THURSDAY, APRIL 21, 1881

SIR WILLIAM HERSCHEL[1]

III.

IN the concluding chapter of his Memoir Prof. Holden presents a Review of the scientific labours of William Herschel designed to enable the general reader to follow the course of his work and discoveries, astronomical and physical, referring to the *Analyse de la Vie et des Travaux de Sir William Herschel*, published by Arago in 1842 for a more detailed and precise account suited to the professional astronomer; also to "A Subject-Index and a Synopsis of the Scientific Writings of Sir William Herschel," prepared by himself and Dr. Hastings, and forming one of the publications of the Smithsonian Institution.

Prof. Holden naturally commences his review with the improvements in optical instruments and apparatus effected by Herschel. Up to his time the principal aids to observation were the Newtonian telescopes of Short and the small achromatics of Dollond, the six-foot Newtonians of the former maker, aperture 9·4 inches, and the forty-six-inch achromatics of Dollond, aperture 3·6 inches, were much esteemed, and one of each class was in use at the Royal Observatory, Greenwich, in 1765. Herschel gives us some account of the progress of his manufacture of telescopes in his description of the forty-feet reflector presented to the Royal Society in 1795. When he resided at Bath, he tells us, he had long been acquainted with the theory of optics and mechanics, and wanted only that experience so essential in the practice of these sciences. This he gradually acquired by way of amusement in his leisure hours (we have seen that he was closely occupied in his profession as a teacher of music), and thus he made "several two-foot, five-foot, seven-foot, ten-foot, and twenty-foot Newtonian telescopes, besides others, of the Gregorian form of eight, twelve, and eighteen inches, and two, three, five, and ten feet focal length," in all, as already stated, he made not less than 200 seven-feet, 100 ten-feet, and about 80 twenty-feet mirrors, in addition to the Gregorian telescopes. The number of stands he invented for these instruments he states it would not be easy to assign. Proceeding further, as early as 1781 he had designed and commenced the construction of what he terms "a 30-feet aërial reflector," and invented and executed a stand for it; he cast the mirror, "which was moulded up so as to come out 36 inches in diameter," but "the composition of the metal being a little too brittle, it cracked in the cooling." It was cast a second time, but here the furnace gave way and the metal ran into the fire. These accidents and the discovery of Uranus, which introduced Herschel to the patronage of the king, put a temporary stop to the construction of a great telescope. In 1783 he finished "a very good twenty-feet reflector with a large aperture," and after two years observation with it, became so convinced of the advantages of such apertures, that he recurred to his previous intention of increasing them still further. Soon afterwards, by the representations of Sir Joseph Banks, president of the Royal Society, Herschel, as his sister relates, obtained "the promise that 2000*l.* would be granted for enabling him to make himself an instrument."

The forty-feet reflector, the *chef d'œuvre* of Herschel's optical and mechanical efforts, was commenced about the latter end of 1785, and, as Prof. Holden remarks, the history of the instrument extends from this date until the year 1811. The work was carried on assiduously with no further interruption than was occasioned by the removal from Clay Hall to Slough, where, soon after arrival, Herschel began to lay the foundation of the whole structure, and the highly-polished speculum was put into the tube, and the first view through it was obtained on February 19, 1787. But he dates the completion of the instrument from a much later period, for the first speculum came out thinner than was intended, and from its weakness did not permit of a good figure being given to it; a second mirror, cast in January, 1788, cracked in cooling; but in the next month it was re-cast and proved of the proper degree of strength. In October following a pretty good figure and polish had been assured, and Herschel says he observed the planet Saturn with it; he continued to work upon it till August 27, 1789, when upon trial on the fixed stars it gave a pretty sharp image, and on the following night he records, "Having brought the telescope to the parallel of Saturn, I discovered a *sixth* satellite of that planet, and also saw the spots upon Saturn, better than I had ever seen them before, so that I may date the finishing of the forty-feet telescope from that time." The diameter of the polished surface of the great mirror was 48 inches. In proof of the efficiency of the mechanism for giving horizontal and vertical motions to so large an instrument he mentions that in the year 1789 he had many times taken up Saturn two or three hours before meridian passage and kept the planet in view with the greatest facility till two or three hours after the passage. On the 17th of September a *seventh* satellite of Saturn, the minute object now called *Mimas*, was discovered with the forty-feet telescope, and though the instrument was used for various purposes till 1811, these discoveries of satellites constitute its most prominent additions to our knowledge. Sir John Herschel has stated that the entire cost of construction, including the apparatus for casting, grinding, and figuring the mirrors, of which two were constructed, amounted to 4000*l.*, which sum was provided by King George III. His father observed the great nebula of Orion with the forty-feet telescope on January 19, 1811, and this was one of his latest observations. In 1839 the wood-work had so far decayed as to be dangerous, and Sir John Herschel pulled it down, but piers were erected upon which the tube was placed. Writing in March, 1847, he remarks that it was so well preserved that "although not more than one-twentieth of an inch thick, when in the horizontal position it sustained within it all my family, and continues to sustain inclosed within it, to this day, not only the heavier of the two reflectors, but also all the more important portions of the machinery."

As Prof. Holden remarks, and a similar opinion has been expressed previously, it is probable that the general public expected more from the forty-feet telescope than it actually performed; but Herschel gave valid reasons why he did not make more extended use of the instrument: the time required to get it into proper working order and

[1] Continued from p. 455.

the number of assistants necessary were impediments in the way of its being utilised for regular observation, and he assures us he "made it a rule never to employ a larger telescope when a smaller will answer the purpose." It is certain that the mirror which was in the tube in October, 1789, the month following that in which Herschel dates the completion of the telescope, was of excellent definition. On the 16th of that month he followed the sixth and seventh satellites (*Enceladus* and *Mimas*) up to the limb of the planet, and witnessed their occultation. Holden writes: "I have never seen so good definition, telescopic and atmospheric, as he must have had on these occasions."

Between the years 1796 and 1799 Herschel made an elaborate classification of stars visible to the naked eye according to their comparative brightness, which he communicated to the Royal Society in four papers published in the *Phil. Trans.* It formed the first general catalogue of the kind, exhibiting the exact state of the sky in his time. A reduction of Herschel's observations was undertaken by Mr. C. S. Peirce, and the results appear in vol. ix. of the *Annals* of the Observatory of Harvard College. So far as we know, their reduction had not been previously attempted. Instances of variability in the light of naked-eye stars were detected during the progress of the classification, the most notable discovery in this direction being perhaps that of the periodical fluctuations of α Herculis, in about sixty days. Another star in the same constellation he considered had totally disappeared in 1791, though he had seen it distinctly in 1781 and 1782.

Herschel was led to his numerous discoveries of double stars by his expectation of being able to determine the parallaxes of stars from measures made at opposite seasons of the year of the distances of pairs which appeared near together, and in the search for such pairs, his first catalogue of upwards of 200 double stars was formed and presented to the Royal Society in 1782. Long had previously measured stars upon a similar plan without success, but Herschel pointed out that his stars were not well chosen.

For the successful application of the method it is necessary that one of the pair of stars should really be situated at a much greater distance from us than the other, and as the most reasonable test of distance, Herschel assumed their difference of brightness, so that he sought for pairs where the components differed widely in this respect. The view therefore which he adopted at this time with respect to two stars seen in close proximity to each other was that one was in nearly the same line of sight as the other, but might be far more distant, thus constituting together what we now term an *optical* double star. From this beginning he was led to the discovery of revolving double stars, stars changing their relative position from year to year; and in 1803 he communicated to the Royal Society his memorable paper: "An account of the changes which have happened during the last twenty-five years in the relative situation of double stars, with an investigation of the cause to which they are owing." He was then satisfied that there were in the heavens pairs of stars which were physically connected with each other. The research for stellar parallax was not successful, but in place of it he discovered the existence of binary systems. He could not in his day decide whether the motions of suns round suns was obedient to the laws of gravitation, but five years after his death the French astronomer Savary proved that one of these revolving double stars, discovered by Herschel, ξ in Ursa Major, really was subservient to that law, and as every student of astronomy will be aware, the number of physically connected systems where the elements of the orbits have been determined, is now a large one, and is gradually increasing.

Following at present the order in which Prof. Holden refers to the scientific labours of Herschel, we now arrive at his researches on planets and satellites, respecting which the improvements he made in the construction of telescopes enabled him to advance knowledge so greatly. He was not particularly occupied with the inferior planets, but he determined the time of axial rotation of Mars with greater precision than before, and also the position of his axis. The times of the rotation of the satellites of Jupiter were found from observations on their changeable brightness, and Herschel also remarked the as yet imperfectly explained phenomena attending the transits of the satellites across the disk of the planet. Saturn, as Holden remarks, was the object of his constant attention: in addition to the discovery of the interior satellites *Enceladus* and *Mimas*, he left upon record an extensive series of observations of the seven attendants upon Saturn at that time known, and determined the time of rotation of the outer satellite *Japetus* upon its axis, by similar observations to those made upon the satellites of Jupiter. He ascertained the time of axial rotation of Saturn, and was the first who had succeeded in effecting this in a reliable manner. He also remarked the curious square-shouldered appearance which the globe of the planet has been suspected to present, and of which we still occasionally hear, though it was long ago proved by Bessel to be an illusion. It is remarkable that notwithstanding Herschel's frequent scrutiny of the planet, with all his experience of observation and the advantages of optical means surpassing by far those of his contemporaries, he does not appear to have at any time suspected the existence of the interior obscure ring. He proved beyond doubt that *Uranus* was attended by two satellites, and believed he had observed four others, and for a long time on his authority the planet was credited with six attendants.

In 1795 Herschel communicated to the Royal Society a memoir upon the nature and construction of the sun and fixed stars. As to the former he adopted a modified view of the theory which had been advanced by his friend Wilson of Glasgow; he regarded the sun as consisting of three essentially different parts: a solid and non-luminous nucleus, cool and perhaps capable of habitation, above it the atmosphere proper, and still higher the clouds or bodies which cause the sun's intense brilliancy. In this paper occurs a remark which, as Prof. Holden observes, has often been brought to bear, in consideration of the causes which maintain the solar light and heat. "Perhaps," he says, "the many telescopic comets may restore to the sun what is lost by the emission of light." We know that however credible in his day points in his theory have given way under our greatly advanced knowledge.

One of the discoveries, or perhaps we should rather say demonstrations, which especially mark his powers of research and reasoning, was that of the motion of the sun and solar system in space and the direction of this translation, which, considered generally, has received confirmation from more recent and refined investigation. Maskelyne had determined the proper motions of a limited number of the brighter stars, and Lambert, Mayer, and Bradley had thrown out ideas upon the subject, and, following up their suggestions, he showed that the sun was really in motion towards a point in the constellation Hercules, and assigned "the apex of solar motion" with what Holden considers an astonishing degree of accuracy. His second paper on this subject (1805) his biographer views as "the best example that can possibly be given of his marvellous skill in reaching the heart of a matter, and it may be the one in which his philosophical powers appear in their highest exercise."

To gain a knowledge of the "Construction of the Heavens," as Herschel termed it, of the laws of distribution of the stars generally, the star-clusters and nebulæ in space, was confessedly a main object of his astronomical labours, and the memoirs bearing upon this subject extend over the whole period of his scientific career. For this purpose he adopted a system of *star-gauging*, which in practice consisted in pointing his 20-feet reflector towards various parts of the sky and counting the number of stars in a field of view 15′ in diameter. In this way, by methodical observation, the great differences in number of the stars in certain portions of the sky over those in other directions were reliably defined, and in extreme cases the difference was very marked, as in one mentioned by Holden, where in R.A. 19h. 41m., N.P.D. 74° 33′, in the constellation Sagitta, the number of stars per field was found to be 588, while in R.A. 16h. 10m., N.P.D. 113° 4′ in Scorpio it was only 1·1—"*ein Loch im Himmel!*" In this part of his review the author briefly touches upon the views entertained by Herschel at various periods between 1784 and 1817; he considers that while at the commencement of his researches the whole subject was in utter confusion, as they progressed data for the solution of some of the most important questions were accumulated, and the results of Herschel's whole labours form the groundwork upon which future investigators must build. "He is the founder of a new branch of astronomy."

The researches for a scale of celestial measures, on light and heat, &c., on the dimensions of the stars, on the variable emission of light and heat from the sun, are briefly referred to. Herschel's observations on the spectra of the fixed stars have been, we believe, very much overlooked. In his memoir in the *Philosophical Transactions* for 1814 he mentions that in 1798 he made some experiments on the light of a few of the stars of the first magnitude, by a prism applied to the eye-glasses of his reflectors, adjustable to any angle and direction, with the following results:—The light of *Sirius* consists of red, orange, yellow, green, blue, purple, and violet; *α Orionis* contains the same colours, but the red is more intense and the orange and yellow are less copious in proportion than they are in *Sirius*. *Procyon* contains all the colours, but proportionally more blue and purple than *Sirius*. *Arcturus* contains more red and orange, and less yellow in proportion than *Sirius*. *Aldebaran* contains much orange and very little yellow. *α Lyræ* contains much yellow, green, blue, and purple." Holden suggests that if we were to attempt to classify these stars by Herschel's observations alone we should put *Sirius* and *Procyon* into one type of stars, which have all the colours in their spectra; *Arcturus* and *Aldebaran* would represent another group, with a deficiency of yellow and an excess of orange and red in the spectrum; *α Orionis* would form a type of those stars, with an excess of red and a deficiency of orange; and *α Lyræ* would represent a sub-group of the first class. The correspondence with Secchi's types and representatives is almost complete.

There remains one other great section of Herschel's researches and discoveries, that relating to the nebulæ and clusters of stars. When he commenced his observations in 1774 very few of these objects were known. Messier's catalogue of sixty-eight such objects did not appear till 1784, and they were chiefly objects found in his long-continued search for comets. Lacaille contributed twenty-eight from his observations at the Cape of Good Hope. Herschel discovered more than 2500, which he distributed in classes as follows:—Class I. "Bright nebulæ" (288 in all); II. "Faint nebulæ" (909); III. "Very faint nebulæ" (984); IV. "Planetary nebulæ" (79); V. "Very large nebulæ" (52); VI. "Very compressed and rich clusters of stars" (42); VII. "Pretty much compressed clusters" (67); VIII. "Coarsely scattered clusters" (88). In addition he pointed out large spaces of the sky covered with very diffused and faint nebulosity, which do not appear to have been re-observed. Holden advises that they should be sought for with a powerful refractor, which would be less open to illusions than Herschel's reflectors, and that the instrument should be used in the way he adopted—in sweeping.

Throughout Prof. Holden's interesting memoir there is evinced the same enthusiastic admiration of Herschel and his scientific labours, and he concludes in the same strain. "He was born with the faculties which fitted him for the gigantic labours which he undertook, and he had the firm basis of energy and principle which kept him steadily to his work. As a practical astronomer he remains without an equal. In profound philosophy he has few superiors."

Lists of Herschel's scientific memoirs and of works bearing upon them, are appended to the volume which has formed the subject of our notice, and which, if it has a fault, is of only too limited extent to do full justice to a long life of discovery and research. We will reiterate the hope expressed by Prof. Holden in his preface, as we understand it, that some member of Sir William Herschel's family may at no distant period "let the world know more of the greatest of practical astronomers" . . . "of a great and ardent mind whose achievements are and will remain the glory of England;" and in this connection, that whatever may be found amongst his manuscripts (and as regards the drawings of the nebulæ, no less an authority than the late Prof. D'Arrest has expressed a strong hope of further publication) may at the same time be given to the astronomical public.[1]

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[1] Prof. Holden's work is published in London by Messrs. W. H. Allen and Co.