

# A Catalog of Interesting Cosmic Objects

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## Introduction

Since the dawn of human consciousness, we have looked to the night sky with a mixture of awe and curiosity. The vast, dark expanse, punctuated by the steady glow of stars and the silent wandering of planets, has served as a canvas for our myths, a

guide for our explorers, and a clock for our civilizations. For millennia, this celestial tableau was the ultimate mystery, a divine and unreachable realm whose secrets seemed forever beyond our grasp. The Mesopotamians charted the heavens on clay tablets, the Egyptians aligned their pyramids with the stars, and the ancient Greeks applied reason and mathematics to celestial phenomena, all driven by a fundamental human impulse: to understand our place in the cosmos. This book is a continuation of that ancient quest, a curated tour of the modern cosmic landscape. It is a catalog not of every object—such a list would be impossibly vast—but of particularly *interesting* ones.

What makes a cosmic object "interesting"? The criteria are as varied as the objects themselves. Some are selected for their sheer extremity: the hottest, the coldest, the biggest, the fastest. Others are here because they are profoundly strange, defying our easy categorization and challenging our understanding of physical laws. Some are cosmic enigmas, their very existence posing questions that astronomers are still struggling to answer. And some are included because they are simply beautiful, their forms sculpted by gravity and light into structures that rival the greatest works of art. From the stellar nurseries where stars are born to the supernova remnants that mark their explosive deaths, from planets made of diamond to entire galaxies that appear to be missing their stars, the universe is a gallery of wonders.

This journey through the cosmic neighborhood and beyond is only possible because of the remarkable evolution of our tools and techniques. For most of history, our understanding was limited to what the naked eye could perceive. The invention of the telescope in the 17th century revolutionized astronomy, revealing that the Moon had craters, Jupiter had its own retinue of moons, and the Milky Way was composed of countless individual stars. This was a profound shift, transforming the heavens from a perfect, unchanging canopy into a dynamic and complex place, much like our own world. That revolution has never stopped. In the centuries since, our ability to probe the universe has grown exponentially. We have built ever-larger telescopes on remote mountaintops, far from the obscuring glare of city lights. More importantly, we have learned to see the universe in colors far beyond the narrow range of visible light our eyes can detect.

Light, or more accurately, electromagnetic radiation, is the primary messenger from the cosmos, and it travels in a vast range of wavelengths known as the electromagnetic spectrum. This spectrum encompasses everything from long-wavelength radio waves, which can be the size of mountains, to incredibly short-wavelength gamma rays, smaller than an atomic nucleus. Each portion of this spectrum tells a different story about the object that emitted it. Radio waves, for example, can penetrate dense clouds of cosmic dust, revealing the structure of our own galaxy and the cool gases where stars are forming. Infrared light showcases the heat emitted by celestial bodies, allowing us to see fledgling stars still swaddled in their dusty cocoons and the faint glow of distant galaxies. At the other end of the

spectrum, high-energy ultraviolet light points to the hottest, most energetic processes, such as those in the vicinity of massive young stars. X-rays and gamma rays reveal the most violent and extreme environments in the universe: the superheated gas swirling around black holes, the explosive deaths of stars, and collisions between neutron stars. By combining observations from across the spectrum, astronomers can assemble a complete picture of a celestial object, much like a doctor uses X-rays, MRIs, and other scans to understand what is happening inside the human body.

Beyond simply capturing images, astronomers use a powerful technique called spectroscopy to dissect the light itself. By passing the light from a distant star or galaxy through a prism-like instrument called a spectrograph, it can be spread out into its constituent colors, creating a spectrum. This spectrum is not a continuous, unbroken rainbow; it is often crossed by a pattern of bright or dark lines. These lines are a kind of cosmic barcode, a chemical fingerprint that reveals precisely which elements are present in the light's source. This is how we know what stars are made of, the composition of a planet's atmosphere, or the density and temperature of a distant nebula. Spectroscopy can also tell us how an object is moving. Due to a phenomenon known as the Doppler shift, the spectral lines of an object moving away from us are shifted toward the red end of the spectrum, while those of an object moving toward us are shifted toward the blue. By measuring this "redshift" or "blueshift," we can clock the speed of stars, the rotation of galaxies, and even the expansion of the universe itself.

These tools have allowed us to catalog an astonishing variety of celestial bodies. The term "cosmic object" is itself incredibly broad, encompassing any aggregation of matter or energy in the universe. The most familiar are stars—massive, glowing spheres of gas that generate energy through nuclear fusion in their cores—and planets, which orbit them. Our own solar system is a microcosm of this basic arrangement. But the cosmic zoo contains far more exotic creatures. There are nebulae, vast interstellar clouds of gas and dust that serve as stellar nurseries or the remnants of stellar death. There are star clusters, gatherings of hundreds to millions of stars bound together by gravity. And there are galaxies, immense, rotating collections of stars, gas, dust, and other objects, often with a supermassive black hole at their center. Even these categories contain a wealth of sub-types: red dwarf stars, blue giants, gas giant planets, icy moons, asteroids, comets, spiral galaxies, and elliptical galaxies, to name just a few.

To make sense of this cosmic menagerie, one must first grapple with the mind-boggling scale of it all. The distances in space are so vast that our familiar units of miles or kilometers become hopelessly cumbersome. Instead, astronomers use the light-year, the distance light travels in a single year, which is roughly 9.46 trillion kilometers. Even with this unit, the numbers remain immense. The nearest star to our Sun, Proxima Centauri, is over four light-years away. Our own Milky Way galaxy is about 100,000 light-years across. And the observable universe—the portion of the

cosmos from which light has had time to reach us since the beginning of time—is a sphere with a diameter of about 93 billion light-years.

Measuring these colossal distances is one of the most fundamental challenges in astronomy. It is accomplished through a succession of methods known as the "cosmic distance ladder." Each "rung" on the ladder is a technique for measuring distance that relies on the calibration of the previous, closer-range rung. For the nearest stars, astronomers use the direct geometric method of parallax, observing the apparent shift in a star's position against a distant background as the Earth orbits the Sun. For greater distances, they rely on "standard candles," objects whose intrinsic brightness is known. By comparing an object's known luminosity with its apparent brightness as seen from Earth, its distance can be calculated. Certain types of pulsating stars called Cepheid variables and a specific kind of supernova explosion (Type Ia) are crucial standard candles that allow us to measure distances to galaxies millions of light-years away. For the most distant reaches of the cosmos, astronomers use the redshift caused by the expansion of the universe to estimate distance.

This sprawling universe that we have mapped is, however, only a fraction of the total picture. One of the most profound discoveries of modern astronomy is that the familiar matter making up stars, planets, and ourselves constitutes only about 5% of the total mass and energy in the universe. The rest is composed of two mysterious and invisible components: dark matter and dark energy.

Dark matter, which is believed to make up about 27% of the cosmos, does not emit, absorb, or reflect any light, making it completely invisible to our telescopes. Its existence is inferred from its gravitational effects on the visible matter that we can see. For instance, astronomers observed that the outer regions of spiral galaxies were rotating so fast that they should fly apart; the visible matter present wasn't generating enough gravity to hold them together. This led to the conclusion that there must be a vast, unseen halo of "dark matter" providing the extra gravitational glue. While we know it's there, the exact nature of dark matter remains one of the biggest unsolved mysteries in science.

Even more enigmatic is dark energy, which makes up the remaining 68% of the universe. In the late 1990s, astronomers studying distant supernovae made a shocking discovery: not only is the universe expanding, but the rate of that expansion is accelerating. Some unknown force is acting as a sort of anti-gravity, pushing everything apart at an ever-increasing rate. Scientists have named this mysterious influence "dark energy." Unlike dark matter, which clumps together gravitationally, dark energy appears to be smoothly distributed throughout space. Its discovery implies a strange and unexpected future for our cosmos, one where galaxies are eventually pushed so far apart that the night sky will become a dark and empty void.

This book, therefore, is a journey into both the known and the unknown. In the

chapters that follow, we will explore 25 distinct cosmic objects, each a landmark on the map of our current understanding. We will visit the Pillars of Creation, towering columns of gas where new stars are being forged. We will venture to the center of our own galaxy to confront Sagittarius A\*, the supermassive black hole that holds the Milky Way together. We will examine planets hotter than most stars and colder than any place on Earth, and we will encounter mysterious visitors from other star systems. Each chapter is a deep dive into a single object, exploring its discovery, its physical characteristics, and the unique scientific questions it poses.

This catalog is not just a collection of facts and figures; it is a testament to the enduring power of human curiosity. From our earliest ancestors who looked up and wondered, to the scientists planning the next generation of space telescopes that will peer even deeper into the cosmic dawn, we are a species driven to explore. The universe is vast, strange, and filled with wonders that we are only just beginning to appreciate. The objects in this book represent some of the most intriguing discoveries made so far, but they are also signposts, pointing the way toward the even deeper mysteries that still await us in the dark. The journey is far from over.

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## **CHAPTER ONE: The Pillars of Creation**

In the vast expanse of the cosmos, few images have captured the human imagination as profoundly as the one unveiled to the public in 1995. Taken by the Hubble Space Telescope, it revealed a breathtaking celestial landscape unlike any seen before: three colossal columns of interstellar gas and dust, silhouetted against a backdrop of ethereal light. The image, officially of a small region within the Eagle Nebula, was so evocative of a cosmic genesis that it was aptly nicknamed the "Pillars of Creation." It quickly became one of the most iconic astronomical photographs ever taken, adorning everything from T-shirts to coffee mugs, a testament to its widespread cultural impact. The image offered a stunning, intricate portrait of a stellar nursery, a place where new stars are born.

The Pillars of Creation are located approximately 6,500 to 7,000 light-years from Earth in the constellation Serpens. They are a relatively small feature within the much larger Eagle Nebula, also known as Messier 16, which spans about 70 by 55 light-years. The Eagle Nebula itself was discovered in 1745 by the Swiss astronomer Jean-Philippe Loys de Chéseaux, but the pillar-like structures within it, technically known as "elephant trunks," were first noted in 1920 on a photographic plate made at the Mount Wilson Observatory. However, it was Hubble's detailed, full-color image that brought their grandeur to the forefront of public and scientific attention. The scale of these pillars is difficult to comprehend; the leftmost and tallest pillar is about four to five light-years in length. To put this into perspective, the distance from our Sun to its nearest stellar

neighbor, Proxima Centauri, is just over four light-years.

The pillars are composed of cool molecular hydrogen and interstellar dust, the fundamental raw materials for star formation. These colossal structures are not static; they are in a constant state of flux, being sculpted and eroded by the intense ultraviolet radiation and strong stellar winds from a cluster of hot, young, massive stars located just outside the frame of the famous image. This process is known as photoevaporation. The powerful radiation from these newborn stars essentially boils away the less dense gas and dust on the surface of the pillars, creating the glowing, wispy edges that are so prominent in the images. The denser pockets of gas and dust, however, can resist this erosion for a longer period. Sheltered behind these dense clumps, the material is shielded from the harsh stellar glare, forming the dark, pillar-like "tails" or "elephant trunks" that point away from the source of the radiation.

The very process that is destroying the pillars is also believed to be triggering the birth of new stars within them. The intense radiation from the nearby massive stars can compress the gas and dust in the denser regions of the pillars, causing them to collapse under their own gravity. As these pockets of material become increasingly dense and hot, they eventually ignite nuclear fusion in their cores, giving birth to protostars. At the tips of the pillars are finger-like protrusions, many of which are larger than our entire solar system. Within these are even denser, shadowed regions known as Evaporating Gaseous Globules, or EGGs. These EGGs act as incubators for embryonic stars, shielding them as they grow. Eventually, these new stars will emerge from their dusty cocoons, and the EGGs themselves will be evaporated by the surrounding radiation.

The original 1995 Hubble image was a composite of 32 different images taken by four separate cameras on the Wide Field and Planetary Camera 2. The final photograph was color-coded to represent the light emitted by different chemical elements: green for hydrogen, red for singly ionized sulfur, and blue for doubly-ionized oxygen. This technique allows astronomers to visualize the distribution and temperature of the gases within the nebula.

Over the years, the Pillars of Creation have been a frequent subject of observation by a host of powerful telescopes, each revealing new layers of detail. In 2014, in celebration of the 25th anniversary of the Hubble Space Telescope's launch, astronomers used its newer, more advanced Wide Field Camera 3 to capture a larger and higher-resolution image of the pillars in both visible and infrared light. The infrared view was particularly revealing, as it allowed astronomers to peer through the obscuring dust and see the newborn stars hidden within the pillars.

The James Webb Space Telescope, with its even more powerful infrared capabilities, has provided the most detailed views yet. Webb's images, released in 2022, penetrate the dust clouds to an unprecedented degree, revealing a multitude of young stars as

bright red spots. These observations have helped researchers to more accurately count the number of newly formed stars and better understand the quantities of gas and dust in the region. The Webb telescope has also captured the dramatic outflows of material from stars that are still in the process of forming. These young stars periodically eject jets of material at supersonic speeds, which collide with the surrounding gas and dust, creating wavy, lava-like patterns at the edges of the pillars.

Observations from other telescopes have added further pieces to the puzzle. The European Space Agency's Herschel Space Observatory captured images in far-infrared wavelengths, which are sensitive to the cold dust within the pillars. NASA's Chandra X-ray Observatory has searched for the high-energy signatures of young stars. While many X-ray sources from young stars were found in the wider region, there was a surprising lack of massive newborn stars within the pillars themselves, suggesting they may be past their peak of star-forming activity.

There has been some debate and speculation about the ultimate fate of the Pillars of Creation. Images from the Spitzer Space Telescope revealed a cloud of hot dust in the vicinity that was initially interpreted as a shockwave from a supernova explosion. This led to the hypothesis that the pillars were likely destroyed by this blast 6,000 years ago, and that due to the 7,000-light-year distance, we would witness their demise in about 1,000 years. However, this interpretation has been contested by other astronomers who argue that a supernova would have produced stronger radio and X-ray signals than have been observed. An alternative explanation is that the dust was heated by the winds from the massive stars in the cluster.

Current evidence suggests that the pillars are not being destroyed by a cataclysmic event, but rather are slowly eroding away through the process of photoevaporation. By comparing the Hubble images taken in 1995 and 2014, astronomers have been able to measure the rate at which the pillars are shrinking. The changes are subtle, indicating a much slower process of erosion than previously thought. It is estimated that the pillars are losing about 70 times the mass of the Sun every million years. Based on their current mass, which is about 200 times that of the Sun, their expected lifespan is about three million more years—a fleeting moment in cosmic terms. While the name "Pillars of Creation" beautifully captures their role as a stellar nursery, an equally fitting name might be the "Pillars of Destruction," as they are slowly being annihilated by the very stars they are helping to create.

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