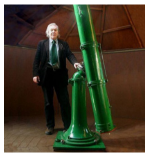



Occasional Notes

No. 4 An Independent Miscellany of Astronomy 2 July 2019

Correspondence of scientists is often dominated by discussion of their work, but it can also reveal aspects of their social lives and relationships. The following brief extracts, for example, provide a glimpse of rural life in the mid-nineteenth century – at least on the border of Kent and Sussex.

In 1840 Sir John Herschel and his family moved to their new home, Collingwood, near Hawkhurst, Kent (see *Occasional Notes* No. 1). On 2 August 1841, Caroline Herschel, who had returned to Hanover after the death of her brother William in 1822, wrote to Lady Margaret: 'I could wish to know something more about the place where you now are. How many miles is Collingwood from London? How many from Hastings? Have you any good people or neighbours about you? I think I read in Watson's Gazetteer, Hawkhurst to be full of poor, and, what is worse, of smugglers. Pray take care of the dear boys and children, that they are not kidnapped in their little rambles from home.' In complete contrast, she added: 'On Sunday I was even honoured with a visit from the Duchess of Anhalt Dessau and the Princess of Rudolstadt, who remained a whole hour with me. They are both daughters of the late Queen.'

Soon afterwards, William Rutter Dawes, on ending his tenure at George Bishop's observatory in Regent's Park, London, sought a new residence, and on 13 January 1844 he wrote to Sir John: 'It is probable that the house at Burwash may have something peculiarly ineligible about it; for though a good-size house, with coach-house stabling, and about an acre of walled garden ground, it is offered to me on lease at only £20 pr ann. But from what you say of Burwash I should fear to venture on that neighbourhood.' He therefore declined this offer, and instead leased a property near Cranbrook, close to Hawkhurst.

Bob Marriott

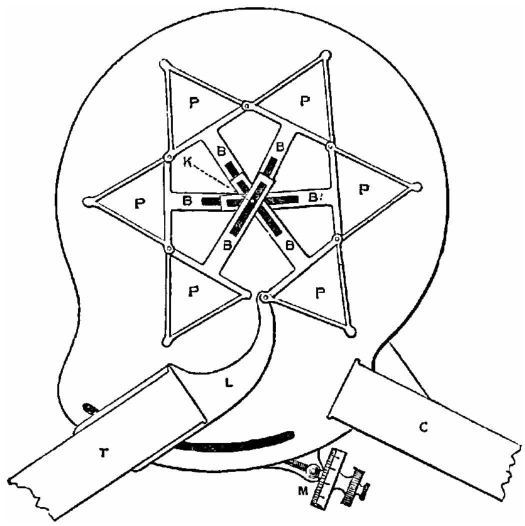
A spectroscope by Browning

At the meeting of the British Assocation for the Advancement of Science held in Liverpool in September 1870, John Browning presented a short paper with the lengthy title 'On a spectroscope in which the prisms are automatically adjusted for the minimum angle of deviation for the particular ray under examination'. The following is the full text.

In spectroscopes of ordinary construction, when several prisms are employed, a great deficiency of light will be noticed towards the more refrangible end of the spectrum. This arises from the fact that the prisms are adjusted to the minimum angle of deviation for the most luminous rays, which are near the other end of the spectrum.

The diagram shows the method in which the change in the adjustment of the prisms to the minimum angle of deviation for each particular ray is made automatically. In this diagram P, P, &c. represent prisms. All these prisms, with the exception of the first, are unattached to the plate on which they stand – the triangular stand, on which the prisms are hinged together at the angles corresponding to those at the bases of the prisms; to each of these bases is attached a bar B, perpendicular to the base of the prism. As all these bars are slotted, and run on a common centre, the prisms are brought into a circle. This central pivot is attached to a dovetail piece, two or three inches in length, placed on the underside of the main plate of the spectroscope, which is slotted to allow it to pass through. On moving the central pivot the whole of the prisms are moved, each to a different amount, in proportion to its distance in the train from the first or fixed prism, on which the light from the slit falls after passing through the collimator C. Thus, supposing the first prism of the train from C, represented in the diagram, to be stationary, and the second prism to have been moved through 1° by this arrangement, then the third prism will have moved through 2°, the fourth through 3°, the fifth through 4°, and the sixth through 5°. As these bars are at right angles to the bases of the prisms, and all of them pass through a common centre, it is evident that the bases of the prisms are at all times tangents to a common circle.

Now for the contrivance by which this arrangement is made automatic. A lever L is attached to the corner of the triangular plate of the last prism; this lever, by its further end, is attached to the support which carries the telescope through which the spectrum is observed. Both the telescope and lever are driven by the micrometer-screw M. The action



of the lever is so adjusted that, when the telescope is moved through any angle, it causes the last prism to turn through double that angle. The rays which issue from the centre of the last prism are thus made to fall perpendicularly upon the centre of the object-glass of the telescope T; and thus the ray of light travels parallel to the bases of the several prisms, and ultimately along the optical axis of the telescope itself, and thereby the whole field of the object-glass is filled with light. Thus the apparatus is so arranged that, on turning the micrometer-screw so as to make a line in the spectrum coincide with the cross wires in the eyepiece of the telescope, the lever L, attached to the telescope and prisms, sets the whole of the prisms in motion, and adjusts them to the minimum angle of deviation for that portion of the spectrum.

The 1876 edition of Browning's *A Plea for Reflectors* carries advertisements for two versions of

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this automatic solar spectroscope. The larger version, for use with reflectors or refractors of 6 inches to 12 inches in aperture, was priced at £42 10s, and the lighter version, for use with telescopes as small as 3 inches in aperture, was priced at £28. (For the current equivalent, multiply the prices by 100.)

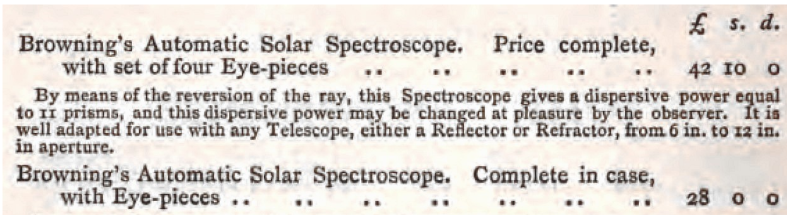
I have used one of these instruments, though of a variant design, to observe solar prominences, in the same way that Norman Lockyer and Jules Janssen independently observed solar prominences without an eclipse after the Indian eclipse of 1868. Indeed, Lockyer used a spectroscope of this type specially made for him by Browning.

In the instrument that I have used, the light passes through the slit and the collimating lens to a reflecting prism, where it is directed into the train and passes through six dispersing prisms. It is then returned by a second internally reflecting prism and again passes through the dispersing prisms, with the last dispersion cancelled by refraction through the first internally reflecting prism through which the light passes to the small viewing telescope. This effective eleven-prism dispersion produces a very long continuum, though only a small part of it is viewable at one time.

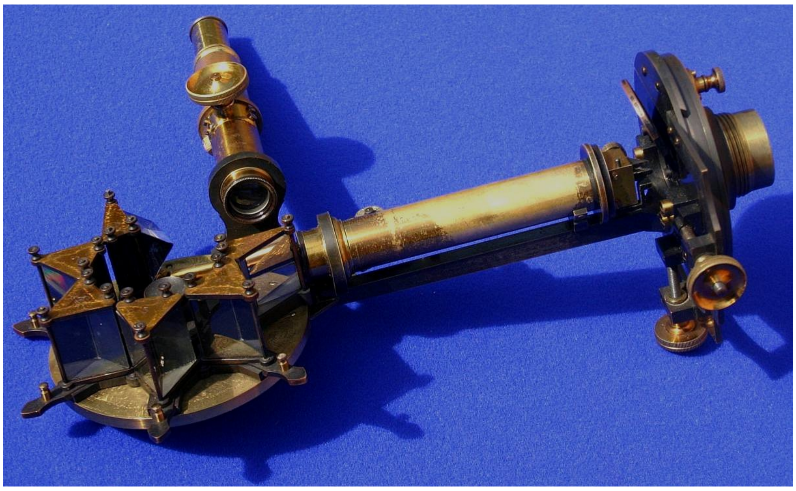
Observing the solar spectrum, awash with absorption lines, is simply a matter of pointing the telescope towards the Sun and adjusting the slit and focus of the spectroscope. The observation of prominences and other phenomena, however, is a more complex affair, and continual adjustments to the spectroscope and the telescope are necessary. The telescope drive is normally set at sidereal rate, not solar rate, and so the rate must be altered otherwise slow-motion adjustments are necessary; the image of the Sun must be perfectly focused on the spectroscope's slit, which must be kept at a tangent to the solar limb (the entire spectroscope can be moved laterally in two axes at right angles); the slit of the spectroscope must be opened to allow enough light through, but be set narrow enough to produce the thinnest possible absorption lines without loss of light or degradation of image; the relative positions of the prisms require adjustment to observe different parts of the spectrum, though they are interconnected and one screw moves all of them; the spectroscope eyepiece must be focused independent of the telescope focus, not only on the spectrum but also on the solar limb; and, due to the positioning of the spectroscope's various adjusting screws, the instrument is not encased, and there is the added task of enveiling it with black opaque cloth to exclude extraneous light while at the same time retaining access to the adjusting screws and the eyepiece. And, of course, the Sun is responsible for the high temperatures which are incompatible with frustration.

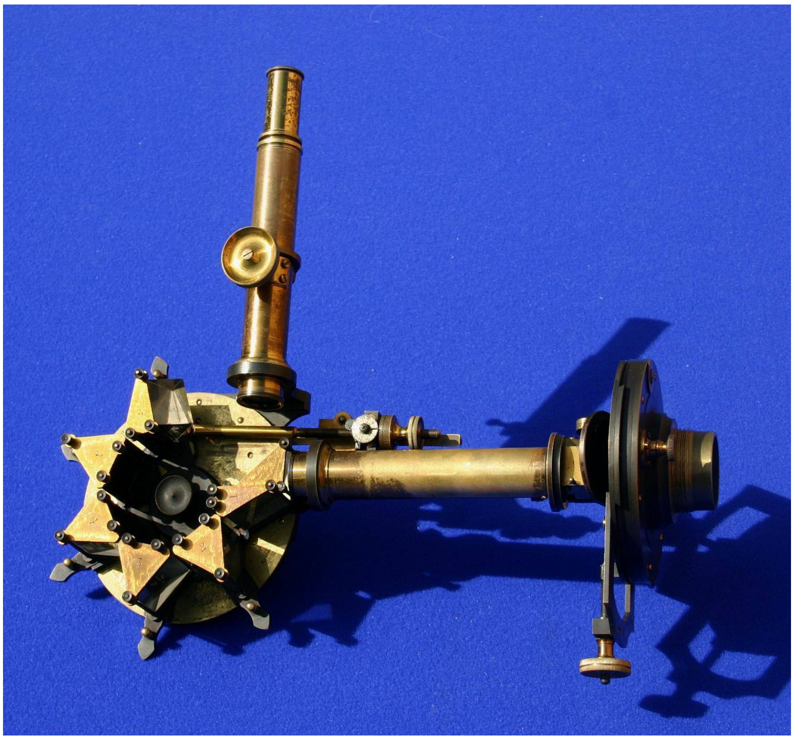
When all requirements are met, the results are impressive. The limb of the Sun quivers along the continuum, while the absorption lines occasionally and momentarily transform into the emission lines of the solar chromosphere – not at the edge of vision, but as a brilliant metamorphosis, with brief glimpses of absorption lines and emission lines side by side along the continuum. When observed during a total solar eclipse, this transformation is referred to as the 'flash spectrum', appearing for less than a second or so when the photosphere is obscured and the chromosphere is visible.

The accompanying spectra in the green and blue were obtained with a digital camera held against the eyepiece, but are an inferior representation of what can be seen by direct visual observation: thousands of sharply focused lines in a continuum of pure colours from far red to deep violet.



	£	s.	d.
Browning's Automatic Solar Spectroscope. Price complete, with set of four Eye-pieces	42	10	0
By means of the reversion of the ray, this Spectroscope gives a dispersive power equal to 11 prisms, and this dispersive power may be changed at pleasure by the observer. It is well adapted for use with any Telescope, either a Reflector or Refractor, from 6 in. to 12 in. in aperture.			
Browning's Automatic Solar Spectroscope. Complete in case, with Eye-pieces	28	0	0





Double and multiple stars in Hercules

Each of the systems included here is described with an extract from W. H. Smyth's Bedford Catalogue – the second volume of *A Cycle of Celestial Objects*, published in 1844 (see *Occasional Notes* No. 2) – followed by an extract from S. W. Burnham's *A General Catalogue of Double Stars within 121° of the North Pole* – a massive work of two volumes published by the Carnegie Institution of Washington in 1906. By incorporating results obtained since that time, current observations can be compared with measures accrued over a period of 240 years. Magnitudes of the components range from 3 to 13, separations range from 0".3 to 115", some of them are stationary, others have been tracked through their orbits, and one of them has an orbital period of only about 34 years. F. G. W. Struve's numbers were first assigned in the 1820s and were commonly used after the publication of his *Mensurae Micrometricae* in St Petersburg in 1837. They are still familar, and are therefore included in this summary list where appropriate. The approximate Right Ascension and Declination of each system is for epoch 2020.00:

		RA	Dec
κ^1 Herculis	Σ2010	16h 09m	17° 00'
γ Herculis	—	16h 23m	19° 05'
23 Herculis	—	16h 24m	32° 16'
42 Herculis	Σ2082	16h 39m	48° 54'
ζ Herculis	Σ2084	16h 42m	31° 33'
η Herculis	Σ2093 *rej*.	16h 43m	38° 54'
43 Herculis	—	16h 46m	08° 33'
46 Herculis	Σ2095	16h 46m	28° 20'
56 Herculis	Σ2110 *rej*.	16h 55m	25° 41'
60 Herculis	—	17h 06m	12° 44'
α Herculis	Σ2140	17h 15m	14° 22'
δ Herculis	Σ3127	17h 15m	24° 50'
ρ Herculis	Σ2161	17h 24m	37° 08'
μ Herculis	Σ2220	17h 47m	27° 45'
300 P. XVII Herculis	Σ2245	17h 57m	18° 20'
95 Herculis	Σ2264	18h 02m	21° 37'
100 Herculis	Σ2280	18h 08m	26° 07'

In the nineteenth century, Right Ascension was often designated AR (as by Smyth), and North Polar Distance, commonly specified in catalogues and ephemera, was eventually replaced by Declination. Observers were cited by Smyth and Burnham with the following abbreviations:

A	Friedrich Argelander	H	John Herschel
Ai	Robert Aitken	Hl	Asaph Hall
β	S. W. Burnham	Ho	G. W. Hough
B	Francis Baily	HΣ	Hermann Struve
Br	Carlo Brioschi	Hu	W. J. Hussey
Com	George Comstock	Je	Jan Jędrzejewicz
Δ	Ercole Dembowski	OΣ	Otto Struve
Da	William R. Dawes	P	Giuseppe Piazzi
Do	W. A. Doberck	Per	Henri Perrotin
Doo	Eric Doolittle	Σ	Wilhelm Struve
Gla	Sergey Glazenap	S	James South
♅	William Herschel	Sp	Giovanni Schiaparelli

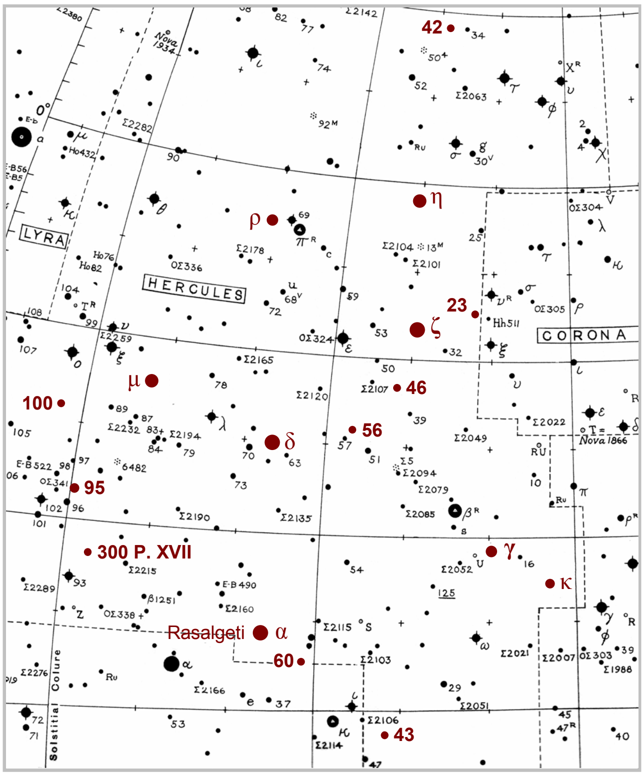
Classically and pictorially, Hercules is upside down, so in Smyth's descriptions the 'hero's left elbow' is south-west, and the 'left thigh' is north-west.

κ^1 Herculis

Smyth

Position 9°.7 Distance 31".4 Epoch 1835.45

A neat double star, on the hero's left elbow; about 30° distant from Wega, in the west-south-west, where it is nearly midway between γ Herculis and β Serpentis. A 5½, light yellow;



B 7, pale garnet, being κ^2 of Piazzi, No. 285, Hora XV. This object is 8 ♅ V, and its measures, at the epochs previous to my observations, are thus registered, including deductions from the ARs and Decs, of the Palermo Catalogue:

♅	Pos. 10° 23'	Dist. 39".98	Ep. 1779.72
P	13° 12'	32".70	1800.00
H and S	9° 35'	31".17	1821.39
Σ	9° 35'	31".21	1832.60

These results, compared with my own, afford strong presumption that the angle of position has remained stationary. There may, however, have been a diminution of distance, especially if the operations of Flamsteed, 132 years before mine, are to be relied on. From M. Argelander, under the able discussion of Professor Struve, the interesting details of this question are:

Pos. 14° 35' Dist. 56".48 Ep. 1703.31

Struve, however, doubts the decrease of distance in so large a ratio. Future observers must decide this point; meantime the near coincidence of direction in the proper motions may be noted:

A	κ^1	AR –0".09	Dec. –0".01
	κ^2	–0".12	–0".21
B	κ^1	–0".75	–0".00
	κ^2	–0".02	–0".01

Burnham

A slight change in distance from proper motion. The movement of the large star 0".088 in 262°.8 (Auwers).

1840.88	9°.4	31".15	OΣ
1850.12	10°.2	30".09	OΣ
1858.12	9°.9	30".52	Δ
1867.12	9°.9	30".36	Δ
1872.91	10°.7	30".18	OΣ
1877.01	10°.2	30".10	Je
1879.09	10°.5	30".18	OΣ
1885.34	10°.5	30".02	Per
1890.40	9°.7	29".88	Gla
1898.47	11°.2	29".66	Doo

γ Herculis

Smyth

An open double star in a dark field, on the hero's left arm. A 3½, silvery white; B 10, lilac; and it points nearly upon a third star at a distance in the *sp* quadrant. This is 19 ♅ V, and when discovered was thus registered:

Pos. 250º 30' Dist. 41".81 Ep. 1780.68

It was then examined by H and S, with these results:

Pos. 243º 46' Dist. 38".32 Ep. 1821.85

Their apparent angular retrogression and diminution of distance here observable in a period of forty-one years, were not confused by my observations; and as the object is difficult under the micrometer, the discrepancies may be imputed to errors in the first observation. γ Herculis is a portion of the *Nasak shámí*, or northern boundary wall of the Arabian garden, described by Kazwíní. It may be readily seen in the mid-distance of a line produced between Rasalague and Gemma, passing also over Rasalgeti. An almost imperceptible movement in space is attributed to γ, of which the following are the most accurately investigated values:

P	AR –0".04	Dec. +0".09
B	–0".02	+0".05

Burnham

The principal star has a small proper motion:

Auwers	0".083 in 308º.6
Rechenberg	0".080 in 305º.3
Measures of B	0".066 in 340º.3

The last value is derived from the five sets of measures of the companion by OΣ, Δ, Doo, and β.

1782.82	249º.0	39".45	♅
1844.09	242º.0	40".36	OΣ
1874.15	238º.8	40".51	Δ
1875.55	239º.6	40".49	OΣ
1897.38	236º.9	41".09	Doo
1903.40	236º.8	40".98	β

23 Herculis

Smyth

Position 20º.1 Distance 36".2 Epoch 1830.72

A double star in a dark field, on the boundary between Hercules and the Northern Crown; it is 1º½ distant from the preceding object [v Coronae Borealis], a little to the eastward of south. A 6, white; B 9, violet; a star at a distance in the *sp*, and another nearly following. This is 38 ♅ V, the 'largest of a telescopic triangle'; it was first noticed in September, 1781, when 36".48 was given as a 'rather narrow distance', and no angle was registered. It was first measured by Sir James South, as follows, but is erroneously entered in his Catalogue as 88 ♅ V:

Pos. 20º 22' Dist. 36".84 Ep. 1825.46

Burnham

The large star has a very small proper motion, 0".020 in 146º.2 (Auwers). The following are the measures since 1783:

1825.46	20º.4	36".84	S
1840.58	19º.7	36".20	OΣ
1874.59	18º.9	34".90	Δ
1875.55	18º.6	35".09	OΣ
1885.80	18º.6	34".57	Franz
1904.54	17º.9	34".11	β

42 Herculis

Smyth

Position 93º.5 Distance 20".0 Epoch 1835.57

A very delicate triple star between the left knee of Hercules and Draco's head, of which only the two forming 63 ♅ IV, are here measured. A 6, orange; B 12, blue; the third star, which is still more minute, makes a neat triangle of the object, in a rich field; and it may be found to the west-south-west of β Draconis, at 6º½ distance: the small components are caught by averting the eye to other parts of the field of view. These are preceded by a 7th-magnitude star on an angle of 211º and 4' 20" distant. A comparison of the above results with the former measures, indicates fixity:

♅	Pos. 93º 42'	Dist. 21".52	Ep. 1782.61
Σ	92º 21'	22".39	1828.43

Burnham

Very little change, but common proper motion.

Auwers	0".023 in 335º.0
Battermann	0".047 in 301º.9

1866.35	91º.9	22".73	Δ
1874.67	91º.3	22".76	OΣ
1900.71	91º.1	23".74	Espin
1905.54	92º.2	23".69	β

ζ Herculis

Smyth

Position 190º.0	Distance 0".5	Epoch 1835.68
176º.3	0".7	1836.73
169º.0	1".2	1838.65
136º.9	1".2	1842.57

A close binary star, over the left hip of Hercules, where with ε, its companion in magnitude, it is rather conspicuous between Wega and Gemma. A 3, yellowish white; B 6, orange tint; a third star of the 9th magnitude in the *nf* quadrant, with Δ AR 23s.6. This wondrous object is 72 ♅ I, and as everything connected with its movements is most important, I may cite the following values for its proper motion in space:

P	AR –0".70	Dec. +0".47
B	–0".45	+0".43
A	–0".47	+0".38

The duplicity of ζ Herculis was first detected under the eagle-gaze of Sir William Herschel, in July, 1782. In October, 1795, he again beheld the *comes*, but it afterwards disappeared, or, under the most delicate treatment, was only wedged; and the able astronomer remarked: 'My observations of this star furnish us with a phenomenon which is new in astronomy; it is the occultation of one star by another. This epoch, whatever be the cause of it, will be equally remarkable, whether owing to solar parallax, proper motion, or motion in an orbit whose plane is nearly coincident with the visual ray.' In this state it remained unobserved for some years; and during 1821, 1822, 1823, and 1825, baffled all the endeavours of H and S to divide, or even elongate. At length Σ caught it double in 1826, though it again became single in two years, and remained so to the Dorpat instrument till 1832, when that persevering observer again measured it. It has since become comparatively of easy vision, for when my friend, the Rev W. R. Dawes, sent me his results, he informed me that, in 1840, he saw both the stars yellow; and that with a magnifying power of 400, they were readily separable with his 5-foot telescope. The several epochs of comparison with my results, by which the *np sf* direction, or retrograde ellipticity of movement, is proved, may be thus given:

♅	Pos. 69º 18'	Dist. 1".00±	Ep. 1782.55
		Single	1802
Σ	23º 24'	0".91	1826.63
		Single	1828.77
	222º 30'	0".81	1832.75

In addition to these published observations, Mr Dawes has obligingly furnished me with the results obtained by him during my residence at Cardiff, which afford beautiful corroborations of the indicated movement; and a momentous hiatus in the new series of angles is filled up:

Pos. 161º 55'	Dist. 1".221	Ep. 1839.758
150º 40'	1".230	1840.655
142º 58'	1".239	1841.651

On the erection of the large telescope at Bedford, this was one of the first objects of my attention; but from Professor Struve's description – 'Magnitudinis constanter notari (3) et (7), colorem majoris album subflavum, minoris subrubrum. Difficultas in stella hac duplici videnda ex splendore oritur majoris' – I did not expect to notch it. Following ♅'s method, I first got my eye and instrument into order by scrutinizing η Coronae; and then turning upon ζ Herculis, felt confident that I saw, and that readily, a red spot on its disc, which, from the above-quoted words, I took for the *comes*. It may, however, have been a spurious image or colour; for on the following apparition of Hercules, in 1831, wishing to show the same phenomenon to Captain Kater and Mr Maclear, I could no longer receive the same impression. But notwithstanding this disappointment, I watched it occasionally under various powers; and, at length, in 1835, became satisfied that it was positively elongated towards the vertical, and at times could trace the deeper-coloured point of the wedge upwards, or towards the south, in an inverted field of view. But all attempts to notch it failed till the summer of 1838, when, though still deserving of Σ's epithet *vicinissimae*, the distance had palpably increased, and the stars were occasionally fairly divorced. As the question was of deep interest, unusual pains were taken with the measures, although, from the difficulty of observation, they could not be stamped with high weights. Indeed, all the evils of a double-wire micrometer had to be encountered; and what with the necessity of using great magnifying powers upon an object, the components of which were so close as occasionally to flow into each other, there were the threads hanging, dragging, and fiddling, proving by jerks, imperceptible under most objects, the inaccuracies of the screw. And yet my micrometer is among the very best of the age; and my telescope was smoothly carried by the equatoreal clock, which had been put into excellent gear. At the last epoch, the stars had widened, and were much less fatiguing to observe; the weights are therefore given with a greater degree of confidence than heretofore. This wonderful object ought to be narrowly looked after by all the new giant telescopes, since it offers, according to Σ's conclusions, the astounding velocity of an apparent and very elliptical orbit revolving in little more than fourteen years! What a motion! Bacon little knew the force of his own expression, when he exclaimed, 'Heavenly bodies have much veneration, but no rest.' My own views, however, do not quite square with this velocity, although they acknowledge one about as astonishing: a scrutiny of the observations leads me to suppose an orbit with an excentricity of 0.4186, and a period of about thirty-five years. This, of course, concludes rather more than one entire revolution to have occurred, between ♅'s epoch of 1782 and Σ's result in 1826.

Burnham

One of the most rapid of the Struve binaries. As more than two revolutions have been made since his first measures, the orbit is fairly well determined. Large proper motion:

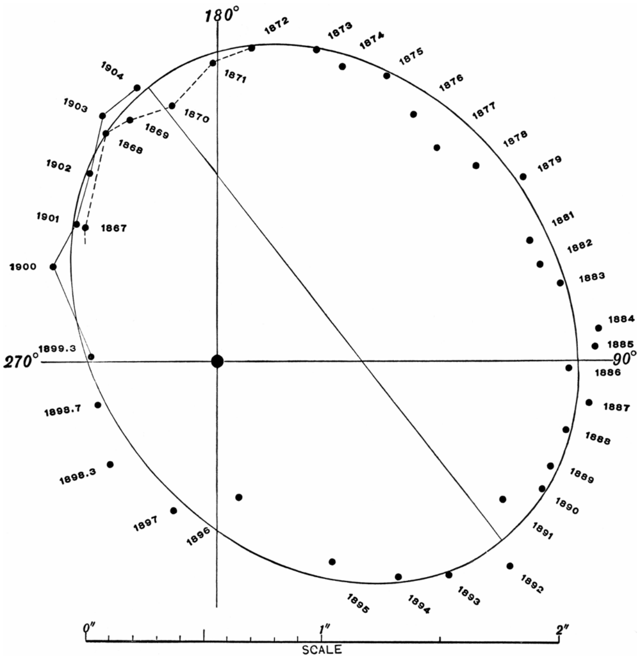
Auwers	0".614 in 311º.0
Bossert	0".615 in 311º.8

The following orbits have been published:

1838	Mädler	36.34 y.	*A.N.* 363
1842	Mädler	31.47	*Dorpat Obsns.* 9, 192
1847	Mädler	30.21	*Fixtern-System* 1, 267
1847	Villarceau	36.36	*A.N.* 668
1853	Fletcher	37.21	*Mem. R.A.S.* 22, 185
1854	Villarceau	36.71	*Comp. Rend.* 38, 218, 869
1867	Reuss	35.30	*Bul. Ass. de France* 1867
1869	Dunér	34.22	*A.N.* 1868
1869	Plummer	36.60	*Mon. Not.* 31, 195
1874	Flammarion	34.58	*A.N.* 1998
1880	Doberck	34.41	*A.N.* 2332
1895	See	35.00	*Evol. Stellar Systems*
1896	Doberck	34.53	*A.N.* 3448
1897	Doolittle	34.55	*A.J.* 460
1900	Lewis	32.40	*Mon. Not.* 61, 74

Many of the measures are more or less uncertain, and doubtless a better results would be found by the use of only the best material. The last revolution is shown on the diagram by thirty-eight yearly positions by some of the best observers, representing altogether measures on 294 nights.

1867	Δ	1896	Com, Lewis
1868	Δ, OΣ	1897	Ai
1869–75	Δ	1898.3	Ai
1876	Δ, H1	1898.7	Ai, Lewis, Bowyer
1877	Δ, H1	1899	Ai, Hu, Lewis
1878	Δ	1900	Ai, Lewis
1879–91	H1	1901	Ai, Lewis, Bryant
1892	Com	1902	Ai, Bryant
1891	Sp, Big	1903	Ai, Doo, Biesbroeck
1894	Lewis, Big, Barnard	1904	Lohse
1895	Com		



η Herculis

Smyth

Position AB round	Distance round	Epoch 1835.65
AC 265º.9	141".0	1835.65
AB 150º.0	0".3	1842.53

A bright star with a distant companion, on the left thigh of Hercules, and nearly in a line with the last two objects [M13 and ζ]. A 3, pale yellow; B, only inferred; C 10, dusky. The proper motion in space of the principal is thus valued:

P	AR –0".24	Dec. –0".09
B	+0".08	–0".07
A	+0".07	–0".07

Here A forms No. 2093 of the Dorpat Catalogue, and was described in 1827 as a first-class *vicinissimae*, like ζ Herculis and v Coronae; and its components were registered of the 4th and 8th magnitudes. Many were the efforts I made at distinguishing a proximate *comes*, but without effect; and when Σ's measures arrived in 1837, finding it was styled *simplex*, I relinquished the attack. Having, however, heard of its subsequent elongation, I re-examined it at Hartwell, and think I may safely give the above details, as tolerable estimations of an egg-shaped object. This star is sufficiently conspicuous to the north-east of Gemma, at about 16º distance; and it is also 19º from Wega, on its western parallel; it forms an equilateral triangle with its own ζ and π.

Burnham

The principal star was thought by Struve to be a very close pair, but afterwards rejected as single in *Mensurae Micrometricae*. Later it was measured by Mä who found from three accordant observations, 155º.7, 0".79 (1841.39). There seems now to be no doubt that the elongation measured was not real. I have examined this star many times at intervals during the past twenty years, with apertures from 6 to 40 inches without detecting the least sign of duplicity at any time. No elongation has been suspected by anyone except Mä since Σ, and there is no longer any reason for retaining it as a close pair. The proper motion is 0".079 in 161º.2 (Auwers). The distant star was measured with the 18½-inch. That instrument shows a fainter star in the same direction, and about two-thirds the distance.

1901.34	262º.2	114".27	β

43 Herculis

Smyth

Position 230º.7 Distance 79".5 Epoch 1832.59

A wide pair of stars, in the asterism of Hercules, but on the shoulder of Serpentarius; it is south-west of Rasalgeti, at 8º½ distance. A 5, rose tint; B 9, light blue; a third and very minute glimpse-star in the *nf* quadrant. This object is 116 ♅ VI, and not 41 ♅ III. Under the latter head I should have concluded Sir William Herschel to have meant A, and the point of light in the *nf*, but that he has registered the components 'both equal'; from which, and the result of the measures, it seems evident that 100 Herculis was the star observed in 1781, by Mr Bryant, of Bath. The mistake occasioned this object to be placed on the working lists, and secured its being well attended to; and the following are the previous results:

♅	Pos. 231º 12'	Dist. 74".62	Ep. 1783.44
Σ	230º 18'	83".70	1819.63
H and S	230º 51'	80".09	1821.42

Burnham

There is no sensible change in the angle, but the distance is slowly increasing. The proper motion of the principal star from meridian positions is 0".050 in 335º.7 (Auwers). The measures of B give 0".023.

1852.55	230º.6	81".90	OΣ
1868.88	230º.3	82".28	Δ
1879.27	230º.5	82".71	Doubiago
1903.40	229º.9	82".51	β

46 Herculis

Smyth

Position 163º.8 Distance 5".1 Epoch 1834.50

A neat double star, on the hero's back, and 7º distant north-by-east from β. A 7½, pale white; B10, sky blue. This fine object is 79 ♅ I, and from its class would seem to have been closer at its discovery than it is now; whilst the interval between the discs, as estimated by ♅, cannot be assumed at more than 2".5. When S measured it, an inference was drawn that the distance had increased materially; and there were symptoms of an angular movement also. The great coincidence, however, between S, Σ, and myself, invalidates the conjecture, and stamps the fixity of both stars; these are the results for comparison:

♅	Pos. 156º 36'	Dist. 2".50±	Ep. 1783.10
S	163º 51'	5".39	1825.05
Σ	163º 56'	4".96	1830.57

The investigations for the proper motions of this star, assign an almost imperceptible amount to the AR; but they are unanimous in giving it none in declination. The next rigid series of meridional observations will perhaps clear it off.

Burnham

The principal star has a proper motion of 0".028 in 290º.8 (Auwers). The stars are relatively fixed.

1868.01	163º.6	5".07	Δ
1902.52	162º.6	5".11	Hu

56 Herculis

Smyth

Position AB 96º.1 Distance 15".0 Epoch 1838.71
AC 170º.0 540".0

A most delicate double star, with several companions, forming a small group inclining from *np* to *sf*, on the hero's right shoulder, at about 6º distance east-north-east of β Herculis, on a line leading upon Wega. A 6½, light yellow; B 13, pale red; C 11, greenish; and between A and C are three minute stars nearly on the parallel with each other. This group forms so severe a test for a telescope, that I requested the Rev James Challis to examine it with the great Northumberland equatoreal, in the autumn of 1841; and at the same time asked the Rev W. R. Dawes to do the same with Mr Bishop's large refractor. It was a gratification to find that their diagrams were in very nice agreement with my own, showing the utility of careful estimation in those cases where the delicacy defies metrical observations. It appears pretty certain that this star has a slight movement in AR; but Mr Baily has extinguished that in declination. These are the registered values:

P	AR –0".26	Dec. –0".05
B	–0".08	–0".00

Burnham

No change. The large star has a proper motion of 0".019 in 238º.3 (Auwers).

1903.32	92º.4	18".04	β

60 Herculis

Smyth

Position 310º.0 Distance 45".0 Epoch 1838.53

A wide double star in a poor field, between the heads of Hercules and Ophiuchus, exactly on the western parallel of α Ophiuchi, which it precedes by 7º. A 5, silvery white; B 12, lilac; and at a distance *sf* are the two stars mentioned by Piazzi, Note 293, Hora XVI, in these terms: ‘Alia 8^{ae} magnit. 34" temporis sequitur 6' ad austrum; et alia 39" temporis 9 ad austrum.’ This object, which, from the minuteness of the *comes*, is here entitled to but small weight, is 133 ♅ V, and was thus registered:

♅	Pos. 300º 00'	Dist. 48".68	Ep. 1783.19

Burnham

The angle in ♅ appears to be too small, and the distance at that time should have been about 46". The proper motion of the principal star is:

Auwers	0".032 in 93º.6
Σ – β	0".061 in 105º.4

The last value is derived from the three sets of measures in 1852, 1878, and 1903. The following are all the measures:

1783.44	307º.0	48".67	♅
1852.22	310º.6	51".57	Σ
1878.92	310º.1	53".11	β
1886.50	310º.1	54".35	Eng
1903.20	309º.2	54".40	β

α Herculis

Smyth

Position 119º.4	Distance 4".6	Epoch 1832.51
118º.9	4".8	1838.71
118º.7	4".5	1842.57

A standard Greenwich star with a companion, on the head of Hercules. A 3½, orange; B 5½, emerald, or bluish green; and there are two distant stars of 10th and 12th magnitudes in the *nf* quadrant, which are remarkable for their lilac tinge. I have here registered the medium brightness, for A was found to be variable by ♅, who compared it with κ Ophiuchi, changing from maximum 3 to minimum 4 in a period of 60¼ days. Σ has since suggested that B also varies from 5 to 7. And it has a proper motion in space, which, however slight, becomes of singular interest in studying its conditions; these are the best investigated values:

P	AR –0".11	Dec. +0".12
B	+0".03	+0".05
A	–0".002	+0".06

This lovely object, one of the finest in the heavens, is 2 ♅ II, and was described to be double by Piazzi, though not always easily seen so. ‘Duplex’, ait, ‘comes sequitur ad austrum; et non semper nee facile distinguitur. Aptius ad id tempus Septemb. initium paulo post solis occasum.’ From the observations of its discoverer it was considered to have undergone an orbital increase of 11º½, in little more than twenty-three years; therefore when Σ attacked it in 1819, he expected to find the angle amount to about 130º. But the result was an actual retrogradation from ♅'s determination, and as the Dorpat astronomer was convinced that he was within 1º of the truth, and indeed his last mean is drawn from five years’ measures, it was concluded, either that the former observations were uncertain, or that one of the stars had *rebroussé chemin*. But all the subsequent measures, however they differ *inter se*, coincide in establishing the fixity of this object, thereby adding another instance to that of γ Andromedae, that highly-coloured stars are not necessarily in motion. The following are the previous results which I compared with my own, in arriving at this conclusion:

♅	Pos. 111º 28'	Dist. 4".74	Ep. 1779.66
	121º 57'	5".05	1803.40
Σ	116º 36'	5".61	1819.60
H and S	119º 33'	5".29	1821.74
Σ	118º 28'	4".65	1829.63
D	120º 23'	4".85	1830.62

A discussion of the delicate observations of ♅ and Σ led Baron de Zach to exhort those Uranian amateurs who wish to be useful, to work in the rich field of double stars: it is, he says, ‘un vaste et un trés-fertile champ à défricher, que nous recommandons aux soins des amateurs qui voudront se rendre utiles, et faire encore autres choses que des observations banales qu’on répète par-tout.’ The principal star is called Rasalgeti, from the Arabian *rás al-játhí*, the kneeler's head; and the casual gazer may pick it up by noting that Altair, Wega, and Rasalague, form a triangle nearly equilateral, the latter being the preceding star, and having Rasalgeti about 5º before it; the heads both of Hercules and Serpentarius lie between Lyra and Scorpio. The galley rhymes afford another clue:

> Amid yon glorious starry host,
>   that feeds both sight and mind,
> Would you the Serpent-bearer’s head,
>   and that of Herc’les find,
> From Altair west direct a ray
>   to where Arcturus glows,
> One-third that distance, by the eye,
>   will both those heads disclose.

Rasalgeti is the *lucida* of Hercules, one of the old forty-eight asterisms, called *’Ev γόνάσιν*, Ingeniculus, Genuflexus, Saltator, and Incumbens Genubus, by the ancients; and represented as a man kneeling, weary, and sad. It was probably therefore not originally figured for the Theban; Eudoxus and Aratus, speaking by the well-known verses of Cicero, merely allude to his sorrow, and tell us:

> Engonasin vocitant, genibus quod nixa feratur.

Manilius, speaking through Sherburne, says:

> Next the cold Bears, the cause t’ himself best known,
> Shines forth a *kneeling* constellation.

This kneeling posture has given rise to momentous discussion; and whether it represents Lycaon lamenting his daughter's transformation, or Prometheus sentenced, or Ixion ditto, or Thamyras mourning his broken fiddle, remains still unsettled. But in process of time, this figure became a hero, and Hyginus mentions both the lion's skin and the club; while the right foot's being just over the head of Draco, satisfied the mythologists that he was crushing the Lernaean hydra. But this is a matter upon which much twaddle has been raked together by the ‘learned’, who fancy they see in this position, as well as a similar one of the Indian Krishna, a bruising of the serpent's head, in illustration of the Mosaic record. The Arabians called it *El-rákis*, the dancer or leaper, and *El-játhí ’alá rukbeteïhi*, the man who kneels on both his knees; an epithet which Bayer, who sadly worries the Orientals, has brought to *Elgezi ale rulxbachei*. The early Venetian editions of Hyginus figure Hercules as going to attack a snake coiled round the trunk of an apple tree; and Bayer depicted a mystic apple-branch in the Theban's hand. Hevelius transformed it into a bunch of snakes, under the name of Cerberus, from the watch-dog of the infernal portals; with the fox carrying a goose for his breakfast, as shown in the *Prodromus Astronomiae*. Some have considered the emblem as typifying the serpent which infested the vicinity of Cape Taenarus, whence a sub-genus of Ophidians still derives its name. At all events a poet, indignant at the heathen exaltations of Hevelius, has said:

> To Cerberus too a place is given,
> His home of old was far from heaven.

This symbol of the ‘tricapitem canem infernalem voracem’ figures among the new constellations which follow Hevelius, in his homage to Urania and the great astronomers, in the elaborate frontispiece to his *Uranographia*. Bode has adopted both the apple-branch and the snakes, in his Atlas, under the style and title of Cerberus et Ramus. This constellation is of great extent and importance, notwithstanding it boasts of no star larger than the 3rd magnitude: yet several of that and the 4th size decorate the head, back, shoulders, hips, thighs, and right ankle of the figure. But though this asterism is not very remarkable to the eye, its double stars, nebulae, and clusters, render it telescopically interesting and glorious. The components have increased as optical means have been enlarged, and the registered numbers are thus:

Ptolemy	30 stars	Hevelius	45
Tycho Brahé	28	Flamsteed	113
Clavius	31	Bode	451

Hevelius, in his *Prodromus Astronomiae*, reported a nebula on the top of Hercules' head, close to Rasalgeti, which Messier searched for in vain. The nearest nebula to this star appears to be 901 ♅ II, but that being too small and faint for the power of their telescopes, the object must have been a comet.

Burnham

There has been no change since the first measures. The principal star is variable from 3.1 to 2.9 m; the period is uncertain, the observations giving from 66.4 to 88.5 days. It has a proper motion of 0".049 in 326º.1 (Auwers).

1848.82	118º.6	4".70	OΣ
1866.54	117º.8	4".65	Δ
1879.92	115º.0	4".58	Sp
1886.66	117º.4	4".68	Hl
1896.49	113º.5	4".82	Hu
1898.52	113º.9	4".68	Ai
1899.47	114º.5	4".75	Gr. Obsy.
1903.46	114º.7	4".62	Biesbroeck

The faint star, C, was detected by Alvan G. Clark. The later measures are:

A and C

1889.58	334º.0	23".51	HΣ
1895.45	334º.4	23".53	Barnard
1899.52	334º.8	24".07	Gr. Obsy.

The fourth star, D, was mentioned by Mitchel. The only recent measure is:

1903.33	39º.0	83".93	β

δ Herculis

Smyth

Position 173º.9	Distance 25".9	Epoch 1830.71
174º.9	24".7	1837.49
175º.1	24".5	1839.62

A binary star, on the hero's left shoulder, and due north of its lucida about 11º, forming a nearly equilateral triangle with it and β. A 4, greenish white; B 8½, grape red. A proper motion is assigned to the primary, which I here submit, although my own observations would dispense with that in AR:

P	AR –0".20	Dec. –0".14
B	–0".05	–0".15
A	–0".10	–0".13

This neat object is 1 ♅ V, and as the movement suspected by the re-examination of H and S is confirmed. it may be recognised as a physical system. The previous measures and epochs which I compare with mine are these:

♅	Pos. 162º 28'	Dist. 33".75	Ep. 1779.61
H and S	172º 10'	28".87	1821.37
Σ	173º 42'	26".11	1829.77

The results show a very appreciable decrease of distance, and a direct angular increase *sp nf*; the object, therefore, as H observed, merits particular attention, 'as the change is contrary to what the presumed proper motion of the large star would alone produce.' My last epoch was under the very best atmospheric and instrumental circumstances; and on the whole I am led to infer, that if all the series could be depended on, B had lately passed its apastron in the south-east portion of its orbit, and that it is slackening its march as it recedes from the extemity of the ellipse, now barely moving a degree in ten years.

Burnham

A system of the 61 Cygni type, the change being due to the difference of the proper motions of the components. Movement of the large star is given from meridian observations:

Auwers	0".154 in 191º.7
Bossert	0".155 in 195º.2
A.G. Ber.	0".157 in 194º.0

The companion is moving nearly at right angles to the other, at a little smaller rate. The measures give the annual motion of the small star, 0".017 in 275º.2. The following measures are shown on Fig. 1:

1780.15	162º.5	34".22	♅
1832.72	174º.0	25".62	Σ
1835.98	174º.5	24".94	Σ
1837.74	174º.4	24".58	Σ
1841.66	175º.9	24".14	OΣ
1847.37	176º.5	23".04	OΣ
1856.01	177º.7	21".61	OΣ
1861.48	179º.2	20".71	OΣ
1865.83	179º.8	20".11	Δ
1870.00	180º.8	19".42	Δ
1872.91	181º.1	18".80	OΣ
1877.01	182º.2	18".30	Δ
1884.53	185º.5	17".00	H1
1890.49	186º.6	16".00	Gla
1895.62	189º.2	15".38	Collins
1902.55	191º.7	14".60	Gr. Obsy.
1904.28	192º.7	14".05	β

On Fig. 2 five positions are shown (1831–1904) as the two stars are actually placed in space at the dates of the respective measures.

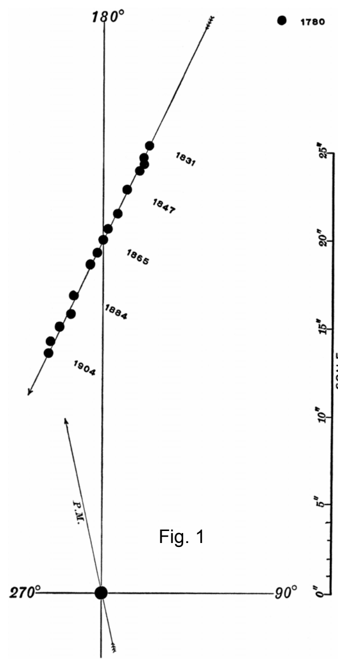


Fig. 1

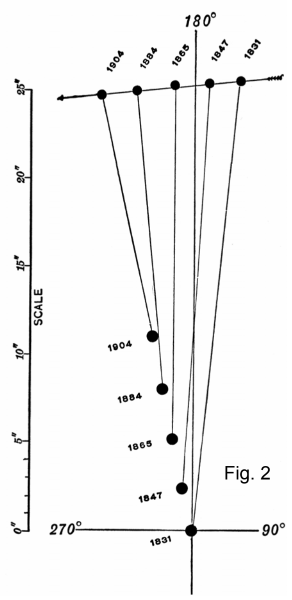


Fig. 2

ρ Herculis

Smyth

Position 308°.5	Distance 3".6	Epoch 1831.60
308°.9	3".7	1839.74

A beautiful optical double star, in the middle of the hero's right thigh; it is 2° to the eastward of π, on the line towards Wega. A 4, bluish white; B 5½, pale emerald. This object is 3 ♅ II, and was entered double by Piazzi, Note 105, Hora XVII, 'Duplex, minor praecedit'. From the earliest strict measures, it was concluded to have made a direct orbital change of nearly 9° in little more than half a century, and the distance to have increased materially; but all the subsequent observations tend to prove its fixity. These are the several measures previous to mine:

♅	Pos.	300° 21'	Dist.	2".97	Ep.	1779.66
H and S		307° 53'		4".46		1821.38
Σ		307° 22'		3".60		1830.35
D		308° 35'		3".96		1830.63

This star is circumstanced similarly to δ Herculis, since if all the epochs could be strictly depended upon, the orbital progress would appear to be equally slow.

Burnham

In later measures the angle is larger, but no sensible change is shown. The principal star has a proper motion of 0".074 in 282°.4 (Auwers), and the companion is moving with it.

1849.08	310°.4	3".73	OΣ
1868.49	310°.7	3".72	Δ
1882.01	310°.3	3".96	Hl
1888.39	312°.0	3".86	HΣ
1890.53	312°.6	3".92	Giacomelli
1895.06	311°.1	4".04	Gla
1904.45	312°.2	3".99	Doo

μ Herculis

Smyth

Position 241°.8 Distance 30".1 Epoch 1837.67

A delicate double star, in the bend of the Theban's right arm; 14° distant from Wega, to the south-west, and preceding β Cygni by about 26°, exactly on the parallel. A 4, pale straw-colour; B 10, cerulean blue. This is 41 ♅ IV, and difficult to measure, especially in distance, from its bearing illumination badly. Still the results are surprisingly coincident, except that ♅'s distance, though marked 18", 'by pretty exact estimation', must have been erroneous, or a misprint for 28". The following are my epochs of comparison:

♅	Pos.	240° 00'	Dist.	18".00	Ep.	1781.78
S		240° 46'		29".30		1825.50
Σ		241° 21'		29".88		1831.60

μ Herculis has a very sensible proper motion, and well deserves attention from those who may be investigating this lamentably deficient department of astronomical knowledge. The assigned values are these:

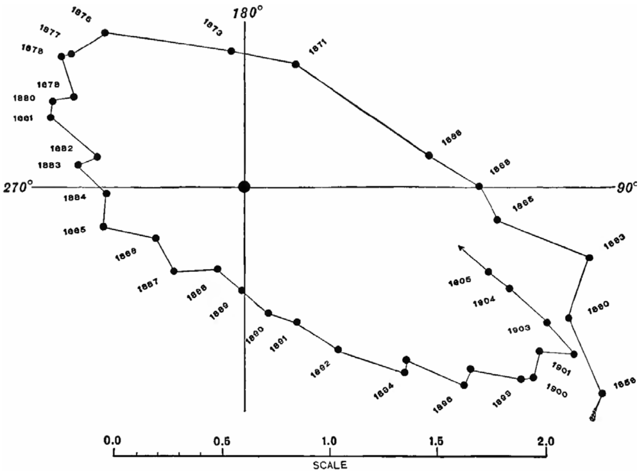
P	AR –0".29	Dec. –0".84
B	–0".36	–0".72
A	–0".39	–0".72

Burnham

The duplicity of the Herschel companion was discovered by Alvan Clark in 1856 with a 7¾-inch refractor. It was soon found to be in rapid motion, and has now completed more than one revolution since its discovery. The following orbits have been found:

1878	Beebe	225 y.	*Am. Jour. Sci.,* 1879
1878	Doberck	54.25	*A.N.* 2287
1888	Celoria	40.65	*A.N.* 2949
1889	Leuschner	45.39	*Pub. A. S. P.* 2, 46
1894	Hall	42.09	*A. J.* 324
1895	See	45.00	*Evol. Stellar Systems*

The observations which follow are shown on the diagram. The mean position is given of the measures in brackets.



1857.50	59°.2	1".82	Da
1859.70	60°.4	2".05	Da
1860.30	67°.7	1".64	OΣ
1862.83	78°.5	1".50	OΣ
1864.43	77°.6	1".80	Da
1865.44	82°.0	1".20	Δ
1866.68	89°.5	1".10	OΣ
1868.50	98°.7	0".88	OΣ
1871.52	156°.8	0".62	OΣ
1873.50	185°.5	0".63	OΣ
1876.60	228°.7	1".01	OΣ
1876.68	216°.0	0".83	Δ
1877.62	229°.9	0".92	Δ
1877.89	235°.6	1".13	OΣ
1878.48	234°.9	1".05	β
1879.45	242°.7	0".90	β
1880.47	245°.9	0".96	β
1880.65	246°.3	1".00	Hl
1881.41	252°.1	0".92	β
1881.55	249°.1	1".01	Hl
1882.52	259°.1	0".70	Hl
1883.09	264°.9	0".96	OΣ
1883.53	262°.1	0".74	β
1883.58	262°.9	0".66	Hl
1884.64	273°.4	0".65	Hl
1885.55	284°.7	0".77	HΣ
1885.56	288°.0	0".61	Hl
1886.59	300°.1	0".38	Hl
1886.74	301°.9	0".59	HΣ
1887.58	321°.5	0".42	Hl
1887.63	320°.6	0".62	HΣ
1888.63	341°.4	0".39	Hl
1888.72	344°.4	0".45	HΣ
1889.51	357°.9	0".55	β
1889.65	0°.6	0".34	Hl
1889.68	358°.3	0".60	HΣ
1890.38	9°.4	0".66	β
1890.55	13°.2	0".51	Hl
1890.59	10°.1	0".65	HΣ
1891.38	18°.5	0".72	β
1891.57	24°.8	0".54	Hl
1891.63	20°.3	0".81	β
1892.37	28°.8	0".89	β
1892.65	31°.6	0".83	Hl

1894.46	37º.9	0".95	Ho
1894.77	41º.6	1".16	Com
1895.58	39º.2	1".03	Ho
1895.58	44º.3	1".14	Ai
1895.60	44º.4	1".16	Com
1896.54	46º.9	1".41	Lewis
1896.65	48º.5	1".37	Com
1897.57	50º.8	1".36	Ai
1899.28	53º.1	1".67	Ai
1899.29	55º.7	1".54	Hu
1899.40	55º.7	1".52	Doo
1900.57	56º.3	1".62	Doo
1901.41	59º.8	1".47	Ai
1901.49	59º.8	1".77	Doo
1901.51	61º.7	1".52	Lewis
1902.44	62º.1	1".78	Hu
1902.46	63º.0	1".86	Doo
1902.67	63º.3	1".54	Lewis
1903.35	65º.4	1".78	Doo
1903.50	65º.2	1".34	β
1903.71	67º.2	1".37	Do
1904.48	68º.6	1".33	Salet
1905.43	71º.3	1".21	β

The large star has a proper motion of 0".811 in the direction of 204º.4 (Auwers), and the close pair is moving with it, so that the three probably form a physical system. There is but little change in the angle and distance of BC from the principal star.

1836.51	241º.9	30".17	Σ
1864.87	243º.6	31".30	Δ
1886.62	243º.8	31".48	Hl
1904.44	244º.5	32".56	Salet

In 1895 See measured a small star about 10" from A in the position angle of 305º.8 with the 15½-inch of the Washburn Observatory (*A. J.* 359). This was probably an illusion, as it has not been seen elsewhere with much larger apertures.

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300 P. XVII Herculis

Smyth

Position 114º.9 Distance 2".5 Epoch 1835.61

A close double star, in the space between the hero's head and the eagle's tail; it is 7º½ north-north-east of α Ophiuchi, or one-quarter of the distance from that star towards γ Lyrae. A 7½, and B 8, both lucid white. This exquisite object was discovered by Σ, and is No. 2245 of the Dorpat Catalogue. Both Σ and H make the components equal in magnitude, but on a very careful comparison I cannot but think B the smallest. The following are the results of the previous observations:

Σ	Pos.	113º 57'	Dist.	2".63	Ep.	1829.18
♅		115º 21'		2".99		1830.59

Burnham

No change since Struve.

1866.51	115º.1	2".65	Δ
1890.36	114º.1	2".65	Giacomelli
1902.46	114º.7	2".68	Hu

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95 Herculis

Smyth

Position 261º.8 Distance 6".1 Epoch 1833.78

A neat double star, between the Theban's head and the eagle's tail, in the spot where Hevelius placed his Cerberus; it is 10º distant from α Ophiuchi on a north-north-east line, which leads upon β Lyrae. A 5½, light apple-green; B 6, cherry-red, besides which there are two small stars in the *sp* quadrant, and a seventh-magnitude in the *np*. This beautiful object is 26 ♅ III, and presents a curious instance of difference in colour between components so nearly equal in brightness. Indeed, it was only on rigid comparison, that I was induced to mark the following star half a magnitude smaller than the preceding one, for the other observers note them as of the same size. Piazzi says, 'Duplex. Comes ejusdem magnitudin. parumper ad boream sequitur.' A slight movement in space has been assigned to A, but it is not sufficiently established yet for entering into the argument of B's being in physical connexion with it or not; the best values are:

P	AR	0".00	Dec.	+0".05
B		+0".04		+0".06
A		+0".02		+0".06

From a comparison of the epochs of ♅ and H and S, there was a hope of 95 Herculis being a binary system, but the later measures go far to prove the object to be optical, and that the proximity of the stars is merely apparent, no connexion existing between them. These are the results for comparison with mine, on which the conclusion is founded:

♅	Pos.	265º 51'	Dist.	6".10	Ep.	1780.69
H and S		261º 52'		6".23		1821.97
Σ		261º 45'		6".06		1829.90

Burnham

Observers differ as to colors. Relatively fixed. The principle star has a proper motion of 0".046 in 305º.6 (Auwers).

1868.30	261º.0	6".03	Δ
1883.69	260º.4	6".15	Sp
1887.59	259º.6	6".22	Hl
1902.53	260º.2	6".34	Hu

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100 Herculis

Smyth

Position 3º.8	Distance 13".6	Epoch 1830.69
2º.8	14".1	1836.52

A neat double star, south of the hero's right hand, where some place the bunch of snakes. A and B, both 7, and both pale white, the preceding star being made the primary. This object is 41 ♅ III, who has erroneously designated it 43 Herculis; and it is formed of Nos. 389 and 390 of Piazzi's Hora XVII. The other measures stand thus:

♅	Pos.	1º 37'	Dist.	11".71	Ep.	1781.78
H and S		2º 25'		14".28		1823.46
Σ		2º 54'		13".85		1831.72

This object lies in a pretty open space midway between Wega and β Ophiuchi; and it is 11º from β Lyrae, on the line towards α Herculis.

Burnham

Relatively fixed. Several faint stars in the field. The proper motions are given by Auwers:

A = 0".028 in 28º.3
B = 0".037 in 316º.5

1865.52	182º.8	14".02	Δ
1890.63	182º.7	14".05	Giacomelli
1898.05	182º.2	14".81	Coleman
1905.76	182º.4	14".00	β

John Edwards' metallic specula

At the meeting of the Board of Longitude on 6 June 1778, the Astronomer Royal, Nevil Maskelyne, presented 'some astronomical problems by the Revd Mr Edwards of Ludlow, which he thinks will be useful to navigation'. Edwards was an Anglican clergyman who supplemented his income by taking in pupils, and in 1773 Maskelyne had hired him as a computer for the *Nautical Almanac*. The almanacs were prepared three or four years in advance, and four computers, working independently at home, were usually needed to carry out the calculations. Edwards was assisted by his wife Mary, who was also an accomplished astronomer and mathematician, and six months of this work earned him more than his annual stipend.

The 'problems' presented to the Board of Longitude related to some of Edwards' experiments with numerous metals and metalloids for producing a highly reflective and colour-free alloy for telescope specula. The minutes of that meeting do not record the details, but the Board resolved 'that the Secretary do pay the said Mr Edwards the sum of £20 out of any money which may be in his hands, as a reward for the said problems',[1] and ordered that the results be published in the *Nautical Almanac*.

With this encouragement, Edwards continued the work. He ground and polished several specula, and during the summer of 1780 Maskelyne tried some of his telescopes in order to compare the quality and performance of the specula with instruments at the Royal Observatory (though there appears to be no evidence that Edwards ever visited Greenwich). On 4 November, Maskelyne informed the Board of Longitude that Edwards had made considerable improvements in the composition of metals, and as evidence he presented some specimens of rough castings and a small speculum, ground and polished, in order to show its compactness and brilliancy. The Board was impressed, and awarded Edwards the sum of £200 – ten times the previous amount – 'to reimburse the expences he may already have been at in making experiments and to enable him to carry them on, in order to bring the abovementioned composition to the greatest degree of perfection in his power.'[2]

Following the Board's earlier resolution, Edwards wrote a detailed account of his work, with directions for making specula, a list of dozens of compositions, methods of casting, grinding, and polishing, and information and advice on the testing of specula, the construction and testing of eyepieces, and collimation. This extensive treatise was completed in July 1781, and was published in 1783 in the *Nautical Almanac* for the year 1787.[3]

The metals and metalloids that Edwards used included platinum, silver, copper, tin, iron, lead, arsenic, bismuth, zinc, crude antimony (antimony sulphide, stibnite), regulus of antimony, martial regulus of antimony – the latter two containing impurities including arsenic, sulphur, zinc, and iron – and alloys including brass and bell-metal. In addition, Sir Joseph Banks supplied Edwards with several ounces of cawk – a fibrous variety of the mineral barite (baryte, heavy spar, barium sulphate) found in Derbyshire and Somerset. The colour is usually white, but can vary with the presence of impurities. Martin Lister had experimented with this mineral more than a century earlier. His method was to melt a pound of antimony in a crucible, and to melt with it an ounce or two of cawk 'in a lump red-hot in readiness'. The mixture was then poured into a clean mortar. This process produced about 15 ounces of vitrum antimonii (glass of antimony), which was well known and historically had been used as an emetic. Lister described cawk stone as a 'very odd mineral', while the vitrum antimonii that he produced was 'like polish'd steel and as bright as the most refined quicksilver'.[4] Edwards considered cawk to be a 'most wonderful stone', but although 'crude antimony, cawk stone 1 or 2 oz' formed a very bright glassy metal like vitrum antimonii it was 'by no means fit for mirrors'.

Edwards tried more than a hundred different mixtures in various combinations and proportions, though many of them were unsuccessful and were not recorded. Those that he did record included the best that had been produced by Isaac Newton, Samuel Molyneux, and John Mudge, though even these were not entirely satisfactory as they each had a yellow tint indicating too much copper in the mix. By far the best of Edwards' compositions was copper 32, tin 15, brass 1, silver 1, arsenic 1:

> A most excellent metal, being by much the whitest, hardest, and the most reflective I have ever yet met with ... This metal, when broken, should appear of a bright, glassy, and quicksilver complexion. If it appears hard and of a dead white, more tin must be added (the copper will sometimes take 16 ounces of tin, if it is very pure). If it appears bluish and rough, more copper or brass must be added.

This was the metal used for the mirrors produced for Maskelyne, who later noted that while 'common reflecting telescopes' produced a dingy copperish appearance to objects, Edwards' telescopes showed a white object perfectly white and all objects of their natural colours:

> I found, by a careful experiment, that they shew objects as bright as a treble object-glass achromatic telescope, both being put under equal circumstances of areas of the aperture of the object metal and object-glass, and equal magnifying powers; whereas the diameter of the aperture of a common reflecting telescope must be to that of an achromatic telescope as 8 to 5, to produce an equal effect.

The 'treble object-glass achromatic telescope' was one of Peter Dollond's $3^{6}/_{10}$-inch f/12.7 triple achromats – two convex lenses of crown glass with a concave of white flint glass between them – the first of which were produced around 1764. But they were expensive, and few of them were made. In 1806, when William Kitchiner acquired one of these telescopes from Alexander Aubert's collection, Peter Dollond said to him: 'Yes, that object-glass is one of the things which is to make me immortal.' Many years later, in 1825, Kitchiner stated that the triple achromats had 'established the fame of this kind of telescope' but that they were 'now extremely rare to be met with'.[5] Maskelyne had therefore matched the quality of Edwards' specula with the quality of one of the finest refractors available. In addition, the specula tried by Maskelyne were 'found very greatly to excell in brightness, and to equal in other respects, telescopes of the same size, constructed by the best artists in London'.

Edwards' work was very hazardous. Specially constructed furnaces and crucibles were required to prepare the

1 Minutes of the Board of Longitude, 6 June 1778, RGO 14/5, 337.

2 Minutes of the Board of Longitude, 4 November 1780, RGO 14/6, 2:12–13.

3 John Edwards. 'Directions for making the best composition for the metals of reflecting telescopes, and the method of casting, grinding, polishing, and giving them the true parabolic figure', in *The Nautical Almanac and Astronomical Ephemeris, For the Year 1787*. London: Peter Elmsly, 1783, pp. 1–48 (separate pagination).

4 Martin Lister. 'Some observations and experiments ... Of the speedy vitrifying of the whole body of antimony by cawk', *Philosophical Transactions of the Royal Society*, 9 (1674), 221–6.

5 William Kitchiner. *The Economy of the Eyes. Part II. Of Telescopes; Being the Result of Thirty Years' Experiments with Fifty-One Telescopes, of from One to Nine Inches in Diameter*. London: Printed for Geo. B. Whittaker, 1825, pp. 26, 28.

alloys, with the melting points of the metals and metalloids ranging from bismuth at 271º C to platinum at 1,768º C, while copper, used frequently, has a melting point of 1,085º C. In addition, inhalation of particles of antimony compounds can affect the respiratory tract, the gastrointestinal tract, and the cardiovascular system. Edwards noted that arsenic, although particularly recommended by Newton. had since been used infrequently. This he attributed to the disagreeable fumes which arose when it was added to the melted mixture in the crucible:

> All the precaution necessary, is to bruise the arsenic coarsely, and introduce it into the crucible with a pair of tongs, having tied it up in a piece of paper; giving it then a stir with a wooden spatula, retaining your breath, avoid it till you can see no more vapours arise from the crucible, when the metal will be ready to be poured into the flasks to cast the speculum.

To this advice, Maskelyne added: ‘I have been assured by two ingenious experimental philosophers, that the fumes of arsenic, even when the garlic smell is very strong, are not in the least prejudicial to the lungs.’

In 1784, a few months after the publication of his treatise, Edwards died from inhalation of arsenic fumes. He was 36 years of age, and his wife Mary, aged 34, was left a widow with two small daughters. She lost their home and her husband’s two sources of income, but inherited his debts, and therefore applied to Maskelyne to ask if she could continue the computing work, to which Maskelyne agreed. A few months later she also thanked him for his assistance in the sale of her husband’s instruments and in settling his accounts with Edward Troughton, Edward Nairne, and Benjamin Cole, but was ‘quite ashamed to give you so much trouble’. She had been obliged to move house and borrow a room, and ‘what I am in your debt must get you to charge on the year 1795 which I will finish as soon as I can have returns of the calculations.’[6] Over the ensuing years she undertook a great deal of work for Maskelyne and was able to pay off her debts, but this work occupied her for most of the rest of her life, and after Maskelyne died and John Pond succeeded him as Astronomer Royal in 1811 her income was reduced and she was still supporting her unmarried daughters. After her death in 1815 her daughter Eliza continued the computing until 1831, when William S. Stratford was appointed Superintendent and established the Nautical Almanac Office as a central bureaucracy to replace the system of home-based computers.

Conjecture does not constitute evidence, but had John Edwards lived longer he might have been commissioned to make instruments for the Royal Observatory or perhaps have manufactured instruments on a commercial basis. Apart from his treatise in the *Nautical Almanac*, his work was not published in the *Philosophical Transactions* nor in popular publications such as the *Gentleman’s Magazine* or the *Universal Magazine*, though a few years later it was summarised briefly in a general entry on optics in *Encyclopaedia Britannica*: ‘The chief excellence of his telescopes arises from the composition, which, from various trials on metals and semimetals, he discovered for the specula, and from the true parabolic figure, which, by long practice, he had found a method of giving them, preferable to any that was known before him.’ Unfortunately, none of Edwards’ telescopes or mirrors have survived.

6 Mary Edwards to Maskelyne, 18 June 1785, RGO 4/187, 10:1.


Copper


Tin


Arsenic


Zinc


Lead


Iron


Silver


Platinum


Bismuth


Cawk (barite, barium sulphate)


Antimony sulphide (stibnite)

Two refractors in New Zealand

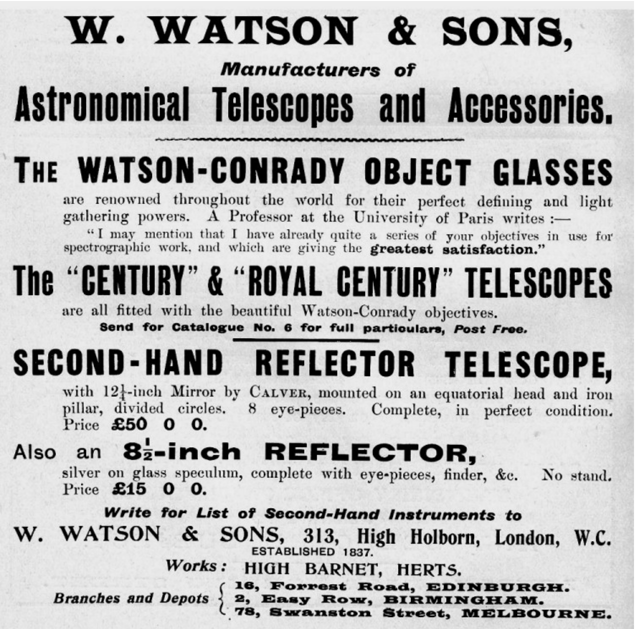
I have recently been corresponding with David Van Voorst, of Rangiora High School, New Zealand. The school has two telescopes – a 3½-inch refractor by Watson and a 3-inch refractor by Dollond – but there is no record of how or when they were acquired.

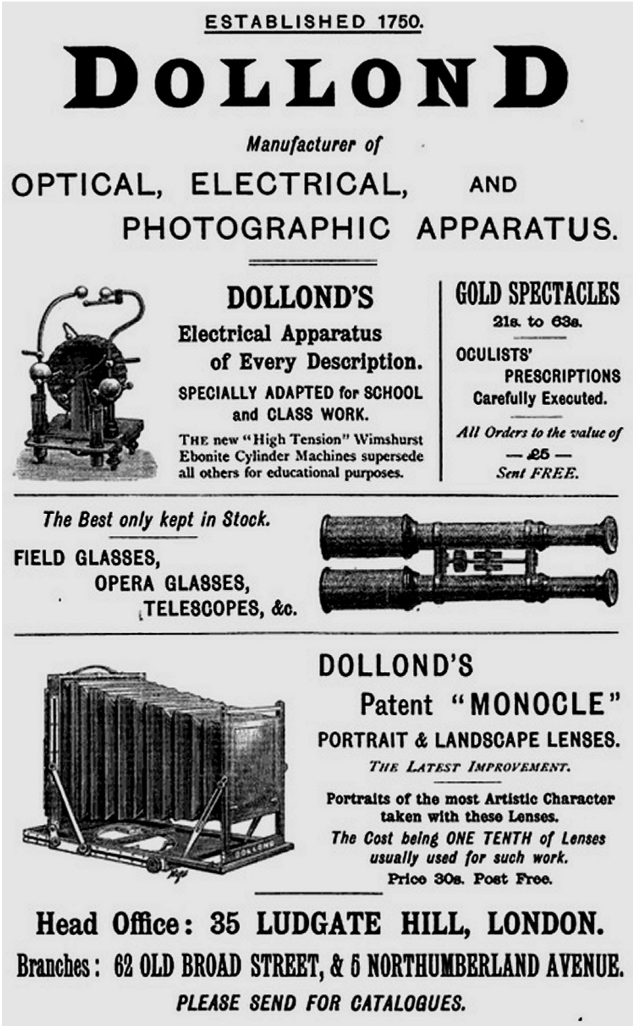
William Watson established his business in London in 1837. By 1868 the premises were located at 313 High Holborn, London, and the name of the company was changed to W. Watson & Son. The elder Watson died in 1881, and in 1883 the name of the company was changed to W. Watson & Sons. From about 1890 the Australian business addresses were 251 Swanston Street and 78 Swanston Street, Melbourne, and in 1908 the name of the company was changed to W. Watson & Sons Ltd. In 1901, A. E. Conrady joined the company as chief designer, and at about the same time the 'Century' and 'Royal Century' designations were introduced. 'Depot 268 Little Collins St Melbourne' (engraved on the school's telescope) is close to Swanston Street, and these locales are a short distance from Williamstown – the original settlement where a small observatory was established in 1853. Melbourne Observatory was founded in 1862, and in 1868 the 48-inch Great Melbourne Telescope began work. The saga of that telescope is well known.

John Dollond and his son Peter established their business around 1750, and the company continued into the nineteenth century with George Dollond. The business later produced other equipment and apparatus, and was eventually subsumed into Dollond & Aitchison. Dollond telescopes were very popular in the latter half of the nineteenth century and the early twentieth century, to the extent that less reputable manufacturers attempted to deceive potential customers by stamping inferior instruments with the name 'Dolland' intentionally misspelt.

Familiarity with the design and style of each instrument can help in assessing dates and ages, but tracing the numbers on these telescopes is difficult, as many archives have not been preserved, though there are exceptions. .

If anyone has further information, particularly concerning Watson's antipodean business activities, please contact David Van Voorst at vvd@rangiorahigh.school.nz.





A 4-inch refractor by Irving

Geoffrey White

I acquired my first telescope in the late 1950s, when I was about ten years old. I saw a telescope hanging on a wall in a secondhand shop in Battersea, South London, and when I asked the price I was told it was 50 shillings, which was quite a lot of money in those days. (When I started work a few years later, in 1965, my wages were £9 per week.) I doubt the shopkeeper expected to see me again, but my birthday was imminent and my mother agreed to buy the telescope for me. It was a 2-inch refractor with a wooden tube, slightly tapering, with a brass drawtube and eyepiece. It did not have a stand, however, so I first used it by resting it on a clothes line to look at the Moon.

As I had also been given some money for my birthday I decided to acquire some form of stand. If I remember correctly, it was someone in the Croydon Group of the Junior Astronomical Society (which later became the Croydon Astronomical Society) who recommended H. N. Irving and Son in Teddington, across the River Thames from Kingston. After making an appointment by telephone I duly arrived and was invited in by Ron Irving's wife. The house was not only their residence but an office and workshops too, and I particularly remember that the room was a complete muddle. There were bookcases around the walls, and in the middle of the room an enormous table completely covered in anything and everything. How he ever found anything was beyond me, but he must have had a system.

Ron made me a simple tripod with an altazimuth head, and I collected it two or three months later, as he could not be rushed. It seemed that he had cut a staircase newel post lengthwise into three to form the tripod legs, which were fitted with hinges so that they could splay out. I had that telescope and tripod for quite a few years and had endless pleasure with it, making drawings of the Moon, observing the planets, double stars, and nebulae, and monitoring sunspot activity. I even managed to obtain a photograph of the Moon with a plate camera and glass plates!

There came the day when, as was common among amateur astronomers, I wanted to make a Newtonian reflector. I decided to make an 8½-inch, so in order to buy the mirror blanks, carborundum, and rouge I sold my 2-inch refractor (a decision that I have always regretted). I made quite a lot of the equatorial head and open tube in the metalwork club at school, and eventually completed it. However, it was very heavy and not at all easy to use, and I cannot remember what happened to it.

At some time in the early 1970s I felt the need to buy a new telescope and decided that I wanted another refractor – an instrument that was portable and would fit into a car. A 4-inch would be ideal, and I therefore consulted Ron Irving again, duly visited him at Teddington, and ordered the instrument, to be equipped with an equatorial head and tripod. I then visited my bank to borrow the money. 'How much is this telescope?' asked the bank manager. '£175', I replied. 'You do know that the Government has placed restrictions on borrowings for luxury items and you have to put down a deposit of at least 40% and then borrow only the balance', came the reply – to which I responded: 'It's not a luxury item. It's a scientific instrument'. The bank lent me the money. Ron Irving could still not be hurried, however, and I collected the telescope about a year later. Now, almost fifty years on, I still have that telescope.

Except when I used my 2-inch refractor I have never been an avid observer, but I have always enjoyed showing people the wonders of the night sky, particularly if they are completely new to astronomy. In 1966 a perfect opportunity arose when the Inner London Education Authority installed a Zeiss planetarium projector and dome at Wandsworth School – a facility which could be visited by pupils from all over the capital – and on 19 May it was opened officially by the Astronomer Royal, Sir Richard Woolley. The Director was Peter Richards-Jones, who had embarked upon a teaching career after serving for many years as a captain in the merchant navy, and I knew him through the Croydon Astronomical Society. Apart from teaching astronomy at Wandsworth School, he also taught an evening class and occasionally asked me to deputise. He was also teaching navigation onboard *Cutty Sark* at Greenwich, and as this occupied much of his time he asked me if I would like to take over his class at the planetarium. It was an ideal opportunity, and I needed no second bidding. The courses ran from September to June, and whenever the sky was clear I set up my 4-inch refractor in the school playground. I taught there for seventeen years, and gave it up only when we decided to leave London and move to Torquay, on the coast of south Devon.

Torquay Boys' Grammar School (which our two sons attended) had an observatory, but I loaned the school my 4-inch refractor for use as a portable instrument. Torquay was, of course, within the path of totality during the total solar eclipse of 11 August 1999, but unfortunately the weather was very poor and we saw only a crescent Sun through the clouds and experienced the darkness during totality. It revived memories of 1973 when I participated in the successful *Monte Umbe* expedition to Mauritania to observe the total solar eclipse of 30 June.

In 2002 we moved to Wellow (a small village near Bath), which again presented the opportunity to introduce the night sky – and the daytime sky – to people who had never looked through a telescope. On the occasion of the transit of Venus on 8 June 2004 we organised a party that was attended by many of the villagers, who observed this very rare astronomical event and were treated to sparkling wine and strawberries. The second of the pair of transits of this century took place on 5–6 June 2012. I set up the telescope to begin observing at sunrise (approaching the end of the transit), and although there was a large amount of cloud I managed to obtain photographs on which Venus can just be seen through the haze, close to the limb of the Sun.

We now live in Malta from October to March each year, and last year I decided to take the 4-inch. However, I was informed by Air Malta that I could not put anything in the aircraft hold that was longer than 1 metre, though I could book an additional seat for the telescope, equatorial head, and tripod. But at the check-in at Heathrow I was told that everything would have to go in the hold at a cost of £50 for each item, even though I had already paid for an extra seat. This was resolved by having everything bubble-wrapped as one item – for an additional fee. When we disembarked at Malta I came to realise how heavy and cumbersome this all was, but we eventually manhandled everything into a taxi and arrived at our house in the early hours of the morning.

The telescope was originally painted in grey Hammerite, but someone at Torquay Boys' Grammar School had painted it white. Furthermore, over the years it had become badly scratched and needed a thorough overhaul. Therefore, last winter I took apart as much as I was able, cleaned all the components, and repainted it. This was a very enjoyable task, as everything was restored to a condition more or less as good as the day I bought it.

The tube is aluminium alloy, the drawtube is stainless steel, and the gear wheels and the cell for the object glass are brass. The equatorial head was made by Charles Frank of Glasgow, the focusing mount is stamped 'IRVING', and, as far as I know, the object glass was made by David Hinds. An excellent eyepiece made by Ron Irving has a focal length of nearly 2 inches and produces a magnification of about 25x, which is ideal for wide-field viewing of the Moon and star-fields. It is a Kellner, as are all the other eyepieces except one – a Ramsden, which, because it has no cemented components, is suitable for projecting a solar image.

In England I have a 5-inch refractor given to me many years ago by H. N. D. Wright – an astronomer, instrument maker, and engineer whom I first met in Croydon in 1959. At the moment it is equipped with an altazimuth mount on a pillar, but it really needs a permanent mount. Despite Wellow being in the middle of nowhere, our garden is very small, and at the moment this telescope resides under the stairs. Nevertheless, I intend to renovate it – eventually.

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