XXV. *Observations on the Nebulæ. By The Earl of* Rosse, *Pres. R.S., &c. &c.*

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In laying before the Royal Society an account of the progress which has been made up to the present date in the re-examination of Sir John Herschel's Catalogue of Nebulæ published in the Philosophical Transactions for 1833, it will be necessary to say something of the qualities of the instrument employed.

The telescope has a clear aperture of 6 feet, and a focal length of 53 feet. It has hitherto been used as a Newtonian, but in constructing the galleries provision was made for the easy application of a little additional apparatus to change the height of the observer, so that the focal length of the speculum remaining the same, the instrument could be conveniently worked as a Herschelian.

Although with an aperture so great in proportion to the focal length, the performance of a parabolic speculum placed obliquely would no doubt be very unsatisfactory, still additional light is so important in bringing out faint details, that it is not improbable in the further examination of the objects of most promise with the full light of the speculum, *undiminished by a second reflexion*, some additional features of interest will come out.

The second reflexion is accomplished in the usual way by a surface of speculum metal; some experiments have been made, suggested by Jamin's paper in the Annales de Chimie for 1848, to procure a surface of silver suited to the purpose, but without complete success. Arrangements also have been for some time in contemplation with the view of effecting the second reflexion occasionally by a small glass prism; and about a year ago a prism was procured from Munich for the purpose: in both cases there would be a great saving of light; but I am speaking of the instrument as it is, not as it may become, if further improved.

The tube reposes at its lower end upon a very massive universal joint of cast iron, resting on a pier of stonework buried in the ground; and it is counterpoised so that it can be moved in polar distance with great facility. A quick motion in polar distance is given by a windlass below, and a slow motion is given by hand above for measurements. The extreme range of the tube in right ascension at the equator is one hour; but greater as the polar distance diminishes. The quick movement in right ascension is given below by a wheel turned by a workman, and the slow motion by hand above; the instrument is therefore completely under the dominion of the observer. The tube is slung entirely by chains, and is perfectly steady even in a gale of wind.

As the chain which governs the movement of the telescope passes over a pulley capable of being brought by a little subsidiary apparatus into a line drawn from the axis of motion parallel to the axis of the earth, the movement of the telescope can be rendered almost exactly equatorial: there was some mechanical advantage in placing the pulley a little out of that line; and for such measurements as we have required, we have found the movement of the telescope sufficiently equatorial without the subsidiary apparatus, and therefore have not up to the present time made use of it. When the telescope is in the meridian, as it moves in polar distance it is guided by a cast-iron arc of a circle about 85 feet diameter nicely planed. The arc is composed of pieces 5 feet long, each adjusted independently in the meridian by the transit instrument, and secured to massive stonework. The horizontal axis of the great universal joint gives motion to an index which points to polar distances on an arc of 6 feet radius, by which the telescope is very quickly set in polar distance. A 20-inch circle with a very delicate level, attached to the telescope, performs the same office, more slowly but with greater accuracy; and also gives polar distances with considerable precision when duly corrected. The whole mounting was planned especially with a view of carrying on a regular system of sweeping, for which it is peculiarly adapted; but the known objects which require examination are so numerous that hitherto we have been fully occupied with them; and the discovery of new nebulæ has as yet formed no part of the systematic work of the observatory.

As yet the telescope is not provided with a clock movement. A clock movement was part of the original design, and there would have been no serious difficulty in carrying it out; but the want of it has not been very much felt, and there were other matters requiring more immediate attention.

Various micrometers have been tried, but upon the whole the common wire micrometer with thick lines succeeds the best. The thick lines are formed by coiling very fine silver wire four times round the forks, soldering it there, and then removing the lower half of the coil. A little spirit varnish unites the fine wires into a thin ribbon with a straight edge, perhaps as perfect as can be made. The micrometer is used without illumination; and I have never failed to see the lines in the darkest night; but of course measurements with thick lines are inferior in point of accuracy to measurements with thin lines in an illuminated field. Unfortunately any micrometrical contrivance which either diminishes the light of the telescope, or renders the field less dark, extinguishes the faint details of the nebulæ, which even with an aperture of 6 feet are often barely perceptible. There have been many ingenious attempts to make fine lines visible in a perfectly dark field, but they have not, at least as far as my experience goes, been entirely successful.

The telescope has two specula, one about three and a half, and the other a little more than four tons weight. Each speculum was originally provided with a system of levers to afford it an equable support: it was placed upon this system before it was ground, and it has rested upon it ever since. The system of levers is a combination of three systems in every respect similar, resting on three points under the centres of gravity of the three equal sectors into which the speculum may be supposed to be divided. Each system consists of one triangle with its point of support directly under its centre of gravity, upon which it freely oscillates. This triangle carries at its angles three similar points of support for three other triangles, under their centres of gravity, and they again at their angles carry in a similar way cast-iron platforms formed of thin ribs so as to make a kind of irregular open-work grating, supported under their centres of gravity. These platforms are all of equal area though not of similar shape. As there are three systems there are therefore twenty-seven platforms, which together make a circular disc about an inch in diameter less than the speculum: when arranged however a little apart so as not to touch, they make a disc about the same diameter as the speculum. Each platform is coated with greased cloth, and may be considered as bearing up one twenty-seventh of the weight of the speculum. Between the platforms and the speculum pieces of tin plate are inserted to diminish the friction as much as possible. The platforms being of open-work, they do not prevent the water in which the speculum is immersed from freely carrying away the heat as it is developed during the process of polishing, which is essential.

It is evident that a speculum so supported will be practically free from strain while in a horizontal position, provided the due action of the levers is not interfered with by any disturbing force; it will be very much in the same condition as if floating in a vessel of mercury; when it ceases to be horizontal however new forces come into play: part of the weight must then be resisted by pressure against the edge. Four very strong segments of cast iron, each about one-eighth of the circumference, were adjusted to the edge by screws, the segments bearing upon the massive castings which sustained the three primary supports of the lever apparatus. Provision was made to allow a little motion perpendicular to the plane of the speculum, to guard as much as possible against strain from the elasticity of the lever apparatus, which was however very small, the yielding being less than one-fortieth of an inch.

The two specula of 3 feet aperture I have so long employed are mounted on a similar principle: they have however fewer points of support, and by a little sacrifice of the condition of perfect equilibrium, the whole system of levers was thrown without difficulty almost exactly into one plane. They are free from perceptible flexure in the different positions of the instrument. With the two specula of 6 feet diameter the case was otherwise. The 3-feet specula, weighing each about thirteen hundred weight, were very much stiffer, in proportion to their weight, than the 6-feet specula. To have made the 6-feet specula of equal proportionate stiffness, either they should have been enormously heavy, or the material should have been so disposed as to give greater stiffness than when simply cast into the shape of a solid disc. Some years ago it was ascertained by experiments, but on a small scale, that it would be practicable to dispose of three-fourths of the material of a speculum so as to secure a great increase of stiffness; the form adopted was a system of hexagonal cells. Whether on a great scale the difficulties would be too serious to be surmounted is a question; however it is with solid discs we have had to deal. The relative stiffness of speculum metal and wrought iron is about five to six three-tenths; yet strange as it may appear, so delicate is the optical test, that strong pressure of the hand at the back of a speculum, four tons weight, and nearly six inches thick, produces flexure sufficient to distort the image of a star. It is obvious, therefore, that a slight inequality in the action of the lever apparatus supporting a 6-feet speculum would produce an amount of flexure sufficient to destroy definition. It has not been found possible so to secure the 6-feet specula as to prevent a slight change of place in a plane parallel to the plane of the levers, and as the levers are not all in one plane as in the case of the 3-feet specula, and a considerable amount of friction exists between the speculum and its lever supports, when the speculum changes place, however slightly, there will be a force tending to disturb the equal actions of the levers. It has been found that when the speculum changes its place one-thirtieth of an inch, still adhering to its levers, unmistakeable distortion will be produced. We have occasionally observed, even during a night's work, the sudden appearance, and the as sudden disappearance of the rudiments of focal lines, the undoubted evidences of flexure; but we have not found that flexure, even to the extent of materially disfiguring the image of a large star, interferes much with the action of the speculum on the faint details of nebulæ, although it greatly lessens its power in bringing out minute points of light, and in showing resolvability where under favourable circumstances resolution had been previously effected.

In the spring of 1848 the heavier of the two specula for nearly three months performed admirably, very rarely exhibiting the slightest indication of flexure. It then remained inactive for some time before and after the solstice, and when we again commenced observing it was found to be in a state of strain; the friction between the lever apparatus and the speculum had no doubt in the meantime increased considerably, and the levers being therefore unable to adjust themselves to some slight but permanent change in the place of the speculum, they no longer supported it equably. It was cautiously raised a little by screws for the purpose of re-adjusting the levers, and to our surprise the unequal strain of the screws was found to have produced permanent flexure, so that the speculum did not again perform well till after it had been reground. From the experiments of Mr. Eaton Hodgkinson and others, we should have been prepared for a change of figure in a mass of cast iron, but with a material so brittle and so elastic as speculum metal, the result was quite unexpected. Recently, in supporting the lighter of the two specula, twenty-seven triangles have been substituted for the twenty-seven platforms, each triangle carrying at its angles three brass balls, so that the speculum rolls freely on eighty-one balls, which support it pretty nearly equably. This appears to be a great improvement, but I will not dwell further on the subject. To describe the experiments which have been made with a view of discovering the best means of supporting very large specula, a question of great theoretical and practical difficulty, would occupy too much space, and would require elaborate engravings; it would besides be foreign to the object of this paper.

The same considerations also forbid any more minute description of the telescope and its mounting.

From what has been said, it is evident that the 6-feet specula being occasionally in a state of strain, were not uniform in their action. There was however another cause of unequal action. The 6-feet specula, after they have been polished, cannot be tested till they have been removed from the laboratory to the telescope, there to await a good night, the great focal length making it impossible to test them while on the engine. Now it has often happened that a speculum which has subsequently proved to be incapable of very fine definition, has remained in the telescope during a succession of moderately good nights, when a great deal of work was done, awaiting a night when the air was in a state to warrant a decisive opinion. Such a speculum might do good work, but it would not resolve difficult nebulæ, neither would it bring out faint points of light, even when wide apart. There is still another cause of the unequal action of our specula far more serious, the varying state of the atmosphere. When the air is unsteady, minute stars are no longer points, the diffused image is much fainter, and single stars, easily seen when the air is steady, are no longer visible. When many minute stars are crowded together the whole become blended, and instead of a resolved nebula we have merely a diffused, perhaps bright nebulosity. The transparency of the air varies also quite as much; and the aspect of the nebulæ changes from night to night, just as the appearance of a distant building alters as the details of the architecture are more or less obscured by the intervening mist. With these facts, the Society will not be surprised should it be in our power at a future time to communicate some additional particulars, even as to the nebulæ which have been the most frequently observed.

The sketches which accompany this paper are on a very small scale, but they are sufficient to convey a pretty accurate idea of the peculiarities of structure which have gradually become known to us: in many of the nebulæ they are very remarkable, and seem even to indicate the presence of dynamical laws we may perhaps fancy to be almost within our grasp. To have made full-sized copies of the original sketches would have been useless, as many micrometrical measures are still wanting, and there are many matters of detail to be worked in before they will be entitled to rank as astronomical records, to be referred to as evidence of change, should there hereafter be any reason to suspect it.

Much however as the discovery of these strange forms may be calculated to excite our curiosity, and to awaken an intense desire to learn something of the laws which give order to these wonderful systems, as yet, I think, we have no fair ground even for plausible conjecture; and as observations have accumulated the subject has become, to my mind at least, more mysterious and more inapproachable. There has therefore been little temptation to indulge in speculation, and consequently there can have been but little danger of bias in seeking for the facts. When certain phenomena can only be seen with great difficulty, the eye may imperceptibly be in some degree influenced by the mind; therefore a preconceived theory may mislead, and speculations are not without danger. On the other hand, speculations may render important service by directing attention to phenomena which otherwise would escape observation, just as we are sometimes enabled to recognize a faint object with a small instrument, having had our attention previously directed to it by an instrument of greater power. The conjectures therefore of men of science are always to be invited as aids during the active prosecution of research.

It will be at once remarked, that the spiral arrangement so strongly developed in Plate XXXV. H. 1622, 51 MESSIER, fig. 1, is traceable, more or less distinctly, in several of the sketches. More frequently indeed there is a nearer approach to a kind of irregular interrupted annular disposition of the luminous material than to the regularity so striking in 51 MESSIER; but it can scarcely be doubted that these nebulæ are systems of a very similar nature, seen more or less perfectly, and variously placed to the line of sight. In general the details which characterize objects of this class are extremely faint, scarcely perhaps to be seen with certainty on a moderately good night with less than the full aperture of 6 feet: in 51 MESSIER, however, and perhaps a few more, it is not so. A 6-feet aperture so strikingly brings out the characteristic features of 51 MESSIER, that I think considerably less power would suffice, on a very fine night, to bring out the principal convolutions. This nebula has been seen by a great many visitors, and its general resemblance to the sketch at once recognized even by unpractised eyes. MESSIER describes this object as a double nebula without stars; Sir WILLIAM HERSCHEL as a bright round nebula, surrounded by a halo or glory at a distance from it, and accompanied by a companion; and Sir JOHN HERSCHEL observed the partial subdivision of the *s.f.* limb of the ring into two branches. Taking Sir J. HERSCHEL's figure, and placing it as it would be if seen with a Newtonian telescope, we shall at once recognise the bright convolutions of the spiral, which were seen by him as a divided ring. We thus observe, that with each successive increase of optical power, the structure has become more complicated and more unlike anything which we could picture to ourselves as the result of any form of dynamical law, of which we find a counterpart in our system. The connection of the companion with the greater nebula, of which there is not the least doubt, and in the way represented in the sketch, adds, as it appears to me, if possible, to the difficulty of forming any conceivable hypothesis. That such a system should exist, without internal movement, seems to be in the highest degree improbable: we may possibly aid our conceptions by coupling with the idea of motion that of a resisting medium; but we cannot regard such a system in any way as a case of mere statical equilibrium. Measurements therefore are of the highest interest, but unfortunately they are attended with great difficulties. Measurements of the points of maximum brightness in the motling of the different convolutions must necessarily be very loose; for although on the finest nights we see them breaking up into stars, the exceedingly minute stars cannot be seen steadily, and to identify one in each case would be impossible with our present means. The nebula itself, however, is pretty well studded with stars, which can be distinctly seen of various sizes, and of a few of these, with reference to the principal nucleus, measurements were taken by my assistant, Mr. JOHNSTONE STONEY, in the spring of 1849, during my absence in London; for some time before the weather had been continually cloudy. These measurements have been again repeated by him this year, 1850, during the months of April and May. Just as was the case last year, in February and March the sky was almost constantly overcast. He has also taken some measures from the centre of the principal nucleus to the apparent boundary of the coils, in different angles of position. The micrometer employed was furnished with broad lines formed of a coil of silver wire in the way I have described, seen without illumination. Some of the stars in the nebula are so bright, I have little doubt they would bear illumination; if so, their positions with respect to some one star might be obtained with great accuracy of course by employing spiders' lines; this season however it is too late to make the attempt. Several of these stars are no doubt within the reach of the great instruments at Pulkova and at Cambridge, U.S., and I hope the distinguished astronomers who have charge of them will consider the subject worthy of their attention. Their better climate gives them many advantages, of which not the least is the opportunity of devoting time to measurements without any serious interruption to other work. I need perhaps hardly add, that measurements taken from the estimated centre of a nucleus, and still more from the estimated termination of nebulosity, are but the roughest approximations; they are however the only measurements nebulosity admits of, and if sufficiently numerous, I think they will bring to light any considerable change of place, or form, which may occur.

The spiral arrangement of 51 MESSIER was detected in the spring of 1845. In the following spring an arrangement, also spiral but of a different character, was detected in 99 MESSIER, Plate XXXV. fig. 2. This object is also easily seen, and probably a smaller instrument, under favourable circumstances, would show everything in the sketch. Numbers 3239 and 2370 of HERSCHEL'S Southern Catalogue are very probably objects of a similar character, and as the same instrument does not seem to have revealed any trace of the form of 99 MESSIER, they are no doubt much more conspicuous. It is not therefore unreasonable to hope, that whenever the southern hemisphere shall be re-examined with instruments of great power, these two remarkable nebulæ will yield some interesting result.

The other spiral nebulæ discovered up to the present time are comparatively difficult to be seen, and the full power of the instrument is required, at least in our climate, to bring out the details. It should be observed that we are in the habit of calling all objects spirals in which we have detected a curvilinear arrangement not consisting of regular re-entering curves; it is convenient to class them under a common name, though we have not the means of proving that they are similar systems. They at present amount to fourteen, four of which have been discovered this spring; there are besides other nebulæ in which indications of the same character have been observed, but they are still marked doubtful in our working list, having been seen when the air was not very transparent; 51 MESSIER, Plate XXXV. fig. 1, is the most conspicuous object of that class.

The question may perhaps suggest itself whether there is not something in the aspect of a spiral nebula, which forces upon us the conviction that it is a system with an organization quite different from that of any known cluster. The only answer I am enabled to give to that question is, that in the exterior stars of some clusters there appears to be a tendency to an arrangement in curved branches, which cannot well be unreal, or accidental. Nos. 480, 1916, 1968, 1972, are the objects in which I observe that peculiarity noted down in our list of observations as suspected. As to 1968, Sir JOHN HERSCHEL uses the following words in his Catalogue, "has hairy-looking curvilinear branches." Careful drawings based on measurements would settle the question, whether the suspected curvilinear distribution of the stars is real or not; this would also perhaps settle another question of interest, whether the distribution of the stars in these objects is reconcileable with the hypothesis of an equal distribution of the stars of the system; as yet however there has not been time to make the required measurements. In passing from the spiral to the regular annular nebulæ, we perceive we are at once engaged with objects of a very different character: still here even there seems to be something like a connecting link; the great round planetary nebula, H 838, Plate XXXVII. fig. 11, with a double perforation appears to partake of the structure both of the annular and spiral nebulæ. There were but two annular nebulæ known in the northern hemisphere when Sir JOHN HERSCHEL'S Catalogue was published; now there are seven, as we have found that five of the planetary nebulæ are really annular. Of these objects, the annular nebula in Lyra is the one in which the form is by far the most easily recognized. I have not yet sketched it with the 6-feet instrument, because I have never seen it under favourable circumstances: the opportunities of observing it well on the meridian are comparatively rare owing to twilight. It was however observed seven times in 1848 and once in 1849. The only additional particulars I collect from the observations, are that the central opening has considerably more nebulosity in it than it appeared to have with the 3-feet instrument, and that there is one pretty bright star in it, *s.f.* the centre, and a few other very minute stars. In the sky round the nebula and near it there are several very small stars which were not before seen, and therefore the stars in the dark opening may possibly be merely accidental. In the annulus, especially at the extremities of the minor axis, there are several minute stars, but there was still much nebulosity not seen as distinct stars.

The other annular nebula of HERSCHEL'S Northern Catalogue is a much fainter object: it has been observed but once with the large instrument, August 1, 1848; but the evidence of resolution appears to have been more complete; many stars were seen in the annulus; one of them was very conspicuous. That a faint nebula should be more easily resolvable than a bright one is not unusual, neither is it contrary to probability; faintness may be owing to distance, or to a wider separation of the stars, either physically or optically; in the latter case it is not unlikely that in a faint nebula they might be seen separate with an instrument of great aperture, while in the brighter and more closely packed nebula they were blended together, owing to imperfect definition, arising out of the state of the air, or instrument. As an example, the dumb-bell is a bright nebula: on three exceedingly fine nights succeeding each other at short intervals, the stars in the brighter parts of the nebula were better shown with 3 feet aperture than they have since been with 6 feet. Very fine nights, when the air seems to set no limits to magnifying power, are extremely rare, and the dumb-bell has not been seen with the great instrument on such nights. On the other hand, on all ordinary nights, a variety of details are shown by the great instrument which were not seen on the finest nights with the smaller instrument. There is another fact I may perhaps add, that while high magnifying power brings out minute stars it extinguishes faint nebulosity. The optical reason is obvious; but in sketching the dumb-bell nebula in 1845 that fact was overlooked, and but one eye-piece was used, a very high one; had there been a low one also used the sketch would have been more complete. To return to the annular nebulæ. The five planetary nebulæ we have ascertained to be annular, are as follows: 464, Plate XXXVIII. fig. 12, has two stars within it; 2075 has one star a little following the centre; 2241, Plate XXXVIII. fig. 13, has no star, but is surrounded with a faint external annulus; 2050 has a perforation not round nor quite symmetrical with the star; 838, Plate XXXVII. fig. 11, has two stars and two perforations. In no instance is the central opening quite dark. The planetary nebula, 2047, is marked in our journal as annular, but the observation is without date and other particulars, and therefore I do not consider it altogether trustworthy. In 2098, Plate XXXVIII. fig. 14, another planetary nebula, we have not detected any perforation, but it has ansæ, which probably indicate a surrounding nebulous ring seen edgeways, just as 450, Plate XXXVIII. fig. 15, has apparently a nebulous ring seen on the flat; and if the annular nebulæ are really hollow shells, the nebulous ring would cover the comparatively transparent centre; 365 and 2037 have never been observed.

Passing from the annular nebulæ to the nebulous stars, there are two objects well-worthy of especial notice.

Sir John Herschel very accurately describes a nebulous star thus:—"A sharp and brilliant star concentrically surrounded by a perfectly circular disc or atmosphere of faint light, in some cases dying away insensibly on all sides, in others almost suddenly terminated*." No. 450 of Sir John Herschel's Catalogue is one of these nebulous stars, and is there thus described:—"A star of the 8th magnitude, exactly in the centre of an exactly round and bright atmosphere, 25″ diameter. The star is quite stellar, not a mere nucleus. Another star, 8th magnitude, distant 100″, and about 85° n p, has no such atmosphere.—A most remarkable object."

Plate XXXVIII. fig. 15 represents this wonderful object as seen with the 6-feet telescope. It has been several times examined, and as yet we have not seen the

* Outlines of Astronomy, p. 605.

slightest indication of resolvability. The outer ring is seen on a pretty good night completely separated from the nucleus surrounding the brilliant point or star. The light is very bright, and always appeared to be flickering, owing no doubt to the unsteadiness of the atmosphere. There is a small dark space to the right of the star, which indicates a perforation similar perhaps to that discovered in Nos. 838, 2050, and others. The annular form of this object was detected by Mr. JOHNSTONE STONEY, my assistant, when observing alone, and the sketch is his; I have however since had ample opportunities of satisfying myself that the object has been accurately represented. Plate XXXVIII. fig. 16 represents the other nebulous star, ι Orionis: the remarkable feature in this object, the dark cavity, not symmetrical with the star, was also discovered by Mr. JOHNSTONE STONEY when observing alone with the 3-feet telescope: I have since seen it several times and sketched it. The components of ι Orionis have not been laid down micrometrically, or even with care by the eye, but the dark cavity with respect to the stars is faithfully represented. If the dark cavity was symmetrical with the stars, it might perhaps be thought by some that the phenomenon was optical, but as it is the thing is impossible. A small double star *n f* has similar openings, but they are not so easily seen. These openings appear to be of the same character as the opening within the bright stars of the trapezium of Orion, the stars being at the edges of the opening. Had the stars been situated all together within the openings, the suspicion would perhaps have suggested itself more strongly that the nebula had been absorbed by the stars. As it is, I think we can hardly fail to conclude that the nebula is in some way connected with these bright stars, in fact that they are equidistant, and therefore, if the inquiries about parallax, now proceeding with so much activity, should result in giving us the distances of these bright stars, we shall have the distance of this nebula.

The long elliptic or lenticular nebulæ are very numerous; I have given three sketches of remarkable objects of this class: the appearance of Plate XXXVII. fig. 7 suggests the idea of an elliptic annular system seen very obliquely. A series of very elliptic shells enveloping the nucleus, seen somewhat obliquely, would perhaps also present the same aspect. The dark chink in Plate XXXVII. fig. 8 might indicate either a real opening, the system being an elliptic ring, or merely a line of comparative darkness, the section through the axis of a very long narrow elliptic shell. In Plate XXXVII. fig. 9 there is a well-marked stratification, which might possibly be the appearance, Plate XXXVII. fig. 7, on the first supposition, would present if seen in another direction. It is to be hoped that as observations multiply, and these extraordinary objects which abound in the heavens are seen in various directions, we shall gradually become acquainted with their real form. At present further conjectures would be to no purpose.

The remaining sketch, Plate XXXVIII. fig. 17, is the dumb-bell nebula as seen with the 6-feet telescope: the sketch is by Mr. JOHNSTONE STONEY, and the form of the nebulosity and its various gradations of intensity have been represented with considerable fidelity. There was no subsequent opportunity of marking in the stars, and therefore they have been inserted at random to complete the general effect, and many minute details are still wanting to make the figure complete.

As we have proceeded with our task of re-examining Sir JOHN HERSCHEL's Catalogue, several groups of nebulæ have been discovered, although new objects have not been as yet sought for. In some cases a nebulous connection has been detected between the individuals of the group, in others not. Sketches have been made and some measures taken. The whole subject of the grouped or knotted nebulæ is one of deep interest; but we have not proceeded sufficiently far with it to make it worth while to enter upon it in the present paper, and it only remains to point out a defect common to all the sketches which might mislead if not specially noticed. In sketching we necessarily employ the smallest amount of light possible, very feeble lamp-light, especially where the objects or their details are of the last degree of faintness. To see the sketch as we proceed it is often necessary to mark it too strongly: this would be of little moment if the excess of colour was always in the same proportion, especially as different eyes form a very different estimate of the relative intensities of a nebula and its representation on paper, but it is not so; the contrast between the faint and bright nebulæ and between the faint and bright parts of the same nebula is very liable to be made too slight. The most important error to guard against is that of supposing that the well-marked confines of the nebula on paper really represent the boundaries of the object in space in all cases. Frequently there is a very gradual fading away at the edge, the last trace of which is either a luminous mist becoming rarer till imperceptible; a gauge-like tissue of the faintish imaginary flocculi, or hairy filaments, which become finer and more scattered till they cease to be visible, showing that the real boundary has not been seen, and that the form of the object would alter if additional optical power could be brought to bear upon it. The same remark applies to the faint interior details, in most cases probably only in part seen.

Plate XXXV. figs. 1 and 2 are seen on a scale of half an inch to a minute; the others are on no regular scale: they are about the size of the figures which accompany Sir JOHN HERSCHEL's Catalogue, the smaller however have been somewhat enlarged where there were details which otherwise could not have been well represented.

Annexed are a few remarks relating to each figure, which seem to make the information conveyed by it more complete: they are for the most part extracts selected from our journal of observations; in a few cases, however, to save space, merely the substance is given.

Where the 3-feet instrument was employed it is specially mentioned; in every other case it was the 6-feet instrument.

Plate XXXV. fig. 1, H. 1622.—This object has been observed twenty-eight times with the 6-feet instrument; it had been repeatedly observed previously with the 3-feet instrument.

September 18, 1843.—Observed with the 3-feet instrument; power single lens, 1-inch focus; a great number of stars clearly visible in it, still HERSCHEL'S rings not apparent, at least no such uniformity as he represents in his drawing.

April 11, 1844.—Observed with the 3-feet instrument, two friends assisting; both saw centre clearly resolved.

April 26, 1848.—6-feet instrument. Saw the spirality of the principal nucleus very plainly; saw also spiral arrangement in the smaller nucleus.

The following measurements were taken by my assistant, Mr. JOHNSTONE STONEY, in the spring of 1849 and 1850.

	Mean of the observations of position.	No. of observations.	Greatest difference between observations and the mean.	Mean of the observations of distance.	No. of observations.	Greatest difference between observations and the mean.
N. *n*.	16° 34′	4	3° 27′	4′ 22″·2	4	9″·6
N. 1.	52 4	1	......	2 6·6	1	
N. 2.	54 0	4	1 57	5 0·0	4	5·4
N. 3.	104 20	2	2 3	2 45·6	2	3·6
N. 4.	111 57	2	0 40	4 3·6	2	0·6
N. 5.	165 35	2	0 31	1 43·2	2	1·1
N. 6.	191 42	1	......	3 54·0	1	
N. 7.	211 2	1	......	2 36·6	1	
7, 8.	270 42	1	......	0 34·8	1	
N. 9.	231 32	4	3 35	1 23·4	3	6·6
9, 10.	197 57	1	......	0 27·0	1	
N. 11.	279 21	4	4 18	1 49·8	3	22·2
11, 12.	225 27	1	......	0 12·6	1	
N. 13.	281 37	2	0 22	3 59·0	1	
14, 15.	297 15	1				
N. 15.	310 34	4	4 17	2 55·8	4	13·8
N. α				3 22·8	2	0·1
N. β	5 7	...	......	1 28·2	3	3·0
N. γ				2 37·8	3	2·4
N. δ				1 46·2	1	
N. ε	95 7	...	......	2 46·8	1	
N. ζ				1 40·8	1	
N. η				3 15·6	1	

Observations.—There is a great discrepancy between the measured position of 11 and 12 and the rough diagram made at the time of observation.

N. 13 is twice noticed in the observing-book.

Once N. 11, 13 is taken as one position; the other times N. 11 and 13 are taken separately, N. 13 being made 1° 40′ less than N. 11; hence 270° 31′ is a more probable position for N. 13 than that given in the Table.

The Greek letters are perpendiculars from N. on tangents to the outsides of the convolutions, the tangents from α, β, γ being vertical, that is, parallel to the position 95° 7′, and those for δ, ε, ζ, η horizontal, *i. e.* parallel to position 5° 7′.

The greater part of the observations were made when the eye was affected by lamp-light, which made it difficult to estimate correctly the centre of the nucleus; it was of importance that no time should be unnecessarily spent, and after the lamp had been used a new measure was taken, as it was judged that the object was sufficiently seen. With the brighter stars this would frequently happen before the nucleus was well defined, as all impediments to vision seem to affect nebulæ much more than stars the light of which would be estimated as of the same intensity. In the foregoing list the greatest discrepancies are in the measures of bright objects, and this is probably the proper account of it. No stars have been inserted in the sketch which are not in the table of measurements. The general appearance of the object would have been better given if the minute stars had been put in from the eye-sketch, but it would have created confusion.

Plate XXXV. fig. 2, H. 1173.—This nebula has been repeatedly observed with the 6-feet instrument.

March 11, 1848.—Spiral with a bright star above; a thin portion of the nebula reaches across this star and some distance past it. Principal spiral at the bottom, and turning towards the right.

March 20, 1848.—Spirality very evident, though night bad: nebula not traced to upper star.

April 16, 1849.—Took measures of the stars 1, 2.

April 17, 1849.—Took measures of the stars 1, 2, 3, 4 from the nucleus; they are as follows:—

No.	Mean of observations of position from north in direction *n. f. s. p.*	No. of observations.	Greatest difference between mean and observation.	Mean of observations of distance.	No. of observations.	Greatest difference between mean and observation.
	° ′		° ′	′ ″		″
1.	34 1	1	......	2 54·6	2	9·6
2.	80 35	2	0 18	1 46·3	3	14·4
3.	117 3	3	0 23	1 48·4	4	13·6
4.	177 57	1	......	2 48·1	1	

Three very minute stars in the eye-sketch have not been inserted, not having been measured.

Plate XXXVI. fig. 3, H. 604.—This nebula was observed frequently with the 3-feet instrument, but nothing remarkable seems to have been made out, except the resolvable character of the nucleus. It was first observed with the great telescope, March 24, 1846, and a tendency to an annular or spiral arrangement discovered; night bad; March 5, 1848, sketched.

March 9, 1848.—"Night excellent, a spiral seen in an oblique direction, resolved well, particularly towards the centre, where it is very bright; Dr. Robinson observing." Observed March 3, 1850; badly seen.

With the single exception of March 3, 1850, we have unfortunately no recent observation of this extraordinary object: it has been passed over, because to observe it, except on a very fine night, would be waste of time.

Plate XXXVI. fig. 4, H. 2205.—Observed frequently, and by many friends. The drawing represents the object with considerable accuracy.

"September 10, 1849.—Spiral, but query whether this is not more properly an annular than a spiral nebula."

The details are faint, but can be seen on any moderately fine night.

Plate XXXVI. fig. 5, H. 131.—This figure represents the central portion of a very large nebula. The nebula itself has not been sufficiently examined, but as yet no other portion appears to have a spiral, or indeed any regular arrangement. The sketch is not very accurate, but represents sufficiently well the general character of the central portion.

"September 6, 1849.—A spiral.

"September 16, 1849.—New spiral; α the brightest branch; γ faint; δ short but pretty bright; β pretty distinct; ε but suspected; the whole involved in faint nebula, which probably extends past several knots which lie about it in different directions. Faint nebula seems to extend very far following: drawing taken.

"September 10, 1849.—An attempt at a drawing taken: fog.

"October 1849.—The whole nebula in flocculi."

Plate XXXVII. fig. 6, H. 444.—"December 19, 1848.—Bright star between; tails and curved filaments; perhaps annulus around the two nebulæ.

"December 22, 1848.—Sketch made.

"February 11, 1849.—Lower streak seems to reach the filaments of right-hand nucleus."

Plate XXXVII. fig. 7, H. 854.—"March 31, 1848.—A curious nebula with a bright nucleus; resolvable; a spiral or annular arrangement about it; no other portion of the nebula resolved. Observed April 1, 1848, and April 3, with the same results."

Plate XXXVII. fig. 8, H. 1909.—"April 27, 1848.—A very bright resolvable nebula, but none of the component stars to be seen distinctly even with a power of a thousand. A perfectly straight and longitudinal division in the direction of the major axis. Resolvability most strongly indicated towards the nucleus.

"May 2, 1848.—Not seen so well as on April 27. Darkness in the middle, along the major axis barely visible.

"April 1849.—A long ray elliptical. Major axis perhaps eight times minor axis. Surface somewhat broken up, and a slight darkness in the direction of the major axis: night indifferent: at intervals a few stars faintly perceptible."

Plate XXXVII. fig. 9, H. 1397.—This sketch was made with great care by my assistant, Mr. JOHNSTONE STONEY, and I have no doubt it is very accurate. Observed and sketched, April 19, 1849. It had been previously observed, March 26, 1848, by my former assistant, Mr. RAMBAUT, and I find the following note by him:—"A most extraordinary object, masses of light appear through it in knots."

Plate XXXVII. fig. 10, H. 399.—Observed December 22, 1848, February 11, 1849, and January 16, 1850, when the drawing was taken. The two comparatively dark spaces, one near the vertex and the other near the base of the cone, are very remarkable.

Plate XXXVII. fig. 11, H. 838.—September 27, 1843.—(3-feet telescope.) Night pretty good; a star in the centre and apparently ragged outline.

March 7, 1848.—(6-feet telescope).—Night bad: aurora. Darkness in the centre; star not certainly seen; outline ragged.

March 11, 1848.—Seen by Dr. Robinson and my former assistant, Mr. Rambaut; sketch made of it. "Two stars considerably apart in the central region; dark penumbra around each spiral arrangement, with stars as apparent centres of attraction; stars sparkling in it, resolvable; night excellent." Note by Mr. Rambaut: "March 5, 1848.—Saw two dark and very large spots in the middle; Lord Rosse remarked that all round its edge the sky appeared darker than the average."

"March 11, 1848.—Remarkably fine night; a brilliant star in the centre; also star to the right; round each a black space (see sketch)." Note by Mr. Rambaut: "March 25, 1848.—Air steady, but slight haze; large star visible. Only at one clear interval could I get a glimpse of the spiral arrangement of this nebula, which I should have totally overlooked had I not seen it so plainly on a former occasion.

"March 26, 1848.—Second bright star visible; spiral arrangement hardly perceptible; not seen so well as on the 11th of March.

"March 27, 1848.—Not seen so well as last night; second star seen at rare intervals, power 468.

"March 28, 1848.—Night hazy, could not see second star."

"March 31, 1848.—Caught one glimpse of second star, but saw the large star very plainly.

"April 1, 1848.—Night hazy; spiral arrangement little more than suspected; nebula very faint.

"April 3, 1848.—Small star distinctly seen; spirals tolerably well brought out; hazy, but air steady.

"April 6, 1848.—First star seen easily, though hazy; the second only occasionally; spiral arrangement hardly discernible.

"January 1850.—Seen very imperfectly; only one of the stars seen.

"March 9, 1850.—Second star only seen for a moment." Several attempts were made to procure measures of position and distance of the two stars this spring, but in vain, the season was so unfavourable. In 1848, the micrometer requiring illumination, no attempt was made. With the micrometer as at present mounted there would not have been the slightest difficulty in procuring measures.

Fig. 12, H. 464.—"Annular nebula at the edge of the cluster M. 46. Sketched December 22, 1848 annular, two stars in it.

"January 27, 1849.—A third star suspected in brightest part.

"January 29, 1849.—Third star strongly suspected.

"February 13, 1849.—Observed, nothing further.

"March 16, 1849.—Saw but two stars in it."

Fig. 13, H. 2241.—"October 31, 1848.—Has a central spot, at moments very dark.

"December 13, 1848.—Nothing more, except perhaps that faint external annulus extends further than had been seen before.

"December 14, 1848.—Note by Mr. JOHNSTONE STONEY:—'Three stars near it, somewhat in this fashion; showed it to Sir JAMES SOUTH.'

"December 16, 1848.—Sketches made by Lord ROSSE and Mr. JOHNSTONE STONEY.

"December 19, 1848.—Drawing confirmed."

Fig. H. 14, 2098.—"Observed October 23, 1848, and sketch made.

"October 25, 1848.—Sketch confirmed.

"August 16, 1849.—Position of ring taken with an eye-piece furnished with a level and a position circle. Inclination of ring to horizon 9°."

Fig. 15, H. 450.—"February 20, 1849.—Most astonishing. The star perhaps a little nearer the *np* edge. Drawing made; breadth of ring less on *f* side.

"February 22, 1849.—Observed again; dark space to the right of star.

"January 16, 1850.—Observed; examined with the 700 and 900 eye-pieces; both the dark and the bright rings seemed unequal in breadth; the light appeared unsteady and flickering. The night was rather foggy, but the sky black."

Fig. 16, H. 361.—"January 28, 1849.—ι Orionis. Dark space in the nebula containing nearest companion; light nearly equable; sketch made; 3-feet telescope employed. All the stars in the neighbourhood are nebulous, of these two a little *sp*, last seem to have dark spaces as in figure. To the *nf* of this there is another smaller double star, suspected to have similar dark spaces to ι Orionis.

"February 16, 1849.—Three-feet telescope confirmed observation of January 28, 1849.

"March 17, 1849.—Large triple star to south of nebula Orionis; confirmed observation of opening in its atmosphere, also the openings at double star *sp* last."

Fig. 17, H. 2060.—"Observed September 9, 1849. Drawing commenced.

"September 16, 1849.—Drawing proceeded with; examined also with 3-feet telescope to find if any evidence of change since drawing in Philosophical Transactions was taken; none decisive."

List of some remarkable Nebulæ.

Spiral or curvilinear.

H. 142, 262, 327, 695, 749, 910, 1002, 1211, 1312, 1368, 1451, 1570, 1776, 2172.

With dark spaces.

264, 368, 491, 514, 692, 731, 788, 857, 887, 1107, 1225, 1909, 2241.

Ray with split.

1041, 1149, 1357.

Knotted nebulæ.

84, 257, 320, 409, 446, 581, 1274, 1901.

Fig. 1.

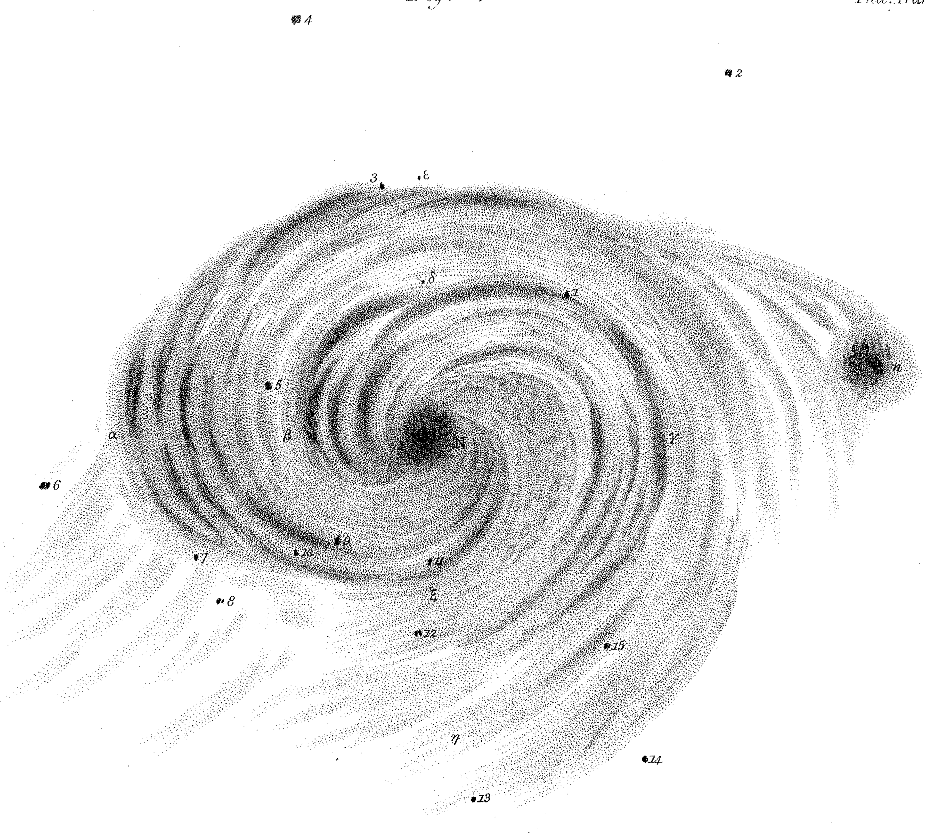

Fig. 2.

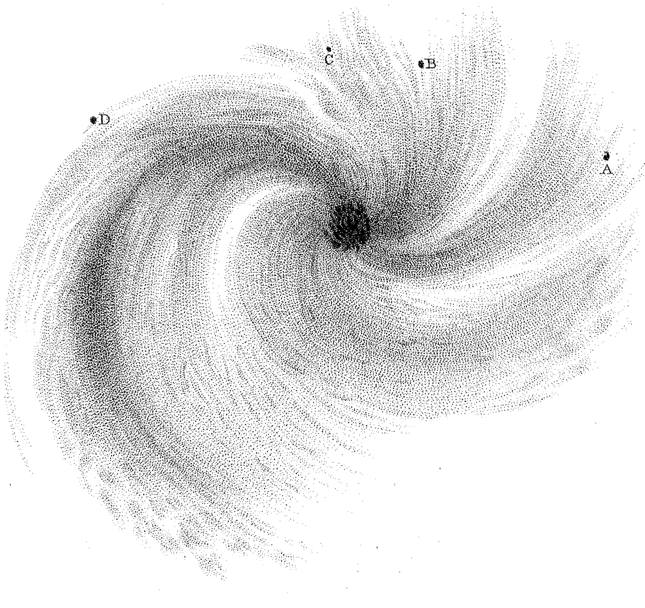

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Fig. 3.

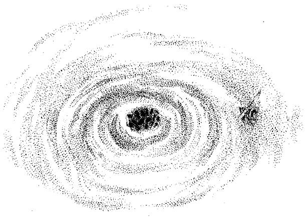
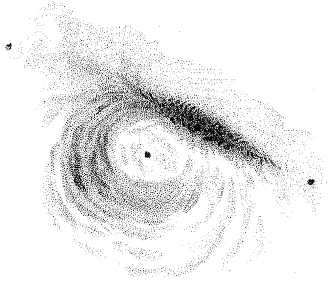


Fig. 4.



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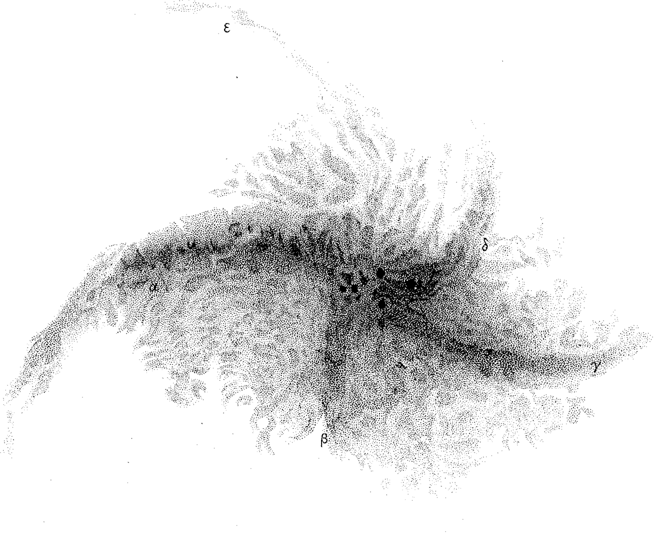

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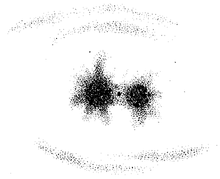
Fig. 9.

Fig. 6.



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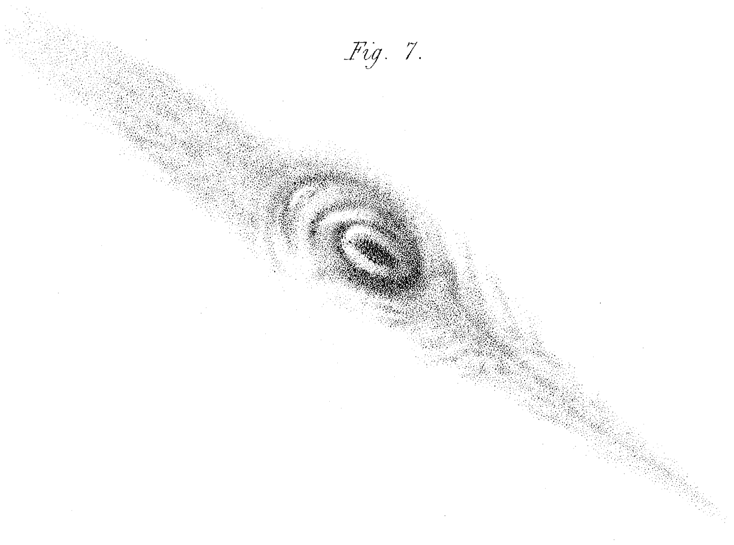

Fig. 10.

Fig. 8.

Fig. 11.

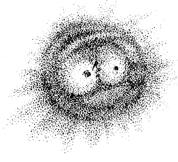

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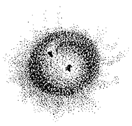
Fig. 12.



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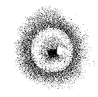


Fig. 13.

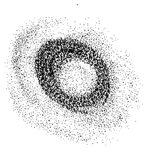
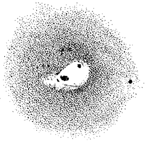


Fig. 16.



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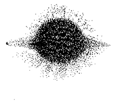
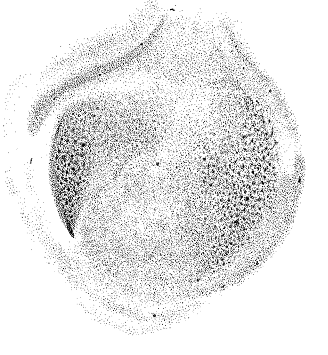


Fig. 17.



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