

MORNING AND EVENING STARS FOR 1910

BY PROF. FREDERIC R. HONEY, TRINITY COLLEGE

The popular expression "morning and evening stars," while signifying those planets which at different periods illuminate our skies, the observer will naturally include in his study of the heavens the fixed stars whose name indicates that they will be invariably found in the same places on the celestial sphere. Their positions in the heavens may be sooner fixed in the memory by first observing the stars of higher magnitude, whose conspicuous brightness easily distinguishes them from those of varying degrees of lesser brilliancy. In this way the heavens may be triangulated visually, and in process of time all the constellations may be easily identified. For such observations a star map is indispensable; and the positions of the stars should be located by right ascensions and declinations, which are given in the Nautical Almanac. The position of the celestial equator, from which declinations are measured, may be determined approximately by observing the stars which are near it on the star map; and in the same way the position of the first meridian, intersecting the celestial equator at a point from which right ascensions are measured, may also be defined. Following this method, seven-eighths of the celestial sphere (at latitude 40 deg.) will come within the range of vision, and the heavens may become an "open book." The distances to the fixed stars are so great that (except to the astronomer) their apparent positions are not disturbed when the earth reaches the opposite point in its orbit—a distance equal to about one hundred eighty-six million miles. For purposes of observation, the earth may therefore be regarded as

the center of the celestial sphere, around which the stars appear to revolve once in a sidereal day, which is nearly four minutes shorter than an ordinary day, a difference due to the revolution of the earth around the sun once in 365¼ days. During this period the earth makes 366¼ rotations on its axis. As a consequence, the stars rise nearly four minutes earlier every day, and during the year the major part of the celestial sphere comes within the range of vision at any assigned hour of the twenty-four. The positions of the planets are continually changing; and in order to discover the region of the heavens in which to search for them, their situation relative to the sun and earth should be determined as illustrated in Plots 1 and 2. The plots of their orbits have been printed in the SCIENTIFIC AMERICAN in the issues of the following dates: March 17th, 1906; February 9th, 1907; February 15th, 1908; and March 6th, 1909; and the positions of all the planets are shown for every day of each year. Together they exhibit the courses of all the planets for the five consecutive years from 1906 to 1910 inclusive. The orbits of the asteroids, which are between those of Mars and Jupiter, Saturn, Uranus, and Neptune, are too small to be visible to the naked eye; the largest of over six hundred being not more than five hundred miles in diameter. Several of the orbits are very eccentric and inclined at large angles to the plane of the ecliptic.

THE SUN AND PLANETS.

In order to bring the plots of the orbits of the planets within the limits of this page, the orbits of the terrestrial planets, which include Mercury, Venus, the earth, and Mars, are drawn to as large a scale as the space permits. Since the diameter of Neptune's orbit is thirty times that of the earth, the plot of the orbits of the major planets, including Jupiter, Saturn, Uranus, and Neptune, are drawn to a scale which is very much reduced. In this plot the orbits of the earth and Mars are repeated by the reduced scale; the region of the asteroids or minor planets is indicated, and the plots together show the continuity of the solar system. The plane of this paper may be taken to represent that of the ecliptic or the earth's orbit; and if it be placed in a horizontal position, a planet which is on one side may be described as being situated above, and on the other side as below the ecliptic. In the plot of each orbit the full line represents that part which is above,

and the dotted line that part which is below the ecliptic. The ascending and descending nodes *N* and *N'* are respectively the points where the planet passes from the space below to that above, and from the space above to that below the ecliptic; and *P*, the perihelion,

by the same distance at aphelion in July. The center of the orbit is at *a*. At a velocity of 18.5 miles per second the earth moves each day on the average nearly 1,600,000 miles, with an increase of velocity at perihelion and diminution at aphelion; making the complete revolution in 365¼ days. The position of the earth is shown at intervals of four days at Greenwich, noon; and intermediate positions and dates may be interpolated by subdivision.

MERCURY.

The plane of Mercury's orbit is inclined at a greater angle (7 deg.) than that of any other of either the terrestrial or major planets. Its eccentricity is also greater than that of any of the planets. By the eccentricity is meant the distance from the center of the orbit to the sun (the linear eccentricity) divided by the semi-major axis. The linear eccentricity is 7.4 million miles; and the length of the major axis is 72 million miles. Mercury's mean distance from the sun is therefore thirty-six million miles with a diminution and increase of 7.4 million miles respectively at perihelion and aphelion. At perihelion the planet moves at a velocity of thirty-five miles a second, which is diminished to twenty-three miles a second at aphelion. Mercury's orbit is a marked illustration of the first two of Kepler's three laws. First: The orbit of each planet is an ellipse, with the sun in one of its foci. Second: The radius vector (i. e., the orbit radius whose length is continually changing) of each planet describes equal areas in equal times. For example, the area of the triangle with the sun as its vertex, and with a base equal to that part of the orbit

included between the dates of August 30th and September 7th, is equal to the area of the triangle with the same vertex and for a base that part included between the dates October 9th and October 17th. In conformity with the second law, the length of the base of the triangle is continually diminishing from perihelion to aphelion, and increasing from aphelion to perihelion; which accounts for the rapid variation in the planet's velocity. Mercury's revolution around the sun is accomplished in very nearly eighty-eight days (87.97). This is repeated over four times during the year, and four dates are attached to each position. Owing to the great variation in the planet's velocity, the positions are shown for every second day.

VENUS.

The orbit of Venus is inclined to the plane of the ecliptic at an angle of 3.4 deg. The eccentricity is less than that of any other planet, and is barely visible in the plot; the distance from the sun to the center of the orbit is less than a half a million miles. As a consequence, the velocity of the planet in its orbit at a mean distance of 67.2 million miles is nearly uniform at the rate of 21.9 miles per second. The period of revolution is 224.7 days. The dates outside the orbit are those which belong to the first revolution; those within, to the second revolution; and that part of the orbit included between the positions of the planet for the first and second revolutions represents the distance traversed in seven-tenths of a day.

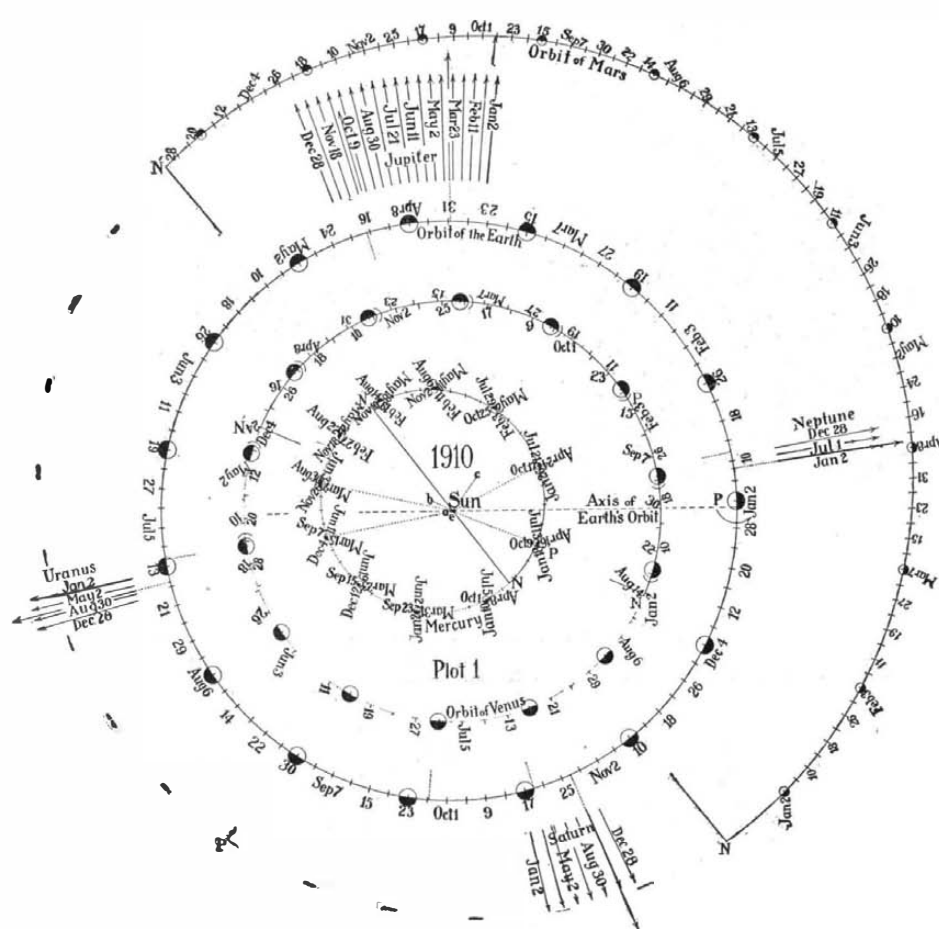
MARS.

The orbit of Mars is inclined at an angle of 1.85 deg.; and the center *c* is 13.2 million miles from the sun. The mean orbit velocity is fifteen miles per second; and the mean distance from the sun is 141.5 million miles. The period is 1.88 years.

THE MAJOR PLANETS.

The inclination of Jupiter's orbit is 1.3 deg., with a linear eccentricity of 23.3 million miles. The planet's orbit velocity is 8.1 miles per second at a mean distance of 483.3 million miles. The period of revolution is 11.86 years. The direction in which the planet is seen from the sun is shown at intervals of twenty days.

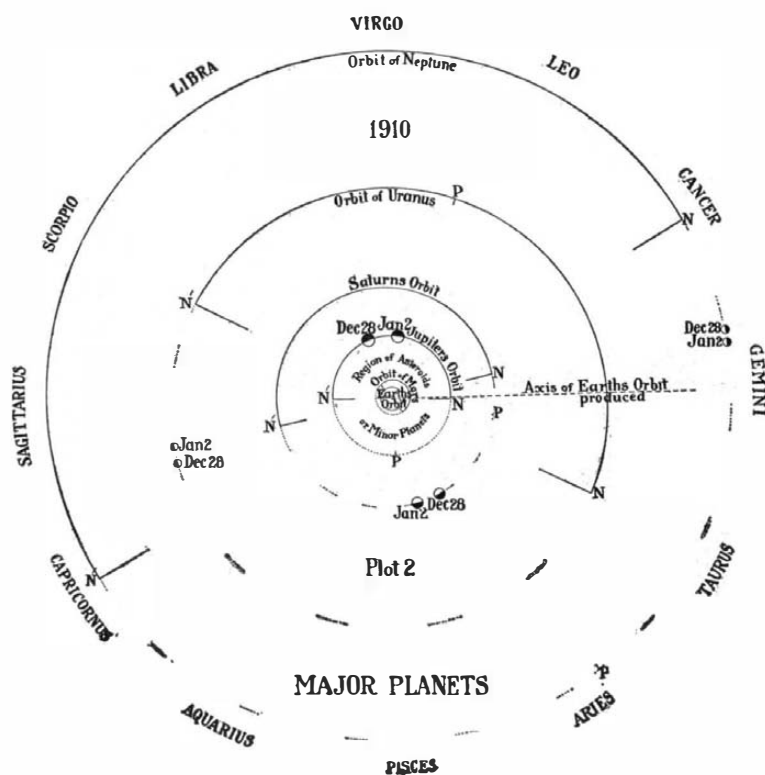
Saturn's orbit is inclined at an angle of 2.5 deg. The eccentricity is nearly fifty million miles; and the mean distance is 886 million miles. The planet's velocity (Concluded on page 153.)



PLOT I.—POSITIONS OF THE PLANETS.

is the point of the planet's nearest approach to the sun. A line joining the points *N* and *N'*, the line of nodes, is the intersection of the plane of the planet's orbit with that of the ecliptic. To avoid confusion, only a portion of this line is represented, except in the case of Mercury's orbit.

It is obviously impossible to represent the diameter of the planets by the same scale. Even those of the giant planets Jupiter and Saturn would shrink to mere points. The same may be said of the sun itself in Plot



PLOT II.—PLANETARY ORBITS.

2; but in Plot 1 its diameter (866,400 miles) would be correctly represented by a measurement a little more than one-half of *e*, which is the linear eccentricity—the distance from the sun's center to the center of the earth's orbit.

THE EARTH.

The earth's mean distance from the sun (92.9 million miles) is diminished by a little over one and one-half million miles at perihelion in January; and increased

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(Concluded from page 152.)

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MORNING AND EVENING STARS FOR 1910.

(Continued from page 146.)

ity in its orbit is 6 miles a second, and the period is 29.46 years. Saturn's position is indicated at intervals of sixty days.

The plane of the orbit of Uranus is inclined at an angle of 0.77 deg. to the ecliptic, which is less than that of any of the other planets. The mean velocity is 4.2 miles per second at a mean distance of 1,781.9 million miles. The center of the orbit is 82.6 million miles from the sun. The planet completes its revolution in 84.02 years; and its position is shown at intervals of 120 days. Neptune's orbit is inclined at an angle of 1.8 deg. Notwithstanding the planet's great distance, the linear eccentricity is only twenty-five million miles. The orbit velocity is 3.4 miles per second, and the mean distance is 2,791.6 million miles. The revolution is accomplished in 164.78 years; and the planet's position is shown at intervals of 180 days.

Neptune's distance from the sun is a very little over thirty times that of the earth

$$\left(\frac{2,791.6}{92.9} = 30.055 \right).$$

The square root of the cube of this number gives the period, which is 164.78 years. This illustrates Kepler's third law, viz.: The squares of the periods of the planets are proportional to the cubes of their mean distances from the sun. By similar computations the relations between the periods and mean distances of all the planets may be shown to be those which are here given.

HOW TO DETERMINE THE MORNING AND EVENING STARS.

A planet whose orbit is within the earth's orbit is morning star between inferior and superior conjunctions, and evening star between superior and inferior conjunctions. Prior to conjunction a planet outside the earth's orbit is evening star, after conjunction it is morning star. It should be noted, however, that when a planet is near conjunction, it is not far enough away from the sun for observation. The longest arrows indicate the directions in which the major planets are seen at opposition; the shortest arrows, the directions in which they would be seen at conjunction if the sun were out of the way. At the date of opposition a planet is visible before and after midnight, and is therefore both morning and evening star.

If the page be turned about one-quarter of the way around, so that the earth in Plot I on January 8th (the date of the opposition of Neptune) is between the reader and the sun, the positions of all the terrestrial planets on this day may be seen without turning the head. The earth rotates in the direction of the arrow. At sunrise an observer emerges from the shadow area; at sunset he enters it. All planets which in the plot are on the right rise before the sun, and are morning stars; those on the left set after the sun, and are evening stars. On January 8th Neptune is above the horizon before and after midnight, and is both morning and evening star. Conjunction of Uranus with the sun occurs on the 11th. Previous to this date Uranus is evening star, and subsequently morning star. On January 7th Saturn is at quadrature, and is evening star. On January 4th Jupiter is at quadrature, and is morning star. On January 17th Mars is at quadrature, and is evening star. On January 25th Mercury reaches inferior conjunction. Before conjunction the planet is evening star, and after conjunction it is morning star. During the month of January Venus is evening star. The planet is at inferior conjunction on February 12th, and after this date is morning star.

The table gives the dates of conjunction (Concluded on page 154.)

The Scientific American Boy

By A. RUSSELL BOND

has just been reported as one of the books at present most in demand at
The New York Public Library, Circulation Department



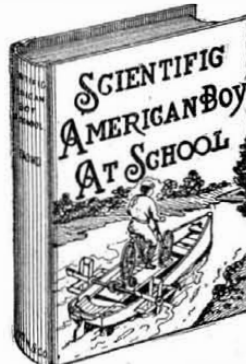
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HAIR GROWS when our Vacuum Cap is used a few minutes daily. Sent on 60 days' free trial at our expense. No drugs or electricity. Stops falling hair. Cures dandruff. Postal brings illustrated booklet. Modern Vacuum Cap Co., 556 Barclay Block, Denver, Colo.

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SELENIUM CELLS of novel design. Model 5: Work surface ¼ x ¼ in. Resistance 2000 ohms; in light 500 ohms. Price \$2. W. S. Gripenberg, V. Kaiken 4, Helsingfors, Finland.

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LISTS OF MANUFACTURERS.

COMPLETE LISTS of manufacturers in all lines supplied at short notice at moderate rates. Small and special lists compiled to order at various prices. Estimates should be obtained in advance. Address Munn & Co., Inc., List Department, Box 773, New York.

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Inquiry No. 9057.—For manufacturers of glass and china balls, used as fixtures or ornaments on lightning rod equipment, also weather vanes for same purpose.

Inquiry No. 9058.—Wanted, firms who make machinery used for pulverizing soap-stone.

Inquiry No. 9060.—Wanted to buy machinery to manufacture seed corn racks.

Inquiry No. 9062.—Wanted to buy a plant for manufacturing muriatic acid.

Inquiry No. 9065.—Wanted to buy a second hand telephone generator.

Inquiry No. 9066.—Wanted complete outfit for export for making rice-flakes and wheat-flakes.

Inquiry No. 9067.—Wanted the address of makers of the Standard Folding Typewriter.

Inquiry No. 9068.—Wanted to buy machinery for manufacturing chewing gum, such as rolling, cutting or wrapping machinery.

Inquiry No. 9069.—For the address of firms making chain cloth, something like ladies' purses are made of.

Inquiry No. 9070.—Wanted, manufacturers of metal castings for art lamp shades.

Inquiry No. 9071.—Wanted, the address of parties making moulds for large concrete vases for flower pots.

Inquiry No. 9072.—Wanted, machinery for making fine chains, such as used by jewelers, etc.

Inquiry No. 9073.—Wanted, machinery to manufacture coconut oil; also the crude material.

Inquiry No. 9074.—Wanted, to buy old model locomotives or steamboats, such as were exhibited with nickel-in-the-slot attachments in ferry-houses, etc.

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(Concluded from page 153.)

tions and oppositions. The relative positions of the earth, the planet, and the sun, at conjunction or opposition, may be tested by a straightedge; or the date of a conjunction or opposition may be ascertained by this means. It should be noted that these dates are usually somewhere between those which are given in the plot and between Greenwich noon of one day and the next.

TABLE.

Greenwich Time.
Opposition. Conjunction.

Neptune	Jan. 8.58	Jul. 11.79
Uranus	Jul. 16.17	Jan. 11.71
Saturn	Oct. 26.87	Apr. 16.62
Jupiter	Mar. 30.75	Oct. 18.71
Mars	.....	Sept. 27.21
Venus	.....	Feb. 12.00 (inf.)
Venus	.....	Nov. 26.04 (sup.)
Mercury	.....	Jan. 25.87 (inf.)
Mercury	.....	May 25.21 (inf.)
Mercury	.....	Sept. 25.83 (inf.)
Mercury	.....	Apr. 5.46 (sup.)
Mercury	.....	Jul. 19.17 (sup.)
Mercury	.....	Nov. 12.08 (sup.)

THE DESIGN FOR THE NEW QUEBEC BRIDGE.

(Concluded from page 148.)

low height of 290 feet necessarily increases the weight of a cantilever, and if used for the towers of a suspension bridge would result in a flat catenary, requiring unusually heavy and expensive cables and anchorages. The great height of the towers and trusses in the Forth Bridge has an important bearing upon its rigidity under fast trains.

The effect of low height and narrow width in raising the weights is shown in the fact that the amount of steel to be put into the Quebec Bridge in a length of 2,800 feet is estimated at over 66,000 tons. The total amount of steel in the Forth Bridge in a length of 5,300 feet is 53,000 tons. In other words, the narrow Quebec structure would require the enormous average amount of 24 tons of steel (about half of which moreover is nickel steel) per lineal foot, whereas the wide and rigid Forth Bridge required an average of only 10 tons of carbon steel per lineal foot. It is true that the train loads assumed for the Quebec Bridge are about three times as heavy; but it is well understood that the weight of steel in any bridge of great span does not increase in anything like the same proportion as the live load.

NEW OVERHEAD ELECTRICAL CONSTRUCTION ON THE NEW HAVEN RAILROAD.

(Continued from page 140.)

building, through the Westinghouse Company, an experimental freight locomotive, preparatory to operating its whole service, freight and passenger, from New York to New Haven, a distance of between seventy and eighty miles, entirely by electric power.

At the time of its construction the present twenty-three miles of electrified line between Woodlawn and Glendale, two miles beyond Stamford, was one of the most courageous and costly experimental works ever undertaken in the broad field of electricity. The story of the unparalleled difficulties with which the company had to contend in developing the system to its present perfection, and at the same time keeping in operation one of the busiest four-track railroads in the world, has been told from time to time and in considerable detail in these columns. To-day this electric zone is running with the regularity of a watch, as may be judged from the fact that the delays through breakdown of the electrical locomotives are shown by the statistics of operation to be 100 per cent less than were the delays under operation by steam locomotives.

The experience gained during the past two or three years has revealed to the engineers some features in which the electric plant is capable of improvement. Particularly is this true of the overhead

(Concluded on page 155.)