap. 17) and David Lewis (1972), we'll characterize existence problems in terms of whether there is a realizer of a particular causal role.[1] What distinguishes an existence problem as being *philosophical* as opposed to scientific is the epistemic context of a putative realizer of the causal role. In particular, what distinguishes an existence problem as being philosophical is that the putative realizer is elusive in a distinctive way.[2]

According to our strategy, which we'll call the *de-constitutionalizing strategy* (or DC strategy), (1) existence problems are characterized in terms of causal roles, and (2) existence problems are categorized as philosophical or scientific on the basis of the epistemic context of putative realizers. We'll argue that the first step of the DC strategy is necessary to avoid begging the question against categorizing existence problems as scientific, and that the second step categorizes existence problems on the basis of a distinction between two ways in which an entity can be elusive. In the case of philosophical existence problems, there are significant reasons to posit entities despite the entities being—in a distinctive sense that we'll clarify—beyond the reach of current science. (The DC strategy only concerns existence problems about which the question of philosophical or scientific categorization can be posed. Thus it does not apply to existence problems that are beyond the reach of science by being philosophical by default—as is, for example, the existence problem of abstract objects. We will return to this point in Sect. 1.2).

We'll proceed as follows: in Sect. 1, we'll clarify what we mean by existence problems, and distinguish existence problems from other problems, in particular problems

[1] Although Armstrong and Lewis took these characterizations to be analyses (Armstrong 1983, pp. 50–51), they need not be taken as such, as Armstrong points out (1983, p. 69). Instead, these characterizations can be understood as core substantive claims about putative entities. Thus, while Armstrong and Lewis distinguished philosophical problems as requiring application of a priori methods, we do not. Nevertheless, we bring to the forefront another aspect of Armstrong- and Lewis-style causal role characterizations, namely their topic neutrality.

Also, although Armstrong and Lewis offered causal role characterizations, their focus was on identification of the realizers of these roles with physical entities, not on the categorization of existence problems. Thus, their primary concern was with problems of constituting nature, not existence problems; we'll discuss this distinction further in Sect. 1.2.

[2] Despite our realist language, since both sides of the realism-antirealism debate can acknowledge a distinction between philosophical and scientific existence problems, our discussion is orthogonal to that debate. While we incline to realism, so far as we can see, our strategy for distinguishing between philosophical and scientific existence problems can be restated in anti-realist terms. So, for example, Bas van Fraassen's (2009) objection to the use of Perrin's early 20th century experimental work to support scientific realism is orthogonal to our concerns; van Fraassen is concerned with the realism-antirealism debate, not a categorization of historical work on atomism as philosophical or scientific.

of constituting nature; here we'll argue that a causal role characterization of existence problems is needed to avoid begging the question against a problem's categorization as scientific. In Sect. 2, we'll present our proposal for categorizing existence problems as philosophical or scientific in terms of a distinction between two sorts of elusiveness. We'll claim that justifications for existence claims are provided by inferences to the best explanation; the distinction we'll draw takes as background a standard account of inference to the best explanation, namely Larry Wright's account (1982, 1995). In Sect. 3, we'll give an account of a transition of an existence problem—namely, that of the ultimate constituents of matter—from philosophical to scientific.

In Sects. 2 and 3, we'll also support the DC strategy with examples. In Sect. 2, we'll show that the DC strategy accounts for relatively uncontroversial categorizations for a number of existence problems: it accounts for the categorization of the existence of a universe-originating entity as a philosophical problem, and the categorization of the existence of neutrinos as a (historical) scientific problem (which has been resolved). In Sect. 3, we'll show that it provides a plausible account of how the existence problem of ultimate constituents of matter has changed since Democritus's hypothesis of atomism. Then, having supported the strategy, we'll argue in Sect. 4 that, employing the strategy, the existence problem of a multiverse is scientific.

It's important to draw the distinction between philosophical and scientific existence problems along the lines we'll propose because other ways of drawing the distinction have often mischaracterized philosophy, taking philosophical work regarding existence as either sterile or as engaging in pseudoscience. Rather, we'll portray philosophy's approach to existence problems as being similar to, and complementary to, science's: similar in that a compelled reason gives significant but inconclusive evidence to posit an elusive entity by way of inference to the best explanation; complementary in that philosophy often prepares the ground for the explanatory and predictive work characteristic of science. Thus, philosophical pursuit of existence problems is neither sterile nor illegitimate.

1 Problems

1.1 Existence problems

We'll offer a general characterization of existence problems before developing a strategy for distinguishing philosophical from scientific ones. We'll start with a preliminary general characterization. Then we'll argue that a causal role characterization of existence problems is necessary to avoid begging the question against a problem's categorization as scientific, and reformulate the general characterization accordingly.

An existence problem arises because there is a compelled reason that provides significant evidence to believe that a particular entity or type of entity exists, but at the same time this reason does not adequately justify the claim that it exists. Thus, despite the compelled reason, more evidence is needed to solve the problem of whether the putative entity exists. Of particular note, the entity has not been detected; it is elusive.

A reason for believing an entity exists is *compelled* just in case the reason is implied by central background beliefs. (We use 'centrality' in the Quinean sense that central

beliefs or claims[3] are accepted as true, and thus are taken as evidence for many further beliefs. Consequently, rejecting a central belief does costly damage to a belief system. [For our purposes, a 'belief system' is that of a relevant community, for example, a relevant scientific community.])

We have in mind that central background beliefs generate compelled reasons in the following way: the central background includes at least one universal generalization and at least one existence claim; from these two sorts of central background beliefs, the compelled reason follows given an instance of a premised universal generalization.

As an example, consider the historical search for neutrinos as having presented an existence problem. In 1930, Wolfgang Pauli posited this subatomic particle (in effect) by an inference to the best explanation for experimental findings that suggested violation of conservation laws in the process of beta decay, a process where an electron is emitted as a result of radioactive decay (Reines 1996, p. 317).

Taking as central background both the idea that every material process obeys conservation laws and the existence of beta decay, it follows that beta decay obeys conservation laws. That beta decay obeys conservation laws is a compelled reason which gives evidence for thinking that neutrinos are produced in beta decay, and, moreover, this evidence is not easily dismissed.

However, while compelled reasons are implied by central background beliefs, the existence of putative entities is not implied. Compelled reasons can provide strong (but by themselves inconclusive) evidence for the existence of putative entities. Compelled reasons do provide strong evidence, if a positing statement turns out to provide the best explanation of the reason. If, by contrast, the positing statement fails to provide the best explanation of the reason, then the best explanation of that *failure* is that something is wrong with the central background—either the compelled reason is implied by a central background belief that is false or the compelled reason is implied by central background beliefs which are so incomplete as to be misleading.

So, in the case of neutrinos, either neutrinos exist, or, if there are none, then conservation laws are false or the central background beliefs relevant to this case are so incomplete as to be misleading (where, for example, more background could show that while every material process, including beta decay, obeys conservation laws, nevertheless, there are no neutrinos). Thus central background beliefs are defeasible. Indeed, due to the experimental findings regarding beta decay, Niels Bohr had considered rejecting the applicability of the laws of conservation of energy and momentum to subatomic processes (Bohr 1932, p. 383; Reines 1996, pp. 317–318; Riordan 2001, p. 1).

At the same time, rejecting central background beliefs produces costly damage to belief systems. From the standpoint of central background beliefs, the evidence for the existence of neutrinos is not easily dismissed—the evidence is, as we have put it, significant.[4]

[3] We take claims to be expressions of beliefs, and will use 'belief' and 'claim' interchangeably.

[4] Centrality is a graded notion—how much damage is done to a belief system through rejection of a central background belief will vary with respect the central background belief. Rejection of laws of logic would do a great deal of damage, whereas, for example, a rejection of conservation laws, or a denial that macro-level change is the result of micro-level change, would do less damage.

However, neutrinos were elusive. Pauli found that in beta decay, there was an apparent loss of energy and angular momentum. To account for this apparent loss, Pauli proposed that a neutrino is emitted, along with the emission of an electron. Yet, in order to give this account, he characterized neutrinos as particles without charge and with very little mass (Riordan 2001, p. 1). But a particle with no charge and very little mass is highly limited in its causal signature, and so hadn't been—and perhaps couldn't be–detected. Indeed, Pauli is famous for conjecturing (during a visit to Caltech): "I have done a terrible thing. I have postulated a particle that cannot be detected" (Reines 1996, p. 318). Thus, neutrinos presented an existence problem.

Summing up what we have so far, a preliminary proposal of the general form of existence problems is:

> (EP prelim) There is a compelled reason that provides significant evidence that something exists; nevertheless, this entity is elusive.

1.2 Causal roles versus constituting natures

Yet, many philosophical and scientific problems are not existence problems. Another sort of problem is one of constituting nature, that is, a problem of what an entity is constituted of. So, for example, the mind-body problem has largely been one of constituting nature, in particular, whether mental states are physical or non-physical (where 'non-physical' means not describable in scientific terms), and, if physical, whether they are multiply realizable.

Existence problems and problems of constituting nature can become intertwined, for one can pose problems in a way that combines an existence problem and a problem of constituting nature. We'll say that an existence problem is *hybridized* when it is posed in a way that explicitly or implicitly identifies the purported entity's constituting nature, and, in particular, when it identifies a constituting nature as being non-physical. So, for instance, were one to contend that there is an existence problem with respect to non-physical mental states, one would explicitly hybridize the problem. As a result, the problem would be categorized as philosophical.[5] However, one can avoid hybridizing existence problems, at least in some interesting cases.

With respect to problems of the constituting nature of mental states, Armstrong and Lewis offer the strategy of first characterizing mental states in causal terms—thus abstracting from the constituting nature of these states—and then taking up the issue of the constituting nature of realizers as a separate step. Since this strategy allows that realizers are either physical or non-physical, they use this strategy to avoid begging the question against dualism. (Armstrong explicitly makes this point, 1968, p. 355 and 1983, pp. 55–56; Lewis suggests it 1972, p. 204 and p. 208.)

Adopting a similar strategy to avoid hybridizing existence problems, we'll characterize existence problems in causal terms, thus abstracting from the constituting

[5] Given our definition of 'non-physical', i.e., as not describable in scientific terms, existence problems involving non-physical entities are philosophical.

nature of putative realizers. These characterizations are, as it used to be said, topic neutral.[6]

Topic neutrality in the characterization of existence problems is required to avoid begging the question against scientific categorization, since identifying a putative entity's constituting nature as non-physical renders the existence problem philosophical. (By contrast, identifying a putative entity's constituting nature as physical does not render the existence problem as scientific. The philosophical or scientific categorization in this case is decided by epistemic context, as we'll describe in the next section.) One *could* contend that there is an existence problem with respect to non-physical mental states.[7] But in this case, since the putative entity is non-physical, one takes up an existence problem that one has already decided is philosophical. If, however, the focus is the question of whether an existence problem is philosophical or scientific, then one must take a step back and abstract from constituting nature.

Topic neutrality is always important to avoid begging the question against scientific categorization; it is always important against a (possible) policy of deciding that elusive entities are non-physical. The importance of topic neutrality is particularly salient, however, with respect to what we'll call the existence problem of a universe-originating entity. Its compelled reason is generated as follows: nothing can come into existence from nothing and the universe exists (central background), so the universe can't come into existence from nothing; that the universe can't come into existence from nothing is a compelled reason which gives significant evidence for thinking that some additional entity originates the universe; nevertheless, this entity is elusive. Because this problem is often posed in the context of considering the existence of God, it has often been hybridized. For, putting the problem in this context, and describing God in terms of omnipotence and omniscience, implicitly identifies the originating entity's constituting nature as being non-physical (assuming that omnipotence and omniscience can only be properties of a something with a non-physical constituting nature).[8] In this case, it's already decided that the existence problem of a universe-originating entity is philosophical.

But one can avoid hybridizing the existence problem of a universe-originating entity by separating the role of originating the universe from omnipotence and omniscience. Indeed, one *should* avoid hybridizing this existence problem because everyone—independently of one's beliefs about God—has a compelled reason that provides

[6] See, for example, D. M. Armstrong (1968, pp. 120–121, p. 355.)

[7] Frank Jackson's Mary thought experiment (1982) suggests an existence problem with respect to (not non-physical states but) non-physical properties. A compelled reason is generated: for all knowledge of what it's like to be conscious of perceptible properties is knowledge of information which isn't knowledge of physical information; furthermore, there is knowledge of what it is like to be conscious of perceptible properties. Therefore, there is knowledge of information which isn't knowledge of physical information. This is a compelled reason providing significant but inconclusive evidence for there being qualia, characterized as non-physical mental properties that are what it is like to be conscious of perceptible properties. Of course, the argument along these lines has been criticized in many ways (in particular, the first claim generating the compelled reason is not central background). But the literature about this argument indicates its evidence is significant.

[8] We assume that omnipotence and omniscience can be causally construed as involving powers that violate natural laws, and therefore are supernatural powers; furthermore, we assume that anything with supernatural powers has a non-physical constituting nature.

significant evidence for a putative universe-originating entity. For, everyone has the compelled reason that the universe cannot have come into existence from nothing. In this case, either an originating entity exists, or, if it doesn't, then the central background belief that nothing can come into existence from nothing is false or the central background beliefs relevant to this case are so incomplete as to mislead one into thinking that an originating entity exists—for perhaps more background could show that while nothing comes into existence from nothing, the universe doesn't require an originating entity.[9] From the standpoint of the central background, everyone has a compelled reason that something plays the universe originating role. But one shouldn't simply assume that God is the realizer without considering the possibility of physical alternatives.[10]

To avoid hybridization, this existence problem should be identified as follows: there is a compelled reason that provides significant evidence to believe that something realizes the causal role *of originating the universe*; nevertheless, this entity is elusive. The topic neutrality of this causal role—allowing for a physical or non-physical realizer—avoids begging the question against scientific categorization.

Sometimes hybridization cannot be avoided. There is the example of non-physical mental states. Also, insofar as one might argue that there is an existence problem of abstract objects, the existence problem is philosophical by default, since abstract objects are defined as not being in space or time and as not having causal properties. Nevertheless, as the example of the existence problem of a universe-originating entity shows, some interesting problems shouldn't be hybridized.

1.3 Existence problems reformulated

Reformulated, our proposal of the general form of existence problems is:

> (EP) There is a compelled reason that provides significant evidence to believe that something realizes a causal role C; nevertheless, this entity is elusive.

This characterization is intended to apply to cases where one can and should avoid hybridization; thus, in this formulation causal role C should be topic neural. Also, 'a compelled reason' merely refers to some compelled reason or other. Consequently, existence problems in general involve some compelled reason or other to think that some elusive entity realizes C. Thus, particular existence problems are identified, not in terms of compelled reasons, but in terms of the values of variable C—such as the existence problem of an entity originating the universe. (When there is a particularly promising physical realizer one might identify the problem in terms of the realizer;

[9] Lawrence Krauss (2012) seems to argue that this central belief is false. But, depending on what Krauss means by 'nothing', he could be arguing that our background beliefs have been so incomplete as to be misleading. Either way, we are skeptical that Krauss has made progress on the issue of why there is something rather than nothing.

[10] Likewise, one shouldn't simply assume that the realizer is physical. Dawkins seems to do this on the basis of thinking that everything that exists must have a scientific nature (2006, pp. 55–57). Note that on our view, even if Dawkins were correct, the physical nature of the realizer doesn't by itself decide that the existence problem is scientific.

doing this does not beg the question against philosophical categorization, since this is decided on an independent consideration, namely epistemic context. In any event, if the realizer becomes less promising, one can always revert to identifying the problem in terms of the values of C.) We'll now turn to distinguishing between two sorts of elusiveness which will serve to divide philosophical and scientific existence problems.

2 When there is no scientific approach to a problem

There are of course many difficult problems in science, and some of the most challenging of these problems involve difficulty with detection. However, we'll draw a distinction on the basis of which we can separate challenging detection problems in science from philosophical existence problems.

According to the DC strategy, both scientific and philosophical existence problems arise when there is a compelled reason to think that a putative entity exists, but it is elusive. The distinction between scientific and philosophical existence problems is founded on a distinction between two sorts of elusiveness: (1) *elusiveness due to the limits of detection techniques that can be put into practice* and (2) *elusiveness due to the limits of scientific theory*.[11]

We contend that justifications for existence claims are provided by inferences to the best explanation. It is standardly accepted that deductive inferences do not provide justifications for existence (independently of existence claims in their premises). Furthermore, while Bayesian approaches are sometimes seen as inductive alternatives which through formalization avoid inference to the best explanation's seemingly objectionable lack of rigor (see Lipton 2004, pp. 55–70 for a discussion of this kind of worry), they have their own (perhaps related) difficulties. For example, in order to make use of the formal apparatus of the Bayes theorem, prior probabilities (so-called priors) must be estimated. However, these estimates are sometimes gross, requiring not only selection of relevant information (out of a wide range of potentially relevant information) but also judgments of probabilities for the information selected. So the supposed advantage gained by appealing to a formal framework is lost, since to get a calculation off the ground, one has to take a stab at selecting relevant information and judging its probability. In fact, it is just these concerns that lead some to suggest that, at its best, the Bayes theorem is nothing more than a formal way of displaying an inference to the best explanation (Weisberg 2009; Weber 2009, pp. 45–46; Wright, personal communication).[12]

Consequently, we'll describe the two sorts of elusiveness in terms of two sorts of inference to the best explanation: one which will characterize scientific claims of existence, and one which will characterize philosophical claims of existence.

[11] Larry Wright (2001) draws a distinction between tractable and intractable investigations which serves as the jumping off point for our distinction between elusiveness due to the limits of detection techniques and elusiveness due to the limits of scientific theory. Wright (personal communication) agrees that our distinction is in line with his.

[12] (Wright 1995, p. 579) also claims that inference to the best explanation and Bayesianism are compatible, as does Brian McLaughlin (2010, pp. 278–281), who also defends inference to the best explanation in other ways.

Scientific claims of existence, speaking *generally*, are inferences to the best explanation which require that the causal relation between a putative entity and its signature (that is, its distinctive causal impact on a detector) is *tractable*. (We understand 'detector' in a broad sense as anything that can be a reliable indicator.) A causal relation is tractable just in case there is information about the relation which is relevant to explaining and predicting its occurrences. Thus, the causal relation between allergens and RAST or skin allergy tests (or even simply hives) is tractable in that such information exists. By contrast, the creationist's proposed causal relation between God and biological species is intractable. There is no information about this relation relevant to explaining and predicting acts of creation. There is merely the claim that such causal relations exist.

As these examples suggest, tractability requires beliefs with enough detail that they can be made relevant to explaining and predicting causal relations between putative entities and their signatures. By contrast, extremely abstract beliefs are not adequately detailed. The distinction between extremely abstract and extremely detailed is, of course, a graded distinction: on one end of the spectrum are extremely abstract beliefs, of the nothing comes from nothing variety. These extremely abstract claims do not (by themselves at least) provide a tie to the world which is specific enough to help nail down the causal signature of a proposed entity. In the middle of the spectrum, detail is rich enough to frame detection-related questions. For example, Robert Boyle's existence claim about corpuscles helped crystallize the view that the relationship between micro- and macro-properties and entities can and should be discovered experimentally (Newman 2010, pp. 206–208). This belief about the relationship between micro- and macro-properties and entities is presupposed by detection of micro-phenomena. Nevertheless, this belief (again, by itself at least) is still not sufficiently detailed to help formulate the causal signature of micro-phenomena. There also needs to be information relevant to explaining and predicting relations between a putative entity and its signature.

A scientific *existence problem*, as a certain kind of scientific existence claim, is one which combines the characteristics of existence problems (that is, that there is a compelled reason for an elusive entity) with there being a tractable causal relation between the putative entity and its signature. Since there is a compelled reason, central background beliefs are at stake. But given a tractable causal relation, beliefs with more detail than (even middle-spectrum) abstract central background beliefs are involved. And with tractability, one is in a position to hypothesize what causal happenings in the world address the existence problem.

Nevertheless, the putative entity is elusive due to the limits of practical detection techniques. This lack of practical detection techniques might be due to, for example, technological limitations (e.g., it's not yet known how to build a sensitive enough detector), funding constraints (e.g., it's known how to build a detector but it's too expensive to fund), or just bad luck (e.g., an adequately sensitive detector has been built, but detection requires a certain amount of luck which so far has been lacking). Metaphorically speaking, even though there is a map with a tractable causal route from the putative entity to a signature, logistical problems inhibit exploring the terrain to check the route.

As an example of a scientific existence problem, consider the case of neutrinos further. Pauli had a compelled reason—namely, that beta decay obeys conservation

laws—which gave significant evidence for thinking that neutrinos exist. There was a tractable causal relation. In fact, it was the formulation of a tractable causal relation which indicated how practically difficult neutrinos were to detect (Reines 1996, p. 318; Riordan 2001, p. 3). Because neutrinos are characterized as having no charge and very little mass, the logistical problems involved with detecting them were daunting. Frederick Reines, who won a Nobel Prize in 1995 for detecting the neutrino, discloses that, since a nuclear bomb explosion is an unusually plentiful source of neutrinos (due to being an unusually plentiful source of beta decay), an early strategy for detection was to place a detector within 100 meters of a nuclear test explosion (1996, pp. 317–319). However, this strategy was unworkable (Reines remarks that it was "a virtually impossible experiment" [1996, p. 319]), and was given up in favor of using a nuclear power reactor as a neutrino source. Using this alternative strategy, successful detection came in 1956, 26 years after Pauli's postulation (Reines 1996, p. 323). The challenge for detection—which was overcome fairly quickly—had to do with elusiveness due to the limits of practical techniques for obtaining this causal signature.[13]

Philosophical claims of existence are inferences to the best explanation which require that there is no tractable causal relation between the putative entity and a signature. A philosophical *existence problem* arises when there is a compelled reason that provides significant evidence for believing that an elusive entity exists, and there is no tractable causal relation between the putative entity and a signature. Intractable existence problems, then, are existence problems involving entities where there is no tractable causal relation. Returning to the map metaphor, there is not even a tentative map of tractable causal routes from the putative entity to a signature. The entity simply does not appear on any current map of tractable causal routes. In such cases one must develop a better understanding of the world—a better or new theory to provide new routes on the map—before one can even begin to address the problem of detection.

Consequently, philosophical existence problems are marked by elusiveness due to the limits of scientific theory. Whether an entity in this epistemic context *can* be encompassed by a map of tractable causal routes is not known (or if it is known that the entity cannot be encompassed, this is because, as with the existence problem of abstract objects, it is a philosophical problem by default).

An example of a philosophical existence problem is that of the existence of a universe-originating entity. Given that nothing can come into existence from nothing and the universe exists, there is a compelled reason that provides significant evidence for thinking that some additional entity originates the universe. While this entity is proposed in the context of central background beliefs, these beliefs are too abstract for the formulation of a tractable causal relation between that putative entity and a signature.

[13] There had been "indirect experimental proofs of [neutrinos'] reality" prior to 1956 (Riordan 2001, p. 4). A distinction between direct and indirect detection can be relevant to determining whether a scientific existence problem is solved, if one holds that direct detection is needed to make an entity non-elusive. If one does hold this, then one needs to distinguish between direct and indirect detection, and say why direct detection is necessary. Fortunately, our distinction between philosophical and scientific existence problems on the basis of tractable causal relations avoids these tricky issues, since both sorts of detection involve tractable causal relations.

2.1 Why philosophical existence problems are not pseudoscientific

Given the depth of ignorance involved in the cases of philosophical existence problems, one might wonder whether such inferences are worthy of serious epistemic consideration. But they are, when understanding of the world gives a compelled reason that provides significant evidence for believing that certain causal roles are realized. And even though the central background beliefs generating compelled reasons in philosophical cases are limited to beliefs of extreme to middle-spectrum abstractness, they, nevertheless, are not readily given up. From this vantage point, one can see that motivations for philosophical existence questions are not idle, despite the distinctively profound ignorance of what is posited.

Also, from this vantage point, the role of compelled reasons distinguishes philosophical existence problems from pseudoscience. Pseudoscience typically doesn't involve compelled reasons at all. But even where it does, no attempt is made to either elaborate background beliefs (with the aspiration to transition to scientific categorization) or to question central background beliefs (with the aim of rejecting putative entities). However, philosophical research (at least in this neck of the woods) is driven by the elaboration of, or questioning of, relatively abstract central background beliefs.

Thus intractable existence problems are better understood as being philosophical than pseudoscientific. They are legitimate existence problems even though science has no approach to the question of how to detect a putative realizer.

In a vacuum of beliefs relevant to detection, an important role of philosophical work is to undertake the cognitive groundbreaking necessary to better understand what's posited (by, for example, developing some central background beliefs in more detail). As we'll show in the next section, in some cases this work is so successful that eventually tractable causal relations to signatures are formulated and the existence problem transitions to science.[14]

3 Transition of existence problems

In many cases of transition from non-scientific to scientific categorization, there is no existence problem. Instead, the transition is from a non-scientific to a scientific understanding of the constituting nature of realizers. For example, there never was a question as to whether something plays the causal role of water. However, there has been a transition from a non-scientific to a scientific understanding of the constituting nature of the realizer of this role.

There are also many cases of existence problems that are introduced as involving tractable causal relations to detectors. Even though neutrinos were elusive, the problem of detection was not one of lacking adequately detailed beliefs relevant to detection. From the beginning, the problem of detection was, rather, a practical problem (Reines 1996, pp. 317–318; Riordan 2001, p. 3).

[14] We are leaving open that in connection with problems other than existence problems philosophy does more than work to shape them up for science.

In addition, however, there are examples where existence problems have made a transition from philosophical to scientific. We'll very briefly describe the existence problem of the ultimate constituents of matter to demonstrate that a single existence problem can transition from being philosophical to scientific, and that the transition does not involve a shift between fundamentally different sorts of epistemic method but rather a shift in epistemic context.

The existence problem with respect to ultimate constituents can be presented as follows: there is a compelled reason (namely, that macro-level material change is produced by small but not infinitely small entities) which gives significant evidence for believing that there is some entity type (or group of types) which plays the role of being a finitely small underlying producer of all material change; but this entity is elusive.[15] So, for example, Democritus characterized atoms as being finitely small underlying producers of material change in order to counter Parmenides's claim that (macro-level) material change is impossible. Democritus's view was that macro-level change is ultimately the result of the size, shape, and motion of atoms (Chalmers 2009, pp. 19–25). But Democritus's claim that atoms exist came with no beliefs detailed enough to bear on detection of these ultimate constituents; in fact, Democritus had a deeply ambivalent attitude toward sensory evidence (Chalmers 2009, p. 40).

In the 17th century, Robert Boyle proposed that corpuscles (which he referred to as *minima naturalia* or *prima naturalia*) are the ultimate constituents of matter. As with the ancient atomist proposal of ultimate constituents, Boyle claimed that corpuscles are the underlying producer of all material change in virtue of having a small number of qualities including size, shape, and motion (Boyle 1674/1989, pp. 118–123; Anstey 2000, pp. 28–30; Chalmers 2009, pp. 99–101).[16] And despite Boyle's view that experimentation could bridge the gap between micro- and macro-properties and entities, he held this view on the basis of abstract beliefs about which explanations qualify as being intelligible (Anstey 2000, pp. 55–56; Chalmers 2009, pp. 101–103 and 2010, pp. 2–3; Newman 2010, p. 206). These beliefs about experimentation were too abstract to provide for a tractable causal relation between corpuscles and their signatures, however. While Boyle helped set the stage for developing tractable causal relations among micro-entities and signatures, this development was left to others.

[15] In presenting this existence problem, we are attempting to capture an intuitive problem rather than represent a particular philosopher's argument (however, the argument is meant to support what is called physical atomism; Chalmers 2009, pp. 31–34 distinguishes physical atomism from the version of atomism developed in response to Zeno). The central background is: change in macro-level material entities is the result of change in micro-level material entities; however, no change (at all) can be produced by infinitely small entities (since infinitely small entities do not have coherent properties relevant to producing change). Furthermore, macro-level material change exists. Therefore, macro-level material change is explained by small but not infinitely small entities. That this is the case is a compelled reason that provides significant evidence that there are finitely small underlying producers of all material change. (Of course, considerations about emergence—which would question the first premise—might not allow this argument to apply to all material change.)

[16] Peter R. Anstey (2000, pp. 43–44, p. 54, pp. 117–118) argues that Boyle held so-called practical atomism, according to which there are physical constraints on the divisibility of matter; this version of atomism is different from atomism developed in response to Zeno.

With the stage thus set, in the 19th century Dalton proposed that atoms are the ultimate constituents of matter, and formulated a tractable causal relation between atoms and their causal signatures. Central background beliefs from which Dalton developed his atomic theory included the idea of an element (as a substance which can't be separated into chemically different substances, as opposed to atomic constituents of this substance), and the idea that elements retain their weights in chemical reactions (Chalmers 2009, p. 137, p. 177). Dalton also assumed the law of constant proportions, which holds that the elements of compounds always combine according to the same ratio of weights.

Dalton's atomism proposed that atoms are constituents of elements, and that atoms of the same element are the same in shape, weight, and other properties. This proposal explained relative combining weights of elements in compounds, and was able to predict two new laws of proportion, namely the law of multiple proportions and the law of equivalent proportions, which were then experimentally supported. Both of these laws, similarly to the law of constant proportions, depend on atoms' relative combining weights (for example, according to the law of multiple proportions, elements, such as oxygen and nitrogen, which combine to form various compounds—NO, N_2O, NO_2—combine in proportions which always can be reduced to small whole numbers) (Chalmers 2009, pp. 177–180). Thus Dalton was able to explain and predict a property of atoms, namely, relative combining weight, and causal relations with atoms became tractable by way of this property. As it happens, Dalton's atomism is mistaken in many ways, including in its claim that atoms are ultimate constituents. Yet, Dalton formulated a tractable causal relation between what he took to be the realizers of the ultimate constituent role and their signatures. With tractability, the existence problem of ultimate constituents of matter transitioned from a philosophical problem to a problem of the science of Dalton's time.[17]

The existence problem of the 19th century continued to be characterized in terms of there being a compelled reason to think that some elusive entity type (or group of types) realizes the causal role of being a finitely small underlying producer of all material change. Thus the characterization of the problem did not change. (Note, though, that in the 19th century and early 20th century as a result, compelled reasons for there being a realizer developed; as a results, compelled reasons included not only the highly abstract central background beliefs, but also detailed central background relevant to detecting realizers.) Furthermore, no fundamentally different epistemic method marks the transition from philosophical to scientific existence problem. Both

[17] Chalmers (2009) argues that atomism wasn't scientific until Jean Perrin's experiments in 1908. However, Chalmers ties scientific categorization of atomism to considerations that settle the question of the existence of atoms (2009, p. 16, p. 233, pp. 238–239). Thus, on Chalmers's view scientific categorization is incompatible with elusiveness.

Chalmers's epistemic demands for scientific categorization seem to be driven by a realist position in the realism-antirealism debate. But we think this debate is orthogonal to the issue of distinguishing between philosophical and scientific existence problems. In the 1930s and 1940s, when neutrinos were elusive due to the limits of practical detection techniques, the existence problem was scientific because the causal relation between neutrinos and their signatures was tractable (Reines 1996, pp. 317–318). This is true whether or not neutrinos are metaphysically real according to some set of criteria.

before and after the transition, inference to the best explanation supports the claim that there are ultimate constituents.

What distinguishes Democritus's inference from Dalton's is the epistemic context. Democritus posited ultimate constituents against a central background so lacking in detail as to not be relevant to formulating a tractable causal relation to a signature. By contrast, Dalton posited ultimate constituents against a relatively detailed central background making possible the formulation a tractable causal relation between these putative entities and their signatures.

Yet, it has recently become pressing to consider whether some highly theoretical areas of physics have veered back to philosophy. Next, we'll examine an example of this development.

4 The problem of anthropic universe production

According to standard accounts, the existence of human life[18] in our universe requires that the universe has complex chemicals, and complex chemicals require that the universe's fundamental physical constants have values within ranges that are narrow with respect to possible values (see, for example, Tegmark 2004, pp. 6–8). Combined with the fact that human life exists in our universe, these points are central background for the compelled reason that our universe's fundamental physical constants are within certain narrow ranges. This compelled reason provides significant evidence for thinking that there is an entity which produces a universe where these constants are within the narrow ranges required for human life. We'll call this entity an anthropic universe-producing entity.[19]

This anthropic universe-producing entity plays a different causal role than the universe-originating entity. The universe-originating entity is posited because there is something rather than nothing. The anthropic universe-producing entity does something far more specific—it produces a universe with physical constants of a certain sort. Even if one can get a grasp of the latter, this need not make any headway in getting a grasp of the universe-originating entity. Nevertheless, one might address both problems at once by contending that both causal roles are realized by God.

But one shouldn't start with the assumption that anthropic universe-production is carried out by God. We have put the existence problem in causal terms to avoid hybridizing the problem and allow consideration of physical alternatives to God.

And, in fact, there is a physical alternative—the multiverse hypothesis. Thus, the multiverse hypothesis presents an existence problem by proposing a physical realizer of the anthropic universe-producing role. One might have thought that when scientists

[18] As Carr (2007, p. 3) notes, the point being made isn't specific to human life, but applies to life in general. In our discussion, however, we'll make reference only to human life.

[19] Hacking (1987) denies that this compelled reason—that our universe's fundamental physical constants are within certain narrow ranges—provide evidence for an anthropic universe-producing entity. However, Bradley (2009) argues that Hacking arrives at this conclusion by ignoring the important role of selection effects; taking selection effects into account, the compelled reason does provide evidence for an anthropic universe-producing entity. For another objection to the idea that this compelled reason provides evidence for an anthropic universe-producing entity, see Juhl (2006); for a response to this objection, see Micah Newman (MS).

propose a physical realizer, an existence problem thereby becomes scientific. But controversy about the scientific categorization of the multiverse hypothesis demonstrates that this is not the case. The DC strategy makes sense of this controversy as being one about whether there is a tractable causal relation between pocket universes and their signatures.

In what follows, we'll further explain the multiverse hypothesis, and argue for its scientific categorization. We'll show that the multiverse hypothesis is much like Pauli's neutrino hypothesis. Indeed, multiverse proponents might have speculated "We have done a terrible thing. We have postulated an entity that cannot be detected"; recent developments indicate that they would have been overly pessimistic, however, just as Pauli was.

4.1 The multiverse hypothesis

The idea of a multiverse crops up in a variety of contexts (for an overview, see Tegmark 2004). We'll discuss only one of the many ideas of a multiverse. This idea is of an indefinitely large number of so-called pocket (or parallel) universes comprising an all encompassing multiverse, where the values of the fundamental physical constants vary amongst pocket universes. Because a multiverse of this sort is likely to encompass some pocket universe with physical constants compatible with human life, some theoretical physicists (in particular, we'll focus on Leonard Susskind and Lee Smolin), propose the multiverse as realizing the causal role of producing an anthropic universe.

It's controversial among scientists as to whether the hypothesis of this sort of multiverse is scientific, however (Carr 2007, p. 14). In fact, the controversy can be described as dividing into two camps: scientists who claim that a multiverse is elusive due to practical detection techniques, and those who claim it is elusive due to the limits of scientific theory. Applying the DC strategy, we'll argue that the multiverse hypothesis is scientific; we'll also suggest why scientists sometimes deny this. Through this example, we hope to demonstrate that the DC strategy can do work with respect to an interesting and pressing controversy.

The multiverse, as encompassing indefinitely many pocket universes, insinuates itself into science (in particular, theories of quantum gravity, that is, theories which seeks to reconcile quantum mechanics and gravity) in two wholly different ways. Particle physicists who support string theory, such as Leonard Susskind, propose a multiverse as a consequence of so-called anthropic reasoning, and claim that the theory of eternal inflation characterizes the causal mechanism by which pocket universes are produced (2007, pp. 257–259, pp. 262–265). But Lee Smolin, a proponent of loop quantum gravity, an important alternative to string theory, derides anthropic reasoning as being unscientific (2007, Sect. 1). Smolin proposes a multiverse as the outcome of physical processes that he proposes according to his theory of cosmological natural selection (CNS) (2007, Sects. 4.2 and 5.2). The recent dispute between Smolin and Susskind with regard to the categorization of Susskind's proposal of a multiverse provides an instructive context for considering the categorization of the multiverse hypothesis more generally.

4.2 Tentative maps with a multiverse

A serious obstacle that any theorist faces in obtaining evidence about other pocket universes is that, if they exist, they exist beyond what is called a cosmic event horizon. Indeed, this obstacle would seem to be insurmountable because the cosmic event horizon marks the point beyond which space is moving away at a speed greater than the speed of light (*greater* than this speed because the receding movement is due to the expansion of space itself). Thus, no light signal from beyond the cosmic horizon could ever reach detectors.

But, in fact, both Susskind and Smolin describe ways of overcoming this limitation.

Susskind appeals to anthropic reasoning. This reasoning is specified in a variety of ways. In some instances it is specified as the truism that since human life exists, physical conditions must be consistent with its existence.[20] However, the reasoning that Smolin decries is much stronger; it is the inference of the existence of a multiverse to explain the coincidence—considering the narrow ranges of fundamental physical constants within which life is possible—that our universe is consistent with human life (Tegmark 2004, pp. 6–8, p. 17; also see Bradley 2009 for an explanation of this reasoning).

Yet, as Smolin points out, anthropic reasoning alone is too speculative to support falsifiable predictions. Furthermore, since Smolin claims that Susskind offers no independent evidence for the existence of other pocket universes, and thus that Susskind *is* relying on anthropic reasoning alone, he concludes that Susskind's multiverse proposal is unfalsifiable. And referencing Karl Popper, Smolin claims that unfalsifiable theories, and thus Susskind's proposal, are unscientific (2007, Sect. 1). (Smolin doesn't use Popper's term 'pseudoscientific'; this is right in our view, since the concern about the scientific categorization of the multiverse hypothesis isn't that it is pseudoscience.)

We agree with Smolin that anthropic reasoning is so abstract that were it the sole basis for a multiverse, there would be no tractable causal relation between other pocket universes and their signatures. The existence problem of an anthropic universe-producing entity would be a philosophical problem, even with the multiverse as a putative physical realizer.

Susskind, however, emphasizes that it is not just anthropic reasoning which supports his case for the existence of a multiverse. In particular, he offers very general grounds on which to think that information about other pocket universes might be contained in the cosmic microwave background (CMB) (2006, pp. 298–301 and Chap. 12). More recently, Stephen M. Feeney, et al.(2010a and 2010b) offer the specific claim that data from the Wilkinson Microwave Anisotropy Probe (WMAP) satellite, the current source of CMB data, might contain signatures of collisions with other pocket universes. Feeney, et al.(2010a, p. 1) lay out a "generic set of signatures" indicating collisions among pocket universes—where collisions occur soon after each colliding pocket's big bang, and leave traces which "are imprinted in the cosmic microwave background"

[20] For some authors, the truism we refer to is termed the 'anthropic principle,' and the form of reasoning we are about to identify is 'anthropic reasoning' (see Weinstein 2006, pp. 1–2, for example). Susskind suggests that he uses 'the anthropic principle' as shorthand for anthropic reasoning (2006, p. 197). The literature is messy with regard to this terminology.

(also see Aguirre and Matthew C. Johnson 2009, for background on formulation of such signatures). Moreover, Feeney, et al. (2010a, p. 5; 2010b, p. 33) note that higher resolution CMB data from the Planck satellite will further test their findings. If these tests are successful, they would provide support for the existence of a multiverse.

Thus, a tractable causal relation to a signature is in the process of being formulated in terms of CMB radiation. While this formulation relies on a considerable amount of theory, this is to be expected in detecting the very smallest entities (for example, neutrinos) and the very largest.

By contrast, Smolin has developed a strategy for determining the existence of other pocket universes even while avoiding anthropic reasoning. CNS holds that a process modeled after natural selection increases the probability that there are human life-compatible pocket universes. In this process, black holes generate new pocket universes in such a way that offspring inherit the fundamental physical constants of parents, except for modifications as a result of a small amount of random variation (Smolin 2007, Sect. 5.2, Paragraph 3); in other words, the process involves what biologists call cumulative selection (Dawkins 1986, p. 45).

Furthermore, according to CNS the primary adaptive characteristic that's inherited is fertility—in the cosmological context, ability to produce large numbers of black holes, since black holes generate new pocket universes. And because universes with large numbers of black holes also have the complex chemistry necessary for human life, pocket universes consistent with human life are not rare (Smolin 2007, Sects. 5.2–6.1). Consequently, CNS predicts that the physical constants of our universe maximize black hole fertility; any information which bears upon this prediction provides independent evidence with respect to the truth of CNS. For example, an indication that any modification of the physical constants of our universe would decrease black hole fertility supports CNS, and in turn, the existence of a multiverse. And an indication that any such modification would increase black hole fertility falsifies CNS (Smolin 2007, Sects. 5.2–6.5).

Thus, Smolin's ingenious method for surmounting the limitation posed by the cosmic event horizon is to in effect use our universe's black hole fertility as a detector of other pocket universes. Again, this detection mechanism relies on a considerable amount of theory.

4.3 The case for scientific categorization: why tentative maps are enough

Despite their differences, it seems that Susskind and Smolin would accept that the existence problem of an anthropic universe-producing entity has the combination of points distinctive of a scientific existence problem: a compelled reason for an elusive causally characterized entity and a tractable causal relation to a signature for the entity. They agree that a multiverse, as the realizer of the causal role, is elusive due to practical detection techniques, rather than due to the limits of scientific theory.

Against them, scientists and philosophers who claim, to the contrary, that a multiverse is elusive due to the limits of scientific theory, contend that both of Susskind's and Smolin's formulations of tractable causal relations rely on a great deal of tentative theory. Smolin is betting on CNS. Susskind is betting on eternal inflation. The truth of all of this theory is undecided, and the common assumption is that some of

this theory will be radically revised or thrown out eventually. Thus, it seems to these opponents of both Smolin and Susskind, there really is no tractable causal relation to a signature of a multiverse. And indeed, it might seem that Smolin's worries about Susskind's theoretical approach can be applied to Smolin's own approach. After all, doesn't the tentative status of Smolin's theoretical approach also indicate a limit of scientific theory?

But if the concern about the scientific categorization of the multiverse hypothesis is with regard to *unfalsifiability*, this concern is unfounded, even accepting Smolin's claims of unfalsifiability targeted at Susskind's approach. For Smolin's approach is specifically tailored to be falsifiable (2007, Sects. 6.3–6.5).

If, instead, the worry is that the truth of the theoretical approaches so far applied is *as a matter of fact* undecided, then the concern is likewise unfounded. While a theory's being tentative has a bearing on its acceptance, it doesn't have a bearing on its scientific categorization. Research science is tentative.

We propose, instead, that what has a bearing on scientific categorization is whether a tractable causal relation between putative entity and its signature can be formulated. Proposed formulations of tractable causal relations (as opposed to the central background against which entities are posited) don't have to be widely accepted science. The epistemic threshold for a causal relation being tractable is much lower than that for being widely accepted science; all that's necessary is that there is information about the relation which is relevant to explaining and predicting the relation's occurrences. We conclude that, whether or not there actually is a multiverse, this existence problem is currently a scientific one.

At the same time, for some scientists the existence of a multiverse might *seem* elusive due to the limits of scientific theory, and so not a scientific problem, for the following reason: given the tentative status of CNS and eternal inflation, as well as of Feeney, et al.'s claim regarding CMB radiation, and other current conjectures relevant to formulating a tractable causal relation between other pocket universes and their signatures, it's easy to think that they all will be thrown out. If that were the case, and no replacing theories were developed, then the existence of a multiverse would be posited against such a highly abstract central background that it would transition to being a philosophical existence problem.

But it's not the case that all of this theory has been thrown out. And *even if* all of it were, that would not be end of the story. It is likely that at least some of the rejected theory would be replaced by theories that would bear on the detection of a multiverse.[21] Thus it's likely there would remain theories providing the detail needed to at least start addressing the problem of detection.

Moreover, the internecine dispute between Susskind and Smolin is easily framed in a way that lends support to our proposal for distinguishing philosophical from scientific existence problems. According to Smolin, if Susskind's approach were the only one, the basis for the multiverse hypothesis would be limited to extremely abstract central background beliefs; despite the proposal of a multiverse as a physical realizer, it *would*

[21] Thagard (1978) notes: "The historical work of Kuhn and others has shown that in general a theory is rejected only when (1) it has faced anomalies over a long period of time and (2) it has been challenged by another theory" (p. 49). See Kuhn (1996, pp. 77–91)

be elusive due to the limits of scientific theory. Furthermore, Susskind's response is to contend, to the contrary, his theoretical approach can provide tractable causal relations, involving in principle (but practically challenging) detection techniques. The pivot point throughout this debate is the question of tractability.

With regard to the philosophical or scientific categorization of the multiverse hypothesis, the physical constitution of the multiverse doesn't settle the question. The DC strategy takes an epistemic approach to deciding the question of categorization. We've shown that the concern about the scientific categorization of the multiverse hypothesis is a concern about this problem being an intractable existence problem. We've argued that intractable existence problems are best understood as philosophical problems, not pseudoscience. However, since physicists are in the process of formulating a tractable causal relation between other pocket universes and their signatures, the multiverse hypothesis is scientific. As had been the case with the neutrino hypothesis, the multiverse hypothesis is proposed in an epistemic context where, despite practical challenges with detection, scientific theory has the resources to formulate a tractable causal relation.

And, as it turned out, optimists about neutrino detection were right. Reines (1996, p. 318) reports that Hans Bethe and Rudolph Peierls conjectured in *Nature* (1934), 4 years after Pauli's postulation: "there is no practically possible way of observing the neutrino." Confronted by Reines in 1956, Bethe retorted, "Well, you shouldn't believe everything you read in the papers" (Reines 1996, p. 318).

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