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WILLIAM HERSCHEL, FLAMSTEED NUMBERS AND HARRIS'S STAR MAPS

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Abstract

The paper discusses the origin of the commonly used Flamsteed star numbers, which are missing in John Flamsteed's British Catalogue (1725) and accompanying *Atlas coelestis* (1729). Johann Elert Bode introduced these numbers in the *Sammlung Astronomischer Tafeln* (1776). Herschel independently created them in 1781 for his third star review. At that time he purchased Flamsteed's *Atlas coelestis* and the question arises, which star chart did he use before, especially when Uranus was discovered. This leads to two star maps, linked to the Welsh astronomer Joseph Harris and based on stars whose positions were measured by Flamsteed and Halley.

Key words

John Flamsteed, Edmond Halley, Johann Elert Bode, Joseph Harris, British Catalogue, *Atlas coelestis*, star reviews, double stars, Uranus

Flamsteed and Halley: Perfectionism and Piracy

Astronomers are familiar with star designations such as 19 Orionis, going back to John Flamsteed (1646–1719), the first Astronomer Royal at Greenwich. This star is better known as Rigel or β Orionis. Though star names are old, Greek letters were not introduced until 1603, by Johann Bayer in his famous star atlas *Uranometria*, based on a catalogue of nearly 1200 stars.[1] A century later, Flamsteed measured the positions of some 3500 stars with a mural arc and sextant. Unfortunately, during his lifetime he published neither his catalogue nor the related star charts, which did not appear until 1725 and 1729 respectively. Surprisingly, neither publication contains Flamsteed numbers! So, who numbered the stars and when? To solve the mystery one must go back to Edmond Halley (1656–1742).

Pressured by Isaac Newton, President of the Royal Society, Halley edited an unauthorized version of Flamsteed's catalogue in 1712, when 100 copies were distributed. The catalogue lists 2866 stars, ordered by constellation. In each constellation they are arranged by increasing right ascension — and grouped in units of 5. The numbers are given in the first column, headed "Britain".[2]

Flamsteed was angry about the pirated edition, not only because Halley had stolen his data, but even more because his work was still unfinished. Flamsteed the perfectionist feared to be linked with incorrect data. A few years later he gained control of 300 as yet undistributed copies and burned the parts he did not like, in front of the observatory. Pages consigned to the flames included the catalogue and the spurious part of the work, which professed to be his observations made with the mural arc.[3] However, for future use he saved at least one copy of Halley's pirated edition, consisting of those parts otherwise burned (mainly the catalogue). A copy — containing unique annotations — is in the

possession of Owen Gingerich;[4] these annotations were made by Flamsteed's assistant Joseph Crosthwait,[5] of course following instructions of the Astronomer Royal. They show that some stars should be moved from one constellation to another and, interestingly, the column "Britain" is crossed out (Figure 1).

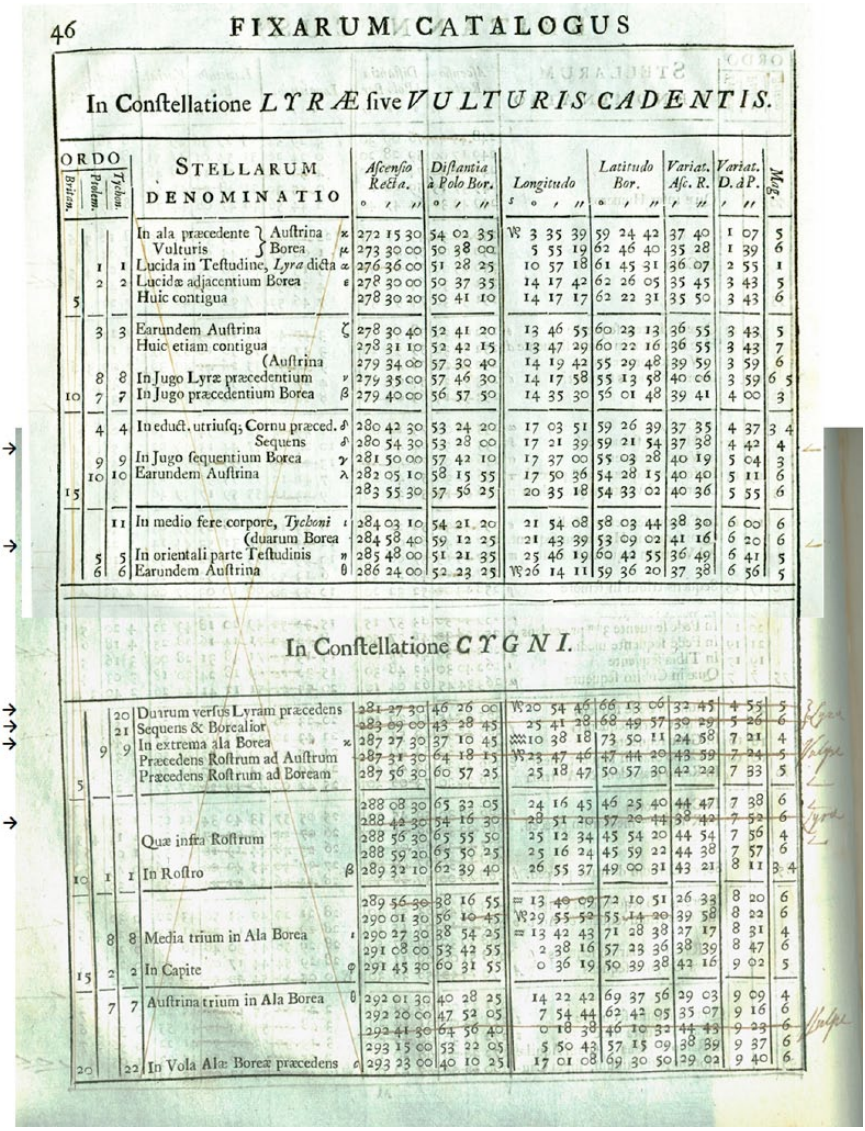
For his edition, Halley used a manuscript of Flamsteed, written in 1707 (and now in Cambridge University Library). It shows the stars grouped in units of 3 and numbered in units of 5. This finding led to the interpretation that it was Flamsteed who invented the (preliminary) numbers — and not Halley.[6] But this must be doubted for two reasons:[7] (1) the different grouping, and (2) the fact that the first column, presenting the numbers in units of 5, seems to be added later (in a slightly different handwriting). The annotations could have been made by Halley when preparing the 1712 catalogue.

In June 1716 Flamsteed sent the rescued part of Halley's catalogue (with Crosthwait's annotations) to Abraham Sharp (1653–1742); Sharp had worked for Flamsteed until 1700 and later was involved in the final publication of the catalogue. The handwritten corrections clearly do not represent Flamsteed's final disposition of the stars (Figure 2). He still had a few years to rethink which constellation the observed stars belonged to, and in particular he decided to include the new constellations introduced by Hevelius. The perfectionistic Flamsteed took his time to fine-tune his catalogue, with the result that the astronomical community had to wait until 1725 — six years after his death! — for the *official* edition: the *Stellarum inerrantium Catalogus Britannicus ad annum Christi completum 1689*, known as the British Catalogue. The star catalogue is contained in the third of three volumes, published as *Historia coelestis Britannica* (vols i and ii give the observational data, dating from 1675–89 and 1689–1720 respectively). The British Catalogue is the basis of Flamsteed's *Atlas coelestis*; this influential star atlas appeared in 1729.[8]

If one compares the published British Catalogue with Halley's 1712 version, there are some remarkable differences. (1) There are no star numbers. (2) The constellations are ordered in a different way. (3) Some stars have been shifted from one constellation to another. (4) 53 stars have been added to those in the first two volumes of the *Historia coelestis*, so we now have 2919 stars; this changes the star order in the affected constellations.

We can only speculate why Flamsteed did not use star numbers. Probably he was not satisfied with his catalogue right up to his death in 1719 and so he refrained from a final numbering — or perhaps he never wanted a numbering, and his wishes were respected by the editors of the British Catalogue. But the commonly used Flamsteed numbers are based on the British Catalogue, and Halley's pirate edition is not the source. Though Halley introduced a "natural" numbering system, it was only preliminary. So the question remains, who introduced them and when they were published?

A possible choice is John Bevis (1695–1771), the creator of the "forgotten" star atlas *Uranographia Britannica*.[9] It is known that the star catalogue on which it is based, made about 1750, contains Flamsteed numbers. Bevis obviously was inspired by Halley. Unfortunately, this work was never published (only the plates were printed, but they do not show numbers).



46 FIXARUM CATALOGUS

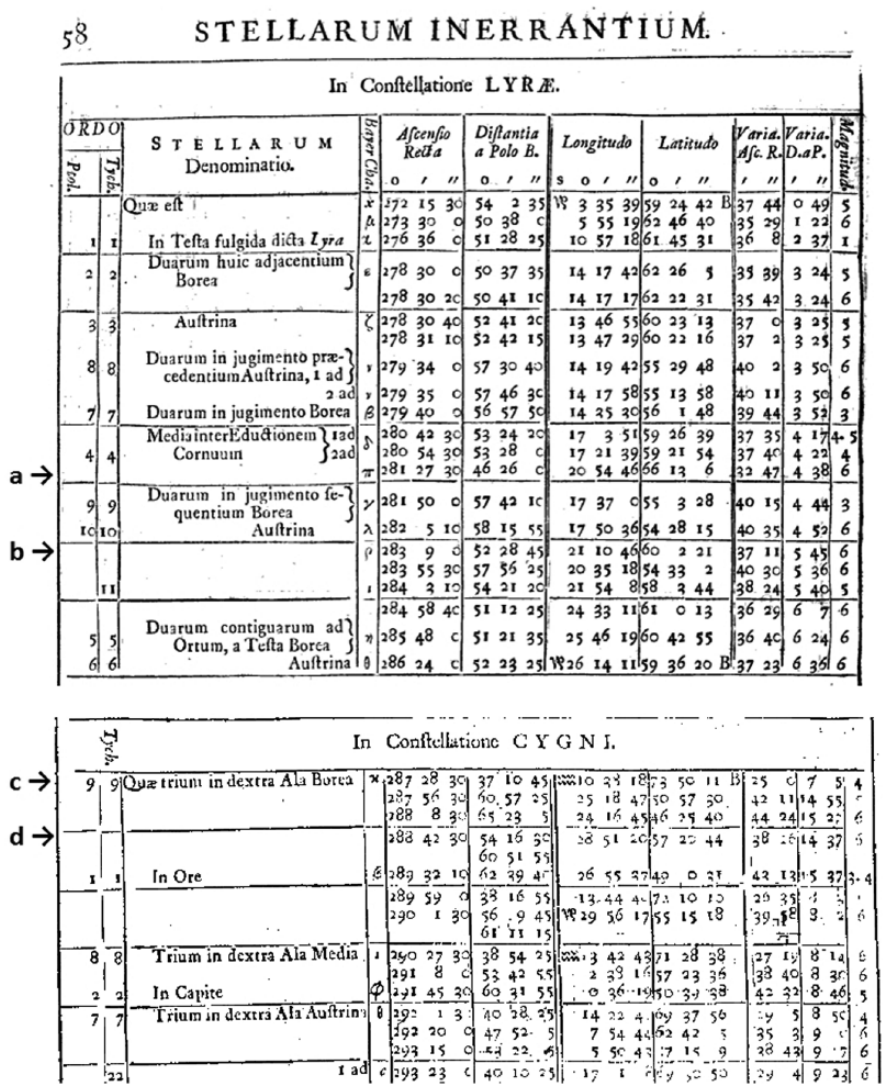
In Constellatione LYRÆ sive VULTURIS CADENTIS.

ORDO Britan.	Ptolem.	Tychon.	STELLARUM DENOMINATIO		Ascensio Recta. ° ′ ″	Distantia à Polo Bor. ° ′ ″	Longitudo ☌ ° ′ ″	Latitudo Bor. ° ′ ″	Variat. Asc. R. ′ ″	Variat. D. à P. ′ ″	Mag.
			In ala præcedente } Auſtrina	ϰ	272 15 30	54 02 35	♎ 3 35 39	59 24 42	37 40	1 07	5
			Vulturis } Borea	μ	273 30 00	50 38 00	5 55 19	62 46 40	35 28	1 39	6
	1	1	Lucida in Teſtudine, *Lyræ* dicta	α	276 36 00	51 28 25	10 57 18	61 45 31	36 07	2 55	1
	2	2	Lucidæ adjacentium Borea	ε	278 30 00	50 37 35	14 17 42	62 26 05	35 45	3 43	5
5			Huic contigua		278 30 20	50 41 10	14 17 17	62 22 31	35 50	3 43	6
	3	3	Earundem Auſtrina	ζ	278 30 40	52 41 20	13 46 55	60 23 13	36 55	3 43	5
			Huic etiam contigua		278 31 10	52 42 15	13 47 29	60 22 16	36 55	3 43	7
			(Auſtrina		279 34 00	57 30 40	14 19 42	55 29 48	39 59	3 59	6
	8	8	In Jugo Lyræ præcedentium	ν	279 35 00	57 46 30	14 17 58	55 13 58	40 06	3 59	6 5
10	7	7	In Jugo præcedentium Borea	β	279 40 00	56 57 50	14 35 30	56 01 48	39 41	4 00	3
	4	4	In educt. utriuſq; Cornu præced.	δ	280 42 30	53 24 20	17 03 51	59 26 39	37 35	4 37	3 4
a →			Sequens	δ	280 54 30	53 28 00	17 21 39	59 21 54	37 38	4 42	4
	9	9	In Jugo ſequentium Borea	γ	281 50 00	57 42 10	17 37 00	55 03 28	40 19	5 04	3
	10	10	Earundem Auſtrina	λ	282 05 10	58 15 55	17 50 36	54 28 15	40 40	5 11	6
15					283 55 30	57 56 25	20 35 18	54 33 02	40 36	5 55	6
		11	In medio fere corpore, *Tychoni*	ι	284 03 10	54 21 20	21 54 08	58 03 44	38 30	6 00	6
b →			(duarum Borea		284 58 40	59 12 25	21 43 39	53 09 02	41 16	6 20	6
	5	5	In orientali parte Teſtudinis	ν	285 48 00	51 21 35	25 46 19	60 42 55	36 49	6 41	5
	6	6	Earundem Auſtrina	θ	286 24 00	52 23 25	♎ 26 14 11	59 36 20	37 38	6 56	5

In Constellatione CYGNI.

a →		20	Dextrum verſus Lyram præcedens		281 27 30	46 26 00	♎ 20 54 46	66 13 06	32 45	4 55	5
b →		21	Sequens & Borealior		283 09 00	43 28 45	25 41 28	68 49 57	39 29	5 26	6
c →	9	9	In extrema ala Borea	ϰ	287 27 30	37 10 45	♏ 10 38 18	73 50 11	24 58	7 21	4
			Præcedens Roſtrum ad Auſtrum		287 31 30	64 18 15	♎ 23 47 46	47 44 20	43 59	7 24	5
			Præcedens Roſtrum ad Boream		287 56 30	60 57 25	25 18 47	50 57 30	42 22	7 33	5
5					288 08 30	65 32 05	24 16 45	46 25 40	44 47	7 38	6
d →					288 42 30	54 16 30	28 51 20	57 20 14	38 42	7 52	6
			Quæ infra Roſtrum		288 56 30	65 55 50	25 12 34	45 54 20	44 54	7 56	4
					288 59 20	65 50 25	25 16 24	45 59 22	44 38	7 57	6
10	1	1	In Roſtro	β	289 32 10	62 39 40	26 55 37	49 00 31	43 21	8 11	3 4
					289 56 30	68 16 55	= 13 49 09	♎ 12 10 51	26 33	8 20	6
					290 01 30	56 10 45	♎ 29 55 52	55 14 20	39 58	8 22	6
	8	8	Media trium in Ala Borea	ι	290 27 30	58 54 25	= 13 42 43	71 28 38	27 17	8 31	4
					291 08 00	53 42 55	2 38 16	57 23 36	38 39	8 47	6
15	2	2	In Capite	φ	291 45 30	60 31 55	0 36 19	50 39 38	42 16	9 02	5
	7	7	Auſtrina trium in Ala Borea	θ	292 01 30	40 28 25	14 22 42	69 37 56	29 03	9 09	4
					292 20 00	47 52 05	7 54 44	62 42 05	35 07	9 16	6
					292 41 30	64 56 40	0 18 38	46 10 32	44 43	9 23	6
					293 15 00	53 22 05	5 50 43	57 15 09	38 89	9 37	6
20		22	In Vola Alæ Boreæ præcedens	ϱ	293 23 00	40 10 25	17 01 08	69 30 50	29 02	9 40	6

FIG. 1. Page of Halley's 1712 unauthorized edition of Flamsteed's star catalogue, showing Lyra and the first stars of Cygnus. The stars are numbered in the column "Britain". The marks in the right margin, made by Flamsteed's assistant, Joseph Crosthwait, show where stars were moved. Stars a and b went from Cygnus (below) to Lyra (above) and two to Vulpecula (compare Fig. 2). The fainter crossed lines cancel Halley's descriptions and the numbers that Flamsteed did not like in the left-most column. Collection of Owen Gingerich.



58 STELLARUM INERRANTIUM.

In Conſtellatione LYRÆ.

ORDO Pol.	ORDO Tych.	STELLARUM Denominatio.	Bayer Char.	Aſcenſio Recta	Diſtantia a Polo B.	Longitudo	Latitudo	Varia. Aſc. R.	Varia. D. a P.	Magnitudo
				o ′ ″	o ′ ″	s o ′ ″	o ′ ″	′ ″	′ ″	
		Quæ eſt	κ	272 15 30	54 2 35	♎ 3 35 39	59 24 42 B	37 44	0 49	5
			α	273 30 0	50 38 C	5 55 19	62 46 40	35 29	1 22	6
1	1	In Teſta fulgida dicta *Lyra*	ε	276 36 0	51 28 25	10 57 18	61 45 31	36 8	2 37	1
2	2	Duarum huic adjacentium Borea	ε	278 30 0	50 37 35	14 17 42	62 26 5	35 39	3 24	5
				278 30 20	50 41 10	14 17 17	62 22 31	35 42	3 24	6
3	3	Auſtrina	ζ	278 30 40	52 41 20	13 46 55	60 23 13	37 0	3 25	5
				278 31 10	52 42 15	13 47 29	60 22 16	37 2	3 25	5
8	8	Duarum in jugimento præcedentium Auſtrina, 1 ad	γ	279 34 0	57 30 40	14 19 42	55 29 48	40 2	3 50	6
		2 ad	γ	279 35 0	57 46 30	14 17 58	55 13 58	40 11	3 50	6
7	7	Duarum in jugimento Borea	β	279 40 0	56 57 50	14 25 30	56 1 48	39 44	3 52	3
4	4	Mediainter Eductionem Cornuum 1ad 2ad	δ	280 42 30	53 24 20	17 3 51	59 26 39	37 35	4 17	4 5
			π	280 54 30	53 28 C	17 21 39	59 21 54	37 40	4 22	4
a →				281 27 30	46 26 C	20 54 46	66 13 6	32 47	4 38	6
9	9	Duarum in jugimento ſequentium Borea	γ	281 50 0	57 42 10	17 37 C	55 3 28	40 15	4 44	3
10	10	Auſtrina	λ	282 5 10	58 15 55	17 50 36	54 28 15	40 35	4 52	6
b →			ρ	283 9 0	52 28 45	21 10 46	60 2 21	37 11	5 45	6
				283 55 30	57 56 25	20 35 18	54 33 2	40 30	5 36	6
	11		ι	284 3 10	54 21 20	21 54 8	58 3 44	38 24	5 40	5
				284 58 40	51 12 25	24 33 11	61 0 13	36 29	6 7	6
5	5	Duarum contiguarum ad Ortum, a Teſta Borea	η	285 48 C	51 21 35	25 46 19	60 42 55	36 40	6 24	6
6	6	Auſtrina	θ	286 24 C	52 23 25	♎ 26 14 11	59 36 20 B	37 23	6 36	6

In Conſtellatione CYGNI.

Tych.									
9	9	Quæ trium in dextra Ala Borea	κ	287 28 30	37 10 45	♒ 10 33 18	73 50 11 B	25 C	7 5	4
				287 56 30	60 57 25	25 18 47	50 57 30	42 11	14 55	C
c →				288 8 30	65 23 5	24 16 45	46 25 40	44 24	15 25	6
d →				288 42 30	54 16 50	28 51 20	57 20 44	38 26	14 37	5
					60 51 55					
1	1	In Ore	ε	289 32 10	62 39 40	26 55 27	49 0 21	42 13	15 37	3 4
				289 59 0	38 16 55	13 44 40	72 10 10	29 35	3 5	
				290 1 30	56 9 45	♒ 29 56 17	55 15 18	39 18	3 2	6
					61 11 15					
8	8	Trium in dextra Ala Media	ι	290 27 30	38 54 25	♒ 3 42 43	71 28 38	27 15	8 14	6
				291 8 C	53 42 55	2 33 16	57 23 36	38 40	8 36	6
2	2	In Capite	φ	291 45 30	60 31 55	0 36 19	50 34 38	42 32	8 46	5
7	7	Trium in dextra Ala Auſtrina	θ	292 1 30	40 28 25	14 22 4	69 37 56	24 5	8 50	4
				292 20 0	47 52 5	7 54 44	62 42 5	35 3	9 0	6
				293 15 0	44 22 45	5 50 43	67 15 9	28 43	9 17	6
	22	1 ad	ε	293 23 C	40 10 25	17 1 C	69 30 50	29 4	9 23	6

Fig. 2. Tables of Flamsteed's British catalogue, published 1725, showing Lyra and the first stars of Cygnus (now on different pages). The Cygnus stars a and b (see Fig. 1) are now in Lyra: a = 13 (π) Lyr, b = 16 (ρ) Lyr. Star c is now 1 (κ) Cyg (note that the right ascension arcminute was corrected from 27 to 28). Star d should move to Lyra, but is still in Cygnus (4 Cyg). The two stars in Fig. 1 moved to Vulpecula became 2 Vul and 10 Vul (page not shown).

The Role of Johann Elert Bode

On the basis of research by Deborah Warner, it has been widely accepted that Flamsteed numbers were introduced by Joseph Jérôme Lalande in his revision of the British Catalogue, published 1783 in the French almanac *Éphémérides des mouvemens célestes*.[10] But this is not the earliest source, for the eminent Berlin populariser of

astronomy Johann Elert Bode (1747–1826) had presented them as early as 1776.[11] The numbers are contained in the *Sammlung Astronomischer Tafeln*, a three-volume collection of astronomical tables, made in partnership with Johann Heinrich Lambert and Johann Karl Gottlieb Schulze. Vol. i contains an 89-page star catalogue, compiled by Bode.[12] This "Stern-Verzeichnis nach vier Astronomen" assembles the star catalogues of Hevelius, Flamsteed, Lacaille and Bradley.[13] Concerning Flamsteed, Bode wrote: "Flamsteads [*sic*] vollständiges Verzeichnis, welches sich in seiner Historia Coelestis 3ten Bandes der 2ten Auflage von 1725 befindet [Flamsteed's complete catalogue which is in vol. 3 of the second edition of the Historia Coelestis of 1725]." When Bode speaks of the second edition, he must regard Halley's publication of 1712 as the first. The catalogue lists 3175 stars. They are arranged by constellation, starting with Cassiopeia (see Figure 3). The first column, headed "Fl. No", gives the correct Flamsteed number. The positions (right ascension, declination) are calculated for 1800. Thus Bode's star catalogue of 1776 is an extended and updated version of the British Catalogue.

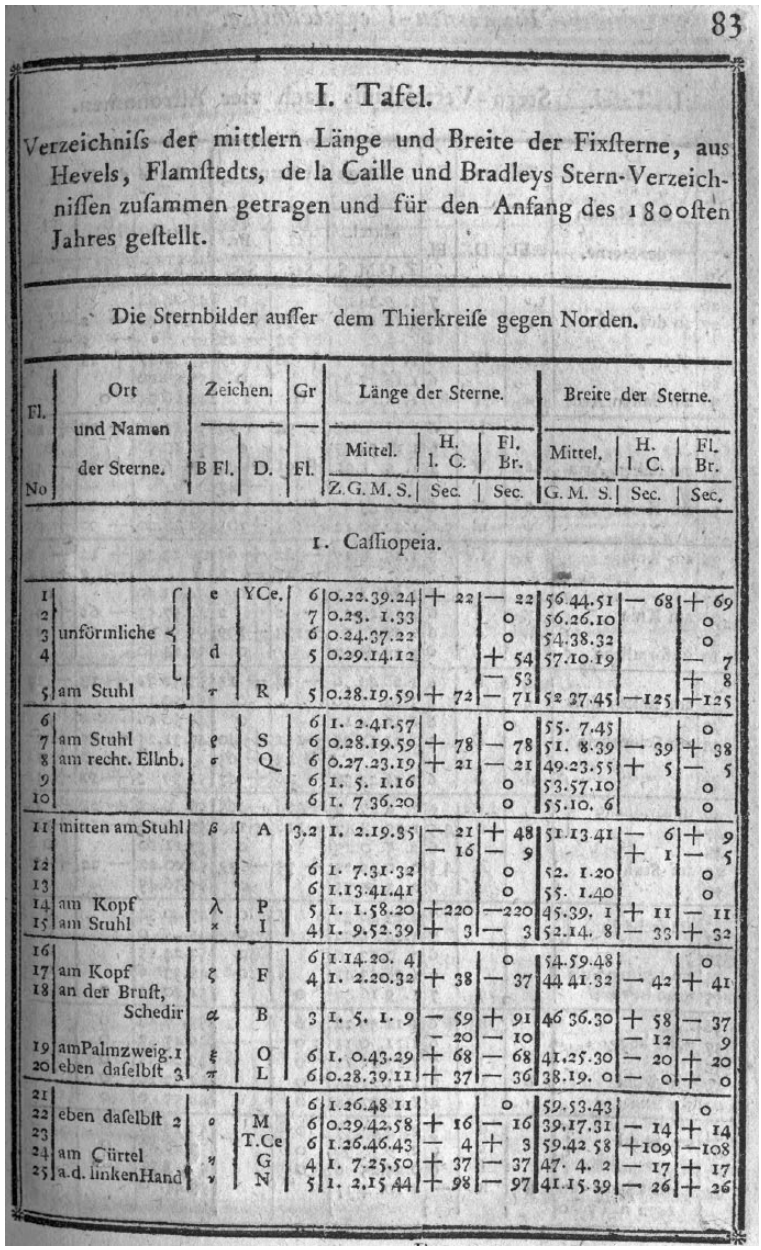
Bode was to use the Flamsteed numbers in his new almanac, *Astronomisches Jahrbuch*. It regularly contained a table, titled "Verzeichnis der 280 der vornehmsten Fixsterne [List of the 280 most prominent fixed stars]". In the first two issues, for the years 1778 and 1779 (published in 1776 and 1777), the table does not show these numbers, but the third almanac, *Astronomisches Jahrbuch für 1781* (published in 1778), does give them.[14] The first column is headed "No. nach Flamsteed" (the table starts with "88 | Algenib im Pegasus"). Strangely, the Flamsteed column is omitted from 1781 (*Jahrbuch* for 1784) onwards.

In 1782 Bode published his popular star atlas *Vorstellung der Gestirne*.[15] The second part of the introduction presents the stellar basis: a catalogue of 5058 stars, covering 37 pages. In its design it is nearly identical to the table in the *Sammlung Astronomischer Tafeln* of 1776. The number of stars is increased by 1883 and the positions are for 1780.[16] Lalande was aware of Bode's work when he created his catalogue of 1783 (the star numbers are identical).[17]

Herschel's Star Reviews, Harris's Star Maps, and Uranus

Except in his early manuscripts, Herschel throughout uses Flamsteed numbers to identify stars. This leads to a number of questions. Since when was he in possession of the British Catalogue and *Atlas coelestis*? What catalogue or star map was he using on 13 March 1781 when he discovered Uranus? Did he know Bode's Flamsteed numbers, or what else was his source?

On 1 March 1774 Herschel started to document the observations he was making at Bath; this is the opening date of his "Journal No. 1".[18] He was using a 5½-ft reflector of 4½ inches aperture, and the first entry concerns Saturn. In a paper of 1783 Herschel tells us that in his early years as an observer he undertook a "first review" of the brighter naked-eye stars down to fourth magnitude.[19] This novice's *tour d'horizon* was carried out with "a Newtonian telescope, something less than 7 feet focal length, a power of 222, and an aperture of 4½ inches"; although it involved only a few hundred of the brightest stars and a modest number of hours of observing time, it must have extended over many months. We are poorly informed about the apertures of Herschel's early 7-ft reflectors, and we know next to nothing about the first review or when it was undertaken; but it



83

I. Tafel.

Verzeichniſs der mittlern Länge und Breite der Fixſterne, aus Hevels, Flamſtedts, de la Caille und Bradleys Stern-Verzeichniſſen zuſammen getragen und für den Anfang des 1800ſten Jahres geſtellt.

Die Sternbilder auſſer dem Thierkreiſe gegen Norden.

Fl. No	Ort und Namen der Sterne.	Zeichen. B Fl.	Zeichen. D.	Gr. Fl.	Länge der Sterne. Mittel. Z. G. M. S.	H. l. C. Sec.	Fl. Br. Sec.	Breite der Sterne. Mittel. G. M. S.	H. l. C. Sec.	Fl. Br. Sec.
					1. Caſſiopeia.					
1		e	YCe.	6	0.22.39.24	+ 22	— 22	56.44.51	— 68	+ 69
2				7	0.23. 1.33		0	56.26.10		0
3	unförmliche			6	0.24.37.22		0	54.38.32		0
4		d		5	0.29.14.12		+ 54	57.10.19		— 7
							— 53			+ 8
5	am Stuhl	τ	R	5	0.28.19.59	+ 72	— 71	52 27.45	—125	+125
6				6	1. 2.41.57		0	55. 7.45		0
7	am Stuhl	ϱ	S	6	0.28.19.59	+ 78	— 78	51. 8.39	— 39	+ 38
8	am recht. Ellnb.	σ	Q	6	0.27.23.19	+ 21	— 21	49.23.55	+ 5	— 5
9				6	1. 5. 1.16		0	53.57.10		0
10				6	1. 7 36.20		0	55.10. 6		0
11	mitten am Stuhl	β	A	3,2	1. 2.19.35	— 21	+ 48	51.13.41	— 6	+ 9
						— 16	— 9		+ 1	— 5
12				6	1. 7.31.32		0	52. 1.20		0
13				6	1.13.41.41		0	55. 1.40		0
14	am Kopf	λ	P	5	1. 1.58.20	+220	—220	45.39. 1	+ 11	— 11
15	am Stuhl	×	I	4	1. 9.52.39	+ 3	— 3	52.14. 8	— 33	+ 32
16				6	1.14.20. 4		0	54.59.48		0
17	am Kopf	ζ	F	4	1. 2.20.32	+ 38	— 37	44 41.32	— 42	+ 41
18	an der Bruſt, Schedir	α	B	3	1. 5. 1. 9	— 59	+ 91	46 36.30	+ 58	— 37
						— 20	— 10		— 12	— 9
19	amPalmzweig. 1	ξ	O	6	1. 0.43.29	+ 68	— 68	41.25.30	— 20	+ 20
20	eben daſelbſt 3	π	L	6	0.28.39.11	+ 37	— 36	38.19. 0	— 0	+ 0
21				6	1.26.48 11		0	59.53.43		0
22	eben daſelbſt 2	o	M	6	0.29.42.58	+ 16	— 16	39.17.31	— 14	+ 14
23			T.Ce	6	1.26.46.43	— 4	+ 3	59.42 58	+109	—108
24	am Gürtel	η	G	4	1. 7.25.50	+ 37	— 37	47. 4. 2	— 17	+ 17
25	a.d. linken Hand	γ	N	5	1. 2.15 44	+ 98	— 97	41.15.39	— 26	+ 26

FIG. 3. First page of Bode's star catalogue, from vol. i of *Sammlung Astronomischer Tafeln*, published in 1776. The first column gives the Flamsteed number. Collection of Owen Gingerich.

may have followed his completion on 1 May 1776 of "a new 7 feet reflector" of which he was later so proud as to cite the instrument in his (mainly musical) autobiographical "Memorandums".[20] Alternatively it may date from 1778, for on 28 January 1778 he observed "Syrius" in the hope of finding a nearby star suitable for parallax observations,[21] and he did the same for Procyon and Castor in the weeks that followed (Castor was found to be double[22]). He had an appropriate reflector about this time, for on 15 May 1778 he notes: "I tried the speculum last night on Saturn and found it to act very well with 3 and 4 inches of aperture."[23]

17 August 1779 marks Herschel's actual turn to stellar astronomy, inspired by the question of parallax and the existence of variable and double stars.[24] He embarked on a "second review", with the 7-ft. With its ingenious azimuthal mounting, any star could be targeted in a minute. Tracking was an easy task too: the telescope had to be moved towards the west, and only a small correction in altitude was needed over time.[25]

Two new document series were created: "Fixt Stars" (describing the observations) and "Review" (the first four give tabular listings of stars). During the first month he discovered no fewer than 20 double or multiple stars, and Herschel's list soon outnumbered that of the German Christian Mayer.[26] The subtitle of Herschel's "Review No. 1" reads "Second Review".[27] The terminology is confusing, but reflects the fact that he made not much of his first star campaign ("first review"). The stars are ordered by constellation and identified by their Bayer designations; new stars were numbered relative to the next known one. The first column (originally blank) was filled with a sign, indicating that an observation had been made. The introduction is headed: "The stars were taken from Harris's Sheet Hemispheres."

"Review No. 2" contains a similar list.[28] And in No. 3 "The stars are arranged in the alphabetic order of the constellations, and are taken from Harris's maps taking in all the stars of Flamsteed and Halley that are in those maps".[29] Whatever these maps are, Herschel must have possessed them at the time of his "first review", perhaps already in 1774. This is shown by a remark of 1783 about the second campaign: "It extended to all the stars in HARRIS's maps, and the telescopic ones near them, as far as the eighth magnitude."[30] Evidently, in his first (and later neglected) campaign the brighter stars on the maps were observed.

So, what are Harris's maps of the hemispheres and who was its author? Harris is likely to be the Welsh astronomer Joseph Harris (1704–64).[31] I put the question to the Dutch historian Elly Dekker, who drew my attention to a work entitled "Stellarum Fixarum Hemisphaerum Boreale (Australe)". Further investigation led to two maps of 25.7″ × 25.2″, printed on thick heavy paper, presenting the northern and southern hemispheres. The headings read:[32]

> STELLARUM FIXARUM HEMISPHERIUM BOREALE. The Northern Hemisphere Projected on the Plane of the Æquator in which all the Stars contained in the Britannick Catalogue (as Published by D^{r} Halley) are carefully laid down and adapted to the beginning of the Year 1690.
>
> STELLARUM FIXARUM HEMISPHERIUM AUSTRALE. The Southern Hemisphere Projected on the Plane of the Æquator in which all the Stars contained in the

BRITANNICK CATALOGUE and those Observ'd by D^r^ Edm. Halley at the Isl. of S^t^ Helena, are carefully laid down and adapted to the beginning of the YEAR 1690. *By Joseph Harris*.

Note that Harris is mentioned on the southern map only. In the literature a publication date of 1721 is often given for both maps. This is impossible, for Harris was only 17 at that time. A few sources give 1728 for the southern map, which fits much better. Harris may well have got in contact with Halley before 1725, when Harris left for Vera Cruz to make astronomical observations. He returned in 1727, and the results of his expedition were presented to the Royal Society in a paper communicated by Halley. This connection might have brought him the authorship for the southern map; it is likely that Harris acted as the draughtsman or even the engraver.

But who was responsible for the northern map? We know that it was engraved and published by the experienced London cartographer John Senex.[33] There is no doubt that Senex published the southern map too. He sold the pair for 8 shillings,[34] satisfying a great demand in England for single-sheet, reliable star charts. The black-on-white printings became popular for both astronomers and navigators. As Harris was involved only in the southern map, Herschel's term "Harris's maps" is, strictly speaking, incorrect.

The date 1721 of the northern map is interesting — and explains Halley's role. When Flamsteed died on 31 December 1719, Halley became his successor as Astronomer Royal at Greenwich. Halley now had untroubled excess to Flamsteed's astronomical estate, especially the final British Catalogue. This must have inspired Halley to continue his task, started with the unauthorized publication of 1712. Obviously, he concentrated on star maps now. Already being acquainted with Senex, the northern map was realized in about a year. It is unknown what had caused the seven years delay for the southern map, for which Halley had delivered stars from his St Helena expedition.

The maps present all Flamsteed stars plus the southern extension (declination < –30°) based on Halley's observations and compiled by Abraham Sharp. Thus the stellar content is identical to that of the *Atlas coelestis* of 1729 (the southern sky is presented in a planisphere, designed by Sharp). However, Harris's maps do not show Halley's Flamsteed numbers. But the six nebulae and clusters, published by him in 1715, are plotted as "Nebula": M 11 (open cluster in Scutum), M 13 (globular cluster in Hercules), M 22 (globular cluster in Sagittarius), M 31 (Andromeda Nebula), M 42 (Orion Nebula) and ω Centauri (globular cluster).[35] Of these, Herschel observed M 11, M 13, M 31 and M 42 before the end of 1781.

Presenting a reliable image of the sky down to about seventh magnitude, the handy maps were ideal for Herschel's star reviews. For he was not interested in absolute positions, and so the (early) epoch of 1690 was no problem.[36] Occasionally he encountered a star that was not plotted. This first happened on 18 February 1780, when he saw "a star not marked in my map tho' visible to the naked eye full as well as μ Draconis … thus it is surprising that it should have been overlooked in the Catalogue or map".[37] Evidently he had also consulted the British Catalogue.

About a year later, Herschel found another unplotted 'star'. On Tuesday 13 March 1781, he looked at some brighter stars of Gemini, continuing an examination of this constellation started the night before.[38] One of these stars, plotted on the northern Harris map, was Bayer's H Geminorum (see Figure 4). While "examining the small stars in the

neighbourhood" with the 7-ft, at 10:30 pm Herschel discovered an extended object, located 3.5° west of H Geminorum — already on Taurus territory. Re-examining the object the following Saturday, Herschel found that it had moved. He first thought it to be a "comet", but the strange object turned out to be a new planet: "Georgium Sidus" = Uranus, about 3 months after its opposition.

It is astonishing that Herschel inspected the vicinity of the 4.2 mag star H Gem up to several degrees distance. The field of view of his standard eye-piece was only 4.5′ — so 3.5° equals 45 field-diameters.[39] No doubt, the working power of 227 was ideal to see if a star (located in the finder) was double. But to sweep large areas it was far from ideal — although Herschel was astonishingly successful.[40] It is interesting that he already had been in the Gemini/Taurus area three times. On 6 October 1779 he observed β and ζ Tau, a day later μ and η Gem, and on 24 September 1780 again β and ζ Tau. The minimum distance to Uranus was only 3° for ζ Tau in 1779 (the distance values for the other dates and stars were 6° to 10°). This was less than the 3.5° to H Gem on the discovery date. As Herschel was the only person inspecting the sky in a systematic (and effective) manner, it was only a matter of time before he encountered Uranus.[41] In 1784 Bode, who was responsible for the name "Uranus", revealed that Flamsteed had already seen the planet on 23 December 1690, listed in the British Catalogue as the 34th star in Taurus (34 Tauri).[42]

William Herschel's Numbering and the Atlas Coelestis

Harris's star maps played a fundamental role in Herschel's second star campaign, ending in September 1781. A month later, on 22 October 1781, he started a "third review", which lasted until 26 September 1783 (see Table 1).[43] Its stellar basis is documented in "Review No. 4", begun in January 1782.[44] It lists all stars of the British Catalogue. The new campaign was undertaken "with the same instrument and aperture [7-ft reflector], but with a very distinct power of 460, which I had already experienced to be much superior to 227, in detecting excessively small stars, and such as are very close to large ones".[45]

When did Herschel become aware of Flamsteed's catalogue? Astonishingly, this was already in 1773. On 10 May he purchased (and carefully studied) an influential book: *Astronomy explained upon Sir Isaac Newton's principles* by James Ferguson, first published in 1756.[48] Therein Herschel could read: "The *British* catalogue, which besides the Stars visible to the bare eye, includes a great number which cannot be seen without the assistance of a telescope, contains more than 3000, in both Hemispheres."[49] No doubt, this was a great motivation. From the first journal it is obvious that Herschel possessed the catalogue in March 1774 (of course, this was the original edition of 1725[50] — there was no other until the revisions of Bode (1776, 1782) and Lalande (1783)), for the fifth journal entry (20 March 1774) mentions it:

> Expected the Moon to occult the 29 Star in Flamsteed's Catalogue of Gemini, near the lucid foot of Pollux which she should do a little after 8, but having no time to make a proper calculation allowing for Refraction and Precession of the Equinoxes since Flamsteed's Catalogue found the Moon had too much south Latitude and would not get so far in the Ecliptic till much later.[51]

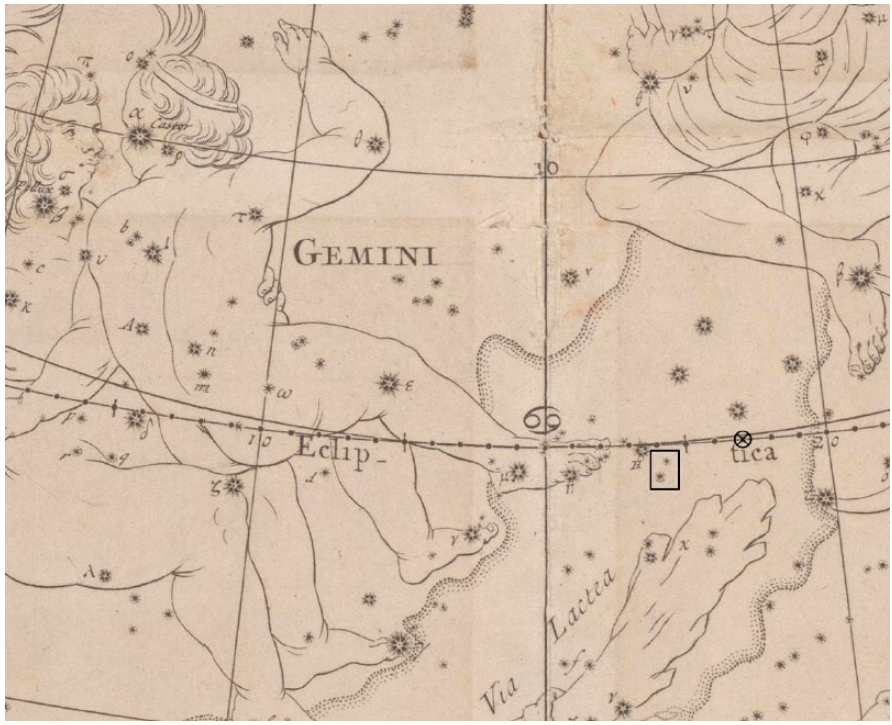


FIG. 4. Detail of the northern "Harris's star map", showing a part of Gemini. The position of Uranus on 13 March 1781 is marked by a cross. For the two stars in the rectangle, see Fig. 5. Courtesy of the National Library of Australia.

No doubt, Herschel had correctly counted the Gemini stars in the British Catalogue, but the star "29" is actually 19 Geminorum. The Moon was about 2° north of this star at the time. Herschel had problems with such numbers, as his entry of 4 April shows. This describes a Saturn observation (the planet stood in Virgo). He mentions the "stars 28, 29 in Flamsteed's catalogue" and was wondering why their observed longitudes and latitudes did not fit with the catalogue values (guessing the longitudes to be "mashed"). Here Herschel had made two mistakes. The stars are not 28 and 29 Virginis but 33 and 34 Librae. Moreover, when counting the Flamsteed stars from the top of the Libra table he did not reach the correct line (missing it by 5). Three days later he realized that "they were telescopic stars", i.e. not catalogued. Herschel also had trouble with the identification of Saturn's satellites[52] (no doubt, he was still in his learning phase).

Later on, Herschel must have laid aside the British Catalogue — there are no further Flamsteed numbers in his records. He now used Harris's maps as his basic tool (alas, we do not have his copy). Perhaps it was again Ferguson who pointed him to the work of Senex (and Harris), for in Ferguson's *Astronomy* we read "On Senex's globes, Bayer's letters are inserted".[53]

Because the northern stars in the British Catalogue and Harris's maps are identical, the "third review" was a repeat. Over the years, Herschel had got greater observational

TABLE 1. Data relating to Herschel's three star reviews (Documents: J = Journal, F = Fixt Stars, R = Review).

	First	Second	Third
Period	1776 or 1778	17 Aug. 1779–20 Oct. 1781	22 Oct. 1781–26 Sep. 1783
Selected stars	names, Bayer	Bayer, Flamsteed	Flamsteed (with number)
Magnitude limit	4	7–8	7–8
Map/atlas	Harris	Harris	Atlas coelestis
Reflector (power)	< 7-ft (222)	7-ft (227)	7-ft (460)
New double stars[46]	2	250	137
New nebulae[47]	0	3	2
Documents	J1, F1	J1–J3, F1, F2, R1–R3	J3–J7, F2–F5, R4

experience and wanted to go into the details of the heavens now. So the difference was the higher magnification (usually 460).

At the time when he changed from Harris to Flamsteed, star numbers reappear in his records. On 21 September 1781 Herschel noted: "Hercules, 23. star by Flamsteed."[54] It is interesting that he was still using Harris's maps in October 1781. In the first "Catalogue of double stars" we read for ι Trianguli ("FL. 6"), found on 8 October: "it is marked b in the small triangle of HARRIS's maps."[55]

Did Herschel create Flamsteed numbers for himself or did he draw on published sources, especially Bode's work? Neither J. L. E. Dreyer, editor of Herschel's scientific papers,[56] nor any later scholar has raised this question. There is no hint that Herschel knew any of Bode's publications showing Flamsteed numbers at that time: the catalogue in the *Sammlung Astronomischer Tafeln* (1776), the list of 280 stars in the *Astronomisches Jahrbuch* published in 1778 (for the year 1781), or those in the following two almanacs. The *Sammlung* might not have been known in Britain, but what about the Berlin *Jahrbuch*?

In a letter to Bode, dated 18 March 1784, Herschel thanks him for "the honour you have done me in sending me your Ephemerides [*Jahrbuch*] for 1784 and 1785".[57] Soon after, Caroline created a list of the "Berliner Ephemeris where useful tables and publications concerning some branches of my Brother's observations are to be found", starting with those published 1781 and 1782.[58] Herschel got the 1781 almanac three years too late. Moreover, it does not show any Flamsteed number — Bode had waived this information in his list of 280 stars.

Bode's star catalogue (printed in the introduction of the atlas *Verzeichnis der Gestirne* and not an independent publication) cannot be a source either. It was published in 1782. However, Herschel must have purchased the work during the next years, perhaps following a hint by Georg Christoph Lichtenberg who wrote to Herschel on 12 January 1783: "Besitzen Sie schon das Sternen-Verzeichnis und die Karten, die Bode in Berlin herausgebracht hat? Sie sind meines Erachtens die besten und vollständigsten, die man hat. [Do you already possess the star catalogue and atlas, published by Bode in Berlin? I think, they currently are the best and most complete.]"[59] About 1785 Herschel asked for another copy of the "catalogue",[60] but Bode was a bit confused and sent him an atlas. Caroline mentions the catalogue in a letter to her brother Dietrich of 4 August 1786, written three days after the discovery of her first comet. She instructs him how to find the object, writing: "All stars of Flamst. are in Bode's Cat. to be found."[61]

It is now obvious that Herschel created Flamsteed numbers for himself. It was a natural task for him to number the stars in the British Catalogue for each constellation — as had Flamsteed (manuscript, 1707), Halley (publication, 1712) and Bevis (unpublished catalogue, about 1750).

What about the *Atlas coelestis*? Did Herschel purchase it together with the British Catalogue, back in 1774? This seems unlikely. Prior to 1781, all statements point to Harris's maps; Flamsteed's atlas is nowhere mentioned (although Herschel may well have been was aware of its existence). Moreover, in 1781 a new British edition was published by C. Nourse of The Strand, London, and this might have led Herschel to buy a copy. He already had turned to Flamsteed's catalogue as the basis for his third review and the *Atlas coelestis* was an ideal companion, eventually replacing Harris's maps.

Fortunately, we have Herschel's copy of the atlas, preserved in the Royal Astronomical Society archive.[62] A single feature tells us that it is not the original edition of 1729: the charts (plates) are numbered P.1–P.27. What is even more interesting: the copy shows Flamsteed numbers (Figure 5), added with a pen — in Caroline's handwriting! This is explained in her second diary: "Flamsteed's Atlas in which the stars had during the winter [1781/82] been numbered."[63] And in Herschel's second "Catalogue of double stars" of 1785 we read:[64]

> It will be required, that the observer should be furnished with FLAMSTEED'S Atlas Coelestis, which must have the stars marked from the author's catalogue, by a number easily added to every star with pen and ink, as I have done to mine. The catalogue should also be numbered by an additional column, after that which contains the magnitudes. I hope in some future editions of the Atlas to see this method adopted in print, as the advantage of it is very considerable, both in referring to the catalogue for the place of a star laid down in the Atlas, and in finding a star in the latter whose place is given in the former.

Alas, we do not have Herschel's copy of the British Catalogue, but we do have his handwritten extract in "Review No. 4". It presents all constellations and the stars within, ordered by a number given in the first column "Fl." (the second shows the Bayer letter). An index lists the plate number for each constellation. Herschel must have got his copy of the *Atlas coelestis* late in 1781,[65] soon after it was published. (A small objection: plate numbers already appear in a British edition of 1753.[66] Thus Herschel could have bought this one; but this seems unlikely.)

Herschel was the first systematically to use Flamsteed numbers. The "Catalogue of double stars" of 1782 is his earliest publication that shows them.[67] It contains "the names of the stars and number in FLAMSTEAD's [*sic*] catalogue" and lists 289 doubles (divided into 6 classes), found between 11 November 1776 and 24 December 1781. Herschel did not commonly apply Flamsteed numbers before 21 September 1781, when 23 Herculis was found to be double (in the catalogue: "Herculis, FL. 23" = no. 38 of class V). Thus it was when preparing the catalogue, read before the Royal Society on 10 January 1782, that he (or more exactly Caroline) added the "FL." numbers.

On 4 August 1782, Herschel had a certain *déjà vu*. What occurred with Harris's maps and his "comet" (Uranus) now happened with the *Atlas coelestis* (again the 7-ft reflector was involved). The matter is documented in "Fixt Stars No. 3" and "Journal

No. 4".[68] In the former we read: "Serpens 5th another Nebulous" and a day after (in the latter): "I discovered a Comet or Nebula but I believe it is a Comet." Herschel made a sketch. The strange object near 5 Serpentis was observed until 11 August: "I cannot perceive with any certainty that it has moved." Further observations were interrupted by the relocation to Datchet. The nebulous object might have induced Herschel to look into Messier's catalogue, lying idle for about 8 months. After observing M 52 in Cassiopeia and M 57 in Lyra on 29 August the case could be closed on 1 September: "On looking over Messier's Catalogue we find it among his Nebula N^{r} 5." The "comet" actually was the globular cluster M 5.

In most cases, the British Catalogue and the *Atlas coelestis* were reliable sources, but they were not infallible. In the first years Herschel was not aware of this and fully trusted Flamsteed. A striking example of how Herschel was misled, is his famous "garnet star" in Cepheus, commonly known as μ Cephei. When he discovered the red star on 27 September 1782 in his third review he noticed that it was "not marked in Fl[amsteed's] Atlas".[69] The star is also missing in the British Catalogue and in Harris's map. This is due to an error by Flamsteed (in Bayer's *Uranometria* it is correctly marked μ). Curiously, the British Catalogue contains a star μ in Cepheus at row 13, but gives an erroneous polar distance and no right ascension. This star (13 Cephei) is actually plotted in the *Atlas coelestis* — but it is not Bayer's μ Cephei![70] Herschel did not realize the truth and thus could only speak of his "garnet star in Cepheus" (adopted by the literature). Later he detected many "novae" (missing Flamsteed stars). Caroline carefully listed all cases and the result was published by the Royal Society in 1798.[71]

Summary and Conclusion

Edmond Halley introduced star numbers in his unauthorized edition of John Flamsteed's (preliminary) catalogue, published in 1712. However, these are not the commonly used Flamsteed numbers. The Astronomer Royal was aware of Halley's initiative but evidently he found star numbers of little use. Thus there are none in the British Catalogue, published posthumously in 1725. It was Johann Elert Bode who introduced Flamsteed numbers in his star catalogue, published 1776 in the *Sammlung Astronomischer Tafeln*. In the following years they also appear in Bode's *Astronomisches Jahrbuch* and his popular star atlas *Vorstellung der Gestirne*. Identical star numbers appear in 1783 in Lalande's edition of the British Catalogue (commonly thought as the origin of Flamsteed numbers).

William Herschel was not aware of Bode's publications in September 1781, when he independently created Flamsteed numbers for his third star observing campaign. He had possessed the British Catalogue since 1774 and in late 1781 he also got a copy of Flamsteed's *Atlas coelestis*, recently reprinted in London. In the meantime he used "Harris's star maps", initiated by Halley. The northern map, published 1721, is the work of John Senex; Joseph Harris made the southern, which appeared seven years later. The maps show all Flamsteed stars (but without numbers). "Harris's star map" was used by Herschel when he discovered the planet Uranus on 13 March 1781 near the star H Geminorum. About six month later he changed to the *Atlas coelestis*, establishing Flamsteed numbers as a standard. With a consistent identification system, Herschel was able to discover and locate a large number of double stars, and, from October 1783, an even larger number of

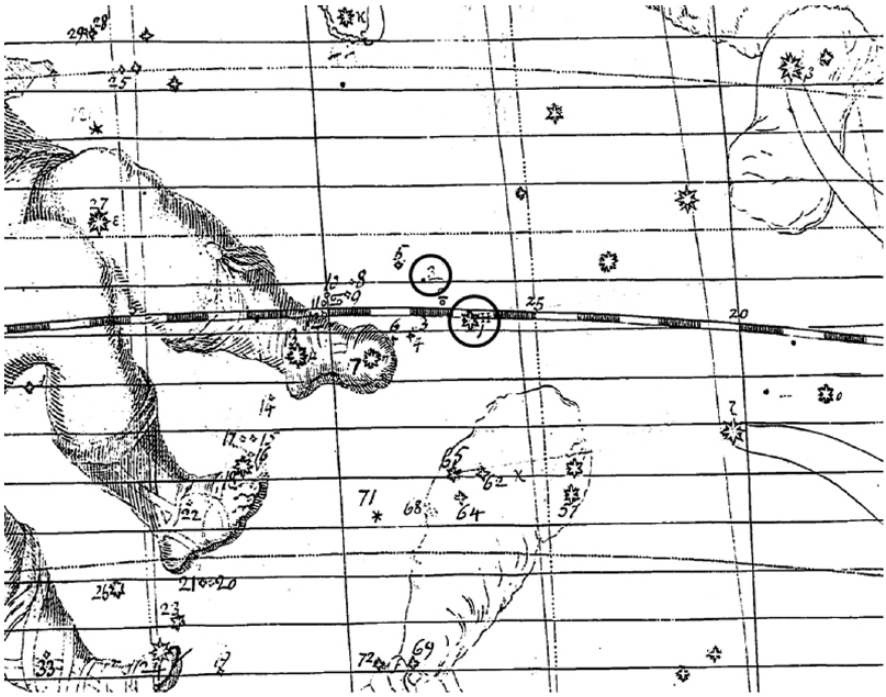


FIG. 5. Detail of P.3 (Gemini) of Herschel's copy of the *Atlas coelestis*. It shows the Flamsteed numbers in Gemini, added by Caroline. Larger circle: H Geminorum, marked "1" (reference star for Uranus); smaller circle: open cluster M 35, marked 35 (only the first digit is legible). Note that the two stars, plotted southwest of H in Harris's map (Fig. 4, rectangle), are missing here — but they are not missing in the *Atlas coelestis* at all. Each plate shows all Flamsteed stars only for the featured constellation (here: Gemini); the neighbouring constellations (e.g. Taurus) are represented only by their brightest stars. Thus the two (faint) stars, marked in Fig. 4, are only shown on the Taurus plate (P.2). The same applies to the rendering of the constellations in the *Atlas coelestis*. Thus Harris's star maps are useful, for they show all details at once.

nebulae and star clusters in his sweeps with the 18.7-inch reflector.[72] This demonstrates that Herschel's successful work — always supported by his talented sister Caroline — was not only based on his superior telescopes, but also on reliable catalogues and maps that showed a sufficient number of faint stars.

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3. F. Baily, *An account of the Revd. John Flamsteed, the first Astronomer Royal* (London, 1835). The preface contains the story of Halley's edition and Flamsteed's response. Part I of Baily's book is a detailed biography; Part II gives a revised version of the British Catalogue.
4. O. Gingerich, "A unique copy of Flamsteed's *Historia coelestis* (1712)", in: F. Willmoth (ed.), *Flamsteed's stars: New perspectives on the life and work of the first Astronomer Royal, 1646–1719* (Woodbridge, 1997), 189–97. There exist a few other copies in the UK with just the parts that were burned, but that owned by Gingerich is the only one with annotations.
5. There are no reliable life dates for Joseph Crosthwait. Some sources give "1681–1719", but this is wrong (note that 1719 is Flamsteed's year of death), Wolfgang Dick, private communication.
6. A. Perkins, "It was Flamsteed indeed", *Sky & telescope*, lxxxii (1991), 454 and 491. Flamsteed's manuscript differs from Halley's publication in the star coordinate format: Halley (and the British Catalogue) gives the right ascension in degrees and the polar distance; the manuscript gives the right ascension in hours and the zenith distance.
7. Owen Gingerich, private communication.
8. Flamsteed's British Catalogue (1725) and *Atlas coelestis* (1729) were edited by his wife Margaret and the mathematician James Hodgson. The southern extension (based on Halley's observation on St Helena) is the work of Flamsteed's friend and early assistant Abraham Sharp. It lists stars below –30° declination, presented in the atlas on a planisphere.
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10. D. J. Warner, Letter to *Sky & telescope*, xlvi (1973), 95; see also: I. Ridpath, *Star tales* (Cambridge, 1989). Lalande's catalogue contains 2884 stars (again for 1690); the numbers appear in the column "Flamsteed" (see ref. 17).
11. F. Schwemin, *Der Berliner Astronom – Leben und Werk von Johann Elert Bode* (Frankfurt, 2006).
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15. J. E. Bode, *Vorstellung der Gestirne auf XXXIV Kupfertafeln nach der Pariser Ausgabe des Flamsteedschen Himmelsatlas* (Berlin and Stralsund, 1782). "Pariser Ausgabe [Paris edition]" indicates Jean Fortin's French version of the *Atlas coelestis*, published in 1771. Bode's atlas is available at the Linda Hall Library: http://lhldigital.lindahall.org/cdm/compoundobject/collection/astro_atlas/id/3179.
16. It is not known why Bode turned back from 1800 to 1780. The positions of 280 stars in the *Astronomisches Jahrbuch* were always calculated for the almanac's target year. Because there was no target year 1780, he perhaps wanted to fill the gap.
17. J. J. Lalande, "Explication du Catalogue Britannique de Flamsteed", *Éphémérides des mouvemens célestes, 1785 à 1792* (Paris, 1782), pp. xxiii–xl; here the author mentions Bode's *Sammlung* of 1776 (p. xxiii). The catalogue is on pp. 17–72.
18. Royal Astronomical Society Herschel Archive (hereafter: RAS) W.2/1.1.
19. W. Herschel, "On the proper motion of the Sun and solar system", *Philosophical transactions of the Royal Society*, lxxiii (1783), 247–83, p. 249.
20. RAS W.7/8.
21. RAS W.4/1, 5.
22. W. Herschel, "Catalogue of double stars", *Philosophical Transactions of the Royal Society*, lxxii (1782), 112–62. Herschel's first catalogue of double stars has 289 entries.

23. RAS W.5/12.1, #45.
24. RAS W.2/2.1, 107–8.
25. Thus Herschel's instrument was a forerunner of the modern Dobson reflector.
26. It was not until December 1781 that Herschel received Mayer's "De novis in coelo sidereo phaenomenis in miris stellarum fixarum comitibus" (1779); the catalogue lists 72 double stars, discovered at Mannheim. It was sent by William Watson, together with the second Messier catalogue of 1780. See: C. A. Lubbock, *The Herschel chronicle* (Cambridge, 1933), 96.
27. *Op. cit.* (ref. 24).
28. RAS W.2/2.2.
29. RAS W.2/2.3.
30. Herschel, *op. cit.* (ref. 19).
31. M. Griffiths, "Joseph Harris of Trevecka", *The antiquarian astronomer*, no. 6 (January 2012), 19–33. Some sources give 1702 for the year of Harris's birth, but Griffiths found that he was christened on 16 February 1704.
32. The maps are presented by the National Library of Australia: www.nla.gov.au/apps/cdview/?pi=nla.map-rm4129-e; www.nla.gov.au/apps/cdview/?pi=nla.map-rm4130-e.
33. D. J. Warner, *The sky explored* (New York, 1979), 242–3; see also: N. Kanas, *Star maps* (New York, 2012), 205–7.
34. See: www.ritzlin.com/gallery/list90-01.html.
35. E. Halley, "An account of several nebulae or lucid spots like clouds, lately discovered among the fixt stars by help of the telescope", *Philosophical transactions of the Royal Society*, xxix (1715), 390–2. The northern map additionally shows Praesepe (M 44). The *Atlas coelestis* contains no nebulae or clusters.
36. This changed in 1784 when Herschel discovered many new nebulae and clusters, requiring modern positions for reference stars taken from the British Catalogue. He introduced an epoch of 1785 (later 1800); the necessary calculations were made by Caroline (RAS C.2/1.2).
37. The star is SAO 30076 (4.8 mag), 3.5° NW of μ Draconis (5.6 mag).
38. RAS W.4/1.1, 91–5.
39. Concerning the 7-ft reflector at power 227, Herschel wrote: "my field of view is 4′ 27″.968"; *op. cit.* (ref. 38), memorandum of March 18. He also reported that the "comet [Uranus] was followed by a small star at the distance of 2/3 of the field", which "is about 2′ 58″"; the star is SAO 77589 (9.2 mag).
40. In Herschel's double star catalogues the maximum distance between the reference star (Bayer, Flamsteed) and the discovered double/multiple star is 4.4° (mean 1.1°). Herschel must have thoroughly scanned the vicinity with his small field of view.
41. When on 17 February 1782 Herschel found the double star III 53 near γ Virginis, he was only 1.4° away from Neptune (7.9 mag)! The star (SAO 138952, 7.3 mag) is listed in the first catalogue of double stars, *op. cit.* (ref. 22).
42. J. E. Bode, *Astronomisches Jahrbuch für 1788* (Berlin, 1784), 243–7.
43. RAS C.3/1.1; RAS W.4/1.5, 440. During this period, Herschel moved from Bath to Datchet (2 August 1782).
44. RAS W.2/2.4.
45. Herschel, *op. cit.* (ref. 19). Indeed, the mean separation of new double stars was halved in the third review.
46. Lubbock, *op. cit.* (ref. 26), 60.
47. J. Ferguson, *Astronomy explained upon Sir Isaac Newton's principles* (London, 1756), sect. 355.
48 W. Herschel, "On the method of observing the changes that happen to the fixed stars", *Philosophical transactions of the Royal Society*, lxxxvi (1796), 166–226, p. 187: "Each page [of Herschel's star table] is divided into four columns, the first of which gives the number of the stars in the British catalogue of Mr. FLAMSTEED, as they stand arranged in the edition of 1725."
49. Herschel, *op. cit.* (ref. 19), 2. The star "near the lucid foot of Pollux" is γ Geminorum.
50. Herschel also claimed to have observed the 4th and 5th satellite of Saturn on 4, 5 and 7 April. Actually, they were the 6th (Titan) and 8th (Japetus).
51. Ferguson, *op. cit.* (ref. 47), sect. 359. The 27-inch celestial globe (the other is a terrestrial) produced by Senex was also based on Halley's pirated edition of the Flamsteed catalogue; it was advertised: "on the Celestial, are placed all the Stars in Mr. Flamsteed's Catalogue, as published by Dr Halley" (Elly Dekker, private communication).

52. RAS W.4/1.2, 140. In "Journal No. 3" the star is already mentioned on 21 August 1781 as "23 Hercules. Flamsteed", but this seems to be a later addition (RAS W.2/1.3, 26).
53. Herschel, *op. cit.* (ref. 22); the name "Harris" appears six times in this catalogue. It contains some double stars (and dates), mentioned neither in the Journals nor in the "Fixt Stars", i.e. these documents are incomplete.
54. J. L. E. Dreyer, *The scientific papers of Sir William Herschel* (London, 1912).
55. Lubbock, *op. cit.* (ref. 26), 203.
56. RAS C.3/6.1, last 3 pages. The first pages of the manuscript list "Extracts from Bodes Jahrbüchern", starting with that published in 1783 (for the year 1786). Herschel had got the first two almanacs (for 1786/87) in 1785, announced in a letter from Bode, dated 13 August 1785. See: Lubbock, *op. cit.* (ref. 26), 207.
57. F. H. Maurer (ed.), *G. C. Lichtenberg, Schriften und Briefe* (Frankfurt, 1983), iv, 342.
58. Lubbock, *op. cit.* (ref. 26), 207. When "Bode's catalogue" is mentioned in manuscripts or publications after 1801 (e.g. in Herschel's third catalogue of nebulae), always Bode's new catalogue and atlas (Uranographia), containing 17240 stars, is meant: J. E. Bode, *Allgemeine Beschreibung und Nachweisung der Gestirne nebst Verzeichniss der geraden Aufsteigung und Abweichung von 17240 Sternen, Doppelsternen, Nebelflecken und Sternhaufen* (Berlin, 1801). The work arrived at Slough on 24 September 1801; see RAS C.4/3.1, 18.
59. Mrs John Herschel, *Memoir and correspondence of Caroline Herschel*, 2nd edn (London, 1879), 71. In the letter to Dietrich, Caroline also mentions Harris's maps: "I believe you have a pair of Harris's maps."
60. RAS C.2/10.
61. *Op. cit.* (ref. 59), 45. For instance, H Geminorum is correctly designated "1" (Fig. 5). Caroline also added Messier objects, marked by a dot and an underlined number.
62. W. Herschel, "Catalogue of double stars", *Philosophical transactions of the Royal Society*, lxxv (1785), 40–126, p. 43. Herschel's second catalogue of double stars has 434 entries. It is interesting that H Geminorum is mentioned as a reference star "H (FL. I^{am}) Geminorum". 2/3° west of it Herschel had discovered a quadruple star (IV 48) on 6 February 1782. The curious ensemble was found a second time, now as cluster VIII 26, on 16 November 1784 (sweep 317); again the reference star was "1 (H) Geminorum". See RAS W.2/3.3.
63. The place of the "Georgium Sidus" at the discovery date is not marked.
64. The plate numbers of the British editions of 1753 and 1781 are identical, whereas Fortin's French edition of 1771 (see ref. 15) has a different chart order and numbering.
65. *Op. cit.* (ref. 22).
66. RAS W.4/1.3, 216–17; RAS W.2/1.4, 21–2.
67. RAS W.4/1.3, 238. The fascinating story of "Herschel's garnet star" will be told in a forthcoming paper.
68. The neighbouring star ν Cephei is problematic too.
69. C. Herschel, *Catalogue of stars, taken from Mr. Flamsteed's observations contained in the second volume of the Historia Coelestis, and not inserted in the British Catalogue* (London, 1798).
70. Wolfgang Steinicke, *Observing and cataloguing nebulae and star clusters: From Herschel to Dreyer's New General Catalogue* (Cambridge, 2010).
71. The two stars are the famous quadruple (trapezium) in the Orion Nebula (11 November 1776) and Castor (8 April 1778); see Herschel's first double star catalogue, *op. cit*. (ref. 22). A third early discovery is listed there: the "periodical star in Collo Ceti" (Mira) on 20 October 1777, but this is wrong (the star was not visible); the correct date is 19 October 1779.
72. The nebulae found by Herschel prior to his sweeps is the subject of a forthcoming paper