Walter Hehl

Chance in Physics, Computer Science and Philosophy

Chance as the Foundation of the World

Springer

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Thalwil, Switzerland

ISSN 2730-7425 ISSN 2730-7433 (electronic)
Die blaue Stunde der Informatik
ISBN 978-3-658-35111-3 ISBN 978-3-658-35112-0 (eBook)
https://doi.org/10.1007/978-3-658-35112-0

This book is a translation of the original German edition „Der Zufall in Physik, Informatik und Philosophie“ by Hehl, Walter, published by Springer Fachmedien Wiesbaden GmbH in 2021. The translation was done with the help of artificial intelligence (machine translation by the service DeepL.com). A subsequent human revision was done primarily in terms of content, so that the book will read stylistically differently from a conventional translation. Springer Nature works continuously to further the development of tools for the production of books and on the related technologies to support the authors.

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Foreword

"All this strengthened my belief that one day I too would be able to be reconstructed from the material I would leave behind. It really can't be that difficult."
Clemens J. Selz, Austrian author,
Foreword by "Bot," 2018.

If reconstructing means pulling a "human-sounding artificial interview" from the material left behind, then that is not very hard. Uploading a human personality directly into a computer would be more like it, and is even impossible according to current understanding. But uniting a person's digital material—all emails, documents, publications, blog posts, and pictures—into digital identity and then using it for reconstruction is easily possible. Clemens Setz has demonstrated this with a "real" journalist asking questions, his digital diaries as a basis, and probably home-grown artificial intelligence. The artificial interviews—as if he were already in inaccessible past—became a massive sales success as the novel "Bot." However, "Bot" caused quite a furore in the professional literary scene.

The German-American computer scientist Joseph Weizenbaum (1923–2008) experienced a premonition of how easily people can be deceived by a computer with his program *Eliza* in 1966. His program was probably intended more as a satire on computers and the human relationship to them, but the simple bot[1] Eliza was seen—to the horror of the inventor—as a kind of clever and serious psychotherapist. Against expectations, *Eliza* was a great success and went down in the history of information technologies. Conversely, one might conclude the depth (or shallowness) of human conversations.

I had the pleasure of seeing Clemens Setz live on stage in an interview in September 2015. It became clear to me: if you write books about your fields of knowledge that are published, then you also deliver the basic material for (sometime later) an artificial *Walter Hehl*. At that time, I had already published three books:

[1] A *bot* is a computer program that performs tasks largely automatically without any human interaction.

- What I thought about current trends in information technology (2008)
- What I understood about the difficulties companies have when they want to innovate (2009, together with manager Rainer Willmanns).

These two books essentially grew out of professional work at IBM, and I actually owe them to the great company and fundamental pioneer of information technology, at least in the twentieth century.

Further in 2012, I tried to understand why we humans have such problems finding and understanding the truth, and how this process works:

- *Die unheimliche Beschleunigung des Wissens* is a story of the Copernicanizations of humanity: Astronomically, physically, and intellectually, we are being stripped of our specialness. We are becoming less and less unique (nor are we, as far as we know, in space).
- Then, as a missionary for the importance of software, in 2016 I wrote *Wechselwirkung*, a book that combines physics, philosophy, and software, which I see as a modernization of the worldview of the Austrian-British philosopher Karl Popper.
- After a detour to rectify the image of Galileo (2017) in public the foundations of religion from the perspective of physics, information technology, and psychology (2019).

From an emotional-human perspective, I have gathered personal memories that are important to me:

- In *Meine fünf Frauen* in 2020, I describe the most important women in my life. A small Sudeten German family history was created.

Behind all these books there is—I must confess—something evangelistic, something possibly unpleasantly instructive. The desire to point out something that is not known to everyone, but should be, is perhaps also a driving force for spending a year or two writing a book. But the books are actually, despite everything, the mainstream of knowledge and not exotic; only sometimes they contain (still) little-noticed truths. Take Galileo, for example, historians know that he tried to use tides to prove the heliocentric worldview, but that his proof was just nonsense. The laymen nevertheless consider him to be the one who "proved" the heliocentric system.

But by a stroke of personal luck, I still see a "missionary" gap in popular knowledge. The serendipity began with a celebratory dinner with the French-US mathematician Benoît Mandelbrot in 1986. He was my dining companion that evening. Mandelbrot was at that time my colleague in the company IBM. He had been a collaborator in IBM research since 1958 and was one of the most famous mathematicians of the twentieth century, though not of the usual abstract kind. He did pragmatic, multipurpose mathematics. Mandelbrot was the creator of the term "fractal" and the discoverer of the "apple man," the mathematical object named after him. All mathematically interested people know this little figure! It is perhaps the most complex structure we know. We will meet his mathematics in the chapter "Chance in nature" (without mathematical formulas).

As a developer in the IBM laboratory in Böblingen and as the head of the test laboratory of processor development, I calculated images of the Mandelbrot set as a hobby. I had a high-resolution printer at my disposal (an IBM 4250 printer which we had developed) and a park of computers (which were also developed in the Böblingen laboratory), with low computing power compared to today's computers, but with extended arithmetic accuracy, and I let them calculate for weeks. The accuracy could be used: It is a property of the Mandelbrot set that the complexity of the structures never stops; one can keep enlarging and delving deeper into the universe of numbers, and new structures keep appearing, often similar to things seen, but not identical. Some of the images (typically at $6000 \times 10{,}000$ pixels[2]) went to an art exhibition, two images appeared in a book on the beauty of fractals by H.-O. Peitgen (Peitgen 1986), and I got to spend the evening with celebratory guest Benoît Mandelbrot.

I got to know his worldview. In his expression, nature is rough (and so is the financial world). By this, he means that smooth, regular, normal-geometric structures as learned in geometry at school are the exception. In addition, there is his idea of self-similarity, which I, as a physicist, can only follow to a limited extent. Self-similarity means that structures repeat identically or similarly at other scales. Physically, structures in other dimensions will only repeat themselves with systematically changed parameters (according to the scaling laws) as already Galilei showed. In mathematics, this possibly goes on indefinitely, smaller or larger. However, Mandelbrot set is only approximately self-similar; however, just this fact is exciting.

Indeed, "roughness" in its sense of "individuality of an object when looked at closely" is everywhere: in liquids, for example, turbulence; in botany, the different leaves on a tree; in humans, the structure of the iris; and in astronomy, the exact distribution of stars, for example, the shape of constellations. In nature, it is usually not the individual detail that matters, such as the ripples on a wave of water, but the laws that apply to all. Science has also devoted itself to this. Most of the time a point or an event does not matter much, but sometimes it does. Famous is the butterfly effect of the meteorologist Edward Lorenz in his work with the ingenious title:

"Can the flap of a butterfly's wings in Brazil cause a tornado in Texas?"

Incidentally, the effect is often misunderstood: The skier who accidentally triggers an avalanche (the "snowball effect") is not an example of the butterfly effect in the general sense; it is the clear catastrophic and unilateral borderline case. The danger was imminent beforehand, and the cause, as well as the effect, was clear. There was also no alternative for the avalanche; the direction of the avalanche is clear. We will discuss an extremely indecisive situation with Norton's Dome.

In evolution, a single case, a coincidence or mutation, could have caused something. This is even more true in human life; then chance even plays a decisive role. If we look closely, coincidence appears everywhere: even the precision of the celestial clockwork is lost when we look closely (and for a longer time). Chance appears indisputably and absolutely in quantum physics, but it is also visible to the naked eye. Yes, we even build machines to create randomness, such as the roulette wheel, or machines that use randomness internally, such as encryption machines.

In the foundations of world order and disorder, rule and chance, physics and computer science are mixed. Chance is related to causality, to the direction of time, to atomic structure, and to creativity and religion. To show this is the aim of the book. Chance brings into our otherwise clear and certain scientific world a great uncertainty of principle.

The following quote from Napoléon Bonaparte may not be an exaggeration at all:

"Le hasard est le seul roi légitime dans l'univers"
"Chance is the legitimate ruler of the universe"
Napoléon Bonaparte, French general, 1769-1821.

The book intends to show that chance is built into the foundations of the world and is thus a third pillar of the construction of our world, alongside or in addition to the main pillars of physics and computer science. To do this, we trace an outline of the history of science, also as a history of chance, and of false and real certainty, and of just as much uncertainty. We try to show how much foreshadowing of modern concepts there was already in ancient science.

A comment on the quotes: I believe a field of knowledge includes the opinions and flashes of brilliance of others. Hopefully, it is a pleasure to read them and think along with them, maybe even refute them.

I learned an argument for citations from the director of IBM's research organization, Paul Horn, circa 2005:

"No matter how many good people you have, there are more outside."
Paul Horn, US computer scientist, born 1944.

It was meant as an argument to work with other research organizations. IBM research was then (and perhaps is now) the best industrial research organization in the computer field.

I think the same goes for quotes and the cultural world. No matter how many good thoughts you have, there are more outside.

Thanks to

I owe my first contact with the topic of chance in the history of science to a seminar on science “From Aristotle and Democritus to Newton” with Prof. August Nitschke in Stuttgart.

In short but intense meetings, I got impulses from my two IBM colleagues:

I learned the ubiquitous importance of chance from and with Benoît Mandelbrot. I learned about the concept of algorithmic complexity (and true randomness) in conversation with Gregory Chaitin. Mandelbrot and Chaitin are among the greatest mathematicians of the twentieth century.

The philosopher Klaus Mainzer has given me support with his work to see chance in its fundamental meaning. Mainzer is a tychist, although he does not use the word “tychism.” What tychism means is explained in the book. The origin is the Greek goddess Tyche, the goddess of fate. For Mainzer, too, coincidence is itself the principle. And: Without chance nothing new comes into being.

I thank my wife Edith for her patience and thorough editing. Any linguistic errors in the text are due to my unchecked corrections and are entirely my responsibility.

Contents

1 Introduction: A Brief History of Science and Coincidence

"The beginning of all science is the astonishment that things are as they are."
Aristotle, Greek natural philosopher, 384 B.C.-322 B.C.

"Ignoramus et ignorabimus - We do not know and we will never know."
Emil du Bois-Reymond, German physiologist, speech in 1872.

"We must know, we will know."
Final sentence of a radio address and inscription on the mathematician's grave.
David Hilbert, German mathematician, speech in 1930.

"The answers you get depend on the questions you ask."
Thomas Kuhn, American philosopher of science, 1922–1996.

The title of this section is adapted from the wonderful book on the whole history of mankind by the Israeli philosopher and historian Yuval Noah Harari. The history of science is the hard part of the history of the world. "Hard" in the sense that the overall process of getting to know it is a random process with some leaps in the process, but the goal is quite clearly ("hard") given: The congruence of nature and mathematics. Also, the tool of universally repeatable experiments ensures correctness (most of the time, anyway). Nature enforces laws by its very nature, mathematics maps them sharply. The popular view "*everything is relative; you could have other science*" is nonsensical to the system of natural science. Actually, this already describes an important part of the book!

The history of the development of science is closely linked with the development of technology. This is quite natural, because knowledge creates power and technology in the form of weapons, means of production and products. This "knowledge is power" is itself probably the most famous saying in the history of science:

W. Hehl, *Chance in Physics, Computer Science and Philosophy*, Die blaue Stunde der Informatik, https://doi.org/10.1007/978-3-658-35112-0_1

"Scientia potentia est" "Knowledge is power".
Sir Francis Bacon, English philosopher, 1561–1621.

There is some confusion around the origin of the quotation in Bacon: Namely, the first occurrence has the form *"scientia potestas est"* and refers to God: Whose knowledge is his power. But we understand this in its later sense, Bacon 1620:

"Human knowledge and human power go hand in hand, for if the cause is not known, the effect cannot be produced."

The classic direction of formulation—from knowledge to power—has always applied in reverse in experimental science: From the ability to build the best experimental devices, the best science follows. One example—telescopes, from Galileo's two-inch telescope in the 1600s to today's 8 m or 10 m telescopes or the Hubble telescope in space.

But the reverse sentence also has a fundamental scientific meaning: From making and being able to make follows understanding. The baroque philosopher Giambattista Vico (1668–1744) introduced this constructive method of acquiring knowledge into philosophy with his principle:

"Verum et factum convertuntur - The true and the made are interchangeable."

Thus, "only that which we have made is knowable as true." This mantra of the philosopher Vico has fundamental meaning in the second pillar of our knowledge, computer science. A working program can prove, for example, that a material behaves as predicted by the finite element program[1] and its physical assumptions. The brilliant computer scientist Alan Turing introduced the method of the principle "*What we can do, we understand*" into computer science in 1950. It leads to the Turing Test named after him, the comparison of human ability with the ability of a computer: Can you have a quasi-human dialogue with a program? Even in Chinese?

There is a whole tower of similar tasks of increasing difficulty, all more or less solved:

Can a computer read script? More precisely: Can it read special, simplified print?

Can it read general print? Can it read handwriting it knows well? Can it read unfamiliar handwriting? Can he talk, for example, read something aloud? Can he write down a spoken conversation? A Chinese conversation? A Swiss-German conversation? Can he translate Chinese into English? Russian into German? Can he answer simple questions from a small field of knowledge? Can he answer general questions? Can he drive a car on the highway with little traffic? In heavy traffic? Can he have a natural general conversation? Can he diagnose a disease? etc.

[1] General digital method for calculating the properties of solids.

Nearly always the solvability of this task was doubted by many laymen (but also experts) at first, after solving then dismissed as a trivial matter until the next task. The author experienced this several times himself, e.g. "*a computer will never be able to drive a car*"—however 30 years ago. The above list is a small history of computers, but the development and the list go on, of course. All the projects behind these questions provided and continue to provide insights into the structure of human language, handwriting, how car driving works, how our brains work. Building a related successful program is proof of understanding a phenomenon.

In addition, there is another property and a fundamental difference. The classical analytical scientific method with observation and experiment (defined as tailored and limited observation) has led us into the depths of nature—the heavyweight limits of our horizon are Big Bang, dark matter, new elementary particles. The knowledge landscape up to this horizon is in principle well explored. The basic property of the method used is the investigation of causality. Knowledge is the understanding of causes; it is a bottom-up approach in the language of software.

These are the scientific sides of understandings, by causes or by construction. Psychologically (or polemically), two types or levels of understanding can be defined:

- The layman (and the classical philosopher):

  A process is understood when it can be grasped within the terms of normal life. This does not change if more noble expressions are used for it; it remains the normal world. Time runs evenly and space is not curved but Euclidean.

  But everyday terms and notions do not go far and need to be corrected again and again (Hehl 2016).

- The physicist says he (or she) has understood it (physically) when the process is understood in *corrected* terms of normal life. The correction may be, for example, that time stretches, space curves, or that the law of energy holds. It is the result of research. One simply gets used to accepting these corrected notions and thinking that way.

This definition is entirely in the spirit of the bon mot of the Hungarian-American mathematician John von Neumann (1903–1957), who said to his physicist friend Felix Smith:

> **"Young man, in mathematics you don't understand, you get used to it."**

There is, of course, both the possibility that people want to express something impossible in colloquial language, as happens in some religions (for example, with the concept of the "Creator"), and, conversely, something simple in physicists' language. Thus, in esotericism and borderline areas of religion, terms from quantum physics are often used; this is suggested by the inherent mysticism of quantum physics. For instance, the Serbian-British physicist Vlatko Vedal (born 1971) says.

"[The vacuum of] quantum physics indeed aligns well with Buddhist emptiness."

The other scientific-technical method of understanding something is the reconstruction of this system property. With this constructive path, one starts conversely from the function as a whole. The direction of knowledge is in terms of software from top to bottom (bottom is the hardware), a top-down approach. Causality is replaced by teleology, the meaning of the whole.[2] By replicating functions, such as language, one gains an understanding of how that function is performed, what errors can occur, what other solutions are possible, and what improvements. Sometimes the understanding succeeds so well that, for example, a game is no longer a game at all, but only an algorithm. It is foreseeable that there will also be digital psychology and artificial souls to understand our feelings and mental defects.

Disturbingly, the building of systems seems to have no visible human or natural limits. But there is no natural law that sets hard limits here.

But let us go to the beginning. We want to look at essential phases in the history of science, information technology and chance together. For this purpose, we divide the history of science and information technology into three major periods: Antiquity, the Enlightenment, and modernity.

1.1 Ancient Science in today's Light

"May the study of Greek and Roman literature ever remain the basis of higher learning."
Johann Wolfgang von Goethe, German poet, published posthumously in 1833.

In science and philosophy, it is the Greeks and the study of their ancient science that teach us the beginning of it all.

As representatives of ancient science, we consider two philosophers and an astronomer and some of their teachings:

- Aristotle as the most important figure of ancient science until the scholasticism and the middle ages and reviled in the Enlightenment,
- Epicurus (or Democritus),
- Ptolemy and his practical scientific achievement.

Another philosopher, Plato, we will mention below as the origin of the "romantic" school of ideas.

Figure 1.1 shows the fresco "The School of Athens" by the painter Raphael da Urbino (1483–1520) in the Vatican. The painter himself is depicted (marked R on the far right) together with 21 of the most important representatives of ancient Greek philosophy and

[2] Teleology from the ancient Greek τέλος *télos* meaning 'meaning, purpose'.

Fig. 1.1 Peripatos—"The School of Athens" by Raphael (1510–1511). Fresco in the Vatican. The fresco glorifies ancient Greece as the cradle of culture. Aristotle is number 15, Epicurus is number 2, Ptolemy is number 20, and Plato is number 14. (Image: Wikimedia Commons, Bibi Saint-Pol)

science. The four persons mentioned, Aristotle, Epicurus, Ptolemy and Plato, are also included.

1.1.1 The Science of Aristotle

> **"If the state of the soul changes, this at the same time changes the appearance of the body, and vice versa: If the appearance of the body changes, this at the same time changes the state of the soul."**
> **Aristotle, Greek natural philosopher, 384 B.C.-322 B.C.**

From today's perspective, Aristotle's worldview is, on the surface, bizarre. For several centuries until the end of the Renaissance, however, it was a consistent, accepted system. Central to his physics is the theory of motion, which he derived largely from direct observation. Here are some statements along with "friendly" interpretations of Aristotle's laws from today's perspective:

- There are two areas of the sky with different laws, beyond the moon and below the moon.
  Compare the atmosphere on the one hand and interplanetary space on the other hand with vacuum. In the atmosphere a satellite burns up after some time, in the vacuum of space it remains almost indefinitely on its orbit. Aristotle, however, considers vacuum to be impossible.
- In the celestial sphere the planets run eternally on circles.
  See in the universe the celestial bodies move on conic sections, the circle is a special case.
- On earth there are natural and forced movements:
  "Naturally" a body tries to get to its natural place, the "fire" up, "heavy" down.

See the center of the earth as the center of gravity.

"Forced" movement comes about through a force on the body. Without force, the body remains stationary.

See the latter corresponds to a movement with friction on a rough surface.

- With a thrown stone or a projectile, he must introduce a curious auxiliary construction so that the projectile flies through the air: The air around the stone carries it on.

  This difficulty is striking and will be solved in the early middle ages with the impetus theory.
- A body falls faster the heavier it is.

  See this is correct for very light bodies and so called creeping motion, e.g. when a bullet falls into oil or at parachute jump.
- The motion of the planets is eternal—but it needs a beginning. Aristotle introduces a kind of abstract god who is invisible and does nothing else: the "unmoved mover".

  See the concept of this mover the launching of a satellite in space, which from now on runs freely and (almost) eternally on its orbit, if it was only brought high enough above the atmosphere.

The picture of Fig. 1.2 illustrates exactly the transition and thus the two world zones of Aristotle with the launching of satellites.

Fig. 1.2 Aristotle's two subworlds in one (Figure: Space and atmosphere. The image illustrates precisely the transition between the worlds with the launching of satellites. (Image: European Global Navigation Satellite System Agency (EGNSSA)/Pierre Carril)

Aristotle tried to integrate his observations and his everyday knowledge into a consistent system. The laws of nature are absolutely valid with him (so there are no miracles!). From his mechanics some of the ideas are transferable to modern times: For example, the part of the sky for one and the mechanics of a body when friction or viscosity dominate. Otherwise, his conception of mechanics earned him the derision of the Enlightenment.

To this is added the soul. For Aristotle it is the general life force, connected with the body, and thus mortal.

Compare with the current view (at least of the author) that life is a kind of running computer, that is, of "software" running on a material basis.

His idea of the holistic connection of body and soul is modern. It is more modern than Descartes'later division into here body, there mind. This dualism naturally fitted well with the hope of a fictional life separate from the body. With the universe eternally existing, the soul mortal, and the impossibility of miracles, it is surprising that Thomas Aquinas managed to integrate Aristotle, so rational, into the teachings of the Catholic Church in the thirteenth century—and for several centuries. But ecclesiastical, anti-Aristotelian notions of a Creator, of an afterlife e and of miracles have nevertheless become deeply ingrained in our collective understanding of the world.

Aristotle also discusses at length the role of chance. Thus he writes (Zekl 1986):

> **"The one (the chance event) has its cause outside of him, the other (the natural event) in itself."**
>
> **Aristotle in "Physics, Lecture on Nature".**

The natural event is completely determined by the laws of nature, the coincidence by "trivialities" or by "providence". The term "providence" means a subset of chance that exists only for humans, not for animals. But providence can be positive (a good fortune) or negative (a bad fortune). Thereby the providence is not put together by a higher being, but "it" adds, the providence is like every coincidence indeterminable in the causes.

For Aristotle, chance is not an explanation; only rules can explain. It can certainly not explain the world as a whole: How is the ordered world to arise from unordered chance? For him, the orderly movement of the planets is proof that there is order and perfection, at least beyond the orbit of the moon.

Considering Aristotle's starting point in the minimal and hazy knowledge of the fourth century BC on the one hand, and the wealth of consistent thought in him on the other, one has to say: chapeau. This is why the ridicule is unjust for the fallacy in women's teeth, popularized by the British philosopher Bertrand Russell. Here is his famous, somewhat disingenuous quote:

> **"Aristotle insisted that women had fewer teeth than men. Although he was married twice, it never occurred to him to recount it."**

Aristotle relied on the knowledge of his time. He knew that stallions have more teeth, he knew that in the real world in humans the number of teeth varied, in women even more than in men. He did not disregard experience; he was on the receiving end of false or inaccurate information. Experience (as a prefiguration of experiment) was even at the heart of his natural philosophy. Here is a word from Charles Darwin, the British naturalist, in 1879:

"Aristotle was one of the greatest observers who ever lived."

1.1.2 The Ancient Atomists

"In reality, there are only the atoms and the void."
Democritus, Greek philosopher, 459 B.C.- 370 B.C.

The origins of atomistic Greek philosophies are the philosophical problems of divisibility of space, time and matter that arose one or two generations before Democritus.

- Divisibility of space and time:
  The best known is probably the turtle of Zeno of Elea or the paradox of Achilles and the turtle: Achilles cannot catch up with the turtle: In the time it takes him to catch up with the tortoise in each case, the tortoise in turn has got further, and so on. The problem will be solved cleanly only 2000 years later with the infinitesimal calculus. If there are physical limits for space and time, these are in any case many orders of magnitude smaller than today's measurability (Planck length and Planck time).
- Divisibility of matter:
  The atomists, such as the philosophers Leucipp, Democritus and Epicurus, do not consider matter to be arbitrarily divisible, for in dividing it one encounters indivisible particles, the atoms, which move in a vacuum.

It is an incredible premonition of reality: There are atoms! The premonition becomes tangible in chemistry in the nineteenth century, in the form of fixed relations between substances in chemical reactions (stoichiometry). Atoms become a scientific reality with Albert Einstein's work on Brownian motion and Ernest Rutherford's collision experiments.

Still at the beginning of the twentieth century the (excellent) Austrian physicist Ernst Mach sneered

"Have you seen any?" after the author and physicist Henning Genz.

as an answer to the question of the existence of atoms. Ancient atomic philosophy speculates further:

- The "ancient" atoms have the shapes of various regular geometric solids such as spheres, tetrahedra and cubes in different sizes.

See atoms are of different sizes, but their size is not sharply defined. Hydrogen is the smallest, Francium the largest. As single atoms they are spherically symmetric, in a compound they have different symmetries.

- The ancient atoms have hooks and eyes with which they connect to form bodies.

  See the atoms can bond with other atoms, to form molecules or bodies. The number of links (bonds) is typical for the respective atom.

- The ancient atoms move in empty space.

  See in gases, the atoms move in space and even consist largely of empty space themselves.

- The ancient atoms move chaotically.

  See the motion of molecules in a gas or the Brownian motion of particles as in Fig. 1.3.

The Roman poet Lucretius describes the idea of chaotic motion very pictorially three centuries later: "*Atoms dance like particles of dust in a beam of light*". It is chance in the modern sense. This is indeed how atoms and particles move, as we have known since the

Fig. 1.3 Typical image of a Brownian motion, comparable to the motion of democritic atoms. (Image of the motion of particles of white ink in water under the microscope. (Picture: Faculty of Physics, LMU Munich)

nineteenth century. It is essentially the statement of the kinetic theory of gases of classical physics.

But in ancient atomism there is another forward-looking concept of chance. The clinamen. Clinamen is a spontaneous small change of motion in the flight of an atom. It must have been a curiosity to the earlier philosophers and non-physicists. Lucretius was ridiculed for it. Today this seems to be an ingenious trick to introduce purposefully "living" chance and to destroy boring simplicity. The German physicist Joachim Schlichting notes that this is the first time in western history that chance has been attributed a constructive role (Schlichting 1993).

Under the influence of gravity, the atoms would all fall parallel vertically without touching each other. That is why there are spontaneous fluctuations. Lucretius writes in *De rerum natura*—On the nature of things in the first century before Christ:

> **"... when bodies plunge straight down through the void with their own weight, then at fluctuating time and place from the course they leap off by a little, so that you are able to speak of changed direction."**

A similar effect is well known in modern physics in a thought experiment, which goes back to the physicist and Nobel laureate Max Planck and one of the founders of quantum theory: It is about 1906 a carbon dust that upsets a too ideal order. We explain the idea in Chap. 5.

In other words, the clinamen and this Planck's carbon dust increase the entropy by leaps and bounds to the realistic equilibrium value.

There is no explanation for the clinamen, but if you are benevolent, you will find the reason for the trembling in quantum theory. It will explain this phenomenon with the "everything rushes" or "everything fluctuates". With randomness and the disordered movement of atoms, which can constantly recombine, it is not far to creativity. With this, there are thoughts in antiquity that are reminiscent of Darwin (though not in Aristotle, as Darwin assumed).

Ancient atomic theory is an approach reminiscent of the chemical phase of evolution. Molecules meet randomly to form larger groups: Complexity is built up.

Atomistic doctrine has yet another fascinating foreshadowing of the modern conception of the world: The existence of two pillars of the world, (inanimate) physics and (somehow animate) computer science. On the world model itself, below, more or at Hehl (2016). The two kinds of world show up in the doctrine of the two kinds of atoms, the robust atoms of the physical world and the subtle ones of the soul. The soul consists of a construct of particularly fine and light "soul atoms", similar to fire atoms. Thoughts are the movements of these soul atoms. When a person dies, the soul atoms dissipate and eventually join a new, emerging soul.

Admittedly it is daring, but is this not the foreshadowing of the two pillars "physics" and "information technology (IT)", of something physical, primary and something mental, secondary? "Mental" here in the sense of information-driven processes, or "software" for short (on hardware)?

A final remark on atomism. The philosophical idea that matter can be divided arbitrarily and indefinitely sees more the substance of a body as a whole. As a scientific idea, arbitrary divisibility has become nonsensical. Matter, if looked at sharply enough, becomes immaterial and dissolves into quantized fields. A pseudo-scientific doctrine still prevalent today assumes arbitrary divisibility: the homeopathy of Samuel Hahnemann (1755–1843). The "good" spirit of a substance remains effective at any dilution, the "bad" spirit is diluted away. The preferred dilution is 1 in 10^{60}. According to atomistic knowledge (not theory!) the dilution is so great that quite certainly not an atom or molecule is left in a globule of medicine! But for the founder of the doctrine in the eighteenth century the atomic doctrine was only deviant and forgotten philosophy.

1.1.3 Ancient Science Using Astronomy as an Example

"We consider it a good principle to explain phenomena by the simplest hypothesis." Claudius Ptolemy, Greek astronomer and mathematician, 100-160 AD.

"Everything should be explained [made] as simple as possible, but not simpler." Attributed to Albert Einstein, 1933.

The movement of the planets is not primarily a matter of uncertainty and coincidence but, on the contrary, of celestial order, albeit a rather complex order. The scientific task in ancient times is the calculation of the locations of the light points of the planets on the celestial sphere. It is mainly about the phenomenon, not about the cause! Of course, the earth is still in the center. The first major complexity that ancient astronomers had to solve was the apparent annual looping motion of the outer planets in the sky. To do this, they had to simulate the still unknown physics, namely the elliptical motion of the planets, i.e. the deviation from the circle with the existence of two foci each instead of a center and non-uniform orbital velocity.

Ptolemy had inherited from his predecessor Hipparchus an ingenious concept that could create loops: Epicycles, that is, he put circles on top of circles. Ptolemy moved some circles away from the center and with about 40 circles for the solar system (sun and the five planets) he got a model that would be used for 1500 years to predict the movements of the planets.

Figure 1.4 shows the observed positions of Venus (and Mercury) as seen from Earth over five years. First, the loops of the orbits show that epicycles fit the planetary problem in principle. To this end, the graph demonstrates a resonance phenomenon between Earth's orbit and Venus' orbit: Five Earth years correspond quite closely to eight Venus years. Otherwise, the course of the planets is a many-body problem in which everyone interferes with everyone else, and which looks quite chaotic if you look long enough. This resonance prevents the otherwise prevailing coincidence and thus keeps both orbital periods together until disturbances become too strong at some point.

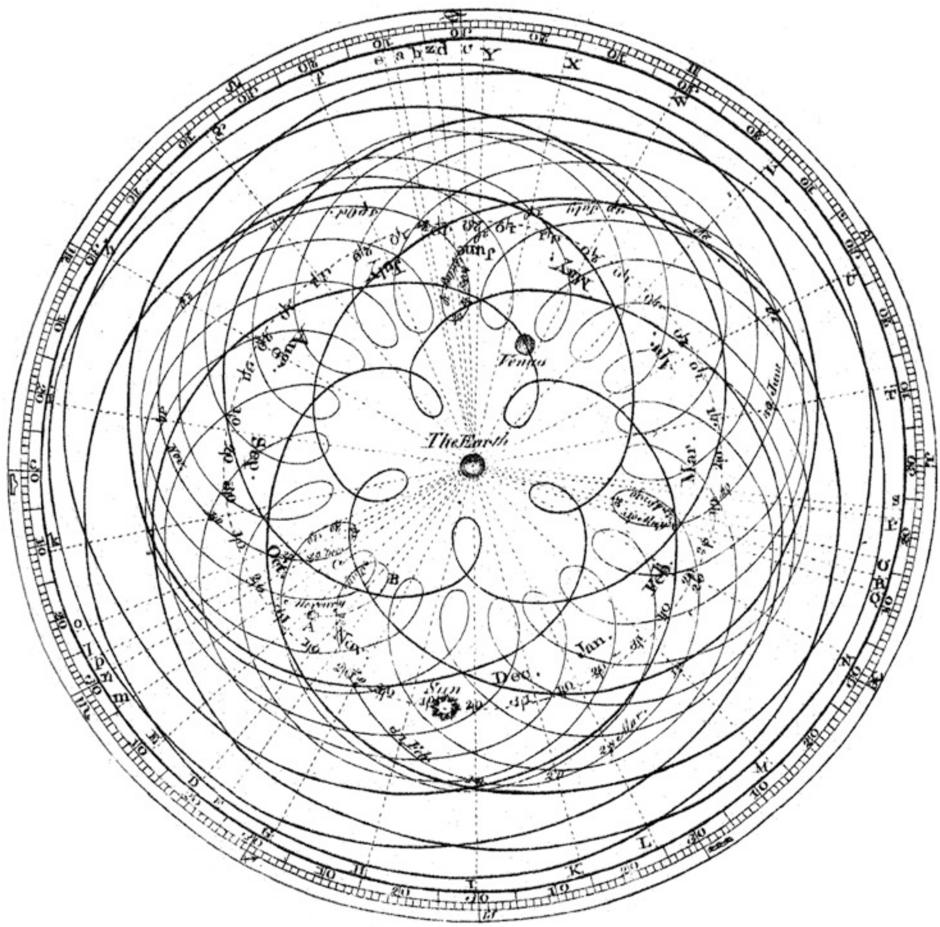

Fig. 1.4 The planetary orbits of Venus and Mercury as seen from Earth. (Image from the first edition of the Encyclopedia Britannica 1771 by James Ferguson after Giovanni Cassini. Note: This is not a diagram of epicycles. Image: Cassini apparent Wikimedia Commons, anonymous)

The method of Ptolemy is used for a millennium and a half, but it has a bad reputation in the sixteenth century. Errors crept in and its artificiality became increasingly visible. Copernicus reverses the basic position of the model and places the sun approximately in the center—but he uses the same procedure of epicycles, first 34 circles, later 40.

He has no proof that now in his construction the earth moves twice, around its own axis in about 24 h, around the sun in about 365 days. He expects better results as indirect proof. His results are depressing; they are worse than Ptolemy's.

Today it is clear why. Copernicus deliberately omitted an effective construct of Ptolemy, which he considered too artificial (the so-called equant).

Ptolemy and Copernicus both solve the "Platonic Axiom," the task Plato, set, they *"save the phenomena*." This expression meant in ancient astronomy to trace the complicated and mysterious orbits of the planets to a mathematics involving only circles and uniform circular motions, and thus to calculate them. These are numerical methods that the Church considers innocuous—until Galileo really means it with the sun at the center of the world.

Johannes Kepler will destroy the ancient premise of circles and be closer to physical reality. Mathematically the "destruction" is actually gentle, circles are after all a subset of ellipses. The astronomical models before are just geometric approximations and series evolutions in circles to reality, to ellipses. This makes Copernicus in particular the last ancient astronomer.

1.2 The Scientific Enlightenment

1.2.1 The Enlightenment in the Natural Sciences

"Nature and natural law were shrouded in night.
God said, 'Let there be Newton!' And the universe was filled with light."
Alexander Pope, English poet, 1688–1744.
Intended as an epitaph for Newton.

One of the precursors of the Enlightenment (and still with one foot in scholasticism) was the physicist Galileo Galilei (1564–1642). For Galileo there were two fundamental "books" of the world: The Bible and nature. Enlightenment was his assessment of this: The texts of the Bible could and should be interpreted in the spirit of the time in which they were written, but nature was unambiguous. The right to interpret the Bible was taken by the Church, and Galileo's conflict was thus pre-programmed. Incidentally, his main scientific argument in the dispute over whether the sun was stationary or moving was a completely false "proof" of the tides, which is now only a historical side note. Scientifically speaking, he should not have gotten involved in the trial (and the church, of course, should not have accused him).

Galileo was not the first to experiment and measure. But his experiment of letting balls roll down an inclined plane arbitrarily slowly and thus easily measurable instead of throwing them from a tower was indeed ingenious and the result unambiguous. In addition, like the Greek philosopher Plato, he emphasized that nature was written in the language of mathematics. However, for him mathematics was simple geometry and rule of three. He did not write a single equation. Overall, as an artist and experimenter, he is a late Renaissance man, similar to Leonardo da Vinci, and not an Enlightenment man. For more on this, see Hehl (2018).

The German astronomer Johannes Kepler (1571–1630) is close to the beginning of the Enlightenment with his discovery of the planetary laws and his mathematical work, but not yet as a person. The observations of the astronomer Tycho Brahe are so accurate that

Kepler cannot obtain the true orbit of Mars using the ancient method with circles on circles in manageable numbers. According to the US physicist and philosopher Thomas Kuhn (1922–1996), such a situation represents a paradigm shift, of which Kuhn says:

> **"Although the world doesn't change when the paradigm shifts, scientists work in a different world afterward."**

It is even possible to specify a meaningful day for the paradigm shift: May 15, 1618. According to Kepler, it is the day of the discovery of the third law named after him. Figure 1.5 shows the law graphically: The cubes of the orbital axes divided by the squares of the orbital periods give a single number. This had to seem like magic. The discovery has nothing to do with Plato and Ptolemy and antiquity. May 15, should be celebrated as World Science Day!

It is a mystery (to me) how Kepler was able to perform his extensive calculations of the Martian orbit without a computer, only with logarithms and in adverse living conditions! As a person Kepler was not an enlightener, rather a mystic. He believed in the harmony of the world, which was to be discovered. Perhaps he even believed in astrology, at least in real horoscopes, as he drew them up himself. From today's point of view, however, it is precisely his holistic view that is sympathetic and attractive.

Kepler already found his laws on the basis of astronomical observations with the naked eye, albeit thanks to the extraordinary observer Tycho Brahe. But it took two simple inventions from the Netherlands to bring about a tangible paradigm shift: The telescope

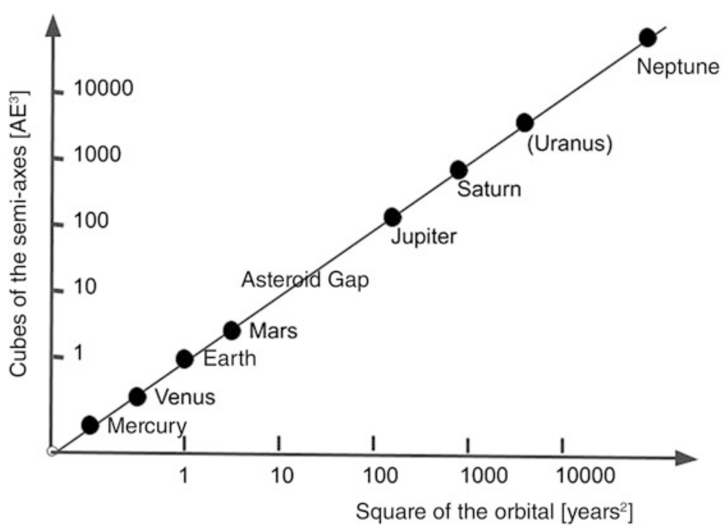

Fig. 1.5 Graphical representation of Kepler's third law. (Image: From "Galileo Galilei kontrovers", Walter Hehl 2017, Springer Vieweg)

and the microscope. With these instruments, man transcends the limits of his senses and sees hitherto unseen and undreamed-of things.

Up to these inventions the world of knowledge had been satisfactorily closed, secured by the words of the Bible and the writings of Aristotle. According to these, the smallest botanical object is the mustard seed and the smallest animal is the flea; no one would think of looking for anything smaller. Indeed, Galileo reports of contemporaries who refused to look through the telescope on this pious grounds!

But now, in a drop of water from the pond, you see a multitude of teeming little animals, and in the night sky there are a multitude of stars that can only be seen through the telescope: What are they for, if we humans cannot see them after all? Surely the world is only for us? Also, the moon has real mountains and is similar to the earth and no longer heavenly-perfect. How then does it remain in the sky?

There is a great uncertainty, which is resolved in the next centuries. It begins with Isaac Newton and his book "*Philosophiae Naturalis Mathematica Principia*", in which the basic concepts and fundamental laws of mechanics are described. Force, inertia, momentum and energy are defined and Kepler's laws are derived. These terms had been used in a confused manner for several hundred years. Newton finds the general law of gravitation: Everything attracts everything. He is thus able to derive Kepler's laws in a sharper form—the circle is closed. But Newton is only a rational physicist during the day, at night he does alchemy or simply chemistry, he even searches for the philosopher's stone. He is a mystic, darker than Kepler. In this sense the saying of the owner of Newton's letters about alchemy is valid:

> **"Newton was not the first enlightener, he was the last wizard."**
> **John Maynard Keynes,**
> **Economist and amateur historian, 1946.**

But still, it is actually legitimate to want to change one element into another. Alchemy is a precursor of chemistry and is a single mystery. Enlightenment in chemistry no longer reaches Newton:

- The French chemist Lavoisier understood combustion as a reaction with oxygen in 1783 and thus banished the false phlogiston theory,
- the integer weight ratios in various chemical compounds observed Dalton 1808,
- the periodic system of elements will create the Russian Dimitri Mendeleev and the German Lothar Meyer in 1869 independently of each other.

Of course, we do not understand why and how atoms combine to form molecules, and why the Periodic Table of elements has this particular structure. But the understanding will be enough to make chemistry a science and to build up a flourishing chemical industry. By the end of the nineteenth century, people will feel they have understood everything important.

Classical physics was particularly successful in explaining the properties of gases: A gas, enclosed in a space, is tamed randomness. However, it is about the behavior of very,