SOLAR SYSTEM MAPS

From Antiquity to the Space Age

NICK KANAS

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About the Author

Nick Kanas is Emeritus Professor of Psychiatry at the University of California, San Francisco, where he directed the group therapy training program. For over 20 years, he has conducted research in group therapy and, for over 20 years after that, conducted space-related research with the European Space Agency and NASA. He was a Principal Investigator of NASA-funded research on astronauts and cosmonauts for over 15 of these years, with over 200 professional publications. Dr. Kanas has been writing and conducting research in space-related activities since 1969 and, in 1971, was the senior author of a NASA technical monograph entitled *Behavioral, Psychiatric and Sociological Problems of Long-Duration Space Missions* (NASA TM X-58067). He is currently the co-author of a Springer textbook entitled *Space Psychology and Psychiatry*, which was given the 2004 International Academy of Astronautics Life Science Book Award, is now in its second edition, and has been translated into Chinese. In 1999, he received the Aerospace Medical Association's Longacre Award and, in 2008, received the International Academy of Astronautics Life Science Award. Dr. Kanas is currently a member and past trustee of the International Academy of Astronautics.

Dr. Kanas has collected antiquarian star maps for over 30 years and has given a number of talks on celestial cartography to amateur and professional groups at the Adler Planetarium, the Lick Observatory, the International Conference on the History of Cartography at Harvard, International Map Collectors Society Conferences in Wellington and Vienna, the Society for the History of Astronomy Meeting in Birmingham, and the Flamsteed Astronomical Society Meeting in Greenwich. He has published articles on celestial cartography in magazines and journals including *Sky & Telescope*, *Imago Mundi*, and the *Journal of the International Map Collectors Society* and is a Fellow of the Royal Astronomical Society in London. An amateur astronomer for over 50 years and an avid reader of science fiction, Dr. Kanas has presented talks on space psychology and on celestial mapping at several regional and WorldCon science-fiction conventions, published two articles on space psychology in *Analog Science Fiction and Fact* magazine, and written a book for upcoming publication Springer's new Science and Fiction series entitled *The New Martians: A Scientific Novel*. He has also written another map-related book for Praxis/Springer entitled *Star Maps: History, Artistry, and Cartography*, which is now in its second edition.

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Foreword

In 1543, Nicolaus Copernicus invented the solar system. “Hold on!” you say. Surely the solar system had been there forever, and Copernicus didn’t just invent it.

Yes and no! What Copernicus had revealed and invented was the arrangement of the planets—a stunningly new way of mapping them. He revolutionized the way humankind would conceive of the planets as a system, controlled by the Sun. “Thus indeed,” Copernicus wrote, “the sun, as though seated on a royal throne, governs the family of planets revolving around it.”

Nick Kanas has documented this revolutionary shift in his ingeniously illustrated album of solar system images, all historical even though the modern views, “postcards from space”, are scarcely a few decades old. Joining the pictures is a rich commentary that points out subtle details and places them in a developing astronomical context.

To those of us impressed with the rapidity of change in the 21st Century, it may seem odd that the authors and illustrators of the 16th Century were so slow to switch their astronomical imagery in the years following the publication of Copernicus’s epoch-making work. But the heliocentric system appeared to attack common sense. Beautiful as it may have appeared to cartographers who could map the heavenly spheres with circles conveniently ringing the Sun, the idea of living on a rapidly spinning ball hurtling around the Sun seemed totally ridiculous. Surely the Earth’s inhabitants would be spun off into space!

There were alternative views. Perhaps the planets did circle the Sun, while the Sun itself carried the entire retinue around a fixed Earth. A theory of this sort was seriously proposed by the great Danish observer, Tycho Brahe. And this, too, is documented in Kanas’s fascinating collection. But by the mid-1700s, such alternative views, along with the ancient geocentric system, were quaint has-beens.

In 1608, the telescope arrived on the scene. Galileo Galilei promptly converted this carnival toy into a scientific discovery machine, and soon there were planets with their moons, new worlds to map and depict. And more charts and maps to collect, for Nick Kanas is an astute collector, always searching for new worlds to conquer. So his quest has taken him from worldwide ancient views to popularizations in a growing America, where curiosity about the heavens and ever-bigger telescopes caught the public imagination. Surely some of that unbounded enthusiasm has fueled the Space Age, with new and different ways of depicting the solar system. Images from a decade ago are already history.

It's a great trip! Get your ticket here!

Owen Gingerich
Harvard-Smithsonian Center for Astrophysics
Cambridge, MA

Preface

In my previous book, *Star Maps: History, Artistry, and Cartography*, now in its second edition, I commented that antiquarian celestial books and atlases used two types of illustrations to describe the heavens: constellation maps and cosmological maps. The first type focused on the location of the stars and other heavenly bodies in the sky with reference to constellations and coordinate systems that measured celestial latitude and longitude (or declination and right ascension in modern parlance). *Star Maps* generally dealt with these kinds of images.

In contrast, the book you hold in your hand, *Solar System Maps: From Antiquity to the Space Age*, focuses on the second type of image and in a sense is a sequel to the first book. It traces how we have conceptualized our place in the cosmos and illustrates this using world view and solar system images from antiquity to the Space Age. Cultural factors are woven into the story from both European and non-European perspectives. Initially, there was no distinction between our solar system and the rest of the universe. The Earth was simply the center of everything, with the planets and stars surrounding it in aethereal shells. Gradually, this world view shifted, with the Sun becoming the center, then its retime of planets being separated from the rest of the cosmos as a true solar system. This required dramatic paradigm shifts in the way we viewed the heavens, sparked by the telescope and our ability to think critically.

In telling this story, I have enhanced the text using images from antiquarian books and atlases, from powerful telescopes on Earth and in space, and from instruments on space probes visiting the planets and their moons. The result is a mapping of the solar system that shows not only the way its grand scheme has been visualized over the centuries, but also the way each component (such as a planet or moon) presented itself topographically and has been interpreted by the observer. A notable exception is the Earth. Entire books have been devoted to terrestrial maps and to images of our planet's surface from space, and to include our home planet in this book would exceed its space limitations (no pun intended!).

Chapter 1 introduces the reader to the general theme of the book, discusses the concepts of world views and paradigm shifts, considers how early maps of the solar system were really maps of the cosmos, and orients the reader to the sky as seen from an Earth-bound perspective. Chapter 2 discusses and illustrates the geocentric Earth-centered world view/ solar system model developed by the Classical Greeks, provides an overview of their constellation system, and describes the continuation of their ideas into the Roman period.

Chapter 3 considers the world views of megalithic Britain and a number of non-European cultures in Sub-Sahara Africa, Egypt, Mesopotamia, India, China, Australia and Polynesia, and the Americas. Chapter 4 continues the Greek geocentric focus into the Middle Ages and early Renaissance, covering Islamic, Byzantine, and central European contributions. Chapter 5 deals with three major paradigm shifts and their sequelae: the development of a heliocentric model by Copernicus (and the various geoheliocentric hybrids that competed with it), the conceptualization of elliptical planetary orbits by Kepler, and the observations made through the telescope by Galileo. Chapter 6 discusses the notions that the universe may be unbounded, that there is a plurality of worlds, and that our solar system can be discussed separately from deep-sky objects (e.g., star clusters, nebulae, galaxies). Chapter 7 describes the conceptualizations of the solar system up to the Space Age, dealing with our Sun, Moon, and the planets and their moons. Chapter 8 continues this story with the special case of Pluto, asteroids, meteors, comets, and components of the Kuiper Belt and Oort Cloud. There is also a discussion of the observations of exoplanets in other star systems. Chapter 9 takes us away from Europe and into the United States, reviewing how this young country quickly moved from being a relative backwater to a major player in the way our solar system and universe are observed and mapped. Finally, Chapter 10 describes advances made since the launch of Sputnik in how our solar system is conceived and visualized.

In an effort to make the text flow more naturally, detailed information and references are placed at the end of the book in separate notes, bibliography, and glossary sections. A unique feature is the inclusion of comparable images from both antiquarian and Space Age sources, which allow the reader to compare and contrast traditional views of the heavens with the latest images acquired by Earth-orbiting telescopes and traveling space probes. Hopefully, these images will enhance the text and provide a vivid reminder of the beauty of our solar system.

Nick Kanas
May 1, 2013

To my wife Carolynn, who continues to be my partner in celestial map collecting and who has encouraged me to write this book.

Acknowledgments

A book of this type cannot be written in a vacuum, and I would like to thank a number of people for their help and support. First and foremost is my wife Carolynn, who has joined me in my quest for finding just the right celestial prints and encouraged me to write this book. Owen Gingerich, Professor Emeritus of Astronomy and History of Science at the Harvard-Smithsonian Center for Astrophysics, has provided valuable astronomical advice and helpful editorial suggestions to an earlier draft of this book and has kindly written a thoughtful Foreword. Both he and my friend and fellow collector Robert Gordon have contributed digital images to the book from their celestial map collections. Peter Barber, Tom Harper, and their staff at the British Library in London have been supportive and helpful during my research and have allowed me to inspect celestial maps and atlases from their vast holdings.

Clive Horwood, my publisher at Praxis Publishing Ltd. in Chichester, England, and his associate Romy Blott have been instrumental in the conceptualization and production of this book. Similarly, Maury Solomon, Editor for Physics and Astronomy at Springer Publishing Company, and her associate Megan Ernst, have been very supportive and helpful during the publication process. David Peduzzi has done a beautiful job with the typesetting, and Christine Cressy has been a diligent copy editor. As with the my previous book *Star Maps*, Jim Wilkie has used his magic to create a stunning cover design that I think captures the scope and beauty of the book's content.

Unless otherwise indicated, the images in this book have been produced from digital photographs I took from antiquarian books and prints that are part of the Nick and Carolynn Kanas Collection. Permission to use and photograph images from other sources have been obtained, and these sources are acknowledged in the legends to the figures. Special mention should be made of NASA for allowing their incredibly beautiful images to be available online for books such as mine, to Wikimedia Commons for providing free online images from antiquarian sources, and to Whitney Hasler and the independent Harvard Book Store in Cambridge, Massachusetts, for providing excellent print-on-demand copies of books from the public domain. I have made every effort to source original copyright holders of images used in this book, and I apologize to any that I may have missed through oversight or inability to contact via e-mail or phone.

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World Views and the Solar System

Galileo Galilei rubbed his eyes. Peering through his spyglass was difficult work. The images were not crystal clear, and the night was cold. But he had seen wonders in God's firmament over the past several evenings: the lunar surface had mountains and valleys, more like the Earth than Aristotle's perfect featureless orb, and faint cloudy areas in the sky had resolved into a multitude of stars never before seen with the naked eye. And now, on January 11, 1610, he would once again be checking on the star-like objects lined up to the east and west of Jupiter. When he first observed them four nights earlier, he thought them to be fixed stars, but on subsequent nights his sketchbook revealed that their numbers and pattern had been different in terms of how they presented themselves, first all to the west, then all to the east. How would they look tonight?

He strained to make out Jupiter through his eyepiece. Yes, the mysterious objects had moved again. Only two were visible, and their distances from the giant planet had shifted relative to the night before. The notions of Copernicus came to mind, who 70 years earlier had written that the so-called wandering stars like Jupiter were orbiting the Sun, not the Earth. Only the Moon went around the Earth. Could the strange objects in his telescope be miniature moons revolving around the mighty Jupiter? Astounded, he thought these observations would please his hoped-for patron, Grand Duke Cosmo II de Medici, who like Jupiter was a giant in his times.

In subsequent nights, Galileo would conclude that there were four such moons orbiting Jupiter, and he would name them the "Medicean Stars" in honor of the de Medicis. Galileo would publish his telescopic findings in March 1610, in a booklet entitled *Sidereus Nuncius*, or *The Sidereal Messenger.* This booklet became an instant success throughout Europe, not only for its findings, but also as an illustration of the power of the telescope to reveal heavenly sights never seen before. In fact, Galileo would be an advocate for this new instrument, which he had heard about just 10 months earlier. His subsequent improvements upon the original design allowed him to produce an instrument of sufficient quality and power to make his revolutionary observations.

N. Kanas, *Solar System Maps,* DOI 10.1007/978-1-4614-0896-3_1,

1.1 PARADIGM SHIFTS AND WORLD VIEWS

The findings of Galileo called for a paradigm shift. A paradigm is a view or model of something that most people accept. Prior to Galileo, most people followed the Aristotelian view that our Moon was made up of a special heavenly substance called aether that was pure, everlasting, and smooth. Features that we see on the lunar surface were merely reflections of the impure and changing Earth. Furthermore, like the Moon and the Sun, the other wandering stars (the planets) were themselves made up of aether, and none had their own moons revolving around them. But with the publication of *Sidereus Nuncius*, this all changed. Now, the Moon was observed to have mountains and valleys like the impure Earth, and another planet, Jupiter, was shown to have its own retinue of moons going around it. The old ideas of what constituted a planet had to change to account for the new observations made by Galileo and his telescope.

But Galileo's findings had even broader implications. They also seemed to shake the current view of the universe and supported the heliocentric ideas put forth by Copernicus, which had our Sun as the center of the cosmos surrounded by the orbiting spheres of the planets and the sphere of fixed stars. This world view is shown schematically in Figure 1.1.[1] (Note that for Figure 1.1 and subsequent images used in this book, the title and year of the source will be given, which may or may not be the first edition. For the listed dimensions, the following principles are followed: 1) measurements are in centimeters; 2) for rectangular images, the distance between the innermost image border is given, first for the vertical then for the horizontal dimension; 3) for circular images, the least distorted vertical or horizontal diameter is given; and 4) the vertical by horizontal dimensions of the entire page are given in cases where the image dimension itself is ambiguous.)

Before Copernicus, most people advocated a geocentric view, where the Earth was in the center of the universe and all the other heavenly bodies revolved around it. But with Copernicus and Galileo, a new world view was called for. The term "world view" refers to the basic concept people have of their total existence: psychological, sociological, political, economic, scientific, religious, etc. It comes from the German term *Weltanschauung*, literally "view or outlook of the world". Changes in world view are usually brought about by paradigm shifts, where a major event or a series of major events leads to a dramatic change in how people view their reality. Copernicus's ideas led to one paradigm shift, Galileo's observations to another.

Note that the world view shown in Figure 1.1 is essentially a view of our solar system, except that the realm of the fixed stars is indicated by the outermost circle in this diagram. At the time, nothing was known about star clusters, nebulae, or galaxies, or for that matter, the outer planets that could not be seen with the naked eye. Consequently, many early maps of our solar system were essentially world view maps, and they will be referred to as such in this book.

Related to the notion of a world view is the expression "world system", or *systema mundi*. The expression *systema mundi* first appeared in the 1580s and 1590s to describe the models put forth by Tycho Brahe (1546–1601) and Nicolas Reimers, a.k.a. Ursus (1551–1600).[2] The world system concept implies a unit composed of an assemblage of constituent parts representing everything that there is. This notion works very well when referring to a closed geocentric universe that is bounded by the sphere of the fixed stars and progresses

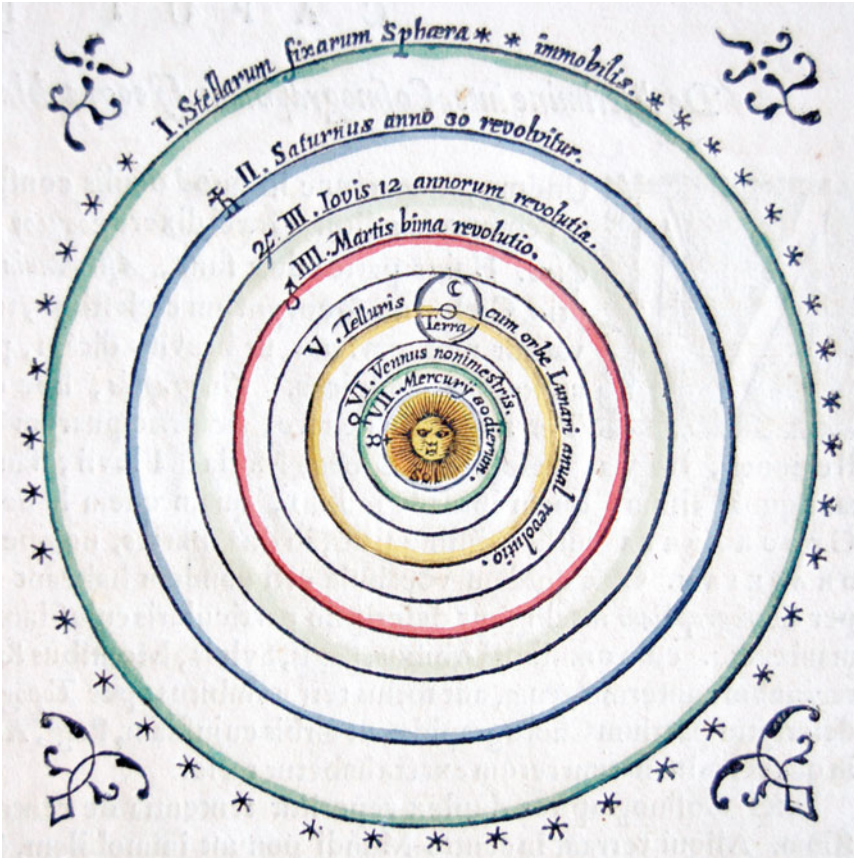

Figure 1.1. The Copernican heliocentric world view, from Blaeu's *Theatrum Orbis Terrarum, sive Atlas Novus*, c.1645, section "Introductio ad Cosmographiam, Eiusque Partes". 11.8 cm diameter (outermost solid circle).

inwardly through a series of concentric spheres representing the planets until reaching the center of it all: the Earth. However, the term begins to lose its meaning when referring to a universe made up of numerous star systems and the heavens become unbounded (although the term is relevant when speaking specifically of an individual "solar system").[3]

In some cases, "world view" and "world system" may refer to the same thing (e.g., a closed geocentric or heliocentric universe). But since the former expression is more general and does not restrict us to an interlinked system, it will be the preferred term used in this book, where the focus will be on how we have viewed our astronomical place in the universe. Of course, if one sees humanity uniquely situated in the center of an entire cosmos created by God, the world view will be quite different from that seen from a perspective of being in one of many solar systems located in an average galaxy among hundreds of thousands of galaxies in a naturalistic universe that may contain other life forms.

Since a paradigm shift challenges current thinking, there is often resistance to the change, and it may take years for it to take hold. In the case of Copernicus, many people continued to advocate a geocentric orientation for decades after Copernicus died. One problem was that the new heliocentric view did not jive with people's perceptions. For example, when we look up at the sky, the Sun and stars appear to revolve around us with roughly the same speed (i.e., once a day). Also, the giant Earth below our feet seems heavy and permanent, and since all terrestrial objects fall downward, it must be at the center of things. So perhaps we should begin our story where the ancients began, by looking up.

1.2 CIRCLES IN THE SKY

1.2.1 Projections of the Earth's Circles

When looking at the sky throughout the year at the same time each day (say noon), the Sun appears to increase its elevation from the horizon to a certain height, then decrease to a certain depth, and so on. We now know that this apparent rising and falling is due to the fact that the Earth's axis is tilted some 23½ degrees to the plane of its orbit, so that as it revolves around the Sun in a year, this affects the apparent height of the Sun in the sky (Figure 1.2). In the summer, the Sun most directly beams its rays to people in the Northern Hemisphere, so it appears to be higher in the sky (left image in Figure 1.2). If we project a line from this highest elevation of the Sun onto the Earth's surface, a circle of latitude is defined as the Earth revolves which is called the Tropic of Cancer. In the winter, the Sun most directly faces the Southern Hemisphere, so to people in the Northern Hemisphere it appears lowest in the sky (right image in Figure 1.2), and a line projected onto the Earth's surface defines a circle called the Tropic of Capricorn. These two extremes of time when the Sun is at its highest or lowest at noon are called the summer and winter solstices, and they occur around June 21 and December 21, respectively. At the midpoint of these two extremes, the Sun shines most directly on the equator, and we refer to these times as the spring (or vernal) equinox (around March 21) and the autumnal equinox (around September 23).

How did the tropics get their names? For millennia, people realized that the so-called wandering stars (i.e., the Sun, Moon, and planets) appeared to move in a circular region of the sky called the ecliptic. This circular region could actually be visualized as the circumference of a sphere with a central axis and a north and south ecliptic pole. The 12 constellations located in the ecliptic were given special significance, and their order as they appeared throughout the year was well known. Because most of these constellations were perceived as animals, they collectively were referred to as the constellations of the zodiac (like the word "zoo", this term comes from the Greek word for "animal").

Look again at Figure 1.2. Imagine yourself at the summer solstice around 500 BC (when the zodiac was established) and looking at the Sun at noon. Although it is daylight and you cannot see the stars, you know that Capricornus was high in the sky at midnight the evening before, so the Sun must now be located half way around the zodiac in Cancer (if there was a sudden solar eclipse, you would in fact see this constellation behind the Sun). So, during the summer, when the Sun is at its highest in the sky for the Northern Hemisphere

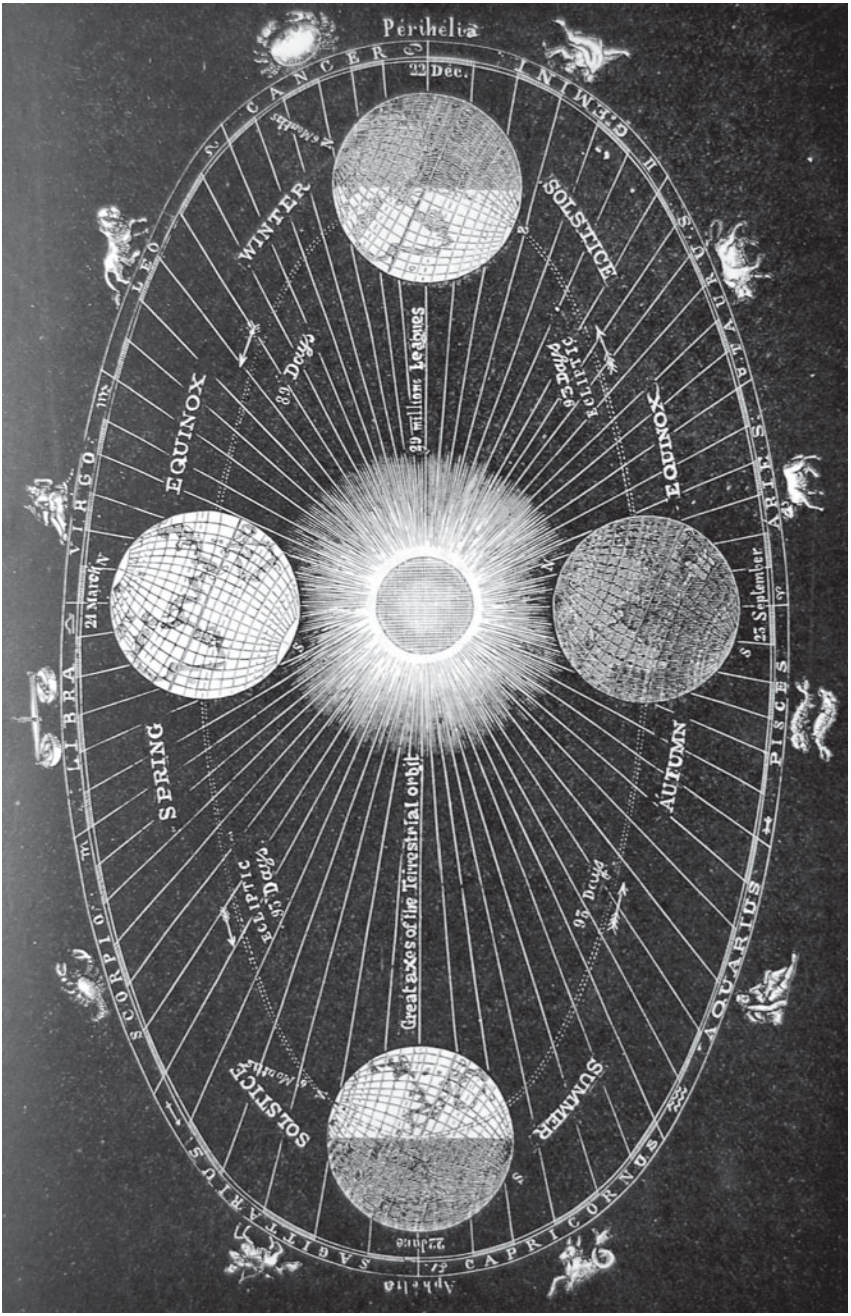

Figure 1.2. An image from the first American edition of Flammarion's *Popular Astronomy*, translated with his sanction by J. Ellard Gore and published in 1894. 23.2 × 15.5 cm (page size). Note the revolution of the Earth around the Sun against the backdrop of the zodiacal constellations.