

## WILLIAM HERSCHEL'S 'HOLE IN THE SKY' AND THE DISCOVERY OF DARK NEBULAE

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**Abstract:** In 1785 William Herschel published a paper in the *Philosophical Transactions* containing the remarkable section “An opening or hole”. It describes an unusual vacant place in Scorpius. This matter falls into oblivion until Caroline Herschel initiated a correspondence with her nephew John in 1833. It contains Herschel’s spectacular words “Hier ist wahrhaftig ein Loch im Himmel” (“Here truly is a hole in the sky”). About a hundred years later, Johann Georg Hagen, Director of the Vatican Observatory, presented a spectacular candidate for the ‘hole’, discovered in 1857 by Angelo Secchi in Sagittarius and later catalogued by Edward E. Barnard as the dark nebula B 86. Hagen’s claim initiated a debate, mainly in the *Journal of the British Astronomical Association*, about the identity of Herschel’s ‘object’.

Though things could be partly cleared up, unjustified claims still remain. This is mainly due to the fact that original sources were not consulted. A comprehensive study of the curious ‘hole’ is presented here. It covers major parts of the epochal astronomical work of William, Caroline and John Herschel. This includes a general study of ‘vacant places’, found by William Herschel and others, and the speculations about their nature, eventually leading to the finding that dark nebulae are due to absorbing interstellar matter. Some of the ‘vacant places’ could be identified in catalogues of dark nebulae and this leads to a ‘Herschel Catalogue of Dark Nebulae’—the first historic catalogue of its kind.

**Keywords:** William Herschel, Caroline Herschel, John Herschel, Johann Georg Hagen, Angelo Secchi, Edward E. Barnard, Herschel’s ‘hole in the sky’, sweeps, star gages, dark nebulae

“Of the great modern philosophers, that one of whom least is known, is William Herschel. We may appropriate the words which escaped him when the barren region of the sky near the body of Scorpio was passing slowly through the field of his great reflector, during one of his sweeps, to express our own sense of absence of light and knowledge: *Hier ist wahrhaftig ein Loch im Himmel.*” (Holden, 1881: 1).

### 1 THE CORRESPONDENCE BETWEEN CAROLINE AND JOHN HERSCHEL

The achievements of William Herschel (1738–1822; Figure 1) in observational astronomy are unrivalled. He discovered numerous double stars, nebulae and star clusters during his epochal survey of the northern sky (Steinicke, 2010). Occasionally peculiar objects came into view, firing his imagination, like ‘garnet stars’ (Steinicke, 2014) or even ‘non-objects’, i.e. fields in the sky which appeared absolutely devoid of stars. The latter are subject of this paper.

The starting point is a correspondence between Caroline Herschel (1750–1848; Figure 2), when living at Hanover, and her nephew John. There are several sources. The first is *Memoir and Correspondence of Caroline Herschel* (Herschel, Mrs J., 1876), published by John Herschel’s wife Lady Herschel, née Margaret Brodie Stewart (1810–1884). A German translation appeared just a year later (Scheibe, 1877). The second is *The Herschel Chronicle* (Lubbock, 1933), published by John Herschel’s daughter, Constance Anne Lubbock (1855–1939). A third source, from John’s perspective, is *Herschel at the Cape: Diaries and Correspondence of Sir John Herschel, 1834–1838* (Evans, 1969). The author is the British astronomer David Stanley Evans (1916–2004).



Figure 1: William Herschel (Steinicke Collection).

On 1 August 1833 Caroline Herschel sent a letter to Lady Herschel at Slough. At that time 41 year old John Herschel (1792–1871; Figure 3) was preparing his South Africa expedition to survey the southern sky; it started in November.



Figure 2: Caroline Herschel ([www.spacerip.com/women-astronomy-caroline-herschel/](http://www.spacerip.com/women-astronomy-caroline-herschel/)).

In a P.S.S. addressed to him, Caroline wrote (Herschel, Mrs J. 1876: 258; her italics; Lubbock, 1933: 372):

Dear Nephew, as soon as your instrument is erected I wish you would see if there is not something remarkable in the lower part of the Scorpion to be found, for I remember your father returned several nights and years to the same spot, but could not satisfy himself about the uncommon appearance of that part of the



Figure 3: John Herschel (Steinicke Collection).

heavens. It was something more than a total absence of stars (I believe). But you will have seen by the register, that those parts could only be marked *half swept*. I wish you health and good success to all you undertake and a happy return to a peaceful home in old England. God bless you all!

The meaning of the terms 'register' and 'half swept' will be explained in Section 4. Beside his sweeps, made at Feldhausen near Cape Town, John Herschel roughly checked the region and replied on 6 June 1834 (Herschel, Mrs J. 1876: 266; his italics; Lubbock, 1933: 373; Evans, 1969: 72): "I have not been unmindful of your hint about Scorpio. I am now *rummaging* the recesses of that constellation and find it full of beautiful globular clusters." Caroline, not happy with John's answer, wrote on 11 September 1834 (Herschel, Mrs J. 1876: 269; Lubbock, 1933: 373):

I thank you for the promise of future accounts of uncommon objects. It is not *Clusters of Stars* I want you to discover in the Scorpion (or thereabout), for that does not answer my expectation, remembering having once heard your father, after a long, awful silence, exclaim: 'Hier ist wahrhaftig ein Loch im Himmel!', and, as I said before, stopping afterwards at the same spot but leaving it unsatisfied, &c.

It is remarkable that Caroline, at the age of 84, remembers this case so well after about 50 years. Forced by his insistent aunt, John checked his records, and found that observations made on 29 July 1834 in sweep 474 match the query. On 22 February 1835 he wrote another letter. It lists "blank spaces" with positions for 1830 (right ascension RA; north pole distance NPD =  $90^\circ$  – declination). John wrote (Evans, 1969: 143–144; his italics):

I have swept well over Scorpio and have entries in my sweeping books of the kind you describe – viz: blank spaces in the heavens *without the smallest star*. For example

RA  $16^h 15^m$  NPD  $113^\circ 56'$  – a field without the smallest star

RA  $16^h 19^m$  NPD  $116^\circ 3'$  – *Antares* ( $\alpha$  Scorpii)

RA  $16^h 23^m$  NPD  $114^\circ 25'$  to  $114^\circ 5'$  – field entirely void of stars

RA  $16^h 26^m$  NPD  $114^\circ 15'$  – not a star 16 m. – Nothing!

RA  $16^h 27^m$  NPD  $114^\circ 0'$  – not a star as far as  $114^\circ 10'$

and so on – then come on the Globular Clusters – then more blank fields – then suddenly the Milky Way comes on as there described (from my Sweep 474. July 29. 1834).

We will see later that this matches the region of Herschel's 'hole'. Obviously, Caroline was satisfied with this information, and the correspondence about the issue terminated here.

## 2 HAGEN'S CANDIDATE: BARNARD 86

What is this obscure 'hole in the sky'? In the literature we encounter the claim that Herschel saw the striking dark nebula Barnard 86 in Sagittarius, and it was located about 6' west of the small open cluster NGC 6520. This cluster was discovered by William Herschel on 24 May 1784 and later catalogued as VII 7 (Herschel, W., 1784d: 496). John Herschel observed the same object from Feldhausen on 15 July 1836 and catalogued it as h 3721 (Herschel, J., 1847: 116). Father and son do not mention the dark nebula 6' to the west, and later neither would return to this region of the sky.

The identification of Herschel's 'hole' with Barnard 86 is due to the Jesuit astronomer Johann Georg Hagen (1847–1930; Figure 4), Director of the Vatican Observatory. In 1928 he published a paper "Die Geschichte des Nebels 'Barnard 86'" ("The History of the nebula 'Barnard 86'") in *Sitzungsberichte der Preussischen Akademie der Wissenschaften* (Hagen, 1928); of course, not one of the common astronomical publications. Hagen was directed to this case by the science journalist Agnes Mary Clerke (1842–1907; Figure 5) who made a notable remark in her book about the Herschels. She wrote that William

... adverted to a black opening, four degrees wide, in the Zodiacal Scorpion, bordered on the west by an exceedingly compact cluster (Messier's No. 80), possibly formed, he thought, of stars drawn from the adjacent vacancy. The chasm was to him one of the most impressive celestial phenomena. His sister preserved an indelible recollection of hearing him, in the course of his observations, after a long awful silence, exclaim, "Hier ist wahrhaftig ein Loch im Himmel!" (Here truly is a hole in the sky); and he recurred to its examination night after night, and year after year, without ever clearing up, to his complete satisfaction, the mystery of its origin. (Clerke, 1895: 67–68).

Triggered by these words, the Vatican astronomer searched for the source, which, unfortunately, was not given. But with the aid of William Alfred Parr (1834–1936), a friend of the Herschel family at Slough, he received a copy of Caroline's letter dated 11 September 1834. In his paper Hagen quotes the relevant part (he was not aware of the earlier correspondence). Concerning size and position of the object, as given by Clerke (4° wide, east of M 80), he wrote: "In saying this, however, she appears to be merely stating her own conviction, as no source is quoted."

To get an impression of the region, Hagen could use an imposing work, published a year before by the American astronomer Edward Emerson Barnard (1857–1923; Figure 6): *A Photo-*

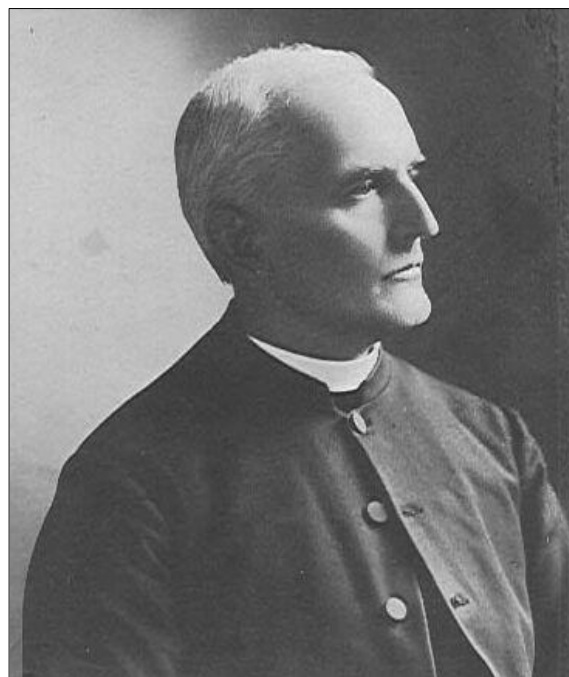


Figure 4: Johann Georg Hagen, Director of the Vatican Observatory (Steinicke Collection).

graphic *Atlas of Selected Regions of the Milky Way* (Barnard, 1927). It particularly features 370 'dark nebulae', designated as B 1 to B 370. The globular cluster M 80 is seen on Plate 13 "Region of the Great Nebula  $\rho$  Ophiuchi" (Figure 7).

Hagen finds that



Figure 5: Science journalist Agnes Mary Clerke (wikimedia.commons).

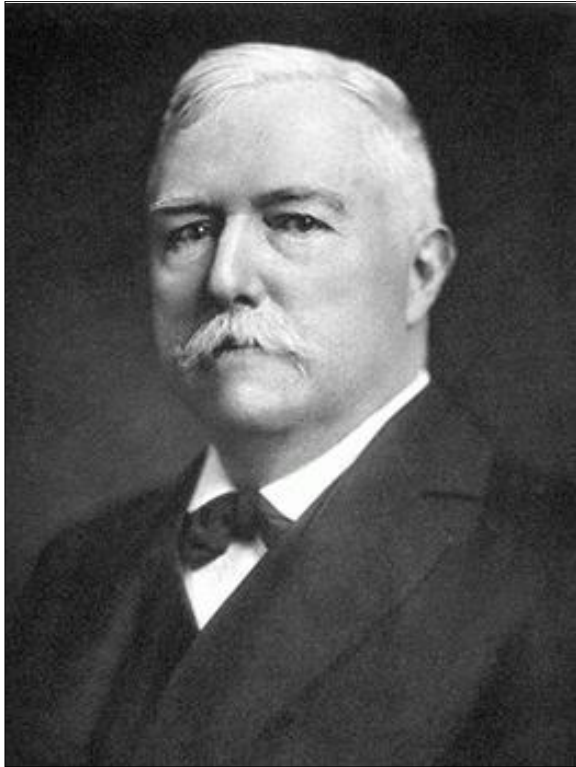


Figure 6: American astronomer Edward Emerson Barnard (en.wikipedia.org).

... the opening mentioned [B 42] is not 'black' but filled up by the bright nebula  $\rho$  Ophiuchi ...

[and] For this reason, another astronomer has placed the 'opening' further towards the East [B 44], where three starless tracts extend for more than four degrees beyond the nebula.

Alas, Hagen does not tell which astronomer is meant. He concludes that

Neither explanation fits Caroline's account. Messier 80 lies in Scorpion, it is true, and the nebula in Ophiuchus adjoining, but Herschel could not see both at the same time, for they lie half a degree apart. Herschel calls this starless region 'an opening or hole' (Scientific Papers I, p. 253), but we might have found more than a hundred openings of equal extent, and it is not easy to see why he should have repeatedly come back to this particular spot, as Caroline suggests, and why this starless region rather than any other should have evoked his exclamation of wonder.

Hagen's statement that M 80 and  $\rho$  Ophiuchi "... lie half a degree apart ..." is incorrect; the true distance is  $\sim 2^\circ$ . Anyway, he presents an unexpected candidate for Herschel's hole: a "... perfectly dark spot ..." found in the summer 1857 by the former Director of the Vatican Observatory, Angelo Secchi (1818–1878; Figure 8). It is located about  $2^\circ$  north of  $\gamma$  Sagittarii. The Jesuit astronomer discovered the object when observing John Herschel's cluster h 3721 (NGC 6250) with the fine 10-in Merz refractor at Collegio Ro-



Figure 7: Part of Plate 13 "Region of the Great Nebula  $\rho$  Ophiuchi" from Barnard's *Photographic Atlas of Selected Regions of the Milky Way*. It shows the striking region around  $\rho$  Ophiuchi (267). Note the dark nebulae B 42 and B 44 south and southeast of the star. M 80 (248) is west of the star; also seen at the bottom are M 4 (261) and NGC 6144 (268).

mano. Secchi wrote (1857: 10): "... a perfectly dark spot of the shape of a pear, about 4<sup>m</sup> large. This spot, by its contrast, shows that the galaxy in that region is quite strewn with stars, which give a white aspect to the firmament." However, the reported size of 4<sup>m</sup> in RA (i.e. 53' at that declination) is rather exaggerated; visually the spot is not larger than 5'. Perhaps Secchi meant 4'. Hagen also celebrates his predecessor as initiator of the idea that 'dark masses' exist in space. He writes: "Secchi was the first astronomer to recognise the dark spots in the Milky Way as nebulous masses, rather than merely as starless regions, or holes." This will be discussed in Section 7. About two decades later, Secchi's pear-shaped object in Sagittarius was independently discovered by two other visual observers.

On 12 August 1876 the French astronomer Étienne Trouvelot (1827–1895; Figure 9) noticed the 'dark spot' with the 26-in Clark refractor of the U.S. Naval Observatory, Washington, and made a drawing. However, the observation is not recorded in the annual report of the Observatory, but it was published 1882 in his book *Astronomical Drawings*. He wrote (Trouvelot, 1882: 133):

I have myself detected such a dark space devoid of stars and nebulosity in one of the brightest parts of the Milky-way, in the constellation Sagittarius, in about 17h. 45m. right ascension, and 27° 35' south declination. It is a small miniature coal-sack or opening in the Galaxy, through which the sight penetrates beyond this great assemblage of stars. Close to this, is another narrow opening near a small, loose cluster.

Trouvelot does not present the drawing in his book. It eventually appeared 1884 in a French magazine (see Section 4).

The French astronomer was followed by Barnard in Nashville. He found the object in July 1883 with his 5-in Byrne refractor. The observation is described in a short note, written for the new magazine *Sidereal Messenger* (Barnard, 1883–84):

It is a small triangular hole in the Milky Way, as black as midnight. It is some 2' diameter, and resembles a jet black nebula. There are one or two faint stars in the following part of it with a small cluster following [NGC 6520]. A small bright orange star is close north preceding [HD 164562], on the border of the opening. Numerous larger dark openings are in its neighbourhood but none is as small and decided as this.

A paper in the common *Astronomische Nachrichten*, titled "Small black hole in the Milky Way", soon followed (Barnard, 1884). He coined the popular name 'Ink Spot' (Barnard, 1913:



Figure 8: Angelo Secchi, the former Director of the Vatican Observatory (en.wikipedia.org).

500): "It is a very striking object in a 5-inch telescope, where it looks like a drop of ink on a luminous sky." Barnard photographed the region on 1 August 1889 with the 6-in Willard lens



Figure 9: French astronomer Étienne Trouvelot (www.fs.ed.us/ne/morgantown/4557/gmoth/trouvelot/).

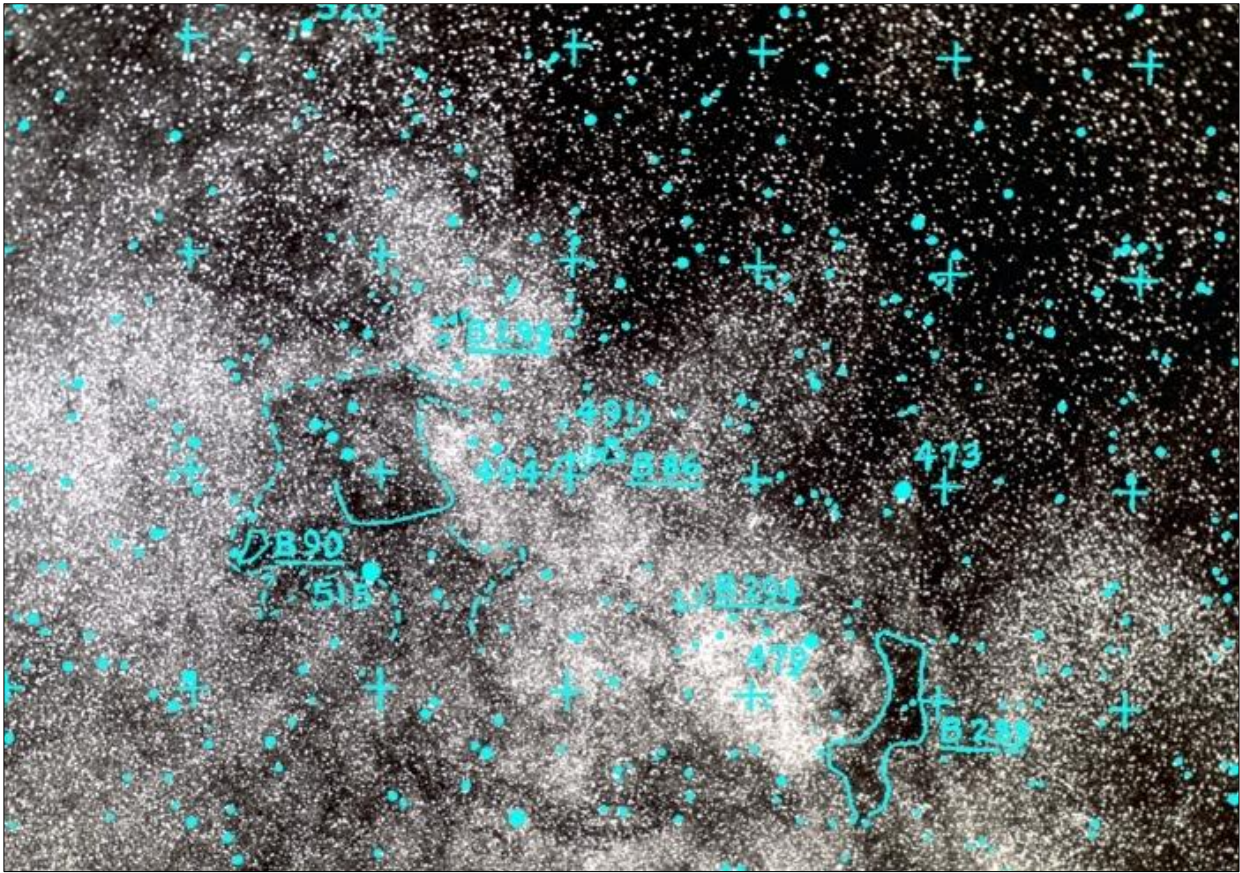


Figure 10: Part of Plate 26 “Great Star Clouds in Sagittarius” of Barnard’s *Photographic Atlas of Selected Regions of the Milky Way*. It shows the region and the tiny dark nebula B 86 in Sagittarius (centre of the photograph).

at Lick Observatory (Barnard, 1890). Later he entered the object as no. 86 in his first catalogue of 182 dark nebulae (Barnard, 1919); there a diameter of 5’ is given. B 86 is shown as a small spot on Plate 26 “Great Star Clouds in Sagittarius” (see Figure 10) of his *Atlas of Selected Regions of the Milky Way* (Barnard, 1927).

Hagen’s citation “Scientific Papers I, p. 253” points to a paper, published in 1785 by Herschel in the *Philosophical Transactions* and reproduced in John Louis Emil Dreyer’s (1852–1926) monumental 2-volume work *The Scientific Papers of Sir William Herschel* (1912: 253). It is titled “Construction of the Heavens” and contains the remarkable section “An opening or hole”. Here Herschel gives all relevant facts about the case:

... in the body of the Scorpion is an opening, or hole ... [It is] at least 4 degrees broad ... the 80th *Nebuleuse sans étoiles* of the *Connaissance des Temps*, which is one of the richest and most compressed clusters of small stars I remember to have seen, is situated just on the western border of it.

Obviously, this is the source of Clerke’s short review (together with the Herschel correspondence). However, Hagen’s treatment of this paper is telling.

The essential evidence for his claim is due to the open cluster NGC 6520, about 6’ southeast of B 86. Hagen (1928: 484) has observed the

pair with the 16-in Zeiss refractor at the Vatican Observatory, reporting a diameter of 15’ for the dark object. He doubts that the globular cluster M 80 was meant because Herschel “... could not see both [hole and cluster] at the same time, for they lie half a degree apart.” He also stresses that Herschel is the discoverer of the open cluster, catalogued as VII 7, and quotes his description: “Considerably rich but pretty coarsely scattered, little more compressed in the middle (*Scientific Papers I*: 291).” Hagen adds:

Herschel’s attention was thus concentrated on this spot [cluster] for some time, and would naturally extend to the neighbouring vacuity, by reason of its small size and the chain of stars encircling it—but chiefly on account of the contiguous star cluster, favoured his theory in a way scarcely to be found elsewhere. An exclamation of wonder in such circumstances is thus comprehensibly enough.

Here Hagen refers to Herschel’s theory of the formation of clusters by gravity, leaving places of less matter (holes). This idea will be discussed later. Based on the presented ‘facts’, the Vatican astronomer comes to the conclusion that Herschel’s ‘hole in the sky’ is identical with Secchi’s ‘dark spot’:

This star cluster [NGC 6520] lies on the confines of the three constellations Sagittarius, Ophiuchus and Scorpio, i.e. within the region which Herschel’s sister indicated from mem-

ory. If, now, we consider that Barnard described the dark nebula connected with this star cluster as 'one of the most impressive objects in the Milky Way', and if we compare the two impressions received by Herschel and Barnard respectively—of a 'hole in the sky' in the one case and of a 'black hole' in the other—there can scarcely be any doubt whatever that the nebula now known as B 86 was the one which evoked the famous exclamation from Herschel. This remarkable object was thus discovered three times within a century, viz., by Herschel, by Secchi, and by Barnard.

Of course, critical remarks about this claim are necessary. To distinguish the arguments, Table 1 might be useful. It compares the facts as presented by

- (1) the Herschel Family, supported by Flammarion, Chambers, Clerke and Gore; and
- (2) Hagen, based on the observations of Secchi, Trouvelot and Barnard.

Hagen does not explain why Herschel has not mentioned the dark object in the description of the cluster VI 7, worth for an exclamation. Also there are problems concerning the distance to the cluster and the size of the hole. Herschel never has claimed to have seen "... both at the same time". Moreover, the true distance is not "... half a degree ..." but about 2°. Hagen's conclusion of a small distance, favouring the close pair B 86/NGC 6520, is not justified. He also did not recognise Secchi's wrong size of 4<sup>m</sup> in RA, which is nearly 1°. This would imply that NGC 6520 lies inside the 'black hole', for the separation is only 6'. Herschel even speaks of a size of 4° for his hole.

The identification of Herschel's hole with B 86, located nearly 25° east of M 80, is essentially Hagen's claim. Secchi, Trouvelot and Barnard never mentioned a connection with it, although they might have known Herschel's paper in the *Philosophical Transactions* of 1785, a standard publication in every observatory library. Hagen surely knew all the facts, but he ignored that they were incompatible—except the description: 'hole' vs. 'black hole'. Was Hagen's argument only based on this literary match?

It seems likely that he wanted to feature the Jesuit, Father Secchi. To achieve this it was helpful, to establish a significant relation between Secchi and Herschel, the distinguished master of visual astronomy. This was done by the claim that Secchi was the second discoverer of Herschel's hole and, moreover, the first person presenting a plausible explanation about its nature: 'dark matter'. This was Hagen's favourite subject. He was the initiator and strongest advocate of the theory claiming the existence of extensive 'obscure nebulae' in space (Hagen, 1921). However, such 'Hagen clouds' were never detected. Facing this, it was natural

for him to leave aside Herschel's paper—it could weaken his arguments.

In 1929 Hagen published a second paper on the issue (Hagen, 1929). He first summarised his earlier result:

It was ascertained with great probability that Herschel's well-known exclamation about a 'hole in the sky' relates to a dark spot, which was entered as No. 86 in the 'Catalogue of Dark Markings in the Sky' by its third discoverer Barnard.

He again criticises Clerke for not giving the source of Caroline's report. But now Hagen has found it in "... the very rare book ..." *Memoir and Correspondence of Caroline Herschel* (Herschel, Mrs J., 1876). To leave no doubt, the Vatican astronomer consulted John's daughter Francisca Herschel (1846–1932) at Slough and got a copy of the relevant letter to Lady Herschel, sent on 1 August 1833, including the "P.S.S."

Table 1: Comparison of the facts concerning the two candidates for Herschel's 'hole in the sky'.

Parameter	Herschel	Hagen
Description	hole	black hole
Constellation	Scorpius	Sagittarius
Size	4°	2'–16'
Cluster	M 80	h 3721 (NGC 6520)
Cluster appearance	very rich and compressed	small, loose
Distance to cluster	2°	6'
Direction to cluster	west	east

### 3 THE DEBATE IN THE JOURNAL OF THE BRITISH ASTRONOMICAL ASSOCIATION

Hagen's paper of 1928 initiated a debate, mainly in the *Journal of the British Astronomical Association*, under the heading 'Hole in the Sky'. It lasted until 1944. The origin was not the paper itself but a translation, done by Hagen's helpful friend William Parr, Librarian of the British Astronomical Association (BAA). It appeared in Volume 39 of the *BAA Journal* (Parr, 1928). For him the Vatican astronomer treats a "... classic episode in 'English' Astronomy." Six years passed until a reply appeared, written by Peter Doig (1882–1952) from the BAA's Historical Section (Doig, 1934). He states:

Father Hagen gives good reason to believe that Barnard 86 is the object in question, although it does not seem absolutely certain from any written account that this is so.

Doig also points to Caroline's opinion that her brother's object

... was something more than a total absence of stars. [For him] ...it appears quite probable, therefore, that Sir William Herschel saw something in the nature of a faint nebulous appearance.

Against it, the South African amateur Hendon Edgerton Houghton (1892–1947) believed that

Hagen's identification was correct, once again quoting parts of the Herschel correspondence (Houghton, 1942).

The issue was also treated by a female member of the Herschel family, Emma Dorothea Herschel (1867–1954), one of John's many grandchildren. However, concerning the nature of the hole, she and her younger brother John Charles (1869–1950) "... have come to the unexpected conclusion that W.H. really intended to convey a diametrically opposite idea!" (Herschel, E.D., 1944). That is:

... it seems to us much more probable that it was the 'beautiful globular clusters', as observed by Sir John, that had absorbed the repeated and wrapt attention of his Father, rather than merely a dark empty hole. It would be interesting if some kind astronomers could tell us whether there is any remarkable 'coal sack' in the neighbourhood at all.

This argument is based on Herschel's standard handbook, bought already in 1773: *Astronomy Explained upon Sir Isaac Newton's Principles*, written by James Ferguson (1710–1776; see Davenhall, 2010). There we read (Ferguson, 1756: 385):

But the most remarkable of all cloudy stars is that in the middle of Orion's sword [M 42]. It looks like a gap in the sky, through which one may see (as it were) part of a much brighter region.

Emma Dorothea focuses on the characters and education of William and Caroline:

I feel also that the parenthesis '(as it were)' in Ferguson, coupled with the constructional emphasis on the word 'wahrhaftig' [truly] by Herschel, both rather subtly suggest a playful allusion to some pre-supposition familiar to everyone at the time. Lady Lubbock appears to sense this innuendo, as she goes on to say [Lubbock, 1933: 62]: 'This idea of light shining through rifts in a dark envelope is a survival of the mediaeval conception of the universe as a series of concentric spheres, the outer and highest of all being the pure Emyrean of heavenly light ... That Caroline appears to have been quite unaware of any such popular belief is perhaps not surprising. Astronomy formed no part of her early interests (music and needlework filled her thoughts), and it is quite likely that she switched on to astronomy under her brother's enlightened influence with a virgin mind devoid of any preconceived ideas. One rather wonders whether the puzzle that had struck in her mind for so many years was ever solved to her satisfaction!

Doig immediately replied that he knows a "... very remarkable 'coal sack' in the neighbourhood of the lowest part of Scorpio, which may be the cause of Sir William Herschel's famous remark." (Doig, 1944). Citing Hagen's paper, he wrote that "Barnard's Nebula 86 ... is the object in question ..."—though in lower Sagittarius.

Strange too is Doig's claim that

... the explanation of Herschel's repeated scrutiny seem to be that he *suspected* something of the kind [obscuring nebulosity], but did not become sufficiently certain to commit himself to an opinion or to publish anything about the object. (his italics).

Here he ignores Herschel's paper.

Just following Doig's note in the *JBAA*, we find an independent reply to Emma Dorothea Herschel's query by the English astronomer Philibert Jacques Melotte (1880–1961). He presents some areas devoid of stars in the southern part of Scorpius, found on the *Franklin-Adams Charts*. Published in 1914 by the English amateur astronomer John Franklin-Adams (1843–1912) they are one of the earliest photographic atlases showing the complete sky. Two areas are near the globular clusters M 80 and M 4. Melotte (1944) writes:

It seems likely that Herschel may have noticed some peculiarity when examining these fields, as the falling off in star density in the obscured areas is very pronounced, and that Caroline Herschel sought further information in confirmation of this, particularly in the case of the most southern area.

Undoubtedly, the case now demanded a more detailed review of Herschel's 1785 paper. This was carried out in 1944 by the British engineer Charles Frederick Nelson Powell (1905–1994). Herschel mainly describes the results of his 'star gages'.<sup>1</sup> This term designates star counts made in the field of view (measuring 15' in diameter) during a sweep—his basic method to determine the distribution of stars on the sphere. Moreover, the star numbers allowed him—by a few assumptions—to figure the spatial structure of the stellar system, i.e. the Milky Way (Steinicke, n.d.). Normally several fields were counted along the sweep path of about 2° length, when the tube of his 18.7-in reflector moves up or down in the meridian. Caroline calculated the mean star number for the fields (usually 10), giving decimal values. The position of a gage is equal to the mean right ascension (RA) and north polar distance (PA) of the fields.

Herschel's paper presents a "Table of star gages", listing the 683 gages made until the beginning of 1785. He wrote:

When five, ten, or more fields are gaged, the polar distance in the second column of the table is that of the middle of the sweep, which was generally from 2 to 2½ degrees in breadth; and, in gaging, a regular distribution of the fields, from the bottom of the sweep to the top, was always strictly attended to.

During this task, Herschel had found many 'vacant places', i.e. fields showing very low star numbers. An extraordinary case is treated in the section "An opening in the heavens" (Her-



schel, W., 1785: 256–257). Powell (1944) quotes the whole content:

Some parts of our system [Milky Way] indeed seem already to have sustained greater ravages of time than others, if this way of expressing myself may be allowed; for instance, in the body of the Scorpion is an opening, or hole, which is probably owing to this cause, I found it while I was gaging in the parallel from 112 to 114 degrees of north polar distance. As I approached the milky way, the gages had been gradually running up from 9.7 to 17.1; when, all of a sudden, they fell down to nothing, a very few pretty large stars excepted, which made them shew 0.5, 0.7, 1.1, 1.4, 1.8; after which they again rose to 4.7, 13.5, 20.3, and soon after to 41.1. This opening is at least 4 degrees broad, but its height I have not yet ascertained. It is remarkable, that the 80th *Nebuleuse sans étoiles* of the *Connoissance des Temps* [M 80], which is one of the richest and most compressed clusters of small stars I remember to have seen, is situated just on the western border of it, and would almost authorise a suspicion that the stars, of which it is composed, were collected from that place, and had left the vacancy. What adds not a little to this surmise is, that the same phenomenon is once more repeated with the fourth cluster of stars of the *Connoissance des Temps* [M 4]; which is also on the western border of another vacancy, and has moreover a small, miniature cluster, or easily resolvable nebula of about 2½ minutes in diameter, north following it, at no very great distance.

Powell consulted Herschel's gage table to get the positions of the vacant fields in question; Table 2 collects the relevant data. Right Ascension (RA) and North Polar Distance (PD) are given for 1690, i.e. the epoch of the *British Catalogue*, compiled by John Flamsteed (1646–1719); Herschel used this important star catalogue for his reference stars (Steinicke, 2014). The star "g Serpentarii" is now called  $\rho$  Ophiuchi and "19 Scorpii" is  $\sigma$  Scorpii. Though the term 'hole in the sky' does not appear in Herschel's paper, it was obvious to Powell that the table describes this 'opening'. He added: "Allowing for the effect of precession, the above 'opening' evidently corresponds to the first of the obscured areas referred to in P.J. Melotte's letter". The second hole, near M 4, also was identified by Melotte.

No doubt, Powell's paper brought the breakthrough. But was this the death of Hagen's claim? Of course, the paper was less influential than that written by a recognized authority like the Director of the Vatican Observatory. So Hagen's wrong identification of the 'hole in the sky' would remain for some time.

Fortunately, serious authors have questioned Hagen's result. An outstanding example is the American astronomer and historian Joseph Ash-

Table 2: Extract from William Herschel's "Table of star gages", relating to the vacancy near M 80 (see text).

RA h m s	PD ° '	Stars	Fields	Memoranda
16 04 19	113 06	0.5	10	Perfectly clear
16 06 28	113 04	0.7	10	Perfectly clear
16 09 28	113 04	1.1	10	Perfectly clear
16 11 28	113 04	1.4	10	The same
16 13 28	113 04	1.8	10	g Serpentarii and 19 Scorpii visible to the naked eye

brook (1918–1980; Figure 11). His important *Astronomical Scrapbook* of 1984 contains a chapter "A hole in the sky" (Ashbrook, 1984: 392–406). It starts with the known Herschel correspondence but Ashbrook rightly adds: "Actually, Sir William's own writings tell a good deal more." Here the 1785 paper is referred to. Concerning Herschel's sweeps and gages, he correctly summarises:

During the course of these sweeps, made with a 157x eyepiece, he frequently stopped to count the number of stars per unit area, as seen in a particular direction, brighter than the limiting magnitude of the telescope. (A rough comparison with modern star counts suggests that this limit was about magnitude 15.) For greater accuracy, Herschel often averaged the counts for as many as 10 neighbouring fields.

From the coordinates given in Herschel's gage table, Ashbrook correctly concludes about the position of the hole:

This is the vicinity of Rho Ophiuchi, and Herschel's 'Loch im Himmel' is unquestionable the Rho Ophiuchi dark nebula, familiar in Milky Way photographs ever since E.E. Barnard's time.

The discovery story of dark nebulae, and especially Herschel's contribution, is discussed by the American historian of astronomy Steven J. Dick (1949–) in his interesting book *Discovery and Classification in Astronomy*. He writes:

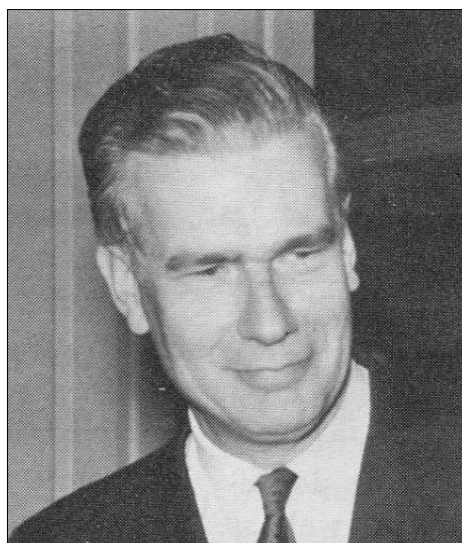


Figure 11: The American astronomer and historian Joseph Ashbrook (Steinicke Collection).

According to his sister and assistant Caroline, coming upon one such spot in Sagittarius (now known as the Ink Spot) she heard him “after a long, awful silence exclaim ‘hier ist wahrhaftig ein Loch im Himmel!’” ... Was Herschel or Barnard the discoverer of what we now know as dark nebulae? (Dick, 2013: 80).

Dick presents a figure showing the dark nebula B 86 and the nearby open cluster NGC 6520. However, the answer to the question “Herschel or Barnard?”—which should better read “Herschel or Secchi?”—is left to the reader.

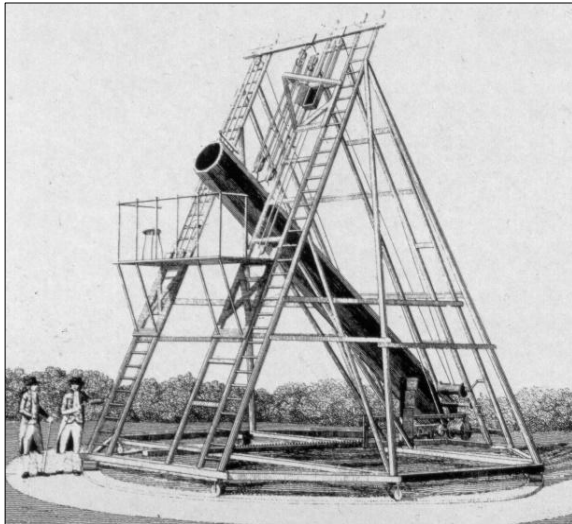


Figure 12: William Herschel's 18.7-in reflector of 20-ft focal length, used for the sweeps. It moved up and down in the meridian. The standard eye-piece had a magnification of 157x and gave a 15' field of view (Steinicke Collection).

#### 4 HERSCHEL'S DISCOVERY OF THE 'HOLE IN THE SKY'

After having cleared up the identification of Herschel's hole, we may ask: “What is the very source?” Of course, it is not the paper in the *Philosophical Transactions* of 1785, which only summarises the observational results. Concerning the discovery date we often read 1785—a simple claim. But what is the true date?

To answer these questions one has to consult the (unpublished) sweep records, carefully compiled by Caroline in different versions. There are additional tables, listing the dates and limits, or even charts, showing the sweep areas and object positions. However, because the sweeps are ordered by date and not by right ascension (like modern catalogues), it is difficult to find out when William searched a certain region, i.e. that of M 80 in Scorpius.

I responded to these queries by referring to a large digital database, although it was not specially designed for this case. It contains all information about Herschel's observations, starting in the early times of his star reviews (1776–1783), followed by his epochal sweep campaign (1783–1802)<sup>2</sup> and ending with observations of special objects in about 1810. Herschel used

various methods and telescopes from 6.2 inches to 48 inches aperture. However, his standard instrument was the 18.7-in reflector (i.e. ‘the large 20ft’; see Figure 12).

The original sources are stored in numerous manuscripts, lists, compilations and charts—mainly the work of Caroline. They are accessible in the Herschel Archives of the Royal Society and the Royal Astronomical Society (RAS) in London. For instance, there are four different versions of the sweep records (alas, the original notes made at her desk during the observation were not kept). The final one contains positions of all objects for the epoch 1800 and additional comments. The digital database is split into many single files, containing different information (e.g. objects, sweeps, dates, instruments).

This database was used to find observations covering the regions around M 80 (Herschel's hole) and M 4 (second hole). The search yields 11 hits. In two observations, made before the sweep campaign, the target was M 4 in Scorpius. On 5 May 1783 the 8.3-in (‘10ft’) reflector was used and on the following night the 12-in (‘small 20ft’). No hole was noted. Seven observations appeared in the sweeps, which mutually overlap (Table 3 gives the data). No doubt, May was the favourite month. The two remaining observations were made in the course of Herschel's later star reviews, using the ‘7ft’, a 6.2-in reflector (Herschel, W., 1792–1800: 3; Herschel, W., 1802–1810: 14). The dates are 9 June 1793 and 10 June 1804. On both nights the double star  $\rho$  Ophiuchi (here called  $g$  Ophiuchi) was visited (see below). Vacant places were not reported.

The sweep areas are visualised in Caroline's “Register of nebulae” (Figure 13). Note that sweeps 215 and 222 are marked by single lines instead of the usual crosses, which means ‘half swept’. This explains her sentence in the letter of 1 August 1833: “But you will have seen by the register, that those parts could only be marked *half swept*.” The term means that the sweep (or a part) was influenced by twilight, moonlight, haze or anything similar. However, this qualification is often not used very strictly. For instance, sweep 222 started with “strong daylight” but at 10:00 pm it was “pretty dark” and about 0:20 am the sky became “perfectly clear”; at 1:00 am “twilight very strong” is noted. Thus, Caroline's attribute ‘half swept’ is justified for only 1.5 hours of the 4.5-hour sweep.

Concerning the sweep records we start with Caroline's first copy (Herschel, C., 1784–1785). In sweep 212 Herschel performed two gages in Scorpius. M 80 was the last observed object, and was “... very bright ... must be visible with an achromatic”.<sup>3</sup> In sweep 215 the globular cluster

Table 3: Sweeps covering the regions about the globular clusters M 80 and M 4. The positions for start and end of a sweep are for 2000; B is the vertical breadth; a sweep marked by a \* was 'half swept'. Herschel's 'hole in the sky' near M 80 was discovered in sweep 222, a second one (near M 4 and NGC 6144) in sweep 223.

Sweep	Date	UT	Place	Start	End	B	Objects
212	11 May 1784	00:30 am–01:05 am	Datchet	15 46–21 30	16 21–23 21	2.0	M 80
215*	14 May 1784	00:20 am–01:00 am	Datchet	15 53–23 42	16 32–25 28	2.0	$\rho$ Oph
222*	21 May 1784	09:15 pm–01:45 am	Datchet	13 17–23 21	17 47–24 32	2.0	M 80, hole in Scorpius
223*	22 May 1784	09:55 pm–02:10 am	Datchet	14 03–24 56	18 15–26 10	2.1	M 4 & NGC 6144, 2nd hole
224*	24 May 1784	10:35 pm–02:00 am	Datchet	14 54–27 00	18 16–28 18	2.2	M 4, 2nd hole
566	26 May 1786	10:50 pm–02:00 am	Slough	15 11–21 55	18 18–23 44	2.6	M 80, hole
741	19 May 1787	10:30 pm–00:50 am	Slough	14 24–17 47	16 40–19 59	2.2	north of M 80

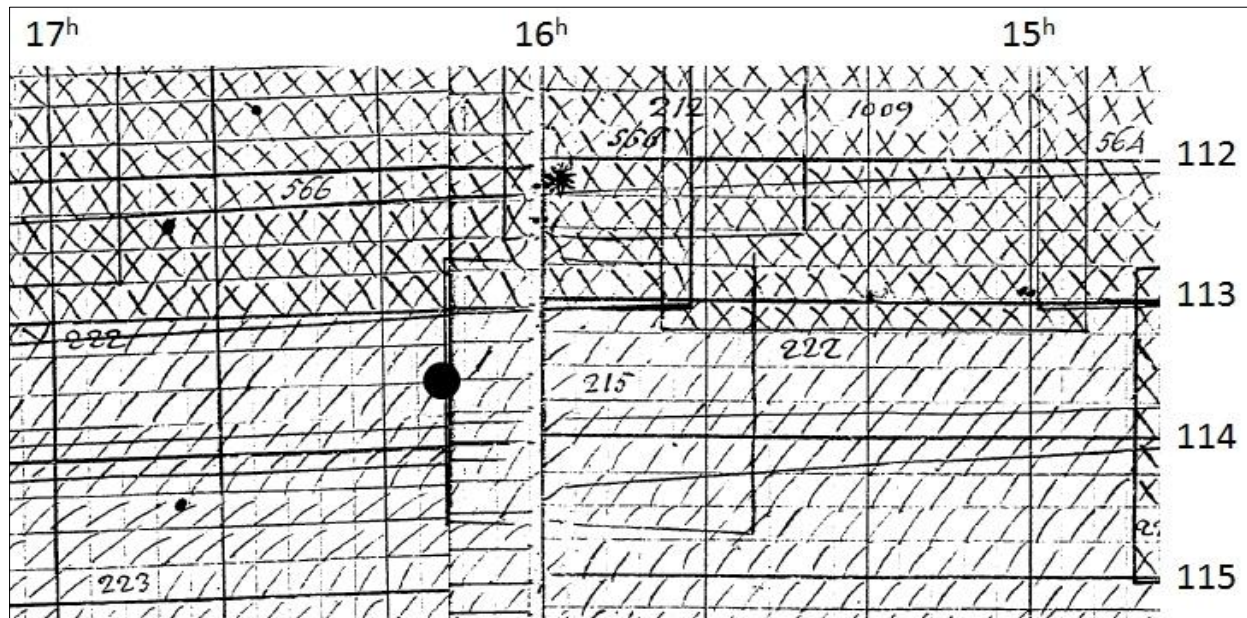


Figure 13: Part of Caroline's "Register of sweeps" (Herschel, W., 1783–1785), which shows the areas of sweep 212, 215, 222 and 566 including Herschel's 'hole' (marked as black spot). The number at right marks the north pole distance (PD = 90°–declination). Note that the sweeps mutually overlap.

was not observed. After a gage over two fields (yielding 32.5) three bright stars were seen. The first was not identified in Flamsteed's catalogue ("star not in Fl"), but it is  $\sigma$  (19) Scorpii (correctly listed in the final version of the sweep records); the second is called  $\gamma$  Serpentarii ( $\rho$  Ophiuchi) and the third is 22 Scorpii. The short sweeps contain no hint for a 'hole in the sky'.

In the long sweep 222 Herschel made 14 gages. Four minutes after he met M 80 (at 0:15 am on 22 May), the star 19 Scorpii was seen. It was taken as a reference star to determine the coordinates of unknown objects. The following gage, taken at 0:20 am, brought a mean star number of only 0.5. It was calculated from 10 fields along the sweep path: 0 . 2 . 0 . 0 . 1 . 1 . 0 . 0 . 0 . 1 = 5/10 = 0.5; the mean position for 1690 was later calculated by Caroline to be RA 16h 4m 19s, PD 113° 6' (see Table 2). The next gage brought a value of 0.7. Then  $\gamma$  Serpentarii ( $\rho$  Ophiuchi) entered the field ("I saw this star plainly double"<sup>4</sup>). The next three gages yielded 1.1, 1.4 and 1.8 ("... in all appearances perfectly clear."). The following note reads: "I see the 19 Scorpii &  $\gamma$  Serpen[tarii] & 22 Scor[p]ii very plainly with my naked eye." The relevant five gages were performed in about 10 minutes; at that time

this area of sky was only 13° above the horizon.

The data leave no doubt that this is the region mentioned by Herschel in his section "An opening in the heavens". However, the term 'hole' is missing in the first record version. But the second, included in Herschel's *Journal no. 9* (Herschel, W., 1784a), includes more data (see Figure 14). Obviously, Caroline had worked out the original information (exclaimed by William, and written down during the observation by her) in more detail—especially concerning the identification of conspicuous objects. Now the globular cluster in Ophiuchus is correctly identified as "Messier 80 Neb." More important is the enhanced note on 19 Scorpii which now reads:

I see the 19 Scorpii &  $\gamma$  Serpentarii & 22 Scor[p]ii very plainly with my naked eye they are of the 5, 5-6 & 6 magnitudes, which at this altitude shews the air to be very clear. So that by the Gages it seems as if there were [sic] a hole in the Scorpion. (my italics).

In the next two record versions we read of "... a Perforation or Hole" (Herschel, W., 1784b; Herschel, W., 1784c) and in the final one, Caroline gives the positions of the five gages for 1800 (precessed from 1690). However, the RA of the first is 4<sup>m</sup> too large (16h 14m 50s instead of 16h

16 5 Gage. 0.2.0.0.1.1.0.0.0.1. = ,5 perfectly clear.

16 7 Gage. 0.0.0.1.2.0.0.0.2.2. = ,7  
 7,7 39 = 34 g Serpentarii 6-32" 2 112 8. The air is so clear that I saw this star plainly double.

16 10 Gage. 0.1.0.1.0.2.5.1.1.0. = 1,1 In all appearance perfectly clear.

16 12 Gage 0.4.2.0.3.0.0.0.4.1. = 1,4

16 14 Gage. 5.0.0.0.5.2.1.0.1.4. = 1,8 I see the 19 Scorpii, g & 22 Serpentarii very plainly with my naked eye tho they are stars, by H. of the 6. 56. 5 m. which at this altitude proves the air to be very clear.

So that by the Gages it seems as if there were a Perforation or Hole in the body of the Scorpion.

16 18 Gage. 3.1.10.11.2.3.1.0.6.10. = 4,7  
 24 Gage 32.10.1.20.14.22.19.5.0.12. = 13,5  
 most of them extremely small.

Figure 14: The relevant part of sweep 222 (22 May 1784, 0:20 am – 0:39 am) recording Herschel's discovery of "a hole in the Scorpion". The naked-eye star  $\gamma$  Serpentarii is now called  $\rho$  Ophiuchi.

10m 50s) and the PDs of the first two are too large by 4' and 6' (113° 27' for both instead of 113° 23' and 113° 21', respectively). These might be 'typos', but if so a rare event, as Caroline's calculations are usually correct.

For the hole Herschel gives a diameter of "... at least 4 degrees ..." but by the star chart it is about 2° (see Figure 15). Due to the sweeping method, he could not survey greater areas (the breadth of sweep 222 was 2°). So the size value is a mere extrapolation.

In the long sweep 223, performed the next night, Herschel found a second hole in Scorpius, about 4° south of the first and near to the globular cluster M 4, located 1.3' west of Antares. North of it the mean star numbers dropped down to 1.6, 2.0 and 3.8; soon after he discovered the globular cluster NGC 6144, 18'

away. Herschel does not use the term 'hole' here but it appears when the vacant place was seen again in sweep 224: "The two next fields above the gage going up the second time were again 0. 0. So that the border of the hole is thereby pointed out." (Herschel, W., 1784c: 630).

Sweep 224 also brought the discovery of VII 7 = NGC 6520, the small open cluster 6' east of B 86. The striking dark nebula is not mentioned, though it certainly was in the field of view. The reason why Herschel missed it is simple: "... daylight very strong." (the sweep is marked 'half swept'). Normally he would have seen the object, which needs a perfect dark sky to get the right contrast.

In sweep 566 no gages were taken. However, Herschel detected some vacant places ("... the night very fine."). They appeared a few

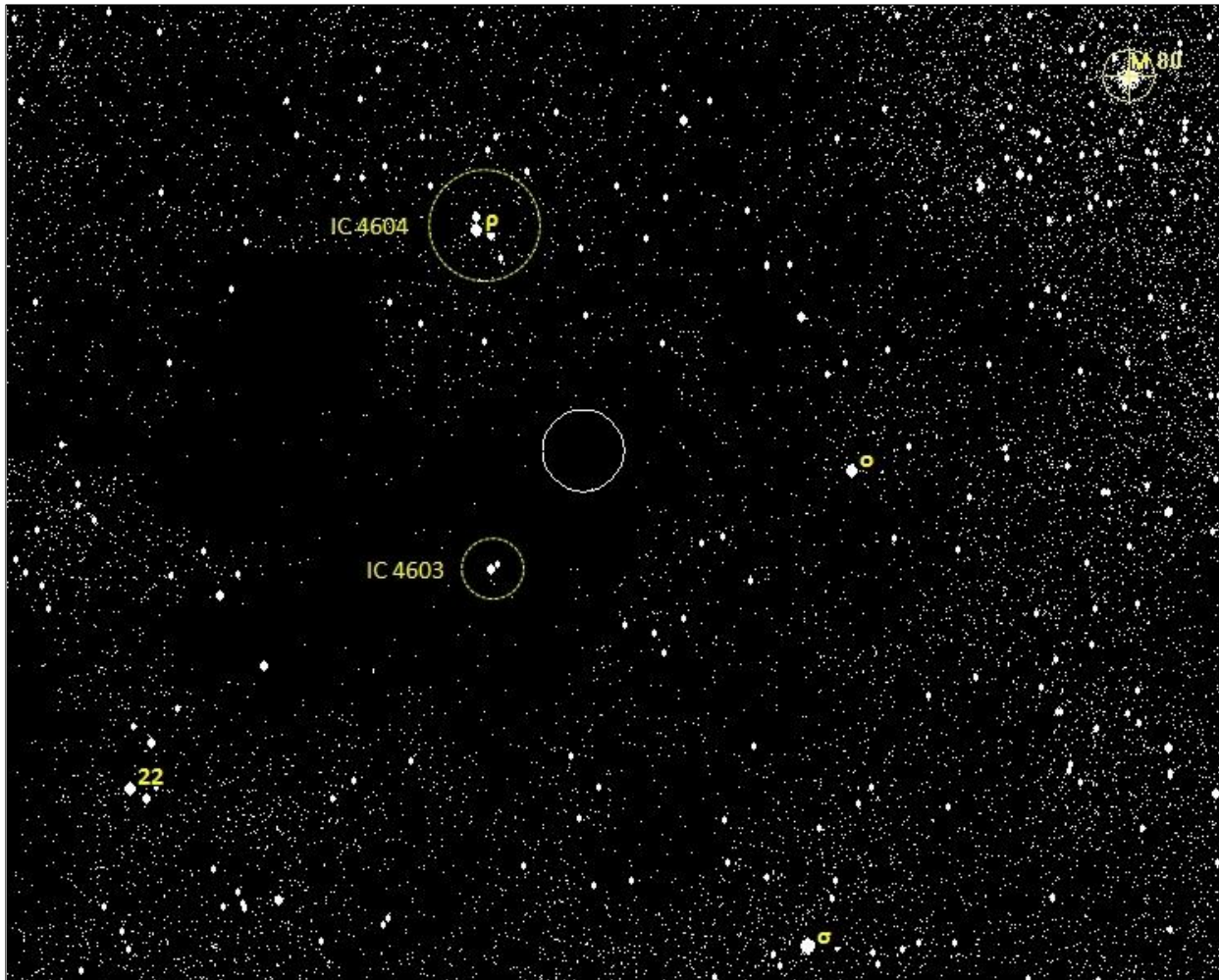


Figure 15: Herschel's hole in Scorpius (at the border to Ophiuchus), located about  $1.7^\circ$  southeast of the compact globular cluster M 80. The circle shows the central field (of 10) on the sweep path. The four bright stars around are  $\sigma$  (20) Scorpii,  $o$  (19) Scorpii,  $\rho$  Ophiuchi and 22 Ophiuchi. Herschel missed the reflection nebulae IC 4603 and IC 4604 ( $\rho$  Ophiuchi Nebula); their sizes are given by the dotted circles.

minutes after M 80 was observed (at about 23:50 pm). Caroline calculated positions matching those of sweep 222. However, sweep 566 was about  $1^\circ$  further north, so that only the northern part of the hole was seen. The notes do not give a hint to the former sweep. Finally, in sweep 741, a region  $5^\circ$  northeast of M 80 brought 20 new vacant places.

An interesting point concerns the reflection nebulae IC 4604, surrounding  $\rho$  Ophiuchi, and IC 4603, around a fainter star  $1^\circ$  south. Barnard wrote (1927: text to Plate 13):

One very striking thing about all the nebulosity in this region is the fact that it is so faint that it cannot be seen with the eye even in a powerful telescope.

This is irritating because both were discovered visually by him in 1882 with the 5-in Byrne refractor at his hometown of Nashville. They were again looked at in 1892 at the Lick Observatory with refractors of 6.5 and 12 inches aperture. Three years later Barnard photographed the region with a 6-in portrait lens, writing: "The Willard Lens had shown that the nebula [IC 4604]

occupied a singularly blank region from which large vacant channels diverged towards the east." (Barnard, 1895). Herschel had not perceived the two nebulae, whereas in other places he was very sensitive to 'extended diffuse nebulosity'. First, according to the sweep data, IC 4603 was not on his path. But what about IC 4604? Its size exceeded his field of view (diameter  $15'$ ) thus there was little contrast, influenced, moreover, by the bright star ( $\rho$  Ophiuchi). This object is a much easier target for a small telescope, like Barnard's, with low magnification and large field of view (a 'comet seeker'). Another factor is the latitude difference between the observing sites of Herschel (Datchet) and Barnard (Nashville); at the latter IC 4604 stands  $30^\circ$  above the horizon (which is  $16^\circ$  higher).

According to Caroline, there should have been more visits to the hole. In her letter of 1 August 1833 to John she writes: "I remember your father returned several nights and years to the same spot." However, there is no evidence, either in the sweep records or in other manuscripts (journals, reviews).

## 5 IDENTIFICATION OF HERSCHEL'S 'HOLE' BY LATER OBSERVERS

The next to observe the region around M 80 was John Herschel in his sweep 474 of 29 July 1834, made at Feldhausen, using an 18.25-in reflector. He informed Caroline about the results in his letter of 22 February 1835. From the given positions it is evident that he saw the hole southeast of M 80 and the neighbouring vacant regions near M 4. His campaign is reviewed in Section 7.

In April 1837 William Henry Smyth (1788–1865) observed both globular clusters with a 5.9-in Tully refractor at Bedford. The results are included in his popular book *A Cycle of Celestial Objects* (Smyth, 1844: 356 and 360). The author explicitly mentions Herschel's vacant regions. The Rev. Thomas William Webb (1807–1885) also saw the vacant region near M 4 with his 3.7-in Tully refractor at Hardwicke (probably in about 1857). The observation is given in his popular book *Celestial Objects for Common Telescopes* (1859), which was inspired by the work of Smyth. Webb writes that M 4 is "... followed by a vacant space without stars distinguishable in my telescope." (Webb, 1859: 233). He also observed M 80, but the hole is not mentioned.

On 11 May 1882 Ormond Stone (1847–1933), Director of Cincinnati Observatory, independently discovered the hole in Scorpius with the 16-in Clark refractor. He communicated this find in the new journal, the *Sidereal Messenger* (Stone, 1882):

In [visually] observing one of our D.M. zones (–23° dec.) a remarkable vacuity was found in the region between 16<sup>h</sup> 17<sup>m</sup> and 16<sup>h</sup> 25<sup>m</sup> right ascension. In this region [at the border of Scorpius and Ophiuchus] there is no star brighter than 9.5 mag., and only one of that magnitude.

Stone's observation was discussed a year later in the June issue of the *Sidereal Messenger* by the German astronomer Christian Heinrich Friedrich Peters (1813–1890), Director of Hamilton College Observatory in Clinton, N.Y. He wrote:

There is nothing new in this; in fact, the absence of larger stars in that region was known about hundred years ago to the elder Herschel. As it seems to have struck Sir William not less than Professor Stone. (Peters, 1883).

Being an expert in the history of astronomy too, Peters knew the relevant sources, particularly Lady Herschel's *Memoir and Correspondence of Caroline Herschel of 1876*. He comprehensively reviewed the case (letters of Caroline and John, especially that of 22 Feb. 1835 presenting the positions), outlining that the 'vacuity' was discovered by William Herschel. Thus Peters is the person who first states the identity of Her-

schel's hole with the vacant places seen by John Herschel on the Ophiuchus/Scorpius border, communicated to Caroline.

Another person who was acquainted with the literature, was the French astronomer and publisher Camille Flammarion (1842–1925). In 1882–1883 three important reports landed on his desk in Paris. The first concerns the discovery of a 'dark space' in Sagittarius by his French colleague Étienne Trouvelot, mentioned in the book *Astronomical Drawings*. Through a private communication he received Trouvelot's drawing (Figure 16). The second was Barnard's note in the *Sidereal Messenger*, announcing the discovery of a 'black hole' in Sagittarius (B 86). For Flammarion the identity was obvious. Then he read Stone's short note in the same journal about a 'vacuity' at the border of Scorpius and Ophiuchus. In 1884 Flammarion wrote a paper titled "Les vides dans le ciel" ("The voids in the sky") for his new journal *L'Astronomie* (Flammarion, 1884). He not only presented the three observations, but also reviewed the historical background, based on the Herschel correspondence. Flammarion concluded: "These are the gaps that had struck Herschel and his sister just a century ago." Was this the result of an independent research? Certainly not, because Flammarion's text strongly looks like a mere translation of Peters' recent account in the *Sidereal Messenger*. However, this paper is not cited—even though it must have been known to him!

Six years later the English amateur George Frederick Chambers (1841–1915) presented a better rendition of Trouvelot's drawing in his book *Descriptive Astronomy* (Chambers, 1890: 111–112). The text is mainly a translation of Flammarion's article, which is cited. Concerning the observations of William Herschel and his son he writes that "Sir John Herschel seems to have returned to the subject [hole]."

More comprehensive is the chapter "Holes in the heavens" in the book *Astronomical Essays*, written by the English amateur John Ellard Gore (1845–1910), who discusses the known facts about the "... absolutely black spot about 4° in width ... east of the globular cluster 80 Messier." (Gore, 1907: 250). Barnard also is mentioned: that he saw "... great nebulous [*sic*] surrounding the stars ρ Ophiuchi and 22 Scorpii." (ibid.).

To summarise the case: Peters, Flammarion, Chambers and Gore were convinced that Herschel's hole and B 86 were different objects. This was long before Hagen entered the scene with his disastrous paper. The Vatican astronomer does not mention these authors; also Trouvelot's observation is missing. It is interesting that the contributions of Peters, Trouvelot and Flammarion were not mentioned in the *JBAA* debate; perhaps because the subject—according

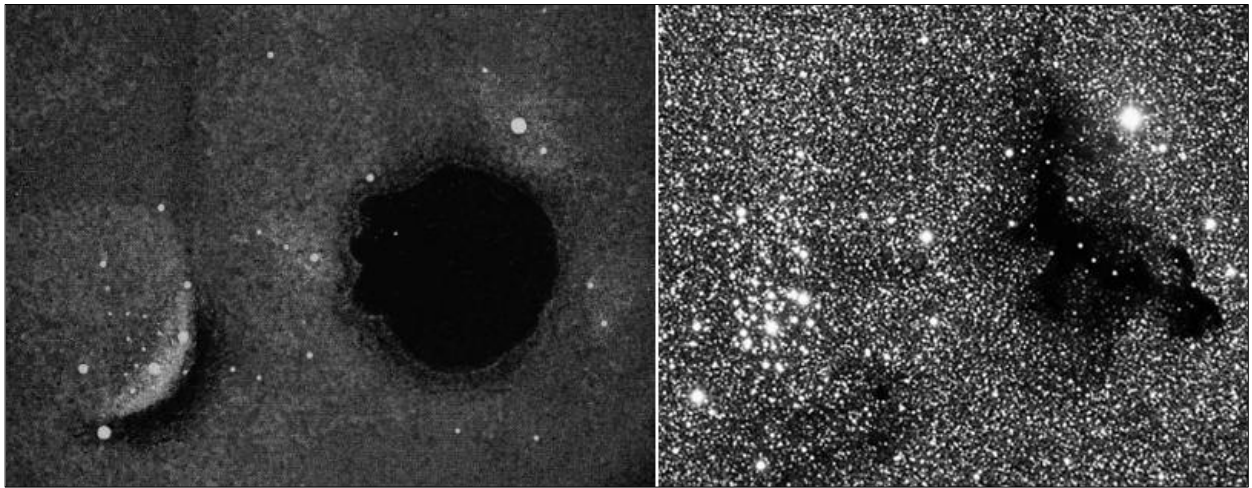


Figure 16: Left: Trouvelot's drawing of the dark nebula B 86 near the open cluster NGC 6520 in Sagittarius; right: modern image (measuring 10' east-west). Note that Trouvelot's "another narrow opening near a small, loose cluster" is real.

to one of the contributors (William Parr)—exclusively concerns "... a classic episode in 'English' Astronomy."

## 6 HERSCHEL'S 'VACANT PLACES'

The matter starts with Herschel's sweep 54 on 19 December 1783 (on that night the first gage was taken). He noticed "... many vacant places ..." in southern Taurus. In sweep 78 (17 January 1784), covering the northern part of the constellation, he even found "... the longest vacant space I ever have seen." The same appeared 11 days later in Virgo (sweep 131). In sweep 189 on 12 April 1784 a gage was taken in Bootes, showing "... about 5 or 6 stars generally in the field." Then seven sweep paths, spread over about one hour of time, showed "... many fields without stars." Caroline determined the average position of this void in Bootes. Some more places were found, and then Herschel encountered the famous fields in Scorpius near M 80 and M 4 on 21 and 22 May 1784 (sweeps 222 and 223). Many more vacant places were detected in later sweeps.

Caroline's register of important subjects and events—her "Temporary Index"—contains a table of 53 'vacant places' (Herschel, C., 1802: 40). For sweep 222 it is noted: "By the gages it appears as if there was a hole ..."; and for sweep 224 we read: "The border of the hole pointed out by this gage." However, this is misleading, for two different 'holes' are meant: near M 80 and M 4, respectively. Later Dreyer, when preparing the *Scientific Papers*, carefully checked the sweep records, stored at the Royal Astronomical Society. Starting at sweep 383 and ending with 741, he lists 77 'vacant places' (Dreyer, 1912: 712–713). Sweep 383 was the first taken after Herschel's paper of 1785 and containing a vacant place. It is astonishing that there is little overlap between Caroline Herschel's and Dreyer's collections (see Figure 17).

A recent investigation of the sweep records yielded no less than 198 vacant places, found in 67 different sweeps. Following Caroline's policy, this includes gages with a mean star number below 5 or non-gaged regions, only recorded as vacant or anything similar. The following plot shows the distribution of all places on the celestial sphere (see Figure 18). They were found between 19 December 1783 (sweep 55) and 2 November 1790 (sweep 976). In 40 sweeps only one place was detected; but we have 15 in sweep 484 (all in Taurus), 20 in sweep 741 (Ophiuchus) and even 22 in sweep 627 (Taurus); often the vacant places are connected.

About half the places (102) lie in or near the Milky Way; they are spread over seven constellations: Cygnus (2), Ophiuchus (30), Orion (7), Sagittarius (1), Scorpius (19), Serpens (3) and Taurus (40). The high number found in Taurus corresponds with observations made by Friedrich Wilhelm Argelander (1799–1875) in the course of the *Bonner Durchmusterung* during the 1850s: "... the region near the horns of Taurus, although close to the Milky Way, is absolutely the poorest in the northern hemisphere." (Clerke, 1890: 361).

Is it possible to identify the Milky Way 'objects' with known dark nebulae? The main catalogues were published by Edward Emerson Barnard (B) in 1927 and Beverly Turner Lynds (1929–) in 1962; the latter objects are designated LBN (Lynds Dark Nebula). In 17 cases (from 10 different sweeps) identification is possible; seven objects bear a B-number. Most successful were the sweeps 222–224 in May 1784, yielding seven known dark nebula. Table 4 may be called a 'Herschel Catalogue of Dark Nebulae'.

What about vacant places outside the Milky Way? Some are real in the following sense: there are directions (e.g. towards the North Galactic Pole in Coma Berenices) showing very few stars

		VACANT PLACES			
		[Extracted from the Sweeps. Places for the Year of Observation.]			
Sweep.	R.A.	P.D.	Stars.		
383 Mar. 10 1785	16 5 22	109 25	0		
	16 6 22	109 20	0		
	16 6 32	109 31	0		
	16 7 22	109 49	0		
	16 7 42	109 12	0		
	16 11 52	110 17	0		
	16 12 22	109 11	0		
	16 12 40	110 25	0		
	16 13 0	111 29	2		
485 Dec. 7 1785	4 17 37	65 29		Upper border of a vacancy, but it is a very irregular one. Do. Do.	
	4 18 30	65 27			
	4 19 17	65 29			
	4 21 35	64 31	0	and many such in the neighbourhood. There is a vacancy between the bright row of stars in the direction of Orion's belt and the Bull's head, Perseus' body and the Milky Way, and I am now in that vacancy.	
	4 22 26	64 22	0		
	4 23 53	64 4	0		
	4 25 17	..	..		
	4 27 26	65 4	0		
	4 28 6	64 10	0		
	4 28 42	65 11	0		
4 29 24	65 15	0			
4 30 54	65 16	0	Intermixed with places that have many stars.		
4 37 51	65 16	0			
4 39 16	..	..	The straggling stars of the Milky Way seem now to come on gradually, most small. They begin now to be intermixed with some larger ones.		
4 43 20	..	..			
516 Jan. 30 1786	5 32 16	98 30	0	Vacant spaces picked out, between stars sparingly and irregularly scattered.	
	5 32 42	100 21	0		
	5 33 5	99 33	0		
	5 34 40	100 39	0		
566 May 26 1786	16 8 52	113 18	}	Vacant between these two places.*	
	16 9 12	112 25			
	16 11 56	112 53			

40  
*Many places &c: S. 54, F. 472.*  
*Appeared &c: S. 75. F. 484*  
*S. 78, 78.*  
*The most vacant &c: S. 191.*  
*S. 156. 157. 158. 166. 166.*  
*Scattered large &c: 167.*  
*Very few &c: 170. 174. 177. 179. 182. 182*  
*Many fields without stars S. 182.*  
*Very few stars S. 187. 187.*  
*Some fields without stars 187. 188.*  
*Very few stars S. 188. 188. 188.*  
*Several fields without stars S. 188. 188. 188.*  
*189. 189. 189. 189.*  
*Very few stars S. 189.*  
*Many fields without st. S. 189. 191. 205.*  
*By the gages it appears as if there*  
*was a hole &c: S. 222.*  
*The border of the hole pointed out by*  
*the gage S. 224.*  
*Many vacant fields, and upon Nebu-*  
*low ground S. 224.*

Figure 17: Parts of the registers of 'vacant places', compiled by Caroline Herschel (1802) and John Louis Emil Dreyer (1912).

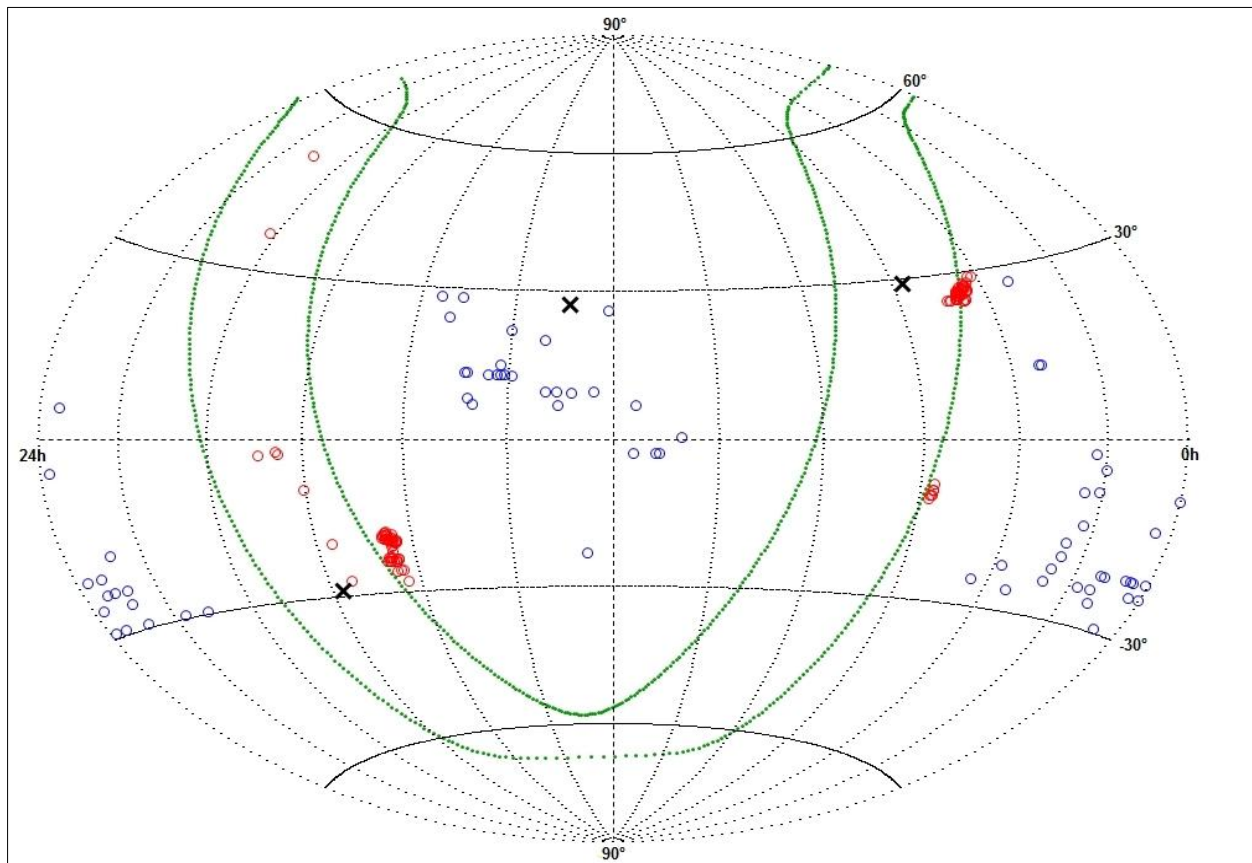


Figure 18: Distribution of Herschel's 198 vacant places on the celestial sphere (red circles = in/near the Milky Way; blue circles = outside the Milky Way). The green curves represent the border of the Milky Way; the crosses mark the Galactic Centre in Sagittarius (left), the North Galactic Pole in Coma Berenices (middle) and the Galactic Anti-Centre in Auriga (right).



Table 4: A 'Herschel Catalogue of Dark Nebulae', listing all 'vacant places' located in or near the Milky Way, which can be identified in the main catalogues of dark nebulae. The (approximate) position is for 2000.0. The most prominent case is the hole in Scorpius near M 80 and  $\rho$  Ophiuchi, identified with B 42. In the last column a \* indicates that the data are based on a star gage; otherwise Herschel only notes a 'vacant place'.

Sweep	Date	Position RA Dec	Const.	Dark Nebula	Remarks
78	17 Jan. 1784	04 08 +29 00	Tau	B 7	*, seen again in sweep 360
222	21 May 1784	16 25 –23 48	Sco	B 42	*, hole in Sco near M 80, seen again in sweep 556
222	21 May 1784	16 30 –23 46	Sco	LBN 457	*
222	21 May 1784	16 32 –23 46	Sco	LBN 462	*
222	21 May 1784	16 36 –23 46	Sco	B 44	*
223	22 May 1784	16 19 –25 44	Sco	B 229	*, near M 4, seen again in sweep 224
223	22 May 1784	16 22 –25 43	Sco	LDN 441	*, near M 4
223	22 May 1784	16 27 –25 44	Sco	LDN 453	*, near M 4 and NGC 6144
224	24 May 1784	17 33 –25 42	Sco	B 78	*
228	16 Jun. 1784	18 01 –09 42	Sgr	LDN 400	near NGC 6517
242	21 Jul. 1784	18 54 –03 08	Ser	LDN 535	*
356	10 Oct. 1785	05 44 –09 30	Ori	LDN 337	*, seen again in sweeps 362 & 516
383	10 Mar. 1785	16 22 –20 23	Sco	B 41	
627	26 Oct. 1786	04 24 +27 00	Tau	LDN 187	*
627	26 Oct. 1786	04 33 +26 00	Tau	LDN 214/229	
627	26 Oct. 1786	04 33 +26 15	Tau	B 19	
862	26 Sep. 1788	21 00 +51 11	Cyg	LDN 989	

other than the brighter ones. Thus, with a telescope like Herschel's (showing stars down to about magnitude 15 under good conditions), one can easily get the impression of a void, i.e. a lack of stars. Of course, modern deep images mostly do not confirm this appearance.

## 7 EARLY SPECULATIONS ABOUT THE NATURE OF 'VACANT PLACES'

How were 'vacant places' interpreted by William Herschel and his followers? Generally, there is no doubt that Herschel favoured the idea of the existence of true voids in the stellar distribution. But it is interesting that in 1782 he thought about the possibility of obscuring matter in space reddening the light (Herschel, W., 1782: 105, first footnote):

An allowance ought also perhaps to be made for some loss that may happen to the light of very remote stars in its passage through immense tracts of space, most probably not quite destitute of some very subtle medium. The conjecture is suggested to us by the colour of the very small telescopic stars, for I have generally found the red, or inclined to red; which seems to indicate, that the more feeble and infrangible rays of the other colours are either stopped by the way, or are least diverted from their course by accidental deflections.

However, this idea was not progressed later. Against it, the existence of true voids supported his theory of the formation of star clusters. This was developed in the paper of 1785. In the section "Formation of Nebulae", five forms of stellar aggregations are defined, and Form V refers to 'Vacant Regions'. Herschel wrote:

... there will be formed great cavities or vacancies by the retreat of the stars towards the various centers which attract them; so that upon the whole there is evidently a field of the greatest variety for the mutual and combined

attractions of heavenly bodies to exert themselves in.

His prime example is the hole in Scorpius. Herschel believed that the gravitational forces of the massive cluster [M 80] would have attracted the stars in its neighbourhood, i.e. "... the stars, of which it is composed, were collected from the place, and had left the vacancy." Beside the pair of the hole in Scorpius and the globular cluster M 80, there are more examples. The second hole (in Scorpius) even has two neighbouring globulars, M 4 and NGC 6144. A third case is the vacant place in Ophiuchus, 45' distant from the globular cluster NGC 6517; both discovered in sweep 228 (all pairs are listed in Table 4).

About 30 years later Herschel wrote that, due to the universal attractive force, the Milky Way is already breaking up into groups, leaving openings or gaps in space (Herschel, W., 1814: 282–283):

... observations ... authorise us to anticipate the breaking up of the milky way, in all its minute parts, as the unavoidable consequence of the clustering power arising out of the preponderating attractions which have been shewn to be every where existing in its compass ... Now, since the stars of the milky way are permanently exposed to the action of a power whereby they are irresistibly drawn into groups ... it is evident that the milky way must be finally broken up, and cease to be a stratum of scattered stars.

The existence of 'vacant places' was an argument against the uniform scattering of stars. However, in 1785, based on the gage data, Herschel had used the assumption of a constant star density to determine the spatial structure of the Milky Way. But later he rejected it due to observational evidence (Steinicke, n.d.). His idea of a flattened stratum of stars remained.

Table 5: An extract of John Herschel's list of 49 vacant regions, showing all cases in the Milky Way which can be identified with dark nebulae in the catalogues of Barnard and Lynds. The (rough) position is for 2000. Three objects were already seen by his father (see Table 4). For B 42 (Herschel's hole) John remarks "not the smallest star".

Sweep	Date	Position		Con	Dark Nebula	Remarks
		RA	Dec			
453	13 May 1834	16 19	-25 55	Sco	LDN 440	
453	13 May 1834	17 32	-26 16	Oph	B 264	
453	13 May 1834	17 34	-26 05	Oph	B 78	WH, seen again in sweep 474
474	29 Jul. 1834	16 41	-24 08	Sco	B 44	WH
588	24 May 1835	16 20	-22 55	Sco	LDN 443	
588	24 May 1835	16 24	-24 01	Sco	B 42	WH, seen again in sweep 793
588	24 May 1835	16 47	-21 17	Sco	LDN 481	seen again in sweeps 588 & 793
608	15 Jul. 1835	18 02	-04 47	Oph	LDN 809	
609	16 Jul. 1835	18 23	-07 05	Ser	LDN 944	
699	7 May 1836	16 53	-15 35	Oph	LDN 504	
722	14 Jul. 1836	16 23	-19 32	Sco	LDN 439	
723	15 Jul. 1836	17 22	-26 53	Oph	LDN 630	
723	15 Jul. 1836	17 28	-26 55	Oph	LDN 649	

John Herschel shared his father's view that vacant regions were due to the absence of stars. He also agreed about the structure of the Milky Way as a flat stratum, at least in principle. For him it seems likely to encounter an empty region in directions where the stellar system has a small extent (Herschel, J., 1902: 712–713). During his southern sky survey (1834–1838) he found many vacant places, and a special paragraph in his bulky publication *Astronomical Results* is dedicated to this subject (Herschel, J., 1847: 381–382); it treats "... fields of view totally devoid of any perceptible star." John Herschel writes:

When such a field has occurred in sweeping, it has usually been noticed as a thing worthy of special remark, and its place taken and registered as *an object*.

He presents a list of 49 cases, found between May 1834 and June 1837. Of these, 35 are located in or near the Milky Way. Table 5 shows identifications of these in the catalogues of Barnard and Lynds. The objects B 42, 44 and 78 were already seen by his father.



Figure 19: John Herschel's drawing of the 'keyhole' dark nebula in the centre of the  $\eta$  Carinae Nebula (the original is black on white). The object is about 2' long; the star  $\eta$  Carinae is left of it.

Curiously the first two vacant fields, mentioned in the letter to Caroline of 22 February 1835 and found in sweep 474 at  $16^{\text{h}} 15^{\text{m}} 113^{\circ} 56'$  and  $16^{\text{h}} 19^{\text{m}} 116^{\circ} 3'$  (1690), are not among the 49 published cases. Further, it is interesting that John has not included the striking dark marking in the centre of the conspicuous nebula around  $\eta$  Carinae (called  $\eta$  Argus at that time). The reason is simple: the great nebula is treated in a special section of the *Astronomical Observations*, headed " $\eta$  Argus and the Great Nebula Surrounding It." Herschel describes the dark marking as a "... singular lemniscate-oval vacuity ..." (see Figure 19). The phenomenon was interpreted (Herschel, J., 1849: 572–573):

The conclusion can hardly be avoided that in looking at it we see through, and beyond the Milky Way, far out into space, through a starless region, disconnecting it altogether from our system.

Later the apt name 'keyhole' was created (Converse, 1873).

We now know that the low star numbers in 'vacant places' of the Milky Way are due to absorbing interstellar matter (dust). Already Secchi, the discoverer of the dark nebula B 86 near NGC 6520 in Sagittarius, had formulated this idea (Secchi, 1877: 32–33). He wrote that such 'black holes' ('fori neri') are

... quite improbable, especially after the discovery of the gaseous nature of the nebular areas and it is instead more probable that this blackness results from a dark nebulosity projected on a lucid background and intercepting its rays ... This very likely applies to the curious hole in the nebula  $\eta$  Argus, which appears in the form of a lemniscate.

However, 20 years earlier the Vatican astronomer had written about B 86:

This spot, by its contrast, shows that the galaxy [Milky Way] in that region is quite strewn with stars, which give a white aspect to the firmament. (Secchi, 1857).

No doubt, spectroscopy had triggered this idea.

Barnard, too, had changed his view about the issue (Dick, 2013: 80–82). During the photographic studies of the Milky Way he found many dark nebulae. In 1906 he was still convinced that Herschel was right in believing that these objects are “... real vacancies among the stars.” (Barnard, 1906). However, first doubts appeared in 1910 and he wondered whether “... the dark spaces of the sky are due to absorbing matter between us and the stars.” (Barnard, 1910). Three years later he wrote

The so-called ‘black holes’ in the Milky Way are of very great interest. Some of them are so definite that, possibly, they suggest not vacancies but rather some kind of obscuring body lying in the Milky Way, or between us and it, which cuts the light of the stars. (Barnard, 1913).

Observational evidence came from the imaged shapes of dark nebulae, being quite similar to those of bright nebulae (Barnard, 1916).

Soon after, the English astronomer William Sadler Franks (1851–1935) started an observing campaign. He visually inspected 42 Barnard objects with a 6-in Cooke refractor, offering a 36’ field of view (Franks, 1930). Among them were four objects found by William Herschel: B 41, 42, 44 and 78. Franks was aware of their discovery and of Secchi’s idea of an ‘obscure nebosity’.

Finally, it is interesting that in more recent times the concept of true holes has been resurrected—and examples presented. This is mainly due to observations by Walter Baade (1893–1960), made in Cygnus (1943) and Sagittarius (1946). In 1944 the Dutch astronomer Jan Oort (1900–1992) concluded that

The region of the great Cygnus cloud investigated by Baade appears to be one of abnormally high transparency. It does not seem unlikely that the brilliance of the cloud is due in larger measure to the absence of absorption. (Oort and Oosterhoff, 1942).

It is interesting that this paper was mentioned by the British amateur Percy Mayow Ryves (1876–1956) in the *JBAA* debate (Ryves, 1944).

Baade’s second hole is the famous ‘Baade Window’, discovered by the German astronomer in 1946. It is about 1° wide and located in the direction of the globular cluster NGC 6522 in Sagittarius<sup>5</sup>—a nice new example of cluster and hole (moreover, the cluster is only 2° south of B 86). Due to low amounts of interstellar dust it offers a view of the Galactic Centre (which is otherwise heavily obscured). This area corresponds to one of the brightest patches of the Milky Way. Thus, we learn that a true ‘hole in the sky’ can either be dark or bright—depending on the remote background. On the other hand, we are now again faced with false ‘Herschel

holes’, though in another sense: dark nebulae detected by the *Herschel Space Observatory*, which has imaged the infrared sky from 2009 to 2013 in high resolution.

## 8 CONCLUSION AND TIMELINE

From the discovery of William Herschel’s hole in May 1784 up to the late 1920’s there was no conflict about its location (near the globular cluster M 80 in Scorpius) and identification as the ‘vacant place’ southwest of the bright star  $\rho$  Ophiuchi (see the Table 6 timeline). But the situation became confusing when the Vatican astronomer Johann Georg Hagen entered the scene, bringing his former Jesuit colleague Father Angelo Secchi into the fray. The latter had discovered a striking dark nebula near the open cluster NGC 6520 in Sagittarius, later catalogued as B 86 by Edward E. Barnard. Against all the evidence, Hagen identified Herschel’s ‘hole’ with Secchi’s object, even though Herschel was very clear about its position and extent in his paper of 1785. Hagen simply ignored the information presented by Herschel in the section titled “An opening or hole”. So Hagen’s claim was not based on facts—it appears to have been more literal, simply relating Herschel’s ‘hole’ with the ‘black hole’ of Secchi and Barnard. Probably Hagen wanted to promote his former Jesuit colleague as the first to present the idea of ‘dark matter’ as the cause for ‘vacant places’ in space.

Fortunately, the strange intermezzo was terminated by the work of Charles Powell—and later Joseph Ashbrook. However, neither of them consulted the original sources, which contain the details of Herschel’s observations made in the sweeps. This has been carried out in the present paper. Perhaps this can help clear up misunderstandings about this subject that are still in the literature—and, of course, on the internet (e.g. see Slootegraaf, 2016). There, for instance, we are faced with ridiculous discovery dates like 1781 (mix-up with Uranus?) or even 1774 and 1884 (Cain, 2016; Starke et al., 2010).

## 9 NOTES

1. Herschel always used the incorrect word ‘gage’ instead of ‘gauge’. Anyway, his term is used in this text.
2. The sweeps are numbered 1 to 1112, dating from 29 October 1783 to 30 September 1802 (but there was an additional sweep, 1113, on 31 May 1813).
3. Although William possessed Messier’s final catalogue from about April 1784, M 80 was not identified by Caroline. This was used in the next version of the sweep records. With “achromatic”, this refers to Herschel’s Doll-and refractor of 39 inches focal length.
4. The star is listed as II 19 in Herschel’s catalogue of double stars.

Table 6: Chronology of Herschel's hole, starting with the discovery and ending with the conclusive paper by Powell about its identity. An asterisk in the 'p Oph' and 'B 86' columns marks the favoured identification, i.e. the dark nebula near  $\rho$  Ophiuchi/M 80 or Barnard 86 in Sagittarius.

Date	Person	Subject	$\rho$ Oph	B 86
22 May 1784	W. Herschel	discovery (sweep 222, Datchet)	*	
1785	W. Herschel	paper in <i>Philosophical Transactions</i> 1785	*	
1 Aug. 1833	C. Herschel	letter to John		
6 Jun. 1834	J. Herschel	letter to Caroline		
29 Jul. 1834	J. Herschel	observation (sweep 474, Feldhausen)	*	
11 Sep. 1834	C. Herschel	letter to John		
22 Feb. 1835	J. Herschel	letter to Caroline (positions)	*	
Apr. 1837	W. H. Smyth	<i>Cycle</i> , observation (M 80, M 4)	*	
1847	J. Herschel	<i>Astronomical Results</i> (49 vacant places)	*	
Summer 1857	A. Secchi	discovery of B 86 (Rome)		
1859	T. W. Webb	<i>Celestial Objects</i> , observation (M 4)		
12 Aug. 1876	E. Trouvelot	2nd discovery of B 86 (Washington)		
1877	A. Secchi	<i>Memoria</i> , dark matter		
11 May 1883	O. Stone	2nd discovery of hole (Cincinnati)		
July 1883	E.E. Barnard	3rd discovery of B 86 (Nashville)		
1883	C.H.F. Peters	identification	*	
1884	C. Flammarion	Trouvelot drawing (copy of Peters)	*	
1890	G. Chambers	<i>Descriptive Astronomy</i> (copy of Flammarion)	*	
1895	A.M. Clerke	<i>The Herschels</i> (letters)	*	
1907	J.E. Gore	<i>Astronomical Essays</i> , identification	*	
1907	E.E. Barnard	dark nebulae		
1912	J.L.E. Dreyer	<i>Scientific Papers</i> (paper of 1785)	*	
1913	E.E. Barnard	dark matter		
1919	E.E. Barnard	first Barnard catalogue		
1927	E.E. Barnard	<i>Atlas</i> , final Barnard catalogue		
1928/1929	J.G. Hagen	letters, identification		*
1928	W.A. Parr	<i>JBAA</i> debate, Hagen paper (translated)		
1930	W.S. Franks	visual observations of Barnard nebulae	*	
1934	P. Doig	<i>JBAA</i> debate, identification		*
1942	H.E. Houghton	<i>JBAA</i> debate, identification		*
1944	P.M. Ryves	<i>JBAA</i> debate, true holes (Baade, Oort)		
1944	E.D. Herschel	<i>JBAA</i> debate		
1944	P. Doig	<i>JBAA</i> debate, identification		*
1944	P.J. Melotte	<i>JBAA</i> debate, identification	*	
1944	C.F.N. Powell	<i>JBAA</i> debate, identification	*	

5. NGC 6522 was found by Herschel on 24 June 1784 in sweep 232. He mentions extremely rich fields here.

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## 11 REFERENCES

- Ashbrook, J., 1984. *Astronomical Scrapbook*. Cambridge, Cambridge University Press.
- Barnard, E.E., 1883–1884. *Sidereal Messenger*, 2, 259.
- Barnard, E.E., 1884. Small black hole in the Milky Way. *Astronomische Nachrichten*, 108, 369.
- Barnard, E.E., 1890. On some celestial photographs made with a large portrait lens at the Lick Observatory. *Monthly Notices of the Royal Astronomical Society*, 50, 310–314.
- Barnard, E.E., 1895. On the great photographic nebula near Antares. *Astronomische Nachrichten*, 138, 211.
- Barnard, E.E., 1906. On the vacant regions of the sky. *Popular Astronomy*, 14, 579–583.
- Barnard, E.E., 1910. On a great nebulous region and

the question of absorbing matter in space and the transparency of the nebulae. *Astrophysical Journal*, 31, 8–14.

- Barnard, E.E., 1913. Dark regions in the sky suggesting an obscuration of light. *Astrophysical Journal*, 38, 496–501.
- Barnard, E.E., 1916. Some of the dark markings on the sky and what they suggest. *Astrophysical Journal*, 43, 1–8.
- Barnard, E.E., 1919. Catalogue of 182 dark markings in the sky. *Astrophysical Journal*, 49, 14–22.
- Barnard, E.E., 1927. *A Photographic Atlas of Selected Regions of the Milky Way*. Washington, Carnegie Institution of Washington.
- Cain, F., 2016. [www.universetoday.com/99596/in-orion-there-really-is-a-hole-in-the-sky](http://www.universetoday.com/99596/in-orion-there-really-is-a-hole-in-the-sky)
- Chambers, G.F., 1890. *Descriptive Astronomy, Volume III*. Oxford, Clarendon Press.
- Clerke, A.M., 1890. *System of the Stars*. London, Longman, Green, and Co.
- Clerke, A.M., 1895. *The Herschels and Modern Astronomy*. London, Cassell & Co.
- Converse, E.M., 1873. Eta Argus. *Appleton's Journal*, 10, 817–819.
- Davenhall, C., 2010. James Ferguson: a commemoration. *Journal of Astronomical History and Heritage*, 13, 179–186.
- Dick, S.J., 2013. *Discovery and Classification in Astronomy*. Cambridge, Cambridge University Press.
- Doig, P., 1934. Notes on Sir William Herschel's 'hole

- in the sky'. *Journal of the British Astronomical Association*, 45, 247–248.
- Doig, P., 1944. A hole in the heavens. *Journal of the British Astronomical Association*, 54, 105.
- Dreyer, J.L.E., 1912. *The Scientific Papers of Sir William Herschel*. London, Royal Society and Royal Astronomical Society.
- Evans, D.S., 1969. *Herschel at the Cape: Diaries and Correspondence of Sir John Herschel, 1834–1838*. Austin, University of Texas Press.
- Ferguson, J., 1756. *Astronomy Explained upon Sir Isaac Newton's Principles*. London, The Globe.
- Flammarion, C., 1884. Les vides dans le ciel. *L'Astronomie*, 3, 419–421.
- Franks, W.S., 1930. Visual observations of dark nebulae. *Monthly Notices of the Royal Astronomical Society*, 90, 326–329.
- Gore, J.E., 1907. *Astronomical Essays*. London, Chatto & Windus.
- Hagen, J.G., 1921. Die dunklen kosmischen Nebel. *Astronomische Nachrichten*, 231, 351–354.
- Hagen, J.G., 1928. Die Geschichte des Nebels "Barnard 86". *Sitzungsberichte der Preussischen Akademie der Wissenschaften, Mathematisch-physikalische Klasse, XXVII. Gesamtsitzung*, 482–485.
- Hagen, J.G., 1929. Weiteres zur Geschichte des Nebels "Barnard 86". *Sitzungsberichte der Preussischen Akademie der Wissenschaften, Mathematisch-physikalische Klasse, XXVI. Gesamtsitzung*, 543–545.
- Herschel, C., 1784–1785. Sweeps No. 3. *Royal Society MS/274*
- Herschel, C., 1802. Temporary Index. RAS C.3/1.1.
- Herschel, E.D., 1944. A hole in the heavens. *Journal of the British Astronomical Association*, 54, 74.
- Herschel, J., 1847. *Astronomical Observations*. London, Stewart & Murray.
- Herschel, J., 1849. *Outlines of Astronomy*. Philadelphia, Lea & Blanchard.
- Herschel, J., 1902. *Outlines of Astronomy*. New York, P.F. Collier & Son.
- Herschel, Mrs J., 1876. *Memoir and Correspondence of Caroline Herschel*. London, John Murray.
- Herschel, W., 1782. On the parallax of the fixed stars. *Philosophical Transactions*, 72, 82–111.
- Herschel, W., 1784a. Journal No. 9. RAS W.2/1.9.
- Herschel, W., 1784b. Sweeps No. 2. RAS W.2/3.2.
- Herschel, W., 1784c. Fixt Stars, Vol. 7. RAS W.4/1.7.
- Herschel, W., 1784d. Catalogue of one thousand new nebulae clusters of stars. *Philosophical Transactions*, 74, 457–499.
- Herschel, W., 1783–1785. Register of Nebulae. RAS W.2/8.2.
- Herschel, W., 1785. On the construction of the heavens. *Philosophical Transactions*, 75, 213–266.
- Herschel, W., 1792–1800. Review No. 5. RAS W.2/2.5.
- Herschel, W., 1802–1810. Review No. 7. RAS W.2/2.7.
- Herschel, W., 1814. Astronomical observations relating to the sidereal part of the heavens and its connection with the nebulous part. *Philosophical Transactions*, 104, 248–284.
- Holden, E.S., 1881. *Sir William Herschel – His Life and Works*. New York, Charles Scribner and Sons.
- Houghton, H.E., 1942. Sir William Herschel's 'Hole in the Sky'. *Monthly Notices of the Astronomical Society of South Africa*, 1, 107.
- Lubbock, C.A., 1933. *The Herschel Chronicle: The Life-story of William Herschel and his Sister Caroline Herschel*. Cambridge, Cambridge University Press.
- Melotte, P.J., 1944. Obscured areas in Scorpio. *Journal of the British Astronomical Association*, 54, 105.
- Oort, J.H., and Oosterhoff, P.Th., 1942. Note on the distance and motions of some extremely remote Cepheids in Cygnus. *Bulletin of the Astronomical Institutes of the Netherlands*, 9, 325–327.
- Parr, W. A., 1928. A hole in the sky. *Journal of the British Astronomical Association*, 39, 261–265.
- Peters, C. H. F., 1883. *Sidereal Messenger*, 2, 125–126
- Powell, C.F.N., 1944. A hole in the heavens. *Journal of the British Astronomical Association*, 54, 142–143.
- Ryves, P.M., 1944. A hole in the heavens. *Journal of the British Astronomical Association*, 54, 19.
- Scheibe, A., 1877. *Caroline Herschel's Memoiren und Briefwechsel (1750–1848)*. Berlin, Verlag von Wilhelm Hertz.
- Secchi, A., 1857. Notes on the nebula of Orion and other astronomical subjects. *Monthly Notices of the Royal Astronomical Society*, 18, 8–11.
- Secchi, A., 1877. *L'Astronomia in Roma nel Pontificato di Pio IX: Memoria*. Roma, Tipografia della Pace.
- Slootegraaf, A., 2016. [www.docdb.net/show\\_object.php?id=barnard\\_86](http://www.docdb.net/show_object.php?id=barnard_86).
- Smyth, W.H., 1844. *A Cycle of Celestial Objects, Volume 2: The Bedford Catalogue*. London, J.W. Parker.
- Starke, T., et al., 2010. Hier ist wahrhaftig ein Loch im Himmel, [https://nhscsci.ipac.caltech.edu/HOPS/uploads/Main/ngc1999\\_paper.pdf](https://nhscsci.ipac.caltech.edu/HOPS/uploads/Main/ngc1999_paper.pdf).
- Steinicke, W., 2010. *Observing and Cataloguing Nebulae and Star Clusters: From Herschel to Dreyer's New General Catalogue*. Cambridge, Cambridge University Press.
- Steinicke, W., 2014. William Herschel, Flamsteed numbers and Harris's star maps. *Journal for the History of Astronomy*, 45, 287–303.
- Steinicke, W., 2015. William Herschel and the 'garnet' stars:  $\mu$  Cephei and more. *Journal of Astronomical History and Heritage*, 18, 199–217.
- Steinicke, W., n.d. William Herschel's 'Star Gages' and the Structure of the Milky Way. In Cunningham, C. (ed.), *William Herschel: His Astronomical Research and Legacy*. London, Springer.
- Stone, O., 1882. *Sidereal Messenger*, 1, 98.
- Trouvelot, E., 1882. *The Trouvelot Astronomical Drawings Manual*. New York, Charles Scribner and Sons.
- Webb, T.W., 1859. *Celestial Objects for Common Telescopes*. London, Longman & Green.

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