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Models without a Target

Modelos sin target

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Abstract

It is frequently acknowledged that some scientific models do not have a target. In that case, it is not clear how surrogative reasoning is possible. In this article, I contend that every model has a target. I argue that targets should not be identified with selected phenomena or with selected portions or aspects of the real world. I intend to show that the target of any model is always the outcome of a complex process of construction, a process that cannot be accounted for solely by means of abstraction from the phenomena. I conclude that although all models have a fixed target, their domain of application may change or even be empty.

Keywords: representation, maps, phenomena, abstraction, ether.

Resumen

Se afirma con frecuencia que hay algunos modelos científicos que no poseen un target. En tal caso, no resulta claro cómo es posible el razonamiento surrogativo. En este artículo defiendo la tesis de que todos los modelos tienen un target. Argumento que los targets no deben identificarse con determinados fenómenos selectos, ni con porciones o aspectos selectos del mundo real. Intento mostrar que el target de cualquier modelo siempre es el producto de un complejo proceso de construcción, proceso que no puede explicarse solamente por medio de la abstracción a partir de los fenómenos. Concluyo que, aunque todos los modelos tienen un target, sus dominios de aplicación pueden cambiar o incluso ser vacíos.

Palabras clave: *representación, mapas, fenómenos, abstracción, éter.*

1. Introduction

It is generally acknowledged that some scientific models do not have a target, but it is not clear at all how we should understand that kind of models. Do they represent anything at all? The standard account of scientific models conceives of them as representations of some selected phenomena or domain of phenomena. There are many examples of models which are able to exemplify a representation relationship: a map represents a territory, an aggregate of plastic balls connected by rods represents the structure of a molecule, and so on. The very concept of representation turned out to be hard to elucidate, but I do not want to address it here.[1] On the standard account, models represent their *target systems* by means of certain (concrete or abstract) objects called the *vehicles* of the representation. Many efforts have been devoted to determining the conditions that must be fulfilled to guarantee that a model *M* represents a target *T*. According to Frigg and Nguyen (2016, 228), denotation is a necessary condition for representation, so that if *M* represents *T*, then *M* denotes *T*. As a consequence, targetless models cannot be conceived of as scientific representations of some phenomena. This implies that models are not always representations, precisely because there are models without a target. But how we should understand them?

A widely acknowledged function of scientific models is *surrogative reasoning*: we use a model (the vehicle of the representation) to obtain information about another object (the target of the representation). More precisely, by applying certain operations on the vehicle (from direct manipulation to solving equations) we learn something about the target. This kind of reasoning is called surrogative because it consists in drawing valid inferences about the structure or the behavior of the model and to attribute the conclusions of those inferences to the target itself.[2] It is then assumed that some propositions which are true of a given model are also true of the target system represented by such a model. Those propositions, of course, should be construed as empirical hypotheses, which are able to be true of the model but false of the target system. In any event, the model itself is used as a generator of new scientific hypotheses, or better, as a tool for inventing those hypotheses. However, according to this scheme, no surrogative reasoning is possible with targetless models. If so, which is the epistemic value of that kind of models?

Any reasonable account of scientific models must provide an explanation of how models are used as surrogates in order to obtain information on their

[1] Frigg and Nguyen (2017) provide a useful guide of this intricate topic and a very extensive bibliography. Most philosophers of science conceive of models as representations. The list of names and works would be too long to be given here. It includes almost all the references in the cited article, even the authors themselves.

[2] The concept of surrogative reasoning was introduced by Swoyer (1991), and elaborated, among others, by Contessa (2007).

target systems, and, at the same time, it must accommodate the (apparently) uncomfortable fact that many models do not have an intended target.[3] At first sight, it seems that the two requirements are incompatible because having a target is a precondition for performing surrogative reasoning.

In this article, I want to sustain the claim that every model has a target, and as a consequence, surrogative reasoning is always possible. The main point of my argument is that we should not identify the target of a model with a phenomenon or a real system. Once we have made the distinction the problem is not whether there are targetless models, but whether or not a given model has a nonempty domain of application.

I will proceed in the following way. In the next section, I will revisit the well-known analogy between maps and models. I will argue that the analogy does not permit to make sense of targetless models, and, more generally, that it is not suitable to understand even targeted scientific models. In section 3, I will address the question of how targets are constructed from phenomena. In section 4, I will analyze how the existence of models without a target has been accounted for. In section 5, I will give a brief historical review of the mechanical models of the ether, an alleged example of models without a target. In section 6, I will intend to make a case for the claim that every model has a target. Finally, in section 7, I will explore the consequences of rejecting the existence of targetless models. I will conclude by pointing out some of the advantages of conceiving of all scientific models as targeted models.

2. Models, maps, and targets

One of the most popular analogies intended to elucidate how scientific models represent their targets is the comparison between models and maps. This strategy had been employed by several philosophers of science in order to explore what scientific theories are and how they are used. Nonetheless, the analogy seems to be suitable for models but not for theories.[4] Ronald Giere was one of the first philosophers of science in conceiving of models as maps and in exploring systematically that analogy.[5] According to the analogy, scientific models represent their targets as maps represent their territories. Like any analogy, it has its limitations, that is, there are both positive and negative analogies between models and maps.

[3] According to Frigg and Nguyen (2017, 55), those are two out of the five conditions of adequacy that any sensible account of models will have to meet. The remaining conditions are the possibility of misrepresentation, the directionality of the representation, and the applicability of mathematics.

[4] I deal with this topic in Cassini (2011).

[5] See Giere (1997, 22-24) and Giere (2006, 72-80).

The most important positive analogy between models and maps, consistently developed by Giere, consists in the fact that there can be many different models of one and the same territory. Some maps may depict certain features of a territory, with an approximate degree of accuracy, and neglect the rest of the features of that territory. Other maps may depict the same features with more detail and accuracy. And a different class of maps may represent other features of the territory, neglecting those very features represented by other types of maps. For instance, there are many different representations of the railway network of a given city; some of them are very simplified and represent just the stops on a straight line, without informing us about the relative distances between the stops or the actual path of the trajectory, which may be curved at some points. Other more detailed maps of the same network may represent the relative distances between the stops, the number of streets the train crosses, and many other features. A different class of maps, say, one intended to represent the rivers and mountains of the region, may entirely neglect the railway network, depending on the purposes for which the map was designed. As everybody knows, all maps belonging to the same or to different types are mutually compatible: they simply represent different perspectives of one and the same territory, or, in some cases, the same perspective with different degrees of accuracy. If we find two incompatible maps of the same territory, we reasonably think that at least one of them has been erroneously designed. All maps are supposed to be complementary representations of a given territory. On the other hand, as it is obvious, no map is capable of representing all the features of one territory in every detail. The possible construction of a one-to-one scale map is a *reductio ad absurdum* of the very idea of mapping. As a consequence, we can say that any map provides an *idealized representation* of the territory, at least in the sense of neglecting some features of that territory and simplifying other features. A map is then an approximate representation of the territory to a certain degree of accuracy.

Something similar happens with scientific models, whose design depends on the specific problem they intend to solve (which, in turn, depend on the interests of the model-builders). Models are always idealized representations of their targets because they abstract some properties of them, which are not represented in the model, and distort other properties, which are represented in the model, but in a way we believe is not accurate or faithful. The way in which the target is represented by a model not only depends on the problem the model is designed to solve, but also on the representational media at our disposal in a given moment and place (limitations of budget and material resources, for instance, play an important role in present big science enterprises). There cannot be any doubt that there exist in science different compatible models of the same phenomena, but it is not the case that all models are complementary. As Margaret Morrison (2015) has pointed out, there are many incompatible models of the atomic nucleus, and those models cannot be conceived of as providing different perspectives of the same target. Or, to mention a simpler case, water can be represented as a continuous fluid or as a discrete aggregate of molecules linked by electromagnetic forces. We can rescue a certain sense of "perspectivism" by saying that those models adopt different points of view (a macroscopic and a microscopic one, respectively), but it is evident that they do not provide compatible representations of water. A continuous model and a discrete model of one and the same substance cannot be used simultaneously.

We find here some relevant negative analogies between geographical maps and scientific models in general. Maps are supposed to be *descriptions* –no matter how schematic or approximate- of an existent territory, but not every scientific model can be understood as a description of some phenomena. If we identify the territory with the target, it seems that there are models which are not similar to maps because they do not have a target. Many scientific models, such as numerical or statistical models, are purely predictive and do not intend to describe any feature of their targets or to explain their behavior. On the other hand, in most cases we have, or we can have in principle, an epistemic access to the territory; not necessarily a direct access, but at least one that is not mediated by any map. In this way, we can verify whether or not the map provides a reliable representation of the territory. For instance, if a map indicates that there is a lake, say, ten kilometers in the west direction from a given point, we can check this information by walking ten kilometers to the west (using compass and odometer) and corroborate whether there is a lake or not in that place. However, we cannot do the same thing with the atomic nucleus in order to see how the nucleons (protons and neutrons) are spatially distributed, say, in concentric shells or orbitals. Our epistemic access to the atomic nucleus and all its properties is unavoidably mediated by a complex network of theories, models, and measuring instruments. In some cases, we cannot even be sure that there exists a real target that was modeled. For example, we have had a rather detailed model of the Higgs mechanism before we have collected any experimental evidence that confirmed the very existence of the Higgs boson.[6]

All maps are representations of a particular territory that it is supposed to be real. Some scientific models also represent a particular target. This kind of models common in the field of engineering, where scale models of houses or bridges are constructed before the real buildings, but it is less usual in sciences, where models usually do not represent a particular object, but rather a type of object, that is, a universal. The cardboard and wire model of the DNA molecule produced by Watson and Crick did not intend to represent the structure of a particular molecule of DNA, but the general structure shared by all DNA molecules. By contrast, a map of the Martian surface is a representation of the

[6] Carroll (2012) is a detailed non-technical account of the discovery of the Higgs boson.

particular object we call planet Mars, but it does not intend to be a representation of other planets similar to Mars in some respects. Mapmakers assume that the territory they intend to represent is real, and they frequently have some previous acquaintance with that territory. Actually, maps are drawn and corrected by means of evidence that proceeds from a direct inspection of the territory, be that evidence collected from sensorial experience or from surveying instruments (such as photos taken by satellites).

Fictional maps (that is, maps of imaginary but not actual territories) belong to the kingdom of literature, but rarely are present in science. Of course, maps and models can misrepresent their intended targets in many ways, but every map is produced on the basic assumption that the territory they intend to represent is a real particular. No scientific map is consciously conceived as merely a useful fiction. Maps usually contain many representational devices which we assume as expedient conventions, for instance, towns are represented, according to the amount of their population, by means of triangles, squares or circles. Those marks do not intend to represent the actual geometrical form of the towns, but they do intend to represent, among other features, the place where the cities are located. If a map contains a mark that indicates the presence of a city where in fact there is no one, it is simply a misrepresentation of the territory, but in no way can be conceived of as a useful fiction. By contrast, scientific models frequently include many components regarded as fictions, that is, elements that do not intend to represent anything that is believed to be real.

These facts show that there are important negative analogies between models and maps and that the analogy itself has limitations, in particular, it is no able to illuminate many significant aspects of the use of target-directed modeling. On the other hand, the very existence of a growing population of models without a target apparently provides a strong negative analogy between maps and models. How should we conceive of models without a target? This is the specific point I will address in the remaining of this article.

3. Constructing targets

Target-directed modeling is undoubtedly the most simple and intuitive case of model building in science. Actually, the philosophical study of models started with this practice of modeling.[7] Over time, it has been acknowledged that the practice is not that simple and straightforward as it may seem at first sight. A naïve account of model building might claim that the starting point of

[7] General books on scientific models, such as Bailer-Jones (2009), Winsberg (2010), Toon (2012), Morrison (2015) and Gelfert (2016), are almost entirely focused on target-directed modeling. A noticeable exception is Weisberg (2013), on which I will deal in more detail in the next section.

modeling is the observation of some phenomenon or collection of phenomena that look surprising or unexplained in the light of the available knowledge. We then proceed to build a model of the observed phenomena, beginning by a rough approximation that is progressively refined and complicated. From this kind of targeted models, we obtain some epistemic access to the modeled phenomena: a certain description and/or explanation of their structure or behavior, or some predictions about their unknown properties or behavior under defined circumstances.

This rather naïve picture of the process of building scientific models is not only excessively simplistic but is misleading in many important respects. In the first place, the starting point of every modeling practice is not the mere observation of a phenomenon, but *the statement of a problem*. An observed phenomenon, no matter how startling may appear, is not a problem until we pose some questions about it. As a consequence, one and the same observed phenomenon can give place to many different problems, depending on the questions we pose, or to no problem at all. For example, the observed desertification of a former humid area may give place to very different kinds of problems for the geographer, the ecologist or the anthropologist, but it may pose no problem to the casual tourist who travels along that area. A scientific problem, like any problem, arises out of some interest of the epistemic agents in understanding or explaining the observed phenomena, or in predicting their future state or behavior.

An observed phenomenon is always a phenomenon *under a certain description*. Under a different description, the same sensorial stimuli may be regarded as an entirely different phenomenon. Observational reports, both in science and everyday life, are framed by general concepts. Those concepts do not necessarily come from technical terms of a scientific theory, but, as it is well known, some scientific phenomena, say, the production of a pair electron-positron inside a particle detector, are heavily theory- laden. In practice, observed phenomena are often described by means of well-entrenched concepts, which all observers belonging to a given scientific community understand. Those concepts belong to the background knowledge that every expert in a given domain of knowledge takes for granted. However, in a different historical context, where those concepts were not available, that description of an observed phenomenon could be utterly unintelligible, and the phenomenon in question could be not acknowledged at all, at least under such specific description. The production of a pair electron-positron, for instance, would have been hardly regarded as a phenomenon before the beginning of the 20th century.

A phenomenon under a certain description is not yet the possible target of a model. The target system of a target-directed model is the outcome of a construction from the phenomena. The starting point of the production of the target is the statement of a definite question concerning a given phenomenon. That question originates a specific problem to be solved by means of the model. Michael Weisberg (2013, 90) has pointed out that target systems are not the phenomena themselves; rather, he claims, they are "abstractions over phenomena". According to his account, scientists start by selecting the phenomena they are interested in studying and then proceed to delimitate the spatiotemporal region in which those phenomena are located. Every phenomenon identified in this way has many properties, but modelers are not interested in studying the total state (the set of all properties) of the phenomenon. Weisberg then states that scientists focus on "some scientifically important subset of these properties" (90) and "abstract away the others" (91). This yields a target system of the model, which is "a subset of the total state of the system" (91). As a consequence, one and the same phenomenon (under the same description) may originate different target systems, depending on the subset of selected properties.

Weisberg's account of the construction of target systems is certainly a step forward with respect to the naïve conception of model's targets as observed phenomena. Nonetheless, the involved process is not that simple. How the important properties of the phenomena are to be selected? This is a crucial question that Weisberg leaves unanswered. Abstraction of properties cannot be the first stage in the construction of a target system. In order to abstract some properties of a given phenomenon scientists must dispose of at least one criterion of relevance; only in the light of such criterion some properties of the phenomenon stand out as relevant. Now the question is: relevant with respect to what? And the answer is: relevant to the solution of the problem posed in the first place. The construction of a model necessarily has to start from a problem. The second step in the construction consists in determining the purpose of the model, that is, what kind of solution is expected from it and to which degree of approximation. This, in turn, is dependent upon the use to which the model is aimed at. So, in the end of the day, the target depends on the purposes for which the model is built, and on the users' interests in having a definite kind of model suitable to such purposes.

Let us take the example of climate models.[8] As we know, there are dozens of such models, which are aimed at different targets. On the other hand, there are very different types of users for those models. The observed phenomenon of the desertification of a former humid region, to which we have already referred, can be easily described by using concepts such as annual mean temperature, annual or monthly precipitation, and others. This phenomenon described that way is not yet the target of any possible model. In order to build a model concerning desertification of a region a definite problem concerning

[8] Recently, climate models have been the focus of a growing interest by philosophers of science. See, for instance, Lloyd and Winsberg (2017) and Winsberg (2018).

that phenomenon has to be posed. Many different problems can be posed, which will determine many different targets, or constraint to build targets, for the models intended to solve those problems. But no concrete model can be constructed without specifying the interest of the potential users of the model. A farmer who works in a nearby region may have a definite and narrow interest in the phenomenon: for him or her the problem is whether the desertification is growing in a preferred direction, more specifically, whether it is directed towards his or her lands, and, in that case, to which rate on a significant timescale. This is a very specific problem whose solution requires a narrow class of potential models. The properties which regarded as relevant to the construction of the target can be selected only on the basis of this problem and the expected solution. In this case, the direction of the process of desertification is highly relevant to the user, and consequently, it has to be selected for the construction of the target. With respect to other problems, posed on the basis of different purposes, this specific property could not count as relevant and would be neglected in the construction of the target.

To summarize: the target is the outcome of a construction performed on the basis a specific description of some phenomena and is guided by the interests and purposes of the modelers, which drive them to pose a well-defined problem and its expected solution. Once the problem has been defined it is possible to identify the target of the model intended to solve that specific problem.

4. Models without a target

Target-directed modeling does not exhaust the practice of building models in science. Many scientific models, apparently, are not intended as a representation of a specific target. In the first place, there is a purely exploratory use of models, which has been analyzed by Axel Gelfert (2016). Gelfert has pointed out that there are several positive analogies between exploratory experiments and the exploratory use of models. Sometimes models are built in order to obtain a preliminary epistemic access to a domain of phenomena that are recently discovered, phenomena on which we have no theories at our disposal. A model is then constructed as a starting point of the research concerning that domain of phenomena. The inquiry on the new domain usually begins with a very simplified and roughly approximate model of the phenomena, which is progressively completed and enriched, resulting in a whole series of models of increasing complexity. In the course of this process, phenomena are often redescribed by means of suitable novel concepts and new problems are posed, which, in turn, may result in the construction of a definite target for some of the models. What is relevant to our purposes here is the fact that the series of models do not start from a well-defined target, although it is able to end by identifying a specific target.[9] In other cases, the suitability of the target is explored by studying the models, a process that may lead to the restatement of the problem posed in the first place, and then to the redefinition of the target itself. In this way, the practice of modeling is not always directed to a target but has to be conceived as a multidirectional complex activity that goes back and forth from phenomena to problems and from targets to models.

Needless to say, the pervasive use of computer simulations in contemporary science has greatly increased the potentialities of exploratory models, in particular of mathematical models. Simulations permit a whole spectrum of variation of initial and boundary conditions, and/or of the values of the different parameters included in a given model. The limits of the applicability of a model can be explored in ways that could be unavailable without powerful computing capacities. The suitability of the target of a model can be discovered after a long process of computer simulation that starts from models without a definite target.

A different class of models without a target is captured by the study of potential or possible targets. Weisberg (2013, 121) calls this practice "hypothetical modeling". However, that expression seems not to be the most appropriate because there is a sense in which all models are hypothetical, that is, they assume that some features or structures of models can be tested and corrected in the light of experience. Maybe it is better to call them counterfactual models. They refer to phenomena we believe are not actual, but are regarded as possible by our accepted theories. An example is provided by models of evolutionary development in counterfactual conditions such as a population of three-sex organisms, or a population that lives within an environment entirely deprived of oxygen. By means of this kind of models we learn about the consequences of our laws of nature, for instance, we can learn which physical or biological processes are possible or viable, and which ones are impossible or unviable. Counterfactual models are studied for its intrinsic interest because they permit to explore the scope and limits of our laws and theories about nature.

Are models without a target purely fictional? Can we say that they are models of non-existing entities or phenomena? I will claim that the answer to these questions should be negative.

According to Weisberg,

> There are two kinds of things that hypothetical models can tell us about real-world phenomena, corresponding to two cases of non-existence. For the first, the theorist constructs a model of a target

[9] This is just one of the many exploratory functions that models are able to fulfill (see Gelfert, 2016, 85-94, for other exploratory uses).

> which, as a matter of contingent fact, does not exist. For the second, the existence of the target is physically impossible. (Weisberg, 2013, 121-122)

A model of the evolution in a population of three-sex organisms would be an example of contingent nonexistence, whereas a model of a perpetual motion machine would be an example of necessary nonexistence.

Frigg and Nguyen characterize the existence of models without a target in the following terms:

> Some of these [targetless models] are models of discredit entities like the aether and phlogiston. But not all models without targets are errors. Architectural models of buildings that have never been erected, and models of theoretical constructs, like three-sex populations or Yang-Mills particles, that were known all along not to exist are cases in point. (Frigg and Nguyen, 2016, 234)

In my view, the problem with these statements is that they overlook the distinction between the targets and the real phenomena. I grant a minimal ontological realism according to which there is a real world that exists in itself and is independent of epistemic agents. But this realism does not apply to targets, which are intentional objects that depend on the modelers' intentions and purposes. The target is a constructed entity, not a thing in itself. Sometimes it is constructed by selecting properties of observed phenomena but is not itself a phenomenon. A model has a target just because the modelers have constructed it, not because it denotes a real entity. As a consequence, it is not possible to define a targetless model as the one that has no denotation.

We cannot draw straightforward conclusions concerning the existence or nonexistence of real phenomena from the intended target of a model. As Frigg and Nguyen acknowledge,

> Sometimes a model that is thought to have a target turns out not to have one (for instance, Maxwell's aether model); sometimes a model that was thought not to have a target is found to have one after all (for instance, Dirac's electron model indicating that there were electrons with a 'wrong' charge, now known as positrons); and sometimes the existence of a target is left open and considered a matter of further study (for instance, models of superstrings). In as far as a model is an act of the imagination, often nothing in that act changes when targets come and go. Many models cross the border from targetless to targeted (and back) unchanged, or stay happily in the buffer zone between the two. (Frigg and Nguyen, 2016, 235)

In Frigg and Nguyen's account, we should say that Maxwell's ether model does not denote anything real, that Dirac's positron model does denote a real entity, and that we still do not know whether superstring models are denotative. As a consequence, we should say that Maxwell's model is a fictional model, because it has no target, whereas Dirac's model is not.

In a recent review article on scientific representation, Frigg and Nguyen express their opinion on the subject in a straightforward way:

> Models of ether, phlogiston, four-sex populations, and so on, are all deemed scientific models, but ether, phlogiston, and four-sex populations don't exist. Such models lack (actual) target systems […]. (Frigg and Nguyen, 2017, 54)

In my view, the target of Maxwell' mechanical ether model was actually the luminiferous ether, whose existence was regarded as necessary by him and all ether theorists of the 19th century. And the target of present superstring models is superstrings, whose existence is postulated by superstring theorists. But such targets are not the real phenomena, which remain unobserved. Those targets are what the modelers intend to represent with their models. For those who constructed the models, they were not fictions at all. Whether luminiferous ether or superstrings really exist is an entirely different question.

We do not have any direct access to reality in such a way that we were entitled to ascertain whether a postulated entity, such as the ether, actually exists or is a pure fiction. Popular science writers, and sometimes also respectable scientists, often claim that we have discovered the existence of some new kind of entities, such as the Higgs boson or dark energy. This is not an epistemologically justifiable claim. We simply have collected evidence that we regard as confirmatory of a theoretical or empirical existential hypothesis. Sometimes the evidence may be compelling, but in any case, we can be wrong. It is possible that in the far future we will reinterpret all that evidence as confirmatory of an entirely different hypothesis that has nothing to do with the existence of the supposed new kind of entity. With respect to the nonexistence of unobserved entities, such as the luminiferous ether, we are not in a position to ascertain anything definitive (as I will try to show in the next section). I do not intend to deny that we have a convincing amount of experimental evidence concerning the existence of some physical entities, such as electrons or protons, and that we do not have very much evidence (if any) concerning the existence of certain theoretically postulated entities, such as the ether or the phlogiston. I simply want to point out that, no matter the amount of confirmatory evidence, existential hypotheses, like any other scientific hypothesis, are fallible and might be discarded in the future.

Whatever we regard as physically possible or impossible is relative to our accepted theories about the physical world. Massive particles accelerating up to the speed of light in vacuum are physically impossible according to the special theory of relativity; nonetheless, they are perfectly possible in the framework of Newtonian mechanics. We can never be able to ascertain that a phenomenon is physically impossible in an absolute sense. Our best confirmed theories could be wrong and replaced by other theories, in the light of which a former physically impossible phenomenon turns out to be possible (or vice versa). The orbital motion of the Earth in ancient and modern physics is a good example of that change. Because we are not able to know that our present theories are true, or even truthlike, we cannot exclude such kind of theory replacement.

On the other hand, whatever we regard as a matter of contingent fact as nonexistent is always relative to the available evidence. As that evidence changes, our judgments concerning contingent existence may undergo radical changes. Until a few decades ago we had no evidence concerning the existence of dark matter, dark energy or exoplanets. For the moment we have no evidence about the actual existence of extraterrestrial life, but no accepted physical or biological theory permits to exclude such possibility. A population of three-sex organisms living on the surface of a remote planet is also a possibility, although unlikely, that cannot be rejected on the basis of our present theories. In conclusion, every judgment concerning contingent or necessary nonexistence is relative to our available knowledge, and, consequently, is revisable in the light of new evidence and new theories.

All this has consequences on what we regard as a fictive or a real phenomenon. A fictive entity is a nonexistent entity, but, as we have argued, we are not able to know that an entity does not exist, unless its existence implied a contradiction. If an entity is not logically impossible, we cannot exclude its existence on the basis of our present knowledge. All we can say is that such an entity is physically impossible with respect to our best confirmed theories. What, then, is a genuine fiction? In my view, the only sensible answer is that scientific fictions are relative to some established theory or background knowledge. A particle that goes through one definite slit towards a screen in the double slit experiment should be regarded as a fiction in the light of orthodox quantum theory because, according to that theory, particles do not have definite trajectories in space. However, in the context of Bohm's quantum theory particles do have definite positions and trajectories in space so that the paths of the particles in the double slit experiment have to be regarded as real phenomena; those trajectories, although they are not observable, can be reconstructed and visually represented. The dependence of existential (or non-existential) judgments upon determinate theories becomes manifest when there are rival theories that disagree on the existence of some physical phenomena, as in the above example.[10]

5. Models of the ether

Were the 19th century models of the luminiferous ether purely fictive? Were they targetless models because they failed to denote a real entity? Do we really know that the ether is a nonexistent entity? An affirmative answer to the first question would be anachronistic, while affirmative answers to the second and third ones would be examples of a naïve realist stance towards scientific theories.

This is not the place to recall the complicated history of the luminiferous ether.[11] Just a few historical remarks will suffice for our purposes in this article. The existence of a material media that was the substrate of light waves was postulated by the end of the 17th century as a necessary requirement for the undulatory theory of light. Huyghens (1690, 11-12) resourced to the old analogy between sound and light in order to argue that the propagation of light waves requires the existence of a material medium, whose vibrations produced all luminous phenomena. This substance, called "ethereal matter", was not observable, and for that reason, its internal constitution, which Huygens assumed to be an aggregate of particles, was rather a matter of speculation. Nonetheless, the mechanical properties of the ether could be inferred from the observable behavior and the empirically determinable properties of visible light. Those properties turned out to be very special because the ether had to be able to vibrate at a high speed, as if it were an extremely rigid solid, but at the same time, it had to offer no resistance to the motion of the material bodies. In any case, the very existence of the ether was not questioned until the beginning of the 20th century, when Einstein put forward his special theory of relativity.

As a matter of fact, Maxwell and all ether theorists of the 19th century assumed that the ether was not a useful fiction, but a real existent physical substance. The luminiferous ether became the electromagnetic ether, the material support of electromagnetic waves. The mechanical models of the electromagnetic ether did not intend to represent its physical structure, but rather its dynamical behavior. Those models were explicitly analogical so that they should not be interpreted literally as descriptions of the real properties of the ether. For instance, they did not assume that the ether was a turbulent fluid,

[10] Bricmont (2016) contains a useful comparison between the standard quantum theory and Bohm's theory, from a standpoint that is sympathetic to the latter.

[11] On models and theories of the ether in the 19th century see Schaffner (1972), a work that includes a useful selection of original sources.

but simply that it behaved, in certain aspects, in a similar way to other material fluids. In any case, those mechanical models were supposed to denote a real substance, whose properties could not be observed, but could be inferred from luminous and electromagnetic phenomena.

The luminiferous ether, which was supposed to fill all the apparently empty space, provided a sort of absolute inertial referential for the motion of all material bodies. As a consequence, the Earth's orbital motion, taken for granted by all physicists of the 19th century, had to become manifest in a sufficiently accurate optical experiment. In 1810 François Arago started a long sequence of null results for different experiments of that kind, both refraction and interference experiments.[12] There was a noticeable exception provided by Fizeau's 1851 experiment concerning the propagation of light in running water, which was interpreted as confirming Fresnel's hypothesis according to which the ether was dragged along by moving transparent media (in proportion to the refractive index of the medium). Fizeau's experiment had a genuine positive result, which reinforced the generalized acceptance of the ether hypothesis. As late as 1902 Poincaré remarked that Fizeau's experiment was so convincing as to force us "to believe we touch the ether with one finger" (Poincaré, 1902, 181).

The demise of the ether hypothesis is usually associated with the rise of the special theory of relativity. However, in his 1905 epoch-making article Einstein just stated that according to his theory "the introduction of a 'light-ether' will prove superfluous" because in his theory "no 'space at absolute rest' endowed with special properties will be introduced" (Einstein, 1905, 141). He did not affirm there that the existence of an ether was incompatible with his theory. In later papers, he gave a step forward with respect to his original work and explicitly stated that his theory "was not compatible with the ether hypothesis" (Einstein, 1911, 341). He even declared that one of the "major results" of the special theory of relativity was that "the hypothesis of the existence of a space-filling medium for light propagation, the so-called light-ether, has to be abandoned" (Einstein, 1914, 5). After the formulation of his general theory of relativity Einstein changed his mind concerning that hypothesis. By 1920 he vindicated the existence of a gravitational ether, which he identified with the space-time continuum and with the gravitational field (Einstein, 1920b). He also revised his stance against the luminiferous ether. In an unpublished manuscript he revisited the topic in the following terms:

> […] My opinion in 1905 was that one should no longer talk about the ether in physics. But this judgment was too radical […]. Rather, it is still permissible to assume a space-filling medium whose states may be imagined as electromagnetic fields (and perhaps also as matter).

[12] Janssen and Stachel (2004) is a useful historical account of those experiments.

> But it is not permissible to attribute to this medium states of motion in every point, like in analogy to ponderable matter. This ether must not be imagined as consisting of particles whose identity could be traced in time. (Einstein, 1920a, 130)

In the framework of the special theory of relativity, the luminiferous or electromagnetic ether is deprived of all mechanical properties, including that of a state of motion (a supposed absolute rest). It follows from this fact that no physical experiment, as a matter of principle, could possibly measure any effect arising from the relative motion of the Earth and the ether. In this way, the existence of a relativistic ether turned out to be compatible with the null results of all ether-drift experiments.[13]

The hypothesis of the existence of the ether was abandoned because both the special and the general theory of relativity were able to be formulated without resourcing to that hypothesis. But no experiment could possibly prove that the ether does not exist, simply because unrestricted existential hypotheses are not refutable from a logical point of view. This is a general lesson: we cannot prove that a certain kind of entity postulated by a given theory does not exist; at most, we can dispose of the corresponding existential hypothesis because we have a theory in which such hypothesis plays no role in the explanation of the known phenomena. The special theory of relativity, for instance, was able to explain the results of all ether experiments without resource to the ether hypothesis. The positive result of Fizeau's experiment was then reinterpreted as a particular case of the relativistic transformation of velocities.[14]

The moral of the ether historical case is that we are not entitled to say that mechanical models of the ether were mere fictions, or that they were targetless models because the ether simply does not exist. Consequently, we cannot say that those models did not represent anything because they did not denote a real entity. As a general rule, it is not possible to determine whether a model does not denote a real phenomenon. Unless the model is self-inconsistent, it is always an open question whether it describes some existing phenomenon or entity in the real world. This fact can be established exclusively in cases in which the phenomena are restricted in space and time. But if the model does not include any restriction concerning the spatiotemporal location of its target, as a matter of principle its lack of denotation cannot be ascertained. As far as we know, a model of a three-sex population on the Earth planet does not denote anything real, but we cannot be sure that there are no three-sex

[13] A detailed account of Einstein's conception of the ether is given by Kostro (2000). See also Cassini and Levinas (2009) for a philosophical discussion of the same issue. All translations of Einstein's works are taken from the edition of his collected papers (Einstein, 1989-2015).

[14] Cassini and Levinas (2018) is a detailed study of this historical episode.

populations of living organisms in remote regions of the universe. This is a well-known fact concerning the denotation of descriptions (and names generally); we know that there are not mountains a hundred kilometers high on the Earth's surface, but we can never know that there are no such mountains on the surface of any planet in the whole universe.

Frigg and Nguyen (2016, 234) referred to the ether (and the phlogiston) as "discredit entities" and to the corresponding models as "errors". From the above considerations, it follows that we are not entitled to say that those models were errors (if this means that they were false descriptions); rather, we should say that they have not been successful and, for that reason, they have been abandoned by scientists. On the other hand, the ether and the phlogiston actually are discredit entities, but not because it has been proved that they are not real. A scientifically discredit entity is not necessarily an unreal entity. Maxwell's mechanical ether was discredited for two different reasons. In the first place, because very peculiar properties had to be attributed to it -such as extreme rigidity and lack of resistance- and these properties appeared to be hardly compatible in the light of the accepted physical theories at that time. In the second place, it was discredited because a long sequence of optical experiments failed to detect any effect of the relative motion between the material bodies and the ether. Nonetheless, no experiment was able to prove that this kind of mechanical ether does not exist. The null result of such experiments, in principle, can be explained, for instance, by several different hypotheses concerning the interaction of the ether and the material bodies. On the other hand, the hypothesis of the relativistic ether did not attribute mechanical properties to the ether, and implied the null result of every optical experiment concerning that entity. This kind of ether is a discredit entity in a similar sense in which Newton's absolute space is discredited: because it has been proved that it is superfluous (as Einstein remarked) for our physical theories. More specifically, the special theory of relativity has shown that we are able to formulate a successful mechanics without postulating absolute space and a successful electrodynamics without postulating electromagnetic ether. But, in any case, it does not follow from this fact that the absolute space and the ether do not exist. The theory by itself does not include or imply any negative existential hypotheses concerning such entities.

6. There are no models without a target

Behind the idea of targetless models, there seems to be a remnant of a naïve realism about the furniture of the world. This happens when we conceive of targets as being simply real-world systems, or parts of the real world. Frigg and Nguyen (2017, 51) say in this respect that "models are representations of a selected part or aspect of the world; this is the model's target system". There are some obvious problems with this definition (or characterization) of targets. In the first place, the real world by itself does not select any aspect or part of it. Every selection has to be performed by epistemic agents on the basis of their background knowledge and their interests, and by means of a set of selecting hypotheses. Because of that, a target system cannot be understood as a part of the real world, but rather as a constructed entity. In the second place, we (human epistemic agents) do not have any direct access to the real world. In order to sustain this claim, it suffices to think about the world of the genes, atoms or elementary particles. In the best case, we have epistemic access to some of the phenomena produced by those kinds of entities. And, as we have remarked in a previous section, the construction of a target from the observed phenomena is a very complex process.[15]

The target system of a model cannot be identified with a portion of the real world or even of the phenomena. The target is the final output of a constructive process that involves many different stages. Generally, the modelers do not go through all the stages of construction. They start from a certain domain of phenomena that have been previously discovered, explored in several ways, and described and redescribed by means of shared concepts and hypotheses. That is, they start from the phenomena under a certain description accepted by a given scientific community in a certain moment. The description of the phenomena may include the previous knowledge of some empirical regularities (often statistical correlations) about the behavior of those phenomena. On many occasions, a model of the data taken from the phenomena is available before the construction of the target of a given model. Granted, some models are purely exploratory and their targets are not very well defined. Nonetheless, any target-directed model has to start from some description (no matter how rough and elementary) of the phenomena to which they are intended to apply.

Which is then the starting point of the construction in the case of the so-called targetless models? Abstraction from observed phenomena does not help us very much here. We can conceive of this kind of models as having an imaginary target, but I do not think that appealing to mental entities could be a very enlightening or explanatory strategy. I am rather inclined to believe that those models are built on the basis of some previously existing theories, as is the case with models of superstrings. In those domains of research where there are no sound theories, or there are no theories at all, targetless models are developed by means of analogies with known theories, using preliminary hypotheses as well as collected data from different domains of phenomena.

[15] I have not intended to elucidate the details of the process here. I just want to point out that it is a complex process of construction. Weisberg's (2013) remarks on the subject in chapter 5 of his book are just a start at understanding how targets are built. The whole issue is still in need of further research.

For instance, a model of a three-sex population that evolves in a given environment is built on the basis of our knowledge of the evolution of two-sex populations in previously explored environments.

Are those models really models without a target? Two reasons have been invoked to believe they have no target. The first is the overly simplistic claim that there are no physical systems to which such models refer or denote; say, three-sex populations do not exist. As I have argued, this kind of negative existential claims are not epistemologically justified. What we are entitled to assert is that for the moment we have no evidence concerning the existence of real systems such as three-sex, or many-sex, populations. The most reasonable attitude is then to suspend the judgment concerning the existence of those systems. It follows from this attitude that we also have to suspend the judgment concerning the existence of the target of models of three-sex populations, or models of superstrings. If so, we cannot say that they are targetless models. We should simply say that we do not know whether they have a target or not.

The second reason to claim that a model has no target is that it has not been constructed from observed phenomena. But this is not a necessary condition for being targetless, because some models which do have a target did not originate by means of abstraction from well-defined phenomena. We are able to build a model on the basis of a principled theory, such as Newtonian mechanics or general relativity, and then proceed to apply it to different phenomena. For example, from Newton's theory of universal gravitation, we can build a model of a two-body system of masses that interact solely by means of the gravitational force. When the theoretical model is ready, we can go on by applying it to different physical systems composed of two bodies, such as the Earth-Moon system or the Sun-Earth system. These two-body systems are phenomena that have been abstracted or isolated from a much more complex phenomenon, a many-body system as it is the Solar System. Nonetheless, the two-body gravitational model was not constructed by means of an abstraction process from the observed phenomena concerning the Earth-Moon system or the Sun-Earth system.

Given that there are significant difficulties to justify the claim that a model has no target, it seems more promising to search for a different approach to solve the problems posed by this kind of models. Those difficulties arise mainly from a rather naïve realist conception of targets as portions or aspects of the real world. I have argued that targets are constructed objects, which cannot be identified with the real world or the phenomena. Consequently, I believe that it is better to think of all models as being directed to a target. Any model is a model of something, and this something is its target. We can conceive of the target as an *intentional object* correlated with the model. In this sense, the target of a three-sex population model is a three-sex population system, regardless of the existence of three-sex populations in the real world. It is possible to think that targets (and models themselves) are abstract entities, although I do not see any clear advantage in categorizing them in this way. It is not my purpose to explore here the ontology of models and targets. This would be the topic for a different article. From my perspective, the problem concerning the the ontological status of models in general is still an open question, and the same remark applies to the targets. In any case, it is a question that I do not regard as particularly relevant to the study of the many uses and functions of models in science. I borrowed the expression "intentional object" from the language of phenomenology, but I do not concede very much importance to this tag. It is simply a reminder that the target of a model is not a phenomenon or a portion of the real world.

It is certainly true that some models are intended to be applied to some domain of the real world, whereas other models are not constructed for this purpose. To be more precise, some models intend to describe the behavior or the structure of some entities that the modelers assume as existing in the real world. This is the case of the mechanical models of the ether in the 19th century or of the superstring models nowadays. Other models are built on the assumption that they do not describe real entities, as is the case with the three-sex population models. The difference between the two kinds of models depends on the background knowledge and the intentions of the modelers. Nonetheless, this difference is not relevant in order to distinguish between models with or without a target. In my view, both types of models do have a target.

7. Conclusion

I have argued that we do not have a clear-cut criterion to distinguish between models with or without a target, and for that reason, it is convenient to conceive of all models as directed to a target. What is then the difference, say, between a two-sex population model and a three-sex population model? The main difference lies in their domains of application. We have found many phenomena to which a two-sex population model can be applied, but we do not know of any phenomena to which a three-sex population model could be applied. We are not entitled to assert that three-sex populations do not exist *simpliciter*. All we can say with certainty is that within the sparse portion of the universe we have effectively explored, we have not found any evidence of their existence.

The difference between what have been called models with or without a target should be recategorized in the light of the former considerations. Given that, according to my proposal, every model is target-directed, the relevant difference becomes that between models with or without *domains of appli-*

cation. The distinction is relative to our knowledge of the phenomena in a given moment. We routinely discover that a given model has a new domain of application, sometimes in the realm of unintended phenomena. Conversely, we have discovered that some models cannot be successfully applied to certain domains of phenomena to which we wanted to apply them, or to which we believed they could be applied. Likewise, we could discover in the future that a model without a known domain of application is able to be applied to new and unexpected phenomena. Perhaps someday we will manage to collect experimental evidence concerning superstrings, or we will discover a three-sex population living on the surface of a remote exoplanet. No matter how unlikely those facts could appear nowadays, we cannot discard the possibility of their existence. For that reason, we are not justified in claiming that a three-sex population model, or a superstring model, has no possible domain of application. Al we are entitled to say is that up to now we have not discovered any phenomena to which those models could be applied.

Models are not the kind of entity that bears truth-values, or that can be confirmed or refuted by experimental evidence. What is capable of being true or false is the statement that a given model applies to a determinate domain of phenomena.[16] A statement of this kind (that a model *M* can be successfully applied to a domain of phenomena *P*) -but not the model *M* itself- is able to be confirmed, to a certain degree, by the evidence we have collected about the phenomena. In some circumstances, the evidence may compel us to regard that statement as false. And, in that case, we will not say that the model has lost its target-or one of its targets-, but rather that its domain of application has been restricted. It is widely acknowledged that the domain of application of models is not fixed once and forever, but rather that it can be extended or restricted, depending on the changes in our knowledge of the phenomena. The target of a model does not come and go; what does undergo changes is the domain of application of the model. The target of a two-body gravitational system model, or the target of a two-sex evolving population model, remains the same through all the changes that its domain of application may experience.

If this is the case, the target of a model must be considered as one of the characteristic properties that identify that model. A change in the target of a given model would then imply a change of model. For instance, the target of the well-known Lotka-Volterra model is a system of predators and preys. The model was originally devised around years 1925-1926 to account for the life cycles of some species of fishes that inhabit the Mediterranean Sea. As a matter of fact, the model found many other domains of application to different systems of predators and preys among different species in different

[16] Those sentences are called "theoretical hypotheses" or "empirical assertions" by the endorsers of the model-theoretic (generally called "semantic") conception of scientific theories.

environments.[17] However, the target of the model was not altered by those extensions of its original domain of application. If we were to modify the target, for instance, to extend the model to a system of many species of predators that interact with one species of prey, the resulting model would be a new and entirely different model, which simply on analogy might be called a Lotka-Volterra model.

If every model has a fixed target, as I have claimed, the problem of how surrogative reasoning with targetless models is possible turns out to be immediately solved. When we work with a model we always learn about its target. By studying a three-sex population model we learn how a three-sex population will behave in certain environmental conditions. Up to this point, there is no difference between that model and a two-sex population model, the Lotka-Volterra model, or any other scientific model. The difference lies in the fact that we presently know many domains of application of a two-sex population model, but no domain of application of a three-sex population model. For that reason, we can check whether the surrogative inferences we have performed about the target of the two-sex model turn out to be true or false, or confirmed to some degree, when they are compared to the evidence we have collected on the phenomena to which the model is intended to be applied. Because we do not know any purported domain of application, we cannot do the same with a three-sex population model (or with superstrings models, or with many other theoretical models). Or, to use the language of the model-theoretic view of theories, we can say that we have tested many theoretical hypotheses (or empirical assertions) concerning two-body gravitational systems and two-sex populations, but no hypothesis concerning superstring models or three-sex population models. Nonetheless, all these models have a definite target we are able to explore by studying the models themselves, independently of their domains of application. The very possibility of performing surrogative reasoning is an essential feature of any scientific model. We could not make sense of this possibility if we were to accept the existence of models without a target.

A final word about fictions: it is possible to conceive of all scientific models as useful fictions, or of some of them, or even to grant that, although models are not fictions, they always contain some fictional components. These and other possibilities have been explored by different authors.[18] Whatever

[17] The Lotka-Volterra model has been one of the favorite case studies for many philosophers of science. See, among others, Weisberg (2012, 10-13) and Gelfert (2016, 58-61).

[18] Suarez (2009) is the standard book on scientific fictions. Frigg and Nguyen (2017) provide a brief general account of the fictionalist conception of models and a survey of the relevant literature. I have employed here the concept of fiction without elucidation, but it certainly is in need of much elucidation.

the position we take on this question, it cannot be based on the distinction between models with and without a target. We should not identify fictional models with models without a target.

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