107. 44,I BOO = STF 1909 = WDS J15038+4739

44,i

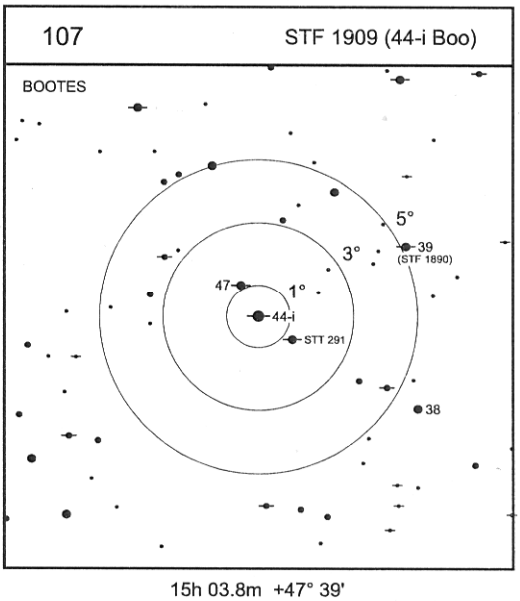
Table 9.107 Physical parameters for ~~STF 1909~~ Boo

STF 1909	RA: 15 03 47.30	Dec: +47 39 14.6	WDS: 15(821)	
V magnitudes	A: 5.20	B: 6.10		
$(B-V)$ magnitudes	A: +0.65	B: +0.94		
μ	-445.84 mas yr^{-1}	$\pm$ 1.44	19.86 mas yr^{-1}	$\pm$ 1.67
μ(A)	-332.06 mas yr^{-1}	$\pm$ 1.97	87.35 mas yr^{-1}	$\pm$ 2.02 (DR2)
μ(B)	-463.68 mas yr^{-1}	$\pm$ 0.67	-7.52 mas yr^{-1}	$\pm$ 0.80 (DR2)
π(A)	77.25 mas	$\pm$ 1.20	42.22 light yr	$\pm$ 0.7 (DR2)
π(B)	78.09 mas	$\pm$ 0.53	41.77 light yr	$\pm$ 0.3 (DR2)
Spectra	A: F7V	Ba: G0Vn	Bb: G0Vn	
Masses ($M_\odot$)	A: 1.04	$\pm$ 0.10	B: 1.28	$\pm$ 0.02
Radii ($R_\odot$)	A: 0.98	$\pm$ 0.04	B: 0.87	$\pm$ 0.02
Luminosities ($L_\odot$)	A: 1.1	B: 0.5		
Catalogues	HD 133640	HR 5618	SAO 45357	HIP 73695
DS catalogues	H 1 15	STF 1909	BDS 7120	ADS 9494
Radial velocity	-10.40 km s^{-1}	$\pm$ 2.1		
Galactic coordinates	80°.370	+57°.066		

History

Although William Herschel discovered the duplicity of 44 Bootis on 17 August 1782 the pair were in the process of closing rapidly, and by 1811 they were only 0″.23 apart, but were then easily seen by Struve at Dorpat in 1832 when the distance had increased to almost 3″. For much of the next century the motion appeared to be mainly in separation as the stars widened. Agnes Clerke [452] summarized some of the early impressions of variability. She notes that in 1781 Herschel considered them considerably unequal, yet in 1787 they were perfectly matched. John Percy [453] says that Herschel discovered two variable stars, 44 Boo and α Her. In 1819, F. G. W. Struve found two magnitudes difference between the stars, from 1822–1833 consistently one magnitude, and between 1833 and 1838 only half a magnitude. In 1921, W. S. Adams [454] took a spectrum of the star and found that it resembled W UMa. The period of variation (0.268 days) was found by

Finder Chart



109. $\mu^{1,2}$ LUP = HJ 4753 = WDS J15185−4753AB

μ Lup Add 32.03 −47° 52 31.1

Table 9.109 Physical parameters for ~~HJ 4753~~

HJ 4753	RA: 15 18	Dec: −41 10 00.32	WDS: 1347(63)	
V magnitudes	A: 4.95	B: 5.05	C: 6.76	D: 14.70
$(B-V)$ magnitudes	A: −0.10	B: −0.08	C: +0.11	D:
μ(AB)	−29.59 mas yr^{-1}	± 0.78	−35.07 mas yr^{-1}	± 0.57
μ(C)	−25.50 mas yr^{-1}	± 0.71	−34.75 mas yr^{-1}	± 0.51 (DR1)
π(AB)	9.72 mas	± 0.71	336 light yr	± 25
μ(C)	−18.60 mas yr^{-1}	± 0.34	−24.32 mas yr^{-1}	± 0.51 (DR2)
π(C)	4.01 mas	± 0.18	813 light yr	± 36 (DR2)
Spectra	A: B8V	B:	C: A2V	
Masses ($M_\odot$)	A: 3.1	B: 3.2	Ca: 1.8	Cb: 0.04 D: 0.05
Luminosities ($L_\odot$)	A: 90	B: 80	C: 100	D: 0.02
Catalogues	HR 5683	HD 135734	SAO 225638	HIP 74911
DS catalogues	HJ 4753 (AB)	DUN 180 (AB,C)	HUB 15 (AD)	
Radial velocity (AB)	14.90 km s^{-1}	± 1.78		
Radial velocity (C)	−6.9 km s^{-1}			
Galactic coordinates	326°.857	+8°.046		

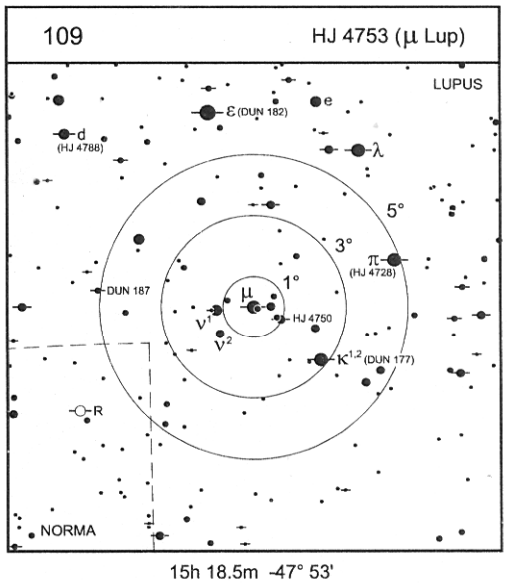
History

James Dunlop had his paper *'Approximate Places of Double Stars in the Southern Hemisphere observed at Parramatta in New South Wales in 1829'* published in the *Memoirs of the RAS*. He measured the difference in RA and declination to yield position angle and separation. Dunlop listed μ Lupi as entry number 180 and measured the difference in RA and declination between the two stars, which can be converted into 21″.00 and 45°.9. John Herschel mentions merely 'Close double' and gives a distance of 2″ and an PA of 173°.5 when he first observed the duplicity of the brighter component in 1836.

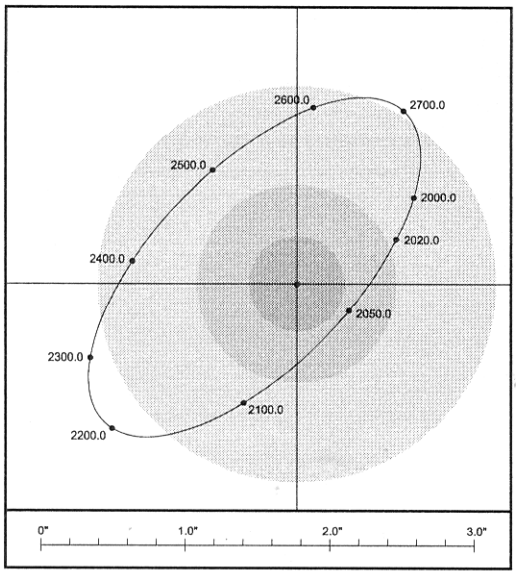
The Modern Era

Modern high-resolution techniques are demonstrating that B stars often form systems of higher multiplicity, and μ

Finder Chart



Orbit



Ephemeris for HJ 4753 AB (2010 to 2100)

Orbit by Zir (2015a) Period: 772 years, Grade: 5

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	121.3	0.89	2060.0	32.5	0.41
2020.0	114.1	0.76	2070.0	8.2	0.50
2030.0	103.8	0.62	2080.0	352.8	0.63
2040.0	87.7	0.49	2090.0	342.8	0.77
2050.0	62.7	0.41	2100.0	336.0	0.91

Lupi is no exception. Hubrig *et al.* [461] found an infrared component 6″.15 distant from A which they conclude is a pre-main sequence star with a mass of 0.05 $M_\odot$. The spectra of C (Veramendi & Genzález [462]) showed that C wa a spectral type A2V but that it was also a single-lined spectroscopic binary of period 12.53 days. When they took a spectrum of the A component they found that it showed two spectra of similar spectral type but radically different rotation velocities (278 km s^{-1} and 50 km s^{-1}), the latter being similar to that of C. If the visual orbit is correct, the stars will close to 0″.5 around 2055 then widen to a maximum separation of 1″.7 in 2230 or so. Gaia has found a proper motion for C very close to that of AB but C gives a negative parallax, although as it is a spectroscopic binary this may affect this result. The radial velocity of C is significantly different from that of AB but Veramendi does not rule out a physical connection, given that the orbit of C is preliminary. If the star found by Hubrig is connected then this is potentially a quintuple system.

Observing and Neighbourhood

A beautiful pair of bright, white stars with the Dunlop companion adding to the beauty of the view. The close binary is slowly getting more difficult to resolve and will need at least 15-cm from now on. This is a rich region for the double star observer. Within 5° are κ^1 Lup (DUN 177) (3.8, 5.5, 143°, 27″, 2010), π Lup (p. xx), DUN187 (7.1, 9.2, 217°, 24″, 2010), and HJ 4788 (4.7, 6.5, 12°, 2″.1, 2016) whilst just 30′ away is HJ 4750 (6.0, 10.4, 15°, 12″.5, 2013).

Measures

HJ4753			
Early measure (JC)	170°.1	1″.5	1851.49
(Orbit	168°.7	1″.31)	
Recent measure (ARY)	119°.0	0″.83	2016.66
(Orbit	116°.7	0″.80)	
DUN 180			
Early measure (SEE)	130°.2	23″.44	1897.13
Recent measure (ARY)	128°.1	23″.22	2016.66

110. ϵ LUP = Δ182 = WDSJ15227−4441AB,C

Table 9.110 Physical parameters for ϵ Lup

DUN 182	RA: 15 22 40.868	Dec: −44 41 22.61	WDS: 5872(22)		
V magnitudes	Aa: 3.6	Ab: 5.1	B: 5.1	C: 9.1	D: 16.2
$(B-V)$ magnitudes	Ab: −0.15	B:	C: −0.12		
μ(AB)	A: −22.86 mas yr^{-1}	± 0.67	B: +8.87 mas yr^{-1}	± 0.59	
μ(C)	A: −12.78 mas yr^{-1}	± 2.5	B: −16.4 mas yr^{-1}	± 2.5	
π	6.37 mas	± 0.70 mas	512 light yr	± 56	
μ(A)	−16.64 mas yr^{-1}	± 1.79	−24.14 mas yr^{-1}	± 1.59 (DR2)	
μ(C)	−6.46 mas yr^{-1}	± 0.09	−13.87 mas yr^{-1}	± 0.06 (DR2)	
π(A)	8.24 mas	± 0.85	396 light yr	± 41 (DR2)	
π(C)	3.69 mas	± 0.52	884 light yr	± 125 (DR2)	
Spectra	A: B5V + ? + ?	B: ?	C: A5V		
Masses ($M_\odot$)	Aa1: 8.5	Aa2: 7.4	Ab: 4.6	B: 4.8	
Luminosities ($L_\odot$)	Aa: 440	Ab: 110	B: 110	C: 12	
Catalogues	HR 5708	HD 136504	SAO 225712	HIP 75264	
DS catalogues	RIZ 13 Aa,Ab	COP 2 (AB)	DUN 182 (AB,C)	RIZ 13 (AD)	
Radial velocity (AB)	7.90 km s^{-1}	± 4			
Radial velocity (C)	−26 km s^{-1}	± 5			
Galactic coordinates	329°.228	+10°.323			

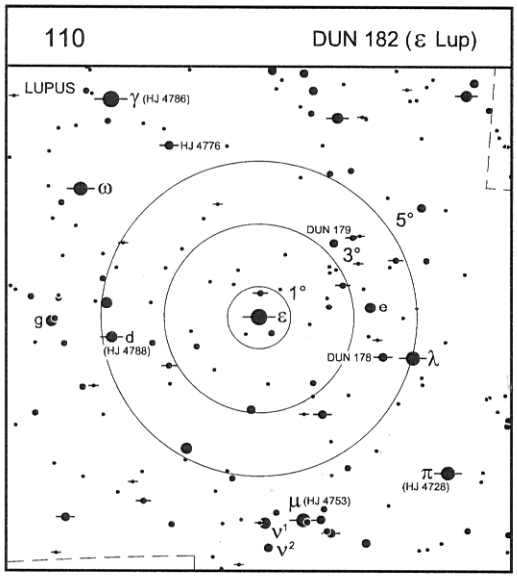
History

At Parramatta John Dunlop measured a faint star 19″ away from ϵ Lupi at a position angle of 174°. He used an achromatic telescope of 46-inches focal length in conjunction with a parallel wire micrometer which he had made himself. The close pair was discovered by Copeland in 1883 (see the entry on ψ Velorum, p. xx). In the 1900s Lick Observatory astronomers were in Chile using a two-prism spectrograph on bright southern hemisphere stars; during this expedition they discovered the spectroscopic binary nature of ϵ, and a period of 4.55 days was quickly established.

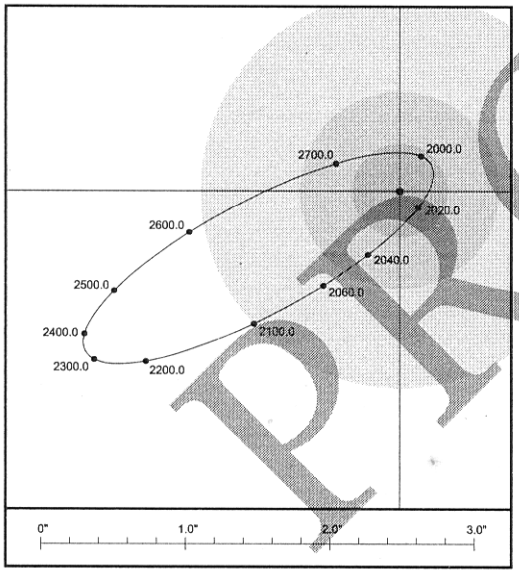
The Modern Era

The system ϵ Lupi is the first known double magnetic massive binary. In a recent survey for duplicity using the *SUSI* interferometer, Rizzuto *et al.* [475] detected a close companion star at a distance of 0″.049, which probably does not correspond to the spectroscopic component but may be related to the star found by Uytterhoeven *et al.* [465], who used 106 high-resolution spectra to find a period of 4.55970 years for the primary; in doing so, however, they also detected apsidal motion with a period of 430 years. This makes ϵ a physical quadruple, and the physical connection of Dunlop's

Finder Chart



Orbit



Ephemeris for COP 2 AB (2010 to 2100)

Orbit by Tok (2015c) Period: 736.69 years, Grade: 5

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	115.1	0.26	2060.0	321.6	0.85
2020.0	47.7	0.17	2070.0	318.5	1.00
2030.0	350.8	0.31	2080.0	316.2	1.13
2040.0	333.8	0.50	2090.0	314.3	1.26
2050.0	326.2	0.69	2100.0	312.8	1.37

component C is questionable. Its spectral type and radial velocity led Thackeray [464] to doubt its connection to the system. The proper motion is also significantly different. DR2 confirms that C is twice as far as A and hence a field star. Another star, with $V = 16$, was found by Rizzuto using wide-field databases.

Observing and Neighbourhood

The Dunlop pair will remain a relatively easy object for 10-cm apertures. The distance is slowly increasing. The star found by Copeland, however, has closed up and is currently near minimum separation, placing it beyond the range of most telescopes for at least 20 years. The system ϵ Lupi lies in a rich field of interesting visual double stars. Within 5° are γ, μ, and two DUN pairs, DUN 178 (6.5, 7.3, 256°, 31″, 2016) – the primary is a close pair (B 1267, 6.5, 9.6, 314°, 1″.2, 1991) – and DUN 179 (7.3, 8.5, 45°, 10″.5, 2016). The star HJ 4788 (magnitudes 4.7, 6.5) was found by John Herschel during sweep 718 (10 July 1836), and he called it f Lup. A spectacular sight in the Johannesburg telescope, RWA measured it at 12°, 2″.1 in 2016, confirming that the pair has closed since discovery (3″.1).

Measures

COP 2			
Early measure (SEE)	280°.8	0″.96	1897.12
(Orbit	275°.4	0″.70)	
Recent measure (TOK)	95°.3	0″.21	2014.18
(Orbit	93°.4	0″.21)	
DUN 182			
Early measure (DUN) :	173°.6	19″.12	1826
Recent measure (ARY) :	168°.9	26″.14	2016.66

111. η CRB = STF 1937 = WDS J15232+3017AB

Table 9.111 Physical parameters for η CrB

STF 1937	RA: 15 23 12.0		Dec: +30 17 00	WDS: 10(1074)
V magnitudes	A: 5.70		B: 5.93	C: 17
$(B-V)$ magnitudes	A: +0.60		B: +0.71	
μ	116.83 mas yr^{-1}	± 0.40	−171.37 mas yr^{-1}	± 0.49
π	55.98 mas	± 0.78	58.2 light yr	± 0.8 (Hipp.)
π	54.1 mas	± 0.64	60.3 light yr	± 0.7 (dyn.)
Spectra	A: G2V		B: G2V	
Masses ($M_\odot$)	A: 1.243	± 0.054	B: 1.100	± 0.039
Luminosities ($L_\odot$)	A: 1.5		B: 1.3	C: 0.00005
Catalogues	HD 137107	HR 5727	SAO 64673	HIP 75312
DS catalogues	H 1 16	STF 1937	BDS 7251	ADS 9617
Radial velocity	7.26 km s^{-1}	± 0.05		
Galactic coordinates	47°.536	+56°.725		

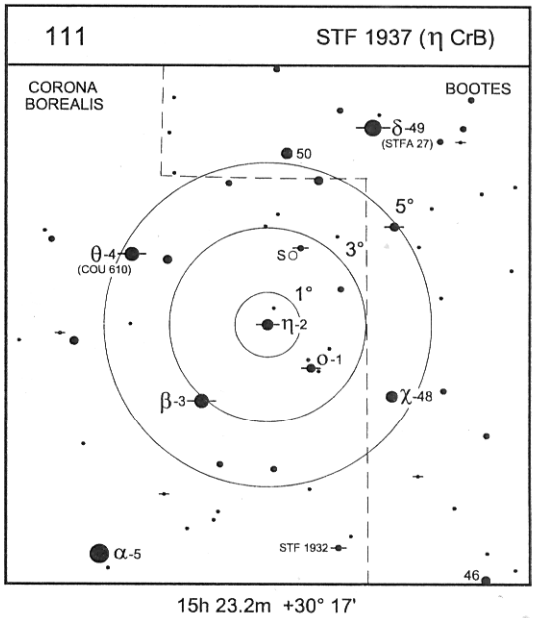
History

This pair was Noted by Sir William Herschel on 9 September 1781 (when the current orbit puts them at a distance of just over 1″). He said that he was able to see them as double at ×227 but commented that he would not have been able to discover them at that power. The stars spend only nine years in every 41-year cycle at a separation of 1 arcsecond or greater, so it was a fortuitous observation. Lewis lists 15 orbits which had been calculated by 1906 including the first, by John Herschel in 1833, when very few reliable observations had been made. Herschel obtained a period of 44 years but by 1850 the elements of the orbit were more or less those which characterize the current orbit.

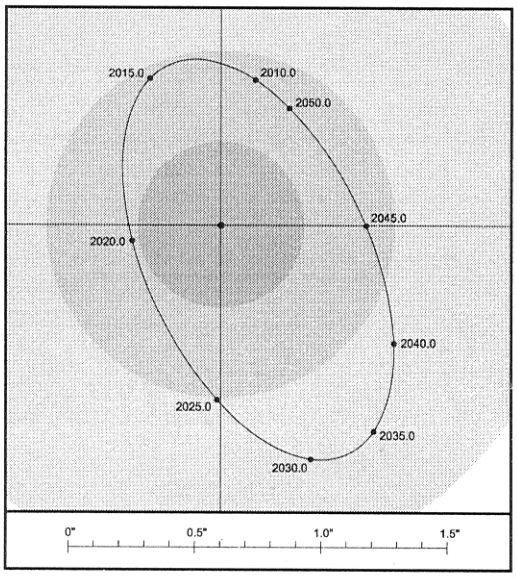
The Modern Era

The *WDS* gives the spectra as F8V and G0V – the types in the table above are from Muterspaugh [621].

Finder Chart



Orbit



Ephemeris for STF 1937 AB (2018 to 2036)

Orbit by Mut (2010b) Period: 41.6296 years, Grade: 1

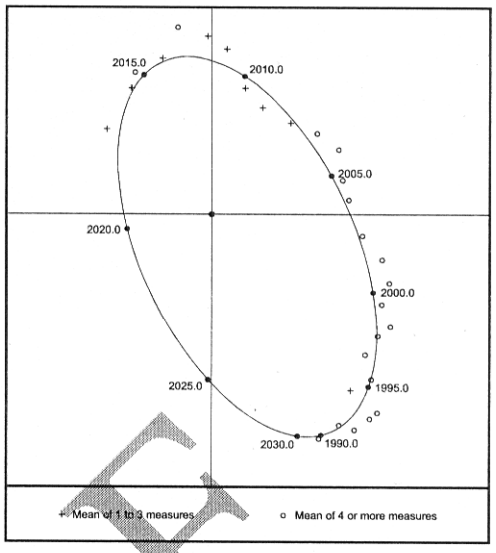
Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2018.0	237.9	0.46	2028.0	13.8	0.91
2020.0	280.0	0.37	2030.0	21.0	1.00
2022.0	326.0	0.43	2032.0	27.2	1.04
2024.0	351.1	0.61	2034.0	33.3	1.03
2026.0	4.7	0.78	2036.0	39.6	0.99

Kirkpatrick *et al.* [466] found a very faint companion of spectral type L8 194″ SE of the bright pair (equivalent to a linear separation of 3600 AU) and they concluded that it is physically connected to AB. The derived V magnitude was 17.0. A search in DR2 around η to 500″ shows no companion stars with a parallax near 55 mas. The WDS notes two faint and distant stars which are unrelated: C is 13.4 at 359°, 74″ and D is 11.0 at 41°, 218″; in each case the separation from AB is increasing owing to the proper motion of the binary pair.

Observing and Neighbourhood

The binary η CrB is easily found nestling close to the bright stars of Corona Borealis. It is one-third of the way between β CrB and δ Boo. This is a wonderful pair for 30-cm as they can be followed throughout their entire orbital cycle and the annual change can be seen without instrumentation. The stars are currently closing quickly and will reach the minimum separation of 0″.36 in 2020. By about 2024 they should again be resolvable in 20-cm. Four degrees NNW is the bright, wide binocular pair δ Boo (STFA 27) (3.6, 7.9, 78°, 105″, 2015),

Measures with 8″ Refractor



Year	PA(°)	Sep(")	No.	Year	PA(°)	Sep(")	No.
1990.42	25.3	1.04	5	2003.55	96.0	0.57	4
1991.46	30.8	1.03	5	2004.52	104.6	0.56	5
1992.58	33.2	1.08	5	2005.47	117.1	0.59	5
1993.54	37.3	1.08	5	2006.43	127.6	0.55	5
1993.59	37.8	0.94	3	2007.43	139.2	0.50	2
1994.48	39.4	1.08	5	2008.53	154.5	0.49	2
1995.52	43.5	0.96	5	2009.58	165.2	0.54	3
1996.49	46.9	0.87	5	2010.56	174.8	0.69	3
1997.52	53.1	0.86	6	2011.58	181.3	0.74	2
1998.54	57.2	0.88	8	2012.55	190.3	0.79	6
1999.52	61.6	0.80	7	2013.56	197.5	0.68	3
2000.48	68.5	0.79	6	2014.59	208.4	0.67	6
2001.48	74.9	0.73	7	2015.66	212.5	0.62	2
2002.52	81.7	0.63	6	2017.59	231.0	0.56	2

which, despite its large apparent angular separation, appears to be a genuine binary pair, although an orbit of 760 centuries in the catalogue might seem to be a leap of faith. Three degrees SSW of η is the binary pair STF 1932 (7.3, 7.4, 267°, 1″.6, 2020), which orbits much more swiftly – every 203 years. I RWA has seen the companion to θ CrB = COU 610 a couple of times with the Cambridge 20-cm but always with difficulty. The WDS seems to show a gradual widening, so it's worth trying now and again (4.3, 6.3, 199°, 0″.8, 2016).

Measures

Early measure (STF)	43°.3	0″96	1829.55
(Orbit	45°.6	0″.94)	
Recent measure (ARY)	212°.5	0″.62	2015.66
(Orbit	211°.4	0″.62)	

112. γ CIR = HJ 4757 = WDS J15234−5919AB

DELETE AB'

Table 9.112 Physical parameters for γ Cir

HJ 4757	RA: 15 23 22.66	Dec: −59 19 14.5	WDS: 1234(67)	
V magnitudes	A: 4.83	B: 6.93		
$(B-V)$ magnitudes	A: −0.11	B: +1.22		
μ	A: −12.97 mas yr^{-1}	± 0.77	B: −34.24 mas yr^{-1}	± 0.70
π	7.27 mas	± 0.81	449 light yr	± 50 (Hipp.)
Spectra	A: B5V + B5V?	B: F8V		
Luminosities ($L_\odot$)	A: 190	B: 25		
Catalogues (A/B)	HR 5704	HD 136415/6	SAO 242463	HIP 75323
DS catalogues	HJ 4757			
Radial velocity	−16.90 km s^{-1}	± 1.78		
Galactic coordinates	321°.245	−1°.963		

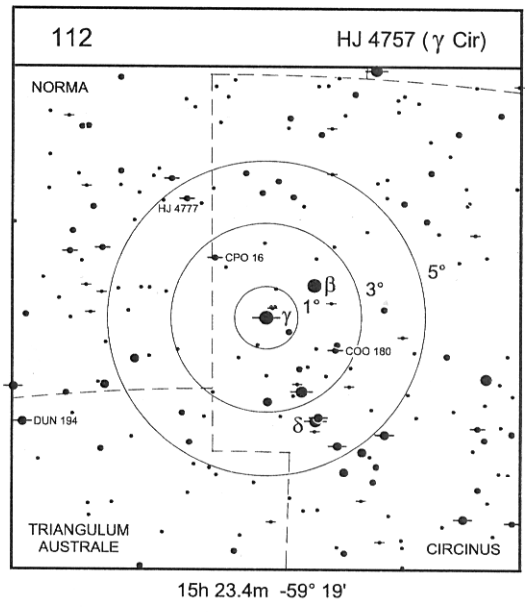
History

John Herschel, using his 20-foot (18-inch aperture) reflector, notes on sweep 575 (22 April 1835): 'Pos 109.8, 110.4. A momentary glimpse with 180 induced me to apply 320 with 12-inches aperture. It was then cleanly divided, and these are good measures'. He gives the separation as 3/4″ and later on during sweep 717 (9 July 1836) 'A beautiful object. Pos 104.4 101.3. The first with 480, which separates the stars by $\frac{1}{4}$ diameter; the other with the same power and an aperture reduced to 6 inches.' On this occasion the separation is given as 1″. He also makes measures on five nights over a two-year period with the 7-foot (6-inch aperture) reflector, which show the angle scattered between 102° and 109°.

The Modern Era

The parallax derived from the orbit by Hartkopf [468] is substantially different to that from Hipparcos. This led

Finder Chart



113. $\mu^{1,2}$ BOO = STFA 28 = WDS J15245+3723AB

Table 9.113 Physical parameters for $\mu^{1,2}$ Boo

STFA 28	RA: 15 24 29.428	Dec: +37 22 37.756	WDS: 19(735) (BC)	
V magnitudes	AaAb(μ^1): 4.33	B(μ^2): 7.09	C: 7.63	
$(B-V)$ magnitudes	AaAb: +0.31	B: +0.63	C: +0.65	
μ(A)	−149.42 mas yr^{-1}	± 0.99	93.96 mas yr^{-1}	± 1.04 (DR2)
μ(B)	−139.14 mas yr^{-1}	± 0.05	90.26 mas yr^{-1}	± 0.04 (DR2)
μ(C)	−152.39 mas yr^{-1}	± 0.04	89.78 mas yr^{-1}	± 0.05 (DR2)
π(A)	28.08 mas	± 0.59	116.2 light yr	± 2.4 (DR2)
π(B)	27.15 mas	± 0.03	120.1 light yr	± 0.1 (DR2)
π(C)	27.23 mas	± 0.27	119.8 light yr	± 1.2 (DR2)
Spectra	Aa: FOIV + ?	B: G0V	C: ?	
Masses ($M_\odot$)	Aa: 2.7	Ab: 1.5	B: 1.1	C: 1.0
Luminosities ($L_\odot$)	Aab: 20	B: 1.5	C: 1	
Catalogues (A/B)	HD 137391/2	HR 5733/4	SAO 64686/7	HIP 75411/5
DS catalogues	CHR 181 (AaAb)	H 6 17 (A-BC)	STFA 28 (A-BC)	BDS 7258 ADS 9626
DS catalogues	H 1 17 (BC)	STF1938 (BaBb)		
Radial velocity (Aa)	8.60 km s^{-1}	± 0.3		
Radial velocity (Bb)	8.50 km s^{-1}	± 0.3		
Galactic coordinates	60°.394	+56°.316		

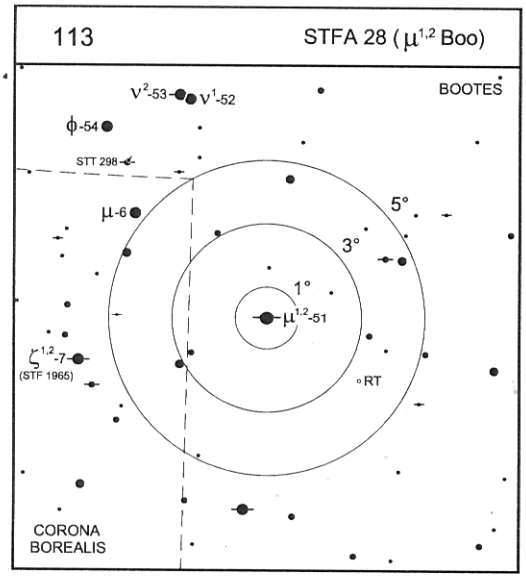
History

On 30 July 1780, Sir William Herschel first noted that μ Boot consists of two bright stars. He described the colours as 'L(arge) reddish w(hite). S(mall) pale r(ed)' The distance was given as 2′8″, which Herschel regarded as an exact estimate. This appears to be an error as the stars have remained fixed at 108″ since the mid 1820s. Returning to the area on 10 September 1781, he then noticed that the fainter of the two was also double and they were 'Both dusky w(hite) inclined to r(ed)'. As it transpired later, the stars in this closer pair were then at their greatest separation.

The Modern Era

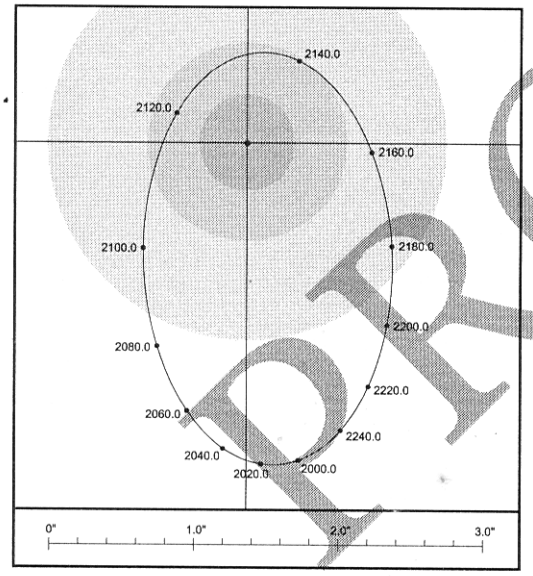
Between 1850 and 1880 the stars that make up component B remained at about 0″.6 and moved 160° retrograde in position angle. Since then they have been widening and reached widest separation in 2010. In a large radial velocity project, using spectra taken at McDonald Observatory around 1960, H. A. Abt [469] and colleagues in 1965 took 13 spectra of μ^1 Boo. Although the spectra showed very broad lines due to rapid rotation, they concluded that the derived velocities fitted a periodic variation with a period of 299 days and an eccentricity of 0.54. Niehaus & Scarfe [470] re-observed μ^1

Finder Chart



15h 24.5m +37° 23'

Orbit



Ephemeris for STF 1938 BaBb (2010 to 2100)

Orbit by Kiy (2014) Period: 265 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	5.9	2.25	2060.0	347.5	1.91
2020.0	2.6	2.24	2070.0	342.6	1.75
2030.0	359.2	2.20	2080.0	336.4	1.55
2040.0	355.6	2.14	2090.0	328.2	1.31
2050.0	351.8	2.04	2100.0	315.9	1.03

Bootis and found no significant variation; the errors in the velocities amounted to 3 or 4 km s^{-1} due to the width of the lines. In a postcript to this paper, however, they said that recent new observations received from Dr Abt, combined with their own spectra, could be interpreted as representing a spectroscopic binary with a period of 4500 days. In 1988, using the 3.6-metre CFHT on Hawaii, McAlister *et al.* [482] and colleagues found that μ^1 was a close pair, and they recorded a separation of 0″.069 with a position angle of 350°.3. In 2010 Muterspaugh *et al.* [620] published a series of very precise measurements of this pair (giving errors in separation in the region of 0″.0002) and found a period of 1368.02 days or 3.75 years. The separation of the stars ranges from 0″.05 to 0″.11 during this cycle. The note in Webb [209] says that μ^1 and μ^2 together 'form one vast system' but this idea is disputed in a recent astrometric study of the group made by Kiyaeva *et al.* [473]. They derived orbits for the interferometric pair AaAb (CHR 181) and the visual binary BC, the ephemeris from which appears above. Kiyaeva also suggested that the two systems μ^1 and μ^2 are not related but happen to be passing in space, because there are significant difference in element abundances between the two pairs.

Observing and Neighbourhood

The stars μ^1 and μ^2 form an easy binocular double. The BC pair has now almost returned to the discovery position in 1782, is well resolved in 75-mm, and will remain so for most of the rest of the century. Smyth noted that μ^1 was flushed-white whilst the components of μ^2 were both greenish-white. Hartung notes pale yellow for the bright star and deep-yellow for the visual binary companion. Nearby are ζ CrB (STF 1965) (p. xx), and STT 298 (p. xx). The components of δ Boo – STFA 28 – although very different in brightness and at a large angular separation are moving through space togther and have the same parallax, according to DR2 (equivalent to a distance of 120 light years). The WDS notes that an orbit is extant but this does not appear in the sixth Orbit Catalogue.

Measures

STF1938			
Early measure (STF)	324°.1	1″.25	1829.73
(Orbit	323°.1	1″.18)	
Recent measure (ARY)	3°.7	2″.31	2016.53
(Orbit	3°.7	2″.25)	
STFA 28			
Early measure (STF)	172°.6	108″.73	1821.78
Recent measure (ARN)	170°.9	108″.13	2012.33

114. γ LUP = HJ 4786 = WDSJ15351−4110 AB

Table 9.114 Physical parameters for ~~HJ 4786~~

HJ 4786	RA: 15 35 08.448	Dec: −41 10 00.32	WDS: 666(102)		
V magnitudes	Aab: 3.44	B: 3.54	C: 17.0	D: 16.4	
$(B-V)$ magnitudes	Aab: −0.18	B: −0.10			
μ	A: −15.62 mas yr^{-1}	± 0.69	−25.43 mas yr^{-1}	± 0.43	
π	7.75 mas	± 0.50	420 light yr	± 27	
Spectra	Aa: B2IV	Ab: —	B: —	C: F1?	D: K5?
Masses ($M_\odot$)	Aa: 9.7	Ab: 1.1	B: 9.5	C: 0.4	D: 0.5
Luminosities ($L_\odot$)	A: 600	B: 550	C: 0.002	D: 0.002	
Catalogues	HR 5776	HD 138690	SAO 225938	HIP 76297	
DS catalogues	HJ 4786 (AB)	RIZ 17 (AaAb)	RIZ 15 (AC)	RIZ 15 (AD)	
Radial velocity	2.3 km s^{-1}	± 5			
Galactic coordinates	333°.194	+11°.891			

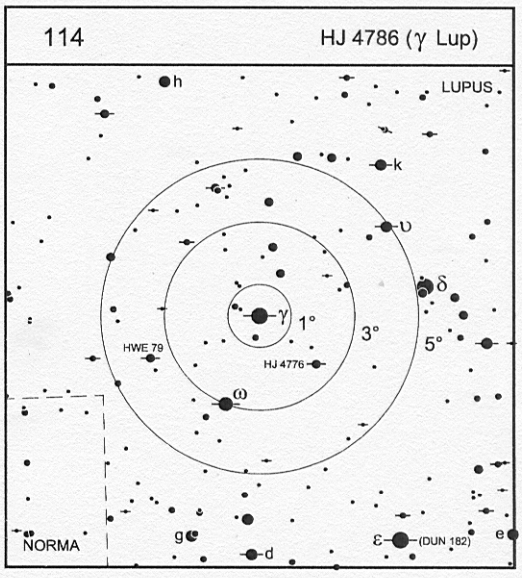
History

John Herschel alighted upon γ Lupi on his sweep 718 (10 July 1836) at Feldhausen. 'Cleanly divided with 480, and the black division well seen. Measures perfectly good and to be depended on'. He gives the distance as 2/3 of an arcsecond. Herschel continues 'With 800 well separated; with 180 and triangular aperture perceived to be double. [This shows the distance to be underrated at two-thirds of a second.]' Herschel observes this star 15 times during his work at the Cape, but concluded that 'there is no evidence for angular motion which can be relied on'.

The Modern Era

The multiplicity of stars on OB associations has been pursued by a number of groups of astronomers in the last few decades. In 1987 Levato *et al.* [474] using the 0.9-metre and

Finder Chart



115. STT 298 BOO = WDS J15360+3948AB

Table 9.115 Physical parameters for STT 298 Boo

STT 298	RA: 15 36 02.22	Dec: +39 48 08.9	WDS: 40(537)	
V magnitudes	A: 6.77	B: 8.44	C: 7.56	
$(B-V)$ magnitudes	A: +1.06	B: +1.30	C: +0.97	
μ(A)	-442.57 mas yr^{-1}	$\pm$ 0.39	55.83 mas yr^{-1}	$\pm$ 0.47 (DR2)
μ(B)	-463.88 mas yr^{-1}	$\pm$ 0.39	45.74 mas yr^{-1}	$\pm$ 0.61 (DR2)
μ(C)	-449.10 mas yr^{-1}	$\pm$ 0.04	50.78 mas yr^{-1}	$\pm$ 0.06 (DR2)
π(A)	44.80 mas	$\pm$ 0.23	72.8 light yr	$\pm$ 0.4 (DR2)
π(B)	44.51 mas	$\pm$ 0.02	73.28 light yr	$\pm$ 0.03 (DR2)
π(C)	43.99 mas	$\pm$ 0.21	74.1 light yr	$\pm$ 0.4 (DR2)
Spectra	A: K1V	B:	C: K3V	
Masses ($M_\odot$)	A: 0.8	B: 0.7	C: 0.9	
Luminosities ($L_\odot$)	A: 0.8	B: 0.2	C: 0.4	
Catalogues (AB/C)	HD 139341/23	SAO 64800/799	HIP 76382/75	
DS catalogues	STT 298	BDS 7732	ADS 9716	
Radial velocity	-66.7 km s^{-1}	$\pm$ 0.6		
Galactic coordinates	64°.113	+53°.779		

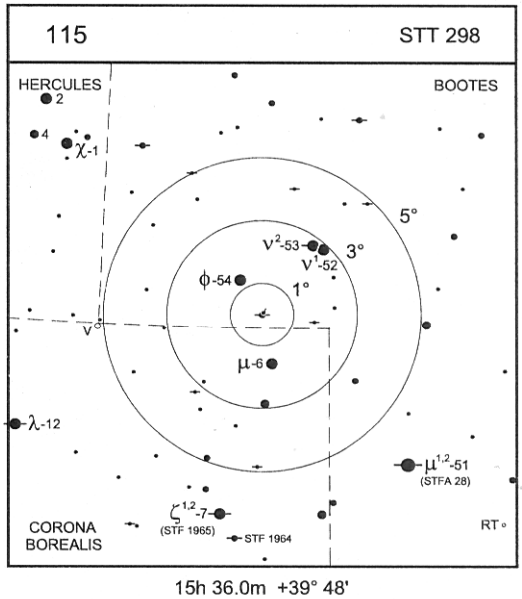
History

Discovered by Otto Struve in 1846 with the 15-inch at Pulkova when close to its widest separation, this binary was observed infrequently until at the end of the 1860s it suddenly began to close quickly and then attracted the attention of the observers of the time. By 1877 the period was given as 56.653 years with rather unwarranted precision.

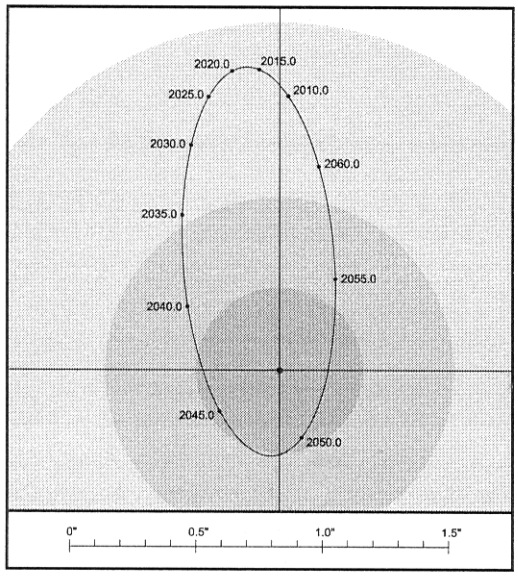
The Modern Era — ADD

The V magnitudes quoted by Hipparcos and given above seem at odds with the visual estimates of Δm recorded in the WDS, when the stars never seem to be more than about 0.3 magnitudes different, and agree with the experiences of RWA when measuring this system. The magnitude 7.6 star at 121″ distance (HIP 76375) is a physical member of the system with almost 100% probability, according to Shaya & Olling [270].

Finder Chart



Orbit



Ephemeris for STT 298 AB (2015 to 2042)

Orbit by Sod (1999) Period: 55.6 years, Grade: 1

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	183.9	1.20	2030.0	201.4	0.96
2018.0	187.0	1.21	2033.0	207.0	0.83
2021.0	190.1	1.19	2036.0	215.0	0.67
2024.0	193.3	1.15	2039.0	228.2	0.50
2027.0	197.0	1.07	2042.0	254.9	0.34

The distance is the same as that to STT 298 AB and the proper motions are very similar. Component D (at 224°, 167″) in the WDS is actually the galaxy NGC 5966.

Observing and Neighbourhood

This binary is quite easily swept up by starting at β Boo at the top of the 'kite' and moving E by 6° to arrive at the wide and bright binocular pair $\upsilon^{1,2}$ Bootis (magnitudes 5.0, 5.0, separation 10′.5), which sports colours of orange and white. Moving a further 1.5° SE will bring you to a fainter wide pair of stars. This is STT 298AB and C, the binary pair being the northern component. At the time of writing STT 298 is close to its maximum separation and should remain resolvable in 15-cm for a decade or so. Four degrees SW is the fine triple $\mu^{1,2}$ Bootis and 4° SSE are $\zeta^{1,2}$ CrB (STF 1965) and STF 1964.

Measures

Early measure (STF)	183°.8	1″.19	1846.49
(Orbit	183°.0	1″.17)	
Recent measure (ARY)	185°.8	1″.18	2014.65
(Orbit	183°.5	1″.19)	

(p. 312) ADD (p. 318)

116. $\zeta^{1,2}$ CRB = STF 1965 = WDS J15394+3638

Delete 1,2

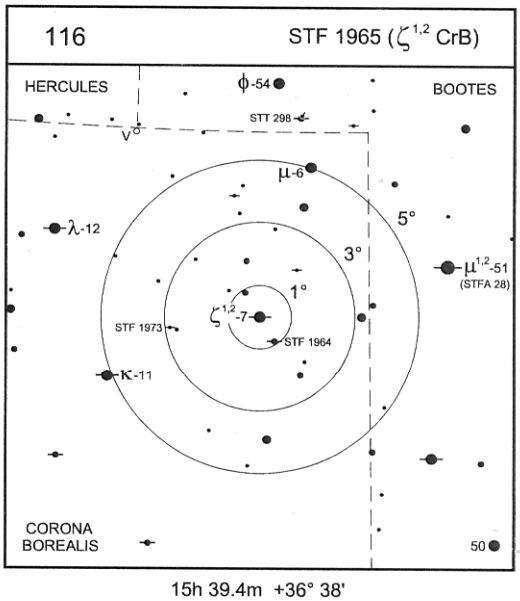
Table 9.116 Physical parameters for $\zeta^{1,2}$ CrB

STF 1965	RA: 15 39 22.68	Dec: +36 38 07.0	WDS: 54(461)		
V magnitudes	A (ζ^2): 4.96	B (ζ^1): 6.00			
$(B-V)$ magnitudes	A: −0.11	B: 0.00			
μ(A)	−15.62 mas yr^{-1}	± 0.27	−7.31 mas yr^{-1}	± 0.34 (DR2)	
μ(B)	−14.20 mas yr^{-1}	± 0.09	−3.87 mas yr^{-1}	± 0.13 (DR2)	
π(A)	6.64 mas	± 0.18	491 light yr	± 13 (DR2)	
π(B)	6.22 mas	± 0.07	524 light yr	± 6 (DR2)	
Spectra	A: B7V + B7V + ?	B: B7V?			
Masses ($M_\odot$)	A: 1.156	± 0.14	B: 1.05	± 0.14	
Luminosities ($L_\odot$)	A: 200	B: 85			
Catalogues	7 CrB	HR 5834	HD 139891	SAO 64834	HIP 76669
DS catalogues	H 2 8	STF 1965	BDS 7352	ADS 9737	
Radial velocity	−0.00 km s^{-1}	± 0.4			
Galactic coordinates	58°.698	+53°.412			

History

Found by Sir William Herschel on 1 October 1779. He noted that the stars were considerably unequal and that the primary was a fine white with the fainter star white inclining to red. In his *Cycle of Celestial Objects*, Admiral Smyth said 'I have obtained a splendid set of measures at Hartwell House, by which it is rendered still more evident, that these stars are optical, and relatively at rest. Indeed, there are few of these objects whose details come out so satisfactorily.' He made the colours bluish white and smalt blue. More recently Sissy Haas finds both stars white. The spectroscopic duplicity of ζ^2 CrB was discovered by W. H. Christie from a plate taken on 4 May 1924 with the 72-inch reflector of the Dominion Astrophysical Observatory at Victoria, British Columbia. More plates were taken and an orbit was calculated by J. S. Plaskett [476], who found a double-line system with a period of 12.60 days and an orbit of very low eccentricilty.

Finder Chart



117. Δ 194 TRA = WDS J15549−6045AB,C

ADD TA

Table 9.117 Physical parameters for Δ 194

DUN 194	RA: 15 54 52.64	Dec: −60 44 37.1	WDS: 11487(24)	
V magnitudes	A: 6.35	B: 8.09	C: 9.97	D: 9.02
$(B-V)$ magnitude	A: +0.12	B: −0.04	C: 0.00	D: +0.01
μ(A)	−0.70 mas yr^{-1}	± 0.11	−3.84 mas yr^{-1}	± 0.13 (DR2)
μ(B)	−1.44 mas yr^{-1}	± 0.41	−1.77 mas yr^{-1}	± 0.54 (DR2)
μ(C)	−3.70 mas yr^{-1}	± 0.06	−6.22 mas yr^{-1}	± 0.06 (DR2)
μ(D)	−0.63 mas yr^{-1}	± 0.06	−4.20 mas yr^{-1}	± 0.06 (DR2)
π(A)	1.16 mas	± 0.09	2811 light yr	± 218 (DR2)
π(B)	2.97 mas	± 0.42	1098 light yr	± 155 (DR2)
π(C)	1.88 mas	± 0.05	1735 light yr	± 46 (DR2)
π(D)	1.16 mas	± 0.04	2811 light yr	± 97 (DR2)
Spectra	A: B9II	B:	C:	D: B5/7III
Luminosities ($L_\odot$)	A: 1750	B: 55	C: 25	D: 150
Catalogues	HR 5898	HD 141913	SAO 253344	HIP 77927
DS catalogues	SLR 11 (AB)	DUN 194 (AB,C)	HJ 4809 (AB,C)	
Radial velocity	−5.00 km s^{-1}	± 4.3		
Galactic coordinates	323°.561	−5°.446		

History

First catalogued by James Dunlop, this system was recovered by John Herschel in 1836 when he listed the two ninth magnitude companions, one of which (D) Dunlop appears to have missed. Herschel does not acknowledge Dunlop's previous observation and allocates HJ 4809 to the three stars. He does not notice the duplicity of A, which was not found until 1891 when Sellors was using the 11.5-inch refractor at Sydney and gave the measured separation as 0″.56. Two years later he found the separation to be 1″.0 and it has remained between 1″ and 1″.2 ever since.

The Modern Era

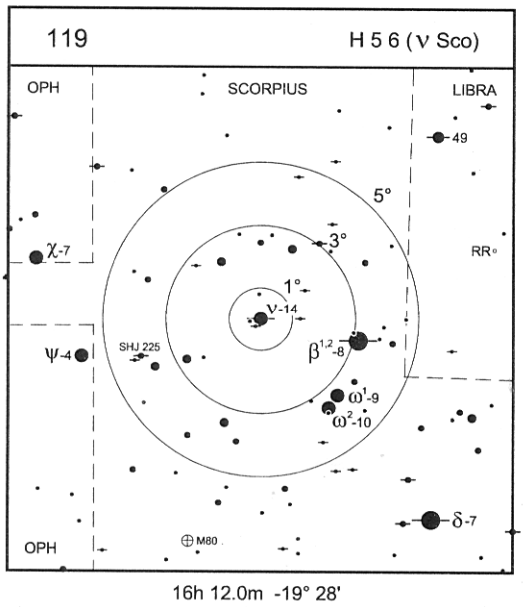
Sinbad gives A as a variable star; it has been observed to vary between V = 6.11 and 6.15 [479]. The proper motions of the four brightest stars in the sysstem are all similar but very small, reflecting the distance of the group.

Observing and Neighbourhood

The two distant companions are within range of large binoculars whilst the close pair needs at least 10-cm. Star C is

spelling

Finder Chart



The Modern Era

In the late 1980s another component was discovered close to A by H. A. McAlister [482] and colleagues. The new component was found 58 mas distant in PA 172° and it was again resolved in the following year. In 2008 attempts to observe the two stars with the 8.1-metre *Gemini* telescope failed, but it was picked up again in 2009–2011 at roughly the same distance as before but on the other side of the brighter star, thus suggesting a highly inclined apparent orbit. Despite the apparently short period, there is no orbit for this system. The visual pairs BU 120 and MTL 2 also show changes, admittedly quite small but mostly in distance, so are the three orbits of these stars all aligned? Stat A is also an SB, as is the Mitchel companion. D. Grellmann *et al.* [483] suggested there was evidence for another late-type companion in the CD system but they regarded the AB and CD groups as independent and unrelated.

Observing and Neighbourhood

Easily found just 1°.5 following the $V = 2.6$ magnitude β Sco, ν Sco is probably the best visual quadruple in the sky. It is much closer than ϵ Lyrae and the stars are of comparable brightnesses. It is low from Europe and the northern United States, and Sue French notes that the stars which ought to appear blue-white according to their early spectral type actually look more like white to yellow to her eyes. The system β Sco (H 3 6) is likely to be at least a physical quadruple star. The Herschel number refers to A (2.6, 4.5, 20°, 13″.7, 2017). Burnham doubled A (BU 947) but the companion is magnitude 10 or fainter and at present only 0″.3 away from A. The period is given as 610 years. Star C has common proper motion with B and is also a close pair (MCA 42) with a period of 38.8 years, never wider than about 0″.1. Much easier is SHJ 225 (7.4, 8.1, 333°, 46″.5, 2013).

Measures

BU 120 (AB)			
Early measure (D)	0°.0	0″.73	1876.35
Recent measure (ARY)	1°.8	1″.55	2016.70
MTL 2 (CD)			
Early measure (SLR)	39°.1	1″.11	1846.58
Recent measure (ARY)	56°.2	2″.48	2016.70
H 5 6 (AC)			
Early measure (SHJ)	338°.2	40″.82	1824.37
Recent measure (ARY)	335°.9	41″.31	2013.70

120. $\sigma^{1,2}$ CRB = STF 2032 = WDS J16147+3352AB

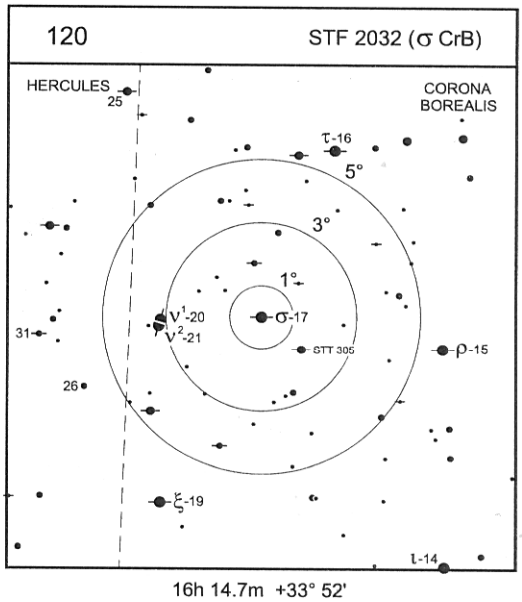
Table 9.120 Physical parameters for ~~STF 2032~~ CrB

STF 2032	RA: 16 14 40.8556	Dec: +33 51 30.950	WDS: 9(1094)		
V magnitudes	AaAb: 5.62	B: 6.49	Ea,Eb: 12.31		
$(B-V)$ magnitudes	A: +0.64	B: +0.69			
μ(A)	-268.33 mas yr^{-1}	$\pm$ 0.10	-86.93 mas yr^{-1}	$\pm$ 0.15 (DR2)	
μ(B)	-291.12 mas yr^{-1}	$\pm$ 0.04	-78.65 mas yr^{-1}	$\pm$ 0.05 (DR2)	
π(A)	44.14 mas	$\pm$ 0.06	73.89 light yr	$\pm$ 0.10 (DR2)	
π(B)	44.15 mas	$\pm$ 0.02	73.87 light yr	$\pm$ 0.03 (DR2)	
Spectra	Aa: G0V	Ab: G1V	B: G1V	Ea: M2.5	
Masses ($M_\odot$)	Aa: 1.137	Ab: 1.090			
Radii ($R_\odot$)	Aa: 1.244	Ab: 1.244			
Luminosities ($L_\odot$)	A: 2.5	B: 1.0	E: 0.005		
Catalogues	HD 146361/2 (A/B)	HR 6063/4 (A/B)	SAO 65165	HIP 79607	
DS catalogues	H 1 3 (AB)	STF 2032 (AB)	BDS 7563	ADS 9979	YSC152 (EaEb)
Radial velocity	-12.30 km s^{-1}	$\pm$ 0.06			
Galactic coordinates	54°.667	+46°.141			

History

Sir William Herschel alighted on this star on 7 August 1780 with the following comment: 'Treble. The two nearest pretty unequal; the third very faint with powers lower than 460. The two nearest both w.(hite), the third d.(usky)'. Herschel observed the close pair again in 1804, by which time they had moved 24° prograde in position angle. Unfortunately no distance measure was made at this time and it was left to Sir John Herschel to do this in 1822, when a further 59° had been traced out. After that the pairs steadily separated, and the brightness of the stars combined with the relatively wide separation made the binary a favourite of observers; to date almost 1100 measures have been made.

Finder Chart



121. α SCO = ANTARES = GNT 1 = WDS J16294-2626 AB

DELETE

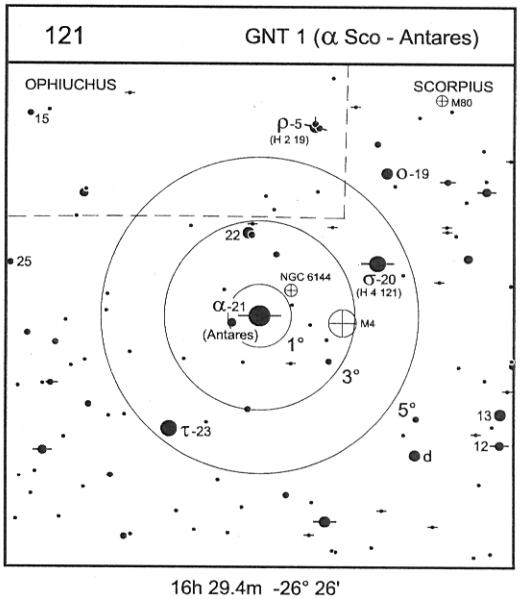
Table 9.121 Physical parameters for α Sco

GNT 1	RA: 16 29 24.45	Dec: −26 25 55.2	WDS: 400(144)		
V magnitudes	A: 0.91V	B: 5.2			
$(B-V)$ magnitudes	A: +1.84	B: −0.2			
μ	−12.11 mas yr^{-1}	± 1.22	−23.30 mas yr^{-1}	± 0.76	
π	5.89 mas	± 1.00	554 light yr	± 94	
Spectra	A: M1.5Ia-Ib	B: B2.5V			
Masses ($M_\odot$)	A: 12.5	B: 7.2			
Luminosities ($L_\odot$)	A: 11400	B: 200			
Catalogues (A/B)	21 Sco	HR 6134	HD 148478/9	SAO 184415	HIP 80763
DS catalogues	GNT 1	BDS 7631	ADS 10074		
Radial velocity	−3.5 km s^{-1}	± 1.8			
Galactic coordinates	351°.947	−15°.064			

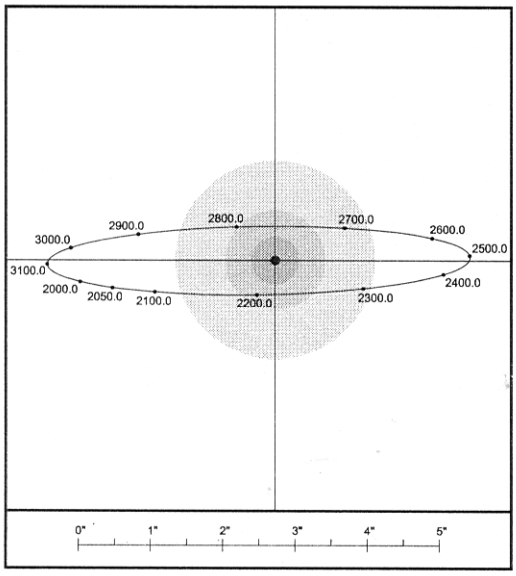
History

The earliest observation of Antares as a double appears to be by the Austrian Johann (or Johannes) Tobias Bürg (1766–1835) from Vienna on 13 April 1819 (1819.28), who suspected a companion in PA 270° [491] during a lunar occultation. When he reported this to his peers, they too hastily dismissed it as caused by lunar atmospheric refraction. The next confirmed direct visual discovery was by James W. Grant (1788–1865) on 23 July 1844, made from Bengal, India and now recognised as GNT 1. Yet another claim appears in Gledhill *et al.* [488], saying that the American Ormsby M. Mitchel (1810–1862) found this while using the newly acquired 11-inch Munich refractor at Cincinnati Observatory. The first measures in the WDS are those of Mitchel in 1846, who, according to Burnham, measured the separation of the pair on 16 nights and the position angle on two. Mitchel was not aware of Grant's observation [487]. It is interesting to note that Dunlop, Rumker, and John Herschel never

Finder Chart



Orbit



Ephemeris for GNT 1 (2000 to 2180)

Orbit by Pal (2005b) Period: 1217.536 years, Grade: 5

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2000.0	276.3	2.72	2100.0	284.7	1.72
2020.0	277.5	2.56	2120.0	287.9	1.48
2040.0	278.8	2.38	2140.0	292.3	1.22
2060.0	280.4	2.18	2160.0	299.2	0.97
2080.0	282.3	1.96	2180.0	310.7	0.73

saw the secondary. W. H. Wright [489] at Lick Observatory noted that Miss Antonia Maury 'finds indications of a faint superimposed spectrum' but this 'probably refers to the telescopic companion'.

The Modern Era

In contrast with our Sun, Antares is a red supergiant, whose diameter is roughly equivalent to the diameter of Jupiter's orbit or about 1.2 billion kilometres.

Measures suggest that these stars either have slowly widened, reaching a maximum of 3″.6, and are now closing or alternatively are slowly closing. The former possibility suggested to the late French double observer Paul Baize in 1978 a preliminary orbit spanning 878 years, with periastron in 1461 AD. Evidence for this is rather scarce, as there has been too little motion (just 3° in position angle) to justify an orbit, and the measures that do exist are quite scattered.

Using both HIP2 parallax and a maximum separation of 3″.6, the projected separation is about 610 AU while the minimum orbital period is between 2130 and 7200 years. Difficulties arise from our poor knowledge of each star. The estimated absolute magnitudes are −5.3 and −0.8, respectively, and the respective effective surface temperatures are 2980 K and 22,500 K. Recent estimates find ages between 10 and 12 million years.

The supergiant primary is an LC-type variable star that unpredictably fluctuates between 0.88 and 1.16 magnitudes, over a period spanning 5.8 years.

Observing and Neighbourhood

Reddish or orangey-red coloured, Antares's popularity is mostly due to its greatly enhanced colour contrast with its fainter blue or green companion, the latter being variously described as blue, turquoise, pale green, greenish, or green. They are split in 10.5-cm but can be glimpsed in 7.5-cm under ideal conditions. Both are more easily seen in full daylight in 20-cm, though smaller apertures might also possible. Whilst in the area, check out the pair σ Sco (H 4 121) (2.9, 8.4, 273°, 20″.3, 2016). In 1976, Morgan *et al.* [490] reported duplicity of the bright star, noting a magnitude 5.7 star at a distance of 0″.3. I RWA felt that he could see this component well enough in 2016 to measure it with the Johannesburg refractor, but it was difficult. Star A is additionally a very close close pair (NOR 1) with a period of 33 years and a separation of a few milliseconds of arc. Two degrees N of σ and a little to the E is ρ Oph, which is more well known for being the site of a large area of interstellar dust clouds and gas. It is also a pretty double star, found by William Herschel – H 2 19 (5.1, 5.7, 338°, 3″.2, 2016).

Measures

Early measure (DA)	273°.2	3″.46	1848.02
(orbit	279°.5	3″.12)	
Recent measure (ARY)	276°.0	3″.16	2016.67
(orbit	277°.2	2″.58)	

122. λ OPH = STF 2055 = WDS J16309+0159AB

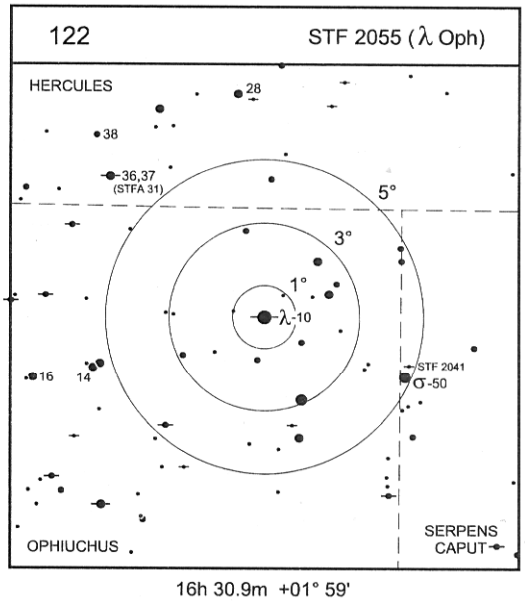
Table 9.122 Physical parameters for ~~STF 2055~~ Oph

STF 2055	RA: 16 30 54.84	Dec: +01 59 02.8	WDS: 17(788)		
V magnitudes	A: 4.15	B: 5.15	C: 11.84	D: 10.9	
$(B-V)$ magnitudes	A: +0.06	B: +0.09			
μ	-30.98 mas yr^{-1}	$\pm$ 0.61	-73.42 mas yr^{-1}	$\pm$ 0.58	
π	18.84 mas	$\pm$ 0.55	173 light yrs	$\pm$ 5	
μ(A)	-32.60 mas yr^{-1}	$\pm$ 0.71	-66.02 mas yr^{-1}	$\pm$ 0.54 (DR2)	
μ(C)	-28.24 mas yr^{-1}	$\pm$ 0.06	-74.50 mas yr^{-1}	$\pm$ 0.04 (DR2)	
π(A)	20.33 mas	$\pm$ 0.41	160 light yr	$\pm$ 3 (DR2)	
π(C)	19.43 mas	$\pm$ 0.04	167.9 light yr	$\pm$ 0.3 (DR2)	
Spectra	A: A0V	B: A0V			
Luminosities ($L_\odot$)	A: 40	B: 20	C: 0.02	D:	
Catalogues	10 Oph	HR 6149	HD 148857	SAO 121658	HIP 80883
DS catalogues	H 1 83	STF 2055	BDS 7649	ADS 10087	
Radial velocity	-16.00 km s^{-1}	$\pm$ 1.5			
Galactic coordinates	17°.123	+31°.845			

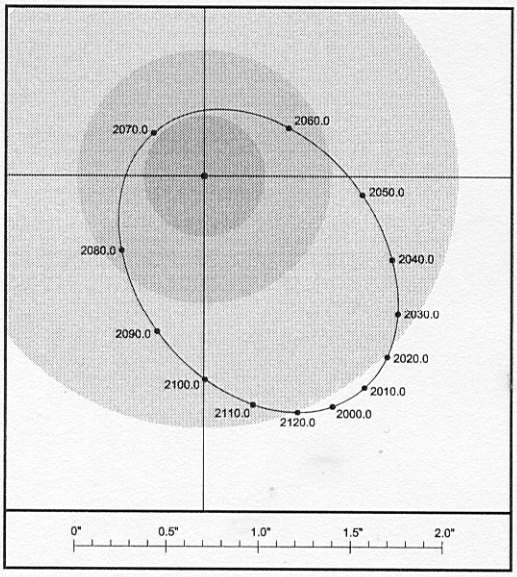
History

William Herschel observed λ Oph on 9 March 1783. his note says 'A very beautiful and close double star. L.(arge). w(hite). S.(mall) blue; both fine colours'. On 20 May 1802 he also reports '...with ×527 I saw it well, but with great difficulty. The object is uncommonly beautiful; but it requires a most excellent telescope to see it well...'. In 1929, E. B. Frost *et al.* [492] published a large paper listing the radial velocities of 500 A stars. Between 1907 and 1928, 11 plates of λ Oph had been taken with the Bruce spectrograph on the 40-inch Yerkes refractor. The conclusion drawn was that the apparent range of velocity variation 'can be attributed to the uncertainty of measurement on very poor lines'. The stars are both early A type dwarfs and spinning fairly, so that the lines are quite broad.

Finder Chart



Orbit



Ephemeris for STF 2055 AB (2015 to 2042)

Orbit by Hei (1993b) Period: 129.0 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	41.1	1.43	2030.0	54.6	1.29
2018.0	43.6	1.41	2033.0	57.7	1.25
2021.0	46.2	1.39	2036.0	61.1	1.20
2024.0	48.9	1.36	2039.0	64.8	1.14
2027.0	51.6	1.33	2042.0	68.9	1.07

The Modern Era

The current orbit, the ephemeris of which is given below, was calculated by Heintz [493] in 1993. In the same short paper he also put forward a strong case for the existence of a third body, evidence for which he found from a series of astrometric plates taken with the 61-cm Sproul refractor. The WDS mentions only the variable radial velocity, and no third body has yet been confirmed or directly imaged. The WDS indicates that star C (169°, 120″, 2013) has the same proper motion as the bright pair so it is likely that it is connected whilst D (247°, 308″, 2002) appears to be a field star. DR2 confirms that C is at a similar distance, and has a similar proper motion, to AB whilst D has a parallax of 15.02 mas.

Observing and Neighbourhood

This star benefits from being at a higher altitude in the sky. In Cambridge, where it culminates 50° from the zenith, it is alway a problematic star to measure, and the separations obtained with the 8-inch refractor over a number of years seem to differ from the expected orbital value by being too large by 0″.2 or so. Smyth found the colours yellowish-white and smalt blue. E. J. Hartung found both stars pale yellow in his 30-cm reflector from Victoria, Australia, whilst more recently Sissy Haas found both lemon yellow in 125-mm at ×200. The faint field stars are unconnected: C is at 167°, 120″, 2013, whilst D is at 247°, 308″, 2002. Three degrees NE is the wide pair 37/36 Her (STFA 31) (5.8, 6.9, 229°, 70″, 2015), which is fixed. More difficult is STF 2041, which is about 10′ NW of the nearby σ Oph. Its stars have magnitudes 7.5 and 10.5 and they are separated by 2″.6 in PA 1° (2010).

Measures

Early measure (STF)	342°.1	0″.81	1828.51
(Orbit	334°.9	0″.79)	
Recent measure (ARY)	43°.9	1″.76	2016.50
(Orbit	42°.4	1″.42)	

124. μ DRA = STF 2130 = WDS J17053+5428 AB

ADD

Table 9.124 Physical parameters for μ Dra

STF 2130	RA: 17 05 20.20	Dec: +54 28 14.3	WDS: 16(797)		
V magnitudes	A: 5.66	B: 5.69	C: 13.7		
$(B-V)$ magnitudes	A: +0.52	B: +0.54			
μ(A)	-56.63 mas yr^{-1}	$\pm$ 0.15	74.11 mas yr^{-1}	$\pm$ 0.14 (DR2)	
μ(B)	-98.41 mas yr^{-1}	$\pm$ 0.13	94.82 mas yr^{-1}	$\pm$ 0.12 (DR2)	
μ(C)	-55.57 mas yr^{-1}	$\pm$ 0.16	85.39 mas yr^{-1}	$\pm$ 0.06 (DR2)	
π(A)	36.80 mas	$\pm$ 0.10	88.6 light yr	$\pm$ 0.2 (DR2)	
π(B)	36.80 mas	$\pm$ 0.06	88.6 light yr	$\pm$ 0.1 (DR2)	
π(C)	36.67 mas	$\pm$ 0.03	88.94 light yr	$\pm$ 0.07 (DR2)	
Spectra	A: F7V	B: F7V			
Masses ($M_\odot$)	A: 1.31	B: 1.51			
Luminosities ($L_\odot$)	A: 3.4	B: 3.3	C: 0.002	D:	
Catalogues	21 Dra	HD 154906/5	HR 6370/69	SAO 30239	HIP 83608
DS catalogues	H 2 13	STF 2130	BU 1088 (AC)	BDS 7875	ADS 10345
Radial velocity	-17.30 km s^{-1}	$\pm$ 0.5			
Galactic coordinates	82°.299	+37°.018			

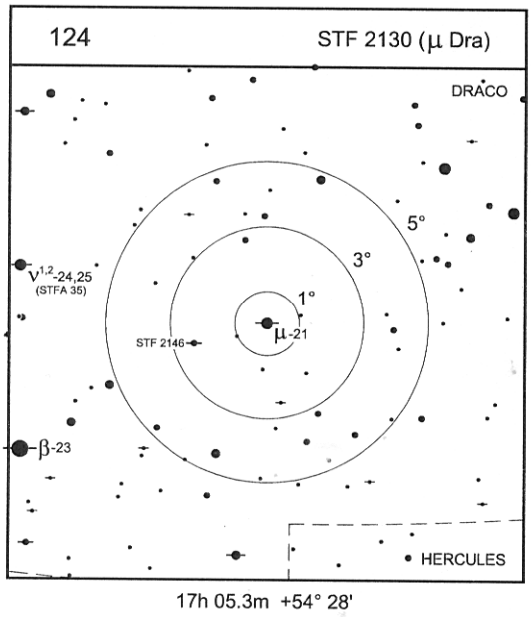
History

William Herschel found this pair on 19 October 1781. He noted that both stars were white and equally bright, and his mean distance measure came to 4″.354. In 1889, using the Lick 36-inch, S. W. Burnham found a faint companion at a distance of 12″.25 which showed no change over the next 10 years, leading Thomas Lewis to declare that it was a physical member of the system.

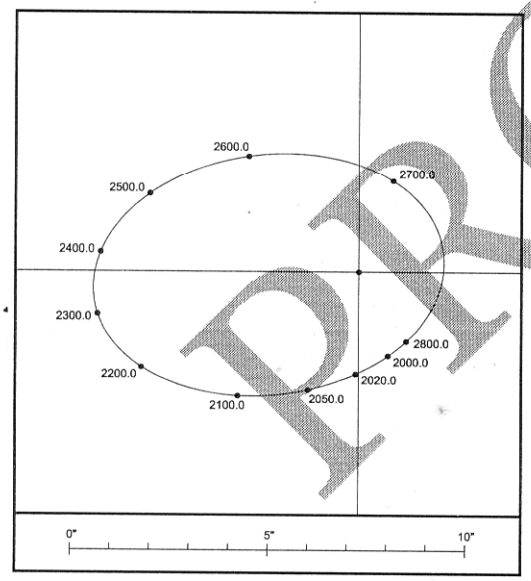
The Modern Era

In 1943 K. Strand [611] found a perturbation with a period of 3.2 years in the motion of AB due to a third body. Using plates taken with the large refractors at Potsdam, Lick, and Sproul, he considered that the amplitude of the perturbation was 'entirely too small to be detected from the visual observations'. In 1966 G. Ishida [503] took a number of spectra of both components of μ Dra but neither conformed to the elements of Strand's orbit, although Ishida did say that he thought the B star was a spectroscopic binary. Heintz [501] was of the opinion that the reported perturbations do not exist. A spectroscopic orbit for the B component is now included in Pourbaix's *Ninth Catalogue of Spectroscopic Binary Orbits* with a period of 2270 days, but a note in the WDS notes that it is a low-grade orbit which needs confirmation. In 2012 J.-L. Prieur *et al.* [504] produced an orbit for AB (the ephemeris of which is given below), which gave a dynamical parallax of 36.3 mas, in close agreement with the Gaia DR2 value given above.

Finder Chart



Orbit



Ephemeris for STF 2130 AB (2010 to 2100)

Orbit by Pru (2012) Period: 812.0 years, Grade: 4

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	8.0	2.41	2060.0	331.6	3.50
2020.0	358.3	2.60	2070.0	327.0	3.74
2030.0	350.1	2.81	2080.0	323.0	3.96
2040.0	343.0	3.04	2090.0	319.3	4.18
2050.0	336.9	3.27	2100.0	316.0	4.40

Star C is at 175°, 13″, 2006 and is confirmed as being physical by Heintz [500].

Observing and Neighbourhood

This is a beautiful pair of white stars, easily seen in 7.5-cm or above. Closest approach (2″.1) was in 1973 and the stars will be separating for many years to come, reaching 6″.7 by around 2330. Four degrees E is the beautiful twin pair of ν Dra (STFA 35) (p. xx), a splendid sight with any optical aid from binoculars up, and 4°.5 WSW is 16/17 Dra, a fine triple for the small aperture (but just off the chart here). The close pair is 5.4, 6.4, 103°, 3″.1 whilst a third star of magnitude 5.5 is 89″ distant on PA 193° but has the same proper motion as the close pair. Like ν Dra this is also a physical system. Closer to μ is STF 2146 (6.9, 8.8, 224°, 2″.6, 2015) with a third star of magnitude 8.9 at 235°, 89″.

354

Measures

Early measure (STF)	208°.1	3″.34	1828.52
(Orbit	205°.2	3″.29)	
Recent measure (ARY)	1°.7	2″.30	2016.89
(Orbit	1°.2	2″.53)	

125. η OPH = BU 1118 = WDS J17104–1544 AB / ADD

Table 9.125 Physical parameters for η Oph

BU 1118	RA: 17 10 22.67	Dec: −15 43 29.7	WDS: 198(225)	
V magnitudes	A: 2.97	B: 3.44		
$(B-V)$ magnitudes	A: +0.13	B: +0.12		
μ	+40.13 mas yr^{-1}	± 1.06	99.17 mas yr^{-1}	± 0.39
π	36.91 mas	± 0.8	88 light yr	± 2
Spectra	A: A2V	B: A3V		
Masses ($M_\odot$)	AB: 7.05 (dyn.)			
Luminosities ($L_\odot$)	A: 40	B: 25		
Catalogues	HR 6378	HD 155125	SAO 160332	HIP 84012
DS catalogues	BU 1118	BDS 7885	ADS 10374	
Radial velocity	−2.40 km s^{-1}	± 0.3		
Galactic coordinates	6°.721	+14°.008		

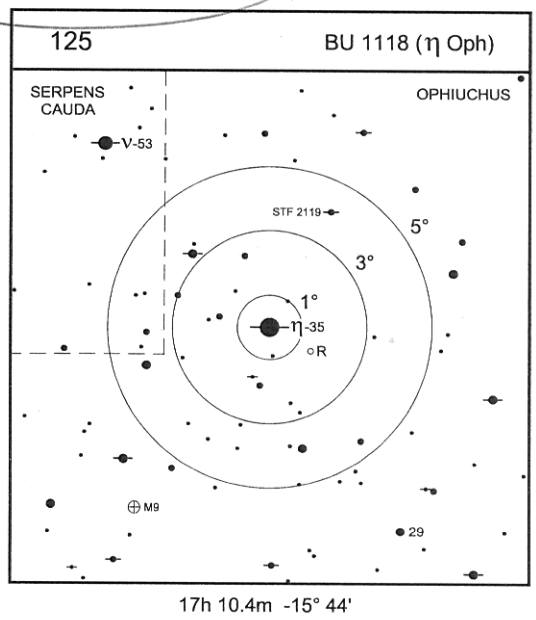
History

This bright binary was discovered by S. W. Burnham in May 1889 using the Lick 36-inch refractor. He was of the opinion that the stars were then near maximum separation, whilst in fact they did not reach this point until 1923 when they were about 0″.6 apart.

The Modern Era

The current orbit predicts a period of 87.5 years. The stars are now closing (338°, 0″.49, 2020) reaching a minimum distance five years hence (38°.0, 0″.14, 2025) and then widening to reach 24°, 0″.35 by 2030.

Finder Chart — ADD



REPLACE FINDER CHART

126. α HER = STF 2140 = WDS J17146+1423AB

Table 9.126 Physical parameters for α Her

STF 2140	RA: 17 14 38.858	Dec: +14 23 25.23	WDS: 45(491)		
V magnitudes	AaAb = 3.48	Ba = 5.6	Bb: 6.6		
$(B-V)$ magnitudes	AaAb = +1.45	BaBb = +0.71			
μ(A)	-7.32 mas yr^{-1}	± 0.92	+36.07 mas yr^{-1}	± 0.97	
π(A)	9.07 mas	± 1.32	360 light yr	± 53	
μ(B)	-8.33 mas yr^{-1}	± 0.63	41.39 mas yr^{-1}	± 0.70 (DR2)	
π(B)	9.91 mas	± 0.50	329 light yr	± 17 (DR2)	
Spectra	A: M5Ib-II	Ba: G5III	Bb: A9IV-V		
Masses ($M_\odot$)	A: 2.7	± 0.6	Ba: ~ 2.5	B: ~ 2.0	
Radii ($R_\odot$)	A: 400	± 70			
Luminosities ($L_\odot$)	Aab: 400	Ba: 60	Bb: 25		
Catalogues	HD 156014/5	HR 6406/7	SAO 102680/1	HIP 84345	
DS catalogues (AB)	Mayer 43	H 2 2	STF 2140	BDS 7914	ADS 10418
	CHR 139 (AaAb)				
Radial velocity	-32.09 km s^{-1}	± 0.22			
Galactic coordinates	35°.534	+27°.818			

History

The system α Herculis has been known as Rasalgethi for thousands of years. The name means the kneeler's head in Arabic and harks back to a time when the stars referred to a kneeling man, before Hercules became part of the constellation canon. It is unmistakeable and sits about 10° directly S of δ Herculis, the south eastern star in the group of six bright stars which make up the Keystone of Hercules. First seen by Neville Maskelyne in 1777, this pair was swept up by William Herschel on 29 August 1779. He found the primary star to be red and the companion 5 arcseconds distant was 'blue tending to green'. Herschel also observed in 1795 that the primary star varied in brightness and thought the period to be 66 days. In 1921 Sanford [505] found that B was a single-lined spectroscopic binary with a period of 51.59 days moving in a circular orbit. He noted the difference in radial velocity between A and B and wondered if the two bright stars were actually an optical pair.

The Modern Era

The current picture of α Herculis is still rather unclear. It is known to consist definitely of four stars. Dr Myron Smith has suggested the presence of another component, because of a long-term change in the radial velocity of the primary star, over and above what is known about the pulsational variations and the effect of the close interferometric companion (a) to A found by Harold McAlister *et al.* [665] using the KPNO 4-metre telescope in 1986. This system, known as CHR 139AaAb, was resolved three times between