XIV. *Astronomical Observations relating to the sidereal part of the Heavens, and its Connection with the nebulous part; arranged for the purpose of a critical Examination.* *By* William Herschel, *LL.D. F.R.S.*

Read February 24, 1814.

In my paper of observations of the nebulous part of the heavens, I have endeavoured to shew the probability of a very gradual conversion of the nebulous matter into the sidereal appearance. The observations contained in this paper are intended to display the sidereal part of the heavens, and also to shew the intimate connection between the two opposite extremes, one of which is the immensity of the widely diffused and seemingly chaotic nebulous matter; and the other, the highly complicated and most artificially constructed globular clusters of compressed stars.

The proof of an intimate connection between these extremes will greatly support the probability of the conversion of the one into the other; and in order to make this connection gradually visible, I have arranged my observations into a series of collections, such as I suppose will best answer the end of a critical examination.

I. *Of Stars in remarkable situations with regard to Nebulæ.**

Among the great number of stars, with nebulosity dispersed between them are some in situations that deserve to be remarked.

IV, 5 is "A pretty bright star situated exactly north of the "center of an extended milky ray, which is about 15 or 20 "minutes in length." By a second observation, two years after the first, it appeared that the star was then included in part of the nebulosity.

V, 46 is "A pretty bright star in the middle of a very bright "nebula, about 10 minutes in length and 2′ broad." See fig. 1.

III, 616 is "A star of the 6th magnitude, about 5′ north of "a very faint nebula, of an irregular figure." By an observation of the same star, two years before, the two objects were then so near each other, as, at first sight, to cause a suspicion that some damp had settled upon the eye-glass and affected the star.

The singularity that five stars should be similarly situated with regard to nebulæ is not very striking; but the difference in the additional observation is worthy of notice, and may suggest a surmise that nebulæ may have considerable proper motions, by which they are occasionally carried towards neighbouring stars: the difference in the clearness of the atmosphere

* See five stars in remarkable situations. II, 246. III, 201. 616. IV. 5. 46. The places of these objects will be found in three catalogues of nebulæ and clusters of stars, published in the Philosophical Transactions for 1786, 1789, and 1802. The reference IV, 5 for instance, points out number 5, in the IVth class.

at different times, however, ought to make us cautious about assigning the cause of the difference in the observations.

2. *Of two Stars with nebulosity between them.**

A more remarkable situation than the former is that of two stars with nebulosity between them, or both included in the same nebulosity.

III, 67 is "An extremely faint nebulosity extended from "one star to a smaller one, at the distance of about 2 minutes "south of the former." See fig. 2.

II, 706. "Two considerable stars are involved in a very "faint nebulosity of 3 or 4 minutes in extent." See fig. 3.

Here I have referred to 19 instances, where two stars have an extended nebulosity between them, or at least are both contained within it. Now, if we were to enter into a calculation of chances to investigate the probability that in every one of these 19 objects, the stars and the nebulosity should be unconnected, we should have to consider that in order to produce this appearance by three objects at a distance from each other, it would be required that every one of them should be precisely in a given line of sight, and that the nebulosity should not only be in the middle of them, but that it also should be extended from the situation of one star to that of the other; and that all this should happen in the confined space of a few minutes of a degree; which cannot be probable. Then, if on the other hand we recollect that in the 8th, 9th, and 10th articles of my paper on the nebulous part of the heavens, I have given 139 double nebulæ joined by nebulosity between them,

* See nineteen double stars joined by intermediate nebulosity II, 16. 706. 732. III, 19. 32. 67. 68. 113. 126. 182. 200. 312. 376. 540. 637. 757. 785. 820. 854.

and that we have now before us 19 similar objects, with no other difference than that instead of nebulæ we have stars with nebulosity remaining between them, should we not surmise that possibly these stars had formerly been highly condensed nebulæ, like those that have been mentioned, and were now by gradually increasing condensation turned into small stars; and may not the nebulosity still remaining shew their nebulous origin?

When to this is added that we also have an account of 700 double stars entirely free from nebulosity,* many of which are probably at no great real distance from each other, it seems as if we had these double objects in three different successive conditions: first as nebulæ; next as stars with remaining nebulosity; and lastly as stars completely free from nebulous appearance.

3. *Of Stars with nebulosities of various shapes attached to them.*

When a nebula seems to be joined to a star, or closely pointing to it, the manner of its appearance deserves our attention. Here follow three different sorts of such conjunctions.†

First sort; I, 143 "On the north preceding side of a pretty "bright star is a considerable, bright nebulosity. It is joined "to the star so as to appear like a brush to it. See fig. 4."

Second sort; IV, 4 "A very small star has an extremely

* See Phil. Trans. for 1782, page 12; and for 1785, page 40.

† See fourteen stars connected with nebulæ.

Nine with a brush I, 143. II, 214. 683. III, 643. IV, 10. 17. 29. 40. 77.

Two with a puff IV, 4. 3.

Three with fan-shaped nebulosity IV, 2. 35. 66.

" faint, and very small nebula attached to it in the shape of " a puff." See fig. 5.

Third sort; IV, 35 " A small star has a small, faint, fan- " shaped nebulosity joining to it on the north preceding side." See fig. 6.

Here we have a list of fourteen objects, in which the probability of a union between the nebulosities and the stars will gradually become more apparent. With regard to the first nine, the particularity of their construction is already very pointed: the conditions are that the nebulosity must be extended; the direction of its extension must be exactly towards the star, and it must also be apparently just near enough to touch it; but that all this should happen cannot be probable; whereas a real contact of the objects, held together by mutual gravitation, will readily account for the whole appearance.

In the two next objects there is already some indication of a union between the nebula and the star, for the roundness of the nebulosity appeared to be a little drawn out of its figure towards the star.

But the last three instances, in which the whole mass of nebulous matter is pointedly directed to the stars, and in contact with them, can hardly leave any room for doubting a union between them.

Now if we admit a contact, or union between these nebulæ and the stars, it deserves to be remarked that stars, in the situation of these fourteen, cannot have been formed from their adjoining nebulosities; for a gradual condensation of the nebulous matter would have been central; whereas the stars are at the extremity of the nebulæ. It is therefore reasonable to suppose that their conjunction must be owing to some

motion either of the stars or of the nebulous matter: a mutual attraction might draw them together. In either of these cases it would follow, that if the nebulosity should subside into the star, as seems to be indicated by the assumed form of the fan-shaped nebulæ, the star would receive an increase of matter proportional to the magnitude and density of the nebulosity in contact with it. This would give us the idea of what might be called the *growth* of stars.

4. *Of Stars with nebulous branches.*

That an intimate connection between the nebulous matter and a star is not incompatible with their nature will clearly appear by the following instances, in which a union is manifested that cannot be mistaken for a deceptive appearance.*

IV, 42 is " A star of about the 8th or 9th magnitude with " very faint nebulous branches extended in the direction of the " meridian: each branch is about one minute in length. Other " stars of the same size, and at the same time in view, are " free from these branches." See fig. 7.

The three objects to which I have referred shew sufficiently that stars and nebulæ may be connected; for a little swelling and increase of light of the branches, at their junction with the star, which generally takes place, seems evidently to be an effect arising from the gravitation of the nebulous matter towards a center, in which the star is situated.

Here again the visible effect of gravitation supports the idea of the *growth* of stars by the gradual access of nebulous matter; for in the present case I may refer to the observations already published in the Phil. Trans. for 1811, where, page

* See three stars with nebulous branches IV, 42. 43. 48.

301, we have an account of twenty-four extended nebulæ, gradually a little brighter in the middle; page 303 there are fifty extended nebulæ, with an increased brightness towards the middle; page 304, we have fifty-four extended nebulæ, with a much greater accumulation of brightness; page 307 there are seven extended nebulæ, in which the central increase of brightness approaches towards the formation of a nucleus. Page 309, we have twenty-seven extended nebulæ, in which the central nucleus is already formed; and finally, page 311 contains the account of twenty-three extended nebulæ, where the nebulosity seems to have so far subsided into the nucleus, as to leave only two opposite faint branches. Who then that has followed up the gradual condensation of an extended nebula till it appeared in the shape of a bright nucleus with faint branches, and finds now in the center of two such opposite faint branches, instead of a condensed nucleus, a star—who, I may ask, would not rather admit that the nucleus had gradually cleared up in brightness, and assumed the lustre of a star, than have recourse to the most improbable of all hypotheses, that a fortuitous central meeting of a star and a nebula should be the cause of such a singular appearance?

5. *Of nebulous Stars.**

The conjunction of the nebulous and sidereal condition is still more clearly manifested in nebulous stars. Having already described many of them in a paper read before the Royal Society in 1791, I shall here only mention two of them.

* See thirteen nebulous stars IV, 19. 25. 36. 38. 44. 45. 52. 57. 58. 65. 69. 71. 74.

IV, 45. " A star of about the 9th magnitude has a pretty " strong milky nebulosity equally dispersed all around it."

IV, 69 is " A star of about the 8th magnitude with a faint " luminous atmosphere of a circular form of about 3 minutes " in diameter; the star is perfectly in the center, and the at- " mosphere is so diluted, faint, and equal throughout, that " there can be no surmise of its consisting of stars, nor can " there be a doubt of the evident connection between the " atmosphere and the star." See fig. 8.

Among the thirteen objects referred to, there are many so variously constructed as to prove not only that nebulous stars are intimately connected with a nebulosity, which from its great regularity might be taken for an atmosphere, but also with the luminous appearances, which have been described as belonging to the nebulous matter that is so widely expanded over various regions of the starry heavens. For instance, in IV, 45. 58. 65 and 69 the stars are perfectly central, which proves that the chevelure is connected with them. In IV, 36. 71 and 74 the nebulosity is likewise attached to the stars, but their nebulosity is more irregularly and extensively expanded, so as to resemble the general mass of nebulous matter.

What has been said of the gradual condensation of the nebulous matter in the case of extended nebulæ, is supported by a much greater number of nebulosities of a spherical form. The different gradations of their condensation are pointed out in the same paper from page 301 to 308; and contain 322 cases in which the fact of the gradual condensation is rendered so evident as not to admit of a doubt. Then, if instead of the last 13 globular nebulæ, page 309, each of which has a nucleus in the middle, we now look at our 13 stars, each of

which is situated in the very center of a globular nebulosity, it will evidently point out the high probability, or rather the certainty, that nebulous stars only differ from round nebulæ containing a nucleus, in the order of condensation, which in the case of the nebulous stars, has been carried to a somewhat higher degree than in the nebulous nuclei.

6. *Of Stars connected with extensive windings of nebulosity.**

The nebulosity which has been shewn to be connected with stars may be fully proved to be of the same nature as the general mass of nebulous matter by the following instances.

IV, 33. "A star situated upon a ground of extremely faint "milky nebulosity diffused over this part of the heavens, has "a milky chevelure surrounding it, which is brighter than "the nebulosity of the ground; but which loses itself imper- "ceptibly in the extreme faintness of the general diffusion of "the nebulous matter." See fig. 9.

The formation of these objects is extremely instructive, as it manifests the affinity between the matter of which stars are composed, and that of the most unshapen chaotic mass of nebulosity. For the vanishing chevelure of a star being equally connected, on the one hand, with the generally diffused nebulous matter, and on the other with the star itself, round which it is in a state of gradual condensation; this double union denotes the mutual gravitation of the whole mass of nebulosity and the star towards each other; and unless this proof can be invalidated, we must admit the fact of the growing condition of stars, that are in the situation which has been pointed out.

This argument also adds greatly to the probability of stars

* See three stars connected with diffusions of nebulosity IV, 24. 33. V. 27.

being originally formed by a condensation of the nebulous matter; for, as it now appears that stars must receive an addition to their solid contents, when they are in contact with nebulosity, there is an evident possibility of their being originally formed of it. Moreover, the affinity between the nebulous and sidereal condition being established by these observations, we may be permitted to conceive both the generation and growth of stars, as the legitimate effects of the law of gravitation, to which the nebulous matter, as proved by observation, is subject.

7. *Of small patches consisting of Stars mixed with nebulosity.*

When a small patch of stars is mixed with nebulosity, there is a possibility of its being a deception arising from their being accidentally in the same line of sight; but it has already been shewn that in such appearances the probability is much in favour of a real union; especially when the objects are numerous;* and in that case there are but two ways of accounting for it.

First, admitting from what has been said, that stars may be formed of nebulous matter, it may happen that the nebulosity still mixed with them is some remaining unsubsided part of that from which they were formed; and in the next place, a union of stars and nebulosity, originally at a distance from each other, may have been effected by the motion of either the stars or the nebulosity.

* See thirty-seven small patches, consisting of stars mixed with nebulosity I, 172. 192. 258. II, 21. 39. 103. 304. 489. 745. 878. III, 8. 43. 61. 64. 71. 143. 144. 146. 147. 165. 185. 204. 227. 256. 271. 349. 471. 538. 559. 560. 568. 583. 595. 697. 922. IV, 75. V, 49.

That such motions may happen has been shewn in the third article, which contains instances of the conjunction of stars with nebulosities of which they cannot have been formed, and which must, consequently, have been united by motion. We also know that nebulæ are subject to great changes in their appearance, which proves that some of the nebulous matter in their composition must be in motion; instances of which have been given in the luminous nebulosity of the constellation of Orion.* It may therefore be easily conceived that any moving patch of nebulous matter must be arrested on its meeting with stars; especially if several of them should happen to be pretty near each other; in which case there will be, as it were, a net spread out for intercepting every nebulosity that comes within the reach of their attraction.

II, 304. "Three or four stars of various sizes are mixed "with pretty strong nebulosity."

III, 165. "Five or six stars forming a parallelogram, are "mixed with very faint milky nebulosity."

III, 697. "Several small stars are contained in faint nebu- "losity about 3 or 4 minutes long and $\frac{3}{4}$ broad." See fig. 10.

IV, 75. "Three stars of about the 9th or 10th magnitude "are involved in pretty strong milky nebulosity."

This collection of thirty-seven objects, consisting of 2, 3, 4, 5, 6, or more small stars that are mixed with nebulosity, contains a variety of instances in which the effect that has been mentioned of the interception of the nebulous matter may have taken place. It is very obvious that nothing positive can be said about the formation of so many starry-nebulous patches; for unless by long continued observation of the same patches

* Phil. Trans. for 1811, p. 320.

we could be acquainted with every change that may happen in the nebulosity or in the magnitude of the stars which apparently compose them, their real union and construction must remain unknown. We can only hint, that every nebulosity which is carried into the region of a small patch of stars will probably be gradually arrested and absorbed by them, and that thus the *growth of stars* may be continued.

8. *Of objects of an ambiguous construction.*

From objects consisting decidedly of stars, but which either have nebulosity mixed with them, or are in such situations as to be seen in the same line with nebulosity, I proceed to give an account of some others, of which my observations have not ascertained into what order we ought to class them.

It has been remarked, on a former occasion, that clusters of stars, when they are at a great distance, may assume a nebulous appearance.* This may be experienced by observing a certain celestial object with a telescope of an inferior space-penetrating power, through which it will be seen as a nebula; whereas with an instrument which has a higher degree of this power, its appearance will be a mixture of nebulosity and stars; and if this power of the telescope is of a still higher order, the stars of the same object will then be distinctly perceived: the nebulosity will no longer be seen, and the object will be entitled to be placed into the rank of clusters of stars.

Other objects there are, where a greater space-penetrating power will only increase the brightness of the nebulosity, and at the same time make the tinge of it more uniformly united

* Phil. Trans. for 1811, page 270.

and of a milky appearance, which will decide it to be purely nebulous.

But when an object is of such a construction, or at such a distance from us, that the highest power of penetration, which hitherto has been applied to it, leaves it undetermined whether it belong to the class of nebulæ or of stars, it may then be called ambiguous. As there is, however, a considerable difference in the ambiguity of such objects, I have arranged 71 of them into the following four collections.*

The first contains seven objects that may be supposed to consist of stars, but where the observations hitherto made, of either their appearance or form, leave it undecided into which class they should be placed.

Connoiss. 31 is " A large nucleus with very extensive ne-
" bulous branches, but the nucleus is very gradually joined to
" them. The stars which are scattered over it appear to be be-
" hind it, and seem to lose part of their lustre in the passage of
" their light through the nebulosity; there are not more of them
" scattered over the nebula than there are over the immediate
" neighbourhood. I examined it in the meridian with a mirror
" 24 inches in diameter, and saw it in high perfection; but its
" nature remains mysterious. Its light, instead of appearing
" resolvable with this aperture, seemed to be more milky."

* See seventy-one ambiguous objects, in four collections.

First collection II, 400. III, 379. 693. 745. V, 2. Connoiss. 1. 31.

Second collection I, 46. 50. II, 27. 78. 79. 180. 195. 199. 207. 554. 609. 771. 822. 850. 855. III, 3. 101. 239. 399. 455. 696. 725. 743. IV, 22. Connoiss. 57. 70.

Third collection I, 44. 47. II. 47. 48. 76. 105. 202. 279. 283. 469. 473. 500. 608. 808. III, 47. 53. 55. 134. 288. 580. 747. 910. V, 1. VI, 38. Connoiss. 81. 82.

Fourth collection I, 52. 103. 122. 249. 288. II, 4. 84. 584. V, 3. VI, 15, 20. Connoiss. 100.

The objects in this collection must at present remain ambiguous.

The next contains 26 nebulous objects, of which the figure has been ascertained to be round or nearly round.

II, 101 is "A pretty large, round, extremely faint easily "resolvable nebula. I can almost see the stars in it. See fig. 11.

Connoiss. 57 is "An oval nebula with an eccentric oval dark "space in the middle; there is a strong suspicion of its con- "sisting of stars. The diameter, measured by the large 10 "feet telescope, is 1′ 28″,3."

The globular form of the objects in this collection, which is deduced from their round figure, will so far ascertain the manner of their construction, that they must either be still in a condensed state purely nebulous, or else, if consisting of stars, that they must be already in a far advanced order of compression, and only appear nebulous on account of their very great distance from us. A middle state between the progressive condensation of a globular nebula and a cluster of stars can have no existence; because a globular nebulosity when condensed can only produce a single star. There is, however, a possibility that a mass of nebulous matter in motion may be intercepted by a globular cluster, in which case the nebulosity must soon assume the form of the cluster, and will finally be absorbed by it.

In the third collection I have placed 26 nebulæ, which not only are described as easily resolvable, but in most of which some stars have actually been seen.

II, 500 is "A very large, easily resolvable, extended, nebu- "lous object. I see a few of the largest stars in it. See fig. 12.

Here the uncertainty in which the descriptions leave us, is that the objects in this collection may be either clusters of stars mixed with nebulosity, or that in consequence of the great distance and compression of the small stars composing a cluster which contains no nebulosity, it may put on the nebulous appearance.

The fourth collection contains 12 nebulous objects, of which the description makes it probable that they belong to the order of clusters of stars.

I, 249 is "A considerably bright extended nebula about 4′ "long and 2′ broad; it is easily resolvable, and I suppose with "a higher power and longer attention the stars would become "visible. It is brighter about the middle."

Connoiss. 100 is "A nebula of about 10′ in diameter, but "there is in the middle of it, a small, bright cluster of supposed "stars."

9. *Of the sidereal part of the Heavens.*

The foregoing observations have proved the intimate connection between the nebulous and sidereal condition; and although in passing from one to the other we have met with a number of ambiguous objects, it has been seen that the apparent uncertainty of their construction is only the consequence of the want of an adequate power in our telescopes, to shew them of their real form. We have indeed no reason to expect that an increase of light and distinctness of our telescopes would free us from ambiguous objects; for by improving our power of penetrating into space, and resolving those which we have at present, we should probably reach so many new objects that others, of an equally obscure construction, would

obtrude themselves, even in greater number, on account of the increased space of the more distant regions of their situation.

From stars mixed with nebulosity we are now to direct our attention to the purely sidereal part of the heavens; and as stars are the elementary parts of sidereal constructions, it will be proper to review what we know of their nature. Having already entered upon this subject in a former paper at some length,* I shall only give a few additional observations, with a summary outline of the former arguments.

The intensity of the light of a star of the first magnitude may be compared with solar light, by considering, that if the sun were removed to the distance at which we generally admit the brightest stars to be from us, its visible diameter could not exceed the 215th part of a second; and its appearance therefore would probably not differ much from the size and brightness of such stars. By reversing this argument we shall be authorised to conclude, from analogy, that stars, were they near enough, would assume the brightness, and some of them perhaps also the size, of the sun; and the consequences that have been drawn from the observations given in my paper on the nature and construction of the sun, may be legitimately applied to the stars; whence it follows that stars, although surrounded by a luminous atmosphere, may be looked upon as so many opaque, habitable, planetary globes; differing, from what we know of our own planets, only in their size, and by their intrinsically luminous appearance.

They also, like the planets, shine with differently coloured light. That of Arcturus and Aldebaran for instance, is as

* Phil. Trans. for 1785, page 68.

different from the light of Sirius and Capella, as that of Mars and Saturn is from the light of Venus and Jupiter. A still greater variety of coloured star-light has already been shewn to exist in many double stars, such as γ Andromedæ, β Cygni, and many more.* In my sweeps are also recorded the places of 9 deep garnet, 5 bright garnet, and 10 red coloured stars, of various small magnitudes from the 7th to the 12th.

By some experiments, on the light of a few of the stars of the first magnitude, made in 1798, by a prism applied to the eye-glasses of my reflectors, adjustable to any angle and to any direction, I had the following analyses.

The light of Sirius consists of red, orange, yellow, green, blue, purple, and violet.

α Orionis contains the same colours, but the red is more intense, and the orange and yellow are less copious in proportion than they are in Sirius.

Procyon contains all the colours, but proportionally more blue and purple than Sirius.

Arcturus contains more red and orange and less yellow in proportion than Sirius.

Aldebaran contains much orange, and very little yellow.

α Lyræ contains much yellow, green, blue, and purple.

The similarity of the general construction of the sun, the stars, and the planets, is also much supported by the periodical variations of the light of the stars observed in many of them;† for these variations can only be satisfactorily accounted for by admitting such stars to have a rotatory motion on their

* See Catalogue of double stars Phil. Trans. for 1782, III, 5. V, 5, &c.

† See Mr. PIGOTT'S Catalogue of variable stars Phil. Trans. for 1786, page 191.

axes, like that which the sun and the planets are known to have.*

10. *Of the aggregation of Stars.*

That stars are not spread in equal portions over the celestial regions is evident to the eye of every one who directs his view to them in a clear night; but if this wanted any proof, the star-gages I have given in the Phil. Trans. for 1785, would abundantly shew that the greatest variety in their distribution takes place; for while in my sweeps many fields of view of the telescope were without a single star, others contained every assignable number, from one to more than six hundred.

In my examination of the heavens, I remarked that in many places there were patches of stars of such a particular appearance that I was induced to call them *forming* clusters. This expression was however only used to denote that some peculiar arrangement of stars in lines making different angles, directed to a certain aggregation of a few central stars, suggested the idea that they might be in a state of progressive approach to them. This tendency to clustering seemed chiefly to be visible in places that were extremely rich in stars. In order therefore to investigate the existence of a clustering power, we may expect its effects to be most visible in and near the milky way, and it is for this purpose I have distinguished the relative situation of the clusters to which I refer.†

* See Remarks on the rotatory motion of stars on their axes, Phil. Trans. for 1796, page 456.

† See twenty clusters of stars; fifteen in the milky way VII, 40. 45. VIII, 16. 18. 35. 36. 42. 47. 50. 56. 60. 61. 64. 67. Connoiss. 6; and five near it VIII, 8. 40. 41. 44. 83.

Connoiss. 6 is "A cluster of stars of various sizes contain-
"ing several lines that seem to be drawing to a centre like a
"forming cluster."

VIII, 35 is "A large cluster of stars considerably com-
"pressed and rich; some of the stars are arranged in a long
"*crooked line.*"

VIII, 44 is "A very coarsely scattered cluster of large stars;
"they form a cross and extend over a large space; not rich."
See fig. 13. The stars about the cluster belong to the milky way.

VIII, 83 is "A cluster of scattered stars above 15′ in dia-
"meter; pretty rich and joining to the milky way, or a pro-
"jecting part of it."

The 20 objects here referred to are not given as instances of the actual formation of clusters, which, being an effect that must undoubtedly require much time, cannot be visible; but merely to draw our attention to a seemingly aggregating arrangement of the stars, which must render it probable that in regions where stars are very numerous, but unequally scattered, a clustering of them may arise from the preponderating attractions residing in different places.

11. *Of irregular Clusters.*

When clusters of stars are situated in very rich parts of the heavens, they are generally of an irregular form and very imperfectly collected; those which are in, and very near the milky way, may indeed be looked upon as so many portions of the great mass drawn together by the action of a clustering power, of which they tend to prove the existence.

I have divided the following 112 objects into two collections.

The first of them contains 80 clusters of which the size or figure has not been particularized.*

VIII, 4 is " A cluster of coarsely and irregularly scattered, " pretty large stars, of nearly one size and colour." See fig. 14.

The stars of these clusters are in general very promiscuously scattered; they are however sufficiently drawn together to shew that they form separate groups; and in many places a defalcation of the number of stars surrounding the clusters is already so far advanced as to indicate a tendency to future insulation.

The second collection contains 32 irregular clusters that are from 2 to 30′ in diameter.†

VII, 4 is " A cluster of large stars about 20 or 25′ in dia- " meter, considerably rich; it is of a coarsely circular figure."

The great number of clusters in these two collections is not only an indication that they owe their origin to a clustering power residing in the stars about their center; but the still remaining irregularity of their arrangement additionally proves that the action of the clustering power has not been exerted long enough to produce a more artificial construction. The

* See eighty irregular clusters of stars, of various unascertained sizes, fifty-three in the milky way; VII, 5. 35. 36. 42. 50. 62. 67. VIII, 4. 5. 6. 13. 15. 19. 20. 21. 22. 25. 27. 28. 30. 31. 33. 34. 37. 45. 46. 51. 52. 54. 55. 57. 58. 59. 63. 72. 76. 79. 82. 84. 85. 86. 87. Connoiss. 7. 8. 16. 18. 21. 24. 25. 26. 29. 36. 38. Eighteen near the milky way; VII, 6. 15. 46. VIII, 2. 11. 23. 43. 49. 62. 65. 68. 69. 73. Connoiss. 20. 34. 39. 41. 48: nine at a distance from it; VII, 3, 54. VIII, 7. 10. 29. 71. Connoiss. 44. 45. 73.

† See thirty-two irregular clusters from 2 to 30′ in diameter; twenty-two in the milky way; VI, 23. VII, 10. 12. 30. 52. VIII, 9. 12. 14. 17. 26. 32. 39. 48. 53. 70. 74. 77. 78. 80. 81. Connoiss. 23. 93. Ten near the milky way VI, 39. VII, 4. 11. 13. 14. 16. 32. 66. VIII, 66. 88.

length of time required for this purpose must, however, greatly depend upon the original situation of the stars exposed to the clustering power.

12. *Of Clusters variously extended and compressed.*

The outlines of clusters of stars in rich parts of the heavens, and even of those that are insulated, are seldom sufficiently defined to arrange such clusters by their figure; and as the following assortment contains some that are variously extended and differently compressed, it will be seen, from the descriptions of a few of them, that the power which has drawn the stars together must have acted under different circumstances.*

VI, 3 is "A cluster of very compressed, extremely small "stars, containing a few large ones. It is of an extended "figure, and, as it were, divided.

In this cluster the observed partial division points out the cause of its being extended, which may be ascribed to a double seat of preponderating attractions at some little distance from each other.

VI, 24 is "A very rich cluster of extremely small and very "compressed stars; it is about 6′ long and 4′ broad."

Here the stars of the cluster are not only much compressed, but the borders of it are moreover sufficiently determined to shew the limits of its extent; from which we may infer that the cluster is advancing towards insulation, and that in the end a gradual concentration may bring it to a globular form.

* See fifteen extended clusters of stars; twelve in the milky way II, 198. VI, 3. 14. 24. 36. VII, 18. 19. 27. 41. 44. 56. VIII, 3. And three near the milky way VII, 29. 64. VIII, 75.

VI, 36 is "A very compressed cluster of small, and some "large stars; extended nearly in the meridian; the most "compressed part is about 8′ long and 2′ broad, with many "stars scattered around it to a considerable distance." See fig. 15.

The construction of this cluster may have arisen from the situation of many stars in the same plane, drawn towards a centre by the clustering power, for any plane seen obliquely will have the appearance of an extended form.

VI, 64 is "A large cluster of stars, of a middling size, ir-"regularly extended, and considerably rich. The stars are "chiefly in rows."

Here each row of stars may have a different preponderating attraction, but every row will attract all the other rows; nay, from the laws of gravitation it is evident that there must be somewhere in all the rows together the seat of a preponderating clustering power, which will act upon all the stars in the neighbourhood.

13. *Of Clusters of Stars of a peculiar description.*

The great variety of ways in which the attractions of unequally scattered stars may produce a clustering power will be further exemplified in the following objects.*

VI, 55 is "A pretty compressed cluster of very small stars; "it is of an irregular figure, and has a vacancy in the middle."

This appearance may be accounted for by supposing, for instance, three, four, or a greater number of preponderating

* See six clusters of stars of a peculiar description; one in the milky way VIII, 24. Three near the milky way VII, 26. 55. Connoiss. 4; and two at a distance from it VII, 1. Connoiss. 30.

attracting centres near each other, situated so as to inclose a certain space, the stars in which, then, cannot be accumulated, while the clustering power arising from the combined attractions will be exerted on the surrounding stars.

Connoiss. 4 is "A rich cluster of considerably compressed "small stars surrounded by many straggling ones. It con- "tains a ridge of stars running through the middle from south "preceding to north following. The ridge contains 8 or 10 "pretty bright stars. All the stars are red."

The curious construction of this cluster is sufficiently accounted for by the bright stars in what is called a ridge; the small stars accumulated about it having somewhat the appearance of the shelving sides of the ridge. The observed red colour was probably owing to the low situation of the object.

VII, 26 is "A cluster of extremely small and pretty much "compressed stars, with a few large ones in the shape of a "hook."

From what has been remarked already it will not be necessary to enter into a consideration of the cause of the uncommon form of this cluster.

Connoiss. 30 is "A brilliant cluster, the stars of which are "gradually more compressed in the middle. It is insulated, "that is, none of the stars in the neighbourhood are likely to "be connected with it. Its diameter is from 2′ 40″ to 3′ 30″. "Its figure is irregularly round. The stars about the centre "are so much compressed as to appear to run together. To- "wards the north, are two rows of bright stars 4 or 5 in a "line."

In this accumulation of stars, we plainly see the exertion of a central clustering power, which may reside in a central

mass, or, what is more probable in the compound energy of the stars about the centre. The lines of the bright stars, although by a drawing made at the time of observation, one of them seems to pass through the cluster, are probably not connected with it.

14. *Of differently compressed Clusters of Stars.*

I have hitherto only considered the arrangement of stars in clusters with a view to point out that they are drawn together by a clustering power, in the same manner as the nebulous matter has, in my former paper, been proved to be condensed by the gravitating principle; but in the 41 clusters of the following two collections we shall see that it is one and the same power uniformly exerted which first condenses nebulous matter into stars, and afterwards draws them together into clusters, and which by a continuance of its action gradually increases the compression of the stars that form the clusters.

The first collection contains 33 clusters, the stars of which are considerably compressed.*

VII, 12 is " A beautiful cluster of pretty compressed stars, " near half a degree in diameter. It is considerably rich, and " most of the stars are of the same size."

The moderate compression of the stars in the clusters of this order renders them fine objects for good telescopes.

The second collection contains 8 clusters in which the

* See thirty clusters of considerably compressed stars; seventeen in the milky way VI, 16. 29. 33. 34. VII, 2 7. 9. 22. 23. 33. 43. 65. VIII, 38. Connoiss. 11. 35. 50. 103. Fifteen near the milky way VI, 6. 22. 42. VII, 12. 17. 20. 21. 24. 34. 47. 57. 58. 59. 63. VIII, 1; and one at a distance from it Connoiss. 67.

compression of the stars is carried to a much higher degree.*

VI, 30 is "A very beautiful rich cluster of very compressed "small stars."

The clusters in this collection are also fine objects; but, on account of their higher compression, require superior telescopes.

15. *Of the gradual concentration and insulation of Clusters of Stars.*

The existence of a clustering power is nowhere so visibly pointed out as in the 39 clusters which are given in the following collection.† My remarks upon them will come with more clearness when applied to a particular description of some of them.

VI, 5 is "A beautiful cluster of very compressed small stars "of several sizes. It is of an irregular round form, about 12 "or 15′ in diameter, and the stars are gradually most com- "pressed in the middle."

Here the gradually increasing compression of the stars points out the central situation of the clustering power; the form is also that of a solid, not much differing from a globular figure; and by the outline of the cluster we may consider it as already in an advanced state of insulation; from these cir-

* See eight clusters of very compressed stars; five in the milky way VI, 27. 30. VII, 8. Connoiss. 22. 46. Two near the milky way VI, 10. VII. 48; and one at a distance from it VI, 4.

† See thirty-nine clusters of gradual concentration; twenty-one in the milky way VI, 5. 13. 17. 18. 25. 26. 28. 32. VII, 25. 28. 31. 37. 38. 39. 51. 60. 61. Connoiss. 28. 37. 52. 71. Seven near the milky way VI, 2. 21. 31. 37. 40. VII, 49. 53; and eleven at a distance from it I, 41. IV, 63. VI, 1. 8. 9. 19. Connoiss. 33. 55. 68. 74. 77.

cumstances we may therefore conclude that this cluster has been long under the influence of the clustering power. See fig. 16.

Connoiss. 68 is "A beautiful cluster of stars, extremely rich, "and so compressed that most of the stars are blended toge- "ther; it is near 3′ broad and about 4′ long, but chiefly round, "and there are very few scattered stars about."

This oval cluster is also approaching to the globular form, and the central compression is carried to a high degree. The insulation is likewise so far advanced that it admits of an accurate description of the contour.

The clusters of this class are beautiful, but can hardly be seen to any advantage without a 20 feet telescope.

16. *Of globular Clusters of Stars.*

The objects of this collection are of a sufficient brightness to be seen with any good common telescope, in which they appear like telescopic comets, or bright nebulæ, and under this disguise, we owe their discovery to many eminent astronomers; but in order to ascertain their most beautiful and artificial construction, the application of high powers, not only of penetrating into space but also of magnifying are absolutely necessary; and as they are generally but little known and are undoubtedly the most interesting objects in the heavens, I shall describe several of them, by selecting from a series of observations of 34 years some that were made with each of my instruments, that it may be a direction for those who wish to view them to know what they may expect to see with such telescopes as happen to be in their possession.*

* See fourteen globular clusters of stars. One in the milky way Connoiss. 19.

Oct. 4, 1810. 40 feet telescope. Space-penetrating power 191.68. Magnifying power 280. "Having been a sufficient "time at the telescope to prepare the eye properly for seeing "minute objects, the 72d of the *Connoissance des temps* came "into the field. It is a very bright object."

"It is a cluster of stars of a round figure, but the very faint "stars on the outside of globular clusters are generally a "little dispersed so as to deviate from a perfect circular form. "The telescopes which have the greatest light shew this best."

"It is very gradually extremely condensed in the centre, "but with much attention, even there, the stars may be dis- "tinguished."

"There are many stars in the field of view with it, but they "are of several magnitudes totally different from the exces- "sively small ones which compose the cluster."

"It is not possible to form an idea of the number of stars "that may be in such a cluster; but I think we cannot esti- "mate them by hundreds."

"The diameter of the cluster is about $\frac{1}{5}$ of the field, which gives "$1' 53'',6$." See fig. 17.

Sept. 4, 1799. 40 feet telescope, power 240. "I examined "the 2d of the Connoiss. It appeared very brilliant and lu- "minous."

"The scattered stars were brought to a good, well deter- "mined focus, from which it appears that the central con- "densed light is owing to a multitude of stars that appeared "at various distances behind and near each other. I could "actually see and distinguish the stars even in the central

Four near the milky way Connoiss. 10. 12. 56. 80; and nine at a distance from it Connoiss. 2. 3. 5. 13. 15. 53. 72. 79. 92.

"mass. The Rev. Mr. VINCE, Plumian Professor of Astronomy "at Cambridge, saw it in the same telescope as described."

May 27, 1791. 40 feet telescope, power 370. "The 5th "of the Connoiss. is a beautiful cluster of stars; I counted "about 200 of them; but the middle of it is so compressed "that it is impossible to distinguish the stars."*

January 5, 1807. 20 feet telescope. Space-penetrating power 75,08. Magnifying power 157.3. "The 56th of the "Connoiss. is a globular cluster of very compressed and "very small stars. They are gradually more compressed "towards the centre."

May 26, 1786. 20 feet telescope. "The 80th of the Con- "noiss. is a beautiful, round cluster of extremely minute and "very compressed stars about 3 or 4′ in diameter; by the "increasing compression of the stars the cluster is very gra- "dually much brighter in the middle."

May 16, 1787. 20 feet telescope. "The 13th of the Con- "noiss. is a most beautiful cluster of stars. It is exceedingly

* A 40 feet telescope should only be used for examining objects that other instruments will not reach. To look through one larger than required is loss of time, which, in a fine night, an astronomer has not to spare; but it ought to be known that the opportunities of using the 40 feet reflector are rendered very scarce by two material circumstances. The first is the changeable temperature of the atmosphere, by which the mirror is often covered with the condensation of vapour upon its surface, which renders it useless for many hours; and in cold weather by freezing upon it for the whole night, and even for weeks together; for the ice cannot be safely taken off till a general thaw removes it. The next is that, with all imaginable care, the polish of a mirror exposed like that in the 40 feet telescope, though well covered up, will only preserve its required lustre and delicacy about two years. The three observations I have given must consequently be looked upon as having been made by three different mirrors; but if we will have superior views of the heavens, we must submit to circumstances that cannot easily be altered.

" compressed in the middle and very rich. The most com-
" pressed part of it is round and is about 2 or $2\frac{1}{2}'$ in diameter,
" the scattered stars which belong to it extend to 8 or 9′ in
" diameter, but are irregular."*

Sept. 24, 1810. Large 10 feet Newtonian telescope. Space-penetrating power 75,82. Magnifying powers 71. 108. 171. 220. " The 3d of the Connoiss. is one of the globular clus-
" ters; very brilliant and beautiful. The compression of the
" stars begins to increase pretty suddenly from the outside at
" $\frac{3}{4}$ of the radius, and continues gradually up to the centre, its
" diameter taking in the outside is full half of the field of the
" glass magnifying 171 times, which gives 4′ 30″."

Nov. 23, 1805. Large 10 feet. " The 15th of the Con-
" noiss. is perfectly round, and insulated. The accumulation
" of the stars towards the centre is more sudden than the 13th
" of the Connoiss. and the scattered stars extend proportion-
" ally much farther. Its diameter is $\frac{1}{6}$ of the field of the glass
" which magnifies 108 times, that is to say 4′ 0″. It passes
" the wire in 13″,0 of time which by calculation gives only
" 2′ 11″,3, but I rely more on the estimation by the known
" field of view which is 24′ 0″; because the limits of the clus-
" ter cannot be properly fixed upon for a transit."

Jan. 13, 1806. Large 10 feet. " The 79th of the Connoiss.
" is a cluster of stars of a globular construction, and certainly

* The 20 feet telescope, on account of the moderate weight of the mirror and the proportionally long wooden tube, has the great advantage that with proper precaution it may be used in any temperature. Sometimes, however, a sudden change from cold to heat towards morning has put a stop to the observations of the night. The mirror will also preserve an excellent polish for several years; and having a second one ready to supply the place of that which is in use the instrument may always be ready for observation.

" extremely rich. Towards the centre the stars are extremely " compressed, and even a good way from it. With 171 the " diameter is a little less than $\frac{1}{3}$ of the field, and with 220 a " little more; the field of one being 9′ 0″, and of the other " 8′ 0″, a mean of both gives the diameter of the cluster 2′ 50″, " but I suppose that the lowness of the situation prevents my " seeing the thinly scattered stars, so that this cluster is pro- " bably larger than it appears."*

Common 10 feet telescope. Space-penetrating power 28,67. " When the 19th of the Connoiss. is viewed with a magnify- " ing power of 120, the stars are visible; the cluster is insu- " lated; some of the small stars scattered in the neighbourhood " are near it; but they are larger than those belonging to the " cluster. With 240 it is better resolved, and is much con- " densed in the center. With 300 no nucleus or central body " can be seen. The diameter with the 10 feet is 3′ 16″, and " the stars in the centre are too accumulated to be separately " seen."

7 feet telescope, space-penetrating power 20,25. " The " 53d of the Connoiss. with 118 is easily resolvable, and some " of the stars may be seen."

It will not be necessary to add that the two last mentioned globular clusters, viewed with more powerful instruments, are of equal beauty with the rest; and from what has been said it

* The large 10 feet telescope is in a considerable degree subject to the obstructions arising from change of temperature, and tarnish; but as it can be directed to any part of the heavens in a few minutes, and is easily prepared for observation, it becomes a very useful instrument when the clearness of the atmosphere is interrupted by flying clouds; or when the place of an object not visible in the finder, or night-glass, is to be ascertained.

is obvious that here the exertion of a clustering power has brought the accumulation and artificial construction of these wonderful celestial objects to the highest degree of mysterious perfection.

17. *Of more distant globular Clusters of Stars.*

The objects contained in this assortment are so like those of the foregoing collection that in my observations I have called them miniatures of the former. Small instruments cannot reach them, I shall therefore describe them as they appear when proper powers are applied to them.*

VI, 35 is "A cluster of very faint exceedingly compressed "stars, about one minute in diameter. It is the next step to "an easily resolvable nebula."

VI, 11 is "A cluster of stars about $1\frac{1}{2}$ or 2 minutes in dia- "meter. It is a good miniature of the 19th of the Connoiss. "not only with respect to the size of the cluster, but also with "regard to the mutual distance and the reduced magnitude "of the stars of which it consists."

Connoiss. 9 is "A cluster of very compressed and extremely "small stars. It is a miniature of the 53d."

Connoiss. 14 is "Like an extremely bright, easily resolv- "able round nebula; but with a power of 300 I can see the "stars of it. It resembles the 10th of the Connoiss. which "probably would put on the same appearance as this, were "it removed half its distance farther from us. The stars are "much condensed in the middle."

* See eleven miniature globular clusters of stars, five in the milky way VI, 11. 12. 35. Connoiss. 9. 62. One near the milky way Connoiss. 14; and five at a distance from it I, 78. III, 709. VI, 7. 41. Connoiss. 75.

Connoiss. 62 is " Extremely bright, round, very gradually " brighter in the middle, easily resolvable, about 4′ in diameter. " With 240 and strong attention I see the stars of it. It is a " miniature of the 3d of the Connoiss."

I, 78 is " Very bright, suddenly much brighter in the " middle, round, about 3′ in diameter. I take it to be a clus- " ter of stars, as it seems to be a miniature of the 2d of the " Connoiss."

III, 709 is " Very faint, round, very gradually brighter in " the middle; about $2\frac{1}{2}$ minutes in diameter." A later observation says " I can perceive some of the stars."

Connoiss. 75 is " A globular cluster of stars, and is a minia- " ture of the third."

I have supposed the clusters of this class to be at a greater distance from us than those of the preceding collection, because the stars of which they are composed are more minute than those of the clusters of which I have called them miniatures; their compression is also closer, and the size of the whole is much contracted, all which particulars are readily explained by admitting them to be more distant. This argument, however, does not extend so far as to exclude a real difference which there may be in different clusters, not only in the size but also in the number and arrangement of the stars.

18. *Of still more distant globular Clusters of Stars.*

It has already been shewn in the 8th article, that when our telescopes have extended vision as far as they can reach with distinctness, they will still shew objects at a greater distance if they are sufficiently bright to be seen, although we should

not be able to ascertain exactly into what class we ought to place them; but as it frequently happened that I saw three objects in succession, the first of which was a brilliant globular cluster of stars, the second a miniature of the former of which the stars could but just be perceived, and the third in every respect a similar miniature of the second as the second was of the first, but in which the stars, though suspected, were no longer to be distinguished, I called them second miniature globular clusters. The following collection contains five of them.*

I, 45 is "A bright round nebula, much brighter in the middle, "but the brightness decreasing very gradually. It is a perfect "miniature of VI, 12, which is itself a miniature cluster of the "19th of the Connoiss."

I, 48 is "A miniature of the 9th of the Connoiss." (which is itself a miniature of the 53d) "I suppose if I had looked "long enough, I might have perceived some of the stars which "compose it."

I, 147 is "A miniature of the 62d of the Connoiss. which is "a miniature of the 3d."

I, 51 and Connoiss. 69 are second miniatures of the 53d.

19. *Of a recurrence of the ambiguous limit of observation.*

In the 16th article I have given a description of the most magnificently constructed sidereal systems; and very little doubt can be entertained but that the objects of the 17th and 18th articles are of the same nature, and are only less beautiful

* See five second miniature globular clusters of stars in the milky way I, 45. 48. 51. 147. Connoiss. 69.

in their appearance as they are gradually more remote. It has already been shewn in the 8th article, that in passing from faint nebulosity to the suspected sidereal condition, we cannot avoid meeting with ambiguous objects, to which I must now add, that the same critical situation will again occur, when from the distinctly sidereal appearance we endeavour to penetrate gradually farther into space. In consequence of this remark, it seems probable that among the numerous globular nebulæ which have been given in my last paper, many beautiful clusters of stars may lie concealed. To this we may add, that several of the great number of objects which have been given as stellar nebulæ, and are probably at a still greater distance from us, may be the last glimpses we can have of such clusters of stars as the 77th of the Connoissance des Temps, which will nearly put on the stellar appearance when it is viewed in a very good common telescope.

This ambiguity, however, being the necessary consequence of the faintness or distance of objects, when seen through telescopes that are not sufficiently powerful to shew them as they are, will not affect any of the arguments that have been used to establish the existence of a clustering power, the effects of which have gradually been traced from the first indication of clustering stars, through irregular as well as through more artificially arranged clusters, up to the beautiful globular form.

The extended views I have taken, in this and my former papers, of the various parts that enter into the construction of the heavens, have prepared the way for a final investigation of the universal arrangement of all these celestial bodies in

space; but as I am still engaged in a series of observations for ascertaining a scale whereby the extent of the universe, as far as it is possible for us to penetrate into space, may be fathomed, I shall conclude this paper by pointing out some inferences which the continuation of the action of the clustering power enables us to draw from the observations that have been given.

20. *Of the breaking up of the milky way.*

The milky way is generally represented in astronomical maps as an irregular zone of brightness encircling the heavens, and my star gages have proved its whitish tinge to arise from accumulated stars, too faint to be distinguished by the eye. The great difficulty of giving a true picture of it is a sufficient excuse for those who have traced it on a globe, or through the different constellations of an Atlas Cœlestis, as if it were a uniform succession of brightness. It is, however, evident that, if ever it consisted of equally scattered stars, it does so no longer; for, by looking at it in a fine night, we may see its course between the constellations of Sagittarius and Perseus affected by not less than eighteen different shades of glimmering light, resembling the telescopic appearances of large easily resolvable nebulæ; but in addition to these general divisions, the observations detailed in the preceding pages of this paper, authorise us to anticipate the breaking up of the milky way, in all its minute parts, as the unavoidable consequence of the clustering power arising out of those preponderating attractions which have been shewn to be every where existing in its compass.

One hundred and fifty-seven instances have been given of clusters situated within the extent of the milky way, and their places are referred to in nine preceding articles. They may also be found in BODE's Atlas Cœlestis, whose delineation of this bright zone I have taken for a standard. To these must be added 68 more, which are in the less rich parts, or what may be called the vanishing borders of the milky way: for this immense stratum of stars does not break off abruptly, as generally represented in maps, but gradually becomes invisible to the eye when the stars are no longer sufficiently numerous to cause the impression of milkiness.

Now, since the stars of the milky way are permanently exposed to the action of a power whereby they are irresistibly drawn into groups, we may be certain that from mere clustering stars they will be gradually compressed through successive stages of accumulation, more or less resembling the state of some of the 263 objects by which, in the tenth and six succeeding articles, the operation of the clustering power has been laid open to our view, till they come up to what may be called the ripening period of the globular form, and total insulation; from which it is evident that the milky way must be finally broken up, and cease to be a stratum of scattered stars.

We may also draw a very important additional conclusion from the gradual dissolution of the milky way; for the state into which the incessant action of the clustering power has brought it at present, is a kind of chronometer that may be used to measure the time of its past and future existence; and although we do not know the rate of going of this mysterious

chronometer, it is nevertheless certain, that since the breaking up of the parts of the milky way affords a proof that it cannot last for ever, it equally bears witness that its past duration cannot be admitted to be infinite.

From the Press of
W. BULMER & Co.
Cleveland-row, St. James's,
London.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

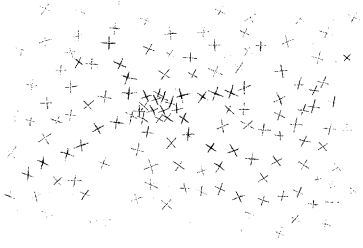

Fig. 14.

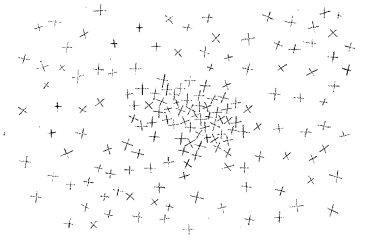

Fig. 15.

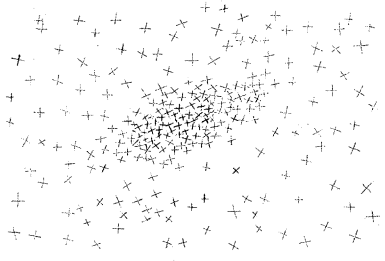

Fig. 16.

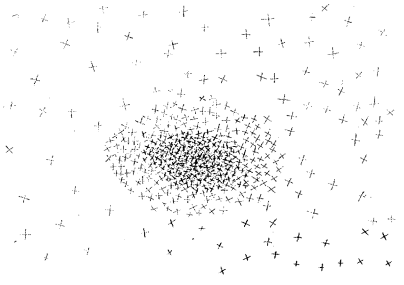

Fig. 17.