Theatre: The Other Side of Physics

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Abstract In the current century, the relationship between physics and theatre is becoming more and more intense and fruitful, so much so that stimulating connections—previously not even suspected—are being discovered between the ways of unfolding reality that are common to both theatrical research and basic physics research. Nevertheless, in most important theatres, it is still difficult to attend scientific performances that are on the bill; on the other hand, there is little theatre in university physics courses, yet. We will analyse the reasons for this situation and highlight the developments of physics theatre from an educational point of view, but above all, we will underline the dual structure of physics and theatre when looked upon from a deep cultural perspective.

Keywords Physics · Theatre · Education · Research

1 The Unreasonable Non-existence of a Physics Theatre as Such

Physics studies eternal and universal laws, which the entire cosmos is expected to obey. Theatre, on the contrary, deals with people and society. It is an art that is immediately consumed, lasting the time of a glance, and soon it is over. It is not like a movie which is always the same, unchanged over the years and the different places. Nor like a book, or a sculpture that lasts for millennia. Theatrical scripts can indeed be re-read identically, and that shows are repeated, but representations are different every time. Theatre is not like physics, whose laws sculpt the structure of the entire universe since the Big Bang. So, what do physics and theatre have in common (Giliberti 2014, 2019, p. 77)?

Although so different, during their history, physics (and more generally science) and theatre have occasionally had some points of contact. In fact, the theatre has

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sometimes been dealing with the social implications of science, even if it hardly pushed science into the foreground of the play. Even today, when putting the so-called science shows on the billboard is not such a risky operation as it was just a couple of decades ago, this action is still hardly carried out by theatre operators. Attending science-theatre shows at science festivals or science museums is, indeed, much easier than seeing titles of scientific plays in the seasons of big theatres next to those written by famous playwrights.

It is useless blaming this on theatre operators; indeed, few people think science can touch, besides people's minds, also people's hearts. *The Conics* are not the title of a Greek tragedy, and *Broken Symmetries* is not a show about the relationship between men and women. Who among the *habitué* would go out on a winter night to a rerun of *The Magnetic Vector Potential*? Just thinking about such a title makes us smile.

Yet the market is full of so-called scientific shows; and on the Internet, there are commercial proposals for shows addressed to schools with spectacular demonstrations, or of performances promoted by large scientific institutions and research bodies concerning the wonders of astronomy or elementary particles; but they are almost always off the bill. In fact, even if there is a growing number of people working on it, science theatre struggles to emerge from an artistic point of view. The great talk that is going on about scientific theatre is more concerning the way to promote scientific initiatives, or the market positioning of shows which would never find a place in important theatre seasons—but which carve out their place for schools or as events in science festivals, or which are presented as children's theatre for the whole family—than questions concerning theatre criticism or poetics, which would indicate a cultural living genre with important works. Whatever science theatre is—in fact, we have not even attempted a definition of it—from a commercial point of view, scientific theatre is often a good operation, and there are many scientific shows that attract large numbers of spectators and fill theatre halls. Nonetheless, important dramas that could, at least broadly speaking, be called scientific theatre can be counted on the fingers of one hand.

Yet, on a slightly deeper look, the absence of science in the great plays appears strange, unreasonable. Indeed, science is a cultural product of man and society, with its several facets, constitutes an important part of the social framework, and contributes significantly to changing our vision of the world. Why, to paraphrase Richard Feynman[1] (Feynman 2000), does the theatre of the present not speak of it?

At the turn of the century, European society witnessed a crisis in vocations toward scientific studies, also due to a perceived cultural superiority of the humanities over scientific disciplines (Brandi et al. 2005). The great efforts of the political, scientific, and academic world have made it possible to change the situation, and now (2023) sciences are, in general, considered by most people to be extremely important for society. But the human, profound aspect, the one that allows to touch—in a way like art—the strings of the human soul, is still generally misunderstood. It is mainly the utilitarian aspect of sciences that is put forward; sciences are, in fact, considered more

[1] "For far more marvellous is the truth than any artists of the past imagined it. Why do the poets of the present not speak of it?"

useful than the humanities, and, therefore, in this historical moment, perhaps even more appreciated or—given the increasing attention to ethical aspects and dangers related to the use of scientific knowledge—even sometimes watched with fear. Of these aspects, only the last one can, in general, provide inspiration to theatre.

My experience concerning physics shows with "Lo spettacolo della fisica"[2] (Fig. 1), however, leads me to be optimistic and believe that in the near future the way will be found for the great theatre to really deal with science; not only for its human or social, and ethical questions, but, above all, for the specifically scientific, and spiritual dimensions that still wait to be disclosed by a theatrical gaze. At least, this is a challenge to what "Lo spettacolo della fisica" is working on. Scientific theatre has extraordinary potentiality that are still to be explored, and we are convinced that a work both physical and theatrical, addressed to public, that makes physics the protagonist of the text is possible, with plays that will be considered as great as the those admired by all of us for centuries, like the tragedies of ancient Greece or the works of Shakespeare.

In the next sections, we first see a very brief history of scientific theatre (with a focus on the theatre of the last decades), and briefly discuss some of the main uses of science theatre in teaching. We will then try to understand the main cultural difficulties that hinder the artistic development of physics theatre and propose a cure for this situation.

2 A Very Short Account of Science-Theatre History

2.1 Ancient Science Theatre

Rites and theatrical performances are very ancient and have always had a didactic role, transmitting the mythological and cultural heritage, as well as the rules of moral behaviour. The beginning of Western theatre can be identified with the dawn of Greek tragedy, and therefore, at its origin, there is no written text to be staged, but only the celebration. Participants were at the same time actors and spectators, so these two functions were not yet separated.

Ancient Greek authors rarely used scientific concepts. No theatrical text concerning Pythagoras or his discoveries, or Archimedes has come down to us; no text concerning science. For the ancient tragedians, nature belonged to the divine and the myth. In this regard, Aeschylus' *Prometheus Bound* is fundamental in the history of Western thought. For Aeschylus, Prometheus, "the prescient", out of love for men, from Hephaestus stole the fire and gave it to humans. In fact:

[2] In 2004, Marina Carpineti, Nicola Ludwig and the author of this chapter (all physicists from the University of Milan) founded the group "Lo spettacolo della fisica" (The show of physics) that, so far (January 2023), has written and performed 8 physics-theatre shows and 3 lesson-shows, reaching more than 150,000 spectators and making more than 400 performances throughout Italy and Europe (see spettacolo.fisica.unimi.it/).

Fig. 1 A picture taken from *Luce dalle stelle* made by "Lo spettacolo della fisica" and performed in 2012 at Teatro Franco Parenti (Milan). *Credits* Fabrizio Favale, Marina Carpineti, Nicola Ludwig, Marco Giliberti

> though they had eyes to see, they saw to no avail; they had ears, but they did not understand; […] They had no sign either of winter or of flowery spring or fruitful summer, on which they could depend but managed everything without judgment until I taught them to discern the risings of the stars and their settings, which are difficult to distinguish. […] Yes, and numbers, too, chiefest of sciences, I invented for them, and the combining of letters, creative mother of the Muses' arts, with which to hold all things in memory. (Aeschylus 1926, lines 457–459)

Prometheus gave men thought, conscience, and knowledge; even the first knowledge, that of Mathematics, and is punished exactly for this: science and technology distance the soul from nature and therefore distance mankind from the divine. This theme has been accompanying the evolution of Western culture for two and a half millennia, and many people still experience the rift between spirituality (in a very broad sense) and science, which reveals, discovers, and makes things cold and unpleasant (Carpineti et al. 2011).

Comedies also reflected this view, and playwrights mocked scholars who disrespected gods with their theories. *Birds* by Aristophanes, for example, (we are in the fourth century BC) is a fantastic comedy in which two Athenians decide to build a world of pleasures and delights alternative to Athens. Helped by two birds, they build the city Nubicuculia halfway between the earth and the sky, in which the moral norms are opposite to those of Athens. Some men, including a mathematician, try to reach Nubicuculia. Upon his arrival, Pisthetaerus, one of the two founders of the city, interrogates him. As soon as Pisthetaerus discovered he is a mathematician; he explodes saying "He's a Thales!" and does not accept him in the city. Thus, science is expelled by Aristophanes from the ideal city of all pleasures.

2.2 Modern Science Theatre

Taking a big leap forward, it was in the sixteenth century that science, and more particularly mathematics, began to put itself at the service of the theatre. With the birth of perspective, scientific foundations were found for the construction of realistic sets. An example among all is given by the *Teatro Olimpico* in Vicenza, one of the first permanent theatres of the modern era. Built by Andrea Palladio in 1585, it is a sort of small reconstruction of a Roman theatre, but with a scenography of narrow streets in perspective and with the sky painted on the ceiling.

It is interesting to observe that in the sixteenth century and then, even more so, in the seventeenth century, the so-called "cabinets of curiosities" were born. They were ancestors of our natural history museums which showed the visitor strange and fascinating findings from the natural world or artefacts from the past.

The first form of didactic theatre was the work of the Jesuits and dates from this period.

> Jesuit drama […] had the triple purpose of proposing examples of piety, of teaching the language of the Church, and of educating the offspring of the aristocratic classes in good personal behavior. [The] last two purposes, above all the last one, were essentially realized in the moment of staging: the actor-student learned, by acting, the speaking pose and the decorous control of the gesture. (Molinari 2011)

The didactic aspect of the theatre, therefore, consists of the fact that it was acted out by the student, something whose importance is perhaps then understood for the first time, and which we still find today, and sometimes with purposes of the same type, in our school.

As far as science is concerned—even if they are not exactly theatre—the dialogues of Giordano Bruno's *La cena delle ceneri* are memorable in which physics and mathematics are explicitly discussed and the Copernican system is proposed in a more general form than the original of Copernicus, with the Sun no longer in the centre of the world, the universe being infinite. We also recall the only comedy

by Giordano Bruno, *Il candelaio*, set in sixteenth century Naples, in which science (understood above all in the sense of knowledge) proves to be a tool against astrology.

In the seventeenth century, a rather particular type of conference show was born: that of the anatomical theatre. It consisted of dissecting a corpse in front of an audience of students. In the anatomical theatres, lessons were held in which an anatomy text was read and commented, on while the surgeons showed the organs described to the public. In addition to the anatomy lessons, we recall many other lessons held by scientists, starting from the beginning of the seventeenth century, that were also structured as conference shows. Among these, Alessandro Volta's lessons in Pavia were full of spectacular visual effects, and those of Louis Pasteur at the *Sorbonne* which were real theatrical episodes with plays of light and catches. Very famous is the 1864 conference on spontaneous generation, which had the dual purpose of teaching the public and having the consent of colleagues. Spectacular lessons have been present everywhere ever since: the tradition continues. Last, but not least, we cannot forget the Christmas Lectures, initiated in the 1820s by Michael Faraday and aimed primarily at children (particularly famous is *The chemical history of a candle*), they continue each year at *Royal Institution.*

At the end of the eighteenth century, circus shows were born in London, above all thanks to Philip Astley, who performed on horseback with great success inside a circle drawn on the ground. Several circus acts are largely based on the laws of mechanics, with the appropriate use of levers, seesaws, etc., and, in some cases, juggling tricks provide the basis for a certain type of performance which, properly commented, are used today as elements of physics educational shows.

Between the eighteenth and nineteenth centuries, a new fracture was created between humanistic and scientific cultures. The various disciplines specialized, and science moved further and further away from ordinary people. For this reason, there was considerable interest in new means of communication, possibly able of bridging this gap. Among the new languages, there was also that of scientific theatre, in the modern sense of the term. In the beginning, a scientific street theatre was born; real shows staged in squares were organized to intrigue and amaze the public with new applications of science (for instance, spectacular electrical and optical phenomena) (Magni 2011).

Elements of science spectacularization can still be seen today in major science museums, such as the *Deutsches Museum* in Munich, the Museum of Science in Boston, the *Palais de la Decouvert* in Paris, or the *Museo Nazionale della Scienza e della Tecnologia* in Milan; they can also be found in many outdoor events of the numerous "open days" organized by research centres or scientific festivals.

At the end of the nineteenth century, we cannot forget the *Ballo Excelsior*, an apology for the most important scientific and technical discoveries of the century. The premiere was made at *La Scala* in Milan in 1881 and then revived in many theatres worldwide.

2.3 Science Theatre of the Last Decades

Often leaving aside spectacular and promotional aspects or the apology of the science of the first scientific theatre, one of the typical forms of modern scientific theatre concerns the lives of great scientists. Many plays are inspired by the lives of great scientists: who are scientists? How do they behave? Several plays tell the life of mathematicians, physicists, and inventors. Often, however, the focus is on the scientist and his/her facets, and, although science gives an important background for the story, it has, in general, a somewhat secondary role, while the human affairs of the protagonist are put forward.

The staging of important scientific problems, which are particularly suitable for theatrical dynamics due to their ethical interest and the reflections they allow on men and society, is also undertaken. In fact, as the historian of physics Pasquale Tucci writes: "When a practice such as science becomes a widespread cultural heritage, it is no longer the exclusive property of those who produced it but becomes an object of debate in which everyone has the right to participate" (Tucci 2007).

Bertolt Brecht's *Life of Galileo* is one of the most famous science-theatre works. Brecht's text not only tells the life of the man-scientist, with his fears and passions, but also addresses the relationship between intellectuals and power, and the responsibility of the man of science towards society. Galileo's choice to abjure before the Church, and thus avoid torture, is the fulcrum of the action. The first draft of the work dates to 1939. In such a time of dictatorship, Brecht gave life to a reflection on the meaning of truth, be it scientific or not. Galileo is presented as a man who has chosen to deny his discoveries to have the possibility of continuing his research, even at the cost of compromising his precarious health. In the second draft of 1945, after the catastrophe caused by the atomic bomb, Brecht changes a bit his attitude and proves to be much more severe and critical towards Galileo and those scientists that do not worry about the consequences of their discoveries. Although sometimes it is thought otherwise, "Brecht himself recommends not considering the drama a pamphlet against the Catholic Church" (Chiusano 1976).

In the matter of J. Robert Oppenheimer is a title of piece, dated 1964, by Heinar Kipphardt that recounts the trial in which Oppenheimer was accused of treason for delaying the construction of the hydrogen bomb in the United States. From being a national hero, as he had been deemed during World War II, Oppenheimer became a possible threat to his country, so he suffered a period of persecution, which ended only after the advent of the Kennedy administration. The work does put the problem of the freedom to choose of the scientist, and about the boundaries of his freedom, and the relationship between science and politics.

In Michael Frayn's *Copenhagen* (1998), the souls of Werner Heisenberg, Niels Bohr, and his wife meet after death, essentially to answer the question asked at the beginning of the play by Margrethe (Bohr's wife): "Why did Heisenberg come to

Copenhagen in 1941, when Denmark was occupied by the Nazis?". This work against the background of the history of quantum mechanics reflects on the role of scientists in the very delicate military and political situations.

Still more recent is *A disappearing number*, a show, written and directed by Simon McBurney, that tells the story of Srinivasa Ramanujan considering many psychological aspects of the relationship between mathematics and worldview. Srinivasa Ramanujan was born in India in the late nineteenth century and was called "the Mozart of mathematics" for his genius. From a very poor family, he studied as an autodidact. He moved to London to collaborate with Professor Hardy, at Cambridge University, and died of tuberculosis at the age of 32, due to the climate and diet which were so different from those of his original country. In the play, the life of the protagonist is intertwined with that of a character of our times: a young mathematician who loves her work and who is fascinated by the figure of Ramanujan. Mathematics is always present in dialogues, and in scenography, with science seen as poetry: an art form that conquers the human soul.

A different style of the theatre play is *Infinities*, written by John Barrow in 2001 and staged by Luca Ronconi, and marks a fundamental point in the history of scientific theatre. Ronconi had in mind a show that was a meeting point between theatre and science but was neither popular nor didactic. For this reason, the theme chosen was infinity, with which, as Ronconi himself says, we remain on the terrain of hypotheses, suppositions, and logical form (Gregori 2001). The place chosen for the performance was not that of the traditional theatre, but the 2500 m^2 space of the former laboratories of the *Teatro alla Scala* in the suburbs of Milan. Thirty-two actors, with nineteen researchers, animated the five spaces of the exhibition: "Welcome to the infinite hotel!", "Living forever", "The paradox of infinite replication", "Infinity is not a large number", and "Where does this play come from?".

One of the novelties was the way the audience participated in the show. People had to follow the path that led from one room to another and once got to the end, they could start over as many times as they wanted indefinitely! The spectator got out with the sensation of having been the protagonist of a truly infinite show and, therefore, an essential part of the same show. The theme was thus reflected in the same structure of the play with the mathematics that did not develop in a lesson. The experience of *Infinities* broke the classic schemes of theatre and created a new language of communication between actors and the audience.

It may also be worth mentioning the works of the South African artist William Kentridge, who offers reflections on time starting from the ideas absolute time of Newton, and the relative time of Einstein with poetic images and socio-political considerations about the colonial era and with the personal psychological meaning of the idea of time, in an optimistic and joyful show.

3 Few Words About the Importance of Theatre in Physics Education

Research results show that dramatizing scientific learning through tools that promote improvisation and reflection on historical narratives—and, therefore also peer interaction—not only engages students but motivates them and helps them to grasp ideas, concepts, and scientific procedures more effectively. It also helps teachers better understand what students are thinking (McGregor 2014). But theatre has a more general action, in fact, it also promotes interaction among school, family, and society (Ødegaard 2003).

Learning is enhanced by the didactic use of theatre; emotional involvement and dramatization develop scientific imagination, allow personal learning styles, and favour an effectively mediated approach to physics. In general, dramas and comedies present a conflict that must be resolved through the interaction with other characters; within this dynamic, theatre helps to reduce cultural and gender gaps and promote a deeper and more humane scientific culture (Giliberti 2021; Fazio et al. 2021). If the conflict/game/script generates questions about physics, an emotional involvement arises that may concern physics itself, which generates active interest in students.

In general, we can distinguish three types of science dramas for educational use: those that promote science as a product, those that highlight the process and nature of science, and those that transmit science as an institution of society. So that the representation, if it is conceived and implemented by the students, can be exploratory (students begin and experientially engage with science), semi-structured (such as a role play), or structured (determined by the teacher with fixed activities, e.g., from a script).

Theatrical performances are no longer considered only as a communication or dissemination tool and are increasingly starting to be validated by physics education research. In general, the use of theatrical tools can promote active learning. The theatrical approach to inquiry-based science education (IBSE) has also been promoted by European teacher training projects. For example, the Physics Education Research Group of the University of Milan worked on the EU project "Teaching Inquiry with Mysteries Incorporated" together with eleven other European partners plus Israel (TEMI) to bring teachers closer to IBSE through theatre. A science-theatre play, entitled "Light Mystery", has been specially prepared for this purpose and shown in Italy and Europe. A commented version of the English script has also been prepared for use by teachers (Fig. 2). Naturally, the problem of teacher training arises, so that they are prepared for theatre-based learning (TBL).

Even in the courses titled "Preparation of teaching experiences" 1 and 2, held by the author for third-year undergraduate students in mathematics and physics, theatre is widely used to promote understanding of physics (for e.g., geometric optics or oscillations) through minds-on embodied activities. A similar discourse can be made for the scientific theatre laboratory held by Marina Carpineti as part of orientation activities for high school students of the Physics Department of the University of Milan.

Fig. 2 A picture taken from *Luce dalle stelle* made by "Lo spettacolo della fisica" and performed in 2012 at Teatro Franco Parenti (Milan). *Credits* Fabrizio Favale, Marina Carpineti, Nicola Ludwig, Marco Giliberti

4 Physics and Culture

As we have seen in the very brief previous historical excursus, with very personal choices on scientific theatre, and, perhaps, except for *Infinities*, none of the famous theatrical performances that we could classify as science-theatre put science in the foreground. Science is the background and support, but it is not the protagonist; just as, on the other hand, in Shakespeare's historical dramas, history is not the protagonist. Yes, theatre deals with man, not with science. To better discuss this idea, it is perhaps worth noting how the present situation comes from an erroneous conception of science (particularly of physics) that we have in our culture, and from a too-closed idea of theatre as well. There are, indeed, various facets and meanings of the word "culture"; as far as we are concerned, we will mainly consider three of them: (1) the personal aspect, (2) the social aspect, and (3) the aspect common to a disciplinary group.

In the personal aspect, culture is rich and productive knowledge that gives a person a broad and personal vision of new ideas and reflections, and new interpretative grids of reality. In the social aspect, on the other hand, "culture" represents the set of ways of thinking, social and political structures, customs, idioms, ways of cooking, relating to others, and so on, and in a self-referential way, of considering the very idea of culture, which characterize a society in a certain period. Finally, there is the aspect of culture as it is understood by a particular discipline differentiated group, such as that of physicists or poets or lawyers. Substantially, it consists of the specific social culture and opinions that are, on average, shared by that group. It is from this last

specific point of view that scientists often complain that science should be a more consistent part of the citizen's (social) culture. However, they hardly wonder why, and in what sense, should science be part of the main culture of the entire society, and not only of single persons or of specialized groups. To be closer to our theme, in fact, in what sense, should physics manifest itself as intertwined with the vision of the world and life that gives meaning to our lives and opens to the future?

We all know that when topics are meaningful to people—for example because they are perceived as useful or beautiful, or fascinating—interest, attention, and desire to understand are often present. It is completely natural to seek a better and happier life, and it is precisely in this sense that perhaps the most significant aspect of culture manifests itself. In our modern society, we often talk about culture as a citizen's duty, or as a social elevator, but perhaps the most important and characterizing element of culture is, in general, overlooked: in fact, culture is culture if it changes our life, if it speaks to us in-depth, modifying our vision of the world and life, and giving us a chance to experience the pleasure of searching, and, sometimes, even of understanding. Culture is the pleasure of continuous research.

Therefore, if we—physicists like I am—believe that physics should be perceived as a culture in a personal and social sense, and not just for a small group of insiders, we have to wonder if the image and vision of the world that emerges from modern physical science are suitable to enrich our lives; and, therefore, whether science, and physics in particular, can, or cannot, play a role that helps us feel better.

The positive answer that is often given in an automatic and stereotyped way to the question "should we—scientists, educators, politicians, communicators …—work for a widespread scientific culture?" which is exaggeratedly uncritical. The main motivation that pushes us to respond positively is, indeed, since our society is unquestionably linked to technology, which is mainly the result of science. However strong, and essential this link may be considered, it is not enough.

For many years, we have been experiencing the results of the first quantum revolution which allowed the growth and development of the electronic industry of computer chips, photovoltaic cells, and all laser-based technology. But now, we have already entered the second quantum revolution, which is greatly involving production systems and, hopefully, making better our lives soon. There are now manmade coherent quantum states of radiation or entangled matter particles with new properties and huge possibilities of applications in new types of computer communication systems and sensors (Dowling and Milburn 2003). The European Union is investing more than one billion euros to create the conditions for public awareness of this second revolution and for fostering an educational system able to prepare enough technicians specialized in quantum technologies. Unfortunately, these efforts, together with the general awareness of the importance of physics in technology are not enough for physics to enter our hearts and sprout, thus generating culture for society.

The link between science and technology is already very clearly perceived by many people, even, perhaps, in an exaggeratedly strong way. Science is "increasingly confused, especially by children and adolescents, with the use of high-tech tools […]. This misleading perception can persist into adulthood and can reduce the interest

in science" (Rustichelli and Stefanon 2012). Indeed, research made more than ten years ago on a thousand upper secondary school students near Milan (Giliberti 2010) showed that most of them consider physics important for society, but more linked to technology than to general culture (Carpineti et al. 2011; Tolstrup Holmegaard et al. 2014). Scientists, from this point of view, do not generally help, in fact, they almost aim at showing the numerous social implications of the research they carry out. If this fact is perfectly understandable from the point of view of medical research—as it has become clear in the pandemic—it is, however, less comprehensible from the basic research viewpoint: an example above all is provided by large research infrastructures such as CERN which, in his life has, perhaps, been more advertised for the birth of the Web or the development of magnetic resonance technologies, than for the research activities about particle physics taking place there. In short, it almost seems that physicists would apologize for the funds spent on basic research, rather than show how much living and vital culture is there in their research, and how great the pleasure of understanding which, in this way, is made available to everyone. When they indulge in the social implications of physics, they often try to fascinate young people with the wonders of applied physics and fail to realize that in doing so they generate interest, which, however, rarely turns into a real fascination with science, rather pushes young people towards applications.

Luckily, people who love knowledge for itself do not seem so few; at least observing how many echoes had the discovery, right at CERN, of the Higgs boson, or that of gravitational waves made by LIGO and VIRGO and the recent "images" of black holes taken a few years ago. The first glimmers of a trend reversal towards fundamental science and research can perhaps be already glimpsed.

Society needs to invest in the value of knowing well before it can spend that knowledge. The greatest cultural aspect of physics for society is more regarding its ability to ask questions about nature than about the answers we obtain. Indeed, we have more questions today than we ever had in the far past when we knew much less. Physics, in the modern sense of the term, was born when we began to understand that a stone falling from the mast of a ship has a trajectory with respect to an observer on the ship, and a different one with respect to an observer stationary on the quay, with neither of them that has more right than the other to claim to see the truth (Bruno 1584). Indeed, the general cultural meaning of physics mainly consists in its drive to transcend common thinking, to transgress the usual interpretation of reality, and understand that questions that have seemed well posed, and decidedly sensible for centuries, are, on the contrary, meaningless. Our opinion is that the fundamental cultural root of physics starts from here, from the need to go beyond questions like "what is the trajectory of the stone?"; or "which is its speed?"; or, as it happens when considering the relativity of simultaneity, beyond questions like "what is happening now on Andromeda?"; or, in the quantum mechanical domain, well beyond the question "is it a wave or a particle?". Without, however, giving up the search for the truth; a search that will become significant when it leads us to the construction of a precise theory within which a precise meaning to "true" answers to well-posed questions will be given.

5 Theatre and Physics

Equipped with the considerations of the previous sections, we can now face the relationship between theatre and science with greater awareness. Preliminary to any real scientific theatre is the understanding that science, while trying to describe the laws that govern the universe, is, at the same time, also speaking about humans, and how they see the world. And since "theatre is an art dealing with the way great themes—geography, history, philosophy, love, …—are coagulated in the human soul, to really have a science-theatre play, it must speak about the world of science, for example of physics, in a such a way that makes people spectators of the show, while seeing and listening about science, also seeing and listening about their lives. On the contrary, people are often used to seeing science as something distant from themselves; they think: "I am not a scientist, after all!", feel far from that world, and get out of it".[3]

Whatever the difficulties of creating a theatre show that speaks to man by talking about science, an awareness serves as our guide; it is the observation that theatre is the ideal tool to address themes that are at the roots of scientific research and questions at the basis of its meaning. Not only a tool for proposing a discussion in society, but because the very conceptual structure of science is intrinsically and naturally of a theatrical nature.

"Science is reality re-imagined" (Ogborn 2011, p. 1). "A scientific explanation is a story. It is a story about how some imagined entities, taken as real, would by their nature have acted together to produce the phenomenon to be explained" (Ogborn 2011, p. 14); passing from the provisional—i.e., ad hoc models—to the permanent-but-transient -i.e., established theories. It follows that the same understanding is storytelling. The form of the narrative respectful of the permanent-but-transient is a theatre in a natural way. A scientific paper is a script: there is a story, a problem, and a challenge to tell. Theatre speaks of the world, and, in turn, the world is the representation that we give of our understanding.

Theatre and physics are like two dual aspects of the same research. The former is ephemeral, but immortal, the latter absolute and universal, but transient. The word "theatre" comes from the Greek verb $\vartheta\varepsilon\alpha o\mu\alpha\iota$, which means to look, to contemplate, with the root of the verb that means admiration or wonder. But we also must observe that $\vartheta\varepsilon\alpha o\mu\alpha\iota$ in Greek is a deponent verb, and, therefore, it has in itself a passive *nuance* that can perhaps be better translated with "being spectators, contemplators".

Physics is a metaphor for the world, and theatre is a metaphor for reality; therefore, physics theatre is a metaphor for a metaphor, a *metaphor squared*. The usual analogies explain new things in terms of simpler and more known things; physics, on the contrary, explains obvious things—like that heavy bodies fall—and less obvious things, like gravitational waves, in terms of abstract constructions that are not obvious at all, but that can be described with precision and studied in every detail since they

[3] From a private video communication with Flavio Albanese (16th January 2023).

are constructed with the fundamental aid of mathematics and "invented" by humans. The usual metaphors carry out a symbolic transposition that makes the speech more significant, such as the phrase "the sea of lavender sways with the blow of the wind" which considers the lavender fields as a sea, making a comparison that easily reinforces ideas. In physics "the electron is a wave function that evolves in the Hilbert space using a unitary operator" is a phrase that makes the idea extremely effective only after long and passionate personal training. Physics operates in reverse, so to speak, like an inverse metaphor.

Concerning gravity, Newton said the famous *Hypoteses non fingo*. In the *General Scholium*, at the end of the *Principia*, he wrote that:

> It is sufficient that gravity exists, acts according to the laws we expound and explains all the movements of the celestial bodies and of our sea.

For this, Leibniz accused Newton of returning to occult phenomena and Huygens said that, therefore, it was not even worth the effort to make complicated calculations about gravitational forces, if, after all, one did not even know its cause.

But physics evolved in the direction Newton had shown, moving forever away from common sense and "understandable" explanations. Since then, the usual explanatory similarities no longer apply in physics or physics education. Since then, it is no longer even possible to carry out a scientific theatre based on popular understanding.

But it will be precisely starting from this awareness that a real physics theatre can be born. It will be his main task—at least, this is the work that I personally, and within the group "Lo spettacolo della fisica" intend to do—to try to make the scientific metaphor direct. This time, therefore, it will no longer work by starting from common reality, but from real, actual physics in all its complexities, with all its language and all its ideas; by doing the reverse work of what it is used to do, which starts from reality to allow reflections and interpretations; by doing, therefore, it too, an inverse metaphor. Thus, theatre and physics will discover each other chasing each other along the faces of the Möbius strip of the human universe.

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