Journal of Astronomical History and Heritage, 11(3), 235-246 (2008).

WILLIAM HERSCHEL'S FIFTY-TWO FIELDS OF EXTENSIVE DIFFUSED NEBULOSITY – A REVISION

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Abstract: Since its publication in 1811, William Herschel's list of fifty-two fields of extensive nebulosity has been largely disregarded, or even discredited, by the astronomical community. Neither he nor his successors decided to include the observations of large structureless fields of background nebulosity in their major catalogues. It was only during a short period in the early twentieth century that astronomers like I. Roberts, E.E. Barnard, and M. Wolf started more serious investigations into the nature and reality of Herschel's nebulosities, but without deriving conclusive results. Those few who tried to understand Herschel's elusive observations were often puzzled by his ambiguous descriptions and frequently tended to reject the nebulosities as being optical illusions, because only a small number of them could be proven by celestial photography. The only unconditional supporter of the reality of the nebulosities was Johann Georg Hagen, who in the 1920s used them as evidence for his hypothesis that nebulous matter covered almost the entire celestial sphere. He claimed to have succeeded in visually observing nebulous matter in every single one of Herschel's fields, which raised sharp opposition from his numerous critics. The questionable quality of Herschel's original descriptions, the weak supporting arguments, and the lack of photographic evidence, finally led historians to conclude that Herschel's fifty-two fields of extensive nebulosity were illusions. But it would seem astonishing that this gifted observer could have been fooled to such an extent. As a first approach to investigate this apparent anomaly, a complete analysis of Herschel's observing books was carried out, and the raw observations of the various catalogued nebulous fields were extracted. Some important stylistic uncertainties in the descriptions of the visual appearance of the nebulosities were cleared up, leading to a better understanding of what Herschel actually saw. Possible sources of error were excluded, or at least qualitatively estimated, for certain regions. One outcome of this project is a completely revised list of fields of largely extended nebulosity observed by Herschel, which certainly does not prove the correctness of all of his observations but does at least clarify the context in which they should be regarded. As a useful by-product, some poorly-known first-time observations of nebulous fields that are well known today by means of photography can now be assigned to William Herschel.

Keywords: W. Herschel, I. Roberts, D. Klumpke Roberts, J.G. Hagen, fifty-two fields of nebulosity, extensive nebulosity, dark clouds.

1 INTRODUCTION

William Herschel's catalogue of more than 2500 non-stellar celestial objects is without doubt one of the great astronomical achievements of this exceptional astronomer. Largely unknown, however, is a list containing fifty-two fields of extensive nebulosity, which Herschel published in 1811 as a supporting argument to his nebular hypothesis (Herschel, 1811: 275-276), all of which were observed as a by-product of his sweeps between 1783 and 1802 (see Figure 1). For the purpose of a final revision of Herschel's objects, his sister Caroline's copies of the eight observing books containing the results of his decade-long sweeps (Herschel, Herschel and Herschel, 2004) were analyzed. As a result, a number of errors and inaccuracies were found and corrected. Furthermore, the terminology used to describe the observed nebulosity—which differed widely from that used by Herschel to describe non-stellar objects in his better-known catalogues of nebulae—was investigated in order to obtain a clearer impression of the appearance of Herschel's objects. The accompanying revised list summarizes all of the noticed peculiarities.

2 BACKGROUND HISTORY

2.1 The Original Observations

From the beginning in 1783, throughout his observing sessions William Herschel casually noticed large areas of sky extending over many square degrees which seemed to be affected by very faint veils of nebulosity, a phenomenon which was completely different from the mostly well-defined spots of nebulosity he came across every clear night. Obviously these observations were always made near the absolute physiological limit of the human eye: in Herschel's (1811: 277) own words "… [the nebulosities] can only be seen when the air is perfectly clear, and when the observer had been in the dark long enough for the eye to recover from the impression of having been in the light." Showing his talent as an extraordinarily careful observer, Herschel logged every such case of an apparent large-scale brightening of the sky background—'bottom' or 'ground', as he called it (see Figure 2). However, this method proved to be quite inexact in terms of gauging the total extension of such areas, and Herschel knew about its limitations when he wrote in his 1811 paper that "… the nebulous state of the heavens could only be noticed when its appearance became remarkable enough to attract attention."

2.2 Cosmological Significance

The first published mentioned this particular type of object occurred in 1791 when Herschel stated that after observing the region of southern Orion he found evidence of

> … a telescopic milky way, which I have traced out in the heavens in many sweeps made from the year 1783 to 1789. It takes up a space of more than 60 square degrees of the heavens, and there are thousands of stars scattered over it. (Herschel 1791: 77).

While this may be the first published account of extensive diffused nebulosity, many years before Herschel was convinced of the stellar nature of all nebulous objects, whether well-defined or large and extended. But it was only in 1811 that he published his opinion that nebular matter must exist in great abundance throughout the Universe, even though the

idea of its general existence was foreshadowed in his 1791 paper. Prior to this Herschel held the opinion that 'real' nebulosity did not exist but could be explained by a clustering of stars too weak to be resolved in the telescope, just as faint stars form the band of the naked-eye Milky Way. Consequently, the term *resolvable* occurs quite often in Herschel's early records when describing the appearance of nebulous objects (cf. Hoskin 1983: 135), indicating that they would presumably be resolved into individual stars if the telescope were powerful enough.

No.	R. A.	P. D.	Paral.	Merid.	Size.	Account of the Nebulosity.
	h ′ ″	° ′	° ′	° ′	Deg.	
1	0 5 2	81 7	1 44	1 55	3,3	Much affected with nebulosity.
2	0 12 31	86 34	3 0	2 34	7,7	Much affected.
3	0 17 17	61 24	0 41	2 40	1,8	Affected.
4	0 20 31	86 34	1 30	2 34	3,6	Much affected.
5	0 25 5	67 8	0 29	2 34	1,2	Much affected.
6	0 31 22	93 4	2 30	2 19	5,7	Appeared to be affected with very faint nebulosity.
7	0 32 54	49 23	1 33	3 1	4,7	Affected with nebulosity.
8	0 34 21	51 17	1 17	2 49	3,6	Unequally affected.
9	0 36 13	47 3	2 37	3 18	8,6	Suspected faint nebulosity.
10	0 43 32	46 58	0 26	3 18	1,4	Suspected faint nebulosity.
11	1 35 32	60 42	0 28	2 40	1,3	Suspected to be tinged with milky nebulosity.
12	2 22 19	71 27	0 29	2 29	1,2	Much affected with nebulosity.
13	3 56 14	65 6	0 29	2 27	1,7	Much affected.
14	4 17 21	55 7	1 4	2 38	2,8	Suspected pretty strong nebulosity.
15	4 18 21	55 6	1 53	2 38	5,0	Suspected nebulosity.
16	4 21 35	97 44	0 30	2 15	1,1	Strong milky nebulosity.
17	4 23 14	69 23	0 29	2 36	1,3	Much affected.
18	4 38 17	69 23	0 29	2 36	1,3	Much affected.
19	4 46 17	63 25	1 46	2 31	4,4	Strong suspicion of very faint milky nebulosity.
20	5 9 44	65 6	1 23	2 27	3,4	Very much affected.
21	5 13 14	65 6	0 29	2 27	1,7	Affected.
22	5 23 59	97 1	2 31	2 31	6,3	Affected with milky nebulosity.
23	5 25 10	92 48	0 30	2 40	1,3	Affected.
24	5 27 2	94 23	1 48	2 32	4,6	Visible and unequally bright nebulosity. I am pretty sure this joins to the great nebula in Orion.
25	5 30 40	92 35	2 45	2 33	7,0	Diffused milky nebulosity.
26	5 31 58	97 1	1 56	2 31	4,9	A pretty strong suspicion of nebulosity.
27	5 38 5	88 55	1 6	2 37	2,9	Affected with milky nebulosity.
28	5 55 55	86 17	0 30	2 34	1,3	Much affected.
29	5 56 36	110 28	1 48	2 48	5,0	Affected.
30	6 33 7	48 39	0 26	3 4	1,3	Affected.
31	9 22 56	108 3	0 29	2 30	1,2	Affected.
32	9 27 19	18 21	0 24	4 4	1,6	Much affected with very faint whitish nebulosity.
33	10 6 56	98 33	3 58	2 17	9,1	Very faint whitish nebulosity.
34	10 10 1	37 58	0 24	4 9	1,7	Much affected.
35	10 34 29	26 44	0 29	3 15	1,6	Affected with very faint nebulosity.
36	10 58 24	26 44	0 42	3 15	2,3	Affected.
37	11 56 59	58 50	0 41	2 54	2,0	Affected with whitish nebulosity.
38	12 7 34	58 50	0 41	2 54	2,0	Affected with whitish nebulosity.
39	13 7 33	55 20	0 27	2 17	1,0	Much affected.
40	13 58 0	55 20	0 42	2 17	1,6	Very much affected; and many faint nebulæ suspected.
41	15 5 7	70 40	1 52	2 31	4,7	Affected with very faint nebulosity.
42	20 58 20	92 17	1 45	2 21	4,1	Much affected with whitish nebulosity.
43	20 48 50	73 38	0 29	2 52	1,4	A good deal affected.
44	20 51 4	46 51	0 59	2 53	2,8	Faint milky nebulosity scattered over this space, in some places pretty bright.
45	20 52 28	91 57	0 49	0 56	0,8	Much affected with whitish nebulosity.
46	20 53 31	47 7	1 8	3 18	3,7	Suspected nebulosity joining to plainly visible diffused nebulosity.
47	21 0 20	76 3	0 44	2 46	2,0	Affected.
48	21 22 27	80 8	0 30	2 15	1,1	Much affected.
49	21 42 16	68 57	0 29	2 36	1,2	Affected.
50	22 52 35	64 47	0 29	2 47	1,3	Much affected
51	22 53 0	64 47	0 42	2 47	1,9	Affected.
52	22 55 29	61 15	0 28	2 37	1,2	A little affected.

Figure 1: Herschel's table of extensive diffuse nebulosity (1800.0) (after Herschel, 1811).

Thus the 1791 account of the "… telescopic milky way …" in Orion should be regarded in accordance with the state of Herschel's cosmology at that time. Once more it indicates Herschel's conviction that large nebulous fields were clearly stellar. From this perspective it is obvious why most observations of extended fields of diffuse nebulosity remained untreated for so many years: Herschel simply did not judge those fields important for his research into the structure of the Universe as there were no stars to be counted and the relevant regions of the sky did not contain any other physical objects of interest. So we have an explanation as to why the fifty-two fields of extensive diffused nebulosity—which Herschel finally published in 1811—never made it into any of his earlier well-known catalogues: it was only in that year that he classified them as a specific class of objects.

However, opinion had changed significantly by the time Herschel published his 1811 paper. At last he had changed his own mind about nebulosity, stating that "… in this new arrangement I am not entirely consistent with what I have in former papers said on the nature of some objects that have come under my observation." He now believed that nebulous matter was very common throughout the Universe, being the material from which stars formed.

In order to support this hypothesis further, Herschel put his observations of nebulae-related objects into a new order: starting from the most extended nebulosities he thought of an evolution up to 'stellar nebulae nearly approaching to the appearance of stars' in order to demonstrate the increasing condensation of nebular matter into stars. As one starting point for this argument Herschel then introduced his thus-far unpublished list of fifty-two "… extensive diffused nebulosities."

2.3 Early Treatment

From the day of its publication not much attention was paid to these areas of nebulosity, which was probably as much a consequence of the exceptional observational equipment that Herschel used for the observations as it was of the missed publicity through not having been included in his three catalogues of nebulae. Possibly he foresaw the difficulties that might arise in trying to verify his observations: "... we find that extreme faintness is predominant in most of [the fields]; which renders it probable that our best instruments will not reach so far into the profundity of space, as to see more distant diffusions of it." (Herschel 1811: 277-278). In fact, during the early nineteenth century there was almost no telescope which matched Herschel's 20 feet reflector, and the few comparable instruments in the hands of professional astronomers (such as J.H. Schröter in Lilienthal) were mostly used for planetary observations. Thus, Herschel's fifty-two fields of extended diffuse nebulosity quickly fell into oblivion and attracted little attention for the next eighty years.

Even William Herschel's son, John, decided to omit these fields of nebulosity from his general catalogue of 1864 (Herschel 1864: 7), even though he had Arthur Auwers' (1862: 42) reduced list of his father's observations and knew about them. His reasons must have been the same as J.L.E. Dreyer's forty-four years later, when, in the Foreword to his second Index Catalogue, published in 1908, Dreyer stated that

> … of the very extensive and diffused nebulosities ... I have only inserted a few fairly well-defined objects of limited size. An object like No. 27 in W. Herschel's list of regions 'affected with nebulosity', filling the whole constellation of Orion, could obviously not find a place

here. (Dreyer 1971: 286).

Thus—just as John Herschel had done previously—Dreyer consciously refrained from including the areas of diffuse nebulosity in his catalogues. Both astronomers must have shared the same arguments: objects of this size and covering such large areas of the sky tend to mask other objects in the same region, thus leading to confusion in identifying more distinct nebulae.

2.4 Observational Attempts Around the Turn of the Century

Whether for these reasons or others, we know of no attempt to re-observe Herschel's areas of diffuse nebulosity until 1891 when the British amateur astronomer, Thomas Backhouse (1891: 1), wrote:

> I have examined with my field-glass [a pair of binoculars of 2.05 inches aperture and 3.8 times magnification] the places of several of these nebulosities, and find that his objects do not agree with those seen with this smaller instrument. It is true there are wisps occupying part, or the whole, of some of the nebulous regions quoted by Sir W. Herschel, but in other cases there is nothing special visible. Also, in the neighbourhood of Herschel's nebulosities, there are numerous faint wisps far more conspicuous with the field-glass than those in the areas he enumerates.
>
> I do not fully understand his list, for some of the regions of nebulosity overlap ... One may conclude from these observations that a large part of the wisps visible with my field-glass were resolved by Herschel's telescope of 20 inches diameter; and that what he saw were fainter nebulosities, or it may be, in some cases, unresolved portions of those seen by me.

Backhouse did observe Herschel's nebulosities in Taurus in the course of examining the extent and detailed structure of some parts of the northern Milky Way, but his judgement about them was rather devastating, even if he was not very influential (for later observers did not refer to his paper).

But the time was favourable for the study of elusive celestial objects. With the application of photography to astronomy large nebulosities raised the interest of many astronomers. Just one year after Backhouse's observations, E.E. Barnard (1892) published Herschel's list anew as of "… extremely great value …" to those interested in photographing such objects. One of the better-known nebulae from the list, Herschel's no. 27, had already been photographed three years before Barnard's paper by W.H. Pickering, and in 1894 by Barnard himself (the so-called 'Barnard's Loop'; see Barnard, 1894), thus giving rise to hope that the other nebulosities might also exist. The high value Barnard attached to Herschel's nebulosities may be estimated from his 1903 statement that

> … this question of large areas of diffused nebulosity in the sky is a very important one, not yet fully appreciated, but which must sooner or later have the highest bearing on a proper understanding of the physical condition of the universe.

In 1896, Isaac Roberts began a photographic survey of the fifty-two nebulosities, the results of which were reported in three different papers (Roberts, 1902; 1903a; 1903b), together with Herschel's table reduced to epoch 1900.0. Roberts' motivation was of course investigative, knowing that

> … no systematic efforts were made to verify Herschel's observations of these 52 regions until six years ago, when the work of photographing them was commenced at my Observatory, using for the purpose the 20-inch reflector and the 5-inch Cooke lens. (Roberts 1903c).

The exposure time was 90 minutes, a standard for his photographic works. Thus Roberts' expectation to unveil the real nature of Herschel's objects was high:

> My long previous experience in photographing the heavens enabled me to judge that under these conditions nebulosity of at least the degree of faintness that could be seen by Herschel with his two- and four-feet reflectors would be shown on the photographic plates.

Nevertheless, as with Backhouse, the result was almost negative: "Of the fifty-two nebulous regions described by Herschel, the photographs showed diffused nebulosity on four of them only; there is no visible trace of diffused nebulosity on forty-eight of the areas". The four positive detections were nos. 7, 25, 44 and 46, with nos. 44 and 46 obviously related to the then well-known nebular complex NGC 7000 (in Roberts' eyes more or less representing the same physical object). In addition, no. 7 was regarded by Roberts as part of the outer areas of M 110, a companion of the Great Andromeda Nebula, thus definitely leading him to the conclusion that not much new was contained in Herschel's list, to the mind of the twentieth century astronomer.

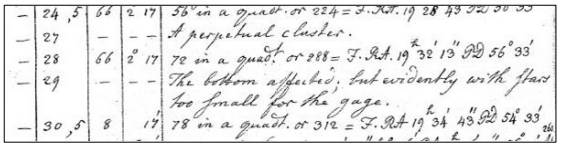

Figure 2: Example of a logbook entry showing an account of the sky background apparently affected by nebulosity. This observation was made during sweep no. 269 on 13 September 1784 and demonstrates Herschel's early view that this type of nebulosity is just a summation effect of faint background stars.

But now that an authority like Roberts had written off Herschel's observations as essentially being deceptions, reactions from the astronomical community quickly occurred—and they were crushing. In the very issues of *Monthly Notices* and the *Astrophysical Journal* where Roberts published his results, Heidelberg astronomer Max Wolf (1903) and Barnard (1903) respectively, published harsh criticisms of his conclusions. Barnard opposed Roberts' opinion on two grounds: first, he claimed that a 90 minute exposure was not sufficient to trace nebulae as faint as Herschel's, and as an example he mentioned Herschel's nebulosity no. 27, its position being in perfect agreement with the earlier-mentioned 'Barnard's Loop' that Barnard had discovered photographically in 1894, but which was totally invisible on Roberts's plates. Second, he thought it

> … a little unreasonable to suppose that Herschel, who made so few blunders compared with the wonderful and varied work that he accomplished, should be so palpably mistaken in forty-eight out of fifty-two observations of this kind. (Barnard, 1903: 77-78).

This second remark clearly shows the great respect that William Herschel still received even by some of the most eminent observers of the time, in not wanting to let his observational work fall into disrepute.

More factual criticisms came from Max Wolf, who considered it strange that Roberts had not been able to

detect the extensive nebulosity of southern Orion, with its dimensions filling dozens of square degrees around the Great Orion Nebula, thus covering Herschel's objects no. 22, 23, and 24. Wolf and Barnard were both able to do so (e.g. see Figure 3), but used much longer exposure times than Roberts had.

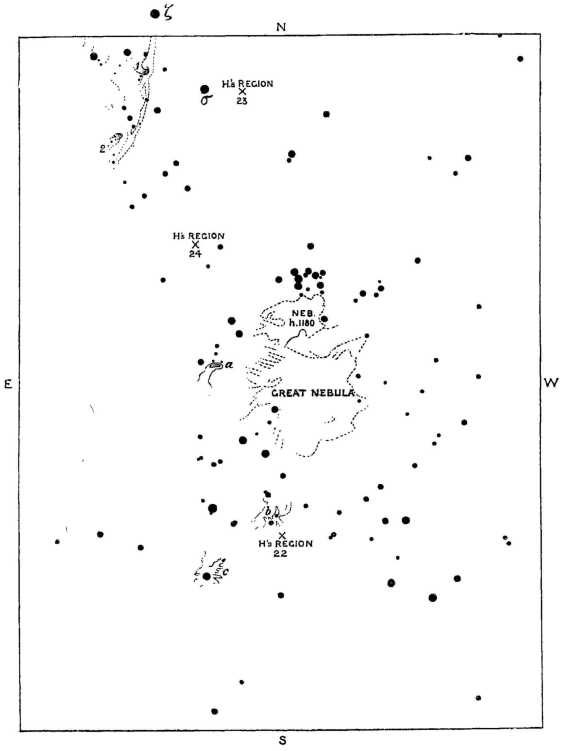

Figure 3: Drawing by Max Wolf to illustrate the situation of Herschel's nebulosities no. 22, 23, 24 in relation to the faint photographic nebulosities about the Great Orion Nebula (after Wolf, 1903: f. 302).

In the end, this dispute proved to be of short duration, probably because Roberts' death in June 1904 left little room for further debate.

Now that only the two advocates of Herschel's nebulosities were left, the general opinion was that Herschel was indeed right, and around 1904 his nebulosities were regarded simply as fainter examples of the well-known diffuse emission and reflection nebulae. But the final word about their reality had yet to be written, since only eight entries were considered confirmed (see Table 1).

2.5 Father Hagen's Observations

Almost twenty more years passed before Herschel's list was analyzed once again. In 1920 the Austrian-American Jesuit astronomer Johann Georg Hagen (1847–1930), then Director of the Specola Vaticana in Rome, had started a program to visually detect what he called 'cosmic clouds' throughout the celestial sphere, using an f/15 16-inch refractor. His results, first presented in 1921 to the Royal Astronomical Society (Hagen 1921a; cf. 1921b), soon met with criticism and refusal because these supposed clouds—which Hagen described as 'obscure'—were not detectable by photography, nor did they influence the light of stars in any measurable way (as Barnard's Milky Way 'dark markings' supposedly did). Nevertheless, up until his death Hagen continued to compile a catalogue of these 'obscure clouds', which he saw as faintly luminous objects covering much of the night sky, and becoming gradually 'denser' (more luminous) towards the Galactic Poles, while towards the Milky Way they seemed to thin out, leaving nothing but black background sky.[1]

In the course of this much-criticized work, Hagen began to search for supporting arguments for his 'cosmic clouds'. One strategy was to find supporters among earlier observational astronomers, and it was not long before Hagen promoted William Herschel as the real discoverer of his clouds by referring to Herschel's 1811 paper. Certainly Hagen (1916) quoted Herschel on the large nebulosities from his very first publication concerning the discovery of large nebulous fields in comparatively high galactic latitudes, but it is revealing to see his growing efforts to relate his own observations to the eminent William Herschel after 1923, when Hagen published Herschel's list anew, together with some historical remarks (Hagen, 1923). At the height of the debate, in 1926, Hagen (1926a-1926f) published his own visual re-observations of all of Herschel's nebulosities in a series of six papers in *Monthly Notices of the Royal Astronomical Society*. The result was nothing short of a sensation in that Hagen confirmed every single one of Herschel's fifty-two extended diffuse nebulosities (see Figure 4)!

Throughout his lifetime, Hagen, always trusted his own eyes more than the photographic plate, and he expressed his satisfaction in the following words: "While it took six hours and more to photograph some of [the nebulosities], six minutes would have sufficed to see them." (Hagen, 1923: 202). Consequently, "… there is no doubt that Herschel's table contains [nebulosities] some of which are known as dark nebulae."

Table 1: A list of Herschel nebulosities that were regarded as confirmed by 1904.

No.	Observer	Object or Region	Area (sq°)	Herschel's Description
07	Roberts	The outer areas of M110	4.7	Affected with nebulosity
22	Wolf	Southwest of Orion Nebula	6.3	Affected with milky nebulosity
23	Wolf	Between Orion's belt and Orion Nebula	1.3	Affected
24	Wolf	In the immediate vicinity (north) of the Orion Nebula (near NGC 1981)	4.6	Visible and unequally bright nebulosity. I am pretty sure this joins to the great nebula in Orion
25	Roberts	40' east of IC 434	7.0	Diffused milky nebulosity
27	Pickering & Barnard	The central part of Barnard's Loop	2.9	Affected with milky nebulosity
44	Roberts	NGC 7000 ('Florida')	2.8	Faint milky nebulosity scattered over this space, in some places pretty bright
46	Roberts	NGC 7000 ('Panama')	3.7	Suspected nebulosity joining to plainly visible diffused nebulosity

Hagen's critics had always focussed on the common conviction that everything visually recognizable must also be photographable, which he passionately denied. He thus advised sceptics to put aside their cameras and look through the telescope, although he seemed not to have any illusions about his appeal. "Should Herschel's skill have been lost by our photographic training of astronomers?" he would ask Robert Aitken some years later (Hagen, 1927).

Basically, Hagen's results were regarded as extremely doubtful, and his confirmation of Herschel's nebulosities was not taken seriously. This is vividly demonstrated by J.L.E. Dreyer (1926), whose response to Hagen's first published note on his observations of the first four of Herschel's nebulosities is telling:

> Before acknowledging that W. Herschel was the discoverer of dark cosmic clouds, it will be well to bear in mind that he does not anywhere make any distinction between the general appearance of the objects examined by Father Hagen and the rest of the fifty-two objects. He certainly saw, or believed that he saw, in all the fifty-two places recorded by him, luminous objects. A few of them are well-known nebulae, such as NGC 7000. Considering his vast experience it is difficult to believe that he saw something totally different in the four places examined by Father Hagen, without realising it and drawing special attention to him.

It is interesting that it was Dreyer who responded to Hagen's paper, the very same Dreyer who had earlier decided not to include Herschel's list in his NGC and IC catalogues. Hagen did not care. In a letter dated 21 January 1926 to fellow astronomer Johann Stein of Valkenburg, he wrote:

> In the January issue of M.N. you will find an article, in which I call W. Herschel the discoverer of the Cosmic Clouds. The 'Council' asked me by Prof. Turner, if I would consider a critical remark by the editors an offence. I answered: no. They don't want Herschel to become involved into my 'deceptions'. I have, however, proved ... that our Cosmic Clouds match exactly with the 52 nebulosities. (Hagen, 1926g).

This statement excellently expresses Hagen's general attitude: he was certainly aware of the prevailing opinion, but any opposition only led him to double his efforts to provide further evidence of the correctness of his observations in a bid to alter that opinion.

In order to have his views prevail, Hagen started to activate other observers, however, he could only interest amateurs and second-rate astronomers. What links almost all later observers is the fact that Hagen had cultivated friendly relations with them over many years, which is evident from their correspondence. In any case it can be stated that almost every publication concerning Herschel's nebulosities (and even Hagen's cosmic clouds) after 1926 was in some way directly related to Hagen's initiative. Whether or not these circumstances caused an observational bias because of the preoccupation of the observers remains to be investigated.

Soon W.S. Franks, the former observing assistant of Isaac Roberts, started his own observing project on Herschel's nebulosities at the Brockhurst Observatory. The idea that Franks would be a suitable observer was put forward by Dorothea Klumpke Roberts (1926), the widow of Isaac Roberts and a long-time friend of Hagen. Franks' good relations with Hagen are also reflected in their correspondence, and finally, both astronomers had even published a joint paper some years before Klumpke Roberts' suggestion (see Franks and Hagen 1923). In one of his publications, Franks (1928) even admits that he had been "… urged by Father Hagen to undertake some visual observations of these neglected and much disputed nebulous regions"—which yet again emphasizes Hagen's persuasiveness. Franks' observing results were generally positive, and by using Hagen's published notes on the nebulosities he was able to trace the brighter objects on up to three occasions but could not detect the six faintest regions.

Herschel No. 28.—The portions *n* and *sf* Herschel's place have density V, the centre of the field has IV to V, and a few regions *sf* it have III to IV.

No. 29.—The pointing of Roberts' plate was about $15' = 1^m$ late on Herschel's place. The centre of the Herschel field has density IV. The portions *f* vary between IV and V, while *p* there are thinner nebulosities of grades III to IV.

No. 30.—From Table I. it appears that the guiding point is cluster N.G.C. 2281. Within this cluster, to the extent of 12′ *pf* and 25′ *ns*, only thin nebulosities of grade I are seen and somewhat denser ones immediately *p* and *f*, estimated as II to III. The rest of the field varies from III to V.

No. 31.—The centre of the field is of density IV to V., while the nebulosities of the entire region vary little around grade IV.

Figure 4: Part of Hagen's observations of Herschel's list of nebulosities. Hagen estimated the visual brightness of the nebulosities using a five-step scale (I-V), where 'I' represented the faintest and 'V' the strongest light impression.

In 1928 Paul McNally (a Jesuit like Hagen) was appointed Director of the Georgetown Observatory, but before taking up this post he spent part of October at Mt. Wilson Observatory where Hagen taught him how to carry out visual and photographic observations of nebulosities (McNally 1929). Although he could not find the time to carry out any further observations once he was settled in Georgetown, after the IAU General Assembly at Leiden he did publish a useful paper containing an historical overview of Herschel's nebulosities (ibid.). McNally's main research preoccupation was also variable stars, and this 1929 paper can be traced back directly to Hagen's influence.

Concerning amateur astronomers, in 1930 and 1931 G. Lehner from Erfurt in Germany was encouraged by Josef Hopmann and Heinrich Osthoff to observe Herschel's nebulosities and some of the more generally-distributed cosmic clouds which Hagen thought he saw near the North Galactic Pole (Lehner 1930/1931). Another amateur who became involved with Herschel's nebulosities was Marcel de Kérolyr. This avid French astrophotographer, who had built the first stationary observatory in Haute-Provence (the Station Astrophotographique de Haute Provence, at Forcalquier), was well known for his excellent wide-field photographs of nebulae which he published in the *Bulletin de la Societé Astronomique de France* during the 1920s and 1930s. What probably made de Kérolyr interesting to Hagen was the fact that he had perfected the technique of photographing celestial objects for many hours, which enabled him to expose his photographs for up to 24 hours, split over several days. In September 1929 Hagen wrote to de Kérolyr, encouraging him to use his skills for the purpose of solving the "… problème international …" of Herschel's nebulosities. Although both were French citizens, no

direct relation between Klumpke Roberts and de Kérolyr can be traced which might lead to the conclusion that she recommended her compatriot to Hagen.

In his paper published only in 1931, one year after Hagen's death, Kérolyr confirmed the successful photography of Herschel's nebulosities 22, 23, 24, 25 and 26 in southern Orion (which was nothing new really), but in addition he published a complete list of visual observations of Herschel's nebulosities, which again served to confirm most of results obtained earlier by Herschel and Hagen.

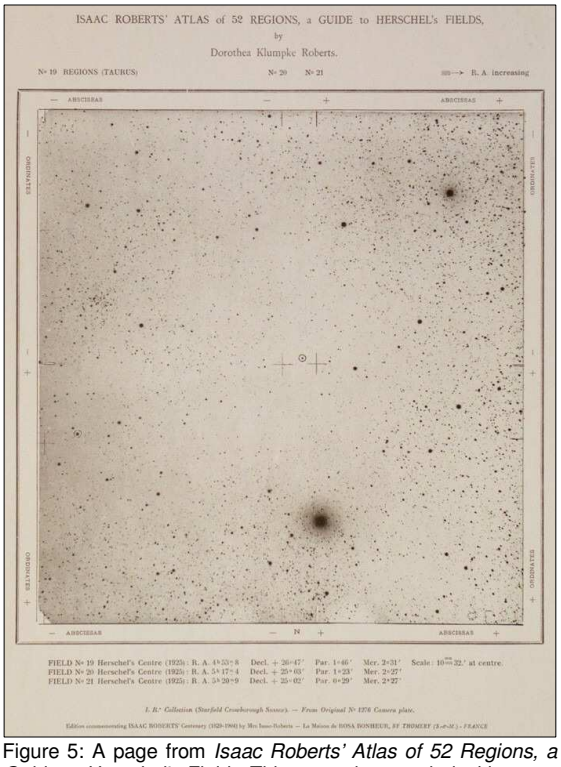

Figure 5: A page from *Isaac Roberts' Atlas of 52 Regions, a Guide to Herschel's Fields*. This page shows nebulosities nos. 20 and 21, and their centres are marked by crosses on the photograph.

2.6 Isaac Roberts' Atlas of Fifty-two Regions

None of the efforts mentioned above was of any avail, and the resonance Hagen had hoped for was negligible. Luckily there was one person who was willing to push his case forward and this was Dorothea Klumpke Roberts,[2] whose husband's photographic experiments on Herschel's nebulosities had started the initial debate soon after 1900. In 1925 Hagen contacted Klumpke Roberts (whom he had known for decades) to ask for contact prints of some of Isaac Roberts' original plates, namely of Herschel objects 27, and 50-51 (Klumpke Roberts, 1925a). From then on, a vivid correspondence developed between the two astronomers, and it quickly showed that Klumpke Roberts was a dedicated supporter of Herschel's (and certainly of Hagen's) cosmic clouds. Before long, Klumpke Roberts (1925b) raised the idea of publishing Isaac's photographs, and over the next three years this plan was put into action—as shown by her correspondence with Hagen, who turned into a mentor. Both astronomers knew that their symbiosis had good prospects to serve their own personal aims: Hagen finally received support from an eminent, influential colleague, while Klumpke Roberts, in her turn, was certainly keen to rehabilitate Isaac, given the criticism he had received as a result of his far-reaching conclusions about the non-existence of Herschel's nebulosities in 1903.[3] As it happened, Isaac Roberts' centenary was to occur in 1929, giving Klumpke Roberts another reason to publish the atlas.

The result of Hagen's and Klumpke Roberts' cooperation was titled *Isaac Roberts' Atlas of 52 Regions, a Guide to Herschel's Fields* (Klumpke Roberts 1928a; see, also, Figure. 5), which was published in July 1928. Klumpke Roberts prepared all the plates and designed the layout while Hagen provided scientific support and advice, and the Foreword (a straightforward text in which Hagen took the chance to get even with his critics).

Immediately after its publication, Klumpke Roberts started to promote the atlas through astronomical societies, taking advantage of meetings of the Astronomische Gesellschaft in Heidelberg (Klumpke Roberts, 1928b) and the IAU Meeting in Leiden (Meetings of Commissions …, 1928); she also advertised the atlas at the 1928 meeting of the Comité National Français d'Astronomie.[4] According to Klumpke Roberts (1928b), the atlas was accepted "… with appreciation and applause …" at the IAU meeting, and even Hubble, who was known to be one of the sharpest critics of Hagen's cosmic clouds, suggested that photographic experiments using yellow filters might be worthwhile. This is a clear indication of the strong impact that Klumpke Roberts' attendance had on the audience (see Klumpke Roberts, 1935).

2.7 Later Activities

With Hagen's death on 5 September 1930 the most determined supporter of Herschel's nebulosities disappeared from the scene, still leaving the matter unsettled. But Klumpke Roberts carried on propagating the accuracy of Herschel's and Hagen's observations. Having learned about the power of skilful political manoeuvring, she used her contacts with astronomers like the late Max Wolf as well as assemblies of the Astronomische Gesellschaft to try to convince the still-numerous critics of her late husband's theories. Klumpke Roberts continued to receive support by continued delivery of photographs from de Kérolyr, which she presented to audiences as slides or as small exhibitions (Klumpke Roberts, 1928b). De Kérolyr finally claimed to have successfully photographed Herschel's nebulosities 12, 14-15, 20-21, 33 and 41, and Klumpke Roberts confirmed that all the photographs of these fields indeed showed traces of nebulosity. However, the reliability of these claims must be questioned given that de Kérolyr also presented a photograph showing the illusive 'Baxendell Nebula' (NGC 7088), which in those days was known to be nonexistent.[5]

In 1932 a supplement volume to the 1928 *Isaac Roberts' Atlas of 52 Regions* … was published, showing additional photographic plates of Herschel's fields of nebulosity that Roberts had exposed around 1900 (Klumpke Roberts, 1932). Klumpke Roberts presented this supplement to the Astronomische Gesellschaft at the 1933 Meeting in Göttingen, for which she was accepted as a member of the Gesel-

lschaft.

Around 1929, Klumpke Roberts donated a prize to the Société Astronomique de France, "… for observing Herschel's diffused nebulosities …" (Klumpke Roberts, 1929). It was "… a modest little prize; nevertheless, I trust it will encourage the members of the S.A.F. in observing diffused nebulosities." She also thought of a prize for the British Astronomical Society, but this idea was not realized. Finally, in 1930 another prize of $100 was donated to the Astronomische Gesellschaft to be granted to an astronomer who had published "… an important work about obscure clouds." (Schmeidler, 1988). Up to 1937 this prize was repeatedly granted to different astronomers, such as Friedrich Becker (Hagen's former assistant in Rome between 1925 and 1926) in 1930 and 1931, and Marcel de Kérolyr in 1935 (he had already received the French prize in 1929). But the list of prize winners threw a sobering light on the status of researching the cosmic clouds, for even the incentive of winning a reasonable amount of money seemingly did not encourage astronomers to strengthen their research in this field—or was it that there was nothing to gain because there was nothing to find?

Whatever research interest there was at this time tended to be concentrated in the German astronomical community, and the outbreak of World War II brought a sudden halt to any interest in cosmic clouds, then with Klumpke Roberts' death in 1942 the last supporter left the stage. Since that date, nothing of substance has been published on Herschel's list of fifty-two fields of diffuse nebulosity.

To the present day, the existence of the majority of Herschel's catalogued nebulosities remains a subject of speculation. Throughout all of his observations Herschel certainly worked at the absolute physiological limit of the human eye, which is to be regarded as one of the reasons why the existence of extensive nebulosities was always met with doubt. Nevertheless, these days successful visual observations of definitely-existing objects with extremely low surface brightnesses are regularly carried out by avid amateur astronomers with optical instruments that are comparable to those used by Herschel.[6] Thus, the existence of Herschel's extensive nebulous fields should not be automatically ruled out. Indeed, besides the few regions which were verified photographically around 1900 by Roberts, Wolf, Barnard and others, there are other fields discovered in recent years which have been shown to contain vast, faint emission and reflection nebulosity (see Section 3.9, below).

It seems that there is still more to be discovered from Herschel's list. What, precisely, was it that Herschel observed? The list does not quite tell the whole story, which makes it seem practical to re-analyze the list in as much detail as possible.

3 THE RE-ANALYSIS OF HERSCHEL'S LIST

As a basis for a final revision of Herschel's objects, his sister Caroline's copies of the eight observing books containing the results of his decade-long sweeps were analyzed. As a result, a number of errors and inaccuracies were detected and corrected. Furthermore, the terminology used to describe the observed phenomena—which differs widely from that used by Herschel to describe non-stellar objects during his other deep sky observations—was analyzed in order to obtain a clear image concerning the appearance of the nebulosities. The resulting revised list summarizes all of the noticed peculiarities in a separate column. Table 3 lists the first four objects in Herschel's list of fifty-two.

3.1 Terminology

So what do these fifty-two nebulosities look like? In general, their appearance is described in Herschel's 1811 publication as being extremely extended throughout the sky and largely structureless, and it is surely not a coincidence that those fifty-two objects were listed directly after a brief description of well-catalogued objects of 'extensive diffused Nebulosity' (i.e. the fifth class according to Herschel's system).

In fact, Herschel often became aware of their existence only through noticing a brightening of the sky background, which he termed as "ground" or "bottom". In order to mark an area as being influenced by nebular matter, the term "affected" was assigned to these regions. Certainly Herschel distinguished, especially throughout his early sweeps, regions "… affected with nebulous ground …" from regions "… affected with milky nebulosity." Nevertheless, the term "affected" always related to the sky background, and Herschel leaves no doubt about the specific meaning of his words: "When this account says affected, it is intended to mean that the ground upon which, or through which we see, or may see stars, is affected with nebulosity."[7] My re-analysis shows that even in cases when in the published list the sky background was marked only as "affected", the original record is always accompanied by the remark "bottom" (only in very early records is "ground" used), which independently proves the direct relation of this term to the sky background.

3.2 Positions and Dimensions

Every position in the revised list was reduced according to the correction values in right ascension and declination given by Caroline Herschel, which she determined by aligning the raw telescopic positional readings of known objects (mostly stars) with their catalogued positions.

Assigning the listed fields to distinct observing records was unambiguously possible (except for nos. 22 and 26), although the values of the published coordinates could not be reproduced precisely, neither in declination, nor in right ascension. Astonishingly, Herschel's published positions are often not very close to the records' geometrical centre, although both sources (the observing books and the published list) were reduced to the same epoch of 1800.0.

The extension of each nebulous field in declination could only be determined from the width of the according sweep zone, since Herschel did not record declinations independently for them. For determining the extension in right ascension, only the preceding and succeeding records were available; no right ascension values were directly recorded for the fields. The objects' dimensions are roughly multiples of 15 minutes of arc, which is the true field of view of his large 20 foot reflector that was used for the sweeps. The listed extensions in declination correspond well to the relevant recorded sweep borders; this is not

generally the case with the right ascension extensions, though. As a general rule of thumb, this extension can be calculated as the difference between the western and eastern neighbouring records, minus 15 minutes of arc. There are, however, a number of objects to which this rule is not applicable.

3.3 Plausibility of the Observations and Possible Sources of Error

Assuming a very low general surface brightness, any observation of Herschel's extensive nebulosities must have been extremely sensitive to interfering light sources like the zodiacal light, aurora borealis or loss of eye adaption due to exposure to artificial light sources (see Herschel, 1811: 270). Throughout his sweeps, Herschel was attentive to such sources of error and therefore tried to distinguish actual object identifications from apparently increased sky brightness. Furthermore, he recorded meteorological peculiarities at the time of observation, such as passing clouds, upcoming mist or high winds. We can imagine the inner conflict between the discoverer and the critical scientist when we read Herschel's thoughts during sweep 340 on 13 December 1784:

> In this sweep I found the same kind of suspected nebulosity again as before ... but removing the telescope sideways to a part 10 or 12 degrees preceding where I had found.

Nevertheless, a number of fields observed under less favourable weather conditions were included in the list, which clearly compromises their credibility.

The influence of zodiacal light can be excluded as a possible source of error for most objects, because even those near the ecliptic were never observed closer than 90° distance from the Sun. Only three fields were observed near 180° ecliptical longitude distant from the Sun, thus offering the actual observation of the gegenschein as a possible explanation. Nevertheless, nos. 17, 18, 20 and 21 (no. 19 also belong to this group, but an influence of the zodiacal light can be excluded) coincide in large part with the extensive dark nebula complexes in eastern Taurus which are known to have a higher surface brightness than the surrounding sky background.[8] Presently it cannot be stated with certainty which of these explanations fits the actual observations better. Finally, the influences of moonlight can be excluded for all but two fields (i.e. nos. 24, 49).

In summary, ~30% of Herschel's extensive nebulous fields that were not described as 'suspected' were observed under questionable circumstances.

3.4 Multiple Observations

In order to strengthen the credibility of his observations, Herschel (1811: 277) wrote:

> I have almost without exception found, in a second review, that the entertained suspicion [of nebulosity] was either fully confirmed or that, without having had any previous notice of the former observation, the same suspicion was renewed when I came to the same place again.

Nevertheless, assuming that the observing log is complete, most of the nebular fields were observed only once. Still, a number of objects were recorded more often; most of these are, however, records made during one single observing sweep. In the case of fields nos. 22 and 26 (but not 23-25), no clear demarcation was possible from the log entries; thus additional datasets in the revised list record all those observations which fell into the region of sky covered by these nebulosities. Both regions cover part of the Hα emission region extending over large sky areas of southern and eastern Orion, which explains the fields' uncertain boundaries.

3.5 Doubtful Observations, Erroneous and Non-existing Records

Nebulosity no. 36 could only be assigned to observational records through comparing their celestial coordinates, while the descriptions of their visual impressions logged in Herschel's observing books differ widely or even contradict the list entries.

No. 38 represents a completely erroneous record. Except for the right ascension value, the complete dataset of the preceding nebulosity no. 37 was copied by mistake and taken as no. 38, including the description. However, nebulosity no. 38 does exist, but it has a completely different dataset.

Positional errors and non-existent objects could be determined directly from the observational data. Essentially, the reasons for such erroneous entries could be cleared up, such as confused numbers or incorrect position calculations. Thus, nos. 42 and 44 contained erroneous positional data, which could be corrected, while nebulosities nos. 9/10 and 50/51 proved to be identical: for each pair of fields—which show almost identical mutual datasets—only one appropriate record could be found in the observing logs.

3.6 Correlations with Better-known Objects

As described above, as early as 1904 astronomers involved in the debate (Isaac Roberts being the most avid promoter) sought to correlate the nebulosities with some of the brighter objects contained in the catalogues of nebulae produced by Herschel and others. Indeed, fields no. 7 and 8 (Messier 31), 22 to 26 (nebulae in southern and eastern Orion), as well as nos. 44 and 46 (NGC 7000), coincide at least in part with better-known and elsewhere-catalogued objects, so one might conclude that Herschel had taken those objects for the corresponding nebular fields, which surely seems an obvious explanation. Nevertheless, the re-analysis of his records shows a clear distinction between both object classes: one finds both classes observed next to each other, and obviously separated as different records.

The most instructive case in this context is certainly the NGC 7000 nebula complex, which covers much of the regions of nebulosities no. 44 and 46; thus a closer look seems worthwhile. Strangely, Herschel describes the appearance of nos. 44 and 46 as

> … in No. 44 of the table, we have an instance of faint milky nebulosity, which, though pretty bright in some places, was completely lost from faintness in others; and no. 46 confirms the same remark. (Herschel, 1811: 278).

This is indeed an odd case: the description leaves no doubt that Herschel really observed the region of the North America Nebula, but strangely enough, among his notes we find in total four different entries for the

region of sky around that object: V-37 (Herschel's catalogue entry no. 37 in the fifth class of nebulae), which finally led to the entry NGC 7000 in Dreyer's catalogue, and the two additional fields nos. 44 and 46 from his list of 52 nebulosities (see Table 2).

The position of nebulosity no. 44 fits NGC 7000 very well, which might suggest that Herschel identified the former nebulosity with the latter nebula. However, the entry for no. 46 shows that he definitely distinguished NGC 7000 from both nebulosities. Whatever Herschel might have thought about this special sky region, he definitely saw three different objects.

3.7 Observations of Nebulosities not Recorded the Original List

Six additional records of sky regions with characteristics similar to the fields previously published were found, which do not have counterparts in Herschel's original list. These fields have been added to the revised list.

3.8 Records of "Pure Ground"

Besides sky regions with brighter background, Herschel recorded a large number of areas (~100) with a remarkably *dark* appearance of the background, and he described these as "clear" or "pure". The re-analysis of his records showed that by these terms Herschel actually noted the apparent absence of nebulosity and not just a lack of faint field stars. For a final verification, these records might represent an important completion of the observational database, since they now allow correlations with both bright and dark areas in modern catalogues. My revised list does not include these records.

3.9 Possible Discoveries Contained in the List of Nebulosities

Aside from those nebulosities that were part of well-known objects like NGC 7000 or the Great Orion Nebula, there are other objects whose discovery should possibly be assigned to William Herschel. Although no systematic correlation of the fifty-two nebulosities with known objects seems to have been performed to date, a preliminary analysis already shows some surprising coincidences. It cannot, though, be stated with absolute certainty that the objects mentioned below were all actually observed successfully by Herschel. Nevertheless, the following listing shows that a mere denial of the reality of most of Herschel's fifty-two nebulosities is premature.

First, as already stated, the large nebulous arc of Hα emission encircling the eastern parts of Orion which around 1900 was named 'Barnard's Loop' coincides in part with nebulosity 27, and represents the brightest part of the Loop. To call Herschel the discoverer of Barnard's Loop would therefore not be too presumptuous, although the overall shape of that nebula remained unknown to him.

Next to be mentioned are no fewer than eight nebulosities (13, 14, 15, 17, 18, 19, 20 and 21), which were catalogued in the region of the Auriga-Taurus dark cloud complex. Today these absorbing clouds are known from photography to have a slightly higher luminosity than the general sky background. The whole complex was also successfully observed visually by other observers,[10] which makes the dark clouds in Taurus and Auriga good candidates for the objects behind Herschel's observations in this area. The connection between the named nebulosities and the dark cloud complex was assumed as early as 1904 when H.C. Wilson (1904) postulated their possible identity.

Table 2: Observing book entries concerning NGC 7000.

Object	Description	Date
V-37	vL. diffused nebulosity plainly visible. bM 7' or 8' l: 6' b. and losing itself gradually.	Sweep 620 24 October 1786
44	B. considerably affected.	Sweep 959 11 September 1790
46	All this time suspected diffused nebulosity throughout the whole breadth of the sweep. RA From 20h52′9″ to 20h55′46″ PD from 45°35′ to 48°38′	Sweep 620 24 October 1786
	Faint milky nebulosity scattered over this space, in some places pretty bright. The brightest part of it about the place of my V.37.	Sweep 959 11 September 1790

Another interesting case is nebulosity 32, which correlates well with a brighter feature in the galactic cirrus near M81/M82 (see Figure 6). This discovery by Allan Sandage (1976) might point to a promising approach to explain some of Herschel's observations of extensive nebulosity, at least those at higher galactic latitudes. Sandage measured the surface brightness as ~24.5 magnitudes per square arc second, thus these nebulosities should indeed be detectable by the human eye under favourable conditions.

Figure 6: Galactic cirrus features in the vicinity of the galaxies M81/M82 (near the left margin). Herschel's nebulosity 32 was catalogued to the upper right from the centre (after Sandage, 1976).

Last, the whole nebulous region of southern Orion around the Great Orion Nebula, covering nebulosities 22 to 26, was catalogued as number 35 of the fifth class in Herschel's catalogue of nebulae and clusters of stars, thus to some extent Herschel nebulosities 22 to 26 were catalogued twice.[9]

A discovery only indirectly correlated with the nebulosities is the following case. While observing the region of σ Orionis, Herschel noticed the bright streak catalogued today as IC 434 and included it in his own catalogue of nebulae and clusters of stars as number 35 of the fifth class. Attached to this region, to the west, lies nebulosity 23. What is most interesting is Herschel's note from sweep 518 of 1 February 1786 of a special feature in the bright streak: "Wonderful black space included in Nebulosities. 48 (σ) Orionis f. 2′ 46″ n 0° 44′ RA 5h 31′ 27″ PD 92° 0′ (1280)." The precise positional data leave no doubt, for on this night Herschel discovered the Horsehead Nebula, which was much later catalogued as number 33 in E.E. Barnard's catalogue of dark nebulae. Till now, this discovery is often credited to Williamina Fleming, who noticed it when measuring a plate of the region taken by E.C. Pickering in 1888.

3.10 Structure of the Revised List

This list, being one principal result of the review of Herschel's list of fifty-two nebulosities, contains all the information found about each object in the observing books, which in case of multiple entries partially resulted in more than one row per object. Also, six notes on objects with characteristics that were similar as the nebulosities but excluded from Herschel's list have been added. Table 3 shows just the first four entries in the revised list. The complete table will be published elsewhere (Latusseck, 2008).

The first seven rows show the original datasets of Herschel's list of extensive fields of nebulosity as published in 1811,[11] with the epoch of the coordinates 1800.0. The abbreviation 'RA' stands for 'right ascension' and 'Decl' for 'declination', but Herschel used 'polar distance' ('PD'; PD = 90° – declination) instead of declination. The next ten columns catalogue the extracted information from Herschel's observational logs. The column 'Recorded description' contains the unchanged records of Herschel's visual impressions during his observation(s) of each field.

4 CONCLUSION

Herschel used the list of fifty-two extensive nebulosities as a supporting argument for his thesis of the existence of real nebulous matter in space. He used his own observational results in a largely uncritical way, though. However, he pointed out that fields containing an uncertain amount of nebulous material—and therefore viewed only as 'suspected'—were intentionally included in his list.

It would seem that Herschel 'sifted' his observing logs somewhat superficially in order to quickly gather material for his list of nebulosities. This view is supported by his opinion that "… the abundance of nebulous matter diffused through such an expansion of the heavens must exceed all imagination." (Herschel, 1811: 277); even if Herschel had overlooked some log entries, this minor flaw would not have affected the general argument that these nebulosities were present in "… great abundance". In addition, the errors that we have identified in this study could be conveniently explained by assuming a rather 'relaxed attitude' concerning the gathering of observational data.

Considering the uncertain circumstances of the observations, Herschel's list is open to attack, and even his own remarks sometimes place their validity into doubt. As mentioned above, since the early twentieth century his nebulous fields have been greeted with widespread suspicion, and today are, in general, viewed as nonexistent, and thus as deceptions.

The matter is not so straightforward, though. Even a cursory analysis shows a number of correlations between Herschel's fields and existing celestial objects which cannot be explained as purely coincidental. The large faint emission nebulosities in Orion (including IC434 and Barnard's Loop) and the galactic cirrus structures near M81/M82 show that a significant percentage of his extensive nebulosities might indeed have physical counterparts. However, it is likely that a larger percentage of Herschel's nebulosities will be proven to be non-existent. A thorough comparison with modern catalogues will surely throw further light on Herschel's elusive objects.

5 NOTES

1. The catalogue was published in the year following Hagen's death, after Friedrich Becker had completed the work of his former master (see Hagen, 1931).
2. Dorothea Klumpke Roberts was an accomplished astronomer in her own right. Born in San Francisco, she was educated in France and was the first woman to obtain a Ph.D. in astronomy in France (from the Sorbonne). She was Director of the Bureau of Measurements at the Paris Observatory and had a substantial list of publications before marrying the much older Isaac Roberts when she was 40 years of age. Already a prize-winner from the French Academy of Sciences, she was elected a Chevalier de la Légion d'Honneur before leaving Paris in 1934 and returning to San Francisco.
3. As an example of how actively Klumpke Roberts tried to rehabilitate her husband's reputation see Klumpke Roberts, 1930.
4. Note by Dorothea Klumpke Roberts to Vesto M. Slipher in his capacity as Chairman of IAU Commission 28 (Nebulae), July 1928.
5. http://www.klima-luft.de/steinicke/ngcic/persons/baxendell.htm
6. For discussions on observations of low surface brightness objects, see for example the following discussion group: http://groups.yahoo.com/group/amastro/
7. For example see Sweep 244 on 27 July 1784:

   > The bottom or ground (if I may so call it) of the heaven is not clear but contains faint patches produced by stars not bright enough to come to a focus in passing the field of view.

8. For example see Sweep 266 on 11 September 1784:

   > The whitish nebulosity from having been in the light is very different from the resolvable nebulous appearance of affected ground of the milky way.

9. Hagen (1921b) claimed to have observed this region successfully in 1920, although his results were met with skepticism.

	Herschel's 1811 description						recorded datasets (from logbook)									
No.	RA 1800.0	Decl. 1800.0	RA extension	Decl. extension	Size	Account of the Nebulosity	Sweep no.	Date of observation	Recorded description	RA 1800.0 Most probable eastern border	Object RA 1800.0	RA 1800.0 Most probable western border	Breadth of Sweep	Decl. top 1800.0	Decl. bottom 1800.0	Remarks
1	00h 05m 02s	+08° 53'	1° 44'	1° 55'	3,3°	Much affected with nebulos-ity	52	1783 Dec 19	Much nebulosity .	23h 41m 02s	00h 02m 02s	00h 08m 02s	01° 40'	+09° 43'	+08° 03'	
							52	1783 Dec 19	Much nebulosity many L.	00h 02m 02s	00h 08m 02s	00h 18m 02s	01° 40'	+09° 43'	+08° 03'	
2	00h 12m 31s	+04° 26'	3° 00'	2° 34'	7,7°	Much affected	338	1784 Dec 13	B much affected.	00h 05m 01s	00h 07m 01s	00h 18m 01s	02° 19'	+04° 36'	+02° 17'	Succeeding sweep record is nebulosity #4.
3	00h 17m 17s	+28° 36'	0° 41'	2° 40'	1,8°	Affected	266	1784 Sept 11	The ground affected.	00h 15m 17s	00h 16m 17s	00h 19m 29s	02° 25'	+29° 50'	+27° 25'	Possible weather interference: preceding: "Very clear"; following: "A faint haziness, very clear, flying haziness, clear again"
4	00h 20m 31s	+03° 26'	1° 30'	2° 34'	3,6°	Much affected	338	1784 Dec 13	B very much affected, rather more so than I have seen it before. I wish it were possible to compare it with some very distant situation.	00h 07m 01s	00h 18m 01s	00h 28m 01s	02° 19'	+04° 36'	+02° 17'	Continuation of nebulosity #2 (from same sweep). Deception? Succeeding record: "In this sweep I found the faint kind of suspected nebulosity again as before at 0h 10'; but removing the telescope sideways to a part 10 or 12 degrees preceding where I had found B very pure I could perceive no difference and believe this kind of deception is owing to the snow which covers the ground, northern lights that illuminate the snow, and a pretty high wind that agitates the air."

Table 3: The initial section of the revised list of Herschel's nebulosities, showing the first four entries.

10. The catalogue record relates even more objects to V-35:

    Diffused m. nebulosity, extending over no less than 10 degrees of PD. and many degrees of RA. It is of very different brightness, and in general extremely F. and difficult to be perceived. Most probably the nebulosities of the 28th, 30, 31, 33, 34, and 38th of this class are connected together, and form an immense stratum of far distant stars, to which must also belong the nebula in Orion.

11. According to his own words, the nebulous fields cover such large sky areas that Herschel was not able to explore their true dimensions. Thus he cut every field by a parallelogram, limited by declination and right ascension.

6 ACKNOWLEDGEMENTS

I would like to thank Father Sabino Maffeo, S.J., of the Specola Vaticana, Castelgandolfo, for kindly permitting me access to the archives of the Vatican Observatory. Almost all letters quoted are from this archive. I also thank Michael Hoskin for his valuable advice concerning the re-analysis of Herschel's list of fifty-two nebulosities.

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