Preface to

Orbits Explained

Astronomers, physicists, and mathematicians find solace as they study the sky at night. The noble quest for astronomical knowledge counters the pressing difficulties of life, providing a gratifying distraction from conflict and from economic concerns. Pondering, recording and rationalizing the endless expanse of space harboring the stars enhances the sentiment that the turmoil here on Earth has hardly any effect out there at all.

For ages, a consistent task has been the study of the motion of the Earth and its companions in our solar system. Claudius Ptolemy, Nicolas Copernicus, Tyco Brahe, Johannes Kepler, and Isaac Newton are among the extraordinary astronomers of the past. Their names are prominent in any written history of astronomy and attest to the gradual and eclectic nature of astronomical discovery. Where does this book fit into such a scheme? The title, *Orbits Explained*, is a hint; chosen specifically for its double meaning.

The first, and literal meaning, refers to the book's stepwise explanation of planetary motion, intended to bring an understanding of orbits to the reader.

The second, and perhaps more presumptuous meaning, suggests that by intertwining the work of others with some original notions, a new and fundamental explanation of orbits might be possible. The new explanation relies only upon theory and logic instead of being dependent on scientific observations and measurements. In philosophical terms an explanation that is based on logic and theory, instead of experience and experiment, is defined to be an *a priori* explanation. This differs from an empirical explanation which, by definition, requires scientific measurements and observations. Accordingly, *Orbits Explained* is an attempt to establish the first *a priori* explanation of orbits. In this regard, consider the following circumstances.

Historically, our knowledge of orbits is so heavily based on the astronomical observations of Tycho Brahe that it is essentially empirical in nature; it was Johannes Kepler who deduced from Brahe's extensive astronomical data that planets behave according to three Planetary Laws. Kepler and Issac Newton were interested in finding the *a* *priori* explanation behind these empirical laws of planetary motion. They both understood that the laws were a good fit for the observations of planetary movements but were not satisfied that a complete understanding had been gained. Newton did indeed find an *a priori* explanation for Kepler's Second Law which states that the line connecting a planet to the Sun sweeps out equal areas in equal times. But that is where the *a priori* trail ended. Beyond that, the rest of Newton's explanations relied on Kepler's observation, as stated in Kepler’s First Law, that orbits are elliptical. Indeed, using this observational premise that orbits are elliptical, Newton proceeded to prove that gravitational force decreases with the square of the distance to the Sun. In turn, this allowed Newton to prove Kepler's Third Law regarding the time it takes to complete an orbit. And that is the way that this has all been passed through generations to us in the present day. We have not been offered an *a priori* explanation for the First and Third Laws of Kepler. Even the most modern methods of orbital mechanics, including those which involve vector calculus, require the empirically derived Inverse Square Law of Force for their proofs.

In *Orbits Explained*, *a priori* proofs of the Planetary Laws are presented which stem from a mathematical device referred to as the "Inverse Proportion Machine" or the "hododyne". This geometrical device mathematically regulates planetary movements precisely and in accordance with basic laws of motion; astronomical observations become unnecessary. Specifically, it is not necessary to know beforehand that orbits are observed to be elliptical or that gravitational force decreases with the square of the distance. Instead, basic properties of motion, such as those relating force and mass, suffice to explain the motion of planets.

While organizing the proofs for an *a priori* system of elementary celestial mechanics, a strategy for a framework emerged. Five carefully chosen interrelated Laws of Planetary Motion were identified as being fundamental. As stated above, Newton proved the Second Law of Kepler using *a priori* methods. Using Newton's proof as a foundation, novel *a priori* proofs were formulated for the remaining four. Accordingly, five *a priori* Laws of Planetary Motion can be stated as follows:

1) Planets necessarily travel in elliptical paths. This is Kepler's First Planetary Law.
2) Planets sweep out equal areas in equal times. This is Kepler's Second Planetary Law.
3) The square of the orbital period is proportional to the cube of the semimajor axis (half the length of the longest dimension) of the ellipse for orbits within a solar system. This property is Kepler's Third Planetary Law.
4) Gravitational force varies inversely with the square of the distance from the Sun. This property is Newton's Inverse Square Law of Force and Distance. It can be considered to be the Fourth Planetary Law.
5) The designated Fifth Planetary Law states that for any given position in its orbit, a planet lacks energy that it would need to escape; the amount of energy lacking is a constant, regardless of the position of the planet. This property is referred to as the Planetary Capture Law. A corollary is that a planet approaches the Sun at the same speed compared to the speed at which it recedes when it is at directly opposite sides of the Sun. This is what keeps the planet in orbit and answers the question directly: Why do planets stay in orbit?

Three themes interweave to achieve the *a priori* proofs. The first is the hododyne. The second is a method of scaling that can be applied to diagrams of orbits in order to render them accurate. The third is a realization that subtle properties of the orbit become evident when the planet is examined while it is at a special position - directly at the end of the minor axis of the ellipse, a position referred to in the book as position "*b*". Admittedly, *Orbits Explained* is not a short and direct set of proofs. Although there are many chapters which follow logically, the trail becomes convoluted and philosophical at times. There is a pulse to the proofs; strong and convincing for most sections, weak yet still effective in others. An example of relative weakness is the scaling method that is applied to diagrams in order to render them accurate. Scaling seems like an amateurish and contrived ploy, to be scoffed at by traditionalists. But scaling is carefully shown to be much more than marginally justifiable. Indeed, there will be numerous similar opportunities for the reader's opinion to waver between endorsement and rejection.

The primary aim is to reach the general reader but it is hoped that the scientist would be jolted by the general theme and endeared to some of the parts . At times, minor instruction is provided in order to bring the general reader's skills up to the level required. In particular, a few basic explanations of vectors are given. Basic introductions to the concepts of force, proportions, velocity, and acceleration are also presented. The mathematical methods include basic elements of algebra, geometry, and trigonometry. Logic is added extensively to the mathematical methods.

I wholeheartedly wish to thank Professor David Goodstein and Archivist Judith Goodstein at The California Institute of Technology for inspiring me - although they may not even be aware of having done so. After reading their book, *Feynman's Lost Lecture - The Motion of Planets Around the Sun*, (Published by Norton Press), I felt compelled to share some thoughts with them regarding a particular aspect of a proof that they described. Professor Goodstein generously agreed to meet with me in his office in May, 2002. It was our only meeting and it took place well before I thought of writing this book. But the event did in fact stimulate me to attempt to design a

complete *a priori* method for explaining orbits. For this phase of the process I should give recognition to my family for humoring me at times when I could not contain my zeal over a mathematical idea - and for tolerating the various mathematical drawings that suddenly came upon the scene at home. Despite the fact that *Orbits Explained* has been written, no one has been asked to or had the opportunity to evaluate any of the proofs or the book as a whole. Professor Goodstein, on that one occasion, and my family are the only ones who have discussed any of my scribbles and sketches with me. In the Spring of 2001, I had started to collect and organize my thoughts by writing and sketching on looseleaf paper. At first I was working on a difficulty I had encountered in *Feynman's Lost Lecture.* My approach to that difficulty was the substance of the meeting with Professor Goodstein. As mentioned, after that meeting my attention shifted to the larger scheme. By the end of 2004 I had a set of eight notebooks containing a mixture of useful strategies and invalid theories. It was only after finishing the notebooks that I decided to write *Orbits Explained.* It follows that any faulty ideas expressed in *Orbits Explained* are my own.

No part of this book is intended to in any way diminish the importance, the mathematical brilliance, the political courage, or the eternal impact of the heroic figures Ptolemy, Copernicus, Brahe, Kepler, Galileo, and Newton. In fact, it is a tribute to them to wish that any of them would have agreed with any of what is written here.

D.S.M.

Los Angeles