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Faculty of Arts and Humanities, Institute of Philosophy and Semiotics

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“...and if you go on, Lisa, you will discover beautiful things!”

CONTENTS

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LIST OF ORIGINAL PUBLICATIONS

1) Lisa Zorzato (forthcoming). The Puzzle of Fictional Models. *Journal for General Philosophy of Science.*

2) Lisa Zorzato (forthcoming). Fiction and Reality: an Uncanny Relationship. *Argumenta*.

3) Lisa Zorzato (2022). The Tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism. *Problemos*, *102*, 50–58. https://doi.org/10.15388/Problemos.2022.102.4

4) Alessandra Morrone & Lisa Zorzato (2021). The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox. *Acta Baltica Historiae Et Philosophiae Scientiarum*, 9:1, 27–50. https://doi.org/10.11590/ABHPS.2021.1.03

5) Stathis Psillos & Lisa Zorzato (2020). Against Cognitive Instrumentalism. *International Studies in the Philosophy of Science*, 33:4, 247–257. https://doi.org/10.1080/02698595.2021.1961420

INTRODUCTION

1. Overview of the thesis

To be a realist about something means to believe in the existence of this "something". In particular, to be a scientific realist is to argue that what scientific theories talk about exists. While with observable objects no problem arises with this claim, with unobservable entities the question about their existence becomes problematic. Realists support their claims based on the belief that empirical success of scientific theories is best explained by their "approximate truth". Therefore, the entities referred to by the theoretical terms appearing in the formulation of a theory populate the world. For example, when a scientific theory, which has been shown to be successful, to make novel predictions etc., talks of electrons, the realist believes that electrons exist in the world. The instrumentalist, who identifies himself/herself as an anti-realist, does not agree and considers scientific theories to be tools for organising, representing, or describing the phenomena. My motivation in engaging in the realism *vs* antirealism debate has been a challenge to realism that seemed particularly strong. It was the crucial role played in science by so-called 'fictional models'. These were indispensable in offering explanations of phenomena while not fitting the traditional framework of realism. I set out to investigate the possibility of reconciling fictional model explanations with scientific realism. In doing so, I found it necessary to differentiate my views from modern philosophical challenges to realism, represented by the works of Kyle Stanford and Darrel Rowbottom. I based my study of fictional models on the work of Alisa Bokulich, who has extensively studied them. My views developed in a direction different from that of Bokulich. I came to the conclusion that the reconciliation I was seeking could be achieved if I introduced a generalised notion of representation. This would make possible a realist interpretation of fictional model explanations, but would strain the connection between success and truth which is central to scientific realism. To overcome this problem, I introduce the notion of *Augmented Determination*: roughly, the idea is that the connection between success of a theory and its truth is not straightforward; rather, it is established in an historically evolving process characterised by a continuous expansion and restriction of possibilities. I shall present cases of fictional model explanations, to show that theoretical claims can be successful although truth cannot be assigned to them[1]. Their success is instead explained by their association with theories that can themselves be considered to be true. In other words, the connection between success and truth is *mediated*. I propose that realism should take into account the historical dimension of truth as revealed to be the best explanation of success.

[1] This situation is typical in high energy physics, where fundamental theories are considered to be only "effective", therefore by definition false. The connection of their success with truth is subject to debate (see, e.g., Ruetsche 2020).

This introduction starts off with the description of the debate between scientific realism and instrumentalism aiming at defining and supporting a realist position. It contains the results of five papers, two of them co-authored. The first step (Section 1) is to circumscribe the debate in its historical framework to identify what the current meaning of realism and instrumentalism is. In this framework, on the one hand I have identified scientific realism as that philosophical position that considers scientific theories as representative and descriptive of the world. It is divided into three main aspects: ontological, epistemic, semantic. In the debate under consideration, the epistemic aspect is what is being discussed: what can be known about the entities that are described by scientific theories? On the other hand, instrumentalism denies knowledge beyond the phenomena dealt with by scientific theories, and claims that the role of scientific theories is merely instrumental.

The second step is to focus on the contemporary version of instrumentalism (Section 2). The first author who gave new life to instrumentalism was Kyle Stanford. Under the label of *epistemic instrumentalism*, Stanford questions the claim that the success of a theory can be a sufficient justification for believing in the existence of the entities that are present in the theory itself. However, it should be stressed that this philosophical position is not general, since Stanford makes a clear distinction between what he calls 'common sense' and science viewed in an instrumentalist spirit. His argument starts with an attempt to answer why scientific theories are empirically successful. The realist would reply "because they are true", but Stanford shows that past theories were able to make predictions similar to those obtainable with alternative theories which subsequently replaced the theories once considered to be true. In this way, he highlights a purported instability of science, and questions the relationship between scientific success and truth.

There have been many criticisms by realists of Stanford's argument. I have articulated an argument of my own to demonstrate the weakness of Stanford's position. To start with, Stanford's argument is threatened by epistemic regress, causing epistemic instrumentalism to fall into scepticism. To avoid the threat, Stanford anchors it to a purported epistemic stability of common sense, as distinct from science, which is destined to always be unstable. In my paper *The tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism,* I reflected on this distinction between common sense and science, and I claimed that there is an osmosis between the two, rather than a distinction like the one advocated by Stanford. The historical example of the Copernican System and its historical and cultural evolution shows that common sense is influenced by, and influences science itself. Consequently, epistemic instrumentalism is anchored to something far from stable and, therefore, risks falling into scepticism.

The second author who rekindled the instrumentalist position is Darrel Rowbottom. He recently presented a position called 'cognitive instrumentalism'. Generally speaking, Rowbottom considers science not merely as a tool, but a tool for understanding phenomena. Science therefore has a relation to the world, since there is an understanding of it, but without claims about objective truth such as the realist makes. The critique of this version of instrumentalism has been developed in collaboration with my co-supervisor, Professor Stathis Psillos. The result of our joint effort has been the paper *Against Cognitive Instrumentalism*. This paper was written in cooperation, there was no division of labour, therefore no credit can be assigned to each one of us individually. Rowbottom suggests that theories are tools for understanding. Our criticism targets his notion of 'empirical understanding', which is the core of his argument. Empirical understanding is a goal, that instrumentalists accept alongside the goal that theories save the phenomena. It is "neither factive nor quasi-factive". According to Rowbottom, this means that empirical understanding goes beyond a theory's saving a set of phenomena but stops short of achieving objective understanding, i.e, grasping an explanation of those phenomena. The reason for this is that a full understanding is too hard, even impossible to achieve. In our criticism we point out that a partial understanding of a phenomenon is still understanding even if a full understanding might require all possible relevant truth.

So far, the discussion was about criticising the work of other authors. In Section 3, I put forward my own views. In the two papers, *Fiction and Reality: an Uncanny Relationship* and *The Puzzle of Fictional Models,* I focus on so-called *fictional models*. In the literature, fictional models usually are not taken literally: they are fictional. I explain the meaning of the term as I use it and draw extensively from the relevant work of Alisa Bokulich: a fictional model in my sense is a model whose target is not in fact instantiated. In certain cases, such models are particularly helpful in explaining and predicting phenomena (for example, Bohr's atom). How is it possible for a fictional model to be explanatory? In the above two papers, I claim that fictional models can be compatible with a realist framework. I draw upon Bokulich's position to explain that fictional models can have a relation with reality. To do so, I introduce the notion of a *ladder of abstractions* to argue that the more abstract the model is, the better it connects at a deeper level with phenomena, and partially grasps some aspect of them. *Fiction and Reality: an Uncanny Relationship* corroborates the argumentation with the example of Bohr's model of the atom. The Rydberg atom is the case studied in the *Puzzle of Fictional Models.* The main conclusion I reach is that fictional models can be both fictional and representational in a certain sense, illustrating the failure of instrumentalism concerning the nature of fictional models.

The third step in my dissertation has been to propose a positive argument for realism (Section 4). There, I develop the original argument, which I call 'Augmented Determination'. As a case study, I invoke the paper *The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox*; co-authored with Alessandra Morrone. This is an interdisciplinary work that considers the concerns of scientists (in this case bioarchaeologists) from a philosophical point of view. Written as a dialogue, the paper focuses on the so-called Osteological Paradox: this is the subject of an eponymous, well known archaeology paper (Wood et al., 1992, The osteological paradox: problems of inferring prehistoric health from skeletal samples. *Current anthropology 33*:4, pp. 343–370) that points out what in philosophy of science is called the problem of underdetermination of theory by data. The conclusion is far from resolving the difficulties of a realist-minded scientist; however, it amplifies the trust that scientists have in science. In particular, the conclusion supports Augmented Determination since it highlights that science is dynamic and that realism can account for its dynamism.

2. The scientific realism debate

As Hacking (1983, p. 26) puts it:

> *Definitions of 'scientific realism' merely point the way. It is more an attitude than a clearly stated doctrine ... Scientific realism and anti-realism are ... movements. We can enter their discussions armed with a pair of one-paragraph definitions, but once inside we shall encounter any number of competing and divergent positions.*

Philosophy of science analyses the nature of scientific knowledge, its purpose, and its characteristics. What is science? Is it made by scientists to merely catalogue facts? Or is it providing some true knowledge about the world? Is it possible to take a scientific theory at face value and accept that there is a kind of unobservable reality, consisting in entities and phenomena, as posited by that theory? Furthermore, is it reasonable to believe that the properties associated with unobservable entities such as spin are real even if not observable?

Questions such as the above are central to the debate between scientific realism and anti-realism[2], stemming from an essential contrast: one side claims that our factual knowledge is restricted to what is given in human senses; the opposite side considers non-observable entities and phenomena (atoms, electrons, quarks and their properties for example, or also, events back in the history like the Big Bang), which can explain observable phenomena.

In general, ontological, epistemic, and semantic issues about entities, phenomena, and facts are the three stances discussed in the debate. Indeed, the most common form of scientific realism is articulated in three basic principles (Psillos 1999; see also Chakravartty 2007). The first is the metaphysical (or ontological) principle: the world is mind-independent. The second is semantic: scientific theories are truth-apt; taking them at face value means that they are truth-conditioned descriptions of the world. Theoretical terms featuring in theories considered to be true refer to entities populating the world. The third is epistemic: scientific theories are offering knowledge about mind-independent reality. As Niiniluoto (2002) puts it:

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[2] In the following, the terms 'realism' and 'anti-realism' will indicate 'scientific realism' and 'scientific anti-realism'.

The case of realism vs. antirealism is alive and philosophically fascinating since it is unsettled. Its vitality and continuing relevance can be seen in the fact that all major philosophical trends of our time can be located, in some way or another, in coordinate positions defined by the axes of reality, truth, and knowledge.

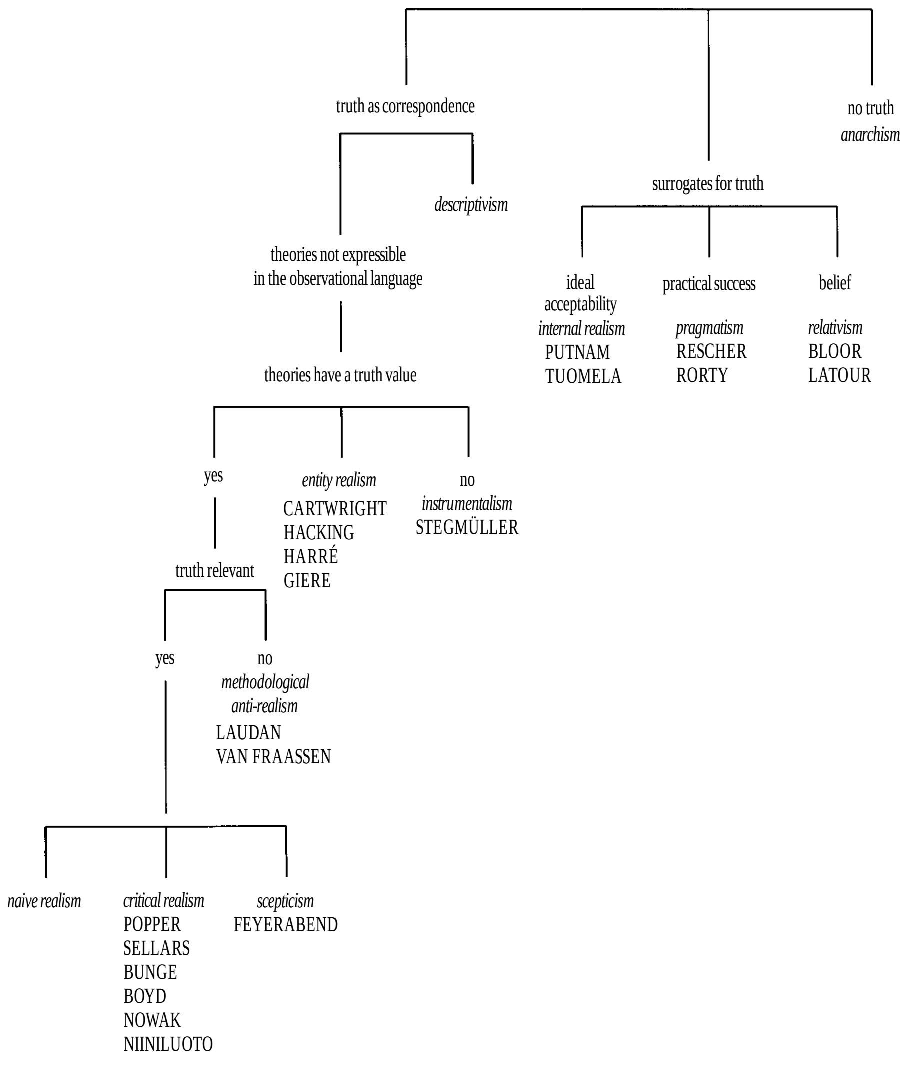
Metaphysical realism, as I said above, states that reality is independent of the presence of minds. Its antithesis is metaphysical idealism, according to which reality exists only as an expression of mind. In the present discussion, metaphysical realism, hence the existence of reality, how it is perceived, and how it 'manifests' itself, is not under question. Semantic realism is, roughly speaking, what underlines the truth-conditions of theories about both observable and unobservable entities. In more detail, the semantic thesis of scientific realism is defined as follows:

Scientific theories should be taken at face value. They are truth-conditioned descriptions of their intended domain, both observable and unobservable. Hence, they are capable of being true or false. The theoretical terms featuring in theories have putative factual reference. So, if scientific theories are true, the unobservable entities they posit populate the world (Psillos 2009, p. 4).

On the opposite side, eliminative instrumentalist and reductive empiricist accounts claim (with a lot of different interpretations and distinctions) that this truth-aptness applies only to the observable world.

Epistemic realism, also called *epistemic optimism* (Psillos 2000, p. 707), is the claim according to which successful scientific theories are approximately true descriptions of the world. Agnostic or sceptical versions of empiricism are on the opposite side (Psillos 2000, p. 707).

To sum up, the definition of scientific realism amounts to the view according to which what is described by our scientific theories is truthfully (if approximately) known by us. It can only be either a fact, or entities, or structures, or states of affairs etc. This is considered the core of realism: it states that claims about unobservables too can be true or false when scientific theories are talking about them. A clarification is needed here: Even if reference to the notion of 'truth' is quite vague and has sparked much discussion, it is undeniable that the concept of truth is central to the debate. On this topic, the map drafted by Niiniluoto can be helpful:



(Niiniluoto 2002)

The view opposite to scientific realism is anti-realism. As for realism, various and different forms of anti-realism have been developed. As McMulling pointed out, *when I say antirealism, I make it sound like a single coherent position. But, of course, antirealism is at least as far from a single coherent position as realism itself is* (1984, p. 9).

The present discussion is focused on the anti-realist view called instrumentalism. Roughly, it is the idea that theories are not offering a true description of reality, but are only saving the phenomena, i.e. they classify phenomena and make empirical predictions. Specifically, theories about unobservables are supposed to be nothing more than useful instruments. Sankey (2008) writes:

One well-known anti-realist position is the position of instrumentalism, according to which talk of theoretical entities is no more than 'useful fiction' or a 'convenient shorthand' (Sankey 2008).

Instrumentalism has been articulated in different ways. Kyle Stanford tried to offer a classification of them:

- *Theoretical discourse is simply a device for organizing or systematizing beliefs about observational experience and its meaning is therefore exhausted by or reducible to any implications it has concerning observable states of affairs (reductive instrumentalism).*
- *Theoretical discourse has no meaning, semantic content, or assertoric force at all beyond the license it provides to infer some observable states from others (syntactic instrumentalism);*
- *Even if such discourse is both meaningful and irreducible, it can nonetheless be eliminated from science altogether (eliminative instrumentalism); and*
- *Even if the literal claims of theoretical science about the natural world are neither reducible, nor meaningless, nor even eliminable, such claims are nonetheless not to be believed (epistemic instrumentalism)*
  (Stanford 2006, p. 402).

Given this, what is realism and what is instrumentalism is still debated. The historical development of the debate will help to delineate its framework at the present.

2.1 The history of the debate

It is common to consider the debate starting from the claim of logical positivism that verification of entities and facts was considered the only and real aim of science. As Carnap wrote: *In the realism controversy, science can take neither an affirmative nor a negative position since the question has no meaning* (Carnap 1968, p. 333). This claim helped spread the idea that logical empiricists should be considered to be instrumentalists. Of course, this is a simplification (see Psillos 2017); however, the point is that in the 1950s, instrumentalism was in vogue, in particular in light of the quantum and relativistic new theories in physics. Craig's Theorem (1956) and Ramsey sentences (1958) were quoted as the main supporting arguments for instrumentalism. Roughly, both of those suggested that the problem of the realism-instrumentalism debate was a linguistic issue. Specifically, Carnap's aim was to demonstrate that the use of the Ramsey-sentence formulation of a theory would be helpful in avoiding questions about the ontology of theoretical entities. The Ramsey-sentence is the formulation of a theory expressed in terms of axioms in a single sentence[3].

---

[3] Following Psillos (2006) "*Ramsey's starting point is that theories are meant to explain facts, those that can be captured within a "primary system" (1931, p. 212). As an approximation, we can think of it as the set of all singular observational facts and laws. The "secondary system" is the theoretical construction; that part of the theory which is meant to explain*

This would cut off all the content that was not ‘observational’. The attempt was reconsidered by Lewis (1970) who offered a new defence of it. According to Psillos (1999, p. 69), this is the point in history in which the metaphysical claim has become a crucial part of scientific realism.

In the 1960s there was the first turn for realism: Wilfrid Sellars (1960) and Grover Maxwell (1962) put the emphasis on truth as the explanation of the success of science. Among others, Karl Popper, Grover Maxwell and J.J.C. Smart advocated scientific realism. The works of Hilary Putnam (1963; 1965; 1973; 1974; 1975b) were demonstrating the possibility of theoretical terms referring to the same entities even across theory change (the topic will be discussed later). Putnam also developed the most famous defence for realism, the so-called No Miracles Argument. The 1980s was a decade of anti-realist backlash: van Fraassen presented his ‘constructive empiricism’, and Larry Laudan (1981) developed the so-called *pessimistic (meta) induction* i.e. that, since successful past theories are currently rejected, there are no reasons to believe that current theories will not meet with the same fate.[4]

Trying to answer *pessimistic induction*, various and different modifications of realism appeared in the panorama. Notably, in 1999 Psillos published “Scientific Realism: How Science Tracks Truth”. It is not an exaggeration to say that this year was the start of the history of realism as it is discussed in the current debate.

The 2000s have been marked by a new turn of instrumentalism, with the view of *epistemic instrumentalism* (Stanford 2006a) based on the argument of *unconceived alternatives.* In the next few years, the focus of realism has been the attempt to block this argument. Recently, instrumentalism has been revitalised by Brad Wray (2018) and Darrell Rowbottom (2019). Even with distinctions, the position of instrumentalism is a real challenge for scientific realism. Currently, it is the relevant and the topical part of the debate.

The motivation of this small and sketchy introduction is to lead to the discussion of the main arguments that are still vital topics in the debate: the No Miracles Argument, the Pessimistic Induction and the Underdetermination of Theory by Data. In the following, I discuss them one by one.

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the primary system. It is a set of axioms and a “dictionary”, that is “a series of definitions of the functions of the primary system (...) in terms of those of the secondary system” (1931, p. 215). So conceived, theories entail general propositions of the primary system (“laws”), as well as singular statements, (“consequences”), given suitable initial conditions. The “totality” of these laws and consequences is what “our theory asserts to be true” (ibid.)”.

[4] Of course, the realist camp was amply represented. See for example Niiniluoto (1984) Is Science Progressive?, and (1988) Truthlikeness; J. Leplin’s collection (1984), especially McMullin in the collection; Harré (1986) Varieties of Realism.

2.2 NMA: The No Miracles Argument

The No Miracles Argument is also called "The Ultimate Argument for Scientific Realism" (Musgrave 1988, p. 229). The definition in Putnam's words is as follows:

> *The positive argument for realism is that it is the only philosophy that does not make the success of science a miracle. That terms in mature scientific theories typically refer ..., that the theories accepted in a mature science are typically approximately true, that the same term can refer to the same thing even when it occurs in different theories—these statements are viewed ... as part of the only scientific explanation of the success of science.* (Putnam 1975, p. 73)[5].

In other words, denying the ability of science to track truth makes the success of the scientific enterprise miraculous. The element of novel predictions was stressed only subsequently (Worrall 1985; Leplin 1997) and it became part of the defence of realism. Suppose that a theory predicts a phenomenon that was hitherto unknown, or even a phenomenon information about which was not employed for the formulation of the theory (use-novelty, Psillos 2007, p. 167): how is it possible for that theory not to be true? Van Frassen (1980) replied to this question: two or even more equivalent and alternative theories can be successful. Thus, scepticism, or at least agnosticism, about truth is suggested (more about this argument, in the following).

In the debate about NMA, R. Boyd (1971) played a prominent role. According to Psillos (2017),

> *Boyd's argument emphasises the importance of an historical context to the no-miracle argument, i.e. if the (approximate) truth of science is taken as the best explanation for its success, there must be some historical understanding of success, and some joining of referential continuity and convergence to truth.*

Boyd indeed underlined the importance of the scientific method: this is evident from the fact that background theories used by scientists are approximately true. In other words, the notion of truth is not *a priori*, but only *a posteriori*, based on the ground for the success of theories and the methods used to develop them.

Psillos (1999 ch. 4; 2017) elaborated his version of NMA on the basis of Boyd. The argument makes a double claim: firstly, scientific realism is the best explanation for theories' success; and, second, there are good reasons to believe in the reliability of the methods that scientists used to achieve a true theory. In other words, NMA shows that scientific methodology is reliable, since scientists are offering true predictions: it would be a miracle (a second one) if the scientific method led to successful theories and those very theories were not true.

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[5] Putnam claims that this argument was already offered by Boyd (1971), and Psillos (1999, 2014, 2017) stresses the importance of Boyd's role. Also, Musgrave (1988, p. 229) highlights names such as Clavius, Kepler and Whewell as predecessors of both Boyd and Putnam.

The idea behind this version is that NMA is an instance of *inference to the best explanation* (IBE)[6]. So branded by G. Harman (1965), IBE says that if theory T is explaining a phenomenon better than other competitors, it is reasonable to choose T. The NMA is then a kind of IBE: the truth of science is inferred from the claim that success of science cannot be accounted for by miracles. Moreover, Psillos's version amounts to claiming that success of scientific methods is explained by realism.

A. Fine (in the same vein, Laudan 1984) noted that this argument is guilty of *vicious circularity* (Fine 1986a; 1986b, p. 161) for two reasons: firstly, the assumption of truth is characteristic of scientific realism so it is already presupposed in the argument's premises of NMA; and, secondly, the explanation of the success of the method of science is inferred *via* the validity of IBE, and this success of method is also the validity of IBE itself. This challenge has been the focal point of the debate, and it is still open.

Psillos, quoting R. B. Braithwaite (1953), distinguishes between premises-circularity and rule-circularity (such an argument has a conclusion that is not one of the premises). The latter is not *viciously* circular. According to some authors (e.g. Worral 2011), Psillos has modified his view, claiming that NMA is not an argument defending realism, but is an argument valid from within the realist perspective (Psillos 2011a, p. 26): "It's not as if NMA should persuade a committed opponent of realism to change sides. But it can explain to all those who employ IBE, in virtue of what it is reliable". Thus, NMA is a reliable argument for inferring IBE (Psillos 2011b, p. 34) without the danger of the circularity fallacy. However, this position concerns only those who are already realists. Recently Park (2016, 2021) supports NMA in a different way: he draws a distinction between the "distinctive view" (such as Psillos' one) and the "reductive view" (his own view). The former sees the NMA as a supportive argument in addition to arguments of scientists in support of their theories. The latter makes no distinction between NMA and scientists' arguments. This defence of realism is stronger than the former, since, according to Park, both realism and the arguments advanced by scientists offer a justification for the truth of scientific theories, implying they are at the same level.

Three points must be noted for the argument of NMA that will be recalled in my argument in support of realism in the second part of this thesis.

1) IBE is the argument that leads to the truth of scientific theories. It is an ampliative reasoning method that crucially contributes to the amplification of knowledge. The amplification of knowledge is directly connected to the progress of science as cumulative steps to the truth. The link between the best explanation and truth is implicit in the IBE reasoning: the best explanation is,

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[6] Some authors consider IBE an ampliative inference, i.e. an abduction (Psillos 2007, p. 441; Barnes 1995). But for some others, IBE and abduction are distinct (Hintikka 1998; McKauhan 2008). According to Mackonis (2011) "the most accurate description of the relation between IBE and abduction is to state they operlap to some degree".

according to the realist, certainly also the true one. Laudan (1981, p. 20) listed what according to him are the crucial claims of realism, and he labels the view that knowledge is cumulative and science is a progress to the truth as "epistemological realism".

2) The objectivity of truth is crucial for a realist position. It means accepting that what theories claim has a correspondence to things that exist in the world. This point is much discussed as far as the distinction between observables and unobservables is concerned. The anti-realist position labelled "instrumentalism" does not accept the realist claim concerning unobservables. Thus, the problem of instrumentalism is how to explain the success of theories that include unobservables, because according to an instrumentalist, those theories are only able to save the phenomena.
3) NMA is often misunderstood by antirealists. It is claimed that when a theory is recognised as true, no other theory should appear in the course of history, otherwise the former theory could not possibly be true. The realist answer to that is that what was responsible for the success of a previously accepted theory is preserved in the successor theory. For now, the emphasis is on the fact that science is a process and the NMA is explaining the success of theories at a moment of history. But there is always a process (and a progress) that realists accept.

2.3 PI: Pessimistic Induction

In the early 1980s, Laudan (1981) elaborated to the highest degree the argument of Pessimistic Induction. The argument itself has different variants. In the definition of H. Putnam:

> *Just as no term used in science of more than fifty (or whatever) years ago referred, so it will turn out that no term used now (except maybe observational terms, if there are such) refers"* (Putnam 1978, p. 25).

There is some confusion in the literature on this topic, because many authors continue to refer to Laudan as the one who ran the PI even if he did not (for more about this topic, Park 2011, p. 22; 2022, p. 24). Independently of whether PI states that most of the current theories are false, Laudan developed a list of twelve past scientific cases that should demonstrate that the success of theories is not a reliable indicator of the truth of a theory as NMA is claiming. He wrote:

> *Most of the past theories of science are already suspected of being false. There is presumably every reason to anticipate that the current theories of science will suffer a similar fate* (Laudan 1977, p. 126).

It is important to stress that in arguing for scientific realism, the target is not confined to refuting Laudan's list, but PI in general.

Another interesting distinction about this argument is the one made by Park (2019b, 2022) between PI and the Humean argument:

> *We should separate the classic PI not only from Laudan's objection but also from the Humean argument. The Humean argument holds that since outdated theories were false, current theories are unwarranted. This argument is similar to the argument that since stones have fallen down, we should be skeptical about whether they will fall down in the future. By contrast, the classic PI is similar to the inductive argument that since stones have fallen down, they will fall down in the future.* (Park 2002, p. 25).

The sceptical conclusion differs from the view called instrumentalism. On the one hand, the instrumentalists claim that scientific theories are useful instruments for predictions and saving phenomena. According to them, a "false" theory of the past may still be a useful instrument in the present (e.g., Newtonian gravity). On the other hand, according to the Humean argument, the falsity of past theories is the reason for being sceptical about the truth of present's theories. Since the instrumentalist does not want to fall into scepticism, the Humean argument cannot be adopted by instrumentalists (this discussion will be relevant in particular for the argument that Stanford (2006) will offer about *unconceived alternatives*). In any case, Laudan's list implicitly contains the inference that, given the historical evidence, the present and the future theories cannot be considered in optimistic terms as the realist wishes.

This argument obviously generated a heated discussion. Devitt (1984) just dismissed the argument claiming that it is overestimated. Some realists recall the theory of reference of Putnam: scientific terms are connected with the object or a property of that object by causal connections. For instance, the ether postulated by Fresnel and Maxwell in conceiving the theory of light was found to be non-referential. On the other hand, Psillos claims (Psillos 1999, p. 282) echoing Hardin and Rosenberg (1982, p. 613–614), ether was referring to the electromagnetic field. A number of realists[7] adopted the so-called 'selective realism' (alternatively called 'deployment realism' or 'preservative realism'). It is based on the *divide et impera* strategy (Psillos 1996), viz. the claim that there is a distinction between core elements of a theory, responsible for its success and retained across theory changes, and auxiliary hypotheses, not contributing to success and liable to be rejected. There are different variations of selective realism. One is 'structural realism': this position claims either that only structures are captured by science, or than only structures exist in the world. Then, even if theories change, the structure persists (among others, Worrall 1989a, 1994). According to this view, Maxwell and Fresnel were right about the structure of optical phenomena, not about the nature of light (for a critique, Psillos 1999). Another version of 'selective realism' is 'entity

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7 Following Park (2017): John Worrall (1989), Philip Kitcher (1993: ch.4, 5), Stathis Psillos (1999: ch.6, 2009), Anjan Chakravartty (2008), Patrick Enfield (2008), Peter Godfrey-Smith (2008), David Harker (2008), Juha Saatsi (2009), and Samuel Ruhmkorff (2011: 882).

realism'. With the slogan "if you can spray them, then they are real" (Hacking 1983, p. 23), it is claimed that if an entity can be manipulated in a laboratory, it is real. The way to overcome PI is that the entity is real, but not the theory about it. In other words, the electron is real, but not the electron theory. Consequently, even if in the history of science some theories were rejected, entity realists would not run into problems (for a critique, Psillos 1999, p. 225–228; Musgrave 2017, p. 88; Park 2022, p. 91).

2.4 UE: Underdetermination of Theory by Evidence

The second prominent argument for anti-realism is the so-called underdetermination of theories by data (Duhem 1914). It stems from Hume's problem of induction, and can be expressed as follows: for any phenomenon, there are more than one theories that can explain it, and the evidence cannot decide in favour of one of them. In turn, Duhem (1914) argued that a hypothesis cannot in principle be chosen from among others without the support of extra assumptions. Thus, when a theory is rejected, it is not clear which hypothesis was responsible for its failure. W.V. Quine (1951) expanded this argument even more, so that it has become different from the classic underdetermination and has been labelled "the Duhem-Quine thesis". Therefore, when a claim about the observable world is confirmed or rejected, it is not clear what network of hypotheses concerning the world beyond the observable may have this claim as a consequence. There can be many networks of hypotheses leading to that particular claim, and empirical data cannot discriminate in favour of one of them. Empirical data underdetermine theoretical constructions. This is how Quine (1975 p. 313) explains the situation:

> *Scientists invent hypotheses that talk of things beyond the reach of observation. The hypotheses are related to observation only by a kind of one-way implication; namely, the events we observe are what a belief in the hypotheses would have let us to expect. These observable consequences of the hypotheses do not, conversely imply the hypotheses. Surely there are alternative hypothetical substructures that would surface in the same observable ways. Such is the doctrine that natural science is empirically underdetermined.*

In the current debate, the underdetermination is not holistic, but "contrastive": it is so called because the issue is to confirm one hypothesis against other possible alternatives (Stanford 2006). The roots of it can be found in the work of Bas van Fraassen, who points out that there are empirically equivalent explanations available for the same phenomenon, so the epistemic belief that a scientific theory is true is not justified (van Fraassen 1980, p. 67).

Bas van Fraassen's position is called 'constructive empiricism' (1980): a constructive empiricist believes science is not appealing to truth, but to empirical adequacy. Specifically, the constructive empiricist claims that truth concerning unobservables cannot be inferred from scientific theories. It is considered one of the most *formidable objections to scientific realism* (Park 2022; also Psillos 2000, defines it as “the only articulated philosophical position” alternative to realism). Its slogan can be reported as follows: “it is not an epistemic principle that one might as well hang for a sheep as a lamb” (van Fraassen 1980, p. 72). In other words, a constructive empiricist is an instrumentalist about unobservables, who requires only empirical adequacy, not truth. Thus, theories about unobservables, if they are empirically successful, should not be believed as true but as empirically adequate (for a critique, see Forrest 1994).

Different replies have been advanced against UT. Laudan and Leplin (1991) made one of the most remarkable replies to UT: even if at present two theories are really equivalent (that is already a quite rare situation), there is no guarantee that this state of affairs will persist and none will be confirmed or discarded. Underdetermination of theories by data may happen, but it not in principle, i.e. there is the possibility of overcoming it. How? Through extra-empirical evidence, such as economy, simplicity, unity, explanatory worth etc.

2.5 Brief parenthesis about truth

Truth has a regulative role (Psillos, 2000) in the context of the realist position, and specifying it means clarifying the position of realism itself. As stated above, variations and interpretations of realism are abundant. However, it is possible to underline two main points on which realism focuses:

1) From empirical success, to the truth of theories.
2) From the truth of theories, to the existence of entities claimed by them (Ellis 2005, p. 372).

In both 1) and 2) the notion of truth is the crucial point: only truth is able to explain success, and there is a correspondence between theoretical terms and entities that is inferred from the truth of the theories. As Saatsi and Vickers (2011, p. 29) claim, “scientific realists seek to establish a link between theoretical truth and predictive success, suitably understood”. Musgrave too (1996, p. 23) states that “science aims for true theories”.
Psillos (2000, p. 713) notes:

> *Realists must grant that their ‘epistemic optimism’ that science has succeeded in tracking truth presupposes a certain epistemic luck: it’s not a priori true that science has been or has to be successful in truth-tracking. If science does succeed in truth-tracking, then this is a radically contingent fact about the way the world is and the way scientific methods and theories have managed to ‘latch onto’ it (see Boyd [1981]).*

Looking at the history of the debate concerning realism and anti-realism, the term ‘true’ has been modified to ‘truthlikeness’ by Popper (1963), (cf. Votsis, 2002). Since the 1990s, the term ‘approximately true’ is the accepted one. Putnam (1990) talks about “sufficiently good situations” to not fall into the trap of the ideal and totally abstract definition of 'truth'. The turn about "truth" has been done by Psillos (1999, ch. 11) who claims that the notion of approximate truth is intuitive, and it can be explained in the following way: P is approximately true, iff approximately P. Park (2022, p. 3) wrote something similar about it: if a man's height is 190,3 cm and the sentence says that he is 190 cm, this sentence is approximately true. Park (*ibidem*) claims that this definition is more suitable for the scientific debate since it makes clear that science deals with approximations and idealisations[8].

Maybe this is not enough for an anti-realist, but "there is no reason to think that a domain-specific understanding of approximation is not robust enough to warrant ascription of approximate truth in statements about each domain" (Psillos 2000, p. 772).

I will argue in the following that, although truth is the best explanation for the success of theoretical claims, the connection between success and truth is much more complex than it may seem. I will present cases where this connection is not straightforward, but mediated in a sense to be explained. This will be the subject of Section 3.

3. What is instrumentalism?

In the above section I have presented the debate between realism and antirealism in general terms. In this section, I want to focus particularly on instrumentalism, and discuss in more detail the issues distinguishing it from realism. Concerning the question what instrumentalism is, Duhem is considered the philosopher who attempted a definition, although without using the term 'instrumentalism'. In 1906, he wrote that "the physical theory never gives us the explanation of experimental laws; it never reveals to us the realities that hide behind sensible appearances" (Duhem 1906, p.38).

According to Stanford (2005), John Dewey referred directly to the term 'instrumentalism', but it is generally assumed that it was Karl Popper (1963, Ch. 3, pp. 101, 111) who gave the precise definition of instrumentalism as "the interpretation of scientific theories as practical instruments or tools for such purposes as the prediction of impending events" (Popper 1963, Ch. 1, pp. 62–63).

> *By instrumentalism I mean the doctrine that a scientific theory such as Newton's, or Schrödinger's, should be interpreted as an instrument, and nothing but an instrument, for the deduction of predictions of future events (especially measurements) and for other practical applications; and more especially, that a scientific theory should not be interpreted as a genuine conjecture about the structure of the world, or as a genuine attempt to describe certain aspects of our world. The instrumentalist doctrine implies that scientific theories can be more or less useful, and more or less efficient; but it denies that they can, like descriptive statements, be true or false.* (Popper 1983, p. 111–112).

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8 See also Niiniluoto 'Truthlikeness' (1987) and 'Critical Scientific Realism' (1999).

Since 1970 more or less, instrumentalism has not played a significant role (Wray, 2019). In the 21st century, the interpretations of what instrumentalism is are more articulated, and there is no standard definition thereof. In 1999, Psillos defined syntactic instrumentalism and semantic instrumentalism as two different positions (Psillos 1999, XX). The latter claims that theoretical assertions cannot be reduced to the observational claims, so it has no meaning (Psillos 1999, p. 301).

Syntactic instrumentalism is diversified in two other positions: the eliminative on the one hand, the non-eliminative on the other. The former is the one that "takes the scientific theories to be merely syntactic/mathematical constructs for the organisation of experimental and empirical facts, and for grouping together empirical laws and observations which would otherwise be taken to be irrelevant to one another. On this view, theoretical claims are not even truth-conditioned, i.e. capable of being true or false; nor do theories imply existential commitments to unobservables." (Psillos 1999, p. 72). Non-eliminative instrumentalism, attributed by Psillos to Duhem, is the position according to which the existence of unobservable reality is not even deemed to be assumed by science.

In more general terms, Psillos states:

> *The nothing but is usually qualified by expressions such as 'in the final analysis' or 'the cash value is nothing but…'. But the key point should be that the credo of the instrumentalist movement is that any kinds of aspirations we might have that science goes beyond the phenomena is unwarranted and/or superfluous.* (Psillos 2022, p. 2).

On the other hand, Rowbottom asserts:

> *Instrumentalism is a philosophical movement (…) it has two key components. First, as one might expect, it involves a cluster of views – both normative and descriptive – on which science, or a significant part thereof, is constructed as an instrument. Second, it involves characterizing the positive role of said instrument solely, or centrally, in terms of observable things (or phenomena).* (Rowbottom 2019).

Stanford wrote that

> *Even our best scientific theories are tools or instruments for guiding our practical engagement with the world rather than literal and/or accurate descriptions of otherwise inaccessible parts of that world.* (Stanford 2006, p. 193).

What can be deduced from the above statements is that instrumentalism is a movement asserting that science is merely an instrument to account for the observable world. Moreover, it is not proposing a justification for the empirical success of scientific theories. I would take this as the point which instrumentalists and realists disagree about. While the realist appeals for support to the no miracles argument (NMA), the instrumentalist is denying any explanation for the success of science. This is the target of the re-enchanted instrumentalism (to quote

Psillos' terminology in Psillos 2022), such as the epistemic instrumentalism of Stanford and the cognitive instrumentalism of Rowbottom.

What type of instrumentalism is the focus of this thesis? This question requires a further explanation of the current variations of instrumentalism.

Recently, Psillos (2022) classified instrumentalism in an accurate way, distinguishing different versions of it. His paper is a guide for whoever wants to tidy up the position of instrumentalism. Currently, the main competitor of scientific realism is so-called "fictionalism".

Fictionalism is "the view that some entities whose existence is implied by the truth of a theory are not real, but useful fictions" (Psillos 2022, p. 9). It has two main cornerstones: denialism and non-eliminativism. The former means that there are some entities whose existence is accepted, and others whose existence is not (their role is to be useful for practical purposes). Usually, epistemic accessibility is clear-cut on the basis of sense perceptions, but it can also be something more sophisticated. The latter claims that scientific discourse has a different approach to the entities whose existence is accepted as opposed to all other entities: these entities, even if they cannot be eliminated from the language, lack an assertoric content, so they are fictions.

To accept both the above cornerstones means to be a fictional instrumentalist. It is possible to be instrumentalist without being a fictionalist (for instance, following Psillos, such as Dewey and Philipp Frank). The fictionalist claims that scientific theories are false because they refer to entities that do not exist:

> *On this view, to say that one accepts the proposition that* p as if *it were true is to say that* p *is false but it is useful to accept whatever p assets as a fiction* (Psillos 2022, p. 9).

The main point of fictionalism is that the *as if* strategy allows the instrumentalist to read the theory as true, but (s)he considers it false since the entities posed by it do not exist. This leads to an internal disagreement between non-eliminativism and denialism: what is the point of denying the reality of some entities if we consider the theory that posits them true? It is a conundrum difficult to solve. Psillos lists the possible ways that authors adopted to deal with this issue: to claim that theoretical terms are eliminable from scientific discourse (Craig 1951), to argue that it is better to be agnostic about the existence of some entities rather than being denialists (van Frassen 1980), to hold that realism and anti-realism are merely different *modes of speech*, claiming that 'reality' is quite a vague concept (Nagel 1961 in Psillos 2022, p. 14). More recently, Stein supported a kind of 'compatibilism' between a 'sophisticated instrumentalism' and an 'enlightened realism' (Stein 1989, 61, in Psillos 2022, p. 18): the 'sophisticated instrumentalism' is, following Psillos, the one that rejects denialism and goes closer to realism because it considers theories as promoters of research; the 'enlightened realism' should be the one who does not invoke truth-referentiality between reality and theory. If so, 'what a realist can do, the instrumentalist can do also' (Stein 1989, 52, in Psillos 2022, p. 19).

What is important about this position is that it clearly opens the door to a new form of compatibilism: the so-called 'epistemic instrumentalism' held by Stanford (2006). I will focus on it in the next section (2.1). There is also another form of fictionalism currently in vogue that is on the rise in the current debate, which is, according to Psillos, purely a new-denialist instrumentalist position: the 'cognitive instrumentalism' as labelled by Rowbottom (2019). Section 2.2 is devoted to it.

3.1 Stanford on epistemic instrumentalism. Neo-instrumentalism

As many philosophers pointed out (Wray 2018; Rowbottom 2019), the contemporary realism/anti-realism debate has been reinvigorated by Stanford's "epistemic instrumentalism" (Stanford 2006, 2009a).

> *This approach might be called 'epistemic' by contrast with earlier 'semantic' or 'linguistic' approaches to instrumentalism because it restricts the set of beliefs to which we regard ourselves as entitled by the dramatic empirical success of our best scientific theories.* (Stanford, 2006a: 194).

This new position expresses the instrumentalist view according to which "we can make perfectly good practical use of the claims of such theories without believing what they say about the natural world" (Stanford 2006, p. 194). Its main argument is based on the mix of under-determination of theory by data and meta induction arguments, namely the "new induction over the history of science" (NI) (Stanford 2006, p. 19). Roughly, NI suggests that the historical record shows the recurrent failure of our scientists to conceive of possible alternatives to the current best scientific theory at time t. Those unconceived alternatives will be taken into account at a later time t_1, showing that the true theory is always among the hypotheses that scientists did not take notice of. In a nutshell, the problem is *how to decide whether or not there really are typically unconceived competitors to our best scientific theories that are well confirmed by the body of actual evidence we have in hand* (Stanford 2006, p. 18). The strategy of Stanford is focused on the problem of *unconceivable alternatives*, putting one of the main problems of science on the table: the method of eliminative inference. According to this method, the pool of possibilities for explaining a specific phenomenon becomes smaller and smaller, so that the best explanation can be isolated from false hypotheses. Stanford claims this is a fairy tale.

Different strategies have been offered against epistemic instrumentalism: some realists claimed that the new induction is not adding something more to the "old" pessimistic induction, so the argument can be blocked already in the beginning (Chakravartty 2008; Enfield 2008). Others insisted that scientific methodology's improvement is shown in very concrete and measurable ways, therefore the number of unconceived theories that are not available at present is certainly smaller than the respective number in the past, and will be even smaller in the future. Hence, the probability that current theories are certainly wrong is less than that for the past ones (Roush 2010; Devitt 2011). Some critics have also argued against the concept of "plausible alternative theories" suggesting that, in the history of science, there have been no well-confirmed alternatives that could compete with the accepted theories as the new pessimistic induction requires (Magnus 2006; 2010).

My critique of epistemic instrumentalism is different from all of these. In my paper "The Tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism" (Zorzato 2022), I isolated specifically the crucial element of 'common sense', fundamental for epistemic instrumentalism, and I explained why it is problematic: far from being stable as epistemic instrumentalism requires, it changes with science. Lacking such stability, the basis for epistemic instrumentalism collapses, letting it sink into scepticism.

I developed my argument in two main steps.

The first step was to isolate the new element that epistemic instrumentalism brought into the debate between scientific realism and instrumentalism: the notion of epistemic stability. This notion is attributed to whatever is not subjected to the problem of unconceived alternatives. In order to avoid falling into an infinite regress, and to stave off the impossible position that no theory can ever be considered true, Stanford (2006, p. 197) claims that there is a stable body of rigorous and literal beliefs in entities or phenomena that are independent of the theories towards which we are adopting an instrumentalist position.

> *I will point out to a specific history of our repeated failures to exhaust the space of serious scientific alternative possibilities, and there is simply no comparable history available of failures to conceive of and therefore consider presumptively plausible alternative explanations for the evidence supporting beliefs like that I am now wearing pants or that I had eggs for breakfast* (Stanford 2006, 36).

In other words, even if the distinction between common sense and science is not sharply drawn, it is intuitively understood. The clearest definition of the difference between common sense and all other theories is in the following words: "fundamental commitment to the reliability of a given theory […] commits us to the truth of whatever implications it may have for entities, events, and phenomena as they are conceived of outside of the theory itself (and indeed outside of all those theories toward which we are adopting an instrumentalist attitude)". Connecting this statement to 'bodies of common sense', Stanford claims: "[T]he instrumentalist will have to frame what she actually believes […] in terms of the entities, events, and phenomena familiar from our everyday experience of the middle-sized bodies of common sense" (Stanford 2006, p. 202).

The issue is brought out in the example about *Drosophila melanogaster* (Stanford 2006, p. 197–198). *Drosophila melanogaster* is a fruit fly used in molecular genetics as a model organism because it does exemplify general genetic features. Stanford mentions it (2006, pp. 197– 98, 200) in elaborating the following point:

instrumentalists can believe in claims of a theory if those can be isolated from the theory which they are connected with. In more detail, the claim that the "bithorax phenotype in *Drosophila melanogaster* is caused by a single mutation in the HOM complex of homeobox genes" is indeed linked to the contemporary genetic theory, but some of its content can be understood independently from the theory itself: for example, that a particular pattern will be shown on the autoradiography whenever a particular material of an organism is modified in the laboratory, or that this pattern will also be shown in the successive generations after the first modified organism. The point is that, even if contemporary genetic theory will turn out to be subjected to the UA challenge in the future, and consequently the claim about the mutation in the HOM complex of homeobox genes being the cause of the bithorax in *Drosophila melanogaster* will not be accepted as true, claims about the patterns appearing in the autoradiography or the re-emergence of the bithorax in offspring of the first organism will still be accepted since the UA challenge leaves them untouched. Hence, concerning the very same middle-sized material object, there are claims about which we are realists and claims about which we have an instrumentalist attitude. In the case of the *Drosophila*, whatever is in the foreground of the genetic theory (the observed patterns) is considered stable: i.e., the fact that there is an entity, that this entity can be manipulated in the laboratory and, also, the predictions about the heritability of some patterns.

This distinction between scientific theory and predictions derived from the body of common sense has been clearly pointed out by Sellars: "We might not have noticed that litmus paper turns red in acid, until this hypothesis had been suggested by a complex theory relating the absorption and emission of electromagnetic radiation by objects to their chemical composition; yet in principle this familiar correlation could have been, and, indeed was, discovered before any such theory was developed" (Sellars 1963, p. 19). Sellars's notion of correlation and its relation with postulation is particularly instructive in understanding properly the distinction between the hypothesis of common sense and science in Stanford, but it is important to stress that the two authors do not share their philosophical points of view. Sellars defined the scientific image as postulational, and the manifest image as correlational "[…] postulational hypotheses [presuppose] correlations to be explained and [suggest] possible correlations to be investigated. The notion of purely correlational scientific view of things is both an historical and methodological fiction. […] Yet it is a useful fiction for it will enable us to define a way of looking at the world which, though disciplined and, in a limited sense, scientific, contrasts sharply with an image of man-in-the world which is implicit in and can be constructed from the postulational aspects of contemporary scientific theory" (Sellars 1991, p. 7). On the one hand, the manifest image presents correlations in the sense that there is a correlation between the middle-sized object and the man-in-the-world's image. On the other hand, the scientific image is postulational, meaning that science is speculating about phenomena and entities behind the observable aspects of objects. Similarly, Stanford articulated his epistemic position as follows: a realist approach is allowed towards whatever is correlational, linked to the body of common sense; contrariwise, an instrumentalist approach is required for theories that are postulating and speculating about claims that are subjected to the problem of unconceived alternatives.

The second step of my argument has been to demonstrate that the epistemic stability of common sense is arguably highly insecure. Common sense and science are mutually influencing one another: there is *osmosis* between the two, not only concerning the content, but also in terms of their stability. Since the relation is mutual, common sense cannot be independent from science, thus it is affected by the problem of unconceived alternatives. The case study I employed to support my argument was the case of the Copernican Revolution. When it was commonsensical to think that the Earth was at the centre of the Universe, there was independence of common sense from science, exactly as Stanford is claiming. But when it was demonstrated that the heliocentric theory was correct, the hypothetical membrane circumscribing common sense was permeable to new and innovative concepts. Of course, the process of accepting the new theory was far from being easy and fast, but the main point is that finally common sense changed its aspect influenced by scientific discovery. The conclusion, therefore, is that the core of epistemic instrumentalism, epistemic stability, is problematic because it does not support such a version of instrumentalism, preventing it from falling into scepticism.

3.2 Rowbottom: cognitive instrumentalism. Neo-instrumentalism 2

As I noticed above, as far as the notion of progress is concerned, Stanford is still an advocate of traditional instrumentalism. Recently, a new approach to the notion of progress has been formulated by Darrell Rowbottom, one of the *few outspoken current instrumentalists* (Psillos 2022), who made the anti-realist position much livelier than ever before. In his book, *The instrument of science: scientific Anti-Realism Revitalized* (for a review, Psillos & Zorzato 2021), Rowbottom develops the position called "cognitive instrumentalism":

> *I call the instrumentalism I propose cognitive for two reasons. First, it involves the idea that science is a cognitive tool –a tool for understanding phenomena – rather than just a tool for 'saving' (or predicting) the phenomena. Second, it involves the idea that the talk of unobservable things within science is primarily a cognitive tool for comprehending how observable things behave* (Rowbottom 2019, Ch. 1).

To start with, why is cognitive instrumentalism still instrumentalism? Because it fits in the kind of movement that, as I noted before quoting Psillos (2022, p. 5), can be defined by the "nothing but" approach. Rowbottom starts from this *"nothing but",* but he adds a "+": the notion of "empirical understanding" (Rowbottom 2019, Ch. 5). Roughly, it is a type of understanding that lies midway between two opposites: subjective understanding (non-factive understanding in which the descriptions of reality are not taken literally), and objective understanding (implying latching onto reality) that allows us to *grasp* the *structure* of a model and to *spot connections* (Rowbottom 2019, p. 119)[9]. In this light, empirical understanding can be paraphrased in the following way: a level of knowledge about the world that concretely concerns the phenomena and their features. Or, in other words, *understanding is a state a subject S is in when the subject possesses mental satisfaction that she grasps why P and takes this "to be sufficient for a desirable end"* (Psillos and Zorzato 2021). The progress of science, the predictions, and the unobservable phenomena are derivative from this point: indeed, notions like memorability, comfort, user confidence, and mental satisfaction in the theoretical model are considered as far as the experience of that model is related to the end for which one intends to use the model. Often, what science needs is not verisimilitude, but know-how and prediction. The exemplary case study is the motion of the bob of a pendulum (Ch. 1). The standard equation,

$$F = -mg \sin \theta$$

is a mere idealisation, because it does not consider factors such as temperature, the material of the bob, the environment in which the pendulum is moving, and so on. So, the harmonic motion that the idealised model describes is not true, and not helpful for understanding and predicting how the phenomena behave. 'De-idealising' the model, by taking into account the multitude of factors involved in the motion of the bob, makes the model intractable, hence unusable. Seeking faithful representation battles against usability. The point, therefore, is to strike a balance between faithful representation and usefulness. Indeed, making models less truth-like, so more idealised, would increase the scope of the model, not in terms of reaching the truth but of predicting and understanding.

> *To distil: having true theories doesn't entail having the predictive ability, especially in so far as it doesn't entail having (cognitively and practically) useful models; having models that faithfully represent their target doesn't entail having useful models; and useful models typically don't faithfully represent their target* (Rowbottom 2019, Ch. 1.2).

The contrast between the real motion of the pendulum and the idealised one allows us, according to Rowbottom, to show how to search for a model that is closer to reality (even if it is not perfect), to improve our empirical understanding without falling into the trap of the "Truth". For example, he continues, the model that puts the Earth at the centre and has the stars rotating around it is more helpful for orientation at sea during the night compared to the heliocentric model (Rowbottom 2019, Ch. 1).

The position about unobservable phenomena goes under the same "+" brand: cognitive instrumentalism shares with the traditional semantic instrumentalism

[9] I have criticised the notion of empirical understanding (Psillos & Zorzato 2021).

the belief that acquaintance with phenomena comes about through sensory experience. However, instead of concluding that it is correct to shun talk about unobservables, it is claimed that, if observable properties or analogies with observable things are involved in scientific discourse about unobservables, then talk about unobservables is allowed (Rowbottom 2019, Ch. 2).

This "*nothing but +*" fails to resolve one of the most pressing questions that the instrumentalist faces: how to explain scientific progress? Whereas the realist argues that a scientific theory's success is best explained by its being true, and if the theory is true, a development in the knowledge about the world ensues, the position of the instrumentalist is unable to suggest reasons and ways for scientific advancement. A realist generally claims that the development of knowledge is a cumulative evolution towards (approximate) truth (Bird 2007; Niiniluoto 2014). As Sklar put it:

> *We may not believe that we have the truth, but we often believe, and believe with very good reason, that the best way of getting closer to the truth is the systematic attempt to obtain a deeper understanding of what we do have, our best current theory to date, inadequate as the theory might be* (Sklar 2000, p. 131 in Psillos & Zorzato 2021).

Cognitive instrumentalism involves an epistemic concept of understanding guaranteeing that no awkward dependence of truth on epistemic values should be involved. I will not rehearse the problems of Rowbottom's instrumentalism "+" here (see Psillos & Zorzato 2021). The understanding is quite pragmatic; it helps predict phenomena, orient research and structure the world. The model of Bohr's atom resembling the solar system is a good example of the "mental satisfaction" that the scientist achieves in constructing a model, without the necessity of a description of reality. Rowbottom concludes,

> *Admiring this model is consistent with thinking that promoting understanding is important, and that ideally the model would have been easier to picture* (Rowbottom 2019, p. 92).

And

> *We saw how it is possible to gain an understanding of empirical laws without generating a true, or even an approximately true, model. That is, on the assumption that Bohr's model isn't approximately true, as it presumably can't be if the contemporary view of the atom is approximately true (as realists tend to think it is). Despite being false, and having many intentional gaps, the model put some theoretical flesh on the Rydberg constant (…)* (Rowbottom 2019, p. 102).

Our criticism in the paper (Psillos & Zorzato 2021) focuses on three components of Rowbottom's cognitive instrumentalism. Broadly speaking, they are: (1) the claim that science progresses not via increased accuracy and faithfulness in representation but through increased predictive power and empirical understanding of the phenomena; (2) the semantic status of scientific discourse and unobservables properties; and (3) the so-called transient nature of scientific theories, meaning they come and go. This last component is similar to Stanford's "unconceived alternatives" argument. I cannot possibly expand on the details of our argument and refer for this to Psillos & Zorzato (2021).

Finally, let me just stress that, *pace* Rowbottom, there are models that work precisely because they are idealised, as they exhibit in their ideal form pertinent to a phenomenon under investigation. A particular case to this situation are models that cannot be de-idealised by definition. These are fictional models, which play an important explanatory role in science. Rowbottom himself mentions this case in a footnote (2019, pp. 125–6, n. 6), and stresses that 'fictions may only be *potentially* explanatory at best', adding that they can only 'serve as vehicles for empirical understanding'. I will argue next against this position, and point to the important role fictional models play in science.

4. Fictional models[10]

In this section, I want to show that scientific realism is compatible with fictional model explanations. By 'fictional models', as I already stressed in the Introduction, I mean models whose targets are not in fact instantiated[11]. Such models play various roles in science. To discuss fictional models, I draw extensively on the work of Alisa Bokulich, who, in a book and a series of papers, has presented characteristic cases of fictional models deployment, both for purposes of explanation and theory development. To accommodate fictional model explanations, Bokulich proposes what she calls the 'eikonic' concept of explanation. The purpose of this is to broaden the range of explanatory models so that fictional ones can be included. In other words, Bokulich proposes a modification of the notion of explanation to include non-causal explanations alongside causal ones. The price to be paid is that scientific realism is at odds with this broadened range. Therefore, Bokulich opts for a modification of realism itself, introducing a kind of 'moderate realism', which, nevertheless, can capture real patterns in the world.

I suggest an alternative. The idea is, instead of modifying the notion of realism, to modify the notion of representation. I base my argument on the writings of Bokulich herself. In particular, in Bokulich 2015, she deals with the case *par excellence*, i.e., J.C. Maxwell's use of his *idle wheels model,* employed in the course of developing his electromagnetic theory.

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[10] The part and the concepts concerning this paragraph are from the article "The Puzzle of Fictional Models", (Zorzato, 2022). I should stress my infinite debt to Vassilis Sakellariou, for his support, help, and intuition about this topic.

[11] I do not deal here with ontological questions about fictional models (see, e.g., Psillos 2020, Fiora Salis 2021, and references therein).

Maxwell's was a mechanical model, based on concepts from classical fluid mechanics as scaffolding in developing a theory in another domain: electromagnetic interactions. It comprised stacks of cells in a fluid forming adjacent vortices rotating in the same direction about parallel axes. For this to be possible, Maxwell introduced in between the vortices round particles in the role of "idle wheels" freely rotating. The rotational velocity of the vortex was assumed to represent the magnetic field strength, and the translatory motion of the idle-wheel particles was assumed to represent the electric current.

Throughout his writings on electromagnetism, the use by Maxwell of the concept of a 'fluid' does not entail an actual substance:

> '*It is not even a hypothetical fluid which is introduced to explain actual phenomena. It is merely a collection of imaginary properties which may be employed for establishing certain theorems in pure mathematics*' (Maxwell 1890/1965, 160).

Later, in his Treatise on Electricity and Magnetism, Maxwell himself, referring to his mechanical model, dispelled any doubts about its fictional character:

> *The attempt which I then made to imagine a working model of this mechanism must be taken for no more than it really is, a demonstration that mechanism may be imagined capable of producing a connexion mechanically equivalent to the actual connexion of the parts of the electromagnetic field.* (Maxwell 1873, 416–417).

Maxwell stresses that fictional models are "collections of imaginary properties". This corroborates what I claimed above, i.e., that at least *some* idealised models must be taken as they are, because they are heuristically used (as in the case of Maxwell) and they are indispensable *exactly* because de-idealisations of them do not exist (see Winsberg 2010, 2018 about climate models; or Knuuttila and Morgan, 2019, about economy models).

Writing about Maxwell's mechanical model, Bokulich (2015) invokes notions such as "physical analogies" and "embodied mathematics". Those were central elements of Maxwell's methodology, in the development of his thought from the idle-wheels-model to embedding his theory in the Lagrangian formulation of classical mechanics. On this basis, Bokulich points to what I will call a 'ladder of abstractions', namely, an hierarchical organisation of mathematical structures, constituent elements of both theories and models. Below the top level of a purely mathematical expression – a Lagrangian in the abstract – there is a level of 'embodiment' of that Lagrangian, which in turn is instantiated at a lower level by kinds of theories addressing specific physical situations. Bokulich attributes an explanatory role to the abstract principles embodied in Maxwell's physical analogies: 'Maxwell is not only highlighting the importance of abstract principles in scientific explanation but also articulating a notion of explanatory depth, according to which some scientific explanations may be counted as "deeper" than others' (Bokulich 2015, p. 35). The hierarchy of mathematical structures of varying degrees of abstraction – corresponding to property relations at varying explanatory depths – alludes to a procedure describing a *successive restriction of possibilities* homing in actual situations in the course of theory building. It amounts to pinpointing the steps taken, the decisions and choices made in advancing to the concrete, casting the beginning of the process not as an abstractly possible but as the essential element in the concrete. In this process, considered as temporally unfolding, every step *at a time* contains telescoped within it all previous steps that evolved *over time*. It is in this sense that *expanding* possibilities going 'upwards' along a 'ladder of abstractions' means going deeper into the object, teasing out representations of its essential properties and their relations.

This being so, a model, if a fictional one, may manage to display structural correspondences with a theory targeting some system at a certain level of abstraction. This is how the model can stand in as a proxy for the theory, and thus play an explanatory role. Moreover, the more abstract the model is, the deeper it grasps patterns of the target system. My argument is supported by an analysis of two cases where fictional models play an explanatory role (Bokulich 2008a). The first such case concerns Bohr's atomic model. Contrary to the account offered by Rowbottom, the explanatory function of Bohr's model is due to structural features of the model which would be made apparent with the advent of quantum mechanics. Bokulich herself connects this model to Bohr's 'correspondence principle' (Bokulich, 2008a). The second case concerns peculiar properties of a so-called Rydberg atom in a strong magnetic field. What is extraordinary in this case, is that the characteristics of a fictional model, a hybrid of classical and quantum concepts, can be calculated from experimental data, even though the model does not describe an existing system. As a matter of fact, in all quantum mechanical cases discussed by Bokulich structural correspondences between fictional models and quantum theory display an association of quantum mechanical density distributions with the density of appropriately defined bundles of fictitious classical trajectories (Bokulich, 2012). It is precisely such structural associations that combine to form the 'ladder of abstractions' I explained above. To sum up, a variety of fictional models, acting as proxies for theories of quantum phenomena, capture not the totality of the phenomena under investigation, but essential aspects of them. It is precisely this that constitutes a partial representation of a target system. As a result, scientists can tease out knowledge of physical connections inherent in the object of investigation but invisible to the proper physical theories concerned. In this way, the requirement of a realist of being connected to reality is respected.

5. Augmented determination. One argument supporting realism

In the previous part of the thesis, I presented the general debate between realism and instrumentalism. In this Section, I offer the original argument of *Augmented Determination*[12]. Roughly, it claims that the link between the success of a theory and its truth is not straightforward, rather is mediated by the continuous process of expansion-restriction of possibilities, and that realism should account for this fact. Let me unpack this. At every juncture of the scientific enterprise, scientists explore a range of possibilities purporting to answer to a physical situation they are faced with. To do this, they deploy both exploratory, mathematically formulated models, and exploratory experimental techniques. This is a process of narrowing down possibilities, until scientists are satisfied that they have reached an account of the actual situation.

The argument of the *Augmented Determination* is connected to both the UT and the PI (and, of course, to the problem of unconceived alternatives developed by Stanford). Both UT and PI paint a picture of scientific progress as proceeding in cycles: success, problems, rejection, replacement –repeated indefinitely. On the contrary, according to the AD, this progress does not evolve in cycles, but is directed: In complex, meandering, branching ways, there is a forward pointing arrow associated with the accumulation of real knowledge about the world. What is underdetermined at a stage of this historical process is not fixed; it presents scientific enquiry with a challenge to be met and resolved in subsequent stages. The pessimism of inductive anti-realist arguments is not fixed either. Through conceptual innovation, discoveries, theory-changes including rejection and replacement, objective knowledge of the world is gained. Pessimism about theoretical claims is refined, its focus is circumscribed, and this contributes to knowledge too. The same holds for the problem of 'unconceived alternatives'. For something to be an alternative requires its being in a position to connect with a given situation, i.e., to be not only 'unconceived' but also conceivable. General Relativity was an unconceived alternative to Newtonian gravity theory in the 19th century. However, it was inconceivable to think of gravitational interactions in terms of curvature variations in a four-dimensional space-time manifold, without radical conceptual innovations. AD counters anti-realist arguments as it stresses the historical dimension and the progress generating character of science, highlighting the many faces and intricacies of the transformation of the inconceivable into the conceivable and eventually the acceptable.

The process may be protracted, scientists may have to wait and see. However, it is not a perpetual situation in principle. True enough, it took a whole century of valiant efforts before scientists accepted the existence of atoms and the non-existence of the ether. They did accept such facts, nevertheless. Augmented Determination does not degenerate into instrumentalism –it does not subscribe to

[12] I thank Vassilis Sakellariou for the suggestion of the name in a personal communication.

denialism about unobservable entities. It shares with mainstream realism the association of success with theories' ability to latch onto the world and account for phenomena in terms of entities, their properties, and processes, both observable and unobservable. It differs from mainstream realism in acknowledging the fact that success of a theory is explainable by truth not in a straightforward way, but through a process of mediation unfolding over time. Augmented Determination sees truth assertions as a process, just as theories themselves evolve in a process. It takes predictive success to support the existence of unobservable entities if that success involves the entities in question. Contrary to all kinds of antirealism, it takes propositions positing such entities to be true.

What I just claimed is supported by the two cases I invoked in the previous Section, Bohr's atomic model and the Rydberg atom. Moreover, AD is in accord with arguments offered by two different sources. One is the solution proposed by Larry Laudan and Jarret Leplin (1991) to the problem of empirical equivalence and empirical underdetermination. The second is the distinction that Bokulich (2014) developed between how-possibly and how-actually models.

– Laudan and Leplin's account.

As well explained by P. Acūna and D. Dieks (2014), Laudan and Leplin in their paper (1991) refuted the problem of underdetermination (and the connected problem of empirical equivalence) on the ground of three points:

1) The variability of the range of the observable (1991, p. 451)
2) The necessity of auxiliary assumptions for novel predictions (1991, p. 452)
3) The instability of auxiliary assumptions (1991, p. 452).

The first point concerns the crucial dependence of entities' observability on the scientific knowledge and the technological resources that are available. The second focuses on the fact that any new observation is distinct from auxiliary assumptions, i.e. the instruments and their use, the background physical theories, the genuine factors that affect a new experiment. This is a crucial point in Duhem's holism (1914) (and Quine's interpretation of it in 1951), according to which any crucial experiment can falsify all rival theories and choose only the true one. Leplin and Laudan underline the necessity of auxiliary assumptions for unknown predictions, to explain that the role played by auxiliary assumptions can distinguish one theory from another, thus the claim of empirical equivalence can be refuted. The last point is linked to the first: the auxiliary information is also affected by the progress and improvement of scientific tools: it may increase in the future, or it may decrease. Consequently, the theory supported by them can also be changed.

I take those three points to mean the following: even if the problem of underdetermination of theory by data cannot be completely resolved, a few points can be claimed. First, UT is not universal, i.e. it is not *a priori* the limit of knowledge.

Second, it is a plausible situation that evidence cannot decide about which theory is true and which is false. As I have explained above, the AD view of the progress of science has a future pointing arrow tracking the accumulation of knowledge about the world. As science progresses, underdetermination cases are resolved, alternatives become conceivable and tested, more and more truths about the world are revealed.

– Bokulich's account.

The attitude of reserving judgment about the truth of theoretical claims in general, in the context of either theories or models, is exemplified in the distinction between 'how possibly' and 'how actually' models discussed in Bokulich (2014).

The former type comprises models that could be responsible for explaining the phenomena. Usually, these models are built before any actual causal structure of the target system is considered. They are hypotheses and speculations. Consequently, there can be multiple models that hypothesise different causes for the same phenomenon. It should be emphasised that for Carl F. Craver (2006) this type of models, not definitively descriptive of the target system, are not explanatory. A model that is instead explanatory is a "how-actually" model (Craver 2006, p. 361). Bokulich (2014) starts off with this distinction but expands it: first, "how-possibly" models are also explanatory. Her case study is the phenomenon called tiger bush: in some semi-arid terrain (in Nigeria for example) there are striking periodic bandings of vegetation. The characteristic of this phenomenon is that it is not explained by any variation in the topography of the territory but appears in a wild variety of plants and soil. In analysing how scientists shift through possible explanatory models for this phenomenon, Bokulich concludes that:

1: there are different levels of abstraction, to which different contexts of explanation correspond (Bokulich 2014, p. 33). These different explanatory contexts can be clarified by considering the relevant contrasts between the classes of explanations.

2: what plays the main role for the distinction between the two categories of explanation is not the quantity of details, but whether the represented mechanism operates in nature. In the case of the tiger bush phenomenon, the more abstract the mechanism, the easier it is to establish it as a how-actually explanation (Bokulich 2014, p. 34).

In other words, what is important to establish in the scale of the models is at what "height of abstraction" a model is placed: the more abstract the model is, the more it grasps something about the target system.

In light of the distinction made by Bokulich, I claim that scientists often offer more models that, at a first stage, appear empirically equivalent: the underdetermination of "how-possibly" models is, at the smaller-scale of scientific practice, a kind of epistemic situation that can easily arise in science. It is also possible that one model is a genuine rival of another one (like in the case of Morrone et. al, 2021). Perhaps, the confirmation of the model that is depicting reality will arrive, perhaps not. This confirmation is retrospective. The admission of this procedure is not a rejection of realism, it rather is the normal procedure in science, that is a complex procedure, comprising errors, attempts and mistakes to find the explanation of a particular phenomenon.

5.1 Realism in the bones (Paper "The Song of the Science Mermaid" Morrone & Zorzato, 2021).

As a case study to illustrate the process of expansion and restriction of possibilities that I mention above, I offer a paleopathological study[13–14].

In my paper co-authored with Alessandra Morrone, "The Song of the Science Mermaid", I presented as a case study the first bioarchaeological analysis in non-adult skeletons in mediaeval Estonia and in the Baltic region. In the cemetery of St. Jacob in the city of Tartu (Estonia), 43 skeletons have been analysed and 10 of those presented abnormal porosity in the long bones. The issue is that this porosity can be explained by several different diagnoses (Morrone et al. 2021) but, among them, two are the most probable: that it is due to the systemic metabolic conditions or that it is due to the normal rapid growth of the non-adult organism (Lewis & Gowland 2007, Lewis 2018).

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13 In general, paleopathology is the study of ancient diseases to try and reconstruct the lives and health conditions of people in past populations (Ortner, 2003). Its studies focus on human and non-human materials and cases. Its findings are mainly related to medicine: what is the history of a disease? How did it manifest itself in a population? With what dynamics did it spread? Sites such as cemeteries or mass graves are the research grounds for a subcategory of paleopathology, called paleoepidemiology. Paleoepidemiology is the study of disease dynamics in the past human population. Space, time, and/or social, cultural, and ethnic factors are those influencing data and results (Ortner, 2003).

14 The articulation of this theme is an original contribution to the more general debate in philosophy of science between realism and anti-realism. I chose this case for a particular reason: During the XX century, the scientific realism debate evolved along with the development of new science: quantum theory. At the same time, also historical sciences such as palaeontology, palaeopathology, archaeology and related areas made considerable progress. Historical sciences, however, had a lot of work to do to be recognised as properly scientific. To give an example, the Nobel laureate physicist Luis Alvarez declared, "I don't like to say bad things about palaeontologists, but they are really not very good scientists. They are more like stamp collectors" (Alvarez 1989, p.281 in Turner 2007 p.6). Therefore, those fields have been completely ignored by philosophers of science. In recent times, some philosophers of science have been interested in the sciences that reconstruct the past (among others, D. Turner 2007; 2011; A. Currie 2018, 2019; A. Wylie 2002), but the field of palaeopathology is still unexplored. Questions concerning the epistemological status of paleopathology are various: what inferences can be made in the case of scientists who face the absence or degradation of data? Can they be considered "genuine" inferences, or should one remain agnostic about the sciences concerning the past? Is it possible to claim that the results of palaeopathological studies are true? How to *believe* that the inferences of the studies of palaeopathology are describing what really (approximately) happened in the past and are not only abstract speculation?

It is not difficult to recognise that scientists are in facing the *underdetermination of theory by data,* i.e., that there are potentially more than one explanation for the same phenomenon. Underdetermination *occurs when there is slack between our observations, or our evidence, and what our theories tell us about the world* (Turner 2011, p. 147)[15]. The problem for the realist is to maintain firmly the concept of truth (at least approximate truth) of scientific explanation. As Worral 2011b notes, p. 158: "*no sensible realist ought to accept a demonstration that two theories deductively entail the same data as showing that those two theories share the same empirical success*".

Before philosophers, palaeopathologists themselves have been worried about those problems. The Osteological Paradox (Wood et al., 1992) concerns the fact that the data involved in studies such as palaeopathology are limited and, by induction, the results of these studies may be unreliable. According to the authors, the materials involved in these studies (human remains) are not representative of the once living population, often offering more possible explanations for the same phenomena. This can be a source of interpretative bias. In the literature, their work is regarded as the study that has undermined palaeopathological research. The debate is still ongoing (Dewitte & Stojanowsky, 2015, Buikstra et al., 2022) and far from a final solution.

In the paper, I claim that the different and alternative explanations that a scientist deals with are "how-possibly" models (Bokulich 2014). In palaeopathology, the role of models is to represent the process that the skeleton is showing: a model narrates the story of the past life of an individual, which starts when the subject is alive and finishes when the skeleton is analysed by scientists. All the story that goes from point A to point B is what I call "the model" developed by palaeopathologists. Such models are articulated when new phenomena emerge, and they are correlated with reality being possibly explanatory of it. In this way, the question of how the inferences of palaeopathology are describing reality is (at least partially) answered, since they demonstrate a link between the explanans and the target system. Moreover, according to the argument of *Augmented Determination,* 1) it is a normal procedure in science to have a range of alternative explanations, and 2) eventually, the support of technology and the advance of knowledge will confirm one solution from among the rest. When this happens, after the expansion of more plausible models, the restriction of the possible theories will result. In this case, the how-possibly model will become a how-actually model.

[15] As stated above, philosophically there is a distinction within underdetermination (Stanford 2009b): "holistic underdetermination" and "contrastive form of underdetermination". The latter arises when there is a possibility that, for each phenomenon for which there is a theory explaining it, there could also be another theory (or theories) with an equally valid claim as an explanation. Holistic underdetermination, on the other hand, arises whenever our inability to test the hypothesis in isolation leaves us underdetermined in our response to a failed prediction or some other piece of disconfirming evidence. For the topic considered in this paper, it is the contrastive underdetermination that is taken into consideration.

M. Strevens (2013, pp. 512–513) claims that there are external and internal conditions for the correctness of explanation. The latter are about the structure of the explanation, what form a set of propositions has, or, in the words of Bokulich, what is the structure of the model. The internal structures of both models about abnormal porosity are constructed involving a logical and deductive argument, stipulating that "*an explanation represents a potential causal history for the explanandum"*. It means that a how-possibly explanation satisfies the internal conditions. However, the external conditions are not satisfied, i.e. they fail to account for how things are outside in the world.

This element is evident in the case of Morrone et al. (2021), but it is an everyday condition for scientists working on problems in palaeopathology. The two models developed in this case study are not mere stories, since they have a strong internal structure, but they face the limits of evidence about the bones from the past. However, this is not a limit in principle: whereas the instrumentalist claims that underdetermination is a limit in principle, the realist claims that there are no limits to knowledge. For instance, palaeopathology has been boosted by the unprecedented development of new methods and tools in the late 20th and early 21st centuries, when palaeopathology became a recognised and independent discipline: the possibility of decoding DNA and RNA, electron microscopy, radiography, and in general new ways of data processing, offered knowledge about the diseases of historical populations with more and more details. The aetiology of tuberculosis in the ancient Mediterranean world, the osteogenesis imperfecta in classical Rome, are all clear examples of how technology, science and knowledge are proceeding hand in hand.

The case I discussed above, illustrating the transition of "how possibly" models being transformed into "how actually" ones, demonstrates the process of exploring the spaces of possibilities in the phase of a physical situation, then proceeding to restrict those possibilities until a satisfactory representation of the actual situation is reached. This is what I described as expansion-restriction of possibilities in the context of the Augmented Determination approach.

6. Summary points

As I wrote in the beginning of this thesis, my motivation has been the challenge presented to realism by fictional model explanations. I have discussed the solution to this challenge offered by Alicia Bokulich in terms of 'moderating' scientific realism to make it compatible with fictional model explanations. I offered instead an alternative, amounting to a generalisation of the notion of representation instead of modifying realism. To this end, I based myself on the notion of 'a ladder of abstractions', establishing structural relations between theories and fictional models, allowing the latter to act as proxies for the former. Fictional models then would offer partial representation of a target system and be amenable to realist interpretations. However, this procedure introduces a more nuanced relationship between the success of fictional model explanations and truth as a possible explanation of that success. In fact, truth does explain the success of fictional model explanations, but not directly: it achieves this because it is assigned to the theories structurally associated with the fictional model in question, and because this model acts as a proxy for the theory. This situation is typical in many branches of physics, but this is beyond the scope of this work. To account for it in the cases I discussed, I introduced the notion of Augmented Determination.

To set the stage for my discussion, I offered an outline of the main developments in the realism vs antirealism debate. I presented the fundamentals of scientific realism, and the principal philosophical trends of antirealism. In particular, I discussed instrumentalism, and its main contemporary representatives: epistemic instrumentalism and cognitive instrumentalism. Of course, open questions remain. I consider questions about the success and truth connection, the transition of how-possibly to how-actually models, and the association of fictional models with theories, to be subject for further research.

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ENGLISH SUMMARY

This thesis aims at explaining the role of fictional models in the panorama of the scientific realism vs antirealism debate. In short, on the one hand, scientific realists consider scientific theories as true descriptions of the world. Antirealists, on the other hand, consider scientific theories to be instruments for classifying phenomena and predicting future events, without assigning truth values to them.

Fictional models represent a challenge for realism, because they play a crucial explanatory roles for phenomena despite not being true descriptions of the world. In the literature, this issue has been extensively discussed by Alisa Bokulich. Her response to the challenge is a moderate kind of scientific realism, compatible with the explanatory, though fictional, character of such models. My alternative proposal to preserve scientific realism, and generalize instead the concept of representation admitting partial representation of aspect of a system. It is based on Bokulich's own analysis of J. Clerk Maxwell's methodology in developing his electromagnetic theory. I explain how a fictional model can be associated with a scientific theory, either a mature one, or one under construction. This association depends on correspondences between mathematical structures that are constitutive elements of both the model and the theory. If the theory is meant to account for a physical system, a fictional model associated with the theory may manage to capture aspects of the theory's target through the path formed in virtue of structural correspondences. In other words, the model acts 'as a proxy' for the theory.

I present arguments that fictional models can be autonomous and partially representational, and play explanatory roles in a variety of situations. The crucial fact is the possibility of structural correspondences between such models and theories established at various levels of abstraction. To describe those possibilities, I introduce the notion of 'a ladder of abstractions', along which such correspondences can be established. In this way, the link between success and truth is maintained: however, now it is not straightforward. It is mediated by the multiple ways in which fictional models can become proxies for theories, ways that have to be theoretically investigated and experimentally tested.

In general, this is the notion of expansion and restriction of possibilities: science is a continuous process of evolution, of gaining knowledge about the world. This process involves the birth, life and death of theories. When a phenomenon is under scientific inquiry, multiple explanations are possible: only one, if any, emerges as the most suitable explanation, the one portrays the world. It is through this process that the position of scientific realism acquires a broader meaning: with the concept of *Augmented Determination*, I suggest that, instead of a direct connection between truth and the success of a theory, a more articulate and complex link between truth and success is acknowledged. The originality of Augmented Determination lies precisely in this recognition.

I conclude my thesis by examining how a range of possible explanations of a phenomenon can be narrowed down to what is the actual case.

This introduction contains the results of five papers, two of them co-authored. Section 1 describes the debate in its historical framework to identify what the current meaning of realism and instrumentalism is. In the debate under consideration, the epistemic aspect is what is being discussed: what can be known about the entities that are described by scientific theories? On the other hand, instrumentalism denies knowledge beyond the phenomena dealt with by scientific theories, and claims that the role of scientific theories is merely instrumental.

Section 2 focuses on the contemporary version of instrumentalism. The first author I deal with is Kyle Stanford. Under the label of *epistemic instrumentalism*, Stanford claims that we should have a realist approach towards some theories and an instrumentalist approach towards others. The criterion for epistemic instrumentalism to distinguish between realist and instrumentalist approaches is the unconceived alternatives challenge: based on the historical record, the theories conceived at any time t will later be replaced by theories which were not conceived at t. The unconceived alternatives would be at least as well confirmed as those they replaced. Since this has been the fate of all past theories, so it will be the fate of the present and the future ones. But this is not the case for all scientific theories: there are some beliefs that are not subject to the unconceived alternatives argument, the so called 'common sense'. In my paper *The tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism,* I question the claim that there exists such a distinction between science viewed under an instrumentalist spirit and common sense,

and I claimed that there is an osmosis between the two. The historical example of the Copernican System and its historical and cultural evolution shows that common sense is influenced by, and influences science itself. Consequently, epistemic instrumentalism is anchored to something far from stable and, therefore, risks falling into scepticism.

The second author who rekindled the instrumentalist position is Darrel Rowbottom. He recently presented a position called 'cognitive instrumentalism'. Generally speaking, Rowbottom considers science not merely as a tool, but a tool for understanding phenomena. Science therefore has a relation to the world, since there is an understanding of it, but without claims about objective truth such as the realist makes. The critique of this version of instrumentalism has been developed in collaboration with my co-supervisor, Professor Stathis Psillos. The result of our joint effort has been the paper *Against Cognitive Instrumentalism*. This paper was written in cooperation, there was no division of labour, therefore no credit can be assigned to each one of us individually. Rowbottom suggests that theories are tools for understanding. Our criticism targets his notion of 'empirical understanding', which is the core of his argument. Empirical understanding is a goal, that instrumentalists accept alongside the goal that theories save the phenomena. It is "neither factive nor quasi-factive". According to Rowbottom, this means that empirical understanding goes beyond a theory's saving a set of phenomena but stops short of achieving objective understanding, i.e, grasping an explanation of those phenomena. The reason for this is that a full understanding is too hard, even impossible to achieve. In our criticism we point out that a partial understanding of a phenomenon is still understanding even if a full understanding might require all possible relevant truth.

In Section 3, I put forward my own views. In the two papers, *Fiction and Reality: an Uncanny Relationship* and *The Puzzle of Fictional Models*, I focus on so-called *fictional models*. In the literature, fictional models usually are not taken literally: they are fictional. I explain the meaning of the term as I use it and draw extensively from the relevant work of Alisa Bokulich: a fictional model in my sense is a model whose target is not in fact instantiated. In certain cases, such models are particularly helpful in explaining and predicting phenomena (for example, Bohr's atom). How is it possible for a fictional model to be explanatory? In the above two papers, I claim that fictional models can be compatible with a realist framework. I draw upon Bokulich's position to explain that fictional models can have a relation with reality. To do so, I introduce the notion of a *ladder of abstractions* to argue that the more abstract the model is, the better it connects at a deeper level with phenomena, and partially grasps some aspect of them. *Fiction and Reality: an Uncanny Relationship* corroborates the argumentation with the example of Bohr's model of the atom. The Rydberg atom is the case studied in the *Puzzle of Fictional Models.* The main conclusion I reach is that fictional models can be both fictional and representational in a certain sense, illustrating the failure of instrumentalism concerning the nature of fictional models.

In Section 4, I develop the original argument, which I call 'Augmented Determination'. As a case study, I invoke the paper *The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox*; co-authored with Alessandra Morrone. This is an interdisciplinary work that considers the concerns of scientists (in this case bioarchaeologists) from a philosophical point of view. Written as a dialogue, the paper focuses on the so-called Osteological Paradox: this is the subject of an eponymous, well known archaeology paper (Wood et al., 1992, The osteological paradox: problems of inferring prehistoric health from skeletal samples. *Current anthropology 33*:4, pp. 343–370) that points out what in philosophy of science is called the problem of underdetermination of theory by data. The conclusion is far from resolving the difficulties of a realist-minded scientist; however, it amplifies the trust that scientists have in science. In particular, the conclusion supports Augmented Determination since it highlights that science is dynamic and that realism can account for its dynamism.

EESTIKEELNE KOKKUVÕTE

Realistlik lahendus fiktsionaalsete mudelite probleemile: laiendatud determinatsioon

Minu doktoritöö püüab seletada fiktsionaalsete mudelite rolli teadusliku realismi ja antirealismi debati taustsüsteemis. Lühidalt, ühelt poolt peavad realistid teaduslikke teooriaid tõesteks maailmakirjeldusteks. Antirealistid, teiselt poolt, peavad teaduslikke teooriaid fenomenide klassifitseerimise ja tulevikusündmuste ennustamise instrumentideks, ilma neile tõeväärtusi omistamata.

Fiktsionaalsed mudelid on realismile väljakutseks, kuna nad mängivad fenomenide jaoks olulist seletuslikku rolli, olgugi, et nad pole tõesed maailmakirjeldused. Kirjanduses on seda probleemi ulatuslikult käsitlenud Alisa Bokulich. Tema vastuseks sellele väljakutsele on mõõdukas teaduslik realism, mis sobib kokku sääraste mudelite seletusliku, ehkki fiktsionaalse iseloomuga. Minu alternatiivne ettepanek on säilitada teaduslik realism ja generaliseerida selle asemel representatsiooni kontseptsioon, mis lubaks süsteemi aspekti osalist representatsiooni. See põhineb Bokulichi analüüsil Clerk Maxwelli elektromagnetismi teooria arendamise metodoloogia kohta. Ma selgitan, kuidas fiktsionaalset mudelit saab seostada teadusliku teooriaga, kas siis küpse teooriaga või alles loomisjärgus olevaga. See seostatus sõltub matemaatiliste struktuuride vastavusest, mis on nii mudeli kui ka teooria aluselementideks. Kui teooria peaks seletama füüsikalist süsteemi, siis teooriaga seostatud fiktsionaalne mudel võib tabada teooria sihtmärgi aspekte tänu strukturaalsete vastavuste kujundatud rajale. Teisisõnu, mudel esindab teooriat.

Ma argumenteerin, et fiktsionaalsed mudelid võivad olla autonoomsed ja osaliselt representatsioonilised ning neil on seletuslikud rollid mitmekesistes olukordades/situatsioonides. Otsustavaks on siin strukturaalse vastavuse võimalus sääraste mudelite ja teooriate vahel abstraktsiooni eri tasemetel. Nende võimaluste kirjeldamiseks võtan ma kasutusele „abstraktsioonide redeli“ mõiste, mille toel saab säärased vastavused kindlaks määrata. Sel moel on tagatud seos edukuse ja tõesuse vahel, kuid enam ei ole see seos otsene. See on vahendatud mitmesugustest viisidest, kuidas fiktsionaalsed mudelid võivad teooriat esindada. Neid viise peab teoreetiliselt uurima ja eksperimendis kontrollima.

Kõige üldisemalt kirjeldab „abstraktsioonide redeli“ mõiste võimaluste laiendamist ja piiramist: teadus on pidevalt arenev protsess maailma kohta teadmiste saamiseks. See protsess hõlmab teooriate sündi, elu ja surma. Kui fenomen on teadusliku uurimise all, on võimalikud mitmed seletused: ainult üks, kui üldse, tõuseb esile kui kõige sobivam seletus, mis maailma kujutab. Selles protsessis saab teadusliku realismi positsioon laiema tähenduse. Leian, et *laiendatud determinatsiooni* kontseptsiooni kaudu tunnistatakse teooria tõesuse ja edukuse otsese ühenduse asemel selgemat ja keerukamat seost tõesuse ja edukuse vahel. Laiendatud determinatsiooni algupärasus seisneb just selles äratundmises. Lõpetan oma doktoritöö, uurides, kuidas fenomeni võimalike seletuste ampluaad saab kitsendada konkreetse juhtumini.

Sissejuhatus hõlmab tulemusi, mis on ilmunud viies artiklis. Kaks neist on kaasautorluses. Sissejuhatuse esimene osa kirjeldab debatti selle ajaloolises raamistikus, et tuvastada realismi ja instrumentalismi praegused tähendused. Vaatlusaluses debatis on arutluse all episteemiline aspekt: mida on võimalik teada entiteetide kohta, mida teaduslikud teooriad kirjeldavad? Instrumentalism teiselt poolt eitab teadmiste olemasolu, mis ulatuksid kaugemale teaduslikes teooriates käsitletavatest fenomenidest, pidades teaduslike teooriate rolli kõigest instrumentaalseks.

Teine osa keskendub instrumentalismi tänapäevasele käsitlusele. Esimene autor, keda vaatlen, on Kyle Stanford. *Episteemilise instrumentalismi* sildi all väidab Stanford, et meil peaks olema mõne teooria suhtes realistlik lähenemine ja teiste suhtes instrumentalistlik. Episteemilise instrumentalismi kriteerium realistlike ja instrumentalistlike lähenemiste eristamiseks on sündimata alternatiivide väljakutse: nagu nähtub ajaloolistest allikatest, asendatakse mingil ajahetkel t sündinud teooria hiljem teooriatega, mis polnud ajahetkel t veel sündinud. Sündimata alternatiivid on tõendatud vähemalt sama hästi kui teooriad, mille nad välja vahetasid. Kuna see on olnud minevikus kõigi teooriate saatuseks, kujuneb samasuguseks ka kõigi praeguste ja tulevaste teooriate saatus. Kuid see ei ole nii kõigi teaduslike teooriate puhul: on mõned uskumused, mis ei allu sündimata alternatiivide argumendile – nn tavamõistuslikud teooriad. Oma artiklis „The Tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism" („Pinge sündimata alternatiivide probleemi ja episteemilise instrumentalismi vahel") sean ma kahtluse alla, kas instrumentalistlikult mõistetav teadus ja tavamõistuslikkus tegelikult eristuvadki, ja väidan, et nende kahe vahel toimub osmoos. Koperniku heliotsentristlik süsteem kui ajalooline näide ning selle ajalooline ja kultuuriline evolutsioon näitavad, et teadus mõjutab tavamõistuslikkust ja see mõjutab omakorda teadust. Seega pole episteemilise instrumentalismi alused stabiilsed ja sel on oht langeda skeptitsismi.

Teine autor, kes instrumentalistliku positsiooni taaselustas, on Darrel Rowbottom. Ta esitles hiljuti „kognitiivse instrumentalismi" positsiooni. Üldiselt peab Rowbottom teadust mitte pelgalt tööriistaks, vaid fenomenide mõistmise tööriistaks. Seega suhestub teadus maailmaga, kuna teadusel on arusaam maailmast, kuid see ei pretendeeri objektiivsele tõele, nii nagu realist seda teeks. Selle instrumentalismiversiooni kriitika on välja töötatud koostöös ühe mu juhendaja, professor Stathis Psillosega. Meie ühiste püüdluste tulemuseks on artikkel „Against Cognitive Instrumentalism" („Kognitiivse instrumentalismi vastu"). Artikkel valmis koostöös ilma spetsiifilise tööjaotuseta ja seepärast ei saa määrata ka kummagi individuaalset panust. Rowbottom leiab, et teooriad on mõistmise tööriistad. Meie kriitika on suunatud tema „empiirilise mõistmise" mõiste vastu, mis on argumentatsioonis keskne. Empiiriline mõistmine on eesmärk, mida instrumentalistid aktsepteerivad koos eesmärgiga, et teooriad peavad säilitama fenomenid. See pole „ei faktiivne ega kvaasifaktiivne". Rowbottomi jaoks tähendab see, et empiiriline mõistmine läheb kaugemale kui nõue säilitada teooria poolt fenomenide kogum, kuid ei jõua objektiivse mõistmise saavutamiseni, s.t. nende fenomenide seletamiseni. Selle põhjuseks on, et täielikku mõistmist saavutada on raske kui mitte võimatu. Oma kriitikas osutame, et ka fenomeni osaline mõistmine on siiski mõistmine, isegi kui täielik mõistmine nõuaks kogu võimalikku asjassepuutuvat tõde.

Kolmandas osas toon esile omaenda vaated. Kahes artiklis, „Fiction and Reality: an Uncanny Relationship" („Fiktsionaalsus ja reaalsus: ebaharilik suhe") ja „The Puzzle of Fictional Models" („Fiktsionaalsete mudelite mõistatus"), keskendun ma nn fiktsionaalsetele mudelitele. Kirjanduses ei võeta fiktsionaalseid mudeleid tavaliselt otseselt, nad on fiktsionaalsed. Ma seletan seda fiktsionaalse mudeli mõistet nii, nagu mina seda mõistan, võttes suuresti aluseks Alisa Bokulichi asjassepuutuva töö. Minu kasutatavas tähenduses on fiktsionaalne mudel selline mudel, mille sihtmärk ei eksisteeri faktiliselt. Kindlatel juhtudel on sellised mudelid eriti kasulikud fenomenide seletamiseks ja ennustamiseks (näiteks Bohri aatom). Kuidas saab fiktsionaalne mudel olla seletuslik? Ülalmainitud artiklites väidan ma, et fiktsionaalsed mudelid võivad ühilduda realistliku raamistikuga. Kasutan Bokulichi positsiooni seletamaks, kuidas saavad fiktsionaalsed mudelid suhestuda reaalsusega. Selle jaoks võtan ma kasutusele „abstraktsioonide redeli" mõiste. Ma väidan, et mida abstraktsem mudel on, seda paremini seostub ta sügavamal tasemel fenomenidega ja haarab osaliselt nende mõningaid aspekte. Artikkel „Fiction and Reality: an Uncanny Relationship" („Fiktsionaalsus ja reaalsus: ebaharilik suhe") kinnitab minu argumentatsiooni Bohri aatomi mudeli näitel. Rydbergi aatomi juhtumit vaatlen artiklis „The Puzzle of Fictional Models" („Fiktsionaalsete mudelite mõistatus"). Minu põhijäreldus on, et fiktsionaalsed mudelid võivad olla nii fiktsionaalsed kui ka teatud mõttes representatsioonilised, illustreerides instrumentalismi ebaõnnestumist seoses fiktsionaalsete mudelite olemusega.

Neljandas osas arendan välja algupärase argumendi, mida nimetan „laiendatud determinatsiooniks". Juhtumiuuringuna kasutan artiklit „The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox" („Teadusmerineitsi laul: filosoofiline triloog osteoloogilisest paradoksist"), mis valmis kaasautorluses Alessandra Morronega. Tegemist on interdistsiplinaarse tööga, mis kaalub teadlaste (antud juhul bioarheoloogide) muresid filosoofilisest vaatepunktist. Dialoogivormis artikkel keskendub nn osteoloogilisele paradoksile, mis on eponüümilise ja laialt tuntud arheoloogiaartikli teemaks (Wood et al., 1992, The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples. *Current Anthropology 33*:4, pp. 343–370). Artikkel toob esile probleemi, mida teadusfilosoofias tuntakse teooria andmetega alamääratuse (aladetermineerituse) probleemina. Meie artikli lõppjäreldus ei lahenda kaugeltki realistlikult meelestatud teadlase raskusi, kuid see võimendab usaldust, mis teadlastel on teaduse suhtes. Eriti toetab meie järeldus laiendatud determinatsiooni, kuna see rõhutab teaduse dünaamilisust ja realismi suutlikkust seda dünaamilisust seletada.

PUBLICATIONS

CURRICULUM VITAE

Name: Lisa Zorzato
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I. Education

2023 PhD candidate in philosophy. University of Tartu. Thesis topic: "Towards a Realist Approach to the Challenge of Fictional Models: Augmented Determination". Supervisors: Endla Lõhkivi, Stathis Psillos.

2020–2022 Visitor at the National and Kapodistrian University of Athens, Athens. Supervisor: Stathis Psillos.

2016. University of Urbino, MA *cum laude* in philosophy. Thesis title: "A Spooky Action at a Distance: Einstein's View Naturalism on Quantum Mechanics". Supervisors: Vincenzo Fano.

2014–2015 Visitor at the University of Utrecht. Mentor: Dennis Dieks.

2012 University of Padua, BA in philosophy. Thesis title: „L'evoluzione del concetto di spazio vuoto, tra fisica e filosofia, da Aristotele a Newton a Einstein".

II. Participation in the research projects

2018–2022 Participation in the ASTRA project PER ASPERA *(2014–2020.4.01.16–0027)*

2018–2019 Participation in the project "Disagreements: Philosophical Analysis (IUT20-5). Principal investigator: Margarit Sutrop.

2018–2020 Participation in the project "Expertise and Fundamental Controversy in Philosophy and Science" (MOBTT45). Principal investigator: Bryan Reed Stewart Frances.

2019–2023 Participation in the project "Philosophical analysis of interdisciplinary research practices" (PRG462). Principal investigator: Endla Lõhkivi.

III. Scholarships

04/01/2020–01/09/2020 Dora Plus Scholarship – Study Mobility at the National and Kapodistrian University of Athens, Greece.

01/09/2020–01/03/2021 Dora Plus Scholarship – Study Mobility at the National and Kapodistrian University of Athens, Greece.

01/03/2021–01/06/2021 Kristian Jaak Scholarship – Study Mobility at the National and Kapodistrian University of Athens.

15/12/2021–15/04/2022 Dora Plus Scholarship – Study Mobility at the National and Kapodistrian University of Athens, Greece.

IV. Teaching

Teaching at the course "Communicating Science" (Professor Djuddah A.J. Leijen)

V. Research

Research interests

Philosophy of Science, Philosophy of Physics, Realism and Antirealism Debate, Fictional Models.

Publications

Peer reviewed publications

(forthcoming). The Puzzle of Fictional Models. *Journal for General Philosophy of Science.*

(forthcoming). Fiction and Reality: an Uncanny Relationship. *Argumenta*.

(2022). The Tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism. *Problemos*, *102*, 50–58. https://doi.org/10.15388/Problemos.2022.102.4

Alessandra Morrone & Lisa Zorzato (2021). The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox. *Acta Baltica Historiae Et Philosophiae Scientiarum*, 9:1, 27–50. https://doi.org/10.11590/ABHPS.2021.1.03

Stathis Psillos & Lisa Zorzato (2020). Against Cognitive Instrumentalism. *International Studies in the Philosophy of Science*, 33:4, 247–257. https://doi.org/10.1080/02698595.2021.1961420

Conference Presentations

2022 Anatomy of the past: The Osteological Paradox in the Light of Philosophy of Science 7th Panhellenic Conference on Philosophy of Science. 1–3 December. Athens University, Athens, Greece.

2022 Fictional models, explanation and Realism. Conference in Urbino, 4th Conference of the P.R.I.N. "The Manifest Image and the Scientific Image" 20–21 June, University of Urbino, Urbino, Italy.

2022 The Puzzle of Fictional models. Conference in Lisbon, History and Philosophy of Science International Conference. 23–24 June. University of Lisbon, Lisbon, Portugal.

2022 Anatomy of the Past. The Future of The Past: Philosophical Issues in the 'Historical' Sciences". 8–9 August. The Hebrew University of Jerusalem, Jerusalem, Israel.

2020 Skeleton for Science: A Scientific Understanding with Fiction. 6th Panhellenic Conference in Philosophy of Science. 3–5 December. Kapodistrian University of Athens, Athens, Greece.

2019 An Attempt to Defend Scientific Realism: Scientific Realism and the Anti-realist Counterarguments. 7th Annual Conference and General Meeting of the Society for Women in Philosophy-Ireland. 6–7 December. University College Cork, Cork, Ireland.

2019 Is there any anchor for Stanford's Antirealism?. 16th International Congress of Logic, Methodology and Philosophy of Science and Technology. 5–10 August. Czech Technical University, Prague; Czech Republic.

2018 No Anchor for Stanford's Scientific Realism. 7Th National Meeting in Analytic Philosophy, 13–15 September. University of Lisbon, Lisbon, Portugal.

ELULOOKIRJELDUS

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I. Haridus

2023	Tartu Ülikool, doktoriõpingud filosoofias. Doktoritöö pealkiri: "Towards a Realist Approach to the Challenge of Fictional Models: Augmented Determination". Juhendajad Endla Lõhkivi ja Stathis Psillos.
2020–2022	Külalisdoktorant Ateena Rahvuslikus Kapodístria Ülikoolis. Juhendaja Stathis Psillos.
2016	Urbino Ülikool, magistrikraad *cum laude* filosoofia erialal. Magistritöö pealkiri: "A Spooky Action at a Distance: Einstein's View Naturalism on Quantum Mechanics". Juhendaja Vincenzo Fano.
2014–2015	Külalisüliõpilane Utrechti Ülikoolis. Mentor Dennis Dieks.
2012	Padua Ülikool, bakalaureusekraad filosoofia erialal. Bakalaureusetöö teema: „L'evoluzione del concetto di spazio vuoto, tra fisica e filosofia, da Aristotele a Newton a Einstein".

II. Osalemine uurimisprojektides

2018–2022	Osalemine ASTRA projektis PER ASPERA *(2014–2020.4.01.16–0027)*
2018–2019	Osalemine projektis „Lahkarvamuste filosoofiline analüüs" (IUT20-5). Vastutav täitja: Margit Sutrop.
2018–2020	Osalemine projektis "Expertise and Fundamental Controversy in Philosophy and Science" (MOBTT45). Vastutav täitja: Bryan Reed Stewart Frances.
2019–2023	Osalemine projektis „Interdistsiplinaarse teadustöö filosoofiline analüüs" (PRG462). Vastutav täitja: Endla Lõhkivi.

III. Stipendiumid

04/01/2020–01/09/2020	Dora Plus stipendium õpirändeks Ateena Rahvuslikus Kapodístria Ülikoolis, Kreekas.
01/09/2020–01/03/2021	Dora Plus stipendium õpirändeks Ateena Rahvuslikus Kapodístria Ülikoolis, Kreekas.
01/03/2021–01/06/2021	Kristian Jaagu stipendium õpirändeks Ateena Rahvuslikus Kapodístria Ülikoolis, Kreekas.
15/12/2021–15/04/2022	Dora Plus stipendium õpirändeks Ateena Rahvuslikus Kapodístria Ülikoolis, Kreekas.

IV. Õpetamiskogemus

Loengukursuse “Communicating Science” õpetamine (vastutav õppejõud professor Djuddah A.J. Leijen)

V. Teadustegevus

Peamised uurimisvaldkonnad

Teadusfilosoofia, füüsika filosoofia, realismi ja antirealismi debatt, fiktsionaalsed mudelid.

Publikatsioonid

Eelretsenseeritud publikatsioonid

(ilmumas). The Puzzle of Fictional Models. *Journal for General Philosophy of Science.*

(ilmumas). Fiction and Reality: an Uncanny Relationship. *Argumenta*.

(2022). The Tension between the Problem of Unconceived Alternatives and Epistemic Instrumentalism. *Problemos*, *102*, 50–58. https://doi.org/10.15388/Problemos.2022.102.4

Alessandra Morrone & Lisa Zorzato (2021). The Song of the Science Mermaid: A Philosophical Trilogue on the Osteological Paradox. *Acta Baltica Historiae Et Philosophiae Scientiarum*, 9:1, 27–50. https://doi.org/10.11590/ABHPS.2021.1.03

Stathis Psillos & Lisa Zorzato (2020). Against Cognitive Instrumentalism. *International Studies in the Philosophy of Science*, 33:4, 247–257. https://doi.org/10.1080/02698595.2021.1961420

Konverentsettekanded

2022 Anatomy of the past: The Osteological Paradox in the Light of Philosophy of Science 7th Panhellenic Conference on Philosophy of Science. 1–3. detsember. Ateena Ülikool, Ateena, Kreeka.

2022 Fictional models, explanation and Realism. Conference in Urbino, 4th Conference of the P.R.I.N. “The Manifest Image and the Scientific Image” 20–21. juuni, Urbino Ülikool, Urbino, Itaalia.

2022 The Puzzle of Fictional models. Conference in Lisbon, History and Philosophy of Science International Conference. 23–24. juuni. Lissaboni Ülikool, Lissabon, Portugal.

2022 Anatomy of the Past. The Future of The Past: Philosophical Issues in the ‘Historical’ Sciences”. 8–9. august. Jeruusalemma Heebrea Ülikool, Jeruusalemm, Iisrael.

2020 Skeleton for Science: A Scientific Understanding with Fiction. 6th Panhellenic Conference in Philosophy of Science. 3–5. detsember. Ateena Rahvuslik Kapodístria Ülikool, Ateena, Kreeka.

2019 An Attempt to Defend Scientific Realism: Scientific Realism and the Antirealist Counterarguments. 7th Annual Conference and General Meeting of the Society for Women in Philosophy-Ireland. 6–7. detsember. Corki Ülikooli Kolletž, Cork, Iirimaa.

2019 Is there any anchor for Stanford's Antirealism? 16th International Congress of Logic, Methodology and Philosophy of Science and Technology. 5–10. august. Tšehhi tehniline ülikool, Praha, Tšehhi.

2018 No Anchor for Stanford's Scientific Realism. 7th National Meeting in Analytic Philosophy, 13–15. september. Lissaboni Ülikool, Lissabon, Portugal.

DISSERTATIONES PHILOSOPHICAE UNIVERSITATIS TARTUENSIS

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