83. 65 UMA = STF 1579 = WDS J11551+4629AB,D

65 UMa .75 Delete 4

Table 9.83 Physical parameters for ~~STF 1579~~

STF 1579	RA: 11 55 05.749	Dec: +46 28 36.64	WDS: 981(78)	
V magnitudes	A = 6.5	B = 9.0	C = 8.72	D = 6.97
$(B-V)$ magnitudes	A: +0.11	B:		
μ	+10.41 mas yr^{-1}	± 0.49	+2.38 mas yr^{-1}	± 0.43
π	4.72 mas	± 0.58	690 light yrs	± 85
μ(A)	22.71 mas yr^{-1}	± 0.49	−19.43 mas yr^{-1}	± 0.63 (DR2)
μ(D)	12.05 mas yr^{-1}	± 0.28	−3.07 mas yr^{-1}	± 0.41 (DR2)
π(A)	11.52 mas	± 0.48	283 light yr	± 12 (DR2)
π(D)	6.23 mas	± 0.27	524 light yr	± 23 (DR2)
Spectra	A3Vn			
Masses	Aa: 3.28	Ab: 2.52	B: 1.81	C: 1.9 D: 2.9 Db: 1.6
Luminosities ($L_\odot$)	A: 15	B: 4	C: 2	D: 35
Catalogues	HR 4560	HD 203483	SAO 43495	HIP 58112
DS catalogues	H 1 72 (AC)	STF 1579 (AC)	A1777 (AB)	BDS 5962 ADS 8347
	BAG 46 (Da)			
Radial velocity (A)	−3.90 km s^{-1}	± 4.4		
Galactic coordinates	149°.122	+67°.682		

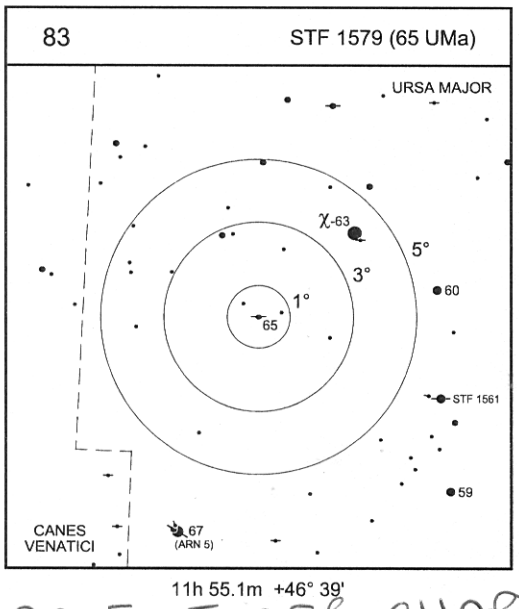
History

This pair, now known as AC, was found by William Herschel at Slough on 20 November 1782, although with some difficulty. He could not see it with ×227 "unless it has been seen first with a higher power". He also noted a further star at 60″, which appeared as bright as component A; it is now known as D. When Robert Aitken observed the pair in 1908 he found that A itself was a close pair (A1777), which was also a rapid binary. The stars were separated by 0″.26 at discovery.

The Modern Era

In 1979, Giménez & Quesada [372] found that star A was a light variable and in 1982 they confirmed [376] that it was an eclipsing binary. The two stars (called Aa1 and Aa2) form DN UMa, which has a period of 1.7304 days with an amplitude of about 0.09 magnitude. These observations were carried out with a 254-mm reflector with a CCD and BVRI filters over four years, as a consequence of which they found another variation of 640 days, representing another component, Ab, around which the Aa1–Aa2 pair were revolving. In 2012, Zasche *et al.* [373] published a comprehensive survey of the astrometry, photometry, and radial velocity of this complex

Finder Chart



REPLACE FINDER CHART

system. They used recent interferometric measures of AB, which have helped to pin down the period to 118 years and the maximum orbital separation to 0″.31. The same study also found a dynamical parallax for 65 UMa of 234 ± 29 parsecs (763 ± 95 light years), placing the system somewhat further away than that found by Hipparcos (see the table). Figure 9.3 shows the hierarchical structure of this complex system. Both the distant Herschel stars are physically connected but estimates of the periods of rotation around AB must be speculative at present. The WDS catalogue shows a further component. Balega *et al.* [374] found component D to be a very close pair (0″.1) in 2009 but there have been no confirming observations as yet. Septuple systems are extremely rare. Tokovinin [557] listed only two – AR Cas and ν Sco. They were not aware of the duplicity of D when they drew up their table. Gaia DR2 places the connection between D and the rest of the group in some doubt.

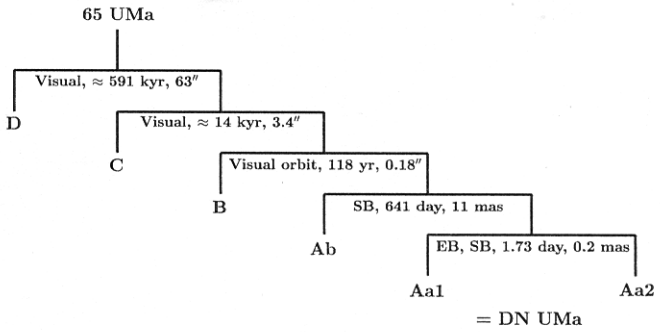


Figure 9.3 The hierarchical structure of STF 1579 as presented by Zasche *et al.* [373].

Observing and Neighbourhood

The system 65 UMa can be found about 8° S of γ UMa. In this group a small aperture will show only the stars A, C, and D. The close visual pair AB is also unequal so any attempt to resolve it visually at present would require a large aperture and good seeing. Unfortunately it will remain below 0″.2 for another 10 years or so, and the significant difference in magnitude (2.5) only adds to the difficulty. Four degrees WSW of 65 is STF 1561 – 6.5, 8.2, 245°, 89″.2, 2020, an orbital pair with period 2050 years. Three point five degrees SSE is 67 UMa, a binocular triple. The components AB are FOR 1 (5.2, 6.7, 62°, 274″, 2012) whilst C is 8.5 at 25°, 395″ to A (ARN 5).

THREE

Measures

AC			
Early measure (STF)	1832.43	36°.5	3″.71
Recent measure (PRI)	2012.38	41°.9	3″.90
AD			
Early measure (STF)	1833.45	113°.8	62″.91
Recent measure (GAT)	2012	113°.9	63″.05

85. STF 1639 COM = WDS J12244+2535AB

ADD

Table 9.85 Physical parameters for STF 1639 Com

STF 1639	RA: 12 24 26.81	Dec: +25 34 56.7	WDS: 68(422)	
V magnitudes	A: 6.74	B: 7.83	C: 11.42	
$(B-V)$ magnitudes	A: +0.27	B: +0.45		
μ(A)	-9.41 mas yr^{-1}	$\pm$ 0.10	-10.87 mas yr^{-1}	$\pm$ 0.06 (DR2)
μ(B)	-15.47 mas yr^{-1}	$\pm$ 0.12	-6.43 mas yr^{-1}	$\pm$ 0.07 (DR2)
π(A)	11.64 mas	$\pm$ 0.05	280 light yr	$\pm$ 1 (DR2)
π(B)	11.70 mas	$\pm$ 0.06	279 light yr	$\pm$ 1 (DR2)
Spectra	A7V	F4V		
Luminosities ($L_\odot$)	A: 12	B: 4	C: 0.15	
Catalogues	HR 4719	HD 108007	SAO 82293	HIP 60525
DS catalogues	STF 1639	BDS 6158	ADS 8539	
Radial velocity (A/B)	-1.10 km s^{-1}	$\pm$ 1.8		
Galactic coordinates	225°.758	+83°.760		

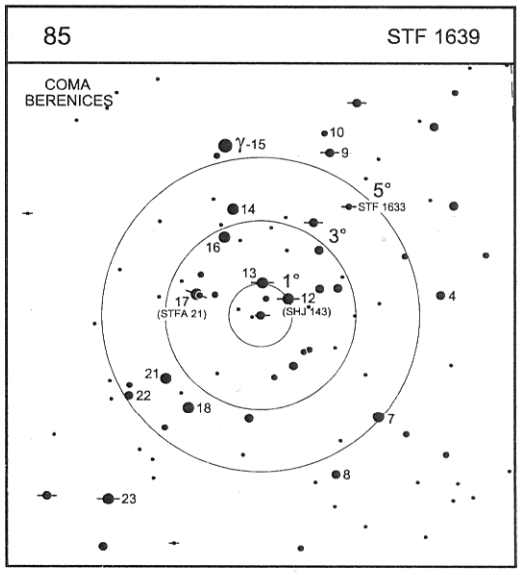
History

Found by F. G. W. Struve in 1828, the pair closed slowly throughout the nineteenth century until in 1892 it appeared single even to Burnham with the Lick 36-inch refractor (when the current orbit predicts a separation of 0″.09 for that epoch). It reappeared several years later and has been widening ever since. Burnham thought that the period would be more than 400 years, and the current orbit shows a period of 575 years although it is still far from certain how long it will be before the companion slowly starts to turn inwards again.

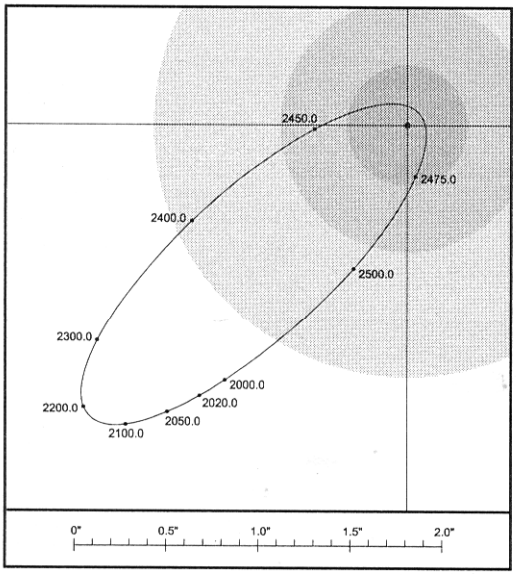
The Modern Era

According to Olevic's orbit [380] the stars will reach their widest separation around 2175, when they will be separated by 2″.35. At present it is a fine object for 15-cm although there is a considerable difference in brightness between the stars. A third star of magnitudes 11.4 can be found 91″ distant in PA 159°. DR2 does not include this star but does show that

Finder Chart



Orbit



Ephemeris for STF 1639 AB (2000 to 2180)

Orbit by Ole (2000b) Period: 575.44 years, Grade: 4

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2000.0	324.6	1.71	2100.0	316.9	2.24
2020.0	322.7	1.86	2120.0	315.7	2.29
2040.0	321.0	1.98	2140.0	314.6	2.33
2060.0	319.5	2.09	2160.0	313.4	2.34
2080.0	318.2	2.17	2180.0	312.3	2.35

the RS CVn variable IL Com (V = 8.1), which is 480″ distant to the E) also has a very similar parallax to the components of STF 1639.

Observing and Neighbourhood

The pair STF1639 is located in the heart of the Coma cluster (Melotte 111) and is a member of the group. A recent paper by Guerrero *et al.* [379] finds that the 25% of the stars in the Coma cluster which they observed were found to be double or multiple, whilst only 5% of the surrounding field stars were not alone in space. STF 1639 forms a tight equilateral triangle with 12 and 13 Com and the finding chart will help to locate it. There are a number of pairs within a few degrees of STF 1639. The nearest is 12 CBe, which was catalogued by Sir James South and Sir John Herschel (SHJ 143). This is a wide and very unequal pair, visible in binoculars. The stars are of magnitudes 4.9 and 8.9 and the separation is 58″. Admiral Smyth noted the colours as straw yellow and rose red. About 1°.5 NW of 12 Com is STF 1633 (magnitudes 7.0, 7.1, 245°, 8″.9, 2017), the yellow components of which are moving through space at more than 0″.1 per year. Webb says 'Very pretty. Solitary'. The object 17 Com is a fine binocular pair – STFA 21 (5.2, 6.6, 250°, 145″, 2012).

Measures

Early measure (STF)	90°.1	2″.41	1837.39
(Orbit	89°.5	2″.30)	
Recent measure (CTT)	324°.2	1″.79	2014.37
(Orbit	323°.2	1″.82)	

86. $\alpha^{1,2}$ CRU = Δ 252 = WDS J12266–6306AB

Table 9.86 Physical parameters for α Cru

DUN 252	RA: 12 26 35.895	Dec: −63 05 56.73	WDS: 694(99) (AB)		
V magnitudes	A: 1.32	B: 1.55	C: 4.82		
$(B-V)$ magnitudes	A: +0.08	B: +0.75	C: −0.14		
μ(A)	−35.83 mas yr^{-1}	± 0.47	−14.86 mas yr^{-1}	± 0.43	
μ(B)	−35 mas yr^{-1}	± 18	25 mas yr^{-1}	± 25	
μ(C)	−38.0 mas yr^{-1}	± 1.0	−15.3 mas yr^{-1}	± 0.9	
π(A)	10.13 mas	± 0.50	320 light yr	± 15	
μ(C)	−39.59 mas yr^{-1}	± 0.33	−14.54 mas yr^{-1}	± 0.37 (DR2)	
π(C)	10.56 mas	± 0.23	309 light yr	± 7 (DR2)	
Spectra	A: B0.5IV + B1V	B: B0.5IV	C: B3/5V		
Masses ($M_\odot$)	Aa: 17.8	Ab: 6.1	B: 15.5		
Luminosities ($L_\odot$)	A: 2400	B: 1950	C: 90		
Catalogues (A/B/C)	26/27 G Cru	HR 4730/1/29	HD 108248/9/50	SAO 251904/—/3	HIP 60718
DS catalogues	DUN 252				
Radial velocity	11.90 km s^{-1}	± 2.4			
Galactic coordinates	300°.127	−0°.363			

History

Discovered by Fr Fontenay whilst in South Africa on 2 June 1685. Using an excellent 12-foot telescope, Fontenay noted that the star in the head of the Cross which is marked 3 by Bayer is actually two beautiful stars separated by their own diameter, and he compares it with Castor in the northern hemisphere. He then mentions a third star (C), which is more distant. James Dunlop observed the three stars in 1826 and allocated number 122 in his catalogue to AB whilst AC became 123; he was the first to measure them. For some unknown reason the system is now known as DUN 252 whilst Dunlop's original number 252 is a very wide pair 2°.5 NW of ϵ Tucanae. John Herschel comments on Rümker's notes about α Crucis: 'Mr Rümker describes it as involved in a milk-white nebulosity (Preliminary Catalogue, pp. 15, 17), a description which I am at a loss to understand, unless it refers to the bright surrounding light of the Milky Way'. Moore at Lick Observatory [385] found a velocity amplitude of 60 km s^{-1} in the C component and in 1932 Neubauer [384] announced that both A and B were spectroscopic binaries with almost identical periods of just under one day.

The Modern Era

Thackeray & Hill [383] presented the results of a radial velocity study of α^1 and α^2 Crucis. They found no sensible variation of velocity in α^2, and the new measurements of the radial velocity of α^1 did not corroborate Neubauer's data.

87. γ CRU = Δ 124 = WDS J12312–5707AB

Table 9.87 Physical parameters for γ Cru

DUN 124	RA: 12 31 09.95	Dec: −57 06 47.5	WDS: 7263(19)	
V magnitudes	A: 1.83	B: 3.65	C: 9.74	
$(B-V)$ magnitudes	A: +1.82	B: +0.14		
μ	−28.23 mas yr^{-1}	± 0.14	− 265.08 mas yr^{-1}	± 0.12
π	36.83 mas	± 0.18	88.6 light yr	± 0.4
Spectra	A: M3.5III	B: A3V		
Luminosities ($L_\odot$)	A: 115	B: 25		
Catalogues	HR 4763/4	HD 108903/25	SAO 240019/22	HIP 61084
DS catalogues	DUN 124			
Radial velocity	21.00 km s^{-1}	± 0.1		
Galactic coordinates	300°.159	+5°.650		

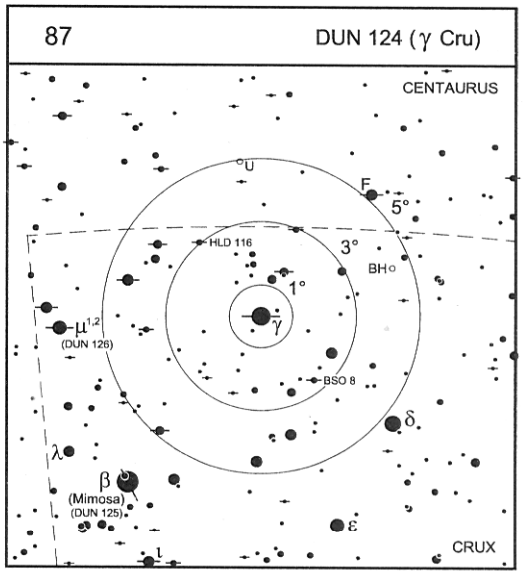
History

A common alternative name for this star is Gacrux. The name seems to have been derived by Elijah Hinsdale Burritt (1794–1893), who produced *The Atlas of the Heavens.* The wide companions were seen by Dunlop.

Modern Era

The object γ Cru is the brightest M giant in the sky and has been investigated for variability. Petit [389] found the range was a few hundredths It has certainly been investigated for radial velocity variations by Murdoch & Clark [388]. Over 900 days they found a total range of 1200 metres per second; although there was no obvious periodicity, several small peaks were seen in frequency space at 90 days or below. The atmosphere of Gacrux contains barium and Kaler [390] believes that this indicates the existence of a white dwarf companion which is seeding the primary. The Dunlop stars are both optical. None of the three stars listed above appear in Gaia DR2.

Finder Chart



Observing and Neighbourhood

Easily found, γ Crucis (DUN 124) is the top star of the cross (p. xx), 1.8, 6.5, 26°, 129″. It is also a binocular target: the primary is an M3 giant and there is a significant colour difference between the reddish-orange primary and the white companion 130″ distant, which is bright and far enough away to be seen in binoculars. Four degrees SE is Mimosa (β Cru, DUN 125). The Dunlop star has magnitude 7.2 and is 23° and 373″ distant from the magnitude 1.3 primary. Robert Innes found an 11th magnitudes star at 326°, 42″.6 and more recently Rainer Anton, working in Namibia, has imaged two more distant magnitudes 11 stars. There is a neat pair (BSO 8) at 1°.5 SW of γ. Its stars are magnitudes 7.8 and 8.0 at 335° and 5″.2, 2016. Head due E to find μ (DUN 126) (p. xx), which is possibly the finest pair for the small aperture besides α. Its white components of magnitudes 3.9 and 5.0 are 35″ apart in PA 17°, 2016. One degree N and a little E is HLD 116 (7.1, 8.9, 182°, 1″.9, 2000).

Measures

AB			
Early measure (PWL)	36°.5	99″.17	1860.11
Linear	36°.4	99″.11)	
Recent measure (ANT)	25°.0	128″.9	2010.27
Linear	25°.0	129″.42)	
AC			
Early measure (CRU)	86°.2	155″.2	1879.50
Recent measure (ANT)	70°.0	165″	2010.27

88. 24 COM = STF 1657 = WDS J12351+1823

Table 9.88 Physical parameters for 24 Com

STF 1657	RA: 12 35 07.76	Dec: +18 22 37.40	WDS: 404(143)	
V magnitudes	A: 5.11	B: 6.53		
$(B-V)$ magnitudes	A: +1.34	B: +0.31		
μ(A)	-3.72 mas yr^{-1}	$\pm$ 0.38	23.11 mas yr^{-1}	$\pm$ 0.24 (DR2)
μ(B)	-2.32 mas yr^{-1}	$\pm$ 0.12	21.24 mas yr^{-1}	$\pm$ 0.08 (DR2)
π(A)	8.58 mas	$\pm$ 0.20	380 light yr	$\pm$ 9 (DR2)
π(B)	8.84 mas	$\pm$ 0.07	369 light yr	$\pm$ 3 (DR2)
Spectra	A: KOII-III	B: A9V		
Luminosities ($L_\odot$)	A: 100	B: 25		
Catalogues (A/B)	HR 4792/1	HD 109511/0	SAO 100160/59	HIP 61418/5
DS catalogues	H 4 27	STF 1657	BDS 6212	ADS 8600
Radial velocity (A/B)	3.03 km s^{-1}	$\pm$ 0.1	4.90 km s^{-1}	$\pm$ 0.5
Galactic coordinates	278°.862	+80°.478		

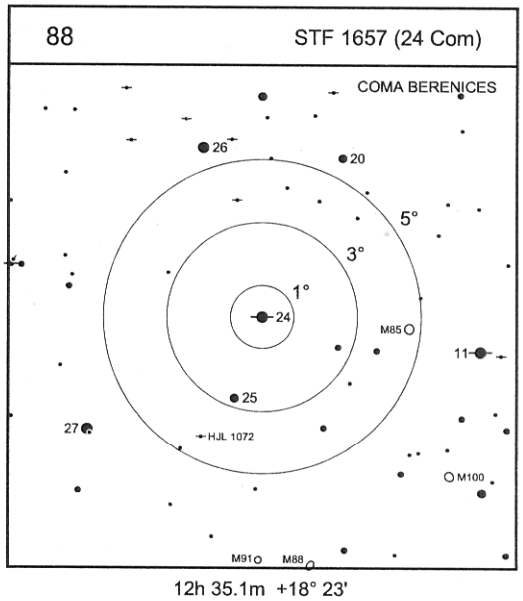
History

Found by William Herschel on 28 February 1781. 'Double. Considerably unequal. L(arge). whitish r(ed).; S(mall). blueish r(red). Mean distance 18″24‴. Position 3° 25′ n(orth) preceding'.

The Modern Era

Star B is a double-lined spectroscopic binary. Adams [391] first noted this on a spectrum which showed two sets of spectral lines separated by an amount equivalent to 127 km s^{-1}. Petrie [392] later derived the correct period, 7.3366 days. Star A is a suspected variable (NSV 5748). Observations were by Petit [389] The quoted errors on the Hipparcos astrometry of the A component are larger than might be expected, but DR2 has nailed the parallaxes with a much higher precision, and the stars are at the same distance within the given errors, so it

Finder Chart



seems certain that A and B are physical and it likely that this is a triple star if not quadruple. The pair can be used as a scale calibrator. At 2015.5, Gaia DR2 measured a position angle of 270°.2 and a separation of 20″.13. The similar proper motions mean that this value will not change significantly for a few years.

Observing and Neighbourhood

F. G. W. Struve gave yellow and blue for the colours whilst Smyth commented that they were 'very brilliant' and found 'orange colour and emerald tint' for the two stars. Greg Stone [126] was impressed with 24 Com but noted that it was not particularly easy to find, and he gave two different methods which can be found on the Star Splitters website. He noted colours of yellow going to orange and summer-sky blue which were most intense in 30-cm, becoming less so with smaller apertures. Two degrees SSE is HJL 1057, a rather wide pair but which appears to have common proper motion (7.6, 9.3, 23°, 118″, 2010).

Measures

Early measure (STF)	271°.9	20″.42	1830.03
Recent measure (HSW)	269°.9	20″.06	2015.36

89. γ CEN = HJ 4539 = WDS J12415–4858

Table 9.89 Physical parameters for γ Cen

HJ 4539	RA: 12 41 31.04	Dec: −48 57 35.54	WDS: 282(181)	
V magnitudes	A: 2.82	B: 2.88	C: 14.4	
$(B-V)$ magnitudes	A: +0.02	B: +0.03		
μ	A: −185.72 mas yr^{-1}	± 0.20	5.79 mas yr^{-1}	± 0.16
π	25.06 mas	± 0.28	130 light yr	± 1.5
Spectra	A: A0IV	B: A1IV		
Luminosities ($L_\odot$):	A: 100	B: 90		
Catalogues	HR 4819	HD 110304	SAO 223603	HIP 61932
DS catalogues	HJ 4539 (AB)	SEE 159 (AB,C)		
Radial velocity	−5.50 km s^{-1}	± 1.78		
Galactic coordinates	301°.255	+13°.880		

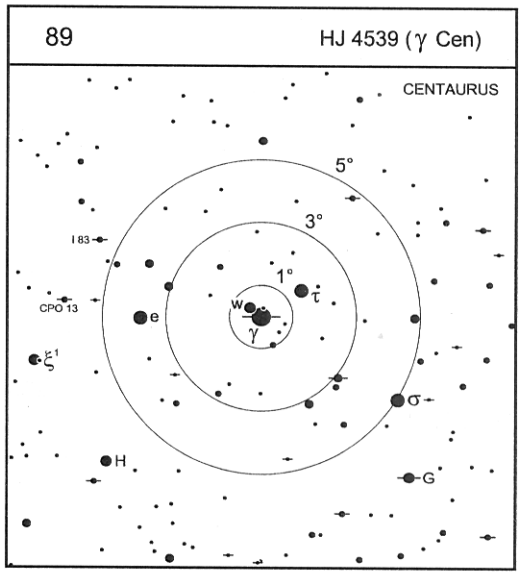
History

John Herschel, 1 March 1835: 'A star 4 m, which I am very much inclined to believe a close double, but could not verify owing to bad definition. Tried 320 but it will not bear that power.' Then 30 days later: '180 with triangular aperture shows it elongated; 320 fairly double and almost divided'. He observed the pair 10 times in all, recording PAs between 345° and 360° and estimated separations ranging between 2/3″and 1″. T. J. J. See found a very faint companion of mag 14.4 at 114° and 58″.2. The distance is increasing rapidly owing to the proper motion of γ.

The Modern Era

The number of measures of this pair (181 to date) compares unfavourably with its more northerly twin γ Vir (1580), reflecting the inequality of double star research between northern and southern hemispheres, even allowing for the fact that γ Virginis has been observed for much longer. Even during the current periastron passage, when the stars have

Finder Chart



there appear to have been no perturbations which might have been induced by an extra component with a mass of 0.3 $M_\odot$. Reports of the variability of one or both components have been made but neither star is in the GCVS. Although many observers of this system see no difference in magnitude, in recent years, a Δm value of 0.69 at V was recorded by Horch *et al.* [395] whilst Riddle *et al.* [394] found Δm to be as much as 0.9 at 745 nm.

Observing and Neighbourhood

The components are both very bright (each around $V = 3.5$), in fact almost equally bright, and well separated even for the small aperture for the next century and a half. I RWA has measured this pair every year, on average for seven nights each time, for the last 28 years. In 1990 it was at 286° and 2″.70, and it closed to around 0″.4 in 2005 (when it was just elongated with the 8-inch refractor at Cambridge at a power of ×600 in PA 150°). At this time the stars were moving in position angle at the rate of 1° every five days. Currently the pair is near 0° and 2″.75 – a total arc of about 285° over the 28 years). There are very few systems in the sky which afford such a good view of orbital motion in action using only the eye. Christopher Taylor, observing with his 12.5-inch Calver reflector at Hanwell, demonstrates this in a series of sketches [13] which he made during the recent periastron passage. Others might be mentioned – α Centauri, which is currently only 4″ apart and the angular motion of which is almost 14° per year, although that southern pair is now widening with increasing (and decelerating) position angle. More impressive is MLO 4 (p. xx). In 2018 the stars moved through almost 60° in the year although the separation is a more challenging 0″.5 and the declination an equally challenging −35°! There are two other pairs in the vicinity: STF 1677 is 2°.5 SSE (7.3, 8.1, 348°, 15″.9, 2015) and, more difficult, is STT 256 (7.3, 7.6, 103°, 1″.1, 2017).

Measures

Early measure (DA)	249°.9	1″.30	1832.20
(Orbit	251°.8	1″.24)	
Recent measure (ARY)	358°.6	2″.88	2018.37
(Orbit	359°.8	2″.73)	

91. β MUS = R 207 = WDS J12463–6806 AB

AB
|
ADD

Table 9.91 Physical parameters for β Mus

R 207	RA: 12 46 16.87	Dec: −68 06 29.1	WDS: 849(86)		
V-magnitudes	Aa: 3.55	Ab: 6.6	B: 4.03		
$(B-V)$ magnitudes	Aab: −0.18	B: −0.16			
μ	A: −41.97 mas yr^{-1}	± 0.43	B: −8.89 mas yr^{-1}	±0.31	
π	9.55 mas	± 0.41	340 light yr	± 15	
Spectra	A: B2.5V	B:			
Luminosities ($L_\odot$)	A: 330	B: 35			
Catalogues	β Mus	HR 4844	HD 110879	SAO 252019	HIP 62322
DS catalogues	R 207(AB)	RIZ 5 (AaAb)	RIZ 5 (AC)		
Radial velocity	42.00 km s^{-1}	± 7.4			
Galactic coordinates	302°.449	−5°.241			

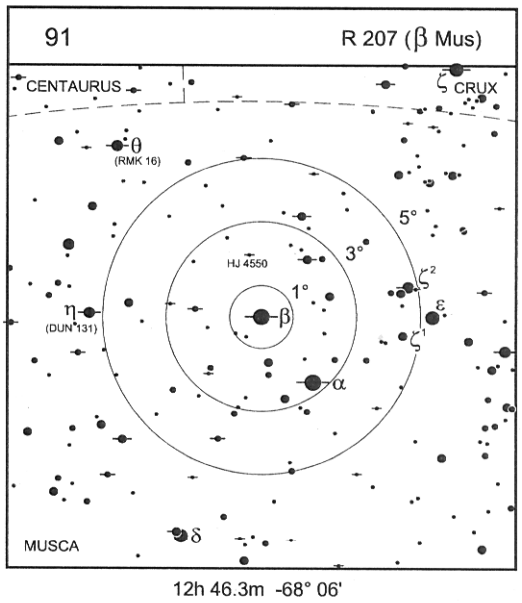
History

The object β Mus was found to be double by H. C. Russell [525] in the course of his work with the 11.5-inch refractor at Sydney Observatory. He notes 'First seen 78.284; one of the closest doubles I know'. The appellation β Mus was given to R 203 in error.

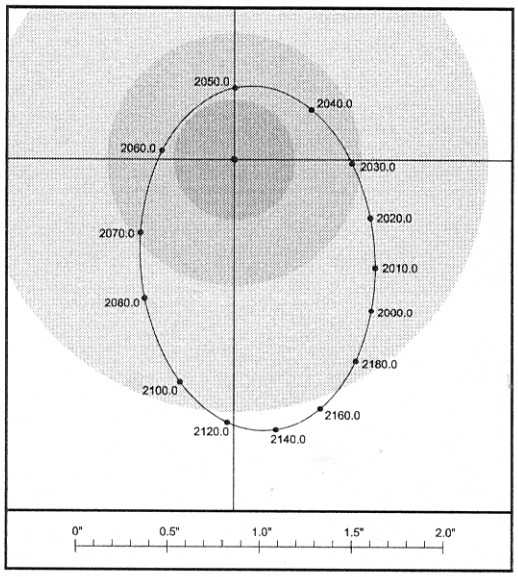
The Modern Era

The pair β Mus is a member of the Sco-Cen OB2 association, which is the nearest site of recent massive star formation to the Sun. It includes three subgroups – Upper Scorpius, Upper Centaurus Lupus, and Lower Centaurus Crux – and its members range from OB stars down to brown dwarfs. The brightest member is Antares. Also included are molecular cloud complexes in Lup, Cha, Cr, and Oph. In 2013 Rizzuto *et al.* [475] published the results of a survey of some of the brighter members of the association using the *SUSI* interferometer to assess the frequency of multiplicity amongst these stars. Using a 15-metre baseline they were sensitive to double

Finder Chart



Orbit



Ephemeris for R 207 AB (2015 to 2060)

Orbit by FMR (2012g) Period: 194.276 years, Grade: 5

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	58.9	0.89	2040.0	123.2	0.50
2020.0	66.7	0.81	2045.0	148.0	0.45
2025.0	76.3	0.72	2050.0	179.7	0.39
2030.0	88.3	0.64	2055.0	221.0	0.35
2035.0	103.6	0.57	2060.0	263.1	0.39

stars with separations between 7 and 200 mas. One of the new binary systems to emerge fom this survey was β Mus Aab. It has a close companion at a distance of about 0″.05 but there is no information on the nature of any binary motion, so it is not yet clear whether the suspected radial velocity variation in star A can be directly attributable to the newly discovered component Ab. To be complete, Rizzuto *et al.* also looked at the space up to 10,000 AU from each star and from 2MASS data they found another faint star with the same proper motion as β. This object has maguitude 15.9 and is 95″ distant.

Observing and Neighbourhood

The β Mus system can be found 8° due S of β Cru (Mimosa). Recent micrometrical and CCD measures have indicated that the orbit is predicting position angles which are more than 5° in advance of those observed – a fact that suggests that the current orbital period may be too short. Both stars are blue-white according to the ASNSW observers. Three point five degrees NE is the fine pair RMK 16 (p. xx), and 2°.8 due E is η Mus (DUN 131), whose stars of magnitudes 4.8 and 7.2 are 58″ apart in PA 332° and therefore accessible to binoculars. One degree N of μ and slightly E is HJ 4550 (7.6, 8.7, 97°, 13″.6, 2016).

274

Measures

Early measure (I)	341°.0	1″.33	1900.36
(Orbit	342°.6	1″.18)	
Recent measure (ANT)	53°.2	1″.01	2016.35
(Orbit	60°.5	0″.87)	

92. 35 COM = STF 1687 = WDS J12533+2115AB

35 Com

Table 9.92 Physical parameters for ~~STF 1687~~

STF 1687	RA: 12 53 17.77	Dec: +21 14 42.1	WDS: 78(388)		
V magnitudes	A: 5.15	B: 7.08	C: 9.76		
$(B-V)$ magnitudes	A: +1.18	B: +0.43			
μ(A)	-49.40 mas yr^{-1}	$\pm$ 0.85	-35.37 mas yr^{-1}	$\pm$ 0.55 (DR2)	
μ(B)	-53.99 mas yr^{-1}	$\pm$ 0.11	-27.53 mas yr^{-1}	$\pm$ 0.06 (DR2)	
π(A)	11.56 mas	$\pm$ 0.34	282 light yr	$\pm$ 8 (DR2)	
π(B)	11.54 mas	$\pm$ 0.06	283 light yr	$\pm$ 1 (DR2)	
Spectra	G7III				
Luminosities ($L_\odot$)	A: 50	B: 9	C: 0.8		
Catalogues	HR 4894	HD 112033	SAO 82550	HIP 62886	
DS catalogues	H 5 130 (AC)	STF 1639 (AB)	BDS 6296	ADS 8695	CHR 150
Radial velocity (A)	-6.091	$\pm$ 0.075 km s^{-1}			
Galactic coordinates	307°.148	+84°.102			

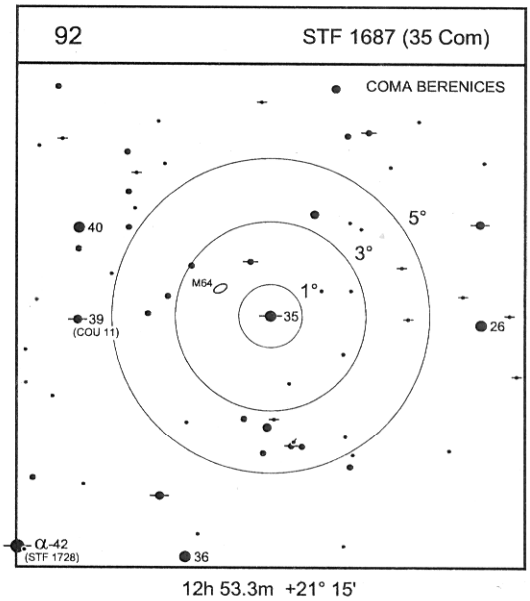
History

The star first entered the double star catalogues when Sir William Herschel found a faint third component, C, on 26 February 1783. He noted that the primary star was red and the companion dusky. At this time the binary companion would have been at a distance of around 1″.4, assuming the current orbit is correct, and perhaps the difference in magnitude was the deciding factor in Herschel's not seeing the close star. It was left to Struve at Dorpat to find B.

The Modern Era

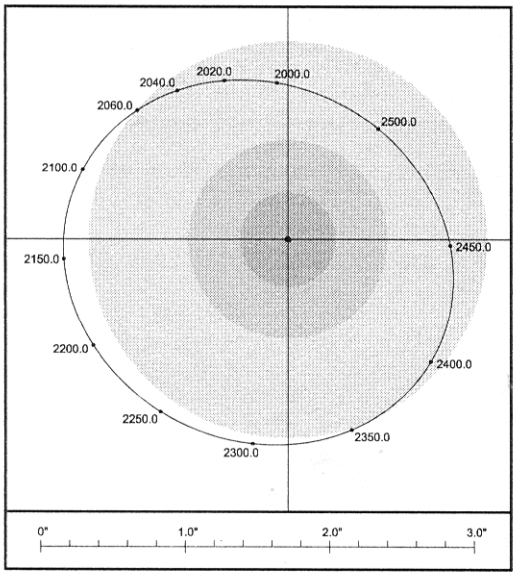
The current orbit is by Drummond [403]. The eccentricity is 0.206 and the stars were closest around 1960 at a separation of 0″.99 whilst the widest separation comes in 2155 when it reaches 1″.56. Star C is physically attached. The French double star astronomer Jacques Le Beau [402] was of the opinion that

Finder Chart



REPLACE FINDER CHART

Orbit



Ephemeris for STF 1687 AB (2010 to 2100)

Orbit by Dru (2014) Period: 539.4 years, Grade: 4

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	193.3	1.13	2060.0	229.3	1.38
2020.0	201.7	1.19	2070.0	235.1	1.42
2030.0	209.4	1.24	2080.0	240.6	1.45
2040.0	216.6	1.29	2090.0	245.9	1.48
2050.0	223.2	1.33	2100.0	251.0	1.50

C was in very slow direct motion around AB. In 2016 C was at 127°, 28″.5. Halbwachs *et al.* [401] in 2012 found that the radial velocity of A varies. They derived a period of 2905 days with an amplitude of 5.5 km s^{-1} and an eccentricity of 0.63.

Observing and Neighbourhood

3°E

One degree to the NNE is the bright galaxy M64. Two degrees S and slightly W is STF 1685 (7.3, 7.8, 200°, 15″.8, 2015). The star 39 Com is one of Paul Couteau's early discoveries (COU 11), although still a formidable challenge for 20–25-cm (6.1, 8.8, 314°, 1″.8, 2015). Star A is double again (CHR 150) – an interferometric discovery by the CHARA group.

Measures

Early measure (STF)	25°.3	1″.43	1829.99
(Orbit	29°.9	1″.37)	
Recent measure (TOK)	193°.6	1″.17	2015.35
(Orbit	195°.1	1″.14)	

93. $\mu^{1,2}$ CRU = Δ 126 = WDS J12546–5711AB,C

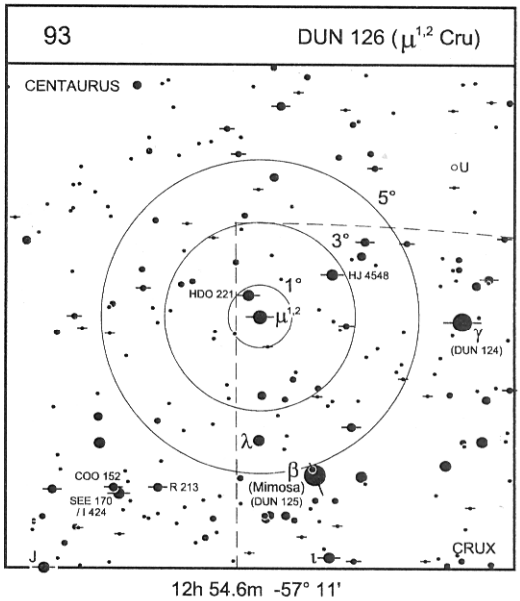
Table 9.93 Physical parameters for μ^1 Cru

DUN 126	RA: 12 54 35.66	Dec: −57 10 40.4	WDS: 2866(36)	
V magnitudes	A: 4.04	B: 5.20		
$(B-V)$ magnitudes	A: −0.17	B: −0.11		
μ (A)	−30.69 mas yr^{-1}	± 0.13	− 13.08 mas yr^{-1}	± 0.11
μ (B)	−32.49 mas yr^{-1}	± 0.23	− 10.92 mas yr^{-1}	± 0.19
π (A)	7.87 mas	± 0.17	414 light yr	± 9
π (B)	8.01 mas	± 0.29	407 light yr	± 15
μ (A)	−28.16 mas yr^{-1}	± 0.22	− 10.34 mas yr^{-1}	± 0.34 (DR2)
π (A)	8.95 mas	± 0.23	364 light yrs	± 9 (DR2)
Spectra	A: B2IV-V	B: B5Vne		
Luminosities ($L_\odot$)	A: 250	B: 100		
Catalogues (A/B)	HR 4898/9	HD 112092/1	SAO 240366/7	HIP 63003/5
DS catalogues	DUN 126			
Radial velocity (A/B)	13.90 km s^{-1}	± 0.7	13.00 km s^{-1}	± 3.7
Galactic coordinates	303°.362	+5°.691		

History

The constellation of Crux, because of the density of bright stars within such a small area of sky, has long been known in history to the peoples of the southern hemipshere. It was not located correctly on celestial globes until 1598. Crux could be used as a guide by navigators to locate due south. A line drawn through γ and α when extended passes close to the South Celestial pole. If a line is drawn through the midpoint of, and at right angles to, the line joining α and β Centauri then that line when extended south crosses the Crux marker close to the SCP.

Finder Chart



in velocity with time. The A star has also been recorded as a pair, using speckle interferometry, with a distance of around 0″.04 [410] and what appears to be rapidly varying position angles with time. This is not the spectroscopic pair but probably the O star, making the A component a triple star. There are two recent reports that B is also a spectroscopic binary – one that the star is an SB2 (Chini *et al.* [409]) and the other, by Sota *et al.* [408], that it is an SB1. An examination of B by Mason *et al.* [410] showed that it was unresolved in a 4-metre aperture. The stars are much too distant to give a parallax measurable by Hipparcos, and an estimate from spectroscopy gives a distance of 2500 pc. Zhekov *et al.* [413] conclude that component A consists of two WR stars and an O supergiant, and they tie the system in to the nearby cluster Danks 2, which is 7500 parsecs away. Sana *et al.* [414] found another component (C) 3″.5 from B in PA 207°. Unravelling the complex nature of the A component will have to wait for DR3. If B is physical, the DR2 parallax confirms the extreme distance of the star, even an approximate value of which defeated Hipparcos.

Observing and Neighbourhood

The system θ Mus sits on the opposite side of the Coalsack Nebula about 5° SE of α Crucis. It is a splendid sight for the small telescope – two white stars, unequal and rather close. There has been very little motion since discovery, so it will remain a fine object for a long time to come. The fine binary star β Mus (p. xx) can be found 3°.5 to the NE, whilst 3°.1 SSE is a beautiful binocular pair η Mus (DUN 131) (4.8, 7.2, 332°, 58″, 2002). A further 1° E is HJ 4586 (7.3, 9.1, 141°, 2″.9, 1991), which is slowly closing. In a curve radiating away from the star m Mus are three visual pairs: the nearest of which is HJ 4579 (7.9, 8.6, 98°, 5″.1, 2010). Next is RST 632 (7.7, 10.6, 302°, 4″.9, 2000), which should be accessible to 20-cm. It is one of the easier pairs in Rossiter's predominantly difficult-to-observe catalogue. Finally MLO 3 (7.0, 9.1, 39°, 1″.7, 2014) has an 09 giant primary; K band imaging studies add four stars within 5″ and B is a very close pair.

Measures

Early measure (HJ)	187°.5	5″.82	1836.38
Recent measure (ANT)	186°.6	5″.36	2007.37

96. α COM = STF 1728 = WDS J13100+1732AB

α Com 13 09 59.29 +17 31 46.0

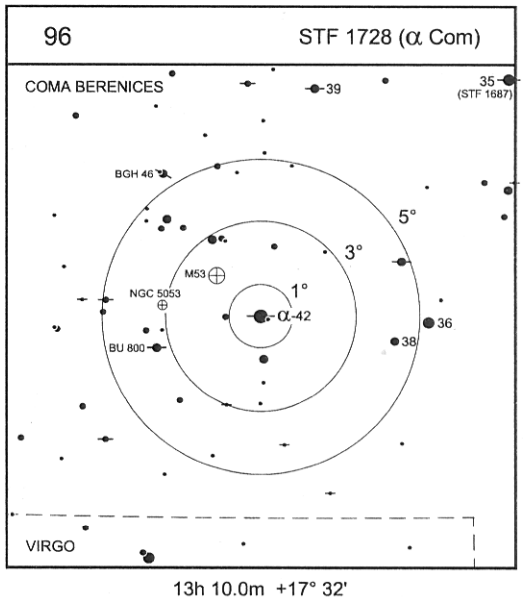
Table 9.96 Physical parameters for ~~STF 1728~~

STF 1728	RA: 13 10 00	Dec: +17 32 00	WDS: 25(642)	
V magnitudes	A: 4.85	B: 5.53		
$(B-V)$ magnitudes	A: +0.59	B: +0.47		
μ	-433.13 mas yr^{-1}	$\pm$ 0.70	141.24 mas yr^{-1}	$\pm$ 0.51
π	56.10 mas	$\pm$ 0.89	58.1 light yr	$\pm$ 0.9
Spectra	F5V	F6V		
Luminosities ($L_\odot$)	A: 3	B: 1.5		
Catalogues (A/B)	HR 4968/9	HD 114378/9	SAO 100443	HIP 64241
DS catalogues	STF 1728	BDS 6406	ADS 8804	
Radial velocity (A)	-16.05 km s^{-1}	$\pm$ 0.21		
Galactic coordinates	327°.933	+79°.489		

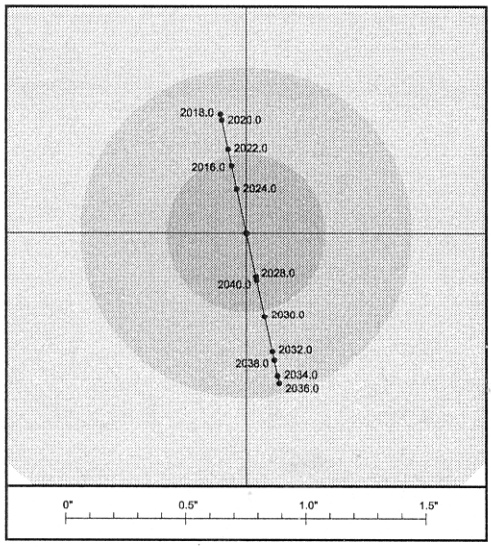
History

F. G. W. Struve found this star, also known as α or 42 Com, in autumn 1827 at a distance of 0″.57 (according to Lewis, or 0″.64 according to Smyth) but by 1833 it was single in his 9.3-inch Fraunhofer refractor and remained that way until 1836, when he measured a distance of 0″.30. It attracted much attention with the observers of the time but it was always a challenging object as it never exceeded 0″.6 in separation and was frequently much less than this. After 20 years or so of observing it was clear that the position angle remained fixed near 192° or 12°; because the stars were ostensibly equally bright it was never clear which quadrant the pair was in. After the conjunction had taken place, did the companion continue to widen in the opposite quadrant, or did it speed around the primary and head back to the same quadrant? In 1866 Otto Struve assumed that the former condition was true and calculated an orbit for the star which gave the period as 25.5 years, which agrees fairly closely with the most recent value and which was based on measures made with telescopes of around 10-inch aperture, with the exception of Otto's own 15-inch refractor at Pulkovo. Otto gave the inclination as 90°

Finder Chart



Orbit



Ephemeris for STF 1728 AB (2018 to 2036)

Orbit by Mut (2015) Period: 25.8524 years, Grade: 1

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2018.0	192.2	0.51	2028.0	12.5	0.18
2020.0	192.2	0.48	2030.0	12.4	0.36
2022.0	192.1	0.36	2032.0	12.3	0.51
2024.0	192.0	0.19	2034.0	12.3	0.61
2026.0	175.2	0.00	2036.0	12.3	0.64

and Burnham notes that an occultation takes place every 13 years and that the orbit is almost in the plane of sight but, without any knowledge of the apparent angular diameters of stars, it appears that no one tried to predict the epoch of a possible eclipse.

The Modern Era

Interest was re-awakened in this system in a paper by Hartkopf & McAlister [415], who produced a new orbit for the pair, based on speckle interferometry, which gave much higher astrometric precision. Their paper, which was received by the *Astronomical Journal* on 28 February 1989, predicted that an eclipse would occur in February 1989 with a depth of about 0.1 mag in *V* and lasting 1.3 days. In 2014, Muterspaugh *et al.* [416], with the benefit of 20 years more observations of the orbit, predicted that the next eclipse would occur around 25 January 2015 (but hopefully on Muterspaugh's sister's birthday, 23 January!) and would last between 28 and 44 hours. As the event approached Huib Henrichs and Marcella Wijngaarden from the University of Amsterdam had planned to observe the eclipse from their home institute and began to take an interest in the logistics of the event. They began to do the photometry on 25 November 2014 and received Muterspaugh's and Henry's paper on 15 December. On 21 December Henrichs calculated the orbit from WDS data, but using separations only. This gave an eclipse date of 28 October 2014. On 16 January 2015 CHARA interferometry measures confirmed that the eclipse had passed. Henrichs also confirmed that the eclipse would have been observable in Amsterdam for at least two hours.

In December 2014 Muterspaugh *et al.* [416] published a paper on `astro-ph`. They admitted that the eclipse had been missed because three visual observations of position angle out of a total of 609 used in the orbital analysis were 180° out. This was enough to skew the time of conjunction by several months and in fact the eclipse had occurred on 18 November (RAW's birthday!). Henry had spent 22 years monitoring the brightness of α Com using the Automated Photometric Telescope at Fairborn Observatory at the University of Tennessee. He had noted that there was a slight sinusoidal variation in brightness, with a period of about a decade.

A secondary eclipse is due in 2026 and, although favourable for northern observers, there is only a 5% chance of observing it, and the next favourable primary eclipse will not be until 2066.

Observing and Neighbourhood

Admiral Smyth thought that 42 Com '... is placed fortunately for the out-door gazer, being midway between Arcturus and Denebola on the parallel, and vertically half way down from Spica to Cor Caroli'. Another way is to start from ϵ Vir, head 7°.5 due N to pick up the stars 36 and 38 Com and then head 2.5° due W. There is an 11.5 mag. star (349°, 85″, 2013); the distance is decreasing owing to the proper motion of AB. The current ephemeris shows that the stars are rapidly widening and by spring 2018 they should be resolvable in 25-cm and be certainly elongated in 20-cm. Three degrees NW is BGH 46 a binocular pair (6.5, 7.6, 58°, 203″, 2011). DR2 shows, that the stars are at similar distances but not the same within the quoted errors (302 light years). A more interesting system is BU 800 (6.7, 9.5, 105°, 7.8, 2014), which was once thought to have a hyperbolic orbit. This is a nearby system; DR2 puts it at 35.8 light years. There are two faint field stars, magnitudes 12.6 and 13.3.

Measures

Early measure(STF)	189°.5	0″.57	1827.83
(Orbit	12°.3	0″.63)	
Recent measure: (NPI)	192°.62	0″.03874	2015.02
(Orbit	192°.66	0″.038)	

much to our knowledge of the motion of the close pair. In 2009 [419] and 2013 [420], Andrei Tokovinin observed the star with the 4.1-metre *SOAR* telescope in Chile and since then there have been no further positive measures. It is likely that the stars form a binary with a period of maybe ten years, and the apparent orbit is highly inclined to the line of sight, restricting the position angle changes to a small range. One of the components of FIN 208 is a variable and goes under the name V790 Cen. The Gaia astrometry of star C shows that there is no physical connection with AB, but Veramendi & González [462] have recently shown that C is itself a short-period spectroscopic binary with a period of 3.85 days.

Observing and Neighbourhood

The system J Cen can be seen almost halfway between β Cen and β Crucis. The Dunlop pair is a fine sight in binoculars and small apertures. Both bright components are B stars. Another Dunlop pair (DUN 142) is 3° N (6.5, 7.6, 90°, 33″.2, 2010). The pair R 223 (6.6, 9.9, 13°, 2″.6, 2008) was almost 6″ apart when first found by Russell.

Measures

FIN 208			
Early measure (FIN)	160°	0″.14	1930.47
Recent measure (TOK)	160°.0	0″.051	2013.24
DUN 133			
Early measure (R)	343°.1	60″.19	1871.42
Recent measure (ARY)	345°.0	60″.56	2010.62

98. ζ UMA = STF 1744 = WDS J13239+5456AB,C

ζUMa

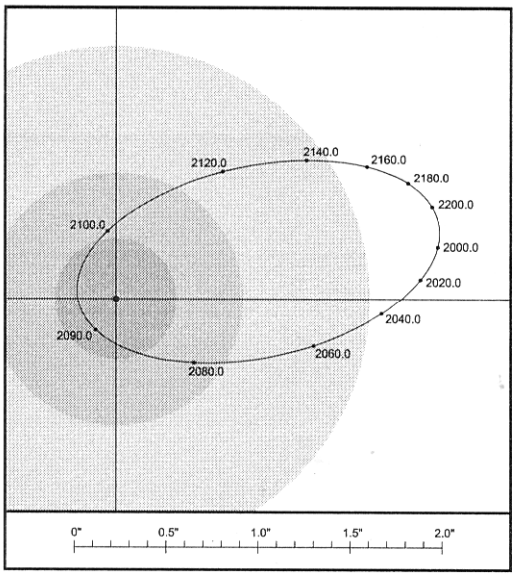
Table 9.98 Physical parameters for ~~STF 1744~~

STF 1744	RA: 13 23 55.42	Dec: +54 55 31.5	WDS: 48(485)		
V magnitudes	AaAb: 2.23	BaBb: 3.88	C: 4.01		
$(B-V)$	A: +0.02	B: +0.17	C: +0.22		
μ (Mizar)	-120.21 mas yr^{-1}	$\pm$ 0.12	-16.04 mas yr^{-1}	$\pm$ 0.14	
μ (Alcor)	-121.2 mas yr^{-1}	$\pm$ 0.5	-22.0 mas yr^{-1}	$\pm$ 0.5	
π (Mizar)	39.91	$\pm$ 0.13	81.7 light yr	$\pm$ 0.3	
π (Alcor)	38.01	$\pm$ 1.71	85.8 light yr	$\pm$ 3.9	
μ(Mizar B)	114.01 mas yr^{-1}	$\pm$ 0.54	-26.45 mas yr^{-1}	$\pm$ 0.50 (DR2)	
μ(Alcor)	113.31 mas yr^{-1}	$\pm$ 0.38	-28.56 mas yr^{-1}	$\pm$ 0.32 (DR2)	
π(Mizar B)	40.50 mas	$\pm$ 0.35	80.5 light yr	$\pm$ 0.7 (DR2)	
π(Alcor)	40.47 mas	$\pm$ 0.22	80.6 light yr	$\pm$ 0.4 (DR2)	
Spectra	A: A2V + A2V	B: A1m + A5V	C: A5V + M3-4V		
Masses	Aa: 2.5	Ab: 2.5	Ba: 1.9	Bb: 0.3	
	Ca: 1.8	Cb: 0.3			
Luminosities ($L_\odot$)	A: 65	B: 14	C: 13		
Catalogues (Mizar)	HR 5054/5	HD 116656/7	SAO 28737	HIP 65378	
Catalogues (Alcor)	80 UMa	HR 5062	HD 116842	SAO 28751	HIP 65477
DS catalogues	Mayer 37 (AB)	PEA 1 (AaAb)	STF 1744 (AB)	BDS 6406	ADS 8891
	PCF 1 (CaCb)				
Radial velocity (Mizar):	-9.6 km s^{-1}	$\pm$ 1.0			
Radial velocity (Alcor):	-6.31 km s^{-1}	$\pm$ 0.38			
Gal. coordinates (Mizar)	113°.111	+61°.579			
Gal. coordinates (Alcor)	112°.769	+61°.469			

History

As one of the components of the tail of the Great Bear, ζ UMa appears to be two stars, which can be seen easily with the naked eye. The brighter of the two is also known as Mizar (V = 2.3), whilst 11′.8 distant is Alcor (C) which is 80 UMa (V = 4.0). Mizar occupies a unique place in the pantheon of visual double stars. It was the first telescopic pair ever noted, it was the first star system to be photographed, and it contains the first spectroscopic binary to be recognised. Benedetto Castelli, using one of his friend Galileo's telescopes, found Mizar to be a close double star on 7 January 1617 [422] and

Orbit



Ephemeris for STF 1768 AB (2015 to 2060)

Orbit by Sod (1999) Period: 228 years, Grade: 3

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	95.1	1.70	2040.0	86.8	1.44
2020.0	93.6	1.66	2045.0	84.7	1.37
2025.0	92.1	1.61	2050.0	82.4	1.29
2030.0	90.4	1.57	2055.0	79.7	1.20
2035.0	88.7	1.51	2060.0	76.6	1.10

The Modern Era

This star was examined by De Rosa *et al.* [514], who were looking for higher multiplicity in a sample of A stars within 75 pc of the Sun – known as the VAST project (Volume limited A STars). They did not find any further components either close in (via observations with adaptive optics on several large telescopes) or distant (using wide-field plate archives) but derived the masses of A and B as given above.

Observing and Neighbourhood

The relatively wide separation at which the pair currently resides is offset by the significant difference in magnitude, and a good night is needed with a 15-cm to get a satisfactory view of the companion. F. G. W. Struve noted colours of white and blue. Smyth did not include the pair in the Bedford Catalogue, owing, no doubt, to its very small separation during the early Victorian epoch. The star STF 1769 is rather faint and wide but is actually a physical quintuple: AC is 7.9, 9.3, 259°, 56″.5, 2013 whilst Struve found a closer component B of magnitude 10.4, now at 46°, 1″.6, 2013. A 16.1 mag star, found by Tokovinin has common proper motion whilst A is also an SB1. The whole group moves through space with a proper motion > 0″.2 per year. The object S 654 is an easy telescopic pair (5.6, 8.9, 239°, 71″.8, 2013). It too also has common proper motion and indeed a third very distant star (SHY 633 AC) also shares it.

ADD 3°N

Measures

Early measure (STF)	78°.9	1″.04	1830.54
(Orbit	77°.5	1″.13)	
Recent measure (ARY)	97°.7	1″.65	2013.30
(Orbit	95°.6	1″.71	

100. STF 1785 BOO = WDS J13491+2659AB

Table 9.100 Physical parameters for STF 1785 Boo

STF 1785	RA: 13 49 04.001	Dec: +26 58 47.57	WDS: 12(875)	
V magnitudes	A: 7.36	B: 8.15		
$(B-V)$ magnitudes	A: +1.2	B: +1.23		
μ(A)	-416.52 mas yr^{-1}	$\pm$ 0.19	-112.02 mas yr^{-1}	$\pm$ 0.12 (DR2)
μ(B)	-462.74 mas yr^{-1}	$\pm$ 0.07	-71.47 mas yr^{-1}	$\pm$ 0.05 (DR2)
π(A)	73.92 mas	$\pm$ 0.07	44.12 light yr	$\pm$ 0.04 (DR2)
π(B)	74.20 mas	$\pm$ 0.05	43.96 light yr	$\pm$ 0.03 (DR2)
Spectra	A: K4V	B: K6V		
Luminosities ($L_\odot$)	A: 0.2	B: 0.08		
Catalogues	HD 120476	SAO 83011	HIP 67422	
DS catalogues	SHJ 168	STF 1785	BDS 6641	ADS 9031
Radial velocity	-20.46 km s^{-1}	$\pm$ 0.09		
Galactic coordinates	78°.969	+76°.610		

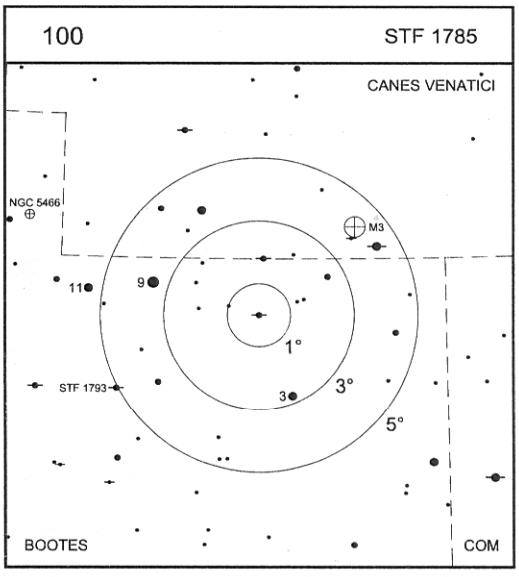
History

The pair was measured by Sir James South in 1823, who derived a distance of 5″.66. This, when plotted with observations taken over the next few decades, seemed to show that the motion of the companion was linear. However, by the turn of the nineteenth century, the characteristic curvature of an orbit became clear and it was supposed that South had made an error in reducing his measurement. Burnham discussed the measurements up to about 1900 and showed that it was perfectly possible to fit the two orbits which were extant then, with periods of 125 years and 199 years, equally well.

The Modern Era

This pair of stars is moving through space at almost 0.5 arcseconds per year and is only 43.7 light years distant. The orbit is reasonably eccentric and at the time of writing the

Finder Chart



101. 3 CEN = H 3 101 = WDS J13518−3300

Delete ';'

Delete ';'

Table 9.101 Physical parameters for 3 Cen

H 3 101	RA: 13 51 49.601	Dec: −32 59 38.71	WDS: 1288(65)	
V magnitudes	A: 4.50	B: 6.01		
$(B-V)$ magnitudes	A: −0.16	B: +0.01		
μ(A)	−34.70 mas yr^{-1}	± 0.86	−27.91 mas yr^{-1}	± 0.79 (DR2)
μ(B)	−36.74 mas yr^{-1}	± 0.27	−23.77 mas yr^{-1}	± 0.19 (DR2)
π(A)	11.10 mas	± 0.43 mas	294 light yr	± 11 (DR2)
π(B)	10.27 mas	± 0.14 mas	318 light yr	± 4 (DR2)
Spectra	A: B5III	B: B8V		
Luminosities ($L_\odot$)	A: 105	B: 30		
Catalogues (A/B)	HR 5210	HD 120709/10	SAO 204916/7	HIP 67669
DS catalogues	H 3 101	DUN 148		
Radial velocity	7.50 km s^{-1}	± 1.6		
Galactic coordinates	317°.282	+28°.189		

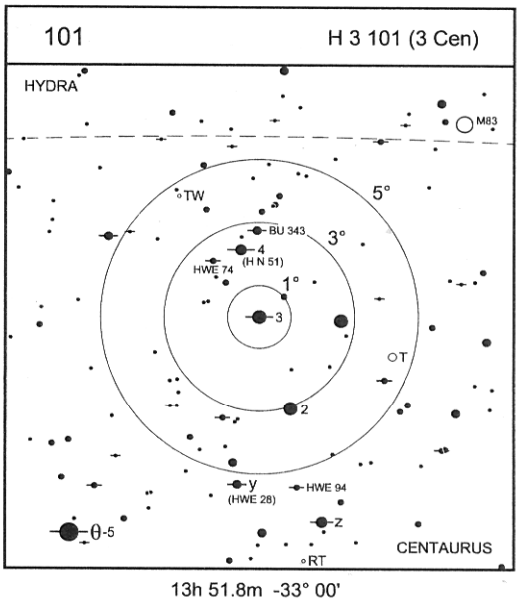
History

Herschel observed 3 Cen and in his report of 31 January 1783 also called it k Cen. His report says 'Double. Considerably unequal. L(arge). d(usky)w(hite).; S(mall). d(usky)p(ale)r(ose). Distance 11″35‴. Position 22° 0′ s(outh) following'. John Herschel also observed it in South Africa and called the star Δ 148.

The Modern Era

Hipparcos photometry of star A reports a range of variability between H_p = 4.27 and 4.32. There are two obvious dips in the data which suggest the star is an eclipsing binary, but there are not enough data to derive a period.

Finder Chart



0.5 $M_\odot$, in which case the companion to B is as late as K7. In 2006 O. Kiyaeva [433] did an extensive astrometric study of the triple system based on photographic plates taken with the 26-inch refractor at Pulkovo between 1982 and 2004. Despite the angular motion over the last two centuries, amounting to just 3° in position angle, Kiyaeva nevertheless produced two orbits for AB with periods of 6101 and 6675 years. These imply systemic masses of 4.2 and 3.6 $M_\odot$. Kiyaeva also produced four astrometric orbits for the BaBb system, and concluded that there was evidence for the duplicity of star A, which was originally inferred by examining the radial velocity of the star as presented by Abt. He produced two large papers [434], [435] of stellar radial velocity determinations taken from the early days at Lick Observatory, and over a 20-year timespan the radial velocity of component A varied by up to 22 km s^{-1}, which was significantly larger than the quoted errors.

Observing and Neighbourhood

The star κ Boo is the easternmost star in a group of three naked-eye stars located 5° NE of the end star in the tail of the Great Bear (η). Sue French finds both stars yellow-white with 130-mm at ×23. Another star in the loose group is ι (STFA 26), which is a wide and easy binocular double (magnitudes 4.8, 7.4, 33°.1, 38″.82, 2016) and which Smyth describes as pale yellow and creamy white, whereas Sue French records it as yellow-white and golden. A close companion to A noted by Struve in 1836 was also tentatively seen by Smyth in 1838, but has been seen by no one else since. This is presumably the source of the appellation STF 4026AB which appears in the SIMBAD entry for this star. W. H. Smyth noted that the stars were 'pale white and bluish', whilst W. S. Franks in 1915 made them yellow and purple. Continue a line from κ through θ Boo and you come to two pairs which are resolution tests for 10-cm and 20-cm: STF 1863 is a binary with period 534 years which is moving very slowly at present (7.7, 7.8, 59°, 0″.65, 2020); STF 1871 is 8.0, 8.1, 313°, 1″.9, 2017.

Measures

Early measure (STF)	237°.7	12″.60	1832.50
Recent measure (WSI)	235°.8	13″.49	2012.66

ADD
('just off the chart
(35' E of STF 1863)')

103. α CEN = RHD 1 = WDS J14396−6050AB

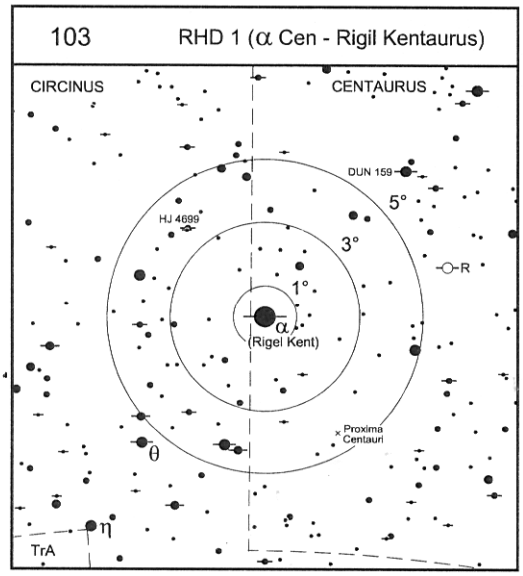
Table 9.103 Physical parameters for α Cen

RHD 1	RA: 14 39 36.494	Dec: −60 50 02.37	WDS: 56(452)	
V manitudes	A: −0.01	B: +1.33	C: 11.13	
$(B-V)$ magnitudes	A: +0.71	B: +0.88	C: +1.82	
μ(AB)	−3619.9 mas yr^{-1}	± 3.9	639.8 mas yr^{-1}	± 3.9 (Kervella)
μ(C)	−3773.8 mas yr^{-1}	± 0.4	770.5 mas yr^{-1}	± 2.0 (Benedict)
μ(C)	−3781.31 mas yr^{-1}	± 0.08	769.77 mas yr^{-1}	± 0.19 (DR2)
π(AB)	747.17 mas	± 0.61	4.365 light yr	± 0.004 (Kervella)
π(C)	768.13 mas	± 1.04	4.246 light yr	± 0.006 (Benedict)
π(C)	768.50 mas	± 0.21	4.244 light yr	± 0.001 (DR2)
Spectra	A: G2V	B: K1V	C: M5.5Ve	
Masses ($M_\odot$)	A: 1.1055	± 0.0039	B: 0.9373	± 0.0033
Masses ($M_\odot$)	C: 0.1221	± 0.0037		
Luminosities ($L_\odot$)	A: 1.5	B: 0.4	C: 0.00005	
Radii ($R_\odot$)	A: 1.2234	± 0.0053	B: 0.8632	± 0.0037
Radii ($R_\odot$)	C: 0.1542	± 0.0045		
Catalogues (A/B)	HR 5459/60	HD 128620/1	SAO 202538	HIP 71683/1
DS catalogues	RHD 1 (AB)	SCZ 1 (CaCb)		
Radial velocity (AB)	−22.332 km s^{-1}	± 0.005 (Kervella)		
Radial velocity (C)	−22.204 km s^{-1}	± 0.032 (Benedict)		
Galactic coordinates	315°.733	−0°.681		

History

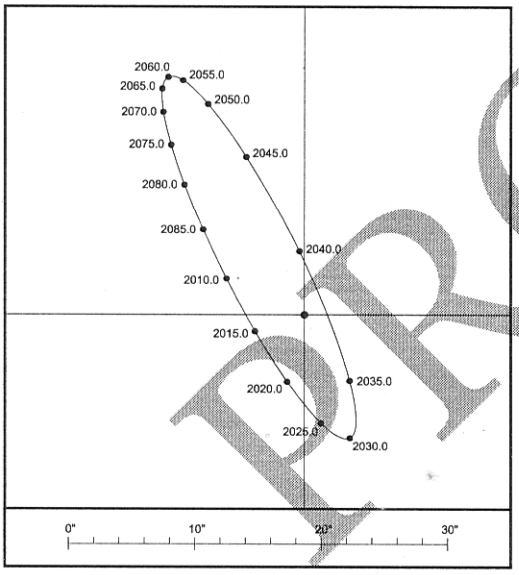
The history of α Centauri as a double star goes back to 1689, when Fr Richaud, a French Jesuit priest, who was in Pondicherry and heading for Siam as part of a six-man mission for King Louis XIV, made a telescopic observation of a comet ("je remarquai que le pied le plus oriental & le plus brillant etoit un double etoile aussi bien que le pied de la Croissade – I noted that the brightest star at the easternmost foot (of Centaurus) was a double star as good as that at the foot of the Cross", i.e. α Crucis. Proxima Centauri was discovered by R. T. Innes [443] in 1915, while working at the Union Observatory in Johannesburg. Innes was blinking two plates taken with the Franklin Adams camera in 1910 and 1915, and after a considerable amount of work he noticed a faint star which showed considerable movement between the two dates. The amount of movement and direction convinced Innes that his star was connected to α Centauri, but its distance was not established until 1928, when H. L. Alden [438] confirmed that it was marginally closer to the Solar System than α.

Finder Chart



14h 39.6m -60° 50'

Orbit



Ephemeris for RHD 1 AB (2015 to 2042)

Orbit by Pbx (2016) Period: 79.91 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	288.2	4.13	2030.0	20.1	10.44
2018.0	327.1	4.46	2033.0	26.9	9.01
2021.0	352.1	6.12	2036.0	42.3	4.48
2024.0	5.5	8.11	2039.0	169.8	3.04
2027.0	13.8	9.78	2042.0	194.5	8.78

The Modern Era — ADD

In 1998 Schultz *et al.* [436] announced that they had found a possible substellar companion to Proxima as a result of observations with the Faint Object Spectrograph fitted to the HST and used as a coronographic camera. They tentatively concluded that it is co-moving with Proxima but the WDS clearly states 'Not a binary' and no confirming observations have yet been made. The refinement of radial velocity methods which allows astronomers to detect shifts as small as several metres per second in stars accompanied by planets has led to the discovery of a planet accompanying Proxima Cen. A recent study by Kervella *et al.* [444] has produced precise values for the masses and radii of the three stars, along with the proper motion, parallax, and radial velocity of the centre of mass of the AB binary system as given above. Whilst it was assumed that Proxima was gravitationally bound to α, a critical piece of evidence had been missing and that was an accurate value for the radial velocity of Proxima. With this established, the authors pronounced on the physical relationship of Proxima Centauri to its bright neighbours. They find Proxima to be gravitationally bound with a high degree of confidence. The period is 550,000 years and the apparent orbit takes Proxima from about 13,000 AU from α to 4300 AU. The star is currently near apastron. Whilst the bright stars are not in DR2, there is a measurement of Proxima, although the *G* magnitude given (8.95) seems at odds with the WDS *V* magnitude of 11.13. The data is given in the table and should be regarded as provisional. The astrometry of Proxima given above is by Benedict *et al.* [439]. Dedicated books on α and Proxima have been written by Martin Beech [441] and Ian Glass [442].

Exoplanet Host

In 2016 Anglada-Escudé *et al.* [440] announced that Proxima was accompanied by a planetary body. The mass was 1.3 times that of the Earth and the period was 11.2 days. The reflex motion that this body produced on Proxima Centauri was only 3 metres s^{-1} peak to peak.

Observing and Neighbourhood

The pair α Centauri is quite simply the best visual double star in the sky. The combination of brightness, rapid orbital motion, and the knowledge that this is the nearest binary star to the Sun make this a 'must-see' for all apertures. Even in the smallest telescopes the stars are brilliant but in large telescopes they are almost too bright to bear. Both stars appear deep yellow to RWA, whilst the ASNSW group make them yellowish and yellowish but darker. The pair is currently

104. ζ BOO = STF 1865 = WDS J14411+1344AB

Delete 2'

Delete 0'

Table 9.104 Physical parameters for ζ Boo

STF 1865	RA: 14 41 08.952	Dec: +13 43 41.90	WDS: 18(746)		
V magnitudes	A: 4.46	B: 4.55	C: 10.98		
$(B-V)$	A: +0.07	B: +0.09			
μ	51.95 mas yr^{-1}	± 0.81	−11.08 mas yr^{-1}	± 0.53	
π	18.56 mas	± 0.76	176 light yr	± 7	
Spectra	A: A0V	B: A0V			
Luminosities ($L_\odot$)	A: 38	B: 35			
Catalogues	HR 5477	HD 129246J	SAO 101145	HIP 71795	
DS catalogues	H N 114 (AB)	STF 1865 (AB)	H 6 104 (AC)	BDS 6955	ADS 9343
Radial velocity	−8.50 km s^{-1}	± 0.6 km s^{-1}			
Galactic coordinates	10°.804	+61°.115			

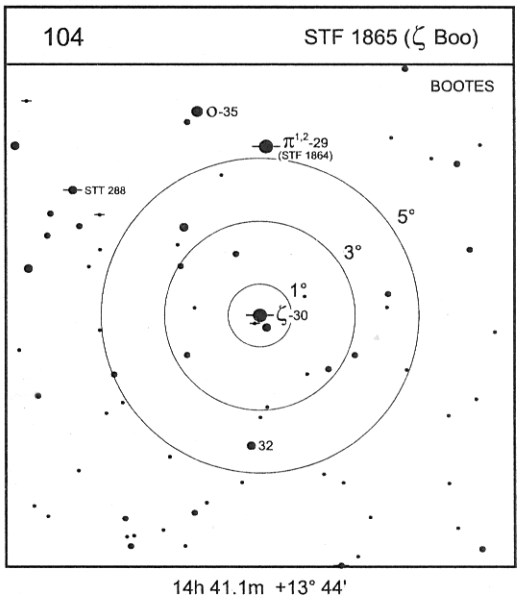
History

On 29 November 1782 William Herschel noted that ζ Boo had 'a very obscure star in view. Extremely unequal … Distance about $1\frac{1}{2}$ minutes. Position almost directly proceding' but, whilst re-observing this system on 5 April 1796, he found the bright star was a close double 'very nearly in contact. I can however see a small division.' The ephemeris from the orbit by M. Scardia gives a distance of 0″.89 for that epoch. South & Herschel [518] measured it in 1823 but got a distance about twice that expected, and from 1830 onwards, when Struve began to observe the pair, the stars closed and the trajectory appeared almost linear. A close approach in 1897 was followed by a reverse of direction around 1950, since when the stars have been closing more rapidly.

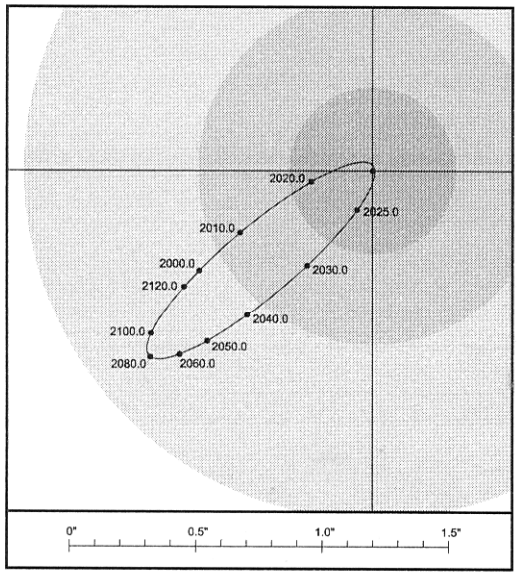
The Modern Era

This system is closely related to γ Vir in terms of orbital dynamics. Two stars of similar mass, brightness, and spectral type are involved, and in each case the apparent orbit is a

Finder Chart



Orbit



Ephemeris for STF 1865 AB (2016 to 2052)

Orbit by Sca (2007f) Period: 125.24 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2016.0	289.3	0.40	2036.0	321.0	0.66
2020.0	280.2	0.25	2040.0	319.1	0.76
2024.0	3.8	0.04	2044.0	317.7	0.84
2028.0	328.2	0.37	2048.0	316.5	0.91
2032.0	323.6	0.53	2052.0	315.5	0.97

highly eccentric ellipse. In the case of γ Vir, $e = 0.88$ whilst that of ζ Boo is 0.98 according to the orbit of M. Scardia [447]. In fact, the eccentricity is the highest known of any visual system and means that the stars are 82 times closer to each other at periastron than at apastron. In 2010, Muterspaugh *et al.* [620] re-calculated the orbit, giving it an eccentricity of 0.9977 which, if true, means that the stars approach each other to 0.3 AU at periastron and are almost 2000 times further away at apastron. The formal error on the eccentricity of this orbit allows a small possibility that the orbit may even be parabolic. The Sixth Double Star Orbital Catalog prefers the slightly less eccentric Scardia orbit, and the ephemeris from that work is given below. Either way the next close approach, due in late 2023, opens up the possibility of observing a change in orbital elements due to mutual tidal effects. The star is included here because the components are both bright and equal and will form a stiff test for larger apertures from 2020 or so.

Observing and Neighbourhood

This pair is closing very quickly and by 2020 the separation will be pushing the resolution of a 50-cm telescope. The shorter orbital ephemeris given above shows that the motion will be extremely swift around autumn 2023, when the stars will be moving at almost 6° per day. At that point the separation will be only 5 mas but in the range of ground-based interferometers. By the spring of 2030 the pair should be split in a 20-cm aperture once more. The wider Herschel companion C is being left behind by the proper motion of AB and is currently 105″ away. There are some splendid pairs in the vicinity. The star ζ forms a equilateral triangle 3° on the side with both π Bootis (STF 1864) (due N) and STT 288 (NE). The object π is a beautiful pair, whose stars are of magnitudes 4.9 and 5.8 and they are currently separated by 5″.4 at PA 113°. STT 288 is a binary pair of 313-year period. The stars are of magnitudes 6.9 and 7.6 and are currently 1″.1, apart although now slowly closing, passing 0″.8 around 2030 before reaching 0″.5 in 2060 or so. A further 4° NE of π is ξ Bootis (STF 1888)(p. xx).

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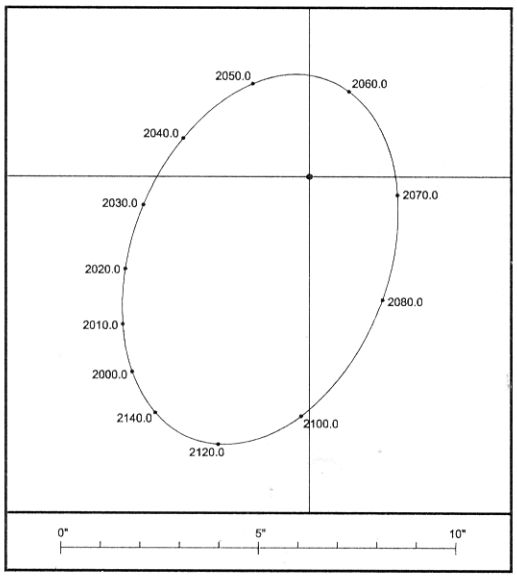
Measures

Early measure (STF)	309°.2	1″.19	1830.47
(Orbit	309°.8	1″.15)	
Recent measure (ARY)	290°.9	0″.50	2013.21
(Orbit	292°.5	0″.49)	

Orbit



Ephemeris for STF 1888 AB (2015 to 2060)

Orbit by Sod (1999) Period: 151.6 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	302.9	5.64	2040.0	253.0	3.34
2020.0	296.5	5.21	2045.0	234.1	3.00
2025.0	288.9	4.74	2050.0	211.2	2.77
2030.0	279.6	4.26	2055.0	185.2	2.61
2035.0	267.9	3.78	2060.0	155.3	2.39

Exoplanet Host?

As a nearby star, ξ Boo has been the target of several observing campaigns to look for signs of exoplanets, which, so far, have proved fruitless. Astronomers used radial velocities taken at the Lick and Keck Observatories over an almost 30 year period [451] to make accurate measures of the radial velocity of the brighter component, but no significant variations were seen apart from a slow linear drift due to the binary companion.

Delete?

Observing and Neighbourhood

One of the best targets for small telescopes in the northern sky, this much observed system can be seen fully resolved at all times in its 151.5 year period orbit even with small apertures, to its proximity to the Sun. It is easily found about 9° following α Boo (Arcturus). The pair will be resolvable in 7.5-cm aperture through the whole orbital cycle. The two stars were separated by 7″.3 in 1978 and will close up to a separation of 2″.1 in 2066. The colour contrast is marked in this pair, owing to the difference in spectral types in the two stars of nearly two full spectral classes, although the bluish tinge mentioned by Smyth (orange and purple) and STF (yellow and purple) has not been experienced by Hartung or the writer, for whom yellow and deep orange seems a better description of the colours of A and B. Nearby are ζ Boo (page xx) and π Boo.

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Measures

Early measures (STF)	334°.2	7″.22	1829.40
Orbit	332°.1	7″.27)	
Recent measure (ARY)	300°.3	5″.26	2018.44
Orbit	298°.5	5″.35)	