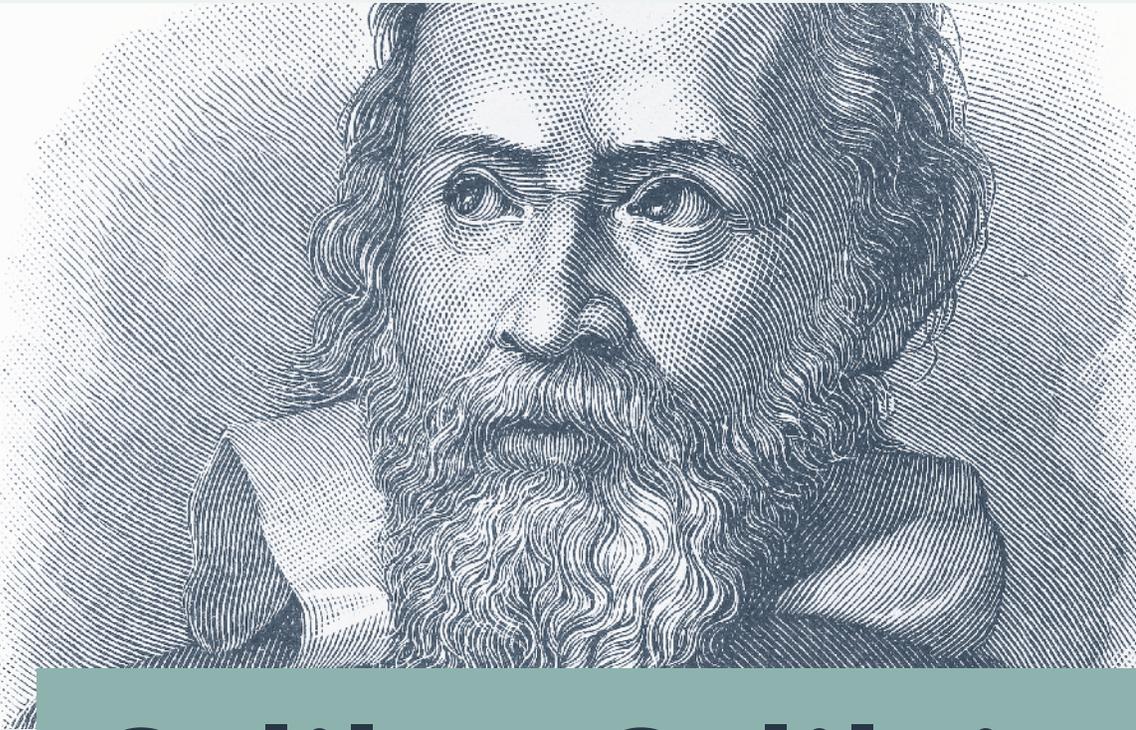


Springer Biographies



Galileo Galilei

At the Threshold of the Scientific Age

WOLFGANG W. OSTERHAGE



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At the Threshold of the Scientific Age

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Preface

Why another book about Galileo? To most readers, his achievements, his life, and his conflict with the church authorities are well known. This book, however, tries to put the complex personality of Galileo into a different perspective. Although it still follows the stations of his life in their historical sequence, it relates his discoveries and theories to today's scientific developments in major fields of physics on the one hand and to ancient teachings on the other hand. Galileo's most important publications are discussed in detail.

The book starts with a broad description of major historical events during Galileo's lifetime, followed by a recounting of his early years in Pisa and his gravitational experiments there. During his time in Padua, he made his first important astronomical discoveries, which led to a first conflict with the church authorities later during his stay in Florence. At the centre of this conflict—as is well known—was his interest in the Copernican world model.

At this stage, a general outline is given of the development of cosmological world models from the ancient Greeks over Ptolemy and Copernicus up to our Standard Big Bang Model. The climax of Galileo's conflict was triggered by the publication of his "Dialogo." The narrative of the book concludes with a summary of his work in his final years in semi-exile in the countryside near Florence, followed by an assessment of the impact of his work for science in general and today's outlook in particular.

At the end, an exhaustive timetable containing the most important historical and scientific events including those of Galileo's life is presented. There is also a table of references used in the book. Most of the letters referred to in the text and some of the passages from his publications have been taken from A. Mudry, *Galileo Galilei: Schriften, Briefe, Dokumente*, Berlin, 1985, and retranslated by myself. Other facts about Galileo's life and circumstances can be found under Galileo.rice.edu.

My thanks go to Springer International Publishing for making this book possible in the first place. Special thanks are due to Dr. Angela Lahee for her patience, Ute Heuser, and Stephen Pfeiffer for his critical language review.

Wachtberg, Germany
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Wolfgang W. Osterhage

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Chapter 1

Introduction



The life of Galileo, one of the founding fathers of modern science, is full of genius, but also of discrepancies, inconsistencies and retractions all of which had already been noticed and documented by his contemporaries. Despite his designation as the “Columbus of the Skies” they were well aware that he was a devout Catholic throughout his life. And he was not alone. In Italy at his time but also in Germany, more than one scholar was forced to wear a mask to hide his true beliefs in public.

Of course, there exists a whole panoply of biographies of this illustrious personality, in which the reader can find everything he wants to look for: his scientific achievements, his academic stations, his family life and last but not least his monumental conflict with the church establishment. So why bother to write another one?

The present book tries to deviate from the classical path of following the life of a prominent personality of historical fame and painstakingly reporting the details of his existence. In fact this is not its objective, although it is catalysed by a biography as such, but it is more a biography of science or rather of specific fields of natural science, of physics in particular. But it becomes evident in its course that even specialist scientific areas like astronomy very quickly stretch out their tentacles into other related subjects of interest such as mechanics or thermodynamics.

The figure of Galileo offers itself as a perfect example for the transition that took place during his lifetime all over Europe—be it political, religious or scientific. Galileo serves as a sort of burning glass, by which the rays of many ideas emanating during his lifetime were bundled and focussed. This book is thus not so much a biography of a single person but represents a tale of an excerpt of human history starting off as early as 490 BC and leaving off in 2012, as can be seen from the time line in Chap. 11. And somewhere in between along this line appears the man whose life serves as the leitmotif of this tale.

Of course, the milestones in this narrative are the personal dates and achievements of Galileo, his academic career, his scientific reflexions and his quarrels with the ancient philosophers. Important events include his major publications and discoveries, which enriched the view of the world, not only for his contemporaries, and his inventions. Already during his lifetime, legend building began, and fame surrounded his name even before his death.

But the foundation of Galileo's fame was not only built on the sober results of his scientific work. One of the main reasons for remembering him more than others is to be found in his conflict with the church. Although he was far from the only person even of his time to have suffered this course of events, his fate had been exploited from the very beginning and is still up to today. This famous conflict is not the key subject of this book, although a whole chapter is devoted to it, but rather the cause of the conflict, i.e. the publication of a book that deals with two competing world models.

The Greek language provides two different translations for our word "time": Chronos and Kairos. Chronos refers to our usual understanding of time as consisting of a sequence of consecutive events to be measured by clocks. Kairos means time fulfilled, accomplished, consummated. The time was ripe at the threshold from the Middle Ages to modern times: Kairos. In fact the whole spiritual and philosophical (in its widest sense as comprising natural philosophy) climate generated this "threshold", and Galileo stands for the symbolic crossing of that threshold.

If we look at the mirror of the time in question, then that time was imprinted with the concurrence of the asynchronous. The church was the real point of reference: it controlled the life of the individual from birth via baptism and marriage up to death. At the same time, it wielded worldly powers. People of the outgoing 16th century were pious as never before or thereafter. At the same time, it was common understanding that man was at the centre of the cosmos.

The time was ripe. The central question that arose and would thereafter never leave the scholarly discussion until today dealt with our position in the world and not only in the cosmos as such. Are we Copernican, i.e. do we believe that man does in the end not occupy a preferred position in the world in any sense of meaning? Or is there still something non-Copernican, which may assign a special place for us in the universe? This was the question in a nutshell taken up in Galileo's *Dialogo*, and this is a question still in contention today.

The Anthropic Principle

As one key element in the dialogue between natural science and the theology of creation, the so-called fine adjustment is cited again and again, i.e. the ideal conditions allowing for the development of human life as such. The fine adjustment of our living space is indeed also the subject of an internal discussion among the sciences that puts the purely statistical arguments about infinitely possible living environments in the cosmos into perspective. In this connection, some time ago an epistemological basic debate was triggered in natural science and in its discourse with theology [1].

The fundamental question thereby is: why are we in a position to discern the world the way it is, and thus are able to describe it within the framework of a comprehensive theory?

If, for example, the neutron-proton mass difference were different by just a tiny amount, there could be not nuclear physics in the present sense, nor could there be

elements or stars. Or: if the energy level in the C^{12} -nucleus did not correspond to 7.65 MeV, there would be no life based on carbon chemistry.

It looks as if many natural constants are just situated within the very narrow bounds that enable human life. This fact is called “the Anthropic Principle”. Opinions diverge about its meaning. These are some:

- Since we are here and observe everything, those parameters just have to be as they are. Otherwise, we would not be there and could not wonder about them.
- Thus Life is something extremely improbable and something very special.
- The universe had been created in just this way to enable life.
- Rubbish.

To delve more deeply into this complex question, let us start with the three slights suffered by mankind:

- Transition from the geocentric to the heliocentric world model; Earth and man are no longer at the centre of the cosmos (Copernicus, Galileo): this means that we have to accept a progressive decentralisation and de-anthropomorphisation. The sun is just one star among many, our Milky Way just one galaxy among many, our cosmos—who knows—maybe only one (fractional) cosmos among many.
- The special status of man among living creatures is doubtful; mechanisms have replaced purpose (Darwin, Monod).
- Man no longer “rules the roost”: the unconscious governs to a high degree (Freud). Recently this has been complemented by evolutionary cognitive science, artificial intelligence, and robot technology.

Against this backdrop, there are the following considerations:

On Earth, there is a life form with a consciousness, an observing intelligence. What must the corresponding universe look like? This question cannot be answered without the following logical steps:

- Consciousness presupposes that there is life.
- Life needs chemical elements as a precondition to come into existence, especially those that are heavier than hydrogen and helium.
- Heavy elements can only originate by thermonuclear reactions with light elements—nuclear fusion.
- Nuclear fusion takes place only in stars and needs at least several billion years to produce significant numbers of heavy elements.
- The time span of several billion years is only at the disposal in a universe which itself is several billion years old and has been extended by several billion light years.
- On the other hand, in later cosmic epochs stars similar to our sun very rarely would come into existence, but mainly white dwarfs with low energies unable to supply a planetary, slowly evolving life form with sufficient energetic support.

Therefore, the answer to the question, why the universe observed today by us is so old and so big, can only be: because otherwise mankind would not be here. This leads to the Weak Anthropic Principle. It says:

The physical universe observed by us has a structure that permits the existence of observers.

But is this really a principle? Principles are introduced to explain something, for example:

- Why is the universe structured the way it is structured?
- Why is it such that life could have developed?

The Weak Anthropic Principle does not possess this explanatory merit. Perhaps it is tautological, something like: a universe allowing for an observer to exist. Well, what else should there be to observe? No. The Weak Anthropic Principle directs our attention to the fact that the possibility of life is linked closely to the overall cosmic development. Does this mean that man has moved to the centre stage again? Again: no. The Weak Anthropic Principle only reminds us to involve the observer in any theory to be constructed.

Another false conclusion from this principle is the following: the basic characteristics of the universe must be such that observers can develop. This is neither logical nor required by natural laws. The only thing that matters is that, if the universe is observed, then its basic characteristics must be such that an observer is possible.

Now there are a number of counter arguments. The first is: the denial that the fine adjustment is essential for the existence of life, because life could be based on something else than carbon. This means that a different type of life could have developed in a universe with different characteristics. Of course this is highly speculative. There is no empirical evidence for a different chemistry of life.

Another objection reads like this: the existence of the fine adjustment is inevitable. Justification: there are infinitely many cosmoses in a multiversum. In all of these, all possible laws, constants, boundary and initial conditions are realised. Our cosmos is then by default a necessity, and there is nothing to wonder about and to explain. The remaining question is: what should these multi-world scenarios look like? Two models are on offer:

- The inflationary model with many parallel cosmoses.
- The oscillating model.

One turns to the idea of a multiverse, which probably can never be verified, to explain certain cosmological characteristics that do not conform to the traditional standard model: anisotropic structure, missing (dark) matter, initial phase etc. The most extensive variant of this theory postulates an infinite number of universes of all imaginable occurrences, such that our universe also must inevitably have come into existence as it is and as we find it. Indeed, our universe has to appear infinitely often with all persons in it!

Or: the fine adjustment is only a clue to some still unknown context of natural laws. The accidental must be eliminated by finding new and deeper principles.

And in the end: the fine adjustment is just random. But the improbable also does happen occasionally.

To continue, and how should it be otherwise, there exists the Strong Anthropic Principle. It says:

The universe has to be conditioned with regard to its laws and composition in such a way that it will eventually generate an observer without fail.

This extended formulation is logically possible but does not follow from the Weak Anthropic Principle and is basically teleological, i.e. purpose and target oriented. The origination of life is declared as a necessary characteristic of the universe. And in this way, the subject to be explained is simply postulated to be. By doing so, the need for justification is removed. The counter question is: why should the Strong Anthropic Principle be valid? Until now, objectives have always been replaced by mechanisms. Furthermore, teleological statements are difficult to falsify.

And finally, there is the Final Anthropic Principle. It says:

In the universe, intelligent information processing life must come into being, evolve and continue to exist forever.

To conclude, one can say that, although these theses do not claim to have a specific physical explanatory value, they have quite impressively worked out that the universe is de facto arranged in a way that suffices for the origination of intelligent beings.

None of these principles, however, proposes an explanation of the way in which observing life may be generated—a life with an exposed position in the cosmos. And on the other hand, there is no conclusion as to whether this intelligence is sufficiently equipped to be able to carry out objective observations at all. The whole question concerning the Anthropic Principle is based on the assumption that our observations are indeed sufficiently correct that the Anthropic Principle makes sense at all.

Quantum mechanics has opened up the general problem of measurement, i.e. observation. It is now universally accepted that the observer is always part of the observed. From this follows a number of epistemological intricacies not to be discussed any further here, but quantum mechanics puts the validity of the Anthropic Principle into yet another perspective.

This Book

So, one of these observers was indeed Galileo. He was in the thick of the transition from the Middle Ages to modern times. This book, although it means to be more than just a repetition of time line events, still follows this sequence from cradle to grave. Most chapters, however, do not start with an anecdote from the life of our hero but introduce a specific aspect of modern science that is either directly

connected to Galileo's discoveries and research results or is the consequence of further developments in relation to his findings or theories since. Through these associations, the relative position of Galileo with respect to other scientists in history can be ascertained and his contribution assessed. Chapter 7 documents the forceful clash of the world models that was at stake. This clash of ideas culminated finally in and was encapsulated by Galileo's trial and its outcome.

Chapter 2

Time and Space (1564–1642)



Time and space are fundamental conceptual constructs indispensable for the mathematical formulation of physical models of our world as we experience it with our senses. But time and space are also everyday concepts in the minds of ordinary people, necessary to accumulate their experiences and consolidate their memories. In this sense, time and space will be considered along the world line of Galileo's life whenever certain events have an impact on his professional career. Time and space in a narrower sense of course contain the personal world line of Galileo himself and thus touch upon the interest of any biographer. The space-time of Galileo's life is filled with the history of his time in and around the places he lived, in Italy, in Europe and in regions further away. These events and circumstances of the time of the vanishing Middle Ages and the dawn of Modern Times had a profound influence on his thinking and thus on the development of his contributions to science, just as they had on the reasoning and beliefs of his contemporaries, and just as our times have on us. Since however, we are concerned with the life and scientific contributions of this man, we will use this chapter to outline the context in which he lived (Fig. 2.1).

Figure 2.1 illustrates this historical context graphically.

The Time of Witch Hunts

There have always been instruments and methods for bringing people deviating from a presumed, generally accepted normality back into line. The first step is to identify these assumed deviations. At various times, the idea of witchcraft emerged already in ancient times. It was developed further and systematised during the Middle Ages to become a virulent source of social control. Witch trials appeared in waves with intermediate cessations in between (Fig. 2.2). There were peaks in the 15th and 16th centuries and again during the time span of our present concern—during the lifetime of Galileo. The emphasis shifted from the accusation of simply practising witchcraft as such by supernatural means to the accusation of direct association with the devil himself.