IMMORTALS OF SCIENCE

COPERNICUS
Titan of Modern Astronomy

by DAVID C. KNIGHT

KNIGHT

COPERNICUS Titan of Modern Astronomy

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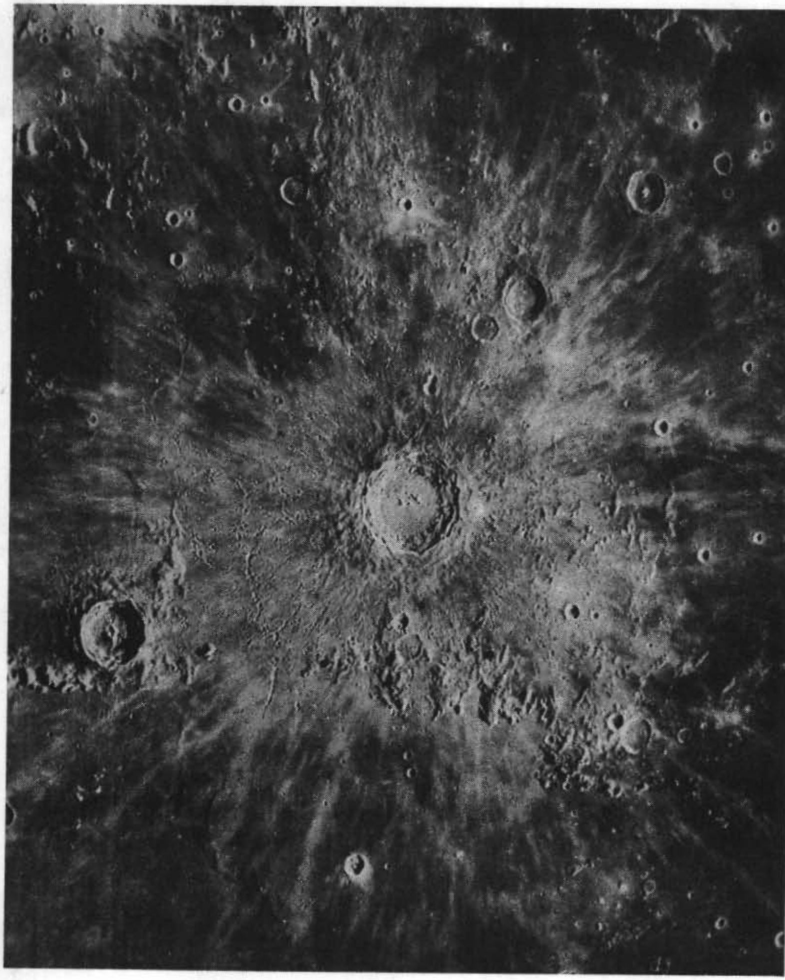

The crater Copernicus on the moon. Located in the Mare Imbrium (Sea of Showers), it is fifty-five miles across, with mountain peaks inside. It was named after Copernicus in 1651 by Father G. B. Riccioli, a Jesuit astronomer of Bologna. (Photo by Lick Observatory)

Symbolic portrait of Copernicus by the Polish artist Arthur Szyk. Represented here as a churchman and scholar, the astronomer holds in his left hand a device illustrating the heliocentric system, with sun at center. Before him is the famous Jagellonian golden globe. Lantern is such as he used on his observation tower at night. (Courtesy of the Kosciuszko Foundation, New York)

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DAVID C. KNIGHT

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COPERNICUS: TITAN OF MODERN ASTRONOMY

THE RELUCTANT REVOLUTIONARY

PROLOGUE

His ancestors could spell the family name a dozen ways and more. Sometimes it was Coprnik or Copirnik or Koprnik. At other times it could be Copernik, Kopirnik, Koppernik, or Koppernigk. More variants included Koppirnik, Koppernig, and Koppirnig. In his youth he would often sign himself (differently from his own brother!) as Coppernic or Coppernicus. As he grew older, he leaned toward the latter spelling with a single "p." It is by this Latinized spelling that history prefers to call him today — Copernicus.

Like the uncertain spelling of his name, the life of Nicolaus Copernicus is an elusive thing. It is full of contrast, of shadows, of vague comings and goings, of the old and the new. History has a hard time pinning down the great astronomer. Some Germans still claim that Copernicus was a German. But the Poles rightly claim him for their own and have erected many monuments to him in their land. He is more than a mere national hero, however; the Poles are doubly proud of him, for he belongs to the whole civilized world.

He was one of the best-educated men of his day. It is possible that he knew five languages — German, Polish, Latin, Italian, Greek — and perhaps a sixth, Hebrew. He attended three of the best universities in Renaissance Europe. Well-rounded and immensely talented, he was a lawyer and a physician. He was a Catholic churchman and also a humanist. He was a painter and a poet. He was an economist and a statesman, a mathematician and patriot. And of course he was an astronomer.

During his lifetime of seventy years, Copernicus appears, disappears, then reappears like some historical wraith. Italy swallows him up twice with little more than his signature on an enrollment paper to show that he was at Padua or Bologna or Ferrara. His own Polish provinces hide his daily activities for years at a time, except for his name scrawled here and there on a property-transfer document.

His very appearance seems to have eluded the artist's brush and the engraver's scribe. The predominant features, it is true, are always present — the thick hair worn short at the neck, the high cheekbones, the squarish jaw. But in the later and largely imaginary portraits there seems no unity running through them. Each somehow seems a different Copernicus. There he sits, or stands, peering out at the beholder, dressed usually in his clergyman's cassock with wide fur collar and short sleeves. Sometimes he holds a tellurian or an armillary sphere. His glance is deep and penetrating, but the large eyes have a dreamy look in them. Nearly always the lips are curved in a faint smile.

Was it a smile of irony — a gentle protest against the bonds of the mighty church that held him, the narrowness of the times in which he lived? Or was Copernicus' smile one that betrayed a secret knowledge — knowledge of an idea so important and revolutionary that it would forever afterward alter men's thinking? We do not know.

But it is not these few surviving portraits of Nicolaus Copernicus that provide the evidence for his greatness, his genius, his individuality. That evidence must always lie in his work. A truly creative man, he was entirely dedicated to his objective. In spite of the limited knowledge of his day, he pursued that objective unswervingly. He knew little personal joy; he never married. He faithfully served his people, his country, his church, thus earning the respect of his contemporaries. But his reward was in reaching out to the heavens, always seeking more proof for his revolutionary theory.

Yet the more proof Copernicus gathered and the more of it he recorded in the manuscript of his life's work, the more reluctant he became to publish it. Did he realize — more fully perhaps than scholars give him credit for today — just how much of a bombshell he was ready to drop in the midst of the limited learning of his day? Never had a single man been in a better position to link the old and the new — to deal medieval thinking a deathblow, and usher in the light of the high Renaissance. Yet the Canon of Frauenburg vacillated and delayed, until at last in his old age friends persuaded him to share his work with the world.

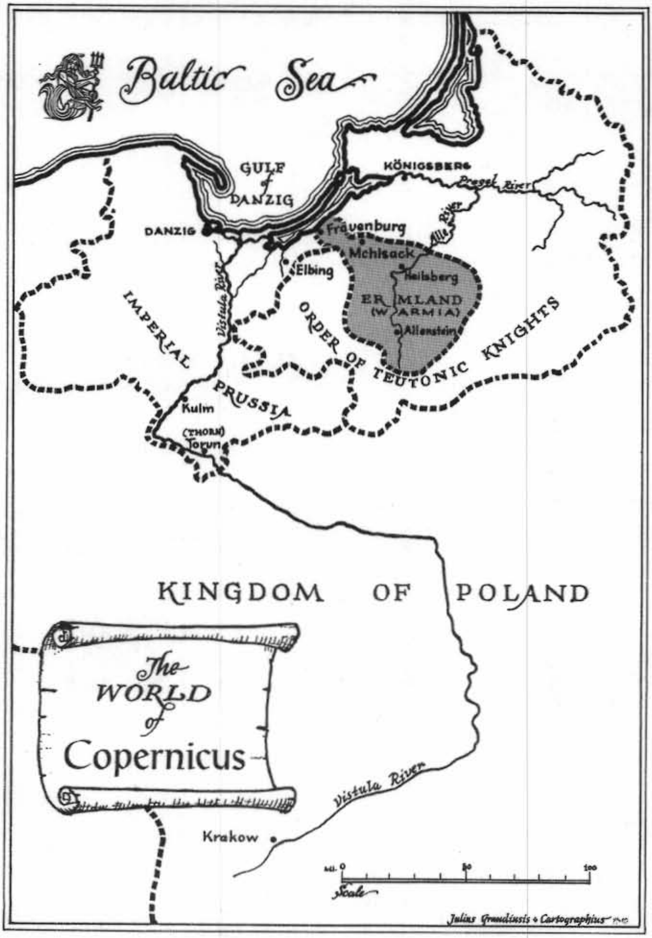
It was only as Copernicus lay on his deathbed that a copy of his finished book reached him. It is known that he reached out and put his fingers on his life's work in his last moments. But, just possibly, did he have the strength to open it — only to find not his own preface but the spurious one of Osiander, proclaiming the work to be, after all, only a theory?

Again, we do not know. Such speculations, like much of Copernicus' shadowy lifetime, remain open to question. But his great book is still with us. And because of it, Nicolaus Copernicus will always be considered one of the truly great men of his or any age. For any biography of Copernicus must of necessity be a biography of that book.

THE WORLD
OF
NICOLAUS COPERNICUS

CHAPTER ONE

When Nicolaus Copernicus was born on February 19, 1473, in Torun, Poland, he was thrust into a politically confused and complicated area of northern Europe. The forces which were to shape the great astronomer's life had been set in motion many years before. Just as no man can separate himself from his environment, so Copernicus could not separate himself from his. To completely understand his world, therefore, we



must go back in time and examine the emerging Polish nation.

After incessant wars during the Middle Ages, Poland was reunited in the fourteenth century under King Casimir the Great, during whose reign the country entered on a new period of prosperity. Casimir established his capital at Kraków, and it grew to be one of the leading cultural cities of Europe. There, in the year 1364, Casimir founded the famous University of Kraków which in the next century attracted some of the best minds in Europe — among them, Nicolaus Copernicus.

Following Casimir's death, his grandniece inherited the Polish crown in the year 1384. This woman soon married the Grand Duke Jagellon of Lithuania, thus founding one of the most fruitful dynasties in Polish history — the Jagellonian. The Grand Duke, taking the name King Ladislas, ruled successfully until about forty years before the birth of Copernicus. Because Poland and Lithuania were now united under one rule, the kingdom became a great power. Indeed, Poland under the Jagellons had never been as powerful before, nor has it been since. In 1410, the combined Polish-Lithuanian forces inflicted a great defeat on the Teutonic Knights, a German military religious order, at the Battle of Tannenberg. With the crushing of the powerful knights, the balance of power was transformed in eastern Europe. For one thing, the domain of the knights now became a Polish fief. For another, under King Ladislas and his successors, eastern Pomerania, large parts of White Russia, and some Ukrainian territories came under Polish rule.

Meanwhile, under the Jagellons, Poland had entered its brilliant Renaissance period. Its art, architecture, and literature flourished. Close cultural links were established with western and southern Europe, where few had existed before. Not only was the University of Kraków becoming a great cultural center, but Poles were attending the famous Italian universities in ever increasing numbers. Copernicus himself formed one of the many "pipelines" that carried information and ideas from the newly awakened learning of Italy northward into Poland.

Still, despite the power and flourishing culture of the Jagellons, the Teutonic Knights remained a thorn in Poland's side. Although they had lost the Battle of Tannenberg, they had by no means lost the war. Even as a Polish fief, forced to pay homage to the Polish kings, the knights could be troublesome. And they continued to remain so throughout Copernicus' lifetime. Possibly if the gentle and scholarly Copernicus hated anyone in his world, it was the Order of the Teutonic Knights.

This Teutonic Order had been founded during the early Crusades of the twelfth century, having been modeled after two other famous orders, the Knights Templars and Knights Hospitalers. Composed mostly of German noblemen, the knights adopted the Augustinian rule of religious life and wore as their distinctive uniform white mantles with a black cross embroidered in gold. In addition to taking the traditional vows of poverty, obedience, and chastity, they adopted as their special mission the fighting of all enemies of the Christian faith. Thus, in later centuries the order became increasingly military in character.

By the thirteenth century, the knights had focused their attention on one pagan enemy in particular. Beyond the Vistula River, stretching northward along the Baltic Sea, lay a territory inhabited by a Baltic people called *Prusi*, or Prussians, who had remained fiercely pagan until this time. For fifty years the knights waged ruthless war against them, and more than once their efforts were on the verge of failure as the Prusi revolted and massacred the Christians. But by 1283 their insurrection was finally quelled, and those Prusi that were left, after this cruel warfare was over, settled down as serfs and adopted Christianity. Thus, all of the territory between the Vistula and a river farther east, the Niemen, was ruled over by the Teutonic Knights. In 1308 the city of Marienburg on the Vistula became the order's seat, and here the Grand Master of the order maintained an impressive court. Colonists flocked in, villages and castles were built, and a lively trade sprang up.

A part of the knights' territories now included a large tract of land known as Ermland (sometimes called Warmia), which the order set up as a separate diocese or see. Practically an independent state, many of the earlier bishops of Ermland were in fact functioning sovereigns of the district; indeed, after 1354, they were acknowledged princes of the German Empire.

Nicolaus Copernicus' uncle, Lucas Waczenrode, became one of these bishops.

After the defeat of the knights by Jagellonian Poles, this situation changed. In 1466 — seven years before Copernicus' birth — Ermland became part of Poland by the Peace of Torun. Yet this left the diocese in a ticklish position. For whoever was bishop of Ermland had on one side of him the powerful Polish Empire, ever anxious to seize more territory from the knights; and, on the other, the knights themselves who constantly dreamed of winning back their lost territories.

When Lucas Waczenrode finally succeeded in having himself consecrated as bishop by the Polish king, he naturally came more and more into the Polish camp. At the same time, of course, he incurred the hatred of the knights. Squeezed between two powerful neighbors, Lucas' main worry was how to survive at all. A shrewd and ambitious man, the Bishop succeeded in walking the thin line between the two, mediated between them, and generally managed to keep his own little diocese of Ermland together. Copernicus, who later was to become a canon under his uncle, the Bishop, had to share these responsibilities.

But all of this still lay far in the future. In the century before Copernicus was born, Poland, first under Casimir the Great, then under the first Jagellon, King Ladislas, was a vast and undeveloped frontier land. Colonists of all kinds were welcomed as settlers. Even to the west, in those lands dominated by the Teutonic Order, the knights encouraged colonists from Holland, Germany, and elsewhere. As in any such period of expansion, all manner of people tried their luck in the new land. Into the Polish lands swarmed tradesmen, farmers, merchants, adventurers, miners, drifters — all eager to carve out new lives for themselves. And, it was from this mass of milling migrants that the ancestors of Nicolaus Copernicus came.

Quite possibly a certain Stanislas Koppernigk who lived in Upper Silesia was one of the astronomer's forebears, for this name appears significantly in records of that region. Toward the middle of the fourteenth century some of this Koppernigk family joined the flood of people entering Poland. One branch of the Koppernigks settled in Kraków itself, which was then the Polish capital. Others settled even farther to the east. The Kraków Koppernigks seem to have gained urban citizenship toward the turn of the century. Evidently they prospered for they bought property and practiced various crafts. Yet, whether the Kraków branch of the family or some other was Copernicus' direct ancestors is still in doubt today.

It is the astronomer's father who first comes into clear focus. His name, like his son's, was Nicolaus and he was known to be a citizen of Kraków. In the middle of the fifteenth century, Nicolaus Koppernigk moved northward up the Vistula River into Polish Pomerania. He settled down in the city of Torun and energetically proceeded to become a prosperous trader in the copper business, on the busy water route of the Vistula. But the elder Nicolaus was ambitious in more ways than one. He began to play politics — and succeeded at it. Not only did he become one of Torun's civic leaders, but he also became an elder or magistrate of the city.

As would his famous son later, Nicolaus Koppernigk had his difficulties with the Teutonic Knights. Some two centuries before, when the knights were subjugating the Prussians, the order had founded Torun as a kind of armed outpost between their own territories and the Poles living to the east. Subsequently, as we know, the knights lost this and other of their lands to the Jagellon Poles. Even so, the knights continued to keep the former Prusi, or native Prussians, firmly under their heel. But as late as the time of Copernicus' father, these still-fierce people rose in revolt against the order. Needless to say, the Poles were sympathetic to such revolt and had even joined the Prussians against the knights. Thus it was that Magistrate Koppernigk, a Polish citizen, became active in the League of Prussian Towns and Districts who were at odds with the knights.

At the time that Nicolaus Koppernigk was building up his mercantile business on the Vistula, there was living in Torun another well-to-do family, the Waczenrodes. They had, in fact, been living there for generations but were originally from Silesia, as was Nicolaus himself. A daughter of this wealthy family, Barbara Waczenrode, became Nicolaus' bride about the year 1463. The couple took up residence in St. Anne's Street in the old part of Torun, where the rich lived.

Four children were born to Magistrate Koppernigk and his wife — two sons and two daughters. Of these, the great Nicolaus Copernicus was the youngest.

THE BOY AND THE BISHOP

CHAPTER TWO

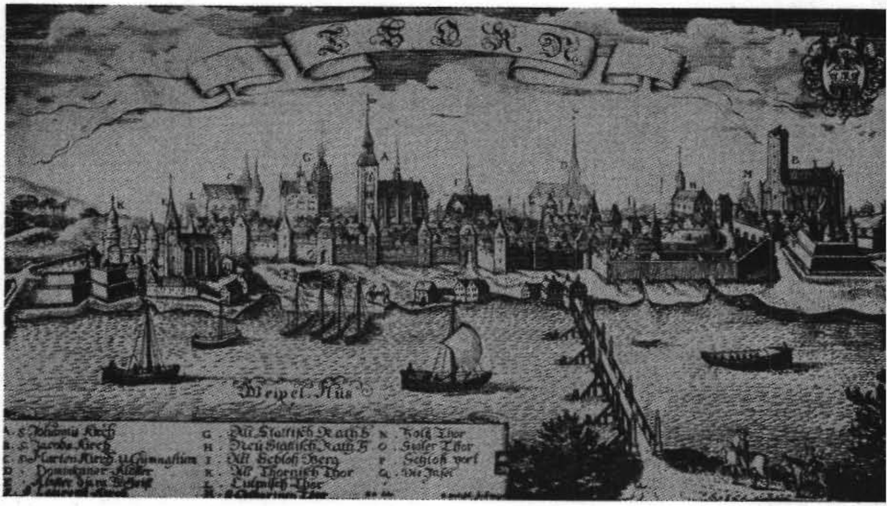
The Vistula River rises on the western slopes of the Carpathian Mountains. On its 680-mile journey to the Baltic Sea, it first flows northwest through foothills, then past Kraków in a northeasterly direction, then almost due north until it reaches Warsaw. Again the great river, lifeblood of Poland, veers northwest past Copernicus' birthplace of Torun — "Queen of the Vistula." From there, it meanders north out onto the vast delta, and at last gives up its waters to the Gulf of Danzig.

Copernicus could not have avoided gazing often at the great river with its busy maritime traffic. Although by Copernicus' time Torun had lost a portion of its trade to the port of Danzig, the number of vessels ascending the river with products from Germany and Holland was still considerable. In the warmer months, lounging about his father's warehouse, Nicolaus watched the ships come and go. In winter, he may have skated on the river with his brother and sisters, for the Vistula freezes solid for two months out of the year.

It is known that the Koppernigks owned vineyards near the Vistula's banks on a hill near a convent. Here, at the family's summer residence, Nicolaus played near the river and heard the shouts of the boatmen over the water. Here, too, as at his father's town house in St. Anne's Street, the boy had contact with the most cultivated families of Torun. Talk of music, art, literature, even science, must have buzzed in his ear — his first contact with those things he would later master in great detail. And of course there was talk of commerce — perhaps the foundation of Copernicus' subsequent deep understanding of money matters and their remedy. The boy, not yet ten, listened and learned.

Sometimes at the Koppernigks' family gatherings there sat at the table a man who was treated with vast respect. Stern-faced with close-cropped hair and penetrating eyes, he wore the robes of a high-ranking Catholic clergyman. In the opinion of the Koppernigks, he was the great man of the family. Later he was to be a key figure in Polish history, and certainly a prime mover in the life of his nephew.

The house in which Copernicus was born, visited by Napoleon in 1807. Much interested in science, the Emperor was surprised that Copernicus' fellow countrymen had not seen fit to honor the great astronomer with a monument in the town of his birth.



Torun, the birthplace of Copernicus.

This man was Lucas Waczenrode, Copernicus' uncle, and brother of his mother, Barbara. Only in his mid-thirties, he was already a canon (or staff clergyman) of Frauenburg Cathedral on the Baltic Sea. His career shared certain similarities with that of his nephew's, (due, no doubt, to his having imposed his own life pattern on Copernicus). Born in 1447, he attended the University of Kraków at the age of sixteen. Later he studied at the University of Bologna in Italy where he received his degree as Doctor of Canon Law in 1475, the year Copernicus was born. Entering the service of the church, Lucas soon won rapid advancement because of his energy and ambition. In the year 1489, he would be appointed Bishop of Ermland, one of the four ecclesiastical dioceses, or districts, into which the church had divided the land of the Prusi for administrative purposes.

The contented family life of the Koppernigks was suddenly interrupted when Nicolaus was ten years old. His father, the copper merchant of Torun, died and Canon Waczenrode generously took over the care of the four Koppernigk orphans. What happened to Copernicus' mother is not known, for there is no further historical mention of her. At any rate, Canon Waczenrode made a good second father to his nieces and nephews. Due to his influence, they came under the general care of the church's educational system. Only one of the children was destined to marry — a sister. The other girl became a nun. Nicolaus and his brother Andreas continued their elementary education in Torun.

When Nicolaus was fifteen, his uncle — a year before he became a Bishop — may have sent him off to the cathedral school of Wloclawek. Situated on the Vistula, some thirty miles south of Torun, this school was considered excellent in preparing young men for higher learning. Its teachers were often graduates of the University of Kraków, and in fact were usually appointed by that institution. Considering its position as a church-dominated school, Wloclawek was remarkably humanistic in its atmosphere. The Humanistic Movement — at this time in full swing — was chiefly a revolt against medieval religious authority and attitudes, and was accompanied by a widespread revival of classical learning stemming from Italy. The humanists themselves formed a kind of intellectual community who traveled from university to university to teach and exchange new ideas. Some were teaching at Wloclawek at this time. One of them was the cathedral's bishop, Peter Mosinski; another was a noted Italian humanist, Philip Buonacorsi, who was responsible for bringing much Renaissance culture to Poland.

If Copernicus did attend Wloclawek, another of his teachers would have been Nicholas Wodka, whose last name meant a kind of Russian distilled liquor. Evidently Wodka did not indulge in alcoholic beverages for he assumed the Latinized name of Abstemius, meaning one who abstains from drinking. Abstemius was an expert in *gnomonics*, or the building of sundials. He and the seventeen-year-old Copernicus may have combined their talents and constructed the sundial on the south side of Wloclawek Cathedral.

It is likely that, assuming he did attend Wloclawek, Nicolaus Koppernigk, by coming into contact with men like Abstemius, first became interested in the movements of the heavenly bodies. Certainly the passage of the sun's rays over the face of his sundial must have aroused his curiosity as to the path of the sun itself. Yet even this is not known for sure. Besides, the youthful Copernicus had his future career to think of. In any event, there lay ahead for the future astronomer the bustling intellectual world of the University of Kraków far up the Vistula.

COPERNICUS GOES TO KRAKOW

CHAPTER THREE

Nicholaus Koppernigk was eighteen when he traveled south up the Vistula to attend the great University of Kraków. With him went his elder brother Andreas. In all probability, the decision to go to the Polish university was made for the young men by their influential uncle, Lucas Waczenrode. The Bishop envisioned a church career for his nephews and attendance at the Kraków university was the initial step in such a ca-

View of Krakow in 1493 during Copernicus' student days. In the center, with two towers, is St. Mary's Church. Location of the University is indicated by the circle.

reer. There were other reasons, too, why the Bishop had selected Kraków for the Koppernigks. Waczenrode himself was a graduate of the university and could thus steer Nicolaus and Andreas toward helpful connections there. Moreover, as a powerful churchman ruling over the vast diocese of Ermland, he could rest assured that his nephews would move in the highest cultural and social circles. Also, the Koppernigks' father had once lived and worked there and his old business acquaintances might come in handy to the young men.

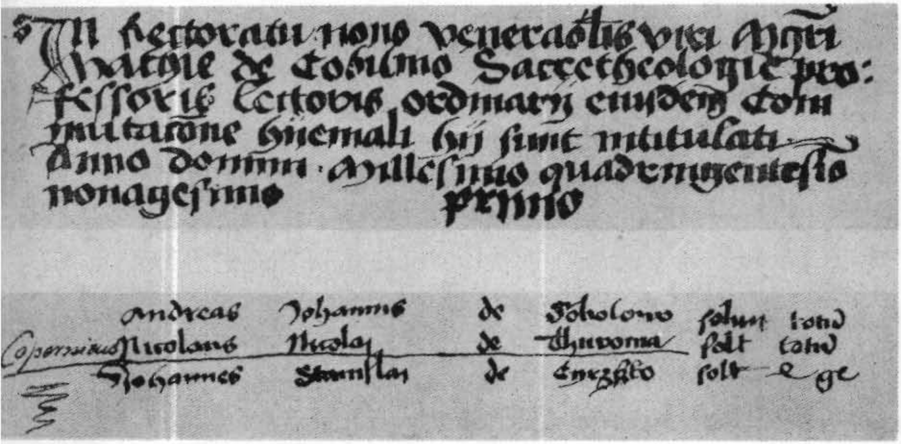
Not only was the city of Kraków the capital of Poland at this time, but it was also a metropolis known throughout Europe for its wealth and culture. Situated as it was across the trade route joining the Orient with central and western Europe, Kraków was a bustling hub of economic activity. The city itself possessed a charm that was felt by strangers and natives alike. Krakóvians were described as "distinguished for their intelligence, manners, and courtesy to strangers," and their city contained everything a man could desire. As far as Copernicus was concerned, all of this could hardly have failed to influence the development of his sensitive mind. In fact, he later declared that he was indebted to Kraków for everything that he ever became.

The university there attracted students from all parts of Europe — Germany, Italy, Switzerland, Hungary, Bohemia, England, even northern Scandinavia. Humanists flocked there to teach and lecture, and young Copernicus was highly influenced by their views. "Near St. Anne's Church," runs one contemporary account, "stands the university, famed for the many learned men who have studied within its walls. It is the seat of every kind of study: rhetoric, poetics, philosophy, physics. The most flourishing of all, however" — and doubtless this appealed greatly to Nicolaus — "is that of astronomy, and I have heard from many witnesses that there is no more famous school in the whole of Germany."

Nicolaus began his studies at Kraków in the winter. He, together with Andreas, may have lived at the home of the married sister then residing in the city; or they may have lived in one of the students' hostels as most of their classmates did. Even this is not known, just as so much of Copernicus' life is not known. At any rate, we know that he was one of about seventy new students, for his name is still preserved on the original enrollment lists. Entered in Latin, it reads "Nicolaus, son of Nicolaus of Torun," and over it, on the same matriculation register for the half-year 1491–92, appears the name Andreas, probably his brother. As might be expected, the register reveals the information that Nicolaus' registration fee had been paid in full.

As was the situation at most universities, students were required to read, write and speak Latin with each other. All textbooks, as well as scholarly works, were written in Latin, for every educated man was required to learn and communicate in that language. Nicolaus Koppernigk, during his undergraduate days at Kraków, learned Latin with a thoroughness that was to show up in his later writings. Since students and professors normally spoke with each other in Latin, they quite naturally Latinized the names of cities and countries — and even their own names. There was, for example, a German humanist at Kraków by the name of Sommerfeld — in English, Summerfield. In Latin, "summer" was *aestas*, "field" was *campus*. Thus, Sommerfeld Latinized his name as Aesticampianus. It is probable that Nicolaus Koppernigk did the same thing about this time, changing his Polish last name to its Latin version of Copernicus.

Nicolaus settled down to serious years of study —



The matriculation register of Krakow University for the half year 1491-92 with the name of Copernicus in the list of entries.

a period during which he acquired the broad educational base required in those times before specializing in individual branches such as law or medicine. Known to be a serious and reserved young man, he drove himself to learn all that his professors could teach him. From a local bookseller named Haller, he began to purchase books that would form the nucleus of his permanent library. Some of these books still exist today with notes in Copernicus' own handwriting. But he found time for play, too. He visited places of interest or beauty in the surrounding countryside, such as the salt mines of Wieliczka, and formed many of the friendships that would benefit him in later years.

Although Copernicus at Kraków was in the midst of humanist and Renaissance influences, he followed the usual pattern of "liberal arts" studies that students were required to take in late medieval times. Some of those studies which passed for "arts" at that time we, today, would call sciences, such as the study of Euclidean geometry. The names of Copernicus' professors are known, as well as the subjects that he heard them lecture on. Two of these subjects were geography and philosophy. The rest definitely came under the headings of mathematics and astronomy — especially the latter, for which Kraków was noted, and for which Copernicus is known to have developed a strong liking. In some of Copernicus' surviving textbooks there are jotted down calculations, suggesting that the young student was already grappling with new ideas in astronomy.

At Kraków, astronomy was still taught largely from the medieval standpoint. That is, it was closely bound up with Aristotle's notions of how the heavenly bodies moved. The main reason why it was studied at all was that it served the church in determining its calendar of holy days. It was also mastered for navigational purposes, for sea commerce was developing rapidly and ships were venturing farther and farther from their home ports. After Copernicus had spent only a year at Kraków, Christopher Columbus had already crossed the ocean and discovered the American continent. In addition to crude instruments, these early sailors depended for oceanic navigation upon specially calculated astronomical tables to determine their positions from day to day.

Furthermore, anyone studying astronomy at this time also had to take a course in astrology. Astrology was an ancient "science" which claimed that the positions of the stars could, and did, influence men's lives and affairs. After Copernicus' great work, astronomy and astrology would become separated, but in the year 1494 Copernicus himself studied the latter subject under a man named Albert Szhamotuly. Nicolaus was taught, for example, that the sign of ascendency in the zodiac at the time of one's birth was sure to affect one's temperament, tendency to disease, financial success or failure, and so forth. But whether or not the great astronomer took such beliefs as the literal truth is of course not known.

Among Copernicus' other astronomical studies was a course in the works of a German mathematician named Regiomontanus. Regiomontanus' real name was Johann Mueller; however, he had changed it to Regiomontanus which is Latin for his birthplace, Königsberg (or King's Mountain in English). Regiomontanus had suggested important changes in calendar reform and had completed an important textbook commenced by the German mathematician Georg Peuerbach. Perhaps Regiomontanus was most widely known for his *Ephemerides*. This work was actually the first almanac of real importance and contained astronomical tables of great accuracy, considering the period in which they were produced. Columbus himself, as well as other navigators, regularly used Regiomontanus' *Ephemerides* on their voyages into strange waters.

As part of the regular curriculum at Kraków, Copernicus and his classmates studied a little medieval textbook entitled *The Sphere*. This work, written in the thirteenth century, actually remained the principal elementary textbook on astronomy for nearly four centuries! Its author was John Sacrobosco (the Latinized name of John of Holywood). From this book Copernicus and his fellow students were taught the elementary theory of the celestial sphere, the rising and setting of the stars, the varying lengths of night and day, climatic differences, and so on. More important than these rudiments, however, was the fact that *The Sphere* contained a short discussion of the Ptolemaic system of planetary movements — the first to be given by a European writer of the Middle Ages. It was from this book and lectures on Ptolemaic theory that Nicolaus first became acquainted with the great astronomical system that he himself was to overthrow many years later.

Copernicus did not formally attend the lectures of one of the most eminent teachers of philosophy then at Kraków. This was Albert Brudzewski, a Polish scholar of acknowledged European fame. Copernicus may have known Brudzewski personally and received astro-

Portrait of Albert Brudzewski, first great teacher of Copernicus.

nomical instruction from him in the form of private lessons. Brudzewski conceivably taught Copernicus how to make astronomical observations and how to handle the instruments for doing so. From the writings that have survived, it is evident that Brudzewski was an advocate of Ptolemy's earth-centered system; in fact, he had to accept it in order to lecture publicly.

Sometime during the end of 1495, or possibly the beginning of the following year, Nicolaus Koppernigk — now signing his name more frequently as Copernicus — returned to his home city of Torun. Although the young man had studied for four years at Kraków, it is known that he took no degrees from the university. For, of the seventy or so students following the same curriculum as Copernicus, barely a fifth carried away a Bachelor of Arts certificate. Still, he had learned much there and had made many friends. Seldom during later years would Copernicus miss the opportunity to visit his old university and renew past friendships.

SOUTH
TO
BOLOGNA

CHAPTER FOUR

The future course of Copernicus' life would now be largely mapped out by his powerful uncle, Bishop Waczenrode. As for Nicolaus, he had no objections to this, for his ambitions appear to have coincided with those of the Bishop. In short, a carefully planned career in the church lay in store for the future astronomer. Actually, many a young man of that day, even though not especially religious-minded, was tempted to become a clergyman, for the clerical life provided security, a good living, respect, and an education. And, the higher the clerical post, the better — for the same reasons.

Few men were better acquainted with all this than Lucas Waczenrode. By the time Copernicus left Kraków, Lucas had been Bishop of Ermland for several years. True, the Bishop often had his hands full mediating between the Teutonic Knights and the Polish king, but at the same time he was, in fact, a ruling prince over hundreds of square miles of territory. The main cathedral and chapter of the diocese of Ermland was at Frauenburg on the Baltic Sea. In reality, Frauenburg was not technically a seacoast town at all, since it was situated in a lagoon called Frisches Haff (Fresh Harbor), about halfway between Danzig and Königsberg.

Eager to give his promising nephew a church career, as well as a comfortable income, Lucas Waczenrode determined at the first opportunity to install Copernicus as one of the canons in his own cathedral chapter of Frauenburg. A canon was one of a limited number of church officials who helped their bishop administer not only the cathedral itself, but the diocese as a whole. By obtaining such an appointment for Nicolaus, Waczenrode could also keep his favorite nephew at his side as his personal assistant. About this time, one of the canons died, creating a vacancy. Unfortunately, the Bishop had to take turns with the Pope himself in appointing new

Portrait of Lucas Waczenrode, Bishop of Ermland (Warmia) and uncle of Copernicus.

canons, and this time the choice fell to the Pope, who appointed his own man. Lucas would thus have to wait for the next vacancy to appoint his nephew.

In the meantime, it was decided that Nicolaus could best employ his time in further study. Copernicus himself was in full accord with this, for he was both eager for more learning and qualified to pursue it because of his years at Kraków. As a matter of fact, in order to conform to the Chapter's rules, it was mandatory that he obtain a degree in theology, medicine, civil or canon law. Canon law was the collected body of laws, rules, and regulations enacted by the Christian church concerning its constitution, its spiritual and temporal administration, and the ecclesiastical government and discipline of the church's religious community. Copernicus' uncle had himself taken his degree in canon law at the University of Bologna and was now determined that his nephew should do the same. Young Koppernigk jumped at the opportunity of traveling to the enlightened south. In those days everyone who could manage it made at least one pilgrimage to Italy, the newly discovered source of long-hidden classical knowledge.

In the fall of 1496 Copernicus set out for the Italian university city where he would live and study for the next three years. Copernicus was now twenty-three. As things turned out, he would spend the better part of the next seven years studying at one Italian university or another, with only one short visit home during that period. Thus, Copernicus necessarily became a part of university living — a proud way of life that had come into being some three hundred years before.

In the latter part of the twelfth century, the revival of learning that had been sweeping Europe gave rise to a new institution, the university. The popularity of centers such as Paris and Bologna, together with the large numbers of students attracted to them, soon led to the organization of associations for mutual protection. These associations developed along the lines of medieval craft guilds. They even took the same name, *universitas*, which simply meant a group of persons gathered together into a corporation. Thus there was a "university" of students or a "university" of teachers, just as there was a "university" of cobblers or tinsmiths. Two of the earliest universities were those at Paris and Bologna, each of which represented two different types of associations. Essentially the one at Paris was controlled by the masters' or teachers' organization, which controlled the student life and granted degrees.

The situation at Bologna was entirely different. Life there was freer. Copernicus especially must have found it so, for at Kraków the students had been largely controlled by their professors. Moreover, at Kraków Nicolaus had been close to home and more or less sheltered by his connections in the city. Unlike Paris, the guild, or university at Bologna, was primarily an association of students, to which the guild of masters was subordinate. There were two reasons for this. First, the students who flocked to Bologna to study law — either civil or canon — were more mature than those at Paris. Often they were men who were already clergymen, lawyers in the employ of a king or prince, or, like Copernicus, students who were later slated to receive benefices of their own. Second, there was the status of the student himself in Bologna. There was one law for the citizen, another for an alien. The students had to forge their own artificial citizenship; this could be harsh on their professors and the townspeople alike. If the town of Bologna refused to grant them privileges, the students' guild could threaten to migrate to another city. This gave the students great bargaining power, for by leaving they could destroy the trade enjoyed by the merchants of the town.

Thus the lives and activities of the Bologna professors were severely regulated. They were not allowed to leave the university, even for a single day, without permission. If a professor left town, he was obliged to deposit with the rector a sum of money as a guarantee that he would return. If he failed to make his lectures interesting enough to attract an audience of at least five, he was fined as if he were absent. A certain amount of ground had to be covered each day. Lectures had to begin on time — and end on time. If the professor skipped a chapter or some point of law, a fine was levied. Nor was he permitted to postpone a difficult question to the end of the hour, lest he make this an excuse for ducking it altogether.

In the early Middle Ages as well as Copernicus' day, students tended to run to different types. Some were diligent and carried away learning and honors from the university; others were aimless and idle, rarely attending a full course of lectures, and wandering from one university to another. There were the poor, who were largely dependent upon charity or what they could earn by copying or doing odd jobs for others. And there were the well-to-do. These were often clergymen with church positions and holdings, who drew a fat revenue therefrom as absentees and indulged their taste for books and fine clothes.

Copernicus — together with his brother Andreas who was also sent to Bologna in 1498 — fell into this latter class of students. For, about a year after Nicolaus left for Italy, Bishop Waczenrode again submitted his nephew's name for election to a canonry at Frauenburg. This time Copernicus was accepted. So was Andreas about two years later. Neither, however, was required to return to Poland to assume his actual church duties. Thus, according to the practices of that time, the two young canons-elect enjoyed a comfortable income from positions they did not have to work at — and which, in fact, were hundreds of miles away.

While the law students at Bologna were more mature than at other universities, they still behaved much as students did elsewhere in the Middle Ages and early Renaissance. They fell in love — and recovered. They penned verses and lampoons. They gambled, drank, and got into debt. Pranks played on townspeople were fairly common, and often led to blows and bloodshed. But here the students had a distinct advantage; as students, they ranked as clergymen and, when in trouble, could plead benefit of clergy. They thus escaped with a lighter punishment than laymen. While many were indulgent toward the student and his escapades, others could see the university as nothing but a corrupter of youth and religion. One medieval saying went: "They seek the law at Bologna, medicine at Salerno, philosophy at Paris . . . but nowhere a life pleasing in the sight of God."

Despite this free-and-easy student life, Copernicus seems to have been one of the more serious scholars at Bologna. This is all the more to his credit, for he was certainly one of the most privileged. Students were gathered together into groups called "nations" which roughly represented the European country or region from which they came. Copernicus was a member of the German "nation" — not only one of the largest at Bologna but also the best privileged.

Copernicus had come to Bologna for the ostensible purpose of studying canon law — and this he did. It was not without good reason that his uncle had sent him there. Bologna was famous for two kinds of legal training. Laymen flocked there to study civil (or Roman) law and ecclesiastics to study canon law. What the former great teacher Irnerius had done to promote the fame of Bologna as a center of civil law, a monk called Gratian did for canon law. Gratian had gathered together the laws of church councils, papal documents, the pronouncements of the church fathers, and the decrees of the early Christian emperors. True, these sources of canon law had been previously put together by others; but there remained much confusion and contradiction among the authorities. These Gratian succeeded in straightening out and resolving into a solid core of church law. The result of Gratian's labors was a textbook called *Concord of Discordant Canons*, a work to which a student might turn for the opinion of the authorities on any matter of ecclesiastical law. Compiled as early as 1148, it continued to form the basis for many lectures during Copernicus' stay at Bologna.

Yet law by no means occupied all of Copernicus' attention; quite possibly he found it rather dull, for in later years he never excelled as a lawyer. Other subjects could and did attract him at Bologna, for his interests tended to embrace every branch of knowledge. He listened to lectures by the Bologna humanists and studied mathematics and Greek.

But it was still astronomy that most intrigued the young Polish canon. He attended lectures in that subject given by a Professor Domenico Maria Da Novara, a famous astrologer in Bologna and also a compiler of astronomical tables. Copernicus even rented a room in Novara's house for a time, since underpaid professors frequently gained extra income by giving lodging to their students. Novara became Copernicus' friend as well as teacher during the young man's stay in Italy. Among the important facts known about Novara is that he was an outspoken critic of the Ptolemaic system of astronomy, partly because of some observations that did not agree closely enough with that theory.

Copernicus spent many hours collaborating with his teacher on astronomical research. Together they carried out measurements of the altitudes of stars, and once calculated the parallax of the moon (its angular shifting with respect to the earth). It was from the work done in these fruitful years with Novara that Copernicus was later to draw the material for his arguments in favor of motion on the part of the earth — an earth which, according to the prevailing thought of the time, did not move. It was also no accident that during these years Copernicus devoted many hours to learning Greek, for only by mastering that language could he hope to extract the real meanings from the works of the ancient Greek philosophers. True, there were Latin translations, but these, in turn, had been translated from the Arabic and were often not to be trusted. Thus Copernicus, rather than reading translations of other translations, was able to read, for instance, the works of the Pythagoreans and others. And the Pythagoreans — almost alone among the ancients — had ventured to suggest that the earth was not the immovable center of the universe at all, but was in motion like the other planets. Novara, himself a leading light in promoting the revival of the classics, encouraged Copernicus in this pursuit. Often the two men would discuss ways in which the errors in the theory of Ptolemy could be corrected.

How much Copernicus and Andreas joined in the merrier side of student life at Bologna is not known. Evidently they were occasionally tempted, for in the closing year of the fifteenth century they had run up some debts — and had run out of money to pay them. This would indicate that they were in the habit of spending money freely for, in addition to their salaries as canons, the two young men also received an allowance from their uncle. They may also have received other income paid them by the Cathedral Chapter of Frauenburg. At any rate, finding themselves penniless toward the end of 1499, the brothers appealed to one of their uncle's secretaries who, fortunately for the Koppernigks, happened to be in Bologna on a vacation. Andreas, clearly the more hot-tempered of the two, even threatened that if money were not soon forthcoming he would run off to Rome and find work there. The secretary from Ermland had none of his own, but he helped obtain a loan for the students from a bank in Rome — to be repayed by their uncle.

The following year brought a change in Copernicus' life. It was now 1500 — the year in which the church was celebrating a great Jubilee, or festival. Pope Alexander VI had issued a papal bull inviting all Christendom to make the pilgrimage to Rome. Thousands flocked there that spring to witness a spectacle of the highest pomp. On Easter Sunday an estimated two hundred thousand Christians knelt to receive the pontiff's blessing. Among them were Copernicus and his brother, doubtless sent there by their uncle as canonical representatives from the Ermland chapter.

Despite the religious nature of this great festival, the Jubilee Year was a dangerous year to be in Rome. As one contemporary report went: "No night passed without four or five murders; bishops and prelates were among the victims. On the morning of May 27, 1500, the Romans saw eighteen hanged from a gallows on the Angels' Bridge, among them the physician and the surgeon of the Lateran hospital, who had made a business of robbery and murder at dawn . . ." And it was during this same year that Pope Alexander's son, the notorious Cesare Borgia, engineered the murder of his sister Lucretia's husband. Proof of the utter lawlessness of those days is the fact that Cesare never had to pay for his crime.

Copernicus fortunately did not become involved in this violence. He stayed on for about a year in Rome, giving astronomical or mathematical lectures to a circle of scholars, scientists, and itinerant humanists then in the city. The lectures seem to have been popular for he was

An artist's conception of Copernicus observing an eclipse in Rome, 1500. (From Louis Figuier, Vies des Savants, *Paris, 1881.)*

applauded for them. Years later, in his great *De Revolutionibus*, Copernicus reported on an eclipse of the moon which he observed in Rome on November 6, 1500.

So Copernicus passed his year in the Italian capital. Winter went and spring came. He had now used up the three years nominally allotted to him for study — and more. Still, the opportunities for further learning in enlightened Italy continued to occupy his mind. The young canon-elect of Frauenburg was already planning to return.

PADUA AND FERRARA

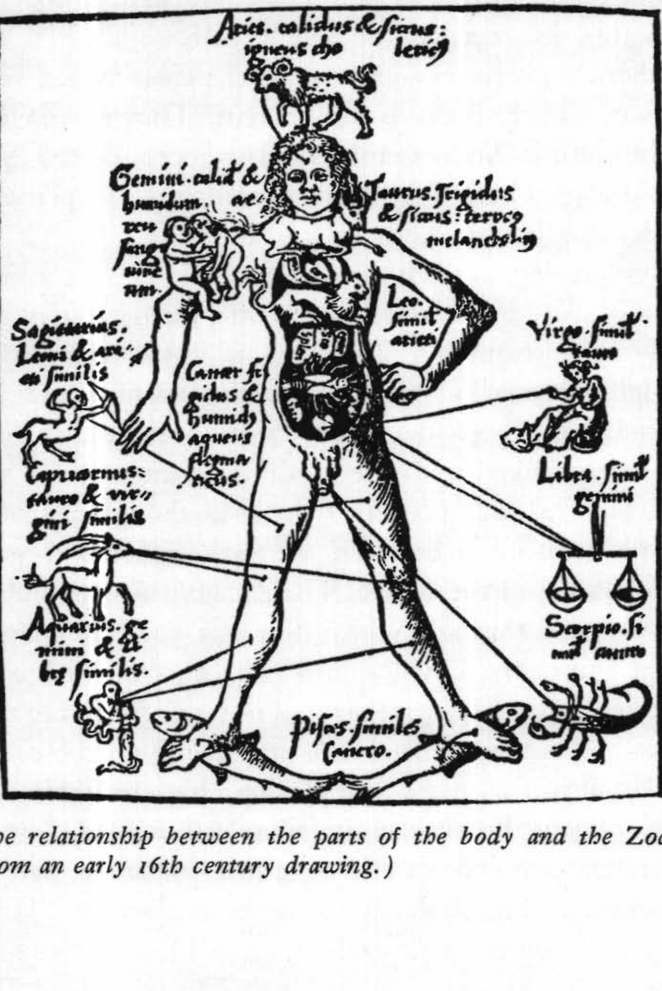
CHAPTER FIVE

Still under the spell of Italy — especially Rome in the Jubilee Year — Copernicus was in no hurry crossing the Alps on his return to Poland. He arrived in Frauenburg in the late spring of 1501. There was a formality that Copernicus now had to attend to; namely, he had to be officially installed as a canon in the Ermland chapter. On July 27 he and Andreas both appeared before their seniors, and the appropriate ceremonies were carried out.* Like his brother, Andreas also planned to return to Italy. Both young men now appealed to their uncle, the Bishop, for permission to do so.

Copernicus especially must have presented a strong case to Lucas Waczenrode. For one thing, he had not yet taken the examination for his law degree. For another, he agreed — and probably himself proposed — that he should take up the study of medicine. This idea appealed strongly to both the Bishop and his chapter, for trained physicians were scarce; by becoming a physician, Copernicus would be that much more useful to the other members when he returned. Accordingly, funds were provided by the Cathedral Chapter which, however, stipulated that he should study medicine. Copernicus was more than willing to comply with this, since he shared the Renaissance eagerness for knowledge of all kinds.

Privately, Copernicus had another reason for wishing to continue his studies in Italy. In his mind he was already forming the conception of a new universe. As yet it was unripe and formless, but the seed of an important idea was nurturing. What he now needed was more scientific evidence drawn from observation and experience. In Frauenburg, on the bleak and remote

* *Although it was a part of the church hierarchy, the office of canon did not require that its incumbent be a fully ordained priest. Despite the assertions of some writers on Copernicus, he was not a priest in the full sense of the word since he never took the so-called higher orders. Copernicus can thus be called a churchman or clergyman, but not a priest.*



The relationship between the parts of the body and the Zodiac. (From an early 16th century drawing.)

shores of the Baltic, Copernicus could hardly hope to gain this. He needed the intellectual stimulus of the southern universities — as well as the clear Italian skies to more clearly observe the heavens. Thus it was that in the autumn Andreas and Nicolaus recrossed the Alps into Italy. There they parted company. Copernicus headed for Padua, Andreas for Rome.

By agreeing to study medicine at Padua, Copernicus automatically provided himself with a further excuse for studying "astronomy" (actually, it was astrology, although necessarily planetary observations were involved). In those days the study of medicine was intimately linked with the motions of the sun and the planets. This was because there was thought to be a mystic connection between the various bodily organs and the signs of the zodiac. The zodiac was the band of the heavens through which the sun and the planets seemed to move. Divided into twelve parts, with each represented by a separate symbol or sign, the zodiac was looked to as the key to events happening on the earth. For example, a man's complexion, his character and temperament, his success or failure, all depended upon where the sun and planets were in a particular sign of the zodiac. One textbook of the period asked: "Why do not all men resemble each other, and why do no men resemble each other completely?" The answer: "The movements of the planets are the cause of it. For each individual everything depends upon the planet which rises or sets in such or such sign of the zodiac on the day of his birth." And, because health and disease were also dependent on the stars and planets, "astronomy" was a fundamental study for anyone who wanted to become a doctor. In fact, most remedies were administered according to the planetary configurations. By observing the stars a doctor was supposed to be able to tell whether a patient was likely to recover, and by the phases of the moon whether or not he should be bled.

Therefore, among audiences attending lectures on "astronomy," there were always a great number of medical students and, vice versa, many professors of astronomy had taken degrees in medicine. Only a good astronomer, it was believed, could possibly be a good physician.

In reality, the science and practice of medicine had changed but little since early medieval times. The basis of instruction was still the writings of Hippocrates, who was called the "Father of Medicine," and Galen, the famous Roman physician. Some useful drugs were employed but very often the connection between the disease and the remedy was purely fanciful. One remedy for spots in the eye (before Copernicus' time but still typical) was this: The patient should take "the worms with many feet that are found between the trunk and bark of trees" in a little wine and water. It was also recommended that the dose be accompanied by several repetitions of the Lord's Prayer. Some improvements, however, had been made. For example, anatomy showed signs of revival. Better textbooks of surgery were being produced. Gynecology and obstetrics, once the monopoly of midwives, became the subject of scientific study. Ophthalmology passed from the hands of the wandering cataract-couchers to those of learned physicians. But even into Copernicus' time, surgery remained barbarous; and magic, astrology, and charms a fundamental part of medical practice. Bleeding, for example, was believed to be a universal remedy, for by so doing, bad spirits or "humors" were supposed to be released from the patient's body.

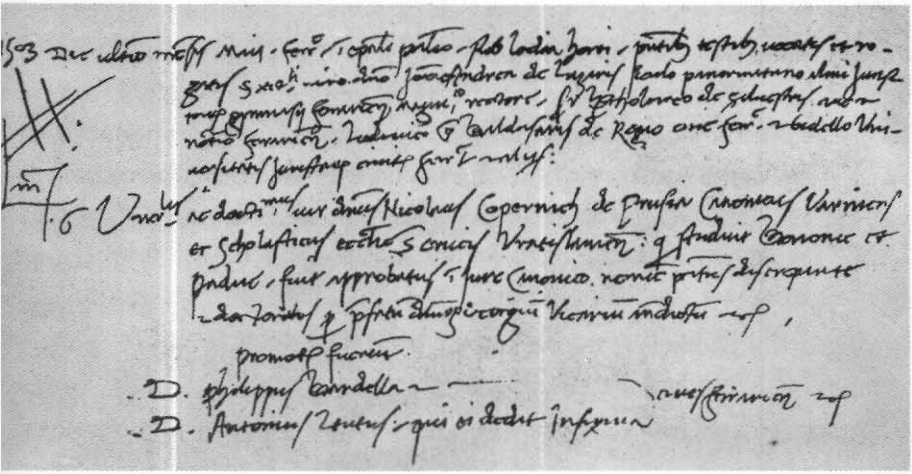
Although anatomy was studied at Padua, no chair for that study existed at the university. The only reason dissection was practiced at all was to help explain the tenets of Galen and one or two other textbooks. There was only one demonstration on a human corpse during the entire school year. Early in the year two bodies — one male, one female — were obtained for this purpose. Usually these were executed criminals, and no student who had not completed two terms of medical training was allowed admittance to the amphitheater. A senior professor would read a chapter from an anatomical textbook while an ordinary professor would explain the text and, with two students as assistants, demonstrate on the cadaver. The dissection itself had to be done by surgeons, usually "barber-surgeons." Onlookers and other professors were not allowed to speak until the entire performance was over. It was also not uncommon for those taking part in the dissection to be given wine

Early print of an anatomical lecture such as those attended by Copernicus. Professor reads Galen or Hippocrates from his chair, while barber-surgeon performs actual dissection under the eyes of the students. (Burndy Library)

and spices for fortification purposes. Only later could Copernicus have attended the demonstrations, for he had not yet completed the requisite two terms of medical study.

Meanwhile he had enrolled in the School of Arts. Here he encountered another of the many freethinking humanistic teachers in Italy at that time. This was Pomponatius who, while a foremost Aristotelian, did not hesitate to question the ancients. Here, too, he met two astronomers then at Padua, named Luca Gaurico and Girolamo Fracastoro. Coming into contact with enlightened men such as these had an important effect on Copernicus; it caused him to question old, established ideas — one in particular: the Ptolemaic system of the universe.

Sometime early in the year 1503, Copernicus interrupted his studies at Padua in order, at last, to take his degree as Doctor of Canon Law. This he did, not at his old alma mater, the University of Bologna, but at another Italian institution, the University of Ferrara. Why did Copernicus choose to take his degree at Ferrara, a place where he was relatively unknown as a candidate for a law doctorate? Possibly because there were fewer distractions — passing the stiff examination called for a period of concentrated study. Or possibly to reduce the expenses involved; these could be high indeed, even for the purse of a well-to-do young canon like Copernicus. Moreover, after the candidate had been seated in the master's chair and awarded his diploma, together with the symbolic cap, book, and gold ring, he was generally expected to celebrate with his friends on a lavish scale — at his own expense. Thus a candidate for a doctor's degree might save himself a considerable sum by quietly appearing at another university — far from his admiring friends — to complete the final ceremonies.



Copernicus' Doctor's Diploma from the Notaries' Archives in Ferrara.

At any rate, Copernicus received his Degree of Canon Law toward the end of May in the palace of the Archbishop of Ferrara, who was also a nephew of the Pope. He did not return immediately to Padua but stayed on in Ferrara for a few months. At that time the city was said to rival Rome in population as well as cultural works. Here the wealthy and powerful Este family held their court, entertained humanists and poets, and caused magnificent buildings to be built. Lucretia Borgia herself was the reigning Dutchess of Ferrara, having married Duke Alfonso d'Este only a year after her brother had murdered her former husband. Still in her early twenties, removed now from stormy family influence, Lucretia had turned over a new leaf. She won wide esteem through her beauty, kindness, and piety, and her brilliant court included the famous poet Ariosto.

Only a few years before Copernicus' arrival in Ferrara, an important book had been published in that city. It was the great Arab astronomer al-Farghani's *Elements of Astronomy*, which greatly aided the revival of science in Europe after the darkness of the Middle Ages. If this important work had escaped Copernicus previously, it could not have failed to fall into his hands during his stay in Ferrara.

With his doctorate of canon law now behind him, Copernicus returned to Padua where he devoted full attention to the study of medicine. It is not known whether Copernicus actually took a degree there as a physician. He probably did not. In any case, he had acquired enough knowledge of the healing arts to be of service to those under his administrational care in Ermland.

In autumn of the year 1503, Copernicus left Italy forever. He would then have been thirty. Off and on, he had spent some seven years of study under Mediterranean skies and, although next to nothing is known about his life there, he certainly returned in possession of one of the most complete educations the times were capable of giving him. For by this time the Canon of Frauenburg was thoroughly grounded in the classics, law, theology, mathematics, medicine, metaphysics, languages — and, of course, astronomy.

Copernicus also returned home a secret revolutionist. His new theory of the universe was now well developed in his mind. He would devote the rest of his life, passed for the most part in the remote solitude of Frauenburg, testing and shaping it into a satisfactory whole.

THE NEPHEW
OF
THE BISHOP

CHAPTER SIX

Upon Copernicus' return to Ermland, he paid a visit to his old university town of Kraków. There he renewed old friendships, visited relatives, and tried out his new theories concerning a sun-centered solar system on the university's professors. Attracted as much as ever by the academic life (he had known little else up to now), Copernicus might have stayed on as a teacher. But this was not to be.

His aging and powerful uncle, Bishop Waczenrode, now pressed for his nephew's return. Still the stern, ambitious, despotic figure he had been in his younger days, Lucas continued to rule the Ermland diocese as a separate state of the church. Having played an influential part in Copernicus' life as uncle and guardian, he was now his nephew's ecclesiastical superior. Until his death in 1512 Lucas would completely dominate Copernicus' activities.

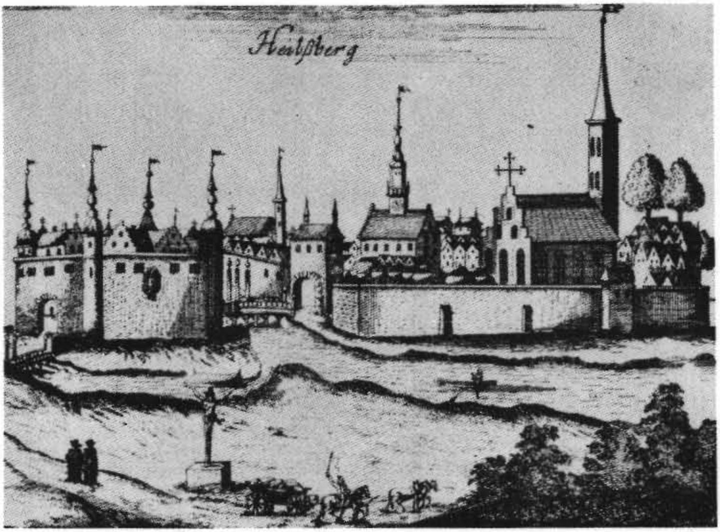
The wily Bishop still played politics with the hand of a master. His old foes, the Teutonic Knights, continued to smart under his clever maneuvers. This was largely due to his having cemented more favorable relations between himself and the Polish crown. Having served as counselor to two previous Polish kings — John Olbracht and Alexander — Wazcenrode was now serving a third — Sigismund, called "the Old." Lucas was still under the spell of his two lifelong objectives: the final and complete expulsion of the Teutonic Knights from their lands on the Baltic coast, in Prussia, and in Pomerania; and the strengthening of the Polish hold on those neighboring territories. Once the crafty Waczenrode had very nearly carried out a plan for completely eliminating his sworn enemies. This was nothing less than getting the entire Teutonic Order transferred to Wallachia (a part of modern Romania) for the purpose of fighting the Muslim Ottoman Turks. But unfortunately for the Bishop this plan fell through. Needless to say, Waczenrode's machinations had earned him the knights' undying hatred. They heaped insults upon him and his family and strove to lessen his authority and influence. So greatly did the knights loathe Bishop Lucas that they were said to pray daily for his death.

Copernicus had been absent from his canonry for so long that everyone expected he would be ordered to fill it immediately. But the Bishop had more imaginative plans for Copernicus — and more personal ones. Waczenrode was now feeling the loneliness of old age, and he wished to have someone near him as an aide and constant companion. Who better than his brilliant, highly educated nephew? Why waste the young man's talents on simple church duties? Thus Lucas kept Copernicus at his side for approximately the next five years. Ostensibly appointed the Bishop's official physician, he actually served the Bishop in many other capacities as well. Copernicus became his uncle's assistant and traveling companion; his private secretary and protégé; his counselor and technical adviser; even his potential successor. Wherever the Bishop went and whatever his business, the young canon was never far away.

In short, Copernicus became like a son to the old churchman. Often he acted as a delegate from the chapter and took part in many meetings of the local Polish diets in various towns. He drew up the official proceedings of the chapter and drafted letters to the Polish king. In serving the Bishop and the chapter so closely, he also shared in the intrigues against the Teutonic Order. Seldom appearing in public, remaining a silent figure behind the limelight of his uncle's activities, Copernicus was really the true shaper of the Bishop's anti-knights policies during his last years.

In order to serve as his uncle's physician and assistant, it was again necessary to obtain an official leave of absence from the Cathedral Chapter at Frauenburg. Under the circumstances, the chapter naturally granted it. Copernicus then went to live in the castle of Heilsberg, the official seat and residence of Ermland bishops. Located a few miles away from Frauenburg, the castle with its towers looked out over the charming countryside and the tiny Alle River. Heilsberg was sumptuously furnished and, except for trips with his uncle, Copernicus lived there for the next few years in princely style. Here, too, he found that he had sufficient leisure to pursue his astronomical interests.

It was at Heilsberg Castle, about the year 1509, that Copernicus laid down the main lines of his lifework — a new system of astronomy that would cause men to drastically change their idea of the universe. At this time he produced a short work whose lengthy title is usually shortened to "Little Commentary." Perhaps because of the revolutionary nature of its contents, Copernicus did not formally publish the little work as a book, but simply circulated copies of the manuscript among certain friends. Fortunately, two copies of it still survive; how-



An old print of Heilsberg Castle on the Alle River.

ever, the treatise had to wait until the nineteenth century to be printed. In this work Copernicus set forth the principles of his heliocentric, or sun-centered, system: all the planetary motions are explainable on the assumption that the planets revolve around the sun, not the earth . . . the sun itself is immovable . . . and the center of the earth is not the center of the universe, but merely the earth's center of gravity and the center of the moon's orbit.

About this same time Copernicus *did* publish another book — the only one he ever published of his own volition in his lifetime. Far from dealing with astronomy, it was a Latin translation of the poetical works of an obscure Greek poet by the name of Theophylactus Symocatta. Just why Copernicus chose to translate these letters from the original Greek is not clear. It may have been that he had used them for practice while learning Greek. And it may have been that he brought it out as proof that he was firmly on the side of the humanists. For, at that time, there was a strong controversy over whether Greek literature ought to be revived or not, because it was thought that heathenism might also be revived with it. At any rate, when he and his uncle journeyed to Kraków in 1509, Copernicus gave the translation to his friend Johann Haller, the bookseller, for publication. In gratitude for all that his uncle had done for him, he dedicated it to the the old Bishop.

A signpost to Copernicus' thinking also appears in this curious translation of rather indifferent Greek poetry. At that time it was customary for authors to ask their acquaintances for introductory poems to be printed in their books. Copernicus had a friend name Rabe (meaning "raven"), alias Laurentius Corvinus ("raven," Latinized), who was a town clerk in the city of Breslau. Copernicus asked him to contribute some verses to his book and Rabe did so. After praising Copernicus' loyalty to Bishop Waczenrode in classical terms, Rabe went on to write that the young canon "explores the rapid course of the moon and the changing movements of the fraternal star and . . . with the planets . . . he knows how to explore hidden causes of things." From this it is clear that Copernicus was thinking deeply about astronomical matters.

During this time, Copernicus had to give up much of his otherwise creative time to the affairs of his office, particularly in helping his uncle to maintain the chapter's ticklish position between the Teutonic Order and the Polish crown. Shortly after Copernicus took up residence at Heilsberg, a new Polish king had come to the throne. This was the young and fiery Sigismund I, one of whose first acts was to call upon the Grand Master of the Teutonic Order to pay him allegiance. The Grand Master, of course, refused and war very nearly broke out. The Bishop, siding as he did with the Polish king, now became the recipient of even more slander and abuse from the order. And Copernicus, as the Bishop's nephew and secretary, received his share of it.

A few years later, in 1512, the Bishop, accompanied by Copernicus, traveled to Kraków for young King Sigismund's wedding and the coronation of his queen. On his way back to Heilsberg Castle after the ceremonies, Bishop Waczenrode began to feel ill. The March weather was severe and by the time the old prelate reached his hometown of Torun he had a raging fever. Three days later, on March 29, 1512, Lucas Waczenrode was dead. Copernicus, his personal physician, had not accompanied him on this part of the journey. Even if he had been there to care for him, it is questionable whether the Bishop could have rallied. The old man, well into his sixties, was worn out by the strain of intrigue and responsibility.

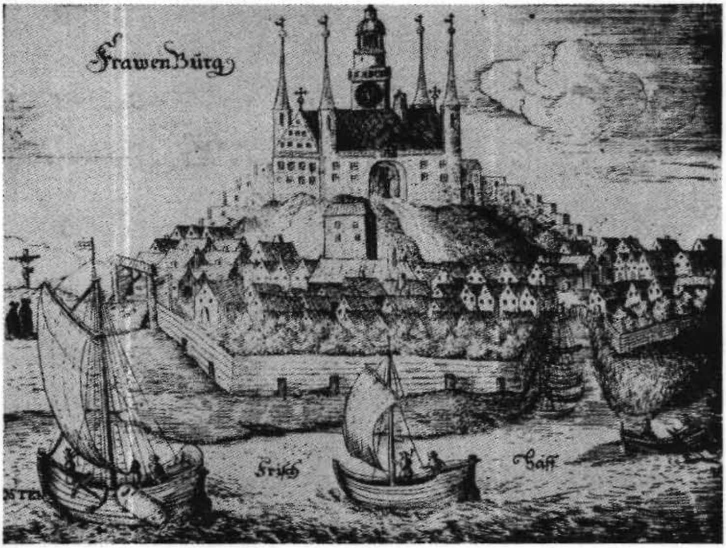
Following the burial of his uncle's body in the cathedral at Frauenburg, Copernicus at last assumed his regular duties as canon. There he would find the time, among his many other occupations, to work out a new system of astronomy. Records show that on June 5, 1512, he observed the planet Mars in opposition.

THE CANON OF FRAUENBURG

CHAPTER SEVEN

Copernicus in the spring of 1512 was in his fortieth year. Apart from brief interruptions at Allenstein and elsewhere, the astronomer was to live out his remaining thirty years at Frauenburg on the Baltic Sea.

Due to the constant strife between the Teutonic Knights and the Jagellonian Poles, the little cathedral town had changed hands several times in recent decades. In order to fortify Frauen-



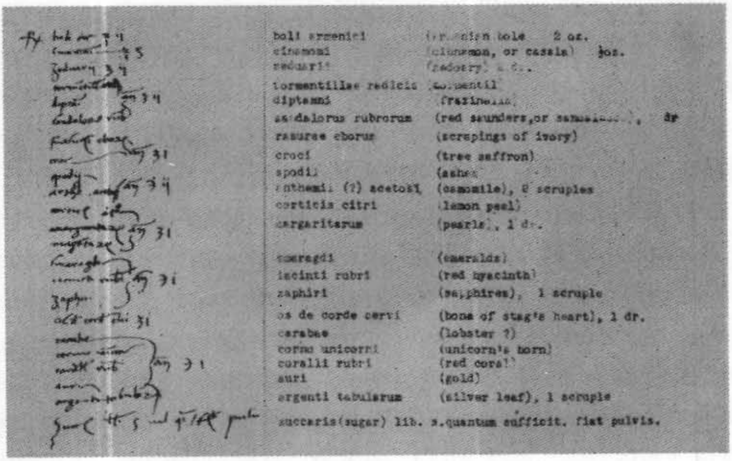
An old print of Frauenburg with Cathedral and water tower.

burg — for it was important militarily — a large wall had been built around the cathedral. The buildings where the canons lived, together with gardens and utility buildings, were located along the inside of this fortified wall. Some of these accommodations, being better than others, were occupied by the senior members of the chapter. Younger canons, of course, received the least comfortable quarters. Every time a death occurred, there would be a general shifting of the occupants to better accommodations.

Copernicus, however, seems not to have been interested in more comfortable quarters, for he occupied the same rooms during his entire residency at Frauenburg. Built into the massive outside wall for greater strength were a number of turret-like towers and it was in one of these — still called "Copernicus' Tower" — that the astronomer lived until his death.

This tower, besides housing Copernicus' dwelling rooms, also served him as an observatory. The cathedral itself stood on a hill some eighty feet high, offering a wide view of the Frisches Haff, the strip of dunes a mile off, and the dark Baltic Sea beyond. Needing an elevated place with a good view, Copernicus chose well, since his tower rooms were slightly above the roof of the church. From this place, Copernicus could see clearly in all directions, except to the east. Of all the astronomical observations he made, Copernicus recorded that more than half of them were made at Frauenburg.

The life of the canons at Frauenburg was not as strict and monastic as one might suppose. At this time there were only sixteen canons living on the hill, although seldom were they all present at one time. While the canons were officially required to reside at or near the cathedral, the fact was that they could easily obtain leave to travel about for one reason or another. One canon, for example, was a secretary to the Polish king, while another functioned as an ambassador in far-off Spain. Copernicus himself, as we have seen, spent many years away from his official duties, as a student in Italy.



Earliest known prescription made out by Copernicus, containing a large number of traditional ingredients. Translations are given from Latin to English. Becoming aware that such "medications" were unreliable, Copernicus later prescribed simpler and more rational ones devoid of ingredients like those above.

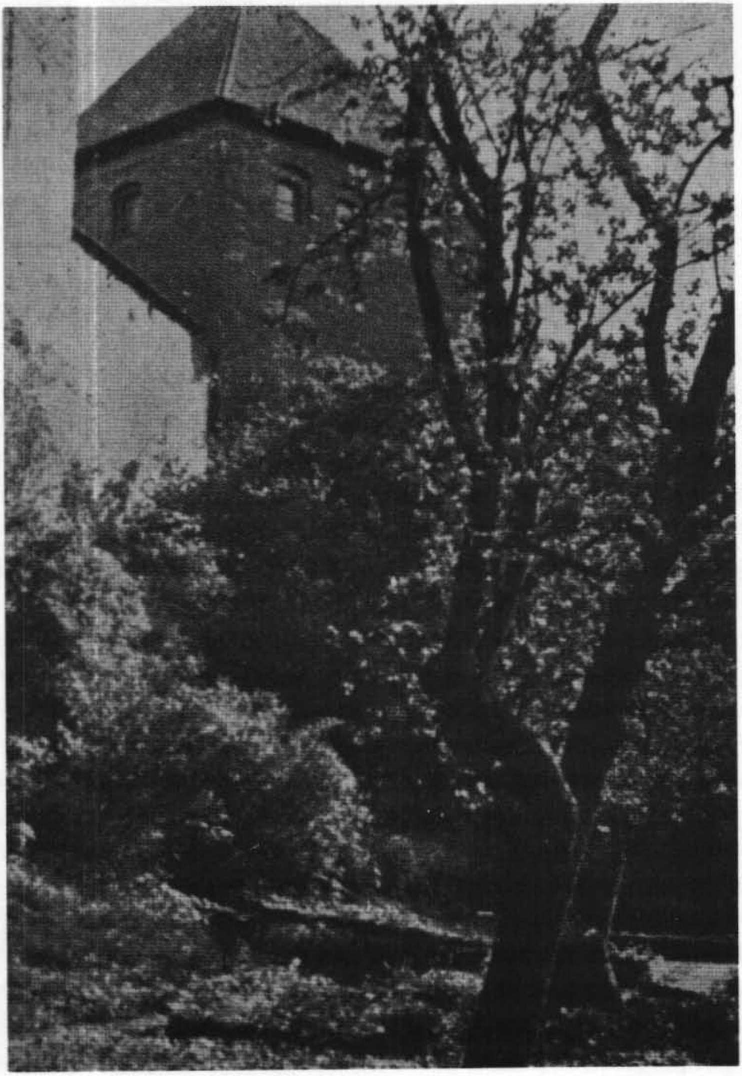
While the canons had specific ecclesiastical duties, such as conducting services and assisting the Bishop in spiritual and administrational matters of the diocese, these men were also, in actual fact, noblemen. They avoided taking holy orders (Copernicus included) if they could possibly do so. They lived and ate well, possessed horses and servants, traveled and studied abroad, owned estates and libraries, intrigued against both the Teutonic Knights and the King of Poland, engaged in trade and gambling, and even fought wars when they had to. Moreover, they were shrewd businessmen. Among them all, they owned one third of all Ermland. Each canon held considerable property in the vicinity of the cathedral; in administering their lands, they had to levy and collect taxes, hold court, mete out justice, and protect their subjects in time of war.

Descended from the same few well-to-do families of Torun and Danzig, they were also frequently related by family intermarriage. One of Copernicus' best friends, Tiedemann Giese, also a canon, may have been distantly related to him. Copernicus' brother, too, had taken up his duties as a canon at Frauenburg. Unfortunately for Copernicus, Andreas did not remain long with the chapter. A few years before, Andreas had caught a disfiguring disease, the dreaded leprosy, which was widespread in Prussia at the time. Copernicus had often tried out his medical skills on him, but with no success. The other canons of the chapter had become alarmed that the disease would spread to them and had granted Andreas a leave of absence to find a cure. But none could be found. Thus, within a few short months after he arrived at Frauenburg, Copernicus was saddened to see his brother forced to leave Frauenburg since the other churchmen were in fear of becoming infected. In any case, the unhappy Andreas did not have long to live. He died abroad about the year 1518, probably in Rome.

Copernicus' light duties at Frauenburg now gave him sufficient leisure to pursue his astronomical work, although he had to lay it aside occasionally to do his share in the administration of the little principality of Ermland. Probably it was during this period that he made the first handwritten draft of his great book. Whether or not he was in correspondence with any of his learned contemporaries at this time is not definitely known. Yet by some means or other Copernicus' fame as a gifted student of astronomy must have spread from distant Ermland to the more cosmopolitan parts of Europe. For in the year 1514, when the question of badly needed calendar reform came before the Lateran Council in Rome, the Pope sent out a call for learned men to aid in this project. Copernicus was likely one of those invited to Rome to rectify the old Julian calendar. Although possibly urged to go by a brother canon, Bernhard Sculteti, who was then on clerical duty with the Pope in Rome, Copernicus apparently declined the invitation. His reason for doing so was a simple one. Not enough was yet known about the true motions of the sun and moon (upon which a new calendar would have to be based) to permit a final settlement of the reform.

At the close of the year 1516, when he was forty-three, Copernicus received a new assignment. The chapter appointed him administrator of two small Ermland districts, Allenstein and Mehlsack, which lay many miles away from Frauenburg. For his headquarters, Copernicus' residence was the fortified castle of Allenstein, situated on the Alle River. Here, together with a small staff of assistants and servants, he lived for four years.

The Cathedral close at Frauenburg.



Copernicus' tower at Frauenburg.

Regularly he rode about with his staff to oversee various transactions of local business. Often, because of some trivial errand such as appointing a farm laborer or transferring a piece of property, he would have to leave Allenstein Castle and ride through his entire district. Travel, of course, was slow and it might take Copernicus a couple of days to go as short a distance as a dozen miles. Fortunately for posterity, however, there has survived a small journal or daybook from this period of Copernicus' life. It is written in his own hand and shows entries made in the presence of witnesses each time a piece of property was transferred from one peasant to another.

Occasionally, Copernicus would leave his routine duties at Allenstein and return to Frauenburg. He would confer with his fellow canons, visit friends, attend chapter conferences and, whenever he could, retire to his tower observatory in order to view the heavens. By no means did he wish to neglect astronomy at this time. But soon Copernicus would have little time to devote to the heavens, for war was brewing again.

THE DEFENDER
OF
ALLENSTEIN CASTLE

CHAPTER EIGHT

Toward the end of the year 1519, war broke out anew between the Teutonic Order and Poland. It had been brewing during the years that Copernicus was administering his two small districts from his headquarters at Allenstein Castle. The Grand Master of the order had secretly recruited armed bands of mercenary soldiers, sending them to Ermland to loot and pillage the defenseless peasantry. The Polish king retaliated by sending his own troops to Ermland. Full-scale war might have occurred earlier than it did had not two other things also happened. First, the Tartars invaded Poland. Second, the Holy Roman Emperor Maximilian I died.

It was about this time that Copernicus, having completed three full years of service at Allenstein, returned to Frauenburg.

When Poland succeeded in throwing back the Tartars and a new emperor had been elected, the Polish king, Sigismund, decided to settle matters once and for all with Grand Master Albert. Since Albert was technically a vassal of the Polish king, Sigismund ordered him to meet him at the city of Torun and do him (Sigismund) homage. The proud Grand Master, of course, failed to appear, whereupon the outraged Sigismund sent the Teutonic Order a challenge and marched into their lands.

For the next fifteen months war raged between the two forces — with neutral little Ermland serving as the battleground. For the innocent civilian population it was a cruel war. No major battles were fought; each side simply took turns slaughtering the peasants loyal to the other side.

At last, the Grand Master suggested that peace talks be opened at Braunsberg, a recently captured city in Ermland. He invited the Bishop of Ermland to take part in these negotiations. But Bishop von Lossainen, who had succeeded Copernicus' uncle as head of the chapter, was a weak and sickly man. Fearing that the Grand Master might hold him hostage, he appointed two canons to go in his stead. One of these was most surely Copernicus for there exists a document — a safe-conduct pass — written by Albert himself which says: "The honored highly learned Mr. Niklas Koppernick" should be given "free, safe, and Christian conduct, to and from . . . together with his horses and servants. . . ."

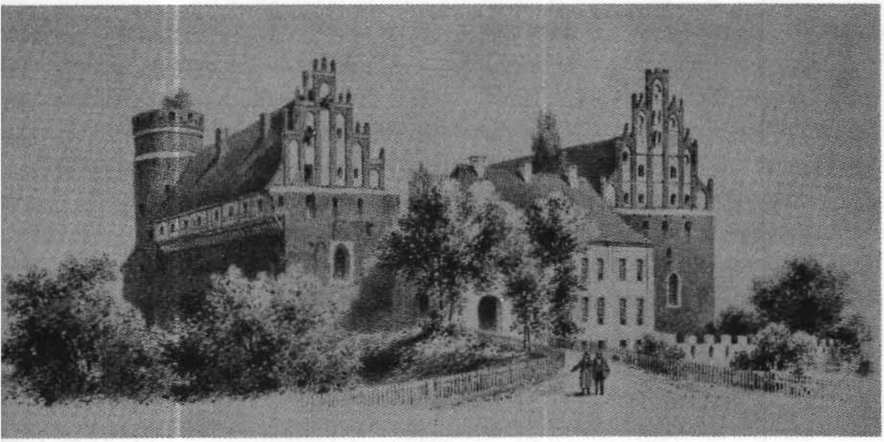
These peace talks, however, came to nothing. Albert tried to exact a promise of allegiance on the part of the Ermland chapter, but Copernicus and the other emissary refused to give this, saying that they would first have to consult with their chapter. It was fortunate that they were allowed to leave the city of Braunsberg alive, for the war soon began to rage again.

Early in the year 1520, Frauenburg itself was overrun by the knights, who set fire to the cathedral town. Behind its walls, the cathedral was safe. Inside it, almost alone, was Copernicus, who had refused to flee to safety with most of the other canons. While his life was surely in danger, the courageous Copernicus did not spend all of his time contemplating that fact, for it is known that he coolly took some astronomical observations during the period of siege.

About this same time, the Polish king succeeded in concluding a peace with the Russians — with whom he had been having difficulties — and could now concentrate more troops against the knights. Consequently, the war began to go badly for the Grand Master and, wily commander that he was, Albert again sent out feelers for an armistice. Once more negotiations came to nothing, for Albert soon learned that help was on the way from Germany so the war continued anew.

Again Copernicus found himself in the thick of it. During the fall of 1520, he had gone back to Allenstein to take up administrative duties a second time. By then, however, Grand Master Albert's forces had laid waste much of this district, burned the villages, killed many of the helpless peasants, and driven off hundreds of others. Besides Copernicus, only two canons of the chapter seem to have remained in the whole of Ermland, one of whom was Heinrich Snellenberg who lived with Copernicus at Allenstein Castle. All the rest had fled to far-off cities like Danzig where they lived an easy life in exile.

When at last the Grand Master decided to lay siege to Allenstein, Copernicus and Snellenberg were the sole defenders, except for a handful of servants. However, the Knights' siege seems to have been a half-hearted one, and Allenstein Castle resisted it successfully. The other remaining chapter member in Ermland, an old archdeacon by the name of John Sculteti, cheered up the defenders with letters from Elbing which said that peace talks were in the air. He also managed to smuggle in to Copernicus some of the crude firearms of the day — the powder and bullets for them would follow, if needed.



Old view of Allenstein Castle.

Finally in 1521, through mediation by the Holy Roman Emperor, an armistice was concluded; both the knights and the Poles were now thoroughly sick of the war. This armistice was to form the basis, in the year 1525, for a more or less lasting peace.

At that time conditions on the Baltic were stabilized when Prussia became a fief of Poland, paid homage to the Polish king, and Grand Master Albert became a duke. Albert even turned Protestant on the advice of the Reformation leader, Martin Luther. Only after that did little Ermland regain the towns and villages which had been taken from her by the Teutonic Order.

Meanwhile, in 1521, Copernicus was left with the job of picking up the pieces wrought by the war in Ermland. Because he had stuck to his post at Allenstein and exercised authority during hostilities with the order, he was rewarded with the title of Commissar of Ermland, meaning that he was to take charge of getting the little country back on its feet until the chapter itself could be brought back and reestablished.

The Canon of Frauenburg had his hands full rebuilding the ravished land. Peasants thought to be dead reappeared and had to be resettled on the land. New disputes arose as to who now owned certain pieces of ground and who did not. Homes had to be rebuilt and the shortage of food remedied. In addition to all this, Copernicus was given another task. The chapter requested him to draw up a detailed list of grievances against the Teutonic Order concerning the many damages done to Ermland. Assisting him in this task was his friend and fellow canon, Tiedemann Giese. Together the two set down in this document how the knights had burned villages and towns, stolen and pillaged, robbed and murdered innocent people, occupied peaceful cities, driven away cattle and other farm animals, and perpetrated other foul deeds. When the list was complete, it was presented to the Prussian Diet meeting in the city of Graudenz.

Copernicus also presented something else at Graudenz. This was his now-famous treatise on money. All during these hard years of poverty and warfare, Copernicus had seen how badly the many different coinages of the land had become debased. Not only did the Poles, the knights, and the Prussians each coin their own money, but so did some of the major cities. Year after year, greedy interests had been putting less and less silver and gold into the coins, so that their value was rapidly becoming worthless. As the great Isaac Newton would do in the next century in England, Copernicus proposed to the Diet at Graudenz that the bad coins be called in, and standardized new ones be issued by one central authority. The representatives at Graudenz listened politely to the learned Canon of Frauenburg, but no effective action was taken on Copernicus' proposal. Blocked by those who stood to gain from the continuing inflation, the measure was soon forgotten. Six years later Copernicus would again present his treatise on money to the Diet with the same result.

It was now the year 1522 and Copernicus, his mission at Graudenz finished, returned to his clerical duties at Frauenburg — and also to a bulky manuscript which he knew needed much revising.

COPERNICUS THE LONELY

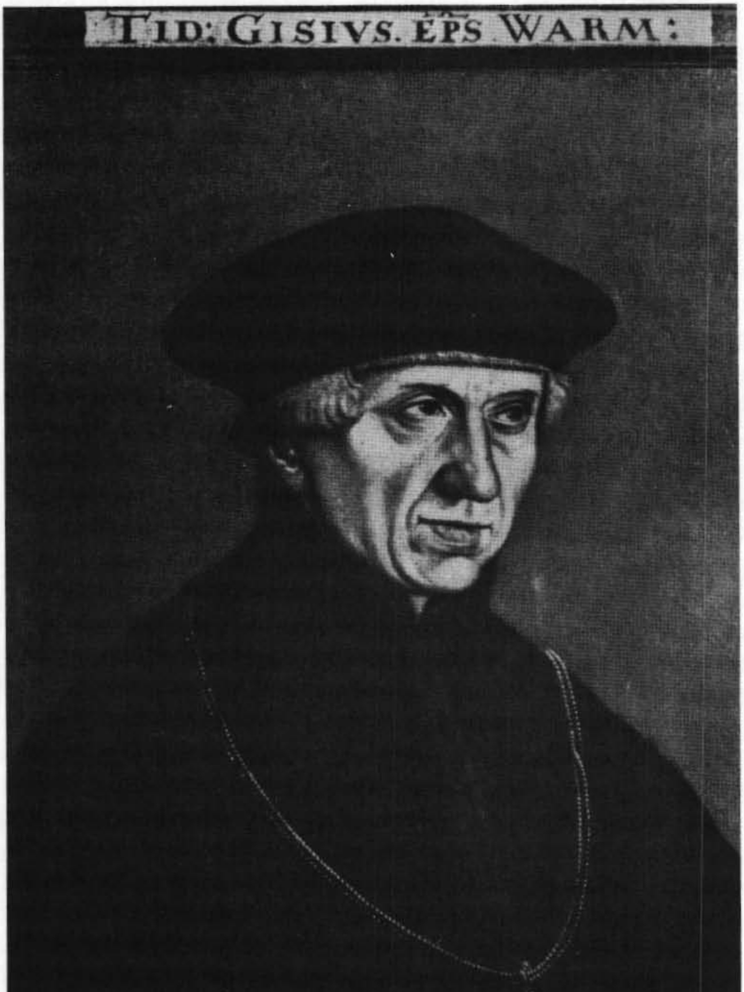
CHAPTER NINE

From the early 1520's until his death in 1543, Copernicus was to find his years filled with increasing loneliness and isolation. With the passage of the seasons, he watched the friends of his youth and young manhood — especially those in the chapter — go to their graves, one by one. While new clergymen were appointed to fill their positions, these were younger men with whom Copernicus could find little in common.

As the astronomer himself grew older, the younger men would take certain duties and responsibilities off his shoulders. As far as Copernicus' astronomical work went, this was good, for it gave the aging canon more time to observe the heavens and to work on his great manuscript.

But as Copernicus approached and passed the age of fifty, he still shared in a large part of the chapter's administrational duties. When his turn came as chapter envoy, he would again tour the outlying estates with a colleague to inspect the local government, collect the rent from the tenants for the cathedral, and in general oversee all that went on. Often the colleague who rode with him was his good friend Tiedemann Giese. In addition, Copernicus helped to work out new craft guild regulations concerning apprentices and journeymen, and even developed a new plan for regulating the size and price of a loaf of bread. After the war with the Teutonic Order, this regulation had become necessary because money and grain prices fluctuated so sharply that Ermland faced an alarming scarcity of food.

Another reason for Copernicus' finding himself increasing isolated was that the Reformation movement, led by the Protestant reformer Martin Luther, was now in full swing throughout the German lands. In the large cities, and especially in Prussia, the new doctrines were beginning to take hold. As we know, the future Duke of Prussia — former Grand Master Albert — was soon



Portrait of Tiedemann Giese, Bishop of Kulm and friend of Copernicus.

to renounce Catholicism and turn Protestant. In Poland, too, the new religious ideas found favor; however, due to the energetic teachings of the Jesuit priests in that land, Poland was to remain a strongly Catholic country. Thus Europe was being rapidly split into two religious camps — the Catholic old-believers and the Protestant new-believers. Whichever stand a man took in the matter could well affect his life. And, being a clergyman, it certainly affected Copernicus.

Oddly enough, Copernicus' superior, Bishop von Lossainen, was rather tolerant toward many of the ideas put forth by Luther and his followers. While the Bishop lived, those with liberal notions about the new religious thinking — which seems to have included Copernicus — had little to fear. But the picture changed in the year 1523 when Bishop von Lossainen died and another member of the chapter, Moritz Ferber, succeeded him. Unlike his mild and tolerant predecessor, Bishop Ferber hated Luther and all he stood for, and actively went on the hunt for anyone who spoke out against Catholicism. Because most of the chapter members followed the line of their strong-willed bishop, Copernicus and others of a tolerant nature were increasingly ignored or treated with obvious coolness.

Copernicus' great friend, the highly learned and respected Tiedemann Giese, also happened to be of a religiously tolerant turn of mind. Copernicus himself did not leave any written record of his views on the reforming movements, and it is only through a book written by Giese that the astronomer's feelings are expressed. Later to become Bishop of Kulm in Prussia and eventually Bishop of Ermland itself, Giese at this time made himself the spokesman for those of liberal views who wished to mediate between the old-believers and the new-believers. Hoping to avoid the split in the church which was to come about anyway, Giese wrote: "Oh, if only the Lutherans were filled with Christian spirit toward the Romans, and the Romans filled with Christian spirit toward the Lutherans . . . the tragedy would not have taken place in our churches. . . ."

At first Giese circulated his beliefs in a manuscript only. Later, however, at the insistence of three of his fellow canons, he had the manuscript printed. One of the most insistent of those three was his friend Copernicus. Indeed, Copernicus authorized Giese to quote him publicly as a supporter of Tiedemann's ideas.

Thus it is clear that the new bishop was well aware of Copernicus' liberal thinking. Why then, if Copernicus was in opposition to his own strict interpretation of Catholicism, did not Ferber attempt to get rid of the astronomer? The answer may well lie in the fact that Copernicus was vastly respected as a physician. Ferber had urgent and frequent need of one, for he suffered from attacks of colic and gout. Far from sending Copernicus away, the Bishop was forever summoning him to his headquarters at Heilsberg in order to receive treatment from the liberal canon. Also, Ferber came to rely on Copernicus to be his spokesman with regard to the currency problem in 1528, and in the following year called the astronomer "well informed" about such matters.

There was also another good reason why Copernicus found himself more and more alone as the years slipped by. It was common knowledge among the other members of the chapter that Copernicus held a different view of the solar system than that held by the Catholic Church. Before the revolt of Martin Luther and his followers, this might not have made too much difference; but with the sweeping conflicts brought on by the Reformation movement, the Catholic Church did not look favorably on any further challenging of established beliefs. Accordingly, Copernicus, with his idea of a sun-centered universe rather than an earth-centered one, further alienated himself from his brother churchmen.

Copernicus, as the 1520's gave way to 1530's, now having more time to himself, filled his days with making observations from his tower and working on his great book. While this work was, of course, little known to the general public, word of it had been getting around in intellectual circles and, here and there, curiosity and admiration for it was shown. Some of these admirers were Catholics who found no heresy in Copernicus' investigations. For, about the year 1530*, when his work was probably first formulated in writing, Copernicus circulated a brief popular account of it as a manuscript. There was interest shown as far away as Rome. Among the interested was the Pope himself, Clement VII, who wished to know more of Copernicus' ideas. Tiedemann Giese repeatedly urged Copernicus to publish his work.

But as the years advanced, Copernicus hesitated all the more. He could not bring himself to a decision to publish his book. There may have been several reasons for his hesitation. Not the least of these was Copernicus' own character. Modest and reserved though he was, the astronomer was also proud and sensitive. One of his biographers claimed that he may once have said, perhaps with some bitterness, "What I know, the public does not approve, and what it approves, I know to be error." In short, Copernicus may well have distrusted the effect his book would have on a scientifically uninformed general public.

But most probably it was fear of misunderstanding and a resulting ridicule of his theory (which indeed contradicted experience) that was the chief reason for Copernicus' hesitating to publish his work. As early as 1531 there was evidence of such ridicule for, in the

* *This work, the* Commentariolus *or "Preliminary Report" was not printed during Copernicus' lifetime. Authorities differ as to when it was actually written. It contains none of Copernicus' own observations and was probably based on the older Alphonsine Tables. The two most striking points in it are that the sun is at the center of the universe and that the earth is in motion.*

town of Elbing that year, a play written by a schoolmaster for a local fair had burlesqued Copernicus as a star-gazing priest.

Actually, during Copernicus' lifetime, the Protestants heaped more abuse on him than did the Catholics. Because certain passages in the Bible suggested that the earth was at rest and not in motion, Martin Luther denounced his ideas. In conversation with some of his followers, Luther had once referred to Copernicus as "the fool who would turn the whole science of astronomy upside down . . ." And, after the astronomer's death, Luther's colleague, Philipp Melanchthon, would likewise speak out against the heliocentric system.

Certainly another reason why Copernicus put off publishing his book was that, as a Catholic clergyman, he feared a conflict with the official teaching of his own church. And indeed, *De Revolutionibus*, though it was first received by the Catholic ecclesiastical authorities without protest, would later be officially rejected by the church for more than two centuries.

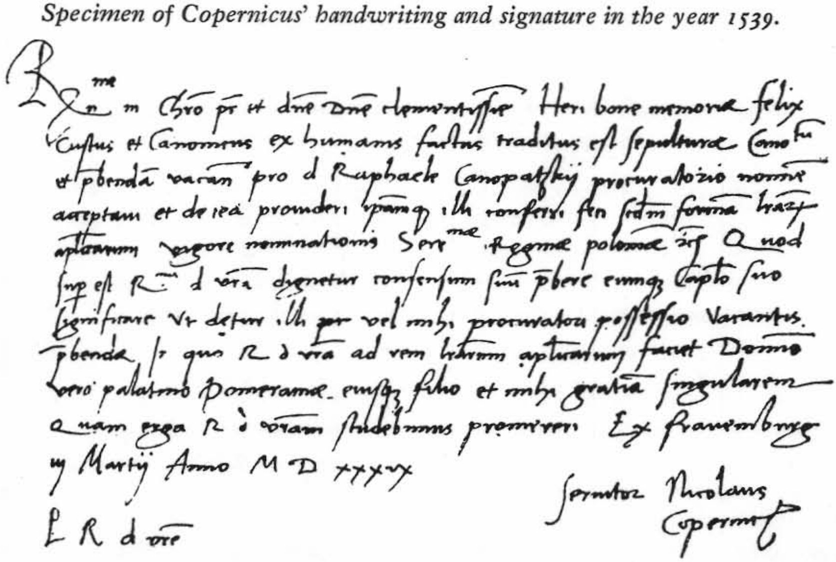
For the time being, however, Copernicus' fears on this score proved groundless. His ecclesiastical superior, the harsh Bishop Ferber, was acquainted with Copernicus' investigations and found no fault with them. Neither did his even harsher successor, Johann Dantiscus, who became Bishop of Ermland in 1538. Tiedemann Giese, by that time himself a bishop, had always been an enthusiastic supporter of his friend. And in

1536, there came a letter to the modest Copernicus from a Cardinal Schönberg in Rome urging him to publish the details of his work. The Canon of Frauenburg valued this letter highly and in the year of his death it was included at the beginning of his life's work.

But Nicolaus Copernicus was now an old man and he found it increasingly hard to come to a decision. Far removed from the mainstream of European activity, alone except for a handful of old friends, he spent the time that remained to him in his observatory, in the efficient administration of the church estates, and in the practice of medicine, with which he had won wide popularity as a good and wise physician.

Thus it is conceivable that the great work of Copernicus' genius might have been tucked away and forgotten on the shelves of some library had not a young stranger arrived at Frauenburg. By his energy and enthusiasm he would move the aged astronomer to give his knowledge to the world.

Specimen of Copernicus' handwriting and signature in the year 1539.



RHETICUS ARRIVES ON THE SCENE

CHAPTER TEN

In spring of the year 1539, a twenty-five-year-old German scholar from Wittenberg came to visit Copernicus at Frauenburg. His name was Georg Joachim of Rhaetia, which, according to the custom of the day, he had Latinized to Rheticus. Somewhat of a genius in his own right, Rheticus had been appointed a professor of mathematics at the University of Wittenberg when he was only twenty-two. Energetic and hungry for knowledge, Rheticus had heard a number of accounts of the epoch-making discoveries of the Canon of Frauenburg and he determined, like the typical wandering humanist that he was, to come to Copernicus and test out their correctness on the spot.

Considering the delicate religious situation at this time, Rheticus took quite a chance in coming to a Catholic land like Ermland. The young man was a Protestant and Protestants were then being persecuted by such Catholic leaders as Bishop Dantiscus. His own university town was a strong center of Lutheranism and, in fact, the stern Lutheran leader Philipp Melanchthon had himself obtained for Rheticus his professorship. Moreover, in coming to study under Copernicus such frowned-upon doctrines as the motion of the earth, Rheticus ran the risk of angering his superiors at Wittenberg. There was a risk for Copernicus, too, in associating with this young Lutheran scholar. It served to further alienate him from his fellow canons, who resented his consorting with a heretic from Wittenberg.

At any rate, Copernicus received the young man and made him welcome. Apparently the astronomer developed an immediate fondness for Rheticus for he began introducing him to important men like Tiedemann Giese at Kulm and even Duke Albert, with whom Copernicus had actually grown friendly in the postwar years. Rheticus, who would spend some two years in Ermland, soon became a devoted disciple of Copernicus and his doctrines. For the rest of his life Rheticus continued to call Copernicus his "Teacher" and became, so to speak, the astronomer's official spokesman for the heliocentric theory.

Immediately after his arrival at Frauenburg, Rheticus plunged with great zeal into the study of Copernicus' manuscript. For several weeks he pored over its text and questioned the astronomer closely as to its meaning. At last the young scholar believed he had mastered the general ideas contained in Copernicus' work, as well as most of the details. Rheticus then wrote the *Narratio Prima de Libris Revolutionum* or *First Account of the Book of Revolutions*. This was a short summary of the great astronomer's work and it was written in the form of a letter to Rheticus' former teacher, the well-known mathematician Johannes Schöner of Nuremberg; however, it was also obviously written for the general public and intended for publication. Actually, the *First Account* analyzes only the last four books of Copernicus' work. It was to be followed by a "Second Account" that was to take up solar and lunar theory in detail. But further "accounts" by Rheticus were not needed, for by that time Copernicus would be ready to publish his entire manuscript.

Late in the year 1539 Rheticus apparently went to the city of Danzig to have the work printed, having Copernicus' permission to do so. There he supervised the setting of type. Appearing the next year, 1540, it was a curious work. Apart from its scientific discussion, it contained a section praising the state of Prussia, quotations from the Latin and Greek, and frequent praise of Ptolemy. The name "Copernicus" appears on the title page, and references to him are always as "My teacher" or "My learned Teacher."

Actually, the true value of Rheticus' *Narratio Prima* lay in the fact that it was the first positive step toward the publication of the complete *De Revolutionibus*. It awakened interest in others to see Copernicus' entire book. And doubtless it served as a prod to Copernicus himself to let his great manuscript finally go to press.

Many readers of Rheticus' little treatise looked forward eagerly to the "Second Account." In addition to sending copies to his friends and colleagues in Germany, Rheticus even sent one to Philipp Melanchthon. Tiedemann Giese eagerly helped to spread the word in other quarters. When Duke Albert of Prussia received his copy, together with a letter from Giese praising Rheticus, the former Grand Master sent to the young author of the *Narratio Prima* a reward.

Publication of his book had now gone beyond mere temptation with Copernicus. Probably sometime after Rheticus' coming, the aging canon had at last made up his mind to delay no longer. A combination of reasons doubtless influenced this final decision. For one thing, Copernicus may have guessed that death was not far off and, whatever the consequences of giving the book to the world might be, he himself would no longer be around to suffer them. For another, the youthful enthusiasm of Rheticus — as well as the encouragement of other friends — probably stimulated him to proceed with publishing the work he had kept largely to himself for so many years. Pride in his authorship may have been a factor as well; for, reasoned Copernicus, if time were indeed running out, then why not go ahead and publish his work in his own way, rather than leave it to others?

It is also possible that as early as 1539 Copernicus may have decided to go ahead. That year he went twice to treat his old friend, Tiedemann Giese, Bishop of Kulm in Prussia, who was suffering from a malarial type of fever. On his second trip to Kulm, which lasted the whole summer, Rheticus was with him. Giese proved not to be seriously ill and the visit turned out to be somewhat of a vacation for all three men. Presumably the urgings of two such strong-willed personalities as Giese and young Rheticus had a deep influence on Copernicus. At any rate, the old man had at last made up his mind to share his theories with the world.

PUBLICATION OF "DE REVOLUTIONIBUS" AND OSIANDER'S PREFACE

CHAPTER ELEVEN

Nicolaus Copernicus had not intended originally to publish his heliocentric theory, but only his planetary tables with directions for their use. But even before the printing of Rheticus' *Narratio Prima*, Tiedemann Giese succeeded in persuading the astronomer to work out his planetary ideas, too. Copernicus' manuscripts, however, proved to be in such a jumbled state that a new draft had to be made up as a copy for the printer.

It was probably Rheticus who spent much of his time during 1541 in making this copy.

By the summer of that year Copernicus apparently completed the trigonometrical part of his book, which subject comprises the last 3 chapters of *De Revolutionibus*. Evidently he and Rheticus worked together very closely on the draft, for some of Copernicus' revisions are commented on in a handwriting thought to be that of the young German professor. And, occasionally, Copernicus would cross out a passage in order to insert something else.

At one point during this period, Copernicus seems to have turned over the manuscript of his work to Tiedemann Giese. But Giese, probably too busy with his many duties as Bishop of Kulm, entrusted it in turn to Rheticus. From that time on, until Rheticus himself had to turn the printing details over to another man, it was the young professor of mathematics who had to make the publishing decisions concerning Copernicus' great book.

Rheticus had decided that Germany was the place to get the great astronomer's manuscript published. He himself was a German, he had many friends there, and it was in Germany that printing facilities were the best at this time. The question was, *Where* in Germany? Evidently Rheticus thought first of his own university town of Wittenberg. He sought the help of the former Grand Master, now Duke Albert of Prussia, sending the Duke a small work on map drawing which he dedicated to the powerful nobleman. Rheticus also begged the Duke to intercede with the University of Wittenberg and the Elector of Saxony to give him permission to publish Copernicus' work in the town. The flattered Duke not only gave Rheticus the recommendation he needed, but also sent him an honorarium.

It was now September, 1541 and Rheticus, armed with Albert's letters of recommendation, left for Wittenberg. It is thought that, together with his own copy of the manuscript, Rheticus also took with him to Germany Copernicus' original handwritten draft. In any case, Copernicus had only been able to make the revisions of the previous year with great effort. His strength was now waning and the time was past for putting any more finishing touches on the book. Besides, he was also a sick man. For, during the second half of this same year, Copernicus began experiencing the first of those deadly hemorrhages that would soon carry him off.

Rheticus' hopes were high as he reverently carried his teacher's great work to be printed in the town of Wittenberg. As it turned out, however, he only succeeded in getting the trigonometrical section of *De Revolutionibus* printed there. Wittenberg was a seething center of Lutheran activity and Rheticus quickly discovered that it could be a dangerous place to launch Copernicus' ideas. Both Luther and Melanchthon got wind of the young man's mission and spoke out bitterly against it. Rheticus cautiously decided to shift publishing operations elsewhere. Actually, Philipp Melanchthon seems to have borne his young protégé no personal ill will, for he provided Rheticus with a letter of recommendation to the vicar of St. Sebald's Church in Nuremberg, where Rheticus had decided to go with Copernicus' manuscript.

Rheticus' decision to go to Nuremberg was a natural one for a young humanist of that day. Since the thirteenth century it had been a free imperial city, independent of the burgraviate of which it was a part. A kind of "German Athens," the city was now in full flower as a center of trade and German Renaissance of culture. Among the German cities, Nuremberg was flourishing in wealth, teeming with talent. It was a refuge for humanists and a fertile ground for new ideas in the arts and sciences. Here lived — or had lived — the great mathematician Regiomontanus, the painter Albrecht Dürer, the poet Hans Sachs, the sculptors Veit Stoss and Peter Vischer, and many, many more. Here were manufactured the first pocket watches, called "Nuremberg Eggs." And here was the home of the *Meistersinger* and prosperous printers. Copernicus' uncle Lucas Waczenrode had had some of the chapter's books printed in the city.

Rheticus had friends in Nuremberg, one of whom was Johannes Petrejus, a bookseller. Petrejus had read the *Narratio Prima* with great interest and, specializing in bringing out mathematical works, had indicated to

View of Nuremberg during the time of Copernicus.

Rheticus his desire to see the complete *De Revolutionibus* with the intention of printing it. It was to this friend and publisher in the free imperial city that Rheticus now entrusted his teacher's manuscript.

Rheticus arrived in Nuremberg during the first half of May, 1542, and Petrejus probably began setting type for Copernicus' book almost immediately. Evidence of this lies in a letter dated June 29, 1542, from a man in Nuremberg to another in the town of Reutlingen: "Prussia has given birth to a new and marvelous astronomer whose theory is now being printed here, a work about one hundred sheets long, in which he maintains . . . that the earth moves and the heavens are motionless. A month ago I saw two sheets printed; the corrector of the printing is a certain teacher from Wittenberg." The "corrector" or editor was, of course, Rheticus. Probably he was also helped in this task by his friend and former teacher, the well-known mathematician Johannes Schöner.

Unfortunately Rheticus did not remain on the job for long. Officially he was still a member of the faculty of the University of Wittenberg, but in trying to champion Copernicus' ideas there, he had come to feel restricted by the opposition he met on all sides. When, therefore, during the summer months of the year 1542, Rheticus received an offer to teach elsewhere, he decided to take it. The appointment was to the University of Leipzig — with it went a higher salary — and in November Rheticus was on his way there. Since Leipzig lay some one hundred miles away from the city of Nuremberg, this meant that for all practical purposes Rheticus could no longer see to the details of guiding Copernicus' book through the press. Someone else would have to be found to take over as editor, and Rheticus had to make the decision. The man he chose to further supervise the printing was a high-ranking 44-year-old Lutheran clergyman by the name of Andreas Osiander.

Osiander is frequently attacked because he took the liberty of inserting an unsigned preface into Copernicus' book. Actually, his decision to do this may have sprung from a well-intentioned attempt to lessen the book's controversial impact. Born in 1498, Osiander at a very young age became one of the first Lutheran clergymen in Nuremberg. Through his powerful sermons, this youthful evangelical preacher did a great deal to further the cause of Lutheranism and the Reformation movement. In fact, it was these very sermons which were largely responsible for winning the former Grand Master of the Teutonic Knights (later to become Duke Albert) over to the Lutheran cause. Osiander loved a fight as well as Luther himself did, but soon his zealous preaching was to turn even the hardy Nurembergers against him and he eventually went north to Königsberg to teach at the university there. It was in that town in 1552 — just ten years after he assumed the editorship of Copernicus' book — that he died at the age of fifty-four.

Osiander was the author of a number of theological works and he was also fond of speculating on astronomical matters. What seemed to interest him more than astronomy itself, however, was the usefulness of the various "hypotheses" concerning that science. Being a Lutheran preacher, Osiander necessarily had to accommodate himself to the views of the powerful Melanchthon — who had written in a textbook that no hypothesis concerning astronomy could really claim to be true. Going along with this view of his superior, Osiander adopted the attitude that it did not actually matter whether an astronomical theory was true or not, but only to what extent it was helpful in making astronomical calculations.

Copernicus and Osiander were no strangers to each other. As early as 1540 they had exchanged letters about fundamental problems, including astronomical ones. In one letter Copernicus, isolated in his cathedral on the far-off Baltic, sought the advice of Osiander, who lived in the mainstream of events and ideas in cosmopolitan Nuremberg. What, the old canon asked of the younger man, would be the reception of a book like his own which dealt with the motions of the earth? Would not those who clung either to theories of Aristotle or Ptolemy be outraged? In April of 1541 Osiander had replied in characteristic fashion: Astronomical hypotheses should not be taken literally, but only as a helpful means for aiding computations concerning the heavenly bodies. Osiander's letter continues: "For who could give us sure information as to whether the irregular course of the sun is produced by an epicyclic or an excentric motion, if we followed the hypothesis of Ptolemy, according to which both are possible." He then urges Copernicus: "Therefore I should think it very desirable if you contributed something on this question in the Preface. Thus you might assuage the Aristotelians and the theologians who, you fear, will contradict you."

In other words, Osiander was advising Copernicus to state at the outset of the book that his theory was just that — a theory — a device like the others that would yield tables useful in telling the future positions of the planets. By doing this Copernicus could, so to speak, get himself "off the hook" with those theologians and scholars who clung to the old notions of planetary motion. Thus there could be no criticism of Copernicus or his book, for the implication would be that the earth did not *really* move.

But this sort of advice did not sit well with the old astronomer. As a scientist, he was much too honest to resort to such tactics. He believed that his theories were true and correct and this was the way he intended to give them to the rest of the world.

And yet, as fate would have it, it was precisely to this man that Rheticus turned over the editorship of the great astronomical work. Thus Osiander, thinking he could soften the revolutionary character of the book by a slight piece of fraud, omitted the original preface written by Copernicus and slipped in an unsigned one of his own. In this short Preface* Osiander wrote that the conclusions of the author were presented as mere hypotheses, without any basis in reality. However, since the fraudulent Preface praised Copernicus highly, it was doubtful whether it was written by him. Nevertheless, some scholars, unsure that the Preface had not been

* *See Appendix for the text of Osiander's fraudulent Preface.*

written by Copernicus himself, continued to include it in the second edition and even the third edition of *De Revolutionibus*. Indeed, for many years the name of the real author of the Preface remained generally unknown. It remained for Copernicus' great follower, Johannes Kepler, to discover that Osiander was the culprit and to first unmask his fraud in print.

Perhaps the greatest harm created by Osiander's Preface was its placement in Copernicus' book. Osiander inserted it right after the title page. Because of this, everything else which followed tended to be altered; that is, everything need not necessarily be taken as truth, but as "hypothesis." This included not only the text of that great work but also two other introductory pieces. One of these, as we know, was the letter from Cardinal Schönberg, of which Copernicus was so proud. The other was a long dedication which Copernicus had composed to Pope Paul III. The old astronomer had taken a great deal of time and effort with this dedication. Why?

Probably the main reason was that, in boldly inscribing the book to the leader of the Catholic Church, he would place himself and his work in a much safer position in relation to those who might persecute him. Copernicus of course took a risk in doing this, for he had no guarantee that the Pope would be pleased with the Dedication or that he would see to it that Copernicus would come under his protection. It was, on Copernicus' part, a "calculated risk" for he knew that Paul III was a far more tolerant, liberal, and scholarly man than some of his predecessors. Therefore, to this understanding and humane man, Copernicus felt safe in pouring out his reasons for making his theories known. In many ways, it is both a revealing and touching document, well worth reading* for anyone interested in the life of Copernicus or in the history of astronomy itself.

Whether or not Copernicus or his book would have received Paul's blessing or protection never came into consideration, for before copies of the book reached the Vatican Copernicus had already expired. Besides, due to Osiander's Preface preceding everything, the Pope or anyone else reading the book might well have been inclined to regard the contents of it as little more than interesting "theories."

Bishop Tiedemann Giese, however, was furious at what had been done to his friend's work. In part, he blamed the printer Petrejus for "letting himself be bribed for another's fraud" by allowing the Preface to be inserted in the book. In a letter to Rheticus, Giese urged the young man to try to set the matter right in a forthcoming meeting of the Council of Nuremberg. While some scholars have speculated that Petrejus favored including Osiander's Preface to help the sale of *De Revolutionibus*, the printer seems to have satisfied the council

* *The Dedication to Pope Paul III is reprinted in the Appendix of this book.*

that he "could not be held responsible for anything." In any case, Osiander admitted privately what he had done. Still, this admission amounted to little; the damage had already been done.

Yet Osiander or no Osiander, the great work had now been launched and the truth contained within its pages was soon to influence the thinking of all civilized men.

ABOUT A BOOK AND THE DEATH OF ITS AUTHOR

CHAPTER TWELVE

As Nicolaus Copernicus lay on his deathbed at Frauenburg on May 24, 1543, one of the first copies of his book reached the dying author from Petrejus' shop in Nuremberg. As an original work of scientific genius, it fully ranks with Isaac Newton's *Principia* and with Charles Darwin's *Origin of Species*.

What kind of a book was it?

The first edition of *De Revolutionibus Orbium*

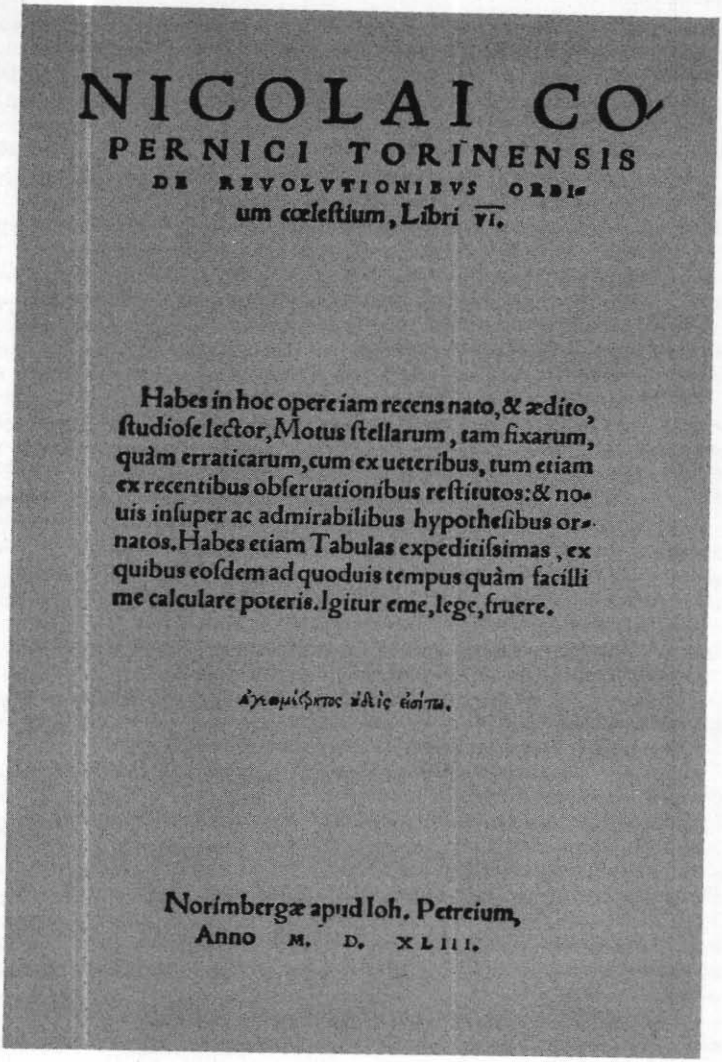
Coelestium was a work of some two hundred pages written in Latin, In addition to the text, it contained (in order) the title, Osiander's Preface (the author's having been removed), the letter from Cardinal Schönberg, Copernicus' Dedication to Paul III, and a table of contents. Somewhat later there was printed a list of *errata* — or printer's errors made in the text, with their corrections. The work was illustrated with a number of woodcuts and the first edition probably consisted of about one thousand copies. It was bound in leather. The pages (folios) were rather small.

Hoping to make a good profit from the publication, Petrejus seems to have overcharged for the book — one account says as much as twenty-eight ducats and six pfennigs. The book was never a financial success, however, and Petrejus did not even bother to reprint it. In fact, twenty-three years were to pass before a second edition of the book was printed in 1566, in Basle, Switzerland; even then, the very pages corresponded with each other in many cases and most of the same errors were reprinted.

Besides sending the new book to its author, Petrejus sent a few free copies to the original editor, Rheticus. The young German professor, in turn, sent copies of it on to some of his friends, including Tiedemann Giese and a Canon Georg Donner, who seems to have been one of Copernicus' closest friends during his last months.

It is significant that Canon Donner, in addition to noting on his copy that Osiander's Preface did not come from his friend Copernicus, also crossed out the words "Orbium Coelestium" of the book's title. Doubtless the reason he did so was because he believed that this was not Copernicus' title. It is not really known for sure what Copernicus proposed to call his book. Perhaps it was simply "The Book of Revolutions." At any rate, since the entire book was divided into six books or parts, the editors added to the title the words *Six Books* (*Libri VI*). Thus, whoever was responsible for its title, the book as it left Petrejus' presses was called *De Revolutionibus Orbium Coelestium Libri VI*, or *Six Books Concerning the Revolutions of the Heavenly Spheres.*

Let us look for a moment beyond the publication year of the immortal *De Revolutionibus.* As we know, the second edition appeared in Basle in 1566, repeating the same errors that were contained in the first edition, and with many new ones added by the printer. In 1617, fifty-one years later, there appeared in Amsterdam the third edition which, through better editing, contained fewer errors. Still another edition appeared in 1854 in Warsaw; this edition, at least, contained the original Preface written by Copernicus and which had been removed by Osiander. Needless to say, all of these later editions were only corrected copies of the original edition printed in 1543 by Petrejus at Nuremberg, for none of these later editions had either Copernicus' original text or Rheticus' copy to work from.



NICOLAI CO-
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI-
um cœleſtium, Libri VI.

Habes in hoc opere iam recens nato, & ædito, ſtudioſe lector, Motus ſtellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obſeruationibus reſtitutos: & nouis inſuper ac admirabilibus hypotheſibus ornatos. Habes etiam Tabulas expeditiſsimas, ex quibus eoſdem ad quoduis tempus quàm facilli me calculare poteris. Igitur eme, lege, fruere.

ἀγεωμέτρητος οὐδεὶς εἰσίτω.

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

Title page of De Revolutionibus Orbium Coelestium. *First edition, Nuremberg, 1543.*

Had Copernicus' original manuscript been lost forever? For centuries it probably lay in some dusty and forgotten corner of one European library or another. But in the middle of the last century it chanced to turn up in the library of a nobleman in Prague.

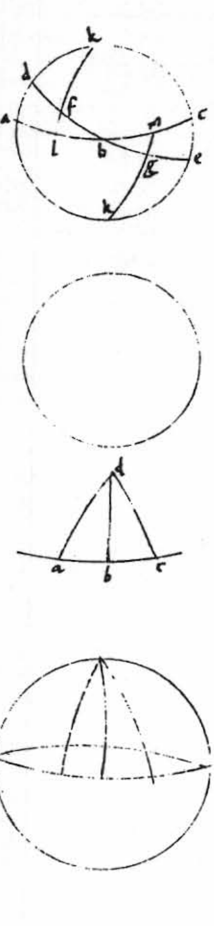
Due to this rare stroke of luck, the first Nuremberg edition and those following it could then be compared by qualified scholars. The deviations from the author's original text were numerous indeed. One Copernican scholar reported that he found practically no page matching in either of the two texts. Another scholar believed that he could recognize evidences of Rheticus' editing; for example, one frequently recurring word is spelled the way Rheticus spelled in the *Narratio Prima*, instead of the way Copernicus would have spelled it. Certainly the two texts are so different that the Nuremberg printers must have set type from a different copy altogether — probably one made by Rheticus.

At any rate, due to the lucky discovery of Copernicus' own manuscript, *De Revolutionibus* could thereafter be printed and read in the form that its author originally intended. This edition, called the Centenary Edition, was published at Torun, the astronomer's birthplace, in the year 1873 — the four hundredth anniversary of the birth of Nicolaus Copernicus.

As for the astronomer's death, it was a lonely, lingering one. His last years had been ones of increasing solitude and even humiliation. In the year 1538 Johann

Dantiscus had become Bishop of Ermland. A former soldier and adventurer, Dantiscus in his later years as a churchman seemed to be trying to atone for the recklessness of his youth by unnecessary strictness and ecclesiastical discipline. In particular, he hated and sought to repress Lutheranism wherever he found it. While he valued Copernicus as a physician, Dantiscus apparently took a dislike to the old canon and in certain ways made life miserable for him. Copernicus' friendship for his young Protestant friend Rheticus was one of the reasons for this. The astronomer was especially saddened when Dantiscus banished as a heretic one of Copernicus' last remaining friends in the chapter, Prelate Alexander Sculteti, whose position Dantiscus wanted for one of his own supporters. In addition, Dantiscus saw fit to drive from Copernicus' household his trusted housekeeper Anna Schillings.

Not only was Copernicus' physical strength waning — fevers were weakening him even before Rheticus' arrival — but a number of other things had also served to wear him out. The growing strife caused by the split in the church saddened him. Increasing solitude depressed him. Perhaps most of all he worried over his book. It had never been as complete as he would have wished it to be. His decision to publish it had caused him much soul-searching and wrestling with his conscience. As early as September of 1540 Copernicus must have seen that death could not be far off and so he made arrangements



eo minore recto facit angulum: quo signifer a recto declinat
Ut iam quidem partium sit lxvi ac xxiii. Est etiam animadvertendum
quod ad aequales signiferi circumferentias: quae ab aequinoctialibus
tropicisque punctis sumuntur, anguli et latera triangulorum sequuntur
aequalia: quemadmodum si descripserimus aequi. circumferentiam
abc et signiferum dbe sese in b signo secantes in quo sit aequinoctium
assumpserimusque aequales circumferentias fb et bg utrique per polum motus
diurni qui sit k bini quadrantes circulorum kfl et kmg: erunt
bina triangula flb et bmg quorum latera bf et bg sunt
aequalia, et anguli qui ad b vertice et qui circa l et m recti. Igitur
per ix sphaericorum aequalium laterum et angulorum. Ita fl et mg
declinationes aequales et ascensiones rectae lb et bm et reliquus
angulus f reliquo g. Eodem modo patebit in assumptis a puncto
tropico aequalibus circumferentiis. Veluti cum ab et bc hinc inde
aequales fuerint a tropico contactu b deductis enim ex d aequinocti-
alis circuli polo quadrantibus da. db: erunt similiter bina tri-
angula abd et dbc quorum bases ab et bc et latus bd utrique com-
mune sunt aequalia et anguli qui circa b recti, per xi sphaericorum
demonstrabuntur triangula ipsa aequalium esse laterum et angulorum
quo manifestum fit, quod unius in signifero quadrantis anguli
tales et circumferentiae expositae reliquis totius circuli quadrantibus
consentiunt. Quorum exemplum canonica descriptione subijciemus
In primo quidem ordine ponentur partes signiferi: sequenti loco de-
clinationes partibus illis respondentes. Tertio loco scrupula quibus
differunt et excedunt has: quae fiunt sub maxima signiferi obliqui-
tate particulares declinationes: quarum summa est scrupulorum xxiiii
Simili modo et in angulorum tabella faciemus; ~~sed ascensionum~~
~~rectarum differentia.~~ Necesse est enim ad mutationem obliquitatis
signiferi omnia mutari quae ipsam sequuntur. Porro in ascensione
recta perquam modica reperitur ipsa differentia: utpote quae decimam
unius temporis partem non excedat: quaeque in horario spatio centesimam
solummodo et quinquagesimam efficiat. Tempora siquidem vocant
prisci, circuli aequinoctialis partes, quae signiferi partibus coori-
untur: quarum utrarumque circulus est, ut saepe diximus ccclx
sed pro earum discretione, signiferi partes gradus: aequi-
noctialis vero tempora plerique nominaverunt: quod et nos deinceps
imitabimur. Cum igitur tantula sit haec differentia
quae merito possit contemni: non piguit et hanc apponere.
~~[illegible]~~
~~[illegible]~~. E quibus tum
etiam in quavis alia signiferi obliquatione eadem patebunt: si pro
~~[illegible]~~
~~[illegible]~~
ligitate

~~ut inferius apparebit~~

hec deleri non debent
usque ad proximum. C.

Facsimiles of two pages from Copernicus' original manuscript of De Revolutionibus *found in Prague showing text, drawings, and tables. Note deletions and corrections. (Burndy Library)*

Canon declinationi meridiano

30 dia	Decli natio		Dif fer	30 dia	Decli natio		Dif fer	30 dia	Decli natio		Dif fer
part	pa	sc	so	part	p	sc	so	pt	p	sc	sc
1	0	24	0	31	11	50	11	61	20	23	20
2	0	48	1	32	12	11	12	62	20	35	21
3	1	12	1	33	12	32	12	63	20	47	21
4	1	36	2	34	12	52	13	64	20	58	21
5	2	0	2	35	13	12	13	65	21	9	21
6	2	23	2	36	13	32	14	66	21	20	22
7	2	47	3	37	13	52	14	67	21	30	22
8	3	11	3	38	14	12	14	68	21	40	22
9	3	35	4	39	14	31	14	69	21	49	22
10	3	58	4	40	14	50	14	70	21	58	22
11	4	22	4	41	15	9	15	71	22	7	22
12	4	45	4	42	15	27	15	72	22	15	23
13	5	9	4	43	15	46	16	73	22	23	23
14	5	32	5	44	16	4	16	74	22	30	23
15	5	55	5	45	16	22	16	75	22	37	23
16	6	19	6	46	16	39	17	76	22	44	23
17	6	42	6	47	16	56	17	77	22	50	23
18	7	4	7	48	17	13	17	78	22	55	23
19	7	27	7	49	17	30	18	79	23	1	24
20	7	49	8	50	17	46	18	80	23	5	24
21	8	12	8	51	18	1	18	81	23	10	24
22	8	34	8	52	18	17	18	82	23	13	24
23	8	57	9	53	18	32	19	83	23	17	24
24	9	19	9	54	18	47	19	84	23	20	24
25	9	41	9	55	19	2	19	85	23	22	24
26	10	3	10	56	19	16	19	86	23	24	24
27	10	25	10	57	19	30	20	87	23	26	24
28	10	46	10	58	19	44	20	88	23	27	24
29	11	8	10	59	19	57	20	89	23	28	24
30	11	29	11	60	20	10	20	90	23	28	24

for a distant relative to officially succeed him in the chapter.

As the winter months of 1542 approached, the astronomer's friends became increasingly concerned about his condition. Canon Donner, who was with Copernicus at Frauenburg, wrote about it to Bishop Giese at Kulm. Giese's reply to Donner in early December plainly shows the esteem in which he held Copernicus.

> Since Copernicus even in his days of good health liked retirement, only a few friends would probably stand sympathetically at the side of the gravely ill man, yet we are all his debtors on account of his pure soul, his integrity, and his extensive learning. I know that he always counted you among the most faithful of his associates. Therefore I beg you to stand by him protectingly if his fate requires this, and to assume the care of the man whom together with me you have always loved, in order that he may not lack brotherly help in his sickness and that we do not appear ungrateful toward a friend who has abundantly earned our love and gratitude.

Christmas passed and the new year arrived. By now, Copernicus had suffered repeatedly from hemorrhage, paralysis, and also a heart attack. Those watching at Frauenburg thought his death was surely near. Bishop Dantiscus himself wrote to an inquiring friend that the end could not be but a few days off.

The miracle was that Copernicus managed to cling to life for nearly five more months. At some time during these last weeks he scribbled on a bookmark: "Oh brevity of life, and our miserable knowledge; and most of it escapes us through the sieve of memory!". Almost surely he must have been in constant pain. Yet he lingered until May 24, 1543.

It is as if he had forced himself to hang on a little longer so that he might see a printed copy of his book. Technically at least this wish was fulfilled, for a copy was indeed brought to him as he lay on his deathbed.

In reality, however, Copernicus was no longer lucid; the mind of the astronomer had become unsound some days before. This is known from a letter written by the faithful Tiedemann Giese to Rheticus during the summer following Copernicus' death. This letter is of special interest because it refers to a biography of Copernicus written by Rheticus which, sad to say, was later lost. Giese hoped for a new printing of the opening pages of *De Revolutionibus* in which Rheticus' biography would appear and from which Osiander's Preface would have been removed. So that Rheticus could add Copernicus' end to his biographical sketch, Giese wrote the following to the young man on July 26, 1543:

> ... I also wish that your biography of the author that you wrote so elegantly and that I once read, be put before the work freed from Osiander's falsification, and since I think that nothing is missing in your story except for the end of his life – he died on the ninth day before the first of June, after a hemorrhage and the paralysis of the right side that followed; many days before he had lost his memory and

intellectual vigor, and his completed book he saw only in his last hour, on the day that he died.

So Copernicus was no more. Presumably he died not knowing that the Preface by Osiander had been retained at the beginning of his book. During his last illness, he had been attended by the vicar and physician, Fabian Emmerich, to whom the dying man had left one of his own medical textbooks with notes in his own handwriting. As for his other books, they went to the chapter's cathedral library. When his estate was divided up, the proceeds went to the family of his married sister.

The body of the old canon was buried in Frauenburg Cathedral, next to the grave of his uncle, Bishop Waczenrode. But like the grave of his great successor Johannes Kepler, the exact spot where Copernicus was laid to rest is not certain. In the year 1581 a memorial plaque was put up on the wall of the church where the grave site was thought to be. In the mid-eighteenth century, however, this memorial was taken down to make room for the epitaph of a bishop named Szembek. Later, another memorial was re-erected to the great astronomer. It remained for the last century to pour forth a flood of works honoring Copernicus. Town after town in Poland erected monuments to him, the most noteworthy being a statue in Torun, his birthplace. In 1830 Warsaw received a splendid monument to him from the chisel of the great Danish sculptor, Bertel Thorwaldsen.

But of Copernicus himself, nothing remained except a few brief signatures on tax slips, a sprinkling of notes in books owned by him, a few friends who did not long survive him, a doctor's diploma and his name in a matriculation register, a few letters and a treatise on money, the house where he was born, the austere tower in which he worked, and a few inept likenesses of his vaguely smiling face.

And of course *De Revolutionibus*.

"CONCERNING THE REVOLUTIONS OF THE HEAVENLY SPHERES"

CHAPTER THIRTEEN

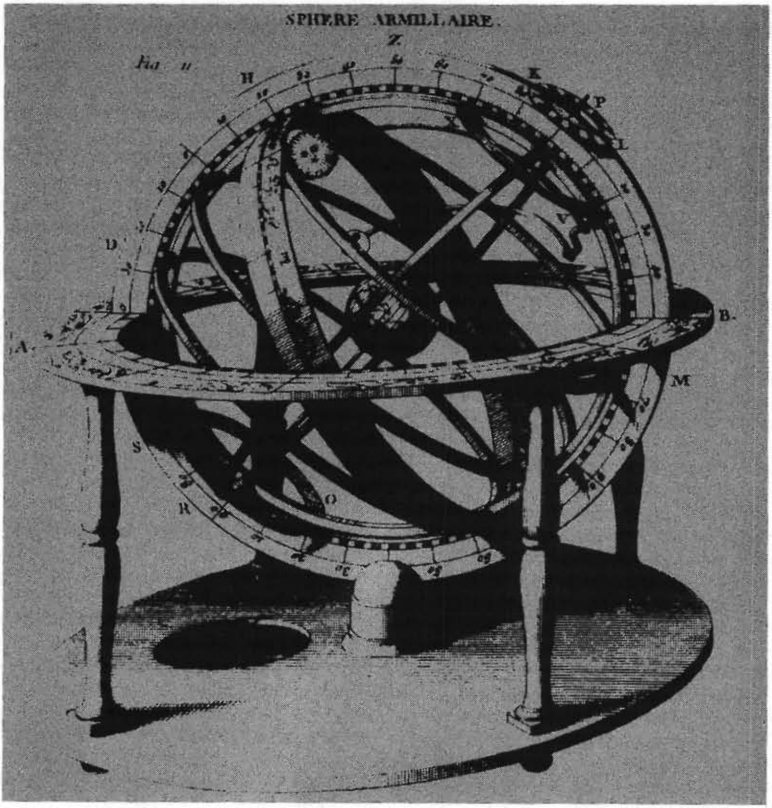
To examine in detail every part of Copernicus' *De Revolutionibus Orbium Coelestium* is beyond the scope of this book. Yet it is important to have a general picture of how his great work was set up. As we already know, in addition to the prefatory material, *De Revolutionibus* is divided into six parts or "books"; these parts in turn are subdivided into chapters.

In Book I Copernicus sketches for the reader his general scheme of the universe as he believes it to be. At the end of this book there are three chapters dealing with plane and spherical trigonometry — the tools and rules which Copernicus uses to build up his later arguments. It was these three chapters of the book that Rheticus had printed in Wittenberg in 1542 and which he brought with him to Nuremberg later that year.

It is the bulk of Book I that gives the layman the clearest overall picture of the heliocentric, or sun-centered, system of Copernicus' "universe." Here are to be found the famous passages in which the author reinforces his basic arguments that the sun lies at the center of the universe and that the earth is in motion. Some of these will be quoted in a later chapter which examines some basic ideas of the heliocentric system.

Book II of *De Revolutionibus* is devoted to spherical astronomy and a description of the armillary sphere. An armillary sphere was an ancient instrument consisting of a number of metal rings representing the celestial equator, the ecliptic (apparent path of the sun through the heavens), and other circles of the celestial sphere. It is to the problems concerned with the movements of the heavenly bodies on this sphere that Copernicus applies the trigonometrical rules laid down in Book I. Often in statues of him, Copernicus is shown holding an armillary sphere; occasionally in portraits he holds one, or there is one standing in the background behind him.

Book II closes with a star catalog, which lists over



Old engraving of an armillary sphere.

1000 stars and their locations on the celestial sphere. The positions of these stars are given by a pair of co-ordinates, or imaginary circles, which cross each other on the celestial sphere. Since early astronomers believed that the stars were "fixed" in the heavens, their locations served as a convenient background for tracking the movements of the planets as they moved across the sky. Copernicus, however, did not use his own observations in compiling this star catalog. Rather, he borrowed Ptolemy's of the second century A.D. Except for correcting a few errors which the catalog was bound to have since that time, Copernicus reprinted it much as Ptolemy had set it down in the *Almagest*. It was, in fact, one of Copernicus' failings that he took as being accurate the astronomical measurements which had come down to him from the Greeks and the Arabs. Also, Copernicus had poor instruments to work with and his own observations were no more precise than those made by the ancient Greeks. Nor was his eyesight supposed to have been the best. Unlike the great Danish astronomer Tycho Brahe, for example, Copernicus was never known as a great astronomical observer. It is of course as a mathematician, original thinker, and creator of a new theory of the universe that the world honors him as a titan of astronomy.

Book III deals with the length of the year and the orbit of the earth. The latter part is devoted to the explanation of tables calculated in such a way that it does not matter whether the earth or the sun is considered in motion. In this book is also brought up a question that bothered Copernicus all of his life: namely, was the center of the universe outside or within the sun? In part, this was due to his assuming planetary motion in circles.

Copernicus' great successor, Johannes Kepler, was later to show that the orbits of the planets were really slightly elliptical.

As for the remaining books, Book IV deals with the motion of the moon and its eclipses, and Books V and VI treat the planetary motions in longitude and in latitude.

In these books of *De Revolutionibus*, Copernicus strove to give detailed accounts of the motions of the earth, the moon, and the planets. In the course of each book Copernicus arrives at a theory, which he backs up with geometrical diagrams of how these bodies move and what paths they follow. He then deduces tables which were supposed to give the predicted future motions and positions of the bodies in question.

The whole trouble with these tables, however, was that they were based either on not-too-accurate observations by Copernicus or on those of the ancients. Kepler and later astronomers would make new and more accurate tables.

Copernicus himself eventually began to suspect that something was wrong. Conceivably it was the biggest disappointment of his later life. Indeed, it may even have served to shorten the astronomer's life. Too late, Copernicus began to distrust the observations of Ptolemy and others. Too late, he began to see that he must begin again to make new observations of the planets if his tables were to be improved. It is for this reason that

Copernicus, in 1537, started to do more and more observing from his tower. It also explains why Copernicus was never quite finished with his book, why he always wanted to do more revising, why it often bears the marks of haste, and why there are so many errors and corrections.

Even granting all this, Copernicus is not remembered today for the inaccuracies of his book, but for his vision in pointing the way toward astronomical truth.

FROM THALES TO PTOLEMY — ASTRONOMY BEFORE COPERNICUS

CHAPTER FOURTEEN

While Nicolaus Copernicus will aways be remembered through the ages as the author of the heliocentric, or sun-centered system, he was not by any means the first man to arrive at the theory that the earth is in motion and that it moves about the sun. Centuries earlier others had suggested the truth; it was Copernicus, however, who succeeded in setting this system down in a book in such a way that it left a lasting impression on all of mankind.

Still, men living long before Copernicus' time had suggested the way. Certain of the ancient Greek philosophers had expressed opinions concerning the movements of the celestial bodies which were far from being in line with the beliefs of their own or later times. Copernicus does not hesitate to acknowledge his debt to some of them in his dedication to Pope Paul III. They were Nicetas of Syracuse who was of the opinion that the earth moved; Philolaus the Pythagorean who ascribed progressive motion to the earth; and Heraclides of Pontus and Ecphantus the Pythagorean who suggested that it revolved in an orbit. While Copernicus says that he read these opinions in quotations from such reliable authors as Cicero and Plutarch, they are nowhere backed up by logical demonstration based on sound astronomical observations. Indeed, such opinions were pure speculations on the part of these early Greeks.

Nevertheless, they led Copernicus to reflect and ponder, forming in his mind the germ from which his heliocentric system was to spring. Until his own time, astronomers had paid little attention to such speculations by these early writers. For fourteen centuries, the astronomical knowledge set down by the Alexandrian Greek, Claudius Ptolemy, had held sway. It, together with certain ideas set forth by Aristotle, had been accepted by most people for all that long time.

Even today, with modern and accurate scientific knowledge at our fingertips, it is no easy matter to describe or grasp the observed motions of the planets. It is small wonder, then, that it took so many centuries to reconstruct the actual workings of our solar system from the observed motions of the bodies in it. The process was not only painfully and laboriously slow, it also took many wrong turns in its quest for the truth.

Leaving aside for the moment some of the more fanciful conceptions of the universe, such as those entertained by the Egyptians and Babylonians, let us look at some of the steps by which this process was effected. Beginning with Thales and culminating in the work of Ptolemy, these were thoughts and ideas about the planetary system contributed by classical Greek philosophers. By tracing some highlights of this Greek thought, one can better appreciate the innovation introduced by Copernicus.

One of the earliest of the Greek thinkers was Thales of Miletus (640-546 B.C.). Thales believed that the earth was a short cylinder or disk floating in water, and that the heaven above the floating earth was a hemisphere moving around, not under it. This upper hemisphere was also supposed to be surrounded by water. Thales not only determined the solstices and the equinoxes, but also made an excellent estimate of the apparent diameter of the sun — about half a degree of arc — which is nearly correct.

A pupil of Thales was Anaximander (611-547 B.C.) who seems to have disagreed with his teacher that water was the origin of all things. While he, too, thought of the earth as a short, flat cylinder, it was not floating in water but suspended freely in the center of the universe, with man occupying one of the flat faces of the cylinder. For Anaximander, the primary cause (or, in philosophy, the First Principle) of all things was something which he called "the boundless." By means of constant motion, this "boundless" cause was supposed to account for the generation and destruction of worlds — a crude sort of cosmogony. Outside the earth, Anaximander's view of the universe becomes an interesting spherical one. He thought that the stars were actually a fiery sphere, hidden by the firmament or arch of the sky, and seen only as points of light shining through pinholes in the firmament.

A contemporary of Anaximander was Anaximenes (585-528 B.C.) who, instead of water or "the boundless," believed that air was the basic universal substance. For Anaximenes the earth was a kind of flat table floating on air, and the sun above it was also flat, like a leaf. He thought that the sun, moon, and stars had evolved from the earth and that these bodies were made of fire. He believed that the star's fiery heat could not be felt because of their great distance. In addition, he pictured them as studs attached to a vast crystal sphere. Anaximenes seems to have been the first to realize that the stars were farther away from the earth than the sun. Also, he made a distinction between the stars and the planets, which latter he thought were "floating" like the sun.

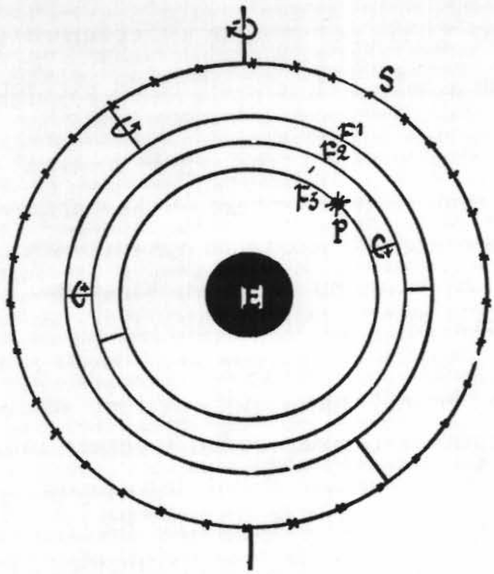
One of the giants of classical astronomy was Pythagoras (572-492 B.C.) who founded a famous school of philosophy, the essence of which was that all things could be expressed in numbers and that all relationships were numerical in nature. Pythagoras seems to have been the first to maintain that the earth was a sphere, probably because he considered the sphere to be the perfect geometrical figure. Likewise, he considered other heavenly bodies to be spherical as well. While some later Pythagoreans (as Copernicus knew) thought of the earth as a planet in motion, Pythagoras himself imagined the earth in space as being in the center of the universe and at rest. The "fixed" stars were supposed to turn from east to west on a moving sphere that was attached to the earth by means of a gigantic axis going through the poles of the earth. The planets moved independently from west to east. Pythagoras has also been said to have been the first to recognize that the morning and evening stars are identical. Later some followers of Pythagoras also placed the stars on a great moving sphere, but at the center of this universe was neither the earth nor the sun. Instead, there was supposed to be an immense central fire, which they variously called the "Altar of Zeus" or the "hearth of the universe." This central fire was thought to be invisible from the earth; it could not be seen because the populated areas of the earth were always supposed to be turned away from the fire. For these Pythagoreans, the earth was only another of a number of heavenly bodies, including the sun, all of which moved in circles about the "Altar of Zeus."

Sometimes Greek thought could backslide to earlier, more primitive ideas. Such retrogression is evident in the notions of the sixth-century Greek, Heraclitus of Ephesus. Heraclitus pictured the sun as being re-created each day; further, he imagined the sun to be only a few inches in diameter! Both the sun and moon were supposed to be bowl-shaped, the phases of the moon resulting from the turning of the bowl.

It was Anaxagoras (born about 500 B.C.) who held that an all-pervading mind, which he called *nous*, was responsible for motion and order by combining masses of particles into actual objects. Moreover, Anaxagoras was such a dedicated astronomer that he believed the whole point of being born was "to investigate sun, moon, and heaven." In so doing, he seems to have had a good commonsense grasp of the solar system. He may have been the first to realize the nature of moonlight and to explain lunar eclipses correctly. The moon, Anaxagoras said, was of an earthly nature with plains and valleys, and it shone with a false light. His idea of the size of the sun was a little closer to the truth than that of Heraclitus: he declared it to be a red-hot mass or a stone on fire that was larger than the Peloponnesus, the southernmost region of continental Greece. A contemporary of Anaxagoras, Empedocles, left evidence that he correctly understood the cause of night, and how eclipses occurred.

In the fourth century B.C., an increasing knowledge about the motions of the planets led to the formation of some complicated geometrical pictures that were supposed to account for them. Perhaps the best known of these was advanced by Eudoxus of Cnidus, who flourished about the year 350 B.C. Eudoxus' model of the universe was an elaborate system of concentric spheres (one within another) with a stationary earth at the center. Through a complicated plan of spheres moving within spheres, the movements of the planets, sun, and moon could be reproduced as they were actually observed in the heavens. No fewer than twenty-seven of these spheres, which were thought to be of a crystalline substance, were required for Eudoxus' model of the universe — three for the sun, three for the moon, four for each of the five known planets, and one for the starry heavens. Callippus, a follower of Eudoxus, later improved on his teacher's model of homocentric spheres, notably by adding another sphere each to Mars, Venus, and Mercury.

It was principally upon this Eudoxian model of nestlike spheres that the great philosopher Aristotle (384-322 B.C.) based his scheme of the universe as recorded in his classic work *On the Heavens*. In essence, what



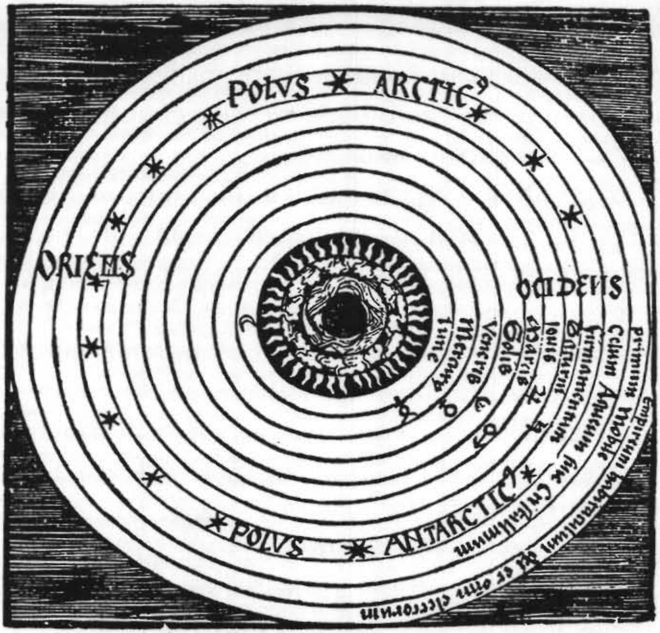
The Eudoxian or homocentric-spheres system of planetary motion, later modified by Callippus and adopted by Aristotle. Drawing shows scheme for one planet only, e.g. Saturn. Earth E *is motionless at center. Starry sphere* S *rotates about earth's center. Inside this sphere and carried about with it are the axes of a second sphere* F1 *rotating at a different speed. Inside this sphere are the axes of a third sphere* F2, *which in turn carries a fourth* F3. *To this is attached the planet* P *whose motion is thus a combination of the motions of all four spheres.*

Aristotle did was to remold Eudoxus' universe into a compact mechanical model which required no fewer than fifty-five spheres to account for the motions of the planets. Once again, the model was a geocentric one — the earth was at the center. Because of Aristotle's vast influence on medieval and Renaissance cosmological thought (even Copernicus took over many of his notions), let us take a closer look at the Aristotelian universe.

In Aristotle's model, the whole universe was contained within the outer sphere of the stars; everywhere inside this celestial sphere there was supposed to be some kind of matter, for no holes, chinks, or vacuums could exist in Aristotle's universe. This, of course, meant that outside the sphere of the stars there was nothing — no space, no material things, not anything at all. In other words, matter and space ended together and, as Aristotle put it, ". . . there is not, nor do the facts allow there to be, any bodily mass beyond the heavens." Thus, the universe was completely self-contained and self-sufficient. However, if matter was supposed to be present everywhere, what about all of the apparent space between the starry shell and, say, the sphere carrying the lowest planet, the moon? This was, in fact, the largest portion of the inside of Aristotle's universe and, he said, it was filled with a single all-pervading element called *ether*. Ether was supposed to gather in the concentric set of nesting spheres to form a gigantic hollow sphere whose surfaces were the outside of the starry heavens and the inner surface of the lunar shell. Ether, moreover, was thought by Aristotle to be a kind of crystalline solid material — although, mysteriously, it was also reputed to be weightless, transparent, absolutely pure, a basic and unalterable heavenly element. From this pure and celestial substance, unlike any of the substances known on the central earth, were made the stars, the planets, and all of the thickly nesting concentric shells which carried them about.

By almost doubling the number of spheres of Eudoxus and Callippus, Aristotle managed to provide the mechanical connection that was necessary to keep the entire nest of concentric ethereal shells turning. Like a vast piece of heavenly clockwork, the outer sphere of the stars provided initial driving power for the rest of the universe. Each outer sphere rubbed against its next interior neighbor until the motive force for the innermost sphere — the one that carried the moon — was at last received. And — by various mathematical and mechanical juggling of these ethereal spheres it was actually possible to account for many of the observed motions of the heavenly bodies. In addition, each of the planets always moved in a perfect circle at a steady rate about its center — an incorrect assumption which Copernicus never doubted in all his life.

It is not at all inappropriate here to reemphasize the almost incredible influence Aristotle had on later ages. Of all the ancient authorities, he was by far the greatest. To the poet Dante, living some sixteen centuries after Aristotle's time, he was "the master of those who know." If a thing could not be found in the writings of Aristotle, it could not be true. The story is told of a medieval student who, having discovered spots on the sun, revealed this fact to a priest, who replied: "My son, I have



The Aristotelian scheme of the universe, as portrayed with Medieval modifications. From inside to outside: spheres of earth, water, air, and fire composing the terrestrial region; planetary spheres carrying Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn; then the fixed stars. Later additions were: crystalline sphere which provided rotation of the pole (and needed for precession of the equinoxes, unknown to Aristotle); the Primum Mobile or First Mover, which impelled the rest; and the Empyrean Heaven, or abode of God and the Saints. Compare with Dante's scheme of the universe.

read Aristotle many times, and I assure you that there is nothing of the kind mentioned by him. Go rest in peace and be certain that the spots which you have seen are in your eyes and not in the sun." With truth, historians often speak of "the dead hand of Aristotle."

Indeed, nowhere did Aristotle's "dead hand" persist more strongly than in this idea of the nested concentric spheres. True, it was largely replaced by the more workable Ptolemaic system after the second century A.D.; but it is also a fact that the cosmology of Aristotle was still accepted by men living in the seventeenth century — more than a hundred years after the death of Copernicus. In the *Divine Comedy*, Dante Alighieri's scheme of the universe is, with minor additions, essentially the same crystalline sphere universe as that adopted by Aristotle from Eudoxus and Callippus.

A man born only about five years before Aristotle, Heraclides of Pontus, made definite steps toward the heliocentric idea — a fact which Copernicus duly notes in his dedication to Pope Paul III. Heraclides clearly recognized that the earth rotates on its axis. And he wrote, "The stars of Mercury and Venus make their retrograde (backward or westward moving) motions . . . about the rays of the sun, forming by their courses a wreath or crown about the sun itself as center. It is also owing to this circling that they linger at their stationary points." Although Heraclides understood this about the *inferior* planets (those that circle the sun in orbits smaller than the earth's — Venus and Mercury), it is doubtful that he realized that the same is true of the superior planets.

Another giant of Greek astronomical thought was Aristarchus, who came on the scene about seventy-five years after Heraclides and whose work on the heliocentric idea was well known to (and acknowledged by) Copernicus. Aristarchus stands out as an observer who looked at the problems of the solar system geometrically and determined to do some original measuring of his own. In principle, his method for determining the distance to the sun was correct. Reasoning that at half-moon, the directions from earth to moon and sun to moon make an exact right angle, Aristarchus concluded that the distance from the sun to the earth must be the hypotenuse of the right triangle formed. Unfortunately, Aristarchus figured the angle sun-earth-moon to be 87°, instead of the true value of 89° 51′, which made his calculation greatly in error. Also, lacking proper instruments, it was difficult to determine the exact moment of half-moon, which threw his calculation off. Nevertheless, considering the fact that trigonometry had not yet been invented, Aristarchus, basing his calculations on rough estimates, displayed a good grasp of the geometry involved. For instance, through his knowledge of eclipses, he came up with a figure for the moon's diameter of .36 that of the earth's (the true value is .27). True, he was way off on his estimate of the size of the sun — 6¾ times the size of the earth (compared with the true value of 108.9 times) — but at least his guess was a great improvement over Anaxagoras' of "larger than Peloponnesus." But most important, Aristarchus was the first to state definitely a heliocentric hypothesis. Archimedes, the famous Greek inventor, wrote of him: "His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit."

The last great giant of classical Greek astronomy was Hipparchus, who lived about 160-120 B.C. and who did much of his work on the island of Rhodes. Hipparchus was first attracted to the study of astronomy when he observed a new star. While almost none of his work has survived, it is known that he compiled a catalog of the fixed stars. It is this catalog which, modified by Ptolemy, has come down to us through the latter's *Almagest*. Indeed, it was essentially this same catalog that Copernicus saw fit to include at the end of Book II of *De Revolutionibus* — and thus was the source of many of Copernicus' errors. In addition to first ascertaining the true length of the year, Hipparchus is probably best known as the discoverer of the precession of the equinoxes.*

** In astronomy, the equinoxes are either of two points of intersection of the ecliptic (apparent path of the sun through the heavens) and the celestial equator. Night and day are of equal length over the entire earth on the dates when the sun's center crosses the celestial equator southward (the vernal or spring equinox, about March 21, or northward (the autumnal equinox, about Sept. 23). Precession refers to the progression or shifting of these equinoctial points, whereby each point reaches a given meridian (circles on the celestial sphere passing through the poles) progressively sooner than a given star in successive passages. This motion results in the earth's axis describing a cone figure – often, in simplified terms, called a "wobble." A complete conical circle in the heavens takes about 25,800 years to make. Due to this processional motion of the earth's axis about the vertical to the plane of the ecliptic, there is a slow westward movement of the equinoctial points at the rate of a small fraction of a degree of arc per year. Hipparchus, by comparing his own observations of the bright star Spica with earlier ones, concluded that the equinoxes are moving backward by 40" a year – a surprisingly good result, since the modern value is about 50.3" a year.*

With the work of Aristarchus and Hipparchus, the age of classical Greek astronomical thought reached its peak. But in the second century A.D. there appeared another Greek, living not in Greece itself but in Alexandria, Egypt, who would have an even greater influence on the face of astronomy than Aristotle. This of course was Claudius Ptolemy, astronomer, mathematician, and geographer, who lived from about 100 to 170 A.D. Ptolemy's principal scientific efforts were documented in a large work of thirteen "books" entitled, *Great System of Astronomy*. However, this work, when it was subsequently translated into Arabic, received the prefix "al" and came to be known by the contracted and more familiar title of *Almagest*. Besides summarizing Ptolemy's planetary and other theories, this impressive tome includes, as we know, the star catalog of Hipparchus. Actually, the star positions given in the catalog portion of the *Almagest* do not include many new observations; Ptolemy simply assembled the previous observations of Hipparchus for use in his own work. However, Ptolemy did do some revising on Hipparchus' figures. Aware of the fact of precession (*see* the footnote), Ptolemy wished to update the star positions to his own time. To do this, he deduced what he thought to be a constant figure for astronomical precession that would carry the star positions forward to his own epoch. Ptolemy's constant was 36″ (seconds) of arc per year. But as we know (from the footnote), the correct figure is about 50.3″

Claudius Ptolemy, from an old engraving.

(even Hipparchus' 40″ was more accurate). The result was that the star positions of the *Almagest* were actually representative of a time about forty-two years *before* Ptolemy's own birth, rather than the period when he was making observations of his own. Small wonder, then, that Copernicus, working with these figures many centuries later, was led astray in his calculations. In fact, the whole problem of accounting for precession caused Copernicus considerable worry, and never did he manage to solve it correctly.

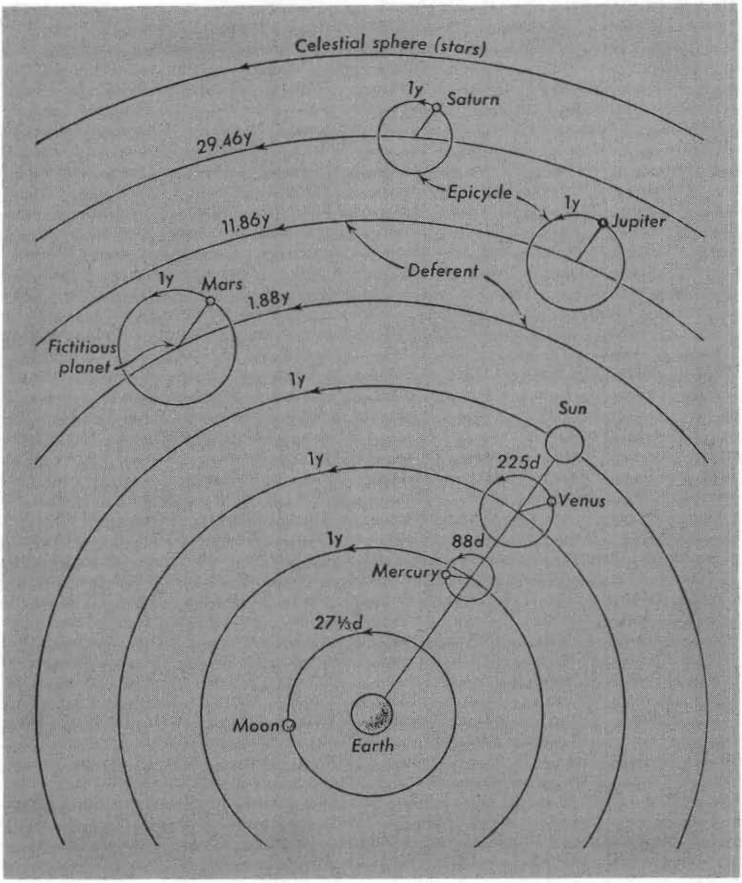
The system by which Claudius Ptolemy attempted to explain the motions of the celestial bodies is called, after him, the *Ptolemaic System*. For fourteen long centuries it remained the generally accepted and authoritative system of astronomy (although the Aristotelian system continued to coexist along with it). In the first decade of the seventeenth century, it was finally overthrown when Johannes Kepler succeeded in improving upon the Copernican system. Yet some idea of its long reign can be appreciated when one considers that, introduced as early as the second century A.D., it was still being taught (side-by-side with the Copernican system) in the early days of our American universities.

According to Ptolemy's system (and unlike the heliocentric ideas of some of the earlier Greeks), the earth was the fixed center of the universe. While Ptolemy's system resembled those of Eudoxus and Aristotle in placing the earth at the center, it departed from them in using circles instead of spheres — except in one instance: the universe was still encased in a vast concentric crystal sphere on which the stars were set. But apart from that, it was, in essence, an elaborate system of circles rolling on circles. Let us examine, in its simplest form, the way Ptolemy's system functioned.

Within the great crystal sphere of the "fixed" stars, with the earth reposing at its center, there revolved the sun, the moon, and the five then-known planets — Mercury, Venus, Mars, Jupiter, and Saturn. The outer planets, namely Mars, Jupiter, and Saturn, had a motion that was really composed of two motions. Each of these planets circled in an *epicycle* about a center point that was called the *fictitious planet* — in other words, the imaginary center of the epicycle. In addition to the real planets' revolving eastward on these epicycles, the center points (or fictitious planets) were also supposed to revolve eastward about the earth on much larger orbital circles, called *deferents*. By orbiting the earth on the deferent, a fictitious planet was presumed to be carried eastward at a uniform rate — that is, once around the sky in one sidereal period* of the planet. But, by simultaneously circling the fictitious planet on its epicycle, the real planet would then be seen to produce loops from time to time.

It was precisely in this looping that Ptolemy's system had definite advantages over Aristotle's. With Aristotle's Eudoxian crystalline spheres, nesting within each other, it was hard indeed to explain the phenomenon called retrograde motion. *Retrograde motion* is the westward or "backward" motion of a planet among the stars, resulting from the fact (as we know today) that we view it from the moving earth. For example, each year, when the earth passes a superior planet such as Mars, the planet appears to move backward for a short time. (It is the same effect as seen when a fast passenger train passes a slower freight train on a parallel track; the freight train appears to move backward.) However, with Ptolemy's loops provided by epicyclic motion, these planetary "backslidings" could be accounted for.

* Sidereal *means measured or marked by the return to the same position with respect to the stars. Thus, the* sidereal period *of a planet is the true period of its revolution around the sun with respect to the stars.*

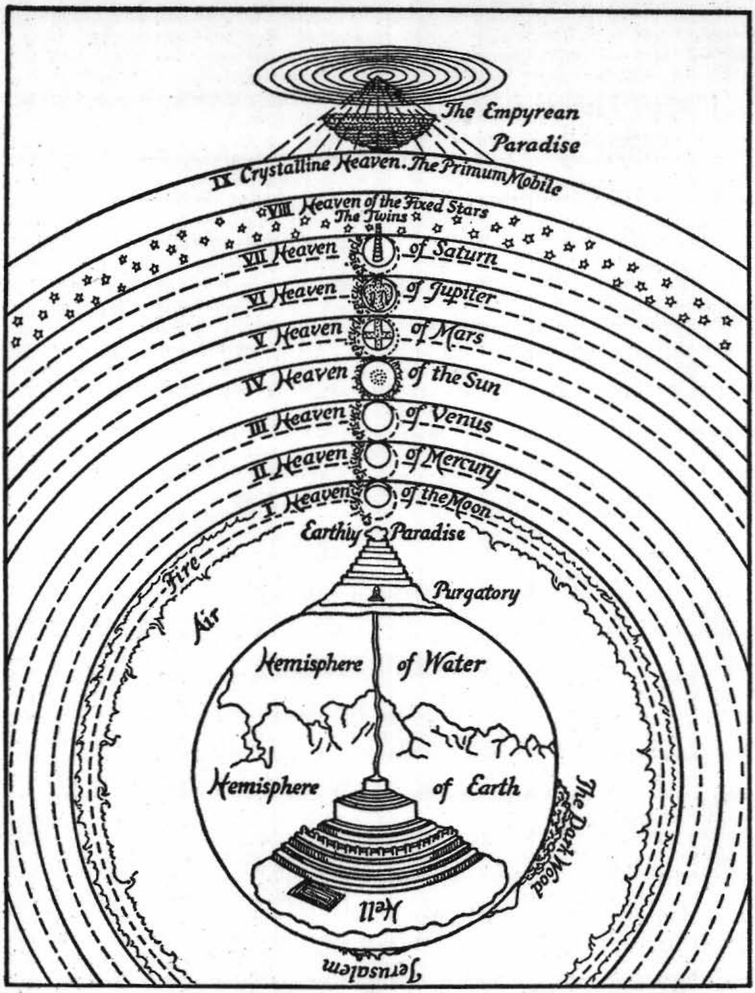


The Ptolemaic system as represented in its simplest form. Planets were supposed to revolve with uniform speed in a small circle, an epicycle, *whose center revolved on a large circle, the* deferent, *whose center was near the earth. Note that Mercury, Venus, and Sun were always in a straight line. Attempts to justify actual observations made many more circles necessary.*

A similar epicycle-deferent arrangement was assigned to the inner planets of Venus and Mercury — with one exception. Their respective fictitious planets were always supposed to be on the straight line between the earth and the sun. Why? Because then and only then would these two planets swing back and forth from one side of the sun to the other, due to epicyclical movement; and, always appearing very close to the sun, it had to be assumed that they revolved around the earth in the same period as the sun.

Unlike the planets, the movements of the sun, moon, and the stars did not require epicycles. However, the motions of all the celestial bodies were either circular in themselves, or combinations of circles upon circles, for Ptolemy — as well as the other ancients — were obsessed with the "perfection" of the circle as a geometric figure. And, since the heavenly bodies implied nothing less than perfection, the idea of their moving in any other geometrical way appeared absurd or unthinkable.

These, then, were the rudiments of the Ptolemaic System. Actually it was far more complicated than this, and Ptolemy found that he had to resort to such devices as off-center circles to make his system conform with actual observations. And, in addition to the mass of details provided by Ptolemy himself, his successors in the next centuries found it necessary to add mountains of others. Finally, the system became so encumbered with epicycles upon epicycles in an effort to predict plane-



Dante's scheme of the universe.

tary motions, that its eventual failure became too obvious to overlook. And yet, it must be remembered that with proper refinements, a geocentric system such as Ptolemy's can give just as good a formal picture of a solar system's workings as a heliocentric one.

After Ptolemy, the tide of scientific thought ebbed in Europe. During medieval times, it was kept flowing by the Moslems. Thanks to them, the star catalog of Ptolemy was preserved and handed down in the *Almagest*. Few medieval European scholars contributed much to astronomy. Even with Roger Bacon's urging for more observation (a lost art in medieval, superstitious Europe) astronomy did not flower again until the Renaissance.

Thus, at the close of the Middle Ages, the accepted European idea of the universe was a geocentric one. It remained so because of the tremendous influence of Aristotelian and Ptolemaic thought. In their ignorance, artists and writers helped to perpetuate this false view of the solar system. The extent of astronomy in the thirteenth century is typified by the sculptured figure of an astronomer on Giotto's campanile in Florence. Holding a quadrant, he shows that this small sighting instrument was about the most precise way there was of studying the stars, for Galileo's telescope was more than three hundred years away. And, to an educated man of the early fourteenth century, the scheme of the universe would have appeared much as it did to Dante.

SOME ESSENTIALS OF THE HELIOCENTRIC SYSTEM

CHAPTER FIFTEEN

During the fourteen centuries before Nicolaus Copernicus came upon the scene, the last word in astronomical knowledge had been that great treatise by Ptolemy known as the *Almagest*. As we have seen, it was reverently regarded as a repository of unassailable truth. Through the passage of these centuries, the Ptolemaic System had succeeded in man's strengthening his own view of himself. For, due to the basic supposition that the earth was at the center of the universe, this geocentrism (earth-centered) idea had given way to its logical corollary — *anthropocentrism*, or man-as-center. In other words, man had come to regard himself as the central fact of the universe.

Then Copernicus came along to throw doubt upon this comfortable belief. Above and beyond the heliocentric ideas of some of the ancients, Copernicus had become skeptical of Ptolemy for a number of reasons. One of these was a fundamental contradiction of the Ptolemaic System; namely, the postulate which stated that the movements of the celestial bodies were made up of uniform circular motions, and the realization that, by actual observation, they sometimes did not move uniformly at all. (In fact, each body was assigned more than one uniform motion, and the final outcome of these multiple motions was intended to eliminate the contradiction; but even so, the system did not always work.)

True, Ptolemy had reconciled this contradiction by use of a device called the *equant* — a kind of slowing down and speeding up of orbital motion — but this did not satisfy Copernicus. For him, the equant was not "legitimate" for it seemed to violate the otherwise uniform circular symmetry of Ptolemy's scheme of epicycles, deferents, and even the off-center circles called eccentrics. All of these latter were acceptable to Copernicus, but not the equant, which made the planets' motion uniform with respect to a center other than its own.

In addition, there was present in Copernicus' mind (and in the minds of others as well) a sneaking suspicion of whether such a complicated system of motions could possibly be real.

Thus it was that a dissatisfied Nicolaus Copernicus came to the conclusion that the universe was actually constructed along different lines from those set forth in Ptolemy's *Almagest*. In short, he conceived that the earth itself was in motion.

In reaching this conclusion, Copernicus' thinking seems to have gone something like this: A number of the ancients had had the idea that the earth was in motion. However, we on the earth do not feel this motion. In fact, such motion goes against our own sense-experience, upon which reason is based. And yet, some of those ancients were of the belief that experience gained through the senses might possibly be an illusion. True, Aristotle and Ptolemy had advanced many arguments that the earth could not be anywhere but in the center of the universe and at rest. But, for Copernicus, these arguments were questionable. Too many doubts seemed to arise when Ptolemy's system was closely studied. Yet, if the universe was not constructed along Ptolemaic lines, how was it really constructed? Perhaps those ancients who conceived of the earth as being subject to movement were right after all. But how can those upon the earth become aware that the earth they are standing on is moving? The answer was obvious — through the (apparent) movements of bodies outside the earth. However, these bodies also have real motions of their own, and thus the problem becomes to distinguish real motion from apparent motion. Perhaps, too, Copernicus speculated, there are bodies that do not move at all and, in that case, which are they? And, as far as the earth goes, how does it move so that it could give rise to apparent movement of other heavenly bodies?

Copernicus knew that when his published book reached the eyes of the public, it would be read by many men who were neither well-versed in astronomy nor in mathematics. Because he realized this, he was very concerned that the public understand the gist of his system without getting bogged down in astronomical and mathematical detail. Thus it was that Copernicus opened his *De Revolutionibus* with the nontechnical sketch of his system which forms the bulk of Book I. It was aimed especially at laymen, who could not be expected to follow the mathematical proofs and presentations developed in subsequent books.

In Book I Copernicus presents his cosmological system which has within it a moving earth. He tries to cushion the reader's shock at this idea by convincing, logical arguments. He goes to great pains to convey to the reader that such an idea is not, after all, so shocking or strange. Actually, many of the ideas in these arguments were not new ones at all — some in fact were downright Aristotelian. Yet, if he had published only

Book I without backing it up with the mathematical demonstrations of later books, he might not have become the astronomical titan that he did become.

Be that as it may, the important kernel, the flavor, the potentiality of the heliocentric system of Book I reveals in easily understood prose the grandeur of Copernicus' work. Therefore, let us look at some of the essentials of the heliocentric system as set forth in Book I, and often as stated in Copernicus' own words.

Copernicus starts off by giving his reasons for the universe being a spherical one:

> First of all we assert that the universe is spherical; partly because this form, being a complete whole, needing no joints, is the most perfect of all; partly because it constitutes the most spacious form, which is thus best suited to contain and retain all things; or also because all discrete parts of the world, I mean the sun, the moon and the planets, appear as spheres; or because all things tend to assume the spherical shape, a fact which appears in a drop of water and in other fluid bodies when they seek of their own accord to limit themselves. Therefore no one will doubt that this form is natural for the heavenly bodies.

He goes on to point out that the earth is also spherical in shape:

> That the earth is likewise spherical is beyond doubt, because it presses from all sides to its center. Although a perfect sphere is not immediately recognized because of the great height of the mountains and the depression of the

valleys, yet this in no wise invalidates the general spherical form of the earth. This becomes clear in the following manner: To people who travel from any place to the north, the north pole of the daily revolution rises gradually, while the south pole sinks a like amount. More stars in the north appear not to set, and in the south some stars appear no longer to rise. Thus Italy does not see Canopus, which is visible to the Egyptians. And Italy sees the outermost star of the River, which is unknown to us in a colder zone. On the other hand, to people who travel toward the south, these stars rise higher in the heavens, while those stars which are higher to us become lower. Therefore, it is plain that the earth is included between the poles, and is spherical. . . .

Copernicus next takes pains to prove that both the land and the water upon it form a sphere. He needs to prove that both the earth and the water are necessary to the composition of the total sphere, so that the two together can participate in the sphere's natural motion:

The waters spread around the earth form the seas and fill the lower hollows. The volume of the waters must be less than that of the earth, otherwise they would swallow up the land (since both by their own weight press toward the same center). Thus, for the safety of living things, stretches of the earth are left uncovered, and also numerous islands widely scattered. Nay, what is a continent, and indeed all of the mainland, but a vast island? . . .

That even the water has the same shape is observed on vessels, in that the land which cannot be seen from the ship can be spied from the tip of the mast. And, conversely, when a light is put on the tip of the mast, it appears to observers on land gradually to drop as the ship recedes until the light disappears, seeming to sink in the water. It is clear that the water, too, in accordance with its fluid nature, is drawn downwards, just as is the earth, and its level at the shore is no higher than its convexity allows. This land therefore projects everywhere only as far above the ocean as the land accidentally happens to be higher. . . .

Copernicus now furthers his arguments by stating that the motion of the heavenly bodies is uniform and circular, or else a combination of such circular motions — since only a circle can bring back a body to its original position. He also argues that a real inequality of motion could only be caused by a change in the motive power or by a variation in the body that is moved, which the astronomer believes to be absurd assumptions. In the language of Book I, here are the key quotations:

We now note that the motion of heavenly bodies is circular. For a sphere, rotation is natural, and by that very action, its shape is expressed. For here we deal with the simplest kind of body, wherein neither beginning nor end may be distinguished, nor, if it rotate always in the same place, may the one be distinguished from the other. . . .

(And, even despite certain observable irregularities [such as retrograde motion], Copernicus says:)

Nevertheless . . . we must conclude that the motions of these bodies are always circular, or made up of circles.

For the irregularities themselves are subject to definite law and recur at stated intervals, and such could not happen if their motions were not circular, for it is only a circle that can thus restore the position of a body as it was before. . . . Any irregularities must come of unevenness either in the moving force (whether inherent or acquired) or in the revolving body. But both of these the mind abhors in relation to the most perfectly disposed bodies.

Nowhere is Copernicus more traditionally Aristotelian in his cosmology than in these passages. Only by circular motion, or a combination of it, can he explain the movements of the heavenly bodies. Indeed, so far, the great astronomer has not treated his readers to the spectacle of anything new at all.

Now, however, Copernicus can no longer resist making the big break with traditional and classical astronomy. In short, he suggests the movement of the earth. The discussion is concerned with whether the earth has a circular motion with its location in the universe. Almost all writers, Copernicus says, agree that the earth is at rest in the center of the universe, and would consider it absurd to think of anything else. Then, in perhaps the most meaningful phrase in all of Book I, Copernicus introduces the idea of relative motion. He *transfers* the apparent motion of the sun to the earth — he interchanges them. A little consideration, he says, will show that the idea of an earth-centered universe has not been settled: . . . *since any change observed may either be caused by a motion of the object observed, or by that* *of the observer, or by different motions of both.* Thus, if the earth did have a motion, it would produce an apparent motion of everything outside it in the opposite direction. In other words, a turning earth going from west to east would therefore account for the rising and setting of the sun, moon, and stars — as, indeed, some of the ancients had already suggested. Moreover, continues Copernicus, if a person were to maintain that the earth was not the center of the universe, although the distance between the earth and the outer portion of the universe is not great enough to be measured against the celestial sphere (or sidereally), yet still enough to be comparable to the orbits of the planets, he might conceivably find the true cause of the apparently irregular motions referable to some center outside the earth.

But here, and well worth quoting in large part, is the famous fifth chapter of Book I:

> Since it has already been proved that the earth has the shape of a sphere, let us investigate whether from its form can be deduced a motion, and what place the earth occupies in the universe. Without such knowledge no certain computation can be made for the phenomena occurring in the heavens. To be sure, the great majority of writers agree that the earth is at rest in the center of the universe, so that they consider it unbelievable and even absurd to suppose the contrary. Yet, when one weighs the matter carefully, he will see that this question is not yet disposed of, and for that reason is by no means to be considered unimportant. Every change of position which is observed is due either to the motion of the observed object or of

the observer, or to different motions of both; for, when the observed object and the observer move in the same manner and in the same direction, then no motion is observed. Now the earth is the place from which we observe the revolution of the heavens and where it is displayed to our eyes. Therefore, if the earth should possess any motion, the latter would be noticeable in everything that is situated outside of it, but in the opposite direction, just as if everything were traveling past the earth. And of this nature is, above all, the daily revolution. For this motion seems to embrace the whole world – in fact, everything that is outside of the earth, with the single exception of the earth itself. But, if one should admit that the heavens possess none of this motion, but that the earth rotates from west to east; and if one should consider this seriously with respect to the seeming rising and setting of the sun, of the moon, and of the stars; then one would find that it is actually true. Since the heavens which contain and retain all things are the common home of all things, why should motion not be attributed to the contained rather than the container, to the located rather than the locater? This opinion was actually held by the Pythagoreans Heraclides and Ecphantus and the Syracusan Hicetas [according to Cicero], in that they assumed the earth to be rotating in the center of the universe, also believing that the stars set due to the intervening of the earth, and rose due to its receding.

If this earthly motion is admitted, then a problem no less serious arises about the position of the earth, even though nearly everyone has previously held that the earth is at the center of the universe. For, grant that the earth is not at the exact center, but at some distance from it which, though small compared with the distance from the celestial sphere, is still considerable compared with the distances

> to the spheres of the sun and other planets. Then calculate the resulting variations in their seeming motions, assuming them to be really uniform and about some center other than the earth's. Perhaps then one may bring forward a reasonable cause for the irregularity of these variable motions. And indeed, since the planets are seen at varying distances from the earth, the center of the earth is surely not the center of their circles. Nor is it certain whether the planets move toward and away from the earth, or whether the earth moves toward and away from them. It is therefore reasonable to hold that the earth has another motion in addition to its daily rotation. Namely: that the earth, in addition to rotating, wanders with several motions and is, indeed, a planet – a view attributed to Philolaus the Pythagorean . . .

In other words, Copernicus in these passages is advising the reader to accept not only the daily rotation of the earth on its own axis, but an orbital motion as well. Viewed by an observer on a moving earth, the retrograde motions of the planets can thus be more simply accounted for than by a maze of epicyclic movements.

By this time, Copernicus is well into his thesis. It is true that he has not proved anything yet, but at least he has shaken his reader's faith in some of the old beliefs. In the next chapter, he goes on to compare the vastness of the heavens to the puny earth. He shows that by comparison to the immense size of the celestial sphere, the earth can only be regarded as a point. Nor does this little point, Copernicus maintains, necessarily rest in the exact center of the starry sphere. Also, it is unreasonable to suppose that this great outer sphere would be spinning around so fast that it makes one revolution every twenty-four hours (accounting for day and night on an earth at rest). If this were the case, however, the earth as an actual body ought to turn along with all the rest of the universe in the same period — and, if it did, there would always be noon at one place on the earth and midnight at another, with no rising or setting. But this difficulty is overcome, says Copernicus, by reflecting that bodies moving in smaller circles always move more rapidly than those describing larger ones. The outmost planet Saturn, for instance, takes thirty years to complete its orbit, and the moon, which is certainly closest to the earth, takes only a month. Thus it must be admitted that the earth rotates on its axis in a day and a night.

In the seventh chapter of Book I, Copernicus feels it necessary to recount some of the arguments of the ancients against this rotation, and the reasons why they thought that the earth was at rest in the middle of the universe. Because such beliefs were exactly what Copernicus was trying to prove wrong, they also are worth giving in detail:

> The ancients tried by various methods to prove that the earth was fixed at the center of the universe. Their chief argument was drawn from the doctrine of the heavy and the light. They argued that the earth is the heaviest element, and that all things of weight move toward it, tend-

ing to its center. Thus, since the earth is spherical, and heavy things move vertically to it, they would all rush together toward the center, if not stopped at the earth's surface. Now, such things of weight moving toward the center must, on reaching it, remain at rest. Even more so, therefore, will the entire earth remain at rest in the center of the universe. For, in receiving all such falling bodies, it must remain immovable by its own vast weight.

Another of the ancients' arguments is based on the supposed nature of motion. Aristotle says that the motion of a single and simple body is simple. A simple motion is either straight or circular. Further, a straight motion may be either toward the center, that is, downward, or away from the center, or upward, or around the center, that is, circular. Now, it is a property only of the heavy elements earth and water to move downward, that is, to seek the center. However, the light elements of air and fire move upward and away from the center. Therefore, we must assign straight motion to these four elements. The celestial bodies, however, have circular motion . . .

If, then, says Ptolemy, the earth moves at least with a daily rotation, the result must be the reverse of that described above. For the motion must be of excessive rapidity, since in twenty-four hours it would have to impart a complete rotation to the earth. Yet, things rotating very rapidly resist cohesion or, if united are apt to disperse unless they are firmly held together. Thus, says Ptolemy, the earth would have been torn apart long ago and, (which is absurd) would have destroyed the heavens themselves. In addition, it is certain that all living creatures and other heavy bodies free to move could not have remained on the earth's surface, but must have been shaken off of it. Neither could falling bodies reach their natural resting place vertically beneath, since in the meantime the earth would have moved out quickly from under them. Also, clouds and everything in the air would continually shift westward . . .

Copernicus next goes on to tell how insufficient these arguments are and to refute them:

For these and similar reasons, it is claimed that the earth is at rest in the center of the universe and that this is certain. However, one who believes that the earth moves would also be surely of the opinion that such motion is natural and not violent. For, whatever is in accord with nature produces effects which are opposite to those produced by violence. Things upon which violence or an external force is exerted must become annihilated and cannot long exist. But whatever happens in the course of nature must work in good condition and smoothly. Needless therefore is Ptolemy's fear that the earth and everything on it would be disintegrated by a natural rotation, for the functioning of nature is something far different from an artificial act. But why did he not fear even more for the universe whose motion would have to be as much more rapid, as the heavens are larger than the earth? Have the heavens become so vast because of their vehement motion, and would they collapse if they stood still? Certainly if this argument were true, the extent of the heavens would become infinite. For the more they were driven aloft by the outward impulse of the motion, the more rapid would the motion become due to the ever increasing circle which it would have to describe in the space of twenty-four hours; and, conversely, if the motion increased, the immensity of the heavens would also increase. Thus velocity would augment size into infinity, and vice versa . . .

But it is also said that outside of the heavens there is no body, nor place, nor empty space; in fact, that nothing at all exists, and that, therefore, there is no space in which the heavens could expand. Yet, truly, this is strange that something could be enclosed by nothing. If, however, the heavens were infinite and were bounded only by their inner concavity, then we have perhaps even better confirmation that there is nothing outside of the heavens, because everything, whatever its size, is contained within them. But, in this case, the heavens would remain motionless . . .

Now, whether the universe be finite or infinite, let us leave to the quarrels of the natural philosophers; for us remains the certainty that the earth contained between poles, is bounded by a spherical surface. If this is so, why then hesitate to grant the earth that power of motion which is natural to its shape, rather than assume a gliding around of the whole universe whose limits are unknown and unknowable? And why then not grant that the *appearance* of a daily revolution belongs to the heavens, its *actuality* to the earth? This relationship is similar to that of which Virgil's Aeneas says: "We sail out of the harbor, and the countries and cities recede." For when a ship is sailing along quietly, everything which is outside of it will appear to those on board to have a motion corresponding to the movement of the ship, and the voyagers are of the false opinion that they with all that they have with them are at rest. This can without doubt also apply to the motion of the earth, and it may appear as if the whole universe were revolving . . .

In a similar manner, Copernicus goes on at length with his refutations of the old arguments. As for the clouds, he says, for example, it must be assumed that not only the earth and water upon it, but also a great portion of the air rotates, too — whether the reason be that the earth and watery matter are of the same substance as the earth, or that it proximity to the earth causes the air to share the earth's rotation.

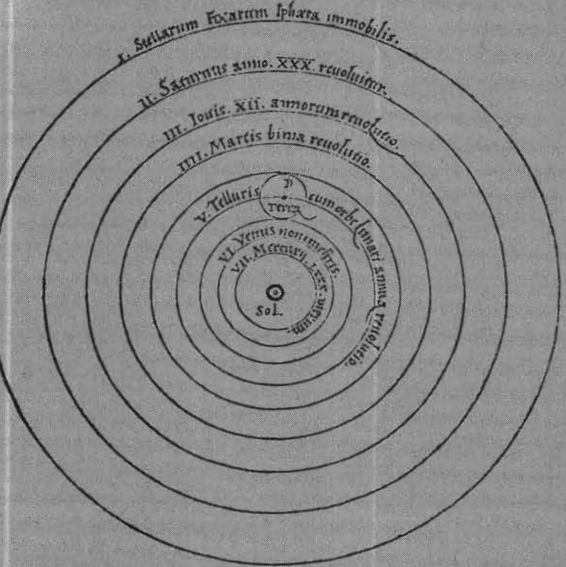
In the ninth chapter of Book I Copernicus next considers whether more than one motion can be assigned to the earth; or, in other words, whether or not it can be considered a planet. He also takes up the question concerning the center of the universe itself:

> Now, since there is no reason why the earth should not have the power of motion, I believe we must investigate whether it also has other motions, so that it can be considered one of the planets. That it is not the center of all the revolutions is proved by the apparently irregular movements of the planets, and their varying distances from the earth, which cannot be explained as concentric circles with the earth at their center. Therefore, since there are several central points, let us investigate whether the center of the universe is or is not the earth's center of gravity.

> I, at least, am of the opinion that gravity is but a natural inclination, accorded to the parts of bodies by the Master of the World so as to combine themselves naturally into spherical shape, forming a unity and a whole. And it is to be assumed that the same natural impulse is also inherent in the sun, the moon, and the other planets, so that they thereby retain this spherical form notwithstanding their various paths.

> If, then, the earth, too, possesses other motions besides that of rotation about its own center, these must necessarily resemble the many outside motions of other bodies having a yearly revolution. For if, assuming the sun to be at rest, we transfer the motion of the sun to the earth, then the morning and evening rising and setting of the stars will be unchanged. Also, we would find that the stations, retrogressions, and progressions of the planets are due not to their own motions but to that of the earth, which their appearances reflect. Lastly, we must place the sun itself at the center of the universe . . .

But Copernicus has still not settled the question concerning which sequence or order the planets are in. This he proceeds to do in the tenth chapter of Book I. In previous schemes of the universe, everyone had been in agreement, at least, about the moon. Obviously it was the nearest "planet" to the earth and it revolved about the "central" earth in the shortest period. Likewise, Saturn, being the greatest distance away from the earth, had the longest period of revolution. As for Jupiter and Mars, their orbits lay respectively inside that of Saturn. But, in the various systems of the universe, there had been some sharp disagreements about where the orbits of Venus and Mercury belonged. Plato, for instance, had placed them outside (the supposed) orbit of the sun. Ptolemy and most others put their orbits inside (the supposed orbit of) the sun. One Medieval astronomer even put Venus outside and Mercury inside the solar orbit. After a number of astronomical discussions about net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono menſe reducitur. Sextum deniq; locum Mercurius tenet, octuaginta dierum ſpacio circũ currens. In medio uero omnium reſidet Sol. Quis enim in hoc



pulcherimo templo lampadem hanc in alio uel meliori loco poneret, quàm unde totum ſimul poſsit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegiſtus uiſibilem Deum, Sophoclis Electra intuentē omnia. Ita profecto tanquam in ſolio re gali Sol reſidens circum agentem gubernat Aſtrorum familiam. Tellus quoq; minime fraudatur lunari miniſterio, ſed ut Ariſtoteles de animalibus ait, maximã Luna cũ terra cognationē habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur ſub hac

Historic diagram from Copernicus' De Revolutionibus *shows the earth clearly sharing its center of revolution with other known planets of the day. (Facsimile from Burndy Library)* the distances of the planets and the diameters of their orbits, Copernicus goes on to say why he thinks a sun-centered universe can best determine the true order of the planets therein:

> I therefore think that the opinion of Martianus Capella and some other Latin writers is not to be overlooked. For they suppose that Venus and Mercury travel around the sun, and thus cannot get further away from it than the convexity of their orbits allows, since the latter do not surround the earth. The sun therefore is the center of their orbits, and the orbit of Mercury is enclosed within that of Venus, which is more than twice as great. If we take occasion of this to refer Saturn, Jupiter, and Mars to the same center, keeping in mind the vast extent of their orbits which enclose those two planets as well as the orbit of the earth, we cannot fail to find the true order of their motions. For it is certain that these are nearest to the earth when in opposition* to the sun, the earth being between them and the sun, but that they are farthest from us when the sun is between them and the earth, thus adequately proving that their center belongs rather to the sun and is, in fact, the same center as that around which Venus and Mercury also move.

In the next sentence, Copernicus shows how he still clings to an old Aristotelian idea — there must not be any empty or unused spaces in the universe:

> It is then necessary that the space left between the orbits of Venus and Mars should be occupied by the earth and

* *Two bodies are in* opposition *when their difference in celestial longitude is 180°. A planet is in opposition when it is on the opposite side of the earth from the sun.*

its companion the moon and all that is below the moon. For we cannot in any way separate the moon from the earth, to which it is undoubtedly nearest, particularly since there is plenty of room for it in that space. Therefore we are not ashamed to maintain that all that is beneath the moon, including the center of the earth, describe among the other planets a great orbit around the sun which is the center of the universe; and that what appears to be a motion of the sun is in reality a motion of the earth; but, that the size of the universe is so great, that the distance of the earth from the sun, though appreciable compared to the orbits of other planets, is as nothing when compared to the sphere of the fixed stars.

Here Copernicus apparently cannot resist a swipe at Ptolemy's complex system of deferents and epicycles. (Actually, his objection is not to deferents and epicycles themselves — Copernicus never thought of discarding them — but, rather, to their excessive number.) At any rate, he continues:

And I maintain that it is easier to admit this, than to let the mind be distracted by an almost endless multitude of circles, which those people are obliged to do who place the earth in the center of the universe . . . If all this is difficult and almost incomprehensible or against the belief of many people, we shall, God willing, make it clearer than the sun itself, at least to those who know something of mathematics.

And with this assertion, Copernicus gives the reader the sequence of the planetary orbits:

The first principle therefore remains undisputed, that the size of the orbits is measured by the period of revolution,

> and the order of the spheres is then as follows, beginning with the uppermost. The first and highest sphere is that of the fixed stars, containing itself and everything and therefore immovable, being the place of the universe to which the motion and positions of all other stars are referred. For while some think that it also changes somewhat,* we shall, when deducing the motion of the earth, assign another cause for the phenomenon. Next follows the first planet Saturn, which completes its orbit in thirty years; then Jupiter, with a period of twelve years; then Mars, which moves around in two years. The fourth place in the order is that of the annual revolution, in which we have said that the earth is contained with moon's orbit as an epicycle. In the fifth place, Venus goes around in nine months; in the sixth, Mercury revolves in a period of eighty days.

Next, perhaps, is the most famous passage in all of *De Revolutionibus:*

> But in the midst of all dwells the sun. For who, in this most beautiful temple, could place this lamp in another or better place than that from which it can at the same time illuminate the whole? Which some not unsuitably call the light of the universe, the soul or the ruler. Trismegistus calls it the visible God, the Electra of Sophocles the all-seeing. So indeed the sun, sitting on the royal throne, steers the revolving family of stars.

So Copernicus has set forth to the reader of *De Revolutionibus* his scheme of the universe. In completing this chapter of Book I, he points out that such an arrange-

* *Copernicus is referring to precession.*

ment of planetary motion will explain to the careful observer of the heavens why the retrograde arc (backward motion against the stars) of Jupiter is greater than that of Saturn and smaller than that of Mars; why that of Venus is greater than that of Mercury; and also why the outer planets are brightest in opposition — all of these phenomena being caused by the motion of the earth. In addition, the astronomer calls attention to the fact that since nothing similar to this arrangement is observed among the fixed stars, it is proof of their vast distance away — compared to which the size of the earth's orbit is as no distance at all.

In broad outline, then, as sketched in Book I, we have Copernicus' universe. Was it a workable universe? Did it contain errors? If so, where was Copernicus led astray? Was it a finite, or measurable, universe? If so, was it too big or too small?

From his insight into the phenomenon of relative motion, Copernicus was able to deduce three motions of the earth. The first is a rotation on its axis, which produces the appearance of a daily revolution of the sky. The second is an orbital revolution around the sun, which manifests itself to us in a yearly course of the latter and greatly complicates the apparent movements of the other planets circulating around the sun. The third movement — a kind of "wobble" of the earth on its axis — was also necessary, of which more will be said later.

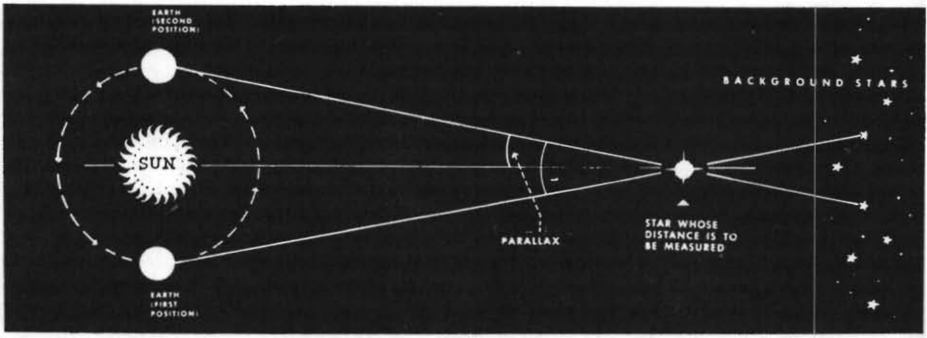
Following the ancients, Copernicus' universe is in the shape of a perfect globe. The inner surface of this globe has attached to it the "fixed" stars which are visible to us. This sphere of the fixed stars, together with its central sun, is regarded as being at absolute rest. How large this universal globe was, Copernicus did not know. But he went so far as to claim that it was finite or measurable, since it had a center (the sun) and it was in a definite shape (a globe).

But if Copernicus ventured no figures for the size of the universe as a whole, he did give some dimensions of the solar system. Of these, some are remarkably accurate. In his universe, the planets revolve with uniform velocity around the sun in epicycles on deferents. The radii of their deferents, as calculated by Copernicus in terms of planetary units (with the earth's given as 1 or unity) are: Mercury, 0.38; Venus, 0.72; earth, 1; Mars, 1.52; Jupiter, 5.22; and Saturn, 9.17. These values differ little from the mean distances of the planets from the sun as calculated today. In addition, the periods of the revolutions of the individual planets around the sun as given by Copernicus are quite near to modern ones.

But some other dimensions of the solar system as calculated by Copernicus were far from accurate. To understand why, it is necessary to know something of the method that he used, namely, *parallax*. Parallax means the apparent difference in the position of a celestial body when it is viewed from different positions. A simple example of this is the apparent shift of an object against some distant background when viewed first with the right eye and then with the left eye alone.

Practically speaking, engineers and surveyors use this same principle in measuring inaccessible objects. Let us say that an engineer wants to measure the width of a river from one of its banks alone. He first measures out a base line on his side; then, from each end of this line, he measures the two angles formed with some object on the far shore, say a rowboat or a tree at the opposite shoreline. Knowing two angles and the length of his base line, the engineer, by simple trigonometry, can solve the triangle formed to give him the distance from the base line to the object — or the width of the river. Using this same method, astronomers can measure the distance to the moon, the planets, and — with the help of very accurate modern instruments today — to the stars as well.

Copernicus also used this basic method to determine the distances of the planets. For his "base line," he made use of the earth's movement. By choosing two points on the earth's orbit on different days of the year and then measuring from each point the angles to a certain planet, Copernicus could calculate a planet's distance in terms of the earth's orbit. Actually, it was not this simple for him because the planet, too, was in motion, as well as the earth, and it was the planet's distance from the sun and not from the earth that he wanted to find out. But



How a stellar parallax is measured. Angles and distances are greatly exaggerated.

the parallactic principle was still valid, for the nearer a thing is the more its seeming direction is changed by a shift in the position of the observer.

But in trying to find out the true dimensions of the solar system by means of the solar (or sun's) parallax, Copernicus was way off. The solar parallax is the angular size of the earth's radius as "seen" from the sun. Not only is this angle very small (modern scientists are still not completely agreed on the exact figure), but calculating it is extremely difficult — so much so that it can only be done with the help of instruments of the highest accuracy. These of course were not available to the Polish astronomer. In fact, Copernicus largely adopted Ptolemys' value for it.

Thus, as regards the earth's distance from the sun (or the radius of its orbit), Copernicus came up with a figure of 1142 earth's radii. Because this is more than 20 times less than the actual figure, the dimensions of Copernicus' solar system are correspondingly much too small. For example, Saturn's distance from the sun, as stated by Copernicus, is not really much greater than that of Mercury's. Similarly far off was his idea of the size of the sun itself. Due to the erroneous parallax, Copernicus thought its diameter was only some 5½ times greater than the earth's. Actually, the sun's diameter is more than 100 times that of the earth's. Five of Copernicus' suns, in fact, would fill up only a little more than the true volume of the planet Saturn. More successful was Copernicus' estimate of the distance of the moon — 60.30 earth's radii as compared with the modern value of 60.27.

While Copernicus claimed his universe to be a finite or measurable one, he also recognized that it was far too large for him — or any other scientist of that day — to prove one important point involving the parallactic principle. This point was that if the earth actually traveled around the central sun once a year, then such a motion should produce an apparent shift in the *stars*. Just how large the universe was is indicated by his own statement that: "According to the senses," the earth and its orbit stand in the same proportion to the universe as a point does "to a body," or an object of finite dimensions to infinity. So far away were the stars, concluded Copernicus, that any annual parallactic shift would be much too small to be noticed.

Because such a shift could not be detected, earlier astronomers had claimed that the earth could not possibly be in motion. Likewise, astronomers who followed Copernicus claimed the same thing. The fact that such displacements had not been observed was one of the chief proofs that Copernicus was wrong and that his theory was untrue. Actually, before the invention of telescopes this effect would have been undetectable. In fact, nearly three hundred years were to pass before a parallactic displacement in the stars was finally measured — and Copernicus was at last proved correct. Today, these minute shifts are concrete evidence of the earth's orbital movement around the sun.

But while Copernicus lived and struggled with his great book, certain other workings of the universe forever eluded him. Trying to fit into a single system all of the movements of the planets was baffling enough for later astronomers equipped with telescopes. Little wonder that Copernicus, a man of the early sixteenth century, often shook his head over them.

Much of Copernicus' trouble lay in his assuming that the movements of the celestial bodies could only be in circles with uniform velocity. In reality, as Johannes Kepler was to point out a few decades later, the paths of the planets actually follow a law that is less complicated than their revolving smoothly about the sun in combinations of circles. Copernicus' heliocentric system, in other words, had to alter its simplicity in order to explain the varying velocities of the planets in their orbits. Copernicus even had a word for these variations between uniform motion and the observed facts. He called them "inequalities." To reconcile them, Copernicus had to suppose the planetary movements were in eccentric circles or in epicycles. Sometimes he even had to resort to a combination of the two in order to account for the "inequalities."

This had been the road taken by Ptolemy and, in part, Copernicus followed it. True, Copernicus, by assuming the earth's movement around the sun, had greatly simplified Ptolemy's complex system. But Copernicus' own system still remained extremely complicated. He devoted enormous time and trouble to it, without ever suspecting the simple laws governing the planets which Kepler would later discover. In trying to adjust his simple system to observed fact, Copernicus toiled largely in vain and probably squandered more than half of his creative time doing so.

Copernicus also spent much of his time filling up pages of the *De Revolutionibus* with attempts to work out a satisfactory theory of precession. In doing so, he had to attribute to the earth a third motion. Besides rotating every twenty-four hours and orbiting the sun once a year, the earth was supposed to perform a kind of flattened figure eight or double axial wobble in the form of two cones. One reason for this assumption was that, once again, Copernicus had relied on inaccurate observations of his predecessors. Another was that, having assumed that the sphere of the fixed stars was absolutely immobile, he had to account in some other way for their slight shifting along the ecliptic (the apparent path of the sun) from the point of the equinox.

But if Copernicus spent much useless time on imaginary precessional inequalities and other astronomical intricacies, he was nearly right in his estimate of the sidereal or star year. It was, in his opinion, so constant a period of time that it might be useful as a basis for computing time — and therefore of reforming the calendar. Copernicus finally found it to be 365 days, 6 hours, 9 minutes, and 40 seconds, which is only 30½ seconds greater than the true figure. Barely four decades after Copernicus' death, Pope Gregory XIII was to use this figure as a help in reforming the calendar that goes by his name today.

And if Copernicus ultimately failed in producing the perfect picture of the universe, let us not forget what he did accomplish. Not only did he show that the assumption of an annual motion of the earth about the sun would simply explain the Ptolemaic irregularities of planetary motion, but he also fashioned a new system of astronomy on that assumption. It was a system upon which others could fruitfully build.

AFTERMATH AND ACCEPTANCE OF THE COPERNICAN THEORY

CHAPTER SIXTEEN

Today we know that we live on a planet belonging to a rather small star, which is a member of a galaxy of some hundred thousand million stars, and that this galaxy itself is but one of a system of galaxies of which in turn fifty millions are within the range of our present telescopes. But to the contemporaries of Copernicus, Man himself was the center of the universe and of creation. An unmovable earth was his platform and the heavens were his canopy. The idea that Man, the favored being, was actually perched upon a globe that wandered through the heavens with a number of others about a still-standing sun was to him, Man, one of the utmost absurdity.

Eventual realization of the truth of the heliocentric idea caused a complete revolution in man's conception of his relation to his universe. But this realization was slow in coming. It did not follow at once because there had to be a transitional period for men's minds to accustom themselves to the new conception. Roughly about a century and a half was necessary for this adjustment, for at the end of this time Sir Isaac Newton's great work had erased most of the opposition to Copernicus' innovation.

After Copernicus' death and the publication of *De Revolutionibus*, there was no immediate revolution. People did not suddenly flock to Copernicus' banner and proclaim the truth throughout the cities of Europe. In fact, *De Revolutionibus* aroused very little interest at first. For one thing, few of those who took the trouble to read the book could understand it. And those who could grasp it were mostly mathematicians and astronomers. Nor did Osiander's Preface help matters any. Thus men often saw the book as merely a helpful "theory" in working out new planetary tables — not as the literal truth. As an astronomical system, it did not matter whether the earth moved around the sun or vice versa —

as long as such a system checked out with actual observations of the heavenly bodies. Yet the advantage of Copernicus' system was that planetary tables were easier to construct from it, and this fact alone played a big part in establishing Copernicus' theory.

One man who made immediate use of the theory was Erasmus Reinhold, who compiled the first tables from it. Not only was Reinhold a contemporary of Copernicus, but his life was also bound up with two figures very familiar to Copernicus — Rheticus and Duke Albert of Prussia, the former Grand Master of the Teutonic Knights. When Rheticus was a professor of mathematics at the University of Wittenberg, there was another mathematics professor there — Reinhold. While Reinhold rejected the Copernican theory, he had great respect for Copernicus and accepted his computations; in one of his books he referred to him as "a second Ptolemy." At any rate, he worked out a set of planetary tables based on Copernicus' theory and published them in the year 1551. Because Duke Albert of Prussia paid for the cost of printing them, Reinhold called them the *Prussian Tables* in the Duke's honor. While they contained errors due to crude observations, these tables were still more accurate than any previous ones had been. They remained in use, in fact, for nearly three-quarters of a century — until Johannes Kepler published his superior *Rudolphine Tables* based on his revisions of the Copernican theory.

During the years immediately following Copernicus' death, *De Revolutionibus* — as well as the works of Rheticus and Reinhold — had become distributed throughout Europe, so that by the 1550's the Copernican theory was fairly well known in scientific circles. But it was in England that its influence was most promptly and widely felt. The reason for this was that England, isolated as she was by the sea and enjoying more freedom under her political system, was less under the sway of Aristotle and other ancients, and hence more receptive to new ideas.

The first English reaction to Copernicus' discovery was in 1551, only eight years after the publication of *De Revolutionibus*. The commentator was Robert Recorde who, though he only lived to be forty-eight, was a man of wide interests and many talents. A Royal Physician to Queen Mary, he was also an accomplished Greek scholar, a brilliant mathematician, a cosmographer, and musician, as well as an astronomer and astrologer. Highly interested in bringing knowledge and learning to the common people who could not read scholarly works in Latin, Recorde spent much of his time writing a number of textbooks in the English language. Like the works of Plato, these books were written in the form of dialogues between a teacher and his student. In the most famous of these works, *The Castle of Knowledge*, the teacher says:

> Copernicus, a man of great learning, of much experience and of wonderful diligence of observation, hath revived

> the opinion of Aristarchus of Samos, and affirmeth that the earth not only moveth circularly about his own center, but also may be, yes and is, continually out of the precise center thirty-eight hundred thousand miles.

While Recorde's student tries to make fun of this idea, the teacher tells him that the notion is beyond anything anyone yet comprehends, and not to "condemn things you do not fully understand."

From this it is clear that Robert Recorde was cautious about his approach to the heliocentric system; he was also of the opinion that the world was not yet ripe for such a startling idea. He advised his readers, at the same time, not to put too much confidence in the generally accepted Ptolemaic system either. Some scholars, in studying his works, are convinced that Recorde was probably the first true Copernican in the English-speaking world.

A few years later, another Englishman by the name of John Field was utilizing Copernicus and Reinhold's tables in preparing an *Ephemeris*, or an almanac, of the computed positions which celestial bodies have occupied or will occupy on certain dates. These and other works of Field's were also believed to be among the first in England to recognize the importance of Copernicus' principles. But, where Robert Recorde at least seems likely to have been persuaded of the possibility of the earth's motion, Field only went so far as to accept the tables.

The next true Copernican to appear in England was a distinguished mathematician by the name of Thomas Digges who, in 1573, published a book that was chiefly concerned with a new star which appeared in the sky that same year. So brilliant was this star* that it could be seen in broad daylight; it is of great interest because it played an important part in establishing the Copernican theory. Digges hoped to test the Copernican system by trying to see whether this new star had an annual parallax, but he could not find any shift at all. Nevertheless, in his little book, Digges complains about the complexity of the Ptolemaic system and defends the Copernican as a more logical approach.

It was in a later book published in 1576 that Digges stoutly stands up for the Copernican theory and, at the same time, helps refute one of Aristotle's oldest notions. This was the idea that the universe is one of limited size and that there is nothing outside the sphere of the fixed stars — not even empty space. According to this view, the heavens would have to turn completely around once

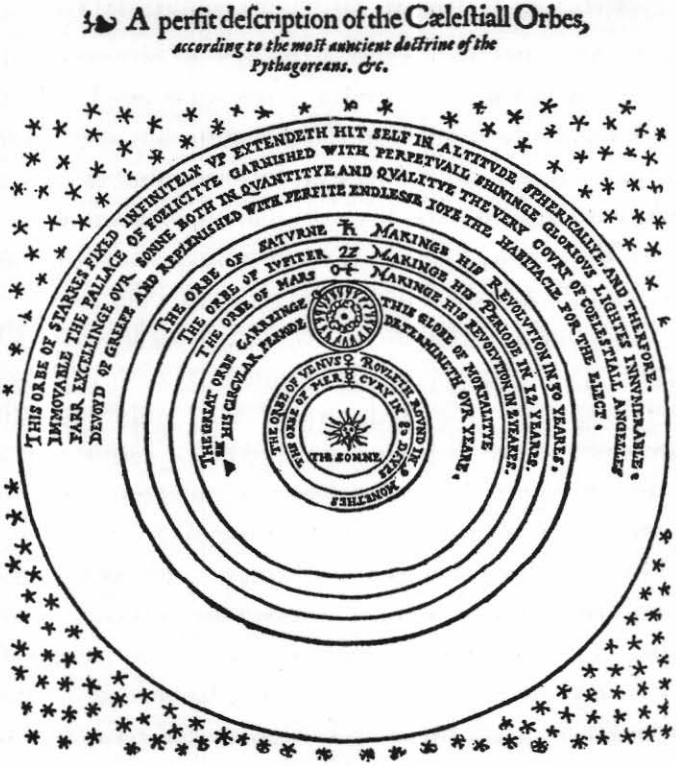
* *This star is of the type that astronomers call* novas *or temporary stars. Their brightness increases in a sudden, intense outburst to tens or hundreds of thousands, often millions, of times their original intensity; afterwards, this brilliance decreases until the star reverts to its original luminosity. Between ten and twenty appear in our galaxy every year. A few exceptionally bright ones, called* supernovae, *are ten to one hundrd million times as bright as our sun. The "new star" of 1572 was a very brilliant nova that appeared in the constellation Cassiopeia. So brilliant was it that it was visible to the naked eye from November, 1572, until the spring of 1574. Because of his description of it, the nova is often known as "Tycho's Star." Another appeared in 1604 and, because of its author's description, is called "Kepler's Star."*

every day in order to account for day and night upon the immobile earth. If any portion of the starry outer shell were located at an infinite distance from the center point around which everything turned, then such a portion would have an infinite distance to travel and it would have to travel at an infinite speed — all in the short space of twenty-four hours. This, claimed Aristotle, was impossible because there was no such phenomenon as infinite speed; therefore, the universe could not be infinite. Copernicus himself did not dispute this view of a limited-sized universe, preferring to leave it as an open question to be settled by "philosophers." What Copernicus did do was to weaken Aristotle's argument by transferring the motion of the heavens to the rotation of earth once a day on its axis. Granting this, the idea of an infinite universe was not beyond the realm of possibility for, no matter how far away the stars might be, the universe was no longer required to spin around at some fantastic speed in the short span of twenty-four hours.

The significant thing about Digges's book is that it contains an illustration of the Copernican universe — but one with an important difference. The first such illustration to appear in an English book, it shows an infinite universe. No longer are the stars restricted to the surface of the celestial sphere. Rather, they extend outward in every direction, studding infinite space. True, Digges still placed the sun at the center, but the way was now open to dethroning the sun from its privileged position. Why? Because it could now be argued that, granting an infinite universe, how could something that is infinite conceivably have any center?

In his famous book *De Magnete*, published in 1600, the pioneer English physicist, William Gilbert, also gave a boost to the Copernican system. Gilbert, however, was only interested in one part of the universe of Copernicus — the rotation of the earth — for this had to do with his great interest in magnetism. Convinced that the earth itself was really one gigantic magnet, causing his compass needles and other objects to point north and south, Gilbert came to believe that it was somehow this mysterious force — magnetism — which not only caused the earth to spin around but that kept the other heavenly bodies moving as well. Because the question of whether or not the earth revolved yearly about the sun did not seem to have much connection with his spinning magnetized needles, Gilbert did not have much interest in that part of Copernicus' theory. While William Gilbert's idea was a mistaken one, his writings nevertheless supported a portion of the Copernican idea and directed later investigators' attention to it.

In the same year that Gilbert's book appeared in England, another Copernican, the Italian friar and scientific investigator Giordiano Bruno, was burnt at the stake in Rome — some say because of his Copernican beliefs, but more correctly because of the sum total of his de-

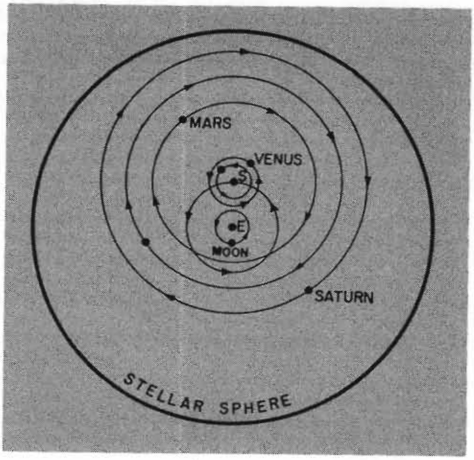


Thomas Digges' infinite Copernican universe. Stars are not in the form of a celestial sphere, but extend into infinite space. Note colorful English spellings of the 16th century.

partures from the Catholic faith. Revolting against many of the old ideas taught by the church, he published a number of writings in the closing years of the century which, being in support of the Copernican theory, served to make it better known throughout Europe. As a

Copernican, Bruno advanced the idea of an infinite universe even farther than had Thomas Digges. To Bruno, space was truly infinite in nature. Our sun was merely another star in a universe of an infinite number of stars, each with its own family of planets. Such a pattern, wrote Bruno, was repeated in infinite variety throughout boundless space. Bruno, of course, could offer no concrete proof of this and his argument for it was chiefly theological. Specifically, the argument was this: Because God possessed unlimited power, He could only find expression in creating an infinite work — anything less would only partially realize His infinite creative powers, which Bruno assumed to be unthinkable.

The fabulous Danish nobleman and astronomer, Tycho Brahe, was the next to exert an influence on the Copernican idea. Unfortunately, Tycho's influence was an adverse one — for he rejected the Copernican theory and devised one of his own. First attracted to astronomy by an eclipse in 1560, Tycho became the most skilled of all the observers of the heavens before the invention of the telescope. A deep respecter of both Ptolemy and Copernicus, Tycho at first was at a loss as to which of their systems was the true one and he determined to seek out the relative merits of each. Of the several decisive tests between them, the only one that Tycho could conceivably attempt to apply was that of measuring the nearby stars' annual parallactic shifts. Because the results were negative Tycho rejected the Copernican system. Ac-



Tycho Brahe's system of the universe.

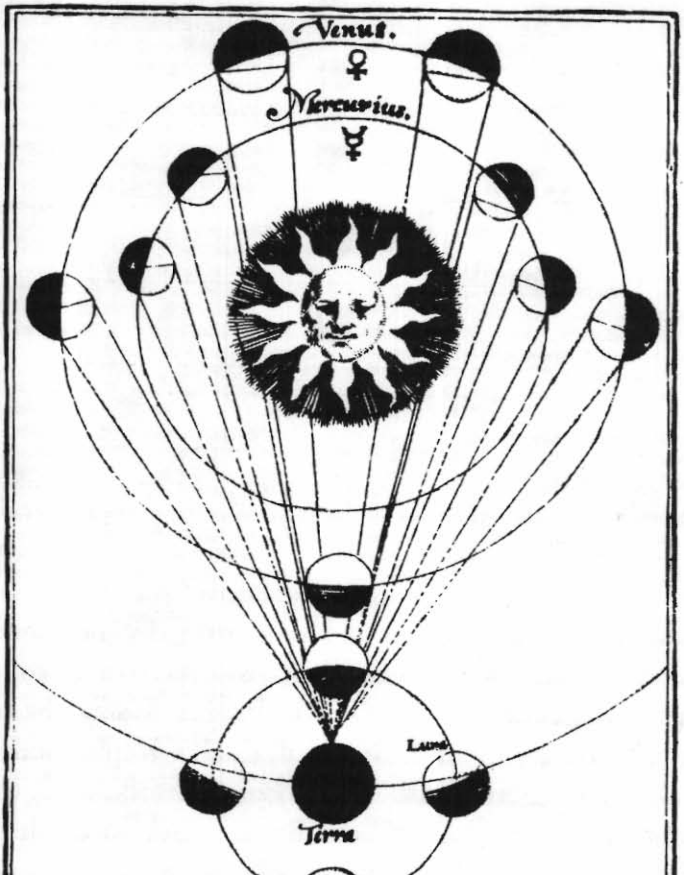
tually he could hardly have guessed how much beyond the power of any naked eye it is to pick up so small an effect. Yet, neither could Tycho accept the Ptolemaic hypothesis, whose complexities and defects were becoming more apparent than ever.

Thus it was that Tycho Brahe evolved his own model, which was a kind of cross between the two. Known as the *Tychonic system*, this scheme once again placed the stationary earth at the center of a rotating celestial sphere. Revolving around the earth were first the moon — and then the sun. Then all the rest of the planets circled about the sun, as in the Copernican theory. Actually, the Tychonic system was short-lived, but it served one great purpose: It led the way toward dealing the Ptolemaic system its deathblow. Since, in the Ptolemaic scheme, the planets Mercury and Venus were always supposed to be between the earth and the sun, they could never appear fully illuminated from the earth — as they would if they were to pass around to the far side of the sun, which they could, according to either the Copernican system or Tychonic system.

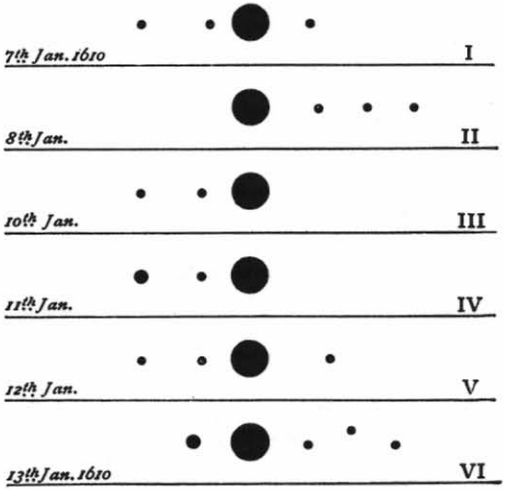
It was the great Italian physicist and astronomer, Galileo, who was the first man to put the Ptolemaic theory to the test, being the first to use a telescope for astronomical observations. In the years following 1610, Galileo carefully watched the planet Venus go through all of its phases, like those of the moon — waxing from crescent to full, then waning. This of course was decisive evidence against the Ptolemaic theory, in which the "full" phase of Venus was impossible.

The choice was now between the Tychonic and the Copernican systems, and Galileo favored the latter. When Galileo began his observations of the planet Jupiter, the Copernican theory recommended itself even more to him. Peering through his telescope, he saw the giant planet accompanied by four moons which were circling around it, all in nearly the same plane. Like the sun and its train of revolving planets, it was a miniature "solar system" of the kind advocated by Copernicus.

But the Copernican theory had its defects, as did every other system which insisted on the old Greek notion of circular orbits for the planets. The man who finally solved the problems of planetary motion was the German astronomer Johannes Kepler, perhaps the warmest and most appealing personality in the entire history of



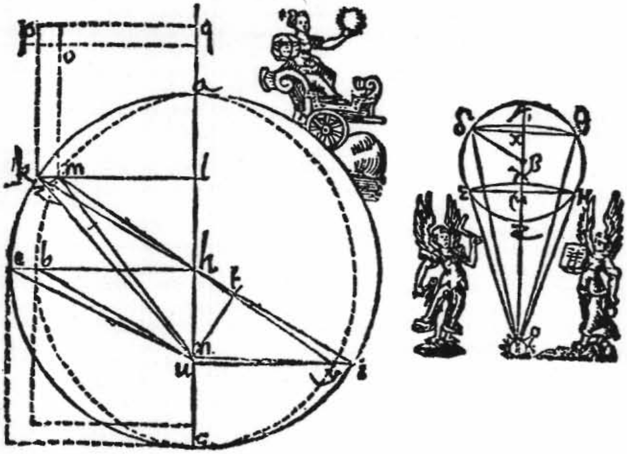
Old illustration shows evidence of falsity of the Ptolemaic system. Full phases of Venus, observed by Galileo in 1610, were not possible in Ptolemy's scheme.



Jupiter's moons, showing stages in their discovery by Galileo. Observation of this miniature "solar system" aided in the acceptance of the Copernican system.

astronomy. An assistant of the stormy Tycho Brahe, Kepler became his immediate successor as royal astronomer at the court of Rudolf II in Prague. Using the invaluable observations of the great Tycho, Kepler undertook the staggering task of analyzing, by the most elementary mathematical means, Brahe's data, in the hope of correctly describing the motions of the planets.

After many years of painstaking trial and error, Johannes Kepler finally triumphed over the problem of planetary motion by evolving three basic laws. In essence, Kepler put his finger on the very problem which



Johannes Kepler's famous figure showing the elliptical nature of Mars' orbit (dotted). Note triumphal chariot which Kepler, in his glee at the moment of discovery, hastily sketched on the diagram.

had led Copernicus astray. He advanced the idea that, contrary to the old Greek notion of the circle being a perfect figure and therefore the only path in which planets could travel, the planets in fact *did not* move about the sun in perfect circles. Rather, Kepler discovered that the planets actually revolve about the sun in slightly elliptical or oval orbits.

Kepler also proved that each planet changes speed as it moves about its orbit. As its oval path brings the planet closer to the sun, the planet picks up speed.

In the light of Kepler's findings, it is little wonder that it took so long to destroy the idea of the circle as the perfect planetary path. For example, the orbit of the earth is very close to being a circle. Some idea of just *how* close can be gained by thinking of an ellipse which measures 100 feet across in one direction and 99½ feet in the other. Small wonder then that Copernicus, not knowing what Kepler knew, was so often baffled by the elusive motion of the planets.

Perhaps the most brilliant man of science of all time was the great Sir Isaac Newton who finally clinched the evidence in favor of the heliocentric theory over any other. On the basis of Kepler's laws and his own laws of motion, Newton was able to deduce his greatest contribution — the law of universal gravitation. According to this law and the laws of motion, Tycho's system could not be true. Newton's theory concerning the planets was firmly based on Copernicus' own arrangement, with the sun at the center of the solar system. But Newton's theory was a much wider one and it was able to account for more phenomena than planetary motion. Since Newton's idea of the universe soon won broad acceptance, so too did the heliocentric theory of Copernicus. Thus Newton marked the end of a long road in mankind's quest for knowledge about his universe.

And yet it was not the end at all. For since Copernicus' day, the universe has continued to "expand" as knowledge itself has expanded. At present we cannot assign any point as its "center," since its boundaries, if any, are unknown. Still, none of those changes made in the universe since Nicolaus Copernicus first challenged the earth-centered idea has had so great an impact on men's minds.

AD LECTOREM DE HYPO-
THESIBVS HVIVS OPERIS.

NON dubito, quin eruditi quidam, uulgata iam de nouitate hypotheseon huius operis fama, quòd terram mobilem, Solem uero in medio uniuersi immobilẽ constituit, uehementer sint offensi, putẽtq; disciplinas liberales recte iam olim constitutas, turbari nõ oportere. Verum si rem exacte perpendere uolent, inueniẽt authorem huius operis, nihil quod reprehendi mereatur cõmisisse. Est enim Astronomi proprium, historiam motuum coelestium diligenti & artificiosa obseruatione colligere. Deinde causas earundem, seu hypotheses, cum ueras assequi nulla ratione possit, qualescunq; excogitare & confingere, quibus suppositis, ijdem motus, ex Geometriæ principijs, tam in futurũ, quàm in præteritũ recte possint calculari. Horũ autẽ utrunq; egregie præstitit hic artifex. Neq; enim necesse est, eas hypotheses esse ueras, imò ne uerisimiles quidem, sed sufficit hoc unum, si calculum obseruationibus congruentem exhibeant. nisi fortè quis Geometriæ & Optices usq; adeo sit ignarus, ut epicyclium Veneris pro uerisimili habeat, seu in causa esse credat, quod ea quadraginta partibus, & eo amplius, Solẽ interdum præcedat, interdũ sequatur. Quis enim nõ uidet, hoc posito, necessario sequi, diametrum stellæ in περιγείῳ plusq; quadruplo, corpus autem ipsum plusq; sedecuplo, maiora, quàm in ἀπογείῳ apparere, cui tamen omnis æui experientia refragatur? Sunt & alia in hac disciplina non minus absurda, quæ in præsentiarum excutere, nihil est necesse. Satis enim patet, apparentiũ inæqualium motuũ causas, hanc artẽ penitus & simpliciter ignorare. Et si quas fingẽdo excogitat, ut certe quãplurimas excogitat, nequaquã tamen in hoc excogitat, ut ita esse cuiquam persuadeat, sed tantum, ut calculum recte instituant. Cum autem unus & eiusdem motus, uarie interdum hypotheses sese offerant (ut in motu Solis, eccentricitas, & epicyclium) Astronomus eam potissimum arripiet, quæ compræhensu sit quàm facillima, Philosophus fortasse, ueri similitudinem magis re-

The Preface by Osiander as it appeared in the First Edition of De Revolutionibus. *English translation is given opposite.*

OSIANDER'S PREFACE

APPENDIX A

To the Reader Concerning the Hypothesis of This Work.

I do not doubt that certain learned men will be much annoyed at the common report of the newness of the arguments of this work; namely, that the earth is movable, but that the sun is immovable in the middle of the universe, and will think that noble doctrines rightly established in the past should not be disturbed. But if they will consider the matter closely, they will find that the author of this work has done nothing worthy of blame. For it is the task of the astronomer to draw up an account of the celestial movements from earnest and skillful observation, and then (when he cannot arrive at the real causes for these things) to think out and invent any hypotheses whatsoever and take them for granted, if thereby these same motions may be rightly calculated, both for the future and the past, by the principles of geometry. Now this author greatly excels in each of these points. For it is not necessary that these hypotheses should be true, or even very probable; but this one thing is sufficient – that they must put forward a calculation agreeing with the observations. Unless by chance anyone be so ignorant of geometry and optics that he holds the epicycle of Venus to be probable, or believes that it is the cause of its being forty degrees and even more, and that it sometimes precedes and sometimes follows the sun. For who does not see, when this is assumed, that it necessarily follows that the planet's diameter when nearest the earth is greater by more than fourfold, and its body is greater by 16 times than it appears when farthest from the earth, which however the experience of all the ages contradicts? And there are other things not less absurd in this teaching, which it is not necessary to discuss here. For it is clear enough that this art entirely and simply ignores the causes of apparent unequal motions. And if he devises these causes by invention, as he certainly does very many, by no means however does he discover this, that he can convince anyone that they are true, unless they rightly form a calculation. When various hypotheses of one and the same motion sometimes offer themselves (as in the sun's motion, the eccentricity, and epicycle of the sun), the astronomer will choose for preference that one which is most easily understood. The philosopher perhaps will require a greater exactitude; neither however will understand or propound anything true unless it has been revealed to him by divine providence. Let us therefore allow these new hypotheses to be known as no less probable than the old ones, particularly as they are at the same time wonderful and easy, and bring with them a huge treasury of most learned observations. Let no one expect anything true, pertaining to hypotheses, from astronomy, for it can show nothing of the sort, lest taking false things for true in some other use, he depart from this teaching more foolish than he came. Farewell.

CARDINAL SCHÖNBERG'S
LETTER
TO COPERNICUS

APPENDIX B

Nicholaus Schönberg, Cardinal of Capua, to Nicolaus Copernicus, Greeting.

Having constantly heard, from the lips of all men, of your talent, I have begun to honor you more fully, and to congratulate our countrymen amongst whom you have flourished with so great renown. For I have perceived that you were not only well versed in the works of the old mathematicians, but also have propounded a new theory of the universe. By it you teach that the earth moves, that the sun is at the bottom of the universe, and indeed holds the central place therein. That the eighth heaven remains immovable and eternally fixed. That the moon, with the elements included in her sphere, placed between the heaven of Mars and Venus, revolves in a yearly course round the sun. And that you have written commentaries on this whole theory of astronomy, and have reduced into tables the motions of the planets, computed from calculations, to the great admiration of everyone. Wherefore I beseech you, most learned man, if I am not troubling you, to impart this your discovery to the learned, and also send to me in the first place your work concerning the sphere of the universe, with the tables, and anything else you have besides belonging to the same matter. Also I have commissioned Theodoricus à Reden to transcribe and send to me everything concerning the matter, at my own expense. And if you will gratify me in this, you will find that you have to do with a man careful of your name, and one anxious to do justice to such great talent. Farewell. At Rome, Calendar of November, 1536.

AD SANCTISSIMVM DOMINVM PAVLVM III. PONTIFICEM MAXIMVM,

Nicolai Copernici Præfatio in libros Reuolutionum.

SATIS equidem, Sanctiſsime Pater, æ
ſtimare poſſum, futurum eſſe, ut ſimul
atq; quidam acceperint, me hiſce meis li
bris, quos de Reuolutionibus ſphærarū
mundi ſcripſi, terræ globo tribuere quoſ
dam motus, ſtatim me explodendum
cum tali opinione clamitent. Necq; enim
ita mihi mea placent, ut nō perpendam,
quid aliȷ de illis iudicaturi ſint. Et quamuis ſciam, hominis phi
loſophi cogitationes eſſe remotas à iudicio uulgi, propterea
quòd illius ſtudium ſit ueritatem omnibus in rebus, quatenus
id à Deo rationi humanę permiſſum eſt, inquirere, tamen alie
nas prorſus à rectitudine opiniones fugiendas cenſeo. Itaq; cū
mecum ipſe cogitarem, quàm abſurdum ἀκρόαμα exiſtimatu
ri eſſent illi, qui multorum ſeculorum iudiciȷs hanc opinionē
confirmatam norūt, quòd terra immobilis in medio cœli, tan
quam centrum illius poſita ſit, ſi ego contra aſſererem terram
moueri, diu mecum hæſi, an meos cōmentarios in eius motus
demonſtrationem conſcriptos in lucem darem, an uero ſatius
eſſet, Pythagoreorum & quorundam aliorum ſequi exemplū,
qui non per literas, ſed per manus tradere ſoliti ſunt myſteria
philoſophiæ propinquis & amicis duntaxat. Sicut Lyſidis ad
Hipparchum epiſtola teſtatur. Ac mihi quidem uidentur id
feciſſe: non ut quidam arbitrantur ex quadam inuidentia
communicandarum doctrinarum, Sed ne res pulcherrimæ, &
multo ſtudio magnorum uirorum inueſtigatę, ab illis contem
nerentur, quos aut piget ullis literis bonam operam impende
re, niſi quæſtuoſis, aut ſi exhortationibus & exemplo aliorum
ad liberale ſtudium philoſophiæ excitentur, tamen propter
ſtupidita

Copernicus' letter to Pope Paul III as it appeared in De Revolutionibus. *English translation is given opposite.*

COPERNICUS' DEDICATION TO POPE PAUL III

APPENDIX C

TO THE MOST HOLY LORD, POPE PAUL III

The Preface of Nicolaus Copernicus to the Books of the Revolutions.

I may well presume, most Holy Father, that certain people, as soon as they hear that in this book about the Revolutions of the Spheres of the Universe I ascribe movement to the earthly globe, will cry out that, holding with such views, I should at once be hissed off the stage. For I am not so pleased with my own work that I should fail duly to weigh the judgment which others may pass thereon; and though I know that the speculations of a philosopher are far removed from the judgment of the multitude – for his aim is to seek truth in all things as far as God has permitted human reason so to do – yet I hold that opinions which are quite erroneous should be avoided.

Thinking therefore within myself that to ascribe movement to the Earth must indeed seem an absurd performance on my part to those who know that many centuries have consented to the establishment of the contrary judgment, namely that the Earth is placed immovably as the center point in the middle of the Universe, I hesitated long whether, on the one hand, I should give to the light these my Commentaries written to prove the Earth's motion, or whether, on the other hand, it were better to follow the example of the Pythagoreans and others who were wont to impart their philosophic mysteries only to intimates and friends, and then not in writing but by word of mouth, as the letter of Lysis to Hipparchus witnesses. In my judgment they did so not, as some would have it, through jealousy of sharing their doctrines, but as fearing lest these so noble and hardly won discoveries of the learned should be despised by such as either care not to study aught save for gain, or – if by the encouragement and example of others they are stimulated to philosophic liberal pursuits – yet by reason of the dullness of their wits are in the company of philosophers as drones among bees. Reflecting thus, the thought of the scorn which I had to fear on account of the novelty and incongruity of my theory, well-nigh induced me to abandon my project.

These misgivings and actual protests have been overcome by my friends . . . who often urged and even importuned me to publish this work which I had kept in store not for nine years only, but to a fourth period of nine years . . . They urged that I should not, on account of my fears, refuse any longer to contribute the fruits of my labors to the common advantage of those interested in mathematics. They insisted that, though my theory of the Earth's movement might at first seem strange, yet it would appear admirable and acceptable when the publication of my elucidatory comments should dispel the mists of paradox. Yielding then to their persuasion I at last permitted my friends to publish that work which they have so long demanded.

That I allow the publication of these my studies may surprise your Holiness the less in that, having been at such travail to attain them, I had already not scrupled to commit to writing my thoughts upon the motion of the Earth. How I came to dare to conceive such motion of the Earth, contrary to the impression of the senses, is what your Holiness will rather expect to hear. So I should like your Holiness to know that I was induced to think of a method of computing the motions of the spheres by nothing else than the knowledge that the mathematicians are inconsistent in these investigations.

For, first, the mathematicians are so unsure of the movements of the Sun and Moon that they cannot even explain or observe the constant length of the seasonal year. Secondly, in determining the motions of these and of the other five planets, they use neither the same principles and hypotheses nor the same demonstrations of the apparent motions and revolutions. So some use only homocentric circles, while others eccentrics and epicycles. Yet even by these means they do not completely attain their ends. Those who have relied on homocentrics, though they have proven that some different motions can be compounded therefrom, have not thereby been able fully to establish a system which agrees with the phenomena. Those again who have devised eccentric systems, though they appear to have well-nigh established the seeming motions by calculations agreeable to their assumptions, have yet made many admissions which seem to violate the first principle of uniformity in motion. Nor have they been able thereby to discern or deduce the principal thing – namely the shape of the Universe and the unchangeable symmetry of its parts. With them it is as though an artist were to gather the hands, feet, head and other members for his images from diverse models, each part excellently drawn, but not related to a single body, and since they in no way match each other, the result would be monster rather than man. So in the course of their exposition, which the mathematicians call their system, . . . we find that they have either omitted some indispensable detail or introduced something foreign and wholly irrelevant. This would of a surety not have been so had they followed fixed principles; for if their hypotheses were not misleading, all inferences based thereon might be surely verified. Though my present assertions are obscure, they will be made clear in due course.

I pondered long upon this uncertainty of mathematical tradition in establishing the motions of the system of the spheres. At last I began to chafe that philosophers could by no means agree on any one certain theory of the mechanism of the Universe, wrought for us by a supremely good and orderly Creator, though in other respects they investigated with meticulous care the minutest points relating to its circles. I therefore took pains to read again the works of all the philosophers on whom I could lay hand to seek out whether any of them had ever supposed that the motions of the spheres were other than those demanded by the mathematical schools. I found first in Cicero that Hicetas had realized that the Earth moved. Afterwards I found in Plutarch that certain others had held the like opinion. I think fit here to add Plutarch's own words, to make them accessible to all:

"The rest hold the Earth to be stationary, but Philolaus the Pythagorean says that she moves around the fire on an oblique circle like the Sun and Moon. Heraclides of Pontus and Ecphantus the Pythagorean also make the Earth to move, not indeed through space but by rotating round her own center as a wheel on an axle from West to East."

Taking advantage of this I too began to think of the mobility of the Earth; and though the opinion seemed absurd, yet knowing now that others before me had been granted freedom to imagine such circles as they chose to explain the phenomena of the stars, I considered that I also might easily be allowed to try whether, by assuming some motion of the Earth, sounder explanations than theirs for the revolution of the celestial spheres might so be discovered.

Thus assuming motions, which in my work I ascribe to the Earth, by long and frequent observations I have at last discovered that, if the motions of the rest of the planets be brought into relation with the circulation of the Earth and be reckoned in proportion to the circles of each planet, not only do their phenomena presently ensue, but the orders and magnitudes of all stars and spheres, nay the heavens themselves, become so bound together that nothing in any part thereof could be moved from its place without producing confusion of all the other parts and of the Universe as a whole. . . .

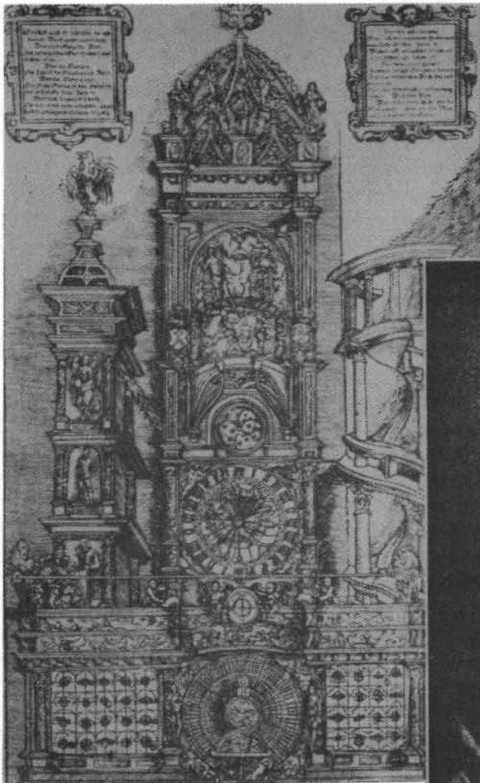
I doubt not that gifted and learned mathematicians will agree with me if they are willing to comprehend and appreciate, not superficially but thoroughly, according to the demands of this science, such reasoning as I bring to bear in support of my judgment. But that learned and unlearned alike may see that I shrink not from any man's criticism, it is to your Holiness rather than anyone else that I have chosen to dedicate these studies of mine, since in this remote corner of Earth in which I live you are regarded as the most eminent by virtue alike of the dignity of your Office and of your love of letters and science. You by your influence and judgment can readily hold the slanderers from biting, though the proverb hath it that there is no remedy against a sycophant's tooth. It may fall out, too, that idle babblers, ignorant of mathematics, may claim a right to pronounce a judgment on my work, by reason of a certain passage of Scripture basely twisted to suit their purpose. Should any such venture to criticize and carp at my project, I make no account of them; I consider their judgment rash, and utterly despise it. I well know that even Lactantius, a writer in other ways distinguished but in no sense a mathematician, discourses in a most childish fashion touching the shape of the Earth, ridiculing even those who have stated the Earth to be a sphere. Thus my supporters need not be amazed if some people of like sort ridicule me too.

Mathematics are for mathematicians, and they, if I be not wholly deceived, will hold that these my labors contribute somewhat even to the Commonwealth of the Church, of which your Holiness is now Prince. For not long since, under Leo X, the question of correcting the ecclesiastical calendar was debated in the Council of the Lateran. It was left undecided for the sole cause that the lengths of the years and months and the motions of the Sun and Moon were not held to have been yet determined with sufficient exactness. From that time on I have given thought to their more accurate observation, by the advice of that eminent man Paul, Lord Bishop of Sempronia, sometime in charge of that business of the calendar. What results I have achieved therein, I leave to the judgment of learned mathematicians and of your Holiness in particular. And now, not to seem to promise your Holiness more that I can perform with regard to the usefulness of the work, I pass to my appointed task.

WHAT DID COPERNICUS LOOK LIKE?

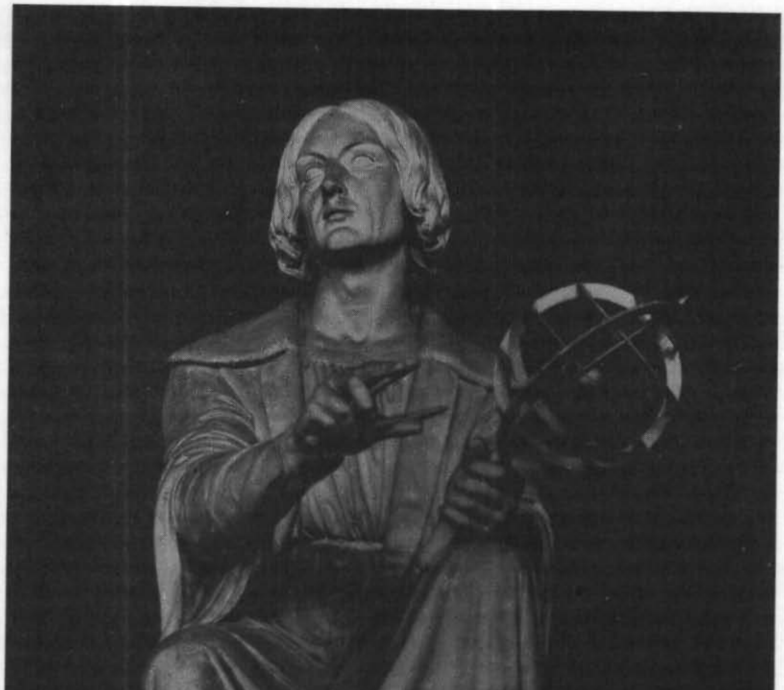
APPENDIX D

On the following pages is a gathering of various paintings, engravings, statues, and other likenesses of the great astronomer.

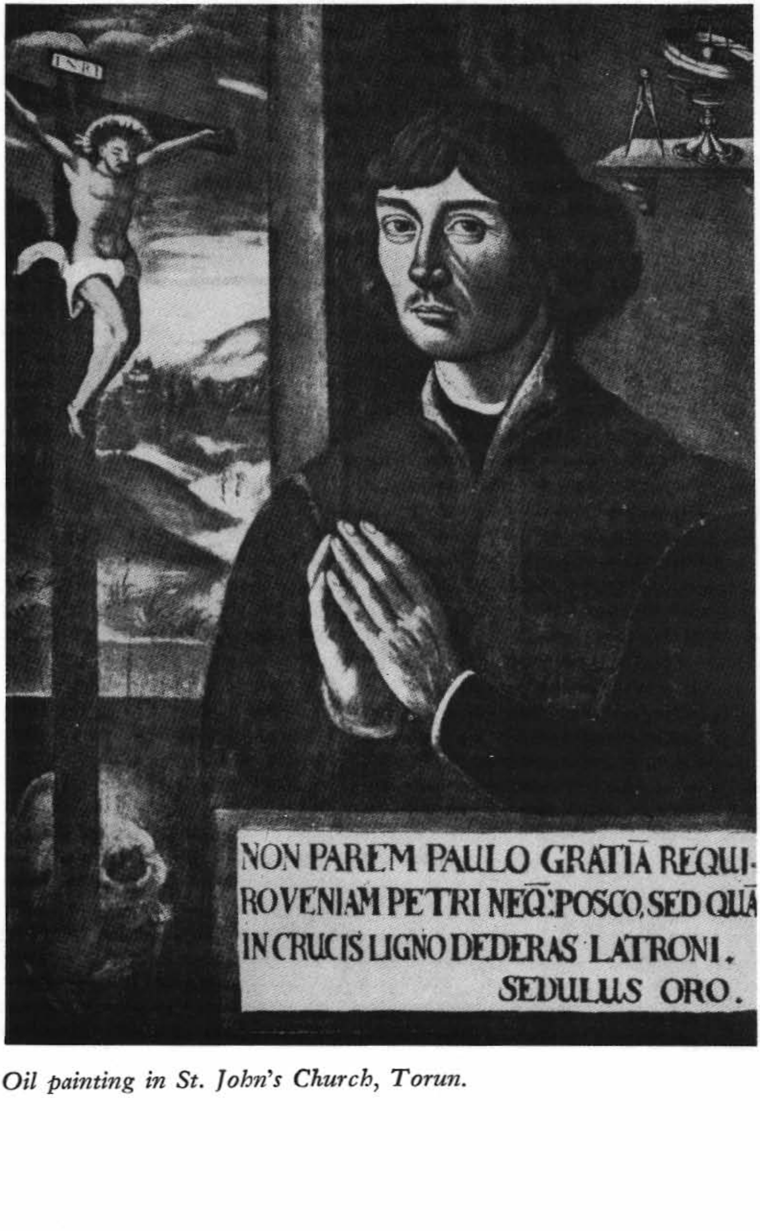


(Above) A contemporary wood cut of the Astronomical Clock Tower of the Cathedral of Strasbourg.

(Right) Copy of self portrait of Nicolaus Copernicus, done by Tobias Stimmer, in 1571, on the Astronomical Clock Tower of the Cathedral of Strasbourg. Lily of the valley may be a symbol of Copernicus's interest in natural philosophy, more particularly in medicine.

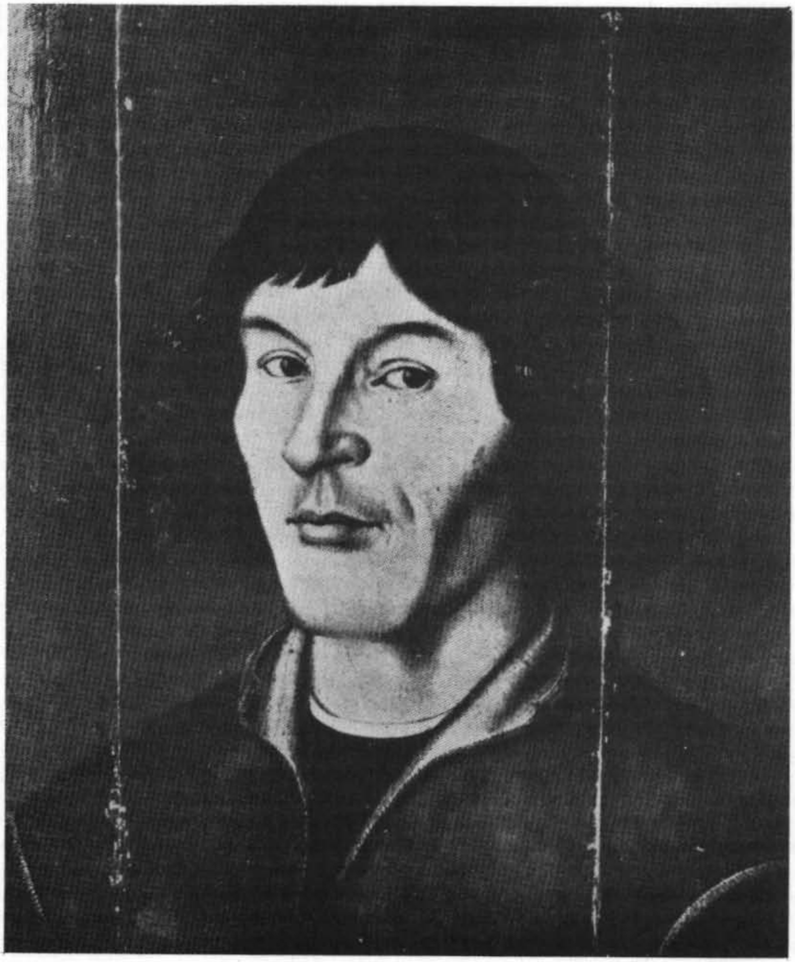


Bertel Thorwaldsen's famous statue of Copernicus.



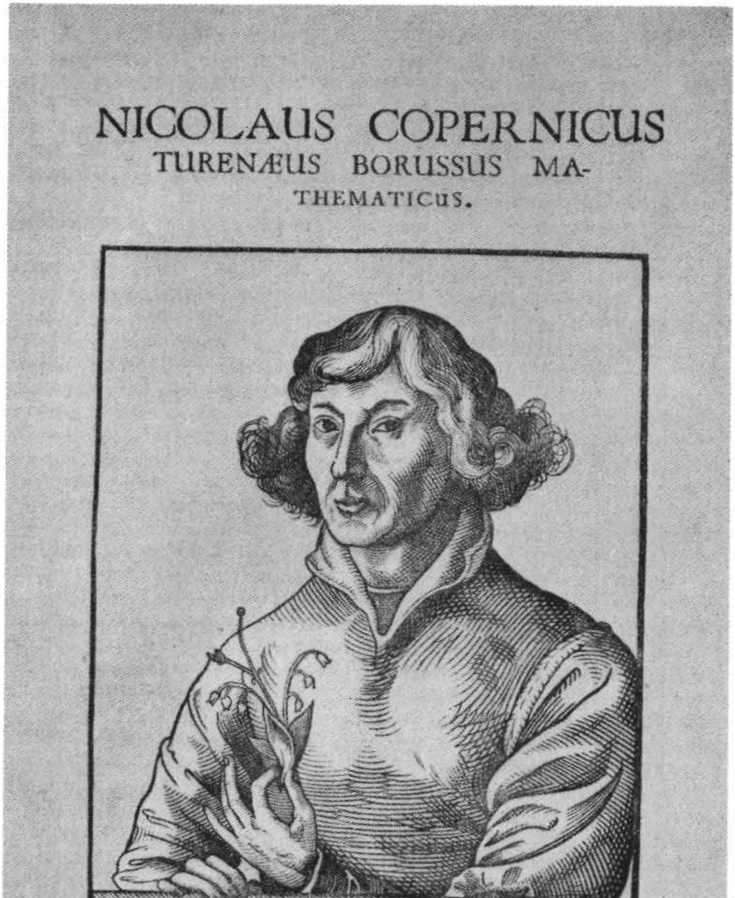
Oil painting in St. John's Church, Torun.

Monument of Copernicus in Torun.



Portrait in the possession of the Copernicus Grammar School, Torun.

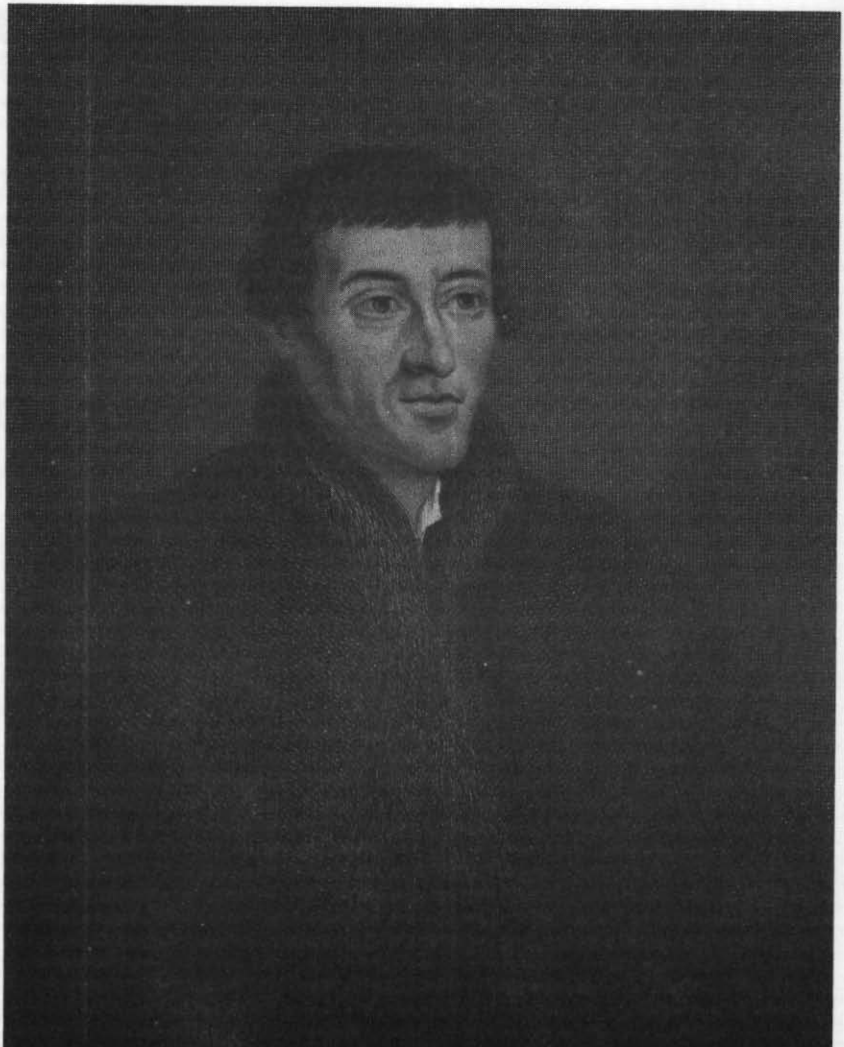
Early engraving, Czartoryski Museum, Krakow.



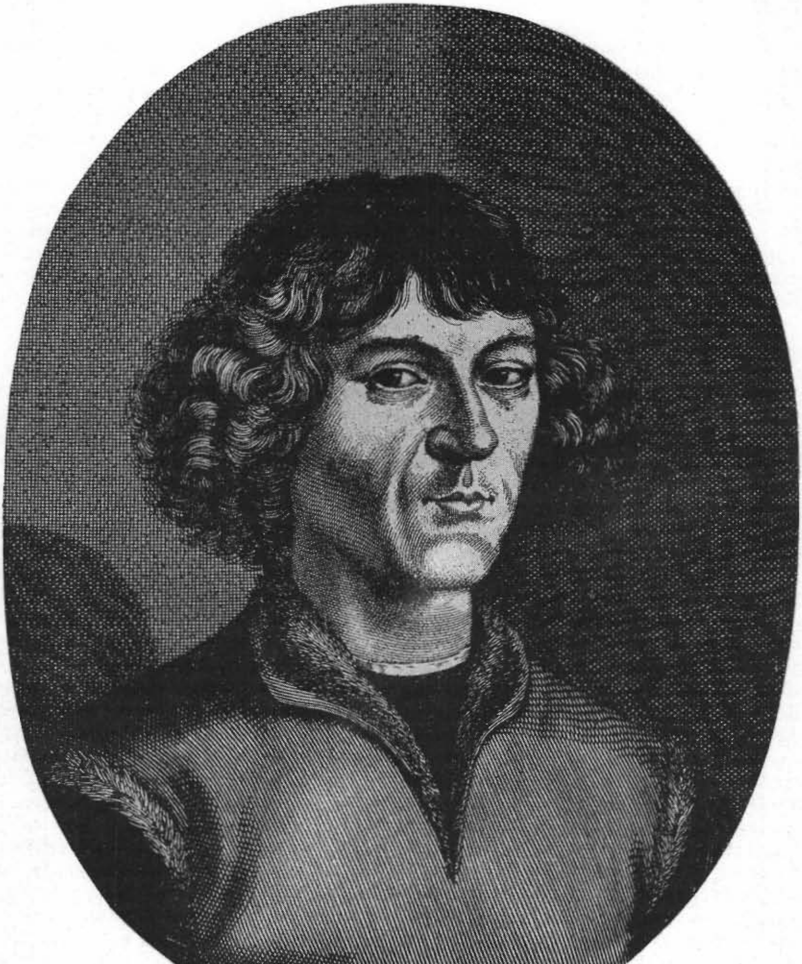
Early wood cut, Bartynowski Collection, Krakow.

Early print, Czartoryski Museum, Krakow.

Steel engraving by E. de Boulanois, Brussels, 1682. (Courtesy of the Kosciuszko Foundation)



From a picture in the possession of the Royal Society, London. Presented by Dr. Wolf of Danzig on June 6, 1776.

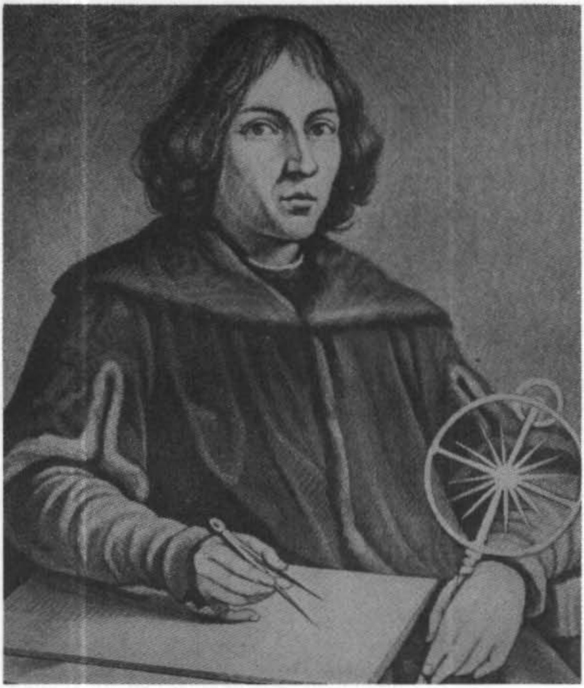


Engraving by Jeremiah Falck of Danzig.

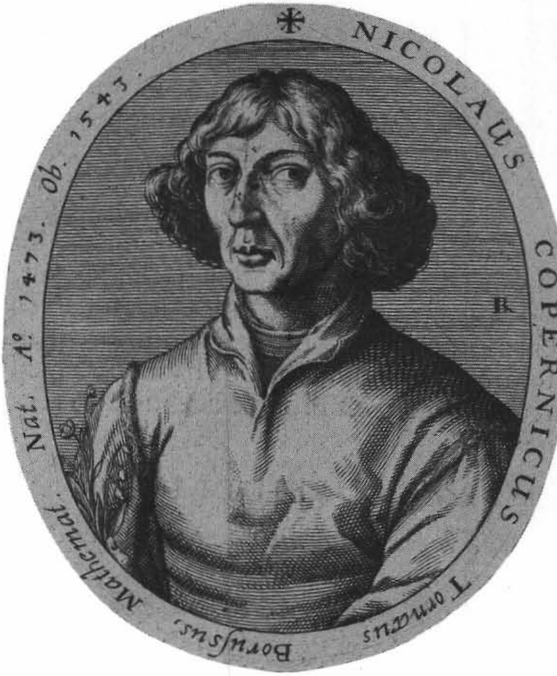
Frequently reproduced is this print by Jacob van Meurs. It appeared in the famous biography of Copernicus by Gassendi, editions of 1654-5. (Facsimile courtesy Burndy Library)

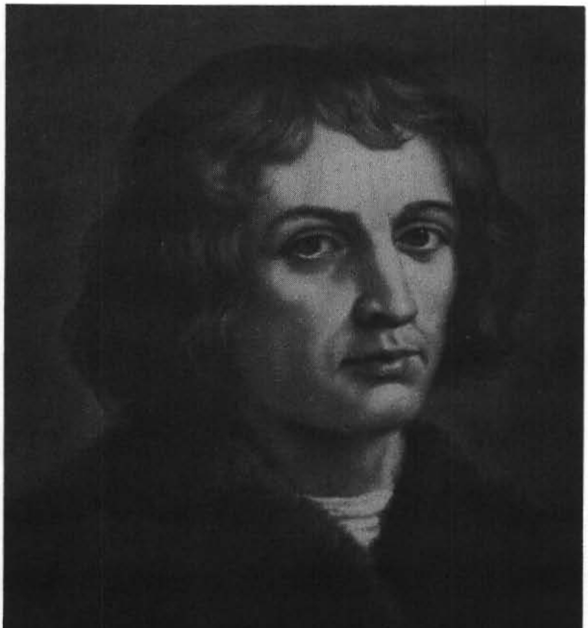
The Copernicus monument in the courtyard of the Jagellon Library, University of Krakow. Copernicus himself studied in this same building. (Courtesy Kosciuszko Foundation)

A modern oil painting by Maxim Kopf done in 1943. It was presented to the astronomer Harlow Shapley for the Harvard Observatory by the Kosciuszko Foundation. (Courtesy the Kosciuszko Foundation)




Nicolas Copernic
Célébre Astronome, Mathematicien,
Philosophe et Médecin, né a Thorn Ville de
la Prusse Royale, mort en 1543. agé de
70 ans
Paris chez Daumont.


NICOLAUS COPERNICUS
Tornaeus Borussus, Mathemat.
Nat. Aº 1473. Ob. 1543.
R.

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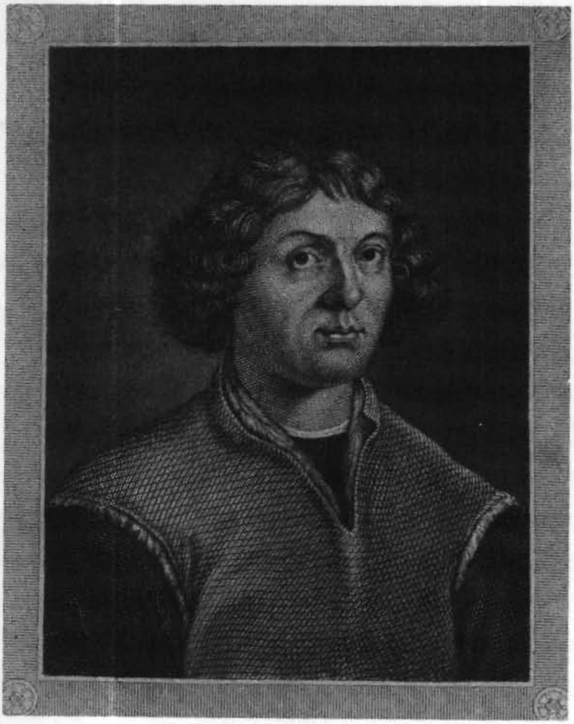
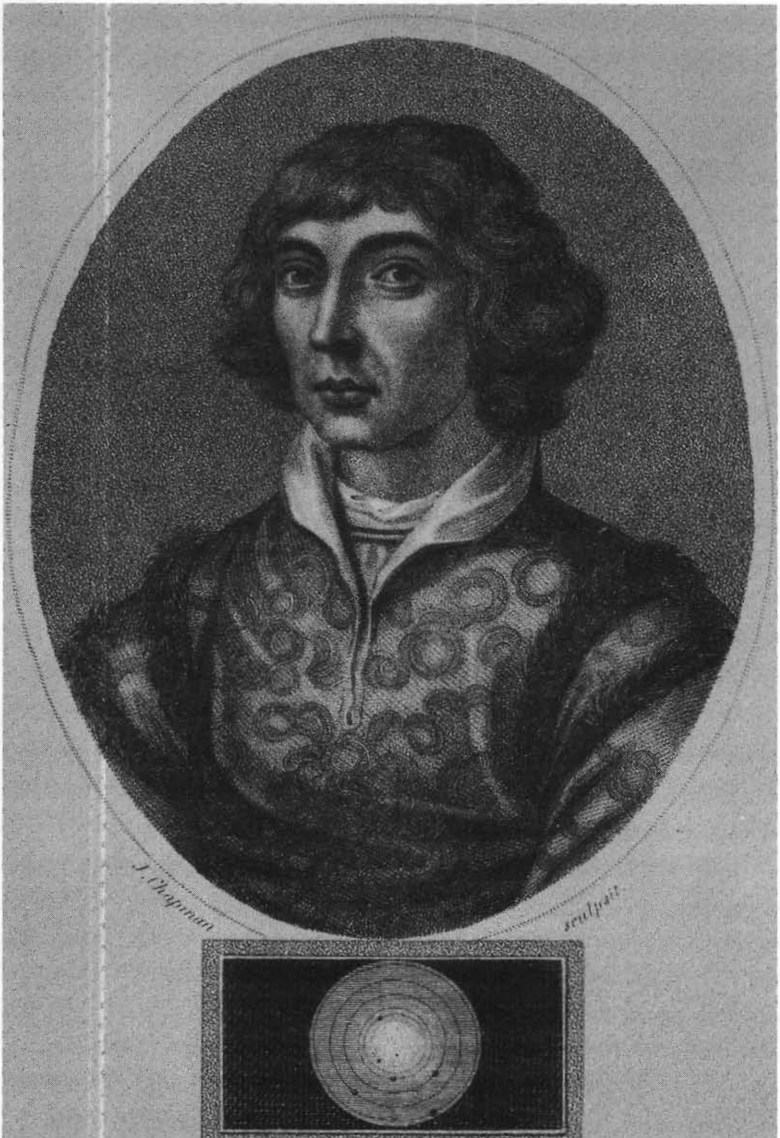



Spes mea in Deo leru
DOMNVS NICOLAVS COPERNICVS, SACERDOS, CANONICVS
REGVLARIS, ASTRONOMORVM KORYPHÆVS.


J. Chapman
sculpsit

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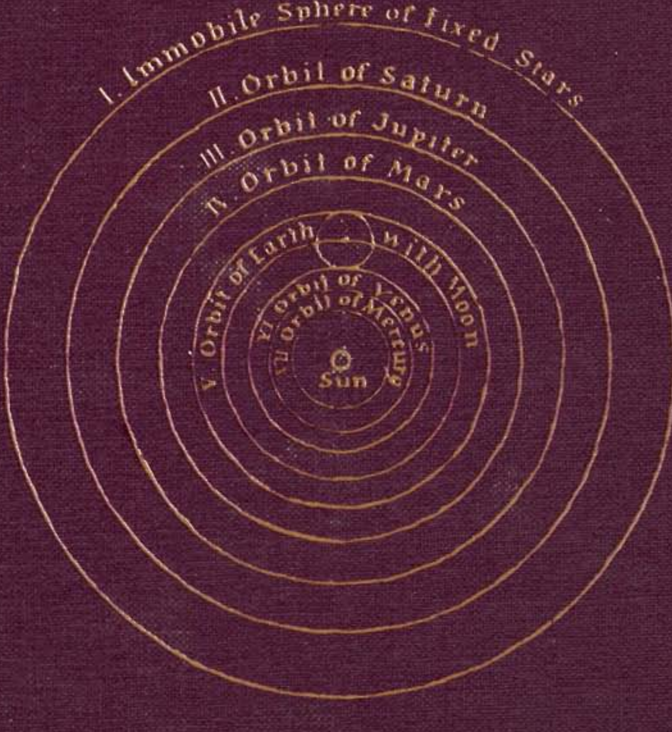

THE HELIOCENTRIC SYSTEM

KNIGHT

COPERNICUS

Titan of Modern Astronomy

WATTS