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The Fixed Stars

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THE FIXED STARS.

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The object of this paper is to give, in a popular form, a brief review of what is known about the fixed stars. Although they have always been objects of interest, have guided the mariner over trackless seas, and have inspired many sublime and noble thoughts, yet, until a comparatively recent date, only three things were known about them; viz., that they retain (approximately) their relative positions, that they are self luminous, and that they are very far away.

The remotest planet of our own system is at no insignificant distance. It is difficult for us to comprehend it when expressed in terms of any unit used in terrestial measurements. The distance from the sun, and consequently the mean distance from us, is 2,772,000,000 miles; but miles lose their meaning in such a number. An express train, running day and night, at the rate of thirty miles an hour, would be over 10,500 years in making this journey. Had the ball of the first cannon fired in the Revolutionary War continued in a straight line with the velocity with which it left the muzzle, it would now be only half way to the orbit of Neptune. So far as known this is the confines of our system, with the exception of a number of comets which, in their eccentric orbits, plunge far beyond. And what a distance it is! It is absolutely awful! Merely to think of it almost makes us dizzy.

But astronomers were not satisfied when they had reached the limits of our own system, and obtained a knowledge of the motions of its bodies and the laws by which they are governed. Success stimulates the mind and urges it to new efforts and greater achievements. Knowing that our whole planetary system is but a small part of the universe, they were anxious to pass its boundaries, and leap the mighty gulf that separates us from the fixed stars. Many attempts were made, but all in vain; many promising methods were tried, but to no purpose—until Prussia gave to the world a Bessel, and Bessel it was who led the way across this bewildering distance.

The distance to the sun is measured by solving the triangle formed by conceiving a line drawn from the sun to the centre of the earth, another from the sun tangent to the earth, and the radius of the earth at the point of tangency. The angle at the sun is the horizontal parallax. As the triangle is right-angled at the point of tangency, the radius of the earth divided by the sine of the parallax will give the distance to the sun. As the different civilized nations will next year repeat their liberality of seven years ago, and send out scientific expeditions for observing the transit of Venus, by means of which the sun's parallax is best obtained, we expect a very accurate value of this angle.

This method, however, is wholly inapplicable to the measurement of the distance to the fixed stars; for so great is their distance that the angle at a star subtended by the earth's radius is entirely inappreciable. It was necessary to look for a longer base line. Our annual journey around the sun furnishes one of great length. Now we are 92,000,000 miles on this side of the sun; in six months we shall be 92,000,000 miles on the other side: that is, we shall be 184,000,000 miles from where we now are. Notwithstanding this mighty change, in six months we shall look in the same direc-

tion for the North Star. Ay, more: so slight is the displacement that it cannot, by direct measurement, be detected with the most accurate instruments. The English astronomer, Bradley, sought diligently to ascertain the parallax of a star by thus taking direct measurements from the opposite extremities of diameters of the earth's orbit. Though he failed in his object, his labors were rewarded with two most brilliant discoveries: viz., *nutation*, or the oscillation of the celestial pole caused by the action of the sun and the moon upon the protuberent equatorial mass, and *aberration*, or the displacement of a celestial body caused by the progressive motion of light in connection with the movement of the earth in its orbit.

It was necessary to devise some other method of determining the parallax of the fixed stars. Sir Wm. Herschel was the first to attempt to apply one which had been suggested by Galileo. The telescope often reveals two stars where the unassisted eye detects but one. These two stars are not necessarily near each other, but may appear so only because situated nearly in the same straight line with the observer. When one of them is much smaller than the other, it is presumably much farther away. Now if the farther one is a little east of the nearer one, a movement on our part toward the east would cause them to separate still farther, and a movement toward the west would cause them to approach nearer to each other. With such a point of reference, a very slight change could be measured with delicate instruments, and, by taking several such points of reference, still greater accuracy could be secured. Herschel began his observations upon such a pair of stars, measuring as frequently as possible and with great care the distance between the two, and noting the direction of the line joining them. Soon a change was observed, but—strange to say—it agreed neither in time nor direction with the motion which parallax would give. Judge

of his astonishment when he discovered that the two stars were revolving around a common center between them. He examined many other pairs with the same result.

Thus was the effort to measure a star parallax again defeated; but rich discoveries were rewarding those who were seeking what began to seem as unattainable as the Philosopher's Stone or the mythical Eldorado. Munich now had her Fraunhofer who had acquired wonderful skill in the construction of refracting telescopes, and Kœnigsberg had her Bessel who was without a superior in the methematical and astronomical field. The combined efforts of these two geniuses produced the celebrated Kœnigsberg Heliometer. Provided with this wonderfully delicate and ingenious instrument, Bessel undertook the accomplishment of what had baffled his predecessors. His method differed from Herschel's only in his choosing for points of reference two minute stars that were farther removed from the one whose parallax was sought. After most careful and oft-repeated measurements Bessel detected a variation, agreeing exactly in time and direction with what parallax required; but it was so slight and gave such an astounding distance that he hesitated. He pursued the investigation through another year and obtained the same result. Still fearing that there might be some mistake, he repeated his observations through another year, and, as the values were the same, all doubts were dispelled, and Bessel announced to the world that he had crossed the hitherto impassable abyss, and measured the distance to one of the fixed stars, 61 Cygni. But how shall we obtain a conception of the amazing distance? Miles, velocities of express trains, and swiftly flying cannon balls, fail to give us an adequate unit. Light, which flashes with a swiftness that will carry it eight times around the world while the clock ticks once, occupies nearly ten years in completing this mighty journey. The subsequent observations of Peters at Pulkova and Johnson at Oxford, have confirmed Bessel's result.

There is at least one star, Alpa Centauri, nearer than 61 Cygni, whose light requires three and a half years in coming to us. From Alpha Lyræ the light comes in twelve and a half years; and from Sirius, the brightest star in the heavens, in fourteen years. The light with which we shall see the North Star to-night started thirty years ago. If the star Alcyone of the Pleiades should be blotted from existence to-night, it would continue to be seen here for five hundred and thirty-seven years; for the light which starts from there to-night cannot reach the earth before the expiration of that time. These distances should be taken with some latitude, as a slight error in so small a parallax makes a great difference in the distance.

After learning that the stars are separated from us by such incomprehensible distances, we are naturally desirous to know something of their size. In the telescope they present no appreciable disc; and, hence, their diameter cannot be measured. Even in a telescope with a magnifying power of several thousand they appear as points; that is, their disc is so small that several thousands of times that disc is still inappreciable. Then are astronomers baffled? Are they compelled to hang up their micrometers and say, "The stars are so far away that their size cannot be determined, even approximately?" As has been stated, there are many Binary Stars, or pairs in which one is revolving around the other. It is easy to demonstrate that the masses of bodies are to each other directly as the cubes of the mean distances of any bodies which revolve around them, and inversely as the squares of the times of the revolution. The star 61 Cygni is thus found to have three-tenths of the mass of the sun, Alpa Centauri three-fifths the mass of the sun, and 70 Ophiuchi three times the mass of the sun. We can determine the amount of light emitted by any star whose distance is known; for, by proper optical instruments and tests, we can ascertain how

much more light the sun gives us than the full moon, and how much more light the moon gives us than a certain star; then, allowing for the greater distance of the star, we can compare the amount of light emitted by the star with that emitted by the sun. It is thus found that 61 Cygni gives half as much light as our sun; Alpha Centauri, four times as much; the Pole Star, eighty-six times as much; Sirius, one hundred times as much; Vega, three hundred and forty-four times as much; Capella, four hundred and thirty times as much; Arcturus, five hundred and sixteen times as much; while Alcyone, the brightest of the Pleiades, blazes with the light of several thousand suns. Our poor little sun! why, it is a mere candle light! It might almost be used for a plaything, if it were not so hot. After all, we remember that the sun is more than a million and a quarter times larger than the whole earth—and yet there is Alcyone in the Pleiades flinging off into space several thousand times as much light. "Twinkle, twinkle, *little* star."

Many peculiarities, not seen with the unassisted eye, appear when the stars are viewed through a telescope. One of these, the duplex character of many stars, has already been mentioned. When Sir Wm. Herschel began his observations upon these stars, in 1780, he knew of only four; but he extended the list to five hundred, and the number is now known to exceed six thousand. Some of these appear double simply because one star, though an immense distance from the other, is situated nearly behind it. Many of them, however, are physically connected and constitute magnificent systems of revolving suns. These are called Binary Stars. 61 Cygni is one of them, and the North Star is another. In all about five hundred are known. Of these there are eight whose periods are less than a century, and one hundred and forty-two whose periods are less than a thousand years. There are instances of triple and quadruple stars that are in revolution

about a common center. More than this: there are whole clusters, like those in Hercules and Centaurus, which undoubtedly form a system and revolve, age after age, in obedience to the same great law of gravitation which holds the planets in their orbits about the sun.

Another peculiaity revealed by the telescope is the great variety of color. Some are red, some blue, some green, some yellow, some like emerald, some like ruby, some like sapphire. In some of the double stars we find the colors combined in striking contrast, such as blue and yellow, green and yellow, white and purple, white and red. It is said that, in the Southern Cross, there is a group of more than a hundred variously colored and tinted suns, so closely clustered as to appear, in a powerful telescope, like a superb bouquet.

If the telescope be directed toward Algol, in the constellation Perseus, the observer will witness a strange, even startling phenomenon. The star, which has been shining steadily as one of the second magnitude, begins suddenly to wane, and, under the eye of the observer, in the short period of four hours, sinks to a star of the fourth magnitude. After twenty minutes it begins to increase, and, in four hours more, shines again as a second magnitude star, remainiug thus a little more than two and a half days, when the same changes are repeated. Mira, or the Wonderful, a star in the Whale, varies between still greater extremes, sinking from the second to the twelfth magnitude, thus diminishing from a bright star to entire invisibility, passing through all its changes in less than a year. In fact, so great is the change in these two stars that it may be observed by the unaided eye. Beta Lyræ varies from the third to the fifth magnitude, and back to the third in less than six and a half days. Eta Argus, one of the brightest in the heavens, dwindles to an insignificant star, scarcely visible with the naked eye, and then returns to its former brilliancy in about forty-six years. More than two hundred of these periodic stars are known.

A still more startling phenomenon is the sudden blazing forth of a star in a part of the heavens where none had been observed before. The first strange occurrence of this kind on record is that observed by Hipparchus more than two thousand years ago. Biot finds in Chinese chronicles an account of the same new star. This star was so brilliant that it was visible in the full light of day. Tycho Brahe says that, one evening in 1572, he "found a group of country people gazing at a star [in Cassiopeia] which he was sure did not exist an hour before." For three weeks it shone with a splendor surpassing that of Sirius, the brightest star in the heavens. It then began to diminish, and, in sixteen months, entirely disappeared from view. Kepler describes a new star which, in 1604, made its appearance in Ophiuchus. It resembled Tycho's star in brightness and duration. Many other instances of the sudden appearance of stars are on record. A new interest has been awakened in these anomalous bodies by the appearance of one in 1866 in the Northern Crown, and another a little more than four years ago in the Swan. The science of spectrum analysis had been developed, and astronomers were anxiously waiting with their spectroscopes to learn what these strange bodies had to say concerning their brilliant but brief career. A marvelous science is that which enables us to determine the materials of a body situated millions of billions of miles from us. There shines the sun; far off in the fathomless space twinkle the stars; and yet we can bring them into our laboratories, analyze their substance and learn their elements. The gem in the Northern Crown shone on the night of its first appearance as a star of the second magnitude; the next night, of the third magnitude; the fourth night, of the fourth magnitude; the fifth night, of the fifth magnitude; the seventh night, of the seventh magnitude, and in two weeks, of the ninth magnitude. The new star in the Swan, when first seen, in November, 1876, was of the third magnitude. In three and a half months it had sunk to the eighth.

We are not, for a moment, to suppose that these new stars, as they are called, are new in the sense that stars have suddenly begun to exist where none existed before. They were there all the same, but invisible. After the cause which renders them visible ceases to act, they again become invisible, but do not cease to exist, nor even change their position in the heavens. The variable stars have definite and, in most cases, well known periods. It is more than probable that the so-called new stars do not differ from these except in the length of their periods and, in some cases, in becoming so indistinct that they cannot be seen even with the telescope. In fact, the new star described by Tycho seems to be the same that blazed out on two preceding occasions at intervals of about three hundred and twelve years. The new star in the Northern Crown occupies the place of a ninth magnitude star recorded in Argelander's charts and catalogue.

Respecting the cause of these changes, many theories have been advanced. Only three of these seem worthy of consideration. One is that proposed by the German physicists, Klein and Meyer. They are of the opinion, referring to the new star in the Northern Crown, that either a planet or one of the star clouds which are scattered through space collided with the star, thus changing its momentum into heat and light. It is very improbable that a planet would come in contact with its sun; for gravity and centrifugal force are self regulating. The planets around our own sun have definite orbits, and Le Verrier has demonstrated that the system is stable. It is still more improbable that a star would come in contact with a nebulous mass; for these nebulæ, as far as known, are separated by distances as great as those of the stars. Another theory, proposed by Mr. Huggins, who carefully examined the same star with the spectroscope, is "that in consequence of some great internal convulsion, a large volume of hydrogen and other gases was evolved from it, the

hydrogen, by its combination with some other element, giving out the light represented by the bright lines [in the spectroscope] and at the same time heating to a vivid incandescence the solid mass of the star's surface." The spectroscope certainly revealed the fact that there were glowing gases on the surface; but there are two serious objections to this theory: one is the almost instantaneous development of so enormous an amount of hydrogen; the other is in the evidence that the new stars are but periodic stars of long intervals, and, consequently, in the extreme improbability that these internal convulsions should occur at regular intervals. Another theory, and it seems to me the most consistent one, is proposed by that keen and vigorous astronomer, Mr. Proctor, whose acute conjectures are often worth as much as other men's demonstrations. Mr. Proctor thinks that our sun is, to a slight extent, a variable star, and that the increase of the solar spots during more than five and a half years and then the decrease for the same time, giving an interval of a little more than eleven years between two consecutive maxima, differ only in degree from the changes in the periodic and the so-called new stars. Whatever explains one, then, explains the other. His theory is that "enormous flights of meteoric masses travel around those stars which thus occasionally break forth in conflagrations," and that, in their eccentric orbits, these meteors plunge through the gaseous envelop of the star, or come in contact with the nucleus itself. His arguments in support of the theory may be briefly stated as follows: *First*—Such meteoric masses are known to travel around our sun, some of them following the trains of comets. The earth annually encounters one of these streams on the 10th of August, and occasionally another on the 12th of November, the latter following in the track of Tempel's Comet, which has a period of thirty-three years. These, by their friction with the earth's atmosphere and their rapid

flights, become heated to redness, and add sensibly to the light received by the earth. It is supposable that the larger comets are followed by larger trains of meteors. "Newton's Comet with its tail a hundred millions of miles in length, all but grazed the sun's globe. The Comet of 1843, whose tail stretched half way across the sky, must actually have grazed the sun." The observations of two independent observers, Hodgson and Carrington, seem to indicate that, on September 1, 1859, the sun was locally increased in light and heat by the friction of meteoric masses, the observed phenomenon being "the passage of two intensely bright bodies across a small part of the sun's surface—the bodies first increasing in brightness, then diminishiug, then fading away." This occasioned intense electric disturbances in all parts of the earth. These meteoric collisions, sufficiently multiplied, would produce the outbursts seen in the variable stars. If the meteors move in elliptic orbits, those of them which do not, at their perihelion, become incorporated with their sun will return at regular intervals. If they move in parabolic or hyperbolic orbits, as have many comets around our sun, they would occasion but one outburst, the escaping ones returning no more. *Second*—The spectroscope seems to indicate that the action which increases the luminosity is from without. "As the new star in the Crown faded from view," says Mr. Proctor, "the bright lines indicative of glowing hydrogen died out, and only the ordinary stellar spectrum remained. In the case of the star in the Swan, the part of the spectrum corresponding to stellar light faded gradually from view, and bright lines only were left, and so changing as to shine with the very tints observed in all the gaseous nebulæ." It has since shone with the single line of the planetary nebulæ. The inference is that this body has a solid nucleus surrounded by nebulous matter, and so long as it is in this normal condition it gives us this monochromatic spectrum, but when the nucleus becomes

heated by the pelting hail of meteoric masses, it gives the true stellar spectrum. Mr. Proctor's theory seems to account for the facts, while the other theories do not. If, for example, we allow the claim of Vogel, in supporting Zœlner's theory, that from the star in the Swan there had been an outrush of glowing gaseous matter from the interior, producing the bright lines of the spectrum, and that the body then cooled until surrounded by a hardened crust giving out only monochromatic light, we are forced to acknowledge that all of the planetary nebulæ are in this same cool, hard-crusted and solid condition; for they give exactly the same spectrum. This, however, their immense size renders impossible. One in Ursa Major has a breadth of two and two-thirds minutes, and if it is no farther away than the nearest star, its volume would be more than eleven millions of millions times that of the sun; and if such a vast body were dense enough to have a solid crust, it would inevitably, by its inconceivably great attraction, draw all its neighboring stars to it. The cause of the changes in the variable stars needs farther investigation. The spectroscope promises the richest results. There has not yet been time to secure a sufficient number of facts, nor to understand, in all their bearings, the import of the facts already learned.

By comparing their positions at different dates, considerably separated, most of the brighter stars are found to have motions of their own. In one star this motion amounts to seven seconds annually. Arcturus has changed more than a degree since catalogued. The term fixed stars, then, is a misnomer. A few years ago Mr. Proctor, after having pictured the proper motions of about twelve hundred stars, expressed his belief that groups of stars are traveling in a common direction with a common velocity, and denominated these groups "star drift." Among others he called attention to such a group in Ursæ Major. Of course only that portion of the star's motion perpendicular to the line of sight could be thus pictured.

Two stars might have the same lateral motions, while motions in the line of sight were in opposite directions. Nevertheless, Mr. Proctor was convinced that Beta, Gamma, Delta, Epsilon and Zeta, Ursæ Majoris, are moving in the same direction with the same velocity, and that Alpha and Eta, of the same constellation, do not belong to this drifting system.

There remains to be mentioned, in this connection, one of the most unexpected and marvelous achievements of modern science—nothing less than the discovery of a means of determining whether a source of light is approaching, receding, or at rest. Dr. Huggins, who has led the way in this field of investigation, has given us a multitude of new and astonishing facts. The principle is easily explained, and as easily understood. The difference of refrangibility in the different rays of light, giving us the colored spectrum, depends upon the different velocities with which these rays pass through material media. In passing through a prism the short waves of violet light are more refracted than the long waves of red light. Now if a source of light is approaching us, a greater number of light waves will reach us in a given time than from such a source at rest. This, in effect, is the same as shortening the waves, and all the lines of the spectrum will be shifted toward the violet end. If the source of light is receding, a fewer number of waves will reach us in a given time, and the lines of the spectrum will be shifted toward the red end. In either case the velocity can be determined by the amount of displacement. As simple as this method seems, now that the discovery has been made, none but a genius of the rarest order would have caught the connection between cause and effect in a phenomenon where that relation is so subtile and apparently hopeless of detection. By this method Dr. Huggins learned that Sirius is rapidly receding from us—so rapidly, in fact, that, some time in the distant future, he will be robbed of the distinction of being the most brilliant star in

the heavens. His instrument being of unsufficient power to enable him to deal with the less brilliant and more rapidly moving stars, the Royal Astronomical Society, with commendable generosity, appropriated a large sum of money for the construction of a superior instrument for the use of Dr. Huggins. With this instrument he has ascertained that some stars are approaching us and some receding from us with velocities amounting, in some cases, to thirty or forty miles per second. Mr. Proctor was naturally anxious that his "star drift" should be subjected to this test, and must have been much gratified when he received from Dr. Huggins a letter stating that the stars in Ursa Major had been examined with the Royal Society's new instrument, and that Beta, Gamma, Delta, Epsilon and Zeta were all found to be receding from the earth with a velocity of about seventeen miles per second, thus constituting, according to Mr. Proctor's prediction, a true drifting system. The same test showed that Eta, of the same constellation, is also receding, but with a different velocity, and that Alpha is approaching, thus confirming, in every particular, Mr. Proctor's sagacious inference. Many of these drifting systems are found in different parts of the heavens. We thus have revealed to us stellar relations unsuspected before, and motions that are bewildering in their maze and rapidity.

After learning that other suns are in motion, we are naturally led to inquire whether our own sun, with all its attendant worlds, is not revolving around some far-off centre. Let us examine the evidences and judge for ourselves. We have seen, from observations upon the Binary Stars, that the law of gravitation extends throughout space. This fact alone affords a proof that suns everywhere are in motion; for, if they attract one another, there must be revolution to give an equal force in the opposite direction to prevent their rushing together. If the orbital motions of the planets in our sys-

tem should cease, the planets would be dashed into the sun. Let us see what the following phenomena indicate: In the region occupied by Orion, the River Po, and the Dove, in the southern heavens, the stars are drawing nearer to one another; while the stars in Hercules, the opposite space in the heavens, are gradually separating. There is but one conclusion to be derived from this; viz., that the sun, with all its planets and comets, is moving onward through space toward the constellation Hercules. The results of Mædler, Argelander, O. Struve, Airy, Dunkin and Galloway, who have examined the evidences with the view of ascertaining the point toward which the sun is now moving, differ by only a small amount. The great astronomer Mædler, who obtained a high reputation for computing the orbits of Binary Stars, undertook the solution of the problem of finding the centre around which the sun is revolving. After carrying his investigations through seven years he arrived at the conclusion that Alcyone, the brightest star of the Pleiades, is that centre. This is the star, it will be remembered, that emits several thousand times as much light as the sun, and is so far away that its light occupies five hundred and thirty-seven years in coming to us. We are sweeping around this or some other centre at a tremendous rate. The computations of Mr. Airy, the Astronomer Royal of England, make it ninety-seven thousand two hundred miles per hour. But even with this astounding velocity the time required for one complete revolution is eighteen million two hundred thousand years.

All are familiar with the appearance of the Galaxy, or Milky Way. It looks like a misty, hazy belt spanning the sky; but the telescope, as is well known, shows it to be composed of countless millions of stars. They are probably not any nearer to one another than the nearest stars are to us; but there are so many of them arranged one behind another, and they are so far away that their mingled rays give us this cloudy appear-

ance. Herschel undertook, with his mammoth reflector, to penetrate the milky way. Hundreds of brilliant orbs filled the field, but the unresolved haze indicated that he had not fathomed the mighty depth. Yet he estimated that within the distance reached by his telescope, not less than five hundred stars were arranged one behind another, each as far from the one before it as 61 Cygni is from us. If that be true, light would be five thousand years in reaching us from the remotest one. Nor is that all: we are not to think this is the limit of the universe. Far off there in the dim distance may be seen a little haze of light not much larger than one's hand. Apply the telescope and thousands of glittering suns burst upon the sight. This is a nebula, so vast that light requires, to flash across its diameter, thousands of years, and so far away that the light with which we see it has been hundreds of thousands of years in charging through the amazing distance. Nor is that all: such clusters are to be numbered in different parts of the heavens by thousands. Nor is that all: each increase in the power of the telescope reveals more clusters on beyond, "far sunk in the depths of space."