William Herschel's Wonderful Decade, 1781-1790

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Abstract. William Herschel was a professional musician for fully half his life, and wished to be remembered as a composer. His achievements in astronomy—as telescope builder, observer, and theoretician—that are recognised by the naming of the current Herschel Space Telescope belong mainly to a single *mirabilis decas*, and this I discuss.

In the summer of 1782, William Herschel (1738–1822) accepted the invitation of King George III to become astronomer to the court at Windsor.[1] He was a musician, trained to the craft from infancy, and for years he had been one of the two leading figures in the musical life of the fashionable spa town of Bath in the west of England. He was already past the midpoint of his life, but as an astronomer he had until now been no more than an enthusiastic and talented amateur. Yet in a single wonderful decade without parallel in the history of astronomy, and embracing his last months as an amateur and his first years as a professional, Herschel so distinguished himself in astronomy that he earned the right to have his name given to a space telescope in the twenty-first century.

The decade begins on 1 January 1781. Herschel the amateur observer had for some years been making his own reflecting telescopes, because the purchase prices quoted for speculum disks seemed to him excessive. Being self-taught he was not preoccupied with the solar system, our little region of the universe, as were the professionals of his day. His ambition was to explore into deep space, investigating what he termed 'the construction of the heavens', and he understood that for this he needed reflectors with large mirrors that would bring faint and distant objects into view. So far his biggest telescope had a twenty-foot focal length and mirrors a modest twelve inches in diameter, and this was of limited use because the tube was crudely slung from a pole and the

1 On Herschel see, for example, Michael Hoskin, *Discoverers of the Universe: William and Caroline Herschel* (Princeton: Princeton University Press, 2011).

Michael Hoskin, 'William Herschel's Wonderful Decade, 1781-1790', eds. Nicholas Campion and Rolf Sinclair, *Culture and Cosmos*, Vol. 16 nos. 1 and 2, 2012, pp. 31-43.
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observer was precariously perched on the top of a huge ladder.[2] But the jewel in his collection was the six-inch mirror for his seven-foot, for this was the finest mirror of its size anywhere on Earth. Back in August 1779 he had set out to familiarize himself with the brighter stars by examining each of them in turn with the seven-foot, asking himself in particular if it was a double star; and the very first night he had found that the Pole Star was double.[3] At the beginning of 1782 he included this star in a catalogue of doubles he sent to the Royal Society with a view to publication.[4] But it was weeks before any other observer, professional or amateur, could confirm his claim, and when verification at last came, the President of the Royal Society, Sir Joseph Banks, personally wrote to Herschel to offer his congratulations.[5]

When the decade began, Herschel had identified rather more than half of the 269 double stars in this first catalogue. But this 'review' of the heavens was about to yield an unexpected trophy of exceptional value. On 13 March 1781 Herschel had arrived at the region around Zeta Tauri, and such was the excellence of his telescope that he instantly saw that one supposed star that came in turn under his examination was anomalous in appearance.[6] He therefore went back to it four nights later, and found that it had altered position: it was nearby, a member of the solar system. He assumed that it was a comet, for what else could it be? Comets were of great interest, then as now, and Nevil Maskelyne at Greenwich and Thomas Hornsby at Oxford eagerly searched for the supposed comet; but they found themselves frustrated, for in their instruments every object near Zeta Tauri looked like an ordinary star. Eventually they and other observers managed to locate the object, and when its motion was analysed it proved to be, not a comet, but a major planet of the solar system, the first to be discovered since the dawn of history. A year into our decade, then, Herschel's review had resulted in a

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2 On Herschel's telescopes the classic work is J. A. Bennett, '"On the power of penetrating into space": the telescopes of William Herschel', *Journal for the History of Astronomy*, Vol. 7 (1976): pp. 75–108.

3 William Herschel, 'Catalogue of double stars', *Philosophical Transactions*, lxxii (1782), pp. 112–62, entry IV.1.

4 Herschel, 'Catalogue'.

5 Banks to Herschel, 15 March 1782, Royal Astronomical Society Herschel Archive, W.1/13.B.4.

6 J. A. Bennett, 'Herschel's scientific apprenticeship and the discovery of Uranus', in G. E. Hunt (ed.), *Uranus and the Outer Planets* (Cambridge: Cambridge University Press, 1982), pp. 35–53.

patiently accumulated catalogue of double stars, and the sensational coup of a new planet. It was evident to Banks and his allies that Herschel was a telescope-maker of exceptional skill and an observer of great dedication, who was wasting much of his time teaching the aristocracy to fiddle.

It was also evident to Banks, a skilled wheeler-dealer, how to bring about the conversion of Herschel into a full-time astronomer. Galileo had long ago exploited the unwritten rules of patronage and had named the moons of Jupiter in honour of Duke Cosimo de Medici: the Medicean stars. By agreeing to the dedication, the Duke had accepted the obligation to appoint Galileo to a prestigious post at court. In similar fashion, under Banks's tutelage Herschel named his planet the Georgian Star, and in return King George appointed Herschel astronomer to the court at Windsor.[7] He took up residence in the nearby village of Datchet in August 1782, a professional astronomer at last. He was accompanied by his younger sister Caroline, whom he had rescued a decade earlier from her life as a household drudge in the family home in Hanover, on the pretext that she might sing in the Handel oratorios he used to mount in Bath.[8] Caroline was to prove a subordinate but crucial partner in the work ahead. Their brother Alexander had also travelled with them from Bath, to help them get settled in. Alexander was a cellist who had come to Bath in 1770 on two years' leave from the Hanoverian Court Orchestra, and was to stay forty-six years.[9] He was ingenious with gadgetry for telescopes and became a skilled brassworker; and in the years ahead, when Bath was out of season, he would regularly go and stay with his brother and sister, and help with the telescopes.

Astronomers of this period could excel in any one of three undertakings: as telescope maker, as observer, and as theoretician. Herschel—in my view, uniquely—excelled in all three. In Bath he had made telescopes for his own use, or for his siblings and closest friends. But after Herschel had been King George's astronomer for a year, the King encouraged him to supplement his salary by making telescopes for sale, and launched the enterprise with an order for five ten-foot

7 Hoskin, *Discoverers of the Universe*, chap. 4.

8 Michael Hoskin, *The Herschel Partnership: as viewed by Caroline* (Cambridge: Science History Publications, 2003); Michael Hoskin, *Caroline Herschel's Autobiographies* (Cambridge: Science History Publications, 2003); biographical sketch of Caroline in Michael Hoskin, *The Herschels of Hanover* (Cambridge: Science History Publications, 2007).

9 See the biographical sketch of Alexander in Hoskin, *The Herschels of Hanover*.

reflectors.[10] Most of the telescopes Herschel went on to make for sale were modest in size (seven-foot or ten-foot) And appropriate for the study of the solar system and the brighter stars.[11] Two others, for the King of Spain and the Empress of Russia, Were larger; the Spanish telescope had a pair of mirrors two feet in diameter, and these had great "light-gathering power", capable of bringing distant and faint objects into view. Its mounting was destroyed by Napoleonic troops, but its optics survive, and a full-scale replica has recently been constructed in shipyards in the north of Spain and erected at Madrid Observatory.

Herschel made his first attempt to construct such 'cosmological artillery' for his own use in 1781, when he was still a musician in Bath. His ambitions were for a mirror no less than four feet in diameter, which would have been by far the largest anywhere, larger even than the reflector whose thirty-inch mirror the geologist John Michell had cast in January of that year; but Herschel was paying for the expensive metal himself and eventually he compromised with a three-foot mirror.[12] He actually constructed some of the mounting for the thirty-foot tube, but it would never have worked in practice. But nothing came of the attempt; for Herschel could not find a foundry to cast so large a mirror, and when he tried to cast it himself in a furnace in the basement of his own home, the mirror cracked on the first occasion, while on the second the molten metal ran out onto the flagstones with near-fatal consequences.

A year after his move to the Windsor area he completed a twenty-foot reflector with eighteen-inch mirrors, and this time it had a stable mounting that allowed the observer to work in safety, either standing on a gallery nine feet wide with a guardrail, or seated in a chair attached to the ladderwork of the mounting.[13] Of this, more anon. But eighteen inches did not satisfy his ambitions, and in 1785 he persuaded King George to fund a 40-foot reflector with mirrors no less than four feet in diameter.[14] When it first saw light in 1789 it was one of the wonders of the age, and astronomers travelled from the Continent to

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10 RAS MS W.7/8, 35–36.

11 Andreas Maurer, 'A compendium of all known William Herschel telescopes', *Journal of the Antique Telescope Society*, no. 14 (1998): pp. 4–15.

12 Hoskin, *Discoverers of the Universe*, pp. 51–56.

13 Michael Hoskin, 'William Herschel and Herschelian reflectors', *History of Science*, vol. 49 (2011): pp. 115–20.

14 Michael Hoskin, 'Herschel's 40ft reflector: funding and functions', *Journal for the History of Astronomy*, vol. 34 (2003): pp. 1–32.

admire it. But it had run seriously over budget, and a furious King had found himself forced to double his subvention or face the total loss of the money he had already invested. Worse still, it proved cumbersome to use, and when (as we shall see) the question it was designed to answer was resolved in 1790 by other means, the great reflector became little more than a white elephant, whose chief function was the after-dinner edification of guests at Windsor Castle.

A forty-foot reflector was one of the instruments on Herschel's standard list of telescopes for sale.[15] However, fortunately, no doubt, none of this size was ever ordered. Herschel married a very rich widow in 1788 and thereafter he had no need to engage in commerce.[16] But he continued so to do, partly to benefit from experience in novel techniques of manufacture that he might exploit in his own instruments, partly no doubt in the hope that fellow astronomers would use the instruments to verify his claims.[17] It may also have been partly because it flattered his vanity to have crowned heads begging to be favoured with the purchase of a Herschel reflector. He himself would prepare the optics on which the instrument's performance primarily depended, while the wooden mounting would be subcontracted to a carpenter, and the brasswork would often be made by Alexander.

Herschel, then, was one of the greatest of instrument builders, but he was also one of the greatest observers. We have seen his early work on double stars, which resulted in one catalogue of 269 objects published in 1782 and another of 434 objects published in 1784.[18] He made individual discoveries of importance. For example, in September1786 he adopted a 'front-view' configuration for his twenty-foot and this greatly increased the light that came to his eyepiece.[19] On 11 January 1787 he chose a sweep that would bring Uranus under scrutiny, and he carefully noted the star-like objects that were close to the planet. The next night,

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15 Maurer, 'A compendium', p.15.

16 Michael Hoskin, 'Mary Herschel's fortune: origins and impact', *Journal for the History of Astronomy*, vol. 41 (2010): pp. 213–23.

17 John Tracy Spaight, ''For the good of astronomy': the manufacture, sale, and distant use of William Herschel's telescopes', *Journal for the History of Astronomy*, vol. 35 (2004): pp. 45–69.

18 William Herschel, 'Catalogue of double stars', *Philosophical Transactions*, vol. 75 (1785): pp. 40–126.

19 Hoskin, 'William Herschel and Herschelian reflectors', pp. 115-20.

two of them were missing: they were moons of Uranus.[20] Again, in the late 1780s Saturn's ring was edge-on to Earth, something that happens every fifteen years or so, and then it may be possible to see moons of Saturn that are normally lost in the glare of the ring. In the summer of 1787, Herschel examined the planet with his twenty-foot, but it was then in a region with many background stars, and although he suspected he had seen a sixth moon, he could not be sure. He tried again the following year, and again in 1789, and now the forty-foot was about to come into operation. He observed the planet for six nights with the twenty-foot, and then, on 28 August, with the forty-foot. Now he was convinced he had discovered a sixth moon, as indeed he had; and within days the forty-foot had revealed a seventh. The astronomical world was thrilled—the great reflector had seen light for the first time, and behold, Saturn had two more moons.[21] Sadly, these were both the first and the last discoveries of note the monster would ever make.

But Herschel's fame as an observer rests on his catalogues of nebulae and clusters of stars. The presence in the sky of milky patches or 'nebulae' had long been recognized, and his contemporary, the French comet-hunter Charles Messier, had for years been assembling a catalogue of nebulae so that he would not mistake them for comets. Messier's final catalogue, published in 1781, ran to just over a hundred such objects.[22] Herschel had seen a handful of nebulae in his Bath days, and late in 1781 his Bath friend William Watson came across the previous version of Messier's catalogue and sent it to him as a present.[23] Throughout 1782 Herschel had too much else on his mind to have time to pursue nebulae, but his sister Caroline was another matter. Once they moved to near Windsor and her career in music was at an end, Herschel encouraged her to become his assistant in astronomy, and he equipped her with a little refractor and told her to go out and look for anything interesting, including "nebulas". Small though her telescope was, she occasionally came across a nebula, but it seemed always to be in the catalogue Watson had sent. On 26 February 1783, however, she came across two, for each of which she noted, "Messier has it not". In fact, the first was in

20 William Herschel, 'An account of the discovery of two satellites revolving round the Georgian Planet', *Philosophical Transactions*, vol. 77 (1787): 125–29.

21 A. F. O'D. Alexander, *The Planet Saturn: A History of Observation, Theory and Discovery* (London: Faber & Faber, 1962), chap. 8.

22 Charles Messier, 'Catalogue des nébuleuses et des amas d'étoiles', *Connoissance des Temps pour 1784* (Paris, 1781): pp. 227–69.

23 William Watson, Jr, to Herschel, 7 December 1781, RAS W.1/13.W.11.

Messier's final catalogue which was then unknown to the Herschels, but it was not in the earlier version that Watson had sent; the second, however, was indeed the discovery of a nebula hitherto unknown to astronomers.[24] The impression Herschel took away with him from the night's viewing was that his sister, a novice observing with a telescope that was little more than a toy, had enlarged the number of nebulae known to science by two: evidently, among the nebulae there were rich pickings.

Impulsively, he set to work to search for nebulae himself, with a small refractor. Then it occurred to him that nebulae—unlike comets—are permanent features of the night sky, and so should be examined methodically with a telescope with the largest possible 'light-gathering power'. His new twenty-foot reflector was nearing completion and would be ideal for the purpose. He passed the summer months familiarizing himself with Messier's nebulae, using his seven-foot reflector, or a ten-foot, or the 'small' twenty-foot that would soon become obsolete.

His first attempts in the autumn of 1783 to 'sweep' for nebulae with the new twenty-foot were ill-judged. He pointed the mounting of the instrument towards the south, and then stood on the observing gallery dragging the tube first to one side of the meridian and then to the other. Meanwhile the sky was rotating slowly overhead, bringing new regions into view. When he noticed something of interest, he used artificial light to make a note of it; but then it took his eyes some time—valuable time—to get dark-adjusted once more. And it was nigh-impossible to keep track of the regions he had 'swept'.[25]

By the end of the year he had learned from his mistakes. He now kept the tube pointing directly south, so that the telescope functioned as a transit instrument, while he himself observed from the comfort and security of a chair. But its field of view was limited and the sky was rotating very slowly, and so he hired a workman to raise and lower the tube in an oscillatory motion; Alexander devised a bell-mechanism that would warn the workman when to stop and backtrack. In this way, he was able to examine a 'horizontal' strip of sky two or more degrees in width.

Nebulae are faint and elusive, and so Herschel needed to give his full attention to the region of sky passing before his eyes. But when he

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24 Michael Hoskin, 'Caroline Herschel as observer', *Journal for the History of Astronomy*, vo. 36 (2005): pp. 373–406.

25 Hoskin, *Discoverers of the Universe* (ref. 1), 92–93.

found a nebula, its location and description had to be recorded, and for this he recruited Caroline. She would be seated at a desk at a nearby window, with instruments and reference works to hand, ready to copy down her brother's shouted description and to record the location of the nebula by reference to a nearby star. To save her freezing to death in the severe winters then usual, she would have her window closed until a tug on a rope told her that her brother had something to communicate. Next day she would write up a fair copy of her record and, in due course, compile catalogues for publication in *Philosophical Transactions*. Just over one hundred nebulae were known to Messier. When our decade ended seven years later, the Herschels, then in the midst of one of the most extraordinary campaigns in history, had already discovered nearly 2300 more.

As a theoretician Herschel nearly always based himself on his own rich store of observations, which posed problems for other astronomers who had to take his word for what he had seen, but on one occasion he analysed data that were available to all.[26] Back in 1718 Edmond Halley had found that three stars were no longer in the positions they had occupied in Antiquity, and since then an increasing number of 'proper motions' of stars had been identified with greater or less confidence. No doubt the Sun and solar system were also in motion, and this in itself would generate apparent proper motions in the stars immediately around us. How then to separate out the pattern of proper motions resulting from our own journey through space from the motions that belong to the stars themselves, and so determine the direction of the solar motion? Tobias Mayer provided the answer in a lecture he gave in 1760: if you are walking towards a wood, the trees to your left will appear to move further left and the trees to your right will appear to move further right. Herschel was the first to see such a pattern in the known proper motions, and this led him in 1783 to propose that we are moving in the direction of the star Lambda Herculis. This is, in fact, the direction accepted today, which makes Herschel's result seem nothing short of amazing, but when we examine his argument we find that he recklessly accepted a tiny alleged motion at face value; and if the motion had had the opposite sign (as could easily have happened) he would have arrived at a very different 'solar apex'.

Most fact-gatherers tend by instinct to be cautious, but not Herschel. In 1785 in *Philosophical Transactions* he gave notice that his

26 William Herschel, 'On the proper motion of the Sun and solar system', *Philosophical Transactions*, Vol. 73 (1783): pp. 247–83.

readers should be prepared for him to theorize too much rather than too little:

> If we indulge a fanciful imagination and build worlds of our own, we must not wonder at our going wide of the path of truth and nature.... On the other hand, if we add observation to observation, without attempting to draw not only certain conclusions, but also conjectural 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.[27]

Herschel's overall goal was to understand "the construction of the heavens", and central to this was the problem of the nebulae. It was obvious that a cluster of stars so far away that telescopes could not distinguish the individuals would appear nebulous; but were all nebulae merely distant clusters of stars, or were some clusters and others truly nebulous, formed of some sort of luminous fluid and located close to us? When Herschel first appeared on the scene, opinion among astronomers was sharply divided.[28] A crucial test was whether a nebula—any nebula—had altered shape in only a matter of years, for a distant cluster could not possibly rearrange itself in so short a time. And Herschel the musician and amateur astronomer understood this from the very start of his career as an observer—indeed he seems the only astronomer to have done so. On the first page of his first observing book, from October 1774, we find a sketch of the Orion Nebula and the comment: "its Shape was not as D^{r} Smith has delineated in his Optics ... perhaps from a careful observation of this Spot something might be concluded concerning the Nature of it."[29]

Robert Smith had reproduced a seventeenth-century sketch of the Orion Nebula in his two-volume *Opticks*, which was Herschel's bible for the construction of telescopes.[30] Herschel did not yet realize how

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27 William Herschel, 'On the construction of the heavens', *Philosophical Transactions*, Vol. 75 (1785): pp. 213–66, p. 213.

28 On the history of observations and theories of nebulae prior to Herschel, see Kenneth Glyn Jones, *The Search for the Nebulae* (Chalfont St Giles, Bucks: Science History Publications, 1975).

29 RAS W.2/1.1, f. 1.

30 Robert Smith, *A Compleat System of Opticks* (Cambridge: Cornelius Crownfield, 1738), Fig. 682.

different the same nebula can appear in different telescopes or under different seeing conditions, and he believed from the sketch in front of him that he had evidence that the Orion Nebula had altered shape. From then on, every couple of years, he returned to the Orion Nebula, and several times confirmed (as he thought) that it had again altered shape.[31]

How then was he to differentiate between 'true' nebulosity and the nebulous appearance of distant star clusters too far away for the individual stars to be visible? It seemed to him that sometimes a nebulosity he encountered looked mottled, while sometimes it was smooth or 'milky'. Not unreasonably he supposed that mottled nebulosity revealed the presence of a star cluster, while the smooth, milky nebulosity arose from what we would term a gas cloud. But then, in 1784, his sweeps brought him to first one nebula in which both forms of nebulosity seemed to be present, and then to a second. In a dramatic switch he now interpreted the two nebulae as star clusters in the form of strata of stars, seen edge-on: the mottled nebulosity came from their stars in the middle distance, the milky nebulosity from their more remote stars. The changes he believed he had seen in the Orion Nebula he now deemed to be illusory: all nebulae were simply star clusters.

The universe of Newton and Leibniz had been unchanging in its essentials, the work of God the Great Clockmaker, in which planets cycled round endlessly; and (according to Newton) the Great Clockmaker intervened if the system's stability ever came under threat. It was part of God's regular servicing contract with the universe he had created, and His way of showing that he continued to care for mankind. The same applied to the universe of stars. The Greeks had spoken of the stars as 'fixed' because it seemed they preserved their positions relative to each other without the slightest change. But Newton knew that the stars were isolated bodies free to move in space, and he claimed that gravity was a universal force. But forces generate movements, and not long after the publication of *Principia* in 1687, Newton was challenged to explain how it could be that the stars were 'fixed' and motionless in a universe dominated by gravity. His solution, known only to his intimates, was to argue that the stars are distributed throughout space with a high degree of regularity, so that each star is pulled in each direction more or less equally by the surrounding stars. But the symmetry of the system of stars is obviously imperfect and so in time gravity will cause them to move.

31 For more on the story that follows, see Michael Hoskin, 'William Herschel and the nebulae', *Journal for the History of Astronomy*, Vol. 42 (2011): pp. 177–92 and 321–38.

Newton could rescue his mechanical, clockwork universe only by calling on God the Great Clockmaker to intervene from time to time and restore the original semblance of order.[32]

To Herschel the existence of star clusters demonstrated that an attractive force—no doubt Newtonian gravity—was at work among the stars. In an almost exact parallel to Newton, Herschel too imagined a universe in which the stars were scattered throughout space with fair regularity. But for him gravity was the great agent of change. Here and there there might be more stars than usual, or larger stars than usual, and then the large gravitational pull that resulted would draw in the surrounding stars, to form a cluster. At first the stars of such a cluster would be widely dispersed, but as time went on—as the cluster got older—the stars would become more and more concentrated: scattered clusters were young and concentrated clusters were old. The cosmos in which we live today is not mechanical, but biological in our conception of it: stars go through a life-cycle, galaxies evolve, even the cosmos itself started with the Big Bang. This transformation began with Herschel's papers of the 1780s on 'the construction of the heavens'.

Herschel was confident that his twenty-foot reflector could reach the border of our star system (or Galaxy) in every direction. This being so, and provided that the stars within the Galaxy were scattered with something approaching uniformity, then the number of stars visible in the twenty-foot in a given direction would be a guide to the distance to the border of the Galaxy in that direction. Herschel could not spare the time to count stars in *every* direction across the heavenly sphere, but he showed how to apply the method, by counting stars across a great circle of the sky, in the first ever exercise in stellar statistics. A corollary was that the great nebulae such as those in Orion and Andromeda—each spread across a region of sky, yet so distant that the stars composing it could not be seen individually—must be so vast they "may well outvie our milky-way in grandeur", and be galaxies even greater than our own.

Six years later, at the end of our decade, new evidence was to force him to alter his opinion once more. On 13 November 1790, he was sweeping as usual, when he encountered "A most singular phenomenon! A star of about the 8th magnitude, with a faint luminous atmosphere, of a circular form, and about 3' in diameter". Back in September 1782, only a month after his move from Bath, he had come across a mysterious object

32 Michael Hoskin, 'Newton, Providence and the universe of stars', *Journal for the History of Astronomy*, Vol. 8 (1977): pp. 77–101.

that was faint like a nebula but seemed to have a disk like a planet, and which he therefore named "a planetary nebula"—the term we still use today for such objects. In the years that followed he found a handful more, and he was at a loss to know what to make of them. The object he had now encountered was in fact another planetary nebula, but this time it was near enough for Herschel to be able to see its central star. It was all-too-evidently a star surrounded by nebulosity: 'true nebulosity' existed after all, and the star was condensing out of the nebulosity by the action of gravity.[33]

And so our decade ended as it had begun, with Herschel convinced of the existence of true nebulosity, and gravity as the great agent of change in the universe. Widely scattered light would form clouds of nebulosity wherever the density of the light was greater than usual, and these clouds would in time condense into stars, and the stars would gather into clusters, scattered at first but then more and more condensed, until, no doubt, gravitational collapse would cause a cataclysmic event out of which the process would begin all over again.

There were drawbacks to this new and all-embracing cosmogony. Herschel reluctantly came to accept that his telescopes could not penetrate to the borders of the Galaxy, which therefore was of indeterminate extent. By contrast, the changes he had long ago observed in the Orion Nebula—changes whose authenticity he accepted once more—showed that it could not be a distant star cluster. Even if it had been, it would no longer have been a galaxy comparable to our own, for the Orion Nebula is clearly finite whereas our Galaxy has no known bounds.

In his final papers, in the second decade of the nineteenth century, Herschel would draw on his great catalogues of nebulae to lay before us samples of nebulae and clusters at successive stages of their

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33 William Herschel, 'On nebulous stars, properly so-called', *Philosophical Transactions*, vol. 81 (1791): pp. 71–88.

evolution under gravity.[34] These stages he compares to “an annual description of the human figure, were it given from the birth of a child till he comes to be a man in his prime”. The clockwork universe of Newton would soon be a thing of the past.

34 William Herschel, ‘Astronomical observations relating to the construction of the heavens’, *Philosophical Transactions*, Vol. 101 (1811): pp. 269–336; ‘Astronomical observations relating to the sidereal part of the heavens’, *Philosophical Transactions*, Vol. 104 (1814): pp. 248–84.