Comets

BY THE REV. J. MITCHELL, M.A., F.R.A.S.

Mysterious visitant whose beauteous light
Among the wandering stars so strangely gleams
Like a proud banner in the train of night
The emblazoned flag of duty it streams
Infinity is written in thy beams
And thought in vain would through the pathless sky
Explore thy secret course, thy circle seems
Too vast for time to grasp. Oh ! can that eye
Which numbers hosts like thee, this atom earth descry.

THIS is the poet's attempt to express his thoughts in reference to Comets ; whether he is correct in his surmising or not, we shall see during the course of this lecture.

We are accustomed to think of the celestial orbs as being the most regular and law-abiding of all created objects. The stars, so far as ordinary sight is concerned, are fixed in space. Centuries pass but they remain precisely in the same place relatively to one another. The Sun is the centre of the solar system and knows no change in brightness or attractive power. The planets with their satellites revolve round the Sun with a perfectly regular and uniform velocity. Order and law reign supreme in the Universe. It is true that occasionally extraordinary phenomena like eclipses occur, but every eclipse, whether solar or lunar, is known beforehand, and each is predicted with the greatest accuracy. But comets, or the vast majority of comets, appear to be exceptions. Some few there are that follow the course of the planets and accept the Sun as their over-lord, but the rest, and this signifies an enormous host, follow their own law. They come when least expected ; from whence they come and whither they go is one great mystery.

Comets until quite recent years have, in every part of the world and in all ages, been regarded as evil portents, presages of disaster. Even as late as the 17th century a certain poet wrote of comets thus :—

" A Blazing Star
Threatens the world with famine, plague and war
To princes death ; to kingdoms many crosses
To all estates, inevitable losses,
To herdsmen rot, to ploughmen hapless seasons
To sailors storms, to cities civil treasons."

In this country comets have, in general, always been regarded as dire portents. An eclipse of the Sun or Moon renders the time being inauspicious and impure, but the rise of a ধূমকেতু (comet) is a still worse portent, *e.g.*, after such an appearance a soldier shall not for 7 days take part in a military expedition. According to the colour and form of a comet its influence for weal or woe depends. Generally speaking, a white tailless or short and straight comet does not produce such evil effects, but a comet in the form of a rainbow is an omen to be dreaded, but if it possesses three crests then the results are direful in the extreme.

101 comets are accounted for thus :—

(1) 25 are produced by fire ; they are blood-red or have the colour of lac. They are found in the East and South and they give rise to a general conflagration.

(2) 25 come from যম. the god of death. They are black in appearance, have crooked tails and are found in the South. They bring death to countless numbers.

(3) The Sun accounts for 25. These are golden in colour and appear in the East and West. Such comets produce unrest and disorder among the princes.

(4) 22 are produced by Mars. They produce hunger and fear and are found in the North and East.

(5) The Moon accounts for 3. These are white and glistening or silvery and their influence on the whole is for good.

(6) Lastly, the Creator himself produces 1. This comet may appear in any part of the sky and the result is universal destruction.

Most of us can remember at least one occasion when the coming of a comet has given rise to the scare that the world would come to an end on a given day. Such a scare got abroad in England in 1872, and in this connection Richard Proctor, the famous Lecturer on Astronomy, tells a good story which has the merit of being true : "In a certain house in Sheffield, Monday, August 12, had been appointed a great washing-day. On the morning of the day, the housekeeper asked for an interview with her master on the subject of the comet. She begged to know if it were really true that the world would be destroyed on that day. Receiving assurances to the contrary, she expressed some degree of satisfaction, "but, Sir," she said, "though what you say may be very true, might it not be just as well after all *to put off the washing-day till to-morrow?*"

Now it is not to be wondered at, that these mysterious visitants gave, and still give, rise to fears. As we have just stated, regularity and order characterise the celestial orbs generally, but comets appear to know no order. They suddenly appear faint and tiny at first, then in a short time they brighten up, shoot out a long tail until in some cases they span the heavens like a flaming torch ; visible, sometimes, even in the day time, and then as mysteriously diminish and disappear.

Comets vary in apparent size and brightness enormously, and as regards number, who can count them ? Kepler stated that they inhabited the ether as fishes the ocean, and that the ocean was not fuller of fishes than the ether of comets. Probably thousands visit our neighbourhood without being seen. Many are so feeble in brightness that only a powerful telescope or the photographic plate can reveal them. On the other hand, the comet of 1744 equalled Venus in brightness and became visible at noon, and as recently as January 1910 a "day-light" comet appeared in the heavens. Then who can forget the magnificent comet of 1882, as it spanned the East Heavens ? This was my first comet and it impressed me greatly.

Comets to the early inhabitants of the world appeared to have little or no connection with the solar system and scarcely any even with the Universe. What were they ? They differed from each other in appearance, and shape, and some apparently in colour. They appeared in every conceivable portion of the heavens. Sometimes in the East before sunrise, sometimes in the West after sunset. Now they appeared in the northern heavens moving across the familiar stars of the Great Bear, now in the South, cultivating the acquaintance of Orion or the Scorpion. Their true paths in the heavens the ancients were absolutely ignorant of, but later they became aware that in some way or other their increase in size and brilliance was due to the Sun, and they noticed, too, that the tails of comets were always turned away from the Sun. Gradually astronomers began to suggest paths in which comets might move. Tycho Brake thought they might move in circles. Kepler and Galileo believed they traversed the solar system in straight lines. Hevelius generally agreed with Kepler, but he threw out the idea that the path might possibly take the form of a parabola, but it was Sir Isaac Newton who put an end to these hypotheses by connecting the movements of comets with the laws that govern the motions of all the heavenly bodies which move within the sphere of the Sun's attraction. Newton was a godsend to the world of intellect and especially of mathematics and astronomy.

And this leads us to the part that Halley played in the discovery of cometary motion. Apart from Halley's connection with the famous comet that bears his name, the world owes more to him than most people realise, for it was largely due to his enthusiasm and generosity that Newton's immortal "Principia" was due, for it was he who urged its writing, it was he who urged the Royal Society to publish it when written, and it was he who bore the entire expense of its publication.

In the Principia, Newton promulgated the theory of gravitation and applied it in many directions, but so far as we are concerned to-night, to the orbit of the great comet of 1680. He stated that it was very probable that some comets might move in elongated ellipses, and that the comet of 1680 might be moving in such an ellipse, and he invited astronomers to apply the principles laid down in his work to all the comets on record. Halley took up the task. He undertook the investigation of the movements of a large number of the comets previously recorded and calculated the paths of 24, to see if any, and if so, which followed the same path. He carefully investigated, in particular, the orbits of the comets of 1531, 1607 and 1682, and he found a remarkable similarity in their elements and he came to the conclusion that they were one and the same comet, and so confident was he that he predicted its return in 1758, and he concluded his memoir as follows: "Wherefore if, according to what we have already said, it should return again about the year 1758 candid posterity will not refuse to acknowledge that this was first discovered by an Englishman."

And candid posterity has given Halley his due, but while giving him his full due as being the first to predict the reappearance of the same comet, great credit must be and is given to the two Frenchmen, Clairaut and Lalande, and also the French lady, Mddle. Horteuse Lepande, who completed Halley's work by predicting with greater accuracy the date of the comet's perihelion passage. On its way here the comet had to pass near the planets Saturn and Jupiter, and the perturbations due to these would be very considerable. These the mathematicians took into consideration and the labour involved was immense. Eventually Clairant announced the 13th April 1759 as the date for the perihelion passage. The actual date was the 12th March 1759, a difference of only 32 days, but what are these in 76 years. It was a triumph, for the difficulties of the problem were most formidable. This will be realised to some extent when it is stated that the comet was delayed 618 days by the two planets, 100 being due to Saturn and 518 to Jupiter.

The next appearance of the comet was still more eagerly looked for and even greater preparations were made by the mathematicians. Again Frenchmen were to the fore. This time the perturbations caused by the new planet "Uranus," before this discovered by Sir William Herschel, had to be taken into consideration. The Frenchmen were joined by two German astronomers, one of them, Rosenberger, being one of the most distinguished mathematicians of the age. Not only did he take into consideration the effect of the larger planets but the smaller ones also—Mercury, Venus and Mars. He fixed November 26, 1835, as the date of the perihelion, but the comet actually passed this point on November 16, 1835, 10 days before the calculated date. This was another triumph for gravitational astronomy.

The honour of the prediction of the last return in 1910 belongs to two Englishmen, Drs. Cowell and Crommelin, both Cambridge men. By a much more simplified process of mathematical reasoning they fixed the perihelion passage within 2·7 days of the actual event, and they conclude their memoir with the following significant words: "There is some small disturbing cause at work whose character is not yet recognised." It may be so. Suppose there is another planet beyond Neptune, that small disturbing cause will, one day, we hope, be discovered and then the course of one comet at any rate will be known.

We are thus led to the conclusion that the orbit of a comet such as Halley's, which re-appears after a given period, in this case about 75 years, must be a closed curve, either a circle or an ellipse. The circle does not seem a popular path. All the planets along with their satellites move in ellipses, though these in almost every case are not far removed from circles. But the comet eschews a circle. The few that return to us periodically move in ellipses. Some, like Halley's, are vastly extended approaching parabolas which is what the ellipse becomes, when it becomes infinitely extended, and this is the path of the vast majority of comets that appear. They come from infinite depths of space, fall into the sphere of the Sun's influence, are attracted, circle round the Sun and rebound into space, never to return. Some we say are caught by the Sun's attraction, but how many are not? How many exist beyond and are never seen?

We have just stated that Halley's Comet moves in an ellipse, but what a zig-zag path it must be after all when it can be delayed 618 days by two planets. It must have a most tortuous course as it makes its way past planets and satellites.

Again, we may compare a comet with the planets. The planets in their various paths round the Sun move in planes inclined only at a slight angle to the ecliptic, *i.e.*, the plane of the Earth's orbit. Mercury's orbit is inclined 7°, Venus 3°, and the rest less. The satellites are more variable. The plane of a comet's orbit may be at any angle to the ecliptic. In the most extraordinary manner it may come and go. The planets all revolve round the Sun in the same direction, but a comet's path may be either direct or retrograde. Halley's Comet is retrograde.

In these days comets have lost all their terrors to the astronomer, because he knows something of their true dimensions. Though they bulk large in volume, yet the mass of the largest must be exceedingly small. The largest telescope fails to magnify the nucleus into a disc even when they approach to a minimum distance. Lexell's Comet of 1770 got entangled among the satellites of Jupiter without causing any inconvenience whatever to Jupiter's followers, and the same comet approached the Earth to within $1\frac{1}{4}$ million miles, yet it showed no disc and did not affect our planet in any way. Seeing that the mass of a comet is so small it is rather surprising and exceedingly interesting to find how wonderfully stable Halley's Comet has been in its ways.

Messrs. Cowell and Crommelin have shown that the inclination of this comet to the ecliptic in 1066 was 16° 5′, in 1607 17° 6′, in 1759 17° 36′ and in 1910 17° 47′, *i.e.*, in nearly a thousand years the inclination has only varied about one degree. Hind has traced the comet back to 11 B.C. and he finds most remarkable stability and regularity in its periodic visitation.

In the early stage, when it is far from the Sun, a comet appears round and nebulous, and apart from its motion among the stars it is not possible then to distinguish it from an ordinary nebula. I well remember, on the 28th February 1910, first catching sight of Halley's Comet. It was circular in shape and nebulous in appearance and there was no nucleus. It could only then be seen through the telescope. Up to March 7 it remained like this, and then it disappeared in the Sun's glare, and it was not until the 20th April that I again caught sight of it in the early morning. In the meantime it had changed in appearance. There was now a well-defined nucleus sharp and bright like a star. This was surrounded by a circular patch and produced into a tail and a bright star was shining through the tail. Speaking about stars inside the comet, on the 27th May, about 7-30 P.M., I noticed a star in the head of the comet only a short distance from the nucleus. For over 2 hours I watched that star. Gradually the nucleus drew nearer until about 9-20 (Standard Time) the star was so close that the two resembled a double star, closer than the components of Polaris and about as close as the components of the well-known double-star Castor, *i.e.*, 5″ apart. When at its nearest point to the nucleus I noticed a very slight diminution in the brightness of the star, but only at this point. Elsewhere the star shone out through the comet's tail and head undimmed in brightness.

Another important feature in connection with this comet was this. On the 19th May 1910 the comet passed between the Earth and the Sun. There was a transit. Now had the comet's nucleus been appreciable in magnitude, it would have been seen as a small point on the background of the Sun's disc. I remember watching most carefully. I also took a photograph of the Sun, but not the slightest speck was discernible and in no part of the world was the slightest trace of the comet seen by any observer.

That physical organ, the comet's tail, we must study a little more closely. Most comets, not all, have a tail at the glorious part of their career. Some have more than one. When No. 3 Comet of 1903 was photographed at Greenwich 9 tails appeared on the plate. Extraordinary changes sometimes take place in this appendage from night to night as a study of the photographs clearly show, *e.g.*, notice the *white spots* travelling along the tail. Probably a new tail is formed each night.

Not only does the tail undergo violent and sometimes disruptive changes but occasionally the comet as a whole suffers violence. Comet Moorhouse of 1908 was one of these. On the night of September 29 it rejoiced in a substantial normal appendage, but all through the night of the 30th violent changes were taking place. A photograph taken on the night of the 1st October revealed the astounding fact that the tail had been separated from the body. In the telescope it looked as if the comet had completely lost its tail, but a photograph shows that a slight connection still existed in the shape of slender streamers. On the 15th October a still more violent change occurred, the comet actually broke in two.

The stuff of which a comet's tail is composed must be in a most highly attenuated condition, otherwise such phenomena as we have been describing could not take place. What, then, can be the condition and composition of a comet so slight in mass and yet so expansive and which yet obeys so precisely the law of gravitation ?

Here I would digress a moment. I would point out the reason why Astronomy should be taken up seriously in this great land of India. We have a wide area, for many months of the year we have perfectly clear skies especially in that part of the year, November, December, January, when the astronomers of Northern Europe find Practical Astronomy almost out of the question. At present apart from a few Government observatories there are in this country very few private observatories that are well equipped and in active use. Take the case of Halley's Comet. Two years ago I went to England on furlough. There I met Mr. Hinks, of Cambridge, a keen and able astronomer and author of a capital book on Astronomy. I asked him about the comet and what they in England thought of it. "A miserable failure," he said. "It was scarcely visible at all. Most people never saw it once." How different here. To us it was a magnificent object. I myself observed it carefully on 32 different occasions. Thus for the cause of the science we should be up and doing that our work might supplement the work of astronomers in other countries.

For our knowledge of the composition of comets we are largely indebted to that grand old amateur astronomer Sir William Huggins, now, alas! no longer with us. In his early days he hesitated between the microscope and telescope. Eventually he decided—and fortunately for Astronomy he did so—in favour of the latter instrument. He fitted up an observatory and for a time systematically observed the planets, but becoming dissatisfied with the routine character of the work he began to cast about for some fresh kind of research upon the heavenly bodies. It was just at this time that Kirchhoff's (1859) great discovery of the true nature and chemical constitution of the Sun by the interpretation of the Fraunofer lines was announced. Here was the very kind of work Huggins wanted. He determined to extend Kirchhoff's method of research to the other heavenly bodies. Then he devised a number of instruments for spectroscopic work; he fitted up a laboratory and for many months was engaged in snapping the spectra of chemical elements. Armed with these he turned his spectroscope on the stars and brought to light the fact that stars are composed of the same elements that exist in the Sun and Earth. He next turned his attention to nebulæ and was the first to discover bright lines in the spectra indicating that they consist of incandescent gases of which H. gas is the most prominent. Incidentally a comet appeared and here again he made a great discovery. He found that there was a continuous spectrum crossed by dark lines. This resembled the solar spectrum and indicated that the comet shone, partly at any rate, with reflected light, but he saw more. He noticed a second spectrum consisting of 3 *bright bands*. This was a still more startling discovery. It proved that the comet had light of its own, that it was incandescent. Further research showed that these bands could be produced in the laboratory and were peculiar to compounds of carbon. A comparison of the carbon-banded spectra of the laboratory with those of the comet showed that they were identical. Thus the mystery was solved or partly solved, for the comet's spectrum is not even yet fully understood, but one thing is certain all research into the composition of comets goes to show that carbon in some form or other is found there in an incandescent state. If any one wishes to see a comet spectrum let him examine the lower part of a spirit lamp or carbon dioxide or monoxide in a vacuum tube with a small spectroscope.

With the knowledge we have now gained from the spectroscope, let us go back to the comet as it approaches the Sun from infinite depths of space. Carbon, we have learned, in some form or other constitutes the most important element in its composition. Carbon is a common element. It is an important constituent of the Sun and planets, and, as we shall see later, of meteorites. On this planet carbon occurs in combination with other elements as carbonates, etc. It also occurs as pure carbon, *e.g.*, diamond, graphite, both of which are found in the older geological rocks. An interesting property of carbon is that it has the power of dissolving or occluding gases such as ammonia. It is to some extent soluble in molten iron and it is also capable of being reduced to a very fine state of subdivision, *e.g.*, smoke. In the laboratory carbon itself is a reducing agent, but is itself reduced from its compounds by various agents and deep down in the Earth where the temperature is exceedingly high such reducing processes are going on. But to return to the comet, it comes along, exceedingly slowly at first. At this stage it may consist of one solid piece of stone, or of several, but its mass is not very great. Its temperature may be low, but it is now in the Sun's influence, its velocity increases and its temperature rises. As it approaches the Sun its temperature rises still higher. Violent chemical reactions begin to take place. Occluded gases are given off and become incandescent. Explosions due to expansions of gases and material owing to the increased temperature take place. The carbon compounds are reduced and the pure carbon fuses and vaporises. Exhalations of carbon and probably other elements are driven off in an extremely attenuated condition, but these come in contact with the radiation of the Sun, *radiant heat, light, etc.* The comet's radiations are overcome and driven back and so the tail is formed. To some extent the radiations from the nucleus extend sunward and thereby we get the corona of the comet.

Spectrum analysis shows that the tail shines largely, almost entirely, by reflected light. And here let us call to mind Tyndall's classic experiment in which incidentally he shows that light itself is invisible. He caused a powerful beam of light to pass through a box in which all the dust particles had settled, the path of the beam was invisible. Then he allowed the slightest trace of impurity or dust to enter the box and the path of the beam instantly became visible though to the eye not a trace of any dust could be seen. This principle has been made use of in the Ultra Microscope from which we expect so much. A concentrated beam of sunlight is passed through a liquid containing in suspension excessively minute particles of various substances and then examined by an ordinary microscope. In this way particles altogether beyond the power of any microscope are illumined and rendered visible.

May not a comet's tail be in such a condition? So excessively minute are the particles of carbon or other substances that unless they were illumined by the sunlight they would be absolutely invisible. So excessively minute are they, finer than the finest dust, that the cloud of them constituting the comet's tail has not the power to dim the light of a star shining through.

Perhaps the most striking discovery made in reference to comets is their connection with meteors. The chief credit for this goes to the famous Italian astronomer, Schiaparelli, of Milan, famous also for his discovery of the canals of Mars. He compared the orbit of the Perseid Meteors, *i.e.*, that shower of meteors that have their radiant point in the constellation Perseus and which appear in August, with that of Comet III, 1862. He found that comet and meteors moved in the same track.

Biela's Comet illustrates this connection also and at the same time provides evidence in other directions. It was discovered in 1772 and periodically it visited us. In 1846 it astonished the world by breaking up into two comets, and so long as they were visible they travelled together side by side. In 1852 the twain again appeared, but now they were farther apart, and this time they appeared only to bid us good bye, for they never re-appeared in that form. In 1872 they were again due to appear, but in their place a substitute came in the form of a great shower of meteors, the Andromedas. On November 27, 1885, and 1892, we had showers with the same radiant point. Thus we have a swarm of meteors converted out of the disruption of a comet.

Perhaps the most interesting case of all is that of the Leonids, which so disappointed us in 1899. In 1799 there was a gorgeous display of meteors. In 1833 a still more brilliant shower. I have often heard my grandfather describe the swarm. On the evening of the shower he was sitting in his room when suddenly a friend rushed in, crying: " John, let us pray, the world is coming to an end, the stars are falling, look," and my grandfather went out. The stars were, indeed, falling in every direction, for the sky, from his description, was full of them.

In 1866 my father was an eye witness. He had been invited to a friend's house on the top of a hill. As he walked up the hillside late in the evening, being somewhat of an amateur astronomer, he examined the sky on his way. It was cloudy, but here and there were openings, and across the clear patches he saw meteors shooting across in a most startling manner.

I, myself, was an eye witness of the 1899 (November 14) shower. I sat up for two whole nights. On the first night I counted and charted about 80 meteors and on the second about 90. It was a sad disappointment, but I hope for a better display in 1933.

Professor Adams found the orbit of this particular shower, *viz.*, the Leonids was an ellipse and that its elements corresponded almost precisely to those of Tempel's Comet of 1866.

Thus we are led irresistibly to the conclusion that there is an intimate connection between comets and meteor swarms.

One thing we should not forget, a very small stone can become a meteor. We remember the guinea-and-feather experiment of our younger days. In a vacuum both fall with the same velocity. The ether of space offers no resistance. A milligram and a ton if started with the same velocity would travel together side by side. Probably in most cases the mass of the ordinary meteor is exceedingly small, but on reaching our atmosphere friction raises its temperature and it becomes incandescent and then is dissipated in the atmosphere. A small amount of matter is therefore capable of producing a fine shower of meteors, hence a comet, small though it be in mass, may be capable, on disruption, of producing a first-class shower of "shooting stars."

Finally, let us turn to the composition of meteorites. In the first place, it is well known that meteorites contain certain gases in solution as it were. Sometimes as much as six times their bulk. The occluded gases are such as Carbon di-oxide, Carbon mon-oxide, Hydrogen, Marsh gas and Nitrogen and the inflammable gases invariably preponderate. On one famous occasion a certain Professor lecturing in the Royal Institution lit up the room for a time with the gas from a meteorite. An examination of such incandescent gases with a spectroscope gives a spectrum similar to that of a comet.

Or take the composition of the meteorites themselves. Carbon is a common element. The specimen presented to this Astronomical Society is one of this type, rich in carbon. Other elements occur of course, such as Sodium and Iron, but these are not inconsistent with the theory that the composition of meteorites resembles the composition of comets.* Thus we are forced to the conclusion that comets and meteors are practically the same substances in different forms. They are similar in composition and they move in the same orbits. Comets are known to have disappeared and their places taken by meteors. Comets in one sense resemble nebulæ. Nebulæ are the stuff out of which suns are made, comets are the stuff out of which meteors are made.

We have come to the end of this lecture. To those who would know the purpose that comets serve in the economy of Nature we have no reply to-night; we can only direct them to the words of the inspired writer, "Oh, Lord, how manifold are all thy works, in wisdom hast thou made them all."

The Great Star Map

By A. B. Chatwood, B.Sc., F.R.A.S., A.M.I.C.E.

The title which I have chosen for this evening's lecture, "The Great Star Map," does not indicate very clearly my subject, which is the Astrographic Chart and Catalogue: the title is due to Professor Turner and I adopted it as I could think of none better.

Perhaps I cannot do better than at once give you some idea of the nature and magnitude of the work carried by my title.

It comprises a map produced entirely by photography showing stars down to the 14th magnitude, say 150,000,000 star images. This map will consist of 22,180 sheets, about 17 or 18 inches by 22 inches, a single copy would form a pile 33 feet high and weigh about 4,000 lbs. The second portion of the work is a catalogue of the positions and magnitudes

* Sodium and Iron, in particular, were conspicuous in the spectrum of Moorhouse's Comet.