Science & Philosophy Volume 7(1), 2019, pp. 21-40

Astroparticle physics, a constructive empiricist account♣

Alessio Gava♦

Abstract

Astroparticle physics is an interdisciplinary field embracing astronomy, astrophysics and particle physics. In a recent paper on this topic, Brigitte Falkenburg (2012) defended that only scientific realism can make sense of it and that realistic beliefs constitute an indispensable methodological principle of research in this discipline. The aim of this work is to show that there exists an anti-realist alternative to this account, along the lines of what Bas van Fraassen showed in his famous book *The Scientific Image* (1980). Problems and results of astroparticle physics can be understood from an empiricist point of view too, namely that of van Fraassen's constructive empiricism, which is a more modest and metaphysics-free alternative to scientific realism. Although constructive empiricism can make sense of science no worse than scientific realism does, van Fraassen's goal is not to demonstrate that his stance is the only viable position, but just that it is not incoherent or proven false by his opponents (see Kusch 2015, 172). In this paper it will be shown that the constructive empiricist stance constitutes a legitimate alternative to scientific realism even when it gets to astroparticle physics and that it does indeed make sense of this new discipline, *pace* Falkenburg.

Keywords: Anti-Realism, Astroparticle Physics, Constructive Empiricism, Falkenburg, van Fraassen.

♣ I would like to thank Dr Alberto Vecchiato (*Osservatorio Astrofisico di Torino*-INAF, Turin, Italy), who read a previous version of this paper and made valuable comments about topics treated in it. *Grazie Alberto*.

♦ *Universidade Estadual do Paraná*, Apucarana (Brazil); alessiogava@yahoo.it. Received on January 24th, 2019. Accepted on June 17th, 2019. Published on June 30th, 2019.
doi: 10.23756/sp.v7i1.450. ISSN 2282-7757; eISSN 2282-7765.

1. Introduction

In her "Pragmatic Unification, Observation and Realism in Astroparticle Physics" (2012), Brigitte Falkenburg gives a historical survey of astroparticle physics, an interdisciplinary field that "*makes the bridge between astrophysics and particle physics*" (p. 327); i.e., studies elementary particles of astronomical origin and their relation to astrophysics and cosmology. Allegedly, the goal of this brand new discipline is to find a unified model of the world, such as Newton and Einstein tried to and despite the well-known incompatibility between quantum theory and general relativity.

According to Falkenburg, "*the goal of finding a unified theory of physics is associated with the belief in genuine, universal laws of nature*" (2012, 328), which is characteristic of scientific realism. As a matter of fact, Falkenburg also reckons that the whole story of astroparticle physics "*only makes sense from a point of view of scientific realism*" (p. 330). The aim of this work is to show that there exists an anti-realist alternative to her account, instead, along the lines of what Bas van Fraassen showed in his famous book *The Scientific Image* (1980).

2. A theory-laden narrative

Falkenburg's short history of astroparticle physics is manifestly theory-laden: "*Cosmic rays were discovered in the course of investigating the ionisation of the air and other gases by means of the cloud chamber and electroscopes*" (p. 328); "*A spectacular astrophysical success of cosmic ray studies was the discovery of the 3K cosmic microwave background (CMB) in 1964*" (p. 329); "*After the discovery of the W and the Z° bosons in 1983, particle physics at the accelerators has been taking place in an innovative desert*" (p. 330); etc.

Of course there is nothing wrong with that, unless one thinks that talking about ionization, CMB, bosons and the like commits her ontologically. Falkenburg seems to think it is the only way this story can be told.

The phenomenology of scientific theoretical advance may indeed be compared to the phenomenology of exploration and discovery in other fields, says van Fraassen, "*and it is also appropriate to talk in this fashion while immersed in the theoretical picture that guides the actual scientific work*" (1980, 74). But this does not mean that one cannot step back and reflect, in order to see if such a point of view on scientific activity is the only legitimate one - and if one is actually committed to believing in the existence of the entities postulated by the theories she relies on.

Admittedly, we all are "*immersed in a language which is thoroughly theory-infected, living in a world [our] ancestors of two centuries ago could not enter*" (p. 81). For instance, it may very well be the case that we have no adequate way to describe a certain box, and the role it plays in our world, except as a VHF receiver, says van Fraassen. From this, however, it does not necessarily follow that we believe that "*the concept of very high frequency electromagnetic waves corresponds to an individually identifiable element of reality. Concepts involve theories and are inconceivable without them (...). But immersion in the theoretical world-picture does not preclude 'bracketing' its ontological implications*" (*ibid.*).

Now, science is indubitably not a mere role-playing game,[1] still a scientist must not let herself be 'pushed too far' by the immersion in the world of science and by the highly-theory-laden language used in the context of the scientific practice. It is in fact possible "*even after total immersion in the world of science to (...) limit one's epistemic commitment while remaining a functioning member of the scientific community - one who is reflective, and philosophically autonomous as well*" (van Fraassen 1980, 83).[2]

A way to do that - and to avoid reifying whatever could not be defined away in a logical-positivist-like reconstruction of the language of science (see van Fraassen 1980, 44) - is by identifying a scientific theory not with a set of axioms and theorems, but rather with a class of mathematical models, as van Fraassen suggests when he defends a 'semantic approach' to theories in alternative to the so-called 'syntactic view'. Focusing on mathematics, instead of on language, makes it easier to resist hypostatization of any sort.

Accordingly, van Fraassen suggests that theories need not be true to be good, but 'only' empirically adequate, which means that all appearances (i.e. structures that can be described in experimental and measurement reports) must be isomorphic to empirical substructures of that model - that is, certain parts of the model must correctly describe (solely) the observable phenomena (see 1980, 64). Asserting a theory to be true, instead, means affirming that it

[1] "*It is not a game: these practices are part of what makes our world a coherent, useful and, even, the sometimes friendly, sometimes inimical place that it is*" (Seager 1995, 477).

[2] William Seager reckons that van Fraassen's notion of 'theoretical immersion' is too language-oriented (or theory-oriented) and might fail to explain the sense of conviction that stems from scientific practice. He prefers, in alternative, the concept of 'virtual reality': "*if we replace theoretical immersion with virtual reality, perhaps we can explain the sense of conviction without endorsing the reality of the micro-world. Conviction stems from immersion in a system of imaging devices and instrument-aided practices that project one into a plausible micro-world*" (Seager 1995, 474). Of course this substitution is perfectly tuned with constructive empiricism, the view of science that van Fraassen proposed in *The Scientific Image*: "*I argue that immersion is more analogous to entering a virtual reality than to learning a language. This metaphor assimilates instrument-based practice as well as theoretical debate and explanation, and can provide an anti-realist view of our micro-practices consonant with constructive empiricism*" (p. 459).

has a model "*which is a faithful replica, in all detail, of our world*" (van Fraassen 1980, 68-69). Now, accepting a theory as empirically adequate requires a leap of faith too, of course, since we will never know whether this is the case. "*Nevertheless there is a difference: the assertion of empirical adequacy is a great deal weaker than the assertion of truth, and the restraint to acceptance delivers us from metaphysics*" (van Fraassen 1980, 69).

This is the point of empiricism, in talks about science: it is possible to make sense of this activity without relying on metaphysics. At the end of the day, what a scientist actually observes, when she detects micro-particles, is a silver-grey line in a cloud chamber or some numerical value in a gauge.[3] According to van Fraassen's constructive empiricism, those are the appearances that must fit into a model of an empirically adequate theory. The postulated entities might fit into it or not, but we will never know.

3. What kind of realism? Van Fraassen's formulation of scientific realism and his empiricist alternative

In his *A Metaphysics for Scientific Realism* (2007), Anjan Chakravartty shrewdly notes: "*Some think there are as many versions of scientific realism as there are scientific realists. That is probably a conservative estimate! There are probably as many versions of realism as there are realists and antirealists*" (p. xii). Falkenburg invokes more than one version, in her paper: entity realism, causal realism, the belief in laws of nature, realism about the phenomena and so on. "*In the practice of physics - she writes - many facets of scientific realism coexist, and the realistic beliefs associated with them differ in being stronger or weaker*" (2012, 341).

She also adds that in astroparticle physics some strong realistic beliefs are kept and others are weakened. In this field of study, in fact,

> *a firm realism about entities, phenomena, their causes, and genuine laws of nature comes together with an instrumentalist attitude towards the models of cosmic sources and the mechanisms of emission and acceleration of cosmic rays. For example, no physicist believes that the estimation of the different contributions to the*

[3] As scientific realists admit too, of course. Here is a passage from Dudley Shapere: "*if the information comes in the radio region of the electromagnetic spectrum, or via weak interactions, it must be transformed into electromagnetic information in the visual wavelengths, or into audible clicks, or into readable printout, or the like*" (Shapere 1982, 508). Therefore, "*as constructive empiricism has it, there is nothing incoherent in the thought that we find out by inference, not observation, 'how unobservable things are'*" (Kusch 2015, 179).

> *'all particle spectrum' (...) is a true model. For obvious reasons, it is considered to be just a crude, tentative idealization (2012, 342).*

Nonetheless, Falkenburg insists that the practice of physics depends on scientific realism. "*The belief in natural kinds and genuine laws of nature is an indispensable methodological principle of research in this field*" (Falkenburg 2012, 343). Falkenburg also reckons that entity realism, causal realism and the like are all features of what can generically be called 'scientific realism' and that this entails the belief in the existence of particles, fields, forces, laws of nature, etc. In addition, she also considers that physics aims at investigating causes and that some models of astroparticles physics are taken as true. Then perhaps she agrees with van Fraassen's formulation of scientific realism: "*Science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true*" (1980, 8).[4]

Van Fraassen shares with the realists the opinion that the language of science must be taken at face value. Theories are not metaphors. When a scientist talks about electrons, she means exactly those subatomic particles we all heard about. Yet, a literal interpretation of the language of science does not entail the belief that these entities exist. As a matter of fact, according to the Dutch philosopher, "*science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate*" (1980, 12) – which is exactly the statement of his anti-realist position, namely constructive empiricism.

How does a constructive empiricist reply to Falkenburg's claim that the practice of physics depends on scientific realism and that only a realist account can make sense of astroparticle physics? Note that van Fraassen thinks that his anti-realist position "*makes better sense of science, and of scientific activity, than realism does*" (1980, 73) - and without inflationary metaphysics.

In science, theory and experimentation go hand in hand. According to van Fraassen,

> *the intimately intertwined development of theory and experimentation is intelligible from an empiricist point of view. For theory construction, experimentation has a twofold significance: testing for empirical adequacy of the theory as developed so far, and filling in the blanks, that is, guiding the continuation of the construction,*

[4] Van Fraassen regards his formulation of scientific realism as quite minimal and adds that it "*can be agreed to by anyone who considers himself a scientific realist*" (1980, 8). He gets to it, in fact, after scrutinizing how important self-declared scientific realists, such as Wilfrid Sellars, Hilary Putnam and Richard Boyd, characterize this view on science. Other authors, however, criticized van Fraassen's formulation, considering it too strong (see Sicha 1992, 522-523). Yet, Falkenburg seems to invoke an even stronger version of realism, therefore she should not have any problems with van Fraassen's characterization.

> *or the completion, of the theory. Likewise, theory has a twofold role in experimentation: formulation of the questions to be answered in a systematic and compendious fashion, and as a guiding factor in the design of the experiments to answer those questions. In all this we can cogently maintain that the aim is to obtain the empirical information conveyed by the assertion that a theory is or is not empirically adequate (1980, 74).*

This applies to astroparticle physics too. Or so I argue.

4. Astroparticle physics, a constructive empiricist account

In her paper, Falkenburg puts forward a short historical survey of this discipline that aims at investigating cosmic rays in order to make the bridge from subatomic particles to cosmic sources.[5]

"*In making the bridge from subatomic particles to cosmic sources - she writes -, astroparticle physics employs (...) realistic beliefs, (...) such as causal realism and the belief in natural kinds and their properties*" (2012, 328). Not only does Falkenburg think that physicists in this field hold realist beliefs, however, but also that these constitute an indispensable methodological principle of research in astroparticle physics (see p. 343).

One might wonder how she knows that "*the physicists who discovered the cosmic rays considered them to be real entities of nature, or* natural kinds*, which have the power to cause observable phenomena in the experimental devices*" (p. 330). But even if this was the case - while, at the same time, we should not forget that important physicists in the history of this discipline were anti-realist, such as Duhem, Mach, Poincaré, Hertz (to some extent), Bohr (of course), to name just a few - does this suffice to conclude that a realist attitude

[5] Falkenburg regards the discovery of the 3K cosmic microwave background (CMB) in 1964 as a spectacular success of cosmic ray studies (see p. 329). CMB is electromagnetic radiation, however, which means that it is composed by photons. Being so, it is not completely clear whether it can legitimately be considered as part of the study of cosmic rays - all the more so since Falkenburg seems to consider them as particles in the classical sense of the word - and if there exists a general agreement, among astroparticle scientists, on including CMB in their research field. In the affirmative case, we see no reason why photons of any other energy level should not be contemplated; but then, one might wonder, are telescopic observations in *any band* of the electromagnetic spectrum part of the astroparticle-physics practice too? (I thank Dr Alberto Vecchiato, of the *Osservatorio Astrofisico di Torino*-INAF, for elucidating, in a recent e-mail message, on the matter of CMB and cosmic rays).

is necessary (or even an indispensable methodological principle of research) in astroparticle physics?[6]

Van Fraassen has shown that the answer is negative.[7] Falkenburg in fact said that cosmic rays were 'discovered' in 1964, but also remembered that CMB had been predicted by Gamow in 1948 (see p. 329). A constructive empiricist might then reply that the story of the 'discovery' of cosmic rays can be re-told, much less glamorously, as that of an observable phenomenon that simply fit the model of a pre-existing theory - note that Falkenburg admits that what is actually seen are observable phenomena in the experimental devices. What Penzias and Wilson observed was a numerical value displayed by a voltmeter that did not fit their initial prediction (model) - they did not observe 'radiation'.[8] Since the theory they were relying on appeared not to be empirically adequate, they looked for another one and found that a group at Princeton had predicted that there would be residual microwave background radiation left over from the Big Bang. Their observation fit the theory the group in Princeton was willing to test.[9]

Let's consider another case mentioned by Falkenburg. According to her, the origin of astroparticle physics might be dated back to the first years of last century, when Victor Hess measured the ionization of the air and realized that it is much stronger in the height than at the ground – something that the Italian physicist Domenico Pacini had done before, actually. She then added: "*By proving the extra-terrestrial origin of this phenomenon, Millikan identified cosmic rays as its cause*" (Falkenburg 2012, 328). Again, what Millikan actually did, a constructive empiricist might rebut, was testing the empirical adequacy of a theory about the ionization of the air (his initial intent was to disprove Hess and Kolhörster's 'discovery'); eventually, he ended up 'filling the blanks' present in it - he even coined the locution 'cosmic rays'. One just

[6] One might also wonder whether, supposing that the majority of the physicists, in any field of the discipline, exhibited realist attitudes, this would constitute an argument in support of scientific realism. It does not, in fact.

[7] He was not referring specifically to astroparticle physics, of course. But his point applies to it too, as we will see.

[8] "*The constructive empiricist will argue that the micro-world remains a mere virtual reality because there is no access to the micro-world except via the devices and practices (and theories) that project us into that world and thus no way to bring the putative micro-world into direct connection with human senses. There is no* ground truth *against which to measure our interpretations of the images delivered to us by our various instruments*" (Seager 1995, 475).

[9] Compare the following passage from *The Scientific Image*, where van Fraassen talks about Robert Millikan's famous oil drop experiment: "*in this case,* theory construction consists in experimentation. *And while it may be natural to use the terminology of discovery to report Millikan's results, the accurate way to describe it is that he was writing theory by means of his experimental apparatus. In a case such as this one,* experimentation is the continuation of theory construction by other means. *The appropriateness of the means follows from the fact that the aim is empirical adequacy*" (p. 77). The same could be said apropos of Penzias and Wilson's 'discovery'.

needs to read again van Fraassen's abovementioned passage about the intertwined development of theory and experimentation to see that Millikan's 'discovery' of cosmic rays is perfectly intelligible from an empiricist point of view too.

The same goes, of course, for this other passage from Falkenburg's short history of astroparticle physics: "*All the predictions of the standard model of particle physics were confirmed at accelerator experiments, including the recent detection of the Higgs particle at the LHC*" (2012, 329). One might reply that in this case theory dictated the formulation of the questions to be answered and acted as a guiding factor in the design of the experiments to answer those questions, while the experiments confirmed that the standard model of particle physics has not proved to be empirically inadequate so far – which is the most one can say about any theory.

The same applies to the other 'discoveries' or confirmations of predictions mentioned by Falkenburg in her paper.[10] Compare the following passage:

> *Atomic physics was developing slowly, as a theory, and at each stage, many blank spaces had to be left in the theory. Rather than fill such a blank with a conjectured answer, as hypothesis, and then testing the hypothesis, one carries out an experiment that shows* how the blank is to be filled if the theory is to be empirically adequate. *Then it is filled, and the theory construction has got one more step forward, and soon there are new consequences to be tested and* new blanks to be filled. *This is how experimentation guides the process of theory construction, while at the same time the part of the theory that has already been constructed guides the design of the experiments that will guide the continuation (van Fraassen 1980, 75).*

Van Fraassen's empiricist reconstruction of the development of atomic physics can be transposed *in toto* to astroparticle physics. Or so I argue.

In light of this, since van Fraassen's empiricist account of the intertwined development of theory and experimentation seems to be able to offer an alternative to Falkenburg's realist-biased history of astroparticle physics, then her belief that the whole story of this discipline "*only makes sense from a point of view of scientific realism*" (2012, 330) perhaps is not well-founded. Particularly, the claim that "*the belief in natural kinds and genuine laws of nature is an indispensable methodological principle of research in this field*" (p. 343) should be qualified, because astroparticle physics, as well as other

[10] And to the 'pragmatic strategies of unification' Falkenburg describes in section three of her paper as well. It is worth remembering, since Falkenburg frequently mentions the 'belief in laws of nature' - which means the belief that the same laws of physics hold inside and outside the laboratory, in every region of the universe - that this is nonunanimous among physicists – as she also admits recalling Mach's notorious instrumental attitude with respect to the concept of 'law of nature'. In *Laws and Symmetry* (1989) van Fraassen argued that "*there is no useful role for the notion of a law of nature. But there is an essentially different concept which can do some of the same work: that of symmetry*" (Morton 1993, 408). Which means that there exist an empiricist alternative to Falkenburg's 'methodological unification strategies' too.

fields of study and research, can advance even if researchers in this area maintain an 'agnostic' attitude with respect to the entities postulated by the theories that constitute the 'background knowledge' they rely on – in fact, doesn't astroparticle physicists keep an instrumentalist attitude towards the models of cosmic sources and the mechanisms of emission and acceleration of cosmic rays (see Falkenburg 2012, 342)? (And doesn't this admission clash with the claim that the belief in natural kinds and genuine laws of nature is an indispensable methodological principle of research in astroparticle physics?)

What van Fraassen maintains is that scientists have, in general, be it in physics or in any other area, a certain picture of the world in mind and it is natural and appropriate to stick to it - or immerse into it, as van Fraassen would say -, even from a linguistic point of view, while doing their job. They don't need to believe that this picture is a faithful representation of the world, however, since when it gets to unobservable entities there is no way of empirically verifying its veridicality – this means that one might think "*the world apparently works as if…*" and suspend the judgement about whether this is really the case. In other words, one can maintain an agnostic/instrumental attitude with respect to that part of the picture that allegedly represents the unobservable portion of the world and focus instead on the part that is a candidate for the direct representation of the observable phenomena.

Even in the case of a scientist with a realist creed, one can always describe her activity as a quest for empirically adequate models of the world. Whatever her opinion about what she is doing, in fact, it can always be reduced to that. Besides, this is a more 'empirically adequate' way of describing scientific activity than as a search for some kind of 'truth' – which is the reason why van Fraassen reckons that his anti-realist position "*makes better sense of science, and of scientific activity, than realism does*" (1980, 73). The rest is metaphysical surplus.

Still, van Fraassen's aim is not to deem scientific realism or anyone with realist inclinations as irrational. Scientific realism *is* a rational description of the scientific enterprise. But it is not the only possible one. Constructive empiricism is a more modest and metaphysics-free alternative, which can make sense of science no worse than scientific realism does - or even better, in van Fraassen's opinion. There is no pretention of phasing realism out: "*it is important to keep in mind that van Fraassen regards 'constructive empiricism' as one of several possible 'stances': his goal is to show that his stance is not incoherent or proven false by his opponents; his goal is not to demonstrate that it is the only viable position*" (Kusch 2015, 172).

If, on the other hand, constructive empiricism succeeds, as it does, in establishing as an alternative to scientific realism, then asserting that the whole story of astroparticle physics "*only makes sense from a point of view of scientific realism*" (Falkenburg 2012, 330) fails to do justice to van Fraassen's view on science – and to astroparticle physics itself. Not to mention that the claim that scientific realism constitutes an indispensable methodological principle of research in this discipline (see Falkenburg 2012, 343) simply proves to be wrong.

5. On van Fraassen's 'immersion in the theoretical world-picture'

Stanislavsky method is a highly famous and influential system of dramatic training developed by the Russian actor, producer, and theoretician Konstantin Stanislavsky between the end of the 19^{th} century and the beginning of the 20^{th}. When an actor uses it, her onstage actions and reactions appear as if they were a part of the real world rather than a make-believe one.

Mutatis mutandis, this is analogous to what van Fraassen has in mind when he talks of "*total immersion (for practical purposes) in the theoretical world-picture*" (1980, 80). William Seager reckons that the concept of 'virtual reality' is even more adequate and writes: "*Someone engaged in what I called our micropractices cannot take the distanced standpoint recommended by CE [constructive empiricism] and continue, for without immersion the practices make no sense*" (1995, 477). This means that a scientist *must* engage in an experiment or a research *as if* the world actually corresponded to the theoretical world-picture she has in mind or to a model of the theory she wants to test, on pain of not succeeding in her job. But, again, this does not commit her ontologically (or epistemically). The scientist might actually believe that the theoretical world-picture she has in mind is a faithful representation of the real world, but she might choose to 'bracket' the ontological implications of her immersion instead – and this is a quite obvious difference with drama in the analogy above, since no actor believes that the real world is that depicted by the play she is working in.

When Falkenburg talks about bosons, gamma rays and the like,

> *such objects have (...) passed every test for being truly in the micro-world just as they appear to be. But such tests are all internal to the virtual world itself. This is why van Fraassen can, and indeed must, say: 'when a realist gives a consciously and deliberately naive description of what happens in an experiment or observation, I do not, of course, want to dispute a single one of his assertions on its own ground' (1985, 297). Leaving aside the rhetorical tone of this remark, we can see what forces it. There is no plausible refutation of realism from within the complex and beautifully articulated virtual reality which supports the conviction that micro-objects exist, and exist as imaged. But there is a way to step back from the virtual world and understand the practices and convictions of its champions in a way that is ontologically neutral (Seager 1995, 476).*

Within the 'complex and beautifully articulated' virtual reality constituted by the theoretical world-picture, "*in which (...) theory is what guides the use of terms and the allowed inferences*" (van Fraassen 1980, 92) - and not only, as Seager remarked -, the assertion that scientific realism constitutes an indispensable methodological principle of research makes sense if interpreted *à la* Seager. As the Canadian philosopher said, someone engaged in scientific practice cannot step back and reflect while doing her job, for without a 'van Fraassian' theoretical immersion such practices make no sense. This means that, within Seager's 'virtual reality' - the realists' own ground where van Fraassen does not intend to dispute a single one of their assertions (see van Fraassen 1985, 297) -, one *must* act as a realist would do. Outside, back to the actual world, however, one can dismiss the realist bias with no further ado. Falkenburg's claim about the alleged indispensability of scientific realism as a methodological principle cannot in fact be endorsed - and does not seem to make sense - *tout court*.

6. The goal of physics

"*The goal of physics is to explain the effects from their causes*", writes Falkenburg (2012, 336). Of course this is a legitimate point of view on the aim of this important discipline, but it is no more legitimate than the constructive empiricist alternative put forward by van Fraassen, according to which the aim of science - and thus of physics too - is 'only' to give us empirically adequate theories (see 1980, 12).

According to the author of *The Scientific Image*, the problem with the realist stand is that "*an unlimited demand for explanation leads to a demand for hidden variables, which runs contrary to at least one major school of thought in twentieth-century physics*" (van Fraassen 1980, 23) - not to mention that "*as Duhem already emphasized, the very search for new and deeper empirical regularities becomes couched in theoretical language*" (p. 73).[11] Our point here, however, is not to try and underline the problems a supporter of a realist stance must cope with, but again to rebut Falkenburg's claim that

[11] As van Fraassen recalls, right at the beginning of his seminal book, "*the opposition between empiricism and realism is old, and can be introduced by illustrations from many episodes in the history of philosophy. The most graphic of these is perhaps provided by the sense of philosophical superiority the participants in the early development of modern science felt toward the Aristotelian tradition. In that tradition, the realists held that regularities in the natural phenomena must have a reason (cause, explanation), and they sought this reason in the causal properties, constituting what they called the substantial forms or natures, of the substances involved in natural processes. The nominalists, who denied the reality of these properties, were in the position of having to reject such requests for explanation*" (1980, 1).

scientific realism is the only viable position when it gets to astroparticle physics.

> *From the medieval debates, we recall the nominalist response that the basic regularities are merely brute regularities, and have no explanation. So here the antirealist must similarly say: that the observable phenomena exhibit these regularities, because of which they fit the theory, is merely a brute fact, and may or may not have an explanation in terms of unobservable facts 'behind the phenomena'- it really does not matter to the goodness of the theory, nor to our understanding of the world (van Fraassen 1980, 24).*

If one's description of scientific activity is based on the assumption that the goal of science is finding out the causes of the regularities in natural phenomena, then it comes as no surprise that she considers scientific realism as the only philosophical position able to make sense of it. But there always exists a nominalist alternative, as old as science itself. Falkenburg's assumption on the aim of physics is definitely not a conceptual truth. Constructive empiricism *is* an alternative to scientific realism, spelt out exactly in terms of the aim of science, which can make sense of this human enterprise - and therefore of astroparticle physics as well - no worse than the latter does.

7. Cosmic messengers

According to Falkenburg, "*the physicists consider cosmic rays to be messenger particles that carry information about cosmic sources and propagate this information to the earth, where it is read out by the physicists*" (2012, 336). They allegedly mediate between the cosmic sources and the detectors on earth (see p. 338). The concept of 'messenger particles', however, is not a theoretical one, but just "*an informal heuristic tool that helps to reconstruct the causal story of cosmic rays*" (*ibid.*). Still, Falkenburg adds, it "*only makes sense from a realistic point of view*" (p. 337), for it "*paves the way to more detailed theoretical explanations of cosmic rays, their causes, and their effects*" (*ibid.*).

She finds an easy parallel in Dudley Shapere's notion of observation, according to which "*observation boils down to the transfer of physical information*" (Falkenburg 2012, 338). Shapere's account, however, is admittedly theory-laden: "*what the astrophysicist (and I) have been referring to as 'observation' in the solar neutrino experiment obviously involves a great deal of inference*" (Shapere 1982, 517). It is then clear that the "*use of the term 'observation' in reference to that experiment departs from ordinary and philosophical usages which associate observation epistemically with perception*" (1982, 485), as Shapere candidly admits too.

Therefore, "*even if we were to accept the view that their usage is perfectly clear, and is misleading only to the uninitiated, the possibility would still remain that it is nevertheless not that of either the philosopher or the ordinary man*" (Shapere 1982, 488-489). This is probably the reason why Shapere's paper, although well-known and discussed in the literature, is not that influential and many if not most readers of his essay have remained unmoved.

According to Shapere, "*science is, after all, concerned with the role of observation as evidence, whereas sense-perception is notoriously untrustworthy*" (1982, 508). Not only, however, a "*survey of the solar neutrino experiment indicates that prior information plays an extensive role in determining what counts as an 'observation' in that case-as astrophysicists use that term*" (p. 505), but what works in the case of the solar neutrino might now work in general: "*I do not claim that the analysis I have given of 'observation' and its cognates as used in the context of the solar neutrino experiment necessarily applies, in all its details, to all cases of scientific use of the term*" (Shapere 1982, 512).

Shapere's account of 'observation' (insofar as it is appropriate to speak this way) is probably not even a generalization of the verb, then, but rather the description of a peculiar use of it by some astrophysicists in a specific case.[12] Admittedly, "*the astrophysicist's usage is a departure from the ordinary*" (Shapere 1982, 511), whereas 'observation' "*in philosophical discussion (...) is meant to have its common use"* (van Fraassen 1992, 18).

Then yes, Shapere's account constitutes a "*parallel to the concept of messenger particles used in astroparticle physics*" (Falkenburg 2012, 339), but this comes as no surprise either, since Shapere's essay is a case study of the detection of neutrinos allegedly coming from the core of the Sun.[13] Both Falkenburg's description of the study of cosmic rays and Shapere's paper are about very similar phenomena, in both cases described from the point of view of scientific realism and, above all, endorsing the standpoint of astrophysicists with a realist creed – or, perhaps, completely 'immersed' in the theoretical picture that guides their actual scientific work. The parallelism is no striking at all.

[12] Falkenburg considers Shapere's account of observation to be both a generalized and a naturalistic one (see her 2012, 328). Filip Buekens and F. A. Muller attribute to van Fraassen and his constructive empiricism a 'Naturalisation Thesis of Observability' instead (see Buekens & Muller 2012, 92). As it has acutely been said, the term 'naturalism' is "*one of the most ambiguous in the history of philosophy*" (Engel 2011, 191, our translation).

[13] Since this work aims at presenting a constructive empiricist alternative to Falkenburg's account of astroparticle physics, we endorse van Fraassens's distinction between 'observing' and 'detecting': "*Microscopes, cloud chambers, laser interferometers and other scientific instruments allow us to detect entities, but* detection *has to be carefully distinguished from* observation*. A look through a microscope does not allow us to observe directly a paramecium; only to observe* an image *of a paramecium, or to* detect *a paramecium*" (Contessa 2006, 456). See also van Fraassen (1980, 16-17 and especially 2008, 93).

Still, it is not clear how Shapere's work can actually support Falkenburg's realist account of astroparticle physics, considering that his account of 'observation' has warmed at most only a few (realist) hearts – and that it admittedly constitutes a departure from the ordinary use of 'to observe'. Indeed, both accounts are an accurate description of some scientific practices 'as seen from the inside', endorsing the point of view of the physicists while immersed in what Seager would call a 'virtual reality' - a kind of realist *Matrix*, some might say. Their narrative is completely couched in theoretical language and describes a world where even simple acts such as 'observing' an entity depend on some background knowledge - something that the layman could not perform then.

But there exist alternatives. When Shapere writes that "*what counts as directly observed (observable), and therefore what counts as an observation, is a function of the current state of physical knowledge, and can change with changes in that knowledge*" (1982, 492, emphasis in the original), one might borrow van Fraassen's words once again and ponder: "*I imagine that he is using 'knowledge' lightly; he is referring to the account of underlying causal mechanisms implied by the accepted theories which form the background to the experimentation*" (1980, 79).[14] Even if these collateral theories are believed to be true, one can still describe the practices reported by Shapere as "*the pursuit of empirical adequacy through total immersion (for practical purposes) in the theoretical world-picture*" (van Fraassen 1980, 80) – and consider that what he calls an observation is nothing else than what van Fraassen calls detection.

The same applies to Falkenburg. Whenever she talks of 'knowledge' in her paper, even when she calls it 'well-established' or 'safe background', one might interpret it as a model (or a set of models) of a theory which has been accepted for it has not proved to be empirically inadequate so far. Some of these models are developed for one specific area but prove to be useful in other fields too or, again, are used as a guiding factor in the design of the experiments (see van Fraassen 1980, 74). "*The transfer of knowledge about particle detection went forth and back between cosmic ray studies and particle physics. In the 1950s, the knowledge was transferred from cosmic ray studies to the construction of highly sophisticated particle detectors for scattering experiments*" (Falkenburg 2012, 329).

When Shapere writes that "*what counts as an observation, is a function of the current state of physical knowledge*" (1982, 492, emphasis in the original) and Falkenburg endorses this claim, then, one might interpret it from an empiricist point of view, as meaning that a detection may or may not fit a pre-existing theoretical model. Again, as van Fraassen has pointed out, in

[14] Van Fraassen is here replying to Richard Boyd, but the same applies, *mutatis mutandis*, to Shapere's work.

experimentation theory helps formulating the questions to be answered (what counts as an observation, for instance), besides being a guiding factor in the design of the experiments to answer those questions. The experiment, on the other hand, can help 'filling the blanks' if a theory is still under construction. "*In all this we can cogently maintain that the aim is to obtain the empirical information conveyed by the assertion that a theory is or is not empirically adequate*" (van Fraassen 1980, 74).

Falkenburg also writes that "*the causal stories of cosmic rays are multi-faceted and indeed disunified*" (p. 336) and explains that different models from astroparticle physics are used to fit the so-called 'all particle spectrum', adding that "*these models give just a rough idea of what kind of cosmic sources and astrophysical processes may contribute to the energy spectrum of cosmic rays.* No physicist believes that nature really is like that" (p. 337, our emphasis)[15] - which seems particularly emblematic.

Moreover, when she develops the parallel with the position spelled out by Shapere, who was convinced that the solar neutrinos might serve to directly observe the interior of the sun, she also adds: "*As we know today, his argument failed. Shapere did not know that the information about the sun carried by the neutrinos is altered due to neutrino oscillations*" (p. 339-340). It would be too easy to remark that one might use this very argument to point to the excessive and unnecessary faith (some) scientific realists put in some theories that might just be wrong. But one might again reason in terms of the so-called 'semantic' approach and observe that Shapere was relying on a model that later proved to be empirically inadequate. Falkenburg prefers concluding that "*the nature of the messenger particles was not sufficiently known*" (p. 340). The two alternatives are legitimate. But this is exactly our point: it is not true that astroparticle physics in general, or the account of 'messenger particles' in particular, only makes sense from the point of view of scientific realism. There exist legitimate anti-realist alternatives, even when it gets to astroparticle physics. Constructive empiricism is one of them.

8. Conclusion

"*In the practice of physics (...) many facets of scientific realism coexist, and the realistic beliefs associated with them differ in being stronger or weaker*", writes Falkenburg (2012, 341). Putting aside another possible remark, that it is not typical of a realist position to admit that belief can come in degrees (see

[15] "*In astroparticle physics, the various 'astro' and 'particle' phenomena of cosmic rays are put together into the 'all particle spectrum', which collects all measurements of cosmic rays and their physical properties and represents all known radiation of extraterrestrial origin*" (Falkenburg 2012, 341).

van Fraassen 1980, 9, note 3), in this paper we have tried to show that while there might be a sense in which Falkenburg's claim can be considered true - that is, when judged from inside 'the realist *Matrix*' -, it cannot be taken as such *tout court*. An anti-realist alternative, such as the one put forward by van Fraassen in the last decades, is feasible, even for astroparticle physics.

In *The Scientific Image*, the Dutch philosopher wondered: "*is the methodology of science and experimental design intelligible on any but a realist interpretation of science?*" (p. 70) and defended that the intertwined development of theory and experimentation is perfectly intelligible from an empiricist point of view. The aim of this paper has been to show that, contrary to what Falkenburg claims, this applies to astroparticle physics as well.

In his recent "Microscopes and the Theory-Ladenness of Experience in Bas van Fraassen's Recent Work" (2015), Martin Kusch discussed van Fraassen's notorious and controversial position on the matter of observation and defended it as a viable alternative to a realist interpretation of the output of devices such as the microscope. Some of Kusch's remarks certainly apply - again, *mutatis mutandis* - to Falkenburg's defence of scientific realism as the only position able to make sense of astroparticle physics and its practices.

When she claims that "*knowledge of physical phenomena, the underlying entities, and their properties is objective and stable*" (2012, 341) or that "*the models of astroparticle physics are taken as true whenever they are based on safe background knowledge*" (p. 342), etc., one might borrow Kusch's reply to Marc Alspector-Kelly and say:

> *What is it that we know here? Does not this knowledge involve theoretical claims? And how are we to relate to them? That is, what does acceptance of the theory involve? (...) Does it merely amount to the claim that there is a regularity (invariance) between various observable phenomena brought about by the (...) system? Clearly, the scientific realist and the constructive empiricist will opt for different answers here (2015, 176-177).*

Falkenburg talks about bosons, cosmic rays, microwave background radiation and the like with ease and has every right to do so. She also thinks that "*cosmic rays and their physical properties could be established as objective, stable phenomena*" (2012, 328). One might observe, however, that her narrative "*rests upon a realist epistemology of instrumentally-aided (...) experience; that this theory has come to shape our very phenomenology of instrumentally-aided sensory experience; and that this shaping explains the strengths of resistance to the constructive empiricist's agnosticism*" (Kusch 2015, 168).

Indeed, Falkenburg's talk gives the false impression that we do not need to marshal arguments in defence of the belief that neutrinos and cosmic rays are objects or that the postulated microstructures are real (compare with Kusch

2015, 173). She even reckons that cosmic rays can be established as objective and stable phenomena, as has just been said. But whether these unobservable (to the naked eye) entities are well-behaved or not, is, for the constructive empiricist, something that we merely infer on the basis of the output of some device (compare with Kusch 2015, 176).

Compare this other passage from Kusch's paper, again directed to Alspector-Kelly:

> *He does not recognize the importance and possibility of reading the results of science in a way that is neutral with respect to the debate between scientific realist and constructive empiricist. He does not take account of the possibility that certain formulations or interpretations of scientific theories - by scientists themselves or philosophers - simply presuppose without argument the truth of scientific realism. (…) van Fraassen is entitled to demand that the scientific evidence be rendered in a neutral way, and that this neutral way is precisely the constructive-empiricist interpretation (2015, 180).*

Something very similar might be said apropos of Falkenburg's account of astroparticle physics. Her interpretation of the practices and experiments in this field *does* presuppose without argument the truth of scientific realism, as when she claims that the goal of physics is to explain the effects from their causes (see 2012, 336).[16] I have replied that this is not straightforward at all and recalled that there exist alternative points of view on science and its aim. Van Fraassen put forward an important anti-realist one a few decades ago, which rejects the scientific realists' 'unlimited demand for explanation', but sure can make sense of physics too.

Borrowing again Kusch's words, one might then say that none of Falkenburg's arguments is launched from a platform that would be neutral regarding the two opposed views (compare with Kusch 2015, 181) and that it would be more illuminating to keep neutrality, instead (see van Fraassen 2001, 155 and 2008, 109). It would be so since it could allow us to identify realist commitments as optional (see Kusch 2015, 172). Even when it gets to astroparticle physics.

Let's consider another example. Falkenburg claims that "*unifying strategies, and in particular the heuristic concept of messenger particles, demonstrate that the practice of physics depends on scientific realism*" (2012, 343). But van Fraassen had already explained that "*there seems to me no doubt that the aim of empirical adequacy already requires the successive unification of 'mini-theories' into larger ones, and that the process of unification is mainly one of correction and not of conjunction*" (1980, 87). Unifying

[16] Because of this, Kusch would probably reply that Falkenburg's argument "*presupposes the realism it seeks to establish*" (2015, 181).

strategies are perfectly intelligible from the point of view of constructive empiricism. Even when analyzing them, realist commitments are optional.

In conclusion, we can confidently say that Falkenburg's opinion that without scientific realism "*neither the problems nor the results of astroparticle physics can be understood*" (2012, 343) is not well-founded. Problems and results of astroparticle physics can be understood from an empiricist point of view too, namely from that of van Fraassen's constructive empiricism. Still, it is worth remembering that "*van Fraassen is not trying to refute the scientific realist. All he is seeking to establish is that the constructive empiricist stance is not incoherent*" (Kusch 2015, 172). It is our contention that he succeeded, even when the topic is astroparticle physics.

References

[1] Buekens, F.; Muller, F. A. (2012). Intentionality Versus Constructive Empiricism. *Erkenntnis,* 76, 91-100.

[2] Chakravartty, A. (2007). *A Metaphysics for Scientific Realism. Knowing the Unobservable*. New York: Cambridge University Press.

[3] Contessa, G. (2006). Constructive Empiricism, observability, and three kinds of ontological commitment. *Studies in History and Philosophy of Science*, 37 (3), 454-468.

[4] Discovery of cosmic background radiation. Retrieved from *http://hyperphysics.phy-astr.gsu.edu/hbase/astro/penwil.html* [accessed: september 01, 2018]

[5] Engel, D. (2011). Naturalismo Epistemológico: qual é a controvérsia, afinal? (pp. 191-205). In: *VII Semana Acadêmica do Programa de Pós-Graduação em Filosofia da PUCRS, 2011, PORTO ALEGRE RS. Semana Acadêmica do PPG em Filosofia da PUCRS, VII Edição, 2011*. Porto Alegre: EDIPUCRS.

[5] Falkenburg, B. (2012). Pragmatic unification, observation and realism in astroparticle physics. *Journal for General Philosophy of Science*, 43 (2), 327-345.

[6] Fraassen, B. C. van (1980). *The Scientific Image*. Oxford: Clarendon Press.

[7] Fraassen, B. C. van (1985). Empiricism in the Philosophy of Science. (pp. 245-308). In: P. M. Churchland & C. A. Hooker (eds.), *Images of Science. Essays on Realism and Empiricism, with a Reply from Bas C. van Fraassen*. Chicago: The University of Chicago Press.

[8] Fraassen, B. C. van (1989). *Laws and Symmetry*. Oxford: Clarendon Press.

[9] Fraassen, B. C. van (1992). From vicious circle to infinite regress, and back again. *Philosophy of Science Association Proceedings*, 2, 6-29.

[10] Fraassen, B. C. van (2008). *Scientific Representation: Paradoxes of Perspective*. Oxford: Clarendon Press.

[11] Kusch, M. (2015). Microscopes and the Theory-Ladenness of Experience in Bas van Fraassen's Recent Work. *Journal for General Philosophy of Science*, 46 (1), 167-182.

[12] Morton, A. (1993). Reviewed Work: *Laws and Symmetry*, by Bas C. van Fraassen. *The Philosophical Review*, 102 (3), 408-410.

[13] Robert Millikan coins the term 'cosmic rays'. (n.d.). Retrieved from *https://timeline.web.cern.ch/robert-millikan-coins-the-term-'cosmic-rays'* [accessed: september 01, 2018]

[14] Seager, W. (1995). Ground Truth and Virtual Reality: Hacking vs. Van Fraassen. *Philosophy of Science*, 62 (3), 459-478.

[15] Shapere, D. (1982). The Concept of Observation in Science and Philosophy. *Philosophy of Science*, 49 (4), 485-525.

[16] Sicha, J. (1992). Reviewed Work: *Images of Science. Essays on Realism and Empiricism, with a Reply from Bas C. van Fraassen* by P. M. Churchland; C. A. Hooker. *Noûs*, 26 (4), 519-525.

[17] Stanislavsky system. (May 05, 2016). In *Encyclopædia Britannica*. Retrieved from *https://www.britannica.com/art/Stanislavsky-system* [accessed: September 02, 2018]