

use Pallas's expression, were quarreling after the death of their master. It appears, then, that the red cheeks of apples and those of our children are produced by entirely similar processes, and that blood is

not peculiar to the animal kingdom. Here, as everywhere, the truth was discerned by popular instinct long before it was discovered by science. The farmer gives the name "bleeding" to the exudation of sap from cut

stems, branches and roots, and wine is called "the blood of the grape"—a designation which acquires a new significance in the light of modern research.—Translated from Prometheus.

# LIGHT PRESSURE AND COMETS' TAILS.\*

WHY A COMET'S TAIL ALWAYS POINTS FROM THE SUN.

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Of the various theories that have been put forward in order to account for the repulsion of comets' tails, besides the electrical theories, probably the most popular is that which ascribes the streaming away from the sun to the effect of light pressure. When radiation of any kind, sunlight or the heat from a fire falls on a surface, it exerts a pressure on that surface tending to drive it back. The light from the lantern which was falling on the screen just now presses against the screen, though the whole pressure is exceedingly minute; the whole pressure of sunlight falling on the earth is something like 150,000 tons weight, a force which is insufficient to make the earth budge so much as one hair's breadth from its path. But on the small particles of a comet's tail its effect may be of importance, because although the force of pressure decreases with the size of the particle, it does not do so so rapidly as the volume or weight, so that the effect on the motion is up to a certain point greater the smaller the particle. In the case of a particle 1/20,000 inch in diameter, the light pressure would just about balance gravitation; such a body would be neither attracted to nor repelled from the sun. For one whose diameter is 1/150,000 inch the repulsion of light pressure would be twenty times gravitation. You will remember that Bredichin found three classes of tails, of which the one most powerfully repelled the repulsion was eighteen times gravitation. We have only to suppose that the particles are of this order of magnitude, in order to account fully for his results. The existence of light pressure was deduced from theoretical considerations, but it does not depend on theory alone. The repulsion can be shown in the laboratory. Hull and Nichols actually tried to make an artificial comet, using the fine particles of lycopodium powder to show the repulsion of the tail. Unfortunately, although a repulsive force was shown, it was due mainly, not to light pressure, but to another effect.

With a particle about 1/150,000 inch in diameter, the repulsion is twenty times the attraction of gravity. Can we proceed to still smaller particles and account for forces of 36, 90 units, or still higher? It appears not. The size mentioned is about the limit, and for small particles we find, instead of increasing repulsion, less repulsion. Very minute particles offer practically no obstacle to the passage of light which, instead of pressing against them, bends freely round. I dare say by suitable assumptions, as to the density of the material, forces of 36 units might be accounted for, but the hypothesis of light pressure seems hardly competent to account for the greater repulsive forces. It must not, however, be supposed that the theory of light pressure is thus discredited; light pressure must act, and probably acts powerfully, on the minute particles which constitute a comet's tail, but a careful analysis of the strange motions and transformations taking place has convinced many astronomers that other forces are at work modifying and in some cases increasing the repulsion. In this connection the evidence that the repulsion is by no means a constant force has obviously a most important bearing.

At first it is with an almost overwhelming sense of the complexity of the problem that we sit down before this mass of material, striving to see through the twisting streamers and changing features to the few simple forces that govern it all. There are, however, a few signs of regularity in the photographs to which it seems most hopeful first to turn. The envelopes are wreaths or veils thrown out toward the sun and flowing away on each side. They are not like the streamers from the nucleus, for they seem quite detached, forming an arch over the head. The mode of formation may be illustrated by a well-known analogy. If you have a fountain consisting of a large number of jets of water in different directions, the limiting surface is a sort of dome in the form of a paraboloid, which, when seen sideways, exactly imitates the envelope of a comet. It is not merely a bounding surface beyond which none of the water is projected; the arch is thickened along this surface. When the water is turned on fuller, the arch rises; if it is turned off gradually it sinks, but if it is turned off suddenly the arch does not subside, but vanishes; the water of course subsides, but the thickening vanishes.

It can hardly be doubted that the envelopes of a

comet are formed in this way; the explosion, from which the envelope results, throws out matter with fairly uniform speed in all directions, this matter being under the influence of solar repulsion, just as in the analogous case the water was under gravitation. By studying them we can learn something of the explosions that produce them; further, in them we are concerned with the general mass of fine particles, so that the study of the rather exceptional knots and luminous patches is supplemented; and, finally, in them we have to deal with the repulsion of the particles, very shortly after they are projected, which is of special importance in the light of the recent evidence that the repulsion may cease to act.

The best defined and most regular envelopes on the Greenwich plates are those of October 27th; the envelopes approach the parabolic form so closely as to confirm our hypothesis as to their formation, and to indicate that any disturbing forces are small. I give below some measures of two of the envelopes shown on that night on plates taken at various times. The first column shows the height of the arch deduced from measures made at the apex, that is to say, by direct measurement; the second column from measures made of the direction of the envelope near the ends of the latus rectum, and therefore deduced indirectly. We have thus two independent determinations of the height.

The accompanying table shows very characteristically the transitory nature of the envelopes and of the explosions. The large one, for instance, formed at about 8 h. 30 m. (it was hardly formed in the first photograph), and in the space of two hours subsided from its original height of 70,000 miles to 40,000 miles; that is the typical behavior of the envelopes; it indicates that the explosion is strongest at first, and

ENVELOPES OF COMET C, 1908 (OCTOBER 27TH).  
(Distance of the vertex of the envelope from the nucleus of the comet.)

Time. H. M.	Outer Envelope.		Inner Envelope.	
	(1) Miles.	(2) Miles.	(1) Miles.	(2) Miles.
8 23	71,000	71,000	43,000	35,000
9 3	64,000	61,000	38,000	30,500
9 32	51,000	50,000	26,500	30,000
10 2	48,000	44,000	16,000	14,000
10 28	42,500	41,000	21,000	19,000

- (1) Deduced from measurements made at the vertex.  
(2) Deduced from measurements of the course of the envelope near the ends of the latus rectum.

then dies down rapidly. But we can make another deduction: the envelope was beginning to form at 8 h. 23 m.; by 9 h. 3 m. the complete arch was visible. Now it can be shown theoretically that the formation of an envelope does not take place instantaneously along the entire arch; if, for example, the material forming the apex left the nucleus an hour previously, that forming the ends of the latus rectum left an hour and twenty-five minutes previously, and so on in proportion. Conversely, we can argue from the fact that the whole arch appeared in so short a time, and that the ends of the latus rectum begin to collapse very little, if at all, after the apex, that the time taken by the matter to travel from the nucleus to the apex must be very small. I dare not trust the figures in the table so far as to calculate that time from them, but probably it will be a very safe outside limit if we say that that time is not more than two hours. A simple calculation shows that, for that to be the case, the solar repulsion acting on these particles must be at least 800 units—far larger than any repulsion calculated by Bredichin, Jaegermann, or others; the velocity of projection would need to be 70,000 miles per hour. These figures are far too startling for us to immediately accept them; though of course if it is admitted that the repulsion acts only for a short time, instead of continuously, it must be correspondingly more powerful during that time. We are at the beginning, not at the end of an investigation; but I am convinced that a great deal is to be learned from the study of these envelopes. Unfortunately they are often very complicated. Sometimes two of them will intersect, or they may be all askew. That need not

be considered surprising, for the simple parabolical form can only occur when the force of the explosion is equal in all directions.

Another feature sometimes possessing some degree of regularity is the waving of the streamers proceeding from the head. This is a feature which will certainly repay a much more careful examination than we have yet had time to give. The most immediately striking feature is that two or more of the streamers often run parallel to one another, their undulations exactly corresponding with the crest of one fitting over the crest of the other. As might be expected, the undulations become larger, both in length and in amplitude, as we proceed outward from the head. Prof. Wolf has published some interesting data on this point. The thought suggests itself that the curves may be spiral curves produced by a rotation of the nucleus of the comet while it is discharging the streamers. The hypothesis is one which can probably be tested by careful measurement; meanwhile it appears to be more probable that the undulations, like so many other features, must be accounted for by changes, perhaps rhythmic changes, in the force of expulsion of the material.

Whatever may be the true cause of the phenomena of comets' tails, it is at least clear that the source of the power which forms them and which directs them is to be found in the sun. I am not sure that the exceptional activity of this comet is not due to the physical state of the sun at the time rather than to the constitution of the object itself. Certainly progress in explaining the phenomena is hampered by our partial ignorance of the electrical and physical conditions of the sun's surface. Therefore I cannot close this discourse without alluding to what is perhaps the greatest result of any that recent years have afforded to astronomy: Prof. Hale's photographs of solar vortices and investigations of their magnetic fields. With the great Tower telescope in the clear atmosphere of Mount Wilson Observatory he obtained photographs of the remarkable structure, revealing to our eyes the gigantic whirlwinds raging over the solar surface above the sun spots. These photographs are taken with the light of one particular wave-length, the H $\alpha$  line of hydrogen. He has gone further and shown, I believe, to the satisfaction of physicists, that the light passing up through these vortices bears the sure marks of having passed through a strong magnetic field, whose lines run perpendicular to the solar surface, and that, according as the vortices rotate clockwise or counter-clockwise, the lines of magnetic force run from or into the sun. The chain of evidence seems to show that the field is produced by the rotation of negatively charged material in these vortices.

It would be hard to exaggerate the value of these latest revelations as to the condition of the sun, far though they are from satisfying our inquiries or enabling us to realize that power which over all the millions of miles convulses the comet and scatters its trailing debris to the remotest parts.

A consular report states that increasing attention is being devoted in German cities to all questions connected with atmospheric conditions. The fact that sunshine lessens as population becomes more dense, and especially when the activity of industrial centers expands superficially and increases in intensity, has long been noted. An increasing tendency to fog has also been observed, and both are effects of the imperfect and incomplete combustion of coal. Modern industry pays toll for this in the injury of delicate fabrics, the general depreciation in the value of many articles of trade and household use, and the increased cost of cleansing. Since the battle is waged with growing energy against tuberculosis, physicians and students of social science feel that the problem of purer air for the dwellers in cities has become one of prime importance. Statistics have been collected for some time past, which demonstrate how little sunshine falls to the lot of the residents of industrial cities, even when the sun is unobscured by smoke particles. In no German city has the loss of sunshine due to fog equaled that of London, where the foggy days during the three months, December, January, and February, increased from eighteen to thirty-one during the last half of the past century.

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