SAMPLE

Cosmic Explorers: Orbital Mechanics

The Physics of Moving in Space

Aira Astralis

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Contents

Introduction

Chapter 01: The Sky That Refused to Be Obeyed

Chapter 02: Gravity's One Rule

Chapter 03: The Shapes of Falling

Chapter 04: Kepler's Laws as Working Tools

Chapter 05: Six Numbers to Know a Path

Chapter 06: Moving Between Orbits

Chapter 07: The Imperfect Sky

Chapter 08: The Quiet Harbors

Chapter 09: The Interplanetary Arithmetic

Chapter 10: Finding Where Everything Is

Chapter 11: The Orbits the World Runs On

Chapter 12: The Crowded Sky

Chapter 13: The Trade Itself

Chapter 14: Fun Facts and Trivia About Orbital Mechanics

Conclusion

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

Introduction

There is a picture of orbital mechanics that everyone carries: neat ellipses drawn around the Sun, planets marching in file, a clockwork of perfect circles. The real subject is stranger, and it is not really about planets at all. It is about what happens when you throw something hard enough that it never comes down, and about the small handful of rules that decide where that something goes next. Every satellite that carries a weather image to your phone, every probe that has ever slipped into orbit around another world, and every maneuver that gently rearranges a space station's path began as an argument about those rules, argued on paper before it was argued by an engine.

The rules are few. Gravity pulls, and it pulls according to a single law that has not been caught slacking since it was written down. A moving object keeps moving unless something stops it. From those two statements, plus a little arithmetic, the whole architecture of spaceflight follows: the shape of every orbit, the speed of every crossing, the price of every change of course, the reason some paths are free and stable while others decay within months. The subject's astonishing property is that this arithmetic is exact. Ballistics on Earth is guesswork in a wind; ballistics in space is bookkeeping, and the bookkeeping is good to a precision that still surprises the people who depend on it.

This book is about that bookkeeping, told as the working trade it has become. It follows the history from the astronomers who first cracked the sky's geometry, through the engineers who turned their curves into launch windows, to the present, when the trade's practitioners spend their days juggling thousands of objects at once and their nights worrying about the ones nobody owns. Along the way it stops on the questions people actually ask. Why does a spacecraft speed up to slow down? Why is it cheaper to fly to distant planets than to hover low? What holds a satellite still over one spot on the equator, and what happens when two of the thousands of tracked objects threaten to share the same piece of sky?

A note on scope and honesty before the launch. This book uses no equations beyond the rules in plain words, quotes no citations, and leans on no statistic that expires with the next launch. Where the field is settled, it says so plainly; where the professionals argue, it says that too. Physics does not change while a book is being printed, but the population of the sky changes daily, and anyone who wants today's census should look for today's census. What does not change is the logic underneath, and that logic is the story here.

One more honest warning. Orbital mechanics is famous for a kind of gentle

perversity: it is the discipline in which the obvious answer is reliably wrong, in which you fire your engine to fall closer to home and arrive faster by braking, in which the quickest way to a higher orbit is to slow down first. The chapters ahead treat that perversity as the subject's charm rather than its obstacle, because it is what the trade's practitioners love about their work: the sky is not an empty stage but a puzzle with consistent rules, the rare kind of puzzle whose pieces all obey one another. Learning to see those rules in everything that flies is the whole education, and the chapters that follow are arranged to give it in order: the rules, the shapes, the tools, the imperfections, and finally the crowded, contested, working sky the rules now govern.

Chapter 01: The Sky That Refused to Be Obeyed

Every science has a founding quarrel, and orbital mechanics was born from an argument about the sky that lasted for most of recorded history. The ancients had the sky almost right and then, in the way of institutions, enshrined the error. The eye says the heavens turn around us, perfect circles, unchanging wanderers, and for centuries the job of astronomy was to rescue that impression with cleverness: circles riding on circles, epicycle upon epicycle, each new precision bought with more scaffolding. The system worked in the way a very complicated lie works, with growing difficulty and no prospect of rest.

The break came from the least dramatic cause available: better data. Tycho Brahe, the last and greatest of the naked-eye observers, spent decades measuring the positions of planets with a patience that has rarely been matched, and his tables were too good to lie to. When Johannes Kepler inherited them, he found that the planet Mars would not fit the ancient geometry no matter how it was stacked, off by an amount any honest observer could see, and rather than blame the data he did something radical: he let the planet choose its own path. The orbit that fit was not a circle with corrections but an ellipse, a simple oval with the Sun sitting off to one side, and with that one concession the entire ancient scaffolding collapsed.

Kepler's announcement, in the early years of the seventeenth century, was modest compared to what it deserved.

He had found the first of three rules, and together they did something no prophecy had done: they made the sky predictable forward and backward, and exactly, rather than approximately and eventually. A planet in an ellipse sweeps out equal areas in equal times, moving fast near the Sun and slowly far away, obeying a rhythm rather than a whim. The squares of the orbital periods run with the cubes of the orbital distances, a proportion so clean it looks like a signature. Kepler did not know why any of it was true. He tried for years to explain the rules with magnetism, with music, with geometry he admired, and got nowhere, but he did something as valuable as explaining them: he published them as facts, openly, with the failed attempts attached, and the honesty held the door open for the person who could walk through it.

The person who walked through was Isaac Newton, and the story is one of the few in the history of science where the myth and the record roughly agree. The falling apple, the plague years, the twenty-year silence before a friend's question dragged the answer out of him: the same rule that pulls an apple

pulls the Moon, diminished by distance exactly as the geometry requires, and with that single identification the sky and the ground became one physics. Newton's mechanics, published in his great book, did more than explain Kepler's rules; it derived them. Ellipses stopped being a curious discovery and became the natural paths of anything moving under a central pull, and the rules Kepler had found empirically fell out of three laws of motion and one law of gravitation as inevitably as a dropped object falls.

The result was a universe that could be computed, and the announcement of that fact changed intellectual history beyond astronomy. The comet that Edmund Halley tracked through old records and predicted to return did return, on schedule, long after the man himself was gone, and its punctual arrival in the sky did more to persuade the educated world of the new mechanics than a library of argument. If a dirty ball of ice, invisible for decades at a stretch, could be commanded by arithmetic to reappear within the tolerance of a small telescope, then the whole machinery of heaven was on the books. The mathematicians who followed Newton, in the great continental tradition, spent two centuries mining the consequences: the way bodies perturb one another, the stable points where a small object can ride in equilibrium, the resonances that can build a solar system or unbuild it.

And yet the trade this book is about did not exist yet, and the reason is worth stating plainly. Celestial mechanics, the science, was complete in outline while humanity still had no vehicle to which it could apply. The astronomers could compute the orbit of anything that already existed; nobody could compute the orbit of a machine that did not exist yet, because nobody could put a machine up. The founders of the discipline therefore worked, by necessity, on planets and comets and moons, using instruments and patience, and their subject was called celestial mechanics for a reason: its objects were celestial and its practitioners were astronomers.

The change came only in the twentieth century, when a third ingredient arrived beside the law and the tables: the rocket, the first object in history that could be argued into an orbit rather than merely discovered in one. What happened when the old arithmetic met a machine that could answer back, and change its own path on command, is the beginning of the trade proper, and it is where the next chapter starts.

The new mechanics proved itself in a way no philosophy ever had: it found a planet with a pen. The outermost giant world, discovered by accident in the previous century, was observed to drift from its predicted course, and the discrepancy set the mathematicians a problem with a beautiful structure. Either the law of gravitation was wrong, or something unseen was pulling. Two

mathematicians, working independently and by pure calculation from the size and direction of the misbehavior, computed where the unseen puller had to be, and when an observer turned a telescope to the computed spot, the planet was sitting in it.

The discovery is the discipline's proudest single event, and not chiefly for the planet. A prediction made on paper, of an object nobody had ever seen, honored to the precision of a telescope's field, closed the argument about whether the sky obeyed arithmetic. From that night forward the question was never whether the machinery governed, but only what the machine was telling the observers they had not noticed yet. The same confidence, applied to the machine age of the next century, is why a flight controller with a table of six numbers will calmly trust that a spacecraft is exactly where the table says, even while it is silent behind the Moon.

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.