SAMPLE

Quantum Gravity

The Quest to Unify Physics

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

Physics finished the twentieth century with two theories, each the best in its field, and the two cannot both be right. The first is quantum mechanics, the laws of the very small, which describe everything a particle can do with a probabilistic exactness no earlier science imagined, and which underlie every atom, molecule, and chip. The second is general relativity, the laws of gravity and the large scale, which describes space and time as one curved fabric and predicts, with the century's most spectacular confirmations, everything from the bending of starlight to the chirp of colliding black holes.

Each theory has passed every test ever set for it; each, in its own domain, is effectively final. And the two are written in languages that cannot be translated into each other, and wherever both must speak at once, in the first instant of the universe and the last moment of a collapsing star, they contradict. The theory that reconciles them, the physicists' white whale for a hundred years, is quantum gravity, and this book is its story: the problem, the attempts, the strange candidate worlds the attempts have built, and the honest account of where the hunt stands.

The reader should be told the book's most unusual fact at the start, because no volume in the physical sciences shares it: quantum gravity has never been observed. Not one confirmed measurement, in a century of hunting, bears directly on any candidate theory, and the reason is a number so extreme it organizes the whole subject, the natural scale where the two theories must collide, a length twenty powers of ten below an atomic nucleus. The experiments that could see it are beyond every machine ever built and every machine anyone knows how to build; the theory that succeeds will be chosen, if it is ever chosen, by mathematics, consistency, and the few indirect fingerprints the universe may have left. The story is therefore the strangest in physics: a century of the trade's best minds, building candidate universes in the dark, waiting for the one measurement that matters, and the honest book tells it that way, with the uncertainty in the foreground, as the series' other volumes never had to.

The chapters follow the hunt in its natural order: the two theories and their quarrel, the natural scale that keeps the quarrel hidden, the black holes and the first instant where it becomes urgent, and the two great candidate programs, strings and loops, with their cousins and rivals. Then the hunters' strategies: the analog experiments, the tabletop proposals, the sky's own tests, and the emerging suspicion, from the thermodynamics of horizons, that space and time themselves may be woven out of something else. The book closes with the questions beneath the physics, what spacetime is and whether

it is fundamental, and the reader who finishes will know the exact shape of the greatest unsolved problem in physical science: not what we do not know, but the precise form of our ignorance, which is the most elegant thing about it.

A note on method, before the story starts, because this book's honesty is its spine. A history of quantum gravity cannot be written the way a history of special relativity can, with each chapter ending in a measurement that settled it, and the chapters ahead do not pretend otherwise: where a claim is mathematics, the book says mathematics; where a candidate has reproduced the one universal clue, the black hole's area law, the book says that and no more; where an experiment has returned null, the null is reported as the blade it is. The reader who wants a theory-of-everything sales pitch should put the book down here, because the true story is better: a century of the finest minds in physics, armed with the two best theories ever built, unable to make them agree, and building, in the darkness at the bottom of the world, the most beautiful mathematics and the strangest pictures of what a place might be.

The story has no verdict yet, and the honest telling of a story without a verdict is a skill the physical sciences have never needed before, and the reader is about to see it practiced.

Chapter 1: The Problem: Two Theories That Cannot Both Be Right

The problem begins with the two theories' two pictures of the world, and the reader should see the collision plainly. Quantum mechanics describes a world of events and chances: a physical state is a spread of possibilities, a measurement updates it, and every observable has an operator and a spectrum, the theory's machinery converting questions into probabilities with a precision measured in decimal places. General relativity describes a world of smooth geometry: space and time are one fabric, curved by mass and energy, and gravity is not a force but the curvature, the planets following the straightest paths through a geometry their own mass helps bend. The quantum world is grainy and probabilistic; the gravitational world is smooth and deterministic; and the century learned to live with the contradiction because the two theories almost never meet.

They meet in two places, and the book's subject is what happens there. The first place is the extreme: the center of a black hole, where matter collapses past every known physics into a point the general theory calls a singularity, a place where its own equations stop meaning anything; the first instant of the universe, where the whole of everything was smaller than any quantum grain the other theory admits; and the gravitational collapse that bridges the two. The second place is everywhere, faintly: gravity, in the quantum picture, should be carried by particles like every other force, and a quantum world in curved geometry raises questions that begin in the first paragraph of the textbooks and are still open. The first place makes the theory urgent; the second makes it fundamental; and the century's failure to build it is the standing wound the rest of the book dresses.

The urgency deserves its numbers, because the numbers are the subject's spine. Gravity is astonishingly weak at the particle scale: two electrons repel each other electrically with a force larger than their gravitational attraction by forty-plus powers of ten, a ratio that makes the gravitational pull of one particle on another the most negligible fact in physics, and this weakness is exactly why the two theories never meet at ordinary scales. The weakness is also what hides the answer: the scale where gravity's pull between particles grows to match the quantum grain, the theory's natural meeting point, lies twenty powers of ten below the size of an atom's nucleus, and the energies needed to probe it are larger than the largest machine's by a factor the largest machines cannot approach.

The problem is thus twofold and ironic: the two theories' meeting place is the

most extreme place in nature and the least reachable, and the reader should hold the irony as the book's organizing fact: the most important question in physics is asked at the one scale the universe does not let its inhabitants visit.

The problem's pedigree deserves its dates, because the reader should know how old the wound is. Quantum mechanics and general relativity were both finished, in their founding forms, within a decade of each other, the quantum in the mid-1920s, the general theory in 1915, and the first serious attempt at their union, by the trade's founding generation, was underway before the quantum's own textbooks were dry. The failure of that first attempt, the non-renormalizable mess the third chapter describes, was established by the 1950s; the modern candidate programs date from the 1970s and 1980s; and the subject's public battles, the landscape quarrel and the firewall fight, belong to the last two decades.

A physicist who joined the first attempt as a student could have lived to see the firewall argument, which the reader should hold as the subject's signature time span: no problem in the history of physics has remained open, at the center of the trade's attention, for a hundred years, and none has ever had to be hunted so long without a single clue.

One sentence, before the pillars, states the whole problem, and the reader should carry it as the book's key. The quantum theory says the world is made of possibilities that need a stage; the general theory says the stage is made of the world's own matter; and a complete physics needs both statements at once, which no mathematics in a century has managed without breaking one. Every candidate theory in this book is a different answer to which statement breaks and how, and the reader who holds the one sentence can navigate every chapter: when a theory is described, ask which half it pays for, the stage or the actors, and the theory's shape will be clear.

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.