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Great Observatories: Kepler

The Planet Hunter

Aira Astralis

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Conclusion

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

Introduction

This book is about a telescope that was told no four times before it was allowed to fly, and then spent nine years rewriting the field of astronomy with data from a single unblinking stare. The Kepler space telescope, named for the seventeenth-century astronomer who first described how planets move, was launched by NASA in March 2009 with a mission statement of disarming simplicity: stare at one patch of sky, continuously, for years, and watch a hundred and fifty thousand stars for the minute, rhythmic dimming that occurs when a planet crosses the face of its sun. What it found there, more than two thousand six hundred confirmed planets and several thousand more candidates, transformed the study of worlds beyond the solar system from a hunt for curiosities into a census, and established, as a matter of measured fact rather than hopeful conjecture, that planets are the rule in our galaxy rather than the exception.

The namesake deserves his sentence, because the mission was a tribute by method. Johannes Kepler, working in the first decades of the seventeenth century with instruments far cruder than anything flown today, deduced that a planet's path is an ellipse with the Sun stationed at one focus, sweeping out equal areas in equal times, and that the square of a planet's orbital period grows as the cube of its distance from its star. Those three laws, published between 1609 and 1621, were the first description of planetary motion to fit the observations exactly, and every orbit computed in this book, every period and distance quoted in its pages, still runs on them. The telescope that borrowed his name repaid the compliment in kind: it found planets by watching the clockwork that Johannes Kepler first read, and its discoveries are his laws demonstrated around other stars, four hundred years on.

The method behind the mission rewards one paragraph of plain explanation before the chapters begin. When a planet's orbit happens to be turned nearly edge-on as seen from the spacecraft, the planet crosses its star once per revolution and blocks a sliver of the starlight: Earth, crossing the Sun, would dim it by about eighty parts per million, roughly one hundredth of one percent, for about thirteen hours once a year. Detecting that requires both exquisite steadiness and unbroken patience, because the signal repeats only as often as the planet orbits, and a convincing detection demands three or four repeats.

No ground telescope can hold that precision through daylight, weather, and sunrise, and no pointing schedule that pauses or moves can catch a yearly event; the mission therefore had to be spaceborne and it had to stare. The chapters that follow tell how such an instrument was imagined, fought for, built, flown, twice crippled, re-invented, and finally silenced, and what it left

behind: a catalog of worlds, a new statistical picture of the galaxy, and an archive that astronomers are still mining for discoveries the mission itself never lived to name.

The era the mission entered helps explain the stakes. By the year the spacecraft launched, a bit more than three hundred planets were known beyond the solar system, nearly all of them giants, most of them hugging their stars in close, hot orbits, because the detection methods of the day were biased toward worlds massive enough to yank their stars around and near enough to yank them often. Nothing firm was known about smaller worlds: Earth-sized planets were beyond every instrument's demonstrated reach, and the honest scientific position was that their abundance could be anywhere from one-in-ten to effectively zero. The mission set out to replace that range with a rate, and the reader should hold the contrast in mind while the chapters run: the field the spacecraft left behind had catalogued more planets in a single data release than the field it entered had found in its entire prior history.

Chapter 1: The Discovery of Kepler

The discovery story begins with the method's awkward adolescence. Planet detection by transit was, through most of the twentieth century, a theoretical possibility with no working example: the chance that any given planet orbits edge-on to our line of sight is small, a few percent even for planets hugging their stars, and the precision needed to see a small planet's crossing was beyond ground-based photometry through the turbulence of the atmosphere. Radial-velocity work, which reads a planet's gravity in the wobble of its star, opened the exoplanet era in 1995 with a hot Jupiter around a Sun-like star, and for a few years the field assumed transits would remain a curiosity. Then, in 1999, a planet already known from its wobble was caught crossing its star from the ground, dimming it by a few percent on schedule, and the community realized the transit method was real, measurable, and reproducible: a planet's passage could be timed, its depth converted directly into a size, and its orbit confirmed in public light curves.

The man who had bet longest on this possibility was William Borucki, a NASA engineer who had been arguing since the early 1980s that a spaceborne transit survey could find Earth-sized planets, and whose proposals for exactly such a mission had been declined, in succession, in the early and mid-1990s and again at the close of the decade, each rejection arriving with the same pair of objections: no one could yet build a photometer stable enough to see an Earth's transit, and no one could prove the stars themselves would cooperate rather than drown the signal in their own variability.

Borucki's answer to the first objection was to build and demonstrate the photometer, a CCD camera whose precision he proved first in the laboratory and then on automated ground telescopes; his answer to the second was a survey design that watched so many stars simultaneously that the statistics of the detections would speak for themselves. In 2001, on the fifth attempt, the concept was selected as a Discovery-class mission, the tenth of that line, and the long argument ended with a launch contract rather than a rejection letter.

The mission that emerged from selection carried a sharper scientific identity than most, because it had been designed around one number: the fraction of Sun-like stars that host Earth-sized planets in temperate orbits. Answering that question dictated everything in the architecture. A planet with a one-year orbit transits once a year, so a convincing detection of an Earth analog requires three to four years of continuous data; the mission's stare had to be long. Earth-crossing-the-Sun dims the star by a hundredth of a percent, so the photometer had to hold its stability at the few-parts-per-million level; the stare had to be precise.

And because bright, nearby stars cover the sky thinly, while a statistical answer needs a statistical sample, the mission needed a field dense with targets: the stare had to be wide, wide enough to hold more than a hundred thousand stars at once. Continuity, precision, and breadth, all at once, from a spacecraft that must never blink, was the requirement; the chapters that follow describe the machine built to meet it.

The chapter's closing observation is the one the field itself now regards as the discovery: the mission was, in effect, a measurement instrument aimed at a hypothesis. Earlier exoplanet discoveries had been individual trophies, each announcing a particular world; the Kepler mission was designed to return a rate, an answer to the question of how common small, temperate planets are, which is a different kind of science and a different kind of risk. If the Earth-analog fraction had proved to be effectively zero, the mission would have spent years to return the most expensive null result in the history of the field. The wager, made before launch and audited in the mission's results, is the subject of this book's later chapters, and the honest summary of the discovery chapter is that the mission's greatest discovery was that the wager was worth making: the transits came, in their thousands, and the galaxy's planets turned out to be hiding in plain statistical sight.

The persistence chapter's details are worth the telling, because they have become the field's favorite founding story. The demonstrations that won the argument were built with borrowed hardware: a small camera mounted on a historic ground telescope, photographing a star field night after night to show that CCD photometry could hold the necessary precision through a real atmosphere, and a laboratory rig that proved the detectors could stay stable over the years a space mission would demand. The reviews of the era were not foolish; they were asking whether the quiet stars needed for the statistics actually existed in useful numbers, whether the photometry could survive the aging of detectors in flight, and whether the field really needed a census before it had a single Earth-sized planet to its name.

What the persistence bought was time for the technology to mature, and by the mission's selection the objections had been answered one by one: the quiet stars were found by the thousands in the target field, the detectors proved their stability in the laboratory, and the need for a census had become the field's consensus, so that the mission launched as the instrument its critics' questions had themselves helped design.

The launch itself, when the decade of argument finally ended, was by the standards of the field a quiet one. The spacecraft rode to orbit on a March night in 2009, was dispatched sunward on its trailing path within hours, and

spent its first weeks in checkout and calibration, its cover still on, while the team verified that the photometer's laboratory behavior had survived the shaking of ascent. The cover came off in April; the first images reached the ground and the team's verdict, recorded in the era's interviews, was relief seasoned with awe: a hundred and fifteen square degrees of sky, a hundred and fifty thousand stars, every one of them measurable at the precision the mission had promised. The stare formally began in May, and with it the clock that the whole mission ran on, four years of transits, each one a small shadow the spacecraft would be waiting for, a patience the field had never before had the means to practice.

The concept's competitive landscape belongs in the discovery story too, because the mission that eventually flew was not the first spaceborne transit survey in the race. The French precursor, a small asteroseismology satellite repurposed for planet-hunting, was already approved and flying while the American concept fought through its proposal rounds, and it proved the method's spaceborne pedigree the hard way: its wide, deliberately defocused stare found the first transiting super-Earth, a lava-world circling its star in a fraction of a day, and demonstrated that a small photometric satellite could hold the precision the method demands.

The American mission's answer to the precursor was scale: where the flying survey watched a few thousand stars, the proposed mission would watch a hundred and fifty thousand, and the difference was the science, because the question the American design asked, the rate of Earth analogs around Sun-like stars, required a sample no smaller instrument could deliver. The two missions ran as friendly rivals for a few years, and the field's memory of the era is honest about the debt: the precursor proved the road, and the mission that followed built the highway.

The institutional backdrop also deserves a card, because the concept's timing placed it inside a larger argument about how planet-hunting should be organized. The turn of the century was the era of the decadal survey, the field's ten-year planning exercises, and the small-mission programs on one side and the flagship aspirations on the other were competing for the same finite budgets; the transit-survey concept, born small and priced as a Discovery mission, was in a real sense a bet that the next great question in the field could be answered by a focused instrument rather than a general-purpose one. The bet's vindication changed the field's planning habits: the mission's success became the standing example, cited in every later decadal argument, that a cheap spacecraft aimed at one question can outperform a flagship aimed at ten, and the discovery chapter should close its institutional ledger with that consequence, the little mission that recalibrated what the field

expects from a little mission.

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.