

Preface

Since the dawn of humankind, our species has sought to understand the nature of the universe around us and our place within it. For the vast majority of our history, we only had our immediate senses—sight, hearing, touch, taste, and a very limited sense of smell. On dark clear nights, huddled around a campfire, our ancestors gazed into the night sky, trying to make sense of the ever-changing view. Like the Sun and the Moon, the stars seemed to rise in the east and set in the west. Our ancestors noted the varying degrees of brightness of the stars in the sky, as well as their various hues—some red or orange, some yellow, and others white. And by carefully watching a few of the brighter luminaries, the most attentive sky gazers noticed that some of these stars wandered in their positions across the sky, sometimes disappearing altogether for months or years on end. These were called “planets,” from the Greek word for wandering star, “planetos.”

The invention of the telescope in Renaissance Europe ushered in a revolution in our understanding of the heavens that continues apace even today. Over four centuries, ground-based telescopes grew ever bigger and more powerful, but they could only see the universe in two principal wavebands—at visible light and at radio wavelengths. But advances in science were beginning to show that there existed other types of radiation—first infrared and then ultraviolet and more recently microwaves, X-rays, and gamma rays—all types of waves that are known collectively as electromagnetic radiation.

In order to see the universe at wavebands beyond the visible and radio parts of the electromagnetic spectrum, scientists had to find ways of penetrating the atmosphere, first by placing detectors on top of very high mountains where the air is thinner and then by using high-altitude balloons and sounding rockets, before the advent of the Space Age, when astronomers could finally build dedicated space-based missions with telescopes sensitive to the various parts of the electromagnetic spectrum blocked by our life-giving air. This is the story of that journey and the incred-

ible new insights that transformed our knowledge of the cosmos utterly and forever. As well as being a story of human courage and single-mindedness, it also tracks the huge advances in technology humankind has enjoyed over the last century. In doing so, these space-based observatories have unveiled objects completely invisible to ground-based telescopes, demonstrating at once the beauty and the extreme danger of the space environment.

The book begins by taking a look at the science of waves, particularly electromagnetic waves, and their behavior and detection. In this opening chapter, we explore the source of much of the electromagnetic radiation in the cosmos—atoms. We'll survey the origin and nature of spectra and how this knowledge helps astronomers unravel a veritable treasure trove of new information about the chemical constitution and physical conditions of the stars and other astrophysical bodies generating them. Finally, we cover some basic astronomy that will help us fully engage with the science discussed in later chapters.

Chapter 2 recounts the incredible allegory of the Hubble Space Telescope, its perilous early days when engineers discovered its giant 96-inch mirror was misshapen, followed by its correction by NASA astronauts. We then explore the rich heritage of images captured by the world's most famous space telescope and how it completely transformed our understanding of the universe, both nearby and billions of light-years away.

We continue our exploration of the electromagnetic spectrum by chronicling the development of infrared (IR) astronomy and how space-based IR telescopes have allowed us to peer deep inside dust-laden star clusters and galaxies, hunting down a variety of cooler celestial objects invisible to even the largest optical telescopes. This chapter discusses important IR telescopes, including ROSAT and the Spitzer space telescope.

Next, we recount the fascinating story of the high-energy universe, beginning by exploring the shortest electromagnetic waves of all—gamma rays—and the extraordinary history of how scientists and engineers built better gamma ray detection systems, carrying them aloft on sounding rockets, as well as a host of sophisticated gamma ray space telescopes over many decades. These include early satellites such as Cos-B, Compton, BATSE, HETE, and more high-tech spacecraft including BeppoSAX, INTE-

GRAL, Swift, and Fermi. Here, we shall explore the mysterious nature of some of the most violent explosions in the universe: gamma ray bursts.

In the next chapter, we explore a waveband closer to the visible region of the electromagnetic spectrum—the ultraviolet universe. While a trickle of long-wave ultraviolet (UV) radiation can penetrate Earth's atmosphere, the vast majority of this radiation can only be detected in space. Space-based UV astronomy got a great boost in the 1970s with the launch of TD-1A and the Dutch ANS satellite. With the advance of technology, more sophisticated UV observatories came to the fore, with the International Ultraviolet Explorer (IUE) and the American-led Extreme Ultraviolet Explorer (EUVE), allowing astronomers to make great leaps forward in understanding a host of astrophysical phenomena from active galaxies, massive young stars, and even new insights into solar system objects.

X-rays have long provided us with a means of seeing the invisible, but it was not for several decades after their discovery that astronomers began to view the cosmos at these wavelengths. Of all the wavebands of the electromagnetic spectrum, it is arguably X-rays that have revealed the most insight into the physics of the Sun and hot OB and A stars. Astronomers have also discovered that cool, M dwarfs emit prodigious amounts of X-ray flares, calling into question whether the planets they harbor could ever sustain life. The earliest X-ray detectors were very primitive, but over the decades, they became increasingly more powerful. Accordingly, we shall explore key X-ray astronomical observatories, including the Orbiting Astronomical Observatory satellites, followed by more specialized missions, including Copernicus, Einstein, Uhuru, and Chandra.

Next, we return to wavelengths that are far too long to be seen by the human eye. The birth of microwave astronomy was essentially ground based, when in 1964 Arno Penzias and Robert Woodrow Wilson discovered the cosmic microwave background radiating almost uniformly across the entire sky. The significance of this serendipitous discovery cannot be overstated, since the unveiling has provided brand-new insights into how the universe must have begun. Described by Robert Gamow as the afterglow of creation, this radiation represents the remnants of the primordial fireball that characterized the hot Big Bang universe. The momen-

tous discovery was followed up by the highly ambitious space missions COBE and, more recently, WMAP. These observatories gained glimpses into how galaxies and their constituent stars emerged from cosmic chaos and how their findings revolutionized our ideas about the origin and evolution of our universe.

By observing the universe across many wavebands, astronomers can gain a complete picture of the underlying nature of astrophysical bodies. It is arguably the Sun that has benefitted most from studies across the electromagnetic spectrum, and, in this capacity, we devote an entire chapter to how this knowledge was applied to our life-giving star and how the contributions made at visual, UV, X-ray, and gamma ray wavelengths have enabled us to piece together our most detailed picture yet of our life-sustaining Sun, with its dark spots, plagues, flares, prominences, and much more. The collective data from across the EM spectrum has provided a more complex picture into the nature of the Sun and, by implication, other stars that inhabit the universe.

The era of precision astrometry, that is, the science of measuring the vast distances to the stars, entered a new era with the launch of the Hipparcos satellite, which cataloged 118,200 stars during a 4-year mission between 1989 and 1993. The spectacular success of Hipparcos was added to with the launch of the European Space Agency's Gaia spacecraft, the ongoing mission of which is to record the positions of up to one billion objects in the heavens in 3-D. In the last decade or so, astronomers have begun to employ orbiting satellites to hunt down and characterize a plethora of extrasolar planets, that is, planets orbiting other stars. We explore the recent success of the Kepler planet-finding mission, how it detects these planets, and the results of the surveys so far.

Finally, we end not with history but with the near future, by taking an in-depth look at the greatly anticipated replacement for the Hubble Space Telescope—the James Webb Space Telescope—which is widely expected to boldly go where no telescope has gone before.

Above all, however, the story of the history of space telescopes is one of human ingenuity, single-mindedness, collaboration, setbacks, and success—a microcosm of the human condition itself.

Space Telescopes

Capturing the Rays of the Electromagnetic Spectrum

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