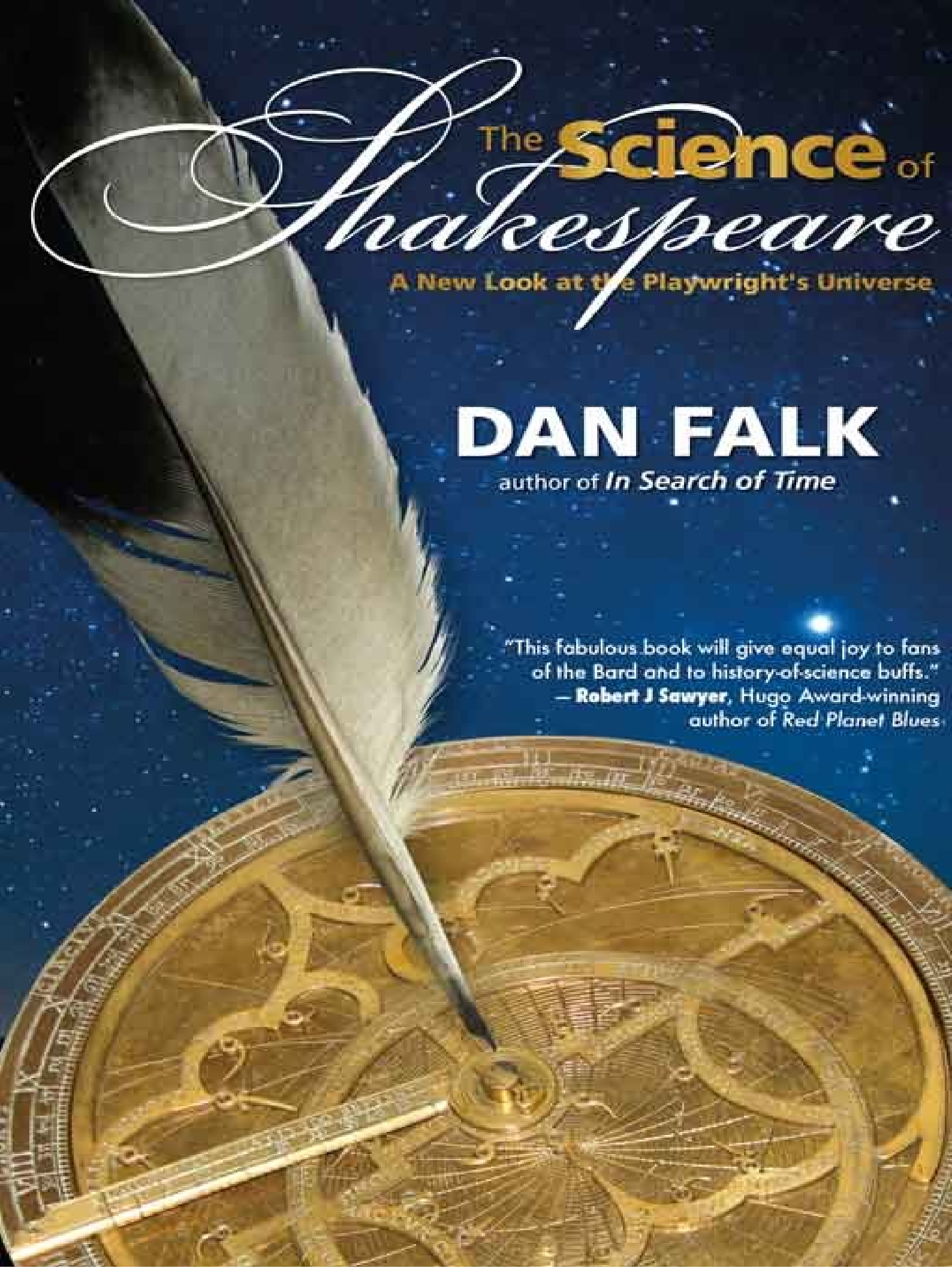
The Science of Shakespeare
A New Look at the Playwright's Universe
DAN FALK
author of In Search of Time
"This fabulous book will give equal joy to fans of the Bard and to history-of-science buffs."
— Robert J Sawyer, Hugo Award-winning author of Red Planet Blues

The Science of Shakespeare

A New Look at the Playwright's Universe

DAN FALK

Published simultaneously in the United States of America by Thomas Dunne Books, St. Martin Press.

Cover design by Julie Scriver.
Cover illustrations: One of four extant brass astrolabes manufactured by the workshop of Geo Hartmann in Nuremberg in 1537. This one is part of the Scientific Instruments Collection of Ya University's Peabody Museum of Natural History, wikimedia (foreground); "Venus and the Night Sk Over Mammoth," John Lemieux, flickr.com (background).

Library and Archives Canada Cataloguing in Publication

Falk, Dan, 1966-, author
The science of Shakespeare : a new look at the playwright's universe / Dan Falk.

Includes bibliographical references and index.
Issued in print and electronic formats.
ISBN 978-0-86492-418-6 (bound). ISBN 978-0-86492-796-5 (epub)

1. Shakespeare, William, 1564-1616 - Knowledge - Science.
2. Science - England - History - 16th century.
3. Science in literature.
I. Title.

PR3047.F34 2014 822.3'3 C2013-907595-X
C2013-907596-8

Goose Lane Editions acknowledges the generous support of the Canada Council for the Arts, th Government of Canada through the Canada Book Fund (CBF), and the Government of New Brunswi through the Department of Tourism, Heritage and Culture.

Goose Lane Editions
500 Beaverbrook Court, Suite 330
Fredericton, New Brunswick
CANADA E3B 5X4
www.gooselane.com

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preface and acknowledgments

As it happens, my love of science and my fondness for Shakespeare date back to about the same tim I was ten or eleven when my parents took me to see *Macbeth* for the first time; and it was around th that they bought me a copy of H. A. Rey's *Know the Stars*, a wonderful children's astronomy boo (Rey was into monkeys as well as astronomy; with his wife, Margaret, he was the creator of Curio George.) I would later come to realize that Shakespeare understood a fair bit about astronomy. Th was obvious from his frequent allusions to sunrises, eclipses, the pole star, and such; but for ma years I gave the matter little thought. I also knew that Shakespeare and Galileo were born in the sa year; but that fact is usually dismissed as little more than an item of trivia. (Sure, 1564 was a go year, but so what?)

A turning point came in January 1996, when Peter Usher, an astronomer, presented a paper titl "A New Reading of Shakespeare's *Hamlet*" at a meeting of the American Astronomical Society. (Th meeting, as luck would have it, was held in my home city of Toronto.) But Usher's work was clear controversial, and his paper made only a mild splash; soon I was back to writing articles about bla holes and the big bang. But in roughly 2010, with Shakespeare's 450th birthday looming, I began dig a little deeper—quickly realizing that I had only scratched the surface of a rich and under-explor topic. I soon discovered that a handful of respected Shakespeare scholars were beginning investigate the playwright's knowledge of science, and astronomy in particular. Another bout of luc One of the scholars at the forefront of this research, Scott Maisano, was based in Boston, where I w living in 2011–12 while a Knight Science Journalism Fellow at the Massachusetts Institute Technology.

Sensing that "Shakespeare and science" would make an intriguing radio documentary, I pitched to CBC Radio's *Ideas*, and they gave me the green light. This book takes advantage of many of t interviews originally conducted for that project. As my research continued, the library became m second home; I audited university Shakespeare classes; and I went to as many Shakespea productions as I could. I've lost track of the total number of performances, but they came in a varieties: indoor and outdoor; minimalist and lavish; no-budget, low-budget, and professional. I lov being a "groundling" for *Henry V* at Shakespeare's Globe in London; I saw multiple *As You Like It Twelfth Night*s, and *Richard III*s; I took in a sadomasochist production of *Antony and Cleopatra* (le just say there was a lot of leather) and an "anarchist" production of *Measure for Measure* in whi Barnardine was played by a hand puppet (which proved quite effective, though it restricted h movements somewhat).

In *The Science of Shakespeare*, I examine the playwright's world, taking a close look at the scien of his day (bearing in mind that "science," as we think of it today, was only just coming in existence). This subject—the birth of modern science—is fascinating in its own right, and I hope th readers will enjoy this work as a history of ideas, focusing on this remarkable period of discovery.

also investigate how these discoveries are reflected in Shakespeare's work, and, more broadly, ho they reshaped society at large. And so, even though much has been written on this period, ar Shakespeare is one of the most-studied figures in history, I hope that, by exploring the connectio between the playwright and this aspect of his world, *The Science of Shakespeare* offers somethi new.

* * *

This book could never have been written were it not for the scholars—too many to name—who hav explored the subject matter within these pages in far greater depth than myself; their books an journal articles have been invaluable. I am particularly indebted to those researchers who allowed m to pester them (sometimes repeatedly) with all manner of Shakespeare questions, and especially tho who allowed me to interview them, microphone in hand, for the CBC Radio documentary. This grou includes Stephen Greenblatt at Harvard, John Pitcher at Oxford, Eric Mallin at the University Texas–Austin, and Colin McGinn, recently retired from the University of Miami. Scott Maisano, wh sat for more than one interview and answered numerous queries, is due a special note of appreciatio Peter Usher, whose work was one of the catalysts for this project, also deserves particular thanks. I a also grateful to numerous museum curators, tour guides, and librarians on both sides of the Atlanti In London, meetings with Boris Jardine at the Science Museum, and Kevin Flude at the Old Operati Theater Museum and Herb Garret, were especially fruitful. Owen Gingerich and Donald Olso answered many of my questions on the history of astronomy, and Ray Jayawardhana pointed me in th right direction on the physics of supernovas. Many scholars have helped me without knowing it; Dav Levy's work, for example, led me to numerous astronomical references in early modern Englis literature. I also thank the professors who welcomed me into their classrooms—a list that includ Gordon Teskey at Harvard, Peter Donaldson at MIT, and Christopher Warley and Jeremy Lopez at th University of Toronto.

I am indebted to my tireless agent, Shaun Bradley of the Transatlantic Agency, and my very patie editor, Peter Joseph of St. Martin's Press, as well as production editor David Stanford Burr and cop editor Terry McGarry. Jessica Misfud was invaluable in helping to gather the images that illustra this work, and I owe special thanks to Marina De Santis for her Italian-to-English translation skill Dr. Maisano generously took the time to look over portions of the manuscript, as did Bill Lattanzi an the ever-supportive Amanda Gefter. (Nonetheless, the reader should not presume that any of th researchers mentioned in the book would necessarily agree with any of the particular conclusions th I draw; and of course any mistakes are purely my own.) My family and friends stood by me at eve step along this journey, and I couldn't have succeeded without their love and support.

Finally, in spite of all my hours in libraries, classrooms, and theaters, I make no pretense of being professional Shakespeare scholar: I'm merely a journalist who is fascinated by science, intrigued b history, and—like millions of people around the world—in awe of Shakespeare's achievement. I'v used footnotes, endnotes, and a thorough bibliography to document my sources and to point the read to further information; yet the book is aimed squarely at non-experts—those who marvel at the wa that science has transformed our world, and those who enjoy reading and watching Shakespeare for th joy of it, as I do.

By the Favor of the Heavens

PROLOGUE

Stratford-upon-Avon, Warwickshire, England
November 19, 1572
6:05 p.m.

"Father!"

A middle-aged man turns to greet his son, one of a dozen schoolboys making their way out of th King's New School and onto Chapel Lane. It's getting cold; the man pulls his cloak to his chest. He thankful to be wearing his new fur cap rather than the felt one he'd had to make do with the previou winter. The boy, as full of energy as ever, doesn't seem to mind the cold.

"You don't need to walk me home, Father. I'm almost nine years old." The boy's breath is visibl in the crisp winter air.

"Eight and a half is not 'almost nine.' But you're right, William, you are a young man now," th father replies. "It happens that I had some business at the church, and I was just on my way back. L us make haste now, your mother and the children are waiting. I hope you didn't give Master Hunt an trouble today?"

"Master Hunt had to leave for Alveston, on account of his mother being sick."

The father is taken aback; usually he is the first to hear any news of that kind. "Is that so?"

"But another teacher took his place," the boy continues. "Master Jenkins. We still had to do all o that Latin grammar. But we also talked about the Bible, and the children in the upper form read poem by Horace, and got to act out a scene from a Roman play."

"Horace was my favorite. Can you remember a few lines?"

"Let me think.… *There is nothing that the hands of the Claudii will not accomplish*—"

"Not in *English*. Horace isn't meant to be read in English. In Latin, William, please."

"Oh, Father, school is out. And I don't *like* Latin."

"Whether you like it is hardly the point. You must learn it to be a gentleman—and, for the next fe years, to escape the birch. Now continue. In Latin."

"Um … *nil Claudiae non perficient manus, quas et* … um … *benignus numine Iuppiter*—"

"*Benigno numine*," his father interrupted, correcting the boy's grammar. "It means 'by the favor o the heavens.' That's enough for now. You did very well, William."

The pair turn from Chapel Street onto High Street. It is now growing dark; the long winter's nig stretches ahead. The full moon will provide some relief, but it is only just creeping above the easte horizon. It has been a cloudy day—a little snow fell earlier—but as the wind blows, the clouds final begin to part. In the southeast shines mighty Jupiter—the same Jupiter the Romans had put their fai in as they marched into battle; the same Jupiter that Horace had rhapsodized over. As they reac Henley Street, William stops and gazes upward.

"What are you looking at, son?"

"It's something Master Jenkins told us about. He said there was a new star in the sky. He said h had been in Oxford yesterday, and everyone was talking about it."

The father lets out a hearty laugh. “Don’t be silly, William. I heard some talk of it also at the guil
but the reverend said it couldn’t be, and of course he is right. It could be a comet perhaps.”

“But Father, Master Jenkins said it was a star. In the constellation of—the queen with the funn
shape. The queen shaped like an ‘M.’”

“Cassiopeia,” the father replies. In spite of himself, he turns northward to see what may be ther
His son turns to follow his gaze. “The Lord doesn’t just create new stars, the way Mr. Smith hamme
out horseshoes. God created the world thousands of years ago, and he doesn’t need to mal
improvements.”

A pause.

“I think that’s it!” William points to a bright star, eastward from the pole, just visible now that th
clouds have passed. It stands just to the left of the unmistakable “M” of Cassiopeia.

The father has to admit there is *something* there. Whatever it is, it’s even brighter than Jupite
Brighter even than Venus had been that morning, as far as he could recall.

“Father—what does it mean?”

“I don’t know, son. And I don’t know that it really is what it appears to be. It could just as well b
the devil’s work as the Lord’s. And now we really must carry on, or supper will be cold. Not t
mention my fingers.”

“I’m coming, Father.” But the boy lingers for one last look as his father heads off down the stree
“It’s beautiful,” he says, and then runs to catch up. “I don’t think it’s a comet, Father, because comet
have tails.”

“More nonsense from Master Jenkins? Well, cats have tails too, but Mrs. Olden’s cat doesn’t hav
one, and it’s still a cat.”

The boy pauses, seemingly deep in thought. “Why doesn’t Mrs. Olden’s cat have a tail?”

“They say Mr. Olden’s dog bit it off,” his father replies.

“Well, maybe a dog bit off the new star’s tail,” the boy offers.

“That’s quite an imagination you have, son. And how many dogs are there in the sky, William?”

Another pause—and then a wide smile. “Two, Father! You showed them to me last winter—the bi
dog and the little dog!”

The father laughs. “You do have quite a wit, don’t you, son? Now say their names in Latin, please.

“Oh, Father! *Canis* … *Canis Major* and *Canis Minor*.”

“Very good, son. By Jove, I swear you’ll make a fine lawyer one day.”

Introduction

“The poet’s eye, in a fine frenzy rolling
Doth glance from heaven to earth, from earth to heaven…”

I’m sitting in a large, airy room on the ground floor of the Houghton Library, a small, elega neoclassical building in the shadows of Harvard University’s gargantuan Widener Library. Th semester is winding down, and there are only eight or nine people in the room, leafing through dus books or clicking away on their laptops. Portraits of forgotten scholars peer down at us, while a gia clock with gold hands looms above the doorway. As a gloomy drizzle falls outside, I stare at tw books on the table in front of me.

They’re both old—four centuries, give or take—though the one on the left had an eighty-year hea start. I gently pick up the first book. Its pale beige cover is made from a pig’s skin stretched ov wood, and may be nearly as old as the pages themselves. (Back then, customers who bought a “boo were actually buying a bundle of pages from the bookseller; one could then pay a bookbinder to put all together in an attractive package.) Scenes from the Bible, barely discernible, have been presse onto the front and back covers; the process was called “blind stamping,” the librarian tells me. On th spine, the author’s name has been nearly obliterated with the passage of time.

Two slim metal clasps, probably brass, hold the covers shut. I gently release them, and lift the fro cover. The pages are stiff and warped, as though they had been damp at one time—who knows ho many years ago—and then left to dry. A blank inside page has a few scribbles from a previous owne as well as a sticker indicating the name of the man—a graduate of the class of 1922—who donated th book to Harvard. Then I come to the title page. Here the author’s name is very legible indeed—thoug the typesetter apparently had trouble fitting it all on one line:

NICOLAI CO-
PERNICI TORINENSIS
DE REVOLUTIONIBUS ORBI-
um coeleſtium, Libri VI.

It’s Latin, of course. And in those days, an “s” looked like an “f,” so it’s actuall “*coelestium*”—“celestial,” or, perhaps more accurately, “heavenly.” The author’s name, in th genitive, is given matter-of-factly as Nicolaus Copernicus of Toruń. The full title is *On th Revolutions of the Heavenly Spheres*, *in Six Books*, often shortened to *On the Revolutions* or *D revolutionibus*, or even “*De rev*”; I figure a tiny bit of Latin won’t hurt us, so I’ll stick to calling it *D revolutionibus*. However we label it, this is the book that turned the universe inside out. At the botto of the page is the publisher’s name (Johannes Petreius), the city where the book was printe (Nuremberg), and the year (1543):

Norimbergae apud Ioh. Petreium,
Anno M. D. XLIII.

Each page makes a peculiarly satisfying sound as it is turned. I soon come to Copernicus's famou diagram, located on page 10 verso (meaning "left-hand page"), nestled between two chunks of Lat text (see figure 0.1). There are more than 140 other diagrams in the book, most of them very technic and now of interest only to historians of science—but this one has become iconic. It may be the mo important diagram in the history of Western thought.

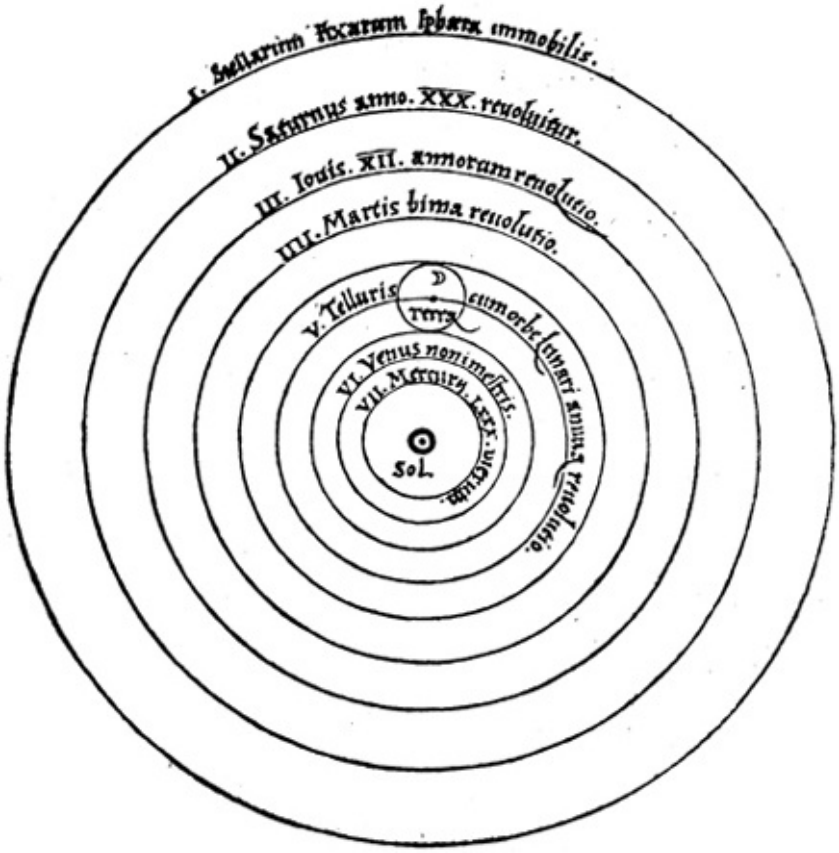

Fig. 0.1 One of the most important diagrams in the history of Western thought: Copernicus's illustration of a sun-centered universe, from *De revolutionibus* (*On the Revolutions*), published in 1543. Image Select/Art Resource, NY

The diagram shows a series of concentric circles; at their center is a very small circle with a dot the middle, labeled "Sol." (My rudimentary Latin is enough to know that "*sol*" is "sun.") The larg circles mark the paths of the planets as they revolve around the sun in their orbits. And there *we* ar the third rock from the sun, a mere dot, labeled "Terra"—Earth. Circling this diminutive dot is anoth tiny object, a little crescent moon. It is a diagram that I had drawn countless times as a nerdy, scienc minded kid,* but you don't get any brownie points for being the hundred thousandth child to do s You *do* get credit for being the person who came up with the picture in the first place.

* * *

The book on my right is a bit larger, measuring about nine-by-thirteen inches; it must weigh three four pounds. Its cover, like that of its companion, is made from wood, this time covered in dark brow leather. The binding is too good to be original; it must have been re-bound a century or two after i pages first came off the press. Someone has also applied a gold-leaf gilt to the edges; the book sti gleams. The writing on the spine is crystal clear, naming both the author and the printers:

SHAKESPEARE
I. JAGGARD
AND
E. BLOUNT
1623

Just inside the cover, a previous owner had pasted a newspaper article from November 11, 1848, c
“The Folios of Shakespeare.” This collection of thirty-six of Shakespeare’s most important plays we
through multiple editions, but it is the first one—the famous First Folio of 1623—that gets pride
place in libraries and museums around the world. The title page will look familiar to any student
Shakespeare. And—a refreshing change from Copernicus—it’s in English:

MR. WILLIAM
SHAKESPEARES
COMEDIES,
HISTORIES, &
TRAGEDIES.

Published according to the True Originall Copies.

Don’t be alarmed by the spelling: Scholars of early modern English assure us that spellings had n
yet been standardized, and Shakespeare himself was known to mix it up even when signing his ow
name.* Just below is the familiar black-and-white engraving by Martin Droeshout—one of only tw
known depictions of the playwright that have a fighting chance of being accurate likenesses (s
figure 0.2). (The other is the funerary monument in Holy Trinity Church in Stratford-upon-Avo
which dates from sometime between the playwright’s death, in 1616, and the publication of the Fir
Folio, seven years later.)

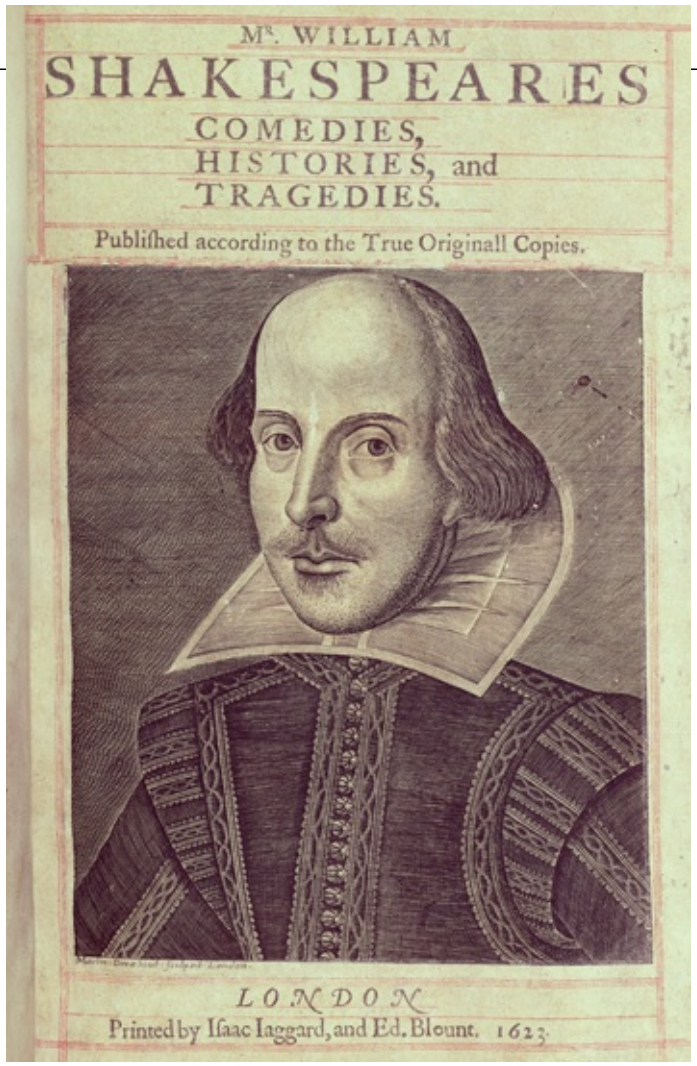

Fig. 0.2 The frontispiece from Shakespeare's First Folio, a collection of thirty-six of his plays, compiled by his colleagues John Heminges and Henry Condell. It was published in 1623, seven years after the playwright's death. The Bridgeman Art Library, London

An introductory note from Shakespeare's friend and fellow playwright, Ben Jonson, asks the read not to spend too much time staring at the portrait; it is Shakespeare's words that will bring hi immortality. The note urges us to "looke Not on his Picture, but his Booke."

* * *

Is there any connection between these two books? Did Shakespeare know about Copernicus revolutionary idea? Did he care? History is so much clearer in hindsight: Looking back after fo centuries, it's obvious *to us* that Shakespeare lived in a remarkable time. The medieval world— world of magic, astrology, witchcraft, and superstition of all kinds—was just beginning to give way more modern ways of thinking. Shakespeare and Galileo were born in the same year, and new ide about the human body, the Earth, and the universe at large were just starting to transform Weste thought. The first modern anatomy book, by the Flemish-born physician Andreas Vesalius, wa published in 1543, the same year as *De revolutionibus*. Is it possible that Shakespeare was unaware these developments—or that he was vaguely conscious of them, but uninterested?

For some literary figures, the impact of this new picture of the world is obvious: In a famou passage from *An Anatomy of the World* (1611), John Donne laments that "the new philosophy calls a in doubt.… The sun is lost, and th'earth, and no man's wit / Can well direct him where to look for it A half century later, John Milton would devote lengthy passages in *Paradise Lost* to a debate over th structure of the cosmos; indeed, he refers to Galileo three times in the poem (once by name; th

astronomer is the only living figure to warrant such a mention). Milton is even said to have met th Italian scientist in person, when Galileo was in his final years, under house arrest, in his villa outsi Florence. By Milton's time, as one scholar puts it, the Copernican system was "a scientific force wi which all thinking men had to reckon." But Milton went to Cambridge, and Donne studied at *bo* Oxford and Cambridge. Shakespeare flourished a little bit earlier, and had only the benefit of his loc grammar school; as Jonson famously quipped, his colleague had only "small Latin and less Greek."

The traditional view is that Shakespeare was unconscious, or barely conscious, of the "ne philosophy." It's not that Shakespeare scholars, or historians of early modern science, have neglecte to look at possible connections between Shakespeare's works and the ideas and discoveries that ma what we now call the Scientific Revolution: They've looked, and concluded—wrongly, I believe—th no such connections exist. As recently as 2005, John Cartwright and Brian Baker, in *Literature a Science: Social Impact and Interaction*, find that "… the greatest poet of the age, Willia Shakespeare, shows little awareness or interest in the achievements or concerns of the astronomers A few years earlier, William Burns declared in *The Scientific Revolution: An Encyclopedia* (2001) th "William Shakespeare … took almost no interest in science." Thomas McAlindon, meanwhil believes that Shakespeare, in spite of being deeply concerned with cosmological matters, showed "n sign of [the Copernican] revolution" in his plays. Why is it so easy to read Shakespeare as a whol prescientific figure? One reason is that Shakespeare's plays are littered with references to th medieval worldview. He frequently mentions the stars and the heavens, typically in a mann consistent with the thinking of the ancient Greek astronomer Ptolemy, dead for fourteen centurie Shakespeare couldn't have known much about the new way of thinking, the theory goes, because ide circulated slowly in those days, and Copernicanism took many decades to reach England, which at a rate was an intellectual backwater. Moreover, Copernicus's novel conception of the cosmos didn really gain intellectual currency until Galileo's telescopic observations lent it some measure observational support—and that came only in 1610, just as Shakespeare was packing his bags for well-earned retirement in his hometown of Stratford.

But perhaps we shouldn't be so hasty. First of all, while acceptance of the Copernican theory cam slowly, finding pockets of enthusiasm in a handful of university towns in central Europe, the theo did attract a number of early adherents in England, where a spirit of intellectual freedom and ration inquiry was in the air (arguably nurtured by the Protestant national faith, in contrast to the mo repressive atmosphere in Catholic Europe).* Copernicus's groundbreaking book had been published 1543, twenty-one years before Shakespeare's birth; by 1556 it was already mentioned favorably in a English book, Robert Recorde's *The Castle of Knowledge*. The first full account of the theory by a Englishman came from astronomer Thomas Digges in 1576 (when Shakespeare was twelve). Digges book included a diagram of the solar system in which the stars were seen to extend outward witho limit, a vision of an infinite cosmos that surpassed even Copernicus in its daring.

As we will see, Shakespeare had multiple connections to the Digges family. (For a time he an Digges's son, Leonard, lived less than three blocks apart in their north London neighborhoo Leonard, a poet, was an early Shakespeare "fan" who contributed an introductory verse at the start the First Folio.) Shakespeare may have encountered England's other great men of science of the da from Thomas Harriot to Queen Elizabeth's own "science advisor," John Dee—the man often pu forward as the model for Prospero in *The Tempest*. And then there was the Italian philosopher an mystic Giordano Bruno, who traveled to England in the 1580s, lecturing on Copernicanism and oth provocative notions. Shakespeare is unlikely to have met Bruno, but may well have encountered h ideas.

Moreover, Shakespeare could have seen at least some of the evidence for the "new astronomy" wi
his own eyes, as hinted at in the fictionalized prologue. In November 1572, a bright new star lit up th
night sky, appearing in the constellation Cassiopeia. (Today we know such an event as a supernov
the explosive death of a massive star.) It was so bright that for several months it outshone even Venu
making it the brightest object in the sky apart from the sun and the moon. (Indeed, it could be spotte
even in daylight.) It was observed by Digges in England, and watched even more closely in Denma
by astronomer Tycho Brahe, whose published account of the new star was making waves even befo
the object had faded from view. The strange and wonderful apparition—today we call it simpl
"Tycho's star"—dealt a shattering blow to the cosmology of the ancients, refuting the idea o
immutable heavenly spheres.

Amazingly, another new star blazed forth thirty-two years later, in 1604, and was studied by th
German mathematician Johannes Kepler.* Shakespeare was forty, and at the height of his career, whe
Kepler's star illuminated the skies of Europe. Even if he somehow failed to see Tycho's star, he coul
not have missed Kepler's. It was a dazzling sight, one that could not be ignored. In fact, Shakespea
lived during a remarkably eventful period in terms of celestial drama: A dazzling comet in 157
displayed a tail stretching one-eighth of the way across the sky, and two more comets appeared
1582 and 1607; and a solar eclipse darkened the skies over Europe in the autumn of 1605. There we
ample reasons for taking an interest in cosmic happenings.

We should also note that England, and in particular London, was hardly a backwater. The city wa
teeming with tradesmen, merchants, and sailors who took a keen interest in what we would now ca
"science," and in particular in the latest technological advances, especially those connected to the a
of navigation. The curriculum at Gresham College in London, founded in 1597, included astronom
geometry, and medicine. Francis Bacon's groundbreaking work, *The Advancement of Learnin*
championing the importance of observation and empirical knowledge, was published in 1605, arou
the time Shakespeare was working on *King Lear*. And the bold ideas penned by the French statesma
and essayist Michel de Montaigne had appeared in English translation two years earlier. (Althoug
Shakespeare scholars routinely discuss Montaigne's influence on the playwright—several of the play
contain passages lifted almost verbatim from the *Essays*—the fact that Montaigne specifical
mentions the Copernican theory is often overlooked.)

But a reassessment may finally be at hand. In the last few years, a handful of scholars have begu
to look more closely at Shakespeare's interest in the scientific discoveries of his time—asking wh
he knew, when he knew it, and how that knowledge might be reflected in his work. Scott Maisano
the University of Massachusetts–Boston, for example, has written extensively on the evidence f
Shakespeare's awareness of the science of his day, and for its influence on his plays, especially th
late romances. Other scholars, like John Pitcher and Jonathan Bate, both at Oxford, hav
acknowledged Shakespeare's interest in contemporary science, discussing it in popular biographi
and in scholarly editions of the plays. One result of this reassessment is that it allows for a famili
passage to be read in a new light. Consider Ulysses's speech in *Troilus and Cressida*, in which h
refers to "the glorious planet Sol / In noble eminence enthroned and sphered…" (1.3.89–90). Th
reference to "spheres" sounds at first like straight-ahead medieval cosmology, including the referenc
to the sun as a "planet." In the 1940s, this passage served as the backbone for E. M. W. Tillyard
thesis that Shakespeare's time ought to be seen as medieval rather than modern, a case he argued
his influential book *The Elizabethan World Picture*. Some current scholars continue to follow
Tillyard's footsteps; in the Arden edition, David Bevington tags the line simply as "a Ptolema
conception." But as Bate points out, by emphasizing the role of the sun, the passage "may hint at th

new heliocentric astronomy." James Shapiro, meanwhile, concedes that Shakespeare knew th Ptolemaic science "was already discredited by the Copernican revolution."

And Shakespeare wasn't quite ready to retire in 1610; he had a few years to go, and would produ five more plays in that time (two on his own, including *The Tempest*, and three more in collaboratio with colleagues). It is from this period that we find *Cymbeline*—and an even more tantalizing hint th the playwright may have been conscious of the new cosmology. This admittedly weird pla combining elements of ancient Britain and ancient Rome, seems to have been written in 1610—ju late enough that Shakespeare could have read Galileo's account of his telescopic discoverie published in the spring of that year. Both Maisano and Pitcher have written in support of th hypothesis. "Jupiter" himself appears near the end of the play, while a stage direction calls for fo ghosts to dance in a circle; could this be an allusion to the planet's four newly discovered moon described by Galileo?

We will also take a look at the work of a more controversial figure, the astronomer Peter Ushe recently retired from Pennsylvania State University. Like Maisano and Pitcher, Usher sees the Jupit scene in *Cymbeline* as a response to Galileo's discovery—but he takes "Shakespearian science" muc further, arguing that examples of the playwright's scientific knowledge can be found in worl spanning his entire career. Usher has taken a particular interest in *Hamlet*, which he sees as a allegory about competing cosmological worldviews. According to Usher, the play references not onl Copernicus, but also Ptolemy, as well as Tycho Brahe, who pushed for a hybrid model of the sola system (a compromise that preserved elements of the ancient Ptolemaic system as well as the ne Copernican model). Digges, too, is central to Usher's theory. When Hamlet envisions himself as " king of infinite space" (2.2.255), could he be alluding to the new, infinite universe described—for th first time—by his countryman Thomas Digges?

Usher's proposal may sound far-fetched—but even skeptics do a double take when they look Tycho Brahe's coat of arms, noticing that two of Tycho's relatives were named "Rosencrans" an "Guildensteren." And Usher isn't quite alone; several mainstream Shakespeare scholars are at lea willing to admit that the playwright was influenced by Tycho's astronomy.

Shakespeare's characters were connected to the cosmos in a way that seems quite foreign to th modern reader. They have, to use Thomas McAlindon's phrase, "cosmic imagination": Whethe crying for joy or shedding tears of anguish, they look to the heavens for confirmation, calling out "Jupiter" or "the gods" or "the heavens" as they struggle to make sense of their lives.

And so we find, not surprisingly, a multitude of references to astrology. But some of Shakespeare characters also speak out *against* such superstitions, as when Cassius declares, "The fault, dear Brutu is not in our stars, but in ourselves, that we are underlings" (*Julius Caesar* 1.2.139–40), or whe Edmond, in *King Lear*, ridicules those who blame their misfortune on the heavens, dismissing suc astrological conceit as "the excellent foppery of the world" (1.2.104). As for religion, thoug Shakespeare often alludes to biblical stories, he never once uses the word "bible." Nor do h characters put much faith in life continuing beyond death. He lived in an age of belief, yet a streak skepticism runs through his work, especially toward the end of his career; in *King Lear* it reaches a almost euphoric nihilism. His characters often call upon the gods to help them, but their despera pleas are rarely answered. Was Shakespeare a closet atheist, like his colleague Christopher Marlowe?

* * *

Of course, one has to tread carefully. Shakespeare is not only the most beloved writer in the Englis language, but also the most closely scrutinized. There is an enormous amount of very goo

scholarship on the playwright's life and work, and a significant amount of not-so-good scholarshi
One reason there is so much to potentially be said about Shakespeare is that *he* said so much: He w
prolific, with an output in the ballpark of 885,000 words. Yet there are only a few scraps
documentation to illuminate his personal life, and we can make only educated guesses regarding h
private thoughts and beliefs. With no diaries, no letters, and no manuscripts, we have to rely
Shakespeare's published works. There is the perpetual danger of attributing the beliefs of h
characters to the playwright himself. And, since Shakespeare uses language that is often challengi
for the modern reader, his precise meanings are sometimes elusive (indeed, sometimes they a
intentionally ambiguous). There is always the temptation to bend the facts to fit one's pet theory. (A
with the Bible, one can find anything in Shakespeare if one looks hard enough.) We will consider
variety of opinions—mainly from established Shakespeare scholars, but occasionally from tho
whose expertise lies in another field but who nonetheless have something to contribute to o
understanding of Shakespeare's world. I will do my best, however, to always indicate how widel
accepted—or not—the various viewpoints are.

In the chapters ahead, we will examine the science of Shakespeare's time, beginning with a detail
look at the astronomical knowledge of his day, and then broadening our canvas to include the physic
and life sciences more generally—along with the astrology, alchemy, and magic with which they we
so deeply intertwined. Throughout the journey we will stop to ask what Shakespeare knew, and how
may have influenced his work. Obviously, Shakespeare was not the Carl Sagan of the Elizabethan Ag
—his first commitment was to his stagecraft, not to philosophy or science.* But I would argue that
close reading of his works reveals the depth of his interest in the natural world, and I hope to sho
that he was more conscious of the changing conception of the cosmos than we usually imagi
Shakespeare's writing often reflects the scientific ideas of his time—and the philosophical problem
they were raising—and the more carefully we look at those ideas the better we can appreciate t
scope of his achievement.

1. “Arise, fair sun…”

A BRIEF HISTORY OF COSMOLOGY

Shakespeare’s audience did not have to look far to see the stars: A wooden canopy projected out ov the stage, and its underside—known as “the heavens”—was decorated with brightly painted stars a constellations. It served its purpose in *Hamlet*, for example, when the prince refers to “this bra o’erhanging firmament, this majestical roof fretted with golden fire” (2.2.283–5) or when Caes declares that “the skies are painted with unnumbered sparks” (*Julius Caesar* 3.1.63).

The view of the universe engendered by this simple theatrical device wasn’t so far off from ho our ancestors had envisioned the cosmos for thousands of years: We look up at night, and we see a uncountable number of stars, brilliant pinpoints of light, seemingly painted on the vast dark canvas the night sky.* And back then, before the light pollution brought by electrical lighting, the sky *real was* black. In *Antony and Cleopatra*, when Lepidus says to Caesar, “Let all the number of the sta give light / To thy fair way!”, we might imagine that the stars truly shone brightly enough for th purpose (3.2.65–66). (In practice, a bit of moonlight would probably help.) The stars were intimate familiar, yet at the same time deeply mysterious. They were certainly far away—climbing the highe hills did not seem to bring them any closer—but how far away, one couldn’t say. Perhaps they lay ju out of reach; a little farther, perhaps, than the great oceans or the highest mountain peaks.

The sun was more familiar, its presence more intimate: the brightest of lights; the giver of lif Everyone knew that it rose in the east and set in the west, but they also knew the subtle variation that pattern over the course of a year: In the winter, the sun makes only a low arc across the southe sky, while summer brings longer days in which the sun takes a much higher path across the sky. Th cycle repeats, with perfect dependability, year after year. A farmer had to know the sun’s movement– but so, too, did a playwright; for the action to be visible, one had to contend with the harsh sunlight midsummer as well as the long shadows of autumn and the all-too-early darkness of the wint months. Sophisticated stagecraft and spectacular costumes mean nothing if audience members have squint to see them. As Peter Ackroyd writes, Shakespeare was “aware of the passage of time and daylight across the open stage, so that he wrote shadowy scenes for the hour when the shadows beg to deepen across London itself.” Stage directions calling for a character to enter “with a torch” “with a light” tend to come in a play’s final act. (There is also some evidence that the Globe wa constructed in alignment with the position of the rising sun on the summer solstice.) Of course, o might misread a signal: In *Romeo and Juliet*, the two lovers famously quibble over the signs of th coming dawn. A bird cries—but was it the lark, or the nightingale? “Night’s candles are burnt out Romeo declares, “and jocund day / Stands tiptoe on the misty mountain tops.” Juliet has heard a seen the same signals, but her wishful thinking interprets them quite differently: “Yon light is not da light, I know it, I: / It is some meteor that the sun exhales.” (The physics of meteors was not y understood; a common guess was that they were vapors “exhaled” by the earth under the sun

influence.) Eventually, Romeo gives in; if Juliet says it is night, so be it:

I'll say yon grey is not the morning's eye,
'Tis but the pale reflex of Cynthia's brow.
Nor that is not the lark whose notes do beat
The vaulty heaven so high above our heads.

(3.5.19–22)

The only tricky part for a modern reader is perhaps the reference to "Cynthia"; in a good scholar edition, a footnote will explain that Cynthia was a name for the moon goddess in Greek mythology. A Romeo notes, a cloud reflecting the light of the moon could indeed be mistaken for the coming dawn.

The rising sun intrudes on the young lovers in *Romeo and Juliet*; it intrudes, too, on th conspirators in *Julius Caesar*. They gather for a nighttime meeting in Brutus's garden to plot the next move—but take time out of their scheming to argue about where, exactly, the sun will rise:

DECIUS

Here lies the east. Doth not the day break here?

CASKA

No.

CINNA

O pardon, sir, it doth, and yon grey lines
That fret the clouds are messengers of day.

CASKA

You shall confess that you are both deceived.
Here, as I point my sword, the sun arises,
Which is a great way growing on the south,
Weighing the youthful season of the year.
Some two months hence, up higher toward the north
He first presents his fire, and the high east
Stands as the Capitol, directly here.

(2.1.100–110)

There are murders to plan, ambitions to thwart, and nations to rebuild—but first, *let's argue about th position on the horizon where the sun will rise!* Nothing will happen, it seems, until this point can b agreed upon. Interestingly, Shakespeare gets it *almost* right. We know that it's mid-March (the "ides and all that), which means it's almost the equinox—and therefore the sun will rise almost due east, n "a great way growing on the south," as Caska proclaims. But he is right that, as the weeks pass, th sun's position as it rises will advance to the north. (But the *time* is a problem: Later in the scene w are told that it's three o'clock—too soon for the sunrise, or even the dawn's early light, at any time o

year.)*

The moon's appearance and movement is every bit as familiar as that of the sun: It, too, rises in th east and sets in the west, though its appearance changes dramatically as it goes through its famili phases, waxing and waning in its monthly cycle. For a few days each month it disappears completel only to reappear as a thin crescent in the western sky, where it shines for a short time after sunse About a week later it reaches "first quarter," shining like a capital "D" in the southern sky. Anothe week passes, and it becomes a majestic full moon, rising opposite the setting sun and shining all nig long. The lunar cycle repeats as dependably as its solar counterpart.

And then there were the stars—"these blessed candles of the night," as Bassanio poetical describes them in *The Merchant of Venice* (5.1.219). They move as well—not haphazardly, but i unison, also from east to west. If you face north, they appear to revolve in a counterclockwi direction, as if attached to a giant pinwheel. Only the north star, or "pole star," seems to remain fixe at the center of this pinwheel. (Known as "Polaris" since the seventeenth century, the north st happens to lie close to the north celestial pole, the imaginary spot that the Earth's axis points toward This basic astronomical fact was, of course, well known to Shakespeare. In *Julius Caesar*, the gener compares himself to the pole star: "… I am constant as the northern star, / Of whose true-fixed an resting quality / There is no fellow in the firmament" (3.1.60–62). Because the other stars mov around the north star in a smooth circle and at a steady rate, one can use the sky itself as a cloc Telling time by the stars is a straightforward task for Shakespeare's characters, as it must have bee for his audience. In *Henry IV, Part 1*, a farmer tracks the time by noting the position of the B Dipper, known in Britain today as "the Plough" but in Elizabethan times as "Charles's Wain," that i "Charles's Wagon": "Charles's Wain is over the new chimney, and yet our horse not packed" (2.1.2- 3).

Although the distance to the stars was unknown, it was convenient to imagine them lying at som fixed distance from the Earth, attached to the inner surface of a vast, transparent sphere. The sphe turned about the Earth, carrying the stars with it; one lived at the center of this arrangement, watchi the heavens' endless procession.

The stars also display a second kind of motion. Along with the daily rising and setting, the enti pinwheel seems to shift slightly from night to night. As the weeks pass, the shift becomes mo noticeable. Consider Orion, the mighty hunter. In autumn, it rises about midnight. By Christma however, it rises much earlier, around the time of sunset. By the following autumn, Orion once aga rises at midnight. This cycle, like that of the seasons, lasts one year. These motions a straightforward and predictable. A shepherd would have known which constellations were visible i which season, and in which direction one would have to gaze.

THE WANDERERS

But there were certain objects in the night sky whose behavior wasn't quite so simple. From ancie times, skywatchers noticed that there were a handful of starlike objects that did not quite move unison with the other stars; they changed their position against the constellations from night to nig and from season to season. Today we call them planets; the word derives from the Greek term fo "wanderer." Five of these wandering stars were known in ancient times—Mercury, Venus, Mar Jupiter, and Saturn.

Although the planets wandered, they did not run amok: One could always depend on finding the within a narrow band that circles the night sky, the belt defined by the twelve constellations of th zodiac. In this respect, they are like the sun and moon, which also keep within the zodiac, and so or

sometimes spoke of seven (rather than five) wandering bodies. But there were some intriguin differences in the paths that these wandering stars seemed to take: Mercury, looking like a di reddish star, moved swiftly—only the moon seemed to move faster—and yet it always appeared clos to the sun. Brilliant white Venus moved a little slower, and strayed a little farther from the sun, bu not too far (neither planet was ever seen *opposite* the sun). Mars, with its distinctive reddish colo moved more slowly than the sun; so, too, did Jupiter and Saturn, both creamy white in color. The paths took them across the entire sky, so that sometimes they were near the sun, sometimes opposi the sun. Of these, Saturn was the slowest of all; it took weeks before its motion against the backgrou stars was perceptible, and required almost thirty years to complete a full circle relative to th background stars.

To the title character in Christopher Marlowe's *Doctor Faustus*, such motions were elementar The doctor distinguishes "the double motion of the planets"—referring to their daily rising an setting, and also to their more complicated motion against the stars of the zodiac. Saturn's motion, h says, is completed "in thirty years, Jupiter in twelve, Mars in four, the sun, Venus, and Mercury in year, the moon in twenty-eight days. Tush, these are freshmen's suppositions" (7.51–56). Actually, th period for Mars is closer to two years than four, but close enough: For Marlowe, and for his learne doctor, this basic comprehension of the heavens—knowing which objects were visible, in which pa of the sky, and for how long—was everyday knowledge.

The planets, however, were more than just points of light in the night sky: They were als associated with gods. Each had its own powers, its own domain of influence. For both the Greeks an the Romans, Venus was the goddess of love; Mars was the god of war. Saturn was a god of agricultu and of time, while Mercury was a kind of messenger, a god of travel—which makes sense, give Saturn's plodding pace and Mercury's swiftness. Jupiter, often the brightest of the planets, was th king of the gods.*

The movement of the planets showed many regularities—but also some downright peculi behavior. From night to night, the planets *usually* edged a little bit to the east; as the weeks passe this was easily observed. Eventually, they completed a full circle against the backdrop of the stars. B for several weeks or months each year they would reverse their direction, moving westward fro night to night, before resuming their usual eastward motion. Astronomers refer to this backtracking a "retrograde" motion, in contrast to the more usual "direct" motion. Again, these were familiar term in Elizabethan times—as much for their use in astrology as in astronomy. In *All's Well That End Well*, Helena plays with this idea, poking fun at Parolles's skills on the battlefield:

HELENA

Monsieur Parolles, you were born under a charitable star.

PAROLLES

Under Mars, I.

HELENA

I especially think under Mars.

PAROLLES