Naturaleza y Tecnología

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

2.600 AÑOS DE COSMOLOGÍA

Roger Coziol [a,*]

[a] Departamento de Astronomia, Division de Ciencia Natural y Exacta, Universidad de Guanajuato. rcoziol@ugto.mx,

Resumen

Hace dos mil seiscientos años se desarrolló en Grecia un nuevo método cognitivo para dar sentido al mundo. Este método fue juzgado necesario por sus creadores para determinar si su sociedad estaba construida sobre fundaciones sólidas, consistentes con la realidad. Debido a su objetivo, este método entró en conflicto directo no sólo con la religión sino también con la política. Sin embargo, el nuevo método era tan poderoso que se convirtió en un importante impulsor de su cultura y un faro para las generaciones futuras. El nombre del método, ciencia, se convirtió en sinónimo del propio conocimiento y hoy se ha desarrollado como la manera más eficiente para explicar el universo en la cosmología moderna.

Palabras clave: Ciencia; Democracia; Cosmología

2,600 YEARS OF COSMOLOGY

Abstract

Two thousand six hundred years ago a new cognitive method how to make sense of the world was developed in Greece. This method was judged necessary by their creators in order to determine whether their society was built on secured foundations consistent with reality. Because of its goal, this method entered directly in conflict not only with religion but also politics. However, the new method was so powerful that it became a major driver of their culture and a beacon for future generations. The name of the method, science, became synonym of knowledge itself and today it developed as the most efficient means how to explain the universe in modern cosmology.

Keywords: Science; Democracy; Cosmology

ISSN 2007-672X
Universidad de Guanajuato

1. The birth of science

There is a common misconception about the purpose of science and its origin in our modern society. For a majority of people, science is solely equivalent to technology. However, although a link obviously exists, these two activities differ by nature and origin. Differing by nature, because while technology focuses on the tools that amplify our actions on reality, science concentrates in explaining reality through our actions on reality. Differing by origin, because whereas any human civilization developed some sort of technology and religion, science as we practice it today only appeared in ancient Greece. This arose at a special moment of its history when the pre-Socratic philosophers developed a new method to explain the universe solely based on reason, explaining reality in terms that can be recognized as true by everyone.

According to Aristotle (384-322 BCE), science developed between the 6th and 5th centuries BCE and was instigated by one man, Thales of Miletus (624-546 BCE).[1] This movement broke with the Greek tradition based on mythology,[2] which role was to offer explanations about the origin of things, giving a sense to the phenomena that are observed and can be experienced in their environment, in order to legitimize their way of life. This mythology was founded on the belief that occurring events in nature are due to the wills of supernatural or metaphysical gods, with human motivations. This is the paradigm that Thales' new way of thinking questioned then rejected, grounded on the conviction that all the phenomena in nature can be described by sequences of causes and effects that are physical instead of metaphysical. Because this happened nowhere else in the world, this event can rightly be qualified as the birth of something new and unique which is science.[3]

2. Why was science created

Some scholars suggested science might have started as a religion, similar to what the Pythagoreans did in the 6th century BCE for mathematics (Coziol, 2018). One example was Max Bernhard Weinstein, a 20th century physicist who defended the thesis that the

[1] There are many URI for this citation, the original source being Book 1 in Aristotle, Metaphysic.
[2] Ex. Omer's poems, "Illiad and Odyssey", Esiod's poems "Theogony" and "Work and Days", written around the late 8th or early 7th century BCE.

[3] According to Professor G. E. R. Lloyd, Science is a modern category since there was no such term in the Greek vocabulary (Lloyd, 1973).

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

way of thinking of the Milesian philosophers was similar to a particular theology called "pandeism" (Kragh, 2019). The parallelism is so obvious that in his book, Greek Philosophical Terms, history Professor Francis Peters called pandeism "the legacy of the Milesians" (Peters, 1967). Pandeism combined pantheism, the belief that reality is identical with divinity (Edwards, 1967), with deism, the belief that once god created the world, he stopped interfering with it. The two concepts together form pandeism, the belief that one god became the universe and then ceased to exist as a separate, conscious entity (Mapson et al., 2017). The apparent similarity with science is the following: if no conscious god interferes with the world, then the causes of all things can only be natural, not supernatural. This indeed looks like the creed of science as created by Thales, rejecting the intervention of gods as causes for the phenomena observed in nature. However, in science the creation of the universe is also a natural phenomenon that must be explained by reason. Thales, for instance, proposed that all matter came from a primordial substance, which is water. This is without any reference to a god becoming the universe.

On the other hand, the parallel with pandeism may be useful in helping us understand what Thales tried to do in developing science. Although it would be very hard to disprove that a god became the universe, proving the non-interference of gods in the natural phenomena seems feasible. It suffices to search for rational explanations involving only physical causes to describe all things. Therefore, it is the belief in physical causes in nature that is the real legacy of the Milesians and this is science not religion.

What the first "scientists" did was to engage themselves in the intellectual task of demonstrating there is no evidence of gods behind any natural phenomenon. They created a new way of thinking about nature, which is science. They also had a practical motive because of the role played by religion in the Greek political system at this epoch, which was perceived as unprincipled and overbearing.

3. The lost connection with democracy

The period from the 7th to 3rd century BCE in Greece was a time of great agricultural and economic achievements, which triggered an important growth of its population and the

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

foundation of many large city-states.[4] How to organize and administer these states was consequently an urgent question. The people unsatisfied with kingship tried different solutions, which eventually led to the creation of democracy.

There are two points about the origin of democracy on which scholars agree: democracy was not limited to Athens (Wallace, 2008) and it did not materialize instantaneously at one particular moment but was the result of a long process spanning a few hundred years, emerging as the solution to various social crises (Raaflaub, 2008). One such crisis happened right in the 6th century BCE (Raaflaub & Wallace, 2008), slightly before Thales' time. During the 7th century, Greece was already a wealthy civilization but this wealth was not distributed uniformly among its population. It was in the hands of kings and aristocrats. At the head of an oligarchic, feudal regime kings were endowed with political and religious prerogatives, while ownership of the lands was reserved to a few members of the higher class. The majority of people, the demos, who produced the wealth of the nation in the first place, were reduced to farm the lands of these privileged individuals in exchange of expensive rents, which left them at the margin of survival. This kind of regime was prone to harsh exploitations and excessive behaviors from the part of aristocrats who had complete power over the demos. More specifically, any citizen that could not pay his debts could be sold with all his family as slaves and exiled (ostracized) out of the city. This type of social/economic system was rejected by the demos who did not accept to be intimidated neither by the rich and powerful nor by wellborn aristocrats. During the 6th century BCE this situation led to many revolts.

Different regimes were experimented by the insurgents. One was mass government, a crude form of democracy, where the citizens (excluding women and slaves) voted on the laws. However, the busy demos did not have much time to lose in politics or administrative duties and thus another solution was tried, offering the power to one man, who they would support as tyrant, a term that at this epoch solely meant elected. Unfortunately, the success of this solution depended totally on the virtues of the tyrant. Usually, the demos tried to choose a wise man or sage, sophost. This was the case of the seven sages.

[4] For the history of democracy, I followed Raaflaub et al. (2008).

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

One of them was Solon (638-558 BCE). After a revolt against the aristocrats, known as Eupatrid, the demos asked him to be their tyrant. He refused, proposing instead to introduce a series of reforms to the Athenian constitution. This was c. 594 BCE, when Thales only had about 20 years. In 507/508 BCE, the lawgiver Cleisthenes adopting the same solution as Solon formalized democracy in Athens (Ober, 2008).

Thales was another of the seven sages. At this epoch Miletus was under the rule of the popular tyrant Thrasybulus. The political regime of Miletus was very sophisticated, the city having formed an alliance with eleven other city-states in the region, a confederation called the Ionians League. Conventionally, Miletus was tied to one of these states, Megara, by a formal colonization treaty that obliged the two cities to act in concordance with each other. In Miletus social peace reigned but not in Megara. At the source of discord, both cities had their own Apollo oracle, like in Delphi,[5] whose principal function was to confirm all the civil laws proposed by the archons, the chief magistrates of the cities.

According to tradition any change to the constitution required to be sanctioned by religious authorities. In normal time, the laws were decided based on their adequation to the wills of gods that appeared as signs in nature that must be decipher (Flower, 2008). For example, one story tells us that the five ephors, some obscured representative of the demos in the Spartan constitution, had to scrutinize the sky every nine years for shooting stars, based on which they would decide whether the gods reject or confirm the kings mandates (Sparta had two kings). However, there was no rule or instance that could verify their decision. In Megara and Miletus, the only persons that were allowed to interpret the signs were oracles (consulted only the seventh of each month) and seers (consulted anytime for any questions). This gave these individuals a lot of power (they were part of the higher class) with obvious questionable consequences in politics, their interpretations frequently—too frequently—favoring the rich aristocrats instead of the demos.

Surely the wise Thales would have noted the incongruousness of this "religious" tradition and that could have motivated him to question

[5] A prehistoric tradition based on the myth of Gaia, Mother Earth goddess and ancestral mother of all life.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

its validity in the case of democracy, a system based on reason with rules that all can understand. More specifically, what if the cause behind the shooting stars had nothing to do with the wills of gods or if the movements of planets in the sky were solely due to physical causes? In general, what if there were no interference of gods behind any natural phenomenon? What would then be the value of an omen read in nature by seers or orally revealed by oracles in trance, knowing that all the phenomena observed (including the trance of the oracle) have natural causes? Within this context, science investigations had a tremendous impact on politics: no more privileges sanctioned by gods to justify the arbitrary actions of aristocrats, kings and tyrants. For the first time the demos could have an intelligent relation with their government and decide their own destiny. This freedom explains both the enthusiasm and high involvement of the people in democratic Athens, as well as their general interests for culture and scientific knowledge. There was a lot of sense in what the first "physicists" were finding, giving a new meaning to reality, replacing mythology with a knowledge that everyone could acquire, equal knowledge making people equal.

4. A modern view of reality

By rejecting gods as sources for the natural phenomena and replacing them by sequences of causal events that are fully intelligible, the first physicists (physikoy, after the Greek word physis, the term for nature) built a new common reference frame (CRF) for the collective consciousness, which allowed people organized in a democratic society to increase the coherence of their actions as a community. In this CRF we can distinguish a continuity between the works of the physikoy and the activity of today scientists, which is particularly evident in cosmology. In science, the universe is the whole body of things and phenomena observed, or more precisely, the complete ensemble of human experiences, which in physics are identified as events (and in mathematics as numbers; that is, numbers are events) and cosmology is the discipline that seeks to explain how all this came to be.

In 585 BCE,[6] Thales proposed that everything came from a primordial—but common—substance, which is water, one of the four

[6] My main source for the description of the ideas in cosmology developed by the pre-Socratic philosophers is Lloyd (1970).

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

basic elements, earth, water, air and fire, recognized at the time by various civilizations to form matter. Following the scientific method, Anaximander (610-546 BCE) and Anaximenes (586-526 BCE), two students of Thales in Miletus, freely criticized this idea with the goal of improving it. According to Anaximander, the primordial substance could not have been common, but indefinite and boundless since it must transform into everything. He also proposed that starting from a seed the cosmos grew like a plant from which emerged all forms and structures. Anaximenes, on the other hand, suggested that although the primordial substance was uncommon, the process by which it transformed into all things was common and could still be observable in nature. He proposed that earth and water formed by condensation, while air and fire formed by rarefaction.

In 1927, the abbot Georges Lemaître, using Einstein's General Relativity theory (GR; 1915),[7] proposed that the universe grew from a primordial egg (Lemaître, 1931). This is the basis of our modern cosmology theory known today as the Big Bang (a term used in 1949 by the famous astrophysicist Fred Hoyle to poke fun at the idea because he believed the universe always existed; a steady state universe). In GR, gravity is not a force, like Newton proposed in 1687, but a component of space and time united in one entity, spacetime, gravity appearing as the curvature of spacetime. By redefining gravity in this way, Einstein was able to resolve an important problem encountered by Newton in cosmology, which was that assuming gravity is a force a universe formed by many masses would collapse on itself. In GR, Einstein obtained a set of mathematical equations bonding the masses to the curvature of spacetime, which when resolved tell us that, in fact, there could be two solutions: a universe form of many masses either collapses or expands. In 1929, Edwin Hubble observed that all the galaxies get farther away from each other at a velocity proportional to their distances, confirming the expansion of the universe. This is the first observational evidence for the Big Bang.

Gravity is the curvature of spacetime. To clarify what this means, one has to think in terms of physical interactions: interactions between two masses, a force according to Newton, is described in GR by a special

[7] There are many books about GR, so I will not recommend one in particular. Personally, I am working on the book written by Wald (1984), which is closer to my view of physics as the topology of interactions.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

structure of spacetime, which is curved instead of linear like in Special Relativity (French, 1968). In SR, Einstein demonstrated that physical interactions between matter (an exchange of energy) cannot happened more rapidly than the velocity of light. This implies that space and time cannot be separated since they are two aspects of the same interaction. This also implies that what we perceive as geometrical forms, objects separated by distance and time, are really ensembles of interactions.[8] In SR, these objects do not have a mass, and consequently the geometry, spacetime, is "flat" (the shortest distance between objects is a straight line). In GR objects do have masses, making the shortest distance a curve (a geodesic), and it took the genius of Einstein to realize that the curvature of spacetime is what we perceive as gravity.[9]

Two thousand six hundred years after the Milesian physicists proposed the universe grew from a primordial substance, modern science was able to "confirm" the idea through observations. However, thanks to GR we can also add something new to this model, which is that the reason why the universe expands is due to the creation of the masses during the Big Bang. According to this hypothesis, this event would have left a trace under the form of a radiation that pervades the whole universe and which, in principle, could still be observed today. Starting from an extremely dense and hot state, a physical condition favoring nucleosynthesis (the formation of the nuclei of atoms), the universe expanded, becoming colder and less dense. Using as a guide these physical conditions and GR solution for the age and evolution of the universe in expansion, George Gamow in 1948 calculated that the temperature of the Big Bang relic should now be close to 3 K.[10] In the 1960s, Arno Penzias and Robert Wilson, two engineers working on a new radio communication antenna using microwaves, detected serendipitously in the sky a radiation coming from all directions. The spectral energy distribution of this radiation has the form of a pure black body[11] with a temperature of 2.7 K (Planck Collaboration, 2017). This radiation is known

[8] The interactions are what we perceive as geometrical connections between objects. In mathematics, this is the subject of topology and in physics, the topology of interactions (what I am working on in Guanajuato).
[9] It takes an astronomical number of masses to perceive spacetime is curved. Locally, at the scale of human interactions, spacetime looks flat.
[10] Absolute temperature unit, where 0 K degree is -273 Celsius; 3 K is thus -275 C.
[11] A black body (BB) is an idealized object that absorbs all radiation and emits energy proportionally to its temperature when in thermal equilibrium with its environment. Stars are close examples of BB.

Naturaleza y TECNOLOGÍA

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

as CMB, the cosmic microwave background. The CMB is the second evidence for the Big Bang.

But the parallels in cosmology do not stop there. Continuing their investigations, the pre-Socratic philosophers discovered a new aspect of reality in epistemology (the study of the nature and bases of knowledge). Implicit in the scientific method of the Milesian school, observations of natural phenomena were at the same time sources and verifications (proofs) for the best reasonable explanations possible. Eraclitus of Ephesus, c. 505 BCE, noted this specificity and became skeptical of science because of its dependence on our five senses, which he considered unreliable, easy to deceived and misleading.[12] This led him to declare that reason alone can be trusted. This motivated Parmenides, c. 480 BCE, to state that "it is and cannot not be", from which he deduced that "the way of the truth is to reject changes as impossible." This predicate is ambiguous because it seems to suggest that reason is a metaphysical entity—a reality above reality explaining all that exists.[13] This misled the first physicists to falsely associate reason with absolute truth, legitimizing in this way metaphysics, in flagrant contradiction with Thales' science. This was a gigantesque faux pas, which confused brilliant minds like Plato and Aristotle,[14] followed by the medieval scholars in the first European university who tried to use science to prove the existence of their god (Grant, 1996).

However, not everyone fell into Parmenides' epistemological trap. Empedocles, c. 445 BCE, advanced that although the senses are limited, the mind could also be fooled and explained that to acquire knowledge about the physical world we must rely on both our senses and reason. At the same epoch, Anaxagoras added that what the senses provide are really "inferences of a reality that cannot be directly observed." Here are two concepts that are still valid in science today, alluding to the possibility that reason is equivalent to a natural sense and referring to reality as something that does not have a human semblance.

[12] Due to the proliferation of conjurers, charlatans or entertainers using magical tricks; Russo (1996).
[13] One makes the same error by assuming reality has an intrinsic mathematical structure; see Coziol, 2018.
[14] Plato called reason the Divine, because he believed that what exists is only created when it takes a meaning through reason. This idea looks strangely similar to one interpretation in Quantum Mechanics that our experiences on reality generate reality.

In modern epistemology, now supported by neurology (the study of the brain), reason is recognized to be part of the cognitive process, as a necessary complement to our five senses (Eagleman & Downar, 2016). This is how the brain puts meanings to what we perceive, by making plans, that is, predicting our actions on reality. Because our brain is not a metaphysical entity, the nature of reasoning is not metaphysical. According to Jean Piaget (1950), intelligence is an adaptative process which consists in "the integration of the action of the subject on the object." This implies that we can only "know" reality through our interactions with reality. This principle is also at the basis of one of the interpretations of Quantum Mechanics (QM), where reality takes a definite form through decoherence, due to the multi-interactions of material particles (Omnès, 1994); and this happens whether we observe it or not.[15]

Ignoring epistemology was one important limit of the Greek science but this was also a grave error of modern physicists in the 20th century working on the development of QM. When they started to experiment with interactions at the scale of the atoms, they were faced with an apparent contradiction about the nature of objectivity in observation. Contrary to what seems natural and intuitive, physical interactions are purely probabilistic, implying that reality is indeterminate. In 2006, the physicist Bernard d'Espagnat introduced the term hidden reality to describe this intangible quality of what exists as described by QM (d'Espagnat, 2006).

Einstein, having previously defined in SR that the velocity of light is the velocity limit for the propagation of any causal (deterministic) interaction in spacetime, was very skeptical of this aspect of QM. He expressed his doubts in a short clause "God does not play dice", in fact, using a well-known dogma as analogy—God (a cause) created the world (an effect)—to express his conviction that the laws of physics must be deterministic, connecting effects to causes. In 1950, he proposed a thought experiment, "Gedankenexperiment", known today as the Einstein-Podolsky-Rosen (EPR) paradox, which once realized would prove the fallacy of QM indeterministic interpretation. In the 1960s, John Stewart Bell translated the EPR paradox into a mathematical formalism consistent with QM (Bell's inequalities), which could be experimentally tested. In 1980s, Alain Aspect

[15] This is the answer to the infamous Schrödinger's cat experiment: the cat (things) is (are) in two physical states at the same time, dead (exist) and alive (do not exist), the actual state being decided by the observer.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

and his team realized this experiment disproving EPR, in support of the QM view that reality is intrinsically indeterminate.[16]

In cosmology, one can retrace the history of the Big Bang using GR down to the primordial universe, which shrinks to a spacetime singularity where everything (matter, space and time) disappears. But before reaching this point, the universe passed through a phase equivalent to a quantum state. This led some physicists to suggest the Big Bang was an indeterministic event, that is, an effect without a cause (Hawking, 1988). Consequently, no god (a cause) created the universe (an effect). This goes way beyond what Thales would have imagined possible: did modern science just "proved" the non-existence of God?

But having apparently solved Parmenides' epistemological conundrum, Empedocles and Anaxagoras did not rest there. They proposed, c. 435 BCE, a new concept of matter, the atoms which means indivisible, giving a concrete form to Anaximander's primordial substance and explaining how this substance can stay the same while transforming into all things (in answer to Parmenides): atoms are infinite in number and in perpetual movement in the void, such that colliding with each other they either rebound or stick together forming new compounds, the different forms they take being at the origin of everything.

The confirmation by modern physicists that matter is constituted of atoms is another fundamental success of modern science, although reality turned out to be more complex. Atoms are not indivisible objects but formed by the interactions of subatomic particles and it is these interactions not the particles themselves that are at the origin of their masses (Hansson, 2014).[17] In cosmology, it was also shown that the Big Bang did not form all the 92 natural elements we observe, but only the lighter ones, hydrogen and helium accounting for 74% and 25% of baryonic matter (common matter that we can see, emitting or absorbing photons, the particles of light). All the rest, the more massive elements up to iron, were formed by sequences of nuclear fusion, a thermonuclear-

[16] Alain Aspect was awarded the Nobel prize of physics for this experiment in 2022.

[17] In the standard model of particles, the mass is assumed to appear from the interactions of particles with the Higgs' Boson. However, this theory was verified only in the case of the electroweak interaction. and does not consider the recent discoveries about the strong nuclear force between quarks, which show that neither the particles nor the force confining the quarks in the protons and neutrons explain their masses.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

quantum interaction between the nuclei of atoms, happening in the dense and hot cores of stars. The fact that abundances of natural elements as measured in the universe agree with the nucleosynthesis model constitutes the third piece of evidence for the Big Bang.

However, there is also something extra in Empedocles and Anaxagoras' proposal. They claimed that "atoms in movement in the void are the only real entity of the whole universe." This predicate introduces one new undefined entity which is the void. At first this addition seems natural, since for the atoms to be in movement there must be "space" between them, but it is also ambiguous because there is no formal definition in physics (other than spacetime in relativity) of what space and time are. The difficulty was noted by Newton who solved it by claiming space and time are absolute (again, metaphysical) entities, in direct violation with Thales' definition of science. Fortunately, this is not how Einstein saw it, considering space (and time) more simply, as the distance between matter. In fact, consistent with an interaction.

The nature of reality in physics appears more clearly when one thinks in terms of interactions: space and time emerge as spacetime, an abstract work-frame necessary to describe interactions (distances) between matter (atoms/particles). What is observable are the interactions, and consequently only these interactions are "real". This is explicit, in Particle Physics, where the particles are equivalent to their interactions.[18] In QM also, space and time lose their intuitive meanings because the wave function of a particle (its mathematical description) spreads over a "volume", which corresponds to the probability of interactions of the particles; an atom is a fuzzy cloud of probabilities, related to the interactions of electrons with protons and neutrons, where electrons can tele-transport (instantaneously) from one orbital (highest probability state) to another, an interaction that involves either the absorption or emission of a photon (a quantum of energy).[19] In terms of interactions, one cannot separate matter from spacetime, such that there is only one "real entity" which is matter-spacetime.

[18] The standard model of particles is really the standard model of interactions of particles; Cottingham & Greenwood (1998).

[19] According to Max Planck, energy, E, is exchanged by packets of light, $E = h\nu$, where ν is the frequency of light and h Planck's constant.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

Unfortunately, the void concept was not eliminated in modern cosmology because many astrophysicists now believe some physical characteristics of "space" is responsible in accelerating the expansion of the universe (Riess et al., 1998). However, if this acceleration is due to dark energy (DE), referring to a strange form of mass-energy ($E = mc^2$) not predicted by QM or GR, then conceiving space as a void or vacuum is neither necessary, since DE in GR simply appear as an extra component of the stress-energy-momentum tensor (the mathematical description of matter-energy) responsible in "curving" spacetime.[20] Similarly in Particle Physics, the void is not "empty space" but conceived as a pool of virtual particles in interactions, appearing and disappearing at rates too fast to be detected.

Interactions are also fundamental in the case of dark matter (DM), another important but unknown massive constituent of matter-energy assumed in cosmology to be necessary to explain the formation of structures in the universe. There are two alleged pieces of evidence for DM, the rotation curves of spiral galaxies, which show excesses in angular momentum (their disks rotating too fast for the visible mass to be in equilibrium), and the large-scale filamentary structures formed by galaxies, percolating (interconnecting) the whole universe. The second piece of evidence is the most constraining in cosmology. As the universe cools down, it first passed by a phase dominated by radiation before transforming into a phase dominated by matter, which happened 60,000 years after the Big Bang. In theory, structures (stars/galaxies) should have started forming at the beginning of the matter-dominated era but it did not because radiation was coupled to matter and each time a structure formed it was destroyed by radiation pressure.[21] Structures started forming only 378,000 years after the Big Bang, after radiation separated from matter (a process known as decoupling), photons escaping as the CMB, leaving free electrons to combine with the nuclei forming the atoms (a phase called recombination). The caveat is that it took a long time after recombination for the first stars in the first galaxies to form and even longer for galaxies to develop into the large-scale structures we observe today. Even for an

[20] Be careful! Matter per se does not curve spacetime, but rather spacetime emerges as curved in presence of masses. Spacetime is not a thing, but a work-frame describing any interaction.

[21] Photons are particles without mass but with momentum p, that is, a quantity of movement proportional to their energy, $p = E/c$; the movement of the particles is the source of the pressure.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

old universe, aged 14 Giga (thousand million) years, there is not enough time after recombination for these large-scale structures to develop. This is where DM was deemed "necessary", with only two conditions required for DM particles: 1- since they are dark, not emitting or absorbing photons, they must not (or very weakly) interact through electromagnetic (electric and magnetic) forces, 2- they must be massive enough to form the seeds (or backbones) of structures that now could start forming long before decoupling.

The preferred candidates for DM were WIMP, weakly-interacting massive particles, because using "new physics"[22] they could have been included in the Standard Model of Interactions of Particles. In theory, WIMP were expected to be detected by the most powerful accelerator of particles, the large hadron collider (LHC). However, despite the huge number of candidates predicted (more than 300) the LHC found none and the chance of direct detection is now almost nil (Misiaszek & Rossi, 2024). The situation is highly embarrassing,[23] considering that the standard model of cosmology cannot work without DM.

The standard model is known as ΛCDM. The abbreviation C stands for cold, because, even not knowing what DM is, numerical simulations of large-scale structures suggest DM cannot be hot, that is, formed of fast-moving particles. The Greek letter Λ (lambda), on the other hand, is a reference to the cosmological constant, a hypothetical "reaction" of space to the curvature of spacetime, introduced ad hoc in GR by Einstein to balance his equations (obtaining a steady state universe). Since Λ opposes gravity, accelerating the expansion of the universe in absence of baryonic masses,[24] the symbol is used today to represent DE, assumed to be the cause of the acceleration of the expansion—although it was clarified that DE is not the cosmological constant and possibly not even a constant.

Up until recently, astrophysicists were very optimistic that ΛCDM was the best model we have to explain the universe. However, this

[22] For example, Supersymmetry or String Theory; the former was "proven" wrong by LHC, while the latter seems unfalsifiable (there is no way to test it experimentally).

[23] DM would be non-baryonic, that is, a form of matter only interacting through gravity, which, complicate things, since gravity is not an interaction (a force) but the curvature of spacetime.

[24] A model of accelerating universe proposed in 1917 by Willem de Sitter (1872-1934).

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

model is a huge quagmire, because it claims that 95% of the matter-energy of the universe is under two forms not predicted by standard physics. Instead of a "theory of everything" modern cosmology seems to have produced a "theory of nothing" with the only parallel possible with the ancient Greek philosophers being the famous quotation of Socrates, "I know I know nothing!"

5. Is the Big Bang model in jeopardy?

Because light in spacetime travels at a finite velocity, we see astronomical objects not as they are but as they were in the past. In principle, therefore, looking very far away we could observe how the first stars and galaxies in the universe formed. This is the main mission of the James Webb telescope (JWST), which started in 2022. To the surprise of astronomers, what it seems to show turned out to be more puzzling than comforting. You may have heard alarmist comments on the internet about its discoveries, some claiming that what the JWST sees "should not exist" or "the Big Bang never happened". These two statements are mostly incorrect. First, the universe does not depend on what we expect because what we observe is what exists, even if we do not understand it. Second, what they should have said instead is that galaxies and black holes (BHs) at their centers seem to form much more rapidly than what ΛCDM allows. However, considering that we know nothing about the mass-energy constituents of the universe in this model, one should not be surprised that new observations, that were not possible until now, are not what we expected.

Actually, not all astronomers were taken aback by the JWST results. These last two years, my group of research at the Department of Astronomy in Guanajuato published two analyses about galaxies and their super-massive BHs (SMBHs), showing before the first results of JWST were public that they formed together extremely rapidly (Cutiva-Alvarez et al. 2023; Torres-Papaqui et al. 2024). The good news is that the problem seems to be related to how fast common baryonic matter collapses to form the "strange" structures we see in the early universe, suggesting that we do not need any new physics to explain them, but only better understand the role of gravity in the formation of structures.

According to Einstein, gravity is not a force but the curvature of spacetime, the masses

ISSN 2007-672X

following curved geodesics. This means that one cannot describe a structure in equilibrium by balancing the electromagnetic force with the gravitational force, $F_{\mathcal{E}m} = F_G$, because gravity is not a force. Like Einstein explained, "People blame gravity for making hard to climb mountains or stairs, or just get out of bed. But these local effects are due to Earth pushing back on us preventing us to fall freely on a geodesic...when we recognize that spacetime is curved and that in free fall we feel no gravity, then the concept of gravitational force disappears completely."

Mathematically one can only balance quantities that have the same nature, as indicated by their physical units, meter, second, kilogram, etc. Thus, force = force, energy = energy, and so on. Consequently, the force that stop baryonic matter to follow

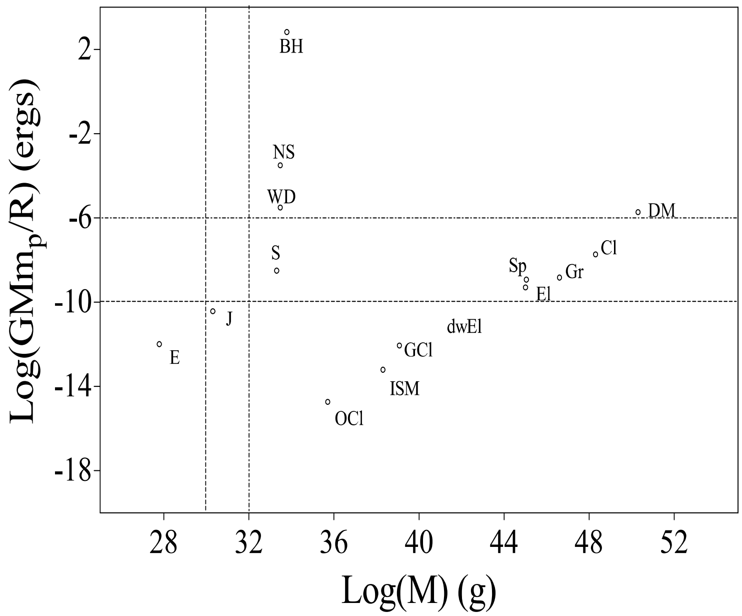

Figure 1 Gravitational-Baryonic Potential: **GBP** = $\boldsymbol{E_G/N}$, where the mass $\boldsymbol{M = Nm_p}$, is the mass of $\boldsymbol{N}$ protons and $\boldsymbol{E_G = -GM^2/R}$, is the gravitational potential energy, where $\boldsymbol{R}$ is the size (radius) of the structure and $\boldsymbol{G}$ the gravitational constant. Structures with different states of matter in equilibrium: Earth (E), Jupiter (J), Sun (S), White dwarfs (WD), Neutrons stars (NS), Black Holes (BH); and Dynamical systems: Open (OCl) and Globular (GCl) star clusters, inter stellar medium (ISM), dwarf elliptical galaxies (dwEl), Spiral and Elliptical galaxies (Sp, El), Groups and clusters of galaxies (Gr, Cl), dark matter (DM). The horizontal lines delimit the range in GBP for stars; The vertical lines indicate mass limit for solid planets and the mass limit to ignite hydrogen fusion; This is an original figure I draw for my course in cosmology using real data.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

geodesics in a structure in equilibrium must have the same nature as the source that form the structure, which could only be baryonic matter because DM does not interact with baryonic matter. What happens therefore is the following. As the masses, M, accumulates locally, spacetime collapses, changing the state of energy of baryonic matter. There are two forms of energy, kinetic, due to movement, E_K, and gravitational, due to the curvature, E_G. The first decreases, tending to a minimum, while the other increases, tending to a maximum. This implies that to form a structure baryonic matter must change to a form that allows higher bonding energies.

As the mass grows, the size of the structures should also be expected to shrink. However, the size is not defined by gravity but by baryonic forces impeding matter to follow geodesics. In equilibrium, the baryonic energy equals the bounding energy, $E_{bar} = E_b$, which must be higher than the gravitational energy, $E_b > E_G$, to form a structure. Since the bounding energy is specific to the curvature of spacetime produced by the masses, this implies that to each curvature must correspond a specific state of energy of baryonic matter, where baryonic forces capable of impeding matter to collapse appear spontaneously. What we expect during the formation of structures, therefore, is a change of physical state of baryonic matter specific to different curvatures of spacetime. This is a new paradigm for the formation of structures.

This paradigm is illustrated in Figure 1, where the gravitational-baryonic potential (GBP; Padmanabhan, 2006) of all the structures observed in our universe are compared with their mass-curvature equivalents. Each single structure, from planets to stars, is related to a different state of matter at equilibrium. Planets are solid and gaseous structures, supported by electrons repulsion and gas pressure due to their density/temperature. Stars are plasma structures supported by radiation pressure due to a fluid of photons produced by thermonuclear[25] fusions in their cores, a physical process proper to nucleosynthesis (the so-called transmutation of elements). Finally, white dwarfs and neutron stars are purely quantum structures, supported by Fermi pressure (energy degeneracy of quantum states; two similar particles cannot be in the same state). Ending with BHs, where no equilibrium is possible

[25] Only possible through quantum tunnel effect.

ISSN 2007-672X
Universidad de Guanajuato

because there is no physical state of baryonic matter (no transformation) that could oppose matter to collapse; matter-energy "disappear" in a singularity of spacetime, leaving only a halo (horizon) of matter-entropy behind.[26]

For multiple stellar systems, the equilibrium is dynamical, established through rotation or velocity dispersion of stars (the macroscopic mechanical analog of temperature/pressure), and equilibrium is possibly never total since the masses of these systems are constantly growing, the more massive (groups and clusters of galaxies) merging to form larger scale structures. In Figure 1, multiple systems seem to trace a sequence in parallel to single structures because the ranges of GBP, with units of energy per baryon, are comparable. This similarity emphasizes two important characteristics of structure formation: 1- the formation of stars is itself a transformation process of baryonic matter necessary for massive structures to gain higher bonding energies, 2- the GBP range for degenerated objects is out of reach for multiple systems because they cannot attain the high densities that allow quantum effects to take place.

Note that since we ignore the physical nature of DM, the extreme position in the GBP diagram is arbitrary, apparently extending the sequence of galaxies to the quantum range (which is inaccessible) just because the mass was extrapolated from the baryonic masses—there is no independent or direct observation of DM. Consequently, the GBP diagram suggests something else that is new, which is that there is a strong coupling between structures formed of baryonic matter and the curvature of spacetime. This coupling does not appear in the ΛCDM model.

6. The Big Bang singularity hypothesis

To conclude this essay, I will (as an exercise) continue the tradition of the physikoy by postulating what could have been the Big Bang based on modern science. This is the Big Bang singularity hypothesis. Some words of caution to the lector before beginning. For this exercise I must describe a few equations which illustrate how some of the most important advances in modern physics and cosmology came from the insights gained by expressing our interactions with reality in mathematical terms. Mathematics is a logical

[26] Entropy is a property of matter, not spacetime. At the horizon of a BH, matter is entangled and the entropy of the BH can be explained as the entropy of entanglement of matter falling onto the BH (Terashima, 2000).

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

method that helps anyone thinking more clearly (Coziol, 2018) and I strongly encourage the lectors not to ignore this powerful tool.[27] Science would not have advanced as it has without mathematics. This said, I will try to be as clear as possible, although I am afraid the flow of ideas will still seem difficult to follow. After all, how the universe came to be is anything but simple.

Following GR, two solutions are possible for the universe: the expansion, the Big Bang, which seems to have a point of departure in a primordial singularity, and the Big Crunch, the universe being so massive that it collapses on itself, ending as a singularity. However, these two singularities do not necessarily need to be the same physically. It depends whether or not information is conserved. By information I mean for the Big Bang the process by which the universe was created, whereas for the Big Crunch it is the whole ensemble of processes by which the universe passed through before collapsing into a singularity. Based on this premise, one can postulate that the singularities are the same if and only if information is not conserved. This is what a recent study about BHs suggested. In 2013, Ahmed Almheiri, Donald Marolf, Joseph Polchinski and James Sully proposed the firewall theory for BH, which contradicts the common assumption in BH physics that nothing happens to an observer crossing its horizon,[28] which is equivalent with information is conserved. Instead, they proposed that information is destroyed, the BH horizon acting as a communication firewall, which is equivalent to the observer "burns up" at the horizon. The term burns up is possibly too colloquial but there is a way to transform this expression into a more formal physical predicate. As baryonic matter falls onto a BH, it gains velocity, theoretically reaching the velocity of light at its horizon. However, following SR, no particle with a mass can reach the velocity of light. Consequently, to make this event consistent with SR one could postulate that on its way to the horizon of a BH any mass must transform into light. Within the new paradigm of structures formation presented in the previous section, this implies that light is the unique state of baryonic matter consistent with the horizon of a BH.

[27] The legend said that the inscription above the door of Plato's Academy was "Let no one who is not a geometer enter".

[28] Like illustrated in the film Interstellar; Cristopher Nolan, 2014 (with the 2017 physics Nobel Laureate Kip Thorne acting as executive producer).

Naturaleza y Tecnología
Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

Now, here is the more complex part. According to the mass-energy relation in SR, the energy of matter is composed of two terms, $E^2 = (mc^2)^2 + (pc)^2$, the first being Einstein's famous energy-mass relation (squared, that is, multiplied by itself), the second being the quantity of movement p, that is, the momentum of a particle (multiplied by c, and also squared, to get the same unit). By symmetry, the energy relation must also be valid for photons, the particles of light, which because they do not have a mass are pure momentum, $p = E/c$. This is what Louis de Broglie realized in 1924 when assuming this symmetry he found that a massive particle with a momentum $p = mv$ (v is the velocity of the particle and m its mass) is equivalent, by its interactions with matter, to a light wave with a wavelength equals to $\lambda = h/mv$, which is another form of Planck's famous equation, $E = h\nu$ (where ν is equals to $\lambda = c/\nu$). In other words, this implies that matter is another form of light.

A few years later, in 1928, Paul Dirac realized something even more incredible. He showed that the wave function of a massive particle, that is, its mathematical expression in QM, is consistent with Einstein's SR (which was already found to be true for light) if and only if to each matter particle there is an anti-matter particle, such that when they interact together, matter transforms into light (this is known as annihilation). As it turned out, photons are their own antiparticles, which means that two photons could also transform into mass (a process called pair production). Together, these two discoveries implies that light and matter are the same, explaining why photons in GR, although they do not have a mass, follow geodesics (the probability of interactions of photons with matter would be nil otherwise).

Photons have another important property relevant for the Big Bang singularity hypothesis, which is that they do not have an history. In Minkowski's spacetime diagram of SR,[29] all interactions happen within the causal cone limited by the velocity of light and there is no simultaneity of point events in different reference frames (RFs). The absence of simultaneity implies that a geometrical (topological) correction must be applied to determine the distances in space and time, Δx and Δt, as measured in different RFs. For

[29] Herman Minkowski was the old professor of Einstein in Göttigen, who showed him using a spacetime diagram how to interpret SR in geometrical terms. This was an important step towards realizing gravity is the curvature of spacetime in GR.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

example, if I estimated the Big Bang happened at a specific moment Δt in my past, an observer in another RF moving at a different constant velocity than mine would disagree because his measurements would indicate the Big Bang happened further in the past, $\Delta t' > \Delta t$. This is the time-dilation effect: "moving clocks run slow" (French, 1968). By moving clocks, one must understand that I considered my system at rest compared to the other observer. But this is purely relative, this effect being symmetric, which means that which observer is in the "faster" RF is irrelevant, the difference in measurements being inverted. However, the dilation time effect is the same, tending to infinity as the velocity of the "fastest system" approaches the velocity of light. This implies that if the other "observer" is a photon, the age of the Big Bang becomes infinite, or rather, photons do not perceive a beginning to the universe. In other words, photons do not have an history.

But there is a catch, which is that there is no way for an observer with a mass to accelerate at the velocity of light, implying that photons in any RF are always the fastest. The symmetry of SR is apparently broken in their case, such that we cannot apply the topological transformation to them. However, the symmetry can be reestablished assuming photons are entangled with their antiparticles, which according to Richard Feynman are photons travelling back in time. Consequently, the fact that there is an antiparticle for the photon not only reinforces the idea that matter and light are the same, as demonstrated by Dirac, but also reinstates the symmetry in SR. In terms of time-dilation and space-contraction, therefore, in the RF of photons time comes to a halt and space shrink to a point. The RF of photons is a physical state that merges eternity with instantaneity, something we can describe as an eternal instant. Light is really a weird form of matter-energy. This is a non-conservative fluid because it is very easy to produce and destroy flows of photons, but, unless they are destroyed by interactions, once photons exist, they are eternal.

Now, putting everything together, first we saw that because information is destroyed, the Big Bang singularity is equivalent to the Big Crunch singularity, which is equivalent to a BH having the mass of the universe. Consequently, this BH must have had a horizon,[30] where matter-energy existed under the form of light since this is the only physical state of baryonic matter consistent with its horizon. But light does not have a mass, so how can the singularity formed in the first place? Because information is not conserved, one might suggest it came from a previous universe. However, this solution seems tautological, because the only part being "observed" would be the end of the universe, the Big Crunch, which also presupposes a Big Bang at its beginning.[31]

One way to break the tautology is to assume the Big Bang emerged from a state of matter-energy that always existed. This could easily be light since this is the only form of matter-energy that we know is eternal. Moreover, in QM there are rules that stipulate that a pure field of photons in a state of high-density matter-energy consistent with the curvature of spacetime of a SMBH having the mass of the universe, would not be stable but would spontaneously transform into mass (Álvarez Domínguez et al., 2024). This suggests that the common primordial substance proposed by Thales that transformed into everything is light.[32]

Therefore, one could imagine a quantum field of photons (in entanglement)[33] has produced spontaneously, in an eternal instant, all the masses of the universe from which emerged a curved spacetime (gravity) that triggered the expansion of the universe, with a topology (connections between events) equivalent to a BH (or a White Hole), which is the Big Bang. Consequently, the fact matter was created from light would explain why baryonic matter is tightly coupled to gravity.

7. Conclusion

In the first book of the Hebrew Bible,[34] Genesis, the first three verses go this way: [1] In the beginning God created the heavens and the earth; [2] Now the earth was unformed and void, and darkness was upon the face of the deep; and the spirit of God hovered over the face of the waters [3] And God said: "Let there be light." And there was light." Light was the third things God created. However,

[30] This is the naked singularity conjecture proposed by Roger Penrose: singularities are always hidden behind an event horizon.
[31] The Big Crunch solution was eliminated by observations, because the mass of the universe, including DM, is too small for the universe to collapse.
[32] An alternative is the universe formed from nothing, a quantum vacuum, but which is not a common form of matter-spacetime while light is.
[33] Entanglement would explain the black body of the CMB and the high entropy of the universe without the need for inflation (I will not explain it here).
[34] Bible, King James version.

Número Especial "30 Aniversario del Departamento de Astronomía"
ISSN 2007-672X
Universidad de Guanajuato

within the Big Bang singularity hypothesis exposed in this essay, light is an eternal form of matter-energy and did not need to be created; so "close but no cigar". On the other hand, in the Rigveda one finds another image: [10.121] Hiranyagarbha existed before the creation, as the source of the creation of the Universe,[35] where hiranya translates as golden or radiant and garbha to filled or womb. This looks strangely similar to eternal light created the world.

Where one might see contradictions between modern science and ancient religions or philosophies, and fragmented knowledge in space and time, I see unity and continuity in the collective consciousness.[36] The different views about the origin of the universe all looks similar. How can that be possible? Actually, there could be a simple reason for this. Although human civilizations change at a very fast rate, the brain evolves much less rapidly, having reached its present form in humans 35,000 years ago (Neubauer et al., 2018). This implies that although the social context has changed enormously our perception of reality did not, being mostly the same.

Consequently, it makes sense to end this essay by citing the wisdom of the ancients. In his book, *About the Nature of Things* ("De Rerum Natura"), the Roman poet and philosopher Lucretius (first century BCE) tells us that "The purpose of science is to liberate humans from the arbitrary of chaos, confirming the place of humanity in the cosmos, which is the beautiful order." This is done naturally by the brain developing reason, as a sixth sense, at the basis of the development of the scientific method. On the other hand, in Buddhist teachings, the "sixth sense" is defined as something more personal, "a cognitive sense that processes complex emotional and mental content, contributing to our sense of self and perception of the world." Now, this is pretty close to how neurologists explain consciousness (Dehaene, 2014). Within the present context, therefore, this suggests that science main purpose in our society would be to expand our consciousness through reason.

Three lessons emerge from 2,600 years of cosmology. 1- the link between science and democracy is not coincidental because only in a democratic society can science find the freedom necessary to fulfill its role, which is

[35] Wikipedia.org/wiki/Hindu_cosmology (2025)

[36] The continuity comes from the history of neurons, a community in each human of billions individual cells.

ISSN 2007-672X

to increase our individual and collective consciousness; and you are free only as long as you can act according to your conscience. 2- the universe does not have a human semblance and consequently what sense we make of it only means something to us; the purpose of science is not to solve the "mystery of reality" but to help us adapt to reality. The last one is possibly the most difficult to grasp: 3- the Big Bang is not just a physical event that happened in the past but an event that is now happening; physically, the Big Bang, the eternal instant, is the present.

Acknowledgements

I would like to thank the University of Guanajuato who allowed me to teach and do research freely these last 25 years. I would also like to thank all my students who let me develop my ideas in astrophysics and cosmology, about "Life, the Universe and Everything". More specifically, I thank my present PhD student Paulina Alejandra Roco Avilez for suggesting light could have been the primordial form taken by matter prior to the Big Bang. Finally, I thank an anonymous reviewer for her/his profound philosophical comments and practical suggestions that helped me improve the quality of my text.

Bibliography

Almheiri, A., Marolf, D., Polchinski, J., Sully, J. (2013). Black Holes: Complementarity or Firewalls? *Journal of High Energy Physics*, vol. 2013, Art. no. 62 Springer.

Álvarez-Domínguez, Á., Garay, L. J., Martín-Martínez, E., and Polo-Gómez, J. (2024). No Black Holes from Light, *Physical Review Letters*, vol. 133, no. 4, Art. no. 041401, APS.

Cottingham, W. N. & Greenwood, D. A. (1998). *An Introduction to the Standard Model of Particles*. Cambridge University Press.

Coziol, R. (2018). Sobre la naturaleza de la matemática y su papel en la ciencia y la sociedad. *Entretextos*, 10(30), 1–16.

Cutiva-Alvarez, K. A., Coziol, R., Torres-Papaqui, J. P. (2023). Probing the rapid formation of black holes and their Galaxy hosts in QSOs. *Monthly Notices of the Royal Astronomical Society*, vol. 521, no. 2, pp. 3058–3076, 2023, OUP.

Dehaene, S. (2014), *Consciousness and the Brain: Deciphering How the Brain Codes our thoughts*. Penguin Books.

ISSN 2007-672X
Universidad de Guanajuato

d'Espagnat, B. (2006). *On physics and philosophy*. Princeton University Press.

Eagleman, D. & Downar, J. (2016), *Brain and behavior: a cognitive neuroscience perspective*. Oxford University press.

Edwards, P. (Ed.) (1967). *The encyclopedia of philosophy*. Macmillan and Free Press.

Flower, M. A. (2008). *The Seer in Ancient Greece*, Berkeley: University of California Press

French, A. P. (1968). *Special Relativity*, W. W. Norton & Company.

Grant, E. (1996). *The foundations of modern science in the Middle Age; their religious, institutional and intellectual contexts*. Cambridge University Press.

Hawking, S. (1988). *A brief history of time*. Bantam Books.

Hansson, J. (2014), On the Origin of Elementary Particle Masses, *Progress in Physics*, vol. 10, no. 2, pp. 71–73.

Kragh, H. (2019). Max Weinstein: Physics, Philosophy, Pandeism. *arXiv e-prints*, Art. no. arXiv:1901.11299, 2019.

Lemaître, G. (1931). The Evolution of the Universe: Discussion. *Nature*, (128), p. 704.

Lloyd, G. E. R. (1970). *Early Greek science: Thales to Aristotle*. W. W. Norton & Co.

Lloyd, G. E. R. (1973). Greek science after Aristotle. *W. W. Norton & Co*.

Mechon (s.f.). *Genesis, Chapter 1*. https://mechon-mamre.org/e/et/et0101.htm

Mapson, K. (Ed.). (2017). *Pandeism, an anthology*. Iff Books, CPI Group ltd.

Misiaszek, M. and Rossi, N. (2024). Direct Detection of Dark Matter: A Critical Review", *Symmetry*, vol. 16, no. 2, Art. no. 201.

Neubauer, S., Hublin, J.-J. & Gunz, P. (2018). The evolution of modern human brain shape. *Science Advances*, vol. 4, no. 1, Art. no. eaao5961.

Ober, J. (2008). I besieged that man: Democracy's revolutionary start. *Origins of Democracy in ancient Greece*. Chap. 4. University of California Press.

Omnès, R. (1994). *The interpretation of quantum mechanics*. Princeton University Press.

Padmanabhan, T. (1993). *Structure Formation in the Universe*. 1993, Cambridge University Press.

Peters, F. E. (1967). Greek philosophical terms: A historical Lexicon. New York University Press.

Piaget, J. (1950). *Introduction à l'épistémologie génétique: Tome 1, La pensée Mathématique. Tome 2, La pensée physique*. Presses universitaires de France.

Planck Collaboration (2017). Planck intermediate results. LI. Features in the cosmic microwave background temperature power spectrum and shifts in cosmological parameters. *Astronomy and Astrophysics*, vol. 607, Art. no. A95, EDP.

Raaflaub, K. A., Ober, J. & Wallace, R. W. (Eds.) (2008), *Origins of Democracy in ancient Greece*. University of California Press.

Raaflaub, K. A. (2008), Introduction, *Origins of Democracy in ancient Greece*. Chap. 1, University of California Press.

Raaflaub, K. A. & Wallace, R. W. (2008), "People's power" and egalitarian trends in archaic Greece. *Origins of Democracy in ancient Greece*. Chap. 2, University of California Press.

Riess, A. G. et al. (1998). Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant. *The Astronomical Journal*. 116 (3): 1009–1038.

Russo, L. (1996). *The forgotten revolution: how science was born in 300 BC and why it had to be reborn*. Springer

Terashima, H. (2000). Entanglement entropy of the black hole horizon, *Physical Review D*, vol. 61, no. 10, Art. no. 104016, APS, 2000.

Torres-Papaqui, J. P., Coziol, R., Robleto-Orús, A. C., Cutiva-Alvarez, K. A., & Roco-Avilez, P. (2024). The Role of Active Galactic Nucleus Winds in Galaxy Formation: Connecting AGN Outflows at Low Redshifts to the Formation/Evolution of Their Host Galaxies. *The Astronomical Journal*, vol. 168, no. 1, Art. no. 37, IOP.

Wikipedia (2025). *Hiranyagarbha*. https://en.wikipedia.org/wiki/Hiranyagarbha

Wald, R. M. (1984), *General Relativity*, The University of Chicago Press.

Wallace, R. W. (2008). Revolution and a new order in Solonian Athens. *Origins of Democracy in ancient Greece*. Chap. 3, University of California Press.