SAMPLE

Great Observatories: WMAP

The Wilkinson Microwave Anisotropy Probe

Aira Astralis

Free sample: Introduction & Chapter 1

putrabooks.github.io

Buy the full book:

Carousell carousell.sg/p/great-observatories-wmap-ebook-pdf-1468063245

Ko-fi

Payhip

Contents

Introduction

Chapter 1: The Discovery of WMAP

Chapter 2: Understanding WMAP

Chapter 3: Key Characteristics of WMAP

Chapter 4: The Science Behind WMAP

Chapter 5: Observation and Measurement of WMAP

Chapter 6: Important Features of WMAP

Chapter 7: WMAP in Context

Chapter 8: Modern Understanding of WMAP

Chapter 9: Research and Exploration of WMAP

Chapter 10: Significant Discoveries About WMAP

Chapter 11: Challenges and Mysteries of WMAP

Chapter 12: Future Directions in WMAP Research

Chapter 13: Fun Facts and Trivia About WMAP

Chapter 14: Conclusion: The Significance of WMAP

Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

There is a picture on the wall of modern cosmology, an oval mottled blue and green and yellow, that looks like a weather map of nowhere; it is, in fact, a portrait of the universe at the age of about 380,000 years, and the instrument that made it is the subject of this book. The Wilkinson Microwave Anisotropy Probe, WMAP, was NASA's dedicated mapper of the cosmic microwave background, the afterglow of the Big Bang, and during its nine years of observation from a post near the Sun it converted cosmology from a science of arguments into a science of numbers.

The numbers deserve the introduction. Before WMAP's era, the universe's basic parameters, its age, its composition, its geometry, were known to the level of vigorous debate; after the mission's data had been worked through, the same parameters were known to a few percent, and the answers formed the modern standard model of cosmology: a universe 13.7 billion years old, spatially flat, made of atoms, dark matter, and dark energy in a recipe the mission fixed precisely. The model's awkward name, the strange fact that the recipe is dominated by ingredients nobody can identify, is part of the discovery's legacy; the measurement that established it is the other part, and both belong in the story.

The mission itself was an exercise in patient extremity. Launched in 2001 to a observing station far outside the interference of the Earth's microwave environment, it scanned the whole sky for years with a pair of telescopes chilled and shielded to a degree the field had not attempted, comparing the sky against itself, dipole by dipole, until the temperature pattern of the cosmic background stood out of the foregrounds at the sensitivity the theory demanded. The instrument's designers had spent a decade on the problem; the team that ran it spent another decade turning its maps into parameters; and the mission's full data release, in 2012, closed a program whose planning had begun in the era before the field even knew the cosmological constant would return.

What follows, chapter by chapter, runs the series' standard course: the mission's origin in the ripples COBE had found and the questions they posed, the physics of the background and its anisotropies, the spacecraft and its observing strategy, the discoveries and their numbers, the context of the competing and successor missions, the challenges of foregrounds and statistics, and the honest account of what the mission settled and what it left open.

A note on numbers before the chapters start, because this mission is the

series' case where the numbers are the story. Where this book quotes the mission's values, the age, the recipe's proportions, the expansion rate, the values are the mission's own published figures, quoted at the mission's precision and rounded as the series rounds; where the successor's refinements matter, the book says so, and the differences, small fractions at the edges of the mission's error bars, are the measurement's health rather than its correction. The reader who wants the full tables, with their errors and correlations, will find them in the mission's published papers, the public archive this book cites, and the successor's confirmations; the reader who wants the story of how the numbers were won is the reader the chapters are for.

The discovery chapter should also note the mission's competition, because the era's history records a race. The European program had its own background mapper in development, the satellite that became the successor, and the American team's launch, arriving years ahead, gave the era's first precision parameters to the WMAP tables; the race's record is friendly by the field's standards, the two teams' instruments complementary in design, and the outcome, an era of two precision measurements rather than one, is the story's happy form. The note belongs here because the discovery's timing, the mission's first-light era of the early 2000s, was itself a competitive fact, and the history that credits the mission's priority should also credit the era's other effort that confirmed it.

Chapter 1: The Discovery of WMAP

The discovery that defines WMAP is a measurement, the measurement of the cosmic background's ripples at the precision that turns them into a table of parameters, and the road to it began with the ripples' first detection.

That first detection, in the early 1990s, was the work of the COBE satellite, this series' own subject for the earlier volume, and it settled two things at once: that the background is a perfect thermal spectrum, the cleanest signature of a hot dense origin, and that it carries anisotropies, temperature variations at the level of a part in a hundred thousand, across the sky. The second finding mattered because the theory said it must: in the inflationary picture, the universe's seed structure came from quantum fluctuations stretched to cosmic scales, and the background's ripples are those seeds, observed at the moment the universe became transparent. COBE saw the seeds exist; it could not, by design, see their structure at the angular scales where the structure encodes the parameters, because its beams were coarse and its sensitivity, for the fine pattern, limited.

The gap defined the opportunity, and the mission that became WMAP was proposed to fill it. The design brief, argued through the 1990s, amounted to five requirements: sensitivity at the level the theory demanded, which meant receivers at the state of the art and years of integration; angular resolution fine enough to see the acoustic peaks, the ripples' harmonic structure, which the theory predicted and the parameters inhabited; a wide frequency range, to separate the cosmological signal from the galaxy's own microwave light; control of systematic errors, the mission's real opponent, at a level never before attempted in this band; and full sky, because the pattern's statistics require the whole sphere. The proposal won approval as a NASA mid-class mission, the same program that had carried the era's great observatory complements, and the team, assembled around the veterans of the COBE anisotropy work and the microwave instrumentation community, spent the 1990s building toward a launch the decade's theory made urgent.

The urgency was real, because the theory was converging faster than the data. The 1990s produced the standard model's skeleton, a flat universe with a cosmological constant, from the supernova distances and the cluster dynamics; the acoustic peak's location, first resolved at the decade's end by balloon and ground experiments, said the universe was near flat; and the parameters waited, half-measured, for an instrument that could see the whole pattern at once. WMAP launched in mid-2001, on a Delta rocket, toward a looping trajectory that used the Moon's gravity to carry it to its station, a orbit around the Sun beyond the Earth's, where the Earth's microwave environment

falls away and the sky can be heard cleanly.

The mission's working life then followed the pattern this series' instrument books know well: a first-year announcement of the age's headline, in this case the first full-sky map at the peak-resolving scales and the parameters it implied, followed by year-on-year refinements as the integration deepened, through the two-year, three-year, five-year, seven-year, and nine-year releases, each one tightening the same numbers and adding the mission's secondary products, the polarization maps, the foreground maps, and the eclipse of the data's systematics. The discovery, in the sense this chapter means it, was the completed set: the standard model of cosmology, established from a single instrument's sky, the field's first precision cosmology, and the standard against which every subsequent mission, and the theory itself, has been measured.

A note on the polarization completes the understanding, because the mission measured it and the field's future runs through it. The background's light is polarized, weakly, by the same scattering physics that made the temperature pattern, and the polarization carries two kinds of information: the ordinary kind, correlated with the temperature, which the mission used to measure the reionization epoch, and the deeper kind, the curl pattern that only gravitational waves from the earliest era could print, which the mission constrained and could not see. The polarization's story is therefore the mission's boundary and the successor generation's target, and the understanding to carry is the field's: the temperature pattern is measured science, the polarization's curls are the frontier, and the same sky holds both.

One more discovery belongs on the list, the quiet one: the mission's measurement of the matter's seed spectrum, the primordial pattern's shape. The theory of inflation predicts the seeds' spectrum's form, nearly scale-invariant with a small tilt, and the mission's spectrum measured the tilt, finding it small and nonzero, the inflationary signature's first quantitative evidence; the measurement's successors, refining the tilt's value, have kept the finding, and the seeds' shape stands as the inflationary picture's observational footing. The discovery is quiet because it is statistical, a number rather than an image, and it belongs on the list for the same reason: the number is the theory's evidence, and the evidence is the era's.

One more origin fact belongs here, the mission's lineage in the balloon-and-ground program. Before the satellite flew, the acoustic peaks' first indications came from the era's daring suborbital instruments, the balloon telescopes that floated above the atmosphere for hours and the ground-based interferometers at the driest sites on Earth, and their results, peak indications at coarse

sensitivity, were the theory's bridge from prediction to sight. The satellite program drew on their experience and superseded their precision, and the balloon program, which continues to this day as the field's test bed, remains the satellite program's ancestor and partner; the discovery chapter's honest lineage runs from the daring short flights to the patient long mission, and the series keeps both.

A paragraph on the serendipity preface, the signal found while looking for something else. The road to the file's subject begins with one of the subject's most accidental detections: a pair of radio engineers testing a ground-based horn antenna in the earlier part of the last century found a faint microwave hiss that would not go away, checked their cables, evicted the pigeons nesting in the horn, ruled out the city, and were left with a noise that came from every direction at once, a steady wash eventually identified as the thermal afterglow of the hot early universe; the discovery, accidental and almost dismissed, opened the field that the file's mission would later measure to the part-per-hundred- thousand.

The origin note worth recording: the subject's founding observation was made by people who were not looking for it, a piece of luck that the field has repaid with deliberate obsession, every later instrument being designed explicitly for the signal the engineers nearly scrubbed away, the pigeon-horn anecdote being the field's creation myth, retold not for the birds but for the moral, that the universe sometimes announces itself as static in someone else's experiment.

A second origin card, on the christening: a mission titled for a man. The instrument of the file carries a person's name, an unusual honor for a hardware project: the mission was named for a founder of the field, a physicist of the background-radiation generation who helped conceive and build its pioneering measurements and who did not live to see the launch, the tribute being both memorial and creed, the mission flying a person's name around its watch; the acronym, expanding to a phrase about probing the background's anisotropy, carries the colleague's surname at its head.

The origin's closing note: the file should register the christening as a sample of how the field honors its builders, telescopes usually named for instruments or patrons, this one for a working scientist, and the gesture suited the mission's character, a collaborative instrument of unglamorous excellence, the name preserving the kind of contribution that hardware biographies usually lose, the years of prototype-building and calibration, a scientist's career compressed into the letters of a satellite's name, orbiting on as a monument in working order.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.