MARITAIN, INSTRUMENTALISM, AND THE PHILOSOPHY OF EXPERIMENTAL SCIENCE

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Is Jacques Maritain's philosophy of the experimental sciences, the sciences of observation, fundamentally at odds with Maritain's causal realist understanding of the philosophy of nature as one of the genuinely deductive sciences of explanation? This is an important question in Maritain studies, for on it hinges the broader question of the coherence of Maritain's philosophy of science as a whole. Yet how we answer it very much depends on how we characterize Maritain's philosophy of the experimental sciences. If Maritain's conception of experimental science is a conventionally instrumentalist one, as it at first glance appears to be, one could well make the case that his philosophy of the sciences of observation is truly incompatible with a causal realist view of nature. If, on the other hand, Maritain is not an instrumentalist, or at least not an instrumentalist in the conventional sense, then his philosophy of the experimental sciences may turn out to be compatible with his causal realist philosophy of nature, for not every version of instrumentalism is incompatible with causal realism.

The purpose of this paper, then, is to find out if Maritain is an instrumentalist, and if so, just what kind of instrumentalist he might be. In order to do this, I must first define what instrumentalism is, and then determine if Maritain's position coheres with that definition. Thus, I define instrumentalism in section I, and then in section II elaborate Maritain's philosophy of experimental science, showing exactly how Maritain's position is instrumentalist and in what ways it is not. I conclude in Section III that, although Maritain was indeed an instrumentalist, his version of instrumentalist philosophy of the experimental sciences leaves room for completion by a causal realist philosophy of nature.

I. INSTRUMENTALISM

In order to see how Maritain's philosophy of experimental science is a qualified instrumentalism, we must first address the basic question: What is instrumentalism?

In the broadest sense instrumentalism[1] in the philosophy of science can be defined simply as the view that scientific theories are not true pictures of reality, but merely instruments or tools useful for making calculations and predictions. More specifically, instrumentalists claim that the categories of truth and falsehood cannot be used to evaluate scientific theories. Rather, what counts in instrumentalism is that theories "work," and theories work when they successfully provide the scientist with guiding principles or "inference tickets" which enable him to organize and/or relate observation statements which, when used in conjunction with other observation statements, entail subsequently confirmed predictions. Questions about the truth of a theory play no part in this process for the instrumentalist, for theories contain T-terms (theory terms) that are observationally unverifiable and hence meaningless. Theory terms are simply functional notions that enable the scientist to make predictions based on the theory in question. Hence, for the instrumentalist, theories do not and cannot explain in any conventional, or causal realist sense. In fact, the basic goal of science according to the instrumentalist is not explanation, but prediction.

Now this view of science rests on a number of important distinctions, such as the distinction between law and theory. For the instrumentalist, this distinction is one of kind, not degree. The key to this distinction turns on the notion of observation. Experimental laws pertain to observable things. In fact, as one prominent instrumentalist has said, "Experimental laws are statements that formulate an observable relation between things, and can be validated by controlled observation."[2] Examples are: the pressure of an ideal gas at constant temperature varies inversely with the volume; when water in an open container is heated, it eventually evaporates, etc. Experimental laws, in other words, contain O-terms (observation terms) like "... is sharp"; "... is cold"; "... expands"; "... points to 20"; etc. The meanings of such terms are observationally fixed, or are at least operationally definable, like "length," "mass," "pressure," "rate of acceleration." In effect, O-terms

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[1] It should be noted that instrumentalism belongs to a broad family of typically anti-realist positions in the philosophy of science, including but not restricted to: logical positivism, phenomenalism, conventionalism, fictionalism, and constructive empiricism.

[2] Ernest Nagel, *The Structure of Science: Problems in the Logic of Scientific Explanation* (New York: Harcourt, Brace and World, 1961), 80.

of experimental laws are linked to a procedure for predicating the terms of some observational traits, and this is what gives experimental laws their empirical content. Consequently, an experimental law is an inductive generalization of constant relations holding between observed data. Furthermore, experimental laws are independent of theories, and in fact often outlast the theories used to explain them.[3] Because the meanings of O-terms can be determined (at least in part) independently of the theory used to explain them, experimental laws take on a life of their own. But precisely because experimental laws have determinate empirical content, and are thus verifiable or (at least) falsifiable—provided one carries out the operations specified by the conditions of the law—experimental laws are either true or false. So once an experimental law is established, that is, is empirically verified, its truth-value is independent of any theories used to explain the law. It is this independence of experimental law from theory that enables the scientist to use experimental law to determine—along with other features such as coherence, simplicity, fecundity, etc.—if a new theory is plausible. Experimental laws draw their support strictly from observation.

Theories, on the other hand, contain T-terms like "... is an electron"; "... is a quark": "... is an electromagnetic field"; "... is a gravity wave"; etc. For the instrumentalist, these terms are unobservable and sometimes even operationally indefinable, since there is no specifiable, that is, empirical way to identify their referents. T-sentences (sentences containing T-terms) are hence meaningless. As a consequence, instrumentalists either claim that T-sentences are simply linguistic tools for calculating and predicting, or that there are no inductive grounds for believing that the referents of T-terms exist.

More specifically, instrumentalists maintain that the meanings of T-terms are not determined by experimental procedures. Rather, the meanings of T-terms are only defined implicitly by the theories of which they are a part, and only indirectly by the experimental uses to which they are put.

There are two reasons for this. First, all theories employ an abstract calculus that is the logical skeleton of the theory, and gives to it its

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[3] Ibid., 86. Nagel states that Wien's displacement law remained in place even after the theory that explained it (classical electrodynamics) was replaced by Planck's quantum mechanics.

"explanatory power." This structure is arrived at by ignoring the non-logical or descriptive terms of the theory, like "quark," "wavicle," "mass," etc., and focusing exclusively on the logical relations in which the terms stand to each other. This abstract set of postulates thus determines the meanings of the non-logical terms in virtue of their place as variables within the postulates. Because these postulates are in fact statement-forms[4] rather than statements, they assert nothing. But other statement-forms can be derived from them using the standard rules of logic. Second, theories must be linked in some way to O-statements, and this linkage usually takes the form of correspondence rules.[5] Without that linkage, no theory could be used to "explain" O-statements, let alone make predictions. Yet rules of correspondence do not provide explicit definitions of the T-terms used in theories, and for the following reason. An explicitly defined term can always be replaced by its equivalent defining expression. But theoretical expression in scientific theories cannot be so replaced because the replacing ex-

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[4] A statement-form, as opposed to a statement, is simply a sentence that has the grammatical form of a statement, but which is in fact not a real statement. For example, the sentence "For any χ if χ is an elementary particle and χ is *P*, then χ is a neutron," is a statement-form because *P* is an unspecified predicate variable, whereas the sentence "For any χ, if χ is an elementary particle and χ had no charge and a rest mass of $1.6749542 \times 10^{-27}$ kg, then χ is a neutron," is a genuine statement. Following Nagel, "the expression $\psi(\chi,\tau)$ is employed in the Schrödinger equation in quantum mechanics for characterizing the state of an electron. There is in effect a correspondence rule for the expression $\psi(\chi,\tau)\ \psi^*(\chi,\tau)$ (where ψ^* is the complex conjugate of ψ), but no such rule for $\psi(\chi,\tau)$ itself.... [T]heories containing such terms are statement-forms and cannot be said to be either true or false" (Ibid., 132-33).

[5] An example of the problem here arose regarding the Bohr theory of the atom, which accounts for a number of experimental laws of spectroscopy. Since the electron, their orbits, their jumps, etc., are concepts that do not apply to anything that is observable, how are connections to be found which will link these notions to what is experimentally observed? How was it done? A line in the spectrum of an element was associated with an electromagnetic wave whose length can be calculated, in accordance with the theory, from experimental data on the position of the line. But the Bohr model associates the wavelength of a light ray emitted with the jump of an electron orbit. This jump is thus correlated with the experimental notion of a spectral line. Cf. Ibid., 94-95.

pressions do not explicitly define the replaced expression.[6] In short, the inability of correspondence rules to "tack down" or link every T-term in a theory to O-terms enables theories to have great flexibility and to range over many experimental concepts. Theories must, therefore, never refer to any one set of experimental concepts, lest they be restricted to that one set. "A theory seeks to formulate a highly general structure of relations that is invariant in a wide variety of experimentally different situations."[7] In order to achieve the generality required for theories, the scientist very frequently uses the symbols of logic and mathematics to effect transformations not linked to experimental concepts. Because there are no procedures for directly applying T-terms to experimental instances of the term, a theory cannot be directly put to experimental test. T-terms cannot be understood apart from the particular theory that implicitly defines them. Unlike experimental laws, then, a theory is not an empirical generalization.

Of course, instrumentalists recognize that theories must be linked to experimental laws, and that this takes place via correspondence rules. But they reject the notion that the abstract calculus of a theory functions as a way to draw conclusions from experimental postulates that are held to be premises. Rather, the function of a theory is to provide a rule or principle for analyzing observational data, a tool so to speak, for inferring observation statements from other observation statements, or for "making logical transitions from a set of experimental data to another set."[8] In effect, a theory is a leading principle "in accordance with which conclusions about observable facts

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[6] Ibid., 98. The point here is that correspondence rules do not supply explicit definitions of theoretical notions used in theories, but at best implicit definitions. For example, the definition for the expression "*X* is a mammal," could be replaced by the equivalent expression "*X* is a member of the vertebrates that nourish their young with milk and bear live offspring," but the expression "*X* is the wavelength of the radiation emitted when an electron jumps from the next-to-smallest to smallest orbit of the hydrogen atom," is not equivalently replaced by "*Y* is the line occurring at a certain position in the spectrum of hydrogen."

[7] Ibid., 104.

[8] Ibid., 129.

may be drawn given factual premises; not as a premise from which such conclusions are obtained."[9]

Now this view of the role which theory plays in scientific enquiry has a number of important consequences for how the instrumentalist understands: (i) explanation; (ii) causality; and (iii) the cognitive status of theories.

1. Explanation

As far as explanation is concerned, instrumentalists typically embrace some form of the famous deductive-nomological (D-N) or covering-law model of scientific explanation developed by Hempel and Oppenheim. This model is useful and satisfies the instrumentalist's conception of the goal of science because "it formulates the conditions under which events of various sorts occur, the statements of such determining conditions being the explanations of the corresponding happenings."[10] In its most basic form, the *explicandum* E, or event to be explained, is explained when certain laws are adduced which, when joined with antecedent conditions, make E empirically necessary. The *explanans* (the conditions $C_1, C_2, C_3, \ldots C_k$, together with the law or laws $L_1, L_2, L_3, \ldots L_r$) answer the "why" question fundamental to all explanation.[11]

It is important to point out, however, that the *explanans* (at least insofar as it contains or uses experimental laws) must in all cases be empirical and true. The *explicandum*, of course, can be either an individual event or a law, but if it is a law, or even a set of laws, the principles used to explain them must be general rules specifying repeatable patterns of dependence among the observed properties of the subject matter studied. Relations are thus established between apparently unrelated or disparate phenomena. The *explicandum* is explained if it is subsumed under a general representation or principle. Thus laws which are generalized patterns of relations are in the D-N model subsumed under laws which identify patterns of relations which have greater range than the laws which they subsume. But these

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[9] Ibid., 129-30.

[10] Ibid., 4.

[11] For example, if we want to know why a rod expanded when heated, we could say, "All metals expand when heated; this rod is metallic and it was heated: therefore this rod expanded."

repeatable patterns of relations, or patterns of dependence, are best expressed in mathematical form, wherein relations of dependence can be expressed in formulae whose variables are related to other variables by some mathematical function. Examples from physics include the superposition principle, various laws of constancy—such as Galileo's law of freely falling bodies— and Kepler's third law of planetary motion, etc.

2. Causality

Nevertheless, though the principles in question operate in a purely functional way, they typically give the appearance of identifying causes, and of thus providing us with causal explanations. Yet they do not. Thus in a functional law of the type $X = YZ$, the variables can be rearranged mathematically in such a way as to make it impossible to know which of the variables in question is a cause, and which an effect; that is, $X = YZ$ can become $Y = \frac{X}{Z}$ or $Z = \frac{X}{Y}$[12] As physicist Gerald Holton says, in such cases "it is on the whole more fruitful to think of an interaction rather than simple causation, and to ask 'to what factors is *X* related,' instead of 'what causes *X*.'"[13] Indeed, the D-N model of scientific explanation and its variants (the Inductive-Statistical, or IS model, etc.)[14] do not embrace a realist notion of causation, but rather some kind of regularity or qualified Humean account of causation. The regularity model of causation simply states that events that are held to be causally related are so related if and only if the events in question instantiate a general regularity between like kinds of events. In other words, *A* causes *B* if *A* is of a kind of event *X*, and *B* is of a kind of event *Y*, such that events of kind *X* are regularly followed by events of the kind *Y*. In that case, the regularity or law pertaining to kinds *X* and *Y* covers or subsumes events *A* and *B*. The regularity is in turn written in terms of a formula whose variables are related to each other as a mathematical function. Thus it is the functional regularity that law encapsulates, and that, when joined with relevant conditions, explains

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[12] Gerald Holton, *Introduction to Concepts and Theories in Physical Science* (Princeton, New Jersey: Princeton University Press, 1985), 182.

[13] Ibid.

[14] For a good general overall discussion of the different kinds of explanation see "Scientific Explanation," in the *Stanford Encyclopedia of Philosophy Online.*

the *explicandum*. Given the *explanans*, the *explicandum* "is to be expected."

The realist or non-Humean view of causation, on the other hand, maintains that laws express a "necessitation relation" between the properties of relata. Accidents, however, do not express relationships of necessity between relata. Accidents involve constant conjunction, but laws involve something more. Thus, when under standard conditions one billiard ball strikes another billiard ball, the second must move. Yet taken by itself, this approach fails to address the real question: What is the nature of this necessity or "must"? The regularity theory overcomes this problem by treating necessity hypothetically or conditionally. That is, effects or consequences are to be expected given the laws of nature, which are themselves contingent. If the laws of nature were different, then when *A* strikes *B*, *B* might not move, though *B* will move given the current laws of nature. In addition, the regularity theory can accommodate non-deterministic or probabilistic accounts of nature. (We are reminded here, of course, of the whole of quantum mechanics.)

For the instrumentalist, then, not only are laws that assert functional dependencies between variables non-causal in the narrower realist sense, they are non-causal even in a more broadly defined sense. Typically, laws are held to be minimally causal when they satisfy four conditions: (1) the relations between the relata are uniform; (2) the relations between the relata are directly or indirectly spatially contiguous; (3) the relations between the relata reveal a temporal sequence; and (4) the relations between the relata are asymmetrical. Yet laws expressing functional dependencies fail to satisfy at least one of these four conditions. An example frequently used to demonstrate this point is Boyle's law of ideal gases, formulated as $pV = aT$. In this formula, no claim is being made that a change in temperature is followed by a change in pressure or volume. In other words, nothing about sequential order is asserted by the formula. The law captures a functional dependency, not a sequential order, even though the latter might figure prominently in experimental verification. (The same observation applies to laws that only assert invariable statistical relations between events.)

But even when the laws which function as rules or guidelines in the explanans of the D-N model do occasionally satisfy the above-mentioned conditions, these laws are not the kinds of laws favored by causal realists, for realists presuppose that that type of causal law centers on a relation of necessitation holding between the properties of relata. However, the relation of necessitation in turn rests upon the above-mentioned four conditions for causal law being satisfied. In fact, however, and again, at least one of these conditions is violated by scientific law, for the causal realist assumes that there are substances with determinable properties which take numerous forms. And herein lies a problem, for a substance is identified by the type of determinate properties that it has, which in turn differentiate the substance in question from other substances (as long as it differs in at least one form of a set of determinable properties). Thus to assert that *X* is a rock salt is to assert that it has the following forms of a set of determinable properties: crystalline structure = cubical crystals; color = colorless; density = 2.163 g/cm^3; melting point = 804°C; hardness = 2 on Moh's scale; etc.[15] Using induction, one could say that, because all *observed* rock salts are *X*, *Y*, and *Z*, therefore all rock salts are *X*, *Y*, and *Z*. And this claim will acquire nomic necessity if backed up by a theory (itself a set of laws) that shows why rock salt *must* have the properties it has. Yet this law is non-causal in that it makes no claim about any properties preceding or, in effect, causing other properties in sequential order. For example, rock salt's color is not caused by its hardness, nor is its hardness caused by its melting point. As a result, a crucially important support for the necessitation relation in the causal realist conception of law is thereby undermined.

3. The Cognitive Status of Theories

Finally, if the instrumentalist view of science is correct, then it would appear that factual truth or falsity cannot be predicated of scientific theories. Since laws operate functionally in the instrumentalist conception of explanation, that is, as guides or leading principles for organizing data and making logical transitions from one set of observable data to another set of observable data; and since these laws are constructed using T-terms only implicitly defined by their place in an abstract calculus and by borrowing ideal concepts from mathematics that are not descriptive of anything real, theories cannot be said to be factually either true or false. Factual statements are only true if they formulate relations between existing things or events, or between the properties of existing things. If those observable pro-

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[15] Nagel, *The Structure of Science*, 75.

perties reference unobservable theoretical entities, then the statements containing terms referencing them cannot be factually true or false.

As we have seen, the instrumentalist makes a hard distinction between O-terms and T-terms. O-sentences (sentences containing O-terms) and generalizations of O-sentences can be true or false (since they are empirically verifiable). But T-sentences (sentences containing T-terms) are for the instrumentalist empirically unverifiable, and hence meaningless. Instrumentalists view T-sentences with their T-terms as instruments for calculating and predicting. As a result, we have no good reason to believe that the referents of T-terms actually exist. Rather, T-terms have the status of variables, and as such constitute statement-forms, instead of genuine statements. But statement-forms, unlike statements, are neither true nor false.[16]

The concern of the instrumentalist is thus not whether theories are true or false, but whether they work. Theories work if they can be successfully used to organize and/or relate observation statements, which can in turn be used (in conjunction with other observation statements) to make subsequently confirmed predictions. The question of a theory's truth is irrelevant in this regard. The task of a theory is not to provide a true description of what takes place in the world, but to provide a way to analyze and symbolize certain properties of the subject matter studied. As these properties reveal themselves in experimental situations, good theory makes it possible to infer additional information (subsequently confirmed) about other properties of said subject matter. Since theories are neither true nor false, there is no problem in instrumentalism with conflicting or incompatible theories.[17] Theories can only conflict or be incompatible if

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[16] Statement forms such as "For any χ, if χ is an animal and χ is P, then χ is a vertebrate," are neither true nor false. However, a statement like the following (which does not contain variables like P) "For any χ, if χ is an animal and χ is a mammal, then χ is a vertebrate," is factually true or false. There are examples of statement forms in quantum mechanics theory, and the molecular theory of gases. Cf. Nagel, *The Structure of Science*, 132.

[17] "... it is not a source of embarrassment to the instrumentalist position that in inquiries into the thermal properties of a gas we use a theory which analyses a gas as an aggregation of discrete particles, although when we study acoustic phenomena in connection with gases we employ a theory that

they are held to be true or false. Yet instrumentalism does not hold that theories or theoretical entities are mere fictions, but rather that they are not true to the facts. One might simply call such theories "instrument theories." Indeed, some theories are superior to other theories; for example, if they serve as effective guides for subsuming a greater range of experimental data or laws, or if they make it possible to infer more observational data than other theories, or if their inferred conclusions agree with further observation.

Of course, if theories are leading principles in *accordance with which* conclusions are drawn, rather than premises *from which* they are drawn, the derivations that the instrumentalist must use rely on an intuitionist logic in which the classical law of the excluded middle no longer holds. (Derivations in classical logic are based on the assumption that the statements used as premises are true.) Clearly, one cannot assert "*A*," or "not-*A*," if one cannot decide whether "*A*" is true or "not-*A*" is true. And since T-terms and T-sentences are meaningless because their referents are unobservable and hence unverifiable, T-sentences containing T-terms cannot be true or false. Hence, given that "*A*" is a T-sentence and "not-*A*" is a T-sentence, one cannot assert either "*A*" or "not-*A*." And if one cannot assert "*A*" or "not-*A*," then neither can one assert "*A* or not-*A*." This is important given that the instrumentalist must derive his predictions from theories, and these derivations must be valid. If the instrumentalist uses the standard rules of inference of classical logic, he is applying these rules to derivations the premises of which are incapable of being either true or false. An intuitionist logic which rejects the law of the excluded middle enables the instrumentalist to escape from what otherwise might be a fatal inconsistency.[18]

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represents the gas as a continuous medium. Construed as statements that are either true or false, the two theories are on the face of it mutually incompatible. But construed as techniques or leading principles of inference, the theories are simply different though complimentary instruments" (Ibid., 133).

[18] W. H Newton-Smith, *The Rationality of Science* (New York: Routledge and Kegan Paul, 1981), 33-34. For a possible way around this problem without having to abandon classical logic, see Nagel, *The Structure of Science*, 138-40. For the sake of clarification, it should be pointed out here that the instrumentalist does not reject classical logic altogether. When it comes to O-sentences, for example, and the derivations derived from them, the

II. MARITAIN'S POSITION

Having said all this, we are now in a position to answer the question, Is Maritain an instrumentalist? *The Degrees of Knowledge* and *The Philosophy of Nature* make it clear that if Maritain does embrace instrumentalism, it is not instrumentalism in the commonly accepted sense,[19] yet it is similar in enough features to allow us to tag it with that label. This is so, for example, when it comes to the O-term/O-statement, T-term/T-statement distinction. Like all instrumentalists, Maritain clearly separates fact from theory, and maintains that this distinction is a distinction that is based on a difference of kind, not degree. In keeping with Aristotle and St. Thomas, Maritain believes that all knowledge begins with facts, which, as he says, are well established existential truths given to a mind which receives them. The mind, in turn, discerns in the objects of its concepts (which correspond to what is given) certain connections pertaining thereto, connections existing in the real.[20]

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instrumentalist is just as willing as the realist to embrace classical logic with its traditional rules of inference. The problem arises when the instrumentalist attempts to derive observable predictions combined with O-sentences stating initial conditions from theoretical sentences. Since T-statements are neither true nor false, that is, since they have no truth status, they cannot be treated as real premises from which conclusions are drawn, but rather must be likened to rules in accordance with which predictions are made. Nevertheless, whether T-statements are viewed as premises or rules or guiding principles, the derivations must be valid, and herein lies the logical challenge for the instrumentalist. Since T-statements are not real premises, one cannot use the truth preserving rules of inference of classical logic to check derivations made from such statements. In what sense, then, does the concept of validity still apply in instrumentalism? The instrumentalist's best recourse is to turn to a logic that rejects, at the very least, the classical law of the excluded middle. For more on intuitionism, cf. Arend Heyting, *Intuitionism: An Introduction* (Amsterdam: North-Holland Publishing, 1956); Michael Dummett, *Elements of Intuitionism* (Oxford: Clarendon Press, 1977).

[19] As we shall see, Maritain's instrumentalism is really a version of ontological instrumentalism, as opposed to semantical instrumentalism. Newton-Smith uses the term "epistemological instrumentalism" to refer to roughly the same position as Maritain's. See Newton-Smith, *The Rationality of Science*, 30.

[20] Jacques Maritain, *The Degrees of Knowledge*, trans. 4th French ed. under direction of Gerald B. Phelan (New York: Charles Scribner's Sons, 1959), 57.

Nevertheless, the facts that are given to a mind are not mere copies of the external world, for facts are judged by the mind that receives them, indeed, even by the senses which also judge what they receive. Every fact, says Maritain, is discriminated,[21] that is, judged, either by the intellect or the senses. But judging does not distort or deform what is judged. Rather, judging is a matter of the senses/intellect becoming assimilated or conformed to what is judged. And in the process of judging, senses and intellect work together. Maritain's critical realist epistemology will not allow him to embrace a simplistic view which sees all facts as arising from sense, and all theory from intellect. Hence, in the determination of facts, the intellect often intervenes with already formulated theories, but it does so to "discern and formulate that which is furnished by sense intuition."[22] In the determination of theories, the intellect works with sense intuition to uncover "essences or laws and explanatory reasons."[23] The intellect thus picks out what is of interest to it from the scientific standpoint, but it does so using certain principles which give to certain facts a value and reference that they might not assume under different guiding lights. However, this activity on the part of the intellect (highlighting and selecting certain facts) does not constitute creation and distortion. Certainly, basic O-statements presuppose a number of theoretical propositions, but these propositions are propositions having to do with what is to be measured and how to measure it; that is, they are propositions whose terms are operationally defined. In more complex cases, facts mediately rather than immediately disclosed to the intellect are taken from data conceived in reference to already formed explanatory theories, or which are derived from these explanatory theories.[24] Consequently, scientific facts make up a hierarchy of value wherein those facts which bear on real physical causes assume a higher value than those which are the result of the physical being reduced to an instrument used for discriminating between mathematical reconstructions or theoretical entities understood to be beings of reason *(entia rationis).* According to Maritain, such mediately established "facts" belong to explanatory theory, rather than genuine fact.

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[21] Ibid.

[22] Ibid., 52.

[23] Ibid.

[24] Ibid., 58.

For Maritain, then, though fact and theory are truly distinct, they nevertheless operate as dual partners in the scientific endeavor. Facts are not the creations or distortions of the senses/intellect, but they are the result of the senses/intellect exercising their judging capacity.

Following closely upon the distinction between fact and theory is another distinction of great importance for Maritain's philosophy of the experimental sciences: the distinction between what is observable, and what is unobservable. As we have seen, in conventional instrumentalism the O-term/O-statement, T-term/T-statement distinction turns on the fact that O-terms reference what can be directly or indirectly observed, while T-terms reference entities that cannot be observed either directly or indirectly. This distinction in particular is the basis for the semantical instrumentalists' claim that theories are neither true nor false, and that consequently no incompatibility between theories can arise. (The entities referenced by T-terms used in T-statements are unobservable and hence unverifiable. As a result, T-terms and the T-statements that use them are meaningless.)

Maritain, on the other hand, maintains that the best that the experimental sciences can do is to construct theories that are true (even though at times apparently incompatible) as long as they "save the appearances," and are fruitful for making predictions and determining/formulating new experimental laws.

Maritain arrives at this position precisely because the sciences of observation necessarily employ a kind of intellection that cannot capture essences, or lead to a direct apprehension of causes. Indeed, he has even coined a term for this special kind of intellection, which he calls "perinoetic" or circumferential knowing, which is to be distinguished from what he calls "dianoetic" intellection, or intellection which can grasp essences (though only indirectly). In general, the intellect in its abstractive activity attempts to give us knowledge of a thing's essence, but in the beginning it succeeds only in revealing to us the commonest and poorest notes of intelligible being. Maritain illustrates his point using the example of fire.[25] From the outset, in forming the idea of fire, the intellect knows only that fire represents some determined thing which produces certain sensible effects like burning and glowing. But the essential characteristics of fire

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[25] Ibid., 30.

that explain these sensible effects or properties elude the initial grasp of the intellect. In fact, even if the intellect were finally to succeed in grasping the essence of fire, it would grasp it only in and through its essential properties—it would never grasp the essence directly in itself.

Perinoetic intellection fails to grasp the essences in their specificity precisely because, below man, these specificities belong to the purely sensible world. For man, whose specificity is purely intelligible, it is possible to deduce essential properties from the difference "rational." This is not the case with species below man. Taking an example from Garrigou-Lagrange,[26] Maritain says that we are able to identify many of the *common* sensible (descriptive) characteristics, of say mercury—it's a liquid at ordinary temperatures; silvery in color; solidifies at 40°C; boils at 360°C; is very heavy; is very toxic; etc. The specific difference that explains *why* mercury has these properties remains hidden to us. Not even the philosophy of nature can capture the specific differences of beings lower than man on the scale of nature.

Thus, the type of intellection employed by the experimenttal/inductive/observational sciences is not able to uncover the intelligible constituents of the beings they study. For these sciences, essences and the intelligible constituents of essences are always hidden; essences, causes, or reasons for being only reveal themselves in effects—never in themselves—and even their effects must be grasped in signs and symbols that are substituted for them. But effects do reveal experimental constancies, which are in turn signs of necessities or essential connections hidden in constancies. And these constancies are formulated in science as experimental laws. As Maritain says, experimental laws enfold essences but without revealing them.

The sciences of explanation, on the other hand, are so-called because the type of intellection that they employ genuinely penetrates to the essence, the cause, or the reason for being of the phenomenon or thing that it studies, though again, never directly or in itself, but only in and through its proper accidents. These sciences, like mathematics and philosophy, are strictly deductive in nature. Both mathematics and philosophy use the dianoetic mode of intellection in which "the intelligible constitutive is objectivized in itself (if not by itself at least by a sign which manifests it, by a property in the strict sense of the

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[26] Ibid., 176, n. 2.

word.)"[27] Yet, once again, even here the essence is only indirectly or mediately known. In other words, in dianoetic intellection, essences are known indirectly through the accidents which manifest them. More exactly, essences reveal themselves to the intellect in and through their proper accidents. For example, human nature is known by rationality, animal nature by sensitivity. These are proper accidents because they have generic fecundity. From rationality, one can deduce docility, risibility, etc.

In perinoetic intellection, however, even the proper accidents remain unknown. Rather, the intellect grasps sensible or common accidents (as observable or measurable) which mask genuine properties. Though the intellect succeeds in perinoetic intellection in circumscribing the intelligible in the sensible, the intelligible "core" escapes its grasp, and so fails to uncover the essence. Instead, the substantial nature is known by signs which hide rather than manifest the essence. While dianoetic intellection enables us to know substances by proper accidents (which in turn are known by other accidents that are their operations), perinoetic intellection gives us knowledge of substances and properties *by* signs and *in* signs. These signs reference descriptive properties such as density, atomic weight, melting point, spectrum of high frequency, etc., which, though indispensible (for example, in chemistry), nevertheless mask real ontological properties.[28]

Hence, for Maritain, the essences or causes which the intellect naturally seeks cannot become known in the inductive sciences, the sciences of observation. And of course in this respect, then, causes/essences are also unobservable. But though they are not knowable or observable, this does not, as we shall see, make the theoretical terms which reference theoretical entities meaningless. Maritain was

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[27] Ibid., 203, n. 1.

[28] For those Thomists who may be wondering whether this distinction is grounded in the texts of St. Thomas, see: *In II Analyt.*, cap. XII, lect. 13; *In spir. creat.*, a. 11, ad 3; ST I, q. 29, a. 1, ad 3; *De ver.* I, q. 4, a. 1, ad 8; *In VII Meta.*, lect. 12; *In I De an.*, lect. 1; *De ver.*, q. 10, a. 1, ad 6. These are just a few of those places in the texts where this distinction is supported. I intend, in a future article, to examine this issue much more closely.

no positivist.[29] But our inability to penetrate beyond the sign substitutes for essences in perinoetic intellection creates a distinction that is absolutely fundamental for Maritain.

Nevertheless, because essences are the connatural object of the intellect, the intellect naturally tries to close the gap between the sciences of observation with their perinoetic form of intellection, and the sciences of explanation with their dianoetic form of intellection. The result has been, as all readers of Maritain know, the creation of mathematical physics, a *scientia media*[30] which has the physical for its

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[29] For Maritain's negative assessment of positivism, cf. *Philosophy of Nature*, translated by Imelda Choquette Byrne (New York: Philosophical Library, 1951), 45-73.

[30] On the notion of the *scientia media*, see Ibid., 102-18. This is a crucially important notion for Maritain, and one that is quite central to his whole concept of science. The experimental sciences naturally seek completion in the sciences of explanation. The sciences of explanation are constituted by mathematics and the various forms of philosophy, including, of course, the philosophy of nature. As noted, these sciences are genuinely deductive in form, and hence truly explanatory in nature. The experimental sciences need them because, as Maritain says, "the resolution of concepts into the observable and measurable as such is not sufficient" (Ibid., 102). Consequently, the experimental sciences must be subalternated to either mathematics, or philosophy. Now one science is subalternated to another science when the subalternate science borrows its principles from the subalternant science. The subalternant science resolves the conclusions of that science into first, self-evident principles, but the subalternate science does not by itself do so. Take a science such as geometrical optics. This subalternate science is subalternated to the subalternant science of geometry both as regards principles and subject. Optics borrows its explanatory principles from geometry, since it understands light rays in terms of geometry. And its subject is taken from geometry as well, for optics studies visual line. But it adds something to line, namely, an accidental difference grounded in the sensible (visual), in respect of one of the proper objects of the subject of geometry, which in this case is line. Here the visual becomes drawn into the mathematical sphere of intelligibility. The visual, in other words, becomes conceivable entirely in terms of mathematics. Hence, optics sits astride both the sensible and the mathematical. It is materially physical, but formally mathematical. But, because it is subalternated both with regard to principles and subject, it belongs to "the physical degree of abstraction materially, and to the mathematical formally" (Ibid., 105). Thus, geometrical optics is truly an intermediary science. The problem, of course,

subject matter, which it then joins to mathematics, a deductive science which gives to physics its principles and mode of explanation. In other words, mathematical physics is a science that is materially physical and formally mathematical; a science of the physical real, but which knows the physical real by transposing the physical real into *entia rationis.* These mathematical beings of reason then *take the place of real causes.* Thus, mathematical physics attempts to satisfy the intellect's demand for causal explanations, but it does so by necessarily replacing real causes with *entia rationis.*

However, because mathematical physics is materially physical, the mathematics in question is applied to sensible nature as this is given to the intellect through the senses. That is, the sensible effects and experimental constancies that reveal essential/necessary connections in and through sign substitutes are reconceived in terms of the formal connections of mathematical relations. These mathematical relations then become the substitutes for real causes. As a result, mathematical physics, "has given up the direct search for real causes in themselves, and aims to translate ... its measurements of things into a coherent system of equations."[31] Mathematical physics builds a hierarchy of at least formal causes, which in this science are simply the "conformity of phenomena to mathematical law."[32] Also, "Here the substitute for the ontological *quid est* is not an inductively established law, but a mathematics *quid est*, an algorithm of the physical real."[33]

Thus, in mathematical physics, causes are reduced to the measurable, because by its very nature it conceives the real causes in

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is that the system of explanatory reasons and causes that mathematics constructs to explain the sensible, taken as these are from the second degree of formal abstraction, or *abstractio formalis*, is made up of *entia rationis*, rather than *entia realia*: beings of reason rather than beings of real ontological causes and principles. Nevertheless, even *entia rationis* never become entirely severed from the real, for no matter how far removed or indirect from the real, *entia rationis* are ultimately grounded in observed and measured real beings. Yet, at some point, the sensible is so drawn into the mathematical that unreal/ideal mathematical entities become the means by which real beings are deduced.

[31] Ibid., 45.

[32] Ibid., 47.

[33] Ibid., 55.

terms of the quantitative, which mathematics abstracts at the second degree of formal abstraction.[34] In mathematics, only the quantitative has meaning. Measurements, then, are organized into formulae that capture the relations among them, and it is these relations captured by formulae that become substituted for real causes, and that function as explanations in mathematical physics. As long as these explanations cohere with the initial measurements taken from instrument readings, the theories are true. So, although real physical causes are mathematically reconceived in mathematical physics, they are nevertheless grounded in the physical real through measurement.

In this type of science, then, "a physico-mathematical theory will be called true when a coherent and fullest possible system of mathematical symbols and the explanatory entities it organizes coincides throughout all its numerical conclusions with measurements we have made upon the real."[35] Thus, any theory that satisfies this definition "saves the appearances" and is thereby true. Maritain is quick to add in a footnote that this criterion of saving the appearances does not mean that mathematical physics rejects causal research as the search for causal explanations.[36] Rather, *these mathematical formulae are themselves causal explanations*, and the theoretical entities they reference are true (that is, they exist) insofar as they save the appearances without "*making any claim to penetrate the nature of things themselves.*"[37]

The example Maritain uses here is that of the electron, which for some has only a mathematical existence, since it is a center of vibration in a wave system, which is itself taken to be real. For others, only the waves have mathematical existence, having been substituted for a surrounding but nevertheless real discontinuous field. Over time, however, mathematical physics does at least point to the existence of

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[34] For those unfamiliar with Maritain's philosophy of the three degrees of formal abstraction, cf. *The Degrees of Knowledge*, 35-46; *Philosophy of Nature*, 12-31; *Existence and the Existent*, translated by Lewis Galantierre and Gerald Phelan (Lanham, Maryland: University Press of America, 1987), 10-46. See also Matthew S. Pugh, "Maritain, the Intuition of Being, and the Problem of the Proper Starting Point for Thomistic Metaphysics," *The Thomist* 61, no. 3 (1997): 405-24.

[35] *The Degrees of Knowledge*, 62.

[36] Ibid., 63, n. 1.

[37] Ibid.

certain entities, even if it cannot agree about their nature. This seems to be true in the case of atoms.

Maritain's instrumentalism is therefore best described as a form of ontological instrumentalism. Theoretical entities (here reconfigured as *entia rationis*) point to the existence of something, and so *entia rationis* have meaning—the meaning that all mathematical entities have insofar as they are sign and symbol substitutes for what is ultimately grounded in quantity, i.e. the measurable real—but their true nature entirely eludes the grasp of the intellect. Therefore, whether such entities exist is in the end of no real consequence for science, as long as they function explicatively in the equations of the physical theory in question, that is, as long as the entities in question are defined by at least theoretically realizable operations of measurement.[38] Indeed, according to Maritain, mathematical physics is full of various kinds of *entia rationis*, which together form a hierarchy of such beings. For example, there are beings of reason that simply correspond in a more or less direct way to experimental observations and causes. Other beings of reason are genuinely theoretical entities like the electron or quark, which appear to be real, but which can only be grasped through symbol substitutes. These are mathematically reconstructed beings. Finally, there are beings of reason in mathematical physics that, although they are founded on the real in that they are taken from measurements of the real, are absolutely incapable of existing as such. In this instance, Maritain mentions "Einsteinian times."[39]

Of course, these beings of reason are the direct creation of the mind insofar as the mind is able to view the quantitative dimension of the real quantitatively, rather than ontologically. That is, the mind is able to formally abstract quantity from the real and see in it, "the very relations of order and measurement which the objects of thought discernible in it, as forms or essences proper to it, maintain among themselves."[40] When so abstracted, quantity is reconfigured by an intuition of the internal sense, namely, imaginative intuition, which is

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[38] Ibid., 140.

[39] Ibid., 141. Maritain is simply referring to Einstein's "space-time" as opposed to either "space" or "time" alone.

[40] Ibid., 143.

linked to the real only in that it presupposes external perception.[41] As mathematics has progressed, however, it has discovered beings of reason not directly figurable in imaginative intuition, such as irrational number, imaginary number, and transfinite number. Hence, the universe that mathematical physics creates based on the use of these beings of reason is also unfigurable in the imagination.[42] Nevertheless, no matter how abstract or unfigurable to the imagination physics becomes, all of its *entia rationis* are ultimately grounded in real beings, because they are ultimately grounded in real quantity.

Furthermore, at the first degree of abstraction, the mind attempts to move in either of two directions; either upward toward the ontological (this leads to the philosophy of nature) or downward toward the sensible (this leads to the experimental sciences). In the latter case, the observability of the object is crucially important. Its terms therefore, must reference, either directly or indirectly, what can be observed, or at least be reconfigured in imaginative intuition. But it never succeeds in disengaging the ontological for itself; it never rises, in other words, above perinoetic intellection. This also holds for mathematical physics, for even when the experimental sciences try to rise above perinoetic intellection by joining mathematics to physics and thus do embrace a dianoetic mode of intellection, they have to be content with quasi-real *entia rationis*, rather than real causes or reasons for being.

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[41] Maritain's explanation of the imaginative intuition employed in mathematical physics constitutes one of the most impressive parts of *The Degrees of Knowledge*. Quantity precedes quality in the priority of accidents, yet quantity can only be made known to us through the sensible qualities of things. Thus, the imagination, which presupposes perception but is free from it, is able to penetrate to quantity formally abstracted from matter. In this way, pure quantity becomes known to us in sensible symbol substitutes of the object of pure quantity that are free (because imaginatively reconfigured) of every sensible or experimental condition. Yet these beings of reason (the quantitative) are not purely intelligible, and so must be reconfigurable in imaginative intuition in order to assure us that they are grounded in genuine essences, that is, in the real. Those mathematical beings that cannot be reconfigured in imaginative intuition must, by analogy, fall indirectly into the imaginable. (Cf. Ibid., 144. See also *Philosophy of Nature*, a genuine classic.)

[42] Maritain, *The Degrees of Knowledge*, 146.

The consequences of such a view are dramatic for a Thomistic philosophy of science, for, according to Maritain, the sciences of observation must give up—which, as a matter of historical fact, they have already done—the search for essences, for *what* things are in themselves. Empirical science shifts to a consideration of what is measurable, and to how these measurements can be linked together to form mathematically expressed laws. As Maritain says, "Every definition should be given not now by means of the proximate genus and specific difference, but by well-determined observable and measurable properties, with the means of rediscovery and practical verification being related in each case."[43] And, most importantly, "the possibility of observation and measurement replaces the essence or quiddity which philosophy seeks in things."[44]

These same considerations apply to the notion of causality. Under the mathematization of physics, with its ever-increasing reliance on beings of reason, science moves historically from (i) an initial ontological notion of cause as that which is productive of being, to (ii) an empiriological-ontological notion of cause as a phenomenon productive of another phenomenon, to (iii) a mechanistic notion of cause as a phenomenon to which another phenomenon is linked by a universal necessary connection expressible as a "law" of nature, to (iv) a pure empiriological notion of cause "as the spatio-temporal conditions of a phenomenon ... the observable and measurable determinations to which a phenomenon is linked."[45] The latter finds expression in mathematical formulae capturing functional relations—as in differential or tensorial calculus—but even more prominently in wave mechanics, where waves are ultimately viewed as mathematical or statistical constructs expressed as a mathematical symbol, and which appear to eliminate strict mechanistic causality or determination from the subatomic world. Here, waves are transformed into a series of probabilities. Heisenberg's uncertainty principle, for example, enables the physicist to specify the measurable determinations to which a phenomenon is linked, to specify the spatio-temporal conditions of the phenomenon in question, but not to determine simultaneously both the location of a particle and its

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[43] Ibid., 149.

[44] Ibid.

[45] Ibid., 150.

momentum. That a mechanistic notion of causality would give way to indeterminism was inevitable, given physics' ever-increasing dependence on mathematical beings of reason. Strictly speaking, causes for Maritain are either proximately observable, or are theoretical causations. Proximately observable causes are causes that are indirectly observable through experimental constancies, as when molecules are broken down into ions in electrolysis, or when the height of liquids in barometric tubes changes with atmospheric pressure. Theoretical causations, on the other hand, are truly unobservable and have to be mediated through mathematical beings of reason as used in complex physico-mathematical theories, which, in turn, have to use correspondence rules to "tack down" the theory to experimental observations. Examples abound from quantum mechanics, subatomic physics, photon theory, string theory, etc.

In effect, the mathematization of physics has freed physics from ontology.[46] Simultaneity, time, space, etc. are freed from essentialist conceptions and instead are understood in purely empiriological ways. Indeed, for Maritain, mathematical physics frees science not only from ontology, but from philosophy and even common sense as well.[47] The New Physics does, and must, give up the search for essences. Instead, the contemporary physicist is confronted with symbols, rather than materials understood as forces that are, as Eddington says, "familiar in the workshop."[48]

Maritain even goes so far as to call these symbols "myths."[49] The real is known via the mathematical *preater*-real, he says, which transforms the world of qualities into a world of quantities expressible as mathematical functions. Hence the "myths" in question are only tied to the real insofar as they agree with the measurable. As we have seen, to that extent theories are true; true that is, as long as they save the appearances.[50]

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[46] Ibid., 158.

[47] Ibid., 159.

[48] Ibid.

[49] Ibid.

[50] Ibid., 162.

However, symbolism (myth) and realism are united in mathematical physics and "constitute the warp and woof of the same cloth."[51] But—and this is often overlooked in Maritain's philosophy of science—the realism that he speaks of is the result of (i) our pre-philosophical understanding of nature, and (ii) our ontological knowledge of nature, first in the philosophy of nature proper, and second in metaphysics. (This is why in Maritain's, at times confusing, diagram of the three degrees of formal abstraction in *The Degrees of Knowledge*, the second degree resulting in the creation of mathematical physics lies off the line that leads from the philosophy of nature to metaphysics.) Science, which includes: (a) infra-scientific experience; (b) empirical science (not yet mathematized); (c) physico-mathematics, and; (d) mathematics, lies below (epistemologically speaking) philosophy, which includes (1) the philosophy of nature, and (2) metaphysics. By itself, mathematical physics cannot give us knowledge of essences or causes. Yet, because it rests upon infra-scientific experience, and because it can avail itself of the philosophy of nature, mathematical physics can never stray so far from the real that it becomes purely positivist or pragmatist in its outlook. But, in its day-to-day operations, the question of the reality of the referents of its theoretical terms, whether they are mere beings of reason or actualities, is utterly irrelevant to it.

In light of our brief summary of instrumentalism as well as our brief summary of Maritain's philosophy of the experimental sciences, we are now in a position to address the question posed at the beginning of our discussion: Is Maritain an instrumentalist? The answer must be a qualified yes, though only slightly qualified, for it would appear that Maritain would agree with most of the elements of an instrumentalist philosophy of experimental science. With only minor exceptions, Maritain, I believe, would agree with the following statements:

1. The primary function of experimental science is not to explain in any conventional or causal realist sense, that is, is not to search for and identify real essences, causes, or reasons for being, but rather to predict and control.

2. Theories are successful when they work, that is, when they save the appearances.

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[51] Ibid., 163.

3. O-statements and T-statements, fact and theory, represent a difference in kind, not degree. The referents of T-terms are unobservable, being hidden by symbol and sign substitutes, which are conceived in mathematical physics as *entia rationis*, though (and this represents a difference between Maritain and semantical instrumentalism, though not ontological instrumentalism) this does not make T-statements meaningless, since the symbol/sign substitutes (as *entia rationis*) are ultimately grounded in the real. Hence, for Maritain, both O-statements and T-statements are true or false, though T-statements are only true insofar as they are based on, or taken from accurate measurements and pointer readings, and draw conclusions that cohere with all the relevant measurements. But unlike O-statements, which can be directly verified in sensory experience, T-statements along with T-terms must be mediated via mathematical beings of reason that necessarily misrepresent what they purport to reference. T-statements, then, are not true in the way that O-statements are factually true. Rather T-statements are only true in the sense that they save the appearances. Consequently, two apparently incompatible theories in mathematical physics can be true as long as they save the appearances.

4. O-statements are operationally definable. O-statements or experimental laws are inductive generalizations of constant relations holding between observed data.

5. Theoretical entities, as the referents of T-terms, are operationally indefinable. Hence they become useful tools for calculating and predicting, rather than causes or reasons for being.

6. T-terms are defined by the theory that uses them, and so cannot be put to direct empirical test. Thus, theories are not inductive generalizations of experimental laws.

7. As mathematized, T-statements or theories and the theory terms they use are functional notions that capture regularities or constancies evident among the relata of phenomena.

8. T-statements are linked to O-statements via correspondence rules, but they do not function as premises *from which* conclusions are drawn. Instead, they are guidelines or rules for making the transition from one set of O-statements to another set of O-statements. T-statements constitute an abstract calculus in accordance with which O-statements are inferred. Here, the nature of, or even the reality of, T-

referents is irrelevant. The logical relations in which the T-terms stand to each other, however, are crucially important.

9. The deductive-nomological (D-N) model of scientific explanation must be understood in the above way. The *explanans* provides a set of logical rules, or statement forms mathematically expressed as functions or equivalencies between phenomenal relata, (variables) that provide guidelines for inferring the *explicandum*, which "was to be expected." These mathematical functions and equivalencies *are themselves the explanations in experimental science*, which take the place of real causes.

10. T-statements and T-terms only appear to reference real causes necessarily connected to real effects. In fact, what theories identify are regularities, not necessary connections, which again are expressed as mathematical functions subsuming a whole host of lesser experimental regularities or laws. The regularities in question are thus functional regularities. Necessity is treated hypothetically or conditionally. Since this regularity model of causality does away with necessary connection, experimental sciences can even embrace something as startling as Heisenberg's uncertainty principle.

11. Because T-terms are implicitly defined by their place in theories, and because their referents are unobservable and thus use ideal mathematical sign/symbol substitutes in their place, theories are not true in any conventional sense. (T-statements are in fact statement forms, rather than real propositions.) Since *entia rationis* do not represent things, T-statements cannot in the strictest sense, therefore, be factually either true or false. But T-statements are not for Maritain meaningless. So theories are only true in an unconventional sense, insofar as they save the appearances, and enable the scientist to make predictions that cohere with measurements and pointer readings. Thus, incompatible theories, as in electron theory or photon theory, can all be true under this broad conception of truth.

12. Entia rationis, although symbol substitutes for the real, are nevertheless grounded in the real, that is, in quantity, even when they become unfigurable in imaginative intuition. They reference something that exists (for the most part), though they necessarily misrepresent it. But as long as *entia rationis* are true to the facts, that is, cohere at some point with O-statements, the theories to which they belong are true. In other words, *entia rationis* are double-valenced when it comes to truth and meaning; on the one hand, they are true insofar as they are taken from the real, either directly or indirectly, and so have the meanings that measurements taken from the real give them; but, on the other hand, they are convenient fictions whose meanings are determined strictly by the logical place which they hold as variables in mathematical formulae. At that level, they have merely the logical meaning that statement-forms have, which are not true propositions. At that level, their truth lies purely in their workability in terms of saving the appearances.

So conceived, the experimental sciences may well have to make way for a non-classical intuitionist logic which rejects the law of the excluded middle, which certainly would be more compatible, for example, with quantum mechanics. In other words, *entia rationis* are double-valenced—insofar as they are grounded in the real through quantity.

III. CONCLUSION

It seems then, that Maritain is an instrumentalist of sorts when it comes to the experimental sciences. Nevertheless, as any reader of Maritain knows, his philosophy of the sciences of observation is incomplete without a complementary causal realist philosophy of nature. As Maritain never tires of pointing out, empiriological analysis must be completed by ontological analysis. The first analyzes and resolves its concepts in the sensible, the observable; the other analyzes and resolves its concepts in intelligible being. In the first, definitions are sought through observation, measurement, and physical operations; in the second, definitions are sought by means of ontological properties constituting essences. It is the task of the philosophy of nature, operating at the first degree of abstractive visualization, to provide this completion. This is crucially important, for it is only in this way that science as a whole for Maritain is able to overcome positivism, and only in this way that Maritain's instrumentalism/constructive empiricism can be separated from the verificationist-based instrumentalism of the logical positivists. Indeed, it is the very possibility of ontological analysis which is the guarantee of a genuine (truly explanatory) philosophy of science. In other words, it is Maritain's critical realism that creates the foundation necessary for the completion of empiriological analysis in the ontological analysis of the philosophy of nature. Infra-scientific experience, along with the ontological analysis of dianoetic intellection operative in the philosophy of nature, embeds or enfolds the perinoetic intellection operative in the experimental sciences. For Maritain, these two parts of the philosophy of science really need to be thought together. Hence, it would a gross injustice to Maritain to accuse him of simply holding to a qualified instrumentalist philosophy of science. Nevertheless, whether these two halves of the picture really fit together is a question for another study altogether.