Inconsistent Reasoning in the Sciences and Strategic-Logical Pluralism

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1. Introduction

The *Principle of Explosion* is one of the most characteristic principles of classical logic (and of any other explosive logic). It says that any (explosive) theory will trivialize if it contains at least one contradiction. A *contradiction* is a pair of propositions, where one is the negation of the other—sometimes contradiction is defined as the conjunction of both propositions. A theory is *trivial* if it is possible to derive any proposition from it. Therefore, any inconsistent (explosive) theory will be trivial.

In light of the above, an important question in the philosophy of science is whether science could be inconsistent and non-explosive at the same time; that is, *can science be inconsistency tolerant?* If science could in fact be tolerant of contradictions, philosophers of science should also address the questions: *How is it possible to make sense of the use of inconsistent theories in science* and *is such a use an indication of scientific irrationality*? With the latter question in mind, philosophers and logicians of science have argued that a study of sensible inconsistent reasoning in the sciences, if possible, could be crucial in the search for a general theory of scientific rationality (Carnielli and Coniglio). Unfortunately, a large number of the philosophical projects that aimed at addressing the possibility of sensible inconsistent scientific reasoning lost sight of the original goal and ended up exclusively "proposing alternative logics that *might* lurk in the background of scientific reasoning" (Brown and Priest, "A Paraconsistent Inference Strategy" 299. My emphasis), missing actual scientific inferential practices and focusing on more general philosophical projects regarding logical pluralism.

Logical pluralism is, sometimes, understood as the recognition that "different kinds of situations, and different logics (or consequence relations) may be appropriate for *reasoning* about them—in the sense that if you know (or assume) that certain things hold in these situations, the logic is guaranteed to give you other things that hold in the situation" (Priest 331. My emphasis). All this in the absence of the assumption that a single correct approach to reasoning exists. For the case of inconsistency toleration in the sciences, philosophical projects on logical pluralism have aimed at pointing out the logics that allow reasoning to be inconsistent and non-trivial at the same time, without paying much attention to the actual cases of alleged inconsistent science.

Considering the apparent failure of many philosophical programs when explaining actual sensible inconsistent reasoning in the sciences, this paper submits a novel approach to the formal analysis of inconsistency in science. My main concern here is methodological, namely: to respond to the question *How can we study and explain cases of inconsistent science from an inferential point of view without losing sight of the actual cases.* In order to do so, here I present a novel type of paraconsistent approach to inconsistent reasoning and argue that such approach could help to deepen our understanding of sensible reasoning in inconsistent contexts.

I introduce a paraconsistent approach to reasoning, namely, the *Paraconsistent Reasoning Strategies Approach* (PRSA), and I argue that the PRSA could, in the long run, ground a theory of scientific rationality and that is, at first, compatible with different views on logical consequence. The plan for this paper goes as follows: First, in Section 2, I briefly describe the phenomenon of inconsistency toleration in science and I enunciate some of the most important requirements for its philosophical understanding. In Section 3, I introduce a case study that illustrates inconsistency toleration in empirical sciences. Section 4 is devoted to characterizing the formal approach to inconsistent scientific reasoning, and to presenting the PRSA and argueing that it can account for inconsistent scientific reasoning. Finally, in Section 5, I explain how the PRSA could allow for a special type of logical pluralism, and in Section 6, I draw some conclusions.

2. Inconsistency Toleration in Science

While consistency in science has been untiringly pursued by philosophers of science and inconsistency has often been seen as negative, the history of science has shown that, at some point in their development, many of our most important theories have been inconsistent. Some of the most famous examples of this are:

Aristotle's theory of motion, early calculus, Bohr's theory of the atom, and classical electrodynamics.

Considering the above, philosophers, historians, and logicians of science have pointed out that contradictions are (safely) ubiquitous in scientific activity, that is, while frequent, they (almost) never threaten the scientific enterprise (Lakatos Laudan, Smith, Meheus 2002, Carnielli and Coniglio). Therefore, nowadays, there is a common agreement on the fact that not all contradictions are equally malign for scientific practice. So, contrary to what the traditional views might suggest, inconsistent theories do not always have to be rejected and inconsistent reasoning is not always an indicator of irrationality.

Inconsistency toleration is a phenomenon which takes place once epistemic agents who believe contradictions are malign are able to identify a contradiction in a relevant part of their reasoning and still reason sensibly from such an inconsistent set of information, that is, they are still able to distinguish between the products of their reasoning that are sensible, given a particular context, from those that are not (Meheus 2002, Carnielli and Coniglio).

Inconsistency toleration does *not* necessarily involve any of the following: (a) the final solution of the contradiction, nor (b) a *real* contradiction 'in action'. One the one hand, when facing a contradiction, scientists could try to solve it and fail at doing so, and we can still call this "inconsistency toleration." Additionally, they also could be using an inconsistent set of propositions without focusing on the contradiction, but if they are aware of its presence and can still prevent triviality, we can keep calling it "inconsistency toleration." On the other hand, if, at a particular time (*t1*), a scientist identifies a contradiction in a particular set of propositions, regards it as not dangerous and remains capable of having sensible reasoning, and later, at a time (*t2*), she discovers that the original set of propositions did not contain a *real* contradiction (but only apparent), we can still call the processes that she followed for the avoidance of triviality, in *t1*, "inconsistency toleration."

Considering the complexity of the phenomenon of inconsistency toleration, philosophers of science have developed three different types of research programs for its study:

> **Historical programs**: these types of programs have a deeply descriptive approach to contradiction in science, "which concerns the question whether inconsistencies commonly appear in science, and whether scientists sometimes accept and reason from inconsistencies" (Šešelja 2).
>
> **Logical programs**: these programs have a more "normative perspective, which concerns the questions whether we can rationally reason from an inconsistent set of premises without ending up in a logical explosion, and if so, how" (Šešelja 2).

> **Methodological programs**: these types of programs have "a normative perspective, which concerns the role of the standard of consistency in evaluations of scientific theories" (Šešelja 2).

Initially, these programs were superficially combined. For instance, a logical approach to inconsistency toleration would develop an analysis of a consequence relation that allows for the tolerance of some contradictions (without rendering logical triviality). And such an approach would test the effectiveness of this consequence relation by providing a formal model of a particular historical case study—without being necessarily meticulous with the historical details of the case. If the consequence relation was shown to be robust enough to explain the proposed case, then some methodological conclusions would be drawn, for instance, the non-explosive character of some contradictions in the sciences (depending on the chosen consequence relation that underlay the reasoning in the scientists).

Nonetheless, and as a result of the most recent discussions on the possibility of inconsistent science (Vickers, Davey), it has become clear that any attempt at the philosophical understanding of the phenomenon of inconsistency toleration should put all these programs together in a more significant way. A satisfactorily approach to inconsistency toleration should allow for a way to understand how it is possible to reason from inconsistent information in science without arriving at arbitrary conclusions, but it should also allow for some insights about the status of consistency in science, and finally, it should help us to describe and explain *actual* cases of inconsistency toleration in science (if any).

In what follows I introduce a case study from nuclear physics that illustrates inconsistency toleration, and I argue that cases like this one deserve an explanation in terms of inferential mechanisms that allow for *good* predictions despite inconsistency and for the avoidance of triviality despite the presence of a contradiction.

3. The (Inconsistent) Nuclear Realm

Some preliminaries: The nucleus of an atom is the small region in which 99.9% of the total mass of the atom is located. The nucleus consists of protons and neutrons bound together. The behavior of the nucleus is explained by appealing to two different forces: the strong nuclear force and the weak nuclear force. The strong nuclear force is what binds nucleons (protons and neutrons) into atomic nuclei, while the weak force is responsible for the decay of neutrons to protons. The *binding energy* of a nucleus is what in large part determines the stability of the nucleus. Any atomic nucleus (of any chemical element) will exhibit binding between protons and neutrons and decay of neutrons and protons. Finally, our current nuclear physics has provided us with, at least, 31 nuclear models that allow us to, at least, describe, predict and measure this type of behavior of atomic nuclei (Cf. Cook, Morrison Chap. 5).[1]

On the one hand, the *Liquid Drop Model* (LDM) is one of the most successful nuclear models. It was formulated under the assumption that the nucleus of an atom exhibits classical behavior (protons and neutrons strongly interact with an internal repulsive force proportional to the number of nucleons). On the other hand, the *Shell Model* (SM) is a nuclear model according to which a shell represents the energy level in which particles of the same energy exist, and so, the elementary particles are located in different shells of the nucleus. According to the SM, the nucleus itself exhibits quantum-mechanical behavior (Heyde 58), that is, for this model "nucleons are assumed to be point particles free to orbit within the nucleus, due to the net attractive force that acts between them and produces a net potential well drawing all the nucleons toward the center rather than toward other nucleons" (Morrison 185).

To measure binding energies of different nuclei, physicists have always preferred LDM, as it is extremely simple and highly accurate. However, while this model is efficiently used for predicting binding energies and fission of many elements, LDM faces serious difficulties when addressing the behavior of atoms of Helium (He), Oxygen (O), Calcium (Ca), Nickel (Ni) and Lead (Pb). Such elements' nuclei are bound more tightly together than predicted by the LDM depending on the number of nucleons that they possess. This is the so-called "magic numbers" phenomenon. Yet, SM can predict binding energies of nuclei with magic numbers (and, oddly, only nuclei of magic numbers). So, if physicists want to measure binding energies of all elements' nuclei they have to, sometimes, see the nucleus as classical and, at other times, as a quantum object. To assume that the atom is describable as a classical entity as well as a quantum object is at its best, problematic, and at its worst, inconsistent.[2]

It is well known that nuclear physicists do not take both models as candidates for the partial truth, they only use them (and combine them) in order to get accurate predictions and measurements, but they do not believe that both models put together realistically describe the empirical domain they "talk about." Nonetheless, this case study demands an explanation about how an inconsistent combination of information—interpreted realistically or not—could *entail* accurate predictions and how scientists could avoid triviality at the same time. Cases like this one require an analysis in terms of inferential procedures that are useful (or needed) for the avoidance of triviality while tolerating inconsistencies, i.e., an explanation in terms of logic.

With that in mind, in the following section I briefly describe two different ways for giving a formal account of inconsistency toleration in science.

4. Paraconsistent Approaches

Logic, understood from an epistemological point of view, is mainly focused on increasing our understanding of human reasoning through the analyses of certain inferential patterns that agents could actually employ (Corcoran). Such a view has provoked critical discussions on a formal and philosophical level. On the one hand, some philosophers have been strongly skeptical regarding the normative role of formal logic in human reasoning (Margáin), while others have accepted that it is not clear if logic can describe the norms of human inferential processes, yet it could still be explicative of some common inferences (Harman). On the other hand, some other logicians have maintained that certain logics could ground a theory of human rationality (Carnielli and Coniglio Chap.1). The latter approach consists in identifying a paradigmatic element of human rationality and analyzing the inferential patterns that are involved in it (which logical principles play a role in that particular type of reasoning, which are clearly avoided, and so on), and then selecting a logic or a group of logics that can describe and explain such inferences. Ideally, the result of such analyses will provide us with, at least, a deeper understanding of human rationality (Carnielli and Coniglio Chap.1 (give specific page numbers).

Following a similar intuition, some schools of *paraconsistent logics*[3] have persistently aimed at providing logics that are supposed to describe and articulate norms for—actual—human reasoning in inconsistent contexts. Let's call these types of programs the *Paraconsistent Logics Approach* (PLAs). The PLAs project is mostly focused on the analysis of different types of logical consequence that could describe sensible reasoning in inconsistent contexts (regardless if they are associated with scientific practices). As part of this approach one could recognize a certain application of the Logic of Paradox (Priest 1984, 2006 specify these in terms of brief title and page numbers), some branches of the Adaptive Logics project (Batens 2002, 2017; Meheus 2002 see above)), and some branches of the Logics of Formal Inconsistency (LFIs) project (Carnielli and Coniglio Chap. 8, 9), among others.

While this enterprise has produced many interesting formal results, it also has been accused of overlooking the actual phenomenon of handling inconsistency in scientific reasoning. This is partially because the type of analysis that this view holds requires strong commitments with very specific (some of them even peculiar) logical consequences, which might not be part of human reasoning at all. In addition, these projects have not yet been able to agree in their explanations of which are the inferences that scientists should follow in order to avoid explosion when reasoning with inconsistent information. Even more alarming, for the same case studies, different and rival explanations have been provided by the supporters of PLAs. And so far it has seemed that either there is no core of shared elements that could explain how certain scientists have dealt with certain contradictions at a particular moment, or there are way too many alternative explanations, so that it is not clear that any of those is actually an explanation for the particular cases.

In the majority of instances, the PLA-explanations of cases of inconsistency toleration are reinforced by specific applications of particular paraconsistent logics. And so, it has been argued that, PLAs draw the attention away from the actual premises and arguments offered by scientists by privileging discussions on which particular notion of logical consequence is, for instance, more virtuous (Brown and Priest, "Bohr's Hydrogen Atom"). For example, in Meheus (2002) the case of Clausius's derivation of Carnot's theorem is presented as a case of inconsistent scientific reasoning, and it is explained by stating that the logic that satisfactorily models this type of reasoning is an Adaptive Logic, in particular, the adaptive logic ANA. In a similar way, Priest (1987, 2006) analyzes the—physical—phenomenon of motion as a contradictory one and provides an understanding of it that suits the basic structures of some dialethic logics. The fact that PLA-explanations tend to privilege very specific logical consequences which further applications to scientific reasoning are not yet clear, makes it less surprising that PLA-explanations face some harsh critiques from the history and philosophy of science. For instance, it has been constantly pointed out that the adoption of only PLAs to historical episodes tends to threaten the understanding of the actual phenomenon (as it was claimed for the case of the Priestian theory of motion, by Boccardi and Macias-Bustos, and by Vickers (186-90) for some other interesting cases of alleged inconsistency toleration).

In the face of these kinds of allegations, a more general type of formal approach to inconsistency toleration has been suggested: general formal tools that do "not focus on identifying or proposing alternative logics that might lurk in the background of scientific reasoning. Instead it focuses on a more directly observable feature of reasoning, viz., how and where different premises are invoked in the course of arguments" (Brown and Priest 299). The result is a type of analysis of inconsistency in (scientific) reasoning through the use of some reasoning strategies; let's call this *the Paraconsistent Reasoning Strategies Approach* (PRSA). Considering that this methodological view makes no assumptions about which is the underlying logic of scientific reasoning, it is considered to be 'minimal' (Brown, "Paraconsistency, Pluralistic Models and Reasoning" page) when used to model specific cases from the history of sciences.

Paraconsistent Reasoning Strategies are specific technical procedures that help to achieve the avoidance of triviality in an optimal way—what is "optimal" would depend on the constrains of each of the cases that are being studied. These strategies suggest ways in which information could be broken apart and transmitted while following some inferential patterns. Even though these strategies often substantiate the general dynamics of certain logics; they are, most of the time, also logic-independent—that is, they are compatible with many and diverse logics.

Paraconsistent reasoning strategies do not necessarily focus on the structure of the scientifically inconsistent theory (or model) itself, but they pay special attention to both the information that epistemic agents often employ to identify the contradiction and the ways in which agents use such information in scientific problem solving and still avoid triviality. This minimal approach to inconsistent scientific reasoning was first sketched through the Rescher-Manor mechanisms and is nowadays incarnated in the strategies that substantiate the dynamics of the so-called Adaptive Logics, *reliability strategy* and *minimal abnormality strategy,* among others (Verdee 2009, Straßer 2014, Batens 2017, and in *Chunk and Permeate* Brown 2016, 2017; Brown and Priest 2004, 2015; Friend 2013; Benham et al. 2014; Priest 2014 (see above)).

In the following section, I briefly sketch how the PRS Approach can allow for a type of logical pluralism when explaining specific cases of scientific inconsistent reasoning.

5. PRSA Logical Pluralism

Usually *logical pluralism* is understood as "the view that there is more than *one correct logic*. Logics are theories of validity: they tell us, for different arguments, whether or not that argument is of a valid form. Different logics disagree about which argument forms are valid" (Russell). If adopting this very general view on pluralism, one could think that the PLAs has, in a sense, reinforced a pluralist perspective on logics applied to scientific reasoning. Nonetheless, the large multiplicity and the irregularity of types of logical consequences that the PLAs has associated to specific cases of inconsistent scientific reasoning, suggest than more than a logical pluralism, this could be close to *logical relativism*.

Logical Relativism is the view that there can be as many *correct* logics as inferential subjects (either individuals or collectives) (Baghramian and Carter Sec. 4.4). This, of course, could diminish the normative component that, intuitively, logics possess. The fact that for the study of inconsistent scientific reasoning, the PLAs have not yet satisfactorily identified a core of shared elements that could explain how certain scientists have dealt with specific contradictions at a particular moment, joined with the fact that the supporters of the PLAs have proposed many rival logical consequence relations to explain each particular case of inconsistent reasoning, suggest that, via PLAs, we have not yet gained much understanding of the inferential mechanisms that underlie human reasoning in inconsistent contexts.[4] While, allegedly, the PLAs have shifted their objects of study from scientific reasoning itself to logical consequence relations in general, and while doing this have gotten close to logical relativism (regarding logics applied to scientific reasoning), the same did not happen to the PRSA.

As the PRSA is mostly interested in analyzing general procedures that help to attain reliable information through the use of inconsistent data in specific cases, and because paraconsistent reasoning strategies are—most of the time—also logic-independent, this allows for a particular kind of logical pluralism, namely:

> **PRSA Logical Pluralism**: exhibits the absence of the assumption that a single correct approach to the logical consequence that underlies the inconsistency toleration processes exists. One specific Paraconsistent Reasoning Strategy (for instance, Chunk and Permeate), can be compatible with many and very different logical consequence relations (from classical logic to a dialethic logic). Each Paraconsistent Reasoning Strategy can be used to explain a diversity of case studies from science by appealing for each of them to specific inferential procedures, for instance, fragmentation (as Chunk and Permeate does) and, at the same time, each strategy leaves room for particular logical consequence relations to rule the reasoning that underlie each of the specific cases.
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> For an exemplar of the versatility of a Paraconsistent Reasoning Strategy one could look at the many applications of Chunk and Permeate : [Brown 2016, 2017; Brown and Priest 2004, 2015; Friend and Martínez-Ordaz; Priest; Sweeney], and conclude that while all these applications are determined by the procedures of chunking sets of information and the allowance of such information to permeate between chunks, they are also explained by the use of different logics that ruled the corresponding chunks and therefore, the reasoning of the scientists.

A pluralist-PRSA view suggests that there is a finite number of equally successful paraconsistent strategies that help to handle contradictions in human reasoning. While these strategies guide very general procedures of information management, such as to *separate the information in maximally consistent sets*, or to *distrust certain types of results*, they are also compatible with different types of logical consequence relation (explosive or paraconsistent, among others).

Now, one could fear that this logical pluralism is actually a type of *logical relativism*. However, I think, that this might not be the case, as, while all Paraconsistent Reasoning Strategies could be abstractly compatible with extremely many and diverse logics, when being employed to model specific cases of scientific reasoning, only some of them would be relevant and suitable for doing this job—depending on the particular cases to be modeled. In addition, even if the different strategies that could be used for formally reconstructing specific cases of inconsistency toleration provide different reconstructions of the same phenomenon, it is very likely that such reconstructions reveal different components of the same episode of scientific rationality, and while doing so enrich our understanding of both the reasoning that took place at that particular moment, as well as the general phenomenon of scientific rationality.

Finally, considering that the PRSA takes into account general elements involved in the most common practices of inconsistency toleration in science, this approach also permits that, depending on the particularities of each case of inconsistency toleration, different logics are used in order to transmit, select, and neglect certain type of information. In order to provide a successful approach to inconsistency toleration a paraconsistent reasoning strategy should describe the use of the most natural information-transmitting inferences into, at least, conditional operations (Meheus), and if doing so, a PRSA could, in the long run, shed light on the basic elements for the preservation of sensible reasoning and scientific rationality in inconsistent contexts.

6. Final Remarks

Inconsistency toleration is a phenomenon that takes place once epistemic agents who, after identifying a contradiction, can still reason sensibly from it. It is possible to identify many instances of inconsistency toleration in science (one of them was presented in Section 3). There are two different formal approaches to inconsistency toleration in science: the *Paraconsistent Logics Approach* and the *Paraconsistent Reasoning Strategies Approach*, while the former faces many difficulties (one of them being to overlook the actual phenomenon of inconsistency toleration), the latter could, through a type of pluralism, maintain the virtues of the Paraconsistent Logics approach and at the same time, give an account of the particularities of each case of inconsistent reasoning in science.[5]

Notes

1. The diversity of models itself is not problematic, especially if "each model has its particular successes, and together they are sometimes taken as complementary insofar as each contributes to an overall explanation of the experimental data" (Morrison 179). However, the case study that I am presenting here illustrates how the basic assumptions required by one model contradict those required by another model.

2. A more detailed description of this case study can be found in [Friend and Martínez-Ordaz Sec. 8].

3. In general terms, a logical consequence relation is said to be "paraconsistent" if it is not explosive, this is, if it does not validate the Principle of Explosion.

4. An important remark: While I consider that the PLA has had significant results on philosophical and formal issues related to logical pluralism and logicality, among other subjects of philosophical study, some philosophers (me included) have struggled in identifying the actual philosophical import of the PLA-views for the understanding of specific cases of inconsistency toleration in the sciences. That said, the philosophical and methodological worries that I express in this section (Sec. 5) are strictly concerned with the formal and philosophical analyses of actual cases of inconsistent scientific reasoning.

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