THE ORIGIN OF ASTRONOMY

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The origin of astronomy, as of all science, lies far back in prehistoric times. Primitive man in his struggle for life could not do without a certain knowledge of the surrounding natural phenomena; the better he was acquainted with them, the better his life was secured. Thus, when he reached the cultural stage which ethnology calls the higher stage of barbarism, a first, merely practical, knowledge of physics, chemistry and biology was contained in his techniques, his agriculture and his cattle raising. At this stage some knowledge of celestial phenomena must also have been present, just as to-day we find it with primitive tribes. Whence did it come? Sometimes the opinion has been expressed that it was the beauty of the starry heavens, the mysterious silent course of its luminaries with their continuous change of aspect, that attracted the attention of man and awakened the desire to find out their cause. This opinion is clearly a reflex of modern conditions, where physics and chemistry are closely tied up with economic life, whereas astronomy stands outside the direct necessities of life and is studied for its own sake, for the beauty of its object and the wide scope of its problems. In opposition to this Schiaparelli (1) rightly argued that the first study of astronomy was imposed upon man by the desire to satisfy the necessities and comforts of his life. Indeed, economic necessities were at the root of his astronomical as well as of his physical and chemical knowledge. The heavens above him belonged as an essential part to the surrounding world which he had to know.

So, to understand the origin of astronomy, we have to see what practical necessities directed the attention of primitive man towards the celestial phenomena. There is first the need for orientation or direction finding. When commerce had developed out of nomadic cattle-herding or coastal fishery, the caravans in the desert and the ships at sea needed the celestial luminaries to guide them. During daytime the Sun and at night the stars directed their travels. Thus the Arabs from olden times were acquainted with a number of stars, especially with the 27 groups which the Moon successively visits in its monthly course. In Homer's Odyssey the goddess Kalypso instructs Odysseus in sailing home to keep the Bear at his left hand. The Polynesian island dwellers in the Pacific, before their contact with Europeans, were well acquainted with the stars; as skilled mariners they steered their vessels by means of the rising and setting points of different stars, as a kind of celestial compass; they had schools for navigation where, by means of globes, young people were instructed in astronomy.

More important still and more universal than for this orientation in space was the use of the heavenly bodies for what may be called the orientation in time, the time reckoning, the calendar. All work of man, at least before the industrial revolution, was bound up with the alternation of the seasons. The natural phenomena on which his activities depend were regulated by the period of the solar year. In Northern and moderate climates they depended on the alternation of a dead winter and a life-abounding summer, in Southern and tropical countries mostly on the alternating of a dry and a wet season. As hunters or fishermen they had to follow the migrations of the animals; as herdsmen or farmers they had to regulate their work according to the seasonal life-periods of animals and plants.

Thus, in the planning of his work, in order not to be misguided by irregularities of the weather, man had to have some independent means for counting the days and recognizing the right time for sowing and harvesting. Such means were provided by the Sun itself, and by other celestial phenomena.

The phenomena connected with the yearly variation of the Sun's declination are *eo ipso* exact indications of the seasons, and were recognized and used as such. Many primitive peoples to-day are found to use the solar phenomena as signs of the time of year. Dayak tribes measure the shadow of a vertical stick held at arm's length to know the month (**2**). The Eskimos and the Zuni Indians are reported to observe the solar solstices by watching the moments of extreme rising and setting at points of the horizon which are marked by stones (**3**); such moments are important dates celebrated by religious rites.

Another important characteristic of the season is given by the stars, most manifestly by their heliacal rising, in the morning just before sunrise. The Australian aborigines at Torres Strait for the beginning of sowing await the appearance of a bright star called Kek, probably Canopus or Achernar, for which a close watch is kept (**4**). Analogous practices are mentioned for other primitive peoples. That the same is true of prehistoric man is indicated by fragments of the oldest historical testimonies. Everybody knows how in ancient Egypt the heliacal rising of Sirius in the month of June was taken to announce the flooding of the Nile. From ancient Greece, Hesiod's poem *Works and Days* mentions for the different rural activities what phenomena of the stars are connected with them; e. g. "When the Atlas-born Pleiades rise, then begin mowing, but ploughing when they disappear" (**5**).

But more than the Sun and the stars, the Moon occupied the chief place in time-reckoning. Its regular changes of phase offered the most practical period for counting the days. Everywhere, with all peoples—even those who afterwards adopted, as we do, pure solar reckoning—the Moon's synodic period of $29\frac{1}{2}$ days was originally the basis of the calendar. The month begins with the first appearance of the new sickle Moon as a slender arc in the Western evening sky and as a consequence the day begins with the evening. The Moon's gradual waxing and waning impressed man as the life-history of a living being, ever again new-born. In the sacred books of many peoples it is said that the Moon has been created for the purpose of measuring the time. The Moon was the oldest and most venerable of the gods; its first appearance was attentively watched and hailed, and still more its fullness, when it dispels the darkness of the night, was celebrated with religious ceremonies.

Thus a certain knowledge of celestial phenomena, as a part of surrounding nature, is present in prehistoric man, involved with all his other technical knowledge in the practical activities of sustaining his life. Often it was a speciality in the hands of old people or priests, who performed the small functions of spiritual leadership in these communities. We cannot truly call it astronomical science, any more than his techniques of making tools and preparing food is called physical or chemical science. Science in the real sense of the word could only arise when man entered into a higher stage of development, the stage of civilization.

The transition from the prehistoric stage of barbarism to civilization is marked by the invention of script. This means more than that from now on written history supplants the oral tradition of legends. The importance of script is that it gives visible form to the conceptions that before had only a spiritual

existence in our mind. The words of the spoken language expressing these conceptions had already been in use for countless generations, as a means of mutual intercourse and incentive to action, but only as part of instinctive practical life; once the fleeting sound had passed, nothing material remained. Through script, however, conceptions acquire an existence of their own, visible and permanent; they can be handled and stored, compared and connected with one another. Now science as a system of generalized knowledge, of relations between general notions and abstract conceptions, becomes possible. Science is theory; it deals with things in general, with the abstractions formed by our mind out of the phenomena. Thus the rise of science as theoretical knowledge must be seen as part of the larger historical process, the rise of civilization.

The origin of civilization has to be sought in the realm of social developments. "War and Class", writes the English historian Arnold Toynbee, "are the two congenital diseases of civilization" (**6**). Now war was inherent in the preceding stages too, during savagery and barbarism. But "Class", i.e. the separation of a ruling class from the working masses, has been the social characteristic of civilization only, in all its forms. Its role in the development of astronomical science must now be traced. The countries to which we have therefore to turn our attention are Babylonia and Greece.

The first civilizations arose about 5000 years ago in the fertile plains of Egypt, Mesopotamia, India and China. Here the silt deposits of the great rivers, Nile, Euphrates, Hoang-ho, offered a good soil of marvellous fertility for a numerous population, but continual care was needed to regulate the water supply by dykes and canals. At regular or irregular moments the river broke through the dykes, flooded the land and deposited new layers of silt. This care could not be left to the separate villages or districts with their often opposed interests and so a strong central power was necessary to provide for the common interest. The multitude of small communities with their own chieftains and deities consolidated into large monarchies. This was rendered possible because the fertility of the soil procured abundant surplus produce for the sustenance of a separate class of ruling officials.

Moreover a strong state power was needed for defence against the poor warlike tribes which in the surrounding mountains and deserts could find a meagre living only. They made it their business to attack and plunder their prosperous neighbours. So a division of labour was necessary; an army of soldiers had to protect the farmers and in time became a ruling group, with their chief as king taking into his hands the judicial and administrative powers. Sometimes the plundering tribes became conquerors and settled as a ruling aristocracy among the subjected farmers; theirs was now the task of staving off new aggressors. The result was the same in both cases. Beside the military power stood the civil officials. With the separate townships organized into a large empire their local deities too were organized into a pantheon and their local priests into a powerful hierarchy, the spiritual leaders of society.

With the appearance of these ruling classes new needs arose. Their greater wealth expressed itself in luxury, in the development of refined arts, in spiritual culture. The conditions were now present for the introduction and spreading of script. The ruling monarchs wanted to glorify their deeds, their victories in war and their temple-building in peace-time. Missives with reports and instructions were interchanged between the king and his officials and governors, and his decrees were fixed as laws by writing them down. Writing as a special

capacity of priests and scribes was also put at the service of private individuals for their business contracts. Thousands of such contracts as well as other documents, written on clay in cuneiform characters, have been dug up from temple ruins of the Babylonian towns and are preserved in our museums.

What was the effect of the new conditions upon the rise of astronomy? A special group of officials had now to pay attention to the celestial phenomena. The regulation of time was one of the chief tasks of the priesthood; from their staged towers they had to observe the first appearance of the new sickle Moon and to announce the new month. Then the Moon reckoning had to be adapted to the seasons of the year. Because 12 periods of the Moon are 11 days shorter than the solar year, every 3 or 2 years a 13th month must be intercalated, not for any theoretical or scientific reason, but in order that the offering of the first crops to the gods may take place at the prescribed time, at the full Moon ceremonies of the first month Nisannu. In such primitive societies the important agricultural activities were at the same time religious festivals; economics and worship, politics and religion formed an indissoluble unity. The service of the gods was bound to strict ritual; the calendar, the time regulation of worship, was a sacred duty of the priests, the source of their prestige and spiritual power. Originally the intercalation of a 13th month took place according to practical necessity; when at the end of the 12th month it appeared that ripeness of the crops and the beginning of harvesting could not be expected in the next fortnight, the 12th month had to be repeated. The inscriptions show that about 2000 B.C. the intercalations took place at irregular intervals, and hence were probably determined by practice.

This may have caused annoyance, but a better way presented itself. When looking out for the new Moon the priests must have perceived that in every succeeding month the surrounding stars had changed, gradually moving farther West till they disappeared, being replaced by more easterly constellations. At the same time new stars rose in the morning twilight. So the phenomena of the stars indicated the seasons and could afford a more regular and exact means for intercalation of the additional months. There are many texts where the names of constellations are connected with the names of months, indicating their use for calendar purposes. An easy rule is given in a text published by George Smith: "When at the first of Nisannu the Moon and star Mulmul (the Pleiades) stand together the year is common; when at the third day of Nisannu the Moon and the star Mulmul stand together the year will be full" (**7**). The latter case means that the first month falls so early in the seasonal year that addition of a 13th month becomes necessary. As a consequence we find that long before 1000 B.C. the Babylonians were acquainted with a considerable number of constellations, by names in inscriptions and by pictures on boundary stones. They are to a great extent identical with our own, evidently transmitted by the Greeks. That in these same centuries also the brightest of the planets, with its alternation as evening and morning star, was perceived, is evident from the famous so-called Nindar-anna tablet from about 1600 B.C., where its phenomena are described, and their significance.

For in the course of time it was no longer only, or chiefly, calendar needs that determined man's interest in the stars. Ever more astrology, the doctrine of the significance of the celestial phenomena for the events on Earth, occupies his mind. Now what happens in the sky is followed with keener interest as signs of the destiny allotted to people and states. Belief in signs and presages is as universal in primitive man as his belief in invisible spiritual powers surrounding

him and influencing his work and life. To win their favour, to find out their intentions, to avert or appease their hostility, by magic charms and incantations is an important part of his daily practice. Most of these spirits have their abode in the heavens; and especially in these Mesopotamian plains, with their resplendent sky, the stars impressed man's mind by their radiant brightness. Thus in early times the conception of a close connection between the stars and man's fortunes had already risen in the mind of the Babylonian priests. Old Sumerian inscriptions speak of the "favourable star" for temple building. This belief was alive through all the centuries when Babylon, as a rich commercial town and the capital of a large empire, had become a centre of culture for the surrounding world. But it intensified to an all-pervading fervour when in the centuries after 1000 B.C. Assyria rose and became the most powerful state in the Near East, extending its dominance not only over Babylon and all Mesopotamia but also over Syria, Palestine and even Egypt. In the vicissitudes of world politics at the time and in the variable fortune of war the need was strongly felt for aids in foreseeing the future. So the astrologers in direct service of the king had to give their omens before every great enterprise, and from all the great sanctuaries the priests had to send regularly their reports on what they had seen in the heavens and the meaning thereof. From the ruins of the library of King Assurbanipal ten thousands of more or less damaged sherds with cuneiform inscriptions have been dug up, many of them containing astrological reports. These enable us to obtain a clear picture of the character and scope of their astronomical observations.

The chief objects observed were the Moon and the planets, because by their variable aspect and irregular wanderings they offered the greatest variety of phenomena suitable for astrological interpretation. The Moon was now observed with more attention in all its phases; especially were its risings and settings observed in the middle of the month, about full Moon. When the Moon is full on the night of the 14th, the normal time, it was a lucky omen; when full Moon happened on the night of the 13th, 15th or 16th, it was abnormal, hence a bad omen. Here astrology and calendar were merged; deviation in the calendar was considered an unlucky sign and had to be restored at the end of the month. The eclipses, of course, were important phenomena, mostly unfavourable; but as to the different sides of the Moon that were successively obscured and the different hours of the night, they had significance for different countries, for Akkad, the southern Babylonia proper, for Elam in the East, for Amurru in the West. So the details were often so well noted that nine centuries afterwards Ptolemy could use them in the construction of his lunar theory.

But the most important effect of astrology was that now besides the Moon the planets strongly captured the attention of man. They were seen wandering between the stars in the most intricate and unexpected ways, as living beings roaming through the starry landscape. They are the stars of the great gods who rule the world and manifest themselves in these bright luminaries. Their appearances and disappearances, their motions through the constellations of the zodiac, their stationary points and retrogradings, their meeting with one another and with bright stars, presented an almost endless variety of phenomena. Although from earlier times we have already a text with omens from Venus, it is in these later centuries of Assyrian power that a high tide of astrology provides us with an abundance of reports containing omens from all the five planets. There we read (**8**): "Mercury went back as far as the Pleiades"; "Jupiter enters Cancer"; "Venus appears in the East"; "Mars is very bright"; "Jupiter appears in the

region of Orion"; "Mars stands in Scorpio, turns and goes forth with diminished brilliancy"; "Saturn has appeared in the Lion"; "Mars approached Jupiter"; and so on. There is not a trace of scientific interest in these texts; the mind of the reporters is entirely occupied by the omens: when such or such happens, "it is lucky for the king, my lord"; or, "copious floods will come"; "there will be devastation"; "the crops will be diminished"; "the king will be besieged"; "the enemy will be slain"; "there will be raging of lions and wolves"; "the gods intend Akkad for happiness"; and so on. Yet, with all those observations, these reports represent a considerable astronomical activity. For the first time in history a large number of data on the planets had been collected; it implies a detailed knowledge of facts about their motion.

This does not mean that we have here the beginning of a science of astronomy. Mere facts do not form a science. Facts are the basis of science. Science is the systematization of facts into general conceptions and rules. Now it might be imagined that these ancient observers, by comparing their observations with old records and looking for regularities, must gradually have detected them. But we must beware of regarding these Babylonian priests as astronomers like ourselves, animated by the same spirit of scientific purpose and scientific research. Such a state of mind certainly was entirely absent then. It is the very problem of the origin of science to discover how it originally came about that, without knowing about scientific aims, people were able to build up scientific theory.

The circumstance that made this possible for astronomy was the occurrence of extremely simple and striking periodicities in the celestial phenomena. What looked irregular on occasional and superficial observing revealed its regularity in a continuous abundance of data. Regularities were not sought for; but regularities imposed themselves, without giving surprise. They aroused certain expectations. Expectation is the first unconscious form of generalized knowledge, like all technical knowledge in daily life growing out of practical experience. Then gradually the expectation develops into prediction, an indication that the rule, the regularity, has entered consciousness. In the celestial phenomena the regularities appear as fixed periods, after which the same aspects return. Knowledge of the periods was the first form of astronomical theory.

Did the astrologers in Assyrian times already possess such knowledge? There are some texts indicating that they did. In one of them (**9**) we read: "To the king, my lord, I sent: an eclipse will take place. Now it has not passed, it has taken place. In its happening the eclipse portends peace for the king, my lord." Here it is stated that a former prediction has been confirmed. The prediction of a lunar eclipse indeed is very simple, because 5 or 6 such eclipses follow one another always regularly with 6 months' interval; and when this series has ended a new series starts 11 or 17 months later. Hence, if an eclipse has been observed we may bet five to one that 6 months later another will take place. There is a difficulty, however; on the average half of them will be invisible because they occur in the daytime, when the full Moon is below the horizon. This irregularity must have hampered the easy discovery of the continuous series by the Babylonian priests. But their own regular observations of the Moon's risings and settings in the midst of the month must have shown them a way towards understanding such gaps. When full Moon happens in the night, then in the morning the Moon will set only after sunrise; Sun and Moon, god Shamash and god Sin, are seen at the same time, one East, the other West. If however, the Moon does not wait for the Sun but sets before sunrise, full

Moon has still to come; and if in such a case an eclipse was expected, it will remain invisible. That the Babylonian priests were aware of these conditions is shown by a published text, probably from the 7th century B.C.: "The eclipse passes, it does not take place. If the king should ask: what omens hast thou seen? —the gods have not been seen one with another" (**10**). Here clearly the eclipse was predicted, and now the reason is given why it must remain invisible.

In the same way some regularities may have been perceived with the planets, and may have resulted in a certain expectation. Thus in an Assyrian text we read: "Jupiter has stood for a month over its reckoned time" (**11**). Hence its time had been reckoned. The most regular phenomena, such as the periodical invisibility of the planets in the vicinity of the Sun, or, for Jupiter and Saturn, their stately course along the zodiac, making a circumference in 12 and in 29 years respectively, must have become practical experience for the astrologers, just as the sequence of the Moon's figures is practical experience for the savage. We may be sure of it without having express statements in written records. Some centuries later we find texts expressly testifying to knowledge of planetary periods, already at a higher stage. But, in the meantime, conditions had changed considerably.

First politically, when those warring little countries of old had been absorbed into the inner peace of the huge Persian empire, the old omens of lucky for Akkad, unlucky for Elam, lost their sense. Then astronomically, the detection and gradually arising knowledge of the periodicity and the periods must have brought about a new attitude of these observers towards the celestial phenomena. They no longer were the ignorant earthlings anxiously looking at the sky for the messages which the supreme masters of the world should inscribe there. They knew in advance what would be inscribed there, they could predict it, they had some kind of spiritual power over it. Their capacity of prediction gave them a new social qualification, as people who know the ways of the gods. Thus their observing activity impelled them to greater zeal and persistence as a ritual duty in the service of the gods who reveal themselves in these stars. It became more conscious and complete, more detailed and precise; distances of the planets to bright stars were noted numerically, hence perhaps measured, although we know nothing of the instruments used.

The result of this now genuinely astronomical practice appears in the rather scanty inscriptions of the following centuries of rule by the Persian and the Seleucid kings. They show that now the larger periods of the planets were known, the common multiples of synodic period and period of revolution: 8 years for Venus, 71 and 83 for Jupiter, 46 years for Mercury, 47 and 79 years for Mars, 59 years for Saturn; after these intervals the phenomena repeat themselves at nearly the same places. These periods moreover were practically applied for prediction purposes, in such a way that the phenomena, observed the appropriate number of years earlier, were transferred, with small corrections, to the year in question. Thus there exists a tablet entitled: "The first day, the phenomena, the motions and the eclipses for the year 140" (i.e. Seleucid Era) (**12**); it gives phenomena of Jupiter for the years 69 and 57, of Venus for 132, of Mercury for 94, of Saturn for 81, of Mars for 61 and 93: exactly the years in which the data will produce the phenomena for the desired year by addition of the periods named. Ephemerides computed in this way have been found for different years, up to the beginning of our era. Here we have astronomical theory in the form of knowledge of the periods consciously applied in prediction.

A still higher and more perfect form of theoretical knowledge was reached by Babylonian astronomy in the last centuries B.C. Although Babylon had lost its greatness and the Chaldaean country, dominated by Parthian kings, was cut off from the new centres of commerce in the Mediterranean, astronomical activity persisted and now reached its highest stage of perfection before it was extinguished. The tablets dug up from the ruins of old city temples of this time, mostly much-damaged fragments, show nothing but rows of numbers arranged in columns, intermingled with the names of months and zodiacal signs. Their structure and meaning have been unravelled by the work of Father F. X. Kugler, S.J., both an able astronomer and an Assyriologist. In the planetary tables each column contains the successive values of the longitude and the date of one of the special phenomena, opposition positions and heliacal rising and setting. All qualitative description, such as proximity to a star or entrance into a constellation, is absent; there is only pure quantity, given with utmost formal precision in sexagesimal fractions. Now for the first time, because all the data are given by mere numerical values, the inequalities in the planetary motions can become evident as a periodical increase and decrease of the successive intervals. The Chaldaean astronomers did not represent them, as we do, by sinusoidal wave functions based on geometrical construction, but by purely arithmetical zig-zag functions, running with constant differences up and down between an upper and a lower boundary where they are reflected. The same procedure was applied in their lunar tables, where time and place of the conjunctions and oppositions, the first sickle Moon and the eclipses were computed by means of exact data on the Moon's different periods.

We are confronted here not only with far more detailed knowledge of the planetary and lunar motions and their periodic inequalities than in the previous records, but also with its presentation in the form of more abstract scientific theory. The previous form was an excellent device for technical prediction based on the knowledge of periods; but for every prediction reference to former observations was necessary. Here the tables stand by themselves, as pure theory, no longer needing any observational datum. They have not the meaning of mere predictions; the rows of numbers embrace past and future undistinguished and can be extended in both directions indefinitely. It is abstract theory in the form of concrete data; instead of by rules stated in words it is given by the regularities in the tables of figures. The curious fact is that we do not know how it originated; these tables appear suddenly, without intermediate forms that could tell us about their relation to former phases of knowledge. This, however, is only part of the general problem of how the different stages of Babylonian astronomy have developed out of or beside one another and from what observational data, a problem hardly tackled as yet.

Babylonian astronomy in the last centuries presents an admirable system of organized, i. e. theoretical, knowledge. But it is merely formal theory, entirely devoid of any physical interpretation. It is numerical knowledge only; nowhere is the question of structure raised. Its mathematics is only arithmetic, with no geometry. It appears that for these Chaldaean astronomers the planets were not solid bodies moving in orbits through space, but rather, as in olden times, luminaries wandering—although now with unravelled regularity—along the firmament. The cause of this restricted character must be sought for in the fact that this science was entirely in the hands of priests, who by a mighty power of tradition were bound to the old forms of worship and ritual. All their astronomical work

was service to the gods: the most modern planetary tables we find to be introduced by the sacral formula: "In the names of god Bel and goddess Beltis, my masters, an omen." So the way to further theoretical progress, to structural physical theory, was barred. If we consider structural theory an essential characteristic of theoretical science, then for the origin of astronomy one step more must be made. For this we have to turn our attention to another people, to the Greeks.

In living conditions and in character Greece and the Greeks, country and people, in every respect present the greatest possible contrast to Babylonia. In this mountainous peninsula, deeply indented by the sea, with good harbours but with only small bits of arable land separated by wild-wooded ridges, the people remained divided in small communities with their local deities and local priests. They became seafarers and merchants, and many of their expanding numbers emigrated and settled on foreign shores, in Asia Minor and Southern Italy. In such traders and colonists a freer, more independent and more daring spirit developed than among farmers staying at home under permanent conditions; they were less bound to tradition, more open to new ideas. Commerce gave rise to industry, the fabrication of wares for export, and inventiveness became the basis of industrial progress. Here, in the Greek colonies, there arose a ruling class of free and wealthy citizens, the first men in history comparable to the burgher class that in modern times placed its stamp upon European society. Here a new spiritual life revealed itself in a flowering of poetry and of new philosophical world-conceptions.

These first Greek philosophers amaze us as much by the boldness of their ideas about world structure as by the scantiness of their knowledge of astronomical phenomena. From Xenophanes and from Heraclitus—famous even now as the first thinker who saw the world as a process of eternal flux—the opinion is reported that the Sun and the stars were formed anew every day. The cosmical theories of these times were not devised to explain celestial phenomena but their object, as shown by B. Farrington (**13**), was to apply known technical processes to the world at large. These Greek philosophers were thinkers, not observers. Simple phenomena such as the identity of evening and morning star or the course of the planets through the zodiac, which with a little attention could have been noticed by anyone, are attributed as great discoveries to famous philosophers. And this situation remains throughout the centuries in which Greece reached the summit of political power and of literary and artistic brilliancy. Plato, who knows and describes the planets in their sequence, their colour and brightness, says of their wanderings that they are incalculable in multitude and marvellously intricate. Eudoxus' famous theory of the homocentric spheres was an attempt to explain the mere qualitative fact of retrograde motions, which he did by means of a most ingeniously devised system of uniform rotations. But it did not fit the retrogressions as they factually were; obviously there were no observational data to test the details of the theory.

Judging from the amount of their observations and detailed knowledge of the celestial luminaries, the Greeks in their most glorious times cannot be said to have been great in astronomy. But they did something else. They developed geometry and a geometrical mode of thinking as a most admirable system of demonstrable truths, fit to become the basis for a future higher stage of astronomy. They developed a conception of the world, or rather a new way of looking at it, as a system of material bodies and spheres moving and revolving in three-dimensional space. They stood within this world as artificers dominating it

mentally, looking from the outside at the constituting bodies with the Earth itself in the midst, handling them as objects of geometry, cutting their spheres with planes and making the circles and triangles objects of geometrical demonstration. In Aristarchus' determination of the relative distance of Sun and Moon we have a fine example of this attitude towards the heavenly world, Greek astronomy at its best. Yet in the work expounding this method the apparent diameter of Sun and Moon is assumed to be 2°, four times too large.

A new epoch set in when as a consequence of Alexander's conquests the Greek and the Oriental world were merged, the Hellenistic era. Now the Greeks got access to the observing practice and to the abundance of observational knowledge of the Babylonians. The Oriental example gives a new impulse; observations are made at Alexandria and elsewhere. But what we know of it deals only with the fixed stars, not with the planets. And Ptolemy afterwards states that Hipparchus from lack of a sufficient number of observations could not bring his theory of the planets to completion. So far, Greek astronomy is seen to keep its former character, but now the Greek thinkers had at their disposal the numerical results of Babylonian astronomy. Now their geometrical world schemes could be filled in by exact data on periods and inequalities; now the numerical perfection of Chaldaean science could assume the form of geometrical structure in space. The result was the epicycle theory, the supreme product of ancient astronomy.

In the epicycle theory we may be said to have reached our goal, true astronomical science. There is a conception of science which considers only the latest truth as real, true science. It sees the epicycle theory as a primitive erroneous system, to be superseded 1700 years later by the true world system. Looking, however, from an historical point of view we see that it represents correctly the relative motions of the planets in their circular orbits, and that only the original assumptions as to the zero point of the motions had to be corrected afterwards. It is scientific theory in the strictest sense of the word, systematization of observational facts in a world structure suited to the computation and prediction of future events. The study of the history of science presents it to our view as a most important stage in the growth of knowledge, conditioned by the entire social development of the time, as the outcome of observing and thinking activities during a long series of centuries, and as the starting point of later progress towards modern science. Thus we understand how at so early a time, when in no other realm of natural phenomena had knowledge risen above the stage of technical experience, astronomy could rise to the high rank of a science.

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