THEORETICAL ENTITIES AND THE ONTOLOGICAL INSTABILITY OF PHYSICS: THE IMPACT ON SCIENTIFIC REALISM

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I. WHAT IS MY TALK ABOUT

In this contribution I tackle the question about the real existence of the entities and kinds that science postulates in order to deal with the World: to *predict* and *intervene* in it.

My question is: Are the entities postulated by theoretical physics ontologically stable?

Scientific ontology is my concern.

II. ONTOLOGY AND EPISTEMOLOGY

The history of Western science shows that the 'road to the truth' is paved with the fossils of terms and theoretical entities that science has been abandoning.

This raises doubts about whether we should believe in the real existence of the entities that physics postulate, i.e. *if theoretical physics is ontologically stable*.

This question transcends the domain of ontology as it has a decisive impact on epistemology.

Indeed, *scientific realism* claims that mature scientific theories are at least approximately true and their theoretical terms refer empirically, that is, the entities referred by scientific terms and concepts really exist.

Is scientific realism viable?

III. NATURAL KINDS

The expression *natural kind terms* was introduced by Quine in an article entitled "Natural Kinds": "Kinds can be seen as sets, determined by their members", but "It is just that not all sets are kinds." (45)

Luis Fernández Moreno identifies "the reference of a general term, like natural kind terms and artifactual terms with its *extension* –by the way, a word of Carnapian origin, A.R. – i. e. with the set of entities to which the term applies." (p. 508), so that "an entity belongs to the extension of a natural kind term if it possesses the underlying properties of the paradigmatic members of the kind."

IV. KINDS AND SCIENCE: THE PERIODIC TABLE OF THE ELEMENTS

According to Bird, *Introduction*: "Chemistry provides what are taken by many to be the paradigm examples of kinds, the chemical elements, while chemical compounds, such as H_2O are also natural kinds of stuff."

•In the periodic table of the elements, the elements of group *IA* (H, Li, Na, K, Rb, Cs, Fr) are known as *alkali metals*, e. d. elements very soluble in water with strong base properties
• the elements of group IIA are *alkaline-earth metals*
• those of group *VIIA* (F, Cl, Br, I, At) are *halogens*, e. d. salts generators;
•These are followed by the *noble gases* (He, Ne, Ar, Kr, Xe, Rn);
•the *transition metals* are located between them, and the *rare-earth metals* are subdivided into two groups in turn: the *lanthanides* and the *actinides*.

•These denominations confirm the existence of kinds of kinds, as Bird maintains.

V. FIRST PROBLEMS IN RELATION TO THE *NATURAL KINDS*

Quine himself recognizes that "The notion of kind changes as science progresses."

•And Bird claims that "kinds are revealed by science", and that "a science can revise which kinds it holds exist. A science can even question a whole category of kinds."

Is the ontology of science facing a problem?

VI. CHEMICAL ELEMENTS AND SCIENTIFIC THEORY: THEORETICAL KINDS

Quine introduces the expression *theoretical kind*: "A theoretical kind…may issue from theory full-blown, without antecedents, for instance the kind which comprises positively charged particles." (49)

•Let's focus on the *noble gases*: $_2$He, $_{10}$Ne, $_{18}$Ar, $_{36}$Kr, $_{54}$Xe, $_{86}$Rn, where the subscript to the left of each gas symbol denotes the corresponding atomic number, i.e. the number of electrons.

•Some questions arise:

- why does each noble gas have a different atomic number?
- How are these electrons structurally arranged in the atom?
- What is the relationship between each noble gas and the one before it?
- Could exist a potentially infinite number of noble gases?

•The answer to these questions can only be given by theoretical physics: Indeed the *shell model* of the atom makes it possible to 'visualize' the so-called *electronic configuration* of the elements of the periodic table, thus providing a *theoretical explanation* of the 103 chemical elements.

•Thus theoretical physics explains the internal structure of the chemical elements (natural kinds)!

VII: THEORETICAL ENTITIES

•What are the theoretical entities of science? Obviously those associated with (referred to by) theoretical terms or *T*-terms.

•Following Sneed-Stegmüller's structuralism some terms may be theoretic with respect to one theory but not with respect to a different one. For example, *force* and *mass* are theoretical concepts for Newtonian mechanics, but *position* is not.

•*Position* however is a *T*-term in special theory of relativity, and *time* too.
•*Space-time* is a *T*-term in special theory of relativity. Etc.

VIII. ELECTRONIC CONFIGURATIONS OF THE NOBLE GASES AND THE THEORETICAL EXPLANATION OF THE PERIODIC TABLE OF THE ELEMENTS

According to the shell model of the atom the electronic configurations of the noble gases are:

$_{2}He$: $1s^2$
$_{10}Ne$: $1s^2 2s^2 2p^6$
$_{18}Ar$: $1s^2 2s^2 2p^6 3s^2 3p^6$
$_{36}Kr$: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
$_{54}Xe$: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6$
$_{86}Rn$: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^6$

A high theoretical implication, that assumes as the foundation of atomic physics the quantum physics, Pauli's exclusion principle, etc., is what allows to *explain* the electronic configuration of each chemical element, and therefore to give a satisfactory *theoretical explanation* of the *Periodic Table of the Elements*.

The chemical elements cease to be mere natural kinds and they clearly acquire the status of theoretical kinds, i.e. theoretical entities.

IX. CHEMICAL ELEMENTS AS THEORETICAL ENTITIES

•The noble gas with the highest atomic number, *Radon*, $_{86}Rn$, contains 86 electrons in six *shells* (*n*=6, and a total number of 15 *subshells*).

•But, what if we inquire into the $n = 7$ shell?
•We should add to the 86 electrons of Radon the number of electrons resulting from adding the superscripts of the following electronic configuration: $7s^2 5f^{14} 6d^{10} 7p^6$, that is: 32 more electrons that would correspond to the noble gas $_{118}X$, of atomic number 118.

•But this noble gas does not seem to exist in nature!

•$_{118}X$ is a purely hypothetical (theoretical) entity!

•We could add as many hypothetical chemical elements as we would like, all of them theoretically possible, but physically nonexistent, the more shells (n = 8,9, ...) we want to postulate.

X. $_{118}Og$ (OGANESSON): OR HOW A HYPOTHETICAL KIND BECOMES REAL

•Niels Bohr was the first to seriously consider in 1922 the possibility of an element with atomic number as high as 118.

•Oganesson is a synthetic element. It does not occur in Nature.

It was first synthesized in 2002 in Russia.

In December 2015, it was recognized as one of four new elements and named November 2016 after Yuri Oganessian.

This is a magnificent example of the extraordinary power of scientific theory!

XI. NEW THEORETICAL KINDS/ENTITIES: WILL BE THE THEORETICAL KINDS/ENTITIES BELOW IN THE FUTURE THE TYPICAL EXAMPLES OF KINDS IN ANALYTICAL PHILOSOPHY/PHILOSOPHY OF SCIENCE?

·The *Standard Model of Elementary-Particle Physics* allows to expand the number of theoretical entities, but also of **kinds of theoretical kinds/entities**. These are the following:

·*Bosons:* elementary particles of integer spin: 0, 1, 2. They are the intermediary particles of physical interactions and obey the quantum statistical mechanics of Bose-Einstein. The photon is the most characteristic boson, the Higgs is also a boson, the particles responsible for the weak interaction are bosons, and the graviton, if any, would also be.

·*Fermions:* semi-integer (an integer+½) spin particles: ½, 1½, 2½, with anti-symmetric wave function, restricted by the Pauli Exclusion Principle; they obey the Fermi-Dirac quantum statistical mechanics. The most characteristic fermion is the electron, which is also a lepton, and fermions are also the six quarks *u*, *d*, *c*, *s*, *t*, *b*.

·*Hadrons:* particles subjected to strong interaction. They include as subclasses (subspecies, subkinds) the baryons and mesons.

·*Leptons:* elementary particles insensitive to strong interaction, they interact through electromagnetic and weak interaction. Leptons are the electron, the tauon, the muon and the three types of neutrinos associated with them.

·*Baryons*: particles consisting of three quarks bound together by gluons. They are hadrons with semi-integer spin and baryon number (quark-antiquark/3) $B = 1$, which is a conserved quantity. Protons and neutrons are baryons.

·*Mesons:* particles consisting of one quark and one antiquark one. Mesons are the kaons and pions.

XII. NEW PROBLEMS WITH ENTITIES AND KINDS.

•In spite of the huge success of theoretical physics, both predictive and technological, many theoretical entities and kinds have disappeared or have been abandoned in the evolution of science.

For instance:
•the paraphernalia of entities in ancient astronomy,
•the four elements + the ether;
•The phlogiston; The caloric; The luminiferous ether;
•Mass: transverse, longitudinal, inertial, gravitational, rest, variable;
•etc.

XIII. SUPERSYMMETRY

•Supersymmetry relates fermions and bosons to each other, so that all currently accepted particles must have a superpartner particle:

•Each quark has a bosonic partner, a *squark*.
•Each boson has a fermion as a partner: the Higgs, the *Higgsino*; the photon, the *photino*.
•Electrons have *selectrons* as partners, and in general leptons have *sleptons* as partners.
•Neutrinos have *sneutrinos* as partners.
•The graviton has the *gravitino* as partner.

XIV. THE FAILURE OF SUPERSYMMETRY

Nonetheless Lee Smolin (2007: 75) claims:

> "For better or worse, nature is not like this. …, *no experiment has ever produced evidence for a selectron*. There appear to be, so far, *no squarks*, *no sleptons*, and *no sneutrinos*. The world contains huge numbers of photons (more than a billion for every proton), but *no one has ever seen even a single photino*."
>
> **Thus, if there are no real super-symmetric particles, the corresponding theoretical kinds/entities must be excluded from the realm of theoretical physics.**

XV. SCIENCE AND REALITY

•Bird is right indeed that, since kinds are revealed by science, "a science can revise which kinds it holds exist."

•Obviously, not everything that science postulates necessarily exists in the world.

•But then, I wonder if we will ever be authorized to definitely identify what really exists in the world, what things the World is made of, **what is the 'real' ontology of the World**.

•Quine wisely advises

> "to rationalize the similarity notion –i.e., the notion of kind, A.R.– more locally and superficially, so as to capture only such similarity as is relevant to some special science" so that "relative similarity notions best suit different branches of science." (p. 54), or: "In general we can take it as a very special mark of the maturity of a branch of science that it no longer needs an irreducible notion of similarity and kind."(p. 55)

A very reasonable point of view, indeed.

XVI. PHILOSOPHICAL REFLECTIONS AND CONCLUSIONS

Philosophical reflections:

1. The disappearance of such a large number of entities/kinds should not lead one to think that there are really no theoretical entities or kinds at all, or that they are dispensable. A strong instrumentalism of entities may seem as exaggerated or unreasonable as a radical version of essentialism. Neither would be demonstrable.

2. According to contemporary standard scientific realism, the mature theories of science are, at least, increasingly reliable descriptions and explanations of the World (Realism of Theories) and the entities they postulate actually exist (Entity Realism). You can be a realist about entities without having to be a theory realist, but not the other way round: a theory realist must necessarily be a realist about entities.

3. Scientific instrumentalism denies the validity of standard scientific realism. In its stronger version, it denies both forms of realism. But a more moderate version might deny the validity of the theory realism (deny *Convergent Realism*), although on the Entity Realism it could maintain that one has to analyze case by case.

Conclusions:

1. I have tried to show that we must accept the instability of the ontology of physics as an indisputable fact of scientific practice, and this has serious repercussions for the realism-instrumentalism debate in the contemporary epistemology.

2. But, what is really relevant is what we can do with the entities and kinds postulated in science, what picture of the world we form ourselves with them, and how we can intervene in it.

3. It does not matter to know what really exists in the World, i.e. what is the irreducible ontology of the World. What really matters is what science postulates in order to deal with the World: That is, to predict and intervene in it.

4. This position is clearly more sympathetic with a pragmatist viewpoint than with a realist stance in the philosophy of science.

XVII. WHAT HAS BEEN MY ARGUMENT IN THIS PRESENTATION?

- I have started with Bird's viewpoint –which picks up an accepted idea in contemporary philosophy of language– that science reveals the existence of kinds. And I have based on this point of view that the chemical elements constitute a paradigmatic example of kinds.
- I have claimed that since theoretical physics explains the existence and features of chemical elements, these ones cease to be mere natural kinds and they acquire the status of theoretical kinds/entities.
- The theoretical prediction of the possible existence of new chemical elements, very recently confirmed experimentally, constitutes an excellent example of how science reveals the existence of kinds.

- But I have not just stayed in the context of the chemical elements. I have shown that contemporary theoretical physics also reveals the alleged existence of theoretical entities, and kinds of kinds, unsuspected a few decades ago. New theoretical entities that could be a new object of theoretical reflection within the framework of contemporary analytical philosophy and the philosophy of science.
- Bird's claim that a science can revise which kinds it holds exists puts the finger on the spot of an unquestionable historical fact: many theoretical entities must be abandoned with scientific development. That is, science is ontologically unstable.
- The amount of super-symmetric entities postulated by contemporary theoretical physics that experimentation has shown to be non-existent is an excellent example of the ontological instability of physics.
- This is an important challenge that scientific realism must face: The theoretical terms of scientific theories do not refer empirically in a necessary way!
- Hence my conclusion in favor of a pragmatic and instrumentalist position according to which the important thing is not what entities really exist, but how we can take advantage of science for our best cognitive relationship with, and intervention in, the World.

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