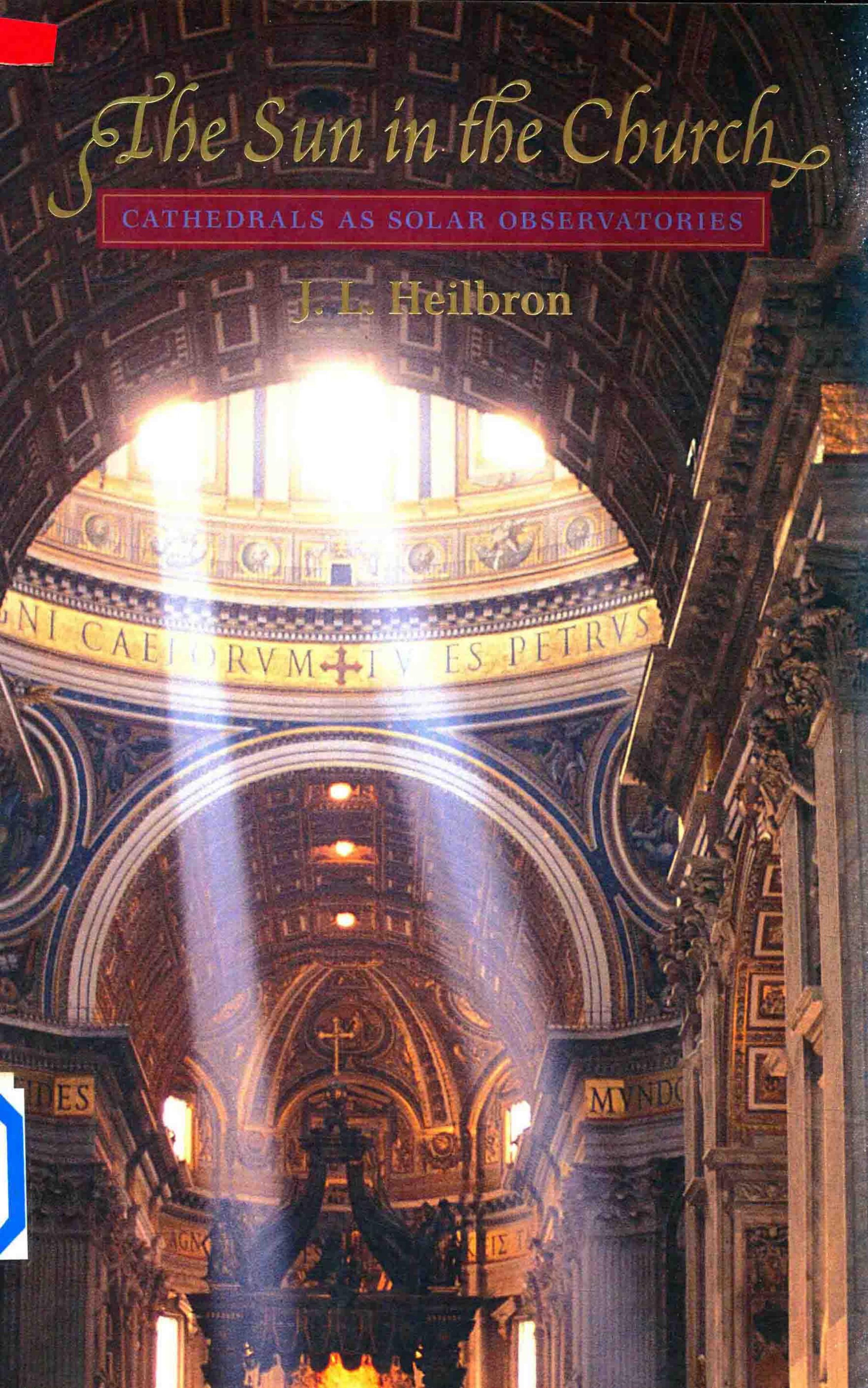
The Sun in the Church

CATHEDRALS AS SOLAR OBSERVATORIES

J. L. Heilbron



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The Sun in the Church

For Alison

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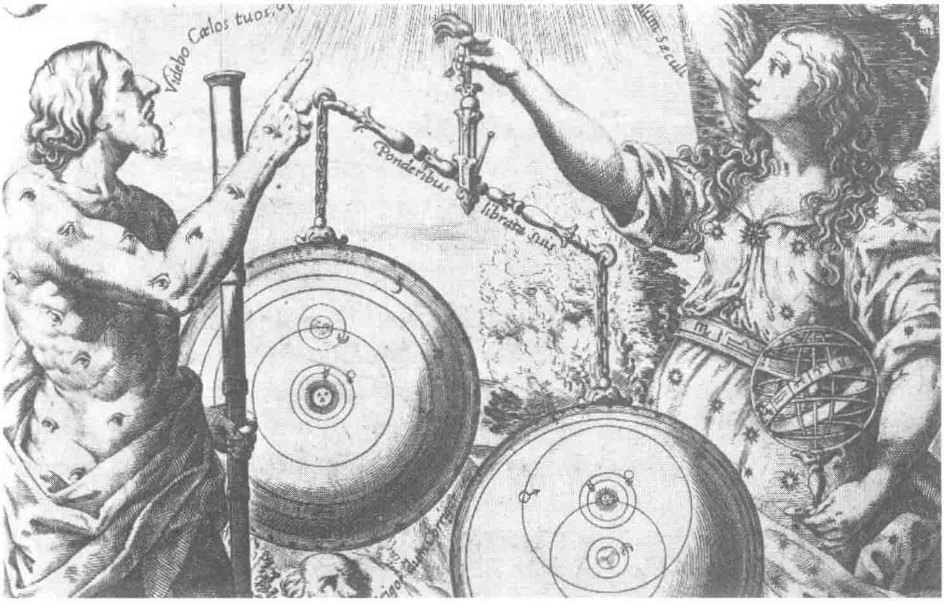

Introduction

The Roman Catholic Church gave more financial and social support to the study of astronomy for over six centuries, from the recovery of ancient learning during the late Middle Ages into the Enlightenment, than any other, and, probably, all other, institutions. Those who infer the Church's attitude from its persecution of Galileo may be reassured to know that the basis of its generosity to astronomy was not a love of science but a problem in administration.[1] The problem was establishing and promulgating the date of Easter.

The old theologians decreed that Easter should be celebrated on the Sunday after the first full moon after the vernal equinox—that spring day on which the hours of daylight and darkness are equal.[2] This special full moon can be observed easily in principle and also often in practice. One needs only to recognize the equinox, wait until the next full moon, and declare the following Sunday to be Easter. That would give the right day for Easter, but not enough time to prepare for it. There lies the administrative problem. In addition, the equinox and the full moon occur at different times at different places on the earth, as, of course, does

Sunday. Even if all observations were correct, Easter might be celebrated on different days in different places. That was unacceptable to an organization struggling to make good its claims to unity and universality.

To avoid these inconveniences, the Church calculated the dates of Easter several years in advance and required observance on the Sundays specified in its tables. Since neither the lunar nor the solar year contains an even number of days, and, moreover, the year does not contain an even number of full moons, and, again, Sundays do not recur regularly on the same calendar dates, the computation of the Easter canon was neither easy nor accurate. Everything depended on exact average values of the periods between successive vernal equinoxes and between successive full moons. Administrators frequently have to make decisions on insufficient data. The bishops accepted the Julian year of 365.25 days as the interval between spring equinoxes and, as an approximation to the average number of full moons, or lunations in a Julian year, a value previously used by the Greeks.

The popes forced consensus on these numbers and procedures during the sixth century. By the twelfth century, however, they could see that the parameters of their predecessors no longer gave Easters in harmony with the heavens. In this emergency, popes encouraged the close study of the apparent motions of the sun and moon. The experts consulted ancient Greek mathematical texts that were then, luckily for them, just being turned into Latin from Arabic intermediaries. The most important of these texts was Ptolemy's "Great Compilation," which showed how to represent the motions of the stars, the luminaries (the sun and the moon), and the planets as seen from a stationary earth. Ptolemy's mathematical hypothesis, that the earth stands still at the center of the universe, seemed the most obvious and satisfactory basis for an exact astronomy. Not only did it conform to the evidence of the senses, it fit perfectly with the physical books of Aristotle, then, by 1200, also newly available.

The key parameter in the Easter calculation was the time of return of the sun to the same equinox. The most powerful way of measuring this cycle was to lay out a "meridian line" from south to north in a large dark building with a hole in its roof and observe how long the sun's noon image took to return to the same spot on the line. The most convenient such buildings were cathedrals; they came large and dark and needed only a hole in the roof and a rod in the floor to serve as solar observatories. The accuracy of the results depended on the care taken in installation: correct positioning of the hole, proper orientation of the rod, and exact leveling of the floor.

This book originated in the pleasant viewing of meridian lines installed in four Italian and one French cathedral during early modern times. They have the merits of beauty and utility, which to some observers were one and the same thing. "If the beauty of astronomical instruments depends on the usefulness of the results that can be obtained from them, then meridian lines can be counted among the most beautiful of things."[3] The writer of these lines, reviewing a *meridiana* built in the early eighteenth century in the assembly room of a small academy of sciences in Siena, had in mind not only measurements for correcting the calendar but also a wide range of fundamental studies. The academy's line proved too small to contribute to either purpose. Its model, the *meridiana* in the grand cathedral of San Petronio in Bologna, was another matter. According to the most authoritative compendium of the natural knowledge of the eighteenth century, it "made an epoch in the history of the renewal of the sciences."[4] Together with its counterparts in Florence, Paris, and Rome, "it would be celebrated in ages to come [to quote another eighteenth-century enthusiast] for the immortal glory of the human spirit, which could copy so precisely on the earth the eternal rule-bound movements of the sun and the stars."[5]

The story of the *meridiane* lies at the intersection, or, perhaps more fairly, at the margins, of many fields now usually held apart: architecture, astronomy, ecclesiastical and civil history, mathematics, and philosophy. Two world-historical events shaped the marginal story: the transformations in applied mathematics, with astronomy in the lead, that are supposed to have given Europeans the capacity to conquer the world,[6] and the Reformation, which, among much else, oversensitized the Catholic Church to deviant thinking. The Catholic Reformation met the new astronomy in the deviant thinker Galileo. The ill-advised condemnation of the theory of a moving earth that resulted from the collision made new difficulties for administrators. The Church needed up-to-date astronomers as much after its mistaken martyring of Galileo in 1633 as it had when the popes first puzzled themselves over Easter.

Renaissance and Astronomy

The Europeans read their translations of the Arabic versions of Greek mathematics, together with Arabic commentaries and analyses, over and over again, expecting—for such was the authority of an Aristotle or a Euclid over the unprepared minds of the best-educated Europeans—that the ancient books would have the answers to contemporary questions. Of all the recovered books, Ptolemy's *Almagest* (to give the great compilation the Anglicized Latinized Arabic title by which it is generally known) was technically the most demanding. The standard medieval version, made from the Arabic in 1185, began to circulate just as natural places for its study, the universities of Paris and Oxford, were forming. But the book far exceeded the capacities of almost all the members of both academies. The primer they needed was supplied by a professor in Paris educated at Oxford, Johannes de Sacrobosco, or John of Hollywood, perhaps the most successful writer of textbooks after Moses and Euclid. Sacrobosco's introduction to Ptolemaic astronomy, *On the sphere*, written around 1220, became required reading for the B.A. at Paris and Oxford; it was the first technical work on astronomy ever printed; and it inspired hundreds of reprintings and commentaries in many languages well into the seventeenth century.[7]

Those who advanced from Sacrobosco to the Latin-Arabic *Almagest* and its commentators had the mixed satisfaction of mastering the method and discovering that it did not work. Most of them relied upon tables derived on Ptolemaic principles by the able polyglot astronomers of Alfonso the Wise of Castille in the middle of the thirteenth century.[8] Alfonso's tables provided the raw material for the calculation of planetary positions for three hundred years even though the predictions disagreed systematically with observations. One adept who noticed a discrepancy was Copernicus, who recorded in his copy of the Alfonsine tables published in 1492 that he once saw Saturn almost a month behind its calculated position.[9]

· WORKING OVER PTOLEMY ·

Two paths lay open to European astronomers frustrated by the disparity between their observations and Ptolemy's theories as gathered from Arabic sources and applied in the Alfonsine tables. One way would be to seek another way, to condemn the Ptolemaic system as fundamentally flawed and, as Copernicus began to do, construct an alternative. This *via moderna* did not recommend itself to men strongly gripped by the achievements of the ancients. Supposing therefore that neither they nor Ptolemy could be responsible for the shortfall in their science, they blamed the long train of transmission to and through the Arabs. During the first half of the fifteenth century scholars fleeing the Turkish stranglehold on Constantinople brought west what many astronomers believed would be the key to modern astronomy, Ptolemy in his original Greek.

The knight who carried this grail to Italy was Cardinal Johannes Bessarion, who, it is said, had learned Latin expressly to translate Ptolemy.[10] Ambassadorial assignments for the Holy See interfered with his project, however, until they took him to Vienna in 1460 to negotiate help for Pius II's proposed crusade to reconquer Constantinople. There he met the professor of mathematics Georg Peurbach and his student Johannes Müller, then twenty-four, who became celebrated under the name Regiomontanus. Peurbach had been trying to improve the old Latin version of Ptolemy by sheer brain power, working backward from known errors. Bessarion arranged for both of his new friends to go to Venice, where he kept his manuscripts; Peurbach was to make an abridgment or *Epitome* of the *Almagest* and Regiomontanus the long-sought translation. Peurbach died just before they were to leave Vienna. The loss, which saddled Regiomontanus with the *Epitome,* was the lesser of the impediments to his realization of Bessarion's project. The greater was that he knew no Greek.

In Italy Regiomontanus busied himself studying Greek and cultivating acquaintance with humanists versed in it. Among them were Paolo del Pozzo Toscanelli, who was to design the first cathedral *meridiana,* and George of Trebizond, a translator of Greek mathematical texts or, as Regiomontanus styled him, "a perverse and impudent blabbermouth." That might have been a mistake. After spending a few years back in central Europe, Regiomontanus returned to Italy in 1476 to advise the Pope, Sixtus IV, about correcting the calendar. He died suddenly in Rome, some say of the plague, others of an adverse comet, still others of poison administered by the vengeful sons of George of Trebizond.[11] Regiomontanus died before he could produce an *Almagest* purged of the errors of the ages. The Greek text he worked on appeared in print in 1538, just as Copernicus was completing the book that would make it obsolete. The true Ptolemy proved little better than the transmitted one for controlling what Regiomontanus, in his indulgent way, called the "worthless" tables of Alfonso.[12]

"Just as Hercules held up the heavens when Atlas became tired, so when his fellow countryman Johannes Regiomontanus passed away, Copernicus revived the science of heavenly motions."[13] This assessment, wrong only in all the details (Regiomontanus was German, Copernicus Polish, and the new Hercules was only three when his Atlas died), is right, where it counts. Copernicus began where Regiomontanus had been thirty-five years before, in Italy, studying Greek and working on Peurbach's *Epitome* (in Copernicus' case, the printed edition of 1496). Copernicus had been sent south by his uncle, the Bishop of Varmia, to prepare himself for a canonry in the bishop's cathedral. The young man studied medicine, law, and the classic literatures as well as astronomy, spending seven years soaking up the sun and the Renaissance. He returned home in 1503 to help his uncle run the diocese and face down the Teutonic Knights. To improve his Greek and to establish himself as a humanist, he published as his first book a Latin translation of an obscure Byzantine poet. The choicer Greek authors had long since found modern editors, luckily for them. Copernicus' Greek was as accurate as the Alfonsine tables.[14]

Among the classical writers Copernicus read was Plutarch, who recorded the Pythagorean opinion that the earth revolves about a central fire and also spins like a wheel.[15] The basic qualitative conception of a planetary system centered on the sun was not far to seek in Renaissance Italy. But no one before Copernicus had had the conviction and energy to develop this classical commonplace into a quantitative astronomy. A crude idea of the magnitude of the technical task of rewriting Ptolemaic theory for a moving earth, taking into account the observations made by star gazers of unequal capacities over a thousand years, may be obtained by counting. In its standard English edition, Copernicus' *De revolutionibus orbium coelestium* has 330 folio pages, 143 diagrams, a hundred pages of tables, and over 20,000 tabulated numbers. It took Copernicus most of the forty years from his return from Italy until his death in 1543 to work it all out. What made him do it is not known.

For the practical astronomer or astrologer concerned to predict the positions of the planets, the merit of the new system would lie in the accuracy of the tables deduced from it. A Protestant professor at the University of Wittemberg, Erasmus Reinhold, undertook the task. His *Tabulae prutenicae*, so named after his patron, the Duke of Prussia, appeared in 1551. They did not make an epoch in astronomy. Since, technically, Copernicus' system was only Ptolemy's with the sun and earth interchanged, and Copernicus' celestial parameters were not always better, and sometimes worse, than his predecessors', Reinhold's tables could not have been much more accurate than Alfonso's.[16] From a purely quantitative point of view, Copernicus left the field much as Regiomontanus had found it a century earlier.

Qualitatively, however, Copernicus' scheme had striking advantages over Ptolemy's. Merely by assigning the earth the third orbit from the center, it explained why the apparent motions of the so-called inferior planets, Mercury and Venus, differ so greatly from those of the superior ones, Mars, Jupiter, and Saturn. Since the inferior planets lie within the earth's orbit, they never appear far from the sun; owing to this confinement, Venus serves as the morning star when west of the sun and the evening star when east of it. The superior planets can appear at any angular distance from the sun as seen from the earth. They are brightest when opposite the sun because they are then closest to the earth. Ptolemy's system needed special and implausible assumptions to account for these and other appearances that followed naturally on Copernicus'.[17]

Against these advantages weighed the obnoxious assumption of the continuous, complicated, and rapid revolutions of a huge heavy body apparently at rest. Aristotelian physics disallowed the earth an enduring natural motion around the center of the universe. Common sense observed that the earth's spinning, which Copernicus proposed as an explanation of the alternation of day and night and the motions of the stars, would cause great easterly winds and leave the birds behind. Theologians objected that Scripture expressly stated that the sun moves, for otherwise Joshua would not have commanded it to stand still.

Copernicus spoke to all these objections in a lengthy dedication of *De revolutionibus* to Pope Paul III. He told the Pope that he had almost resolved not to make his system public for fear that its novelty and peculiarity would arouse the ignorant. But two of his friends, a bishop and a cardinal, pressed him to publish. He yielded and chose the Pope as judge and dedicatee, "for even in this very remote corner of the earth where I live you are considered the highest authority by virtue of the loftiness of your office and your love for all literature and astronomy [the pope was a devoted astrologer]."[18]

As for the babblers who might bend Scripture into censure, "I despis[e] their criticism." They know nothing. Great theologians have written childishly about the earth's shape. They should stick to their business. "Astronomy is written for astronomers," that is, for mathematicians. They will recognize the theoretical merits of the new approach and also the utility to the church in its values for the parameters needed to reform the calendar. "But what I have accomplished in this regard, I leave to the judgment of Your Holiness in particular and of all other learned astronomers."[19]

Copernicus was too ill and too distant from his publisher to see his masterpiece through the press. The supervision was entrusted to a bellicose Lutheran theologian, Andreas Osiander, who cultivated astronomy primarily for its usefulness in dating the Apocalypse. He thought to strengthen the protection afforded by the dedication to the Pope, which carried negative weight with his co-religionists, by a foreword of his own, which he did not sign, probably so as not to add to the book's burden an association with a controversial theologian. The truth, according to Osiander, is that there is no truth in astronomy. Various hypotheses can account for the appearances. In this predicament, the astronomer should pick the one easiest to grasp. "Therefore alongside the ancient hypotheses, which are no more probable, let us permit these new hypotheses also to become known, especially since they are admirable as well as simple and bring with them a huge treasure of very skillful observations. So far as hypotheses are concerned, let no one expect anything certain from astronomy, which cannot furnish it, lest he accept as the truth ideas conceived for another purpose, and depart this study a greater fool than when he entered it."[20]

· WORKING OUT COPERNICUS ·

In 1563 a Danish noble boy (he was then sixteen) attending the University of Leipzig observed a grand conjunction (an alignment of Jupiter and Saturn) a month away from the date given in the tables. He thought the discrepancy intolerable. He later wrote that the experience inspired his resolution to depart from the usual practice of astronomers, who based their hypotheses on a few measurements of the planets made at theoretically significant times, and to renew astron-