Zeitschrift: Archives des sciences et compte rendu des séances de la Société

Herausgeber: Société de Physique et d'Histoire Naturelle de Genève

Band: 46 (1993)

Heft: 3: Archives des Sciences

Artikel: Galileo and the popularization of science

Autor: Rubbia, Carlo

DOI: https://doi.org/10.5169/seals-740456

Archs Sci. Genève	Vol. 46	Fasc. 3	pp. 273-289	Décembre 1993

GALILEO AND THE POPULARIZATION OF SCIENCE[1]

BY

Carlo RUBBIA*

ABSTRACT

On 7 December 1592, Galileo Galilei gives his inaugural lecture as a newly appointed professor at the University of Padua. At 28 he is already famous with results in mathematics, in physics, and in applied science, and he comes from Pisa where he has held a chair for three years. He has already put to remarkable use his magnificent combination of keen observation and mathematical idealization and rigour, which clearly makes him the founder of our modern scientific approach. His book *De motu antiquora*, which combines some of his past works, already departs clearly from the Aristotelian way of thinking. His polemical style is already apparent in many incisive verses which he has written.

INTRODUCTION

The enormous power of science and its consequent responsibility stems from the strength of the new scientific method born in this very place with Galileo Galilei. It was here that the quest for the "why", the very reasons for the existence of life and every phenomenon, was relinquished for the first time to tackle a new question, more within the reach of man's tools: to understand "how" things happen. This was how the inductive-deductive method, based on experimental observation, measurement and mathematization was introduced.

The basic Laws of Nature which, in the language of mathematics, regulate physical phenomena, were thus discovered. The great power of Science comes from the predictive power of these equations which, in turn, is rooted in the universality of laws. A physics law establishes the relation between physical dimensions which is able to describe the behaviour of all known phenomena at the moment of its discovery. This is why it is universal and enables man to extrapolate observations in time and space. By making measurements in the laboratory, it is possible to obtain accurate information on what happened billions of years ago, on what will happen in billions of years and at a distance of billions of kilometres.

Thanks to this enormous power acquired on the surrounding world, mankind was freed of the atavistic reverential fear of Nature, of hunger, of cold, diseases and the barriers of distance.

* CERN, CH-1211 Genève 23.

[1] Talk presented on the occasion of the 400th Anniversary of Galileo's professorship in Padua. Text prepared with the collaboration of P. Catapano, M. Jacob and J.P. Revol.

The technological progress brought about by scientific knowledge also caused considerable social changes. In a few generations time, a society where the majority had no specific competencies evolved to full employment thanks to industrialization. Under the pressure of the social power acquired by workers, who had become necessary to run production equipment, lower classes made enormous steps forward in their social position. This is only an example of progress caused by advancements in fundamental science. The rapid increase of wealth induced by technology has, in turn, stimulated a remarkable increase in the general interest for scientific culture as well as in the number of researchers in various fields. Science is indeed the Mother of Technology.

Paradoxically, the ability to master the world which provided man with the keys to remove the fear of the unknown, also brought about the risk of a renewed separation between Nature and man. When the complexity and quantity of unknown phenomena exceed a critical threshold, man can be faced again with a barrier of unintelligibility of the external world thus returning to a status of ignorance and fear. Some of the most common worries of people are the use and applications of nuclear energy, genetic engineering and the devastating effects of chemical waste on the environment caused by the abuses of wild industrialization which are often attributed to Science. Confidence in Science is thus often questioned along with the freedom of scientists.

Galileo was the first to open science to a larger community, by explaining clearly, by demonstrating in simple experiments the points he was making and by using a language accessible to all. With him, the power of scientific reasoning was to be extended to all human activities.

This new power which Galileo gave to science implies a great responsibility for the scientist, in particular today when tools provided by science can bring the best or the worst to mankind depending on how they are used by society. Scientific power represents both the hope of solving the many dramatic problems faced by our world today but also the danger of terminating abruptly the history of man on the earth.

It is our deep belief that popularizing science is the best way to bring to the world the rational thinking which it needs to face the ethical problems which the much needed applications of science are bringing with them.

GALILEO THE POPULARIZER OF SCIENCE

In a letter to Fortunio Licetti written in 1640, two years before he died, he said that he regarded the 18 years which he spent in Padua as 'the most beautiful ones in his life'. He certainly enjoyed the extreme liberty of thought for his time that scientists could find in the Republic of Venice. He indeed crossed many scientific swords with his colleague Cremonini, but they remained very close friends. He appreciated the company of the many intelligent and open-minded people whom he met in Venice, and it is in a

Venetian palace where he located the 'action' of his *Dialogo*, his celebrated work which he was not to write until long after he had left Padua (plate p. 276). Among the three characters who debate in the book, Giovanfrancesco Sagredo is a Venetian nobleman with an open mind who, though neutral at the beginning, is eventually to become extremely interested in the ideas of Copernicus. In Venice, Galileo spent much time in the arsenal, with a keen interest in the sophisticated technology at work there.

He never dissociated science from its applications, and explicit reference to his experience in the arsenal comes back even in his last major work *Discorsi*. As a professor in Padua, he had a workshop associated with his chair, and it is from this workshop that originated the numerous instruments which he so cleverly designed and used for many of his discoveries. He wrote relatively little while in Padua but it is here that took place much of his thinking about mechanics, and many of his discoveries on naturally accelerated bodies, which he later exposed in great detail in his major books.

Galileo's work in Padua is a wealth of theoretical thinking and in experimentation. However in connection with his popularizing science, a special mention should be given to his writing, while in Padua, in 1606, of *Le operazioni del compasso geometrico militare* (plate p. 277). The principle of this apparatus, based on proportional lengths, was already known but Galileo brought it to a form which could actually be used. After lecturing on it to his students for some years, he wrote this book and, what is special for the time is that it is written in Italian. Galileo thus addresses himself to students and to potential users and not only to the scientific community of his time. This shows his desire to reach far beyond the academic circles to make the world at large participate in the scientific adventure. The publication of this book actually triggered some polemical reaction, in particular from Baldassare Capra. This was mainly, as is often the case among scientists, on the issue of priority. But Capra wrote in Latin.

With Galileo's Paduan work with magnets and, starting in 1609, with the astronomical telescope, one sees again his constant desire to broaden the use of scientific instruments through brilliant innovations which turn them into fully reliable tools for further applications and for scientific discoveries. He would have been amused to know that ultraviolet light would later be used to check for forgery in the archive of his trial! It is in Kepler's *Diottrica*, written in 1611, that one finds the full theory of the astronomical telescope, but it is to Galileo's genius that one owes the actual construction of the first reliable powerful telescopes, and their use for a trustworthy astronomical exploration. This trust in the instrument was based on the many successes which he met with in terrestrial observations. This is how the instrument was justified in his mind for other uses, such as pointing it at the sky. It was indeed not easy to prove to everyone that the instrument was increasing human perception and not deforming it!

Galileo constantly broke down the walls compartmentalizing scientific knowledge and those separating it from wider-ranging applications, many times addressing as large an audience as possible in their own vernacular language. He is a great example for us in the art of popularizing science. He was, in that sense, the skilful initiator of a process for which we feel a great need today.


DIALOGO
di
GALILEO GALILEI LINCEO
AL SER.mo FERD. II. GRAN. DVCA DI
TOSCANA
Stefan Della Bella F.

LE OPERAZIONI
DEL COMPASSO
GEOMETRICO,
ET MILITARE.

DI

GALILEO GALILEI
NOBIL FIORENTINO

LETTOR DELLE MATEMATICHE
nello Studio di Padoua.

Dedicato

AL SERENISS. PRINCIPE DI TOSCANA
D. COSIMO MEDICI.

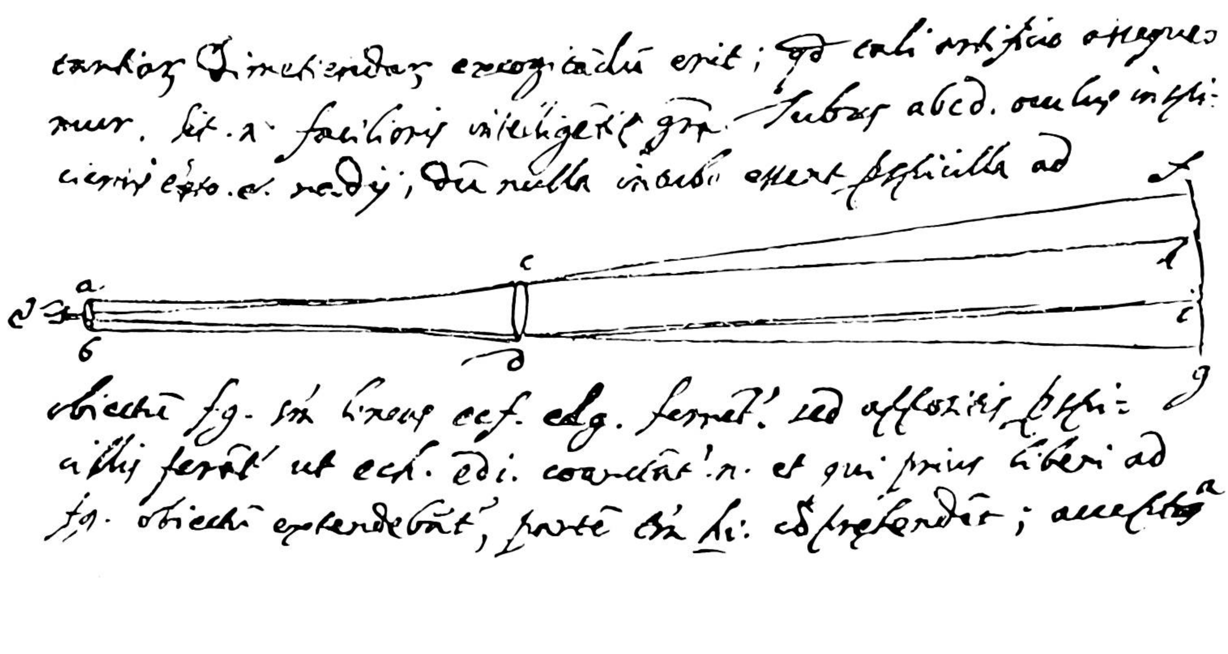
IN PADOVA,

In Casa dell'Autore, Per Pietro Marinelli. M D C V I.

Con licenza de i Superiori.

His famous astronomical discoveries in Padua were reported to the scientific community in his book *Sidereus nuncius*, published in 1610, but his 'dedication' of his discovery of the satellites of Jupiter to the Duke of Tuscany, calling them the 'Medicean planets', clearly shows his willingness to greatly enlarge the circle of people interested in research and supporting it. Despite insurmountable technical difficulties, he also insisted for a long time that this discovery should have a practical application with the measurement of longitudes.

We are close to the end of Galileo's stay in Padua and, at that time, he feels entrusted with a mission, namely to make the great new discoveries of his time, to which he already contributed so much, become part of the way of thinking of society at large and not only part of the technological applications used by society. This willingness is based on the deepest and greatest work which he undertook in Padua and in particular his study, description, and understanding of free fall. Here, we see his



departure from the traditional Aristotelian separation of two motions, upward and downward, to reach the concept of universality in free fall, and his impressive association of the law of motion to arithmetics and geometry, thus bringing mathematical precision and rigour to the study of a natural phenomenon. Through his clever experiments with the inclined plane he has beautifully demonstrated the power of the scientific approach that we owe to him, an approach based on observation, explanation, prediction and verification.

In Padua, whilst first teaching dutifully the Ptolemaic system, he became convinced of the validity of the Copernican system. As he indeed said in a letter to Kepler in 1597, 'Several years ago, I converted myself to the doctrine of Copernicus, thanks to which I discovered the causes of a great number of natural effects for which, without any doubt, the commonly admitted hypothesis is untenable'.

The presentation of the new dynamics of the cosmos is bound to raise great interest, as today when we talk about the Big Bang. However, it is a great risk at his time when the overwhelming culture clearly separates earthly phenomena from those proper to the heavens. Yet Calileo wishes to share with others an approach based on scientific reasoning, which is so compelling to him, and which, he knows, should be extended to the whole cosmos.

Galileo indeed wishes to bring to the widest possible audience not only the applications of science but the great powerful beauty of the scientific method based on observation, reasoning, and the design of specific crucial experiments. He wants to show the interplay between theory and experiment, which are of limited value separately, but which become the access to knowledge when put together. He wants to show why it is necessary to set our knowledge in the framework of principles because as he said, 'The understanding of a single effect from its very causes, allows our mind to understand and predict other effects without having to rely each time on experiment'. Observation should not result in empirical rules but in conceptual rules! Galileo also wants to show that science is not a closed activity limited to scientists but a phenomenon of general interest that should reach all levels of society. His support of the Copernican system will be presented in the *Dialogo*, but only between the lines, as a conclusion which the reader should reach by himself, by understanding the way in which the scientific method proceeds, a scientific method which should be applied to all walks of life. It is probably this last point which frightened some people, far more than the heliocentric theory.

Galileo already has immense prestige but, for this major work, he needs time and support, and this is one of the reasons for his departure to Florence.

This support and free time will be provided in Florence, whereas in Padua, as he said, 'It is contrary to common practice that one could obtain a salary from a republic, however rich and generous it might be, without having to accomplish some important public service'. He has indeed announced a major work *Systema mundi* in *Sidereus nuncius*. He has still to write it. However, it will take many years before he can bring it to completion in 1630. This is his *Dialogo*, published in 1632. By that time, he has already had some serious problems with the ecclesiastical authorities in 1616. This will become much worse in 1633 after the book has appeared. Nevertheless, as we now know, his point was made and he was eventually recognized as being right. It just took far more time than he anticipated when he left Padua!

The *Dialogo* teaches a lesson to today's popularizers. Beyond its presentation of the Ptolemaic and Copernican systems, it makes the reader participate in the process of research. And this reader should not be only a scientist. The book is indeed written in Italian to approach a wide cultivated audience. It has the clarity needed for that, whereas, until then, the presentation given to basic science made it very difficult for non-scientists to understand. In the *Dialogo*, science is not oversimplified but made accessible! Galileo uses a masterpiece of rhetorical strategy to convince the reader and makes him share the excitement of discovery through logical thinking and critical observation. As we know, however, Galileo's illuminating and refreshing breeze generated a storm at that time. As particle physicists we may even note with some amusement that the publication which first made it well-known to the world at large was in Latin, the scientists' English of the time, and by a Dutch publisher named Elzevir!

We shall come back to Galileo as a great master in popularizing science, but we shall now look in general terms at the great challenge which this popularization presents to us today.

POPULARIZATION AND TEACHING IN OUR TIME

The applications of science dominate our modern life and we rely heavily on them for our daily tasks and our well-being. Yet science remains a 'closed book' to many. The public at large has a poor understanding of what science is all about. One even witnesses the spread of an anti-science attitude emphasizing the alarming applications of technological innovations associated with recent scientific results, while forgetting the many beneficial ones, and not realizing the beauty and range of the great intellectual achievements which make science one of the most precious gems of our culture.

Scientists look at science as the understanding of the way the world works. Science is knowledge which is deemed good, and it is presented without any reference to ethical values, which are by essence dissociated from its formulation. Yet it is well known that the use of science raises many ethical questions. Facing them is a problem for society, but scientists have the duty to inform so that the implications of scientific results are clearly perceived. One has to try to avoid that decisions are made from misconceived pictures which non-scientists may more easily grasp. In connection with this, one may note that Galileo was even asked to abjure, among other things, that 'the Sun was at rest', a statement which had to be wrong for the Church of his time, but which was also so much at odds with his principle of inertia that he could not have made it himself!

The call of this information duty is particularily strong for physicists in connection with nuclear energy. It is probably even stronger today for biologists in connection with research on the genome.

As part of this cardinal responsibility for information we have to respond to a more specific call, which may be considered, at first sight only, as more selfish, and which is to convince the public that basic research is worth supporting. Its practical benefits are far from clear to many and yet it costs a lot of money in a world with many pressing priorities.

This is particularily the case in physics. Physics research increasingly relies on large facilities or instruments. These tools are required for a growing number of research pursuits that strive to extend the limits of mankind's knowledge. The great size, complexity, and cost of the facilities calls for a strong support from society. As this support is granted we are repeatedly hard-pressed to better convey to the public at large, namely the taxpayers, the reasons for our expensive research. As scientists we are convinced that the money is well spent and we do our best to optimize resources through an expanding cooperation and collaboration at the international level. Yet the

DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SUPREMO
DELLO STUDIO DI PADOVA, E PISA.

E Filosofo, e Matematico primario del Serenissimo
Gran Duca di Toscana.

Dove ne i congressi di quattro giornate si discorre sopra i due massimi Sistemi del Mondo TOLEMAICO, e COPERNICANO;

Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'una, quanto per l'altra parte.

IN QUESTA SECONDA IMPRESSIONE

Accresciuto di una Lettera dello stesso, non più stampata, e di varj Trattati di più Autori, i quali si veggono nel fine del Libro.

DEDICATO ALL'ILLUSTRISS. ED ECCELLENTISS. SIGNORE

IL SIGNOR

D. CARLO CARAFFA PACECCO,

Duca di Maddaloni, Marchese di Arienzo, Conte di Cerreto; Principe della Guardia, &c.

IN FIORENZA, MDCCX.

public has to be convinced. We need its benevolent attitude. As scientists we share the enthusiasm associated with scientific research and discovery. This is a key motivation in addition to mere curiosity. We have, however, to better share with the public this excitement which we so easily feel ourselves. Physics now depends so much on public support that it cannot thrive without it.

We are, however, sadly aware of a lack of interest on the part of the public at large and we have to try our best to change this into sympathy. We are also aware of the fact that, throughout the industrialized world, in Europe, in the United States, and in Japan, fewer and fewer high-school students are taking physics as a major subject. Physics is considered too difficult compared to the personal interest it represents, and the first contacts with physics may not always be exciting. This is really worrisome for the future of our field. A partial answer is certainly in a better popularization of physics research and in a better teaching of physics. We are convinced that physics is great, that it is a brilliant intellectual endeavour, beneficial in many ways to mankind. We have to convince others that this is the case and we have to stir enthusiasm among young people. There is much to learn from what Galileo did and from how he did it.

How can we best benefit from the example which he left with us? We can first gather strength from it. Galileo was an indefatigable fighter for the propagation of knowledge. Motivated by that we can take action in various ways. We can also learn from Galileo's teaching how to teach physics better.

Another level at which one should make a special effort is that of physics teachers. Are they not int the best possible position to convey to young people the excitement for science that we would so much like to spread in the world at large? They do their best but they have to be helped. We should better share with them the excitement of physics in the making so that they could better share it with their students. If we fail with the teachers we shall fail all the way, and we cannot afford to fail.

Such contacts are useful but, more generally, the research community should become more concerned about physics education at the high-school level. There are many ways in which academic physicists should get more involved, helping with the making of good textbooks for instance. In this country Edoardo Amaldi put a magnificent effort into that despite the pressing calls of many other activities. The use of computers in high-school teaching should also be developed with the help of the research community. A good physics education is of cardinal importance. It has a strong influence on the quality and quantity of future research physicists. It is the only contact with physics which most people will ever have.

GALILEO AS A PHYSICS TEACHER

We have to recognize that most of our textbooks, at the high-school level but also at the university level, do not offer a good picture of scientific practice. As Thomas Kuhn said: 'Normal science means research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledge for a time as supplying the foundation for its higher practice. Today such achievements are recounted, though seldom in their original form, by science text books, elementary or advanced. These text books expand the body of accepted theory, illustrate many or all of its successful applications, and compare these applications with exemplary observations and experiments'. The textbook format provides useful reading and teaching for the development of technical skills to solve already defined problems, those which are to come at the examinations. However, they do not usually provide any feeling for the undifferentiated – the way it was before physics could put some order among phenomena. They do not provide any hints of the games of conceptions and presuppositions which are played to interpret the puzzling reality. They do not teach how to observe and think, and observe again, which is the way research works. The role of the subject is fundamental in the research but it disappears from the classroom! The often painful approach which eventually resulted in success is left to the specialist of the history of science. It is of course considered to be the proper, and standard practice, to eliminate from the formulation of science all subjective parts. Science is actually considered as a body of knowledge which is gradually built up and where the roles of the many individuals who contributed to it are merged into the whole. Indeed the formulation which we can now give to many chapters of physics is far clearer, far more compact, and far more penetrating than it appeared when these chapters first came into being, and when certainty only gradually overcame doubt. It is considered better to forget about the sweat, tears, but also burst of joy (!) of physics in the making. Yet the role of the individual in the creation process remains overwhelming. As Pauli put it so vividly, 'The bridge, leading from the initially unordered data of experience to the ideas, consists in certain primeval images pre-existing in the soul – the archetypes of Kepler. These primeval images should not be located in consciousness or related to specific rationally formulizable ideas. It is a question, rather, of forms belonging to the unconscious region of the human soul, images of powerful emotional content, which are not thoughts, but beheld as if it were pictorially. The delight one feels, on becoming aware of a new piece of knowledge, arises from the way such preexisting images fall into congruence with the behaviour of the external objects'. This is so important in the conceptualization process but it is not to be found in physics text books. We should try to better convey the processes at work in the creation of physics.

The 'subject' does appear in the textbook even though all efforts are apparently made to eliminate it. As remarked by Fabio Bevilacqua, the most famous textbooks on classical electrodynamics, those of Planck, Sommerfeld, Pauli, Landau, and Feynman, all present the field in a masterly way. Yet there are remarkable differences of methodological and physical interpretation. There are, of course, in all of them the same basic facts and results but, whilst some emphasize a deductive approach, others favour an inductive one. One thus realizes that these great minds approached the same body of knowledge in different ways. This is part of the great wealth of physics even though it is not too important for solving examination problems. To convey a good feeling for it, we still have much to learn from Galileo.

In the *Dialogo*, Galileo wishes to show the way the scientific mind works and to teach how to combine thinking and observation. Whilst he stands for Copernicus, he does not try to prove that Copernicus is right. This is something which the reader may eventually conclude for himself. Galileo wants to show that all the strong objections held against the motion of the Earth do not resist a correct understanding of mechanics. He wants to point out how common sense might be misleading. Did people not think that a moving Earth should leave objects behind when bodies were known to fall vertically? Mechanics had no yet been addressed in the quantitative and logical way that he himself had followed. Galileo repeatedly makes the point that many phenomena can be considered in different ways. The motion of the Earth around the Sun had to be inferred from astronomy. Free fall, when properly understood, had nothing to do with it. The Earth may be at rest but it may just as well be moving. He patiently refuted all the casual objections of his time which many people held as obvious truth. The book is written as a discussion between three characters, in a narrative style, and in Italian, for people of his time. It makes a mockery of the frequently quoted separation between a humanistic culture and a scientific culture. Yet it is very deep. The principle of inertia and the principle of relativity are there, perfectly introduced and formulated. One may argue that his lively presentation of scientific discovery, in 1630, was different from the one which he actually lived through in 1604, while in Padua, and also that many of the experiments which are referred to are 'gedanken' ones. This is not important. The important thing is that the book shows what physics is and also the way physics is made, thruth being gradually reached through an ingenious pattern of observations, inductions, deductions, and observations again. As Galileo said of his potential readers: 'I want them to realize that Nature, in much the same way as she has given them eyes to see her works, has also provided them with a brain to study them and understand them'. His illustration of the relativity principle from all that one may observe *inside* a ship, whether the ship is at rest or moving with a constant velocity, is a masterpiece. In particular, free fall is the same in both cases. Had he also considered the velocity of light inside the ship (much beyond the instrumental power of his time!) he could have reached Einstein's special relativity principle. The key lesson of the two great minds is the same: we should rely on principles and not on passing common sense. Principles have to be freely invented. Yet they take their value only through an uncompromising confrontation with observation.

One could imagine a modern 'hour' of the *Dialogo* based on the debate between Bohr and Pauli about the puzzling result presented by the β decay spectrum. For Bohr this new type of process could well not obey the laws of the conservation of energy, so far held as a principle but not yet put to the test in this particular type of process. For Pauli, the principle had to be kept with its full force, and, therefore, a new particle, with surprising penetrating properties, had to exist. We are in 1931. It is only in 1956 that Pauli could say, 'The extraordinary technical difficulties of the experimental demonstration of this reaction were finally overcome by Cowan and Reines'. We now teach that there are three and only three species of light neutrinos after the LEP experiments on neutrino counting. Neutrinos have a tremendous importance in particle physics and in

Esperienza che mostra, come il moto comune è impercettibile.

Vorrei, per tor d'error questo filosofo, potergli dire, che una volta andando in barca, facesse d'havervi un vaso assai profondo pieno d'acqua, & havesse accomodato una palla di cera, ò d'altra materia, che lentissimamente scendesse al fondo, sì che in un minuto d'hora, appena calasse un braccio, e facendo andar la barca, quanto più velocemente potesse, talchè in un minuto d'hora facesse più di cento braccia, leggiermente immergesse nell'acqua la detta palla, e la lasciasse liberamente scendere, e con diligenza osservasse il suo moto. Egli primieramente la vedrebbe andare a dirittura verso quel punto del fondo del vaso, dove tenderebbe, quando la barca stesse ferma; & all'occhio suo, & in relazione al vaso, tal moto apparirebbe perpendicolarissimo, e rettissimo; e pure non si può dir che non fusse composto del retto in giù, e del circolare intorno all'elemento dell'acqua.

astrophysics. Because of the way we teach physics, the long march which led from a controversial hypothesis to a scientific fact may soon be unknown to many.

The *Dialogo* is a masterpiece of rigour and clarity. It was even too much so. Too many people could read what was on the lines and, in particular, between the lines. Galileo, as we know, got into deep trouble. Science is not 'black and white', and this is what the public often does not like in it. The public is for certainty when one of the great virtues of science is to keep doubt and questioning alive, as so magnificently pictured by Dürer in his Melancholia. Science carefully quotes conditions and known precision. Galileo already knew that better than others. Yet his statements were often deformed into a (Dominican) 'black and white', and fuelled that way into a controversy amplified by the political context of the time. Galileo had actually shown that one could not consider the Copernican system as contradicting known facts, but only as contradicting a too crude and erroneous interpretation of those facts. Yet the Copernican system came under vicious attack and Kepler could complain that 'competent people could no longer work in peace on it, when they had the possibility to do so for 80 years'.

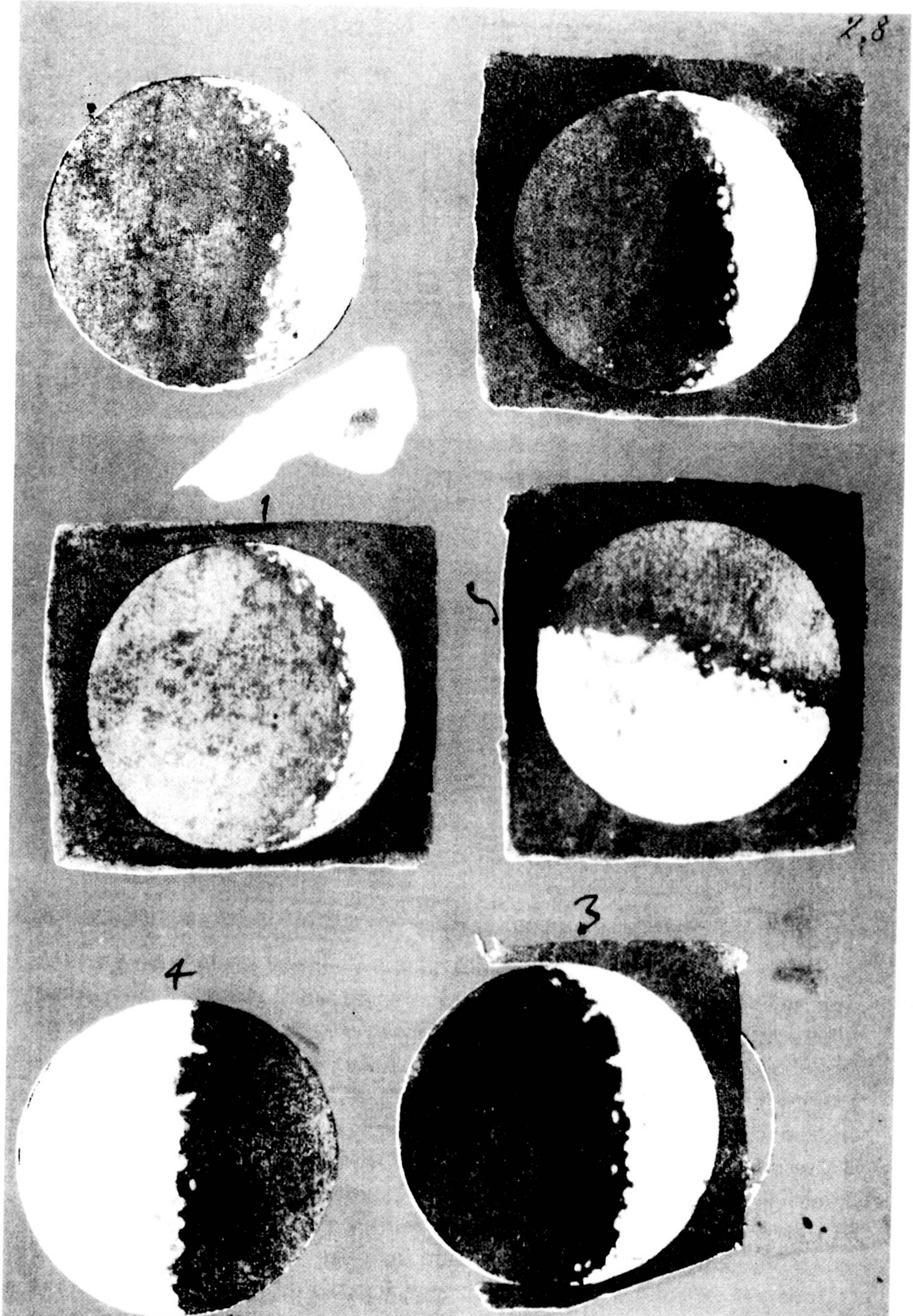
Indeed when, despite the tremendous set back of his trial, Galileo will later publish his *Discorsi*, through Elzevir again (!), in 1638, he does not meet with further trouble. Yet, the *Discorsi* is, between the lines, as pro-Copernican as the *Dialogo*. It uses the same narrative and discussion approach. However, through its style and content, it is addressed far more to specialized scientists than to a general audience. It is a physics book with a lot about theories, experiments, in particular those with the inclined plane, and their subtle interplay. Can one say that it was not condemned because those who could have condemned it could no longer understant it? It is certainly more complicated. The *Dialogo* was condemned by people who thought they understood too well what was behind it, while they actually misunderstood what was explicitly in it.

FOLLOWING GALILEO IN POPULARIZING SCIENCE

We should certainly aldmire Galileo as a great master in popularizing science when we feel such a great need for popularizing today. The way he explains so well how science progresses should entice us to write more about it using the many recent examples which we have in mind. Is it not more exciting to try to share with the public at large than a list of results? This may even be more informative to non-scientists than some formulae taught to be used as recipes. History does not repeat itself but it often stutters. If people are not properly informed about what science is about, we could well meet with irrational and emotional reactions against science. We should not forget that we live in a (modern) world where astrology books are extremely popular! Support for science could well receive a devastating blow from ill-understood aspects of environmental sciences and, even more so, genetic engineering. The mission of Galileo when he leaves Padua, and meets with the long fight which is to follow, has much to do with our popularizing mission today, and, maybe, with the difficulties which we may encounter some day, even though the context is very different. We should therefore try to learn from Galileo's skills and successes, but also from his mistakes and failures.

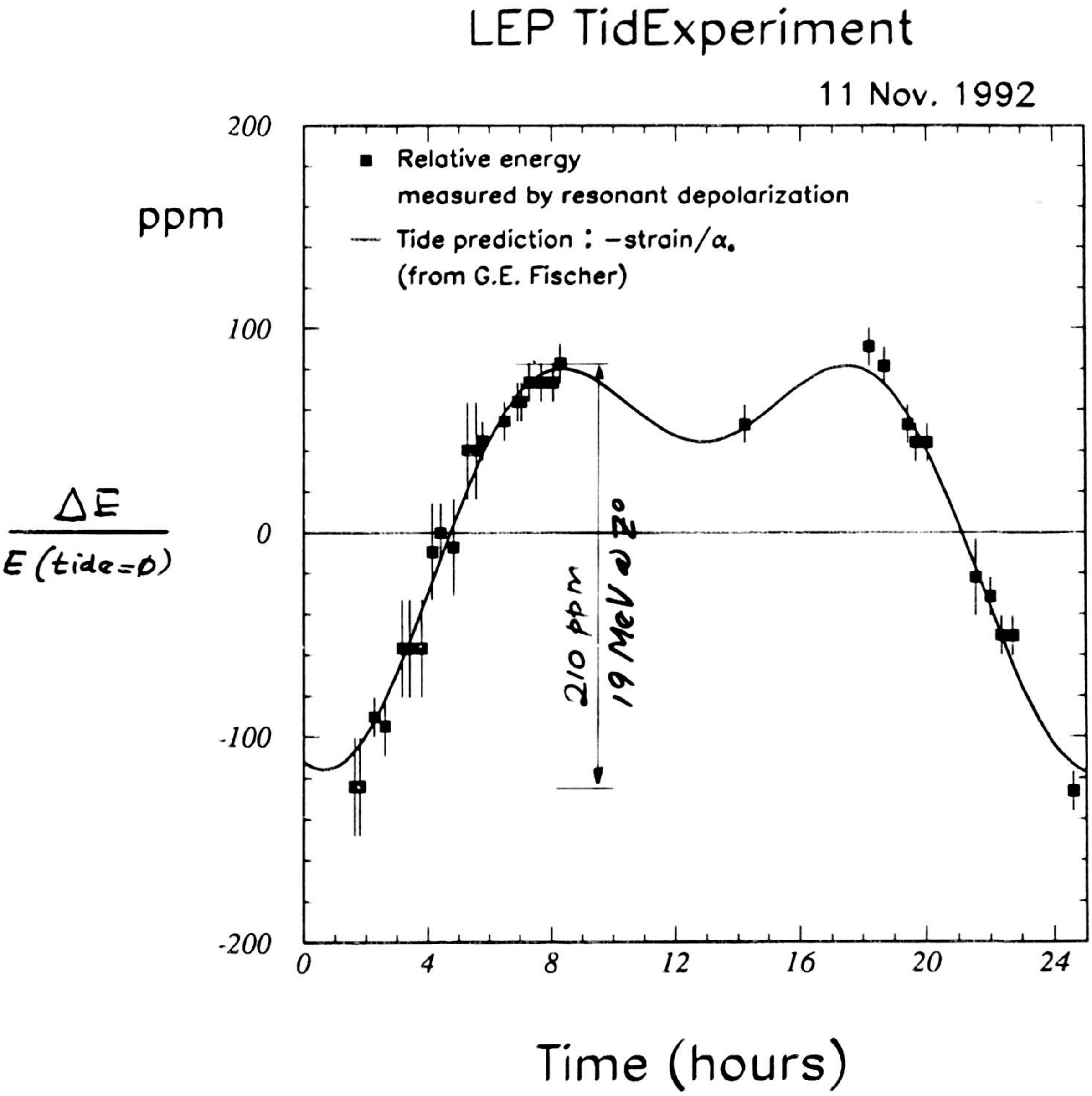
Galileo was right on most issues but he was not always right. He was extremely confident and sure of himself and, because of that, he liked to enter polemical debates too much, sure as he was to always win. This is particularly the case when he is in Rome in 1615, before his first big troubles started in 1616. As was reported at that time, 'before answering objections, he would first amplify them and reinforce them with new arguments which looked very strong, to then make them stumble altogether and bring further ridicule upon his detractors'. In his more polemical works, and in particular in *Il Saggiatore*, he goes rather astray from the careful logics of his purely scientific works. For instance, his distinction between primary and secondary qualities for language, separating the formulation of science (primary!), which is here to stay, from the common language (secondary), used only for intuitive illustrations, and which is to disappear after scientific knowledge is available, goes too far. Galileo argued that God, who knows perfectly both languages, could have preferred to use the second one when first revealing parts of his creation to man, but that the merely allegorical images of this language should be gradually replaced by the true language of God, as more and more accessible through the logics of science. He hoped to rally the support of the Church but just angered them that way. Indeed, whilst he was the greatest scientist, he met with more highly talented debaters on the grounds of pure methodology.

Yet, one may admire him even when he is in error. Whilst he argued on poor grounds with his theory of tides, and also missed capillarity in his theory of floating bodies, his logic at properly defining the *system* to which properties should be applied remains a corner-stone of modern science. One may also quote his closing remark to the debate whether the Moon was perfectly spherical, as a heavenly body should be, despite the mountains which he had reported seeing, and which were no longer challenged as a telescope artefact. It had been argued that there could be a transparent substance on the


1
3
4

Moon which would still make it perfectly spherical. 'A beautiful invention,' he said. 'It is just lacking the property of being proven or only that of being provable'.

By popularizing science Galileo tried to awaken the modern scientific spirit in the minds of the largest possible number of people. He tried to bring science outside the private sphere of scientists, making it also a general-interest phenomenon permeating all levels of society. He put tremendous energy into this endeavour. He was bold, and sometimes too bold for his time and for his knowledge. Yet he leaves with us a



The energy of the electrons and positrons accelerated in the Large Electron-Positron (LEP) collider at CERN depends upon the actual length of the machine, which pulsates according to the tidal motion of the crust of the Earth.

magnificent example of what can be done and should be done in our task of promoting science. Let us follow him in a more humble but still indefatigable way.

We should present Galileo's dramatic picture of the moon (plate p. 287), with its specific features which deny its heavenly character. With our largest instrument at CERN, LEP, an electron-positrion collider which is at present the largest accelerator in the world, we are also looking at the moon. The dimensions of the machine are so large and its engineering is so precise that we can see the tidal motion of the earth crust (fig. p. 288).