Chapter 4 Tycho Brahe: The First Modern Astronomer

There couldn't have been a more colorful, outrages, or passionate individual than Tyge Brahe, better known by his Latinized name, Tycho Brahe, to be the harbinger of what is considered modern astronomy; to start the process of extricating the study of the stars into two distinct disciplines, astrology and astronomy.

Tycho Brahe, son of Otto Brahe and Beatte Bille, both families of high Danish nobility, attended the universities of Copenhagen and Leipzig with the intention of studying law. His interest in alchemy and astronomy was aroused and soon pursued that study with all the ardor of a tyro. He traveled through the German region attending the universities of Wittenberg, Rostock and Basel continuing his studies in science. He bought a few astronomical instruments to make his own observations and soon learned that not only had he accumulated more observations of the planets than in all the existing catalogs, they were far more accurate. To Tycho accurate recording of observations was the key for celestial analysis.

The red bearded Danish nobleman, who died seven years before the telescope was invented, was a quarrelsome man. His temper gave rise to a celebrated mishap. As a young student at Rostock, Germany, Tycho quarreled at a dance with another Danish nobleman. Two days later, two days before his 20^{th} birthday, they renewed the quarrel and fought a duel with swords. In this duel, Tycho lost by a nose, literally; he lost part of his nose. To cover the gap, Tycho fashioned some sort of metal insert made of gold or silver to hide the disfigurement. He carried a box of ointment that he used to rub his nose. In his portraits you can see that something is wrong with his nose, but you can't tell if it is the tip or the bridge of the nose that was injured.

The story that Tycho lost his nose in a duel and thereafter wore an artificial one became widely spread, but remained mostly apocryphal, what gave it more credence was a stanza in the Astronomers' Drinking Song. (I'm not making this up.):

The noble Tycho places the stars,
Each in its due location;
He lost his nose by spite of Mars,
But that was no privation:
Had he lost his mouth, I grant
He would have felt dismay, sir,
Bless you! He knew what he should want
To drink his bottle a day, sir!

Tycho’s Supernova

Tycho Brahe returned to Denmark in 1570 to launch his career in astronomy, but it was not until he published a tract on a “new star” he observed in Cassiopeia in November, 1572 that he established a name in this field and launched the revolution in astronomy. *De nova et nullius aevi memoria prius visa stella* ("Concerning the Star, new and never before seen in the life or memory of anyone," was published in 1573 with reprints in 1602 and 1610. Though not the first to observe it, this “star” in Cassiopeia is known as Tycho’s Supernova because of this work.

The “new star” challenged the ancient models of the heavens and the Aristotelian dogma of the immutable realm of the stars. This boosted Tycho’s determination to produce better astrometric star catalogs and the need for better, more accurate instruments. At its brightest, the new star rivaled Venus in luminosity and remained visible to the naked eye until 1574 and slowly faded into invisibility by the end of that year. Its importance lay, not only that it ignited inquiry in the field but that it established Tycho Brahe as an astronomer.

After giving a course of lectures on astronomy at the University of Copenhagen, Tycho accepted an offer from King Frederick II to fund the building of his observatory. The king also gave Brahe the little island of Hven in the Sont near Copenhagen in a fief to build his observatory, which became the finest observatory in Europe.

Tycho’s Observatory: Uraniborg

The island is about two thousand acres in area with most of the inhabitants living in a village near the northern coast. Though most of the villagers were farmers who tilled forty farms in common, the Hven had a windmill, a paper mill in 1590, a large dam and enough workshops of artisans capable of constructing his instruments.

Near the center of the island, at the highest point, about one hundred and sixty feet above sea level, Tycho built Uraniborg, which would be his home and observatory for over twenty years. Ostentatious is the first adjective that comes to mind when you first see the image of Tycho’s building that looked more like a fairyland castle than an observatory. Tycho erected this three-story edifice exactly in the center of a square enclosure the walls of which were about 255 feet long, eighteen and one–half feet high, and seventeen feet wide at the base. At the center of each wall was a semicircular bend about seventy–six feet in diameter that enclosed a pavilion. There were gates at the eastern and western corners, and above the gates were kennels in which two English watchdogs were kept to warn of arrivals. At the northern corner was a small house for servants in the same Gothic–Renaissance style as the main house. A similar house at the southern corner housed a printing office. The press was installed in 1584. Four roads directed exactly to the cardinal points led from the main house to the gates and houses. Within the enclosure were flower gardens and about 300 trees of various species. The house was also exactly square with its four walls about fifty-one feet long and thirty-eight feet high oriented along the cardinal points. He had a mural of a quadrant painted on one of the walls to measure the location of stars as they crossed the meridian. Brahe dedicated the observatory to Urania, the Muse of astronomy and hence the source of the name for the complex.

Tycho's Toys

Urinborg was the first custom-built observatory in modern Europe and almost the last built without a telescope as the primary instrument. To place the stars in their proper location, Tycho improved on the existing tools like the quadrant, and invented others and made all these instruments extraordinarily large to increase precision. Below are the instruments he described and depicted in his 1598 book, ***Astronomiae Instaurata Mechanica.***

The Mural Quadrant

The quadrant was large with a radius of about six feet. The arc was large enough that each minute was subdivided with six transversal points of ten seconds making it possible to read off measurements of 5 seconds. Over the center of the quadrant, was a square hole that could be opened and closed and that contained a brass cylinder along both sides of which the observer could sight, using one of two pinnules on the quadrant.

The Brass Azimuthal Quadrant

Tycho Brahe's brass azimuthal quadrant, 65 centimeters (about 25.5 inches), was one of the first instruments built on Hven and was used to observe the comet of 1577. It had the estimated accuracy of 48.8 arc seconds. The accuracy of the observations depended on the instruments and the care with which they were used. Although Tycho's instruments were without magnification, error was minimized by their huge size and by the graduations carefully marked on them to facilitate angular measurements on the celestial sphere, altitudes, and azimuths. Tycho checked instruments against each other and corrected for instrumental errors.

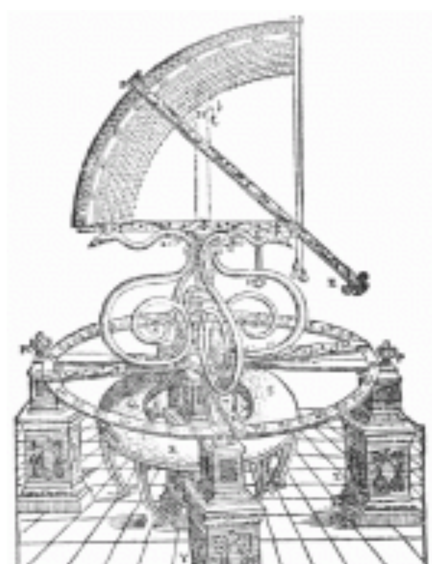


Figure 11 Brass Azimuthal Quadrant

The Great Globe

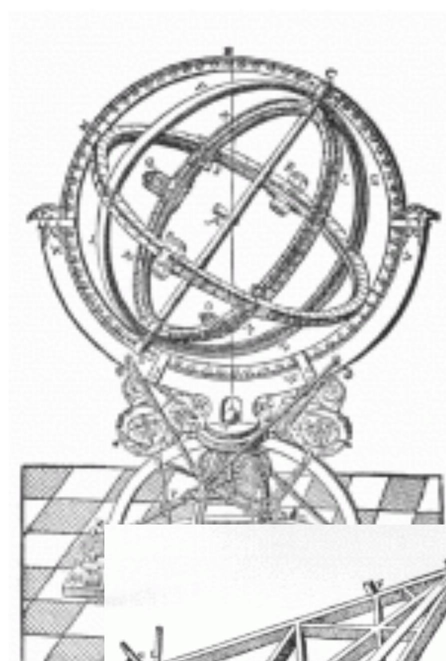
Figure 12 The Great Globe

Tycho's great globe, about 1.6 meters (about 63 inches) in radius, came in service in late 1580. Most of the work involved making the hollow wooden globe as perfectly spherical as possible, after which it was covered in brass plates.

The globe had two primary purposes; to record the position of stars observed by Tycho and as a computational device to convert the local azimuth/altitude measurements into conventional coordinates used to record stellar and planetary positions. By 1595 he had 1000 accurately observed stars inscribed on the globe.

1581 Armillary Sphere

An "armillary sphere" was a tool used to determine latitude and longitude of an observed objects on the celestial sphere, a three dimensional astrolabe. Tycho's 1581 armillary sphere, based on the Hipparchus/Ptolemy model, consisted of four armillary rings all covered in brass except the meridian ring that was made of massive steel to support securely the other three rings. The diameter of this device was 117 cm (about 46 inches). Tycho rapidly gave up on using large versions of the classical armillary sphere, as he found their accuracy compromised by flexing and bending due to the great weight of the various components.



Figure

The Triangular Astronomical Sextant

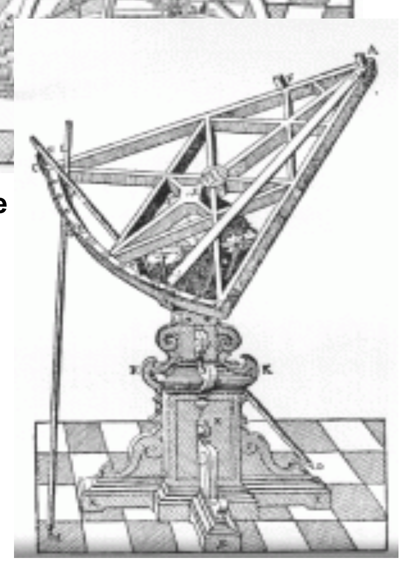


Figure 14 Triangular Sextant

The triangular astronomical sextant was used to determine angular distance between stars. This was an improvement over the mural sextant in that it could be adjusted in any orientation thus measuring the distance between stars directly. The triangular sextant covered 60° arc and, of course, smaller than the mural sextant for portability reasons. Tycho Brahe's sextant was large to get better precision, but his greatest improvement for this tool was a "globe" mount that not only facilitated orientation of the sextant and could be used with other instruments.

Brahe's largest triangular was made of brass mounted on a wooden frame with a radius of 155 centimeters (a little over 61 inches) and could estimate one-quarter of a minute arc.

1585 Great Equatorial Armillary

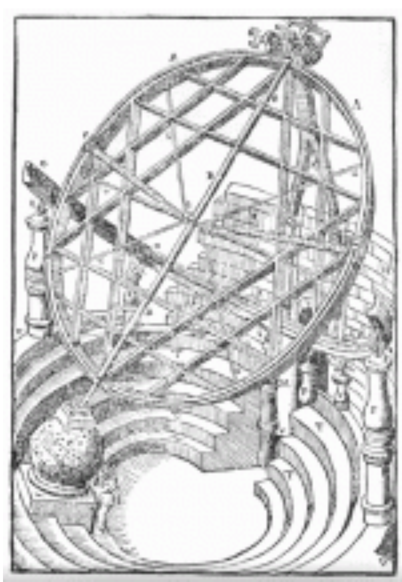


Figure 15 Great Equatorial Armillary

This was one of Tycho Brahe's great inventions. The new armillary was simplified to only one ring and a fixed semi-circle, but still had the same capability of the previous, more complicated, models without having so many sighting adjustments. This model also had the added advantage of being able to be made larger and thus easier to make accurate measurements. The diameter of the ring is 272 cm (almost 9 ft.). The fixed semi-circle that represents the equator is 350 cm (almost 11.5 ft.).

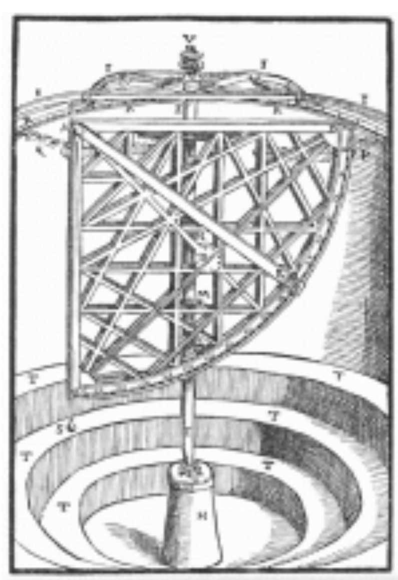


Figure 16 Revolving Wooden Quadrant

The Revolving Wooden Quadrant

The revolving wooden Quadrant was used not only to determine altitude, but more accurately azimuths. The wooden frame is arranged in various ways to insure rigidity in the plane with the instrument itself are made of brass. The radius of the tool is 155 cm (a little over 61 inches). It had an estimated accuracy of 32.6 seconds of arc.

The Revolving Steel Quadrant

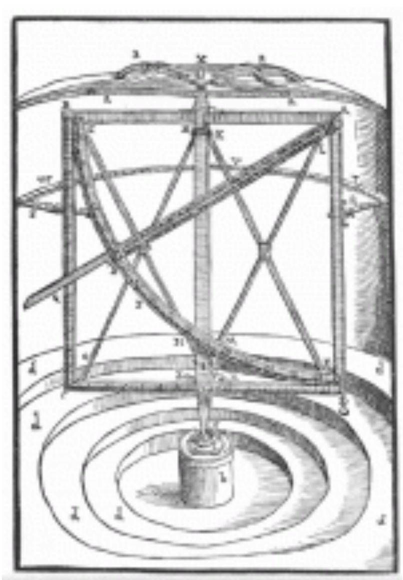


Figure 17 Revolving Quadrant

This quadrant is entirely made of solid steel mounted on a solid steel square for rigidity and support. This quadrant was larger than the wooden quadrant with the radius measuring 194 cm (a little over 76 inches) and thus better accuracy with graduations down to a ten second arc.

Stjerneborg

Tycho Brahe quickly learned that the large instruments at Uraniborg, especially those on the parapets, were adversely affected by the turbulent winds and the slight vibrations transmitted through the floor. Around 1581, he built Stjerneborg (Castle of the Stars), a new, mostly underground,

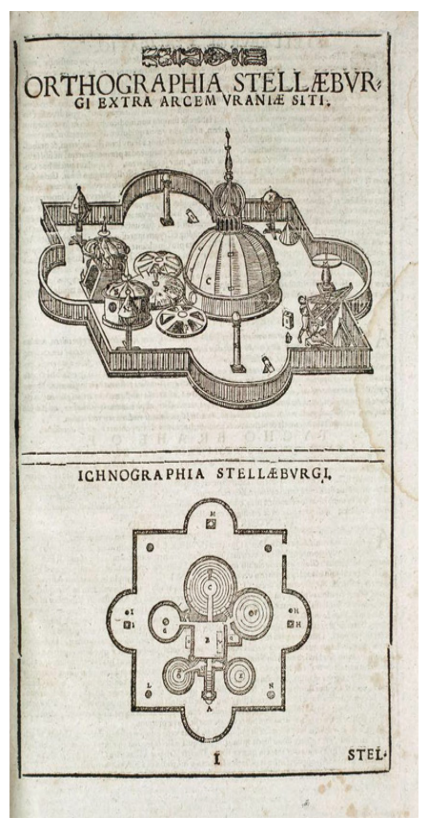


Figure 28 Drawing and layout

observatory about a hundred feet south of Uraniborg. In lay out, it was almost a mirror image of the first, but without the living quarters.

The observation pods were covered with roofs or domes that could be rotated or panels removed mounted on walls that extended about two feet above the ground. Tycho Brahe solved two major problems with the underground observatory; protection from the wind and a very firm foundation for stability of his larger instruments. As added bonus he had more room for the student astronomers and a cross check of observation reading with the instruments at Uraniborg.

From these two observatories, Tycho Brahe, dressed in royal garb, not out of respect for his avocation, but as a visual confirmation of his royal status, making sure no one would confuse him for a commoner. This was probably in reaction to the ridicule he received from his family who labeled him as a “stargazer.”

It was here that Brahe with all his assistants compiled the most complete and accurate star catalog in world at that time. Most of his assistants student astronomers and researchers with one of them being Johannes Kepler.

Tycho Brahe’s personal life was as bizarre as his public life. Jorgen Thygesen Brahe, an uncle, “kidnapped” Tycho as a baby and reared him as his own in an arrangement that seemed okay with his parents who never attempted to reclaim him. 1572 was a good year for Tycho, a star exploded in Cassiopeia that established him as an astronomer and he fell in love with Kirsten Barbara Jørgensdatter, a commoner, he could never marry, but they formed a common union that lasted until his death almost thirty years later. The union survived through eight children of which two died in infancy, a pet, beer drinking, elk that had the run of the castle, a dwarf court jester that Tycho thought had psychic powers who ate under the dining room table and other Tycho escapades and eccentricities. The tame elk, that followed Tycho like a loyal dog, came to a tragic end when in a drunken state fell down the castle stairs, broke a leg and had to be killed.

While Danish law did not allow “mixed” marriages, that is a marriage between a noble and a commoner, it did grant common law wives full rights and privileges and the children of such a union were considered legitimate.

Tycho Brahe was a great astronomer, but may not have been a good administrator of his ward. The new Danish king Christian IV may have used this rationale to rescind the fief, but his complete humiliation the astronomer and the tearing down the observatory leaving few traces of its existence implies a more vindictive motive in this dismissal. The rumors that Brahe had had a passionate affair with his mother was bad enough but the rumor that he may not been sired by King Frederick II and thus not a “natural born” king may have played a larger factor in this action than the pretended rationale. If sense a hint of elements of

Hamlet in this story; it isn't just coincidence. Shakespeare wrote the tragedy in 1599. Of course, Shakespeare always used several sources to build his stories and it looks the Brahe incident in Denmark was one of them.

Thus Brahe accepted the invitation the invitation the offer of the Bohemian king and Holy Roman emperor Rudolph II to be the official imperial astronomer in Prague. He brought his toys with him and built a new observatory in Benátky nad Jizerou and there with his assistant Johannes Kepler continued observing until his untimely and mysterious death in 1601.

Tycho Brahe and Johannes Kepler

Of all the student astronomers he trained at Uraniborg, Johannes Kepler is the most famous and, of course, would surpass him as an astronomer/scientist. For years Tycho denied Kepler access to his planetary data which implies a dislike or distrust of his assistant, but that's not necessarily so. Scientists of that time did not share data with fellow scientists until they published their results and then only what was needed to confirm the results. Often scientist shared intermediate discoveries only with their closest friend and then in code or in form of a puzzle like an anagram. It was not until after Kepler rejoined Brahe in Prague to work on the new, exact planet tables in Prague that relented and gave him the Martian data.

The Mars Puzzle

Mars was baffling. It became inexplicably brighter, then the motion was not steady—it stopped, went backwards, stopped and continued on its course.

Pliny called it *"inobservabile sidus."*

A Roman astronomer, trying to calculate the motion of Mars became deranged and in a rage, repeatedly bumped his head against a stonewall. (I don't know scientist/engineers could calculate anything with the Roman numeral system.)

The Babylonians viewed the behavior as omens to be interpreted rather than explained.

In the 4th Century B.C., Eudoxus of Cnides developed a system of homocentric spheres to explain the motion of the planets. It explained the motion, but not the change in brightness.

In 250 B.C., Aristarchus of Samos proposed a complete heliocentric system that explained the change in brightness, but positioning was not quite right.

Apollonius and Hipparchus returned to geocentric system with epicycles.

Tycho Brahe recognized Johannes Kepler’s genius and, no doubt, worried he might eclipse him as an astronomer and, probably felt safe giving him the Martian data and it’s one of the greatest ironies in science that it was precisely because of the difficulty of this data that drove Kepler to discover the Three Laws of Planetary Motion propelling his status over his mentor.

The Bizarre Death of Tycho Brahe

Not wanting to be rude or break etiquette, Brahe did not excuse himself from the king’s table, but instead held his urine until his bladder burst and he died from the ensuing infection.

That’s the prevailing legend of Tycho Brahe’s bizarre death and, of course, it’s not completely true. In fact, it is impossible for anyone to hold his urine by will until his bladder bursts. It’s almost as if Brahe deserve an equally bizarre death as a marker for crazy, bizarre life. It makes a good story and a lesson to children. “It’s not healthy to hold it.”

Like in all legends, there were some elements of truth in the story. Tycho Brahe was at a king’s function, but he couldn’t urinate or very little. He returned to his home in excruciating pain. The doctor diagnosed it as kidney stone in the urinary tract. Brahe lived in excruciating pain for nine days before expiring on October 24, 1601 at the age of fifty-four. An autopsy revealed that he was not suffering from kidney stone.

His assistant, Johannes Kepler, was a consistent visitor of the ailing Tycho Brahe revealing more of a caring relationship than is normally associated with these two ‘bigger than life’ astronomers. Kepler found Brahe in varying moods from lamenting if anything had really been done to pleading for him to forsake the heliocentric model and support his hybrid geocentric system, Tycho considered the Copernican heliocentric model, but even with his high precision instruments he could not detect the parallax predicted by the model. For his instruments not to detect a parallax meant that the background stars were more than 52 times the distance to Jupiter and that, to him was impossible.

He also knew the Ptolemaic geocentric model with all its epicycles was not right so he built hybrid geocentric model with the Moon and Sun revolving around the earth and all the other visible planets revolving around the Sun. All the orbits were perfect circles. As strange as this model may seem to us now, the model worked with the observed data. Tycho had used the Kepler’s proposed planetary laws to place his planets at the right distance.

From cradle to grave abnormality defined Tycho Brahe. From the moment he was "kidnapped" as a baby by his uncle to be reared as his son with an understanding with his parents through the nose chopping duel, his common law marriage, palatial and under ground observatory, psychic dwarf jester who ate under the table, the pet, beer-drinking elk and all the other crazy things that marked his remarkable life; it was almost fitting that it should terminate in such an untimely, bizarre way seven years before the telescope was invented. We can only speculate was instruments who could have invented with that new technology.

The anomalism that was Tycho Brahe did not end with his death.

Every one knew that he had lost part of his nose in a duel and that he had fashioned a prosthesis to cover the gap, but what was never recorded was the nature of the gap. Was it the bridge or the tip of the nose that was missing? It was this burning curiosity combined with his mysterious death that prompted some scholars to exhume Tycho Brahe from his tomb in Our Lady before Týn Cathedral in Prague three hundred years later in 1901.

It was the bridge of the nose that was missing. While the prosthesis was not found, the green stain on the skull indicates that the prosthesis had a high copper content. People described the prosthesis as gold or silver in color and that he would often remove briefly to put an ointment or a wax on the edge of the piece and quickly re-insert it. It is likely that he had several prosthetic noses made of varying metals for special occasion and another for daily use.

While the exhumation answered the question about the nose it did uncover even greater mysteries: he was not alone in the tomb. There was with him the skeletal remains of a woman and it wasn't his common law wife! They don't even know is she was a contemporary or just a corpse, many years later, in need of burial.

As part of the exhumation, they snipped a bit of the moustache. Chemical analysis of the mustache revealed high mercury content giving a hint of the cause of his death may have not been natural and raised the possibility that he may have been poisoned.

The mysteries uncovered by the 1901 exhumation prompted another exhumation in 2010. This exhumation confirmed the cause of death--a bladder infection.