Tucholsky Wagner Zola Scott Sydow Fonatne Freud Schlegel
Turgenev Wallace
Twain Walther von der Vogelweide Fouqué Friedrich II. von Preußen
Weber Freiligrath
Kant Ernst Frey
Fechner Fichte Weiße Rose von Fallersleben Richthofen Frommel
Hölderlin
Fehrs Engels Fielding Eichendorff Tacitus Dumas
Faber Flaubert
Eliasberg Ebner Eschenbach
Feuerbach Maximilian I. von Habsburg Fock Zweig
Ewald Eliot Vergil
Goethe London
Elisabeth von Österreich
Mendelssohn Balzac Shakespeare
Lichtenberg Dostojewski Ganghofer
Rathenau
Trackl Stevenson Doyle Gjellerup
Tolstoi Hambruch
Mommsen Lenz
Thoma Hanrieder Droste-Hülshoff
von Arnim
Dach Verne Hägele Hauff Humboldt
Reuter
Karrillon Rousseau Hagen Hauptmann
Garschin Gautier
Defoe Baudelaire
Damaschke Hebbel
Descartes
Hegel Kussmaul Herder
Wolfram von Eschenbach Schopenhauer
Darwin Dickens
Melville Grimm Jerome Rilke George
Bronner
Bebel
Campe Horváth Aristoteles Proust
Voltaire Federer
Bismarck Vigny Barlach Herodot
Gengenbach Heine
Storm Casanova Tersteegen Grillparzer Georgy
Lessing Gilm
Chamberlain Langbein Gryphius
Brentano
Lafontaine
Strachwitz Claudius Schiller Kralik Iffland Sokrates
Schilling
Katharina II. von Rußland Bellamy
Gerstäcker Raabe Gibbon Tschechow
Löns Hesse Hoffmann Gogol Wilde Vulpius
Gleim
Luther Heym Hofmannsthal Morgenstern
Klee Hölty
Roth Klopstock Kleist Goedicke
Heyse
Luxemburg Puschkin Homer Mörike
La Roche
Horaz Musil
Machiavelli
Kierkegaard Kraft Kraus
Navarra Aurel Musset
Lamprecht Kind Moltke
Nestroy Marie de France Kirchhoff Hugo
Laotse Ipsen Liebknecht
Nietzsche Nansen
Marx Ringelnatz
Lassalle Gorki Klett
von Ossietzky Leibniz
May
vom Stein Lawrence Irving
Petalozzi
Platon Knigge
Pückler Michelangelo Kafka
Sachs Kock
Poe Liebermann
Korolenko
de Sade Praetorius Mistral Zetkin

The publishing house tredition has created the series **TREDITION CLASSICS.** It contains classical literature works from over two thousand years. Most of these titles have been out of print and off the bookstore shelves for decades.

The book series is intended to preserve the cultural legacy and to promote the timeless works of classical literature. As a reader of a **TREDITION CLASSICS** book, the reader supports the mission to save many of the amazing works of world literature from oblivion.

The symbol of **TREDITION CLASSICS** is Johannes Gutenberg (1400 – 1468), the inventor of movable type printing.

With the series, tredition intends to make thousands of international literature classics available in printed format again – worldwide.

All books are available at book retailers worldwide in paperback and in hard-cover. For more information please visit: www.tredition.com

tredition was established in 2006 by Sandra Latusseck and Soenke Schulz. Based in Hamburg, Germany, tredition offers publishing solutions to authors and publishing houses, combined with worldwide distribution of printed and digital book content. tredition is uniquely positioned to enable authors and publishing houses to create books on their own terms and without conventional manufacturing risks.

For more information please visit: www.tredition.com

Kepler

Walter W. (Walter William) Bryant

Imprint

This book is part of the TREDITION CLASSICS series.

Author: Walter W. (Walter William) Bryant
Cover design: toepferschumann, Berlin (Germany)

Publisher: tredition GmbH, Hamburg (Germany)
ISBN: 978-3-8491-6562-8

www.tredition.com
www.tredition.de

Contents.

Chapter I.

Astronomy Before Kepler.

In order to emphasise the importance of the reforms introduced into astronomy by Kepler, it will be well to sketch briefly the history of the theories which he had to overthrow. In very early times it must have been realised that the sun and moon were continually changing their places among the stars. The day, the month, and the year were obvious divisions of time, and longer periods were suggested by the tabulation of eclipses. We can imagine the respect accorded to the Chaldaean sages who first discovered that eclipses could be predicted, and how the philosophers of Mesopotamia must have sought eagerly for evidence of fresh periodic laws. Certain of the stars, which appeared to wander, and were hence called planets, provided an extended field for these speculations. Among the Chaldaeans and Babylonians the knowledge gradually acquired was probably confined to the priests and utilised mainly for astrological prediction or the fixing of religious observances. Such speculations as were current among them, and also among the Egyptians and others who came to share their knowledge, were almost entirely devoted to mythology, assigning fanciful terrestrial origins to constellations, with occasional controversies as to how the earth is supported in space. The Greeks, too, had an elaborate mythology largely adapted from their neighbours, but they were not satisfied with this, and made persistent attempts to reduce the apparent motions of celestial objects to geometrical laws. Some of the Pythagoreans, if not Pythagoras himself, held that the earth is a sphere, and that the apparent daily revolution of the sun and stars is really due to a motion of the earth, though at first this motion of the earth was not supposed to be one of rotation about an axis. These notions, and also that the planets on the whole move round from west to east with reference to the stars, were made known to a larger circle through the writings of Plato. To Plato moreover is attributed the challenge to astronomers to represent all the motions of the heavenly bodies by uniformly described circles, a challenge generally held responsible for a vast amount of wasted effort, and the postponement, for many centuries, of real progress. Eudoxus of Cnidus, endeavouring to account for the fact that the planets, during every apparent revolution round the earth, come to rest twice, and in the shorter interval between these "stationary points," move in the opposite direction, found that he could represent the phenomena fairly well by a system of concentric spheres, each rotating with its own velocity, and carrying its own particular planet round its own equator, the outermost sphere carrying the fixed stars. It was necessary to assume that the axes about which the various spheres revolved should have circular motions also, and gradually an increased number of spheres was evolved, the total number required by Aristotle reaching fifty-five. It may be regarded as counting in Aristotle's favour that he did consider the earth to be a sphere and not a flat disc, but he seems to have thought that the mathematical spheres of Eudoxus had a real solid existence, and that not only meteors, shooting stars and aurora, but also comets and the milky way belong to the atmosphere. His really great service to science in collating and criticising all that was known of natural science would have been greater if so much of the discussion had not been on the exact meaning of words used to describe phenomena, instead of on the facts and causes of the phenomena themselves.

Aristarchus of Samos seems to have been the first to suggest that the planets revolved not about the earth but about the sun, but the idea seemed so improbable that it was hardly noticed, especially as Aristarchus himself did not expand it into a treatise.

About this time the necessity for more accurate places of the sun and moon, and the liberality of the Ptolemys who ruled Egypt, combined to provide regular observations at Alexandria, so that, when Hipparchus came upon the scene, there was a considerable amount of material for him to use. His discoveries marked a great advance in the science of astronomy. He noted the irregular motion of the sun, and, to explain it, assumed that it revolved uniformly not exactly about the earth but about a point some distance away, called the "excentric". [1] The line joining the centre of the earth to the excentric passes through the apses of the sun's orbit, where its distance from the earth is greatest and least. The same result he could obtain by assuming that the sun moved round a small circle, whose centre described a larger circle about the earth; this larger circle carrying the other was called the "deferent": so that the actual motion of the sun was in an epicycle. Of the two methods of expression

Hipparchus ultimately preferred the second. He applied the same process to the moon but found that he could depend upon its being right only at new and full moon. The irregularity at first and third quarters he left to be investigated by his successors. He also considered the planetary observations at his disposal insufficient and so gave up the attempt at a complete planetary theory. He made improved determinations of some of the elements of the motions of the sun and moon, and discovered the Precession of the Equinoxes, from the Alexandrian observations which showed that each year as the sun came to cross the equator at the vernal equinox it did so at a point about fifty seconds of arc earlier on the ecliptic, thus producing in 150 years an unmistakable change of a couple of degrees, or four times the sun's diameter. He also invented trigonometry. His star catalogue was due to the appearance of a new star which caused him to search for possible previous similar phenomena, and also to prepare for checking future ones. No advance was made in theoretical astronomy for 260 years, the interval between Hipparchus and Ptolemy of Alexandria. Ptolemy accepted the spherical form of the earth but denied its rotation or any other movement. He made no advance on Hipparchus in regard to the sun, though the lapse of time had largely increased the errors of the elements adopted by the latter. In the case of the moon, however, Ptolemy traced the variable inequality noticed sometimes by Hipparchus at first and last quarter, which vanished when the moon was in apogee or perigee. This he called the evection, and introduced another epicycle to represent it. In his planetary theory he found that the places given by his adopted excentric did not fit, being one way at apogee and the other at perigee; so that the centre of distance must be nearer the earth. He found it best to assume the centre of distance halfway between the centre of the earth and the excentric, thus "bisecting the excentricity". Even this did not fit in the case of Mercury, and in general the agreement between theory and observation was spoilt by the necessity of making all the orbital planes pass through the centre of the earth, instead of the sun, thus making a good accordance practically impossible.

Footnote 1: See Glossary for this and other technical terms.

After Ptolemy's time very little was heard for many centuries of any fresh planetary theory, though advances in some points of detail were made, notably by some of the Arab philosophers, who obtained improved values for some of the elements by using better instruments. From time to time various modifications of Ptolemy's theory were suggested, but none of any real value. The Moors in Spain did their share of the work carried on by their Eastern co-religionists, and the first independent star catalogue since the time of Hipparchus was made by another Oriental, Tamerlane's grandson, Ulugh Begh, who built a fine observatory at Samarcand in the fifteenth century. In Spain the work was not monopolised by the Moors, for in the thirteenth century Alphonso of Castile, with the assistance of Jewish and Christian computers, compiled the Alphonsine tables, completed in 1252, in which year he ascended the throne as Alphonso X. They were long circulated in MS. and were first printed in 1483, not long before the end of the period of stagnation.

Copernicus was born in 1473 at Thorn in Polish Prussia. In the course of his studies at Cracow and at several Italian universities, he learnt all that was known of the Ptolemaic astronomy and determined to reform it. His maternal uncle, the Bishop of Ermland, having provided him with a lay canonry in the Cathedral of Frauenburg, he had leisure to devote himself to Science. Reviewing the suggestions of the ancient Greeks, he was struck by the simplification that would be introduced by reviving the idea that the annual motion should be attributed to the earth itself instead of having a separate annual epicycle for each planet and for the sun. Of the seventy odd circles or epicycles required by the latest form of the Ptolemaic system, Copernicus succeeded in dispensing with rather more than half, but he still required thirty-four, which was the exact number assumed before the time of Aristotle. His considerations were almost entirely mathematical, his only invasion into physics being in defence of the "moving earth" against the stock objection that if the earth moved, loose objects would fly off, and towers fall. He did not break sufficiently away from the old tradition of uniform circular motion. Ptolemy's efforts at exactness were baulked, as we have seen, by the supposed necessity of all the orbit planes passing through the earth, and if Copernicus had simply transferred this responsibility to the sun he would have done better. But he would not sacrifice the old fetish, and so, the orbit of the earth being clearly not circular with respect to the sun, he made all his planetary planes pass through the centre of the earth's orbit, instead of through the sun, thus handicapping himself in the same way though not in the same degree as Ptolemy. His thirty-four circles or epicycles comprised four for the earth, three for the moon, seven for Mercury (on account of his highly eccentric orbit) and five each for the other planets.

It is rather an exaggeration to call the present accepted system the Copernican system, as it is really due to Kepler, half a century after the death of Copernicus, but much credit is due to the latter for his successful attempt to provide a real alternative for the Ptolemaic system, instead of tinkering with it. The old geocentric system once shaken, the way was gradually smoothed for the heliocentric system, which Copernicus, still hampered by tradition, did not quite reach. He was hardly a practical astronomer in the observational sense. His first recorded observation, of an occultation of Aldebaran, was made in 1497, and he is not known to have made as many as fifty astronomical observations, while, of the few he did make and use, at least one was more than half a degree in error, which would have been intolerable to such an observer as Hipparchus. Copernicus in fact seems to have considered accurate observations unattainable with the instruments at hand. He refused to give any opinion on the projected reform of the calendar, on the ground that the motions of the sun and moon were not known with sufficient accuracy. It is possible that with better data he might have made much more progress. He was in no hurry to publish anything, perhaps on account of possible opposition. Certainly Luther, with his obstinate conviction of the verbal accuracy of the Scriptures, rejected as mere folly the idea of a moving earth, and Melanchthon thought such opinions should be prohibited, but Rheticus, a professor at the Protestant University of Wittenberg and an enthusiastic pupil of Copernicus, urged publication, and undertook to see the work through the press. This, however, he was unable to complete and another Lutheran, Osiander, to whom he entrusted it, wrote a preface, with the apparent intention of disarming opposition, in which he stated that the principles laid down were only abstract hypotheses convenient for purposes of calculation. This unauthorised interpolation may have had its share in postponing the prohibition of the book by the Church of Rome.

According to Copernicus the earth is only a planet like the others, and not even the biggest one, while the sun is the most important body in the system, and the stars probably too far away for any motion of the earth to affect their apparent places. The earth in fact is very small in comparison with the distance of the stars, as evidenced by the fact that an observer anywhere on the earth appears to be in the middle of the universe. He shows that the revolution of the earth will account for the seasons, and for the stationary points and retrograde motions of the planets. He corrects definitely the order of the planets outwards from the sun, a matter which had been in dispute. A notable defect is due to the idea that a body can only revolve about another body or a point, as if rigidly connected with it, so that, in order to keep the earth's axis in a constant direction in space, he has to invent a third motion. His discussion of precession, which he rightly attributes to a slow motion of the earth's axis, is marred by the idea that the precession is variable. With all its defects, partly due to reliance on bad observations, the work showed a great advance in the interpretation of the motions of the planets; and his determinations of the periods both in relation to the earth and to the stars were adopted by Reinhold, Professor of Astronomy at Wittenberg, for the new Prutenic or Prussian Tables, which were to supersede the obsolete Alphonsine Tables of the thirteenth century.

In comparison with the question of the motion of the earth, no other astronomical detail of the time seems to be of much consequence. Comets, such as from time to time appeared, bright enough for naked eye observation, were still regarded as atmospheric phenomena, and their principal interest, as well as that of eclipses and planetary conjunctions, was in relation to astrology. Reform, however, was obviously in the air. The doctrine of Copernicus was destined very soon to divide others besides the Lutheran leaders. The leaven of inquiry was working, and not long after the death of Copernicus real advances were to come, first in the accuracy of observations, and, as a necessary result of these, in the planetary theory itself.

Chapter II.

Early Life of Kepler.

On 21st December, 1571, at Weil in the Duchy of Wurtemberg, was born a weak and sickly seven-months' child, to whom his parents Henry and Catherine Kepler gave the name of John. Henry Kepler was a petty officer in the service of the reigning Duke, and in 1576 joined the army serving in the Netherlands. His wife followed him, leaving her young son in his grandfather's care at Leonberg, where he barely recovered from a severe attack of smallpox. It was from this place that John derived the Latinised name of Leonmontanus, in accordance with the common practice of the time, but he was not known by it to any great extent. He was sent to school in 1577, but in the following year his father returned to Germany, almost ruined by the absconding of an acquaintance for whom he had become surety. Henry Kepler was obliged to sell his house and most of his belongings, and to keep a tavern at Elmendingen, withdrawing his son from school to help him with the rough work. In 1583 young Kepler was sent to the school at Elmendingen, and in 1584 had another narrow escape from death by a violent illness. In 1586 he was sent, at the charges of the Duke, to the monastic school of Maulbronn; from whence, in accordance with the school regulations, he passed at the end of his first year the examination for the bachelor's degree at Tübingen, returning for two more years as a "veteran" to Maulbronn before being admitted as a resident student at Tübingen. The three years thus spent at Maulbronn were marked by recurrences of several of the diseases from which he had suffered in childhood, and also by family troubles at his home. His father went away after a quarrel with his wife Catherine, and died abroad. Catherine herself, who seems to have been of a very unamiable disposition, next quarrelled with her own relatives. It is not surprising therefore that Kepler after taking his M.A. degree in August, 1591, coming out second in the examination lists, was ready to accept the first appointment offered him, even if it should involve leaving home. This happened to be the lectureship in astronomy at Gratz, the chief town in Styria. Kepler's knowledge of astronomy was limited to the compulsory school course, nor had he as yet any particular leaning towards the science; the post, moreover, was a meagre and unimportant one. On the other hand he had frequently expressed disgust at the way in which one after another of his companions had refused "foreign" appointments which had been arranged for them under the Duke's scheme of education. His tutors also strongly urged him to accept the lectureship, and he had not the usual reluctance to leave home. He therefore proceeded to Gratz, protesting that he did not thereby forfeit his claim to a more promising opening, when such should appear. His astronomical tutor, Maestlin, encouraged him to devote himself to his newly adopted science, and the first result of this advice appeared before very long in Kepler's "Mysterium Cosmographicum". The bent of his mind was towards philosophical speculation, to which he had been attracted in his youthful studies of Scaliger's "Exoteric Exercises". He says he devoted much time "to the examination of the nature of heaven, of souls, of genii, of the elements, of the essence of fire, of the cause of fountains, the ebb and flow of the tides, the shape of the continents and inland seas, and things of this sort". Following his tutor in his admiration for the Copernican theory, he wrote an essay on the primary motion, attributing it to the rotation of the earth, and this not for the mathematical reasons brought forward by Copernicus, but, as he himself says, on physical or metaphysical grounds. In 1595, having more leisure from lectures, he turned his speculative mind to the number, size, and motion of the planetary orbits. He first tried simple numerical relations, but none of them appeared to be twice, thrice, or four times as great as another, although he felt convinced that there was some relation between the motions and the distances, seeing that when a gap appeared in one series, there was a corresponding gap in the other. These gaps he attempted to fill by hypothetical planets between Mars and Jupiter, and between Mercury and Venus, but this method also failed to provide the regular proportion which he sought, besides being open to the objection that on the same principle there might be many more equally invisible planets at either end of the series. He was nevertheless unwilling to adopt the opinion of Rheticus that the number six was sacred, maintaining that the "sacredness" of the number was of much more recent date than the creation of the worlds, and could not therefore account for it. He next tried an ingenious idea, comparing the perpendiculars from different points of a quadrant of a circle on a tangent at its extremity. The greatest of these, the tangent, not being cut by the quadrant, he called the line of the sun, and associated with infinite force. The shortest, being the point at the other end of the quadrant, thus corresponded to the fixed stars or zero force; intermediate ones were to be found proportional to the "forces" of the six planets. After a great amount of unfinished trial calculations, which took nearly a whole summer, he convinced himself that success did not lie that way. In July, 1595, while lecturing on the great planetary conjunctions, he drew quasi-triangles in a circular zodiac showing the slow progression of these points of conjunction at intervals of just over 240° or eight signs. The successive chords marked out a smaller circle to which they were tangents, about half the diameter of the zodiacal circle as drawn, and Kepler at once saw a similarity to the orbits of Saturn and Jupiter, the radius of the inscribed circle of an equilateral triangle being half that of the circumscribed circle. His natural sequence of ideas impelled him to try a square, in the hope that the circumscribed and inscribed circles might give him a similar "analogy" for the orbits of Jupiter and Mars. He next tried a pentagon and so on, but he soon noted that he would never reach the sun that way, nor would he find any such limitation as six, the number of "possibles" being obviously infinite. The actual planets moreover were not even six but only five, so far as he knew, so he next pondered the question of what sort of things these could be of which only five different figures were possible and suddenly thought of the five regular solids. [2] He immediately pounced upon this idea and ultimately evolved the following scheme. "The earth is the sphere, the measure of all; round it describe a dodecahedron; the sphere including this will be Mars. Round Mars describe a tetrahedron; the sphere including this will be Jupiter. Describe a cube round Jupiter; the sphere including this will be Saturn. Now, inscribe in the earth an icosahedron, the sphere inscribed in it will be Venus: inscribe an octahedron in Venus: the circle inscribed in it will be Mercury." With this result Kepler was inordinately pleased, and regretted not a moment of the time spent in obtaining it, though to us this "Mysterium Cosmographicum" can only appear useless, even without the more recent additions to the known planets. He admitted that a certain thickness must be assigned to the intervening spheres to cover the greatest and least distances of the several planets from the sun, but even then some of the numbers obtained are not a very close fit for the corresponding planetary orbits. Kepler's own suggested explanation of the discordances was that they must be due to erroneous measures of the planetary distances, and this, in those days of crude and infrequent observations, could not easily be disproved. He next thought of a variety of reasons why the five regular solids should occur in precisely the order given and in no other, diverging from this into a subtle and not very intelligible process of reasoning to account for the division of the zodiac into 360°. The next subject was more important, and dealt with the relation between the distances of the planets and their times of revolution round the sun. It was obvious that the period was not simply proportional to the distance, as the outer planets were all too slow for this, and he concluded "either that the moving intelligences of the planets are weakest in those that are farthest from the sun, or that there is one moving intelligence in the sun, the common centre, forcing them all round, but those most violently which are nearest, and that it languishes in some sort and grows weaker at the most distant, because of the remoteness and the attenuation of the virtue". This is not so near a guess at the theory of gravitation as might be supposed, for Kepler imagined that a repulsive force was necessary to account for the planets being sometimes further from the sun, and so laid aside the idea of a constant attractive force. He made several other attempts to find a law connecting the distances and periods of the planets, but without success at that time, and only desisted when by unconsciously arguing in a circle he appeared to get the same result from two totally different hypotheses. He sent copies of his book to several leading astronomers, of whom Galileo praised his ingenuity and good faith, while Tycho Brahe was evidently much struck with the work and advised him to adapt something similar to the Tychonic system instead of the Copernican. He also intimated that his Uraniborg observations would provide more accurate determinations of the planetary orbits, and thus made Kepler eager to visit him, a project which as we shall see was more than fulfilled. Another copy of the book Kepler sent to Reymers the Imperial astronomer with a most fulsome letter, which Tycho, who asserted that Reymers had simply plagiarised his work, very strongly resented, thus drawing from Kepler a long letter of apology. About the same time Kepler had married a lady already twice widowed, and become involved in difficulties with her relatives on financial grounds, and with the Styrian authorities in connection with the religious disputes then coming to a head. On account of these latter he thought it expedient, the year after his marriage, to withdraw to Hungary, from whence he sent short treatises to Tübingen, “On the magnet” (following the ideas of Gilbert of Colchester), “On the cause of the obliquity of the ecliptic” and “On the Divine wisdom as shown in the Creation”. His next important step makes it desirable to devote a chapter to a short notice of Tycho Brahe.

Footnote 2: Since the sum of the plane angles at a corner of a regular solid must be less than four right angles, it is easily seen that few regular solids are possible. Hexagonal faces are clearly impossible, or any polygonal faces with more than five sides. The possible forms are the dodecahedron with twelve pentagonal faces, three meeting at each corner; the cube, six square faces, three meeting at each corner; and three figures with triangular faces, the tetrahedron of four faces, three meeting at each corner; the octahedron of eight faces, four meeting at each corner; and the icosahedron of twenty faces, five meeting at each corner.

Chapter III.

Tycho Brahe.

The age following that of Copernicus produced three outstanding figures associated with the science of astronomy, then reaching the close of what Professor Forbes so aptly styles the geometrical period. These three Sir David Brewster has termed “Martyrs of Science”; Galileo, the great Italian philosopher, has his own place among the “Pioneers of Science”; and invaluable though Tycho Brahe’s work was, the latter can hardly be claimed as a pioneer in the same sense as the other two. Nevertheless, Kepler, the third member of the trio, could not have made his most valuable discoveries without Tycho’s observations.

Of noble family, born a twin on 14th December, 1546, at Knudstrup in Scania (the southernmost part of Sweden, then forming part of the kingdom of Denmark), Tycho was kidnapped a year later by a childless uncle. This uncle brought him up as his own son, provided him at the age of seven with a tutor, and sent him in 1559 to the University of Copenhagen, to study for a political career by taking courses in rhetoric and philosophy. On 21st August, 1560, however, a solar eclipse took place, total in Portugal, and therefore of small proportions in Denmark, and Tycho’s keen interest was awakened, not so much by the phenomenon, as by the fact that it had occurred according to prediction. Soon afterwards he purchased an edition of Ptolemy in order to read up the subject of astronomy, to which, and to mathematics, he devoted most of the remainder of his three years’ course at Copenhagen. His uncle next sent him to Leipzig to study law, but he managed to continue his astronomical researches. He obtained the Alphonsine and the new Prutenic Tables, but soon found that the latter, though more accurate than the former, failed to represent the true positions of the planets, and grasped the fact that continuous observation was essential in order to determine the true motions. He began by observing a conjunction of Jupiter and Saturn in August, 1563, and found the Prutenic Tables several days in error, and the Alphonsine a whole month. He provided himself with a cross-staff for determining the angular distance between stars or other objects, and, finding the divisions of the scale inaccurate, constructed a table of corrections, an improvement that seems to have been a decided innovation, the previous practice having been to use the best available instrument and ignore its errors. About this time war broke out between Denmark and Sweden, and Tycho returned to his uncle, who was vice-admiral and attached to the king's suite. The uncle died in the following month, and early in the next year Tycho went abroad again, this time to Wittenberg. After five months, however, an outbreak of plague drove him away, and he matriculated at Rostock, where he found little astronomy but a good deal of astrology. While there he fought a duel in the dark and lost part of his nose, which he replaced by a composition of gold and silver. He carried on regular observations with his cross-staff and persevered with his astronomical studies in spite of the objections and want of sympathy of his fellow-countrymen. The King of Denmark, however, having a higher opinion of the value of science, promised Tycho the first canonry that should fall vacant in the cathedral chapter of Roskilde, so that he might be assured of an income while devoting himself to financially unproductive work. In 1568 Tycho left Rostock, and matriculated at Basle, but soon moved on to Augsburg, where he found more enthusiasm for astronomy, and induced one of his new friends to order the construction of a large 19-foot quadrant of heavy oak beams. This was the first of the series of great instruments associated with Tycho's name, and it remained in use for five years, being destroyed by a great storm in 1574. Tycho meanwhile had left Augsburg in 1570 and returned to live with his father, now governor of Helsingborg Castle, until the latter's death in the following year. Tycho then joined his mother's brother, Steen Bille, the only one of his relatives who showed any sympathy with his desire for a scientific career.

On 11th November, 1572, Tycho noticed an unfamiliar bright star in the constellation of Cassiopeia, and continued to observe it with a sextant. It was a very brilliant object, equal to Venus at its brightest for the rest of November, not falling below the first magnitude for another four months, and remaining visible for more than a year afterwards. Tycho wrote a little book on the new star, maintaining that it had practically no parallax, and therefore could not be, as some supposed, a comet. Deeming authorship beneath the dignity