

Review Article

Study of Important Space Missions and Evaluation of Discovering the Astonishing Universe

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Abstract

The evaluation of space missions and their influence on the understanding of universe is complicated. They provide both scientific data and insights along with inspire inquisitiveness and fostering a sense of sensation about the cosmos. It has started with the space race of the 20th century, as a result of humans have boarded on a journey through time and space with some of the most groundbreaking and life-changing space missions. NASA's astrophysics division is dedicated to exploring the universe, pushing the boundaries of what is known of the cosmos, and sharing its discoveries with the world. The division continues growing humanity's understanding of how the universe began and progressed. NASA researchers are making advancement towards addressing the appealing questions of life in the universe, the early beginnings of the universe, and how it all works with leading-edge technologies and groundbreaking science. The Apollo missions, was a great attempt of courage in human civilization; not only landed humans on the Moon but also brought back samples that helped scientists understand lunar geology and planetary science. The Hubble Space Telescope has revolutionized astronomy, offering fabulous images of distant galaxies and nebulae, and has led to groundbreaking discoveries like the measurement of the universe's expansion rate and the identification of exoplanets. Mars rover missions have advanced our understanding of alien geology and climate, paving the way for future human missions to the red planet. These missions have not only transformed how we see the universe but also describe how we live on earth, contributing to our understanding of the solar system and beyond. Astronomers recently spotted this black hole's flare-up through XMM-Newton and XRISM's X-ray technology and noted that it appeared to fade quickly, creating the fast-moving winds. It is a review article to explore and appraise the important space missions on the basis of historical evidence and evaluating the urge of discovering mind set to know the multifaceted cosmology and astonishing Universe.

Keywords

Space Mission, Apollo, NASA, SpaceX, ISS, JWST

1. Introduction

Space missions use telescopes and spacecraft to study the universe, explore the solar system, and search for life. Early programs like Pioneer and Voyager paved the way, while current missions such as the ISS conduct experiments in Earth's

orbit. Future plans include returning humans to the Moon through Artemis and eventually sending missions to Mars. Space exploration drives the development of new technolo-

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gies that have practical applications on Earth in fields like telecommunications, medicine, and transportation [1].

Robotic spacecraft have been sent to orbit planets like Venus, Mars, Jupiter, and Saturn, while telescopes like the James Webb Space Telescope (JWST) observe distant objects. Satellites are used for purposes like weather forecasting, environmental monitoring, and communication [2]. From ancient times through much of the twentieth century, astronomy—the study of stars and nearby planets—was the only practical way for humans to explore space.

Early explanations of planetary motion were rooted in religion, but growing scientific understanding replaced dogma with natural laws. With advances in ground-based astronomy and the invention of modern liquid-fueled rockets, humanity entered the Space Age and began exploring the vast “cosmic ocean”. Public support for the space program, during the Cold War era, allocated millions of dollars to the exploration of space, but this trend has ceased in the later part of the twentieth-century [3]. The peak of space exploration, as a function of government and public support, reached its apex in the 1970s, with the Apollo program. The public has generally been more supportive of the manned exploration program, but the costs and the values at risk are often viewed as barriers to the support of space exploration as a whole. Today, economic resources for space exploration are scarce and public, and thus government support is relatively low [4].

The glorious Apollo missions are impossible to reconstruct, and instead there has been a steady trend towards unmanned space exploration. What the future of space exploration will hold is highly dependent on the rising generation, and the values they hold towards space exploration. There are thirteen remarkable space missions in recent history and each representing major scientific, technological, and human achievements [5]. These missions have expanded our understanding of the universe and demonstrated the power of persistence, collaboration, and innovation in space exploration. It is true that both the Soviet Union and the United States adapted older military missiles as the motive power to enter space, but both also independently designed new rockets [6].

Unlike ships, the motive power was no longer natural wind power. The core of the new rockets was their engines, and the history of engine development is fraught with uncertainty and contingency. At every stage, from the V-2s and their successors, to the Apollo first-stage F-1 engines with their famous early “combustion instability” problems, and to the SSMEs, it was never assured that access to space would be possible, and it is still not cost-effective [7]. Another of the perennial debates of the Space Age was whether reusable or expendable launch vehicles were best; history records that despite its utility and magnificent engineering, even the reusable Space Shuttle was never cost-effective [8].

The engineering challenges inherent in the design of rockets and spacecraft were legion. Design decisions were sometimes brilliant, often modified, and occasionally second-guessed after accidents and failures, whether human or robotic, and the

agonizing but detailed accident reports of those failures make for compelling reading about the importance and far-reaching consequences of engineering decisions [9]. Space programs require extensive institution building, management, and funding. Unlike the Age of Discovery, where Magellan’s 1519 expedition lost most of its crew with little risk management, the Space Age emphasizes careful risk management. Agencies like NASA are so thorough in minimizing danger that they are sometimes criticized for being overly risk-averse. One of the greatest policy challenges is to find the proper balance between risk and exploration, and this, too, should be informed by history [10].

Today, SpaceX which is a private American aerospace company as well as space transportation company headquartered at the Starbase development site in Starbase, Texas is owned by Elon Musk [11]. As of 2025, SpaceX is the world’s dominant space launch provider, its launch cadence eclipsing all others, including private competitors and national programs like the Chinese space program [12].

SpaceX, NASA, and the United States Armed Forces work closely together by means of governmental contracts. “You want to wake up in the morning and think the future is going to be great – and that’s what being a spacefaring civilization is all about. It’s about believing in the future and thinking that the future will be better than the past” [13]. “And I can’t think of anything more exciting than going out there and being among the stars” [14]. NASA has collaborated with SpaceX by providing operational expertise and prioritizing safety in the development of crewed spacecraft. This partnership, though challenging, has been productive, merging NASA’s established legacy with SpaceX’s innovative approach, reminiscent of the 1960s space race. Overall, space missions have broadened our understanding of the universe, uncovered cosmic phenomena, advanced the search for life beyond Earth, and showcased human scientific ingenuity.

2. Literature Review and History of Space Discovery

The Age of Discovery and the Age of Space are linked by shared fundamental drivers—specifically motivations, infrastructure, voyagers, funding, and risk—which underscore the enduring strategic parallels between historical exploration and modern cosmic endeavors. The Age of Discovery was driven primarily by the desire for new trade routes to Asia (spices, silks), the spread of Christianity, and the quest for national glory and empire expansion [15].

Also known as the Age of Exploration, this era was part of the early modern period and overlapped with the Age of Sail. It was a period from approximately the 15th to the 17th century, during which seafarers from European countries explored, colonized, and conquered regions across the globe [16]. The Age of Discovery was a transformative period when previously isolated parts of the world became connected to form

the world-system, and laid the groundwork for globalization [16]. The extensive overseas exploration, particularly the opening of maritime routes to the East Indies and European colonization of the Americas by the Spanish and Portuguese—later joined by the English, French, and Dutch—spurred international global trade.

The interconnected global economy of the 21st century has its origins in the expansion of trade networks during this era. The Age of Discovery required the development of new ship-building techniques (like the boat and caravel), navigational tools (like the compass and astrolabe), and port facilities for repair and resupply [17]. This Age's explorers were highly skilled navigators, sailors, and military personnel trained to endure long voyages and uncertain conditions [18]. Missions at that time were often financed by royal patrons and wealthy merchants seeking exclusive rights to new territories and trade [19]. In the Age of Discovery, adventurers usually faced unknown ocean currents, disease (scurvy), shipwreck, hostile encounters, and the simple danger of falling off the map into the unknown [20].

On the other hand, the Space Age is a period encompassing the activities related to the space race, space exploration, space technology, and the cultural developments influenced by these events, beginning with the launch of Sputnik 1 on October 4, 1957 [21], and ending with the completion of the Apollo-Soyuz Test Project that marked the conclusion of the Space Race in 1975. The Space Age is characterized by changes in emphasis on particular areas of space exploration and applications. Initially, the United States and the Soviet Union invested unprecedented amounts of resources in breaking records and being first to meet milestones in crewed and uncrewed exploration [21, 22]. The United States established NASA and the USSR established the Kosmicheskaya programma SSSR to meet these goals [23].

At the same time, other nations became space-loving and they formed organizations such as the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the Indian Space Research Organization (ISRO), and the China National Space Administration (CNSA). When the USSR dissolved, the Russian Federation continued their program as Roscosmos [24]. The Age of Space is motivated by Cold War competition (the Space Race), technological superiority, national prestige, scientific curiosity, and the potential for exploiting extraterrestrial resources [25]. This demanded the construction of massive launch complexes, powerful rockets, tracking stations, and global communication networks.

Explorers of this Age, astronauts and cosmonauts, are highly trained pilots, engineers, and scientists selected for their physical endurance, technical expertise, and psychological resilience [26]. However, space programs (like NASA) were funded by national governments, supported by massive taxpayer investment driven by geopolitical competition, and are increasingly supplemented by private ventures today [27]. In the Age of Space, voyagers and space travel involve immense technical dangers, including launch failure, radiation

exposure, equipment malfunction in a zero-gravity vacuum, and the potentially fatal consequences of re-entry [27].

NASA and the Space Age represent the most recent chapter in a millennial-long tradition of exploration, serving as a primary engine of human culture that unifies geopolitical, technological, and scientific progress under the singular drive to discover. Surveying the vast array of history, historians have often found “symmetry in the narrative arc of the Great Ages of Discovery” or traced that tradition back even to the Paleolithic Era in an attempt to find a “global historical context” for the Space Age [28].

The Paleolithic Era aside, prior to the Space Age, historians often distinguished two modern Ages of Exploration: the Age of Discovery in the 15th and 16th centuries associated with Prince Henry the Navigator, Columbus, Magellan, and other European explorers, and the Second Age in the 18th and 19th centuries characterized by further geographic exploration such as the voyages of Captain Cook, underpinned and driven by the scientific revolution [29]. Some now distinguish a Third Age, beginning with the IGY and Sputnik, primarily associated with space exploration, but also with the Antarctic and the oceans. The Space Age is inspired by the distinguished Harvard maritime historian J. H. Parry, as he published his classic volume *The Age of Reconnaissance: Discovery, Exploration and Settlement, 1450 to 1650* [30].

NASA's first 50 years may also be characterized as “The Age of Reconnaissance,” or to put it more broadly, as the first stages of “The Age of Discovery.” Physicist and space historian Thomas P. Hughes saw “the possibility of moving up onto a level of abstraction where the terrain of the past is suggestive of the topography of the present and its future projection” [31]. Michael Griffin said, “Decades of commitment were required to build up our network of transcontinental railroads and highways, as well as our systems for maritime and aeronautical commerce. It will be no quicker or easier to build our highways to space, and the commitment to do it must be clear and sustaining” [32]. He also added, “NASA will build the ‘interstate highway’ that will allow us to return to the moon, and to go to Mars.” Similarly, he has compared polar exploration to lunar exploration, arguing that the Apollo program was like the singular forays of Scott or Byrd, while the current plans to establish a base on the Moon are more like the permanent presence that several countries have had in the Antarctic since the 1950s, requiring international collaboration [33].

There is no doubt that exploration is part of the American character and that federally funded exploration has been a significant part of American history [34]. Historians notwithstanding, space as a new frontier has always been a driver of the U.S. space program and remains very much in NASA's lexicon. Nevertheless, it is an analogy that needs to be used with qualification and caution [35]. The concepts of “discovery” and “exploration” are frequently found throughout space literature, and very recent past in the Vision for Space Exploration, billed as “a new spirit of discovery,” enunciated by President George W. Bush in January 2004, and yet again in

NASA's subsequent new strategic objectives released in a report titled "The New Age of Exploration" [36].

While the "New Age of Exploration" promotes a synergy between robotic reconnaissance and human presence, the National Research Council notes that while these complementary approaches are conceptually ideal for expanding cosmic frontiers, they remain logistically and operationally difficult to integrate. To achieve that balanced partnership with the limited resources at hand, in the midst of turbulent events and ever-changing economic and political conditions on Earth, has been one of NASA's great challenges over the last 50 years [37]. Wernher von Braun was fond of comparing his proposed voyages to Mars to the voyages of Magellan. When Laurence Bergreen researched his book *Voyage to Mars: NASA's Search for Life Beyond Earth*, about the Pathfinder, the Mars Global Surveyor, and the unsuccessful 1999 voyages to Mars, he found references to the Age of Discovery and Magellan rampant within NASA. "After the tenth or maybe the twentieth time the name Ferdinand Magellan was mentioned to me," he recalled, "a dim light bulb eventually illuminated in my mind" [38].

The experience led him to write his gripping account, *Over the Edge of the World: Magellan's Terrifying Circumnavigation of the World*. The book by historians Glen Asner and Stephen Garber on the events leading up to the Vision for Space Exploration has been published under the title *Origins of 21st-Century Space Travel: A History of NASA's Decadal Planning Team and the Vision for Space Exploration, 1999–2004*. Work on it was mentioned as "forthcoming" in earlier NASA newsletters and articles as the research and writing phases were completed around 2007 [39]. For space science, like nuclear science and all technology, has no conscience of its own. Whether it will become a force for good or ill depends on man, and only if the United States occupies a position of preeminence can we help decide whether this new ocean will be a sea of peace or a new, terrifying theater of war [40]. And it is significant when historians and journalists build on the analogy, as in the official history of Project Mercury, entitled *This New Ocean*, or William Burrows's classic history of the Space Age with the same title [41].

But it is even more significant when NASA workers see themselves in the tradition of the Age of Discovery, for that idea, once individually and institutionally internalized, becomes a part of NASA culture and a powerful force in itself [42]. Space historian Andrew Chaikin tells us about five books that capture the thrill and achievement of our venturing into the great beyond. He said, "If I could magically go back in time and give NASA a different pathway at the end of the Apollo programme, I would not choose the space shuttle programme that we ended up with – but then neither would NASA. The shuttle was sold on the promise that it would reduce the cost of getting into low earth orbit and we could do it routinely, as often as once a week. But costs were still high, and the shuttle never did make space flight routine" [43].

The most momentous moment in space history: Michael

Collins, who piloted the first mission to the moon, provides a view of space exploration from the cockpit. In his autobiography *Carrying the Fire* (1974), Michael Collins conveys, in a very personal way, the drama, beauty, and humor of that adventure [44]. It's a profound and personal account of his experiences in space. Released in 1974, it was later re-released in 2009 and 2019 to coincide with significant anniversaries of the Apollo 11 mission. Collins, who flew in space twice as part of the Gemini 10 and Apollo 11 missions, shares his insights on the early years of the space race, the human tensions, and the physical realities of space travel [45]. His narrative is filled with humor, drama, and a new perspective on time, light, and movement from someone who has seen the Earth from the other side of the moon. The book is praised for its engaging prose and candid assessments of fellow astronauts and officials within NASA [46].

Apollo Paperback (written by Charles Murray) is the classic account of how the United States got to the moon [47]. It is a book for those who were part of Apollo and want to recapture the experience and for those of a new generation who want to know how it was done. It is an opinion shared by many Apollo veterans [48]. Another interesting book, *Beyond: Visions of the Interplanetary* by Michael Benson (2003) highlights NASA's unmanned missions since the 1960s that explored planets, moons, and the Sun. Through stunning, carefully processed images—from Mars's vast canyons to Saturn's icy moons—the book visually transports readers to distant and alien worlds. The sight of a giant canyon on Mars, or the icy surface of one of Saturn's moons, or the pockmarked face of Mercury, give us the ability to transport ourselves to these alien landscapes [49].

The great writing *The Red Limit: The Search for the Edge of the Universe* written by Timothy Ferris in 2002 is full of thrill. This book, addressed by critics as a classic of modern science and awarded the American Institute of Physics Prize, is the tumultuous tale of groundbreaking discoveries by a group of scientists whose rivalries and emotions played as important a role as their intellectual brilliance [50]. In *The Red Limit*, the author guides readers through scientific breakthroughs that reveal the expanding universe. Once thought to be static, the universe was shown in the late 1920s to be expanding when astronomers discovered that distant galaxies appear red-shifted, indicating they are moving away from Earth.

Another fascinating book is *Mars and the Mind of Man* by Ray Bradbury (1973). It recounts how, on November 12, 1971—just before NASA's Mariner 9 became the first spacecraft to orbit another planet—Caltech professor Bruce Murray convened a panel of thinkers to discuss the historic mission's implications. The panel included Carl Sagan and science fiction icons Ray Bradbury and Arthur C. Clarke in a conversation moderated by New York Times science editor Walter Sullivan [52]. What unfolded was a quilt of perspectives on the relationship between mankind and the cosmos, the importance of space exploration, and the future of our civilization [53].

Two years later, the record of this conversation was released in *Mars and the Mind of Man*, alongside early images of Mars taken by Mariner 9 and a selection of “afterthoughts” by the panelists, looking back on the historic achievement [54].

Space tourism is a niche segment of the aviation industry that seeks to give tourists the ability to become astronauts and experience space travel for recreational, leisure, or business purposes [55]. Since space tourism is extremely expensive, it is a case of a very small segment of consumers that are able and willing to purchase a space experience [56]. There are several options for space tourists. Crouch et al. (2009) investigate the choice behavior between four types of space tourism: high-altitude jet fighter flights, atmospheric zero-gravity flights, short-duration suborbital flights, and longer-duration orbital trips into space [57]. Find the few motivational factors behind space tourism in order of importance, like vision of earth from space, weightlessness, high-speed experience, unusual experience, and scientific contribution. One current option for space tourists is to be taken up into the stratosphere in a supersonic fighter jet [58]. MiGFlug acts as a sales agent for this unique space tourism activity, which usually involves reaching an altitude of 20–22 km. At such an altitude, the curvature of the earth can be seen, the sky is dark, and it is possible to see into space [59].

Possibly human-base space exploration is going to enter into next generation. A good time to get commercial benefit from accessible and amicable wealth and asset in space. NASA, SpaceX, European Space Agency and other organizations around the globe are trying to explore the potential benefits in space. Today Mars has captured the imagination of scientists, engineers, and space enthusiasts alike. Traditional proposals involve timescales of centuries and even millennia to regenerate Mars [60]. Again, a number of Earth-like planets have already been discovered, but they are thousands of light years away [61]. There may be some different thinking along with philosophical discussion and ethical debate on the reasoning behind why humanity should and must become a multi-planet species [62].

The last major leap in the USSR–USA Space Race was the Skylab and Salyut programs, which established the first space stations for the U.S. and USSR in Earth orbit following termination of both countries' moon programs [63]. At the conclusion of the Apollo program, crewed flights from the United States were rare, then ended while the shuttle program was getting ready to kick into gear, and the space race had been over since the Apollo–Soyuz test project of 1975 started a period of U.S.–Soviet cooperation. The Soviet Union continued using the Soyuz spacecraft [64]. The shuttle program restored spaceflight to the U.S. following the Skylab program, but the Space Shuttle Challenger disaster in 1986 marked a significant decline in crewed Shuttle launches. Following the disaster, NASA grounded all Shuttles for safety concerns until 1988 [65]. During the 1990s, funding for space-related programs fell sharply as the remaining structures of the now-dissolved

Soviet Union disintegrated and NASA no longer had any direct competition, engaging rather in more substantial cooperation like the Shuttle–Mir program and its follow-up, the International Space Station [66].

In the early 21st century, the Ansari X Prize competition was set up to help jump-start private spaceflight [67]. The winner, SpaceShipOne in 2004, became the first spaceship not funded by a government agency [68]. Today, countries now have space programs, from related technology ventures to full-fledged space programs with launch facilities [69]. There are many scientific and commercial satellites in use today, with thousands of satellites in orbit, and several countries have plans to send humans into space [70]. Some of the countries joining this new race are France, India, China, Israel, and the United Kingdom, all of which have employed surveillance satellites [71]. Today, NASA has since trusted on Russia and SpaceX to take American astronauts to and from the ISS [72].

NASA is currently constructing a deep-space crew capsule named the Orion. NASA's goal with this new space capsule is to carry humans to Mars. The Orion spacecraft is due to be completed in the early 2020s. NASA is hoping that this mission will “usher in a new era of space exploration” [73]. Again, a major factor affecting the current Space Age is the privatization of space flight [74]. A significant private spaceflight company is SpaceX, which became the proprietor of one of the world's most capable operational launch vehicles when they launched their current largest rocket, the Falcon Heavy, in 2018. Actually, SpaceX has changed what we all think about space. Its reusable rockets that land back on the launch pad are a thing of wonder, but by now, relatively routine. Its massive Falcon Heavy rocket recently completed its first commercial mission without a hitch, and space is now on the cusp of taking US astronauts up to the International Space Station (ISS) [75].

Elon Musk, founder and CEO of SpaceX, has proposed establishing a Mars colony of one million people by 2050. To support this vision, SpaceX is developing Starship, a fully reusable, two-stage super heavy-lift launch vehicle. Currently built and launched from Starbase in Texas, it is intended as the successor to the company's Falcon 9 and Falcon Heavy rockets [76]. Blue Origin, founded in 2000 by Amazon founder Jeff Bezos, is developing rockets for space tourism, satellite launches, and future missions to the Moon and beyond. The company is fully privately funded, largely through Bezos's personal investment, including selling about \$1 billion of Amazon stock annually to support its activities.

In April 2019, a deal was signed with NASA to allow Blue Origin to test its BE-3U and BE-4 liquefied natural gas rocket engines at NASA's Marshall Space Flight Center also in Huntsville. The 300-foot-tall, vertical firing test stand 4670 was used by NASA in the 1960s to test the massive Saturn V rockets that took the Apollo spacecraft to the moon, as well as engines for the space shuttle [77]. Blue Origin is going large and getting big, though it's got some way to go to reach the

size of SpaceX. On the other hand, Richard Branson's company Virgin Galactic is concentrating on launch vehicles for space tourism. A spinoff company, Virgin Orbit, air-launches small satellites with their Launcher One rocket [78].

Virgin Galactic plans to build a fleet of spaceships and begin ferrying hundreds of tourists into space. And Branson has plans for the future of the company and far longer trips into space, potentially lasting for days or even longer. He added, "We'll be building orbital spaceships, so that people who want to go for a week or two can" [79]. Elon Musk has stated that the main reason he founded SpaceX is to make humanity a multiplanetary species, and cites reasons for doing it including ensuring the long-term continuation of our species and protecting the "light of consciousness" [80]. On June 18, 2025, a SpaceX Starship rocket exploded during a static fire test at the Starbase facility in Texas due to a "major anomaly." Yet, future missions continue. The true essence of the Space Age lies in humanity's choice to pursue cosmic exploration despite pressing Earthly challenges—a decision that will shape the legacy of NASA and the global community by 2058.

3. Background and Understanding of Modern Cosmology

Modern cosmology is a dynamic interplay of theoretical and experimental endeavors, continually evolving to surmount novel challenges. The discipline necessitates systematic reconstruction to harmonize theory with emerging observational data at each juncture. A watershed moment in this ongoing debate unfolded with the revelation of supernova dimming [81], a phenomenon that revealed the limitations of the Friedmann–Lemaître–Robertson–Walker metric (herein Friedmann metric). To address this dissonance, the cosmological constant was introduced to align the theoretical predictions with empirical insights [27].

Present-day surveys and astronomical observations indicate that galaxies are increasingly moving away from us. At the core of current cosmological discussions is the significant challenge of understanding the formation of structures and the evolution of galaxies amidst the backdrop of the accelerated expansion in the late-time universe [83]. The Friedmann model, rooted in the cosmological principle, has effectively described the universe's evolution in line with empirical observations [84]. However, the mystery of dark energy and the force driving cosmic acceleration remains a persistent challenge in contemporary physical cosmology.

Various attempts to explain cosmic acceleration rely on concepts such as the cosmological constant or scenarios dominated by dark energy. However, the perplexities surrounding the cosmological constant pose significant puzzles [85]. Adding to these difficulties is the potential violation of the cosmological principle when homogeneity or isotropy falters in galaxy structure formation [86]. As for three-dimensional red-

shift, surveys delve deeper into the cosmos, revealing structures lacking a transition to homogeneity [87]. Now, questions arise regarding the steadfastness of the cosmological principle [88].

The galaxy distribution in recent observations (light) and the simulation of dark matter distribution (matter) display significant inhomogeneity on the largest statistical scale available [89]. The matter distribution exhibits even greater inhomogeneity, challenging the search for the cosmological principle in the current observed light or matter distribution in the universe [90]. Recent studies on the angular scale of cosmic homogeneity using the Sloan Digital Sky Survey's Sixteenth Data Release (SDSS-IV DR16) of a luminous red galaxy sample based on a model-independent approach found a homogeneity of [91].

This finding was recently challenged through a homogeneity test for the matter distribution based on the Baryon Oscillation Spectroscopic Survey Data Release 12 CMASS galaxy sample [92]. It was found that the observed distribution of matter is statistically unlikely to be a random arrangement up to a radius of, which is approximately the largest statistically available scale. The identification of large quasar groups (LQGs) further catalyzes the debate, suggesting an inherent inhomogeneity incompatible with prevailing cosmological paradigms [93]. Such revelations underscore the need for a profound cosmological reassessment [94].

Accurate testing of the standard model's predictions for the spatial distribution of luminous astronomical sources requires high-resolution cosmological simulations of many isolated galaxies, using robust data-driven detectors to prevent misinterpretation. While 2D projections suggest isotropy and homogeneity, 3D catalogs reveal complex, inhomogeneous galactic distributions. These divergent findings regarding the transition to homogeneity confound attempts at a unified perspective [95]. The contrasting nature of these observations challenges the conventional assumption of cosmic homogeneity and isotropy. The implications have a potential impact on understanding cosmic acceleration and the need for an additional dark energy component [96].

Researchers find it necessary to explore alternative models of dark energy or its modified forms to account for the cosmic acceleration of the universe, considering the observational anomalies of the standard model and its lack of physical motivation [97]. The proposed model includes scenarios where the scalar field replaces the cosmological constant to represent dark energy and modified gravity theories [98]. Recent observations, such as the unexplained Hubble parameter tensions, large-scale anisotropies, and massive disk galaxies at higher redshifts, pose challenges to the Friedmann model and the concordance model of cosmology in general.

For example, the Hubble parameter determined from the cosmic microwave background (CMB) radiation differs from that determined using Type Ia supernovae and the redshift of their host galaxies. While one possible explanation is the incompleteness of the concordance model, alternative theories

propose that the standard redshift model, as a distance–scale factor relation, might be incomplete [99]. Addressing these observations supports modifications to some foundations of cosmology based on the cosmological principle [100]. Modifying the standard redshift relation may offer a plausible explanation for investigating recent Hubble tensions [101].

Some other models propose cosmic acceleration as an emergent phenomenon [102]. The fundamental effect of cosmic evolution on photon propagation is cosmological redshift. In the standard model, cosmological redshift is a theoretical function of the scale factor derived from the Friedmann metric. However, researchers are now reconstructing this scale factor–redshift relation from observations rather than relying on its theoretical form [103]. One drawback of remapping cosmological models is the unknown function of the observed redshift, increasing the degree of freedom of the equation. This issue has been addressed by introducing function parameterization through Taylor expansion before adopting a parametric approach.

Related work includes a cosmological model proposed to explain the accelerated expansion of the universe by modifying the standard redshift relation [104]. It has been demonstrated that combining Friedmann equations with a modification of redshift remapping may lead to a self-consistent framework under the assumption of the inadequacy of the Friedmann model [105]. The parametric [106], non-parametric [107], and modified standard redshift models [108] are expected to address the cosmological constant problem.

However, all these ambitious objectives hinge upon an indispensable prerequisite—an abundance of accurate and expansive cosmological data. Despite the growing body of observational data, persistent limitations require a careful interpretation of the current cosmological models' completeness and accuracy [109]. The upcoming Vera Rubin Observatory holds the potential for a transformative ten-year exploration, armed with a 3.6 Gigapixel camera [110], ready to survey the entire visible night sky and delve into cosmic intricacies [111].

Again, the parametric model proposed [112] in 2015 introduces modifications to the traditional redshift paradigm, seeking to refine our understanding of cosmic dynamics. This model introduces parameters that account for modifications in redshift space, enabling a more precise interpretation of observational data. By incorporating these factors, it provides a detailed and accurate representation of redshift-related cosmic phenomena.

On the other hand, the non-parametric model, as formulated by Wojtak and Prada in 2017, takes a distinct approach by avoiding predefined parameters, allowing for greater flexibility in modeling cosmic phenomena [113]. Non-parametric models, avoiding fixed parameters, provide a flexible, data-driven framework that effectively interprets complex redshift-related phenomena where traditional models may fall short.

4. Thirteen Important Space Mission of

Human History

On October 4, 1957, Sputnik I launched from the U.S.S.R.'s Baikonur Cosmodrome, becoming the first human-made object in space. Orbiting Earth 1,440 times over 21 days, it ushered in the Space Age, provided insights into atmospheric density, and remained in orbit until January 4, 1958. Later, the Soviet Venera missions, including Venera 7—the first to land on another planet—revealed Venus's harsh environment, returning valuable data despite lasting less than an hour on the surface. Decades later, the 13th Venera mission snapped the first ever images of the Venusian surface [79].

Yuri Yuri Gagarin (1934–1968), a Soviet pilot and cosmonaut, became the first human in space aboard Vostok 1 on April 12, 1961, completing one orbit of Earth in 108 minutes before safely parachuting back. Following rigorous test missions, the USSR also sent Valentina Tereshkova into space on June 16, 1963, making her the first woman to orbit Earth on Vostok 6 and inspiring generations of women astronauts. The 26-year-old Soviet cosmonaut became the first woman to visit space on June 16, 1963, when she embarked on a three-day mission aboard the Vostok 6 spacecraft. She completed a total of 41 orbits around Earth, cementing her place in history and inspiring generations of women astronauts for decades to come [78].

The Apollo program (1961–1972), also known as Project Apollo, was the United States human spaceflight program led by NASA, which landed the first humans on the Moon in 1969 [83]. Apollo 11 showcased humanity's ambition and technological skill, with Neil Armstrong and Buzz Aldrin walking on the Moon on July 20, 1969, while Michael Collins orbited above. The crew conducted experiments and collected samples before returning safely. Apollo 13, launched in 1970, faced a critical in-flight explosion, but the quick problem-solving of the astronauts and mission control ensured their safe return, highlighting human ingenuity and resilience in space exploration.

Launched in 2018, NASA's Parker Solar Probe is the first mission to "touch" the Sun, flying closer than any previous spacecraft to study the corona, solar wind, and magnetic fields. Protected by a 4.5-inch-thick carbon-composite heat shield that withstands nearly 2,500 °F and intense radiation, the probe operates mostly autonomously and uses Venus gravity assists to gradually approach the Sun while collecting critical data on solar phenomena. It has already passed through the solar corona and discovered magnetic "switchbacks"—sudden reversals in the Sun's magnetic field—that may explain how solar wind accelerates. Its final and closest approach will happen in 2024 [70].

Launched in 1977, NASA's twin Voyager 1 and 2 spacecraft explored the outer planets during a rare planetary alignment, providing the first detailed images of Jupiter, Saturn, Uranus, Neptune, and their moons. Each carries a Golden Record with Earth's sounds and images for potential extraterrestrial life. Voyager 1 became the first human-made object to

enter interstellar space in 2012, followed by Voyager 2 in 2018, and both continue sending valuable data on the heliosphere and beyond, over 45 years after launch. These missions remain iconic examples of the endurance and reach of human-made technology [51].

Launched in 1990, the Hubble Space Telescope (HST) faced an early setback when its main mirror caused blurry images, later corrected in a 1993 servicing mission with the COSTAR device. Named after Edwin Hubble, it has become one of NASA's most versatile observatories, capturing stunning images of distant galaxies, nebulae, supernovae, and planets. Hubble has transformed modern astronomy, helping measure the universe's expansion, determine its age and size, discover thousands of exoplanets, and reshape both scientific understanding and public perception of the cosmos. In 2021, engineers resolved another major issue when Hubble's computer system failed, again proving the dedication and ingenuity required to maintain such long-term missions [66].

Mars Pathfinder, an American robotic mission, landed on Mars in 1997, deploying the Carl Sagan Memorial Station and the 10.6 kg Sojourner rover—the first rover to operate beyond the Earth–Moon system. Sojourner explored the Ares Vallis region, analyzing Mars's atmosphere, climate, and geology. The mission successfully used airbags for a safe landing and concluded in 1998. The mission collected evidence suggesting that Mars once had flowing water and that the atmosphere is heated by the planet's surface. Sojourner made its final transmission in September 1997, but by then it was already considered a great success [49]. After 20 years in space, the Cassini spacecraft and Huygens probe concluded their mission on September 15, 2017. A joint effort by NASA, ESA, and the Italian Space Agency, Cassini studied Jupiter during a flyby, explored Saturn's rings, and examined its moons over a full seasonal cycle, ending with a planned descent into Saturn's atmosphere to protect the moons' potential biological environments.

The International Space Station (ISS), built between 1998 and 2011, is a multinational, continuously crewed laboratory in low Earth orbit since November 2000. Roughly the size of a football field, it serves as a research platform, astronaut home, and testbed for deep-space technologies. The ISS has enabled microgravity experiments and other scientific research, demonstrating global cooperation, though Russia plans to withdraw in 2024, with operations now extended through 2030. It also tests technologies and studies the long-term effects of spaceflight on the human body, paving the way for future long-duration missions to the Moon and Mars [54].

Launched in 2004 by the European Space Agency, the Rosetta mission was the first to orbit a comet and deploy a lander, Philae, onto its surface. Arriving at comet 67P/Churyumov–Gerasimenko in 2014, Philae's historic landing—despite limited solar power—gathered 72 hours of data, revealing complex organic molecules. The mission concluded on September 30, 2016, with Rosetta's controlled impact on the comet. Ro-

setta continued to orbit the comet until 2016, when it was deliberately crashed onto its surface, ending a mission that changed how we understand comets and the early solar system [86]. The mission provided a wealth of data on comets, including the detection of ancient ice with a different composition from Earth's water and the identification of chemical compounds like hydrogen sulfide, ammonia, and formaldehyde.

Launched on March 7, 2009, from Cape Canaveral, the Kepler space telescope—named after astronomer Johannes Kepler—discovered over 2,600 exoplanets using the transit method, detecting tiny dips in starlight caused by planets passing in front of stars. Its original mission ended in 2013, but the K2 mission continued from 2014 until its retirement in 2018, identifying 1,284 new planets, nine of which were in the habitable zone. By the end of its nine years, Kepler found over 2,600 planets among more than half a million stars [49].

In December 2015, SpaceX made history by landing the Falcon 9 first stage upright at Cape Canaveral after deploying 11 ORBCOMM satellites, marking the first recovery of an orbital-class rocket and advancing reusable, cost-effective spaceflight. By March 14, 2021, SpaceX had launched a Falcon 9 first stage for the ninth time, setting a record that highlighted the rapid progress of the industry. The company just surpassed Boeing in NASA funding, with \$2.04 billion in fiscal year 2022 and is expected to lead crew flights in the coming year [114].

Launched in 2020 and landing in 2021, NASA's Perseverance rover—accompanied by the Ingenuity helicopter, the first powered aircraft on another planet—is exploring Mars' Jezero Crater. Its mission is to search for signs of ancient microbial life and collect rock and soil samples for a future return to Earth, advancing our understanding of Mars' past habitability as part of the “follow the water” strategy. Information on the mission's latest findings can be found on the NASA Perseverance site [114].

The James Webb Space Telescope (JWST), launched on December 25, 2021, is the most advanced space telescope ever built, featuring a 6.5-meter gold-plated mirror and infrared-optimized instruments. Designed to study every stage of cosmic history, JWST observes distant galaxies, star formation, and exoplanet atmospheres. In July 2022, it revealed thousands of galaxies in unprecedented detail, including the oldest known galaxy, CEERS-93316, forming just 235 million years after the Big Bang and located 35 billion light-years away. Webb was built to last up to ten years, but the precise alignment of its mirrors and other apparatus means it may keep providing data and spectacular images of celestial phenomena for longer [113]. One of its most powerful tools, the Mid-Infrared Instrument (MIRI), enables deep exploration of the early universe. Early images from JWST have revealed hidden binary stars, galaxy collisions, and the most distant galaxies ever observed, marking a new era in astronomy.

These thirteen missions illustrate the evolution of space exploration—from studying the solar system up close to observing the distant universe. They show that scientific discovery is

a long, complex process of risk, failure, and innovation, with each mission answering some questions while raising new ones. Historically, space was observed through ancient astronomy, but it was only in the twentieth century that humans sent probes and astronauts, making space exploration fall into three main categories: astronomy, unmanned probes, and manned missions. The exploration of space is value based, that is, man has "reason" to send men to the moon and to study distant galaxies, just to name a couple such values [85]. For a more complete exploration of man's "reason," The accumulation of discarded equipment in orbit poses a significant risk to future space exploration by potentially colliding with functioning satellites.

5. Complexity of Cosmology and Unsolved Mysteries of the Universe

The following collection of astrophysical and cosmological subjects explores some of the most intriguing and unconventional frontiers in modern science. These subjects venture beyond the well-charted realms of classical astronomy into areas where theory, observation, and speculation converge [117]. From anomalies in black hole properties and mysterious galactic emissions to hidden dimensions, exotic matter states, and the very nature of time and reality, this section deals with phenomena that defy standard models. It highlights both puzzling observational data and bold theoretical frameworks, emphasizing the dynamic, evolving nature of our quest to understand the universe at its most fundamental level [116].

The Missing Baryon Problem and the Cosmic Web: In cosmology, the missing baryon problem is an observed discrepancy between the amount of baryonic matter detected from shortly after the Big Bang and from more recent epochs. Observations of the cosmic microwave background and Big Bang nucleosynthesis studies have set constraints on the abundance of baryons in the early universe, finding that baryonic matter accounts for approximately 4.8% of the energy contents of the universe. At the same time, a census of baryons in the recent observable universe has found that observed baryonic matter accounts for less than half of that amount [126]. This discrepancy is commonly known as the missing baryon problem. The missing baryon problem is different from the dark matter problem, which is non-baryonic in nature. A major unsolved issue in cosmology is the Missing Baryon Problem, where about half of the expected ordinary matter (baryons) in the universe remains undetected [125]. Theoretical predictions and Cosmic Microwave Background data suggest baryons should constitute about 5% of the universe, but only half have been observed. These "missing baryons" are thought to reside in the warm-hot intergalactic medium (WHIM), a diffuse, filamentary gas at 100,000–10 million K. Weak UV and X-ray emissions make it hard to detect, but methods like quasar absorption lines, fast radio burst analyses, and X-ray observa-

tions by Chandra and XMM-Newton provide supporting evidence. Future observatories like Athena and the Square Kilometer Array will likely enhance our understanding of these hidden baryons and their roles in cosmic evolution [128].

Cosmic Ray Conundrums: Cosmic rays or Astro-particles are high-energy particles or clusters of particles (protons or atomic nuclei) that move through space at nearly the speed of light. They originate from the Sun, from outside of the Solar System in the Milky Way, and from distant galaxies [127]. Ultra-High-Energy Particles are another puzzling phenomenon involves Ultra-High-Energy Cosmic Rays (UHECRs), which possess energies far beyond what human-made accelerators can achieve. Their exact origins and acceleration mechanisms remain unknown, and due to interactions with the CMB (Greisen–Zatsepin–Kuzmin or GZK cutoff), such high-energy particles should lose energy over long distances. Since UHECRs are charged [121], magnetic fields deflect their paths, obscuring their sources. Potential sources include active galactic nuclei, gamma-ray bursts, or even the decay of ancient supermassive particles. Ground-based observatories like the Pierre Auger Observatory and the Telescope Array detect these particles through extensive air showers [128], while upcoming missions like POEMMA aim to improve source tracking. Studying UHECRs could open new insights into high-energy astrophysics, quantum gravity, and dark matter [124].

The Hubble Tension: The Hubble Tension refers to the persistent discrepancy between the universe's expansion rate measured from the early universe (~ 67.4 km/s/Mpc from the Cosmic Microwave Background) and local measurements (~ 73 km/s/Mpc using Cepheid variables and Type Ia supernovae). This mismatch, known as the "Hubble Crisis," challenges the standard Lambda-CDM model and our understanding of dark energy, dark matter, or gravity. This mismatch cannot be easily explained by errors, implying potential new physics or revisions to the standard cosmological model [120]. Proposed explanations include evolving dark energy, extra relativistic particles, or altered gravitational laws. New approaches using cosmic chronometers, gravitational wave "standard sirens," and baryon acoustic oscillations aim to clarify the true expansion rate and refine our understanding of cosmic evolution [119].

Intergalactic Shadows: Unseen Structures of the Cosmic Web. The hypothesis that stars exist only in galaxies was disproven in January 1997 with the discovery of intergalactic stars. The Cosmic Web not only consists of visible galaxies but also vast, faint regions of gas and dark matter forming filaments and voids [132]. These intergalactic regions are hard to observe directly, but methods such as studying the Lyman-alpha Forest in quasar spectra and gravitational lensing help reveal their presence. These "intergalactic shadows" may hold clues about galaxy formation and the behavior of dark energy in low-density environments. Understanding the structure and role of these hidden regions is vital for developing accurate models of the universe's growth [129].

Gravity Unbound: Questioning General Relativity on Cosmic Scales. The gravitational binding energy can be conceptually different within the theories of Newtonian gravity and Albert Einstein's theory of gravity called General Relativity [130]. Einstein's General Relativity works well within the solar system but faces challenges on cosmic scales, as phenomena like cosmic acceleration and galaxy rotation curves imply the existence of dark energy and dark matter, which remain unobserved. Alternatives—such as Modified Newtonian Dynamics (MOND), extra-dimensional theories, and entropic gravity—propose modifications to gravity itself, while black hole merger data and future missions like LISA may offer insights that could reshape our understanding of gravity and spacetime.

Quantum Gravity Frontiers: Quantum Gravity studies regions where both gravitational and quantum effects are significant, such as near black holes or the early universe. Its goal is to unify General Relativity and Quantum Mechanics, with candidates including Loop Quantum Gravity, which models spacetime as discrete units, and String Theory, describing particles as vibrating strings in higher dimensions. Some theories suggest spacetime itself emerges from quantum information. Despite limited experimental access due to extreme energy requirements, gravitational wave studies and high-energy experiments continue to explore these theoretical frontiers [123].

Relativity Extreme: Time Dilation and Cosmic Chronology Challenges highlight the counterintuitive effects of Einstein's Special and General Relativity in extreme conditions, where time and space warp under high speeds or intense gravity. Experiments confirm these effects, from atomic clocks on fast jets to GPS adjustments, while near black holes, falling objects appear “frozen.” On cosmic scales, redshifted galaxies trace time's passage, shaping our understanding of the universe's age and evolution, and some quantum theories suggest that time itself may be emergent, breaking down near singularities. These insights challenge classical notions of past, present, and future, with profound implications for cosmology [118].

Spectral Riddles: The Enigma of Diffuse Interstellar Bands (DIBs). DIBs are mysterious absorption lines in starlight caused by unknown interstellar molecules. Possible candidates include complex organic molecules like PAHs and fullerenes, but no definitive identification has been made [122]. Variations in the bands based on environment complicate the search, which now includes laboratory simulations and machine learning. Solving the DIB puzzle would improve our understanding of interstellar chemistry and the physics of space [132].

Anomalous Trajectories: The Flyby Anomaly refers to unexplained changes in spacecraft velocity observed during Earth flybys, first noticed in the 1990s. Despite accounting for tracking errors, atmospheric effects, and gravitational variations, no definitive explanation has been found. Relatedly, anomalous trajectories—paths that deviate significantly from

expected patterns—are studied using data analysis and machine learning for applications in navigation, security, and behavioral analysis. The pattern seems to depend on the trajectory geometry, prompting speculation about unknown physics. Understanding this anomaly is important for precise spacecraft navigation and may have broader implications for gravitational theory [143].

The Silent Pioneers: The Quest for Population III Stars. Population III stars—the universe's first stars—remain hypothetical. Formed from pure hydrogen and helium shortly after the Big Bang, they were likely massive, bright, and short-lived, initiating the production of heavier elements. Although never observed directly, researchers look for their signatures in extremely metal-poor stars and distant galaxies. Some may have collapsed directly into black holes, evading detection. Finding evidence of these stars would help explain early cosmic chemical enrichment and galaxy formation [139].

Stellar Genesis Revisited: Metallicity shaped the formation of the first stars. In the metal-free early universe, gas cooled inefficiently, producing extremely massive stars, possibly hundreds of times the Sun's mass. Their intense radiation ionized surrounding hydrogen, initiating the epoch of reionization, while later metal enrichment from supernovae enabled the formation of more diverse stars. Understanding this process is key to modeling stellar evolution and the development of cosmic structure [145].

Unconventional Black Holes: Recent black hole observations, including gravitational wave detections, reveal unexpected properties that challenge classical models. Intermediate-mass black holes (~30 solar masses) bridge the gap between stellar and supermassive black holes, raising questions about their formation. Spin measurements vary widely, with some near theoretical limits and others unusually slow or misaligned, implying complex histories. Black holes in the “mass gap” (~50–120 solar masses) suggest alternative formation channels like direct collapse or primordial origins, while speculative objects such as gravastars or fuzzballs remain unproven. These anomalies continue to refine our understanding of black hole physics and cosmic evolution [143].

Microwave Whispers: Observations of the Milky Way's microwave emissions have revealed anomalous signals unexplained by standard astrophysical processes. First detected by COBE and confirmed by WMAP and Planck, these emissions may arise from rapidly spinning dust grains, cosmic-ray interactions with interstellar dust, magnetized grains, or exotic particle processes like axion decay linked to dark matter. Despite progress, no current model fully explains the observed features. Missions like NASA's SPHEREx and laboratory studies aim to clarify this emission's origins, which could reshape our understanding of interstellar dust and galactic physics [143].

Magnetic Mysteries: The Role of Cosmic Magnetic Fields in Shaping the Universe. Cosmic magnetic fields thread through galaxies, galaxy clusters, and the intergalactic me-

dium, influencing charged particles, star formation, and galactic dynamics [144]. The origins of cosmic magnetic fields are uncertain, possibly arising from early-universe plasma fluctuations and amplified by galactic dynamos. Observed to align with structures like spiral arms and black hole jets, they are studied indirectly via polarization and cosmic ray deflection. Magnetic fields may interact with dark matter and dark energy, influencing cosmic structure and expansion, yet their elusive nature makes them one of the least understood forces in cosmology.

Neutrino Enigmas: The Ghostly Messengers of the Cosmos. Neutrinos are nearly massless, neutral particles born in stars, supernovae, and the Big Bang. Their weak interaction with matter allows them to travel vast distances, carrying unique astrophysical information. Massive detectors like IceCube at the South Pole catch rare neutrino events in ice [115]. The 1987A supernova neutrino burst offered pivotal insight into stellar death. Neutrino oscillations flavor changes en route demand physics beyond the Standard Model. Detecting the cosmic neutrino background could unlock secrets of the early universe, further illuminating fundamental forces and astrophysical phenomena.

Gamma Ray Surprises: Unexplained Emissions from the Galactic Center. The Fermi Gamma-ray Space Telescope has detected excess gamma radiation from the Milky Way's center; exceeding emissions expected from known sources like the central black hole. The diffuse emission pattern implies an extended origin [140]. Possible sources include dark matter annihilation, cosmic ray interactions with gas, or unknown astrophysical objects like micro-quasars. None of these fully explain the signal. Investigating these emissions could lead to breakthroughs in particle physics, galactic structure, and indirect dark matter detection [137].

Rethinking Inflation: Alternative Scenarios for the Universe's Birth. Inflation theory posits a rapid expansion of the universe just after the Big Bang, solving puzzles like flatness and homogeneity [131]. Yet, the inflation field driving this expansion is hypothetical and undetected. Alternatives propose cyclic universes, eternal pre-Big Bang states (emergent universes), or quantum fluctuations birthing universes in a multiverse. Some models suggest inflation varies across regions.

Cosmic Strings and Topological Defects: Traces from the Early Universe. Topological defects such as cosmic strings may be relics from symmetry-breaking phase transitions in the early universe, similar to cracks in cooling crystals [134]. Cosmic strings, if they exist, would be thin yet immensely dense, producing unique gravitational lensing. Other defects include domain walls and magnetic monopoles, though none have been conclusively observed. While inflation remains the leading structure formation theory, efforts to detect such relics via gravitational waves, gamma rays, or CMB anomalies continue. Discovery would illuminate early-universe physics [142].

Baryogenesis and Beyond: The Puzzle of Matter-Antimatter Imbalance. The universe's matter dominance contradicts the expectation of equal matter and antimatter production.

This asymmetry likely arose through baryogenesis—processes involving CP violation, baryon number violation, and non-equilibrium conditions. The CP violation seen in the Standard Model is insufficient, prompting theories like electroweak baryogenesis, lipogenesis, and new physics. Particle collider experiments and astrophysical studies seek to uncover the root cause, addressing one of cosmology's most profound puzzles [136].

Ghostly Galaxies: The Enigma of Ultra-Diffuse Structures. Ultra-diffuse galaxies (UDGs) are puzzling objects as large as the Milky Way but with very few stars. Some appear nearly devoid of dark matter, while others seem dominated by it [135]. Found in both clusters and isolated regions, these galaxies may form through tidal stripping, inefficient star formation, or as remnants of ancient starbursts. Their diversity challenges traditional galaxy formation theories and highlights gaps in our understanding of baryonic and dark matter interactions.

Challenging Constants: Are Nature's Numbers Truly Universal? Physical constants like the speed of light, gravitational constant, and fine-structure constant underlie the laws of nature. Some studies explore whether these might vary over time or space, which would dramatically alter our understanding of physics [133]. Quasar observations and atomic clock experiments test for such variations. Though no conclusive changes have been detected, the implications are vast. Theoretical models like string theory suggest these constants could emerge from deeper geometrical properties of space or extra dimensions [141].

Phantom Dimensions: Theories like string theory suggest extra spatial dimensions beyond the observable three, likely compactified and currently undetectable, which could explain gravity's relative weakness. Brane cosmology envisions our universe as a 3D surface within higher-dimensional space, offering potential insights into dark matter, dark energy, and the multiverse. Experiments at particle colliders and astrophysical observations attempt to test these hypotheses, though direct evidence remains elusive [136].

Time's Labyrinth: Temporal Anomalies and the Possibility of Cosmic Time Travel. Temporal Anomalies and the Possibility of Cosmic Time Travel" is likely a phrase you've come across as a conceptual or descriptive title, as there is no single definitive book with this exact name that serves as a central, well-known work on the topic. Instead, the phrase "Time's Labyrinth" and variations of the concept appear in several different contexts, ranging from fiction to philosophical discussions. Relativity confirms time dilation, but more speculative models allow for closed time-like curves—paths through spacetime enabling backward time travel [82]. Theoretical structures like wormholes or cosmic strings might permit such loops if negative-energy matter exists. However, paradoxes such as the grandfather paradox and questions about causality make this idea controversial. While future-directed time travel aligns with known physics, reverse time travel remains speculative but conceptually rich [144].

Artificial Gravity: Speculative technologies for deep-space travel include artificial gravity, which counters the harmful effects of weightlessness on long missions. The most feasible method uses spacecraft rotation to generate centrifugal force, while other concepts—like electromagnetic manipulation or exotic matter-based gravity control—remain largely theoretical. While these remain theoretical, rotating habitats are being considered in current mission planning, offering practical steps toward sustained human space exploration [145].

The Simulation Hypothesis: Are We Living in a Cosmic Construct? The simulation hypothesis proposes that what one experiences as the real world is actually a simulated reality, such as a computer simulation in which humans are constructs. There has been much debate over this topic in the philosophical discourse, and regarding practical applications in computing. The simulation hypothesis suggests that our reality might be a high-fidelity simulation by an advanced civilization [138]. If such simulations are numerous, statistically we could be one of them. Quantum mechanics oddities and finely tuned constants are cited as potential clues. Some propose experiments to detect signs of computational limits in the universe. However, critics argue such simulations may be infeasible and the hypothesis may be untestable. Still, it provokes deep questions about reality and consciousness [130].

Exotic States of Matter: Beyond ordinary matter—solids, liquids, gases, and plasma—extreme conditions reveal exotic states. Examples include Bose-Einstein condensates, where atoms act as a single quantum entity, quark-gluon plasma resembling the early universe, and possible strange matter in neutron stars. Hypothetical forms include supersolids, time crystals, Planck stars, and negative-mass matter. These states challenge known physics and offer novel insights and technologies, driving both experimental and theoretical research [118]. Exotic states of matter go beyond solids, liquids, gases, and plasmas, showing unique quantum behaviors under extreme conditions. Examples include Bose-Einstein condensates, superfluids, quark-gluon plasma, time crystals, and superconductors. Studying these lab-created states advances fundamental physics, informs quantum computing, and helps us understand cosmic phenomena.

6. Conclusion

Both the Age of Discovery and the Age of Space carry inherent risks and tragedies. Historical analyses, from the Augustine Report (1990) to the Columbia Accident Investigation Board (2003), emphasize that exploration inevitably involves risk. As the Augustine Report notes, the space program reflects a national heritage of risk-taking, passed down from early explorers and adventurers. Strategic, scientific, and economic imperatives continue to drive nations into space, providing a long-term framework for understanding human ambition and greatness. The Space Age opens vast new possibilities—likely not utopian, but once imagined in science fiction and now realized in fact. While technological challenges

remain and economic benefits may take time to materialize, humanity's conquest of space has the potential to profoundly shape our story, as we expand into the solar system and explore our place in cosmic evolution. Achieving cosmic understanding is an ongoing journey, where each discovery reveals more of the universe's vastness and complexity. Modern physics even suggests our perceived reality may be a holographic projection of deeper structures. Scientific progress, like a particle collider of ideas, continually refines knowledge, confronting unknowns and unresolved tensions. From the 1920s discovery of galaxies' recession, which confirmed the expanding universe, to today's frontier challenges, exploration remains a dynamic process of discovery and insight.

In the late 1990s, astronomers discovered that the universe's expansion is accelerating, not slowing, leading to the inference of dark energy, which makes up roughly 70% of the universe and earned the 2011 Nobel Prize in Physics. Advances like the Hubble and James Webb Space Telescopes have enabled precise measurements of cosmic parameters, revealing links between quantum mechanics and cosmology. Current challenges include the "Hubble Tension," a significant discrepancy in measured expansion rates, and the uncertain nature of dark energy, which future missions like the Roman Space Telescope aim to clarify. The finite speed of light limits observations to the visible universe, leaving the universe's full scale and ultimate fate unknown.

The universe is often viewed by some scientists as an intricate tapestry, with every individual element (stars, galaxies, life forms) representing a thread. Understanding the cosmos is like appreciating the immense and complex pattern of the whole, recognizing how all the threads interweave to form a masterpiece. Or, we may see, the universe is often viewed as an intricate tapestry, with every individual element (stars, galaxies, life forms) representing a thread. Understanding the cosmos is like appreciating the immense and complex pattern of the whole, recognizing how all the threads interweave to form a masterpiece. Historically (from Aristotle to Copernicus), the universe was metaphorically an onion, with the Earth at the center, surrounded by concentric, crystalline spheres. Understanding the cosmos was peeling back these layers. This contrasts with modern understanding, but highlights how metaphors evolve with knowledge. Metaphors for cosmic understanding often compare the vast and abstract nature of the universe to more familiar, tangible human experiences or objects. These comparisons help to conceptualize complex scientific and philosophical ideas. So, this discussion accentuates a profound truth that the cosmos is far more intricate and mysterious than once believed. By addressing open questions about dark matter, magnetic fields, time, neutrinos, inflation, and even the possibility of a simulated reality, this collection illustrates how modern astrophysics and cosmology are increasingly interwoven with cutting-edge physics, speculative ideas, and technological innovation. Ultimately, the evaluation suggests that the astonishing nature of the universe is inseparably

linked to its uncertainties. Each new discovery provides answers to old questions while simultaneously paving the way for deeper, more challenging mysteries, embodying the dynamic nature of scientific exploration. This analysis and the findings not only challenge existing paradigms but also offer glimpses into deeper layers of physical law, potentially reshaping our understanding of existence itself. As observation improves and theory advances, the answers to these questions may unlock entirely new dimensions both literally and metaphorically of cosmic understanding.

Abbreviations

CMB	Cosmic Microwave Background
CNSA	China National Space Administration
ESA	European Space Agency
HST	Hubble Space Telescope
ISRO	Indian Space Research Organization
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JWST	James Webb Space Telescope
Lambda-CDM	Lambda Cold Dark Matter (Standard Cosmological Model)
NASA	National Aeronautics and Space Administration
NASA-JSC	NASA Johnson Space Center
NBL	Neutral Buoyancy Laboratory
UHECRs	Ultra-High-Energy Cosmic Rays
WHIM	Warm-Hot Intergalactic Medium
XMM-Newton	X-ray Multi-Mirror Mission - Newton
XRISM	X-ray Imaging and Spectroscopy Mission

Author Contributions

Khandakar Akhter Hossain is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Bainbridge, W. S. (2025). The impact of space exploration on public opinions, attitudes, and beliefs. In S. J. Dick (Ed.), *Historical studies in the societal impact of spaceflight*. NASA.
- [2] BBC. (2018, February 3). Voyager 1. https://web.archive.org/web/20180203195855/http://www.bbc.co.uk/science/solarsystem/space_missions/voyager_1
- [3] National Aeronautics and Space Administration. (n.d.). Where are Voyager 1 and Voyager 2 now? Retrieved January 7, 2026, from <https://science.nasa.gov/mission/voyager/where-are-voyager-1-and-voyager-2-now/>
- [4] National Aeronautics and Space Administration. (2009, July 2). Exploration. https://web.archive.org/web/20090702153058/http://adc.gsfc.nasa.gov/adc/education/space_ex/exploration.html
- [5] Planetary Society. (2025). China's plans for outer solar system exploration. <https://www.planetary.org/articles/chinas-plans-for-outer-solar-system-exploration>
- [6] Hunley, J. D. (2008). *Preludes to U.S. space-launch vehicle technology: Goddard rockets to Minuteman III*. University Press of Florida.
- [7] Bilstein, R. E. (1980). *Stages to Saturn: A technological history of the Apollo/Saturn launch vehicles* (NASA SP-4206). NASA.
- [8] Butrica, A. J. (1998). Reusable launch vehicles or expendable launch vehicles? A perennial debate. In D. Dick & R. Launius (Eds.), *Critical issues in the history of spaceflight* (pp. 301–341). NASA.
- [9] Brown, A. (2006). Accidents, engineering, and history at NASA, 1967–2003. In D. Dick & R. Launius (Eds.), *Critical issues in the history of spaceflight* (pp. 377–402). NASA.
- [10] Stine, D. D. (2007). U.S. civilian space policy and priorities: Reflections 50 years after Sputnik. Congressional Research Service.
- [11] SpaceX. (2025a). SpaceX missions. <https://www.spacex.com/mission>
- [12] SpaceX. (2025b). Together, NASA and SpaceX are stronger, and so is America. <https://arstechnica.com/science/2019/03/together-nasa-and-spacex-are-stronger-and-so-is-america/>
- [13] Raychaudhuri, T. (1982). *The Cambridge economic history of India: Volume 1, c.1200-c.1750*. Cambridge University Press.
- [14] Paine, L. (2013). *The sea and civilization: A maritime history of the world*. Random House.
- [15] Arnold, D. (2006). *The age of discovery, 1400-1600*. Routledge.
- [16] Washburn, W. E. (1962). The meaning of "discovery" in the fifteenth and sixteenth centuries. *The American Historical Review*, 68(1), 1–21. <https://doi.org/10.2307/1847180>
- [17] Pagden, A. (1993). *European encounters with the New World: From Renaissance to Romanticism*. Yale University Press.
- [18] Kleinhenz, C. (2004). *Medieval Italy: An encyclopedia* (Vol. 1). Routledge.
- [19] Butel, P. (2002). *The Atlantic*. Taylor & Francis.
- [20] Pethokoukis, J. (2022, May 11). America is launching a new space age. American Enterprise Institute. <https://www.aei.org>
- [21] Williams, M. (2015, June 27). What is the Space Age? *Universe Today*. <https://www.universetoday.com>

- [22] International Astronautical Federation. (2022). ROSCOSMOS. <https://www.iafastro.org>
- [23] Garcia, M. (2017, October 5). 60 years ago, the Space Age began. NASA. <https://www.nasa.gov>
- [24] Harrison, T., Cooper, Z., Johnson, K., & Roberts, T. G. (2017). Escalation & deterrence in the Second Space Age [Unpublished report]. <https://doi.org/10.13140/RG.2.2.15240.11525>
- [25] Schefter, J. (1999). The race: The uncensored story of how America beat Russia to the moon. Doubleday.
- [26] Garber, S. (2004). Sputnik and the dawn of the Space Age. NASA History. <https://history.nasa.gov>
- [27] Ade, P. A. R., Aghanim, N., Arnaud, M., Ashdown, M., Aumont, J.,... & Zonca, A. (2016). Planck 2015 results: XIII. Cosmological parameters. *Astronomy & Astrophysics*, 594, A13.
- [28] Pyne, S. J. (1993). The third great age of discovery. In S. J. Dick & K. Cowing (Eds.), *Risk and exploration: Earth, sea and the stars* (NASA SP-2005-4701). NASA.
- [29] Goetzmann, W. H. (1986). *New lands, new men: America and the second age of discovery*. Viking.
- [30] Parry, J. H. (1981). *The age of reconnaissance: Discovery, exploration and settlement, 1450 to 1650*. University of California Press.
- [31] Mazlish, B. (1965). *The railroad and the space program: An exploration in historical analogy*. MIT Press.
- [32] Hughes, T. P. (1965). *The development of western technology since 1500*. Macmillan.
- [33] Griffin, M. (2005, December 2). The space economy. [Speech]. NASA. <https://www.nasa.gov>
- [34] Griffin, M. (2005, November 15). Federally funded exploration and the American character. [Speech]. NASA.
- [35] Philbrick, N. (2003). *Sea of glory: America's voyage of discovery, the U.S. exploring expedition, 1838-1842*. Viking.
- [36] McCurdy, H. (1997). *Space and the American imagination*. Smithsonian Institution Press.
- [37] The White House. (2004). *A renewed spirit of discovery: The president's vision for U.S. space exploration*. Government Printing Office.
- [38] National Research Council. (2005). *Science in NASA's vision for space exploration*. The National Academies Press. <https://doi.org/10.17226/11225>
- [39] Bergreen, L. (2000). *Voyage to Mars: NASA's search for life beyond Earth*. Riverhead Books.
- [40] Kennedy, J. F. (1962, September 12). Address at Rice University on the nation's space effort. [Speech]. Rice University, Houston, TX.
- [41] Burrows, W. E. (1998). *This new ocean: The story of the first space age*. Modern Library.
- [42] NASA. (2023, November 24). NASA culture and the tradition of discovery. <https://www.nasa.gov>
- [43] Swenson, L. S. Jr., Grimwood, J. M., & Alexander, C. C. (1966). *This new ocean: A history of Project Mercury*. NASA.
- [44] Collins, M. (1974). *Carrying the fire: An astronaut's journeys*. Farrar, Straus and Giroux.
- [45] Collins, M. (2009). *Carrying the fire: 40th anniversary edition*. Farrar, Straus and Giroux.
- [46] Allen, B. (Ed.). (2004). *NASA Langley Research Center's contributions to the Apollo program*. NASA Langley Research Center.
- [47] Murray, C., & Cox, C. B. (1989). *Apollo: The race to the moon*. Simon & Schuster.
- [48] McNutt, R. L. Jr. (2015, December 15). The legacy of Apollo. [Speech]. Johns Hopkins University.
- [49] Benson, M. (2003). *Beyond: Visions of the interplanetary*. Harry N. Abrams.
- [50] Ferris, T. (2002). *The red limit: The search for the edge of the universe*. HarperCollins.
- [51] Zamora, B. R. (2024, May 13). Forward progress on Gateway, humanity's first lunar space station. SciTechDaily. <https://scitechdaily.com>
- [52] Bradbury, R., Murray, B., Sagan, C., Clarke, A. C., & Sullivan, W. (1973). *Mars and the mind of man*. Harper & Row.
- [53] Harwood, W. (2013, May 30). The Mariner 9 legacy. CBS News.
- [54] Spitzer, L. (1979). The space telescope. *Quarterly Journal of the Royal Astronomical Society*, 20, 29.
- [55] Nelson, J. (2014, February 19). The economics of space tourism. *Forbes*.
- [56] NASA. (2024, May 16). International Space Station overview. <https://www.nasa.gov>
- [57] Crouch, G. I., Devinney, T. M., Louviere, J. J., & Islam, T. (2009). Attitudes and determinants in the selection of space tourism services. *Tourism Management*, 30(3), 441-454.
- [58] Reddy, M. V., Nica, M., & Wilkes, K. (2012). Space tourism: Research recommendations for the future of the industry and sustainable ventures. *Tourism Management*, 33(5), 1093-1102.
- [59] MiGFlug. (2017). Space flight in a supersonic jet. <https://www.migflug.com>
- [60] Kawaguchi, Y., et al. (2020, August 26). DNA damage and survival time course of deinococcal cells during exposure to space. *Frontiers in Microbiology*, 11, 2050.
- [61] European Space Agency. (2025, November 14). Rosetta mission overview. <https://www.esa.int>
- [62] NASA. (2025, November 14). Rosetta & Philae. <https://www.nasa.gov>

- [63] BBC. (2015, April 30). The history of space stations. <https://www.bbc.com>
- [64] NASA. (2011, March 17). Kepler mission launch. <https://www.nasa.gov>
- [65] Chou, F., Hawkes, A., & Cofield, C. (2018, October 30). NASA retires Kepler Space Telescope. NASA.
- [66] Borucki, W. J., et al. (2010, February). Kepler planet-detection mission: Introduction and first results. *Science*, 327.
- [67] SpaceX. (2025). SpaceX mission overview. <https://www.spacex.com>
- [68] Belfiore, M. (2014, March 13). The rise of private spaceflight. *Popular Mechanics*.
- [69] Morring, F. Jr. (2014, October 20). The commercial space launch market. *Aviation Week*.
- [70] Belfiore, M. (2013, September 30). Musk: SpaceX now has all the pieces. *Popular Mechanics*.
- [71] Chang, K. (2022, September 15). The new race for the moon. *The New York Times*.
- [72] Wall, M. (2021, February 17). SpaceX Crew-2 launch to ISS. <https://www.space.com/spacex-crew-2-astronaut-mission-launch-explainer>
- [73] NASA. (2021). Mars 2020 Perseverance mission. <https://www.nasa.gov>
- [74] Overbye, D. (2022, August 23). James Webb Telescope and the privatization of discovery. *The New York Times*.
- [75] O'Callaghan, J. (2023, January 23). SpaceX Falcon Heavy first commercial mission. *Forbes*.
- [76] Fisher, A., Pinol, N., & Betz, L. (2022, July 11). The engineering of Starship. *Aerospace America*.
- [77] Atkinson, N. (2022). Blue Origin and the future of engines. *Universe Today*.
- [78] Virgin Galactic. (2025). Famous space missions through history.
- [79] NASA. (2009, July 2). Space exploration archive. <https://www.nasa.gov>
- [80] Zamora, B. R. (2024, May 13). SpaceX and the multiplanetary future. *Ars Technica*.
- [81] Cooke, R. J., Pettini, M., & Steidel, C. C. (2018, March 12). One percent determination of the primordial deuterium abundance. *The Astrophysical Journal*, 855(2), 102. <https://doi.org/10.3847/1538-4357/aaab53>
- [82] Wall, M. (2021, February 17). The sounds of Mars: NASA's Perseverance rover will put ears on the Red Planet for the first time. *Space.com*. <https://www.space.com/perseverance-mars-rover-microphones-sounds>
- [83] Starburst Magazine. (2025). Science fiction novel wins the Booker Prize. <https://www.starburstmagazine.com>
- [84] Graham, M. L., Sand, D. J., Zaritsky, D., & Pritchett, C. J. (2015, July 2). Confirmation of hostless Type Ia supernovae using Hubble Space Telescope imaging. *The Astrophysical Journal*, 807(1), 83. <https://doi.org/10.1088/0004-637X/807/1/83>
- [85] Chandrasekhar, S. (1939). *An introduction to the study of stellar structure*. University of Chicago Press.
- [86] Keenum, R. (2021, July 28). Unbound: Worlds Apart review. *Screen Rant*. <https://screenrant.com>
- [87] Mermin, N. D. (2009). *It's about time: Understanding Einstein's relativity*. Princeton University Press.
- [88] Rindler, W. (1977). *Essential relativity: Special, general, and cosmological*. Springer-Verlag.
- [89] Bk, S. (2025). The World Views of the Universe Since the Beginning of Civilization over the last 10,000 Years Since the Last Ice Age Current. *Open Access Journal of Astronomy*, 3(2), 1–72. <https://doi.org/10.23880/oaja-16000162>
- [90] Binney, J., Mohayaee, R., Peacock, J., & Sarkar, S. (2025). Manifesto: challenging the standard cosmological model. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 383(2276). <https://doi.org/10.1098/rsta.2024.0036>
- [91] Zhang, S. N., & Liu, Y. (2008). Studies on the angular scale of cosmic homogeneity.
- [92] Chapline, G. (1998, July). Homogeneity test for matter distribution.
- [93] Natural wormholes as gravitational lenses. (1995).
- [94] Penzias, A. A., & Wilson, R. W. (1965). A measurement of excess antenna temperature at 4080 Mc/s. *The Astrophysical Journal*, 142, 419–421.
- [95] Carlson, P., & De Angelis, A. (2011). Nationalism and internationalism in science. *Il Nuovo Saggiatore*.
- [96] Sloan, T., & Wolfendale, A. W. (2013, November 7). Understanding cosmic acceleration.
- [97] A journey into metaphysical realms. (n.d.). Retrieved November 17, 2025.
- [98] Cheng, J. (2012). *The physics of astronomical telescopes*. Springer.
- [99] Rosenberg, D. (1997). Incompleteness of the concordance model.
- [100] Sutter, P. (2022, January 21). Foundations of cosmology and the cosmological principle. *Space.com*. <https://www.space.com/foundations-of-cosmology-cosmological-principle>
- [101] Grabianowski, E. (2011, May 7). Investigating Hubble tensions. *HowStuffWorks*.
- [102] Manjoo, F. (2022, January 26). Emergent phenomena in cosmology. *The New York Times*.
- [103] Zhang, S. N., & Oganov, A. R. (2013). Reconstructing the scale factor.

- [104] Yakubu Yakubu profile. (2025, November 17).
- [105] Sebastian Hettrich. (2025, November 17).
- [106] Smithsonian National Air and Space Museum. (n.d.). Parametric models in space.
- [107] Lewis, C. (2016, December 16). Non-parametric analysis of redshift.
- [108] Howell, E. (2018, May 4). *Modified standard redshift models*. Space.com. <https://www.space.com/modified-standard-redshift-models>
- [109] Chatzky, A. (2021, September 23). Cosmological data limitations. Council on Foreign Relations.
- [110] Ansari X-Prize Overview. (2010, September 23). Vera Rubin Observatory camera.
- [111] Ivezić, Ž., Kahn, S. M., Tyson, J. A., Abel, B., Acosta, E., Allsman, R., ... & York, D. G. (2019). LSST: From science drivers to reference design and anticipated data products. *The Astrophysical Journal*, 873(2), 111. <https://doi.org/10.3847/1538-4357/ab042c>
- [112] Bassett, B. A., et al. (2015, November 17). Parametric model proposal.
- [113] Alshammari, F. (2024). A critical examination of the standard cosmological model: Toward a modified framework for explaining cosmic structure formation and evolution. *Galaxies*, 12 (1), 5. <https://doi.org/10.3390/galaxies12010005>
- [114] Pandey, B., & Sarkar, S. (2016). Testing the isotropy of the universe with the low-frequency radio sky. *Monthly Notices of the Royal Astronomical Society*, 460(3), 2848–2852. <https://doi.org/10.1093/mnras/stw1121>
- [115] Starburst magazine: Science fiction novel wins the Booker Prize. (2025). Starburst Magazine. <https://www.starburstmagazine.com/science-fiction-novel-wins-the-booker-prize/>
- [116] Smithsonian National Air and Space Museum. (n.d.). First space stations. <https://airandspace.si.edu/stories/editorial/first-space-stations>
- [117] Strauss, S. (2008, July). Space medicine at the NASA-JSC, Neutral Buoyancy Laboratory. *Aviation, Space, and Environmental Medicine*, 79(7), 732–733.
- [118] Bassett, B. A., Fantaye, Y., Hložek, R., Sabiu, C., & Smith, M. (2015). A tale of two redshifts. arXiv. <https://arxiv.org/abs/1312.2593>
- [119] Brough, S., Collins, C., Demarco, R., Ferguson, H. C., Galaz, G., Holwerda, B., Martinez-Lombilla, C., Mihos, C., & Montes, M. (2020). The Vera Rubin Observatory legacy survey of space and time and the low surface brightness universe. arXiv. <https://arxiv.org/abs/2001.11067>
- [120] Di Valentino, E. (2021). Cosmological tensions: Hints for a new concordance model? [Paper presentation]. The Sixteenth Marcel Grossmann Meeting.
- [121] Mandal, S., Pradhan, S., Sahoo, P. K., Harko, T., & Mandal, S. (2023). Cosmological observational constraints on the power law $f(Q)$ type modified gravity theory. *European Physical Journal C*, 83, Article 10939. <https://doi.org/10.1140/epjc/s10052-023-10939-3>
- [122] Pandey, B., & Sarkar, S. (2016). Probing large-scale homogeneity and periodicity in the LRG distribution using Shannon entropy. *Monthly Notices of the Royal Astronomical Society*, 460(2), 1519–1528. <https://doi.org/10.1093/mnras/stw967>
- [123] Pâris, I., Petitjean, P., Ross, N. P., et al. (2017). The Sloan Digital Sky Survey quasar catalog: Twelfth data release. *Astrophysical Journal*, 597, A79. <https://doi.org/10.3847/1538-4357/aa8f97>
- [124] Riess, A. G., Yuan, W., Macri, L. M., et al. (2022). A comprehensive measurement of the local value of the Hubble constant with 1 km s^{−1} Mpc^{−1} uncertainty from the Hubble Space Telescope and the SH0ES team. *Astrophysical Journal Letters*, 934(1), L7. <https://doi.org/10.3847/2041-8213/ac7064>
- [125] Shahalam, M., Ayoub, S., Avlani, P., & Myrzakulov, R. (2024). Dynamical system analysis in descending dark energy model. arXiv. <https://arxiv.org/abs/2402.01270>
- [126] Tian, S. (2017). The relation between cosmological redshift and scale factor for photons. *Astrophysical Journal*, 846(1), Article 1538.
- [127] Wamalwa, D. S., & Omolo, J. A. (2010). Generalized relativistic dynamics in a non-inertial reference frame. *Indian Journal of Physics*, 84(12), 1241–1255. <https://doi.org/10.1007/s12648-010-0136-4>
- [128] Wang, B., Abdalla, E., Atrio-Barandela, F., & Pavón, D. (2024). Further understanding the interaction between dark energy and dark matter: Current status and future directions. arXiv. <https://arxiv.org/abs/2402.00819>
- [129] Wojtak, R., & Prada, F. (2016). Testing the mapping between redshift and cosmic scale factor. *Monthly Notices of the Royal Astronomical Society*, 458(3), 3331–3340. <https://doi.org/10.1093/mnras/stw479>
- [130] Wojtak, R., & Prada, F. (2017). Redshift remapping and cosmic acceleration in dark-matter-dominated cosmological models. *Monthly Notices of the Royal Astronomical Society*, 470(4), 4493–4511. <https://doi.org/10.1093/mnras/stx1529>
- [131] National Aeronautics and Space Administration. (2024, May 16). NASA's International Space Station overview.
- [132] Atkinson, N. (2022). Hubble has looked back in time as far as it can and still can't find the first stars. *Universe Today*. <https://www.universetoday.com>
- [133] Spitzer, L., Jr. (1979). History of the space telescope. *Quarterly Journal of the Royal Astronomical Society*, 20, 29–36.
- [134] Belfiore, M. (2013, September 30). Musk: SpaceX now has "all the pieces" for truly reusable rockets. *Popular Mechanics*. <https://www.popularmechanics.com>
- [135] BBC. (2015, April 30). Rosetta: The whole story. <https://www.bbc.com/future/bspoke/story/20150430-rosetta-the-whole-story/>

- [136] Borucki, W. J., Koch, D., Basri, G., et al. (2010). Kepler planet-detection mission: Introduction and first results. *Science*, 327(5968), 977–980. <https://doi.org/10.1126/science.1185402>
- [137] Chang, K. (2022, September 15). Life on Mars? This could be the place NASA's rover helps us find it. *The New York Times*.
- [138] Fisher, A., Pinol, N., & Betz, L. (2022, July 11). President Biden reveals first image from NASA's Webb Telescope. NASA. <https://www.nasa.gov>
- [139] Harwood, W. (2013, May 30). Four years after final service call, Hubble Space Telescope going strong. CBS News. <https://www.cbsnews.com>
- [140] Kawaguchi, Y., Shibuya, M., Kinoshita, I., et al. (2020, August 26). DNA damage and survival time course of deinococcal cell pellets during 3 years of exposure to outer space. *Frontiers in Microbiology*, 11, Article 2050. <https://doi.org/10.3389/fmicb.2020.02050>
- [141] Moring, F., Jr. (2014, October 20). NASA, SpaceX share data on supersonic retropropulsion. *Aviation Week*. <https://aviationweek.com>
- [142] National Aeronautics and Space Administration. (2011, March 17). Kepler mission launch. https://web.archive.org/web/20111112062226/http://www.nasa.gov/mision_pages/kepler/launch/index.html
- [143] National Aeronautics and Space Administration. (2015, December 25). NASA spaceflight real-time data tracking.
- [144] National Aeronautics and Space Administration. (2021). NASA Mars 2020 Perseverance mission. <https://science.nasa.gov/mission/mars-2020-perseverance/>
- [145] National Aeronautics and Space Administration. (n.d.). Rosetta & Philae. <https://science.nasa.gov/mission/rosetta-philae/>