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1910.

ANNUAL GENERAL MEETING.

MONDAY, MAY 9TH, 1910.

THE RIGHT HON. THE EARL OF HALSBURY, F.R.S. (PRESIDENT), IN THE CHAIR.

The Minutes of the preceding Annual General Meeting were read and confirmed.

An Address to His Majesty King George V. was moved from the Chair and adopted, all present standing.

The Annual Report was presented and adopted.

The following Members of the Council were elected :—

Rev. Chancellor J. J. Lias, M.A.*
Rev. H. J. R. Marston, M.A.
E. W. Maunder, Esq., F.R.A.S.
Theo. G. Pinches, Esq., LL.D., M.R.A.S.*
Ven. Archdeacon Beresford Potter, M.A.
Ven. Archdeacon W. M. Sinclair, M.A., D.D.*
Rev. J. H. Skrine, M.A.
E. J. Sewell, Esq.
J. W. Thirtle, Esq., LL.D., M.R.A.S.

The Annual Address was then delivered.

ADDRESS ON THE RETURN OF HALLEY'S COMET IN 1910.

By A. C. D. CROMMELIN, Esq., D.Sc., F.R.A.S.

WE have the privilege this year of welcoming a rare visitor, that few indeed of those now living have seen before, or can expect to see again. Its visits occur at intervals of three-quarters of a century, or more exactly it makes thirteen visits in 1,000 years. The idea of welcoming a comet is one that would have sounded strange to our ancestors, who regarded these visitors with terror as most ill-omened and precursors of plague, famine, and war. Their terror was not wholly unreasonable, for even from our modern standpoint, comets remain

* Retiring Members re-elected.

in many respects very mysterious; to the ancients the mysteries that they presented were quite baffling, and seemed to traverse all that they knew, or thought they knew, about the heavenly movements, which they rightly regarded as the embodiment of majestic law and order. "Let them be for signs and for seasons and for days and years"; "He hath established them for ever and for ages of ages; He hath made a decree, and it shall not pass away." We may not all of us realise how fully these movements were understood even 2,000 years ago; thus Fathers Epping and Strassmaier published a work a few years ago on the Babylonian astronomy as revealed by the cuneiform tablets, in which they showed that a regular astronomical almanac like our Nautical Almanac was published year by year, predicting the places of the sun, moon, and planets for the year. (Father Kugler is now bringing out a still fuller treatise on the same subject.) When they came to the comets, however, their power of prediction utterly broke down. These were utterly unlike the other bodies in their appearance and their movements, which refused to conform to the Zodiac or track of the planets, but were at random in all directions, and in all parts of the heavens. They were often so extremely rapid as to suggest great proximity, possibly even within the confines of our own atmosphere, in which case the apprehension was quite natural that evil effects, such as pestilence and famine, might be the result of their approach. It was indeed almost impossible for the ancients to form a true idea of the cometary movements; their mathematical knowledge was not sufficient. Seneca, an illustrious Roman philosopher, who lived at the beginning of the Christian era, made a remarkable prediction about comets. "Some day there will arise a man who will demonstrate in what regions of the heavens the comets take their way; why they journey so far apart from the other planets; what their size, their nature" (*Quest. Nat.*, lib. vii, c. xxvi). For over 1,600 years this remarkable prophecy remained a dead letter; then at last the man appeared, of whom it is said:—

Nature and Nature's laws lay hid in night,
God said "Let Newton be," and all was light.

Newton showed that, under the force of gravitation attracting according to the law of the inverse square of the distance, four forms of orbit were possible; first, the circle, which is very nearly the course pursued by the earth and most of the planets. Secondly, the ellipse, or oval, which shades through all varieties of flattening from an almost circular form, as in the orbits of

Mars and Mercury, to an extremely elongated form. Thus in the case of Halley's comet the breadth is a quarter of the length, but the ellipse may be still more flattened than this; there is indeed no limit to the amount, and we are led on to the third form, the parabola, which we may look on as simply an ellipse of infinite length. The fourth form, the hyperbola, does not occur much in the heavens, and need not detain us. Newton soon saw that comets might be explained by supposing them to move in very elongated ellipses, or even in parabolas, remaining invisible for most of the time, and only being visible for a short time, when in the portion of their orbit nearest to the sun. Halley, who had more inclination than Newton for the huge arithmetical computations required, entered into the new ideas with enthusiasm, and computed the orbits of all the comets for which observations of the necessary accuracy were available. They were twenty-four in number, and went back for about 200 years before his time. By a piece of good fortune, which he had most richly merited by his assiduous labours, the same comet occurred three times in his list, and when he came to tabulate the results he noticed that the comets of 1531, 1607, 1682 were travelling in practically the same orbit round the sun. It should be mentioned that the assumption of parabolic motion was made in the first instance, as the necessary computations were simplified, since all parabolas are similar curves, and tables can be made which will serve for all cases, while in the case of ellipses different tables would be required for every case. When he noticed the resemblance of orbits he at once conjectured that this was the same body returning at intervals of three-quarters of a century. On finding the elements of the necessary ellipse to correspond with this period, he saw that it satisfied the observations of the comet better than the parabolic assumption, and this strengthened his conclusion. The only thing against it was that the intervals between the returns were not exactly equal; the first being fifteen months longer than the second. This puzzled him for a time till he recollected that, even in the case of the planets, one revolution was not exactly equal to another. It is true that the differences here were only minutes or hours, not months or years; the cause of the irregularities he knew to be the perturbations which the planets produce on each other's motion, and he saw that these would be greater in the case of the comet, which passed at times very much closer to the giant planets than these can do to each other; further, in an elongated orbit a small alteration in the velocity, when not very remote from the sun, has a much greater effect on the period than would be the case in a circular orbit. Halley was quite right in these conclusions, and we now know that the planetary influences can alter the period by even more than the fifteen months required by the case before him; the total range is five years, the longest on record is seventy-nine years, four and a half months, between A.D. 451 and 530; the shortest is that in the revolution just completed, which is seventy-four years, five months. Making a rough allowance for the action of Jupiter, Halley said the comet might be expected to return to perihelion at the end of 1758, or the beginning of 1759; be it noted that this was the first time in the world's history that the return of a comet had been predicted; Halley was fully conscious of the new epoch in astronomy that he was opening, and said, "Quo circa si secundum predicta nostra redierit iterum circa annum 1758, hoc primum ab homine Anglo inventum fuisse non inficiabitur aequa posteritas." It is rather a curious commentary on these words that it is just in England that we find scepticism expressed as to the fulfilment of the prediction. The well-known *Gentleman's Magazine*, in its issue for Oct., 1758, has these verses, which show that the writer had not even taken the trouble to find exactly what Halley had predicted, fancying that he had dated the comet's return a year earlier than he had actually done :—

Comet that came in eighty-two,
Would come, it was foretold, anew,
Late in the last, or soon this year,
That sees, tho' late, none such appear
An insignificant delay!
It will come yet, some sages say;
Tho' it should not appear, say some
As sure as fortune, it will come.
Prediction, this, that bears the shape,
To vulgar eye, of an escape;
Or trick of cometary learning,
To set itself above discerning.
Now, Mr. Urban, you must know,
Wager was laid, a year ago,
That it would come; and time within
Last year, or present, is to win.
Should it then come, and not be seen,
Pray, in your ancient magazine,
To which both parties have referred,
Let the uncommon case be heard.

That public sense may try the cause,
And tell us by what wondrous laws,
We may be sure, in any year,
That Comets come which don't *appear*.
For tho' philosophers may sing,
That calculation proves the thing,
Pray, let them tell us how they show
That this, their calculation's true.

At the very time when these scornful words were being written in England, the well-known French astronomers, Clairaut and Lalande, were so convinced of the truth of Halley's prediction, that they undertook, and with the help of Madame Lepaute, successfully carried out the computation of the planetary perturbations for the two revolutions of the comet, 1607–1682, and 1682–1759. It was necessary to compute the earlier revolution to find the actual angular velocity of the comet in 1682, and the later one, in order to find how much that velocity was modified by planetary action during the ensuing round. Their result was successful, considering that the masses of Jupiter and Saturn were still imperfectly known, and that Uranus and Neptune were undiscovered. The date they assigned was just a month too late, the comet being found by the amateur astronomer Palitsch, on Christmas day, 1758, and passing its nearest point to the sun on March 13th, 1759. After the discovery the *Gentleman's Magazine* executed a remarkable *volte-face*, and forgot its earlier attitude. In its issue for May, 1759, it published these verses, which are dated New York, April 16th, 1759:—

Hah! There it flames, the long-expected star,
And darts its awful glories from afar!
Punctual at length the traveller appears,
From its long journey of near fourscore years.
Lo! the reputed messenger of fate,
Array'd in glorious but tremendous state,
Moves on majestic o'er the heavenly plane,
And shakes forth sparkles from its fiery train.
Ah! my misfortune that I live retired,
And nought avail me arts I once acquired?
Here, like a hermit, in my lonely cell,
Far from the mansions where the muses dwell.
I'm forced to act the common gazer's part,
Alas! unfurnished with the aids of art.
O for the tube, with philosophic eye,
To trace the shining wanderer through the sky!

O for the ampler arch, in nicer mode,
To mark its stages through the azure road!
But vain the wish! Oh! ye that can survey
The glorious orb, and track its radiant way;
While vulgar crowds with dull attention gaze,
And gaping wonder at the silver blaze:
Ye sons of science, from your high abodes,
Descry its oblique path, and mark its nodes,
Explore with what velocity 'tis hurled,
And how exact its period round the world.
Now, now in this delightful work engage,
Pursue the steps of the sagacious sage,*
And be this wiser than the former age.

I think these verses are of sufficient interest to reproduce, as showing the ideas that were prevalent in England both before and after the comet was seen. Perhaps Halley's reputation shone all the more brightly from the temporary scepticism; it was certainly a noble achievement to have robbed this comet of the superstitious dread which for centuries had accompanied its appearance, and to have transformed it from an aimless wanderer to a permanent member of the solar system, whose behaviour can now be foretold almost as accurately as that of the planets.

Halley recognised that his comet might be carried backwards as well as forwards, by studying cometary records, and he was successful in identifying the comet of 1456 as the same body. Before that time his efforts were less successful; failing to realise how greatly the period of the comet might be altered by the action of the planets, he proceeded with a uniform time-interval, and deduced a series of returns which were all erroneous, extending back to the comet stated to have been observed at the death of Julius Cæsar, and that very brilliant one that is said to have signalised the birth of Mithridates.

It was not till the nineteenth century that the early history of the comet was placed on a more satisfactory basis. M. Laugier showed that Halley was wrong in taking the comet of 1380 as his; the right one was that of 1378; he also showed that the comets of A.D. 451 and 760 were in all probability the same body. A few years later Dr. Hind, who was for many years the superintendent of the Nautical Almanac, drew up a list of conjectural identifications for every return from 12 B.C. to A.D. 1301, some fairly certain, from the exactitude with which their paths had been described, other admittedly vague

* Dr. Halley.

and doubtful. In the last few years a large piece of computational work, in which I have borne a part, has been carried out, with the object of testing Hind's list.

The effect of the planets on the period of the comet has been calculated for each revolution, and conjecture has given place to certainty. On the whole Hind's list was singularly accurate, but he was seriously wrong in two cases; in A.D. 608 he was one and a half years too late, and in A.D. 1223 nearly a year too late. The history of the comet now extends with certainty to 240 B.C., and with some degree of probability to 613 B.C., in the autumn of which year a comet passed through the Great Bear. The great cometographer Pingré fancied that this comet might be alluded to by the prophet Jeremiah (i, 13); "I see a boiling caldron, and the face thereof from the face of the north." He even conjectured that the "rod watching" in verse 11, might be the tail of the comet; Pingré suggested that the tail was seen before the head had risen; when the latter appeared it resembled a caldron with steam rising from it. The insertion of the word "north" lends colour to the suggestion that a celestial apparition may be indicated.

These guesses seem to me to be extremely doubtful, but the interest of finding a possible reference to our comet in Scripture justified us in quoting them. Two revolutions later, in 467 B.C., both Anaxogoras and Aristotle relate that a meteoric stone fell at Aegospotami, and that a comet was seen at the same time. It is interesting to find these events mentioned in juxtaposition at such an early date. This comet was also seen in China, but unfortunately no details are given of its track through the constellations, so its identification is doubtful. Three revolutions later we come to our first certain identification, in 240 B.C., when the Chinese annals state that a comet was seen first in the east, then in the north, and finally for sixteen days in May in the west. The return in 12 B.C. is interesting, being so near the birth of Our Lord, which according to the date assigned by Lt.-Col. Mackinlay, fell four years later. This comet is described with great fulness in the Chinese annals, to which we are indebted for most of our knowledge of ancient comets; the European records are far less precise, and in this case simply relate that "A comet was seen for several days, it appeared suspended over the city of Rome; then it appeared to break up into several little torches." Halley's comet next appeared in A.D. 66, January, four years before the fall of Jerusalem. It is not impossible that this was the comet resembling a sword, which according to

Josephus, appeared suspended over Jerusalem shortly before its fall. At least we have no certain record of any other comet nearer the time of the fall. Then follow returns on A.D. 141 March 25th, A.D. 218 April 6th (described as a terrifying spectacle, preceding the death of the Emperor Macrinus), A.D. 295 April 7th, A.D. 373 November 7th, A.D. 451 July 3rd. This comet came about the time of the defeat of Attila by Ætius; it is referred to by Idatius, who says it was seen as a morning star in June, and an evening star in July. The Chinese annals accurately describe its course from the Pleiades through Leo, ending near Beta Leonis. A.D. 530 November, when it was described as very grand and terrifying, resembling a burning torch; A.D. 607 March, A.D. 684 October. This appearance is interesting, from a rough sketch in the *Nuremberg Chronicle*, that purports to represent it; there is however no proof that it is really contemporary; A.D. 760 June, very full Chinese record, enabling Laugier to confidently identify the comet as Halley's; A.D. 837 February 25th, taken by Louis le Debonnaire as a sign of his approaching death. A.D. 912 July, a return which till lately rested on computation only, no observation being known. A Japanese astronomer, Hirayama, has now found a record of its visibility in Japan from July 19th to 28th. A.D. 989 September 2nd; A.D. 1066 March 25th; this is the apparition that is associated with the Norman Conquest. The terror that it caused in England is illustrated by the manner in which it was apostrophised by Elmer, a monk of Malmesbury; "Venisti, multis matribus lugende; dudum est quod te vidi, sed nunc multo terribiliorem te intueor, patriae hujus excidium vibrantem." It is perhaps permissible to note of this same Elmer that he invented a flying machine, the wings being operated by his hands and legs, and launching himself from a high tower, flew for a furlong; but caught in a sudden gust and becoming panic-stricken, he fell headlong, and was lamed for life, a disaster which he ascribed to his having omitted to give his machine a tail.

On the other side of the Channel William of Normandy took the comet as of good omen for himself, and one of his courtiers wrote the following doggerel lines upon it:—

Caesariem, Caesar, tibi si natura negavit
Hanc, Willelme, tibi stella comata dedit.

As is well known, the comet is portrayed on the Bayeux tapestry, and this is the oldest representation of it that is certainly authentic. Crude as it is, there are two features that are confirmed by modern photographs—the tail streamers, radiating like a fan from the nucleus, and the luminous masses which have the aspect of moving rapidly outwards.

A group of Normans gazes at the comet in wonder "Isti mirantur stellam." In the adjoining panel of the tapestry Harold is represented quaking on his throne under the combined terrors of the comet, the landing of the Norsemen, and the threatened Norman invasion.

A.D. 1145, April 19th. This return is of special interest, since the perihelion passage was on the same day as in the present year, and consequently the motion and behaviour of the comet are closely similar. Some interesting colloquial details are given by Hirayama. It was first seen about April 20th as a morning star; by May 9th its tail was 5° long; about May 15th it passed the sun, and became an evening star. The next day the chronicler says, "The tail was 5° long, directed towards the east; the end was concealed by clouds; I went out of the door and saw it." On May 17th the tail was 20° long. On June 4th the head was seen, but the tail had disappeared, to the astonishment of Moronaga, a friend of the chronicler. The tail reappeared on June 8th, and moonlight is stated to have been the cause of its disappearance earlier. We have, however, in modern times some undoubted cases of the disappearance of tails for a time. It was followed in Japan till June 18th, and in China till July 14th. It will scarcely be followed so long with the unaided eye at the present return. I have myself no doubt that the intrinsic lustre of the comet has greatly declined since the middle ages, though it is right to say that Dr. Holetschek, a great authority on the subject, takes an opposite view.

The return of September, 1222, is one in which we (Mr. Cowell and myself) may justifiably take some pride, as we were the first to show that this grand object was Halley's comet; the much feebler object of July, 1223, had previously been taken for it. That of 1222 must have been a very striking sight; the Japanese say that the head was white, and as large as the half-moon; the tail was red, 17° in length. The European records state that in August a star of the first magnitude appeared, very red, with a long tail pointing to the zenith. Compared with it the moon appeared as if dead, and seemed to have no more light. The fact that both in Europe and Japan it was compared to the moon shows what a splendid object it must have been.

Historians also give a glowing account of its splendour in October, 1301, when it appeared in mid-September in Gemini, and went through Ursa Major to Corona and Hercules, being visible for forty-six days. It was seen in all parts of the known world, but, as in most of the ancient returns, the Chinese records are much the most precise; indeed without their aid it would have been quite impossible to carry back this long chain of identifications. Let us give them the credit they deserve for their patient, long sustained vigils, which have added so greatly to our knowledge of the history of this comet.

We have now an array of some twenty-nine observed returns, many of them recorded as objects of great splendour. The first reflection suggested by them is the close touch that we are brought into with far-distant centuries, in being able to contemplate the very same body that has so often filled the world with wonder and admiration; but besides the sentimental aspect, there are, I think, some deductions of value with regard to the constitution of this and other comets. Dr. Johnston Stoney some years ago developed the theory of planetary atmospheres from the standpoint of the kinetic theory of gases; the gaseous molecules are moving with speeds of miles per second, hydrogen having the greatest speed, and the speeds of the others diminishing as their density increases. Now each planet has a certain speed which suffices to carry objects away from its surface. In the case of the sun it is 383 miles per second, for Jupiter 37, for the other giant planets upwards of 13, for the Earth 7, Venus 6, Mars and Mercury 3, the Moon 1½ miles per second.

An explanation is found of the fact that hydrogen is found in the sun and giant planets, but not in the smaller ones, its molecular speed being too high. The earth can retain the denser gases, but the moon cannot, and her airless condition is thus explained. Now there is no doubt, from what we know of the mass of comets, that their critical speed is much lower even than that of the moon; hence it is clearly impossible that they could permanently retain a gaseous envelope; that which we see surrounding them is not, therefore, of the nature of a permanent atmosphere, but is perpetually escaping from the head of the comet, and perpetually being renewed. The tail that we may see in Halley's comet to-day is a different one from what was seen a month ago. At every return for two thousand years it has been seen to eject a series of huge tails, which streamed away into space, and could not be recovered by it. Now there must be some storehouse to contain all this gas, and the storehouse must be of a much denser nature than the gas, since it moves as though under gravitation alone, while the tail does not. And, seeing that we know that a close connection exists between the comets of 1862, 1866, and Biela's comet with the Perseid, Leonid and Andromedid meteor showers respectively, and further that the meteors that have fallen to earth and have been chemically analysed have been found to contain much occluded gas, especially hydrogen, which with its compounds is indicated in cometary spectra, it seems to me a most natural and probable deduction to draw that the reservoir containing the gas of comets' tails is a dense form of meteors; in fact, I should scarcely have thought it a matter of dispute, had not several well-known astronomers expressed doubts about the connection of comets and meteors. There is the further argument for the presence of a nucleus made of solid matter, that it appears to move exactly as if under the force of gravitation alone.

The calculations of its motion are made on this assumption, and the difference between theory and observation in the time of its perihelion passage amounts to only three days in a period of some 27,000 days, showing that the action of non-gravitational forces on the head is barely sensible; but on the tail matter these repulsive forces far exceed gravitation, showing that the particles of the nucleus are much denser than those of the tail, and no doubt solid. I even venture to assert that the solid matter in the head of Halley's comet is not mere dust, but is in the form of pretty large lumps, at least several feet across, since otherwise I should expect the supply of gas to have been exhausted after a few returns. I think it is likely that the loss of gas occurs only when the comet is near the sun, the occluded gas being drawn out, either by the action of heat or some other exciting cause. When in the cold of outer space it probably sinks into a torpid condition and is devoid of envelopes.

An exceedingly rare event is about to happen this month, which may throw some light on the constitution of the comet's head; I make out that this event, the transit of the comet over the disc of the sun, only happens if the perihelion passage falls in one particular half day of the entire year; that is, that one return in 700 or once in 50,000 years. Unfortunately the sun will be below our horizon when the comet crosses it, but astronomers in more favoured lands will be on the alert, notably at the Kodaikanal Observatory in India, whence Mr. Evershed writes to me that they are making preparations to photograph the sun in ultra-violet light, and in other methods that seem to give the best hope of success.

Let us however consider the conditions, and we shall see that failure is quite likely; the comet will be 15,000,000 miles distant, or sixty times as far away as the moon. At that distance a lump of matter five miles in diameter would appear only one-fifteenth of a second across; this would be the very tiniest particle that would be separately visible; smaller particles might however be seen as a dusky patch, but only if they are closely congregated. There is no chance of seeing any of the gaseous envelopes of the comet against the brightness of the solar background. Even failure to see anything of the transit will teach us something, since we shall be able to fix superior limits to the size and density of the particles forming the nucleus. Since the tail of a comet points almost exactly away from the sun, it was at once seen that there was a possibility of our going through the tail at the time of the transit. The only element of doubt is whether the length of the tail will be sufficient to reach us; it will need to be 15,000,000 miles long, and Dr. Holetschek's researches show that it has only just attained this length at the more recent returns. Even if the tail does reach us, it is of such ethereal tenuity that it is quite doubtful whether we should be able to detect its presence when in the midst of it; there would be no contrast in this case, as when we see it from without on the black background of the sky, it would fill the whole heavens with a sort of diffused glare; something of the kind was recorded when we went through the tail of a comet in 1861 (it is instructive to see the apparent form of that comet when it was very near the earth; owing to perspective it appeared like a widely opened fan; we may look for a similar appearance if the tail of Halley's comet reaches us). Dr. Birkeland makes the suggestion that if we pass through the tail there may be a striking auroral display; this does not seem impossible, since the aurora is now thought to be due to the excitement of certain gases in our upper air by electrons emitted by the sun, of very similar nature to those supposed to form comets' tails. It is hardly likely that the presence of the tail would be sensible in any other way; arrangements have however been made by which any abnormal manifestation would be fairly sure to be detected.

So much has lately been written about the physics of comets' tails that it is almost necessary to include some discussion of it. There is no question that there is some agency driving the tail-particles outwards from the sun much more potently than gravitation can pull them in; but as regards the nature of this action it is difficult to decide between three contending hypotheses. (i) That it is the pressure of light acting on the very tiny particles emitted by the head; this action is quite insensible compared with gravity in the case of large bodies, but when the diameter of the particle is of the same order as the wave length of light it becomes important, being equal to gravity when the diameter is $\frac{1}{200000}$ inch and twenty times gravity for a diameter of $\frac{1}{150000}$ inch, after which it appears to diminish again. There is a difficulty about this theory for explaining all the facts in that it would involve an almost constant acceleration of the tail matter through the whole length of the tail. (ii) That it is electrical repulsion from the sun acting on the charged particles emitted by the head. Mr. Eddington has pointed out that we might on this assumption explain the cessation of repulsion at a certain distance by gradual neutralisation of the charge. (iii) The third explanation, which has been put forward in a number of slightly varying forms in recent years, suggests that the sun and not the comet's head is the originator of the greater part of the tail matter; the function of the head being the repulsion of this matter to form the envelopes and also rendering it luminous; the theory involves the large assumption that the discharge of these ions or electrons is unceasingly going on in all directions round the sun, for comets emit tails whatever their direction from the sun may be; in this they differ from the streams of matter forming the corona or producing magnetic storms and auroræ on the earth; for these, as Mr. Maunder has shown, are ejected along definite stream-lines, and could only produce some momentary excitement in a comet's tail, not the long-enduring phenomena with which we are familiar.

To my mind both the telescopic and photographic, and I may add the spectrographic, study of comets seems to show that the head, coma, and tail form a single entity, and that the tail belongs to the head and is emitted by it, not by the sun. Halley's comet itself may add to our knowledge of cometary physics, for at the return of 1835 it was the scene of very active changes; on October 10th Smyth noticed a curious brush of light issuing from the nucleus, resembling the luminous sector drawn by Hevelius in 1682. The next day it had developed into a lucid sector, with two rays spreading on either side of the nucleus across the direction of the tail. On October 12th Struve saw it attended by two delicately-shaped appendages of light, one preceding, the other following the nucleus. At other times, he says, it was surrounded by a semicircular veil, which extended back in a double train of light to a vast distance. Bessel tried to explain some of the changes of shape by supposing a rotation of the comet in five days, and Professor W. H. Pickering adopted the same explanation for the changes of shape of some recent comets. There are, however, difficulties in the way, for a volume of gas has no rigidity, and cannot rotate as a whole; even if we admit a controlling force, each molecule of the tail would rotate with a different period, according to its distance from the axis. It seems to me that a rotation of the head would produce a semblance of rotation in the tail emitted by it. The structure in this case would be spiral, a form suggested by some of the photographs of Morehouse's comet of 1908. On its emergence from the sun's rays in 1836, Halley's comet was best placed for southern observers, and Sir J. Herschel and Maclear at the Cape made drawings of it. It seems to have lost its tail in January, two months after perihelion, so we must be prepared for a similar phenomenon in June next. Morehouse's comet, in like manner, went through a tailless phase several times during its period of visibility. It appears that all predictions as to the brilliance of a comet at any particular time are quite uncertain; we can predict its distance from sun and earth, but not these physical changes, to which some comets seem to be much more subject than others.

We have the great advantage of photography during the present apparition for giving a continuous and reliable record of all the variations, as also for enabling the comet to be detected eight months before perihelion passage, at which time it was of the sixteenth magnitude, that is, it only gave $\frac{1}{10000}$ of the light of a sixth magnitude star, which itself is barely visible to the unaided eye. For the first few months the comet brightened up rapidly, and by mid-November it was an easy object in telescopes of moderate size, being as bright as the tenth magnitude. Then the increase seemed to be arrested, and it only increased very slightly in brightness up to the middle of January; but by the end of that month there were evident signs of a tail forming, and by mid-February the comet was seen by the naked eye by Professor Wolf, who had also been the first to detect its presence on the photographic plate.

A photograph taken at Juvisy showed quite a conspicuous tail, and a drawing at the beginning of March showed a remarkable double tail, not unlike some of the sketches made in 1835. The comet was then lost in the sunlight, but reappeared as a morning star about the middle of April. It had greatly brightened during its absence, and was now of the second magnitude. At 4.30 a.m. on April 20th it passed its perihelion, and commenced another revolution, which will not be completed till early in 1986. I have myself seen it early in May, when it was quite conspicuous, in spite of its being very near the horizon, and the sky having begun to brighten. We have thus every reason to look for a fairly good display as an evening star during the last ten days of May, though it is right to warn those who saw the great comet of 1882, or Donati's comet in 1858, that there will be nothing to compare with these from a spectacular point of view. It may not even equal the bright object which formed a nine days' wonder last January. It is just because the old records speak of it as one of the brightest comets of its time, that I think it must have greatly declined since then.

A few words on the subject of computing the perturbations may be of interest. The planets are pulling the comet all the time, altering its speed and direction of motion and thus changing the ellipse in which it is moving round the sun. Whatever method we employ, we have to calculate the distance and direction of the comet from each of the larger planets at short intervals of time during the whole revolution. The old method assumed the comet to move for some time exactly in some definite ellipse, and the disturbances were calculated and added up; their combined effect applied to the ellipse gave a new ellipse, and the comet was then assumed to follow this for another space of time, and so on. This method was both cumbrous and inexact; Mr. Cowell devised the better plan of not making the assumption of elliptical motion at all, but determining the curvature at each point of the path, from the whole of the forces acting (solar and planetary) and then building up the path, arc by arc, from these curvatures. It is necessary when the comet is near the sun, and the curvature great, to compute it with extreme accuracy; the unit of length at this part of the orbit was taken as the eleventh decimal of the distance from the earth to the sun, or about 5 feet. Needless to say, we do not know the actual place of the comet to anything like this degree of accuracy, in fact, not within some 20 miles. But unless the curvature were investigated with a much higher degree of accuracy than the actual place is known, errors would arise in the deduced path, which would be very serious at the end of a revolution. Far the largest perturbations are those that arise when the comet is passing near Jupiter, and it is interesting to note that the perturbations arising at one of these approaches do not make a very appreciable alteration in the comet's place for the next year or two, but show their full effect when it comes back seventy-five years later. For the perturbations are really small changes in the amount and direction of the motion, and it takes time for these to develop into appreciable alterations in the comet's place.

The revolution just completed is much the shortest on record, and this is due to the fact that both in 1834 and in 1836 Jupiter was placed exactly behind the comet and reduced its speed considerably on each occasion. That a record passage should be the result of reduced speed sounds rather paradoxical, but the case is like that of a thrower's arm being held when he throws a stone into the air; it will not rise so high and comes back to earth sooner. So the comet has not gone so far into space as usual on the last revolution, and the sun's attraction has been able to bring it back more quickly. Our own earth assisted in the shortening of the revolution to the extent of one week, the comet having been near us in October, 1835. One of the chief points of interest in the calculation is to see whether there is any indication of unknown forces acting on the comet. The actual return is three days later than the calculated one, and from the precautions taken, it is inferred that at least two of these days are due to some unknown cause, not to errors in the calculation. The unknown cause may be a planet beyond Neptune, or a resisting medium or the reaction produced on the nucleus by the emission of the tail-matter.

Two quotations from Sir G. Airy's address on presenting the Astronomical Society's medal to Professor Rosenberger in 1835 come in very appropriately here: "How are these wild bodies to be disciplined to our service? They are to be sent forth as spies; they are to go in directions in which no planets move; they are to explore spaces in which no other bodies are known to exist; and they are to return bringing us an account, such as the physical astronomer can read, of the forces to which they have been subjected, and of the nature of the spaces through which they have passed. Have the anomalous motions of Uranus caused some astronomers to suspect the existence of a large planet beyond him? Then may we hope that Halley's or Olbers' comet will, in some revolution, feel its effect while far beyond our sight, and will return to our eyes still bearing in its disturbed motions a trace of the perturbations which it has undergone. Has it for ages past been conjectured that some matter exists in the planetary space which in time may sensibly affect the motions of the most dense bodies? Then will the comparative insignificance of the comets be more likely to feel its effects."

"We have seen a comet whose last appearance it is probable that no man living can distinctly recollect—whose period exceeds the limit of ordinary life—whose path extends into spaces far beyond any which in other parts of physical astronomy we have need to consider—we have seen it return within a day of its computed time, and have traced it through the heavens, describing nearly the path which had been laid down for it. I confess that the sight of this strange body and the contemplation of the uniformity of the law which has guided its motions, and of the acquaintance with that law and the power of tracing its effects, which man has acquired, have been to me a source of intense pleasure. And I doubt not that the same gratification has been experienced by every astronomer who has been accustomed to regard his sublime science on the one hand as the most severe exercise of the intellect, and on the other hand as the study which leads most certainly to a knowledge of the general laws of the universe."

I hope I have now said enough to show that Halley's comet, while it cannot in these modern days offer us a spectacle of surpassing grandeur, ought nevertheless to awaken deep interest in all thoughtful minds, from the long vista of history down which it carries us, from its being the first comet in the world's history whose return was ever foretold, and perhaps most of all from its association with the great Englishman whose name it will bear for all time.