STUDY TO DEVELOP A SCIENTIFIC NARRATIVE TO ILLUSTRATE THE FATE OF THE UNIVERSE WITH THE HELP OF MODERN ASTROPHYSICS AND QUANTUM COSMOLOGY

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Abstract

Astrophysicists model the lifecycles of stars, perceiving that in the distant future, no new stars will form, leading to a dark universe. Astrophysics suggests the universe will likely end in a Heat Death or Big Freeze, and that is driven by accelerating expansion from dark energy. However, modern cosmology holds that that the universe began around 13.8 billion years ago with the Big Bang, has been growing since, and is presently dominated by dark energy, causing accelerated expansion. Data from the Planck mission and other observatories suggest the universe is spatially flat and will continue expanding, supporting the Big Freeze scenario. The cosmos will become cold, dark, and empty as galaxies drift apart, stars burn out, and matter eventually breaks down. Other theoretical fates include a Big Rip or a Big Crunch. The most widely accepted scenario, driven by dark energy accelerating the universe's expansion, is that the universe will continue to expand until all stars burn out and black holes evaporate, reaching maximum entropy. However, if the universe's density were high enough, gravity could overcome the current expansion, causing the universe to stop expanding and eventually collapse back into a singular point. On the other hand, if the density of dark energy increases over time, it could become strong enough to tear galaxies, stars, planets, and eventually atoms apart. Again, a theory suggesting a cyclical scenario where a Big Crunch is followed by a new Big Bang, implying a series of universes. Actually, the future of the universe is still a subject of research, with its final state depending heavily on the precise nature of dark energy and the total amount of matter (dark and baryonic) in the cosmos. This is an investigative study to illustrate a probable scenario of the fate of the universe based on modern astrophysics and cosmology.

Keywords. Astrophysics, cosmos, WUM, BBM, dark energy, black hole, Big Freeze, Big Crunch

1. Introduction

Modern Astrophysics is the branch of science that uses physics and chemistry to understand the formation, evolution, and demise of stars, planets, galaxies, nebulae, and other cosmic objects.[1] Unlike classical astronomy, which focuses on the positions and motions of celestial bodies, astrophysics seeks to understand their physical nature—what they are and how they work.[2] The field of Astrophysics is broad, encompassing phenomena from tiny subatomic particles to the largest cosmic structures. Cosmology, a key branch of Astrophysics, studies the universe's origin and development, including the Big Bang, dark matter, and dark energy.[3] Stellar Astrophysics focuses on the life cycles of stars, from their formation in nebulae to their end states as white dwarfs, neutron stars, or black holes. Galactic Astrophysics explores the structure and evolution of our Milky Way and other galaxies. Meanwhile, High-Energy Astrophysics investigates extreme phenomena such as quasars, gamma-ray bursts, and active galactic nuclei.[4]

Quantum cosmology is the attempt in theoretical physics to develop a quantum theory of the universe.[5] This approach seeks to address open questions in classical physical cosmology, particularly those related to the universe's early phases.[6] Classical cosmology is based on Albert Einstein's general theory of relativity (GTR or simply GR), which describes the evolution of the universe very well, as long as you do not approach the Big Bang. It is the gravitational singularity and the Planck time where the theory of relativity fails to provide what must be demanded of a final theory of space and time. Therefore, a theory is needed that integrates relativity and quantum theory.[7] Such an approach is attempted, for instance, in loop quantum cosmology, loop quantum gravity, string theory,

[1] Zeilik, M. and Gegory, S.A. (1998) Introductory Astronomy and Astrophysics. 4th Edition, Saunders College Publishing, Philadelphia, accessed on 11 Mar 2026

[2] Keeler, James E. (November 1897). "The Importance of Astrophysical Research and the Relation of Astrophysics to the Other Physical Sciences". The Astrophysical Journal. 6 (4): 271–288, doi:10.1086/140401, accessed on 11 Mar 2026

[3] https://www.cambridge.org/highereducation/books/an-introduction-to-modern-astrophysics/140DDF8A480C3841DCCD76D66984D858/contents/351D92F23E4D4016D6261254E763B10E, accessed on 11 Mar 2026

[4] Maoz, Dan (2016). Astrophysics in a Nutshell. Princeton University Press. p. 272. ISBN 978-1400881178, accessed on 11 Mar 2026

[5] Bojowald, Martin (2015). "Quantum cosmology: A review". Reports on Progress in Physics, 78 (2): 023901. arXiv:1501.04899, doi:10.1088/0034-4885/78/2/023901. PMID 25582917. S2CID 18463042, accessed on 11 Mar 2026

[6] Chiou, Dah-Wei (2015). "Loop quantum gravity". International Journal of Modern Physics D. 24 (1): 1530005–1530331. arXiv:1412.4362, doi:10.1142/S0218271815300050. S2CID 16655619, accessed on 11 Mar 2026

[7] Stephen Hawking wrote 1999: So what the singularity theorems are really telling us, is that the universe had a quantum origin, and that we need a theory of quantum cosmology, if we are to predict the present state of the universe."Quantum Cosmology, M-theory and the Anthropic Principle – Stephen Hawking". Archived from the original on 2015-02-14. Retrieved 2015-02-14, accessed on 11 Mar 2026

and causal set theory.[8] In quantum cosmology, the universe is treated as a wave function instead of classical spacetime.[9] However, the most likely long-term fate of the universe is Heat Death, in which expansion continues, leaving a cold, dark, and empty universe.

Because full gravity is complex, investigations that avoid symmetry assumptions or perturbative methods typically address conceptual issues. As mentioned earlier, cosmology is unique in physics because no external observer can exist. This fact affects how we interpret observations classically, but its significance is clearer in quantum cosmology. Traditional interpretations of quantum mechanics often depend on external observers, making them unsuitable for cosmological scenarios.[10] Quantum cosmology involves studying the universe as a whole as a quantum system. It encompasses two main challenges. The first concerns developing a quantum version of the universe's dynamics, particularly examining the quantum features of the simplified dynamical systems, assuming the universe is homogeneous. Classical models, such as the Friedmann-Robertson-Walker model, are vital in cosmology and are thought to describe the universe's large-scale structure accurately. Quantizing these models is valuable for several reasons: it offers a simplified setting to explore conceptual issues in Quantum Gravity (QG) and test potential solutions, and it provides a means to investigate what a quantum theory of gravity might reveal about the physics near and at the Big Bang, where quantum gravitational effects are expected to be significantly dominant.

The advent of Einstein's general theory of relativity revitalized interest in and research on cosmology, the study of the universe on its largest scale. Under Newtonian theory, cosmology primarily focused on one question: how matter is spread out in an infinite, Euclidean space. Einstein's theory, however, significantly expanded this question. Cosmologists now had to consider numerous possible matter distributions, geometries, and dynamics for each. All these possibilities were linked through Einstein's gravitational field equations, which determined which matter arrangements could correspond with specific geometries and how the entire system might change over time.[11] Understanding the structure and evolution of the universe comes through Nuclear Physics and the Physics of Ionizing Radiation. These fields explain how matter forms, how stars produce energy, and how elements are synthesized over time. By analyzing the behavior of protons and neutrons in atomic nuclei and examining the radiation emitted during stellar processes, scientists can piece together the universe's history from the Big Bang to today and make predictions about its final fate.[12] The formation and development of stars, gravitational collapse, neutron stars and black holes, the structure and formation of galaxies, the expansion of the universe, the very early universe, primordial and stellar nucleosynthesis, and the unification of interactions in unitary field theories are discussed in those two parts of Physics.[13]

The end of the universe remains a complex issue in both science and philosophy, with no definitive answer. Scientists have proposed various hypotheses about the ultimate fate of the universe, including Big Rip, Big Crunch, and Heat Death. All those possibilities will discuss in this article later. Regardless of where the universe ultimately leads, it has no direct bearing on the purpose of biological evolution. All this is certainly very beautiful and beneficial from the point of view of our knowledge of nature, the universe and the possibilities of technological applications for the benefit of enlightening life here on Earth and possibly its expansion into space.[14] However, for fair neutrality, it is probably worth mentioning the other side of the coin. Humans are still deficient in ample knowledge. Willingly admit what we do not know about the universe and the nature of matter until now. Humans can pose many questions about the universe and the physical nature of matter that our scientific knowledge cannot yet answer. And the number of questions is certainly incomplete. A few primary but important questions need to be answered. Astrophysics in general and quantum cosmology in particular will continue to try to find the answers to those questions. Author will try to illustrate the whole scenario and narrate the story of creation and ultimate fate of universe in light of modern concept and advancement of Astro Physics.

a. How did the universe create? We have no idea yet about the "mechanism" of the origin or creation of the universe. It is only known that in the beginning the universe was very hot and dense. And we know most of the mechanisms of how it gradually cooled and transformed its material content to its current cold state with a very low average material content. This is supported by astronomical observations and laboratory experiments on particle accelerators.[15] However, we cannot say anything about the very beginnings in the first approximately 10^{-43} to 10^{-36} seconds.

b. What is the core of gravity? The classical Newtonian concept of gravity, which works well in practice, has been generalized in the general theory of relativity.

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[8] Klebanov, Igor & Maldacena, Juan (2009). "Solving Quantum Field Theories via Curved Spacetimes", Physics Today. 62 (1): 28, doi:10.1063/1.3074260, accessed on 11 Mar 2026

[9] He, Dongshan; Gao, Dongfeng; Cai, Qing-yu (2014). "Spontaneous creation of the universe from nothing". Physical Review: D. 89 (8) 083510, doi:10.1103/PhysRevD.89.083510. S2CID 118371273, accessed on 11 Mar 2026

[10] https://www.researchgate.net/publication/358918610_Lectures_on_classical_and_quantum_cosmology, accessed on 11 Mar 2026

[11] https://sites.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/relativistic_cosmology/index.html, accessed on 11 Mar 2026

[12] Mayer, Maria Goeppert (1949). "On Closed Shells in Nuclei. II". Physical Review. 75 (12): 1969–1970, doi:10.1103/PhysRev.75.1969, accessed on 12 Mar 2026

[13] Rugh, S. and Zinkernagel, H. (2001) Studies in History and Philosophy of Modern Physics, 33, 663-705,

[14] Feynman, R.P. (2011) Six Easy Pieces: Essentials of Physics by Its Most Brilliant Teacher. Basic Books, New York.

[15] Chow, T.L. (2008) Gravity, Black Holes, and the Very Early Universe: An Introduction to General Relativity and Cosmology. Springer, New York.

And that works perfectly in the entire universe, and describes it as curved spacetime. Again, the curvature of spacetime caused by mass and energy, rather than just a traditional force acting at a distance.[16] It dictates that objects (and light) follow paths through this warped geometry, bringing them together. While weak on atomic scales, it shapes the large-scale universe. However, the reason why matter curves spacetime in its surroundings is not known. So far, we do not know what gravity is, only how it works. Perhaps the future complete unitary field theory will answer this, but from the opposite side: how do "condensations" in the geometry of spacetime create what appears to us as matter?

c. Why is there a huge amount of matter and almost no antimatter in the universe? According to the laws of the symmetrical formation of particles and antiparticles, at the beginning of the universe both should have been created in the same ratio (or 1:1). And that would lead to complete annihilation and the universe would contain only radiation. The observable universe is dominated by matter, with a tiny, crucial asymmetry, as antimatter is effectively absent in large quantities. It is estimated that for every billion antimatter particles, a billion-and-one matter particles were created, leaving a ratio of roughly 1 leftover matter particle for every 10^9 annihilation events.[17] All the matter that exists in the universe resulted from this slight excess after annihilation. We do not know for sure why this asymmetry of matter and antimatter occurred.[18]

d. What is the internal structure of the elementary particles of the microworld? According to the Standard Model of particle physics, true elementary particles—such as quarks, leptons (including electrons and neutrinos), and bosons—do not have an internal structure. They are considered point-like, zero-dimensional objects, meaning they are not made of smaller components and cannot be broken down further. Direct investigation of the inside of particles of the microworld is not possible. This is possible only by the destructive method of mutual collisions of particles in accelerators, while studying new particles that fly out. In this way, it was possible to reveal the internal quark-gluon structure of hadrons, especially protons and neutrons. For other hadrons - pions, kaons, hyperons - their quark structure is assumed in a model, based on analogy. For leptons, such as electrons or muons, no internal structure has been discovered, they are considered to be "point". Their observed properties, such as spin or magnetic moment, are considered to be their inherent characteristics, without proper explanation. So, we have to admit that we do not yet know the nature of most of the particles that make up our world. This explanation is expected; probably in the more distant future, from unitary field theories.

e. What is the ultimate fate of the universe? Based on existing observational evidence, determining the universe's future and evolution has become a legitimate cosmological question, beyond the largely untestable constraints of mythological or theological beliefs. Several potential futures have been proposed by various scientific hypotheses, including that the universe could have existed for a finite or infinite amount of time, and attempts to explain the manner and circumstances of its origin. Observations by Edwin Hubble during the 1930s–1950s revealed that galaxies were moving away from each other, leading to the currently accepted Big Bang theory. This implies that the universe began very dense approximately 13.787 billion years ago and has been expanding and, on average, decreasing in density ever since.[19] Most cosmologists agree that the universe is flat in shape and will keep expanding indefinitely. To understand its origin and final destiny, one must consider factors such as the average motion of galaxies, the overall shape and structure of the universe, and the quantities of dark matter and dark energy present contains.[20,21]

2. Historical Chronology and Literature Review

2.1 Incomprehensible Incomprehensibility of Quantum Physics

In contemporary physics, there are several findings, theories, and hypotheses that deal with phenomena in the deep microworld or very distant universe - in areas inaccessible to our direct observation and experience. In attempts to understand and explain them, ideas and concepts appear that are difficult for our "common sense". And that has developed from observing the surrounding macro world to understand. One such area is the special and especially general theory of relativity. And that is sometimes said to be "incomprehensibly-comprehensible", to which this entire book of ours ", Gravity, Black Holes and the Physics of Spacetime", is essentially dedicated. Even less understandable for us is quantum physics, and that is sometimes said to be ‘incomprehensibly incomprehensible.’ These hidden aspects are discussed from various perspectives in the branch of ‘Nuclear Physics and Physics of Ionising Radiation’. Astro Physics in general and Quantum Physics in particular are extremely successful for investigating the structure of matter, as well as in applications, but their fundamental inner nature is hidden from our understanding by a mystery.

2.2 World Universe Model (WUM)

In 1937, Paul Dirac introduced the large number hypothesis and the hypothesis of a 'variable gravitational constant,' later adding the idea of ‘continuous creation of matter’ in the universe. The Hypersphere

[16] Einstein, A. (1905) Annalen der Physik, 17, 891-921, accessed on 12 Mar 2026

[17] Segal, I. E. (December 1993). "Geometric derivation of the chronometric redshift". Proceedings of the National Academy of Sciences USA. 90 (23): 11114–11116, doi:10.1073/pnas.90.23.11114

[18] https://home.cern/science/physics/matter-antimatter-asymmetry-problem, accessed on 12 Mar 2026

[19] Wollack, Edward J. (10 December 2010). "Cosmology: The Study of the Universe". Universe 101: Big Bang Theory. NASA. Archived from the original, accessed on 12 Mar 2026

[20] https://science.nasa.gov/dark-matter/, accessed on 12 Mar 2026

[21] Tegmark, Max (2014). Our Mathematical Universe: My Quest for the Ultimate Nature of Reality (1 ed.). Knopf. ISBN 978-0-307-59980-3, accessed on 12 Mar 2026

World Universe Model (WUM) builds on these concepts but proposes a different mechanism for matter creation. This model suggests that the universe is a 3D hypersphere surface expanding into a fourth spatial dimension, maintaining a constant energy density equal to the critical energy density. [22] WUM suggests that dark matter particles (DMPs) are continuously created from the 4D nucleus, thereby producing luminous matter via annihilation, and provides a framework for calculating cosmological parameters that match observations, such as the Hubble parameter and the cosmic microwave background temperature.[23]

However, WUM is a natural extension of classical physics. It is proposed as an alternative to the dominant Big Bang Model (BBM), which is based on General Relativity (GR). WUM and BBM are fundamentally different models. First, instead of the initial singularity with infinite energy density and rapid spacetime expansion (Inflation) in BBM, WUM suggests there was a fluctuation- specifically, a 4D nucleus of the universe with an extrapolated radius equal to the basic size unit of ' a'- existing in an eternal universe with finite energy density (about 10^4 times less than nuclear density) and a finite expansion of the nucleus in its fourth spatial dimension at the speed of light, which is the gravitodynamic constant. Second, while BBM implies a virtually infinite, homogeneous, and isotropic universe around the initial singularity, WUM describes a three-dimensional, finite, yet unbounded universe and that is an hypersphere of a 4D nucleus- featuring a patchwork of luminous superclusters (over≧103), which formed in various locations at different cosmological times. The universe's medium, composed of protons, electrons, photons, neutrinos, and dark matter particles, is homogeneous and isotropic, but the distribution of macro-objects is spatially inhomogeneous, anisotropic, and varies over time non-simultaneously.[24]

The strongest observational evidence supporting the validity of WUM includes: first, the Microwave Background Radiation and Intergalactic Plasma indicate the presence of a Medium. Second, the Laniakea Supercluster, with a binding mass of approximately 10^17 M⊙, contains the Milky Way (MW) and about 105 nearby galaxies, which did not originate from the Initial Singularity. Third, the MW is gravitationally bound to the Virgo Supercluster (VS) and possesses an Orbital Angular Momentum that greatly surpasses its rotational angular momentum. [25] Furthermore, the mass-to-light ratio of VS is about 300 times greater than the Solar ratio. Similar ratios are observed in other superclusters, supporting the presence of significant Dark Matter in the universe. Additionally, astronomers have identified the most distant galaxy, HD1, approximately 13.5 billion light-years away. WUM forecasts the discovery of galaxies at a distance of around 13.8 billion light-years. The three main pillars of the universe are Dark Matter, the Medium of the universe, and Angular Momentum WUM.[26]

Today, many researchers feel a sense of stagnation in Physics. In some ways, the current situation mirrors the end of the 19th century, when the prevailing view was that Physics was nearly complete. Discoveries in special and general relativity, quantum physics, and elementary particles challenged that belief, sparking a century-long era of progress in physics. The brilliant minds of Einstein, Planck, Bohr, Dirac, Heisenberg, and Schrödinger led to the development of groundbreaking theories based on limited experimental evidence.[27] During the 20th century, their theories were confirmed and expanded through new experimental data. Today, the pendulum might have swung too far, with all results needing to align within the current framework. Adjustments to the frameworks are made as needed, and especially inconvenient results may even be discarded at times.[28] It might be the right moment to suggest new fundamental models that are simpler than existing ones, and also to explore new research fields.

WUM is suggested as an alternative to the dominant BBM. In BBM, the universe's beginning links to the Initial Singularity—an infinitely dense point—and to Cosmological Inflation, which describes a rapid exponential expansion of spacetime. This expansion, occurring at nearly infinite speed in the early universe, stretched the universe to about 93 billion light-years across in less than 10^{-32} seconds. The total size of the universe remains unknown and could be of infinite extent.[29] The initial singularity is a gravitational singularity anticipated by General Relativity to have existed before the Big Bang (BB), containing all the energy and spacetime universe. [30] From a physical perspective, the presence of a mathematical singularity is a flaw in any theory. It indicates that the model fails to account for

[22] D. Valev (2019). "Evidence of Dirac large numbers hypothesis" (PDF). Proceedings of the Romanian Academy. 20 (+4): 361–368, accessed on 12 Mar 2026

[23] Poulin, V., Smith, T.L., Karwal, T. and Kamionkowski, M. (2019) Early Dark Energy Can Resolve the Hubble Tension. Physical Review Letters, 122, Article ID: 221301, accessed on 12 Mar 2026

[24] https://phas.ubc.ca/quantum-gravity-and-cosmology, accessed on 12 Mar 2026

[25] Netchitailo, V. (2017) Mathematical Overview of Hypersphere World-Universe Model. Journal of High Energy Physics, Gravitation and Cosmology, 3, 415-437, accessed on 12 Mar 2026

[26] https://www.scirp.org/journal/paperinformation?paperid=120558, accessed on 12 Mar 2026

[27] Case, Stephen (2015). "'Land-marks of the universe': John Herschel against the background of positional astronomy". Annals of Science. 72 (4): 417–434, doi:10.1080/00033790.2015.1034588, accessed on 12 Mar 2026

[28] Hearnshaw, J.B. (1986). The analysis of starlight. Cambridge: Cambridge University Press. pp. 23–29. ISBN 978-0-521-39916-6, accessed on 12 Mar 2026

[29] Hetherington, Norriss S., (2015), McCray, W. Patrick. Weart, Spencer R. (ed.). Spectroscopy and the Birth of Astrophysics. American Institute of Physics, Center for the History of Physics. Archived from the original on September 7, 2015, accessed on 12 Mar 2026

[30] Ricard, Y. (2007) 7.02—Physics of Mantle Convection. In: Bercovici, D. and Schubert, G., Eds., Treatise on Geophysics: Mantle Dynamics, Vol. 7, Elsevier Science, Amsterdam, 31-87, accessed on 12 Mar 2026

certain important physical phenomena that would prevent such a situation from occurring singularity.[31]

However, preventing the initial singularity in BBM is not possible. A finite universe likely began through a different process—a fluctuation in the eternal universe at a finite size and energy density. This fluctuation's size can grow at a finite rate, eliminating the need for cosmological inflation. Nonetheless, this raises questions about the mechanism of continuous matter creation. In 1964, F. Hoyle and J. V. Narlikar proposed explaining new matter's appearance via a "Creation field" or "C-field." In 1974, P. Dirac discussed continuous matter creation through two mechanisms: an additive process, spreading uniformly across space, and a multiplicative process, proportional to the existing amount matter).[32] WUM adheres to the concept of continuous matter creation through an additive process but introduces a different mechanism for matter generation. The key distinctions between BBM and WUM are the presence of the Medium of the World—which includes protons, electrons, photons, neutrinos, and dark matter particles—and the source of the World's energy, the Eternal Universe.[33]

We believe that incorporating a range of hypotheses that are currently unknown or overlooked by mainstream science is essential for developing a new cosmology. Below, we will discuss hypotheses from classical physicists like Newton, Le Sage, McCullagh, Riemann, Heaviside, Tesla, Dirac, and Sakharov, and expand on them within this framework WUM.[34] The hypotheses presented are not original, nor do we claim ownership of them. Instead, we expand on existing hypotheses and introduce new ones within the WUM framework. The primary goal of the model is to unify and clarify existing results in Classical Physics into a cohesive view of a New Cosmology. Numerous findings from WUM are cited in this work without detailed explanation or justification.[35,36,37]

2.3 History of Dark Matter

The history of Dark Matter (DM) dates back to at least the mid-1800s. G. Bertone and D. Hooper offer an excellent overview of this history. In 1844, F. Bessel suggested that the proper motion of stars like Sirius and Procyon could only be explained by faint companion stars exerting gravitational influence. Two years later, in 1846, U. Le Verrier and J. C. Adams proposed the existence of a new planet to account for anomalies in Uranus's motion. Besides dark stars and planets, 19th-century astronomers also considered DM in the form of dark "nebulae". In 1877, A. Secchi wrote,'Among these studies there is the interesting probable discovery of dark masses scattered in space, whose existence was revealed thanks to the bright background on which they are projected. Until now they w ere classified as black cavities, but this explanation is highly improbable, especially after the discovery of the gaseous nature of the nebular masses.' As soon as astronomical photography was invented, scientists began to notice that stars were not evenly distributed across the sky. Dark regions were observed in dense stellar fields.[38] In 1904, Lord Kelvin was among the first to estimate the amount of dark matter in the Milky Way (MW) using a dynamical approach. His reasoning was straightforward yet impactful: if stars in the MW can be viewed as a gas of particles influenced by gravity, then one can relate the system's size to the stars' velocity dispersion. H. Poincare was intrigued by Kelvin's idea of applying the "theory of gases" to the MW's stellar system. By 1906, he explicitly mentioned "dark matter" and noted that because Kelvin's predicted velocity dispersion is roughly the same as observed, the dark matter amount was likely less than or comparable to the visible matter.[39]

Nebular Hypothesis. The most widely accepted model for the formation of the Solar System (SS) is the Nebular hypothesis, first proposed in 1734 by E. Swedenborg and further developed by I. Kant in 1755. According to this hypothesis, about 4.6 billion years ago, the SS formed from the gravitational collapse of a massive molecular cloud spanning light-years. Most of the mass concentrated at the centre, becoming the Sun, while the remaining material flattened into a protoplanetary disc from which planets and other SS bodies originated formed.[40],[41] The Nebular hypothesis is not without its critics. In his "The Wonders of Nature", V. Ferrell outlined the following counter-arguments:

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[31] J. P.Uzan (2003). "The fundamental constants and their variation, Observational status and theoretical motivations". Reviews of Modern Physics. 75 (2): 403, doi:10.1103/RevModPhys.75.403, accessed on 12 Mar 2026

[32] Dirac, P.A.M. (1974) Cosmological Models and the Large Numbers Hypothesis. Proceedings of the Royal Society of London. A338, 439, accessed on 12 Mar 2026

[33] Netchitailo, V. (2020) World-Universe Model—Alternative to Big Bang Model. Journal of High Energy Physics, Gravitation and Cosmology, 6, 133-258, accessed on 15 Mar 2026

[34] Netchitailo, V. (2020) World-Universe Model Predictions. Journal of High Energy Physics, Gravitation and Cosmology, 6, 282-297, accessed on 15 Mar 2026

[35] Netchitailo, V.S. (2013) Fundamental Parameter Q. Recommended Values of the Newtonian Parameter of Gravitation, Hubble's Parameter, Age of the World, and Temperature of the Microwave Background Radiation. viXra:1312.0179v2, Available from: https://vixra.org/abs/1312.0179, accessed on 15 Mar 2026

[36] Netchitailo, V.S. (2015) 5D World-Universe Model. Multicomponent Dark Matter. Journal of High Energy Physics, Gravitation and Cosmology, 1, 55-71, accessed on 15 Mar 2026

[37] Netchitailo, V.S. (2016) 5D World-Universe Model. Neutrinos. The World. Journal of High Energy Physics, Gravitation and Cosmology, 2, 1-18, accessed on 15 Mar 2026

[38] Netchitailo, V.S. (2022) Unidentified Infrared Discrete Emission Bands. Journal of High Energy Physics, Gravitation and Cosmology, 8, 243-253, accessed on 15 Mar 2026

[39] Netchitailo, V.S. (2019) High-Energy Atmospheric Physics: Ball Lightning. Journal of High Energy Physics, Gravitation and Cosmology, 5, 360-374, accessed on 14 Mar 2026

[40] Netchitailo, V.S. (2016) Overview of Hypersphere World-Universe Model. Journal of High Energy Physics, Gravitation and Cosmology, 2, 593-632, accessed on 14 Mar 2026

[41] Netchitailo, V.S. (2019) Solar System. Angular Momentum. New Physics. Journal of High Energy Physics, Gravitation and Cosmology, 5, 112-139, accessed on 14 Mar 2026

• It contradicts the basic physical principle that gas in outer space never clumps together; it always disperses outward;

• Every planet and moon in SS possess distinct structures and features. How can each one differ if they all originated from the same nebula?

• In SS, 98 per cent of the total angular momentum is held by the planets, while an overwhelming 99.8 percent of all the mass lies with our Sun;

• Jupiter holds 60 percent of the planet's angular motion, a fact that evolutionary theory cannot explain. This unusual distribution was the main reason for the failure of the Nebular hypothesis.

• It is impossible for the Sun to transfer angular momentum to the planets. However, this transfer would be necessary if any evolutionary theories about the Solar System's origin are to hold accepted.

The Lunar Origin Fission Hypothesis was proposed by G. Darwin in 1879 to explain the origin of the Moon by rapid rotation of the Earth, on which the equatorial gravitational attraction was nearly overcome by centrifugal force.

2.3 Bing Bang Model (BBM)

Special Relativity. The principle of relativity originates from Galileo and was integrated into Newtonian physics. By the late 19th century, the discovery of electromagnetic waves prompted some physicists to propose the existence of a substance called “Aether". They believed this Aether served as the medium for wave propagation and provided an absolute reference frame for measuring speeds, which they thought were fixed and motionless relative to Earth or other fixed points. The Aether was envisioned to be elastic enough to support electromagnetic waves, which could interact with matter, yet offered no resistance to bodies moving through it.[42] The results from various experiments, including the 1887 Michelson–Morley experiment, led to the development of the theory of Special Relativity (SR), which describes the relationship between space and time. In 1905, A. Einstein formulated SR based on two postulates: (1) The laws of physics are the same in all inertial frames—which are frames of reference moving at constant velocity—and the light source must also be in that frame. (2) The speed of light in a vacuum is constant for all observers, regardless of the motion of the light source. Lorentz invariance is fundamental to SR. Einstein’s approach was to reject the concept of an “Aether” and the notion of absolute rest. In relativity, any frame moving uniformly observes the same physical laws, and the speed of light in a vacuum is always measured as c, even by different systems moving at constant velocities.

General Relativity. General Relativity (GR), introduced by A. Einstein in 1915, is a geometric theory of gravitation and a foundational framework in modern physics. It extends Special Relativity (SR) and refines Newton’s universal law of gravitation, describing gravity as a feature of four-dimensional spacetime. Einstein’s field equations are nonlinear and complex to solve, but in 1916, K. Schwarzschild derived the first exact solution—the Schwarzschild metric—paving the way for understanding the late stages of gravitational collapse and the formation of objects now known as Black Holes (BHs). In 1917, Einstein applied his theory to the universe, initiating relativistic cosmology. He assumed a static universe and added the cosmological constant to his equations to align with this presumption. By 1929, observations by Hubble and others proved the universe is expanding, a phenomenon explained by Friedmann’s 1922 solutions, which do not need a cosmological constant. Einstein later called the cosmological constant his "biggest blunder." It’s important to note that Aether was discarded in 1905 with SR, and the Friedmann equations were first derived in 1922 from Einstein’s gravitational field equations for the Friedmann–Lemaître–Robertson–Walker metric, describing a universe filled with a perfect fluid characterised by density ρ and pressure p.

Big Bang Model. The BBM framework is based on General Relativity and simplifications like space homogeneity and isotropy. The Lambda Cold Dark Matter (ΛCDM) model describes BBM by including three main components: a Cosmological constant Λ linked to dark energy, hypothesized Cold Dark Matter, and Ordinary matter.[43],[44],[45] Dark Matter: G. Bertone and D. Hooper offer a comprehensive review of dark matter alongside Big Bang model insights. Following the failures of hot dark matter, it became evident that cold dark matter better explains the patterns observed in large-scale structures. The term WIMPs, introduced by G. Steigman and M. Turner in 1984, originally encompassed all particle dark matter candidates, including axions and gravitinos. However, its definition has since narrowed to particles interacting via the weak force. By the late 1980s, it was widely accepted among astrophysicists and particle physicists that most of the universe's mass consists of cold, nonbaryonic particles, positioning cold dark matter of an unknown elementary particle as the leading paradigm. The ΛCDM model relies on six key parameters: baryon density, dark matter density, dark energy density, scalar spectral index, curvature fluctuation amplitude, and reionisation optical depth. These parameters are mostly not derived from current theories; others are set to “natural' values, such as a total density of 1.00 and negligible neutrino masses. The model can be extended to include cosmological inflation and is often called the Standard Model of Big Bang cosmology. The Four Pillars of Standard

[42] Netchitailo, V.S. (2021) Hypersphere World-Universe Model: Evolution of the World. Journal of High Energy Physics, Gravitation and Cosmology, 7, 508-530, accessed on 14 Mar 2026

[43] Netchitailo, V.S. (2020) World-Universe Model—Alternative to Big Bang Model. Journal of High Energy Physics, Gravitation and Cosmology, 6, 133-258, accessed on 14 Mar 2026

[44] Netchitailo, V.S. (2022) Decisive Role of Dark Matter in Cosmology. Journal of High Energy Physics, Gravitation and Cosmology, 8, 115-142, accessed on 14 Mar 2026

[45] Netchitailo, V.S. (2022) Hubble Tension. Journal of High Energy Physics, Gravitation and Cosmology, 8, 392-401, accessed on 14 Mar 2026

Cosmology are: universe expansion, the origin of cosmic background radiation, light-element nucleosynthesis, and galaxy and large-scale structure formation.

Expansion of the Universe. Recent evidence strongly confirms Hubble's law, indicating that a galaxy's recessional velocity v is proportional to its distance d, expressed as v=Hd, with H being Hubble's constant. Rewinding galaxy movements suggests they originate from a single point at t = 0, a cosmological Singularity characterized by infinite energy density. This highlights one of the limitations of Standard Cosmology—the Horizon problem. "Why does the universe look the same in all directions when it arises out of causally disconnected regions? This problem is most acute for the very smooth cosmic microwave background radiation". This issue was addressed by introducing Cosmological Inflation, a theory proposing an extremely rapid, exponential expansion of space in the early universe. This swift expansion enlarged the universe's linear dimensions by at least a factor of 10^26, increasing its volume by at least 10^78. The inflationary period lasted less than 10^−32 seconds after the singularity. After this epoch, the universe continued expanding but at a slower pace. L. Verde, T. Treu, and A. G. Riess summarized the 'Workshop at Kavli Institute for Theoretical Physics, July 2019'. It remains uncertain whether the observational discrepancy results from systematics or poses a significant challenge to the Standard Model.

Origin of Cosmic Background Radiation. According to BBM, approximately 380,000 years after BB, the universe's temperature dropped enough for nuclei to combine with electrons, forming neutral atoms. Consequently, photons interacted less frequently with matter, causing the universe to become transparent and leading to the creation of Microwave Background Radiation (MBR). This event, known as Decoupling, marked the moment when photons began to travel freely. These photons have continued to propagate, though they have become fainter and less energetic as the universe's expansion stretches their wavelengths. The photons present at decoupling are the same ones we observe in MBR today. So, why is MBR a perfect blackbody? WUM states that wavelength is a classical concept, whereas photons are quantum objects, which only four-momenta.[46] They do not possess specific wavelengths, by definition. Within the WUM framework, the black-body spectrum of MBR results from the thermodynamic equilibrium of photons with the Intergalactic Plasma (IGP), whose existence has been confirmed experimentally proved.

Nucleosynthesis of Light Elements. Big Bang Nucleosynthesis (BBN) describes the formation of nuclei other than hydrogen during the early universe stages. It is believed that primordial nucleosynthesis occurred roughly between 10 seconds and 20 minutes after the Big Bang, leading to the creation of most of the universe's helium, primarily as helium-4, along with small amounts of deuterium, helium-3, and a tiny fraction of lithium-7. All elements heavier than lithium were produced much later through stellar nucleosynthesis in the evolution and explosion of stars.[47] The history of BBN starts with R. Alpher's calculations in the 1940s. In the 1970s, efforts intensified to identify processes that could generate deuterium. Although the universe's deuterium concentration aligns with the Big Bang Model (BBM), it's too high for models assuming the universe is mostly protons and neutrons. Currently, the standard explanation is that non-baryonic dark matter, rather than baryons, constitutes most of the universe's mass. Modern cosmology states that lithium was synthesized in the Big Bang. However, a discrepancy exists: older stars have less lithium than expected, while some younger stars have more. M. Anders et al. reported the first measurement of the 2H (α, γ)6Li cross section at Big Bang energies, ruling out BBN lithium production as an explanation for observed 6Li. In the WUM framework, nucleosynthesis of all elements, including light ones, occurs inside dark matter cores of macro-objects during their evolution. Stellar nucleosynthesis is well understood, originating from the renowned B2FH paper. Within WUM, this theory should also consider self-annihilation of heavy dark matter fermions in macro-object cores.

Formation of Galaxies and Large-Scale Structures. The formation and evolution of galaxies can only be explained through gravity within an inflationary framework combined with dark matter and dark energy. The standard Hot Big Bang Model offers a foundation for understanding how galaxies form. Around 10,000 years after the Big Bang, the universe's temperature had decreased enough that the energy density became dominated by massive particles, overtaking the radiation and light that had previously held sway.[48] This change in the form of the main matter density meant that the gravitational forces between the massive particles could begin to take effect, so that any small perturbations in their density would grow. This highlights one of SC's shortcomings—a density fluctuation problem. The analysis shows that the Four Pillars of SC are model-dependent and insufficient to support BBM. BBM violates the law of angular momentum conservation. BBM relies on the following assumptions.

- Homogeneity and isotropy of space.
- Physical laws are invariant across all inertial frames.
- The speed of light in a vacuum remains constant for all observers.
- Photons have zero mass.
- Cold Dark Matter's existence is a key aspect of BBM.

Angular Momentum Problem. The angular momentum problem is one of the most critical problems in BBM that must be solved. Any theory of the evolution

[46] Netchitailo, V.S. (2021) Solar System. Angular Momentum. Dark Matter Reactors. Journal of High Energy Physics, Gravitation and Cosmology, 7, 1353-1372, accessed on 14 Mar 2026

[47] Netchitailo, V.S. (2021) From the Beginning of the World to the Beginning of Life on Earth. Journal of High Energy Physics, Gravitation and Cosmology, 7, 1503-1523, accessed on 14 Mar 2026

[48] Netchitailo, V.S. (2020) World-Universe Model Predictions. Journal of High Energy Physics, Gravitation and Cosmology, 6, 282-297, accessed on 14 Mar 2026

of the Universe that is not consistent with the Law of Conservation of Angular Momentum should be promptly ruled out. SC cannot answer the following questions.[49]

- Sun accounts for approximately 0.3% of the total angular momentum of SS, while about 60% is attributed to Jupiter;
- SS has an orbital angular momentum that far exceeds its rotational angular momentum;
- MW galaxy is gravitationally bound with Virgo Supercluster (VS) and has an orbital momentum, which far exceeds its rotational angular momentum;
- How did MW galaxy and SS obtain their substantial orbital angular momenta?
- To the best of our knowledge, the Standard Model does not answer these questions. WUM is the only cosmological model in existence that is consistent with this Fundamental Law.

3.5 Black Holes

Einstein's field equations for gravity in 3 + 1 dimensions spacetime are mathematically solved by BH. The Schwarzschild solution, which characterizes the gravitational field in the spherically symmetric, static, vacuum condition, is the most basic BH solution. The mass of an object that generates the same gravitational field is the only characteristic that characterizes this solution. It is now widely acknowledged that supermassive compact objects exist at galactic centers. It is commonly believed that the central mass is a Supermassive Black Hole (SBH).[50] However, there is evidence indicating the contrary. N. Hurley-Walker discovered the previously unidentified radio galaxy NGC1534 in 2013. Although it is somewhat close to Earth, it is far fainter than it should be if the core black hole was accelerating the electrons in the jets. Another possibility is that there was never a BH at all.

In 2014, L. Mersini-Houghton claimed to have shown mathematically that existing theories of BH generation are incorrect given specific assumptions regarding BH firewalls. According to her, the star loses mass due to Hawking radiation at a rate that makes it insufficiently dense to form a black hole. Outstanding 1.3 mm measurements of the radio source at the location of the supermassive black hole Sgr A* were presented by the Event Horizon Telescope (EHT) Collaboration in 2022. Sgr A* was simultaneously monitored at near-infrared and X-ray wavelengths as well as 22, 43, and 86 GHz. Astronomers published the first picture of the accretion disk surrounding Sgr A* using EHT. The EHT Collaboration asserted that Sgr A* is an SBH based on the results collected. Astronomers must provide answers to a few key questions:

- The Age of the World and the Age of MW are comparable. Methuselah, the oldest star in MW, is almost as ancient as the Earth. How might Sgr A* grow so rapidly if it is an SBH?
- Where did the purported SBH favorable spin come from?
- Their models in the "best-bet region" feature low inclinations of 30˚ and 10˚, which are at odds with the MW galaxy's disk shape and bipolar astrophysical jets—astronomical phenomena in which matter outflows are released as extended beams along the axis of rotation;
- The MW galaxy, which includes Sgr A*, has a large orbital angular momentum and is gravitationally confined by VS (Section 2.4). How was this significant orbital angular momentum acquired by the MW galaxy?
- What is the process by which the Galactic Centre emits gamma rays?

The EHT Collaboration's results can be described as follows within the context of WUM. Nonetheless, all of the acquired experimental data support the existence of the supermassive compact object composed of DMPs at MW Center. .[51]

- The dense, brilliant ring with a radius of 3.17×10^{10} m dominates the photograph. The extra gamma-ray emission from Sgr A* is caused by the relatively dim interior of the ring, which is composed of DM Fermions DMF1 (1.3 TeV) and DMF2 (9.6 GeV).
- The inside of Sgr A* continuously absorbs Dark Matter Particles (DMPs). The result of DMPs self-annihilation is Ordinary Matter. The Interior continuously re-emits it into a shell surrounding it.
- In the area of the Shell's atomic nuclei, strong gamma quants with an energy of at least 1.02 MeV generate highly concentrated electron-positron couples;
- The brilliant, dense region is made up of Ordinary Matter and Electron-Positron plasma, a compact nonthermal radio entity with a radius of 2.9×10^{10} m that produces the strongest radio emission.
- The area between 3.17×10^{10} m and 1.88×10^{12} m is filled with DM Fermions DMF3 (3.7 keV), which self-annihilate and cause X-rays from the center of MW; the enclosed mass of the Supermassive Compact Object of 4.154×10^{6} M² is the mass of the MW DM Core, which is composed of DMF1 and DMF2 with the Ordinary Matter and Electron-Positron Shell and DMF3 Shell; Sgr A* has obtained the orbital angular momenta as a result of the rotational fission of VS;
- The angle of inclination between Sgr Arotational *'s angular momentum vector and line of sight is approximately 90˚.

3. Methodology

The contemporary relativistic cosmology has already emerged from the stage of unfounded speculations and idle theorizing. So, it is no longer "mythology and has become an important part and extension of astrophysics and the natural sciences. It can give a consistent picture of the structure and evolution of the universe as a whole, and this picture is built on

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49 Netchitailo, V.S. (2021) Hypersphere World-Universe Model. Journal of High Energy Physics, Gravitation and Cosmology, 7, 915-941, accessed on 14 Mar 2026

50 Netchitailo, V.S. (2022) Center of Milky Way Galaxy. Journal of High Energy Physics, Gravitation and Cosmology, 8, 657-676, accessed on 14 Mar 2026

51 Ludwig, G.O. (2021) Galactic Rotation Curve and Dark Matter According to Gravitomagnetism. The European Physical Journal C, 81, Article No: 186, accessed on 14 Mar 2026

the proven laws of physics , and its predictions agree well with the observations. Let us therefore consider some general aspects of the relationship between cosmology and physics.[52] The methodology of physical cognition consists of three main elements like observation, experiment and theory. In the early stages of the development of physics, the first of these methods like observation played a decisive role. For example, let us recall only Newton's law of gravitation based on astronomically observed Kepler's laws of planetary motion. However, Newton was already doing mechanical experiments that resulted in his three basic laws of motion. With the further development of physics, accompanied by a profound improvement in experimental techniques. The role of observation declined rapidly, especially since the early 20th century, when for the reveal the laws of the microstructure of matter.

It was necessary to conduct increasingly sophisticated and costly experiments.[53] It is powerful yet accurate accelerators in conjunction with subtle detection electronics. The method of observation seemed already entirely historic and the relationship between physics and astronomy is one-way: physics in its laboratories reveals the fundamental laws of nature, and that allow to explain and predict astronomically observed phenomena in space. In recent years, however, this relationship has begun to change. Indeed, contemporary relativistic cosmology has shown that the universe, in its very hot and dense initial phase, was a kind of unique "laboratory" of high-energy physics, in which the processes took place intensively, that we are now trying to observe with the greatest effort on massive accelerators, and even those phenomena whose laboratory implementation is not hopeful in the foreseeable future.[54] The cosmological consequences of current theories of elementary particles especially unitary theories have proven to be so clear and obvious, that their confrontation with astronomical observations distant universe makes it possible to set strong constraints on the parameters of these theories of elementary particles, and sometimes even their verification or rejection.

In addition to optical observations (including spectroscopic) with increasingly larger and more powerful telescopes and radio telescopic observations using large antenna systems (interconnected), it is primarily a detailed measurement of the properties of microwave relic radiation - its homogeneity, fluctuations (depending on the angular distance and wavelength), polarization. Already at the time of the separation of radiation from matter, there were germs of future structures in the universe, so these photons passed through places with different gravitational potentials, which led to small changes in their energy and wavelength - a slight cooling or heating.[55] These fluctuations should be visible even now, as slightly warmer and colder "spots" in the otherwise isotropic distribution of relic radiation - they represent a kind of "paleontological imprint" of the structures of the early universe. The temperature difference is very small, of the order of 10^{-5} degrees, so the relevant methods of their data measurement are constantly being improved. In the future, then the detection of primordial gravitational waves or detection of relict neutrinos.[56]

For a detailed study of relic radiation, the COBE satellite (Cosmic Background Explorer) was launched in 1989, the WMAP satellite (Wilkinson Microwave Anisotropy Probe) in 2001, an even more sensitive PLANCK probe in 2007 was launched. NASA's Cosmic Background Explorer (COBE) satellite was launched on November 18, 1989, via a Delta rocket to study the cosmic microwave background (CMB) and early universe. It operated until December 1993, confirming the Big Bang theory with precise measurements of the CMB's blackbody spectrum and finding early evidence of structural anisotropy.[57] WMAP was a NASA spacecraft operating from 2001 to 2010 which measured temperature differences across the sky in the cosmic microwave background (CMB) – the radiant heat remaining from the Big Bang.[58] Planck was a space observatory operated by the European Space Agency (ESA) from 2009 to 2013. The project aimed to map the anisotropies of the cosmic microwave background (CMB) at microwave and infrared frequencies, with high sensitivity and angular resolution. The mission provided data that substantially improved upon previous observations by NASA's WMAP.[59] At first glance, it might seem that nuclear and particle physics, dealing with the smallest known particles of matter, has very little to do with cosmology, which, on the other hand, examines the largest possible objects in the universe. However, current research refutes this view. Both in the form of elementary particles and in cosmology, it was possible to develop so-called standard models, which explain very well the results of almost all physical experiments and astronomical observations. On the other hand, they raise new questions and problems - how to "find common ground of things"?

At present, in the mutual interest of physics and cosmology are the fundamental principles of our world. In cosmology, these are questions of the origin of our universe, the basic laws which control him, his ultimate destiny. In particle physics, these are questions of the nature of matter: how did matter originate? what is its structure - what are its basic building "stones" and

[52] https://www.cambridge.org/core/books/relativistic-cosmology/7CBB180DDF5B86C0BDB11390CC9FDEED,

[53] Qian, W.H. (2023) Journal of Modern Physics, 14, 271-286, accessed on 14 Mar 2026

[54] Netchitailo, V. (2019) Solar System. Angular Momentum. New Physics. Journal of High Energy Physics, Gravitation and Cosmology, 5, 112-139, accessed on 14 Mar 2026

[55] Qian, W.H. (2022) Journal of High Energy Physics, Gravitation and Cosmology, 8, 417-431, accessed on 14 Mar 2026

[56] Netchitailo, V. (2018) Analysis of Maxwell's Equations. Cosmic Magnetism. Journal of High Energy Physics, Gravitation and Cosmology, 4, 1-7, accessed on 14 Mar 2026

[57] Arny, Thomas T. (2002). Explorations: An Introduction to Astronomy (3rd ed.). Dubuque, Iowa: McGraw-Hill. ISBN 978-0-07-241593-3, accessed on 14 Mar 2026

[58] Beringer, J.; et al. (Particle Data Group) (2013). "Astrophysics and Cosmology". Review of Particle Physics. This article incorporates text from this source, which is in the public domain, accessed on 14 Mar 2026

[59] https://www.nasa.gov/mission_pages/planck/overview.html, accessed on 14 Mar 2026

how do these interact? what are the mechanisms of these building blocks that create such complex objects as galaxies, stars, planets - and ultimately living matter? This creates a very remarkable connection between the microworld and the mega-world. All the most basic aspects of matter and the universe seem to rooted in those first prime fractions of a second after the Big Bang, when the properties of the physical interactions themselves were formed. The laws of physics that prevailed in these extreme conditions are not yet well known - we do not know what the structure of space and time was then, what was the number of dimensions, how matter was formed. At that time, the macroworld and the cosmos, then non-existent in the present sense, intertwined with the microworld of quantum laws.[60]

However, some current (and especially future) concepts of unitary theories of fields, interactions and elementary particles could shed some light here, in co-production with experiments of high-energy particle interactions on successively built large accelerators. The finer the details of the structure of matter we want to penetrate - and thus also the greater the depth of knowledge of the structure of the universe - the higher the energy of the particles we must use. It can be said that high-energy particles are certain "probes" into the deepest details of the structure of matter and at the same time into the earliest moments of the evolution of the universe.[61] Two seemingly very remote parts of physics: the theory of elementary particles examining the smallest objects and cosmology examining the largest of the whole universe; thus, combine to form a unified picture of the world. The successes of research in one area can be very penetrating in the other area of knowledge. It is this dialectical unity of the microworld, macroworld and mega-world that is the characteristic trend in contemporary fundamental physics.[62] Physically, we humans are just a tiny powder in the universe. Spiritually, however, we go far beyond this insignificance. We are able to know and understand the vast universe and its structure, functioning, and evolution. In this article scientific narration of creation and end story of universe will be illustrated on the basis of history, chronological development of astro physics with special emphasis on quantum cosmology.

4. Formation of First Galaxies and Large Black Holes

The current standard astrophysical mechanisms for the formation of the first galaxies are based on the situation after the end of the "dark ages" in the universe about 200 million years after the big bang, when clouds of hydrogen + helium gas began to cluster around the initial inhomogeneities (originating from density fluctuations of the post-inflationary period) by gravitational attraction. A large-scale structure of the network concentration of matter around large voids was gradually formed. In them, gravitational contraction then produced the first large protostars that transformed into 1st generation stars - galaxies were formed. These 1st generation stars were mostly significantly larger than today's stars, about several hundred M¤. They lived only relatively briefly, several million years, and then exploded as supernovae, which enriched the interstellar space with heavier elements. All of this is probably correct in principle. However, the latest observations show that the earliest galaxies are somewhat "more advanced" than would be expected from their age. So perhaps we do not yet know the exact models of galaxy formation well. Small and medium-sized black holes are formed by the gravitational collapse of sufficiently massive stars.[63] There were a large number of these in early galaxies. By gradual merging of "stellar" black holes, black holes with masses of several thousand M¤ can be formed. Supermassive black holes of 10^6-10^9 M¤ could grow to these masses in billions of years. However, they are also observed in much earlier galaxies.[64] Could they perhaps form in a non-stellar way, by direct gravitational collapse of large dense clouds of gas. But we do not know the exact mechanism.

Black holes are probably the most mysterious objects in the universe. Smaller black holes of stellar mass are formed at the end of the evolution of sufficiently massive stars, which, after consuming all their thermonuclear fuel, are no longer able to resist their gravity and succumb to complete gravitational collapse. In the center of galaxies, there are also giant black holes with more than a million times greater mass. A common feature of all black holes is that they are surrounded by an event horizon, from under which nothing, not even light, can escape. And in the center of a black hole, according to mathematical models of a black hole and that is the simplest is the Schwarzschild black hole. And there is a point where there is an infinite curvature of spacetime, infinite gradients of gravitational. According to mathematical models, all collapsing matter should end up in this singularity, even matter that was later absorbed by the black hole. This is certainly an unacceptable result according to the classical theory of black holes.[65] According to quantum physics, nothing

[60] Braibant, S.; Giacomelli, G.; Spurio, M. (2009). Particles and Fundamental Interactions: An Introduction to Particle Physics. Springer. pp. 313–314. ISBN 978-94-007-2463-1, accessed on 14 Mar 2026

[61] Yukawa, Hideki (1935). "On the Interaction of Elementary Particles. I". Proceedings of the Physico-Mathematical Society of Japan. 3rd Series. 17: 48–57. doi:10.11429/ppmsj1919.17.0_48, accessed on 14 Mar 2026

[62] Radvanyi, Pierre (January–February 2011). "Physics and Radioactivity after the Discovery of Polonium and Radium" (electronic). Chemistry International. 33 (1). online: International Union of Pure and Applied Chemistry. Archived from the original on 9 July 2023, accessed on 14 Mar 2026

[63] Carr, B., Kühnel, F. and Visinelli, L. (2021) Constraints on Stupendously Large Black Holes. Monthly Notices of the Royal Astronomical Society, 501, 2029-2043, accessed on 16 Mar 2026

[64] Mehrgan, K., Thomas, J., Saglia, R., Mazzalay, X., Erwin, P., Bender, R., et al. (2019) A 40-Billion Solar Mass Black Hole in the Extreme Core of Holm 15A, the Central Galaxy of Abell 85. The Astrophysical Journal, 887, Article No. 195, accessed on 16 Mar 2026

[65] Hawking, S.W. (1998) A Brief History of Time: From the Big Bang to Black Holes. Introduction by Carl Sagan; Illustrations by Ron Miller. Bantam Dell Publishing Group, New York.

so pathological as a singularity should happen. In the immediate vicinity of the center of a black hole, quantum fluctuations of the geometry of spacetime would strongly increase, up to fluctuations of topology, so that the spatial singularity would dissolve in the topological foam of quantum fluctuations. So, we don't actually know what's inside a black hole, at its center.

5. Formation of Dark Matter and Dark Energy

We observe that the gravitational effect in galaxies and galaxy clusters is stronger than would correspond to the usual glowing and non-glowing matter contained there. So, there must be some substance that exhibits gravity, but which we do not see astronomically. We call it dark because it does not glow and matter because it interacts gravitationally in the same way as matter. But we do not know what it is. It was thought that it could be hard-to-see objects made of dust, brown dwarfs, or black holes in the halo of galaxies; this has not yet been confirmed. Physically, it seems that dark matter could be made of weakly interacting massive particles WIMPs, which gravitate due to their mass, but apart from gravity, exhibit only weak interactions. Their detection by nuclear and radiation physics methods is therefore very difficult; despite intensive efforts over many decades, it has not yet been possible. When astronomically measuring the rate of retreat of very distant type Ia supernovae, we surprisingly observe that the universe is expanding at an accelerated rate, instead of its expansion being slowed down by the attractive gravitational effect of matter. Therefore, in addition to gravity, there must be something in the universe that acts in the opposite direction, against gravity. It is astronomically invisible, so we call it dark and energy, because it supplies the energy needed for acceleration. However, we do not know what it is. It may be an inherent property of space-time (such as the cosmological constant), or some kind of "quintessence" (dark energy and the accelerated expansion of the universe).[66]

Dark matter and dark energy are distinct, unseen components that formed in the early universe, making up roughly 95% of the total mass-energy content, with dark matter acting as the cosmic scaffolding that clumped together and dark energy acting as the uniform repulsive force causing accelerated expansion. Dark matter likely formed fractions of a second after the Big Bang, similar to ordinary matter, while dark energy is believed to be the energy of vacuum space that came to dominate the universe’s expansion roughly 5 billion years ago. Dark matter is an invisible, non-baryonic form of matter that exerts gravitational pull but does not interact with light. Scientists believe dark matter formed in the first fractions of a second after the Big Bang around the same time as ordinary matter. It clumped together, forming a "cosmic web" or halo around galaxies, providing the gravitational scaffolding needed for gas to gather and form stars.[67] Dark energy is a mysterious force, uniformly distributed across space, that drives the accelerated expansion of the universe. Dark energy has likely existed from the beginning, but its influence was negligible compared to the attractive gravity of matter and radiation in the early universe. Einstein proposed that, this is the energy of empty space. As space expands, more space is created, meaning the total amount of dark energy increases, pushing galaxies apart faster. A dynamic energy field that fills space, potentially changing in strength over time, rather than remaining constant like the cosmological constant.[68] It pushes galaxies apart, dominating the current 68% of the universe's mass-energy content.

6. The Evaluation of Time

End of Time. All fundamental physical laws are time invariant; no equations in physics contain a time direction. We can apply them in one direction or the other and there is nothing to show which direction is correct. A fundamental exception is the 2nd law of thermodynamics, which as a statistical principle shows that natural processes spontaneously proceed in the direction of increasing entropy, as a measure of the disorder of the system. Physical statistics explains this by saying that the number of disordered states of a system of particles is always significantly higher than the number of ordered states. Biochemical processes of life seemingly go against this current of increasing entropy. New aspects regarding the passage of time were brought by the special and general theories of relativity. Actually, we don't really know what time is? How did primordial life arise at the molecular and cellular level? Biologists have well researched the evolution of the amazing diversity of life; chemists have well researched the complex biochemical processes at the molecular-cellular level. Although much remains to be explored here, the essence of life is already well understood. However, we do not know how primordial life arose at the molecular chemical pre-cellular level, including the establishment of reproduction and inheritance RNA, DNA? And we do not know also whether and how life could develop outside Earth, on other planets in the universe? And how to search for it?

From the point of view of the general theory of relativity, initial singularity was not only the beginning of the universe, but also the beginning of time. What about the passage of time and causal relationships in the final stages of the evolution of the universe? In the case of a closed universe, the situation is to some extent inversely analogous to the beginning of the universe. All causal relationships end in the vicinity of the final

[66] Netchitailo, V. (2019) Dark Matter Cosmology and Astrophysics. Journal of High Energy Physics, Gravitation and Cosmology, 5, 999-1050, accessed on 16 Mar 2026

[67] Bird, Simeon; Albert, Andrea; Dawson, Will; Ali-Haïmoud, Yacine; Coogan, Adam; Drlica-Wagner, Alex; Feng, Qi; Inman, Derek; Inomata, Keisuke; Kovetz, Ely; Kusenko, Alexander; Lehmann, Benjamin V.; Muñoz, Julian B.; Singh, Rajeev; Takhistov, Volodymyr; Tsai, Yu-Dai (1 August 2023). "Primordial black hole dark matter". Physics of the Dark Universe. 41 101231, doi:10.1016/j.dark.2023.101231, accessed on 16 Mar 2026

[68] https://www.wtamu.edu/~cbaird/sq/2014/07/25/is-there-any-difference-between-antimatter-dark-matter-dark-energy-and-degenerate-matter/#, https://www.wtamu.edu/~cbaird/sq/2014/07/25/is-there-any-difference-between-antimatter-dark-matter-dark-energy-and-degenerate-matter/#:~:text=Dark%20energy%20is%20weak%20and%20mostly%20operates,thinly%20but%20evenly%20throughout%20the%20entire%20universe.

singularity (they cannot be extended analytically beyond this world point) - the great collapse also represents the end of time. In the case of the open universe, from a mathematical point of view, the coordinate time continues undisturbed to infinity. However, from the real point of view of the operationalist conception of time in the final stages of open space, where there will be no more phenomena and events ("thermal death"), we do not have time how and with what to measure and in fact is not "what" to measure. In this sense, even in the open universe, the end of time effectively occurs.

The Arrow of Time. What actually distinguishes between the past and the future? what determines the direction of time? This asymmetry of time - the "arrows" that point from the past to the future is plays a crucial role in our daily experience. All basic laws of physics have the property of time reversibility. If these laws allow a certain causal sequence of events, then they also allow a sequence of time-reversed events. The laws of mechanics allow the reversal of every movement of a body. Similarly, the laws of electrodynamics do not distinguish between the future and the past. So, the laws of physics are at their deepest level symmetric in time. If we remain purely at the level of mathematically formulated laws of physics, we will find no difference between the past and the future. Yet, we observe a strong causal direction in all the actual events in nature. Natural events always take place in one particular direction, while in the opposite direction never as the glass Bootle can roll spontaneously from the table and break, but the broken shards will never spontaneously combine in the original glass. The observed mechanisms of this temporal direction of natural phenomena can be divided into four categories:

1. The radiation arrow of time. It also called the electromagnetic arrow. It is given by the fact that the island system of accelerating moving charges emits electromagnetic waves, which carry energy from the source at the speed of light, while these waves will be manifest on distant bodies in the future. The energy of the radiating system also decreases in the future. In addition to these "retarded" waves, the laws of electrodynamics formally allow for "advancing" waves. As waves coming from infinity that the source absorbs; these waves can also be understood as waves radiated into the past. In fact, with each spontaneous emission of the source, we observe only the retarded emission of waves. The same applies to the emission of gravitational waves.

2. The thermodynamic arrow of time. According to the 2nd law of thermodynamics, is determined by the monotonic increase of the entropy of an isolated system near thermodynamic equilibrium. Time flows in the direction in which things age, hot objects cool, systems decompose, their disorder increases spontaneously. From this regularity also derives the biological arrow of time, indicating the direction of biological evolution and the individual course of life of man and all living beings, accompanied by ageing. The very laws of motion of the system's individual parts also allow movements that decrease entropy. Still, their probability is significantly lower than that of movements that, according to statistical physics, increase disorder (entropy). This is because in practice, the number of disordered states is incomparably greater than the number of ordered states. The second thermodynamic theorem is thus a statistical consequence of the fact that there are many more disordered states than ordered states. And this situation is basically given by the initial conditions. States with high entropy significantly exceed those with low entropy. Therefore, almost every change in the system will most likely lead to a state with higher entropy. The time arrow of entropy growth is simply a statistical tendency of systems to evolve toward more common and frequent states. Although violation of the 2nd law of thermodynamics takes place locally, it only occurs on small spatial and temporal scales, or a molecule with a certain velocity (corresponding to the average thermal energy in a gas) with collisions with surrounding molecules can significantly accelerate (or slow down), but only for a very short time; then it returns to normal.

3. The cosmological arrow of time. It is determined by the observation that as time grows, so does the expansion of the universe.

4. The psychological arrow of time. It is based on the fact that our memory reflects the part of events which we call the past and which is clearly distinguished from the future in our psychic understanding. So we have a kind of "psychic feeling" for the passage of time, part "Space and time".

The question naturally arises as to whether all these manifestations of time are somehow connected to each other; or whether there is a "primary" or "universal" arrow of time, which is manifested by said "partial" arrows of time. So, let's look at the possibilities of merging or reducing at least some of them. The psychological and thermodynamic arrows of time seem to be essentially the same. The psychological arrow of time is a consequence of the thermodynamic arrow, because mental processes share an arrow of time determined by thermodynamics. If we imagine the brain as a physico-chemical system of neurons performing logical operations and recording sensory sensations in memory, all these operations are irreversible for thermodynamic reasons. It is necessary to expend energy to arrange the memory elements in the brain into a certain state, while a part of it is always dissipated in the form of heat and thus increases the disorder of the whole system. According to the laws of thermodynamics, this increase in disorder is always higher than the increase in order in memory. The direction of time in which our memory records data thus agrees with the direction in which disorder grows - with the direction of entropy growth. It can even be said that the disorder (entropy) increases with time, actually because we conceive and measure time in the direction of increasing entropy?

Finding a direct connection between the radiation (electrodynamic) and thermodynamic arrows of time is not easy. The electromagnetic arrow is in a way a manifestation of the principle (or requirement) of causality in the Minkowski spacetime of (locally) inertial systems, within which Maxwell's electrodynamics works. The thermodynamic (entropic) arrow of time is determined by the laws of statistical mechanics applied to a situation where the initial conditions imply a significantly larger number of disordered than ordered states. The laws of mechanics itself reflect, among other things, causal relationships. The idea that "field equations also determine the regularities of the motion of their resources" can also help to find connections. Perhaps it will be ideologically possible to combine all of this comprehensively in future unitary field theory.

As for the cosmological arrow of time, which points in the same direction as thermodynamics, it is probably just a coincidence: we live by coincidence in a stage of expanding space, so the arrow of time is now identical with the expansion of the universe. If the universe is closed and the expansion is replaced by contraction in the future, nothing will change on the arrow of time in locally inertial systems (as well as on local laws of physics in general). Still, agreement with the arrow of universe evolution will turn into a contradiction including temporarily Stefen Hawking. Once thought that the cosmological arrow of time is the primary, and that as the evolution of the universe transitions from the stage of expansion to the state of contraction, the direction of the passage of time is also reversed. Now, however, they have mostly seen the error of this view and accepted the position of Zeldovich and Novikov on the irrelevance of the cosmological arrow of time. In the early days of quantum physics, antiparticles (such as the positron) were considered to be particles with "negative energy", or particles moving "backwards in time" (formal coordinate transformations in the Dirac equation allow this). At one time, these concepts played an important heuristic role in the development of particle physics. Now these misleading notions are abandoned, and both particles and antiparticles have an "equal" place in the standard model, in applications as well as in unitary schemes. They have nothing to do with the direction of time!

Now talk about the ‘arrow of time and the anthropic principle’. The agreement of the thermodynamic, cosmological and psychological arrows of time can be put into a certain connection with the anthropic principle and the work "Anthropic principle or cosmic God".[69] We necessarily live in the "intermediate" stage of the expansion of space. In the late stages of the universe's evolution, the conditions for the existence of life and intelligent information processing will not be suitable. There will be no one to study the connection between the expansion or contraction of the universe and the time direction in which entropy increases. In accordance with the concept of inflationary expansion and the anthropic principle, the universe expands almost exactly at a critical speed, so that the shrinkage phase either does not occur at all or occurs only after a very long time. In the meantime, all the stars will go out, the galaxies will collapse, and no more free energy sources will be available. The universe will enter a state of almost maximum disorder, which will no longer increase locally - the thermodynamic arrow of time will actually disappear. Thus, life and all orderly processing of information will disappear. It can therefore be concluded that the common essence of all "partial" arrows of time is the principle of causality for each locally inertial frame of reference. In analysing the various possibilities of the evolution of the universe, we are therefore entitled to proceed from the concept that there is a clear universal "arrow of time" determining the direction of evolution of physical systems in each locally inertial frame of reference. These local arrows of time are transmitted from one place to another by means of special and general relativistic transformational laws and create a branching causal structure in the spacetime of the entire universe.

7. The Future Development of the Universe (Hidden-Dark Matter)

What is the future development of the universe? It is very difficult to decide which of the two basic branches of evolution is realized in the real universe. The accuracy of measuring the deceleration parameter q remains insufficient, and when determining the average density of matter in space, the problem of hidden matter (dark, non-radiant substances) arises. If we take only the "luminous" mass contained in galaxies and in clusters of galaxies, we would indicate an open space. However, it turns out that this "luminous" substance is far from representing all the matter in the universe. Hidden dark matter in galaxies and clusters of galaxies When monitoring the dynamics of the rotation of galaxies, it shows that the real (gravitational) mass of galaxies appears about one order larger than that from luminosity astronomically determined mass; according to today's observations, the galactic halo is much larger in size than previously thought and probably contains a larger portion of the total mass of galaxies. Even greater disproportion arises in galaxy clusters, where the relevant difference is almost two orders of magnitude, so that at the observed relative velocities of the individual galaxies, the system-cluster of galaxies can be stably gravitationally bound.

This is evidenced by the analysis of the motion of very sparse glowing gas around galaxies. If the mass of the galaxy were concentrated only in the visible region, the orbital velocity of the surrounding glowing gas would be inversely proportional to the square root of the distance from the center of the galaxy (according to Kepler's law). In a simplified spherically symmetric model, at a distance $\underline{r}$ from the center of the galaxy, the orbital velocity of a substance will be given by the relation $v^2 = G.M(r)/r$, where M(r) is the mass contained in a sphere of radius $\underline{r}$. For a constant density of matter, r(r) = r, then inside will be v2 = (4/3) pr G.r2 (orbital velocity will increase in direct proportion to the distance r). At the same time, outside the galaxy, the dependence $v^2 = G.M/r$ will apply, where $\underline{M}$ is the total mass of the galaxy. Outside the galaxy, according to Newton's laws, the orbital velocity of matter (gases) should decrease with the square root of the distance.

[69] https://astronuclphysics.info/AntropPrincip.htm, accessed on 16 Mar 2026

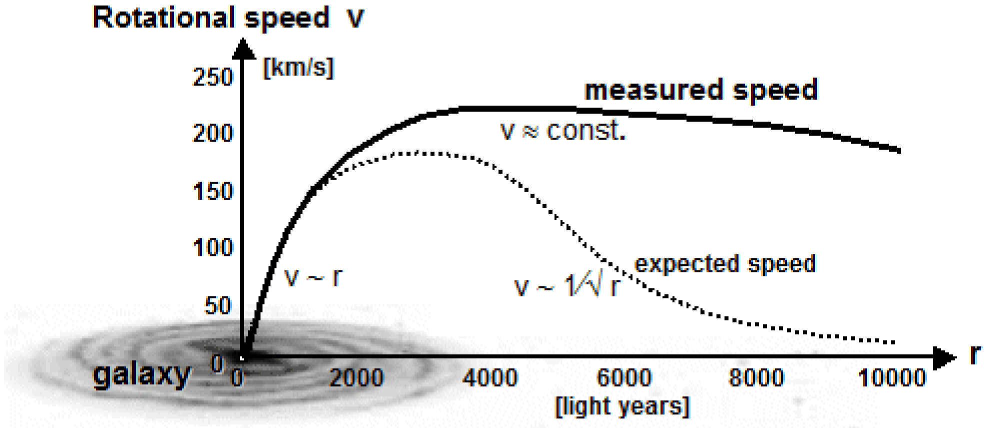

Figure 1: Typical rotation curve

In reality, it is observed that up to a distance of several radii of the visible part of the galaxy, the gas orbital velocity remains roughly constant (solid curve in Fig 1, which is flat), so that in this non-radiative region the mass density appears to be approximately the same as in the luminous areas of the galaxy. Typical rotation curve, which dependence of the orbital velocity of matter on the distance from the canter of the galaxy has been shown in figure 1 above. It can be said that stars in galaxies and galaxies in galaxy clusters orbit, and overall, they move so fast that centrifugal force and inertia would have long ago had to scatter them into space, if they had not been held by the gravity of some unknown hidden mass. This fact was pointed out in 1934 by F. Zwicky, who at the observatories in Mt. Wilson and Mt. Palomar observed faster movement by spectroscopy of galaxies at the edge of a cluster of galaxies and stars in the peripheral parts of galaxies, than would correspond to the law of gravity at astronomically determined masses of luminous matter.

To explain this paradox, it is necessary to assume that in galaxies a much stronger gravitational field acts than corresponds to the classical mass of electrons, nucleons, atoms, ions that form stars (with planets) and interstellar gas. There must be a large amount of some hidden and non-radiant dark matter that has gravitational effects. The measured rotational curves of ordinary galaxies show a content of at least 70% of dark matter (up to 90% in dwarf galaxies). Measurements of motions in large systems of galaxy clusters show that hidden matter is not only contained in galaxies, but is distributed throughout the universe, with different local densities. The average density of dark matter in the entire observable universe is estimated at 2×10^{-27} kg/m^3. However, due to gravity, it can cluster into much larger concentrations in the centers of galaxies. On the other hand, in large cosmic voids, the density of dark matter is estimated to be about 10-times lower.

This hidden mass should be composed of particles that are affected only by gravitational and possibly weak interaction (the effect of weak interaction would be negligible due to the low effective cross section and short-range). Still, they are not affected by strong and electromagnetic interactions (or electromagnetic interaction does not manifest observationally). Hidden matter would be affected - and would affect the surrounding universe - only gravitationally. In short, galaxies rotate too fast to be held together by the gravity of the visible matter in stars and interstellar gas. So, there should be a kind of hidden gravitational "glue" that holds galaxies and clusters of galaxies together, so that the stars do not fly away from the rotating galaxies into the surrounding universe. Without this hidden matter, galaxies and galaxy systems would be unstable and would not hold together.

8. Dark Matter and Black Hole

Dark Matter. Dark matter is therefore a hypothetical form of matter that is spread over very large regions of the universe. It holds together the galaxies that orbit faster in the peripheral regions, than would correspond to the gravity of visible matter; the same is true in galaxy clusters. It is called "dark" because it does not emit, absorb or reflect any electromagnetic radiation, making it invisible to telescopes. However, its existence (and some basic properties, especially its distribution) can be derived from its gravitational effects on visible matter, radiation and on the large-scale structure of the universe. Below, we briefly discuss these effects and try to find possibilities for revealing the nature and composition of dark matter. The formation of galaxies and galaxy clusters in the era of matter was significantly influenced by the universe's matter composition. If this substance were composed only of protons, electrons and atoms of hydrogen and helium, intense radiation (from the not too long time of the radiation era) would hinder and prevent the formation of galactic structures for a long time - the universe would remain homogeneous, smooth, without large-scale structures. The presence of dark matter, which does not directly interact with radiation, soon allowed gravitational contractions to "win" over the destructive effects of radiation. The observed faster (earlier) formation of galactic structures requires additional (only gravitationally interacting) matter, dark matter, than would correspond to the dynamics of known matter during the expansion of the universe. This is perhaps the most important cosmological indicator for hidden matter - it enabled, among other things, the formation of our Galaxy, in which the solar system, planet Earth, the evolution of life and our existence.

Dark matter should be about 10 times more in galaxies and galaxy clusters than luminous (or radiation-absorbing) matter - it is dominant on a large spatial scale. The name "dark matter" could lead to the misconception that this substance will absorb light much like the dark clouds of interstellar dust. Nothing like this is observed, "dark" or rather "hidden" matter is perfectly transparent to light and other electromagnetic radiation. It does not emit, absorb or reflect electromagnetic radiation, it shows only a universal gravitational interaction and probably also a weak interaction (see below). If this is the case, dark matter is not able to dissipate its internal energy, it cannot "settle" in large quantizes near the stars, its accretion is negligible. It can collect and gravitate only in huge formations of matter such as galaxies and clusters of galaxies. It can be said that dark matter can be a kind of "backbone" or "skeleton" on which ordinary luminous matter is "packed". For example, a massive star, if it is inside a cloud of dark matter, can in principle absorb a small amount of dark matter by spherical accretion (radiation and stellar wind do not prevent this). A gravitationally bound disk of rotating dark matter can form around massive compact objects such as black holes, but with virtually no accretion. Due to the absence of friction, the orbiting dark matter cannot get rid of excess angular momentum in any way and therefore cannot descend to progressively lower orbits to finally be absorbed by a black hole. It will continuously orbit around. This phenomenon can be expected especially for supermassive black holes in the center of galaxies, where a greater concentration of dark matter is assumed and the dark-matter rotating disk can be very massive. Although it does not directly contribute to accretion, it can greatly influence the structure and dynamics of the normal-mass accretion disk. In addition to its gravitational influence on the motion of glowing astronomical objects like stars, galaxies. Dark matter manifests itself in an attractive gravitational influence on the propagation of light - the effects of a gravitational lens.

For the curvature of electromagnetic rays, it does not matter whether the gravitational substance is glowing or dark. In this way of gravitational lensing, it would be possible to detect the distribution of dark matter even without a direct link to luminous matter even hypothetical dark galaxies? The question naturally arises, what is this hidden dark matter made of? In particular, they could be the usual forms of matter such as ionized intergalactic gas, molecular clouds, infrared or brown dwarfs similar to Jupiter (stars so light that they did not ignite thermonuclear reactions), burnt-out stars of the 1st generation, after which left black dwarfs, neutron stars and the like. They could also be numerous smaller black holes of stellar origin. As most of the degenerate matter hidden in these black holes has a baryon origin. This component is called baryon dark matter and is not fundamentally very different from the commonly known substance composed of atoms and that is more than 99.9% by weight here is made up of baryons- protons and neutrons in the nuclei of atoms.

Black Holes. Black holes of small and medium masses could generally be ideal candidates for dark matter, as they do not emit light and, due to their very small dimensions, practically do not absorb light from an astronomical point of view. Stellar black holes of mass $>\sim 3M_\odot$ (formed by the collapse of massive stars at the end of their evolution) are too few. An interesting hypothesis, however, is the black holes of primordial origin, which could have formed in large numbers from the hot, extremely dense plasma that filled the universe immediately after the Big Bang. Microscopic quantum fluctuations they increase to a macroscopic scale during inflationary expansion- regions with significantly lower and higher densities of matter and energy have emerged, from which all structures in the universe later created. In the very early stages of the universe, soon after the inflation period, a large amount of significant condensation could be present, which could quickly collapse into black holes. This would create a large number of primordial black holes of various weights, especially low ones. These primordial black holes can be considered of non- baryonic origin. They formed before nucleosynthesis. Their detection is very difficult; it could perhaps be possible through gravitational microlenses.

If some compact object (with a mass of at least $10^{-9} M_\odot$) were to pass through the line of sight from a more distant star towards us during its movement, it could cause a transient achromatic brightening of the star. The mass of this transiting compact object could be estimated from the degree of this brightening. Such gravitational microlenses are very rarely observed; those few cases are not distinguishable from free-moving errant planets? If the hypothesis of primordial black holes were to be confirmed, it would be a very plausible origin of dark matter, as there would be no need to look for any unknown particles outside the standard model. Alternatively, primordial black holes may form at least part of the dark matter. Un-structuredness and spreading-out of dark matter. Now question is, what distribution and what structures can dark matter form? Interstellar gas composed of ordinary matter like hydrogen and helium can condense by gravity to form globules, protostars, and stars. At first glance, dark matter could do the same. However, contraction and collapse require the way in which the particles lose the kinetic energy generated by the adiabatic compression and slow down so that gravity prevails and the contraction can continue. In ordinary matter, this occurs loss of kinetic energy through electromagnetic interactions, radiation of electromagnetic waves. However, dark matter particles do not have an electromagnetic interaction and have no way to lose energy. From this point of view, dark matter probably cannot form more complex gravitationally compressed star-sized structures.

For similar reasons, dark matter cannot contribute significantly to accretion on compact objects. Ordinary matter trapped in the accretion disk loses kinetic energy and angular momentum due to friction caused by electromagnetic interactions. And it moves in a spiral until it is absorbed. Dark matter probably does not show friction. Its particles would orbit the compact object constantly in the disk. Only particles coming with a very small impact parameter can be captured - in the case of dark matter, only spherical accretion can occur, which is generally inefficient. According to current knowledge or hypotheses, dark matter does not form local structures; it is spread out in clouds comparable in size to galaxies. This is probably the case in the current cold, rarefied universe. Now, what is the role of dark matter in the early universe? It could be different in the early, dense universe, during the formation of the first stars and galaxies. Dark matter, in close contact with atomic-baryonic matter, could significantly participate in the gravitational contractions of dense, extensive clouds of this mixture. Clusters of dark matter could have initiated the formation of galaxies. Also, the early massive stars of the 1st generation could contain, in addition to the usual atomic-baryonic matter, a certain amount of dark matter, and that collapsed in the protostar phase together with molecular clouds of hydrogen and helium. Dark matter could also be involved in the early formation of giant black holes, present at the canter of most galaxies.[70]

The more complex dynamics of the expansion of the universe. Some new aspects in the issue of the distant future of the universe, in relation to the mean density of matter in the observed part of the universe, are now brought about by the presumed inflationary expansion of the early universe. As a result of this inflationary stage, the radius of the universe would probably be many times (by many orders of magnitude) larger than the horizon, than the observable region of the universe. The local density in the observed part of the universe may then differ somewhat from the global mean. That means that even very accurate determination of the average density of matter in the observed universe it cannot decide on its own between a closed and an open universe, especially if this measured density will be near to the critical density. After a sufficiently long time, the density of matter in the now observed part of the universe mixes with the density of matter in other parts of the universe, and the total density can move to the "opposite side" of the $r = r_{crit}$ limit than now. Let us recall that, according to current quantum cosmology of the inflationary model, a closed universe is expected, albeit very close to the planar one.

9. Accelerated Expansion of the Universe and Dark Energy

According to the standard cosmological model, the expansion of the universe is hampered by the attractive gravitational effects of matter. It must therefore slow down both in the closed universe (where it would eventually contract) and in the open universe (where the expansion will slow down, but it never stops completely). After all, to quantify the deceleration of the expansion of the universe, we introduced the so-called deceleration parameter q. Again, the gravity of dark matter in particular should make a decisive contribution to slowing down the expansion of the universe. The cosmological constant in Einstein's gravitational equations, according to previous ideas, perhaps may have played a decisive role in the inflationary expansion of the universe at the very beginning, but did not need to be considered for further evolution of the universe.[71] However, the dynamics of expansion (or contraction) of the universe, and the time course of the scale factor or expansion function a(t) and the expansion history of the universe, can be find out by determining the relationship between the cosmological redshift Z in the spectrum of distant objects and their distances. These distances are derived from the ratio of the actual and observed (apparent) luminosity of suitable standard candles.

For large cosmological distances, type Ia supernovae are suitable "standard beacons", which astronomers are currently able to observe with the help of large telescopes up to distances of more than 6 billion light-years. Supernova Ia can be identified by the shape of the spectrum, their brightness is determined from the course of the light curve - the increase, peak and decrease of the brightness of the supernova. Photometric measurements of such different distant supernovae (with different Z 's) make it possible to determine how the universe expanded at different time periods. By performing multiple measurements at different distances, we can create a graph that maps the expansion of the universe as a function of its age. In 1998-99, two groups of American astronomers undertook the astronomical mapping of the dynamics of space expansion by photometric measurement of a large number of type Ia supernovae. The first group was led by A. Reiss and B. Schmidt (Space Telescope, Baltimore) within the project 'High-Z Supernova Search', which aimed to search for supernovae with large redshift Z. The second group (Supernova Cosmology Project) was led by S. Perlmutter in Lawrence Berkeley Laboratory. The original goal of these observations was to find out how big the slowdown in the expansion of the universe is.

These accurate photometric measurements of distances to supernovae of type Ia are very useful for very distant supernovae. Type Ia (high value Z) are less bright than would correspond to their cosmological red shift Z in universe, the expansion of which slows down due to the gravitational effects of the mass. For closer supernovae with a smaller Z, the relationship between distance and redshift corresponded to the standard scenario. However, the most distant galaxies seem to have driven "something" further than the usual Fridman expansion of the universe. Respectively (which is the same thing), these very distant galaxies, corresponding to the earlier periods of the universe, are moving away at a slower speed than would correspond to Fridman's dependence.

From such a measured relationship between the cosmological redshift and the distance of supernovae, it was surprisingly observed that the expansion of the universe is probably not slowing down at the moment, but is accelerating on the contrary! The expansion of the universe has normally slowed down only to about half the current age of the universe, to about 6-7 billion years, but then began to accelerate, which continues. A supernova of type Ia arises in a close binary star consisting of a giant star and a white dwarf, where matter is transferred from the giant to a white dwarf, whose mass gradually increases. It then crosses the Chandrasekhar limit (1.4 M¤) and the white dwarf explodes thermonuclearly, which manifests itself as a type Ia supernova explosion. All type Ia supernovae explode ac-

[70] https://astronuclphysics.info/Gravitace4-8.htm#Kvasary-Mechanismus, accessed on 16 Mar 2026

[71] https://astronuclphysics.info/Gravitace5-5.htm, accessed on 16 Mar 2026

cording to the same mechanism and with the same initial mass and therefore the amount of energy released is practically the same every time.

It has been hypothesized that this accelerating expansion is caused by a kind of pervasive vacuum so-called dark energy or DE with a negative energy density so high, that its repulsive effects overcome the gravitational action of all matter in the universe. In the simplest case, it is assumed that dark energy and emerging repulsive action are distributed approximately homogenous in space. This mysterious hidden or dark energy is sometimes referred to as the fifth state or quintessence. The general theory of relativity, leading to a negative pressure that would induce antigravity repulsion at cosmological distances, acting opposite to the gravitational attraction of ordinary matter. That would be the simplest explanation of dark energy (various hypothetical possibilities to explain the origin of dark energy. So, if dark energy is the energy of (empty) space itself, then as the universe expands, more dark energy comes into the universe, which causes the expansion to accelerate, it is still faster. According to current cosmology, the primary cause of the universe's expansion is the energy-momentum left over from the Big Bang. And the repulsive force of dark energy, when it prevails over the attractive cosmic gravity, will further accelerate this expansion permanently. According to current knowledge, it seems that the universe will not only expand forever, but its expansion will continue to accelerate more and more.

If the dark energy density is constant over time or decreases more slowly than the density of ordinary matter. After the end of the initial inflation expansion and the onset of the Fridman expansion, a period of deceleration would take a long time, when the gravitational effects of total matter (shining + hidden) prevail over the repulsive forces of dark energy and the expansion slows down. After a proper reduction in the density of the mass, a reversal would occur. For a short time, the two forces would be balanced or indecisive universe, then dark energy would prevail and cosmic expansion would eventually go from the deceleration stage to acceleration and the constant acceleration of expansion, towards the thermal death of the universe. Unless a convincing alternative astrophysical explanation of the observed data for distant supernovae is found, the accelerated expansion of the universe and the existence of dark energy must be taken very seriously. It would be one of the most surprising and mysterious discoveries in the history of astronomy. The processing of some newer and larger sets of several hundred distant type Ia supernovae somewhat reduces the statistical significance of the data from the first observation, further measurements will specify. Evolution of cosmological models, where time course of radius a (scale factor) of the universe, depending on the value of cosmological constant L and mass distribution density r (r_{crit} is the value of critical mass density, a_E and L_E denote values of space radius and cosmological constant corresponding to Einstein's cosmological model). And that has been shown in figure 2 below.

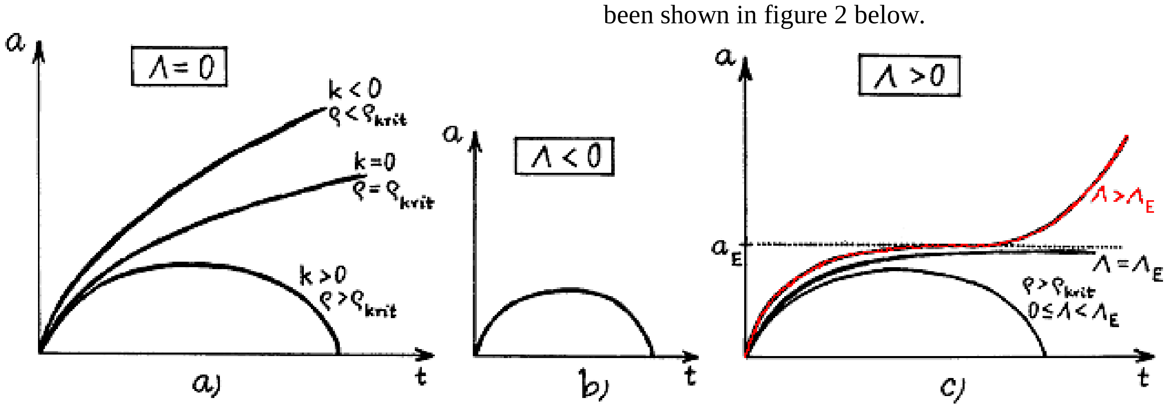

Figure 2: Evolution of cosmological models

Three Indications for Dark Energy. Now have three independent indications for the accelerated expansion of the universe. The measurement of supernovae Ia is the most important; it is a direct indication, and it has been discussed above. In addition, there are two other indirect, looser and model-dependent indications—inhomogeneities of relic radiation in correlation with the large-scale structure of the universe. The small anisotropies of relic radiation reflect inhomogeneities in the distribution of matter just after the end of the radiation era. One possible origin of these inhomogeneities may be the so-called acoustic horizon of density waves and oscillations in the hot plasma of the lepton and radiation era. It is believed that galaxies later formed from these initial inhomogeneities, stretched by the expansion of space over long distances of hundreds of millions of light-years. Their current distribution - clustering - depends on the dynamics of the expansion of the universe. Detailed analysis of relic radiation inhomogeneities performed by COBE and WMAT satellites, and even more sensitive analysis of relic radiation is performed by the PLANCK satellite, and its correlations with astronomical mapping of the large-scale distribution of galaxies suggest that the observed clustering structure corresponds to the accelerated dynamics of space expansion. After all, even the comparisons of the density of galaxy clusters with low and high redshifts give a slight indication of accelerated expansion. Equation of state of dark energy can be modelled in a simple general form as an "ideal liquid" $p_{de} = w.c^2.r_{de}$ Where p_{de} is the pressure, r_{de} is the dark energy density, and w is the state constant. If the universe were filled only with the dark energy "de", the acceleration ä of the scale function a(t) with time is given by substituting p_{de} and r_{de} into 2.

Table 1:

The "functioning" of this contribution of dark energy in the dynamics of the expansion of the universe depends on the value of the coefficient w in the equation of state of dark energy $p_{de} = w.c^2.r_{de}$

a)	**w> 0**	=>	ordinary gravitational matter slowing down expansion (here, an irrelevant case)
b)	**w <-1/3**	=>	general dark energy accelerating expansion; quintessence
c)	**w = -1**	=>	cosmological constant L, generating vacuum dark energy
d)	**w <-1**	=>	aggressive dark energy (quintessence) accelerating expansion exponentially above all limits- phantom energy

Measurement of the dynamics of the expansion of the universe using quasars. In addition to supernovae Ia, the dynamics of the expansion of the universe extend to even greater distances. So, earlier periods can be studied using quasars. Quasars are giant black holes in the center of galaxies that absorb a large amount of surrounding gas in a large accretion disk, part of which is ejected along the axis of rotation in massive jets. The absolute magnitude (actual radiant power) of quasars is different. Still, it turns out that this absolute magnitude is related to the spectrum of quasar radiation, especially to the ratio of ultraviolet and X-ray radiation. Quasars, with spectrometric analysis, can then, in principle, be used as "standard candles " for measuring the greatest cosmological distances. At present, these spectrometric measurements are performed on a large number of quasars of different distances.

10. The Influence of Dark Energy on the Evolution of the Universe

Dark energy is very dilute but ubiquitous, and its effect is cumulative. It is imperceptible on terrestrial scales and within the solar system, but it may be dominant on a cosmological scale throughout the universe. Current estimates indicate that approximately 4% of ordinary ("luminous" or absorbent) matter in the universe can be observed, compared to about 70% of dark energy and 25% of dark (hidden, non-radiant) matter. Therefore, if the presence of dark energy (or a non-zero cosmological constant) is truly established, it will alter our conceptions of the dynamics of the universe's evolution, which now consists of three stages rather than the prior two.

- Fast expansion dynamics during the initial phase of the inflationary period.
- The cosmos expanded according to the standard Fridman model, first dominated by radiation and thereafter by matter. The gravitational pull of matter slows the universe's rate of expansion (visible and, above all, hidden). The density of stuff, both visible and dark, decreases as the cosmos grows.
- Dark energy takes over once the universe's matter has been sufficiently diluted. The universe's pace of expansion ceases slowing down and starts to increase instead. A repulsive cosmological member will eventually force the universe to behave as an almost empty de Sitter universe with exponential expansion. This is a sort of late "2nd inflation phase" that is incredibly sluggish compared to primordial inflation because the vacuum energy density, cosmological constant, and Hubble constant H are all several orders of magnitude smaller than they were at the beginning. However, during this late accelerated expansion stage, "heat death" and an open universe would occur. Studies of supernovae indicate that this "tipping point" between the acceleration and slowing of space expansion occurred approximately 5-7 billion years ago. At that time, antigravity forces caused a lethal "tipping of the weighing pans" due to dark energy.

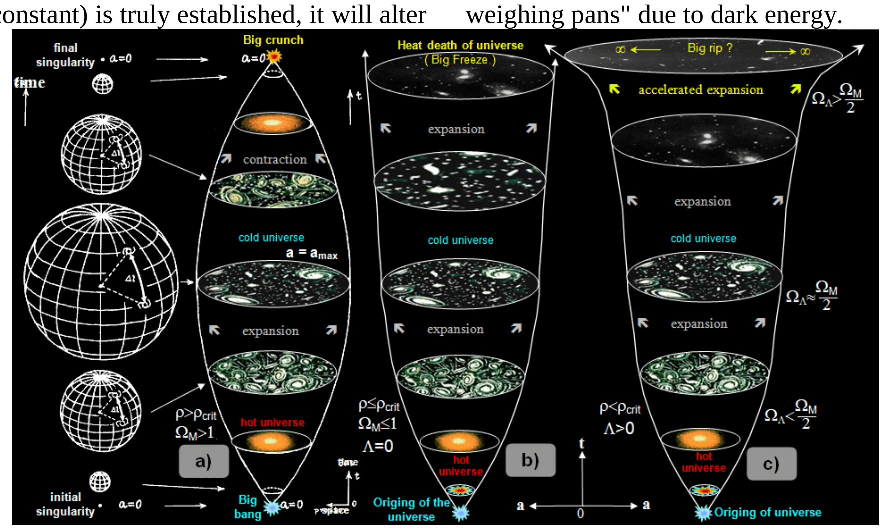

Figure 3: Different possibilities of the dynamics of the evolution of the universe. a) Closed space. b) Open space. c) Open universe with final accelerated expansion

In the universe, hidden (dark, non-radiant) matter and hidden (dark) energy fundamentally have opposing functions. The universe and its structures are held together by hidden matter, which also prevents or slows down the universe's expansion. The distribution of hidden matter in the early universe was the primary driver of the formation of enormous structures, such as galaxies and galaxy clusters (at the beginning of the matter era). And the galaxies and galaxy clusters are still held together by gravity through this dark matter. However, if hidden energy prevails, its repulsive effects prevent structures from forming and cause the cosmos to expand worldwide at an ever-increasing rate.

The new cosmological model, which incorporates hidden matter and energy, is frequently called Lambda Cold Dark Matter (LCDM), in which the acceleration of expansion is described by the cosmological constant lambda (L). With the exception of the inflationary stage, dark energy had no involvement in the early cosmos. However, in the far future, it might have a significant impact; it could even blow the universe apart and dissolve it in nothingness. The "duel" between dark matter and dark energy, between their attracting and repulsive gravitational effects, will therefore determine the final fate of the universe in the future if the idea of dark (hidden) matter and energy proves to be correct. The visible glowing material is passively transported away by dark matter and energy, which create the global structure of spacetime. Because of its modest representation, it only has a secondary function in the dynamics of the cosmos. On the other hand, luminous matter acts as a source of electromagnetic signal, an indicator that enables us to map the dynamics and distribution of motion of both luminous and hidden matter in far-off space. Dark energy is most likely a field attribute of spacetime rather than the typical material, substance, or particle nature. For the foreseeable future, it will only be possible to speculate about the nature of dark energy or alternative explanations for the accelerated expansion of the universe, even though recent astronomical observations may make it possible to specify the representation of dark energy and perhaps even estimate its equation of state and the relationship between pressure p and density ρ. Thus far, there are essentially four options or hypotheses.

1. Negative pressure and vacuum energy. Regarding the ideas of unitary field theories' phase transitions. This was thought to be a "false vacuum" energy density of the same type that led to a large accelerated inflation expansion at the beginning of the cosmos. According to this theory, even the current vacuum may be "somewhat false." Still, it only produces a "little" accelerated expansion of the universe because its energy density is several orders of magnitude lower than it was at the beginning. According to this theory, the vacuum energy density is constant throughout space and time, independent of the universe's expansion, and equivalent to the cosmological constant L in Einstein's gravitational equations. Immanently "woven" into the hypothetical "yarn" of the space-time structure, it would be an immutable fundamental form of energy (case c in table 1). There are theories regarding the potential modest change in certain scientific "constants," but they mostly assume the cosmological constant and the dark energy it produces are immutable.

2. a brand-new field. The fifth interaction, which fills the cosmos, is sometimes referred to as quintessence (case b in Table 1). Generally speaking, the field of this interaction will no longer be constant; instead, it will be dynamic, with varying strengths over time and in different regions of the cosmos. Quintessence can be repulsive (as it seems now) or even enticing, depending on the ratio of its potential to kinetic energy at a particular moment. It varies as the universe expands; if it was initially set at a particular intensity, it should diminish with expansion, but at a rate different from the density of matter, radiation, or hidden matter. However, generally speaking, this unidentified field of the fifth interaction may be controlled and evolve according to its own dynamics, of which we do not yet know; we can think of three possibilities. As predicted by the closed universe model shown in Fig. 3a, its intensity may ultimately decline, causing the universe to stop expanding and eventually shrink. Dark energy would then become attractive, eventually collapsing in a "great crash" (which doesn't seem plausible anymore). Alternatively, it might stay roughly constant, resulting in a steady, slow acceleration in a situation like the cosmological constant's vacuum energy (Fig. 3b). As an alternative, we may envision the quintessence field becoming more intense over time, which would accelerate the universe's expansion indefinitely and possibly tear apart all of its structures, as depicted in Fig. 3c.

3. Variations from relativity's general theory. A somewhat different dynamics of the universe's evolution at extreme cosmic distances than that predicted by the "classical" general theory of relativity, which is well proven at shorter "astrophysical" distances, may be the reason for the accelerated expansion. It is necessary to create a new theory of gravity. The alteration of the current situation does not appear to be particularly likely. GTR shouldn't contradict other experiments and findings that have been satisfactorily explained.

4. There is no such thing as dark energy. Its fast expansion is only an optical delusion. Alternative theories regarding the existence or nonexistence of dark energy and accelerated expansion. It seems sensible to investigate the observable phenomenon of the universe's faster expansion using more easily comprehensible and credible reasons, given the enigmatic nature of the hypothesized dark energy. Our incomplete cosmological understanding of the universe's large-scale structure may be the source of what we perceive as dark energy. The Fridman model suggests that the universe's expansion may not be entirely homogeneous and isotropic. The universe is not entirely uniform and smooth. It is made up of several structures. Large cosmic voids are surrounded by a "cosmic network" comprising many galaxies. According to GTR, the geometry of spacetime, including the local expansion rate, is likewise impacted by the universe's inhomogeneous matter distribution. Large voids accelerate time relative to regions of the cosmos with higher matter densities (conventional and dark matter) or return the flow of time to normal. Radiation from the far-off universe frequently travels through these areas with varying gravities, and a small increase in its redshift can build up here. After all, the expansion may appear faster to us at other far-off places because we, as observers at the edge of our galaxy, may also be inside a sort of enormous "bubble" with a slightly lower Hubble expansion velocity. Therefore, it is possible that dark energy and accelerated expansion do not exist, and that the universe's matter inhomogeneity may trick us into simulating an expansion rate that differs from what is predicted.

This could appear to be a rather comprehensible and convincing explanation of the deceptive nature of the universe's accelerating expansion. But let's examine the universe's actual observed global inhomogeneities. The variations in matter density on the local cosmic scales of planets, stars, and galaxies are enormous—on the order of ~1030. However, the cosmos is extremely uniform on large scales, with density variations of about 0.01 per cent (less than 1 particle in 10,000). On a large cosmological scale, the cosmos remains highly uniform even though its (very little) matter eventually clumped into galaxies and "cosmic webs" at birth. In contrast to the enormous voids, the amount of matter in the cosmos is comparatively very little (on average, about 1 proton per cubic meter of space). Therefore, the faster expansion cannot be explained by the astronomically reported inhomogeneities. Therefore, the cosmological constant L and accelerated expansion are still regarded as fixed components of modern cosmology. Nevertheless, the most challenging unresolved issue in astrophysics and cosmology at the moment is the nature of dark energy.

The Late Accelerated Expanding Universe.

Because of its fast expansion and normal gravitational attraction, the cosmos would look very different in the distant future than it does now. Two completely different things will happen globally in such a universe: 1) All of the expanding matter in the universe, including distant galaxies that are not gravitationally bound to one another, will rapidly recede until they are out of our line of sight beyond the event horizon, "disappear" both causally and visually, are "swept" from our cosmic horizon, and enter the "invisible." We can picture this as a new expanding space is created between distant galaxies so quickly that even light appears to be slow to keep up with the rate of expansion—it is insufficient to carry information between them. 2) On the other hand, when adjacent galaxies continue to be attracted to one another by gravity, they will unite into a single huge "super galaxy." In a few hundred billion years, the visible universe will consist of a single massive galaxy surrounded by a vast, insurmountable void. One option for the ultimate future of the observable universe is that parts of the galaxy may eventually collapse into a gigantic black hole in the far future (hundreds of trillions of years). Let's compare this bleak prediction with the previously given reflection.

Astrophysics and Cosmology in the Late Accelerated Universe. It is also worthwhile to consider the observational and epistemic aspects of this development. In a hypothetical science fiction scenario, let's imagine that life and eventually an intelligent civilization would emerge in hundreds of billions of years in the late accelerated expanding universe on a suitable planet around some star in this super galaxy. These "humans" would create cutting-edge science and technology, refining tools to enhance life and explore space and environment, even though they won't physically resemble us. At this point, both Earth and our civilization will vanish, along with all of our knowledge. From the start, they will have to develop their own understanding of the natural world and the cosmos. It is unlikely that transhumanism will become a reality anytime soon. Compared to our present astronomers, these future astronomers might reach entirely different conclusions about the cosmos as a whole. In the vast void of space, even the biggest telescopes would be unable to detect any far-off galaxies whose spectral shift would indicate the universe's expansion. They would discover that there are no other galaxies in the cosmos and that they reside in a single, massive galaxy, likely elliptical and with minimal gas. Relic radiation, which is now microwave, is no longer observable due to its extreme dilution and elongation. What kind of cosmological theory these future observers would develop is difficult to predict. They most likely wouldn't even imagine a cosmos formed by the Big Bang. Accelerated expansion will "obliterate" any traces of the universe's early evolution and begin irreversibly.

They would observe a large number of stars of different generations and metallicities, and could build a robust framework for stellar nuclear astrophysics, well explaining the formation of heavier elements in the universe. By spectrometric analysis, they would determine the abundances of the light elements' hydrogen, deuterium, and helium in interstellar space. It's hard to say what kind of theory they would create for the origin of these elements. At the theoretical level of fundamental physics, they would be able to investigate elementary particles, atoms, and other structures through accelerator experiments. They would create what we now call special relativity and quantum physics. Of course, they would easily examine Newton's current law of gravitation. The question is, would they also build our general theory of relativity, or would they arrive at another relativistic physics of gravitation? By applying the model to the entire homogeneous and isotropic universe (even though its observable universe wouldn't be like that!), they could arrive at an analogy of Fridman's equations. One of their solutions - the universe expanding from a hypothetical singularity - they might find theoretically interesting, but so bizarre that they probably wouldn't relate it to the real universe, which would appear completely different at the time. Observational facts, followed by the application of physical laws, provide an astrophysical model of the universe. However, the ways we discovered these fundamental phenomena in the universe will not remain available permanently. Our ability to explore fundamental questions about the structure and evolution of the universe depends on when and where in cosmic history we happen to live. This also applies to any possible other civilizations that may arise in different stages of the universe's evolution. From the point of view of the current scenario of space evolution, we can welcome that we are fortunate to live at a suitable time when we have a good view of distant space. By analyzing astronomical observations (not only in optical and electromagnetic) we can get a realistic idea of universe evolution almost to period of its origin.

If the very intense (case d in Table 1) "phantom" dark energy continues to drive the expansion of the universe with increasing speed, in about a billion years, we will not even see our "fingertips", because everything around us will move away at super-light speed. The exponential course of expansion leads to an ever-accelerating expansion, which could theoretically approach infinite speed in the distant future. Conjecturing this scenario "to the end" may lead to the idea that ever-accelerating expansion will not only absolutely distance (beyond the horizon) all distant structures in space, as outlined above in the "Late Accelerated Expanding Universe" passage, but that dark energy will eventually overcome all interactions and binding forces. "Antigravity" will tear apart all bound structures - gradually galaxies, planetary systems, stars. In the final phase, according to some ideas, the atoms would rupture, and even the elementary particles themselves, and perhaps even the structure of space-time, would rupture. Such a scenario of cosmic evolution is sometimes referred to as the "big rip".

Mysteries of Nature. The existence of hidden or dark matter substance and even more hidden, darker and more mysterious dark energies in the universe is a great challenge not only for astrophysics and cosmology, but also for elementary particle physics, if we look for its source at the quantum level. The problem of explaining a non-zero but very small cosmological constant L represents a major challenge for unitary field theories. In current quantum field theories, including a large number of quantum fluctuations, the value of rL is found to be more than 120 orders of magnitude higher. To analyze this problem, one could perhaps say its own even the anthropic principle. Anthropic justification in co-production with the idea of a multiverse - a huge set of different universes with different properties of elementary particles, fundamental interactions and thus the amount of vacuum energy. And even different dimensions of space, could reflect, at least on a philosophical level, these hidden mysterious properties.

Origin and Evolution of the Universe. For better clarity, a large amount of knowledge and hypotheses about the origin and evolution of the universe are discussed in this article, and it will be expedient to briefly and simplified recapitulate within the framework of the current standard cosmological model in several points, capturing the basic processes:

1. Creation of the universe. It is assumed to have occurred approximately 13.8 billion years ago in an explosively hot so-called big bang. The hypothetical initial singularity was rather a "topological foam" of spacetime. In the beginning there was no causality or any laws of physics, all physical forces were connected. At the Planck time of 10^{-43} s, gravity began to operate; the strong, weak and electromagnetic interactions were still unified. Spacetime was created, followed by the rapid expansion of the universe.

2. Inflationary expansion of the universe. It occurred almost immediately after the Big Bang and after gravity became independent, at 10^{-35} seconds. It was very violent but short, after about 10^{-32} seconds it stopped, and the universe was already expanding according to Fridman's model. The inflationary expansion of the very early universe ensured that the universe became globally smooth and flat. The energy of inflationary expansion was transformed into elementary particles - leptons, quarks, gluons. The strong interaction is separated from the electro-weak one. Quarks and gluons were initially free, forming the so-called quark-gluon plasma. It is assumed that as yet unknown particles of so-called dark matter may also be created here.

3. Hadron era. After the first microsecond, due to the strong interaction in the quark-gluon plasma, the free quarks combine into hadrons, mainly protons, neutrons and unstable mesons. Due to the so-called baryon asymmetry, slightly more matter than antimatter was created (in a ratio of $1:10^9$).

4. Lepton era. In a time of 10^{-4} s, the nucleons and antinucleons annihilated each other (into pions which decayed into muons, electrons and neutrinos), only a small excess of 10^{-9} nucleons remained. An equilibrium mixture of light particles - leptons - electrons, positrons, neutrinos, mixed with photons prevailed.

5. Primordial cosmological nucleosynthesis. In 10 s. - approx. 1000 s., the fusion of protons and the remaining free neutrons took place to form the nuclei of deuterium ^2H, tritium ^3H, helium ^4He and ^3He, in a small amount of beryllium, lithium, boron. The final result of this primordial nucleosynthesis was the representation of atomic nuclei: 75% hydrogen ^1H, 25% helium ^4He, a small amount of deuterium ^2H ($\sim 4\times10^{-2}$ %), helium ^3He ($\sim 2\times10^{-3}$ %) and a trace amount of Li, Be, B. Heavier elements could have formed much later, in stars.

6. Photon era of radiation. In all the above-mentioned early periods of the universe, there was a high temperature - great kinetic energy of particles and photons, the matter in the universe was in a plasmatic state. In the period ~10 s. ÷ 10^{13} s., radiation-dominated photon plasma prevailed in space.

7. Formation of atoms and era of matter. In about 380,000 years, when the temperature dropped below 3000 °K, protons and helium nuclei combine with electrons to form neutral atoms of hydrogen and helium. The universe becomes transparent to light; its mass is made up of gaseous hydrogen and helium.

8. Formation of large-scale structures and creating of galaxies and stars. After the formation of atoms ("recombination"), the "dark age" occurred, because the radiation from the early hot universe had already died out and there were no stars yet. Cold matter, gaseous hydrogen and helium, begins to organize itself into large-scale structures through gravitational contraction, galaxies and clusters of galaxies are formed (the formation of large structures was also greatly assisted by the so-called dark matter). Gravitational contraction of denser gas clouds creates the first generation of stars, which end the "dark age" with their radiation. Massive stars thermonuclearly synthesize heavier elements from hydrogen and helium, explode as supernovae and enrich the surrounding matter with heavy elements. The stars of the next generations are then created from this substance, including our Sun. After their formation, stars are surrounded by clouds of residual gas ("protoplanetary disks"), in which planets orbiting the central star (such as the planets of the solar system, including Earth) gradually form.

9. Late evolution, the future of the universe. During all these processes, the expansion of the universe was still taking place, which was gradually slowed

down by the attractive gravitational action of all the matter of the universe, including dark matter. However, this deceleration of expansion lasted only about 7 billion years. After sufficient dilution of the gravitating matter, the so-called dark energy, which has anti-gravitational effects, began to prevail. The deceleration of the expansion gradually decreased until it turned into an acceleration of the expansion. This situation continues even now and the continued accelerated expansion of the universe is expected in the future. In the distant future

11. Possibilities of 'End of Universe'

Astrophysics and cosmology are concerned in particular with the study of the evolution of space objects and the cosmos as a whole. The current expansion of the universe, where individual possibilities are examined beforehand, is the fundamental knowledge of astronomy. The topic of where the universe's evolution is heading in the future is just as fascinating and fundamental as the question of the universe's origin and early phases. What happens to all of space's incredible structures and matter? According to the conventional cosmological model, the universe's future relies on whether the average density of cosmic mass r is less or larger than the critical density r_{crit}, excluding improbable scenarios like a stable or oscillating cosmos.

Closed universe. The universe is closed at supercritical density and will only expand to a certain point before gravity takes over, expansion stops, and shrinkage begins. The redshift turns the relic radiation blue, and its temperature initially rises slowly but eventually grows indefinitely. This process continues until the universe reaches a very dense, hot state (theoretically a singularity), and the universe undergoes gravitational collapse, sometimes known as a Big Crunch or a Big Collapse. Every construction will be demolished, along with the material that makes it up. Therefore, the last stages of a closed universe occur, roughly speaking, in reverse order to the early universe's birth and expansion; when the energy of the relic radiation increases, the atoms of interstellar and stellar matter will once more disintegrate into elementary particles. In contrast to the early universe, there will actually be a large number of compact objects in the final stage, such as neutron stars and black holes, which rapidly expand and eventually merge due to particle and radiation accretion. Recent astronomical measurements suggest that this closed-space scenario is unlikely.

Open Universe. According to the mainstream cosmological model, the universe will expand continuously beyond all bounds if the density of cosmic matter is below the critical density. Gravity will slow the expansion, but it will never stop. There will be "enough time" to implement extremely laborious astrophysical evolution scenarios for stars, galaxies, and the entire universe. According to the astrophysical scenario of stellar evolution, the Sun will gradually run out of hydrogen in 5–7 billion years and begin to expand into a red giant. The inner planets Mercury, Venus, and perhaps Earth and Mars will be gradually consumed by them. This red giant transforms into a white dwarf after a few million years. Meanwhile, the solar system's planets will likewise experience full manifestations of gravitational instability, with some planets perhaps exiting the system entirely.

Galaxies' gas and dust will produce several additional generations of stars over the next 10 to 30 billion years, enriching the cosmic matter with heavier elements through nucleosynthesis. But hydrogen, which is the usual "fuel" for stars in galaxies, is rapidly running out. The star birthrate is decreasing in most galaxies. The majority of galaxies will burn out after 100 billion years. After that, there won't be any more material for the creation of new stars, and the cosmos will descend into an ever-deepening darkness that will only sporadically be briefly illuminated by supernova explosions, which are the dying stage of some of the last enormous stars. Only the compact bodies of the latest stages of stellar evolution—white dwarfs, black dwarfs, neutron stars, and black holes—remain after the last stars die out. They will orbit the supermassive black holes at the heart of the galaxies with the remaining diluted gas, and their material will progressively cool until it reaches the temperature of the surrounding cosmos. It will take a very long time. In roughly 1015 years, a white dwarf will cool to a black dwarf state.

Neutron star fusions, which originated as a component of binary or many systems, will be minor occurrences throughout this time. They will radiate the circulation's kinetic energy as gravitational waves as they orbit one another, progressively getting closer until they eventually merge. Along with the gravitational wave flash, a significant amount of neutron material is released during this event. This material then explosively nucleosyntheses to form a hot, high-concentration mixture of heavy elements. The surrounding dark cosmos will be momentarily illuminated by these hot regions of matter before they quickly expand and vanish. Whether the proton decays into leptons as predicted by some grand-unification theories, albeit with a very long half-life >1033 years; in an open universe, however, there is enough time or remains a stable particle as it appears from experience to date, will determine the future fate of these remaining structures. That is unknown at this time. These material configurations in the wide cosmos might not change indefinitely in the case of stable protons.

However, the quantum tunneling effect might happen on such unfathomably long-time scales: light atomic nuclei might be able to overcome the electric repulsive barrier between themselves, resulting in cold nuclear fusion and the spontaneous fusion of light nuclei into heavier ones. The tunnel effect in this case has almost no probability since cold nuclear fusion is not conceivable under normal conditions. But even this tiny likelihood could appear over a time horizon of about >>10100 years? This hypothetical theory of cold nuclear fusion suggests that lighter atomic nuclei in compact cosmic objects, such as star remnants, could progressively combine into heavier ones up to iron, a process that could take more than 101000 years to achieve. They might then collapse into black holes or neutron stars. However, there will never be an experimental way to confirm this mechanism, therefore it will always stay theoretical. Protons in the nuclei of atoms in the atmosphere and inside compact bodies will gradually decay in the second scenario, known as proton instability (except black holes). Their temperature will remain slightly below zero at a few tenths of a °K due to the energy lost during this decay. Leptons and radiation will be released into the surrounding space when the matter from black dwarfs, neutron stars, gasses, and the remaining planets gradually breaks down.

In the meantime, gravitational waves that take away rotational energy cause the majority of galaxies to collapse into enormous black holes. After roughly 1035 years, the majority of what's left in space are black holes, which are encircled by light particles and sparsely distributed radiation. Black holes will first expand due to accretion, but their quantum evaporation takes over once the temperature of relic radiation has sufficiently dropped. Hawking's quantum mechanism causes black holes to evaporate after a very long time (about 1060 years), leaving the cosmos mostly composed of extremely sparsely distributed particles and continuously cooling and diluting radiation. Only a bland, sparse collection of subatomic particles—electrons, positrons, photons, and neutrinos—will remain from the formerly magnificently structured universe. These particles will fly in the never-ending darkness of the perpetual freezing wasteland without interacting with one another. There will be no more events or phenomena, time seems to have stopped, and the universe will be essentially dead and empty. According to the principles of thermodynamics, all useable energy will be exhausted (degraded into waste heat and radiation); life could not exist in such a setting, and all chemical reactions would cease. The "great cold" or the "thermal death" of the universe are terms used to describe this unending freezing extinction of all structures and events. What does "the Future of the Universe" entail? There are two options for how this expansion might proceed: 1) That in the future the expansion will end and turn into contraction. Thus, a great crash is the collapse of the universe and will cause it to vanish. 2) The expansion will go on indefinitely, but the attracting gravity of stuff will essentially slow it down. Option 1 has already been dropped as of right now. Furthermore, recent astronomical measurements of type Ia supernovae that are extremely far away further demonstrate that the evidence.

The cosmos is continuously growing. For the first nine billion years or so, the expansion slowed down. However, after that, it started to pick up speed, and the universe is currently growing more quickly. We have no idea how or if it will all end. Different possibilities of "great cooling - heat death of the cosmos" or even "huge rip" because of the universe's exponentially rising pace of expansion are being proposed. This has to do with dark energy's as-yet-unknown characteristics. There will undoubtedly always be a number of unanswered questions because resolving one issue typically prompts more. This inherent restriction of our understanding should be freely acknowledged. Some experts have some issues with this because they are rather "scholastically" focused on teaching at universities. They attempt to be "extremely clever" and replace "axioms" that pupils have "to buffoon" with some inexplicable phenomena, issues, or qualities; it seems learned and scholarly. There should be some space for independent thought and an attempt at an informal, illustrated comprehension of the true essence even when there is no other option. It may include a few fairly unconventional and speculative theories at the conclusion that it was unable to fully incorporate into the continuity of astrophysics and cosmology interpretation. Below is a description of those speculative theories.

Loss of Information in a Black Hole. The characteristics of black holes have been thoroughly covered above. With the exception of the total mass, charges, and rotating momentum, all information regarding the specific characteristics of the collapsing matter is lost to the outside world when a black hole is created through gravitational collapse. Both hair and microscopic structure are absent from black holes. The phrase "a black hole has no hair" is a metaphor for this, meaning that it just possesses mass, charge, and rotational angular momentum. This peculiar circumstance is referred to as the ‘paradox of information loss’. Quantum evaporation: what is it? or matter coming back from a black hole. In the context of classical or non-quantum physics, black holes are attributed to the actual temperature (proportional to the surface gravity) and the actual entropy (proportional to the surface horizon) based on this analogy, creating a kind of ‘thermodynamics of black holes’. There would be inconsistencies in these thermodynamics. Regardless of the strength of the surface gravity, a black hole's temperature must be absolute zero since, according to classical physics, it may absorb bodies and radiation but cannot release anything. Similarly, since a black hole might theoretically be created by the collapse of an arbitrarily large number of tiny particles, the entropy of a black hole should be infinite according to classical physics, independent of the size of the horizon surface. Therefore, in classical physics, the comparison between the rules of thermodynamics and black hole mechanics would have no deeper scientific significance and would merely be an outward and essentially random similarity.

Black hole features have only been studied in terms of the classical general theory of relativity; quantum phenomena have not been taken into consideration. Since there is yet no fully developed quantum theory of gravity, a fully consistent quantum method is not yet possible. Therefore, we have to settle with a sort of "semi-quantum" strategy: we will only quantize other physical fields, leaving gravity unquantized. To put it another way, we will use quantum physics to explain how matter moves and how non-gravitational fields behave in curved spacetime (against the background of unquantized geometry of spacetime - in the unquantized gravitational field). It can be anticipated that this semi-quantum approximation will accurately describe reality in almost every scenario, with the exception of phenomena in the immediate vicinity of singularities, since the effects of quantitation of spacetime itself can be applied significantly in microscales of the order of ~10-33 cm (see §B.3), while they are very small in the scales of ordinary physics (i.e., above 10-13 cm). Entropy is a measure of a system's disorder from the perspectives of statistical physics and information theory.

The black hole's entropy is then measured by this massive amount of lost information. The somewhat deceptive term "holographic principle" was later used to the proportionality between the horizon's surface and the entropy of the absorbed materials.

Holographic Principle. A ‘holographic image’ in optics is created in such a way that a beam of coherent light from a laser is split into two parts, one of which hits the photographic layer directly, and the other part after reflection from the imaged object. Both of these beams interfere and create a structure of thin interference stripes on the photographic emulsion, carrying information about the phase differences of the two beams. If we then irradiate this two-dimensional image with coherent light again from a laser. The reflected rays reconstruct the same phase differences that created the image - the impression of a three-dimensional image of the original object is created. The holographic image has the interesting property that even from a fragment of the hologram we can see the entire three-dimensional image, albeit with a lower resolution. The two-dimensional surface of the black hole's horizon carries all the information appropriately reduced "the black hole has no hair" about the three-dimensional configurational masses absorbed in the black hole, just as a two-dimensional hologram carries information about a three-dimensional object. However, the similarity with holography ends here, because specific detailed information about the absorbed matter except for the mass M, the momentum of the rotational moment J and possibly the electric charge Q is lost and cannot be reconstructed in any way.

However, some experts in the field of astrophysics and unitary field theories (started with G. Hooft and L. Susskind) liked the holographic idea and led them to believe that in a similar way all information about other systems, not only black holes, could be locate on the surface area) of the area in which they are located. A thought experiment with a very large black hole could indirectly point to this, around whose horizon the usual laws of physics would apply as in a state of weightlessness, in a free-falling locally inertial system there would be only tiny tidal forces. Below the horizon, based on the holographic proportionality between the surface of the black hole's horizon and its entropy, we can imagine that all information about the matter inside is localized on the horizon, whose surface maintains information about the entire internal space. However, this interpretation is not very physically correct, because the theorem "a black hole has no hair" and the proportionality between the surface of the horizon and entropy applies to the outer, not the inner, space of the black hole.

The holographic principle was further generalized in connection with the construction of superstring theory: "Information degrees of freedom about a system inside a volume V-can be localized encoded on the surface V of this volume, while the information density does not exceed one bit per Planck surface lp2". The holographic principle is generally the statement that information about an N-dimensional region (its interior) is encoded at the N-1 dimensional boundary of that region. Within the general theory of relativity, it is theoretically supported only at the horizons of black holes. In other cases, it is only an extrapolation and analogy and which is an unsubstantiated hypothesis. So, the universe is apparently not holographic. However, holographic concepts are sometimes used in different variants of superstring theory. However, Superstring theory is a theoretical framework in physics proposing that the fundamental constituents of the universe are not point-like particles, but tiny, vibrating one-dimensional "strings". It aims to unify quantum mechanics and general relativity, incorporating "supersymmetry" to include both bosons and fermions, potentially serving as a "Theory of Everything". Question is holographic universe possible? An adequate skeptical answer is ‘Probably not’

Universe may inside a Gigantic Black Hole. The development of black hole astrophysics in the 1960s - 1980s and the attractiveness of these exotic objects led to yet another bizarre hypothesis: That our entire universe with all the galaxies, nebulae, stars, planets and other structures that can be seen through telescopes or inferred from detection of electromagnetic or corpuscular radiation and possibly gravitational waves could be located inside a gigantic black hole. And existing inside an even larger whole or the multiverse. However, there is no direct connection with the multiverse hypothesis like ‘Anthropic principle and the existence of multiple universes.’ The origin of this universe could then be explained by an equally bizarre idea: that the Big Bang was a kind of Big Bounce, where the gravitational collapse in the previous universe created a "wormhole." The outlet of which opened into a new expanding universe? So, all unverified assumptions, furthermore, from an astrophysical point of view, it would not be consistent with the cosmological principle of global homogeneity and isotropy of the universe. In the outward direction, towards the horizon of the black hole, a sparser distribution of galaxies would be observed than towards the center, towards the singularity. No edge of the universe at the horizon, nor condensation in the direction towards the center and possibly fall into the singularity, is not observed. Some astrophysicists like the idea of the universe inside a black hole, but mainly popularizers and those interested in the fields of philosophy, culture and social sciences. They find it exciting and mysterious. However, it does not correspond to the real universe that we observe and live in which.

Universe may be a Giant Quantum Computer. Successful analyzes and computer simulations of many processes in the universe using powerful computers with sophisticated software have given some authors the impression that this is not just a random success of erudite astrophysicists and computer experts, but because the universe itself is a kind of gigantic software system, that we are just trying find out. And from the point of view of evolution, the Universe is a kind of autodidactic system...? Surely most experts do not mean this completely unfounded science fiction hypothesis literally, but rather metaphorically! "We could be living in the digital world depicted in the Matrix without knowing it?" Probably not! The literal hypothetical that "the universe is a computer" is definitely not true. Instead, a more plausible claim should be: "A number of processes in the universe can be software algorithmized" and analyzed on large computers possibly quantum computers in the future, allowing them to better understand, simulate, and extrapolate into the future. Philosophically, this suggests that the universe is knowable in terms of the idea of the material unity of the world.

Cosmic Consciousness. The universe may be a living thing that is aware of itself. This sci-fi idea is too subjective and anthropomorphic to discuss in detail in our Astro-physics thesis. Astrophysics and cosmology view the universe as a barren and inhospitable place consisting almost entirely of empty space and inanimate matter. Life is extremely precious. On Earth, matter organized itself to a high level of complexity by special mechanisms and gradually created living beings like Stars, planets, life in the universe. We don't yet know if this has happened in other places in the universe. Some philosophers, alternative naturalists and environmentalists, in the spirit of anthropomorphism, would like to see the universe not completely dead, but the Universe as a living, evolving and learning system with which we humans would live in harmony with each other, because a better and sustainable life on Earth, without crises and devastation of the natural environment. This is certainly a positive motivation. However, somewhat deceptive here can be the uncompromising motivation against materialism, which wrongly equates objective enlightened scientific materialism, which helps to protect nature by better knowledge of reality, with vulgar human materialism, leading to selfishness, consumer society and the devastation of nature. However, here is no objective confirmation of this idea.

12. The Ultimate Fate or Death of Universe

Theoretically, phantom dark energy is a very unstable type of dark energy whose density rises as the universe expands, possibly causing a Big Rip. It is referred described as "phantom" due to its peculiar characteristics, which imply repulsive pressure greater than the energy density itself. It is a hypothetical extension beyond standard dark energy, which has a constant density. Gravity now appears to be stronger at the scales of galaxies and galaxy clusters than would be expected for "luminous" or absorbing matter made up of protons, neutrons, and electrons as measured by astronomers. Thus, dark-hidden gravitational matter is introduced. Conversely, gravity looks less on the larger cosmological scales, where the universe expands, than would be expected given the total attraction of ordinary and dark matter particles. As a result, dark energy is a weak antigravity that acts against gravity and apart from matter—is introduced. Dark energy is needed in current models of the universe to account for the acceleration of space expansion that has been detected based on measurements of supernova distances in far-off galaxies (which appear to be more distant than they should be if the expansion of the universe did not accelerate). But new observations are being assessed, alternative possibilities are being investigated, and the problems of dark matter and dark energy are still being debated.

The question now is, how will the universe end? Or what is the universe's final destiny? Everything that has originated, existing, and is evolving must eventually come to an end or extinction and that based on all of our observations of nature and life. We also believe that the entire cosmos possesses this quality. This article has examined several astrophysical processes that could eventually lead to the extinction or death of the universe as we know it in the far future. The evolution and extinction of the universe is a cosmological framework tracing the universe from its origin in the Big Bang through its expansion to its eventual, inevitable end. The universe is currently experiencing an accelerating expansion driven by dark energy, making the most likely ultimate fate a Big Freeze or Heat Death, although other scenarios like the Big Rip or Big Crunch remain possibilities. For the sake of clarity, let's list the main ways that our universe can go extinct, be destroyed, or die based on current astrophysics and cosmology:

1. Thermal/Heat Death, often known as the Big Freeze, is the universe's infinite expansion. The adiabatic expansion will continue indefinitely if the gravity of matter in space is unable to slow down and stop cosmological expansion. This will result in an infinite dilution of the average density of matter and a drop in temperature to almost zero. The expanding universe depletes all energy, all processes in the universe cease, and Big Freeze or Thermal Death occurs, as discussed in Open Universe above. [72] This mechanism, therefore, remains theoretical. In the second scenario, known as proton instability excluding black holes, protons within atomic nuclei in the atmosphere and inside compact objects will slowly decay. Their temperature will stay just below zero, at a few tenths of a Kelvin, due to energy loss during decay. As matter from black dwarfs, neutron stars, gases, and remaining planets gradually decomposes, leptons and radiation will be emitted into space. Meanwhile, gravitational waves that remove rotational energy continue to propagate. [73] In actuality, this is a situation where the cosmos asymptotically approaches absolute zero temperature due to continuing expansion. [74]

According to this theory, the world eventually approaches a state of maximum entropy, where everything is distributed uniformly and there are no energy gradients, which are necessary to support information processing, including life. In this scenario, stars are pre-

[72] Tegmark, Max (May 2003). "Parallel Universes". Scientific American. 288 (5): 40–51, accessed on 16 Mar 2026 doi:10.1038/scientificamerican0503-40, accessed on 16 Mar 2026

[73] Werlang, T.; Ribeiro, G. A. P.; Rigolin, Gustavo (2013). "Interplay Between Quantum Phase Transitions and the Behavior of Quantum Correlations at Finite Temperatures". International Journal of Modern Physics B. 27: 1345032, doi:10.1142/S021797921345032X, accessed on 16 Mar 2026

[74] Glanz, James (1998). "Breakthrough of the year 1998. Astronomy: Cosmic Motion Revealed". Science. 282 (5397): 2156–2157, doi:10.1126/science.282.5397.2156a, accessed on 16 Mar 2026

dicted to form properly for 1012 to 1014 (1–100 trillion) years, but eventually the gas supply required for star formation would run out. This scenario has gained momentum as the most likely outcome. The universe will gradually and unavoidably become darker when current stars run out of fuel and stop shining. Black holes will eventually rule the cosmos, yet as they emit light, they will eventually fade away. Radiation from Hawking.[75] The Poincare recurrence theorem, thermal fluctuations, and the fluctuation theorem could all lead to a spontaneous entropy drop over infinite time.[76] Any of the three spatial models can accommodate the heat death scenario, but it necessitates that the universe eventually reach a minimum temperature. It could only happen in a flat or hyperbolic geometry in the absence of dark energy. It might also happen in a closed universe with a positive cosmological constant.

2. The Big Crunch is the universe's collapse. The expansion of the universe will cease if the density of matter in the universe is high enough for its gravitational pull to overcome the cosmological expansion caused by the Big Bang. This will be followed by a contraction that will progressively accelerate and the universe will end in gravitational collapse, which is the final, extremely hot and dense end of the universe or the theoretically collapses with singularities and that is known as the Big Crunch. It is occasionally believed that the Big Bang and the creation of a new universe might happen again following this universe's collapse, although this is merely an unproven theory.[77] A symmetric theory regarding the universe's ultimate destiny is the Big Crunch hypothesis. Similar to how the Big Bang theory began as a cosmic expansion, this theory postulates that the universe's average density will be sufficient to halt its expansion and cause it to start contracting. The outcome is unclear; at large scales, unknown quantum processes must be taken into account. A straightforward estimate would have all of the universe's matter and spacetime collapse into a dimensionless singularity back into how the cosmos began with the Big Bang.

The universe's temperature would be so high in the final moments of the Big Crunch that atoms and atomic nuclei would disintegrate and be drawn into already-forming black holes. Similar to the Big Bang, all of the universe's substance would be compressed into an endlessly hot, infinitely dense singularity at the Big Crunch. [78] A new universe might be created if a second Big Bang occurs after the Big Crunch. However, some physicists have suggested that a dark energy fluctuation may lead to a Big Crunch-style event. Since measurements have only been available for a brief period of time and could reverse in the future, recent information indicates that this scenario is unlikely but has not been ruled out. It was predicted in the 1960s and 1970s that the cosmos will collapse in roughly 100 billion years.[79] Recent astronomical studies indicate that the cosmos is most likely open and that this closed space hypothesis is not very feasible.

3. The Big Rip is the universe's infinite, accelerating expansion. This theory supports the earlier theory of endless expansion: the accelerated expansion of the universe could progressively accelerate exponentially indefinitely if the density of dark energy were high enough and the expansion of the universe would potentially rise. This would separate the planets from the stars by first dispersing galaxy clusters, then individual galaxies.[80] Stars, planets, molecules, atoms, atomic nuclei, elementary particles, and ultimately the structure of space-time would all be broken down by the internal pressure of rapidly expanding space. The current Hubble constant describes a rate of acceleration of the cosmos that is great enough to increase the distance between local objects like galaxies, which are held together by gravity, but not large enough to destroy them.[81]

All material objects in the universe, beginning with galaxies, would eventually (in a finite amount of time) disintegrate into unbound elementary particles, radiation, and beyond if the Hubble constant were to steadily climb to infinity. The universe ends as what is essentially a singularity as the energy density, scale factor, and expansion rate become infinite.[82] A more abrupt huge rip might happen in the unique scenario of phantom dark energy, which is thought to have negative kinetic energy and would cause a faster rate of acceleration than other cosmological constants predict.[83] Thus, a cyclic model of the cosmos that reverses its

[75] Adams, Fred C.; Laughlin, Gregory (1997). "A dying universe: the long-term fate and evolution of astrophysical objects". Reviews of Modern Physics. 69 (2): 337–372, doi:10.1103/RevModPhys.69.337, accessed on 16 Mar 2026

[76] Linde, Andrei (2007). "Sinks in the landscape, Boltzmann brains and the cosmological constant problem". Journal of Cosmology and Astroparticle Physics. 2007 (1): 022. arXiv:hep-th/0611043, accessed on 16 Mar 2026doi:10.1088/1475-7516/2007/01/022, accessed on 16 Mar 2026

[77] Perlmutter, Saul (April 2003). "Supernovas, Dark Energy, and the Accelerating Universe". Physics Today. 56 (4): 53–60, doi:10.1063/1.1580050, accessed on 15 Mar 2026

[78] Davies, Paul (1997). The Last Three Minutes: Conjectures About the Ultimate Fate of the Universe. Basic Books. ISBN 978-0-465-03851-0, accessed on 15 Mar 2026

[79] Adams, Douglas (1995). The restaurant at the end of the Universe (1st ed.). New York: Ballantine Books. ISBN 978-0-345-39181-0, accessed on 15 Mar 2026

[80] Harrison, E. (1992). "The redshift-distance and velocity-distance laws". The Astrophysical Journal. 403: 28–31, doi:10.1086/172179, accessed on 15 Mar 2026

[81] Croton, Darren J. (14 October 2013). "Damn You, Little h! (Or, Real-World Applications of the Hubble Constant Using Observed and Simulated Data)". Publications of the Astronomical Society of Australia. 30 e052, doi:10.1017/pasa.2013.31, accessed on 16 Mar 2026

[82] Braibant, S.; Giacomelli, G.; Spurio, M. (2009). Particles and Fundamental Interactions: An Introduction to Particle Physics. Springer. pp. 313–314. ISBN 978-94-007-2463-1, from the original on 15 April 2021, accessed on 16 Mar 2026

[83] Ludwick, Kevin J. (2017-09-14). "The viability of phantom dark energy: A review". Modern Physics Letters A. 32 (28): 1730025, doi:10.1142/S0217732317300257, accessed on 16 Mar 2026

growth very soon before the impending Big Rip was one use of phantom dark energy in 2007. If the mass-energy of every point in the universe is dense enough to collapse into black hole core material that will bounce after reaching a maximum threshold of compression, generating the next big bang, this cyclic model may get more complex. The quantity and dynamics of the behavior of the enigmatic and ghostly dark energy, about which we now know very little, will determine whether and when such an event could occur. Only wildly speculative estimations for 100–200 billion years have been found thus far.

4. The Big Bounce is the collapse of an earlier cosmos. One cosmological theory regarding the beginning of the known universe is the Big Bounce hypothesis.[84] A scientific theory about the origin of the known universe is called the Big Bounce. It comes from the Big Bang's oscillatory universe or cyclic repetition theory, which holds that the first cosmic event was caused by the collapse of an earlier universe.[85] After inflation theory surfaced as a solution to the horizon problem, which had arisen from advancements in observations exposing the large-scale structure of the cosmos, it lost significant attention in the early 1980s.[86] According to this idea, the universe will repeatedly experience a Big Bang followed by a Big Crunch.[87]

One variation of the Big Bang theory of cosmology holds that the cosmos was initially infinitely dense. Such a description appears to contradict other more widely accepted theories, particularly the uncertainty principle of quantum physics.[88] Consequently, a different interpretation of the Big Bang idea has emerged as a result of quantum mechanics, namely that the universe tunneled into existence and had a finite density consistent with quantum mechanics before growing in a way controlled by classical physics.[89] Additionally, if the universe is closed, this theory predicts that if a universal singularity is attained or a repulsive quantum force induces re-expansion, the collapsing universe will give rise to another universe in a Big Bang-like event.[90] It was discovered that inflation was unavoidably eternal, producing an infinite number of distinct universes with generally distinct characteristics, implying that the characteristics of the observable universe are purely coincidental.[91] As a predicted and falsifiable potential solution to the horizon problem, a different idea was developed that featured a Big Bounce.[92] Investigation continued as of 2022.[93]

5. False vacuum quantum transition is known as vacuum instability. The quantum cosmology of the very early cosmos, which makes the assumption of inflation expansion, served as the inspiration for this quite strange scenario. A phase transition from a false highly stimulated vacuum to a real vacuum with a reduced energy density coincides with (and causes) the universe's very rapid exponential expansion. Although our current vacuum in the cosmos may not be the real lowest, it is also somewhat fake and has a propensity to transition to a genuine vacuum with even lower energy. In this scenario, a tiny bubble of a true low-energy vacuum may form somewhere in the cosmos. This bubble has the potential to grow exponentially at super-light speeds, and it will ultimately give way to the entire universe. Theoretically, this disastrous vacuum breakdown process might happen at any time. However, the very fact of the peaceful existence of our universe for more than 13 billion years suggests that the probability is very small, it is estimated that in the next perhaps 10^{100} years there will be no such catastrophe. Moreover, according to some other hypotheses, this process would did not destroy our universe, but could lead to the creation of a parallel other universe in a topologically different space.

Analytical Result. A study that was published in Physical Review Letters in May 2023 states that the Big Bounce should have left marks in the cosmic microwave background (CMB), or primordial light. However, when comparing Planck satellite observations with the simulated CMB in the scenario that the universe bounced on itself only once, that specific bounce

[84] Abelev, B.; Adam, J.; Adamová, D.; Aggarwal, M. M.; Aglieri Rinella, G.; Agnello, M.; Agostinelli, A.; Agrawal, N.; Ahammed, Z.; Ahmad, N.; Ahmed, I.; Ahn, S. U.; Ahn, S. A.; Aimo, I.; Aiola, S. (2014-11-10). "Beauty production in pp collisions at s=2.76 TeV measured via semi-electronic decays" (PDF). Physics Letters B. 738: 97–108, doi:10.1016/j.physletb.2014.09.026, accessed on 16 Mar 2026

[85] Novello, M.; Bergliaffa, S. E. Perez (2008-07-01). "Bouncing cosmologies". Physics Reports. 463 (4): 127–213, doi:10.1016/j.physrep.2008.04.006, accessed on 16 Mar 2026

[86] Finelli, Fabio; Brandenberger, Robert (2002-05-15). "Generation of a scale-invariant spectrum of adiabatic fluctuations in cosmological models with a contracting phase". Physical Review D. 65 (10) 103522, doi:10.1103/PhysRevD.65.103522, accessed on 16 Mar 2026

[87] Ashtekar, Abhay; Pawlowski, Tomasz; Singh, Parampreet (2 October 2006). "Quantum nature of the big bang: Improved dynamics". Physical Review D. 74 (8) 084003, doi:10.1103/PhysRevD.74.084003, accessed on 16 Mar 2026

[88] Brandenberger, Robert; Peter, Patrick (2017). "Bouncing Cosmologies: Progress and Problems". Foundations of Physics. 47 (6): 797–850, doi:10.1007/s10701-016-0057-0. ISSN 0015-9018, accessed on 17 Mar 2026

[89] Halliwell, J. J. (1991). "Quantum cosmology and the creation of the universe". Scientific American. 265 (6): 76, 85, doi:10.1038/scientificamerican1291-76, accessed on 17 Mar 2026

[90] Lehners, Jean-Luc; Steinhardt, Paul J. (2013). "Planck 2013 results support the cyclic universe". Physical Review D. 87 (12) 123533, doi:10.1103/PhysRevD.87.123533. ISSN 1550-7998,

[91] McKee, Maggie (25 September 2014). "Ingenious: Paul J. Steinhardt – The Princeton physicist on what's wrong with inflation theory and his view of the Big Bang". Nautilus. No. 17. NautilusThink Inc. Archived from the original on 23 January 2017, accessed on 17 Mar 2026

[92] Steinhardt, Paul J.; Turok, Neil (2005). "The cyclic model simplified". New Astronomy Reviews. 49 (2–6): 43–57, doi:10.1016/j.newar.2005.01.003. ISSN 1387-6473, accessed on 17 Mar 2026

[93] Ijjas, Anna; Steinhardt, Paul J. (January 10, 2022). "Entropy, black holes, and the new cyclic universe". Physics Letters B. 824 136823, doi:10.1016/j.physletb.2021.136823, accessed on 17 Mar 2026

signature was not discovered.[94] It is less likely that a second Big Bang, which would create a new universe, would occur after the Big Crunch, where gravity reverses expansion. .[95] Although not completely ruled out, other hypothesized scenarios, such as the Big Rip (where expansion tears apart atoms), are likewise thought to be less likely based on available observational data.[96] Variant/option No. 1 seems to be the most likely manner to terminate the cosmos based on existing astrophysical knowledge. (Heat/Thermal Death or the Universe's Great Freeze). This is the most widely accepted model, according to astrophysicist Katie Mack, because measurements of dark energy indicate that it behaves like a cosmological constant, and that causing an accelerated expansion that results in dilution rather than a cataclysmic collapse or tear. [97] The vast astrophysical uncertainties we have regarding the universe's global structure, the dynamics of its evolution, and the nature and equations of state of dark matter and dark energy must be emphasized. We may only have a limited understanding of the metagalaxy's current properties, which could drastically alter in the far future. As a result, none of the potential end-of-the-universe scenarios are assured.

Revision of Accelerated Expansion of Universe. The accelerated expansion of the universe was inferred in 1998-99 from measurements of about 60 type Ia supernovae and was widely accepted in the following years as discussed above. However, more recent frequency shift measurements and analyzes of 740 Type Ia supernovae scattered in various directions across the sky, likely show a smaller rate of accelerated expansion, than was inferred from the first measurements. Moreover, it has been shown here that this acceleration is not exactly the same in all directions, that it may be a relatively local effect (it is directed along our apparent motion relative to the cosmic microwave radiation) and cannot be unambiguously attributed to dark energy, which would cause the same acceleration in in all directions. This could indicate that the acceleration is an observational artefact of our cosmological location, and perhaps even lead to the abandonment of the concept of accelerated expansion and dark energy.

However, doubts about the accelerated expansion of the universe and dark energy also arise from more precise astrophysical properties of the objects from which this hypothesis arose - white dwarfs and their explosions - type Ia supernovae. More recent, more detailed analyses of a large number of supernovae (e.g. in the DESI project ....) have shown that the brightnesses of type Ia supernovae are in fact significantly influenced by the age of the white dwarfs, from which they are formed. Younger white dwarfs were formed from stars of the 2nd and 3rd generations, already enriched with higher metallicity. Supernovae from younger white dwarfs are therefore generally more intense, while supernovae from older white dwarfs, composed only of hydrogen and helium, are weaker. These changes in the brightness of supernovae affect the resulting observational data in essentially the same way as dark energy. The fading of distant supernovae can therefore arise not only as a result of cosmological effects, but also as a result of details of stellar astrophysics. This may lead to an observational overestimation of the distance of high-redshift supernovae. Definitive decisions about the expansion history of our universe will emerge only from spectrometric measurements of a much larger number of supernovae and other very distant one's objects, using large telescopic systems. However, accelerated expansion is still considered a fixed part of current cosmology.

Basic Composition of Universe. Physical cosmology's fundamental goal is to explain the universe's global structure and evolution as well as what mass or matter, fields, and particles and that is composed of. It has been discovered that during the universe's evolution, the makeup of the matter that fills it underwent substantial changes. From fluctuating fields and quanta in the early universe right after the Big Bang to quarks and baryons (protons, neutrons), photons, electrons, muons, neutrinos, light atomic nuclei of hydrogen and helium following initial nucleosynthesis, and ultimately all heavier atoms created during nucleosynthesis in stars and during the supernova explosion. The Elements-Abundance graph shows that the universe's composition has settled down to roughly 75% hydrogen, 25% helium, and a small number of heavier elements,[98] All this is ordinary matter made up of baryons, electrons, photons.

But the idea of dark matter and dark energy is drastically different; they are complementary to our previous understanding of the universe's makeup. Figure 4 below depicts the matter-energy mix of the current cosmos based on existing knowledge. There is a significant gnoseological component to this global composition as well. Up until recently, we believed that we would gradually learn everything there is to know about the universe through astronomical observation of glowing objects and absorbing clouds of gas and dust in optical, infrared, radio, X, or gamma electromagnetic radiation. All we needed were larger and more sophisticated telescopes and other instruments. As it turns out, humans can only see around 4% of the universe's stuff in this way. About 25% of dark matter and 70% of dark energy are still unknown to humans. Therefore, stars, nebulae, or galaxies are not necessary for the universe's overall characteristics or its evolution. This brilliant or otherwise astronomically detectable matter in space is only

[94] Van Tent, Bartjan; Delgado, Paola C. M.; Durrer, Ruth (2023-05-09). "Constraining the Bispectrum from Bouncing Cosmologies with Planck". Physical Review Letters. 130 (19) 191002, doi:10.1103/PhysRevLett.130.191002. ISSN 0031-9007, accessed on 17 Mar 2026

[95] Sutter, Paul (March 2023). "Dark energy could lead to a second (and third, and fourth) Big Bang, new research suggests". Space.com, accessed on 17 Mar 2026

[96] https://www.space.com/astronomy/how-will-the-universe-end, accessed on 17 Mar 2026

[97] https://www.cbc.ca/radio/quirks/sep-26-tailings-pond-detoxification-baboon-friendship-and-longevity-ancient-dna-in-dirt-and-more-1.5736876/, accessed on 17 Mar 2026

[98] https://astronuclphysics.info/Prvky-zastoupeni.gif, accessed on 17 Mar 2026

the "tip of the iceberg"; we are unable to see the main mass. The majority of the cosmos is composed of unknown and invisible things. The fact that we know so little about the universe is a disheartening discovery. Basic composition of universe has shown in figure 4 below and these values were obtained by a detailed analysis of the correlation of the LCDM model with extensive astronomical observations and sensitive measurements of intensity, spectrum and subtle fluctuations of relic microwave radiation

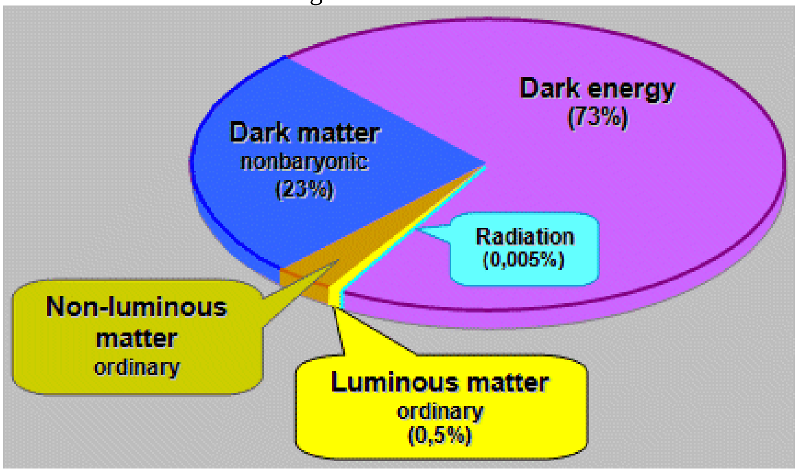

Figure 4: Basic composition of universe

13. Astrophysics and Cosmology: Hope for Human Society and Global Civilization

The latest and best evidence available on the space density of matter and the expansion rate of the universe suggest that we are on a one-way trip: the collective gravity of everything in the universe is insufficient to halt and reverse the cosmic expansion. Currently, the most successful description of the universe and its origin combine the big bang with our modern understanding of gravity, derived from Einstein's general theory of relativity. The early universe was a trillion-degree maelstrom of matter mixed with energy, affectionately known as the primordial soup. During the fourteen-billion-year expansion that followed, the background temperature of the universe has dropped to a mere 3° on the absolute (kelvin) temperature scale. As the universe continues to expand, this temperature will continue to approach zero. Such a low background temperature does not directly affect us on Earth because our Sun grants us a cozy life. But as each generation of stars is born from the interstellar gas clouds of the galaxy, less and less gas remains to compose the next generation of stars. Eventually the gas supply will run out, as it already has in nearly half the galaxies in the universe. The small fraction of stars with the highest mass collapse completely, never to be seen again. Some stars end their lives by blowing their guts across the galaxy in a supernova explosion.[99] This returned gas can then be tapped for the next generation.

But the majority of stars including Sun is ultimately exhaust the fuel at their cores and, after the bulbous giant phase, collapse to form a compact orb of matter that radiates its feeble leftover-heat to the frigid universe. So, if sun or other stars burn out and no new ones are formed to replace them, then the universe will eventually contain no living stars. What about Earth? We rely on the Sun for a daily infusion of energy to sustain life. If the Sun and the energy from all other stars were cut off from us then mechanical and chemical processes, where life included on and within Earth would wind down. Eventually, the energy of all motion gets lost to friction and the system reaches a single uniform temperature. This would really be bad. The starless Earth will lie naked in the presence of the frozen background of the expanding universe. The temperature on Earth will drop the way a freshly baked pie cools on a window sill. Yet Earth is not alone in this fate. Trillions of years into the future, when all stars are gone, and every process in every nook and cranny of the expanding universe has wound down, all parts of the cosmos will cool to the same temperature as the ever-cooling background. At that time, space travel will no longer provide refuge. Even Hell will have frozen over. We may then declare that the universe has died. And that is not with an explosion, but with a cry.

A sense of despondency regarding the ultimate viewpoint and the meaning of our existence will inevitably be suggested in us if we mix the knowledge of modern astrophysics and cosmology about the evolution of the cosmos with other risks from a human perspective. The threat to humanity and the length of human civilization are multifaceted. We put ourselves in the greatest risk. Hatred and deadly wars are fostered by greed, selfishness, and pride, particularly among celebrities and the wealthy and powerful of this world who pretend to control and manipulate others often with religious causes, greed to wealth along with regional and global conflict. Potential worldwide conflicts involving existing WMDs could endanger human civilization as a whole. Natural raw materials are wasted, garbage is contaminated, and the environment is completely destroyed due to consumer society. Particularly in Africa, Asia, and some troublesome minority in Western nations, there is an overpopulation of people, particularly unproductive individuals, who will parasitize nature and civilization. This population

[99] https://neildegrassetyson.com/essays/1996-06-ends-of-the-world/, accessed on 17 Mar 2026

growth could result in violent conflicts and the destruction of the natural world, endangering human civilization as a whole, unless widespread enlightenment and efficient birth control are implemented. Unjust social institutions founded on human inequity must also be eliminated. Some of the ignorant and careless individual have been brainwashed with wrong religious ideologies that allow them to harm their neighbors. Only when humanity works together harmoniously will it be able to pull on a single rope and, maybe, avert some horrible threats in the future.

Earth's atmosphere. Earth's present atmosphere is a 78% nitrogen and 21% oxygen mixture, vital for life and climate regulation through greenhouse gases, but it is currently being rapidly modified by anthropogenic emissions. Future atmospheric changes include increased greenhouse gases and warming by 2050, followed by long-term, inevitable deoxygenation over millions of years due to a brightening sun. Rapid changes are driven by human activity like pollution, fossil fuel use, etc. Long-term changes are driven by the natural evolution of the Sun and Earth's geological cycles.[100] The proper environment like temperature, humidity, pressure for many kinds of life, including humans, is greatly influenced by the Earth's atmosphere. Increasing the quantity of so-called greenhouse gases, particularly CO2, might cause our biosphere's temperature to rise unfavorably in severe circumstances, with the exception of levels that are unsuitable for life. By evaporating into the surrounding universe, the Earth steadily loses its atmosphere and may someday become a dead planet with no atmosphere at all. A gradual, inevitable reduction of oxygen to levels incapable of supporting complex life is expected as the Sun grows hotter and brighter. The atmosphere will eventually shift to a lower-oxygen, methane-rich state.[101] The oxygenated atmosphere, which allows for complex life, has a total estimated lifespan of about 1 billion years.

Planet Earth. The future of Planet Earth is a complex interplay between immediate human-driven environmental shifts and long-term natural, cosmic, and geological evolution. While the planet faces significant risks within this century, its ultimate fate is tied to the aging Sun, which will render it uninhabitable in roughly 1 billion years and destroy it in about 7.5 billion years. Continued global warming is expected, with temperatures projected to reach or exceed 1.5°C above pre-industrial levels within decades. Key threats include the melting of glaciers and sea ice, accelerated sea-level rise, increased frequency of extreme heat waves, droughts, and intensified tropical cyclones. Widespread species loss, known as the Holocene extinction, is ongoing due to human habitat destruction, pollution, and climate change. Our Mother Earth poses a grave threat to us as well. A hellish fire of molten rocks rages beneath the tiny layer of the earth's crust that we live on, which is divided into a number of lithospheric plates. Where lithospheric plates converge, earthquakes and volcanic activity take place. Massive streams of hot molten rocks rise by thermal convection in the earth's mantle beneath the thin layer of the crust, resembling a time bomb. Lava gushes violently under extreme pressure, resembling a devastating super volcano, if it melts to the surface. In addition to destroying hundreds of kilometers of land, such a super volcano can produce thousands of kilometers of volcanic gas and dust, which can obstruct sunlight and result in a catastrophic ecological disaster with drastic climate change. One of the region’s most at risk from a catastrophic super volcano is Yellowstone National Park in North America.

The Sun's luminosity will increase by about 10% over the next billion years, leading to a moist greenhouse effect that will cause the runaway evaporation of the oceans. This will lead to the extinction of most life on the surface. As the Sun enters its red giant phase, it will expand significantly, likely engulfing and vaporizing Earth.[102] The Earth's magnetic field, which shields it from a torrent of charged particles from the Sun, may deteriorate in the far future, posing another concern. The whirling semi-fluid outer region of the nucleus functions as a magnetohydrodynamic dynamo that produces the Earth's magnetic field. This nucleus cools and hardens throughout the planet's later phases of evolution, diminishing the magnetic field and ultimately vanishing. Because the possibility of life on a planet's surface has two negative outcomes. Increased levels of harsh ionizing radiation that are detrimental to living things start to penetrate the biosphere from space. Additionally, a star's solar wind is a powerful stream of charged particles that can spray into the surrounding universe and destroy the atmosphere. Water evaporates more quickly as a result of the atmosphere's disappearance, and the stellar wind also carries this steam into space. Life on Earth could not continue if the atmosphere and water were to disappear and the stellar wind also carries this steam into space. Life on our planet could not continue if the atmosphere and water were lost.

Near Space (like Asteroids). Not only do well-known planets like Earth orbit the Sun, but there are also many smaller bodies in the solar system that range in size from tens or hundreds of kilometers—small planets or asteroids—to fractions of millimeters, several centimeters, and meters (meteorites). Those name asteroid, which means star- like arose from the fact that the sun illuminated by nearby bodies of ground-based telescopes look like tiny points of light, like distant stars, unlike the stars but move across the sky like planets. Some of these objects can travel across the planets' orbits, collide with them, be drawn in by their gravitational pull, and strike their surface at speeds of tens of

[100] https://astrobiology.com/2025/08/as-earths-atmosphere-changes-so-will-its-response-to-geomagnetic-storms.html, accessed on 22 Mar 2026

[101] https://www.facebook.com/techtimespage/posts/a-new-nasa-supported-study-has-modeled-what-our-planets-distant-future-might-loo/835616455940761/, accessed on 17 Mar 2026

[102] https://science.nasa.gov/climate-change/effects/#:~:text=, accessed on 17 Mar 2026

kilometers per second. Impact craters from these bodies' impacts are widely scattered throughout all terrestrial planets. The orbit of the Earth is also crossed by thousands of the aforementioned bodies. Similar to meteors, small bodies burn in the atmosphere; the amount of fallout from such a meteor is thought to be millions of tons annually. The Earth's atmosphere efficiently shields us from tiny space missiles because tiny meteor bodies burn there rather than falling to the ground. Because friction in the atmosphere causes them to lose nearly all of their kinetic energy, even larger meteorites that strike the earth's surface do not constitute a greater threat and most of their mass evaporates.

Unfortunately, the Earth's orbit is also intersected by the orbits of asteroids and larger bodies; thankfully, this usually happens when the Earth is not at the specific location. Astronomers claim that ‘we live in a space shooting range’ because there is a chance that an asteroid will strike Earth and that Earth will strike an asteroid. Larger bodies that weigh more than 1000 tons and have a diameter of tens of meters pose a serious threat and it would cause only a local catastrophe. A planet several kilometers in length and weighing more than 1012 kg would abruptly release energy larger than 1022 J, which is equivalent to the detonation of more than a million thermonuclear bombs. Massive volumes of rocks, gas, and dust would be ejected into the atmosphere in addition to instantly destroying a region spanning thousands of kilometers. A significant portion of the earth's surface could be burned by a fiery meteor shower caused by molten rocks falling to the surface. The sun's radiation would be considerably reduced for a longer amount of time if large amounts of expelled dust remained in the atmosphere for numerous years. This would result in drastic climate change and a worldwide environmental disaster. Most likely, humanity would not endure! An asteroid collision of this kind is believed to have happened 65 million years ago, at which point dinosaurs and the majority of other species of plants and animals went extinct. We do not yet have the chance to stop such a cosmic catastrophe. The Earth has collided with asteroid-sized cosmic bodies on multiple occasions in the past, and it is likely to do so in the future, with deadly repercussions for the continuation of human civilization. Finding dangerous asteroids and anticipating a potential cosmic collision are becoming increasingly feasible thanks to current astronomy technologies. There are essentially two fundamental approaches to preventing an imminent disaster:

1. We could prevent an oncoming collision by altering the trajectory of such a potentially hazardous cosmic body, either by diverting it or altering its speed so that it crosses the Earth's orbit when the Earth is not there, if we knew its future orbit well in advance many years. The application of a force, ideally perpendicular to the instantaneous direction of movement, could have an impact on such a path deflection. The usage of nuclear charge is proposed; if it were to explode, the energy would create a rocket effect and mostly by ejecting molten material from the crater, which would cause the asteroid's orbit to be deflected. or using powerful laser beams for shelling. It is also being considered to launch a spacecraft into orbit close to an asteroid, which would cause the asteroid's orbit to be deflected by gravity.

2. Another option would be to shatter the explosion's body, but several pieces would fall to Earth in their original orbits. A worldwide disaster might not be brought on by the individual pieces. However, it is a debatable and less-than-ideal method that is only appropriate for tiny asteroids (fragments of which would mostly burn in the atmosphere). But we don't now have enough missile capability to carry out any of these interventions and that perhaps in 50 years! As long as humanity doesn't squander its resources on pointless wars, armaments, and political and religious conflicts. The asteroid "falling on our head" while we do nothing except watch.

Distant Universe (like supernovae, gamma-ray bursts). Large amounts of radiant energy, particularly hard ionizing radiation, would likely strike Earth if some of the closer or nearby stars within a distance of roughly 30 light-years across exploded as supernovae. This could potentially cause a catastrophic natural disaster that could endanger life as we know it! Even from an even more distant universe, hundreds or thousands of light-years, narrowly collimated gamma-ray bursts emitted by collapsing objects - massive stars, neutron star collisions, accretion disks around black holes - can be potentially dangerous to us, if their rotational axis is turned toward us. The entire solar system would be impacted, not just Earth. These high-energy occurrences are important for humans from an astrophysics perspective. Another major concern for planetary life is the possibility of cosmic radiation from catastrophic processes in space.

Sun and It's Future. Our life-giving star Sun will destroy humanity even if we are able to prevent catastrophic wars, asteroid collisions, mega volcanoes, and other natural disasters, as well as shield the planet from a large flash of cosmic rays from a nearby supernova explosion or neutron star fusion. The Sun's present radiant power will rise by roughly 40% during the next three billion years. The oceans will evaporate, the Earth's temperature will rise by tens of degrees, and all life will perish. The Sun will reach the end of its evolution and run out of thermonuclear fuel, particularly hydrogen, in roughly 5 billion years. After then, the Sun inflates and, like a red giant, consumes and evaporates all of the inner planets, including Earth, becoming a planetary nebula before turning into a white dwarf. Additionally, if Mercury, Venus, Earth, and Mars orbit at the same distance as they do now, the Sun in the red giant stage will be big enough to swallow them all. However, the ensuing consequence may allow Earth and Mars to escape this fate. The Sun will produce much more solar wind in the latter stages due to its increased radiative strength, which will transport a sizable portion of its material into space outside the solar system. As a result, the Sun's overall mass will decrease, increasing the orbits' radii. The Earth can orbit at a safe distance that the Sun's swollen surface cannot reach if the Sun's mass is substantially decreased in this way. Nevertheless, the Earth would be a barren planet with a scorching, dry surface where life could no longer thrive even if this advantageous evolution occurred.

The only option to keep Earth habitable over time in the face of the Sun's increasing radiant output is to progressively expand Earth's orbit around the Sun. It would be enough very slowly, on the order of millimeters each year. We don't currently have the technical means to do so, hence it's sci-fi. However, our descendants will probably have far more energy resources in the far future. Furthermore, it is theoretically possible to employ asteroid energy and gravity to raise Earth's orbit. The asteroid could be carefully directed into a tight coronary orbit with Earth, where it would gravitationally transfer kinetic energy to the Earth in the direction of orbit. In this fashion, life may theoretically maintain Earth's habitability for roughly 5 billion years. However, because the Sun's radiation varies somewhat quickly, this would already be an issue in the last phases of its evolution. High-energy gas streams from an expanding envelope would strike the ground. Then it would be helpful if the Sun's (the white dwarf's) brilliance drastically decreased and the harsh ultraviolet component dominated the radiation. The earth would need to be swiftly transferred to a closer orbit since it would freeze in a far orbit[103]. Intense UV radiation would wipe out life and the atmosphere if we brought the Earth to a very close orbit to preserve the temperature as in the science fiction scenario. However, if human society survives at all at that point, it will undoubtedly change into something entirely new.

Global Evolution and Extinction of Universe.

Until the solar system ends, humanity could be able to leave Earth and the Solar system and settle on others suitable spacecraft. So far, it seems less believable. However, we probably wouldn't have any hope if the cosmos were closed and imploded into a massive collision or blazing fire. We wouldn't pose a serious threat if the universe were open, at least not for the foreseeable future. Finding regions of local entropy fluctuation, where energy supplies are still accessible for the advancement and upkeep of civilization, would become more challenging in an expanding and constantly cooling cosmos. In the end, the ‘destruction of human civilization’ would result from the ‘heat death of the cosmos’. When food, an ordered type of energy, is given to living things, the majority of it gets transformed into heat. And that is an energy form that is disorganized. Even if civilization changes in the far future and intelligent information from living things' surroundings is processed into electronic forms, like as anthropic principle or cosmic God. In theory, the fundamental thermodynamic process would remain unchanged. However, information processing would become much more energy-efficient. According to the laws of thermodynamics, this increase in disorder is always greater than the increase in order in memory. Even the arrangement of electronic memory elements in a particular state requires energy, and a portion of it is always dissipated in the form of heat, increasing the clutter of the entire system. This idea would simply postpone civilization's demise due to heat death.

What is more terrifying is that our entire universe is also a small experiment done by a high-dimensional big boss. The idea of the multiverse, which is an endless number universe, could be represented by some, but only hypothetical, prospect of perpetual existence. A theoretical cosmological theory known as the multiverse postulates that there are other, potentially infinite, separate worlds in addition to our own.[104] Together, these universes are often called parallel or bubble universes—comprise everything in existence, including all space, time, matter, energy, and physical laws. However, multiverse is still primarily a theoretical concept, the multiverse provides a framework to address fundamental questions about the nature of space, time, and existence.[105] While a single universe may die due to collapse or heat death, the multiverse as a whole will endure forever, and fresh life may emerge in individual worlds. But we have no hope in this. In any event, we can say that the theories and knowledge of modern cosmology and astrophysics sadly do not provide us with a true understanding of the eternal existence and advancement of human civilization.[106] However, we may reassure ourselves that the knowledge we now possess is undoubtedly incomplete. Many things may go undetected; we may not even know what they are. And we might be able to draw some hope from this human ignorance.

14. Conclusion

Simply described, quantum cosmology is the application of quantum concepts to the entire cosmos. Despite this extremely lofty mission description, present physics can already do this task, at least in part. There are two primary useful simplifications in practice. First, it is predicated on the finding that the early cosmos was relatively simple in that it was homogeneous and highly isotropic in space. This proposes an approximation approach in which perturbations are added as a tiny correction once geometries and matter configurations are precisely isotropic and homogeneous on spatial slices. Second, the semi-classical approximation is commonly used, which involves working to leading or first subleading order while taking into account an expansion in Planck's constant ¹ in the dimensionless inverse Planck mass. Therefore, at the conclusion of the computations, it is necessary to verify if the approximations were appropriate. However, using these assumptions, it is possible to uncover quantum processes in the early cosmos

[103] Abelev, B.; Adam, J.; Adamová, D.; Aggarwal, M. M.; Aglieri Rinella, G.; Agnello, M.; Agostinelli, A.; Agrawal, N.; Ahammed, Z.; Ahmad, N.; Ahmed, I.; Ahn, S. U.; Ahn, S. A.; Aimo, I.; Aiola, S. (2014-11-10). " Beauty production in pp collisions at s=2.76 TeV measured via semi-electronic decays" (PDF). Physics Letters B. 738: 97–108, doi: 10.1016/j.physletb.2014.09.026, accessed on 16 Mar 2026

[104] Romeo, Jess (7 January 2022). "The Real Science of the Multiverse". JSTOR Daily. JSTOR, accessed on 17 Mar 2026

[105] Swain, Frank (2017). The Universe Next Door: A Journey Through 55 Alternative Realities, Parallel Worlds and Possible Futures. London: New Scientist. p. 12. ISBN 978-1-4736-5867-7, accessed on 22 Mar 2026

[106] Ijjas, Anna; Steinhardt, Paul J. (January 10, 2022). & quot; Entropy, black holes, and the new cyclic universe & quot; Physics Letters B. 824 136823, doi: 10.1016/j.physletb.2021.136823, accessed on 17 Mar 2026

rather well. In order to comprehend quantum gravity (or holography), entanglement and other fundamentally quantum events give rise to classical spacetime and Einstein's equations. Using this method, it has been discussed in cosmic physics, which deals with expanding universes with a big bang. However, because the holographic gravity theories contain a negative cosmological constant, their generic cosmological solutions feature time-dependent scalar fields that can result in realistic cosmic evolution with accelerated expansion in late time. This makes the theories simply impractical. Observationally, the presence of decreasing dark energy sets these models apart from the Lambda-CDM model.

In the microworld, quarks, leptons, and bosons are examples of structureless or elementary particles. Once more, fundamental particles might be thought of as excitations or ripples in an underlying quantum field that penetrates all of space-time, since Internal Structure as Quantum Fields lacks physical elements. A ripple in the electron field is an electron. On the other hand, a photon is an electromagnetic field ripple. These particles are not merely empty spots; a cloud of virtual particles, which are transient variations in these fields, surrounds them. Conversely, protons and neutrons were once believed to be fundamental particles, but it is now understood that they are composite particles like hadrons. Protons are now made up of one down quark and two up quarks. One up quark and two down quarks make form a neutron. Gluons, which continuously exchange color charges to bond these quarks together, act as glue. Some theoretical models, like string theory, imply that particles might not be zero-dimensional points but rather small vibrating strings of energy, despite the fact that measurements have revealed no interior structure down to 10-19 meters. There is currently no experimental evidence to corroborate the preon idea put out by others, which postulates that quarks and leptons are made up of smaller particles. The end of the universe is extinction, so the purpose of evolution is to delay the process of extinction. This is like the end of life is death, and the purpose of living is to try to delay the process of death and leave a trace in the world after death.

The most plausible future is one in which expansion never stops. The universe will turn into a cold, dark emptiness with maximum entropy when the stars run out of fuel. The Big Freeze or Heat Death, in which expansion continues and the universe becomes cold, dark, and empty, is the most likely long-term outcome. Dark energy may someday triumph over gravity and tear apart stars, galaxies, and perhaps even atoms if it becomes more powerful. Gravity might reverse the expansion and cause the universe to collapse back into a high-density, high-temperature singularity if the density of the universe is high enough or closed universe. a cyclical scenario in which the expansion and contraction cycle may be repeated when a Big Crunch sets off a new Big Bang. The final result is largely dependent on the universe's density and how dark energy, which propels the accelerated expansion, behaves. According to observations, the universe is flat and will keep expanding forever. All of the aforementioned possibilities, however, are predicated on a basic version of the dark energy equation of state. The Heat Death, also known as the Big Freeze, is the most likely way the universe will end, according to current astrophysical understanding and cosmological consensus. This is the anticipated outcome of the dark energy-driven acceleration of the universe's expansion. But as the name suggests, not much is currently understood about the physics of dark energy. If the hypothesis of inflation is genuine, the universe went through an episode dominated by a different kind of dark energy in the earliest moments of the Big Bang, but inflation terminated, indicating an equation of state more complex than those assumed for present-day dark energy. The dark energy equation of state might alter once more, which would have unpredictable and difficult-to-parameterize effects. The possibilities surrounding dark energy and dark matter's involvement in the cosmos are unclear since their nature is still mysterious, if not speculative.