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Review

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Steven Weinberg's Explanation of the World and a Discussion of the True Story of Modern Cosmology

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Abstract. Should practicing physicists write books about the history of physics? Some historians strongly oppose this idea, believing that physicists generally cannot address historical issues objectively. However, it will be argued here that the specialists' view and analysis of the past is absolutely essential to complement that of historians in their own terms. To wit, even such a high-ranking figure as the last Steven Weinberg could not escape criticism from historians. Weinberg received strong criticism after the publication of his book *"Explaining the World: The Discovery of Modern Science",* which he devoted to the history of physics from the ancient Greeks to the present day. He was accused of judging the past exclusively from the point of view of the present, that is, from what we now know with great certainty. The present article aims to show, with the help of this example and another one, how it is possible to find a healthy balance between these two confronting attitudes. In particular, it will be sustained that most of the scientists about whom history books are written, were considerably more intelligent than many of us, the present-day scientists, in spite that they often said all kinds of nonsense – if we judge them from a current perspective, with all the knowledge we now have accumulated. The main thesis of the paper will be that great care should be taken to try to balance as much as possible these two diametrically opposed approaches, and to show how this can be achieved in practice. All this will be explained in detail, with the help of several important, specific situations. The main results obtained and an analysis of the practical implications of the outcome of the research carried out here will be given in the closing section.

Keywords: history of science; Steven Weinberg; explain the world; whiggism; modern cosmology; cosmological revolutions.

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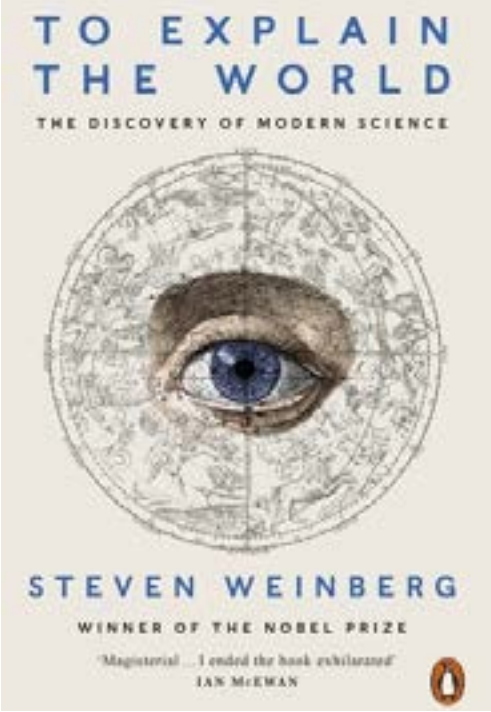
Introduction

Steven Weinberg as a first reference

In the author's book *"The True Story of Modern Cosmology",* published by Springer [1] (the previous version in Spanish, *"Modern Cosmology from its Origins"*, appeared in Ed. Catarata [2]), it is described in detail how, during the last century, sky observers and pioneering theoretical physicists shaped our current understanding of the universe while, at the same time, they turned cosmology into a modern science. But, before going into the details of this research, let us start by putting it in context. This will be done by taking as a reference another book: *"To Explain the World: Discovery of Modern Science"* [3], written in 2015 by the late Steven Weinberg, a great theoretical physicist who passed away in July 2021.

It will prove to be most appropriate to proceed in this way, taking into account the criticism (sometimes fierce) that active scientists-researchers at the various frontiers of knowledge usually receive from historians, when the former (dare) dedicate themselves to writing a book on the history of science. Taking this one as a paradigmatic example, we will now dwell on what happened to Weinberg himself, a physicist of an exceptional category, a myth, for many theorists. Not even a character of such a high level could escape criticism. We are talking about a great Nobel Prize winner who, as the also laureate Frank Wilczek wrote in Nature [4]: "… *took the fundamental understanding of nature to new levels of power and completeness, and played a key role in formulating and establishing the two standard models of current theoretical physics: the standard model of fundamental interactions and the standard model of cosmology"*.



Weinberg was undoubtedly a colossal theorist who unified two of the four fundamental forces of nature and shaped the image that physicists (and also ordinary people) now have of our universe. To be even more precise, some of his more qualified colleagues argue that Weinberg's really crucial contribution to particle physics was not just the unification of the weak forces and electromagnetism (important as that discovery is), but his definitive articulation of how effective quantum field theories, which have now become of major importance, should be treated precisely.

Weinberg wrote a number of excellent books, which have educated several generations of theoretical physicists. His popular work *The First Three Minutes: A Modern View of the Origin of the Universe* [5] made him universally known to the general public. We will not dwell further on his merits, since anyone reading this – if (unlikely) he/she does not know Weinberg well enough – has at disposal numerous recent and well-documented memories, with detailed explanations of all that he did (see, for example, the one in Physics Today [6]). An excellent discussion of his work appeared in an article in the *Revista de Física,* written by Luis Álvarez Gaumé (in Spanish) [7].

Weinberg received the said criticism after the publication of his book, already mentioned, *"Explaining the World: The Discovery of Modern Science"* [3] (Fig. 1), which he dedicated to the history of physics, from the ancient Greeks to the present day. This is indeed a brilliant and ambitious book where he expressed, among other things, his vision shared by many other scientists that genuine science transcends history and culture. The critics were especially harsh in his case, perhaps precisely because of his exceptional status, which allowed them to shine and get publicity, at his expenses (this is not seldom). Although it could also be understood as a reaction, to a certain extent understandable, to the contempt that historians have sometimes received from some active scientists. They are often reproached for not having made any relevant, original contribution to the advancement of science, and even for not adequately understanding current theories! When it was published, the book gave wings to the pens of the most combative historians and philosophers, who were very upset by Weinberg's approach to history. They accused him, among other things, of judging the past exclusively from the point of view of the present, that is, from what we now know about nature with great certainty. This view is often called the "Whig interpretation of history" and is characterized by viewing past events through the prism of a constant advance towards enlightenment, which completely ignores the dead ends and blind alleys that so often appear along the way. In other words, it is considered as *"history written by the winners".*

In fact, it may seem surprising at first glance – when one thinks about it, that scientists maintain two apparently very different discourses on this issue and on the development of science in general. On the one hand, they take great satisfaction in proclaiming that we are continually acquiring knowledge, that we are learning more and more about how the world works. But it is also often claimed that it is good to be wrong, from time to time, to get weird results; and that the real root of future progress is that there are always things that we do not yet know how they work. We might add that the truly exciting part of science lies in realizing what we do not yet know, and how we can fill those important gaps.

It is a paradigmatic case that the moment we are in now in cosmology is a most exciting one in this sense. As is well known, the conclusion has been reached that we do not know what 95% of our universe is made of! All this discourse may seem rather contradictory, but in fact it is not at all: both attitudes or approaches complement each other smoothly; one could even say that they feed off each other, in a very positive and fruitful way.

Be that as it may, seen in perspective, what is unquestionable is that we are always progressing towards greater knowledge (especially if we admit that *knowing that we do not know* is also a form of knowing). To give an example, it must be clearly understood, to begin with, that the validity of Newtonian mechanics was never called into question by Einstein's discoveries: it just happened that its domain of applicability (thought by Newton to be *universal,* what proved not to be) was delimited clearly. From the side of active science, many historians are accused of not being able to understand a point as basic and elementary as this one. For it is a very clear fact that, despite our later discoveries, Newtonian mechanics remains exactly as valid as it was before the advent of general relativity and quantum physics; always, of course, *within its very wide domain of applicability.* And today we still use the equations derived from Newton's laws for many and very important applications in physics and engineering, which are not affected at all by the discoveries.

It is sometimes difficult to properly understand that science is, in fact, radically different from other forms of human knowledge, corresponding to many other areas. Because, in fundamental physics, there are some things that, like Newton's laws, we are absolutely certain to know completely and that *will never change,* no matter how much physics progresses and new and ever more advanced theories appear. Basic science is an increasingly accurate representation of how the Universe works, and this accuracy is constantly improving and expanding; it never goes backwards, under any circumstances (a highly recommendable reading in this respect is: "The best books on The History of Science", https://fivebooks.com/best-books/history-science-matthew-cobb/, by Matthew Cobb, in an interview with Jo Marchant).

In any case, by calling Plato "silly," Aristotle "tedious," and Galileo "behind his time," Weinberg's book commits – in the opinion of the aforementioned historians – all the sins that they usually attribute to Whiggism [8]. In his book, Weinberg gives them clear reasons for their criticism:

"I will approach the dangerous ground that contemporary historians most carefully avoid: judging the past according to the standards of the present. [...] Some historians of science avoid at all costs referring to current scientific knowledge in their studies of the science of the past. Quite the contrary, in my case, I will make full use of present knowledge to clarify the science of the past."

And, as another aspect of the subject, referring to the subtitle of the book, *"The discovery of modern science,"* Weinberg explains its profound significance, stating that it is a fact that science is not "constructed," but "discovered"; In the same way that agriculture was not built, but discovered: *"the physical reality of the Universe is what it is, and it is just waiting to be discovered."*

In sharp contrast to the above, Thomas Kuhn, among other great thinkers and historians, considers in his writings that linear and cumulative progress can generally be a problematic notion and that history should properly try to *understand the world of the past on its own terms.* Weinberg explicitly dismisses this idea in his book, stating clearly that: *"I do not share it."* The goal of his work is not, as he declares, *"to understand the past on its own terms,"* but *"to judge the past according to the standards of the present."* And he claims that it is precisely from this perspective that we should be able to understand the past in its own terms. And he claims that it is precisely from this point of view that Plato was *"foolish"* and Aristotle *"wrong about the laws of nature"* – though he admits that the latter was at the same time *"clear and serious"* in his statements. He also says that Galileo's emphasis on geometry over algebra *"left him behind"* what he might have achieved by proceeding otherwise. He also considers Bacon to have been overrated and adds that, despite the praise of Baconianism by several generations of thinkers, *"I am not clear that the work of any major scientist has ever been improved by reading Bacon."* Weinberg also believes that Descartes has been greatly overrated, noting that: *"It is remarkable how many mistakes Descartes made in so many aspects of his approach to nature."* Newton is, in this sense, one of the few who escapes his criticism, stating that his achievements *"provided the paradigm that all subsequent science followed as it became modern."* Let us leave it at that, for now.

Methodology

An example of the origins of modern cosmology

The extensive introduction above – on the orientation of Weinberg's book and the criticisms it received – should serve to put into context the historical approach to which the present author

tried to adjust in his own book. It may be summarized by saying, at the outset, that his intention was to place himself smoothly in the middle field of all the preceding considerations. We will now see how this could be realized.

It is very true that, as Kuhn states, linear and cumulative progress can generally be a *"rather problematic notion"* when thinking in a generic scientific field. There are many and very important examples that can be put on the table to support this statement. But it must also be considered that the concept of Science is extremely broad and varied, and that these considerations *can be of very different validity and applicability* in its various domains or areas of knowledge. Let us just recall here that more than one reputable specialist has even dared to imagine as a possibility (however remote) that the paradigm of natural selection in the evolution of species could falter and have to be drastically modified in the future. In this field, then, as well as in various areas of medicine and in many others, Kuhn's statement turns out to be absolutely valid and adequate. Particularly interesting is the discussion on this point that can be found in: *"The Whig History of Science: An Exchange",* by Arthur M. Silverstein, with the corresponding response by the same Steven Weinberg (https://www.nybooks.com/articles/2016/02/25/the-whig-history-of-science-an-exchange/).

However, quite on the contrary, in the field of fundamental physics, in the most basic and essential principles of physical reality, progress is indisputable, and the line, in constant ascent, that goes from the past to the present, and beyond, is clearly identifiable, in an objective and rigorous manner. Here, it is not possible to disagree with Weinberg.

The point where it is difficult to agree with Weinberg is that the vision of past formulations and discoveries in physics should be made exclusively with the eyes of what we know today. It is quite necessary (or at least very convenient) to adopt a more open criterion in this sense. A journey back in time (*gedanken Zeitrückreise,* as the author has often called it) is very essential in many cases. Sometimes, we must forget for a while everything that we now know and delve fully into certain episodes of past times, *reasoning only with the knowledge that was at hand at that time.* And this is what the present author does, quite often, in his book. With all the information in hand, each case is then analyzed. Although, at the same time, a well-deserved extra bonus is given to those scientists who were cleverer (or lucky, if you will), capable of finding the “right” path in those circumstances of the past, of discovering the path that truly led to the future knowledge that we now possess.

This has important value, of course, but always in a way that is a balanced and additional bonus, and not an “all or nothing” issue. It is also necessary to seriously consider the often-decisive influence of luck in these discoveries: chance is a very important factor, which is often too little talked about and which has in fact proven to be crucial in a good number of scientific discoveries of enormous importance. This is conveniently emphasized in various passages of the author’s book (Fig. 2).

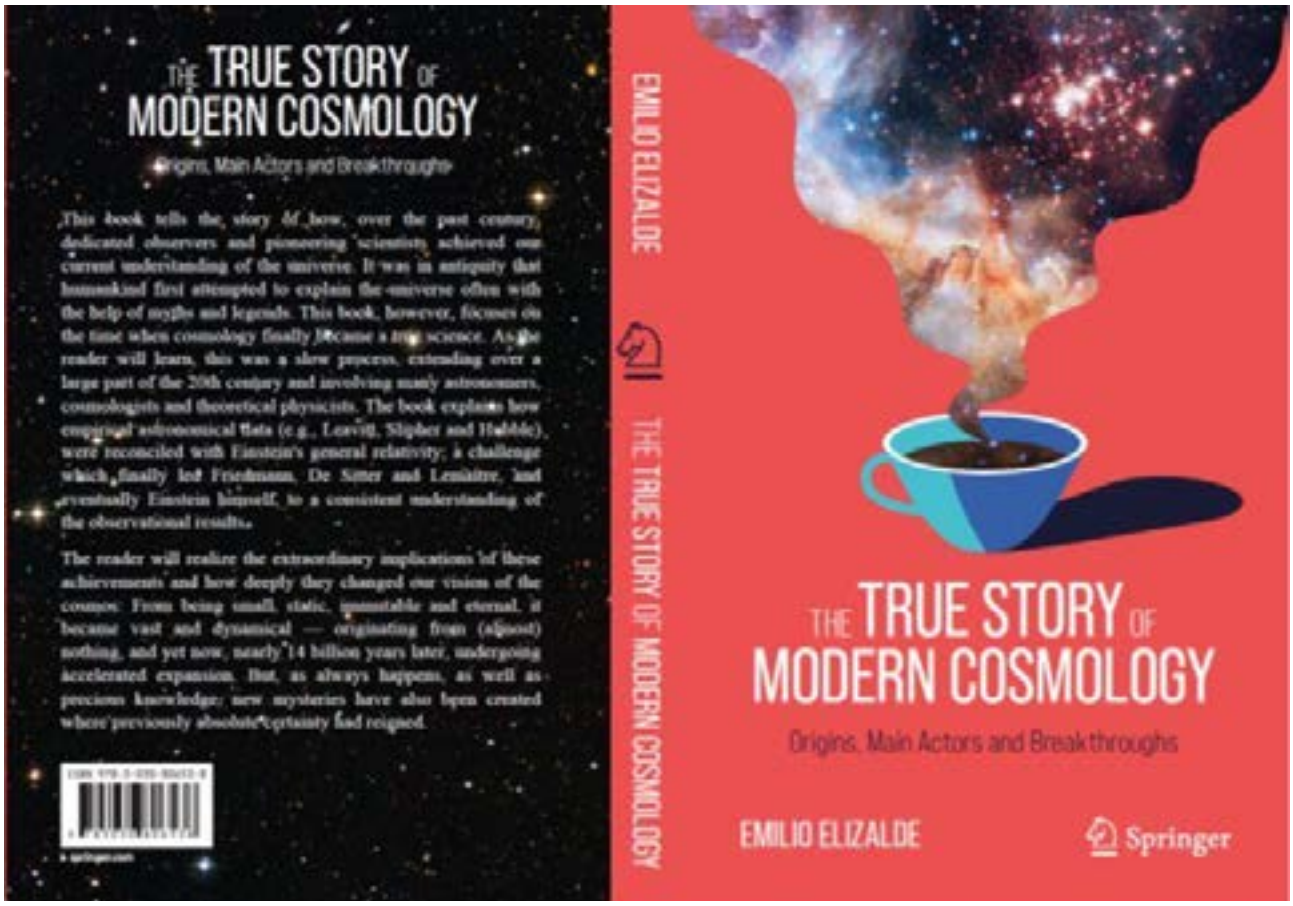


Fig. 2. The cover and back covers of *"The True Story of Modern Cosmology: Origins, Main Actors and Breakthroughs"*, recently published by Springer, aim to convey the book's essence and objectives. On the front cover, the steam coming from a hot coffee cup draws a famous region of the Milky Way where stars are constantly being born from huge concentrations of dust and gas. The steam continues to spread, impregnating the entire book, all the way to the back cover, where we find a deep field image of the sky with some of the oldest stars in the universe, the furthest away from us. The image on the cover wants to convey the author's kind advice that all the lessons in this book, about the birth and evolution of the universe, should be always taken in small sips, sitting in a comfortable place, while enjoying a cup of good, freshly brewed coffee, or the reader's favorite drink. It is the best way to delve into this unique story of the cosmos.

Leaving aside the aforementioned rivalries between scientists and historians – which should be to a certain extent understandable for the reasons already mentioned – one of the great arguments for disagreement is the one just referred to above: while historians of science strictly place themselves, as good historians, in the era and circumstances in which the scientific discoveries took place, scientist-historians usually describe the past in terms of our current knowledge, thus giving a vision that is often radically different from the first. Thus, great historical figures who constructed excellent theories, according to the time in which they were proposed, but which were later shown to be completely wrong (think, for example, of the

theories that considered the Earth, or later the Sun, as the center of the Universe, or that of Aristotle's spheres) are absolutely minimized (even ridiculed, at times) by scientist-historians, due to the irrefutable fact, proven a posteriori, that those theories are now, and will ever be in the future, completely wrong.

It is, on the other hand, an indisputable reality that there is a very important difference between the progress of science and that of other disciplines of human culture. In fact, the most precious jewel of scientific knowledge is the fact that science is cumulative: we now know much more about the world, and in a better way, than we did a hundred years ago. This cannot be said in the same way, for example, of artistic creation, since no one can prove (this example is borrowed from Weinberg's) that Keats was a better writer than Shakespeare. Nor can anyone prove that among the works of writers after Keats there was any that improved on his. In a way, one could think that in literature we are going backwards! Or, at least, that we have not advanced at all in many centuries, depending on how you look at it. And the same could be said of many other fields, such as painting or music: who has so far managed to surpass Bach, Mozart or Beethoven? Well, in someone's opinion, it turns out that yes, all three may have been surpassed by far – by an esoteric musician whose name will nobody remember in ten years; but this will never be a universal opinion, since the overwhelming majority of people do not think at all like that guy. And the fact is that "better" does not really mean anything objective in these cultural contexts. Basic science, on the contrary, is progressive, since it is based on previous knowledge, all of which has been verified with extraordinary and indisputable rigor (some cheating will inevitably appear, from time to time, but this is soon uncovered and dismissed). The interesting thing about scientific knowledge is that this progress is incredibly non-linear, since it is quite true that mistakes are continually made and that the work that must be done to find the optimal way out – that is, the one that leads to the correct path of the occasional labyrinth that one stumbles into so many times – often turns out to be, in retrospect, the most interesting, the most exciting part of the research endeavor.

However, it often happens that when scientists describe aspects of the history of their own subject, especially in textbooks or popular books, they often forget about this more laborious part and do so in a way that makes it seem as if everything was flat, linear, and inevitably led to where we are now. That is one reason why some historians are so frustrated by scientists who write history. Professional historians love to dwell on all the derivations, on every single wrong theory that was developed in parallel with the one that has eventually proven to be correct, and they seem to find all these possibilities *equally exciting and valuable.* They have been trained to be critical of everything and to think very carefully, analyzing the many different aspects of history; so, it turns out that often the wrong theories can end up being as interesting or even more interesting – so that they devote pages and pages to them – *rather than to the right ones.* This is in sharp contrast to the way in which working scientists deal with past events, which is much more practical, direct, and aggressive, with little or *no understanding of mistakes made.*

To repeat it again, in the author's book, he has tried to find a healthy balance between both attitudes. In particular, it is defended that we should never think that our colleagues from the past were stupid. Most of the scientists about whom history books are written were considerably more intelligent than many of us. And yet, they often said all kinds of nonsenses, if we judge

them from a current perspective. Let us recall here the maps of the universe before Copernicus: Anaximander placed the stars closer to us than the Sun, and he did so with scientific criteria that were fully valid and reasonable in his time! This must be acknowledged. He could not do better! How could these very intelligent people believe things that we now know to be so palpably false? How did we manage to acquire the understanding we have today of things? What was the process followed to get here? To answer such questions honestly and properly, we have to try to reconstruct what scientists of the past thought in their own time and environment, with the knowledge available to them at their time. And the right way to do this is to forget, *if only for a moment,* all the theories and concepts that appeared later. This is a sane exercise, often performed in the author's version of the origins of cosmology as a science.

In the book, a very conscious attempt to try to balance as much as possible these two diametrically opposed approaches have been carried out. For a scientist working on theories and models that have been proven correct as of now (although also on some issues that are still being tested), it is difficult to abstract oneself from the perspective of the last century and the evolution that cosmological knowledge experienced, in the right direction (despite following an often tortuous path) until it ended up with the two cosmological revolutions that have been most clearly identified in the book, corresponding to this period (they will be described below). But at the same time, on many occasions, "journeys back in time", are undertaken, to immersing oneself fully in past eras and analyzing the facts within the strict framework of the knowledge that was available at those times (not more, nor less). In order to be able to appreciate its value in a more honest way: the value corresponding to the moment in which the model was proposed, and which may be radically different from the value that is currently given to it, seen in perspective from the knowledge that we have today. The author expects to have achieved this purpose. Albeit long, this has been a necessary discussion to adequately clarify the different approaches considered.

Discussion

Specific issues in the case under discussion

In the author's book, it is explained how, over the past century, pioneering observers and scientists succeeded in achieving our present understanding of the universe. Humanity had tried this repeatedly in ancient times, though often through the help of myths and legends. The book's story focuses essentially on the time when cosmology was finally able to become a genuine science. The reader will no doubt appreciate that this was a slow process, spanning much of the twentieth century and involving astronomers, cosmologists and theoretical physicists alike. It is explained, in all detail, how empirical astronomical data (Leavitt, Slipher and Hubble) were reconciled with Einstein's theory of general relativity – a challenge that was far from easy, fraught with many difficulties, but which ultimately led Friedmann, de Sitter and Lemaître, and finally Einstein himself, to an understanding of the observational results that was consistent with the theory.

The book provides explanations that are easy to understand, but at the same time absolutely rigorous. In short, it describes how we came to know the origin and expansion of our world. It also helps the reader to grasp in a colloquial way the deep meaning of general relativity and the

mystery of cosmic acceleration. And it shows *"in a masterful way"* (copying here the words of some reviews that have been written about the book) *"how research sheds new light on the paths that lead to the progress of our knowledge of the universe."*

To be more specific, the book consists of the following nine chapters:

1. Introduction: The awakening of cosmic consciousness.
2. What is a scientific theory?
3. The first cosmological revolution of the 20th century.
4. The theory of general relativity and its main solutions.
5. The Hubble-Lemaître law and the expansion of the universe.
6. The Big Bang theory.
7. Towards the very moment of the creation of the universe.
8. The second cosmological revolution of the 20th century.
9. Conclusion.

Bibliography.

Index.

Overall, a 300-page history with almost the same number of images of some of the fundamental episodes that led to the birth of modern cosmology. For reasons described in the text, the origin of modern cosmology is argued to have taken place in the year 1912, at a time characterized as the moment when cosmologists *first had at their disposal the basic tools essential* to making it a true science. Namely, for the first time in history, they had at disposal the instruments and procedures necessary *to calculate the positions and velocities of distant celestial objects.* This objective was fully achieved when, later on, they were able to use the physical theories that emerged from the great revolutions of the first third of the twentieth century: the general theory of relativity and quantum mechanics. These theories made it possible to describe, with increasingly precise models, the origin, structure, evolution and behavior of the universe as a whole. And taken to extremes – although not strictly valid within these limits – these theories also provide a plausible idea of how and when the origin of the cosmos occurred and what its future evolution will be.

The book ends with a bibliography, containing some 250 references, and a final index, with entries for nearly 600 terms that appear in the text.

Main findings and a general discussion

The conclusions begin with a brief reference to Stigler's law of eponymy, which states that: *"no discovery is known by the name of the person who actually made it".* This is a very strong statement, and several examples of it are considered, some of which have appeared along the text. Next, the final result that the author has reached after the exciting journey through the development of cosmology in the 20th century is particularly highlighted. The knowledge acquired during this hundred-year-long journey led him to the clear identification of two authentic revolutions of exceptional importance.

Such a statement may seem exaggerated, given that, however much we search in the literature, we seldomly find an explicit reference to such cosmological revolutions, in these same terms. However, under the perspective here taken, with the procedure and methods outlined in previous sections, it is eventually undeniable that astronomical observations throughout the 20th century completely changed our vision of the Universe:

• From being small, static, immutable and eternal, it became revealed to be enormous, expanding and having had an origin from "nothing" or "almost nothing" some 13.8 billion years ago (1st revolution).

• Later, it was also learned that its expansion accelerates without stopping, thus creating an absolute mystery where almost complete certainty had previously reigned, at least for a while (2nd revolution).

The first revolution can be framed, very precisely, in the period 1912-1932: starting with the discoveries of Leavitt and Slipher in 1912 and provisionally ending with those of Hubble, and with the inclusion of the theoretical advances made by Einstein, Friedmann, De Sitter and Lemaître. It reached its peak in 1929, with the publication of Hubble's results, which were confirmed in 1931. Finally, the scientific theory of the expansion of the universe with an origin in the past was adopted by specialists and formulated in the very famous Einstein-De Sitter model of 1932 [9].

However, its definitive completion still had to wait for three key, momentous events to occur later:

• An elaborate formulation of the Big Bang model.

• Its full corroboration, by the detection of the cosmic microwave background (CMB).

• And a major reshuffle (inflation), which would only come fifty years later, and which was, in fact, the prelude to the second cosmological revolution.

The second revolution occurred in the period 1985-2005, again a span of twenty years. It can be confirmed, with conclusive evidence, that it originated in the mid-1980s, with the first discussions on models of cold dark matter with a non-zero Λ term, which did fit the results of astronomical observations much better; and that, taken seriously, already implied that the universe expansion *should be accelerating.* It reached its peak in 1998-99, when the famous results of the SNIa supernovae appeared (Riess, Schmidt, Perlmutter et al.). But it could not be fully confirmed until about six years later, by the results from other very important observations. In particular, the precise analysis of the cosmic microwave background (CMB) radiation, results corresponding to the early formation processes of galaxies; additional and much more precise results from SNIa supernovae; data from the distributions of nearby galaxies; independent ones coming from baryon acoustic oscillations (BAO); and some more.

In other words, it is true that the ΛCDM theory, which was already being built since the mid-1980s around various results of cosmological observations, received its most striking boost thanks to the discovery of the accelerated expansion using Type Ia supernovae as standard candles. But these results did nothing more than *to confirm* what the theoretical adjustments of previous astronomical observations had already been stubbornly indicating for some time: that cosmic expansion was accelerating! And, in addition, the striking results obtained with the supernovae still required further independent, and more precise, verification by several other, independent procedures, for their definitive acceptance.

Both the modified gravity models and the use of Λ now provide solid theoretical frameworks, based on the fundamental laws of physics, to try to understand this surprising and extraordinary fact. But so far no one has been able to achieve this in a definitive and convincing way.

The *similarities between the two revolutions* mentioned are very remarkable:

• Their gestation period was exactly the same: *twenty years.*

• In addition, there were always some outstanding leaders who claimed to be the true (and only) discoverers, who *tried to claim all the credit* for the advances exclusively for themselves.

o Hubble and his Mount Wilson observatory, in the first case,

o Riess, Schmidt, Perlmutter and their SNIa observations, in the second.

In the book it is clearly argued that these claims are not sustainable, that they do not fit the reality of the facts. The history was much richer and more complex (as Nobel Prize laureate Jim Peebles dixit) and involved many other decisive contributions along the way that led to the findings and the final confirmation of the discoveries, in both cases.

Furthermore, it is also true that these two cosmological revolutions cannot be fully described by looking only at what happened during the respective twenty-year intervals. It must be admitted that the above is still an incomplete approach, a somewhat crude simplification. This is understandable, as it always happens that way when one aims at the description of any revolution. If we take the French Revolution as an example, it cannot be reduced to the events of July 14, 1789. Revolutions are always long, rather extended in time, and rarely occur in a linear or coherent way; however, they produce in the end great transformations in thought, in knowledge and in the organization of people and societies. Namely, if we refer to the most famous Scientific Revolution, as a second example, it took place during what historians sometimes call the "long 17th century," which many specialists consider to have actually extended from the 16th century, when modern techniques began to be used to investigate anatomy and astronomy, all the way to Darwin himself, that is, well into the 19th century (although some authors cut it off earlier). Anyway, it is a very long period, in which much of what we now recognize as Science was slowly condensed and in which materialistic explanations were sought for the first time in all areas of research.

Conclusions

We have started with the late Steven Weinberg and ended up with James Peebles, both of them Nobel Prize laureates in Physics. According to what we have learned in the introspective research carried out above, it must be recognized that cosmological models are being reformulated continuously, as more and better astronomical data accumulate. There is no such linear path but a quite long and winding road to knowledge. However, one thing is very clear from this study: when we now look back at the last century and observe it in true perspective from the end to the beginning, strictly comparing our view of the universe at the end of the 19th century with the corresponding view at the end of the 20th century, we will appreciate that, certainly, the cosmological models are being reformulated continuously, as more and better astronomical data accumulate. However, one thing is very clearly manifested from this analysis. Namely, when we now look back at the last century and observe it in the mentioned perspective, it is then and only then that this vision from the outside, wide-ranging and with an open mind, suddenly opens our eyes to the following, amazing reality:

• Astronomical observations throughout the 20th century had extraordinary, almost unbelievable implications, which completely changed our view of the cosmos.

• From being small, static, immutable and eternal, it became enormous, expanding and it was discovered that it had had an origin from "nothing", or "almost nothing" (1st revolution).

• Later, it was also discovered that its expansion is accelerating non-stop, thus creating an enormous mystery where absolute certainty had previously reigned (2nd revolution).

These are, without any doubt, two impressive revolutions in our knowledge of the cosmos. Two of the most extraordinary discoveries ever made in the entire History of Humanity.

And which, in turn, has given rise to another exciting era. Because our current lack of knowledge about the precise nature of dark matter and dark energy, that is, about 95% of the content of our universe, of the precise value of the Hubble constant, the mechanisms working at the origin and early evolution of the cosmos, and so on, open up a future before us that will undoubtedly be full of new and very intense emotions.

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Стивен Вайнбергтің әлемді түсіндіруі және қазіргі космологияның шынайы тарихын талдау

Аңдатпа. Физика саласында жұмыс істейтін ғалымдар физика тарихына арналған кітаптар жазуы керек пе? Кейбір тарихшылар бұған үзілді-кесілді қарсы, өйткені олардың айтуынша, физиктер тарихи мәселелерге объективті түрде қарай алмайды. Дегенмен, бұл мақалада мамандардың тарихты өз көзқарасымен бағалауы мен талдауы тарихшылардың көзқарасын толықтыру үшін аса маңызды екені дәлелденеді. Айталық, белгілі физик Стивен Вайнбергтің өзі де сынға ұшырағаны. Ол «Explaining the World: The Discovery of Modern Science» атты кітабын ежелгі гректерден бастап қазіргі заманға дейінгі физика тарихына арнаған еді, алайда бұл еңбегі үшін тарихшылар тарапынан қатты сынға ұшырады. Себебі, Вайнберг өткенді қазіргі білім деңгейімен, яғни қазіргі көзқарас тұрғысынан бағалады деп айыпталды. Осы мақалада дәл осы мысал мен тағы бір жағдай арқылы екі түрлі көзқарастың арасындағы тепе-теңдікті қалай табуға болатыны көрсетіледі. Атап айтқанда, тарих кітаптарында баяндалатын ғалымдар қазіргі физиктерге қарағанда әлдеқайда зерек болғаны, бірақ қазіргі біліммен бағаласақ, олар кейде қисынсыз тұжырымдар айтқаны туралы ой қозғалады. Мақаланың негізгі тезисі – біржақты көзқарасқа жол бермей, бұл екі әдістемені үйлестіріп, тәжірибеде қалай жүзеге асыруға болатынын көрсету. Бұл мәселелер нақты мысалдармен және тәжірибелік талдаулармен толық ашылады. Зерттеу нәтижелері мен оның тәжірибелік маңызы соңғы бөлімде баяндалады.

Түйін сөздер: ғылым тарихы; Стивен Вайнберг; дүниені түсіндіру; виггизм; қазіргі космология; космологиялық төңкерістер.

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Объяснение мира Стивена Вайнберга и анализ истинной истории современной космологии

Аннотация. Должны ли практикующие физики писать книги по истории физики? Некоторые историки категорически против, считая, что физики, как правило, не могут объективно освещать исторические вопросы. Однако в данной статье утверждается, что взгляд и анализ специалистов крайне важны для дополнения исторического подхода. Даже такой выдающийся учёный, как Стивен Вайнберг, подвергся критике со стороны историков. После публикации своей книги «Explaining the World: The Discovery of Modern Science», посвящённой истории физики от античных греков до современности, он был обвинён в том, что оценивает прошлое исключительно с позиции настоящего — опираясь на современные знания. Цель данной статьи — на этом и ещё одном

примере показать, как можно найти здоровый баланс между этими двумя противоположными подходами. В частности, подчеркивается, что многие из учёных, о которых пишут историки, были значительно умнее нас, современных исследователей, несмотря на то, что с нынешней точки зрения они нередко говорили странные вещи. Основной тезис статьи – необходимость соблюдения баланса между двумя противоположными взглядами и демонстрация того, как это можно реализовать на практике. Всё это будет подробно объяснено на ряде конкретных примеров. Основные выводы и анализ практических последствий проведённого исследования представлены в заключении.

Ключевые слова: история науки; Стивен Вайнберг; объяснение мира; виггизм; современная космология; космологические революции.

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