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Lancaster Intelligencer.

TUESDAY EVENING, FEB. 24, 1880.

Light and Eclipses.

Paper Read Before the Star Club, February 20th, by Miss Mary Martin.

After having had presented to us the subjects of our Earth, its Moon and fellow planets, their centre the Sun, a possible theory of their evolution, together with the majestic circle, the zodiac, we come to that medium by which these visible, "most ancient heavens," in their glory and beauty are known to us. Light, from some source or other, is so common a thing in our experience that we forget the magnitude of its work until we attempt to marshal its forces. Without it life would become extinct and animation cease. Without it all nature is nothing; the heavens fade; the earth dies. Without it we are surrounded, if we can for a short time exist, with black darkness—the darkness that may be felt—and, if we are to take their plagues literally, I cannot conceive how the Egyptians could have waited for a worse plague to fall upon them than "the horror of great darkness."

But, instead of considering the state of a universe without this most inspiring element, let us regard it, not in the order of its creation, nor as a necessarily evolved force, but in the view of some of its less hidden mysteries. And first let us inquire,

How Does the Sunlight Get to Us?

The motion of light is explained by the wave-theory. It is assumed that all space between us and the sun and stars is filled with a subtle, delicate ether, and that through it the great heart of our system, by its pulsations, sends out light and life to us in unceasing waves. So we must dismiss the poetical idea of "swift-winged arrows of light," and imagine a series of undulations, moving with a speed which no mind can comprehend, straight away from their source, through utter darkness, through cold, black space, never stopping, never resting, till they strike upon the earth and warm it, or upon the eye and produce vision. And in the same way we have the light of stars, though the waves, traveling the enormous distances between them and us, have become old and feeble by the time we receive them. Indeed, so great is their distance that when we look at a star we do not see the star of to-day, but that of years ago.

The velocity of these waves is about 185,000 miles per second, and the time of their traversing the distance from the Sun—92,000,000 miles—is 8½ minutes. Imaginative comparisons have been made between this degree of swiftness and that of several things with which we are somewhat acquainted. We are told that it would take a cannon ball about thirteen years to traverse the same distance, and the sound of its explosion somewhat longer; that it would take an express train about 200 years; that it would take sensation about 132 years to travel from a finger-tip so far removed from a brain. Sound and sensation are fast travelers, measured by ordinary standards, but when we conceive of light as moving a million times faster than sound, and ten million times faster than sensation, we can scarcely believe that the mind *is* "swifter than the darting ray."

The discovery of the rate of propagation of light-waves is due to a Danish astronomer, Rœmer, and it was made while he was engaged in observing eclipses of the moons of Jupiter. The inner one of the four satellites revolves around its primary in 42 hours, and is eclipsed in every revolution. Rœmer noticed that each successive return into the shadow of the planet was after a perceptibly longer interval, and that, after a hundred returns, the moon was fifteen minutes behind what apparently should have been the proper instant for its eclipse. Upon reflection the astronomer concluded that this difference was caused by the fact that the Earth and Jupiter had moved farther away from each other, and that if light, the agent communicating the eclipse, required time for its passage through space, it obviously would need *more* when the planets were farther away from, than when they were nearer to, each other. Subsequent calculations established the fact that when the Earth is in that point of its orbit most remote from Jupiter the eclipse of the satellite occurs 16½ minutes later than when at its nearest. And since it then is 185,000,000 miles farther from Jupiter, the calculation is easily made to gain the velocity of light.

The same result is obtained independently of the moons of Jupiter by means of the aberration of the light of certain stars, by which is meant the displacement of these stars owing to the progressive movement of light, together with that of the motion of the Earth in its orbit. It is found by this means that light travels 10,089 times as fast as the Earth. Besides, several delicate and accurate methods for measuring the velocity of artificial light have been devised, which confirm the results obtained from these observations, and so we may conclude that the speed which has been already named is very nearly correct.

We will assume that we are acquainted with certain laws of physics, viz.: that a ray of light moves in straight lines so long as the medium it traverses is of uniform density; that, striking upon some surface, it is caused to rebound or is absorbed; and that entering a rarer or a denser medium it is broken or refracted; and will then consider

The Composition of Light.

In its perfect state light is white, but the white ray is a compound of a series of other rays, so mixed as to neutralize each other. If the unbroken ray is passed through a prism, the solar spectrum, an oblong image of these dispersed rays, five times as long as wide, is produced, showing the waves spread out; the slower ones with longer undulations having fallen behind at the lower end of the line, and the more rapid ones having run up to the farther end. In this passage through the prism the light is refracted, and each of its component parts—the red, orange, yellow, green, blue, indigo, or violet ray, running into each other through an infinite series of gradation—is made refractory in its own degree, the red being least turned out of the straight course, and the violet most.

Now, light comes in undulations to the eye as sound to the ears; a certain number of vibrations of a musical chord produces one sound, and as these vibrations are increased or diminished this one is varied; so with light. If its vibrations fall upon eye at the rate of 396 to 470 millions of millions per second red light will be the one seen, and if from 716 to 765 millions of millions, violet will be the result. The remaining prismatic colors depend upon the intermediate numbers. These vibrations are as marvelous in respect to their size as to their speed; so very small are they that more than 50,000 are contained in a single inch. And if this is true how many must there be in the vast space between us and the sun, and how many must pass any one point in a single second or strike upon the eye in that short period!

The color of an object depends then upon the size of waves which come back to the eye, and we see things differently according to their power of absorbing or extinguishing certain of the rays which fall upon them. When the light which enters an object is wholly absorbed we call it black; if on the contrary all kinds of light are reflected from it we call it white, and between these two extremes lie the substances which absorb the rays unequally. When the sunlight strikes a green leaf it has the power of absorbing and making use of all the rays except the green, and so they may come to the eye. Every pansy with the tips of its petals sending to us deep violet waves, then shading with an exquisite gradation to yellow, and back again until towards the heart of the flower almost every ray is absorbed, leads us to wonder not only at the delicacy of coloring, but at the differences of construction in so very small a space, which will here throw off the violet, and again from some change in structure which no human eye can detect, absorb these and throw off some other. We have the plant-stem reflecting one kind of waves, the leaves another, the nearer envelopes of the flower another, and each petal, or sometimes minute parts of a petal, still another.

"——Who can paint
Like Light? Can imagination boast
Amid his gay creation hues like these,
And can he mix them with that matchless skill,
And lay them on so delicately fine,
And lose them in each other, as appears
In every bud that blows?"

The mind is unable to grasp any idea of the millions of millions just referred to, and especially when they succeed each other in a brief second, but in point of fact when sunlight flashes upon the eye, shocks as frequant as these enumerated strike upon its nerve structure. And not only does light do work directly for the day-spring from on high with this velocity, but in like manner it darts from every reflecting surface with an infinitude of rays from each one, and tells with unerring truth the story of mountain, river and plain, and of minute and delicate objects as well.

Besides the visible image shown in passing a ray of light through a prism there are also invisible heat and chemical spectrums, the former being at the red end of the line and the latter at the violet, and these differ from light only as red and violet differ from each other. To prove that heat vibrations may be turned into light, if a platinum wire is warmed by the electric current it will at first emit waves of heat but no light. Strengthening the current the wire will presently glow with a sober red light, and if the temperature of the platinum is sufficiently increased, shorter and shorter waves are produced until we have the successive introduction of all the colors of the spectrum. After having seen this experiment we may conclude that color is all in the eye.

Upon the chemical or actinic rays depends the art of photography which has proved of very great importance in registering those astronomical phenomena which, from their short duration and constant shifting, baffle all ordinary description. Though many telescopic observations had been made upon the sun-spots, and careful drawings of them given, it was not till the sun took his own picture that a satisfactory result was obtained. When the difficulty of gaining an instant with suitable atmospheric and solar conditions was surmounted, the result was a picture which surprised the most careful observers. The views of "rice-grains and willow leaves" are a delight to the unscientific, as well as a revelation to the astronomer. The appearance of the corona at the time of a total eclipse, which from the effect of its very grandeur upon the minds of the observers prevented any just description, has in the same way been caught at various moments and examined. The views of the moon, too, have revealed her topography to the student of astronomy with as much clearness as could the best telescopes. Photography, which means "light drawing," is, however, a misnomer for the art, as a picture is not made by the luminous rays, but by *dark ones*, which produce chemical changes in certain compounds.

Strictly speaking, light is the agent which, acting upon the eye, produces vision, and now that we have these three always-associated radiant forces—luminous rays, which produce vision; heat rays, which affect all kinds of matter; and chemical rays, which decompose and combine elements—we may reflect not only on its visible effects, flooding earth, air and heavens with the brightness, comfort and beauty which constantly appeal to the senses, but might also follow it into the earth, where it has stored up flame and heat and power for ages to come, and where it now stirs into life every tiny seed, But that is not our purpose, and we will return to the *luminous* prismatic ray.

It was Sir Isaac Newton who first decomposed light by passing the beam from a hole through a prism. But this spectrum was not pure, because the prism gave a series of overlapping images of the aperture. More than a hundred years after, the spectrum obtained by passing light through a narrow opening or slit was examined, and it was found crossed in various places by fine dark lines. These lines, known as "Fraunhofer's lines," because he made them the subject of investigation and experiment, have been the means of many important discoveries, especially in solar and stellar physics. Fraunhofer found that they did not vary at any season nor at any time of day; that the 590 he at first counted were always present, in their exact positions, and that the light from the Moon and from Jupiter contained the same system of lines as the direct sunlight, and he concluded that the cause for them existed in the Sun.

By means of the spectroscope metals in a state of luminous vapor may be examined, and from many cases it has been generalized that each line in the spectrum has its definite place, which is the result of the laws of structure in the substance which gives the spectrum. By making numerous comparisons between the spectra of known elements, as hydrogen, copper, iron, lead, &c., and those of the sun and stars, the coincidences disclosed fully prove that many of these exist in the heavenly bodies, although there are also many lines not known to pertain to terrestrial bodies. These points will be further developed when the class has its promised paper on optical instruments, but we may conclude from what has been said that light reveals to us the elements of the stars and how they differ from each other.

Absorption of Light by the Atmosphere.

Let us now observe some of the practical everyday effects of our principles of absorption and reflection of light. To get to the Earth light must pass through the air, and, as we might certainly expect from every combination of Nature's making, the union of the two is the source of many delights to the creature that uses his senses. The atmosphere is one of the most transparent of bodies, and it consequently has the power of transmitting a great deal of light to the earth; but besides, it absorbs some rays and reflects others—more especially the blue. So by this particular reflection, instead of our looking out into a black sky, as would be the case if there were no atmosphere, those rays are brought to the eye which are most pleasing.

Now, if air turns aside this one ray in the passage of light through it, it follows that the more air the light encounters, the greater will be the loss of that ray. This proves to be the case, for at the time the beams of the rising or setting sun reach us athwart the wide stretch of atmosphere towards the horizon, the blue rays have disappeared, and there are left the red, yellow or purple, to make the gorgeous coloring which we have in the morning or evening, varied according to atmospheric conditions.

The gleams that

"——illume the gates
Of the lost sun. They bring
No increase like the gains of sun and showers;
Only a moment's brightness to the earth,
Only a moment's gleam in common life—
Yet who would change them for the wealth of worlds?"

If we remember that we see through less atmosphere when looking directly overhead than when looking towards the horizon, and that the more air the light passes through, the more blue rays are pushed aside, we can easily see why we can look at the sun in the morning or evening, while at noonday we would be blinded; why the blue of the sky is deeper overhead than towards the horizon, and why it grows more intense at greater elevations.

If there should be an immediate transition from the brightness of full sunlight to the blackness of midnight, we would lose a most delightful part of the day—twilight—as well as be put to considerable inconvenience in adjusting our eyes and employments to the sudden change. Full daylight, however, *gradually* fades away into darkness, and the night *gradually* makes way for the morning again. After the Sun sinks below the horizon it still shines upon the particles of air above, and these reflect the light to the earth—that is, its strong and little-refrangible red rays, because of the great amount of intervening atmosphere. In passing, it may be noted that, astronomically speaking, twilight lasts in the evening until the Sun has sunk eighteen degrees below the horizon, or until stars of the sixth magnitude are visible, and begins in the morning when he is again within a like number of degrees.

There are also certain

Phenomena Due to Refraction

to which we will yet give a moment. Probably very few people, however dull or ignorant, have not at some time been thrilled with the beauty of that arch spanning the heavens—"the bow set in the clouds." The solar rays are decomposed by the rain-drops and then reflected back to the eye, the observer being between the rainbow and the sun. Then the twinkling of the stars! These would not seem so friendly to us if they were shining as cold, fixed points, but owing to the various layers of air being of different densities their rays are broken and the twinkling light is the result. There are also the halos around the moon, and less frequently around the sun, caused by the refraction and decomposition of light-rays by particles of moisture or crystals of ice, in the higher regions of the atmosphere, which may be seen as distinct beauties. Not only does light awaken us to the magnificence of the heavens and the brightness of the earth, but the glorious halo of the Moon, the resplendent corona of the Sun, "the foam of the sea-shore, the plumage of the birds, the various films that float upon the surface of waters, the delicate tints of flowers and rich hues of plants, all combine to remind us that every ray of light comes like an angelic artist sent from heaven, bearing upon his palette the most celestial tints with which to beautify the earth and show the illimitable glory of God."

Eclipses.

All the planets, primaries and secondaries, have their halves in alternate illumination and shade, and since the Sun, their central source of light, is much larger than any of them, they cast conical shadows in the direction opposite to him. These shadows depend in size upon the diameter of the planets and their distances from the Sun. That part of the shadow in which, in case of a solar eclipse, the spectator can see no portion of the Sun's disc, is called the *umbra*; and the space of partial illumination between the umbra and full light is called the *penumbra*.

If the Sun were merely a point of light the shadows cast would be all umbra, but being larger there is also a partial shadow. This may be made clear by taking two candles to represent the opposite edges of the Sun, placing them rather near together, and observing the shadow they cast on the wall of some object; on either side of the dark shadow thrown by both candles will be a lighter one thrown by only one.

The shadow cast by any of the primary planets converges to a point before it reaches its next outer neighbor, but it may fall upon and eclipse its own satellite, and the shadow of the latter may fall upon and eclipse its primary.

The cause of our own solar or lunar eclipses may be clearly understood by reference to any figure representing the relative positions of the Sun, Earth and Moon. The only point not there made manifest is why an eclipse of the Sun does not occur at every new-moon, or an eclipse of the Moon every time she passes over to the other side of the Earth, or is full. But this is made clear when we know that the plane of the Moon's orbit is inclined to that of the Earth about five degrees, so that full Moon is sometimes above or below the shadow of the Earth, and the latter above or below the shadow of the new-moon.

When the Moon is at or near either of her nodes—that is near either point where the orbit of the Moon penetrates the ecliptic twice in every year there will be an eclipse of the Sun or of the Moon, as the case may be. Accurately, if the Moon is within seventeen degrees of her node, when in conjunction, she will eclipse the Sun; and if within twelve degree of her node when in opposition she will be eclipsed more or less. There are then about 33 degrees—twice 16½—in which eclipses of the Sun may occur; and 21 degrees in which eclipses of the Moon may occur, about the node. This gives 66 degrees of the 360 for eclipses of the Sun, and 42 for those of the Moon; and the proportion of solar to lunar eclipses is as 66 to 42 or as 11 to 7.

Solar eclipses are of three kinds, which vary with the apparent magnitudes and positions of the Sun and Moon. *First:* If their centres are on a straight line with the Earth's and if the apparent diameter of the Moon exceed that of the Sun, there is a *total* eclipse. Since the Moon is much smaller than the Sun, it must be borne in mind that it is her comparative nearness to us which causes her ever to appear equal to or greater than the Sun, as may be demonstrated by holding a penny immediately before his eye which will be seen to obscure a very large object. *Second:* If the centres of these three bodies are in the same relative position, but the Moon being so far removed from the earth that its apparent diameter is lessened, or, explained in other words, if its shadow comes to a point before it reaches the earth, there will be an *annular* eclipse, the Sun being visible all around the Moon, forming a ring of light visible around the edge of the Sun. *Third:* If the Moon does not pass centrally over the Sun, but covers only a portion of it, large or small, there is a *partial* eclipse.

In any of these cases the observer must station himself within the region of the umbra for a perfect view of the eclipse, or of the penumbra for any view at all—the eclipse not being visible to outsiders. The breadth of the Moon's umbra at the distance of the Earth, does not exceed 160 miles. Referring to Baer's almanac you will find that the eclipse of Jan. 11, this year which was total for California, was partial for western Missouri, and farther east was not seen at all.

Total eclipses are of rare occurrence, so that descriptions of them are of interest to those who have not had the good fortune to see one. Mr. Lockyer, in his Astronomy, says that a total eclipse of the sun is at once one of the grandest and most awe-inspiring sights it is possible for man to witness. As the eclipse advances, but before the disk is wholly obscured, the sky grows of a dusky lurid, or purple, or yellowish crimson color, which gradually gets darker and darker, and the color appears to run over large portions of the sky irrespective of the clouds. The sea turns lurid red. This singular coloring and darkening of the landscape is quite unlike the approach of night and gives rise to a feeling of sadness. The Moon's shadow sweeps across the surface of the earth and is even seen in the air; the rapidity of its motion and its intenseness produce a feeling that something material is rushing over the Earth, and at a speed perfectly frightful. All sense of distance is lost; the faces of men assume a livid hue, flowers close, fowls hasten to roost, cocks crow, birds flutter to the ground in fright, dogs whine, sheep collect together as if apprehending danger, horses and oxen lie down, obstinately resisting the whip and goad; in a word, the whole animal world seems frightened out of its usual propriety.

Premising that Bailey's beads (so named from the observer who first discovered them) are dots of light on the edge of the moon, and are caused by the sun shining through the depressions between the lunar mountains; and that the odd protuberances referred to have been proved by the spectroscope to be masses of hydrogen gas so hot as to shine by its own light, I will read part of the report of the eclipse of 1869, as seen by Gen. Mayer of the U. S. signal service, from White Top mountain, near Abingdon, Virginia:

"The telescopic appearance of the corona or aureola during the totality, exhibited a clear yellowish bright light, closely surrounding the lunar disk and fading gradually, with perhaps some tinge of pinkish green, into the hue of the darkened sky. Upon this corona, extending beyond its brightest portion, the well-defined rose-colored prominences were projected at various points of the circumference. * * * To the unaided eye the eclipse presented during the total obscuration, a vision magnificent beyond description. As a centre stood the full and intensely black disc of the Moon, surrounded by the aureola of a soft, bright light, through which shot out, as if from the circumference of the Moon, straight, massive silvery rays seeming distinct and separate from each other, * * the whole spectacle showing upon a background of diffused rose-colored light.

"The approach of the Moon's shadow did not appear to be marked by any defined line, or the movement of any dark column of shade through the air. The darkness fell gradually, shrouding the dim earth below in most impressive gloom. * * At the same time, and in vivid contrast, the clouds above the horizon were illuminated with a soft radiance; those towards the East with the lights of a coming dawn, orange and rose prevailing; those northward and westward with rainbow bands of varied hues.

"A very cursory examination only could be given the stars and planets visible during the totality, as in a clear twilight at evening, Venus and Mercury, near the apparent place of the Sun, exhibited an unexpected brilliancy, and a member of the observing corps was impressed with the number of stars visible, and counted to those of the first magnitude only. * * * The fall of the temperature was marked as the obscuration approached and reached totality, the breezes continued to feel quietly during the increasing darkness as at an approaching sunset.

"At the moment of emersion the first rays of the sun showed themselves at several detached points on its western limb, forming again the Bailey's Beads which united in a delicate crescent. * * * It was a striking circumstance connected with the whole phenomena that so many of its details could be observed with the unaided eye. Some among our guides saw very readily Baily's Beads, exclaiming that the sun was breaking to pieces, and could distinguish without difficulty some of the protuberances."

Eclipses of the Moon.

Lunar eclipses are of two kinds, which are, first, *total*, if the moon is entirely immersed in the earth's shadow, and second, *partial*. There can be no annular eclipses of the moon, because in any case when she has her centre on the same line as the earth, the shadow of the latter will be greater than the moon's disc. Since eclipses of the moon are caused by a real cutting off of her light, it follows that they may be seen on any part of the earth to which she is visible, and while a total eclipse of the sun cannot last more than four minutes in any one place, a total eclipse of the moon may last nearly two hours, and the gradual coming on and going off of the shadow may increase the entire time of the eclipses to three or four hours.

This difference will be made clear when we recall that the apparent diameter of the Moon exceeds that of the Sun by a very small amount, while the cone of the Earth's shadow even when it reaches the Moon is nearly three times greater than the diameter of the latter.

In a lunar eclipse the moon is *gradually* darkened as she enters the earth's penumbra and then when she is *gradually* immersed into the real shadow. Even when she is totally eclipsed she does not become entirely invisible, but still shines with a dull red light, which is refracted into the shadow by the Earth's atmosphere through which the sunlight must pass in order to reach the Moon.

As she travels from West to East we first see her eastern side slightly dim, and this is the first contact with the penumbra of almanacs. And as she emerges from the umbra we have the last contact with the dark shadow, and, finally, last contact with the penumbra, and the eclipse is over.

Eclipses can be calculated with a great degree of certainty by any one for years to come, but for ages which are past, owing to their known periodic recurrence, as well as many other observations. They are calculated by astronomers to the second, by more complex methods, but for an explanation of which persons interested are referred to Newcomb, or any other authority upon this interesting subject.

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