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Post-Graduate Address

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Our Knowledge of Comets.

Few of the departments of astronomy have been more continuously and carefully studied in the centuries past, than the one which pertains to comets, yet none is more interesting today, not only to the astronomer but also to those who only occasionally turn their thoughts toward things unearthly. There is something about these wonderful bodies, their vast proportions, the suddenness of their appearance and mystery of their nature, well calculated to arrest attention. In the earlier centuries they seem to have been universally regarded with terror, as harbingers of some dire calamity to mankind;

"Threatning the world with famine, plague and war;
To princes death; to kingdoms many curses;
To all estates, inevitable losses;

To husbandmen not; to ploughmen hapless seasons
To sailors: storms; to citizens, civil treasons".

Even in the present age the sudden appearance of a brilliant comet, like those of 1881 and 1882, produces a profound impression and causes much speculation concerning its origin nature and probable purpose.

On an average, about twenty five of these "blazing stars" become visible to the eye in each century. Many times that number are seen with the aid of a telescope and doubtless many more are beyond the reach of even the most powerful "optick tubes". Probably the speculations of the illustrious Kepler is true: "that the celestial spaces are as full of comets as the sea of fish, only a small portion of them coming within range of our telescopes."

Let us, with the aid of a powerful telescope, follow one of these mysterious visitors on it

journey to the sun and note the phenomena which it may exhibit. It is now about three times the distance of the earth from the sun and appears as a simple round patch of nebulous light nearly uniform in all its parts. It has been traveling for hundreds, perhaps thousands of years through the intensely cold space in the outer parts of the solar system. Gradually the meteoric particles of which the comet is composed begin to glow with the increasing light and heat received from the sun and in the central part, where the light and heat are concentrated by reflection from particle to particle, a condensation appears, which gathers intensity from day to day. Finally a point or disc of light appears in its center which shines with a light approximating that of the planets. This is called the nucleus. Later on a

faint streak of light or tail is seen extending in the direction opposite the sun. The great majority of comets never get beyond this stage of development, but the one which we now follow is destined to approach very near to the sun and to undergo a degree of heat as intense as that of the cold through which it has recently passed. Swifter and swifter it flies almost straight toward the great center of light and hotter and hotter become the solar rays. Violent action appears to take place on the sunward side of the nucleus, and great volumes of vapor rise toward the sun with astonishing velocity. Jets are thrown up to the height of thousands of miles in an hour. Sometimes the whole hemisphere of the nucleus appears as one gigantic volcano, belching forth an enormous fan-shaped jet.

of glowing vapor. But, what do we see? Three jets, after rising toward the sun, fall back, not upon the nucleus, but fast it on all sides, as if repelled by some force from the sun, and form a hollow cylinder which extends far out into the tail. This hollow cylinder is transparent in the middle portion, like a glass tube, so that it has the appearance of two bright streams of matter flowing away from the nucleus. The first direction of the cylinder is exactly opposite the sun but it gradually curves backward, unable to keep up with the nucleus in its ever hastening flight.

Let us pass on and watch the behavior of the comet in the immediate vicinity of the sun. The temperature increases until it becomes two thousand times hotter than red hot iron. The nucleus becomes a

seething molten mass in which violent convulsions are taking place and masses of vapor, and perhaps of molten matter, are ejected with terrific force. But, strange to say, these do not rise to such a height as before. The repulsive force from the sun seems to have proportionately increased and the streams flow away immediately into the tail. This latter feature expands to an enormous extent and near the head becomes so brilliant as to be visible in midday and close to the sun.

The velocity is now so great that the comet seems about to pass the sun in a straight course and to fly off to the opposite part of the heavens, but here "Old Sol" exerts his powerful arm of attraction and whisks the little nucleus around him with incredible speed and hurls it

like the shot from a sling, back in nearly the same direction whence it came. The head of the comet has passed within 300,000 miles of the sun's surface, through indeed the very atmosphere of that luminary. Out of this fiery ordeal it comes shorn of everything but the nucleus. The magnificent tail which it possessed but a few hours before has been left behind, to be dissipated in the interplanetary space. The smaller particles composing the head have been completely volatilized and driven away. Streams of matter, however, still issue from the nucleus, even more abundantly than before, and in a few days a new tail is formed, more brilliant and of grander proportions than its predecessor. This tail is not behind the nucleus, but in advance and again in the direction opposite the sun. We can

watch its growth from night to night, for it is not formed instantaneously, or even with the velocity of light, as many have supposed. It takes from twenty to forty days for the streams from the nucleus to reach the distance at which they vanish. Sometimes there are condensations in the streams of matter which may be recognized from night to night until they reach a distance of a hundred millions of miles from the head of the comet. As they move outward they gradually fall back from the straight line, giving to the tail a gracefully curved form. Some of the particles seem to be driven off with greater velocity than others producing tails of different lengths and of different degrees of curvature. One long narrow branch seems to be propelled much more swiftly than the others and is therefore

much straighter. Others are extremely faint, very short and greatly curved. The brightest tail extends to a distance of not less than 200,000,000 miles from the nucleus. The thickness of the tail is nowhere less than 100,000 miles and its greatest width is about 10,000,000 miles. It seems almost incredible that such a vast appendage could be evolved from so small a body, and yet it is so attenuated that the faintest stars may be seen through the thickest portion.

Meanwhile the nucleus has been suffering the effects of the tidal action produced by its close approach to the sun. It must have the tenacity of steel in order to avoid being pulled apart by the tremendous tides, which continue for many days. Soon we find it becoming greatly elongated and in

a few days breaking up into two, three and many, smaller nuclei. As the comet recedes farther from the sun it gradually cools off, the evaporation becomes less abundant, the tail diminishes in size and splendor, until all finally disappear, the last aspect being the same as the first: a faint, circular, nebulous speck.

In this brief sketch, I have given only those phenomena which I have personally observed in the comets of the last six years. Most of them were exhibited by the one Great Comet of 1882, whose sudden appearance in September of that year, shining in midday close to the sun, startled astronomers themselves. This remarkable object came from the direction of the giant star Sirius, moving in an almost straight course toward the sun, swept around

that great center at a distance of less than 300,000 miles from the sun's surface, with an incredible velocity of a million miles per hour, and is now receding in almost exactly the same direction whence it came. Its speed is constantly diminishing and at the extreme part of its orbit will be only five miles per hour. The one half of its revolution around the sun was described in about four hours but the other half will take not less than 750 years.

The origin of comets is still a disputed question. They come from all directions in space and move in very eccentric paths across the sky. Some move around the sun in the same direction as the planets; others take exactly the opposite course. Some come up from below the ecliptic; others plunge down from the north polar regions and disappear in the

opposite part of the heavens. Still others appear to move straight toward the sun, but suddenly sweep around that great center, and fly off in the same direction whence they came. Their real paths through space are extremely elongated ellipses, so elongated, indeed, that in most cases they cannot be distinguished from the parabola or infinite ellipse.

The prevailing opinion is that comets originate outside of the solar system, either as fragments of the original chaotic nebula, out of which the starry worlds were formed, or as having been ejected from the stars and having come by chance within the influence of the sun's attraction; that the greater number of them simply pass through the solar system and out again never to return; but that a few happen

to pass near some of the planets and are. by their attraction drawn into closed orbits around the sun.

The millions of stars which surround us on every side are all remarkably like our own sun. Many of them are even larger and more powerful than he. Reasoning from analogy we may suppose that each of these suns is also attended by comets; hence we are led to the conclusion that millions of comets projected forth from millions of suns during countless ages past, are now flying through space in every direction,— restless messengers from star to star. By mere chance some of these must fall within the sun's far-reaching power and be drawn into our planetary system.

On the other hand, there are serious objections to this theory, and some eminent astronomers

are arrayed against it. The problem is beset with difficulties and requires for its solution more accurate data than those which we now possess. Practically, for as long a time as history shall last, we may regard them as members of our system, for supposing the sun's power to extend only half way to the nearest star, it would take 10,000,000 years for a comet to pass beyond that limit.

The physical nature of these bodies is even more problematical than their origin. The vast proportions which some of them assume, compared with the small quantity of matter which even the largest actually contains, their perfect transparency and the mysterious force by which the tail is driven away from the sun while the nucleus is held firmly in its course, are almost incomprehensible. Recent researches

by Professors Newton, Schiaparelli, Zöllner, Bredichin and others have thrown much light upon these problems; but we must acknowledge that they are still far from satisfactory solution.

The most probable explanation is that comets consist of small detached particles, partly solid and partly gaseous, so widely separated as to allow the light of stars to pass between them unhindered, and so small that the individual particles cannot be distinguished, but all combined give a continuous light. The nucleus is a denser aggregation of the larger particles, which, perhaps, when near the sun become fused together and form a planet-like body. The tail is composed of detached particles of vapor and gas, thrown off from the nucleus and the smaller meteoric bodies composing

the head of the comet, by an electric force generated in the process of evaporation, and driven outward by an electric force from the sun.

Regarding the influence of comets upon the earth, I may say in conclusion that they produce no physical effect whatever. There is about one chance in a million that a comet may strike the earth, and if we should happen upon that one chance, the only serious consequence would be a shower of meteors more or less brilliant. One happy influence they do exert. They excite our curiosity and direct our thoughts to the contemplation of the grand problems of the universe which surrounds us.