Gestalting Structures in Physics

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Abstract

The basic questions for human conception are what, where, and when. It may not be a coincidence that the primary base units in the International System of Units, kilogram, meter, and second, are the units for mass, length, and time – the quantities that are first needed to answer the questions what, where and when. For a deeper understanding of nature and natural phenomena we certainly need more than that – since antiquity thinkers have tried to understand the primary causes and the laws behind natural processes. Principles that have survived through centuries comprise the ideas of conservation, balance and symmetry. For gestalting the structures of modern physics we follow the evolution of the development from antique metaphysics to modern empirical science and the related picture of reality.

Introduction

From antique metaphysics to empirical science and the modern picture of reality

The antique inheritance to natural sciences is in great part contained within Aristotle's *Metaphysics* (Aristotle, 350 BC, 1) and *Physics* (Aristotle, 350 BC, 2) culminating in the philosophical ideas of natural philosophy which emerged over the two preceding centuries. Aristotle started his book *Metaphysics* with the statement: *"All men by nature desire to know"*. Aristotle saw that the goal of science is to obtain wisdom which requires understanding of the first causes and principles, *"…the point of our present discussion is this, that all men suppose what is called Wisdom to deal with the first causes and the principles of things…"*. Aristotle defined the criteria of sciences, *"… and the most exact of the sciences are those which deal most with first principles; for those which involve fewer principles are more exact than those which involve additional principles, for example, arithmetic and geometry…"*. Aristotle thought that an effect is related to its cause via causality; actuality is preceded by potentiality.

Since antiquity, existence has been understood either as eternal without beginning, end or boundaries – or as a finite entity with birth, development, and fading or destruction according to laws to be identified. The early philosophers, Thales, Anaximander, and Anaximenes tried to base their explanations of natural phenomena on observed regularities without divine presence or supernatural guidance. Anaximander taught that the universe originates in the separation of opposites in the primordial matter *apeiron*; that the cosmic order is controlled by balance and harmony; and that the individual parts are changing but the whole is conserved. Heraclitus spoke about the common basis and the law of nature, *logos*, behind everything; existence is expressed via continuous change and the harmony of opposites. Changes reflected the laws of conservation: *"The amount of rain is equal to the amount of water evaporated"*.

The purpose of this study is to trace the paths to the currently predominating theories – and to follow the development of the ideas and concepts needed in gestalting the structures behind our scientific picture of reality. The start of the path studied is traced to Thales (c. 625–546 BC), who is generally regarded as the grandfather of the scientific tradition in western culture. Figure 1 outlines the progress in terms of a graph showing the cumulative number of top one hundred plus scientists since 600's BC to early 1900's with major contribution to our physical picture of reality.

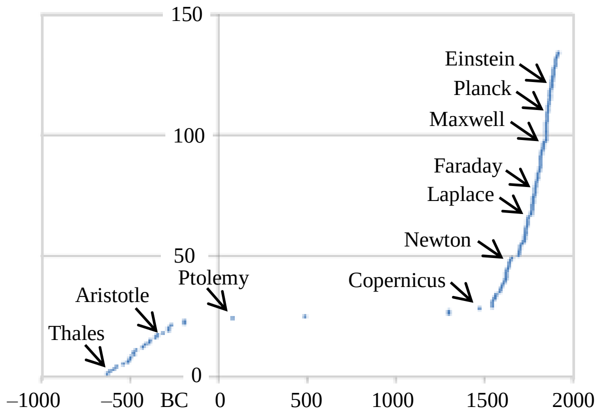

Figure 1. The growing group of thinkers with a major contribution to the development of natural sciences from the 600's BC to the early 1900's, ordered by the year of birth (Suntola, 2012, 14). The vertical axis is the cumulative number of scientists with major a contribution to the development. The active antique era was followed by about 1500 years of cessation, with practically zero progress in science. The development toward present mathematical physics and empirical science was triggered by Newton's Principia in the late 1600's preceded by the Copernican revolution.

Antique science was concentrated in the philosophy of basic principles – empirical science was restricted mainly to astronomy that produced models for describing the motions of celestial bodies. Motions of celestial bodies were more or less independent of the "earthly" physical phenomena described by Aristotle's laws of motion. The concept of matter was restricted to a qualitative description of the properties of matter. Ideas about the structure of matter were divided between the concept of a continuous substance of everything and the idea of more or less independent undivided atoms. At a philosophical level, the antique heritage was important; continuity, the cross-linkage of everything, cause and effect, natural balance and harmony as well as the mathematical beauty were understood as fundamental principles of nature. Philosophy alone, however, was not enough to make nature understandable. The golden antique era faded gradually during the terminal centuries BC; for reaching the goals of natural science antique metaphysics had to wait more than 1500 years for the emergence of an empirical approach with advanced instruments and developed mathematical methods. Copernicus's new outlining of the solar system created a basis for a unified view of celestial observations and the laws of motion formulated in Newton's Principia. Newton's work meant the start of a new era in the development of natural sciences, the era characterized by mathematical physics and empiricism. The laws of motion required definitions for inertial force and mass; the linkage to celestial mechanics was then based on the equivalence of inertial force and the gravitational force as a centripetal force toward a mass. The huge progress in mathematics in the 1700's finalized the success of Newtonian mechanics, and the picture of the world seemed completed in the early 1800's.

Observations on electromagnetic phenomena in the early 1800's necessitated a major re-evaluation of the broadly established picture of reality. Mathematical description of electromagnetism required the conception of new quantities and re-evaluation of the laws of mechanics. A solution was found from the concept of energy, which was hidden in the concept of living force, *vis viva*, introduced by Newton's contemporary Gottfried Leibniz. When formulating the observed characteristics of electricity and magnetism into a comprehensive mathematical model, James Maxwell created a mechanical analogue of the interaction between potential energy and the energy of motion, which made it possible to express the functions of a harmonic oscillator and propagating wave in terms of electrical quantities. In mechanics, energy was recognized as work and the integrated force, and the primary conservable in closed systems. Importantly, the concept of energy created a bridge between electromagnetic, mechanical, chemical, and thermodynamic systems.

Electromagnetic radiation, and especially the propagation velocity of radiation, created new problems. Observations on electromagnetic phenomena seemed to follow the classical relativity principle but infringed the linear Galilean transformation behind the relativity principle. The relativity principle was saved by redefining the coordinate quantities, time and distance, as functions of the velocity, and later on of the gravitational state between the object and the observer. Such a redefinition made the Galilean transformation nonlinear but allowed local phenomena to look the same for any observer. Another type of problem in the classical picture of reality arose from the behavior of atomic phenomena. The continuity of physical quantities like location, velocity and energy was threatened. Further, the difference between quantities like particles and waves was blurred; particles showed wavelike properties and waves particle-like properties. The description of atomic phenomena became detached as quantum mechanics with its specific postulates. Quantum mechanics proved to be a powerful formalism, with the capability of precise predictions of phenomena observed or to be observed; the price of the success was a further confusion of the picture of reality already dimmed by the theory of relativity.

Space, matter, and motion

Gestalting of space

The central topics in antique natural sciences were space, matter, and motion. The underlying metaphysical principles were seen in regularities, mathematical beauty, the harmony of opposites, and the identification of the first causes. Following the antique era, the description of matter and motion stayed at an abstract and idealistic level for almost two thousand years. The description of space and the celestial bodies was more like the opposite; the early outlining of skies was just a description of the observations; in Anaximander's model dating from the sixth century BC, fixed stars and planets were placed on one celestial sphere revolving around the flat Earth. Planets were called "wanderers" (Greek "aster planetes", wandering star) because of their irregular motion compared to the uniform rotation of the fixed stars. The early celestial picture comprised the spherical symmetry of the sphere of stars and planets, and a cylindrical symmetry of the wheels of the Sun and the Moon, Figure 2.

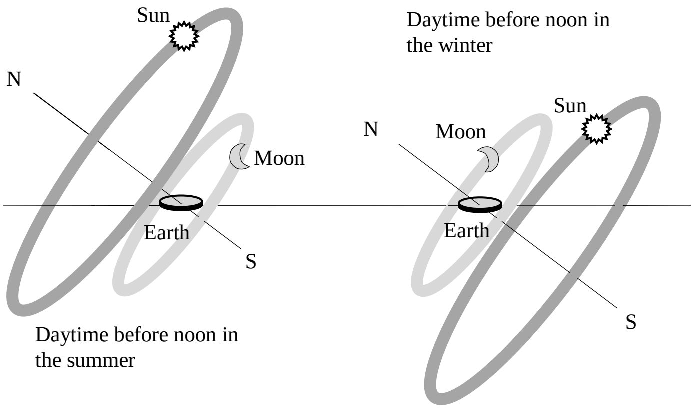

Figure 2. Anaximander's universe comprised a flat Earth surrounded by the sphere of fixed stars and planets (not in the picture). The wheels for the Moon and the Sun were behind the sphere of stars. The annual change of the seasons was explained by motion of the solar wheel in the direction of the south-north axis.

For a long time Venus, which was observed in the vicinity of the Sun, both in the morning and in the evening, was interpreted as two different stars – the morning star and the evening star. When Pythagoras described the Earth as a sphere instead of a disk, the morning star and the evening star were identified as the same planet. Attempts to apply spherical symmetry to the motions of planets and the Sun and the moon were not successful. The Ptolemaic planetary system in the second century AD summarized the antique outlining of skies and the description of the observations without a view of the mechanisms of the motions of the celestial objects. Ptolemy's Almagest (Ptolemy c. 85-165 AD, 3,4) remained the main work and authority in astronomy for more than one thousand years.

Copernicus's work in the 16th century combined metaphysical conception and the empirical understanding of celestial motions. In the preface of his De Revolutionibus, he justifies the spherical symmetry of the universe and the solar system by the perfection and simplicity of the spherical form. To confirm this view he tried to fit old observations into the heliocentric model, and studied the consequences that resulted from his assumed motions of the celestial bodies. The final success of Copernicus's work, however, had to wait for almost two hundred years. The material for the empirical proof of the Copernican system was obtained by Tycho Brahe with his precise observations. Johannes Kepler was looking for mathematical beauty and simplicity, and identified the observed planetary orbits as ellipses. The process of gestalting the solar system and the mechanisms behind planetary motions is a prime example of successful interaction of intuition, deduction, metaphysics and empiricism. Combining the system outlined by Copernicus and the mathematical intuition and analysis of observations by Kepler, Newton was able to identify the mechanical laws behind the system and to develop the necessary mathematics to introduce a complete mathematical theory of mechanics, Figure 3.

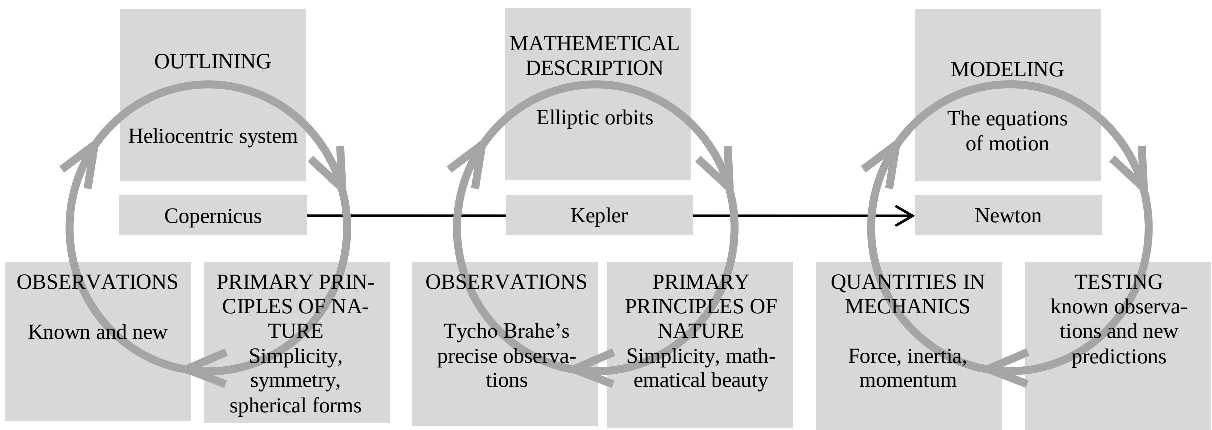

Figure 3. Interaction of intuition and deduction in the process that led to mathematical physics and celestial mechanics. Copernicus outlined the coordinate system where planetary motions can be described in harmonious geometry characteristic of natural systems. Kepler found the mathematical beauty and precise expressions applicable in Copernicus's system, and Newton found the laws of motion behind Kepler's orbits.

Newton's success in finding the physical basis behind Kepler's ellipses required fundamental preliminary work for defining the necessary physical quantities like force, mass, momentum, acceleration and inertia and for combining the quantities into usable laws of motion. In a metaphysical sense, perhaps the most challenging quantity was gravitation – what makes masses attract each other? Newton chose a practical approach, instead of speculating on the nature and origin of gravitation he simply solved the centripetal force that, when linked to the inertia of the planet, would result in a Keplerian elliptic orbit. The choice can be seen as an important step in directing the development of physical sciences towards empiricism.

Newton's masterwork Principia *(Philosophiæ Naturalis Principia Mathematica)* was published in 1687 (Newton, 1687, 5). It was an unambiguous proof of the Copernican solar system and it marked the beginning of a scientific revolution and the era of mathematical physics. The significance of Newton's role as the pioneer of mathematical physics can hardly be overestimated. However, it is worth noting the prior work on the calculus and the basic principles of the laws of motion and gravitation: the Copernican system, Kepler's orbits and laws, Galilei's findings on accelerating motion and the relativity principle, René Descartes's concept of the laws of motion, the conservation laws, and the momentum, Christiaan Huygens's centrifugal force and the solution of the pendulum, and the bases of calculus by Pierre de Fermat and John Wallis. Newton's work meant a breakthrough of empiricism. In the Principia, Newton wanted to base his conclusions on observations and to accept the observed facts as such rather than as consequences of hypotheses. Newton did not, however, deny the order and law in nature. The metaphysical basis in his thinking is reflected in the General Scholium at the end of the Principia (A new translation by I. Bernard Cohen and Anne Whitman, 1999, 6): *"This most elegant system of the Sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being. And if the fixed stars are similar systems, they will all be constructed according to a similar design and subject to the dominion of One, especially since light from the fixed stars will not fall upon one another as a result of their gravity, he has placed them at immense distances from one another".* Newton saw God as one and the same God always and everywhere, *"omnipresent not only virtually but also substantially; for action requires substance"*.

Newtonian celestial mechanics and clockwork reality was further established by the phenomenal development of mathematics and analytical methods in the 18th century. Pierre-Simon Laplace solved the effects of mutual interactions of planets on their orbits and showed the astonishing stability of the solar system. In his book *Exposition du système du monde (The System of the World)* Laplace discusses also the possibility that the solar system has evolved from a globular mass of incandescent gas rotating around an axis through its center of mass. Further, he developed the idea of the possibility that the nebulae were distant galaxies comparable to the Milky Way. Laplace summarized his ideas in the book *The system of the world* (Laplace 1830, 7). The success in celestial mechanics and Newtonian mechanics led to scientific determinism; in his tract *A Philosophical Essay* (Laplace, 1814, 8) Laplace describes his causal determinism, referred to as Laplace's demon as: *"We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes"*.

Conditions for a scientific approach to cosmology were not created until the early 20th century, when observation at cosmological distances became possible and the general theory of relativity offered a theoretical basis for the description of the structure and development of space. The term cosmology may have been introduced by the German philosopher Christian Wolff in his book Cosmologia Generalis (Wolff, 1730, 9) . Philosophical ideas of galaxies, nebulae and the buildup of the solar system had been presented by, for example, Immanuel Kant, Thomas Wright, and Johann Lambert in the 18th century. The theoretical bases of modern cosmology and predictions for observables are mainly based on observations and interpretations of the general theory of relativity between 1910 and 1940. An overview of the historical development from Anaximander's skies to modern cosmology is presented in Figure 4. Gestalting of the cosmological appearance of relativistic space is difficult; mathematically, space is described as a three-dimensional structure developing with time. It may be closed, "flat" or open, depending on the mass density. "Flatness" means balance between the motion of the expansion and the gravity of mass in space, Figure 5.

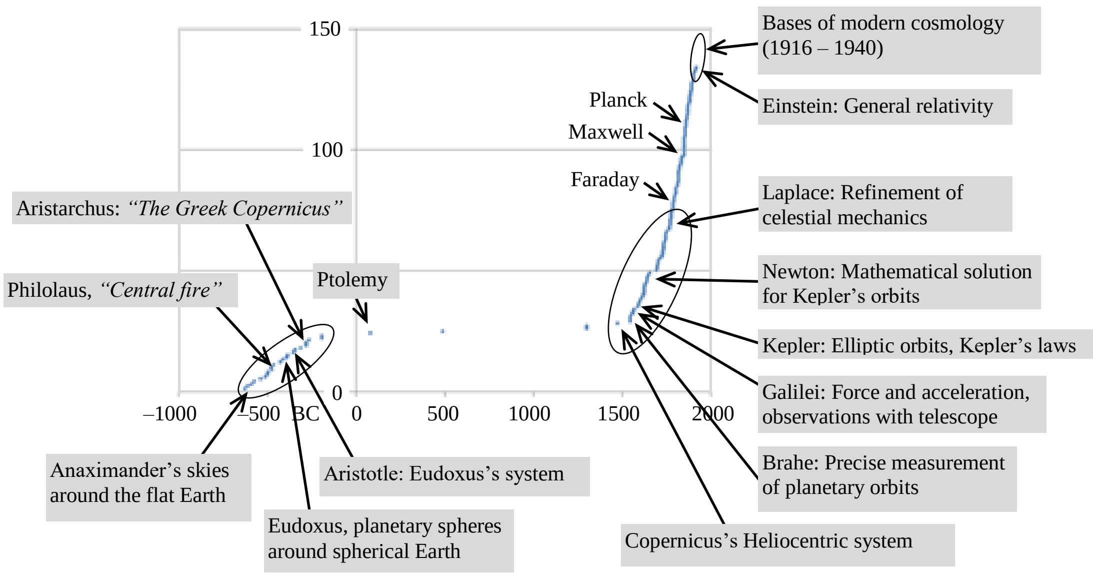

Figure 4. Development steps in the gestalting of skies, space and cosmology.

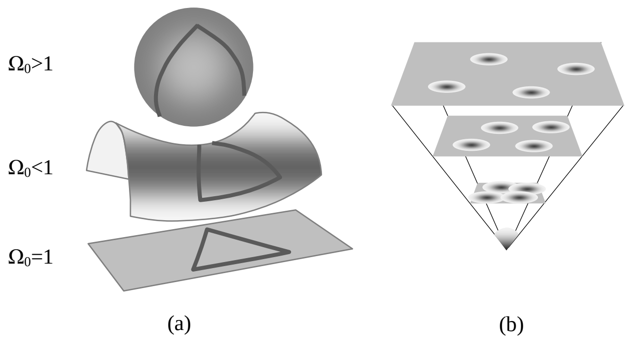

Figure 5. (a) In the Friedmann, Lemaître, Robertson, Walker (FLRW) cosmology the geometry of space is determined by the value of the density parameter Ω, which may be equal to one, or higher or lower than one. When Ω=1 the space is "flat"; rather than flat geometry, it means balance of expansive motion and gravitation. Ω>1 means closed space characterized by positive curvature leading to contraction after certain era of expansion. Ω<1 means open space characterized by negative curvature. (b) Galaxies are assumed to conserve their size in expanding space.

Gestalting of matter and mass

Key questions in gestalting matter are the nature of the basic substance, continuity versus discontinuity, and the relationship between local and the whole. Anaxagoras shared the holistic view of Heraclitus: *"Everything is a part of the same whole"* or *"everything has its share of wholeness"*. The ideas of the atomists rejected the idea of continuity and removed the local from the whole. Two thousand years later, in his monadology (Leibniz, 1714, 10) Leibniz reflected Anaxagoras's ideas of the linkage between local and the whole; *"monad is a perpetual living mirror of the universe"*. Mathematically, the idea of the local as the mirror of the whole (or the rest of space) is reflected, for example, in the delta function and the Fourier transformation; the Fourier transformation of a local delta function is a function equally everywhere – like the inverse of zero, which is infinite. Also, it is known that the rest energy of all matter and material objects is essentially equal and opposite to the total gravitational energy in space (Feynman, 1962, 11) – or the rest energy of any mass object is equal and opposite to its gravitational energy due to the rest of space, which, energetically, links the local to the whole. In a broad sense, the wave packet description of a particle in quantum mechanics can be interpreted as a linkage between local and the rest of space; a wave packet is a superposition of waves with all wavelengths; it has a finite value in the location of the particle and zero everywhere outside the particle. However, the wave packet of the waves it contains does not describe the particle or its momentum, but the probable location for finding the particle.

The wave nature of matter is described in terms of Compton and de Broglie wavelengths that couple the rest energy and momentum of a particle to electromagnetic radiation with corresponding energy and momentum expressed by the Planck equation. The wave nature of a particle made the essence of mass and matter even more abstract than the abstract apeiron. Some of the properties of matter are explained in terms of particle-like properties, another part as wave-like properties. Vice versa, certain properties of light, like the photoelectric effect, are described in terms of particle-like photons proposed by Albert Einstein in 1905 by interpreting the energy quantum in Planck's equation as a localized burst of radiation or a light particle.

Newton's equation of motion, $F = ma$, defined mass as the property that determined the inertial force of the object. In Principia, Newton defined gravitation as a property that is proportional to the mass (as the amount of material), which meant that both the inertial force and the gravitational force were proportional to mass and properties defining mass.

The definition of mass was complicated in the late 19th century, when the inertial property of electrons was observed to increase with the increasing velocity of the electron. The special theory of relativity defined the mass of a moving object as the relativistic mass that increases without limits when the velocity approaches the velocity of light. On the other hand, the concepts of rest mass and rest energy in special relativity made mass appear as an expression of energy. Figure 6 gives an overview of the development of the concepts of mass, matter, and material objects.

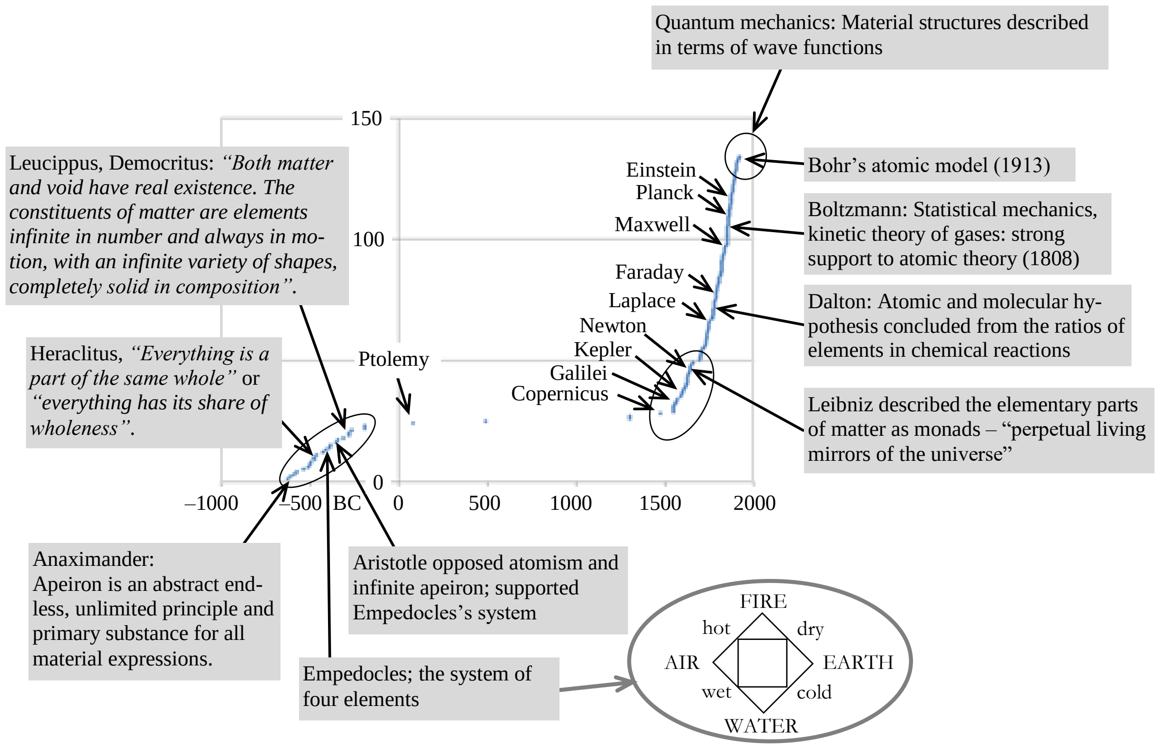

Figure 6. Development steps in the gestalting of mass, matter and material.

Gestalting of motion

In Aristotle's metaphysics motion was obtained by actualizing potentiality. Motion was maintained by a movent proportional to velocity and opposed by the resistance of the medium – *if an ox stops drawing a plough, the plough stops*. In Aristotle's physics free fall due to gravitation was natural motion taking the object to its natural place at a velocity that is proportional to the weight of the object. In a broad sense, Aristotle's natural motion can be interpreted as a tendency towards minimum potential energy, which is also the case when light objects move upwards by being replaced by heavier air. The movent of Aristotle's forced motion was understood as an external factor. The first thinker to understood the movent as an internal property of the moving object was probably John Philoponus, theologian, philosopher, and polymath in Alexandria in the 6th century AD. He thought that motion was maintained by the "energy of motion" *(incorporeal motive enérgeia), impetus* that the moving object received from the source of the motion. Motion continues as long as impetus is not removed. Resistance of air and work against gravity removes impetus thus resulting in slowing or stopping of the motion. According to Philoponus, planets moving in their orbits in empty space are not subject to the resistance of air, and therefore they maintain their impetus, velocity and orbit. Philoponus assumed that the propagation of non-material light carries impetus.

The concept of impetus was next developed – about one thousand years later – by the French priest and philosopher Jean Buridan in the 1300s. Qualitatively, Buridan identified impetus as momentum. Reconsideration of Aristotle's natural/forced motion had to wait for Galileo Galilei's experiments with a pendulum and falling objects in the late 1500s. Galilei's experiments and his conclusions created a firm basis for the works of René Descartes, Christiaan Huygens, Gottfried Leibniz, and Isaac Newton for identifying the central quantities characterizing motion. René Descartes defined momentum as the product of velocity and the "size" of the object. Also, he postulated the conservation of momentum in elastic collisions. Christiaan Huygens and Gottfried Leibniz defined momentum as the product of velocity and mass. Leibniz concluded, based on Galilei's and his own experiments, that the "living force", *vis viva*, that a falling object gets from gravitation is not the momentum, mv, but a quantity proportional to the second power of velocity, mv^2.

Leibniz defended strongly the conservation of vis viva (in modern terms, kinetic energy). The philosophy behind the conservation of vis viva was closely related to Aristotle's entelecheia, or actualization of potentiality – most concretely seen in the cases of a pendulum and falling objects. In the case of elastic collision, Leibniz assumed, that living force is first accumulated into "dead force", *vis mortua*, in the elasticity of the material, and then converted back to living force at the release of the tension in the material. The conservation of the sum of the potential energy and the kinetic energy, as identified by Leibniz, was finally understood as a central principle in energetics and thermodynamics in the late 1800s. The concept of the interplay of potential energy and the energy of motion was essential for James Clerk Maxwell when he formulated his famous *Maxwell's equations* (Maxwell 1873, 12). In his book *Science and Hypothesis*, *Chapter VIII*, (Poincaré, 1905, 13) Henry Poincaré discusses the concept of energetics as a fundamental perspective in dynamics and a potential solution to problems met in classical mechanics.

Isaac Newton's successful solution of celestial mechanics and the equations of motion behind it directed the description of motion primarily on mathematics based on force and acceleration as the basic quantities. Laplace's, Lagrange's, and Hamilton's formalisms derived from Newton's equations of motion implicitly defined the concepts of energy and potential. The physical importance of energy as a main conservable was understood in the late 1800's – force, however, continued to conserve its position as the primary quantity; energy became a derived quantity, as integrated force.

Implicitly, the concept of motion assumes the state of rest as the reference. In Newton's world Sun, or more precisely, the barycenter of the solar system, served as the reference at rest for planetary motion. Newton's equation of motion, however, assumes a local state of rest and the relativity principle that allows any observer in non-accelerating motion to consider his state as the state of rest.

The Newtonian world was linear, unlimited and infinite – in the Newtonian world the velocity of an object increases linearly as long as there is a constant force acting on the object. In the late 1800s, observations on the coupling of the velocity of light to the velocity of the observer and the object, gave the impression that the velocity of light has a special role as the maximum velocity obtainable in space. More support was obtained from the velocity of electrons accelerated in cathode ray tubes; at high velocities the increase in their velocity was less than predicted by the linear Newtonian equation of motion. The non-linearity was interpreted as an increase of the mass of the electron, probably without limits when the velocity approaches the velocity of light.

For describing the observations, local space and time were modified by coordinate transformations affected by the velocity of the object observed. Originally, the transformations were coupled to possible changes in the structure and dimensions of the material in motion. In his special theory of relativity Einstein postulated the Lorentz transformation as a consequence of the principle of relativity, and a property of reality. In the relativistic Einsteinian world the velocity of an observer is added to the velocity of the observed motion in a non-linear manner so that the sum of the two velocities never exceeds the velocity of light. The definition of the velocity of light as a natural invariant required time to be a variable that, in Herman Minkowski's interpretation, can be seen as the measuring rod of the fourth dimension perpendicular to the three space dimensions. The special theory of relativity produced new expressions for momentum and kinetic energy, and created the concepts of rest energy and rest mass that allow the interpretation of mass as a form of energy. The non-linear increase of momentum was interpreted as "relativistic mass" or just an intrinsic property of momentum.

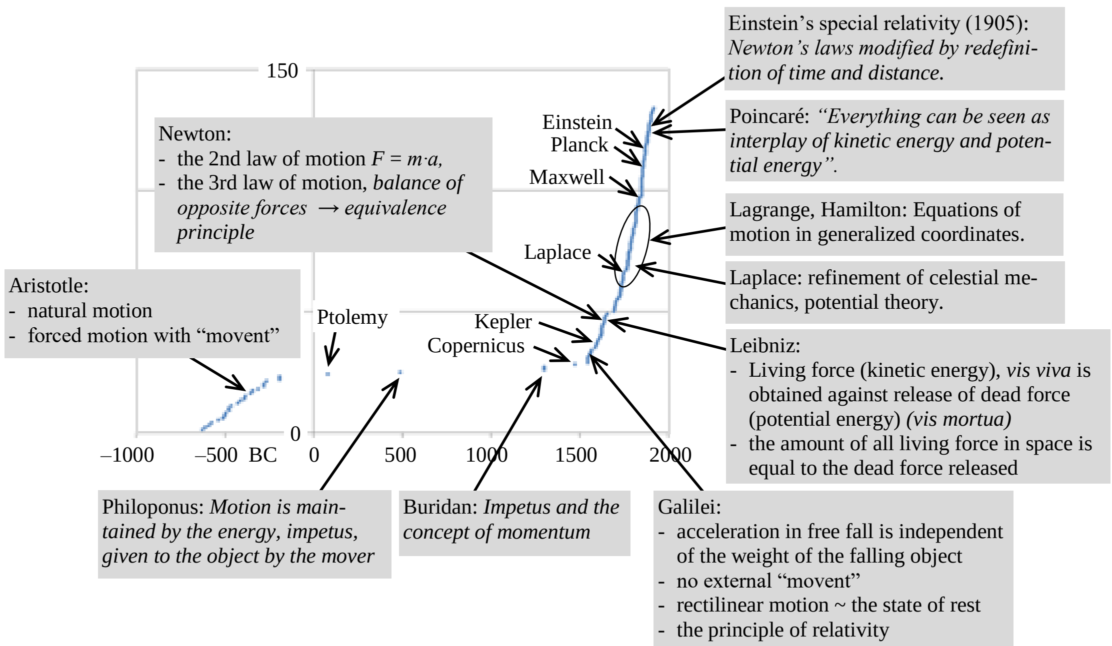

Figure 7. Development steps in the gestalting of motion.

Figure 7 summarizes important development steps in the description of motion. Aristotle's *entelecheia* reminds us of the cause of the motion that in the case of free fall is the gravitational energy released. Philoponus realized that the *impetus* maintaining the motion is obtained from the cause of motion, equally in free fall and in "forced motion". The development of the description of motion was guided, for a long time, by Newton's laws based on the concepts of force, action and reaction, acceleration, and a local state of rest as formulated in Principia. The principle of action and reaction can be interpreted as a local manifestation of the conservation of energy, as illustrated in Lagrange's and Hamilton's formalisms. In an energy approach, motion is determined by the energy available for motion in the system studied. In an energy system the state of rest appears as the state with zero kinetic energy in the system. The energy based state of rest is met, for example, in planetary systems and in any rotational system as well as in closed systems in thermodynamic studies.

Metaphysics and empiricism

As shown by the historical development, successful gestalting of physical structures and processes requires outlining of the primary laws and systems to be described, as well as detailed analysis of empirical observations. A prime example of balanced gestalting is the process behind Newton's laws of motion, celestial mechanics, and mathematical physics as illustrated in Figure 3. Philosophical principles are not enough for successful scientific theories – antique philosophers identified fundamental laws and principles of nature but were not able to apply them in functional description of physical phenomena. Also, they saw the mathematical beauty of natural structures and processes but were not able to refine the view into scientific models. Mathematical physics has shown its power since Newton's Principia turning the balance from philosophy to empiricism. Empiricism without necessary metaphysical bases or "an overall gestalting of the system" leads to mathematical description of observations rather than to a solid scientific theory. Present theory structures suffer from diversification and a multitude of postulates behind the descriptions of matter, motion and space. The description of matter is dominated by quantum mechanics; the description of motion by the theory of relativity and the spacetime concept. Figure 8 summarizes the postulates behind theories in different areas of physics. We may see the challenge of the 21th century physics in re-establishing the balance between metaphysics and empiricism in Poincaré's spirit *"we prove with logic, but invent with intuition"* (Poincaré, 1905, 13, Suntola, 2012, 14).

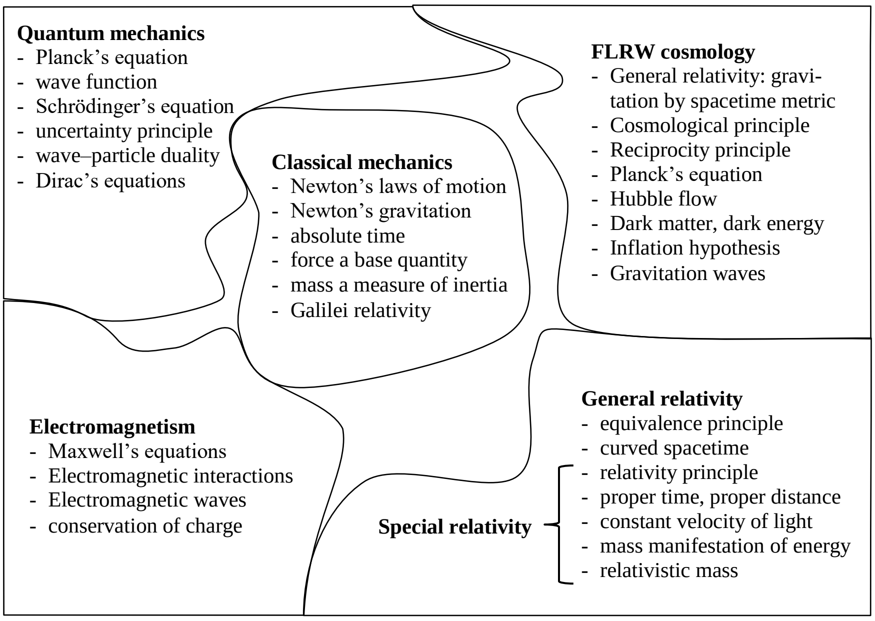

Figure 8. The big puzzle – the multitude of postulates behind present theory structures. The challenge of the 21th century physics can be seen in the unification of the prevailing theory structures – and in the gestalting of a covering picture of physical reality.

Bibliography

1. Aristotle, Metaphysics (350 BC), English translation by W. D. Ross, The Internet Classics Archive, http://classics.mit.edu/Aristotle/metaphysics.html.
2. Aristotle, Physics (350 BC), English translation by W. D. Ross, The Internet Classics Archive, http://classics.mit.edu/Aristotle/physics.html.
3. Fitzpatrick, R., A Modern Almagest, http://farside.ph.utexas.edu/syntaxis/Almagest.pdf
4. Manitius, K. (1912), Des Claudius Ptolemäus Handbuch der Astronomie, openlibrary.org, http://archive.org/stream/desclaudiusptole01ptoluoft#page/n3/mode/2up.

5. Newton, I. (1687), Philosophiae naturalis principia mathematica (Latin), openlibrary.org, http://archive.org/stream/philosophiaenatu02newt#page/n5/mode/2up.
6. Newton, I. (1726), Principia, Third edition, English translation by I. Bernard Cohen and Anne Whitman (1999)
7. Laplace P-S. (1830), The system of the world, English translation by H.H Harte, openlibrary.org, http://archive.org/stream/systemofworldtra01lapluoft#page/n5/mode/2up.
8. Laplace, P-S. (1814), A Philosophical Essay, English translation by F.W Truscott, 1902: openlibrary.org, http://archive.org/stream/philosophicaless00lapliala#page/n5/mode/2up.
9. Wolff, C. (1730), Cosmologia Generalis, Google book, http://books.google.fi/books?id=8to-AAAAcAAJ&printsec=frontcover&hl=fi#v=onepage&q&f=false.
10. Leibniz, Monadology (1714), http://www.earlymoderntexts.com/pdf/leibmona.pdf.
11. Feynman, R. (1962), W. Morinigo, and W. Wagner, Feynman Lectures on Gravitation (during the academic year 1962-63), Addison-Wesley Publishing Company, p. 10 (1995).
12. Maxwell, J.C. (1873), A treatise on electricity and magnetism (1873), openlibrary.org, wikisource.org, Posner Center, http://posner.library.cmu.edu/Posner/books/CALL1/537_M46T_1873_VOL._2/vol0/part0/copy0/sct/title.jpg.
13. Henri Poincaré, Science and Hypothesis (1905), openlibrary.org, http://archive.org/stream/sciencehypothesi00poin#page/122/mode/2up.
14. Suntola, T. (2012), The Short History of Science – or the long path to the union of metaphysics and empiricism, Physics Foundations Society, http://www.physicsfoundations.org/.

Summary

In this treatise the gestalting of structures in physics is followed along the historical path of known scientific development from metaphysics to empiricism and from intuitive ideas to deductive reasoning and mathematical verification. Antique natural science was rich in general principles but failed in bringing the ideas to a practical level. The scientific revolution, culminating in Newton's Principia, showed the power of empiricism and mathematical physics. Further development of physics was guided strongly by empiricism, maybe at the cost of necessary metaphysical perspective and the related gestalting of the unifying principles behind theories in different areas.

Author's biography

Tuomo Suntola, born in 1943, graduated MSc (1967) and PhD (1971) in Electron Physics in the Electrical Engineering Department at Helsinki University of Technology. Dr. Suntola has a far-reaching academic and industrial career comprising pioneering work from fundamental theoretical findings to successful industrial applications like the Atomic Layer Deposition method as an enabling technology for advanced semiconductor devices.