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WILLIAM HERSCHEL AND THE 'GARNET' STARS: μ CEPHEI AND MORE

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Abstract: Although William Herschel's 'Garnet Star' (μ Cephei) is a prominent object, the story of the discovery of this famous red star is not well documented. Prior to and after Herschel, the identification of this star was the subject of confusion in various catalogues and atlases. The case is complex and involves other stars in southern Cepheus, including double stars, found by Herschel in the course of his star surveys.

It is also fascinating to learn that μ Cephei is not the only star called "garnet" by him. This study reveals that there are 21 in all, resulting in a "Herschel Catalogue of Garnet Stars"—the first historical catalogue of red stars. Among them are prominent objects, which in the literature are credited to later observers. This misconception is corrected here, for Herschel was the true discoverer of all of them. The most interesting cases are Hind's 'Crimson Star', Secchi's 'La Superba', John Herschel's 'Ruby Star' and Schmidt's V Aquilae.

Finally, we discussed whether Herschel speculated about the physical nature of his garnet stars, many of which are now known to be variable.

Keywords: William Herschel, Herschel's 'Garnet Star', John Herschel, Jérôme Lalande, red stars, variable stars, double stars, star catalogues, star atlases, spectroscopy

1 HERSCHEL'S DISCOVERY IN 1782

The fourth magnitude star μ Cephei (Erakis), commonly known as 'Herschel's Garnet Star', is one of the most prominent naked eye red stars in the sky. The standard reference to this is William Herschel's paper "On the proper motion of the Sun and Solar System", which was published in the *Philosophical Transactions of the Royal Society* (Herschel, W., 1783a: 257). Therein, a special section mentions "Stars newly come to be visible …", where nine examples are listed. The third of these, which impressed the ethnic German astronomer because of its peculiar colour, is described as follows:

> A very considerable star, not marked by Flamsteed, will be found near the head of Cepheus. Its right ascension in time is about 2′ 19″ preceding Flamsteed's 10th Cephei, and it is about 2° 20′ 3″ more south than the same star. It is of a very fine deep garnet colour such as the periodical star o Ceti [Mira] was formerly, and a most beautiful object, especially if we look for some time at a white star such as α Cephei, which is near at hand [4° northwest], before we turn our telescope to it.

When did Frederick William (later Sir William) Herschel (1738–1822; see Figure 1) discover the 'Garnet Star'? The exact date can be found in his "Journal No. 4", covering the period of his 'third star review' in which all Flamsteed stars were inspected (and this campaign resulted in the discovery of many new double stars). Herschel's telescope was a reflector of 6.2 inches aperture and 7 feet focal length (the very instrument with which he found Uranus on 13 March 1781; see Figure 2). The Journal entry for 27 September 1782 reads:

> A very considerable star not marked in Fl[amsteed's] Atlas, its place should be there about 45′ past 21^h. 32½ Deg Polar distance. It is of a very deep fine garnet. This must be looked at often. Very beautiful indeed. (Herschel, W., 1782a: 32; see Figure 3).

Figure 1: William Herschell (after Holden, 1881: Title Page).

Thus we know that Herschel discovered the 'garnet star' in Cepheus on 27 September 1782, and that the observation was made from Datchet. He later copied the note into the third folder on the "Fixt Stars" (Herschel, W., 1782b: 238).

On that same September night Herschel discovered seven double stars: I 48, I 49, III 70, III 71, III 72, IV 78, IV 79 (designated by class and

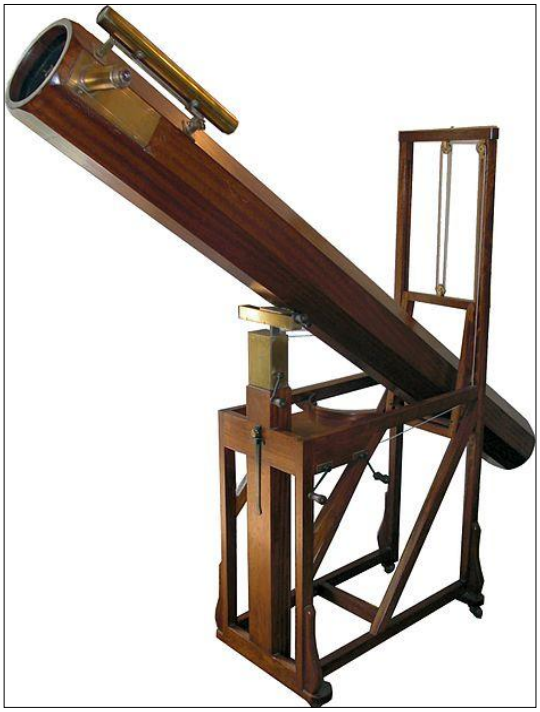


Figure 2: A replica of the telescope that Herschel used to discover Uranus and his Garnet Star in Cepheus (en.wikipedia.org).

number; Herschel, W.,1785). All are in Cepheus, and four of them (I 49, III 71, III 72, IV 79) are near the Garnet Star in the southern part of the constellation. Herschel (1782–1783a: 349) again surveyed the area on 16 March 1783:

> New Garnet Star Cephei, uncommonly beautiful [magnification] 460. With 932 finely distinct, seems of a larger diameter[1] than stars of that size as generally seen in the finder. With 1504 very well defined. The diameter is not larger than that of 10 Cephei with the same power. The colour continues the same with all the powers, with the naked eye rather larger than the 9th Cephei.

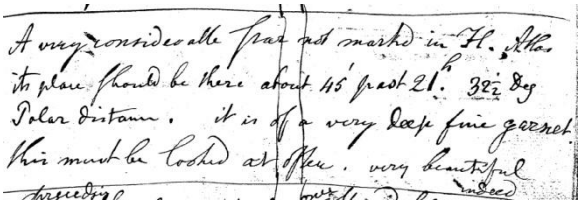


Figure 3: Herschel's note about the discovery of the Garnet Star in Cepheus, dated 27 September 1782 and contained in "Journal No. 4" (Herschel, W., 1782a: 32). The two vertical lines indicate that the text was later copied to another folder ("Fixt Stars No. 3").

On 24 March 1783, Herschel (1782–1783a: 351) revisited the double stars III 71 and III 72, located 1.3° southwest of the Garnet Star. Another observation followed on 5 April 1783:

> Garnet Star Cephei. With the 20ft reflector is a most beautiful object; the colour being very vivid & the same as before described. There are great many stars about it. (Herschel, W., 1782–1783a: 363).

The reflector in question is the 'small 20-ft' with an aperture of 12 inches (Figure 4). On 21 May 1783 the Garnet Star was the target of a 'prismatic experiment' at the 10-ft reflector. Herschel used a prism at the eyepiece and described the colours seen in the continuous spectrum; of course, due to the low dispersion, no lines were seen, and the red part of the spectrum dominated, which showed the lowest refraction. Herschel (1782–1783a: 385) wrote:

> The spectrum of α Cephei with 10ft reflector power about 100 gave the colours r o y g b p v [red, orange, yellow, green, blue, purple, violet]. The Garnet Star gave only r y g perhaps o may be there in some small degree. I repeated the experiment several times on both stars but could find no b p v in the Garnet Star.

On 29 September 1783 Herschel (1782–1783a: 443) showed the Garnet Star to his friends Alexander Aubert and Charles Bladgen, using the standard 7-ft reflector and the brand-new 'large 20-ft' reflector with an aperture of 18.7 inches (Figure 5).

The star also appeared in two of his sweeps for nebulae, made at Slough. Sweep 768 (16 October 1787): "7 m. of a deep orrange [*sic*] colour, or pale garnet. Very different from all the stars in this neighbourhood. U[794]" (Herschel, W., 1787–1790). Because the star was not in Flamsteed's catalogue it was entered in a list of 'unknown stars', getting the number 794 (hence 'U[794]' in the quotation). The reference star for the position was 14 Cep, which was 2.5° to the southeast. And in sweep 875 (1 November 1788) we have: "6 m. garnet colour. U[794]." with the reference star 10 Cep, 2.4° to the north. It is interesting that Herschel does not mention his earlier observations; perhaps he thought the garnet-coloured star was a new object. It seems that he was not expecting to encounter this object in these sweeps. Table 1 lists all eight obser-

Table 1: Herschel's observations of the Garnet Star. Sources: J = Journal, F = Fixt Stars (with page number; see References).

Date	Source	Telescope	Remarks
1782, September 27	J4, 32; F3, 238	7-ft	"very deep fine garnet"
1783, March 16	J5, 43; F4, 349	7-ft	"New Garnet Star Cephei"
1783, March 24	J5, 46; F4, 351	7-ft	double stars near Garnet Star (III 71, III 72)
1783, April 5	J6, 5; F4, 363	small 20-ft	"Garnet Star Cephei"
1783, May 21	J6, 17; F4, 385	10-ft	"prismatic experiment"
1783, September 29	F5, 443	7ft, large 20-ft	visitors: Alexander Aubert, Charles Bladgen
1787, October 16	sweep records	large 20-ft	sweep 768, U[794]
1788, November 1	sweep records	large 20-ft	sweep 875, U[794]

vations of the Garnet Star that Herschel made over a period of six years.

2 OTHER OBSERVERS, VARIABILITY AND CATALOGUING

The next to observe Herschel's Garnet Star was Guiseppe Piazzi (1746–1826; Figure 6) in late August 1799, using the 3-inch Ramsden refractor at the Palermo Observatory. It is listed in his star catalogue (Piazzi, 1803) as an anonymous star of magnitude 6 in Cepheus (Hora XXI). The English translation of the separate note reads:

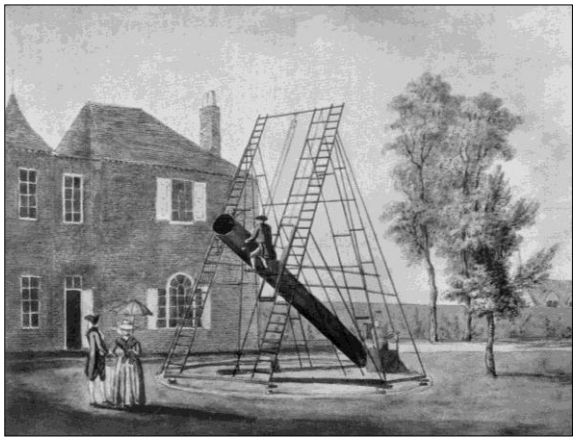


Figure 4: Herschel's 'small 20-ft' telescope at Datchet (after Dreyer, 1912: Volume 1, Plate B).

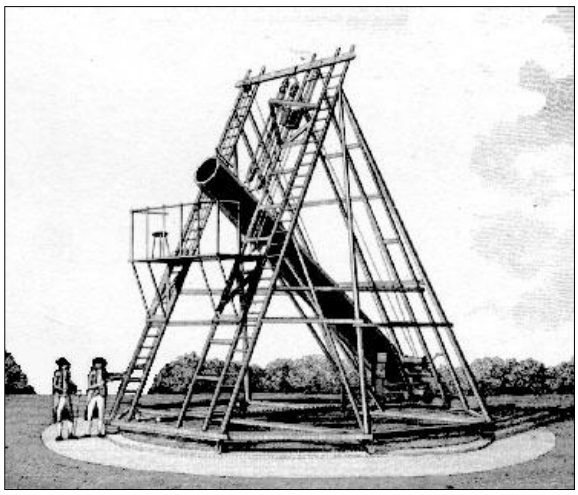


Figure 5: Herschel's 'large 20-ft' telescope (http://faculty.humanities.uci.edu/bjbecker/ExploringtheCosmos/week6d.html)

"Star of this obscure red colour supposedly first appeared around 1782."[2] Piazzi refers to Herschel's publication of 1783. In the second edition of his catalogue Piazzi (1814) refers to the star as 'Garnet Sidus'. All entries are numbered now, and Herschel's star is number 285 in Hora XXI, which led to the later designation 285 P. XXI (but the terms XXI P. 285 and P. XXI. 285 also were used).

It is interesting that the Garnet Star was not observed by Joseph Jérôme Lefrançois de Lalande (1732–1807) in the course of his measure-

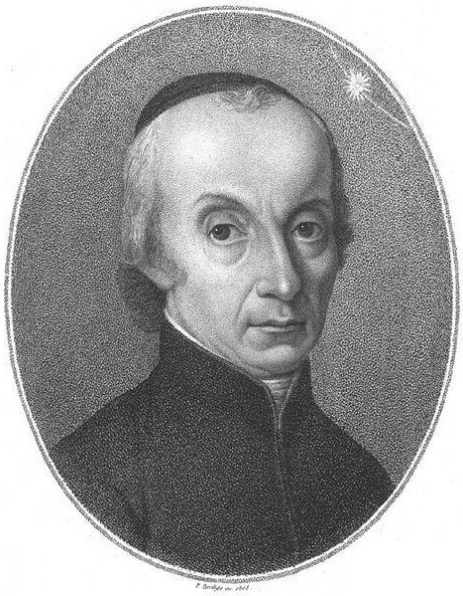


Figure 6: Giussepe Piazzi (en.wikipedia.org).

ments at Paris in the late eighteenth century, when he recorded 47,390 stars down to visual magnitude 9. Thus, the object is missing from his great catalogue *Histoire Céleste Française* (Lalande, 1801; cf. Baily, 1847). Magnitude and colour could not have been the reason, for Lalande did observe comparable red stars (see below).

Herschel's Garnet Star is anonymously listed in the zone observations made by Friedrich Wilhelm August Argelander (1799–1875; Figure 7) at the Bonn Observatory from 1841 to 1844. The measurement was made on 11 September 1842. Argelander listed the position for 1842 and noted it as "… very red." (see Oelzen, 1852). The magnitude was estimated as 3, which is surprisingly bright, and this led John Russell Hind (1823–1895; Figure 8), the observer at Bishop's Observatory in Regent's Park (London), to speculate about its possible variability: "The remarkable

Figure 7: F.W. Argelander (en.wikipedia.org).

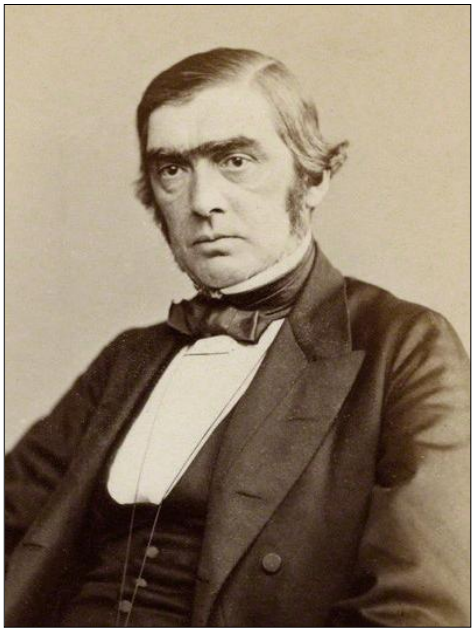


Figure 8: J.R. Hind (en.wikipedia.org).

garnet-stars [*sic*] in Cepheus appears to be fluctuating in brilliancy." (Hind, 1848a). Intrigued by this remark, Argelander—who was very interested in variable stars—watched this star from 1848 to 1864 (Argelander, 1869: 371–372), and it became clear to him that the red colour created difficulties when it came to making magnitude comparisons with nearby stars. During the early years that he monitored this star Argelander was supported by his assistants, Johann Friedrich Julius Schmidt (1825–1884) and Eduard Schönfeld (1828–1891).

In 1861 the young George Frederick Chambers (1841–1915) published a list of 99 variable stars in his influential *Handbook of Descriptive and Practical Astronomy* (Chambers, 1861). Herschel's Garnet Star is no. 92, and is listed as: "μ Cephei, Sir W. Herschel 1782." That he cites 1782

Figure 9: Eduard Schönfeld (en.wikipedia.org).

is interesting, because it is not mentioned in Herschel's 1783 publication (and Piazzi only noted "… circa annum 1782."). What was Chambers' source? It must have been Herschel's second catalogue of double stars where we find the following entry:

> III. 71. Tiaram Cephei praecedens.[3] Sept. 27, 1782. Treble. About 1½ degree preceding the *Garnet Star*, in a line parallel to ι and ζ Cephei ... The place of the *Garnet Star*, reduced to the time of FLAMSTEED'S Catalogue, is about AR 21 h. 45′. P.D. 32°½. (Herschel, W., 1785: 83).

We know from Herschel's unpublished Journal that this is one of the double stars that was discovered on the same night as the Garnet Star. Chambers therefore must have concluded that the date "Sept. 27, 1782" was when the Garnet Star also was discovered, though this is not mentioned explicitly. An enlarged version of Chambers' list of variable stars subsequently appeared in *Astronomische Nachrichten* (Chambers, 1864), but no additional information is given about the Garnet Star.

In the same year Eduard Schönfeld (Figure 9) published a catalogue of 119 variable stars, which included μ Cepheus as no. 112, with a magnitude range of 4–5:

> Sir W. Herschel's Garnet Star, thought to be new by him; but, as Argelander has shown, it already appears in the Almagest. In 1848 Hind called attention to the variability of the star; however, the reasons were not sufficiently convincing at that time, thus Argelander had doubts. But later the latter could confirm the variability by comparisons over several years. Among all naked eye northern stars the Garnet Star has the most intense red colour. (Schönfeld, 1864).

In Schönfeld's second catalogue the star is no. 135 (Schönfeld, 1875).

In 1872 Julius Schmidt (Figure 10), by now Director of the Athens Observatory, published a report of his observations, titled "μ Cephei, Herschel's 'Garnet Star'." (Schmidt, 1872). The variability was later studied by several astronomers (e.g. Hassenstein, 1938; Percy at al., 2001). The star in fact varies with a semi-regular period of 800–1000 days around a mean visual magnitude of 4.5, with Δv ~1.

The Garnet Star is also listed in the first comprehensive catalogue of 280 red stars, published by the Danish astronomer Hans Carl Frederik Christian Schjellerup (1827–1887) and titled "Catalogue of red, isolated stars which became known before 1866" (Schjellerup, 1866). Here no. 253 is "W. Herschel's *Granatstern*". It also appears in the red star catalogues of George Chambers (1867: 591; 1887) as no. 266 and no. 656, respectively, and John Birmingham (1816–1888) as no. 594 (Birmingham, 1877).

Herschel's Garnet Star was also featured by the great Victorian popularisers of astronomy in their observing guides: William Smyth (1788–1865; 1844), Thomas Webb (1807–1885; 1859) and William Darby (1864). All three used the Piazzi designation 285 P. XXI. It is interesting that there is no reference to μ Cephei. The first to publish the Bayer designation was Chambers (1861); hence it is also present in his update of Smyth's *Cycle* (Chambers, 1881: 639).

3 WILL THE REAL μ PLEASE STAND UP!

The identification of μ Cephei was a problem that extended over centuries. The case looks like a cabinet of curiosities. Five other stars are involved, including ν Cephei (2.3° north of μ and variable too) and Herschel's double star IV 79 (3.2° southeast of the Garnet Star). It is interesting to compare some important star catalogues and atlases of the time. Table 2 below shows all six relevant stars (see Figure 11 for their positions). The correct identification is given in the second row.

Johann Bayer (1572–1625) created the designation "μ Cephei" in his famous *Uranometria* (Bayer, 1603; Berberich, 2010). This work uses Claudius Ptolemy's star catalogue, given in the *Almagest*, but adds many new stars. Ptolemy lists 11 principal stars in Cepheus, and two additional ones under "Informatae" (Peters and Knobel, 1915). The first of them ("Precedens tiaram"), given as magnitude 5, is Bayer's μ Cephei; the second is the famous variable star δ Cephei ("Sequens tiaram"). Alas, Bayer reverses Ptolemy's sequence in assigning the numbers 13 and 12 for μ and δ in his star list (instead of 12 and 13); the chart, however, shows the correct order. Only two of the six stars

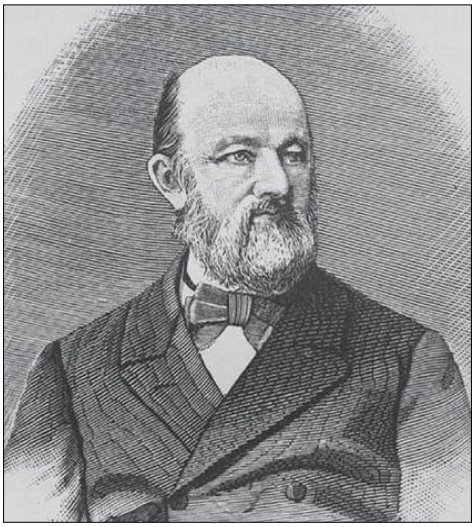


Figure 10: Julius Schmidt (en.wikipedia.org).

in Cepheus listed in Table 2 were known to Bayer: μ and ν (chart A of Figure 12). Although no coordinates are given in his star list, a celestial grid marks the position.

The next relevant observer is John Flamsteed (1646–1719; Figure 13). His British Catalogue (Flamsteed, 1725) contains a Cepheus star called μ (Figure 14): the 13th entry in that constellation (thus later designated 13 Cephei). But the position for 1690 is incomplete: a polar distance of 34° 50′ 10″ is given, but no right ascension (AR). However, the PD does not match Bayer's star! Thus, 13 Cephei is a different object, 2.6° southeast of Bayer's μ. A similar case is the nearby star ν Cephei: Flamsteed erroneously lists it as 15 Cephei, located 2.6° southeast of ν.

Curiously, the first to present a map of all stars of the British Catalogue was not Flamsteed.

Table 2: Problematic stars in southern Cepheus (shown in Figure 2) and their appearance in some important historic works. Wrong or incomplete identifications – relative to the correct one in the second row – are marked in bold italics.

Star	μ	13	IV 79	14	ν	15
Correct identification	μ = Garnet Star	13 Cep	IV 79 = N. 57	14 Cep	ν = 10 Cep	15 Cep
Bayer 1603	μ	--	--	--	ν	--
Flamsteed 1725/29	--	***μ = 13 Cep***	--	14 Cep	***10 Cep***	***ν = 15 Cep***
Harris 1727	--	***μ = 13 Cep***	--	14 Cep	***10 Cep***	***ν = 15 Cep***
Herschel 1782	***Garnet Star***	--	***IV 79 = μ = 13 Cep***	14 Cep	***10 Cep***	***ν = 15 Cep***
Bode 1782	(μ)	***μ = 13 Cep***	--	14 Cep	***10 Cep***	***ν = 15 Cep***
Wollaston 1789	***Garnet Star***	***IV 79 = μ = 13 Cep ?***	***N. 57***	14 Cep	***10 Cep***	***ν = 15 Cep***
Bode 1801	-	***154 = IV 79 = μ = 13 Cep***	147	165 = 14 Cep	***139 = σ = 10 Cep***	***171 = ν = 15 Cep***
Piazzi 1814	***285 = Garnet Sidus***	***347***	--	385 = 14 Cep	***297 = 10 Cep***	***399 = ν = 15 Cep***
Baily 1835	***--***	***2997 = μ = 13 Cep***	--	3016 = 14 Cep	2984 = ν = 10 Cep	3025 = 15 Cep
Baily 1845	***7582***	***7643 = μ = 13 Cep***	7631	7683 = 14 Cep	7595 = ν = 10 Cep	7696 = 15 Cep
Argelander 1843	***XXI P. 285***	--	--	***385 = μ = 14 Cep***	297 = ν = 10 Cep	399 = 15 Cep
Argelander 1859	+58 2316	+55 2644	+55 2638	+57 2441	+60 2288	+59 2456
Heis 1872	μ	13 Cep	--	14 Cep	ν = 10 Cep	15 Cep

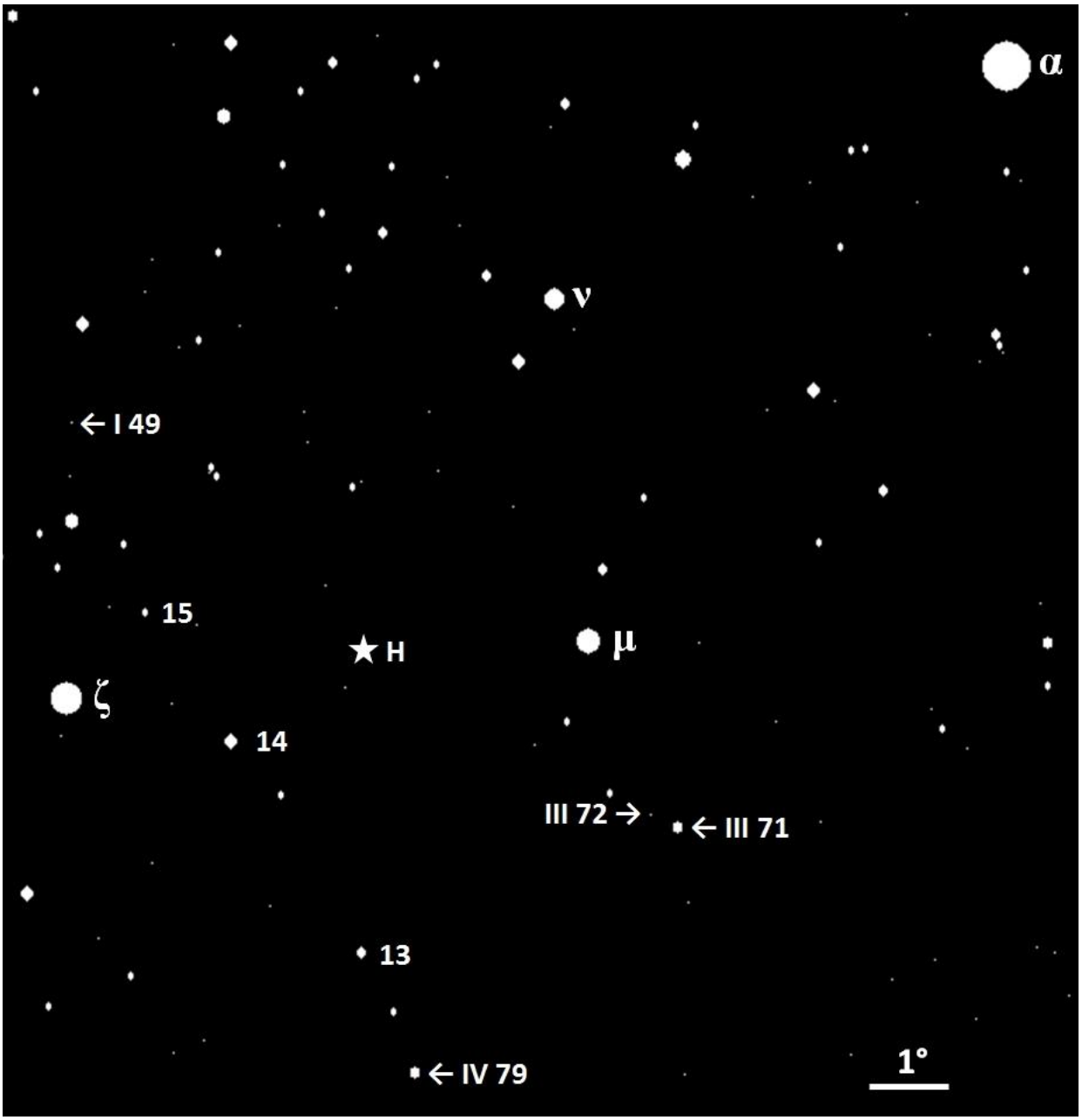


Figure 11: Map showing the stars listed in Table 2 (area around μ Cephei). Herschel's position of the Garnet Star is marked by an 'H', and the locations of his double stars I 49, III 71 and III 72 also are given.

Two years before Flamsteed published his *Atlas Coelestis* (1729), the Welsh astronomer, Joseph Harris (1702–1764; Steincke, 2014), produced a pair of single-sheet charts, showing the skies of the northern and southern hemispheres (Harris, 1727). Due to the missing AR and wrong PD, 13 Cephei is incorrectly labelled μ in Harris' northern map and the position of the true Bayer star is blank! For ν it is analogous: 15 Cephei is labelled ν, while the true Bayer star is 10 Cephei (Figure 12, chart B). Flamsteed's *Atlas Coelestis* shows the same, but there is no label "ν" (Figure 12, chart C).

Now William Herschel comes into play. At the time of his third star review he was using Flamsteed's British Catalogue and *Atlas Coelestis*. For quick identifications, he still had Harris' star maps at hand. The discovery night of the Garnet Star (27 September 1782) brought a lot of confusion. When Herschel tried to identify the "… very beautiful …" object, he saw that it was "not marked by Flamsteed" (actually it was Caroline Herschel who did this job). There is no object at the position of the Garnet Star (Bayer's μ Cephei) in the British Catalogue and the related charts. But the data reduction brought an error too! The calculated position "… relating to the time of Flamsteed …" (1690) led to RA = 21^h 45′ and PD = 32° 30″ (Herschel, W., 1782b). This is strange, for while the PD is that of Bayer's μ Cephei, the RA is that of Flamsteed's 13 Cephei (see Figure 11, "H")—a curious mix! When preparing his *Philosophical Transactions* paper "On the proper motion of the Sun …", which was read

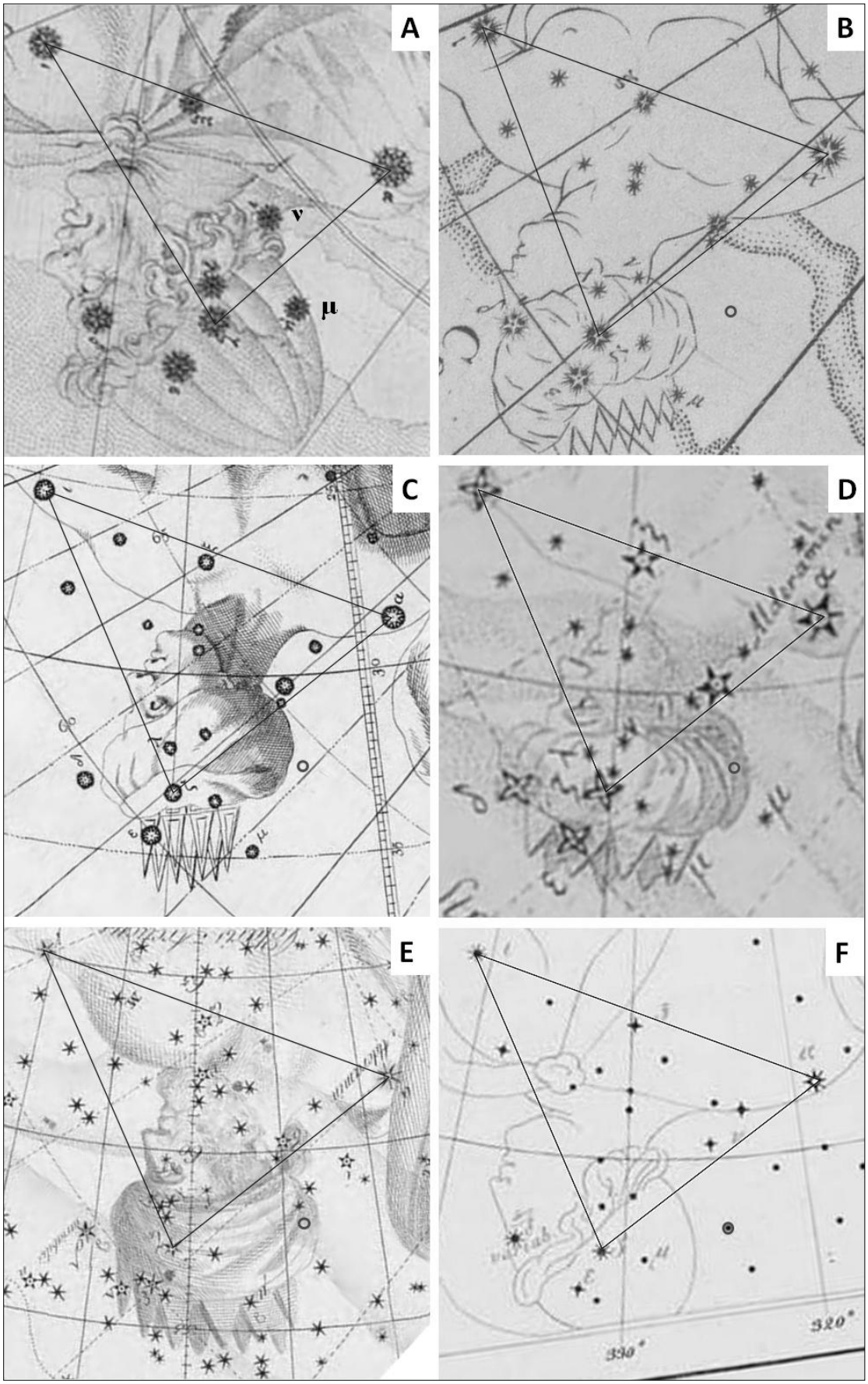


Figure 12: Comparison of the southern Cepheus area in six important atlases or maps: A = Bayer, B = Harris, C = Flamsteed, D = Bode 1782, E = Bode 1801, F = Argelander. For orientation all charts are rotated to have north up and equally scaled (the triangle connects α, ι and ξ Cephei). The position of Bayer's μ Cephei is marked by a small circle (right below centre).

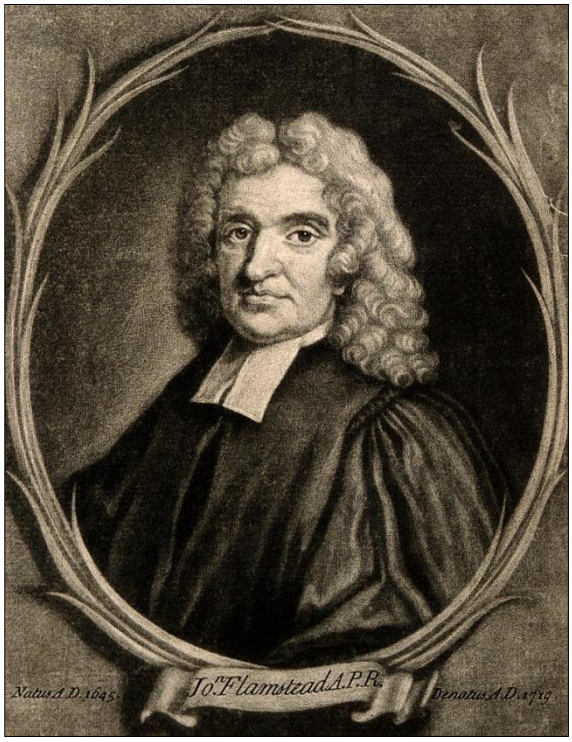
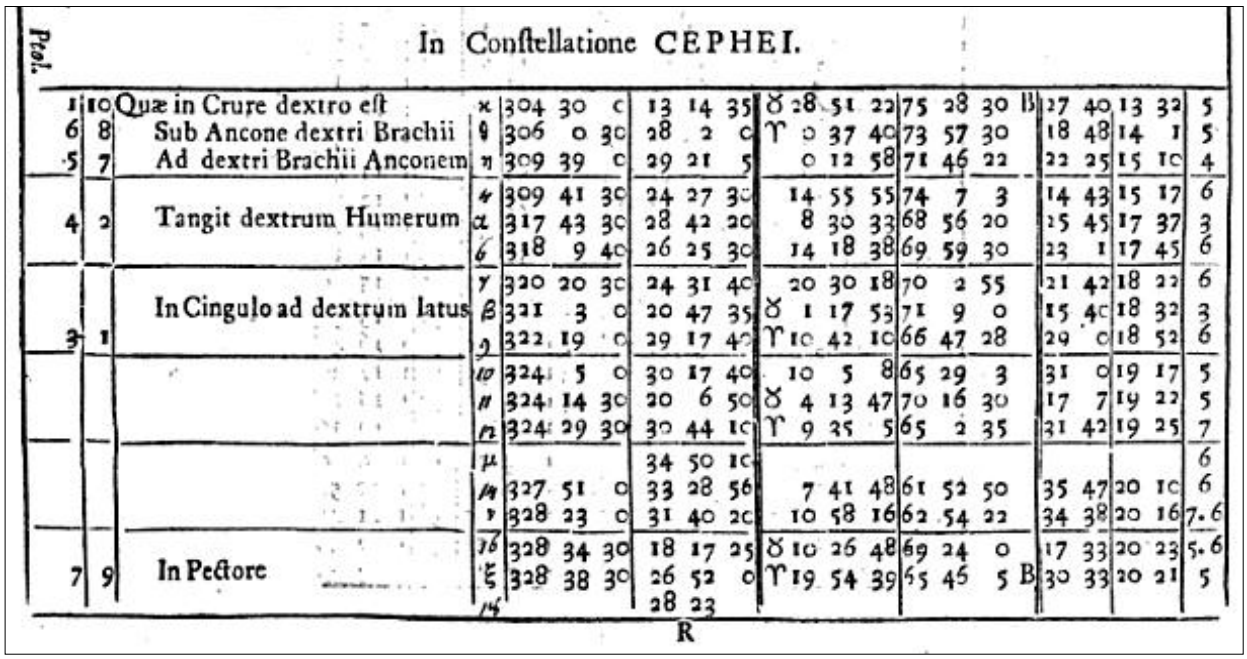


Figure 13: John Flamsteed (en.wikipedia.org).

on 6 March 1783, Herschel became aware of this error. Therein the place of the Garnet Star is correctly given relative to 10 Cephei: 2′ 19″ preceding, 2° 20′ 3″ south!

Further confusion is demonstrated when Herschel announces a new double star (IV 79, see Figure 11), which was found later that same September night: "μ Cephei. Fl 13. double. 4th Class." He not only equates μ Cep with 13 Cep, but also identifies Flamsteed's star with the new pair, athough located about 1° southwest (the magnitudes matched). Herschel had no reliable data for 13 Cep. This is reflected in Caroline Herschel's list of the Flamsteed stars with positions for 1690, arranged in zones of constant polar distance (Herschel, C., 1786). The star μ 13 is listed in zone 30–35°, but only the PD is given. In her compilation of all double star observations, we still have "μ Cephei Fl. 13", and three observations are listed: 27 September and 21 December 1782 and 16 August 1783 (Herschel, W., 1776–1781: 202). But in William Herschel's second catalogue of double stars (Herschel, W., 1785) we read for IV 79: "Prope μ Cephei Fl. 13", where "prope" means "near to". Thus he must have noticed the error. There is no observation of the true 13 Cephei, neither in the reviews nor during the sweeps.

During sweep 765 on 14 October 1787 Herschel discovered a new double star, and it was observed again two days later during sweep 768 (which also marked his last observation of the Garnet Star). Later this object was named N. 57 in a list of 145 new double stars that were found during the sweeps (Herschel, W., 1822). Around the end of 1787, Herschel described 15 of the new double stars (N. 57 and 58 being the last) in a manuscript that he would send to Francis Wollaston (1731–1815) for inclusion in his new star catalogue (see below).[4] Herschel did not identify IV 79 and N. 57, and the first to do so was Friedrich Georg Wilhelm von Struve (1793–1864), who published it in his *Catalogus Novus* (Struve, 1827). This double star is no. 2840 (modern designation Σ 2840), and is identified with Cephei 147 (see below) and H. N. 57 =


In Conſtellatione CEPHEI.

1	10	Quæ in Crure dextro eſt	×	304	30	c	13	14	35	♉	28	51	22	75	28	30	B	27	40	13	32	5
6	8	Sub Ancone dextri Brachii	ϑ	306	0	30	28	2	0	♈	0	37	40	73	57	30		18	48	14	1	5
5	7	Ad dextri Brachii Anconem	η	309	39	c	29	21	5		0	12	58	71	46	22		22	25	15	10	4
			ω	309	41	30	24	27	30		14	55	55	74	7	3		14	43	15	17	6
4	2	Tangit dextrum Humerum	α	317	43	30	28	42	20		8	30	33	68	56	20		25	45	17	37	3
			ζ	318	9	40	26	25	30		14	18	38	69	59	30		23	1	17	45	6
			γ	320	20	30	24	31	40		20	30	18	70	2	55		21	42	18	22	6
		In Cingulo ad dextrum latus	β	321	3	0	20	47	35	♉	1	17	53	71	9	0		15	40	18	32	3
3	1		ϑ	322	19	c	29	17	40	♈	10	42	10	66	47	28		29	c	18	52	6
			ι	324	5	0	30	17	40		10	5	8	65	29	3		31	0	19	17	5
			κ	324	14	30	20	6	50	♉	4	13	47	70	16	30		17	7	19	22	5
			π	324	29	30	30	44	10	♈	9	35	5	65	2	35		31	42	19	25	7
			μ				34	50	10													6
			ψ	327	51	0	33	28	56		7	41	48	61	52	50		35	47	20	10	6
			ρ	328	23	0	31	40	20		10	58	16	62	54	22		34	38	20	16	7.6
			τ	328	34	30	18	17	25	♉	10	26	48	69	24	0		17	33	20	23	5.6
7	9	In Pectore	ξ	328	38	30	26	52	0	♈	19	54	39	65	46	5	B	30	33	20	21	5
							28	23														

R

Figure 14: Extract from Flamsteed's British Catalogue. μ Cephei is the 13th entry in Cepheus. Note that Flamsteed numbers are inserted by hand where no Bayer letter is present. Owen Gingerich (private communication) conjectures that this could be Bode's copy (the original is at the Bayerische Staatsbibliothek).

H. IV. 79. The situation is clarified by the note: "μ Cephei itaque non est H. IV. 79." Later John Herschel (1867) copied this result in the synopsis of his father's double star observations.

On that remarkable September night Herschel found three other double stars in the same area as the Garnet Star:

> Preceeding the new Garnet Star in Cepheus. Treble. One of the 3rd Class the other of the 4th Class. [III 71, and] … Just following the above treble star. Double 3rd Class. [III 72].

Two of these were ~1.4° southwest of the Garnet Star, and the third star was a "Double 1st Class" (I 49), although the described location does not match the star that was referred to (Figure 11 shows the locations of III 71, III 72 and I 49). No doubt, to Herschel southern Cepheus was a confusing area!

In 1782 the Berlin astronomer Johann Elert Bode (1747–1826; Figure 15) presented an astonishing version of the case in his popular star atlas *Vorstellung der Gestirne* (Bode, 1782). We are now faced with two stars labelled μ Cephei (Figure 13, chart D)! One is at the position of 13 Cep and the other is 1.3° southwest of the Garnet Star (and therefore it accidentally matches the position of Herschel's double star III 71). However, Bode's star catalogue, with positions for 1780, only lists one μ (which corresponds to 13 Cep), and the identification of ν Cephei is still wrong.

The next relevant person is Herschel's friend Francis Wollaston. In his zone catalogue, giving positions for 1790, the situation for μ Cep is similar to Herschel's view (Wollaston, 1789). The Garnet Star is included: "… mentioned by Hersc. as supposed to be new 1782±, a pretty considerable Star." However, Herschel's identification of IV 79 with 13 Cep and μ is now doubted. Thus, Wollaston's note for 13 Cep reads:

> Whether this be the same as *μ Cephei*, N° 13 of Flamsteed, is uncertain; since this is an imperfect observation. Herschel sets *μ* down as a double star (IV. 79).

It is not clear what is meant by "imperfect observation". Herschel's record does not mention any problems. Wollaston also lists the new double star N. 57 (the true IV 79): "a double star (Hers. M.S.) Oct. 1787."

In 1801 Bode published his *magnum opus*, the *Uranographia* (Bode, 1801a), showing stars down to magnitude 8. Unlike in 1782, there is now only one μ at the 13 Cep position (see Figure 13, chart E), but curiously, in the accompanying catalogue (Bode, 1801b), with positions for 1801, this star is listed as no. 154 in Cepheus and identified with Herschel's double star IV 79 (whereas the true IV 79 is no. 147 in Cepheus)! Later, Caroline Herschel (1750–1848;

Figure 15: J.E. Bode in about 1802 (en.wikipedia.org).

Figure 16) identified N. 57 with "No. 147 Cephei of Bode's Cat." in the final copy of the sweep records, without mentioning IV 79 (Herschel, W., 1786–1787: sweep 765). The situation for ν Cep had changed too: to make matters worse, the false ν (10 Cep) was called "σ Cephei", even though there is no such star in Bayer's *Uranometria*!

How does Piazzi manage the case? He lists the Garnet Star as no. 285 (Hora XXI) in his Palermo star catalogue of 1814 (but μ is not mentioned). Meanwhile, star no. 347 (13 Cephei) is

Figure 16: Caroline Herschel in 1829 (after Clerke, 1895: f. 114).

Figure 17: Francis Baily (en.wikipedia.org).

referred to as a Hevelius star and no. 299 is incorrectly called 15 ν Cephei, while the true ν is no. 297 (10 Cephei).

Eventually, Francis Baily (1774–1844; Figure 17), an expert in producing star catalogues, would correct some of these errors. In his revision of the British Catalogue (1835) the star 13 Cephei μ is listed as no. 2997 (with the position for 1690). There is an interesting remark in the notes about Flamsteed's observation:

> It was observed on Sept. 28, 1692, at about 8h 47m; but the time of transit is only approximately noted; and I have therefore left the right ascension doubtful.

The reason for the missing AR of 13 Cep is clear now, but it is surprising that the wrong identification of μ as 13 Cep remains, even though Baily had compared Flamsteed's catalogue with Bayer's atlas. However, the puzzle of ν Cephei was solved: for star no. 2984 we have "10 Cephei ν", and Baily's note reads: "Flamsteed has erroneously annexed the letter ν to 15 Cephei, instead of this star, to which it properly belongs." The true 15 Cep is no. 3025. The corrections also were transferred to Baily's *British Association Star Catalogue* (BAC) of 1845, with positions for 1850. Herschel's Garnet Star is included (no. 7582), without any comment. It is interesting that this star is even featured in Alexander von Humboldt (1769–1859) in his monumental *Kosmos* (Humboldt, 1850), where it is called "Granat-stern" (Garnet Star), with a reference to Baily's BAC 7582.

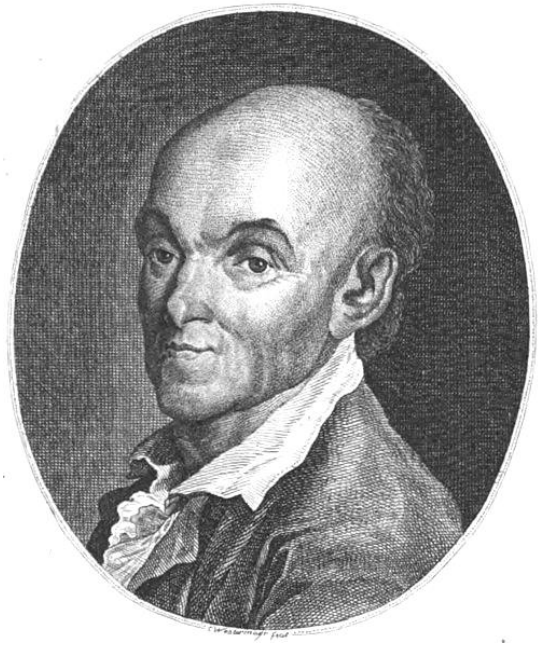


Figure 18: An engraving of Jerôme Lalande by Conrad Westermayr (en.wikipedia.org).

One would think that only the identification of the Garnet Star with μ Cep and the assignment of 13 Cep as a separate star were left, were it not for Argelander's account in his *Uranometria Nova* (1843). This catalogue and atlas contains all naked-eye stars with positions for 1840. During his zone observations he had noticed the "red star" in Cepheus, correctly identifying it with Piazzi's XXI P. 285. However, Bayer's μ Cephei is now placed at the position of 14 Cephei = XXI P. 385, while 13 Cephei is missing altogether! However, it also was Argelander who eventually would clear up the remaining puzzle some years later in his report on variable stars:

> I now come to the star P. XXI. 285, Garnet sidus, to which the elder Herschel first called attention, due to the deep garnet colour and because he thought it to be new. This is a mistake, for, on the contrary, it is known a very long time, namely 1 informium circa Cepheum in the Almagest. Reducing the position for 1800 … one gets AR 324° 38′, Decl. +57° 51′ in close agreement with Piazzi … only Flamsteed deviates … The star is definitely Bayer's μ Cephei, and only his slightly wrong plot of the position had induced me to take 14 Fl. [14 Cephei] for μ. (Argelander, 1849).

This also implies that 13 Cep is a different star.

From this date on, all of these stars in Cepheus are correctly designated. Argelander's *Bonner Durchmusterung* lists all six stars shown here in Table 1 with precise positions for 1855, but no identifications are given (Argelander, 1859). An example of correct naming is the *Catalogus Stellarum* of Eduard Heis (1872) with positions for 1855. The first to identity the Garnet Star with μ Cephei is Chambers in his 1861 *Handbook*: "μ Cephei, Sir W. Herschel 1782." Being familiar with astronomical literature, he obviously knew Argelander's result. All later catalogues of variable or red stars—except for Schjellerup (1866) with "W. Herschel's *Granatstern*"—followed this view.

4 THE FIRST PUBLISHED CATALOGUES OF RED STARS AND HIND'S DISCOVERY

The earliest published compilation of red stars is by Jérôme Lalande (Figure 18; 1804) and contains 33 "Étoiles rouges" (Figure 19). The table gives AR and zenith distance for 1800; to get the PD one has to combine this with the latitude of Paris (41.2°). Lalande found these red stars during his observations for the *Histoire Céleste Française* (1801). Subsequently, his list was reprinted by Baron von Zach (1822b) in his *Correspondence Astronomique*.

John Frederick William Herschel (1792–1871; Figure 20) is the author of the second published catalogue of red stars, listing 76 objects. It is based on his observations at Slough and the Cape of Good Hope, covering the northern and southern skies, respectively. The table appears as Appendix D in his tome *Astronomical Observations* (1847), and is headed "Approximate places of seventy-six ruby coloured, or very intensively red, insulated stars, noticed in the course of observation, in either hemisphere." It gives position for 1830, magnitude and a des-

Figure 20: A photograph of Sir John Herschel taken by Julia Margaret Cameron in April 1867 and now in the Metropolitan Museum of Art in New York (en.wikipedia.org.).

TABLE des Étoiles rouges.

ASC. DR.	DISTANCE AU ZÉNIT.		ASC. DR.	DISTANCE AU ZÉNIT.	
2h 23′	72d 12′	Midi.	12h 34′	2d 17′	
3. 40.	11. 31.	Nord.	13. 7.	71. 0.	
4. 41.	34. 58.	Midi.	13. 16.	60. 29.	68 ν Vierge.
4. 43.	46. 38.	5 Orion.	14. 7.	31. 32.	
4. 44.	41. 23.		14. 22.	17. 32.	25 ρ Bouvier.
4. 54.	47. 56.		14. 25.	11. 17.	
5. 19.	50. 4.	31 Orion.	19. 0.	24. 57.	
5. 20.	30. 22.	119 Taureau.	20. 5.	70. 42.	
5. 44.	2. 56.	35 π Cocher.	20. 15.	77. 40.	
6. 22.	10. 13.		21. 7.	10. 21.	Nord.
6. 58.	60. 26.		21. 35.	51. 57.	
8. 44.	30. 49.		21. 37.	28. 48.	Nord.
8. 58.	17. 2.		22. 49.	75. 1.	
10. 0.	56. 13.		22. 56.	40. 34.	1 Pégase.
10. 28.	61. 7.		23. 36.	46. 27.	
10. 41.	68. 57.	Bien rouge.	12. 28.	79. 41.	Un peu terne.
11. 7.	14. 37.	54 ζ Lion.			

Figure 19: Lalande's list of red stars. For 'Nord' the zenith distance must be taken as negative.

cription for each star (but no discovery date). Herschel uses the term 'ruby', but one object is described as 'garnet': an anonymous 9th magnitude star in Cassiopeia (no. 3). On 15 March 1834, during sweep 432, he discovered the reddest star in the sky: DY Crucis (no. 41):

> In the field of β Crucis. The fullest and deepest maroon red; the most intense blood red of any star I have seen. It is like a drop of blood, when contrasted with the whiteness of β Crucis.

The strongest rival to DY Crucis was found by Hind in October 1845. Using the 7-inch refractor at Bishop's Observatory, he discovered an extraordinary star in Lepus. However, he did not publish the find until April 1850 in the *Astronomische Nachrichten* #712. Hind reported on the "Position of a Scarlet Star between Orion & Eridanus" (Hind, 1850a). In the next issue (#713) he provided a little more detail: "I may mention also a remarkable crimson star in Lepus of about the 7th. magn. the most curious object I have seen." (Hind, 1850b). In a letter to William H. Smyth dated 14 January 1850 Hind wrote:

> … in October 1845, I remarked a most fiery or scarlet star on the confines of Lepus and Orion … This is by far the most deeply-coloured of any that I have yet seen, and in striking contrast with a beautifully white star preceding it one minute. (Smyth, 1864).

Another description reads:

> Of the most intense crimson, resembling a blood-drop on the blackground of the sky; as regards depth of colour, no other star visible in these latitudes could be compared to it. (Chambers, 1881: 121).

The unusual object is commonly known as 'Hind's Crimson Star'. It is variable (as discovered by Schmidt in 1855), has the designation R Lep; and m_v varies between 5.5 and 11.7 with a period of 427 days. Chambers (1865) wrote:

> Its light was of a very intense crimson colour, greatly surpassing in depth several of Sir J. Herschel's 'Ruby' stars, called by him 'intense', &c., and also Piazzi's garnet *sidus* in Cepheus.

5 A HERSCHEL CATALOGUE OF GARNET STARS

A thorough study of William Herschel's unpublished reports, impeccably edited by Caroline, recently revealed that Herschel's Garnet Star μ Cephei is not a singular case as there are more stars described as 'garnet'. The search produced surprising results.

Perhaps of greatest importance is the fact that the credit for the discovery of 'Hind's Crimson Star' must go to William Herschel! He discovered this object during sweep 365, on 4 February 1785, at about 7 p.m., from Datchet. At this time the star was 20° above the horizon, and Herschel noted: "A bright garnet star about 9 m. a most beautiful colour." (Herschel, W., 1784–1785). The position was determined relative to 60 Eridani, which was 2.7° to the southwest. There were no further observations, and this 'garnet star' was later referred to as U^{450} in his list of 'unknown' stars.

Another interesting object is known in the literature as 'Herschel's Ruby Star'. However, here 'Herschel' refers not to William but to his son, John. The star in question is no. 70 in his list, and as a variable star was later designated RT Capricorni. He found this beautiful object during sweep 298 on 22 February 1830, using the 18.25-inch reflector at Slough, and described it as "A fine ruby star. Pure ruby colour. This is perhaps the finest of my 'ruby stars'." (Herschel, J., 1847: 449). However, John Herschel was not the first to catalogue this star as Lalande observed it on 19 July 1795 and entered it as "étoile rouge" no. 25 in his list.

There are two more red stars observed by John Herschel that are interesting. No. 19 is the variable star BL Orionis, seen on 23 January 1832 during sweep 393 and described as "vivid red" (Herschel, J., 1830–1832). Two days later he saw no. 27 during sweep 395, writing: "Very fine red, between ruby and orange. Brick red." This was the variable star X Cancri.

In fact, John Herschel's 'ruby stars' RT Cap, BL Ori and X Cnc were all recorded earlier by William Herschel at Datchet. The first to be discovered was X Cnc, on 31 December 1782, with the 7-ft telescope, and Herschel (1782–1783a) noted in his report: "68 (·) [Cnc] 6 more [stars] one garnet towards δ [Cnc]." Alas, there is a problem with the magnitude of Flamsteed's 68 Cnc: Flamsteed lists it as 6 but Baily says 8, which is correct. Thus, most star catalogues omit this star. It is located about 5° east of δ Cnc. Right in between we find Herschel's garnet star X Cnc. RT Cap was discovered on 8 August 1784 during sweep 246, using the 18.7-inch reflector. At the time, Herschel (1784) noted: "A star of very deep, fine, garnet colour. 9 m." (U^{203}). Finally, BL Ori was seen on 15 October 1784 during sweep 293: "A most beautiful garnet coloured star. 8 m." (U^{327}; Herschel. W., 1784–1785).

At first sight it is remarkable that John Herschel was not aware of these discoveries made by his father, as he had access to all the records at Slough, but this can be explained. Caroline, his aunt, was the bookkeeper, managing the records, lists and catalogues, and making various copies, extracts and compilations. Obviously, John was fully dependent on this perfect bureaucracy, and largely benefitted from his aunt's activities. Perhaps the best example of this was

Caroline's "zone catalogue" of 1825, which listed all Herschel nebulae and clusters with positions for 1800 in zones of constant PD. This work 'won' her the Gold Medal of the Royal Astronomical Society in 1828, and John used it as the basis for his plan to reobserve the Herschel objects. Obviously, he did not need to inspect the original data, except for doubtful cases. At the Cape of Good Hope the situation was quite different, as here John had to concern himself with all tasks and was in full control.

Finally, let us look at 19 Piscium, another celebrated red star in the literature. This is Lalande's "étoile rouge" no. 32 and identical with the variable TX Psc. William Herschel saw it on 8 October 1785 (during sweep 461 at Clay Hall) as "deep orange red or pale garnet". This is the only case where the master was pre-empted, for the discovery credit goes to Tobias Mayer at the new Göttingen Observatory. This German astronomer observed the star on 14 September 1756, describing it as "rubicunda" (Zach, 1822a). 19 Psc also was seen by Piazzi (182 P. XXIII), who referred to it as a "Stella subrubei coloris".

An examination of William Herschel's records revealed 21 single stars that he called 'garnet' (see Table 3). For this task, Caroline Herschel's "Temporary Index", which lists "Coloured Stars", was helpful (Herschel, C., 1802: 29). Although some objects are called 'garnet', the compilation is not complete and sometimes differs from the observational records. For instance, Caroline

Table 3: A Herschel catalogue of garnet stars; 15 of the 21 objects were found in the sweeps (see text). Antares, though described as "pale garnet", is ignored here. Except for γ CMi, 6 Aur and 5 Lac, all of these stars are variable.

Star	V	B–V	Date	Ref	Sweep	Colour	U	Lal	JH	Schj	Birm	'Discoverer'	Name
o Ceti	6.5	1.1	1780, Sep. 8	F1, 74	280	rather garnet; garnet but not deep			8	19	40	W. Herschel 1780	Mira
γ CMi	4.3	1.4	1782, Feb. 9	F2, 189		fine garnet						W. Herschel 1782	
6 Aur	6.5	2.7	1782, Mar. 5	F2, 196		garnet					91	Birmingham 1876	
μ Cep	4.0	2.4	1782, Sep. 27	F2, 238	768; 875	very deep fine garnet; garnet colour	794			253	594	W. Herschel 1782	Herschel's Garnet Star
5 Lac	4.4	1.7	1782, Oct. 4	F3, 247		fine garnet					612	Birmingham 1876	
119 Tau	4.3	2.1	1782, Dec. 28	F3, 288		garnet		12		59	111	Lalande 1797	CE Tau
X Cnc	6.4	2.1	1782, Dec. 31	F4, 295		garnet			27	115	211	J. Herschel 1832	
W Ori	6.1	3.4	1784, Jan. 23		99; 526	claret coloured; garnet coloured	13	6		50	96	Lalande 1794	
RT Cap	8.9	4.0	1784, Aug. 8		246	very deep fine garnet colour	203	25	70	238	545	Lalande 1795	J. Herschel's Ruby Star
χ Cyg	4.4	1.8	1784, Sep. 6		258	beautiful garnet	220			232	518	Schmidt 1856	
BL Ori	6.0	2.3	1784, Oct. 15		293	most beautiful garnet coloured	327		19	74	144	J. Herschel 1832	
W CMa	6.6	2.4	1785, Jan. 31		363	deep garnet coloured	440	11		89	166	Lalande 1797	
R Lep	7.8	5.8	1785, Feb. 4		365	bright garnet...most beautiful colour	450			49	94	Hind 1845	Hind's Crimson Star
19 Psc	5.0	2.6	1785, Oct. 8		461	deep orange red or pale ganet		32		273	648	Mayer 1756	TX Psc
RY Mon	7.5	4.4	1786, Feb. 24		529	deep garnet colour	637			88	165	Bessel 1824	
U Hya	4.8	2.7	1786, Mar. 19		541; 997	deep garnet colour; very deep coloured ...almost garnet		15		132	242	Lalande 1798	
W Hya	7.7	1.3	1786, Mar. 28		550	deep garnet colour	657				313	Argelander 1851	
S Cep	7.4	4.7	1787, Oct.10		762	deepest and most brilliant garnet colour	787	29		250	588	Lalande 1789	
RY Dra	6.3	3.1	1790, Mar. 20		954	deep garnet colour	939			155 b	298	d'Arrest 1874	
V466 Per	8.1	4.0	1790, Dec. 28		989	very deep garnet colour	976					Espin 1895	
6 Gem	6.3	2.6	1792, Feb. 17	R5, 1		deep garnet					139	Birmingham 1876	BU Gem
V419 Cep	6.6	2.3	1794, Oct. 14		1060	very deep garnet colour	1040	27		247	579	Lalande 1797	

lists μ Cephei as "7 m. deep orrange [*sic*] & c. S[weep] 768", where the term "garnet" is missing Herschel (1814) himself gives the number of garnet and red stars found in the sweeps in his paper "Astronomical observations relating to the sidereal part of the heavens":

> In my sweeps are also recorded the places of 9 deep garnet, 5 bright garnet, and 10 red coloured stars, of various small magnitudes from the 7th to the 12th. (Herschel, W., 1814).

However, the current study lists 15 single garnet stars instead of Herschel's 14. Alas, he does not identify the stars, so the "10 red coloured stars" are not analysed here (Caroline mentions only 8, two of which were later catalogued by Birmingham). Also ignored are the 16 stars found as a component of a double or multiple system and described as "garnet". Among them is a pair with a red star and a garnet star, observed on 30 July 1780: VI 18 = v1 and v2 Coronae Borealis (m_v = 5.2 and 5.4, and separation 6').

Table 3 may be called the "Herschel Catalogue of Garnet Stars". The stars are sorted by discovery date. Columns 2 and 3 give the mean visual magnitude (most of the stars are variable) and the colour index. These data are from the SIMBAD (2015) database as available on the internet. The reddest stars have the largest B–V values (for a variable star B–V changes too and the value is highest at minimum brightness); Hind's Crimson Star (R Lep) reaches 5.8. Herschel's second reddest star is S Cephei with 4.7 (found during the northern sweep 762). Column Ref gives the number of the "Fixt star" folder (F plus page); R5 is "Review No. 5" (Herschel, W., 1792–1800). Next are the sweep numbers (three stars were seen twice; the date refers to the first sweep) and Herschel's colour description. Only eight stars were known to him (from the British Catalogue); unknown stars were later numbered (U). Lal, JH, Schj and Birm give the number in the lists of red stars by Lalande (1804), John Herschel (1847), Schjellerup (1866) and Birmingham (1877). The column titled 'Discoverer' names the astronomer credited with the discovery of the red star in the literature (plus the year). Of course, the Bayer and Flamsteed stars were already observed and catalogued earlier, but the colour was not recorded—or in most cases probably was not perceived with the naked eye or a small instrument. Indeed, for a fainter star a sufficient magnification is needed to detect the red colour (the eye is not very sensitive to faint red light). For his star reviews Herschel used magnifications of 227× and 460× (using the 7-ft), and in the sweeps the standard was 157× (with the large 20-ft telescope). The last column gives the common name or variable star designation.

Looking at the date, we see that μ Cephei was not Herschel's first 'garnet star'. This honour goes to o Ceti (Mira). On 8 September 1780 he noted:

> The colour was very remarkable being darker red (or rather garnet colour) than any I remember to have seen before among the fixt stars. (Herschel, W., 1775–1781: 74).

There are five more colour descriptions of Mira (Herschel, W., 1777–1810: 15–21): "garnet" (22 October 1781), "fine garnet" (21 August 1783), "garnet but not deep" (sweep 280, 20 September 1784) and "deep garnet colour" (2 December 1790). Meanwhile, John Herschel entered Mira in his list as "very fully ruby" (no. 8). Probably the redness of Mira was perceived by other observers, before William Herschel, but was not reported (Argelander, 1869: 320–326). Herschel's second garnet star, γ Canis Minoris, might be a similar case.

The first garnet star mentioned during a sweep is W Orionis, 7° west of the stars in the Belt. However, during the early sweep 99, performed on 23 January 1784 at Datchet, Herschel did not get a reliable PD. This was corrected in sweep 526 (on 22 February 1786). This star is no. 6 in Lalande's list. Herschel's last garnet star, the variable V419 in Cepheus, is also mentioned by Lalande (no. 27), and was found on 14 October 1794 (from Slough) during northern sweep 1060. Piazzi later noted: "Rubei coloris" (61 P. XXI).

Table 4, below, lists all important early catalogues of red stars.

6 TWO OTHER EXCEPTIONAL STARS

There are two other interesting discoveries, hidden in Herschel's handwritten observing notes, although the term 'garnet' is not used for these exceptional stars.

On 18 November 1781, shortly after "5^h in the evening", Herschel saw a red star. His note in Journal No. 3 sounds cryptic: "the trefoil is north

Table 4: Important early catalogues of red stars, including the new compilation of Herschel's garnet stars.

Author	Publ.	Objects	Number	Remarks
Herschel, W.	--	"garnet stars"	21	observations 1780–1794, northern sky
Lalande	1804	"Étoiles rouges"	33	obervations 1793–1798, northern sky
Herschel, J.	1847	"ruby stars"	76	observations 1827–1836, whole sky
Schjellerup	1866	"rothe, isolierte Sterne"	280	supplements 1866, 1874
Chambers	1867	"red stars"	293	
Birmingham	1877	"red stars"	713	observations
Chambers	1887	"red stars"	719	
Birmingham, Espin	1890	"red stars"	766	observations

following κ & colour reddish" (Herschel, W., 1781–1782a: 40). Fortunately, a later copy in "Fixt Stars No. 4" is more detailed:

> … in the trefoil near k Aquilae. The trefoil is north following, colour inclining to red. Too low for other observations and the colour not to be trusted to. (Herschel. W., 1781–1782b: 171).

What is this "trefoil near k Aquilae", and which "reddish star" is meant? The star 9 Aquilae (now η Scuti) was called 'k' by Flamsteed in the British Catalogue; it is labelled with this letter in the *Atlas Coelestis*; there is no 'k Aquilae' in Bayer's *Uranometria* (Baily, 1835: 622, note for no. 2552). Herschel used the term 'trefoil' for a triangle of stars with comparable magnitudes. The triangle north following k (i.e. to the north-east) is framed by 12 (i), 14 (g) and 16 (λ) Aquilae; a fourth star, 15 (h), lies between 14 and 16 (see Figure 21). Is there a red star in or near this asterism? Yes, there is a very remarkable exemplar: V Aquilae, one of the reddest stars in the sky! There is no doubt that Herschel saw this conspicuous object, even though the observation was difficult: at 5:30 p.m. the southern part of Aquila was about to set and the red star was only ~15° above the horizon.[5] Herschel never viewed this red star again.

Usually the discovery of V Aql is credited to Julius Schmidt (1872), but it has been shown (see Steinicke, 2011) that already Bessel had observed this red star in 1823 during his zone observations. William Herschel's observation is mentioned in Caroline's compilation under the heading "Low situations not proper observing the colours of stars" (Herschel, C., 1802: 29). There is no doubt that if he had been able to view it at a higher altitude Herschel would have applied the term 'deep garnet' to this very red star (which has a maximum visual magnitude of 6.9, and B–V = 4.3). V Aql was later catalogued as no. 222c by Schjellerup (1874) and no. 483 by Birmingham (1877).

Finally, we come to the remarkable red star, commonly known as 'La Superba'. The name was created by Angelo Secchi (1818–1878; Figure 22) and belongs to the variable star Y Canes Venatici, which is identical to Schjellerup 152 (Secchi, 1872; 1877). The Italian astronomer and pioneer of spectroscopy was fascinated by the strange spectrum, belonging to his rare spectral class IV (now called 'carbon stars'). 'La Superba' was Secchi's prototype. In the literature, Lalande is credited with the discovery; he observed this star on 3 April 1791 and entered it as no. 18 in his list of "étoiles rouges". However, three years

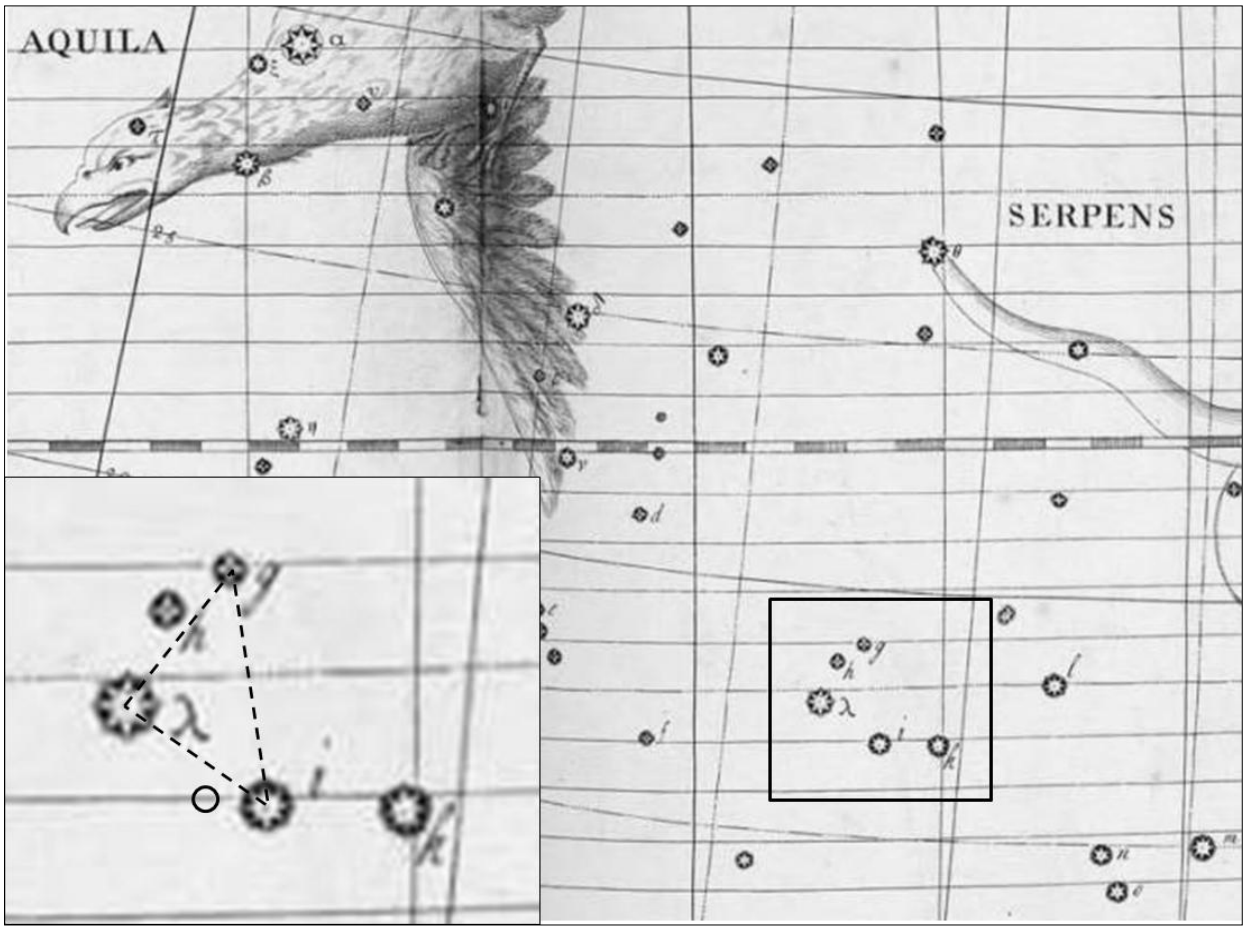


Figure 21: An extract from Flamsteed's *Atlas Coelestis* showing the southern Aquila with Herschel's trefoil northeast of *k* Aquilae. The circle in the inset marks the position of the red star V Aquilae.

earlier, on 27 April 1788, William Herschel discovered this object during sweep 833 at Slough, noting: "7 m. Deep red." It was later listed by Caroline as 'unknown star' U^{817}. Y CVn appears in Birmingham's catalogue as no. 290; the maximum visual magnitude is 4.9 and the B–V is 2.5. Herschel's catalogue contains three stars, later classified as spectral class IV by Secchi (1869): RT Cap, W CMa and U Hya. The stars μ Cep, Mira and X Cnc belong to class III (Betelgeuse type).

7 THE PHYSICAL NATURE OF RED STARS AND CRITICAL VOICES

Even though Herschel was more interested in nebulae and star clusters (see Steinicke, 2010), did his observations of red stars cause him to

Figure 22: Angelo Secchi (*Popular Science Monthly*, 1877–1878).

speculate about the physical reason for star colours? Although his experiments with heated metals and the detection of the Sun's infrared radiation would imply that he did, in fact there is little indication of this. Only in 1814 did he write:

> They [the stars] also, like the planets, shine with differently coloured light. That of Arcturus and Aldebaran for instance, is as different from the light of Sirius and Capella, as that of Mars and Saturn is from the light of Venus and Jupiter. A still greater variety of coloured starlight has already been shewn to exist in many double stars, such as γ Andromedae, β Cygni, and many more … By some experiments, on the light of a few of the stars of the first magnitude, made in 1798, by a prism applied to the eye-glasses of my reflectors, adjustable to any angle and to any direction, I had the following analyses. (Herschel, W., 1814).

A few remarks follow on the colour of the light from Sirius, Betelgeuse, Procyon, Arcturus and Vega, but there is no attempt to explain the associated physics, and he then turns to variable stars. However, at a much earlier date Herschel (1782b: 258–259) did mention the effect of atmospheric refraction on star colour: "The atmosphere will colour the stars." He also noted that especially at low elevations objects would appear redder. It would seem that to William Herschel the garnet stars were probably only a curious phenomenon.

Similarly, John Herschel did not remark on the physical nature of 'ruby stars' in his various publications. However, he discussed the case with Hind, who had written in a letter dated 6 September 1848 (one day after Hind announced the variability of Herschel's Garnet Star):

> … a very great proportion of the changeable stars I have discovered are red, in fact, I have learned to be suspicious of all ruddy stars. (Hind, 1848b).

Later, Argelander took over and developed the new field of variable star astronomy. But the physical explanation for the red star phenomenon had to wait for the development of astrophysics. Secchi was a pioneer in this field, creating an innovative spectral classification (Hearnshaw, 2014). But from the observational point of view, the case was still open around 1880 (for a review on the history of carbon stars see McCarthy, 1994). However, the strong connection between red and variable stars was accepted. In 1877, the British astronomer, John Birmingham wrote:

> The Red Stars must be considered as a class of heavenly bodies particularly worthy of attention; for not alone, as compared with the other stars, do they seem to differ most widely in constitution from our own sun, but they show a peculiar inclination to periodic change, while some of the most noted Variables are found amongst them … The redness of a star has given rise to the singular conceit that it shows a cooling down, or, as we might say, an approach to a final snuffing out of the luminary; but one might think that the fact of periodic variation of tint in many of the Red Stars ought to go far in disproving this proposition. (Birmingham, 1877: 249).

Another point was the visual redness of the stars. Birmingham commented on this, referring to eminent observers:

> It has been well remarked by Schmidt that no stars have been found of a perfectly red, or blood colour, such as may be seen in the solar protuberances: even stars like the "crimson" in Lepus, or Herschel's "garnet star," are no exceptions; and the reddest star that we see still shows a mixture of yellow. This perfectly agrees with my own observations; and in stars even described by myself as deep red, I must

be understood to use the term only in a conventional sense and in comparison with the other stars classified along with them.

One example is his find of 22 May 1881, using a 4.5-inch Cooke refractor: the "deep red or crimson star" V Cygni, 2.8° north of Deneb (Birmingham, 1881). This star is variable with a visual magnitude of 7.7 at maximum and an exceptional B–V value of 6.4 (at minimum). Even though William Herschel scanned the region on 27 September 1788 (during sweep 866), he missed this star.

Birmingham also mentions Wilhelm Struve, who had doubted the redness of several double star components observed by William Herschel. Birmingham lists 13 examples, where Herschel attributed a red colour but Struve saw a white star. Struve speculated that the reason might be the telescope that Herschel used: speculum mirror reflectors "… as is well known had a reddening tendency." But Birmingham was not convinced, and he presented various counter-examples (i.e. of stars seen as white by Herschel but redder by Struve).

Finally, it is historically interesting that William Herschel discovered many of the prominent red stars, and his celebrated 'Garnet Star', μ Cephei, was only the opener. It has been shown that the Herschel collection, as presented here, is the forerunner to the later catalogues, and that full credit for the master is long overdue!

8 NOTES

1. The term "diameter" means the size of the optical image in the eyepiece, which depends on the magnification.
2. All English translations from foreign sources are by the author.
3. "Tiaram Cephei praecedens" in this quotation means that the double star precedes the crown of Cepheus.
4. In fact, the number of new double stars might have been 16 according to a note in Caroline's double star compilation (Herschel, W., 1784–1802).
5. This was Herschel's second object of two seen during this observing session. The first was 17 Draconis (a double star that he found on 8 August 1780). Thus, starting at 5 p.m., he turned his telescope from Draco to southern Aquila, 66° across the sky!

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