ASTRONOMY

AN INTRODUCTION

by

HERMANN V. BARRAVALLE

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COVER PHOTO:

A Milky Way Nebulosity, known as the "Cone Nebula" consisting of a chaotic mass of gas and dust. The background against which the "Cone" is silhouetted is lighted by a group of stars embedded in it with most of the illumination coming from a star seen above and slightly to the right of the "Cone". The rings around the stars are "halation circles" caused by light reflected from the back of the Photographic plate during the exposure. A 200 inch Hale telescope of the Palomar Observatory operated jointly with the Mount Wilson Observatory the California Institute of Technology photographed it.

Courtesy of Wide World Photos.

HERMANN VON BARAVALLE, Ph.D 1898-1973

Dr. Hermann von Baravalle was an internationally known mathematician and educator. For many years head of the Mathematics Department of Adelphi College (now Adelphi University), Dr. Baravalle authored a wide range of books and monographs in English and German. He was a pioneer in the Waldorf School Movement and was responsible for the founding of several of these schools. Dr. Baravalle appeared regularly as lecturer and conference leader in Universities and other educational institutions throughout the United States and in Europe as well as being active in mathematics programs of the National Science Foundation.

PREFACE

The truly valid introduction to the stars is a walk through open country on a clear night with the gaze turned heavenward. The watcher must be filled with wonder if he really looks at what is one of the most awesome spectacles possible in this earthly life. If the contemplative, questioning mood is allowed to prevail, the sky itself answers the questions that arise within him as he looks.

In words, pictures and charts this book aims to help the answers come and the observer to interpret the vast wisdom and mystery which the heavens unfold as they contribute to man's enrichment. This book was first written to help teachers present astronomy to sixth-grade children in keeping with the Waldorf School Plan of teaching.* Only later was it seen to have value for both adults and children seeking to understand the stars, especially those to whom an over-heavy burden of technicalities is but an encumbrance.

In the so-called "space age," in which man reaches out to touch and even land on heavenly bodies, and cosmic experimentation extends adult interest in "other worlds;" it is natural that every schoolchild and many younger ones know of space flights and interstellar weightlessness. "Space ships" and "green men" are part of their armory of toys. Television shows them hair-raising, earth-splitting take-offs to the moon, men moon-walking and floating like feathers in outer space, globe-circling astronatus in fast-spinningorbits controlled from fantastic computer centers — all the paraphernalia and trappings of man-made, twentieth century "miracles" which truly compete with the mysteries of the stars above.

Compete? Yes, but with a difference, perhaps even not with full success! For even these outer-space 'miracles" -- moon-landings, weightlessness, measurement with an accuracy almost beyond human comprehension -- are as though dwarfed alongside the still greater miracle, not merely of the stars themselves, but of a child's wonder at them -- his astonishment when an older person pinpoints the "Big Dipper" for him for the first time.

The young child's first lessons concerning the vast universe are those of night and day. He breathes -- he lives -- these rhythms. Without any teaching, he knows day and its sun, night and its moon, and gradually those points of light which puncture the night sky's blackness. At first sporadic and imaginative, his interests later become more specific. Only gradually does he become ready for a systematic study of astronomy. Through all his life, these changes assert themselves in the character of his interests, including his interest in the stars. These interests change like the changes in the sky itself --.

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*A plan inaugurated by Rudolf Steiner at the founding of the Waldorf School, Stuttgart, Germany, in 1919, and now in wide use throughout the world.

whimsical like the weather, or orderly like the movements of the stars and plants

The stars may be, not merely studied, but experienced in as orderly a way as their own; and, if so experienced, the stars will in turn transmit this orderliness to the observer who tries to understand them. This book presents the stars as they show themselves directly to experience. Merely cramming the head full of concepts picked up from conversation, articles or popular literature has no place in this work nor in any scheme of things based on reality. Such repetitive mechanical approaches lead to conceit rather than an experience of the stars or of any kind of reverence for the universe. Only a few questions based on realities of the sky reveal the shallowness of some approaches to astronomy. This book is meant to suggest such questions about the stars.

It shows the stars as man-centered, man-experienced. The star charts and diagrams in these pages, too, depict aspects on a hemisphere seen from within, as people actually see the sky when they look at it. The usual star-map is of just the opposite, showing daily changes in the positions of the stars and constellations in the form of parallel circles, drawn as though seen from without. The gap between these two styles of presentation — the one a picture from without and the other a picture which has meaning only if seen from within, from experience, is not easy to bridge over. And when learning is not experienced from within, it becomes mechanical. People study the "mechanics" of the sky and become lost in it.

The following chapters show the stars as people really see them. They are before us, behind us and at the sides. We have but to turn to see them coming in upon us from different directions. These pages show them as they actually appear specifically — from whatever direction — and bring systematically together the different sky-views in a way which activates and sharpens the visualizing power of the observer.

The methods outlined in this book embrace important educational and human values because they stimulate a rich gymnastic of the mind, which systematically strengthens the mental powers.

The student of the stars who utilizes these methods will thus find them an aid to immediate observation of the stars, while at the same time he builds a foundation upon which to trace the findings of astonomy through successive historical epochs. Once he confronts the actual astonomical phenomena in the heavens, he establishes a safe basis on which all different views and conclusions may rest in his understanding— just because, by developing his own powers for observing and thinking about the stars, he has opened himself and increased his own strength for penetrating the realities of the worlds around him.

I
OBSERVING THE STARS IN THE COURSE OF A SINGLE NIGHT

People's capacities vary for observing what appears before them. One may spend a whole night on a fishing boat, and later remember the changing positions of the stars during the night, the rotating movement of the Great Dipper or the rising of a constellation from the horizon. Another recalls but little.

On top of a mountain at night, perhaps knowing none of the names of the stars or constellations, one may wonder what "fixed stars" are, having somewhere heard the expression. Do "fixed stars" stay in their places, and only planets move?

The long-and-short of the matter is that not everyone is an accurate observer. And to study the stars, the first approach is to observe them.

Suppose we face the stars to the south of us. For one who does not yet know the stars, a compass may even help determine which direction is south. A certain bright star shines before us, among many others. It is just so high above the horizon. Will it stay there at the same spot all night? Or will its position change? The patient observer will see after not too long a time that its position is changing. What course does its movement take?

Imagine these observations being made from a classroom. The teacher draws the line of the horizon on the blackboard, with a star above this horizon-line, as described above. The teacher lets the students come to the blackboard and draw lines indicating what course they think the star will take when it moves. The resulting lines may sometimes go in almost all directions. These lines on the blackboard alone will make the students realize how much there is for them to learn. Finally the teacher tells them that after a while the star will be farther to the right. Then, above some point along the horizon-line, teacher locates a star on the blackboard. If this star is to the left in the southern sky, it will rise slightly and proceed to the right. If the star is to the right, it will gradually descend. The further a star is to the right, the more steeply it will descend.

LEONARDO DA VINCI'S OBSERVATIONS OF THE STARS

In similar manner Leonardo da Vinci conducted his studies of perspective. Seated and facing a window, he drew on the window-pane with a crayon a picture of the landscape that he saw before him. By drawing the position of a star on the window-pane, and doing it repeatedly, for instance, half an hour later, then one hour later, etc., he obtained the curve of the star's course by thus noting in picture form the star's successive positions and connecting the successive points. One must only take care to keep one's head in the same spot when making the pictures. The curve can also be obtained photographically by exposing film in a camera to the starlight for some hours. Each star will then draw its own course on the film. Curves thus obtained are shown in Figure 1.

FACING THE STARS TO THE SOUTH

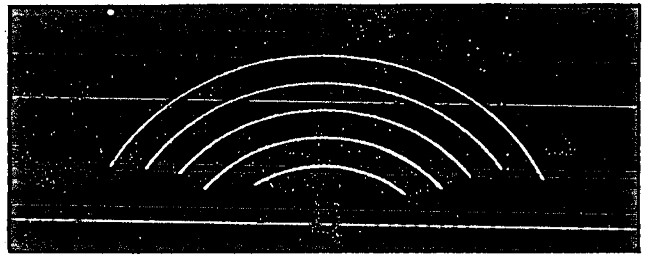


Figure 1. The left-to-right courses of the stars as the observer facing south sees them appear to move aboe the Southern horizon.

These circular, convex arcs vault over the southern horizon, keeping always the same distances from one another. They are parallel.

FACING THE STARS TO THE NORTH

Let us now do a complete right-about-face, and face the stars to the north of us. The clear night sky surrounds us, but the picture before us is a wholly different one. The stars above the horizon to the left of due north descend as the night goes on, and those to the right ascend, while those directly above due north move toward the right. The further the stars are to the left of due north, the more steeply they descend; and the further they are to the right, the more steeply they ascend. The curves of their motions through the night are shown in Figure 2.

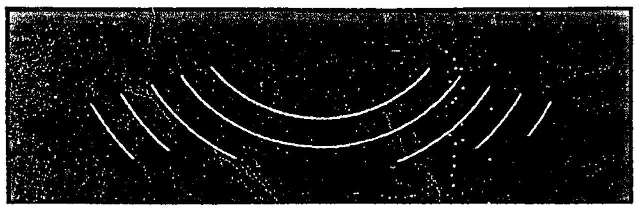


Figure 2. The right-to-left courses of the stars above the Northern horizon as we wee them when facing north.

These circular concave arcs represent the courses which we see the stars above the northern horizon follow from right to left, with the lower arcs disappearing under the horizon and coming up again — "bathing in the ocean," as the Greeks called this phenomenon, though one in our time usually describe such manifestations in concepts rather than pictorially.

FACING THE STARS TO THE EAST

Now let us face the stars above the horizon to the east of us — that part of the sky in which all stars ascend. From all places in the United States and Europe, we see the stars rise in the eastern sky and move through the night toward the right. We see them ascend more steeply from due east than from the southeast. Figure 3 shows the lines of their daily ascent up from the eastern horizon. The line which starts at the due-east horizon-point move straight up into the sky. the lines starting to the right of that due east point form convex circular arcs rising up from the horizon; those to the left, concave circular arcs. The straight line is the line of the so-called Celestial Equator ("aequus" = "level," "equal," hence "straight"). Holding a ruler in one's hand, with arm outstretched in the direction of the Clestial Equator will show that equator's straightness. The stars ascending from its rising point, due east, will advance through the night exactly along the rul'ers edge.

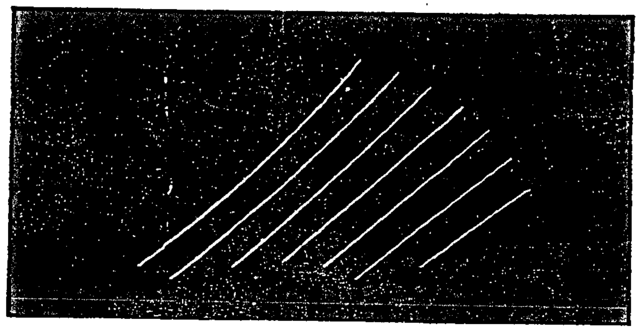


Figure 3. The rising courses of the stars up from the Eastern horizon as we see them when we face east.

Such a straight line is non-existent in plane geometry. It combines the qualities of both a straight line and a circle. It belongs to the geometry of a sphere seen from within. The horizon at sea is a line of this kind. A photograph taken from a ship shows a horizon-line as a straight horizontal. Yet we know that this same horizon-line runs in front of us, behind us and at both sides of us. We have to turn around to follow it.

FACING THE STARS TO THE WEST

Let us now face west and look at the western sky. The opposite picture appears before us. In the west, all stars descend. Those which set exactly at the due-west point descend on an inclined straight line whose straightness can again be tested by watching those particular stars follow straight along the edge of a ruler held with outstretched arm. To the right of this due-west center point, the courses of the stars are circular concave arcs; and to the left, circular convex arcs.

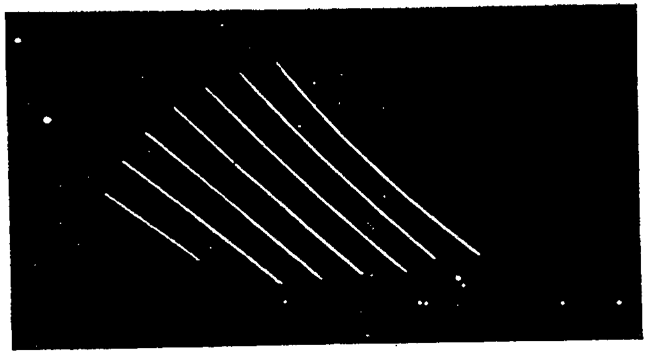


Figure 4. The courses of the stars above the Western horizon as we see when we face west.

BY COMBINING THE FOUR SKY-PICTURES TO SOUTH, NORTH, EAST AND WEST, WE FORM THE CUPOLA OF THE SKY ABOVE US

With these four major pictures in mind — the celestial scenes which confront us above the horizon as we face south, north, east and west — we may now extend and combine them to form one vast picture filling the entire cupola of the sky above us.

We may first extend the picture of the southern sky, adding to it more and more parallel convex arcs all the way up to the Celestial Equator. We now see that the same stars which rise exactly in the east set exactly in the west, their full courses lying along the Celestial Equator. We may then extend the courses of the stars farther north in the eastern and western sky, lenthening the concave arcs above the northern horizon far and high above us to the zenith, the point straight over our heads, to form complete circles.

Every single concave circular arc — in other words, the course of every single star — can be extended to form a complete circle. The farther north they are, the smaller these circles. We see them as concentric circles gradually diminishing in size to their common center (See Figure 5).

This common center is called the Celestial Pole; the star nearest to it, the Pole Star.

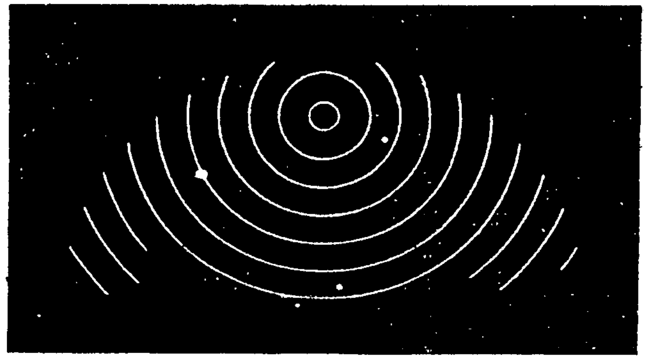


Figure 5. The courses of the stars in the Northern sky form concentric circles around the Celestial Pole.

THE CELESTIAL EQUATOR'S CENTER IS WITHIN OURSELVES

Tracing the circular arcs which at the horizon are north of either the due-east point or the due-west point, we always find their center to be the Celestial Pole. Tracing any of the arcs above the southern horizon and pointing to their center, we find ourselves pointing in exactly the opposite direction — downward.

With this picture in mind, we can ask: Where does the center of the Celestial Equator lie? It does not lie in any direction outside of ourselves. Its center is right within us.

Compared with the daily courses of single stars, the courses of the constellations of stars reveal two kinds of motions. Any constellation above the northern horizon, like the Great Dipper, revolves completely around its Pole Star center. It can be seen successively in all positions along this circular path. Constellations near the Celestial Equator never completely revolve in this way. They swing about 45 degrees to the right, then back, and then 45 degrees to the left, performing a kind of oscillating motion.

What about the speed of the stars? How fast do they move in their courses? Their speed of travel actually varies with position. Stars on or near the Clestial Pole move slowly. Those on the Celestial Equator move the fastest. All the circles — the smallest as well as the largest — are traversed once in the same time-period of 24 hours. It is possible to measure distances in the sky by hand-widths. Measuring vertically upwards from the horizon to the zenith, we come to a distance of nine hand-widths. Thus one hand-width represents 90/9, which is 10 degrees. A star which moves 360 degrees along the Celestial Equator in 24 hours thus covers in one hour 15 degrees or 1½ hand-widths.

II

OBSERVING THE STARS IN THE TROPICS AND IN THE ARCTIC REGIONS

From one part of the earth to another appear progressive changes in landscape, climate, plants and animals, and also the stars in the sky. Even more striking than the beauty and loneliness of the Norwegian fjords are the impressions of the midnight sun.

Journeying southward, we see the arcs described by the stars over the southern horizon reach ever higher and higher. They continue to rise ever more steeply from the eastern horizon, and to descend more steeply in the west, all the way to the earth's equator.

At the equator the arcs rise up vertically from the horizon, and come down vertically to the horizon. Figure 6 shows the curves described by the stars above the southern horizon at this equatorial latitude — all of them semi-circles around the due-south horizon point, and larger semi-circles further to the left and right.

Turning to face north from our standpoint on the equator, we see the same kind of picture of the semi-circular arcs. There are no longer concave arcs above the northern horizon nor convex arcs above the southern horizon.

Figure 6. The courses of the stars of the tropical sky as we see them above the Southern and Northern horizon when we stand at the earth's equator.

Facing east at the equator, we see the Celestial Equator rising vertically. The arcs to its left and right are circular arcs which rise perpendicularly from the horizon.

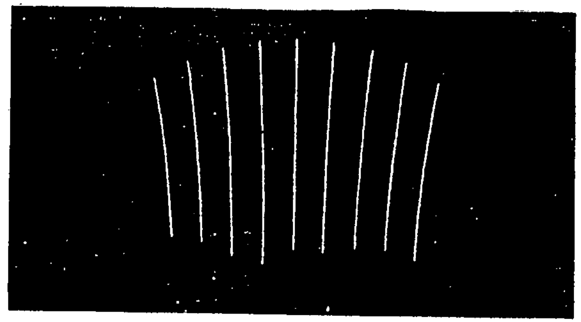


Figure 7. The courses of the stars in the tropical sky as we see them above the Eastern and Western horizon when we stand at the earth's equator.

Facing west, we see exactly the same picture, except that the stars no longer rise along these lines, but descend. The stars at this equatorial latitude not only rise and set in a vertical direction, but reach greater heights above the horizon and dip to greater depths below it than at any other latitude. The changes between light and darkness accordingly come more rapidly. Dawn and dusk are shorter, changes of temperature quicker.

THE STARS AS SEEN FROM THE NORTHERN HEMISPHERE AND FROM THE SOUTHERN

Conditions generally in the arctic regions are opposite to those at the earth's equator. The stars are no exception. Their courses in the arctic sky likewise show a picture opposite to that seen in tropic skies. Instead of the vertical courses which predominate in the tropics, the horizontal direction prevails in arctic latitudes. At the North Pole all stars proceed above the horizon from left to right without changes in altitude. The Celestial Equator lies at horizon level, and the Pole Star shines down from the zenith. Figure 8 pictures the courses of the stars

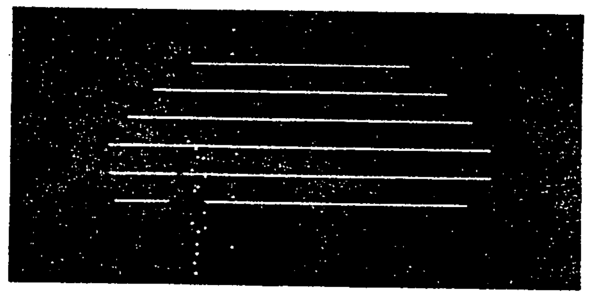


Figure 8. Courses of the stars as we observe them above the horizon at the poles of the earth, whether we face North, South, East or West — all of them straight horizontals.

as seen to the north, south, east, and west at any time we see them in the arctic regions. These star-courses always take the form of horizontal lines, moving always from left to right.

At the South Pole the star-courses are also all horizontals, except that the stars in the antarctic skies proceed from right to left.

The celestial landscape at the poles harmonizes with the earthly one — wide, snow-covered plains and complete lack of trees or other vertical elements. The gradual transition from the pictures seen in temperate zones to those seen in the tropics and the arctic regions provides challenges for all willing to visualize to themselves this transition as it really occurs. Students studying in the way may draw these pictures of the stars and the respective landscapes. Many drawings made in this way by Waldorf School students over the years are challenging to the imagination and the thinking faculties.

THE SOUTHERN HEMISPHERE

In the southern hemisphere, the pictures of north and south are just the opposites of the corresponding ones seen in the northern hemisphere. Concave arcs appear over the southern horizon, convex arcs over the northern. This reversal is in keeping with the fact that the frigid zone is toward the south; the tropic zone to the north. The New Zealander goes to the north island for more sunshine, to the north side of a house for a sunny room.

The stars along the Celestial Equator appear, too, of course, to move in exactly the opposite direction from that in which the very same stars appear to move when seen from the northern hemisphere. They rise in the east from the right and descend in the west to the left.

III
OBSERVING THE NIGHT SKY IN THE COURSE OF A YEAR

On successive nights over weeks and months, the courses of the stars remain exactly the same. Changes occur only in the times when the different star-groups appear, and are particularly observable just before dawn and just after dusk, when the stars are seen rising and setting in relation to the horizon. Before dawn, new star-groups after a time are seen rising in the east, as those already risen climb higher in the sky. After dusk, star-groups previously seen are no longer visible in the western sky.

Corresponding changes are seen to occur at any hour of the night when observations are made over a series of nights. On successive nights, star-groups above the eastern horizon are seen to be higher up

in the heavens when observed repeatedly at the same hour. In the west, star-groups are found nearer to the horizon as the nights go on. Facing the south, one observes the star-groups progressing always toward the west as time passes.

Devices similar to those used for studying the stars' daily courses can make clear these observations over a series of nights. Photographs of the night sky may be taken at the same hour on successive nights — for instance, every night at 10 o'clock. Limiting the time of the photography to the same fixed hour causes the camera to register, not the stars' movements from one hour to another on a given night, but their progression from night to night through the year. The successive positions of the stars from night to night, joined together, picture the curves of their motion through the year. For the southern or the northern, the eastern or the western sky, the curves pictured for the advancing year exactly repeat those for the advancing day. The year of twelve months repeats the day of twenty-four hours. The following correspondences are thus seen to exist in the changes of the courses of the stars over the twelve months of the year and over the twenty-four-hour-day:

Daily changes	**Yearly changes**
24 hours	12 months
2 hours	1 month
1 hour	2 weeks
½ hour	1 week
4 minutes	1 day

HOW STAR-CLOCKS TELL STAR-TIME IN ASTRONOMICAL OBSERVATORIES

The night sky, observed at the same hour on two successive nights, is thus seen to change as much from one night to the next as in 4 minutes on a single night. Small as the nightly change may seem, its cumulative development over longer periods of time becomes significantly large. After only a month, the change in star positions for, say, 10 o'clock is seen to be as much as during two hours of a single night. A star on the Celestial Equator changes its position 15 degrees (1½ hand-widths) in one hour; in two hours, 30 degrees (three hand-widths). Corresponding changes take place in the yearly cycle every two weeks and every month respectively. The exact change in the night sky from Christmas midnight to Christmas at 2 a.m. will be noted from midnight of December 24 to midnight of January 24. The view of the stars at midnight of December 24 will be seen at 8 p.m. two months later. The Christmas midnight sky reappears earlier and earlier in the evenings in Spring until its last appearance after dusk in March. It is thus seen performing its yearly travels through the night. Then it can be seen before dawn again in the early morning sky in the Fall. Any aspect of the starry sky, any constellation of the zodiac, first becomes visible before dawn, and is last seen after dusk.

Astronomical observatories use ordinary clocks which run differently from usual clocks. They register the hours of the recurring aspects of the night sky. These clocks tell "star time." They tell, for instance, at Christmas midnight, the same time as at 8 p.m. two months later. They move ahead two hours every month, 24 hours in a year. Only at one time of year do they coincide with ordinary clocks -- namely, at the beginning of Spring, on March 21. Using star time, it is possible to set up convenient tables for locating the stars and for listing the times of their risings and settings.

IV
OBSERVING THE SUN IN THE COURSE OF THE DAY AND IN THE COURSE OF THE YEAR

Ask any one how much time it takes for the sun to set — in other words, from the time when its disc first touches the horizon until it completely disappears — and the answer may be "one minute" or "a half-hour" or any time-span between those two. If the questioner is a teacher dealing with students, he may note down the answers, then ask the students to check their answers by actually observing a sunset and report their findings the following day.

For points in the United States and in most of Europe, it takes the sun between two and three minutes to set, depending upon geographical latitude — longer the farther north the observer goes, shorter in the south. At the equator, the setting time is exactly two minutes.

At what locations on the horizon-line does the sun rise and set? Does the whole course of the sun from rising to setting correspond with the curves of the courses of the stars as described above? Yes, it does.

After the sun has set and darkness has come, an afterglow of daylight is still visible on the western horizon -- first lighter, gradually more faded, but still perceptible for a long time after sunset. This afterglow appears in a limited area within a circular arc above the horizon. Continuing this arc to round out the full circle of which it is a part, then locating the circle's center, one discovers this center to be a point under the horizon; also that this centerpoint does not remain fixed as the hours go by, but gradually moves from the west towards the north. The light shines from the sun, which is continuing its course under the horizon.

The moving center-point thus established marks the changing position of the sun after setting. In northern countries, a shining of this kind is visible all night. From the sunset point on the horizon, this afterglow gradually moves northwestward, and at midnight stands in the north. After midnight it continues to the northeastward, then to the east, until its center is finally at the point on the eastern horizon where the sun rises.

THE SUN'S COURSE

It is also possible to observe, not only the sun's daily, but its yearly course. In summer the sun rises in the northeast, sets in the northwest, and is at noon high in the southern sky. The observer can see its course changing as summer progresses, and see the changed position within the range of the concave arcs shown as in the picture of the eastern heavens (Figure 3, left side).

In winter he observes the sun's course again changing within the range of the convex arcs shown in the east to the right of the Celestial Equator (Figure 3, right side), and stretching lower in the southern sky. In March (exactly on March 21) and in September (exactly on September 23) the sun's course through the sky follows the Celestial Equator. Its path through the sky is seen as a straight line.

As summer approaches, it is seen to move upward day by day from the Celestial Equator to ever higher arcs, reaching its highest position on June 21. After that date the sun's course moves downard again, reaching the Celestial Equator in September and its lowest position of the year on December 21, the time of the shortest days and the longest nights.

In the temperate zone, in winter, when day breaks at 8 a.m. and darkness comes again at 4 p.m., the day consists of only eight daylight hours and there are sixteen dark hours. One-third of the twenty-four-hour day is light, and two-thirds dark. Also, at this time of winter, only one-third of the sun's total course is above the horizon; two-thirds, below the horizon.

At the geographic latitude of 45°, half-way between the North Pole and the earth's equator (Maine is in that latitude in eastern United States; Oregon in the west; in Europe, northern Italy), it is possible to picture very specifically the sun's arc of travel through the sky. The Celestial Equator passes from the due-east horizon-point to the due-west horizon-point, moving along a parth 45° above the due-south horizon-point, a path half-way between the horizon and the zenith. And nearly half the distance between the Celestial Equator's path and the horizon lies the path of the sun at the depth of winter (23½° below the Celestial Equator). At the height of summer, the sun's path is exactly the same distance above the Celestial Equator. Through the summer months the sun mounts higher and higher above the southern horizon until it reaches this peak height nearly half-way between the Celestial Equator and the zenith (23½° above the Celestial Equator).

The lenthening of the days from December to June does not proceed in equal steps. It begins very slowly around Christmas, then gradually speeds up, continuing until March, when it speeds up most quickly. Thereafter the days lenthen every more slowly. In later summer they shorten again; becoming markedly shorter by September and shortening continuously thereafter through the first half of December, the speed of change going from slow to quicker and finally to slow again.

LENGTHENING AND SHORTENING OF DAYS

To follow most clearly the changes in the sun's daily path through the sky with the lengthening and shortening of the days, it is best to observe repeatedly day after day, the sun's mid-day position. Its path changes within the range of one-quarter to three-quarters of the distance between the southern horizon and the zenith. The sun's path is seen to be mounting, first slowly, then more quickly, then slowly again, from its low winter position to its high summer position. And the return of the sun from its high summer position to its low winter position follows the same pattern of change in pace from slow to faster and again to slower. A musical chord vibrates according to the same mathematical law of changing pace.. It is called harmonic motion, and also applies to the speed of movement of a pendulum or a swing.

Every shadow made by the sun follows a course of movements which repeat in their own way the daily path of the sun itself. One has but to put up a pole two or three feet high to observe that even in a few minutes' time a mark indicating the shadow of the pole upon the ground will have to be changed to keep up with the moving shadow. Similarly, a pencil erected vertically on a horizontal drawing-board will throw a shadow whose end-point gradually traces a curve on the board (Figure 9). This curve reflects two kinds of motions. One is the rotation of the shadow around the pole; the other is the change between longer and shorter.

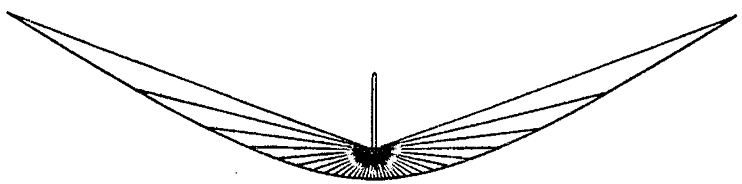


Figure 9. The movement of the shadow of a pole — indeed, of every shadow of an object on a sunlit surface — repeats in its own way the daily path of the sun.

Before sunset and immediately after sunrise, all shadows are long. While the sun is in the east, all shadows point to the west. When the sun arrives over the southern horizon, all shadows point to the north. When the sun is in the west, all shadows turn from the north to the east. The curve described by any shadow's end-point is an hyperbola. These hyperbolae change through the course of the year. Figure 10 shows the month-to-month changes in the curves traced by the end-point of the shadow of the rod or pencil (A in Figure 10).

Among these hyperbolae forms is a straight line, described by the shadow's end-point in March and September, when the sun's course lies along the Celestial Equator. The straight line which the sun itself now draws in the heavens is seen in the shadow on the ground. In Figure 10, three curves are drawn above the straight-line stage and three below. The curves above the straight line lie closer to the rod.

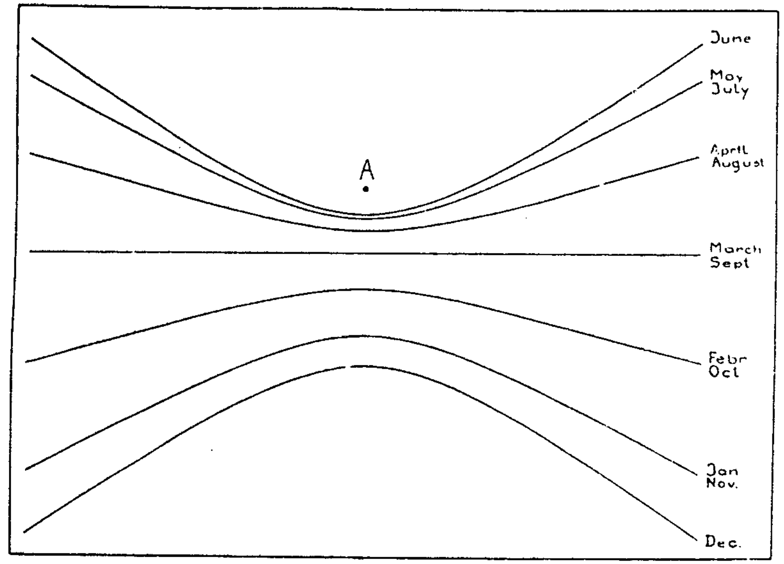


Figure 10. Shadow hyperbolae drawn from month to month by the end-point of the shadow of a rod [Point A in figure 10] erected vertically upon a horizontal surface.

They are drawn during the time of shorter shadows, during the half-year of the summer. The one next to the straight line is the curve for April; the next, for May; the third, for June. There are also three curves below the straight line. They lie farther away from the rod, and represent the months of longer shadows, the half-year of the winter. The hyperbolae of the half-year of the summer close in around the rod. Those of the half-year of the winter turn away from it. These contrasting curves are projections of the contrast between the convex and concave arcs of the sun's movement through the sky.

V

OBSERVING THE SUN IN THE TROPICS; OBSERVING THE SUN IN THE ARCTIC REGIONS

The earthly observer who follows the courses of the different stars in the sky can see that the same courses are traced also by the sun at different times of the year — a fact that is true at any latitude or in any country on earth.

At the earth's equator, the Celestial Equator will be observed rising up perpendicularly from the eastern horizon, proceeding directly overhead, then descending perpendicularly to the western horizon. The sun follows this same course on March 21 and September 23. At these times the sun stands at noon in the zenith, and can be seen to shine straight down into even the deepest well. At these times a vertical rod casts no shadow.

From the earth's equator, too, the Celestial Equator is seen to be the mid-position which the sun's path reaches in the course of the year. If one stands facing east at the equator on earth, the sun's daily course is seen to lie to the left of the Celestial Equator during the half-year of the summer, to the extent of 23½° at its fullest swing in that direction, and to lie correspondingly to the right of the Celestial Equator during the half-year of the winter. This 23½° arc can be measured along the eastern horizon from the due-east point to the point where the sun comes up at sunrise, or again along the western horizon from the due-west point to the point where the sun goes down at sunset.

It can also be measured at noon by its distance from the zenith. In summer and winter alike it does not reach the zenith, and its course lies 23½° below the zenith at its low points in June and December. In both these months, from the earth's equator, the sun is seen to stand at noon equally high above the horizon. In these months, in summer and in winter, the height of the sun above the earth is the same. Consequently, at these two opposite periods of the year, at the earth's equator, it is equally warm and equally light. In fact, there is at the equator no difference between summer and winter.

AT THE EQUATOR: PERPENDICULAR RISING AND SETTING — THE SEMICIRCULAR COURSE

At the earth's equator, when the daily ascent of the sun becomes perpendicular in the east and its descent perpendicular in the west, its path is seen to be a semi-circle reaching over the sky from east to west. Day and night are of equal length. Sunrise is at 6 a.m., sunset at 6 p.m. There are twelve hours in a day and twelve hours in a night. The rhythm of the day has achieved the maximum regularity. The rhythm of the

year has lost its significance. Of the two main rhythms of our lives, the rhythm of the day and the rhythm of the year, the rhythm of the day is now taking over.

In the tropics, the change of temperature between day and night is greater than between summer and winter. It is very different in the north temperate zone, where the weather may be expected to change more drastically with the course of the year, bringing beautiful autumns and clear October days — say, in New York — and snow in the first months of the year.

In tropical countries, even the weather changes with the day's rhythm, with perhaps sunshine in the mornings, clouds between 1 and 2 p.m., pouring rain between 2 and 3 p.m., and clear sky and sunshine at 4:30 p.m.

AT THE EARTH'S POLES

What is true of the sky in the arctic regions is most clearly expressed at the North Pole. In fact, conditions at both of the earth's poles represent to a larger or smaller degree those prevailing throughout the whole of the arctic or antarctic region, whichever it may be.

The movement of the stars at the poles is horizontal (see Figure 8) So is the movement of the sun. The Celestial Equator at the poles is at horizon level; so is the path of the sun in March and September. Half of the sun's daily trips through the sky take place below the horizon. The sun actually remains below the horizon for a half-year; that is the time of the polar night. For several days it is at sunrise level. Then, by the principle of harmonic motion, its path appears again above the horizon. The sun rises to 23½ above the horizon in June at the North Pole, and to the same height above the horizon in December at the South Pole. The highest summer positions of the sun in both polar regions are approximately the same distance above the horizon as its lowest winter positions are below the horizon.

THE RHYTHM OF THE DAY AND THE RHYTHM OF THE YEAR

In the polar regions, sunrise does not occur within the day's rhythm as it is known in the temperate zones. There the day's rhythm has been taken over by the rhythm of the year.

Only one sunrise per year takes place in the arctic region, and that sunrise is in the Spring. And the only sunset is in the Fall. Light and darkness, too, no longer change with the day in the frozen north, but with the year. There is not maximum mid-day height of the sun. The sun is equally high at morning, at evening and even at midnight.

In northern Norway I was surprised to hear that the predominance of the year over the day extends deeply even into human life. Fishermen in these regions remain awake for twenty-four hours in summer, with no more than a kind of an afternoon rest. Throughout the whole summer, the Eskimos gather in provisions for winter, whereas in the tropics life proceeds from day to day. In the winter the opposite condition prevails in the arctic regions, with the rhythm of the year predominating and its distinctive characteristics supplanting those of the rhythm of the day.

What do we learn from these rhythms?

In the tropics, day takes over. The year is insignificant.

In the arctic regions, the year takes over. The day is insignificant.

Such observations induce observers to reflect upon their own lives, upon the rhythms of humanity, and to realize that if they live in the temperate zones they have most likely accepted the days and the years as a matter of course without reflecting upon what conditions are in another region of the world, where either the rhythm of the year or the rhythm of the day almost exclusively prevails.

Dwellers in the temperate zones may then experience what it means to congratulate themselves that they enjoy the inter-play of both of these great rhythms.

VI
OBSERVING THE MOON, POINTER TO THE SUN

The moon's aspects for the observer are most varied. At full moon he sees the complete moon-disc; at other times, half-circles or various sickle forms. Always the sun is seen as a full disc, the stars as points of light. Only the moon appears in these varying shapes.

Whether at full moon, or at half-circle moons, or at sickle moons, one-half of the total surface of the moon is always lighted by the sun, while one-half is in darkness. Sometimes we are facing the lighted side; at other times, more or less of the dark side. When the moon appears as a half-circle, we are facing half of its light side and half of its dark side. At the time of the small moon-sickles, only a little of the light side and much of the dark side are toward us.

A sickle moon shows two border-lines. One is the edge of the moon-disc; the other, the line separating the lighted side from the dark side. If one imagines the border between the lighted side and the dark side continuing all the way around the moon, half of it visible and half invisible, one pictures the two halves together as an ellipse-form

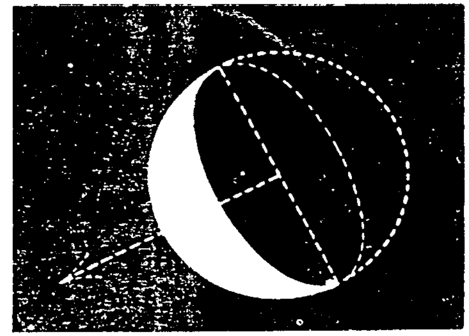


Figure 11. Imagining the border-line between lighted and dark portions of the moon-disc to be continued all the way around the moon, one pictures an elliptical form.

When we see the moon as a half-circle, the ellipse flattens to a straight line. When the moon is full, this ellipse widens to the full circle of the moon, coinciding with its outer edge. In Figure 11, an arrow is drawn from the center of the moon through the middle of its lighted side. This arrow points in the direction from which the sun's light comes to it and illuminates it.

Figure 12 shows a semi-circle moon aspect. The border separating the lighted portion from the dark is seen as a straight line. Perpendicular to this line is the arrow pointing to the sun. At full moon, such an arrow has to be drawn from its center straight toward us. This arrow, prolonged, would pass through us as observers and through the earth itself to the sun beyond. For there beyond us, on the opposite side of the earth, is the sun when the moon is full. We as observers from the earth are directly between the moon and the sun.

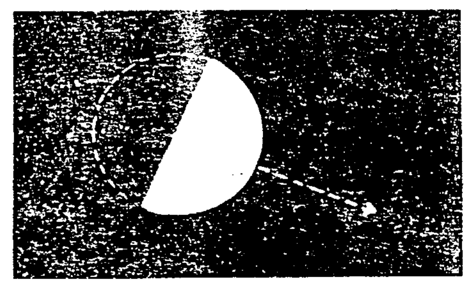
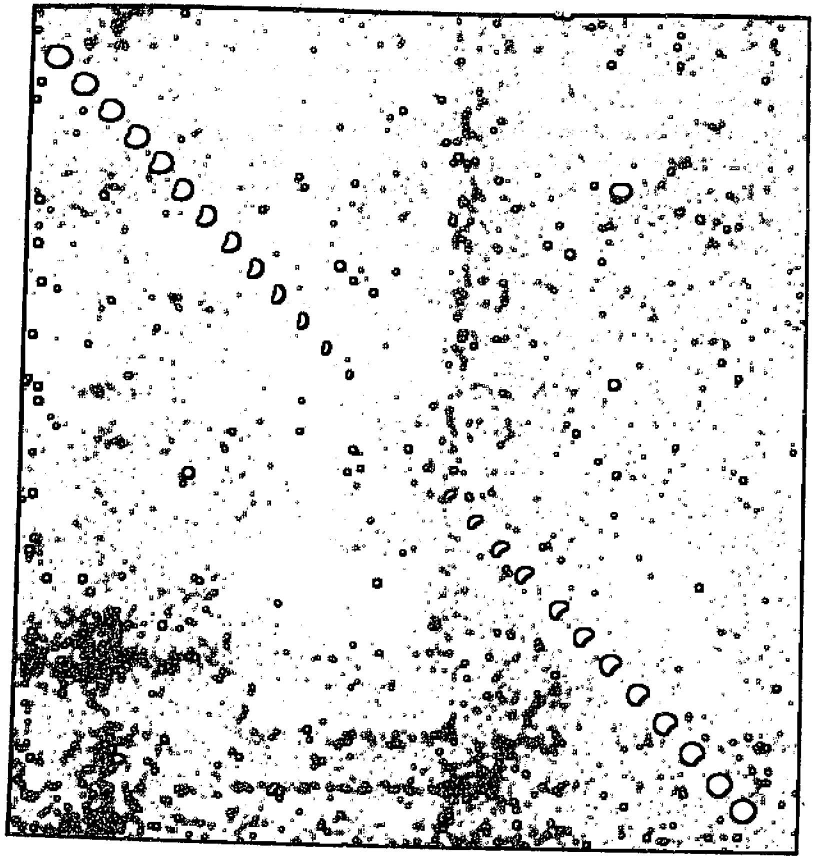


Figure 12. The line separating the lighted and dark portions of the disc of a half-moon is seen as a straight line.



Full Moon passing through total eclipse March 13, 1960, New York City. Eclipse took place as shadow of earth fell across the moon. Exposures were made at five-minute intervals with black portion in middle representing moon's full eclipse which lasted an hour and 25 minutes. Wide World Photos.

Solar eclipse viewed from Jersey City with the Statue of Liberty in the foreground. Wide World Photos.

THE MOON TELLS THE POSITION OF THE SUN

Whenever the moon is visible in the sky, it tells the position of the sun. With the moon as guide, the observer can follow the whole course of the sun under the horizon.

When the full moon is rising in the east, the sun is setting in the west, diametrically across the earth from the moon. During the first evening hours, when the full moon is rising above the eastern horizon, the sun has descended just as low under the western horizon. At midnight, when the full moon stands high above the southern horizon, the sun is equally low under the northern horizon.

In winter, when the sun follows a lower course, which brings it at night far below the horizon, the full moon rides high in the sky. In summer, when the sun takes a higher course, which brings it less far below the horizon, the full moon is only as high as the winter sun.

The observer may read from a semi-circular moon the direction of the sun's position along its path for that particular time of year. Simply by stretching out an arm to mark a line as from the center of the moon through the middle of its lighted side (see arrow, Figure 11), he will be pointing in the direction of a spot below which the sun then stands. When the dividing-line separating the moon's lighted portion from its dark position is in a vertical position, and the lighted outer arc of the moon curves to the right The sun at that time is setting on the western horizon, while the moon itself is at its highest position in the southern sky. During the first half of the night, the moon so aspected is descending to the west, and it sets at midnight. As it descends, the dividing line between its visible lighted portion and its dark portion gradually changes from a vertical to a horizontal position, and the semi-circular arc of the moon gradually becomes like a cup opening upward, with its convex side toward the earth.

At other times, when the dividing-line between the moon's lighted and its dark portions is again vertical, but with its semi-circular lighted arc to the left, an arm outstretched in the direction of the sun points horizontally to the left. The sun at such a time is rising on the eatern horizon, while the moon is at its highest position in the southern sky. At such a time, during the first half of the day, the moon is descending toward the west and is seen in daylight until it sets at noon. During that same half-day, the moon's appearance has changed, so that an arrow drawn perpendicular to the line dividing its lighted from its shadowed portions points increasingly upwards. This change occurs during daytime hours as the sun moves higher in the sky, but is clearly observable. For some days every month the moon is visible for such daytime observation.

THE SICKLE MOON

The moon's sickles can also tell the sun's position. What is wrong, for instance, in Figure 13?

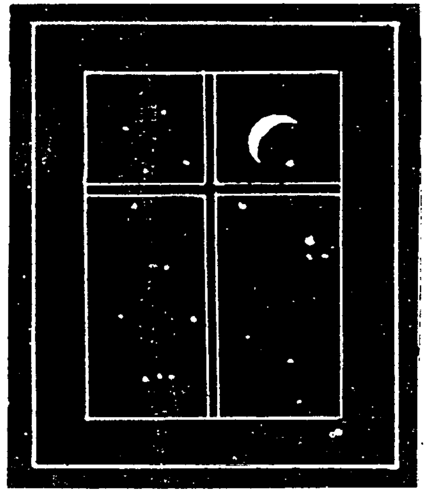


Figure 13. What is wrong with this picture?

While the moon's sickle is tilted as in this picture, the arrow drawn to point in the direction of the sun, would have to point upward. The sun would be high above the horizon; it would then be day, and the stars could not be seen.

The moon's sickles stand upright at sunrise and sunset. When a sickle moon appears before sunrise, it is always on the eastern horizon, and is in a cup-like position. The arrow points to the left and downward, indicating the position of the sun that is still below the horizon. When later the sun rises, the sickle is curved towards the left and stands vertically, while the arrow is horizontal and indicates the spot along the eastern horizon where the sun appears. As the sun mounts higher and higher above the horizon, the sickle takes on the aspect of a cup overturned with the arrow pointing upward to the sun.

In the evening sky, the sickle moon appears only in the west, curved always to the right. At sunset, the sickle is in a vertical position. Afterward it assumes the cup-like shape, remaining visible but a short time after sundown; and the narrower the sickle becomes, the briefer the period of its visibility.

The full moon is visible all night long; the half-moon, half the night; the sickles, only small portions of the night. When the "full moon" stage has passed, the moon gradually disappears from the sky. It disappears in two ways: Its lighted portion slowly becomes smaller and smaller, and it illuminates the night sky for everbriefer and briefer lengths of time.

The stars, the sun and the moon all follow the daily paths indicated in Figures 1 to 4. But only the sun follows this path in exact accord with the rhythm of the day. The stars go ahead of the sun, and the moon stays behind the sun.

At evening a sickle moon is never seen but in the western sky. It sets on an average of three-quarters of an hour later on each successive evening, thus remaining visible each evening for a longer time, while simultaneously its lighted portion grows larger each night until it reaches the semi-circular and later the full-moon stage.

At morning the sickle moon is never seen but in the eastern sky, where it rises before the sun. It rises later every morning, the time of its visibility shortening until it is seen no longer.

The time after this sickle moon's disappearance from the morning sky is the time of the "dark of the moon," and its reappearance in the evening sky marks the time of the "new moon." The new moon's name refers to the first thin "new moon" sickles, which grow larger and larger as the moon lingers longer behind the sun.

Because the stars on the contrary move progressively ahead of the sun, the star-groups first appear briefly in the morning, rising more and more ahead of the sun and thus remaining visible more and more of the night before the sun rises, until at length they are rising in the east as the sun is still only setting from the previous day, and are shining all night long for a time before finally disappearing from the evening sky.

The moon does exactly the reverse. Because the moon lingers increasingly behind the sun, each new moon appears in the evening after sunset, growing in light and duration until it becomes a full moon.

Afterward it is visible over gradually shorter periods, at length only for the second half of the night, then finally only very briefly, after which it vanishes entirely in the morning.

From the evenings of the first new sickle moon, the moon grows fuller through the night, and is visible for ever more and more of the night.

SUMMARY

To summarize, briefly —

1. The sickle moon, curved to the right, is visible in the evening, setting in the first hours of the night.

2. The moon's half-circle, curved to the right, is visible in the evening and through the first half of the night, setting at midnight.

3. The full moon, rising in the evening, setting at sunrise, is visible the whole night long.

4. The moon's half-circle, curved to the left, rising at midnight, is visible through the second half of the night, setting in the later morning.

5. The sickle moon, curved now to the left, rising in the last hours of the night, remains visible in the morning sky during the day.

VII
OBSERVING THE PLANETS: FLEXIBILITY IN THE COSMOS*

Five stars, different from all the others, appear at times in the night sky. All five shine brightly at night in some months, and during others can hardly be seen. These five include the brightest of all stars, the morning star and the evening star — actually one and the same star — appearing sometimes before sunrise, and at other times after sunset.

This brightest of stars is Venus.

Not only does the light of these five stars vary, but their positions among the other stars vary, too.

Of all the stars in the sky, other than these five, we may imagine a triangle whose three points are any three of them, and observe this triangle night after night without discovering any change in its form. The triangle is sometimes higher in the night sky, sometimes lower; the triangle turns; but it always retains the same form. Yet once let one of these five "special" stars be included among the three points of the triangle, and the triangle is seen to move into many forms, because this one special and "different" star — this one of "the five" — does not follow the pattern of movement common to all the other stars in the sky.

These five "different" stars are therefore called "movable stars," or "planets." In contrast to them, all the other stars are called "fixed stars." The word "finxed" refers to their positions with respect to other stars, not to any fixed altitude nor permanent, immovable position.

Three of these planets may appear at any or all hours of the night. The other two are never seen at midnight; they appear only in the morning and evening sky. The three planets which may appear all night long are Mars, Jupiter and Saturn. Those two which are never seen at midnight, but only in the morning and evening sky, are the planets Venus and Mercury.

**In this chapter figures were updated and text edited by the staff of Savitria Press.*

JUPITER

The brightest of those first three planets which may appear all night long — also the brightest of the three and brightest star ever seen all night — is Jupiter. When Jupiter shines all night, it rises evening after evening among the same group of fixed stars. Repeated observation, night after night, will show its position among them, however, to be shifting — even after a week, more obviously after a month.

Jupiter may, for instance, have progressed a considerable distance to the right. Then continuing observations over several months may reveal this progression to the right to reserve itself, so that Jupiter is seen to be moving in the very opposite direction — to the left.

Figure 14 shows Jupiter's movement in 1977. From January through July of that year Jupiter was in the star-group of Taurus moving to the right until sometime in January, when it turned to the left. In the summer it moved into Gemini. Just at the end of the year, it started again to reverse its direction of movement, proceeding once more to the right and so continuing approximately as far as it had moved to the right at the beginning of the year. Still later its course moved again to the left.

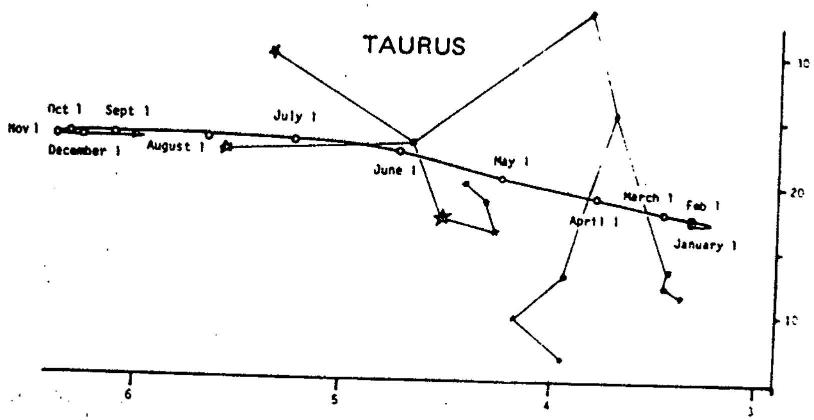


Figure 14. Movement of Jupiter in 1977.

The numerals at the right in Figure 14 show the number of degree of Juipter's arc above the Celestial Equator at each stage of the planet's path, and those at the bottom of the diagram indicate the advance in the daily course. If at a given moment the point marked "4" is above "due south," the point marked "5" will be at that position an hour later.

MARS

Mars, too, is seen from time to time for extended nocturnal periods, shining bright and slightly reddish in the night sky. Its position among the surrounding stars is also seen to shift if repeatedly observed night after night. Its changes are even greater than those of Jupiter.

Figure 15 shows the positions of Mars in the first half of 1980, when the planet cuts a picturesque curve in the constellation Leo. At the

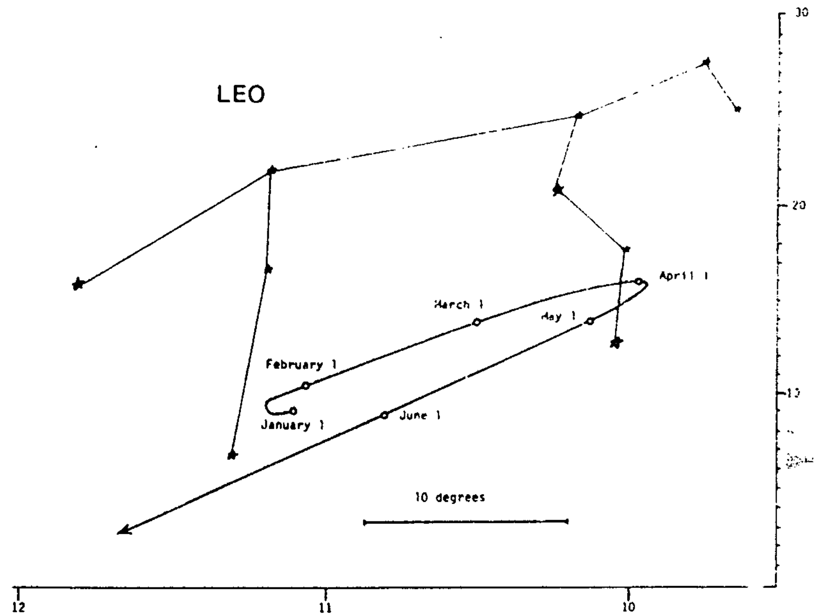


Figure 15. Positions of Mars in the first half of 1980.

beginning of that year the path of Mars moves to the left; sometime in January it turns to the right, until April when it curves again to the left. In May and June it moves farther and farther to the left. The scale at the right in Figure 15 marks the number of degrees of the path of Mars at that period above and below the Celestial Equator. The scale at the bottom of the chart marks hours of passage along its daily course, the zero point being the position of the sun when it is on the Celestial Equator on March 21.

To the left of Leo is Virgo. Both these star-groups belong to the twelve constellations comprising the zodiac. When Mars continues on its course to the left, it passes through all twelve zodiacal groups which extend in a vast ring around the full circle of the sky. Then Mars will pass again through Leo.

The curve of the path of Mars is different every year. Figure 16 shows the Mars curves from 1926 to 1941. The sequence started with an open

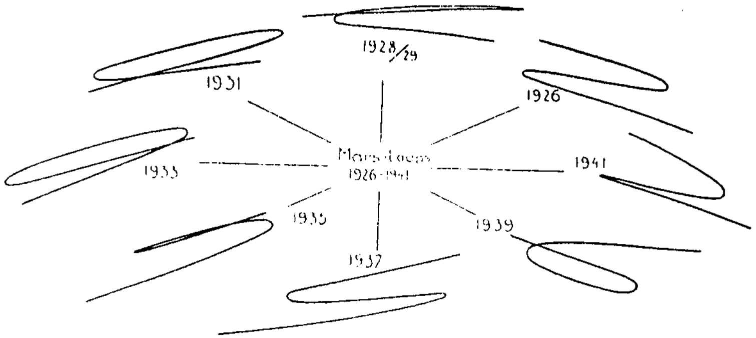


Figure 16. The curves of Mars from 1926 to 1941, showing the orderly development of their metamorphoses.

"Z" form in 1926. In 1928 and 1929 the form shifted to a narrow loop. The loop widened in 1931. In 1933, the loop form followed a line which crossed its own path, moving from left to right at the crossing-point. The loop narrowed in 1935. Then in 1937 the path of Mars became again an open form in the shape of an "S." The loop line turned downward in 1939. The form for 1941 was a transition from that downward loop to an open "Z" type of form.

This sequence is characteristic not only of the path of Mars, but also of that of Jupiter. Jupiter goes through a retrogression once every year, and its loops are smaller.

The loops of Saturn are still smaller and narrower.

VENUS AND MERCURY

The other two planets, Venus and Mercury, which appear only at morning and evening, are always seen in the vicinity of the sun, either a little closer or a little farther away from it. They either precede the sunrise in the morning, appearing to the right of the sun, or else they follow the sunset, when they appear to the sun's left. Whether Venus is to the right or to the left of the sun determines whether it is the morning or the evening star.

Figure 17 shows the positions of Venus as it appeared in the vicinity of the sun in 1977. At the beginning of that year Venus stood to the left of the sun. Because its position was at the same time higher than the sun, Venus was at that time in good visibility as the evening star. At the beginning of April, Venus was close to the sun. It came close to the sun again at the very end of the year

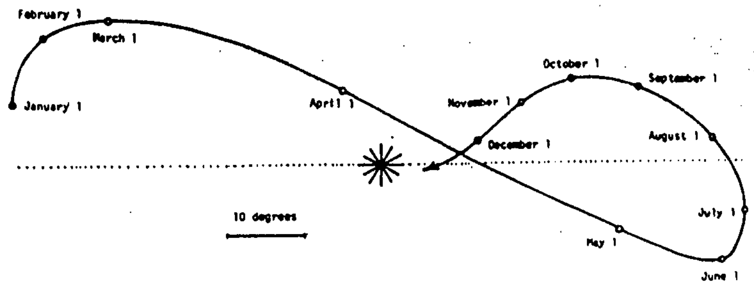


Figure 17. Positions of Venus as it appeared in the vicinity of the sun in 1977.

Most of the year, Venus was seen as a morning star. It was not, as such, however, in very good visibility, while it was lower than the sun in May and June. Figure 17 shows the distance of 10°, as that picture is scaled (equivalent of a "hand's width" as seen in the sky), in the arc of Venus, and makes it possible to judge the planet's distance from the sun at different times. Throughout the year, Venus is never farther than five "hand-widths" from the sun.

Its curve is different from year to year, showing even greater variety than the curves of Mars, Jupiter and Saturn. Depending upon its curve, Venus's visibility varies. In some years it is to be seen a great deal, both as the morning and as the evening star; in other years it is visible much less of the time. When its visibility in the United States and in Europe is poor, it is much more to be seen in the southern hemisphere, where its prominence is the reverse of what it is at latitudes north of the equator because it is so near to the sun.

Mercury, being still closer to the sun, is therefore visible only at dawn and dusk. If it is to the right of the sun, it is the morning star; if to the left, it is the evening star. Its visibility changes much more frequently than that of Venus. Venus passed once across the sun in 1977; Mercury, six times in 1979.

Figure 18 shows the positions of Mercury in relation to the sun in 1979. The distance of 10° on this scale (a "hand's width" as seen in the

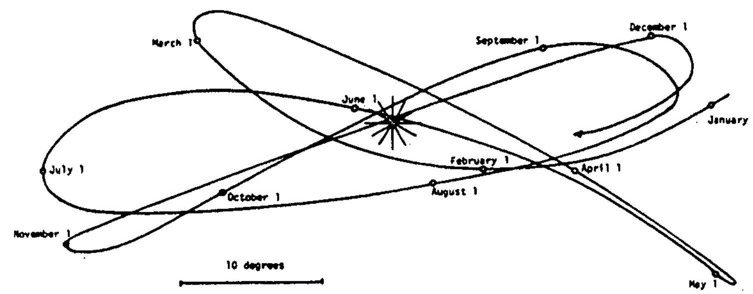


Figure 18. Positions of Mercury in relation to the sun in 1979.

sky) is indicated below the diagram. From this unit of measure as a guide, it is seen that Mercury remained always within 30° of the sun in that year.

Its curves form three loops to the left and three loops to the right in the course of a year. Some of the loops are more rounded, like the loop to the right downward; some are narrower, as the middle loop to the right. Some loops are more rounded, as the middle loop to the left; some are narrower, like the loop to the right downward. Some loops are longer, others shorter.

Figure 19 shows the Mercury loops of the following year.

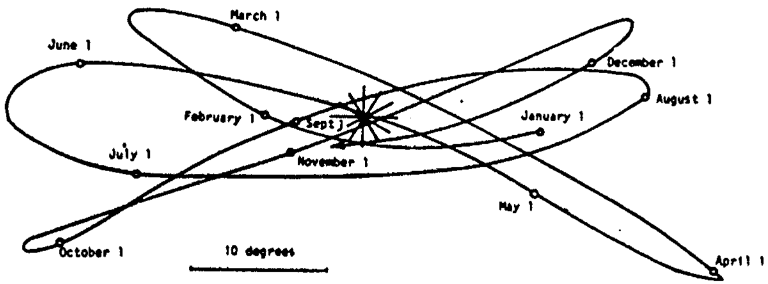


Figure 19. Mercury's loops in 1980.

Comparing Figures 18 and 19 shows numerous changes from one year to the next. The loop in Figure 18 to the right downward becomes more round in Figure 19. The two upper left loops of Figure 18 come closer together in Figure 19, etc.

The times of Mercury's clearest visibility in any year are easy to determine. In 1980, for instance it is best visible as a morning star at the end of November and as an evening star at the end of February and again at the beginning of July. At these times, Mercury is higher than the sun, as well as farthest away from it, and therefore least likely to be obscured by the sun's brightness.

Mercury's clearest visibility in 1980 is in the southern hemisphere, where visibility is the reverse of what it is in the northern hemisphere. Its clearest morning visibility for the southern hemisphere is in April; its clearest evening visibility, the end of October. Because the sun is highest in summer and lowest in winter, and Mercury stays in the vicinity of the sun, Mercury rises close to the sun in summer and sets close to it in winter.

To the observer marking the sun's positions above the southern horizon at noon day after day throughout the year, not only its rising and falling are evident, but also an another kind of movement is seen. At some times of the year the sun has already passed due-south at noon, and stands already slightly to the right of that point. At other

times of the year the sun has not yet reached due-south at noon, and stands to its left.

There is great mobility in our cosmos.

The sun's position at noon, day after day progressively, follows the form of a "figure 8," or lemniscate (see Figure 20). The dotted horizontal straight line shows the Celestial Equator, and the mark at its center indicates the direction of exact south. Half of the "8"-shaped curve is above, and half below, the Celestial Equator. Photographs of the sun at noon, taken each day on the same film, would show the "figure 8" form as completed after one full year.

The same type of photograph of Mercury would show this planet not

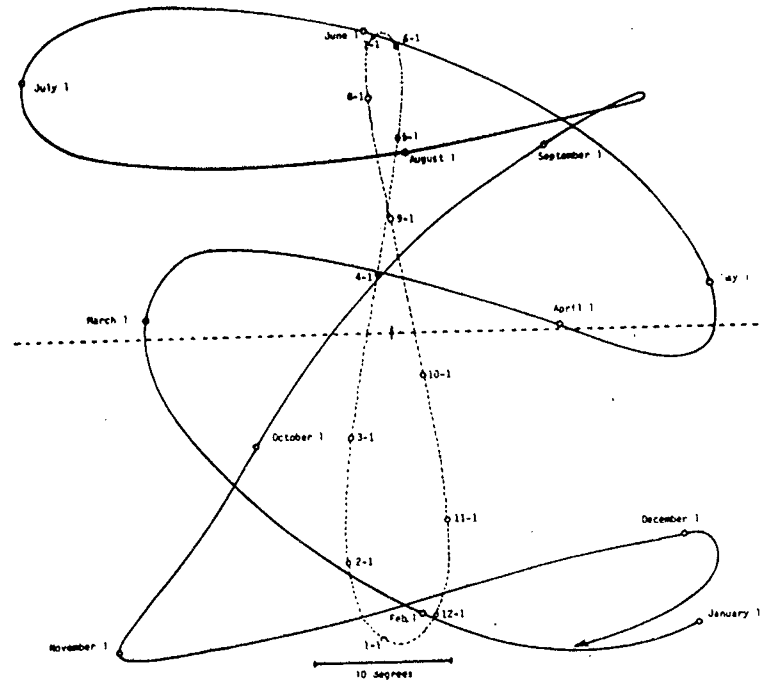


Figure 20. Mercury's path follows in close relationship to that of the sun, above and below the Celestial Equator [dotted horizontal line] in summer and winter respectively, throughout the year. Its 1979 curves are shown here.

only going high with the sun in summer and low with the sun in winter, but also following a curve from left to right of the sun and above and below the sun. Figure 20 shows this curve for 1979. Following the direction of the arrow, this Mercury curve starts in low winter positions, then rises by mid-March to a level about 7° above the Celestial Equator, afterward drops again until April, then performs its major rise from April until June. In this major rise, Mercury advances with the sun in April and May (see Figure 18), as the sun lifts in the sky to summer height.

Mercury reaches a second maximum altitude the middle of August, then rapidly descends until November 1. After another rise in November, Mercury drops to its winter low in December. This type of curve, showing Mercury's successive positions at a given time each day, most effectively suggests its quick mobility through the course of a single year.

Figure 21 shows the corresponding but considerably different curve of Mercury for the following year, 1980. Here again the dotted

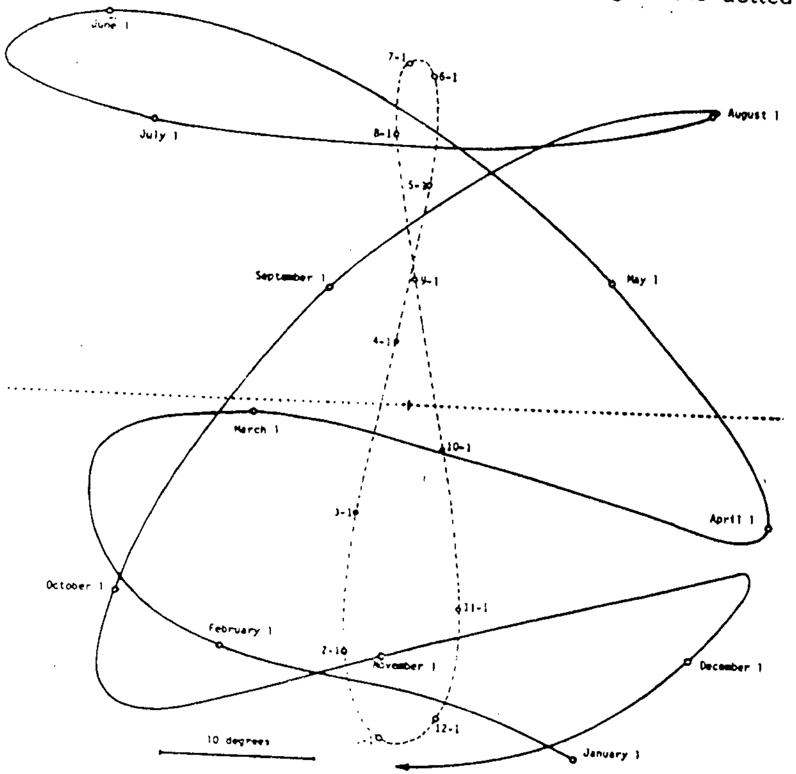


Figure 21. Curves of Mercury in 1980 show both similarities and differences, compared with those of 1979 [See Figure 20].

horizontal line indicates the Celestial Equator; the dotted "figure 8" line, a joining together of the noon positions of the sun throughout the year. The curve of Mercury again starts low in winter, then lifts to summer heights, and finally descends once more in the following winter.

A comparison of the Mercury curves for 1979 (Figure 20) with that for 1980 (Figure 21) shows some elements of similarity and reflects in other respects considerable change. The loop in the upper left, for instance, has shrunk in 1980 as contrasted with 1979, but the loop in the upper right has slightly expanded. For example, the loop in the middle left, which reached up in 1979 drops down in 1980. Every curve is an individual event. In no two years is that curve ever the same.

Figure 22 shows another picture of the Mercury curve of 1980 — once more in a three-dimensional aspect. It is identical with the curve shown in Figure 21, but omitting all references to months, times and positions of the sun. The solid lines in Figure 22 indicate the portions of its path wherein Mercury is seen to light up most and shine; the dotted lines, those portions wherein it fades more from view, loses visibility. Mercury comes nearer to us in the solid lines; is farther away in the dotted lines.

The Mercury curve is seen to change every year. The picture for each year is different. Such pictures of palentary appearances suggest the remarkable flexibility of cosmic events, and help to make this cosmic flexibility manifest.

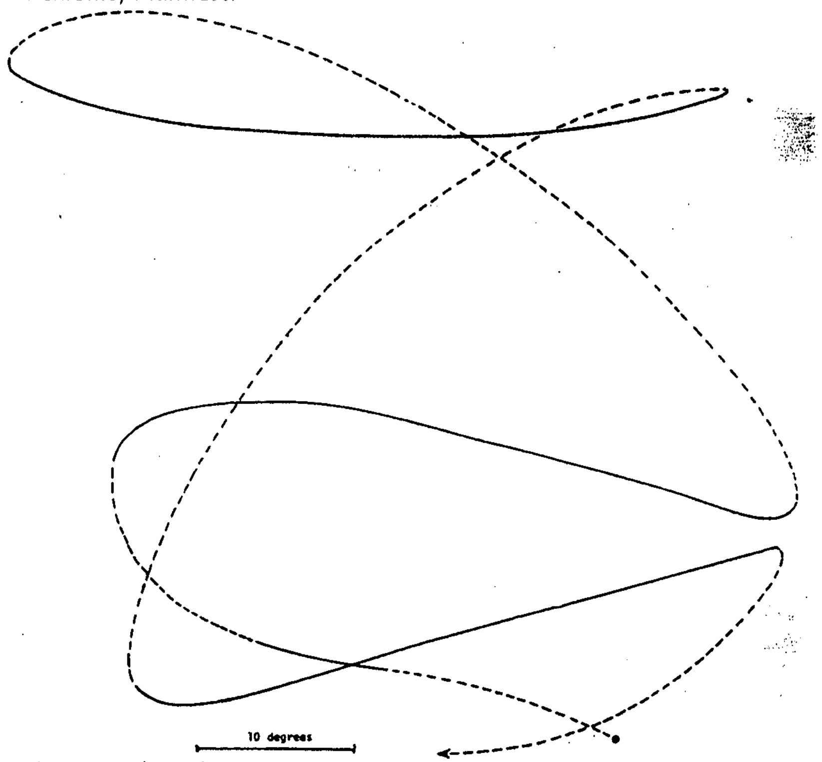


Figure 22. Three-dimensional aspect of Mercury curves in 1980, with solid lines indicating portions of its path in which Mercury lights up and shines and is nearer to us, and dotted lines those portions where it loses visibility and is farther distant.

VIII
OBSERVING THE ZODIAC: PRECESSION OF THE EQUINOXES, THE COSMIC YEAR

There are twelve star-groups which are distinguished from all others, because they and only they form the background against which the positions of the sun, the moon and the planets are established for human observation. They comprise what is called the "zodiac." Figure 23 shows the twelve zodiacal groups.

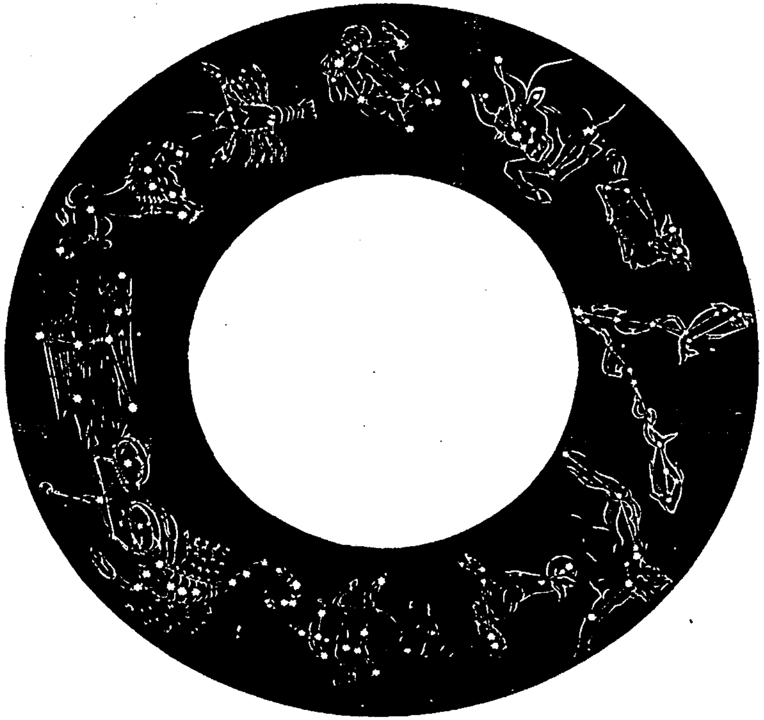


Figure 23. The zodiac's twelve star-groupings, or constellations.

At the top of the circle in this picture is the constellation Gemini; to its immediate right. Taurus. Thence around the circle clockwise appear the twelve zodiacal star-groups in the order in which their names and traditional signs are listed below (the signs are those commonly used in astronomy):

Gemini	♊	Sagitarius	♐
Taurus	♉	Scorpio	♏
Aries	♈	Libra	♎
Pisces	♓	Virgo	♍
Aquarius	♒	Leo	♌
Capicorn	♑	Cancer	♋

Among the stars at night, part of the zodiac is always visible. From the position of the sun in relation to that of the moon or any planet, it is always possible to locate the zodiac. A straight line connecting the position of the sun (as judged, for instance, by the center of the after-glow on the western horizon) with the moon or a planet, then continued from horizon to horizon across the whole sky, will pass through the zodiacal star-groups.

Two of these twelve zodiacal groups, Pisces and Virgo, are precisely on the Celestial Equator. They rise with it in the east, and set with it in the west. They never leave it. The zodiacal star-groups of Leo, Cancer, Gemini, Taurus and Aries run their daily courses above the Celestial Equator; those of Aquarius, Capricorn, Sagittarius, Scorpio and Libra, below it.

The highest of the daily courses of all these twelve star-groups above the Celestial Equator is the path of Gemini; the lowest, that of Sagittarious. When Gemini stands high in the southern sky, it is near to the zenith. At such a time, the visible portion of the zodiac spans the sky from the east high over the south and down to the west. The zodiac rides in its highest position.

HARMONIC MOVEMENTS OF THE ZODIAC

When Sagittarius stands at its high point in the southern sky, it is low above the horizon as compared with the other constellations of the zodiac. At such a time, the visible portion of the zodiac is in its lowest position. Once in every twenty-four-hour period the zodiac appears in its high position, and once — twelve hours later — in its low position.

Through the course of the year, its high and low positions come at different hours. At Christmas, the high position comes at midnight; in June, the low position at that hour. All the lifting and lowering movements of the zodiac proceed in harmonic motion, spreading a truly beautiful rhythm around us.

In daytime, when we do not see the stars, the zodiac still rides above us. It is always there, though by day we do not see it because of the brightness of the sun. It moves in the path followed by the sun. Therefore, at noon in summer, when the zodiac stands in high position, the zodiacal star-group of Gemini is concealed directly behind the sun. At noon in winter, when the zodiac stands in low position, the zodiacal star-group of Sagittarius is directly behind the sun.

In March and in September, when the sun is at the height of the Celestial Equator, it is in Pisces and Virgo respectively. The position of the sun on March 21 is marked by a zero in Figure 15 (page 47). The constellation of Pisces is invisible in March, because the sun shines then directly in the midst of this star-group. Because the stars move ahead of the sun in their daily course, each month another constellation rides through the sky with the sun —

In March . . . Pisces	In September . . . Virgo
In April . . . Aries	In October . . . Libra
In May . . . Tarus	In November . . . Scorpio
In June . . . Gemini	In December . . . Sagittarius
In July . . . Cancer	In January . . . Capricorn
In August . . . Leo	In February . . . Aquarius

THE SIDEREAL YEAR AND PRECESSION OF THE EQUINOXES

Over long millennia of time, the constellations of the zodiac move sufficiently ahead of the sun each year that at the beginning of spring, on March 21, the sun starts traveling through the sky in a different zodiacal sign. The zodiacal star-groups have moved ahead of the sun, slowly but continuously, so that the next star-group in the zodiac has at last advanced far enough forward to begin the spring of the year with the sun.

Thus, at the time of the Greek and Latin civilizations, each year Aries began riding with the sun every March 21, marking the start of spring. Aries was in that ancient age in the spring position of the sun on the Celestial Equator, and in relation to the sun Pisces then occupied the present position of Aquarius, and Aquarius that of Capricorn. Capricorn was then in the present position of Sagittarius, and Cancer in that of Gemini.

In still earlier times, Taurus occupied the spring position of the sun. The zodiac was at that time two constellations removed from the yearly positions of today in relation to the sun. The average time that passes before one constellation is replaced by the next in its relation to the sun is 2,160 years. Twice this number of years — or 4,320 years — backward in time, the ancient Egyptian era was in flower.

Not only the constellations of the zodiac, but all stars, change in this way in their relation to the sun. The position of the Pole Star was formerly occupied by other stars long millennia ago. The rhythm of these changes for the whole zodiac is twelve times 2,160 years, or 25,920 years, traditionally called the "cosmic year" or the "Platonic year." In 25,920 years from now, the sun will be riding again in the same zodiacal sign in which it moves now at the spring of the year.

Nothing in our universe is stationary. Everything is in a flow of motion and change, as Heraclitus notice 2,500 years ago.

CLOSING REMARKS

Would any one dare consider the material contained in these chapters too complicated to be called an Introduction to Astronomy? Certainly young boys and girls have received it in the past with interest and enthusiasm. Even many who are far from being botanists study the forms of the flowers and the leaves, which are scarcely too complicated for the understanding despite their intricate richness. Why should a study of the stars seem more forbidding?

For human beings, old and young, the direct language of cosmic facts creates a fresh, lively attitude toward the cosmos, such as no kind of man-made interpretation nor extrapolation can possibly produce with respect to our solar system — despite all manner of celestial explosions, dazzling speeds, cosmic collisions, etc., etc.

Can minds crammed all week long with such abstract views and conceptions have restored for them in a few short Sunday school lessons a real reverence for the universe? Vastly more important than great mountains of detail, particularly for young people, is the whole human attitude of the individual communicating it.

The stars will reveal their secrets — the secrets of the universe — to him who looks inquiringly upon them. Understanding of what they tell about themselves can help the inquiring observer develop the human attitude toward the whole of life which opens other people to his communications and renders the facts contained in them comprehensible and of value.

So great is what the stars can tell men of orderly movement and harmony. So great is what human beings can tell one another of the deepest and most impressive truths of man's life in a universe of such grandeur as the stars demonstrate it to be.

The End

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