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ORIGINAL ARTICLE

Galileo's reasons between science, technology, and epistemology

Las razones de Galileo entre ciencia, tecnología y epistemología

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Abstract

Background: *Galileo's Dialogo offers the opportunity to follow the conceptual change that led Galileo to transform from a Ptolemaic to a Copernican. This shift involved a re-evaluation of how scientific knowledge is understood to originate.* **Objectives:** *This paper analyzes Galileo's Dialogo to trace this conceptual change from Ptolemaic to Copernican views. A primary objective is to outline Galileo's resulting epistemological conception, specifically how he rethought the traditional empiricist image for explaining the genesis of science.* **Method:** *The analysis is grounded in a hermeneutic-internalist reading of Galileo's Dialogue Concerning the Two Chief World Systems.* **Results:** *In outlining his conceptual change, Galileo emphasizes how the traditional empiricist image to explain the genesis of science is to be rethought and replaced with an epistemological conception by virtue of which our theories must "do violence to sense" in order to build theories based on an assumption ex suppositione* **Conclusion:** *For Galileo, too, the role and function of experience remain decisive, but for him only experimental experience can determine whether a theoretical prediction is correct or incorrect.*

Keywords: *Experience. Reason. Experimental dimension. Conjecture. Predictions. Epistemology.*

Resumen

Antecedentes: *El Diálogo de Galileo ofrece la oportunidad de seguir el cambio conceptual que llevó a Galileo a transformarse de ptolemaico a copernicano. Este cambio implicó una reevaluación de cómo se entiende que se origina el conocimiento científico.* **Objetivos:** *Este artículo analiza el Diálogo de Galileo para rastrear este cambio conceptual de las visiones ptolemaicas a las copernicanas. Un objetivo primordial es delinear la concepción epistemológica resultante de Galileo, específicamente cómo repensó la imagen empirista tradicional para explicar la génesis de la ciencia.* **Método:** *El análisis se fundamenta en una lectura hermenéutico-internalista del Diálogo sobre los dos máximos sistemas del mundo de Galileo.* **Resultados:** *Al esbozar su cambio conceptual, Galileo subraya cómo la imagen empirista tradicional para explicar la génesis de la*

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ciencia debe ser repensada y sustituida por una concepción epistemológica en virtud de la cual nuestras teorías deben «hacer violencia al sentido» para construir teorías basadas en un supuesto ex suppositione. **Conclusión:** *También para Galileo, el papel y la función de la experiencia siguen siendo decisivos, pero solo la experiencia experimental puede determinar si una predicción teórica es correcta o incorrecta.*

Palabras clave: *Experiencia. Razón. Dimensión experimental. Conjetura. Predicciones. Epistemología.*

Introduction

"Doubting in philosophy is the father of invention, paving the way for the discovery of truth."

Galileo to Benedetto Castelli, December 3, 1639

I was lucky enough to be able to do my PhD thesis on Galileo Galilei with Prof. Evando Agazzi as my tutor. For 4 years, I was thus able to discuss Galileo's work and thought with Prof. Agazzi in different venues and international contexts: In Freiburg (Switzerland), Paris, Warsaw, Genoa, London, etc., on all these occasions, Professor Agazzi always found the time and availability to meet with me and discuss various aspects of the great Pisan scientist's work. Not only that but also studying Agazzi's texts dedicated to Galileo allowed me to better understand his epistemology and also his reading of the *objective* scope of scientific knowledge. Indeed, Agazzi always defended the realism of Galileo's scientific position. This allowed me to discuss Galileo's work and thought with him from different points of view. The theses that are now developed here on Galileo's reasons are also the fruit of this debt I owe to Prof. Agazzi. I only hope that my reading of Galileo's work will be able to make up, at least in part, all the debt I owe to Prof. Agazzi's epistemological lesson.

Foreword

Galileo's reasons can only be our reasons. For what reason? Because it is historically true, as a thinker like Bertrand Russell (1872-1970) used to observe, that three centuries of modern science have changed the history of mankind more than 4,000 years of pre-scientific culture. Of course, this assertion may well come across as a sort of punch in the stomach, but its "stinging" character does not diminish the truth with which, like it or not, we have to reckon. Not least because it follows from Russell's approach that science, as such, can only be rooted in scientific thought. But the latter is by no means a "feeble" thought or, indeed, a lack of thought, because everything would be resolved in calculation. Certainly, calculation also plays a fundamental role within scientific thought. However, the latter cannot at all be reduced to calculation as such. And it cannot be reduced to the dimension of calculation alone, since science, pace Heidegger, thinks and its thought is a strong thought that has profoundly influenced and changed, for better or for worse, the history of mankind.

It is therefore necessary to have a good understanding of the "reasons of Galileo" which concern, at the time, both the reasons of scientific thought and also the reasons of the technology itself. This opens up a vast and extremely wide field of investigation, because in the contemporary era, we are faced with the construction of a complex and highly articulated technical-scientific heritage, which requires to be subjected to study and also to a precise historical-critical (and epistemological) examination. For my part, in this contribution, I will deal only with the epistemological dimension. After all, when talking about the technical-scientific heritage, it is easy to see how science is currently experiencing a moment of overall difficulty, whereby technology ends up distinguishing our knowledge, with the risk that in this eminently pragmatic and operational key, the dimension of technology might end up by engulfing science as the authentic *scientific thought*. However, it is quite clear that a science reduced to technology alone risks disappearing, precisely because it is a science, that is to say because it is capable of producing its own original and autonomous *scientific thought*. Naturally, in the short space of this article, it is not possible to address this problem in all its breadth and depth. However, it is possible to carry out a detailed examination of Galileo's work to see how, in the reflections of the scientist from Pisa, scientific thought was progressively constructed and configured, finally allowing the genesis of modern science itself.

With the historical pendulum or the epistemological one?

Allow me to begin this reflection by recalling a famous, and truly extraordinary, passage by Campanile, simply entitled *Galileo*[1]:

> When Galileo made his great discovery while observing the oscillations of the pendulum, he went to tell the Grand Duke the news.
> "Your Excellency," he said, "I have discovered that the world moves."
> "Really?" said the Grand Duke, amazed and also a little alarmed. "And how did you discover it?"
> "With the pendulum."
> "Goodness! What did you hit it with?"
> "What do you mean, what? With the pendulum, that's all. There was nothing else around when I made the discovery."
> "I understand, but what did you hit it with? A blunt object? A weapon? Your hand?"
> "With the pendulum, only with the pendulum."
> "Bless your heart, I understand. You have discovered that the world moves when you hit it. That is, that it moves when you hit it. You couldn't have hit it with anything. And it takes a pretty good contraption to hit the world in such a way as to make it move."
> The great astronomer and mathematician laughed heartily.
> "Your Excellency," he said, "but you think that "with the pendulum" goes with "it moves." No. It goes with "I discovered." "With the pendulum I discovered that the world moves. I discovered it with the pendulum."
> "By striking the world. I see."
> "But no. With the pendulum. With the pendulum!"
> "But who do you hit with it? And with what?"
> "Not with it, with the pendulum!"
> "What a way of reasoning! Not with it, but with it!"
> In short, he had to write it down for him on a piece of paper.

How can we avoid the incredible and irresistible misunderstanding highlighted by Campanile? Perhaps, it would have been enough to say "with *the pendulum*," in this way the misunderstanding, caused by the phonetic overlap of “with the pendulum” with “by hitting it,” would have immediately collapsed and not even arisen. This famous and formidable text by Achille Campanile (1899-1977) came to mind while I was considering the different–and often clearly contrasting and even aporetic–interpretations to which the work and thought of Galileo Galilei have been variously subjected over the centuries. In fact, as I analytically illustrated in an old book of mine, *Il flauto di Popper* (Popper's flute), published back in 1994, Galileo's work has often been used by epistemologists not so much to actually understand Galileo's thinking and his authentic “epistemology,” but on the contrary, to identify in Galileo's work and thought an exemplification, possibly paradigmatic, of the epistemology supported and defended by this or that particular philosopher of science. In short, from this point of view, epistemologists have generally turned to Galileo's work not so much with the programmatic intent of understanding it in its precise theoretical, historical, and communicational context. On the contrary, they have considered Galileo's work as a convenient *supermarket,* where the epistemologist can buy, at his free choice, often at very low prices, *historical examples* or concrete *historical cases,* able to confirm and corroborate a specific epistemological *belief*.

Let's be clear about this: this did not only happen when Galileo's work was under consideration, but more generally, it concerned the entire history of scientific thought. In this deliberately distorting perspective, many exponents, even eminent (and very eminent) ones, of the epistemological community have shown, in several cases and contingencies, that they have no particular sensitivity for the *historical study* of scientific thought (and not only, in fact, of Galilean thought, but of almost all scientists, more generally).

All these epistemologists share, moreover, an eminently *theoretical* point of view, according to which–to quote an intelligent and acute Popperian sophisticate like Imre Lakatos–the epistemologist in his rational reconstructions of different scientific theories should, in fact, show how actual history has “behaved badly” in the light of the *reconstruction of rational* epistemological reflection. With the paradoxical consequence–as inevitable as it is decidedly anti-historical–that the *rational reconstruction* of the history of science should be included *in the texts* of books, relegating the real and actual history of science to *the notes to the text*, which would thus document, with its own articulated *historical experience*, its substantial *irrationality*. An inevitable irrationality, by virtue of which it can then be argued that the history of science, by its intrinsic nature, never measures up to epistemological reflection. Therefore, the curious “epistemological pendulum” to which reference can be made here does not at all concern historians of science as such (some of whom have, moreover, made essential and fundamental contributions to a better understanding of Galilean thought), but above all, and in the first place, to epistemologists convinced that they can define, once and for all, the very *essence of* scientific knowledge.

An hermeneutic historiography of the internal?

It is needless to add how this decidedly anti-historical attitude has been able to flourish above all in countries and cultures that do not have a particular sensitivity for the historical dimension as such. For those who, on the other hand, come from a different background of *historical studies* (also in a broad sense), this decidedly anti-historical stance can only be seen for what it is:

a substantial, systematic, and aggravated misinterpretation of the history of scientific thought as such. Not only that: behind this misinterpretation, it is not at all difficult to discern a dogmatically *presentist* approach, in the name of which it is presumed, in fact, to be possible to judge the history of scientific thought of the past, taking as a starting point not the past considered in its autonomous and effective historical configuration, but solely our current cognitive and technical heritage that would thus constitute a sort of absolute yardstick for being able to "judge" history. Faced with this position, however, it is legitimate to object that history should not "judge" the past at all; if anything, it should help us to better "understand" it in all its movements and in all its multiple articulations.

After all, it is well known that *factum infectum fieri nequit.* For this reason, we must strive to understand a lexicon that is no longer ours and problems that are no longer addressed according to our conceptual categories, also using investigative tools that can only be profoundly different from our own. In fact, critically immersing oneself in history implies full awareness of the difficulty of a historical-critical investigation that should lead us to *epochalise* our knowledge and our very way of posing and solving certain problems. From this point of view, the study of history is a challenge to our own knowledge and to our present time, to be able to recover all the *potentialities* that have structured and variously qualified each past. A *past* that we must, therefore, be able to understand *critically*, also in the latent potentialities of what has distinguished its own (historical) *present*. In fact, the past was not just a *past*, because at the time, it was the *present*, alive and full of specific *potential*. Not all this potential was realized, and so historical understanding must be able to keep this in mind, in order to reconstruct the precise articulation of this same *past*, conceived and known, as a *historical present*.

If we fail to adopt this specific critical approach–both methodological and hermeneutic–then what is dismissed at its roots is the very *understanding of the history of scientific thought*. A historical approach implies, on the contrary, a very different cultural (but also epistemological, *of course*!) approach. Which one? The one that should lead us to fully immerse ourselves in the precise historical and theoretical context in which that particular scientific theory (or that particular technological artifact) was conceived and outlined. In other words, we cannot build an effective knowledge of the history of thought if we do not adopt a substantially *hermeneutic internalist* approach, able to make us understand the precise meaning of the language used by this or that scientist, in that precise, and irremediable, historical moment. The historian must always be able to explain the *beliefs of* the past to us, not by directly comparing them with our own, but rather by helping us understand *the reasons* that once made them plausible, acceptable and even taken for granted and not at all evident. In other words, a scientific theory from the past must always be understood *within the* context of its own *structure*, its *assumptions* and also the *beliefs* that made it plausible, reasonable and therefore also acceptable. Only by consciously carrying out this historiographical critical-conceptual reversal will it be possible to enter into deep harmony with a specific school of thought, with its exact conceptual movements and also with the peculiar meaning of its own language, which is also historically dated.

This happens not because there is an underlying *incommensurability* in the history of thought–as, for example, a great historian of science such as Thomas Samuel Kuhn (1922-1996) thought–but precisely because scientists themselves, although they are on different and even openly conflicting theoretical fronts, are nevertheless always able to *understand each other* and *comprehend* each other. A hermeneutic historiography that does not try to predict the future must therefore be able to move within this precise horizon of critical reflection, making us aware that the *understanding of* science can never be separated from the *understanding of its history*. In other words, it is necessary to be able to outline a *historical philosophy of science*, having, in fact, the ability to intertwine the "study of science in history" with the "history of science" itself, since history and science constitute the two poles, indispensable and autonomous, of an intimate and fruitful correlation that can and must find expression within a coherent and conscious hermeneutic historiography of scientific thought.

The conceptual change in the Galileo's dialogue

An admirable and striking example of the ability of scientists to always be able to understand each other, even when starting from very divergent and conflicting theoretical assumptions, is offered, in a truly emblematic way, by Galileo's *Dialogue Concerning the Two Chief World Systems*. In general, when presenting this work, the emphasis is on the fact that the three speakers, Salviati, Sagredo, and Simplicio, correspond to precise figures who, in turn, interpret some particular and different conceptual traditions. In this way, Salviati is undoubtedly assimilated to Galileo's official spokesman, also remembering how, in this way, the Pisan scientist wanted to *immortalize* the memory of his intelligent pupil who had predeceased him. Sagredo, besides being a historical friend (and diplomat) of Galileo, embodies the figure of a calm and rational man who wants to listen, learn, and critically evaluate the different *arguments that* underpin both the Copernican and the Ptolemaic theories. In this case too, Galileo once again wanted to immortalize the memory of his great Venetian friend (a true "connoisseur of the subject"), who, moreover, with great foresight, had openly advised him not to abandon a Republic like that of Venice, to go and live in a Principality like that of the Medici (the Grand Duchy of Tuscany), which would inevitably have afforded him less protection. Finally, the third interlocutor is Simplicio, who would then be the dogged exponent of the Aristotelian and Ptolemaic metaphysical tradition.

This is the *standard,* accepted interpretation of Galileo's *Dialogue* which, undoubtedly, captures some of the actual aspects of this masterpiece of scientific literature (and also of literary literature, as Giacomo Leopardi clearly demonstrated in his admirable *Crestomazia italiana della prosa* of 1827). However, if we instead consider the model of internalist hermeneutic historiography, as mentioned above, it is legitimate to ask whether the traditional and usual *standard* presentation of this work and also of these three characters in the *Dialogue* exhausts its intimate and extraordinary critical potential. This is a question that cannot be avoided, precisely because Galileo was not born a *Copernican* at all. On the contrary, Galileo too was trained in the Ptolemaic and Aristotelian conception, from which he then progressively moved away. Well, from the point of view of hermeneutic-internalist historiography, Galileo's *Dialogue* is configured, if anything, as the extraordinary documentation of the doubts, questions, answers, arguments and also counter-arguments with which Galileo nurtured, month after month, year after year, decade after decade, his progressive critical detachment from the Ptolemaic position to finally and convincingly embrace the Copernican one.

In other words, from this point of view, the Galilean *Dialogue should be read and interpreted* as a documentation, truly extraordinary, of the profound *change in concept* that progressively took place in Galileo's mind, soul and very reflections during the course of his complex, and certainly not univocal, maturation toward Copernicanism. But from this point of view, Simplicio's questions and objections are exactly the questions and objections that Galileo gradually raised, in the depths of his personal reflection, *against* the traditional Ptolemaic conception and also *against* the Aristotelian one, in which he had initially been trained. Through this progressive critical maturation, Galileo finally arrived, *with conviction*, at a decisive and coherent Copernican vision of the solar system. This should again demonstrate that, in the critical transition from the Ptolemaic to the Copernican perspective, Galileo was always able to understand, with rigour and conceptual precision, both the Ptolemaic and the Copernican astronomical models. Between these two "systems," there is no supposed hermeneutic "incommensurability," precisely because the scientist from Pisa shows that he was always able to dominate both the Copernican and the Ptolemaic theories *conceptually*. After all, the *Dialogue* emphasizes in an extraordinary way how *the choice* between these two different and opposing astronomical theories can only be rooted, in the final analysis, in the *best possible* arguments (*à la* Mill!) put forward by one theory or the other in the context of their close and emblematic critical confrontation. This, in turn, is confirmation of the fertility of this hermeneutic, internalist line of interpretation, which provides us with a masterpiece of scientific literature that is able to document, page after page, dialog after dialog, how the *conceptual change* that finally led Galileo to convincingly embrace the Copernican perspective actually occurred.

Subversion of the whole natural philosophy?

This documentation appears important and historically relevant also because the transition from the Ptolemaic theory to the Copernican theory implies a different mental, conceptual and even epistemic approach. A new way of reasoning of which Galileo is perfectly aware, because on the 1st day of the *Dialogue,* he makes Simplicio exclaim at a certain point:

> This way of philosophizing tends to subvert all natural philosophy, and to disorder and throw into turmoil heaven and earth and the whole universe. But I believe that the foundations of the Peripatetics are such that there is no need to fear that with their ruin new sciences can be built[2].

Thus, with Galileo as a Copernican, a "subversion" of almost all traditional natural philosophy was introduced. A subversion that could only "disorder and throw into turmoil the heavens and the Earth and the whole universe". Galileo was therefore fully aware of the truly revolutionary scope of his Copernican move, so much so that he made Salviati reply as follows:

> Do not be afraid to subvert your ideas about the sky or the Earth, nor fear their subversion, nor even that of philosophy; because, as for the sky, it is in vain that you fear what you yourselves consider unalterable and impassible; as for the Earth, we seek to ennoble and perfect it, while we try to make it similar to the heavenly bodies and in a certain way put it almost in heaven, from where your philosophers have banished it. Philosophy itself cannot but receive benefit from our disputes, because if our thoughts are true, new acquisitions will have been made, if false, by rejecting them, the first doctrines will be confirmed even more. Take thought rather of some philosophers and see to it that you help and support them, because as for science itself, it cannot but advance[2].

In this way, Galileo makes his readers perceive all the radical innovation of his new way of proceeding, which configures scientific research (and also philosophical reflection) as part of a new, very different and revolutionary *conceptual style*, which is paradoxically tautological, thanks to which one searches for the truth that can only coincide, *Socratically*, with truth itself. This is why, in this critical sense, philosophy, or the knowledge of nature, can only benefit from these investigations and critical reflections. For what reason? Precisely because in this way it will be possible to acquire new knowledge, or to eliminate and reject arguments that turn out to be false. For this fundamental reason, the research that Galileo looks at is configured, by its intrinsic nature, as a *critical and open* research, able to confront, precisely *critically,* any argument. The latter can therefore no longer be justified on the basis of the authority of this or that figure in the Western conceptual tradition, because it must instead accept the risk of confronting, on equal terms, all the different antagonistic arguments, since true knowledge can only arise from this close critical confrontation of which the *Dialogue* is an eminent document.

In advocating this new approach to philosophical and scientific research and reflection, Galileo is also well aware that his stance implies a truly revolutionary conceptual reversal. So much so that on the 3rd day of the *Dialogue,* he explicitly states that he cannot "find an end to my admiration, at how Aristarchus and Copernicus could have made reason do so much violence to sense, that in opposition to this reason became the master of their credulity"[2]. In this way, the traditional empiricist conception, with which the no less traditional "correspondence" theory has often been historically intertwined, are both placed within a very precise critical tension that feeds a different conceptual approach, by virtue of which each theory no longer springs from experience as such, because, on the contrary, it requires the intervention of a *new rational point of view*, able to do "so much violence to sense, that against it has become the master of their credulity."

In this new epistemological perspective, knowledge does not spring from experience as such, but rather from the ability to "do violence to sense," or rather, from the ability to construct a theory that, at first glance, is in flagrant conflict with experience itself. In this way, Galileo shows that he is well aware that the relationship between theories and experiments (or better yet, between theories and the experimental dimension) is never univocal and must always be critically rethought. Certainly *against* the backdrop of this realization one could affirm, with Alessandro Volta, that facts can always disprove a theory, while, on the contrary, a theory can never disprove facts. However, *against* the widespread and deeply rooted scientific common sense that leads us to attribute an eminent and pre-eminent role to the experimental dimension, Galileo is instead one of the very first scientists to realize that knowledge can only progress thanks to our ability to outline a new conception–even one that is decidedly *counterfactual*–of the dimension of experimental experience. Not that the latter does not play a fundamental and decisive role, also for Galileo, in helping us to evaluate our knowledge. However, this essential role is not *upstream* of theories, but *downstream* of these same theories. In short: for Galileo, the world, as such, teaches us nothing unless we are able to *think about it* and *conceive of it* in an innovative way, in the light of some of our own free theoretical assumptions (assumptions *ex suppositione*), from which we can then derive predictions, which will finally be subjected to careful experimental verification.

Violating the senses?

Precisely for this reason, Galileo could not stop admiring Aristarchus and Copernicus, because both had the strength and the *conceptual and theoretical* ability to know how to go *beyond* and *beyond* what the most immediate sensory experience seemed to suggest to them at first glance. So both saw the sun rise over the horizon to reach its *zenith* and, finally, set. However, they did not stop at this first impression, but, considering all the problems connected with the Ptolemaic theory, they began to see if, with a different and new heliocentric and heliostatic approach (therefore, no longer geocentric and geostatic) that it was possibly possible to explain the movements of the celestial bodies *better*. However, it was precisely in this new conceptual approach that the greatest difficulty lay, to be able to construct a *new science* capable of opening wide the doors to cognitive research. For this reason, Galileo's progressive "Copernican" maturation is not only important in terms of the affirmation and defense of the Copernican system as such but also implies a *new way of understanding knowledge* and, therefore, modern science itself. A modern science that springs, then, from a new and revolutionary epistemological approach, by virtue of which knowledge no longer starts so much from experience as such, precisely because this same experience always implies the ability to know how to think *critically about* it and also in a profoundly innovative way. The decidedly *counterfactual* aspect of scientific theories is rooted precisely within this new theoretical, methodological, and epistemological awareness.

After all, Galileo himself, on the occasion of his previous astronomical observations made with the revolutionary "long-sighted cannon," soon found himself faced with this new and revolutionary theoretical scenario. So, if you read the pages dedicated by Galileo, in *Sidereus Nuncius,* to his sensational "discovery" of the Medicean planets (and, even more, the nocturnal letters with which Galileo promptly informed his correspondents of his multiple celestial observations made in the winter of 1609 and in the spring of 1610), we can see how the identification of these new, small lights that variously appeared and disappeared alongside Jupiter ended up constituting an *empirical evidence* for which the scientist from Pisa was still unable to provide a precise *explanation*. This explanation finally emerged from the repeated hypothetical attempts with which Galileo stubbornly tried to imagine, in a decidedly innovative way, these curious celestial movements. The hypothesis he finally arrived at, which was to consider these luminous phenomena as small moons that revolve around Jupiter, and therefore variously irradiated by the Sun (they could also disappear from observation when they are completely immersed in the shadow cone of this large planet), constitutes, from this perspective, a true *victory of the human spirit* that finally managed to understand the strange and unexpected behavior of these small celestial bodies, or rather these astronomical phenomena. But to reach full awareness of the *speculative nature* of our scientific explanations, Galileo had to overcome and *critically* challenge a consolidated and widespread tradition, dating back more than a 1,000 years, according to which knowledge can only spring *directly* from experience as such.

Naturally, in terms of the most immediate *Lebenswelt* and the world of practice, this empirical knowledge plays a specific role that has undoubtedly contributed to strengthening human life on our planet. However, if this aspect constitutes its point of *strength,* it is also, at the same time, its point of weakness. Why is this? Because as soon as we try to detach ourselves from the immediate experience of *living life* as such, this traditional empiricist approach shows all its limitations. Why is this? Precisely because it doesn't allow us to develop a *counterfactual* conception of the world and of experience itself. Galileo, studying the natural world, observing the starry sky and also carrying out his first and famous experiments concerning the motion of a rigid body falling to the ground, soon realized that if he wanted to achieve effective knowledge of all these complex physical phenomena, he had to abandon all traditional metaphysical (and finalistic) explanations and instead outline new conjectural theories *ex suppositione*, through which he could, in fact, try to better understand the phenomena in their own phenomenal-experimental manifestation. Instead, *new conjectural theories ex suppositione*, through which he could, in fact, try to better understand the phenomena in their own phenomenal-experimental manifestation. The scientific revolution inaugurated by Galileo is rooted exactly on this level, where we become critically aware of the–inevitable–gap that always exists (and cannot help but exist) between our *mathematical* and *conceptual* understanding of the world and the most immediate *phenomenal dimension* of physical and material reality itself.

The scientist as "philosopher surveyor"

By creating an original critical fusion between geometry and the study of reality, Galileo once again and with full awareness ended up breaking a glorious tradition of thought, in the name of which even the possibility of using mathematics as a heuristic tool to understand and learn about the reality of the physical world was denied. According to the traditional Aristotelian conception of the world, everything that is located in the sub-lunar zone is characterized by an ontological precariousness and mutability that prevent the use of mathematics to study these phenomenal and ever-changing aspects of nature. In the *Dialogue,* it is Simplicius who, once again, becomes an uncompromising defender of the traditional Aristotelian conceptual approach. In fact, on the 2nd day of the *Dialogue,* it is he who raises a crucial problem, namely, that concerning the use of mathematics in the study of a specific physical reality such as that of the sub-lunar world, dominated by *panta rei,* the incessant intrinsic (and ontological) mutability and the corruption that distinguishes and ontologically dominates everything.

Simplicio's objection is not without its own intrinsic force. In fact, he observes, preliminarily, that what happens in the geometric sphere is radically different from what happens in the actual physical world in which all men live and work. In Euclidean geometry, in fact, a perfect sphere and a perfect plane come into contact–if the sphere is placed on the table–in one and only one point. On the other hand, in the real and actual world in which we live, being surrounded by imperfect objects, it is never possible to create a perfectly spherical sphere, just as it is not possible to create a plane that is perfectly planed and reduced to a completely homogeneous physical surface, perfectly smooth, and free of any (even minimal) roughness. On the contrary, in our real and actual life, we always have to deal with necessarily imperfect planes and spheres precisely because we are in the sub-lunar world. When these imperfect spheres and planes are put in relation to each other, they contradict what is stated in the abstract, in its perfect eidetic world, by geometry, which constructs a geometric world that has nothing to do with our sensible world, that is, the world of *practical experience*, in which all men live and die. In fact, an imperfect sphere will always and necessarily touch an imperfect plane not in a single point (as happens in Euclidean geometry where one always works with perfect bodies), but in a *plurality of points*. It is therefore impossible to apply mathematics to study empirical reality. And it is impossible precisely because the latter, in its ontological imperfection, turns out to be infinitely more complex and richer than the simple and orderly universe, abstract and eternal, of Euclidean geometry. Therefore, Simplico concludes, we cannot resort to the use of mathematics and geometry to understand an imperfect, transitory, and ever-changing world. Moreover, this realization has been established since the most ancient times of classical Greek culture, for which mathematics and geometry could only be applied within the world of super-lunar celestial bodies. Why? Precisely because these celestial bodies are, by their intrinsic ontological nature, perfect and unchangeable in that they are eternal and constitute, in fact, *ideal models that are perfect and unchangeable.* For this fundamental reason the ancient Greeks applied mathematics and geometry only to the study of the super-lunar world which, by its intrinsic nature, in their eyes, it was a perfect world, free of imperfections, and blemishes, such that it was also physically made up of the so-called *fifth essence*, which was also eternal, perfect, unchangeable, and perfectly transparent.

Faced with this traditional and drastic objection (both methodological and ontological), Galileo adopted a two-pronged strategy of dialogue. First, he tries to dismantle, at its very heart, the disruptive heuristic force of Simplicio's example. And he does so by observing that there would be no particular problem in constructing a theory which states that two imperfect bodies–such as an imperfect sphere and an imperfect plane–can and indeed *must be* necessarily touching in *several points*:

> Therefore, whenever you apply a material sphere to a material plane, you apply a non-perfect sphere to a non-perfect plane; and you say that these do not touch at one point. But I say to you that even in the abstract an immaterial sphere, which is not a perfect sphere, can touch an immaterial plane, which is not perfect, not at one point, but with part of its surface; so that up to this point what happens in concrete, happens in the same way in the abstract: and it would be quite a new thing if calculations and reasoning made with abstract numbers did not correspond to gold and silver coins and merchandise in concrete[2].

Galileo tried to parry, in some way, the decisive objection put forward by Simplicio. However, his first response can only appear weak and very lame. In fact, Galileo almost seems to minimize the example given by Simplicio, claiming, with *nonchalance,* that one can always construct an imperfect theory that states that an imperfect sphere and an imperfect plane always, and necessarily, touch not in one point but *in several points*. Thus, Galileo argues in the first instance, there would be no particular difficulty in relating an abstract theory to the complexity of the actual world. Furthermore, it is clear that with this first response, Galileo also tries to re-evaluate the traditional Aristotelian "correspondence" concept, according to which a theory is true if, and only if, it is a perfect duplication of what happens in reality. In short, we could say in our own language that a theory is true if, and only if, it constitutes a sort of "photocopy" of the real world, thus paradoxically deriving from a perfect isomorphism of imperfection...

However, it is easy to see how this first and immediate response is not at all the real answer, the one with which Galileo tries instead to overcome Simplicio's objection. This first lame response seems to depict what generally happens in real dialogs in the world of practice, between two people who staunchly support decidedly alternative theses. In these situations, when faced with a serious objection, an interlocutor immediately tries, at first glance, to "bide time," putting forward a first draft of an answer, which is presented while the mind of the same interlocutor is instead trying, frantically and desperately, to identify a much more valid, effective, and possibly decisive answer. Galileo admirably reproduces this characteristic pattern of dialog, and then immediately introduces his real answer, which he also wants to be his definitive "lion's roar." In fact, Salviati's intervention continues, radically changing the communicative tone, with a decidedly rhetorical question, which immediately makes the reader understand how we are about to arrive at Galileo's true and decisive answer:

> But do you know, Mr Simplicio, what happens? Just as if you wanted the calculations to work out for sugar, silk and wool, the computer has to do his sums for crates, incentives and other baggage, so when the philosopher and surveyor wants to recognize in concrete terms the effects demonstrated in the abstract, he has to deduct the impediments of the material; if he can do that, I assure you that things will be verified no less accurately than arithmetical calculations. Errors therefore do not consist in the abstract or the concrete, nor in geometry or physics, but in the calculator, who does not know how to do the right sums[2].

This is the true and emblematic answer that Galileo puts forward to neutralize, at the root, the critical charge of Simplicio's objection and to characterize, at the same time, the precise physiognomy of the way in which, in his opinion, the scientist (or rather "the philosopher-geometer") must always know how to operate in order to determine an effective cognitive increase of reality. From what Galileo said, it is clear that the "geometric philosopher" must first *demonstrate, in the abstract*, his theory, which he will then have to construct in a decidedly *conjectural way*, basing it on mathematical inferences that will allow him to construct, *deductively*, a theoretical body. But he must then show the actual and possible cognitive scope of this theoretical construction. In this way, the "philosophical surveyor" must directly relate the consequences that can be drawn from his abstract mathematical theory with the material reality he wants to study and understand. But in placing these consequences in direct relation with the experimental world, the "philosophical surveyor" must also be able to always be able to "*deduct" the impediments of the material*. In other words, the scientist can never base his work on the extrinsic results of experimental experience as such, but must instead know how to *interpret these* and *read them* in the light of his theory, to identify the very elements *that constitute* a specific, delimited, objective knowledge. An objective knowledge that, therefore, *due to its intrinsic nature* can never constitute an exhaustive knowledge of reality, precisely because it must instead select a few elements, or rather those that it can actually grasp within its theoretical and prospective gaze. In this peculiar hermeneutic key, the relationship between the perfection of mathematics and the infinite complexity of nature can then find a fruitful and meaningful critical link, within which, precisely by "eliminating the impediments of matter," it is possible to outline an *objective knowledge* of the world.

This Galilean response is not at all extemporaneous, casual or marginal, because it often recurs in his works and also in his most diverse writings. Without now carrying out an analytical survey of this importance, it is enough to remember how this approach emerges, for example, in Galileo's scientific masterpiece, his *Discourses and Mathematical Demonstrations Relating to Two New Sciences* (1638). The ability to "eliminate the impediments of matter" emerges, for example, in the study of the fall of heavy objects because, in this case, Galileo, criticizing Aristotle, is well aware that "if the resistance of the medium was totally removed, all matter would fall with equal speed"[3]. In fact, studying what is "sensibly" shown by nature, again in relation to the fall of different weights in space, Galileo writes as follows: "although extremely unequal in weight, in the middle more than any other part, if not very small, the difference in speed is very small and almost imperceptible, it seems that we could very probably conjecture that in a vacuum, their speeds would be completely equal"[3]. Similarly, when discussing "motion equally, that is uniformly accelerated, I mean that which, starting from rest, acquires equal moments of velocity in equal time intervals,"[3] Galileo uses the same conjectural approach, not considering it at all necessary to develop an ontological-metaphysical investigation concerning reality as such:

I do not think it is appropriate at the present time to investigate the cause of the acceleration of natural motion, around which various philosophers have produced various judgments, reducing it some to the approach to the center, others to successive parts of the medium to be broken, others to a certain extrusion of the surrounding medium, which, in rejoining behind the moving object, it presses and continuously pushes away; these fantasies, with others to follow, should be examined and solved with little effort[3].

But then how should a scientific examination of motion proceed?

For now, Galileo replies, it is enough for our author that we understand that he wants to investigate and demonstrate some aspects of accelerated motion (whatever the cause of its acceleration) in such a way that the moments of its velocity increase, after its initial calm, with that very simple proportion with which the continuation of time grows, which is to say that in equal times equal additions of speed are made; and if it is found that the accidents that will be demonstrated occur in the motion of naturally descending and accelerated bodies, we can consider that the assumed definition includes such motion of bodies, and that it is true that their acceleration increases as time increases and the duration of the motion increases[3].

From this point of view, for Galileo, the "geometric philosopher" can then be compared and compared to the marble quarry workers "who uncover and extract the marbles from the earth, in which the sculptors then make marvelous images appear, which were hidden under a rough and shapeless crust"[3]. The identification of the laws that can express the constant and regular connection that can be established between the different "passions" allows us to know the world *objectively*. From this perspective, if the experiment is configured as the fundamental and decisive heuristic moment of scientific investigation, mathematics also plays an equally fundamental role, because it allows both the construction of a theory and the submission of experimental results to a precise logical verification. This is also confirmed by the famous letter that Galileo wrote to Giovanni Battista Baliani from Florence on 7 January 1629. Here, thanking Baliani for sending him his treatise *De motu naturali gravium solidorum* and giving an account of the results set out in the *Discourses and Demonstrations Concerning Two New Sciences*, Galileo writes that he has tackled the problem of the motion of rigid bodies on earth with different aggression; because I do not suppose anything other than the definition of motion, of which I want to discuss and demonstrate the accidents, imitating Archimedes in this way in the Spiral Lines, where he, having declared what he means by motion made in the spiral, which is composed of two equable ones, one straight and the other circular, he immediately goes on to demonstrate his passions. I declare that I want to examine the symptoms that occur in the motion of a mobile which, starting from a state of rest, moves with increasing speed always in the same way, that is, that the increase in speed does not grow in leaps, but evenly according to the growth of time[4].

This confirms that Galileo always starts from a precise "definition," from which he constructs a theory whose logical-mathematical consequences must then be subjected to experimental verification–or falsification–so much so that in the same letter he adds the following:

But returning to my treatise on motion, topic *ex suppositione* above the defined manner; so that if the consequences did not correspond to the accidents of the natural motion of descending bodies, it would matter little to me, since nothing derogates from Archimedes' demonstration that there is no mobile in nature that moves in spiral lines. But in this I have been, I will say so, adventurous, since the motion of the falling bodies and its accidents respond precisely to the accidents demonstrated by me of the motion defined by me[4].

Of course, Galileo was not “lucky” at all–as he states with great *humility*–but he was the first genius in the history of humanity to finally understand the dynamics and laws of motion of rigid bodies on Earth.

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