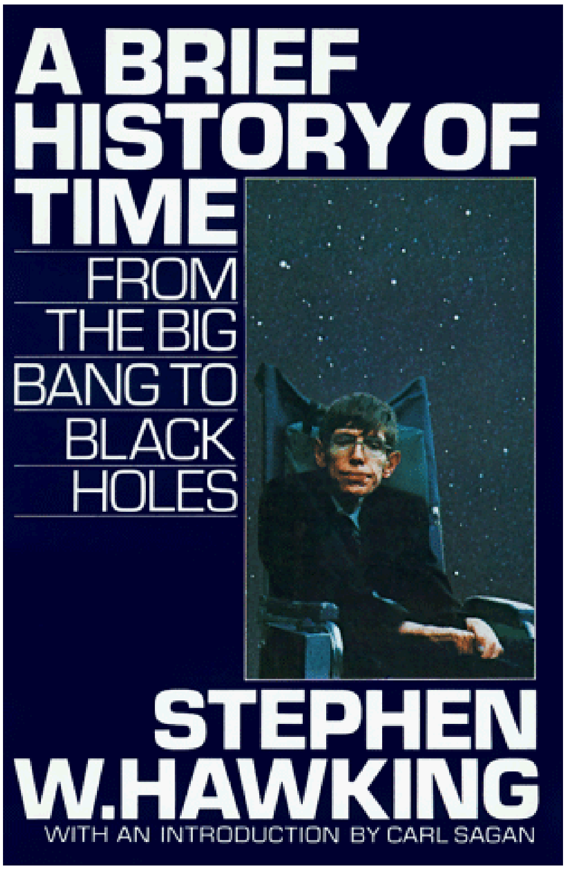
Beauty takes time!

(*A Brief History of Time*. By Stephen Hawking. Bantam, Pbk, reissue edition March 1, 1988)

Aires Ferreira
Centro de Física Teórica – UP



The history of the XX century was one of great achievements. A multitude of revolutions in various domains, from literature to experimental science, has prevailed over established ideas of modern age in a way never seen before. Stephen Hawking, recognized by some as the best theoretical physicist of the 2nd half of the XX century, for breakthroughs on the understanding of exotic objects known as black holes, had a *dream*: a popular book about the Universe that people could buy at airports capturing the great discoveries of his time. This dream came true in 1988: *A Brief History of Time*.

Why recalling a classical of popular scientific literature in a fast developing science?

Today no major scientific project eludes the news. This however doesn't mean that one knows about the real goals of such projects; media always tend to phantasize about potential discoveries. Indeed, if one wishes to understand the importance and relevance of such projects without the usual noise from the media, a reading of a serious text about the essential of general relativity and the quantum theory of fields --- the most well-tested and successful theories ever --- is compulsory.

With so many books of the kind, Hawking's book is a good choice for a few reasons I will explain briefly. To begin with, it makes a special focus on intriguing and non-tested predictions of the aforementioned theories. This happens to be so for a good part of the questions asked by scientists in the eighties remain unanswered. In fact, this book is written in such an up-to-date style that by choosing a random page one would infer that it was written just before the Large-Hadron-Collider (LHC) came in the news:

“The present generation of particle accelerators can collide particles at energies of about one hundred GeV, and machines are planned that would raise this to a few thousand GeV. But a machine that was powerful enough to accelerate particles to the grand unification energy would have to be as big as the Solar System – *and would be unlikely to be funded in the present economic climate*.“ [*A Brief History of Time*, Chapter 5, my emphasis]

The latter being an example of Hawking’s wit. Some of the covered issues are in fact the main motivation for projects well known to the public. I am thinking about the Laser-Interferometer-Space-Antenna (LISA), Hubble and the LHC projects, just to name a few. The interested reader may read more about these projects in the Appendix below.

I think these are good enough reasons to explore *A brief history of time.* Allow me to give a personal opinion about its own merit as a popular book on science.

After more than twenty years from the first edition, this is still the most fascinating book of the kind. *A Brief History of Time* takes the reader through a space-time travel of beauty and mystery which begins in the hot era immediately after the Big-Bang and ends fifteen billion years afterwards with rational beings, such as the reader and myself, thinking about their own origins.

Although Hawking’s book is not the right place to learn how physicists can be so sure about nature’s behavior to the point of predicting never seen phenomena in a quantitative fashion (for this I refer the reader to *The Character of Physical Law* from Richard Feynman) it provides a journey through the most important topics of Cosmology and Physics. Apart from the celebrated equation about the mass-energy equivalence,

E=mc^2,

which have entered into one’s mental frameworks due to its large impact thus gaining the status of more than a mere equation, this book has no mathematics at all and Hawking's clear exposition can be followed without difficulty.

I read it as an adolescent and learned about the thermodynamic arrow of time for the first time. That the universe had a clear arrow of time pointing to the future was clear and intuitive, but that one could actually look at this arrow with a precise thermodynamic reasoning was a kind of mystery that I could only completely unveil years later in my undergraduate studies in Physics:

“[...] we don’t see broken cups gathering themselves together off the floor and jumping back onto the table is that it is forbidden by the second law of thermodynamics. This says that in any closed system disorder, or entropy, always increases with time. In other words, it is a form of Murphy’s law: things always tend to go wrong! An intact cup on the table is a state of high order, but a broken cup on the floor is a disordered state. One can go readily from the cup on the table in the past to the broken cup on the floor in the future, but not the other way round.” [*A Brief History of Time*, Chapter 9]

In other words, the direction of time is the direction of increasing disorder (entropy). As human beings we have this concept clearly inside our minds since we are kids: one easily distinguishes between a moving forward and moving backwards videotape. The title, *A Brief History of Time*, was therefore a good choice since it focus on the cosmological evolution and on the concept of time throughout its eleven chapters. One of the chapters is actually devoted to possible means of distorting space-time in our favor in order to "gain" time. A fashionable example of this is the wormhole concept, i.e., a tunnel in space-time allowing to reach a distant region of the Universe without actually having to travel all the way to it. This is a highly theoretical possibility which could allow traveling to the past. Hawking's sense of humor, once again, put it very clear:

"So what one needs, in order to warp space-time in a way that will allow travel into the past, is matter with negative energy density. Energy is a bit like money: if you have a positive balance, you can distribute it in various ways, but according to the classical laws that were believed at the beginning of the century, you weren't allowed to be overdrawn. So these classical laws would have ruled out any possibility of time travel. However, as has been described in earlier chapters, the classical laws were superseded by quantum laws based on the uncertainty principle. The quantum laws are more liberal and allow you to be overdrawn on one or two accounts provided the total balance is positive. In other words, quantum theory allows the energy density to be negative in some places, provided that this is made up for by positive energy densities in other places, so that the total energy remains positive. [...]" [*A Brief History of Time*, Chapter 10]

Wormholes, like black holes or gravitation waves, are possibilities arising from Einstein's general relativity. The XX century has taught us, more than one time, that when one theory makes good predictions (eventually confirmed in the laboratory) one should not put its more "strange" predictions aside... because science will surprise us sooner or later!

Final remarks:

If after reading this book the reader wishes to learn the issues covered in *Brief History of Time* with more detail and some mathematical rigor he/she should seriously consider to read *A Road to Reality* by Roger Penrose: an extensive pedagogical review on Mathematics and Physics.The reader interested in complexity issues such as the origin of life or large-scale structure is recommend to give a look at the almost *poetical* text by Hubert Reeves, *Patience dans l'azur: L'evolution cosmique*.

Appendix on LISA, LHC and Hubble

LISA project aims to find evidence for a simple consequence of Einstein's field equations: gravitational waves. Remote giant bursts of galaxies and *supernova* distort the space-time so strongly that fluctuations will travel away in all directions like waves in a lake. LISA aims to detect directly these gravitational waves [1].

The Hubble project has its name after the great astronomer Edwin Hubble. In the thirties, Hubble found that the relative velocity between galaxies in the observable Universe is greater as their mutual distance increases [2]. The telescope Hubble made probably the most important scientific discoveries of the past ten years by measuring Hubble's rate of expansion with accuracy and capturing visible light with 13 billion years! This telescope continues to reveal surprises: last year it was found that the Universe seems to be accelerating, i.e. its rate of expansion is getting stronger!

Finally, the famous and wide-spread announced LHC is the largest of its kind, capable of accelerating particles nearly up to the speed of light, it is expected to find the particle originating mass in the Universe according to the Standard Model of particle physics.

If you find all this subjects too technical or difficult, I recall that new science is difficult even for scientists. The *beauty* takes time and effort to understand! In this regards, I cannot help to recall a funny story I knew about when I read Hawking's book for the first time. It took some years for Einstein's revolutionary ideas being accepted and even comprehended by his pairs. In a response to a physicist in a meeting of the Royal Society, Eddington confronted with the myth that only three persons understood Eintein's theory (Eddington being one of them) replied “on the contrary, I am trying to think who the third person is!”

[1] The hypothesis of gravitational waves follows intuitively from what it means space-time according to relativity, i.e. a sort of elastic medium able to gain local curvature by masses or energy “standing on it” (like a bowling ball on top of a bed sheet for instance). Like every elastic medium that supports sound propagation, the “gravitational medium” should support its own waves also.

[2] This entails a profound conclusion: the Universe is expanding in a way consistent with Einstein field equations therefore supporting the Big-Bang hypothesis. To understand how such statements can be done basely solely on the light captured by telescopes, one must understand the concept of *redshift*; distant objects emit light and this light has a spectrum which depends on the kind of particles and atoms that gave origin to it. This light can be analyzed and the constituents of distant bodies deduced from it. On the other hand, the so-called Doppler effect implies that one will perceive a slightly different color for light emitted by a moving source: the faster the source the greater this difference will be. The resulting shift in the spectrum will be towards its red part when the source is moving away and towards the blue part when the source is getting closer. By observing the type of shifts in a large group of galaxies, Hubble found that the Universe is expanding.