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On the Construction of the Heavens. By William Herschel, Esq. F. R. S.

William Herschel

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XII. *On the Conſtruction of the Heavens.*

By William Herſchel, *Eſq. F. R. S.*

Read February 3, 1785.

THE ſubject of the Conſtruction of the Heavens, on which I have ſo lately ventured to deliver my thoughts to this Society, is of ſo extenſive and important a nature, that we cannot exert too much attention in our endeavours to throw all poſſible light upon it; I ſhall, therefore, now attempt to purſue the delineations of which a faint outline was begun in my former paper.

By continuing to obſerve the heavens with my laſt conſtructed, and ſince that time much improved inſtrument, I am now enabled to bring more confirmation to ſeveral parts that were before but weakly ſupported, and alſo to offer a few ſtill further extended hints, ſuch as they preſent themſelves to my preſent view. But firſt let me mention that, if we would hope to make any progreſs in an inveſtigation of this delicate nature, we ought to avoid two oppoſite extremes, of which I can hardly ſay which is the moſt dangerous. If we indulge a fanciful imagination and build worlds of our own, we muſt not wonder at our going wide from the path of truth and nature; but theſe will vaniſh like the Carteſian vortices, that ſoon gave way when better theories were offered. On the other hand, if we add obſervation to obſervation, without attempting to draw not only certain concluſions, but alſo conjectural views

views from them, we offend againſt the very end for which only obſervations ought to be made. I will endeavour to keep a proper medium; but if I ſhould deviate from that, I could wiſh not to fall into the latter error.

That the milky way is a moſt extenſive ſtratum of ſtars of various ſizes admits no longer of the leaſt doubt; and that our ſun is actually one of the heavenly bodies belonging to it is as evident. I have now viewed and gaged this ſhining zone in almoſt every direction, and find it compoſed of ſtars whoſe number, by the account of theſe gages, conſtantly increaſes and decreaſes in proportion to its apparent brightneſs to the naked eye. But in order to develop the ideas of the univerſe, that have been ſuggeſted by my late obſervations, it will be beſt to take the ſubject from a point of view at a conſiderable diſtance both of ſpace and of time.

Theoretical view.

Let us then ſuppoſe numberleſs ſtars of various ſizes, ſcattered over an indefinite portion of ſpace in ſuch a manner as to be almoſt equally diſtributed throughout the whole. The laws of attraction, which no doubt extend to the remoteſt regions of the fixed ſtars, will operate in ſuch a manner as moſt probably to produce the following remarkable effects.

Formation of nebulæ.

Form I. In the firſt place, ſince we have ſuppoſed the ſtars to be of various ſizes, it will frequently happen that a ſtar, being conſiderably larger than its neighbouring ones, will attract them more than they will be attracted by others that are immediately

immediately around them; by which means they will be, in time, as it were, condenſed about a center; or, in other words, form themſelves into a cluſter of ſtars of almoſt a globular figure, more or leſs regularly ſo, according to the ſize and original diſtance of the ſurrounding ſtars. The perturbations of theſe mutual attractions muſt undoubtedly be very intricate, as we may eaſily comprehend by conſidering what Sir ISAAC NEWTON ſays in the firſt book of his Principia, in the 38th and following problems; but in order to apply this great author's reaſoning of bodies moving in ellipſes to ſuch as are here, for a while, ſuppoſed to have no other motion than what their mutual gravity has imparted to them, we muſt ſuppoſe the conjugate axes of theſe ellipſes indefinitely diminiſhed, whereby the ellipſes will become ſtraight lines.

Form II. The next caſe, which will alſo happen almoſt as frequently as the former, is where a few ſtars, though not ſuperior in ſize to the reſt, may chance to be rather nearer each other than the ſurrounding ones; for here alſo will be formed a prevailing attraction in the combined center of gravity of them all, which will occaſion the neighbouring ſtars to draw together; not indeed ſo as to form a regular or globular figure, but however in ſuch a manner as to be condenſed towards the common center of gravity of the whole irregular cluſter. And this conſtruction admits of the utmoſt variety of ſhapes, according to the number and ſituation of the ſtars which firſt gave riſe to the condenſation of the reſt.

Form III. From the compoſition and repeated conjunction of both the foregoing forms, a third may be derived, when many large ſtars, or combined ſmall ones, are ſituated in long extended, regular, or crooked rows, hooks, or branches; for they will alſo draw the ſurrounding ones, ſo as to produce figures

of

of condenſed ſtars coarſely ſimilar to the former which gave riſe to theſe condenſations.

Form IV. We may likewiſe admit of ſtill more extenſive combinations; when, at the ſame time that a cluſter of ſtars is forming in one part of ſpace, there may be another collecting in a different, but perhaps not far diſtant quarter, which may occaſion a mutual approach towards their common center of gravity.

V. In the laſt place, as a natural conſequence of the former caſes, there will be formed great cavities or vacancies by the retreat of the ſtars towards the various centers which attract them; ſo that upon the whole there is evidently a field of the greateſt variety for the mutual and combined attractions of the heavenly bodies to exert themſelves in. I ſhall, therefore, without extending myſelf farther upon this ſubject, proceed to a few conſiderations, that will naturally occur to every one who may view this ſubject in the light I have here done.

Objections conſidered.

At firſt ſight then it will ſeem as if a ſyſtem, ſuch as it has been diſplayed in the foregoing paragraphs, would evidently tend to a general deſtruction, by the ſhock of one ſtar's falling upon another. It would here be a ſufficient anſwer to ſay, that if obſervation ſhould prove this really to be the ſyſtem of the univerſe, there is no doubt but that the great Author of it has amply provided for the preſervation of the whole, though it ſhould not appear to us in what manner this is effected. But I ſhall moreover point out ſeveral circumſtances that do manifeſtly tend to a general preſervation; as, in the firſt place, the indefinite extent of the ſidereal heavens, which must produce a balance that will effectually secure all the great parts of the whole from approaching to each other. There remains then only to see how the particular stars belonging to separate clusters will be preserved from rushing on to their centers of attraction. And here I must observe, that though I have before, by way of rendering the case more simple, considered the stars as being originally at rest, I intended not to exclude projectile forces; and the admission of them will prove such a barrier against the seeming destructive power of attraction as to secure from it all the stars belonging to a cluster, if not for ever, at least for millions of ages. Besides, we ought perhaps to look upon such clusters, and the destruction of now and then a star, in some thousands of ages, as perhaps the very means by which the whole is preserved and renewed. These clusters may be the *Laboratories* of the universe, if I may so express myself, wherein the most salutary remedies for the decay of the whole are prepared.

Optical appearances.

From this theoretical view of the heavens, which has been taken, as we observed, from a point not less distant in time than in space, we will now retreat to our own retired station, in one of the planets attending a star in its great combination with numberless others; and in order to investigate what will be the appearances from this contracted situation, let us begin with the naked eye. The stars of the first magnitude being in all probability the nearest, will furnish us with a step to begin our scale; setting off, therefore, with the distance of Sirius or Arcturus, for instance, as unity, we will at present suppose, that those of the second magnitude are at double, and

those

those of the third at treble the diſtance, and ſo forth. It is not neceſſary critically to examine what quantity of light or magnitude of a ſtar intitles it to be eſtimated of ſuch or ſuch a proportional diſtance, as the common coarſe eſtimation will anſwer our preſent purpoſe as well; taking it then for granted, that a ſtar of the ſeventh magnitude is about ſeven times as far as one of the firſt, it follows, that an obſerver, who is incloſed in a globular cluſter of ſtars, and not far from the center, will never be able, with the naked eye, to ſee to the end of it: for, ſince, according to the above eſtimations, he can only extend his view to about ſeven times the diſtance of Sirius, it cannot be expected that his eyes ſhould reach the borders of a cluſter which has perhaps not leſs than fifty ſtars in depth every where around him. The whole univerſe, therefore, to him will be compriſed in a ſet of conſtellations, richly ornamented with ſcattered ſtars of all ſizes. Or if the united brightneſs of a neighbouring cluſter of ſtars ſhould, in a remarkable clear night, reach his ſight, it will put on the appearance of a ſmall, faint, whitiſh, nebulous cloud, not to be perceived without the greateſt attention. To paſs by other ſituations, let him be placed in a much extended ſtratum, or branching cluſter of millions of ſtars, ſuch as may fall under the III^d^ form of nebulæ conſidered in a foregoing paragraph. Here alſo the heavens will not only be richly ſcattered over with brilliant conſtellations, but a ſhining zone or milky way will be perceived to ſurround the whole ſphere of the heavens, owing to the combined light of thoſe ſtars which are too ſmall, that is, too remote to be ſeen. Our obſerver's ſight will be ſo confined, that he will imagine this ſingle collection of ſtars, of which he does not even perceive the thouſandth part, to be the whole contents of the heavens. Allowing him now the uſe of a

4 common

common telescope, he begins to suspect that all the milkiness of the bright path which surrounds the sphere may be owing to stars. He perceives a few clusters of them in various parts of the heavens, and finds also that there are a kind of nebulous patches; but still his views are not extended so far as to reach to the end of the stratum in which he is situated, so that he looks upon these patches as belonging to that system which to him seems to comprehend every celestial object. He now increases his power of vision, and, applying himself to a close observation, finds that the milky way is indeed no other than a collection of very small stars. He perceives that those objects which had been called nebulæ are evidently nothing but clusters of stars. He finds their number increase upon him, and when he resolves one nebula into stars he discovers ten new ones which he cannot resolve, He then forms the idea of immense strata of fixed stars, of clusters of stars and of nebulæ (*a*); till, going on with such interesting observations, he now perceives that all these appearances must naturally arise from the confined situation in which we are placed. *Confined* it may justly be called, though in no less a space than what before appeared to be the whole region of the fixed stars; but which now has assumed the shape of a crookedly branching nebula; not, indeed, one of the least, but perhaps very far from being the most considerable of those numberless clusters that enter into the construction of the heavens.

Result of Observations.

I shall now endeavour to shew, that the theoretical view of the system of the universe, which has been exposed in the

(*a*) See a former paper on the Construction of the Heavens.

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foregoing part of this paper, is perfectly consistent with facts, and seems to be confirmed and established by a series of observations. It will appear, that many hundreds of nebulæ of the first and second forms are actually to be seen in the heavens, and their places will hereafter be pointed out. Many of the third form will be described, and instances of the fourth related. A few of the cavities mentioned in the fifth will be particularised, though many more have already been observed; so that, upon the whole, I believe, it will be found, that the foregoing theoretical view, with all its consequential appearances, as seen by an eye inclosed in one of the nebulæ, is no other than a drawing from nature, wherein the features of the original have been closely copied; and I hope the resemblance will not be called a bad one, when it shall be considered how very limited must be the pencil of an inhabitant of so small and retired a portion of an indefinite system in attempting the picture of so unbounded an extent.

But to proceed to particulars: I shall begin by giving the following table of gages that have been taken. In the first column is the right ascension, and in the second the north polar distance, both reduced to the time of FLAMSTEED'S Catalogue. In the third are the contents of the heavens, being the result of the gages. The fourth shews from how many fields of view the gages were deduced, which have been ten or more where the number of the stars was not very considerable; but, as it would have taken too much time, in high numbers, to count so many fields, the gages are generally single. Where the stars happened to be uncommonly crouded, no more than half a field was counted, and even sometimes only a quadrant; but then it was always done with the precaution of fixing on some row of stars that would point out the division of the field,

so

ſo as to prevent any conſiderable miſtake. When five, ten, or more fields are gaged, the polar diſtance in the ſecond column of the table is that of the middle of the ſweep, which was generally from 2 to 2½ degrees in breadth; and, in gaging, a regular diſtribution of the fields, from the bottom of the ſweep to the top, was always ſtrictly attended to. The fifth column contains occaſional remarks relating to the gages.

I. Table of Star-Gages.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
0 1 41	78 47	9,9	10	
0 4 55	65 36	20,0	10	
0 7 54	74 13	11,3	10	Moſt of the ſtars extremely ſmall.
0 8 24	49 7	60	1	
0 9 52	113 17	4,1	10	* The gages marked with an aſteriſk
0 12 52	113 17	3,2	10	* are thoſe by which fig. 4. tab.
0 16 48	67 44	11,9	10	VIII. has been delineated.
0 21 52	113 17	3,9	10	*
0 22 21	87 10	5,9	10	
0 28 26	46 54	60	1	
0 31 38	46 54	40	1	
0 33 33	65 32	20,4	10	
0 34 22	56 38	20	1	
0 35 22	55 38	24	1	
0 36 39	76 32	11,3	10	
0 39 56	78 43	8,1	10	
0 40 29	48 43	60	½	
0 44 21	87 10	7,6	10	
0 46 22	69 51	11	10	
0 46 33	65 32	13	10	
0 48 42	58 47	40	1	
0 48 50	58 13	17	1	
0 53 18	67 41	9,8	10	A little hazy.
0 53 40	45 37	73	1	
0 54 10	75 16	13	1	

R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
0 55 10	73 16	14	1	
0 56 4	74 0	15	1	
0 57 52	113 17	3,8	10	*
0 59 10	74 25	14	1	
1 0 16	74 16	11,1	10	
1 1 10	74 5	11,2	10	
1 1 18	111 0	5,2	10	Very clear for this altitude.
1 2 52	52 0	28,1	10	Moſt of the ſtars very ſmall.
1 3 52	113 17	2,8	10	*
1 4 15	94 52	7,5	10	
1 4 33	65 32	11,0	10	
1 5 55	78 31	9,2	10	
1 7 27	45 23	58	1	
1 12 0	58 37	20	1	
1 12 48	60 19	13	1	
1 13 4	94 50	6,3	10	
1 15 51	48 40	30	1	
1 18 21	48 40	58	1	
1 23 21	48 40	44	1	
1 27 30	65 42	12,9	10	
1 31 21	87 7	5,8	10	
1 32 4	94 50	7,3	10	
1 33 10	100 8	6,4	10	
1 33 32	92 35	7,1	10	
1 34 52	60 8	17	1	
1 43 30	65 42	14,4	10	
1 45 24	69 43	7,1	10	
1 48 4	100 12	4,9	10	
1 54 24	76 28	12,1	10	
1 58 55	61 55	15,0	10	
2 4 28	87 5	6,4	10	
2 4 36	78 38	9,3	10	
2 7 12	94 56	7,8	10	
2 8 0	83 3	7,3	10	
2 10 4	100 12	4,3	10	

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
2 11 30	65 45	14,8	10	
2 16 27	110 54	4,2	10	*
2 19 27	76 24	9,9	10	
2 22 17	45 31	82	1	
2 23 6	60 16	14	1	
2 23 19	113 8	4,2	10	*
2 24 6	58 30	15	1	
2 27 40	115 21	3,0	10	* The ſituation too low for great accuracy.
2 30 0	94 56	6	10	
2 31 23	76 22	13,8	10	
2 35 14	87 2	5,6	10	
2 38 0	94 56	6,6	10	
2 42 7	61 50	14,8	10	
2 47 32	74 3	11,1	10	Moſt of the ſtars exceedingly ſmall.
2 49 22	92 55	9,0	10	
2 49 30	110 55	6,1	10	*
2 50 0	94 56	6,8	10	
2 54 53	76 22	9,2	10	
2 59 56	81 10	6,1	10	
3 1 53	78 37	4,1	10	
3 1 56	81 10	5,1	10	
3 4 53	78 37	3,5	10	
3 10 20	100 2	6,8	10	
3 11 6	59 29	7,0	5	In a part of the heavens which looks pretty full of ſtars to the naked eye.
3 13 6	59 29	6,1	10	
3 15 6	59 29	9,4	10	
3 22 57	83 1	10,3	10	
3 23 21	92 49	10,1	10	
3 29 41	46 35	55	1	
3 35 0	62 1	15	1	About 15 ſtars generally in the field.
3 35 12	100 3	7,4	10	
3 36 1	113 3	4,9	10	*
3 42 49	46 10	54	1	
3 48 16	99 59	8,1	10	
3 55 11	74 2	11,0	10	

R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
4 1 24	92 48	13,8	10	
4 6 18	82 57	13,4	10	
4 8 31	114 55	4,2	10	*
4 12 41	69 33	15,3	10	And many more, extremely ſmall,
4 16 34	112 45	6,2	10	* ſuſpected.
4 26 34	112 45	8,8	10	*
4 27 11	70 41	25	1	
4 28 41	70 1	17	1	
4 29 5	69 24	30	1	
4 30 14	99 50	9,7	10	
4 31 19	67 33	15,6	10	
4 32 29	69 2	36	1	
4 33 31	114 55	8,1	10	*
4 42 14	86 27	19,9	10	
4 53 22	72 59	56	1	
4 57 45	83 22	38	1	
4 58 45	84 36	35	1	
5 1 16	69 23	34	1	
5 3 45	83 29	17,7	6	
5 10 52	69 22	74	1	
5 11 22	96 37	24	1	
5 17 22	96 15	8,9	8	
5 18 0	80 46	30	1	About 30 ſtars in the field, not very
5 21 7	92 52	19,1	10	exactly gaged.
5 24 12	66 5	36	1	
5 27 3	68 52	58	1	
5 27 48	110 40	17,7	10	*
5 33 4	76 10	65	1	
5 33 12	66 26	86	1	
5 33 17	114 59	13,5	10	*
5 34 45	70 33	50	1	
5 36 30	62 1	20—30		From 20 to 30 ſtars in the fields, not
5 37 4	74 26	140	½	very exactly gaged.
5 38 45	70 8	73	1	
5 41 12	66 43	60	1	

R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
5 44 0	116 43	11,5	10	*
5 45 30	83 30	50	1	
5 47 34	112 34	19,3	10	*
5 48 30	62 1	30	1	About 30 stars in the field; not very
5 48 44	92 51	22,4	5	exactly gaged.
5 49 0	80 5	50	1	
5 52 14	93 14	44	1	
5 52 30	83 30	60	1	
5 53 0	80 5	110	1	
5 55 4	92 56	57	1	
5 56 40	70 27	73	1	
5 57 0	80 5	60	1	
5 57 37	110 33	19,6	10	*
5 58 51	88 36	90	1	
5 59 30	83 30	80	1	
6 0 23	86 38	24,1	10	
6 1 0	80 5	70	1	
6 4 0	80 5	90	1	
6 5 4	67 17	120	1/4	Very unequally scattered.
6 6 14	96 16	52	1	
6 6 30	83 30	80	1	
6 6 30	80 5	70	1	
6 6 38	91 45	54	1	Like the rest, or many such fields.
6 6 40	68 24	56	1	
6 9 0	80 5	74	1	
6 9 34	113 35	26	1	*
6 11 0	62 1	30—40	1	Between.
6 11 0	80 5	63	1	The least number of stars in the field I
6 11 34	112 5	33	1	* could find in this neighbourhood.
6 11 37	90 15		1	About 60 or 70 generally.
6 14 4	68 11	178	1/4	
6 14 38	90 15	77	1	
6 17 45	62 1	50	1	
6 18 14	96 12	38	1	Very unequally scattered.
6 19 14	93 59	72	1	

R.A.			P.D.		Stars.	Fields.	Memorandums.
H.	M.	S.	D.	M.			
6	26	17	114	59	15,9	10	
6	27	14	94	36	132	½	*
6	27	32	70	23	50	1	
6	31	48	115	40	40	1	
6	34	44	92	25	94	1	
6	34	55	79	5	50	1	Generally about 50 ſtars.
6	36	0	94	56	62	1	Twilight.
6	37	15	75	5	70	1	Generally about 70 ſtars.
6	39	8	99	7	50	1	*
6	40	0	116	43	31,3	10	
6	43	25	79	5	67	1	
6	44	28	100	30	67	1	*
6	49	5	87	21	120	½	*
6	49	30	77	31	50	1	Many fields like this.
6	49	44	92	33	120	½	
6	51	8	98	33	78	1	*
6	52	0	116	21	48	1	
6	52	25	79	5	60	1	About 60 ſtars.
6	52	44	92	59	98	1	
6	54	9	111	11	45	1	*
6	57	8	100	1	34	1	*
6	57	38	98	50	83	1	*
6	58	39	112	48	81	1	*
7	0	25	79	5	70	1	
7	4	0	92	3	102	1	*
7	4	38	98	59	70	1	*
7	5	9	111	11	70	1	*
7	8	9	112	15	62	1	*
7	12	8	100	5	118	½	*
7	15	38	98	12	112	½	*
7	19	0	91	51	58	1	*
7	20	0	78	59	48	1	
7	25	9	111	21	168	¼	* One of the richeſt fields.
7	28	9	112	34	204	¼	* A field like the reſt.
[illegible]	33	3	115	28	86	1	

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
7 41 9	113 26	108	½	*
7 53 4	86 39	28,3	10	*
8 1 4	111 15	80	1	*
8 3 4	113 31	66	1	
8 6 38	100 5	40	1	
8 7 38	99 3	45	1	*
8 11 8	99 25	24,2	10	*
8 12 34	112 15	52	1	*
8 22 4	111 30	35	1	*
8 31 4	112 1	33	1	
8 32 24	112 7	30	1	
8 35 4	112 17	24	1	
8 35 14	111 19	20	1	
8 40 4	111 11	22	1	*
8 45 4	113 22	13	1	
8 46 39	91 26	20,3	10	*
8 48 4	112 23	16,2	10	
8 57 25	66 20	8,3	10	*
9 5 38	91 22	13,8	10	*
9 10 4	115 17	14,0	10	
9 20 4	112 23	15,8	10	
9 20 40	99 12	11,1	10	
9 20 58	88 7	11,5	10	*
9 35 4	112 23	13,0	10	
9 38 4	115 17	10,1	10	
9 38 8	90 23	7,9	10	*
9 42 16	86 16	7,7	10	*
9 45 49	112 21	13,2	10	Strong twilight.
10 0 4	115 17	9,1	10	
10 16 8	88 8	7,2	10	*
10 19 32	91 14	6,5	10	
10 25 8	88 8	4,9	10	*
10 26 0	81 41	5,6	7	*
11 4 4	81 38	5,3	6	*
11 7 36	91 14	5,6	10	

 R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
11 10 6	115 23	6,5	10	Twilight.
11 16 52	81 38	3,1	8	*
11 20 37	91 17	4,9	10	
11 53 43	81 39	6,0	5	*
12 5 6	78 57	2,2	13	*
12 30 40	79 3	3,4	11	*
12 46 51	81 40	4,6	13	*
12 48 19	79 4	3,9	13	*
12 53 45	101 45	9,3	10	Twilight.
12 57 8	99 56	8,1	10	Pretty ſtrong day-light.
13 1 19	79 4	3,8	12	*
13 17 27	101 45	8,6	10	Twilight.
13 22 49	100 1	8,4	10	Some day-light.
13 27 57	101 45	11,3	10	
13 31 10	75 55	5—6	1	* Generally about 5 or 6 ſtars in the field.
13 38 53	104 27	8,5	10	
13 48 49	100 1	9,2	10	Strong twilight.
13 51 27	101 45	10,0	10	
13 55 44	58 11	7,4	10	* Twilight.
13 57 53	104 27	12,3	10	Moſt very ſmall.
14 9 49	100 1	11,2	10	Twilight.
14 13 52	113 4	9,7	10	
14 14 57	101 45	8,8	10	
14 24 49	81 53	2,7	6	
14 29 45	100 5	13,3	10	
14 30 7	66 3	8,8	10	* All ſizes.
14 30 8	80 38	3,5	13	
14 33 22	58 7	8,9	10	* Chiefly ſmall.
14 33 52	113 4	10,3	10	
14 39 57	101 45	14,0	10	All ſizes.
14 40 36	64 47	6,4	10	
14 44 11	114 54	10,3	10	
14 49 52	113 4	12,8	10	
14 51 14	58 10	9,2	10	* Twilight.
14 52 58	60 41	4,4	10	* Strong Aurora borealis.

R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
14 53 7	66 15	9,0	10	Chiefly large.
14 55 36	64 47	6,6	10	Most very small.
14 59 11	114 54	8,8	10	
15 2 42	62 48	8,3	10	
15 3 7	66 15	9,5	10	
15 4 36	64 47	5,0	10	
15 8 37	113 0	14,1	10	
15 8 45	93 5	9,4	12	Very small.
15 13 42	62 48	8,9	10	
15 15 44	58 17	10,0	10	* Twilight.
15 19 48	60 40	4,9	10	* Strong Aurora borealis, so as to affect the gages.
15 20 0	75 52	9,5	4	
15 21 0	93 5	10,9	12	
15 26 7	81 53	11,0	5	
15 28 48	99 51	13,1	10	
15 29 7	66 15	10,6	10	All sizes.
15 29 44	58 17	8,9	10	* Twilight.
15 32 0	75 51	6	6	
15 33 52	111 32	12,8	10	
15 35 0	75 51	6,5	6	
15 42 2	58 14	13,1	10	* Twilight.
15 42 3	116 56	18,6	10	
15 42 53	113 47	32,5	2	The stars too small for the gage.
15 46 30	93 5	10,8	12	
15 48 37	113 0	17,1	10	
15 48 46	63 4	12,4	10	
15 49 52	111 32	18,1	10	The situation so low that it requires attention to see the stars.
15 50 20	114 55	9,2	10	
15 57 3	116 56	7,2	10	
16 0 2	58 14	12,2	10	* Twilight.
16 0 3	116 56	6,1	10	
16 0 12	114 57	1,6	10	
16 3 12	114 57	2,0	10	
16 4 0	75 43	13	6	All sizes.
16 4 19	113 6	,5	10	Perfectly clear. See p. 256.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
16 4 46	63 4	12,0	10	Moſt ſmall.
16 4 52	99 57	14,6	10	Moon and twilight.
16 6 28	113 4	,7	10	Perfectly clear.
16 7 12	66 15	13,3	10	
16 8 6	115 1	3,8	6	
16 8 11	93 9	12,2	12	
16 8 16	116 48	11,6	10	
16 9 28	113 4	1,1	10	Perfectly clear. See p. 256.
16 11 28	113 4	1,4	10	The ſame.
16 13 28	113 4	1,8	10	*g* Serpentarii and 19 Scorpii viſible to the naked eye.
16 13 52	58 24	14,2	10	* Moſt ſmall.
16 14 42	63 7	15,1	10	Moſt very ſmall.
16 15 37	80 40	9,7	12	All ſizes.
16 17 28	113 4	4,7	10	
16 20 51	81 57	13,8	6	
16 23 0	73 43	24	1	
16 23 28	113 4	13,6	10	
16 24 11	93 9	13,6	12	Require attention to be ſeen.
16 25 7	80 40	14,6	13	
16 27 32	68 23	21,6	10	Twilight.
16 29 16	116 48	50,4	10	
16 30 37	80 40	34	1	
16 31 12	66 15	18,4	10	Strong twilight.
16 32 28	113 4	20,3	10	Moſt extremely ſmall.
16 32 52	58 24	15,6	10	* Moſt ſmall.
16 35 42	63 7	16,5	10	*
16 35 48	93 15	18,6	12	All ſizes.
16 38 12	66 15	20,1	10	Strong twilight.
16 38 45	107 57	19,9	10	Strong twilight.
16 40 51	113 14	41,1	8	
16 45 32	68 23	19,0	4	Hazy.
16 51 45	107 57	29,8	10	
16 52 22	66 26	16,6	10	Day-light pretty ſtrong.
16 55 42	63 7	26,6	10	* Strong twilight.
17 1 34	58 11	18,8	10	* Strong day light.

R.A.

R.A. H. M. S.	P.D. D. M.	Stars.	Fields.	Memorandums.
17 3 22	66 26	35	1	* Day-light too ſtrong for gaging.
17 6 36	98 38	13,7	10	Moſt ſmall, and more ſuſpected.
17 9 30	116 55	7,6	10	
17 9 32	68 23	32,3	10	
17 11 10	66 26	38	1	* Day-light pretty ſtrong.
17 13 24	63 21	32,8	10	* Strong day-light.
17 17 36	111 47	15,3	10	Moon and day-light.
17 25 7	108 5	23	10	
17 27 29	116 48	25	1	
17 28 32	68 23	42,2	5	* Twilight.
17 30 29	116 48	42	1	
17 33 29	116 48	52	1	Day-light very ſtrong.
17 34 36	98 38	18,5	10	Very ſtrong twilight.
17 39 34	120 0	84	1	Moſt large.
17 40 41	114 52	77	1	Day-light very ſtrong.
17 41 29	116 48	82	1	Day-light very ſtrong.
17 43 45	105 3	80	1	Flying clouds.
17 48 0	61 18	25,6	5	Moſt large.
17 50 4	56 16	27,2	10	Twilight.
17 50 7	108 5	59	1	Like the reſt in this part of the heaven.
17 52 7	108 5	118	1	Many ſuch fields juſt by.
17 52 17	98 43	7,6	10	
17 52 30	62 12	40	1	Moſt large.
17 52 32	68 19	54	1	* Strong day-light.
17 55 7	108 5	232	½	
17 55 15	106 6	112	1	Many ſuch fields.
17 55 38	112 54	112	½	
17 57 30	60 28	38	1	Moſt large.
17 58 37	103 24	35	1	
17 58 41	118 57	64	1	
17 58 49	122 17	17	1	
17 59 1	108 8	320	½	
17 59 19	104 24	68	1	
18 0 13	122 11	27	1	
18 3 49	120 42	19	1	

R.A.

R.A. H. M. S.	P.D. D. M.	Stars.	Fields.	Memorandums.
18 5 17	98 47	65	1	
18 6 37	90 36	9,4	10	Too ſoon for gaging, not having been long enough out in the dark.
18 7 4	62 14	40	1	Moſt large.
18 7 4	56 16	38,2	5	
18 7 37	103 25	88,0	3	
18 10 7	120 58	20	1	
18 10 52	61 8	78	1	Chiefly large.
18 11 49	104 6	170	½	
18 13 37	104 16	238	½	
18 13 52	93 11	2,0	7	
18 14 46	56 20	48	1	
18 15 28	92 42	3,4	7	
18 16 52	92 42	8,9	7	
18 18 40	92 42	13,8	7	
18 19 37	102 34	9,5	2	
18 20 7	103 18	19	1	
18 20 46	92 42	25,8	6	
18 21 1	103 55	22	1	
18 21 12	90 41	8,6	10	
18 21 31	103 36	24	1	
18 22 4	62 7	48	1	Large and ſmall.
18 22 4	56 16	39,6	5	
18 22 19	104 6	14	1	
18 22 37	103 45	30	1	
18 24 3	115 10	35	1	
18 24 4	109 35	35	1	Twilight.
18 24 7	102 31	30	1	
18 24 10	92 59	88	1	
18 24 43	103 39	25	1	
18 25 37	102 34	39	1	
18 26 17	98 3	111	1	
18 26 25	103 57	60	1	
18 26 47	97 43	250	1	
18 27 1	120 58	30	1	
18 27 55	120 44	32	1	

R.A.			P.D.		Stars.	Fields.	Memorandums.
H.	M.	S.	D.	M.			
18	28	7	102	51	13	1	Extremely ſmall.
18	28	8	91	44	39	1	Moſt ſmall.
18	28	25	103	9	20	1	Extremely ſmall.
18	28	37	122	25	12	1	
18	29	25	103	24	20	1	Extremely ſmall.
18	29	47	97	50	150	1	
18	29	49	121	39	24	1	
18	30	34	57	18	62	1	
18	31	10	92	42	13,7	7	
18	31	10	108	53	74	1	Twilight.
18	31	13	103	19	112	1	All ſizes.
18	31	17	97	53	188	½	Many more ſuſpected.
18	31	34	62	34	76	1	* Large and ſmall.
18	31	49	121	39	19,3	10	
18	33	4	108	43	88	1	Twilight.
18	33	7	103	53	146	½	
18	34	5	98	34	130	1	
18	34	47	71	53	78	1	*
18	34	58	60	41	80	1	Large and ſmall.
18	36	34	110	12	83	1	Twilight.
18	36	34	91	37	176	¼	
18	36	47	72	28	224	½	*
18	37	34	93	29	5	1	
18	38	1	104	14	118	½	
18	39	40	93	52	116	¼	
18	40	28	92	47	10	1	
18	40	47	71	48	236	¼	*
18	41	22	91	37	156	¼	
18	42	49	121	39	15,2	10	Very clear for this altitude.
18	43	17	72	8	368	¼	*
18	43	33	119	21	21	1	
18	44	34	112	43	53	1	
18	44	34	60	34	84	1	All ſizes.
18	47	32	91	14	328	¼	
18	48	4	110	12	83		

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
18 50 16	60 55	136	½	Many of them ſmall.
18 51 4	57 26	84	1	
18 51 32	108 26	36,8	5	Strong twilight.
18 52 49	115 30	26,2	5	
18 54 4	57 18	93	1	
18 54 8	91 14	328	¼	
18 54 55	104 23	180	½	
18 55 4	108 41	80	1	
18 55 16	62 31	206	½	
18 59 8	91 14	328	¼	
18 59 26	72 37	40	1	Too ſoon for gaging.
19 1 2	71 40	75	1	
19 1 34	56 47	127	1	Moonlight.
19 2 29	74 53	204	¼	* Twilight.
19 2 37	103 16	160	½	
19 2 49	121 39	14,1	10	
19 3 34	55 56	146	½	☽
19 6 34	61 8	196	½	And many ſmall beſides.
19 7 34	56 56	130	½	☽
19 7 52	57 59	116	½	
19 8 38	92 8	120	½	
19 9 37	109 1	60	1	
19 9 40	56 51	130	1	☽
19 12 59	75 21	58	1	*
19 13 50	59 59	256	¼	
19 13 52	59 29	158	½	
19 14 2	72 15	60	1	*
19 14 4	61 21	279	⅓	Too crowded for accuracy.
19 14 55	103 36	64	1	Changeable focus.
19 15 40	55 26	160	1	☽ bright.
19 16 50	60 43	296	¼	
19 16 59	73 23	56	1	*
19 17 44	108 12	50	1	
19 18 23	78 9	196	¼	*
19 18 28	61 21	279	⅓	

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
19 19 52	57 14	180	1/2	
19 19 56	108 12	55	1	
19 20 51	60 55	384	1/4	
19 21 1	78 47	472	1/4	*
19 21 34	55 17	208	1/2	D bright.
19 22 27	62 29	320	1/4	
19 24 36	56 49	224	1/4	
19 24 49	104 24	36	1	Changeable focus.
19 24 50	60 43	296	1/4	
19 24 53	113 51	18,3	10	
19 25 4	57 9	190	1/2	D bright.
19 25 16	64 18	280	1/4	
19 25 22	59 36	340	1/4	
19 25 37	103 50	55	1	Changeable focus.
19 27 36	72 34	424	1/4	* Too ſmall and too crowded to be cer-[tain of the number.
19 27 44	61 8	240	1/3	
19 28 1	103 30	45	1	Changeable focus.
19 28 6	56 49	288	1/4	
19 28 52	59 26	344	1/4	
19 28 52	56 47	186	1/2	D very bright.
19 29 46	65 10	34	1	
19 30 36	74 33	588	1/4	*
19 30 36	54 53	312	1/4	
19 31 33	92 34	62,2	5	*
19 32 9	109 44	23,8	10	
19 32 15	62 35	296	1/4	
19 33 4	55 34	212	1/2	D
19 33 7	103 12	50	1	Changeable focus.
19 33 14	61 8	240	1/3	
19 33 20	58 59	232	1/4	
19 34 51	115 44	14,1	10	
19 35 34	63 19	256	1/4	
19 36 6	54 57	384	1/4	
19 36 37	102 31	68	1	Changeable focus.
19 36 50	60 35	296	1/4	

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
19 40 33	63 0	296	¼	
19 40 46	59 12	192	¼	
19 40 48	74 33	588	¼	*
19 42 33	73 14	352	¼	*
19 43 30	57 23	130	½	☽
19 43 56	64 27	124	½	Moſt large.
19 45 36	77 58	140	½	* Faint ☽.
19 45 37	103 3	50	1	
19 46 21	73 14	352	¼	*
19 46 51	115 44	12,8	10	Strong twilight.
19 47 8	60 35	312	¼	
19 47 18	109 46	20,9	10	
19 47 22	57 38	312	¼	Very unequally ſcattered.
19 49 6	57 13	268	¼	
19 49 48	56 51	120	½	☽
19 50 5	92 39	39,2	5	* Moſt ſmall.
19 51 37	62 37	51	1	
19 52 0	57 15	220	½	☽
19 53 1	60 36	80	1	
19 53 28	63 40	52	½	
19 53 40	54 59	306	¼	
19 53 49	121 39	7,7	10	
19 54 0	55 12	160	½	☽
19 54 12	78 3	120	½	* Faint ☽.
19 54 22	59 58	136	¼	
19 55 7	62 41	48	1	
19 56 19	60 44	112	½	
19 56 22	57 17	192	¼	
19 57 19	62 34	45	1	
19 57 40	58 29	104	½	
19 59 49	62 37	41	1	
20 0 21	79 3	56	1	* Strong ☽.
20 0 24	55 12	184	½	☽
20 0 25	60 33	80	1	Moſt of the ſtars extremely ſmall.
20 0 51	115 44	12,2	10	Twilight.

R.A.			P.D.		Stars.	Fields.	Memorandums.
H.	M.	S.	D.	M.			
20	1	39	79	34	68	1	* Strong ☽.
20	5	26	56	34	46	1	☽
20	5	27	72	56	280	¼	
20	6	23	107	27	22,6	10	
20	6	43	62	32	75	1	Many ſmall.
20	8	26	56	27	47,4	5	☽
20	8	27	72	56	280	¼	
20	8	58	103	37	38	1	
20	9	6	109	40	24,2	5	
20	9	52	102	48	31	1	
20	12	22	58	14	76	½	
20	17	20	76	12	184	¼	Some twilight.
20	18	51	115	44	10,6	10	Twilight.
20	20	58	61	27	88	1	
20	21	36	71	28	104	½	Hazy.
20	22	56	56	27	66	1	☽
20	22	58	103	26	20	1	
20	24	51	115	44	9,3	10	Twilight.
20	25	58	103	26	22,8	10	Changeable focus.
20	25	59	67	27	248	¼	
20	26	1	92	44	30,8	5	*
20	26	46	109	37	16,7	10	Not clear.
20	26	49	121	39	7,7	10	A little hazy.
20	27	33	96	7	39	1	Moſt ſmall.
20	34	51	115	44	9,5	10	☽
20	35	53	61	20	142	½	
20	37	18	58	28	108	½	
20	37	34	97	6	26,6	10	*
20	38	1	92	44	28,2	5	*
20	39	42	66	37	78	½	
20	40	22	56	21	192	¼	
20	41	11	67	54	108	½	
20	41	56	74	33	116	½	
20	42	59	62	14	112	½	
20	43	1	70	29	76	1	

R.A.			P.D.		Stars.	Fields.	Memorandums.
H.	M.	S.	D.	M.			
20	43	30	54	47	260	¼	Moſt of the ſtars of the ſame ſize.
20	44	59	70	6	80	1	
20	47	13	60	46	120	½	
20	49	1	92	44	27,0	5	*
20	49	10	57	11	248	¼	Moſt of a ſize.
20	50	59	103	26	17,2	3	
20	51	23	68	30	70	1	
20	53	29	103	26	17,4	5	
20	54	1	107	47	10,3	10	
20	56	59	103	26	14,9	10	Moſt extremely ſmall.
20	57	55	61	25	64	1	Twilight.
20	59	1	92	44	21,4	5	*
21	1	6	96	43	40	1	* Moſt ſmall.
21	3	29	66	39	80	½	
21	3	53	73	9	55	1	
21	6	13	69	23	40	1	A little hazy.
21	6	55	103	32	11,1	10	
21	7	49	109	45	12,8	10	
21	7	59	64	58	110	½	
21	9	25	61	36	75	1	Strong twilight.
21	10	13	60	39	70	1	Strong twilight.
21	11	17	73	18	50	1	
21	11	42	96	13	25	1	*
21	12	1	92	44	16,4	5	
21	15	3	109	56	15,3	10	
21	16	43	59	7	76	½	
21	18	54	57	20	50	1	
21	20	18	96	43	24	1	*
21	21	0	107	49	8,1	10	
21	22	14	76	33	30,0	5	
21	25	31	92	44	8,0	5	
21	29	12	83	11	21,6	5	
21	30	58	78	57	18,9	10	
21	32	10	57	14	25	1	
21	33	1	92	44	15,4	5	Strong twilight.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
21 34 55	97 17	13,6	10	*
21 36 38	65 55	42	1	
21 38 20	65 38	60	1	
21 39 55	96 17	18	1	*
21 41 52	58 42	44	1	
21 43 22	109 55	11,5	10	*
21 45 4	59 39	52	1	
21 48 22	59 30	29	1	
21 51 52	58 56	61	1	
21 51 55	97 17	11,5	10	*
21 54 22	109 55	12,8	10	*
21 57 49	59 37	60	½	
21 58 4	75 7	33	1	
21 58 19	59 6	40	½	
21 58 43	58 34	32,6	5	☽
21 58 49	58 20	34	1	
22 2 25	60 9	42,6	5	
22 2 52	109 55	7,4	10	*
22 3 56	71 48	25,1	10	
22 7 22	109 55	8,9	10	*
22 10 28	75 2	26	1	
22 11 32	97 14	10,7	10	* Twilight.
22 11 35	65 48	26,6	5	
22 18 32	97 14	9,1	10	* Twilight.
22 20 35	109 58	8,3	10	*
22 20 55	78 54	11,7	10	Bright ☽.
22 27 41	95 4	8,1	10	
22 30 35	109 58	5,0	10	*
22 31 28	73 59	17,3	10	
22 33 6	76 52	16,5	10	
22 34 40	61 56	20,1	10	
22 35 35	109 58	7,1	10	*
22 36 49	71 57	18,5	10	
22 39 41	82 5	19	1	
22 40 5	65 48	21,3	10	

R.A.

R.A.	P.D.	Stars.	Fields.	Memorandums.
H. M. S.	D. M.			
22 43 55	60 9	26,7	10	Faint ☽
22 45 3	80 47	13,2	10	
22 45 30	58 38	17,2	10	☽
22 48 49	71 57	13,4	10	
22 52 9	78 43	8,2	10	☽
22 52 41	95 4	8,9	10	
22 55 40	71 54	11,6	10	
22 56 55	67 53	12,1	10	
22 58 19	78 42	9,2	10	☽
23 0 27	113 12	4,4	10	
23 0 30	58 38	18,7	10	☽
23 2 59	65 50	21,3	10	
23 5 35	109 58	7,3	10	☽
23 8 52	95 1	7,5	10	Moſt extremely ſmall.
23 10 4	64 55	26	1	
23 11 40	61 48	21,1	10	
23 12 40	71 54	11,9	10	
23 17 50	81 0	9,7	10	
23 23 58	69 48	12,1	10	
23 25 32	113 12	3,1	10	*
23 32 2	69 51	9,5	10	
23 33 20	79 45	10	1	
23 43 2	69 51	10,9	10	
23 44 47	45 24	50	1	
23 46 52	113 17	4,2	10	*
23 46 55	65 36	15,3	10	
23 59 21	87 10	5,6	10	
23 59 56	95 4	7,8	10	

P R O B L E M.

The stars being supposed to be nearly equally scattered, and their number, in a field of view of a known angular diameter, being given, to determine the length of the visual ray.

Here, the arrangement of the stars not being fixed upon, we must endeavour to find which way they may be placed so as to fill a given space most equally. Suppose a rectangular cone cut into frustula by many equidistant planes perpendicular to the axis; then, if one star be placed at the vertex, and another in the axis at the first intersection, six stars may be set around it so as to be equally distant from one another and from the central star. These positions being carried on in the same manner, we shall have every star within the cone surrounded by eight others, at an equal distance from that star taken as a center. Fig. 1. (tab. VIII.) contains four sections of such a cone distinguished by alternate shades, which will be sufficient to explain what sort of arrangement I would point out.

The series of the number of stars contained in the several sections will be 1 . 7 . 19 . 37 . 61 . 91 . &c. which continued to n terms, the sum of it, by the differential method, will be $na + n \cdot \frac{n-1}{2} d' + n \cdot \frac{n-1}{2} \cdot \frac{n-2}{3} d''$, &c.: where a is the first term d', d'', d''', &c. the 1st, 2d, and 3d differences. Then, since $a = 1$, $d' = 6$, $d'' = 6$, $d''' = 0$, the sum of the series will be n^3. Let S be the given number of stars; 1, the diameter of the base of the field of view; and B, the diameter of the base of the great rectangular cone; and, by trigonometry, we shall have $B = \frac{\text{Radius.}}{\text{Tang. } \frac{1}{2} \text{ field}}$. Now, since the field of view of a telefcope is a cone, we fhall have its folidity to that of the great cone of ftars, formed by the above conftruction as the fquare of the diameter of the bafe of the field of view, to the fquare of the diameter of the bafe of the great cone, the height of both being the fame; and the ftars in each cone being in the ratio of the folidity, as being equally fcattered (*b*), we have $n = \sqrt[3]{B^2S}$. And the length of the vifual ray $= n - 1$, which was to be determined.

(*b*) We ought to remark, that the periphery and bafe of the cone of the field of view, in gaging, would in all probability feldom fall exactly on fuch ftars as would produce a perfect equality of fituation between the ftars contained in the fmall and the great cone; and that, confequently, the folution of this problem, where we fuppofe the ftars of one cone to be to thofe of the other in the ratio of the folidity on account of their being equally fcattered, will not be ftrictly true. But it fhould be remembered, that in fmall numbers, where the different terminations of the fields would moft affect this folution, the ftars in view have always been afcertained from gages that were often repeated, and each of which confifted of no lefs than ten fields fucceffively taken, fo that the different deviations at the periphery and bafe of the cone would certainly compenfate each other fufficiently for the purpofe of this calculation. And that, on the other hand, in high gages, which could not have the advantage of being fo often repeated, thefe deviations would bear a much fmaller proportion to the great number of ftars in a field of view; and therefore, on this account, fuch gages may very juftly be admitted in a folution where practical truth rather than mathematical precifion is the end we have in view. It is moreover not to be fuppofed that we imagine the ftars to be actually arranged in this regular manner, and, returning therefore to our general hypothefis of their being equally fcattered, any one field of view promifcuoufly taken may, in this general fenfe, be fuppofed to contain a due proportion of them; fo that the principle on which this folution is founded may therefore be faid to be even more rigoroufly true than we have occafion to infift upon in an argument of this kind.

The

The same otherwise.

If a different arrangement of the ſtars ſhould be ſelected, ſuch as that in fig. 2. where one ſtar is at the vertex of a cone; three in the circumference of the firſt ſection, at an equal diſtance from the vertex and from each other; ſix in the circumference of the next ſection, with one in the axis or center; and ſo on, always placing three ſtars in a lower ſection in ſuch a manner as to form an equilateral pyramid with one above them: then we ſhall have every ſtar, which is ſufficiently within the cone, ſurrounded by twelve others at an equal diſtance from the central ſtar and from each other. And by the differential method, the ſum of the two ſeries equally continued, into which this cone may be reſolved, will be $2n^3 + 1\frac{1}{2}n^2 + \frac{1}{2}n$; where n ſtands for the number of terms in each ſeries. To find the angle which a line vx, paſſing from the vertex v over the ſtars v, n, h, l, &c. to x, at the outſide of the cone, makes with the axis; we have, by conſtruction, vs in fig. 3. repreſenting the planes of the firſt and ſecond ſections $=$ $2 \times \text{coſ.}30^\circ = \varphi$, to the radius ps, of the firſt ſection $= 1$. Hence it will be $\sqrt{\varphi^2 - 1} = vp = \frac{1}{2}vm$; or $vm = 2\sqrt{\varphi^2 - 1}$: and, by trigonometry, $\frac{R\varphi}{2\sqrt{\varphi^2-1}} = T$. Where T is the tangent of the required angle to the radius R (*c*); and putting $t =$ tangent of half

(*c*) In finding this angle we have ſuppoſed the cone to be generated by a revolving rectangular triangle of which the line vx, fig. 2. is the hypotenuſe; but the ſtars in the ſecond ſeries will occaſion the cone to be contained under a waving ſurface, wherefore the above ſuppoſition of the generation of the cone is not ſtrictly true; but then theſe waves are ſo inconſiderable, that, for the preſent purpoſe, they may ſafely be neglected in this calculation.

half the given field of view, it will be $\frac{T}{t} = B$, the baſe of the cone. And $\frac{\sqrt{\varphi^2 - 1}}{\varphi} = d$, will be an expreſſion for vp, in terms of vs, which is the mutual diſtance of the ſcattered ſtars. Then having $\frac{B^2S}{2} = n^3 + \frac{3}{4}n^2 + \frac{1}{4}n$, we may find n; whence $2dn - d$, the viſual ray, will be obtained.

The reſult of this arrangement gives a ſhorter ray than that of the former; but ſince the difference is not ſo conſiderable as very materially to affect the concluſions, I ſhall, on account of the greater convenience, make uſe of the firſt.

We inhabit the planet of a ſtar belonging to a Compound Nebula of the third form.

I ſhall now proceed to ſhew that the ſtupendous ſidereal ſyſtem we inhabit, this extenſive ſtratum and its ſecondary branch, conſiſting of many millions of ſtars, is, in all probability, *a detached Nebula.* In order to go upon grounds that ſeem to me to be capable of great certainty, they being no leſs than an actual ſurvey of the boundaries of our ſidereal ſyſtem, which I have plainly perceived, as far as I have yet gone round it, every where terminated, and in moſt places very narrowly too, it will be proper to ſhew the length of my ſounding line, if I may ſo call it, that it may appear whether it was ſufficiently long for the purpoſe.

In the moſt crowded part of the milky way I have had fields of view that contained no leſs than 588 ſtars (*d*), and theſe were continued for many minutes, ſo that in one quarter of an hour's time there paſſed no leſs than 116000 ſtars through the field of view

(*d*) See the table of Gages, p. 235.

view of my telescope (*e*). Now, if we compute the length of the visual ray by putting $S=588$, and the diameter of the field of view fifteen minutes, we shall find $n=\sqrt[3]{B^2S}=498$; so that it appears the length of what I have called my sounding line, or $n-1$, was probably not less than 497 times the distance of Sirius from the sun. The same gage calculated by the second arrangement of stars gives $\sqrt{\varphi^2-1}=1.41421$; $\frac{R\varphi}{2\sqrt{\varphi^2-1}}=$ tangent of 31° 28′ 55″,77; $\frac{T}{t}=B=280,69$; $\frac{\sqrt{\varphi^2-1}}{\varphi}=d=,81649$; $\frac{B^2S}{2}=23163409,7=n^3+\frac{3}{4}n^2+\frac{1}{4}n$; where $n=284,8$ nearly; and $2dn-1=464$, the visual ray.

It may seem inaccurate that we should found an argument on the stars being equally scattered, when in all probability there may not be two of them in the heavens, whose mutual distance shall be equal to that of any other two given stars; but it should be considered, that when we take all the stars collectively there will be a mean distance which may be assumed as the general one; and an argument founded on such a supposition will have in its favour the greatest probability of not being far short of truth. What will render the supposition of an equal distribution of the stars, with regard to the gages, still less exposed to objections is, that whenever the stars happened either to be uncommonly crowded or deficient in number, so as very sud-

(*e*) The breadth of my sweep was 2° 26′, to which must be added 15′ for two semi-diameters of the field. Then, putting $161=a$, the number of fields in 15 minutes of time; $,7854=b$, the proportion of a circle to 1, its circumscribed square; $\varphi=$ sine of 74° 22′, the polar distance of the middle of the sweep reduced to the present time; and $588=S$, the number of stars in a field of view, we have $\frac{a\varphi S}{b}=116076$ stars.

denly

denly to paſs over from one extreme to the other, the gages were reduced to other forms, ſuch as the border-gage, the diſtance-gage, &c. which terms, and the uſe of ſuch gages, I ſhall hereafter find an opportunity of explaining. And none of thoſe kinds of gages have been admitted in this table, which conſiſts only of ſuch as have been taken in places where the ſtars apparently ſeemed to be, in general, pretty evenly ſcattered; and to increaſe and decreaſe in number by a certain gradual progreſſion. Nor has any part of the heavens containing a cluſter of ſtars been put in the gages; and here I muſt obſerve, that the difference between a crowded place and a cluſter may eaſily be perceived by the arrangement as well as the ſize and mutual diſtance of the ſtars: for in a cluſter they are generally not only reſembling each other pretty nearly in ſize, but a certain uniformity of diſtance alſo takes place; they are more and more accumulated towards the center, and put on all the appearances which we ſhould naturally expect from a number of them collected into a group at a certain diſtance from us. On the other hand, the rich parts of the milky way, as well as thoſe in the diſtant broad part of the ſtratum, conſiſt of a mixture of ſtars of all poſſible ſizes, that are ſeemingly placed without any particular apparent order. Perhaps we might recollect, that a greater condenſation towards the center of our ſyſtem than towards the borders of it ſhould be taken into conſideration; but, with a nebula of the third form, containing ſuch various and extenſive combinations, as I have found to take place in ours, this circumſtance, which in one of the firſt form would be of conſiderable moment, may, I think, be ſafely neglected. However, I would not be underſtood to lay a greater ſtreſs on theſe and the following calculations than the principles on which they are founded will permit; and if here-

after

after we ſhall find reaſon, from experience and obſervation, to believe that there are parts of our ſyſtem where the ſtars are not ſcattered in the manner here ſuppoſed, we ought then to make proper exceptions.

But to return: if ſome other high gage be ſelected from the table, ſuch as 472 or 344, the length of the viſual ray will be found 461 and 415. And although, in conſequence of what has been ſaid, a certain degree of doubt may be left about the arrangement and ſcattering of the ſtars, yet when I recollect, that in thoſe parts of the milky way where theſe high gages were taken, the ſtars were neither ſo ſmall, nor ſo crowded, as they muſt have been on a ſuppoſition of a much farther continuance of them, when certainly a milky or nebulous appearance muſt have come on, I need not fear to have over-rated the extent of my viſual ray. And indeed every thing that can be ſaid to ſhorten it will only contract the limits of our nebula, as it has in moſt places been of ſufficient length to go far beyond the bounds of it. Thus, in the ſides of the ſtratum oppoſite to our ſituation in it, where the gages often run below 5, our nebula cannot extend to 100 times the diſtance of Sirius; and the ſame teleſcope, which could ſhew 588 ſtars in a field of view of 15 minutes, muſt certainly have preſented me alſo with the ſtars in theſe ſituations as well as the former, had they been there. If we ſhould anſwer this by obſerving that they might be at too great a diſtance to be perceived, it will be allowing that there muſt at leaſt be a vacancy amounting to the length of a viſual ray not ſhort of 400 times the diſtance of Sirius; and this is amply ſufficient to make our nebula a detached one. It is true, that it would not be conſiſtent confidently to affirm that we were on an iſland unleſs we had actually found ourſelves every where bounded by the

ocean,

ocean, and therefore I ſhall go no farther than the gages will authoriſe; but conſidering the little depth of the ſtratum in all thoſe places which have been actually gaged, to which muſt be added all the intermediate parts that have been viewed and found to be much like the reſt, there is but little room to expect a connection between our nebula and any of the neighbouring ones. I ought alſo to add, that a teleſcope with a much larger aperture than my preſent one, graſping together a greater quantity of light, and thereby enabling us to ſee farther into ſpace, will be the ſureſt means of compleating and eſtabliſhing the arguments that have been uſed: for if our nebula is not abſolutely a detached one, I am firmly perſuaded, that an inſtrument may be made large enough to diſcover the places where the ſtars continue onwards. A very bright milky nebuloſity muſt there undoubtedly come on, ſince the ſtars in a field of view will increaſe in the ratio of n^3, greater than that of the cube of the viſual ray. Thus, if 588 ſtars in a given field of view are to be ſeen by a ray of 497 times the diſtance of Sirius; when this is lengthened to 1000, which is but little more than double the former, the number of ſtars in the ſame field of view will be no leſs than 4774: for when the viſual ray r is given, the number S of ſtars will be $=\frac{n^3}{B^2}$; where $n=r+1$; and a teleſcope with a three-fold power of extending into ſpace, or with a ray of 1500, which, I think, may eaſily be conſtructed, will give us 16096 ſtars. Now, theſe would not be ſo cloſe but that a good power applied to ſuch an inſtrument might eaſily diſtinguiſh them; for they need not, if arranged in regular ſquares, approach nearer to each other than 6″,27; but what would produce the milky nebuloſity which I have mentioned is the numberleſs ſtars beyond them, which in one respect the visual ray might also be said to reach. To make this appear we must return to the naked eye, which, as we have before estimated, can only see the stars of the seventh magnitude so as to distinguish them; but it is nevertheless very evident that the united lustre of millions of stars, such as I suppose the nebula in Andromeda to be, will reach our sight in the shape of a very small, faint nebulosity; since the nebula of which I speak may easily be seen in a fine evening. In the same manner my present telescope, as I have argued, has not only a visual ray that will reach the stars at 497 times the distance of Sirius so as to distinguish them (and probably much farther), but also a power of shewing the united lustre of the accumulated stars that compose a milky nebulosity, at a distance far exceeding the former limits; so that from these considerations it appears again highly probable, that my present telescope, not shewing such a nebulosity in the milky way, goes already far beyond its extent: and consequently, much more would an instrument, such as I have mentioned, remove all doubt on the subject, both by shewing the stars in the continuation of the stratum, and by exposing a very strong milky nebulosity beyond them, that could no longer be mistaken for the dark ground of the heavens.

To these arguments, which rest on the firm basis of a series of observation, we may add the following considerations drawn from analogy. Among the great number of nebulæ which I have now already seen, amounting to more than 900, there are many which in all probability are equally extensive with that which we inhabit; and yet they are all separated from each other by very considerable intervals. Some indeed there are that seem to be double and treble; and though with most of these it may be, that they are at a very great distance from each

 other,

other, yet we allow that ſome ſuch conjunctions really are to be found; nor is this what we mean to exclude. But then theſe compound or double nebulæ, which are thoſe of the third and fourth forms, ſtill make a detached link in the great chain. It is alſo to be ſuppoſed, that there may ſtill be ſome thinly ſcattered ſolitary ſtars between the large interſtices of nebulæ, which, being ſituated ſo as to be nearly equally attracted by the ſeveral cluſters when they were forming, remain unaſſociated. And though we cannot expect to ſee theſe ſtars, on account of their vaſt diſtance, yet we may well preſume, that their number cannot be very conſiderable in compariſon to thoſe that are already drawn into ſyſtems; which conjecture is alſo abundantly confirmed in ſituations where the nebulæ are near enough to have their ſtars viſible; for they are all inſulated, and generally to be ſeen upon a very clear and pure ground, without any ſtar near them that might be ſuppoſed to belong to them. And though I have often ſeen them in beds of ſtars, yet from the ſize of theſe latter we may be certain, that they were much nearer to us than thoſe nebulæ, and belonged undoubtedly to our own ſyſtem.

Uſe of the gages.

A delineation of our nebula, by an application of the gages in the manner which has been propoſed to be done in my former paper, may now be attempted, and the following table is calculated for this purpoſe. It gives us the length of the viſual ray for any number of ſtars in the field of view contained in the third column of the foregoing table of gages from $\frac{1}{10}$ to 100000. If the number required is not to be found in the firſt column of this table, a proportional mean may be taken between the two nearest rays in the second column, without any material error, except in the few last numbers. The calculations of resolvable and milky nebulosity, at the end of the table, are founded, the first, on a supposition of the stars being so crowded as to have only a square second of space allowed them; the next assigning them only half a second square. However, we should consider that in all probability a very different accumulation of stars may take place in different nebulæ; by which means some of them may assume the milky appearance, though not near so far removed from us; while clusters of stars also may become resolvable nebulæ from the same cause. The distinctness of the instrument is here also concerned; and as telescopes with large apertures are not easily brought to a good figure, nebulous appearances of both sorts may probably come on much before the distance annexed to them in the table.

TABLE II.

Stars in the field	Visual ray.	Stars	Ray.	Stars.	Ray.	Stars.	Ray.	Stars.	Ray.
		31	186	71	245	210	352	700	527
0,1	27	32	188	72	246	220	358	800	551
0,2	34	33	190	73	247	230	363	900	573
0,3	39	34	192	74	249	240	368	1000	593
0,4	43	35	193	75	250	250	374	10000	1280
0,5	46	36	195	76	251	260	378	100000	2758
0,6	49	37	197	77	252	270	383		
0,7	52	38	199	78	253	280	388		
0,8	54	39	201	79	254	290	393		
0,9	56	40	202	80	255	300	397		
1	58	41	204	81	256	310	401		
2	74	42	206	82	257	320	406	636175 or resolvable nebulosity	5112
3	85	43	207	83	258	330	410		
4	93	44	209	84	259	340	414		
5	101	45	210	85	260	350	418		
6	107	46	212	86	261	360	422		
7	113	47	214	87	262	370	426		
8	118	48	215	88	263	380	430		
9	123	49	217	89	264	390	433		
10	127	50	218	90	265	400	437		
11	131	51	219	91	266	410	441		
12	135	52	221	92	267	420	444	2544700 or milky nebulosity	8115
13	139	53	222	93	268	430	448		
14	142	54	224	94	269	440	451		
15	146	55	225	95	270	450	455		
16	149	56	226	96	271	460	458		
17	152	57	228	97	272	470	461		
18	155	58	229	98	273	480	464		
19	158	59	230	99	274	490	468		
20	160	60	232	100	275	500	471		
21	163	61	233	110	284	510	474		
22	166	62	234	120	291	520	477		
23	168	63	236	130	300	530	480		
24	170	64	237	140	308	540	483		
25	173	65	238	150	315	550	486		
26	175	66	239	160	322	560	489		
27	177	67	240	170	328	570	492		
28	180	68	242	180	335	580	495		
29	182	69	243	190	341	590	498		
30	184	70	244	200	347	600	500		

Section

Section of our sidereal system.

By taking out of this table the visual rays which answer to the gages, and applying lines proportional to them around a point, according to their respective right ascensions and north polar distances, we may delineate a solid by means of the ends of these lines, which will give us so many points in its surface; I shall, however, content myself at present with a section only. I have taken one which passes through the poles of our system, and is at rectangles to the conjunction of the branches which I have called its length. The name of poles seemed to me not improperly applied to those points which are 90 degrees distant from a circle passing along the milky way, and the north pole is here assumed to be situated in R.A. 186° and P.D. 58°. The section represented in fig. 4. is one which makes an angle of 35 degrees with our equator, crossing it in 124½ and 304½ degrees. A celestial globe, adjusted to the latitude of 55° north, and having σ Ceti near the meridian, will have the plane of this section pointed out by the horizon, and the gages which have been used in this delineation are those which in table I. are marked by asterisks. When the visual rays answering to them are taken out of the second table, they must be projected on the plane of the horizon of the latitude which has been pointed out; and this may be done accurately enough for the present purpose by a globe adjusted as above directed; for as gages, exactly in the plane of the section, were often wanting, I have used many at some small distance above and below the same, for the sake of obtaining more delineating points; and in the figure the stars at the borders which are larger than the rest are those pointed out by the gages. The intermediate parts are filled up by ſmaller ſtars arranged in ſtraight lines between the gaged ones. The delineating points, though pretty numerous, are not ſo cloſe as we might wiſh; it is however to be hoped that in ſome future time this branch of aſtronomy will become more cultivated, ſo that we may have gages for every quarter of a degree of the heavens at leaſt, and theſe often repeated in the moſt favourable circumſtances. And whenever that ſhall be the caſe, the delineations may then be repeated with all the accuracy that long experience may enable us to introduce; for, this ſubject being ſo new, I look upon what is here given partly as only an example to illuſtrate the ſpirit of the method. From this figure however, which I hope is not a very inaccurate one, we may ſee that our nebula, as we obſerved before, is of the third form; that is: *A very extenſive, branching, compound Congeries of many millions of ſtars*; which moſt probably owes its origin to many remarkably large as well as pretty cloſely ſcattered ſmall ſtars, that may have drawn together the reſt. Now, to have ſome idea of the wonderful extent of this ſyſtem, I muſt obſerve that this ſection of it is drawn upon a ſcale where the diſtance of Sirius is no more than the 80th part of an inch; ſo that probably all the ſtars, which in the fineſt nights we are able to diſtinguiſh with the naked eye, may be comprehended within a ſphere, drawn round the large ſtar near the middle, repreſenting our ſituation in the nebula, of leſs than half a quarter of an inch radius.

The Origin of nebulous Strata.

If it were poſſible to diſtinguiſh between the parts of an indefinitely extended whole, the nebula we inhabit might be ſaid

ſaid to be one that has fewer marks of profound antiquity upon it than the reſt. To explain this idea perhaps more clearly, we ſhould recollect that the condenſation of cluſters of ſtars has been aſcribed to a gradual approach; and whoever reflects on the numbers of ages that muſt have paſt before ſome of the cluſters, that will be found in my intended catalogue of them, could be ſo far condenſed as we find them at preſent, will not wonder if I aſcribe a certain air of youth and vigour to many very regularly ſcattered regions of our ſidereal ſtratum. There are moreover many places in it where there is the greateſt reaſon to believe that the ſtars, if we may judge from appearances, are now drawing towards various ſecondary centers, and will in time ſeparate into different cluſters, ſo as to occaſion many ſub-diviſions. Hence we may ſurmiſe that when a nebulous ſtratum conſiſts chiefly of nebulæ of the firſt and ſecond form, it probably owes its origin to what may be called the decay of a great compound nebula of the third form; and that the ſub-diviſions, which happened to it in length of time, occaſioned all the ſmall nebulæ which ſprung from it to lie in a certain range, according as they were detached from the primary one. In like manner our ſyſtem, after numbers of ages, may very poſſibly become divided ſo as to give riſe to a ſtratum of two or three hundred nebulæ; for it would not be difficult to point out ſo many beginning or gathering cluſters in it (*f*). This view of the preſent ſubject throws a conſiderable light upon the appearance of that remarkable collection of many

(*f*) Mr. Michell has alſo conſidered the ſtars as gathered together into groups (Phil. Tranſ. vol. LVII. p. 249.); which idea agrees with the ſub-diviſion of our great ſyſtem here pointed out. He founds an elegant proof of this on the computation of probabilities, and mentions the Pleiades, the Præſepe Cancri, and the nebula (or cluſter of ſtars) in the hilt of Perſeus's ſword, as inſtances.

hundreds

hundreds of nebulæ which are to be ſeen in what I have called the nebulous ſtratum of Coma Berenices. It appears from the extended and branching figure of our nebula, that there is room for the decompoſed ſmall nebulæ of a large, reduced, former great one to approach nearer to us in the ſides than in other parts. Nay, poſſibly, there might originally be another very large joining branch, which in time became ſeparated by the condenſation of the ſtars; and this may be the reaſon of the little remaining breadth of our ſyſtem in that very place: for the nebulæ of the ſtratum of the Coma are brighteſt and moſt crowded juſt oppoſite our ſituation, or in the pole of our ſyſtem. As ſoon as this idea was ſuggeſted, I tried alſo the oppoſite pole, where accordingly I have met with a great number of nebulæ, though under a much more ſcattered form.

An Opening in the heavens.

Some parts of our ſyſtem indeed ſeem already to have ſuſtained greater ravages of time than others, if this way of expreſſing myſelf may be allowed; for inſtance, in the body of the Scorpion is an opening, or hole, which is probably owing to this cauſe. I found it while I was gaging in the parallel from 112 to 114 degrees of north polar diſtance. As I approached the milky way, the gages had been gradually running up from 9,7 to 17,1; when, all of a ſudden, they fell down to nothing, a very few pretty large ſtars excepted, which made them ſhew 0,5, 0,7, 1,1, 1,4, 1,8; after which they again roſe to 4,7, 13,5, 20,3, and ſoon after to 41,1. This opening is at leaſt 4 degrees broad, but its height I have not yet aſcertained. It is remarkable, that the 80 *Nebuleuſe ſans étoiles* of the *Connoiſſance des Temps*, which is one of the richeſt and moſt compreſſed

preſſed cluſters of ſmall ſtars I remember to have ſeen, is ſituated juſt on the weſtern border of it, and would almoſt authoriſe a ſuſpicion that the ſtars, of which it is compoſed, were collected from that place, and had left the vacancy. What adds not a little to this ſurmiſe is, that the ſame phænomenon is once more repeated with the fourth cluſter of ſtars of the *Connoiſſance des Temps*; which is alſo on the weſtern border of another vacancy, and has moreover a ſmall, miniature cluſter, or eaſily reſolvable nebula of about $2\frac{1}{2}$ minutes in diameter, north following it, at no very great diſtance.

Phænomena at the Poles of our Nebula.

I ought to obſerve, that there is a remarkable purity or clearneſs in the heavens when we look out of our ſtratum at the ſides; that is, towards Leo, Virgo, and Coma Berenices, on one hand, and towards Cetus on the other; whereas the ground of the heavens becomes troubled as we approach towards the length or height of it. It was a good while before I could trace the cauſe of theſe phænomena; but ſince I have been acquainted with the ſhape of our ſyſtem, it is plain that theſe troubled appearances, when we approach to the ſides, are eaſily to be explained by aſcribing them to ſome of the diſtant, ſtraggling ſtars, that yield hardly light enough to be diſtinguiſhed. And I have, indeed, often experienced this to be actually the cauſe, by examining theſe troubled ſpots for a long while together, when, at laſt, I generally perceived the ſtars which occaſioned them. But when we look towards the poles of our ſyſtem, where the viſual ray does not graze along the ſide, the ſtraggling ſtars of courſe will be very few in number; and therefore the ground of the heavens will aſſume that purity which I have always obſerved to take place in thoſe regions.

Enumeration of very compound Nebulæ or Milky-Ways.

As we are uſed to call the appearance of the heavens, where it is ſurrounded with a bright zone, the Milky-Way, it may not be amiſs to point out ſome other very remarkable Nebulæ which cannot well be leſs, but are probably much larger than our own ſyſtem; and, being alſo extended, the inhabitants of the planets that attend the ſtars which compoſe them muſt likewiſe perceive the ſame phænomena. For which reaſon they may alſo be called milky-ways, by way of diſtinction.

My opinion of their ſize is grounded on the following obſervations. There are many round nebulæ, of the firſt form, of about five or ſix minutes in diameter, the ſtars of which I can ſee very diſtinctly; and on comparing them with the viſual ray calculated from ſome of my long gages, I ſuppoſe, by the appearance of the ſmall ſtars in thoſe gages, that the centers of theſe round nebulæ may be 600 times the diſtance of Sirius from us.

In eſtimating the diſtance of ſuch cluſters I conſulted rather the comparatively apparent ſize of the ſtars than their mutual diſtance; for the condenſation in theſe cluſters being probably much greater than in our own ſyſtem, if we were to overlook this circumſtance and calculate by their apparent compreſſion, where, in about ſix minutes diameter, there are perhaps ten or more ſtars in the line of meaſures, we ſhould find, that on the ſuppoſition of an equal ſcattering of the ſtars throughout all nebulæ, the diſtance of the center of ſuch a cluſter from us could not be leſs than 6000 times the diſtance of of Sirius. And, perhaps, in putting it, by the apparent size of the stars, at 600 only, I may have considerably under-rated it; but my argument, if that should be the case, will be so much the stronger. Now to proceed,

Some of these round nebulæ have others near them, perfectly similar in form, colour, and the distribution of stars, but of only half the diameter: and the stars in them seem to be doubly crowded, and only at about half the distance from each other: they are indeed so small as not to be visible without the utmost attention. I suppose these miniature nebulæ to be at double the distance of the first. An instance, equally remarkable and instructive, is a case where, in the neighbourhood of two such nebulæ as have been mentioned, I met with a third, similar, resolvable, but much smaller and fainter nebula. The stars of it are no longer to be perceived; but a resemblance of colour with the former two, and its diminished size and light, may well permit us to place it at full twice the distance of the second, or about four or five times that of the first. And yet the nebulosity is not of the milky kind; nor is it so much as difficultly resolvable, or colourless. Now, in a few of the extended nebulæ, the light changes gradually so as from the resolvable to approach to the milky kind; which appears to me an indication that the milky light of nebulæ is owing to their much greater distance. A nebula, therefore, whose light is perfectly milky, cannot well be supposed to be at less than six or eight thousand times the distance of Sirius; and though the numbers here assumed are not to be taken otherwise than as very coarse estimates, yet an extended nebula, which in an oblique situation, where it is possibly fore-shortened by one-half, two-thirds, or three-fourths of its length, subtends a degree or more in diameter, cannot be otherwife than of a wonderful magnitude, and may well outvie our milky-way in grandeur.

The firft I fhall mention is a milky Ray of more than a degree in length. It takes *k* (FL. 52.) Cygni into its extent, to the north of which it is crookedly bent fo as to be convex towards the following fide; and the light of it is pretty intenfe. To the fouth of *k* it is more diffufed, lefs bright, and lofes itfelf with fome extenfion in two branches, I believe; but for want of light I could not determine this circumftance. The northern half is near two minutes broad, but the fouthern is not fufficiently defined to afcertain its breadth.

The next is an extremely faint milky Ray, above ¾ degree long, and 8 or 10′ broad; extended from north preceding to fouth following. It makes an angle of about 30 or 40 degrees with the meridian, and contains three or four places that are brighter than the reft. The ftars of the Galaxy are fcattered over it in the fame manner as over the reft of the heavens. It follows ε Cygni 11,5 minutes in time, and is 2° 19′ more fouth.

The third is a branching Nebulofity of about a degree and a half in right afcenfion, and about 48′ extent in polar diftance. The following part of it is divided into feveral ftreams and windings, which, after feparating, meet each other again towards the fouth. It precedes ζ Cygni 16′ in time, and is 1° 16′ more north. I fuppofe this to be joined to the preceding one; but having obferved them in different fweeps, there was no opportunity of tracing their connection.

The fourth is a faint, extended milky Ray of about 17′ in length, and 12′ in breadth. It is brighteft and broadeft in the middle, and the ends lofe themfelves. It has a fmall, round, very faint nebula juft north of it; and alfo, in another place, a fpot, brighter than the reft, almoft detached enough to form

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a different nebula, but probably belonging to the great one. The Ray precedes α Trianguli 18′,8 in time, and is 55′ more north. Another obſervation of the ſame, in a finer evening, mentions its extending much farther towards the ſouth, and that the breadth of it probably is not leſs than half a degree; but being ſhaded away by imperceptible gradations, it is difficult exactly to aſſign its limits.

The fifth is a Streak of light about 27′ long, and in the brighteſt part 3 or 4′ broad. The extent is nearly in the meridian, or a little from ſouth preceding to north following. It follows β Ceti 5′,9 in time, and is 2° 43′ more ſouth. The ſituation is ſo low, that it would probably appear of a much greater extent in a higher altitude.

The ſixth is an extenſive milky Nebuloſity divided into two parts; the moſt north being the ſtrongeſt. Its extent exceeds 15′; the ſouthern part is followed by a parcel of ſtars which I ſuppoſe to be the 8th of the *Connoiſſance des Temps*.

The ſeventh is a wonderful, extenſive Nebuloſity of the milky kind. There are ſeveral ſtars viſible in it, but they can have no connection with that nebuloſity, and are, doubtleſs, belonging to our own ſyſtem ſcattered before it. It is the 17th of the *Connoiſſance des Temps*.

In the liſt of theſe muſt alſo be reckoned the beautiful Nebula of Orion. Its extent is much above one degree; the eaſtern branch paſſes between two very ſmall ſtars, and runs on till it meets a very bright one. Cloſe to the four ſmall ſtars, which can have no connection with the nebula, is a total blackneſs; and within the open part, towards the north-eaſt, is a diſtinct, ſmall, faint nebula, of an extended ſhape, at a diſtance from the border of the great one, to which it runs in a parallel

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direction, resembling the shoals that are seen near the coasts of some islands.

The ninth is that in the girdle of Andromeda, which is undoubtedly the nearest of all the great nebulæ; its extent is above a degree and a half in length, and, in even one of the narrowest places, not less than 16′ in breadth. The brightest part of it approaches to the resolvable nebulosity, and begins to shew a faint red colour; which, from many observations on the colour and magnitude of nebulæ, I believe to be an indication that its distance in this coloured part does not exceed 2000 times the distance of Sirius. There is a very considerable, broad, pretty faint, small nebula near it; my Sister discovered it August 27, 1783, with a Newtonian 2-feet sweeper. It shews the same faint colour with the great one, and is, no doubt, in the neighbourhood of it. It is not the 32d of the *Connoissance des Temps*; which is a pretty large round nebula, much condensed in the middle, and south following the great one; but this is about two-thirds of a degree north preceding it, in a line parallel to β and ν Andromedæ.

To these may be added the nebula in Vulpecula: for, though its appearance is not large, it is probably a double stratum of stars of a very great extent, one end whereof is turned towards us. That it is thus situated may be surmised from its containing, in different parts, nearly all the three nebulosities; *viz.* the resolvable, the coloured but irresolvable, and a tincture of the milky kind. Now, what great length must be required to produce these effects may easily be conceived when, in all probability, our whole system, of about 800 stars in diameter, if it were seen at such a distance that one end of it might assume the resolvable nebulosity, would not, at the other end, present

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us with the irresolvable, much less with the colourless and milky sort of nebulosities.

A Perforated Nebula, or Ring of Stars.

Among the curiosities of the heavens should be placed a nebula, that has a regular, concentric, dark spot in the middle, and is probably a Ring of stars. It is of an oval shape, the shorter axis being to the longer as about 83 to 100; so that, if the stars form a circle, its inclination to a line drawn from the sun to the center of this nebula must be about 56 degrees. The light is of the resolvable kind, and in the northern side three very faint stars may be seen, as also one or two in the southern part. The vertices of the longer axis seem less bright and not so well defined as the rest. There are several small stars very near, but none that seem to belong to it. It is the 57th of the *Connoissance des Temps*. Fig. 5. is a representation of it.

Planetary Nebulæ.

I shall conclude this paper with an account of a few heavenly bodies, that from their singular appearance leave me almost in doubt where to class them.

The first precedes ν Aquarii 5′,4 in time, and is 1′ more north. Its place, with regard to a small star Sept. 7, 1782, was, Distance 8′ 13″ 51‴; but on account of the low situation, and other unfavourable circumstances, the measure cannot be very exact. August 25, 1783, Distance 7′ 5″ 11‴, very exact, and to my satisfaction; the light being thrown in by an opaque-microscopic-illumination (*g*). Sept. 20, 1783, Position 41° 24′ south

(*g*) It may be of use to explain this kind of illumination for which the Newtonian reflector is admirably constructed. On the side opposite the eye-piece an opening is to be made in the tube, through which the light may be thrown in, so as to fall on some reflecting body, or concave perforated mirror, within the eye-piece, ſouth preceding the ſame ſtar; very exact, and by the ſame kind of illumination. Oct. 17, 1783, Diſtance 6′ 55″ 7‴; a ſecond meaſure 6′ 56″ 11‴, as exact as poſſible. Oct. 23, 1783, Poſition 42° 57′; a ſecond meaſure 42° 45′; ſingle lens; power 71; opaque-microſcopic-illumination. Nov. 14, 1783, Diſtance 7′ 4″ 35‴. Nov. 12, 1784, Diſtance 7′ 22″ 35‴; Poſition 38° 39′. Its diameter is about 10 or 15″. I have examined it with the powers of 71, 227, 278, 460, and 932; and it follows the laws of magnifying, ſo that its body is no illuſion of light. It is a little oval, and in the 7-feet reflector pretty well defined, but not ſharp on the edges. In the 20-feet, of 18,7 inch aperture, it is much better defined, and has much of a planetary appearance, being all over of an uniform brightneſs, in which it differs from nebulæ: its light ſeems however to be of the ſtarry nature, which ſuffers not nearly ſo much as the planetary diſks are known to do, when much magnified.

The ſecond of theſe bodies precedes the 13th of FLAMSTEED's Andromeda about 1′6 in time, and is 22′ more ſouth. It has a round, bright, pretty well defined planetary diſk of about 12″ diameter, and is a little elliptical. When it is viewed with a 7-feet reflector, or other inferior inſtruments, it is not nearly ſo well defined as with the 20-feet. Its ſituation with regard to a pretty conſiderable ſtar is, Diſtance (with a compound glaſs of a low power) 7′ 51″ 34‴. Poſition 12° 0′ ſ. preceding. Diameter taken with 278, 14″ 42‴.

The third follows B (FL. 44.) Ophiuchi 4′,1 in time, and is 23′ more north. It is round, tolerably well defined, and pretty bright; its diameter is about 30″.

piece, that may throw it back upon the wires. By this means none of the direct rays can reach the eye, and thoſe few which are reflected again from the wires do not interfere ſenſibly with the fainteſt objects, which may thus be ſeen undiſturbed.

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The fourth follows η Sagittæ 17′,1 in time, and is 2′ more north. It is perfectly round, pretty bright, and pretty well defined; about ¾ min. in diameter.

The fifth follows the 21ſt Vulpeculæ 2′,1 in time, and is 1° 46′ more north. It is exactly round, of an equal light throughout, but pretty faint, and about 1′ in diameter.

The ſixth precedes *h* (Fl. 39) Cygni 8′,1 in time, and is 1° 26′ more ſouth. It is perfectly round, and of an equal light, but pretty faint; its diameter is near 1′, and the edges are pretty well defined.

The planetary appearance of the two firſt is ſo remarkable, that we can hardly ſuppoſe them to be nebulæ; their light is ſo uniform, as well as vivid, the diameters ſo ſmall and well defined, as to make it almoſt improbable they ſhould belong to that ſpecies of bodies. On the other hand, the effect of different powers ſeems to be much againſt their light's being of a planetary nature, ſince it preſerves its brightneſs nearly in the ſame manner as the ſtars do in ſimilar trials. If we would ſuppoſe them to be ſingle ſtars with large diameters we ſhall find it difficult to account for their not being brighter; unleſs we ſhould admit that the intrinſic light of ſome ſtars may be very much inferior to that of the generality, which however can hardly be imagined to extend to ſuch a degree. We might ſuſpect them to be comets about their aphelion, if the brightneſs as well as magnitude of the diameters did not oppoſe this idea; ſo that after all, we can hardly find any hypotheſis ſo probable as that of their being Nebulæ; but then they muſt conſiſt of ſtars that are compreſſed and accumulated in the higheſt degree. If it were not perhaps too hazardous to purſue a former ſurmiſe of a renewal in what I figuratively called the Laboratories of the univerſe, the ſtars forming theſe extraordinary nebulæ, by ſome decay or waſte of nature, being no longer fit

fit for their former purposes, and having their projectile forces, if any such they had, retarded in each others atmosphere, may rush at last together, and either in succession, or by one general tremendous shock, unite into a new body. Perhaps the extraordinary and sudden blaze of a new star in Cassiopea's chair, in 1572, might possibly be of such a nature. But lest I should be led too far from the path of observation, to which I am resolved to limit myself, I shall only point out a considerable use that may be made of these curious bodies. If a little attention to them should prove that, having no annual parallax, they belong most probably to the class of nebulæ, they may then be expected to keep their situation better than any one of the stars belonging to our system, on account of their being probably at a very great distance. Now to have a fixed point somewhere in the heavens, to which the motions of the rest may be referred, is certainly of considerable consequence in Astronomy; and both these bodies are bright and small enough to answer that end (*b*).

Datchet near Windsor,
January 1, 1785.

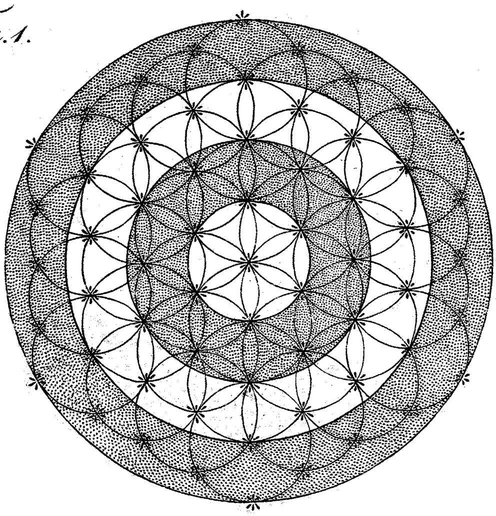
W. HERSCHEL.

(*b*) Having found two more of these curious objects, I add the place of them here, in hopes that those who have fixed instruments may be induced to take an early opportunity of observing them carefully.

Feb. 1, 1785. A very bright, planetary nebula, about half a minute in diameter, but the edges are not very well defined. It is perfectly round, or perhaps a very little elliptical, and all over of an uniform brightness: with higher powers it becomes proportionally magnified. It follows γ Eridani 16′ 16″ in time, and is 49′ more north than that star.

Feb. 7, 1785. A beautiful, very brilliant globe of light; a little hazy on the edges, but the haziness goes off very suddenly, so as not to exceed the 20th part of the diameter, which I suppose to be from 30 to 40″. It is round, or perhaps a very little elliptical, and all over of an uniform brightness: I suppose the intensity of its light to be equal to that of a star of the ninth magnitude. It precedes the third *b* (FL. 6.) Crateris 28′ 36″ in time, and is 1° 25′ more north than that star.

Fig. 1.



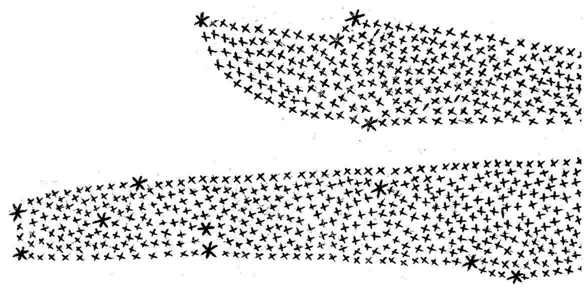
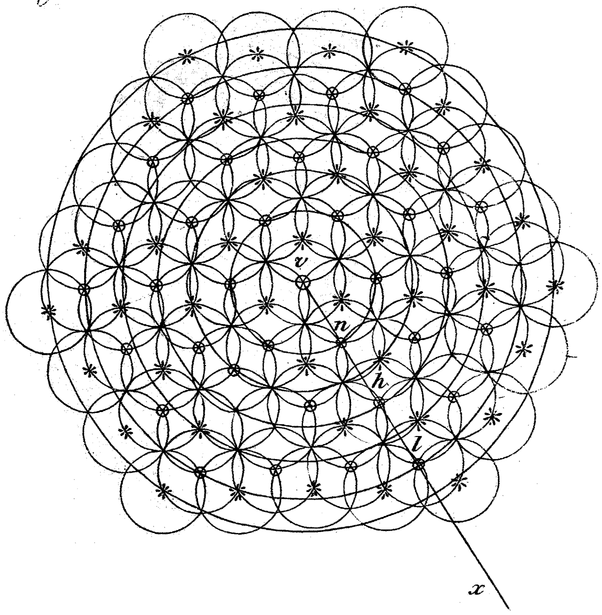


Fig. 2.



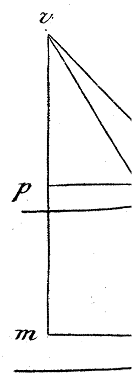


Fig. 4.

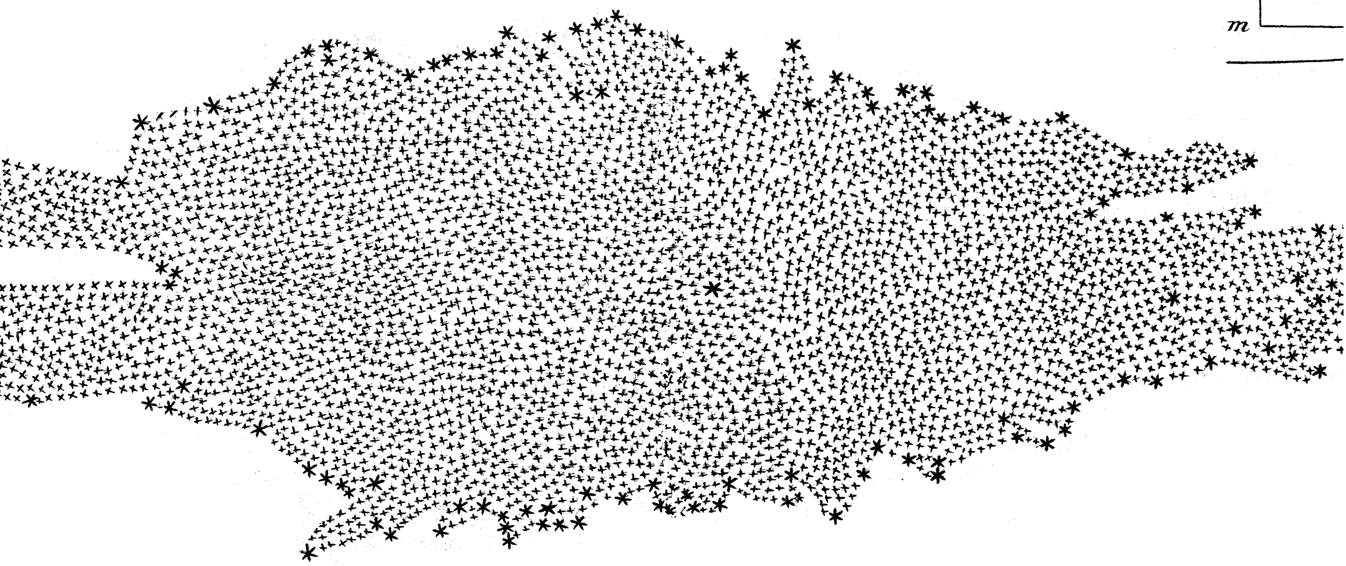


Fig. 5.

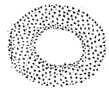
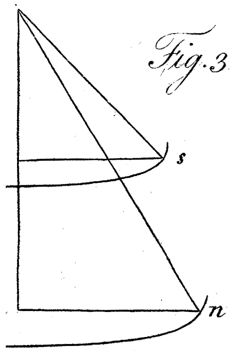


Fig. 3.



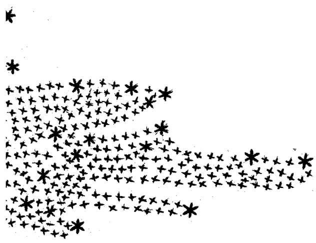


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Fig. 1.

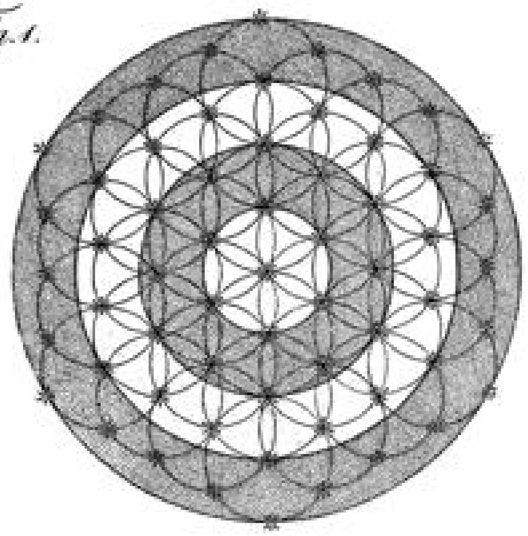
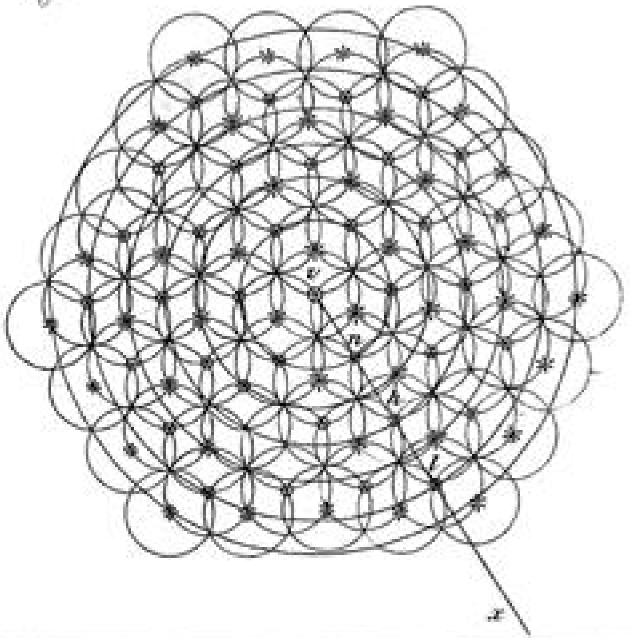


Fig. 2.



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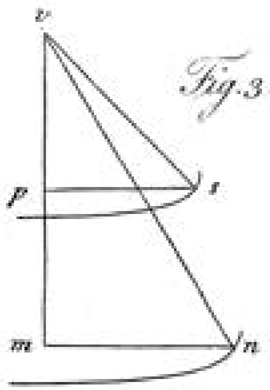

Fig. 4.

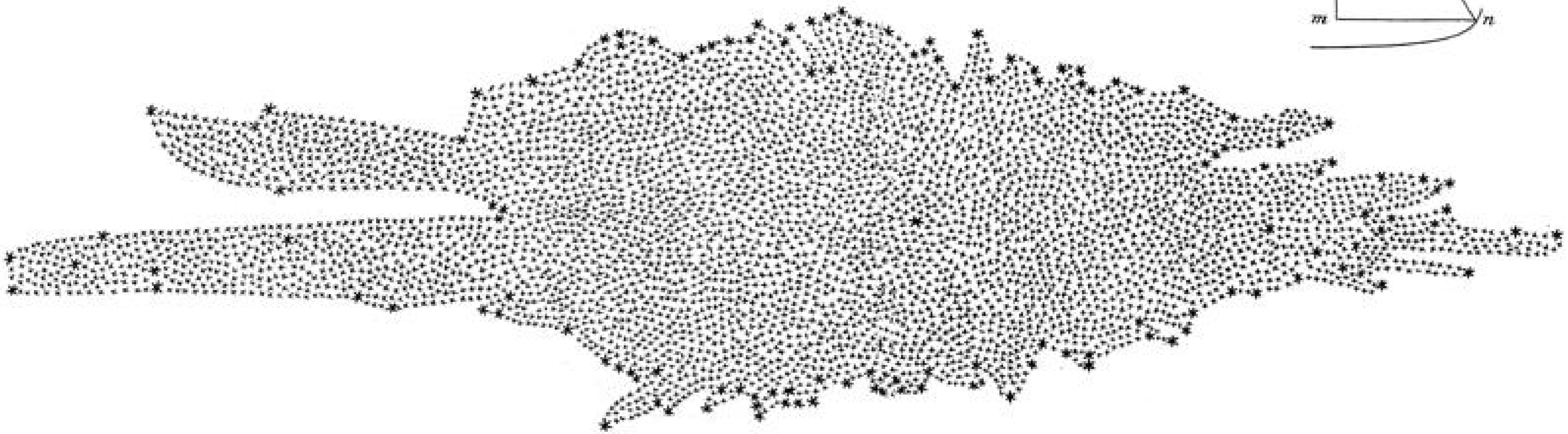

Fig. 5.