127. δ HER = STF 3127 = WDS J17150+2450AB

Table 9.127 Physical parameters for δ Her

STF 3127	RA: 17 15 01.91	Dec: +24 50 21.15	WDS: 210(219)		
V magnitudes	Aa: 3.31	Ab: 4.4	B: 8.3	C: 10.5	D: 10.6
$(B-V)$ magnitudes	A: +0.08	B:			
μ(A)	-22.79 mas yr^{-1}	$\pm$ 0.57	-156.52 mas yr^{-1}	$\pm$ 0.62 (DR2)	
μ(B)	-105.30 mas yr^{-1}	$\pm$ 0.04	+5.29 mas yr^{-1}	$\pm$ 0.05 (DR2)	
π(A)	42.78 mas	$\pm$ 0.35	76.2 light yr	$\pm$ 0.6 (DR2)	
π(B)	10.11 mas	$\pm$ 0.30	323 light yr	$\pm$ 10 (DR2)	
Spectra	A: A1IV	B: G4IV-V			
Masses ($M_\odot$)	A: 2.5				
Radii ($R_\odot$)	A: 2.2				
Luminosities ($L_\odot$)	Aa: 22	Ab: 8	B: 4		
Catalogues	65 Her	HR 6410	HD 156164	SAO 84951	HIP 84379
DS catalogues	H 5 1 (AB)	STF 3127 (AB)	BNU 5 (AaAb)		
Radial velocity (A/B)	-40.0 km s^{-1}	$\pm$ 2	-4 km s^{-1}	$\pm$ 5	
Radial velocity (B)	4.05	$\pm$ 2.57 (DR2)			
Galactic coordinates	46°.824	+31°.423			

History

This binary was found by William Herschel on 9 August 1779. 'Double. Extremely unequal. L(arge).w(hite).; S(mall). inclining to r(ed). Distance 33″.75. Position 72° 28′ s(outh). following'. Herschel calls the primary star Flamsteed 11. Merrill [571] observed the bright component with the 100-inch Mount Wilson stellar interferometer and found it single at the 0″.03 level. Abetti [511] added faint companions C (353°, 174″, 2013) and D (93°, 192″, 2010), which appear to be unconnected to δ.

The Modern Era

The primary is a multiple system. The WDS notes that it is a spectroscopic binary and in 1980 Bonneau & Foy [512] resolved A into two stars, with a magnitude difference of about 1.5 in V and a separation of 0″.095 using a speckle camera on the 1.9-metre reflector at Haute Provence. Three further resolutions were reported in 1988/9 by Ismailov *et al.* [513], which, if accurate, show rapid orbital motion, but no observations of this companion have been made since then. It is possible that this is the spectroscopic companion but no

129. MLO 4 SCO = WDS J17190−3459 AB

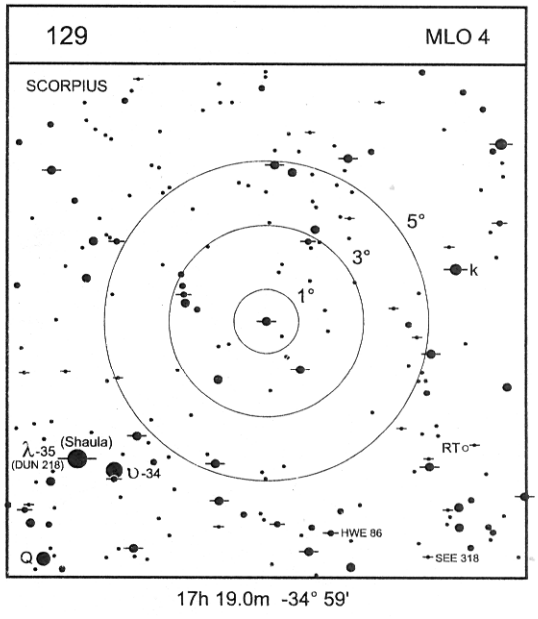
Table 9.129 Physical parameters for MLO 4

MLO 4	RA: 17 18 57.16	Dec: -34 59 23.1	WDS: 165(248)		
V magnitudes	A: 7.38	B: 8.82	C: 10.6	D: 12.5	
$(B-V)$ magnitudes	A: +1.02	B: +1.30			
μ	1129.76 mas yr^{-1}	± 9.72	−77.02 mas yr^{-1}	± 4.67	
π	146.29 mas	± 9.03	22.3 light yr	± 1.4	
μ(C)	1131.61 mas yr^{-1}	± 0.11	−215.55 mas yr^{-1}	± 0.08 (DR2)	
π(C)	138.02 mas	± 0.09	23.63 light yr	± 0.02 (DR2)	
Spectra	A: K3V	B: K5V	C: M1.5V		
Masses ($M_\odot$)	A: 0.73	B: 0.69	C: 0.37		
Luminosities ($L_\odot$)	A: 0.04	B: 0.01	C: 0.002	D:	
Catalogues	142 G Sco	HR 6426	HD 156384	SAO 208670	HIP 84709
DS catalogues	MLO 4 (AB)	BU 416 (AB)	HJ 4935 (AB,C)	SEE 509 (AD)	BDS 7929
Radial velocity	0.00 km s^{-1}	± 3.7			
Galactic coordinates	351°.842	+1°.423			

History

On sweep 792 at Feldhausen during his survey of the southern heavens, John Herschel observed the star Brisbane 6097 to be double and noted 'position estimated from diagram'. He gives no separation or magnitudes, simply an estimated position angle of ±130°. The pair was given the catalogue number HJ 4935 and the WDS gives the magnitude as 10.27 and the current separation as 33″. What is more interesting is why Herschel did not divide the primary star, which we now know must have been separated by 1″.6 at the epoch at which he observed it. The double nature of the primary was reported at Melbourne Observatory in 1867 [526]. In 1875, S. W. Burnham [523] noted the close pair with the 6-inch Clark, and it became β 416. He also included it in his *General Catalogue* even though it lies 3° S of the southernmost limit of the catalogue (121° from the North Pole). Aitken is more

Finder Chart



130. 41G ARA = BSO 13 = WDS J17191−4638 AB

Table 9.130 Physical parameters for 41 Ara

BSO 13	RA: 17 19 03.85	Dec: −46 38 10.1	WDS: 455(134)		
V magnitudes	A: 5.61	B: 8.88			
$(B-V)$ magnitudes	A: +0.89	B:			
μ(A)	1029.64 mas yr^{-1}	± 0.15	107.00 mas yr^{-1}	± 0.16 (DR2)	
μ(B)	952.22 mas yr^{-1}	± 0.67	143.18 mas yr^{-1}	± 0.56 (DR2)	
π(A)	113.82 mas	± 0.13	28.66 light yr	± 0.03 (DR2)	
π(B)	120.18 mas	± 0.48	27.14 light yr	± 0.11 (DR2)	
Spectra	A: G8V	B: M0V			
Masses ($M_\odot$)	A: 0.81	B: 0.52			
Radii ($R_\odot$)	A: 0.79	B: 0.48			
Luminosities ($L_\odot$)	A: 0.4	B: 0.02			
Catalogues (A)	41G Ara	HR 6416	HD 156274	SAO 227816	HIP 84720
DS catalogues	BSO 13				
Radial velocity	25.3 km s^{-1}	± 0.1			
Radial velocity (A/B)	26.04 km s^{-1}	± 0.20	25.06 km s^{-1}	± 1.07 (DR2)	
Galactic coordinates	342°.299	−5°.268			

History

This pair was first noted at Parramatta in 1825 during the observations being made for the Brisbane Catalogue. Innes [528] noted that it was subsequently unobserved for more than half a century, until 1880, when it was included in the Argentine General Catalogue, and a few weeks later picked up independently by Russell [525], who gave it his running number R 297.

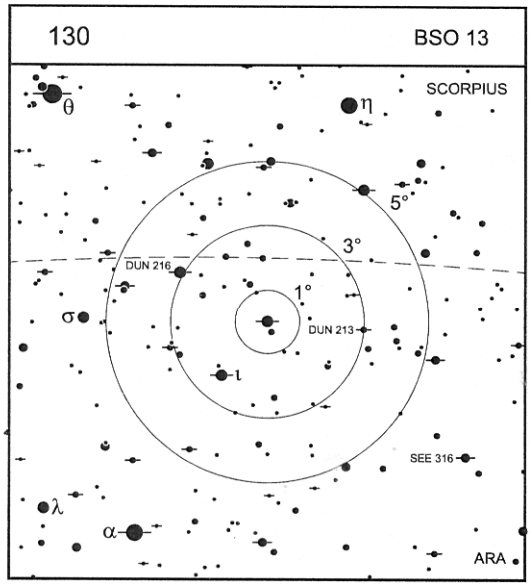
The Modern Era

The current orbital period is 953 years but this is a rather preliminary value as the stars have not yet been observed at widest separation.

Exoplanet Host?

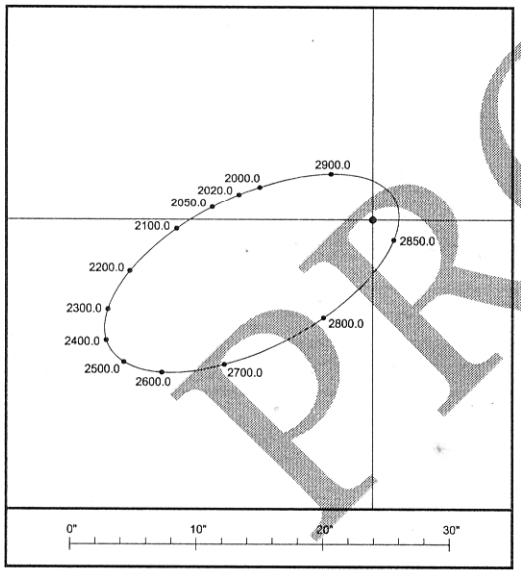
The pair BSO 13 has been surveyed [528] by radial velocity methods for signs of a planetary family; there is a linear

Finder Chart



17h 19.1m -46° 38'

Orbit



Ephemeris for BSO 13 AB (2010 to 2100)

Orbit by Sca (2013d) Period: 953.0 years, Grade: 5

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2010.0	256.3	10.05	2060.0	267.0	13.31
2020.0	259.0	10.76	2070.0	268.6	13.89
2030.0	261.3	11.43	2080.0	270.0	14.44
2040.0	263.4	12.08	2090.0	271.4	14.97
2050.0	265.3	12.71	2100.0	272.6	15.49

increase in the systemic radial velocity of the primary star of 9.6 metres per second per year, which indicates the presence of a stellar mass companion with an estimated period of over 500 years.

Observing and Neighbourhood

Found half-way between η Sco and α Ara, this is a beautiful pair with colours of deep yellow and orange. The different spectral types and the size and period of the apparent orbit almost make it a southern equivalent of η Cas. An easy object for the small aperture, the stars of this nearby binary were separated by only 2″ in 1905 but will widen for about four centuries until reaching a maximum separation of 23″.1 around 2420. Two faint field stars, magnitudes 13.4 and 14.4, are being left rapidly behind by the proper motion of AB. As of 1999, they were at 267°, 145″ and 290°, 95″ respectively. Nearby is the fine triple DUN 216+HJ 4949 (p. xx) and also DUN 213 (6.9, 8.3, 168°, 8″.3, 2016). The fine pair SEE 316 is 4° SW (magnitudes 6.3, 7.7, 173°, 1″.0, 2016). Little orbital motion has been shown since discovery, but the WDS notes that the primary has a composite spectrum.

Measures

Early measure (I)	69°.6	2″.12	1900.64
(Orbit	68°.8	2″.09)	
Recent measure (ARY)	258°.3	10″.78	2014.25
(Orbit	258°.0	10″.52)	

131. $\rho^{1,2}$ HER = STF 2161 = WDS J17237+3709AB

Delete 1, 2

Table 9.131 Physical parameters for $\rho^{1,2}$ Her

STF 2161	RA: 17 23 40.97	Dec: +37 08 45.3	WDS: 80(385)		
V magnitudes	A (ρ^2): 4.96	B (ρ^1): 5.91			
$(B-V)$ magnitudes	A: −0.03	B: 0.00			
μ(A)	−42.32 mas yr^{-1}	± 0.57	2.67 mas yr^{-1}	± 0.61 (DR2)	
μ(B)	−40.39 mas yr^{-1}	± 0.19	7.14 mas yr^{-1}	± 0.18 (DR2)	
π(A)	8.34 mas	± 0.34	391 light yr	± 16 (DR2)	
π(B)	9.04 mas	± 0.11	361 light yr	± 4 (DR2)	
Spectra	A: B9.5III	B: A0Vn			
Luminosities ($L_\odot$)	A: 120	B: 45	C:	D:	
Catalogues (A/B)	75 Her	HR 6485/4	HD 157779/8 (B/A)	SAO 66001/0	HIP 85112
DS catalogues	Mayer 46	H 2 3	STF 2161	BDS 8003	
	ADS 10526	MCA 48 (AaAb)			
Radial velocity	−21.0 km s^{-1}	± 2			
Galactic coordinates	61°.442	+32°.710			

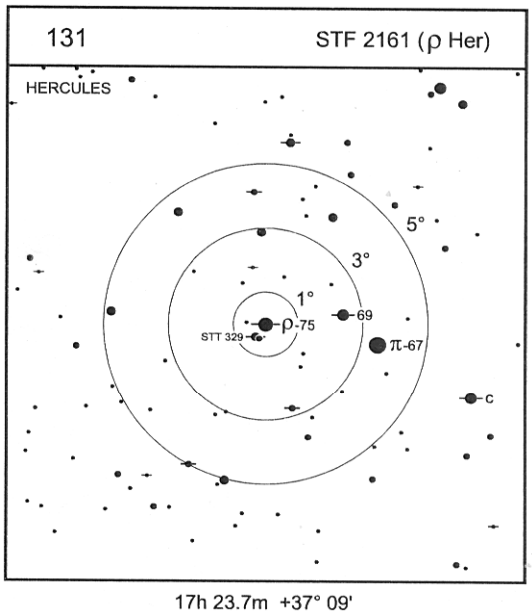
History

This double star was first noted by Christian Mayer and appears as number 46 in his catalogue, as arranged by Jorge Schlimmer. William Herschel then observed it on 29 August 1779, when he found the stars 'Pretty unequal. Both w.(hite)'.

The Modern Era

The brightness and relatively wide separation of the stars has made this a popular object for measurement, and the *WDS Observations Catalog* currently contains 385 observations of the STF numbered pair. In 1981, during a survey with the Canada–France–Hawaii Telescope (CFHT), H. McAlister [529] and colleagues resolved the primary component of ρ into two stars. The measured separation was 0″.29. In 1985 the pair was unresolved when observed by two independent groups of observers using telescopes of apertures 1.9 and

Finder Chart



have varied little from 312° and 61″.8 over 200 years, so the large differences in separation in the measures of Herschel and Flamsteed are unexplained.

The Modern Era

Both components are spectroscopic binaries, according to WDS, but the MSC catalogue has only orbital parameters for the A component, which has a period of 38 days.

Observing and Neighbourhood

Found in the head of the Dragon, a glorious pair of white stars that can be seen in hand-held binoculars and are brilliant even in small telescopes. Gary Seronik [534] produced a rough guide to deciding whether you can resolve a particular separation in binoculars. Take the power of the binoculars (7 in 7 × 50, say) and divide into 300. In this case you get 43″. Greg Stone has tested this and finds it works quite well but will need to be modified in cases where the stars are faint or unequal. He reports that he can resolve ν Dra in 8 × 42. Moving 4° to the W brings you to μ Draconis (p. xx), a beautiful binary; continue in the same direction by 5° and you alight on the bright triple star 17/16 Dra (STF2078, 5.4, 6.4, 5.5, 103°, 3″.1, 19°, 89″.3, 2016). Just over 1° to the NNE of ν is the binary STF 2199 (8.0, 8.6, 51°, 1″.9, 2020), which is seen well in 20-cm. This pair has a near 1300-year orbit and will be slowly widening for the next century or so.

Measures

Early measure (STF)	313°.0	61″.72
Recent measure (SMR)	310°.9	61″.85

in the spectral types. Both stars are giants and the primary is more than a whole spectral class earlier than its companion, so some contrast might be expected. Smyth's little book on double stars, usually called *Sidereal Chromatics* for short, explains what his terms for colour hue actually represented. He admitted that he used inexact epithets and then presented a table explaining what these terms meant. The table can be found in the Appendix. By apple green he meant brownish green and cherry red is actually pale red, rather than the deeper hue that modern observers might take it to mean.

The Modern Era

Although the WDS gives a separation for 1777 as the first measure known for this pair, it is an estimate only; William Herschel measured the stars in 1781 and came up with a distance of 6″.1. There has been little change in separation or position angle since that date.

Observing and Neighbourhood

The controversial historical observations of colour in each star make this double a target for the small aperture. Recent estimates show little difference in hue and certainly not the spectacular colours noted by Smyth and Piazzi Smyth. In 1968 with an 8.3-inch (21-cm) reflector RWA found both stars white, whilst John Nanson [535], observing in July 2010 with 3-inch aperture at ×133, noted that both stars were white but 'with just a hint of yellow on closer examination'. With an 8-inch f/5.9 Newtonian at ×240 in 2009, Jeremy Perez [536] noted colours of light blue and light yellow, an impression RWA also received recently with the Cambridge 8-inch. One degree E is STT 341, a rapid binary of 20-year period; the orbit is highly inclined and very eccentric (7.8, 8.8, 87°, 0″.20, 2020). The stars will widen to 0″.49 in 2029, which is as far apart as they get; given the difference in magnitude, this pair will test the largest apertures and the seeing. Four degrees S and slightly W is an easier proposition, STF 2245 (7.4, 7.6, 11°, 2″.5, 2017).

Measures

Early measure (STF)	261°.8	6″.06	1829.90
Recent measure (ARY)	258°.0	6″.37	2014.68

Add 'AB'

Bob, (the double shown on the chart is AG)

135. τ OPH = STF 2262 = WDS J18031−0811AB

Table 9.135 Physical parameters for τ Oph

STF 2262	RA: 18 03 04.920	Dec: −08 10 49.26	WDS: 27(633)	
V magnitudes	A: 5.30	B: 5.94		
$(B-V)$ magnitudes	A: +0.43	B: +0.41		
μ(A)	12.09 mas yr^{-1}	± 0.46	−37.65 mas yr^{-1}	± 0.45 (DR2)
μ(B)	31.13 mas yr^{-1}	± 0.68	−30.01 mas yr^{-1}	± 0.44 (DR2)
π(A)	18.62 mas	± 0.34	175 light yr	± 3 (DR2)
π(B)	18.59 mas	± 0.35	175 light yr	± 3 (DR2)
Spectra	A: F2V + ?	B: F5V		
Masses ($M_\odot$)	Aa: 1.93	Ab: 0.34	B: 1.64	
Luminosities ($L_\odot$)	A: 18	B: 10		
Catalogues (A/B)	HR 6734/3	HD 164765/4	SAO	HIP 88404
DS catalogues	H 1 88 (AB)	STF 2262 (AB)		
Radial velocity	−38.39 km s^{-1}	± 0.28		
Galactic coordinates	20°.061	+6°.870		

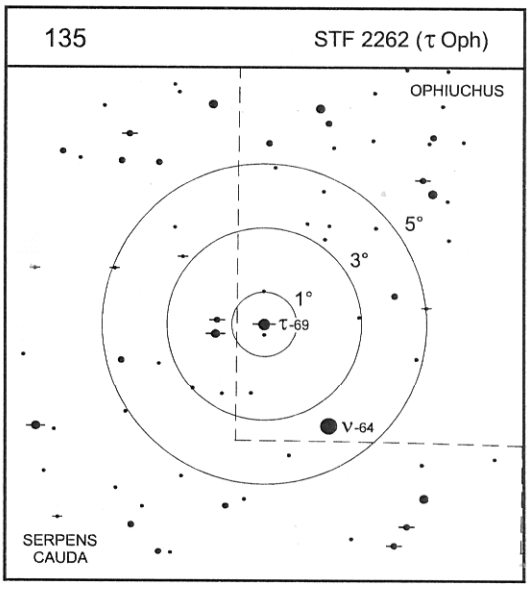
History

This was first seen by William Herschel on 28 April 1783, and reported in his second double star survey paper in 1784. 'The closest of all my double stars; can only be suspected with 460; but 932 confirms it to be a double star. Pretty unequal. Both p(ale)r(ed) or w(hitish)r(ed)'. Star C (maguitude 11.3 at 125°, 100″.8, 2000) was first measured by W. H. Smyth. Although the distance and angle have not changed since 1880, Smyth's distances of 1832 and 1838 were given as 83″.1 and 82″.7, and his angles are about 10° out, too.

The Modern Era

Star A was found to be an SB1 with a period of 184.085 days, but little is known about the companion. Tokovinin in his MSC gives a mass of 0.34 $M_\odot$. Shaya and Olling [270] have shown that the chances of C being physical are almost 100%.

Finder Chart



18h 03.1m -08° 11'

BY Draconis class of variables whilst the AAVSO classify it as belonging to the RS CVn class.

Exoplanet Host?

A long-term radial velocity monitoring programme carried out with the 2.7-metre reflector at McDonald Observatory between 1988 and 2006 was able to rule out any giant planets in the system beyond 8 AU.

Observing and Neighbourhood

A spectacular binary star, one of the finest in the sky. Its brightness and the beautiful colours of its components combined with an ease of resolution make it a top target for the small telescope user. Admiral Smyth noted colours of pale topaz and violet whilst T. W. Webb found yellow and orange in 1850 as did E. J. Hartung about a century later, and the observers of the ASNSW around 1980 made them yellow and orange yellow. Only 17 light years away, this is one of the closest stars to the Sun. It is also one of the most observed. The WDS lists at least 1730 measurements since the pair was discovered. The significant magnitude difference between the two stars amounting to almost two magnitudes does tend to make measurement with a filar micrometer more difficult than for equally bright stars. The pair is currently opening and will reach maximum separation (6″.7) in 2025. This is a nearby stellar system, so even at closest separation (1″.5) the stars can be seen in a small aperture and can therefore be followed around the whole of the 88-year orbit. In the true orbit, the stars are 12 AU apart at periastron and 35 AU distant at apastron. Two degrees to the NE is 73 Oph (STF 2281 (p. xx). To the WNW, 1°.5 is 67 Oph, one of Herschel's class VI pairs, H 6 2 (4.0, 8.0, 142°, 54″.3, 2014). The star BU 1202 sits about a degree N of 67 Oph and two distant stars can be seen with 15-cm. These are C (maguitude 10.2) at 28°, 105″, 2011, whilst E (8.4) is at 138°, 90″, 2011. The pair AB is faint, unequal, and was last seen in 1996 at 0″.6. Following BU 1202 by about 50′ is STF 2266 (7.9, 9.6, 188°, 8″.7, 2016).

366

Table 9.1 Faint field stars within 5 arc minutes of 70 Oph

Comp	Epochs	PA1	PA2	Sep1	Sep2	Mags	
AB	1777 2014	82	128	7.0	6.2	4.22	6.17
AC	1878 2013	198	326	71.4	93.1		12.05
AD	1905 2009	252	315	70.0	129.3		14.36
AR	1905 2012	73	26	105.0	164.8		12.87
AS	1878 2009	50	10	87.2	202.6		12.45
AT	1905 2013	103	45	120.3	128.4		12.25
AU	1905 2009	329	337	142.4	255.5		13.79
AV	1886 2013	224	276	165.9	144.5		10.83
AY	1924 2009	5	357	158.3	250.5		14.73
AZ	2000 2000	163	163	68.3	68.3		16.04
BC	1899 2000	208	322	50.8	81.2	6.17	12.05
BD	1900 2000	247	311	69.3	120.0		14.36
BR	1908 2000	70	29	104.7	154.3		12.87
BZ	1900 2000	168	163	68.4	70.2		16.04
VT	1905 2009	73	72	247.4	247.5	10.83	12.25
VW	1906 2009	270	270	180.5	180.4		11.77
VX	1906 2012	250	252	16.6	17.4		13.88

Measures

Early measure (STF)	135°.7	5″.31	1830.84
(Orbit	134°.4	5″.31)	
Recent measure (ARY)	125°.2	6″.44	2018.47
(Orbit	122°.4	6″.53)	

138. 73 OPH = STF 2281 = WDS J18096+0400 AB

1
ADD

Table 9.138 Physical parameters for 73 Oph

STF 2281	RA: 18 09 33.89	Dec: +03 59 35.8	WDS: 73(406)		
V magnitudes	A: 6.03	B: 7.96	C: 12.6		
$(B-V)$	A: +0.33	B: +0.66			
μ	48.88 mas^{-1}	± 0.65	−2.96 mas yr^{-1}	± 0.50	
π	18.25 mas	± 0.60	179 light yr	± 6	
μ_*(A)	32.59 mas yr^{-1}	± 1.69	0.01 mas yr^{-1}	± 1.31 (DR2)	
π(A)	10.24 mas	± 1.08	319 light yr	± 34 (DR2)	
Spectra	A: F0V	B: G1V			
Luminosities ($L_\odot$)	A: 30	B: 5			
Catalogues	HR 6795	HD 166233	SAO 123187	HIP 88964	V2666 Oph
DS catalogues	H 1 87	STF 217	BDS 8380	ADS 11111	
Radial velocity (A/B)	−8.80	± 2.8 km s^{-1}			
Galactic coordinates	31°.725	+11°.132			

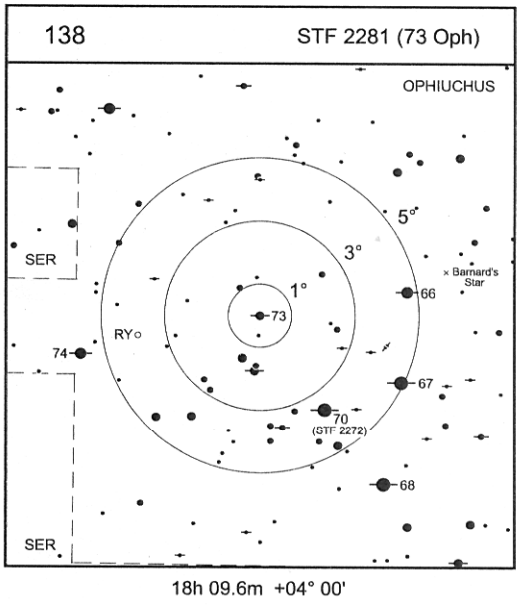
History

The pair 73 Oph was found as a difficult double star by William Herschel on 27 April 1783. He noted that it was 'A very minute double star. Considerably unequal. L(arge) r(ed). S(mall) r(ed). With 227 not to be suspected unless known to be double, but may be seen wedge-formed, and with long attention I have also perceived a most minute division.' During the nineteenth century the companion began to close slowly and by 1900 it made a close approach to A (to within almost 0″.1) and then around 1930 began to head back towards the third quadrant again.

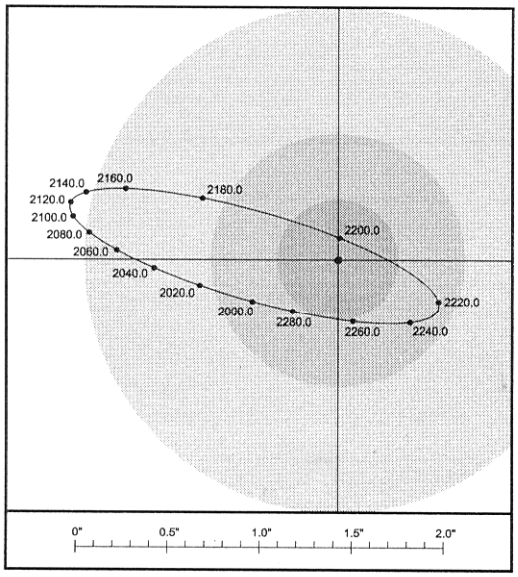
The Modern Era

In 2003 Fekel & Henry [542] wrote a paper for the *Astrophysical Journal* in which they analyzed the light variations of the star V2502 Oph. In their observing they used 73 Oph

Finder Chart



Orbit



Ephemeris for STF 2281 AB (2015 to 2060)

Orbit by Sod (1999) Period: 294 years, Grade: 2

Year	PA(°)	Sep(")	Year	PA(°)	Sep(")
2015.0	283.5	0.70	2040.0	340.9	1.00
2020.0	280.7	0.77	2045.0	337.0	1.06
2025.0	278.2	0.83	2050.0	333.3	1.11
2030.0	276.1	0.89	2055.0	329.7	1.16
2035.0	274.3	0.95	2060.0	326.2	1.21

as a check star and found that it too also varied in brightness. Further investigation showed that 73 Oph A is a γ Doradûs variable with a period of 0.67 days and an amplitude in the V band of about 0.006 magnitude. The γ Doradûs variables are similar to Cepheids, but the pulsations are far more akin to water waves on the surface of the Earth, and the change in luminosity is much smaller than that in the classical Cepheid variables. The GCVS now includes 73 Oph in the catalogues as V2666 Oph. The current visual orbit shows that the stars will continue to separate for about another century.

Observing and Neighbourhood

A significant factor in resolving this pair at the moment is the question of the magnitude difference. The WDS gives magnitudes for A and B of 5.97 and 7.52, whereas the Hipparcos satellite observed both components in the early 1990s and obtained magnitudes in the Tycho B and V system. These are similar to Johnson's B and V but when the transformation is made the two components have V magnitudes of 6.03 and 7.96 respectively. RWA has made two measures of the pair in the last few years but there is a significant difference between the measured and orbital position angles, which is no doubt due to the difficulty of seeing component B clearly. A faint star of magnitude 12.6, 68″ distant in position angle 194°, is unconnected to the visual binary system. The pair is easily found just over 2° NE of 70 Oph (p. xx). About 3° slightly N and W of 73 Oph is Barnard's star (see the finding chart).

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Measures

Early measure (STF)	259°.7	1″.54	1831.05
(Orbit	257°.2	1″.48)	
Recent measure (TOK)	285°.9	0″.7063	2014.76
(Orbit	283°.6	0″.70)	

139. α LYR = VEGA = H 5 39 = WDS J18369+3846AB

Table 9.139 Physical parameters for Vega

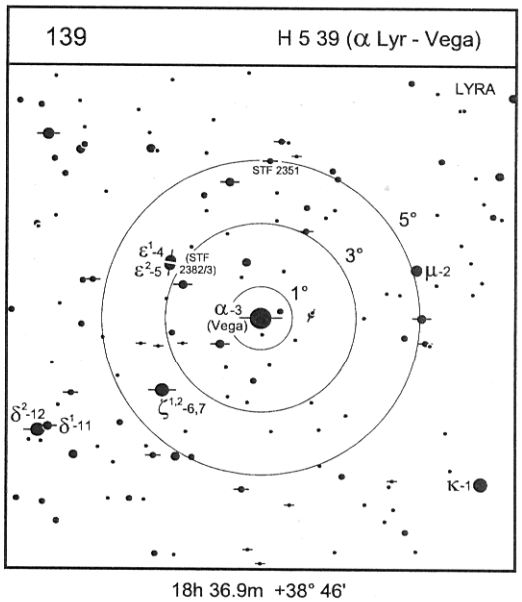
H 5 39	RA: 18 36 56.336	Dec: +38 47 01.28	WDS: 900(83)		
V magnitudes	A: 0.09	B: 9.5	C = 11.0	D = 11.	E = 9.5
$(B-V)$ magnitudes	A: 0.00	B:			
μ (A)	+200.94 mas yr^{-1}	± 0.32	286.23 mas yr^{-1}	± 0.40	
π (A)	130.23 mas	± 0.36	25.04 light yr	± 0.07	
μ (B)	4.06 mas yr^{-1}	± 0.04	0.54 mas yr^{-1}	± 0.04 (DR2)	
π (B)	1.46 mas	± 0.03	2230 light yr	± 45 (DR2)	
Spectra	A0V				
Masses ($M_\odot$)	A: 2.71	± 0.02			
Luminosities ($L_\odot$)	A: 44	B: 60			
Catalogues	3 Lyr	HR 7001	HD 172167	SAO 67174	HIP 92162
DS catalogues	H 5 39 (AB)	STFB 9 (AC/AE)	BDS 8692	ADS 11510	
Radial velocity	−20.60 km s^{-1}	± 0.2			
Galactic coordinates	67°.448	+19°.237			

αLyr .34 .3

History

When William Herschel observed Vega on 24 September 1781 he found great difficulty in seeing the maguitude 9.5 field star in the glare of Vega itself. He noted that it was easier to see with no moonlight, and he obtained a separation of 37″. A month later he made a measurement of the diameter of the star and with his micrometer and a power of ×6450 he obtained a value of 0″.3553. Attempting this observation will have necessitated some skill at the telescope since he notes that Vega crossed the field of this high-power eyepiece in less than three seconds. He was of the opinion that with a 6-inch aperture there was enough light from Vega to bear a magnification of ×100,000. Vega was the first star to be photographed (at Harvard in 1850) and in 1872 Henry Draper took the first photographic stellar spectrum – that of Vega.

Finder Chart



REPLACE FINDER CHART

The Modern Era

Vega is of considerable interest to modern astronomers because of the disk of material which surrounds it and is confirmed from infrared observations by IRAS and Spitzer, which may presage the formation of a solar system. It is also one of the nearest A stars to our Solar System and appears to be rotating very quickly. Recent measures put the rotational velocity at about 270 km s^{-1}. As a consequence the star is very oblate in shape – the polar radius is 2.36 $R_\odot$ whilst the equatorial radius is 2.82 $R_\odot$ [544]. Dynamically Vega belongs to the Castor moving group, but its membership is uncertain as it is considerably older than the other members. SIMBAD has more than 2300 references to the star. The angular diameter of Vega has been directly measured a number of times and the current value, obtained from observations with the Navy Prototype Optical Interferometer as 2.71 mas ± 0.02 [546], is about 100 times smaller than Herschel's measurement. The NPOI currently has six imaging stations, with baselines between 10 and 97 metres, but four more will be added to extend the baseline to 432 metres. The current limiting magnitude is about $V = 6$.

Observing and Neighbourhood

The brightest star in the northern sky, with the exception of the orange Arcturus, Vega is a member of the Summer Triangle along with Altair in Aquila and Deneb in Cygnus. Unmistakeably, in mid-summer Vega is near the zenith in the UK. The B star is now more than 80″ away from the primary star, making its observation easier than it would have been in Herschel's time. With the Cambridge 8-inch the companion is barely visible when the micrometer field illumination is on. In a dark sky 15-cm should suffice to see it. The group of faint stars listed in the WDS entry on Vega are all unconnected, as indeed is star B. For more information on the field of Vega, see the article by Juerg Schlimmer [543]. The Double-Double (p. xx) is 1°.5 NNE whilst 1°.5 SE is ζ Lyr (STFA 38) (4.3, 5.6, 150°, 43″.8, 2017) whilst the WDS adds four distant stars with magnitudes between 13 and 16. A neat pair can be found 2°.5 N and slightly E. This is STF 2351 (7.6, 7.6, 160°, 5″.1, 2017).

Measures

Early measure (STF)	137°.8	42″.95	1836.14
Recent measure (SMR)	183°.7	82″.13	2016.37

372

140. STF 2398 DRA = WDS J18428+5938

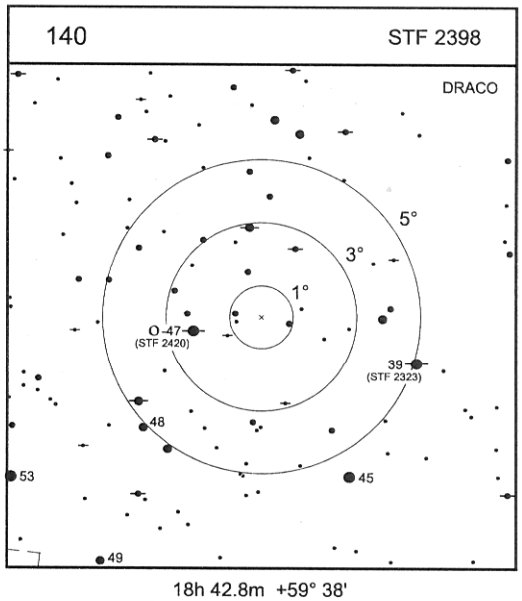
Table 9.140 Physical parameters for STF 2398

STF 2398	RA: 18 42 46.69	Dec: +59 37 49.4	WDS 32 (610)	
$\dot{V}$ magnitudes	A: 9.11	B: 9.96	C: 12.2	D: 13.5
$(B-V)$ magnitudes	A: +1.79	B: +2.02		
μ(A)	-1311.91 mas yr^{-1}	$\pm$ 0.18	1792.19 mas yr^{-1}	$\pm$ 0.22 (DR2)
μ(B)	-1400.02 mas yr^{-1}	$\pm$ 0.03	1862.41 mas yr^{-1}	$\pm$ 0.39 (DR2)
π(A)	283.95 mas	$\pm$ 0.06	11.487 light yr	$\pm$ 0.002 (DR2)
π(B)	283.86 mas	$\pm$ 0.11	11.490 light yr	$\pm$ 0.004 (DR2)
Spectra	A: M4	B: M4.5		
Radii ($R_\odot$)	A: 0.36	$\pm$ 0.006	B: 0.33	$\pm$ 0.011
Luminosities ($L_\odot$)	A: 0.002	B: 0.001		
Catalogues (A/B)	HD 173739/40	SAO 31128/9	HIP 91768/72	
DS catalogues	STF 2398	BDS 8798	ADS 11632	
Radial velocity (A)	-1.07 km s^{-1}	$\pm$ 0.09	B: -1.09 km s^{-1}	$\pm$ 0.09
Galactic coordinates	89°.288	+24°.231		

History

Found by F. G. W. Struve at Pulkovo, this pair initially encouraged little follow-up interest owing to the faintness of the stars and the relatively large angular separation. By the end of the nineteenth century, however, proper motions had been obtained which were shown to be significantly large. This led to a number of parallax determinations by Kapteyn (0″.35), Flint (0″.32), Lamp (0″.35), and Schlesinger (0″.30)[194], which gave an average value of 0″.32 corresponding to a distance of 10 light years. The maguitude 12.2 star C was first seen by Barnard [553] on 1 August 1904, with the 40-inch at Yerkes at powers of ×700 and ×1300. He was responding to a request, possibly from Burnham, to measure the AB pair. The seeing was reported to be 'often very poor'. The separation between A and C, which was 51″ at the time of Barnard's observation, has now increased to more than 250″.

Finder Chart



141. $\epsilon^{1,2}$ LYR = STF 2382/3 = WDS J18443+3940AB,CD

Reduce to 2 decimal places

Reduce to 1 decimal place

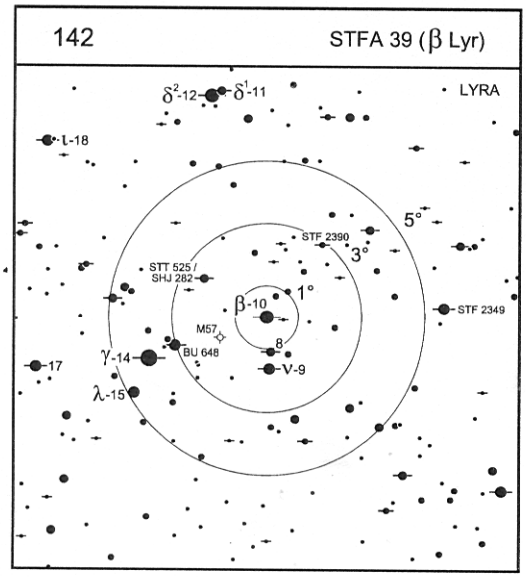
Table 9.141 Physical parameters for ϵ Lyr

STF 2382 (AB)	RA: 18 44 20.3459	Dec: +39 40 12.453	WDS: 35 (603)		
STF 2383 (CD)	RA: 18 44 22.7806	Dec: +39 36 45.785	WDS: 28 (617)		
V magnitudes	A: 5.15	B: 6.10	C: 5.25	D: 5.38	
$(B-V)$	A: +0.14	B: +0.23	C: +0.19	D: +0.25	
μ(A)	9.30 mas yr^{-1}	± 0.48	75.29 mas yr^{-1}	± 0.48 (DR2)	
μ(B)	1.83 mas yr^{-1}	± 0.11	49.55 mas yr^{-1}	± 0.09 (DR2)	
μ(C)	6.97 mas yr^{-1}	± 0.32	49.93 mas yr^{-1}	± 0.26 (DR2)	
μ(D)	4.14 mas yr^{-1}	± 0.23	66.45 mas yr^{-1}	± 0.20 (DR2)	
π(A)	17.97 mas	± 0.23	181.5 light yr	± 2.3 (DR2)	
π(B)	20.41 mas	± 0.05	159.8 light yr	± 0.4 (DR2)	
π(C)	20.19 mas	± 0.13	161.5 light yr	± 1.0 (DR2)	
π(D)	20.06 mas	± 0.12	162.6 light yr	± 1.0 (DR2)	
Spectra	A: A3V	B: F0V	C: A6Vn	D: A7Vn	
Luminosities ($L_\odot$)	A: 21	B: 7	C: 15	D: 14	
Catalogues (AB/CD)	HR 7051/2	HD 173582/607	SAO 67310/09	HIP 91919/26	
DS catalogues (AB/CD)	Mayer 57/8	H 2 5	STF 2382/3	BDS 8783/5	ADS 11632
Radial velocity (AB)	−31.2 km s^{-1}	± 1.7 km s^{-1}			
Radial velocity (CD)	−24.40 km s^{-1}	± 1.7 km s^{-1}			
Galactic coordinates (AB)	68°.849	+18°.198			
Galactic coordinates (CD)	68°.795	+18°.171			

History

The unusual nature of ϵ Lyrae was revealed in 1777 when Christian Mayer turned his 2.7-inch aperture telescope onto the system. He noted that each of the two bright components, separated by about 210″ (and therefore visible to the unaided eye) was a double star. Using the most recent orbits allows an estimate of the separations of each pair for 1777. Both ϵ^1 Lyra (also called 4 Lyr, and the slightly brighter of the two) and ϵ^2 were 3″.0 apart. According to Juerg Schlimmer in his discussion of Mayer's catalogue (JDSO), ϵ^2 represents the closest pair in Mayer's list. The system came under the scrutiny of William Herschel on 29 August 1779 and part of his phrase 'A very curious double-double star' has stuck and the Double-Double is now known to most astronomers and often features in public night-observing sessions during the autumn.

Finder Chart



star. The close, eclipsing pair has been resolved in the infrared (at 1.6 microns) by the CHARA Interferometric Array – hence the catalogue number of this pair. A paper in 2008 by Zhao *et al.* [561] showed that the orbital plane is almost edge-on to the line of sight and the maximum apparent separation is near 0.9 mas. They were able to confirm that the orbital period of 12.9 days corresponds to the period derived from eclipse photometry. In 2002, Roberts *et al.* [562] using a 3.6-metre telescope on the summit of Haleakala on the Hawaiian island of Maui, detected a close-in star in the near infrared. The distance was 0″.5 and the new object was of magnitude about 8.2. Despite a number of repeated attempts, only one positive detection of this star remains. All the stars appear to be very distant, but Gaia DR2 measurements still show considerable uncertainty in the parallaxes.

Observing and Neighbourhood

The small aperture sees four stars (A, B, E, and F). Star E is at 317°, 67″, 2014, distance increasing and F is at 18°, 86″, 2014, distance also increasing. The two Burnham components are very faint and probably need 25- or 30-cm on a dark night to be seen. The star STF 2390 is 1°.5 NNE of β and rather faint and close for the smallest apertures (7.4, 8.6, 155°, 4″.3, 2016). The wide pair SHJ 282 AC is 1° ENE (6.1, 7.6, 350°, 45″.3, 2017) and has a test for 15-cm in star A, which was doubled by Otto Struve at Pulkova. The star STT 525 is 6.1, 9.1, 129°, 1″.8, 2011. Two point five degrees W is STF 2349, which has a naked-eye primary (5.4, 9.4, 204°, 7″.2, 2016). Just north of γ is the binary BU 648, a 61.4-year system which is at widest separation in 2018 (5.3, 8.0, 232°, 1″.3, 2020.0)

Measures

Early measure (STF)	149°.8	45″.75	1835.23
Recent measure (RWA)	148°.9	45″.43	2010.53

hosts an exoplanet (HD 175541b) which has a minimum mass of 0.657 Jupiter masses. It was found by radial velocity variations in 2007 and has a period of 297.3 days. This star forms the very wide pair TOK 620 with another maguitude 8.1 at 270° and 842″. Both have similar proper motions but early Gaia results show that the bright star is about five times closer to us than its companion.

Observing and Neighbourhood

A glorious, brilliant white pair of stars for the small telescope and which also provide a fine sight in binoculars providing that they can be firmly mounted. Alya is probably best found by first acquiring the 3.0 maguitude star ζ Aql, moving 2° NW to the maguitude 4.0 ϵ Aql and then heading due S for a further 15°. The maguitude 6.8 star at 421″ is not related to the pair - this solar-type star is twice as close to us as θ. Two and a half degrees S is the wide pair STTA 176 (7.4, 7.5, 113°, 94″, 2011), whilst 3° WNW is the fine pair STF 2375 (6.3, 6.7, 121°, 2″.4, 2017), which hosts Tweedledum and Tweedledee (p. xx).

Measures

Early measure (STF)	103°.8	21″.65	1830.05
Recent measure (WSI)	103°.2	22″.43	2014.65

49

144. ζ SGR = HDO 150 = WDS J19026–2953 AB

AB
|
ADD

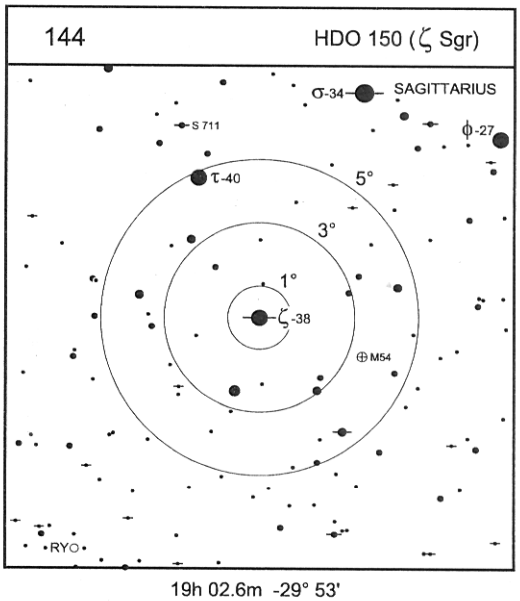
Table 9.144 Physical parameters for ζ Sgr

HDO 150	RA: 19 02 36.72	Dec: −29 52 48.4	WDS: 239(201)		
V magnitudes	A: 3.40	B: 3.58	C: 10.63		
$(B-V)$ magnitudes	A: +0.14	B: +0.11			
μ	10.79 mas yr^{-1}	± 1.00	21.11 mas yr^{-1}	± 0.65	
π	36.98 mas	± 0.87	88 light yr	± 2	
Spectra	A: A2III	B: A4IV			
Masses ($M_\odot$)	AB: 5.27	± 0.37 (dyn.)			
Luminosities ($L_\odot$)	A: 27	B: 23			
Catalogues	38 Sgr	HR 7194	HD 176687	SAO 187600	HIP 93506
DS catalogues	H 5 78 (AC)	HDO 150 (AB)	BDS 8965	ADS 11950	
Radial velocity	24.70 km s^{-1}	± 0.7			
Galactic coordinates	6°.840	−15°.354			

History

On 4 August 1782 William Herschel was sweeping in Sagittarius and came across ζ Sgr, noting that it had a faint and distant companion: 'Extremely unequal L(arge). r(ed). S(mall). d(usky). Distance Vth class … A third star. Distance about four times as far as the former…' (The third star does not appear in the WDS, probably because it is too distant.) Attempts to look at the field taken with the Schmidt telescopes shows that ζ is so overexposed that any near neighbours are obliterated. Between 1866 and 1872 Harvard College Observatory carried out a programme of micrometric measurement of double stars using the East Equatorial (15-inch aperture). The programme was led by Professor Joseph Winlock and he also participated in the observing. Joseph Winlock was born in Kentucky in 1826 and ended up in Cambridge, Massachusetts as a computer working for the American Ephemeris and Nautical Almanac. He was eventually appointed third director

Finder Chart



Bob,
There is a 3rd star in the WDS — H 5 78 AB, C

148. $\beta^{1,2}$ CYG = ALBIREO = STFA 43 = WDS J19307+2758 AB

delete 9

Table 9.148 Physical parameters for β Cyg

STFA 43	RA: 19 30 43.281	Dec: +27 57 34.85	WDS: 133(275)		
V magnitudes	Aa: 3.37	Ac: 5.16	B: 4.68		
$(B-V)$ magnitudes	A: +1.25	B: +0.18			
μ(A)	-7.17 mas yr^{-1}	$\pm$ 0.25	-6.15 mas yr^{-1}	$\pm$ 0.33	
μ(B)	-1.90 mas yr^{-1}	$\pm$ 0.19	-1.02 mas yr^{-1}	$\pm$ 0.27	
π(A)	7.51 mas	$\pm$ 0.33	430 light yr	$\pm$ 19	
π(B)	8.16 mas	$\pm$ 0.25	400 light yr	$\pm$ 12	
μ(B)	-0.99 mas yr^{-1}	$\pm$ 0.26	-0.54 mas yr^{-1}	$\pm$ 0.28 (DR2)	
π(B)	8.38 mas	$\pm$ 0.17	389 light yr	$\pm$ 8 (DR2)	
Spectra	Aa: K3II	Ab: B9.5V	B: B9.5		
Masses	Aa: 14.5	Ab: 3.0 : B: 3.2			
Luminosities ($L_\odot$)	Aa: 580	Ac: 120	B: 155		
Catalogues (A/B)	6 Cyg	HR 7417/8	HD 183912/3	SAO 87301/2	HIP 95947/51
DS catalogues	H 5 5	STFA 43	BDS 9374	ADS 12540	MCA55 (AaAc)
Radial velocity (A/B)	-24.07 km s^{-1}	$\pm$ 0.12	-18.80 km s^{-1}	$\pm$ 2.2	
Galactic coordinates	62°.110	+4°.572			

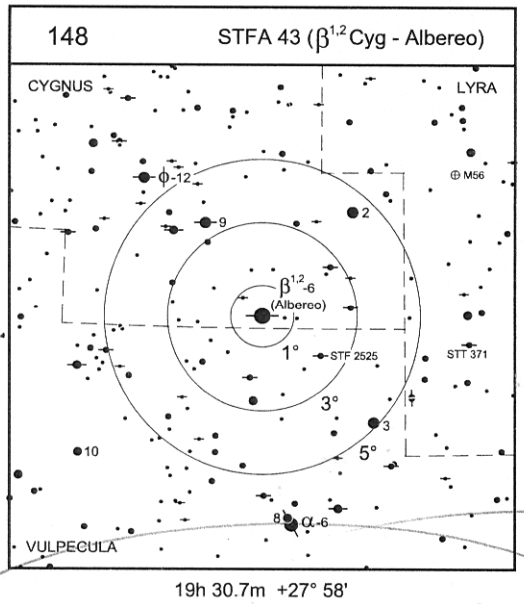
History

The pair β Cygni was first measured by Bradley in 1755 using his meridian circle. He noted that star B transited two seconds later than star A. The pair was then picked up by William Herschel on 12 September 1779. He noted 'L(arge star). pale r(ed)., s(mall star). a beautiful blue'. It was mainly of interest to subsequent generations of astronomers because of the colour contrast. Indeed, W. H. Smyth dedicated 15 pages in his volume called *'Sidereal Chromatics'* summarizing the colours of each star as determined by his côterie of astronomical friends and acquaintances (including Sir Rowland Hill, the man who was responsible for the British Post Office), William Huggins; eventually even the Astronomer Royal George Airy contributed, via one of the members of staff at the Royal Observatory. Smyth's conclusion was that the colours were yellow and blue. *Sidereal Chromatics* has been re-issued (in black and white) by Cambridge University Press.

The Modern Era

Miss Maury placed the star on the list of composite-spectrum objects in 1897. W. W. Campbell [568] announced in 1918 that a series of spectrographs of the brighter component taken between 1898 and 1918 using the Mills spectrograph on the 36-inch refractor on Mount Hamilton (Lick Observatory) show a small but definite decrease in radial velocity and noted that this was not due to orbital motion around the B star but rather due to the presence of a much closer star

Finder Chart



REPLACE FINDER CHART

accompanying A. The duplicity of the brightest star (= MCA 55) was not confirmed until 1976, when McAlister & Hendry [569] made some measures with a speckle camera on the 2.1-metre telescope at McDonald Observatory; it was then measured visually by Charles Worley [570] using the 26-inch refractor at the USNO in Washington. This begs the question, why wasn't it seen by the great observers around the turn of the last century, during the course of the intense surveys? According to the orbit of M. Scardia *et al.* [572], it was certainly somewhat wider at that time (~ 0″.6) but perhaps the star was never examined. After Campbell's discovery of the changing radial velocity in the A component, Merrill [571] observed both components with the 100-inch reflector at Mount Wilson and the stellar interferometer and found each 'apparently' single. It may be that Dr Scardia's orbit, which is, at least, a fair reflection of the existing 42 years of observations, needs significant revision and that the closest separation is considerably smaller than previously thought. Professor Roger Griffin has been monitoring the radial velocity of star A for four decades and it is by no means certain that the observed change in radial velocity so far corresponds to the 213-year binary period derived by Dr Scardia and colleagues. Two other close-in components have been announced but the reality of these is not certain. In 1978 Bonneau & Foy [573], using the 1.9-metre reflector at Haute Provence, measured a companion to A at 0″.125 and 160° but this does not seem to correspond to be the McAlister component. In 2000 Prieur *et al.* [574] found a star at 160° and 0″.045, but this does not correspond to MCA 55 either. There is reason to believe that Aac and B are physically linked, albeit with a very long orbital period. An argument to this effect was made by Roger Griffin [577]. The revised Hipparcos parallaxes do not quite agree, even after allowing for the quoted errors, but the duplicity of A will be a factor and Gaia might be expected to resolve this question, although it has not appeared in the DR2 catalogue, whilst the B star has done so. Professor Griffin also argues that for there to be two such bright stars close together is more than coincidental. There is clearly more to be found out about this fascinating system.

Observing and Neighbourhood

Finding β Cygni is very straightforward. It is the bright star at the bottom of the 'Cross' of Cygnus. The smallest apertures, and firmly mounted binoculars, will show this dazzling object. Owners of large apertures (30-cm upwards) should occasionally look at A when the seeing is good. Although the close visual companion to A is about 2 magnitudes fainter, there might be an opportunity to see an elongation. The pair should now start to slowly separate. Christopher Taylor [575], using a 12.5-inch (31-cm) Calver reflector at ×820, saw A divided on 17 October 1996. The glory of this pair is the colour contrast. Many people see the stars as yellow and blue but some observers report specific shades. Admiral Smyth in his Bedford Catalogue alludes to topaz yellow and sapphire blue, whilst more recently E. Hartung noted deep yellow and pale bluish. Most recently, John Nanson records gold and blue. Robert Burnham, in his Handbook, thinks that one should avoid too high a magnification, or too small or too large an aperture, in order to see the colours of this fine pair at their best. He suggests that with 6-inch (15-cm) aperture, a magnification of ×30 is optimal. Walter Scott Houston [578] reported splitting the wide pair in firmly held 7 × 50 binoculars. The orbital pair STF 2525 can be found 1°.2 SW. This long-period binary (P = 883 years) will widen for another three centuries before reaching 3″.3 (8.2, 8.4, 289°, 2″.2, 2020). Further in the same direction, 3° W of Albireo is the triple star STT 371. The close pair (7.0, 7.6, 159°, 0″.7, 2015) will test a 10-cm aperture but the 9.8 maguitude companion at 271°, 47″, 2007 should be somewhat easier. There is a fourth component at 7°, 47″, 2002, of maguitude 11.5.

149. 16 CYG = STFA 46 = WDS J19418+5032 AB

Delete 3'

Delete 2'

Table 9.149 Physical parameters for 16 Cyg

STFA 46	RA: 19 41 48.953	Dec: +50 31 30.22	WDS: 36(583)	
V magnitudes	A: 5.95	B: 6.20		
$(B-V)$ magnitudes	A: +0.72	B: +0.69		
μ(A)	-148.30 mas yr^{-1}	$\pm$ 0.06	-158.96 mas yr^{-1}	$\pm$ 0.07 (DR2)
μ(B)	-134.97 mas yr^{-1}	$\pm$ 0.05	-162.49 mas yr^{-1}	$\pm$ 0.05 (DR2)
π(A)	47.28 mas	$\pm$ 0.03	68.99 light yr	$\pm$ 0.04 (DR2)
π(B)	47.28 mas	$\pm$ 0.03	68.99 light yr	$\pm$ 0.04 (DR2)
Spectra	A: G1.5Vb	B: G3V		
Masses ($M_\odot$)	A: 1.07	$\pm$ 0.05	B: 1.05	$\pm$ 0.02
Radii ($R_\odot$)	A: 1.22	$\pm$ 0.02	B: 1.12	$\pm$ 0.02
Luminosities ($L_\odot$)	A: 1.5	B: 1.2		
Catalogues (A/B)	HR 7503/4	HD 186408/27	SAO 31898/9	HIP 96895/901
DS catalogues	H 5 36	STFA 46	ADS 12815	BDS 9560
Radial velocity (A/B)	-27.61 km s^{-1}	$\pm$ 0.08	-28.02 km s^{-1}	$\pm$ 0.08 (DR2)
Radial velocity (A/B)	-27.21 km s^{-1}	$\pm$ 0.15	-27.73 km s^{-1}	$\pm$ 0.16 (DR2)
Galactic coordinates	83°.340	+13°.215		

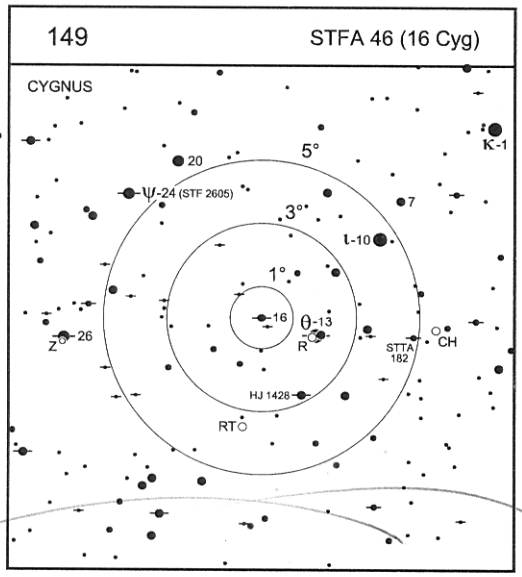
History

This binary was possibly found by Hodierna. His description mentions a pair in the right wing of the Swan. William Herschel picked it up on 5 October 1781. 'Almost equal. Both pale r(ed). Distance 30″.

The Modern Era

Between 1960 and 2007, a series of photographic plates centred on AB were taken at Pulkovo Observatory using the 26-inch refractor and reported by Kiselev & Romanenko [579]. Astrometric analysis of the plates shows a perturbation in star B in both right ascension and declination with a period of about eight or nine years. The amplitude is about 0″.02. An orbital period of > 20,000 years was given; the orbital semimajor axis was 900 AU and the eccentricity > 0.65. In 1999 Hauser & Marcy [580] found the the most likely period of AB to be 135.127 centuries. Adaptive optics observations of the system have revealed very faint images close to both stars. In 2002, Patience *et al.* [581] reported the existence of a star of maguitude 11.9 in the K band at a distance of 15″.8 from B. They also noted a closer companion to A at 205° and 3″.43. This star had first been found, a few months before, by Turner *et al.* [582] in 1998 using adaptive optics on the Mount Wilson 100-inch reflector, at 207°and 3″.15. As the large proper motion of A and B would soon leave behind any faint stars which just happened to be in the field of view, this was solid evidence that here was a physical companion to

Finder Chart



REPLACE FINDER CHART

A. Trilling & Brown [583] thought that the companion to A was a distant giant star many times further away than A and hence unrelated.

Exoplanet Host?

The components of 16 Cyg have been investigated both by high-precision radial velocity techniques and by adoptive optics with large telescopes searching for other stellar companions and planets, In 1996 Cochran *et al.* [584] discovered a body orbiting B with a period of 799 days, a velocity semi-amplitude of 50.6 km s^{-1}, and a likely mass of 2.4 Jupiters.

Observing and Neighbourhood

The pair 16 Cyg is easily found as it is about 6° due N of the maguitude 2.9 star δ Cyg, itself a long-period binary of note and the right-hand star in the 'Cross' of Cygnus. Smyth found both stars to be a pale-fawn colour. Also nearby, 1°.5 to the SW is HJ 1428 (6.6, 10.2, 233°, 34″, distance increasing); another 3° further W brings you to STTA 182 (7.5, 8.6, 297°, 73″, distance increasing), whilst continuing another 3° further one finds the binary star STF 2486 (6.5, 6.7, 202°, 7″.2, 2020, not on the chart), whose projected orbital period of 3100 years means that motion is extremely slow. Our pain 16 Cyg lies just 2′ W of the Blinking Planetary NGC 6826. Three degrees NE is ψ Cyg (STF 2605) (5.0, 7.5, 177°, 2″.8, 2014); in 1996 the primary star was found to be a close pair (YR 2); their separation ranges between 0″.03 and 0″.14 in a period of 55 years.

pair

Measures

Early measure (STF)	136°.3	37″.30	1837.30
(Orbit	136°.0	37″.39)	
Recent measure (WSI)	132°.8	39″.67	2014.68
(Orbit	133°.1	39″.74)	

28'

151. θ SGE = STF 2637 = WDS 20099+2055AB,C

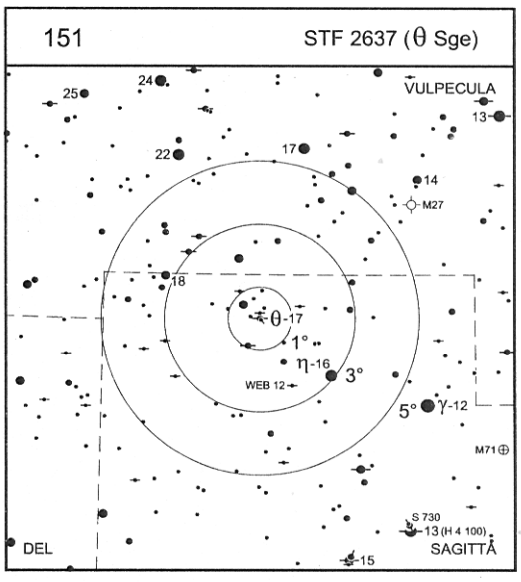
Table 9.151 Physical parameters for θ Sge

STF 2637	RA: 20 09 56.71	Dec: +20 54 55.6	WDS:459(133)(AB)	803(90) (AC)	
V magnitudes	A: 6.39	B: 8.63	C: 6.95		
$(B-V)$ magnitudes	A: +0.37	B: +0.73	C: +1.15		
μ(A)	58.39 mas yr^{-1}	± 0.05	98.27 mas yr^{-1}	± 0.04 (DR2)	
μ(B)	64.73 mas yr^{-1}	± 0.04	101.80 mas yr^{-1}	± 0.04 (DR2)	
μ(C)	5.40 mas yr^{-1}	± 0.04	−4.78 mas yr^{-1}	± 0.04 (DR2)	
π(A)	22.33 mas	± 0.07	146.1 light yr	± 0.5 (DR2)	
π(B)	22.38 mas	± 0.03	145.7 light yr	± 0.2 (DR2)	
π(C)	3.87 mas	± 0.04	843 light yr	± 9 (DR2)	
Spectra	A: F3V	B: G5V	C: K2III		
Luminosities ($L_\odot$)	A: 5	B: 0.5	C: 100	D:	
Catalogues (AB/C)	17 Sge	HR 7705	HD 191570/1	SAO 88266/70	HIP 93351
DS catalogues	H 3 24	STF 2637	BDS 9955	ADS 13442	
Radial velocity (A/B)	−43.10 km s^{-1}	± 0.6	−5.2 km s^{-1}	± 0.9	
Galactic coordinates	60°.573	-6°.688			

History

Found by William Herschel on 8 August 1780, the close stars were described as extremely unequal and Herschel noted that they were pale red and dusky, with the third and more distant star C given as pale red. He did not measure any angles but gave the distances of AB and AC as 11″ and 67″ respectively. Smyth, writing in the Bedford Catalogue, took him unfairly to task by reporting that Herschel's distances were 11″ 4‴and 59″ 49‴. It is ironic to note that Smyth's own measures were later called in question by no less a person than S. W. Burnham.

Finder Chart



REPLACE FINDER CHART

The Modern Era

There is some confusion as to the spectral types of the three stars. The WDS does not give consistent values, so the spectral types given above are taken from SIMBAD. The close stars certainly form a physical pair: the Gaia DR2 parallaxes for each component are to all intents and purposes equal. Star C is unrelated and is separating from AB owing to the proper motion of the close couple.

Observing and Neighbourhood

The system θ Sge can be found 2.5° SE of the Dumbbell Nebula (M27) and about 3° NNE of γ Sge, the brightest star in the constellation. It is a superb sight in small telescopes. The close pair are both white or yellowish-white and the distant C component is distinctly orange, as befits a K star. However, the colours of the stars can differ depending on the source of information. W. H. Smyth found the close pair to be pale topaz and grey, whilst C was pearly-yellow; more recently Sissy Haas sees A and B as white, whilst C is grey. Smyth notes a wide double which 'follows A on the parallel'. It is not clear which pair this is but there is a wide south pair, (no. 737), just 5′ N with magnitudes of 7.9 and 9.2 at 100″; the primary is a K star. Not on the chart but 2°.5 W of γ and a little S is is the triple star ζ Sge (STF 2585) – a much tougher prospect than θ and which requires apertures in excess of 50-cm to see it as triple. The easier task is to divide AC (magnitudes 5.0 and 9.0 at 8″.4), but, in testing a new 12-inch objective bound for Lick Observatory in 1875, A. G. Clark noted the duplicity of the bright star. This is a short-period highly inclined system with a period of 23.2 years, whose separation will be 0″.19 in 2020 and will increase to a maximum value of 0″.24. One of the pairs attributed to Thomas William Webb can be found 1°.5 SW. WEB 12 has stars of magnitudes 8.4, 8.4 at 77°, 41″, 2015. The stars are fixed. The system 13 Sge (H 4 100), about 4° SW, is a coarse triple (10.1, 10.0, 5.6, 265°, 297°, 24″, 113″) as is S 730, which is only 6′ distant (7.2, 8.5, 10.2, 14°, 338°, 13″, 79″).

Measures

AB			
Early measure (STF)	316°.7	11″.41	1832.82
Recent measure (ARY)	330°.0	11″.74	2014.68
AC			
Early measure (WSI)	226°.6	70″.70	1832.82
Recent measure (SMR)	321°.9	90″.84	2013.73

3.0°

South (Capital Letter)

Should this be 221°

153. β DEL = BU 151 = WDS J20375+1436AB

Table 9.153 Physical parameters for β Del

BU 151	RA: 20 37 30	Dec: +14 36	WDS 20(733)		
V magnitudes	A = 4.11	B = 5.02	C = 13.5	D = 11.4	E = 11.63
$(B-V)$ magnitudes	A: +0.43	B: +0.56			
μ	118.09^{-1}	$\pm$ 0.47	-48.06 mas yr^{-1}	$\pm$ 0.43	
π	32.33 mas	$\pm$ 0.47	101.0 light yr	$\pm$ 1.5	
Spectra	A: F5IV	B: F2V			
Masses	A: 1.75 $M_\odot$	$\pm$ 0.00	B: 1.47 $M_\odot$	$\pm$ 0.04	
Luminosities ($L_\odot$)	A: 19	B: 6			
Catalogues	6 Del	HD 196524	HR 7882	SAO 106316	HIP 101769
DS catalogues	BU 151 (AB)	HJ 5545 (AC)	H 4 75 (AD)	STF 2704 (AD)	BDS 10363
	ADS 14073				
Radial velocity	-22.7 km s^{-1}	$\pm$ 0.9 km s^{-1}			
Galactic coordinates (A)	58°.881	$-15°.651$			

History

Sir William Herschel found a faint star almost 26″ distant from β on 1 August 1781. He noted: 'Extremely unequal. hardly visible with 227; pretty strong with 460.' This star is what is now known as component D and the system was included in Struve's 'Mensurae Micrometricae' as STF 2704 AD. The WDS gives its V magnitude as 11.4. John Herschel then found a 13.5 maguitude star in 1828. The close pair was discovered by S. W. Burnham in August 1873 using his 6-inch Clark refractor. Burnham had no micrometer at that time and turned to Baron Ercole Dembowski in Italy for help. Dembowski measured the pair in 1874 with his 7-inch refractor, with the result which is given here. By 1903 the star had been observed so assiduously that there were nine orbits extant by that time. Labitzke [597] added another faint companion E of maguitude 11.6 in 1922.

Finder Chart