Astronomy—The Oft-Forgotten School Subject

by

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translated by Ted Warren

Astronomy has never enjoyed a distinguished place among modern school subjects. Despite the decisive meaning of our globe's daily rhythm and the changing of the seasons for all life on earth, the study of astronomy lacks a certain relevance that would bring more focus to it as a school subject. A few sections can be found in the final pages of geography books, a situation that not even modern space travel has been able to change.

Is this exaggerated? Do most people know the modern scientific worldview of our solar system with the planets circling in continually wider elliptic paths? And that the shining stars are newer suns in space, perhaps with planets circling. And who does not know there are star clouds that in truth are huge Milky Way-like system galaxies far, far away? Most significantly we associate astronomy to the foundation of reliability: magnificent [astronomical!] numbers. Temperatures of millions of degrees, massive formations as large as entire planetary systems, density thousands of times more concentrated than gold. And most impressive are the enormous distances. Just to the moon it is as long as circumnavigating the earth, it is 150 million kilometers to the sun, the closest fixed star is four light years away. Does everyone know what a light year is? The diameter of the Milky Way is 100,000 light years, enough to give you goosebumps when you read these numbers. Kant must have felt this when he spoke of devotion for the starry heavens above and the moral laws within. Did someone say education in our times is weak in astronomy?

Very few people know the starry heavens. In general, beyond the Big Dipper and perhaps Orion's Belt, people know no other constellations. They cannot tell the difference between a star and a planet, cannot follow the changing phases of the moon, do not know how many degrees the sun stands above the horizon, do not even notice the changing positions of the starry heavens when they are on vacation in Greece. The simple fact is that the stellar sky is becoming more and more closed for mankind in pace with increased access to general knowledge. Some have an intellectual relationship to astronomy, others continue to walk outside and recite their favorite poet, for example Henrik Wergeland:

How Venus shines tonight.
Do the heavens also have a spring?

Poetry is only powerful when our feet are not frozen! Therefore few successfully overcome the schism we encounter here, and such a human schism it is: between experience and knowledge. It appears to be the signature of our culture that this schism will not be closed but remain an open wound within each person.

Is it possible to close it? Rather than further theorizing, I simply ask, "How can we achieve a relationship to the starry heavens we observe? What we see with our eyes matches up so poorly with what we know. For where in the world is the solar system? What is so simply and delicately laid out in textbooks is impossible to see, either by day or by night. It is simply not possible to discern between near and far, everything is chaotic and not even the Big Dipper that was behind my neighbor's house three months ago is still in the same place. To my surprise nothing I have learned in the books can be used, observation and concept collide head-on.

What we have learned in astronomy are models of thought won over centuries and millennia of battles for knowledge, by geniuses in crisis and hard work, in desperation and ecstasy. For us it is simply dried-out knowledge, not worth the paper it is written upon, if we have not taken part, all so briefly, in how it was acquired. In astronomy the models actually stand directly in the way of our observations. If astronomy shall have a place in school that can help children create a more wholesome relationship to our cosmos, we need to begin at the other end and ask: What do we see?

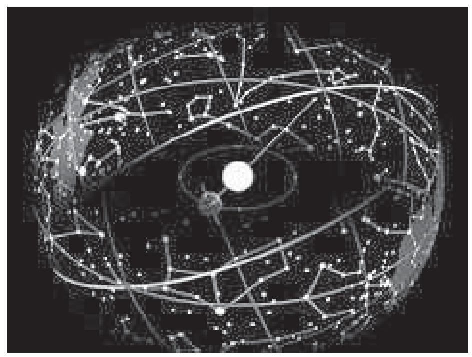
The first main lesson

What do we see? With that question we begin our lessons in the astronomy block in the winter of the seventh grade in Oslo, Norway. We start with the drama that takes place outside, the archetype of our experience of the world: the sunrise. The pole of life, light and darkness meeting in the long winter night, is briefly relieved by the short winter day and we can study the movements of the sun through the sky. How does it truly move? And how was the sun a week ago? How was it at New Year's Eve? And what will we see in late spring? We all know a lot, the shortest days are near the new year, the longest at the end of June, and there is always someone with peculiar explanations: everything is due to the slanting of the earth's axis, something she has read in a book.

It is important to not go too fast. First we shall get to know the sun's daily movements across the heavens. It rises at a slant, climbing gradually slower before it reaches the top—culminating at midday. Thereafter the sun follows a symmetrical movement down to the horizon and then it sets. When the daylight is shortest, the bow is smallest: it is a low winter sun. Yet the sunrise slowly changes position, moving more towards the east, and accordingly it sets more in the west, while the culmination point becomes higher. The culmination is always in the south. Yes, that is the south! And if we know the south we can find the other three directions. Then we ask: how long into the spring do we go before the sun stands up directly in the east? The vernal equinox, March 21, and the corresponding fall equinox, September 23. On those days the sun rises in the east, sets in the west, and day and night are of equal length.

Homework: how many days does the summer half year have and how many does the winter half year have? The surprising answer is: 186 for summer and 179 for winter. The explanation—we wait a bit!—What do you think? If someone answers: the earth moves faster in the winter, that is correct, but, again, this is something she has just read. As a teacher I can imagine answering, "Next year you will learn about Johannes Kepler who discovered the law behind these phenomena." But first we need to get to know the starry heavens.

To do so we need to know the sun's daily movements. We must know the movements well enough to imitate them; we stand up, turn to the south and point with our hands. Many think this is much too simple and consider it superficial. But they are fooling themselves, for these movements are the most important to understand. They are the same movements all heavenly bodies take during the day, as observed from the earth. During the first days we work with this pattern that is taken daily by all heavenly bodies (except for meteors and satellites that are influenced by the earth's rotation).



The Earth in its orbit around the Sun causes the Sun to appear on the celestial sphere moving over the ecliptic, which is tilted on the equator.

Our calendar makes for an interesting study. Right away there are problems involved. The sun's yearly movements must be presented, a movement that cannot be observed directly because of the sunlight, though it has been known for centuries. The sun's movement in the Ecliptic through the twelve signs of the Zodiac has been known since the Babylonian Civilization, an impressive achievement. I always challenge my pupils to figure out how it was possible to discover. How long does it take the sun to move once around the Zodiac? We all know—a little less than 365.25 days. So how can we best assess the extra one-fourth day? This is a piece of practical mathematics that has been resolved in a variety of ways through the ages, with each way of solving the fraction a reflection of the cultural epoch that created the method. Think, for example, about the Egyptians who did not have a leap year and therefore experienced a slowly backwards shifting of the seasons that after 1440 years amounted to one full year. The “mistake” reflects the slow rhythm that played an important role in the Egyptian culture.

The next step is to work with the many phenomena of the moon. Naturally the most well-known phases are the full moon and the new moon. But in which direction does the new moon open? At what time of day do we see it? With effort we order in our observations: the new moon is an evening phenomenon and it opens to the left, away from the sunset. The new moon waxes from evening to evening, while it becomes visible for longer periods of time. And when it is full, it stands opposite the sun. As the moon only reflects sunlight, its dependence on the sun is obvious. Its cycle is reflected in its name: one month. Twelve times each year the moon grows into the full moon, hence our twelve months. Someone always asks: does it happen accurately? No, there is an error of roughly one day per month, which adds up to twelve days per year. We can speak of a “moon year” as 354 days, something that plays a role in many cultures, for example in Islam, where the month of fasting, Ramadan, is calculated according to the phases of the moon and therefore moves backwards each year by twelve days.

The course of the moon is not so complicated. It is interesting to study how the course changes from month to month, and how it happens characteristically within the seasons. The first thing we notice is that the new moon in the spring is very easy to see. If we consider the slanting of the sun’s path, it is easy to understand why. For the most part the moon follows the sun’s path, the Ecliptic. From February to March the sun climbs many degrees higher in the sky. The moon accomplishes this same climb in just two to three days. Therefore it becomes visible high above the sunset. The spring new moon is a well-known sight. It eventually reaches the sun in the signs of the Zodiac during the summer, but it moves quickly towards the signs in the fall. Therefore the full moon in the spring is not especially high in the sky. To the contrary, at the new year the full moon is high because it stands opposite the low winter sun and thus reaches its fully-lighted phase in the summer constellations of the zodiac, Gemini and Cancer.

During the summer it is the opposite. The sun stands high in the sky while the full moon, now in the winter constellations of the Zodiac, hangs low on the horizon just above the islands on the lakes. The waning moon is a less considered phenomenon. It is observed by roaming poets who come home early in the morning and write about how beautiful the new moon shone above the treetops!

More normal citizens must wait until the early fall mornings to observe the waning moon while it follows us on the way to work. We all remember the special feeling of the waning moon in October and November; high in the east it lies with the opening to the right and the morning sun “behind” it towards the horizon. Whenever I speak about the waning moon in the classroom the students have a whole reservoir of experiences they bring forth. And when they go home after classes, they see the same moon they have seen hundreds of times as if for the first time!

That is the point. Daily observations are the most fun. Children can be filled with impressions from sensational space explorations or telescopes, but it is better to know what our own eyes can tell us.

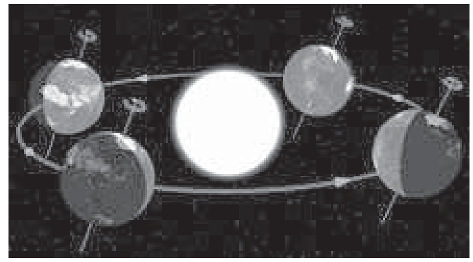


Diagram of the Earth's seasons as seen from the north. Far right: December solstice

The sun and the moon, the calendar, the Zodiac and an evening or two under the stars—this is already a lot! We should let it rest for some months before the next astronomy block. Or maybe we can fit in an orientation among the heaven's other constellations or draw the globe of the heavens in which we stand, while it moves once each day? This is what we need to become a stargazer: a truly naïve, geocentric model of the heavens, in which all of the bodies are attached to the inside of a globe where our sight creates an unlimited radius from the center of the globe. This model shall be our helper for a long time forward.

At this point we can weave the important threads into geography and work with the children's understanding of the earth's position in space. If we travel north to the heaven's North Pole, which in Oslo is sixty degrees over the horizon, we increase degrees in the sky by one degree for each line of longitude we pass. At the same time the heaven's equator will sink accordingly, and eventually the sky of the southern hemisphere will disappear below the horizon. If we already know the path of the sun, the phenomenon of the midnight sun is easy to understand. Yes, also the moon and other heavenly bodies become visible all day long! But let us continue our thoughts concerning the polar regions. What happens there?

Only the northern hemisphere is visible, but it is visible day and night! And what is the result? Of course we have the midnight sun for half a year, from the Spring Vernal Equinox to the Fall Vernal Equinox. For the other half year the sun goes down and we have a half-year of winter night. We can also say that the rhythm of a day and the rhythm of a year fall together. The year becomes a day.

We will experience just the opposite if we travel south. The heaven's North Pole sinks while the heavenly equator rises. Eventually the North Pole lies on the horizon in the north and at the same time the South Pole becomes visible in the south. We are on the Equator: within a day the whole starry heaven passes over us and the heaven's equator lies right above us on the zenith, and right in the east and the west. The day is almost like the whole year, divided in two by day and night, and the seasons are gone.

A thought for reflection: between these polarities we humans live our lives: the southerners more strongly in the daily changes, the northerners more strongly in the change of seasons. Where are these elements found in balance?

The second main lesson

A less accessible area for children is the study of the planets, their rhythms and movements. But it is within their reach! In the eighth grade it is natural to study the planets as it meets their need to observe something that requires patient observations. For many fifteen-year-olds this can be a balance to their restlessness and unfocused self-indulgence.

Before we start this block it is wise to work with the starry sky above, something that can be made more accessible through the Greek sagas that provide the background for the names of the constellations. Perseus, Cepheus, Cassiopeia and Andromeda are some of the most important constellations but also the hunter Orion with the Dogs, the Great Bear, the Little Bear, and Hercules are some of the easiest to learn. I begin with the last two stars of the Great Bear, also known as the Big Dipper. These give us starting point for the circumpolar constellations (those that never go below the horizon at our longitude), and then we can move out to the larger oval that is created by the brightest—stars Capella in Auriga, the twins Castor and Pollux, Prokyon in the Little Dog and Sirius in the Big Dog, Rigel (one of Orion's feet) and Aldebaran, the Bull's red eye, not far from the well known seven stars of the Pleiades. The entire oval is a wonderful section of the heavens that is entirely visible on clear winter evenings in the south.

Then we can approach the Zodiac again, now from its various positions. It runs through the above-mentioned oval in the sky and when it is in the south the Zodiac has its "high" position in the firmament, high because we see the summer constellations. But also the Ecliptic's two slanted positions are important; the eastern slant is filled with the evening constellations of the fall and the western slant is typical for the March-April evenings. The Ecliptic's low position on our longitude with light summer evenings is not an unknown sight. But is better to observe that part of the Zodiac at another time of day, preferably when one of the planets is there. The constellations in this area, Scorpio, Sagittarius, Capricorn are relatively inconspicuous constellations that we may need a planet to locate them. This may be a good way to begin a systematic approach to planetary observations.

The five visible planets are naturally placed into two groups: Venus/Mercury and Mars/Jupiter/Saturn. We will not yet use the descriptions "inner planets" and "outer planets." First we need to observe the phenomena that make these descriptions natural. Let's begin with Venus.

The queen of the heavens has amazed and surprised many people. Concerning light intensity it can outshine all heavenly bodies but the sun and moon. Many people do not realize that it can be seen in full daylight. Like Wergeland many have noticed Venus on clear spring evenings. An intense white light shines above the sunset before any other stars appear. And one can observe it week after week and month after month. It is easy to see that it is fairly “close” to the sun, and increases the angle slowly until, after a few months, it reaches an approximately 48 degree angle to the sun and sets three to four hours later each day. Then it remains steady before getting “closer” to the sun again. A short while thereafter the largest angle follows the maximum light strength. We can assume that the reason for this is that it is closer than before but not so close to the sun that the sunlight limits its clarity. In this phase it can be seen at midday, though it does not last long. After a few weeks in the sunlight it disappears. If we were to make a drawing of its path, a beautiful orbit would appear including a meeting with the sun in the middle. Soon it reappears from the “other” side, as the morning star. Relatively quickly it reaches the same maximal degree, turns around and is pulled fairly slowly towards the sun again where it reaches its western light maximum and disappears after a half year in the sunlight. This time it is not visible for a longer period of time, almost half a year, and then it finally reappears to become, once again, the evening star. It has completed a synodic cycle. Many viewers are disappointed when in the following spring they do not find Venus in the same place as the previous year, but that is not the planet’s rhythm. The cycle around the sun, as seen from the earth, takes 584 days or roughly 19 months. What is the Venus rhythm in relation to our year? Five Venus cycles are almost identical with eight earth years. Only two days make the difference. The Venus cycle lasts almost exactly three-fifths of a year. Practically the same Venus cycle we witnessed in 1983 was repeated in 1991, 1999 and 2007. An eight-year rhythm is apparent, a period of time during which Venus traces a pentagram, a five-pointed star in the Ecliptic with its orbits: harmoniously drawn with 72 degrees space between. If we draw a diagram of Venus for the eight-year period we will know where to look for the planet at any time.

Our accessibility to Mercury is nowhere near as easy. The moving war god is volatile and demands a lot of whoever searches for him. It is told that Copernicus never experienced the planet with his own eyes, something not only caused by the meteorological conditions at the Baltic Sea, but also because he was not a practical astronomer. Instead, his contribution was to solve the riddle of the planetary orbits, something we can do best on a piece of paper!

In principle Mercury moves just as Venus, but its furthest degree of distance to the sun is merely 28 degrees, and it is therefore never longer from the light of the sun than a maximum of a few hours. Therefore we will find it a few hours after sunset or before sunrise, and moreso because of the Ecliptic’s angled position, only on spring evenings or fall mornings. Then it stands in a higher positioned constellation than the sun and receives something additional that corresponds to the new moon in the spring and the new moon in the fall. But for only a short period of a couple of weeks can we see it, and during such a period, we must pay attention to spring afternoons when we have clear western horizons or good eastern horizons on fall mornings. To sight Mercury requires interest and focus. Mercury has such a short cycle that you have the chance once every spring and fall. 116 days are used in a synodic cycle or just less than four months. During that time it accomplishes a cycle that covers its upper position or conjunction with the sun "behind," the largest eastern angle (evening star), the lowest position ("before") and the largest western elongation where it appears as the morning star. Then it returns to its usual conjunction.

The rhythms of Mercury are well established within one year. Three cycles is 3 x 116 = 348 days, something that makes Mercury's period of visibility for every year advance (365 minus 348, or roughly 17–18 days) "earlier." For example if the largest eastern elongation happens on April 18, the following year it will happen around April 1, then March 13, thereafter February 24, then the beginning of February and thereafter January. As it approaches Christmas and New Year's Day, we no longer have any advantage from the Ecliptic's slanted position. If we look for the next time the planet has the largest eastern angle, it falls not on April 18, as it did seven years ago, but on April 25, one week extended. Mercury's rhythm of seven years does not quite fit. The fact that this "fit" will be corrected within forty-six years, or one hundred forty-five Mercury cycles, can be easily calculated. The surprising fact is that this was known in ancient times. A diagram of this planet's movement in relation to the sun will be roughly the same after forty-six years.

Mercury and Venus make up one group of planets. Though their rhythms are very different, they have significant factors in common: they are both near the sun as seen from the earth. If you understand one of them, you can easily understand the other. We find a very different picture when we work with the other group of visible planets: Mars, Jupiter and Saturn. These planets do not move within limited angles, but regularly achieve the largest possible angle of 180 degrees. In astronomy we call this opposition. The planets stand directly south at midnight. At the same time they stand in the middle of an orbit that was very difficult to explain for many years. They also have their maximum brightness. The orbits, that for the inner planets take place before the sun and are therefore maximally removed from direct observation, take place opposite the sun, and even the newest amateur, by paying attention for several months, can follow the orbits with the naked eye. Yet each planet has its own tempo and rhythm.

It is easiest to begin with Jupiter and Saturn; both move slowly across the starry heavens. Our sun takes one year to move once through the Zodiac, the moon takes twenty-seven days. Jupiter takes twelve years! And Saturn, thirty years, considered one human lifetime. No wonder that throughout history Saturn has been related to life and death. In the old geocentric model Saturn was the guardian of the border between the changeable and the constant, between time and eternity. Its symbol is a simplified human figure with a scythe.

Because they both move in the same direction as the sun, they are overtaken almost every year, Saturn most often, actually every 378 days, Jupiter every 399 days or after thirteen months. Jupiter moves within one sign of the Zodiac for every time it is overtaken. Saturn remains for two to three years in each of the Zodiac's signs. A calculation that is fun to set up in class is an equation to find out how often Jupiter overtakes Saturn. It happens every twenty years. The last time was 2001.

Many conditions make Mars much more irregular and therefore harder to understand than the other planets. Why not wait to learn about it and then also prepare the transition to another theme, a historical perspective of our worldviews? It was the warlike planet Mars that Johannes Kepler wrestled with to discover the planet's exact laws of movement, later known as "Kepler's Three Laws."

In principle, Mars acts like Saturn and Jupiter. But the cycle time along the Ecliptic is barely two years and the sun will therefore overtake it approximately every twenty-six months. Notice the word approximately. The synodic cycle can vary up to fifty days and it appears to resist every regularity. Roughly stated we can say that Mars makes an orbit (in opposition to the sun) less than every two years and seven orbits within fifteen years. Then it makes a new series of orbits, somewhat altered from the first. During a fifteen-year series the light intensity set its own rhythm: the orbit in 1969 showed very intense light as Mars shone at the same time as Jupiter but red! It shone weaker for a while and was at a minimum in 1977. In 1980 it was strong again and in 1984 it was very strong! The light intense orbits take place in a part of the Zodiac not easily observable, the fall/winter sign we know as Scorpio. In Norway it is very low on the horizon, in New York it is fine and in Australia it is a beautiful sight, though the sun is in the north during the afternoon! Let us return to the irregularities of Mars. While the planet might irritate us, for a man like Kepler this was a challenge. He quickly noticed that Mars's movements contraindicated Copernicus's circle theory. Here was one planet at least that did not follow the idea of a circular orbit. The circle movements were in no way Copernicus's original ideas. They were a thousand years old—the earth as God's middle point, and everything orbiting in perfectly formed circles because they have one middle point, The One. Yet, even the Copernican representation of the heavens was known in Ancient Greece. It was reawakened but not fully accepted until sixty years after his death.

What appears on earth is so enormous that even a genius is not enough? Kepler is a symbol for the power of thought, the original and creative concept, unafraid and persistent. While his representation of the heavens contributed much to modern mathematics and physics, it was not enough. What was missing is the new world-historical quality of knowledge: it shall be free of all speculation; it shall be built upon precise data, by correctly collected data and ordered observations, possible errors shall be removed, and everything shall be controlled and open. Is it possible for him to find new numbers and new observations or must he rely on Hipparch's tables from ancient times?

Yes, in Denmark a certain nobleman with a nose made of silver sat on his island. On Ven in Oresund he and his many assistants worked through the clear, starry nights in his observatory Uranienborg, observing, measuring and writing. Page up and page down, book after book were filled with numbers as dry as a modern telephone book. But Tycho Brahe did not share his research. It was his private property and reserved for formulating his own representation of the heavens. His numbers were not accessible, while far away in Germany, a poor boy sat near his mother's arm watching a nova light up in the starry heavens. He was twenty-five years younger than Brahe, from another class and nationality. If our representation and knowledge of the universe was to be developed any further, they must meet. Their two dramatic biographies must bring them where they do not want to go, but must go. Indeed, they met at Kaiser Rudolf's Court in Prague just before Brahe died. The protocols, filled with Brahe's observations of Mars, came into the hands of the only one who could put them to use, Kepler.

A restless search for the truth began. A heavy battle with numbers was fought with new mathematical models, doubt and anxiety. For Kepler, if anyone, was a deeply religious man. In him the decisive thought arises: the ellipse! But it has two focal points! Yes, but it must be an ellipse: one focal point is empty, in the other stands the sun.

Mars and its strongly eccentric orbit caused great interest in the planetary orbits, and clarity for a large part of our scientific and technological development. There are many reasons to work thoroughly with astronomy. The portal to the new science we praise so highly is Kepler's work with the orbits of Mars. By deepening our understanding of the biographies of Brahe and Kepler, the students' respect for both poles of human knowledge can be awakened, namely the poles we call observation and thinking. Both are necessary parts of a whole, the very same whole we strive for in astronomy lessons at the Waldorf school by allowing the phenomena to live and grow into science