

XVI. *Astronomical Observations relating to the Construction of the Heavens, arranged for the Purpose of a critical Examination, the Result of which appears to throw some new Light upon the Organization of the celestial Bodies.* By William Herschel, LL.D. F. R. S.

Read June 20, 1811.

A KNOWLEDGE of the construction of the heavens has always been the ultimate object of my observations, and having been many years engaged in applying my forty, twenty, and large ten feet telescopes, on account of their great space-penetrating power to review the most interesting objects discovered in my sweeps, as well as those which had before been communicated to the public in the *Connoissance des Temps*, for 1784, I find that by arranging these objects in a certain successive regular order, they may be viewed in a new light, and, if I am not mistaken, an examination of them will lead to consequences which cannot be indifferent to an inquiring mind.

If it should be remarked that in this new arrangement I am not entirely consistent with what I have already in former papers said on the nature of some objects that have come under my observation, I must freely confess that by continuing my sweeps of the heavens my opinion of the arrangement of the stars and their magnitudes, and of some other particulars, has undergone a gradual change; and indeed when the novelty of the subject is considered, we cannot be surprised

that many things formerly taken for granted, should on examination prove to be different from what they were generally, but incautiously, supposed to be.

For instance, an equal scattering of the stars may be admitted in certain calculations; but when we examine the milky way, or the closely compressed clusters of stars, of which my catalogues have recorded so many instances, this supposed equality of scattering must be given up. We may also have surmised nebulae to be no other than clusters of stars disguised by their very great distance, but a longer experience and better acquaintance with the nature of nebulae, will not allow a general admission of such a principle, although undoubtedly a cluster of stars may assume a nebulous appearance when it is too remote for us to discern the stars of which it is composed.

Impressed with an idea that nebulae properly speaking were clusters of stars, I used to call the nebulosity of which some were composed, when it was of a certain appearance, *resolvable*; but when I perceived that additional light, so far from resolving these nebulae into stars, seemed to prove that their nebulosity was not different from what I had called milky, this conception was set aside as erroneous. In consequence of this, such nebulae as afterwards were suspected to consist of stars, or in which a few might be seen, were called *easily resolvable*; but even this expression must be received with caution, because an object may not only contain stars, but also nebulosity not composed of them.

It will be necessary to explain the spirit of the method of arranging the observed astronomical objects under consideration in such a manner, that one shall assist us to understand

the nature and construction of the other. This end I propose to obtain by assorting them into as many classes as will be required to produce the most gradual affinity between the individuals contained in any one class with those contained in that which precedes and that which follows it: and it will certainly contribute to the perfection of this method, if this connection between the various classes can be made to appear so clearly as not to admit of a doubt. This consideration will be a sufficient apology for the great number of assortments into which I have thrown the objects under consideration; and it will be found that those contained in one article, are so closely allied to those in the next, that there is perhaps not so much difference between them, if I may use the comparison, as there would be in an annual description of the human figure, were it given from the birth of a child till he comes to be a man in his prime.

The similarity of the objects contained in each class will seldom require the description of more than one of them, and for this purpose, out of the number referred to, the selected one will be that which has been most circumstantially observed; however, those who wish either to review any other of the objects, or to read a short description of them, will find their place in the heavens, or the account of their appearance either in the catalogues I have given of them in the *Philos. Trans.* or in the *Connoissance des Temps* for 1784, to which in every article proper references will be given for the objects under consideration.

If the description I give should sometimes differ a little from that which belongs to some number referred to, it must be remembered that objects which had been observed many

times, could not be so particularly and comprehensively detailed in the confined space of the catalogues as I now may describe them; additional observations have also now and then given me a better view of the objects than I had before. This remark will always apply to the numbers which refer to the *Connoissance des Temps*; for the nebulae and clusters of stars are there so imperfectly described, that my own observation of them with large instruments may well be supposed to differ entirely from what is said of them. But if any astronomer should review them, with such high space-penetrating-powers, as are absolutely required, it will be found that I have classed them very properly.

It will be necessary to mention that the nebulous delineations in the figures are not intended to represent any of the individuals of the objects which are described otherwise than in the circumstances which are common to the nebulae of each assortment: the irregularity of a figure, for instance, must stand for every other irregularity; and the delineated size for every other size. It will however be seen, that in the figure referred to there is a sufficient resemblance to the described nebula to show the essential features of shape and brightness then under consideration.

1. *Of extensive diffused Nebulosity.*

The first article of my series will begin with extensive diffused nebulosity, which is a phenomenon that hitherto has not been much noticed, and can indeed only be perceived by instruments that collect a great quantity of light. Its existence, when some part of it is pointed out by objects that are within the reach of common telescopes, has nevertheless obtruded

itself already on the knowledge of astronomers, as will be seen in my third article.

The widely diffused nebulosity under consideration has already been partially mentioned in my catalogues.*

The description of the object I shall select is of No. 14 in the 5th class, and is as follows: "Extremely faint branching nebulosity; its whitishness is entirely of the milky kind, and it is brighter in three or four places than in the rest; the stars of the milky way are scattered over it in the same manner as over the rest of the heavens. Its extent in the parallel is nearly $1\frac{1}{2}$ degree, and in the meridional direction about 52 minutes. The following part of it is divided into several streams and windings, which after separating, meet each other again towards the south." See figure 1.

This account, which agrees with what will be found in all the other numbers referred to, with regard to the subject under consideration, namely, a diffused milky nebulosity, will give us already some idea of its great abundance in the heavens; my next article however will far extend our conception of its quantity.

2. *Observations of Nebulosities that have not been published before.*

It may be easily supposed that in my sweeps of the heavens I was not inattentive to extensive diffusions of nebulosity, which occasionally fell under my observation. They can only be seen when the air is perfectly clear, and when the observer

* See Phil. Trans. for 1786, page 471; for 1789, page 226; and for 1802, page 503. The following ten nebulosities are in the Vth class, No. 13, 14, 15, 17, 28, 30, 31, 33, 34, 38.

has been in the dark long enough for the eye to recover from the impression of having been in the light.

I have collected fifty-two such observations into a table, and have arranged them in the order of right ascension. In the first column they are numbered ; in the second and third columns are the right ascension and north polar distance of a place which is the central point of a parallelogram comprehending the space which the nebulosity was observed to fill. They are calculated for the year 1800.

The length and breadth of the parallelograms are set down in the 4th and 5th columns in degrees and minutes of a great circle. The time taken up in the transit of each parallelogram having been properly reduced to space by the polar distance given in the 3d column, in order to make it agree with the space contained in the breadth of the zone described by the telescope ; the dimensions of the former space therefore is in the parallel, and that of the latter in the meridian. My field of view, being fifteen minutes in diameter, its extent has been properly considered in the assigned dimensions of the parallelograms. It is however evident that the limits of the sweeping zone leave the extent of the nebulosity in the meridian unascertained. The beginning of it is equally uncertain, since the nebulous state of the heavens could only be noticed when its appearance became remarkable enough to attract attention. The ending is always left undetermined ; for, as the right ascension was only taken once, I have allowed but a single minute of time for the extent of the nebulosity in that direction, except where the time was repeatedly taken with a view to ascertain how far it went in the parallel ; or when the circumstances of its brightness pointed out a longer duration.

The sixth column of the table contains the size of the observed nebulosity reduced to square degrees and decimals, computed from the two preceding columns; and in the last I have given the account of these nebulosities as recorded in my sweeps at the time they were made; namely within a period of nineteen years, beginning in 1783 and ending in 1802.

When this account says *affected*, it is intended to mean that the ground upon which, or through which we see, or may see stars, is affected with nebulosity.

Table of extensive diffused Nebulosity.

No.	R. A.			P. D.		Paral.	Merid.	Size.	Account of the Nebulosity.	
	h	'	"	°	'	°	'	Deg.		
1	0	5	2	81	7	1	44	1 55	3,3	Much affected with nebulosity.
2	0	12	31	85	34	3	0	2 34	7,7	Much affected.
3	0	17	17	61	24	0	41	2 40	1,8	Affected.
4	0	20	31	86	34	1	30	2 34	3,6	Much affected.
5	0	25	5	67	8	0	29	2 34	1,2	Much affected.
6	0	31	22	90	4	2	30	2 19	5,7	Appeared to be affected with very faint nebulosity.
7	0	32	54	49	23	1	33	3 1	4,7	Affected with nebulosity.
8	0	34	21	51	17	1	17	2 49	3,6	Unequally affected.
9	0	36	13	47	3	2	37	3 18	8,6	Suspected faint nebulosity.
10	0	43	32	46	58	0	26	3 18	1,4	Suspected faint nebulosity.
11	1	35	32	60	42	0	28	2 40	1,3	Suspected to be tinged with milky nebulosity.
12	2	22	19	71	27	0	29	2 29	1,2	Much affected with nebulosity.
13	3	56	14	65	6	0	29	2 27	1,7	Much affected.
14	4	17	21	55	7	1	4	2 38	2,8	Suspected pretty strong nebulosity.
15	4	18	21	55	6	1	53	2 38	5,0	Suspected nebulosity.
16	4	21	35	97	44	0	30	2 15	1,1	Strong milky nebulosity.
17	4	23	14	69	23	0	29	2 36	1,3	Much affected.
18	4	38	17	69	23	0	29	2 36	1,3	Much affected.
19	4	46	17	63	25	1	46	2 31	4,4	Strong suspicion of very faint milky nebulosity.
20	5	9	44	65	6	1	23	2 27	3,4	Very much affected.
21	5	13	14	65	6	0	29	2 27	1,7	Affected.

No.	R. A.	P. D.	Paral.	Merid.	Size.	Account of the Nebulosity.
	h. m. s.	° ' "	o ' "	o ' "	Deg.	
22	5 23 59	97 1	2 31	2 31	6,3	Affected with milky nebulosity.
23	5 25 16	92 48	0 30	2 40	1,3	Affected.
24	5 27 2	94 23	1 48	2 32	4,6	Visible and unequally bright nebulosity. I am pretty sure this joins to the great nebula in Orion.
25	5 30 40	92 35	2 45	2 33	7,0	Diffused milky nebulosity.
26	5 31 58	97 1	1 56	2 31	4,9	A pretty strong suspicion of nebulosity.
27	5 38 5	88 55	1 6	2 37	2,9	Affected with milky nebulosity.
28	5 55 55	86 17	0 30	2 34	1,3	Much affected.
29	5 56 36	110 28	1 48	2 48	5,0	Affected.
30	6 33 7	48 39	0 26	3 4	1,3	Affected.
31	9 22 56	108 3	0 29	2 30	1,2	Affected.
32	9 27 19	18 21	0 24	4 4	1,6	Much affected with very faint whitish nebulosity.
33	10 6 56	98 33	3 58	2 17	9,1	Very faint whitish nebulosity.
34	10 16 1	37 58	0 24	4 9	1,7	Much affected.
35	10 34 29	26 44	0 29	3 15	1,6	Affected with very faint nebulosity
36	10 58 24	26 44	0 42	3 15	2,3	Affected.
37	11 56 59	58 50	0 41	2 54	2,0	Affected with whitish nebulosity.
38	12 7 34	58 50	0 41	2 54	2,0	Affected with whitish nebulosity.
39	13 7 33	55 20	0 27	2 17	1,0	Much affected.
40	13 58 0	55 20	0 42	2 17	1,6	Very much affected; and many faint nebulae suspected.
41	15 5 7	70 40	1 52	2 31	4,7	Affected with very faint nebulosity.
42	20 58 20	92 17	1 45	2 21	4,1	Much affected with whitish nebulosity.
43	20 48 50	73 38	0 29	2 52	1,4	A good deal affected.
44	20 51 4	46 51	0 59	2 53	2,8	Faint milky nebulosity scattered over this space, in some places pretty bright.
45	20 52 28	91 57	0 49	0 56	0,8	Much affected with whitish nebulosity.
46	20 53 31	47 7	1 8	3 18	3,7	Suspected nebulosity joining to plainly visible diffused nebulosity.
47	21 0 26	76 3	0 44	2 46	2,0	Affected.
48	21 29 27	80 8	0 30	2 15	1,1	Much affected.
49	21 42 16	68 57	0 29	2 36	1,2	Affected.
50	22 52 36	64 47	0 29	2 47	1,3	Much affected.
51	22 53 6	64 47	0 42	2 47	1,9	Affected.
52	22 55 29	61 15	0 28	2 37	1,2	A little affected.

In looking over this table, it may be noticed that I have inserted several nebulosities that were only suspected. Had I been less scrupulous at the time of observation the word suspected would generally have been omitted; for with this nebulosity, as well as with the great number of nebulae that in my catalogues are marked suspected, I have almost without exception found, in a second review, that the entertained suspicion was either fully confirmed, or that, without having had any previous notice of the former observation, the same suspicion was renewed when I came to the same place again.

When these observations are examined with a view to improve our knowledge of the construction of the heavens, we see in the first place that extensive diffused nebulosity is exceedingly great indeed; for, the account of it, as stated in the table, is 151.7 square degrees; but this, it must be remembered, gives us by no means the real limits of it, neither in the parallel nor in the meridian; moreover the dimensions in the table give only its superficial extent; the depth or third dimension of it may be far beyond the reach of our telescopes; and when these considerations together are added to what has been said in the foregoing article, it will be evident that the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination.

By nebulous matter I mean to denote that substance, or rather those substances which give out light, whatsoever may be their nature, or of whatever different powers they may be possessed.

Another remark of equal importance arises from the consideration of the observed nebulosities. By the account of the table we find that extreme faintness is predominant in most

of them ; which renders it probable that our best instruments will not reach so far into the profundity of space, as to see more distant diffusions of it. In No. 44 of the table, we have an instance of faint milky nebulosity, which, though pretty bright in some places, was completely lost from faintness in others ; and No. 46 confirms the same remark. It has also been already mentioned in the first article, that the nebulosity in V. 14 was brighter in three or four places than in the rest. The stars also of the milky way which were scattered over it, and were generally very small, appeared with a brilliancy that will admit of no comparison with the dimness of the brightest nebulosity. In consequence of this, we may already surmise that the range of the visibility of the nebulous matter is confined to very moderate limits.

3. *Of Nebulosities joined to Nebulæ.*

The nature of diffused nebulosity is such that we often see it joined to real nebulæ ; for instances of this kind we have the fourteen following objects.*

The account of the three first nebulæ being shortened in the catalogue, I give it here more at length.

No. 81 in the first class is “ A considerable bright and large
“ nebula. Its nebulosity is of the milky kind, and a small
“ part of it is considerably brighter than the rest. The great-
“ est extent of the milkiness is preceding the bright part, and
“ the termination of it is imperceptible.” To No. 207 should be added “ It seems to join to imperceptible nebulosity on the
“ south preceding side ;” and to No. 214, “ It terminates

* See I. 81, 207, 214. IV. 41. V. 32, 35, 37, 44, 51, 52. *Connaissance des Temps* 17, 42, 64, 78.

“ abruptly to the north and is diffused to the south.” See fig. 2.

No. 42 of the *Connoissance* is the great nebula in the constellation of Orion discovered by HUYGHENS. This highly interesting object engaged my attention already in the beginning of the year 1774, when viewing it with a NEWTONIAN reflector I made a drawing of it, to which I shall have occasion hereafter to refer; and having from time to time reviewed it with my large instruments, it may easily be supposed that it was the very first object to which, in February 1787, I directed my forty feet telescope. The superior light of this instrument shewed it of such a magnitude and brilliancy that, judging from these circumstances, we can hardly have a doubt of its being the nearest of all the nebulae in the heavens, and as such will afford us many valuable informations. I shall however now only notice that I have placed it in the present order because it connects in one object the brightest and faintest of all nebulosities, and thereby enables us to draw several conclusions from its various appearance.

The first is that the extensive diffused nebulosities contained in the objects of the preceding articles are of the same nature with the nebulosity in this great nebula; for when we pursue it in its extensive course it assumes precisely the same appearance as the before-mentioned diffused nebulosities.

The second consequence we may draw from the circumstance of its containing both the brightest and faintest nebulosity joined in one object is a confirmation of an opinion already conceived in the second article, namely, that the range of the visibility of nebulous matter is what may be called very limited. The depth of the nebula may undoubtedly be ex-

ceedingly great, but when we consider that its greatest brightness does not equal that of small telescopic stars, as may be seen by comparing four of them situated within the inclosed darkness of the nebula, and several within its brightest appearance, with the intensity of the nebulous light; it cannot be expected that such nebulosities will remain visible when exceedingly farther from us than this prime nebula: the ratio of the known decrease of light will not admit of a great range of visibility within the narrow limits whereby this shining substance can affect the eye.

From this argument a secondary conclusion may be drawn, which adds to what has already been said in the foregoing article, namely, that if our best telescopes cannot be expected to reach the nebulous matter, which by analogy we may suppose to be lodged among the very small stars plainly to be seen by them; the actual quantity of its diffusion may still farther exceed even the vast abundance of it already proved to exist. A nebulous matter, diffused in such exuberance throughout the regions of space, must surely draw our attention to the purpose for which it probably may exist; and it must be the business of a critical inquirer to attend to all the appearances under which it will be exposed to his view in the following observations.

4. *Of detached Nebulosities.*

The nebulosities of the preceding articles are not restricted to an extensive diffusion; we meet with them equally in detached collections; I shall only mention the following six.*

V. 21 consists of "A broad faint nebulosity extended in the

* See I. 92. V. 21, 26, 36, 41, 42.

“ form of a parallelogram with a short ray from the preceding corner towards the south. The nebulosity is nearly of an equal brightness throughout the parallelogram, which is about 8' long and 5 or 6' broad, but ill defined.” See fig. 3, *a, b, c.*

5. Of milky Nebulæ.

When detached nebulosities are small we are used to call them *nebulæ*, and it is already known from my catalogues that their number is very great. It will therefore be sufficient to refer only to a few, of which the nebulosity is of the milky kind.*

No. 9 in the 5th class is “ A large, extended, broad, faint nebula; its nebulosity, like that of the preceding one (which is DE LA CAILLE’s last but one in the Catalogue des *Nebuleuses du Ciel Austral*†) is of the milky kind.”

The only purpose for which the *nebulæ* of these two classes have been placed in this connection, is to show that large detached nebulosities, whatever may be their appearance, as well as those *nebulæ* expressly called milky, partake of the general nature of the diffused nebulous matter, pointed out in the preceding articles.

6. Of milky Nebulæ with Condensation.

In looking at the beautiful nebula in Orion; to which I refer, because every common good telescope will shew it sufficiently well for the present purpose; we perceive that it is not equally bright in all its parts, but that its light is more

* See I. 204, III. 1, 116. IV. 7, 20, 30. V. 9, 25.

† See *Connoissance des Temps* for 1784, page 272.

condensed in some places than in others. The idea of condensation occurs so naturally to us when we see a gradual increase of light, that we can hardly find a more intelligible mode of expressing ourselves than by calling it condensed. The numerous instances that will be given hereafter of nebulae that have this kind of condensation, renders it unnecessary to refer to more than the following four.*

The first of these, No. 11 in the first class, is “A bright nebula of some extent, although not very large. It is of an irregular figure, and the greatest brightness lies towards the middle. The whitishness of this nebula is of the milky kind.” See figure 4.

By attending to the circumstances of the size and figure of this nebula, we find that we can account for its greater brightness towards the middle in the most simple manner by supposing the nebulous matter of which it is composed to fill an irregular kind of solid space, and that it is either a little deeper in the brightest place, or that the nebulosity is perhaps a little more compressed. It is not necessary for us to determine at present to which of these causes the increase of brightness may be owing; at all events it cannot be probable that the nebulous matter should have different powers of shining such as would be required independent of depth or compression.

7. *Of Nebulae which are brighter in more than one Place.*

It is not an uncommon circumstance that the same nebula is brighter in several different places than in the rest of its compass. The following six are of this sort.†

* See I. 11, 84. III. 457. IV. 12.

† See I. 165, 213, 261. II. 297, 406. III. 49.

No. 213 in the first class is “A very brilliant and considerably large nebula, extended in a direction from south preceding to north following. It seems to have three or four bright nuclei.” See fig. 5.

From this construction of the nebula, we may draw some additional information concerning the point which was left undetermined in my last article; for since there it was proposed as an alternative, that the nebulous matter might either be of a greater depth or more compressed in the brightest part of the nebula then under consideration, we have now an opportunity to examine the probability of each case. If here the appearance of several bright nuclei is to be explained by the depth of the nebulous matter, we must have recourse to three or four separate very slender and deep projections, all situated exactly in the line of sight; but such a very uncommon arrangement of nebulous matter cannot pretend to probability; whereas a moderate condensation, which may indeed be also accompanied with some little general swelling of the nebulous matter about the places which appear like nuclei, will satisfactorily account for their superior brightness.

The same method of reasoning may be as successfully applied to explain the number of unequally bright places in the diffused nebulosities which have been described in the 1st, 2d, and 3d articles. For instance, in the branching nebulosity V. 14, we find three or four places brighter than the rest—in the nebulosity No. 44 of the table we have places of different brightness. In the nebula of Orion, there are many parts that differ much in lustre; and in V. 37 of the same article I found, by an observation in the year 1790, the same variety of appearance. In all these cases a proportional condensation

of the nebulous matter in the brighter places will sufficiently account for their different degree of shining.

This way of explaining the observed appearances being admitted, it will be proper to enter into an examination of the probable cause of the condensation of the nebulous matter. Should the necessity for such a condensing cause be thought to be admitted upon too slight an induction, a more detailed support of it will hereafter be found in the condition of such a copious collection of objects, as will establish its existence beyond all possibility of doubt.*

Instead of inquiring after the nature of the cause of the condensation of nebulous matter, it would indeed be sufficient for the present purpose to call it merely a condensing principle; but since we are already acquainted with the centripetal force of attraction which gives a globular figure to planets, keeps them from flying out of their orbits in tangents, and makes one star revolve around another, why should we not look up to the universal gravitation of matter as the cause of every condensation, accumulation, compression, and concentration of the nebulous matter? Facts are not wanting to prove that such a power has been exerted; and as I shall point out a series of phenomena in the heavens where astronomers may read in legible characters the manifest vestiges of such an exertion, I need not hesitate to proceed in a few additional remarks on the consequences that must arise from the admission of this attractive principle.

The nebula, for instance, which has been described at the beginning of this article, as containing several bright nuclei, has probably so many predominant seats of attraction, arising

* See Article 24.

from a superior preponderance of the nebulous matter in those places; but attraction being a principle which never ceases to act, the consequence of its continual exertion upon this nebula will probably be a division of it, from which will arise three or four distinct nebulae. In the same manner its operation on the diffused nebulosities that have many different bright places, will possibly occasion a breaking up of them into smaller diffusions and detached nebulae; but before I proceed with conjectures, let us see what observations we have to give countenance to such expectations.

8. *Of double Nebulae with joined Nebulosity.*

In addition to the instances referred to in the preceding article, of nebulae that have more than one centre of attraction I give the following list of what may be called double nebulae.*

The 316th nebula in the second class to which in the catalogue is joined the 317th, consists of “two small faint nebulae of an equal size within 1' of each other. Each has a seeming nucleus, and their apparent nebulosities run into each other. Their relative position is in a direction from south preceding to north following.” See fig. 6, *a* and *b*.

Each of the fifteen objects referred to contains two nuclei or centers of attraction, and if the active principle of condensation carries on its operation, a division of their at present united nebulosities must, in the end, be the consequence. I

* See I. 56, 176, 178, 193. II. 80, 271, 309, 316, 832. III. 45, 644. IV. 8, 28. *Connoiss.* 27, 51.

have given two figures for the same double nebulae. For, although the nebulosities of figure *b*, when seen in the direction of the dotted lines will appear to run together, they may nevertheless be at some small distance from each other; but the same cause which will bring on a separation of it in figure *a* will also make two distinct nebulae of figure *b*.

With regard to their being double nebulae, it may be objected that this double appearance may be a deception; and indeed if this were a double star, instead of a double nebula, there might be some room for such a surmise. But on two accounts the case is very different. In the first place, we have not nebulae without number at all distances to which we might have recourse, in supposing one to be far behind the other, as we have stars behind stars to produce an appearance of their being double. In the next; if what has been said of the confined range of the visibility of the nebulous matter be recollected, especially where it is so faint as in the double nebula which has been described, we cannot harbour an idea that the two objects of which it is composed are very far asunder. Add to this their great resemblance in size, in faintness, in nucleus, and in their nebulous appearance; from all which I believe it must be evident that their nebulosity has originally belonged to one common stock.

9. Of double Nebulae that are not more than two Minutes from each other.

To add to the probability of the separation of nebulae, we ought to have a considerable number of them already sepa-

rated. The following twenty three are completely divided although not more than two minutes from one another.*

A description of II. 714 is "Two pretty bright nebulae; they are both round, small, and about 2' from each other, in a meridional direction."

Of III. 755 is "Two very faint, very small extended nebulae within $1\frac{1}{2}'$ from each other."

That all these nebulae are really double, is founded on the reason already assigned in the last article. Then if we would enter into some kind of examination how they came to be arranged into their binary order, we cannot have recourse to a promiscuous scattering, which by a calculation of chances can never account for such a peculiar distribution of them. If, on the contrary, we look to a division of nebulous matter by the condensing principle, then every parcel of it, which had more than one preponderating seat of attraction in its extent, must in the progress of time have been divided.

No doubt can be suggested on account of the great length of time such a division must have taken up, when we have an eternity of past duration to recur to.

10. *Of double Nebulae at a greater Distance than 2' from each other.*

It may well be supposed that more than one attractive center would not be so frequent a case in small distances, as in nebulosities of a more extended compass; accordingly we find that separated nebulae at more than 2' from each other are much

* See I. 116, 190, 197. II. 8, 28, 57, 111, 178, 450, 714. III. 92, 228, 280, 591, 687, 719, 755, 855, 886, 943, 952, 959, 967.

more numerous. The following 101 double nebulae referred to will confirm this statement.*

No. 36 and 37 in the first class are "Two small bright nebulae, both a little extended."

No. 74 and 75 in the second class are "Two pretty bright nebulae; the preceding of them is almost round; the following very much extended in length; they are not far from the same parallel, and about 8 or 10' distant from each other."

No. 127 and 128 in the third class are "Two extremely faint nebulae, about 3' from each other, and nearly in the same parallel. The second is a very little brighter than the first, and is of an irregular round figure."

It is remarkable that in the description of all these 101 nebulae, there are not more than five or six which differ so much in brightness from one another, that we could suppose them to be at any considerable different distance from us; and equal brightness or faintness runs through them all in general; but supposing that any two nebulae should even differ as much from one another, as the set of the first class which has been described, is different from the faintness of the last described set, yet this would not nearly amount to the difference in the brightness of one part of the nebula in Orion from that of another of the same nebula.

* See I. 28, 36, 90, 145. II. 17, 44, 55, 61, 74, 84, 85, 115, 118, 121, 139, 153, 167, 219, 228, 233, 333, 388, 426, 429, 455, 518, 546, 550, 580, 614, 679, 684, 692, 751, 764, 787, 789, 841, 842, 865, 868. III. 9, 15, 35, 44, 51, 62, 97, 117, 121, 127, 129, 138, 154, 159, 162, 166, 167, 172, 196, 199, 210, 216, 231, 250, 277, 306, 323, 335, 344, 351, 377, 402, 404, 407, 416, 422, 431, 511, 546, 551, 572, 574, 592, 629, 635, 657, 678, 707, 758, 781, 798, 800, 802, 807, 869, 897, 917, 957, 959, 974.

11. *Of treble, quadruple, and sextuple Nebulæ.*

If it was supposed that double nebulæ at some distance from each other would frequently be seen, it will now on the contrary be admitted that an expectation of finding a great number of attracting centers in a nebulosity of no great extent is not so probable; and accordingly observation has shewn that greater combinations of nebulæ than those of the foregoing article are less frequently to be seen. The following list however contains 20 treble, 5 quadruple, and 1 sextuple nebulæ of this sort.*

Among the treble nebulæ there is one, namely V. 10, of which the nebulosity is not yet separated. “Three nebulæ seem to join faintly together, forming a kind of triangle; the middle of which is less nebulous, or perhaps free from nebulosity; in the middle of the triangle is a double star of the 2d or 3d class; more faint nebulosities are following.”

Among the quadruple nebulæ we have III. 358. “Four nebulæ, all within three minutes. The largest is faint and small; the other three are less and fainter. They form a small quartile, the largest being the most north of the preceding side.”

“The nebulæ which form the sextuple one are all very faint and very small; they take up a space of more than 10 or 12 minutes.”

* See *treble nebulæ*. I. 17. II. 50, 123, 141, 171, 215, 392, 447. III. 85, 94, 117, 156, 300, 358, 382, 592, 873, 900, 945. V. 10.

Quadruple. II. 482, 568. III. 356, 358, 562.

Sextuple. III. 391.

12. *Of the remarkable Situation of Nebulæ.*

The number of compound nebulæ that have been noticed in the foregoing three articles being so considerable, it will follow, that if they owe their origin to the breaking up of some former extensive nebulosities of the same nature with those which have been shewn to exist at present, we might expect that the number of separate nebulæ should far exceed the former, and that moreover these scattered nebulæ should be found not only in great abundance, but also in proximity or continuity with each other, according to the different extents and situations of the former diffusions of such nebulous matter. Now this is exactly what by observation, we find to be the state of the heavens.

In the following seven assortments we have not less than 424 nebulæ; some of them of unascertained size, figure, or condensation; and the rest with only the first of these three essential features recorded.

The reason for not having a more circumstantial account of such a number of objects, is that they crowded upon me at the time of sweeping in such quick succession, that of sixty-one I could but just secure the place in the heavens, and of the remaining three hundred and sixty-three, I had only time to add the relative size.*

* See *sixty-one nebulæ*. II. 30, 66, 68, 70, 109, 114, 117, 125, 138, 170, 174, 176, 345, 361, 390, 391, 496, 499, 541, 542, 543, 572, 573, 629, 631, 806, 898. III. 20, 26, 31, 33, 39, 41, 42, 89, 103, 189, 193, 205, 332, 353, 363, 364, 365, 390, 413, 432, 481, 482, 483, 484, 485, 669, 670, 705, 796, 819, 930, 934, 936. *Connoiss.* 84.

Ten extremely small nebulæ. III. 98, 108, 194, 195, 230, 238, 297, 526, 545, 639.

One hundred and thirty-six very small nebulæ. II. 22, 64, 67, 72, 91, 93, 287.

Neither of the nebulae in these seven divisions will require a description, as the title of each assortment contains all that has been ascertained about them ; but their number and situation, especially when added to those that will be contained in the following articles, completely supports what has been asserted, namely, that the present state of the heavens presents us with several extensive collections of scattered nebulae, plainly indicating by their very remarkable arrangement, that they

354, 367, 464, 497, 527, 544, 640, 641, 675, 720, 724, 739, 876. III. 6, 13, 22, 24, 34, 37, 38, 104, 111, 140, 164, 166, 186, 190, 237, 247, 255, 283, 285, 302, 303, 304, 309, 315, 317, 319, 325, 326, 333, 338, 339, 343, 354, 385, 386, 387, 389, 398, 411, 412, 421, 425, 430, 433, 435, 437, 443, 444, 453, 459, 460, 467, 470, 501, 507, 509, 525, 539, 544, 578, 579, 607, 618, 623, 625, 634, 638, 640, 641, 645, 650, 652, 659, 666, 702, 704, 708, 716, 718, 731, 733, 738, 762, 766, 775, 787, 788, 789, 799, 803, 809, 827, 831, 833, 836, 837, 838, 839, 848, 849, 866, 875, 883, 884, 894, 895, 905, 912, 913, 919, 956, 960, 961, 962, 965, 966.

Forty two not very small nebulae. I. 119. II. 65, 73, 100, 163, 248, 327, 352, 375, 382, 472, 606, 639, 765, 821, 838. III. 17, 30, 249, 281, 321, 327, 366, 375, 504, 548, 615, 628, 647, 660, 667, 698, 712, 715, 734, 751, 773, 774, 840, 850, 941. *Connoiss.* 89.

One hundred and seven small nebulae. I. 25, 123. II. 18, 42, 46, 60, 71, 92, 94, 169, 264, 294, 324, 343, 350, 351, 356, 363, 374, 379, 381, 395, 396, 397, 398, 441, 493, 512, 529, 530, 559, 577, 578, 678, 710, 743, 778, 779, 794, 800. III. 25, 48, 57, 59, 60, 69, 74, 192, 206, 235, 243, 308, 328, 329, 334, 337, 350, 380, 420, 446, 458, 462, 464, 475, 478, 502, 516, 517, 529, 550, 588, 611, 651, 661, 664, 668, 721, 722, 723, 729, 761, 763, 769, 779, 780, 794, 797, 814, 826, 833, 841, 843, 861, 880, 881, 894, 915, 924, 925, 926, 927, 928, 939, 950, 951, 954, 969.

Fifty-eight pretty large nebulae. I. 22, 24, 85, 169, 283. II. 34, 83, 107, 119, 137, 146, 296, 342, 358, 362, 366, 380, 383, 384, 385, 386, 387, 419, 498, 630, 652, 670, 713, 748, 801, 844, 862, 903, 905. III. 14, 18, 40, 70, 75, 76, 102, 213, 261, 279, 318, 340, 367, 372, 374, 415, 454, 473, 503, 543, 599, 662, 790, 970.

Ten large nebulae. II. 106, 120, 175, 176. III. 28, 361, 440, 480. V. 6. *Connoiss.* 58.

owe their origin to some former common stock of nebulous matter.

To refer astronomers to the heavens for an inspection of these and the following nebulae, would be to propose a repetition of more than eleven hundred sweeps to them, but those who wish to have some idea of the nebulous arrangements may consult Mr. BODE's excellent *Atlas Coelestis*. A succession of places where the nebulae of my catalogues are uncommonly crowded, will there be seen beginning over the tail of Hydra and proceeding to the southern wing, the body and the northern wing of Virgo, Plate 14. Then to Coma Berenices, Canes venatici, and the preceding arm of Bootes, Plate 7. A different branch goes from Coma Berenices to the hind legs of Ursa major. Another branch passes from the wing of Virgo to the tail and body of Leo, Plate 8.

It will not be necessary to point out many other smaller collections which may be found in several plates of the same *Atlas*.

On the other hand, a very different aspect of the heavens will be perceived when we examine the following constellations. Beginning from the head of Capricorn, Plate 16, thence proceeding to Antinous, to the tail of Aquila, Plate 9, to Ramus Cerberus, and the body of Hercules, Plate 8, to Quadrans Muralis, Plate 7, and to the head of Draco, Plate 3. We may also examine the constellations of Auriga, Lynx, and Camelopardalus, Plate 5.

In this second review, it will be found that here the absence of nebulae is as remarkable, as the great multitude of them in the first mentioned series of constellations.

13. *Of very narrow long Nebulæ.*

In order to advance in our knowledge of the condition of the nebulous matter, we may investigate the form of its expansion by the figure of the nebulæ that have been observed. The following five are particular instances of some that were much extended in length, but very little in breadth.*

No. 254 in the 3d class is “A very faint nebula, extended from north-preceding to south-following. It is about 5' long and less than $\frac{1}{4}$ minute broad.” See fig. 7.

The expansion of the nebulous matter in general may be considered as consisting of three dimensions; these may all be either nearly equal, or one of them may be much less than the other two; or the extent of two of them may be very inferior to that of the third. The nebulæ which have now been referred to exclude a nebulosity of three nearly equal dimensions, which can never be seen under less than two of them. When two of the dimensions of the nebulous matter are nearly equal, one of them may indeed be only visible; but then the chance that the other should be exactly parallel to the line of sight, is by no means favourable. The most plausible way of accounting for the apparent figure of these nebulæ is, therefore, to admit that the expansion of the nebulosity consists indeed of a very narrow length, and not much depth. This form when ascribed to nebulous matter, is sufficiently uncommon for us to expect to see many nebulæ of the figure of extended rays.

* See I. 23, 206. III. 254. IV. 72. V. 20.

14. *Of extended Nebulæ.*

This class of nebulæ, which are chiefly extended in length, but at the same time have a considerable breadth, is very numerous. I have divided the nebulæ it contains, which are 284, into five assortments as follows.*

II. 514 is "A faint nebula extended from south-preceding to north-following; it is about 2' long and 1' broad." See fig. 8.

III. 523 is "A very faint nebula extended from south-preceding to north-following; it is 3 or 4' long and nearly 3' broad."

* See *one hundred and sixty-one extended nebulæ of various small sizes.* I. 80, 89, 194, 202, 234. II. 14, 53, 72, 82, 108, 133, 145, 164, 206, 260, 262, 278, 280, 305, 348, 414, 436, 437, 486, 507, 520, 522, 574, 585, 611, 627, 638, 642, 649, 668, 682, 696, 700, 723, 731, 742, 772, 785, 786, 802, 809, 810, 826, 830, 831, 835, 837, 844, 847, 853, 859, 885. III. 4, 23, 56, 58, 65, 66, 73, 79, 82, 100, 110, 132, 183, 218, 225, 236, 241, 242, 244, 248, 258, 265, 305, 313, 314, 316, 342, 347, 348, 355, 369, 370, 406, 410, 419, 427, 429, 441, 442, 445, 450, 479, 487, 490, 494, 496, 499, 510, 514, 515, 520, 521, 528, 554, 557, 567, 569, 570, 586, 598, 599, 601, 612, 613, 619, 646, 649, 653, 677, 681, 682, 713, 714, 727, 730, 732, 752, 767, 771, 778, 783, 792, 804, 806, 808, 811, 812, 813, 816, 832, 845, 846, 874, 885, 892, 904, 914, 920, 929, 932, 942, 948, 949, 973.

Sixty-two extended nebulæ of various large sizes. I. 14, 20, 76, 141, 189, 212, 215, 220, 253. II. 3, 17, 23, 63, 113, 126, 134, 147, 152, 156, 165, 188, 221, 235, 251, 300, 326, 335, 344, 355, 378, 407, 453, 492, 525, 548, 566, 579, 595, 607, 619, 628, 671, 687, 703, 750, 755, 762, 799. III. 253, 282, 290, 346, 414, 492, 498, 508, 610, 689, 740, 766, 776, 921.

Thirty one extended nebulæ from $\frac{3}{4}$ to 2' long. II. 150, 181, 222, 237, 365, 479, 510, 514, 535, 582, 624, 654, 655, 674, 763, 798, 807, 829, 881, 897, 899, 901. III. 203, 368, 506, 556, 620, 648, 692, 906, 907.

Twenty-four extended nebulæ from 2 to 5' long. I. 94, 174, 201. II. 227, 284, 291, 402, 432, 490, 536, 558, 600, 664, 747, 784, 900. III. 362, 523, 524, 553, 603, 710, 711, 717.

Six extended nebulæ from 5 to 15' long. I. 134, 153, 285. II. 824. V. 5, 23.

I. 134 is “ A considerably bright nebula, 7 or 8 minutes long “ and about 3' broad.”

The considerable breadth of these *nebulæ*, although chiefly extended in length, proves that two of the dimensions of the nebulous matter, namely, the breadth and depth, are probably not very different ; for if the depth, which is the dimension we do not see, should be equal to the length, the chance of its being out of sight is not sufficiently probable to happen very frequently. It is therefore to be supposed that the extension in length is really the greatest ; for as we actually see it under this form, we are assured that it is at least as long as it appears, whereas one of the other dimensions, if not both, must certainly be less than the length. This kind of expansion admits of the utmost variety of lengthened form and position ; and from the great number of *nebulæ* to which I have referred, the existence of such nebulosities is fairly to be deduced.

15. Of *Nebulæ* that are of an irregular Figure.

Among the various figures that may be seen in *nebulæ* we have a great many that are of an irregular appearance ; I have divided the following ninety-three into two assortments.*

I. 61 is “ A very bright small nebula north-following a

* See *sixty-one irregular nebulae of various small sizes*. I. 61, 284. II. 185, 242, 259, 274, 281, 306, 339, 415, 445, 586, 597, 601, 605, 647, 744, 761, 834, 886, 893, 907. III. 12, 83, 191, 259, 273, 287, 301, 310, 456, 465, 485, 486, 493, 495, 533, 535, 537, 555, 581, 582, 605, 642, 663, 675, 699, 701, 724, 735, 795, 817, 834, 847, 851, 868, 879, 893, 963, 976, 977.

Thirty-two irregular nebulae of various large sizes. I. 138, 246, 248, 282. II. 43, 81, 149, 289, 346, 349, 360, 421, 467, 468, 495, 587, 651, 681, 711, 749, 756, 804, 877. III. 137, 257, 274, 463, 683, 695, 765, 911, 938.

“ star of the 9th magnitude. It is of an irregular figure.” See fig. 9.

II. 289 is “ A faint pretty large nebula ; it is of an irregular “ triangular figure.”

By calling the figure of a nebula irregular, it must be understood that I saw no particular dimension of it sufficiently marked to deserve the name of length ; for had there been such a distinction, its extension in the longitudinal direction would have been recorded, or, as it frequently happened, for want of time, the nebula would shortly have been called extended. From this consideration it follows, that the nebulous matter which assumes an irregular figure when seen in a telescope, cannot be very different in two of its dimensions ; and this leaving the third entirely undetermined, it may be of greater, equal, or less extent than either of the other two. But to be greater or less than the dimensions that were seen it would require the particular situation of the third dimension in either case to be in the direction of the line of sight, which is so far at least improbable, that we may fairly suppose the unseen dimension not to differ much from either of the former two.

16. *Of Nebulæ that are of an irregular round Figure.*

The apparent figure of the nebulae contained in the foregoing articles has already assisted me in a great measure to assign the expanded form of the nebulous matter of which they consist. The irregular round appearance of the following fifty-five nebulae however, being of a much more marked description than the former, will lead to more decisive conclusions. I have divided them into three assortments.*

* See *twenty-eight nebulae of an irregular round figure of various small sizes.* I.

No. 177 in the third class is "A very faint nebula of an irregular round figure, about 2 or 3 minutes in diameter." See fig. 10.

The appearance of an irregular round figure necessarily requires that the extent of two dimensions of the nebulous matter should be nearly equal in every direction at right angles to each other. The unseen dimensions may certainly be longer or shorter than the visible irregular diameter; but then it must be absolutely extended centrally in the line of sight, which is a condition that has no probability in its favour; and the greater the number is, of such nebulae, the less is the probability that the form of the nebulous matter should be irregularly cylindrical, or conical. For, except an irregular cylinder or cone, placed in the particular required situation, no expansion of the nebulous matter but an irregular globular one can be the cause of the irregular round figure of the above-mentioned nebulae. Then since the irregular globular form has this advantage above the cylindrical and conical figure, that it will answer the required end in any situation whatsoever, it is certainly that which ought to be admitted as the cause of the observed appearance.

This method of reasoning upon the form of the nebulous matter from the observed figure of nebulae, will lead us a step farther than it might have been supposed. For granting it to

231. II. 97, 191, 243, 254, 273, 336, 560, 758, 895, 896. III. 208, 224, 311, 474, 566, 600, 614, 621, 673, 674, 688, 728, 784, 813, 835, 931, 955.

Twenty-one nebulae of an irregular round figure of various large sizes. I. 69, 108, 161. II. 197, 240, 494, 513, 537, 538, 552, 685, 727, 872, 890. III. 426, 447, 558, 862, 876. V. 7. *Connoiss.* 70.

Six nebulae of an irregular round figure of a mean diameter from 1 to 5'. III. 131, 177, 223, 261, 542, 617.

be highly probable, that the appearance of irregular round nebulae are owing to so many irregular globular expansions of nebulous matter, it will be necessary to direct our attention to the cause which has formed this matter into such masses. To ascribe an highly improbable event to chance is not philosophical; especially as a forming cause offers itself to our view, when we direct an eye to the globular figure of the planets and satellites of the solar system.

17. *Of round Nebulae.*

From what has been said, it appears that the figure of nebulae is a subject of more interest than mere curiosity. The following fifty-seven were observed to be round, and I give them here in four assortments.*

As the title of each sort gives all that is necessary for the present purpose relating to the various sizes of round nebulae, a description of one of the last will be sufficient. The observation of I. 269 says, that it is "A considerably bright round nebula of about one minute in diameter." See fig. 11.

The arguments which I have given in the foregoing article, where only nebulae of an irregular round figure were considered, need not be repeated when a regular circular form is presented to our view; for the additional number of nebulae,

* See *three round nebulae*. III. 381, 511, 754.

Forty-one round nebulae of various small sizes. I. 275. II. 54, 218, 223, 225, 329, 659, 760, 803. III. 11, 50, 78, 94, 95, 96, 149, 150, 180, 181, 209, 221, 222, 295, 371, 451, 477, 505, 622, 631, 671, 684, 726, 760, 800, 801, 810, 842, 888, 909, 946, 971.

Ten round nebulae of various large sizes. I. 7, 124, 252. II. 19, 481, 889. III. 54, 77, 112, 452.

Three round nebulae from 1 to 6' in diameter. I. 269. II. 593. V. 16.

and the regularity of their figure are both greatly in favour of a conclusion, that the mass of the nebulous matter which occasions their appearance must be of a globular form.

In the last article I have only directed our attention to the cause of this very particular construction, but from the observations of the nebulæ above referred to, we may now more confidently assign the attraction of gravitation as the principle which has drawn the nebulous matter towards a center, and collected it into a spherical compass.

I have already shewn that the same principle appears to be the cause of the condensation of the nebulous matter in the bright places of nebulæ that shine with unequal degrees of light in the different parts of their extent,* and a concurrence of arguments established upon very different foundations cannot fail to give additional weight to the reasonings by which they are supported.

18. *Of Nebulæ that are remarkable for some particularity in Figure or Brightness.*

Among the nebulæ, which I have described as of an irregular figure, the following might have been inserted; but the real form of the nebulous matter of which they consist is probably as irregular as the figure or brightness of the nebulæ themselves. I have arranged thirty-five of them into three assortments.†

* See Article 7.

† See two nebulæ of remarkable figure. I. 286. V. 19.

Ten unequally bright nebulæ. I. 254. II. 200, 210, 422, 557, 591, 646. III. 142, 245, 534.

Twenty-three nebulæ that are brightest on one side. I. 113, 162. II. 26, 27, 136.

V. 19 is "A considerably bright nebula about 15' long and 3' broad; its length is divided in the middle by a black division at least three or four minutes long." See fig. 12.

The nebulous matter of this nebula is probably a ring in a very oblique position with respect to the line of sight.

II. 646 is "A pretty bright, large nebula, of an irregular figure; it is unequally bright."

The inequality of its brightness in different parts may arise from unequal condensation or from greater depth of nebulous matter.

II. 313 is "A pretty bright nebula, a little extended in the parallel. The greatest brightness is towards the following side, which is also the broadest; the preceding part being more like a ray proceeding from it."

The irregular figure of these latter kind of nebulae may be admitted to arise from the as yet imperfect concentration of a nebulous mass, in which the preponderating matter of it is not in the center.

19. *Of Nebulae that are gradually a little brighter in the middle.*

The investigation of the form of the nebulous matter in the 13, 14, 15, and 16th articles has been founded only upon the observed figure of nebulae; and in the 17th article the globular form of this matter deduced from the round appearance of nebulae, has been ascribed to the action of the gravitating principle. I am now entering upon an examination of nebulae of which, besides their figure, I have also recorded the different degrees of light, and the situation of the greatest brightness

155, 313, 332, 364, 369, 370, 442, 506, 531, 555, 589, 623. III. 120, 153, 286, 676, 700. V. 22.

with respect to their figure. These observations will establish the former conclusions by an additional number of objects, and by the decisive argument of their brightness, which points out a seat of attraction.

In the following four assortments are one hundred and fifty nebulae, which all agree in being a little brighter in the middle. This increase of brightness must be understood to be always very gradual from the outside towards the middle of the nebula, whatever be its figure; and although this circumstance, for want of time, has often been left unnoticed in the observation, I am very sure that had the gradation of brightness been otherwise, it would certainly not have been overlooked.*

III. 853 is "A very faint small nebula; it is very gradually "a little brighter in the middle."

III. 488 is "A very faint extended nebula, near 3' long,

* See *Thirty two nebulae, the particular figure of which has not been ascertained, gradually a little brighter in the middle.* II. 201, 401, 424, 444, 457, 528, 532, 616, 617, 648, 673, 677, 736, 904. III. 90, 106, 148, 331, 436, 472, 489, 519, 596, 633, 654, 655, 656, 686, 853, 860, 896, 978.

Twenty-four extended nebulae, gradually a little brighter in the middle. II. 184, 192, 252, 285, 412, 478, 480, 565, 621, 688, 906. III. 141, 233, 449, 461, 468, 488, 532, 577, 736, 890. V. 8, 40, 50.

Twenty nebulae of an irregular figure, gradually a little brighter in the middle. II. 213, 357, 403, 471, 487, 491, 524, 533, 594, 717, 729. III. 272, 428, 434, 626, 690, 857, 903, 947. V. 29.

Seventy-four round or nearly round nebulae, gradually a little brighter in the middle. II. 7, 40, 102, 129, 131, 162, 190, 249, 258, 267, 276, 286, 290, 308, 320, 338, 428, 459, 474, 476, 477, 509, 516, 526, 602, 637, 699, 726, 737, 770, 780, 797, 811, 812. III. 62, 63, 94, 105, 121, 122, 123, 133, 162, 163, 252, 292, 296, 298, 330, 388, 409, 448, 466, 497, 522, 597, 608, 665, 680, 746, 750, 753, 818, 822, 823, 824, 858, 867, 889, 891, 908, 917, 918, 923.

“ and above 2' broad ; it is gradually a little brighter in the middle. Fig. 13.

II. 549 is “ A very large and pretty bright nebula of an irregular figure ; it is a little brighter in the middle.” Fig. 14.

II. 812 is “ A faint, small, round nebula ; it is very gradually a little brighter in the middle, and the increase of brightness begins at a distance from the center.” Fig. 15.

It is hardly necessary to say that the united testimony of so many objects can leave no doubt about the central seat of attraction, which in every instance of figure is pointed out to be in the middle.

The only remark I have to make, relates to the exertion of the condensing power, which in the case of these nebulae appears to have produced but a very moderate effect. This may be ascribed either to the unshapen mass of nebulous matter which would require much time before it could come to some central arrangement of form either in length, or in length and breadth, or lastly in all its three dimensions. It may also be ascribed to the small quantity of the preponderating central attractive matter ; or even to the shortness of its time of acting : for in this case millions of years, perhaps are but moments.

20. *Of Nebulae which are gradually brighter in the middle.*

By the general description of a nebula, when it is said to be gradually brighter in the middle, we are to understand that its light was observed to be obviously brighter about the center than in other parts. Had the nebulae of this class been only a little brighter, or had they been much brighter in the middle,

such additional expressions would certainly have been used; except where time would not allow to be more particular. I have sorted two hundred and twenty-three of these nebulae like the foregoing, according to their figure, into four classes.*

II. 409 is "A pretty bright and pretty large nebula; it is
"very gradually brighter in the middle."

I. 55 is "A considerably bright, extended nebula about 4'
"long and 2' broad, in a meridional direction; it is gradually
"brighter in the middle." Fig. 16.

I. 266 is "A considerably bright, and pretty large nebula,
"of an irregular figure; it is gradually brighter in the mid-
"dle." Fig. 17.

I. 98 is "A considerably bright, and pretty large round
"nebula; it is brighter in the middle, the brightness diminish-

* See *Thirty-nine nebulae of an unascertained figure, gradually brighter in the middle.* I. 19, 49, 264. II. 24, 49, 87, 88, 89, 90, 319, 337, 347, 368, 373, 409, 440, 515, 534, 590, 610, 634, 636, 672, 783, 830, 840, 856, 857, 858, 860, 861, 863. III. 275, 584, 587, 602, 872, 892, 935.

Fifty extended nebulae gradually brighter in the middle. I. 1, 55, 62, 131, 199, 241, 259, 263, 279. II. 1, 10, 52, 77, 95, 132, 135, 157, 203, 205, 211, 253, 266, 302, 325, 405, 417, 508, 539, 545, 583, 592, 613, 625, 643, 656, 667, 697, 709, 730, 773, 880, 882. III. 246, 267, 589, 594, 864, 902. V. 4, 39.

Twenty-nine nebulae of an irregular figure, gradually brighter in the middle. I. 95, 196, 227, 266. II. 36, 56, 96, 130, 226, 265, 295, 314, 353, 423, 433, 434, 475, 488, 553, 596, 657, 663, 690, 793, 819, 825, 887. III. 397, 500.

One hundred and five round, or nearly round nebulae, gradually brighter in the middle. I. 5, 12, 54, 70, 98, 106, 120, 148, 168, 186, 211, 222, 229, 243, 245, 274. II. 50, 51, 128, 151, 158, 160, 161, 196, 208, 224, 247, 255, 256, 263, 275, 293, 307, 312, 330, 331, 333, 359, 376, 399, 408, 411, 435, 458, 461, 465, 511, 517, 523, 562, 567, 580, 588, 594, 614, 615, 622, 632, 633, 635, 662, 712, 719, 741, 769, 777, 792, 817, 818, 845, 851, 852, 865, 866, 873, 879, 883, 884, 888, 902. III. 2, 88, 107, 138, 139, 220, 491, 527, 541, 609, 694, 739, 749, 825, 829, 865, 870, 871, 882, 899, 900, 933, 937, 940, 972.

“ing very gradually from the center towards the circumference.” Fig. 18.

From the account of these nebulæ, we find again that all what has been said concerning the seat of the forming and condensing power of the nebulous matter, is abundantly confirmed by observation.

I have only to remark that, the exertion of the gravitating principle in these nebulæ, is in a more advanced state than with those of the last article; and that the same conceptions which have already been suggested, namely, the original form of the nebulous matter; its quantity in the seat of the attracting principle; and the length of the time of its action, when properly considered, will sufficiently account for the present state of these nebulæ.

21. *Of Nebulæ that are gradually much brighter in the middle.*

The nebulous matter which appears under the various forms of the following four assortments, containing two hundred and two nebulæ, assumes now a more condensed aspect, than that under which it was seen in either of the two foregoing collections; and thus by its gradually greater compression, gives us a still more decisive indication of the central seat of attraction.*

* See *Twenty-five nebulæ of unascertained figure, gradually much brighter in the middle.* I. 73, 121, 127, 140, 155, 181, 287. II. 35, 177, 187, 299, 439, 452, 540, 653, 658, 669, 686, 694, 795, 828, 855, 871. III. 863. *Connoiss.* 99.

Fifty-four extended nebulæ, gradually much brighter in the middle. I. 29, 31, 33, 35, 38, 53, 58, 64, 72, 82, 86, 93, 97, 101, 104, 125, 154, 157, 164, 184, 209, 233, 239, 274, 271, 277. II. 12, 13, 31, 37, 182, 212, 231, 282, 318, 416, 431, 463, 504, 604, 612, 626, 691, 701, 702, 704, 725, 753, 775, 875. III. 179, 198. V. 47. *Connoiss.* 49.

II. 828 is "A pretty bright small nebula, very gradually
"much brighter in the middle."

I. 101 is "A considerably bright pretty large nebula, ex-
"tended in the meridional direction, about 4' or 5' long; much
"brighter in the middle." In the 40 feet telescope I saw the
very gradual increase of brightness towards the middle of its
length; a longer extent of the nebula was also visible.
Fig. 19.

I. 219 is "A very bright considerably large nebula of an
"irregular figure, very gradually much brighter in the mid-
"dle." Fig. 20.

I. 63 is "A bright round nebula of about one minute in
"diameter; it is much brighter in the middle, and very faint
"towards the border." Fig. 21.

The greater difference between the comparative brightness
of the center, and the outward parts of these nebulae, may
certainly be ascribed to the same causes that have been consi-
dered in the two foregoing articles; but in the present case,
and taking into the account that this is already a third step of
condensation from a little brighter to brighter; then, to much

Nineteen nebulae of an irregular figure, gradually much brighter in the middle.
I. 10, 26, 59, 66, 109, 110, 114, 115, 219, 235, 237, 276. II. 2, 20, 438, 503, 734,
827. III. 299.

*One hundred and four round or nearly round nebulae, gradually much brighter in
the middle.* I. 8, 16, 21, 30, 42, 63, 65, 67, 68, 74, 79, 83, 87, 88, 100, 102, 105,
111, 112, 118, 129, 135, 136, 142, 144, 147, 150, 158, 159, 166, 171, 175, 182,
185, 216, 218, 221, 232, 238, 244, 257, 260, 265, 273, 278. II. 5, 11, 38, 69, 98,
148, 230, 236, 245, 250, 257, 269, 270, 277, 288, 292, 301, 303, 309, 311, 328,
418, 420, 446, 462, 466, 556, 561, 564, 575, 598, 632, 644, 645, 660, 666, 695,
707, 728, 738, 757, 767, 774, 782, 816, 823, 839, 854, 874. III. 250, 284, 512,
531, 624, 744, 859, 878. *Connoiss.* 59, 96.

brighter, there appears to be some foundation for supposing rather that this greater effect is produced by a longer time of the action of the attractive principle, than that it should arise merely from an original more favourable expansion of the nebulous matter.

22. *Of Nebulæ that have a Cometic appearance.*

Among the numerous nebulæ I have seen, there are many that have the appearance of telescopic comets. The following are of that sort.*

I. 4 is “ A pretty large cometic nebula of considerable brightness ; it is much brighter in the middle, and the very faint chevelure is pretty extensive.” Fig. 22.

By the appellation of cometic, it was my intention to express a gradual and strong increase of brightness towards the center of a nebulous object of a round figure ; having also a faint chevelure or coma of some extent, beyond the faintest part of the light, gradually decreasing from the center.

It seems that this species of nebulæ contains a somewhat greater degree of condensation than that of the round nebulæ of the last article, and might perhaps not very improperly have been included in their number. Their great resemblance to telescopic comets, however, is very apt to suggest the idea, that possibly such small telescopic comets as often visit our neighbourhood may be composed of nebulous matter, or may in fact be such highly condensed nebulæ.

* See *Seventeen cometic nebulæ*. I. 3, 4, 34, 217. II. 6, 15, 33, 59, 104, 153, 154, 241, 315, 404. III. 5, 21. *Connoiss.* 95.

23. *Of Nebulæ that are suddenly much brighter in the middle.*

From the third degree of visible condensation, I have in the 21st article intimated, that the length of the time of the action of the attracting principle, would explain the observed gradual accumulation of the nebulous matter. In the following eighteen nebulæ we may see a still more advanced compression of it, amounting almost to the appearance of a nucleus.*

II. 814 is "A small faint nebula, very suddenly much " brighter in the middle."

I. 39 is "A very bright nebula, extended from south-preceding to north-following, about 4' or 5' long, and 3' broad; it is much brighter in the middle, but the brightness breaks off abruptly, so as almost to resemble a nucleus." Fig. 23.

I. 256 is "A very bright pretty large nebula of an irregular " figure; it is suddenly much brighter in the middle." Fig. 24.

I. 99 is "A very bright, small, round nebula; it is very " suddenly much brighter in the middle." Fig. 25.

From the appearance of these nebulae, we see plainly that a progressive concentration of the nebulous matter has an existence; it is also remarkable that the condensation in long nebulae inclines towards the shape of a nucleus, as well as in

* See *One nebula of unascertained figure, suddenly much brighter in the middle.* II. 814.

Seven extended nebulae, suddenly much brighter in the middle. I. 39, 91, 96, 200, II. 183, 505. *Connoiss.* 66.

Two nebulae of an irregular figure, suddenly much brighter in the middle. I. 256. II. 521.

Eight round or nearly round nebulae, suddenly much brighter in the middle. I. 99, 138. II. 410, 413, 698. III. 251, 685. *Connoiss.* 54.

round ones, which can be ascribed only to the continued action of the attracting principle, tending to draw the nebulous extended expansion into a globular form.

A nucleus, to which these nebulae seem to approach, is an indication of consolidation; and should we have reason to conclude that a solid body can be formed of condensed nebulous matter, the nature of which has hitherto been chiefly deduced from its shining quality, we may possibly be able to view it with respect to some other of its properties.

24. *Of round Nebulae increasing gradually in brightness up to a Nucleus in the middle.*

It has already been proved, from the figure and central brightness of round nebulae, that the nebulous matter of which they consist must be admitted to be of a globular form; but the following thirteen nebulae lead me to a remark which not only applies to them, but to all the round nebulae of the last five articles, which added to these amount to three hundred and twenty one. They are not only round, but the gradual condensation from the circumference to the very center being of equal density of light at equal central distances, every ring or circle drawn round the center, bears witness to the existence of a central attraction. For whatever may be the intensity or ratio of the concentration at any given central distance, it follows, from the equality of brightness at the assigned distance, that no figure but a globular one can with any kind of probability explain the appearance; and that the concentration, as well as the figure, is produced by a general gravitation of the nebulous matter.*

* See I. 2, 6, 132, 151, 173, 236, 272. II. 25, 189, 716, 864. III. 518. IV. 6.

I. 151 is "A considerably bright and considerably large, "round cometic nebula; it is very gradually much brighter "in the middle, with a nucleus in the center." Fig. 26.

From the description of these *nebulæ*, we find that an actual nucleus has been formed in the attracting center; and that consequently a certain degree of consolidation of the nebulous matter is highly probable; for, although the quality of shining only points out the existence of something that is luminous, yet from analogy we have reason to conclude that certain material substances must be present to produce the light we perceive; and that they must be opaque, may be inferred from every thing we know about shining substances.

25. *Of Nebulæ that have a Nucleus.*

It may be expected that some considerable change will take place in the appearance of a nebula after it has come to a certain degree of continued gradual condensation. We are as yet so little acquainted with the nature and distribution of this matter, that an application of mathematical calculations, founded on the attraction of gravitation, for want of data, cannot be applied in order to suggest to us what appearance might next be expected; I shall therefore proceed in a regular manner to give the observations, which shew what these appearances are, without entering into any theoretical discussions.

In the following two assortments we have forty *nebulæ*.*

* See *Twenty-seven extended nebulae, with a nucleus.* I. 43, 77, 126, 156, 170, 180, 208, 224, 240, 250, 255, 270, 280, 281. II. 238, 460, 759, 768, 796, 846, 849, 891. V. 18, 24, 48. *Connoiss.* 63, 101.

Thirteen round or nearly round nebulae, with a nucleus. I. 107, 133, 139, 152, 167, 203, 225. II. 99, 501, 746, 754. III. 178. *Connoiss.* 90.

Number 63 of the *Connoissance des Temps* is "A very bright nebula, extending from north-preceding to south-following 9 or 10' long, and near 4' broad; it has a very brilliant nucleus." Fig. 27.

I. 107 is "A very bright round nebula, about $1\frac{1}{2}$ minutes in diameter; it has a bright nucleus in the middle." Fig. 28.

The nuclei of these nebulæ, after what has been proved, of the existence of a condensing power, I need not hesitate to ascribe to the longer continuance of its action, which appears to bring on a consolidation; and that this may be the consequence we may conclude, not only from the power of condensing, which argues a sufficient quantity of matter, but also from the quality of shining; for this proves that the substance which throws out the nebulous light is endowed with some other of the general qualities of matter besides that of gravitation.

A second remark I have to make is, that the opaque nature of the nebulous matter which was before inferred from analogy, is here supported by observation; for these consolidated nuclei have a considerable resemblance to the disks of planets; and if this matter consisted only of a luminous substance, the increase of light would probably far exceed their observed lustre: this being the case, the power of arresting light in its passage is an additional quality, very different from those which have already been mentioned, and seems to be analogous to properties which we know to belong to hard and solid bodies.

26. *Of extended Nebulæ that shew the Progress of Condensation.*

When the nebulous matter is much extended in length, it appears from the following nebulæ, that with those which

have a nucleus completely formed, the nebulosity on each side of it is comparatively reduced to a fainter state than it is in nebulæ of which the nucleus is apparently still in an incipient state. These faint opposite appendages to the nucleus I have in my observations called branches.

In some nebulæ there is also an additional small faint nebulosity of a circular form about the nucleus, and this I have called the chevelure. The following two assortments contain twenty-eight nebulæ of this kind.*

Number 65 of the *Connoissance* is “ A very brilliant nebula “ extended in the meridian, about 12' long. It has a bright “ nucleus, the light of which suddenly diminishes on its “ border, and two opposite very faint branches.” Fig. 29.

I. 205 is “ A very brilliant nebula, 5' or 6' long and 3 or 4' “ broad; it has a small bright nucleus with a faint chevelure “ about it, and two opposite very extensive branches. Fig 30.

The construction of these nebulæ is certainly complicated and mysterious, and in our present state of knowledge it would be presumptuous to attempt an explanation of it; we can only form a few distant surmises, which however may lead to the following queries. May not the faintness of the branches arise from a gradual diminution, of the length and density of the nebulous matter contained in them, occasioned by its gravitation towards the nucleus into which it probably subsides? Are not these faint nebulous branches joining to a nucleus, upon an immense scale, somewhat like what the zodiacal light is to our sun in miniature? Does not the chevelure

* See *Twenty-three extended nebula with a nucleus and two opposite faint branches*. I. 9; 13, 15, 27, 32, 75, 130, 160, 163, 187, 188, 195, 223, 228, 230. II. 101, 650, 733. IV. 61. V. 43. *Connoiss.* 65, 83, 98.

Five with a nucleus, chevelure and branches. I. 194, 205, 210. V. 45. *Connoiss.* 94.

denote that perhaps some of the nebulous matter still remaining in the branches, before it subsides into the nucleus, begins to take a spherical form, and thus assumes the semblance of a faint chevelure surrounding it in a concentric arrangement? And, if we may venture to extend these queries a little farther—will not the matter of these branches in their gradual fall towards the nucleus, when discharging their substance into the chevelure, produce a kind of vortex or rotatory motion? Must not such an effect take place, unless we suppose, contrary to observation, that one branch is exactly like the other; that both are exactly in a line passing through the center of the nucleus, by way of causing exactly an equal stream of it from each branch to enter the chevelure at opposite sides; and, this not being probable, do we not see some natural cause which may give a rotatory motion to a celestial body in its very formation?

27. Of round Nebulæ that shew the Progression of Condensation.

When round nebulæ have a nucleus, it is an indication that they have already undergone a high degree of condensation. From their figure we are assured that the form of the nebulosity of which they are composed is now spherical, whatever may have been its original shape; and being surrounded by a chevelure, we may look upon its different evanescent degrees of faintness as a sign whereby to judge of the gradual progress of the consolidation of the nucleus. The following seventeen nebulæ are given in two assortments.*

* See fifteen round or nearly round nebulæ, with a nucleus and faint chevelure. I. 40, 137, 226, 242, 251, 262. II. 321. III. 291, 373. IV. 23, 54, 56, 59, 76. *Connoiss* 32.

Two nebulæ with a nucleus and chevelure resembling nebulous stars. II. 32. III. 99.

IV. 23 is “ A considerably bright nebula with a very bright nucleus, and a chevelure about 3 or 4' in diameter.” Fig. 31.

III. 99 is “ A small nebula with a pretty bright nucleus and “ very faint chevelure ; it is almost like a nebulous star.” Fig. 32.

The chevelure of these nebulæ consists probably of the rarest nebulous matter, which not having as yet been consolidated with the rest, remains expanded about the nucleus in the shape of a very extended atmosphere; or it may be of an elastic nature, and be kept from uniting with the nucleus, as their elasticity causes the atmospheres of the planets to be expanded about them. In this case we have another property of the nebulous substance to add to the former qualities of its matter.

With those nebulæ where this chevelure is uncommonly faint, and the nucleus very bright, the consolidation appears to have reached a still higher degree, and their resemblance to nebulous stars may lead to very interesting consequences.

28. *Of round Nebulæ that are of an almost uniform Light.*

The argument that the nebulous matter is in some degree opaque which is given in the 25th article, will receive considerable support from the appearance of the following nebulæ ; for they are not only round, that is to say the nebulous matter of which they are composed is collected into a globular compass, but they are also of a light which is nearly of an uniform intensity except just on the borders. I give these nebulæ in two assortments.*

* See Four from 2' to 4' in diameter. IV. 50, 62, 67. Connoiss. 97.

Twelve nebulæ from $\frac{3}{4}$ of a minute to 2' in diameter. I. 267. II. 186, 209, 705, 836, 870. III. 152, 877. IV. 13, 14, 16, 39.

Number 97 of the *Connoissance* is "A very bright, round nebula of about 3' in diameter; it is nearly of equal light throughout, with an ill defined margin of no great extent."

IV. 13 is "A pretty faint nebula of about 1' diameter; it is perfectly round, and of an equal light throughout; and the edges of it are pretty well defined." Fig. 33.

Admitting that these sixteen nebulae are globular collections of nebulous matter, they could not appear equally bright, if the nebulosity of which they are composed consisted only of a luminous substance perfectly penetrable to light; at least this could not happen unless a certain artificial condensation of it were introduced, which can have no pretension to probability in its favour. Is it not rather to be supposed, that a certain high degree of condensation has already brought on a sufficient consolidation to prevent the penetration of light, which by this means is reduced to a superficial planetary appearance?

29. *Of Nebulae that draw progressively towards a Period of final Condensation.*

In the course of the gradual condensation of the nebulous matter, it may be expected that a time must come when it can no longer be compressed, and the only cause which we may suppose to put an end to the compression is, when the consolidated matter assumes hardness. It remains therefore to be examined, how far my observations will go to ascertain the intensity of its consolidation.

The following two assortments contain seven nebulae, from

whose appearance a considerable degree of solidity may be inferred.*

IV. 55 is "A pretty bright round nebula, almost of an even light throughout approaching to a planetary appearance, but ill defined, and a little fainter on the edges; it is about $\frac{3}{4}$ or 1 minute in diameter." Fig. 34.

IV. 37 is "A very bright planetary disk of about 35" in diameter, but ill defined on the edges; the center of it is rather more luminous than the rest, and with long attention a very bright well defined round center becomes visible." Fig. 35.

In these nebulae we have three different indications of the compression of the nebulous matter of which they are composed: their figure, their light, and the small compass into which it is reduced. The round figure is a proof that the nebulous mass is collected into a globular form, which cannot have been effected without a certain degree of condensation.

Their planetary appearance shews that we only see a superficial lustre such as opaque bodies exhibit, and which could not happen if the nebulous matter had no other quality than that of shining, or had so little solidity as to be perfectly transparent. That there is a certain maximum of brightness occasioned by condensation, is to be inferred from the different degrees of light of round nebulae that are in a much less advanced state of compression; for these are gradually more bright towards the center; which proves that brightness keeps up with condensation till the increase of it brings on a con-

* See *Four nebulae of a planetary appearance.* IV. 55, 60, 68, 78.

Three planetary disks with a bright central point. II. 268. IV. 37, 73.

solidation which will no longer permit the internal penetration of light, and thus a planetary appearance must in the end be the consequence ; for planets are solid opaque bodies, shining only by superficial light, whether it be innate or reflected.

From the size of the nebulæ as we see them at present, we cannot form an idea of the original bulk of the nebulous matter they contain ; but let us admit, for the sake of computation, that the nebulosity of the above described nebula IV. 55, when it was in a state of diffusion, took up a space of 10' in every cubical direction of its expansion ; then, as we now see it collected into a globular compass of less than one minute, it must of course be more than nineteen hundred times denser than it was in its original state. This proportion of density is more than double that of water to air.

With regard to planetary disks, which have bright central points, we may surmise that their original diffused nebulosity was more unequally scattered, and that they passed through the different stages of extended nebulæ, gradually acquiring a nucleus, chevelure, and branches. For in nebulæ of this construction, the consolidation of a nucleus is already much advanced at the time when a considerable quantity of nebulous matter, on account of its greater central distance, remains still unformed in the branches ; and if the condensation of the nucleus should keep the lead, it will come to a state of great solidity and maximum of brightness by the time that the rest of the nebulosity is drawn into a planetary appearance.

30. Of Planetary Nebulæ.

The objects of which I shall give an account in this article have so near a resemblance to planets, that the name of planetary nebulæ very justly expresses their appearance; for notwithstanding their planetary aspect, some small remaining haziness, by which they still are more or less surrounded, evinces their nebulous origin. In my catalogues the places of the following ten have been given.*

IV. 18 is "A beautiful bright round nebula, having a pretty well defined planetary disk of about 10 or 12" in diameter. It is a little elliptical, and has a very small star following, which gives us the idea of a small satellite accompanying its planet. It is visible in a common finder as a small star."

Fig. 36.

IV. 27 is "A beautiful very brilliant globe of light, hazy on the edges, but the haziness going off suddenly. I suppose it to be from 30 to 40" in diameter, and perhaps a very little elliptical. The light of it seems to be all over of the uniform lustre of a star of the 9th magnitude. The haziness on the edges does not exceed the 20th part of the diameter."

IV. 51 is "A small beautiful planetary nebula, but considerably hazy upon the edges; it is of a uniform light, and considerably bright, perfectly round, and about 10 or 15" in diameter."

IV. 53 is "A pretty bright planetary nebula of nearly 1' in diameter; it is round, or a little elliptical; its light is uniform, and pretty well defined on the borders."

* See Planetary nebulæ IV. 1, 11, 18, 26, 27, 34, 51, 53, 64, 70.

IV. 64 is "A beautiful planetary nebula of a considerable degree of brightness, but not very well defined, about 12 or 15" in diameter."

The remarks which have been made on the nebulae of the foregoing article, will here apply with additional propriety; for the light of these planetary nebulae must be considerably more condensed than that of the foregoing sets. The diameter of four of them does not exceed 15," so that if we again suppose the original diffused nebulosity from which they sprang of 10' in cubical dimensions, we shall have a condensation, which has reduced the nebulous matter to less than the one-hundred and twenty-two thousandth part of its former bulk.

One of them, number 34 in the 4th class, appeared even in the 20 feet telescope, with the sweeping power, like a star with a large diameter, and it was only when magnified 240 times that it resembled a small planetary nebula; nor can any of these nebulae be distinguished from the neighbouring small stars in a good common telescope, night glass, or finder.

When we reflect upon these circumstances, we may conceive that, perhaps in progress of time these nebulae which are already in such a state of compression, may be still farther condensed so as actually to become stars.

It may be thought that solid bodies, such as we suppose the stars to be from the analogy of their light with that of our sun when seen at the distance of the stars, can hardly be formed from a condensation of nebulous matter; but if the immensity of it required to fill a cubical space, which will measure ten minutes when seen at the distance of a star of the 8th or 9th magnitude, is well considered, and properly compared with the very small angle our sun would subtend at the same

distance, no degree of rarity of the nebulous matter, to which we may have recourse, can be any objection to the solidity required for the construction of a body of equal magnitude with our sun.*

A circumstance which allies these very compressed nebulae to the character of many of our well known celestial bodies, such as some of the planets and their satellites, the sun and all periodical stars, is that very probably most, if not all of them, turn on their axes. Seven of the ten I have mentioned are not perfectly round, but a very little elliptical. Ought we not to ascribe this figure to the same cause which has flattened the polar diameter of the planets, namely, a rotatory motion?

At the end of the 26th article I have already pointed out one configuration of the nebulous matter, of which the final condensation seems to be properly disposed for bringing on a rotatory motion of the nucleus ; but, if we consider this matter in a general light, it appears that every figure which is not already globular must have eccentric nebulous matter, which in its endeavour to come to the center, will either dislodge some of the nebulosity which is already deposited, or slide upon it sideways, and in both cases produce a circular motion ; so that in fact we can hardly suppose a possibility of the production of a globular form without a consequent revolution of the nebulous matter, which in the end may settle in a regular rotation about some fixed axis. Many of the extended, and irregular nebulae are considerably elliptical, and the irregular

* A cubical space, the side of which at the distance of a star of the 8th magnitude is seen under an angle of 10', exceeds the bulk of the sun {220360000000000000} two trillion and 208 thousand billion times.

round ones shew a general approach to the oval form; now these figures are all favourable to a surmise, that a rotatory motion may often take place even before the nucleus of a nebula can have arrived to a state of consolidation. An objection, that this remarkable form of planetary nebulae may be owing to chance, will hardly deserve to be mentioned, because the improbability of such a supposition must exclude it from all claim to refutation.

31. *Of the Distance of the Nebula in the Constellation of Orion.*

In my 3d article I concluded, from the appearance of the great nebula in Orion, that the range of the visibility of the diffused nebulous matter cannot be great, because we may there see in one and the same object, both the brightest and faintest appearance of nebulosities that can be seen any where. It will therefore be a case of some interest, if we can form any conception of the place among the fixed stars to which we ought to refer the situation of this nebula; and this I believe my observation of it will enable us to determine pretty nearly.

In the year 1774, the 4th of March, I observed the nebulous star, which is the 43d of the *Connoissance des Temps*, and is not many minutes north of the great nebula; but at the same time I also took notice of two similar, but much smaller nebulous stars; one on each side of the large one, and at nearly equal distances from it. Fig. 37 is a copy of a drawing which was made at the time of observation.

In 1783, I examined the nebulous star, and found it to be faintly surrounded with a circular glory of whitish nebulosity, faintly joining to the great nebula.

About the latter end of the same year I remarked that it was not equally surrounded, but most nebulous towards the south.

In 1784 I began to entertain an opinion that the star was not connected with the nebulosity of the great nebula of Orion, but was one of those which are scattered over that part of the heavens.

In 1801, 1806, and 1810 this opinion was fully confirmed, by the gradual change which happened in the great nebula, to which the nebulosity surrounding this star belongs. For the intensity of the light about the nebulous star had by this time been considerably reduced, by the attenuation or dissipation of the nebulous matter; and it seemed now to be pretty evident that the star is far behind the nebulous matter, and that consequently its light in passing through it is scattered and deflected, so as to produce the appearance of a nebulous star. A similar phenomenon may be seen whenever a planet or a star of the 1st or 2nd magnitude happens to be involved in haziness; for a diffused circular light will then be seen, to which, but in a much inferior degree, that which surrounds this nebulous star bears a great resemblance.

When I reviewed this interesting object in December 1810, I directed my attention particularly to the two small nebulous stars, by the sides of the large one, and found that they were perfectly free from every nebulous appearance; which confirmed not only my former surmise of the great attenuation of the nebulosity, but also proved that their former nebulous appearance had been entirely the effect of the passage of their feeble light through the nebulous matter spread out before them.

The 19th of January 1811, I had another critical examination of the same object in a very clear view through the 40-foot telescope; but notwithstanding the superior light of this instrument, I could not perceive any remains of nebulosity about the two small stars, which were perfectly clear, and in the same situation, where about thirty-seven years before I had seen them involved in nebulosity.

If then the light of these three stars is thus proved to have undergone a visible modification in its passage through the nebulous matter, it follows that its situation among the stars is less distant from us than the largest of the three, which I suppose to be of the 8th or 9th magnitude. The farthest distance therefore, at which we can place the faintest part of the great nebula in Orion, to which the nebulosity surrounding the star belongs, cannot well exceed the region of the stars of the 7th or 8th magnitude, but may be much nearer; perhaps it may not amount to the distance of the stars of the 3d or 2nd order; and consequently the most luminous appearance of this nebula must be supposed to be still nearer to us. From the very considerable changes I have observed in the arrangement of its nebulosity, as well as from its great extent, this inference seems to have the support of observation; for in very distant objects we cannot so easily perceive changes as in near ones, on account of the smaller angles which both the objects and its changes subtend at the eye. The following memorandum was made when I viewed it in 1774; “ its
“ shape is not like that which Dr. SMITH has delineated in his
“ optics, though somewhat resembling it, being nearly as in
“ fig. 37: from this we may infer that there are undoubtedly
“ changes among the regions of the fixed stars; and perhaps

“ from a careful observation of this lucid spot, something may
“ be concluded concerning the nature of it.”

In January 1783, the nebulous appearance differed much from what it was in 1780, and in September it had again undergone a change in its shape since January.

March 13, 1811. With a view to ascertain such obvious alterations in the disposition of the nebulous matter as may be depended on, I selected a telescope that had the same light and power which thirty-seven years ago I used, when I made the above-mentioned drawing; and the relative situation of the stars remaining as before, I found that the arrangement of the nebulosity differs considerably. The northern branch *N* still remains nearly parallel to the direction of the stars *a b*; but the southern branch *S* is no longer extended towards the star *d*; its direction is now towards *e*, which is very faintly involved in it. The figure of the branch is also different; the nebulosity in the parallel *P F* of the three stars being more advanced towards the following side than it was formerly.

I compared also the present appearance of this nebula with the delineation which HUYGHENS has given of it in his *Systema Saturnium*, page 8, of which fig. 38 is a copy. The twelve stars which he has marked are sufficient to point out the arrangement of the nebulous matter at the time of his observation. By their situation we find that the nebula had no southern branch, nor indeed any to the north, unless we call the nebulosity in the direction of the parallel a branch; but then this branch is not parallel to a line drawn from *a* to the star *b*; moreover the star *f* is now involved in faint nebulosity, which also reaches nearly up to *g*, and quite incloses *h*. The star *b*

which is now nebulous, is represented as perfectly out of all nebulosity, and can hardly be supposed to have been affected when HUYGHENS observed it.

The changes that are thus proved to have already happened, prepare us for those that may be expected hereafter to take place, by the gradual condensation of the nebulous matter ; for had we no where an instance of any alteration in the appearance of nebulae, they might be looked upon as permanent celestial bodies, and the successive changes, to which by the action of an attracting principle they have been conceived to be subject, might be rejected as being unsupported by observation.

The various appearances of this nebula are so instructive, that I shall apply them to the subject of the partial opacity of the nebulous matter, which has already been inferred from its planetary appearance, when extremely condensed in globular masses ; but which now may be supported by more direct arguments. For when I formerly saw three fictitious nebulous stars, it will not be contended that there were three small shining nebulosities, just in the three lines in which I saw them, of which two are now gone and only one remaining. As well might we ascribe the light surrounding a star, which is seen through a mist, to a quality of shining belonging to that particular part of the mist, which by chance happened to be situated where the star is seen. If then the former nebulosity of the two stars which have ceased to be nebulous can only be ascribed to an effect of the transit or penetration of their light through nebulous matter which deflected and scattered it, we have now a direct proof that this matter can exist in a state of

opacity, and may possibly be diffused in many parts of the heavens without our being able to perceive it.

That there has been shining as well as opaque nebulous matter about the large star, appears from several observations I have made upon the light which surrounded it. In 1783 the nebulosity about it was so considerable in brightness, and so much on one side of it, that the star did not appear to have any connection with it. The reason of which is plainly, that the shining quality of the nebulous matter then overpowered the feeble scattering of the light of the star in the nebulosity.

32. *Of Stellar Nebulæ.*

It has been remarked that diffused nebulosities may exist unknown to us, among the more distant regions of the fixed stars; and though we may not be able to see a nebulous diffusion that is farther from us than the moderate distance at which we now have reason to suppose the faintest visible nebulosity of the nebula in Orion to be placed; yet if some former diffusion of the nebulous matter should be already reduced into separate and much condensed nebulæ, they might then come within the reach of telescopes that have a great power of collecting light: this being admitted, there is a probability that some of the various diffusions of the nebulous matter, from which our present nebulæ derive their origin, may have been much farther from us than others. For, in every description of figure, size and condensation, of which I have given instances, we find not only very bright and very large, but also faint and small, as well as extremely faint and extremely small nebulæ; and the same gradations will now be found to run through that class which I have called stellar

nebulæ. This classification was introduced in my sweeps when the objects to be recorded came in so quick a succession that I found it expedient to express as much as I could in as few words as possible, and by calling a nebula stellar, I intended to denote that the object to which I gave this name was, in the first place as small, or almost as small, as a star; and in the next, that notwithstanding its smallness, and starlike appearance, it bore evident marks of not being one of those objects which we call stars, and of which I saw many at the same time in the telescope.

The following three collections contain one hundred and seventeen stellar nebulæ, which have been assorted by their brightness, that their comparative condensation might be estimated according to the different distances at which we may suppose other nebulæ of the same degree of light to be placed.*

I. 71 is "A considerably bright, very small, almost stellar nebula; the brightness diminishing insensibly and breaking off pretty abruptly. The whole together is not more than about 7 or 8" in diameter." A second observation, made in a remarkable clear morning, says, that "the greatest brightness is towards the following side, and that the very faint nebulosity extends to near a minute."

This is probably a condensation of a former nucleus with surrounding chevelure.

I. 268 is "A very bright, very small, round stellar nebula." Fig. 39.

This may be a former planetary nebula in a higher state of condensation.

* See *First assortment containing six of the brightest stellar nebulæ*. I. 71, 268. II. 110, 603. IV. 32, 46.

II. 110 is "A very bright small stellar nebula or star
"with a bur all-around." Fig. 40.

This star with a bur is probably one that was formerly a planetary nebula with a pretty strong haziness on the borders.

II. 603 is "A pretty bright stellar nebula, or a pretty considerable star with a very faint chevelure." Fig. 41.

This may have been a planetary nebula with a faint haziness about the margin.

IV. 46 is "A very small pretty bright, or considerably
"bright stellar nebula, like a star with burs."

It may have been a pretty well defined planetary nebula.

If it should be deemed singular that we have not a greater number of bright stellar nebulae, I must remark that, if the stellar is a succession of the planetary state, the number of bright stellar is sufficiently proportionable to that of the planetary nebulae; and as the faint nebulae are far more numerous than the bright ones, so it will be seen by the references in the two next assortments, that in proportion as brightness decreases, we have a much more copious collection of stellar nebulae.*

II. 663 is "A pretty bright very small stellar nebula."

This nebula and the rest of them, which are all of the same description, must be looked upon as condensations of distant nebulae that had nuclei, or were nearly about the planetary condition.†

* See *Second assortment containing eleven stellar nebulae of the next degree of brightness.* II. 119, 178, 179, 204, 232, 663, 676, 689, 703, 820, 867.

† See *Third assortment containing one hundred stellar nebulae of several degrees of faintness.* II. 127, 194, 244, 340, 341, 425, 443, 448, 449, 454, 550, 551, 576, 618, 620, 692, 693, 718, 721, 722, 735, 746, 781, 815, 848. III. 81, 109, 114, 119,

In this collection of nebulae we have many of a different description. In some, the mark whereby they were distinguished from stars was their figure, the object not being so small but that its figure might still be perceived. Of others, some difference in the brightness between the center and outside was visible; and many of them were only called stellar, because by some deficiency or other in the appearance it was evident they were not perfect stars. Instances of every sort will be seen in the following descriptions.

II. 424 is "A very faint stellar nebula, or a little larger."

II. 805 is "An extremely faint very small round stellar nebula."

II. 425 is "A faint very small stellar nebula, of an irregular figure."

III. 145 is "A very faint stellar nebula; a little extended."

III. 691 is "A considerably faint stellar nebula, suddenly much brighter in the middle."

33. *Of Stellar Nebulae nearly approaching to the Appearance of Stars.*

The starlike appearance of the following six nebulae is so considerable that the best description, which at the time of observation I could give of them, was to compare them to stars with certain deficiencies.*

125, 136, 145, 151, 161, 167, 168, 169, 170, 171, 172, 173, 175, 188, 215, 231, 232, 234, 240, 260, 276, 277, 278, 289, 294, 320, 322, 341, 400, 401, 418, 422, 423, 424, 438, 439, 469, 476, 530, 536, 561, 562, 563, 564, 565, 571, 576, 590, 606, 627, 672, 691, 706, 737, 741, 764, 768, 770, 772, 777, 786, 793, 805, 815, 821, 828, 843, 852, 855, 856, 916.

* See *Three stars with burs*. II. 655. IV. 47, 49.

IV. 49 is "A pretty bright stellar nebula, like a star with a
"small bur all around."

The other two are of the same nature.*

IV. 15 is "A stellar nebula, or rather like a faint star with
"a small chevelure and two burs."

The other two are nearly of the same description.

34. *Of doubtful Nebulæ.*

It may have been remarked, that many stellar nebulæ of my catalogues have the memorandum added to their descriptions that they were confirmed with a higher magnifying power, and that this was sometimes attended with difficulty, and sometimes could not be successively done.

A collection of thirty-four nebulæ that come under this description is as follows : †

II. 470 is "A small stellar nebula." By a second observation a doubt entertained in the first was removed with 240, which shewed it "pretty bright, but hardly to be distinguished from a star."

III. 29 is "A very faint extremely small stellar nebula or
"rather nebulous star." The sweeping power left me rather
"doubtful ; 240 verified it.

It must be noticed, that in these nebulæ the doubt which was entertained did not relate to the existence of the objects, but merely to their nature; and when the suspected nebula was so faint that even its existence was doubtful, a higher

* See *Three stars with a faint chevelure.* IV. 15, 21, 31.

† See *First assortment containing twenty-five verified stellar nebulæ.* II. 470, 502, 661. III. 29, 80, 84, 124, 135, 174, 184, 187, 202, 207, 214, 226, 264, 266, 268, 269, 513, 549, 604, 742, 748, 964.

power was applied only with a view to ascertain whether the object existed as nebula or as star; for had the suspicion of its existence not been accompanied with the expectation of its being a nebula, it could never have been attempted to be verified.*

III. 270 is "A very faint extremely small stellar nebula; " 240 verified it with difficulty, and considerable attention, the " night being uncommonly clear."

When difficulty is mentioned, it is always to be understood that a considerable time as well as attention was required in the examination before a decisive opinion could be formed.†

III. 7 is "A nebulous star, but doubtful of the nebulosity. " With 240 the same doubtful appearance continues." Fig. 42.

With this object the doubt which remained could only relate to the nature of it; for being at first sight taken to be a nebulous star, its existence could not be a subject for examination; but the unresolved doubt, whether an object is a nebula or a star, must certainly be allowed to be as great a proof of identity as we can possibly expect to see.

35. *Concluding Remarks.*

The total dissimilitude between the appearance of a diffusion of the nebulous matter and of a star, is so striking, that an idea of the conversion of the one into the other can hardly occur to any one who has not before him the result of the critical

* See *Second assortment*, containing five stellar nebulae verified with difficulty. III. 115, 212, 219, 262, 270.

† See *Third assortment*, containing four objects that could not be verified. III. 7, 176, 263, 293.

examination of the nebulous system which has been displayed in this paper. The end I have had in view, by arranging my observations in the order in which they have been placed, has been to shew, that the above mentioned extremes may be connected by such nearly allied intermediate steps, as will make it highly probable that every succeeding state of the nebulous matter is the result of the action of gravitation upon it while in a foregoing one, and by such steps the successive condensation of it has been brought up to the planetary condition. From this the transit to the stellar form, it has been shown, requires but a very small additional compression of the nebulous matter, and several instances have been given which connect the planetary to the stellar appearance.

The faint stellar nebulæ have also been well connected with all sorts of faint nebulæ of a larger size ; and in a number of the smaller sort, their approach to the starry appearance is so advanced, that in my observations of many of them it became doubtful whether they were not stars already.

It must have been noticed, that I have confined myself in every one of the preceding articles to a few remarks upon the appearance of the nebulous matter in the state in which my observations represented it; they seemed to be the natural result of the observations under consideration, and were not given with a view to establish a systematic opinion, such as will admit of complete demonstration. The observations themselves are arranged so conveniently that any astronomer, chemist, or philosopher, after having considered my critical remarks, may form what judgment appears most probable to him. At all events, the subject is of such a nature as cannot fail to attract the notice of every inquisitive mind to a contem-

plation of the stupendous construction of the heavens; and what I have said may at least serve to throw some new light upon the organization of the celestial bodies.

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POSTSCRIPT.

It will be seen that in this paper I have only considered the nebulous part of the construction of the heavens, and have taken a star for the limit of my researches. The rich collection of clusters of stars contained in the 6th, 7th, and 8th classes of my Catalogues, and many of the *Connoissance des Temps*, have as yet been left unnoticed. Several other objects, in which stars and nebulosity are mixed, such as nebulous stars, nebulae containing stars, or suspected clusters of stars which yet may be nebulae, have not been introduced, as they appeared to belong to the sidereal part of the construction of the heavens, into a critical examination of which it was not my intention to enter in this Paper.

WILLIAM HERSCHEL.

Slough, near Windsor,

May 26, 1811.

Fig. 1.



