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ORIGINAL RESEARCH

A deductive variation on the no miracles argument

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Abstract

The traditional No-Miracles Argument (TNMA) asserts that the novel predictive success of science would be a miracle, and thus too implausible to believe, if successful theories were not at least approximately true. The TNMA has come under fire in multiple ways, challenging each of its premises and its general argumentative structure. While the TNMA relies on explaining novel predictive success via the truth of the theories, we put forth a deductive version of the No-Miracles argument (DNMA) that avoids inference to the best explanation entirely. Instead, a relatively simple empirical framework and a probabilistic analysis can accomplish the ambitious goals of the TNMA while entirely sidestepping its problems. This close-but-distinct argument has many independent strengths and comparatively few weaknesses. Indeed, objections tailored specifically to the DNMA reveal surprising insights into how exactly NMAs are neither circular nor question-begging, as has been widely speculated.

Keywords No miracles argument · Inference to the best explanation · Scientific realism · Selective realism · Isolationism · Deployment realism · Patchwork view · Underdetermination of theory by evidence

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1 Introduction

The core of the Traditional No-Miracles Argument (TNMA) can be stated simply: the wild predictive success of science can only be explained by the truth of our scientific theories; any competing explanation would require nothing short of a miracle. The TNMA has, however, come under heavy fire from a variety of directions. Many of the seminal criticisms of the TNMA revolve around its reliance on inference to the best explanation (IBE). As such, key objections to the TNMA could be sidestepped if the argument can be reformulated so as not to place abduction at its locus.

This manuscript will proceed in four stages. First, we present the TNMA and a few of its most familiar objections, each of which targets the TNMA's reliance on IBE. Second, we will develop a framework for a Deductive No-Miracles Argument (a DNMA) that, *a fortiori*, does not rely on IBE. Third, we will consider a range of objections, using each as an opportunity to refine our DNMA. Finally, we will show how our DNMA sidesteps the familiar objections to the TNMA discussed at the outset.

2 The traditional no-miracles argument

The appropriate definition of "scientific realism" is contested (Chakravartty, 2017); however, that debate is largely tangential to our purposes in this paper. In what follows we will rely on Boyd's (1984) seminal four-part definition of scientific realism:

i. "Theoretical terms" in scientific theories (i.e., non-observational terms) should be thought of as putatively referring expressions; scientific theories should be interpreted realistically.
ii. Scientific theories, interpreted realistically, are confirmable *and in fact often confirmed* as approximately true by ordinary scientific evidence interpreted in accordance with ordinary methodological standards.
iii. The historical progress of mature sciences is largely a matter of successively more accurate approximates to truth about both observable and unobservable phenomena. Later theories typically build upon the (observational and theoretical) knowledge embodied in previous theories.
iv. The reality which scientific theories describe is largely independent of our thoughts or theoretical commitments. (p. 45)

Put somewhat less technically, realists hold that scientific claims aim to describe the world, that many of the claims made by our best theories are true, and that theoretical (scientific) claims often constitute knowledge about the world (Boyd, 1984; Chakravartty, 2017, § 1.2).

The TNMA is the foremost defense of scientific realism. The TNMA argues that:

> [Realism] is the only philosophy that doesn't make the success of science a miracle. That terms in a mature science typically refer […], that the theories in a mature science are typically true, that the same term can refer to the same thing

> even when it occurs in different theories—these statements are viewed by the scientific realist not as necessary truths but as the only scientific explanation of the success of science and hence as part of any adequate scientific description of science and its relations to its objects. (Putnam, 1975)

The conclusion, that scientific realism is probably true, follows from a tripartite argument:

1. Predictive success does not have any satisfactory explanation absent realism.
2. Scientific realism explains predictive success.
3. Thus, scientific realism is probably true.[1] (From 1 to 2, IBE)

Unfortunately for the realist, both of the premises *and* the cogency of the argument have been challenged.

Take the first premise. What does "satisfactory explanation" mean here? If it is mere avoidance of appeal to miracles, then it seems that the anti-realist can meet the explanatory challenge. Van Fraassen (1980) gives one such explanation on behalf of empiricist views: given a selection effect in favor of predictively successful theories, it is no surprise that the theories that are most prevalent after selection are the predictively successful ones.[2] This requires no appeal to miracles and may appear to provide a satisfactory explanation of predictive success, thus putatively falsifying the first premise.

Laudan (1981) challenges the second premise, i.e. the claim that scientific realism can explain predictive success. The argument against it is short and sweet. Theories that are *true* will be successful, but theories that are *approximately true* have no such guarantee. However one wants to understand the "approximately" in "approximately true" (e.g. Boyd, 1984; Worrall, 1989; Psillos, 2022), approximate truth will fall short of the predictive power of the genuine article. There is thus no guarantee (or even any particularly high probability) that an approximately true theory will make, or be able to explain, successful predictions.[3]

Not only have the premises of the TNMA been challenged, the structure of the argument has similarly come under fire. For example, Fine (1986) argues that the use of abduction creates circularity, as it presumes a realist framework. Fine's objection is straightforward. Suppose for a moment that anti-realists are correct and there exist successful theories whose posited entities do not obtain. It follows that the abductive step between observation and confirmation is not reliably realist. Worries of begging the question now loom. If the TNMA uses the same kind of abduction, then the TNMA begs the question as the anti-realist denied the reliability of IBE for sussing extratheoretical entities and relations in the first place (Fine, 1986, p. 85–86). If a dif-

[1] Putnam 1975, 73. Cf. Chakravartty § 2.1; Dawid and Hartmann 2018, 4063–4064.

[2] This objection, like all we list here, is disputed, and we do not take a stand on its success. For instance, this objection explains why we keep successful theories, but not how theories can be predictively successful. See, e.g., Alai 2014b, § 7.

[3] Much turns on how approximately true is cashed out; "partly true" coupled with selective realism explains successful predictions (cf. Musgrave, 2006–2007).

ferent kind of abduction is at work in the TNMA, it is unclear what the structure of the abductive reasoning is supposed to be or why we would think that it is reliable.[4]

The TNMA is rife with controversy. Each of the above objections are both specific and seminal. Furthermore, as Dawid and Hartmann put it, "the debate on all these points continues until this day" (2018, p. 4064). While the prospect of an entirely vindicated TNMA remains open, there is nonetheless reason to hope for a defense of realism that can sidestep these criticisms.

3 The DNMA

3.1 Validity, strength, and truth

In this section we will develop the foundational framework for a Deductive No-Miracles Argument (DNMA). After introducing the framework on which our DNMA rests, we will consider various ways in which the framework falls short of providing a successful defense of scientific realism. By identifying and shoring-up gaps, we will eventually arrive at a full-fledged defense of scientific realism.

Our initial framework starts with an observation from Evan Fales. Valid deductive arguments with true premises guarantee true conclusions. By contrast, a valid argument with false premises will have a conclusion whose truth-value is random (Fales, 1996, 443).[5]

An example can help illustrate. Suppose there is an urn filled with balls. Some of the balls weigh 12 ounces while some of the balls weigh 16 ounces. A ball is selected at random from the urn and the following *modus ponens* is used to infer the weight of the ball:

(1) If a ball is pulled from the urn, then it weighs 12 ounces.
(2) This ball was pulled from the urn.
(3) Therefore, it weighs 12 ounces.

The first premise is, of course, false. Some of the balls weigh 16 ounces. What is the probability that the conclusion of this argument is true? It's the same as the base rate of 12-ounce balls in the urn. So if 50% of the balls weigh 12 ounces, then the probability that the above inference leads one to a true belief is 50%. If 25% of the balls weigh 12 ounces, then the probability that the above inference leads one to a true belief is 25%. In the first case, the probability that one arrives at a true belief is equivalent to winning a coin toss. In the second case, the probability that one arrives at a true belief is equivalent to rolling a 4 on a 4-sided die.

A similar point can be made regarding inductive arguments. The case is, however, somewhat more complicated. Because inductive strength comes in degrees, a single

[4] For a few (of many) responses to Fine, see Musgrave (1989) and Psillos (1999, 242).

[5] This is not entirely accurate as you can tack on a bunch of superfluous (false) premises to a valid argument form and end up with a valid argument. For now, nothing of any importance turns on making this formulation precise so, for the sake of your sanity and ours, we'll leave it as is.

false premise in an inductive argument will not always block the inference from premises to conclusion. Consider, for example, a track-record argument that includes 100 observational statements, two of which are false. It is unlikely that the two false premises constitute any significant challenge to the relevant inference.

Though inductive arguments are comparatively more forgiving when it comes to false premises, Fales' observation applies here as well. The greater number of false premises involved in a strong argument, the closer to random the truth-value of the conclusion becomes. Widespread false premises are more than sufficient to undermine an inductive inference.

Again, suppose that one has an urn with balls, some of which weigh 12 ounces and some of which weigh 16 ounces. Further suppose that one uses the following statistical syllogism to infer the weight of a ball pulled from the urn:

(1) Most of the balls pulled from the urn have weighed 12 ounces.
(2) This ball was pulled from the urn.
(3) Therefore, this ball weighs 12 ounces.

As before, if either premise is false, one's ability to reason from the premises to a true conclusion rests entirely on luck. If the first premise is false, i.e., most of the balls pulled from the urn do not weigh 12 ounces, the probability that one reasons to a true conclusion is the same as the base-rate of 12-ounce balls in the urn. Alternatively, if the second premise is false, the probability that one reasons to a true conclusion is the same as the base-rate of 12-ounce balls in whatever population the ball came from. Either way, reasoning to a true conclusion requires luck.

Though ball and urn examples are artificial, they are nonetheless effective at making the point. Reasoning to a true conclusion from false premises is a matter of luck and largely depends on the relevant base rates. Complicating the above cases by adding additional properties or by obscuring the appropriate base-rate calculation does not fundamentally change the analysis.

3.2 Probability, predictive success, and truth

It is a small step to move from the above considerations to an argument for the truth of the premises of a predictively successful inference. Suppose we are pulling balls from an urn. We know that half of the balls weigh 12 ounces while the other half weigh 16. Pulling a ball from the urn, we use the following line of reasoning:

(1) If a ball is red, then it weighs 12 ounces.
(2) This ball is red.
(3) Therefore, it weighs 12 ounces.

Suppose we weigh the ball, and the conclusion is true: the ball weighs 12 ounces. Assuming that either (or both) of the premises is false, there is a 50% chance that one could reason from those premises to a true conclusion.

Suppose we then pull a second ball from the urn, use the same line of reasoning, and again confirm the truth of the conclusion by weighing the ball. As before, if we assume that either (or both) of the premises is false, there is again a 50% chance that one could reason from the above premises to a true conclusion. Furthermore, on the assumption that the premises are false, we should treat these two predictions as probabilistically independent as there is no (known) underlying pattern that would probabilistically relate the weights of the two balls. We can thus calculate the probability of twice reasoning from false premises to a true conclusion by multiplying the probability of each event occurring (just as one would calculate the probability of consecutive dice rolls). In this case, that probability is 0.5 * 0.5, or 0.25. It follows that, after two instances of correctly reasoning from the above premises to a true conclusion, there is a 75% probability that the premises are true. The ability to reliably reason from premises to an unknown and improbable true conclusion thus constitutes evidence of the premises' truth.

3.3 Probability, predictive success, and a defense of scientific realism

From the above line of argumentation, it is a short step to providing a defense of scientific realism. Consider, for example, the Eddington experiment in which the observed shift of the stars during a solar eclipse was taken to confirm general relativity. While we will have more to say about identifying the relevant base rates in a moment, let us make the anti-realist friendly assumption that the relevant ratio is 1:100. (The actual base rate is likely to be much lower than this.) On the assumption that the portions of general relativity used to make this prediction are false, there is an approximately 1% probability that one could reason from these premises to a correct prediction about the shift and location of the stars. The fact that humans successfully reasoned from portions of general relativity to an accurate prediction of the appearance of the stars during a full solar eclipse thus offers striking evidence in favor of those portions of general relativity.

We can develop this argument more schematically. Assume that we have some arbitrary predictively successful scientific theory. Call this theory "Good ol' Theory" (GoT). Theories, by themselves, do not make any predictions. Rather, to move from a theory to predictions, the theory must be paired with relevant auxiliary hypotheses (Duhem, 1954, chp. 6; Chakravartty, 2017, § 3.1). Thus, because the process of moving from a theory to predictive success is inferential, considerations about the probability of reasoning from false premises to true conclusions are immediately relevant.

Our null hypothesis is that GoT is not even approximately true. From this assumption and granting the above considerations regarding validity and strength, it follows that any inference from GoT will have a conclusion with a random truth-value. Just as the probability that a die is fair goes down each time we roll a consecutive six, each time we infer an accurate prediction from some set of the propositions that constitute GoT, the probability that those propositions are false decreases. It follows that the fact that portions of GoT are predictively successful constitutes evidence that those portions of GoT are true. The DNMA framework thus allows for a straightforward case against those anti-realists who either deny that our best scientific theories are true or embrace skepticism about the truth of our best scientific theories (cf. Chakravartty, 2017; Kitcher, 2001, p. 161–163).[6]

3.4 The DNMA precisified

At times, the TNMA and the DNMA may look very similar. A formal reconstruction of the DNMA can thus be instructive:

1. If T were false, then the probability that T is a theory from which one has reasoned to a successful prediction (i.e., predicted), Pr_m, is equivalent to the base rate of Pr_m occurring, Br_m. [premise, § 3.1]
2. If T were false, then the probability that T is a theory from which one has reasoned to (i.e., predicted) each true, novel, improbable,[7] and independent prediction are probabilistically independent. [premise, § 3.2]
3. If T were false, then the probability that T is a theory from which one has reasoned to (i.e., predicted) a large number of true, novel, improbable, and independent predictions, Pr_1, Pr_2, … Pr_n, is equivalent to (Br_1 * Br_2 * Br_3 … * Br_n). [1, 2, probability]
4. If T were false, then it is prohibitively improbable that T is a theory from which one has reasoned to (i.e., predicted) a large number of true, novel, improbable, and independent predictions. [3, probability]
5. T is true or it is prohibitively improbable that scientists have made a large number of true, novel, improbable, and independent predictions, Pr_1, Pr_2, … Pr_n by reasoning from T. [4, LEM]
6. Scientists have made a large number of true, novel, improbable, and independent predictions, Pr_1, Pr_2, … Pr_n, by reasoning from T. [premise]
7. Therefore, T is exceedingly likely to be true [5, 6, disjunctive syllogism or law of total probability][8]

The DNMA is valid; it is impossible for the premises to be true while the conclusion is false. But why does this matter? Core challenges to scientific realism attack the connection between observation and confirmation that appear to be needed for our scientific theories to be justified. It is thus problematic to try and defend scientific realism via inferential steps that are only justified *a posteriori*. The same skeptical challenges that beset the scientific realist are likely to beset any *a posteriori* attempt

[6] We have not yet provided a complete defense of scientific realism, as some constructivists may be happy to embrace our conclusions here. We believe this framework provides a starting point for an argument against the constructivists as well, but the wide range of constructivist views and the complex and nuanced nature of the argument we plan to advance forces us to pursue that project elsewhere.

[7] Though the ultimate probabilistic outcome will depend greatly on the exact ratios of “large number” “novel” and “improbable”. A great many novel, nontautological, but nevertheless probable (“easy”) predictions can still count in favor of T, just as much as, e.g., relatively fewer but harder predictions.

[8] The transformation from “prohibitively improbable” to “exceedingly likely” is due to the law of total probability: if the probability of one disjunct is prohibitively low, then the probability of the other disjunct(s) is exceedingly likely. Alternatively, affirming the premise “If Pr(P) = prohibitively low, then ~P” and then drawing the implication “~P” turns the inference into straightforward disjunctive syllogism.

to justify one's inferential steps—Fine's (1986) criticism of the TNMA is a concrete example of this more general challenge.

All the inferential steps in the DNMA are either deductively valid or can be justified via basic rules of probability that, themselves, can be known *a priori*. The upshot is that, unlike the TNMA, the inferential steps in the DNMA are immune from the skeptical challenges that beset scientific realism. The DNMA's immunity from such skeptical challenges is thus of central philosophical importance.

One may, nonetheless, be concerned that the DNMA is merely a disguised version of the TNMA. It is thus worth noting key distinctions between the two arguments. First, we wish to highlight that the DNMA functions even in cases where it is widely agreed that there are no explanatory considerations at work.

By way of illustration, consider Bromberger's (1966) seminal criticism of the deductive-nomological (DN) model of explanation. Bromberger noted that two different calculations regarding the height of a flagpole and the length of its shadow both fit the DN model. In the first instance, one calculates the length of the shadow based on the height of the flagpole and the angle of the sun. This calculation meets the criteria on explanation proposed by the DN model. Furthermore, the calculation seems genuinely explanatory: the length of the shadow is explained by the height of the flagpole and the angle of the sun.

In the second calculation, one calculates the height of the flagpole based on the length of the shadow and the angle of the sun. This calculation also fits the DN model's criteria on explanation, but the calculation is *not* explanatory. The length of the shadow and the angle of the sun *do not* explain the height of the flagpole.

Notice, however, that by the lights of the DNMA, successfully calculating the (unknown) height of the flagpole counts as evidence of the truth of the values assigned to the length of the shadow and the angle of the sun. For were the values assigned to the length of the shadow and the angle of the sun inaccurate it is unlikely (though still possible) that one would successfully calculate the height of the flagpole. Furthermore, by hypothesis, the relevant calculation is **not** explanatory. Given that the DNMA nets evidence for premises in an argument that is widely considered to be bereft of explanatory considerations, it follows that the DNMA does not rely on covertly leveraging explanatory considerations.

It is further worth noting that while the TNMA, and IBE more generally, involve a comparison between the theoretical merits of theories, the DNMA involves no such comparison. The DNMA's ability to avoid any claims comparing the theoretical merits of theories not only serves to distinguish it from the TNMA and IBE more generally, it also allows the DNMA to avoid a criticism of the TNMA that has recently received much press. Because the DNMA does not involve comparing the theoretical merits of different theories, there is no concern that the DNMA attempts to infer from relative premises to an absolute conclusion (Wray, 2008, 323; Mizrahi 2013, 401) and the DNMA concomitantly sidesteps the Bad Lot objection (van Fraassen, 1989, 142–143) entirely.[9]

[9] It may, however, appear that some versions of the TNMA do not involve a comparative element. The TNMA is often reconstructed as an Argument to the only Explanation (IoE), where realism is proffered as the only explanation of predictive success (Psillos, 1999; Alai, 2014a, § 1; 2014c, § 3–5). If realism is the

3.5 Four key features of the DNMA

At this stage, four key features of the DNMA are worth highlighting. First, while much of the literature on scientific realism focuses on abstract logical and probabilistic space, the DNMA does not. Instead, the DNMA focuses on the probability of concrete reasoning events—actual instances of humans engaging in reasoning or building predictive theories—and calculates the probability of these events leading to a specific outcome (i.e., a true conclusion).

Second, the DNMA does not directly confirm theories. Rather, it provides evidence in support of premises that have been used to reason to a true conclusion. In this regard, the DNMA is unlike seminal presentations of the TNMA, in which the TNMA aimed to vindicate, wholesale, the approximate truth of our best scientific theories (Putnam, 1975; Boyd, 1984). The DNMA's more piecemeal approach to theory confirmation mirrors the core innovation of deployment realism, a version of the TNMA developed by Psillos (1994, 1999), Kitcher (1993), Musgrave (1988, 2006–2007), and in particular, Alai (2014a, 2014b, 2017, 2018, 2021).

Third, the probabilistic calculation that lies at the heart of the DNMA requires that the various predictions of a theory are independent of one another, are novel (more on this latter condition in § 5.2), and are improbable. A theory's ability to repeatedly, and accurately, predict the same phenomenon does little to increase the probability that the theory is true. In part, this follows from the novelty requirement (see § 5.2). It also, however, results from the fact that the probability of the truth of propositions from which one reasoned to a true conclusion is driven up by multiplying the base rate of accurately predicting each phenomenon, i.e., the probability of the truth of the propositions from which one has reasoned to a large number of true conclusions is equal to: 1-(Br_1 * Br_2 * Br_3 … * Br_n). Where predictions are not independent of each other, e.g., where one is repeatedly and accurately predicting the same phenomenon, one cannot treat each prediction as probabilistically independent and, as such, one cannot multiply the base rates as in the above calculation.

For the purposes of readability, we will often talk about propositions being confirmed by the *number* of accurate predictions that have been made using said propositions as premises. The raw number of accurate predictions is, however, unimportant. What matters is the number of novel, independent, and accurate predictions. In what follows, the reader should thus understand talk of the *number* of accurate predictions to be shorthand for a more unwieldy claim about the number of novel, independent, and accurate predictions.

Finally, note that the importance of explanatory (or predictive) scope falls immediately out of the initial DNMA framework. Each time we reason from a portion of a theory to an accurate prediction, the probability that that portion of the theory is false

only explanation of predictive success, then it may appear that the TNMA does not involve a comparative element after all. This appearance is, however, misleading. The inferential pattern in IoE is generally justified as an extension of IBE (Lipton, 1993, 2004; Douven, 2021, § 1.2). IoE should thus be understood as a limiting case of IBE where the explanation in question is trivially the best explanation in virtue of being the only available explanation. The comparative component of IBE remains in IoE, though this can be disguised by the fact that, in IoE, the comparative claim is trivially true.

decreases. Therefore, the greater the explanatory (or predictive) scope of a theory, the lower the probability that the propositions in question are false.

3.6 Is the DNMA best understood as a no miracles argument?

Like the TNMA, the DNMA aims to show that, were our best scientific theories false, it would take a miracle to secure the predictive success of these same theories. As such, the DNMA fits the bill of a No Miracles Argument. We have thus framed the DNMA as a variant of the No Miracles Argument originally developed by Putnam (1975) and Boyd (1984). The DNMA is, however, more atavistic than this framing suggests.

A historically popular view—now considered naïve—held that scientific theories were confirmed via accurate predictions (e.g., Nicod, 1924; Hempel, 1945). As a result of objections that we will consider shortly, this comparatively straightforward view of scientific confirmation has largely been abandoned and replaced with the contemporary focus on IBE as the primary means by which scientific theories are justified (Boyd, 1984; Psillos, 1999; Lipton, 2004; Douven, 2021). By contrast, the DNMA embraces this putatively "naïve" view and holds that scientific theories are confirmed via accurate prediction.

4 Base rate problems and defeating steel men

We have now offered a framework for a DNMA that appears to mirror the key moves made by the TNMA while eschewing non-deductive argumentation. Most of the remaining manuscript will be dedicated to considering and responding to objections. Along the way we will highlight key features of the DNMA and, in so doing, put flesh on what is currently a fairly bare-bones framework.

The role of base rates in the DNMA may stand out as particularly problematic. How, exactly, are these base rates supposed to be determined? If we cannot determine the relevant base rates, it is unclear the extent to which the DNMA can confirm scientific theories. In a similar vein but perhaps more problematically, if the base rates end up being too high, the DNMA will fail to provide sufficient evidence to establish the truth of propositions that have been used to reason to predictive success.

By way of illustrating the problem, suppose that the relevant base rate for some prediction is 0.1%. Given that the truth-value of a prediction inferred from false premises is equal to chance, it follows that the probability of reasoning to this true conclusion from false premises is 0.1%. Now suppose that some arbitrary theory makes exactly one prediction and that prediction is accurate. Given such a low base rate of predictive success, though we only have one datum, it gives us good reason to think that the theory in question is true. Should we receive a second accurate prediction, we will be exceedingly confident.

But now consider the same situation with a higher relevant base rate, e.g. 90%. Here an accurate prediction is exactly what we expect from the first prediction, and likely the second as well. Thus the evidential impact of predictive success drops precipitously. Yet the DNMA rests on exactly such probabilistic impact. How then are we to determine the relevant base rates?

There are two different routes we consider in approaching the issue. The first is to simply reemphasize the term “improbable” when used in the DNMA. Recall that the premise is “Scientists have made a large number of true, novel, **improbable**, and independent predictions, Pr_1, Pr_2, … Pr_n by reasoning from T.” Proper emphasis on this point means that only “hard” *pre*dictions (rather than retrodiction or accommodation of the data) will get to count, and will have a low enough base rate that our argument will succeed.

Nonetheless, so long as the number of true, novel, and independent predictions is adequate, our argument is powerful enough to support our current best theories as approximately true even if the base rate of predictive success is ludicrously high. In short, we intend to do the opposite of building a straw man. We will defeat a steel man—an impossibly strong version of the objection.

Let us suppose that the base rate of predictive success is universally 0.95—that is, that the probability of some randomly generated set of propositions being predictively successful in an experimental test is 95%. This is, obviously, much too high.[10] Yet even using an implausibly high base rate of 0.95, we find that we only need to have a mere 14 probabilistically independent novel predictions for the truth thesis to be more likely than not: $(0.95)^{14} = \sim 0.488$.[11]

However one individuates theories, their interactions, and their novel predictions, many of our best theories have at least 14 probabilistically independent successes.[12] Thus, even given a universally and implausibly high base rate, the probability is better than not that portions of our best scientific theories are true.

5 False but predictively successful theories

The existence of false but predictively successful theories pose a number of challenges for the DNMA. Some of these are fairly minor. Others are potentially devastating. In this section, we will work through each in turn. Our initial discussion will revolve around a familiar case study from the history of science.

[10] Suppose we come up with a random formula for predicting the path of a thrown ball. To think such a formula has a 95% chance of even roughly predicting the path is, in a word, absurd. Even cases of binary prediction (particle is negatively charged or not) are hard to get above 50% without losing novelty.

[11] Note that this might not be sufficient to trust that T is true, but this is not our claim. Much depends on the kind of claim as well—is it one of great precision, or just to such-and-such significant digits? Cf. § 6.4 and § 6.5 on this point.

[12] Consider, to take just one example, the Standard Model of physics. The Standard Model is a set of theories that describes three of the four known fundamental forces (electromagnetic, weak, and strong interactions; it excludes gravity) and classifies all elementary particles (6 leptons, 6 quarks, 4 gauge bosons, and the Higgs boson). Just these entities' theories alone that make up the Standard Model adds up to 20 different theories, all of which interact with each other, constantly, all of the time. $0.95^{20} = 0.358$.

5.1 The case study: ptolemaic cosmology

According to Ptolemaic cosmology, the Sun, the Moon, and the other planets orbit the center of the universe: Earth's center. Most other celestial bodies are affixed to a spherical background and each orbiting body rotates on other circular planes (known as epicycles). Ptolemaic cosmology had striking successes, able to trace with surprising accuracy the paths of stars and major planets alike, and perhaps most notably, generating novel predictions such as the dates of certain solar and lunar eclipses. (FP7, 2021, §II).

5.2 Ptolemaic cosmology as a counterexample

A first, rather flat-footed objection, holds up Ptolemy's cosmology as a counterexample to our argument. Given the theory's predictive successes, the DNMA would seem committed to the truth of Ptolemaic cosmology. But the theory is, in retrospect, clearly false. It thus may appear that Ptolemaic cosmology can drive a reductio of the DNMA.

For the moment we will assume, for the sake of argument, that Ptolemaic cosmology had genuine predictive successes. We will eventually critically assess this assumption. Yet even when this assumption is granted, a number of responses are available to the proponent of the DNMA.

First, the DNMA offers a probabilistic argument. The DNMA is thus entirely compatible with the existence of false yet predictively successful scientific theories. The fact that there is a low probability that any individual false theory makes accurate predictions is compatible with a high probability that, over the course of human history, there have been many such theories.

Second, it is worth questioning the extent to which Ptolemy's cosmology was strikingly successful. To make this clearer, let's mark the distinction between *strikingly successful* theories and theories *with striking successes*. Ptolemaic cosmology had some striking successes and is mostly remembered for this reason. Textbook blurbs will mention that Ptolemy was the first to develop a reliable method for predicting solar and lunar eclipses, but often leave out that devotees constantly worked and reworked Ptolemy's model to account for its many inaccuracies. Many other phenomena, including the trajectory of planets through the sky, moved from imprecise to flatly incorrect. Thus, its place in history comes more from its striking successes than its status as a strikingly successful theory, which it was not.[13]

Third, Ptolemaic cosmology achieved its predictive successes at the cost of being notoriously convoluted. While it is widely agreed that simplicity is a super empirical virtue,[14] there is significant disagreement about whether, and how, simplicity is truth-conducive. Happily, one can rather straightforwardly recover the veridicality of simplicity from the DNMA.

[13] Ptolemy's system was a vast improvement on, say, Hipparchus's system, in which common errors could be as great as 30 degrees. Nevertheless, Ptolemy's system still had common errors up to 10 degrees—that is to say, merely enormous, rather than catastrophic.

[14] See (Baker, 2016) for a historical and contemporary review.

The DNMA aims to give evidence in support of scientific realism by considering the etiology of novel predictive successes. Given a standard etiology, where scientists reason to novel predictive successes from propositions they take to be true, predictive success is evidence of the truth of the premises. This is not, however, the only possible etiology of predictive success. It is also possible to effectively P-hack one's way to predictive success. The more predictions a theory makes, the greater the probability that it will make a large number of true predictions. For example, given a base rate of 20% predictive success, a random theory that makes five predictions is likely to get lucky and get a prediction right.[15] A theory that makes 1,000 predictions is likely to have a seemingly impressive 200 predictive successes. Furthermore, by adjusting the theory and auxiliary hypotheses, it is possible to keep the 200 predictive successes while pruning the predictive failures away (this is effectively what van Fraassen's (1980) criticism of the TNMA amounts to). The resulting theory is, however, likely to be a convoluted mishmash—far from the paradigm of simplicity.

Just as P-hacked results do not confirm (or disconfirm) a theory, predictive successes that are a result of P-hacking do not provide evidence of a theory's truth. Rather, they are merely an artifact of playing the predictive odds before obscuring the incriminating evidence. It is thus unclear if the notable predictive successes of Ptolemaic cosmology count in favor of the theory's truth or, given the theory's notorious complexity, if Ptolemaic cosmology's predictive successes are the result of many blind squirrels finding a few nuts (and someone burying all the squirrels who died of starvation under six feet of concrete).

Finally, and likely the cause of the theory's notoriously convoluted structure, Ptolemaic cosmology achieved its predictive successes via the addition of a large number of ad hoc hypotheses. Not only can the DNMA offer some reason to think that simplicity is a truth-conducive method of theory selection, it offers a distinct reason to be suspicious of ad hoc hypotheses. This is a notable result because, while ad hoc additions to one's theory are intuitively problematic, it can be difficult to justify this intuition (Barnes, 2021).

The DNMA rests on the claim that it is unlikely that one will be able to reliably infer from a false theory to a true prediction. When one introduces an ad hoc hypothesis, one is not thus inferring. Rather, one starts out knowing the observational outcome and then reverse engineers the theory to get the desired result. When one reasons in this way, the probability of having a theory that successfully "predicts" the observational outcome is 1. Consequently, securing accuracy by introducing ad hoc hypotheses does not increase the probability that a theory is true. From the perspective of the DNMA, many of the "predictive successes" of Ptolemaic cosmology are not predictive successes at all, but rather retrodictive successes and, as such, offer no evidence of the theory's truth.

A predictively successful but false theory like Ptolemaic cosmology may seem to provide a counterexample that undermines the DNMA. When the challenge posed by false but predictively successful theories is understood in this way, the DNMA

[15] Hence our repeated emphasis on improbability and the distinction between "easy" and "hard" guesses, which would drive this number down. Nevertheless, hard guesses, once known, can be accommodated, and thus can also be p-hacked in this way, requiring—as we will conclude shortly—that we recover novelty.

appears to have ample resources to defuse the objection. There are, however, alternative ways of pushing the challenge.

5.3 The DNMA says nothing about inaccurate predictions

As noted in the previous section, though Ptolemaic cosmology makes a number of accurate predictions, it also makes a number of inaccurate predictions. These inaccurate predicates may appear to challenge the DNMA. The DNMA holds that a history of successful predictions gives evidence of a theory's truth. But what then of predictive failures? The DNMA makes no mention of these. Are we tethered to Ptolemaic cosmology by its predictive successes, regardless of its myriad failures?

The short answer is: no. A theory's predictive successes are only one portion of the full evidential picture. The evidence in favor of a theory's truth must be weighed against the evidence to the contrary, including predictive failures. Providing an account of that broader process of assessing and weighing all of the evidence falls outside the scope of this paper.[16] Many false predictions with a few true predictions is evidence of many false components and a few true ones, and vice-versa. With regard to our best theories—those with few predictive failures and a rich history of predictive success—the totality of evidence surely supports the truth of many components of those theories. In other cases, like Ptolemaic cosmology, the totality of evidence clearly indicates that few, if any, components of the theory are true.[17] For a broad range of cases in between, the verdict will remain unclear until we are in a position to assess and weigh the evidence both indicating and contra-indicating the theory's truth.

5.4 Underdetermination of theory by evidence

Ptolemaic cosmology is an interesting historical example in part because it accounted for nearly all the same empirical data as its successor, Copernican cosmology. Though the Copernican model of the universe similarly turned out to be inaccurate, the predictive similarity of the two theories highlights an important phenomenon: for any given set of observations, there are an infinite number of empirically adequate but false theories. This phenomenon, known as *the underdetermination of theory by evidence*, poses a forbidding obstacle for the scientific realist. For any given true theory, T, and any given set of observations, O, there are an infinite number of false theories each of which stands in a symmetrical relation to O. Thus, insofar as O confirms T, it seems that O similarly confirms each member of an infinite set of false theories. Which is just to say: O doesn't offer any confirmation for T at all.

The underdetermination of theory by evidence may appear to present an equally significant challenge for our DNMA. On at least one reading, we have argued that predictive success provides evidence that a set of propositions is true. But given that,

[16] This kind of account has, of course, been developed elsewhere. Of particular interest is the work of deployment realists previously cited.

[17] Assuming falsely that they were truly predictive, rather than merely retrodictive, as was actually the case. Accurate retrodiction is no surprise!

for any set of observations, there are an infinite number of empirically adequate yet false theories, it is unclear how predictive success could constitute evidence of truth.

The first thing to notice is that we have now used the DNMA to recover the super-empirical virtues of explanatory scope (see § 3.5), simplicity, and novelty (see § 5.2). It is certainly true that a neo-Ptolemaic cosmology[18] could, with enough ad hoc hypotheses, account for all the empirical observations as our contemporary understanding of the solar system. Yet any such neo-Ptolemaic cosmology would fall short on a number of super empirical virtues. Our DNMA thus already has some buttressing against the underdetermination of theory by evidence.

More importantly, our DNMA undermines the core claim motivating the underdetermination of theory by evidence. Key to the challenge is the symmetry between true and false theories: for some given set of observations, O, a true theory and infinitely many false theories stand in the same evidential relation to O—they all account for the observed phenomena.

The DNMA undercuts this key symmetry. The DNMA does not rest on the claim that *the ability to account for observed phenomena provides evidence that a set of propositions is true*. Rather, it rests on the related yet distinct claim that *having **actually reasoned** from a set of propositions to predictive success provides evidence that those propositions are true*. Yet the number of theories from which we have *actually* reasoned to predictive success is quite limited.

In order for the underdetermination of theory by evidence to present an objection to the DNMA, one would have to have multiple theories that (i) are empirically adequate, (ii) have *actually* been used to reason to (novel) predictive success, and (iii) are equally super-empirically virtuous. Yet in such a case the evidence seems truly equivocal; agnosticism seems like the appropriate response. Thus, in those few cases where the underdetermination of theory by evidence remains relevant to the DNMA, the realist would do well to embrace the skeptical conclusion.

Here, the DNMA's shift away from logical space and to concrete reasoning events pays real dividends. The symmetry that lies at the core of the underdetermination of theory by evidence only exists when we think about confirmation and the relationship between a theory and observations in terms of logical possibility and abstract logical relationships. This symmetry disappears when, like the DNMA, we think about theory confirmation in terms of the probabilistic relationships that hold between actual events. The DNMA thus elegantly sidesteps the underdetermination of theory by evidence, a seminal and perennial problem for scientific realism.

[18] That is, some kind of epicyclic geocentrism that orders the planets correctly. Indeed, Einstein and Infeld note that such a view could even account for the elliptical orbits of the various planets in their textbook on the history of physics. Relativity affirms that one can formulate physical laws such that they hold true and correctly predict the paths of celestial objects regardless of what is chosen as the "center" of the solar system. The planets move in ellipses relative to the Sun, but the planets do not move elliptically relative to the Earth (Infeld, 1966, 212).

6 The inverted miracles objection

The existence of false yet predictively successful theories raise a number of related objections to the DNMA. The DNMA has ample resources to respond to many of these. The *inverted miracles objection*, however, poses a unique challenge; the ultimate fate of the DNMA likely rests on its ability to respond to this objection. In this section we will present the objection and sketch a potential response, but will not declare ultimate victory. Though we are optimistic that the DNMA remains viable, our sense is that the case remains open.

6.1 The objection

The *inverted miracles objection* is best illustrated by an example. Suppose that an arbitrary set of false propositions makes 10 true, independent predictions and the base rate of true, independent predictions is 50%. The probability of this occurrence is $.5^{10}$ or approximately 0.098%. Now imagine an arbitrary set of false propositions makes 100 true, independent predictions with this same base rate. The probability drops precipitously. If the relevant false propositions have been used to make enough true, independent predictions, the probability of the propositions in question being false is infinitesimal. If there is a set of known false propositions that the DNMA finds had an essentially zero probability of achieving their level of predictive success, then the relevant propositions can drive a *reductio* of the DNMA.

The mere possibility of a false yet predictively successful theory (or false yet predictively successful propositions) fails to pose any threat to the DNMA. An *actual* such theory (or set of propositions) is needed. Newtonian mechanics is perhaps the best candidate for a theory that can feed the objection.[19] Newtonian mechanics has afforded an astounding range of predictive success and, consequently, by the lights of the DNMA (likely) has an infinitesimal probability of being false. Yet we now know that Newtonian mechanics is false. Newton mechanics thus appears to present a potentially fatal objection to the DNMA.

6.2 Deployment realism and the IMA

There are a number of potential ways a realist could defuse the inverted miracles argument (henceforth, IMA). The most paradigmatic and promising responses restrict the scope of the realist's commitments. Of these, we are particularly interested in *deployment realism*.[20]*Deployment realism* (sometimes called *selective realism*) is perhaps the most subtle and promising member of the realist family. The view has been developed by a number of high-profile defenders and carefully engages with the history of science (Kitcher, 1993; Psillos, 1999; Musgrave, 2006–2007; Alai 2014a, 2014b, 2014c, 2014d, 2018, 2021).

[19] Indeed, it features on numerous lists of successful-yet-false theory lists. See, e.g., Lyons (2002, 70–72), and Vickers (2013, 191–194).

[20] Though not these authors' endorsed position, structural realism also can provide an answer to this objection. Indeed, any adequately realist account of theory change should be satisfactory.

Deployment realism holds that explaining the success of a novel theory's predictions does not require the truth of *all* its tenets, just those *essential* to the derivation of that prediction. Deployment realism thus happily admits that theories are almost always false, but holds that select hypotheses (auxiliary or primary) are true. The true parts of the theory can be combined to make valid inferences to novel predictions, whilst other parts of the theory are misleading or irrelevant (or even unknown; see Alai, 2014d, p. 266–268).[21]

The DNMA and deployment realism share a commitment to the piecemeal vindication of scientific theories. Deployment realism provides a justification for piecemeal confirmation that has historically revolved around IBE, while the DNMA draws on *a priori* probabilistic considerations to arrive at a similar conclusion. Nonetheless, because deployment realism and the DNMA both argue that predictive successes confirm individual hypotheses rather than theories as a whole, if deployment realism's piecemeal approach to confirmation can provide a solution to the IMA, the same should be true about the DNMA's piecemeal approach to confirmation. In other words, what the two share is a commitment to lightening the realist burden—restricting the scope of the realist's commitments.[22]

Deployment realism may appear to offer an elegant solution to the IMA. Consider one of Newtonian mechanics' most famous successes, the hard and novel prediction of the position and mass of the then-unknown planet of Neptune.[23] Does this success of Newtonian mechanics threaten to undermine the DNMA? Consider how the deployment realist responds:

> …deployment realism points out that Newton's gravitation theory includes both the false claim that there exists a gravitation force, and the approximately true claims that a body's trajectory is a direct function of the product of its mass and other masses, an inverse function of the square of distances, etc. … Neptune's existence and properties are derivable just from the latter (approximately) true claims, while the former false one is idle in this respect (Alai, 2014d, p. 269).

Alai's key move is to show that only *portions* of Newtonian mechanics were needed to make the relevant predictions. Deployment realism further holds that *only* those portions of Newtonian mechanics deserve to be treated realistically. In Vickers' words: "all the realist needs to do is show that the specific [putatively false] assumptions identified by the antirealist do *not* merit realist commitment. And she can do

[21] For an interesting series of hard cases for deployment realism or replies attempting accommodation, see Laudan (1981), Psillos (1994, 2022), Lyons (2002, 2003), Chang (2003), Doppelt (2005), Alai (2014d, 2017, 2018, 2021), Vickers (2017) Boge (2021), and Tulodziecki (2021). For more theoretical criticisms, see Stanford (2006), Lyons (2006), Peters (2014).

[22] Whether this entails that the DNMA uses deployment realism or that the DNMA uses a parallel but different scope-restricting move does not matter to the authors. For an alternative scope-restricting move that is not deployment realism, see § 6.4. Structural realism, though not the authors' view, may also provide an adequate solution.

[23] Hard and easy predictions are just descriptors for how improbable a lucky guess would be. For binary questions, it would be easy to get a lucky guess, since the probably is 50/50. For Newton, predicting that an undiscovered planet existed somewhere in the universe would be easy, but predicting the position and mass of an undiscovered planet is quite hard. See Alai 2014d, 275–276.

this without saying anything about how to identify the posits which *do* merit realist commitment" (2017, p. 3224).

Given the DNMA's emphasis on *actual* reasoning events, the DNMA can mirror deployment realism in pulling the same scope-limiting move and thereby restricting the premises confirmed by a successful prediction. The DNMA's piecemeal approach to confirmation can thus avoid the concern raised by the striking success of having accurately predicted the location and mass of Neptune. The fact that Newtonian mechanics involved false but idle premises is not bothersome.

6.3 The IMA tightened

Despite the initial promise of deployment realism and other scope-limiting moves, it is unclear if it successfully defeats the IMA. Consider a more specific example, similarly drawn from Newtonian mechanics. Consider, e.g., Newton's Second Law: F=MA. The law has afforded an astounding range of predictive success and, consequently, by the lights of the DNMA (likely) has an infinitesimal probability of being false.[24] Yet in relativistic mechanics, Newton's Second Law does not hold. The falsity of Newton's Second Law thus appears to present a potentially fatal objection to the DNMA.

The piecemeal approach to confirmation shared by deployment realism and the DNMA gains little traction here. Newton's Second Law is no idle premise; it is a key piece of the reasoning used to generate a wealth of predictive successes. Yet Newton's Second law is nonetheless false. The piecemeal approach to confirmation embraced by both selective realism and the DNMA can thus only keep the wolves from the door for so long.

6.4 The IMA answered again

There are a number of ways that one might try and answer this tightened version of the IMA. For example, one could try and show that Newton's Second Law didn't have such great predictive success after all. Such a line of argumentation would, however, serve as double edged sword for the DNMA. Newton's Second Law, though ultimately false, is arguably one of the most predictively successful hypotheses in the history of science. Any attempt to undermine the extent to which predictive success provides evidence for Newton's Second Law thus threatens to undermine the DNMA's ability to marshal evidence for a wide swath of scientific theories. It is possible that the proponent of the DNMA could thread this needle, undermining the evidence for the Second Law without undermining the evidence for nearly all scientific theories. This is, however, a daunting challenge and one that we would rather not take on unless absolutely forced.

An alternative response draws on an account of what the realist is committed to given what scientific theories *are*. When Newton formulated his laws, he was aim-

[24] For some instances of this, consider how it has made predictions about planetary bodies, bodies on earth, underwater, bodies on planes, and so on. There are also corroborative ways to get independence, such as when it interacts with other laws.

ing at describing universal laws that would be true no matter the context. The view that science aims at universal laws is now in recession. Instead, prevailing view is increasingly a *patchwork* or *isolationist* view (Cartwright, 1999; Cat, 2017).[25]

The driving force behind isolationist views is that there are few, if any, descriptions of phenomena that are sufficiently general to merit the term "universal law." Various fields in science are neither unified hierarchically nor in a substitutionary sense. Even our best theories are quite limited by their context. Evolutionary theory is one of our most successful theories in biology, but its principles are neither entailed by nor generalize to our best theories of chemistry or physics. Even within fields like physics there is significant disunity. Our best theories of quantum mechanics are famously disunified from general and special relativity. Every purported scientific law has *ceteris paribus* clauses (Cartwright, 1999, chp. 6); all scientific laws are notoriously context-sensitive.

Isolationism may allow for areas in which there is local integration or unity. In a rather famous instance of this, Einstein showed that Brownian motion, originally a biological phenomenon, could be explained by physics' method of statistical mechanics (Einstein, 1905). Nevertheless, the descriptions or representations of phenomena from different individual sciences remain independent from each other. Thus, in a case in which two fields (like physics and biology) both describe the same phenomenon, isolationism takes no stand on whether one is reducible to or more foundational than the other (Cat, 2017, § 3.2).

By embracing isolationism, a proponent of the DNMA can hold that Newtonian physics and its branches are essentially simplifications of more accurate, but disunified fields. Slow (far less than 3×10^8 m/s), small (near or less than 10^{-9} m) objects are best described by quantum mechanics. As the object gets larger, classical mechanics is more apt to provide the correct description. As the speed increases, quantum field theory is more apt to provide the correct description. And as both speed and mass increase, relativistic mechanics are the most accurate method for ascertaining correct predictions. As of yet, there is no best method or unifying theory for extremely small and extremely massive objects. The fields are not, however, completely disunified; there are local integrations.[26] The isolationist view of scientific theories thus allows one to hold that classical mechanics are simplifications and approximations; Newton's Second Law is true, under certain conditions and other things equal.

The IMA argued that there are false propositions, e.g. Newton's Second Law, that have probability of nearly 1 under the DNMA. A quick *modus tollens* may seem to follow. Isolationist views, however, reject the view that scientific theories make universal claims. The truth of Newton's Second Law is thus compatible with the Second Law's failure to accurately describe the behavior of very small, very large, very fast,

[25] The view has gained significant support since it came into the mainstream. Cf. Cartwright 1999.

[26] Statistical mechanics may be an example of integration between classical or quantum mechanics and more macro phenomena, such as Einstein's (1905) aforementioned ability to account for Brownian motion with such tools.

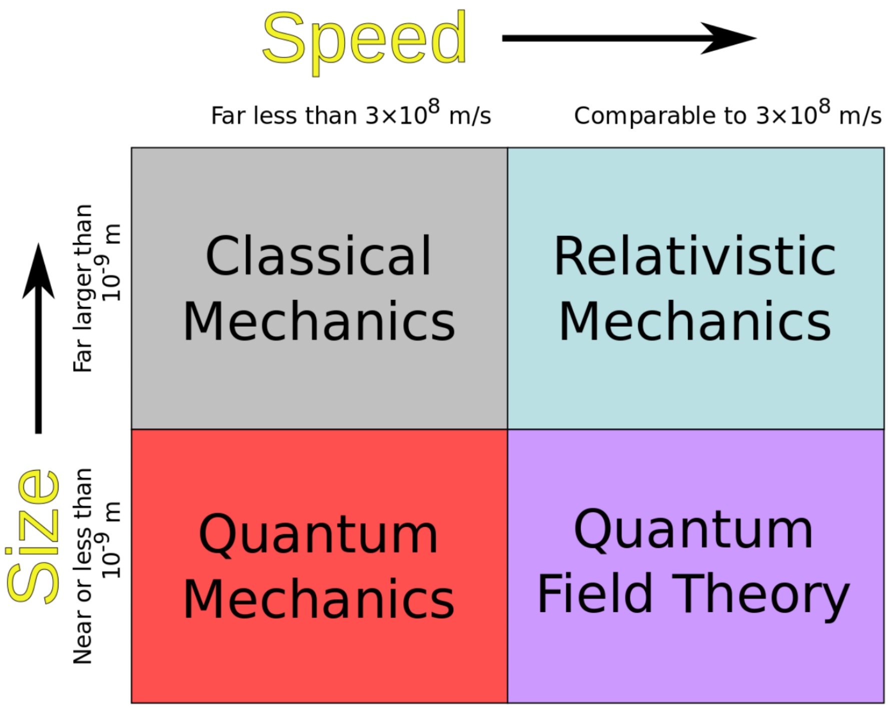

Fig. 1 Apt field for description by speed and mass

and very slow objects. By embracing isolationism,[27] the proponent of the DNMA can deny the central premise of the reformulated IMA; Newton's Second Law is true after all.

6.5 Remainders

Two rather glaring criticisms remain. First, Newton and many after him took Newton's Second Law to be a universal claim, rather than just a claim about medium-sized, slow goods. Given the DNMA's emphasis on concrete reasoning events, this fact may appear to present a fatal objection to our attempt to answer the IMA via an isolationist framework. Whether or not isolationism is true, Newton (and others) derived impressive predictive successes from a theory they took to be universal. It may thus appear that the DNMA is committing to holding that Newton's Second Law, understood as a universal claim, has a probability of nearly 1.

[27] One might not need to embrace isolationism in its entirety, or isolationism as such at all. Again, what is most important is that one find a way to make two moves: (i) confirm that there "is truth" (here, with isolationism, an instance of the law) to the successful theory, and (ii) denying that the realist is committed to the overgeneralization of that true instance. Musgrave (2006–2007), for instance, provides one such answer that parallels the moves we make here without explicitly committing to isolationism, though the views and moves appear to be kindred spirits.

Happily, though initially daunting, this objection is likely less problematic than it appears. Notice that Newton's belief that *F=MA is a universal law* is not, itself, a required premise in any successful predictions. The law, rather than a belief about the law's universality, carries all of the predictive weight. Given that claims about the universality of Newton's Second Law are not, themselves, required to generate successful predictions, Newton's belief that the Second Law was universal garners no confirmation via the DNMA. It is notable that, in responding to this objection, we have returned to the piecemeal approach to confirmation embraced by deployment realism and the DNMA. Isolationism may be able to do important work in defending the DNMA; however, the path paved by deployment realism remains indispensable.

A second objection notes that, in holding that Newton's Second Law is true, we appear to be committed to some notion of "approximate truth," a commitment that has historically been a weak point for the realist (Laudan, 1981; Musgrave, 2006–2007; Psillos, 2022, § 2.3) and one that the DNMA has aimed to avoid (see § 9). Even the isolationist cannot hold that Newton's Second Law is true, full stop. Rather, we now know that Newton's Second Law is, with regard to medium sized slow goods, accurate within any degree of reasonable exactitude.[28] But push the demands of precision far enough and Newton's Second Law gets it wrong, even with regard to medium-sized slow goods.

It follows that even the isolationist must admit that Newton's Second Law is only approximately true. Does it follow that, in drawing on isolationism to respond to the IMA, the DNMA finds itself committed to a problematic notion of approximate truth? Here we think the answer is "no."

There is a scope ambiguity in the claim that *Newton's Second Law is approximately true*. One could read this with "approximately" in the primary scope: It is *approximately* true that Newton's Second Law describes the behavior of medium-sized slow goods. This reading gives rise to any number of familiar philosophical problems.

One could, however, read the same sentence with "approximately" in a secondary scope: It is true that Newton's Second Law *approximately* describes the behavior of medium-sized slow goods. When "approximately" is placed in a secondary scope, it is philosophically innocuous. We can read this latter claim as something along the lines of: Newton's Second Law accurately describes the behavior of medium-sized slow goods up until such-and-such significant digits. Read this way, there is nothing philosophically troubling about approximate truth nor is there any mystery regarding how Newton's Second Law, being only approximately true, could afford predictive success (within such-and-such significant digits).[29]

As a final point, it is worth noting that it may be that one cannot be a deployment realist without also being an isolationist. Deployment realism aims to strip away claims whose scope is unnecessarily wide—such as claiming that a theory is universal when we only need it to be field specific. The deployment realist may thus

[28] So reasonably exact, in fact, that NASA uses Newtonian physics to calculate trajectories for their nearby space missions, sans Mercury due to the proximity of the Sun.

[29] Some deployment realists have made exactly this move. See, e.g., Alai (2014d).

quickly find themselves committed to the field-specific view of theories definitive of isolationism.[30]

7 Traditional objections

At the outset of the manuscript we promised that the DNMA would be able to (easily) sidestep seminal objections to the TNMA. We are now in a position to fulfill that promise. The TNMA argues as follows:

1. Predictive success does not have any satisfactory explanation absent realism.
2. Scientific realism can explain predictive success.
3. Thus, scientific realism is probably true.

Van Fraassen argued that, contra premise 1, empiricist views can provide a perfectly satisfactory explanation of predictive success. Because the DNMA does not rely on any special explanatory powers of scientific realism, it is untroubled by van Fraassen's critique. By the lights of the DNMA, we should not conclude the predictively successful theory is true because no other satisfactory explanation is available. Instead, we ought to believe predictively successful theories are true because the probability of a false theory having an impressive record of success is prohibitively low. Explanation never enters the picture and van Fraassen's objection passes us by.

Laudan criticized the second premise, arguing that while *truth* can explain predictive success, it is unclear if the same can be said about *approximate truth*. Because the TNMA attempts to infer from predictive success directly to approximate truth (via IBE), it would be a fatal blow for the TNMA if approximate truth does not have the resources to explain a theory's predictive successes.

As was the case regarding van Fraassen's criticism of the TNMA, the DNMA sidesteps Laudan's critique. Rather than attempting to infer the *approximate truth* of a theory from predictive success, the DNMA infers from predictive success to the *truth* of propositions. Laudan has no qualms about the link between truth and predictive success, describing it as "self-evident" (1981, p. 30). As such, Laudan's criticism of the TNMA is silent regarding the link the DNMA draws between predictive success and truth. Whatever force Laudan's objection holds regarding the TNMA, it misses the mark entirely when it comes to the DNMA.

Finally, Fine argued that the TNMA was circular. The TNMA is an instance of IBE and anti-realists antecedently reject the reliability of IBE. Therefore, the TNMA putatively offers no evidence against anti-realism. The DNMA, however, does not rely on IBE and is thus immune to the charge of circularity. As with the previous objections, there are no Jedi mind tricks needed; we really don't have the droid they're looking for.

Key objections to the TNMA challenged, in one way or another, the TNMA's reliance on IBE. The DNMA, however, eschews abduction and relies on probabi-

[30] As anti-realists can be isolationists, it should be clear that the inverse is not true. The isolationist need not embrace deployment realism.

listic inference only. As such, the DNMA easily sidesteps objections that have long entangled the TNMA.

8 The promises and potential of DNMA

A full-blooded scientific realist may be worried that the DNMA fails to vindicate a large enough swath of scientific theories. Many of our best scientific theories—such as neo-Darwinian theory and the theory of plate tectonics—are rich with explanatory power but, one may be concerned, lack the kind of novel predictive successes the DNMA requires.

It is unclear if the key premise of this argument is true, i.e., it is unclear that neo-Darwinian theory and plate tectonics lack predictive power. For example, neo-Darwinian theory might predict the presence of certain fossils within certain rock groups that link reptiles to birds, the likes of which has not been found yet.[31] Such a prediction would count as novel and thereby clear the bar (Kitcher, 1982).[32]

Yet even if, contra the above evidence, one accepts the claim that many of our best theories lack the predictive power necessary for vindication by the DNMA, there remains the potential for the DNMA to serve as the foundation for a realist-friendly argument for vindicating our ordinary methods of scientific reasoning, including IBE.

Suppose that the DNMA is successful, and we have reason to believe that a number of our scientific theories are true. The evidence that the DNMA uses as grist for its mill is our historical success reasoning from a theory to novel, successful, and improbable predictions. The DNMA is thus silent regarding our methods of theory generation and selection. If the DNMA provides reason to believe that a number of our scientific theories are true, we can run a parallel probabilistic argument regarding the methods by which we initially arrived at the theories in question. If our methods of theory generation and selection were not truth-conducive the probability of arriving at a number of true theories using these methods would presumably be quite slim. Thus, if the DNMA is successful, we can give an argument with a very similar structure, partly anticipated by Mario Alai (2014a § 1, 2014b, 2018), that vindicates the truth-conduciveness of our methods of theory generation and selection:

(1) If our methods of theory generation and selection were not truth-conducive, there is a low probability that we would arrive at a large number of true theories using these methods.
(2) We have used our methods of generation and selection to arrive at a large number of true theories. (From the DNMA)
(3) Our methods of theory generation and selection are likely truth-conducive. (From 1 to 2)

[31] Kitcher's (1982) actual example is too long to place in the text of this paper; it has to do with the tenrecs of Madagascar and four novel predictions on its proposed evolutionary history.

[32] We thank an anonymous reviewer for very helpful comments in this section, some of which we have simply adopted wholesale.

(4) If our methods of theory generation and selection are likely truth-conducive, then theories we arrive at using these methods are likely to be true.
(5) Therefore, theories we arrive at using our methods of theory generation and selection are likely to be true. (From 3 to 4)

While crucial details remain to be filled in, there is at least some promise that, once the DNMA has established the truth of a critical mass of theories that have a wealth of novel predictive successes, we can use an argument with a parallel structure to vindicate our methods of theory generation and selection (including IBE and a wide range of super empirical virtues) and, thereby, the realist status of those theories we've arrived at via these methods.

9 DNMA undefeated

The TNMA argues that the miraculous predictive success of science can only be explained by scientific realism, but is enmeshed in endless debate due to its reliance on IBE. We proposed an alternative, the DNMA, as a way to secure the same goods without the concomitant controversy. The basic argument is straightforward: once we observe that reasoning with false premises reduces the promise of a true conclusion to chance, we can turn the observation around into a probabilistic inference that a very favorable ratio of true conclusions indicates that the premises are true (given a strong or valid argument). It is then a short step to using this same method to confirm those portions of scientific theories that have an impressive history of affording accurate prediction.

We then canvassed four objections to showcase the DNMA's resilience. A discussion of base rates was outfitted in our finest steel armor and defeated. We then considered false but predictively successful theories and the underdetermination of theory by evidence, but the DNMA was unbothered. We then raised the inverted miracles argument, to which we provided a promising, albeit imperfect, response. Finally, the traditional objections were shown, as promised, to pass the DNMA like ships in the night. Though the ultimate verdict for the DNMA is open, the DNMA should be explored as a novel and full-throated defense of scientific realism.

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Declarations

Conflict of interest Neither author has any conflicts of interest.

References

Alai, M. (2014a). Novel predictions and the no miracle argument. *Erkenntnis*, *79*(2), 297–326.
Alai, M. (2014b). Why Antirealists can't explain success. In F. Bacchini, S. Caputo, & M. Dell'Utri (Eds.), *Metaphysics and ontology without myths* (pp. 48–66). Cambridge Scholars Publishing.
Alai, M. (2014c). "Explanatory Realism." in E. Agazzi (ed.), Science, Metaphysics, Religion. Proceedings of the Conference of the International Academy of Philosophy of Science, Siroki Brijeg 24–24 July 2013, Franco Angeli, Milano 2014.
Alai, M. (2014d). Defending Deployment Realism against Alleged Counterexamples. In G. Bonino, G. Jesson, & J. Cumpa (Eds.), *Defending realism. Ontological and epistemological investigations*. De Gruyter.
Alai, M. (2017). "Resisting the historical objections to realism: is Doppelt's a viable. *Solution?" Synthese*, *194*(9), 3267–3290. https://doi.org/10.1007/s11229-016-1087-z.
Alai, M. (2018). How Deployment Realism withstands Doppelt's criticisms. *Spontaneous Generations: A Journal for the History and Philosophy of Science*, *9*(1), 122–135.
Alai, M. (2021). The historical challenge to realism and essential Deployment. In T. D. Lyons, & P. Vickers (Eds.), *Contemporary scientific realism: the challenge from the history of Science* (pp. 183–215). Oxford University Press.
Baker, A. (2016). "Simplicity." in E. Zalta (ed.) Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/simplicity/.
Barnes, E. C., "Prediction versus Accommodation", The Stanford Encyclopedia of Philosophy (Fall 2021 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/fall2021/entries/prediction-accommodation.
Boge, F. (2021). Incompatibility and the pessimistic induction: a challenge for selective realism. *European Journal for Philosophy of Science*, *11*(2), 1–31. https://doi.org/10.1007/s13194-021-00367-4.
Boyd, R. (1984). The current status of scientific realism. In J. Leplin (Ed.), *Scientific realism* (pp. 41–82). University of California Press.
Bromberger, S. (1966). Why questions. In R. Colodney (Ed.), *Mind and Cosmos*. University of Pittsburgh Press.
Cat, J. (2017). "The Unity of Science." in E. Zalta (ed.) Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/scientific-unity/.
Cartwright, N. (1999). *The Dappled World: a study of the Boundaries of Science*. Cambridge University Press.
Chang, H. (2003). Preservative realism and its discontents: revisiting caloric. *Philosophy of Science*, *70*(5), 902–912. https://doi.org/10.1086/377376.
Chakravartty, A. (2017). "Scientific Realism." in E. Zalta (ed.) Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/scientific-realism/.
Dawid, R., and Stephan Hartmann (2018). The No Miracles Argument without the Base Rate Fallacy. *Synthese*, *195*, 4063–4079.
Doppelt, G. (2005). Empirical success or explanatory success: what does current scientific realism need to explain? *Philosophy of Science*, *72*, 1076–1087.
Douven, I. (2021). "Abduction." In E. Zalta (ed.) Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/abduction/.
Einstein, A. (1905). On the Movement of small particles suspended in Stationary Liquids required by the Molecular-Kinetic Theory of Heat. *Annalen der Physik*, *322*(8), 549–560.
Encyclopædia, & Britannica (Eds.). (2022). inc. (n.d.). The Frequency of Solar and Lunar eclipses. Encyclopædia Britannica. Retrieved March 31, from https://www.britannica.com/science/eclipse/The-frequency-of-solar-and-lunar-eclipses.
Fales, E. (1996). Plantinga's case against naturalistic epistemology. *Philosophy of Science*, *63*, 432–451.
Fine, A. (1986). "The Natural Ontological Attitude." In The Shaky Game. Chicago: The University of Chicago Press. FP7 ESPaCE Program. 2021. "History of Eclipses: Observations and Predictions." Retrieved from https://promenade.imcce.fr/en/pages4/468.html.
Hempel, C. (1945). Studies in the logic of confirmation. *Mind*, *54*, 1–26.
Infeld, L., and Albert Einstein (1966). *The evolution of physics*. Simon and Schuster.
Kitcher, P. (1982). *Abusing Science: the Case Against Creationism*. The MIT Press.
Kitcher, P. (1993). *The Advancement of Science: Science without Legend, Objectivity without Illusions*. Oxford University Press.

Kitcher, P. (2001). Real realism: the Galilean Strategy. *Philosophical Review*, *110*(2), 151–197.
Laudan, L. (1981). A confutation of Convergent Realism. *Philosophy of Science*, *48*, 19–49.
Lipton, P. (1993). Is the best good enough? *Philosophy of Science*, *48*, 19–49.
Lipton, P. (2004). *Inference to the best explanation* (2nd ed.). Routledge.
Lyons, T. D. (2002). "The Pessimistic Meta-Modus Tollens." In Clarke and Lyons Recent Themes in the Philosophy of Science: 63–90.
Lyons, T. D. (2003). Explaining the success of a scientific theory. *Philosophy of Science*, *70*, 891–901.
Lyons, T. D. (2006). Scientific realism and the Stratagema de divide et impera. *British Journal for the Philosophy of Science*, *57*(3), 537–560.
Mizrahi, M. (2013). The pessimistic induction: a bad argument gone too far. *Synthese*, *190*(15), 3209–3226. https://doi.org/10.1007/s11229-012-0138-3.
Musgrave, A. (1988). The Ultimate Argument for Scientific Realism. In R. Nola (Ed.), *Relativism and realism in Science* (pp. 229–252). Kluwer Academic Publishers.
Musgrave, A. (1989). NOA's Ark—Fine for realism. *The Philosophical Quarterly*, *39*(157), 383–398.
Musgrave, A. (2006–2007). "The 'Miracle Argument' for Scientific Realism." The Rutherford Journal: The New Zealand Journal for the History and Philosophy of Science and Technology 2: http://www.rutherfordjournal.org/article020108.html.
Nicod, J. (1924). Le problème logique de l'induction. Paris: Alcan. (English translation: Nicod, Jean. 2000. "The Logical Problem of Induction." In Foundations of Geometry and Induction. Routledge.
Peters, D. (2014). What elements of successful scientific theories are the correct targets for 'Selective' scientific realism? *Philosophy of Science*, *81*(3), 377–397. https://doi.org/10.1086/676537.
Psillos, S. (1994). A philosophical study of the transition from the caloric theory of heat to thermodynamics: resisting the pessimistic Meta-induction. *Studies in the History and Philosophy of Science*, *25*(2), 159–190.
Psillos, S. (1999). Scientific Realism:How Science Tracks Truth. Routledge.
Psillos, S. (2022). "Realism and Theory Change in Science" in E. Zalta (ed.) Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/entries/realism-theory-change/.
Putnam, H. (1975). What is a Mathematical Truth? In H. Putnam (Ed.), *Mathematics, Matter and Method, Collected Papers* (2 vol.). Cambridge University Press.
Stanford, K. (2006). *Exceeding our grasp: Science, History, and the Problem of Unconceived Alternatives*. Oxford University Press. https://doi.org/10.1093/0195174089.001.0001.
Tulodziecki, D. (2021). Theoretical continuity, approximate truth, and the pessimistic Meta-induction: revisiting the Miasma Theory. In T. D. Lyons, & P. Vickers (Eds.), *Contemporary scientific realism: the challenge from the history of Science* (pp. 11–32). Oxford University Press.
van Fraassen, B. (1980). *The scientific image*. Oxford University Press.
van Fraassen, B. (1989). *Laws and symmetry*. Clarendon Press.
Vickers, P. (2013). A confrontation of Convergent Realism. *Philosophy of Science*, *80*(2), 189–211.
Vickers, P. (2017). Understanding the selective Realist Defence against the PMI. *Synthese*, *194*(9), 3221–3232. https://doi.org/10.1007/s11229-016-1082-4.
Worrall, J. (1989). Structural realism: the best of both worlds? *Dialectica*, *43*(1–2), 99–124.
Wray, A. (2008). *Formulaic Language: pushing the boundaries*. Oxford University Press.