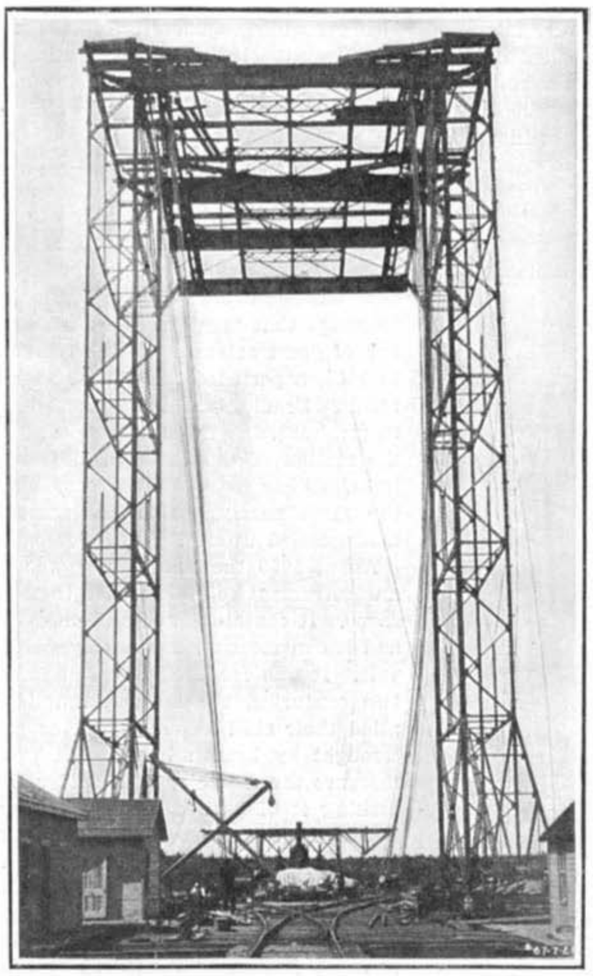
second respectively. As the wheel revolves, the teeth come in contact with a spring, which is in connection with the electric current, closing the circuit and causing the sounder to respond. The absence of the twenty-ninth tooth causes the twenty-ninth signal to be omitted, and indicates the approach of a half minute; that of the last five announces the approaching conclusion of the minute. All this takes place in the next to the last minute of the final hour. There is a third warning interval of twenty seconds before the supreme signal; but this is produced not automatically but by the telegraph operator at the observatory, and occurs when he moves the switch key, which throws out of the circuit the wheel marking the seconds, and throws into the circuit the wheel marking the minutes.

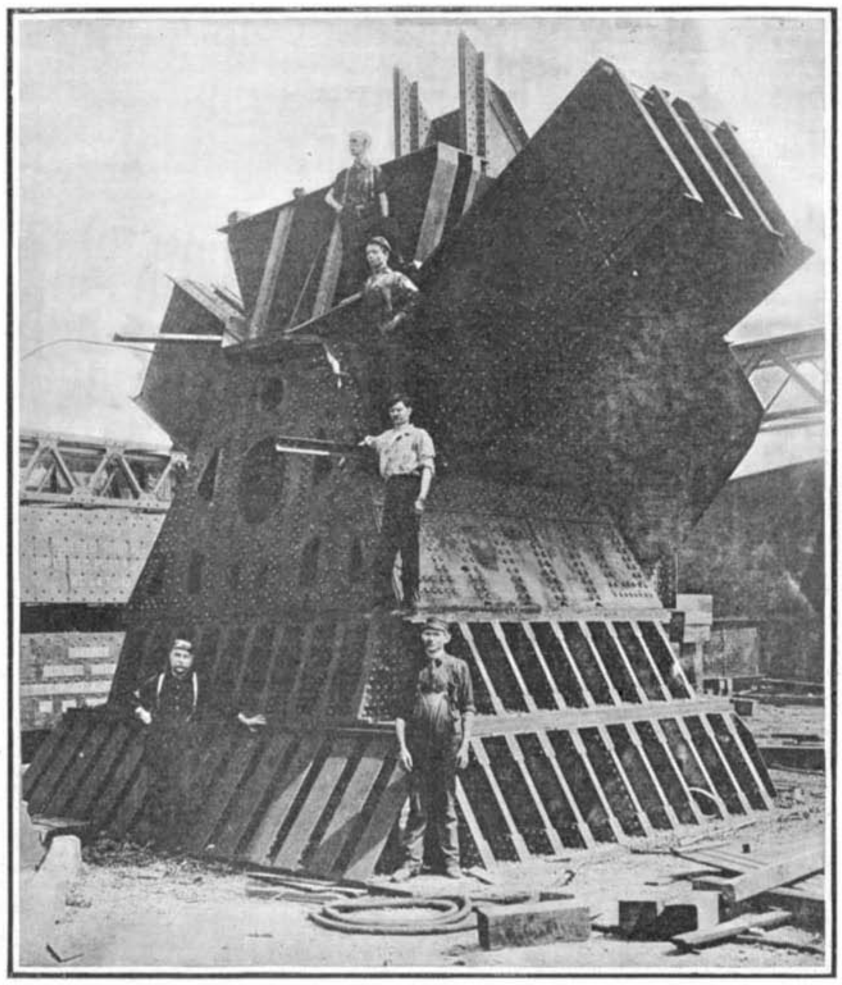
In the final hundredth of the last second of the last hour at Washington, the tooth of the minute wheel touches the spring which closes the circuit. Simultaneously, the announcement is flashed to every part of the country, the flow of the current serving of itself to release the time-balls which have been hoisted to the tops of the staffs in various cities. How rapidly the signal travels may be appreciated from the fact that it is flashed from Washington to San Francisco in one-fifth of a second. Since the time signal is sent out from Washington at noon, or at 12 o'clock standard Eastern time, and there are four different standard times in the United States, determined by geographical locations, the signal from Washington will reach the Central, Mountain, and Pacific time belts at 11 o'clock, 10 o'clock, and 9 o'clock A. M. respectively. On the last night of the year, the time signal—which in this instance marks the advent of the New Year—is sent entirely around the world, traveling over 1,180,000 miles of wire and cables, and making the circuit of the globe in ten seconds.

At present about 75,000 clocks are on the wires connected with the signal clock, but as in some instances one of these is utilized to regulate hundreds of other timepieces, the time standard as computed at the observatory is now depended upon in the principal communities throughout the country.

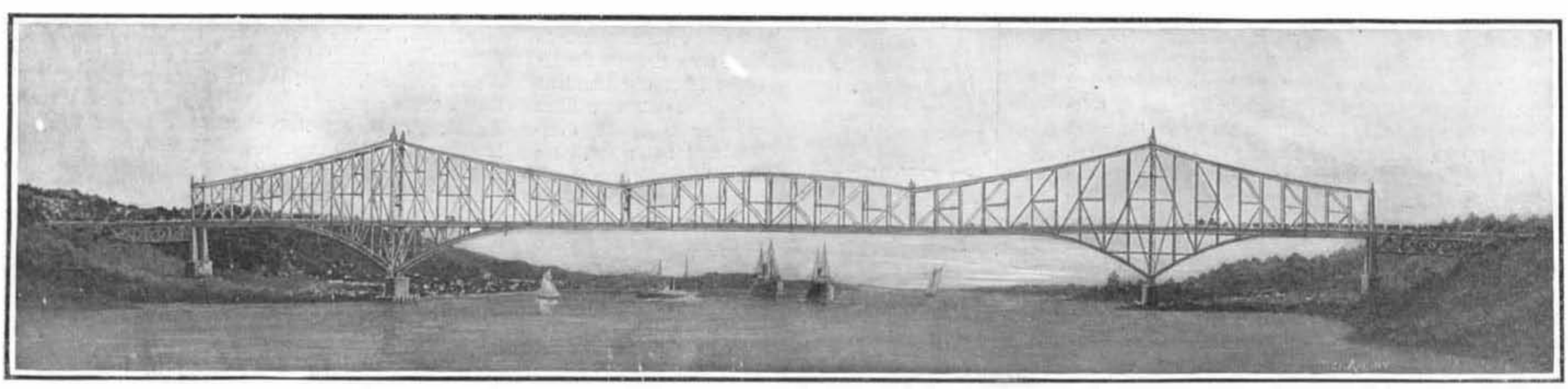
In addition to the instruments referred to, the Naval Observatory is also notable for the reason that it contains what is considered to be the finest telescope in the United States—with the exception of the Lick, in California, and that in the University of Chicago. It has a 26-inch glass and cost $46,000.



End View of Main Traveler for Erecting the Bridge.
Width, 100 feet. Height, 215 feet. Over-reach, 66 feet.



One of the Four Pedestals and Main Shoes Which Carry the Whole Weight of the Bridge. Weight 278 Tons.



River span, 1,800 feet. Two anchor spans, 500 feet each. Two shore spans, 214 feet. Total length, 3,228 feet. Height of towers, 315 feet. Suspended span, 675 feet long by 130 feet deep. Width of bridge, 75 feet.

This Bridge, Now Building at Quebec, Will Have the Longest Single Span in the World.

THE NEW ST. LAWRENCE RIVER BRIDGE.

THE ST. LAWRENCE RIVER BRIDGE, QUEBEC.

The noble bridge now under construction at Quebec across the St. Lawrence River will be one of the most notable bridges in the world. In one respect indeed it will rank as the greatest structure of its kind ever constructed; for its main span across the river will have a total length in the clear, between towers, of 1,800 feet, which is exactly 90 feet more than the length in the clear of each of the two cantilever spans of the bridge across the Forth, near Edinburgh, Scotland.

The bridge is being built by the Phœnix Bridge Company for the Quebec Bridge and Railway Company. It will cross the St. Lawrence River at a point about six miles above the city of Quebec, and about 165 miles below the city of Montreal. In the intervening stretch of the St. Lawrence there is no other crossing, and the great width of the river below Quebec renders the bridging of it below that city out of the question. Hence the new thoroughfare will prove of the greatest benefit to the districts lying between Montreal and the sea. Apart from its convenience for foot passenger and vehicular traffic, which must necessarily be local, it will form an invaluable link between the important railway systems on each side of the river. On the north side are the Great Northern Railway of Canada, the Quebec & Lake St. John Railroad, and the Canadian Pacific; on the south side are the Grand Trunk Railroad, the Intercolonial Railroad, and the Quebec Railway; and immediately upon the completion of the bridge a transfer of business between these systems will become possible.

The depth of the river, and the necessity for keeping this great waterway free from obstructions, prevent the use of piers, and call for bridging the channel with a single span. A comparative study of the problem showed that even for a span of this magnitude, a cantilever would be more economical than a suspension bridge, and the plans herewith shown were adopted.

The structure consists essentially of two giant cantilevers, carrying a huge central suspended span. It is approached by two short deck spans. The latter, which are each 214 feet in length, extend from the shore to the two massive anchor piers, to which the anchor arms of the cantilevers are bolted down, and which serve to counterbalance the weight of the central suspended span, and the heavy live load which it will be called upon to carry. The anchor arms are 500 feet long, the river arms 562½ feet long, and the central suspended span is 675 feet long. The height of the cantilevers over the anchor piers is 96 feet 9¾ inches, at the towers 315 feet, and at the portals to the center span, 97 feet 5½ inches.

The bridge has a very large capacity, the floor having a total width, out to out, of 75 feet. It is designed to carry two lines of steam railroad, two trolley lines, two highways, and two sidewalks, the latter being placed outside and the rest of the traffic between the trusses, which are spaced 67 feet between centers. The clear headway above high water is 150 feet.

In a bridge of this magnitude the parts are necessarily of great size, and the huge proportions are well shown in the accompanying illustration of the main shoe and pedestals, which are placed upon the main piers and have to carry the whole load of the bridge. They are of built-up rolled steel girders, not a single casting being used in the completed structure. The weight of each one is 278 tons. As might be expected, the size of the individual members is enormous, the sections of the bottom of the main post being 54 feet in length, 10 feet in width and 4 feet in depth, and the weight of each piece being 70 tons; while the intermediate sections of the main post weigh 24 tons, have a length of 66 feet, and a section measuring 10 feet by 4 feet. The I-bars for the most part are 15 inches and 16 inches in depth, and in a few cases they will be as much as 18 inches in depth. Most of the pins are 12 inches in diameter; but the main lower pins, which will transmit the enormous load from the cantilever to the shoes above mentioned, are 24 inches in diameter. The main chords are 54 inches deep by 68 inches wide, while the main post, over the river pier, is 10 feet wide by 4 feet in depth. The main plate floor beams are 10 feet in depth.

The bridge is being erected by means of the huge main traveler, shown in the accompanying illustration, which is 100 feet in width by 215 feet in height, and has an over-reach of 66 feet. The traveler is served by four electric hoists, and it can handle the heaviest sections, which weigh as high as 105 tons. The material for the bridge is placed in a storage yard near the end of the structure, which is 750 feet in length and is served by two 70-foot electric cranes.

A Few Facts About the International Exposition, Milan, Italy.

In order appropriately to celebrate the completion of the Simplon tunnel—one of the greatest triumphs of engineering—an international exposition under royal patronage will be held in Milan from May to November, 1906. It will be the largest European exposition ever held outside of Paris. Practically all of the European countries will participate officially, as well as several of the Asiatic nations.

In the transportation section, retrospective exhibits will show the historical development of the various methods of travel.

The dominant feature will be motion. All products, as far as possible, must be shown in connection with the processes, thus filling the halls with live exhibits.

Arrangements will be made for field tests and competitive trials in all classes where it is expedient.

An especial feature will be the automobile display, to which an entire pavilion will be devoted. This "show" will terminate in mid-summer, so that machines exhibited may be sold for early delivery.

The great success that attended the Turin exhibition of decorations has prompted the Milan authorities to set aside a special pavilion for decorative arts. They are very desirous to see the United States well represented in the section.

One large building will contain all forms of welfare work, grouped under the several heads: Mutual assistance and insurance, co-operation, savings institutions and popular credit, protection of labor and insurance against enforced idleness.

Milan is the center of the most productive section of Italy. Its population is one and a half millions, while Lombardy, no part of which is more than three hours distant, has nearly five million inhabitants.

Genoa, the port of entry, is less than one hundred miles distant. The cost, therefore, of transporting exhibits from the United States will be comparatively cheap.

Owing to the fact that a large proportion of the labor is employed in the shops and factories, there is available only a small number of food-producing workmen. This makes it imperative that supplies be secured from abroad. The authorities of the exposition recognizing this condition will inaugurate about June 15 a special food show. It will be well for the American producers of food stuffs to profit by the opportunity to display their products.

A Balloon Race.

The long-distance balloon race which started October 15 from the gardens of the Tuileries has resulted so far as known as follows:

Boulanger in the balloon "Eden" landed on October 16 at 1:40 o'clock at Annaberg, Germany, a distance of 810 kilometers from Paris. David in the balloon "Cambronne" landed at Platting on the Austrian frontier, 780 kilometers, at 7 o'clock A. M. Maison in the balloon "Concorde" landed at Neustadtsalle, Bavaria, at midnight, 610 kilometers.

Erik Tollander de Balsch, in the balloon "Finland," landed at midnight at Metz, 282 kilometers. Bachelard, in the balloon "Phoebe," landed at 10:30 P. M. in a tempest at Engreux, 290 kilometers. Le Blanc, in the "Albatross," landed at 1 o'clock A. M., October 16, at Densborn, Germany, in a snowstorm, 340 kilometers. Oultremont, in the balloon "Belgique," landed at 9:15 P. M., October 15, in a violent tempest, at Kirin, Oldenburg, 398 kilometers. Von Willer, in the balloon "Centaure," landed at 3 o'clock P. M., October 15, in a tempest at Darmstadt, 480 kilometers.

Gasnier, in the "Eole," arrived at 9 o'clock A. M., October 16, at Rulles, Luxembourg; Blanchet, in the "Archimède," at 9 o'clock at Beaufort, Luxembourg; Duprat, in the "Belle Hèléne," on the Belgian frontier, in a terrific snowstorm; Balzon, in the "Académie Aeronautique," at 7:20 A. M., October 16, near Vouziers; Jacques Faure, in the "Kabylie," at 10:30 A. M., October 16, at Kirchdorf, Hungary.

An Economy Test for American Automobiles.

On October 30 the New York Motor Club will start a six-day economy test. Runs will be made to Philadelphia, Albany, and Southampton, L. I. Strict account will be kept of all fuel and oil used and repairs made, and the results will show the cost of transportation per passenger per mile as compared with the railroad fares. No allowance will be made for repairs to tires, which will also figure in the general expenses. It is expected that some twenty cars will participate in the test, and that much interesting and valuable data will be obtained.

MEASURING THE DISTANCE OF A STAR.

BY PROF. EDGAR L. LARKIN.

No conception whatever can be had of the magnitude of the visible universe until the distances of the stars are known. None of the millions of human beings that have lived and died knew the distance of even one star from the earth until within the last seventy years. To all who lived before the advent of modern astronomy, the stars were points in a rigid firmament, only a short distance "above" the earth. They were made to give light to the earth's inhabitants, a belief incredible to relate, still lingering in the minds of some. Before A. D. 1542, ignorance was at its lowest depth. But in that auspicious year Copernicus gave his book to the world teaching that the earth revolves around the sun. Of course the people raised strenuous opposition. This was expected. But unrest and perplexity filled at least one of the ablest minds in Europe, that of Tycho. From the days of Aristotle and Ptolemy, the theory that the sun revolves around the earth dominated men's minds. Not one law could be discovered so long as it was believed that the earth is the center of the universe and at rest. Copernicus upset this doctrine, and made the sun the center of planetary motion. The great Tycho Brahe actually rejected this basic truth of nature. His mathematical powers must have told him that Copernicus was right in asserting that the earth moves around the sun. But when he saw that if this is true, the entire orbit traversed by the earth around the sun, that mighty ellipse, shrinks and subsides into nothingness, his mind was simply submerged by the immensity of the idea, and all it led to. For twenty years he toiled in an observatory making measurements with every accuracy possible without telescopic aid. And he failed to detect the slightest displacement of any star throughout the year. For it is certain that if the earth moves around the sun, the stars in position at right angles to the plane of the orbit must shift to and fro at intervals of six months corresponding with the displacement of the earth from side to side of its majestic pathway. So he taught that the earth is at rest. He could not force himself to admit that the diameter of the orbit of the earth as seen from any star is next to nothing, and that the earth is next to next to nothing, and man an infinitesimal so minute that no combination of figures is able to tell how small he is. Tycho could measure four minutes of arc with some approach to accuracy; still he could not detect the slightest displacement of a star. He at once knew that the stars were not less than one thousand times farther away than the sun. Saturn at that time was the known limit of the solar system, and if the hypothesis of Copernicus were true, the stars must be at least one hundred times more distant. This vast space again overwhelmed his mind. He argued that Nature would not so waste space. But Copernicus advanced arguments that Tycho could not overthrow, so Tycho compromised. He made the five planets revolve around the sun, and the sun around the earth, immovable in the center of the universe. At that epoch, it is probable that if Tycho had an instrument capable of measuring one second of arc and had he tested it on any star, the Copernican system would have been crushed. For he would have discovered that the stars do not shift even one second in six months. For with an annual shifting of one second of arc the star in question would have been known by Tycho to be 206,265 times more distant than the sun. Medieval minds would have collapsed and an indefinable fear would have settled down on mankind, when thinking of its littleness.

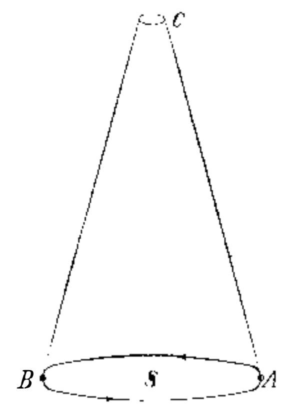
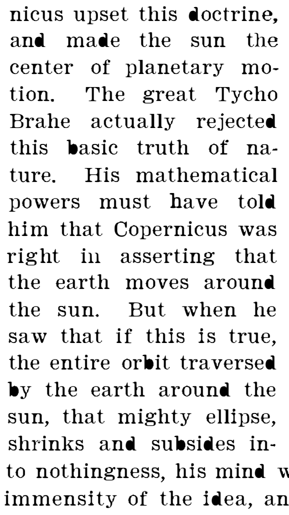


FIG. 1.—S is the sun. A is the earth's place on its orbit to-day; and B its position six months later. The arrows on the orbit of the earth show the direction of its motion. C is a very minute orbit apparently traversed by a star once each year. It took 230 years from the date of invention of the telescope to detect and measure it.



Bessel's Method of Finding the Distance of a Star.

FIG. 2.—Showing the sun S, in the center of the earth's orbit, and places of the earth at intervals of six months, at A and B. C is a star whose distance is sought. D and E are two stars, presumably so much more distant than C, that they cannot show displacement as the earth moves from A to B. The angles E, D and C, and the lengths of the lines E D, C D and E C, are often measured with precision. In this way Bessel found the shifting and thereby the distance of 61 Cygni. The reader will understand that all the angles in Fig. 2 are immensely exaggerated. All the early astronomers thought that two lines drawn to a star from opposite sides of the earth's orbit were parallel as are the two lines F and G. And more than two centuries in incessant toil were consumed in finding that they are not exactly parallel. For the line A B, 186,000,000 miles in length, is next to nothing.

Matters moved on apace. Tycho died, and the Copernican doctrine spread. Then came Galileo with his little telescope, and pointed it full on the distant stars in A. D. 1610. This aroused Europe, and the exciting search began. Astronomers now armed with instruments that magnified were able to detect far less displacements of stars than could be detected by Tycho. And they began to watch. Thus they noted the position of a star, its direction in space and its distance from other nearby stars and recorded these determinations. In six months they repeated the process with great care. They were dumbfounded. Although the earth had moved from its first place, by the diameter of its mighty orbit, no trace of motion, however minute, could be detected in the stars, even in a telescope that magnified two hundred times. A number of great astronomers tried their hands from 1542 to 1650, a period of 108 years, with total failure as a result. Bradley and Molyneaux detected a motion of stars; but in a direction opposite to any caused by the motion of the earth. This was the aberration of light. Other astronomers after elaborate trials with the most nearly perfect instruments that could be made, failed utterly.

About 1650 the micrometer was invented. This is an instrument to be attached to the eye-end of a telescope. It contains fixed and movable spider's threads, and it can measure excessively small angles and intervals. It was crude at first, but during the succeeding two centuries, the most accomplished mechanics applied their skill in making it as perfect as anything wrought by human hands. At present it is able to measure the diameter of a spider line. The object of making it of such extreme accuracy is to be able to measure the diameter of the earth's orbit as seen from the stars. For next to nothing is the diameter seen from stellar distances.

Passing the labors of the Herschels and the Struves and many other eminent astronomers, who made use of every conceivable method of finding the distance of a star, we descend rapidly to Bessel and Henderson, two illustrious observers, who finally succeeded, and reaped the reward of two centuries of labors surpassing those of Hercules. Bessel, at last, in 1840, found the distance of the star 61 Cygni. He used a different kind of telescope, the heliometer with a divided object glass. He employed the method known as triangulation. He selected two stars adjacent to 61 Cygni and measured a network of triangles, whose sides were the distances from star to star and from each star to 61 Cygni. He repeatedly measured these angles from October, 1837, to March, 1840, and had the extreme good fortune to see 61 Cygni move. And the direction of motion was as it should be, if caused by the annual circuit of the earth. He found that if we go to 61 Cygni, turn and look this way with a powerful telescope and micrometer, the distance of the earth from the sun would measure 0.3483 second of arc. The arc of any circle in length equal to the radius contains 206,265 seconds, which divided by 0.3483 equals 590,000. That is, the star is at the colossal distance of 590,000 times that of the sun. To reduce this to miles, multiply by 93 million. The result is so enormous that the ablest mathematicians never try to begin to think about it. Light, known to move with the unthinkable speed of 186,000 miles during one second of time, requires nine years to traverse the abyss. Before this work of Bessel, Henderson, in the observatory at the Cape of Good Hope, made extended observations on the bright star Alpha Centauri, not visible in the United States. His instruments were not nearly so accurate as those of Bessel; yet he detected a displacement of the star. Maclear in 1839-40 made more accurate measurements, and later observers with far better instruments have finally deduced a parallax of 0.75 second of arc. Parallax means the angle subtended by the radius of the earth's orbit as seen from a star. Now 206,265 divided by 0.75 equals 275,020, the number of times that Alpha Centauri is more distant than the sun. This is 25 trillion miles; and that star is our nearest neighbor, so far as is known. Light requires 4.3572 years to reach us from the nearest neighbor our sun has. But there are so many stars whose distances are so much greater than these two, that the 25 trillion miles is used merely as a yard-stick to measure them. Of late, these minute displacements of stars are measured on photographic plates after long exposure to the stars. Great attention is paid to parallax determinations, for without them we must forever remain ignorant of even approximate dimensions of the sidereal structure. Some astronomers think that so great precision is now had, that parallaxes of 0.1 second of arc are obtained. And perhaps fifty stars are measured with this degree of accuracy. A star with one-tenth of a second parallax is 2,062,650 times more remote than the sun. These are "near-by stars," for there are millions of stars so distant that no instrument, however