V. *Observations of a Comet, with Remarks on the Construction of its different Parts.* *By* William Herschel, *LL.D. F.R.S.*

Read December 19, 1811.

THE comet which has lately visited the solar system has moved in an orbit very favourably situated for astronomical observations. I have availed myself of this circumstance, and have examined all the parts of it with a scrutinizing attention, by telescopes of every degree of requisite light, distinctness, and power.

The observations I have made have been so numerous, and so often repeated, that I shall only give a selection of such as were made under the most favourable circumstances, and which will serve to ascertain the most interesting particulars relating to the construction of the comet.

As my attention in these observations were every night directed to as many particulars as could be investigated, it will be most convenient to assort together those which belong to the same object; and in the following arrangement I shall begin with the principal part, which is

The planetary Body in the Head of the Comet.

By directing a telescope to that part of the head where with the naked eye I saw a luminous appearance not unlike a star; I found that this spot, which perhaps some astronomers may call a nucleus, was only the head of the comet; but that within

its densest light there was an extremely small bright point, entirely distinct from the surrounding glare. I examined this point with my 20 feet, large 10 feet, common 10 feet, and also with a 7 feet telescope; and with every one of these instruments I ascertained the reality of its existence.

At the very first sight of it, I judged it to be much smaller than the little planetary disk in the head of the comet of the year 1807; but as we are well assured that if any solidity resembling that of the planets be contained in the comet, it must be looked for in this bright point; I have called it the planetary body; in order to distinguish it from what to the naked eye or in small telescopes appeared to be a nucleus, but which in fact was this little body with its surrounding light or head seen together as one object.

With a new 10 feet mirror of extraordinary distinctness, I examined the bright point every fine evening, and found that although its contour was certainly not otherwise than round, I could but very seldom perceive it definedly to be so.

As hitherto I had only used moderate magnifiers from 100 to 160, because they gave a considerable brightness to the point, it occurred to me that higher powers might be required to increase its apparent magnitude; accordingly the 19th of October, having prepared magnifiers of 169, 240, 300, 400, and 600, I viewed the bright point successively with these powers.

With 169 it appeared to be about the size of a globule which in the morning I had seen in the same telescope and with the same magnifier, and which by geometrical calculation subtended an angle of 1″,39.

I suspected that this apparent size of the bright point was

only such as will spuriously arise from every small star-like appearance; and this was fully confirmed when I examined it with 240; for by this its magnitude was not increased; which not only proved that my power was not sufficient to reach the real diameter of the object, but that the light of this point was, like that of small stars, sufficiently intense to bear being much magnified.

I viewed it next with 300, and here again I could perceive no increase of size.

When I examined the point with 400, it appeared to me somewhat larger than with 300; I saw it indeed rather better than with a lower power, and had reason to believe that its real diameter was now within reach of my magnifiers. Curiosity induced me to view it in the 7 feet telescope with a power of 460; and notwithstanding the inferior quantity of light of this instrument, the magnitude was fully sufficient to show that the increase of size in this telescope agreed with that in the 10 feet.

Returning again to the latter I examined the bright point with 600, and saw it now so much better than with 400, that I could keep it steadily in sight while it passed the field of view of the eye-glass.

With this power I compared its appearance to the size of several globules, that have been examined with the same telescope and magnifier, and by estimation I judged it to be visibly smaller than one of 1″,06 in diameter, and rather larger than another of 0″,68.

It should be noticed that I viewed the globules, which were of sealing wax, without sunshine, in the morning after the observation as well as the morning before; referring in one

case the bright point to the globules, and in the other the globules to the bright point.*

The apparent and real Magnitude of the planetary Body.

The size of the bright point being much more like the smallest of the two globules, I shall add one quarter of their difference to 0″,68, and assume the sum, which is 0″,775 as the apparent diameter of the planetary disk.

Then by a calculation from some corrected elements of the comet's orbit, which, though not very accurate, are however sufficiently so for my purpose, I find that the distance of the comet from the earth, at the time of observation, was nearly 114 millions of miles; from which it follows that the bright point, or what we may admit to be the solid or planetary body of the comet, is about 428 miles in diameter.

The Eccentricity and Colour of the planetary Body.

The situation of the bright point was not in the middle of the head, but was more or less eccentric at different times.

The 16th of October that part of the head, which was towards the sun was a little brighter and broader than that towards the tail, so that the planetary disk or point was a little eccentric.

The 17th I found its situation to be a little beyond the centre, reckoning the distance in the direction of a line drawn from the sun through the centre of the head.

The 4th of November it was more eccentric than I had ever seen it before.

* A similar method was used with the comet of 1807. See Phil. Trans. for 1808, page 145.

Nov. 10, I found no alteration in the eccentricity since the last observation.

The colour of the planetary disk was of a pale ruddy tint, like that of such equally small stars as are inclined to red.

The Illumination of the planetary Body.

The smallness of the disk, even when most magnified, rendered any determination of its shape precarious; however had it been otherwise than round, it might probably have been perceived; the phasis of its illumination at the time of observation being to a full disk as 1,6 to 2.

From this as well as from the high magnifying power, which a point so faint could not have borne with advantage, had it shone by reflected light, we may infer that it was visible by rays emitted from its own body.*

The Head of the Comet.

It has already been noticed that the brightest part of the comet seen by the naked eye, appeared to contain a small star-like nucleus. When this was viewed in a night glass, or finder, magnifying only 6 or 8 times, it might still have been mistaken for one; but when I applied a higher power, such as from 60 to 120, it retained no longer this deceptive appearance; which evidently arises from an accumulation of light,

* On the subject of the nature of the light by which we see this comet, I may refer to what has been said in my paper of observations on that of the year 1807. Those who wish also to consult the opinion of an eminent philosopher, whose valuable works on meteorological subjects are well known, will find it expressed at large in a letter from Mr. De Luc, addressed to Mr. Bode, so far back as the year 1799, and reprinted in Mr. Nicholson's Journal, published the 1st of March 1809.

condensed into the small compass of a few minutes; and which of course will vanish when diluted by magnifying.

Sept. 2, I saw the comet at Glasgow, in a 14 feet Newtonian reflector; but being very low, the moon up, and the atmosphere hazy, it appeared only like a very brilliant nebula, gradually brighter in a large place about the middle.

The 9th and 10th of September at Alnwick, I viewed it with a fine achromatic telescope, and found that, when magnified about 65 times, the planetary disk-like appearance seen with the naked eye, was transformed into a bright cometic nebula, in which, with this power, no nucleus could be perceived.

The 18th of September the star-like object in my large 10 feet reflector, when magnified 110 times, had the appearance of a fine globular, lumininous nebula; it seemed to be about 5 or 6 minutes in diameter, of which one or two minutes about the centre were nearly of equal brightness. The small 10 feet showed it in the same manner.

In all my instruments this bright appearance was equally transformed into a brilliant head of the comet, with this difference, that when high powers were applied, the central illumination which moderately magnified, was pretty uniform, became diluted into a gradual decrease from the middle towards the outside; losing itself by imperceptible degrees, especially towards the sides and following parts, into a darkish space, which from observations that will be given hereafter, I take to be a cometic atmosphere.

The Colour and Eccentricity of the Light of the Head.

The colour of the head being very remarkable, I examined it with all my different telescopes; and in every one of them,

its light appeared to be greenish, or bluish green. Its appearance was certainly very peculiar.

The disposition of the light of the head was likewise accompanied with some remarkable circumstances; for notwithstanding a general accumulation about the middle, there seemed to be a greater share of it towards the sun, than a portion in that situation of the circumference was entitled to, had it been uniformly arranged; and if we look upon the head as a coma to the planetary point, the eccentricity of its light will be still more evident; for this point was constantly more or less farther from the sun than the middle of the greatest brightness of the light surrounding it. The eccentricity of the head was indeed so considerable, that considering the difficulty of seeing the point, it might easily have escaped the notice of one who looked for it in the centre of the head.

The apparent and real Magnitudes of the Head.

With an intention to ascertain the dimensions of the various parts of the comet, I viewed the head in the 7, 10, and 20 feet telescopes, and estimated its size by the proportion it bore to the known fields of the eye-glasses that were used. I shall only mention two estimations: September 29, the 10 feet gave its apparent diameter $3'\ 0''$. With the 20 feet Oct. 6, it was $3'\ 45''$.

From a calculation of the 20 feet measure, which I prefer, it appears that the real diameter of the head at this time was about 127 thousand miles.

A transparent and elastic Atmosphere about the Head.

In every instrument through which I have examined the comet, I perceived a comparatively very faint or rather darkish interval surrounding the head, wherein the gradually diminishing light of the central brightness was lost. This can only be accounted for by admitting a transparent elastic atmosphere to envelope the head of the comet.

Its transparency I had an opportunity of ascertaining the 18th of September, when I saw three very small stars of different magnitudes within the compass of it; and its elasticity may be inferred from the circular form under which it was always seen. For being surrounded by a certain bright equidistant envelope, we can only account for the equality of the distance by admitting the interval between the envelope and the head of the comet to be filled with an elastic atmospherical fluid.

The Extent of the cometic Atmosphere.

When I examined the comet in the 20 feet telescope the 6th of October, the circular darkish space, which surrounded the brightness, just filled the field of the eye-glass; which gives its apparent diameter 15 minutes. This atmosphere was therefore more than 507 thousand miles in diameter; but its real extent of which, as will be seen, we can have no observation, must far exceed the above calculated dimensions.

The bright Envelope of the cometic Atmosphere.

When I observed the comet at Alnwick in an achromatic refractor with a magnifying power of 65, I perceived that the head of it was partly surrounded by a train of light, which

was kept at some considerable distance by an interval of comparative darkness; and from its concentric figure I call this light an envelope.

The Figure, Colour, and Magnitude of the Envelope.

On viewing this envelope in telescopes that magnify no more than about 16 times, or in finders and night glasses with still lower powers, I found that its shape, as far as it extended, was apparently circular; but that in its course it did not reach quite half way round the head of the comet. A little before it came so far it divided itself into two streams, one passing by each side of the head.

The colour of the envelope in my 7, 10, and 20 feet telescopes had a strong yellowish cast, and formed a striking contrast with the greenish tint of the head.

The distance of the outside of the envelope from the centre of the head, in the direction of a line drawn from it to the sun, was about 9′ 30″; and supposing it to have extended sideways, without increase of distance as far as a semi-circle, this would give its diameter about 19 minutes. By computation therefore its real diameter must have exceeded 643 thousand miles.

The Tail of the Comet.

The most brilliant phenomenon that accompanies a comet is the stream of light which we call the tail. Its length is well known to be variable, but the measures or estimations of its extent cannot be expected to be very consistent from several causes foreign to its actual change.

The 2d of September, the moon being up, the comet very low, and the atmosphere hazy, I could perceive no tail.

The 9th, it had a very conspicuous one, about 9 or 10 degrees in length.

On the 18th, the length was 11 or 12 degrees.

The 6th of October it was 25 degrees.

The 12th I estimated it to be only 17 degrees long.

The 14th it appeared to extend to $17\frac{1}{2}$ degrees.

The 15th, by very careful attention, and in a very clear atmosphere, I found the tail to cover a space of $23\frac{1}{2}$ degrees in length.

The greatest real Length of the Tail.

Of the two observations which were made of the greatest length of the tail of the comet, I prefer that of the 15th of October, on account of the clearness of the night.

The apparent length being $23\frac{1}{2}$ degrees, its real extent, taking into the calculation the oblique position in which we saw it, must have been upwards of 100 millions of miles.

The Breadth of the Tail.

The variations in the breadth of the tail will hardly admit of any description; the scattered light of the sides being generally lost by its faintness in such a manner as to render its termination very doubtful.

The 12th of October its breadth in the broadest part was $6\frac{3}{4}$ degrees, and about 5 or 6 degrees from the head it began to be a little contracted.

The 15th, it was nearly of the same breadth about the middle of its length.

By calculating from the observation of the 12th, we find that the real breadth of the tail on that day was nearly 15 millions of miles.

The Curvature of the Tail.

The shape of the tail with respect to its curvature is generally considered only as it relates to the direction of the motion of the comet; it is nevertheless subject to variations arising from causes that will be noticed in the next article, but which are not taken into the account of the following observations.

The 9th and 10th of September the curvature of the tail was very considerable.

The 18th, I remarked, that towards the end of the tail its curvature had the appearance as if, with respect to the motion of the comet, that part of the tail were left a little behind the head.

The 17th of October the tail appeared to be more curved than it had been at any time before.

Dec. 2, the flexure of the curvature of the tail, contrary to its former direction, was convex on the following side.

The general Appearance of the Tail.

On account of the great length and breadth of the tail of the comet, a night glass with a large field of view is the most proper instrument for examining its appearance. Mine takes in $4^{\circ}\ 41'$.

By viewing the comet with this glass I found the tail to be inclosed at the sides by the two streams which I have described as the continuation of the bright arch, or envelope surrounding the head.

Sept. 18, I observed that the two streams or branches arising from the sides of the head, scattered a considerable portion of their light as they proceeded towards the end of the tail,

and were at last so much diluted that the whole of the farthest part of the tail, contained only scattered light.

Oct. 12, I remarked that the two streams remained sufficiently condensed in their diverging course to be distinguished for a length of about six degrees, after which their scattered light began to be pretty equally spread over the tail.

Oct. 15. The preceding branch of the tail was $7^\circ\ 1'$ in length. The following was only $4^\circ\ 41'$; which caused the appearance of an irregular curvature.

Nov. 3. The two branches were nearly of an equal length.

Nov. 5. The length of the preceding stream was $5^\circ\ 16'$; that of the following about $4^\circ\ 41'$.

Nov. 9. The two branches might still be seen to extend full 4 degrees, but their light was much scattered.

Nov. 10. The preceding branch was $5^\circ\ 16'$ long; the following one only $3^\circ\ 31'$; the preceding one was also fuller and broader.

In the course of these observations I attended also to the appearance of the nebulosity of the tail.

Sept. 18. The appearance of the nebulosity, examined with a 10 feet reflector, perfectly resembled the milky nebulosity of the nebula in the constellation of Orion, in places where the brightness of the one was equal to that of the other.

Nov. 9. The tail of the comet being very near the milky-way, the appearance of the one compared to that of the other, in places where no stars can be seen in the milky-way, was perfectly alike.

The Return of the Comet to the nebulous Appearance.

From the observations of the decreasing length of the tail, the diminution of brightness and increased scattering of the streams, and from the gradually fainter appearance of the transparent atmosphere, brought on by the contraction and more scattered condition of the envelope, I had reason to suppose that all the still visible cometic phenomena of planetary body, head, atmosphere envelope, and tail, would soon be reduced to the semblance of a common globular nebular; not from the increase of the distance of the comet, which could only occasion an alteration in the apparent magnitude of the several parts, but by the actual physical changes which I observed in the construction of the comet.

The gradual vanishing of the planetary Body.

Nov. 4. 10 feet reflector. I saw the planetary disk with 289. It was rather more eccentric than usual.

Nov. 9, I saw it imperfectly with 169. It was more visible with 240; but the nebulosity of the envelope overpowered its light already so much that no good observations could be made of it.

Nov. 10. Large 10 feet. I had a glimpse of the disk and its eccentricity,

Nov. 13, I tried all magnifiers, but could no longer perceive the planetary body.

The Disappearance of the transparent Part of the Atmosphere under the Cover of the scattered Light of the contracted Envelope.

Nov. 4. In the night-glass, that part of the atmosphere which used to separate the envelope from the head, could no longer be distinguished.

In the 10 feet reflector, with a large double eye-glass, I found the envelope drawn nearer to the head, its central distance at the vertex being less than 7′ 10″; and the atmosphere was almost involved in the scattered haziness of the streams.

Nov. 5. The envelope was still disengaged from the head, but much scattered light had nearly effaced the cometic atmosphere on the side towards the sun.

Nov. 9. The atmosphere was nearly covered by the approximation, or scattering light, of the envelope. Its vertical distance was 5′ 45″.

Nov. 10. The envelope could only be distinguished from the head by a small remaining darkish space, in which the atmosphere might still be seen. The vertical distance of the envelope was 4′ 46″.

Nov. 13. The atmosphere was almost effaced by scattered light towards the sun, but on the opposite side it was darker, or rather more transparent.

Nov. 14, 15, and 16. The atmosphere was gradually more covered in.

Nov. 19. I found in the 10 feet telescope, the envelope so broad and scattered as to leave no room for seeing the atmosphere; and the comet seemed to be fast returning to the mere appearance of a nebula.

Nov. 24. The envelope was turned into haziness; and on the side towards the sun, the comet had already the appearance of a globular nebula, with a faint hazy border.

Dec. 2. The haziness of the border was of a different colour from the light of the head, which preserved its former greenish appearance.

Dec. 9. The envelope, which had been turned into a hazy border of light, in which state I saw it again the 5th, was very unexpectedly renewed. It was however very narrow and much fainter than it used to be. By four measures I found its distance from the centre of the head to be about $4\frac{3}{4}$ minutes.

Dec. 14. The narrow faint envelope of the 9th existed no longer.

If the scattered light near the head should not be raised again, all observations of the atmosphere must be at an end; for the space beyond this light being equally clear, we have nothing left to point out any extent that might be supposed to contain a transparent elastic fluid, notwithstanding it should remain in its former situation.

Uncommon Appearances in the Dissolution of the Envelope.

Nov. 4. 10 feet. The envelope was double towards the sun, and divided itself at each side into three streams; the outside ones being very faint, and of no great length.

Nov. 5. On the preceding side the envelope was very faintly accompanied by an outer one, but not on the following side.

Nov. 13. On the following side the envelope diverged into three streams, the two outside ones being very faint and narrow; but on the preceding side there was but one additional

streamlet, which was at the distance of the outermost one of the opposite side.

Nov. 14. On the preceding side there was a very faint outward stream, and on the following side there was a still fainter and shorter stream, also on the outside.

Dec. 14. There was only one short and faint outside stream at the preceding side.

Uncommon Variations in the Length of the Streams.

It has already been mentioned, that the streams or branches were subject to a considerable difference in their respective lengths; in order if possible to discover the cause of the observed changes, I continued my observations of them.

Oct. 15 and Nov. 5 and 10, the preceding branch was the longest.

The 3d and 9th of November the branches were of equal length.

The 13th, the following was 4° 6′ long, the preceding only 3° 31′.

The 14th. They were both of the equal length of about 3° 31′.

The 15th. The preceding branch was 3° 31′ long, the following 4° 6′.

The 16th. The preceding was 3° 13′ long, the following 3° 48.

The 19th. The branches were equal, and about 4° 23′ long.

Dec. 2. The branches were nearly equal and about 3° 12′ long; they joined more to the sides than the vertex, and had lost their former vivid appearance; their colour being changed into that of scattered light.

The 9th and 14th. The branches were already so much scattered that observations of them could no longer be made with any accuracy.

Alterations in the Angle of the Direction of the Envelope.

Nov. 4. 10 feet reflector. Large double eye-glass. The streams departed from their source in a greater angle of divergence. This probably arose from a contraction of the envelope towards the sun, but not about the root of the streams, where it remained extended as before.

Nov. 13. 10 feet. The angle of the bending of the envelope at its vertex was considerably enlarged. In the night-glass the divergence of the streams themselves was certainly not increased.

Nov. 24. 10 feet. The divergence of the light, which may still be called the envelope, although no longer to be distinguished from the head, was from 60 to 65 degrees; but in the night-glass, the branches which were hardly to be seen were closer together than formerly.

The additional faint duplicates of the envelope Nov. 4, 5, 13, and 14 always departed from the vertex in an angle considerably greater than the permanent interior streams.

The Shortening of the Tail.

The 5th of November, the air being very clear, I found, when attending to the tail of the comet, that its length was much reduced; its utmost extent not exceeding $12\frac{1}{2}$ degrees.

The 9th, it was 10 degrees long.

The 15th. In the night glass the tail was much shortened.

The 16th. With the naked eye the tail was nearly $7\frac{1}{2}$ degrees long.

The 19th. Its length was about 6° 10′.

Dec. 2. The tail was hardly 5 degrees long and of a very feeble light.

The 9th, the length of the tail was not materially altered.

The 14th, it still remained as before, but the end of it was much fainter.

Increasing Darkness between the Streams that inclose the Tail.

The 4th of November the darkness near the head on the side from the sun was grown more conspicuous, and much less filled up with scattered light.

The 5th, the darkness of the atmosphere on the side opposite the sun was stronger than on the sun side.

The 10th. A considerable darkness prevailed between the two branches of the tail.

The 14th. In the tail, close to the head, there was a large space almost free from scattered light; where the small stars of the milky-way are as bright as if nothing had intercepted their light.

The 16th. The space between the streams was of a considerable darkness.

The 19th. 10 feet reflector. The darkness between the streams was increased.

Dec. 9. The space close to the head on the side from the sun was quite dark, or rather transparent.

The 14th. Many small stars of the milky-way were in the dark interval of the tail close to the head of the comet.

Of the real Construction of the Comet, and its various Parts.

Hitherto I have only related the appearances of the several parts of the comet, in order to determine their linear extent; but the observations which are now before us, contain facts that will allow me also to ascertain the construction of the comet and its various parts in their solid dimensions.

From the laws of gravitation we might be allowed to conclude that the planetary body containing the solid matter of the comet must be spherical; but actual observation will furnish a more substantial argument; for in no part of the long, geocentric path described by the comet, did I see its little disk otherwise than round; whereas it would not have preserved this appearance, if its construction were not spherical.

If what has been said in my last paper, when treating of round nebulæ, be remembered, the head of the present comet, which by observation appeared round like a nebula, cannot be supposed to be of any other than a spherical construction. With my collection of round nebulæ the arguments, however, which proved their globular form, rested only, though very soundly, upon the doctrine of chances, and the known effects of gravitation; but here, on the contrary, while nebulæ remain in their places, the geocentric position of the head of the comet has undergone a change amounting to a whole quadrant; in all which time I have observed it to retain its roundness without any visible alteration; from which it necessarily follows that its form is globular.

With regard to its transparent cometic atmosphere, we have not only the constant observations of its roundness, during the abovementioned long period of the comet's motion, to

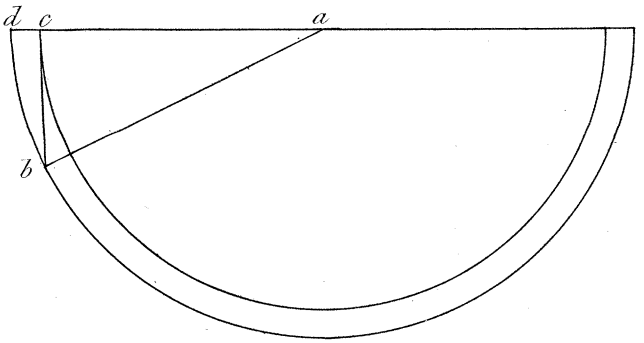
prove it to be spherical; but in addition to this, I have already shown that it is of an elastic nature, for which reason alone, had we no other, its globular figure could not be doubted.

A most singular circumstance, which however must certainly be admitted, is, that the constant appearance of the bright envelope, with its two opposite diverging branches, can arise from no other figure than that of an inverted hollow cone, terminating at its vertex in an equally hollow cap, of nearly a hemispherical construction; nor can the sides or caps of this hollow cone be of any considerable thickness.

The proof of this assigned construction is, that the bright envelope has constantly been seen in my observation as being every where nearly equidistant from the transparent atmosphere; now if that part of it which in a semi-circular form surrounds the comet, on the side exposed to the sun, were not hemispherical, but had the shape of a certain portion of a ring, like that which we see about the planet Saturn, it must have been gradually transformed from the appearance of a semicircle into that of a straight line, during the time that we have seen it in all the various aspects presented to us by a geocentric motion of the comet, amounting to 90 degrees.

That this hemispherical cap is comparatively thin, is proved from the darkness and transparency of that part of the atmosphere which it covers; for had the curtain of light, which was drawn over it, been of any great thickness, the scattered rays of its lustre would have taken away the appearance of this darkness; nor would the atmosphere have remained sufficiently transparent for us to see extremely small stars through it.

It remains now only to account for the semi-circular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appearance of the bright envelope; but this, it will be seen, is the immediate consequence of the great depth of light near the circumference, contrasted with its comparative thinness towards the centre. The 6th of October, for instance, the radius of the envelope was 9′ 30″ on the outside, and 7′ 30″ on the inside; and as the greatest brightness was rather nearer to the outside, we may suppose its radius to have been about 8′$\frac{3}{4}$. Then if we compute the depth of the luminous matter at this distance from the centre, we find that it could not be less than 248 thousand miles; whereas in the place where the atmosphere was darkest, its thickness would be only about 50 thousand; so that a superior intensity of light in the ratio of about 5 to 1, could not fail to produce the remarkable appearance of a bright semi-circle, enveloping the head of the comet at the distance at which it was observed.*

I have entered so fully into the formation of the envelope, as the argument, by which its construction has been analysed, will completely explain the appearance of the streams of light inclosing the tail of the comet, and indeed its whole construction.

The luminous matter as it arises from the envelope, of which it is a continuation, is thrown a little outwards, and assumes the appearance of two diverging bright streams or branches; but if the source from which they rise be the circular rim of

* From the measure of the envelope, whose diameter the 6th of October was 643032 miles, we have the radius *a b*, Plate III, 321516. Then if *c d* be 25000, we find the angle *b a c*, of which *a c* is cosine 22° 44′ 37″; and the sine *b c*, which is the depth, will be to the versed sine *c d*, which is the thickness, as 4,972 to 1. And if *a d* is 9′ 30″, the greatest brightness which is at *c* will give the distance *a c* equal to 8′ 45″,7. This calculation being made for that part which is convex towards us, the addition of the concave opposite side will double the dimensions of the depth and thickness.

an hemispherical hollow shell, the luminous matter in its diverging progress upwards can only form a hollow cone; and the appearance of the two bright streams inclosing the tail, after what has been said of the envelope, will want no farther explanation.

Add to this that, having actually seen these brilliant streams remain at the borders of the tail in the same diverging situation during a motion of the comet through more than 130 degrees, the hollow conical form of the comet's tail is in fact established by observation.

The feebler light of the tail between its branches is sufficiently accounted for by the thinness of the luminous matter of the hollow cone through which we look towards the middle of the tail compared with its great depth about the sides; and indeed the comparative darkness of the inside of the cone and transparency of the atmosphere seen through the envelope, bear witness to their hollow construction; for, were these parts solid, both the cone and the hemispherical termination of it must have been much brighter in the middle than towards the circumference, which is contrary to observation.

Of the solar Agency in the Production of Cometic Phenomena.

As we are now in a great measure acquainted with the physical construction of the different parts of the present comet, and have seen many successive alterations that have happened in their arrangement, it may possibly be within our reach to assign the probable manner in which the action of such agents as we are acquainted with has produced the phenomena we have observed.

In its approach to a perihelion, a comet becomes exposed to the action of the solar rays, which, we know, are capable of producing light, heat, and chemical effects. That their influence on the present comet has caused an expansion, and decomposition of the cometic matter, we have experienced in the growing condition of the tail and shining quality of its light, which seems to be of a phosphoric nature. The way by which these effects have been produced may be supposed to be as follows.

The matter contained in the head of the comet would be dilated by the action of the sun, but chiefly in that hemisphere of it which is immediately exposed to the solar influence; and being more increased in this direction than on the opposite side, it would become eccentric, when referred to the situation of the body of the comet; but as the head is what draws our greatest attention, on account of its brightness, the little planetary body would appear to be in the eccentric situation in which we have seen it.

Now, as from observed phenomena, we have good reason to believe the comet to be surrounded by a very extensive, transparent, elastic atmosphere; the nebulous matter, which probably, when the comet is at a distance from the perihelion, is gathered about the head in a spherical form, would on its approach to the sun be greatly rarefied, and rise in the cometic atmosphere till it came to a certain level, where it could remain suspended, for some time, exposed to the continued action of the sun.

In this situation we have had an opportunity of seeing the transparent atmosphere, which, but for the suspension of the nebulous matter, we might never have discovered; and in-

deed, how far it may extend beyond the region which contained the shining substance, we can have no observation to ascertain, on account of its transparency. In consequence of the darkish interval, occasioned by the atmospheric space, the suspended light appeared to us in the shape of a very bright envelope.

The brilliancy of the envelope, and its yellowish colour, so different from that of the head, and probably acquired by its mixture with the atmospheric fluid, are proofs of the continued action of the sun upon the luminous matter, already in so high a state of rarefaction; and if we suppose the attenuation and decomposition of this matter to be carried on till its particles are sufficiently minute to receive a slow motion from the impulse of the solar beams, then will they gradually recede from the hemisphere exposed to the sun, and ascend in a very moderately diverging direction towards the regions of the fixed stars.

That some such operation must have been carried on, is pretty evident from our having seen the gradual rise, and increased expansion of the tail of the comet; and if we saw the shining matter, while suspended in the cometic atmosphere, in the shape of an envelope, it follows that, in its rising condition, it would assume the appearance of those two luminous branches which we have so long observed to inclose the tail of the comet.

The seemingly circular form, and the stream-like appearance of the luminous matter having been already explained, we may now see the reason why it can rise in no other form than the conical; for a whole hemisphere of it being exposed to the action of the sun, it must of course ascend equally every where all around it.

That the luminous matter ascending in the hollow cone, received no addition to its quantity from any other source than the exposed hemisphere, we may conclude from its appearance; which notwithstanding the great circumference of the cone it filled, at the altitude of 6 degrees from the head, was never seen with increased lustre; although the diameter of an annular section of it, in that place, must have been nearly 15 millions of miles, and was but little more than half a million at its rising from the envelope.

This consideration points out the extreme degree of rarefaction of the luminous matter about the end of the tail; for its expansion, while still much confined in the streams, at the altitude which has been mentioned, must have exceeded the density it had at rising about 524 times; but when afterwards it extended itself so as to produce nearly an evenly scattered light over the whole compass of the end of the tail, we may easily conceive to what an extreme degree of rareness its expansion must have been carried.

The vacancy occasioned by the escape of the nebulous matter, which after rarefaction passed from the hemisphere exposed to the sun into the regions of the tail, was probably filled up, either by a succession of it from the opposite hemisphere, or by a rotation of the comet about an axis; and the gradual decomposition of this matter would therefore be carried on as long as any remained to replace the deficiency.

That such a kind of process took place, seems to be supported by the observations which were made during the regression of the comet from its perihelion. For the space between the branches of the tail, very near the head of the comet, became gradually of a darker appearance than before;

which indicated the absence of the nebulous matter that had formerly been lodged there.

A rotatory motion of the comet, which has been suggested, would also explain the frequent variations in the length of the opposite branches which inclosed the tail; for if any portion of the cometary matter should be more susceptible of being thrown into a luminous decomposition than some others, a rotatory motion would bring such more susceptible matter into different situations, and cause a more or less copious emission of it in different places.

The additional short and faint double streams of nebulous light which issued from the vertex or side of the enfeebled envelope, in the gradual regress of the comet, tend likewise to add probability to the conception of a rotatory motion; for the changeable appearance of the situation of these streamlets might arise from a periodical exposition of some remaining small portions of less rarefied matter, when nearly the whole of it had been exhausted.

Of the Result of a Comet's Perihelion Passage.

After having given a detail of phenomena, and entered into a research of the most likely manner in which they were produced, I shall only mention what appears to me to be the most probable consequence of the perihelion passage of a comet.

The quality of giving out light, although it may always reside in a comet, as it does in the immensity of the nebulous matter, which I have shown to exist in the heavens, is exceedingly increased by its approach to the sun. Of this we should not be so sensible, if it were not accompanied with an almost

inconceivable expansion and rarefaction of the luminous substance of the comet about the time of its perihelion passage.

It is admitted, on all hands, that the act of shining denotes a decomposition in which at least light is given out; but that many other elastic volatile substances may escape at the same time, especially in so high a degree of rarefaction, is far from improbable.

Then, since light certainly, and very likely other subtile fluids also escape in great abundance during a considerable time before and after a comet's nearest approach to the sun, I look upon a perihelion passage in some degree as an act of consolidation.

If this idea should be admitted, we may draw some interesting conclusions from it. Let us, for example, compare the phenomena that accompanied the comet of 1807 with those of the present one. The first of these in its approach to the sun came within 61 millions of miles of it; and its tail, when longest, covered an extent of 9 millions. The present one in its perihelion did not come so near the sun by nearly 36 millions of miles, and nevertheless acquired a tail 91 millions longer than that of the former. The difference in their distances from the earth when these measures were taken was but about 2 millions.

Then may we not conclude, that the consolidation of the comet of 1807, when it came to the perihelion, had already been carried to a much higher degree than that of the present one, by some former approach to our sun, or to other similarly constructed celestial bodies, such as we have reason to believe the fixed stars to be?

And that comets may pass round other suns than ours, is

rendered probable from our knowing as yet, with certainty, the return of only one comet among the great number that have been observed.

Since then, from what has been said, it is proved that the influence of the sun upon our present comet has been beyond all comparison greater than it was upon that of 1807; and since we cannot suppose our sun to have altered so much in its radiance as to be the cause of the difference; have we not reason to suppose that the matter of the present comet has either very seldom, or never before passed through some perihelion by which it could have been so much condensed as the preceding comet? Hence may we not surmise that the comet of 1807 was more advanced in maturity than the present one; that is to say, that it was comparatively a much older comet.

Should the idea of age be rejected, we may indeed have recourse to another supposition, namely, that the present comet, since the time of some former perihelion passage, may have acquired an additional quantity (if I may so call it) of *unperihelioned* matter, by moving in a parabolical direction through the immensity of space, and passing through extensive strata of nebulosity; and that a small comet, having already some solidity in its nucleus, should carry off a portion of such matter, cannot be improbable. Nay, from the complete resemblance of many comets to a number of nebulæ I have seen, I think it not unlikely that the matter they contain is originally nebulous. It may therefore possibly happen that some of the nebulæ, in which this matter is already in a high state of condensation, may be drawn towards the nearest celestial body of the nature of our sun; and after their first perihelion pas-

sage round it proceed, in a parabolic direction, towards some other similar body; and passing successively from one to another, may come into the regions of our sun, where at last we perceive them transformed into comets.

The brilliant appearance of our small comet may therefore be ascribed either to its having but lately emerged from a nebulous condition, or to having carried off some of the nebulous matter, situated in the far extended branch of its parabolic motion. The first of these cases will lead us to conceive how planetary bodies may begin to have an existence; and the second, how they may increase and, as it were, grow up to maturity. For if the accession of fresh nebulous matter can be admitted to happen once, what hinders us from believing a repetition of it probable? and in the case of parabolic motions, the passage of a comet through immense regions of such matter is unavoidable.

WM. HERSCHEL.

Slough, near Windsor,
Dec. 16, 1811.